Building Asphalt Pavements that Perform

GERRY HUBER

HERITAGE RESEARCH GROUP
Primary Cause of Death (Interstate)

- Rutting
- Fatigue Cracking
- Low Temperature Cracking
- Durability (raveling, block cracking, stripping)
- Other
Marshall Mix Design
1980s and early 90s
- 12 years
  - 6% air void design
  - 30 to 40% natural sand
  - 10 to 12% in-place air voids

Main Cause of Death
- Cracking
- Rutting
Superpave Mix Design
- 17 years
  - 4% air voids
  - 10 to 15% natural sand
  - Volumetric acceptance
  - 7 to 8% in-place air voids

Main Cause of Death
- Not stripping
- Not rutting
- Some cracking
- Some longitudinal joints
Building Pavements to Perform

- **Project 1**
  - Existing JCP with HMA Overlay
  - Remove overlay by milling
  - Crack and Seat Concrete
  - Overlay with 5.5 inches HMA
Project 1 Current Condition (2012)

- **EB**
  - Some delamination in limited area (about 10% length of outside driving lane)
  - Some cracking and deterioration

- **Westbound**
  - Some cracking and deterioration
Project 1 EB

- Typical
Project 1 Westbound

- Typical
Rut Depth Project 1 Westbound

Left Wheel Path

Right Wheel Path
Project 1 Westbound Measured IRI

Project 1 (0.1 mile lengths)
- Mean = 62 in/mi
- 90% reliability = 80 in/mi
Building Pavements to Perform

- **Project 2**
  - Existing JCP with HMA Overlay
  - Mill to remove overlay
  - Rubblize Concrete Pavement
  - Overlay with 12 inches HMA
Project 2 Current Condition (2012)

- All four lanes (age 14 years)
- Almost no distress
- Smoothness about 25 in/mi
Project 2 NB (2012 typical)

- Paved 1998
Project 2 SB (2012 typical)

- Paved 1998
Project 2 Current Condition (2012)

- Southbound
  - Some cracking and deterioration

- Northbound
  - Some cracking and deterioration
- Mean = 29 in/mi
- 90% reliability = 36 in/mi
## Pavement Condition at Age 14 years

<table>
<thead>
<tr>
<th>Project</th>
<th>Project 1 EB</th>
<th>Project 1 WB</th>
<th>Project 2 SB</th>
<th>Project 2 NB</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRI Mean</td>
<td>71</td>
<td>62</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>90th Percentile</td>
<td>100</td>
<td>80</td>
<td>36</td>
<td>38</td>
</tr>
<tr>
<td>Rut Mean</td>
<td>0.10</td>
<td>0.11</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>90th Percentile</td>
<td>0.16</td>
<td>0.19</td>
<td>0.13</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Keys to Good Performance

- Design
  - Adequate asphalt binder
- Production (PWL)
  - Air voids acceptance
  - VMA (asphalt binder content) acceptance
- Placement (PWL)
  - Segregation
  - Density
  - Joints
Optimizing Laboratory Mixture Design as it Relates to Field Compaction

John E. Haddock
NCAUPG Meeting
23 January 2013
St. Louis, MO
NCAT Study (Report 03-02, Mallick et al.)

$y = 0.3216e^{0.8427x}$

$R^2 = 0.391$
Concept

- Low field air voids improves durability
- Requires changing mixture design process
- Keep effective binder content (volume) the same
- Design at 5% and compact to 5%
  - Keep the voids at 5% (reduce traffic densification)
Perform Three Mix Designs

- Two 9.5 mixtures
  - 3-10 million ESALs
  - 10-30 million ESALs
- One 19.0-mm mixture
  - 10-30 million ESALs
- 100 gyration mixtures
  - Dolomite
  - Limestone
  - Blast furnace slag
  - PG 64-22
Approach

- Adjust gradation to achieve 5% voids at different gyrations
  - 70, 50 and 30 gyrations
  - Maintain effective binder content in 5% air void mixtures
  - Bailey method used to guide adjustments
## Experimental Matrix

<table>
<thead>
<tr>
<th>Traffic (ESAL)</th>
<th>No. of Gyrations</th>
<th>Mixture Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-10 million</td>
<td>30</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>x</td>
</tr>
<tr>
<td>10-30 million</td>
<td>30</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>x</td>
</tr>
</tbody>
</table>
## 19.0-mm Mixture Designs

<table>
<thead>
<tr>
<th></th>
<th>Trial Number</th>
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<tbody>
<tr>
<td></td>
<td>N100</td>
</tr>
<tr>
<td>$P_b$, %</td>
<td>4.7</td>
</tr>
<tr>
<td>$P_{be}$, %</td>
<td>4.1</td>
</tr>
<tr>
<td>$V_a$, %</td>
<td>4.0</td>
</tr>
<tr>
<td>VMA, %</td>
<td>13.6</td>
</tr>
<tr>
<td>VFA, %</td>
<td>70.7</td>
</tr>
</tbody>
</table>
Mixture Gradations

Percent Passing

Sieve Size Raised to the 0.45 Power, mm

- N100
- N70
- N50
- N30
Approach

- Test mechanical properties of mixtures
  - Same (or better) mechanical properties in the 5% air void mixtures
  - Do not sacrifice rutting resistance for higher density
  - Test 100 gyration mixtures at 7% and others at 5% air voids
  - Determine number of gyrations to achieve 5% air voids and similar (or better) mechanical properties
Testing

- Dynamic modulus test
  - Stiffness
  - Rutting
  - Fatigue cracking
- Flow number test
  - Rutting
Dynamic Modulus Results

Modulus, MPa vs. Reduced Frequency, Hz

N100  N70  N50  N30
Dynamic Modulus @ 50°C

E* @ 25 Hz

Number of Gyrations

E* @ 50°C

0 20 40 60 80 100 120

0 200 400 600 800 1000 1200 1400 1600 1800 2000
## Flow Number Results

<table>
<thead>
<tr>
<th>Gyrations</th>
<th>Average Flow Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>162</td>
</tr>
<tr>
<td>70</td>
<td>386</td>
</tr>
<tr>
<td>50</td>
<td>348</td>
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<tr>
<td>30</td>
<td>185</td>
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</tbody>
</table>
Summary

- Design HMA at 5% air voids
- Construct to 5% air voids
- Rut resistance improved
- Stiffness improved
- Durability improved
- Pavement life improved