Paver Thermal Profiling, Intelligent Compaction and Rolling Density Meter (GPR)

Curt Turgeon PE  State Pavement Engineer
February 7, 2018

Everything you need to know

Presentation Breakdown

- Paver Mounted Thermal Profiling – SHRP2 25%
  - AASHTO PP-80
- Intelligent Compaction of Asphalt Pavements 25%
  - AASHTO PP-81
- Rolling Density Meter - SHRP2 50%
  - Draft AASHTO PP (2019?)
  - Draft AASHTO Standard for Data Files (2019?)
### MN Intelligent Compaction and Thermal Profiling History

<table>
<thead>
<tr>
<th>Year</th>
<th>Intelligent Compaction</th>
<th>Paver Mounted Thermal Profiling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Paver Mounted Thermal Imaging Equipment

- **Total Number of Projects**
  - Intelligent Compaction: 132
  - Paver Mounted Thermal Profiling: 156

### Monetary Price Adjustment

**Thermal Segregation**

- Exclude following surface temp. readings:
  - $< 180 \, ^\circ F$
  - Paver stops $> 1$ min. in length

**Thermal Segregation – Range**

- Range = $T_{max} - T_{min}$

![Range Equation](image)
### Sublot Temperature Differential

<table>
<thead>
<tr>
<th>Range</th>
<th>Thermal Segregation Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range ≤ 25.0°F</td>
<td>Low</td>
</tr>
<tr>
<td>25°F &lt; Range ≤ 50°F</td>
<td>Moderate</td>
</tr>
<tr>
<td>50°F &lt; Range</td>
<td>High</td>
</tr>
</tbody>
</table>

Not all paver stops create roughness, not all roughness is from paver stops. Fewer paver stops equals fewer opportunities to create roughness.

---

### Intelligent Compaction

![Diagram of Intelligent Compaction](image)

Figure Courtesy of Trimble
**Observe Rolling Operations**

- **Thermal**
  - Real time in field and anywhere online
  - Easy to interpret or diagnose
  - Follow proper practices = success

- **Intelligent Compaction**
  - Real time for roller operators
  - Multiple rollers and parameters
  - Currently limited to after the fact diagnosis. (one to two day delay depending upon complexity)
  - Real time field analysis coming soon

---

**Thermal and IC Synopsis**

---

**Effects of Technology on Process Control**

- **RDM Theory**

<table>
<thead>
<tr>
<th>Material</th>
<th>Dielectric Value</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1</td>
<td>Radar travels very fast (fastest)</td>
</tr>
<tr>
<td>Water</td>
<td>81</td>
<td>Radar travels very slowly (slowest)</td>
</tr>
<tr>
<td>Asphalt Mix</td>
<td>4 – 8</td>
<td>Not as fast as through air</td>
</tr>
</tbody>
</table>

Asphalt Mix composition
- Aggregates: 4-9
- Asphalt binder: 2
- Air: 1

**Lower Air Content → Higher Dielectric**

**Higher Dielectric → Higher Density**
Rolling Density Meter (RDM)

- RDM is an air-coupled GPR with 2.0 GHz sensor(s)
- 3 antennas can be spaced from 1 to 2.5 ft apart
- RDM operates in passes in regions of interest (e.g., near longitudinal joint)
- Data acquisition relatively quick
  - 10 dielectric reading per foot of travel
  - 1584 tests per minute walking at 3 mph

RDM vs other GPR-based Tools

- Strict Performance Specification

<table>
<thead>
<tr>
<th>Measure Description</th>
<th>Required Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Term Dielectric Stability</td>
<td>Max: 0.06</td>
</tr>
<tr>
<td>Mid Term Dielectric Stability</td>
<td>Max: 0.08</td>
</tr>
<tr>
<td>Long Term Dielectric Stability</td>
<td>Max: 0.08</td>
</tr>
<tr>
<td>Inter-Antenna Dielectric Variation*</td>
<td>Max: 0.08</td>
</tr>
<tr>
<td>Inter-Antenna Amplitude Variation*</td>
<td>Max: 5%</td>
</tr>
</tbody>
</table>

*Multi-channel systems only

RDM Performance Improvement

➢ Measurement difference among the antennas?

Field Testing – SHRP 2

- Objectives
  - DOT personnel training
  - RDM technology evaluation/refinement
  - Test protocols and specifications development
- Projects
  - US-52 near Zumbrota, Minnesota
  - HWY 2 in Lincoln, Nebraska
  - US-1 near Cherryfield, Maine
  - State Rte 9 near Clifton, Maine
  - I-95 near Pittsfield, Maine
  - US-14 near Eyota, Minnesota
Rolling Density Meter

Related Dielectric Measurements to Air Void Content

TH52: 32 cores

$y = 15.652e^{-1.013x}$

$R^2 = 0.6887$

Core Measured Air Voids

RDM Measured Dielectric

Effect of Roller Number and Binder Content

Median Density

- 4 rollers, no added binder (control): 93.4% MTD
- 5 rollers, no added binder: 93.1% MTD
- 4 roller, added binder: 93.0% MTD
- 5 roller, added binder: 94.0% MTD

Section with added binder + 5 rollers has the highest density
### TH 52: Comparison with Other Factors

**Local decreases (blue) at unconfined edges**

**Local increase after Added Roller**

Dielectric

### Evaluation of Compaction at Longitudinal Joint

<table>
<thead>
<tr>
<th>Location</th>
<th>Relative Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainline</td>
<td>93.5%</td>
</tr>
<tr>
<td>Unconfined side of the joint</td>
<td>91.4%</td>
</tr>
<tr>
<td>Confined side of the joint</td>
<td>92.5%</td>
</tr>
<tr>
<td></td>
<td>Std Deviation</td>
</tr>
<tr>
<td></td>
<td>0.94%</td>
</tr>
<tr>
<td></td>
<td>1.22%</td>
</tr>
<tr>
<td></td>
<td>1.8%</td>
</tr>
</tbody>
</table>

**TH 52 – Longitudinal Joint**

[Graph showing relative density with colors for mainline, confined joint, and unconfined joint]
**Rolling Density Meter - 2017**

**I-35 Echelon Paving**

- Best way to compact the joint?
  - First pass roller offset of joint?
  - First pass roller overlap joint?

---

### Interstate 35 – OFFSET OF JOINT
**Passing Lane Mat vs Joint Histogram**

<table>
<thead>
<tr>
<th>Group Name</th>
<th>Stationing range, ft.</th>
<th>Offset range, ft.</th>
<th>Color</th>
<th>Samples</th>
<th>50th Percentile Dielectric</th>
<th>90th Percentile Dielectric</th>
<th>Dielectric Range (50th-10th)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing Mat</td>
<td>507+24 to 1012+13</td>
<td>10 to -2</td>
<td>Red</td>
<td>197,309</td>
<td>4.27</td>
<td>5.36</td>
<td>0.19</td>
</tr>
<tr>
<td>Passing Joint</td>
<td>0.7 to 0.3</td>
<td>Green</td>
<td>37,864</td>
<td>4.90</td>
<td>4.17</td>
<td>4.30</td>
<td>0.13</td>
</tr>
</tbody>
</table>

- Increased compaction in mat vs joint can be observed on-site by increase in dielectric
- Mat and Joint had similar consistency with dielectric ranges of 0.19

---

### Interstate 35 – OVERLAP OF JOINT
**Driving Lane Mat vs Joint Histogram**

<table>
<thead>
<tr>
<th>Group Name</th>
<th>Stationing range, ft.</th>
<th>Offset range, ft.</th>
<th>Color</th>
<th>Samples</th>
<th>50th Percentile Dielectric</th>
<th>90th Percentile Dielectric</th>
<th>Dielectric Range (50th-10th)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving Mat</td>
<td>507+24 to 1012+13</td>
<td>0 to 0.7</td>
<td>Brown</td>
<td>95,306</td>
<td>5.18</td>
<td>5.27</td>
<td>0.15</td>
</tr>
<tr>
<td>Driving Joint</td>
<td>0.3 to 0.7</td>
<td>Blue</td>
<td>257,307</td>
<td>5.14</td>
<td>5.27</td>
<td>0.14</td>
<td></td>
</tr>
</tbody>
</table>

- No statistically significant decrease in joint compared to mat
- No statistically significant increase in variability at the joint
**Interstate 35 – Passing Lane Offset Comparison**

- First ½ mile stretch
- Most of the increase occurs in the first 500 ft when 4 ft. away from the joint
- Gradual increase over 2500 ft occurs at 2 ft. from the joint

**Interstate 35 – Local Variation Offset Comparison**

- First 500 ft local comparison
- Can observe cyclical variation in the mat at different compaction levels
- Both offsets show similar variations in compaction

**Interstate 35 – Local Variation Offset Comparison**

- 1000 ft comparison after increase in compaction
- Can observe cyclical variation in the mat at similar compaction levels
- Variability within offsets are lower

**County Road 86 – Consultant vs MnDOT Repeatability**

- Increased compaction in mat vs joint can be observed on-site by increase in dielectric
- Mat had slightly better consistency than joint (0.21 range vs 0.28 range)
Intelligent Construction Data Management

Current Pooled Fund Participants

11 States

http://www.pooledfund.org/Details/Study/583

Total Commitments (TPF Website) $726,500
Total Funds Received $396,500

Vendor’s cloud Server
Automatic Wireless Transmission
Manually “Push”
Project and Machines IDs setup
Vendor’s cloud Server
Upgrade d or gridded data files
User log-in for access
Storage time

IC/PMTP data

Direct Download to Veta from Cloud

Veta 5.0

Strategic Implementation Through Cooperative Pavement Research
QUESTIONS?