Using Real-Time Smoothness Measurements to Improve the Initial Smoothness of Portland Cement Concrete Pavement

SHRP2 Solutions Webinar
13 November 2017
Webinar Agenda

• Introduction by FHWA
• Session 1: Fundamentals and Importance of Pavement Smoothness
• Session 2: Overview of Real-Time Smoothness Technology
• Session 3: RTS for Achieving Initial Pavement Smoothness
• Session 4: Agency and Contractor Perspectives
• Session 5: Lessons Learned from RTS Equipment Loan Program
• Session 6: Q&A with Panelists
Webinar Presenters

- Tom Yu, FHWA
- David Merritt, The Transtec Group, Inc.
- Gary Fick, Trinity Construction Management Services, Inc.
- Kevin Merryman, Iowa DOT
- Craig Hughes, Cedar Valley Corp.
Real Time Smoothness

Tom Yu
FHWA Office of Infrastructure
SHRP2 R06E - Real-Time Smoothness Measurements on PCC

BENEFITS:
- SHRP2 Solution provides real-time information for process control of smoothness
- Allows for immediate adjustments to equipment and operations
- Minimizes pavement grinding and remediation
- Better quality control
- Potentially better long-term performance

PRODUCTS:
- Model Specifications
- Guidelines
- Documentation of profiler performance and recommendations

Non-Destructive Testing Tools
SHRP2 RTS Implementation Program

- Equipment Loan Program
- Showcase
- Workshops
- Documentation of results/case studies
- Specification Refinement
R06E - Tools to Improve PCC Smoothness During Construction

Lead Adopter Agencies

Additional Equipment Loans
Real-Time Smoothness
FHWA follow-on support program

• **Equipment Loan / Demos:**
  – Total of 6 on-site demos over 2 years
  – Contacts
    • David Merritt
    • Gary Fick
    • Tom Yu

• **Training of MCT staff**

• **Webinar**
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Session 1: Fundamentals and Importance of Pavement Smoothness

- Importance of Pavement Smoothness
- Fundamentals of Pavement Smoothness Measurement and Interpretation
Importance of Pavement Smoothness

Key reasons why smoothness is important (Agency Perspective):

1. It’s important to the user (taxpayer).
2. Smoother roads last longer.
3. Smoother roads stay smoother longer.
4. Smoother roads are safer.
5. Smoother roads save money.
Importance of Pavement Smoothness

Key reasons why smoothness is important

(Contractor Perspective):

1. Reflects the quality of your work.
2. $$$
Measuring Pavement Smoothness

Profilograph vs. Profiler

- We want to measure the “true” profile or the true shape of the pavement surface.
- Profilers give us a better representation of the pavement profile.

Inertial Profilers
(high speed and lightweight)

Walking Profilers
Profilograph vs. Profiler

• We want to measure the “true” profile or the true shape of the pavement surface.

• Profilers give us a better representation of the pavement profile.

Real-Time Profilers
Measuring Pavement Smoothness

Pavement Profile from Real-Time Smoothness (RTS) System

![Graph showing pavement profile with Elevation (in.) on the y-axis and Distance (ft) on the x-axis. The graph displays two lines representing data from the RTS system.]
Interpreting Pavement Smoothness

Profilograph Index (Prl) vs. International Roughness Index (IRI)

• The Prl is a measure of pavement smoothness related to a profilograph trace.
• IRI is a better representation of actual ride quality, or what the user (driver) experiences based on vehicle response to the pavement profile.
PCC Pavement Smoothness Specifications

Merritt et al. 2015
PCC Pavement Smoothness Specifications

• Summary of IRI-based specification thresholds for PCC pavements:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Incentive Upper Limit</th>
<th>Full Pay Lower Limit</th>
<th>Full Pay Upper Limit</th>
<th>Disincentive Lower Limit</th>
<th>Disincentive Upper Limit</th>
<th>Threshold for Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI &amp; IRI (22 states) min</td>
<td>39.9</td>
<td>40.0</td>
<td>54.0</td>
<td>54.1</td>
<td>67.5</td>
<td>60.0</td>
</tr>
<tr>
<td>max</td>
<td>70.0</td>
<td>71.0</td>
<td>93.0</td>
<td>93.1</td>
<td>140.0</td>
<td>150.0</td>
</tr>
<tr>
<td>avg.</td>
<td>56.2</td>
<td>56.5</td>
<td>71.7</td>
<td>72.5</td>
<td>95.3</td>
<td>96.9</td>
</tr>
<tr>
<td>HRI (CO only)</td>
<td>57.9</td>
<td>58.0</td>
<td>67.0</td>
<td>67.1</td>
<td>85.0</td>
<td>85.0</td>
</tr>
</tbody>
</table>

Merritt et al. 2015
PCC Pavement Smoothness Specifications

- Range of Incentive/Disincentives applied for ride quality:

<table>
<thead>
<tr>
<th>Pay Adjustment Basis</th>
<th>Maximum Incentive</th>
<th>Maximum Disincentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ per lot (0.1 mi) 9 states</td>
<td></td>
<td></td>
</tr>
<tr>
<td>min</td>
<td>$200</td>
<td>-$250</td>
</tr>
<tr>
<td>max</td>
<td>$1,600</td>
<td>-$1,750</td>
</tr>
<tr>
<td>avg.</td>
<td>$879</td>
<td>-$900</td>
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<tr>
<td>$ per lot (SY) 2 states</td>
<td></td>
<td></td>
</tr>
<tr>
<td>min</td>
<td>$1.40</td>
<td>-$1.12</td>
</tr>
<tr>
<td>max</td>
<td>$1.40</td>
<td>-$1.40</td>
</tr>
<tr>
<td>avg.</td>
<td>$1.40</td>
<td>-$1.26</td>
</tr>
<tr>
<td>$ per lot (1.0 mi) 1 state</td>
<td>$7,350</td>
<td>-$7,350</td>
</tr>
<tr>
<td>$ per lot (0.01 mi) 1 state</td>
<td>$50</td>
<td>-$500</td>
</tr>
<tr>
<td>$ per lot (500 ft.) 1 state</td>
<td>$250</td>
<td>-$250</td>
</tr>
<tr>
<td>Extended Pay Adjustment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ per lot (0.1 mi) 13 states (NJ excluded)</td>
<td>$200</td>
<td>-$250</td>
</tr>
<tr>
<td>Percent Contract Price 7 states</td>
<td>min</td>
<td>102%</td>
</tr>
<tr>
<td>max</td>
<td>108%</td>
<td>50%</td>
</tr>
<tr>
<td>avg.</td>
<td>105%</td>
<td>75%</td>
</tr>
</tbody>
</table>

Merritt et al. 2015
PCC Pavement Smoothness Specifications

- Summary of localized roughness provisions for IRI-based specifications:

<table>
<thead>
<tr>
<th>Method</th>
<th>Number of States</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Asphalt</td>
<td>Concrete</td>
</tr>
<tr>
<td>Continuous IRI (25 ft. baselength)</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Fixed Interval IRI</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Profile Moving Average (25 ft. baselength)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Profilograph Simulation (25 ft. baselength)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Straightedge Only</td>
<td>18</td>
<td>4</td>
</tr>
</tbody>
</table>

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Session 2: Overview of Real-Time Smoothness Technology

• Real-Time Smoothness (RTS) Description
• Benefits and Limitations of RTS Technology
• Typical RTS Configurations
What is RTS Measurement?

Real-time Smoothness refers to measuring and evaluating the concrete pavement surface profile during construction, somewhere along the paving train while the concrete surface is still wet (plastic).
RTS Benefits

• Innovative tool for evaluating concrete pavement smoothness in real time.

• Tool that can be used for quality control and process improvements.

• Process improvements as a result of timely feedback.

• Improved understanding about how construction artifacts can affect smoothness.
RTS Limitations

• Not a replacement for conventional profiling for acceptance.

• Not a replacement for better practices to construct smoother pavements.
RTS Profilers

Ames Engineering Real Time Profiler (RTP)
Paver-Mounted GOMACO Smoothness Indicator (GSI)
RTS Profilers

Stand-Alone GOMACO GSI Machine
### RTS Mounting

- Typically mounted to the back of the paver (main pan or finish pan).
- Can also be mounted to a trailing work bridge or texture/cure cart.
- Typically mounted mid-lane, in the lane wheelpaths (corresponding to hardened profile acceptance), or where profile is traditionally rougher.
RTS Mounting
RTS Measurements

- Real-time feedback, viewing and analysis capabilities:
RTS Measurements

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RTS Measurements

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Session 3: RTS for Achieving Initial Pavement Smoothness

- Why use RTS?
- Step-by-Step Implementation of RTS Technology
Reasons for Using RTS Equipment

• Reduce disincentives
• Increase incentives
• Anticipated change in smoothness acceptance requirements
  ▪ Prl to IRI
  ▪ Change in localized roughness specification limits
Implementation of RTS

- Smoothness is the “heartbeat” of the paving operation.
  - An EKG indicates that something is abnormal with the heart, but does not diagnose the underlying cause(s).
  - RTS is similar to an EKG. The profile feedback indicates if there are issues with the paving operation, but doesn’t diagnose the root cause.
  - Process adjustments are then made to improve the RTS results.
Using RTS Systems

• **Step 1 – Establish a baseline**
  - Monitor results for 1 to 2 days.
  - Keep processes static, but make ordinary adjustments.
  - Observe typical responses to the ordinary adjustments and make notes or add event markers in the RTS.
    - Mixture
    - Vibrators
    - Speed
    - Head
    - Paver stops
    - Etc.
Using RTS Systems

- The RTS results are higher than the QC hardened profiles – what’s up with that?
  - Don’t panic
  - Just focus on making the RTS results better (lower IRI)
  - QC profiles will improve as well
Using RTS Systems

• Step 2 – Pick the low hanging fruit

• Eliminate large events that cause excessive localized roughness.
  ▪ Stringline/stringless interference
  ▪ Paver stops
  ▪ Padline issues
  ▪ Etc.
Localized Roughness Events

- Stringless system interference
Localized Roughness Events

- Running the paver out of concrete
Localized Roughness Events

- Stopping the paver

### Event Log

<table>
<thead>
<tr>
<th>St.Start</th>
<th>St.End</th>
<th>Description</th>
<th>Date/Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>91+10 st</td>
<td>0+00 st</td>
<td>PAVER STOP</td>
<td>10:58a 10/01</td>
</tr>
<tr>
<td>91+71 st</td>
<td>0+00 st</td>
<td>PAVER STOP</td>
<td>11:13a 10/01</td>
</tr>
<tr>
<td>92+02 st</td>
<td>0+00 st</td>
<td>PAVER STOP</td>
<td>11:28a 10/01</td>
</tr>
<tr>
<td>94+56 st</td>
<td>0+00 st</td>
<td>PAVER STOP</td>
<td>12:13a 10/01</td>
</tr>
<tr>
<td>97+14 st</td>
<td>0+00 st</td>
<td>PAVER STOP</td>
<td>01:02p 10/01</td>
</tr>
<tr>
<td>97+41 st</td>
<td>0+00 st</td>
<td>PAVER STOP</td>
<td>01:08p 10/01</td>
</tr>
</tbody>
</table>
Using RTS Systems

• Step 3 – Adjust the paving process to improve overall smoothness
  - Maintain a consistent head
  - Lead/draft to get the paver as flat as possible
  - Sensitivities
  - Vibrators (height and frequency)
  - Mixture
  - Paver operation
  - Paving speed
Overall Smoothness

- Eliminating big events gives you a new “baseline” to adjust from.
  - Systematically make changes in small increments.
  - Get a minimum of 0.1 mile with consistent paving (no big events) and then evaluate if the adjustment made things smoother.
  - Continue adjusting in small increments and evaluating every 0.1 mile.
Overall Smoothness

- Stay focused and incredible things can happen

*Over a mile paved per day – average IRI = 28 in/mi:*
Using RTS Systems

• Step 4 – Identify repeating features using a ProVAL PSD plot and adjust processes when possible.
  ▪ Joints
  ▪ Dumping/Spreading loads
  ▪ CRCP bar supports
• Dowel baskets or insertion.
Repeating Features

- Load spacing.
Repeating Features

- Transverse bar supports.

![Graph showing slope spectral density vs wavelength (ft) with a peak at 4 feet wavelength.](image)
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Session 4: Agency and Contractor Perspectives

Contractor: Craig Hughes, Vice-President Operations
Cedar Valley Corp., LLC

Agency: Kevin Merryman, PCC Field Engineer
Office of Construction and Materials, Iowa
Department of Transportation
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Equipment Loans

- Idaho, I-84
- Nebraska, I-80
- Michigan, I-69
- Texas, SH99
- Pennsylvania, I-81
- Iowa, Lyon Co. L-26
- Illinois, I-90
- Utah, I-215
- Utah, I-15
- California, SR-46
- Iowa US-20
Idaho, I-84

- Ames RTP

- Project Info
  - Widening of an existing interstate pavement
  - 12” JPCP over asphalt base (portion over agg. base)
  - 24’ paving width, 15’ joint spacing with dowel baskets
  - Stringless paving
  - Concrete deposited in front of paver with placer.
Idaho, I-84
• Changes to the concrete mixture after the first half of Day 1 were evident in the RTP smoothness data.

• There was no clear correlation between material head height (in the grout box) and profile or roughness.

• Paver stops were monitored closely, no clear correlation between paver stops and roughness could be established.
Pennsylvania, I-81

- Gomaco GSI

- Project Info
  - Mainline paving of interstate pavement
  - 8” JPCP unbonded overlay
  - 24’ paving width, 15’ joint spacing with dowel baskets
  - Stringless paving
  - Concrete deposited in front of paver with placer.
Pennsylvania, I-81
Pennsylvania, I-81

- Real-time and hardened profiles parallel each other
- 20 in/mi difference
Pennsylvania, I-81

- Power Spectral Density for real-time and hardened profiles explains some of the 20 in/mi difference
Pennsylvania, I-81

i. Shorter wavelength roughness in the hardened profile is likely from macrotexture (burlap drag and tining) applied behind the GSI sensors.
ii. Real-time roughness at the 5’ wavelength was significantly reduced by hand finishing. This roughness is the primary contributor to the difference between real-time and hardened IRI.
iii. Joint spacing had slightly larger influence on roughness in the hardened profile than in the real-time profile, this is likely a result of curling and warping of the slabs.
iv. Long wavelength roughness is similar in both real-time and hardened profiles.
Utah I-15

- Ames RTP

- Project Info
  - Mainline paving of I-15
  - 9” JPCP over 3” HMA
  - 22’ paving width, 15’ joint spacing with inserted dowels
  - Matching existing pavement on one side
  - Stringless paving
  - Concrete deposited in front of paver
Utah I-15

- IRI on 150 ft base-length from ProVAL
- Matches what we were seeing in real-time the previous night
- IRI cycles up and down every ± 350’? Most pronounced on the right side of the paver, but still present on the left.
Illinois I-90

• Gomaco GSI

• Project Info
  ▪ Mainline paving of I-90
  ▪ 13” JPCP over 3” WMA
  ▪ 26’ paving width, 15’ joint spacing with inserted dowels
  ▪ Matching existing pavement on one side
  ▪ Stringless paving
  ▪ Concrete deposited in front of paver
Illinois I-90
Illinois I-90

- DBI malfunction during paving.
- Do finishers help?

![Graph showing IRI (in/mi) over distance (ft)]
Iowa US-20

- Gomaco GSI
- Project Info
  - Mainline paving of US-20
  - 10” JPCP over granular subbase
  - 26’ paving width, 20’ joint spacing with dowel baskets
  - Stringline controls
  - Concrete deposited in front of paver using a placer/spreader
• Specification change from PI to IRI is planned.

• Real-time evidence that IRI does not correlate to PI.
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