Enhanced Durability Through Increased In-Place Pavement Density

FHWA and Asphalt Institute Workshop
Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density

Key:
- Orange: Workshop Only (15)
- Blue: Demonstration projects (10)
Evolution of Traffic

• Interstate highways - 1956
• AASHO Road Test - 1958-62
  • still widely used for pavement design
  • legal truck load - 73,280 lbs.
• Legal load limit to 80,000 lbs. - 1982
  • 10% load increase
  • 40-50% greater stress to pavement
• Radial tires, higher contact pressure
• FAST Act raising load limit to 120,000 lbs. (in select locations)
Led to Rutting in 1980s

Courtesy of pavementinteractive.org
Which led to...Superpave

• Fixed the rutting problem
• Gyratory compaction lowered binder contents
• Add in higher and higher recycled materials?
Improved Compaction = Improved Performance

A BAD mix with GOOD density out-performed a GOOD mix with POOR density for ride and rutting.

WesTrack Experiment
Effect of In-Place Voids on Life
Colorado DOT Study
Tensile Strength & Moisture Susceptibility vs. Air Voids
AASHTO T 283

Sample Air Voids

Tensile Strengths, kPa

0 200 400 600 800 1000 1200

Dry Strength
Wet Strength
TSR

0.908
0.785
0.743
0.698

0.68 0.73 0.78 0.83 0.88 0.93

TSR (Ratio)
# FHWA Performance Based Mix Design

<table>
<thead>
<tr>
<th></th>
<th>Fatigue Cracking</th>
<th>Rutting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Air Voids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For every 1% increase</td>
<td>40% increase</td>
<td>22% decrease</td>
</tr>
<tr>
<td><strong>Design VMA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For every 1% increase</td>
<td>73% decrease</td>
<td>32% increase</td>
</tr>
<tr>
<td><strong>Compaction Density</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For every 1% lower in-place Air Voids</td>
<td>19% decrease</td>
<td>10% decrease</td>
</tr>
</tbody>
</table>

Increasing Density Improved Both!

Courtesy of Nelson Gibson
“A 1% decrease in air voids was estimated to improve the fatigue performance of asphalt pavements between 8.2 and 43.8%, to improve the rutting resistance by 7.3 to 66.3%, and to extend the service life by conservatively 10%.”
Choosing a Gradation

Finer Gradations
More Compactable
More Workable
Less Permeable

Requires better aggregate
Higher binder contents

Courtesy of NCAT
Reduce Permeability

Design to a **minimum** lift thickness

- ≥ 3X NMAS on fine graded mixtures
- ≥ 4X NMAS on coarse graded mixtures

Do not neglect future pavement preservation
Balance the Mix Design

Strength/Stability
Rut Resistance
Shoving
Flushing Resistant

Smooth Quiet Ride
Skid Resistance

Don’t attack one half at the expense of the other half!!

Durability
Crack Resistance
Raveling
Permeability
Future Balanced Design Concept

- **APA Rutting (mm)**
- **Overlay Tester Fatigue (cycles)**
- **Optimum AC% (JMF)**

Area of Balanced Performance: 5.2 - 5.9%

Courtesy of Tom Bennert
• Design at 5% air voids and compact to 5% voids in field (95% $G_{mm}$)

• Lower design gyration to increase in-place density
  • No change in rutting resistance
  • No change in stiffness
  • Improve pavement life
    • Reduced aging

• Maintained Volume of Eff. Binder ($V_{be}$)
  • Increased VMA by 1%
Lab Screening

• Flow Number (rutting evaluation)
  • N100/4/7   840 cycles
  • N30/5/5    1180 cycles

• Stiffness
  • N100/4/7   2,072 MPa
  • N30/5/5    2,645 Mpa

Note: gradations had to be altered to maintain Effective Asphalt Contents

Courtesy of Gerald Huber
Balancing the Paving Operation
Uniform Paving Train Operation

• Determine plant production rate
• Plan for sufficient, timed mix delivery
• Establish a constant paver speed
• Assure ample rollers are available
  • Keep water trucks up to the rollers
Successful Tack Coat

The Ultimate Goal:
Uniform, complete, and adequate coverage
Consequences of Debonding

Courtesy of NCAT
Proper Tack Coat Application

- Specify and monitor adequate tack coat application
  - Allow the use of alternate materials
    - Low Tracking tack
    - Modified materials
    - Paving grade binders

A well compacted pavement section will not perform if it is not properly bonded!!
Successful Longitudinal Joints

Notched Wedge

Butt
### PA: How Did it Work?

**In-place Density Summary, Reported by PA DOT**

<table>
<thead>
<tr>
<th>Year</th>
<th># Lots</th>
<th>Avg. Roadway Density, %TMD</th>
<th>Avg. Joint Density, %TMD</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>18</td>
<td>93.9</td>
<td>87.8</td>
<td>begin measuring at Jt.</td>
</tr>
<tr>
<td>2008</td>
<td>43</td>
<td>94.1</td>
<td>88.9</td>
<td>method spec</td>
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<tr>
<td>2009</td>
<td>29</td>
<td>94.1</td>
<td>89.2</td>
<td>method spec</td>
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<tr>
<td>2010</td>
<td>No data</td>
<td>transition to PWL spec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>137</td>
<td>94.1</td>
<td>91.0</td>
<td>PWL, LSL 89%</td>
</tr>
<tr>
<td>2012</td>
<td>162</td>
<td>94.0</td>
<td>91.6</td>
<td>PWL, LSL 89%</td>
</tr>
<tr>
<td>2013</td>
<td>167</td>
<td>93.9</td>
<td>91.4</td>
<td>PWL, LSL 89%</td>
</tr>
<tr>
<td>2014</td>
<td>316</td>
<td>94.1</td>
<td>92.3</td>
<td>PWL, LSL 90%</td>
</tr>
<tr>
<td>2015</td>
<td>493</td>
<td>92.6</td>
<td></td>
<td>PWL, LSL 90%</td>
</tr>
</tbody>
</table>
### PA: Annual Statewide Totals on Incentives/Disincentives for Joint Density

<table>
<thead>
<tr>
<th>Year</th>
<th>Incentive Payments</th>
<th>Disincentive Payments</th>
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<tbody>
<tr>
<td>2011</td>
<td>$268K</td>
<td>$99K</td>
</tr>
<tr>
<td>2012</td>
<td>$489K</td>
<td>$63K</td>
</tr>
<tr>
<td>2013</td>
<td>$588K</td>
<td>$25K</td>
</tr>
<tr>
<td>2014</td>
<td>$1,002K</td>
<td>$127K</td>
</tr>
</tbody>
</table>

Note: MI and CT have averaged over 91.5%, and AK over 92.0% density at the joint over recent construction seasons.
Improve Longitudinal Joints

Permeable Longitudinal Joints will:

- Cause safety concerns
- Necessitate premature maintenance
- Contribute to delamination
- Severely impact the life cycle performance
- Joint density no less than 2% mat density requirement
Uniformity is the key!

A small “s” gives the average a lot of flexibility

High “s” provides for little cushion for the average

Uniformity comes from balancing plant/delivery/paver/compaction!
Premise:

✓ Compaction is essential for long-term pavement performance
✓ There are many compaction enhancements currently in use
✓ Compaction goals can be improved
FHWA Demonstration Project Field Project Results

• 8 of 10 projects to date

• Three Key Lessons:
  1. Follow best practices
  2. Inter-relationship between:
  3. Higher density is achievable

- Mix Design
- Field Verify
- Field Density Acceptance
Processes and Technologies

• None are Found on All of the Projects
• Processes:
  • Altered Rolling Pattern
    • Additional Roller Passes
    • Altered Roller Spacing
    • Added Rollers to Compaction Process
  • Modified Mix Design
    • Increased Asphalt Content
• Technology
  • Intelligent Compaction
  • Ground Penetrating Radar
Preliminary Results

• Process Changes
  • Altered Roller Patterns
    • Increased Density
    • 0.3-1.9% ↑
  • Modified Mix Design
    • Increased Density
    • 1.2% ↑

• Technology
  • No Preliminary Results Available
Maximizing Our R.O.I.

- Infrastructure loads continue to rise
- Budget availability continues to fall
- Increased pavement life can be economically achieved
- Research conservatively shows that a 10% increase in pavement life can be achieved by increasing compaction by 1%.

What would a 3% increase in compaction do for our industry?
Specify Increased Compaction

• Shoot for 94% TMD
  • Regularly achieved on airfields throughout the country.

• Use Percent Within Limit specifications
  • A 92% LSL demands 93 – 94% compaction target
  • Use a one sided test – LSL only
  • Consider high side outlier testing

• Assure Density is achieved on the road
  • Consider Cores for acceptance
  • Require adequate gauge calibration
  • Regularly determine $G_{mm}$ on plant produced mix

• Pay for increased compaction – 5% Bonus
Promote Innovation

• Encourage / require Intelligent Compaction
• Use WMA – compaction aid
• SHRP2 – IR
• Consider alternative rollers
  • Pneumatic
  • Vibratory Pneumatic
  • Oscillatory
  • ?
Increased compaction = Increased Performance
Better “Return on Investment” for the taxpayers
More Successful Pavements = More Tonnage for the HMA Industry !!!

Thank you for your time!!!