Guidelines for Building Smooth Concrete Pavements

CP Tech Center Webinar
13 November 2019

National Concrete Pavement Technology Center

THE TRANSTEC GROUP
The World's Pavement Engineering Specialists

Webinar Agenda

- Welcome and Introduction
- Concrete Pavement Smoothness Specifications
- Guidelines for Building Smooth Concrete Pavements
- Real-Time Smoothness and Other Tools for Monitoring Smoothness
- Q&A

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Webinar Speakers

- Peter Taylor, National Concrete Pavement Technology Center
- Tom Yu, FHWA
- Gary Fick, The Transtec Group, Inc.
- David Merritt, The Transtec Group, Inc.

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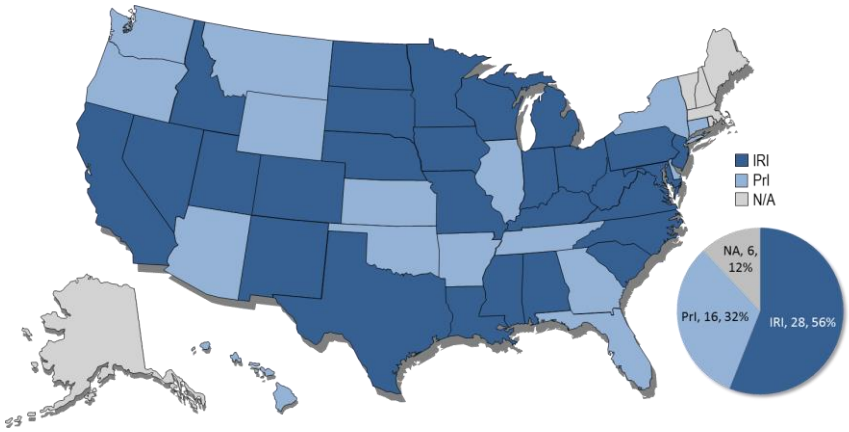
Concrete Pavement Smoothness Specifications

- Current (2019) Specifications for PCCP: Smoothness Index



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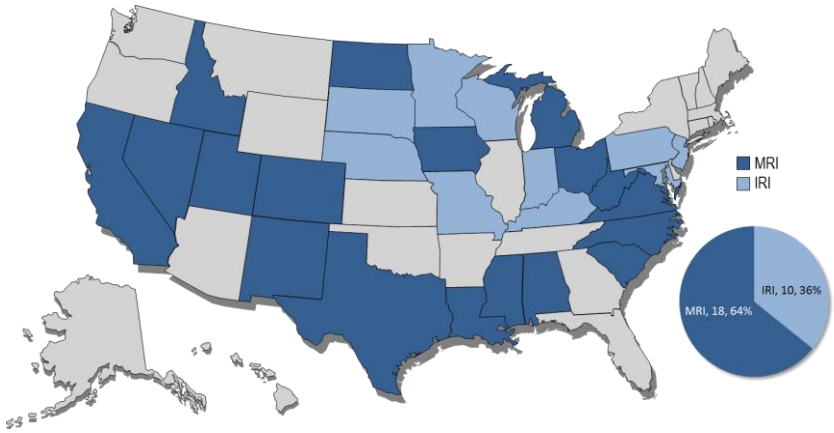
Concrete Pavement Smoothness Specifications

- Current (2019) Specifications for PCCP: IRI Basis



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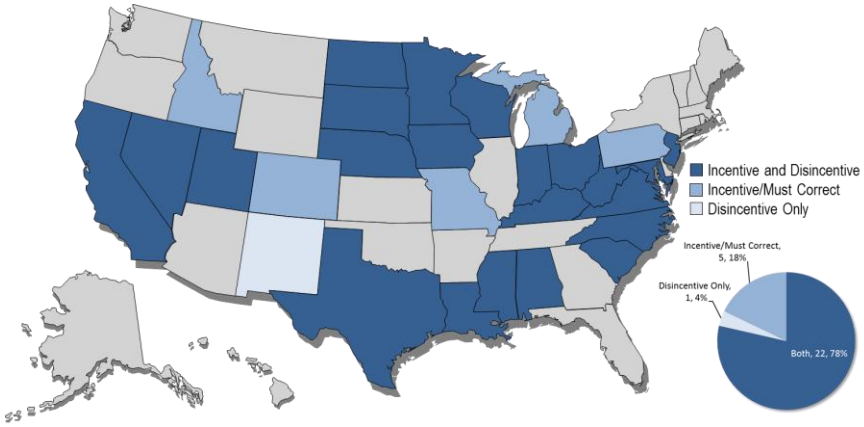
Concrete Pavement Smoothness Specifications

- Current (2019) Specifications for PCCP: Pay Adjustments



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Concrete Pavement Smoothness Specifications

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

	Incentive Upper Limit	Full Pay Lower Limit	Full Pay Upper Limit	Disincentive Lower Limit	Disincentive Upper Limit	Threshold for Correction
Min	39.9	40.0	54.0	54.1	67.5	67.5
Max	68.0	68.1	93.0	93.1	140.0	140.0
Avg	56.8	57.1	72.3	71.8	94.2	93.9

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Concrete Pavement Smoothness Specifications

- Summary of IRI-based specification incentives and disincentives (28 states)

Incentive/Disincentive Basis		Max Incentive	Max Disincentive
$ per lot (0.1-mi) *14 states*	*Min*	$200	-$250
	Max	$1,700	-$2,250
	Avg	$1,087	-$1,088
$ per lot (SY) *3 states*	*Min*	$0.50	-$1.12
	Max	$2.80	-$1.12
	Avg	$1.65	-$1.12
$ per lot (1.0 mi) *1 state*		$7,350	-$7,350
$ per lot (0.01 mi) *1 state*		$50	-$500
$ per lot (500 ft) *1 state*		$250	-$250
All $ per 0.1 mi lot, extended *20 states*	*Min*	$200	-$250
	Max	$1,971	-$5,000
	Avg	$1,002	-$1,240
Pct. Contract Price *8 states*	*Min*	101%	97%
	Max	108%	50%
	Avg	105%	80%

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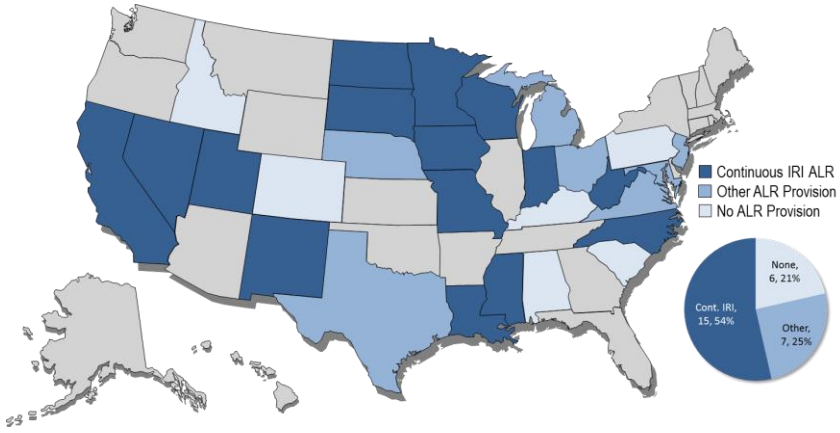
Concrete Pavement Smoothness Specifications

- Current (2019) Specifications for PCCP: Localized Roughness Provisions



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Concrete Pavement Smoothness Specifications

- Localized Roughness Provisions (22 states)

Method	Number of states	Range	
Continuous IRI (25 ft baselength)	15	80-200 in/mi (Avg. 148 in/mi)	
Fixed Interval IRI	4	25 ft segment: 120-160 in/mi	0.01 mi (52.8 ft) segment: 100-125 in/mi
Profile Moving Average (25 ft baselength)	1	0.15 inches	
Profilograph Simulation (25 ft baselength)	2	0.3 inches in 25 ft.	

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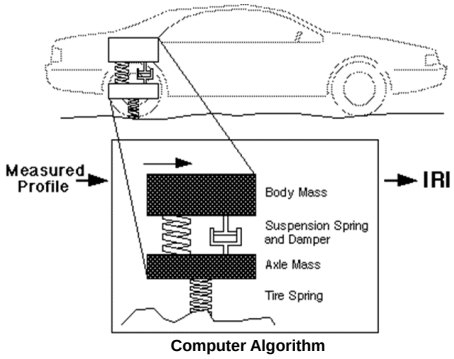
Concrete Pavement Smoothness Specifications

- Why IRI?
  - Objective measure of pavement *Ride Quality*, not just *Smoothness.*
  - Simulates vehicle response (suspension motion) to the true pavement profile.



Computer Algorithm

Little Book of Profiling

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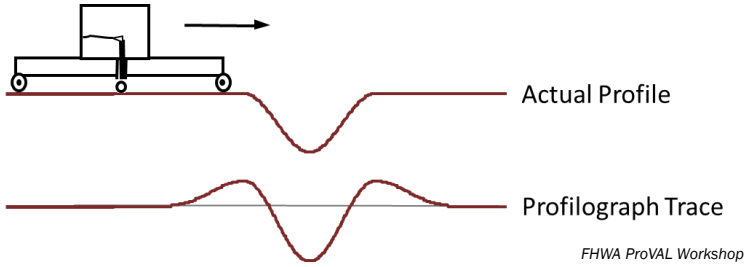
Concrete Pavement Smoothness Specifications

- Why IRI?
  - Profilograph trace is not the true pavement profile, but the profilograph's interpretation of the true profile - a "mechanical filter."



FHWA ProVAL Workshop

"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)

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Concrete Pavement Smoothness Specifications

- Why switch to IRI?
  - Inertial Profiler (IP) technology is readily available and affordable.

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Concrete Pavement Smoothness Specifications

- Why switch to IRI?
  - IP sensor issues with longitudinal tined/diamond ground surfaces have been resolved with wide footprint sensors.
  - Efficiency of data collection
  - Safety for workers
  - HPMS reporting uses IRI

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Concrete Pavement Smoothness Specifications

- Model Specification for PCCP Smoothness
  - Incentive-based IRI specification for new construction
  - Based on AASHTO R 54 with added commentary
    - Agencies can adapt to state-specific practices/preferences
    - Provides a summary of national averages for IRI thresholds and pay adjustments
  - Addresses key issues specific to concrete pavement
    - JPCP curl/warp – diurnal changes in profile and roughness, time of day for profile data collection
    - Highlights importance of QC and tools such as real-time smoothness

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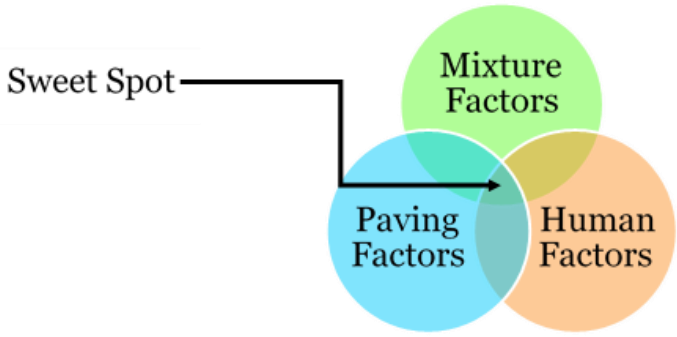
Guidelines for Building Smooth Concrete Pavements

- Impacts on initial smoothness



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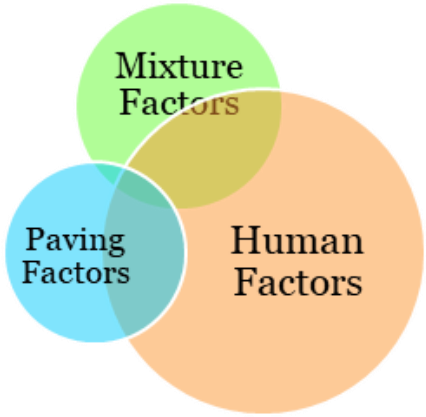
Guidelines for Building Smooth Concrete Pavements

- 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

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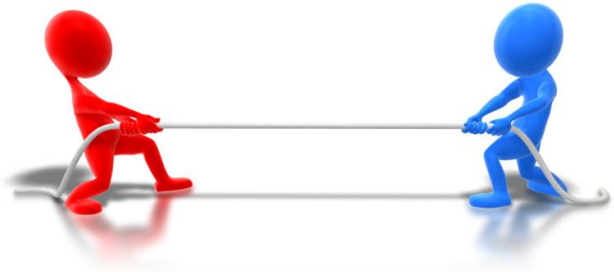
Guidelines for Building Smooth Concrete Pavements

- 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



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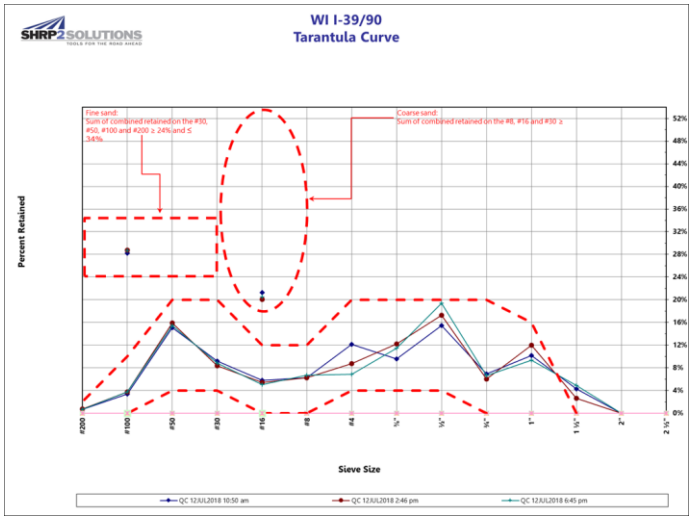
Guidelines for Building Smooth Concrete Pavements

- Materials and Mixtures
  - Tarantula curve



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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

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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)

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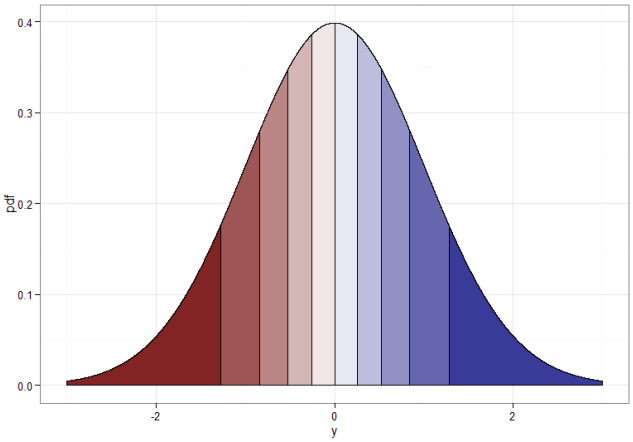
Guidelines for Building Smooth Concrete Pavements

- Mixture Production
- Uniformity, Uniformity, Uniformity
  - Within batch
  - Between batch



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Guidelines for Building Smooth Concrete Pavements

- Mixture Production
- Uniformity

Factors	Recommendations
Mixture proportions	Calibrate scales and water meters regularly to assure that mixture proportions are within specified tolerances.
Total water content	Maintain stockpiles at a moisture content above saturated surface dry (SSD).
	Draw aggregates from areas of the stockpiles that have known moisture contents.
	Update moisture compensation values in the plant control system to match the aggregate stockpile moistures. Moisture content testing of the aggregate stockpiles and adjustment of the moisture compensation value should be performed at least twice per day and more frequently if
Aggregate gradation	Reject aggregates that do not meet job mix formula tolerances.
	Observe proper stockpiling techniques to minimize segregation. Blending of individual aggregate stockpiles may improve uniformity and mitigate moisture variability.
Air content	Monitor air content at the plant and adjust admixture dosages as needed.
Segregation of the mixture during transport	Maintain the haul route in a manner that minimizes excessively rough sections which can segregate the concrete mixture in non-agitating trucks.

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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

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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

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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

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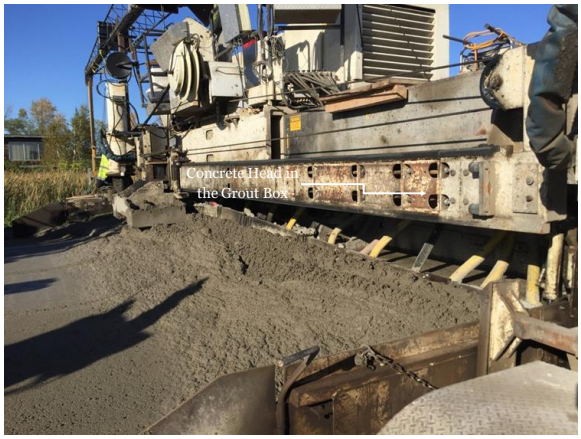
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Subbase Preparation
  - Finished to appropriate tolerance (±0.01')
  - Maintain a uniform head of concrete



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Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Trackline
  - Adequate width
  - Finished to appropriate tolerance (±0.01')
  - Stable

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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

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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.)

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Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Spreading Concrete
  - React to changes in concrete head level quickly
  - Communication is key

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Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Paver Speed
  - Minimize stops
  - Consistent speed
  - Slow down when necessary, but not too much
  - "Rhythm"

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Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Vibrators
  - Frequency is speed dependent
  - Rebound from stiff base
  - Adjust height

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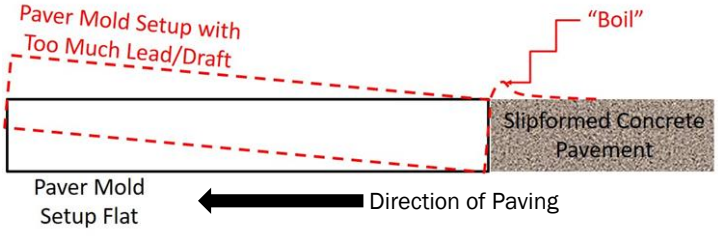
Guidelines for Building Smooth Concrete Pavements

- 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



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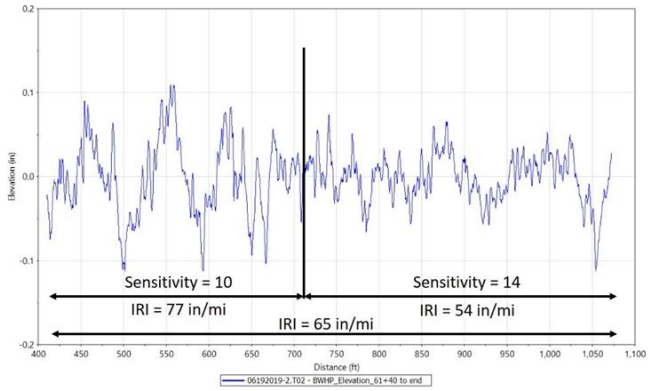
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Hydraulic Response (sensitivity)
  - Slight adjustments can have significant impacts



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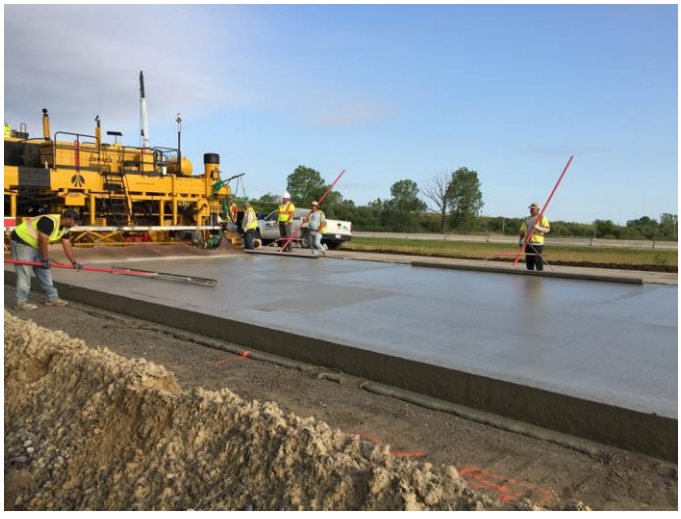
Guidelines for Building Smooth Concrete Pavements

- 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’)



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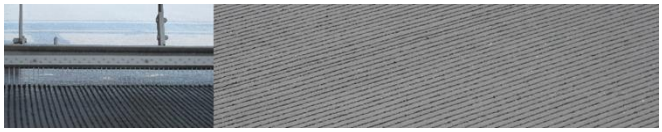
Guidelines for Building Smooth Concrete Pavements

- 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



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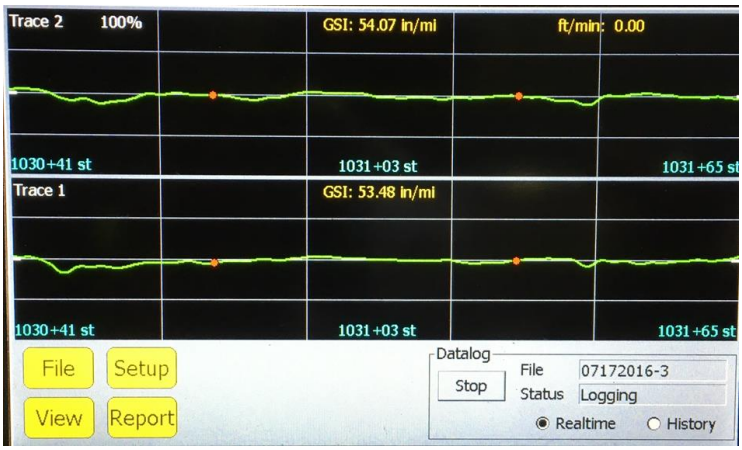
Guidelines for Building Smooth Concrete Pavements

- 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



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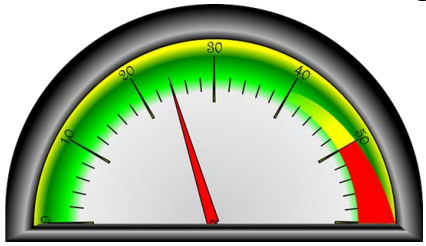
Guidelines for Building Smooth Concrete Pavements

- 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



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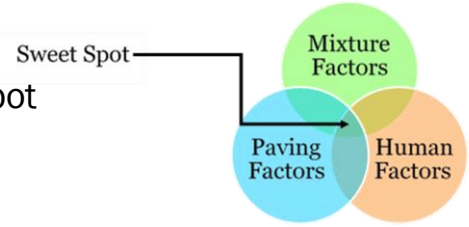
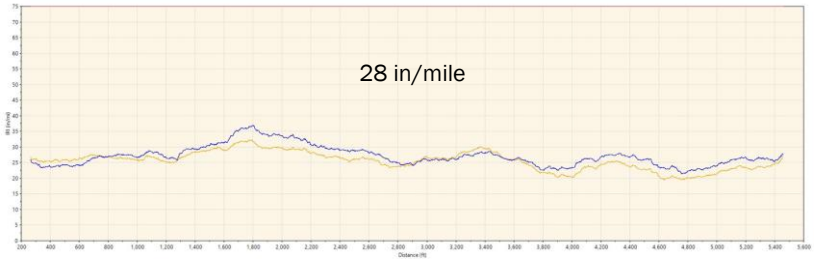
Guidelines for Building Smooth Concrete Pavements

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





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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

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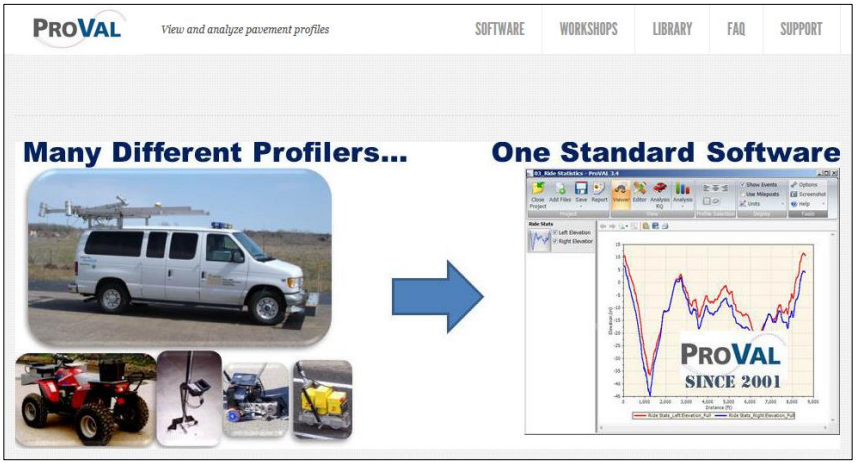
FHWA ProVAL Software



www.RoadProfile.com

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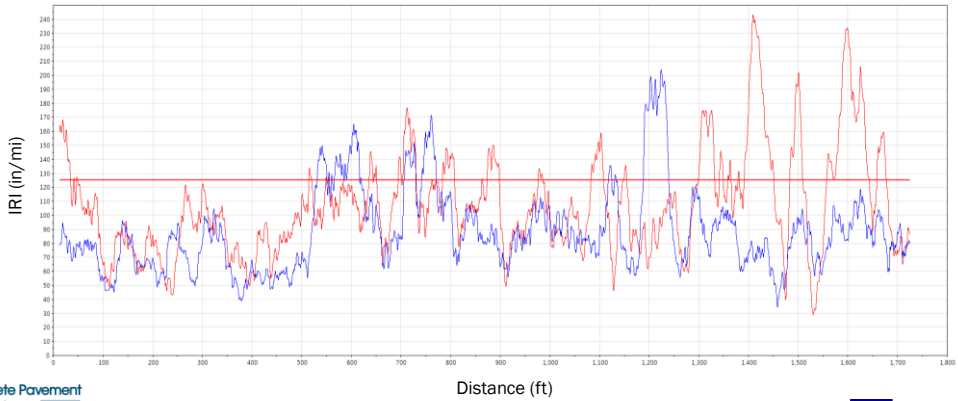
ProVAL Software: Analysis Tools

- Roughness Report
  - Compute and summarize IRI for profiles.
  - Identify Areas of Localized Roughness.



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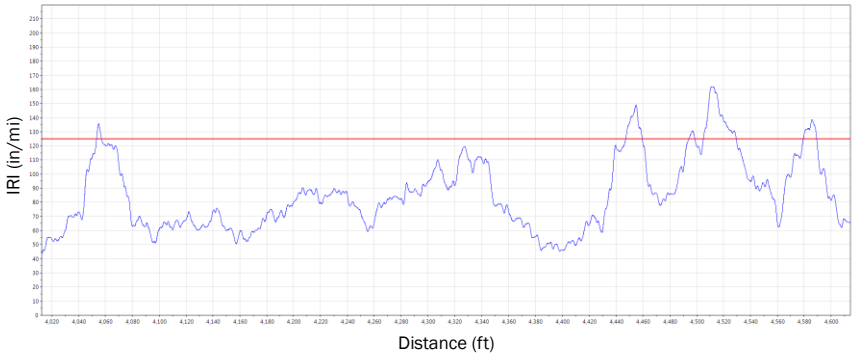
ProVAL Software: Analysis Tools

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



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ProVAL Software: Analysis Tools

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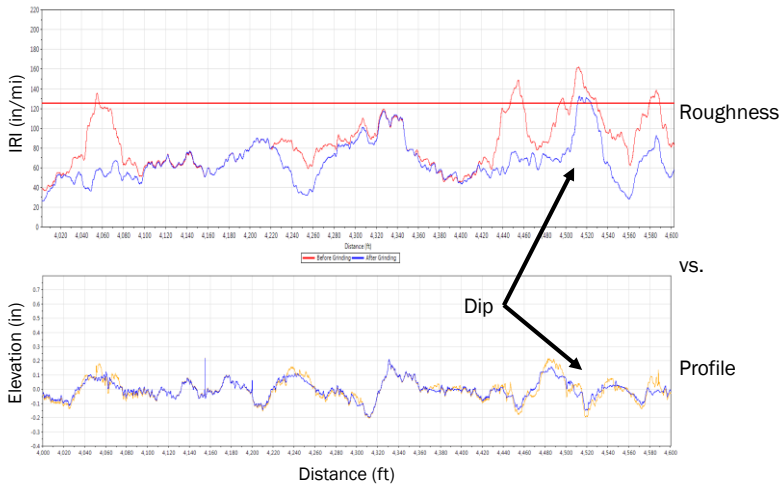

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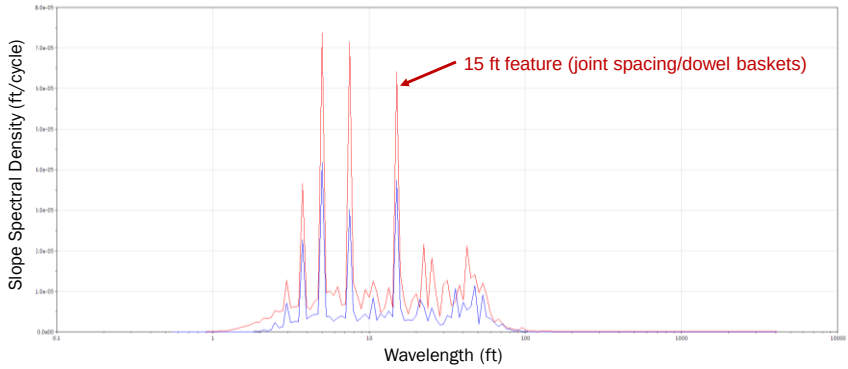
ProVAL Software: Analysis Tools

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



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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).

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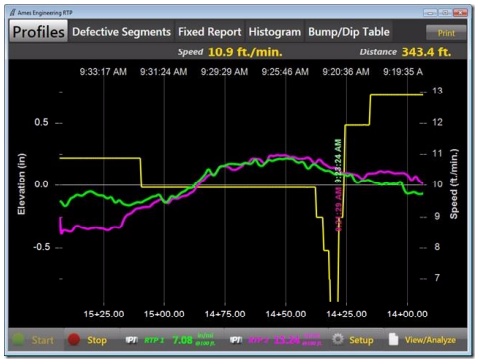
Real-Time Smoothness

- Real-time feedback, viewing and analysis capabilities:



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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.

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SHRP2/FWHA RTS Implementation

- 2010 – 2013: SHRP2 RTS technology evaluation
- 2014 – 2017: SHRP2 RTS technology implementation
  - 11 equipment loans
  - 8 workshops
- 2017 – 2019: FHWA RTS technology implementation
  - 10 equipment loans (7 completed)
  - On-call technical support
  - 2 webinars (1 completed)
  - Guide Specification
  - Guidelines for Best Practices

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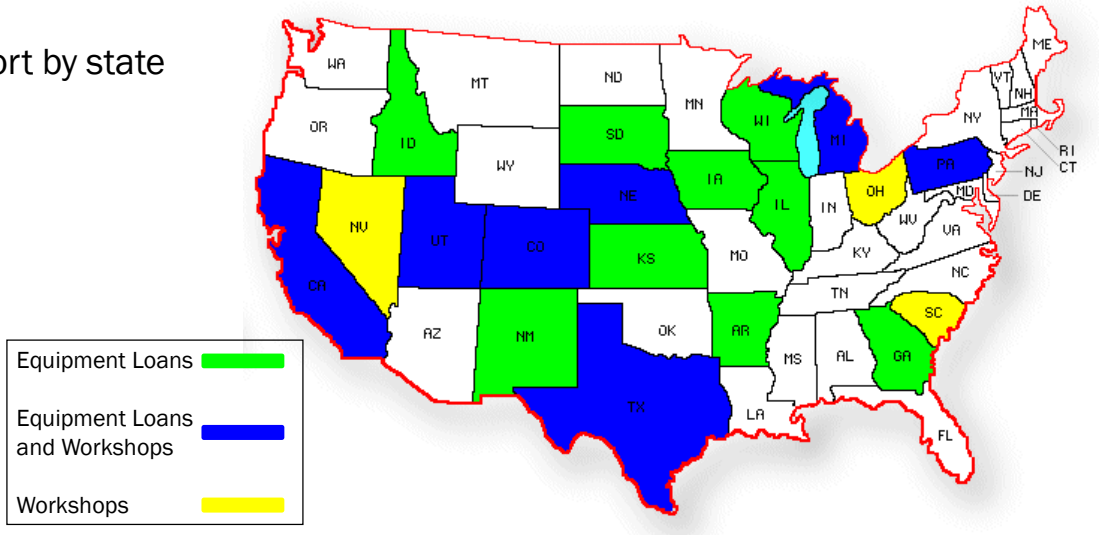
SHRP2/FWHA RTS Implementation

- Effort by state



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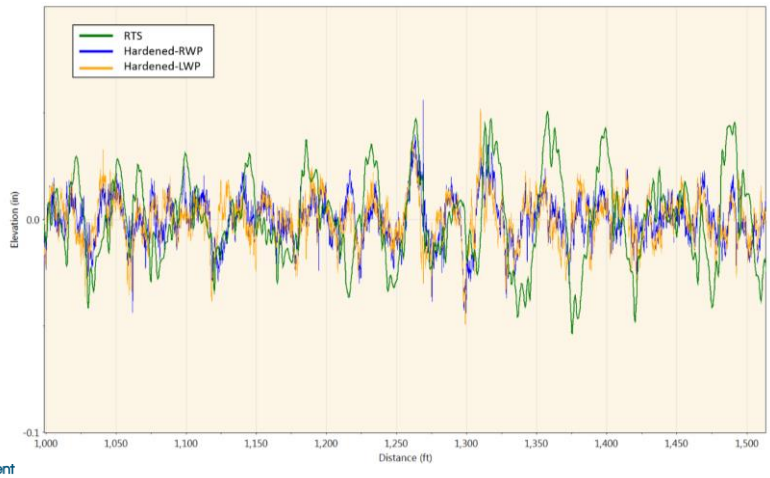
Real-Time Smoothness: Comparison with Hardened Profiles

- Raw profiles are different but trends are similar



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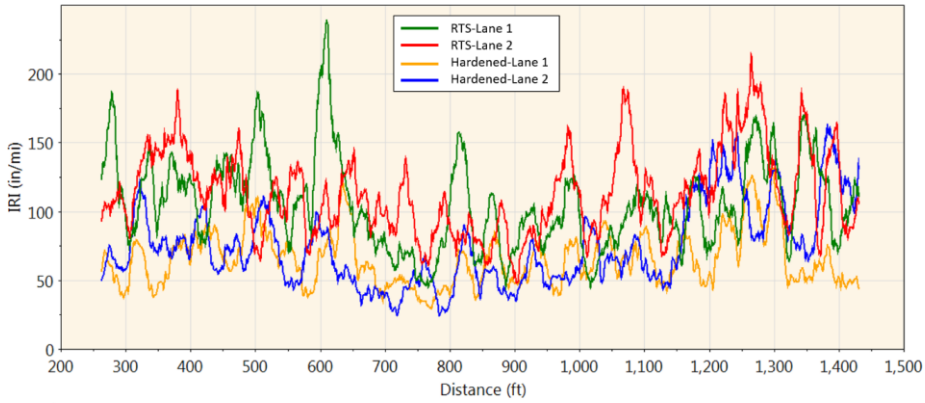
Real-Time Smoothness: Comparison with Hardened Profiles

- Roughness results are different (RTS generally higher) but trends are similar.



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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.

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Real-Time Smoothness: Comparison with Hardened Profiles

Project A

	Segment	RTS IRI (in/mi)	QC MRI (in/mi)	Difference (in/mi)
Day 1	1	113.2	67.0	46.2
	2	77.3	57.0	20.2
	3	79.9	64.6	15.3
Day 2	1	90.0	53.2	36.7
	2	108.9	77.5	31.4
	3	114.4	57.2	57.1
Day 3	1	111.7	65.3	46.4
	2	118.2	71.0	47.2
	3	116.4	68.0	48.4
	4	94.9	61.9	33.1
Day 4	1	122.6	64.5	58.1
	2	122.5	61.9	60.7
	Avg.	105.8	64.1	41.7

Project B

	Segment	RTS IRI (in/mi)	QC MRI (in/mi)	Difference (in/mi)
Day 1	1	66.2	61.1	5.1
	2	65.7	62.2	3.5
	3	58.0	48.8	9.2
Day 2	1	59.3	51.6	7.7
	2	59.4	47.7	11.7
	3	62.5	45.1	17.4
	4	54.3	48.2	6.2
Day 3	1	54.7	44.1	10.6
	2	65.6	57.8	7.8
	3	69.6	57.6	12.0
	4	70.9	61.1	9.8
Day 4	1	58.1	53.0	5.1
	2	91.8	66.3	25.4
	3	71.2	54.3	17.0
	4	86.5	66.5	20.1
	Avg.	66.3	55.0	11.2

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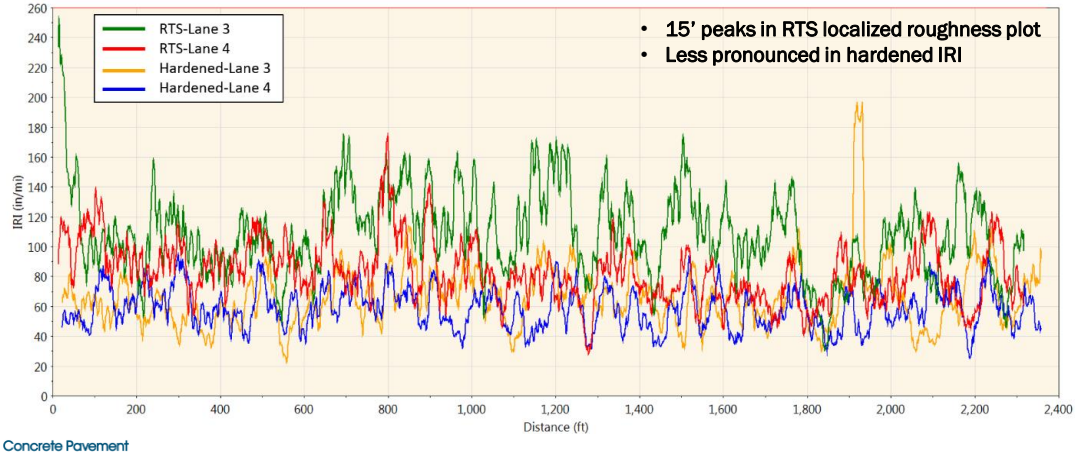
Real-Time Smoothness: Features in Profiles

- Joint spacing/dowel basket effects



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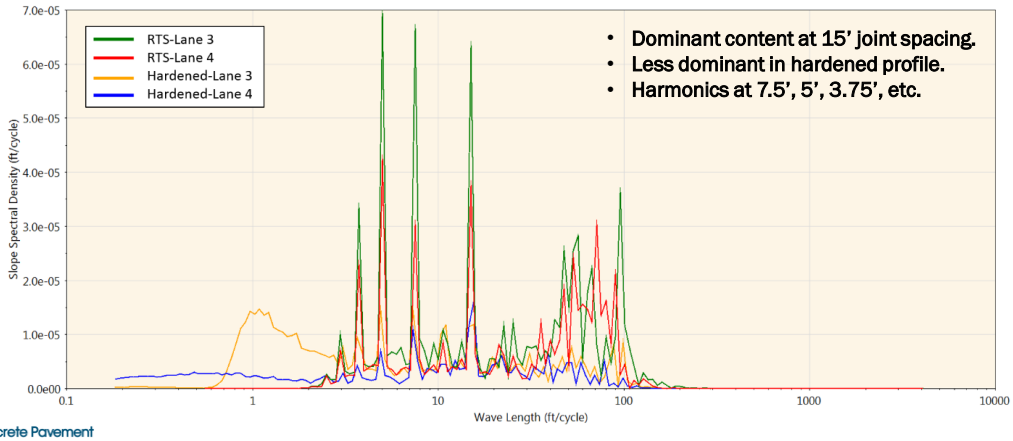
Real-Time Smoothness: Features in Profiles

- Joint spacing/dowel basket effects



- Dominant content at 15' joint spacing.
- Less dominant in hardened profile.
- Harmonics at 7.5', 5', 3.75', etc.

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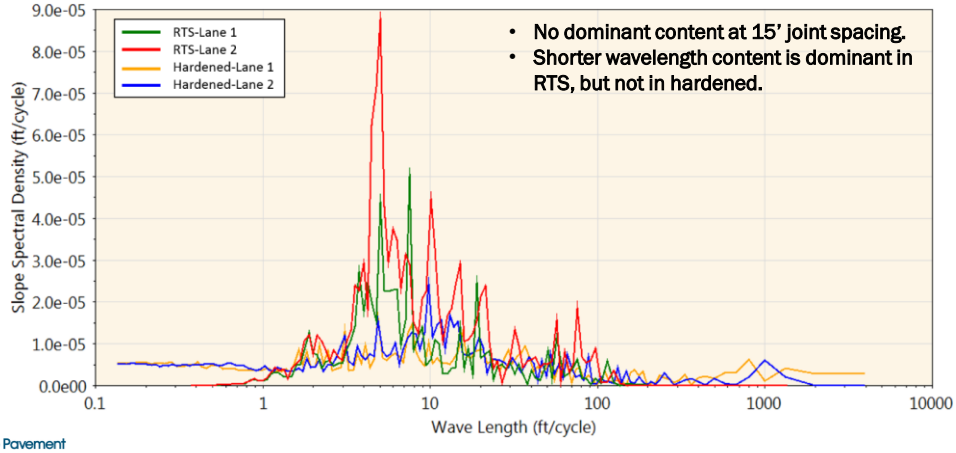
Real-Time Smoothness: Features in Profiles

- Project utilizing Dowel Bar Inserter



- No dominant content at 15' joint spacing.
- Shorter wavelength content is dominant in RTS, but not in hardened.

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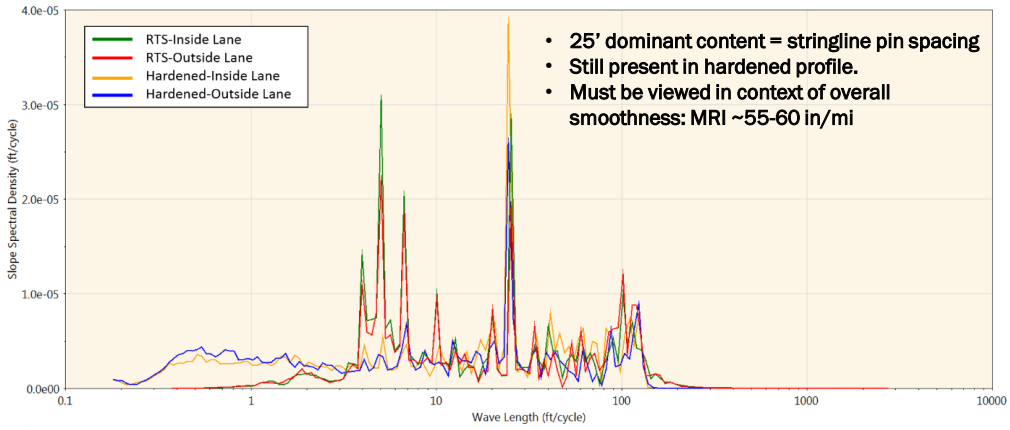
Real-Time Smoothness: Features in Profiles

- Stringline and Stringless System Effects



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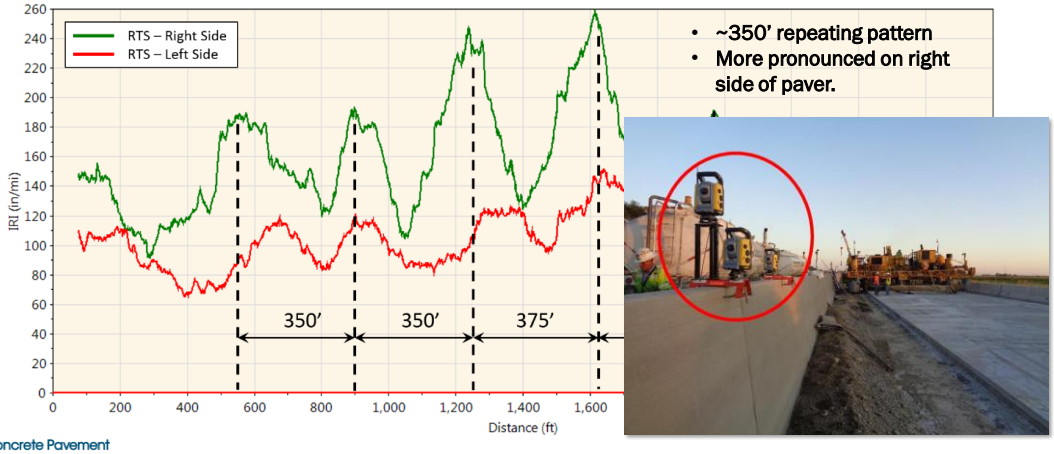
Real-Time Smoothness: Features in Profiles

- Stringline and Stringless System Effects



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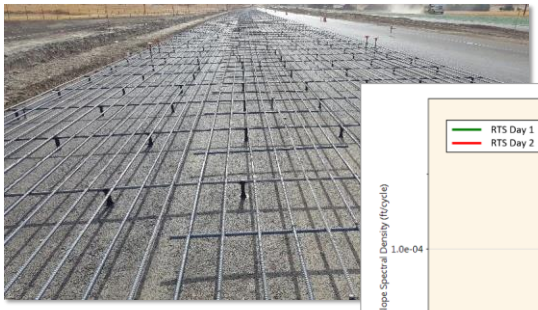
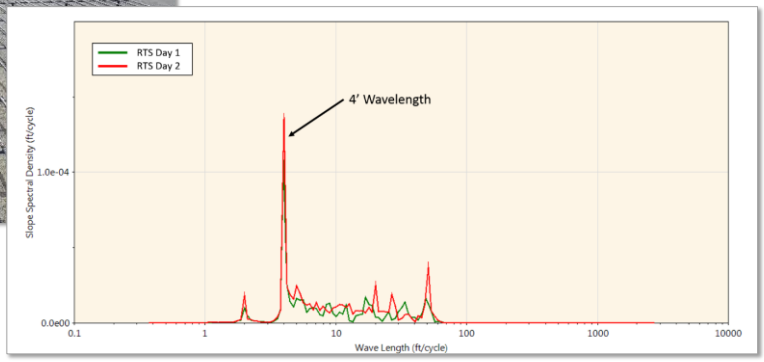
Real-Time Smoothness: Features in Profiles

- CRCP Bar Supports





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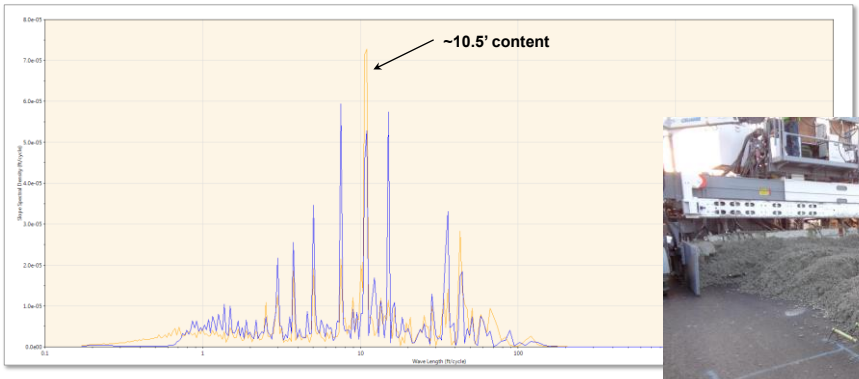
Real-Time Smoothness: Features in Profiles

- Load Spacing



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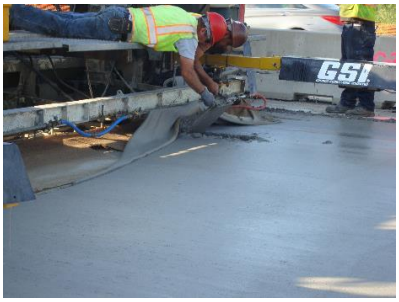
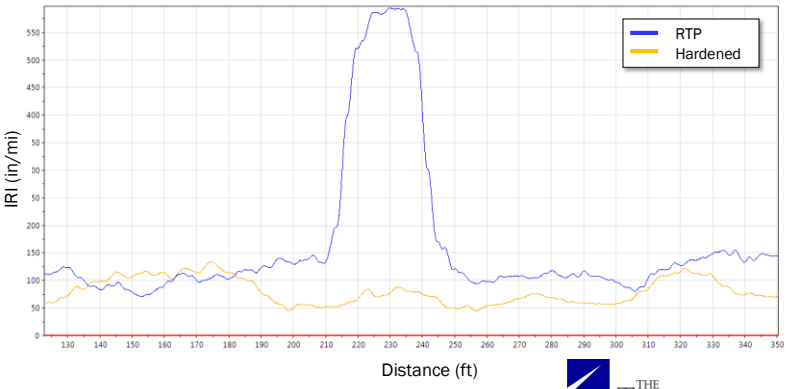
Real-Time Smoothness: Features in Profiles

- Localized roughness – improvement from finishers





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Webinar Recap

- ✓ We reviewed the current state-of-the-practice for concrete pavement smoothness specifications.
- ✓ We discussed guidelines for best practices for constructing smooth concrete pavements.
- ✓ We discussed ProVAL and Real-Time Smoothness as tools for monitoring pavement smoothness during construction.

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Questions?

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