Impact of WMA Additives on Modified Asphalt Mixtures

Sponsored by:
Paramount Petroleum Inc.

Conducted by:
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WMA TWG, Oklahoma City
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Objective

- Evaluate the use of WMA additives with typical polymer-modified and terminal blend tire rubber asphalt mixtures from NV and CA

Two Phase Study:

Phase I: Moisture Damage

Phase II: Performance Tests

Materials

- **1 aggregate source:**
  - *Lockwood* pit, Granite Construction – meets NDOT and Caltrans specs
- **3 binder types: supplied by Paramount**
  - *PG 64-22* – unmodified binder
  - *PG 64-28 NV/PM* – polymer-modified binder that meets both NV and PM specs
  - *PG 64-28 NVTR/TR* – terminal blended rubber binder that meets both NVTR and TR spec

Materials (Cont'd)

- **3 WMA additives:**
  - *Sasobit* (Sasol Wax North America)
  - *Advera* (PQ Corporation)
  - *Evotherm* (MeadWestvaco) *– wasn't received on time*
- **2 anti-strip additives:**
  - *Liquid anti-strip*: Morlife 5000 at 0.5% by wt of binder (Dow Chemical Company)
  - *Hydrated lime*: 1.0% dwa added on wet aggregates

Mix Designs

- Hveem Mix Design for heavy traffic: NV and CA specs
- Single aggregate gradation that meets both:
  - NDOT: Type 2C
  - Caltrans: ¾” Max – Type A
- Conduct Actual Designs of HMA & verify for WMA

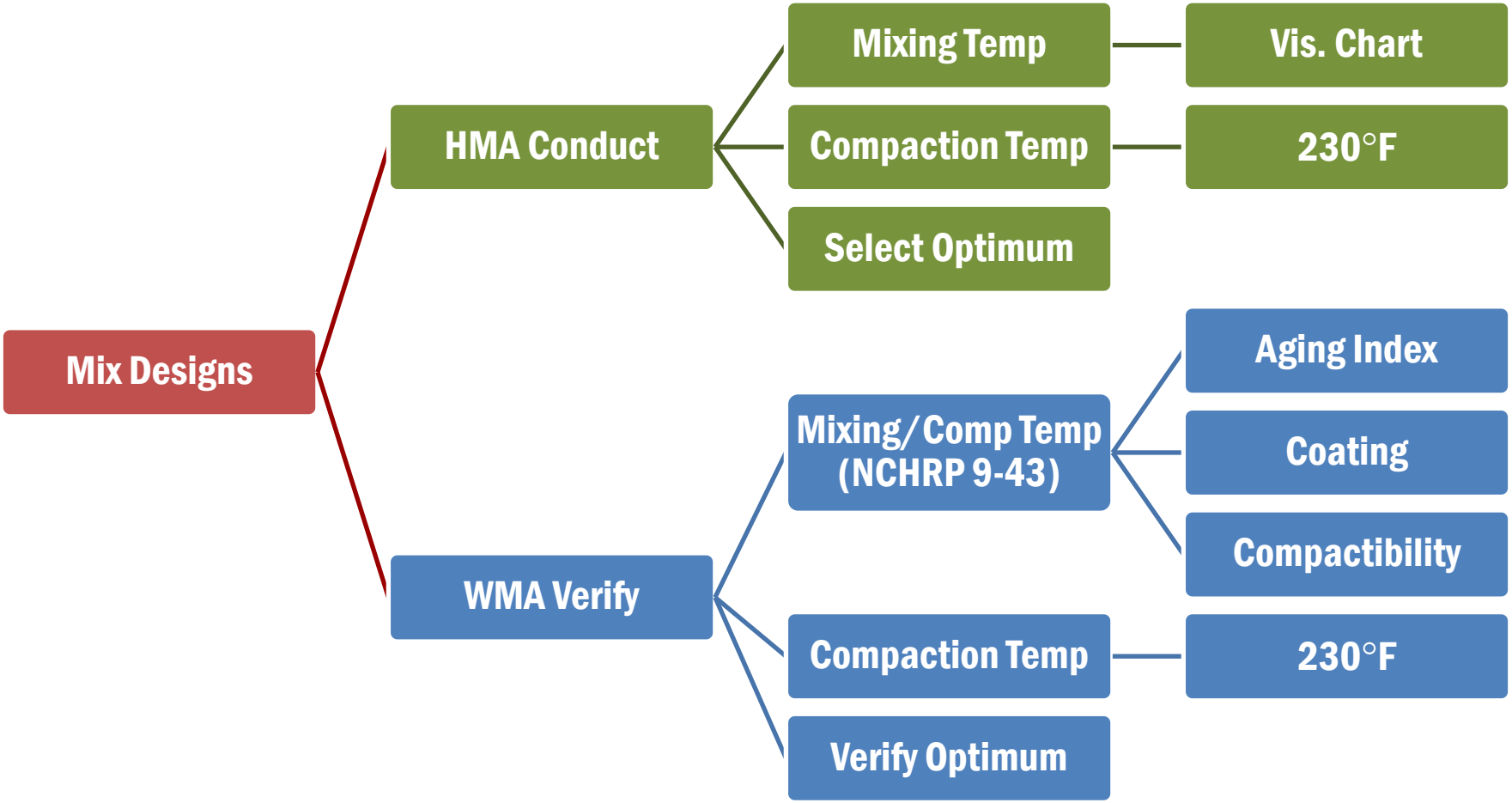
Evaluated Mixtures

	HMA	WMA - Advera	WMA - Sasobit
PG 64-22	X	X	X
PG64-28NV/PM	X	X	X
PG64-28NV-TR/TR	X	X	X

X = un-treated, Lime-treated, Liquid-treated

Total: 27 mixtures

Mix Designs Process

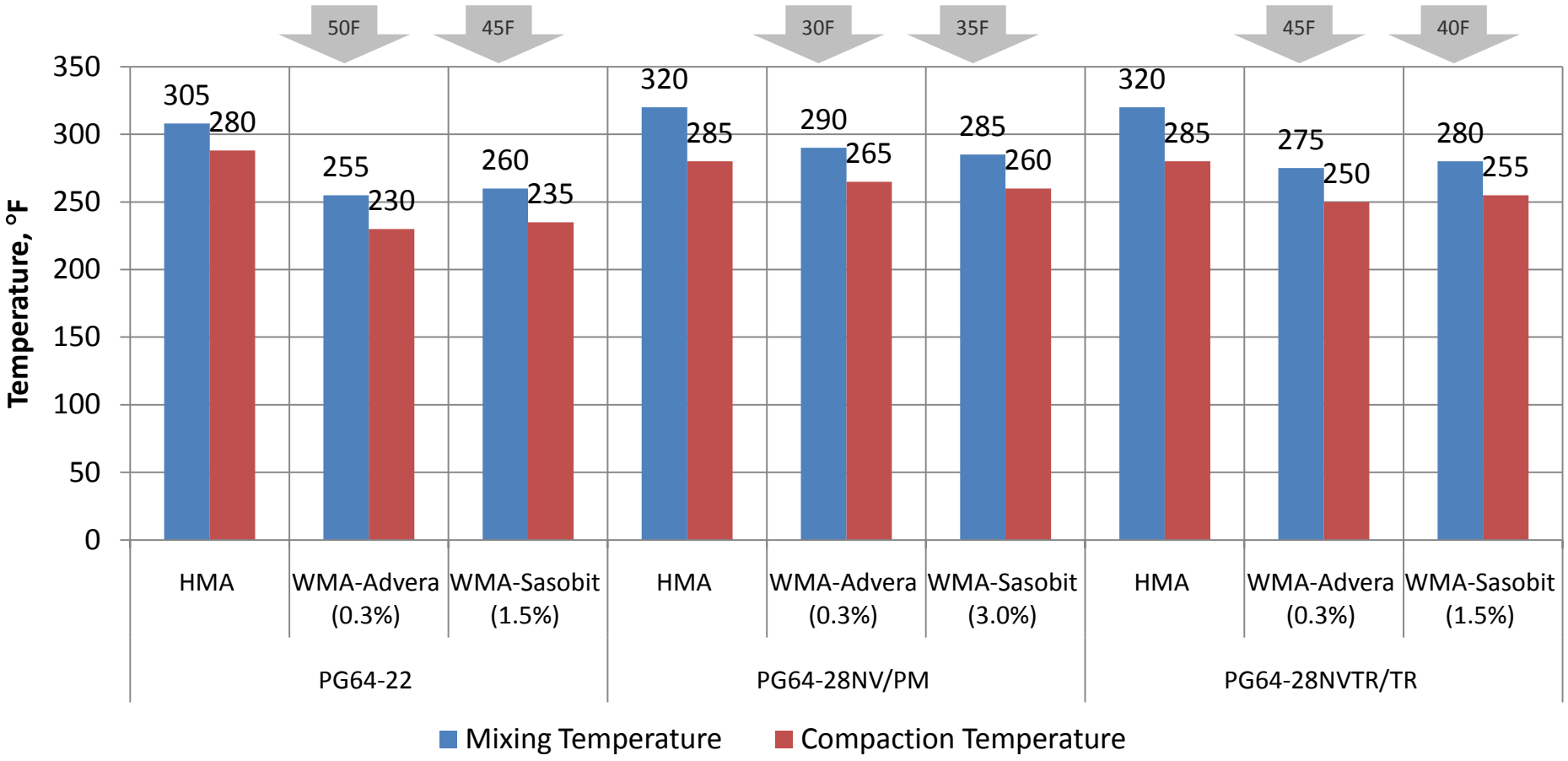


WMA Temperatures

- **WMA production temperatures**
  - ***Mixing Temperature***
    - **Aging Index (AI) – min mixing temp**
    - **Degree of Aggregate Coating (T195)**
  - ***Compaction Temperature***
    - **Compactability in Superpave Gyratory:**

      N_{92} @ (T_{Comp} - 54°F) $\leq$ 1.25*N_{92} @ T_{Comp}
    - **Not used in Mix Designs**

Mixing/Compaction Temperatures



Verify Optimum Designs for WMA and Treated Mixtures

- At the HMA Optimum and +/- 1%
  - Mix at WMA mixing temperature
  - Compact at 230°F
  - Measure stability, Va, VMA and VFA
  - Select optimums

Optimum Binder Contents

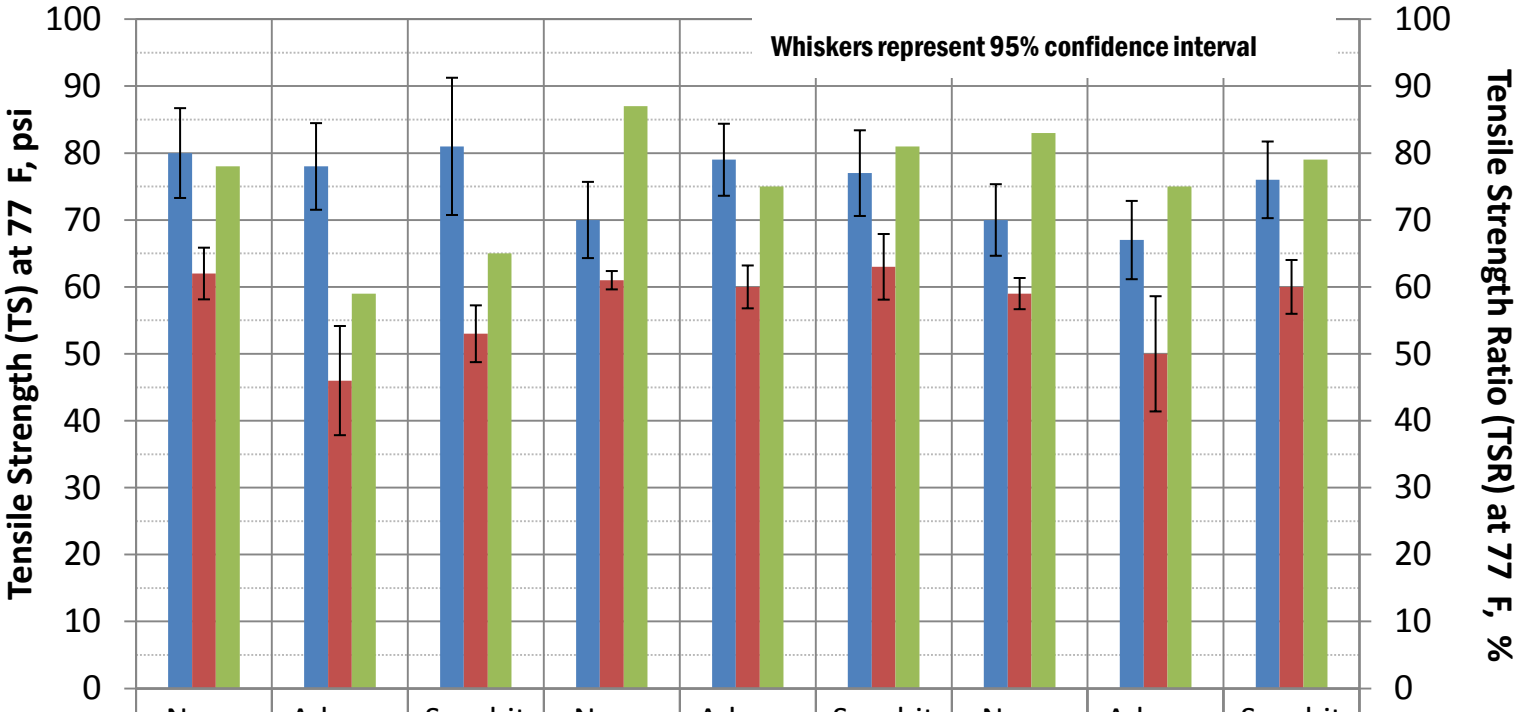
Mix Type	Treatment	PG64-22	PG64-28NV	PG64-28TR
HMA	Un-treated	5.7	5.8	5.7
	Lime-Treated	5.6	5.6	5.6
	Liquid-Treated	5.7	5.8	5.7
WMA-Advera (0.3% by TWM)	Un-treated	5.7	5.8	5.7
	Lime-Treated	5.6	5.6	5.6
	Liquid-Treated	5.7	5.8	5.7
WMA-Sasobit (1.5% by WB)*	Un-treated	5.7	5.8	5.7
	Lime-Treated	5.6	5.6	5.6
	Liquid-Treated	5.7	5.8	5.7

*** 3.0% Sasobit by WB was used for the PG64-28NV binder**

Moisture Sensitivity

Tensile Strength at 77°F

Un-treated Mixes

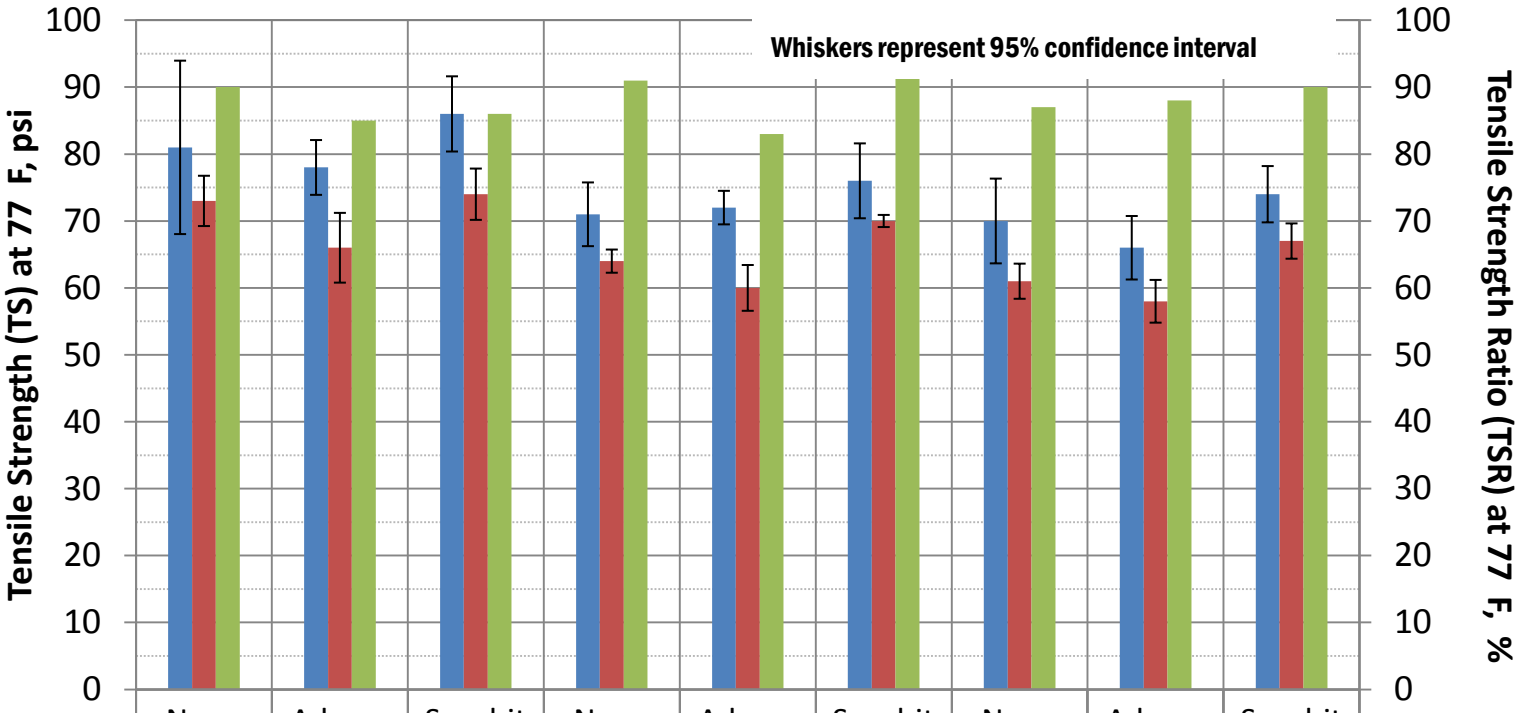


	PG 64-22			PG 64-28NV			PG 64-28NVTR		
	None	Advera	Sasobit	None	Advera	Sasobit	None	Advera	Sasobit
Unconditioned TS, psi	80	78	81	70	79	77	70	67	76
Conditioned TS, psi	62	46	53	61	60	63	59	50	60
TSR, %	78	59	65	87	75	81	83	75	79

Moisture Sensitivity

Tensile Strength at 77°F

Lime-treated Mixes

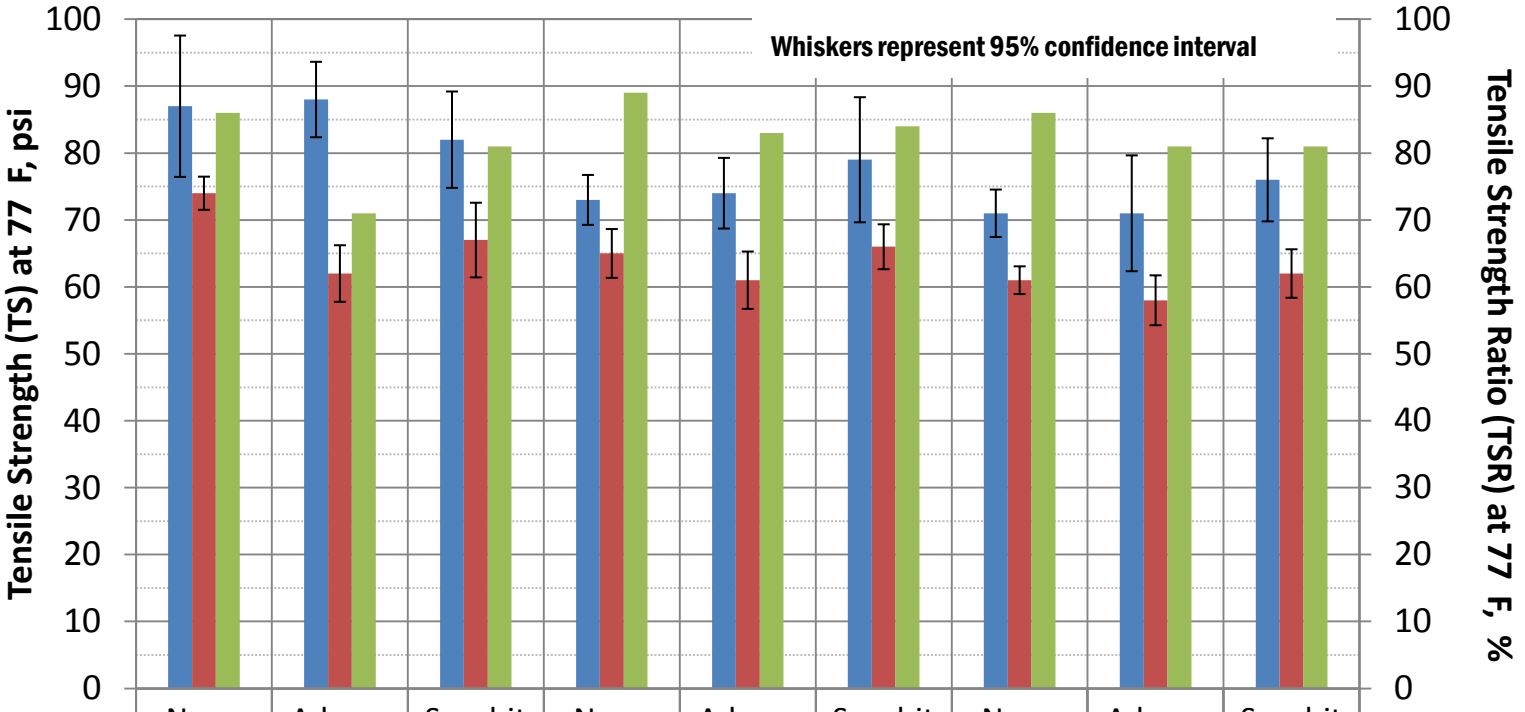


	PG 64-22			PG 64-28NV			PG 64-28NVTR		
	None	Advera	Sasobit	None	Advera	Sasobit	None	Advera	Sasobit
Unconditioned TS, psi	81	78	86	71	72	76	70	66	74
Conditioned TS, psi	73	66	74	64	60	70	61	58	67
TSR, %	90	85	86	91	83	92	87	88	90

Moisture Sensitivity

Tensile Strength at 77°F

Liquid-treated Mixes



	PG 64-22			PG 64-28NV			PG 64-28NVTR		
	None	Advera	Sasobit	None	Advera	Sasobit	None	Advera	Sasobit
Unconditioned TS, psi	87	88	82	73	74	79	71	71	76
Conditioned TS, psi	74	62	67	65	61	66	61	58	62
TSR, %	86	71	81	89	83	84	86	81	81

Experimental Plan – Phase I

Resistance to Moisture Damage

– WMA mixtures prepared at identified Mixing & Compaction temperatures

I. Impact of Residual Moisture on Un-treated Mixes

II. Impact of Anti-strip Additives
   - Lime
   - Liquid Anti-Strip (LAS)

III. Impact of Long-Term Aging

Determining Aggregate Residual Moisture

Process

- Add 2% water above SSD & soak for 15-18 hrs: *moist aggregate*
- *Calibration time: 100% dried moist agg.* at HMA mixing temp.
- Use *calibration time* to heat *moist aggregate* at WMA mixing temp.
- Moisture left in WMA agg. is: *residual moisture*

Impact of Residual Moisture

Measured Aggregate Residual Moisture

Mix Type	Treatment	PG64-22	PG64-28NV	PG64-28TR
HMA	Un-treated	0.00%	0.00%	0.00%
WMA-Advera (0.3% by TWM)	Un-treated	0.77%	0.13%	0.25%
WMA-Sasobit (1.5% by WB)*	Un-treated	0.68%	0.20%	0.15%

*** 3.0% Sasobit by WB was used for the PG64-28NV binder**

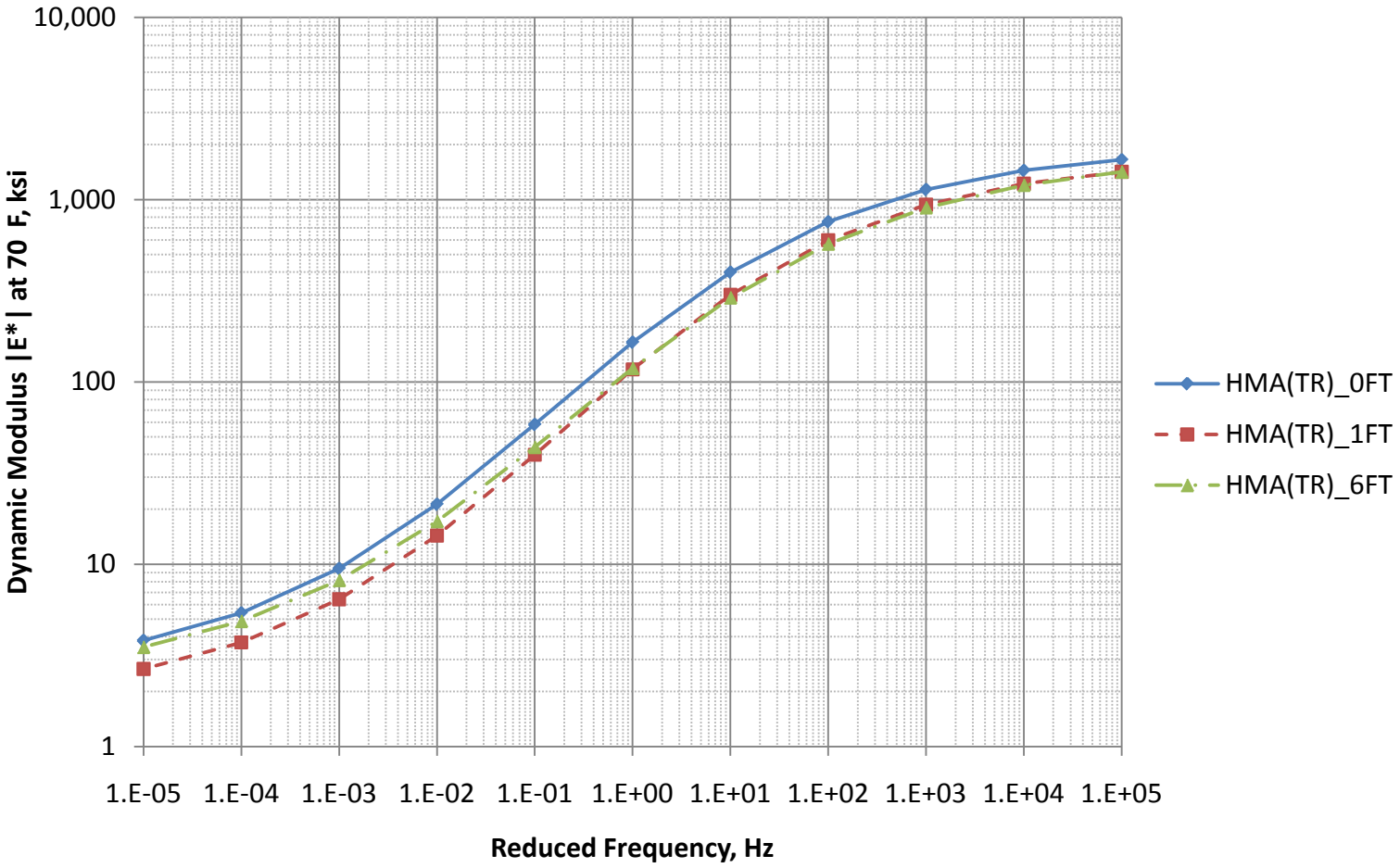
Impact of Residual Moisture

Experimental Plan

Property	Un-treated Mixes								
	PG 64-22			PG 64-28 NV/PM			PG 64-28 NVTR/TR		
	None	Advera	Sasobit	None	Advera	Sasobit	None	Advera	Sasobit
Without Residual Moisture									
$\|E^*\|$ vs. F-T cycles (unaged)	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles
With Residual Moisture									
$\|E^*\|_{Moist}$ vs. F-T cycles (unaged)	--	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	--	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	--	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles

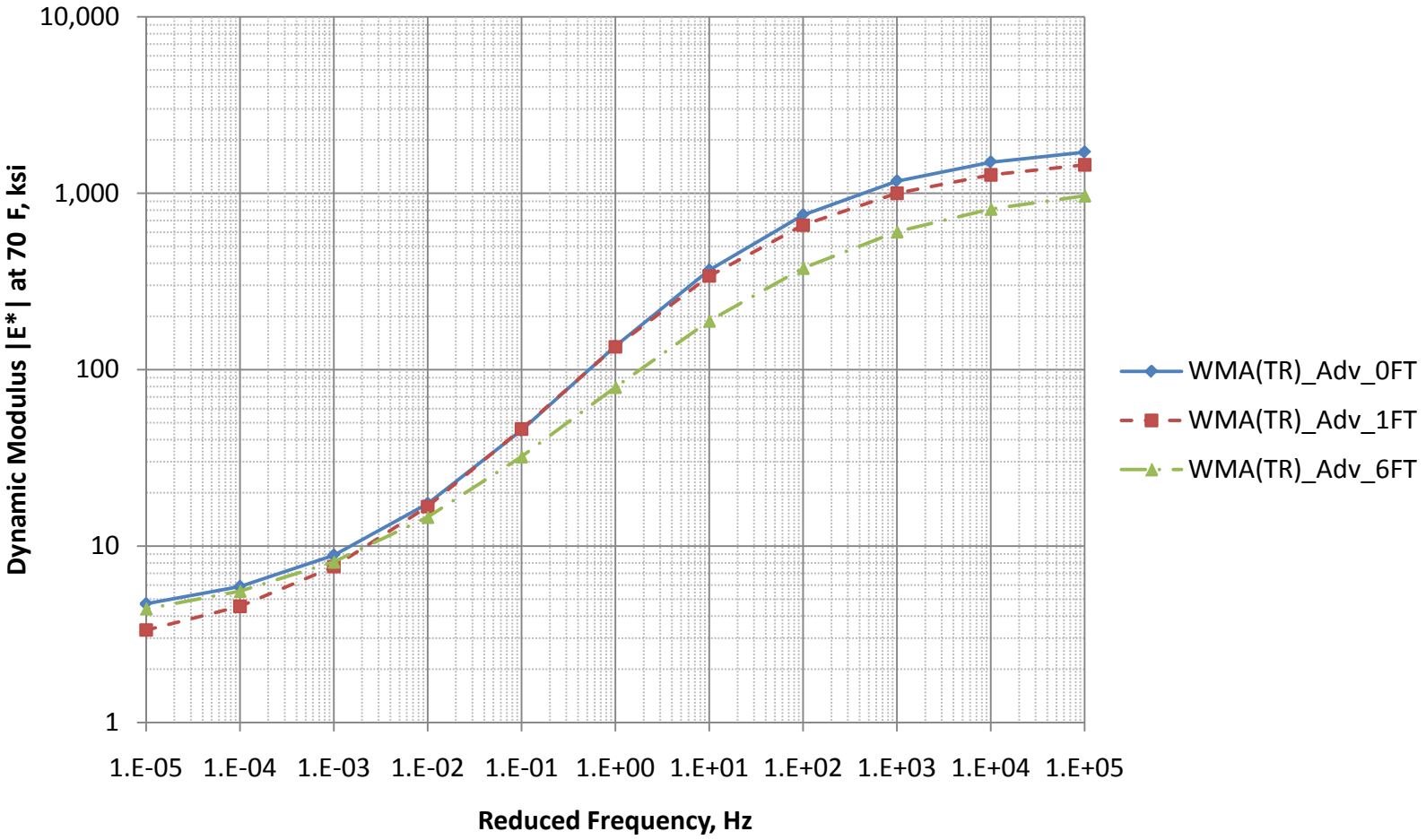
Impact of Residual Moisture

Selected Test Results – PG64-28TR Mix



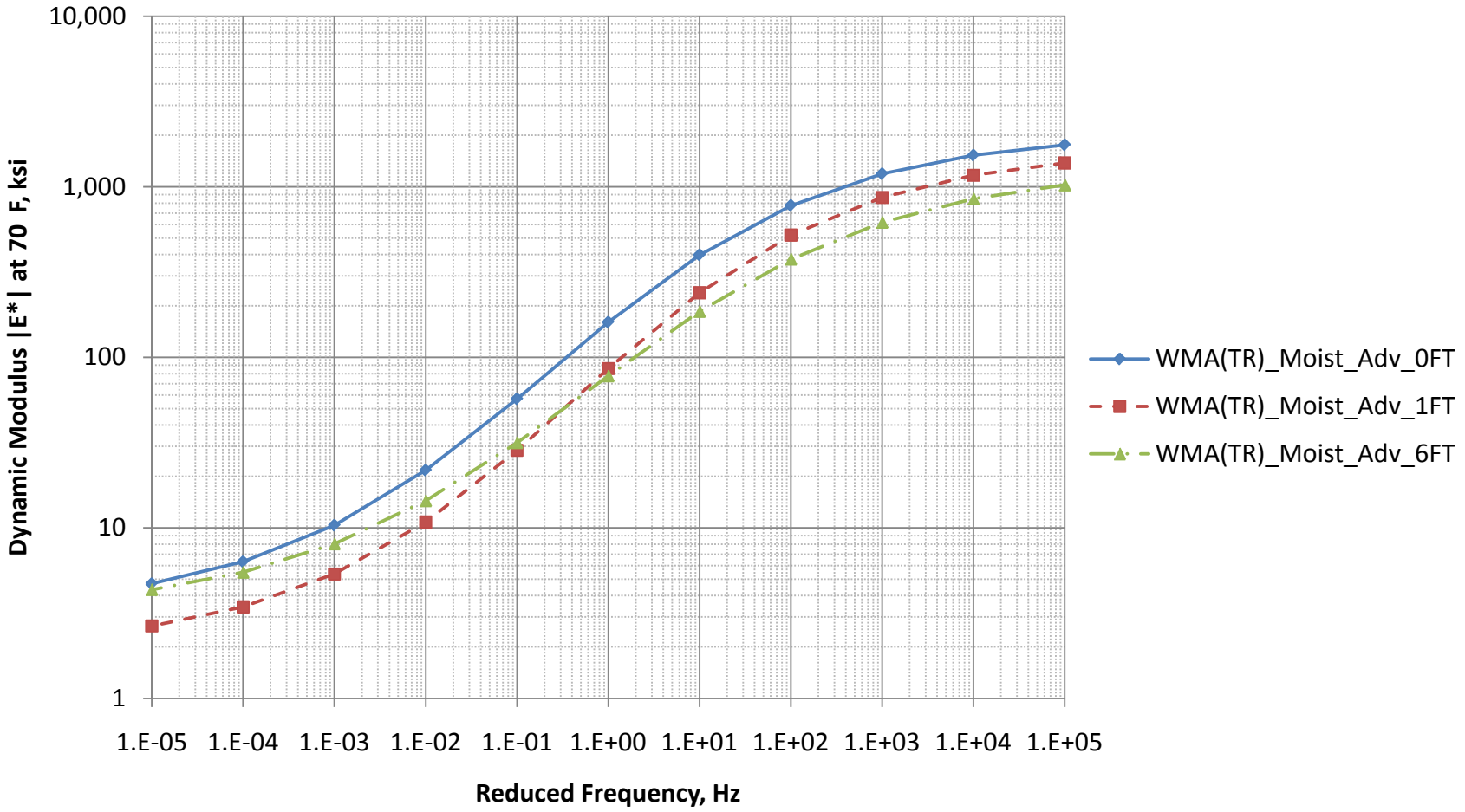
Impact of Residual Moisture

Selected Test Results – PG64-28TR Mix



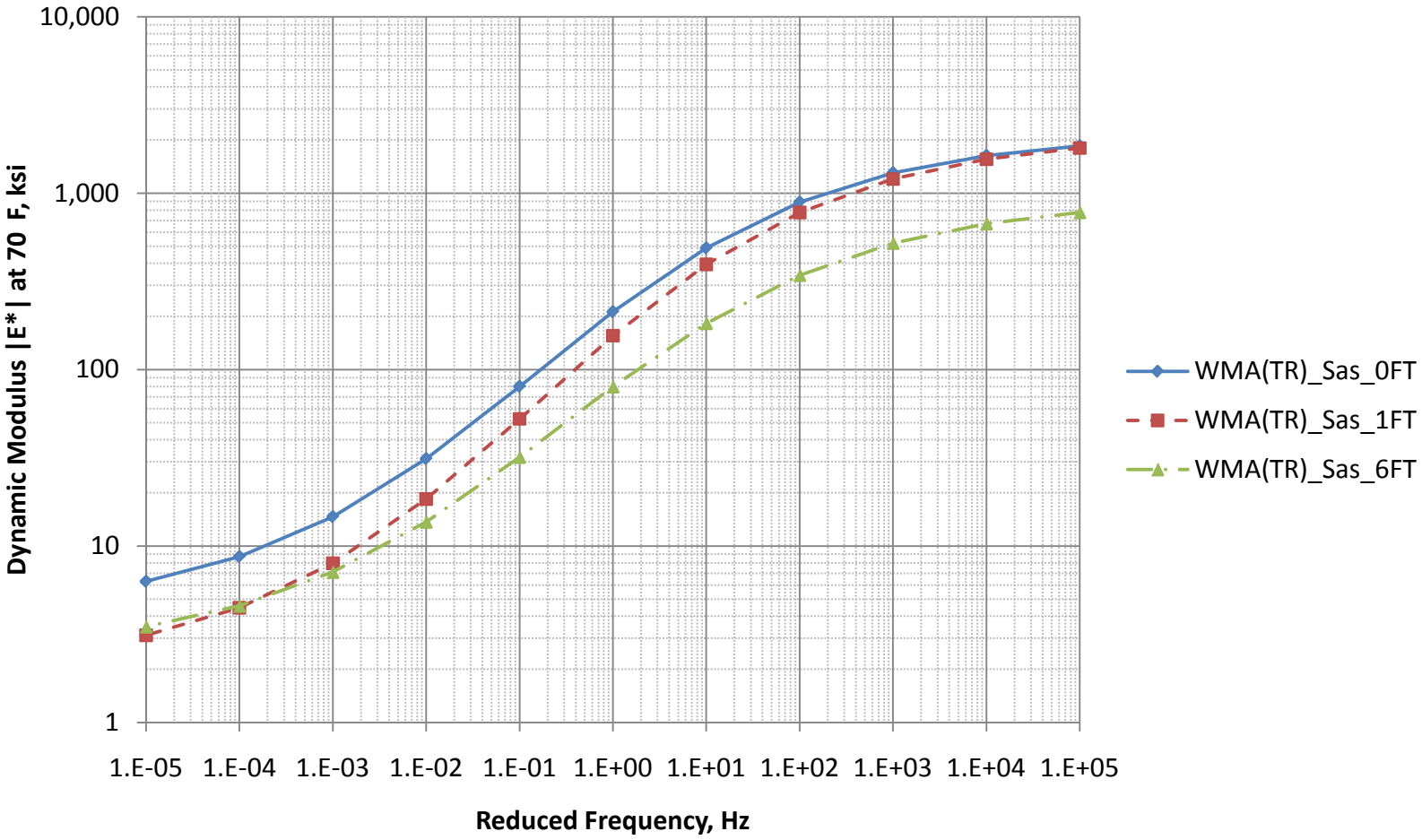
Impact of Residual Moisture

Selected Test Results – PG64-28TR Mix



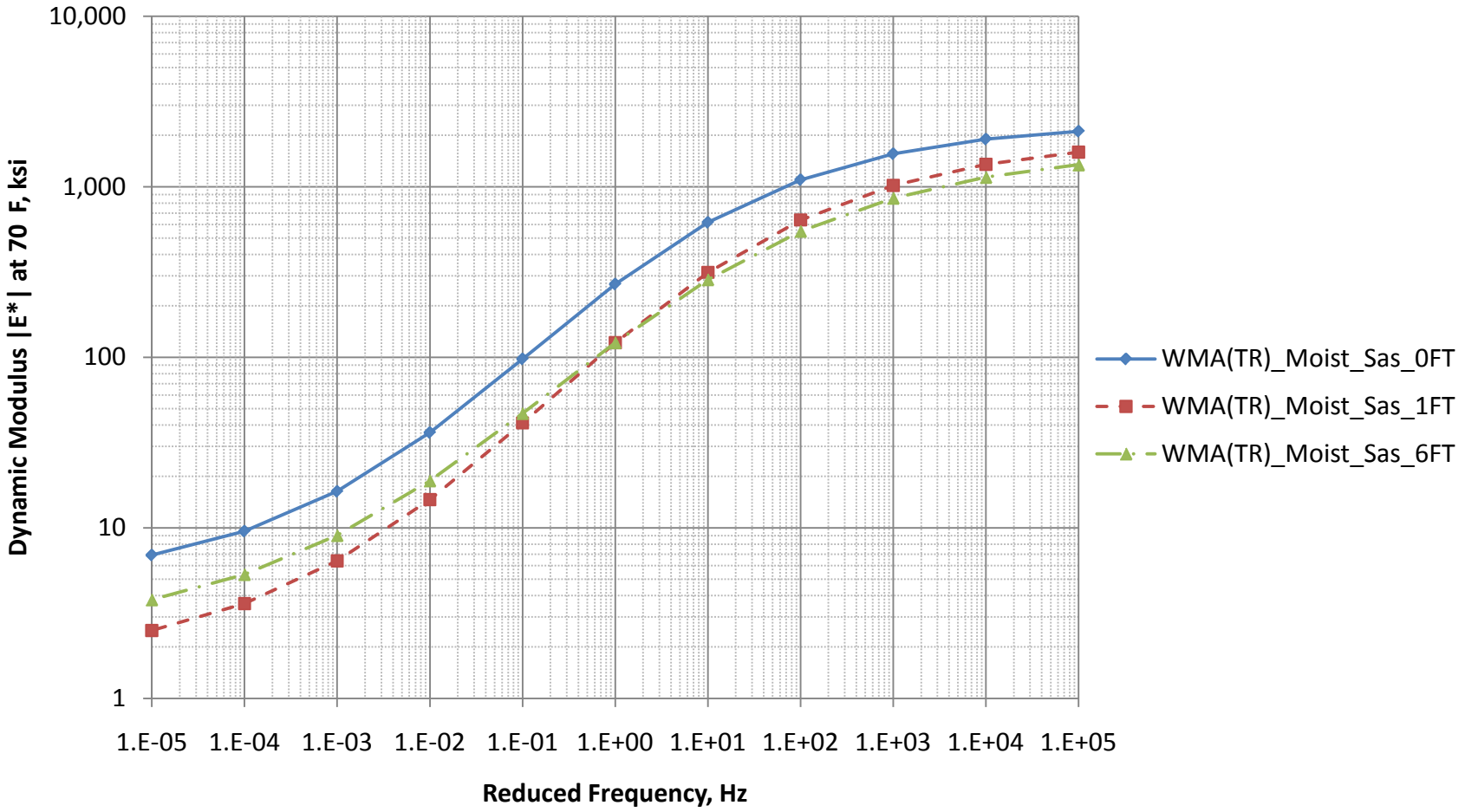
Impact of Residual Moisture

Selected Test Results – PG64-28TR Mix



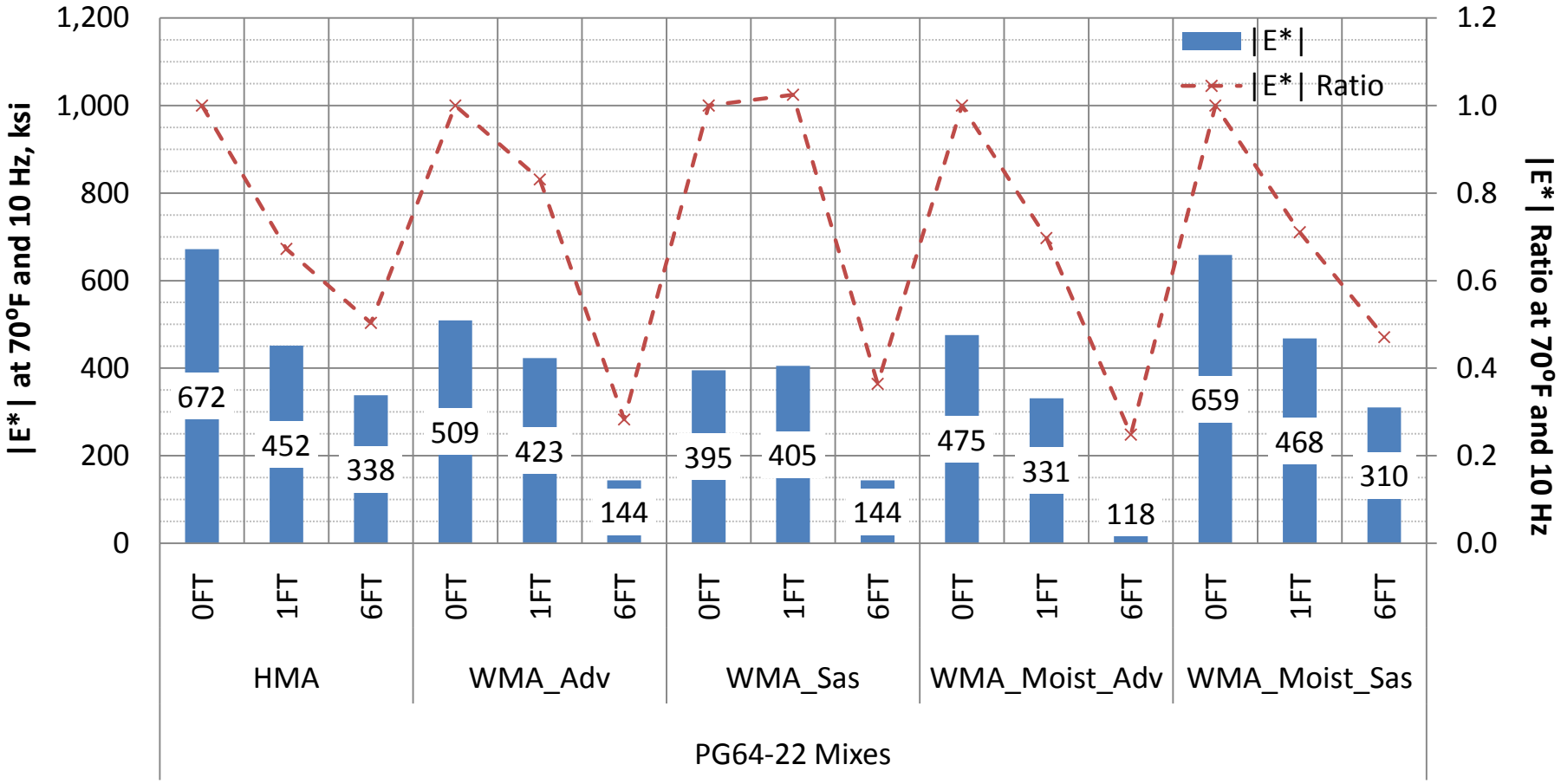
Impact of Residual Moisture

Selected Test Results – PG64-28TR Mix



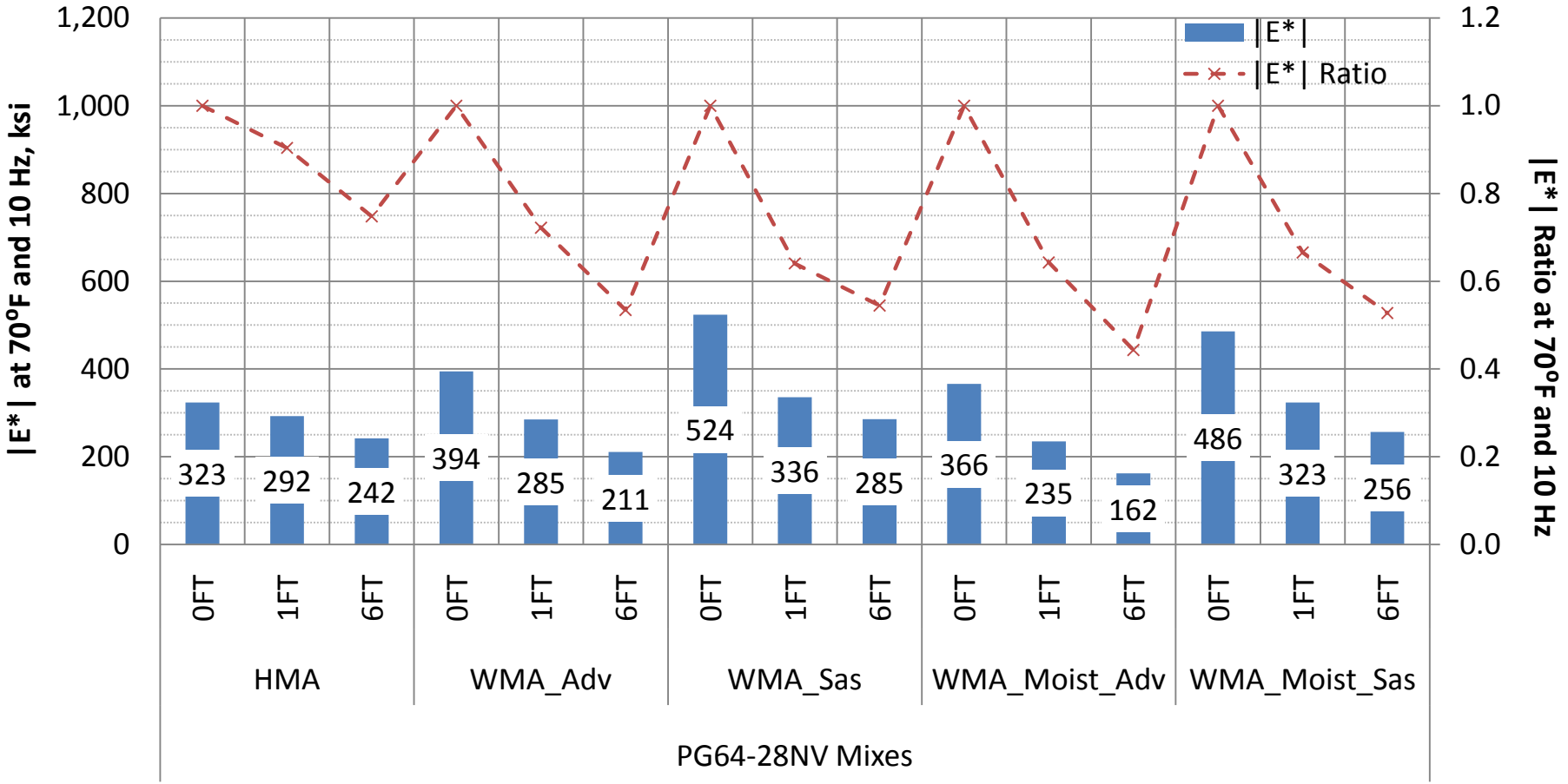
Impact of Residual Moisture

Summary of Results – PG64-22 Mixes



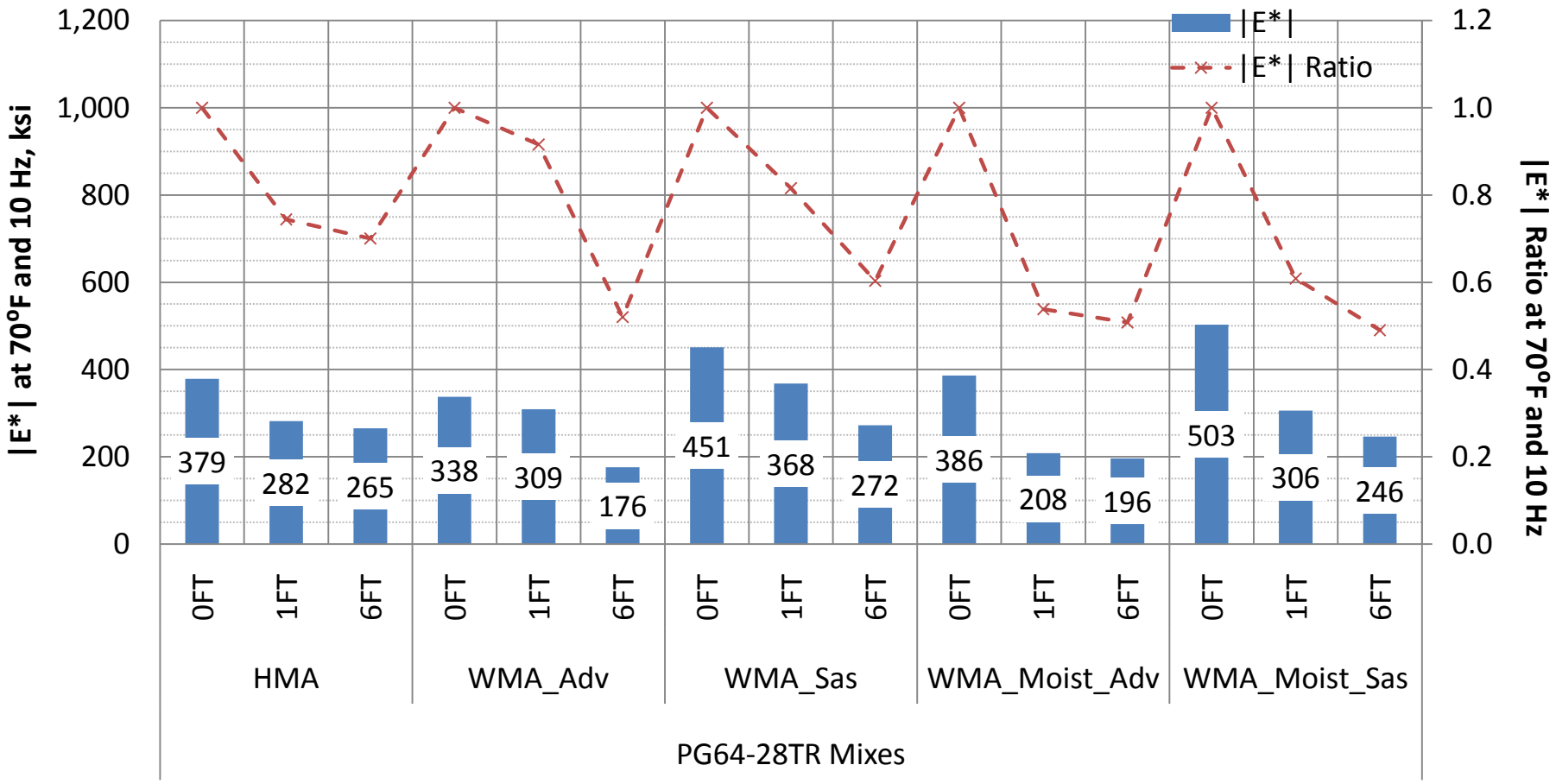
Impact of Residual Moisture

Summary of Results – PG64-28NV/PM Mixes



Impact of Residual Moisture

Summary of Results – PG64-28NVTR/TR Mixes



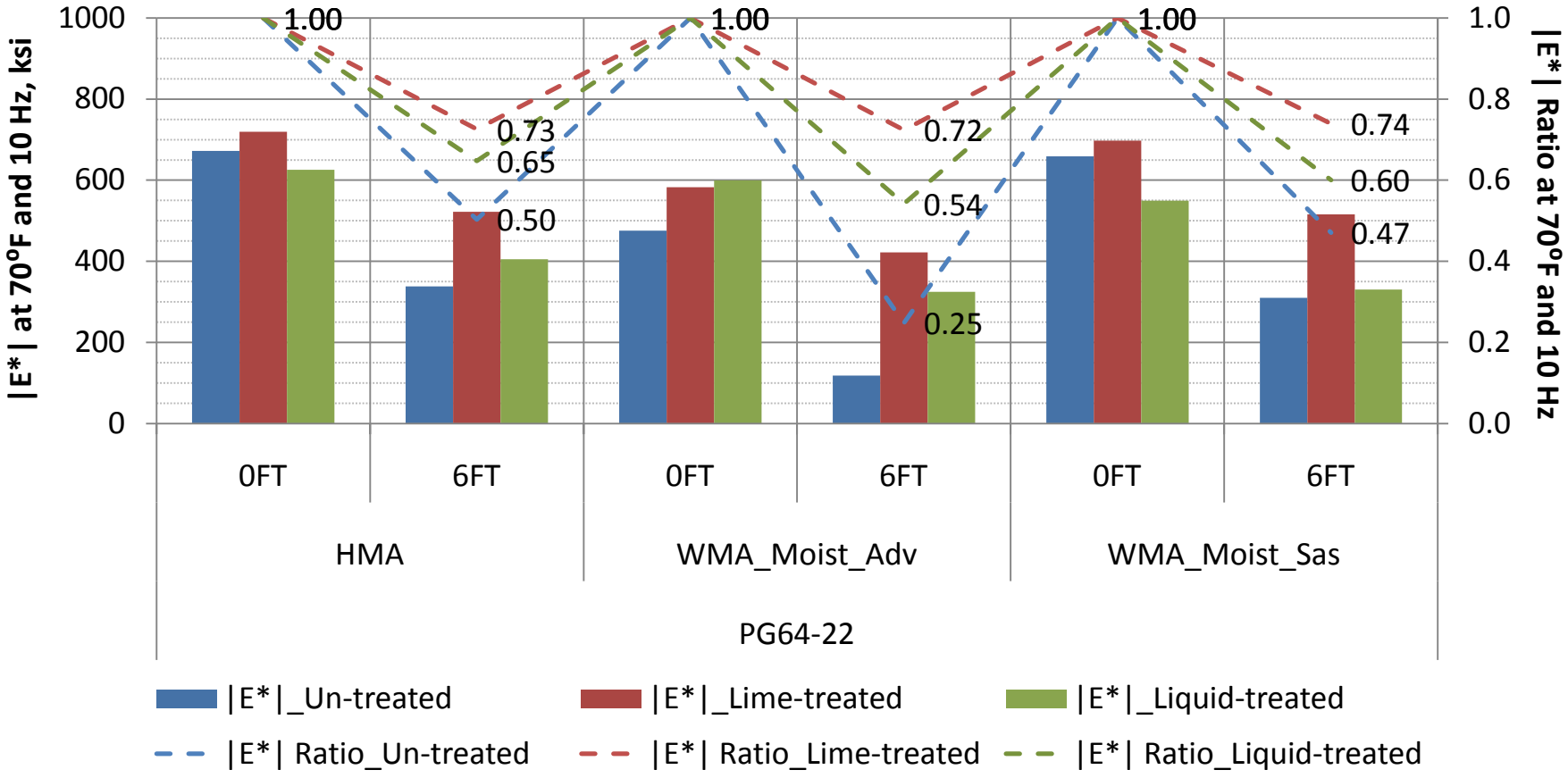
Experimental Plan/Number of Samples

Impact of Antistrip Additives

Property	Lime-treated Mixes / Liquid-treated Mixes								
	PG 64-22			PG 64-28 NV/PM			PG 64-28 NVTR/TR		
	None	Advera	Sasobit	None	Advera	Sasobit	None	Advera	Sasobit
	Without Residual Moisture								
$\|E^*\|$ vs. F-T cycles (unaged)	3 @ 0 and 6 FT cycles	--	--	3 @ 0 and 6 FT cycles	--	--	3 @ 0 and 6 FT cycles	--	--
	With Residual Moisture								
$\|E^*\|_{Moist}$ vs. F-T cycles (unaged)	--	3 @ 0 and 6 FT cycles	3 @ 0 and 6 FT cycles	--	3 @ 0 and 6 FT cycles	3 @ 0 and 6 FT cycles	--	3 @ 0 and 6 FT cycles	3 @ 0 and 6 FT cycles

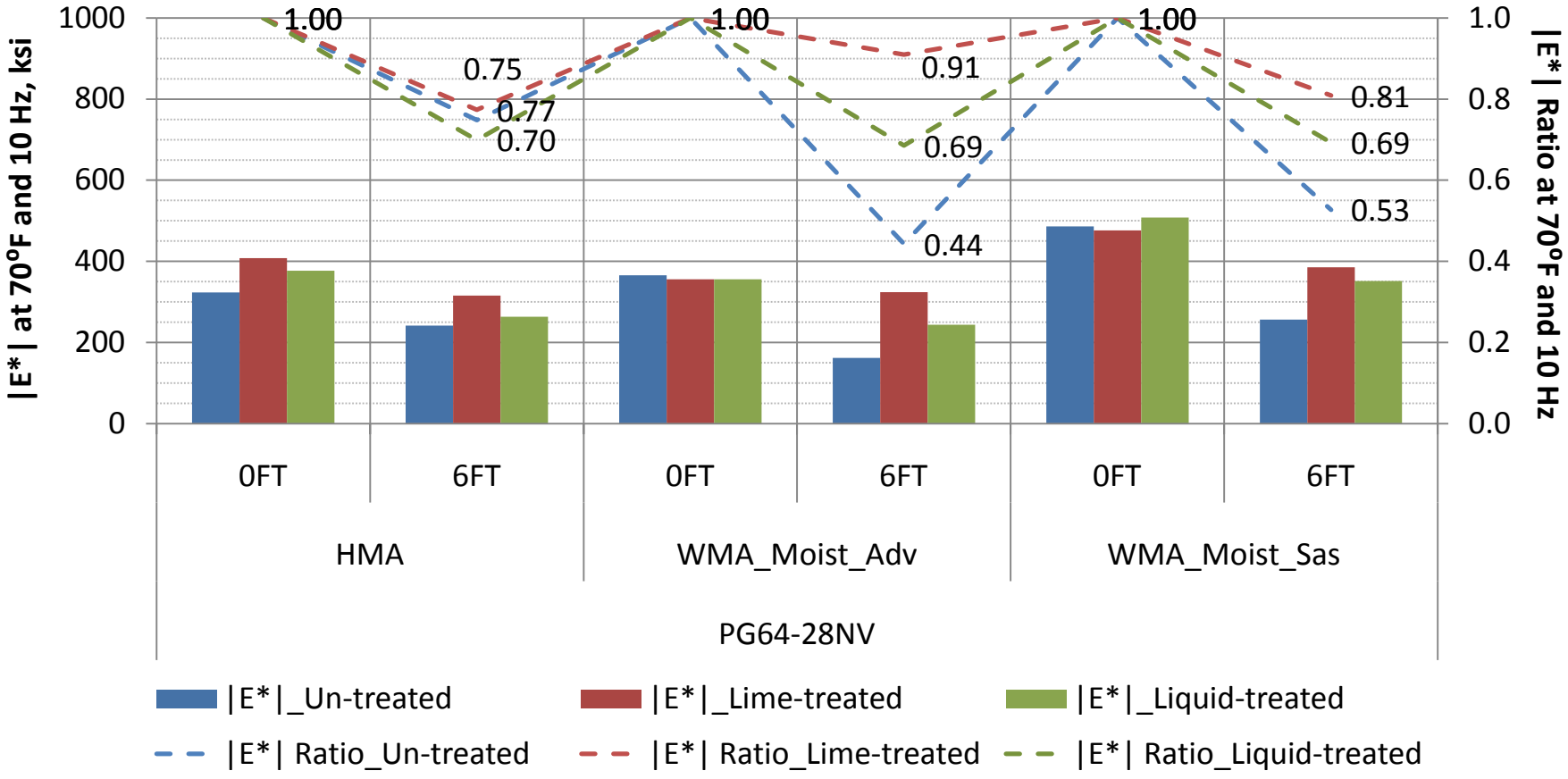
Impact of Antistrip Additives

Summary of Results – PG64-22 Mixes



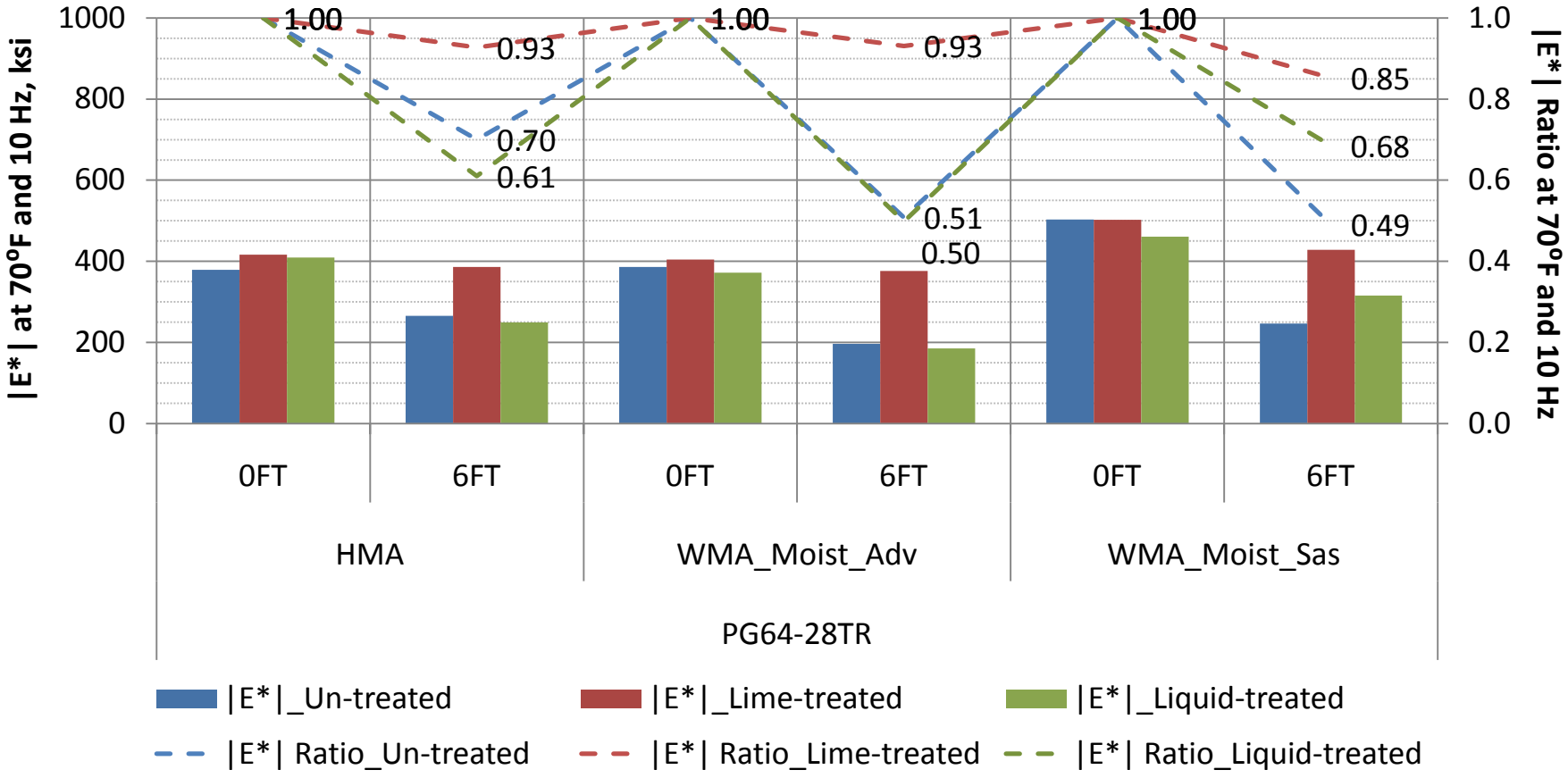
Impact of Antistrip Additives

Summary of Results – PG64-28NV Mixes



Impact of Antistrip Additives

Summary of Results – PG64-28TR Mixes



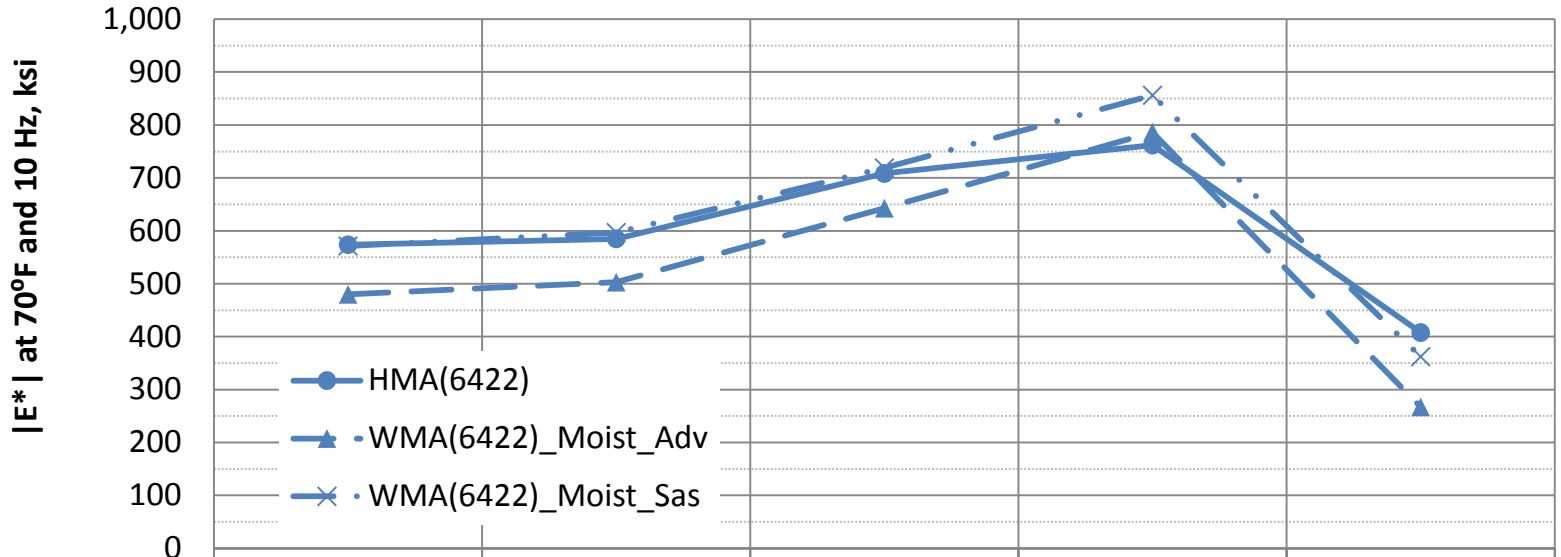
Experimental Plan/Number of Samples

Impact of Long-Term Aging

Property	Un-treated Mixes								
	PG 64-22			PG 64-28 NV/PM			PG 64-28 NVTR/TR		
	None	Advera	Sasobit	None	Advera	Sasobit	None	Advera	Sasobit
	With Residual Moisture for Advera and Sasobit WMA mixes								
$\|E^*\|_0$ (initial, t =0 days)	X	X	X	X	X	X	X	X	X
$\|E^*\|_{14}$ (after conditioning for 14 days at room temperature over the counter)	X	X	X	X	X	X	X	X	X
$\|E^*\|_{16}$ (after oven conditioning for 2 days at 185°F)	X	X	X	X	X	X	X	X	X
$\|E^*\|_{19}$ (after oven conditioning for 3 days at 185°F)	X	X	X	X	X	X	X	X	X
$\|E^*\|_{31}$ (after 6 F-T cycles)	X	X	X	X	X	X	X	X	X

Impact of Long-term Aging

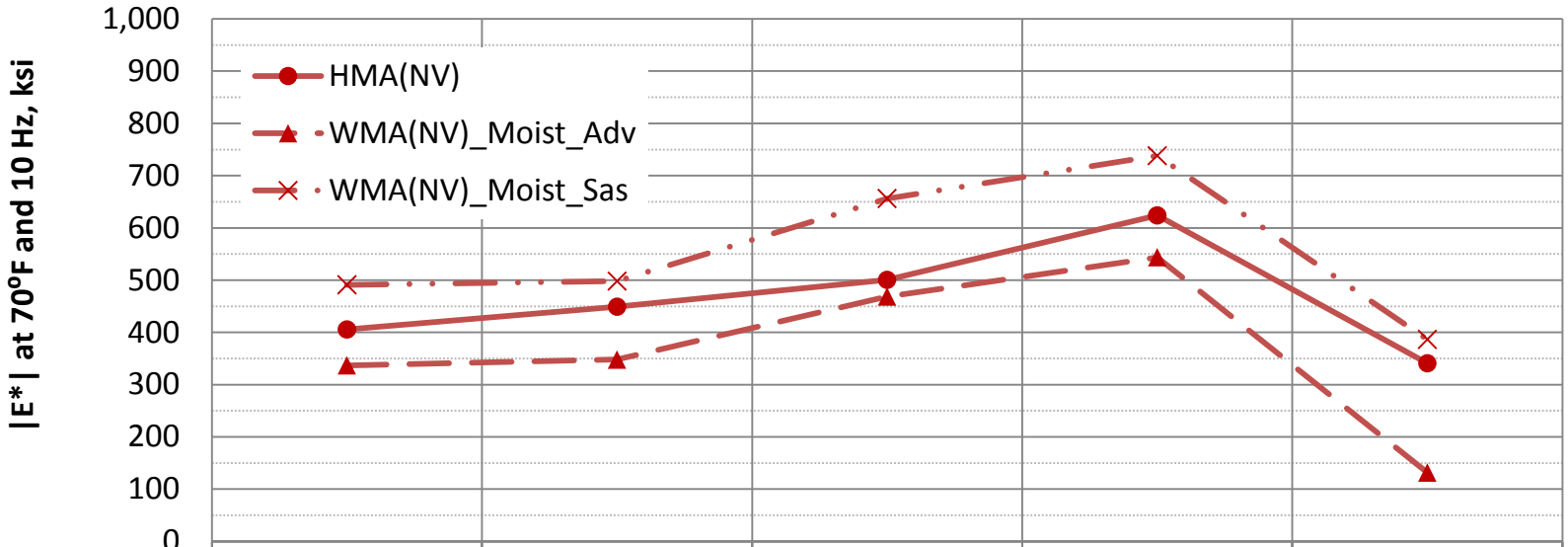
PG64-22 Un-treated Mixes



	0 Initial	14 At room Temp for 14 days	16 In oven for 2 days at 185 F	19 In oven for 3 days at 185 F	31 After 6 FT Cycles
	Time (Days)				
HMA(6422)	573.8	584.9	708.3	761.7	407.8
WMA(6422)_Moist_Adv	479.8	502.7	642.4	786.2	267.2
WMA(6422)_Moist_Sas	571.3	596.8	718.7	856.1	362.2

Impact of Long-term Aging

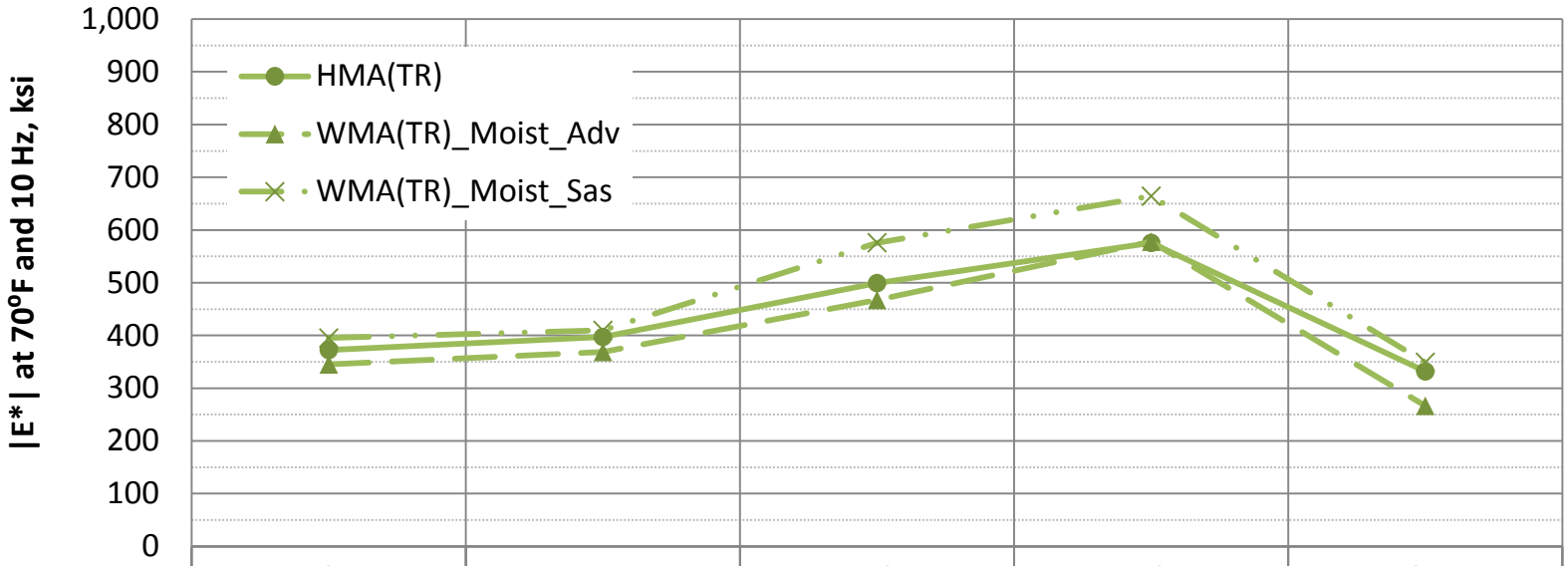
PG64-28NV Un-treated Mixes



	0 Initial	14 At room Temp for 14 days	16 In oven for 2 days at 185 F	19 In oven for 3 days at 185 F	31 After 6 FT Cycles
	Time (Days)				
HMA(NV)	405.7	449.2	500.4	623.9	341.1
WMA(NV)_Moist_Adv	336.9	347.9	468.5	543.7	131.9
WMA(NV)_Moist_Sas	491.1	498.1	656.2	738.2	386.5

Impact of Long-term Aging

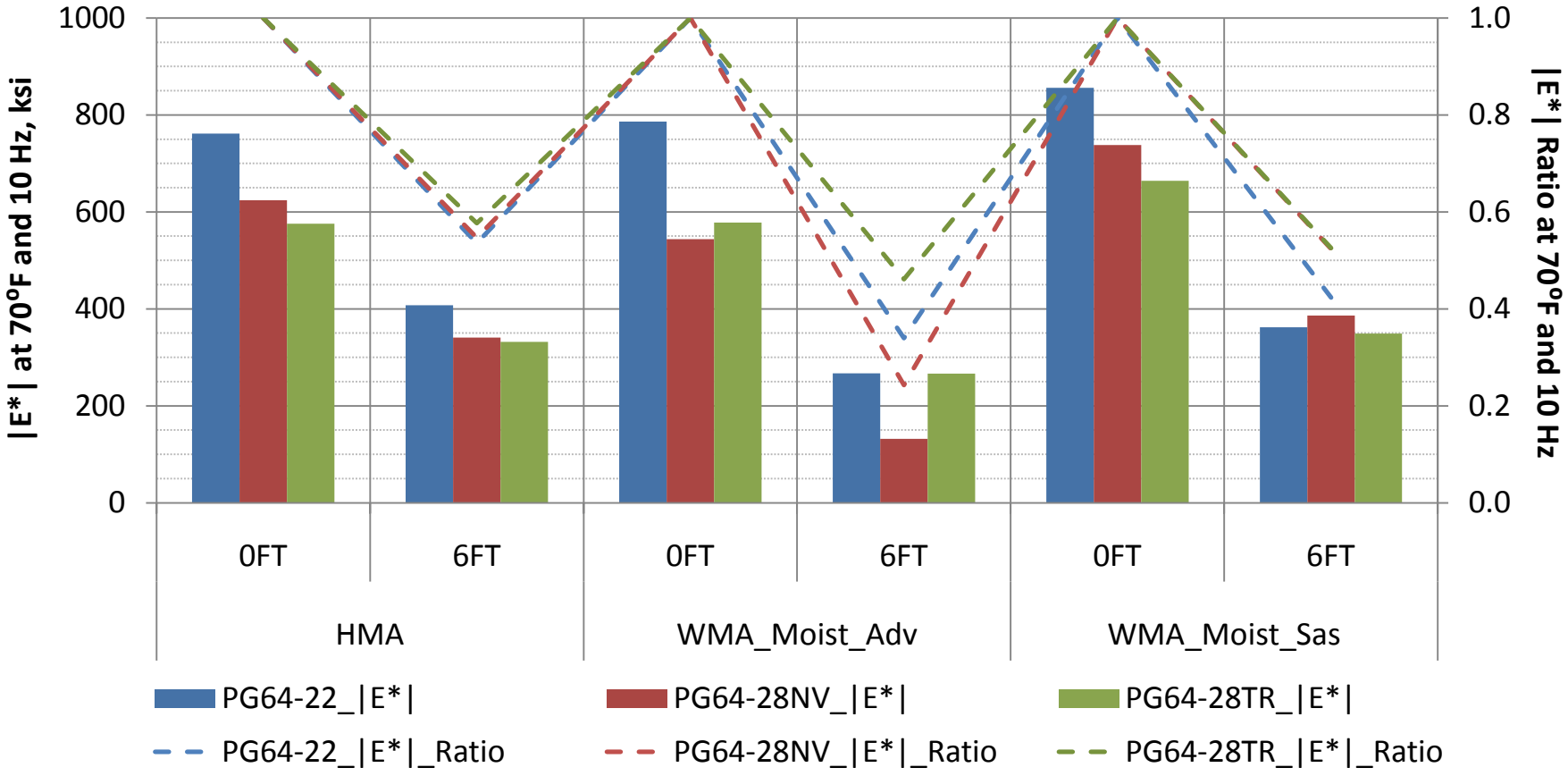
PG64-28TR Un-treated Mixes



	0 Initial	14 At room Temp for 14 days	16 In oven for 2 days at 185 F	19 In oven for 3 days at 185 F	31 After 6 FT Cycles
	Time (Days)				
HMA(TR)	372.5	397.3	499.2	575.5	331.9
WMA(TR)_Moist_Adv	345.0	368.6	467.3	578.0	266.4
WMA(TR)_Moist_Sas	395.0	409.6	575.8	664.1	349.0

Impact of Long-term Aging

|E| and |E*| Ratios of aged specimens*



Future Work

- **Phase I:**
  - Add Evotherm and Lab-foaming mixes
- **Phase II:**
  - Mixtures' evaluation for Rutting, Fatigue and thermal cracking
  - Conduct mechanistic analysis


THANK YOU
QUESTIONS?