NJDOT CHALLENGES ON COMPOSITE PAVEMENT

2018 NORTH EASTERN STATES MATERIALS ENGINEERS’ ASSOCIATION

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PAVEMENT DESIGN
Acknowledgement

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  Associate Professor, Rutgers University
Outline

- Basic Information of Composite Pavement
- Challenges of Composite Pavement
- Composite Pavement Rehabilitation Strategies
- Case Studies
Basic Information of Composite Pavement
COMPOSITE PAVEMENT

HMA/ASPHALT

CONCRETE
Composite Pavement Rehabilitation Goals

- Improve Pavement Condition
- Improve Ride Quality
- Improve Safety
- Extend Life
- Typically Functional Overlay – Minor Rehab
- Sometimes A Structural Overlay – Major Rehab
- Reduce Life Cycle Costs
- Increase Customer Satisfaction
  - Noise Reducing Surface(s)
Challenges of Composite Pavement
Risk of Removing HMA Overlay
Challenges of Removing HMA Overlay:

Pavement Recommendation:

Mill 3” and Pave with 3” SMA
12.5 MM Surface Course
Challenges of Removing HMA Overlay:

Core Information:

Lane 1 Core information was 5.25” to 7.75” HMA over PCC.

Lane 2 Core information was not available during design.

Lane 3 Core information was 3.5” to 19.5” HMA over PCC.
Challenges: Pavement ME Analysis for Composite Pavement

### Design Structure

<table>
<thead>
<tr>
<th>Layer type</th>
<th>Material Type</th>
<th>Thickness (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible</td>
<td>12.5-M-SMA (National Paving)</td>
<td>2.5</td>
</tr>
<tr>
<td>Flexible (existing)</td>
<td>12.5-M64 (Stavola - Bound Brook, NJ)</td>
<td>1.5</td>
</tr>
<tr>
<td>Cement_Base</td>
<td>Soil cement</td>
<td>9.0</td>
</tr>
<tr>
<td>NonStabilized</td>
<td>A-1-a</td>
<td>6.0</td>
</tr>
<tr>
<td>Subgrade</td>
<td>A-1-a</td>
<td>Semi-infinite</td>
</tr>
</tbody>
</table>

### Volumetric at Construction:

- Effective binder content (%): 10.7
- Air voids (%): 7.0

### Traffic

<table>
<thead>
<tr>
<th>Age (year)</th>
<th>Heavy Trucks (cumulative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 (initial)</td>
<td>3,500</td>
</tr>
<tr>
<td>2024 (5 years)</td>
<td>3,074,640</td>
</tr>
<tr>
<td>2029 (10 years)</td>
<td>6,247,350</td>
</tr>
</tbody>
</table>

### Design Outputs

#### Distress Prediction Summary

<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Distress @ Specified Reliability</th>
<th>Reliability (%)</th>
<th>Criterion Satisfied?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal IRI (in/mile)</td>
<td>170.00</td>
<td>97.79</td>
<td>Pass</td>
</tr>
<tr>
<td>Permanent deformation - total pavement (in)</td>
<td>0.75</td>
<td>100.00</td>
<td>Pass</td>
</tr>
<tr>
<td>AC total fatigue cracking: bottom up + reflective (% lane area)</td>
<td>25.00</td>
<td>0.00</td>
<td>Fall</td>
</tr>
<tr>
<td>AC total transverse cracking: thermal + reflective (ft/mile)</td>
<td>2500.00</td>
<td>100.00</td>
<td>Pass</td>
</tr>
<tr>
<td>AC bottom-up fatigue cracking (% lane area)</td>
<td>25.00</td>
<td>100.00</td>
<td>Pass</td>
</tr>
<tr>
<td>AC thermal cracking (ft/mile)</td>
<td>1000.00</td>
<td>100.00</td>
<td>Pass</td>
</tr>
<tr>
<td>AC top-down fatigue cracking (ft/mile)</td>
<td>2000.00</td>
<td>100.00</td>
<td>Pass</td>
</tr>
<tr>
<td>Permanent deformation - AC only (in)</td>
<td>0.25</td>
<td>100.00</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Challenges: Pavement ME Analysis for Composite Pavement

Distress Charts

IRI

- Initial IRI: 63
- 170
- 147.4
- 107.9

Total Rut Depth (Permanent Deformation)

- 0.75
- 0.44
- 0.33

AC total bottom up + reflective cracking (% lane area)

- Fatigue Cracking (%)
  - 51.96
  - 25

AC total thermal + reflective cracking (ft/mile)

- Transverse Cracking (ft/mile)
  - 2500
  - 205.57

Legend:
- Red: Threshold Value
- Dotted line: @ Specified Reliability
- Dashed line: @ 50% Reliability
Challenges: Composite Pavement

- NJDOT’s concrete/composite pavement infrastructure continuing to age and deteriorate
- PCC reconstruction costly
- Rubblization is option, but require minimum of 6 inches Overlay
- PCC rehabilitation generally not successful
- Most simple rehabilitation technique – Hot Mix Asphalt (HMA) Overlay
  - Unfortunately, high deflections at PCC joints/cracks creates excessive straining in HMA overlay
  - Most cases, cracking initiated in HMA above crack/joint in PCC (called Reflective Cracking)
Challenges: Composite Pavement

- When reflective crack reaches pavement surface
  - Affects overall integrity of pavement
    - Smoothness – intermittent cracking also affects safety
    - Pathway for water intrusion
    - Area for immediate raveling
- Little guidance on how to design HMA overlays for PCC pavements
  - HMA material/mixture selection
Modes of Reflective Cracking

- **Mode 1** – Poor Load Transfer at joint/crack results in independent movement of PCC slabs
- **Mode 2** – Excessive Vertical Bending at PCC joint/crack (Pure Tensile Straining)
- **Mode 3** – Horizontal Deflections (PCC slab expansion and contraction) due to environmental cycling
Reflective Cracking: Mode 1

- Mode 1 – Poor Load Transfer at joint/crack results in independent movement of PCC slabs
“Poor load transfer...”
“Poor load transfer...”

Mode 1: Vertical Shear Stress
“causes shear stresses in the overlay.”
“causes shear stresses in the overlay.”
“causes shear stresses in the overlay.”
“causes shear stresses in the overlay.”

Mode 1: Vertical Shear Stress
Mode 1: Vertical Shear Stress
Mode 1: Vertical Shear Stress
“Over many repeated loads...”
“Over many repeated loads...”
“reflection cracks develop.”
“reflection cracks develop.”
“reflection cracks develop.”
“reflection cracks develop.”
“reflection cracks develop.”
Reflective Cracking: Mode 2

- Mode 2 - Tensile stress at bottom of AC layer
  - Poor support
  - Weak base
  - Load Associated Problem (Traffic Loading)
“Traffic loads at the joint...”

Mode 2: Horizontal Tensile Stress due to load
“Traffic loads at the joint...”

Mode 2: Horizontal Tensile Stress due to load
“cause tensile stresses at the bottom of the overlay.”

Mode 2: Horizontal Tensile Stress due to load
“cause tensile stresses at the bottom of the overlay.”
"cause tensile stresses at the bottom of the overlay."

Mode 2: Horizontal Tensile Stress due to load
“Over many repeated loads...”

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“Over many repeated loads...”

Mode 2: Horizontal Tensile Stress due to load
“Over many repeated loads...”

Mode 2: Horizontal Tensile Stress due to load
“reflection cracks develop.”

Mode 2: Horizontal Tensile Stress due to load
“reflection cracks develop.”
“reflection cracks develop.”
Reflective Cracking: Mode 3

- Mode 3 – Horizontal Tensile Stress
  - Thermally Induced stresses
  - Magnitude depends on Slab length (or Crack spacing), 24 hour temperature change, and coefficient of thermal expansion of PCC
“Slab shrinkage under cooling temperature...”

Mode 3: Horizontal Tensile Stress due to climate
“Slab shrinkage under cooling temperature...”
“Slab shrinkage under cooling temperature...”
“causes tensile stresses in the overlay.”
“causes tensile stresses in the overlay.”
Mode 3: Horizontal Tensile Stress due to climate
Mode 3: Horizontal Tensile Stress due to climate
Mode 3: Horizontal Tensile Stress due to climate
“Over many cycles...”

Mode 3: Horizontal Tensile Stress due to climate
“Over many cycles...”

Mode 3: Horizontal Tensile Stress due to climate
“reflection cracks develop.”

Mode 3: Horizontal Tensile Stress due to climate
“reflection cracks develop.”
Composite Pavement Rehabilitation Strategies
Composite Pavement Rehabilitation Strategies

Full Depth Repairs before Milling
- Full Depth Concrete Pavement Repair, HMA (453006)
- Hot Mix Asphalt Pavement Repair (401021)

Mill and Overlay with Better Mixes
- AROGFC
- Polymer modified HMA
- HPTO
- SMA
- Reflective Crack Relief Interlayer (RCRI) or Strata
- Binder Rich Intermediate Course, 4.75 MM
Full Depth Repair with HMA (typically before milling)
Mill & Overlay with HMA

Surface Milling
Why premium mixes?

Better fatigue life
Better durability
Increased skid/safety
Reduced noise
Increased customer satisfaction
Better reflective crack resistance
Asphalt Rubber Open Graded Friction Course
High Performance Thin Overlay
SMA 12.5mm Surface Course
Case Study-Route
202
Rt.202 SB (MP 13.4-17.03) – Maintenance Resurfacing Contract No. 268 (2007)

Visual Survey of JRC Pavement

Rehab. Design of Asphalt Outside Shoulder
  ◦ Roadway Excavation
  ◦ Pave with 3” min. & var. HMA 25M64 Base Course
  ◦ Pave with 4” (2 lifts) of high quality HMA

Full Depth Concrete Repairs with Very Early Strength Concrete

Overlay Design with 4” (2 lifts) of high quality HMA

3 test sections and 1 control section

BEFORE REHAB

SDI = 2.07

Ride Quality
- MP 13.4-14.75, IRI=197.2
- MP 14.75-15.25, IRI=154.7
- MP 15.25-15.75, IRI=143.8
- MP 15.75-17.03, IRI=151.5
- Ride Quality for the project, IRI=168.6

AFTER REHAB

SDI = 5.0

Ride Quality
- MP 13.4-14.75, IRI=88.3
- MP 14.75-15.25, IRI=78.0
- MP 15.25-15.75, IRI=77.7
- MP 15.75-17.03, IRI=75.0

Ride Quality for the project, IRI=80.4

BEFORE REHAB

AFTER REHAB

IRI Versus Year

- 13.4 to 14.7
- 14.7 to 15.7
- 15.7 to 17

![Graph showing IRI Versus Year from 2006 to 2016](image-url)
Case Study-Route 70
Rt. 70 (MP 8.61-12.06) - Maintenance Roadway Repair Contract No. 327 (2007)
Rt.70 (MP8.61-12.06)- Maintenance Roadway Repair Contract No. 327 (2007)

Located high deflection joints (> 15 mils deflection) with FWD during construction

Failed joints were successfully (reduced deflection < 10 mils) grouted with HDP by Uretek

Full Depth Repairs with HMA were performed on high severity joints/areas
Rt.70 (MP8.61-12.06)- Maintenance Roadway Repair
Contract No. 327 (2007)

<table>
<thead>
<tr>
<th>BEFORE REHAB</th>
<th>AFTER REHAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDI = 1.56</td>
<td>SDI = 5</td>
</tr>
<tr>
<td>Ride Quality IRI = 157</td>
<td>Ride Quality IRI = 94</td>
</tr>
</tbody>
</table>
Rt.70 (MP8.61-12.06) - Maintenance Roadway Repair
Contract No. 327 (2007)

BEFORE REHAB

AFTER REHAB
Rt. 70 (MP8.61-12.06) - Maintenance Roadway Repair
Contract No. 327 (2007)

IRI Versus Year

Case Study-Route
130
Route 130 Main St to Rt 1
Resurfacing -2016

Limit of the project:
MP 72.68 to MP 74.12
MP 76.03 to MP 80.97
MP 81.59 to MP 83.58

Total Lane Miles of the project: 33.56

Prime Contractor: Trap Rock Industries, LLC

Letting Date: June 23, 2015

Project Completed: June 17, 2016
Visual Survey of Composite Pavement

Cores performed to establish proper milling depth

Full Depth Repair areas identified by visual survey during final design

Calculated approximately 20 million ESAL’s

Overlay Design consisted of milling 3” depth and resurfacing with:

- 2” Stone Matrix Asphalt 12.5 MM Surface Course
- 1” Binder Rich Intermediate Course, 4.75 MM
# BRIC - SPECIFICATION

<table>
<thead>
<tr>
<th>Sieve Sizes</th>
<th>Percent Passing(^1)</th>
<th>Production Control Tolerances(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
<td>100</td>
<td>±0%</td>
</tr>
<tr>
<td>No. 4</td>
<td>90-100</td>
<td>±4%</td>
</tr>
<tr>
<td>No. 8</td>
<td>55-90</td>
<td>±4%</td>
</tr>
<tr>
<td>No. 30</td>
<td>20-55</td>
<td>±4%</td>
</tr>
<tr>
<td>No. 200</td>
<td>4-10</td>
<td>±2%</td>
</tr>
<tr>
<td>Asphalt Binder Content (Ignition Oven)</td>
<td>7.4 % minimum</td>
<td>±0.40%</td>
</tr>
<tr>
<td>Maximum Lift Thickness</td>
<td>1.5 inch</td>
<td></td>
</tr>
</tbody>
</table>

1. Aggregate percent passing to be determined based on dry aggregate weight.
2. Production tolerances are for the approved JMF and may fall outside of the wide band gradation limits.
## Table 902.09.03-2 Volumetric Requirements for Design and Control of BRIC

<table>
<thead>
<tr>
<th></th>
<th>Required Density (% of Max Sp. Gr.)</th>
<th>Voids in Mineral Aggregate (VMA)</th>
<th>Dust to Binder Ratio</th>
<th>Draindown AASHTO T 305</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Requirements</strong></td>
<td>@ ( N_{\text{des}} ) (50 gyrations)</td>
<td>( \leq 99.0 )</td>
<td>( \geq 18.0 % )</td>
<td>0.6 – 1.2</td>
</tr>
<tr>
<td><strong>Control Requirements</strong></td>
<td>@ ( N_{\text{max}} ) (100 gyrations)</td>
<td>( \leq 99.0 )</td>
<td>( \geq 18.0 % )</td>
<td>0.6 – 1.3</td>
</tr>
</tbody>
</table>
# BRIC - SPECIFICATION

## Table 902.09.03-3 Mix Design Performance Testing Requirements for BRIC

<table>
<thead>
<tr>
<th>Test</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Pavement Analyzer (AASHTO T 340)</td>
<td>&lt; 6 mm@ 8,000 loading cycles</td>
</tr>
<tr>
<td>Overlay Tester (NJDOT B-10)</td>
<td>&gt;700 cycles</td>
</tr>
</tbody>
</table>

## Table 902.09.03-4 Production Performance Testing Requirements for BRIC

<table>
<thead>
<tr>
<th>Test</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Pavement Analyzer (AASHTO T 340)</td>
<td>&lt; 7 mm@ 8,000 loading cycles</td>
</tr>
<tr>
<td>Overlay Tester (NJDOT B-10)</td>
<td>&gt; 650 cycles</td>
</tr>
</tbody>
</table>
BRIC – Performance Analysis

- Evaluated changes in SDI to evaluate performance of BRIC on New Jersey pavement sections
- BRIC analysis difficult as always overlaid with a surface course
  - Analysis looked at performance with and without BRIC
  - Analysis looked at different surface courses
- Compared performance life for different scenarios
  - All data averaged for same “system” compared
- An SDI value of 2.4 is a trigger for rehabilitation
BRIC – Performance Analysis

Time After Construction (Years)

SDI

9.5mm SMA with BRIC
12.5mm SMA with BRIC
9.5mm SMA with 12.5M64
12.5mm SMA with 12.5M64
12.5mm Surface with BRIC
9.5 or 12.5 Surface – No BRIC
BRIC – In- Service Life Evaluation

- Performance of BRIC material highly dependent on the surface course overlaying the BRIC
  - SMA overlays performed best
    - Still “flexible” enough to withstand residual vertical straining
  - Dense graded overlays performed the worst
    - Too “stiff” – can not withstand residual flexing
- SMA alone provides a good alternative
  - Not as good performance but could be beneficial for areas of “good” concrete conditions
Route 130 Main St to Rt 1
Resurfacing -2016

BEFORE REHAB
SDI = 2.4
Ride Quality IRI = 178

AFTER REHAB
SDI = 5
Ride Quality IRI = 65
Route 130 Main St to Rt 1
Resurfacing -2016
QUESTIONS?

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Thanks