
Presented By:

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Where It Started!

Multi-Year Status of State Highway System

% of System Lane Miles

Data Collection Cycle

Source: NJDOT Pavement Management System
NJ’s Reasoning for BMD
("Performance Based Mix Design")

- **Existing asphalt mixtures**
  - Early 125 and 100 $N_{des}$ mixes were dry
  - Significant cracking issues
    - Flexible (top-down); Composite (transverse)

- **Traffic conditions**
  - 29% increase from 1990 to 2006
  - 30% projected from 2006 to 2025
    - 99 billion miles traveled

- **Climate conditions**
  - Precipitation: 43 to 48 inches per year
  - Air Temperature: > 30 days over 90F; > 80 days less than 32F

- **Pavement conditions**
  - Over 60% of NJDOT pavements are composite
NJDOT began utilizing performance testing in mixture design in 2006
- BMD Approach A
  - Asphalt content below, at, and above volumetric optimum
  - Different binder grades
Early NJ BMD Research (2006)

- Rutting (AASHTO T340)
  - As binder content increased, rutting increased
  - But magnitude lessened when binder grade improved

- Cracking (AASHTO T321 & NJDOT B-10)
  - At below volumetric optimum and at optimum, similar fatigue properties were observed
  - At above optimum, significant improved
Early NJ BMD Research (2006)

**600 µs, 15°C**

- PG64-22: 5,526
- PG64-22: 10,992
- PG64-22: 25,392
- PG76-22: 4,782
- PG76-22: 16,159
- PG76-22: 33,607
- PG82-22: 5,832
- PG82-22: 14,128
- PG82-22: 42,142

**0.025 in, 25°C**

- PG64-22: 1% Below 12, 1% Above 109, Optimum 2,383, PG76-22: 1% Below 155, Optimum 391
- PG64-22: 1% Below 40, Optimum 533, PG76-22: 1% Below > 5,000, Optimum > 5,000
- PG82-22: 1% Below > 5,000, Optimum > 5,000

**Flexural Fatigue Life at 600 Micro-strains (cycles)**

**Overlay Tester Fatigue Life (cycles)**
Have we been doing asphalt mixture design incorrectly for modified asphalt binders?

NCHRP 9-9A

- Hveem – less emphasis on sample air voids and more emphasis on stability but recognized importance of air voids on durability.
- Marshall (USACE) – calibrated laboratory compaction effort to densification that occurred with accelerated loading sections
  - General approach taken today where field densification levels are “calibrated” to gyrations
    - But what if we have binders that are more resistant to field densification than others?
**Wheelpath Densification**

- **Wheelpath Densification**
  - Mix design assumes we want to optimize asphalt content to provide stable and durable mix after densification has taken place (i.e. ≈ 4% air voids)
  - Example: NCHRP 9-9A (Nebraska & Missouri)

<table>
<thead>
<tr>
<th>State</th>
<th>Initial AV%</th>
<th>4 Yr ΔAV%</th>
<th>4 Yr MESAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nebraska</td>
<td>9.0</td>
<td>-4.8%</td>
<td>0.068</td>
</tr>
<tr>
<td>Missouri</td>
<td>6.5</td>
<td>-2.0%</td>
<td>8.4</td>
</tr>
</tbody>
</table>

Unmodified PMA
**Wheelpath Densification**

- **NCHRP 9-9A Data**
  - Pavements with neat binders consolidated at a rate 6 times more than modified binders (40 projects)
  - According to volumetric mix design rules, if air voids above 4% after compaction, additional asphalt binder added
    - For same aggregate gradation; lower gyration level ≈ increased AC

(Prowell & Brown, 2007)
NJDOT Efforts
NJDOT – Field Performance Comparisons

- Change in Mix Design Practice
  - Clear that performance could be improved if using modified binders with mix design procedures/criteria to encourage higher asphalt contents

- Implementation
  - Started in 2007 with performance criteria initially developed using mix testing database and “engineering judgement”
    - Tackled one issue at a time

\[
SDI = SDI_0 - e^{-\frac{(A-B \cdot C) \cdot \ln(1+\frac{1}{Age})}{Age}}
\]
NJDOT High Performance Thin Overlay (HPTO)

- **Volumetric**
  - Design AV = 4%
  - \( N_{des} = 75 \)
  - VMA ≥ 14%
  - VFA 65 – 78%
  - RAP ≤ 15%
  - No performance test requirements

- **HPTO**
  - Design AV = 3.5%
  - \( N_{des} = 50 \)
  - VMA ≥ 18%
  - Min AC% ≥ 7%
  - No RAP
  - APA Rutting ≤ 4.0mm
  - Overlay Tester ≥ 600 cycles

1” Thick Lift with or without milling
NJDOT High Performance Thin Overlay (HPTO)

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*Improvement of > 5 Years of Service Life*
Stone Matrix Asphalt (SMA) with Bituminous Rich Intermediate Course (BRIC) for Composite Pavements

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  - Design AV = 4%
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  - $N_{des} = 75$
  - VMA ≥ 17%
  - Min. AC% ≥ 6%
  - No RAP

- **BRIC**

Over 60% of NJDOT Pavements are Composite
Combining modified asphalt mixtures as system to mitigate reflective cracking

### Volumetric
- Design AV = 4%
- $N_{\text{des}} = 75$
- VMA ≥ 14%
- VFA 65 – 78%
- RAP ≤ 15%
- No performance test requirements

### SMA
- Design AV = 2.5%
- $N_{\text{des}} = 50$
- VMA ≥ 18%
- Min AC% ≥ 7%
- No RAP
- APA Rutting ≤ 6.0mm
- Overlay Tester ≥ 700 cycles

### BRIC
- Design AV = 4%
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**Improvement of > 10 Years of Service Life**
High Recycled Asphalt Pavement (HRAP) Mixtures

- **Volumetric**
  - Design AV = 4%
  - $N_{\text{des}} = 75$
  - VMA ≥ 14%
  - VFA 65 – 78%
  - RAP ≤ 15%
  - No performance test requirements

- **HRAP**
  - Design AV = 4%
  - $N_{\text{des}} = 75$
  - VMA ≥ 1% over Volumetric
  - VFA 65 – 85%
  - Unlimited RAP%
  - Modified binders, WMA, Recycling Agents

**Performance criteria based on 0% RAP mix**

<table>
<thead>
<tr>
<th>Test</th>
<th>Surface Course</th>
<th>Intermediate Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>APA @ 8,000 loading cycles (AASHTO T 340)</td>
<td>PG 64-22</td>
<td>PG 76-22</td>
</tr>
<tr>
<td></td>
<td>&lt; 7 mm</td>
<td>&lt; 4 mm</td>
</tr>
<tr>
<td></td>
<td>&lt; 7 mm</td>
<td>&lt; 4 mm</td>
</tr>
<tr>
<td>Overlay Tester (NJDOT B-10)</td>
<td>&gt; 200 cycles</td>
<td>&gt; 275 cycles</td>
</tr>
<tr>
<td></td>
<td>&gt; 100 cycles</td>
<td>&gt; 150 cycles</td>
</tr>
</tbody>
</table>
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Addition of RAP reduces elastomeric properties. Need to increase VBE to include more virgin liquid. Compensates for lack of RAP binder transfer to virgin aggregate.
High Recycled Asphalt Pavement (HRAP) Mixtures

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Only 3 projects with significant field performance, but projected 5 to 8 years benefit

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Aging concrete pavements, when applicable, rubblized
Utilized as base aggregate course for perpetual pavement design

- Option #1
  - Design and construct the pavement to achieve a high stiffness, resulting in a pavement structure with minimal deflections/strains
    - Traditionally done with excessive thickness and cement treated base/subbase and subgrades

- Option #2
  - Design/construct the asphalt materials, especially the base course, to be strain tolerant (i.e. – design the asphalt material to bend without cracking under resultant tensile strains)
Evaluated maximum tensile strain with selected HMA thickness over rubblized PCC
- Used JULEA software – same in MEPDG
- 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
  - Designing HMA to meet pavement performance needs – “Role Reversal”
Bituminous Rich Base Course (BRBC)

- **Volumetric**
  - Design AV = 4%
  - $N_{\text{des}} = 75$
  - VMA ≥ 13%
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  - RAP ≤ 25%
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- **BRBC**
  - Design AV = 3.5%
  - $N_{\text{des}} = 50$
  - VMA ≥ 13.5%
  - No RAP
  - PG76-28
  - APA Rutting ≤ 5.0mm
  - Flexural Beam Fatigue (Based on project needs)

Example: NJ I295, MP45 to 57.3; 23 Overpass Structures Requiring Undercutting
Bituminous Rich Base Course (BRBC)

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  - Design AV = 4%
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**Project Saved:**
- Over 170,000 tons HMA
- Over 2700 round trips of delivery trucks
- Approximately $7 million
Bituminous Rich Base Course (BRBC)

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Example: NJ I295, MP45 to 57.3
After 10 years, 2022 saw 1st Pavement Preservation treatment
More aggressive design/construction on NJ Rt 70 through conservation preserve
- Greatly limited overlay thickness due to runoff regulations
- Completed in 2020 and performing very well

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMA</td>
<td>2&quot;</td>
</tr>
<tr>
<td>BRBC</td>
<td>3&quot;</td>
</tr>
<tr>
<td>Rubblized PCC</td>
<td>8&quot;</td>
</tr>
<tr>
<td>Non-stabilized Subbase (A-2-4)</td>
<td>12&quot;</td>
</tr>
<tr>
<td>Non-stabilized Subgrade (A-2-4)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Data</th>
<th>Sample ID</th>
<th>Micro-strain</th>
<th>Fatigue Life (NR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#12</td>
<td>400</td>
<td>42,514,195</td>
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<tr>
<td></td>
<td>#14</td>
<td>400</td>
<td>33,332,300</td>
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<td></td>
<td>#15</td>
<td>400</td>
<td>31,930,795</td>
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<tr>
<td></td>
<td>#16</td>
<td>800</td>
<td>422,485</td>
</tr>
<tr>
<td></td>
<td>#17</td>
<td>800</td>
<td>292,576</td>
</tr>
</tbody>
</table>

\[ y = 2.73777x + 24e^{-1.79460x} \]
Implementation of BMD (Approach A) in NJ has:
- Resulted in improved field performance
  - Increase 5 to 10 years of service life!
- The increase service life provides;
  - A more sustainable system
  - Allocate $ sooner for preserving Good pavements
  - Allocate $ rehab/reconstruct Average to Poor

Where is it going?
Where It’s Going!

Multi-Year Status of State Highway System

Data Collection Cycle

% of System Lane Miles

Source: NJDOT Pavement Management System
As Ted Lasso reminded us..  
“Be curious, not judgmental...”

Thank you for your time!

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