How Low is too Low?
Assessing the Risk of Low Air Voids using Accelerated Pavement Testing

Eyal Levenberg, Technion
Rebecca McDaniel, Purdue University
Tommy Nantung, Indiana DOT
Low Air Voids

- During construction
  - Excess binder
  - Excess fines

- Too low
  - Plastic flow
  - Rutting and shoving under traffic
  - Flushing and bleeding
  - Increased maintenance
  - Shorter pavement life
What to Do?

- Remove and replace?
  - Contractor risk – mix might still perform

- Leave in place with reduced pay?
  - How much reduction?
  - DOT risk – mix might fail
How Low is Too Low?

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

- Implemented Superpave in 1992-93
- Began 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
- Wanted more objective way to determine action
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 Phase III

- Sections S7 (A&B) and S8 (A&B)
- 50 mm (2 in) surface removed and replaced with low void mix
Low QC Voids Experiment

\[ y = 94.24e^{-0.82x} \]

\[ R^2 = 0.66 \]

Track Sponsor
Meeting – 8/26/08
APT Experiment
Air Voids in APT

<table>
<thead>
<tr>
<th>Lane</th>
<th>Top 50 mm</th>
<th>Lower 50 mm</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>High fines</td>
</tr>
<tr>
<td>3 &amp; 4</td>
<td>~2%</td>
<td>~4%</td>
<td>High binder</td>
</tr>
</tbody>
</table>

Each lane is 1.5 m (5 ft) wide and 6 m (20 ft) long.

355 to 430 mm (14 to 17 in.) pavement on 405 mm (16 in.) cement stabilized soil.
Drilling Plan
Rut Depths
Rut Depths

Lane 3, LH

Rutting [mm]

3000 Passes
12900 Passes
50 mm holes

Transverse Location [mm]

100 200 300 400 500 600 700 800 900 1000 1100
Modeling

- Rutting ‘driving forces’
  - Shear - shape change
  - Volumetric - density change
- Subsystem approach
- A simple VP model

\[ \dot{E}_{ij}^{vp} = \frac{s_{ij}}{\eta_S} + \frac{p \delta_{ij}}{\eta_V} \]

- Resistance to shear deformation
- Resistance to volumetric deformation

\[ s_{ij} = \sigma_{ij} - \frac{\sigma_{kk}}{3} \delta_{ij} \]

\[ p = \frac{\sigma_{kk}}{3} \]
Modeling

- Four layer system
- Assumed Poisson’s ratio
- Backcalculated moduli from FWD
- Simulated moving wheel load
- Computed profiles compared to measured
- Refined model and simulation repeated
Modeled Rut Depth
Modeling

Low AVC @ z=0

Reference case

Low AVC @ z=8"
## Decision Support Tool

### Table: AVC [%] vs Traffic intensity (20 year)

<table>
<thead>
<tr>
<th>AVC [%]</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2.9</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2.8</td>
<td>2</td>
<td>2</td>
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<tr>
<td>2.7</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2.6</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2.5</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

1 = Accept  
2 = Reduce Pay  
3 = Reject
Monetary Reduction

- How to determine appropriate pay reduction?
- Assess impact on life cycle
  - QRSS (NCHRP 9-22) – based on MEPDG
  - As-designed vs. As-built
  - How much was life cycle reduced?
    - Rough rule of thumb $10,000/lane mile/yr
- Analysis in progress
Conclusions

- Currently air void levels below 2-3% appear problematic regardless of position.
- Cause of the low voids does not matter.
- Risk to agency and contractor.
- Preliminary decision support tool being refined to consider impact on service life.
- Drilled holes provide some insight – need refinement.
For more information:

Rebecca S. McDaniel
Technical Director
North Central Superpave Center
765/463-2317 ext 226
rsmcdani@purdue.edu
https://engineering.purdue.edu/NCSC

Modeling questions:
Eyal Levenberg
Technion
elevenbe@techunix.technion.ac.il