BMD Case Studies and Ongoing Research

Balanced Mix Design

“Hot” Topic

Moving Target
Presentation Outline

- Industry case study
- NCAT Test Track experiments
- State research studies

Cargill Case Study

- Two BMD surface mixes
  - Control: 30% RAP, PG 64-22
  - Experimental: 45% RAP, PG 64-22, rejuvenator (dosed to provide similar performance as the control mix)
- Virginia DOT provisional specification on BMD
  - Rutting: APA rut depth $\leq$ 8.0 mm
  - Cracking: IDEAL-CT$_{index} \geq 70$
  - Overall durability: Cantabro mass loss $\leq$ 7.5%
Control Mix BMD Optimization

- Selected a VDOT-approved 30% RAP volumetric design
- Conducted performance tests; failed IDEAL-CT$_{\text{index}}$ = 44.9
- Increased binder content and re-tested the mix

<table>
<thead>
<tr>
<th>Total (New) Binder Content</th>
<th>IDEAL CT$_{\text{index}}$</th>
<th>APA Rut Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2% (3.9%)</td>
<td>44.9</td>
<td>2.7</td>
</tr>
<tr>
<td>5.7% (4.4%)</td>
<td>104.9</td>
<td>3.7</td>
</tr>
<tr>
<td>6.2% (4.9%)</td>
<td>141.9</td>
<td>4.0</td>
</tr>
</tbody>
</table>

- Design air voids = 2.9%, VMA = 15.8% @ $N_{\text{des}} = 50$

Experimental Mix BMD Optimization

- Designed a 45% RAP volumetric mix with rejuvenator
- Conducted performance tests; failed IDEAL CT$_{\text{index}}$ = 44.1
- Increased binder content and re-tested the mix

<table>
<thead>
<tr>
<th>Total (New) Binder Content</th>
<th>IDEAL CT$_{\text{index}}$</th>
<th>APA Rut Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2% (3.0%)</td>
<td>44.1</td>
<td>3.2</td>
</tr>
<tr>
<td>5.7% (3.5%)</td>
<td>62.0</td>
<td>2.8</td>
</tr>
<tr>
<td>6.2% (4.0%)</td>
<td>109.6</td>
<td>4.0</td>
</tr>
</tbody>
</table>

- Design air voids = 2.4%, VMA = 16.2% @ $N_{\text{des}} = 50$
NCAT Test Track Section N3

N3A: 30% RAP control mix
N3B: 45% RAP, rejuvenator mix
In-place density: 96% to 97%

NCAT Test Track Experiments
Experiment Objectives

Implementation of performance testing and criteria for BMD

Performance comparison for BMD versus volumetric mixes

ODOT BMD Approach

- Hamburg Wheel Tracking Test (HWTT) for rutting resistance; max. rut depth of 12.5 mm at 50C
- Illinois Flexibility Index Test (I-FIT) for cracking resistance; min. flexibility index of 8.0
- Cantabro for information only
- Allow up to 15% RAP in surface mixes
- 3 to 4 percent design air voids
ODOT Section N9

- 1.5 in. mill and inlay
- 9.5mm S5 mix ($N_{\text{des}} = 80$)
- PG 76-28 SBS-modified binder
- 15 percent RAP
- Volumetric design with performance verification
- Binder content = 5.6%
- Design air voids = 4.0%
- VMA = 15.5%

ODOT Section S1

- 5.5 in. mill and inlay (2 lifts)

<table>
<thead>
<tr>
<th>Surface Mix</th>
<th>Base Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5mm S4 mix ($N_{\text{des}} = 65$)</td>
<td>19mm S3 mix ($N_{\text{des}} = 65$)</td>
</tr>
<tr>
<td>PG 70-28 SBS binder</td>
<td>PG 64-28 SBS binder</td>
</tr>
<tr>
<td>12% RAP</td>
<td>30% RAP with rejuvenator</td>
</tr>
<tr>
<td>Binder content = 5.8%</td>
<td>Binder content = 5.2%</td>
</tr>
<tr>
<td>Design air voids = 3.4%</td>
<td>Design air voids = 3.4%</td>
</tr>
<tr>
<td>VMA = 16.2%</td>
<td>VMA = 14.0%</td>
</tr>
</tbody>
</table>
ODOT Section S1

- Performance modified volumetric design
  - Select 3 initial asphalt contents
  - Determine optimum based on HWTT & I-FIT results
  - Verify volumetric properties

Performance Diagram (Design)
**TxDOT BMD Approach**

- HWTT for rutting and moisture resistance; max. rut depth of 12.5 mm at 50°C
- Overlay Test (OT) for cracking resistance
  - Min. critical fracture energy (\(G_c\)) of 1.0 in.-lb/in.²
  - Max. crack progression rate (\(\beta\)) of 0.45 (surface)
- \(\Delta T_c\) requirement for asphalt binder
- Max. RAP/RAS binder replacement ratio
  - Surface: 20 percent
  - Intermediate: 30 percent
  - Base: 40 percent
TxDOT Sections S10, S11

- 2.5 in. mill and inlay
- S10 BMD, S11 volumetric control
- TxDOT 12.5mm SP-C surface mix ($N_{des} = 50$)
- PG 70-22 SBS-modified binder
- 20 percent RAP binder replacement ratio
- Volumetric design with performance verification
- S10: 5.5% $P_b$, 16.6% VMA ($G_{se}$)
- S11: 4.7% $P_b$, 15.0% VMA ($G_{se}$)

Performance Diagram (Design)

- OT Crack Progression Rate ($\beta$)
- HWTT Rut Depth (RD)

- Control Mix
- BMD Mix
- $RD \leq 12.5$
- $\beta \leq 0.45$
MnDOT BMD Study

- “Balanced Design of Asphalt Mixtures”
- Texas A&M Transportation Institute (Newcomb, 2018)
- Developed a BMD framework for MnDOT projects
- Volumetric Design with Performance Optimization
  - Volumetric design to select volumetric OBC
  - Performance testing at volumetric OBC, -0.5%, and +0.5%
    - HWTT for rutting evaluation on STOA samples (2 hours at Tc)
    - I-FIT, IDEAL, and DCT for cracking evaluation on LTOA samples (4 hours at Tc)
  - Select performance OBC passing all test requirements
  - Final OBC = Performance OBC + Production Tolerance (0.4%)
WisDOT BMD Study (ongoing)

- “Balanced Mixture Design Implementation Support”
- National Center for Asphalt Technology (PI: West)
- To develop an implementable BMD specification for WisDOT projects
  - Economics
  - Materials availability
  - Construction consideration
  - Additives

NCAT Proposed BMD Process for WisDOT

1. Select a mix design variable for modification
2. Conduct HWTT & IDEAL-CT tests at 3 modification levels
   - Performance Passed?
     - Yes
     - Determine optimum modification level
     - Conduct DCT & TSR tests
     - Performance Passed?
       - Yes
       - Accept modified mix design
     - No
     - No
   - No
3. "Sweet Zone"
Other State DOT Studies

<table>
<thead>
<tr>
<th>State DOT</th>
<th>Research Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>Simplified Performance Based Specifications for Long Life AC Pavements</td>
</tr>
<tr>
<td>Idaho</td>
<td>Development and Evaluation of Performance Measures to Augment Asphalt Mix Design in Idaho</td>
</tr>
<tr>
<td>Indiana</td>
<td>Performance Balanced Mix Designs for Indiana’s Asphalt Pavements</td>
</tr>
<tr>
<td>North Dakota</td>
<td>Performance-Based Testing Specifications for Asphalt Pavement Constructions in North Dakota</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>Implement Balanced Asphalt Mix Design in Oklahoma</td>
</tr>
<tr>
<td>Texas</td>
<td>Develop Guidelines and Design Program for Hot-Mix Asphalts Containing RAP, RAS, and Other Additives through a Balanced Mix Design Process</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Analysis and Feasibility of Asphalt Pavement Performance-Based Testing Specifications</td>
</tr>
<tr>
<td></td>
<td>Regressing Air Voids for Balanced HMA Mix Design</td>
</tr>
</tbody>
</table>

Thanks! Questions?