SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

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

SHRP2 Solutions Webinar
13 November 2017

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO
The Voice of Transportation

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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.

National Concrete Pavement Technology Center

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Real Time Smoothness

Tom Yu
FHWA Office of Infrastructure

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO
The Voice of Transportation

TRB

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

- SHRP2 Solutions Implementation effort (2014-2017):
- Equipment Loan Program
- Showcase
- Workshops
- Documentation of results/case studies
- Specification Refinement

National Concrete Pavement Technology Center

Tech Center

U.S.Department of Transportation
Federal Highway Administration

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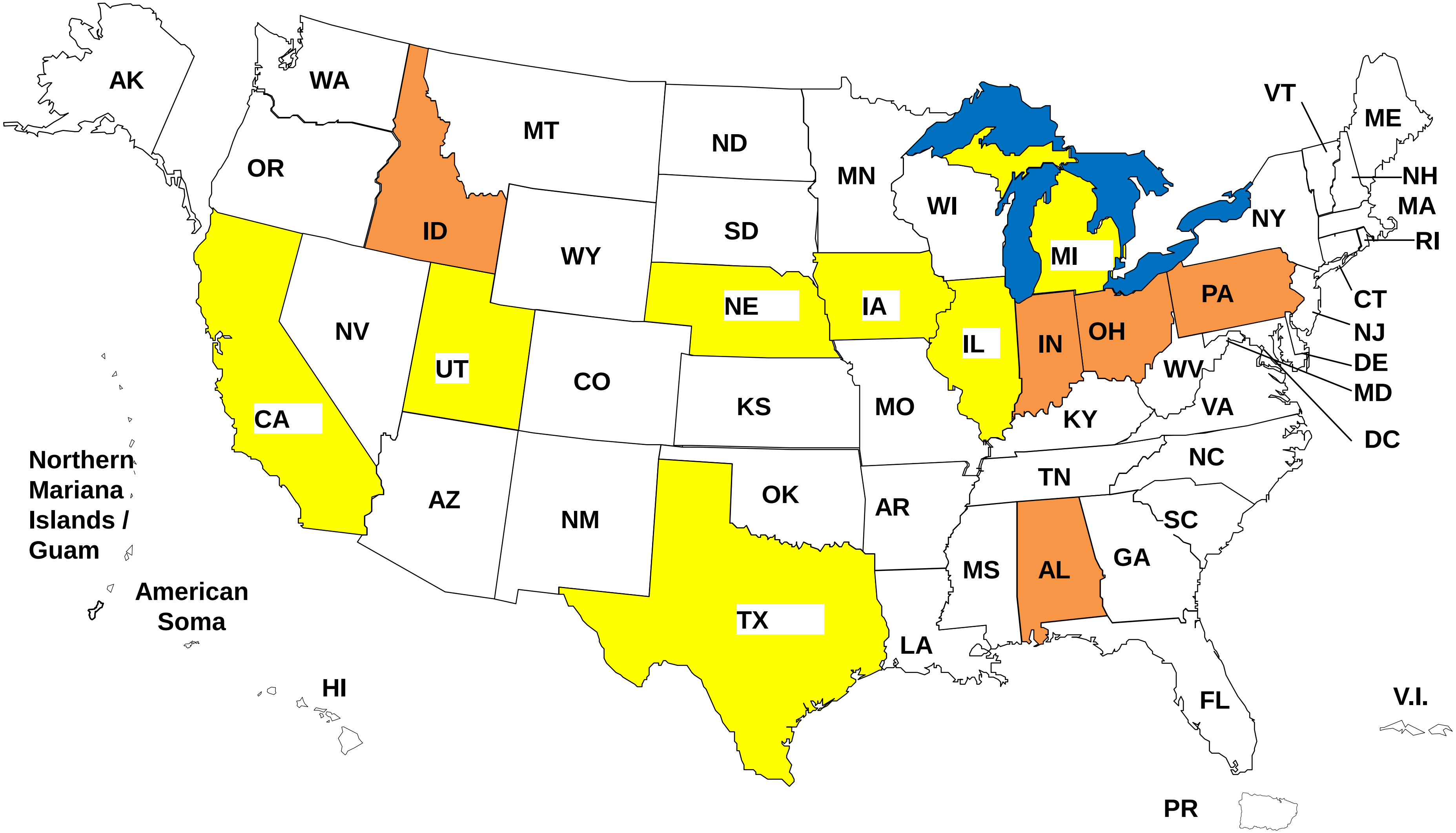
R06E - Tools to Improve PCC Smoothness During Construction



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

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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.

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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

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Measuring Pavement Smoothness

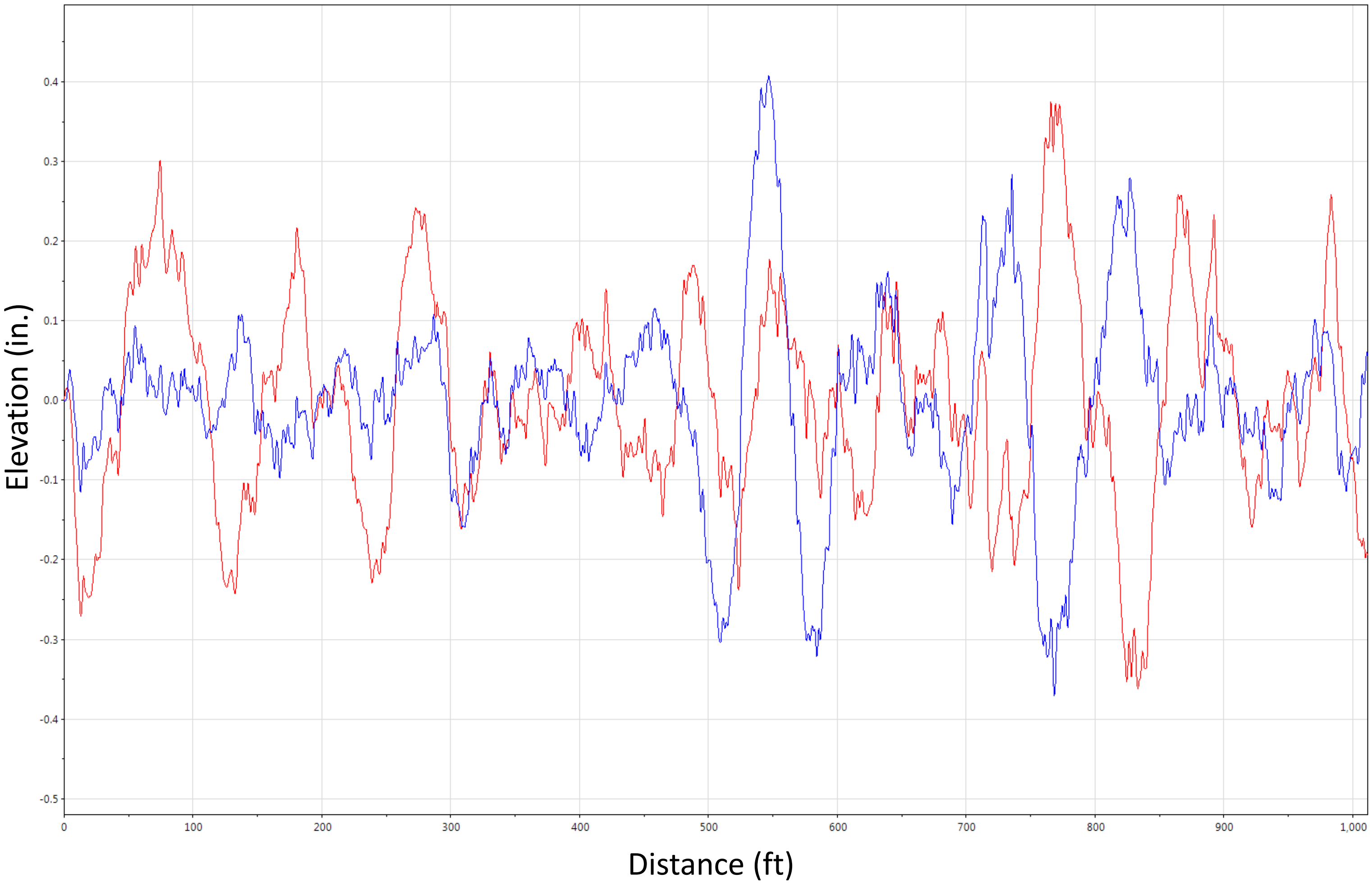
Profilograph vs. Profiler

- **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.**

Real-Time Profilers

Measuring Pavement Smoothness

Pavement Profile from Real-Time Smoothness (RTS) System

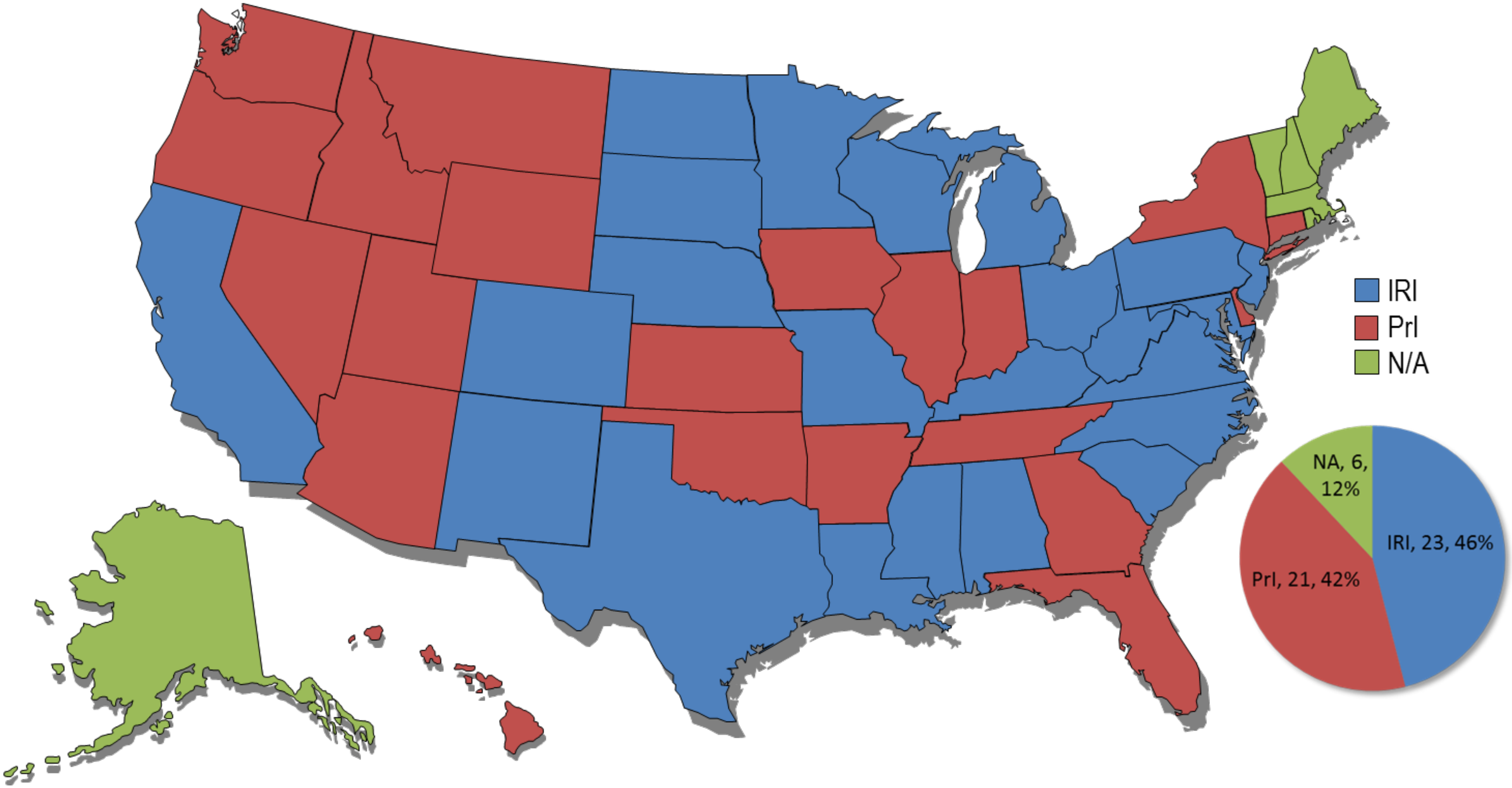


Interpreting Pavement Smoothness

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

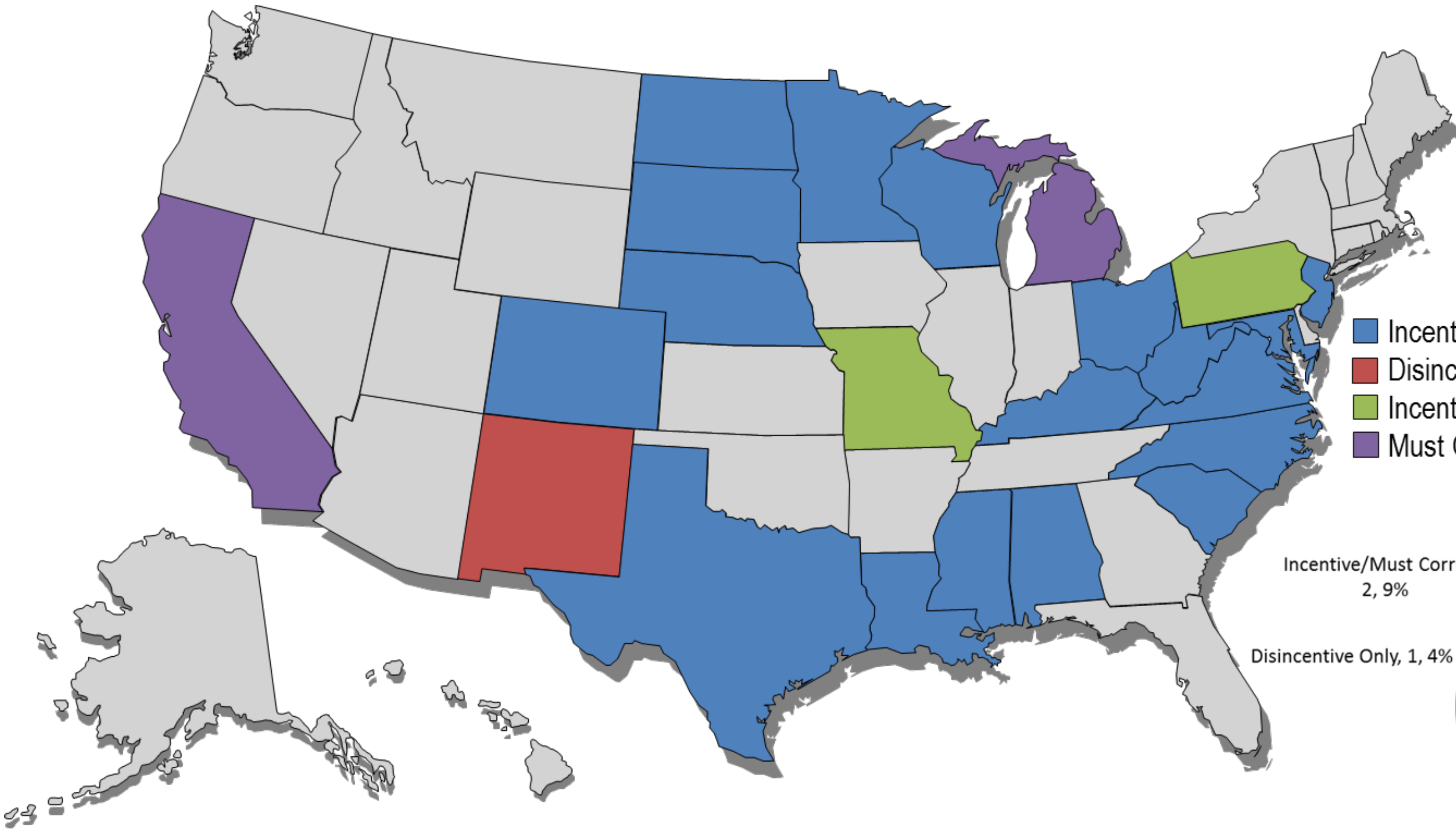
- **The PrI is a measure of pavement smoothness related to a profilograph trace.**
- **IRI is a better representation of actual ride quality, or what the user (driver) experiences based on vehicle response to the pavement profile.**

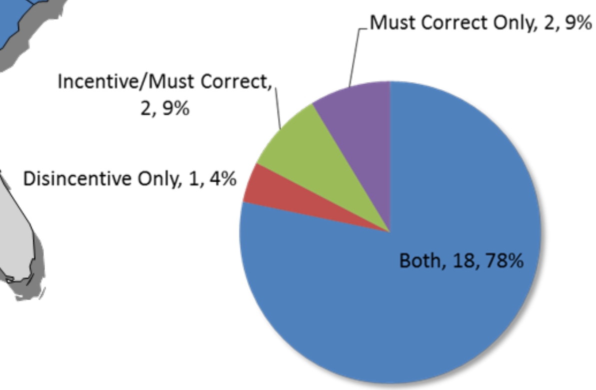
PCC Pavement Smoothness Specifications



Merritt et al. 2015

PCC Pavement Smoothness Specifications





Merritt et al. 2015

PCC Pavement Smoothness Specifications

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

		Incentive Upper Limit	Full Pay Lower Limit	Full Pay Upper Limit	Disincentive Lower Limit	Disincentive Upper Limit	Threshold for Correction
MRI & IRI (22 states)	*min*	39.9	40.0	54.0	54.1	67.5	60.0
	max	70.0	71.0	93.0	93.1	140.0	150.0
	avg.	56.2	56.5	71.7	72.5	95.3	96.9
HRI (CO only)		57.9	58.0	67.0	67.1	85.0	85.0

Merritt et al. 2015

PCC Pavement Smoothness Specifications

- Range of Incentive/Disincentives applied for ride quality:

Pay Adjustment Basis		Maximum Incentive	Maximum Disincentive
$ per lot (0.1 mi) *9 states*	*min*	$200	-$250
	max	$1,600	-$1,750
	avg.	$879	-$900
$ per lot (SY) *2 states*	*min*	$1.40	-$1.12
	max	$1.40	-$1.40
	avg.	$1.40	-$1.26
$ 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
Extended Pay Adjustment $ per lot (0.1 mi) *13 states (NJ excluded)*	*min*	$200	-$250
	max	$1,600	-$1,750
	avg.	$825	-$831
Percent Contract Price *7 states*	*min*	102%	90%
	max	108%	50%
	avg.	105%	75%

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Merritt et al. 2015

PCC Pavement Smoothness Specifications

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

Method	Number of States		Range	
	Asphalt	*Concrete*		
Continuous IRI (25 ft. baselength)	11	12	80 in/mi	200 in/mi
Fixed Interval IRI	4	4	25 ft. segment: 150-160 in/mi	0.01 mi (52.8 ft.) segment: 100-125 in/mi
Profile Moving Average (25 ft. baselength)	4	1	0.15 inches	0.4 inches
Profilograph Simulation (25 ft. baselength)	2	2	0.3 inches	0.4 inches
Straightedge Only	18	4	1/8-inch in 16 ft.	1/4-inch in 10 ft.

Merritt et al. 2015

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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).

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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)

RTS Profilers

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

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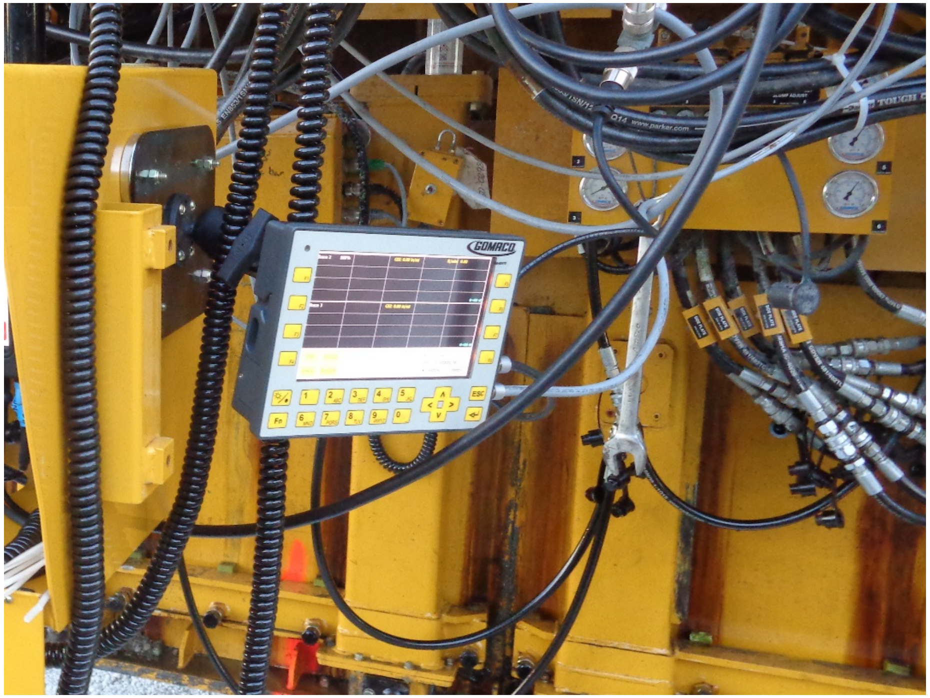
RTS Mounting

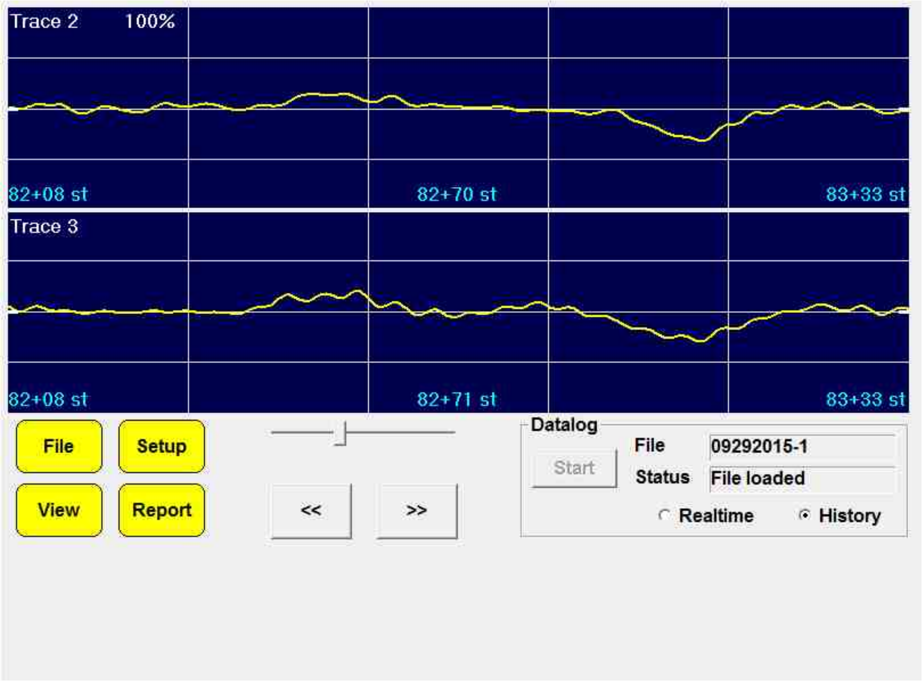
RTS Measurements

- Real-time feedback, viewing and analysis capabilities:

RTS Measurements

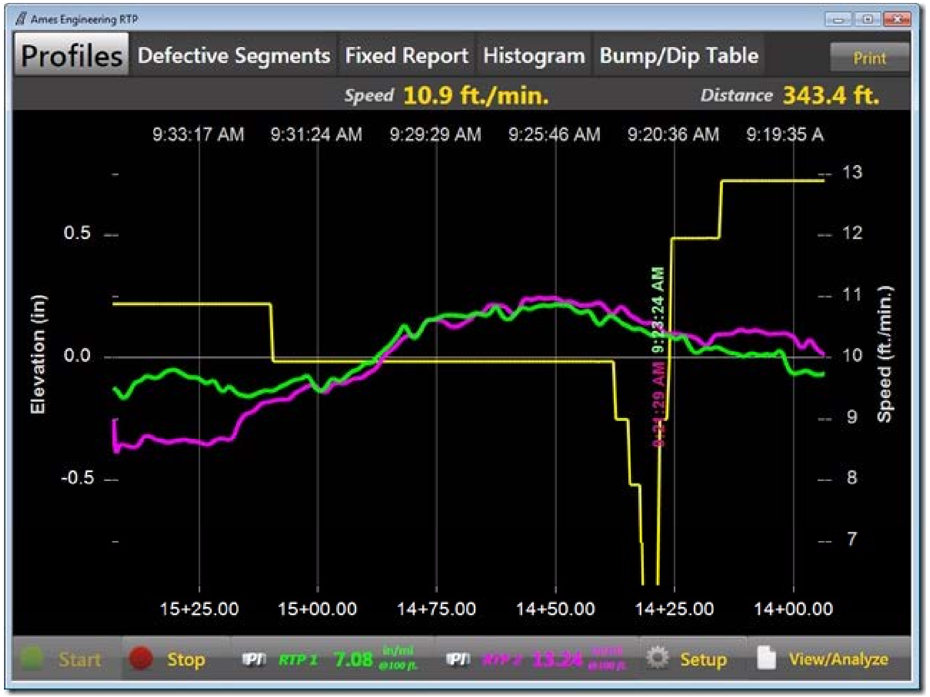
- Real-time feedback, viewing and analysis capabilities:





RTS Measurements

- Real-time feedback, viewing and analysis capabilities:



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Session 3: RTS for Achieving Initial Pavement Smoothness

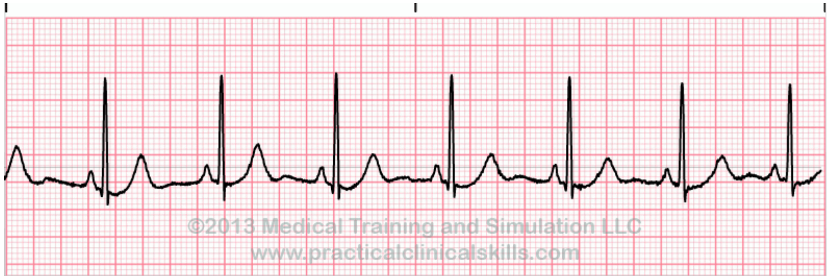
- Why use RTS?
- Step-by-Step Implementation of RTS Technology

Reasons for Using RTS Equipment

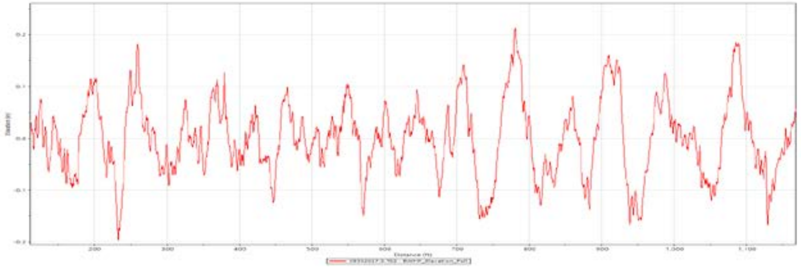
- Reduce disincentives
- Increase incentives
- Anticipated change in smoothness acceptance requirements
  - PrI to IRI
  - Change in localized roughness specification limits

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.



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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.

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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.

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Localized Roughness Events

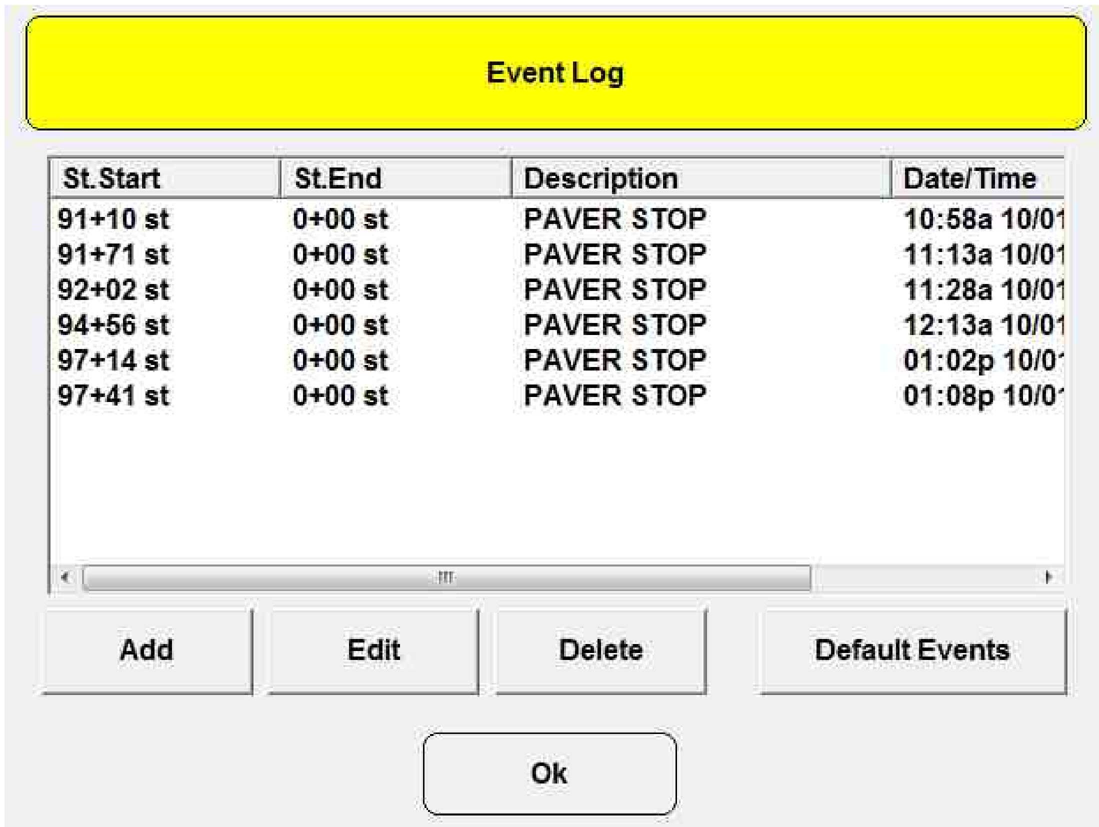
- Stringless system interference

Localized Roughness Events

- Running the paver out of concrete

Localized Roughness Events

- Stopping the paver



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

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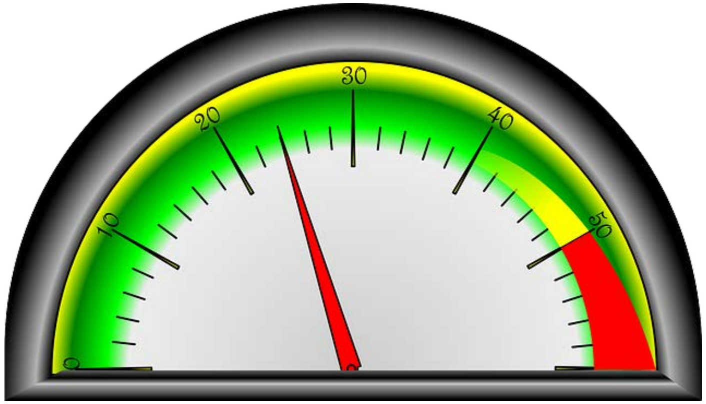
Overall Smoothness

- **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.



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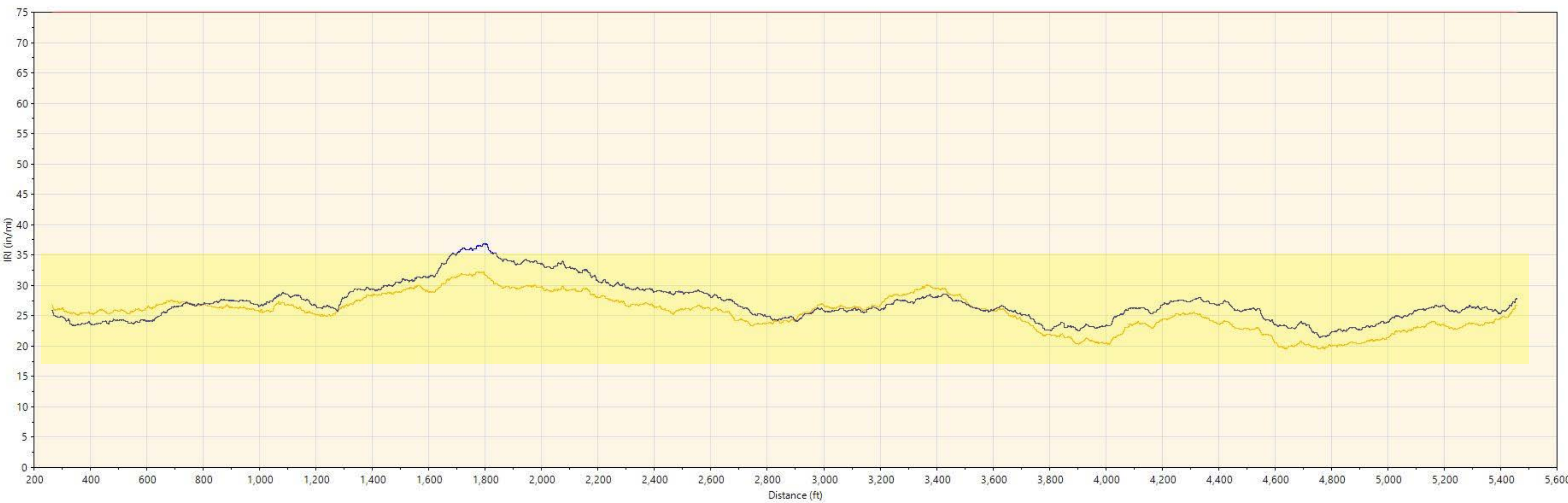
Overall Smoothness

- Stay focused and incredible things can happen

Over a mile paved per day – average IRI = 28 in/mi:



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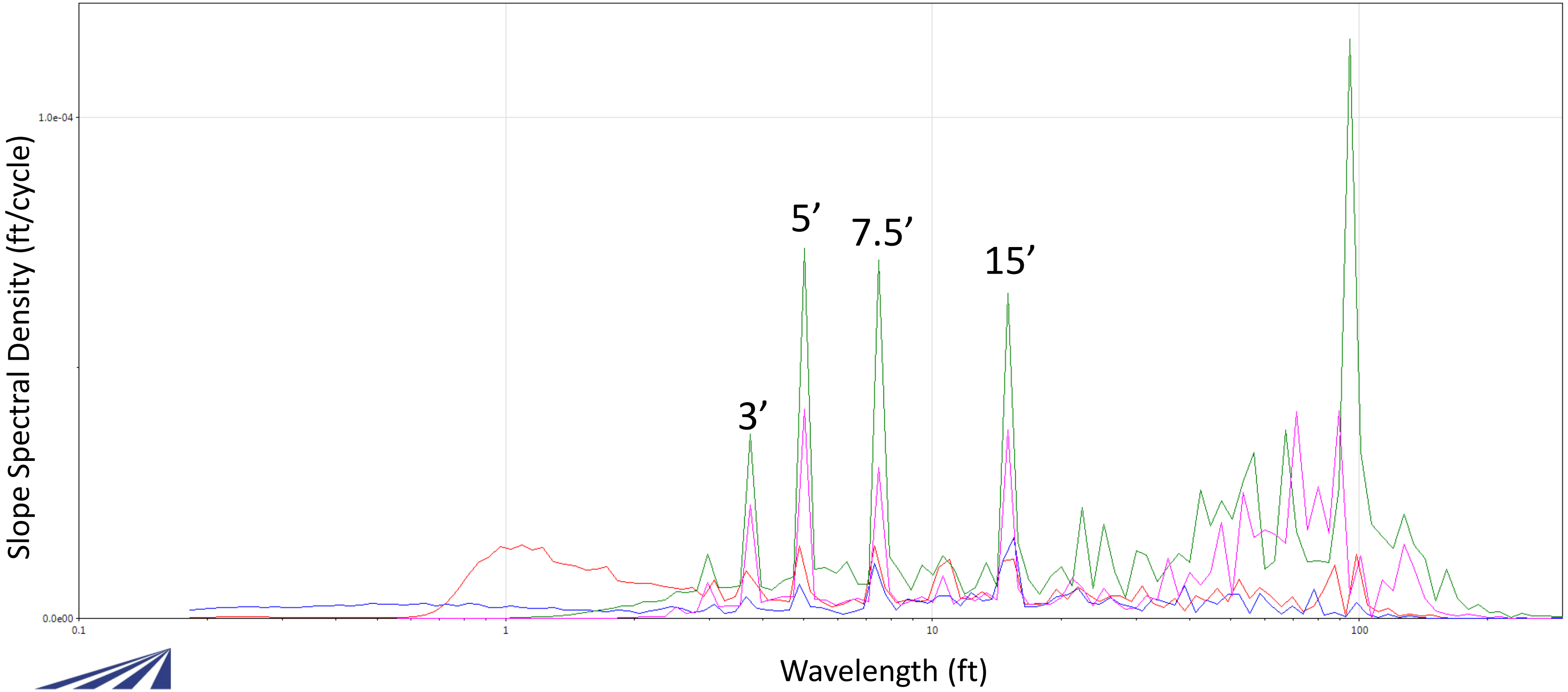
Using RTS Systems

- **Step 4 – Identify repeating features using a ProVAL PSD plot and adjust processes when possible.**
  - Joints
  - Dumping/Spreading loads
  - CRCP bar supports

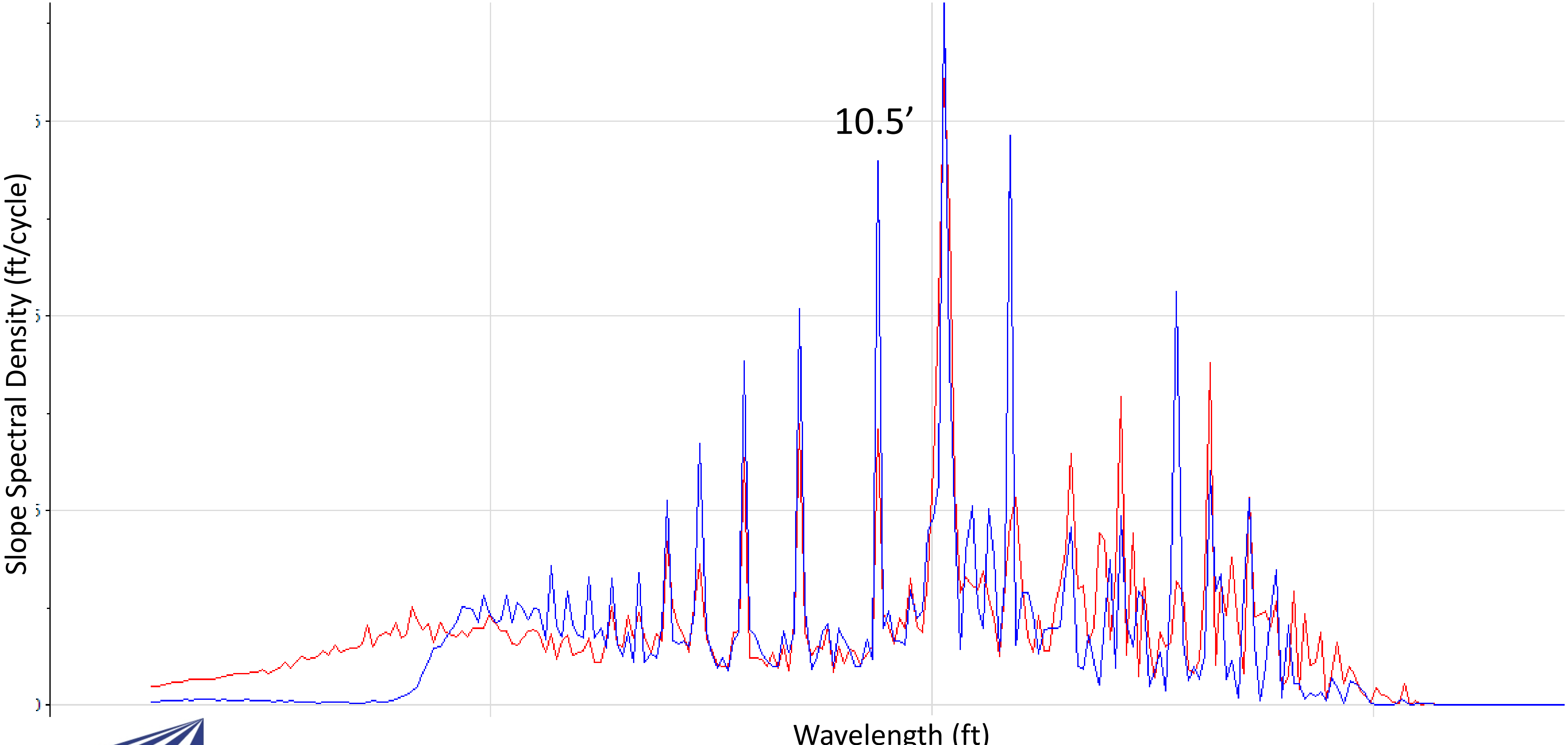
Repeating Features

- Dowel baskets or insertion.



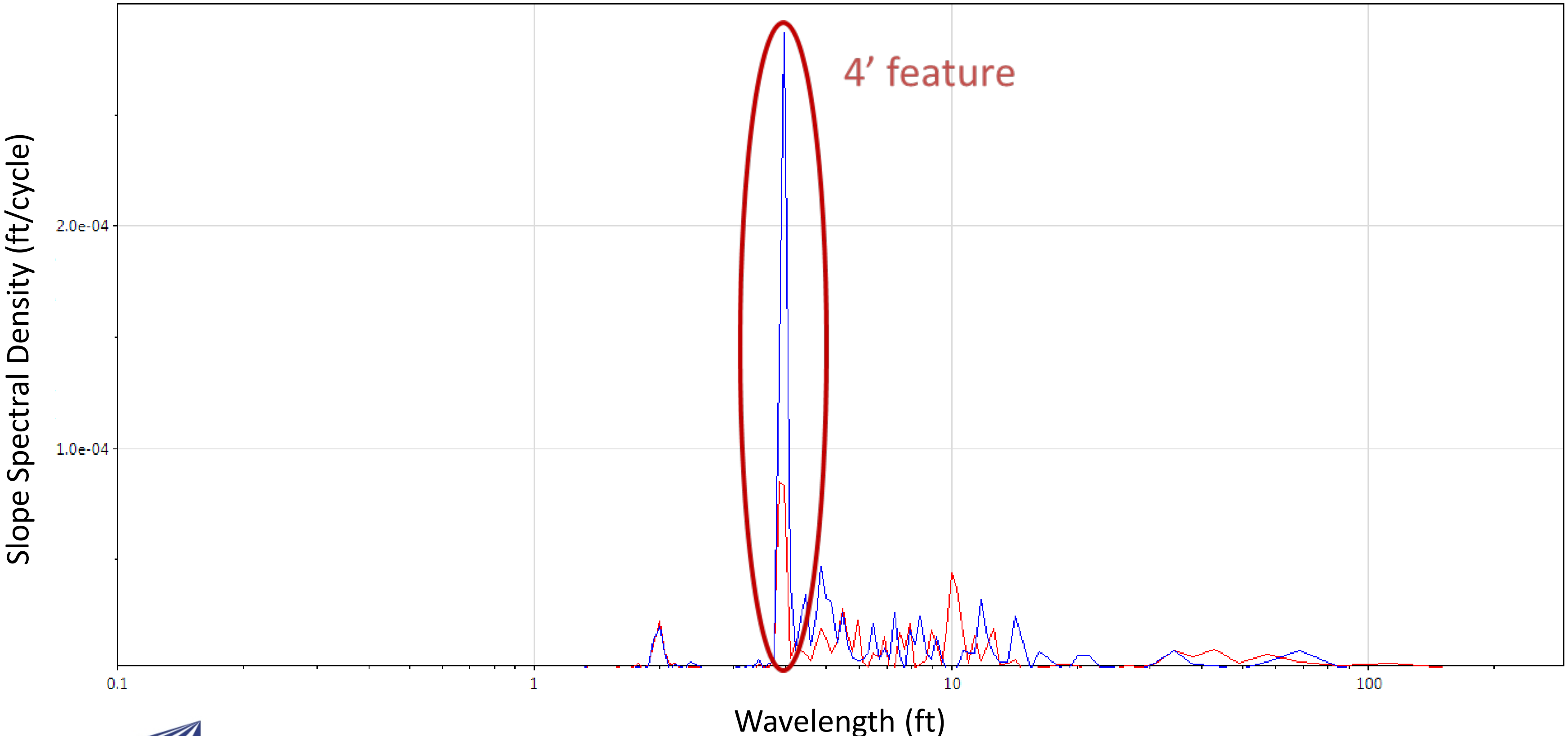
Repeating Features

- Load spacing.



Repeating Features

- Transverse bar supports.



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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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Session 5: Lessons Learned from RTS Equipment Loan Program

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

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.

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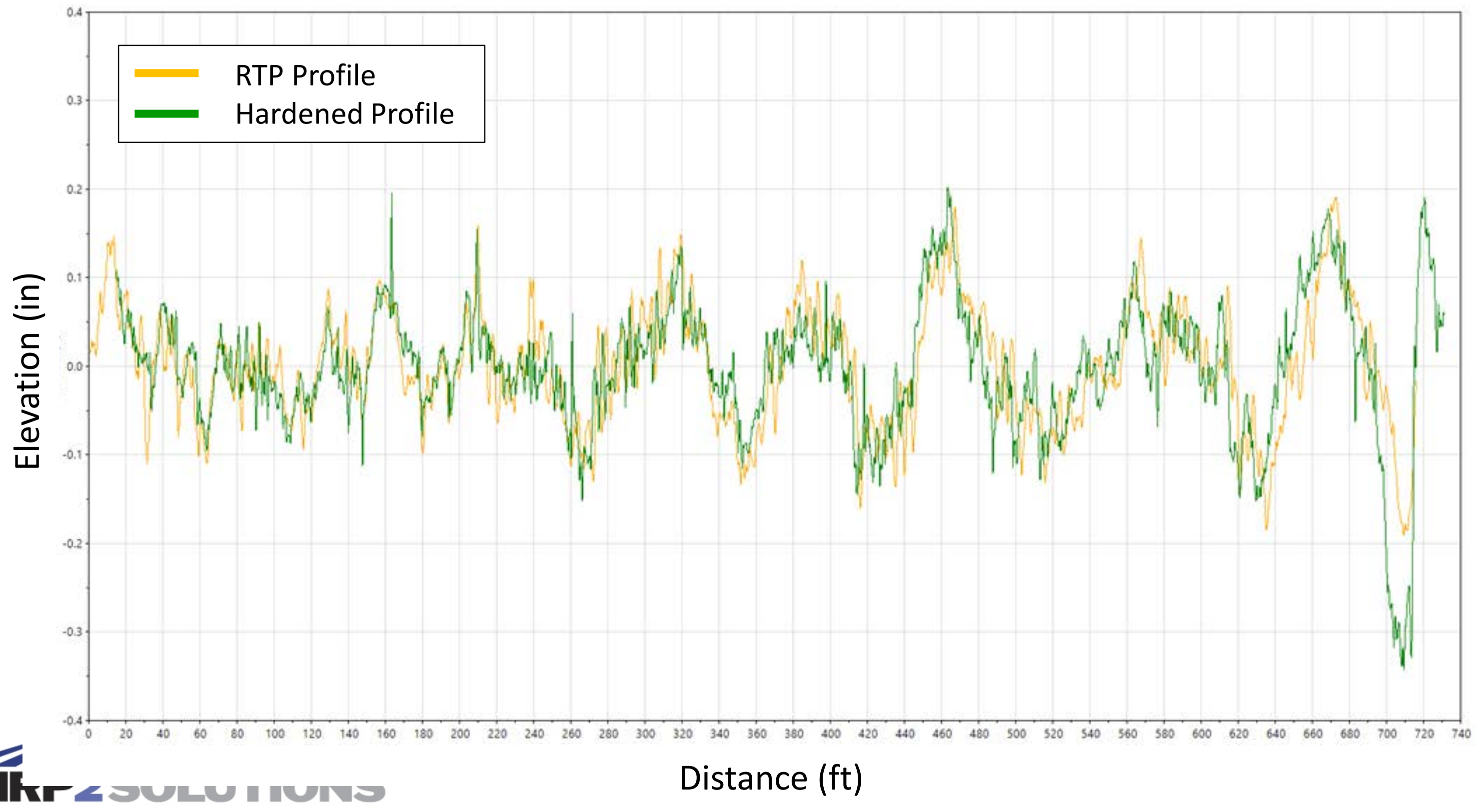
Pennsylvania, I-81

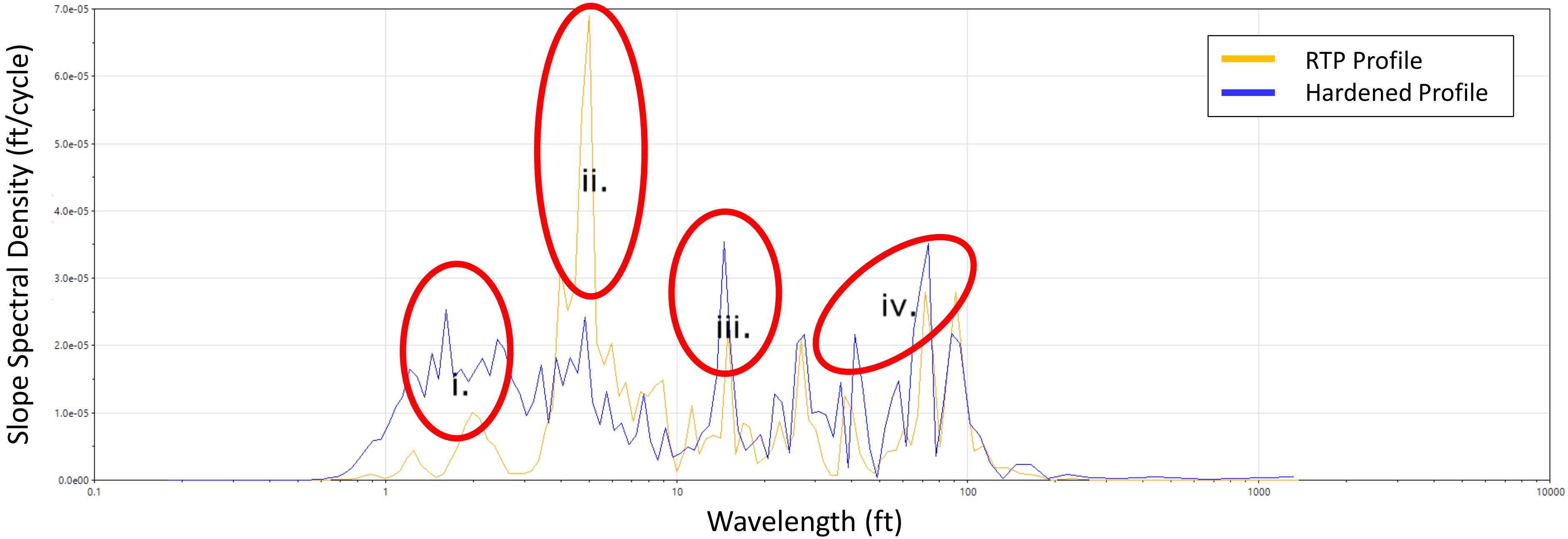
Pennsylvania, I-81

- Real-time and hardened profiles parallel each other
- 20 in/mi difference



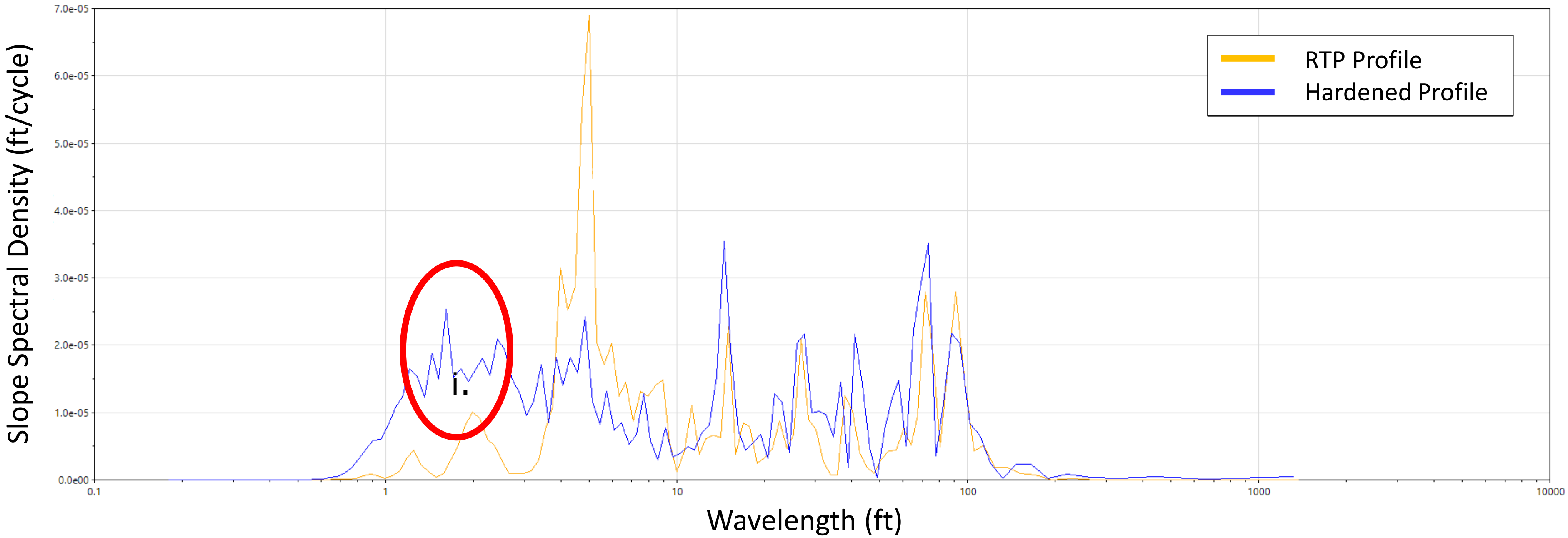
Pennsylvania, I-81

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



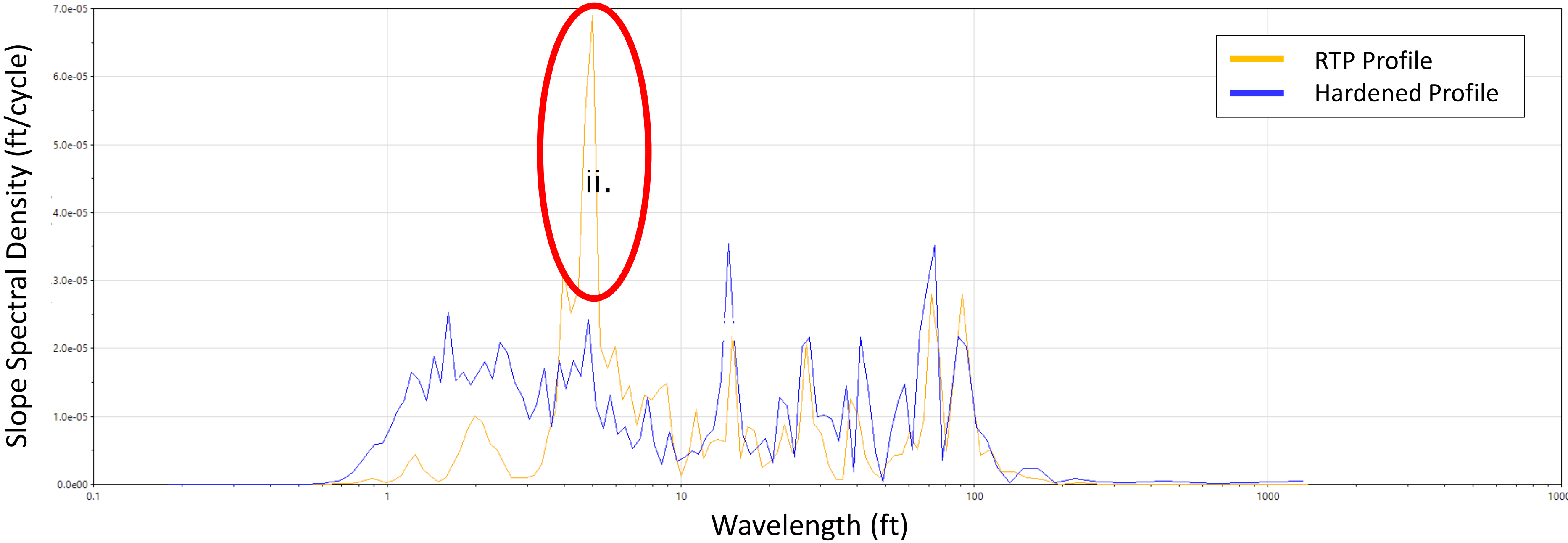
Pennsylvania, I-81

i. Shorter wavelength roughness in the hardened profile is likely from macrotexture (burlap drag and tining) applied behind the GSI sensors.



Pennsylvania, I-81

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.



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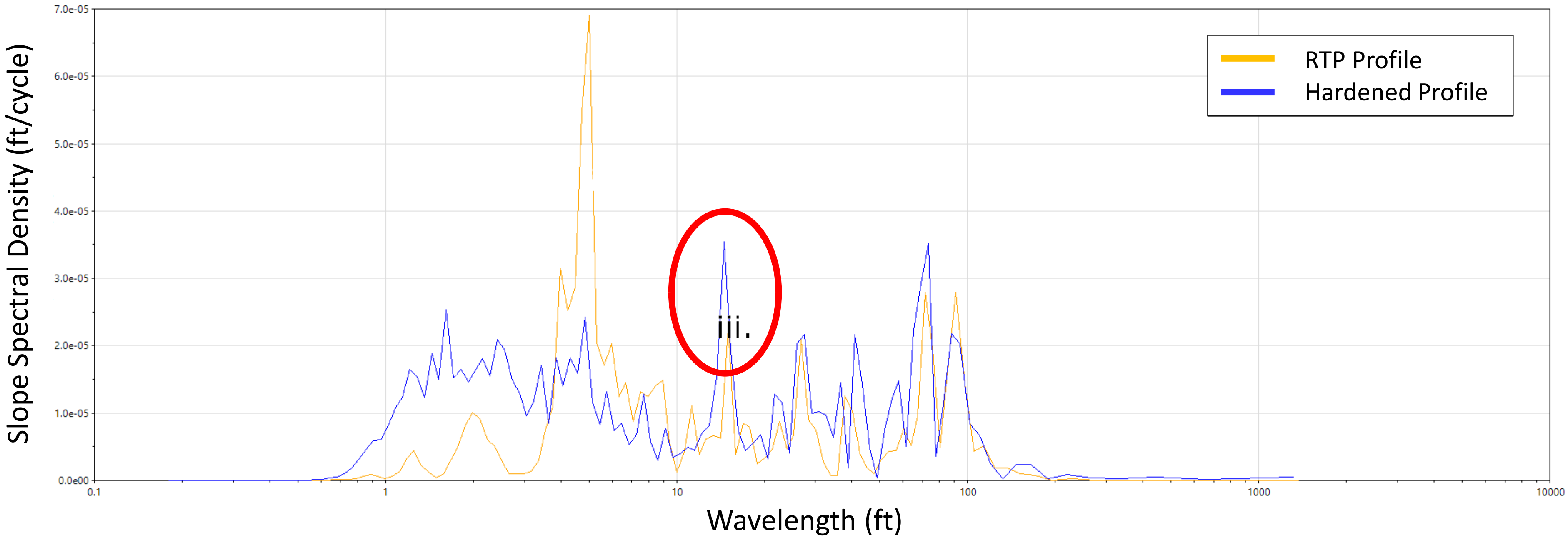
Pennsylvania, I-81

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.



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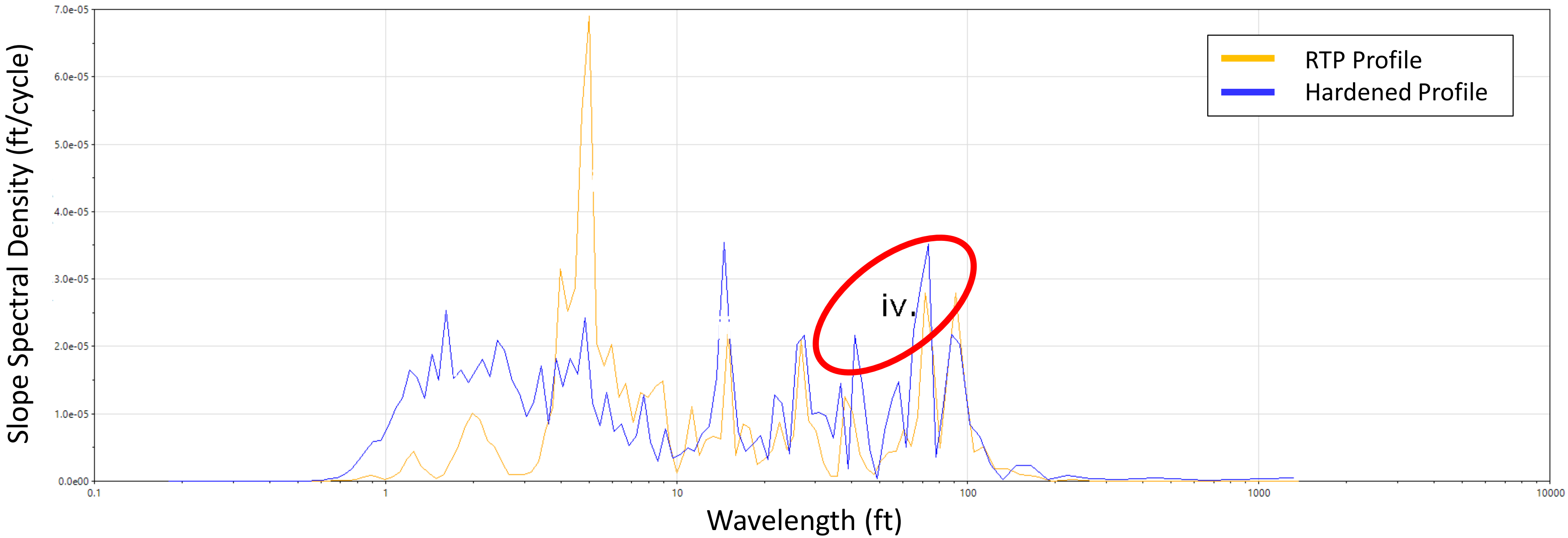
Pennsylvania, I-81

iv. Long wavelength roughness is similar in both real-time and hardened profiles.



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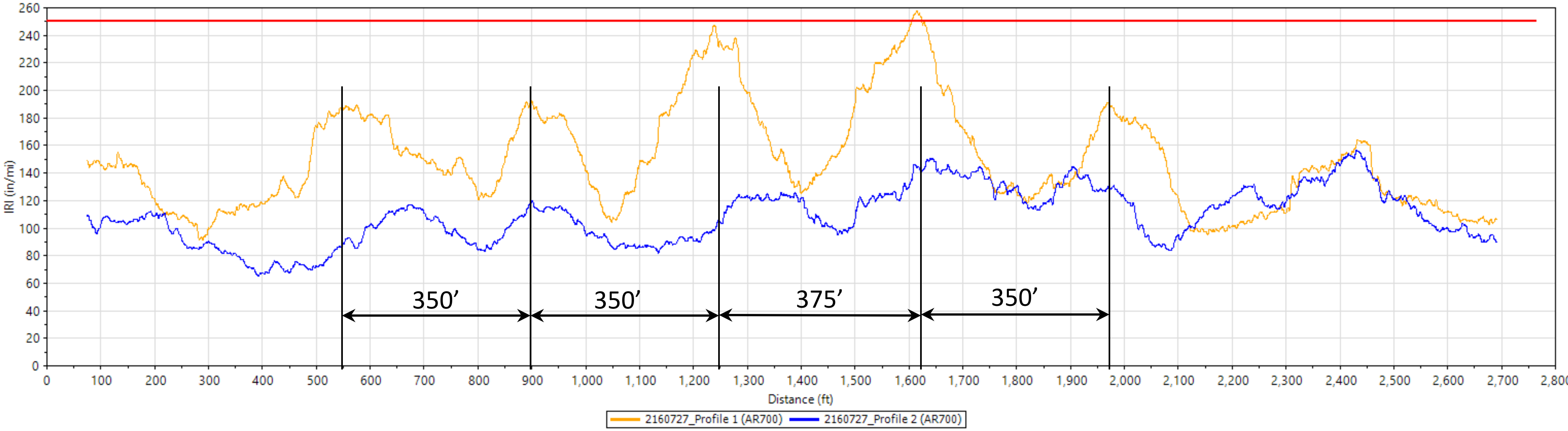
Utah I-15

- **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

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.



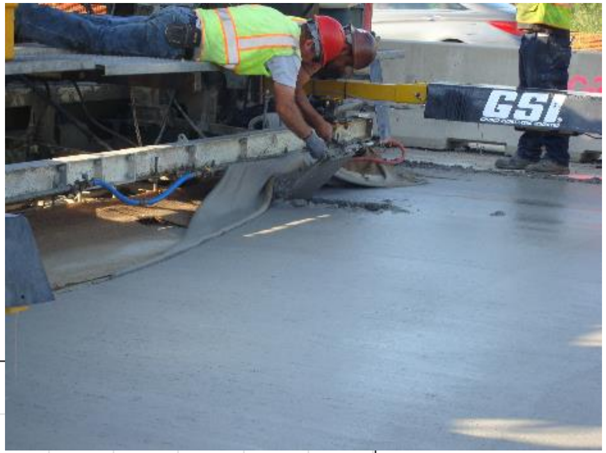
Illinois I-90

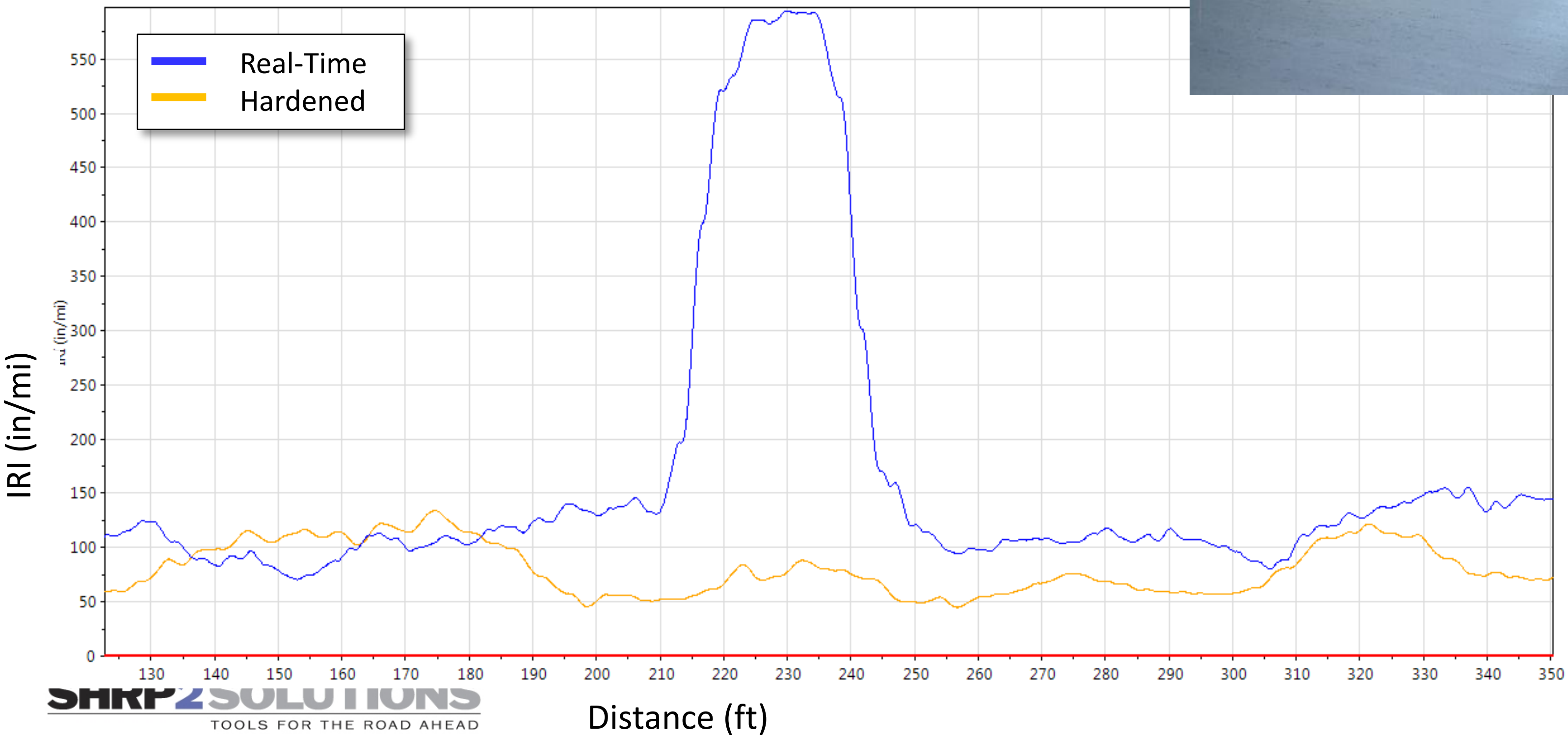
- **Gomaco GSI**
- **Project Info**
  - Mainline paving of I-90
  - 13” JPCP over 3” WMA
  - 26’ paving width, 15’ joint spacing with inserted dowels
  - Matching existing pavement on one side
  - Stringless paving
  - Concrete deposited in front of paver

Illinois I-90

Illinois I-90

- DBI malfunction during paving.
- Do finishers help?





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

Iowa US-20

Iowa US-20

- Specification change from PI to IRI is planned.
- Real-time evidence that IRI does not correlate to PI.

Profile Index Report

Trace: 1 2 3 4 5 6 7 8

Segment	P.I. (in/mi)	Dist	St.Start	St.End
1	21.40	528.00'	10947+16 st	10952+44 st
2	26.70	528.00'	10952+44 st	10957+72 st
3	17.90	528.00'	10957+72 st	10963+00 st
4	23.90	528.00'	10963+00 st	10968+28 st
5	15.33	526.83'	10968+28 st	10973+55 st
Avg	22.47	2112.00'		

Profile Index Parameters

Min scallop height	0.03"	Scallop resolution	0.01"
Min scallop width	2.00'	Blanking band	0.00"
Segment length	528.00'		

Change

Ok

IRI Report

Trace: 1 2 3 4 5 6 7 8

Segment	I.R.I (in/mi)	Dist	St.Start	St.End
1	59.37	528.00'	10947+00 st	10952+28 st
2	68.16	528.00'	10952+28 st	10957+56 st
3	70.36	528.00'	10957+56 st	10962+84 st
4	78.15	528.00'	10962+84 st	10968+12 st
5	55.01	528.00'	10968+12 st	10973+40 st
6	74.95	30.17'	10973+40 st	10973+70 st
Avg	66.21	2640.00'		

IRI Parameters

Segment length 528.00'

Change

Ok

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- 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

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