Improving Quality Control with Intelligent Compaction

Bob Horan, P.E.
Asphalt Institute Regional Engineer
Richmond VA
Washington DC 1907

Intelligent Hauling Units?
How Does IC Help with QC?

• “Real-Time” Feedback to Roller Operator
  – On-Board, Color-Coded Mapping
    • Improved roller patterns
    • Improved temperature control
    • Ability to make adjustments “on-the-fly”

• Permanent Records of Compaction Data

• “Mapping” of Underlying Materials
  – RMV (Roller Measurement Values) readings
    • Locates “soft spots”
    • Identifies irregular support for compaction
Why Intelligent Compaction?

Why Do We Need IC?

• Proper in-place density is vital for good performance

• Conventional compaction equipment and procedures have shortcomings and too often produce poor results

• Intelligent compaction technology appears to offer “a better way”
What is Intelligent Compaction?

An Innovation in Compaction Control and Acceptance
What is Intelligent Compaction?

Vibratory Single Drum Soil Roller

Vibratory Tandem Drum Asphalt Roller
Tandem Drum IC Roller Suppliers

Ammann/Case

Volvo

Dynapac

Bomag America

Caterpillar

Sakai America
IC Roller Requirements

- Roller Measurement Value (RMV)
- GPS-Based documentation system
- Color-coded display (on-board)
- Surface temperature measurement system
- Optional: automatic feedback system
Available Tandem Drum IC Rollers

Bomag

Sakai
## Roller Measurement Values (RMVs)

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Roller Measurement Value</th>
<th>Measurement Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sakai</td>
<td>Compaction Control Value; <strong>CCV</strong></td>
<td>Unitless</td>
</tr>
<tr>
<td>Bomag</td>
<td>Vibration Modulus; <strong>E_{VIB}</strong></td>
<td><strong>Mn/m^2</strong></td>
</tr>
</tbody>
</table>
Color-Coded On Board Display
Global Positioning System (GPS)

GPS Base Station

GPS Radio & Receiver

GPS Rover

Real Time Kinematic (RTK) GPS Precision
Mat Surface Temperature Measurement

Infrared Thermal Gauge
“Real-Time” Feedback to Roller Operator
• Roller Passes

Shoulder (Supported)

Longitudinal Joint

Paving Direction

Number of roller passes

1 2 3 4 5 6 7 8

 Courtesy Sakai America
Color-Coded On Board Display
Roller Operator Training
Improved Rolling Patterns

Before

After

Sakai IC roller

Indiana ICPF Project
Permanent Records of Compaction Related Data and Data Analysis
Data Analysis - PA ICPF
Data Analysis - PA ICPF
Data Analysis – PA ICPF

SW880 breakdown compaction

Mean: 28.48
STD: 15.45
COV: 0.54
Improving QC using IC

“Mapping of Underlying Layers Prior to Paving
“Mapping” of Underlying Materials

• Use of RMV color-coded mapping to measure support prior to paving of:
  – Subgrade soil materials
  – Stabilized subbase materials
  – Aggregate base materials
  – Existing asphalt pavements
  – Rubblized concrete pavements
• Underlying Support affects compatibility of subsequent layers
“Mapping” of underlying layers

Mapping of the subgrade / agg. base layer

Minnesota ICPF Project
HMA non-wearing course layer map, $a = 0.6$ mm, $f = 3000$ vpm

Class 5 aggregate subbase layer map, $a = 0.6$ mm, $f = 2500$ vpm

Reflection of hard spots on the HMA layer

Reflection of hard spots on the HMA layer

Reflection of soft spots on the HMA layer

$y = 2.45 \ln(x) + 2.3$
$R^2 = 0.69$

Sakai IC roller
IC Mapping (SB passing lane)

- Soil subgrade mean CCV ~ 5
- Rubblized PCCP mean CCV ~ 14
- Crack&Seat PCCP mean CCV ~ 18

2800 vpm Low amp
Future Research Needs - IC

• Improve correlation of Density vs. RMV
• Standardization of RMV
• Explore GPS Technology
  – Use of advanced, high prec. GPS technology
  – “Stand-Alone” (non RTK) GPS Technology
• IC Data Management
  – Improvements in on-board roller software
  – Data collection/storage
  – Data analysis/reporting
Summary

• Intelligent Compaction is a major innovation in compaction technology
• Research/field projects show that IC can offer a valuable tool to improve QC of the compaction process
• IC technology is now readily available in U.S.
• More work is need to address various issues
• Stay tuned!
What’s Next?

Caterpillar Remote Wireless Capabilities
We’ve Come a Long Way

1924 Buffalo Springfield Steam Roller
Improving QC with IC

Questions?
Improving QC with IC

- Shortcomings in the Compaction Process...

Limited “On The Fly” Feedback

Over or Under-Compaction Can Occur
Improving QC with IC

- Shortcomings in Density Acceptance Process...

Limited Number of Locations

After Compaction is Complete
Mountainous, Curvy, Heavily Forested Roadways

Pennsylvania ICPF Project
• Operational Instructions (for data collection and transfer) are fairly quick and easy
• However, where manufacturer support is not on-site, collection and transfer of data to agency is problematic
• IC software supplied to agencies and contractors for data analysis is difficult to use
TB 01A Intermediate HMA Layer

Roller pass

Sakai CCV

Surface temperature (°C)

Georgia ICPF Project

Sakai IC roller
Data Analysis - VA ICPF
MS ICPF Project

TB02A (5-day cure) TB02B (6-day cure) TB02C (7-day cure)

TB 2B-2 TB 2B-1 TB 2C-2
TB 2B-2 TB 2C-1
TB 2A-1

TB 2A-2

TB 2A-3

TB 2B-1 TB 2C-1

TB 2B-2 TB 2C-2

Graph showing COVs for TB02A (5-day cure), TB02B (6-day cure), and TB02C (7-day cure).
“Mapping” of Base and HMA Layers

Minnesota ICPF Project
### Test bed 02 Mapping

#### Bomag Evib

<table>
<thead>
<tr>
<th>Done</th>
<th>650 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start date</td>
<td>12:35:17 PM 7/21/2009</td>
</tr>
<tr>
<td>End date</td>
<td>12:41:51 PM 7/21/2009</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evib [MN/m²]</td>
<td>226</td>
<td>350</td>
</tr>
<tr>
<td>Amplitude [mm]</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Frequency [Hz]</td>
<td>50</td>
<td>67</td>
</tr>
<tr>
<td>Speed [km/h]</td>
<td>5.5</td>
<td>6.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EVIB [MN/m²]</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 350</td>
<td>13 %</td>
</tr>
<tr>
<td>313–350</td>
<td>29 %</td>
</tr>
<tr>
<td>276–313</td>
<td>21 %</td>
</tr>
<tr>
<td>238–276</td>
<td>7 %</td>
</tr>
<tr>
<td>200–230</td>
<td>3 %</td>
</tr>
<tr>
<td>&lt; 200</td>
<td>15 %</td>
</tr>
<tr>
<td>Σ</td>
<td>200–350 65 %</td>
</tr>
</tbody>
</table>

AVG-value [MN/m²] 236
Increase 0
Standard deviation 96

---

#### MD ICPF Project

---

#### MD US 340 EBL
Future GPS Research?

• Increase practical knowledge of research, agency and contractor personnel
• Simplify GPS setup and use
  – Any improvements to make GPS “plug and play” will speed acceptance of IC technology
• Use of “advanced” GPS technologies
  – Virtual Reference System (VRS)
  – GPS repeaters
  – Internet base stations and server/client systems
  – Stand-alone, high precision GPS
Issues with IC Data Management

- Data format
- Data collection
- Data storage
- Data processing
- Develop independent software tool
  - Efficient
  - Accurate
  - Fast
Summary

• Research and field projects have shown:
  – Intelligent Compaction is an important innovation that can improve the compaction process and QC practices
  – IC equipment is available now
  – Generally, roller operators and project personnel find IC technology “user friendly” and a valuable tool
  – More research is needed to address issues with standardizing RMV, with data management and with GPS