Enhanced Durability Through Increased Density

November 16, 2016
Corpus Christi, Texas

Tim Aschenbrener, P.E.
FHWA
Senior Asphalt Pavement Engineer
Materials and Quality Assurance Team
Office of Asset Management, Pavements and Construction
Lakewood, Colorado

Overall Objective

Ultimately, achieving the in-place asphalt pavement density that results in the highest asphalt pavement performance.

Our Visit

1. The Importance of % Density
2. FHWA – AI Compaction Workshop
3. Field Demonstration Projects
4. Wrap Up

Compaction is Important

- Golfer, M., "What 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."

NCAT Report 16-02 (2016)

"A 1% decrease in air voids was estimated to:
- improve fatigue performance by 8.2 and 43.8%
- improve the rutting resistance by 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

Average Increase in Fatigue Life for 1% Decrease in Air Voids

- TPHRC
- AI 2010: 9.2%
- WesTrack 2002: 8.7%
- UCB 1996: 11.9%
- UCB 1969: 27.2%
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>TmLC</td>
<td>10.0%</td>
<td></td>
</tr>
<tr>
<td>AI 2010</td>
<td>10.9%</td>
<td></td>
</tr>
<tr>
<td>WT rc</td>
<td>7.3%</td>
<td></td>
</tr>
<tr>
<td>WT f/f+</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

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

*Compaction is important, but not a cure-all remedy*

Our Visit

1. The Importance of % Density
2. FHWA – AI Compaction Workshop
3. Field Demonstration Projects
4. Wrap Up

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

Workshop

- Feedback Very Positive
  - Formal training
  - Comprehensive:
    - Mix design to
    - Finish roller to
  - Measurement and Acceptance
  - Back to the basics focus
    - Learned new topics
    - Reinforced others

- Workshops to Date
  - 10 locations
  - > 450 participants

Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density

Key:
- **PR** Demonstrations projects (10)
- **Workshop Only** (15)

Map showing locations in the United States.
Our Visit

- The Importance of Density
- FHWA – Al Compaction Workshop
- Field Demonstration Projects
- Wrap Up

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

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>Added 1 to 2 vibratory passes</td>
</tr>
<tr>
<td>Test Section 2</td>
<td>3 rollers – added pneumatic</td>
</tr>
</tbody>
</table>

State #1 Experiment Density Results (%)

<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>
</table>
| Control    | 10-ton vibratory roller (8 passes)  
4-ton vibratory roller (7 passes) |
| Test Section | 10-ton vibratory roller (10 passes)  
4-ton vibratory roller (7 passes) |

State #2

<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
How Is Acceptance Determined

How Is Acceptance Determined?

- Simple averaging
- Other advanced statistics such as AAD
- PWL

PennDOT Case Study

Minimum Lot Average

NYSDOT Case Study

PWL: Lower Specification Limit

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Contractor’s Compactive Effort</th>
</tr>
</thead>
</table>
| Control    | 6 rollers
            - 2 vibratory in echelon (5 to 7 passes each)
            - 2 pneumatic in echelon (5 to 7 passes each) |
| Test Section 1 | 5 rollers – added 1 vibratory roller |
| Test Section 2 | 5 rollers – added 0.3% asphalt |
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

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 $G_{mm}$

- Control achieved maximum incentive
- Additional roller did not change % density
- Mix design adjustment resulted in % density increase

Selecting Optimum with Superpave

What Changes Were Made to AASHTO Standards?

- Gyrations
- Air Voids
- Voids in the Mineral Aggregate (VMA)
- Is There Additional Criteria?

Combination of Changes

54% (14 of 26) Made 2 or More Changes

State #5

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Contractor’s Compactive Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>???.</td>
</tr>
<tr>
<td>Test Section 1</td>
<td>4 rollers – 3 vibratory rollers in echelon 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>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide Avg.</td>
<td>93.6</td>
<td>---</td>
</tr>
<tr>
<td>Control</td>
<td>94.4</td>
<td>---</td>
</tr>
<tr>
<td>Test Section 1</td>
<td>96.1</td>
<td>+1.7</td>
</tr>
</tbody>
</table>

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

- Implementing PWL specification
- Control and test section both obtained maximum incentive

State #6

**Experiment** | **Contractor’s Compactive Effort**
---|---
Control | 1 vibratory roller (9 passes)
1 pneumatic roller (14 to 18 passes)
1 finish roller (passes)

Test Section | Same rollers and passes
Decreased roller spacing
Increased pneumatic weight by 3 tons

State #6

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Density Results (%)</th>
<th>n</th>
<th>LSL</th>
<th>PWL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>93.1</td>
<td>77</td>
<td>91.0</td>
<td>90.3</td>
</tr>
<tr>
<td>Test Section</td>
<td>93.0</td>
<td>11</td>
<td>92.0</td>
<td>93.3</td>
</tr>
</tbody>
</table>

Standard deviation changes from 1.58 to 0.67 / Reference is $G_{mm}$

- Additional effort by contractor was minimal
- Uniformity improvements showed LSL could be 1% higher

Percent Within Limits

- 8 of 10 projects to date
- 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)
**Next Steps**

- Summary report on 10 projects’ construction
  - Potential follow-up on field performance
- Best practices communication
  - Summary document
  - Tech Brief
  - Additional training workshops (funding dependent)
- Potential to extend field experiment with more states
  - Dependent on funding
  - Dependent on state interest

---

**Thank you**

**QUESTIONS / COMMENTS:**

TIM ASCHENBRENER, P.E.
FHWA
SENIOR ASPHALT PAVEMENT ENGINEER
MATERIALS AND QUALITY ASSURANCE TEAM
OFFICE OF ASSET MANAGEMENT, PAVEMENTS AND CONSTRUCTION
LAKEWOOD, COLORADO
(720) 963-3247
TIMOTHY.ASCHENBRENER@DOT.GOV