Enhanced Durability of Asphalt Pavements Through Increased In-Place Density

PAPA Annual Conference

18 January 2017
Overall Objective

Ultimately, achieving the in-place asphalt pavement density that results in the highest asphalt pavement performance.
1. The Importance of Density
2. FHWA – AI Compaction Workshop
3. Field Demonstration Projects
4. Summary
Compaction is Important

  - Compaction is the single most important factor that affects pavement performance in terms of durability, fatigue life, resistance to deformation, strength and moisture damage.

- Geller, M. Synthesis 152
  - “Compaction is the most economical alternative for achieving an increase in the life expectancy of new and rehabilitated pavement.”

  - “The amount of voids in an asphalt mixture is probably the single most important factor that affects performance throughout the life of an asphalt pavement. The voids are primarily controlled by asphalt content, compactive effort during construction, and additional compaction under traffic.”
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
Washington State DOT Study

Effect of In-Place Voids on Life
Washington State DOT Study

In-situ Air Voids, %

Percent Service Life

Compaction Level

93%  92%  91%  90%  89%

7 8 9 10 11
Effect of Percentage of Air Voids on Fatigue Life
20C, 500 microstrain

\[ N_f = -1361.88 \times AV^2 + 15723.35 \times AV + 88162 \]

\[ R^2 = 0.98 \]

**UK-AI Study**
1.5% increase in density leads to 10% increase in fatigue life.
<table>
<thead>
<tr>
<th>Study</th>
<th>Avg Field</th>
<th>Avg Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFHRC</td>
<td>19.0%</td>
<td></td>
</tr>
<tr>
<td>AI 2010</td>
<td>9.2%</td>
<td></td>
</tr>
<tr>
<td>WesTrack 2002</td>
<td>8.7%</td>
<td>11.9%</td>
</tr>
<tr>
<td>UCB 1996</td>
<td></td>
<td>15.1%</td>
</tr>
<tr>
<td>UCB 1969</td>
<td></td>
<td>27.2%</td>
</tr>
</tbody>
</table>
Average Decrease in Rut Depth for 1% Decrease in Air Voids

<table>
<thead>
<tr>
<th></th>
<th>Avg Field</th>
<th>Avg Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFHRC</td>
<td>10.0%</td>
<td></td>
</tr>
<tr>
<td>AI 2010</td>
<td>22.7%</td>
<td></td>
</tr>
<tr>
<td>WT rc</td>
<td>10.9%</td>
<td></td>
</tr>
<tr>
<td>WT f/f+/c</td>
<td>7.3%</td>
<td></td>
</tr>
<tr>
<td>WT rc</td>
<td>66.3%</td>
<td></td>
</tr>
<tr>
<td>WT oc</td>
<td>9.6%</td>
<td></td>
</tr>
<tr>
<td>WT f/f+</td>
<td>11.5%</td>
<td></td>
</tr>
</tbody>
</table>

WT - 2002 WesTrack
"A 1% decrease in air voids was estimated to...

• improve fatigue performance between 8.2 and 43.8%,

• improve rutting resistance between 7.3 to 66.3%,

• extend the service life by conservatively 10%"

http://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep16-02.pdf
Research from New Jersey

Y(time) = -1.1 X (Air Voids) + 16.6
R² = 0.32
Reasons for Compaction

Cracking
- To improve fatigue cracking resistance
- To improve thermal cracking resistance

Rutting
- To minimize prevent further consolidation
- To provide shear strength and resistance to rutting

Moisture Damage
- To ensure the mixture is waterproof (impermeable)

Aging
- To minimize oxidation of the asphalt binder

Although not a “cure-all remedy”, compaction is important!!
1. The Importance of % Density
2. FHWA – AI Compaction Workshop
3. Field Demonstration Projects
4. Summary
Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density

Workshop Only (15)

Demonstration projects (10)

Mobile Asphalt Testing Trailer (2)
Workshop Outline

1. Introduction
2. Mixture Factors Effecting Compaction
3. Compaction Best Practices
4. Other Best Practices
5. Measurement & Payment
6. New Technologies
7. Wrap Up
Mix Design

- Fine graded
- Lower gyrations
- Increase Vbe
  - Balanced mix design
  - Superpave 5
<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 (Increasing Density)</td>
<td>19% decrease</td>
<td>10% decrease</td>
</tr>
</tbody>
</table>

Courtesy of Nelson Gibson
Best Practices

• Mix production
• Tack coat
• Paving operations
• Compaction
  • # of rollers
  • IC
• Pave IR
• Longitudinal Joints
Measurement and Payment

- Increase Limits
- PWL vs. Average
- One sided PWL
Effect of Lift Thickness On Achieving Density

- **Suit-Kote-NY-75 gyration/600kPa - 9.5mm mixture**

Effect of Lift Thickness On Achieving Density

- **Suit-Kote-NY-75 gyration/600kPa-9.5mm mixture**
Slope = 2.72
A 5 mm reduction in thickness results in a 1.43% decrease in density.
• Feedback Very Positive
  • Formal training
  • Comprehensive:
    • Mix design to
    • Finish roller to
    • Measurement and Acceptance
  • Back to the basics focus
  • Learned new topics and reinforced others
  • over 450 participants
Our Visit

1. The Importance of Density
2. FHWA – AI Compaction Workshop
3. Field Demonstration Projects
4. Summary
FHWA Demonstration Project
Field Project Results

- 8 of 10 projects constructed to date
- Three Key Lessons:
  1. Follow best practices
  2. Inter-relationship between:
  3. Higher density is achievable
State #1

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Contractor’s Compactive Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2 static rollers in echelon (≈10 passes each)</td>
</tr>
<tr>
<td>Test Section 1</td>
<td><strong>Added 1 to 2 vibratory passes</strong></td>
</tr>
<tr>
<td>Test Section 2</td>
<td>3 rollers – <strong>added pneumatic</strong></td>
</tr>
</tbody>
</table>
State #1

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Density Results (%)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>93.5</td>
<td>---</td>
</tr>
<tr>
<td>Test Section 1</td>
<td>93.2</td>
<td>Not significant</td>
</tr>
<tr>
<td>Test Section 2</td>
<td>95.4</td>
<td>+ 1.9</td>
</tr>
</tbody>
</table>

Average of 10 core densities each / Reference is $G_{mm}$

- 2 static rollers achieved full incentive
- Using vibratory mode resulted in no change in % density
- Adding pneumatic increased % density
## State #2

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Contractor’s Compactive Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10-ton vibratory roller (8 passes)</td>
</tr>
<tr>
<td></td>
<td>4-ton vibratory roller (7 passes)</td>
</tr>
<tr>
<td>Test Section</td>
<td>10-ton vibratory roller (10 passes)</td>
</tr>
<tr>
<td></td>
<td>4-ton vibratory roller (7 passes)</td>
</tr>
</tbody>
</table>
# State #2

## Density Results (%)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Density Results (%)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>91.7</td>
<td>---</td>
</tr>
<tr>
<td>Test Section</td>
<td>92.5</td>
<td>≈ + 1</td>
</tr>
</tbody>
</table>

Average of 6 cores each / Reference is $G_{mm}$

- Only 1 compaction roller needed to meet specification
- Adding 2 passes increased % density
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Contractor’s Compactive Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4 rollers</td>
</tr>
<tr>
<td></td>
<td>- 2 vibratory in echelon (5 to 7 passes each)</td>
</tr>
<tr>
<td></td>
<td>- 2 pneumatic in echelon (5 to 7 passes each)</td>
</tr>
<tr>
<td>Test Section 1</td>
<td>5 rollers – <strong>added 1 vibratory roller</strong></td>
</tr>
<tr>
<td>Test Section 2</td>
<td>5 rollers – <strong>added 0.3% asphalt</strong></td>
</tr>
</tbody>
</table>
### State #3

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Density Results (%)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>92.9</td>
<td>---</td>
</tr>
<tr>
<td>Test Section 1</td>
<td>92.9</td>
<td>No change</td>
</tr>
<tr>
<td>Test Section 2</td>
<td>94.1</td>
<td>+ 1.2</td>
</tr>
</tbody>
</table>

Average of 8 core densities each / Reference is $G_{mm}$

- 4 compaction rollers needed to meet specification
- 1 additional roller did not change % density
- Mix design adjustment resulted in % density increase
- Added new technology: IC, IR, and RDM
## State #4

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Contractor’s Compactive Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2 vibratory rollers in echelon (5 passes each)</td>
</tr>
<tr>
<td></td>
<td>1 pneumatic roller (11 passes)</td>
</tr>
<tr>
<td>Test Section 1</td>
<td><strong>Added 1 vibratory roller</strong></td>
</tr>
<tr>
<td>Test Section 2</td>
<td>4 rollers</td>
</tr>
<tr>
<td></td>
<td><strong>Added 0.3% asphalt</strong></td>
</tr>
</tbody>
</table>

![Construction Equipment](image1.jpg)

![Completed Road](image2.jpg)
## State #4

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Density Results (%)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>94.1</td>
<td>---</td>
</tr>
<tr>
<td>Test Section 1</td>
<td>94.4</td>
<td>+ 0.3</td>
</tr>
<tr>
<td>Test Section 2</td>
<td>95.3</td>
<td>+ 1.2</td>
</tr>
</tbody>
</table>

Average of 12 nuclear gauge readings each / Reference is $G_{\text{mm}}$

- Control achieved maximum incentive
- Additional roller did not change % density
- Mix design adjustment resulted in % density increase
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Contractor’s Compactive Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Current minimum sublot specification</td>
</tr>
<tr>
<td>Test Section 1</td>
<td>New PWL specification&lt;br&gt;4 rollers – 3 vibratory rollers in echelon&lt;br&gt;1 vibratory on joint (4 vibratory &amp; 1 static pass)</td>
</tr>
</tbody>
</table>
State #5

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Density Results (%)</th>
<th>Change</th>
<th>Pay Factor</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide Avg.</td>
<td>93.6</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Control</td>
<td>94.4</td>
<td>---</td>
<td>0.97</td>
<td>1.55*</td>
</tr>
<tr>
<td>Test Section 1</td>
<td>96.1</td>
<td>+1.7</td>
<td>1.04</td>
<td>0.95*</td>
</tr>
</tbody>
</table>

Average of 5 cores each / Reference is $G_{mm}$

* Statewide averages

- Implementing PWL specification
- Control and test section both obtained maximum incentive
• 8 of 10 projects constructed

• Key Lessons:
  1. Follow best practices
     • 6 of 8 increased density from control
     • 4 of 8 had equipment issues
  2. Inter-relationship between:
     • Mix design / Field mix verification / Density specification
     • 2 of 8 had “dry” mixtures
  3. Higher density is achievable:
     • Optimistically: higher density with best practices only (8 of 8)
     • Pessimistically: higher density with additional roller (4 of 8)
1. The Importance of Density
2. FHWA – AI Compaction Workshop
3. Field Demonstration Projects
4. Summary
Summary

• Density is critical to performance
• Improving density is possible
  • Mix design changes
    • Fine gradation
    • Lower gyrations
    • Increased Vbe
  • Best practices
    • Mix production
    • Tack coat
    • Paving
    • Compaction
  • Specification changes
• Lift thickness
  • Changes are likely
Next Steps...

• State’s summary reports on all 10 projects
  • follow-up activities on field performance
• FHWA’s best practices communication
  • Summary document
  • Tech Brief
  • Additional workshops
• Extend field experiment
  • Dependent on FY17 funding
  • Dependent on State interest
Thank you

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