EL09-2016 **Implementation Assistance Program**

Tools to Improve PCC Pavement Smoothness During Construction (R06E)

Seeking widespread adoption of the real-time smoothness (RTS) technology by contractors and agencies who routinely construct PCC pavements will be achieved through:

1. **Equipment Loan Program**
2. **Showcases**
3. **Workshops**
4. **Case studies/results Documentation**
5. **Specification Refinement**
6. **Marketing & Outreach**

SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

FIELD REPORT:
UTAH EQUIPMENT LOAN #9

INTRODUCTION

The Federal Highway Administration (FHWA) has contracted with the National Center for Concrete Pavement Technology (CP Tech Center) for *Implementation Support for Strategic Highway Research Program II (SHRP2) Renewal R06E Real-time Smoothness Measurements on Portland Cement Concrete Pavements During Construction*. One of the tasks included in this contract is equipment loans to contractors. This task involves facilitating the loan of real-time smoothness equipment for field trial use on 11 designated PCC pavement construction projects. The scope of this task includes the following activities:

- Provide equipment (GOMACO GSI or Ames RTP) and labor for a field trial of 10 to 30 paving days
- Provide technical assistance for equipment installation start-up and operation
- On-call technical support throughout the duration of the field trial
- Planning, coordination and execution of the field trials
- Contact the recipient within 5 days of notice to proceed from the COR
- On-site support for at least 2 weeks
- Maintain a master list of field trial participants and update the list quarterly

This report summarizes the activities and findings of an equipment loan conducted in Utah.

PROJECT DETAILS

The equipment loan was performed in July and August of 2016 on a project in Salt Lake County, Utah. Table 1 summarizes the pertinent project details.

Table 1. Salt Lake County, UT, I-15 Project Information

<table>
<tr><th>Item</th><th>Details</th></tr>
<tr><td>Project Location</td><td>Mainline paving of I-15 in Weber and Box Elder Counties, UT.

</td></tr>
<tr><td>Route</td><td>I-15</td></tr>
<tr><td>Agency</td><td>Utah Department of Transportation (UDOT)</td></tr>
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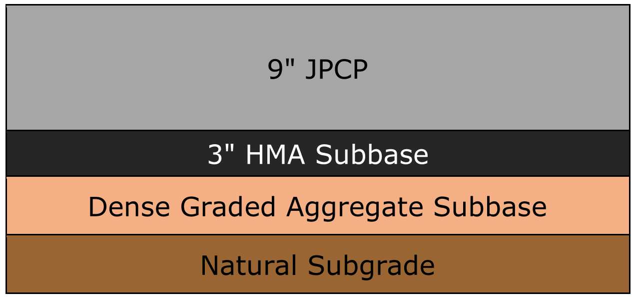
Item	Details
Paving Contractor	Geneva Rock Products, Inc.
Paving Equipment	Gomaco 2800 paver with DBI and Trimble stringless machine control
Real-Time System	Ames RTP
Typical Section	9” jointed plain concrete pavement (JPCP) on 3” HMA subbase. 
Joint Spacing	Transverse: 15’ c/c (Matching joints from existing lanes) Longitudinal: 12’ c/c
Gomaco GSI Setup	Paver width = 22’ Sensor #1: approximate 15’ off edge nearest existing pavement. Sensor #2: approximate 3’ off edge nearest existing pavement.
Miscellaneous Details	A vibrator monitor was in use; vibrators were consistently operated in the range of ±9,000 vpm. Burlap drag behind the auto-float. Hand finishing consisted of a 12’ straightedge.

IMPLEMENTATION ACTIVITIES

Installation of the RTP took place on the morning of July 15, 2016. Collection of real-time profile data began the night of July 20, 2016 and continued through the night of August 8, 2016.

Table 2 provides a summary of the R06E team’s on-site technical support activities.

Table 2. Summary of R06E On-Site Activities

Date	On-Site Implementation Activities
15JUL2016	Install RTP.
20JUL2016	Complete RTP install and real-time profile data collection, 7:00 pm to 6:30 am.
21JUL2016	Real-time profile data collection, 8:00 pm to 5:30 am.
26JUL2016	Real-time profile data collection, 8:00 pm to 7:30 am.
28JUL2016	Real-time profile data collection, 8:00 pm to 3:30 am.
29JUL2016	Real-time profile data collection, 6:30 pm to 12:30 am.
30JUL2016 through 08AUG2016	RTP was left with the contractor for continued unsupervised use.
09AUG2016	Uninstall the RTP.

OBSERVATIONS, DATA and ANALYSES

This equipment loan was initiated through discussions with the local concrete pavement association representative. It was planned to coincide with the *Real-Time Smoothness Technology National Showcase* held in Salt Lake City, UT on August 9th, 2016. Both the contractor and UDOT were interested in utilizing the RTS equipment because UDOT had just recently transitioned from a profilograph index (PI) to an international roughness index (IRI) for pavement smoothness acceptance.

The paving observed by the SHRP2 team was rural mainline paving. I-15 was widened to the inside median. The primary challenge to achieving smoothness for this project was the influence of matching the existing I-15 mainline pavement which can introduce roughness which wouldn't otherwise be present for pilot lane paving. Geneva's crews demonstrated quality workmanship and a clear understanding of slipform paving materials and processes. No major issues were observed during our tenure on the project.

Figures 1 through 4 illustrate different aspects of the project and RLW's paving processes.

Figure 1. RTP (yellow ovals) Installed Behind the Dowel-Bar-Inserter (with OCB).

Figure 2. Concrete Dumped Directly in Front of the Paver and Right Side of Paver Matching Existing Slab.

Figure 3. Typical Finishing Hand Finishing Behind the Paver

Figure 4. Trimble Stringless Robotic Lasers Setup on Median Barrier

CONCRETE MIXTURE

Initial smoothness is sensitive to the workability and uniformity of the concrete mixture. The mixture proportions used by Geneva are shown in Table 3.

Table 3. Concrete Mixture Proportions

SHRP2 SOLUTIONS — TOOLS FOR THE ROAD AHEAD

REAL-TIME SMOOTHNESS IMPLEMENTATION

Mix Design & Proect Info.

General Information

Project:	I-15 FARR WEST TO BRIGHAM CITY
Contractor:	GENEVA
Mix Description:	SLIPFORM MAINLINE
Mix ID:	
Date(s) of Placement:	

Cementitious Materials	Source	Type	Spec. Gravity	lb/yd³	% Replacement by Mass
Portland Cement:	HOLCIM	II/V	n/a	526	
GGBFS:					
Fly Ash:	HEADWATERS	F	n/a	132	20.06%
Silica Fume:					
Other Pozzolan:					
				658	**lb/yd³**
				7.0	**sacks/yd³**

Aggregate Information	Source	Type	Spec. Gravity SSD	Absorption (%)	% Passing #4
Coarse Aggregate #1:	GRANITE WELLS	n/a	n/a	n/a	n/a
Intermediate Aggregate:			n/a	n/a	n/a
Fine Aggregate #1:	GRANITE WELLS	n/a	n/a	n/a	n/a
Fine Aggregate #2:					

Coarse Aggregate %:	n/a
Intermediate Aggregate %:	n/a
Fine Aggregate #1 % of Total Fine Agg.:	n/a
Fine Aggregate #2 % of Total Fine Agg.:	n/a
Fine Aggregate #1 %:	n/a
Fine Aggregate #2 %:	n/a

Mix Proportion Calculations

Water/Cementitious Materials Ratio:	0.360
Air Content:	6.00%

	Volume (ft3)	Batch Weights SSD (lb/yd3)	Spec. Gravity	Absolute Volume (%)
Portland Cement:	n/a	526	n/a	n/a
GGBFS:	n/a			
Fly Ash:	n/a	132	n/a	n/a
Silica Fume:	n/a			
Other Pozzolan:	n/a			
Coarse Aggregate #1:	n/a	1,851	n/a	n/a
Intermediate Aggregate:	n/a			
Fine Aggregate #1:	n/a	1,154	n/a	n/a
Fine Aggregate #2:	n/a			
Water:	n/a	233	1.000	n/a
Air:	n/a			
		3896		
	Unit Weight (lb/ft³)	**144.3**		

Admixture Information	Source/Description	oz/yd3	oz/cwt
Air Entraining Admix.:	WR GRACE	41.00	6.23
Admix. #1:	WR GRACE	30.00	4.56
Admix. #2:			
Admix. #3:			

Combined gradation data is provided in Table 4 and Figures 5 and 6.

Table 4. Tabular Sieve Analysis Data

SHRP2 SOLUTIONS TOOLS FOR THE ROAD AHEAD

REAL-TIME SMOOTHNESS IMPLEMENTATION

Combined Gradation Test Data

Project: I-15 FARR WEST TO BRIGHAM CITY
Mix ID: n/a
Sample Comments: MIX DESIGN FROM GENEVA
Test Date: SUPPLIER AVERAGES (coarse JUN thru AUG 2015; fine OCT thru NOV 2015)

Total Cementitious Material: 658 lb/yd^3

Agg. Ratios:	61.60%	0.00%	38.40%	0.00%	100.00%

Sieve	Coarse	Intermediate	Fine #1	Fine #2	Combined % Retained	Combined % Retained On Each Sieve	Combined % Passing
2 ½"	100%		100%		0%	0%	100%
2"	100%		100%		0%	0%	100%
1 ½"	100%		100%		0%	0%	100%
1"	100%		100%		0%	0%	100%
¾"	84%		100%		10%	10%	90%
½"	42%		100%		36%	26%	64%
⅜"	22%		100%		48%	12%	52%
#4	1%		99%		61%	13%	39%
#8	1%		85%		67%	5%	33%
#16	1%		67%		74%	7%	26%
#30	1%		46%		82%	8%	18%
#50	0.4%		19%		92%	11%	8%
#100	0.3%		3%		99%	6%	1%
#200	0.2%		1.2%		99.4%	0.8%	0.6%

Workability Factor: **35.8** 20% Coarse Sand
Coarseness Factor: **72.0** 26% Fine Sand

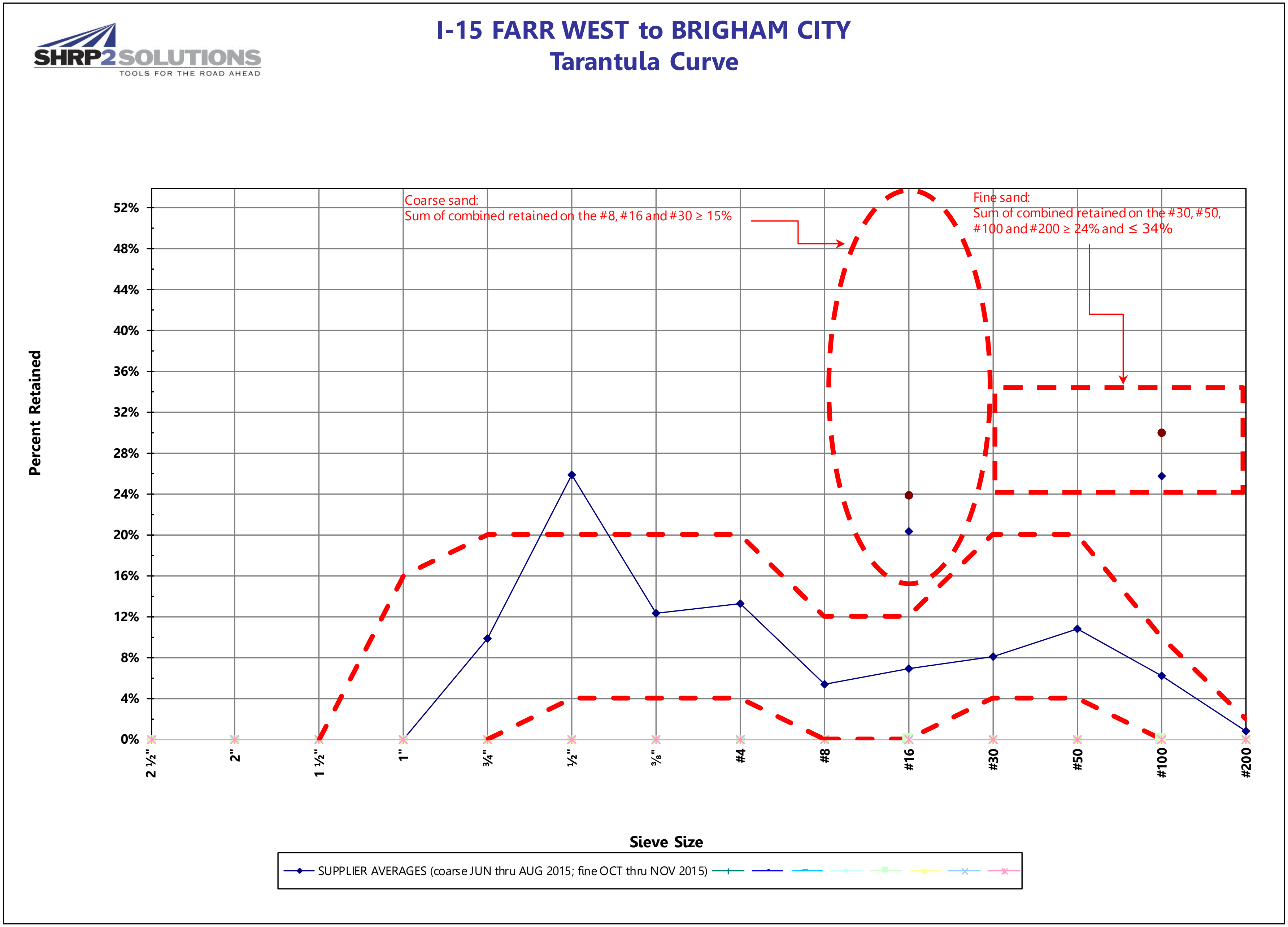


Figure 5. I-15 Combined Percent Retained (Tarantula Curve)

I-15 FARR WEST to BRIGHANM CITY

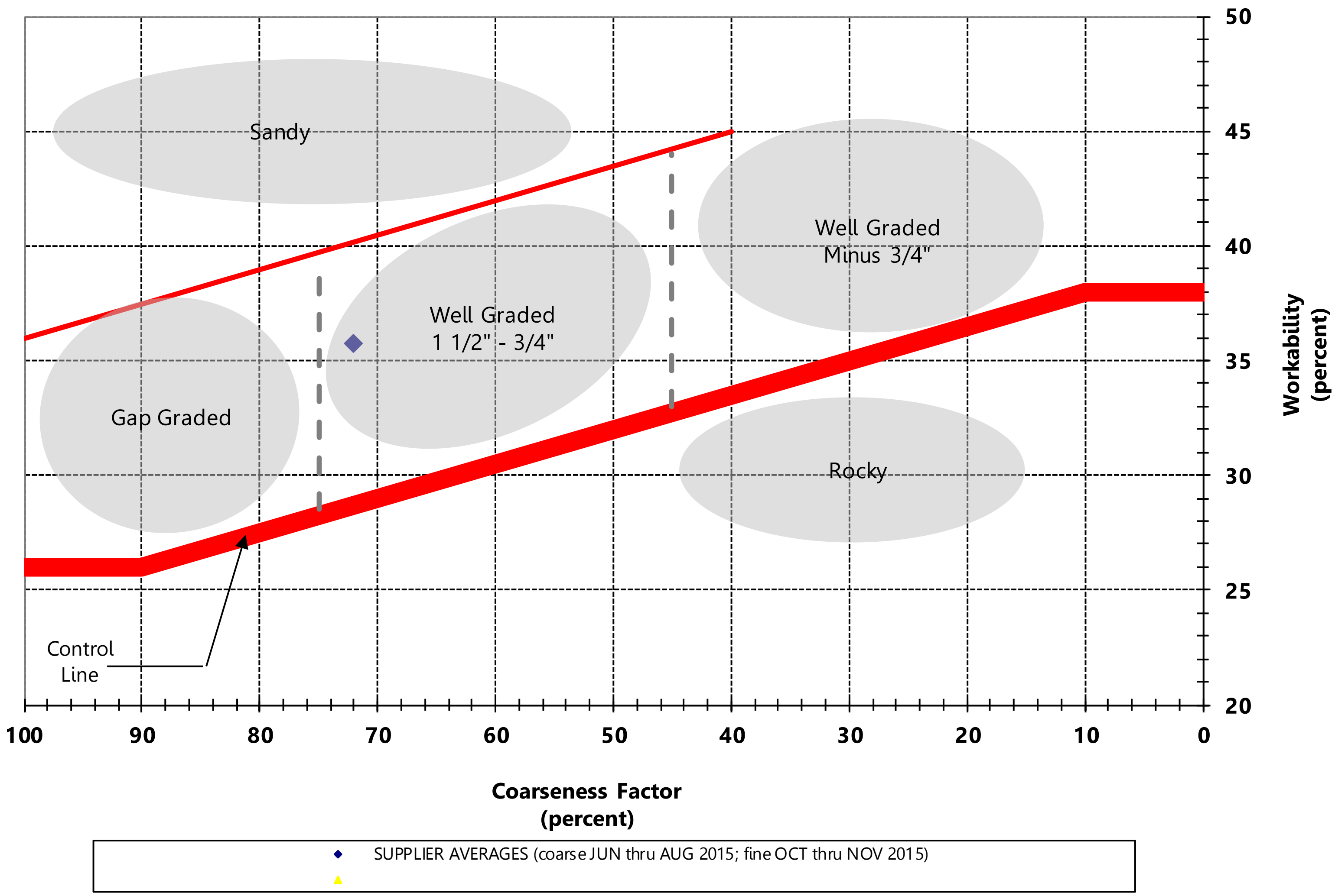


Figure 6. I-15 Combined Gradation Coarseness and Workability Factors

PROFILE CHARCTERISTICS

The following information is provided to illustrate how real-time smoothness systems can be used as a tool to improve the initial smoothness of concrete pavements.

Real-Time Smoothness (RTS) vs. Hardened QC Profile

There was an approximate two-week delay in receiving hardened profile data files from Geneva. This made matching the station limits between hardened and real-time profiles difficult. In general, the real-time profiles were approximately 100 in/mi and the hardened profiles were approximately 65 in/mi. This is a larger difference than we are accustomed to seeing. Based upon our observations during the equipment loan, we attribute this larger than normal difference to vibration of the RTP sensors from operation of the dowel-bar inserter and short wavelength surface irregularities imparted by the oscillating correcting beam. The short wavelength surface irregularities were picked up by the RTP but subsequently removed by the auto-float and hand finishing, thus did not influence the hardened profiles.

Stringless Control System Influence on Real-Time Smoothness

During the equipment loan, it was observed that the IRI values fluctuated regularly. On the night of July 27, a pattern of increasing and then decreasing IRI was apparent at intervals of approximately 350′ (Figure 7), and particularly on the right side of the paver. This matched the spacing between the stringless robotic total stations controlling the paver's elevation and steering, with the right side of the paver being further from the stringless total stations than the left side.

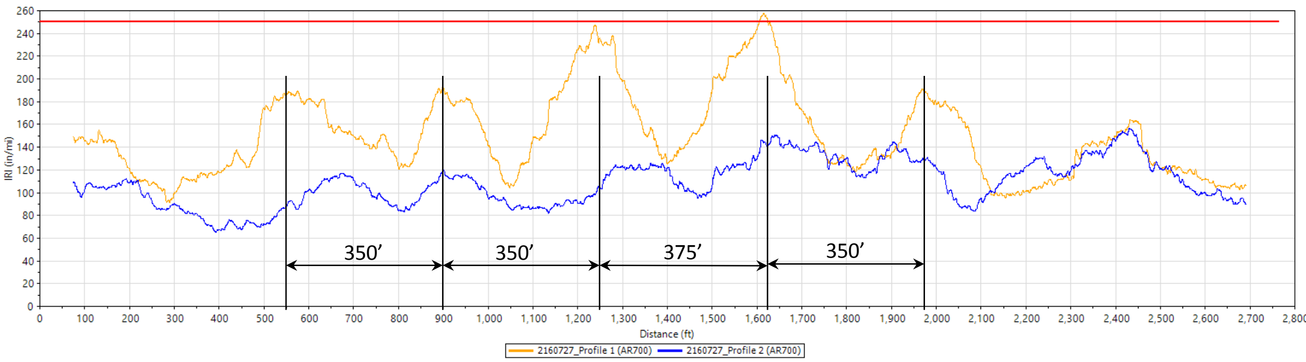


Figure 7. Real-Time Profile Data Illustrating Fluctuation of IRI Corresponding to Stringless Gun Swaps (IRI based on 150′ base length matches real-time settings as viewed on the screen 27JUL2016)

Once this relationship was observed, the contractor reduced the distance between robotic total stations to improve IRI results.

Repeating Profile Features

The power spectral density analysis (PSD) from ProVAL shows the 15′ joint spacing and 13′ from concrete load spacing as the dominant wavelengths contributing to roughness in the hardened profile (Figure 8). The PSD for hardened profile was run with a butterworth band pass at 1′ to 30′ to remove the influence of long wavelength roughness from the operation of the stringless system.

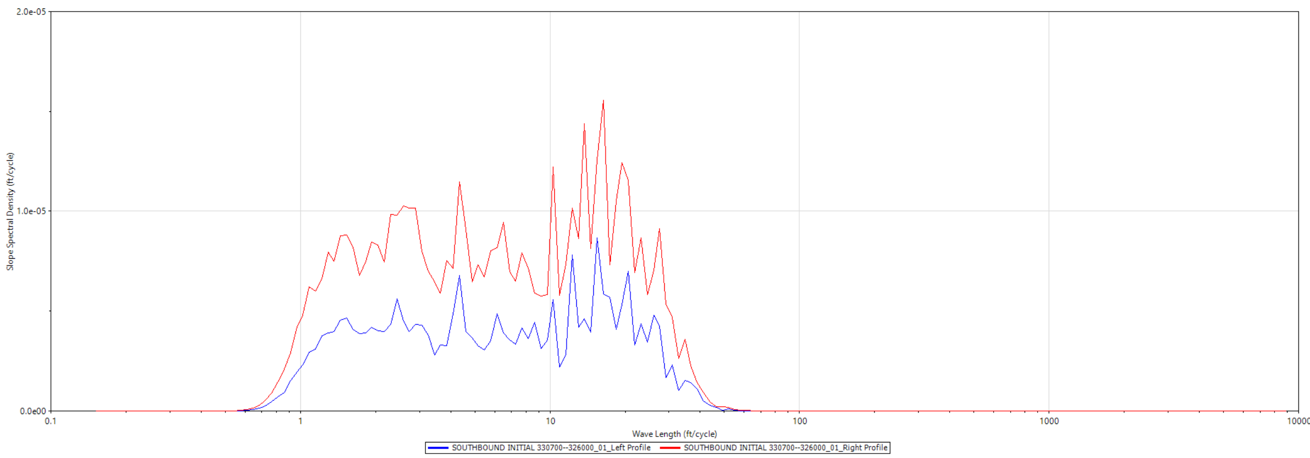


Figure 8. PSD Analysis Showing Joint Spacing at 15′ and Concrete Loads at 13′ with Associated Harmonic Wavelengths Contributing to Pavement Roughness

CONCLUSIONS and LESSONS LEARNED

The following points summarize the preliminary conclusions made from profile analyses and on-site documentation, as well lessons learned from the equipment loan.

Profile Analyses:

- Real-time IRI measurements for the right side of the paver which was matching the existing pavement was consistently rougher than the left side.
- Besides the long wavelength roughness influenced by the spacing of the stringless total station swaps, the joints (inserted dowels) and concrete load spacing had the largest influence on real-time IRI measurements.

SHRP2 Implementation Team and Contractor Observations

- An exit interview was conducted with the paving superintendent. His observations regarding real-time smoothness measurements included:
    - The RTP was useful in identifying the impact of spacing on the stringless gun swaps.
    - Real-time profile information is useful for identifying impacts on smoothness and then verifying the effectiveness of changes to the paving process.
- Soon after the SHRP2 equipment loan, the paving superintendent expressed interest in purchasing an RTP pending budget approval from management.