Pennsylvania’s Experience with Thin Asphalt Overlays

Northeast Asphalt User Producer Group Annual Meeting
Newark, DE
October 20, 2016

Mansour Solaimanian, PhD, PE
Penn State University
Outline

1. THMAO As A Pavement Preservation Strategy
2. Mix Design and Evaluation
3. Construction
4. Quality Control
5. Performance Evaluation
THIN OVERLAYS FOR PAVEMENT PRESERVATION
PennDOT Research Project on THMAO

- Four Year Project: June 2012 – June 2016
- Initiated by PAPA/PennDOT
- Included Three Demonstration Projects
- Research Team:
  - Penn State (Prime Contractor)
  - Advanced Infrastructure Design
  - Quality Engineering Solutions, Inc.
  - Penetradar Corporation
Pilot Projects
<table>
<thead>
<tr>
<th>Activity</th>
<th>Reconstruction</th>
<th>Major Rehabilitation</th>
<th>Minor Rehabilitation</th>
<th>Preventive Maintenance</th>
<th>Routine Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase Capacity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase Structural Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve Pavement Condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restore Serviceability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extend Service Life</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Pavement Preservation

- Depends
How Thick is Thin Asphalt?

- Placed up to 1.25 inches in thickness

- Ultrathin layers: between 0.5” and 1.0”
## Practice in Other States

<table>
<thead>
<tr>
<th>State</th>
<th>Term</th>
<th>Type</th>
<th>Sieve mm</th>
<th>%Pass</th>
<th>Thickness, in</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td>Ultrathin Bonded Wearing Course</td>
<td>4.75mm</td>
<td>9.5</td>
<td>100</td>
<td>40-55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.5mm</td>
<td>12.5</td>
<td>100</td>
<td>85-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MI</td>
<td>HMA Ultra-Thin</td>
<td>12.5</td>
<td>100</td>
<td>99-100</td>
<td>75-95</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.75</td>
<td>100</td>
<td>97-100</td>
<td>75-95</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC</td>
<td>Ultrathin Bonded Wearing Course</td>
<td>12.5</td>
<td>100</td>
<td>85-100</td>
<td>28-44</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.75</td>
<td>100</td>
<td>85-100</td>
<td>28-44</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.75</td>
<td></td>
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</tbody>
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## Practice in Other States

<table>
<thead>
<tr>
<th>State</th>
<th>Term</th>
<th>Type</th>
<th>Sieve mm</th>
<th>%Pass</th>
<th>Thickness, in</th>
</tr>
</thead>
<tbody>
<tr>
<td>NY</td>
<td>6.3 mm Polymer Modified HMA</td>
<td></td>
<td>9.5</td>
<td>100</td>
<td>3/4 - 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.3</td>
<td>90-100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.75</td>
<td>90 (Max)</td>
<td></td>
</tr>
<tr>
<td>OH</td>
<td>Smoothseal</td>
<td>Type A</td>
<td>9.5</td>
<td>100</td>
<td>5/8 – 3/4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.75</td>
<td>95-100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.36</td>
<td>90-100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type B</td>
<td>12.5</td>
<td>100</td>
<td>3/4 - 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.5</td>
<td>95-100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.75</td>
<td>85-95</td>
<td></td>
</tr>
<tr>
<td>TX</td>
<td>Crack Attenuating Mix (CAM)</td>
<td></td>
<td>12.5</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.5</td>
<td>95-100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.75</td>
<td>70-90</td>
<td></td>
</tr>
</tbody>
</table>
Mat Thickness/NMAS Ratio

NMAS: Nominal Max. Aggregate Size

Aggregate
NMAS

Mat Thickness
0.5 to 1.25 in

3 \leq \text{Ratio of Thickness to NMAS} \leq 5
## Importance of NMAS in Thickness

### Table shown with:

**Mat Thickness:**
- from 1.5 inches to 0.50 inches,

**NMAS:**
- from 12.5 mm to 4.75 mm

<table>
<thead>
<tr>
<th>Mat Thickness</th>
<th>NMAS</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>In</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>1.50</td>
<td>38.1</td>
<td>12.5</td>
</tr>
<tr>
<td>1.25</td>
<td>31.8</td>
<td>9.5</td>
</tr>
<tr>
<td>1.00</td>
<td>25.4</td>
<td>6.3</td>
</tr>
<tr>
<td>0.75</td>
<td>19.1</td>
<td>6.3</td>
</tr>
<tr>
<td>0.50</td>
<td>12.7</td>
<td>6.3</td>
</tr>
</tbody>
</table>

- **Good**
- **Ok**
- **Avoid**
Significance of Aggregate Skid Resistance Level in Thin Asphalt

Two of the Most Important Properties Affecting Friction (Skid Resistance) Are:

1. Aggregate Microtexture
2. Pavement Macrotexture
Significance of SRL in Thin Asphalt

As thickness gets smaller, harder to develop macro and more demand on micro.
2

MIX DESIGN AND EVALUATION
6.3 mm NMAS Mix
Placed at 1 inch thickness

Aggregate:  Skid Resistance Level (SRL): E
Polymer Modified Binder: PG 76-22 (for heavier traffic)
Gyration Level:  75
Design Air Void: 4%,  Min. Design VMA: 16.5%
Design Binder Content: 6.7%;  7.0%;  6.9%
NO RAP/RAS
6.3 mm NMAS Mix

Aggregate Gradation of Three Pilot Projects

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td># 200</td>
<td>0</td>
</tr>
<tr>
<td># 50</td>
<td>10</td>
</tr>
<tr>
<td># 16</td>
<td>20</td>
</tr>
<tr>
<td># 8</td>
<td>30</td>
</tr>
<tr>
<td># 4</td>
<td>50</td>
</tr>
<tr>
<td>6.3mm</td>
<td>70</td>
</tr>
<tr>
<td>9.5mm</td>
<td>90</td>
</tr>
</tbody>
</table>

- SR 0220
- SR 0230
- SR 0022
Performance Evaluation - HWTD

Specimens under water
Test Temperature: 50ºC
20,000 Passes
50 Passes per minute
158-lb load
Performance Evaluation - HWTD

Thin Asphalt Overlay Project
Hamburg Wheel Tracking Tests - 8/23/2012

1st Pilot Project – SR 0022

Rut Depth, mm

Right Track

Left Track

Temperature = 50ºC
Performance Evaluation – Texas Overlay Tester
Performance Evaluation – Overlay Tester

Test Temperature: 25°C
# of load cycles: 1000
Or until load reduced to 93% of original

- Repeated loading (triangular form) under constant deformation
- Deformation magnitude per load cycle: 0.025 inches (0.6 mm)
- Duration of each load cycle: 10 seconds

Cycles to failure > 500
Good Performance
Tack Coat Evaluation

Direct Shear Applied at the Asphalt-Concrete Interface
Tack Coat Evaluation

Trimmed Core

Tested Specimen in Direct Shear
Tack Coat Evaluation

Shear Strength = 44.5 psi (307 KPa) - Good Performance

THMAO Project
Tack Coat Evaluation - Core # 5

Deformation Rate: 1 mm/min
Test Temperature: 25.5°C
Recommended Requirements for Design of Asphalt Mix for Thin Lifts

Asphalt Binder

- PG 76-22 or PG 64E-22 if ESALs > 3M
- PG 64-22 if ESALS ≤ 3M
- PG 76-22 or PG 64E-22 if grade ≥ 5% regardless of traffic level.

Mix Design

- 75 Gyrations
- Air Void: 4.0%
- VMA: 16.5%
# Recommended Requirements for Design of Asphalt Mix for Thin Lifts

**Aggregate, SRL E**

<table>
<thead>
<tr>
<th>AGGREGATE GRADATION REQUIREMENTS, PERCENT PASSING</th>
<th>Pilot Projects %Pass#4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieve Size</td>
<td>Min. – Max.</td>
</tr>
<tr>
<td>3/8”</td>
<td>100 Min.</td>
</tr>
<tr>
<td>1/4”</td>
<td>90-100</td>
</tr>
<tr>
<td>No. 4</td>
<td>85 Max</td>
</tr>
<tr>
<td>No. 8</td>
<td>37-55</td>
</tr>
<tr>
<td>No. 50</td>
<td>8-25</td>
</tr>
<tr>
<td>No. 200</td>
<td>3-10</td>
</tr>
</tbody>
</table>
Recommended Requirements for Design of Asphalt Mix for Thin Lifts

**Tack Coat, CSS-1h**

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Residual Application Rate (Gallons/Square Yard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Asphalt Mixture</td>
<td>0.03 to 0.04</td>
</tr>
<tr>
<td>Oxidized Asphalt Mixture</td>
<td>0.04 to 0.06</td>
</tr>
<tr>
<td>Milled Asphalt Mixture</td>
<td>0.05 to 0.07</td>
</tr>
<tr>
<td>Milled PCC</td>
<td>0.05 to 0.07</td>
</tr>
<tr>
<td>Portland Cement Concrete</td>
<td>0.05 to 0.07</td>
</tr>
</tbody>
</table>
CONSTRUCTION OF THIN OVERLAYS
Repair/Prepare the Base
Repair/Prepare the Base
Repair/Clean before Tacking
Emulsion Tack Coat Application
Rollers Follow Paver Closely

Concern with Mat Temperature
THMAO Project - N. Cameron Street, EB, Travel Lane
Mat Temperature (Spot Measurement) - 7/25/2012

Mat Temperature, °F

Pavecool Prediction (Wind Speed = 11 mph)

Measured

Elapsed Time from Placement, minutes
SR 230 – Finished Overlay
SR 220 – Finished Overlay
QUALITY CONTROL OF THIN OVERLAYS
Mat Temperature
Infrared Measurements

* Map shows inferred distance.
* Temperature changes are denoted by variations in color. Scale in in Fahrenheit.
* The GPR reference line start location is denoted in the infrared maps.
* Blankfield IR readings labeled on maps.
Thermal Segregation

- \( \Delta T \leq 25 \, ^\circ F \) Mild
- \( 25 < \Delta T \leq 50 \, ^\circ F \) Moderate
- \( \Delta T > 50 \, ^\circ F \) Severe

- Less Temp. Variation
- More Uniformity
- More Temp. Variation
- More Variability
Pave-IR™
for thermal profiling

- Continuous Temperature Measurement Using Infrared Sensor Bars
- Gives Paver Speed, Idle Time, Position
Pave-IR™ for thermal profiling
Coring for Density & Lab Testing
Can GPR provide a reliable estimate of mat density?
Air Coupled GPR
Dielectric Distribution Map

LOW dielectric area (estimated HIGH air voids)

HIGH dielectric area (estimated LOW air voids)
GPR Dielectric-Air Void Relationship

SR 220 - Lycoming Co. - PA Section 1

\[ y = 169.7e^{-0.651x} \]

\[ R^2 = 0.9167 \]
PERFORMANCE OF THIN OVERLAYS
Nov., 2013  
≈ 15 months after paving
Performance – SR 0022

45 months after paving

04.18.2016 08:57
Performance – SR 0022

45 months after paving
Performance – SR 0022

45 months after paving
SR 230 – Before THMAO
SR 230 – Performance

34 months after paving
SR 230 – Performance

34 months after paving
SR 220 – Performance

32 months after paving
SR 220 – Performance

32 months after paving
Skid Resistance Results
Friction Improvement

SR 0022

Average Skid Number vs. Month of Service
Constructed in July 2012

Data: Courtesy of PennDOT BOMO
Friction Improvement

SR 0230

Average Skid Number vs. Month of Service
Constructed in June 2013

Data: Courtesy of PennDOT BOMO
Friction Improvement

SR 0220
Average Skid Number vs. Month of Service
Constructed in September 2013

Data: Courtesy of PennDOT BOMO
Rutting
Rutting

average Rut Depth vs. Month of Service
SR22
constructed in July 2012

Data: Courtesy of PennDOT BOMO
Rutting
Average Rut Depth vs. Month of Service
SR230
constructed in June 2013

SR 0230

Data: Courtesy of PennDOT BOMO
Rutting

SR 0220

Average Rut Depth vs. Month of Service
SR220
Constructed in September 2013

Data: Courtesy of PennDOT BOMO
Ride Quality & Smoothness
Ride Quality (Smoothness) Improvement

SR 0022

Average IRI vs. Month of Service
SR 0022
Constructed in July 2012

Data: Courtesy of PennDOT BOMO
Ride Quality (Smoothness) Improvement

SR 0230
IRI vs. Month of Service
SR230-Seg 290 East Travel Lane
Constructed in June 2013

Data: Courtesy of PennDOT BOMO
Ride Quality (Smoothness) Improvement

SR 0220

IRI vs. Month of Service
SR220-Seg 10 North Passing Lane
Constructed in September 2013

IRI (in./mile) vs. Months from Construction

- Left WP
- Right WP

Data: Courtesy of PennDOT BOMO
Summary

- Thin Asphalt A Good Tool for Surface Treatment
- Proper Base Repair is a MUST
- Improved Ride and Friction
- Improved Ride and Friction Maintained
- Minimal Rutting Observed
Summary

- **Concerns:**
  - Rapid Mat Cooling
  - Reflection of cracks is a challenge on jointed or cracked pavement

- **Advanced Tech for Quality Control:**
  - GPR-Density results are promising
  - Thermal Imaging

- **Good Mix Lab Performance:**
  - Rutting and Moisture Resistance (HWTD)
  - Crack Resistance (Texas Overly Test)
Thank You!