MnROAD
Safer, Smarter, Sustainable Pavements Through Innovative Research

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

NCAT/MnROAD Cracking Group

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DEPARTMENT OF TRANSPORTATION

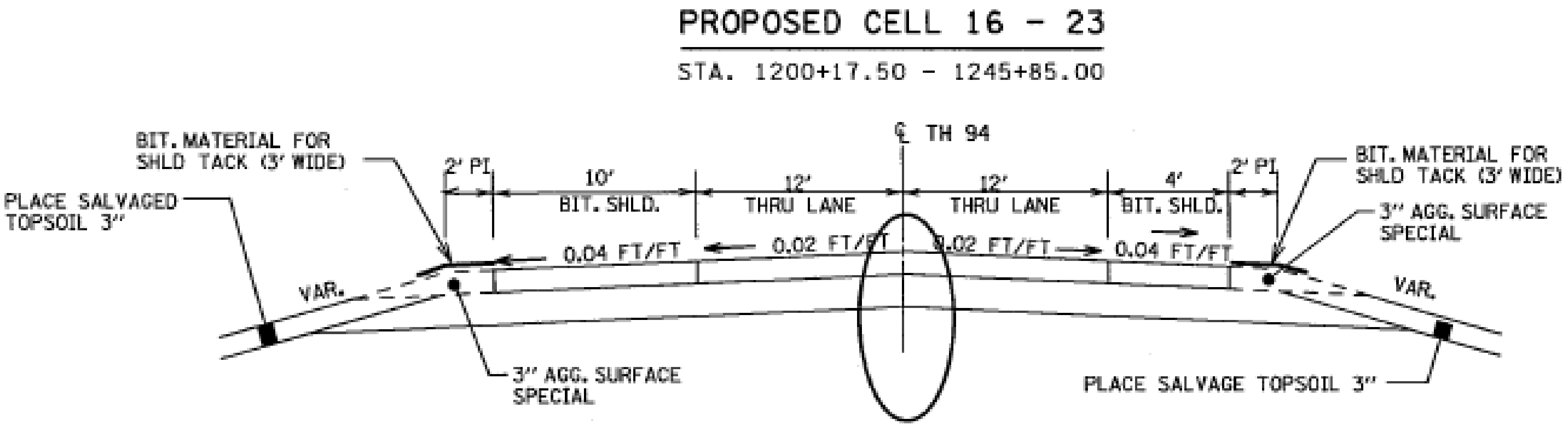
Outline

- Project Background and Section Description
- Field Performance at MnROAD
- Correlations between Lab and Field
- Conclusions
- Implementation Takeaways

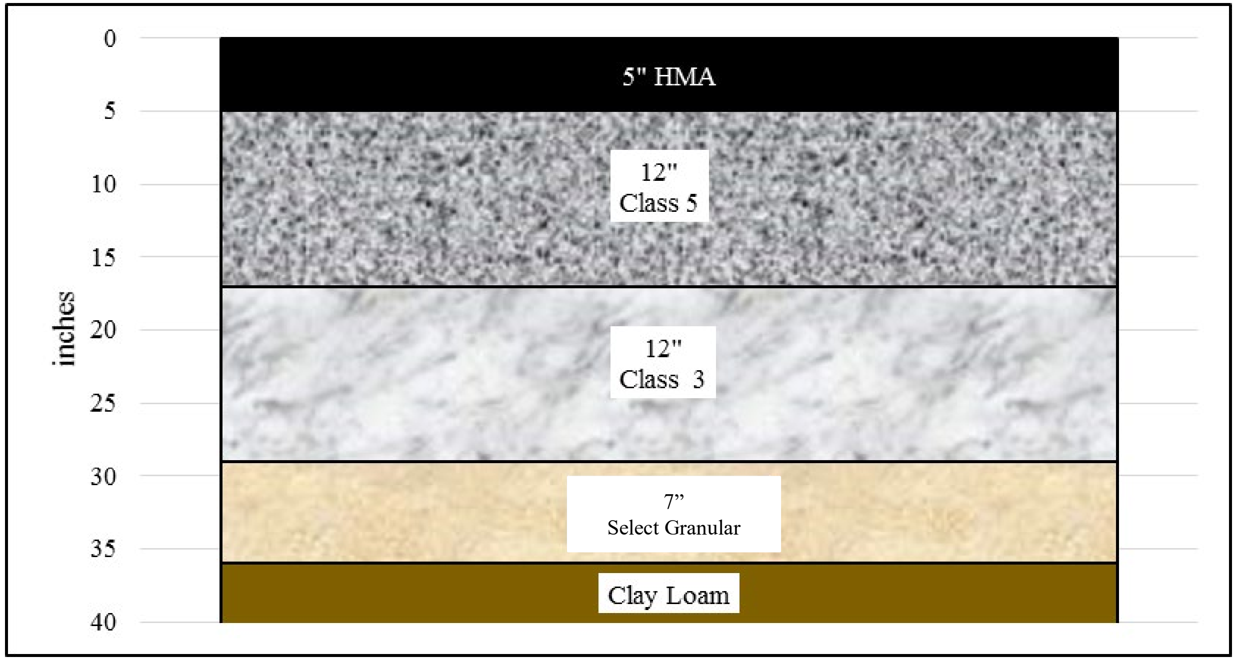
Cracking Group Experiment

- Primary objective
  - Correlate lab cracking tests to field performance
- MnROAD focused on Low-Temperature Cracking (LTC)
- Suite of lab cracking tests being performed by MnDOT, NCAT, and numerous others
- Identify the test(s) that best correlate with each type of field cracking

Constructed Section Typical



- HMA paved in 2 lifts
- All lifts and shoulders paved with same mix in each cell



Mixture Overview

						VIRGIN BINDER		EXTRACTED (PAV)	
CELL		RAP %	RAP	RAS %	RAS	SPEC PG	CONT. PG	CONT. PG	ΔTC
16	Moderate RAP + RAS	20	86.5-19.8	5	120.7-23.0	64S-22	64.5-27.0	71.5-26.7	-1.9
17	Low RAP + RAS	10		5		64S-22		73.2-26.2	-2.1
18	Moderate RAP	20		0	NA	64S-22		71.1-26.5	-1.4
19	Moderate RAP, extra AC	20		0		64S-22		70.8-25.8	-0.2
20	High RAP, softer binder	30		0		52S-34	56.3-35.8	63.3-32.2	-0.9
21	Moderate RAP, softer binder	20		0		58H-34	63.2-35.6	70.2-30.3	-2.1
22	Limestone agg. and 9.5 mm NMAS	20		0		58H-34	63.1-36.5	72.0-30.0	-3.5
23	Moderate RAP, Highly mod. Binder	15		0		64E-34	73.4-37.8	72.0-31.7	-3.6

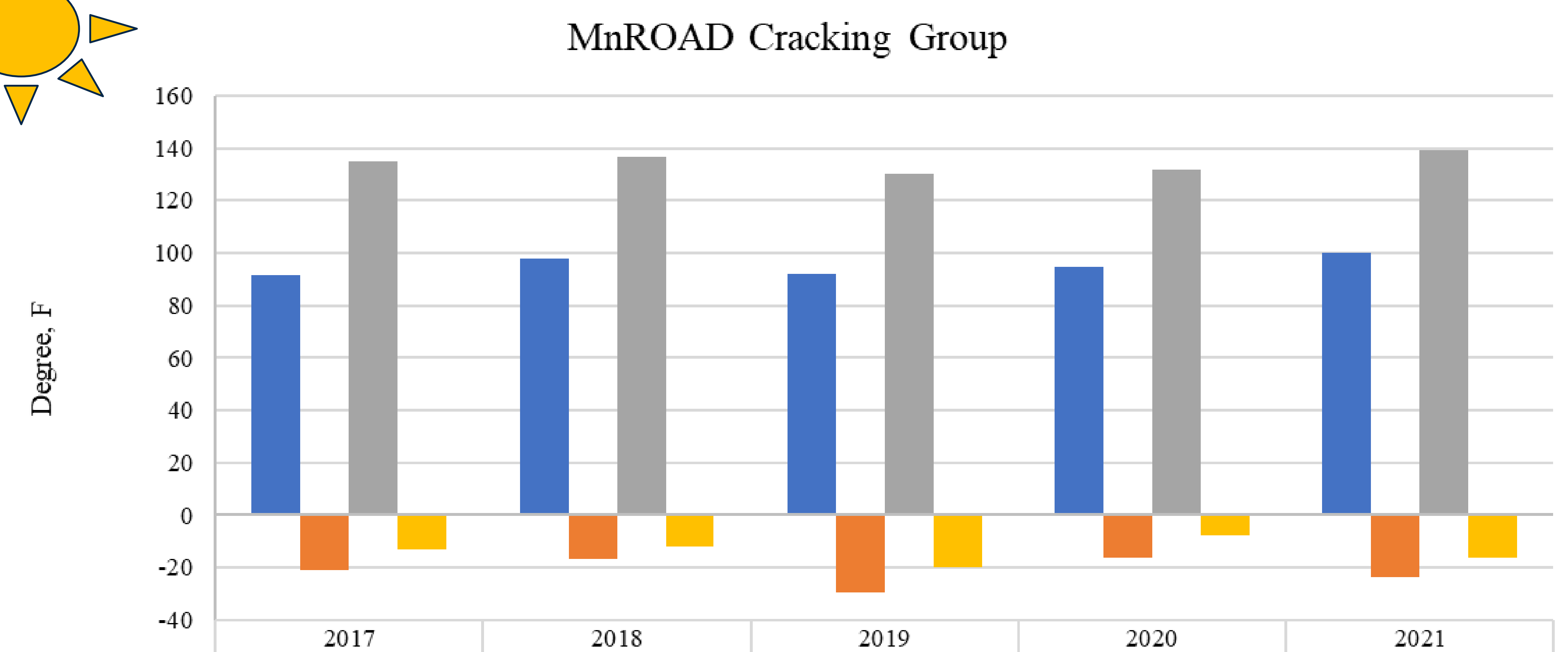
Cracking Susceptibility

- Mixtures selected to achieve range of low-temperature cracking (LTC) potential
  - Based on input from pooled-fund sponsor states
- Contractor selected, procured materials, submitted to NCAT
- NCAT performed mix designs
- Contractor produced/placed mixture

Traffic and Weather

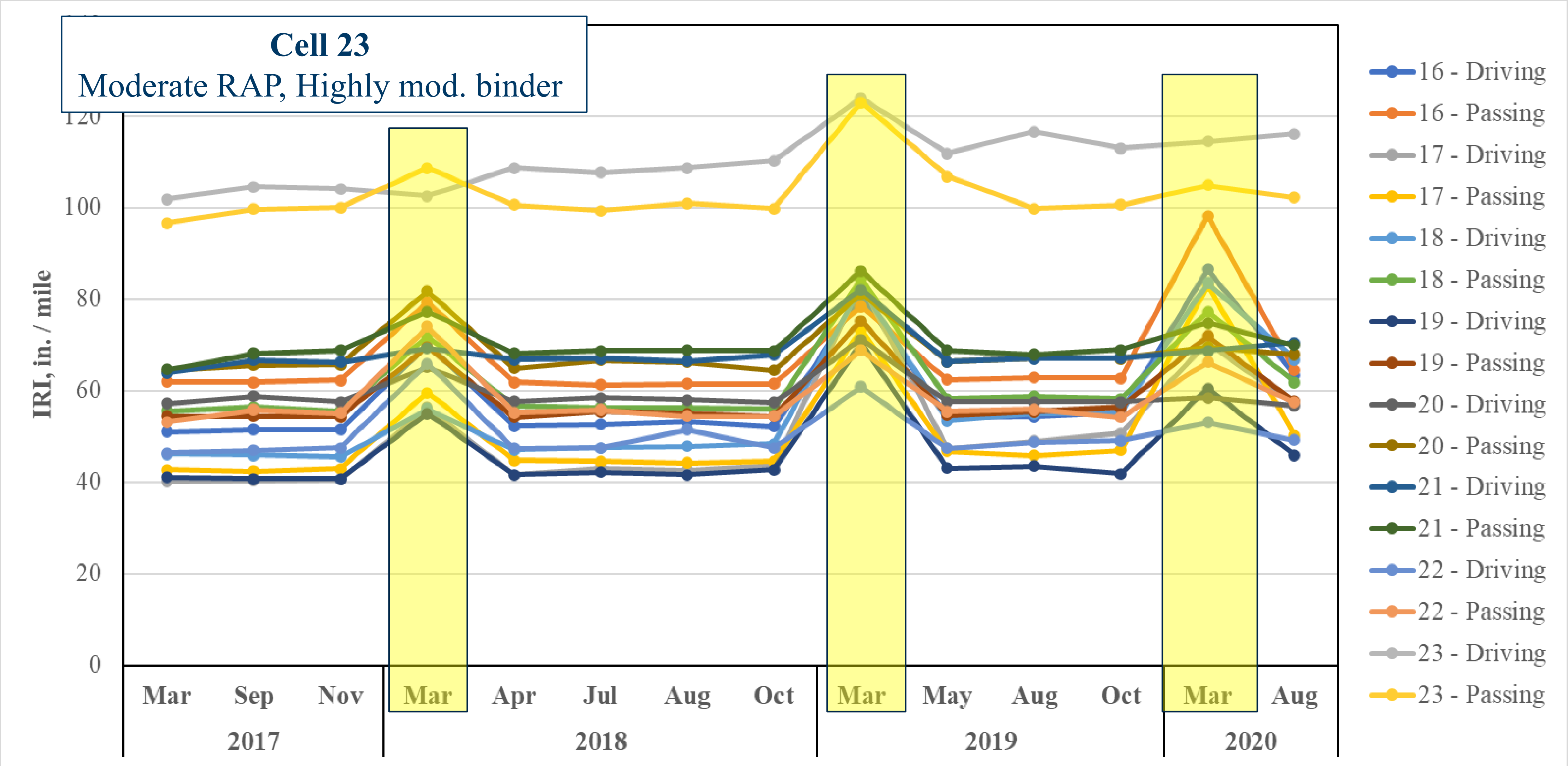
Open to traffic:
November 2, 2016

~3,900,000 ESALs
through Spring 2021

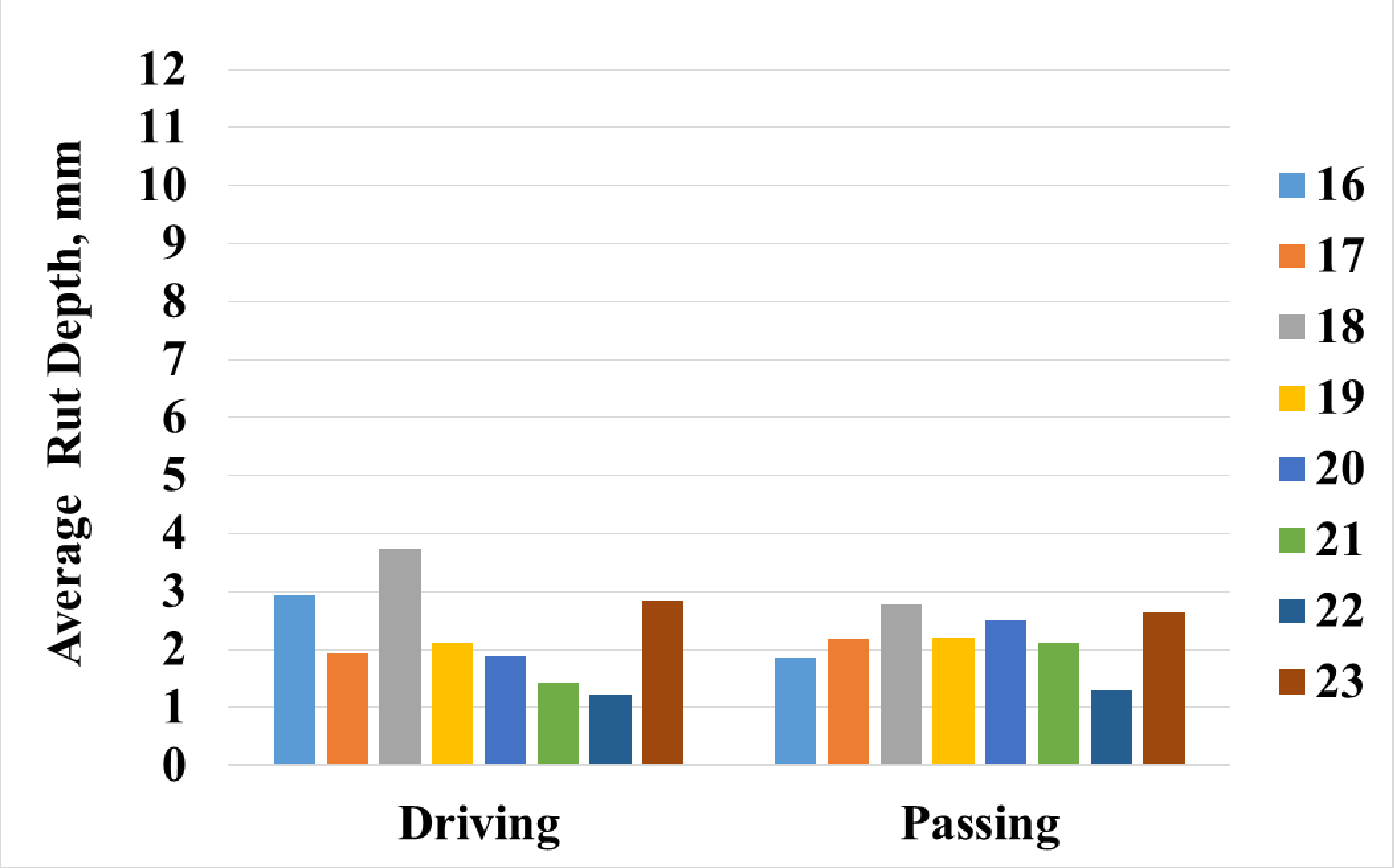


	2017	2018	2019	2020	2021
AIR -MAX	91.463	97.952	92.156	94.667	99.806
AIR - MIN	-21.001	-16.69	-29.578	-16.222	-23.773
HMA - MAX	135.104	136.382	130.28	131.63	139.064
HMA - MIN	-12.892	-11.704	-19.768	-7.582	-15.97

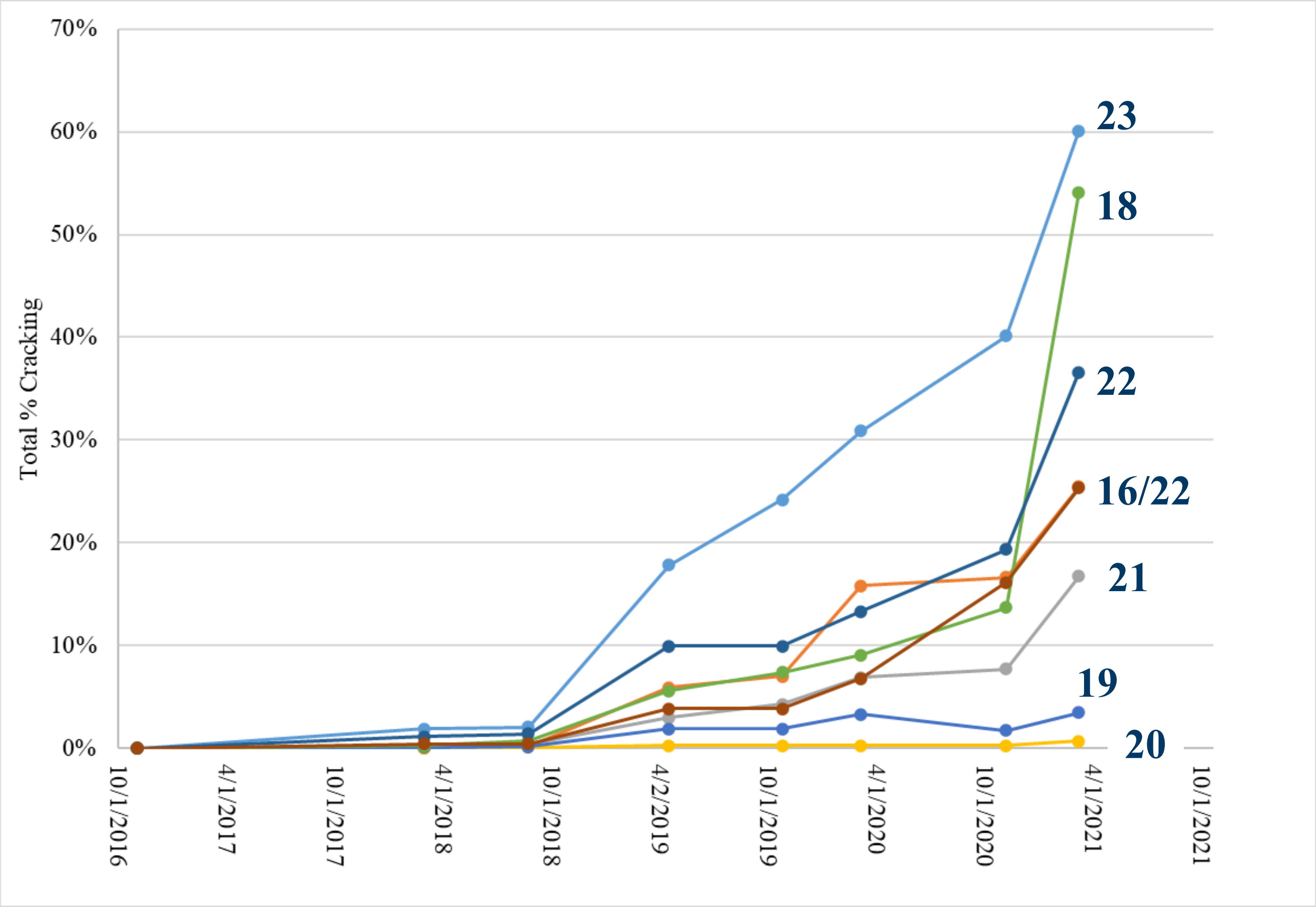
Performance - Ride



Rutting Performance



Performance - Cracking

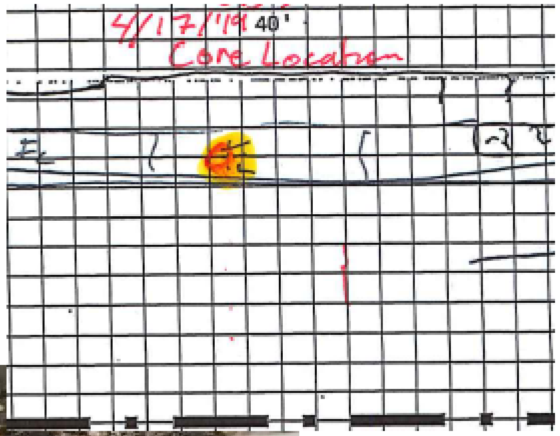


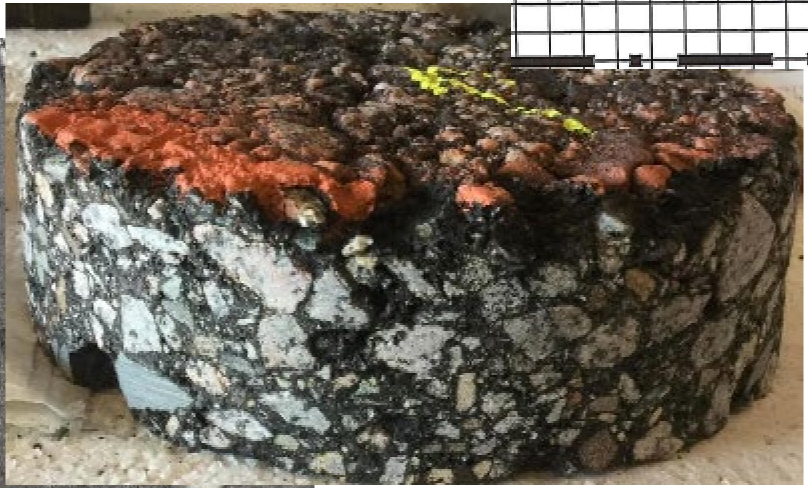
- Little distress before Winter 2018/2019
- Limited "traditional" transverse LTC
  - Difficult to separate LTC from load related distress
- Forensic investigation identified delamination as contributor to cracking
  - Cores in fatigue areas did not have cracking in lower HMA lift
  - Bond strength testing indicated strong bond in uncracked areas
  - "Delayed delamination" most likely due to water intrusion through longitudinal construction joints

Final distress survey conducted 3/8/2021

Performance – Cell 23
Moderate RAP, Highly mod. binder

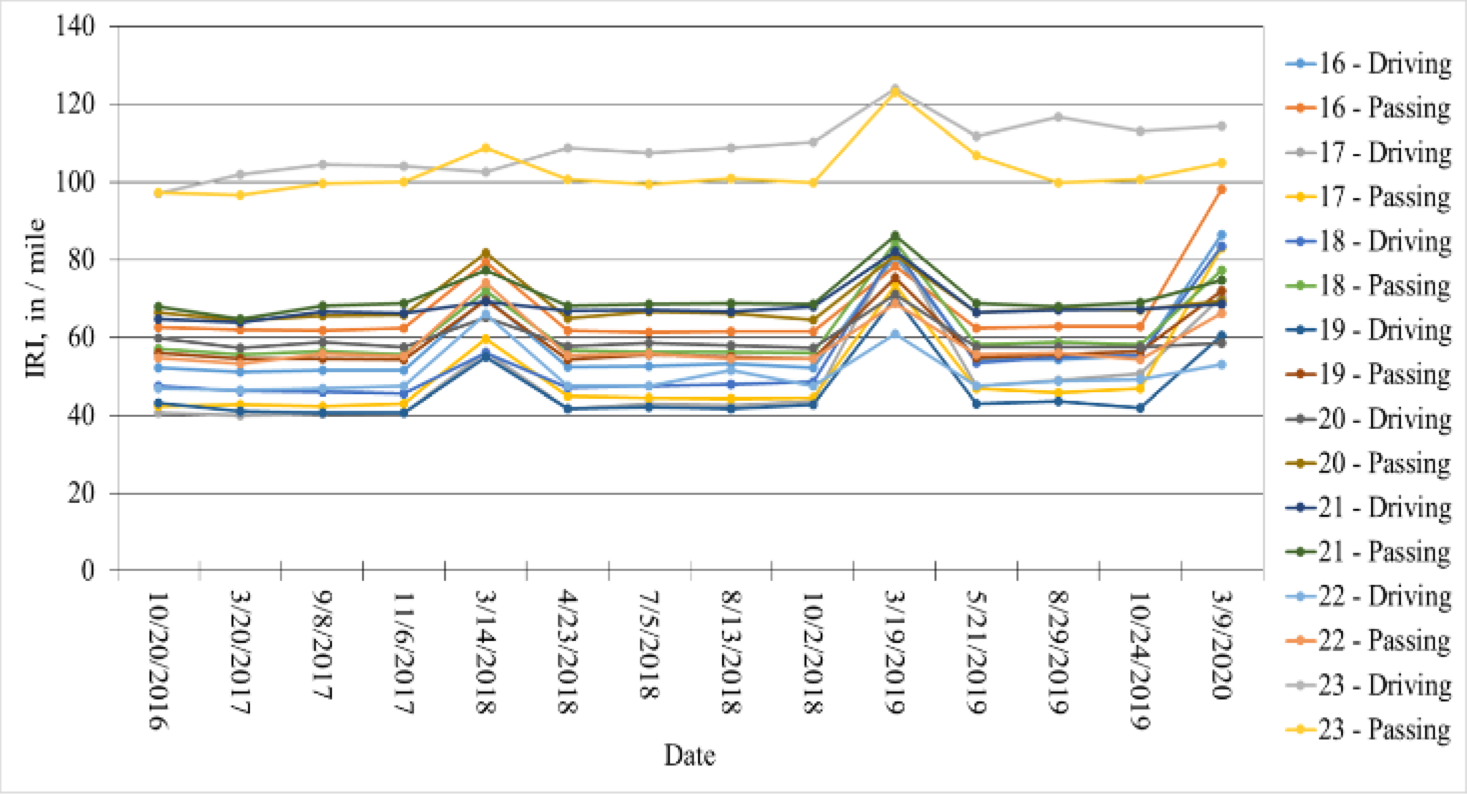
- Largest amount of load related distress
- Delamination under surface lift (2/3 cores)
- Lower lift has no signs of distress in cores





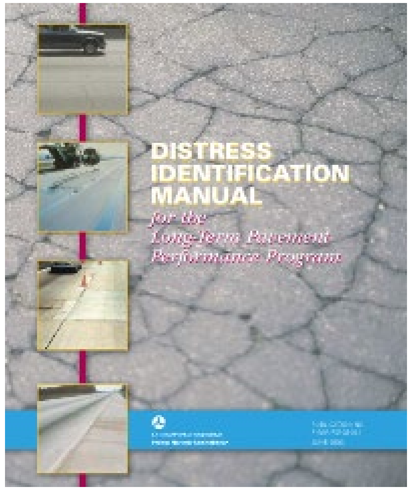
Cell 23 Excluded from Lab Test Comparison

- Cell 23 was excluded from lab test comparisons
  - Construction related issues
    - Higher initial IRI
    - Mid-lane paver gear-box cracking
    - Base/subgrade higher in-place moisture
    - Much larger variability in FWD data
  - Delamination evident earlier than others
  - Highest responses from instrumentation



Low Temperature Cracking Analysis

- Need to observed LTC without confounding influence of traffic loading
- Driving lane shoulder (10’) had transverse cracks with little other distress
- Shoulders paved with same lifts and thicknesses as entire Cell
- Visual distress survey on shoulders



Lo… alysis - Shoulder

22	Limeston…
21	Moderate…
20	High RAP,…
19	Moderate…
18	Moderate…
17	Low RAP …
16	Moderate…

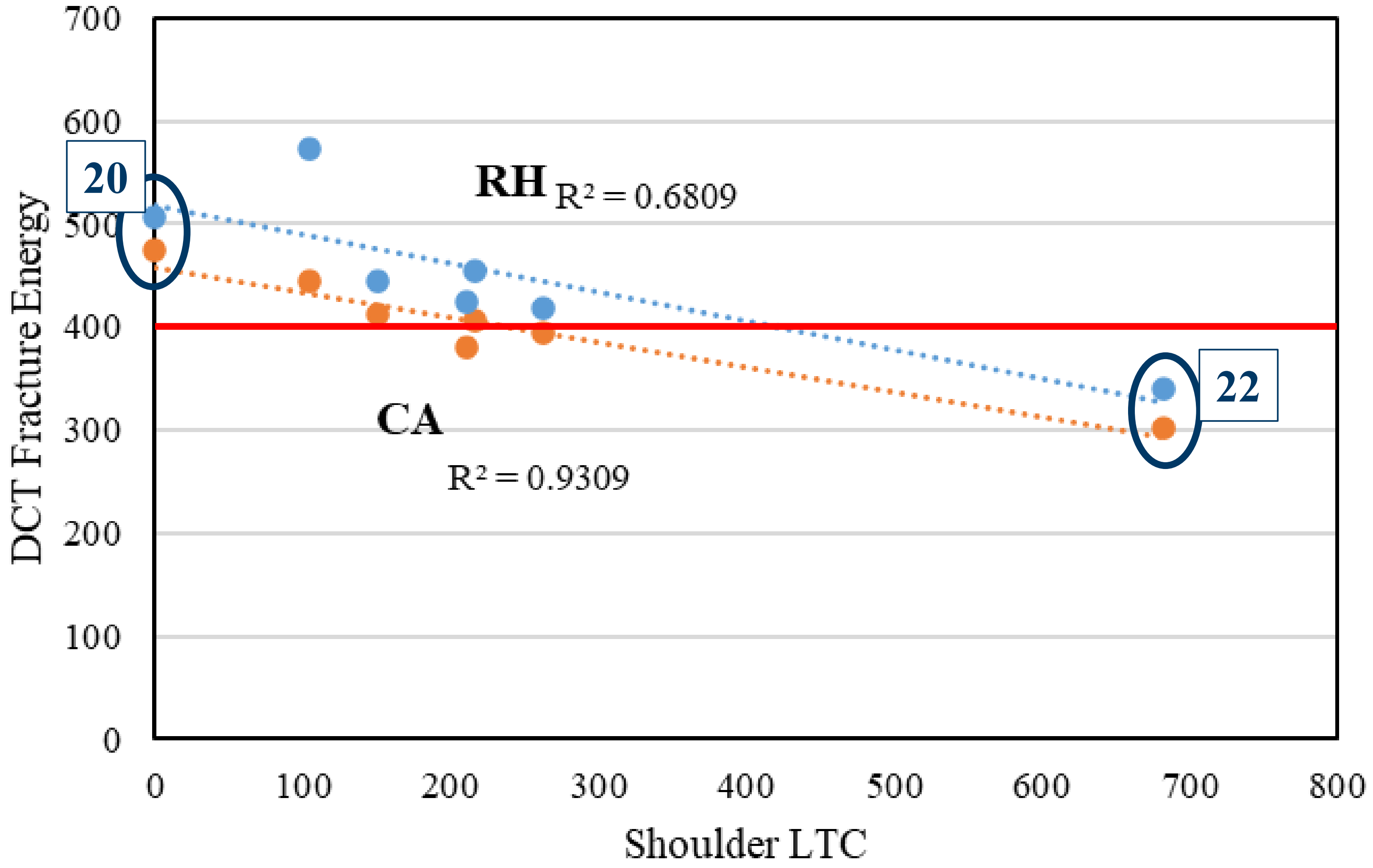
Correlation to Thermal Cracking in Shoulder

Test	R^2	
	RH	CA
DCT Fracture Energy	0.68	0.93
IDT Creep Compliance & Strength	0.04	0.36
Low Temp. SCB-Fracture Energy -12°C	0.47	NA
Low Temp. SCB-Fracture Energy -24°C	0.76	NA
UTSST	0.39	0.27*
IDEAL-CT	0.29	0.52
I-FIT	0.06	0.67
NCAT OT(10°C)-Nf	0.95	0.16
NCAT OT(10°C)-β	0.91	0.64
ACCD	0.21	0.18

Best correlations highlighted in red, $R^2 \geq 0.67$

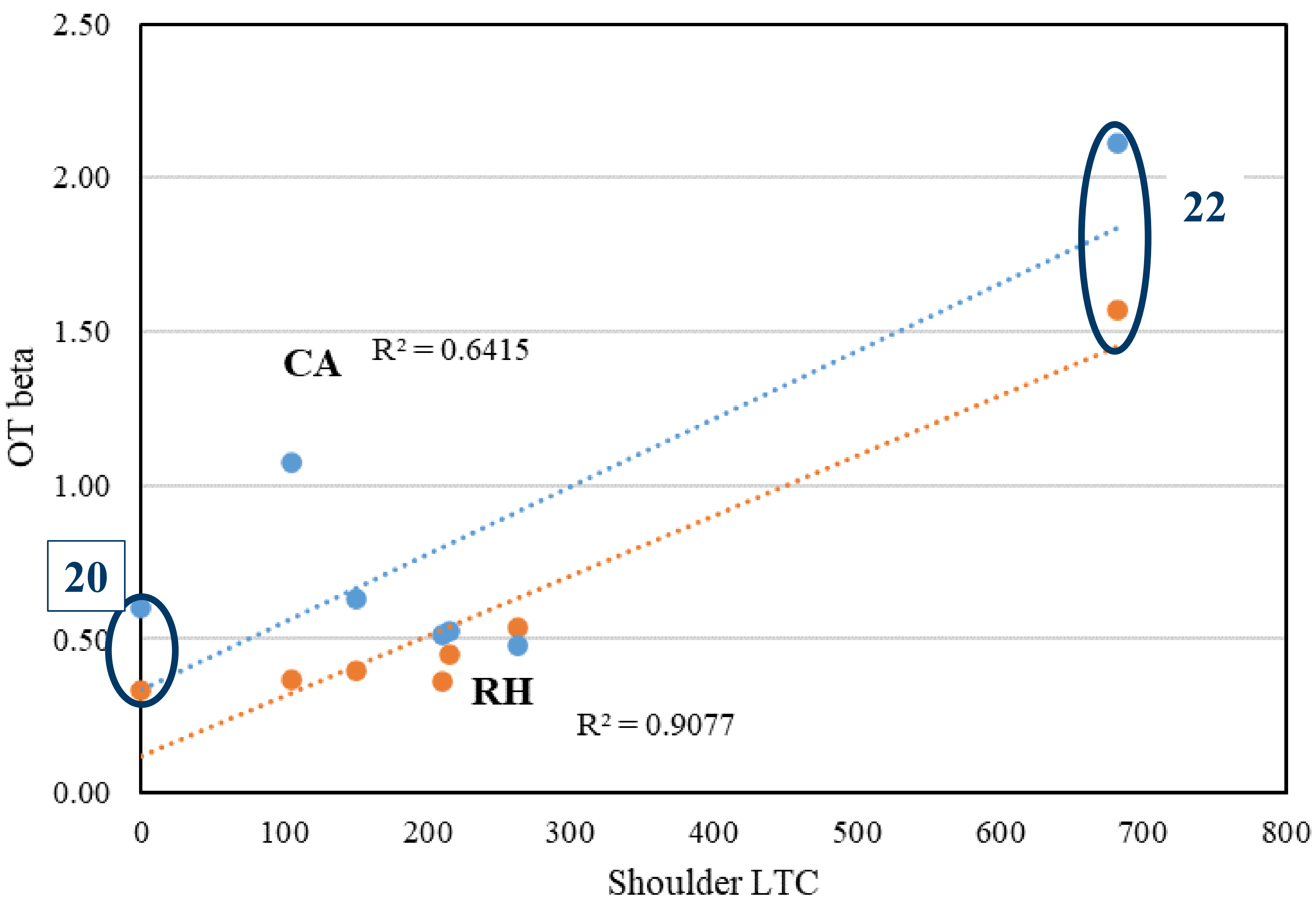
* LTOA AASHTO R30

DCT



DCT Fracture Energy
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
Shoulder LTC
20
22
RH
R² = 0.6809
CA
R² = 0.9309

NCAT OT β


2.50
2.00
1.50
1.00
0.50
0.00
OT beta
0
100
200
300
400
500
600
700
800
Shoulder LTC
CA
R² = 0.6415
RH
R² = 0.9077
20
22

Identification of Best/Worst

Test	RH	
	20 Best?	21 Worst?
DCT Fracture Energy	NO	YES
IDT Creep Compliance & Strength	YES	NO
Low Temp. SCB-Fracture Energy -12°C	YES	YES
Low Temp. SCB-Fracture Energy -24°C	YES	YES
UTSST	NO	YES
IDEAL-CT	NO	YES
I-FIT	YES	YES
NCAT OT(10°C)-Nf	YES	YES
NCAT OT(10°C)-β	YES	YES

Test	CA	
	20 Best?	21 Worst?
DCT Fracture Energy	YES	YES
IDT Creep Compliance & Strength	YES	YES
Low Temp. SCB-Fracture Energy -12°C	NA	NA
Low Temp. SCB-Fracture Energy -24°C	NA	NA
UTSST	NO	NO
IDEAL-CT	NO	YES
I-FIT	YES	YES
NCAT OT(10°C)-Nf	NO	YES
NCAT OT(10°C)-β	NO	YES

Concluding the Experiment

- Wide range of field performance observed
  - Rutting and ride good for all sections until potholes occur
  - Cracking caused by multiple mechanisms (construction related, load related, environmental)
  - LTC results impacted by material (narrow low PG range) and structural (delamination) properties
- LTC on shoulders correlated with laboratory testing
  - DCT and NCAT OT β had best correlations
  - Other tests able to identify best/ worst

Implementable Takeaways from MnROAD CG

- PG can be deceiving. Continuous grading provides more info
- Cell 20 (PG 52S-34) had best overall performance in field
  - Highest RAP content; No significant rutting
- Emphasized the "basics" of paving
  - Bonding between lifts; High moisture in base/ subgrade; longitudinal construction joints
- More binder = better cracking performance in field (cells 18 v 19)
- MN Limestone aggregate more susceptible to cracking than granite aggregate (cells 21 v 22)

Acknowledgements and Questions

MnDOT Research

MnROAD Team

NCAT Team

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Thank you again!

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