Balanced Mix Design & Pavement Design with VDOT PG76E-28

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VPRIS 2019
June 18, 2019
Outline

- What is highly modified asphalt?
  - In Virginia it’s PG 76E-28
- NCAT test track section performance
- AASHTOWare™ Pavement ME Design modeling
- FLEXPave™ software modeling
- Mixture Design – Pavement Design
- Conclusions
Raj Dongre – DLSI
Buzz Powell – NCAT
David Timm – Auburn U
Richard Willis – NAPA
Richard Kim – NCSU
Mary Robbins – NCAT
Nam Tran – NCAT
Adam Taylor - NCAT
What Is Highly Modified Asphalt?

- Highly Modified Asphalt is exactly what it says, asphalt with more than double the normal amount of SBS polymer.
- This gives a much denser polymer network with up to 10X rutting and fatigue cracking resistance.

Over 5,000,000 tons in over 70 projects around the world have demonstrated superior performance at reduced thickness.
## HiMA Specifications North America

<table>
<thead>
<tr>
<th>Standard</th>
<th>AASHTO M 320</th>
<th>AASHTO T 301</th>
<th>AASHTO M 332</th>
<th>AASHTO T 350</th>
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<tbody>
<tr>
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<td>PG specification</td>
<td>Elastic Recovery</td>
<td>PG specification</td>
<td>MSCR Recovery</td>
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<tr>
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<td>95%</td>
<td></td>
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<td>PG 76E-28</td>
<td>90%</td>
<td></td>
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<td>Utah</td>
<td>PG 70E-34</td>
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<td>Iowa</td>
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<td>Oregon</td>
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<td>Washington</td>
<td>PG 76-34</td>
<td>90%</td>
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</table>
National Center for Asphalt Technology Test Track

- 5 trucks, 16 h/day, 5 days/week
- Axle load: 18 kip
- Speed: 45 mph
Control (S9) and HiMA (N7) Section Designs

Section S9 - Control
178 mm Standard Hot Mix
- 32 mm (PG 76-22; 9.5 mm NMAS; 80 Gyrations)
- 70 mm (PG 76-22; 19 mm NMAS; 80 Gyrations)
- 76 mm (PG 67-22; 19 mm NMAS; 80 Gyrations)

Section N7
145 mm Highly Modified Hot Mix
- 32 mm (7½% SBS; 9.5 mm NMAS)
- 57 mm (7½% SBS; 19 mm NMAS; 80 Gyrations)
- 57 mm (7½% SBS; 19 mm NMAS; 80 Gyrations)

Dense Graded Crushed Aggregate Base
- $M_r = 85$ MPa
- $n = 0.40$

Test Track Soil
- $M_r = 200$ MPa
- $n = 0.45$

Lift thicknesses limited by 3:1 thickness:NMAS requirement

150 mm

Courtesy Prof. David Timm, Auburn U.
N7 Crack Map at 20 Million ESALs

S9 resurfaced at 17 million ESALs

N7 cracking is superficial top-down
AASHTOWare™ Pavement ME Design

- Traditional layered elastic model
- Comprehensive input data

- Fatigue cracking model
  \[ N_{f-HMA} = k_f(C)(C_H)\beta_{f_1}(\varepsilon_t)k_f^2\beta_f^2(E_{HMA})k_f^3\beta_f^3 \]  
  \( \leftarrow \) from AMPT tensile fatigue or flexural fatigue

- Permanent deformation model
  \[ D_{p(HMA)} = \varepsilon_{p(HMA)}h_{HMA} = \beta_{r_1}k_{\varepsilon}\varepsilon_{r(HMA)}10^{kr_1}\eta^{kr_2}\beta r_2 T^{kr_3}\beta r_3 \]  
  \( \leftarrow \) from AMPT Fn or other deformation test
## Predicted damage summary

<table>
<thead>
<tr>
<th>Pavement Distress</th>
<th>S9</th>
<th>N7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Permanent Deformation, mm</td>
<td>10.2</td>
<td>8.4</td>
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<tr>
<td>AC Permanent Deformation, mm</td>
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<tr>
<td>Bottom-Up Cracking, % Area</td>
<td>18</td>
<td>1.5</td>
</tr>
</tbody>
</table>

## Measured damage summary

<table>
<thead>
<tr>
<th>Pavement Distress</th>
<th>S9</th>
<th>N7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Permanent Deformation, mm</td>
<td>6.0</td>
<td>1.6</td>
</tr>
<tr>
<td>AC Permanent Deformation, mm</td>
<td>6.0</td>
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<tr>
<td>Bottom-Up Cracking, % Area</td>
<td>10</td>
<td>0</td>
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</tbody>
</table>
HiMA Market Applications - Where Does it Add Value?

- Structural Applications
  - With a sound base, thinner pavements with lower upfront cost
  - Demonstrated in many field applications & Ohio University APLF
  - With weak base, much longer lifetime can be achieved

- Thin Overlays
  - Superior resistance to reflective cracking BUT requires finer, richer mix.

- Preservation Surfacing such as micro surfacing

- Open Grade Mixes for Reduced Raveling

- SAMI Layers

- High Stress Applications – ramps, intersections

- AASHTOWare® Pavement ME Design works for HiMA designs
In General Terms, What Does HiMA Do to Mixture and Performance Characteristics?

- Modulus
- Cracking Resistance
- Rutting Resistance
- Cracking Versus Rutting
- Structural Integrity
Dynamic Modulus Testing Results - 9.5 mm NMAS Mixtures

![Graph showing dynamic modulus testing results for Surface-Control and Surface-HPM mixtures. The graph plots reduced frequency (Hz) on the x-axis and dynamic modulus (ksi) on the y-axis. The graph illustrates the modulus variation at different frequencies.](image-url)
Four Point Bending Beam Fatigue Results

Full sinusoidal loading. Cited strains are ½ amplitude.
TX DOT Overlay Specifications - Coarse Dense Mix

TX DOT C Mix Hamburg & Overlay Test Results

12.5 mm max Hamburg
TX DOT specification
TX DOT Overlay Specifications - Fine Rich Mix

TX DOT Overlay Test Results

- 12.5 mm max Hamburg
- 750 min Overlay
- TX DOT specification
Thickness Reduction Capability

**Good quality sub base**

1. Thickness determined by asphalt strain criterion
2. Thickness determined by sub grade strain criterion

**Poor quality sub base**

HiMA = Highly Modified Asphalt
HiMA Mixture and Pavement Design Concepts

- So how should these observations apply to design principles?
- Structural Pavement – Strong Base
- Structural Pavement – Weak Base
- Overlay – Undamaged Pavement
- Overlay – Damaged Pavement
- Waterproof Bridge Deck
- SAMI
Structural Pavement - Strong Base

- Lowest strain. Best Case!
- Key distress—bottom up fatigue cracking
- Solution—standard mix design, perhaps slightly richer, 0.2-0.3%.
- Thinner pavement design for lower up front cost and life cycle cost for a perpetual pavement.

1 ¼" (PG 76-22 E, 9.5 mm NMAS, 80 gyrations)

2 ¼" (PG 76-22 E, 19 mm NMAS; 80 gyrations)

2 ¾" (PG 76-22 E, 19 mm NMAS; 80 gyrations)
- Moderate strain.
- Key distress—risk of subbase, subgrade damage, bottom up cracking.
- Solution—rich bottom layer, little or no thickness reduction.
- Likely more expensive up front cost, but perpetual pavement vs. rehab every few years.
Overlay - Undamaged Pavement

- Low strain.
- Key distress—should be able to achieve substantial thickness reduction, but be aware of potential for rutting below surface.
- Solution—standard mix design, perhaps 0.2-0.3% richer to be on the safe side.
- Thinner pavement for lower up front cost and life cycle cost.
Overlay - Damaged Pavement

- Very high localized strain.
- Key distress—reflective cracking.
- Solution—take advantage of rutting resistance with a finer, richer mix than standard, e.g., New Jersey HPTO mix
- Mix expensive up front mix, but much better life cycle cost analysis.

SECTION 406 – HIGH PERFORMANCE THIN OVERLAY (HPTO)

406.01 DESCRIPTION
This Section describes the requirements for constructing high performance thin overlay (HPTO).

406.02 MATERIALS

406.02.01 Materials
Provide materials as specified:
- Tack Coat: Emulsified Asphalt, Grade RS-1, SS-1, SS-1h, Grade CSS-1 or CSS-1h
- HPTO
Waterproof Bridge Deck Mix

- Key distress—fatigue cracking, water permeation
- Solution—very rich fine mix with <2% voids.
- Lower cost & far better workability than alternatives.

SECTION 555 - BRIDGE DECK WATERPROOF SURFACE COURSE

555.01 DESCRIPTION
This Section describes the requirements for constructing bridge deck waterproof surface course (BDWSC).

555.02 MATERIALS
555.02.01 Materials
Provide materials as specified:
- Tack Coat 64-22, PG 64-22 ................................................................. 902.01.01
- Tack Coat:
  - Cut-Back Asphalt, Grade RC-70 ........................................................ 902.01.02
  - Emulsified Asphalt, Grade RS-1, SS-1, SS-1h, Grade CSS-1 or CSS-1h 902.01.03
- Joint Sealer, Hot Poured ................................................................. 914.02
- Polymerized Joint Adhesive ............................................................ 914.03

![Graph showing load cycles vs. microstrain for different mixes](image-url)

![Diagram showing comparison of Good quality sub base vs. Poor quality sub base](image-url)
Stress Attenuating Mix Interlayer (SAMI)

- High strain. Low voids.
- Key distress—reflective cracking.
- Solution—very rich fine mix with low voids.
- Lower cost than thick structural layer.

Assessment of Asphalt Interlayer Designed on Jointed Concrete

Based on the substantial reduction in reflective cracking and only marginal cost increase from using this interlayer in this research project, it is recommended that localDOTs adopt this asphalt (SAMI) interlayer project in Iowa consider using the crack-relief interlayer to delay reflective cracking.
La Quinta, CA near Palm Springs Standard slurry on left shows tearing. HiMA slurry on right - only superficial scuffing. After one week of service 90% reduction in power steering burns in cul-de-sacs

1-31-2014

Type II Slurry

HiMA Type II Slurry
Ongoing Research

- **Virginia**
  - Field Performance and Economic Analysis of Pavement Sections with Highly Polymer-Modified Asphalt Overlays – Habbouche, Boz, Diefenderfer, VTRC – started June 2019

- **Florida**
  - Structural Coefficients of High Polymer Modified Asphalt Mixes Based on Mechanistic-Empirical Analyses and Full-Scale Pavement Testing – Habbouche, Hajj, UNR – in final review
  - Evaluation of FC-5 with PG 76-22 HP to Reduce Raveling BE287: Final Report – Arámbula-Mercado, Karki, Park, TAMU, Caro, Torres, Sánchez-Silva, U de los Andes
Conclusions

▪ NCAT section N7 developed fine surface cracking late in its life, but forensic analysis showed that the cracking was minor top down cracking not impacting the structural integrity of the pavement.

▪ Highly modified asphalt may be useful in perpetual pavement design.

▪ Demonstrated performance up to 20 million ESALs shows that the thickness of pavement structures may be reduced while retaining or even improving long term performance.
Conclusions

- AASHTO M 332 specifications (plus R%) have been effective to specify HiMA binders for commercial applications.
- Standardized test methods in increasingly common use are adequate to characterize HiMA mixtures for the purpose of pavement design.
- The current Pavement ME Design protocol is suited to designing perpetual pavements with highly modified asphalts. Relative global calibration factor adjustment with Level 1 design gives performance predictions that agree well with actual field performance relative to known structures.
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