



# Impact of WMA Additives on Modified Asphalt Mixtures

Sponsored by:  
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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: 3/4" Max – Type A**
- **Conduct Actual Designs of HMA & verify for WMA**



# Evaluated Mixtures



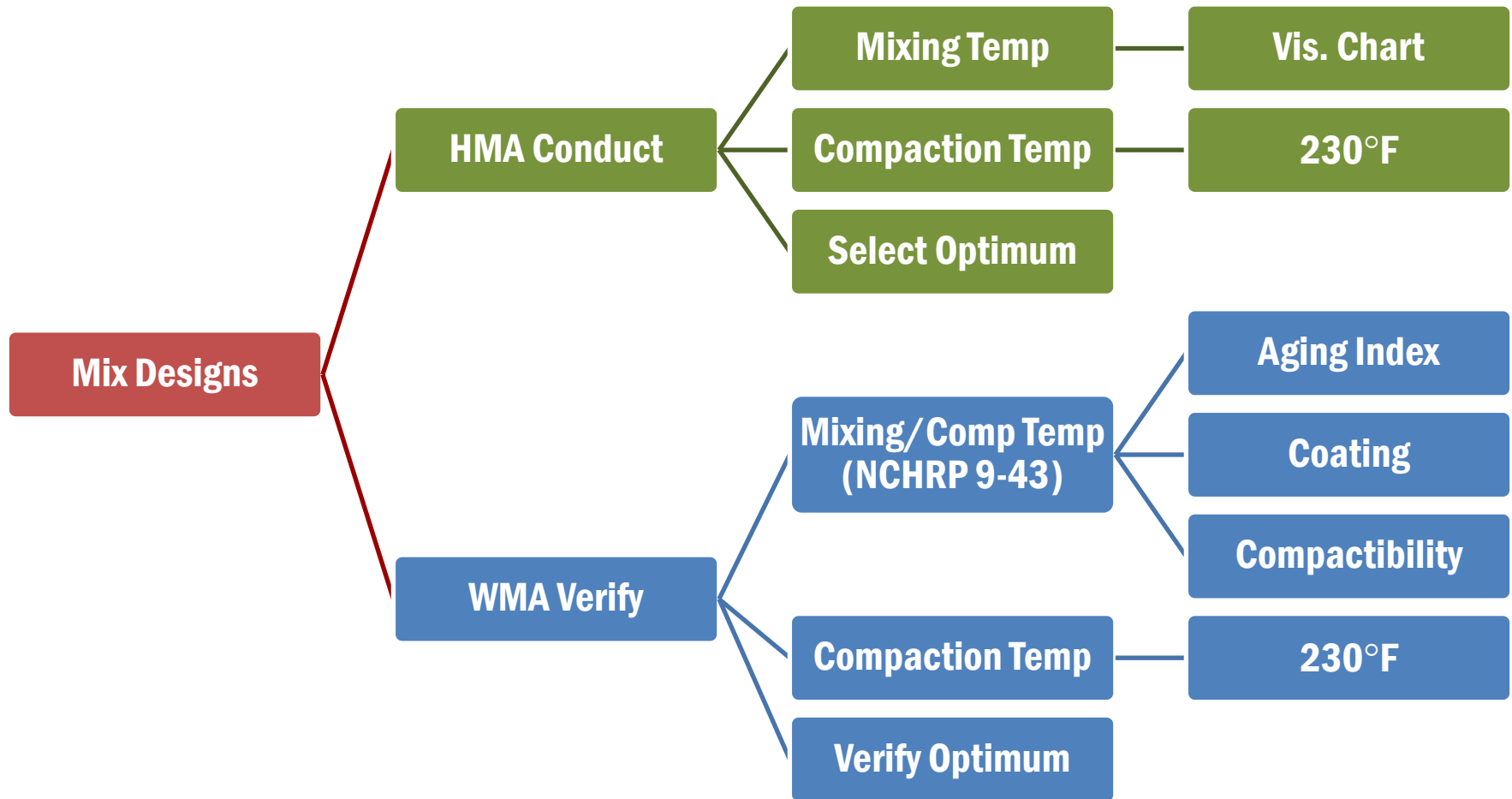
	HMA	WMA - Advera	WMA - Sasobit
PG 64-22	X	X	X
PG64-28NV/PM	X	X	X
PG64-28NV-TR/TR	X	X	X

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*

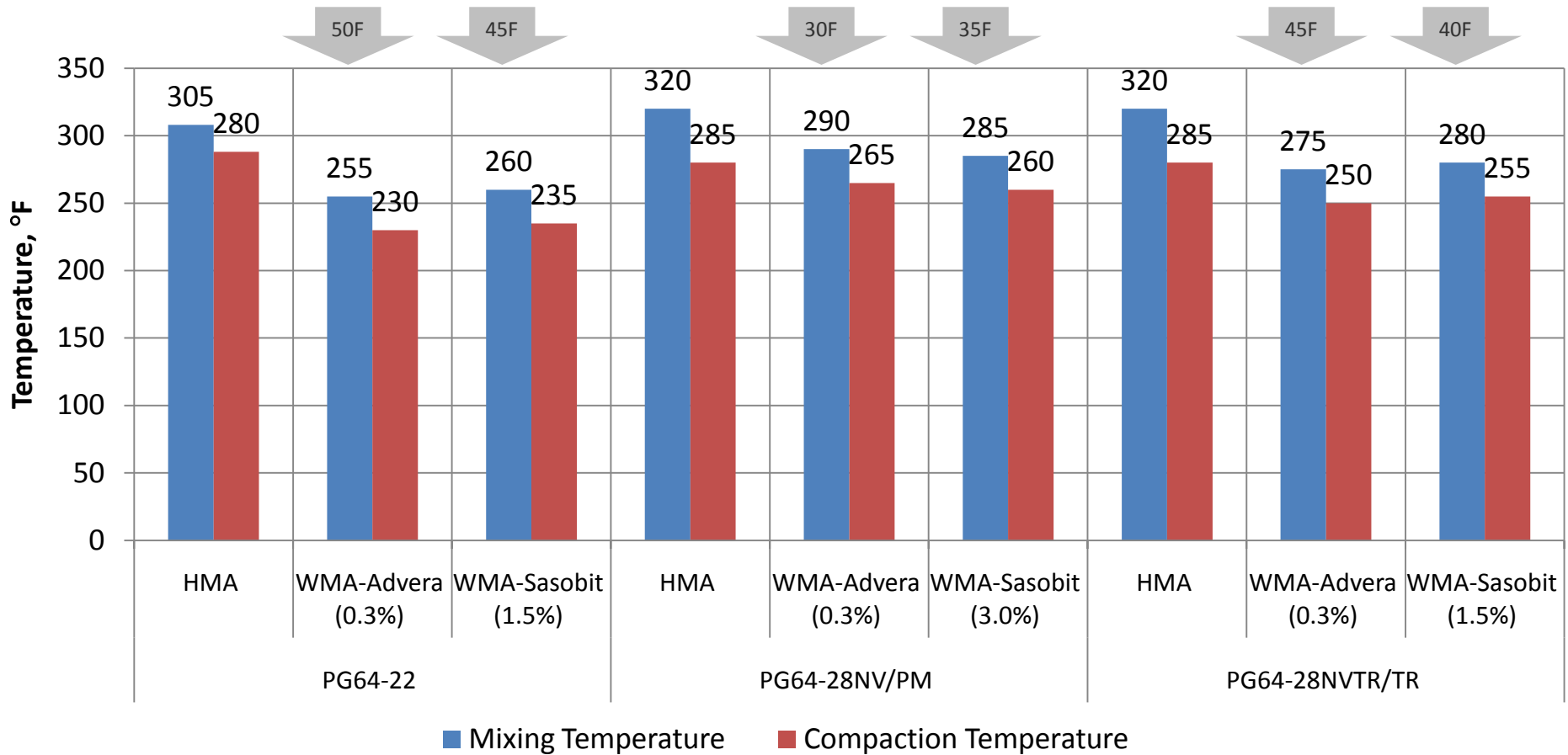
- **Compactability in Superpave Gyratory:**

- $$N_{92} @ (T_{Comp} - 54^{\circ}F) \leq 1.25 * N_{92} @ T_{Comp}$$

- **Not used in Mix Designs**



# Mixing/Compaction Temperatures



# Verify Optimum Designs for WMA and Treated Mixtures



- **At the HMA Optimum and  $\pm 1\%$** 
  - **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**

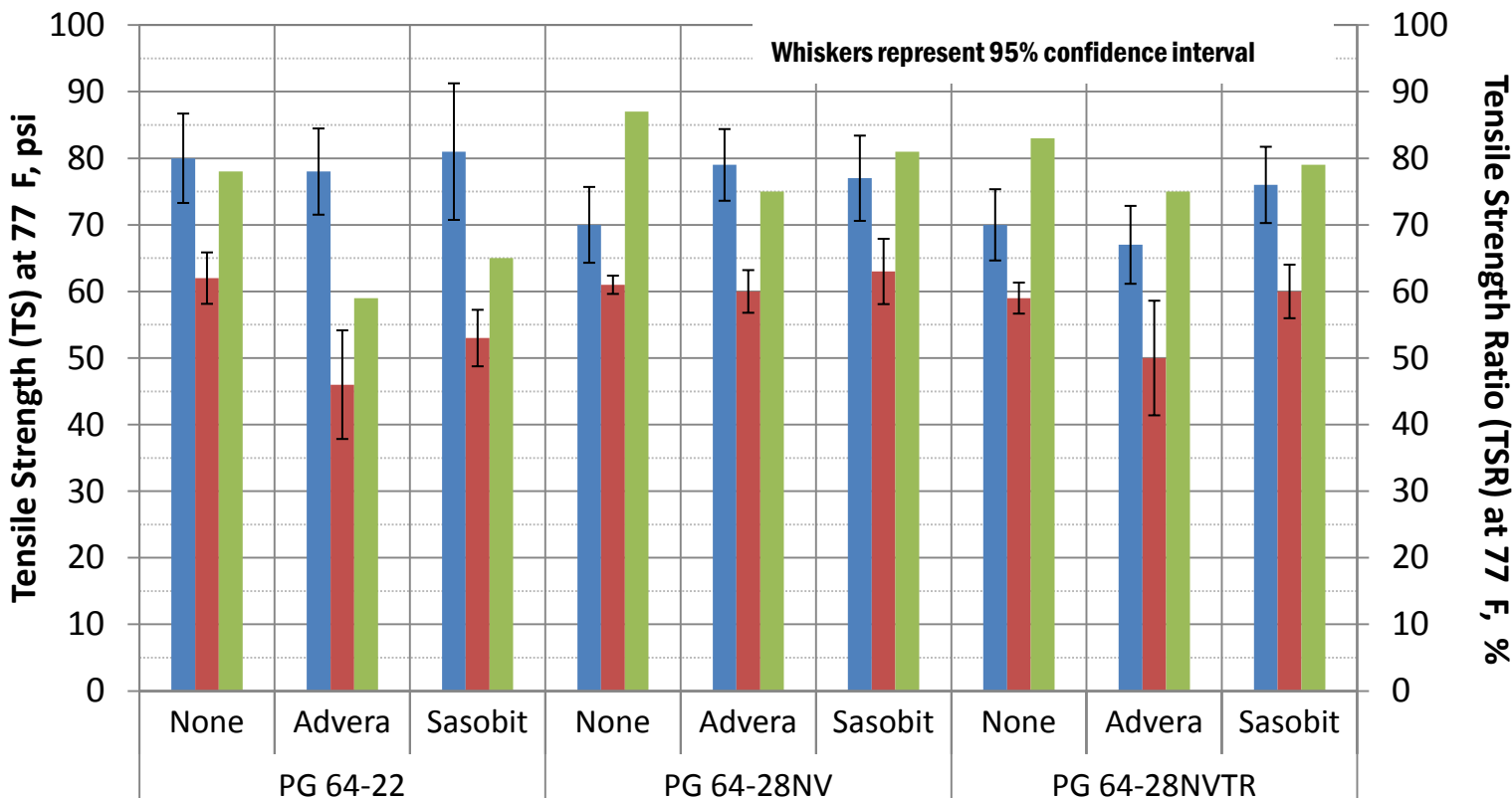


# Moisture Sensitivity

## Tensile Strength at 77°F



### Un-treated Mixes



■ 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





# 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

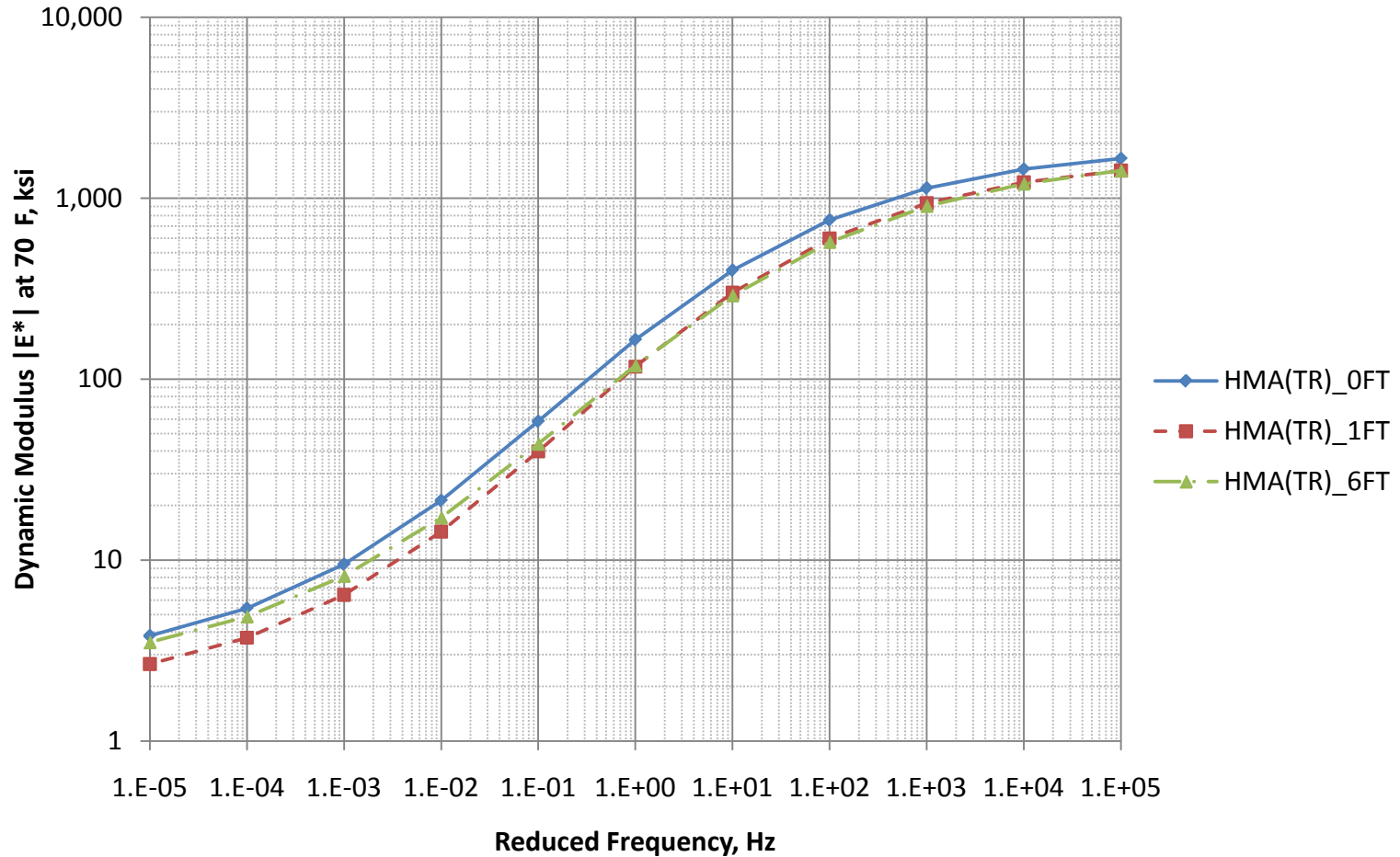


Property	Un-treated Mixes								
	PG 64-22			PG 64-28 NV/PM			PG 64-28 NVTR/TR		
	None	Advera	Sasobit	None	Advera	Sasobit	None	Advera	Sasobit
<b>Without Residual Moisture</b>									
$ E^* $ vs. F-T cycles (unaged)	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1 and 6 FT cycles	3 @ 0, 1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



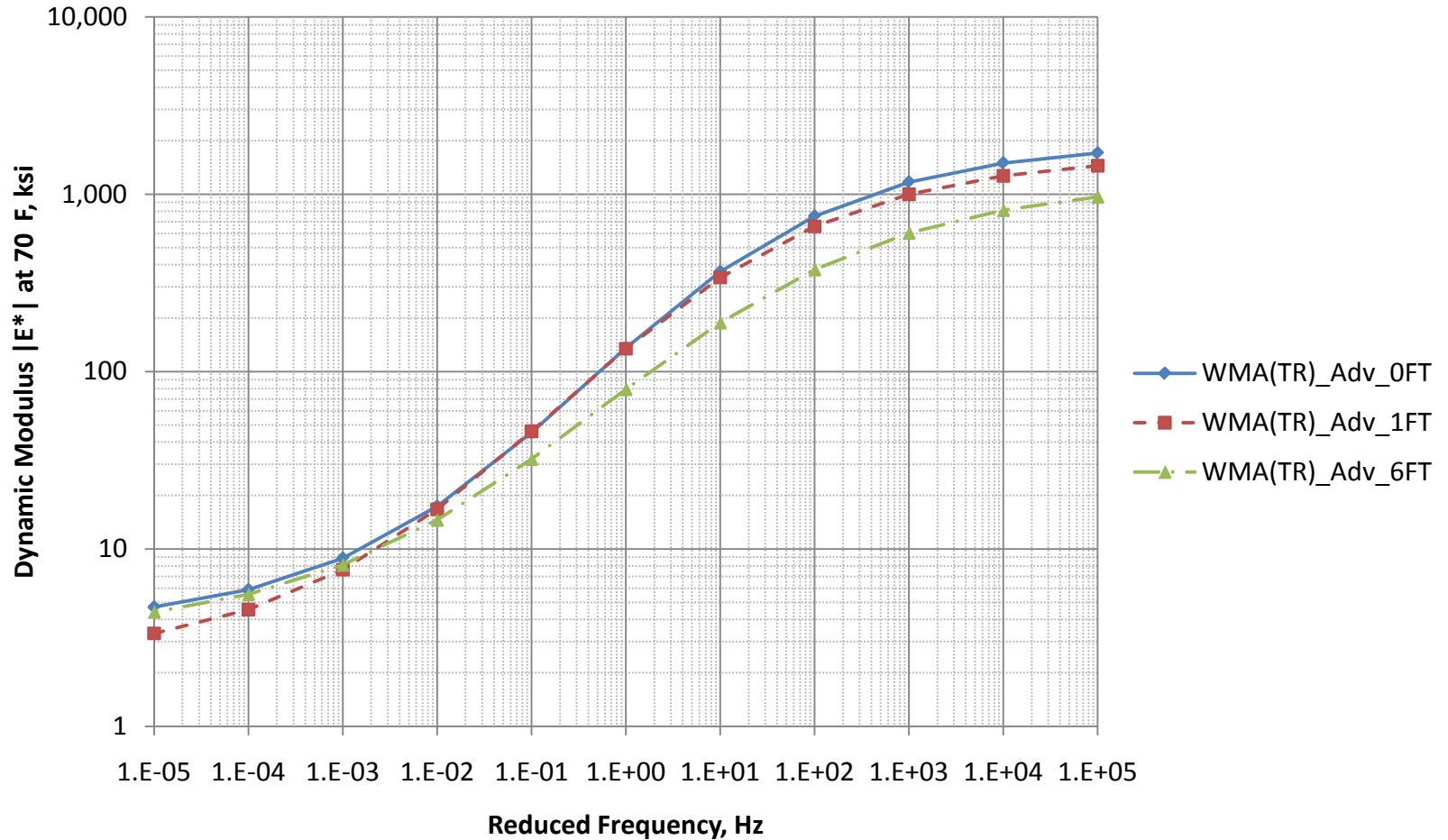
# Impact of Residual Moisture

## Selected Test Results - PG64-28TR Mix



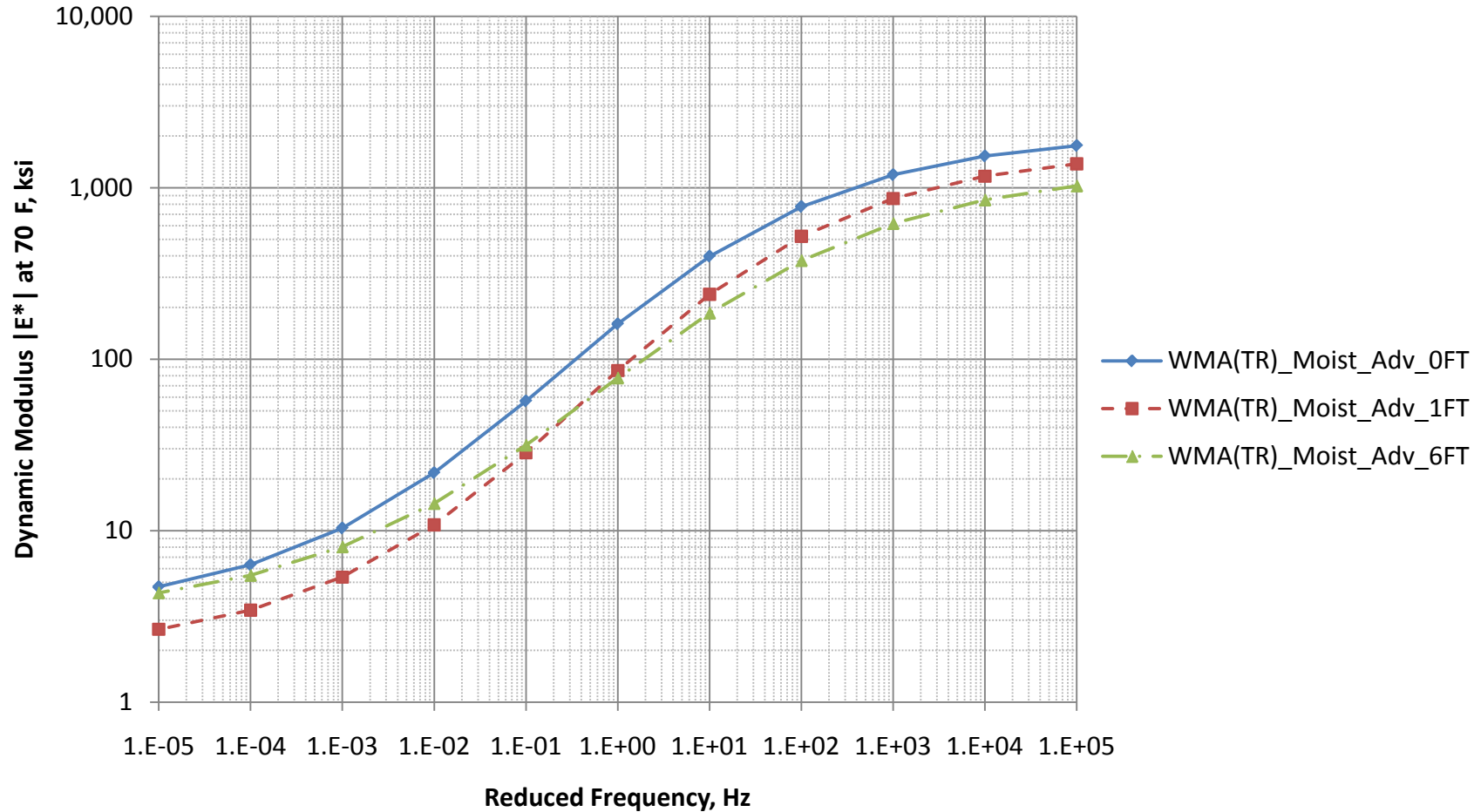
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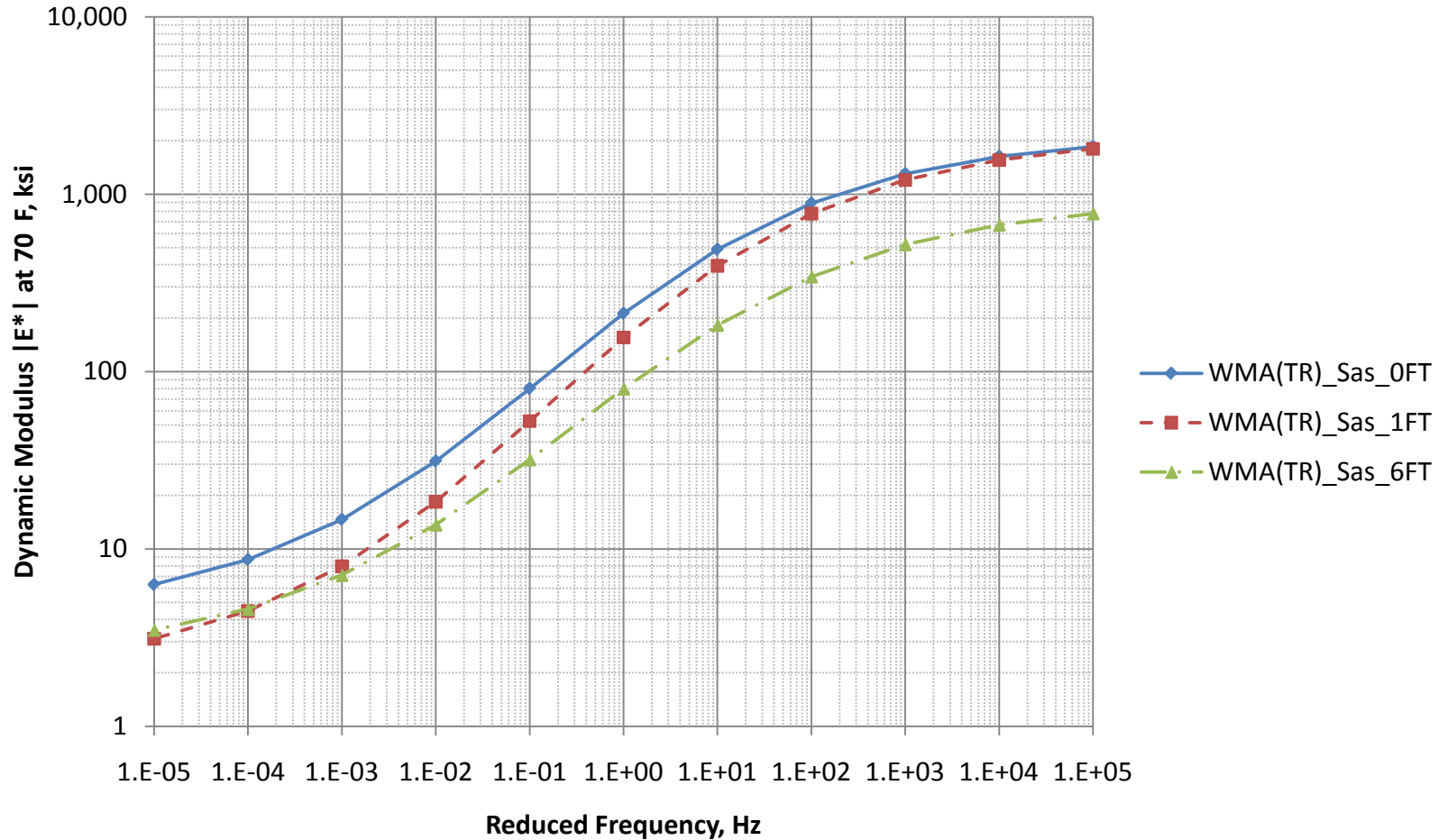
# Impact of Residual Moisture

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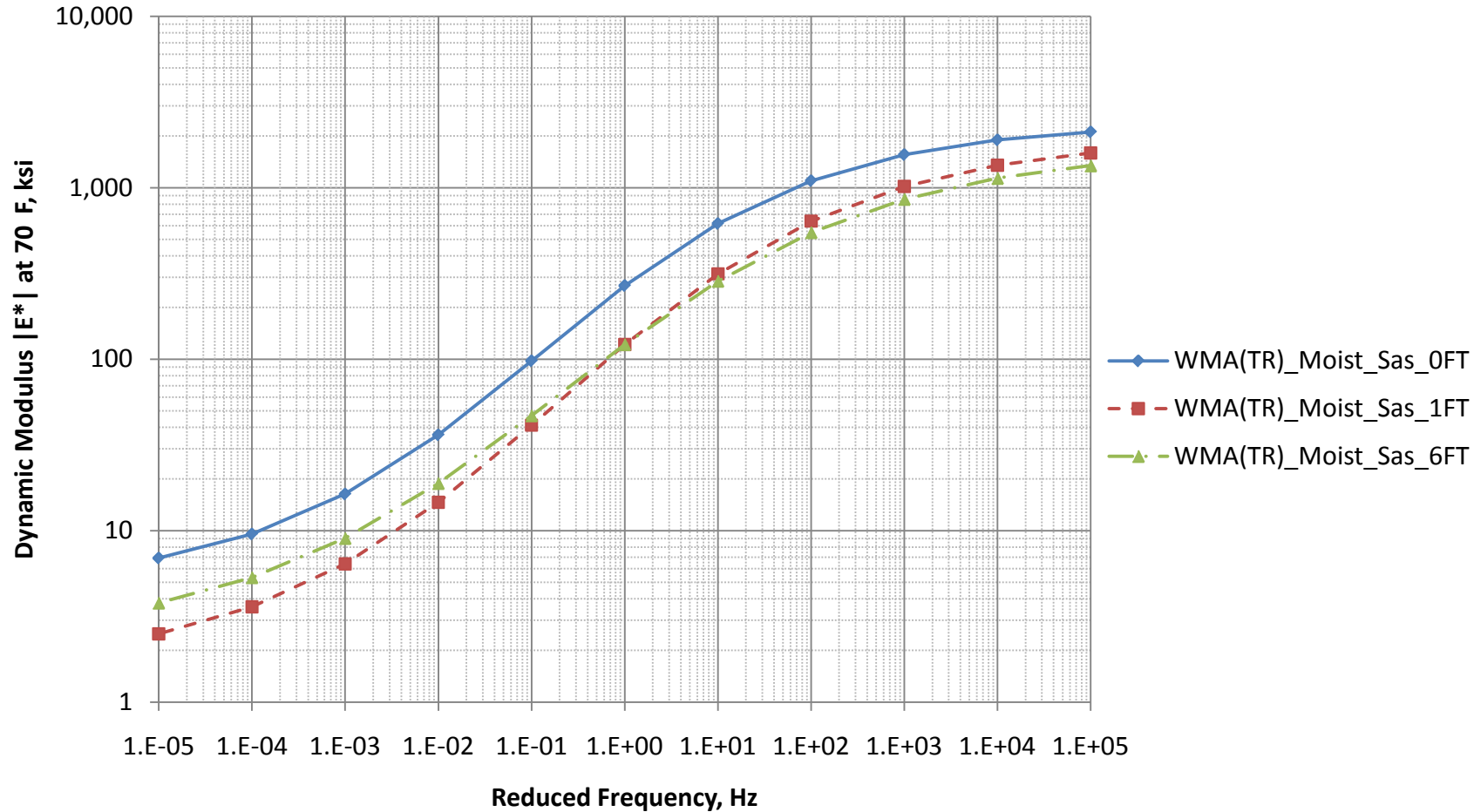
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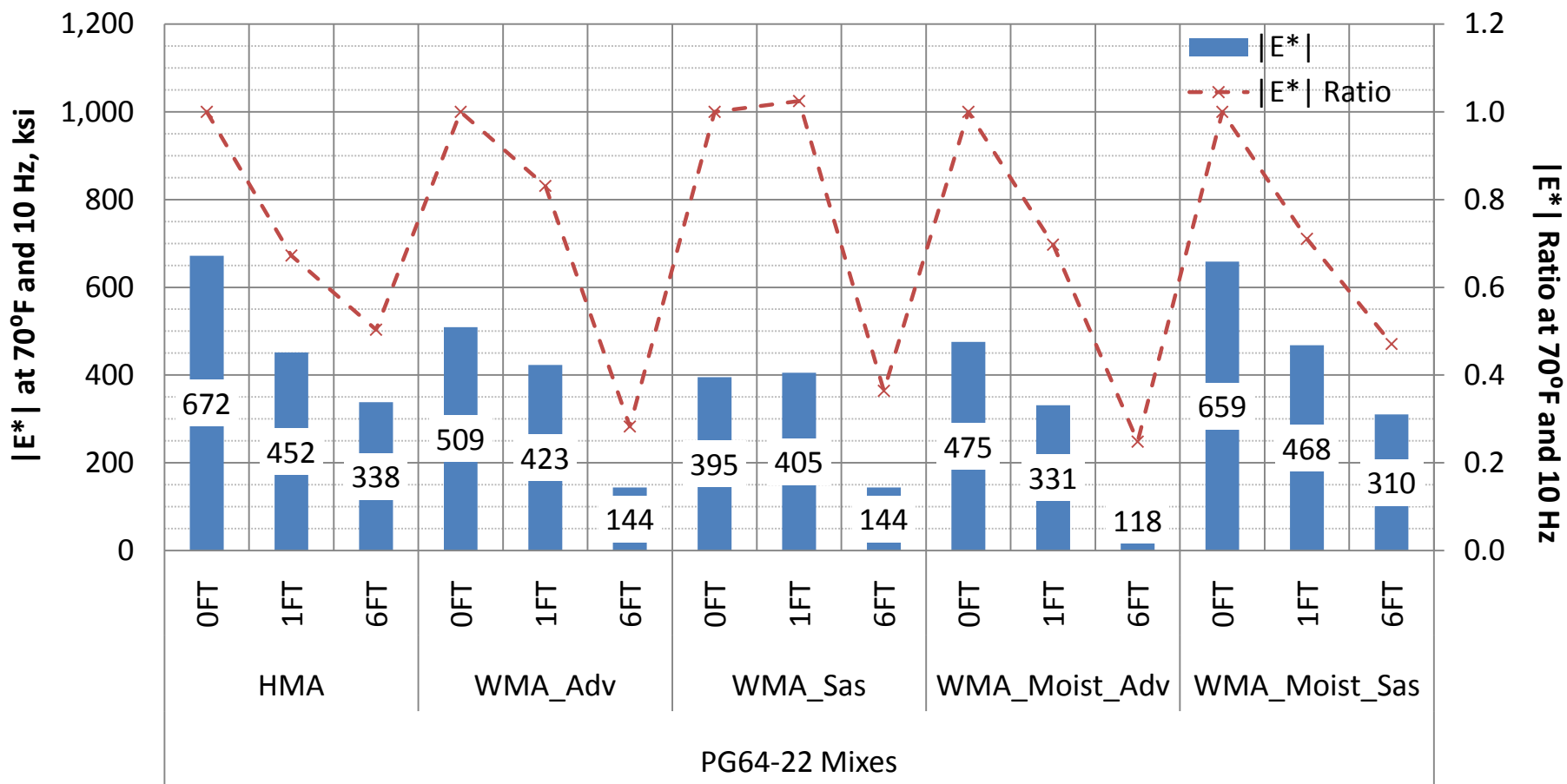
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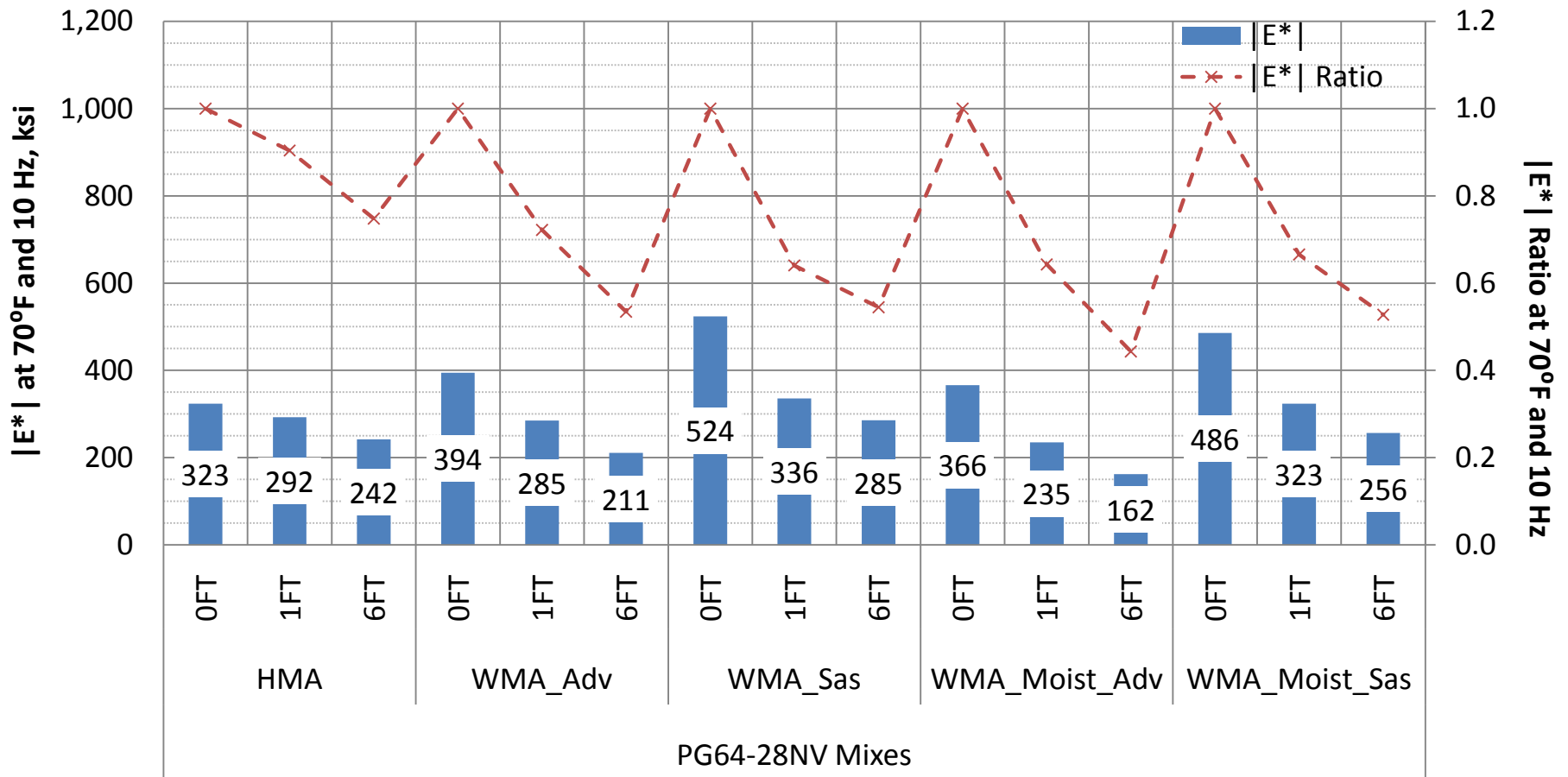
# Impact of Residual Moisture

## Summary of Results - PG64-22 Mixes



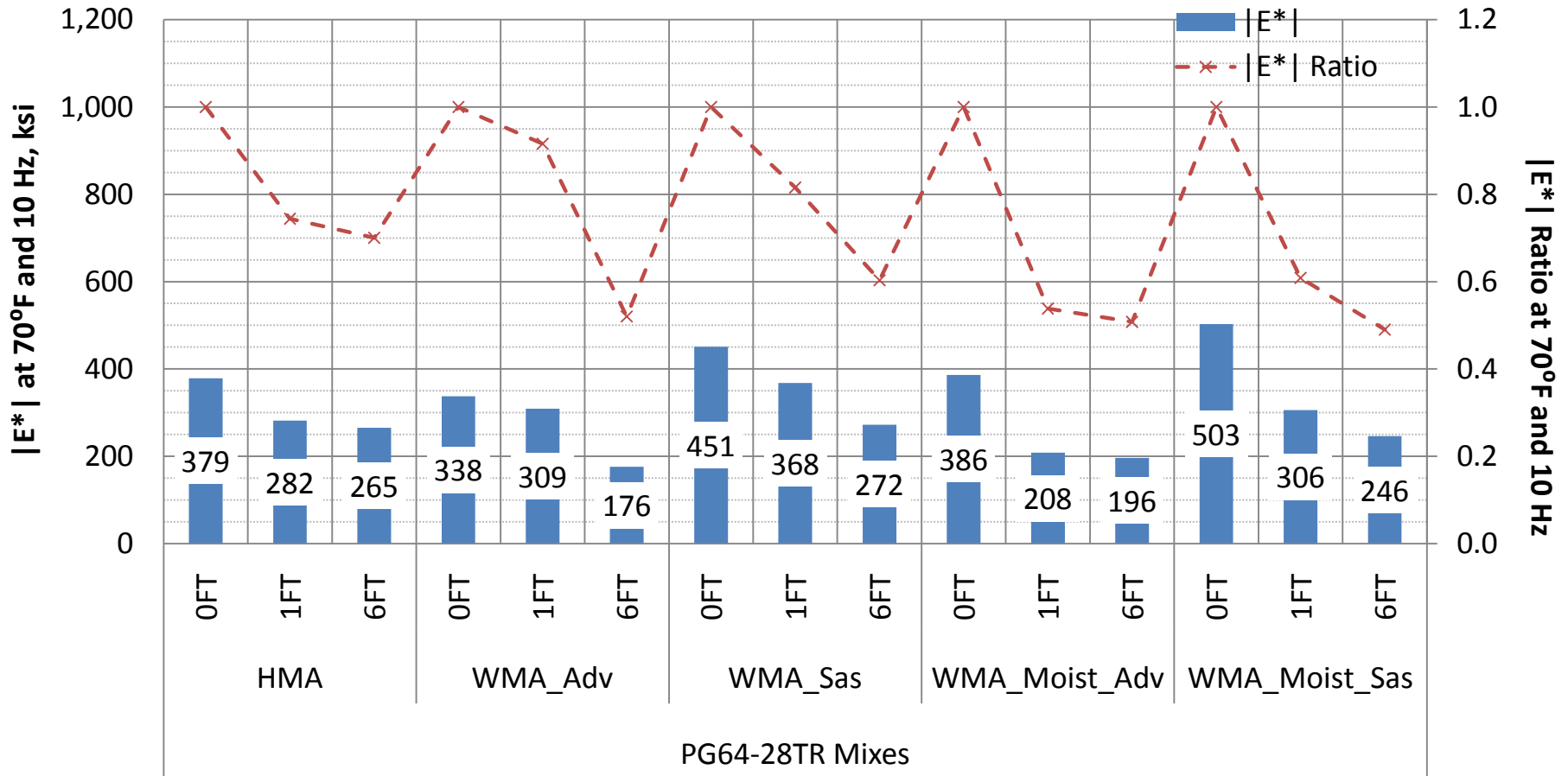
# Impact of Residual Moisture

## 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*

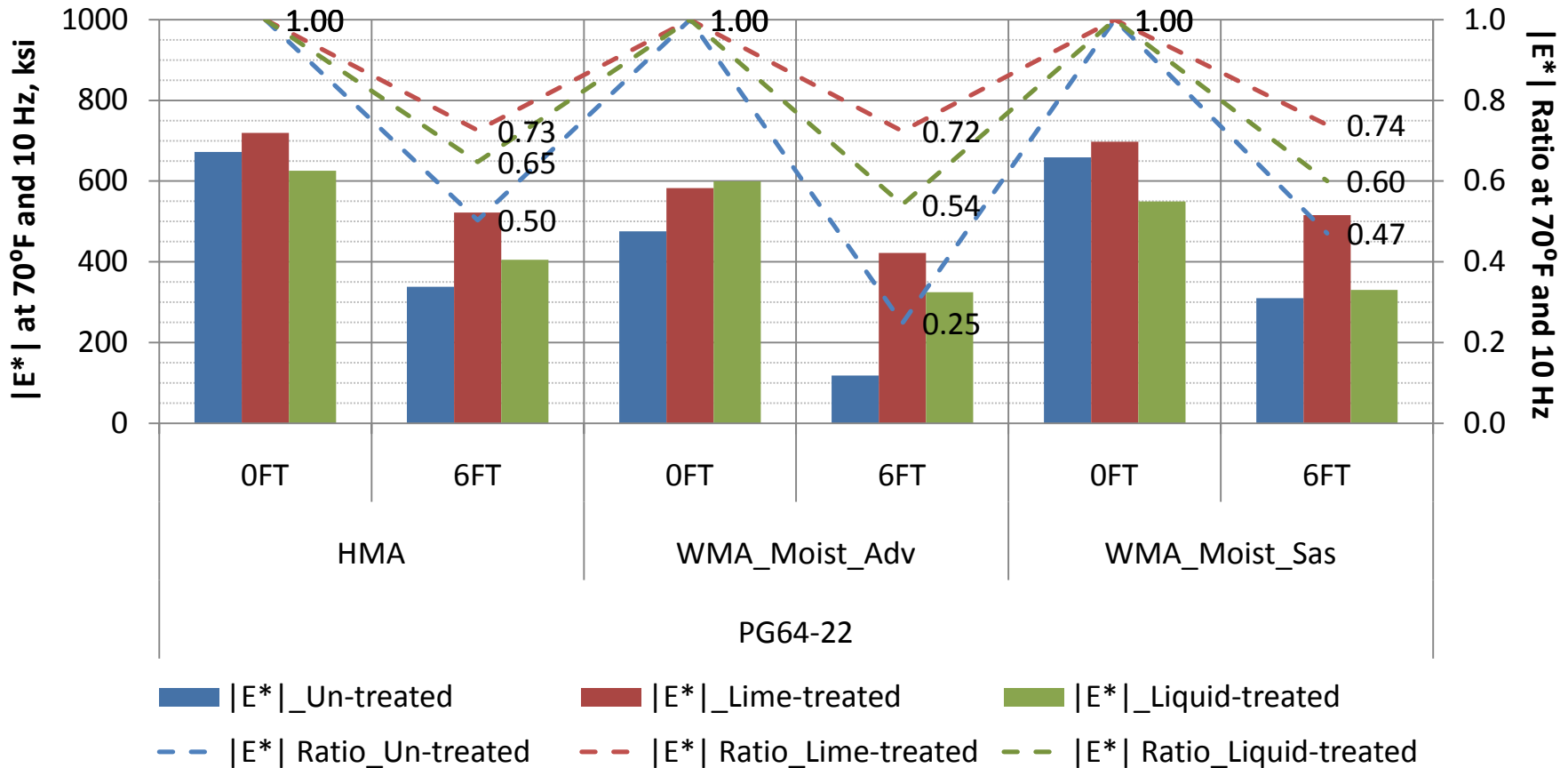


Property	Lime-treated Mixes / Liquid-treated Mixes								
	PG 64-22			PG 64-28 NV/PM			PG 64-28 NVTR/TR		
	None	Advera	Sasobit	None	Advera	Sasobit	None	Advera	Sasobit
	<b>Without Residual Moisture</b>								
<b> E*  vs. F-T cycles (unaged)</b>	<b>3 @ 0 and 6 FT cycles</b>	--	--	<b>3 @ 0 and 6 FT cycles</b>	--	--	<b>3 @ 0 and 6 FT cycles</b>	--	--
	<b>With Residual Moisture</b>								
<b> E* <sub>Moist</sub> vs. F-T cycles (unaged)</b>	--	<b>3 @ 0 and 6 FT cycles</b>	<b>3 @ 0 and 6 FT cycles</b>	--	<b>3 @ 0 and 6 FT cycles</b>	<b>3 @ 0 and 6 FT cycles</b>	--	<b>3 @ 0 and 6 FT cycles</b>	<b>3 @ 0 and 6 FT cycles</b>



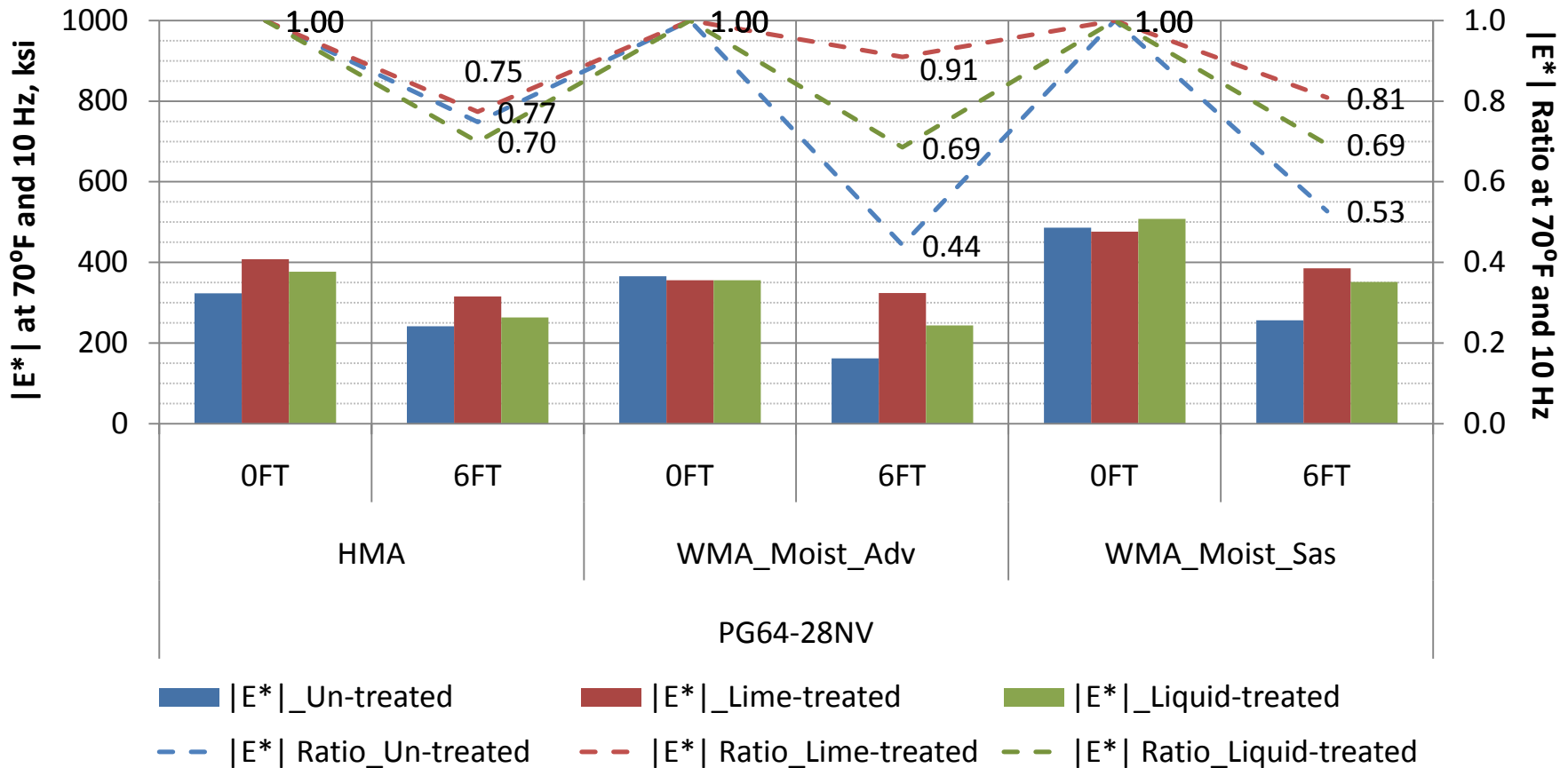
# Impact of Antistripping Additives

## Summary of Results - PG64-22 Mixes



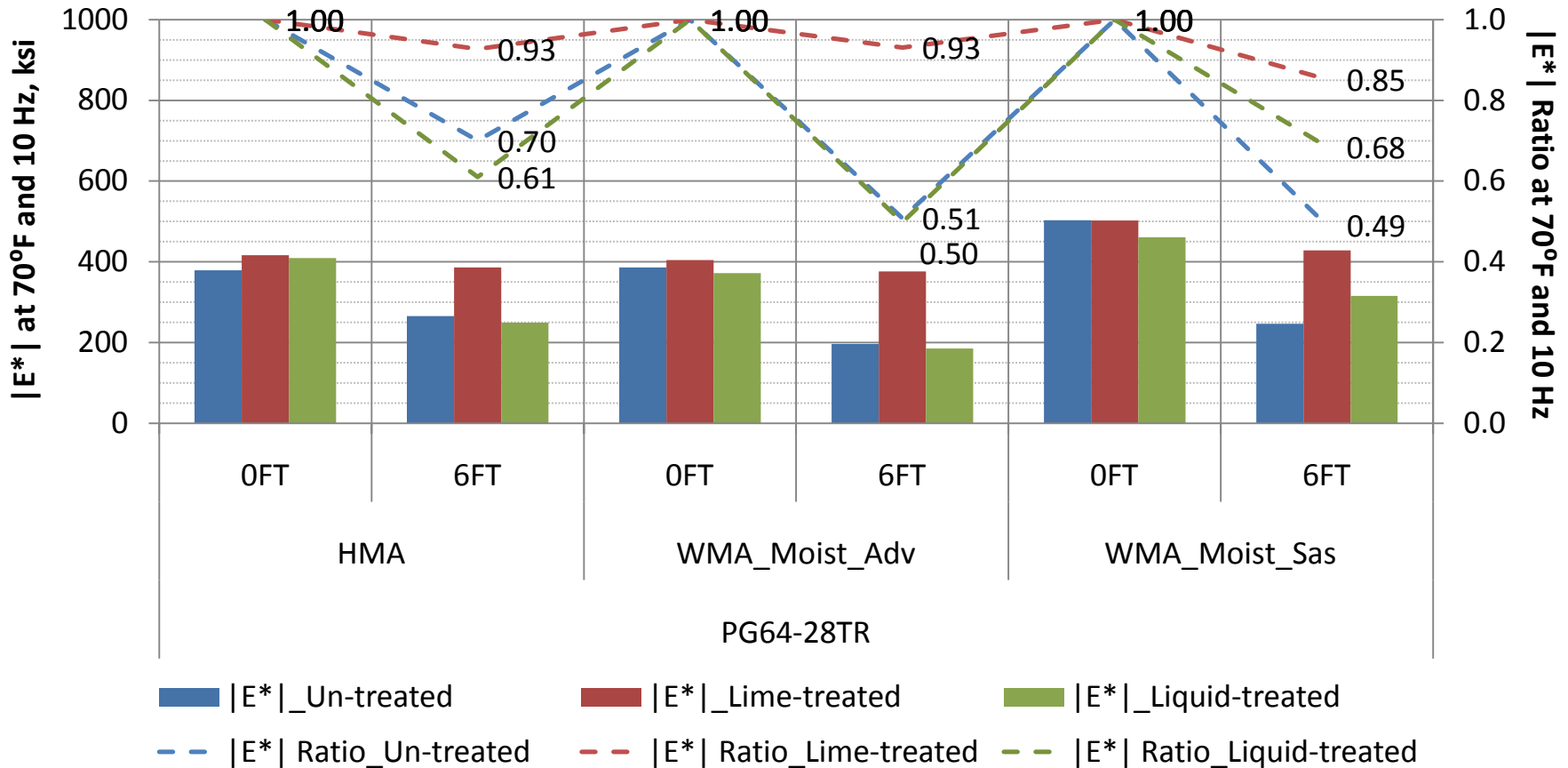
# Impact of Antistripping Additives

## Summary of Results - PG64-28NV Mixes



# Impact of Antistripping Additives

## Summary of Results - PG64-28TR Mixes



# Experimental Plan/Number of Samples

## *Impact of Long-Term Aging*

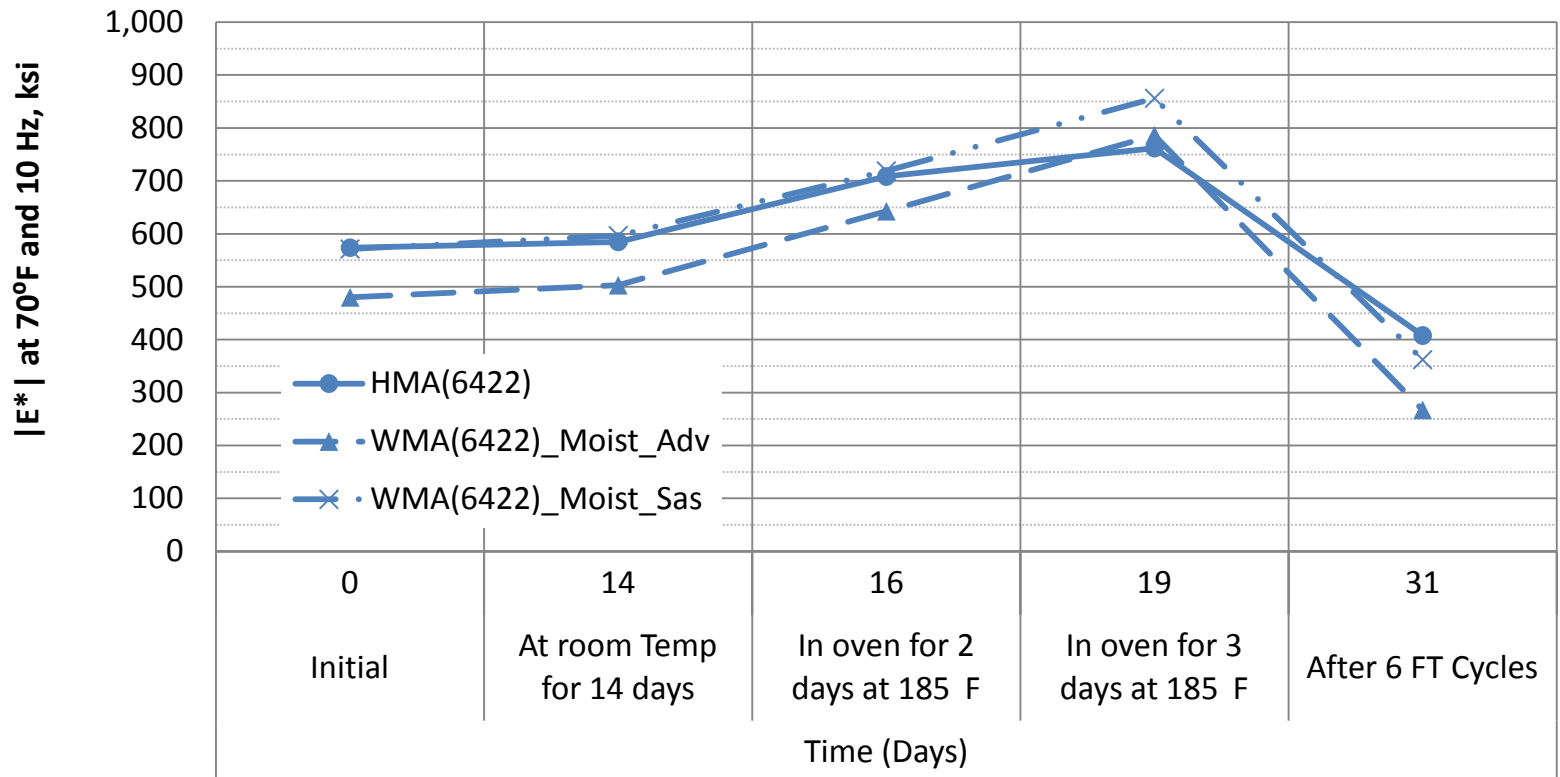


Property	Un-treated Mixes								
	PG 64-22			PG 64-28 NV/PM			PG 64-28 NVTR/TR		
	None	Advera	Sasobit	None	Advera	Sasobit	None	Advera	Sasobit
	<b>With Residual Moisture for Advera and Sasobit WMA mixes</b>								
$ E^* _0$ (initial, t =0 days)	X	X	X	X	X	X	X	X	X
	↓	↓	↓	↓	↓	↓	↓	↓	↓
$ E^* _{14}$ (after 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

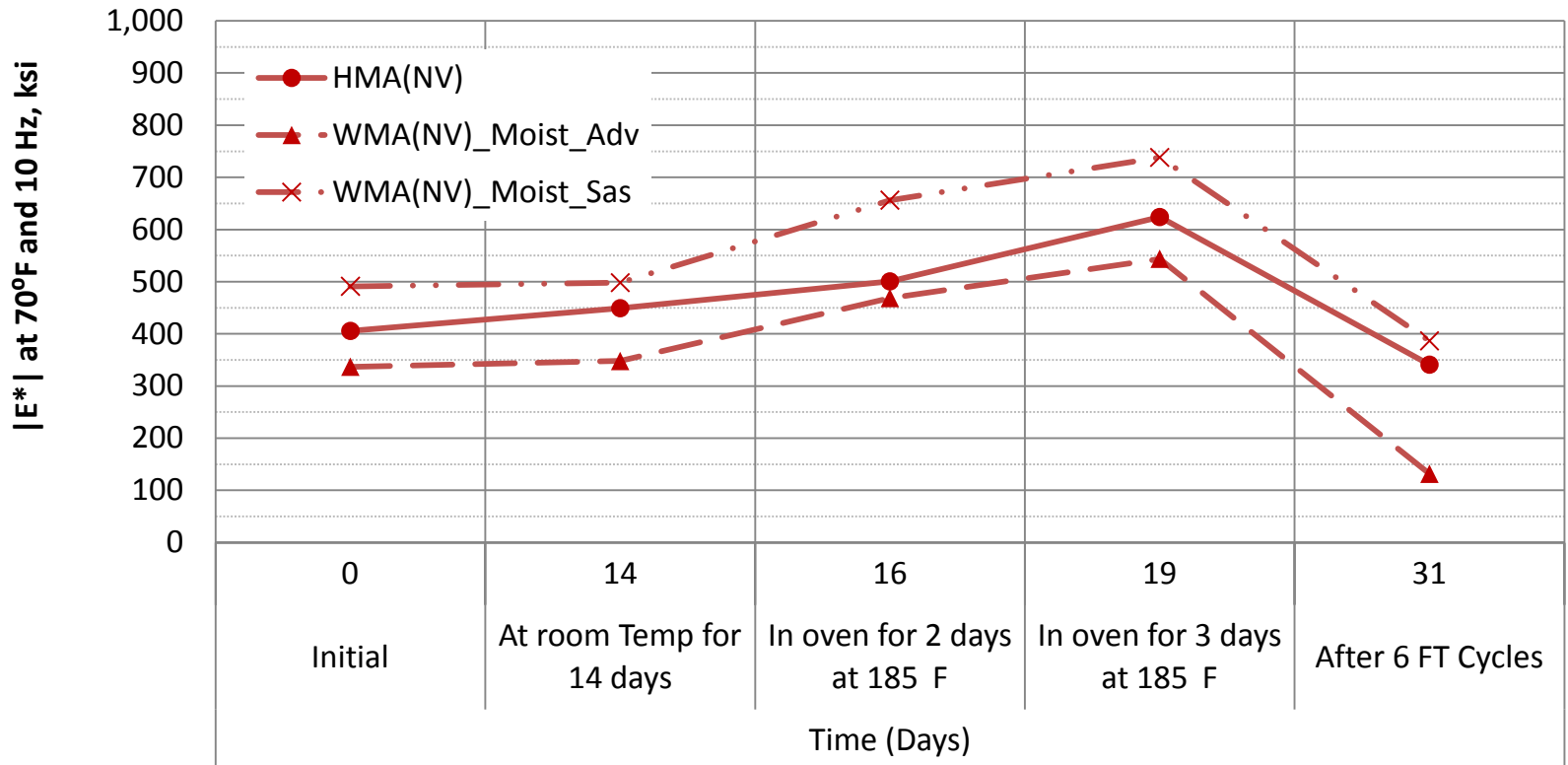


● HMA(6422)	573.8	584.9	708.3	761.7	407.8
▲ WMA(6422)_Moist_Adv	479.8	502.7	642.4	786.2	267.2
✕ WMA(6422)_Moist_Sas	571.3	596.8	718.7	856.1	362.2



# Impact of Long-term Aging

## PG64-28NV Un-treated Mixes

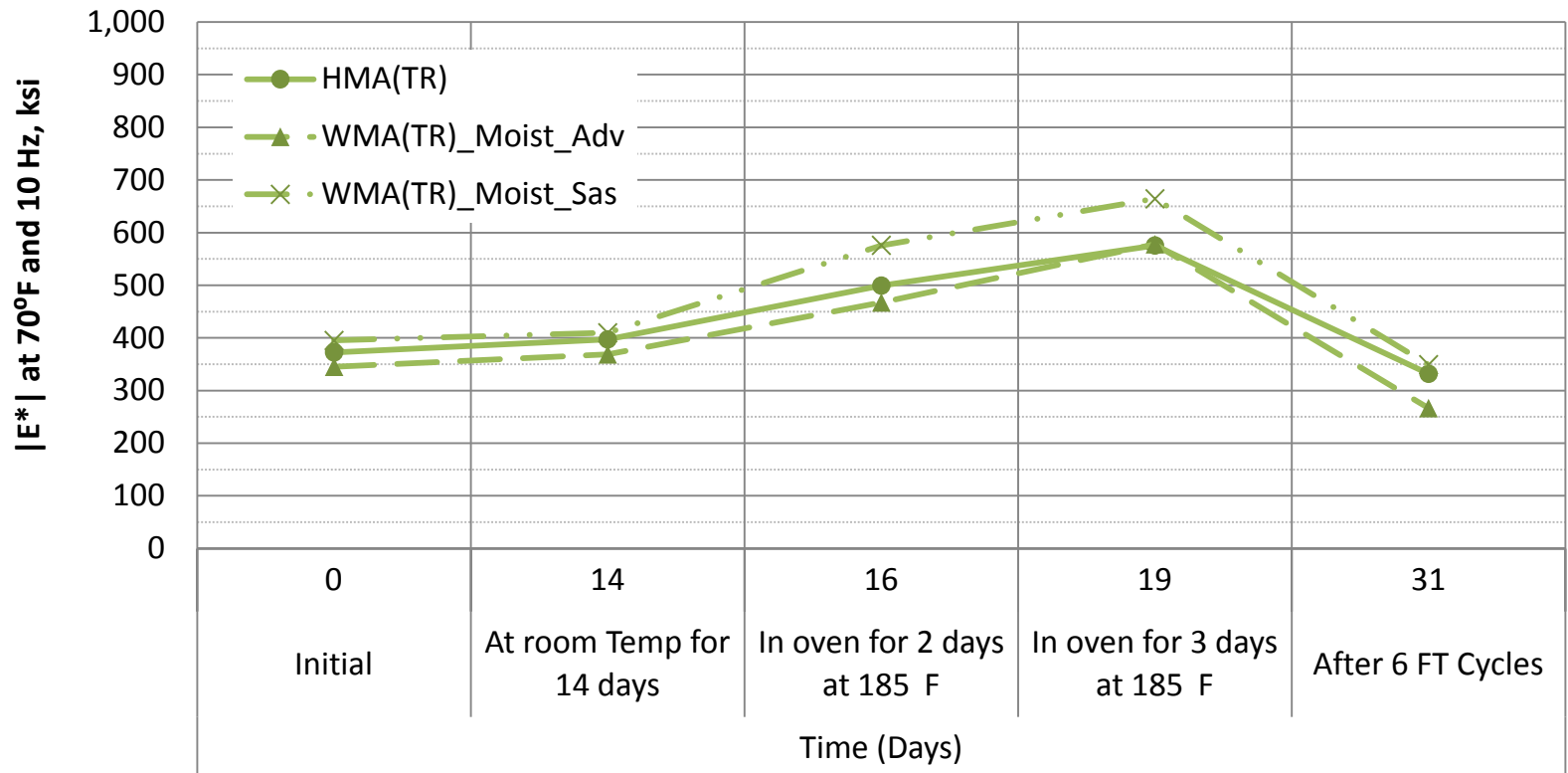


● HMA(NV)	405.7	449.2	500.4	623.9	341.1
▲ WMA(NV)_Moist_Adv	336.9	347.9	468.5	543.7	131.9
× WMA(NV)_Moist_Sas	491.1	498.1	656.2	738.2	386.5



# Impact of Long-term Aging

## PG64-28TR Un-treated Mixes

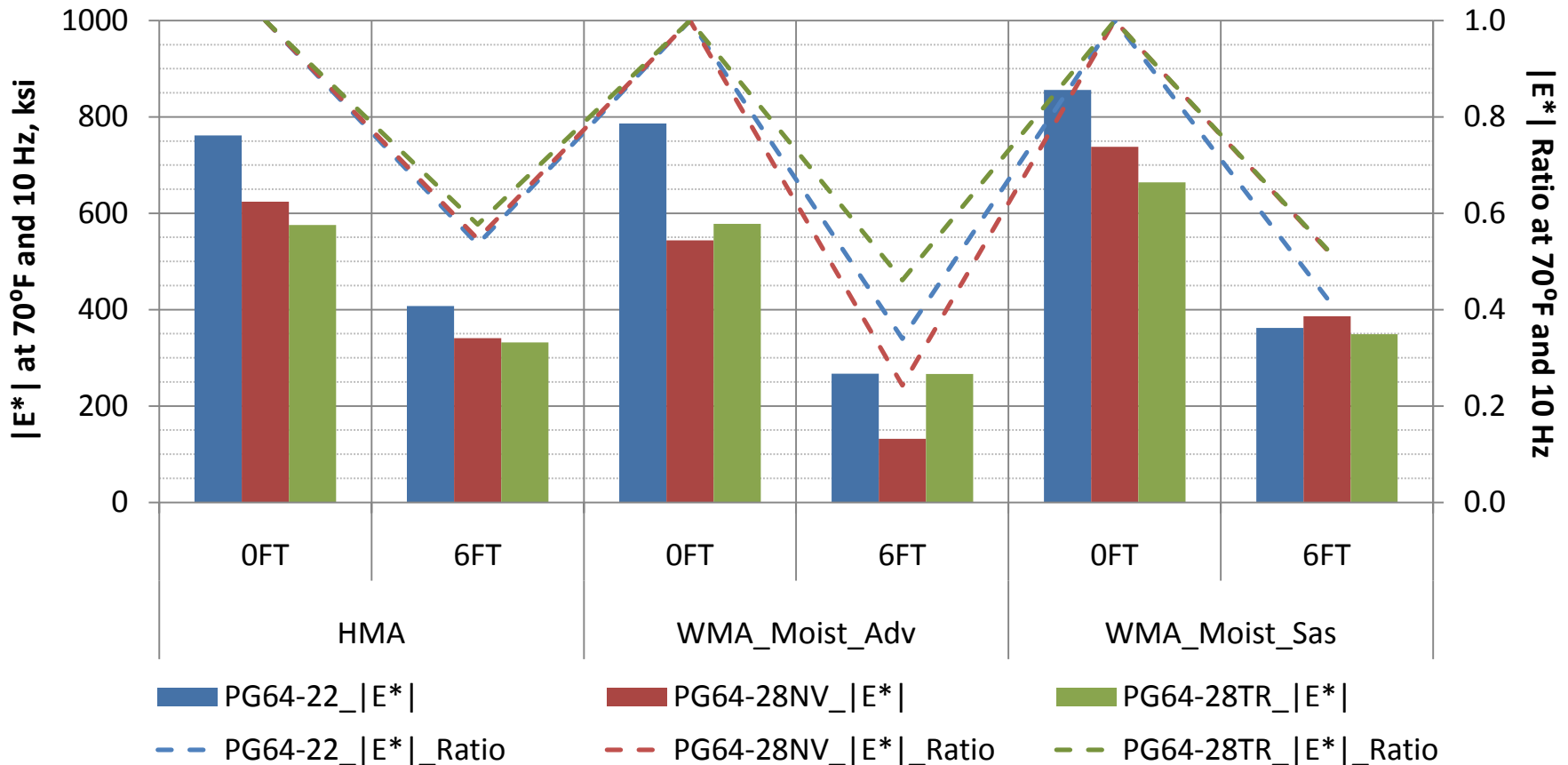


● HMA(TR)	372.5	397.3	499.2	575.5	331.9
▲ WMA(TR)_Moist_Adv	345.0	368.6	467.3	578.0	266.4
✕ WMA(TR)_Moist_Sas	395.0	409.6	575.8	664.1	349.0



# 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?**