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
September 23, 2010

Superpave 9.5-mm 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 to 37.5 mm) in thickness. Composition of the mixture for the PMTOL shall be coarse aggregate, fine aggregate, internal fiber (if included in the mixture), and polymermodified asphalt binder.

Surface Preparation of Existing Pavement
It is recommended that the existing pavement surface be prepared as outlined in NEPPP Information Series 125 Table 1 “Suggested Approaches to Surface Preparation Prior to Thin Overlay Based on Distress.”

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

Polymer Modified Asphalt Binder
The polymer modified asphalt binder shall be a performance grade of PG76-34 or PG82-34. PG82-34 is recommended for roadways exhibiting low severity cracking. The PG82-34 is recommended for roadways with little or no distresses. If milling of the existing pavement surface is necessary, either grades can be used. The asphalt emulsion shall provide moisture resistance per AASHTO R25 “Specifying Fiber-Reinforced Polymer-Modified Hot-Mix Asphalt.”

Aggregates
The aggregate blend for the PMTOL shall meet the Superpave aggregate consensus properties requirements listed in Table 5 of AASHTO M202 “Superpave Volumetric Mix Design” and the sound property requirements noted in Table 1. The aggregate blend shall be classified as coarse or fine as outlined in AASHTO M223 Section 5.3 - Gradation Classification.

Table 1. Superpave Source Property Requirements

<table>
<thead>
<tr>
<th>Test</th>
<th>Applicable Method</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA Abrasion, % loss</td>
<td>AASHTO T168 or ASTM C139</td>
<td>24% max.</td>
</tr>
<tr>
<td>Soundness, % loss</td>
<td>AASHTO T104 or ASTM C68</td>
<td>14% max.</td>
</tr>
</tbody>
</table>
AASHTO TSP2 Regional DOT Partnerships

- 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
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
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
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

Bitumen phase  Swollen polymer phase

Bitumen + 2½ % polymer

Bitumen + 5 % polymer

Bitumen + 7½ % polymer

Polymer absorbs bitumen swelling 5-10X
Crack Propagation in Toughened Composite

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

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°C

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

<table>
<thead>
<tr>
<th>Old System</th>
<th>New System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subgrade</strong></td>
<td><strong>Subgrade</strong></td>
</tr>
<tr>
<td><strong>Subbase</strong></td>
<td><strong>Subbase</strong></td>
</tr>
<tr>
<td><strong>6 ½” Base Course</strong></td>
<td><strong>3” PMA Base Course</strong></td>
</tr>
<tr>
<td><strong>1 ¾” Binder Course</strong></td>
<td><strong>1 ½” PMA Binder Course</strong></td>
</tr>
<tr>
<td><strong>1 ¾” (PMA) Wearing Course</strong></td>
<td><strong>1 ½” PMA Wearing Course</strong></td>
</tr>
<tr>
<td>Thickness depending on local conditions</td>
<td>Thickness depending on local conditions</td>
</tr>
</tbody>
</table>

This is an example; depending on local conditions other types may apply.
## Cost Comparison: Highly Modified vs. Conventional

<table>
<thead>
<tr>
<th>mix type</th>
<th>thickness</th>
<th>cost per ton</th>
<th>per sq yd</th>
<th>total</th>
<th>cost reduction per sq yd</th>
<th>% cost reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>modified wearing course</td>
<td>1.75 &quot;</td>
<td>$84.00</td>
<td>$16.52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unmodified binder course</td>
<td>1.75 &quot;</td>
<td>$70.00</td>
<td>$13.77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unmodified base course</td>
<td>6.5 &quot;</td>
<td>$65.00</td>
<td>$47.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>10.0 &quot;</td>
<td></td>
<td></td>
<td>$77.77</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 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”)

N=1000
N=5000
N=9000

Unmodified (10”)

N=1000
N=9000
## Comparative Damage

<table>
<thead>
<tr>
<th>Distress</th>
<th>10” unmodified</th>
<th>6” highly modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear deformation</td>
<td>2.05E-2</td>
<td>0.78E-2</td>
</tr>
<tr>
<td>Compressive deformation</td>
<td>1.27E-2</td>
<td>0.70E-2</td>
</tr>
<tr>
<td>Longitudinal cracking</td>
<td>1.31E-3</td>
<td>0.02E-3</td>
</tr>
<tr>
<td>Vertical cracking</td>
<td>7.72E-4</td>
<td>4.41E-4</td>
</tr>
<tr>
<td>Transverse cracking</td>
<td>8.65E-4</td>
<td>0.79E-4</td>
</tr>
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</table>
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

Control (178mm HMA)

1 ¼” (PG 76-22; 9.5mm NMAS; 80 Gyrations)

2 ¾” (PG 76-22; 19mm NMAS; 80 Gyrations)

3” (PG 67-22; 19mm NMAS; 80 Gyrations)

Experimental (145mm HMA)

1 ¼” (Kraton Modified, 9.5 mm NMAS)

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

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

Dense Graded Crushed Aggregate Base

\[ M_r = 12,500 \text{ psi} \]
\[ n = 0.40 \]

Test Track Soil

\[ M_r = 28,900 \text{ psi} \]
\[ n = 0.45 \]

Lift thicknesses limited by 3:1 thickness:NMAS requirement

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°F (same used for PG 76-22 surface mixes), delivered to track 335°F, temperature behind screed 300°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

E*, ksi

Kraton
Surface Control
Binder Control
Base Control

Log frequency

 Courtesy Prof. David Timm, Auburn U.
NCAT Rutting & Cracking Performance as of 7/11/11

Cycle of Construction by Color (Blue=2003, Red=2006, Yellow=2009); High RAP with Texture; WMA with Green Outline; Thinner Structural Sections in Brown Boxes (All Others on Perpetual Foundations); Trucking Percent Complete via Height of Gray Box on Y-axis

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

<table>
<thead>
<tr>
<th>N7 - 5 ¾” HIMA over sound base</th>
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<tr>
<td>5 ¾” HiMA Pavement</td>
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### Oklahoma Perpetual Pavement Experiment

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<tr>
<td>5” Conventional Structural Overlay</td>
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<tr>
<td>Oklahoma Pavement – Failed due to severe subgrade rutting</td>
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<table>
<thead>
<tr>
<th>N9 – 14” HMA over weak base</th>
</tr>
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<tbody>
<tr>
<td>Oklahoma Pavement – Still Sound</td>
</tr>
</tbody>
</table>

Weak subgrade = poor soil for construction
10” pavement
paved Aug. 2006
5” rehabilitation
Aug. 2009
10 months old
Section N8 – June 29, 2010 – 4.0 MM ESALs

10” pavement
paved Aug. 2006
5” rehabilitation
Aug. 2009
10 months old
### Oklahoma proposed design modification

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**Standard subgrade = good soil for construction**

**Weak subgrade = poor soil for construction**
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

10” pavement
paved Aug. 2006
5” rehabilitation
Aug. 2009
5 ½” mm HiMA rehab
Aug. 2010
10 months old
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.
### Oklahoma proposed design modification

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- **Standard subgrade** = good soil for construction
- **Weak subgrade** = poor soil for construction

- **Oklahoma Pavement – Failed**
  - due to severe subgrade rutting
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.
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

N71

- 10°C
- 15°C
- 21°C
- 28°C
- 35°C

Cycles

Strain, με
Results – Premium Polymer Modification

Endurance Limit (50M cycles) from range of temperatures

![Endurance Limit Chart]
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
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

### Control (178mm HMA)
- 1 ¼” (PG 76-22; 9.5mm NMAS; 80 Gyrations)
- 2 ¾” (PG 76-22; 19mm NMAS; 80 Gyrations)
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### Test Track Soil
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Courtesy Prof. David Timm, Auburn U.
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N71

- 10°C
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- 21°C
- 28°C
- 35°C

Fit to VECM

MEPDG