Effect of Low Air Voids

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MS&T Asphalt Conference
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Air Voids

- Too High
  - Rutting under traffic
  - Increased binder aging
High Air Voids

- Research and experience show high air voids can be a major problem
- Increased permeability
  - Increased binder aging, cracking and raveling
  - Increased moisture damage
  - Increased densification under traffic
- Big problem in some states with early Superpave projects
Impact of High Voids

Ravelling increases as air content increases.

Service life reduced about 10% for each 1% air voids over 7%!
Air Voids

Too low

- Plastic flow
- Rutting and shoving under traffic
- Flushing and bleeding
High Voids

Typically a compaction problem

Change rollers, rolling patterns, temperature, etc.
Low Voids

- Typically mix problem
  - Mix design problem
  - Poor quality control

- Redesign or adjust mix
- Remove and replace
How Low is Too Low?

- Design at 4% or 3-5%
- Foster – in situ air voids ≤ 2.5% shoved
  - Instability at 3% for 4.75mm DGA
- NCAT – rutting mixes had air voids ≤ 3%
- WesTrack – minimal rutting in section with 1.6% air voids in situ
- Harvey and Tsai recommend design AV = 2% (perpetual pavement base)
Factors Affecting Severity

- Type of roadway – traffic level, climate
- Depth within pavement structure
- Strength/stiffness of mix

*How do you know if it is safe to leave in place?*
Indiana History

- Aggressively implemented Superpave beginning in 1992-93
- Began implementing volumetric acceptance of HMA in 2001
- Volumetric acceptance on all HMA in 2003
- Pay factors depend on binder content, VMA, air voids and density
- Plate sampling and density cores
Substandard Results

If first sample “fails,” backup sample is tested

If backup sample also fails, suspect subplot is referred to Failed Materials Committee for disposition

- Leave in place at reduced pay
- Remove and replace
Concern

- Some sublots exhibited air voids < 2%
- Removal and replacement was indicated
- Costly for contractors ($30/Mg \times 1000 \text{ Mg})
- Testing variability issues and extenuating circumstances
Referee Testing

- INDOT offered referee testing at contractor’s option and cost
  - Traffic control, coring, testing
- Low air void mixes tested for mix stiffness
- Results considered when determining pay factors or remove/replace
Rationale

- Low air void mixes could exhibit stability problems
- If mix stiffness is adequate, rutting would not likely develop
- Low air voids and low stiffness would likely signal performance problems
- Adequate stiffness $\geq 250$ MPa (36,200 psi) at 10 Hz and 40°C (SST Frequency Sweep)
Application of Results

- If average of three tests $\geq 250$ MPa, remain in place at reduced pay.
- If average $\leq 250$ MPa, remove and replace at contractors expense.

Relatively few cases overall:
- Almost no cases after 1-2 years.
- About half the results favored leaving in place.
- When left in place, pay reductions ranged from 15-50%.
- No performance problems observed.
Tool Worked – Why Change?

- Low voids still occur occasionally
- Referee testing no longer used
- SST testing temperamental, uncommon
- No technical guidance on pay reduction
- Applied equally to all mixes, roads, etc.
- Risk to agency (poor performance) and contractor (cost)
Initiated Research

Two Pronged Approach
- NCAT Test Track 2006
- INDOT/Purdue Accelerated Pavement Testing (APT) Facility

Assess agency and contractor risk
Recommend decision strategy for managing risk when accepting or rejecting low air void mixes
NCAT Test Track

- INDOT sponsored two sections in 2006
- NCAT subdivided each:
  - Four 31.5m (100 foot) test sections
- Another section serves as control
- Perpetual pavement sections
- 50mm (2 in) surface removed and replaced with low void mix
## Comparison of Sections

<table>
<thead>
<tr>
<th>Section</th>
<th>Design Air Voids %</th>
<th>In Situ Air Voids %</th>
<th>Binder Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>S7A</td>
<td>1.4</td>
<td>2.2</td>
<td>6.5</td>
</tr>
<tr>
<td>S7B</td>
<td>2.1</td>
<td>3.9</td>
<td>6.1</td>
</tr>
<tr>
<td>S8A</td>
<td>2.0</td>
<td>3.9</td>
<td>6.2</td>
</tr>
<tr>
<td>S8B</td>
<td>1.0</td>
<td>2.3</td>
<td>6.1</td>
</tr>
<tr>
<td>N5*</td>
<td>4.0</td>
<td>5.2</td>
<td>5.8</td>
</tr>
</tbody>
</table>

*Control
Rutting in 2008

Track Sponsor
Meeting – 8/26/08
Rutting Performance

Equivalent Single Axle Loadings

Avg Rut Depth (mm)

ARAN  Dipstick  ALDOT Gauge
Rutting Comparison

Rut Depth, mm

S7A: 18.8
S7B: 15.9
S8A: 14.4
S8B: 35.4
N7: 2.7
Poor Performance

- All four sections rutted severely by 2-08 (~5.6 × 10^6 ESALs)
- Safety concern for trucking
- Mixes removed and replaced with more low void mixes in 2-08
- New mixes also rutted beginning 5-08
Low QC Voids Experiment

$y = 94.24e^{-0.82x}$

$R^2 = 0.66$
APT Experiment
## Air Voids in APT

<table>
<thead>
<tr>
<th>Lane</th>
<th>Top 50mm</th>
<th>Lower 50mm</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>~4%</td>
<td>~2%</td>
<td>High binder</td>
</tr>
<tr>
<td>2</td>
<td>~4%</td>
<td>~2%</td>
<td>Gradation</td>
</tr>
<tr>
<td>3</td>
<td>~2%</td>
<td>~4%</td>
<td>High binder</td>
</tr>
<tr>
<td>4</td>
<td>~2%</td>
<td>~4%</td>
<td>Gradation</td>
</tr>
</tbody>
</table>

*Constructed December 2009, loading in progress.*
Potential Products

- Minimum air void content specification
  - Establish level to remove and replace
- Test method to determine when to remove and replace (dynamic modulus?)
- Decision tree considering life cycle
NCHRP 9-22 Performance Related Specifications

- Fugro Consultants
- Software to predict pavement performance based on as-built volumetrics and material properties
- QRSS – Quality-Related Specification Software
- Compare to as-designed to assess change in service life
- Evaluating applicability to low voids issue
Conclusions

- Currently air void levels below 2-3% appear problematic.
- Occasionally lower void mix can perform acceptably.
- Risk to agency and contractor.
- There are options to consider:
  - Test stiffness or modulus of mix.
  - Evaluate performance/life cycle impacts.
For more information:

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