Guidelines for Building Smooth Concrete Pavements

ICPA Workshop

06 February 2020

Gary Fick, Project Manager, The Transtec Group, Inc.

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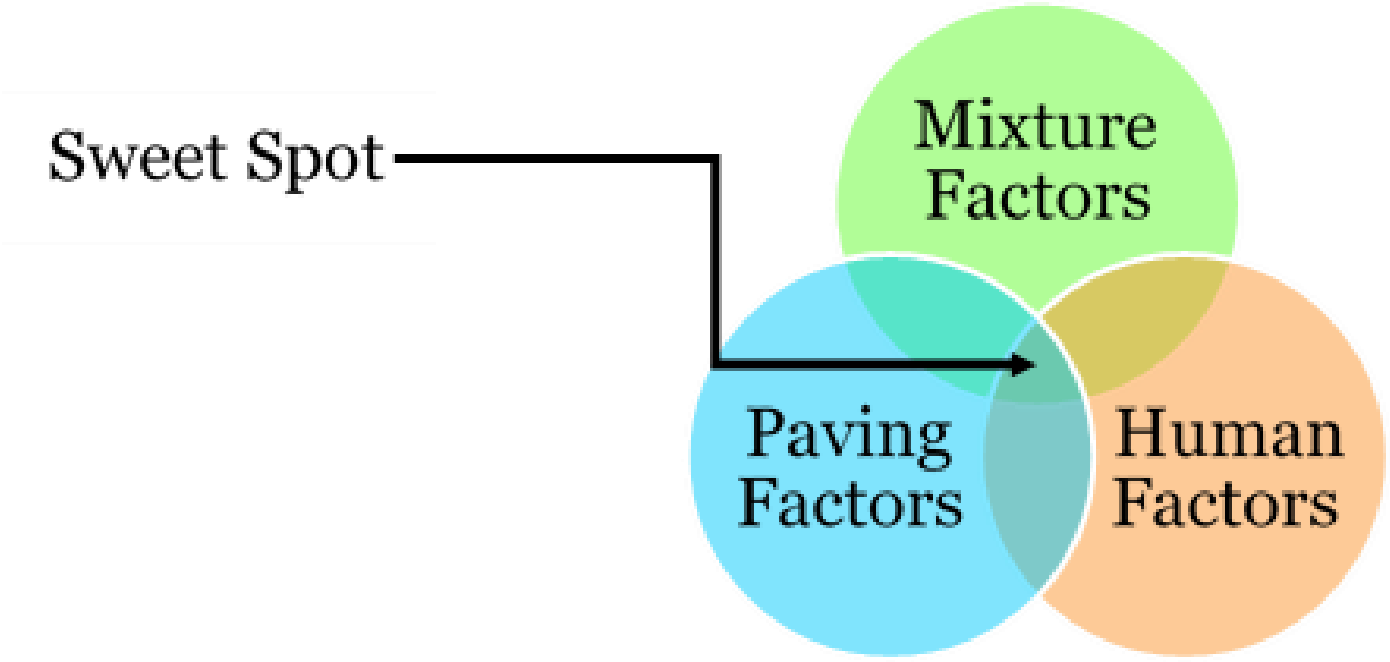
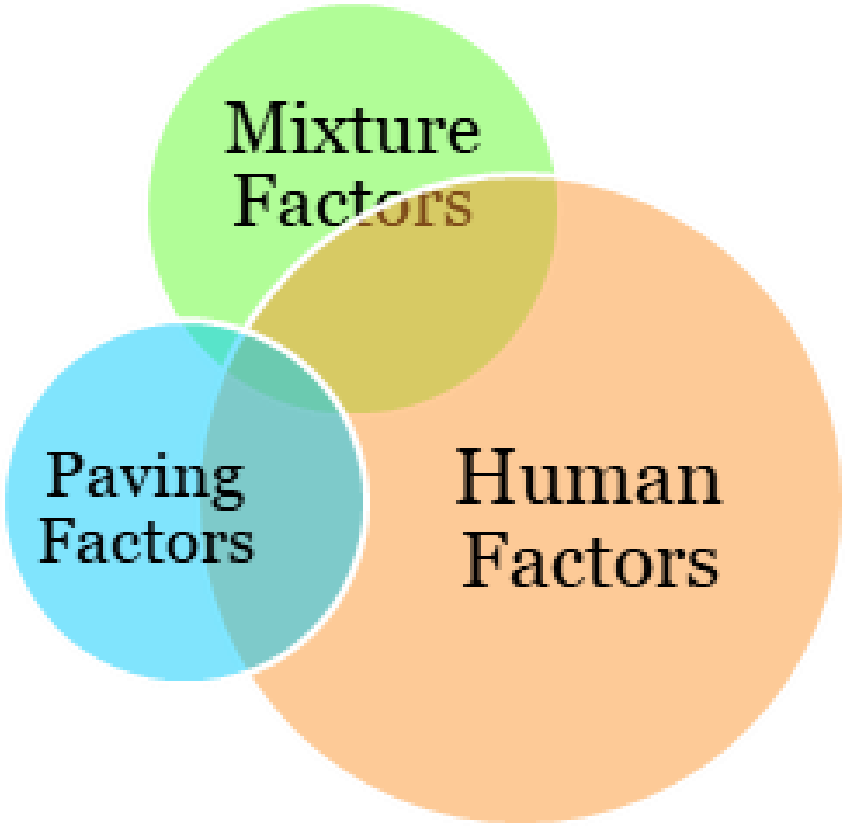
Guidelines for Building Smooth Concrete Pavements

- Impacts on initial smoothness



Guidelines for Building Smooth Concrete Pavements

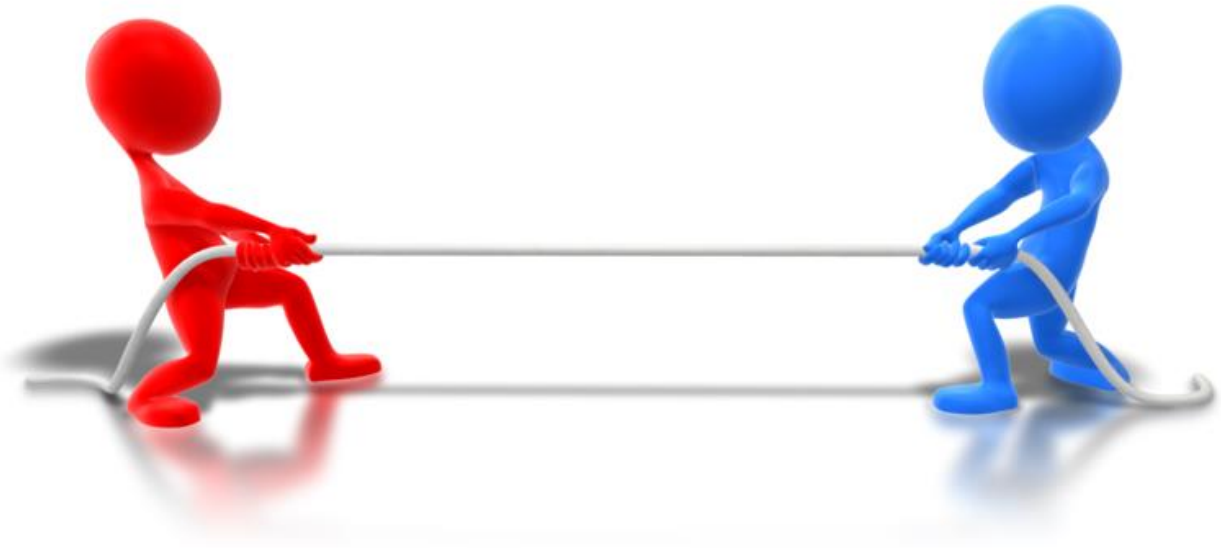
- Paving factors includes design elements
  - Vertical curves
  - Superelevation transitions
  - Project phasing (jigsaw puzzle)
  - Blockouts (gaps)
  - Matching existing lanes
  - Equipment clearance and trackline



  - **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**

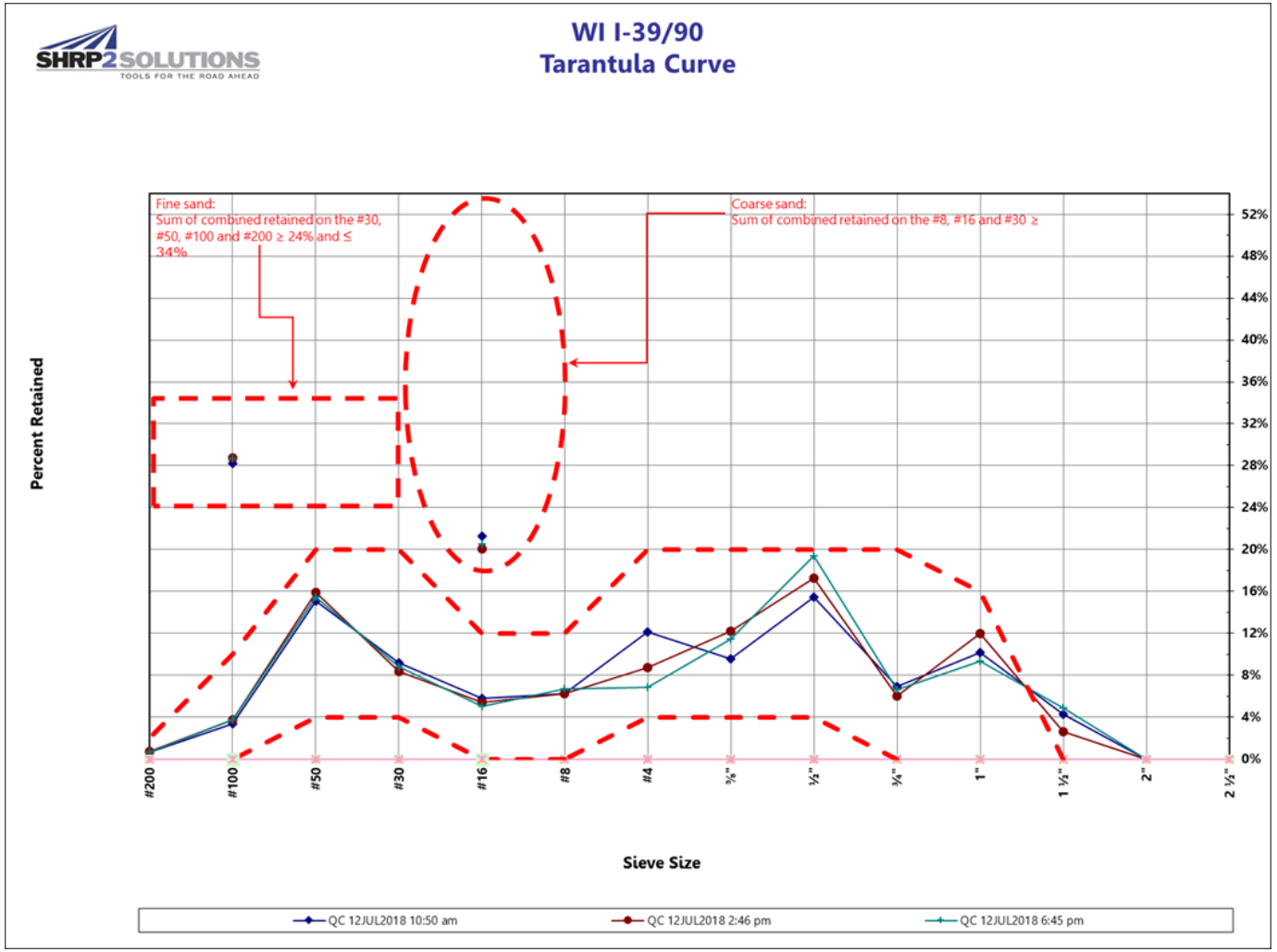
Guidelines for Building Smooth Concrete Pavements

- 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



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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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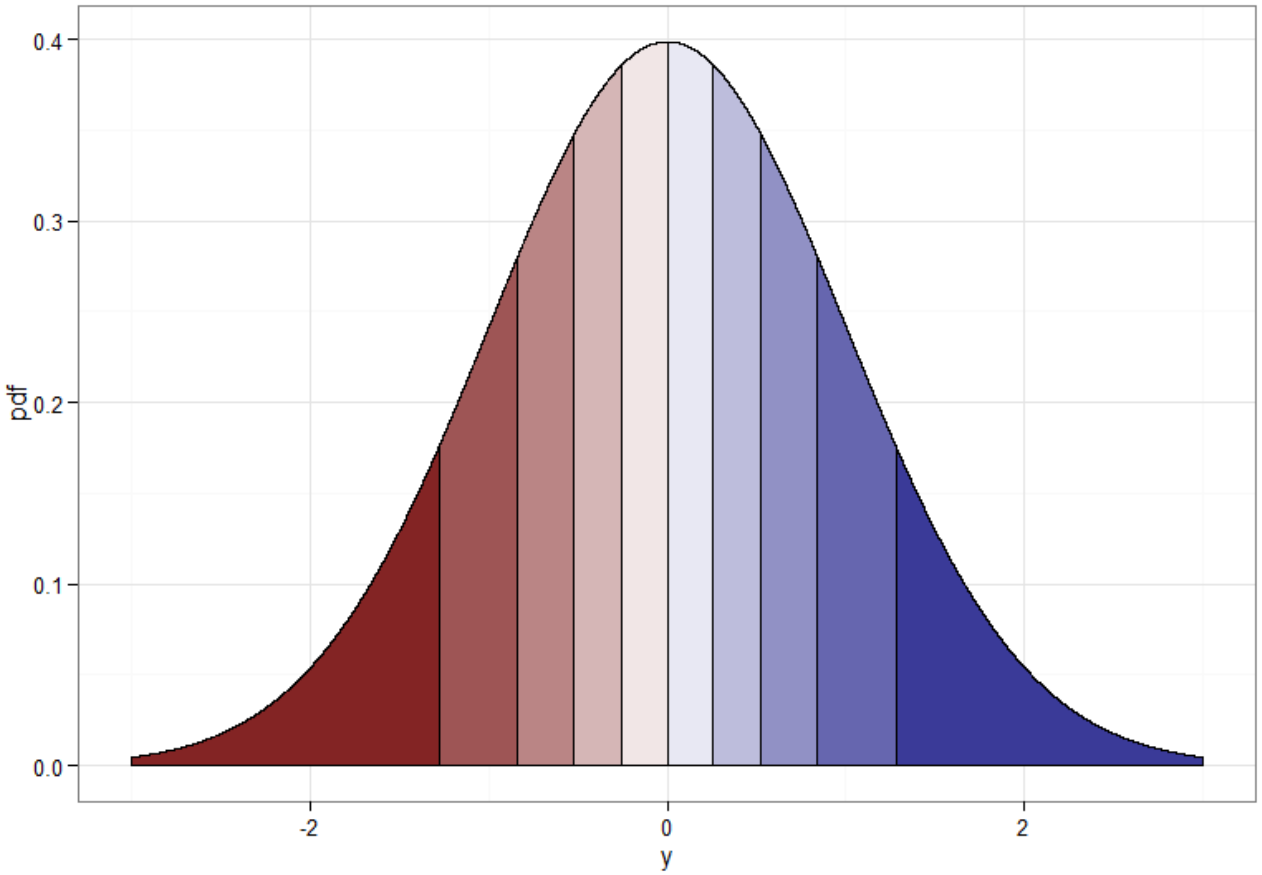
Guidelines for Building Smooth Concrete Pavements

- 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)

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.

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

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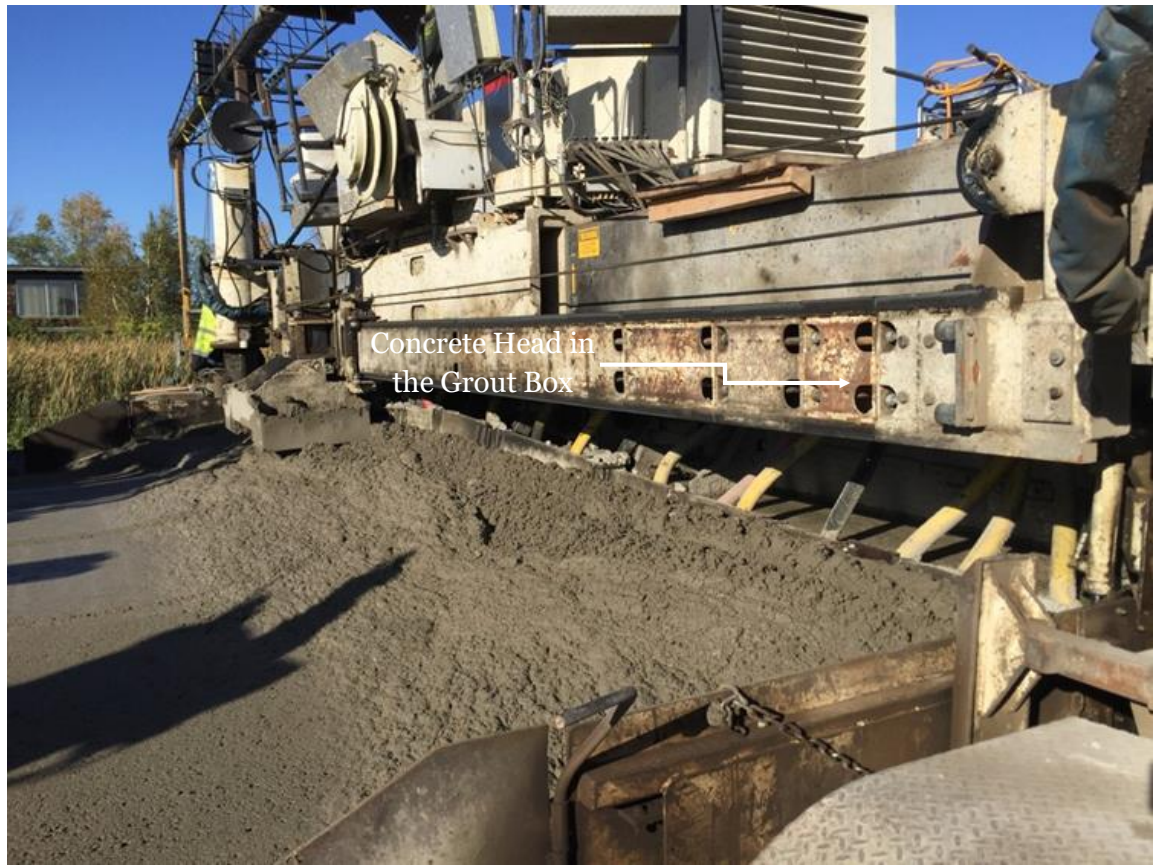
Guidelines for Building Smooth Concrete Pavements

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



Guidelines for Building Smooth Concrete Pavements

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

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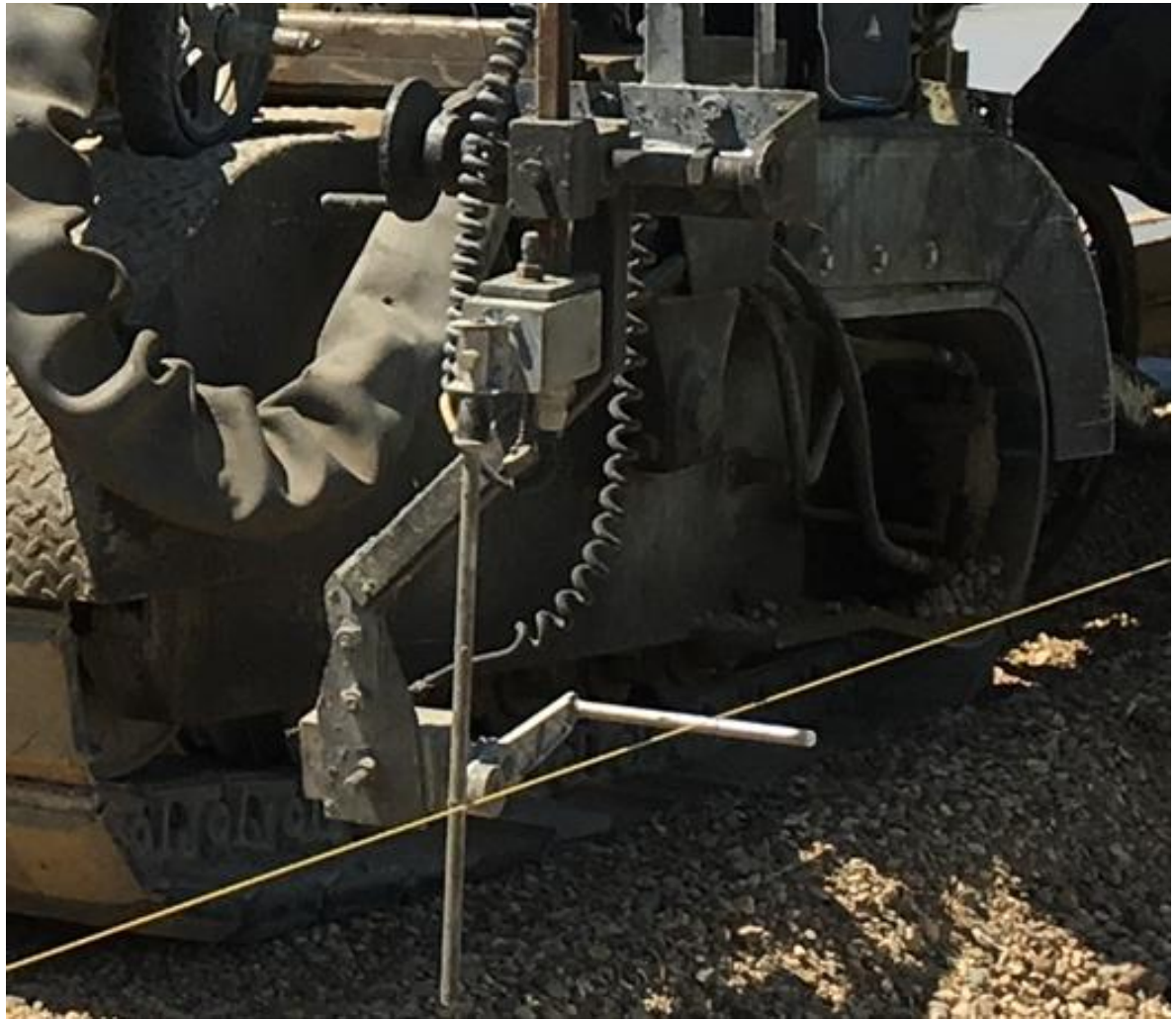
Guidelines for Building Smooth Concrete Pavements

- 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



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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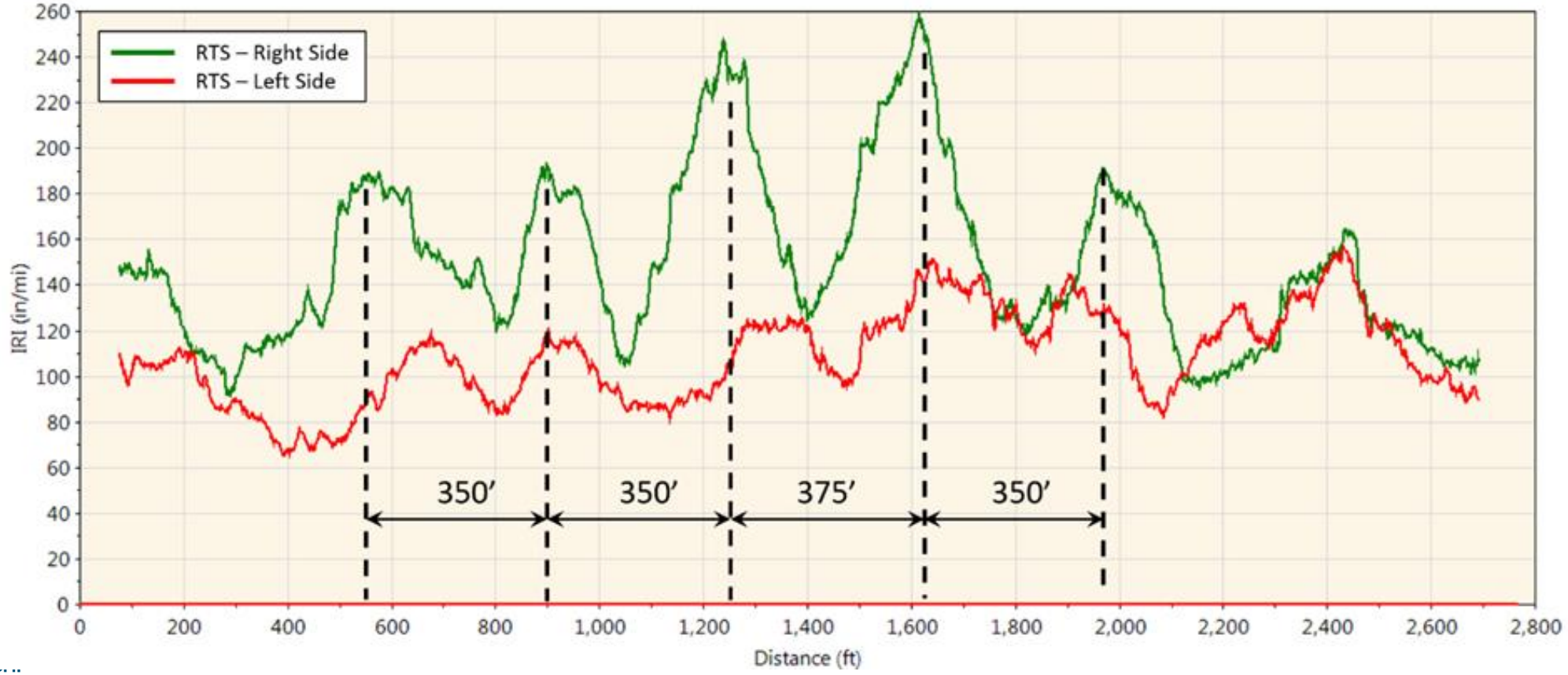
Guidelines for Building Smooth Concrete Pavements

- Cyclical change in IRI related to distance between the paver and robotic total station.



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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

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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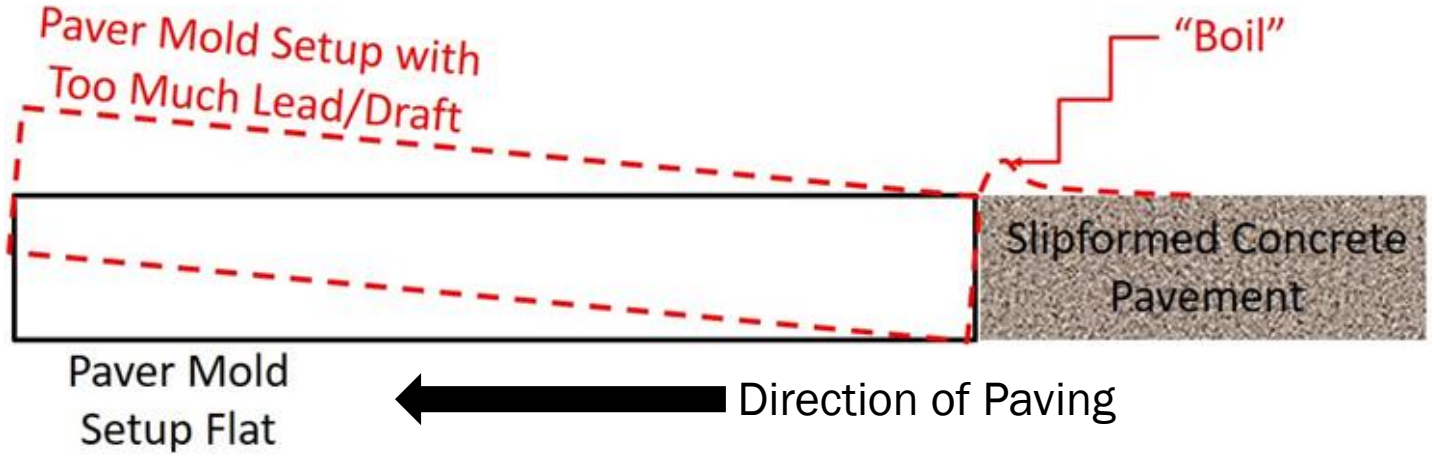
Guidelines for Building Smooth Concrete Pavements

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

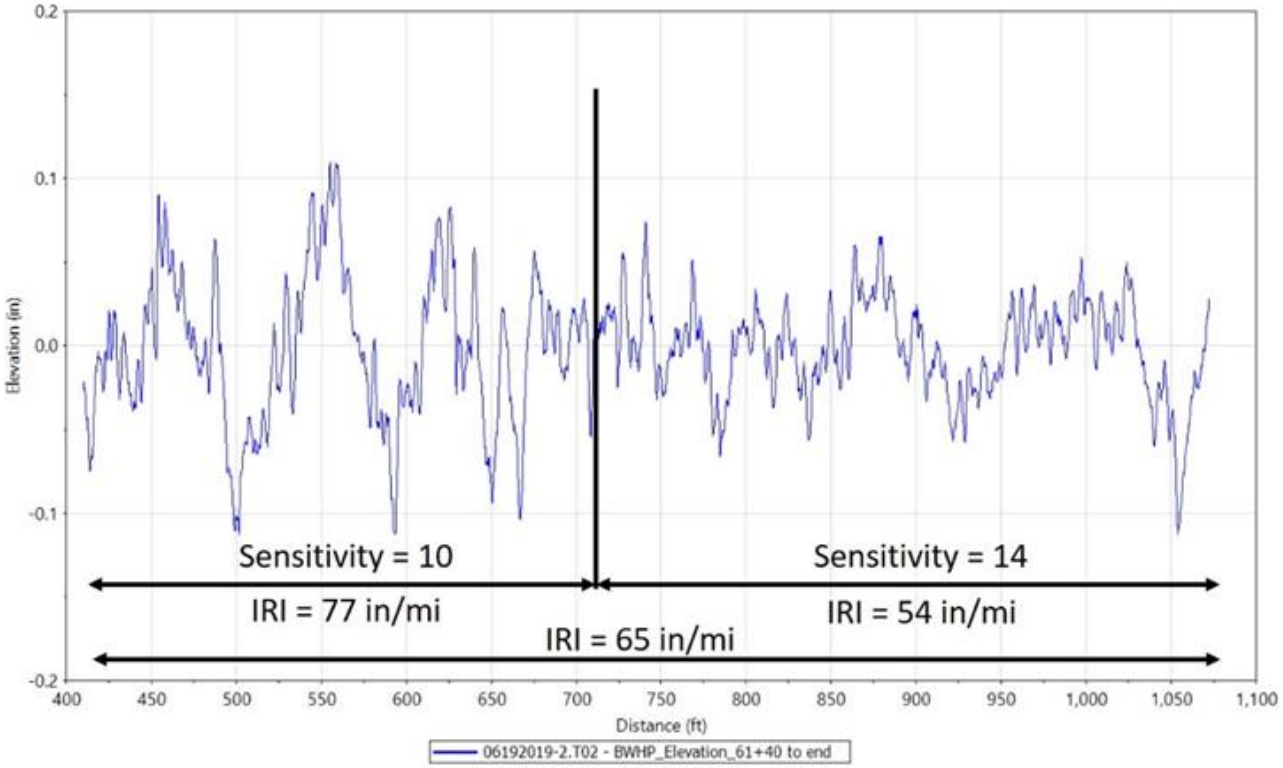
Guidelines for Building Smooth Concrete Pavements

- 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



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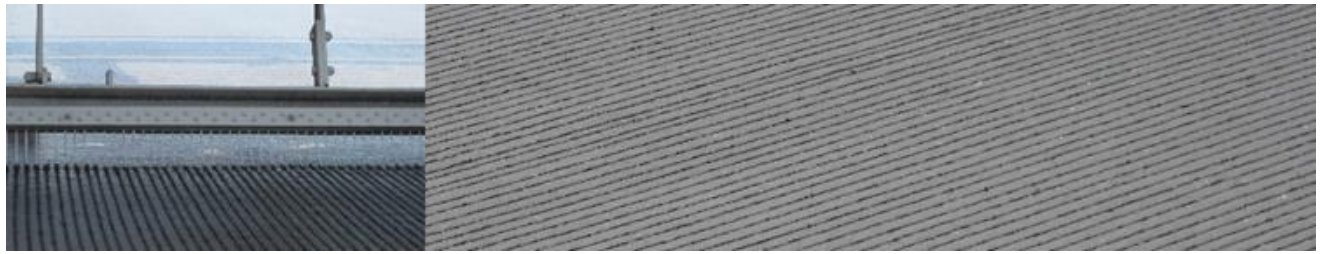
Guidelines for Building Smooth Concrete Pavements

- 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’)

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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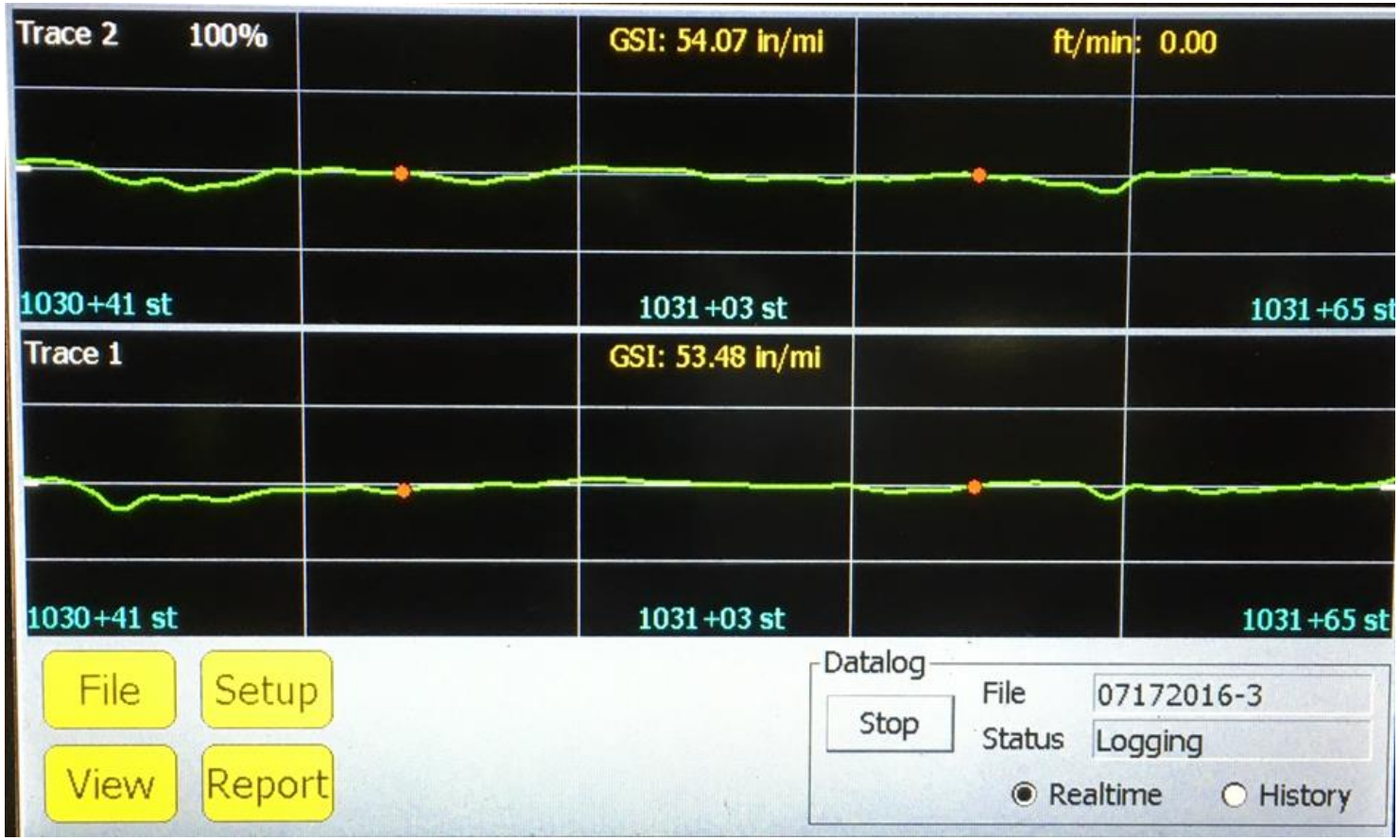
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Real-Time Smoothness
  - QC feedback loop reduced from 18 hours to 2 hours
  - Not a replacement for <u>conventional profiling</u> for acceptance
  - Not a replacement for <u>better practices</u> to construct smoother pavements



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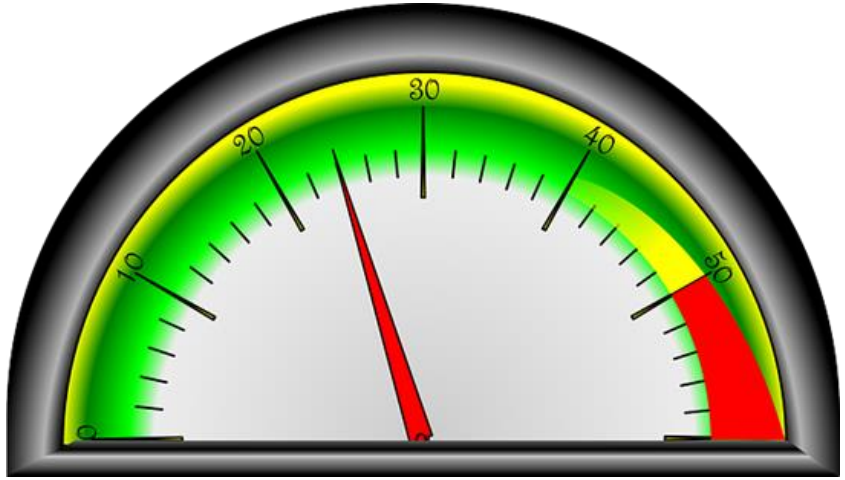
Guidelines for Building Smooth Concrete Pavements

- 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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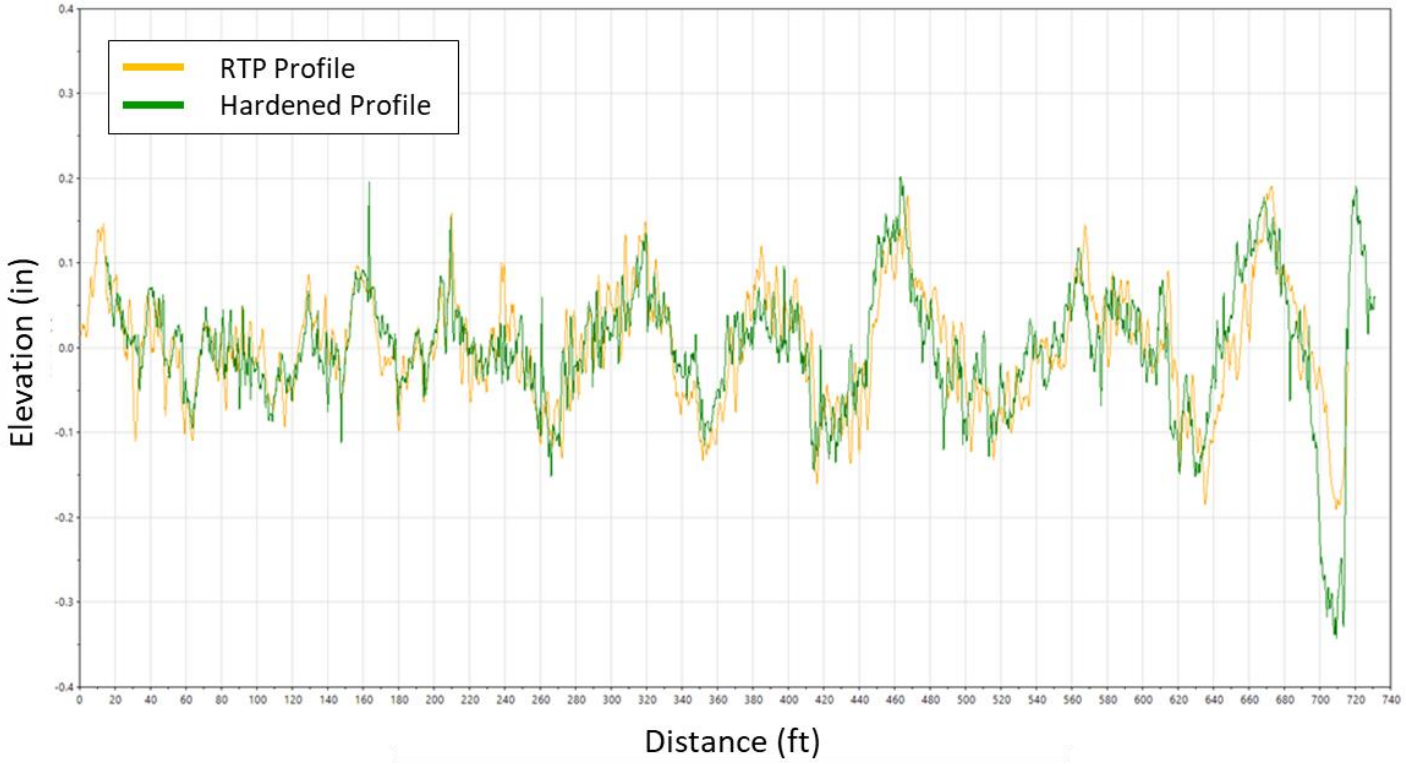
Guidelines for Building Smooth Concrete Pavements

- Slipform Paving – Real-Time Smoothness
  - Real-time profile parallels hardened profile



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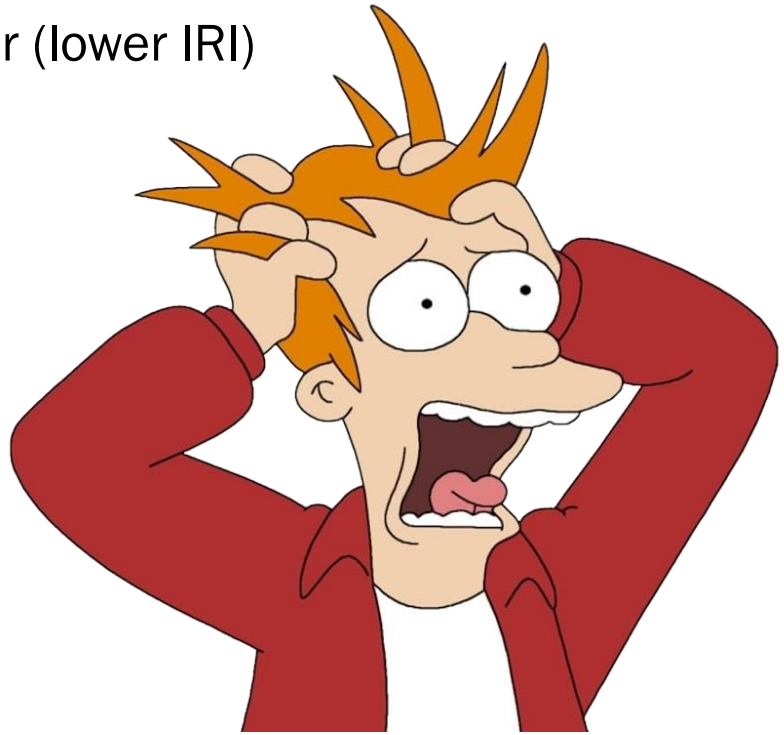
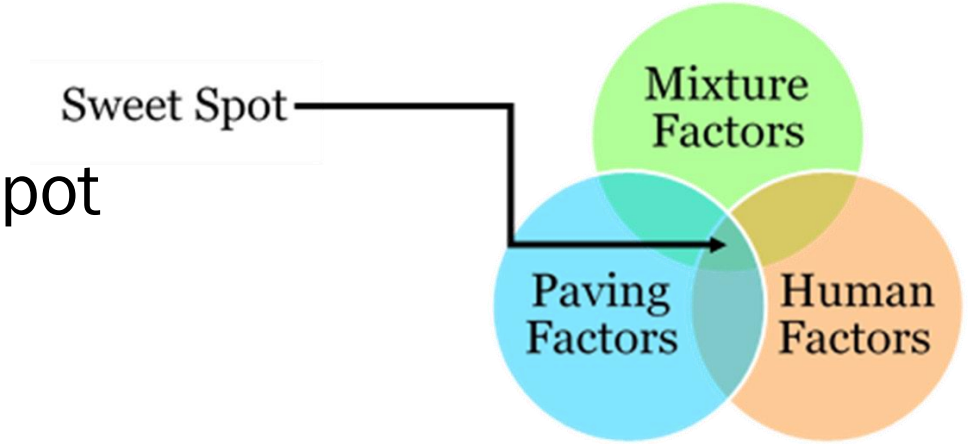
Guidelines for Building Smooth Concrete Pavements

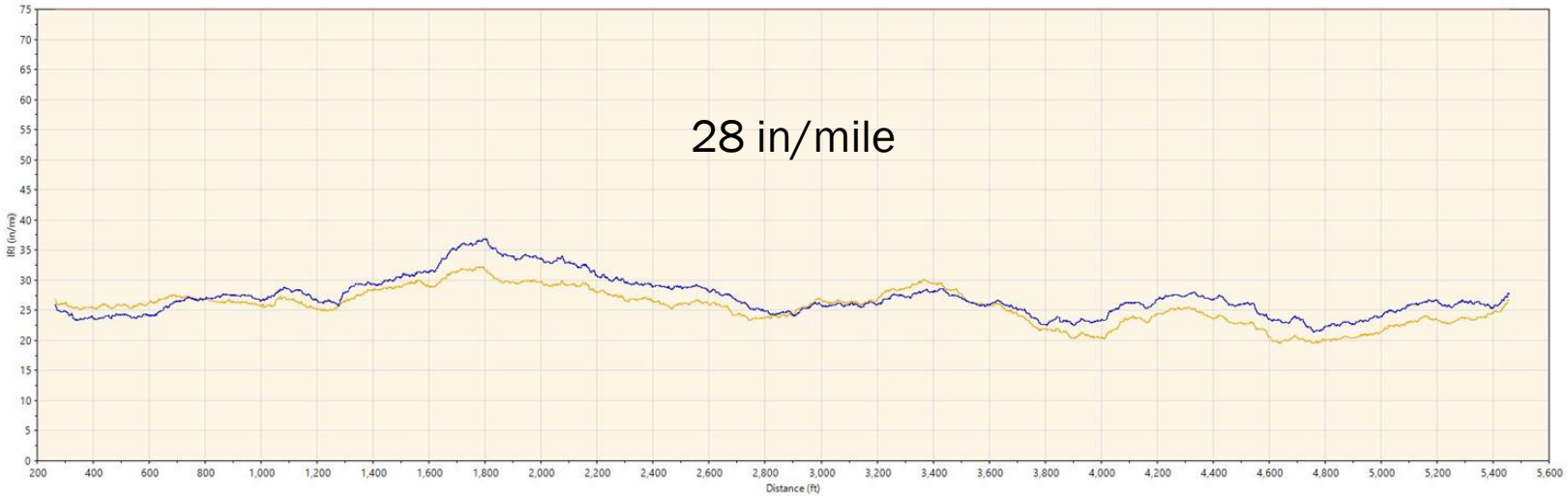
- Slipform Paving – Real-Time Profile
  - The RTS results are higher than the QC hardened profiles – what's up with that?
    - Don't panic
    - Just focus on making the RTS results better (lower IRI)
    - QC profiles will improve as well



Guidelines for Building Smooth Concrete Pavements

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





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Questions?

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Specifying and Measuring Concrete Pavement Smoothness in the 21st Century

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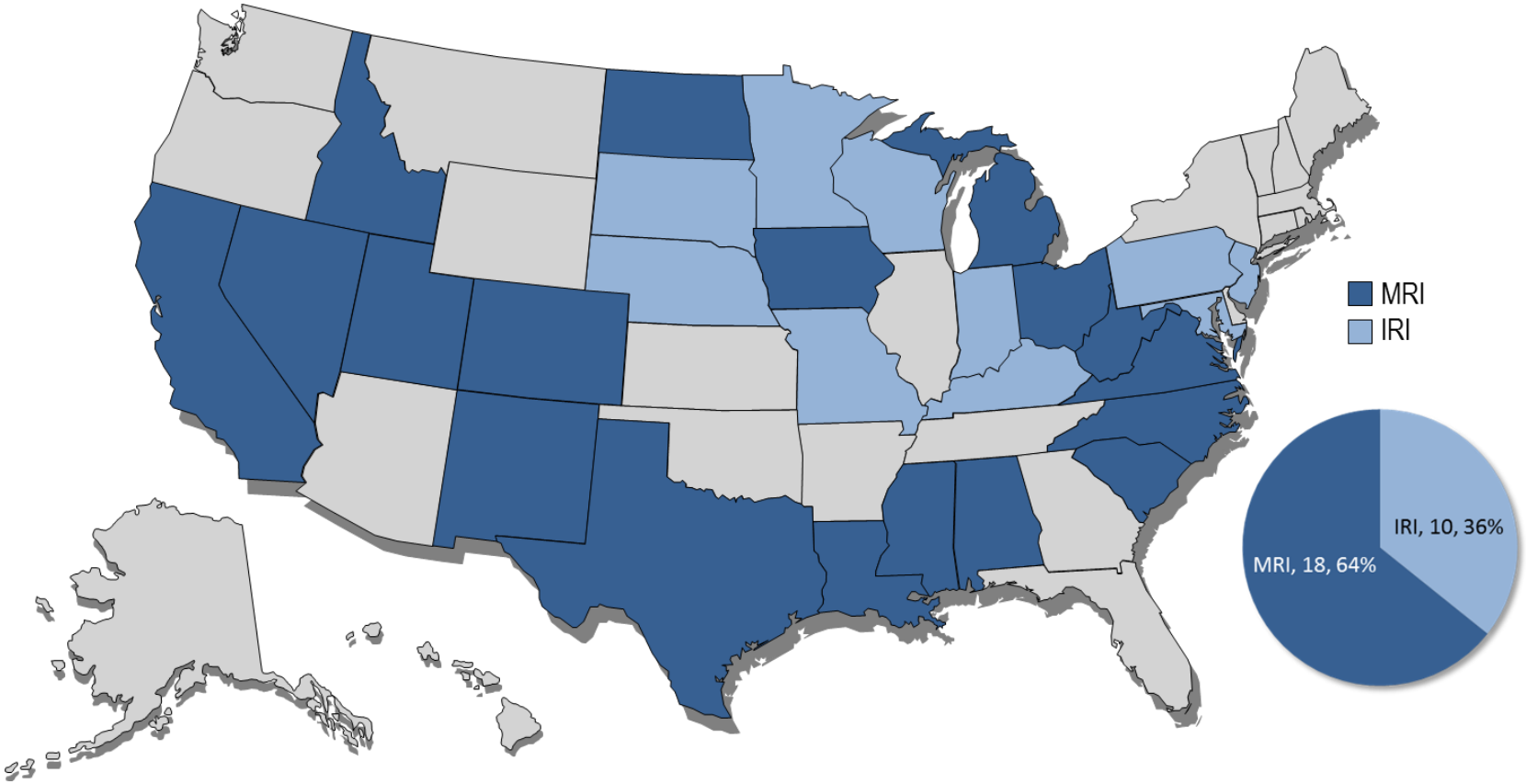
Concrete Pavement Smoothness Specifications

- Current (2019) Specifications for PCCP: IRI Basis



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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

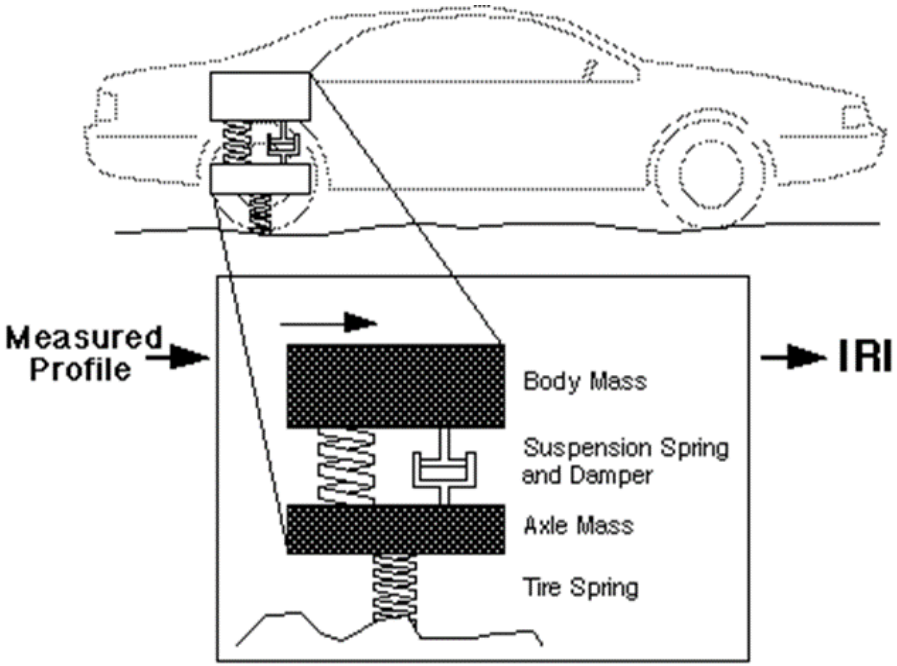
Concrete Pavement Smoothness Specifications

- 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.	

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").

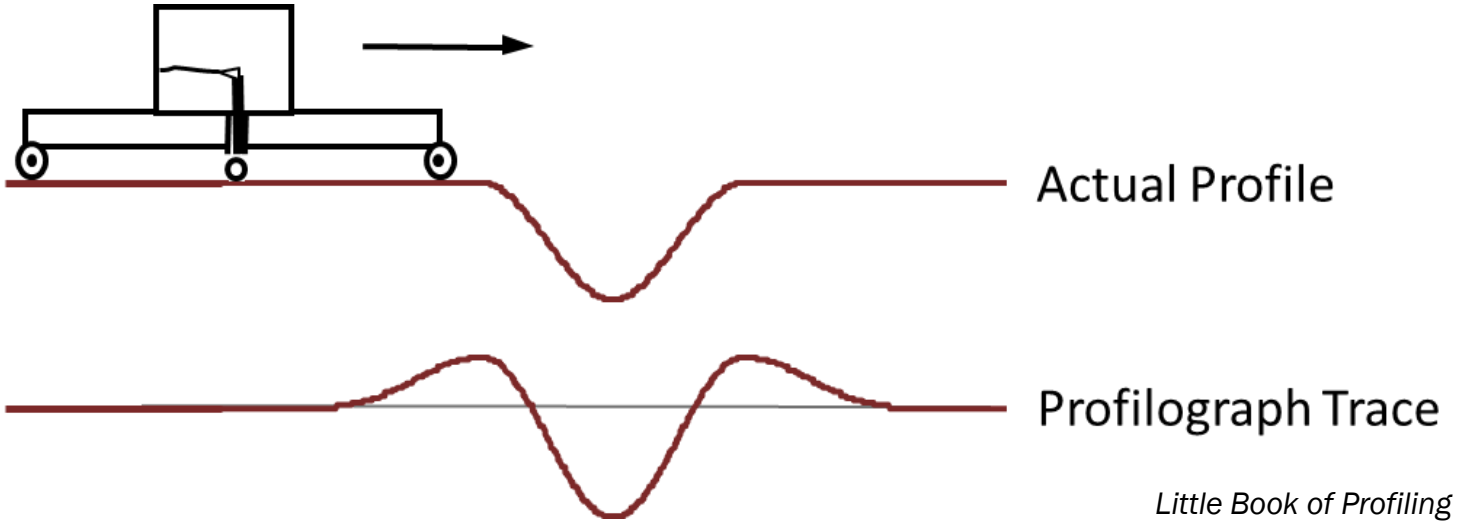


Computer Algorithm

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."



Little Book of Profiling

"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.

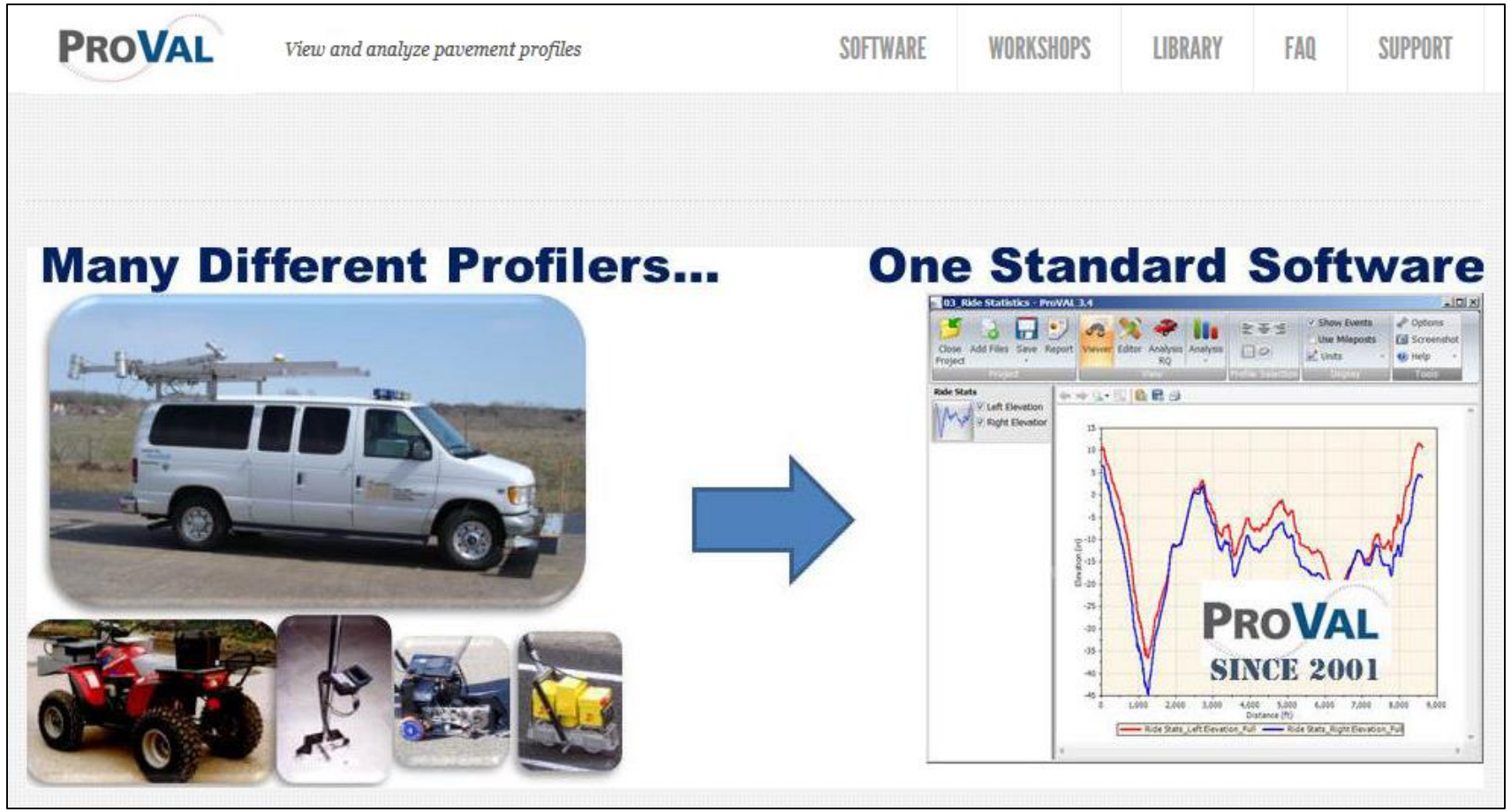
Concrete Pavement Smoothness Specifications

- 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



www.RoadProfile.com

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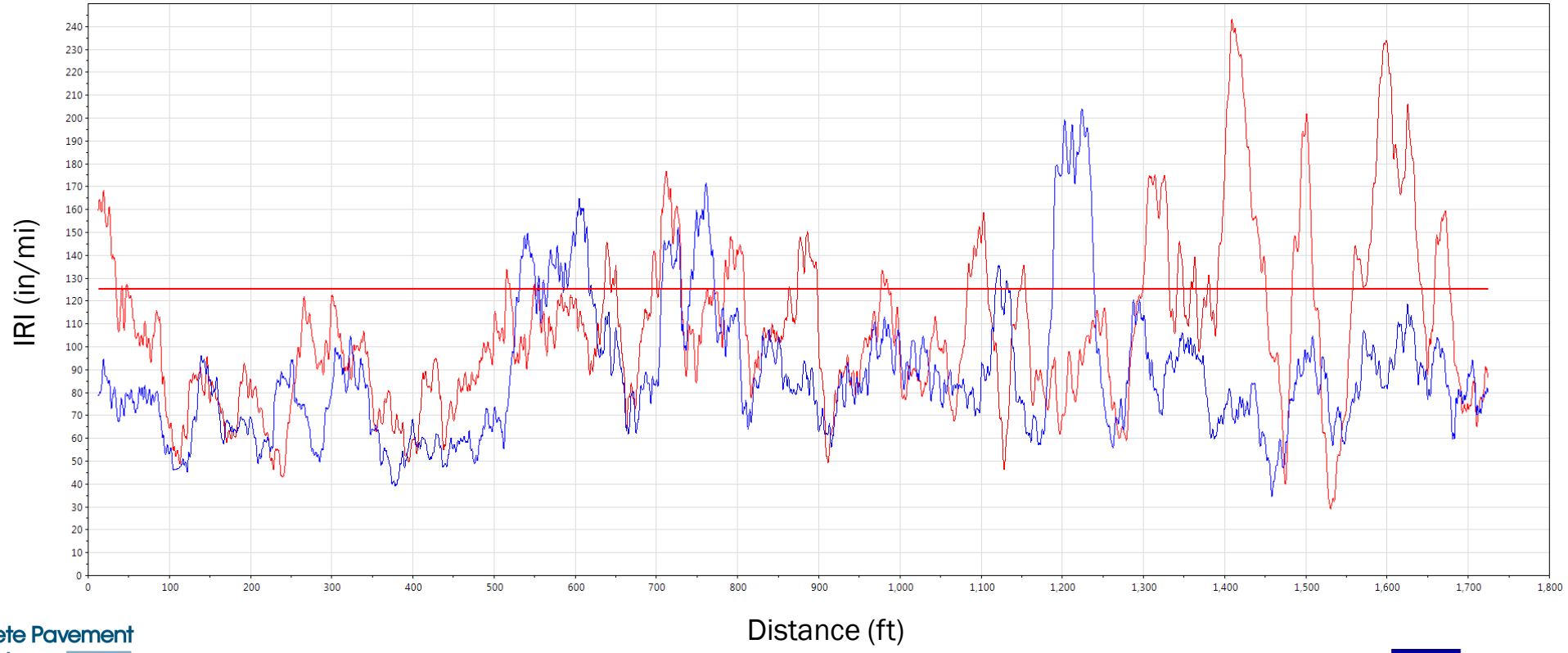
ProVAL Software: Analysis Tools

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



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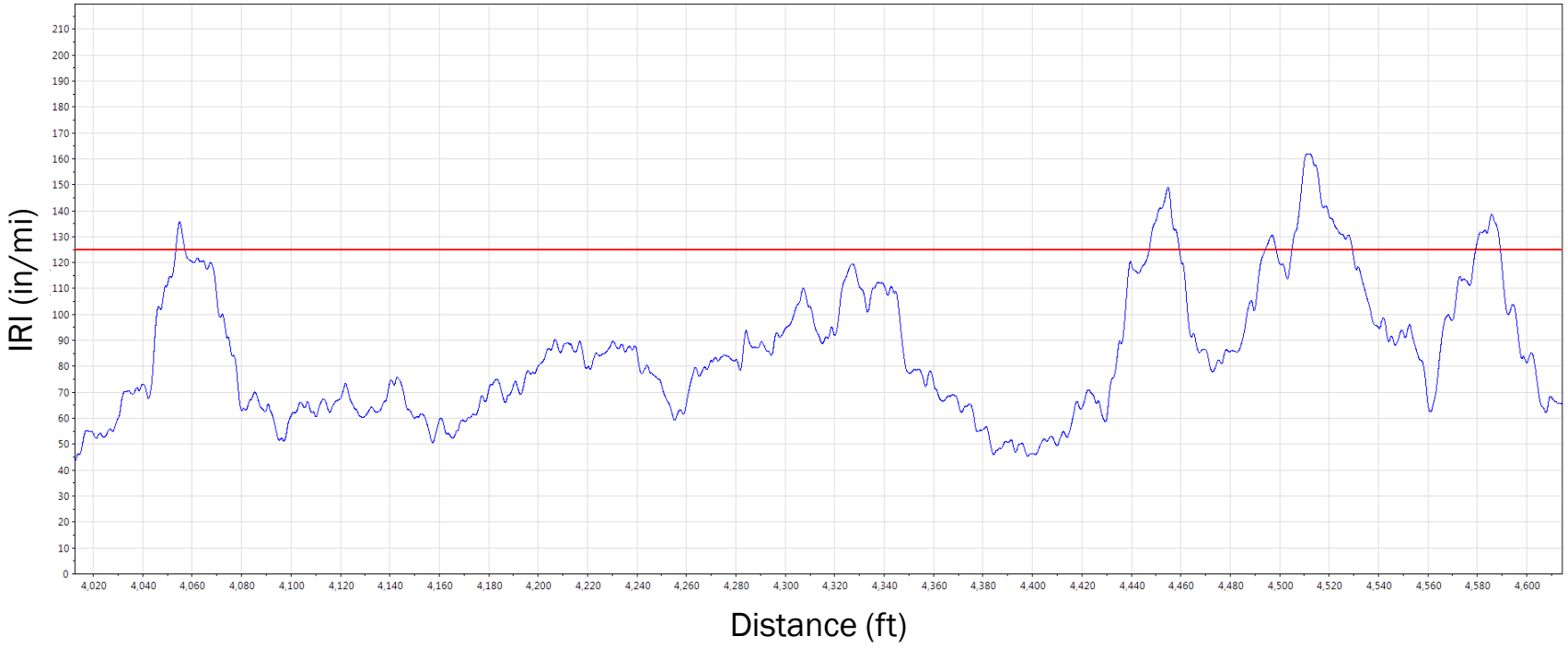
ProVAL Software: Analysis Tools

- 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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ProVAL Software: Analysis Tools

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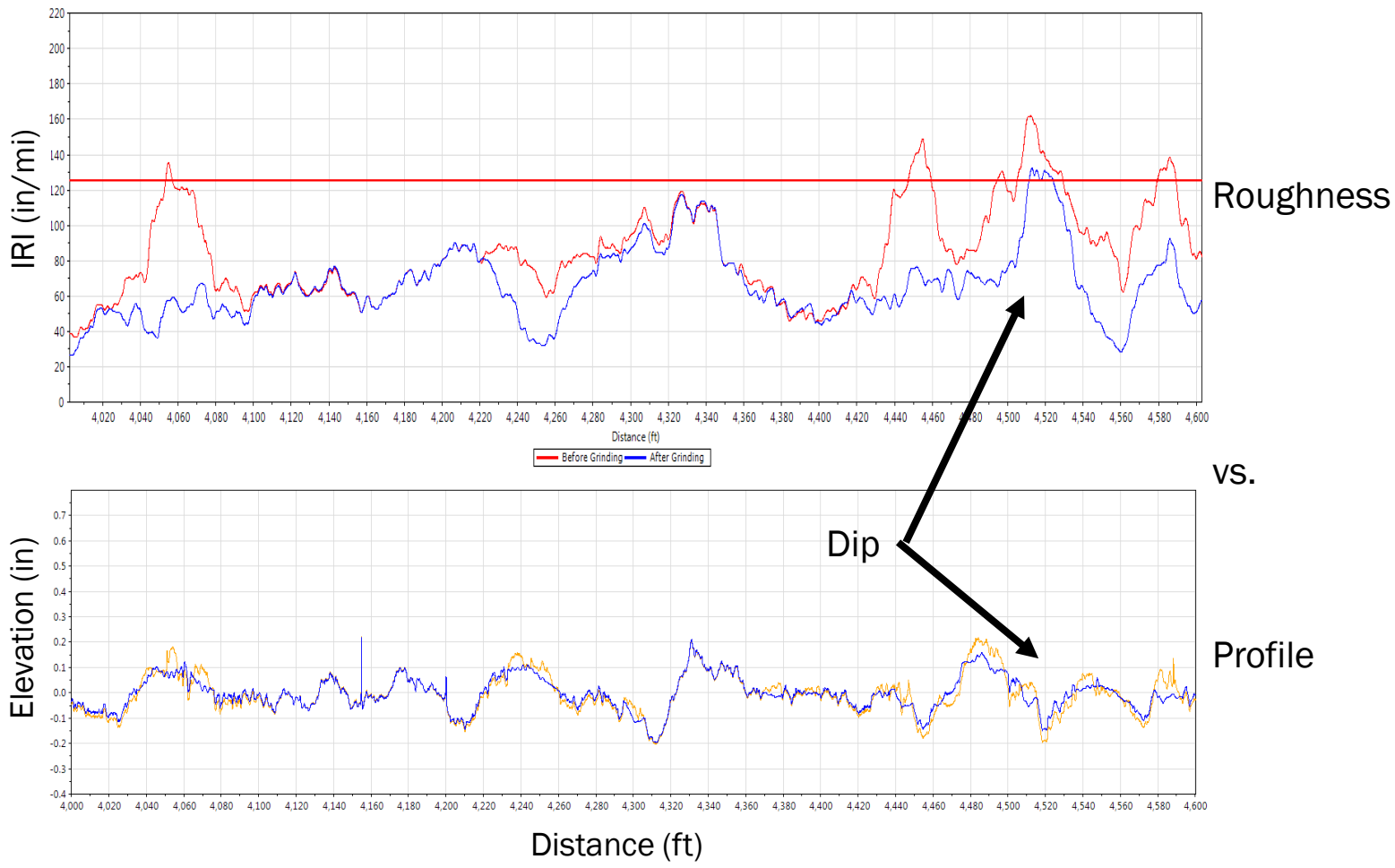

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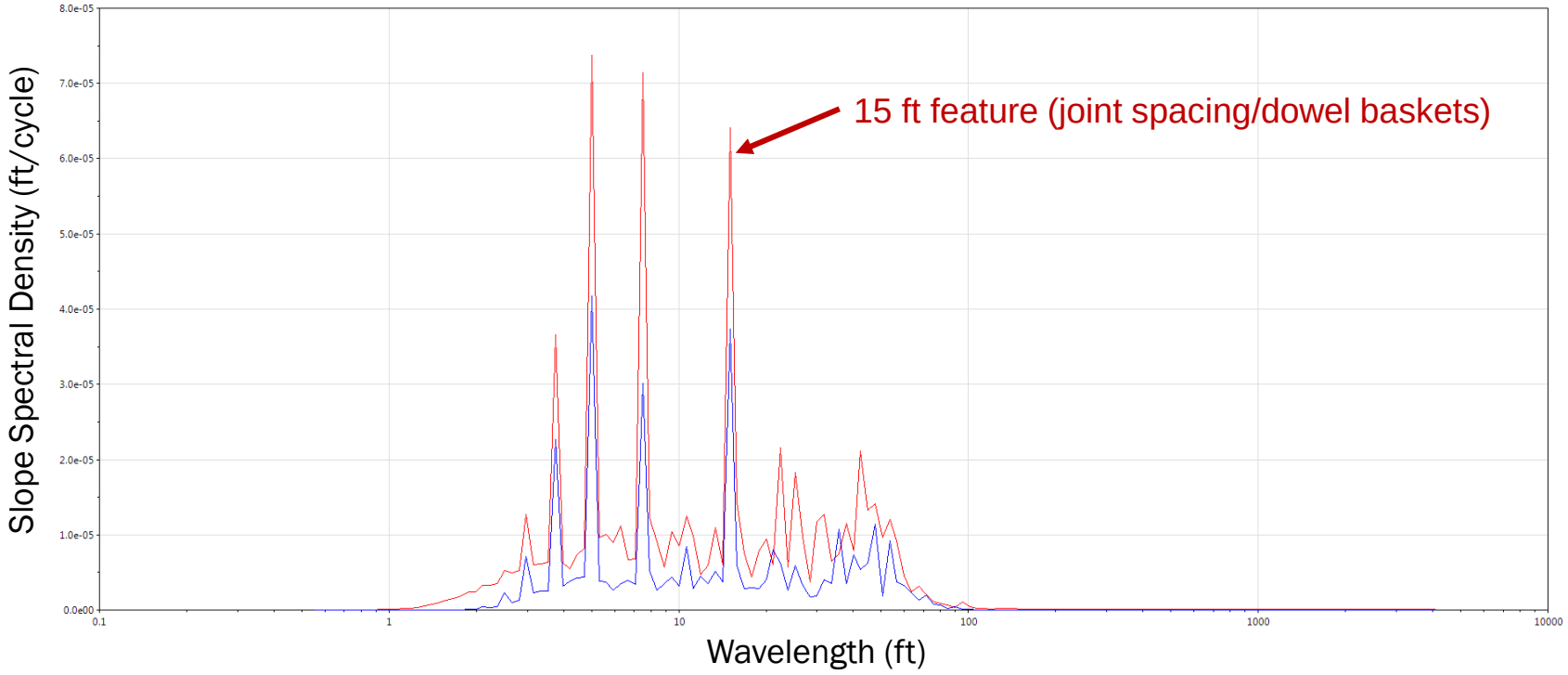
ProVAL Software: Analysis Tools

- 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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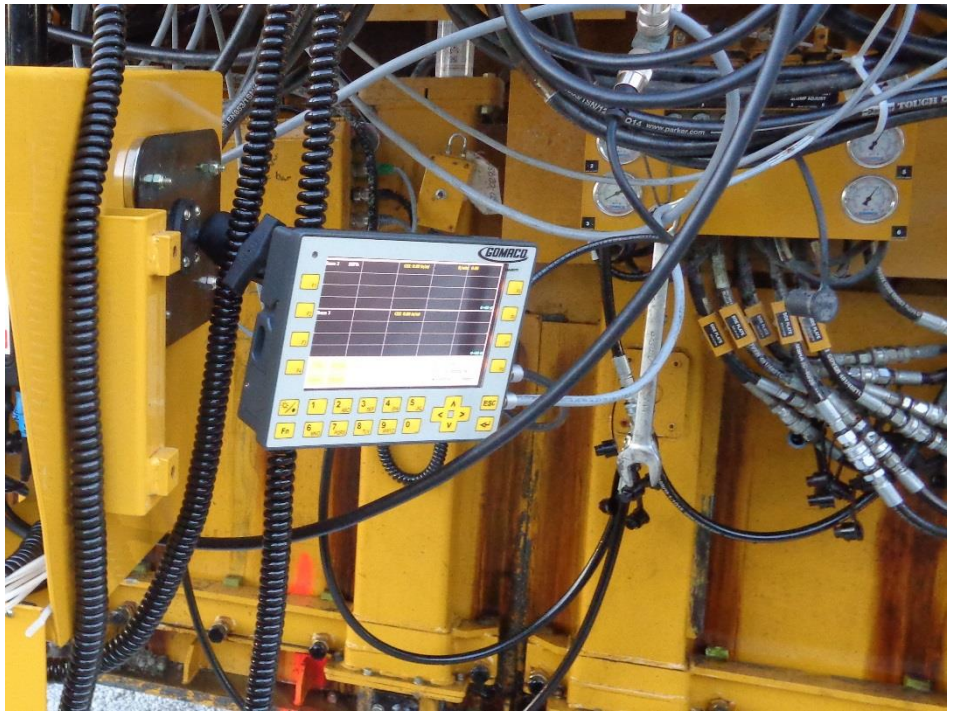
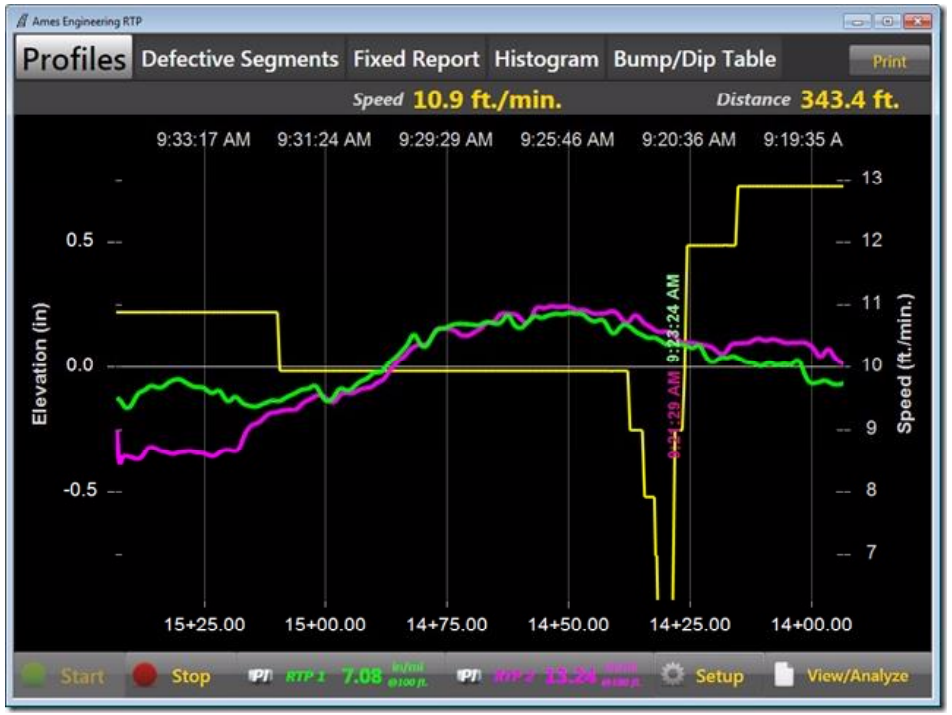
Real-Time Smoothness

- 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.

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

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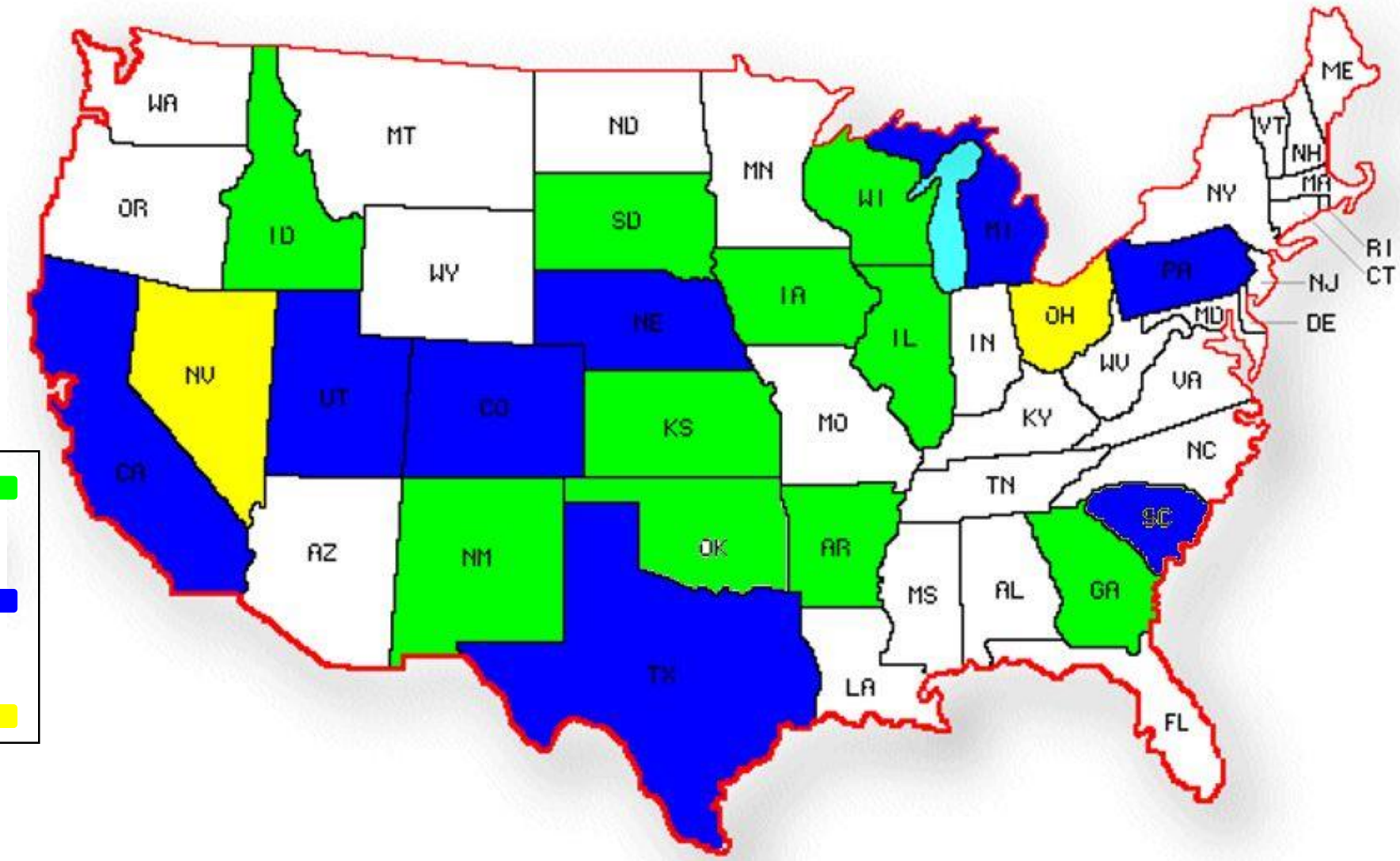
SHRP2/FWHA RTS Implementation

- Effort by state



Equipment Loans

Equipment Loans and Workshops

Workshops

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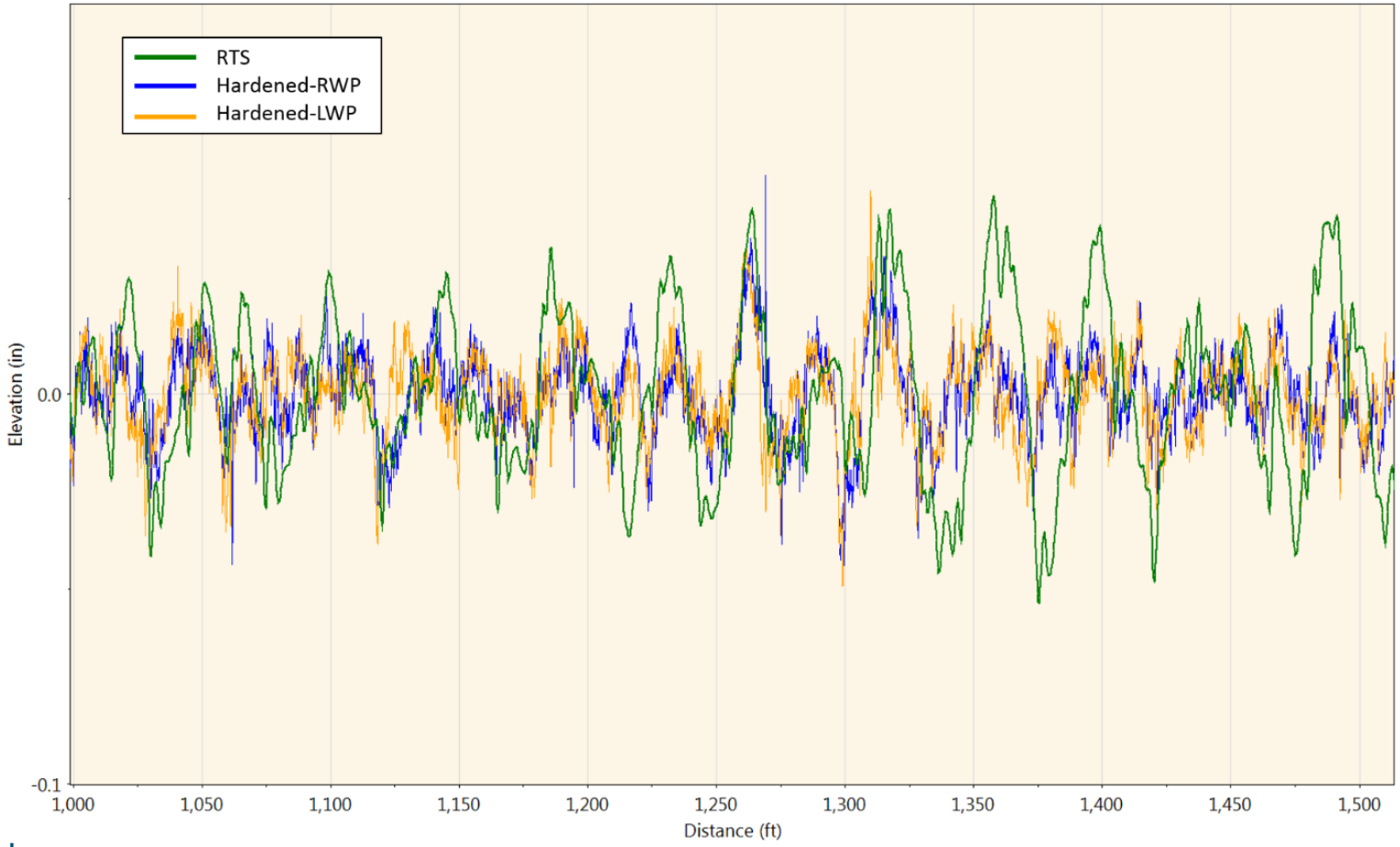
Real-Time Smoothness: Comparison with Hardened Profiles

- Raw profiles are different but trends are similar



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Real-Time Smoothness: Comparison with Hardened Profiles

- 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

Project A

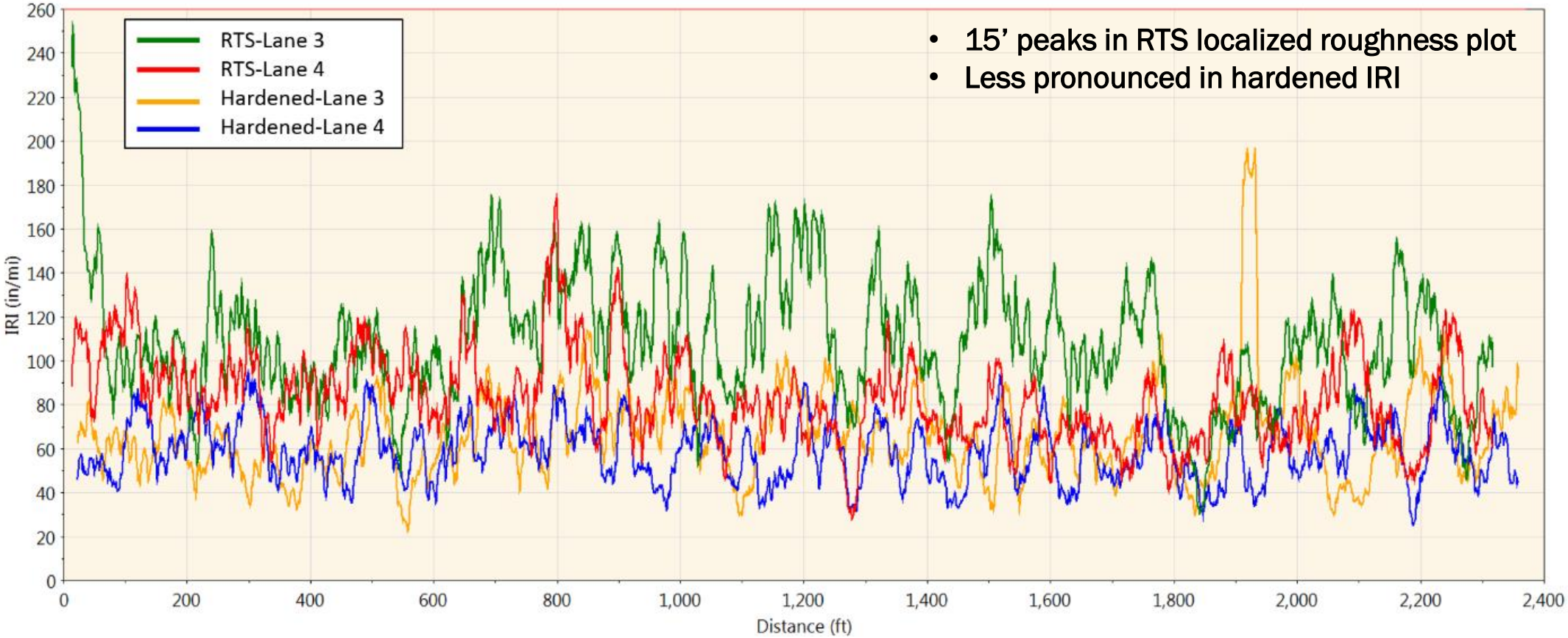
	Segment	RTS IRI (in/mi)	QC MRI (in/mi)	Difference (in/mi)
Day 1	1	113.2	67.0	46.2
	2	77.3	57.0	20.2
	3	79.9	64.6	15.3
Day 2	1	90.0	53.2	36.7
	2	108.9	77.5	31.4
	3	114.4	57.2	57.1
Day 3	1	111.7	65.3	46.4
	2	118.2	71.0	47.2
	3	116.4	68.0	48.4
	4	94.9	61.9	33.1
Day 4	1	122.6	64.5	58.1
	2	122.5	61.9	60.7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

Real-Time Smoothness: Features in Profiles

- Joint spacing/dowel basket effects



- 15’ peaks in RTS localized roughness plot
- Less pronounced in hardened IRI

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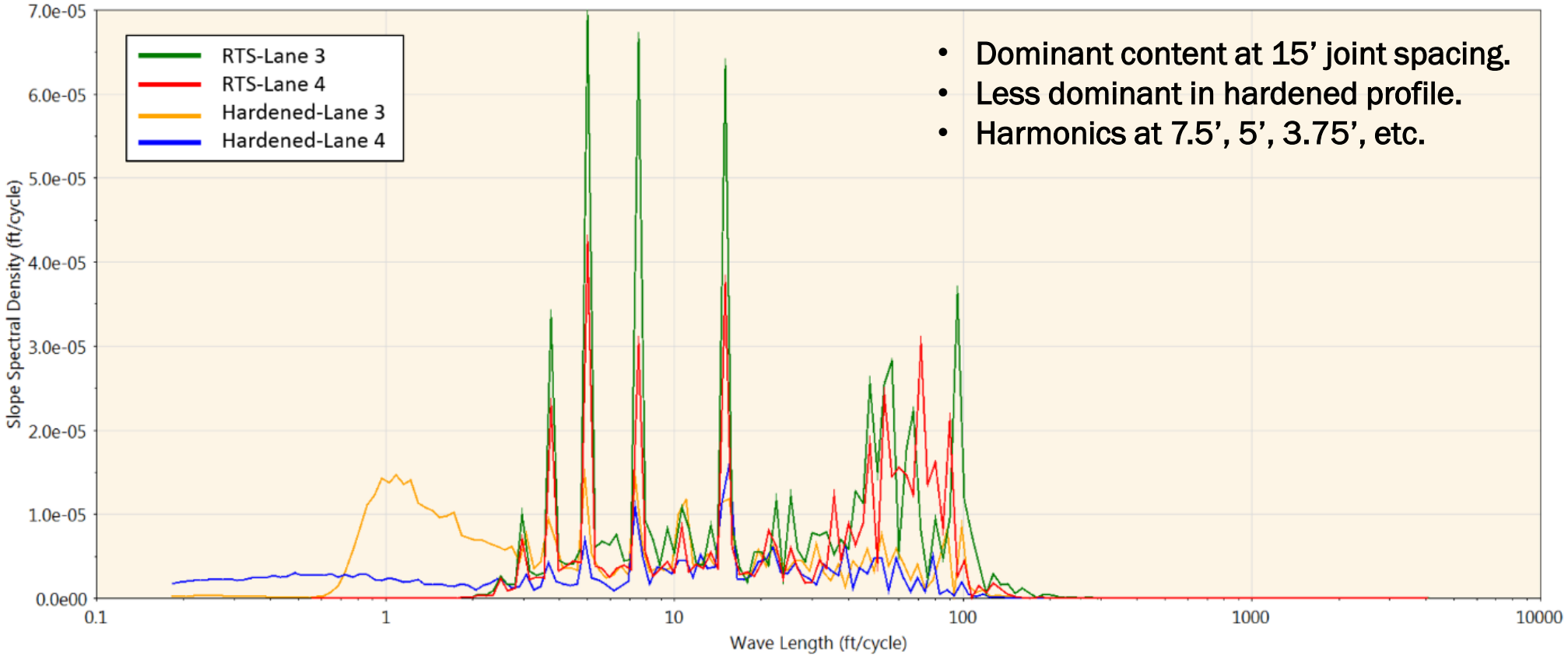
Real-Time Smoothness: Features in Profiles

- 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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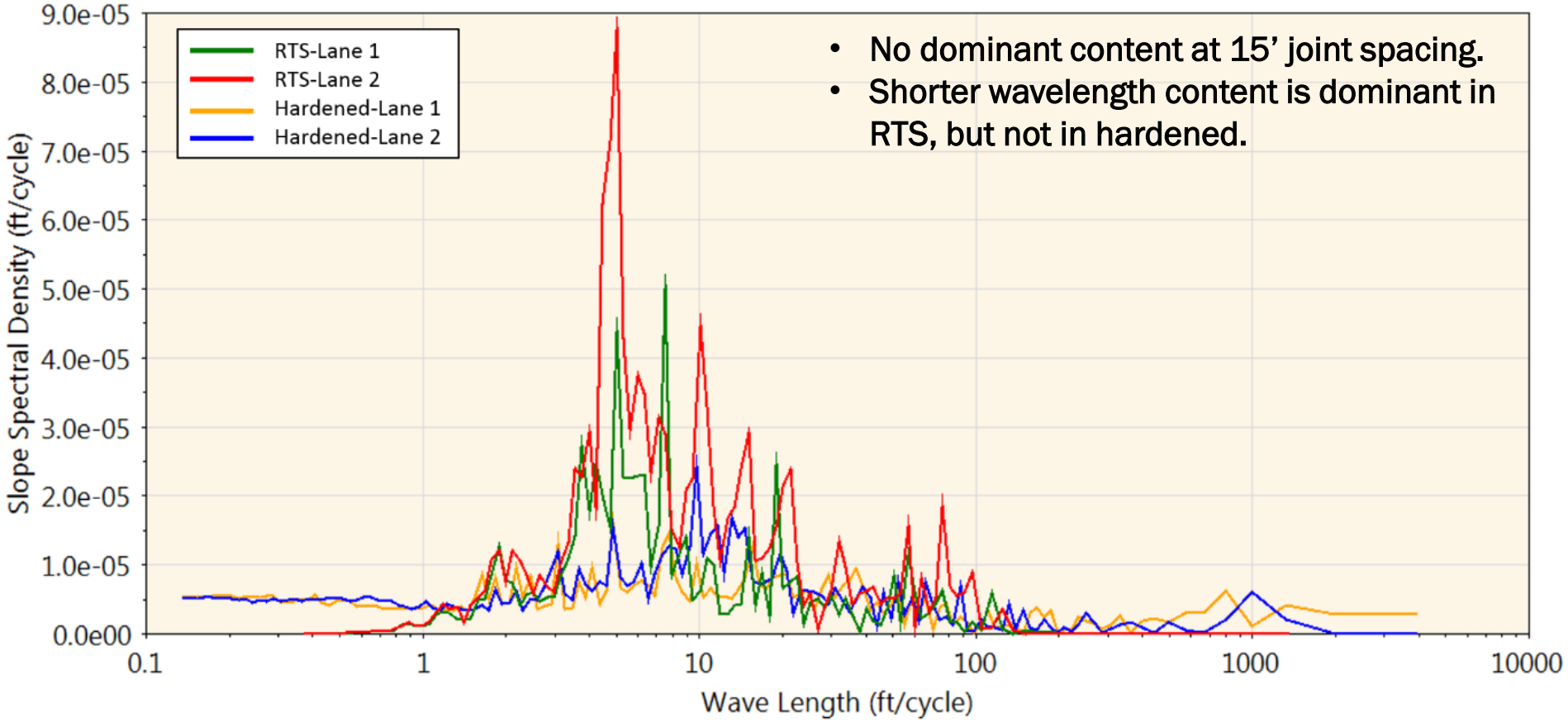
Real-Time Smoothness: Features in Profiles

- 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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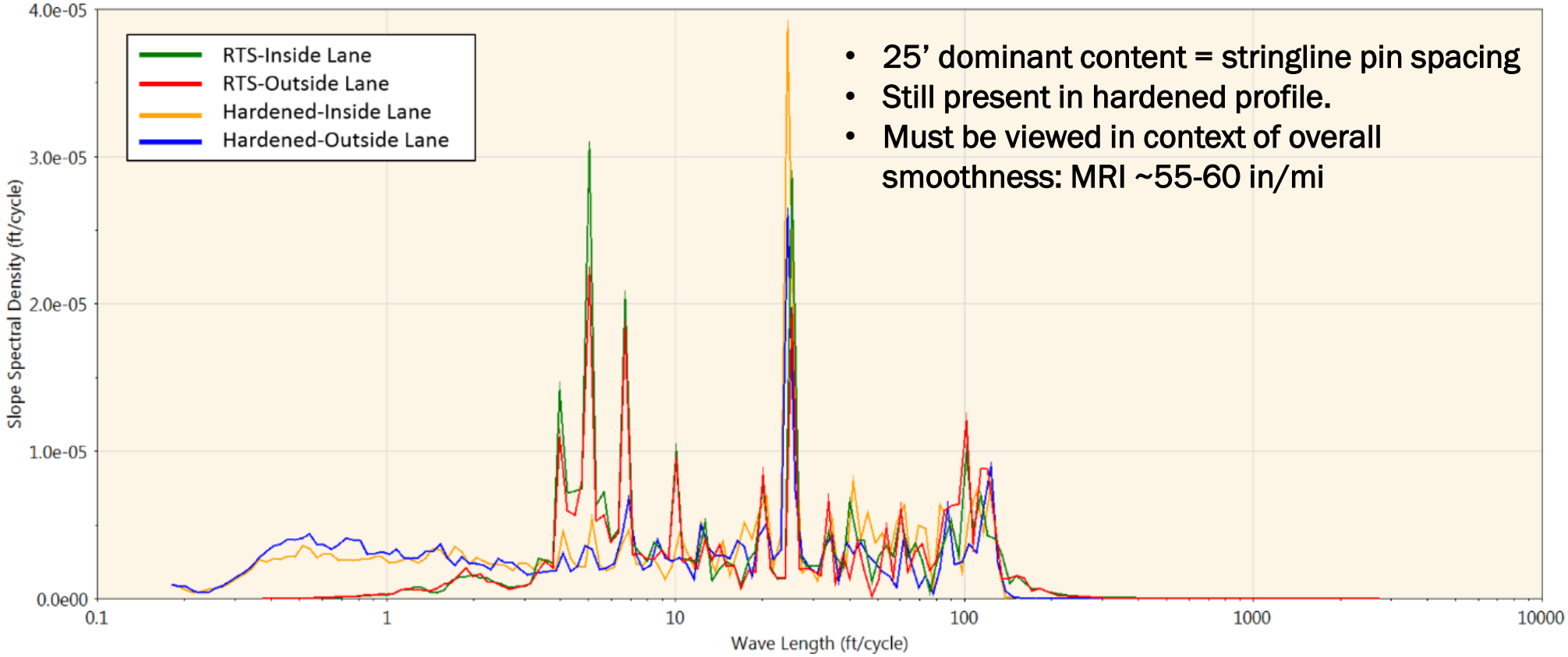
Real-Time Smoothness: Features in Profiles

- Stringline and Stringless System Effects



- 25’ dominant content = stringline pin spacing
- Still present in hardened profile.
- Must be viewed in context of overall smoothness: MRI ~55-60 in/mi

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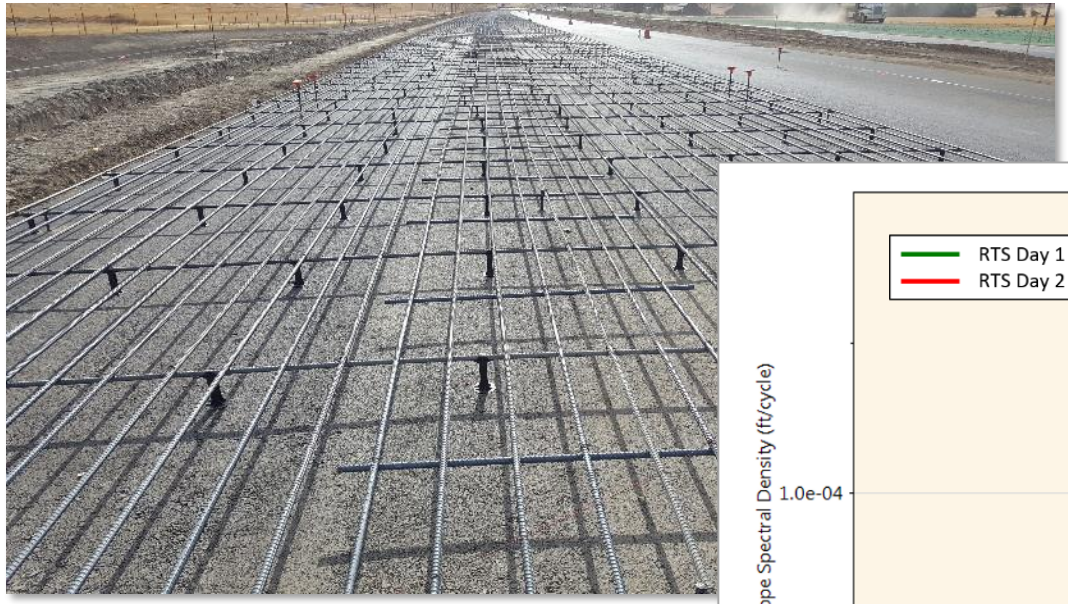
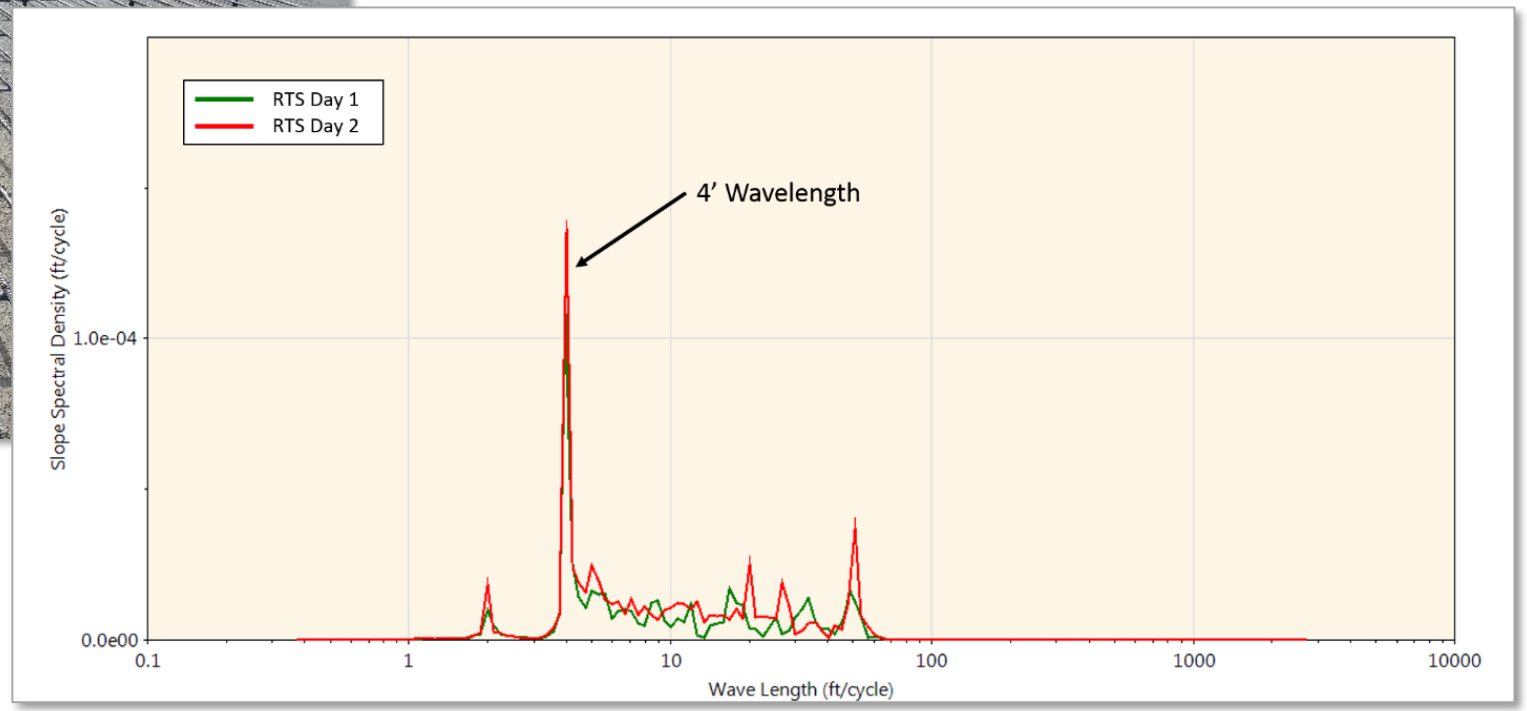
Real-Time Smoothness: Features in Profiles

- CRCP Bar Supports





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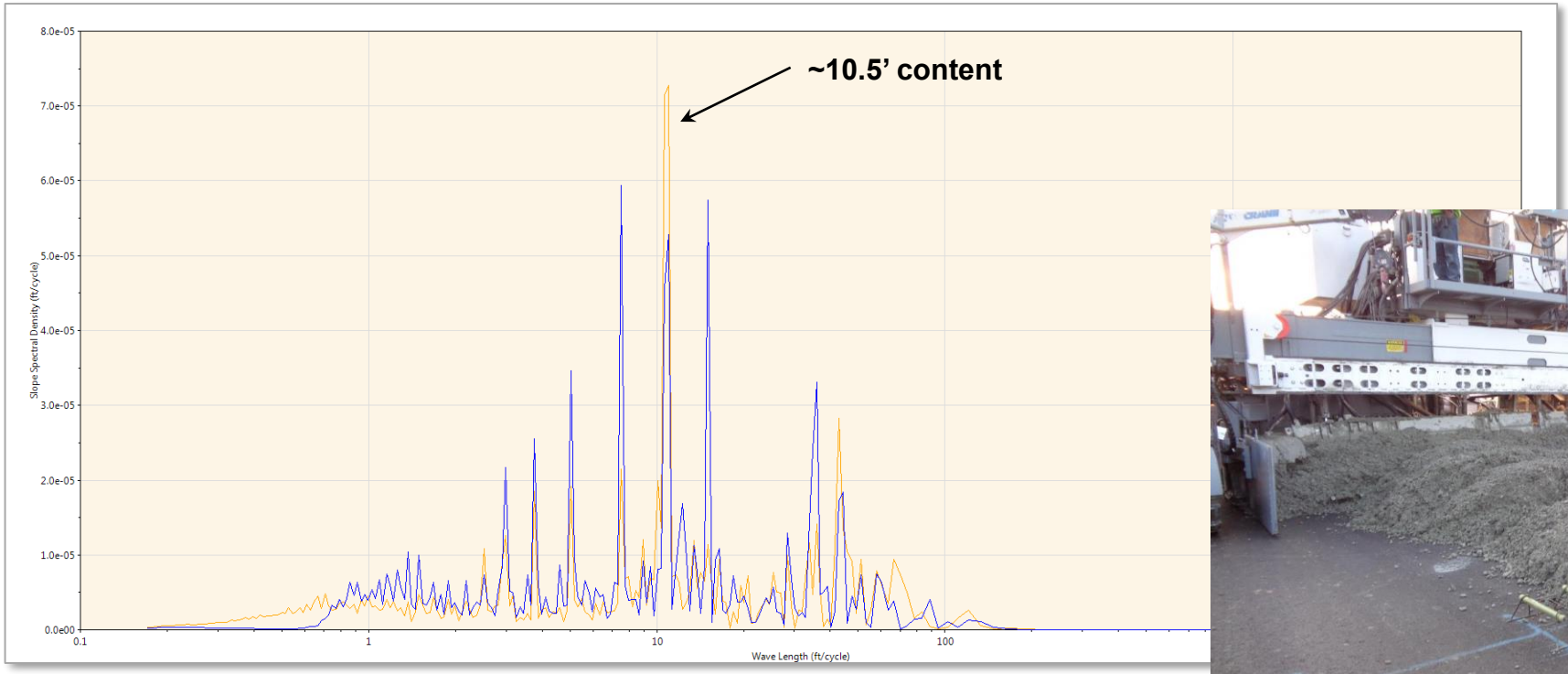
Real-Time Smoothness: Features in Profiles

- Load Spacing



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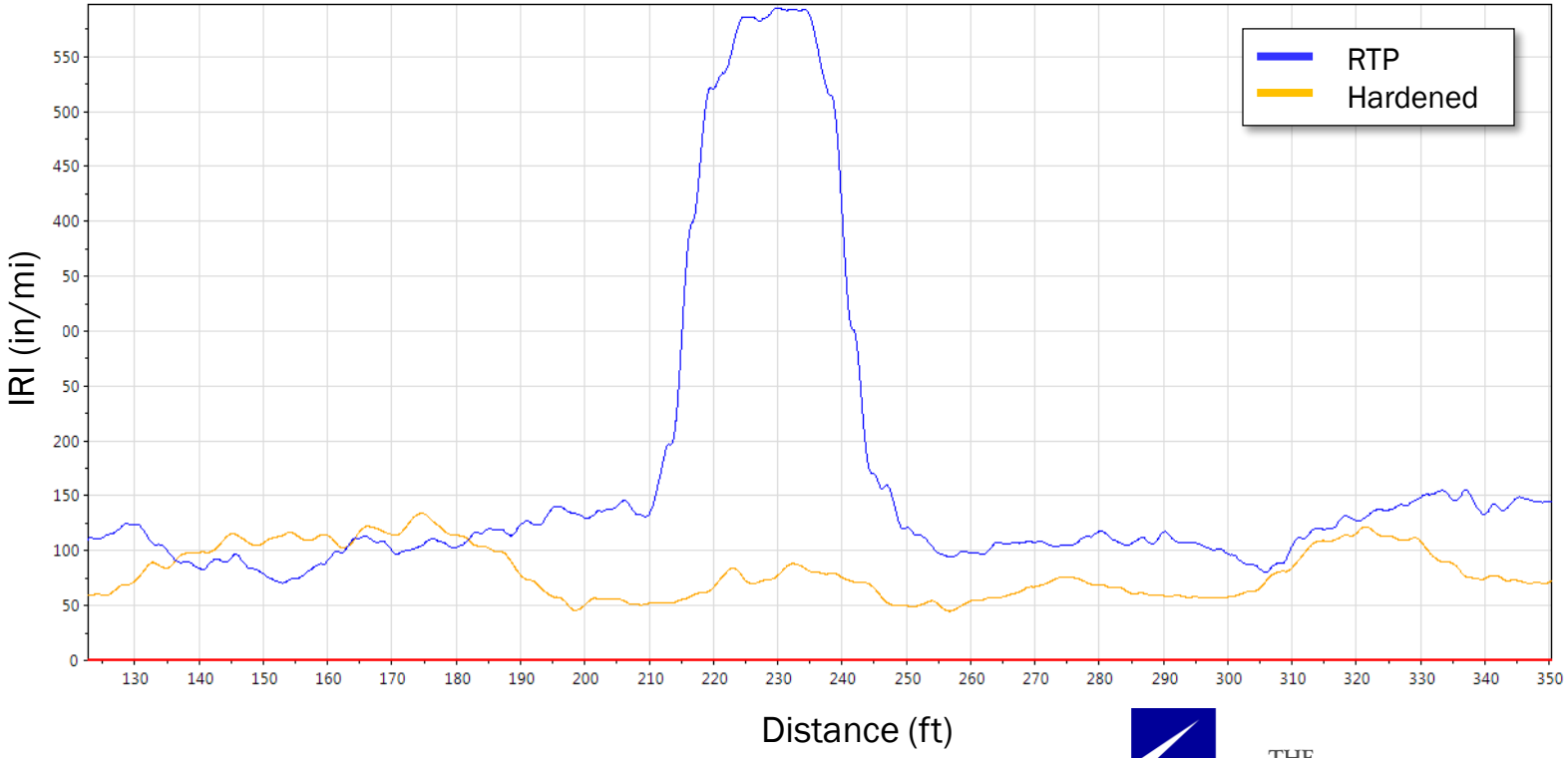
Real-Time Smoothness: Features in Profiles

- Localized roughness – improvement from finishers



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Questions?

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