Problem

- Fatigue cracking
- Wheel path cracking
- Raveling

Inadequate Binder In The Mix

- Since the inception of Superpave mixtures, Wisconsin has seen binder content in mixes decrease
Items To Address And A Possible Solution

Need to put our thinking caps on

- Raise VMA
- Better monitor aggregate specific gravities
- Test Actual Binder Content
- Effective binder content
- Air Void Regression
Raise VMA

• Add 0.5% to most surface mixes
  - For 12.5mm mixes, [1] 14.5 for LT and MT mixes.
  - For 9.5mm mixes, [2] 15.5 for LT and MT mixes
Aggregate Specific Gravities

- Contractor determined gravities are used
- Now verifying gravities with department samples
- Agg sources are verified more often, 1-3 years instead of 5
Asphalt Binder Content Determination

• Previous
  ▪ AC by calculation.
  ▪ AC by nuclear gauge reading, optional.
  ▪ AC by inventory, optional.

• Current
  ▪ AC by ignition oven according to AASHTO T308 (CMM 836.6.3.6),
  ▪ by chemical extraction according to AASHTO T-164 method A or B; or
  ▪ by automated extraction according to ASTM D8159 as modified in CMM 836.6.3.1.
Effective Binder Content

• Started to be used by one region
• Requires many mix designs to be replaced with new designs or
• Would take years to fully implement

Not chosen to use statewide
Air Void Regression (AVR)

The Best Solution

• WisDOT AVR process, benefits, concerns
• Wisconsin Highway Research Program (WHRP) Research completed by NCAT
• WisDOT Performance Testing Data
Air Void Regression

• Design at the typical 4.0% air voids
• Meet all criteria for 4.0%
  ▪ Gyratations, VMA, Dust to Binder, Percent Binder Replacement, etc
• Use the design points to determine binder content at 3.0%
• Use the 3.0% volumetric properties.

Existing 4.0% air void designs can be used as well as new ones
No mass redesigns are needed
Air Void Regression

Original 4.0 Optimum
%AC = ~ 5.7

Regressed 3.0 Optimum
%AC = ~ 6.1
Volumetric Properties at 3.0%

- Binder content, % (Pb).
- Maximum specific gravity (Gmm).
- Bulk specific gravity (Gmb).
- Air voids, % (Va).
- VMA (voids of the mineral aggregate), %.
- VFB (voids filled with binder) also called VFA (voids filled with asphalt), %.
- TSR (tensile strength ratio).
- TSR Compaction Effort (N = "x").
Benefits

• Increased virgin binder added, 0.3 to 0.4%
• Increased durability, increased asphalt film thickness
• Increased in place density/decreased permeability
• Improved workability- easier paving
• No change to existing 4.0% designs except computing 3.0% volumetrics
Concerns

• Cost
  ▪ Increase of $1 to $2 per ton

• Stability
  ▪ WisDOT is confident in the dense graded aggregate structure
  ▪ Reduced LT mESALS from below 2 mESALS to below 1 mESALS
Research, WHRP by NCAT

- Wisconsin Highway Research Program project 16-06
- Regressing Air Voids for Balanced HMA Mix Design
- Evaluate 6 common mix designs in Wisconsin regressed to lower air voids

Research Report

Research Brief
Flexibility Index for LT mix

- 4.0% Air: 8.0
- 3.5% Air: 10.3
- 3.0% Air: 12.2

(1) LT 58-28 28/0
Flexibility Index for MT mixes

<table>
<thead>
<tr>
<th></th>
<th>(2)MT 58-28 20/0</th>
<th>(4)MT 58-34 36/0</th>
<th>(5)MT 58-34 37/3</th>
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<tbody>
<tr>
<td>4.0% Air</td>
<td>5.8</td>
<td>6.3</td>
<td>4.5</td>
</tr>
<tr>
<td>3.5% Air</td>
<td>9.6</td>
<td>7.7</td>
<td>5.1</td>
</tr>
<tr>
<td>3.0% Air</td>
<td>12.5</td>
<td>13.2</td>
<td>6.5</td>
</tr>
</tbody>
</table>
Flexibility Index for HT mixes

![Chart showing flexibility index for HT mixes with different air contents and asphalt contents.](chart.png)
16-06 Hamburg Wheel Testing Corrected Rut Depth

• Corrected Rut Depth and Stripping Number are determined from Hamburg Wheel Data to separate the effects of rutting and stripping

• Fan Yin formerly at TTI now at NCAT promotes this method
Corrected rut depth (CRD) (Yin et al., 2014 – TRR 2446)

![Graph showing corrected rut depth and stripping number](image)

- **Corrected Rut Depth**
- **Total Rut Depth**
- **Rut Depth Caused by Stripping**
- **Stripping Number** (where stripping occurs)
Corrected Rut Depth for LT mix

Corrected Hamburg Rut Depth (mm) - 46°C

20,000 Passes

(1)LT 58-28 28/0

- 4.0% Air: 5.2
- 3.5% Air: 6.7
- 3.0% Air: 6.8
Corrected Rut Depth for MT mixes

<table>
<thead>
<tr>
<th></th>
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<th>3.5% Air</th>
<th>3.0% Air</th>
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</thead>
<tbody>
<tr>
<td>(2) MT 58-28</td>
<td>4.3</td>
<td>4.8</td>
<td>5.6</td>
</tr>
<tr>
<td>(4) MT 58-34</td>
<td>3.3</td>
<td>3.9</td>
<td>3.6</td>
</tr>
<tr>
<td>(5) MT 58-34</td>
<td>1.5</td>
<td>1.6</td>
<td>1.9</td>
</tr>
</tbody>
</table>

20,000 Passes (mm) - 46°C
Corrected Rut Depth for HT mixes

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<th>4.0% Air</th>
<th>3.5% Air</th>
<th>3.0% Air</th>
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</thead>
<tbody>
<tr>
<td>(3) HT 58-28 15/0</td>
<td>2.8</td>
<td>2.8</td>
<td>3.4</td>
</tr>
<tr>
<td>(6) HT 58-34 16/3</td>
<td>2.7</td>
<td>2.6</td>
<td>2.6</td>
</tr>
</tbody>
</table>
16-06 Conclusions

- “based on the I-FIT FI results, the regressed air voids approach to mix design will have a significant, positive impact on the cracking resistance of the mixtures”
- “designing Wisconsin asphalt mixtures with the air voids regressed to 3.0 percent is not likely to cause any problems with increased rutting susceptibility”
- “Results from this project indicate that the regressed air voids approach can improve cracking resistance without compromising the deformation resistance of asphalt mixes”
Research, WisDOT data

- Performance Testing on Pre-2020 AVR mixes (I-FIT)
- Performance Testing on 2020 AVR mixes (IDEAL-CT)
Flexibility Index (PM/ST)

Pre-2020

Improved Rutting Performance

Improved Cracking Performance

Hamburg Wheel Wheel Passes to 12.5mm rut depth

LT
MT
HT
SMA

Interlayer
Performance Testing on 2020 AVR mixes

![Graph showing a scatter plot with CT Index (PM/LT) on the y-axis and Hamburg Passes to Failure / Rut Depth on the x-axis. The graph includes data points labeled S, H, and V.]

- CT Index (PM/LT)
- Hamburg Passes to Failure / Rut Depth

Data points labeled S, H, and V are presented in different colors and symbols.
Summary

- Even with AVR, WisDOT mixes are stable
- AVR provides additional cracking resistance (along with other benefits)

“Performance testing completed in this research indicates 3.0% regressed air voids will improve pavement life in Wisconsin.”

– Steve Hefel, WisDOT
Air Void Regression

Increased asphalt binder → increased cracking resistance
Questions?

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