New Jersey’s Innovative Approach for I295 Reconstruction

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Robert Sauber, NJDOT (Retired)

NEAUPG
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Project Summary

- Reconstruction of I295 consisting of old PCC
  - Rubblization used for speed and cost

- Constructed between 1972 to 1974 and reached terminal serviceability over a decade ago

- Magnitude of problem and lack of funding prevented earlier actions
Project Specifics

- **Project Limits**
  - MP 45 to 57.3
  - 4’ inside and 12’ outside shoulders = total paved width of 52 ft

- 21 structures within project limits resulting in 20 undercut locations to maintain underclearance

- NJDOT agreed to limit full closure period to 59 days during summer recess when traffic was “lower”
Initial Pavement Design

- Initial design conducted with 1993 AASHTO Pavement Design
  - 12” of HMA over rubblized PCC
  - Rubblized PCC and subgrade modulus determined using FWD data from similar rubblized PCC project
Problem with Design Thickness

- For 12” thickness, required 2400 linear feet (+ width of bridge) of PCC removal and box outs for each structure
  - Total 16,000 ft or 3 miles of removal and replacement
- From past experience, box outs around rubblized PCC problematic and some other necessary box out areas required 2 ft of removal (clay subgrade needed removal)
Typical Box Out
Different Design Approach

- NJDOT could save a lot of time and money from box cut and under cuts if total HMA height 8 inches.
- Looked at pavement response in MEPDG (typical NJ HMA materials) and noted bottom-up cracking could be potential issue at 8 inches thick
  - Slight HMA rutting
- NJDOT decided on perpetual pavement design with “rich” bottom layer
Change in Design Methodology

- Evaluated maximum tensile strain with 8” HMA over rubblized PCC
  - Used JULEA software – same in MEPDG
  - Resulted in 82 micro-strains (rounded up to 100 microstrains to be conservative)

- Final design pavement cross-section
  - 2” SMA Surface
  - 3” 19M76 Intermediate Course
  - 3” of NJDOT Bottom Rich Base Course
    - Designed specifically for this project
    - Utilized Endurance Limit concept
Endurance Limit

- Used methodology in NCHRP Report 646
- Conduct flexural beam fatigue at 400 and 800ms
  - 3 samples each
- Use 95% confidence interval with a selected # of repetitions
What Mix to Use?

- With performance evaluation in place, Rutgers University began testing plant produced mixes in Fall 2009
- Different base course mixes were evaluated – none were successful
  - Must achieve an Endurance Limit greater than 100 micro-strains at 100,000,000 cycles (NCHRP 9-38 had used 50,000,000 cycles)
- Required design of new mixture
  - Bottom Rich Base Course - BRBC
Endurance Limit – 19L64

Endurance Limit (Tensile Strain) for 100,000,000 Cycles

19L64 = 59 micro-strains (FAILED)
19L64 + 25% RAP = 47 micro-strains (FAILED)
Endurance Limit – 19M76

Calculated Endurance Limit for 100,000,000 Cycles

19M76 + 25% RAP = 68 Micro-strains (FAILED)

*Determined at a 95% Confidence Level

Fatigue Life (cycles)

100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100

Micro-strain

100
1,000
10,000
10,000

19M76 + 25% RAP
# BRBC Specification

## Table 902.07.03-1 BRBC Grading of Total Aggregate

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing by Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>minimum</td>
</tr>
<tr>
<td>1”</td>
<td>100</td>
</tr>
<tr>
<td>¾”</td>
<td>90</td>
</tr>
<tr>
<td>½”</td>
<td>--</td>
</tr>
<tr>
<td>#8</td>
<td>23</td>
</tr>
<tr>
<td>#200</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Minimum Percent Asphalt Binder by Mass of Total Mix: 5.0%

## Table 902.07.03-2 Volumetric Requirements for Design and Control of BRBC

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Required Density (% of Max Sp. Gr.) @ N&lt;sub&gt;det&lt;/sub&gt; (50 gyrations)</th>
<th>Voids Filled with Asphalt (VFA)</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>Design Requirements</td>
<td>96.5</td>
<td>70 - 80</td>
<td>≥ 13.5 %</td>
<td>0.6 – 1.2</td>
<td>≤ 0.1 %</td>
</tr>
<tr>
<td>Control Requirements</td>
<td>95.5 – 97.5</td>
<td>70 - 80</td>
<td>≥ 13.5 %</td>
<td>0.6 – 1.3</td>
<td>≤ 0.1 %</td>
</tr>
</tbody>
</table>

## Table 902.07.03-3 Performance Testing Requirements for BRBC

<table>
<thead>
<tr>
<th>Test</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Pavement Analyzer (AASHTO TP 63)</td>
<td>&lt; 5 mm@ 8,000 loading cycles</td>
</tr>
<tr>
<td>Flexural Fatigue Life of HMA (AASHTO T 321)</td>
<td>&gt; 100,000,000 cycles@ 100 microstrains</td>
</tr>
</tbody>
</table>
- No RAP
- No natural sand
- Binder
  - PG76-28 (NJDOT Spec)
  - RTFO Elastic Recovery > 60% @ 25°C (AASHTO T301)
- Performance Specification
  - APA and Flexural Beam
    - Must supply for mix design verification and control (1st Lot and every 5th Lot after)
Required BRBC Protocol

- Conduct volumetric mix design
- Supply loose mix for performance testing (fatigue and rutting)
- If pass, conduct test strip
  - Loose mix sampled and again tested (fatigue and APA)
- If pass, allowed to produce for project
  - 2 suppliers had passing designs
  - 1 supplier had failing design
General Bid Costs

- Final bid costs of BRBC equal or less than that of SMA on job

<table>
<thead>
<tr>
<th>LINE NO / ITEM CODE / ALT</th>
<th>QUANTITY</th>
<th>ITEM DESCRIPTION</th>
<th>UNIT PRICE</th>
<th>AMOUNT</th>
<th>UNIT PRICE</th>
<th>AMOUNT</th>
<th>UNIT PRICE</th>
<th>AMOUNT</th>
<th>UNIT PRICE</th>
<th>AMOUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0078 4080003P</td>
<td>177626.000 T</td>
<td>BOTTOM RICH BASE COURSE</td>
<td>85.75000</td>
<td>15231601.00</td>
<td>90.90000</td>
<td>16146385.20</td>
<td>91.20000</td>
<td>16199673.60</td>
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<tr>
<td>0079 401099M</td>
<td>155975.000 T</td>
<td>HOT MIX ASPHALT 25 M 64 BASE COURSE</td>
<td>54.75000</td>
<td>8559331.25</td>
<td>62.35000</td>
<td>9725041.25</td>
<td>63.40000</td>
<td>9888815.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0080 401108M</td>
<td>950.000 U</td>
<td>CORE SAMPLES, HOT MIX ASPHALT</td>
<td>72.85000</td>
<td>69207.50</td>
<td>500.00000</td>
<td>475000.00</td>
<td>112.68000</td>
<td>107046.00</td>
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<tr>
<td>0081 400006M</td>
<td>82228.000 T</td>
<td>STONE MATRIX ASPHALT 12.5 MM SURFACE COURSE</td>
<td>97.75000</td>
<td>8037787.00</td>
<td>82.00000</td>
<td>6742696.00</td>
<td>97.53000</td>
<td>8019696.84</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Endurance Limit of BRBC

Calculated Endurance Limit for 100,000,000 Cycles

Lot #1 BRBC = 126 Micro-strains (PASS)

* Determined at a 95% Confidence Level

Fatigue Life (cycles)

- 100,000,000
- 10,000,000
- 1,000,000
- 100,000
- 10,000
- 1,000
- 100
- 10

Micro-strain

- 10,000
- 1,000
- 100

Winslow Lot #1 BRBC

10,000
QC Test Results - Fatigue
QC Results - APA

< 5mm APA Rutting Criteria
QC Results – Flow Number

NCHRP 9-33 Test Parameters Used

Flow Number (cycles)

<table>
<thead>
<tr>
<th>Lot</th>
<th>Flow Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>1,579</td>
</tr>
<tr>
<td>#2</td>
<td>1,659</td>
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<tr>
<td>#3</td>
<td>1,288</td>
</tr>
<tr>
<td>#4</td>
<td>407</td>
</tr>
<tr>
<td>#5</td>
<td>1,507</td>
</tr>
<tr>
<td>#6</td>
<td>499</td>
</tr>
<tr>
<td>#7</td>
<td>1,499</td>
</tr>
<tr>
<td>#8</td>
<td>1,242</td>
</tr>
<tr>
<td>#9</td>
<td>1,074</td>
</tr>
<tr>
<td>#10</td>
<td>1,063</td>
</tr>
<tr>
<td>#11</td>
<td>1,060</td>
</tr>
<tr>
<td>#12</td>
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<td>#16</td>
<td>1,074</td>
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<tr>
<td>#17</td>
<td>1,074</td>
</tr>
<tr>
<td>#18</td>
<td>1,074</td>
</tr>
<tr>
<td>#19</td>
<td>1,074</td>
</tr>
<tr>
<td>#20</td>
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<td>1,074</td>
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Final Project Quantities

- As of July, total project cost: $79 million (significantly lower than engineers estimate)
  - BRBC saved $5.8 million ($10 million in material offset by $4.2 million increased premium mix cost)
- BRBC = 177,628 T
- 19M76 Intermediate = 127,078 T
- 12.5 SMA = 82,228 T
Other Innovative HMA on I295

Bridge Deck Wearing Course (BDWC)
Water Proof Wearing Course Mix

- Mix designed to provide a thin, rut and fatigue resistance mixture for bridge deck overlays
- Can be placed on bridge deck without vibratory
- Asphalt mixture must also be “water proof” or low permeability
- “Sealing older bridge structures”
Water-Proof Wearing Course

Mix design specifications

- \( N_{\text{design}} = 50 \) gyrations
- Air voids @ \( N_{\text{design}} = 1\% \)
  - Low permeability!
- Requires a highly polymer-modified binder (but no binder grade specified)
  - SemMaterials Product: 76-BD
  - Rosphalt 50
- No natural sands – stone or manufactured sands
- Mixture performance of mix design will dictate acceptance
## Water Proof Wearing Course - Specifications

<table>
<thead>
<tr>
<th>Table 555.02.01-1 Job Mix Formula Requirements for BDWSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieve Size</td>
</tr>
<tr>
<td>½”</td>
</tr>
<tr>
<td>3/8”</td>
</tr>
<tr>
<td>#4</td>
</tr>
<tr>
<td>#8</td>
</tr>
<tr>
<td>#16</td>
</tr>
<tr>
<td>#30</td>
</tr>
<tr>
<td>#50</td>
</tr>
<tr>
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</tr>
<tr>
<td>#200</td>
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<tr>
<td>Minimum Percent Asphalt Binder by Mass of Total Mix</td>
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Water Proof Wearing Course - Specifications

Table 555.02.01-2 Volumetric Requirements for Design and Control of BDWSC

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<tr>
<td><strong>Design Requirements</strong></td>
<td>$N_{des} (50 \text{ gyrations})$</td>
<td>99</td>
<td>$\geq 18.0 %$</td>
<td>0.3 – 0.9</td>
<td>$\leq 0.1 %$</td>
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<tr>
<td><strong>Control Requirements</strong></td>
<td>98 - 100</td>
<td>90 - 100</td>
<td>$\geq 18.0 %$</td>
<td>0.3 – 0.9</td>
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Table 555.02.01-3 Performance Testing Requirements for BDWSC

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<td>APA @ 8,000 loading cycles (AASHTO TP 63)</td>
<td>&lt; 3 mm</td>
</tr>
<tr>
<td>Flexural Fatigue Life (AASHTO T 321)</td>
<td>&gt; 100,000 cycles</td>
</tr>
</tbody>
</table>

Beam Fatigue Run at 15C, 1500 micro-strains
Water Proof Wearing Course – Design Acceptance

1. Perform volumetric design and NJDOT verification
2. Supply Rutgers University loose mix for performance testing
3. Produce mix through plant and pave test strip off site
4. Sample during production and supply Rutgers University loose mix for performance testing
1st Project – Rt 87 Absecon Inlet Bridge

- A.E. Stone produced first BDWC mix
- 1900 tons placed and compacted to a 2-inch thickness in 2 days
- Core densities all between 2 to 4% air voids
Rt 87 Absecon Inlet Bridge – 2008 NAPA Quality in Construction Award Winner!

for Non-Typical Asphalt Project
Summary

- NJDOT utilized a performance-based approach to design and build a “perpetual pavement” out of an aging I295 PCC pavement
- Consisted of developing BRBC mix – but saved NJDOT almost $6M
  - Performance testing required for acceptance
- BDWC used to “preserve” bridge decks
Thank you for your time!

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