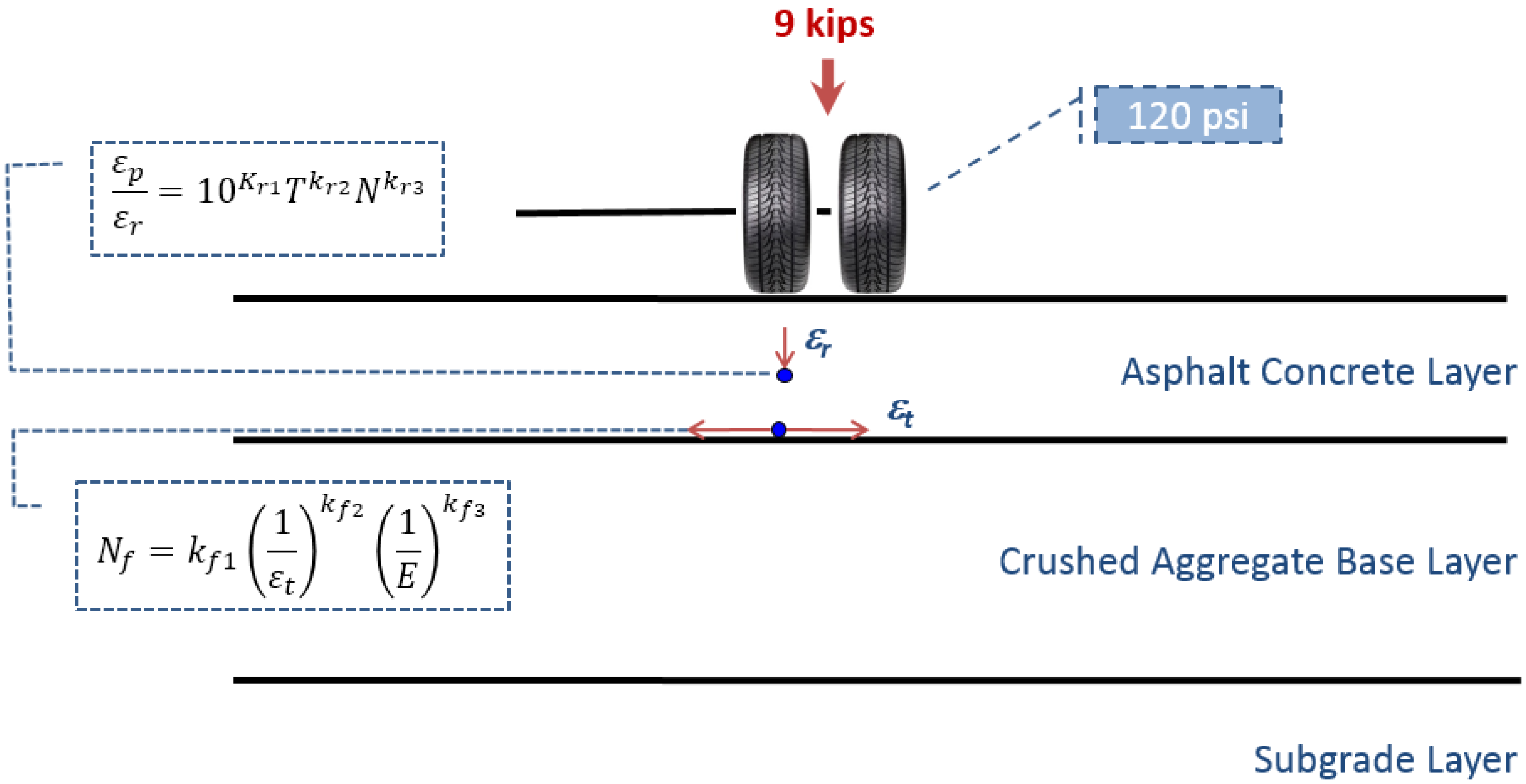
# Benefits of Polymer-Modified Asphalt Binders


Peter E. Sebaaly, PhD, PE
Professor & Director WRSC
University of Nevada


# PMB: Thirty Years of History

- Nevada: 100% Polymer-modified Binders
- Polymer with Tire-rubber and WMA
- Florida: High Polymer Modified
- Cold In-Place Recycling (CIR)

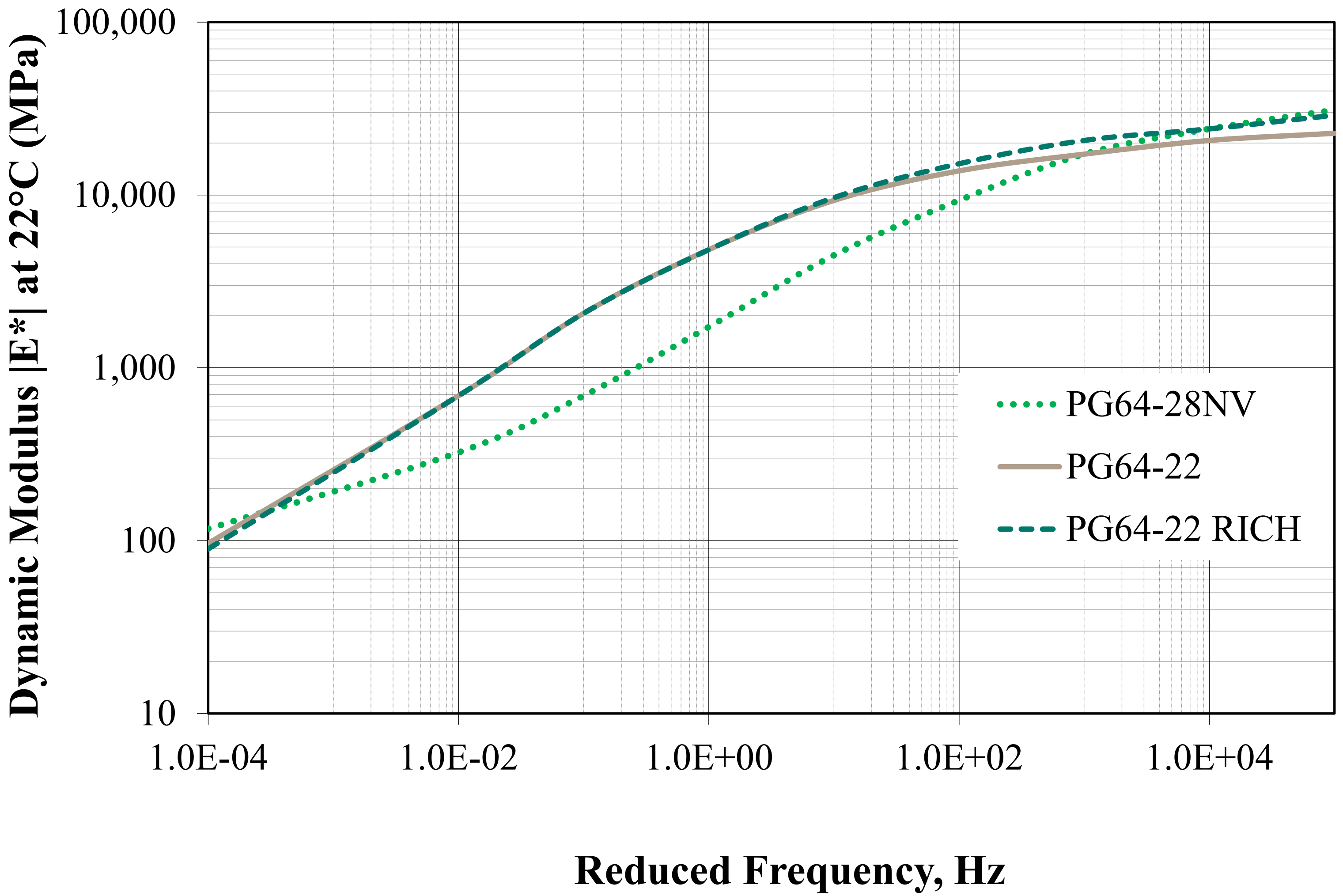
# Mechanistic Analysis



# Why Polymer-Modified Binders In Nevada

- PG64-28NV – North
- PG76-22NV – South
- Both SBS Modified Mandatory
- Started by NDOT: Counties and Cities Followed

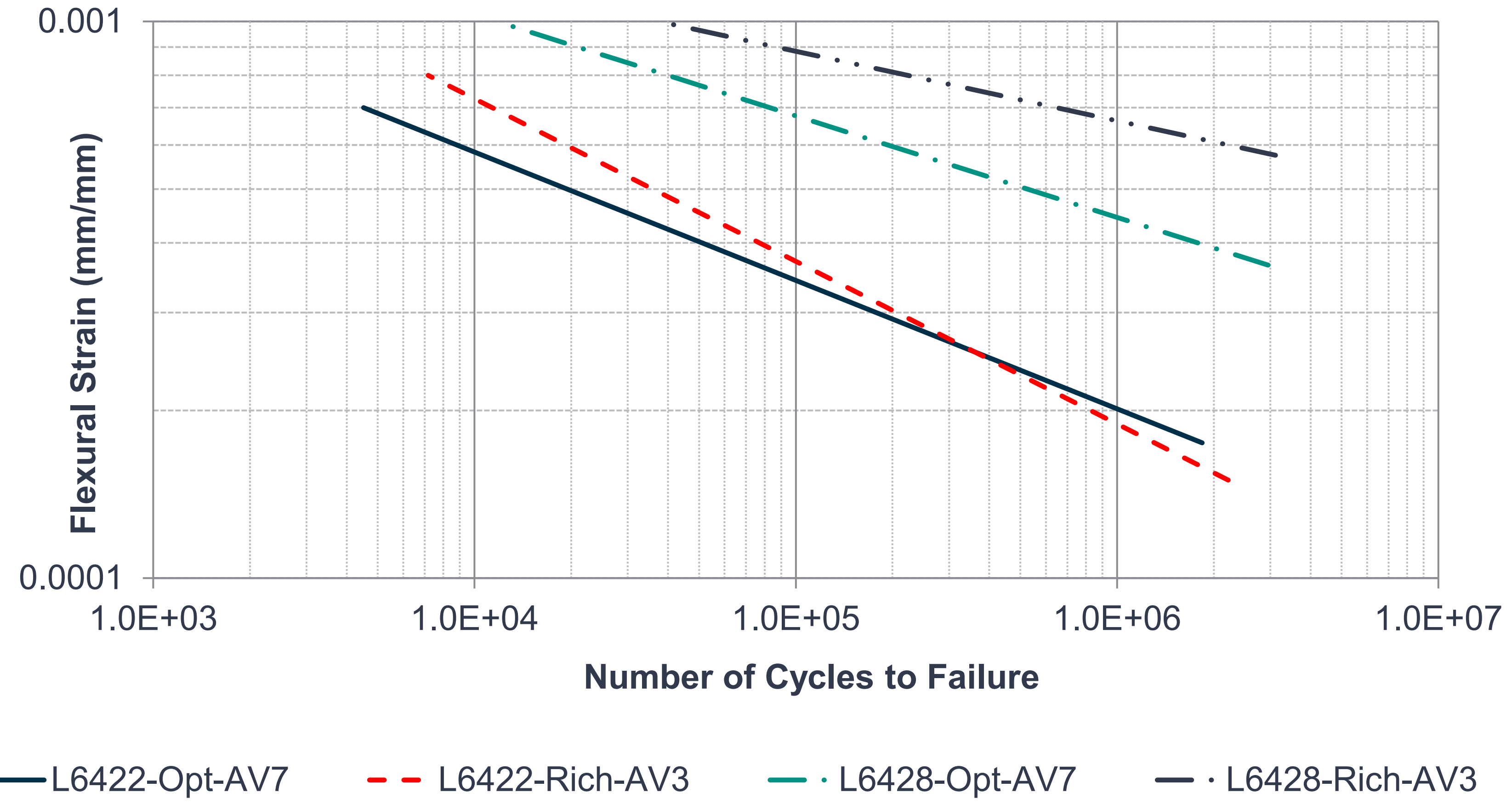
# Engineering Property: E* Master Curve



# Resistance to Rutting: APA

| | PG64-22 | PG64-22 RICH | PG64-28NV |
|---|---|---|---|
| Rut Depth, mm | 6.5 | 7.1 | 2.5 |
| Std Dev | 0.59 | 0.43 | 0.04 |
| COV | 9% | 6% | 1% |

# Resistance to Fatigue Cracking: BBF



# Why Polymer-Modified Binders In Nevada

| 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 | |

# Why Polymer-Modified Binders In Nevada

| 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 | | |

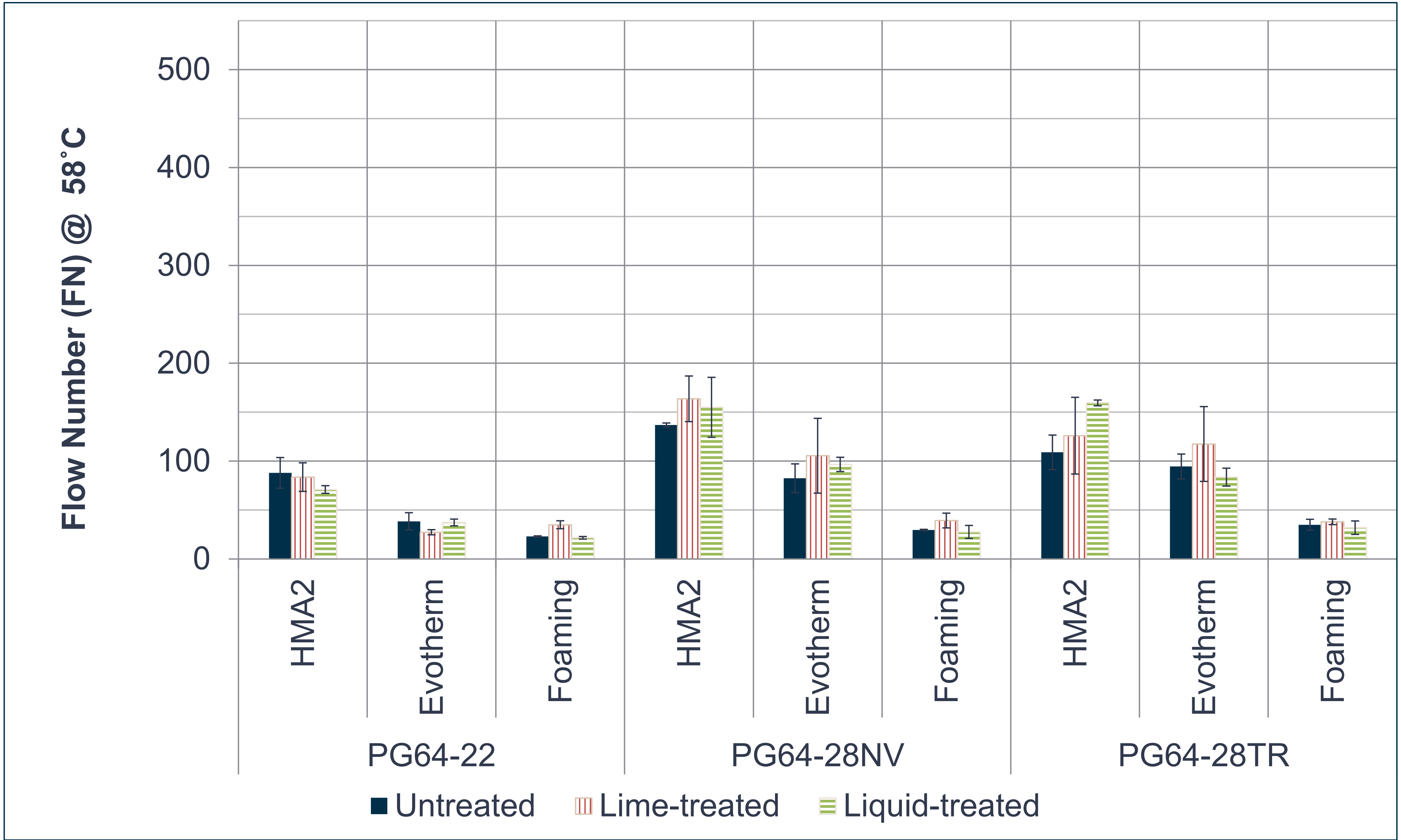
# Why Polymer-Modified Binders In Nevada - Locals

| 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<br>2.0” PG64-28NV<br>2.0” PG64-22 | Fast | 204 | 540,000 |
| | Slow | 285 | 220,000 |
| Structure 2<br>2.0” PG64-28NV<br>2.0” PG64-22 rich | Fast | 200 | 2,200,000 |
| | Slow | 285 | 560,000 |
| Structure 3<br>2.0” PG64-28NV<br>2.0” PG64-28NV | Fast | 264 | will not fail in fatigue |
| | Slow | 407 | 33,000,000 |

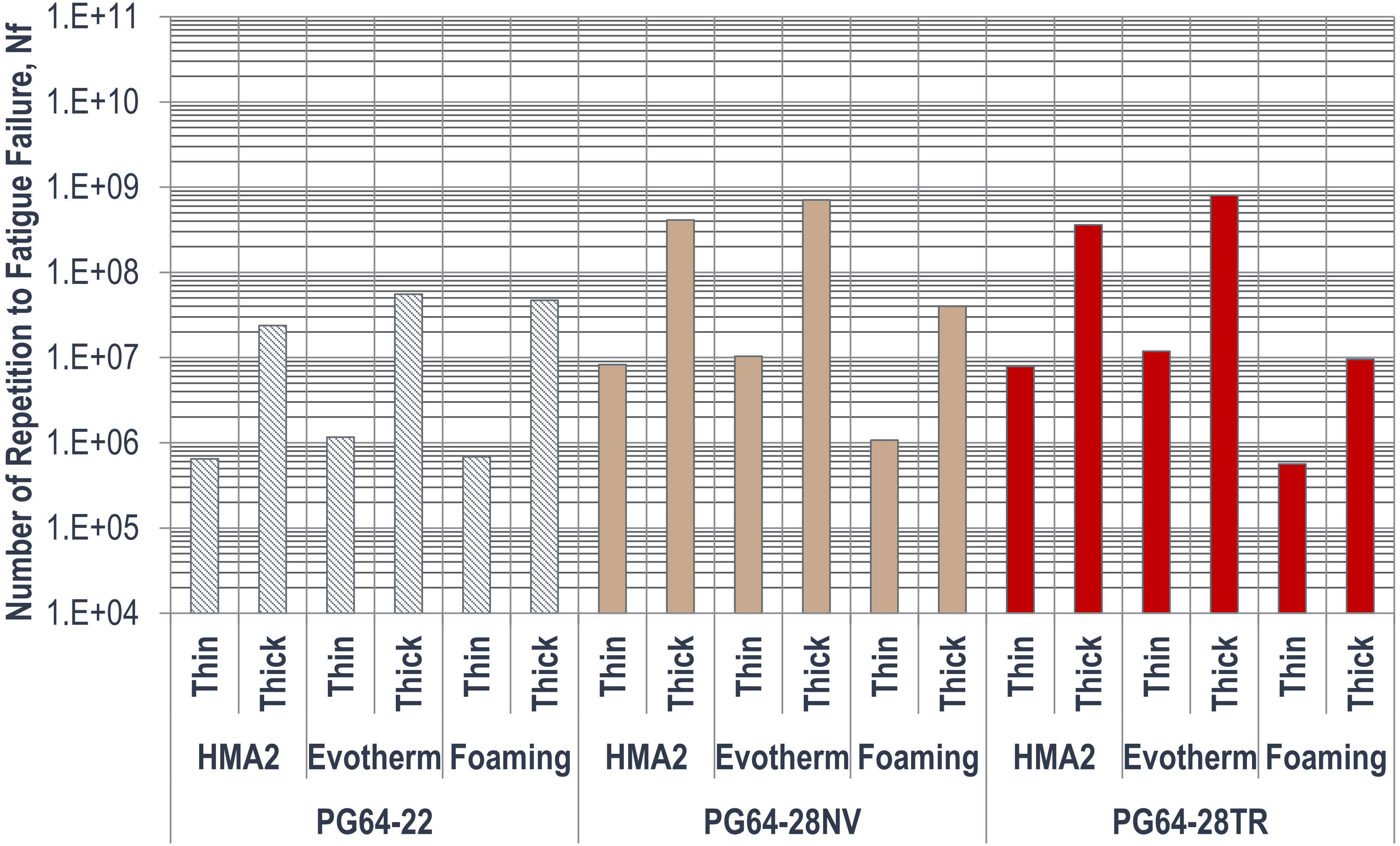
# Modification with Polymer and Tire Rubber

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

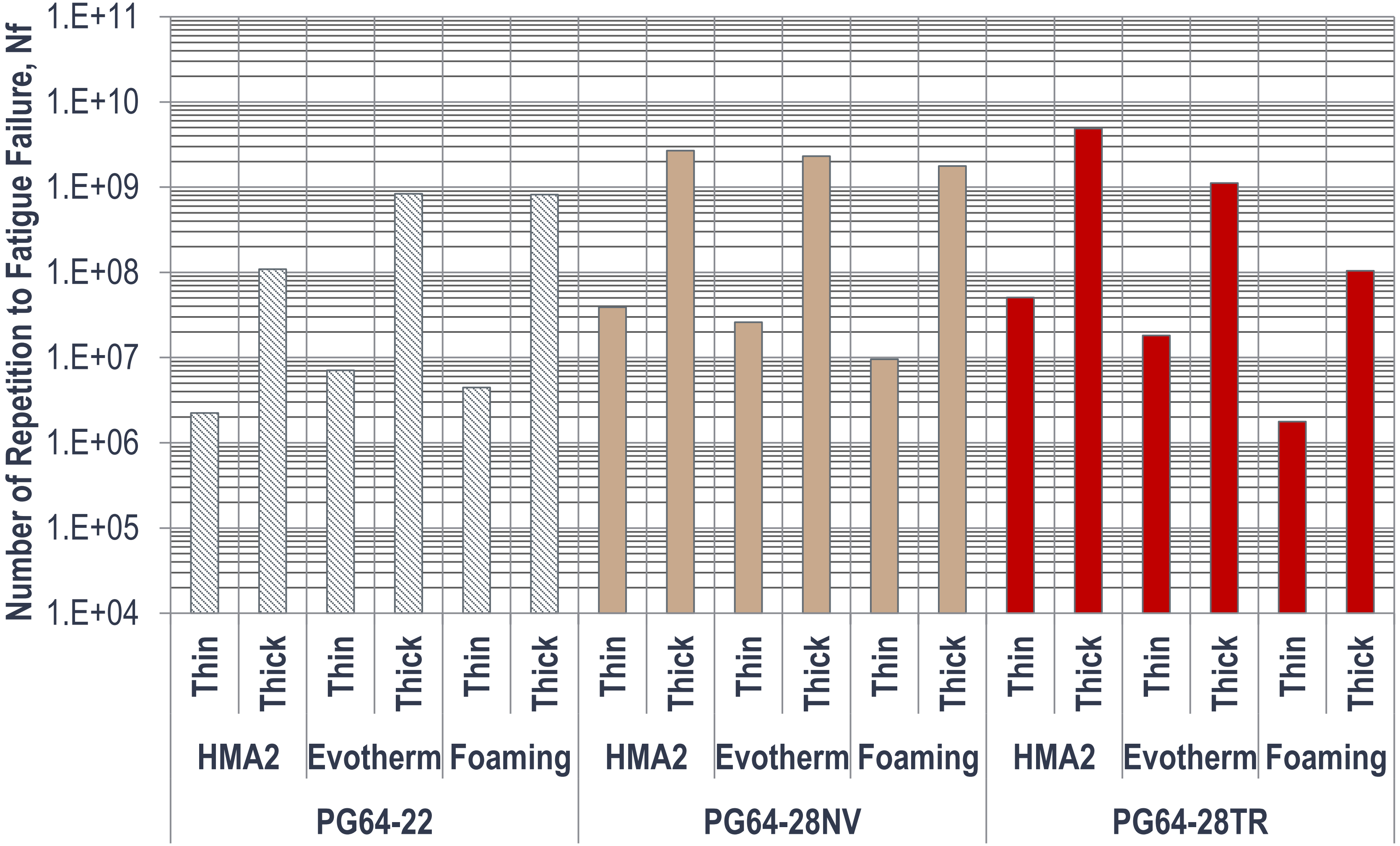
# Resistance to Rutting: FN



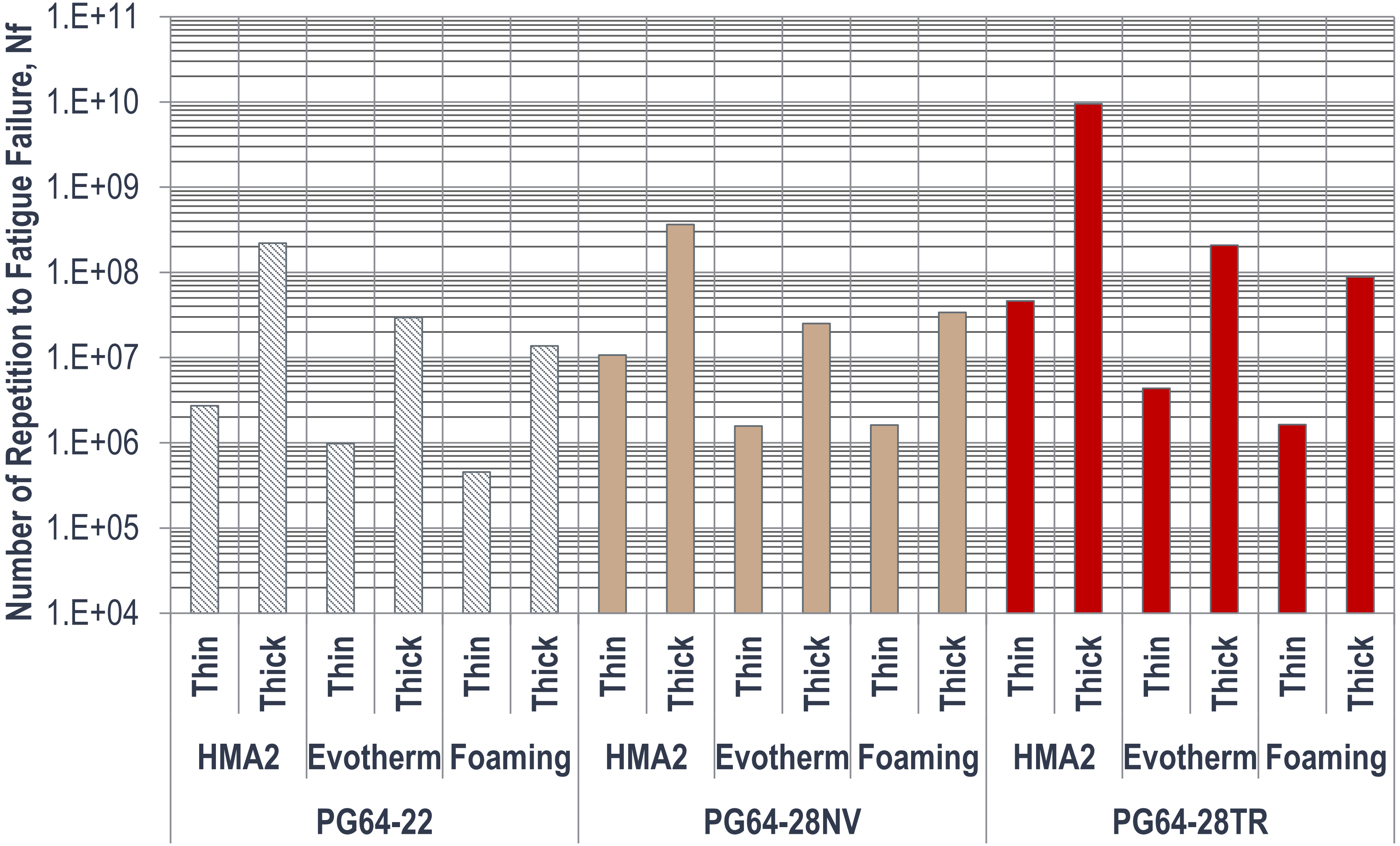
# Fatigue Life of Un-treated Mixtures



# Fatigue Life of Lime-treated Mixtures



# Fatigue Life of Liquid-treated Mixtures



# Florida DOT: High Polymer Modification

I. Laboratory Evaluation of HP Binders and Mixes

II. Flexible Pavement Modeling using 3D-MOVE

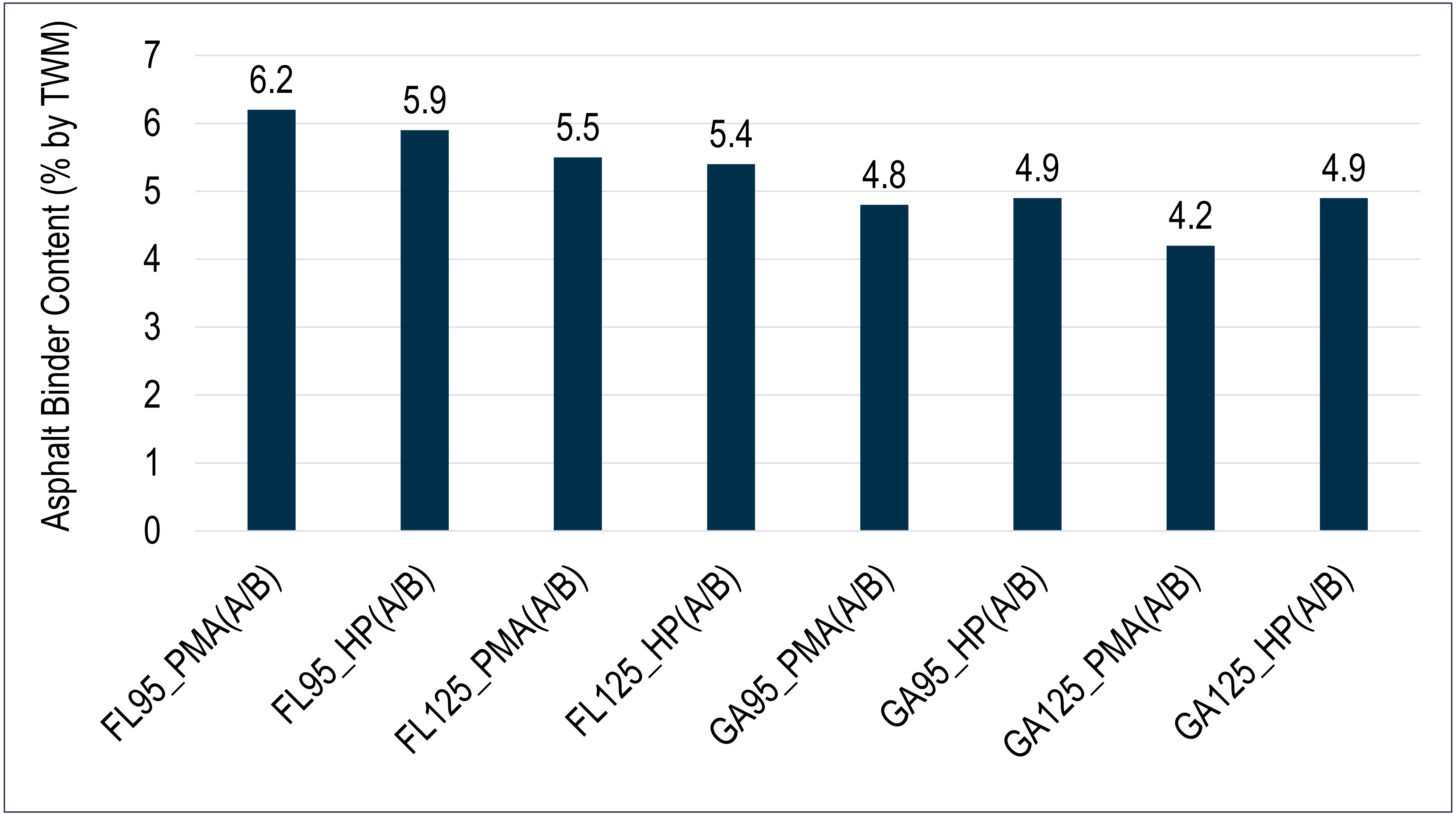
III. Determination of Structural Coefficient for HP Mixes

IV. Verification using Full-Scale Testing (PaveBox)

# ASPHALT BINDERS

| Binder Source / ID | Continuous Grade based on AASHTO M320 | |
|---|---|---|
| | PMA | HP |
| A | **PG75.7-26.5**<br>(Base Binder: PG64-22,<br>%SBS = 3.2% & %R = 81.4%) | **PG93.5-34.6**<br>(Base Binder: PG52-28,<br>%SBS = 7.6% & %R = 92.5%) |
| B | **PG75.8-24.6**<br>(Base Binder: PG67-22,<br>%SBS = 3.0% & %R = 48.5%) | **PG98.5-30.1**<br>(Base Binder: PG52-28,<br>%SBS = 8.0% & %R = 97.7%) |

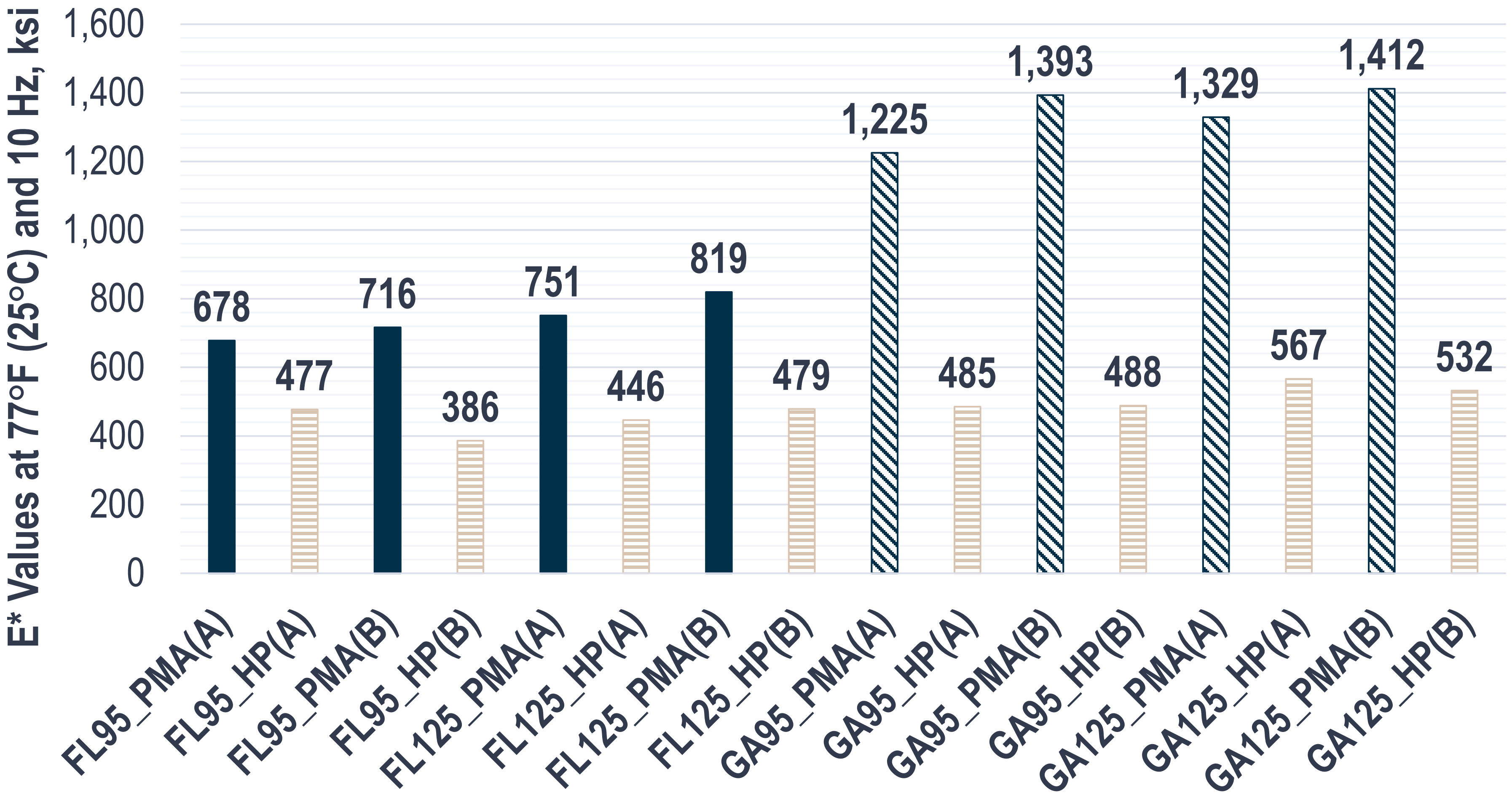
# Superpave Mix Designs



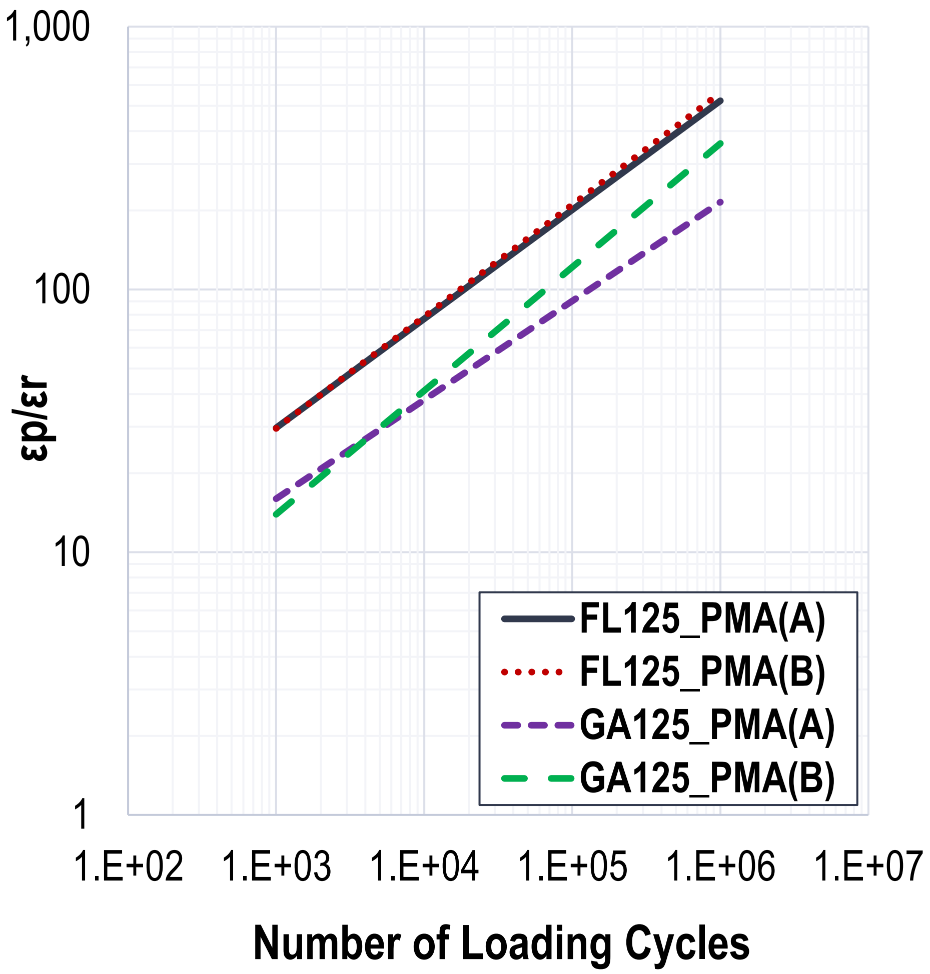
# Laboratory Evaluation of Mixtures

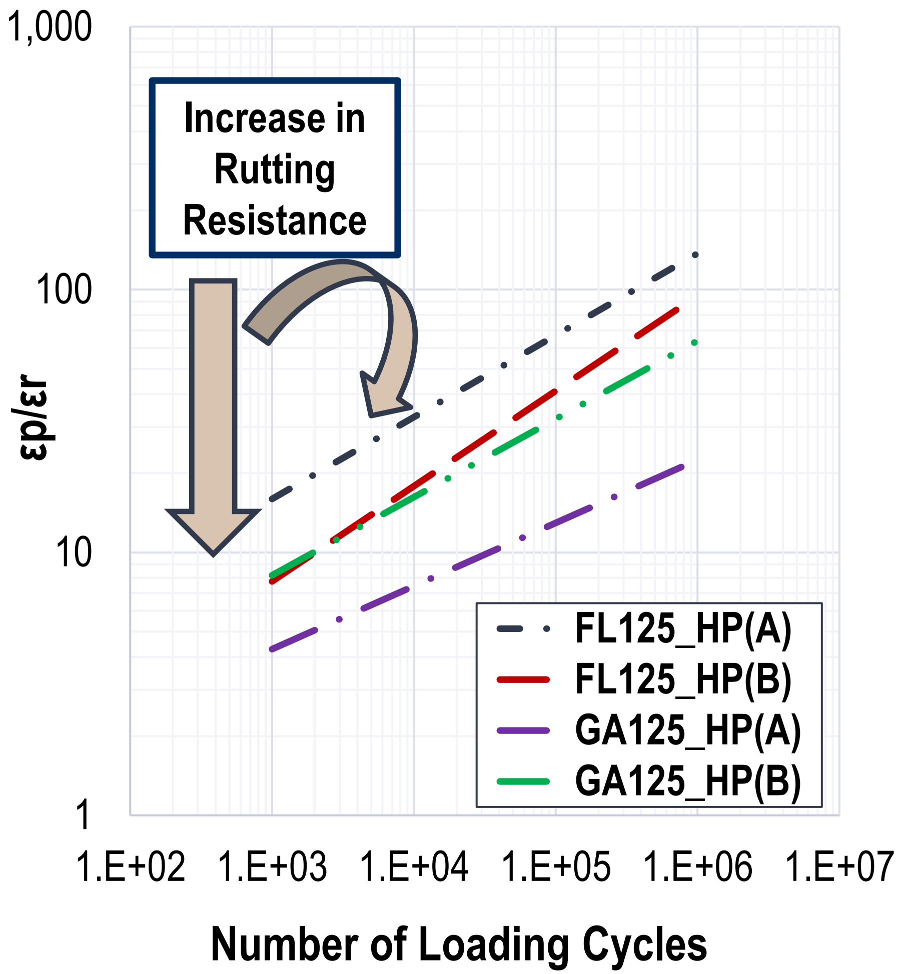
| Performance & behavior | Dynamic Modulus | Resistance to Rutting | Resistance to Fatigue cracking | Resistance to Top Down Cracking | Resistance to Reflective cracking |
|---|---|---|---|---|---|
| Observations: HP versus PMA | ↓ *Lower E* & Lower δ* | ↑ *Lower & flatter rutting relationships* | ↑ *Higher & flatter fatigue relationships* | ↑ *Variable $D_1$ & lower m* | ↑ *Higher OT cycles, Lower $G_c$, & Lower CPR* |

# Engineering Property: Dynamic Modulus

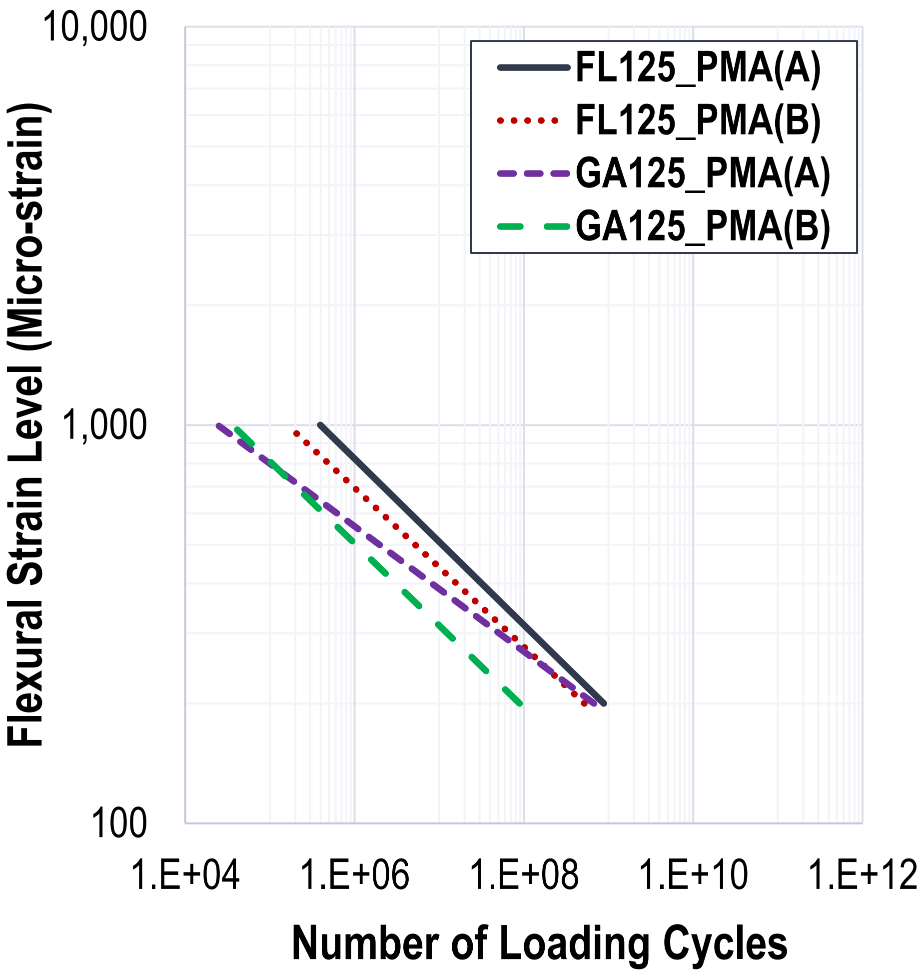


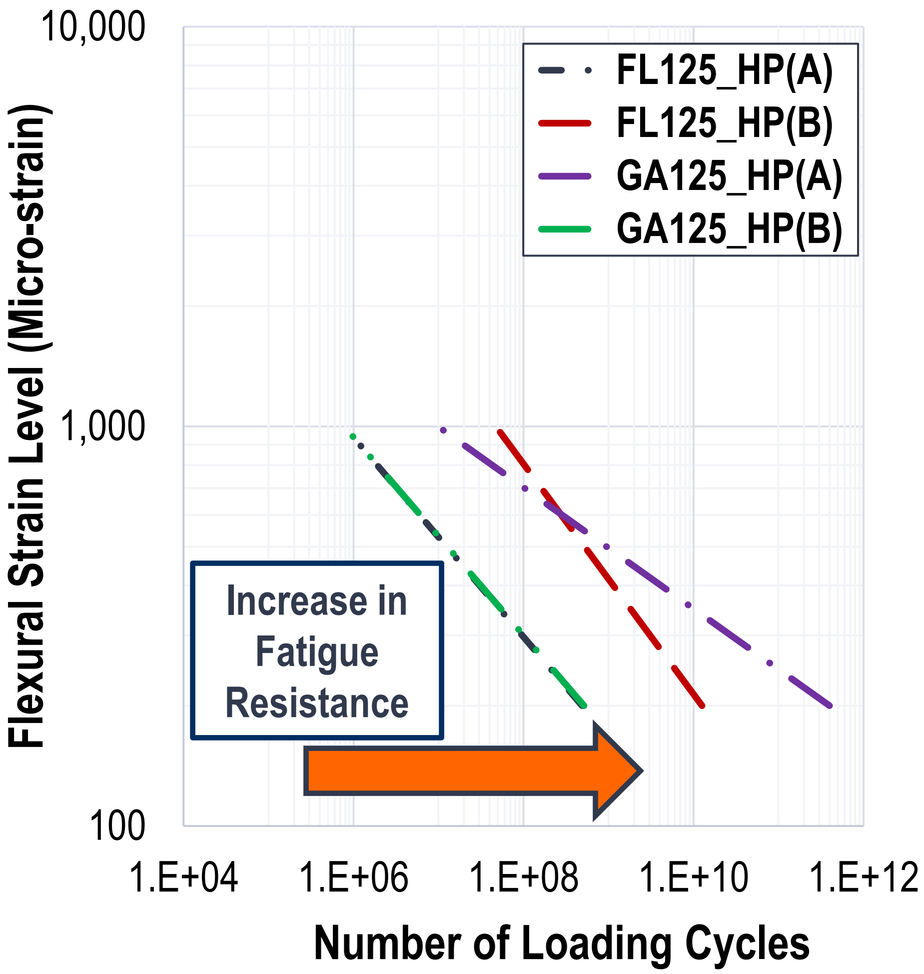
# Resistance to Rutting: RLT @122°F



# Resistance to Fatigue Cracking: BBF @77°F



# Flexible Pavement Mechanistic Analysis: Fatigue

| Mix ID | | FL125_PMA(A) | | | FL125_HP(A) | |
|---|---|---|---|---|---|---|
| Case ID | Speed (mph) | Thickness of AC PMA layer (inch) | Max strain at bottom of AC layer (microns) | $N_f$ (millions) | Equivalent strain at bottom of AC layer | Equivalent thickness of AC HP layer (inch) |
| 1 | 0 | 4.50 | 320 | 49.5 | 987 | 2.50 |
| 2 | 8 | 4.50 | 224 | 45.0 | 384 | 3.00 |
| 3 | 45 | 4.50 | 180 | 28.1 | 253 | 3.75 |

$$a_{AC\text{-}HP\ (FC)} = (D_{PMA} / D_{HP})^{*}0.44$$

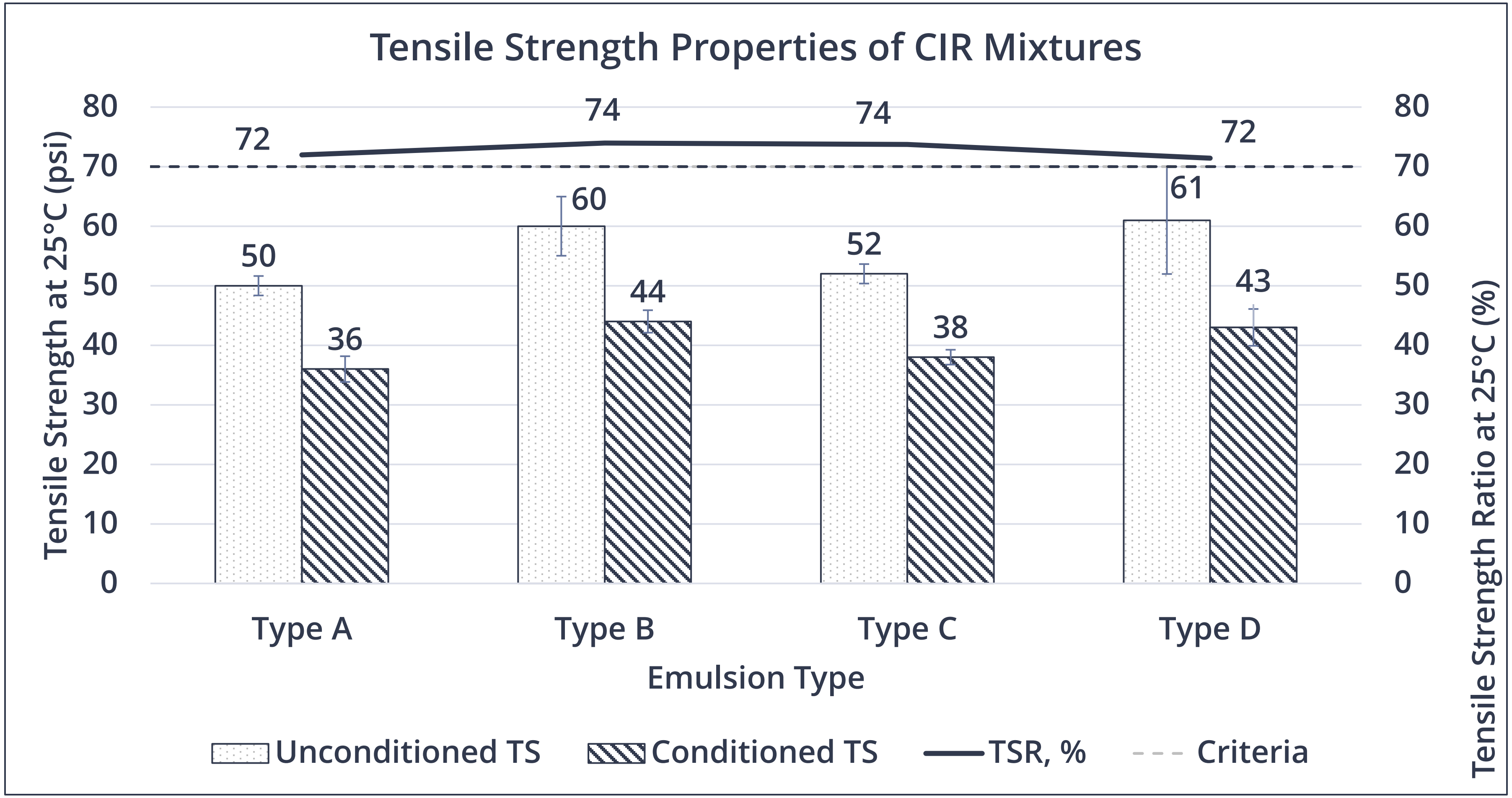
**Structural Coefficient**
0.79
0.66
0.53

**HP section needs to be verified for AC Rutting & Shoving, Total Rutting, Top-Down Cracking, and Reflective Cracking.**

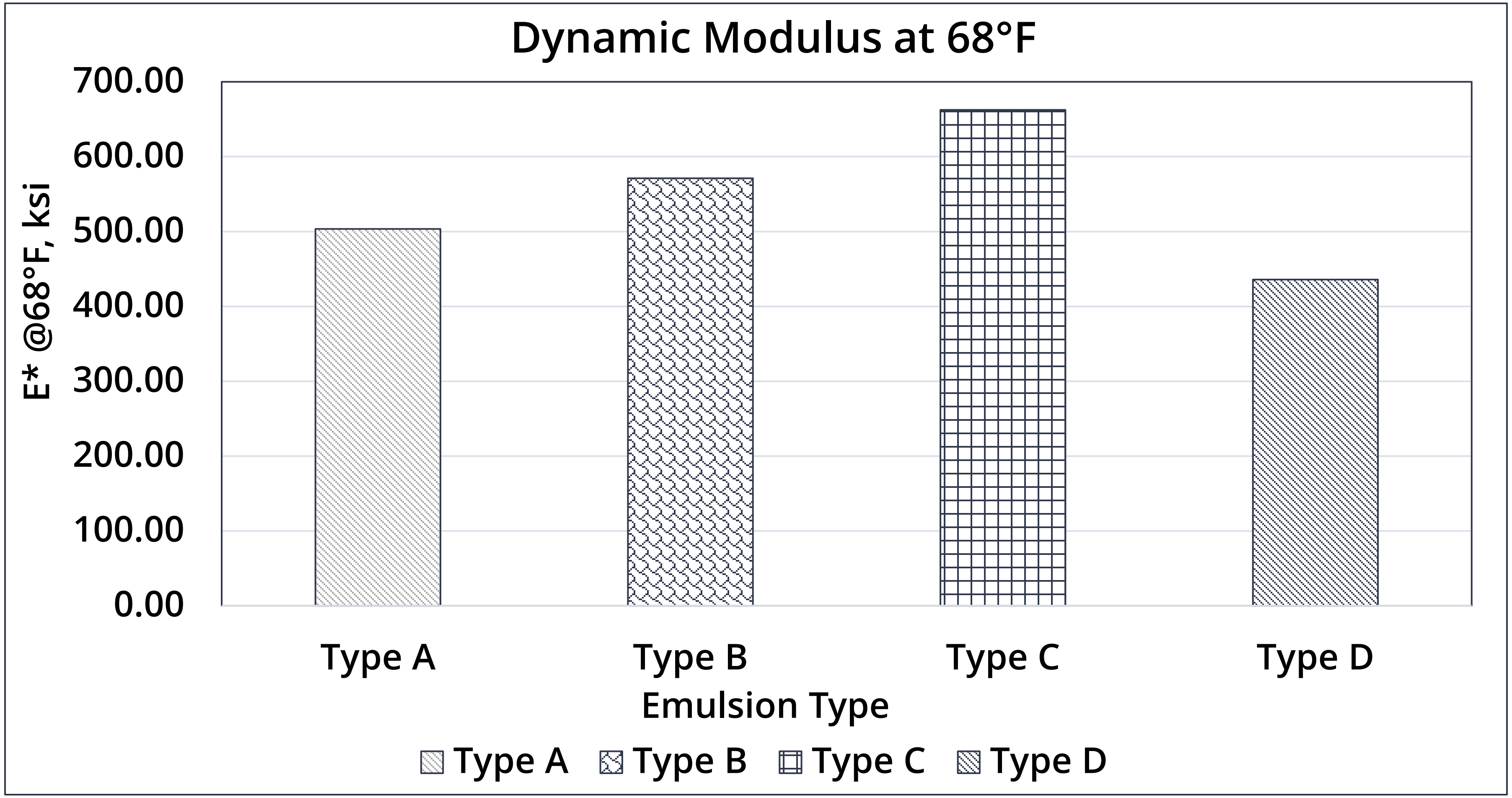
# Conclusions and Recommendations

- HP AC mixes showed better performance characteristics than corresponding PMA control AC mixes.
- Fatigue-based SC for HP AC mixes: $a_{HPAC} = 0.54$
- Verification process concluded that $a_{HPAC} = 0.54$ would lead to the design of HP pavements that offer equal or better resistance to the various distresses as the designed PMA pavements with SC of 0.44
- This conclusion held valid for the design of both new & rehabilitation projects

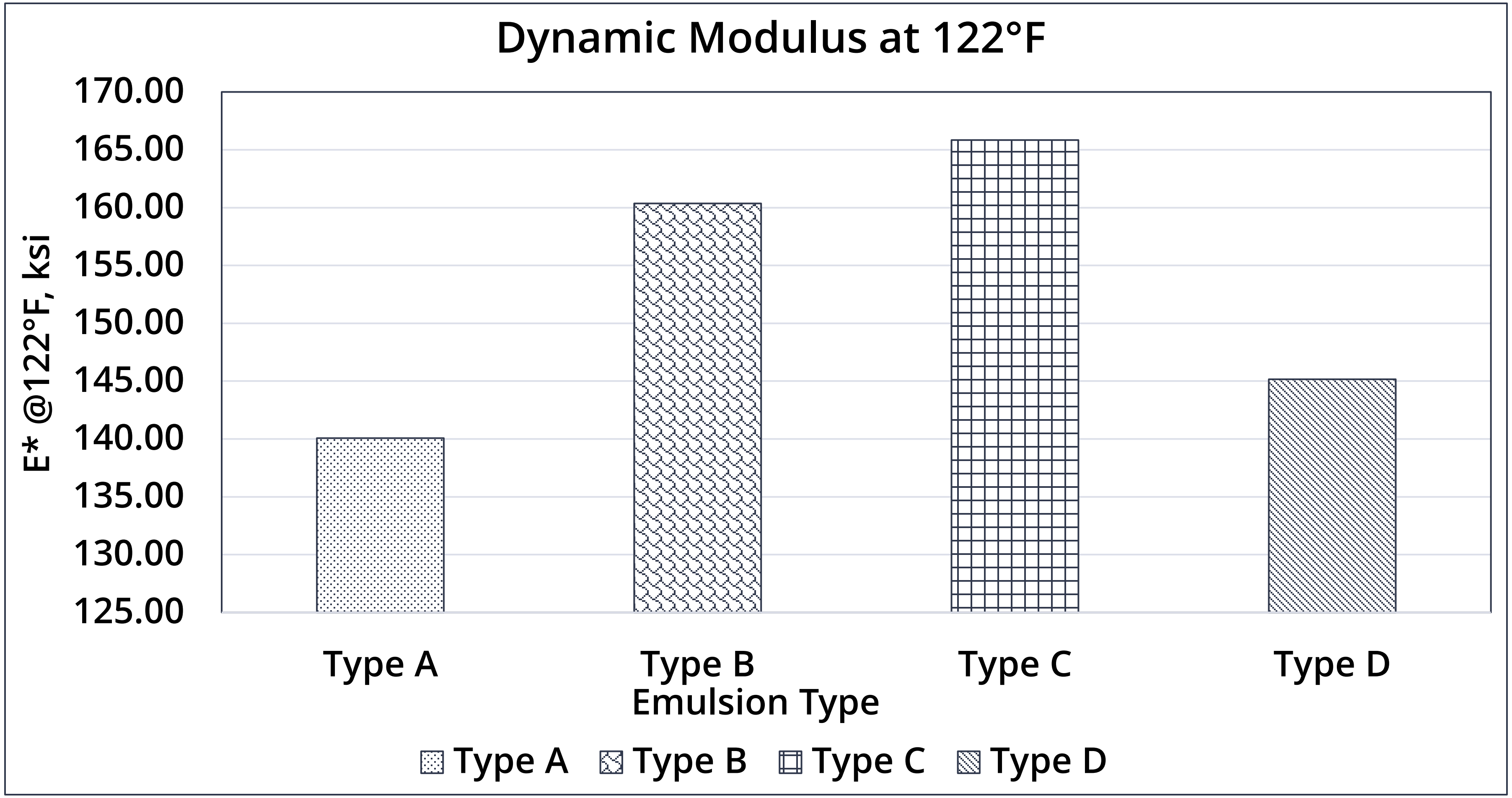
# Polymer-Modified Emulsions: CIR-Mixtures



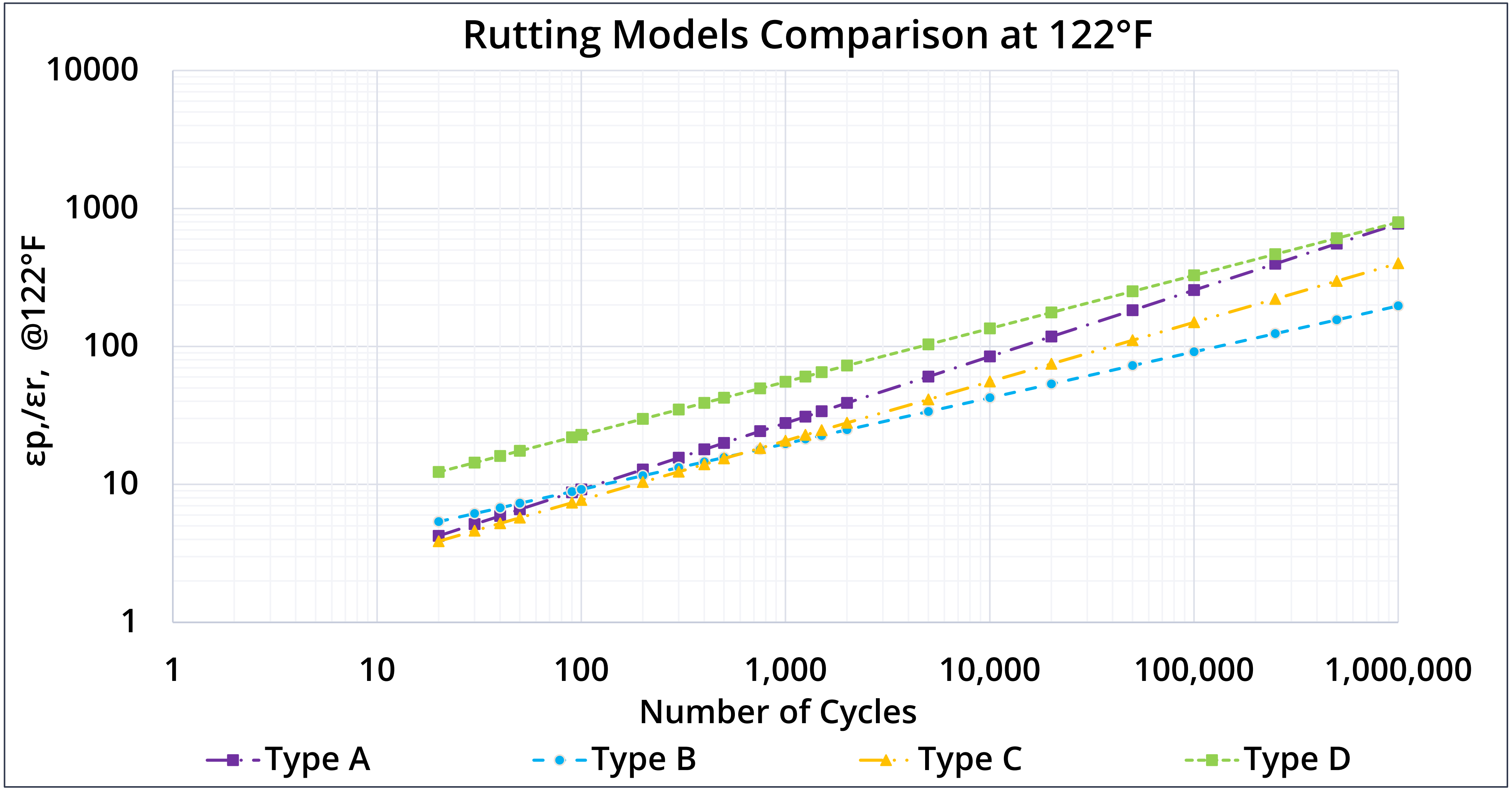
# Engineering Property: E*



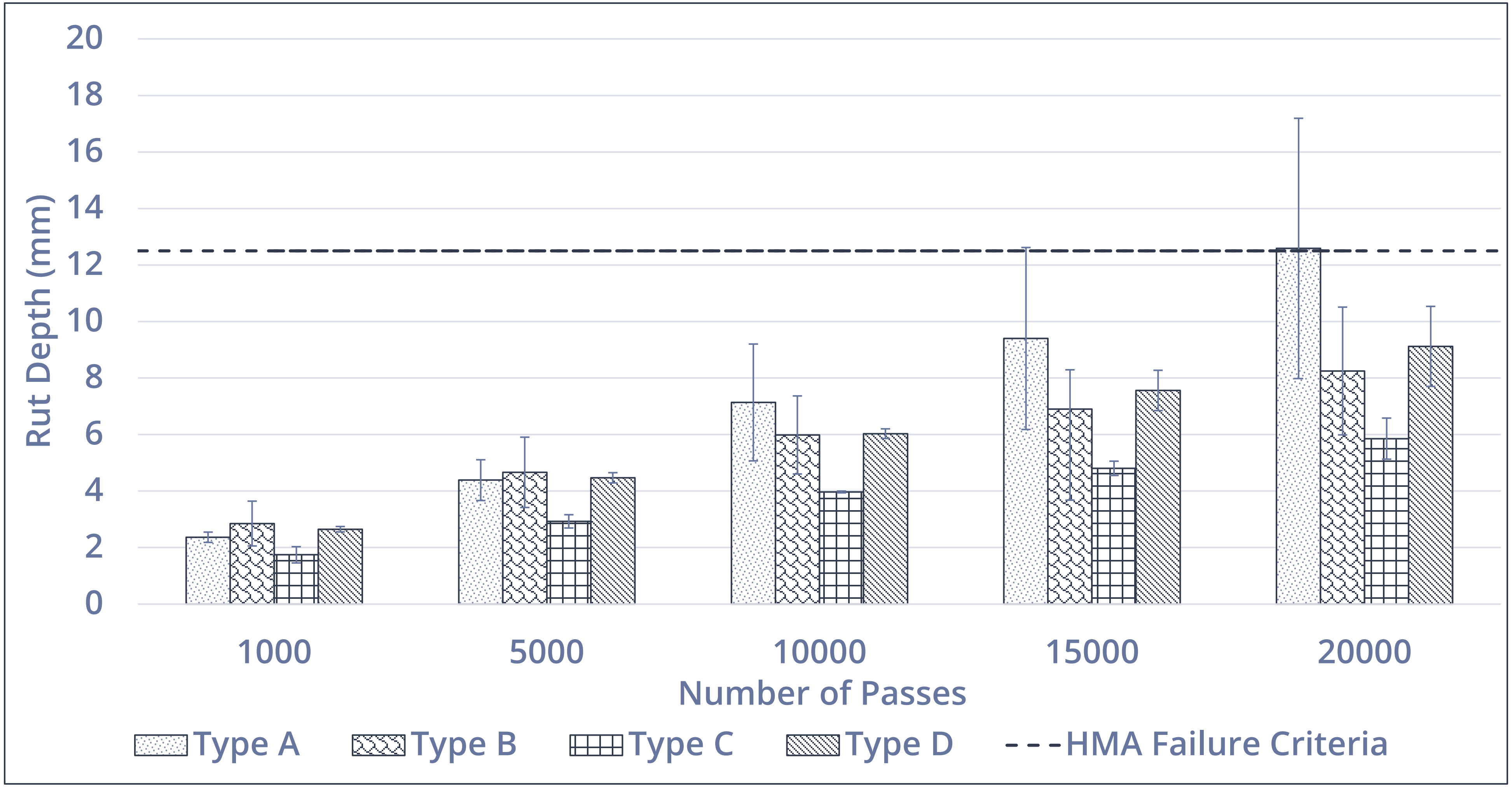
# Engineering Property: E*



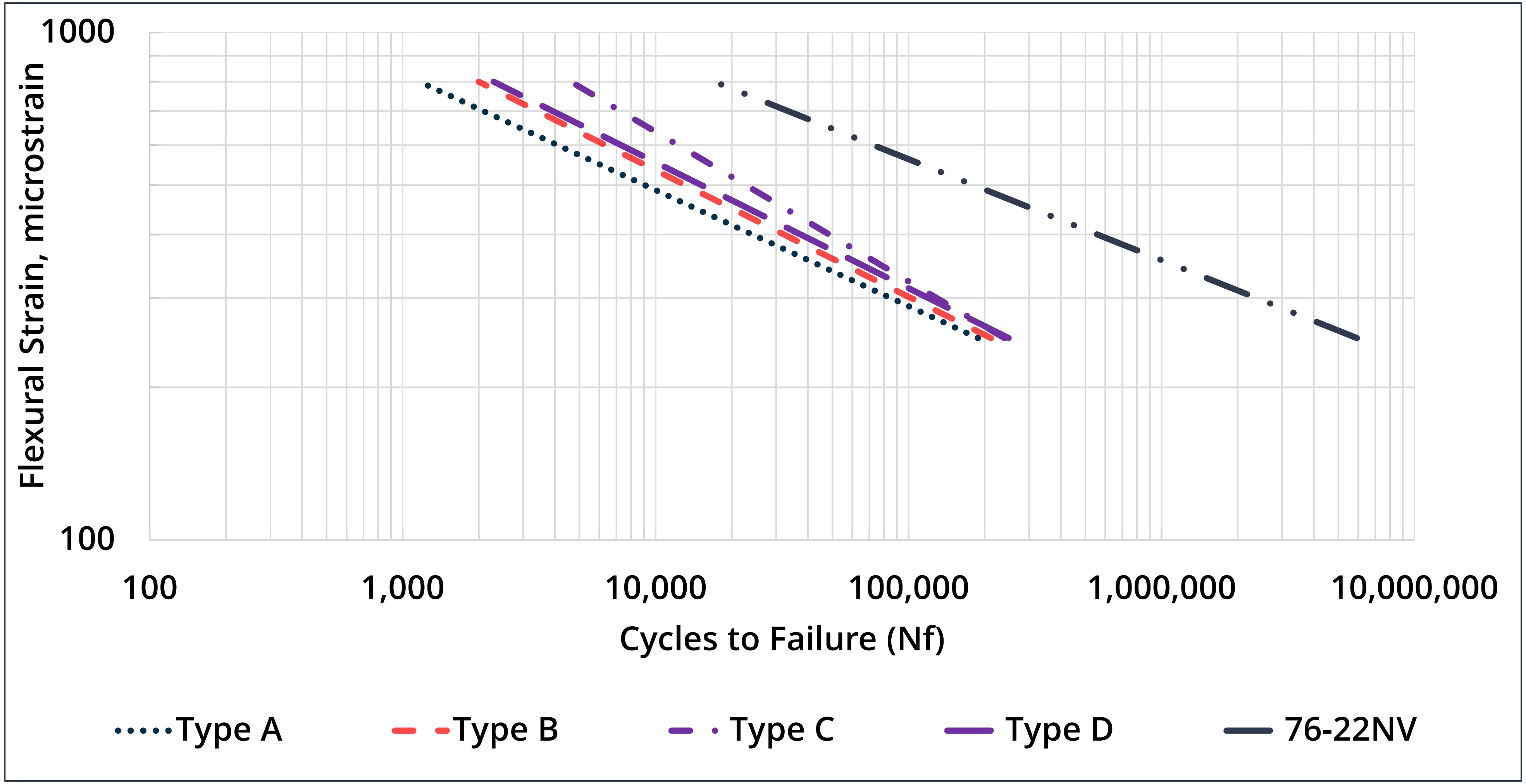
# Resistance to Rutting: RLT



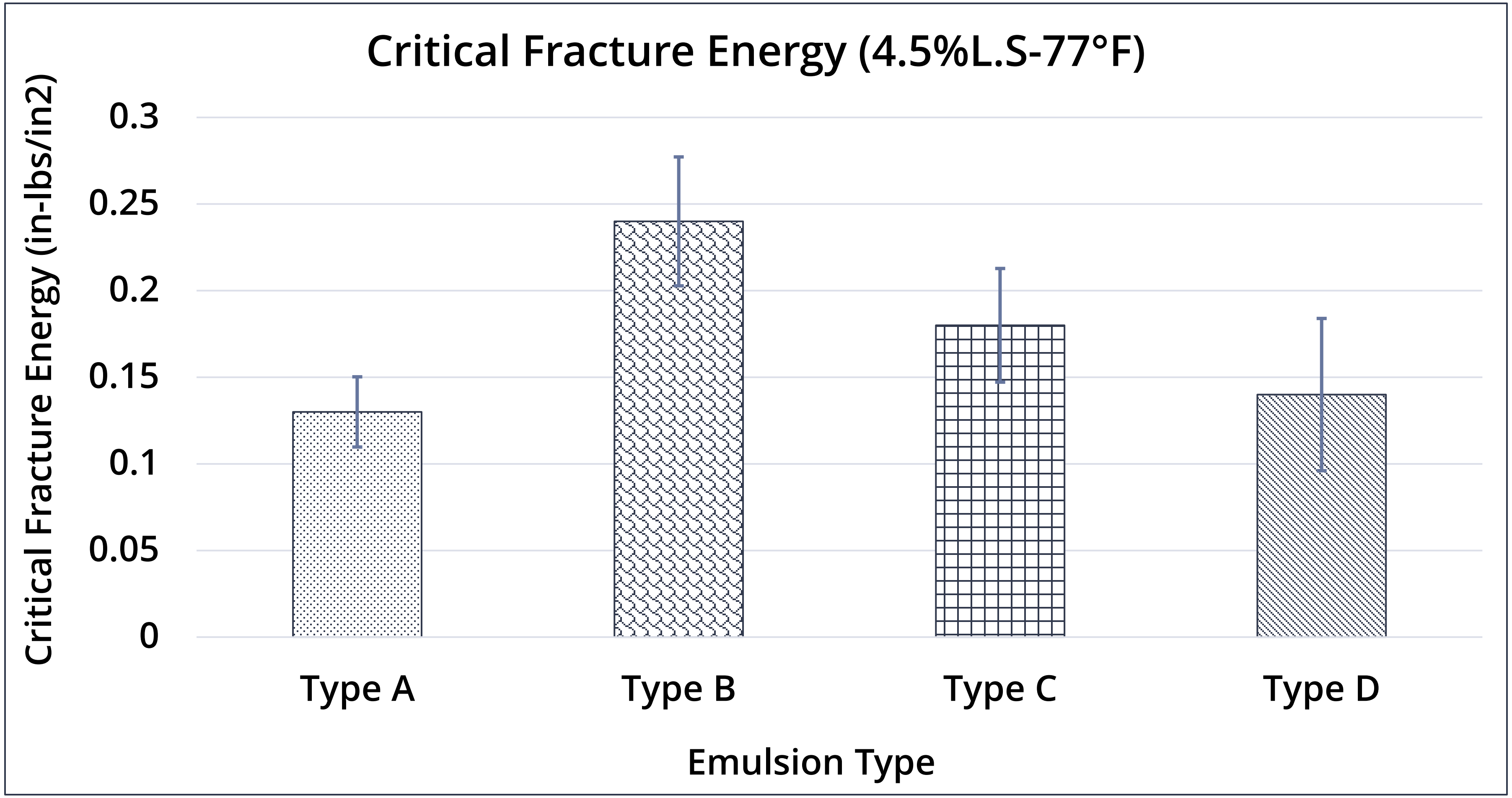
# Resistance to Rutting: HWTT



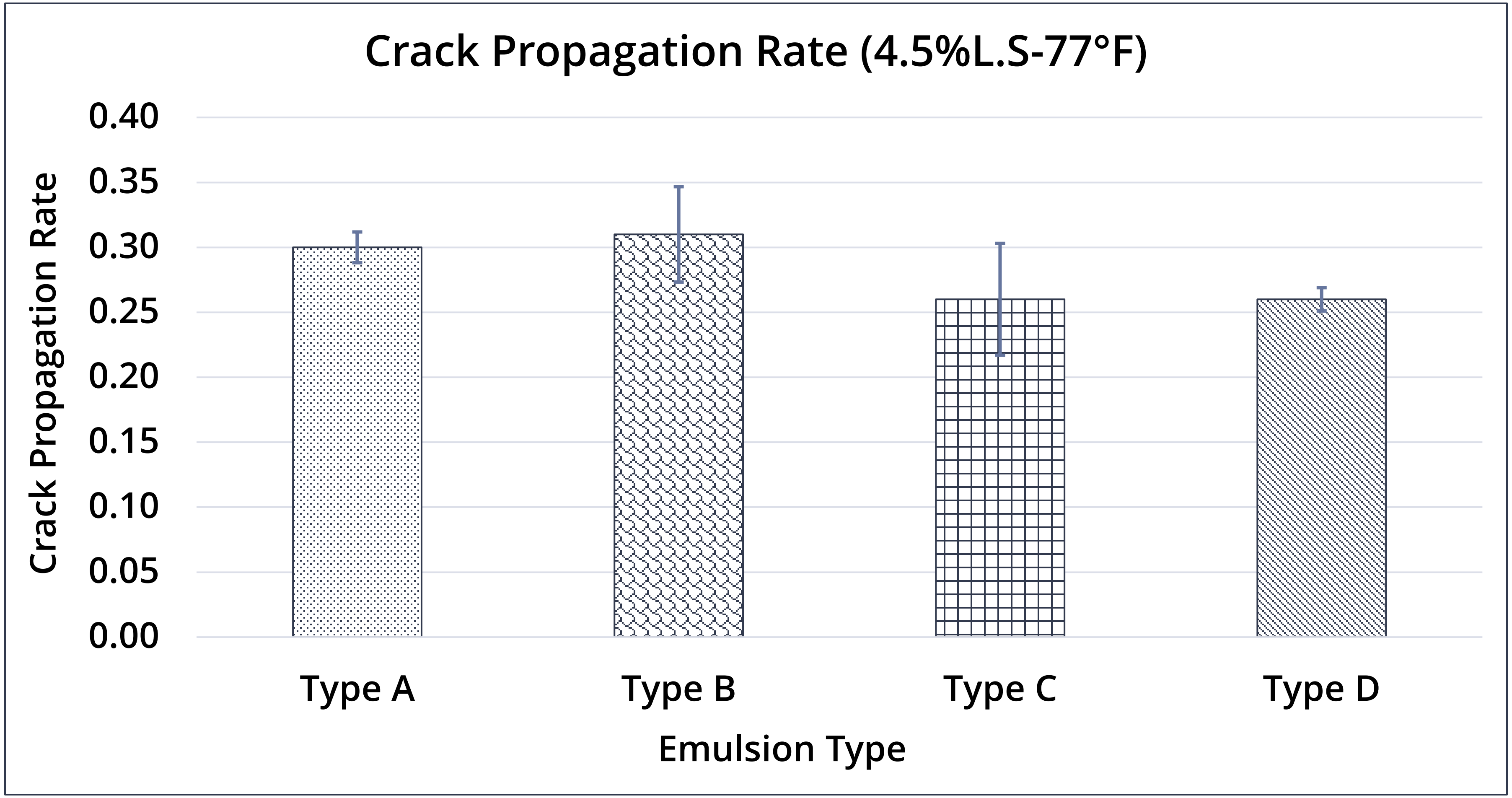
# Resistance to Fatigue Cracking: BBF



# Resistance to Reflective Cracking: TX-OL



# Resistance to Reflective Cracking: TX-OL



# Thank you!

Peter E. Sebaaly, PhD, PE
Professor and Director of WRSC
University of Nevada
psebaaly@unr.edu | 775-240-0958