Lessons Learned from Real-Time Smoothness Technology Demonstrations
ACPA 2017 Annual Meeting
San Diego, California
30 November 2017
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What is Real-Time Smoothness?

Real-time Smoothness (RTS) 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 Profilers

GOMACO Smoothness Indicator (GSI)  
Ames Engineering Real Time Profiler (RTP)

SSI Dynamic Profiler (not shown)
Real-Time Feedback and Tracking of Events
Implementation of Real-Time Smoothness

• 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).
    ![EKG Image]
  • 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.
    ![RTS Image]
SHRP2 RTS Implementation Program
Continuing FHWA Support

2014-2017: SHRP2 Solutions
Implementation effort

• Equipment Loan Program
• Showcase
• Workshops
• Documentation of results/case studies
• Specification Refinement

2017-2019: FHWA RTS Technology Implementation

• Equipment Loans
• Briefings
• Webinar
• Coordination with FHWA Mobile Concrete Lab
Equipment Loan Program

- Idaho, I-84
- Nebraska, I-80
- Michigan, I-69
- Texas, SH99
- Pennsylvania, I-81
- Iowa, Lyon Co. L-26
- Illinois, I-90 Tollway
- Utah, I-15
- Utah, I-215
- California, SR46
- Iowa, US 20

- 8 JPCP, 2 CRCP, 1 Thin Overlay
- Varying slab thickness and base/subbase types
- Daytime and nighttime paving
- Varying paver types and setup (paver width, concrete delivery, finishing operations)
- Varying mix designs
- Dowel baskets and DBI
- 9 stringless, 2 stringline
Lessons Learned from RTS Equipment Loan Program

1. RTS vs. Hardened Profiles
2. Features Picked Up by RTS
3. Benefits for Contractors and Agencies
Lessons Learned:
1. RTS vs. Hardened Profiles

• Raw profiles are different but *trends* are similar
Lessons Learned:
1. RTS vs. Hardened Profiles

- Roughness results are different (RTS generally higher) but *trends* are similar.
Lessons Learned:
1. RTS vs. Hardened Profiles

- There is no fixed correlation between RTS and hardened numbers.
- In general, RTS numbers will always be higher, but the degree is project/crew/equipment specific.
- Any correlation will need to be established during the first few days of paving.
Lessons Learned:
1. RTS vs. Hardened Profiles

- **Rule of thumb:** the higher the RTS numbers, the greater the difference between RTS and hardened, the lower the RTS numbers, the smaller the difference.

<table>
<thead>
<tr>
<th>Project A</th>
<th></th>
<th>Project B</th>
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<tbody>
<tr>
<td></td>
<td>Segment</td>
<td>RTS IRI (in/mi)</td>
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<tr>
<td>Day 1</td>
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<td>113.2</td>
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<tr>
<td></td>
<td>2</td>
<td>77.3</td>
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<tr>
<td></td>
<td>3</td>
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<td>3</td>
<td>114.4</td>
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<td>Day 3</td>
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<td>111.7</td>
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<tr>
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<tr>
<td></td>
<td>2</td>
<td>122.5</td>
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<tr>
<td>Avg.</td>
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<td>105.8</td>
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Lessons Learned from RTS Equipment Loan Program

1. RTS vs. Hardened Profiles

2. Features Picked Up by RTS

3. Benefits for Contractors and Agencies
Lessons Learned:
2. Features Picked Up by RTS

- Joint spacing/dowel basket effects
- 15’ peaks in RTS localized roughness plot.
- Less pronounced in hardened IRI.
Lessons Learned:
2. Features Picked Up by RTS

- Joint spacing/dowel basket effects

- Dowel basket effect is reduced in hardened profile as finishers remove much of this shorter wavelength content.

- Dominant content at 15’ joint spacing.
- Less dominant in hardened profile.
- Harmonics at 7.5’, 5’, 3.75’, etc.
Lessons Learned:
2. Features Picked Up by RTS

• Stringline and Stringless System Effects

• 25’ dominant content = stringline pin spacing
• Still present in hardened profile.
• Must be viewed in context of overall smoothness: MRI ~55-60 in/mi
Lessons Learned:
2. Features Picked Up by RTS

• Stringline and Stringless System Effects

- ~350’ repeating pattern
- More pronounced on right side of paver.
Lessons Learned:
2. Features Picked Up by RTS

- CRCP Bar Supports
Lessons Learned:
2. Features Picked Up by RTS

- Load Spacing
Lessons Learned:

2. Features Picked Up by RTS

• Localized roughness/improvement from finishers
Lessons Learned from RTS Equipment Loan Program

1. RTS vs. Hardened Profiles
2. Features Picked Up by RTS
3. Benefits for Contractors and Agencies
Lessons Learned:
3. Benefits for Contractors & Agencies

• Primarily a QC tool for contractors
  ▪ Not so much for identifying localized roughness
  ▪ Evaluating effects of changes during paving on smoothness
  ▪ Identifying “systematic” issues in the paving operation

• NOT a replacement for conventional (hardened) QC profiling.

• Transition from PrI to IRI specifications.
Lessons Learned:
3. Benefits for Contractors & Agencies

- Finding (and maximizing) the “sweet spot” for improving smoothness:
• Equipment adjustments that can be reflected in RTS measurements:
  - Paver speed
  - Vibrator frequency
  - Vibrator height
  - Sensitivity of paver elevation controls (hydraulics and stringless)
  - Oscillating correcting beam frequency
  - Draft (angle of attack)
  - Others
• Process adjustments that can be reflected in RTS measurements:
  ▪ Concrete workability
  ▪ Concrete delivery/spreading procedures
  ▪ Stringline tension
  ▪ Hand finishing techniques (when sensors are mounted to a trailing work bridge)
  ▪ Concrete uniformity
  ▪ Stopping the paver vs. slowing the paver
  ▪ Concrete head (height and uniformity)
  ▪ Others
Lessons Learned:
3. Benefits for Contractors & Agencies

• Example from North Dakota
  ▪ Specification: Full Pay = 50-54 in/mi, Correction > 68 in/mi, ALR (25’ baselength) = 80 in/mi.
  ▪ Approx. 1.1 miles of paving: average IRI = 28 in/mi.
Lessons Learned:
3. Benefits for Contractors & Agencies

• Example from North Dakota
  ▪ Mixture Factors: optimized gradation mix, tailored for the project.
  ▪ Human Factors:
    • Conscientious crew, everyone knew their job (no panicking)
    • Experienced
    • Good communication
  ▪ Paving Factors:
    • Minimal design challenges (mostly tangent, little grade)
    • Well-maintained paver
    • Base trimmed to grade through padline
    • Two placer-spreaders = minimal “work” by paver
  ▪ RTS used as a “smell check” QC tool.
Real-Time Smoothness for Concrete Paving

Questions and Discussion