Update on the MnROAD-NCAT Project to Validate Mix Cracking Tests and other one-off studies on Simple Mixture Cracking Tests

Randy West

Mix ETG Meeting
Fall River, MA
September 14, 2016

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MnROAD + NCAT
Cracking Group Experiments

MnROAD

Safer, Smarter, Sustainable Pavements Through Innovative Research

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ADEM
Alabama Department of Environmental Management

ALABAMA
Department Of Transportation

COLLABORATIVE AGGREGATES LLC

CO
CDOT

Department of Transportation
United States of America

FP²

State of Florida
Department of Transportation

GDOT
Georgia Department of Transportation

Illinois Department of Transportation

KENTUCKY TRANSPORTATION CABINET

SHA
State Highway Administration
Maryland Department of Transportation

MDOT
Michigan Department of Transportation

MDOT
Mississippi Department of Transportation

Minnesota
Department of Transportation

MoDOT

NEW YORK STATE OF OPPORTUNITY.
Department of Transportation

State of North Carolina
Department of Transportation

DOT
Oklahoma Department of Transportation

SCDOT
South Carolina Department of Transportation

TN
TDOT
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VDOT
Virginia Department of Transportation

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Objective

Objective: to validate laboratory cracking tests by establishing correlations between the test results and measured cracking in real pavements using real loading conditions

Scope

NCAT Test Track

- Top-down cracking

MnROAD

- Low-temperature cracking

Cracking Group Sections

Section	Surface Mix Description
N1	20% RAP (0.20 binder ratio) PG 67-22
N2	Same as N1 with 96% in-place density
N5	Same as N1 except 0.5% low AC, low density
N8	20% RAP & 5% RAS with PG 67-22
S5	35% RAP with PG 58-28
S6	Same as N1 with HiMA PG76-28E
S13	Arizona style asphalt-rubber mix

cracking expectation

- low
- med.
- high

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CG Performance to Date
April 25, 2016
2.3 MESALs

Section	Description	Rutting[1] (mm)	IRI[2] (in/mi.)	MTD (mm)	Cracking
N1	20% RAP (Control)	0.9	72.3		0
N2	Control w/ High Density	0.9	47.2		0
N5	Low AC, Low Density	0.2	63.6		0
N8	20% RAP 5% RAS	0.8	41.5		0
S5	35% RAP PG 58-28	0.8	58.5		0
S6	Control w HiMA	0.7	51.5		0
S13	AZ Rubber Mix	1.7	69.5		0

[1] based on ALDOT gauge

[2] IRI data from Aug. 22 2016

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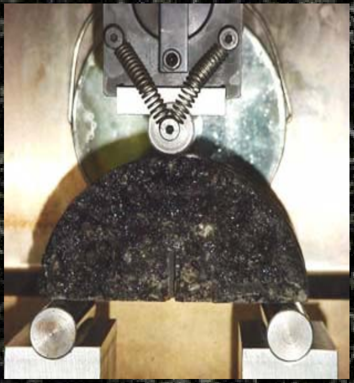
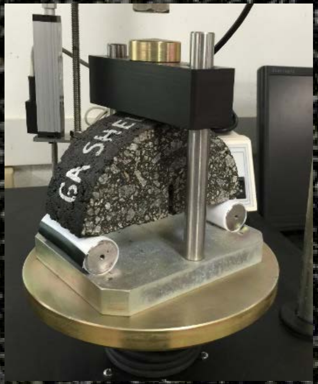
Tests for Top-Down Cracking Resistance

NCAT will conduct these tests on both LMLC and PMLC samples that are aged and unaged.

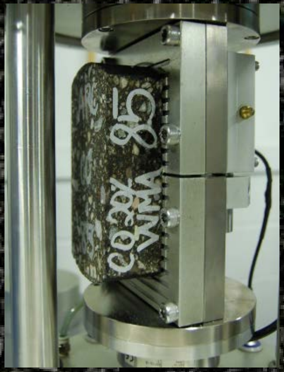


SCB-LA



SCB-IL

OT-TX



OT-NCAT

Energy Ratio

Nflex Factor

Cantabro

Materials were sampled for complementary studies funded by sponsoring agencies. 99 buckets of mix sampled per test section.

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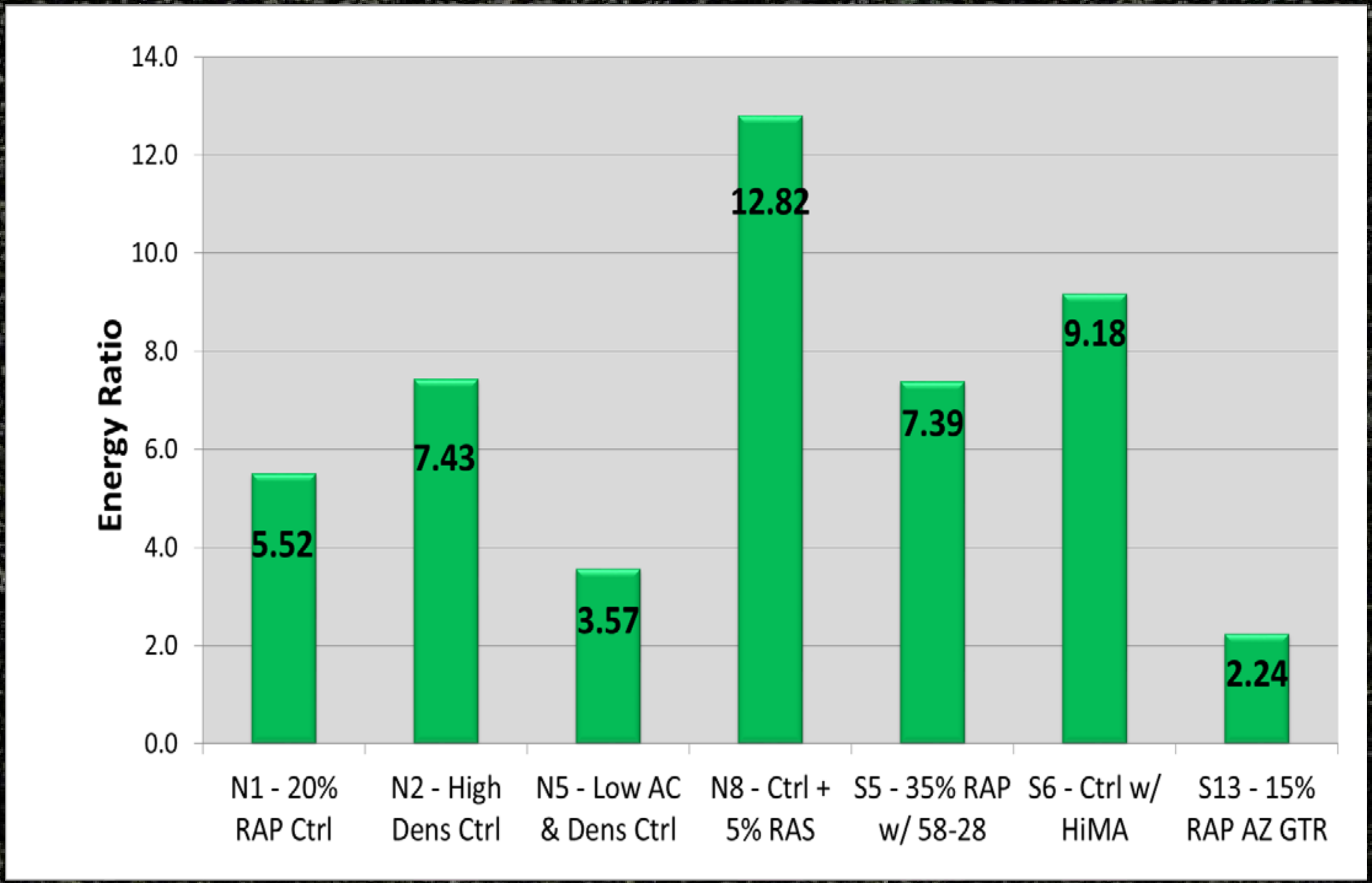
Energy Ratio



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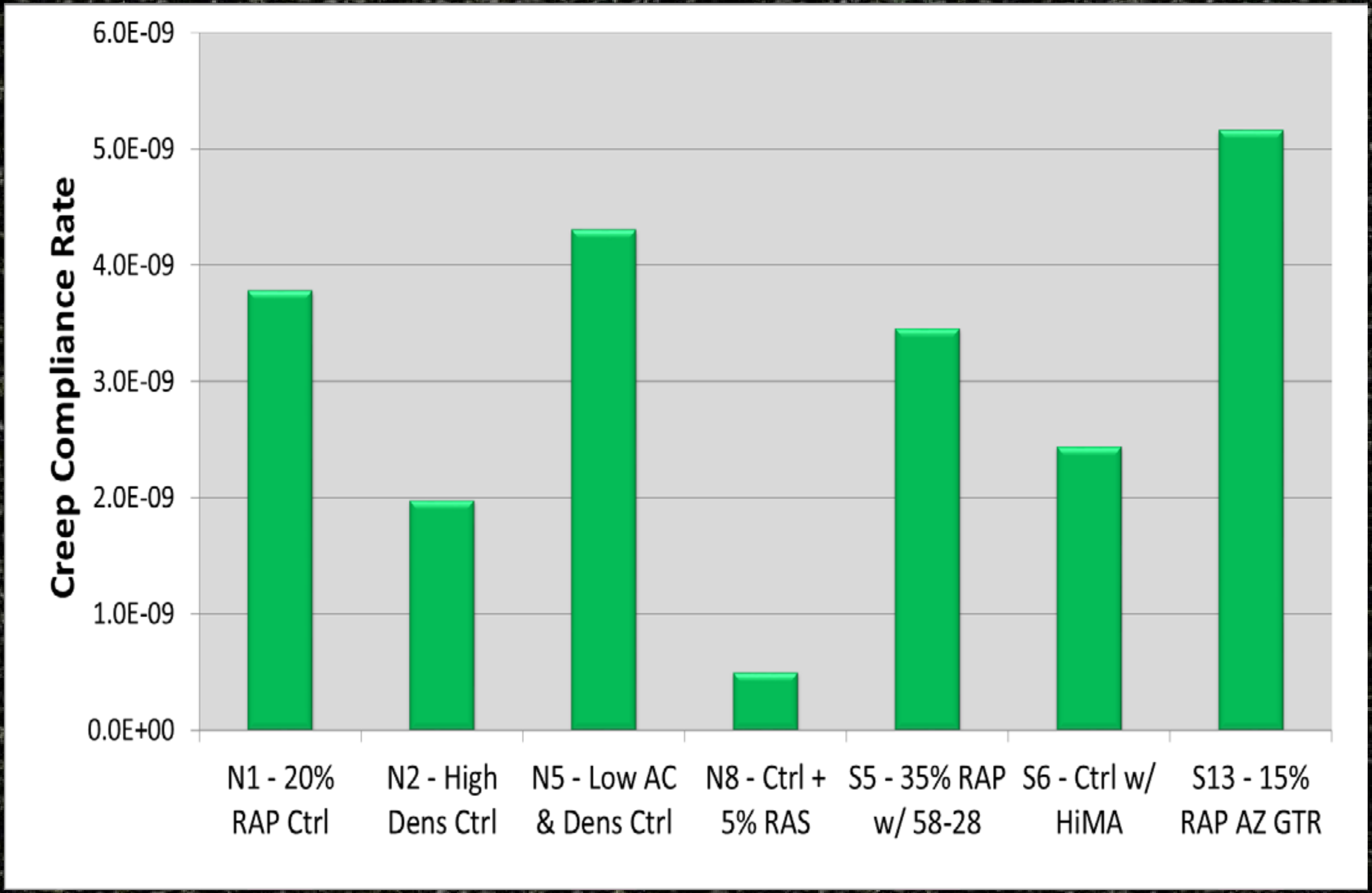
Creep Compliance



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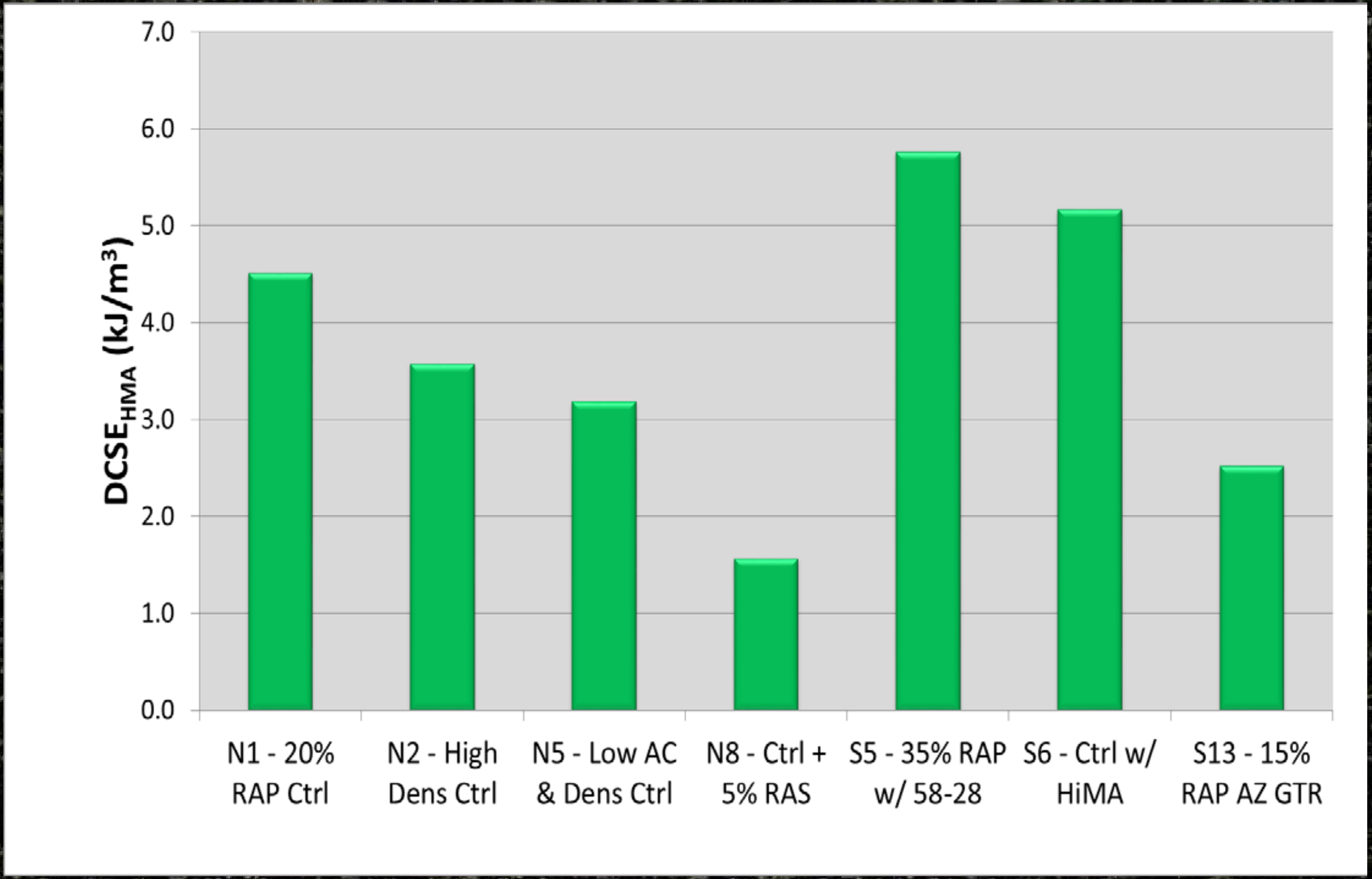
$DCSE_{HMA}$



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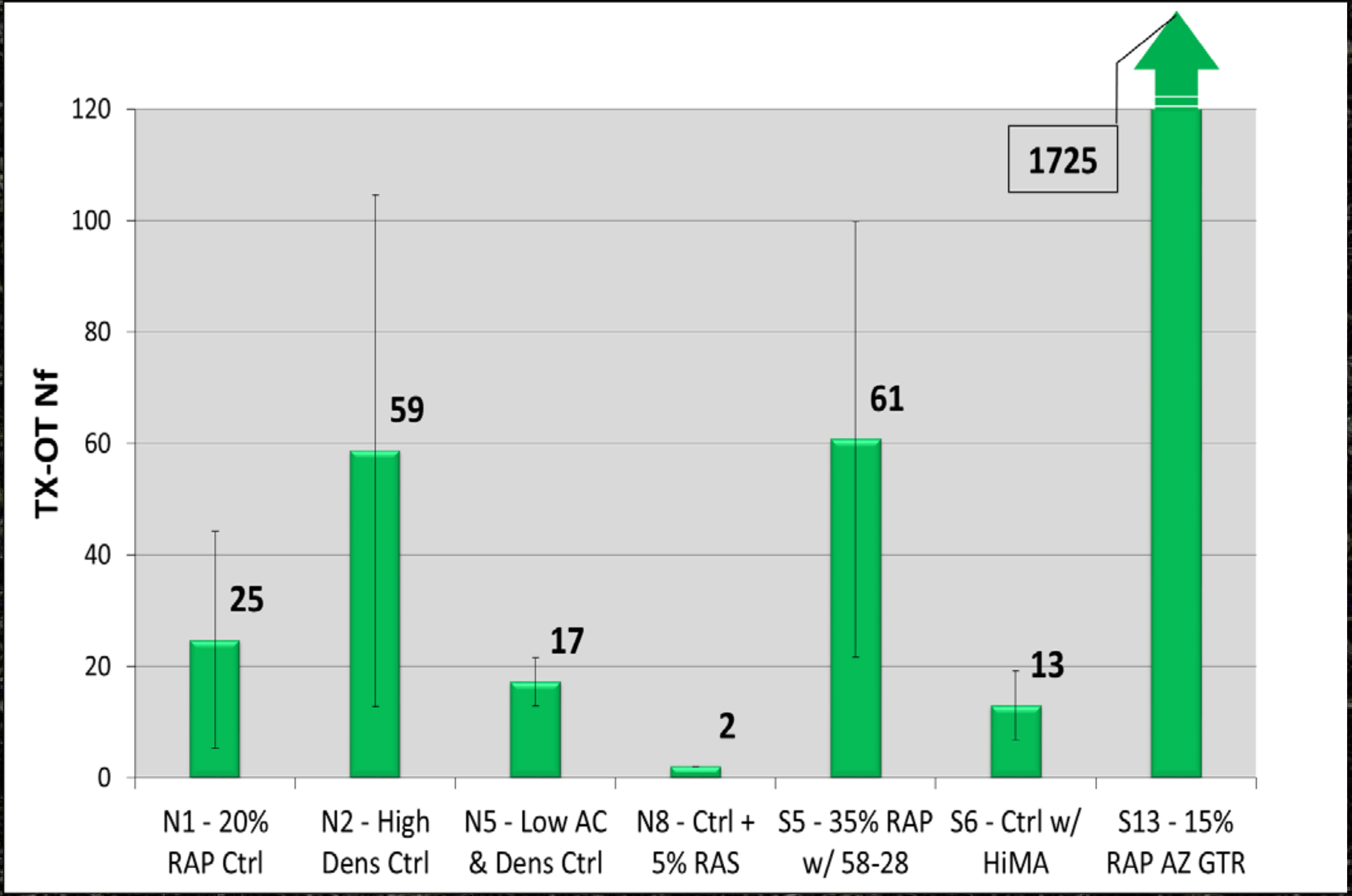
TX-OT



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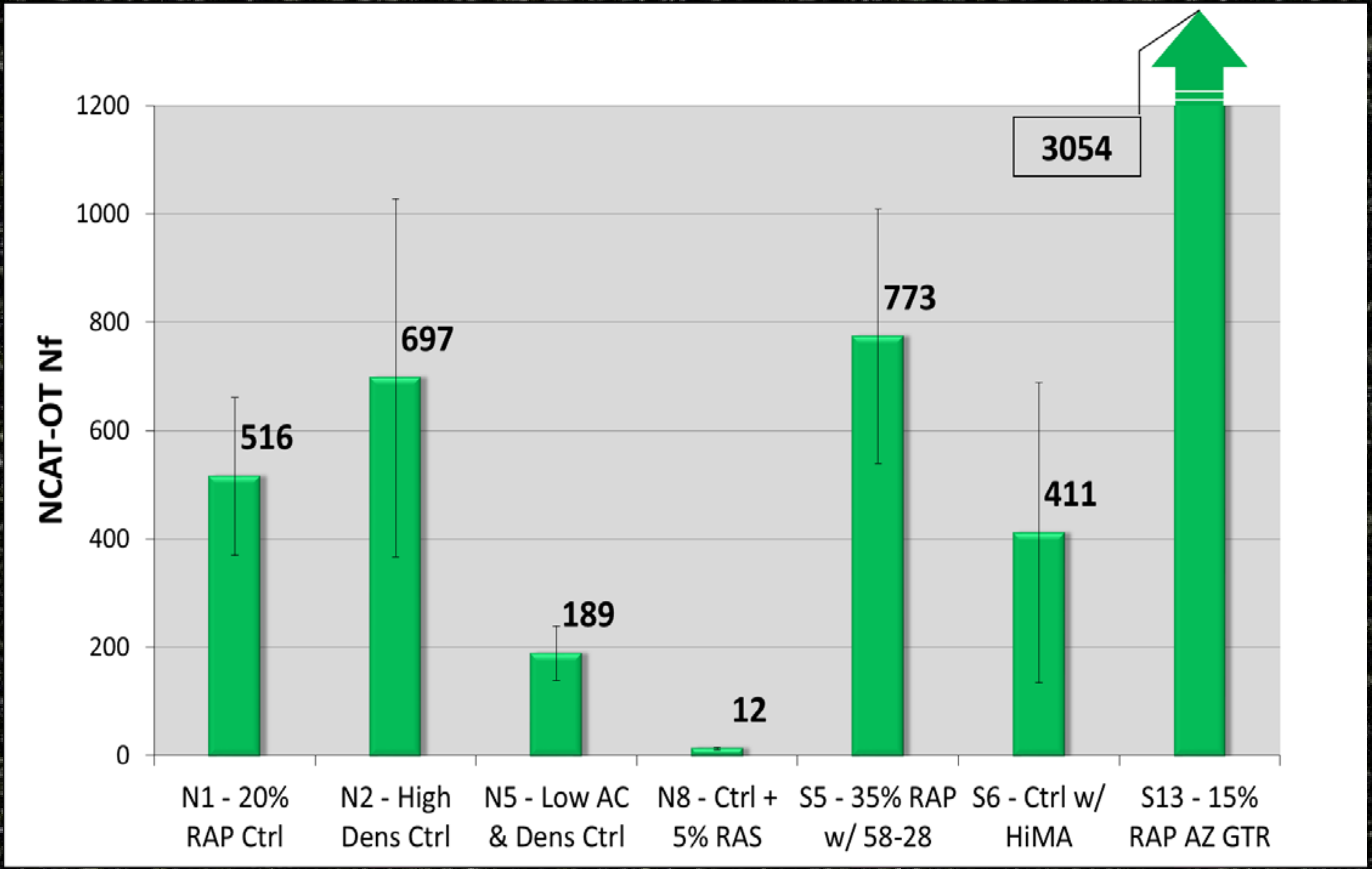
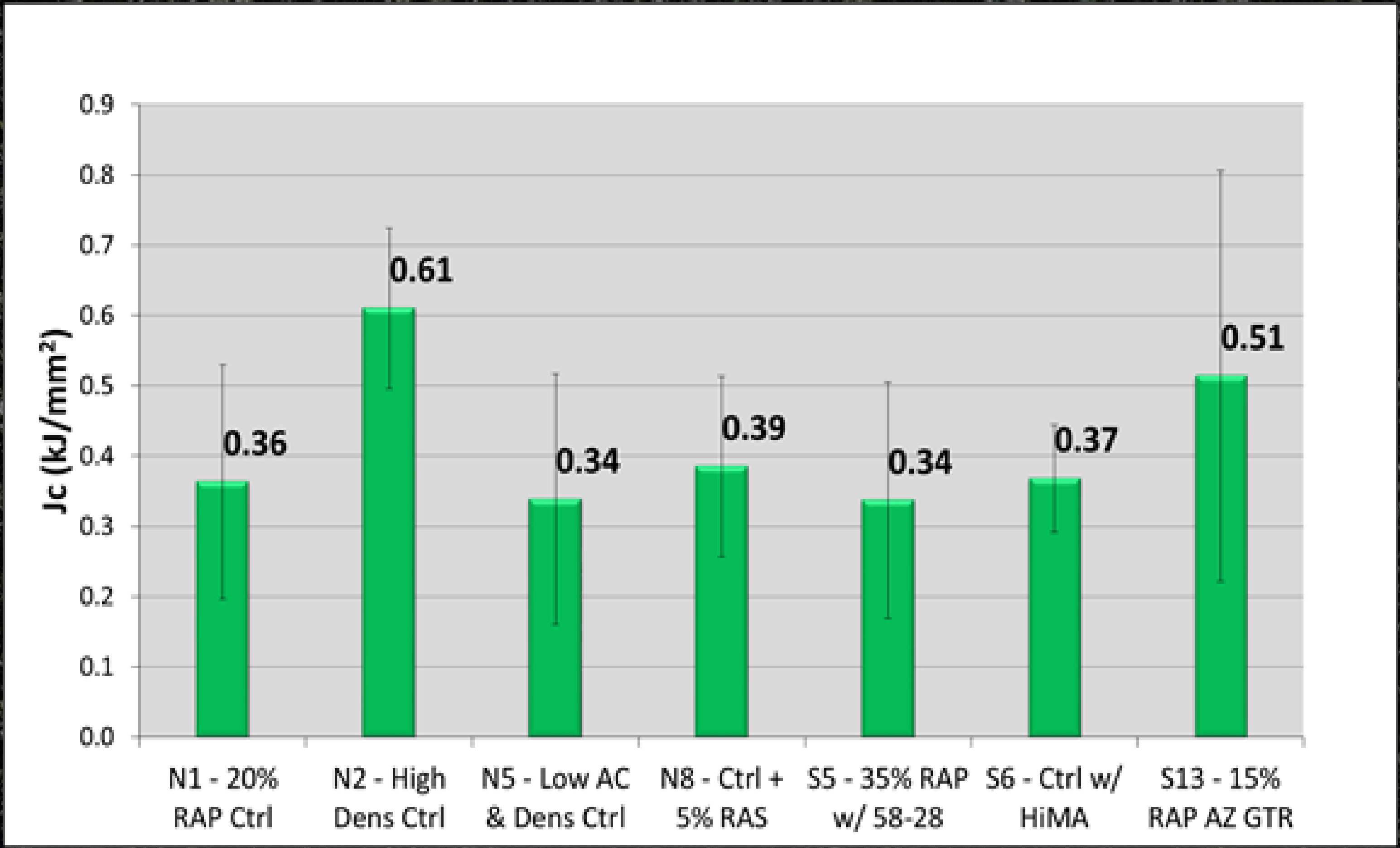
NCAT-OT


3054
1200
1000
800
600
400
200
0
NCAT-OT Nf
516
697
189
12
773
411
N1 - 20% RAP Ctrl
N2 - High Dens Ctrl
N5 - Low AC & Dens Ctrl
N8 - Ctrl + 5% RAS
S5 - 35% RAP w/ 58-28
S6 - Ctrl w/ HiMA
S13 - 15% RAP AZ GTR

SCB



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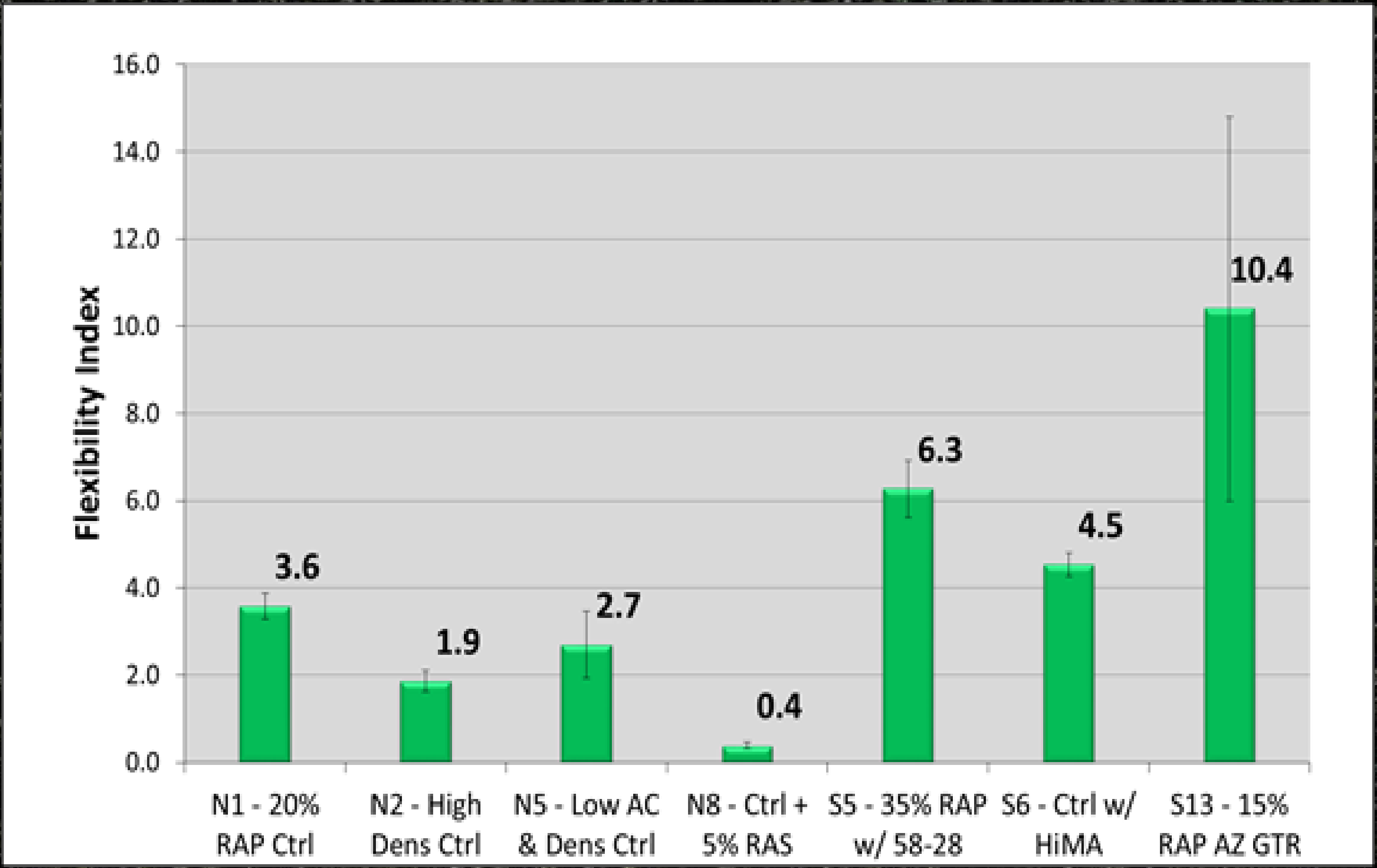

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NCAT CG Experiment Status

- Reheated PMLC testing completed
- Sample preparation underway for unaged LMLC
- Aging protocol yet to be established for aged LMLC and aged PMLC

MnROAD Test Section Update

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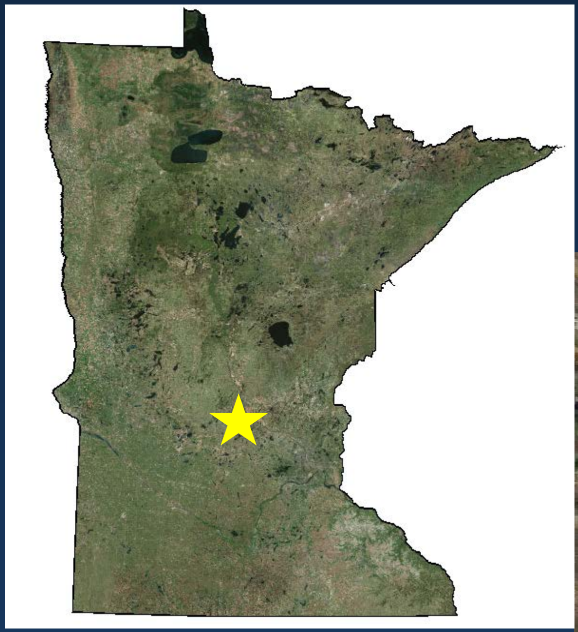
Site Location



MnROAD Mainline

Cracking Group Cells 16-23

Asphalt Mixtures

CELL NO	BINDER GRADE	ABR %	RAS
16	64S-22	30-40	Yes
17	64S-22	20-30	Yes
18	64S-22	15-25	No
19	64S-22	15-25	No
20	52S-34	25-35	No
21	58H-34	15-25	No
22[1]	58H-34	15-25	No
23	64E-34[2]	10-20	No

All mixes are 12.5 mm NMAS

All mixes are Ndes = 80 and target air voids = 4.0% except cell 19 which has Ndes = 100 and target air voids = 3.0%

[1] Cell 22 limestone

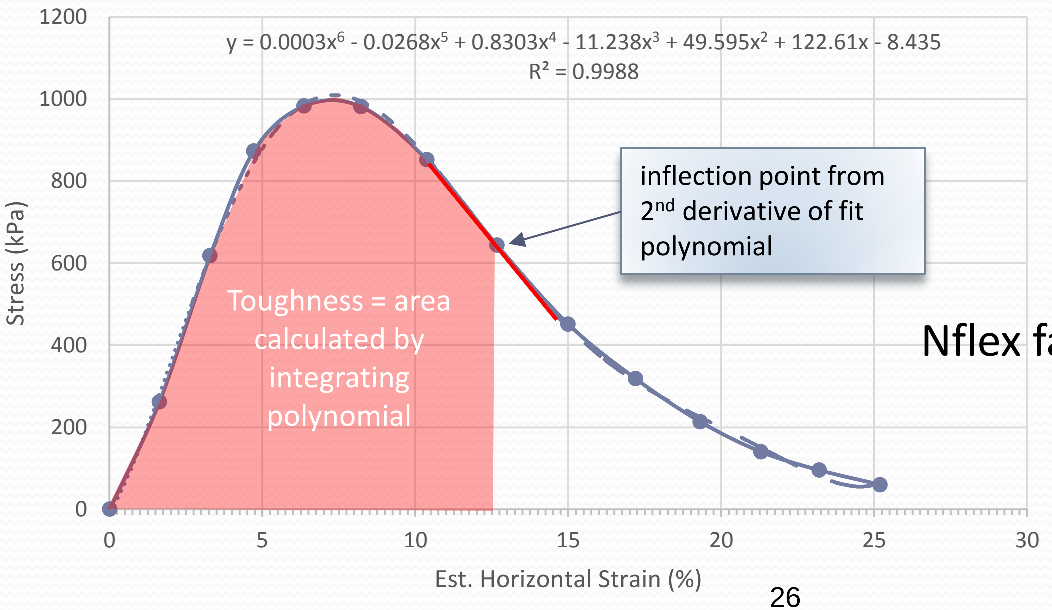
[2] Highly modified asphalt binder

Cracking Modes and Testing

- Types of cracking to be investigated
  - Low temperature a given
  - Top-down likely
  - Fatigue also possible
- PMLC testing
  - Low temp: DCT-MN and IDT Creep or SCB-MN
  - Intermediate temp: SCB-IL, OT, BBF
  - E*, TSR, Hamburg, loose mix, cores
- Sampling for other research studies

IDT Nflex factor

- 50 mm thick specimens
- Ram rate = 50 mm/min.
- Temp. = 25°C
- Area under σ vs. έ to post peak inflection point divided by slope at that point



inspired by IL-SCB method

$$\text{Nflex factor} = \frac{\text{Toughness at inflection pt.}}{\text{slope at inflection pt.}}$$

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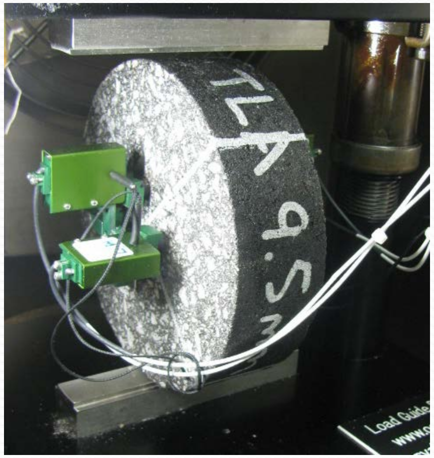
Refining Nflex Factor

- Draft test method, AASHTO format
- Phase 1 Experiment
  - Effect of temperature - completed
  - Effect of loading rate
- Phase 2 Experiment
  - Effect of asphalt content
  - Effect of air voids
  - Effect of PG grade

PMLC Mixes from TT
- E7B – virgin mix, hybrid binder
- E8B – RAP & RAS, PG 76-22

LMLC Mixes
- virgin mixes
- Short & Long Term Aged



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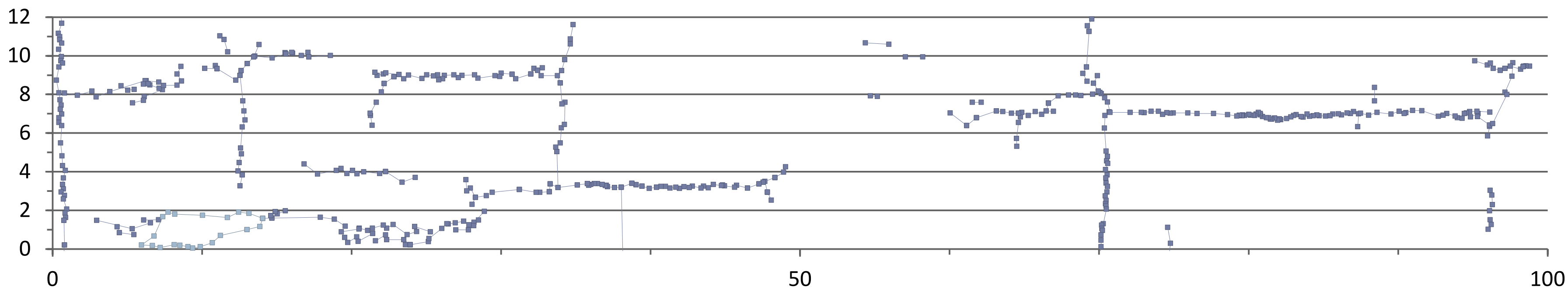
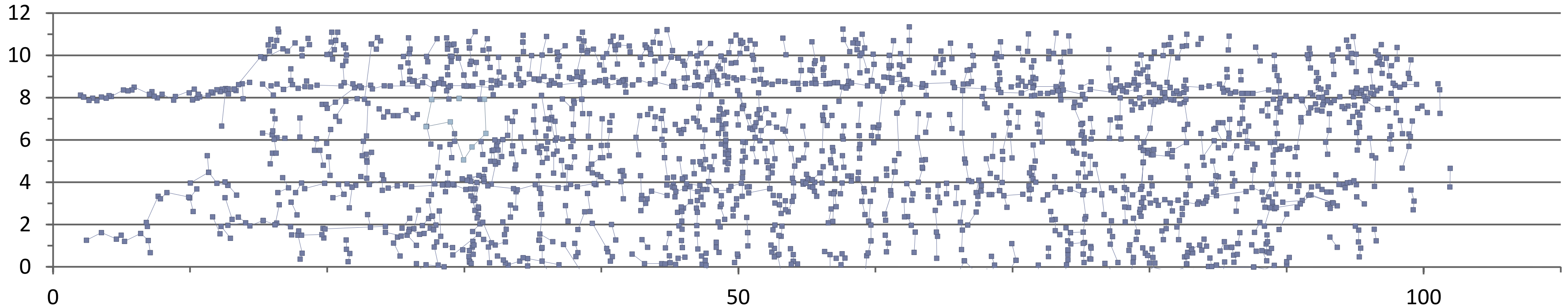
E07B



Virgin mix, Hybrid 76-22 binder

15% of Lane Area Cracking

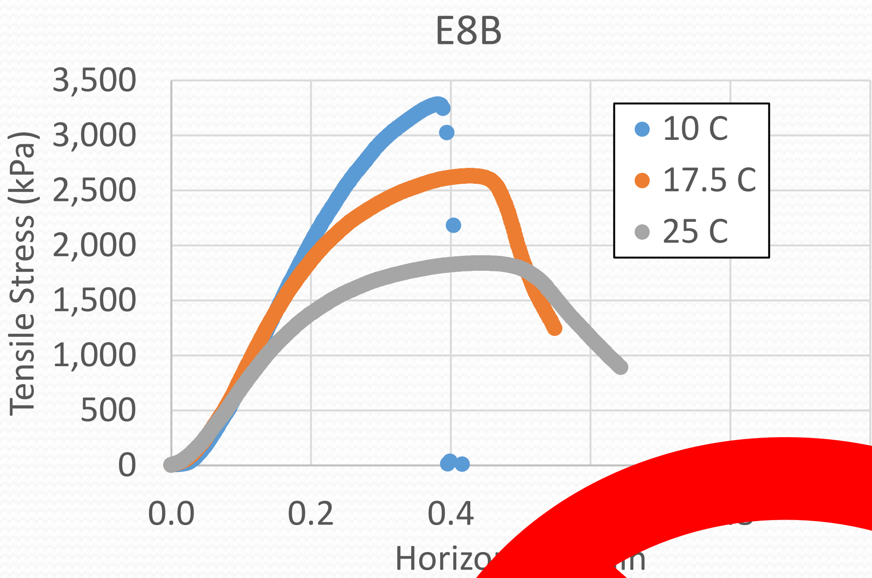
E08B

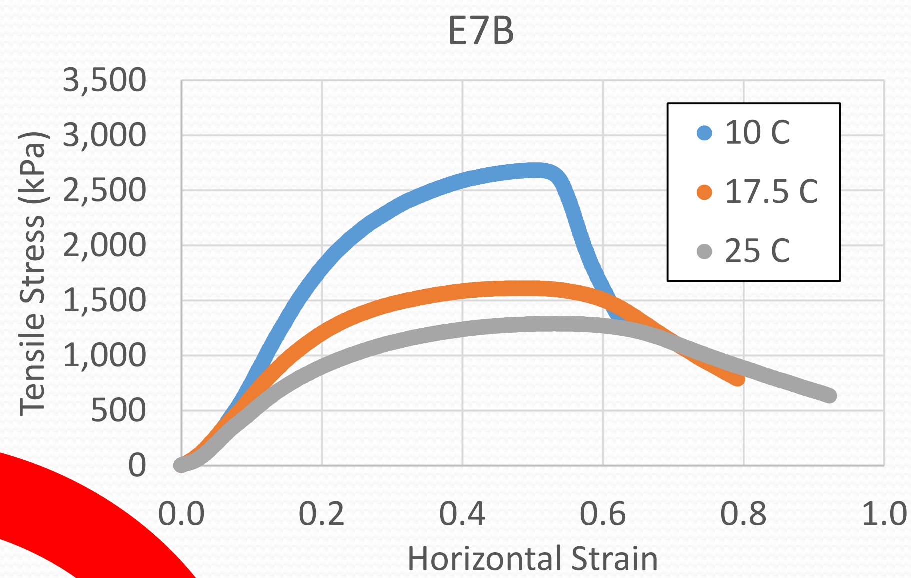


20% RAP 5% RAS, SBS 76-22 virgin binder

73.4% of Lane Area Cracking

Refining Nflex Factor





Mix	[illegible] (brittle)			E7B (ductile)		
Test Temp.	10	[illegible]	25	[illegible]	17.5	25
Poisson's ratio	0.21	0.2[illegible]	0.32	[illegible]	0.30	0.28
Toughness	755	813	[illegible]	[illegible]	954	720
Brittleness slope	[illegible]855	27,434	10,1[illegible]	[illegible],583	4,099	2,273
Nflex Factor	[illegible]	[illegible]	[illegible]	73.8	235.9	316.5

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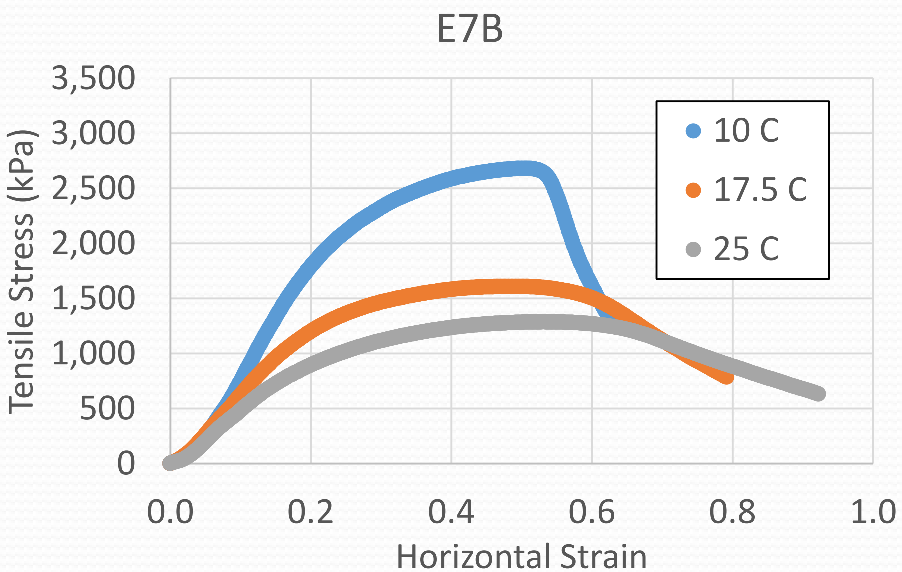
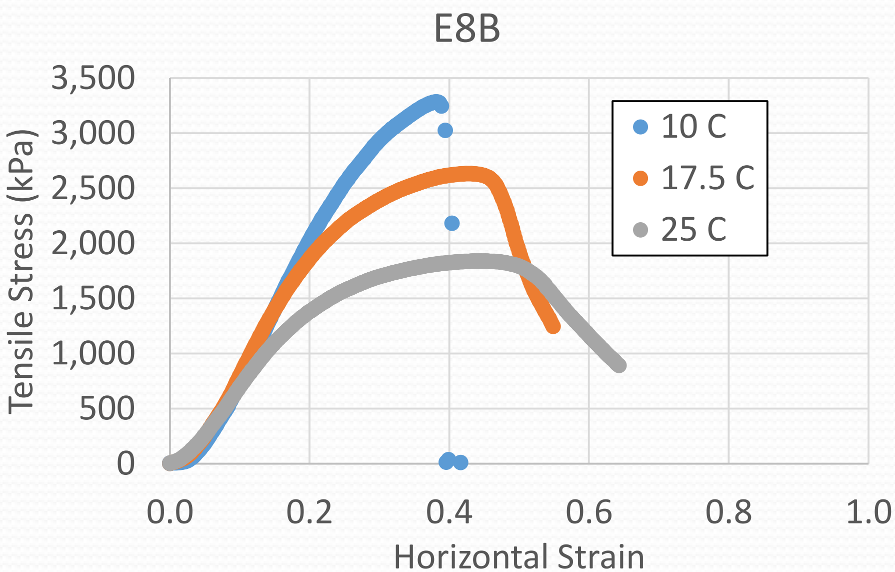
Effect of Temperature





Mix	E7B (ductile)			E8B (brittle)		
Test Temp.	10	17.5	25	10	17.5	25
Poisson's ratio	0.21	0.30	0.24	0.22	0.23	0.32
Toughness	1,214	999	776	760	853	856
Brittleness slope	-17,564	-4,459	-2,618	-100,878	-42,375	-12,448
Nflex Factor	0.08	0.22	0.30	0.01	0.02	0.08

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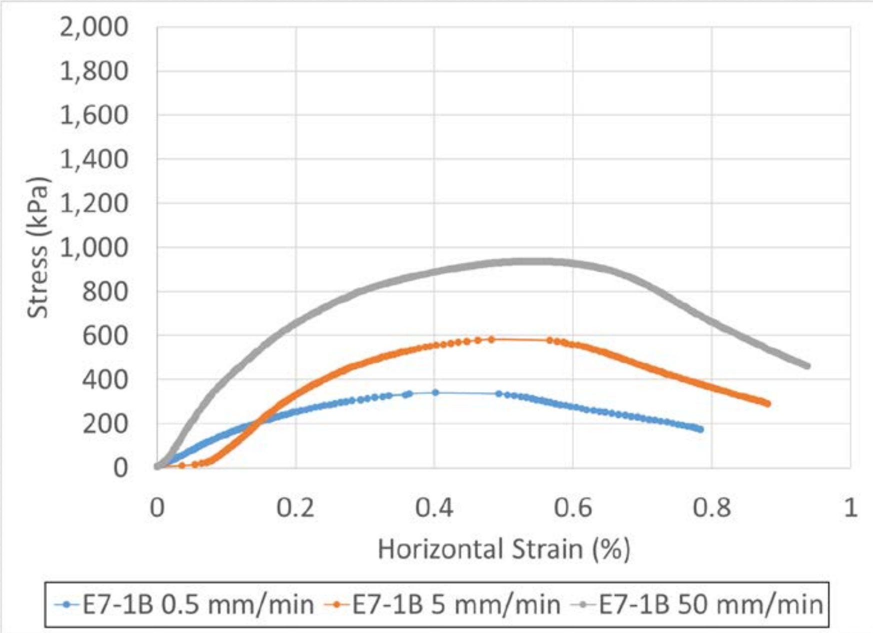
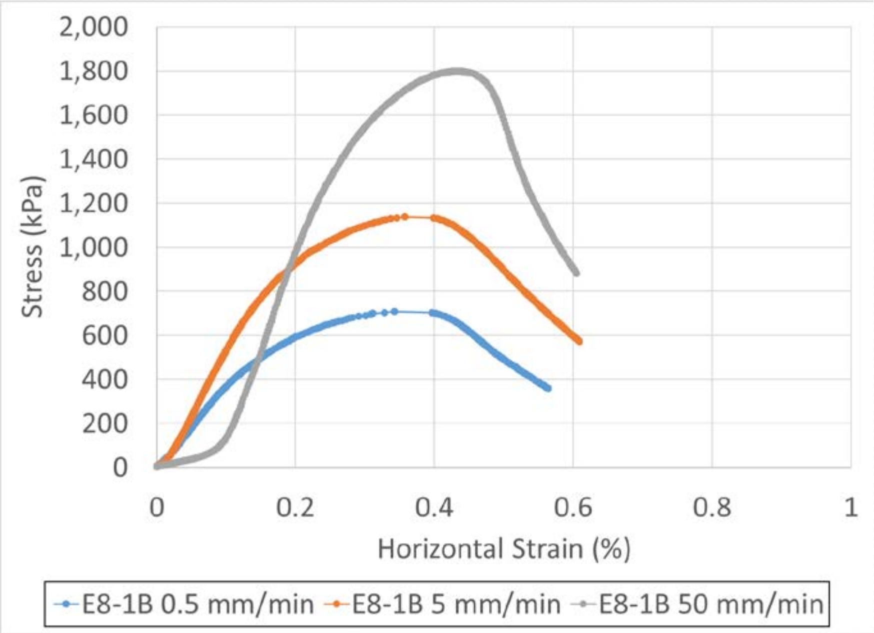
Effect of Loading Rate





Mix	E7B (ductile)			E8B (brittle)		
Rate (mm/min)	0.5	5	50	0.5	5	50
Poisson's ratio	0.38	0.30	0.25	0.28	0.29	0.27
Toughness	194	323	578	252	403	702
Brittleness slope	-698	-1,152	-1,991	-2,371	-3,518	-6,124
Nflex Factor	0.28	0.28	0.30	0.11	0.11	0.12

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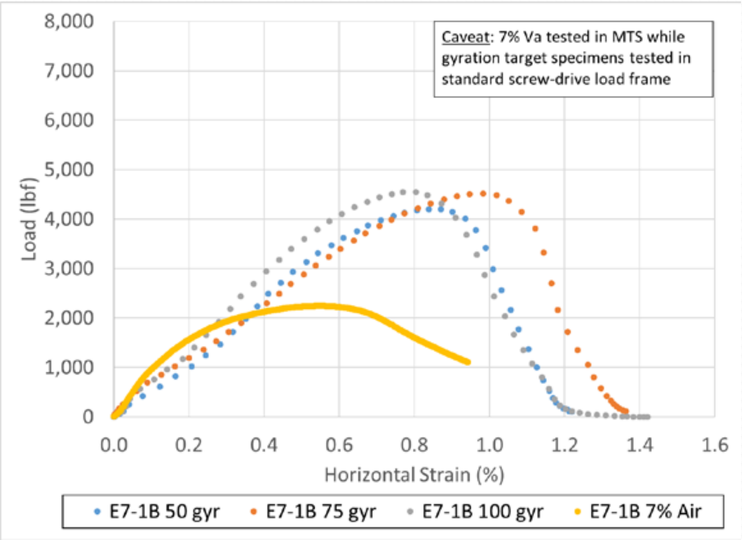
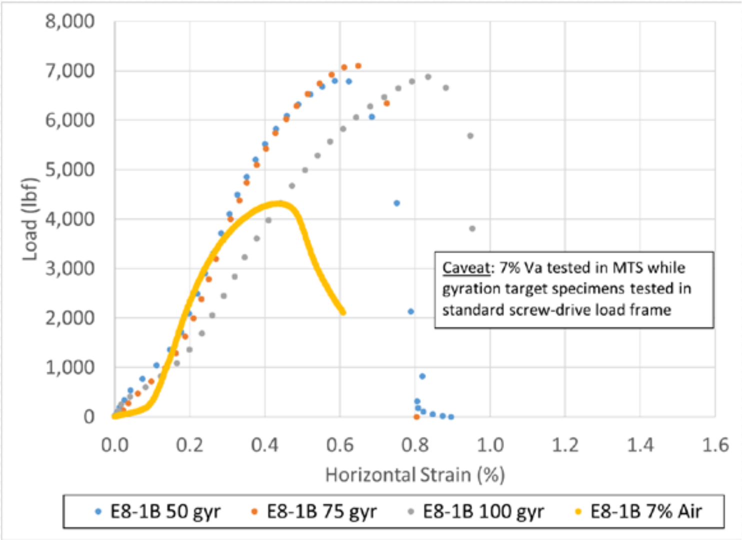
Effect of Air Voids





*=Limited Post-Peak Data in Brittle Mix – Higher Variability

Mix	E7B (ductile)				E8B (brittle)			
Avg. Air Voids (%)	2.5	1.6	1.0	7.0	3.7	3.0	2.6	7.2
Gyration Level	50	75	100	Ht.	50	75	100	Ht.
Toughness	1,114	1,120	1,102	578	1,347	1,243	1,265	702
Brittleness slope	-6,276	-6,837	-5,809	-1,991	-14,769	-7,902	-9,905	-6,124
Nflex Factor	0.18	0.17	0.20	0.30	0.09	0.20*	0.14*	0.12

Summary (to date)

- Nflex Factor ranks mixture ductile v. brittle behavior
- Nflex Factor increases with temperature
- Poisson’s Ratio from instrumented specimens fell in expected range at 25° (0.24 to 0.38)
  - Assume Poisson’s Ratio of typical HMA is 0.35
- Nflex Factor did not change with loading rate, though the slope and toughness change
- Load-Displacement curves significantly different for specimens compacted to a height versus to a gyration level

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Additional SCB (Jc) and IDT (Nflex Factor) Experiments

- Primary objectives were to examine the effects of reheating of mix for specimen compaction and the effect of loading rate (0.5 mm/min. and 50 mm/min.)
- Mixes were obtained from three field projects with test sections to evaluate rejuvenators or WMA
- Plant mix samples compacted to N_{design}

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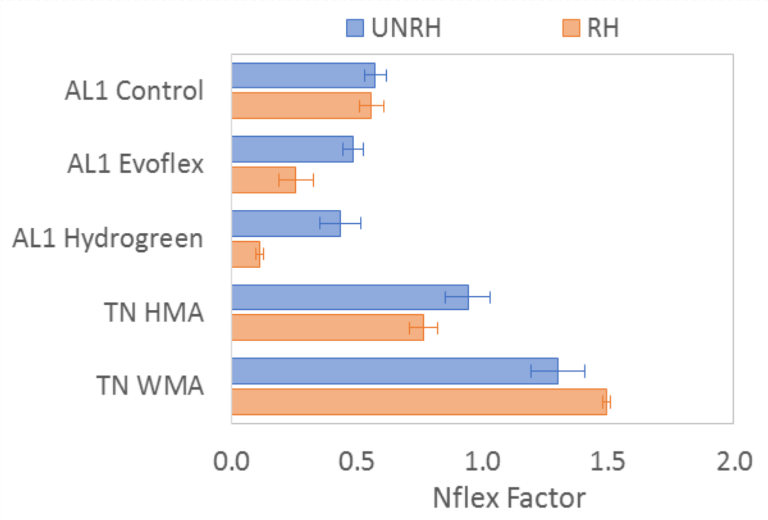
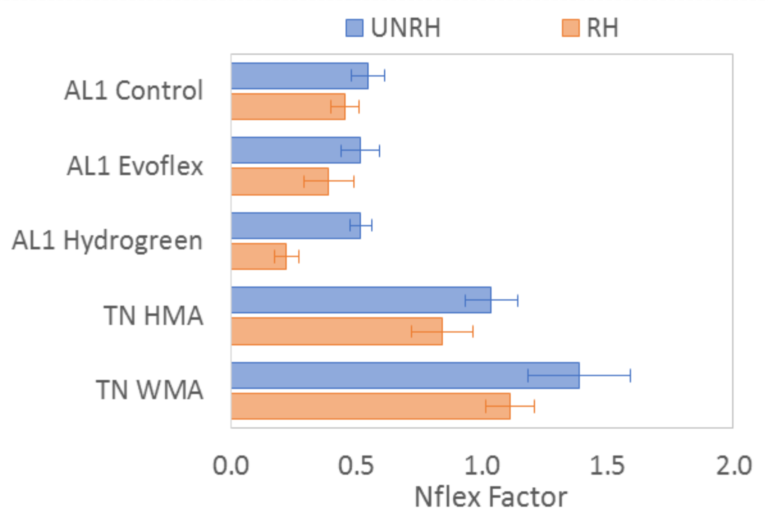
Nflex Factor

Loading Rate = 0.5 mm/min.



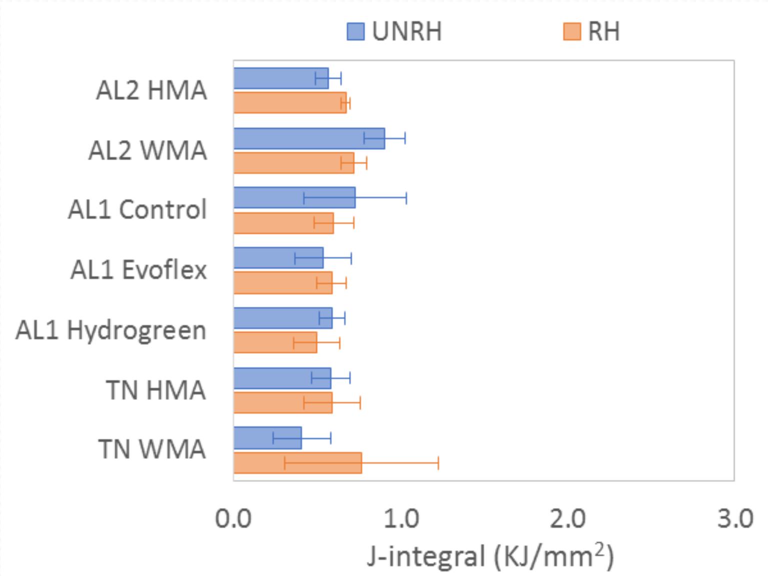
Loading Rate = 50 mm/min.



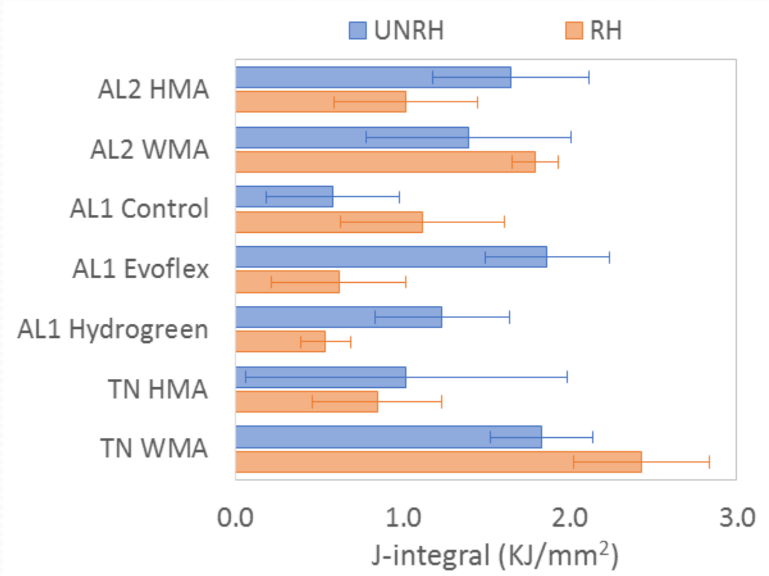
- Reheating significantly reduces Nflex Factor.
- Loading rate did not have consistent or a statistically significant effect on Nflex Factor.

SCB J-integral

Loading Rate = 0.5 mm/min.



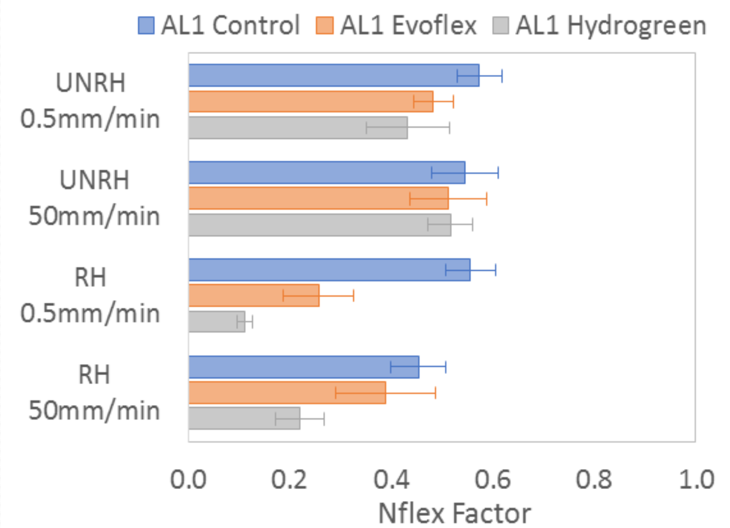
Loading Rate = 50 mm/min.



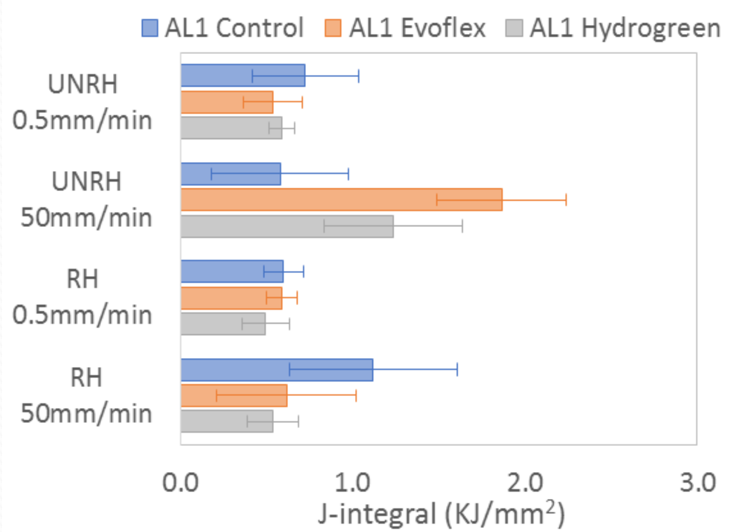
- Reheating did not have consistent or a statistically significant effect on J-integral.
- The higher loading rate statistically increased J-integral values and its variability.

Effect of Reheating on Rejuvenator

IDT Nflex Factor



SCB J-Integral



AL1 Mix	Tukey's Grouping			
	IDT Test UNRH Specimen	IDT Test RH Specimen	SCB Test 0.5 mm/min	SCB Test 50 mm/min
Control Mix	A	A	A	A
Evoflex Mix	A	B	A	A
Hydrogreen Mix	A	C	A	A

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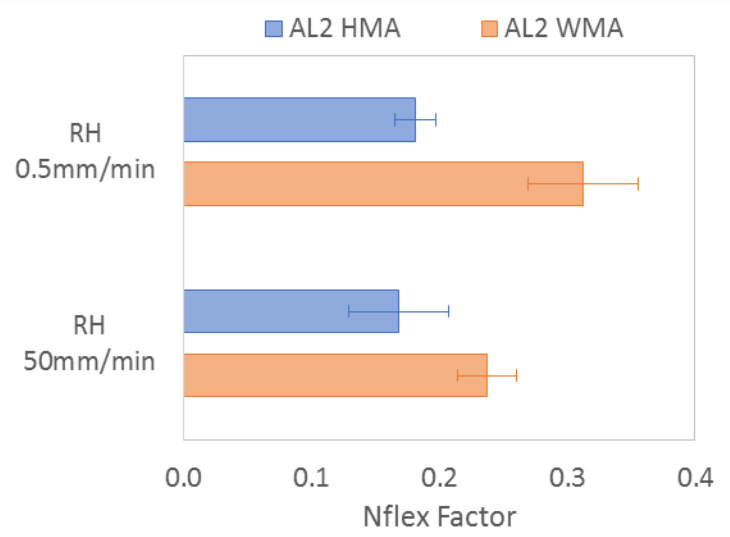
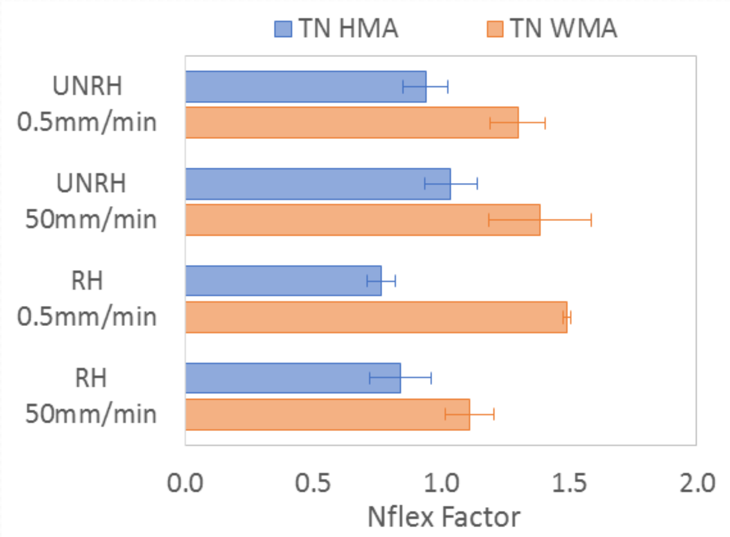
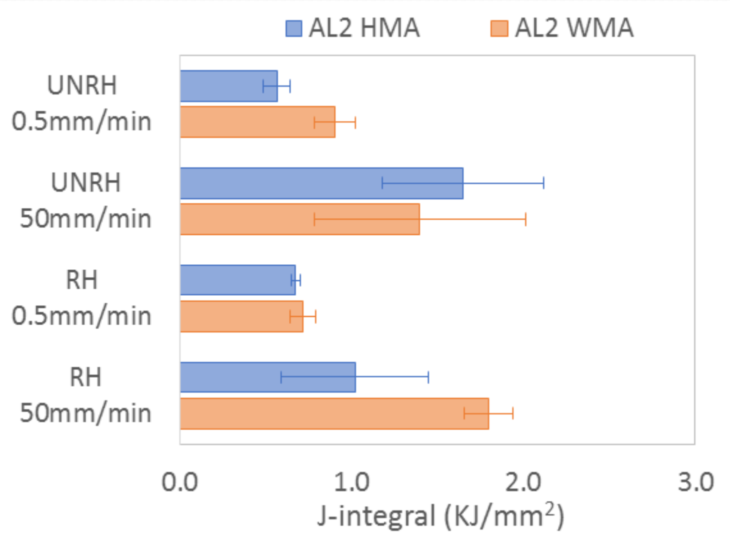
Effect of WMA (Nflex Factor)

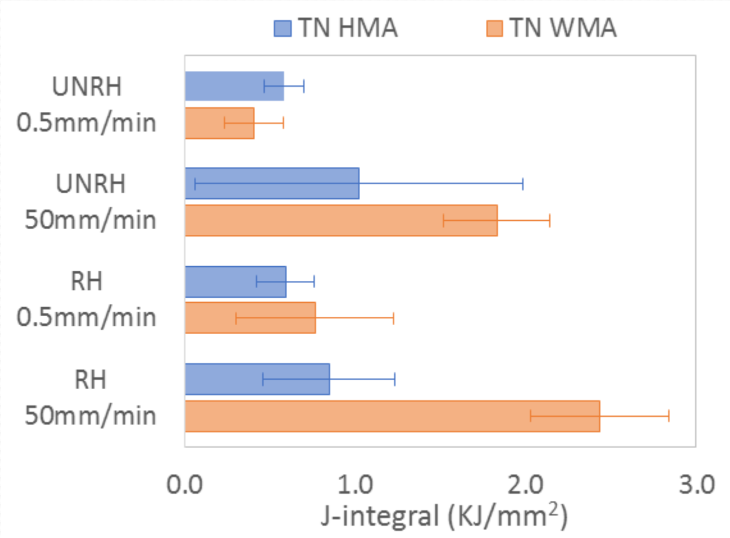




- WMA improved Nflex Factor results regardless of mix, loading rate, and reheating.

Effect of WMA (J-Integral)





- WMA did not have a consistent effect on J-Integral results except for reheated samples tested at 50 mm/min.

Cracking Tests

- Different tests provide very different results for mixes
- Agreement with field performance will have to be the key factor in deciding which test(s) should be used.

Relationship to Performance

Field Performance

		Good	Bad
Test Result	Fail	Type I Error Contractor Suffers	Correct
	Pass	Correct	Type II Error Agency Suffers

25 YEARS 1986 - 2011
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