NCHRP 9-49A Project Update: Performance of WMA Technologies: Stage II – Long-term Field Performance

Binder ETG Meeting
Oklahoma City, OK
Sept 15, 2015

Outline

- **Objectives & Research Progress**
- **Preliminary Findings**
  - Transverse Cracking
  - Top-down Longitudinal Cracking
  - Rutting & Moisture Susceptibility
  - Material Property Changes Over Time
    - MT I-15 Project
    - TN SR 125 Project
    - IA US 34 Project
- **Summary and Future Work**

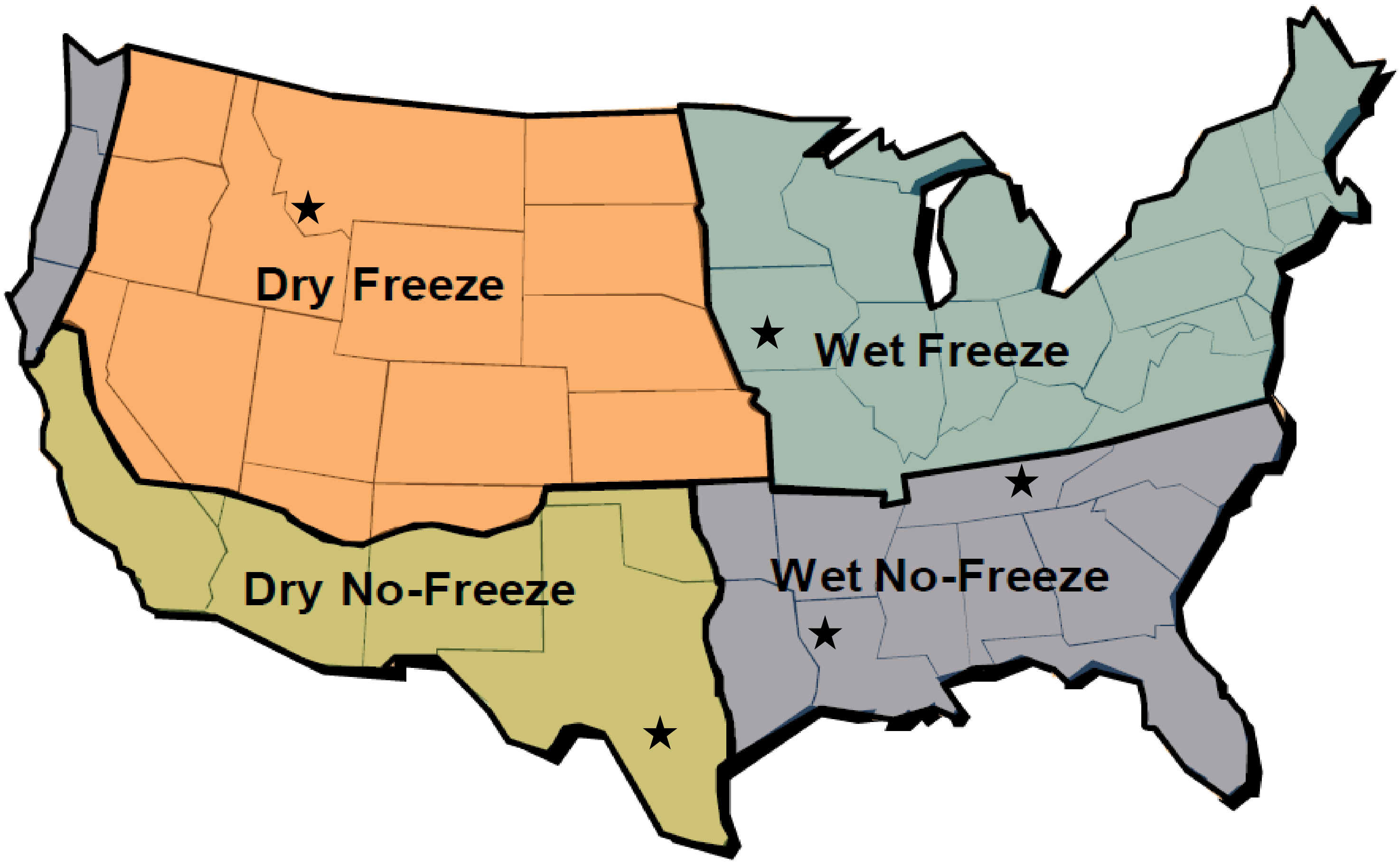
Research Objectives

- To identify the material and engineering properties of WMA pavements that are *significant determinants* of their long-term field performance, and

- To recommend *best practices* for the use of WMA technologies.

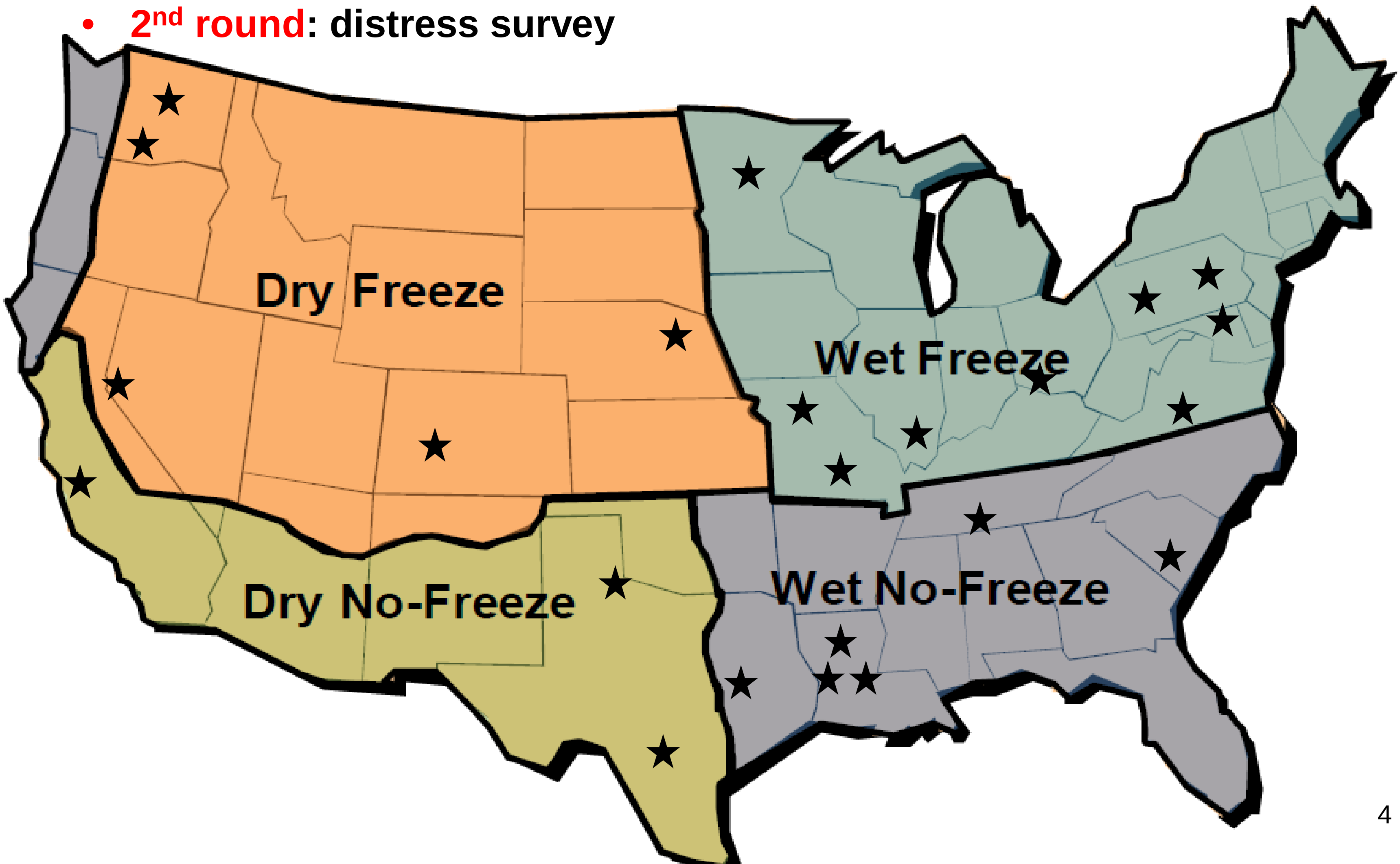
New (2011 Construction) Pavement Projects

- **5 Projects = 10 HMA-WMA pairs**
- **1st round: pre-overlay distress survey, construction monitoring, on-site sample compaction, field cores, and falling weight deflectometer tests**
- **2nd round: field cores and distress survey**

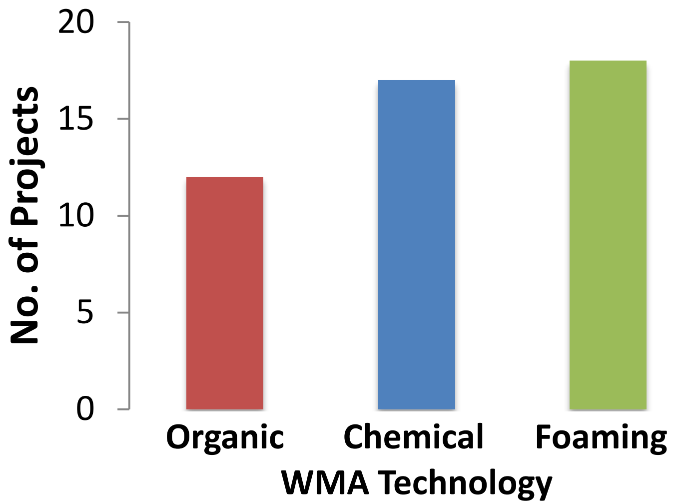


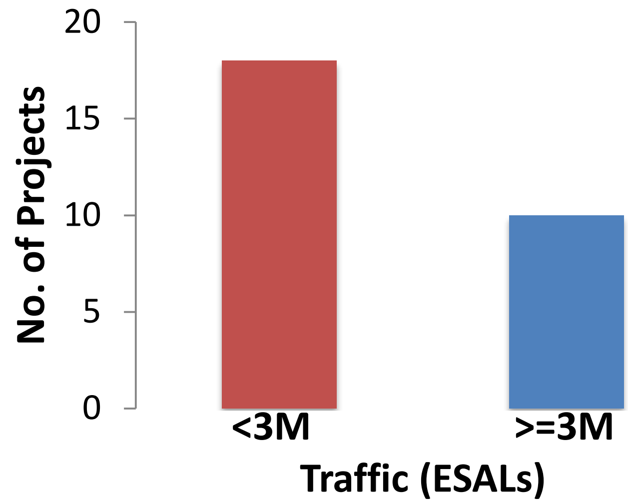
In-service (as of 2011) Pavement Projects

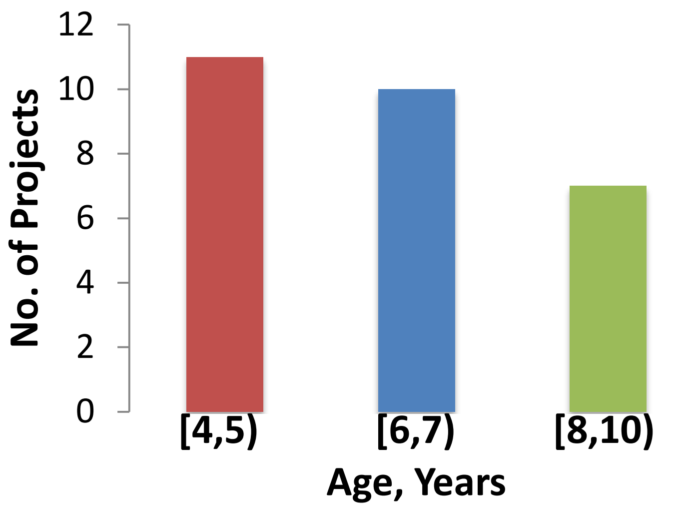
- **22 field projects + 1 HVS = 40 HMA-WMA pairs**
- **1st round: distress survey, field cores and falling weight deflectometer tests**
- **2nd round: distress survey**

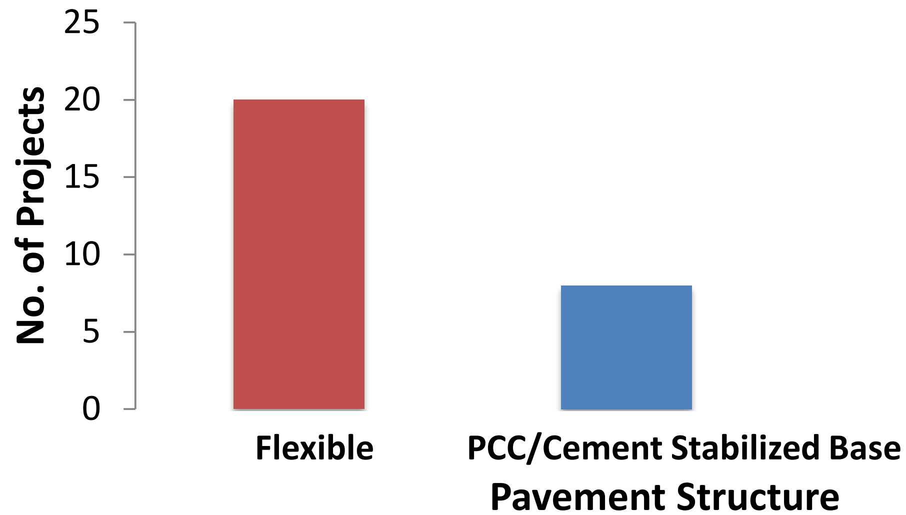


Projects Distribution





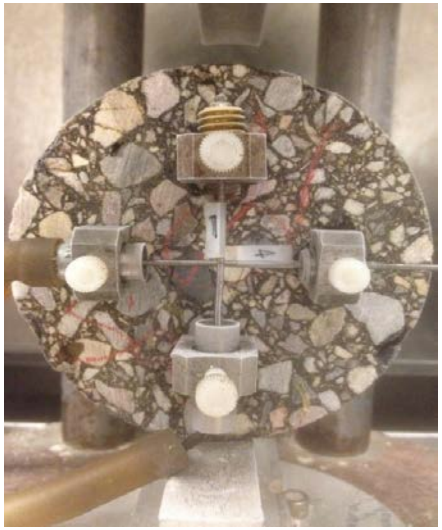


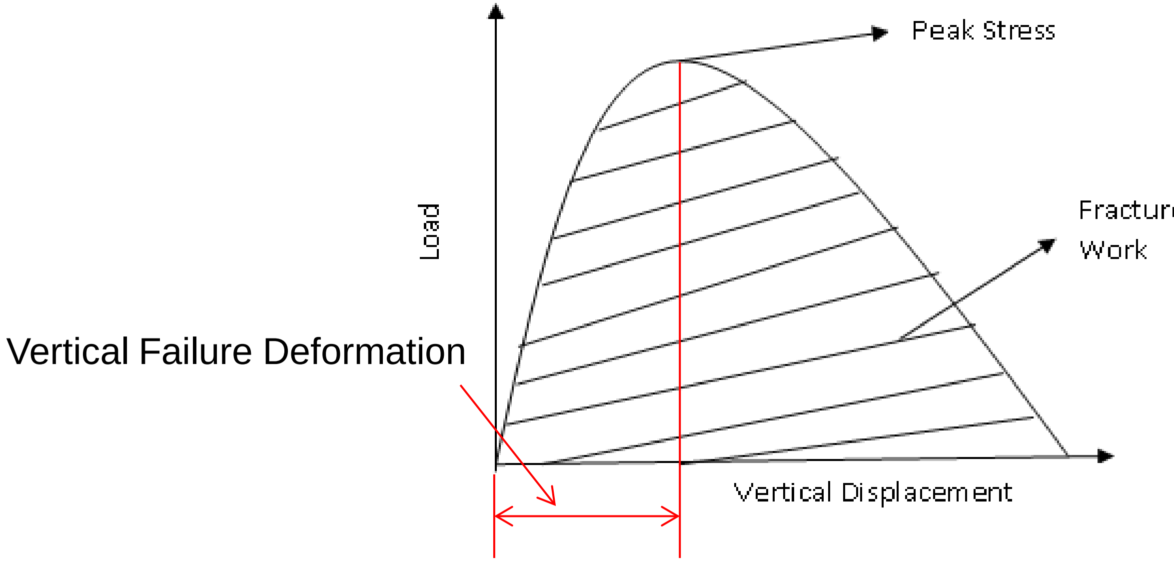


Project	MT I-15	TN SR 125	IA US 34	TX FM 973	LA US 61
Construction Year	2011	2011	2011	2011	2012
Warm Mix	Sasobit, Evotherm DAT, Foaming	Evotherm 3G	Sasobit, Evotherm 3G	Evotherm 3G, Foaming	Sasobit, Evotherm 3G
Mixing Temp., °F	H (315-320) W (283-300)	H (320-350) W (290-320)	H (330-340) W (265-280)	H (310-340) W (249-290)	H (325) W (295)
Compaction Temp., °F	H (290-300) W (269-285)	H (311-335) W (275-290)	H (253-265) W (220-239)	H (268-291) W (221-268)	H (277-316) W (245-250)
Design Thickness, in.	2.5	1.25	1.5	2.0	2.0
Traffic	3 million (3,170 AADT, 26.3% truck)	0.39 million (3,470 AADT, 13% truck)	3 million (6,450 AADT, 10.9% truck)	3 million (11,300 AADT, 4.3% truck)	9 million (34,138 ADT, 14% truck)
Aggregate	Siliceous	Gravel & Sand	Limestone, Quartzite & Sand	Gravel, Limestone & Dolomite	Granite & Limestone
NMAS, in.	3/4	1/2	1/2	3/4	1/2
Asphalt Binder	PG 70-28	PG 70-22	PG 58-28	PG 70-22	PG 76-22
Anti-stripping Agent	Hydrated Lime, 1.4%	AZZ-MAZ, 0.3%	None	None	0.6%
Polymer-modified	SBS	Yes	None	N/A	SBS
Asphalt Content, %	4.6	6.0	5.44	5.2	4.7
G_{mm}	HMA (2.458) Sas (2.466) Evo (2.459) Foam (2.453)	HMA (2.352) Evotherm (2.355)	HMA (2.423) Sasobit (2.428) Evotherm (2.429)	HMA(2.406) Evotherm (2.405) Foaming (2.420)	HMA (2.464) Sasobit (2.468) Evotherm(2.464)
Sampling Date	Sep. 15-17, 2011	Oct. 24-31, 2011	Sep. 6, 2011	Dec. 1, 2011	May 16-June 6, 2012
RAP or RAS	None	10% RAP	17% RAP	None	15% RAP
Structure	2.5" overlay + 7" existing HMA + 16.2" base (non-stabilized) + infinite subgrade	1.25" overlay + 8" bituminous base + 6" min. aggregate base + infinite subgrade	HMA & Sasobit: 1.5"overlay + 5" existing HMA + 7" PCC + subgrade Evotherm: 1.5" overlay + 3" existing HMA + 9" PCC + subgrade	2" overlay + 8" existing HMA + 10" base + 141.1" subgrade (lean clay)	2" overlay + 8" existing HMA + 8" PCC + 6" cement treated soil subgrade

Mixture Test Summary

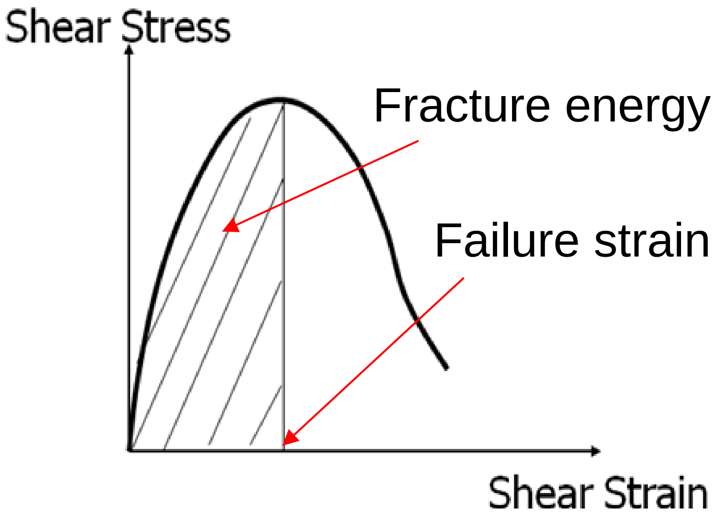
Mixture Test	IDT Dynamic Modulus/Creep Compliance	Fatigue-IDT Fracture at Room Temp	Thermal Cracking-IDT Fracture at Low Temp	Rutting/Moisture - Hamburg
Testing Conditions	Temp.: −4, 14, 32, 50, 68, 86ºF; Frequency: 20, 10, 5, 1, 0.1, 0.01 Hz Duration: 100 seconds	Temp.: 68ºF Loading rate: 2 in./min	Temp.: 14ºF Loading rate: 0.1 in./min	Temp.: 122ºF Wet condition
Material Properties	Dynamic modulus; Creep compliance	IDT strength; Fracture work density; Vertical failure deformation Horizontal failure strain	IDT strength; Fracture work density; Vertical failure deformation; Horizontal failure strain	Rut depth; Stripping inflection point (SIP); Cycles
References/ Standards	AASHTO T322 Wen et al. 2002	AASHTO T322	AASHTO T322 Wen 2012	AASHTO T324





Binder Test Summary

Binder Test	PGs	Rutting: MSCR	Fatigue: Monotonic at Room Temp	Thermal Cracking: Monotonic at Low Temp
Testing Conditions	Different temp depending on the test (DSR, BBR)	Stress: 0.1, 3.2kPa Temp.: 98% Reliability from LTPP Bind	Temp.: 68°F Shear strain rate: 0.3 s^{-1}	Temp.: 41°F Shear strain rate: 0.01s^{-1}
Material Properties	PG; BBR stiffness; m-value	$Jnr_{0.1}$, $Jnr_{3.2}$; $R_{0.1}$, $R_{3.2}$	Maximum stress; Fracture energy; Failure strain	Maximum stress; Fracture energy; Failure strain
References/Standards	AASHTO MP1/T240/T313	AASHTO T350	Wen et al. 2010	Wen 2012



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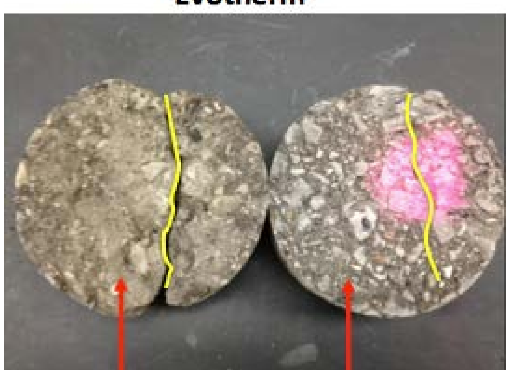
Transverse Cracking

Reflective

Surface-initiated

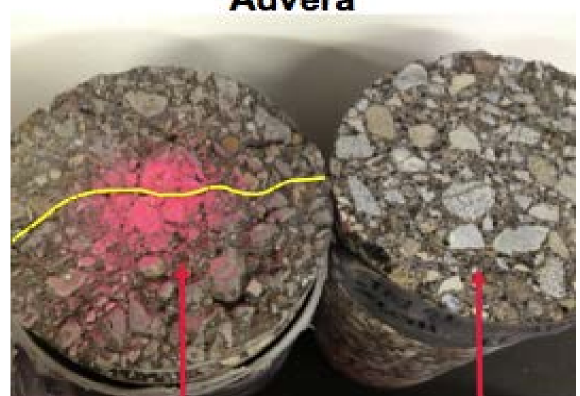
Evotherm



Underlying

Overlay

Advera

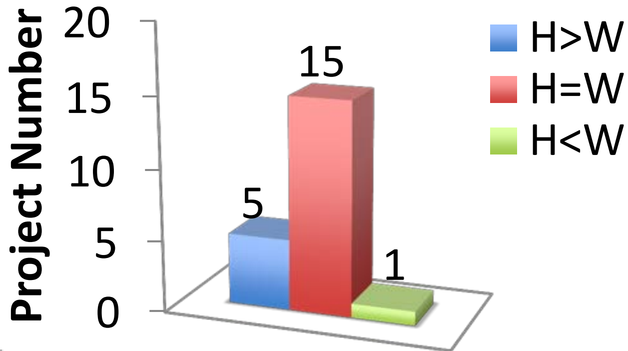


Overlay

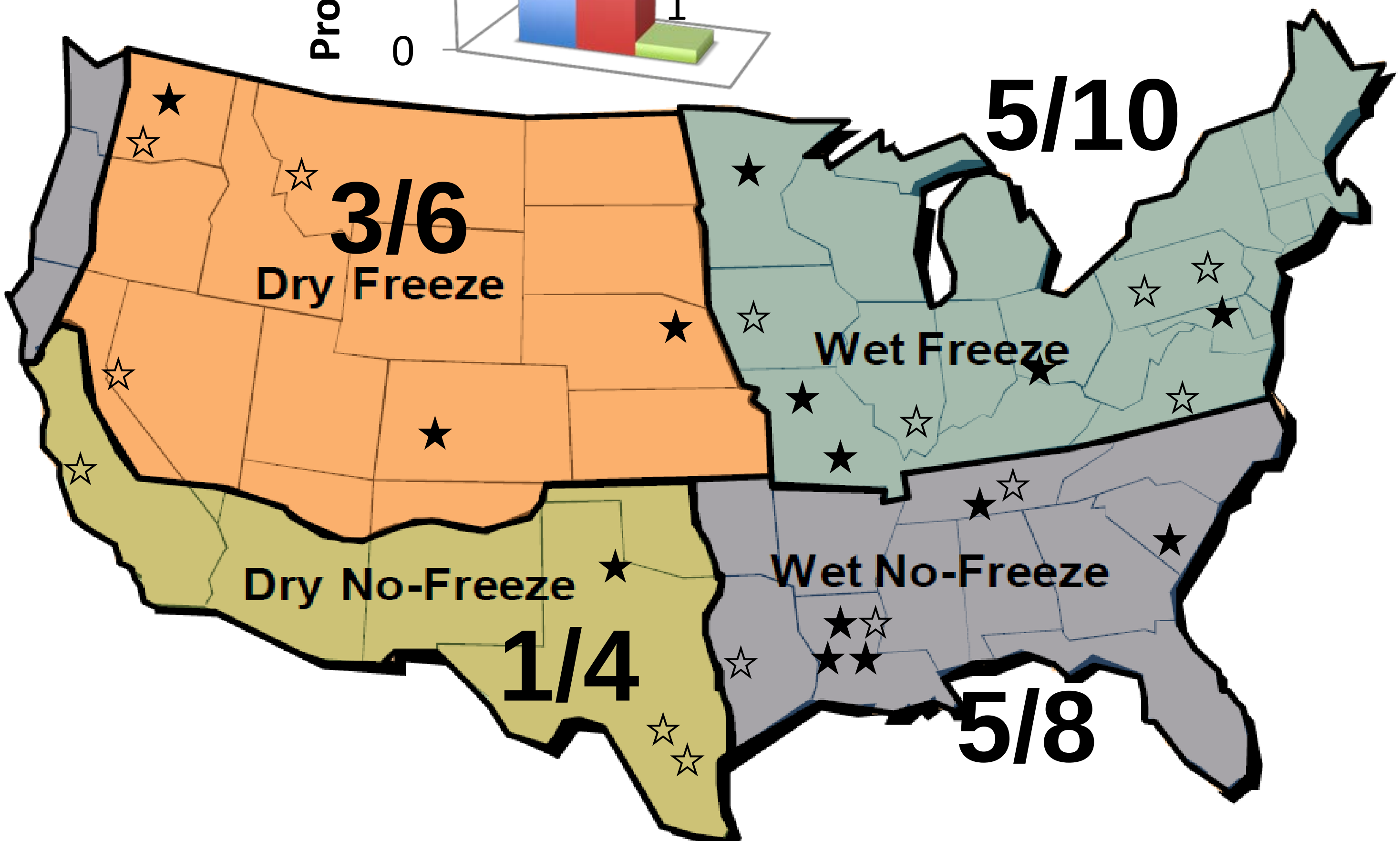
Underlying

1st Round HMA/WMA Transverse Cracking Comparison

14 (21 H-W Pairs) out of 28 projects exhibited transverse cracking

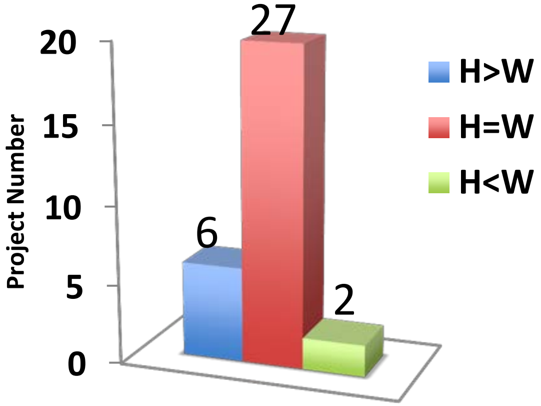


- H>W: HMA has more cracking than WMA
- HMA has slightly more transverse cracks than WMA.



2nd Round HMA/WMA Transverse Cracking Comparison

22 (35 H-W pairs) out of 28 projects exhibited transverse cracking



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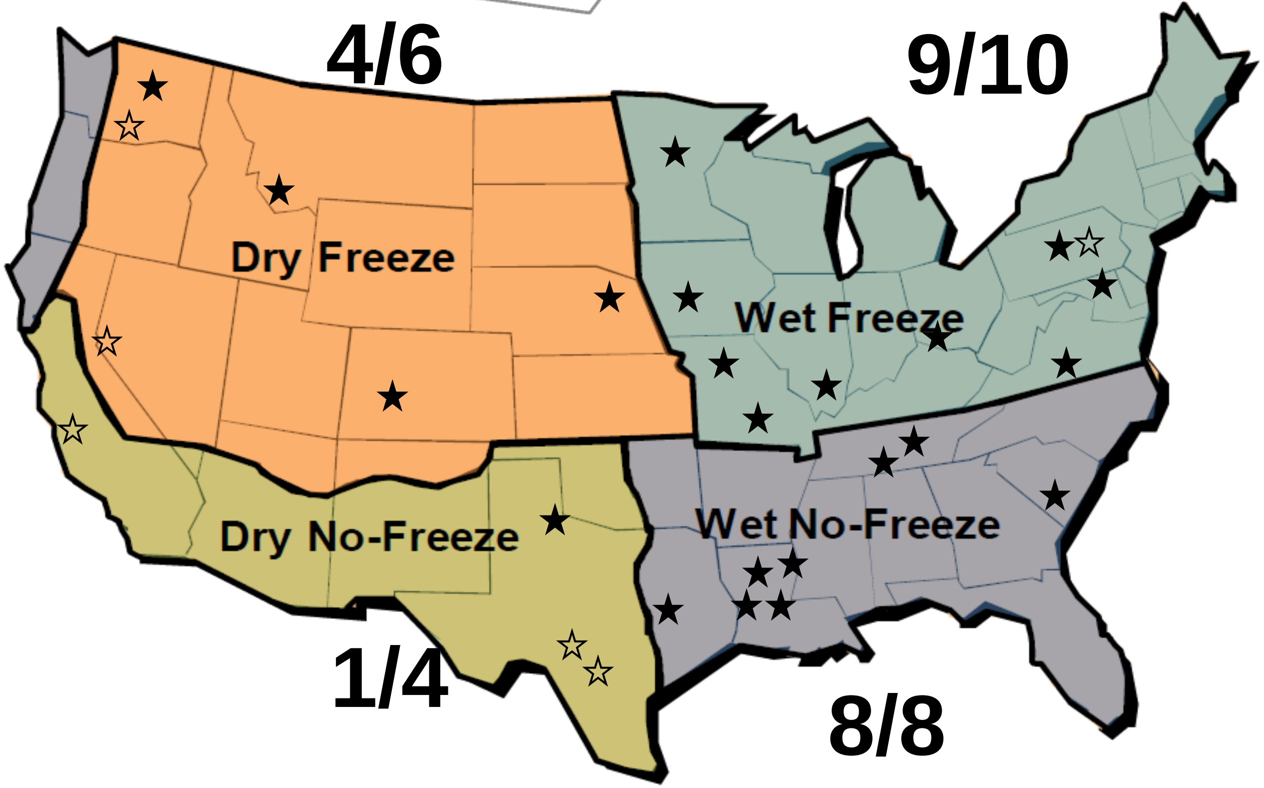


Significant Determinants of Transverse Cracking

Compare Material Properties

- H>W, H=W, H<W (t-test)

Compare Field Performance

- H>W, H=W, H<W (t-test)

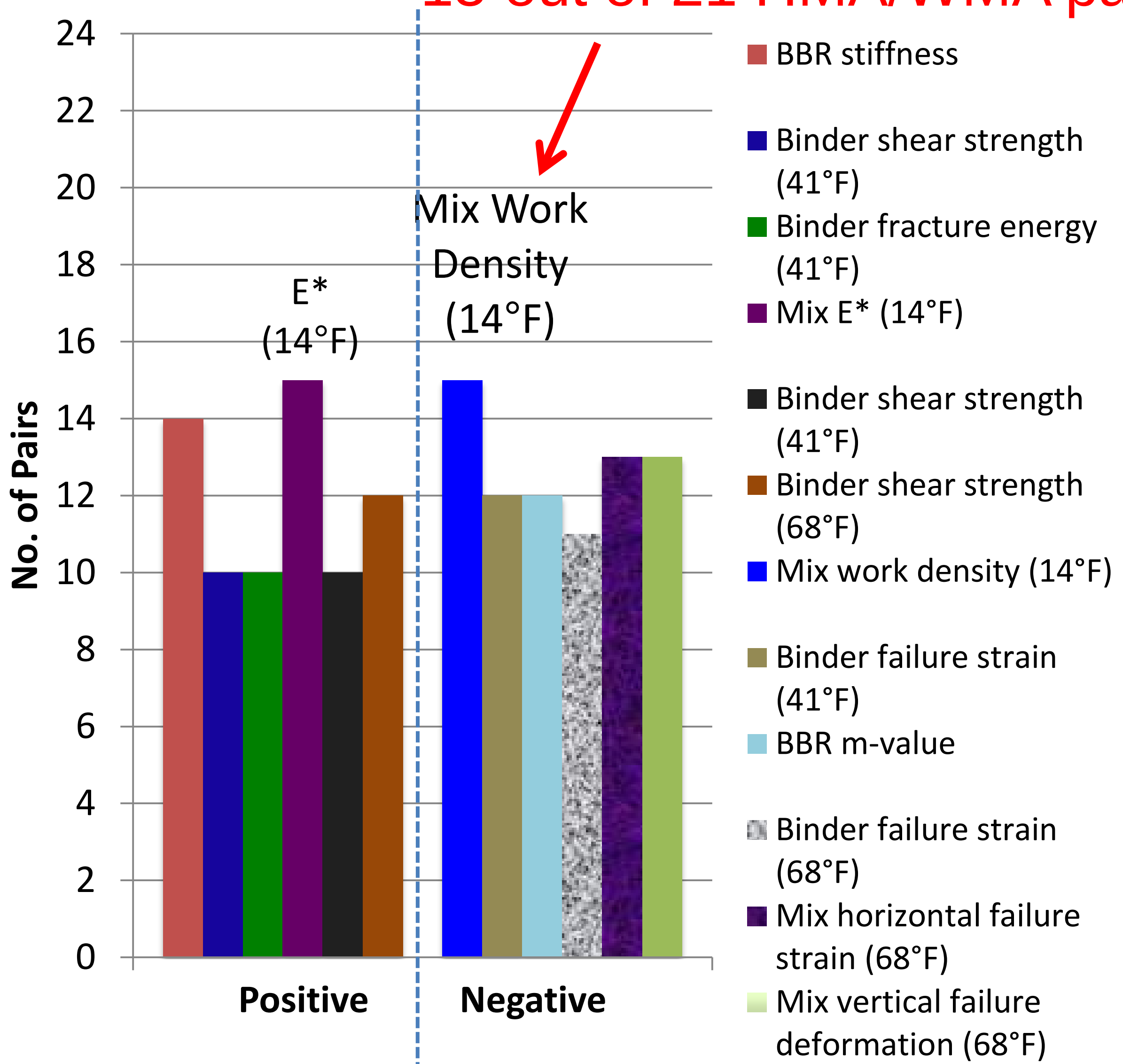
Compare the two rankings

- Consistent trend
- No consistent trend

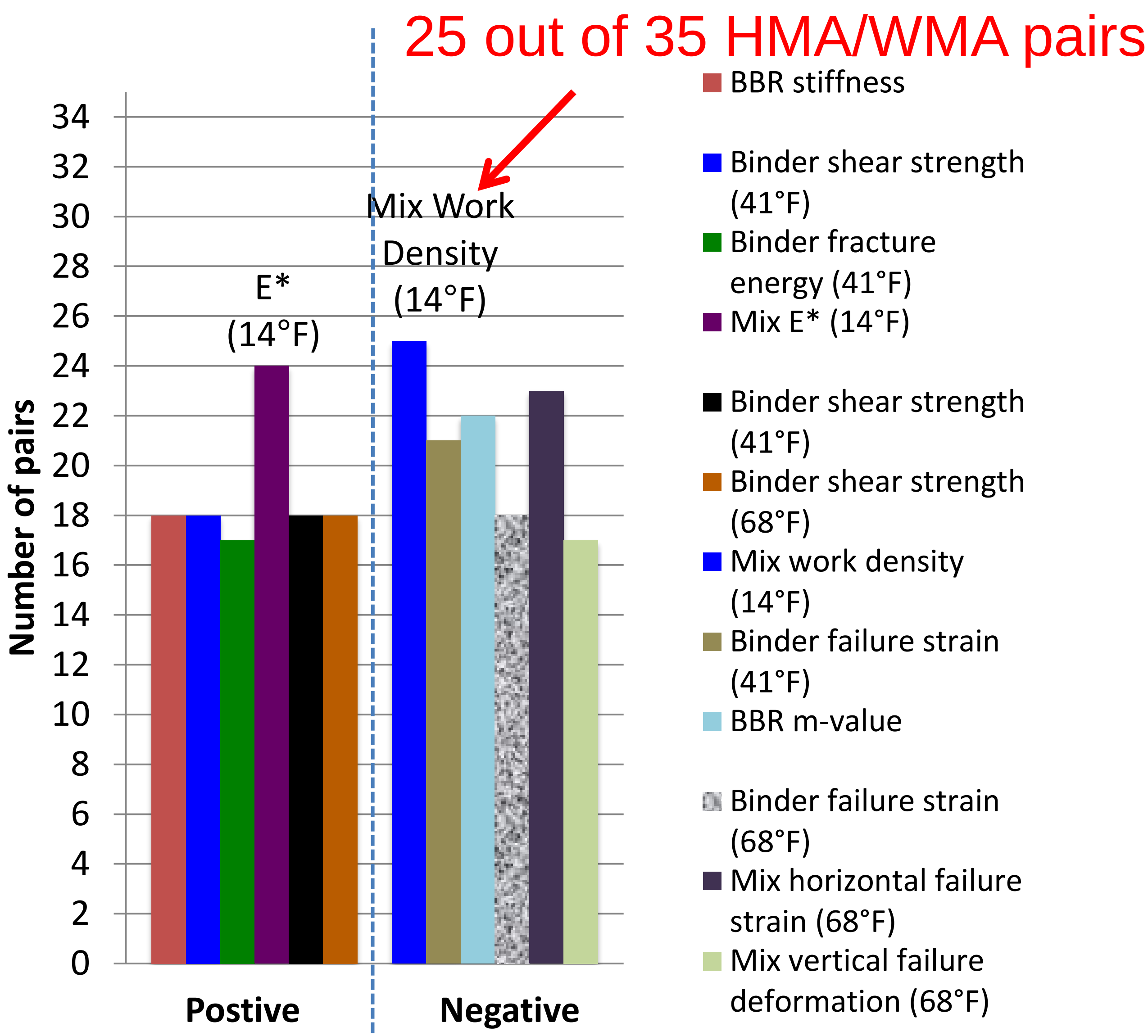
- Summarize the number of pairs with consistent trend and determine the promising indicator

Significant Determinants for Transverse Cracking Based on 1st Round Results

15 out of 21 HMA/WMA pairs



Verification: Significant Determinants for Transverse Cracking Based on 2nd Round Results



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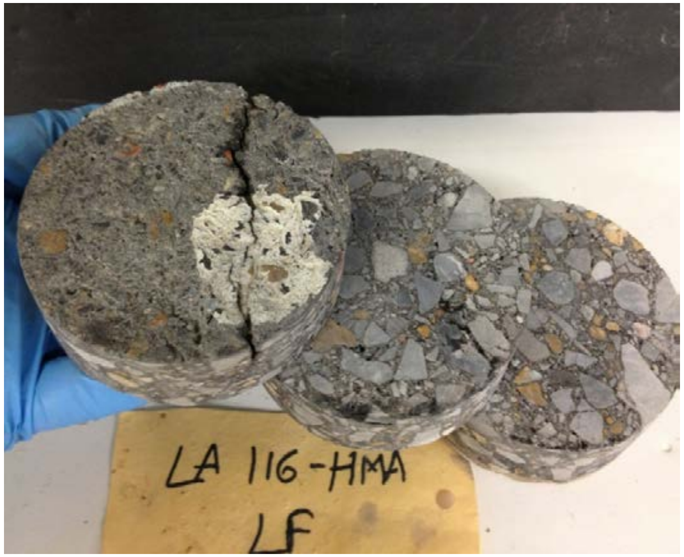
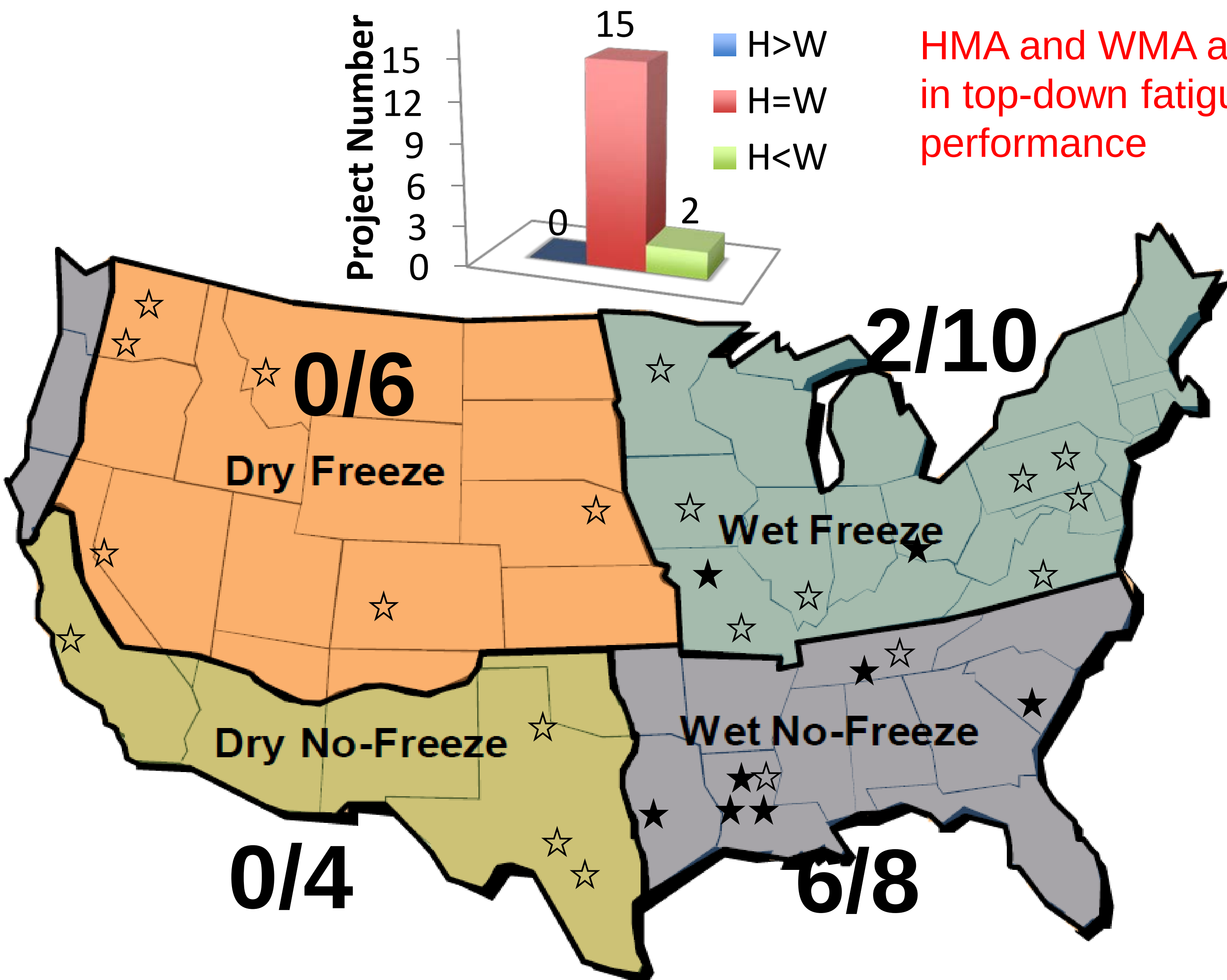
Top-down Fatigue Cracking



1st Round HMA/WMA Top-down Cracking Comparison

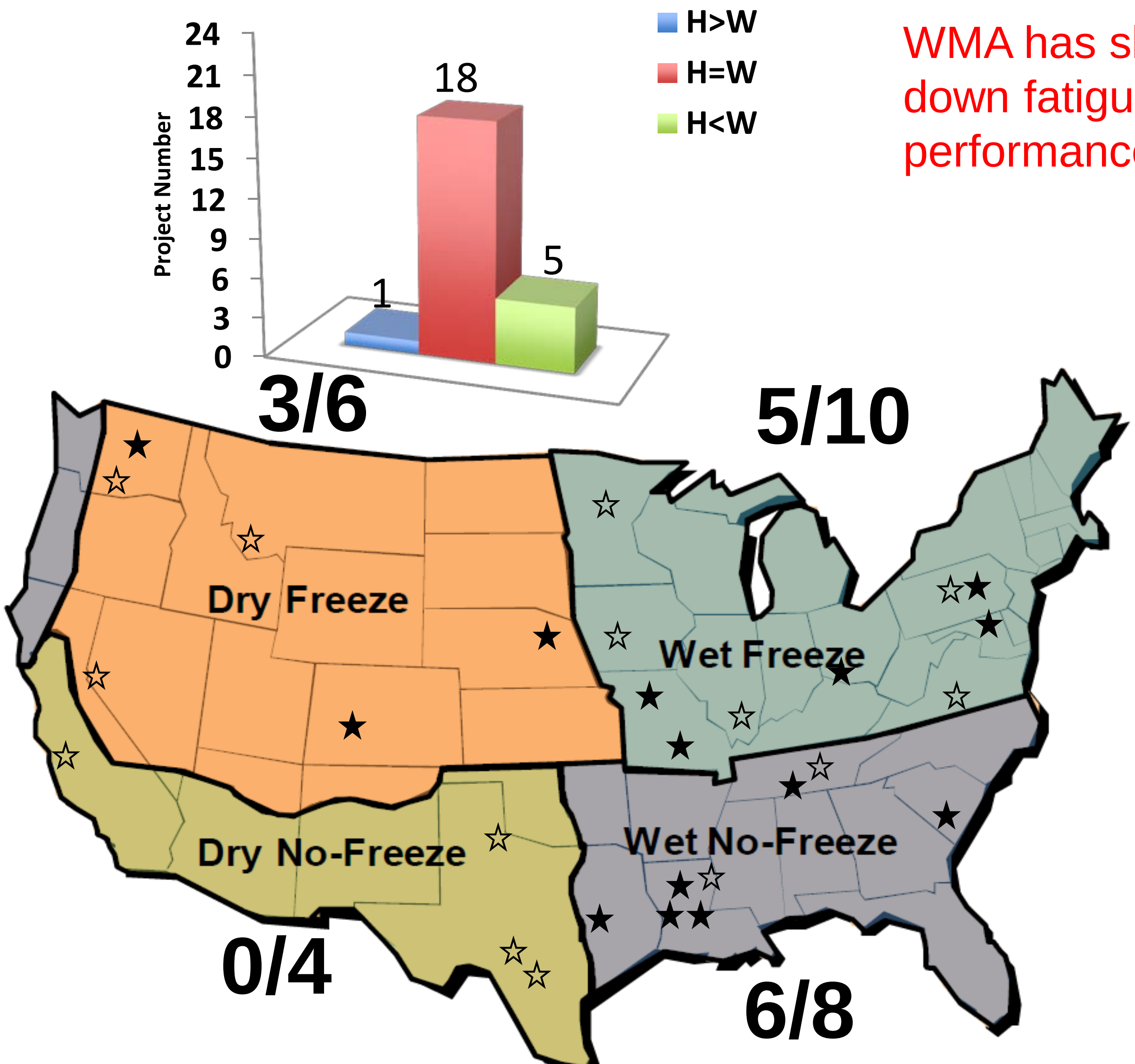
8 (17 H-W pairs) out of 24 projects exhibited top-down longitudinal cracking.



HMA and WMA are comparable in top-down fatigue cracking performance

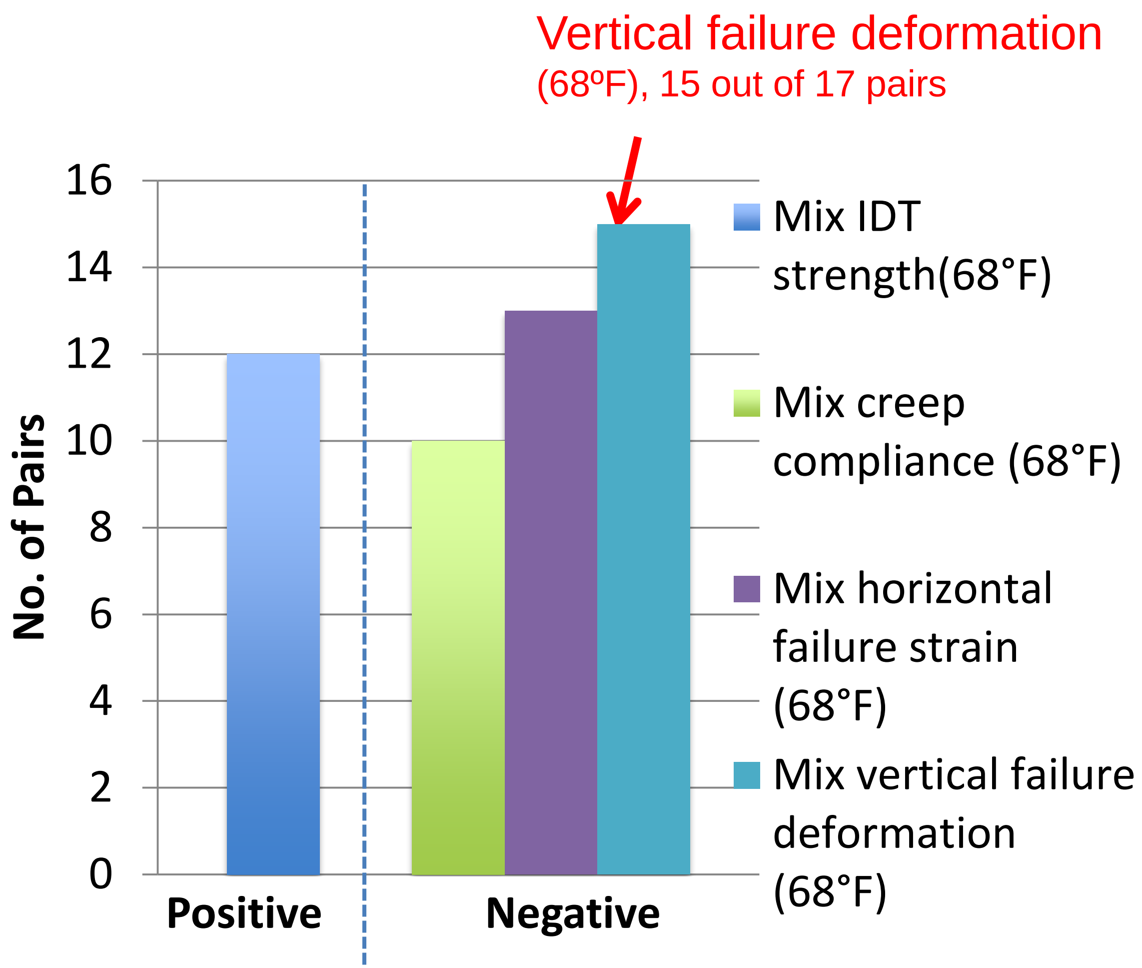
2nd Round HMA/WMA Top-down Cracking Comparison

14 (24 H-W pairs) out of 28 projects exhibited top-down longitudinal cracking.

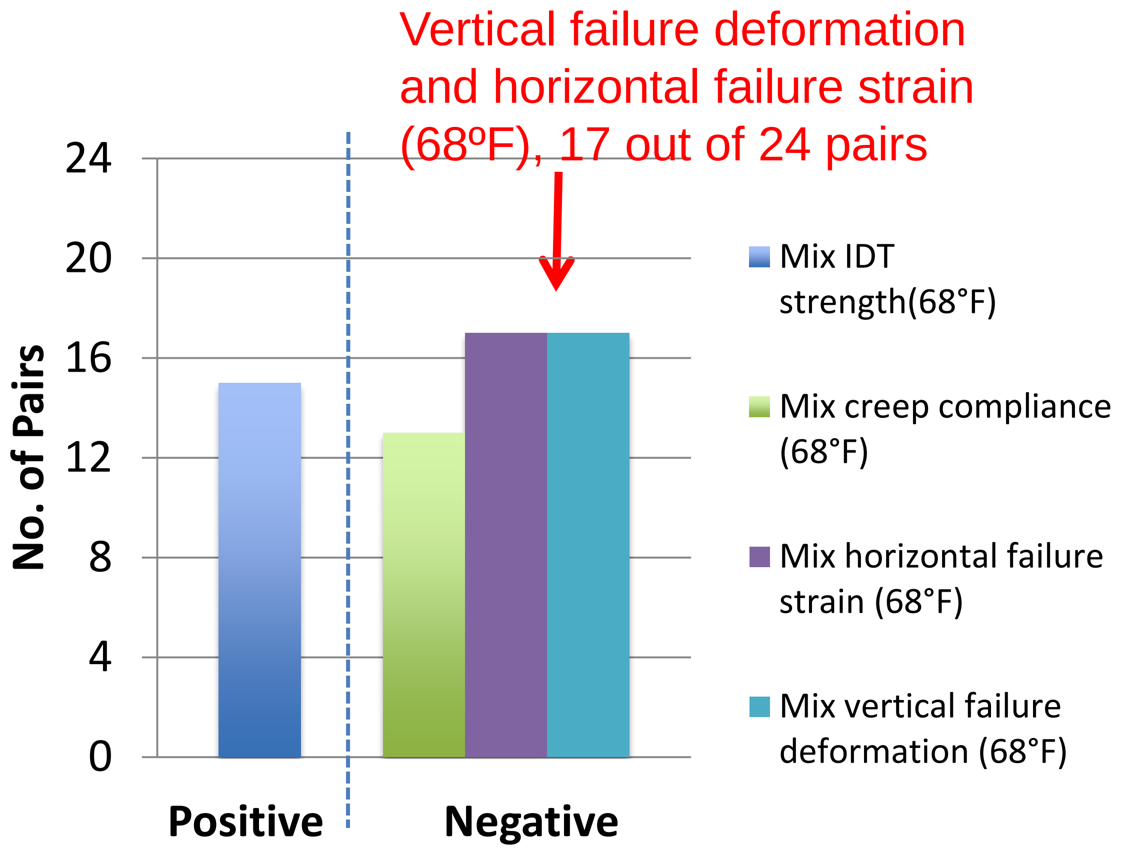


WMA has slightly more top-down fatigue cracking performance than HMA

Significant Determinants for Top-down Longitudinal Cracking Based on 1st Round Results



Verification: Significant Determinants for Top-down Cracking Based on 2nd Round Results



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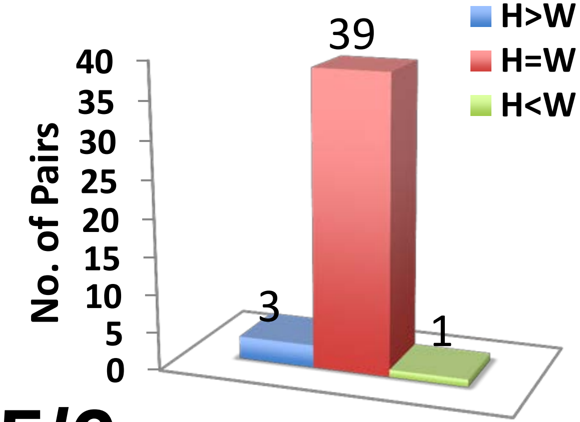
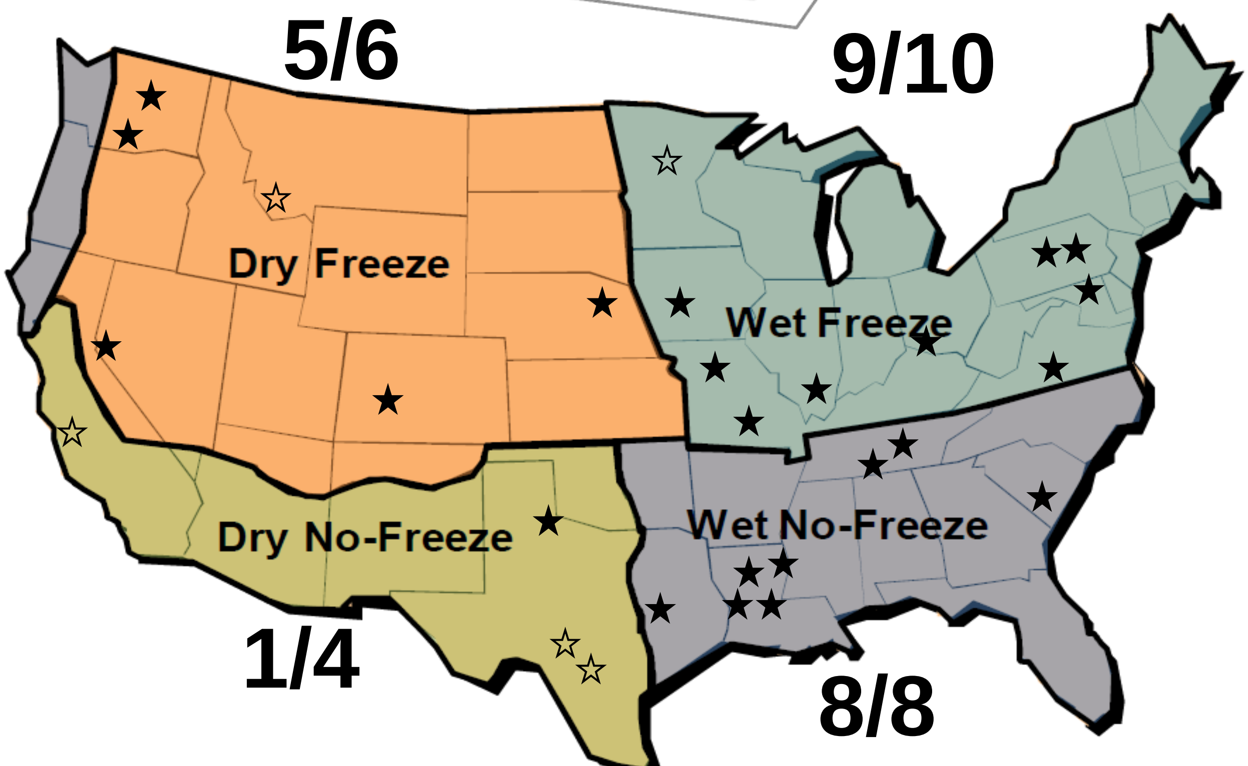
Rutting

2nd Round HMA/WMA Rutting Performance Comparison

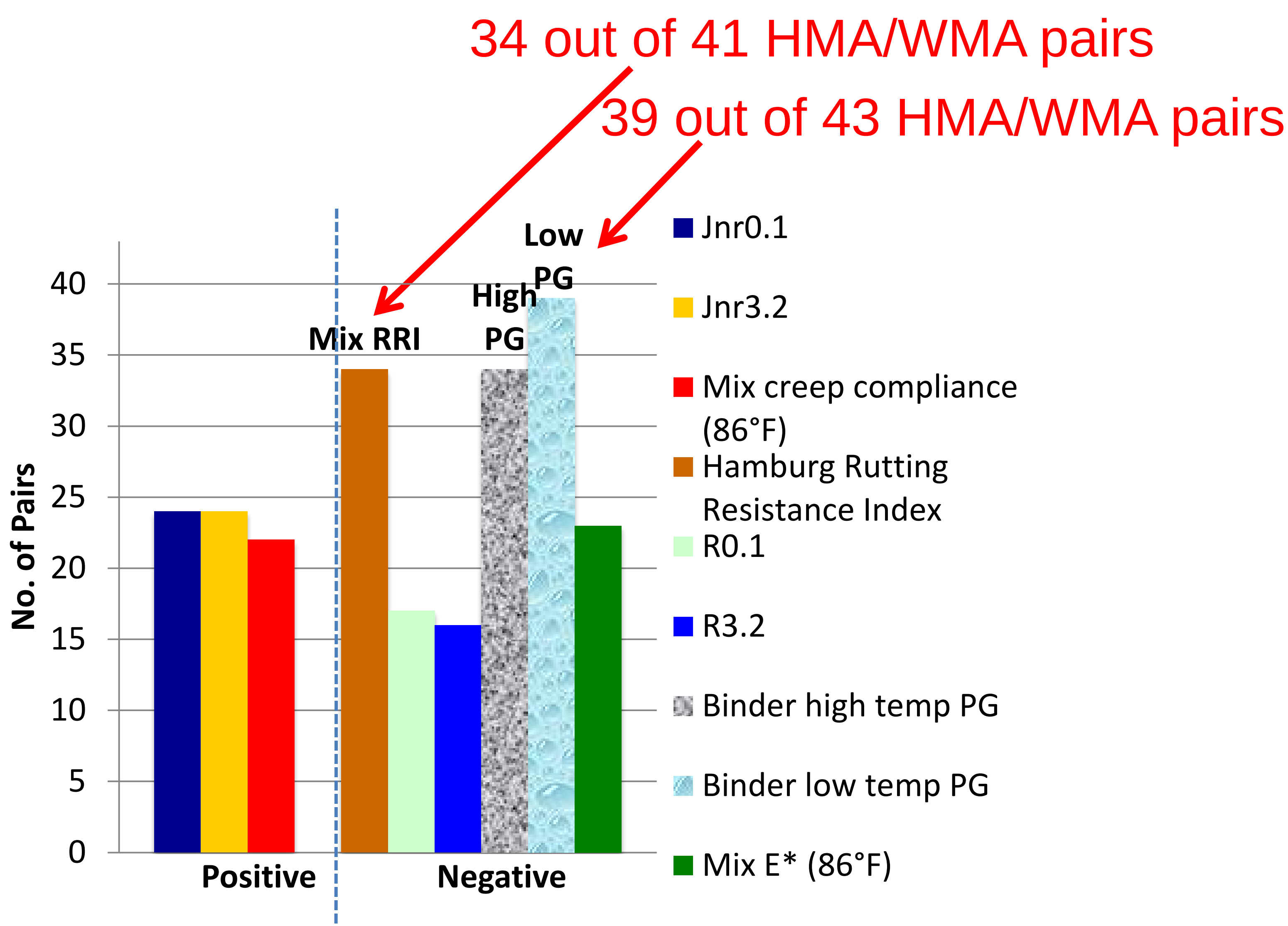
23 projects (43 H-W pairs) exhibited measurable rut depth.



HMA and WMA are comparable in rut depth



Significant Determinants for Rutting Resistance



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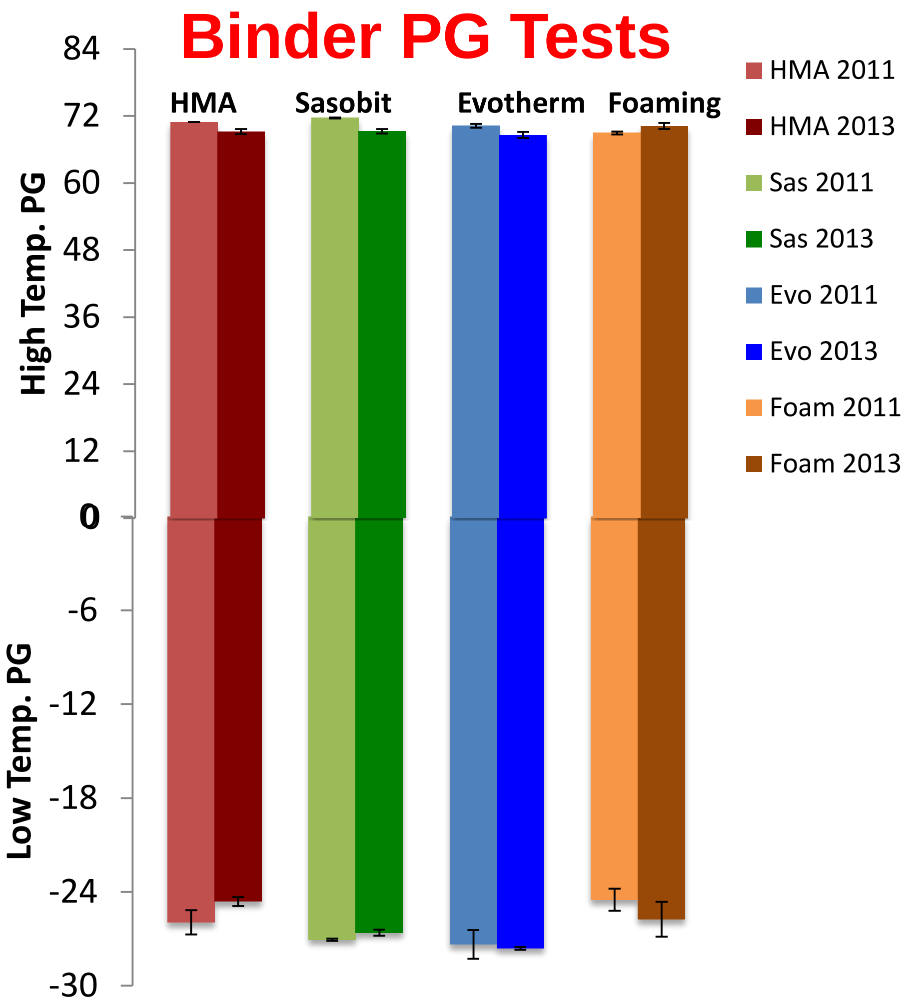
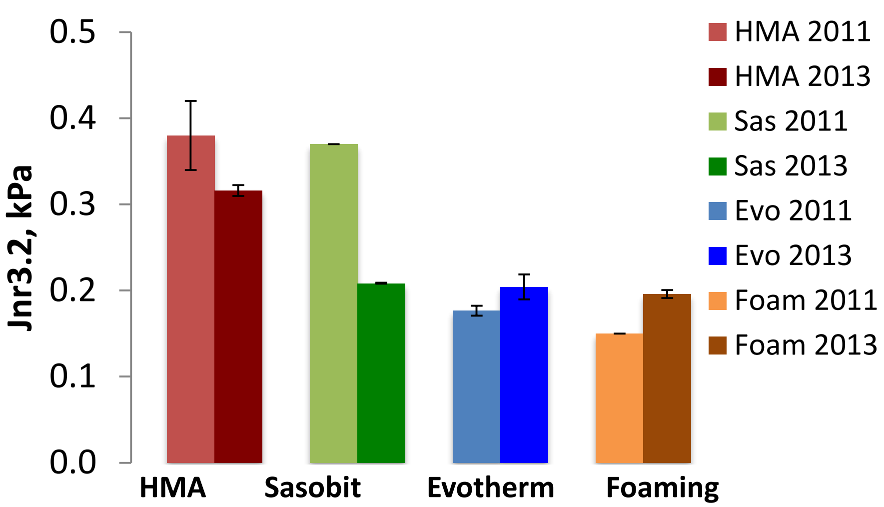
MT I-15 Project: Chip Seal On the Surface

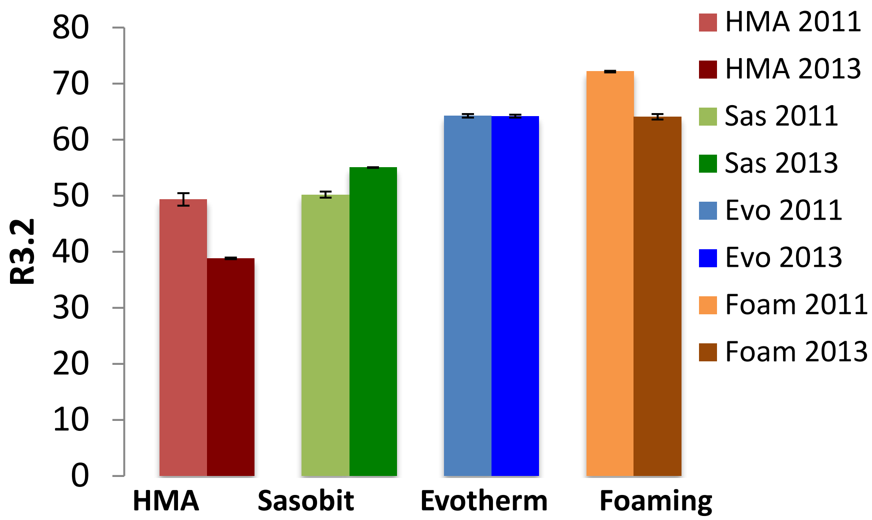
MT I-15 Project: 2013 Vs 2011 Field Cores



MT I-15 Project: 2013 Vs 2011 Field Cores

Binder MSCR Tests



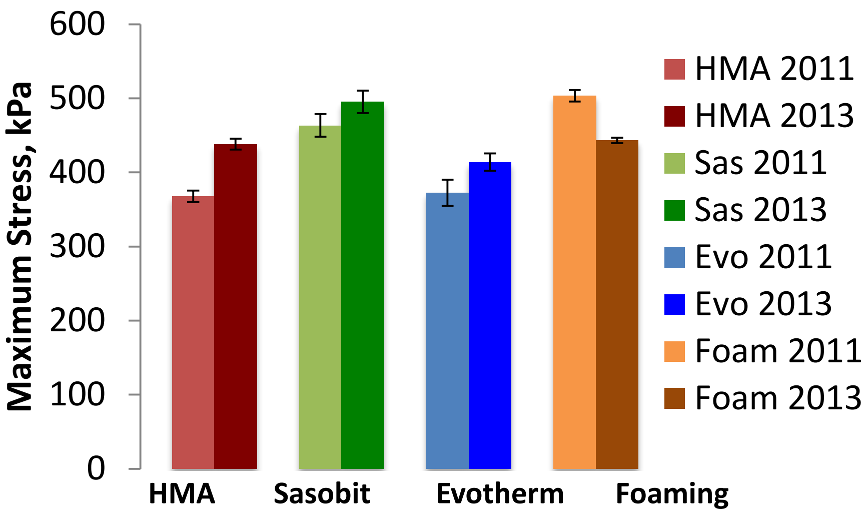


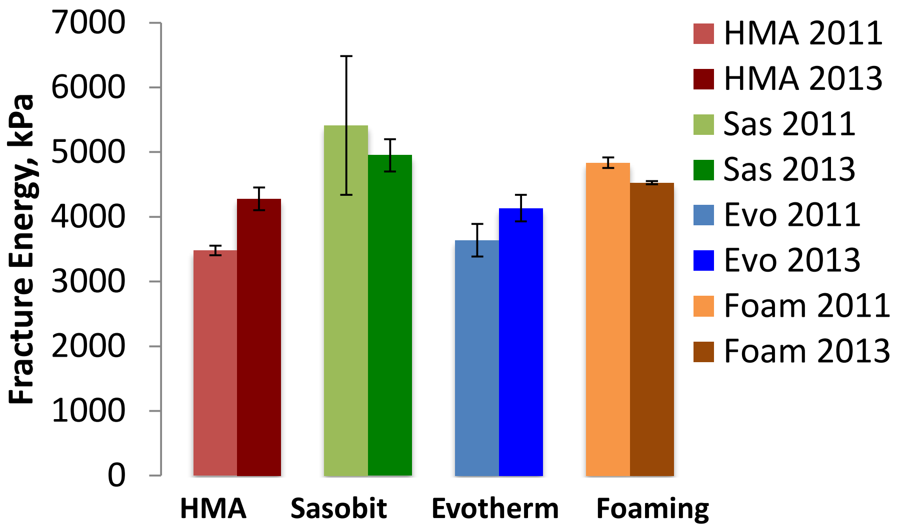
2013 vs 2011	HMA	Sasobit	Evotherm	Foaming
d2s, Jnr3.2 (31.3%)*	18.4% (=)	55.8% (<)	14.5% (=)	26.6% (=)
d2s, R3.2 (17.3%)*	23.8% (>)	9.2% (=)	0.12% (=)	11.8% (=)

* Source (Anderson 2014)
http://www.webpages.uidaho.edu/bayomy/IAC/54th/Presentations_54th/2.%20IAC2014_MSCR_Mike%20Anderson.pdf

MT I-15 Project: 2013 Vs 2011 Field Cores

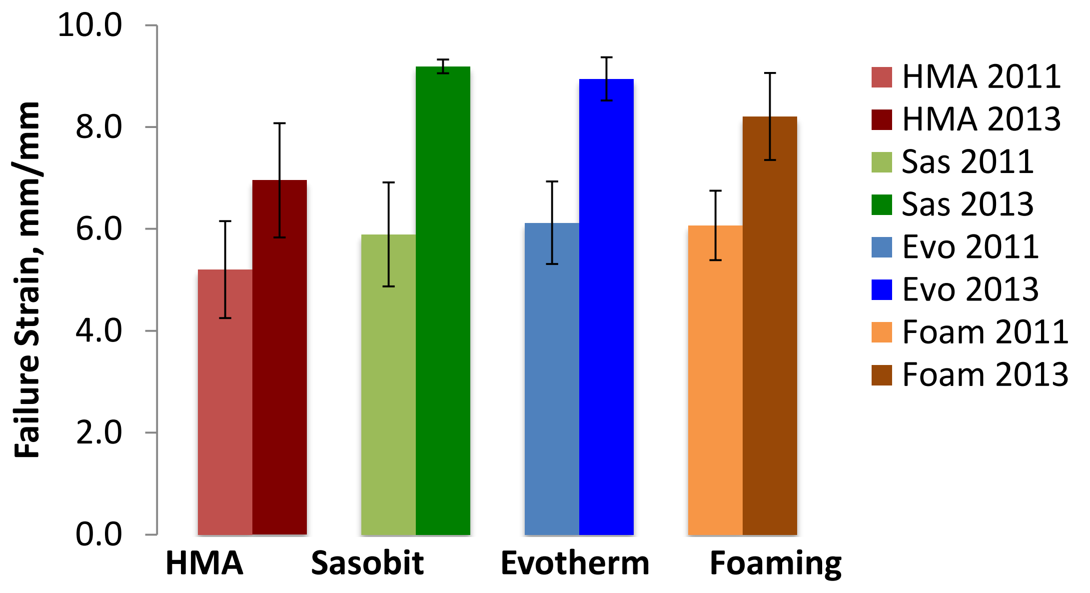
Binder Fracture Tests at Intermediate Temperature





MT I-15 Project: 2013 Vs 2011 Field Cores

Binder Fracture Tests at Low Temperature



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TN SR 125 Project: HMA Pavement

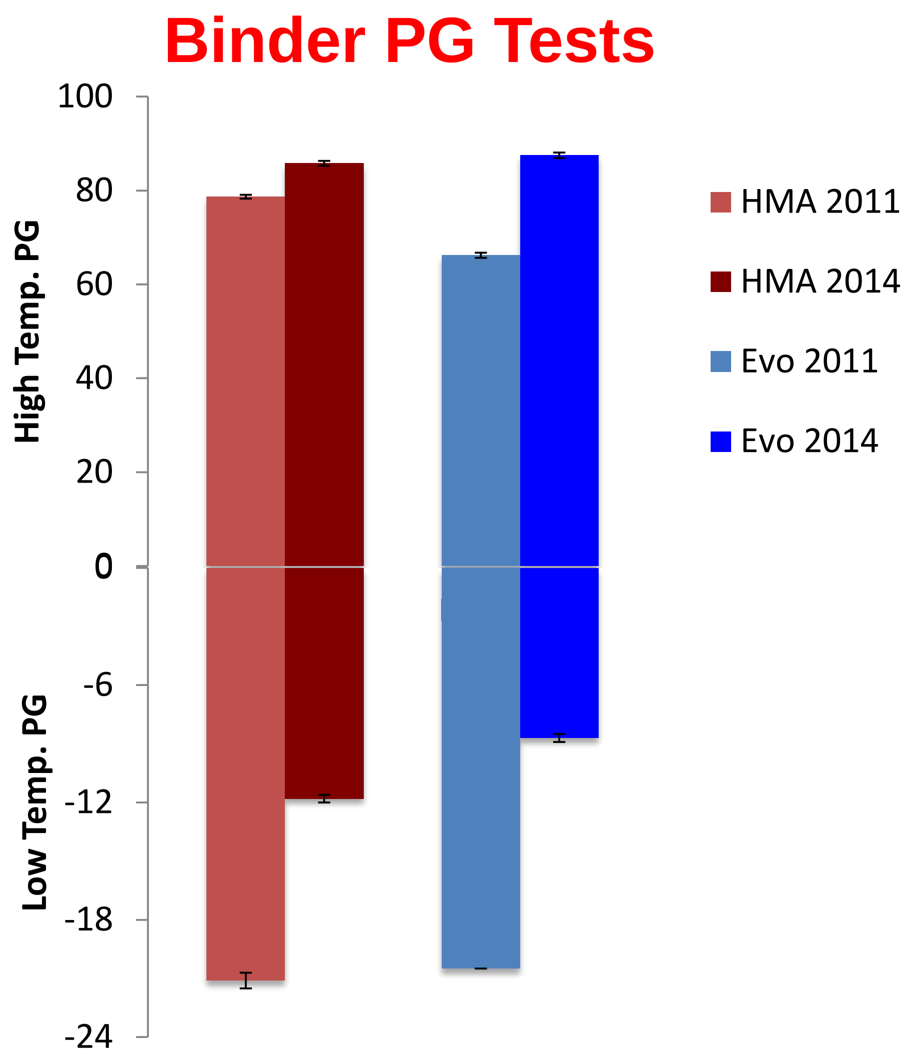
Before Construction

During Construction

After Construction

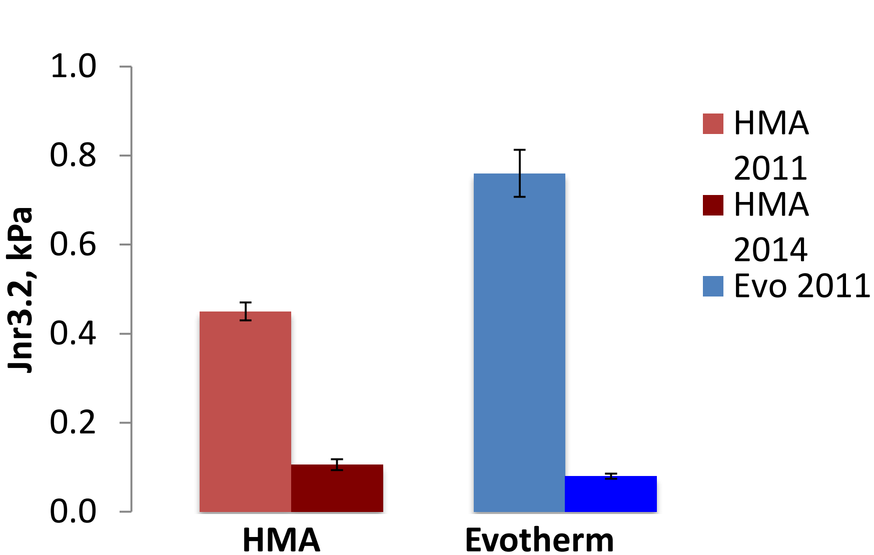
3 years After Construction

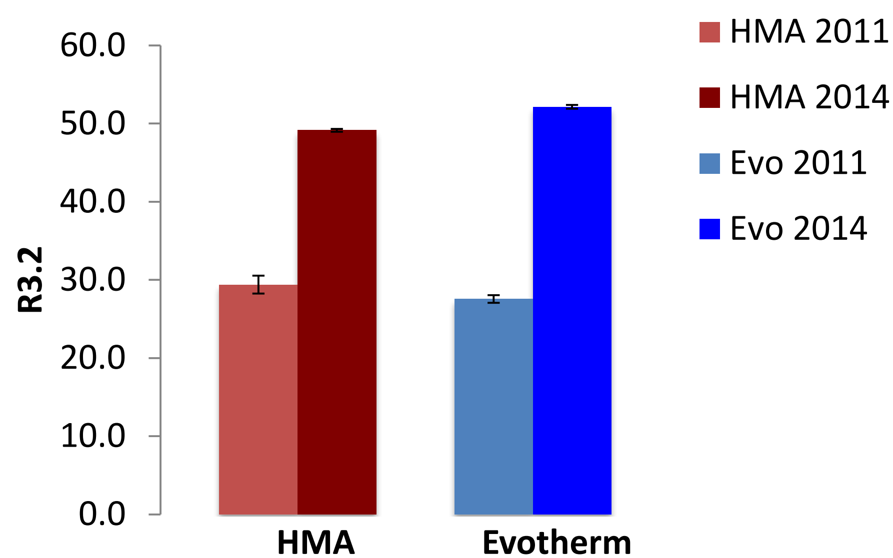
TN SR 125 Project: 2014 Vs 2011 Field Cores



TN SR 125 Project: 2014 Vs 2011 Field Cores

Binder MSCR Tests





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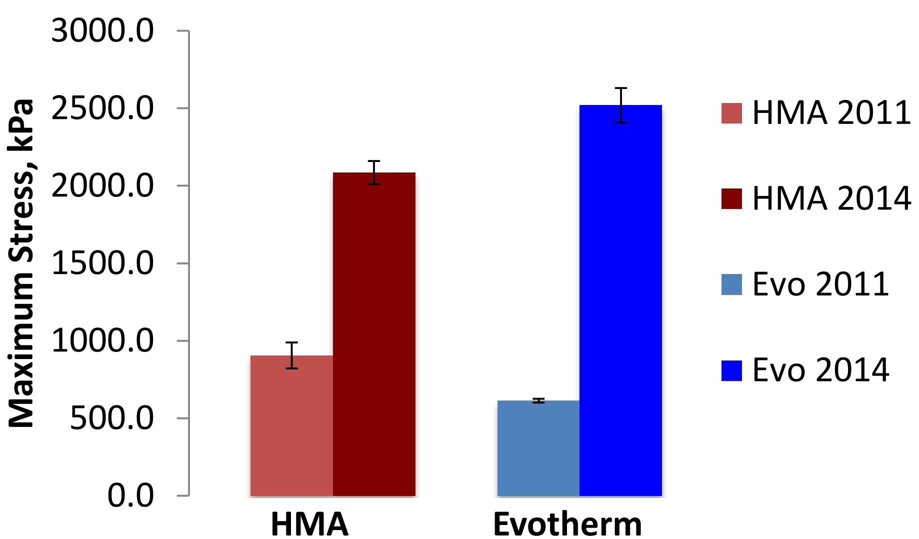
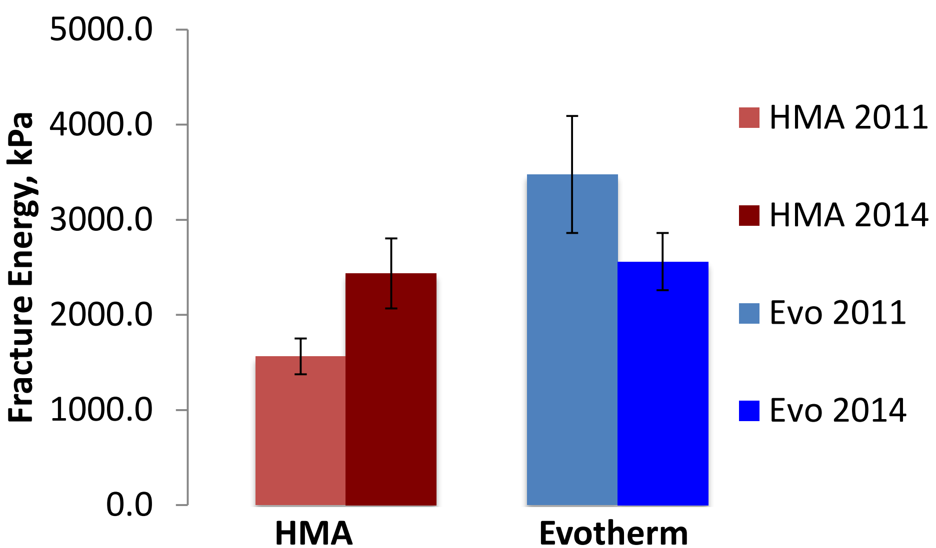
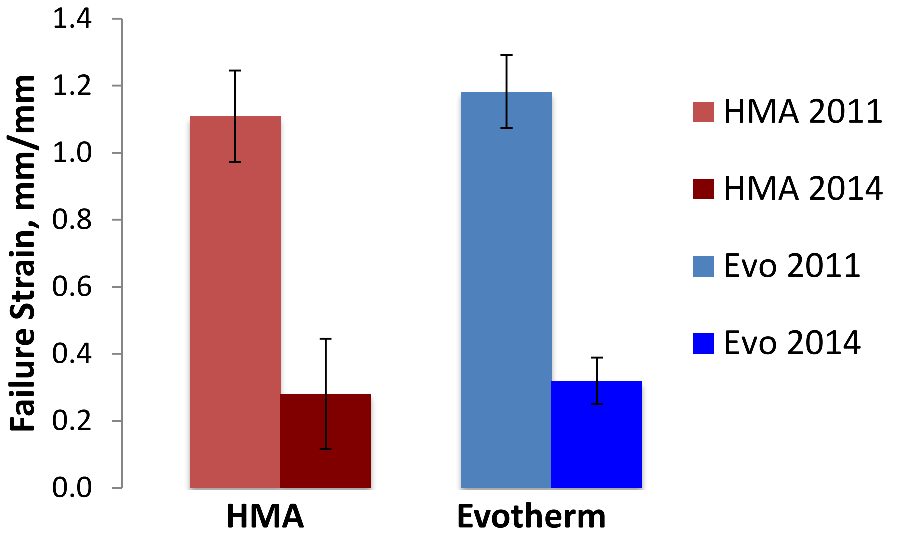




TN SR 125 Project: 2014 Vs 2011 Field Cores

Binder Fracture Tests at Low Temperature



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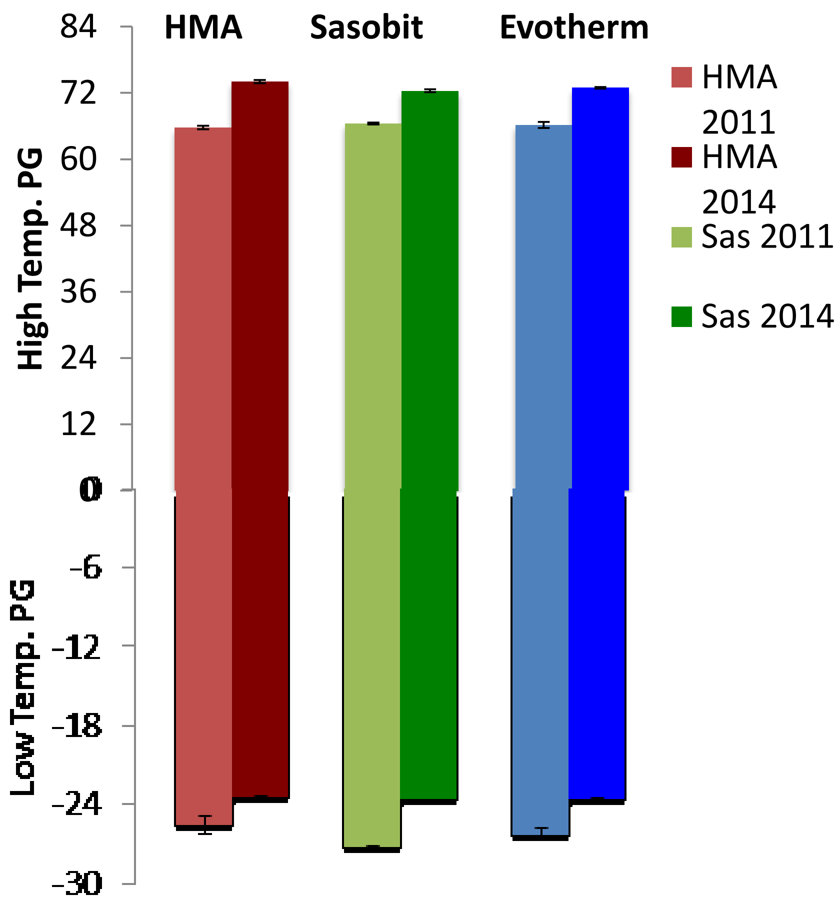
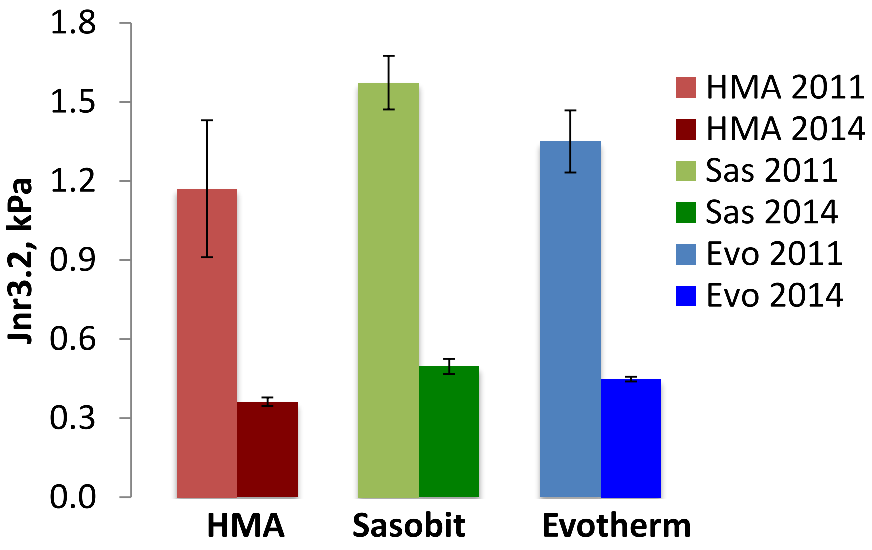
IA US 34 Project: 2014 Vs 2011 Field Cores

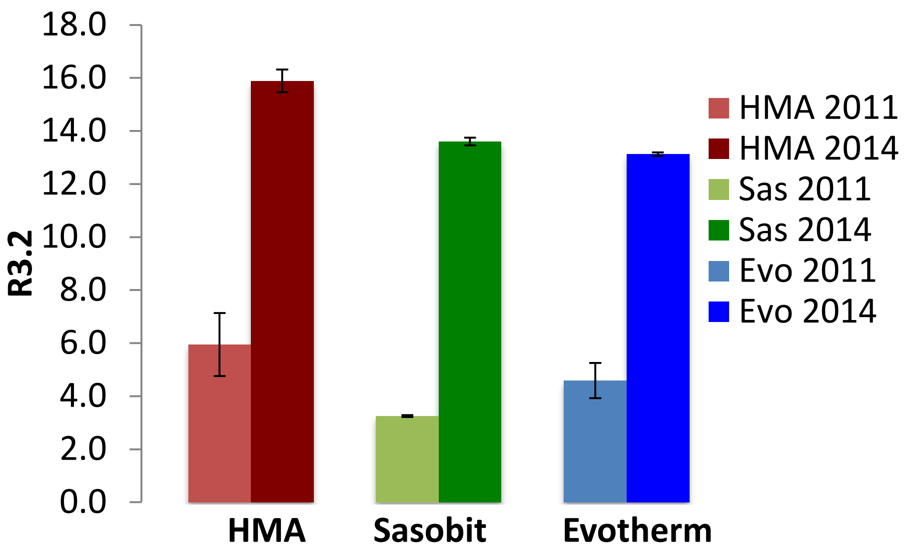
Binder PG Tests



IA US 34 Project: 2014 Vs 2011 Field Cores

Binder MSCR Tests





IA US 34 Project: 2014 Vs 2011 Field Cores

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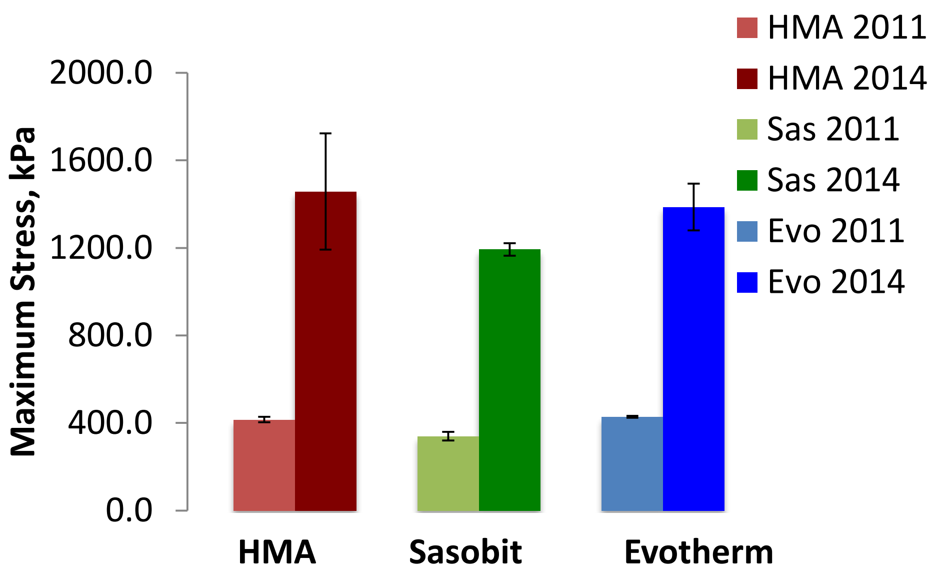

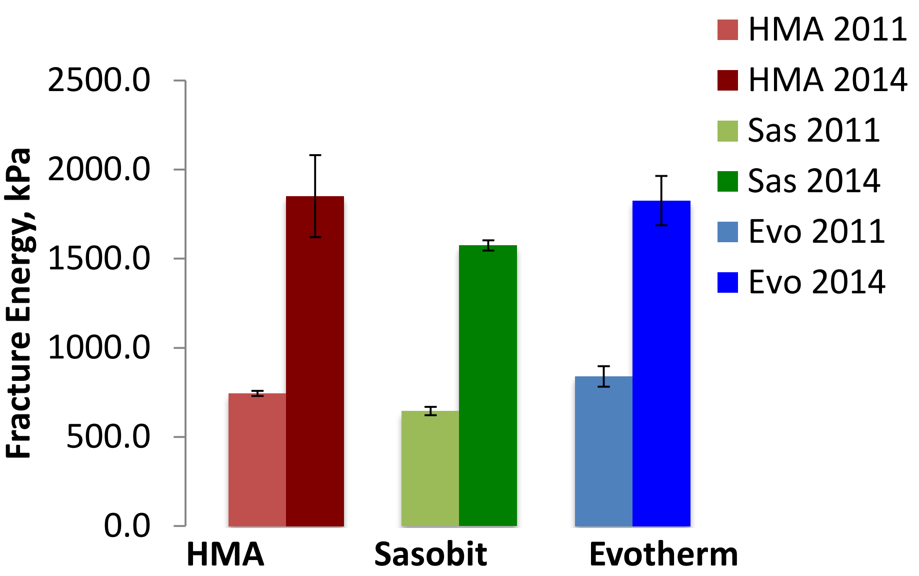

IA US 34 Project: 2014 Vs 2011 Field Cores

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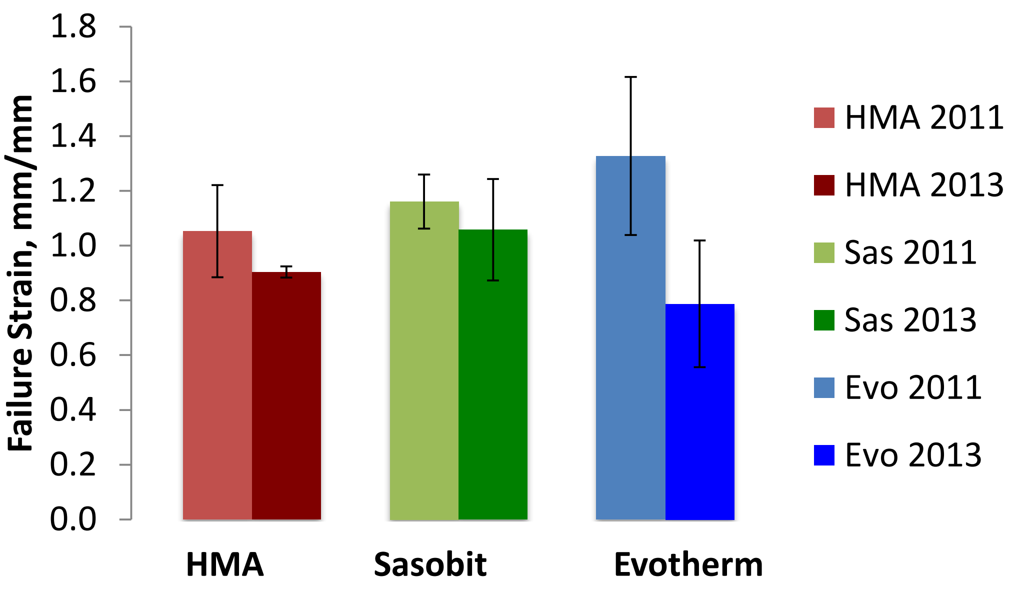


Analysis

Carbonyl area (function of aging temperature and time)

Arrhenius Equation

$$CA = CA_{tank} + M(1 - \exp(-k_f t)) + k_c t$$

$$k_f = A_f \exp(-E_{af}/RT)$$

$$k_c = A_c \exp(-E_{ac}/RT)$$

linear

Inverse of log crossover modulus

linear

Crossover frequency

G* and δ

$$G^*(\omega) = G_g \left[1 + \left(\frac{\omega_c}{\omega}\right)^{\frac{\log 2}{R}}\right]^{\frac{-R}{Log\ 2}}$$

$$\delta(\omega) = \frac{90}{\left[1+\left(\frac{\omega}{\omega_c}\right)^{\frac{\log 2}{R}}\right]}$$

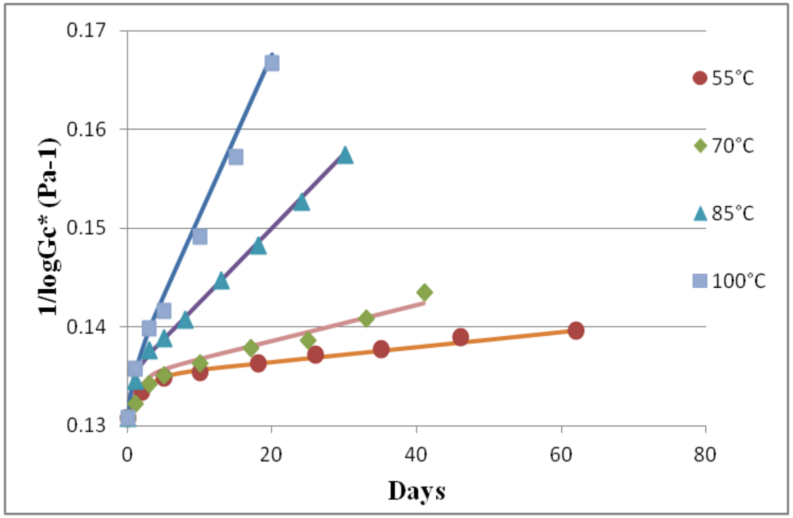
Aging

- Asphalt Binder:
  - IA PG58-22, MT PG70-28(SBS)
    LA PG76-22(SBS)

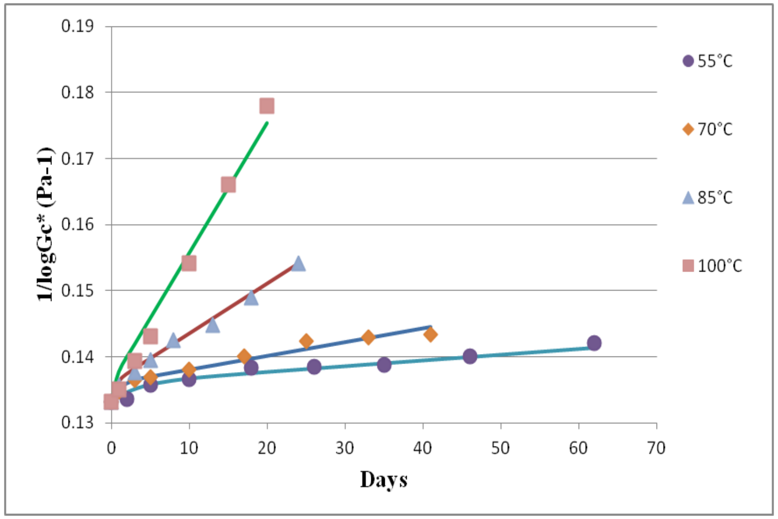
Temperature	Aging time, days
55°C	2,5,10,18, 26, 35, 45, 60, 90
70°C	1, 3, 6,10,15, 22, 30, 40
85°C	1, 3, 5, 8,13,18, 24, 30
100°C	1, 2, 4, 6, 8,11,14,17

≤1mm

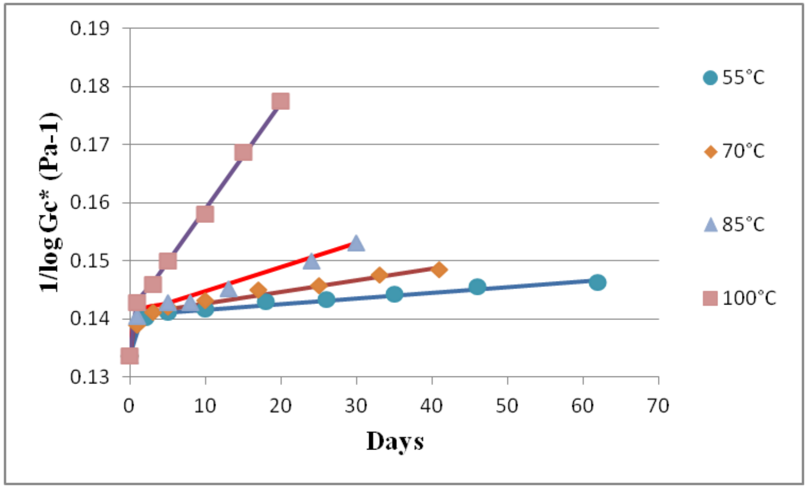
Analysis of crossover modulus data



PG 58-28



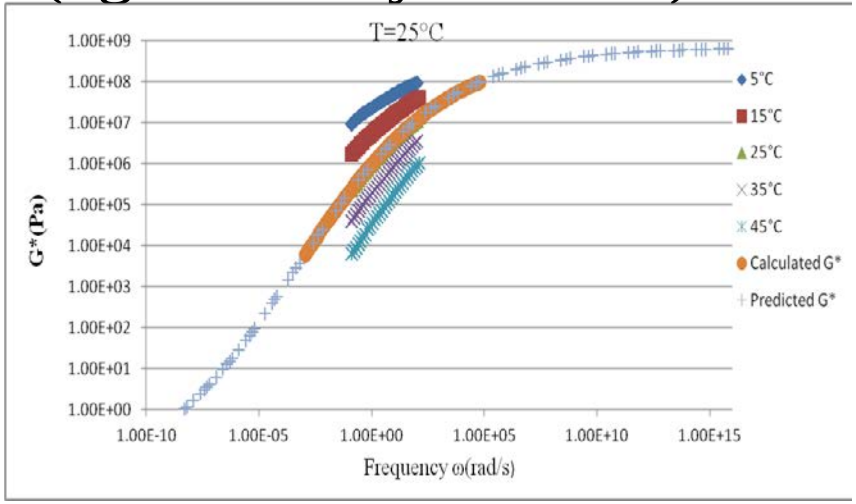
PG 70-28



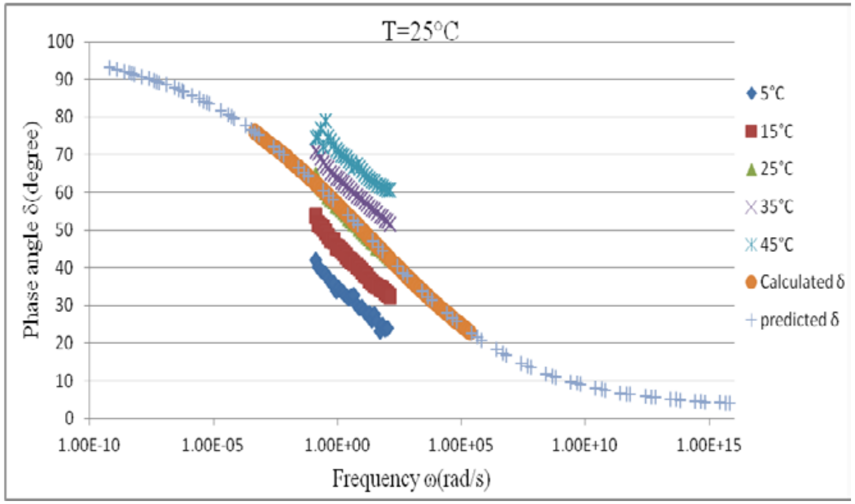
PG 76-22

Figure 1/log Gc* growth of PG binders at four temperature in air

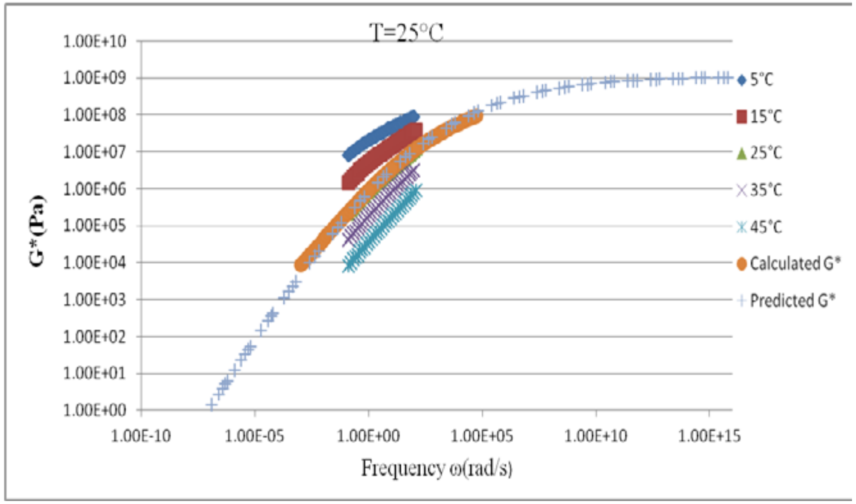
Predicted master curve of G* and δ (CA model) (aged 40 days at 70C)



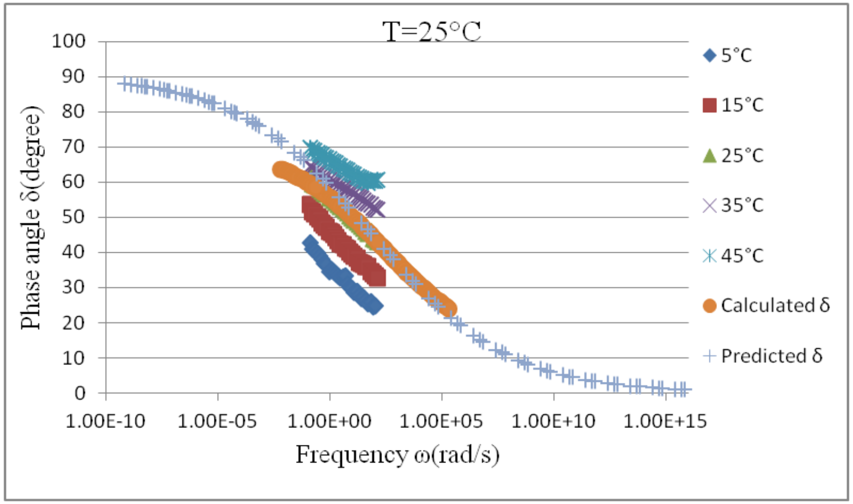
PG58-28 G*



PG58-28 δ



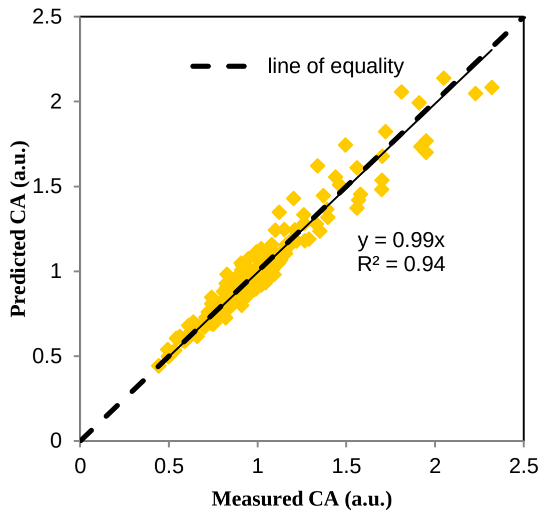
PG70-28 G*



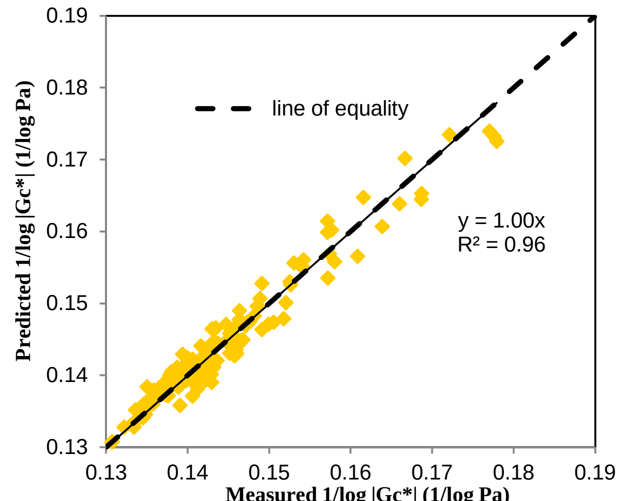
Block 1

PG70-28 δ

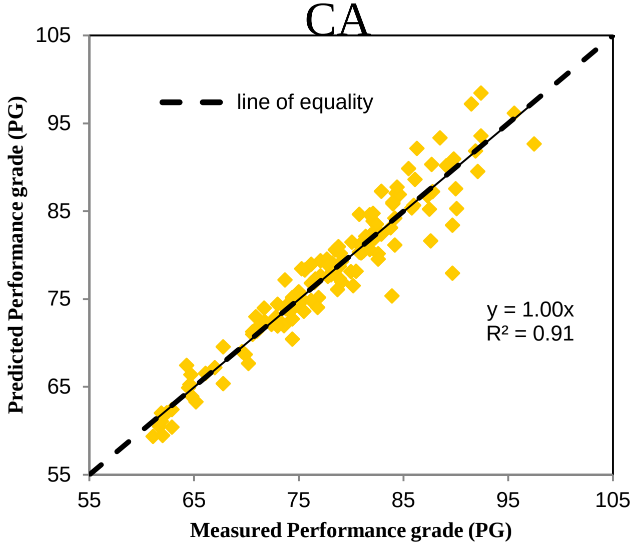
Use Universal Model Parameters



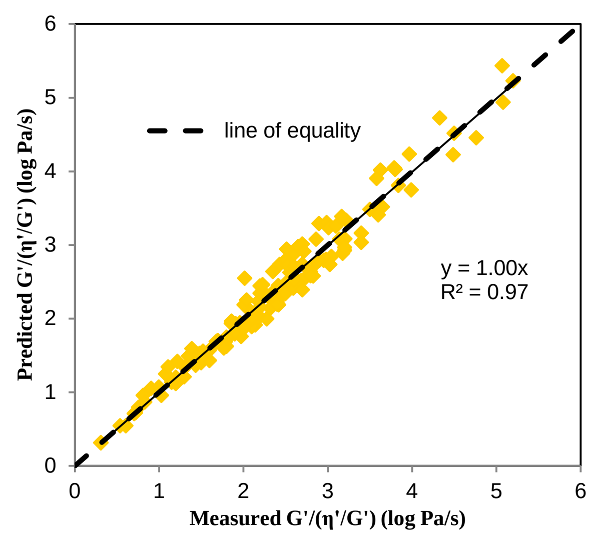
CA



Shear Modulus



Performance Grade



DSR Function

Thank You!

Any questions?