Polyphosphoric Acid in Combination with Styrene-Butadiene-Styrene Block Copolymer: Laboratory Mixture Evaluation

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Workshop on Polyphosphoric Acid Modification of Asphalt Binders

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  - Steve Johns

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Background

- PPA is used as a modifier for more than a decade either as a solo modifier or in conjunction with polymers and more recently with Ground Tire Rubber.
- Misperception leads to link PPA usage with pavement failures with no evidence
- Needs of research on mix properties in terms of typical mode of failure – permanent deformation, moisture sensitivity and fatigue

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Mixture Laboratory Study

- Conducted using three different asphalt binders
  - Neat binder
  - SBS-only modified
  - SBS + PPA modified
- Mixture performance tests
  - Dynamic Modulus, AASHTO TP62 (STOA and LTOA)
  - Flexible Beam Fatigue, AASHTO T321 (STOA and LTOA)
  - Repeat Load/Flow Number (STOA)
  - Susceptibility to Moisture Damage, AASHTO T283

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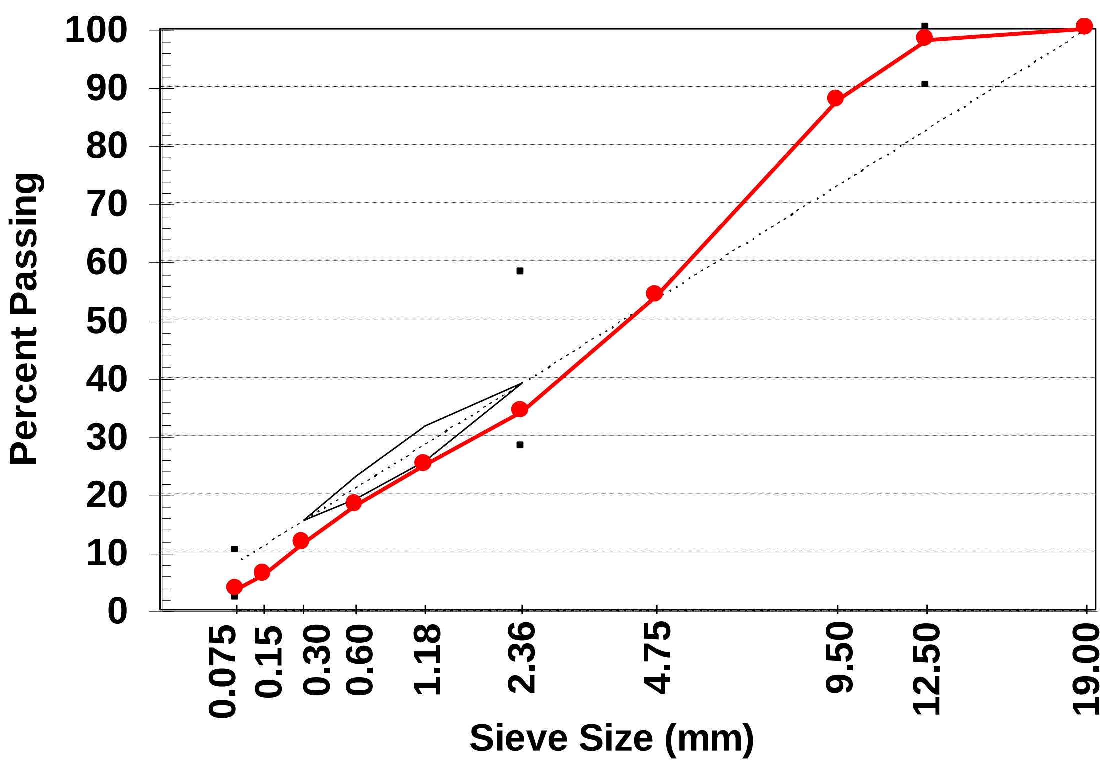
Materials

- Asphalt binders
  - Neat binder: PG64-22
  - Modified Binders
    - PG76-22: 4.25% SBS Only
    - PG76-22: 2.5% SBS + 0.5% PPA
- Aggregate
  - Granitic gneiss
    - Pyroxene granite containing bands of magnetite
    - Oligoclase gneiss containing amphibolite

Mixture Design Properties



Binder Content (%)	5.3%
VMA (%)	14.5%
G_{mm} (g/cm³)	2.483
G_{sb} (g/cm³)	2.621
Percent Passing	
19mm	100
12.5mm	98.1
9.5mm	87.7
4.75mm	54.1
2.36mm	34
1.18mm	25
0.6mm	18.1
0.3mm	11.5
0.15mm	6.1
0.075mm	3.5

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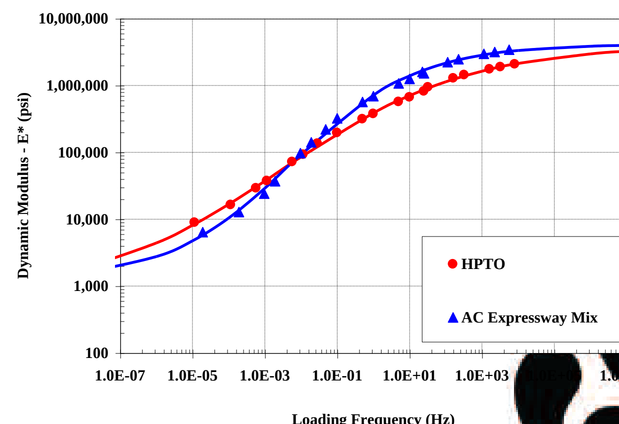
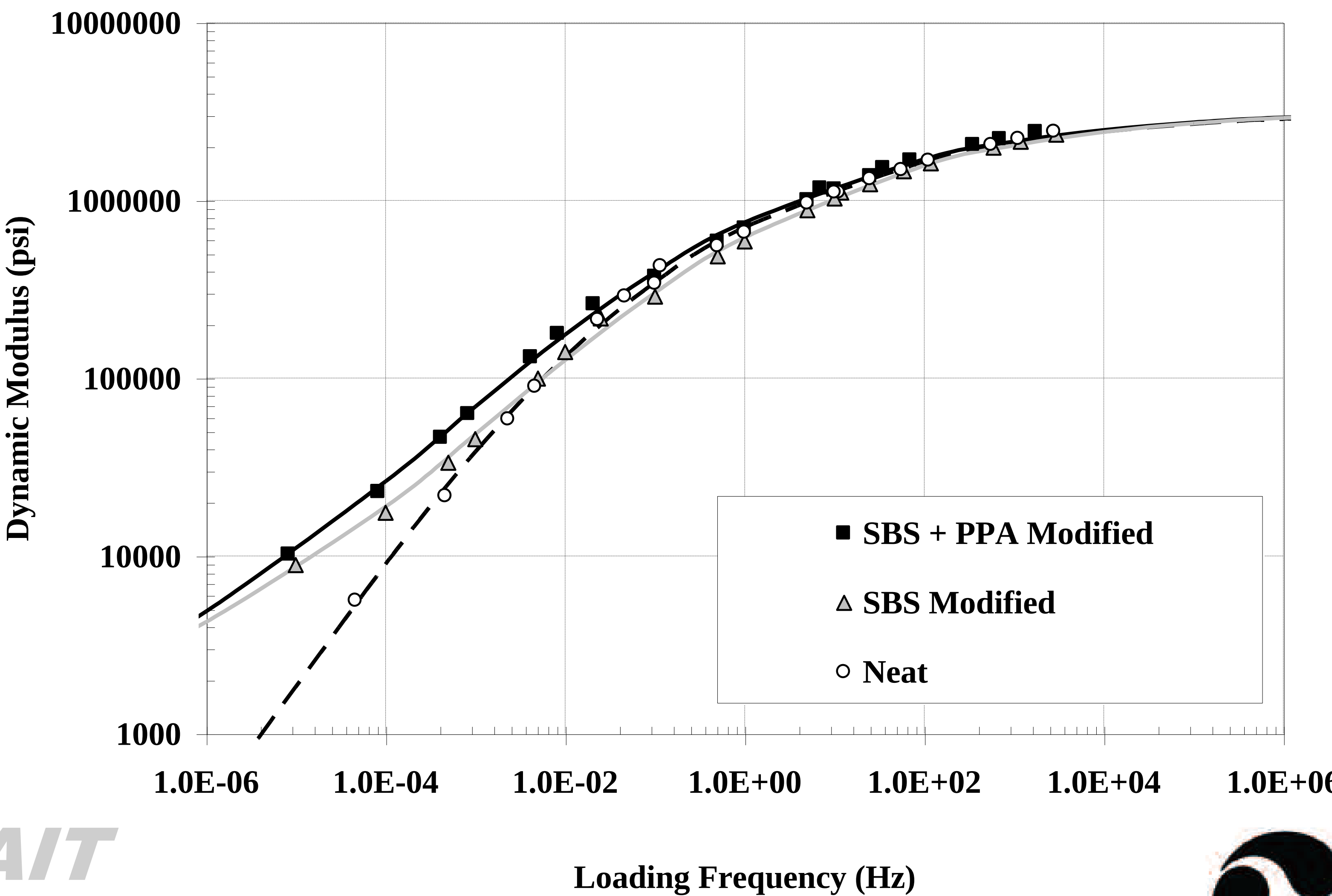
Dynamic Modulus Testing

- Used to evaluate the mixture stiffness at different temperatures and loading speeds
  - 4.4, 20, and 45°C
  - 25, 10, 5, 1, 0.5, 0.1, 0.01 Hz
- Test sensitive to changes in binder grades, RAP, production temperatures, etc. (anything that would influence stiffness)



E* - Short Term Oven Aged



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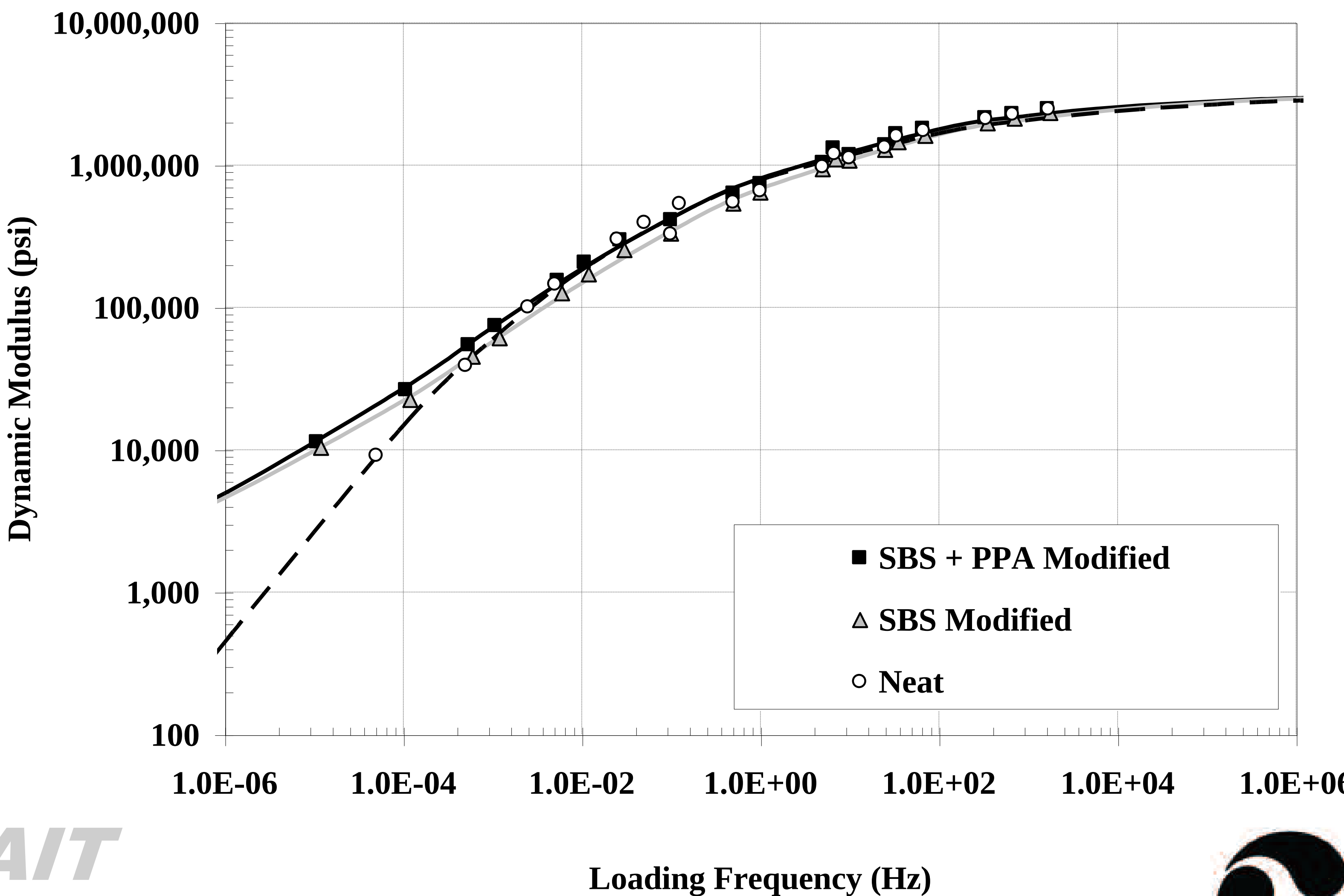
E* - Long Term Oven Aged



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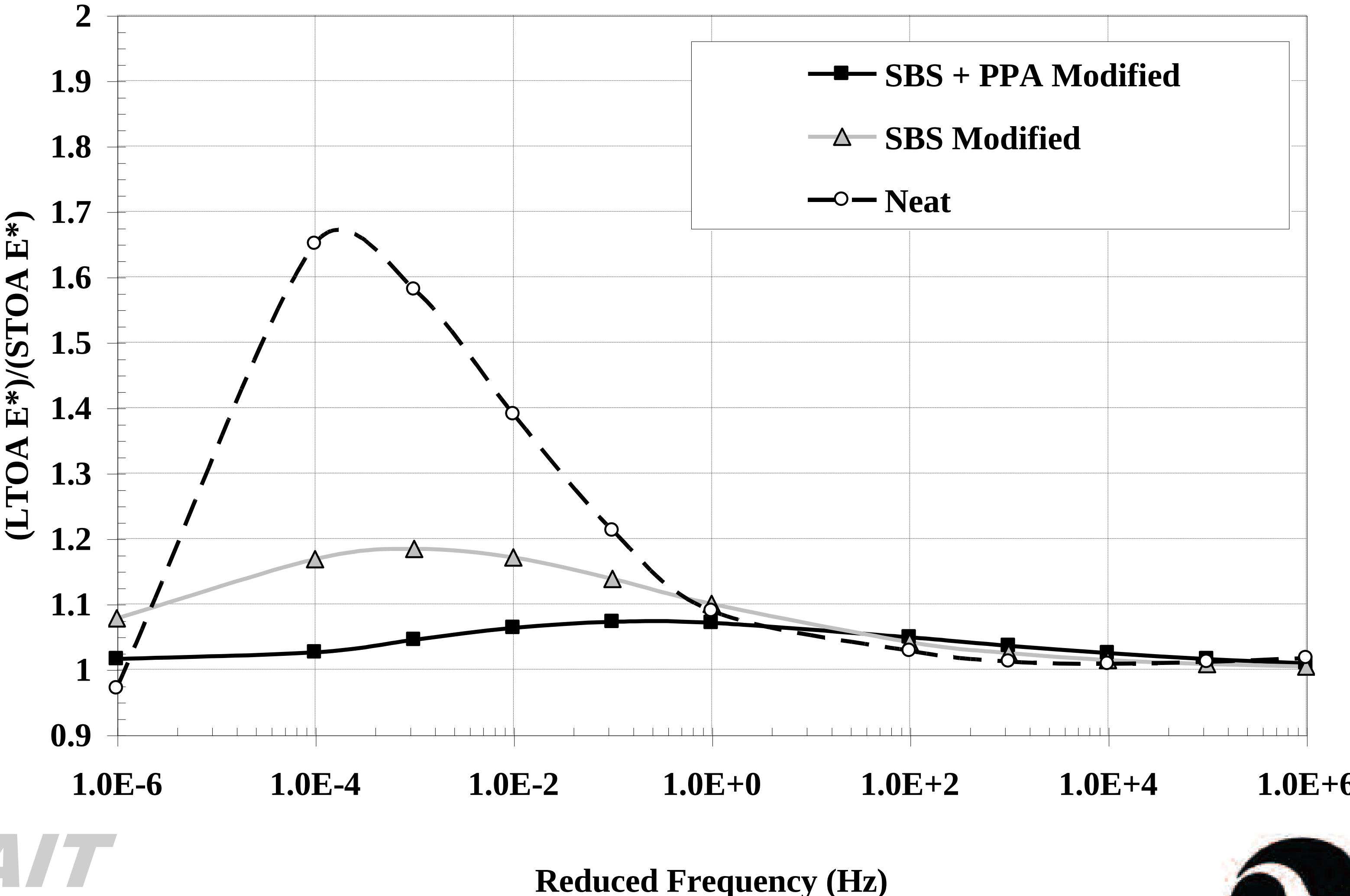
E* Aging Ratio



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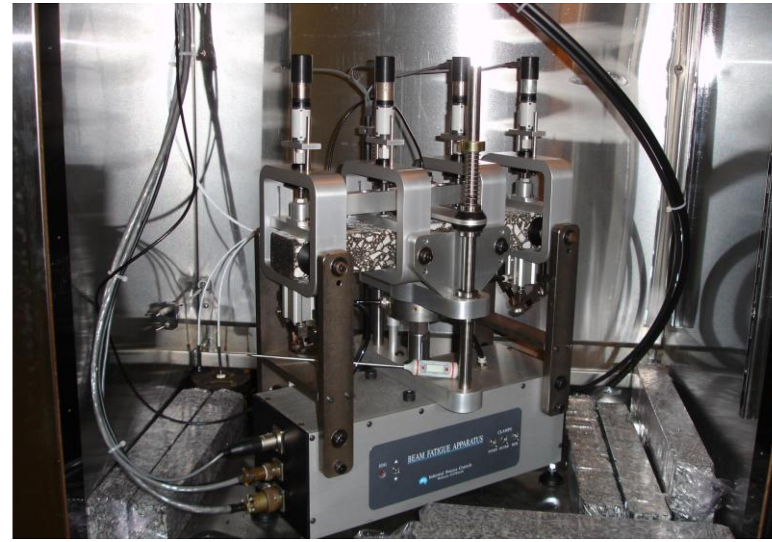
Fatigue Evaluation

- Flexural Beam Fatigue Device, AASHTO T-321, 10 Hz, 20°C
- Tests mix's ability to withstand repeated bending which causes fatigue failure (Crack Initiation)
- Run at different tensile strains to simulate different applied loads



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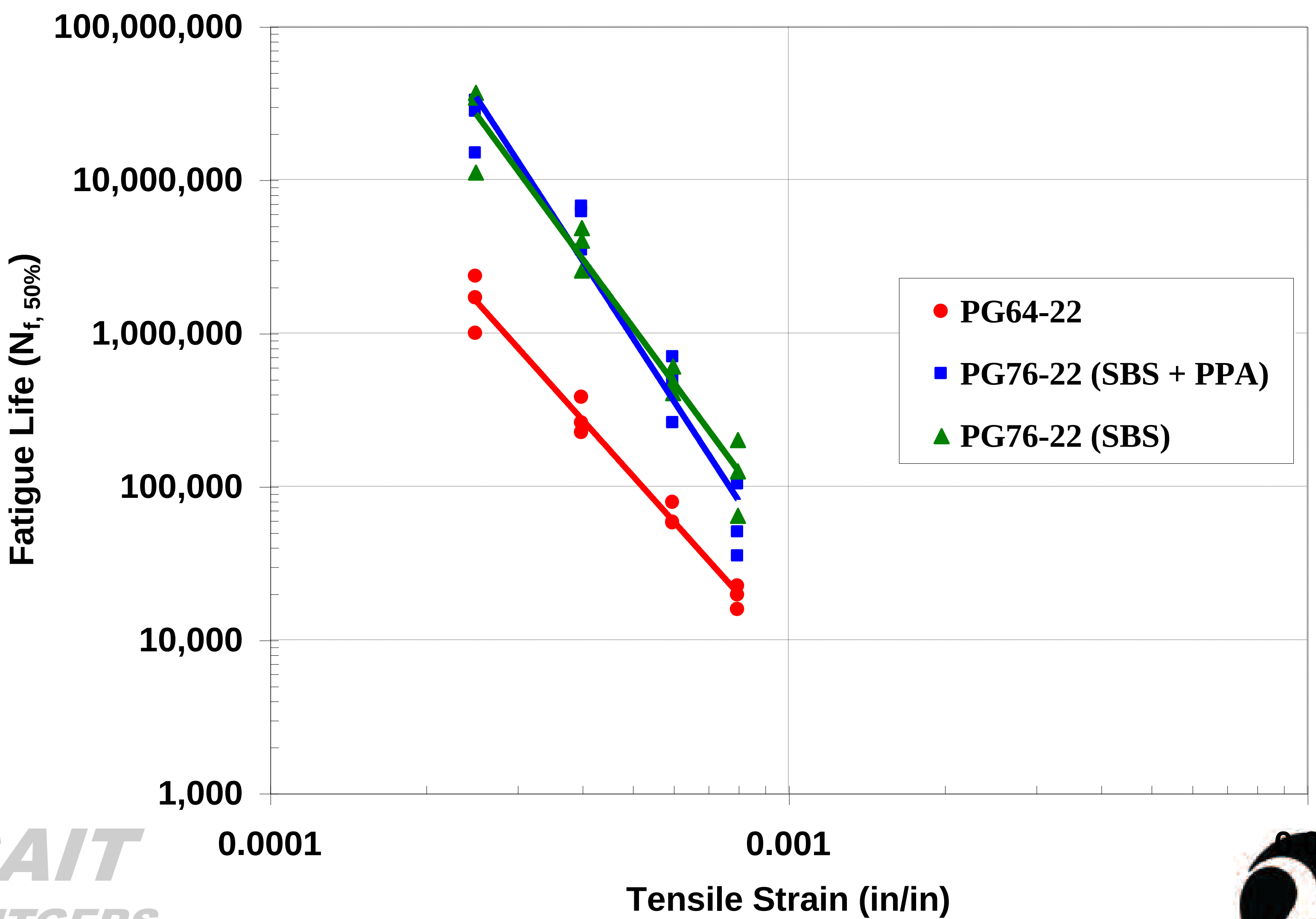
AASHTO T321 - STOA



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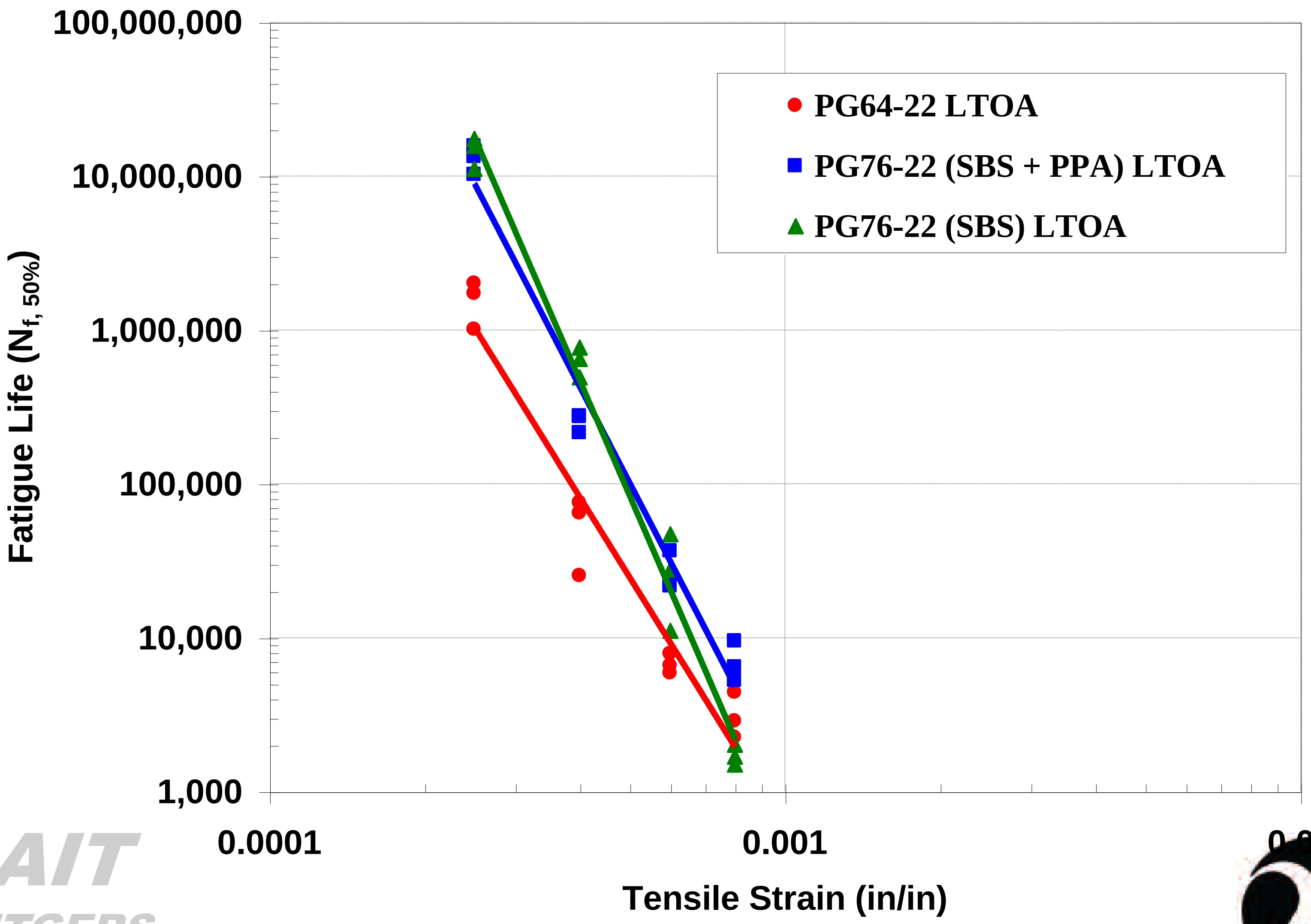
AASHTO T321 - LTOA



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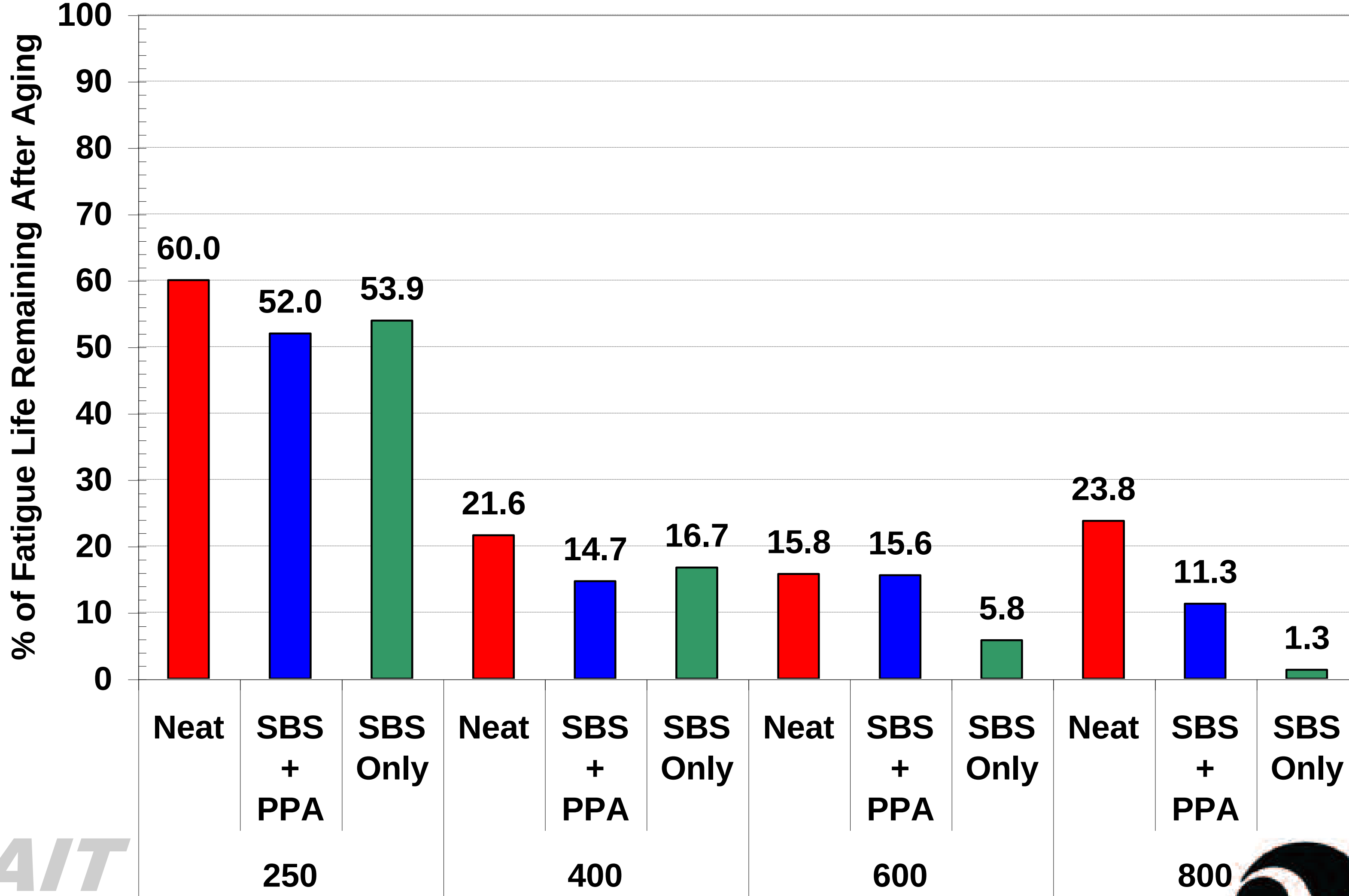
Decrease in Flexural Fatigue Due to Aging



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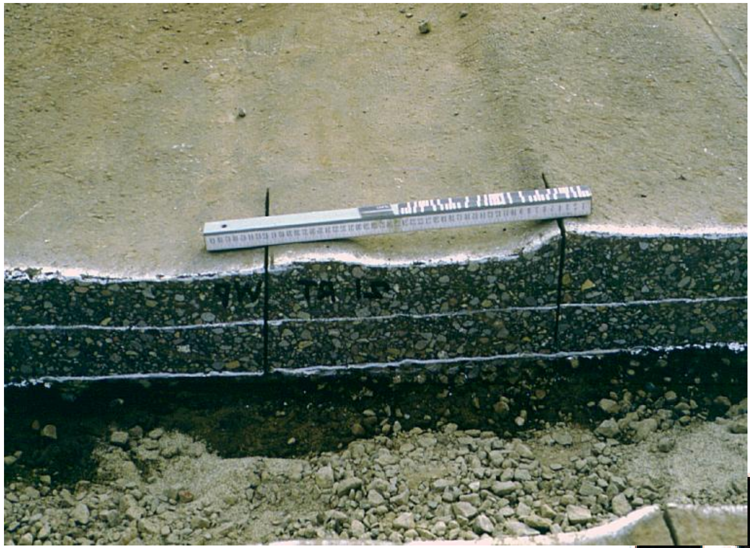
Permanent Deformation

- Unconfined, uniaxial repeated loading (NCHRP 465, Appendix B)
- 10 psi deviatoric
- 50 percent reliability, 7-day average maximum pavement temperature at a depth of 25 mm for New Jersey = 54.4°C



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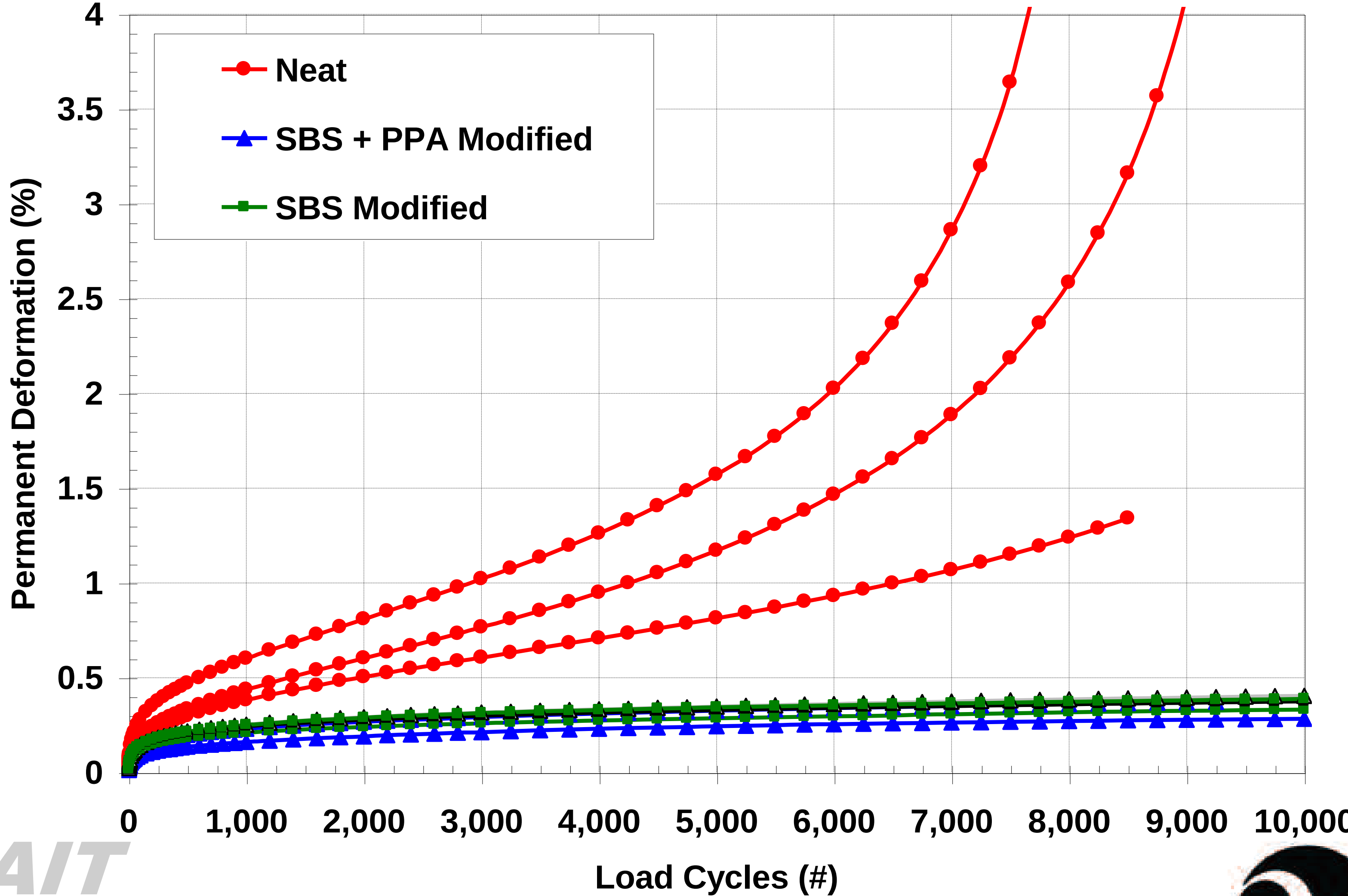
Repeated Load Permanent Deformation



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Evaluation of Permanent Deformation Data

- Permanent deformation data evaluated using preliminary guidelines developed by AAT for the MDSHA
- The guidelines based on limiting rutting in HMA to 10mm

Traffic Level, million ESAL	Permanent Axial Strain After 5,000 load cycles for 10 psi Axial Load, %
0.1	15.7
0.3	5.10
1.0	1.49
3.0	0.49
10	0.14
30	0.05
100	0.01

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HMA Rutting Prediction

Sample Type	Sample ID	ε_p @ 5,000 Cycles (%)	Estimated Traffic to 10mm Rut Depth (Million ESAL's)
Neat	#1	1.57	1.2
	#2	1.17	
	#3	0.82	
	Average	*1.19*	
	Std Dev.	*0.38*	
SBS Modified	#1	0.29	4.3
	#2	0.33	
	#3	0.34	
	Average	*0.32*	
	Std Dev.	*0.03*	
SBS + PPA Modified	#1	0.24	4.5
	#2	0.35	
	#3	0.33	
	Average	*0.31*	
	Std Dev.	*0.06*	

Tensile Strength Ratio (TSR)

- Susceptibility to Moisture Damage conducted in accordance with AASHTO T283
- Tensile Strength Ratio (TSR) determined for each binder type

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Tensile Strength Ratio (TSR)

Specimen Type	Average Air Voids (%)	Indirect Tensile Strength (psi)		Average TSR (%)
		Dry	Conditioned	
Neat	7.2	164.6	126.2	76.7
SBS+PPA	6.9	230.5	204.8	88.9
SBS	7.1	221.3	194.4	87.8

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Conclusions from Study

- Dynamic modulus testing showed that both modified asphalts provided very similar modulus values after undergoing long-term oven aging
  - The SBS+PPA modified asphalt achieved slightly higher modulus values at higher test temperatures at the short-term oven aged (STOA) condition
  - When evaluating the ratio between LTOA and STOA modulus, the SBS+PPA asphalt achieved slightly lower ratios than the SBS modified asphalt. This may indicate that the SBS modified asphalt underwent a greater extent of age hardening when compared to the SBS+PPA modified asphalt.

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Conclusions from Study

- SBS+PPA modified asphalt binder provided fatigue and durability resistance as well as SBS only binder
  - Flexural Beam Fatigue test results on short-term and long-term oven aged samples were statistically equal at a 95% confidence level
  - Tensile Strength Ratio (TSR) tests concluded that the SBS+PPA modified asphalt achieved a slightly higher TSR value than the SBS modified samples

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Conclusions from Study

- Repeated Load Permanent Deformation testing conducted on hot mix asphalt samples showed that both the SBS and SBS+PPA asphalts achieved almost identical resistances to permanent deformation when tested in uniaxial compression

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Thank you for your time!

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