Northeast Pavement Preservation Partnership

2011 Annual Conference

November 8, 2011

Marriott Courtyard Boston
275 Tremont Street
Boston, Massachusetts

"HiMA Thin Lift Asphalt"

•2010 summer survey by NCPP

•13 respondents/11 NEPP state DOT members

•Dr. Walaa Mogawer, professor and director of the

Highway Sustainability Research Center/ UMass Dartmouth

•Lead Discussion States:

NJDOT	NHDOT
RIDOT	VTAOT
PennDOT/PAPA	MD SHA
MADOT	

NEPPP Regional Specification for HiMA Thin-Lift Overlay

September 23, 2010

Superpave 9.5mm Highly Polymer-Modified Thin Overlay Specifications

Description

A Superpave 9.5 mm Polymer-Modified Thin Overlay (PMTOL) pavement preservation strategy used to extend a pavement's service life without improving its structural capacity. This mixture is a preventive maintenance strategy that can be applied to pavements in good condition that do not require structural rehabilitation. The PMTOL ranges from 0.75 to 1.5 inch (19.0 mm to 37.5 mm) in thickness. Composition of the mixture for the PMTOL shall be coarse aggregate, fine aggregate, mineral filler (if needed), and a polymer modified asphalt binder. Also, ***up to*** 25 percent RAP can be included in the mixture. The mixture without RAP and the mixture with RAP will be designated as mixtures A and B, respectively.

Surface Preparation of Existing Pavement

It is recommended that the existing pavement surface be prepared as outlined in NAPA Information Series 135 Table 1 "Suggested Approaches to Surface Preparation Prior to Thin Overlay Based on Distresses."

Materials

All materials must be approved by the agency prior to production and placement of the PMTOL.

Polymer Modified Asphalt Binder

The polymer modified asphalt binder shall have a performance grade of PG76-34 or PG82-28. PG76-34 is recommended for roadways exhibiting low severity cracking. The PG82-28 is recommended for roadways with little or no distresses. If milling of the existing pavement surface is necessary, either binders can be used. The asphalt supplier shall provide testing in accordance with AASHTO R29 "Grading or Verifying the Performance Grade of an Asphalt Binder" Section 6.0 – *Test Procedure for Grading an Unknown Asphalt Binder* and AASHTO M320 to verify the performance grade of the asphalt binder. Additionally, the modified asphalt binder shall be tested in the Asphalt Binder Cracking Device (ABCD) to determine the thermal cracking temperature of the binder.

Aggregate

The aggregate blend for the PMTOL shall meet all the Superpave aggregate consensus properties requirements listed in Table 5 of AASHTO M323 "Superpave Volumetric Mix Design" and the source property requirements noted in Table 1. The aggregate blend shall be classified as coarse or fine as outlined in AASHTO M323 Section 6.1.3 – *Gradation Classification*.

Table 1 - Superpave Source Property Requirements

Test	Applicable Method	Limitations
LA Abrasion, % loss	AASHTO T96 or ASTM C131	40% max.
Sodium Sulfate Soundness, % loss	AASHTO T104 or ASTM C88	16% max.

- September 2010 specification completion
- NHDOT demonstration commitment
- VTAOT demonstration commitment
- PAPA for PennDOT review
- MADOT for review

AASHTO TSP2 Regional DOT Partnerships

September 23, 2010

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Test	Applicable Method	Limitations
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Sodium Sulfate Soundness,	AASHTO T104 or	16% max.

Mineral Filler
Mineral filler, if necessary in addition to that naturally present in the aggregate, shall meet the requirements of AASHTO M17 or ASTM D242.

Tack Coat
Tack coat shall be either polymer modified emulsion or the performance grade asphalt binder specified by the State DOT suitable for the location where the mixture will be placed.

Job Mix Formula
The PMTOL mixture shall be a Superpave 9.5 mm mixture conforming to the gradation and asphalt binder content requirements detailed in Table 2:

Table 2 – Mixture Requirements for a PMTOL

Sieve Designation	Percent by Mass Passing	Production Tolerances
12.5 mm (1/2")	100	± 6
9.5 mm (3/8")	90 – 100	± 6
4.75 mm (#4)	≤ 90	± 6
2.36 mm (#8)	32 –67	± 4
0.075 mm (#200)	2 – 10	± 1
Asphalt Binder %	Min. 6.5	± 0.3

AASHTO R35 "Standard Practice for Superpave Volumetric Design for Hot-Mix Asphalt" shall be used to develop a mixture that will meet the specified design criteria in accordance with AASHTO M323 "Standard Specification for Superpave Volumetric Mix Design." A copy of all design test data used in developing the mix design, including graphs, shall be submitted with the mixture design. The job mix formula shall establish the percentage of aggregate passing each sieve and the percentage of polymer modified binder to be added to the aggregate. Also, all mixtures shall meet the volumetric properties outlined in AASHTO M323 Table 6. No change in the job-mix formula may be made without prior written approval.

In addition to the criteria previously noted, the mixture will satisfy the following criteria depending on whether or not RAP is included in the mixture:

Table 3 -Mixture A (No RAP)

Property	Device/Test	Criteria
Thermal cracking temperature of the modified asphalt binder	Asphalt Binder Cracking Device (ABCD)	Equal to or colder than the low temperature performance grade of the binder
Thermal cracking temperature of extracted binder from the mixture	Asphalt Binder Cracking Device (ABCD)	± one grade from the low temperature performance grade of the binder
Thermal cracking temperature of mixture	Thermal Stress Restrained Specimen Tensile Strength Test (TSRST) - AASHTO TP10-93	± 6°C from the low temperature performance grade of the binder
Cracking	Overlay Test -TXDOT Test Designation Tex-248-F	Mixtures shall exhibit average overlay test cycles to failure (93% load reduction) ≥ 300
Fatigue Life*	Flexural Beam - AASHTO T321	≥100,000 Cycles
Rutting	Asphalt Pavement Analyzer - AASHTO TP 63 at the standard PG high temperature for the project location	Average rut dept for 6 specimens is ≤ 4 mm at 8,000 loading cycles

* It is preferred that the strain level should be equal to the strain in the existing HMA layer or alternatively use a strain level of 750 micro strain when PG76-34 is used and use a strain level of 500 micro strain when a PG82-28 is used.

Table 4 -Mixture B (If RAP is included in the mixture)

Property	Device/Test	Criteria
Thermal cracking temperature of the modified asphalt binder	Asphalt Binder Cracking Device (ABCD)	Equal to or colder than the low temperature performance grade of the binder
Thermal cracking temperature of extracted binder from the mixture	Asphalt Binder Cracking Device (ABCD)	± one grade from the low temperature performance grade of the binder
Thermal cracking temperature of mixture	Thermal Stress Restrained Specimen Tensile Strength Test (TSRST) - AASHTO TP10-93	± 6°C from the low temperature performance grade of the binder
Cracking	Overlay Test -TXDOT Test Designation Tex-248-F	Mixtures containing RAP shall exhibit average overlay test cycles to failure (93% load reduction) within ± 10 percent of the overlay test cycles to failure of control specimens without RAP [minimum of three test specimens per mixture]
Fatigue Life*	Flexural Beam - AASHTO T321	≥100,000 Cycles
Rutting	Asphalt Pavement Analyzer - AASHTO TP 63 at the standard PG high temperature for the project location	Average rut dept for 6 specimens is ≤ 4 mm at 8,000 loading cycles

* It is preferred that the strain level should be equal to the strain in the existing HMA layer or alternatively use a strain level of 750 micro strain when PG76-34 is used and use a strain level of 500 micro strain when a PG82-28 is used.

3

RECLAIMED ASPHALT PAVEMENT
The amount of RAP in the PMTOL mixture will be limited to 25 percent RAP or the amount of RAP corresponding to 1% binder replaced, whichever is less. The percent binder replaced shall be calculated by the following equation:

$$\text{Binder Replacement, \%} = \frac{(\text{Percent Binder in the RAP}) \times (\text{Percent RAP in Mixture})}{\text{Total Percent Binder in Mixture}}$$

Fractionated RAP is preferred, but not required. RAP shall be clean and free of all foreign material. The maximum size of RAP should correspond to the NMAS used in the mixture (9.5 mm). All volumetric properties are the same as for the PMTOL mixture without RAP (mixture A).

Extensive testing of the RAP material shall be completed prior to the mixture design. Copies of all test results must be submitted with the PMTOL mixture design for JMF approval. No material may be added to the RAP stockpiles after the requisite testing samples have been taken. Table 5 outlines the required RAP testing and the corresponding number of replicates (random sampling shall be used throughout):

Table 5 – Required RAP Testing

Test	Applicable Method	Number of Replicates
Binder Content	AASHTO T308 (Ignition Oven) or AASHTO T164 (Centrifuge)	4
Extraction and Recovery of RAP Binder	AASHTO T319 (Rotovap) or T170 (Abson)	Replicates sufficient to provide quantity adequate for subsequent binder testing
Determine Performance Grade of Extracted Binder	AASHTO R29 - Section 6.0	4
Recovered RAP Aggregate Gradation	AASHTO T11 & AASHTO T27	4
Specific Gravity of Recovered RAP Aggregates	AASHTO T84 & T85	4
Maximum Theoretical Specific Gravity of RAP	AASHTO T209	4

No changes in the source, location or type of RAP will be permitted once the JMF has been approved.

- MNDOT HiMA test section
- ORDOT HiMA test section

New Hampshire Department of Transportation

“HiMA Thin Lift Asphalt”

- U.S. Route 202 in Rochester
- Two Lane Engineered Asphalt Pavement
- 2010 Leveling + Patching
- 4600 ADT in 2010
- Two Mile Test Section
- 1” Thickness
- 25% RAP content
- Placed at 290-300°F


MACK
94
Aero
36


156
CONTINENTAL PAVING, INC.
ROADTEC
RP190


DANGER
PINCH POINT


ROADTEC
RP·190
720
CARLSON
ROADTEC


HD 120
OSCILLATION
398
CONTINENTAL
PAVING, INC.
HAMM


ASTEC
CHATTANOOGA, TENNESSEE U.S.A.
MACK
MACK

Vermont Agency of Transportation

“HiMA Thin Lift Asphalt”

- U.S. Route 7 in Danby
- Two Lane Engineered Asphalt Pavement with Paved Shoulders
- 2011 Crack Filling/Sealing + Leveling
- 4300 ADT
- Two Mile Test Section
- 1” Thickness
- One Mile Virgin Aggregates and One Mile 25% RAP content
- Placed at 295-300°F


MACK
MACK
SAFETY IS NO ACCIDENT
USDOT 106058


MACK
SAFETY IS NO ACCIDENT
STOP


HYPAC
CATERPILLAR
CAT


SLOW
MACK
MACK


62.4024
362
RAPIDS
USDOT108058
AP-1055D
CAT

Minnesota Department of Transportation

“HiMA Thin Lift Asphalt”

- TH 100 in Metro District
- Multiple Lanes, North Barrel, Engineered Asphalt Pavement
- 1 ½” and 2” mill + inlay for project
- 66,000 ADT
- 1 ½” Thickness and 2” Thickness Test Sections
- Placed at 290°F


FALLING ASPHALT CHUNKS
CAT


BARTON


MIKE
CLAIRMONT
MACK


DYNAPAC
Asphalt Temperature Meter
HAYDEN-MURPHY
HARDRIVES INC
ROGERS, MN 428-8886


6
1122
WEIGH-TRONIX

2012

- ORDOT Contract with Knife River Corporation
- MADOT in Review
- TNDOT in Review

HiMA Structural Contracts in Review

- ALDOT
- OKDOT
- KSDOT
- LADOTD

Performance and Design of Thin, Highly Modified Pavements

Bob Kluttz, Kraton Polymers

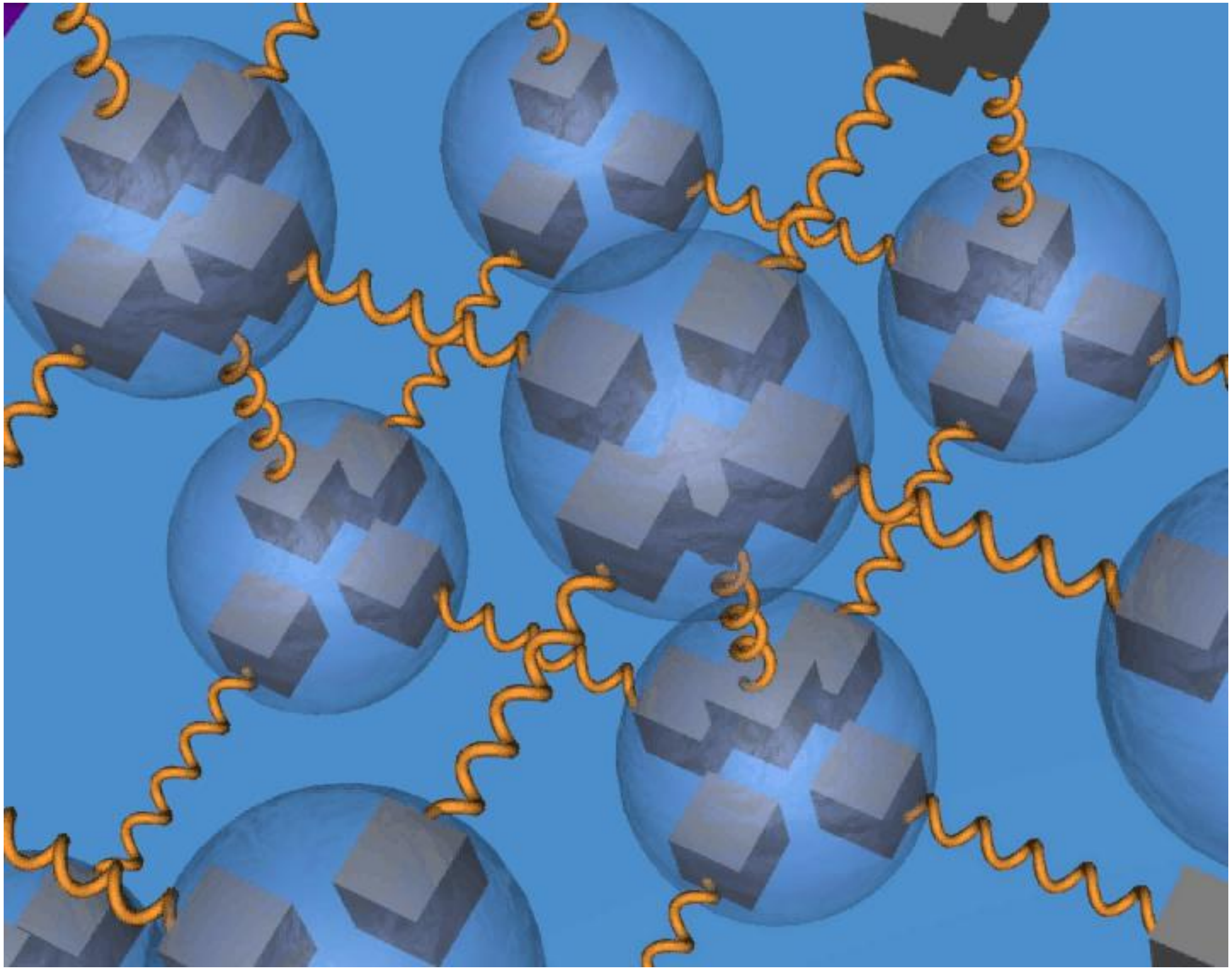
Northeast Pavement Preservation Partnership

Boston, MA – November 8, 2011

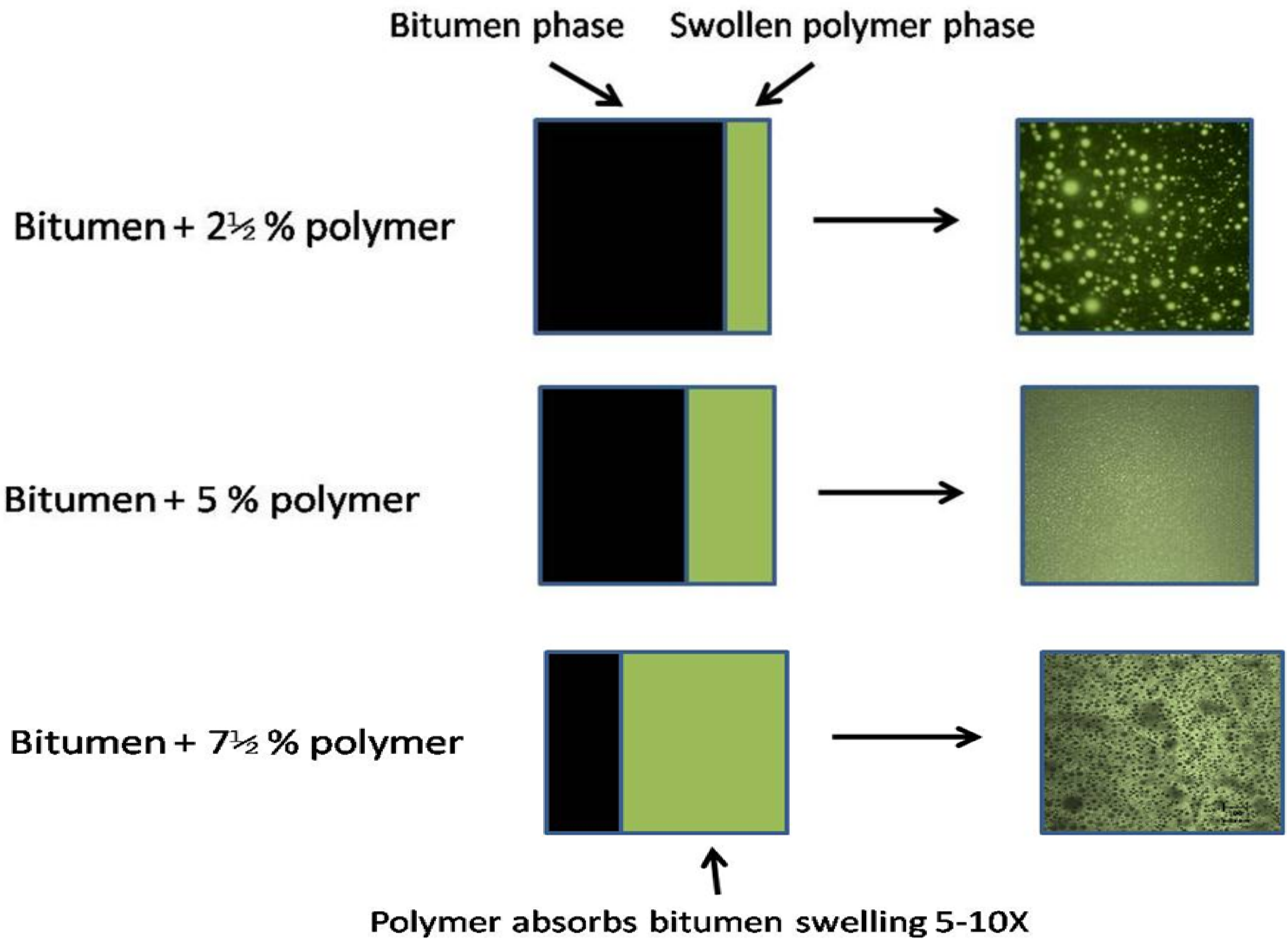
Outline

- How SBS Works in Bitumen and Asphalt Pavement
- Background of the Studies
- Material Property Testing and Advanced Modeling
- Pavement Trials
- Performance of Structural Sections
- Pavement Design
- Conclusions

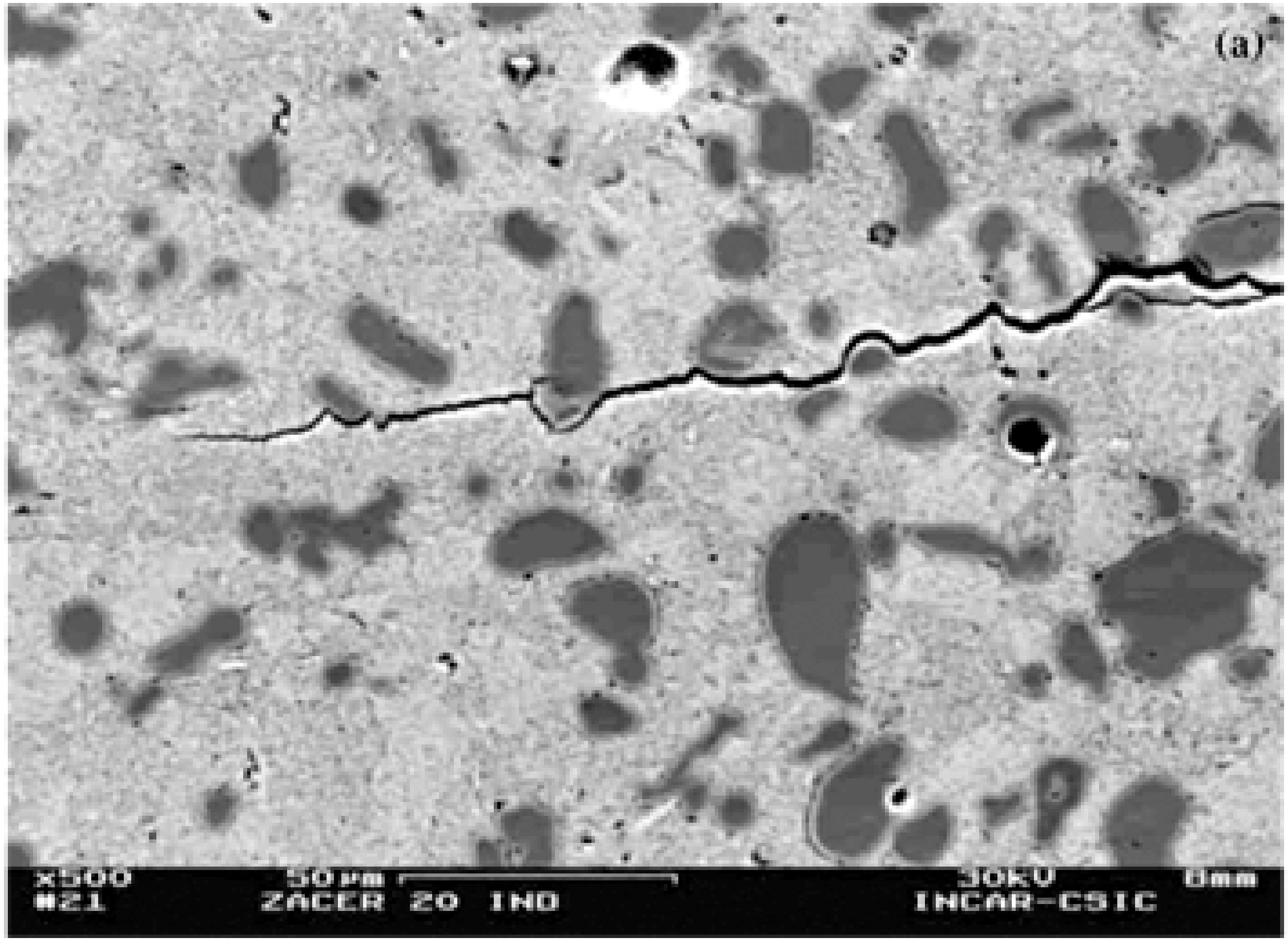
SBS in Bitumen



Phase Morphology



Crack Propagation in Toughened Composite



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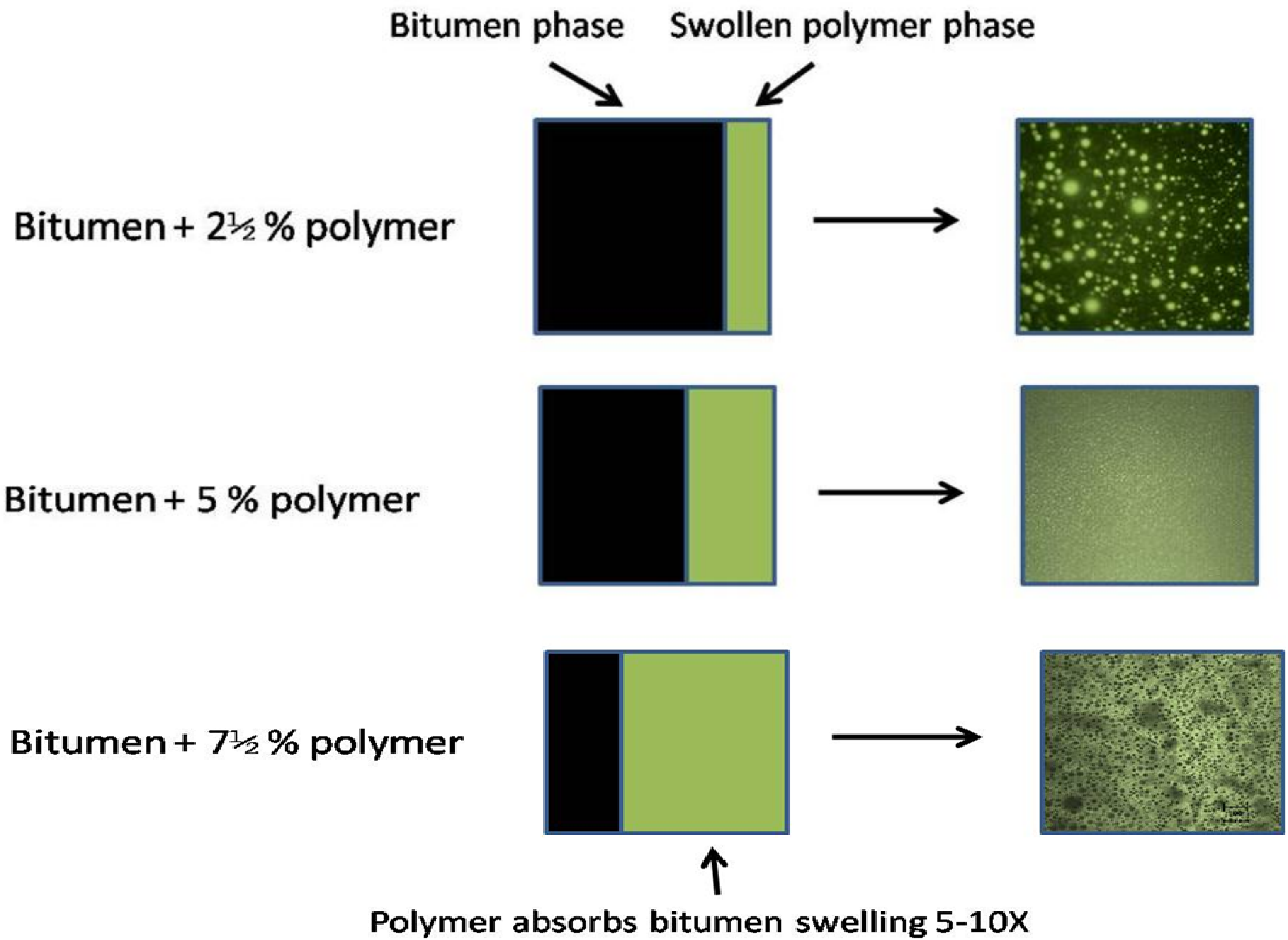
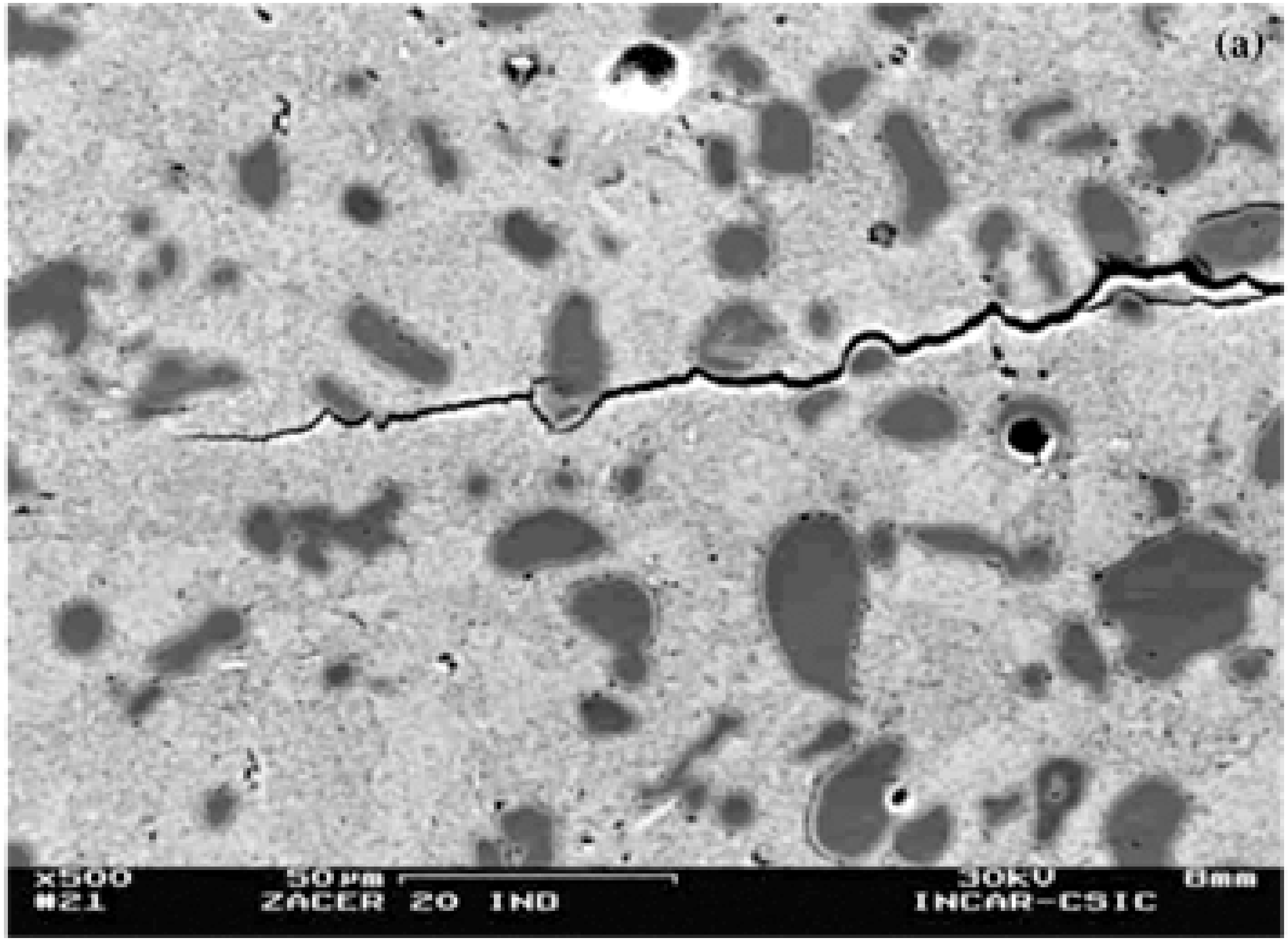
Phase Morphology



Crack Propagation in Toughened Composite



Source: www.scielo.br/img/fbpe/mr/v4n3/a13fig5a.gif

Background of the Study

- Higher traffic intensities and pavement loadings require more durable pavements.
- Higher traffic intensities also command longer maintenance intervals to increase availability of the road.
- Environmental pressure is increasing; reduction of use of natural resources such as aggregate and less emissions are highly desired.
- SBS modification has proven benefits in wearing courses over the past decades in every relevant property.

→ Use the benefits of SBS to create a polymer modified base course asphalt that can fulfill the requirements of today and tomorrow.

→ Technical challenge: compatibility and workability with relatively hard base bitumen.

Material Testing and Advanced Modeling

- Beam Fatigue testing in conjunction with the Road Engineering Section of Delft University of Technology
- Materials property testing with Road Engineering and advanced modeling work with the Mechanics Section at Delft.

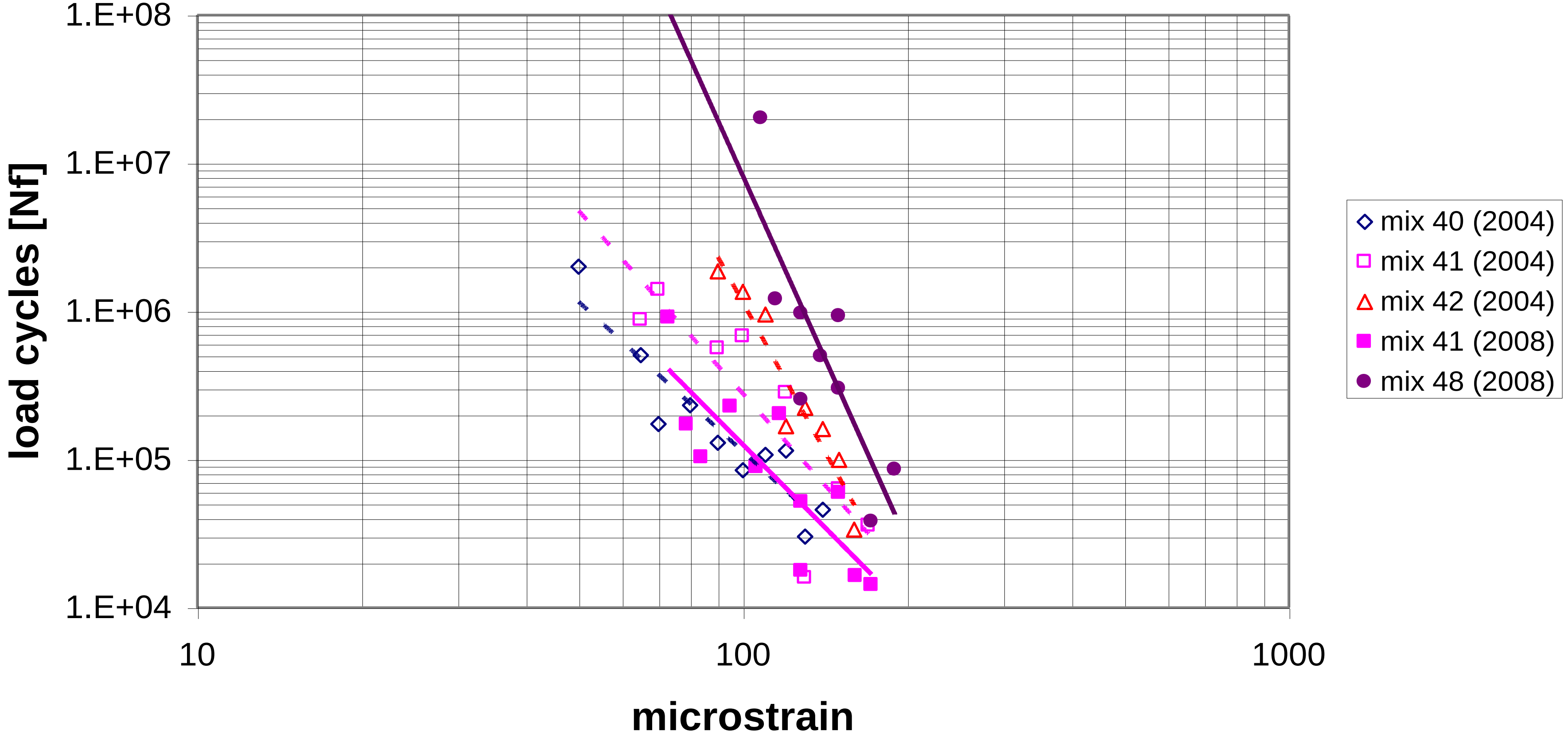
- Goal was to test the viability of high polymer content, high modulus mixtures and to understand how much performance benefit might be achieved.

- Kraton Polymers
  - Willem Vonk, Erik Jan Scholten,Bob Kluttz
- Technical University Delft – Road & Railways
  - Andre Molenaar, Martin van de Ven,Tariq Medani
- Technical University Delft - Mechanics
  - Tom Scarpas, Xueyan Liu

Initial Testing – Four-point Bending Beam

- Same 40 pen base bitumen for all binders
- Design study to determine effect of SBS polymer type and loading

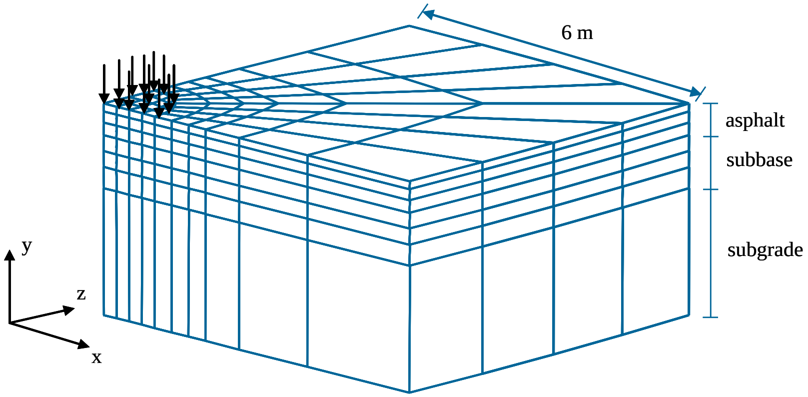
Beam Fatigue Results



Full sinusoidal loading. Cited strains are ½ amplitude

Advanced Modeling Using ACRe Model

- Asphalt Concrete Response (ACRe) model developed at Delft University
- Desai response surface for hardening and softening
- Crack plane response simulation with Hoffman surface
- CAPA 3D Finite Element Code developed at Delft University



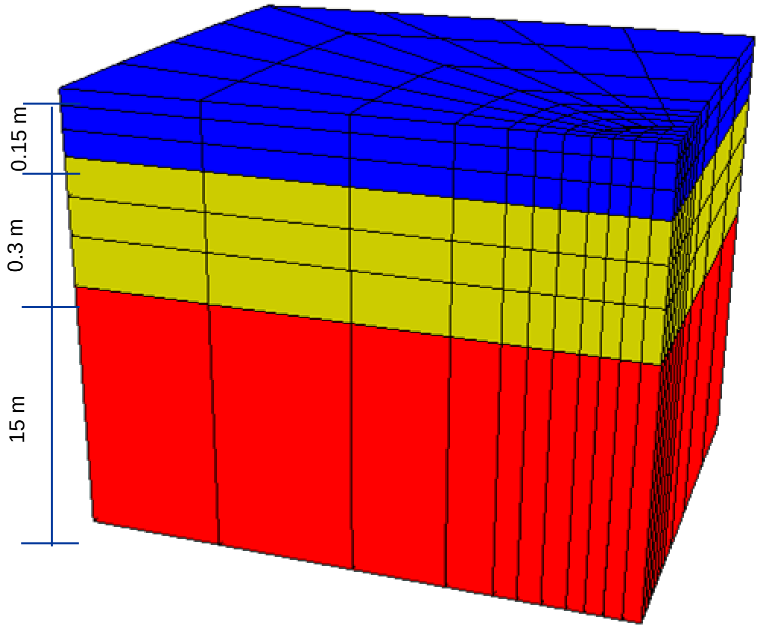
Scarpas, A, Gurp, C.A.M.P. van, Al-Khoury, R.I.N. and Erkens, S.M.J.G., Finite Element Simulation of Damage Development in Asphalt Concrete Pavements. 8th International Conference on Asphalt Concrete Pavements, Seattle, Washington, U.S.A., 1997.

Pavement Structure and Loading

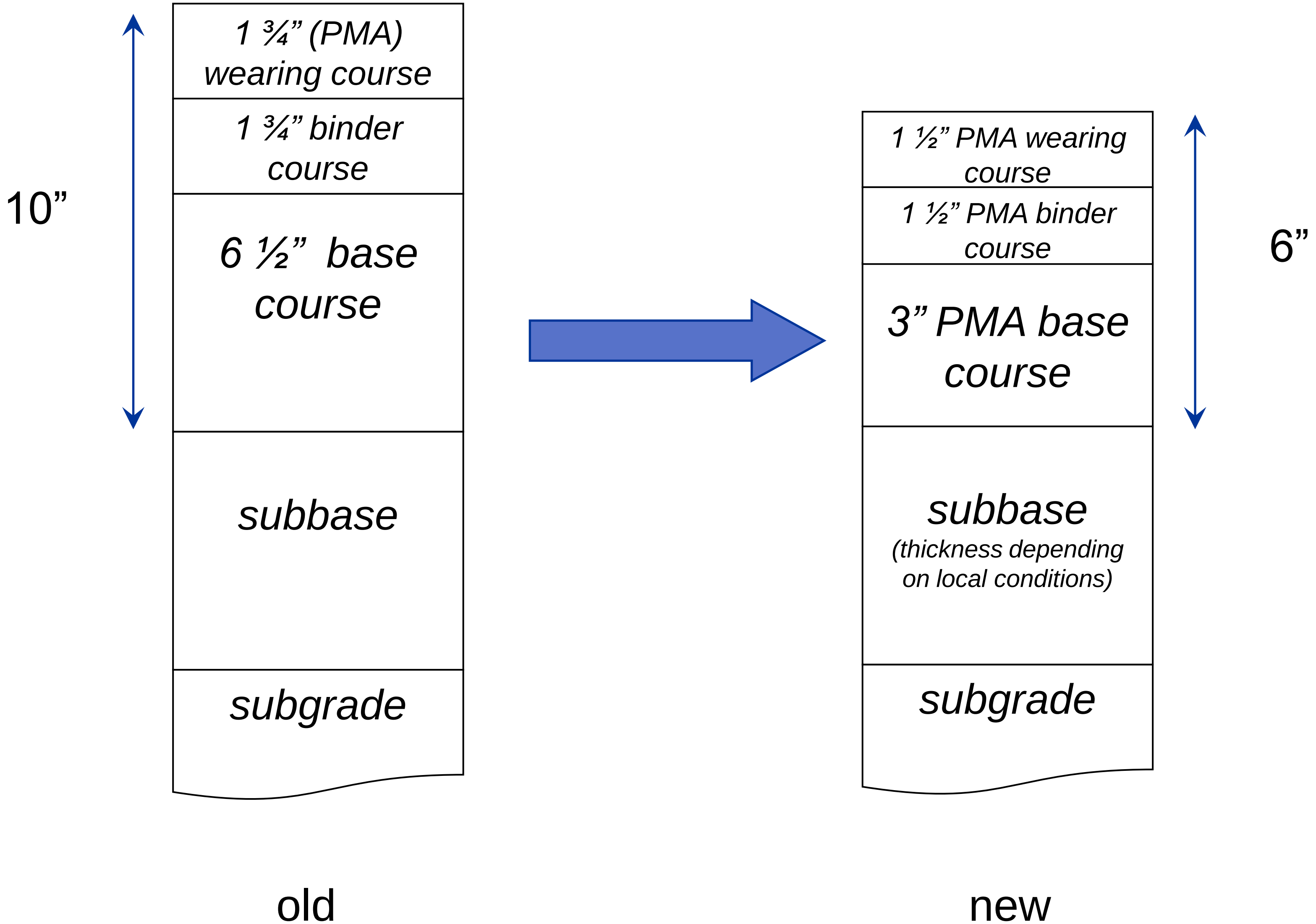
Three layers structure:
- Bound layer - E1 = 1000 MPa (145,000); h = **6” or 10”**
- Unbound subbase - E2 = 300 MPa (43,500 psi); h = 12”
- Subgrade - E3 = 100 MPa (14,500 psi); h = 50’

Constant temperature: T = 20^{o}C

Stationary dynamic load:
800 kPa (115 psi) – 25 ms



Proposed System



This an example; depending on local conditions other types may apply

Cost Comparison: Highly Modified vs. Conventional

mix type	thickness	cost per ton	per sq yd	total	cost reduction per sq yd	% cost reduction
modified wearing course	1.75 "	$84.00	$16.52			
unmodified binder course	1.75 "	$70.00	$13.77			
unmodified base course	6.5 "	$65.00	$47.48			
total	10.0 "			$77.77		
modified wearing course	1.75 "	$84.00	$16.52			
modified binder course	1.75 "	$84.00	$16.52			
modified base course	6.5 "	$91.00	$66.48	$99.52	-$21.75	-29%
	5.5 "	$91.00	$56.25	$89.29	-$11.52	-15%
	5.0 "	$91.00	$51.14	$84.18	-$6.41	-9%
	4.5 "	$91.00	$46.02	$79.07	-$1.29	-2%
	4.0 "	$91.00	$40.91	$73.95	$3.82	5%
	3.5 "	$91.00	$35.80	$68.84	$8.94	12%
	3.0 "	$91.00	$30.68	$63.73	$14.05	19%

based on example from previous slide, material costs only

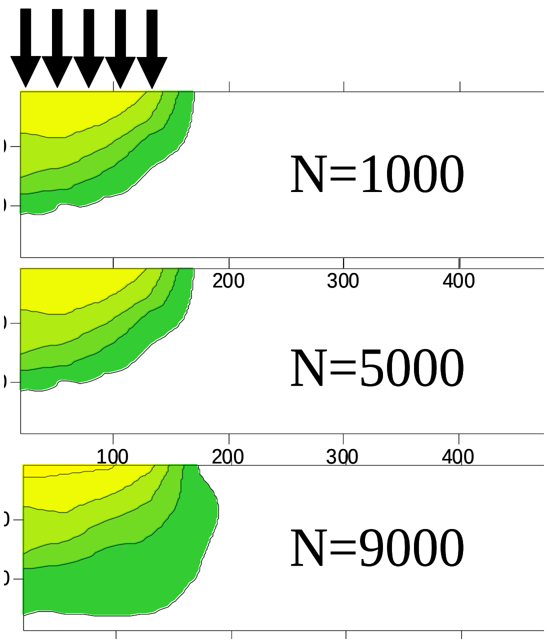
base data:
SMA unmodified wearing mix: $70/ton
unmodified base mix: $65/ton

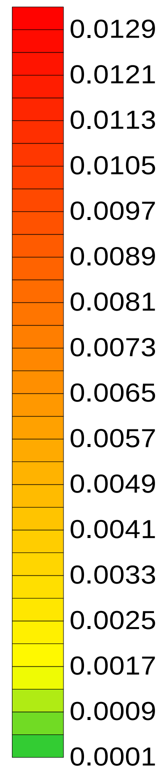
assumptions:
PMA wearing mix + 20%
PMA base mix + 40%

Modeling Results

Highly Modified (6”)

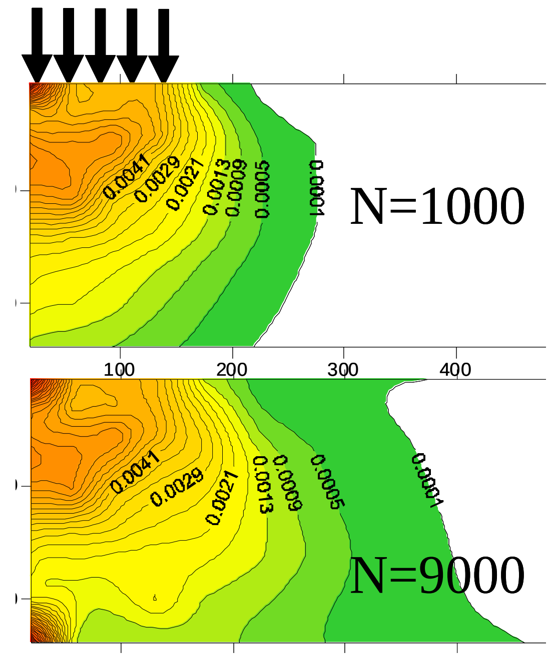
total damage





Unmodified (10”)

total damage



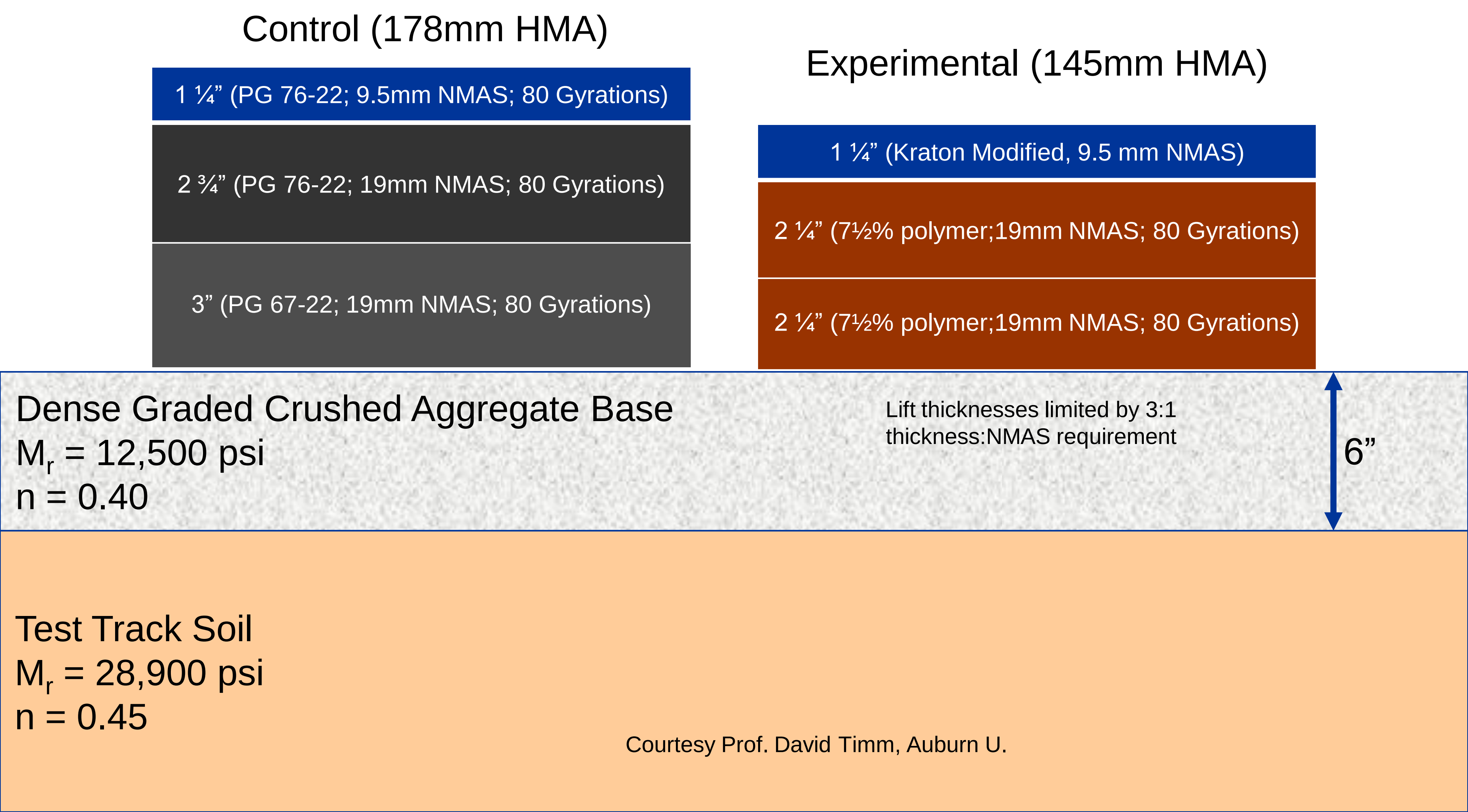
Comparative Damage

Distress	10" unmodified	6" highly modified
Shear deformation	2.05E-2	0.78E-2
Compressive deformation	1.27E-2	0.70E-2
Longitudinal cracking	1.31E-3	0.02E-3
Vertical cracking	7.72E-4	4.41E-4
Transverse cracking	8.65E-4	0.79E-4

Paving Trials to Date

- June 2009 – Thirteen city streets in Belpre, OH. Two 1” lifts, 9.5mm NMAS fine mix PG -28 base bitumen. No production or construction problems despite inclement weather.
- July 2009 – Section N7 (part of pooled fund group program) at NCAT test track, PG -22 base bitumen. Again, no problems with production or construction. Mix behaved like conventional PG 76-22 asphalt concrete.
- May 2010 – Slow, heavy traffic intersection in Georgia. PG -28 base bitumen No construction issues. Mix ran “easier than normal 76-22”
- August 2010 – NCAT Section N8, similar structure to N7.
- October 2010 – Port of Napier, New Zealand container loading wharf
- August-September 2011 – Thin lift overlay trials in Minnesota, Vermont and New Hampshire
- October 2011 – Structural rehabilitation, Parana, Brazil

Cross Sections Evaluated



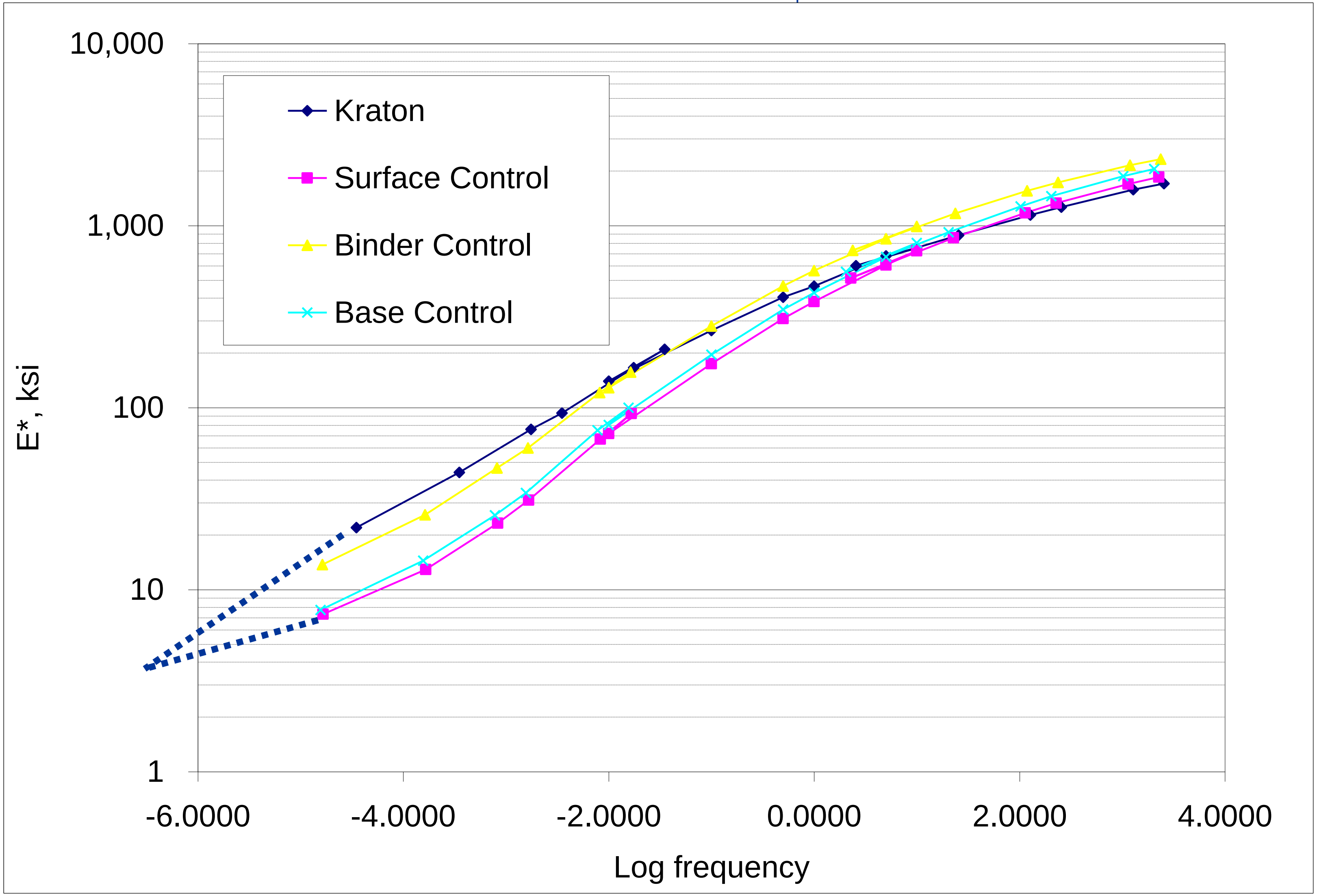
Courtesy Prof. David Timm, Auburn U.

NCAT Construction Overview

- Binder, PG 67-22 + 7½% SBS polymer, shipped 6+ hours. No issues with handling.
- Mixing temperature 340^{o}F (same used for PG 76-22 surface mixes), delivered to track 335^{o}F, temperature behind screed 300^{o}F.
- Mix came out of truck cleanly. Density easily achieved with conventional rolling pattern.
- No issues with shoving, however mixture appeared to “knead” as a unit under the roller.
- Truck trafficking commenced 8/28/09.

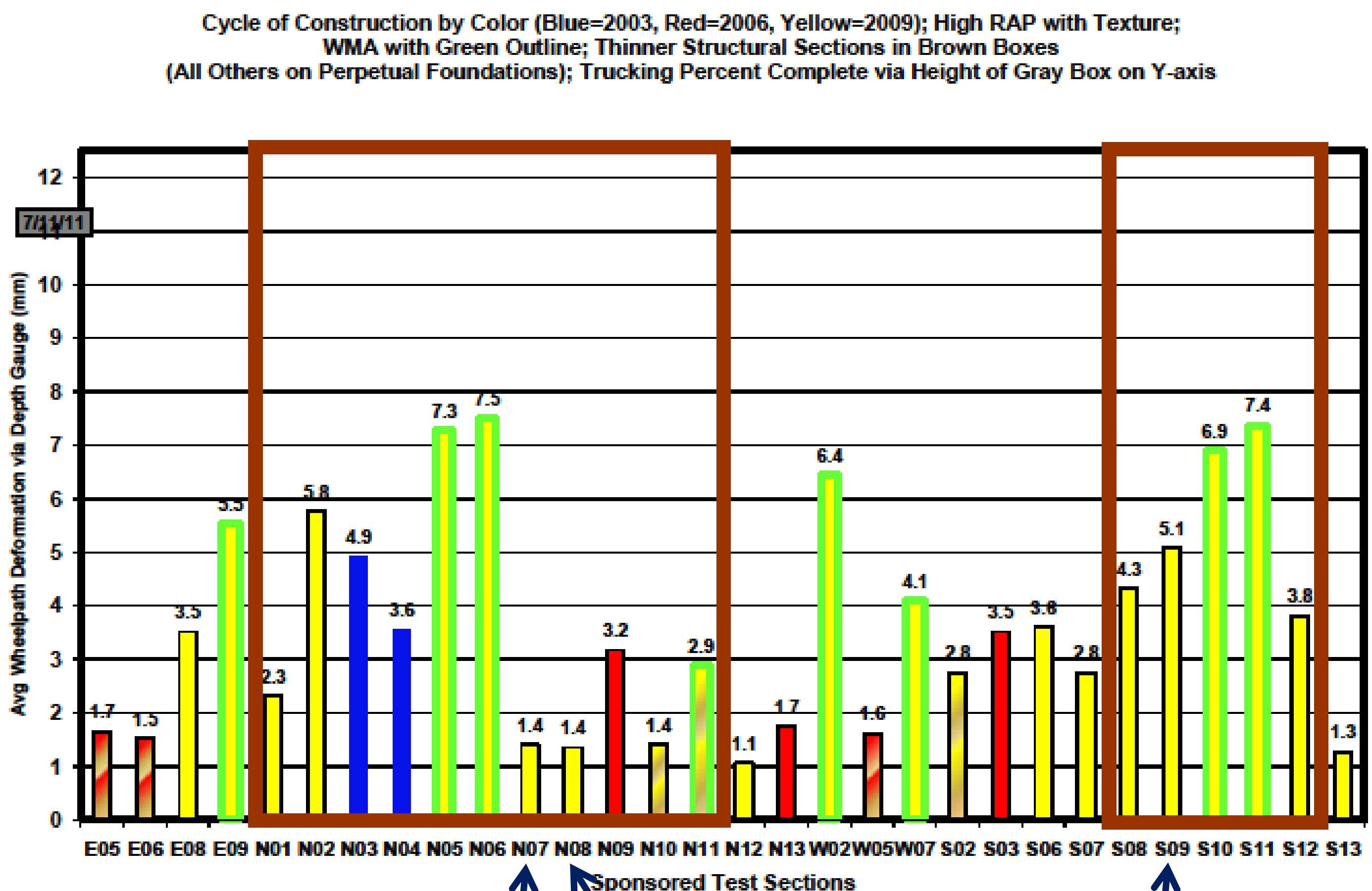
- NCAT & Auburn University – Dr. Buzz Powell, Dr. Nam Tran, Prof. Richard Willis, Prof. David Timm, Mary Robbins

Master Curve Comparison



Courtesy Prof. David Timm, Auburn U.

NCAT Rutting & Cracking Performance as of 7/11/11



Thin rehab section

Thin structural section **Standard control**

So far, no cracking on any of the pooled fund group experiment sections

2006 NCAT Construction Cycle

Oklahoma Perpetual
Pavement Experiment

N8 – 10” HMA
over weak base

N9 – 14” HMA
over weak base

10” Oklahoma Perpetual
Pavement Design

14” Oklahoma Perpetual
Pavement Design

Weak subgrade = poor soil for construction

2009 NCAT Construction Cycle – August 2009

Kraton Polymers HiMA Experiment

Oklahoma Perpetual Pavement Experiment

N7 - 5 ¾” HIMA over sound base

N8 – 10” HMA over weak base

N9 – 14” HMA over weak base

5 ¾” HiMA Pavement

5” Conventional Structural Overlay

Oklahoma Pavement – Failed due to severe subgrade rutting

Oklahoma Pavement – Still Sound

Standard subgrade = good soil for construction

Weak subgrade = poor soil for construction

Section N8 – June 29, 2010 – 4.0 MM ESALs

10” pavement
paved Aug. 2006
5” rehabilitation
Aug. 2009
10 months old

Section N8 – June 29, 2010 – 4.0 MM ESALs

Kraton
Giving Innovators Their Edge

10” pavement
paved Aug. 2006
5” rehabilitation
Aug. 2009
10 months old

2009 NCAT Construction Cycle – August 2010

Kraton
Giving Innovators Their Edge

Oklahoma proposed design modification

N7 - 5 ¾” HIMA
over sound base

1 ¼” (7½% polymer; 9.5 mm NMAS)

2 ¼” (7½% polymer;19mm NMAS; 80 Gyrations)

2 ¼” (7½% polymer;19mm NMAS; 80 Gyrations)

Standard subgrade = good soil for construction

N8 – 10” HMA
over weak base

1 ¼” (7½% polymer; 9.5 mm NMAS)

2 ¼” (7½% polymer;19mm NMAS; 80 Gyrations)

2 ¼” (7½% polymer; 9.5mm NMAS; 80 Gyrations)

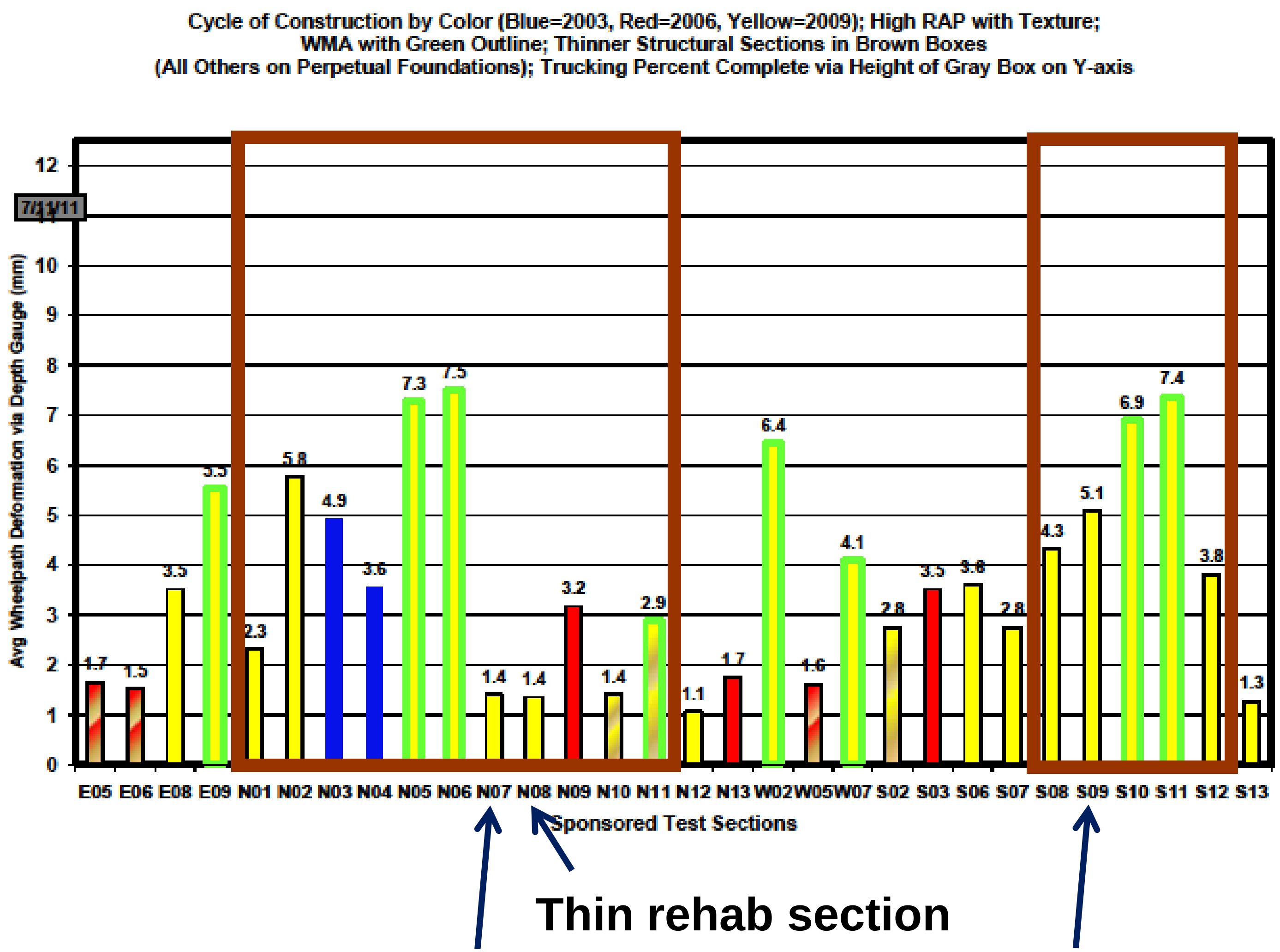
Oklahoma Pavement – Failed due to severe subgrade rutting

Weak subgrade = poor soil for construction

N9 – 14” HMA
over weak base

Oklahoma Pavement – Still Sound

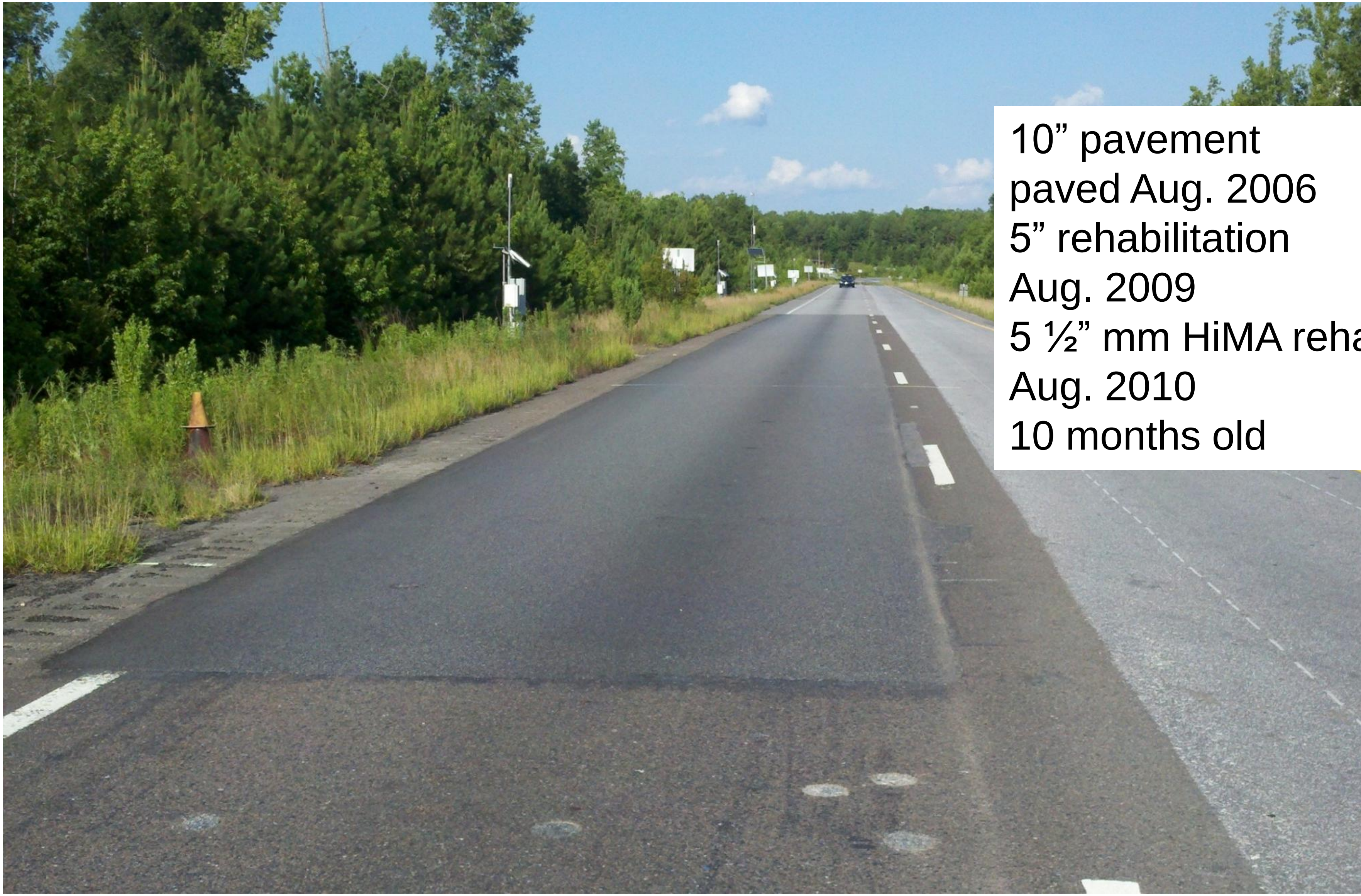
NCAT Rutting & Cracking Performance as of 7/11/11



So far, no cracking on any of the pooled fund group experiment sections

Section N8 – June 20, 2011 – 4.2 MM ESALs

Kraton
Giving Innovators Their Edge



10” pavement
paved Aug. 2006
5” rehabilitation
Aug. 2009
5 ½” mm HiMA rehab
Aug. 2010
10 months old

Section N8 – Sept. 12, 2011 – 5.27 MM ESALs

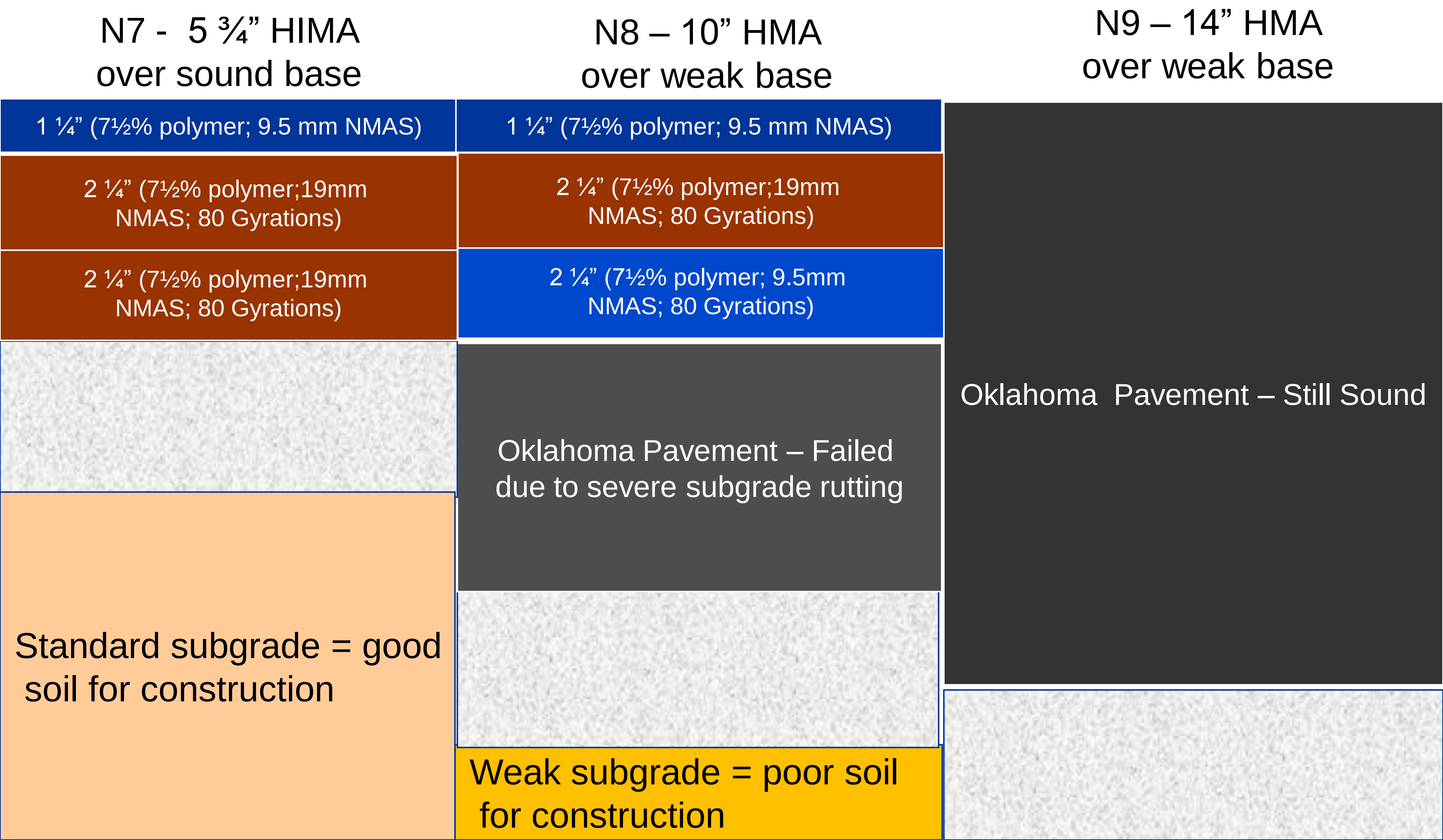
Kraton
Giving Innovators Their Edge

10” pavement paved Aug. 2006
5” rehabilitation Aug. 2009
5 ½” HiMA rehab Aug. 2010
13 months old

Similar crack appeared in first overlay at 2.7 MM ESALs
Oklahoma will sponsor this section through the 2012 cycle to monitor further deterioration and evaluate preservation strategies.

2009 NCAT Construction Cycle – August 2010

Oklahoma proposed design modification



Pavement Performance Prediction

- So how do we design pavements to meet performance needs?
- What (realistic and practical) methodology of pavement design will accurately predict performance?
- What mixture properties and specifications?
- What changes to mix design?
- What binder properties and specifications?

- Do not currently have adequate models for reflective cracking! Needed to address preservation strategies.

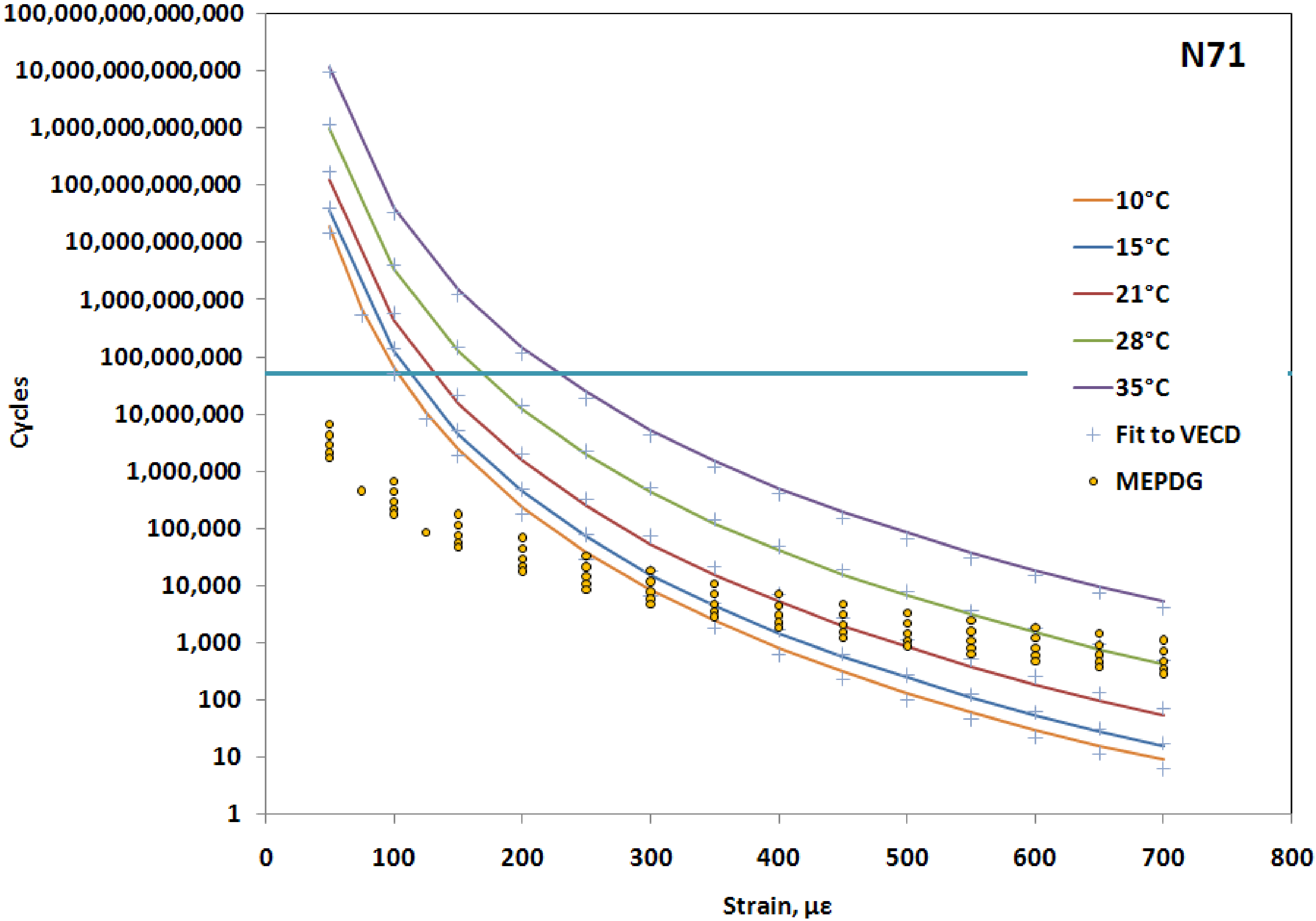
Performance Prediction – Mixture – 1

- **Modeling Results from TFHRC and NCSU**

- Modeling fatigue behavior from basic material properties (AMPT) using a Simplified Viscoelastic Continuum Damage (S-VECD) model
- Testing conducted at Turner Fairbank Highway Research Center and the National Center for Asphalt Technology
- Data presented at the Models and Mixture Expert Task Group meetings, March 2011.

- TFHRC – Nelson Gibson, Xin Jun Li
- NCSU - Richard Kim, Shane Underwood
- NCAT - Nam Tran, Randy West, Buzz Powell
- DLSI – Raj Dongré
- AAT - Don Christensen and Ray Bonaquist

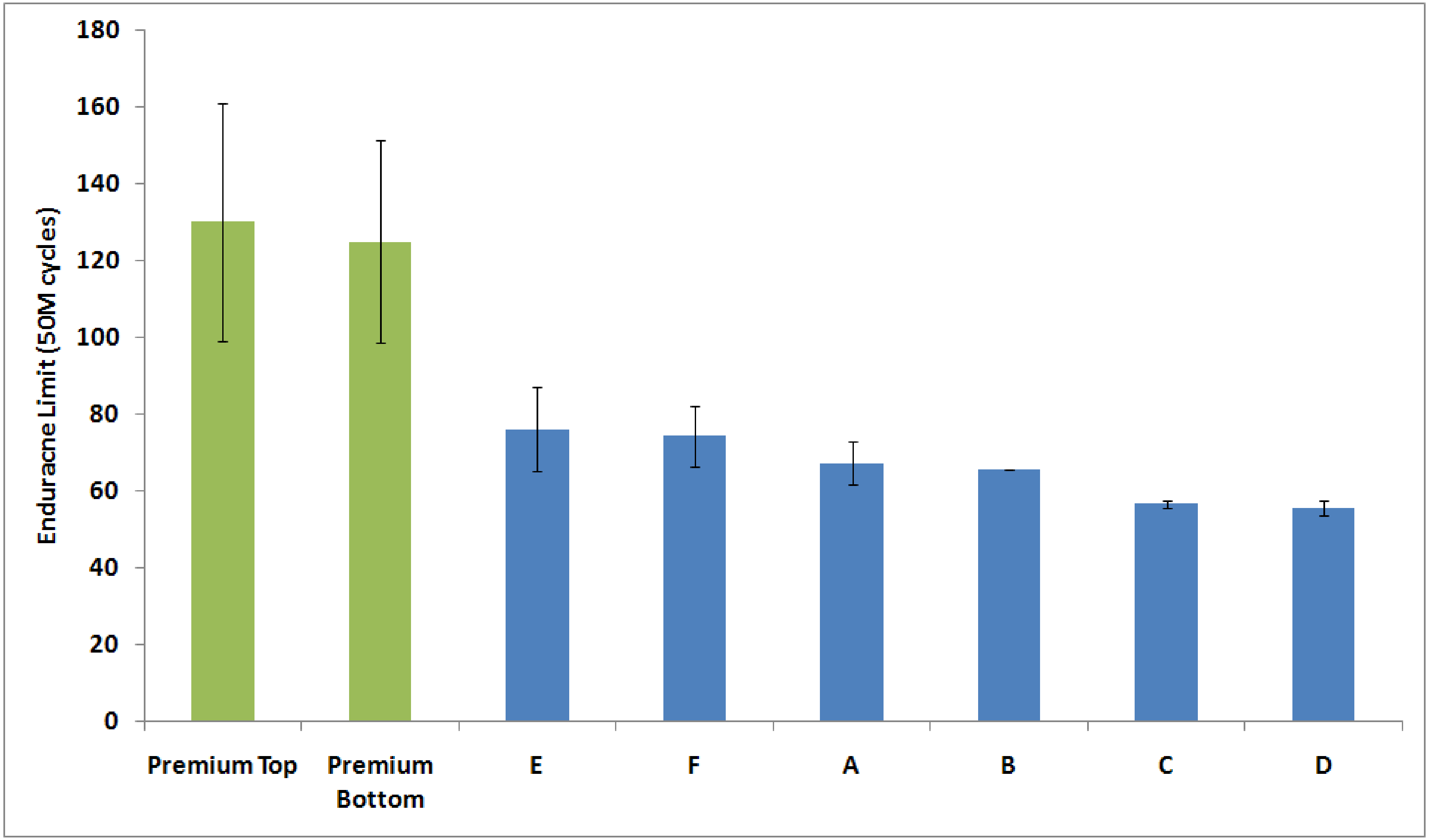
Results – Premium Polymer Modification



Results – Premium Polymer Modification

Kraton
Giving Innovators Their Edge

Endurance Limit (50M cycles) from range of temperatures



Performance Prediction – Pavement – 2

- **Modeling Using MEPDG and Revised Estimated Endurance Limits**

- Estimate endurance limit from AMPT mastercurve and IDT strength testing.
- Adjust MEPDG calibration factors accordingly.
- Full depth construction project in Parana, Brazil to be paved in December.

- ARA – Harold von Quintus
- DLSI – Raj Dongré
- UF – Rey Roque

Performance Prediction – Pavement – 3

- **Modeling Using MEPDG**
- **Revised Estimated Endurance Limits using beam fatigue and/or S-VECD model**

- Estimate endurance limit from AMPT mastercurve and push-pull fatigue testing or from 4-point bending beam fatigue data.
- Adjust MEPDG calibration factors accordingly.
- Rehabilitation project SP 300 near São Paulo, Brazil. Due to strong substructure, bound layer thickness reduced by 50%.

- TFHRC – Nelson Gibson, Xin Jun Li
- NCSU - Richard Kim, Shane Underwood
- NCAT - Nam Tran, Randy West, Buzz Powell
- DLSI – Raj Dongré

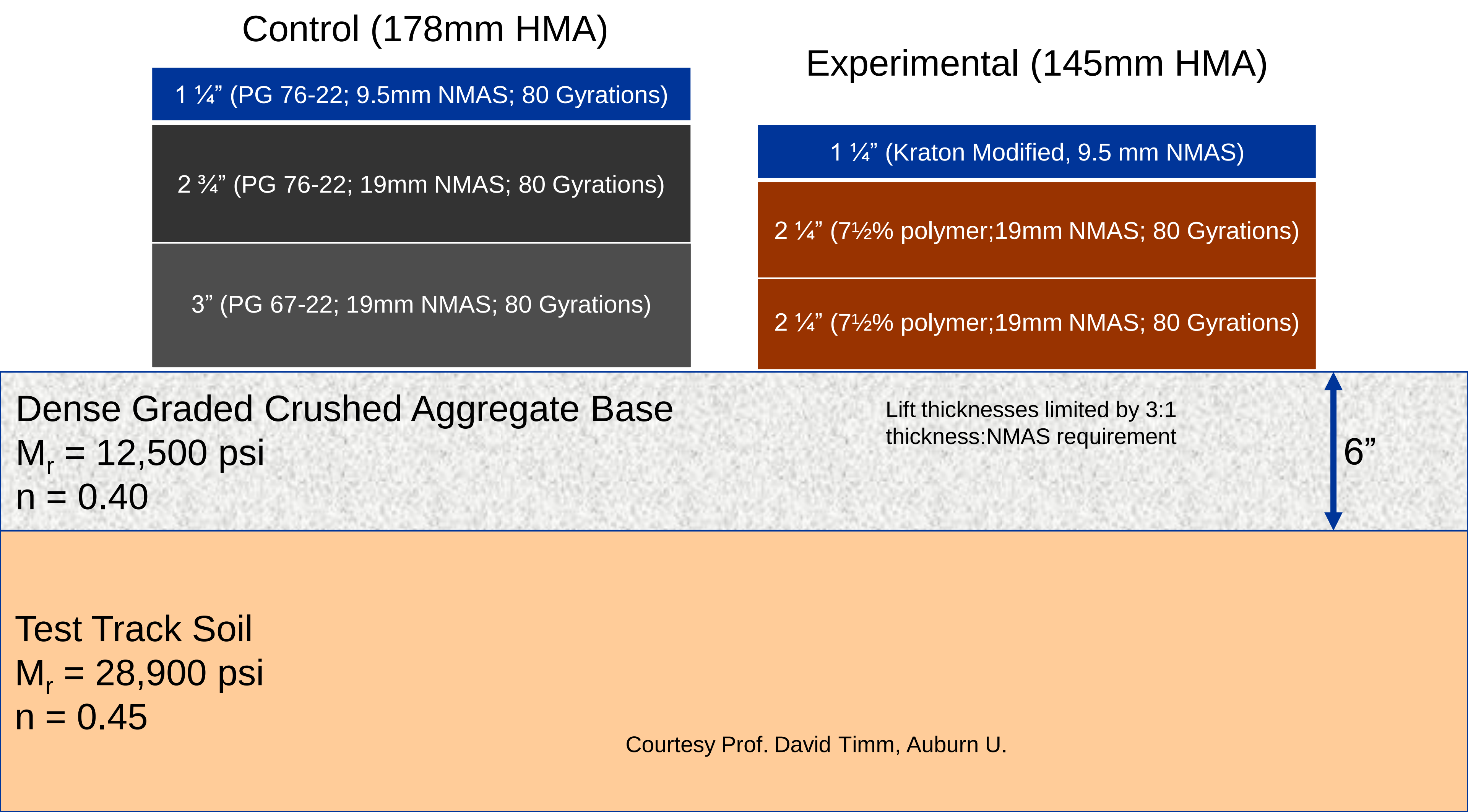
Binder Performance/Specifications

- Low Temperature – current BBR is generally good. T_c and or ABCD may offer improvement.
- High Temperature – MSCR J_{nr} is suitable.
- Fatigue??
  - UWM Linear Amplitude Sweep test?
  - Queen's U/MTO Double Edge Notched Tensile test?
  - Other?
- A key issue is the appropriate test temperature – How to determine? Equi-modulus temperature?

Conclusions

- Highly modified binders can give dramatic improvement in pavement resistance to rutting and fatigue damage.
- Thickness reduction can more than offset increased material costs.
- In severe distress situations, highly modified binders can possibly double pavement life.
- Current modeling and design software may be used to predict material performance characteristics and rationally design pavements.
- Current field trials in the northeast will help determine if there is benefit for preservation strategies.

Cross Sections Evaluated



Results – Premium Polymer Modification