Guidelines for Building Smooth Concrete Pavements

ICPA Workshop
06 February 2020
Gary Fick, Project Manager, The Transtec Group, Inc.
Guidelines for Building Smooth Concrete Pavements

• Impacts on initial smoothness
Guidelines for Building Smooth Concrete Pavements

- Paving factors includes design elements
  - Vertical curves
  - Superelevation transitions
  - Project phasing (jigsaw puzzle)
  - Blockouts (gaps)
  - Matching existing lanes
  - Equipment clearance and trackline

- Specification limits should be adjusted for design elements that prohibit conformance with the specification
- A grinding pay item should be included when matching existing pavement
Guidelines for Building Smooth Concrete Pavements

• Materials and Mixtures
  • Performance engineered mixtures (PEM), optimized for:
    • Durability of the mixture
    • Economics
    • Sustainability
    • Utilization of locally available materials
    • Workability of the mixture
    • Other performance objectives
Guidelines for Building Smooth Concrete Pavements

• Materials and Mixtures
  • Tarantula curve
Guidelines for Building Smooth Concrete Pavements

• Materials and Mixtures
• Response to vibration in the lab
  • Box test
  • VKelly

• The paver is the field QC test
Guidelines for Building Smooth Concrete Pavements

• Mixture Production
  1. Supply uniform concrete to the paving operation
  2. Produce and deliver the concrete at a rate that will allow the paving operations to maintain a consistent speed with minimal paver stops (consistent delivery)
Guidelines for Building Smooth Concrete Pavements

• Mixture Production
• Uniformity, Uniformity, Uniformity
  • Within batch
  • Between batch
Guidelines for Building Smooth Concrete Pavements

- Mixture Production
- Uniformity

<table>
<thead>
<tr>
<th>Factors</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixture proportions</td>
<td>Calibrate scales and water meters regularly to assure that mixture proportions are within specified tolerances.</td>
</tr>
<tr>
<td>Total water content</td>
<td>Maintain stockpiles at a moisture content above saturated surface dry (SSD).</td>
</tr>
<tr>
<td></td>
<td>Draw aggregates from areas of the stockpiles that have known moisture contents.</td>
</tr>
<tr>
<td>Aggregate gradation</td>
<td>Reject aggregates that do not meet job mix formula tolerances.</td>
</tr>
<tr>
<td></td>
<td>Observe proper stockpiling techniques to minimize segregation. Blending of individual aggregate stockpiles may improve uniformity and mitigate moisture variability.</td>
</tr>
<tr>
<td>Air content</td>
<td>Monitor air content at the plant and adjust admixture dosages as needed.</td>
</tr>
<tr>
<td>Segregation of the mixture during transport</td>
<td>Maintain the haul route in a manner that minimizes excessively rough sections which can segregate the concrete mixture in non-agitating trucks.</td>
</tr>
</tbody>
</table>
Guidelines for Building Smooth Concrete Pavements

• Equipment Setup
  • Paving mold
  • Vibrators
  • Tiebar inserter(s) – centerline and/or pavement edge
  • Dowel bar inserter (DBI)
  • Steering and elevation control (stringline or 3-D machine control)
  • Dry run
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving - Mixture adjustments
  • Subtraction/Addition of water (not to exceed the w/cm of the approved mixture design)
  • Adjustment of admixture dosages
  • Minor reproportioning of aggregates
  • Heating or cooling the mixture
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Process Adjustments
  - Make measured and methodical adjustments one at a time
  - Be data driven
  - Keep a meticulous log of process adjustments and events that have the potential to impact pavement smoothness measurements
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – Subbase Preparation
  • Finished to appropriate tolerance (±0.01’)
  • Maintain a uniform head of concrete
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Trackline
  - Adequate width
  - Finished to appropriate tolerance (±0.01’)
  - Stable
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – Stringline
  • Stringline pins spaced at no greater than 25 ft. c/c
  • Tension the stringline using a winch. Check and re-tension stringline that has been in place for more than five days
  • Raise the stringline where the base course is high (less than design thickness of concrete pavement will be constructed)
  • “Eyeball” adjust the stringline for smoothness
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – 3D Controls
  • Evaluate IRI of the model
  • Monitor the following:
    • **Distance between the robotic total station and the paver**
    • Line of sight issues between the robotic total station and the prism mounted on the paver
    • High winds causing movement to the robotic total station and/or the prism mounted on the paver
    • 3-D system errors (radio, software, hardware, wiring, batteries, etc.)
Guidelines for Building Smooth Concrete Pavements

• Cyclical change in IRI related to distance between the paver and robotic total station.
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Spreading Concrete
  - React to changes in concrete head level quickly
  - Communication is key
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – Paver Speed
  • Minimize stops
  • Consistent speed
  • Slow down when necessary, but not too much
  • “Rhythm”
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Vibrators
  - Frequency is speed dependent
  - Rebound from stiff base
  - Adjust height
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – Paver Attitude (Lead/Draft)
  • Stay as flat as practical
  • One person responsible for adjustments
  • Reduce lead/draft when paving uphill
  • Increase lead/draft when paving downhill
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – Hydraulic Response (sensitivity)
  • Slight adjustments can have significant impacts
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – Hand Finishing
  • When done correctly, it improves initial smoothness
  • Many different approaches
    • Float to fill surface voids first (16’ to 12’)
    • Straightedge to cut bumps and fill dips last (16’ to 20’)

National Concrete Pavement Technology Center

THE TRANSTECH GROUP
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – Texture and Cure
  • Even with line lasers, texture will influence IRI results – strive for uniformity
  • Cure completely to mitigate early age warping effects on IRI
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Real-Time Smoothness
  - QC feedback loop reduced from 18 hours to 2 hours
  - Not a replacement for conventional profiling for acceptance
  - Not a replacement for better practices to construct smoother pavements
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Real-Time Smoothness
  - Sensor generally placed in the center of each lane
  - 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
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – Real-Time Smoothness
  • Real-time profile parallels hardened profile
Guidelines for Building Smooth Concrete Pavements

• Slipform Paving – Real-Time Profile
  • 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
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Staying in the Sweet Spot
  - Stay focused
  - Make appropriate adjustments
  - Train the crew
  - Continuous improvement

28 in/mile
Questions?
Specifying and Measuring Concrete Pavement Smoothness in the 21st Century

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Concrete Pavement Smoothness Specifications

• Current (2019) Specifications for PCCP: IRI Basis
Concrete Pavement Smoothness Specifications

- Summary of IRI-based specification thresholds for concrete pavement (28 states)

<table>
<thead>
<tr>
<th></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>
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<td>72.3</td>
<td>71.8</td>
<td>94.2</td>
<td>93.9</td>
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</table>
Concrete Pavement Smoothness Specifications

• Localized Roughness Provisions (22 states)

<table>
<thead>
<tr>
<th>Method</th>
<th>Number of states</th>
<th>Range</th>
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<tbody>
<tr>
<td>Continuous IRI</td>
<td>15</td>
<td>80-200 in/mi (Avg. 148 in/mi)</td>
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<tr>
<td>(25 ft baselength)</td>
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<td></td>
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<tr>
<td>Fixed Interval IRI</td>
<td>4</td>
<td>25 ft segment: 120-160 in/mi</td>
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<tr>
<td>Profile Moving Average</td>
<td>1</td>
<td>0.15 inches</td>
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<tr>
<td>(25 ft baselength)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profilograph Simulation</td>
<td>2</td>
<td>0.3 inches in 25 ft.</td>
</tr>
<tr>
<td>(25 ft baselength)</td>
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<td></td>
</tr>
</tbody>
</table>
Concrete Pavement Smoothness Specifications

• Why IRI?
  • Objective measure of pavement *Ride Quality*, not just *Smoothness*.
  • Uses the true profile to compute vehicle response to deviations in pavement profile ("roughness").

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*Little Book of Profiling*
Concrete Pavement Smoothness Specifications

• Why IRI?
  • Profilograph trace is not the true pavement profile, but the profilograph’s interpretation of the true profile - a “mechanical filter.”

“No claim is made that the roughness or riding quality of a pavement is directly or completely reflected by the profile index.” (Francis Hveem, 1960)
Concrete Pavement Smoothness Specifications

• Why switch to IRI?
  • Inertial Profiler (IP) technology is readily available and affordable.
Concrete Pavement Smoothness Specifications

• Model Specification for PCCP Smoothness
  • Incentive-based specification for new construction
  • Commentary-rich version of AASHTO R 54
    • Agencies can adapt to state-specific practices/preferences
    • Summary of national averages for IRI thresholds and pay adjustments
• Key issues specific to concrete pavement
  • JPCP curl/warp – diurnal changes in profile and roughness, time of day for profile data collection
  • Highlight importance of QC and tools such as real-time smoothness
Tools for Monitoring Smoothness

- Check your work DAILY
- Use FHWA ProVAL Software to analyze your profile data
- Check your hardened profiles after each day of paving
- Check your profiles as you pave with Real-Time Smoothness
FHWA ProVAL Software

Many Different Profilers...  One Standard Software

www.RoadProfile.com
ProVAL Software: Analysis Tools

• Roughness Report
  • Compute and summarize IRI for profiles.
  • Identify Areas of Localized Roughness.
ProVAL Software: Analysis Tools

- Smoothness Assurance Module (SAM)
  - Side-by-side comparison of profile and roughness
  - Diamond grinding simulation – will it help?
ProVAL Software: Analysis Tools

• Smoothness Assurance Module (SAM)
  • Side-by-side comparison of profile and roughness
  • Diamond grinding simulation – will it help?

Before Grinding

After Grinding

Distance (ft)

Before Grinding
After Grinding

Yes
No

Yes
Yes
No

IRI (in/mi)
ProVAL Software: Analysis Tools

- Smoothness Assurance Module (SAM)
  - Side-by-side comparison of profile and roughness
  - Diamond grinding simulation – will it help?

![Graph showing IRI vs. Distance, Roughness vs. Profile, and Dip vs. Distance](image)
ProVAL Software: Analysis Tools

• Power Spectral Density (PSD)
  • Identify dominating (repeating) features to contribute roughness.
  • Helps to identify potential issues in the paving operation.

15 ft feature (joint spacing/dowel baskets)
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).
Real-Time Smoothness

• Real-time feedback, viewing and analysis capabilities:
Real-Time Smoothness

• Benefits:
  • Tool for evaluating concrete pavement smoothness in real time (vs. 24+ hours later).
  • Allows for process improvements as a result of timely feedback.
  • Improved understanding about how construction artifacts can affect smoothness.

• Limitations:
  • Not a replacement for conventional profiling for acceptance – it’s a QC tool!
  • Not a replacement for better practices to construct smoother pavements.
SHRP2/FWHA RTS Implementation

• 2010 – 2013: SHRP2 RTS technology evaluation
  • 5 field evaluations

• 2014 – 2017: SHRP2 RTS technology implementation
  • 11 equipment loans
  • 8 workshops

• 2017 – 2019: FHWA RTS technology implementation
  • 10 equipment loans
  • On-call technical support
  • 2 webinars
  • Guide Specification
  • Guidelines for Best Practices
SHRP2/FWHA RTS Implementation

- Effort by state
Real-Time Smoothness: Comparison with Hardened Profiles

- Raw profiles are different but trends are similar
Real-Time Smoothness: Comparison with 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.
- 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.
# Real-Time Smoothness: Comparison with Hardened Profiles

<table>
<thead>
<tr>
<th>Segment</th>
<th>RTS IRI (in/mi)</th>
<th>QC MRI (in/mi)</th>
<th>Difference (in/mi)</th>
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<tbody>
<tr>
<td>Day 1</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>113.2</td>
<td>67.0</td>
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<td>2</td>
<td>77.3</td>
<td>57.0</td>
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<td>3</td>
<td>79.9</td>
<td>64.6</td>
<td>15.3</td>
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<td>Day 2</td>
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<td>1</td>
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<td>3</td>
<td>114.4</td>
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<td>Day 3</td>
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<tr>
<td>1</td>
<td>111.7</td>
<td>65.3</td>
<td>46.4</td>
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<td>3</td>
<td>116.4</td>
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<td>4</td>
<td>94.9</td>
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<td>Day 4</td>
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<td>Avg.</td>
<td>105.8</td>
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</tbody>
</table>
Real-Time Smoothness: Features in Profiles

- Joint spacing/dowel basket effects

- 15' peaks in RTS localized roughness plot
- Less pronounced in hardened IRI
Real-Time Smoothness: Features in Profiles

- Joint spacing/dowel basket effects
  - Dominant content at 15' joint spacing.
  - Less dominant in hardened profile.
  - Harmonics at 7.5', 5', 3.75', etc.
Real-Time Smoothness: Features in Profiles

• Project utilizing Dowel Bar Inserter

- No dominant content at 15’ joint spacing.
- Shorter wavelength content is dominant in RTS, but not in hardened.
Real-Time Smoothness: Features in Profiles

• 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
Real-Time Smoothness: Features in Profiles

- CRCP Bar Supports
Real-Time Smoothness: Features in Profiles

- Load Spacing

~10.5' content
Real-Time Smoothness: Features in Profiles

- Localized roughness – improvement from finishers
Questions?