A Retrospective on 16 Years of Productive Collaboration: The NCAT Impact on Development of WMA, Recycling, & Pavement Preservation Markets Around the World

NCAT Pavement Test Track Conference

24 June 2021

Ingevity

A Brief History of NCAT-INGEVITY Cooperation

2005

Lab study of Evotherm at NCAT

Worlds' first test track study of WMA at NCAT

Indianapolis: 2nd WMA trial in the USA supported by NCAT

2006

1st Trial in Beijing, China

NCAT published results of Evotherm WMA lab study

2007

WMA TWG formed

NCAT support at the I-70 CO DOT WMA trial of Evotherm: 0°C air temp. ~11,000 ft. altitude

NCAT published Test Track perform-ance of Evotherm at TRB 2007.

2008

NCAT Support for the Award-winning Ft. Worth, double-lift WMA section on BU-287 using PG 76-22 at 275°F surface mix

2009

Ingevity- RIOH China delegation visits NCAT

1st Intern'l WMA Conference

NCAT Test track comparison of Double-Barrel Green & Evotherm

Other WMA technologies (e.g., Thiopave) built on Test Track

NCAT seminars in New Dehli India to support WMA consideration for multi-billion dollar infrastructure expansion plans

2010

Oct. 11-13, 2011, 2nd Intern'l Conf. on WMA in St. Louis, MO,

Buzz Powell Mentioned the Lee Co. Rd. 159 Project

2011

July: Lee Co. Rd. 159 construction of Pave-ment Preser-vation treat-ments as part of the NCAT Green Group study

Small 2005 Evotherm section endures over 16 MM ESAL's.

NCAT Report 12-10.

2012

A Brief History of NCAT-INGEVITY Cooperation

Ingevity Hebei delegation visit visit NCAT

NCAT US 280 Pavement Preservation & Recycling Experiment
Ingevity support for mixture designs for micro-surfacing & emulsion-based CCPR/CIR sections

WRI / NCAT / Ingevity monitor aging of Lee County Road 159 & US 280 sections

MN DOT: MN Road & NCAT **Partnership on Pavement Preservation** for northern climates on high-volume US 169 and low-volume CASH 8 in Mille Lacs County (Colorado, Illinois, Maryland, Minnesota, Michigan, New York, and Wisconsin)

Ingevity support of Recycling & FDR emulsion production & mixture designs for NCAT / MN ROAD construct Pavement Preservation
Ingevity delegation from Mexico

In the Beginning: 2005 - World's First WMA Pavement Test Section

NCAT Lab Design

FIELD PERFORMANCE OF WARM MIX ASPHALT AT THE NCAT TEST TRACK

"Account of the 2005 Evotherm Test Track Construction"

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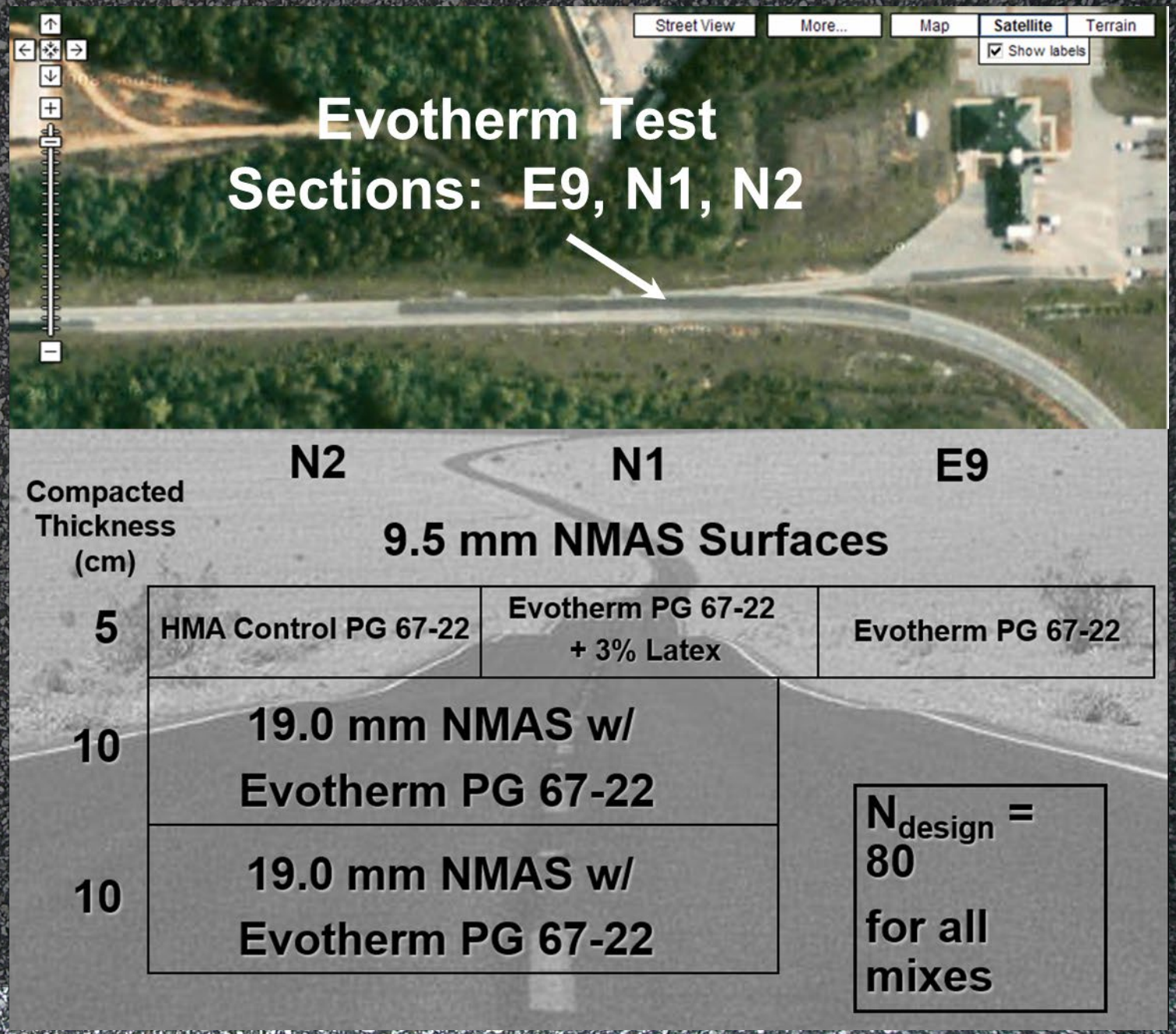


Mix produced 7:00 PM

Mix held in silo at 115°C overnight

Mix loaded out 1:30 PM – next day

Mix placed at 3:15 PM

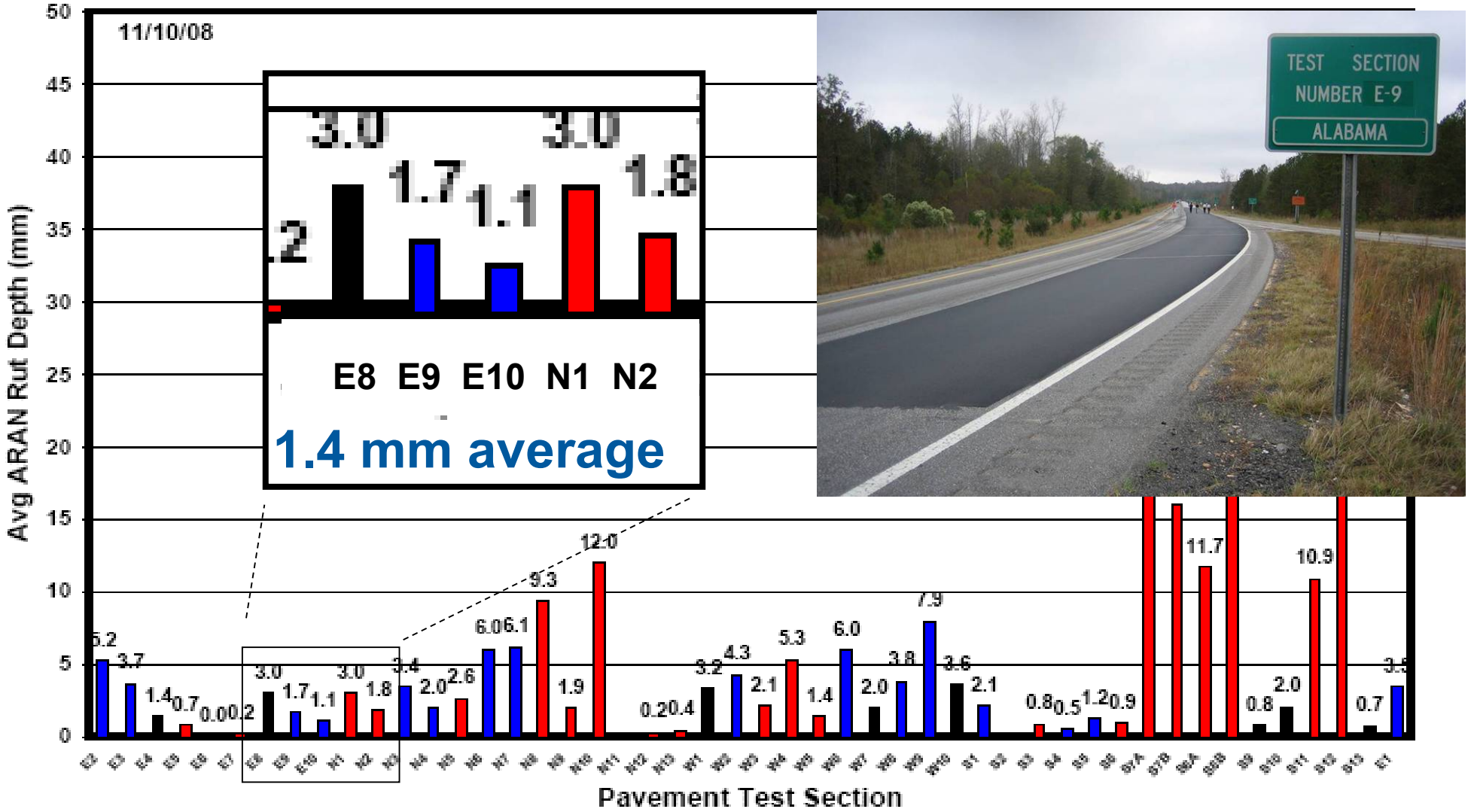
Mix laid at 96°C

Traffic returned 5:00 PM

"11/10/08"

Rutting Performance

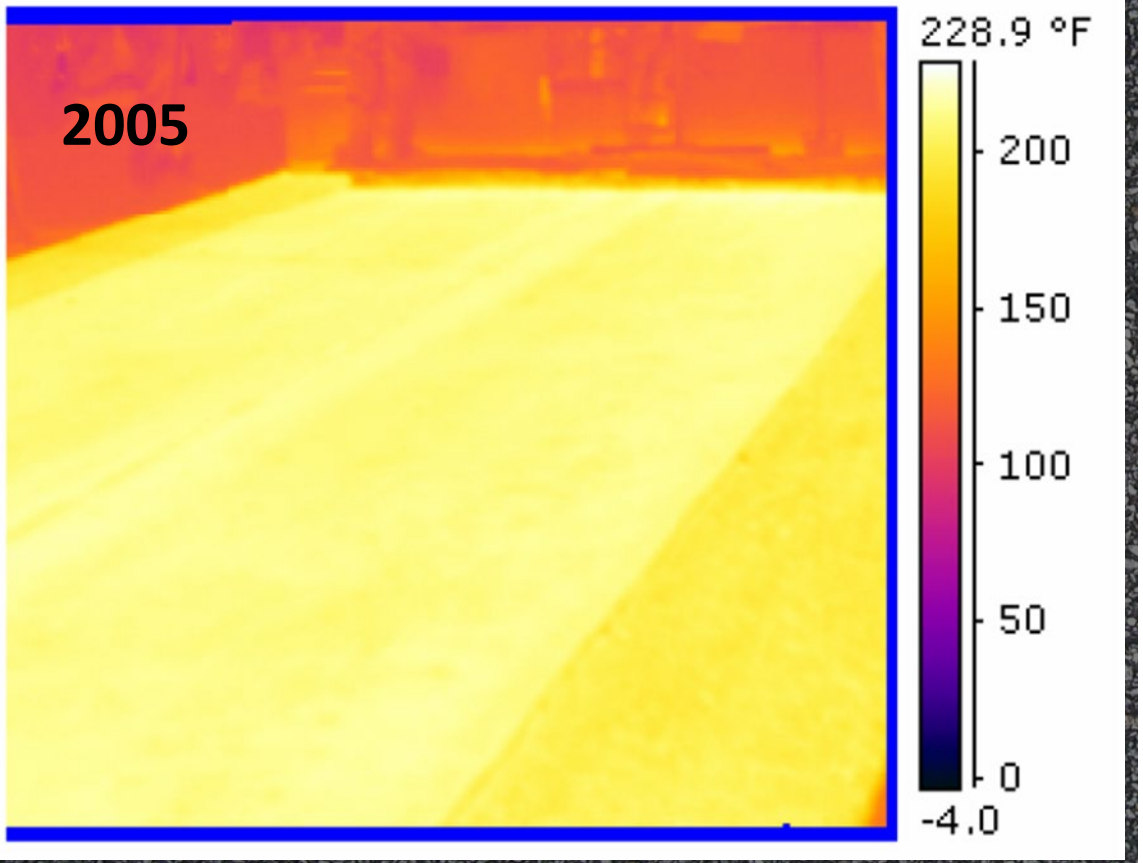
Cycle of Construction Shown by Color (Black=2000, Blue=2003, Red=2006), N1-N10 & S11 Structural (M-E)



In the 2009 Rebuild

Table 1.1 Complete Listing of Test Sections on the 2009 NCAT Test Track

Test Sec	Study HMA (in)	Surface Mix Stockpile Materials	Year of Completion	Design Methodology	Specified Binder	Total HMA (in)	Base Material	Sub-Grade	Research Objective(s)
E2	4	Calcined Bauxite	2005	Proprietary	Epoxy	24	Granite	Stiff	HVS PG67 Validation w/ High Friction Epoxy Surface
E3	4	Calcined Bauxite	2005	Proprietary	Epoxy	24	Granite	Stiff	HVS PG76 Validation w/ High Friction Epoxy Surface
E4	4	Granite	2000	Superpave	PG76-22	24	Granite	Stiff	Performance of Coarse Gradation
E5	**2**	**Grn/Lms/Snd (45% RAP)**	**2006**	**Superpave**	**PG67-22**	**24**	**Granite**	**Stiff**	**RAP Mix Design/Construction/Performance**
E6	**2**	**Grn/Lms/Snd (45% RAP)**	**2006**	**Superpave**	**PG76-22**	**24**	**Granite**	**Stiff**	**RAP Mix Design/Construction/Performance**
E7	2	Grn/Lms/Snd (45% RAP)	2006	Superpave	PG76-22s	24	Granite	Stiff	RAP Mix Construction/Performance w/ Sasobit
[illegible]									
E9	**1.5**	**Granite**	**2010**	**Superpave**	**PG67-22**	**24**	**Granite**	**Stiff**	**Shell Thiopave WMA Certification Program 5/11/10**
E10	2	Granite/Limestone/Sand	2005	Superpave	PG76-22	24	Granite	Stiff	Evotherm Warm Mix w/ Latex
N1	**0.75**	**Granite (15% RAP)**	**2009**	**PFC**	**PG76-22**	**7.75**	**Limerock**	**Stiff**	**Surface Cracks in PFC via Spray Paver & M-E Design**
N2	**0.75**	**Granite (15% RAP)**	**2009**	**PFC**	**PG76-22**	**7.75**	**Limerock**	**Stiff**	**Surface Cracks in PFC via Tack Paving & M-E Design**
[illegible]									



First FLIR photos of WMA pavement showing the uniformity of low temperature (229°F) across the mat.

12/23/2011

Quadrant: E
Section: 10

"2011"

Surface Mix and Materials

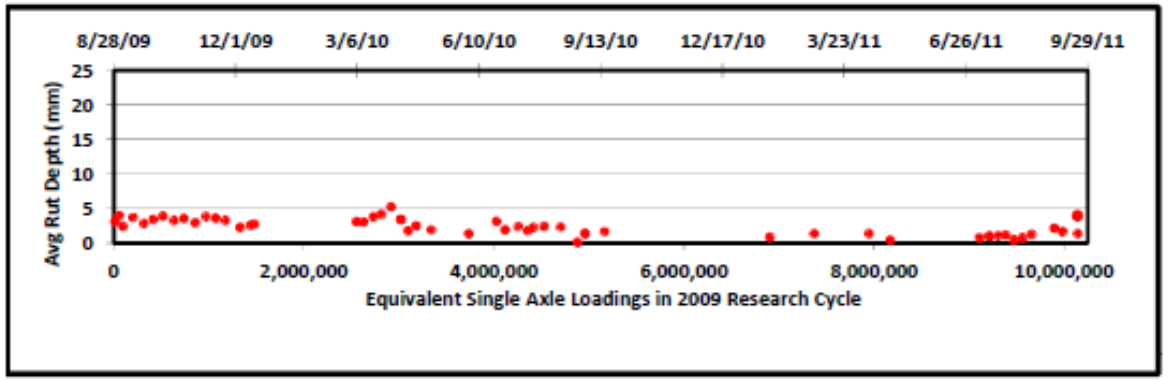
Year of Completion:	2005
HMA Design Methodology:	Superpave
Specified Binder:	PG76-22
Surface Mix Stockpile Materials:	Granite/Limestone/Sand

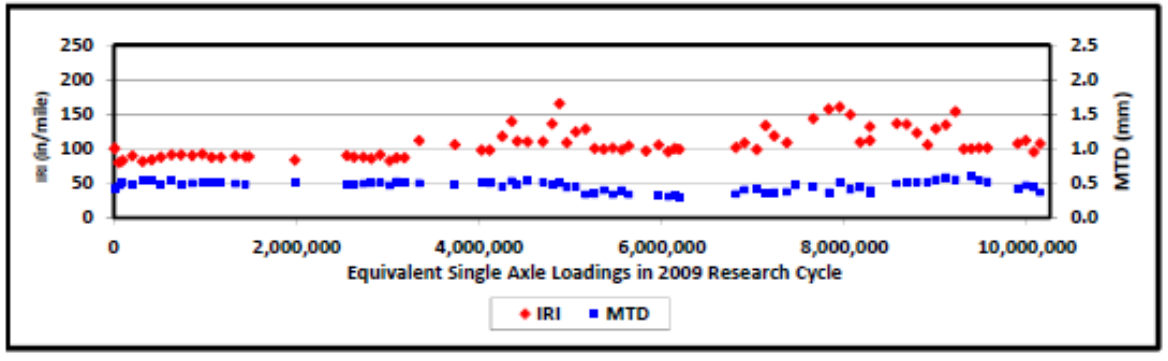
Structural Buildup Information

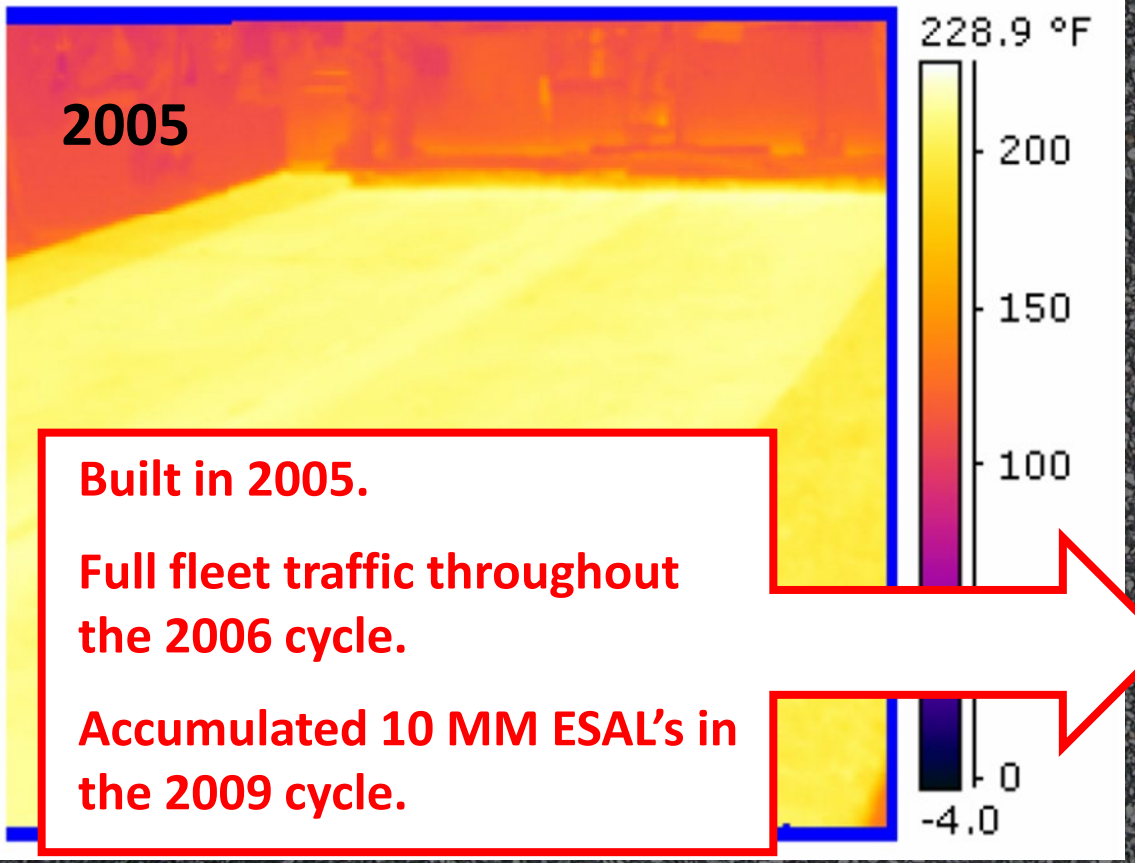
Study HMA (in):	2
Total HMA (in):	24
Base Material:	Granite
Subgrade:	Stiff

Research Objective: Evotherm Warm Mix w/ Latex

Preliminary Field Performance Data







Built in 2005.

Full fleet traffic throughout the 2006 cycle.

Accumulated 10 MM ESAL's in the 2009 cycle.

First FLIR photos of WMA pavement showing the uniformity of low temperature (229°F) across the mat.

12/23/2011

Quadrant: E
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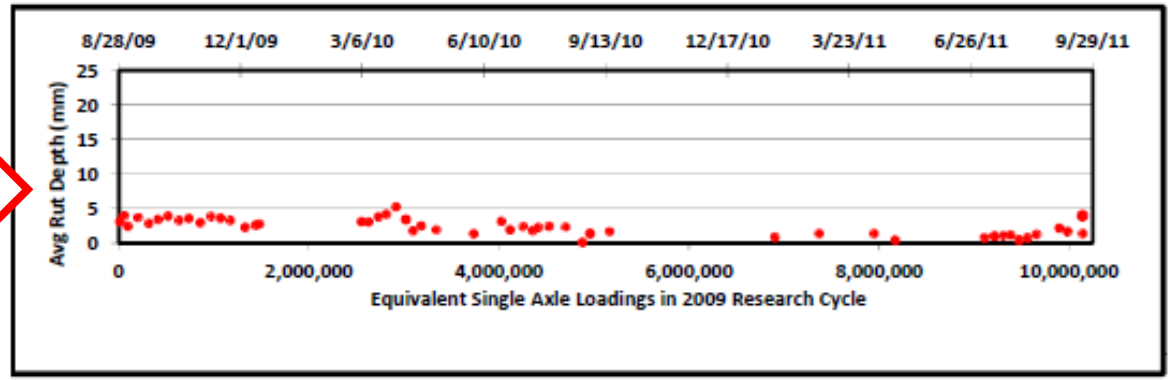
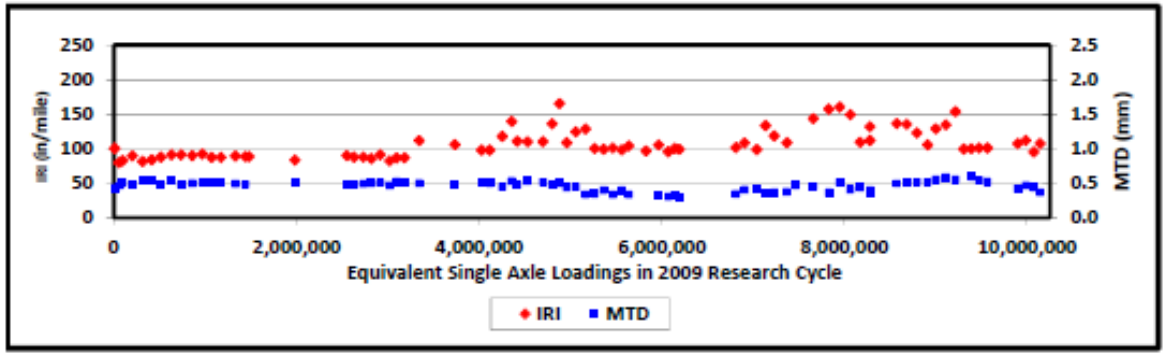
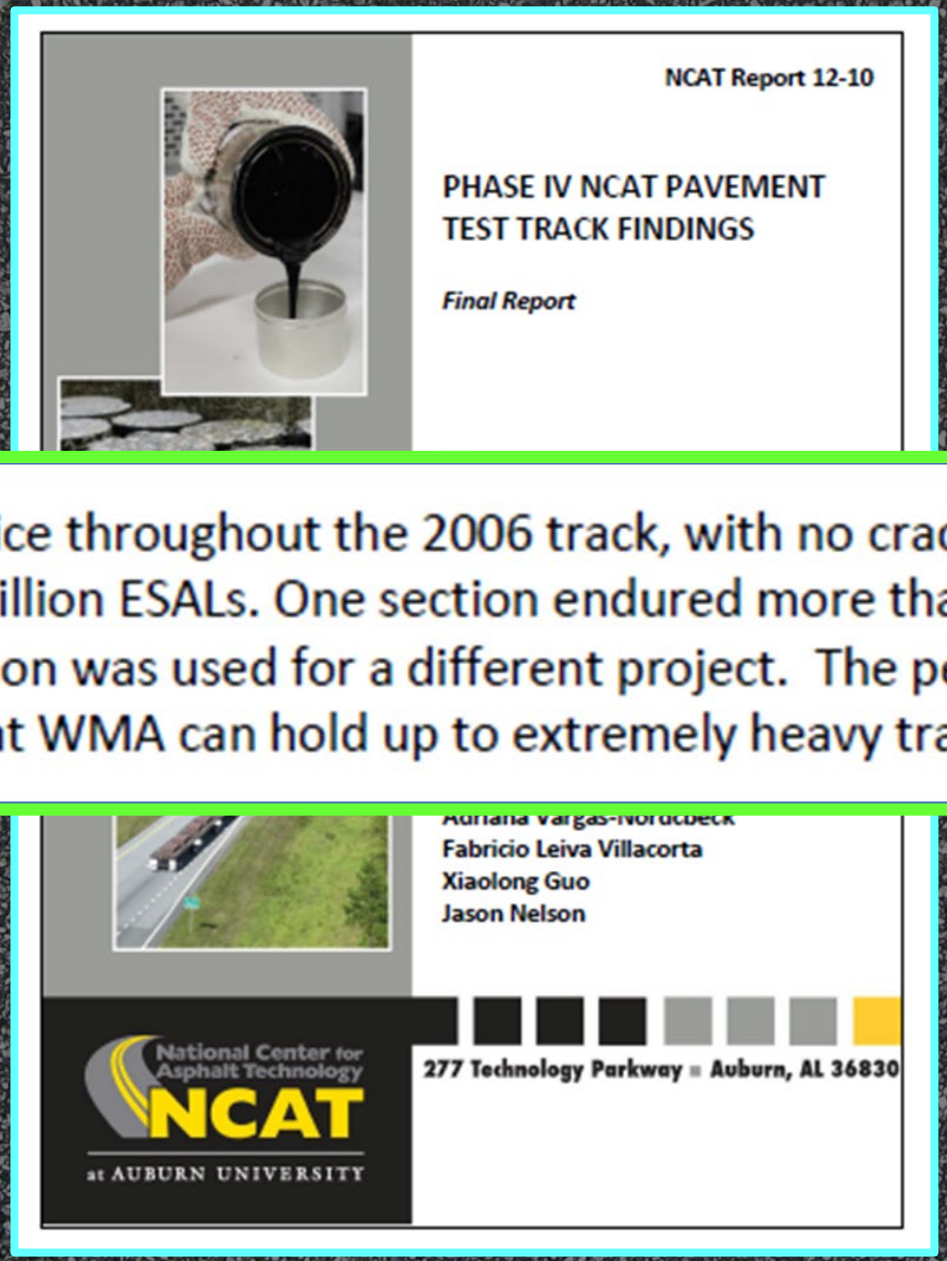




In the 2012 NCAT Report on the 2009 Cycle…



Both sections remained in service throughout the 2006 track, with no cracking and rutting performance comparable to HMA for 10.5 million ESALs. One section endured more than 16 million ESALs on the 2009 track before the test section was used for a different project. The performance of those test sections was early evidence that WMA can hold up to extremely heavy traffic.

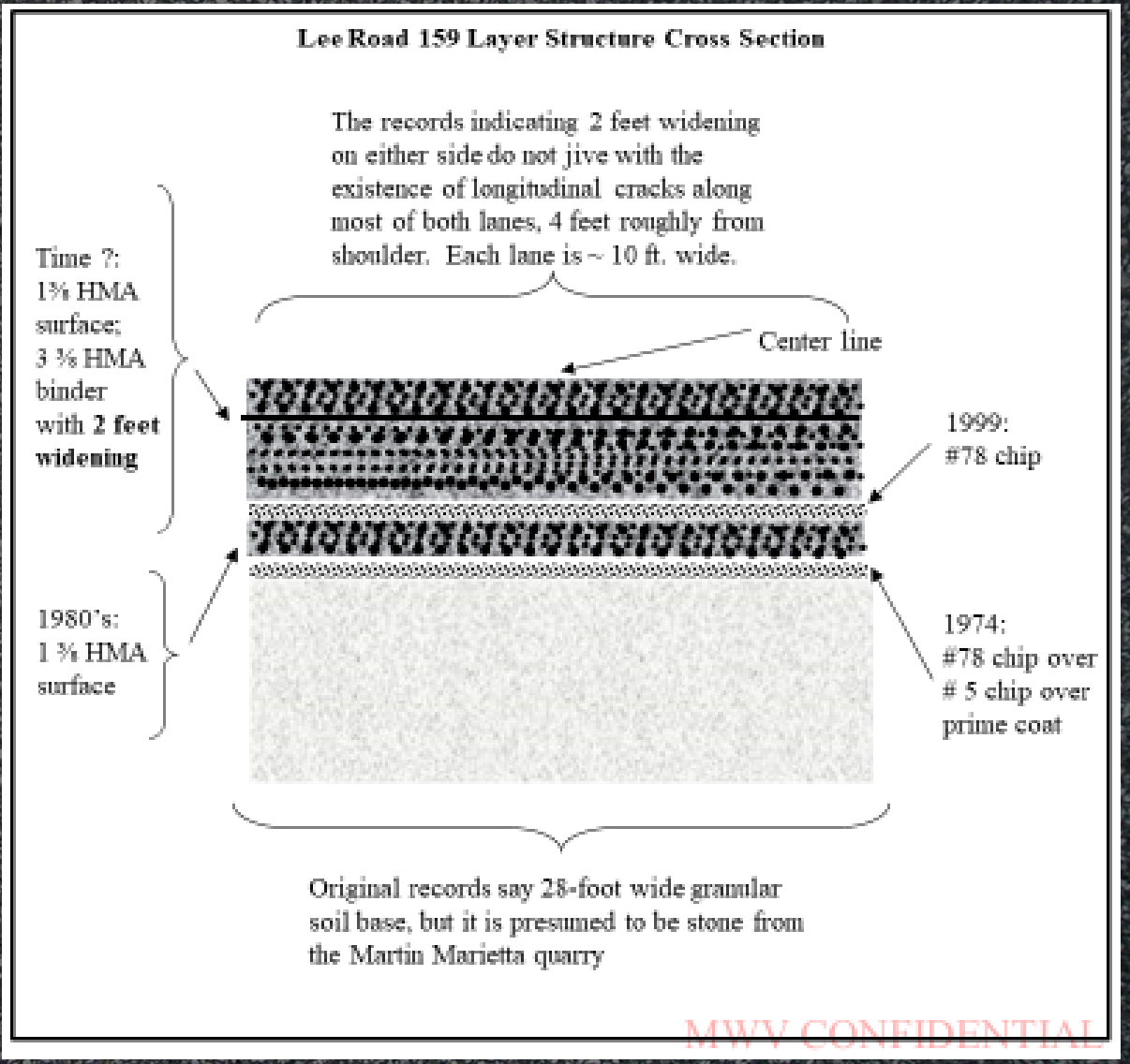
2011 – 2012: Lee County Road 159

May 11, 2011, NCAT Pavement Test Track sponsor's meeting. There was discussion of evaluating emulsion-based maintenance technologies on the Test Track.

At the 2nd WMA conference in St. Louis, Oct 11-13, 2011, Buzz Powell shared his vision of a field experiment to put pavement preservation treatments on the road that leads from a Martin Marietta quarry and East Alabama Paving hot plant near the NCAT test track.

12 April 2012, Mike Buckingham (COLAS), Tim Harrowood (VANCE BROS), Mark Ishee (ERGON), Jim Moulthrop (FPP), Mike Oleary (INGEVITY), and E Crews (INGEVITY) met with Buzz at Lee County Road to discuss the viability of his idea. At that time, the sentiment for support was not exactly unanimous. The road was distressed to an extent that most thought that pavement preservation treatments would not be shown in the best light.

Lee County Road 159



Lee County Road 159

Fibermat

Scrub Seal

2015 US 280 SCALE-UP OF LEE COUNTY ROAD 159

2015 US 280 SCALE-UP OF LEE COUNTY ROAD 159

2015 US 280 EMULSION & FOAM CCPR & CIR

Wirtgen KM220


DYNAPAC
2:37:16 10 IX 2015


4:32:55 10 IX 2015

4:57:45 10IX15 rain beginning on tacked, paint-striped emulsion-based CCPR section

6:57:04 10IX15 rain washed off striping

September 11, 2015, 8:30 AM, after a heavy downpour, after being open to traffic the night before.

White stripe washed off in rain.

Only minor raveling at beginning of section where trucks bounced from HMA to CIR section.

No rutting.


6:08:32 a.m. 11 Sept. 2015 Emulsion CCPR after rain
and two nights open to traffic.

Field Performance – US 280

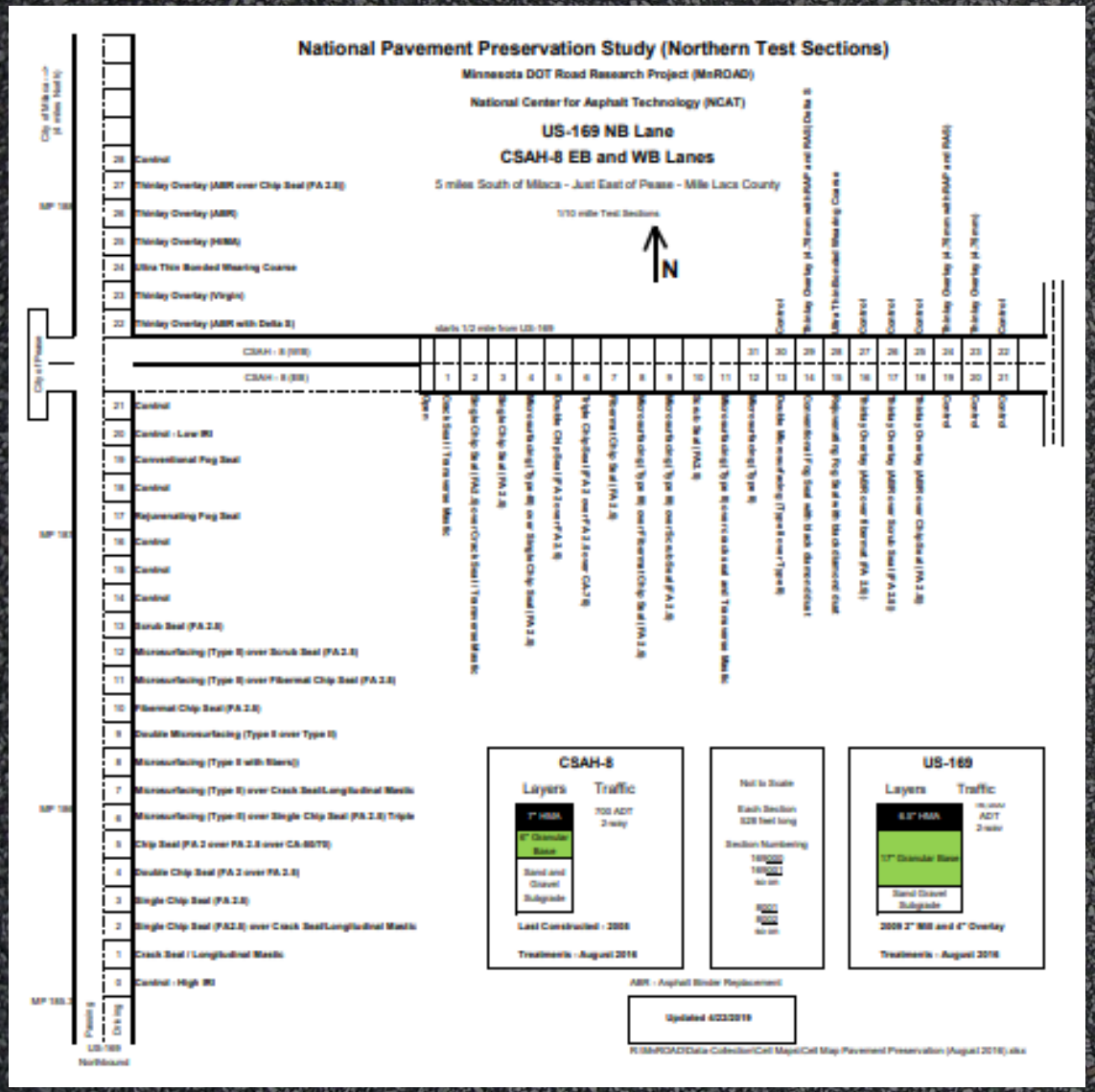
Section	Description	Rutting (mm)	IRI (in/mi)	Cracking (%)
U40	Foamed CCPR	4.3	86.1	8.2
U41	Emulsion CCPR	3.6	92.9	2.2
U43	Emulsion CIR	4.5	98.7	2.0
U44	Foamed CIR	4.4	66.3	1.0

Lowest a

Highest a

Adriana Vargas, PhD, "Structural Contribution Of Recycled Sections On Lee Road 159 And US 280," NCAT Test Track Conference, Seventh Research Cycle, 22-24 June 2021.

MN DOT: NCAT-MN ROAD PRESERVATION PROJECT 2016



This experiment constructed low- and high-volume pavement preservation sections (off the MnROAD site). The 31 test sections are similar to the treatments constructed by NCAT using the materials and construction methods used by MnDOT.

https://www.dot.state.mn.us/mnroad/ncatpartnership/pavementpreservation/index.html

2019: NCAT / Mn ROAD 70th Street Recycling & Stabilization Project

Mix Properties of Emulsion CIR (Meigs C

- 2.8% Emulsion (64% residue) = 1.9% A
- 2% Add Water
- 0% Cement
- In-place density of 130 pcf

Emulsion CIR

2019: NCAT / Mn ROAD 70th Street Recycling & Stabilization Project

Emulsion SFDR

- Wirtgen 3800 CR recycler used for CIR
- Windrow & motor grader proved difficult for foam, so used paver instead
- Hamm H16 padfoot used for compaction
- Mix designed by AET
- Mix Properties of Emulsion SFDR (Meigs SB-EE Virtus SE-2)
  - 3% Emulsion (64% residue) = 1.9% AC
  - 2.5% Add Water
  - 1% Cement
  - In-place density of 135 pcf








NCAT / Mn ROAD 70th Street Recycling & Stabilization Project

Ingevity Mobile Lab Trailer

- Samples compacted on G2 gyratory for each recycling section
  - 4 Marshall stability strengths
  - 4 HWT
  - 6 Ideal CT
  - 3 DCT
- Samples were compacted to height to match field density
- Most were only going 5-10 gyrations
- Due to schedule being pushed, the “planned” short term strengths were not collected for all sections
- Samples were cured in MnDOTs warehouse for several weeks before shipping to CHS

NCAT / Mn ROAD 70th Street Recycling & Stabilization Project

Emulsion CCPR

- Ingevity designed with FHR and PC 2024, but had issues getting supply from FHR
- H.G. Meigs supplied CIR-EE that uses SBT-50 instead
- Mix Properties of Emulsion CCPR
  - 3.5% Emulsion (64% residue) = 2.2% AC
  - RAP moisture (3.6%) + Added water for coating (0.5%
  - 0% Cement
  - In-place density of 138 pcf
  - as

Delegations from China

Colombia y Perú

Delegation from México

Key Benefits of 16 Years of Collaboration

Through partnership with NCAT, we have improved our ability to build field experiments that will accurately reflect (& confirm) performance of both new and traditional asphalt paving technologies

Through the field results of NCAT studies, we have developed long-term field results to support (& refine) theory & to substantiate laboratory findings both domestically & internationally

Through support of NCAT work, we add to the global body of knowledge & experience that proves the superior performance & sustainability of asphalt-based paving technologies

On Behalf of the Ingevity Team,

Thank You!

Questions?

KRATON

Implementation of HiMA Binders from the NCAT 2009 Track Cycle

Bob Kluttz

2021 NCAT Test Track Conference

The Journey

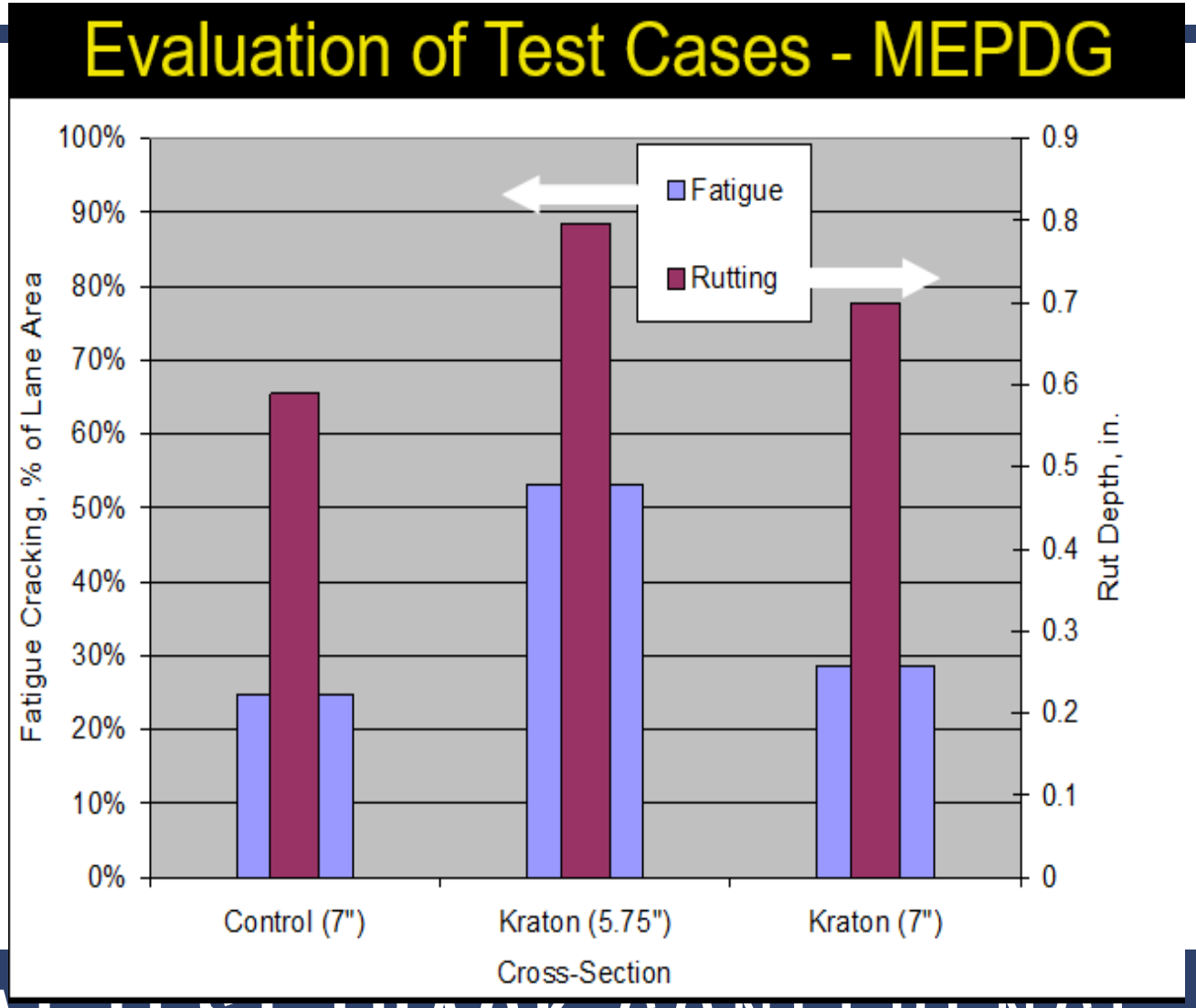
- Where We Started
- Working with NCAT - 2009
- Adding in Oklahoma - 2010
- Adding in the Green Group - 2012
- Adding in the Cracking Group – 2015
- State Implementation
- A Multipurpose Tool
- We’re Getting Help
- FHWA EDC-6 TOPS
- What Are We Doing Today
- Learnings

Where We Started

- TU Delft starting ~2004
- Modeling base course performance with 3-D finite element model
- Really great results!
- But a hard sell for a DOT pavement design engineer!
- Hence…

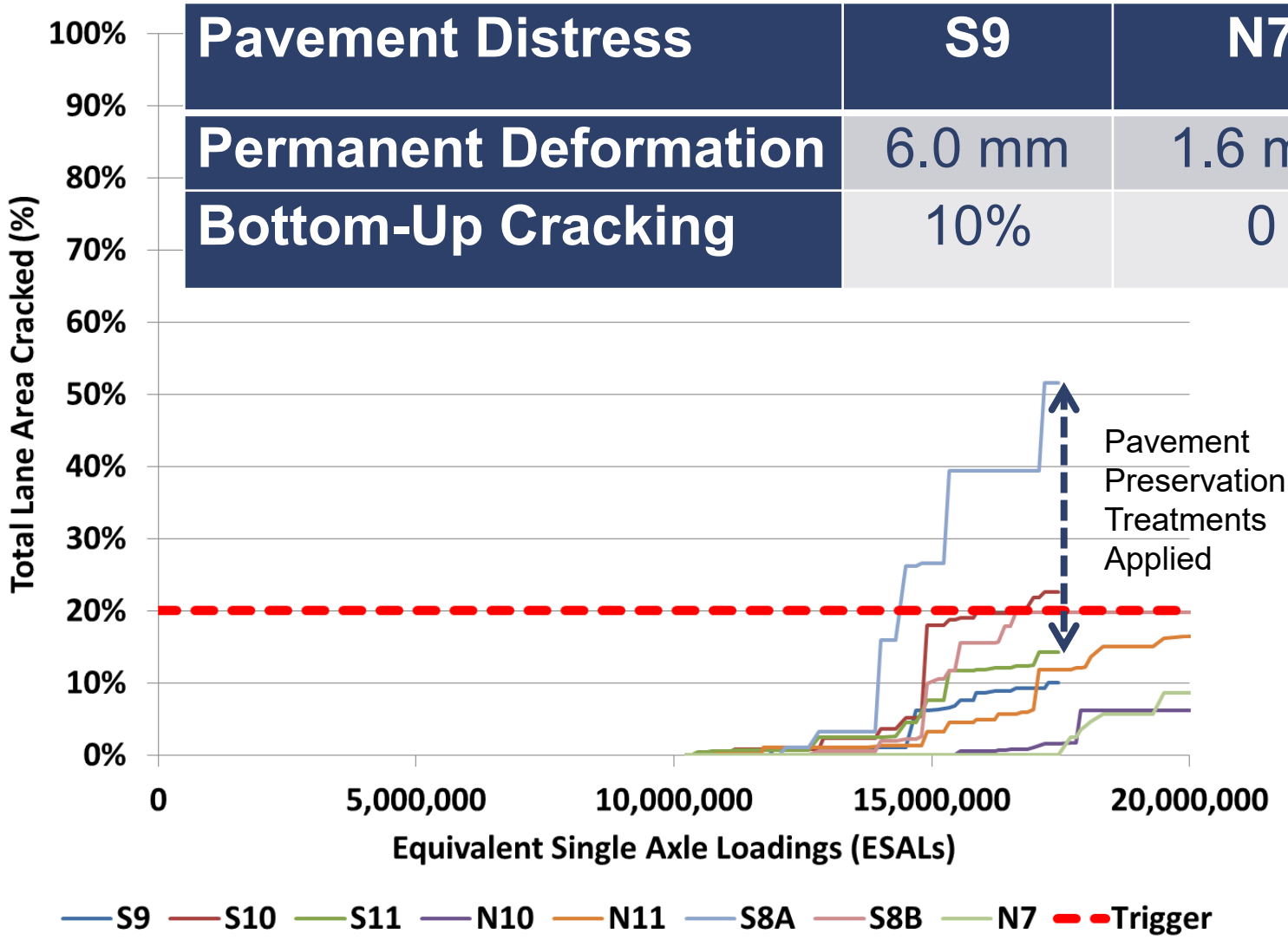
Working with NCAT - 2009

- Proposed a thin HiMA pavement
- But NCAT was reluctant!
- BTW – where did 5 ¾” come from?

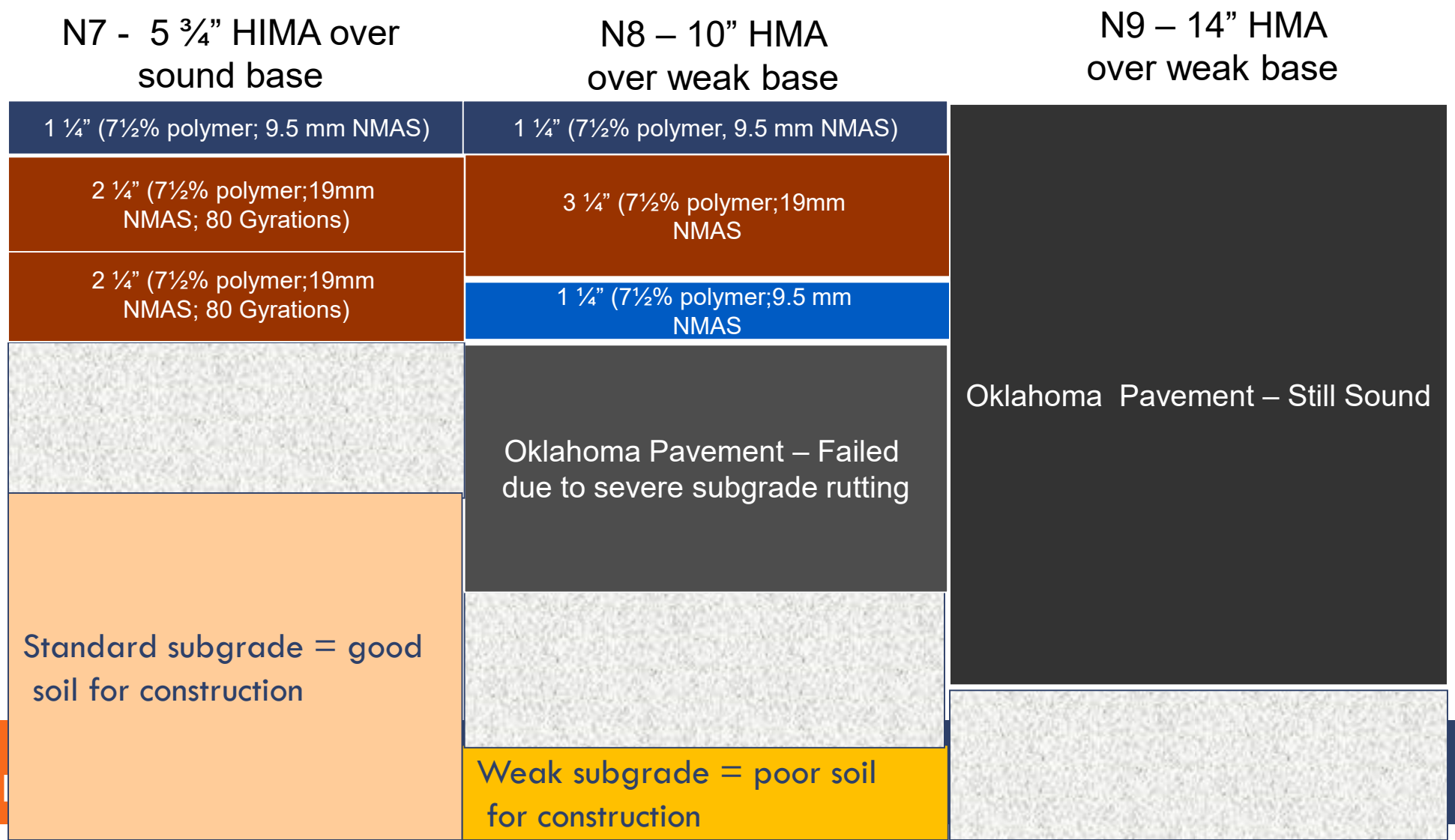


Working at NCAT 2009 - 2015

Pavement Distress	S9	N7
Permanent Deformation	6.0 mm	1.6 mm
Bottom-Up Cracking	10%	0

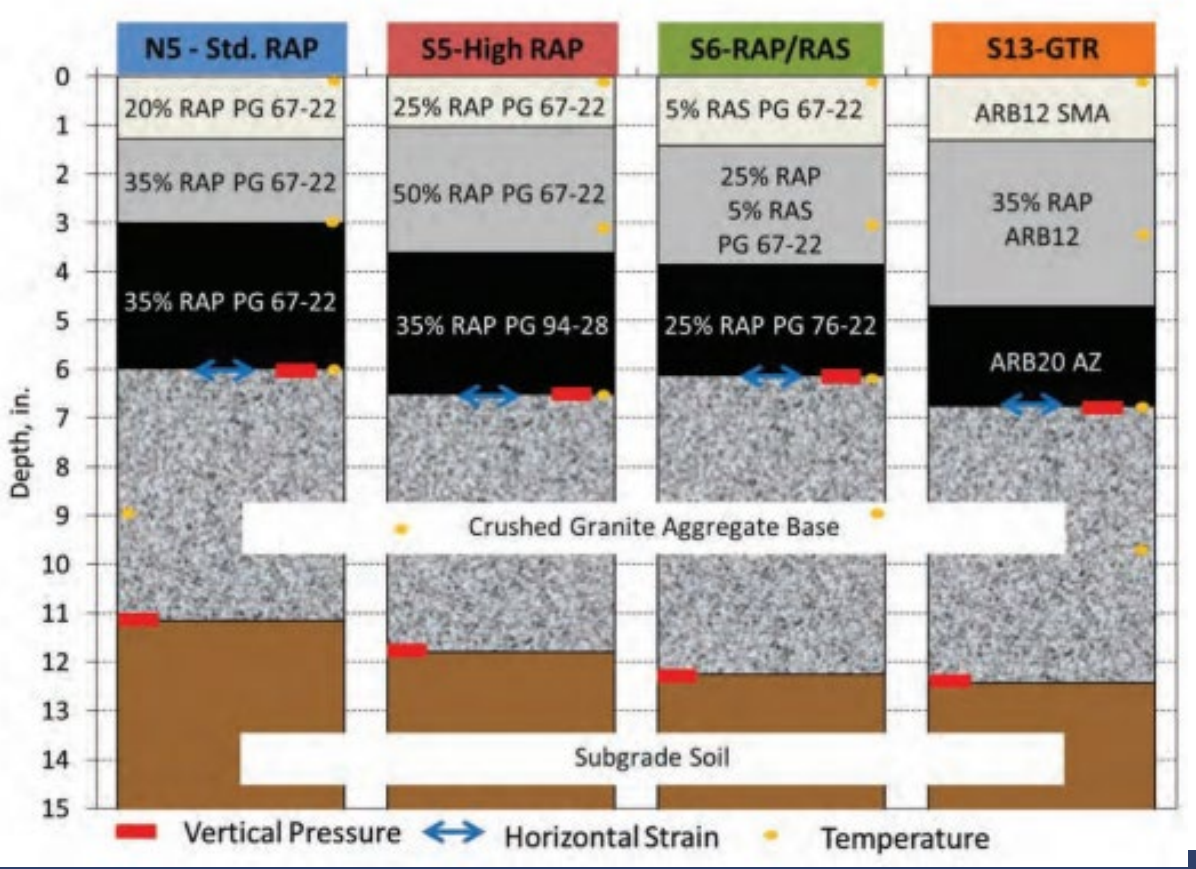


Adding in Oklahoma 2010 - 2015



Adding in Green Group 2012

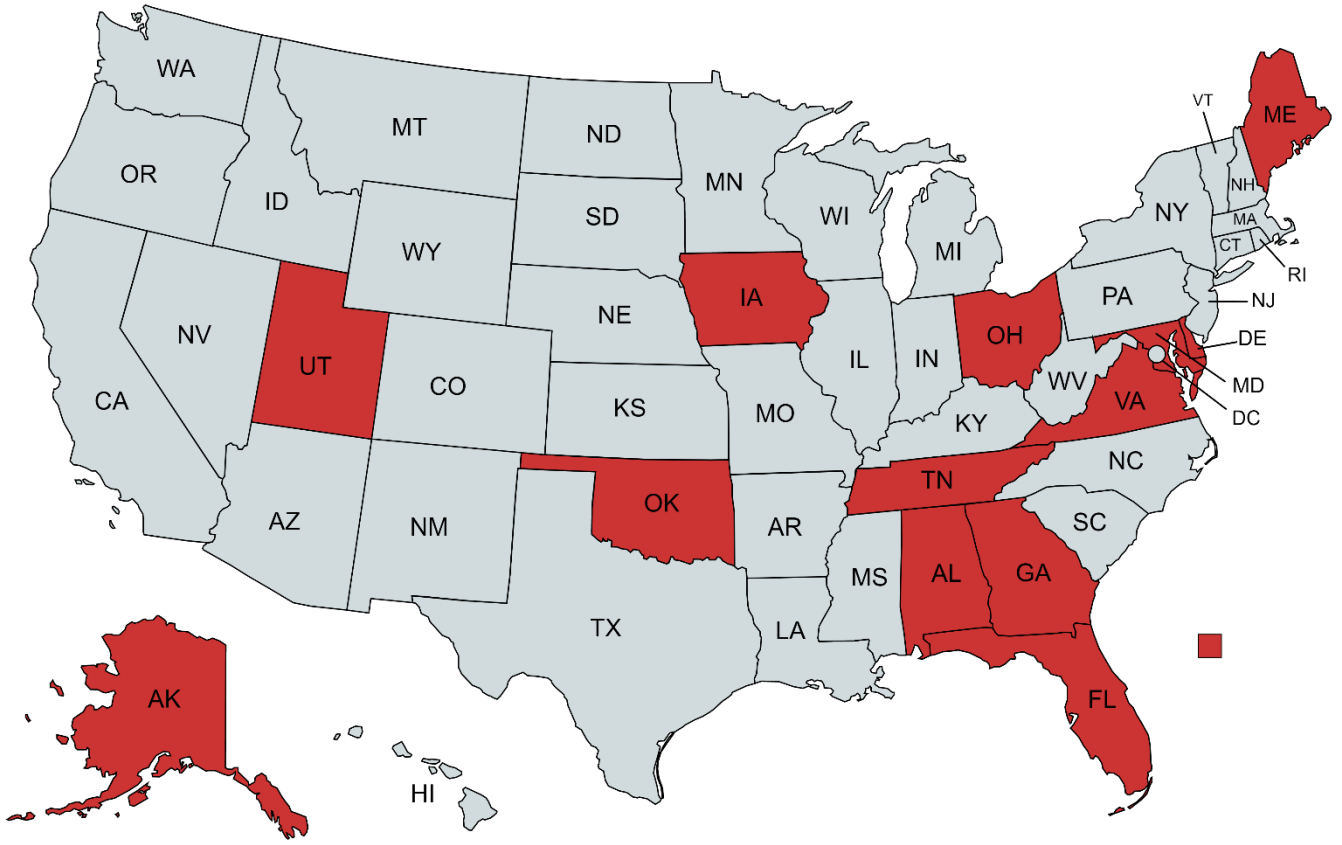
- Four sections using high levels of RAP/RAS along with asphalt rubber
  - S5 base – paved 285 °F/WMA
  - S5 – premature tack coat failure. Rebuild gave best performance.



Adding in Cracking Group 2015

- High strain top-down cracking study of seven 6” pavements
- HiMA used for base & binder course to ensure no bottom up cracking.
- After two cycles S6 HiMA surface mix exhibited 1% surface cracking.

“State” Implementation



Also cities, bridges, raceways, ports, airports

A Multipurpose Tool

- Agencies (not necessarily us!) have found applications in a variety of areas outside of structural pavements:
  - High Performance Thin Overlays (HPTO)
  - Bridge Deck Waterproof Surface Courses (BDWSC)
  - Rich Intermediate Layer (RIL)
  - Mitigating studded tire damage
  - Bus pads
  - Airport runways and taxiways
  - Ports for slow, heavy loading vehicles

We're Getting Help

- FDOT sponsor, UNR PI 2019
- Recommend increasing structural coefficient 0.44 → 0.54
- https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/research/reports/fdot-be321-rpt.pdf
- FDOT sponsor, TTI PI 2019
- HiMA in OGFC up to 50% increase in service life
- https://ntlrepository.blob.core.windows.net/lib/67000/67800/67840/fdot-be287-rpt_Rem.pdf
- VDOT sponsor, VTRC PI 2020
- HiMA in SMA construction up to 34% increase in service life
- http://www.virginiadot.org/vtrc/main/online_reports/pdf/21-r16.pdf

FHWA EDC-6 TOPS Initiative

- **Every Day Counts** – "A state-based model that identifies and deploys **proven, yet underutilized innovations**—saving time, money and resources that can be used to deliver more projects."
- **Targeted Overlay Pavement Solutions** – Includes HiMA – "DOTs in Florida, Georgia, New Jersey, New York City, Tennessee, and Virginia found highly modified asphalt in thin overlays is more resistant to reflective cracking. It has increased pavement life by two to four times for DOTs in Alabama and Oklahoma."

What Are We Doing Today

- Pavement ME comparative design w/ Global Recalibration
- Talking to four new states in last three months through TOPS interest
- Lots of job stories
- BMD and pavement design
- Detailed LCCA analysis
- Specification development (M 332 >> M 320!)

Learnings

- HiMA can help address a broad range of issues. This has allowed Kraton to provide a consultative approach vs. “selling” and share how others in similar situations have leveraged HiMA design.
- Road owners who have used HiMA to address a specific issue have generally expanded the application uses of HiMA in other projects in their state.
- The number of direct PMA suppliers looking to provide an innovative portfolio for different applications has grown.
- As to challenges, many states approach issues as unique to them. This may result in brand new trial/adoption efforts vs. leveraging the work of other states.

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- Richard Kim – NCSU
- Mary Robbins – NCAT
- Nam Tran – NCAT
- Adam Taylor - NCAT

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Impact of NCAT - Cargill Sponsorship

Hassan A. Tabatabaee, Ph.D.

Global Technical Manager,
Asphalt Solutions

Cargill® Helping the world thrive

Cargill in Asphalt

Be the Industry leader in high-performance and sustainable asphalt additives.

- Rejuvenation
- Cold Mix
- Rheology
- Warm Mix
- Emulsions
- Stabilizers

State-of-the-art Asphalt Lab

- Customer custom formulation services
- Compositional and analytical evaluation
- Advanced rheology and thermal analysis

Cargill Anova® Rejuvenators

Cargill Anova Asphalt solutions have been proven in millions of tons of pavement around the globe.

We support our customers throughout entire lifecycle.

NCAT Sponsorship: Objective

Objectives and Motivation:

1. Create agency-trusted data to provide confidence in use of BMD for rejuvenated high-RAP HMA.
2. Create independently measured and verified field and lab performance


EQUIPMENT WORLD'S
BETTER ROADS
EQUIPMENT BETTER ROADS

Cargill, NCAT, MnROAD launch project to give states 'real-world data' on new design principles

Joy Powell | August 30, 2018

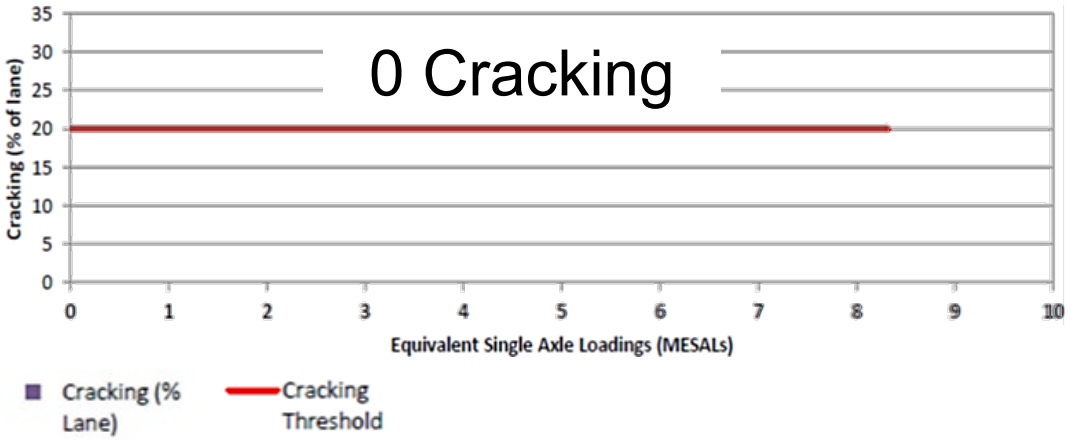
- In early 2018 Cargill partnered with NCAT to develop 45%RAP rejuvenated sections
  - Aggregates and RAP were shipped in from Virginia for the project
- Control VDOT mix:
  - 30% RAP (24% ABR); PG64-22 Binder + Anova® 1501 Warm Mix Additive

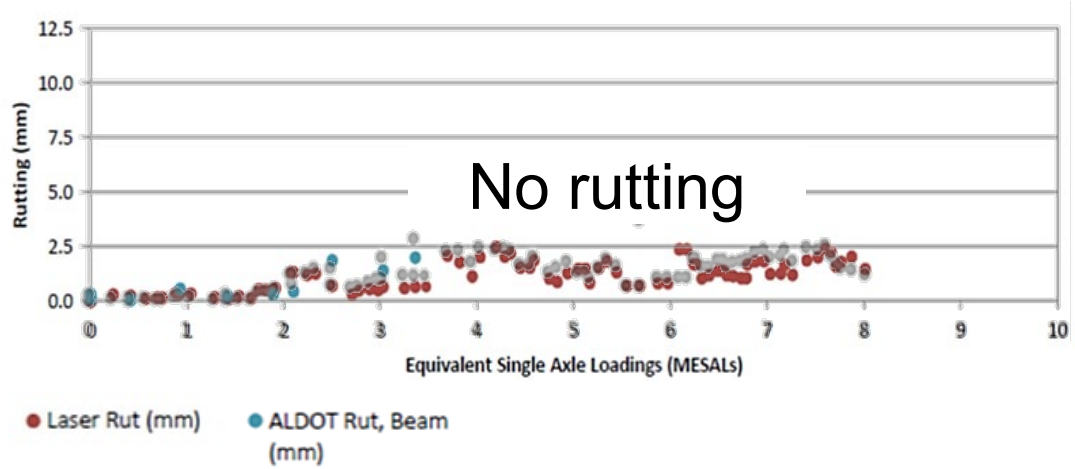
  High RAP Mix:
  - 45% RAP (38% ABR); PG64-22 Binder + Anova® 1815 Rejuvenator

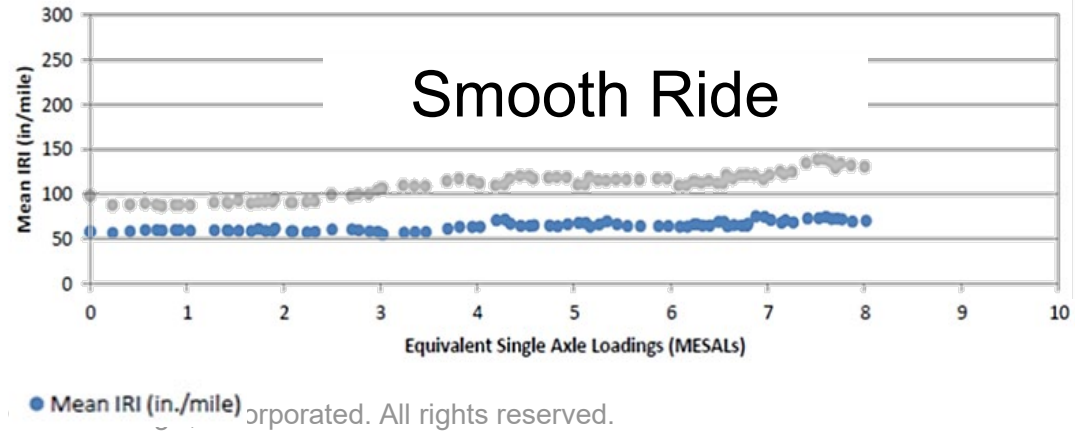
Cracked Area

Permanent Deformation

Ride Quality







Field Performance

45% RAP + Anova® Rejuvenator

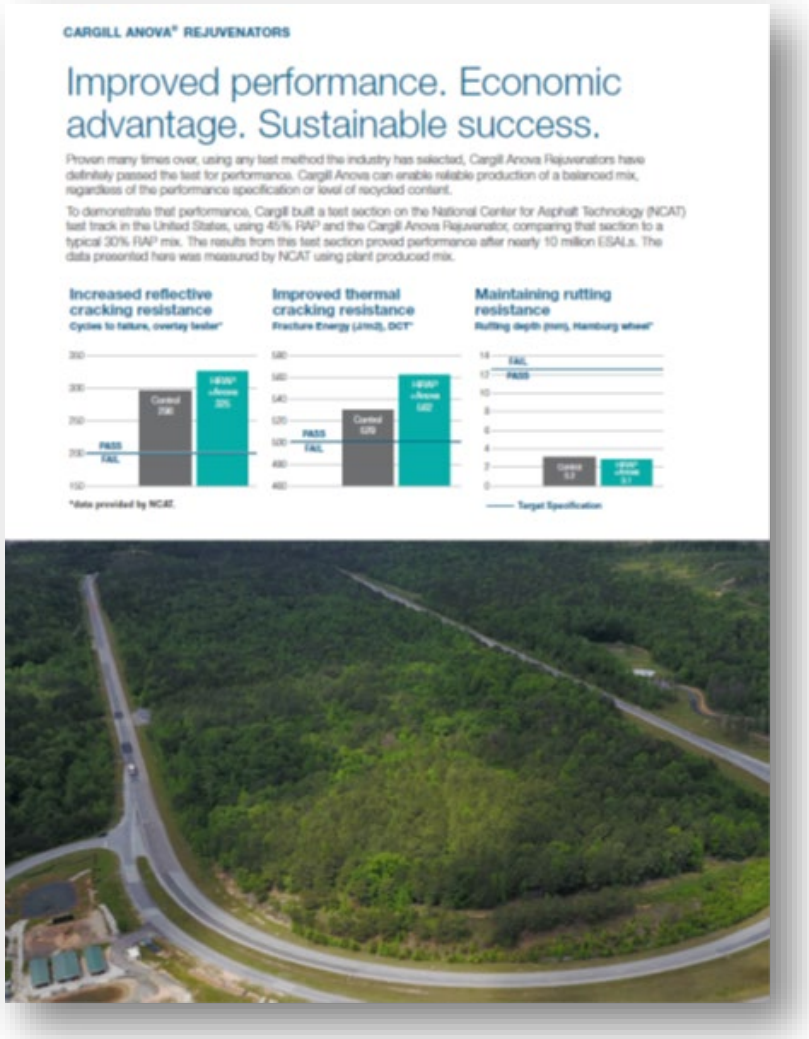
~10 Million Loadings: 0 cracking

- No cracking observed in sections so far after full cycle of loadings.
- Sections showing good rutting and smoothness
- Smoothness of the high RAP rejuvenated section looks especially good.

- Will continue to **20 million ESALs** during 2nd 3-year cycle of loading.

Impact of NCAT Sponsorship for Cargill

- Outwardly, most visible outcome is test track performance
  - Independent verification of product claims and efficacy from a trusted industry source
- However, equal value from less visible fundamental research component:
  - Creation of a body of data corresponding to proposed DOT specifications and test, to show how rejuvenated High-RAP BMD can work



Example 1: Correlation Studies Across All Parameters

Mix Designations	RAP (%Wt. Mix)	PG Binder	Additive	Comments
NCAT 9.5mm 30%RAP Control	30	PG64-22	Anova 1501	
NCAT 9.5mm 45%RAP Rejuvenated	45	PG64-22	Anova 1815	
NCAT 9.5mm 45%RAP No Rejuvenator	45	PG64-22	Anova 1501	
MnROAD 12.5mm 25%RAP Control	25	PG58-28	None	
MnROAD 12.5mm 45%RAP Rejuvenator	45	PG58-28	Anova 1815	

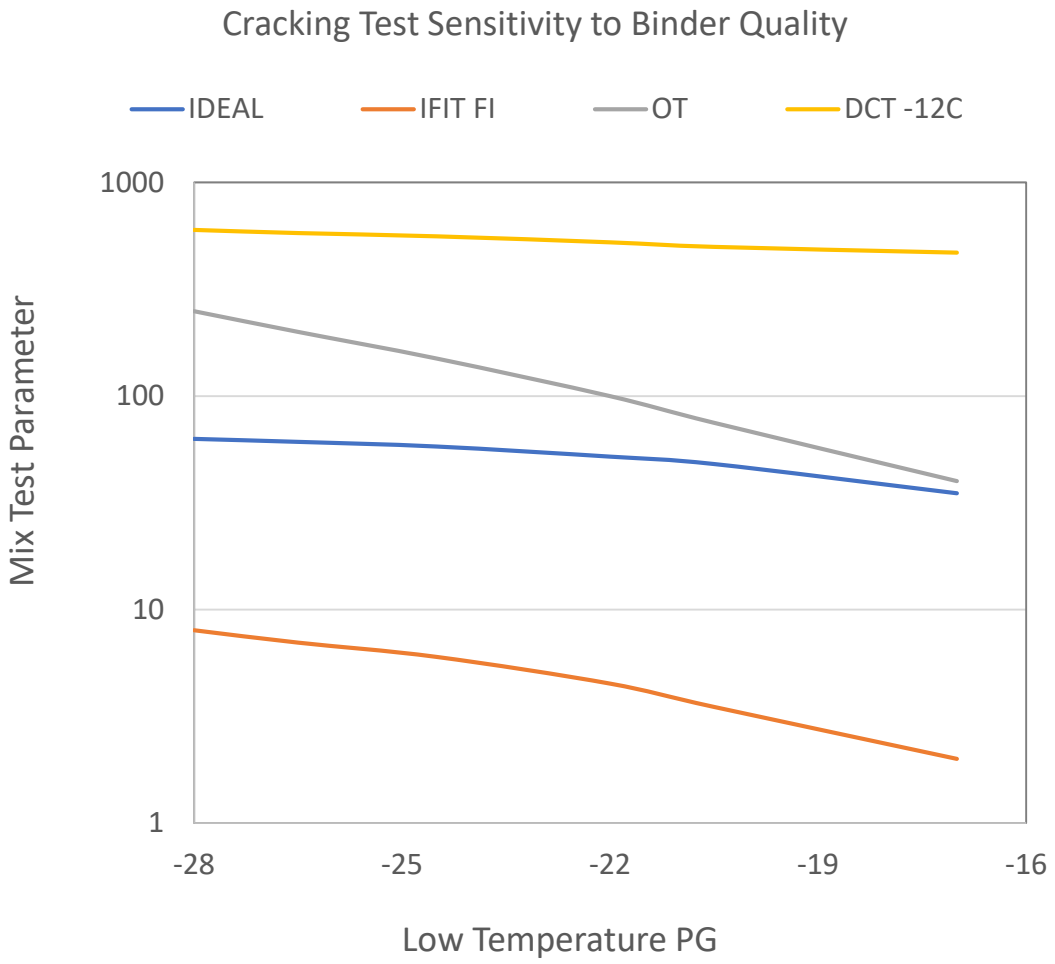
Priority #	Test	NCAT			MnROAD		Test Method	Comments and Criteria
	Mixture Tests (Run by NCAT)**	30%RAP Control	45%RAP-Rej	45% RAP-No Rej	25%RAP Control	45%RAP-Rej		
1	IDEAL	X	X	X	X	X	VDOT	
	IDEAL (Long Term Aged)	X	X	X	X	X	VDOT	
2	DCT	X	X	X	X	X	D7313-MnDOT	
	DCT (long term aged)	X	X	X	X	X	D7313-MnDOT	
3	IFIT	X	X	X	X	X	TP-124	
	IFIT (long term aged)	X	X	X	X	X	TP-124	
4	Overlay Tester	X	X	X	X	X	NJ B-10	
	Overlay Tester (long term aged)	X	X	X	X	X	NJ B-10	
5	Contabro	X	X	X	X	X	VDOT	
6	Hamburg	X	X		X	X	T-324	
7	APA	X	X		X	X	VDOT	
8	TSR	X	X		X	X	T-283	
9	4 point bending (long term aged)	X	X	X	X	X	NYDOT	To be performed if spec'd by NYDOT
10	AMPT E* (Replace with Push-Pull?)	X	X		X	X	NYDOT	
	Binder tests (Cargill)							
	Initial RAP extraction/recovery/PG	X	X	X	X	X		
	Binder PG grading (w/ & wo/ Rej.)	X	X	X	X	X		
	Extract/recovery/PG (Vol. Des. mix)	X	X	X	X	X		
	Extract/recovery/PG (Opt. Des. mix)	X	X	X	X	X		

***all tests are at R30 Short term aged, unless designated otherwise*

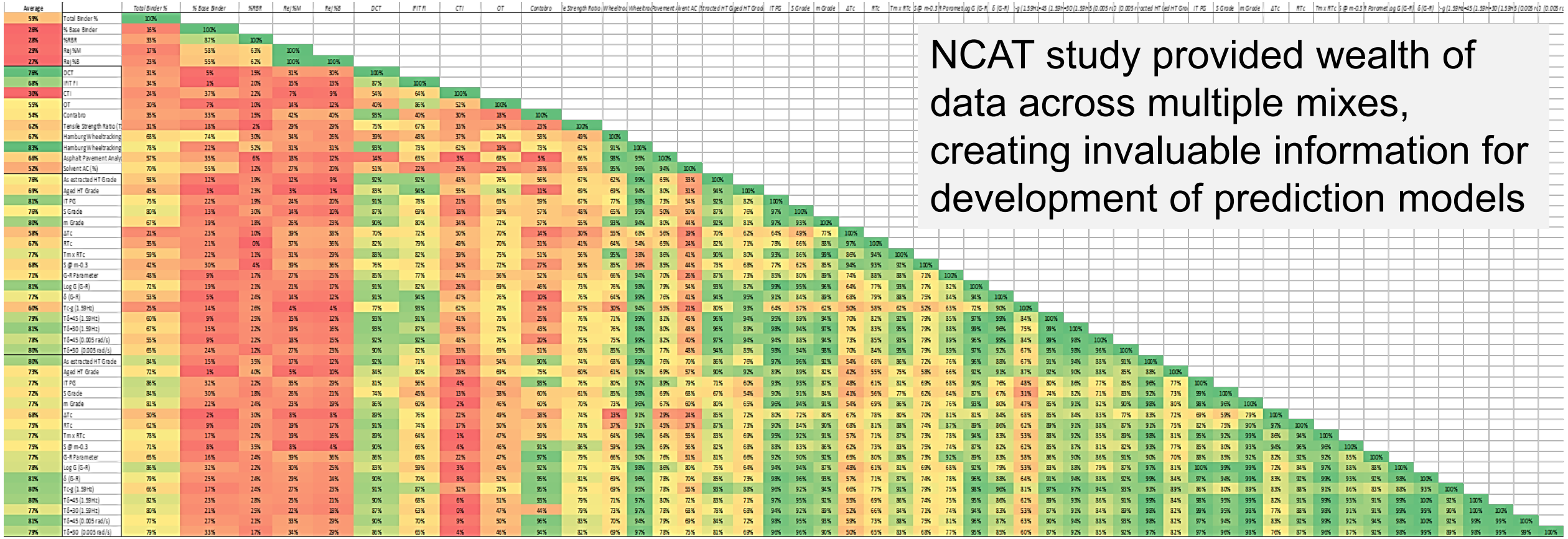
Example 1: Mix Limit Threshold Comparisons

- NCAT test plan, spanning multiple BMD tests across 17 mix iterations
  - (when including all VMD designs, BMD LPLC samples, and BMD PPLC samples from both the NCAT and MNROAD test track)

- The data allowed for analysis of a broad range of binder grades spanning close to 4 Performance grades
  - Results provided a unique opportunity for sensitivity analysis of cracking tests vs. binder quality measures.

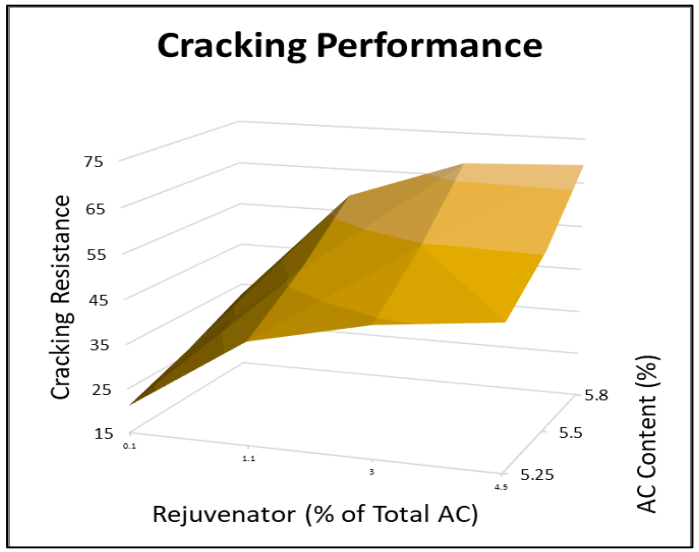


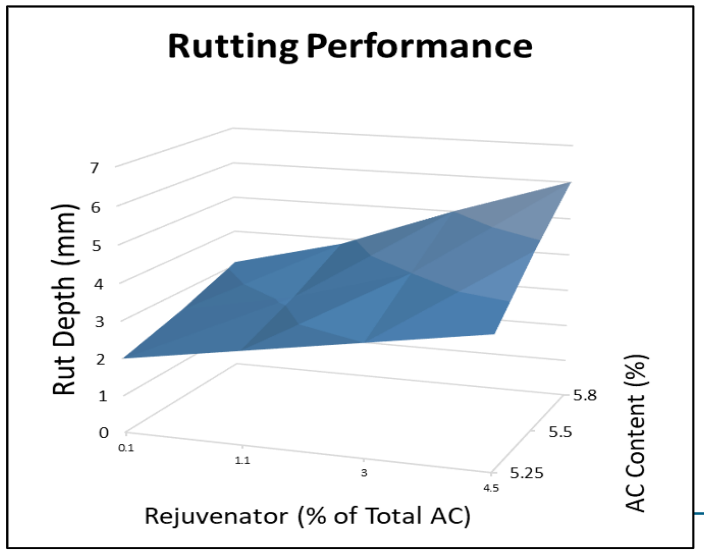
Example 2: Correlation Studies Across All Parameters



NCAT study provided wealth of data across multiple mixes, creating invaluable information for development of prediction models

Performance-Related High RAP-Rejuvenated Design





Check if RA meets basic safety / physical requirements

ASTM D4552-20

Establish initial dosage and check rejuvenated binder properties
(e.g. m-grade,
or change in ΔTc with aging)

Backed by NCAT Binder-Mix Analysis Findings

VMD + Performance Check or BMD

NCHRP 9-58 or NAPA RA Guide

Summary

- Implementation of high RAP + Rejuvenator in agency “spec” mixes requires a framework that provides **transparency and reliability for all stakeholders**.

- Independent evaluation and monitoring by NCAT on the produced test sections has provided a significant amount of credibility for the use of the technology.
  - Demonstrates high reliability of using performance-based designs with engineered rejuvenators
  - Provides BMD data for interested agencies.
  - Has provided the necessary foundational data to efficiently create dosing and designs for various agency specs such as those of VDOT, MNDOT, NJDOT, ILDOT, DeIDOT, NYSDOT, City of Columbus, City of Phoenix, etc.

NCAT: Independent Expertise

- Partnership with NCAT has also provided Cargill and the industry access to world class independent expertise on materials and design that are intimately familiar with how our technology works as a result of the partnership.
  - A resource for private companies like Cargill to get candid and constructive technical and application feedback.
  - A resource for agencies and industry to directly obtain independent feedback on the product.