EL11-2017 **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

National Concrete Pavement Technology Center
Tech Center

FIELD REPORT:
IOWA US 20 EQUIPMENT LOAN

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

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:

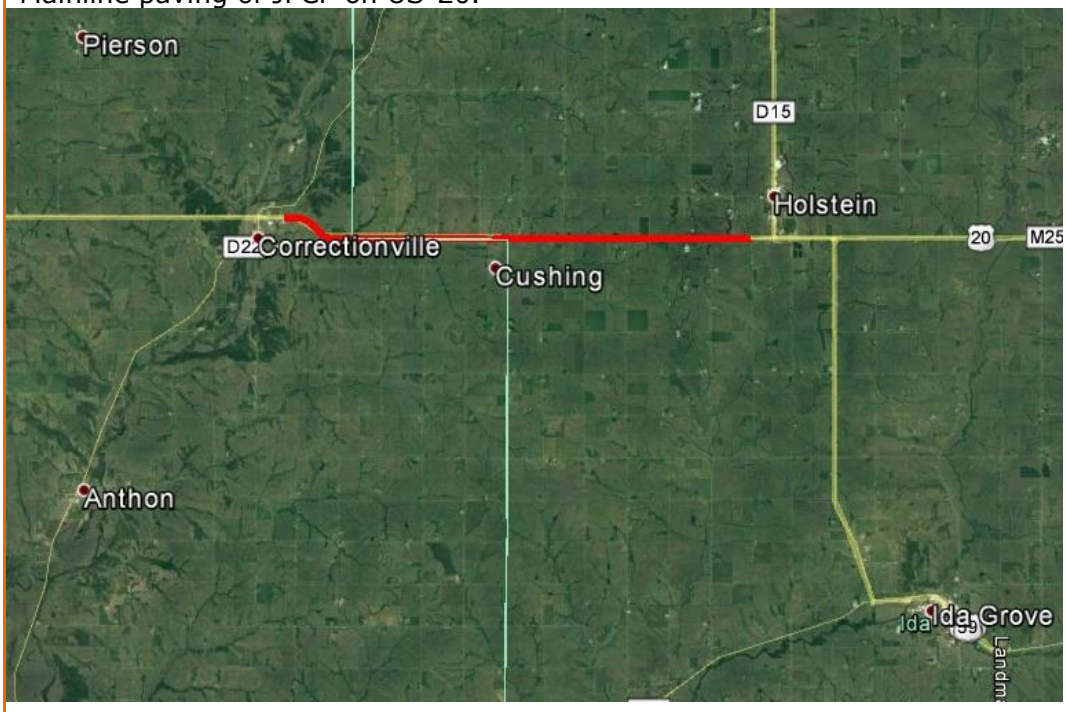
- Provide equipment (GOMACO GSI or Ames RTP) and labor for a field trial of 10 to 30 paving days
- Provide technical assistance for equipment installation start-up and operation
- On-call technical support throughout the duration of the field trial
- Planning, coordination and execution of the field 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

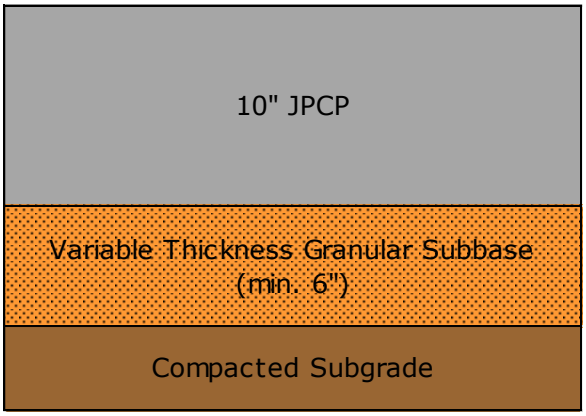
This report summarizes the activities and findings of the equipment loan conducted in Iowa.

PROJECT DETAILS

The equipment loan was performed in May of 2017 on a project in Woodbury and Ida Counties, Iowa. Table 1 summarizes the pertinent project details.

Table 1. Woodbury and Ida Counties, IA, US-20 Project Information

Item	Details
Project Location	Mainline paving of JPCP on US-20. 

Item	Details
Route	US-20
Agency	Iowa Department of Transportation (IADOT)
Paving Contractor	Cedar Valley Corporation (CVC)
Paving Equipment	Guntert-Zimmerman S-850 paver
Real-Time System	Gomaco GSI
Typical Section	10” jointed plain concrete pavement (JPCP) on granular subbase on compacted subgrade. 
Joint Spacing	Transverse: 20’ c/c Longitudinal: 12’ passing lane and 14’ truck lane
Gomaco GSI Setup	Paver width = 26’ Sensor #1: approximate center of eastbound passing lane Sensor #2: approximate center of eastbound truck lane
Miscellaneous Details	A vibrator monitor was in use; vibrators were consistently operated in the range of 6,400 to 7,500 vpm. Burlap drag behind the trailing finishing pan. Hand finishing consisted of a 20’ straightedge and 16’ channel float. Stringline pins at 25’ c/c.

IMPLEMENTATION ACTIVITIES

Installation of the GSI took place on the morning of April 20, 2017. Collection of real-time profile data began the morning of May 8, 2017 and through June 19, 2017.

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
20APR2017	Install GSI.
08MAY2017	Real-time profile data collection, from approximately 10868+75 to 10882+03.
09MAY2017	Real-time profile data collection, from approximately 10890+75 to 10918+32.
10MAY2017	Rain out.
11MAY2017	Real-time profile data collection, from approximately 10919+00 to 10945+27.
12MAY2017	Real-time profile data collection, from approximately 10947+00 to 10973+54.
15MAY2017	Real-time profile data collection, from approximately 10974+25 to 10976+10.
16MAY2017	Real-time profile data collection, from approximately 10976+75 to 10999+12.
22MAY2017 through 26MAY2017	GSI was left with the contractor for continued unsupervised use.
30MAY2017	Real-time profile data collection, from approximately 11139+75 to 11167+55.
31MAY2017	Real-time profile data collection, from approximately 11168+00 to 11187+11.
01JUN2017 through 18JUN2017	No mainline paving.
19JUN2017	Uninstall GSI.

OBSERVATIONS, DATA and ANALYSES

This equipment loan was initiated through a real-time smoothness briefing that was presented at the Iowa concrete paving conference in January of 2016. Representatives from CVC requested the equipment loan. Their interest was primarily due to future adoption of IRI for smoothness acceptance by IADOT.

The paving observed by the SHRP2 team was typical mainline paving, CVC's crews demonstrated quality workmanship and a clear understanding of slipform paving. No major issues were observed. Figures 1 through 6 illustrate different aspects of the project and CPC's paving processes.

Figure 1. GSI Installed Directly at the Rear of the Paver

Figure 2. Typical Hand Finishing With a Straightedge and Channel Mop

Figure 3. Belt Placer/Spreader Ahead of the Paver

Figure 4. Concrete Spread Ahead of the Paver

Figure 5. Stable and Trimmed Paver Track Line

Figure 6. US-20 Looking East Towards the Paver

CONCRETE MIXTURE

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

Table 3. US-20 Concrete Mixture Proportions

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REAL-TIME SMOOTHNESS IMPLEMENTATION

Mix Design & Proect Info.

General Information

Project:	WOODBURY/IDA COUNTY US-20
Contractor:	CEDAR VALLEY
Mix Description:	SLIPFORM MAINLINE
Mix ID:	16005QMC-1
Date(s) of Placement:	

Cementitious Materials	Source	Type	Spec. Gravity	lb/yd^3	% Replacement by Mass
Portland Cement:	GCC-PUEBLO PC29002	I/II	3.140	449	
GGBFS:					
Fly Ash:	HW-PORT NEAL FA015C	C	2.660	112	19.96%
Silica Fume:					
Other Pozzolan:					
				561	**lb/yd^3**
				6.0	**sacks/yd^3**

Aggregate Information	Source	Type	Spec. Gravity SSD	Absorption (%)	% Passing #4
Coarse Aggregate #1:	LG EVERIST-WASHTA	GRAVEL	2.680	n/a	n/a
Intermediate Aggregate:	LG EVERIST-LARRABEE	PEA ROCK	2.670	n/a	n/a
Fine Aggregate #1:	LG EVERIST-WASHTA	NATURAL	2.640	n/a	n/a
Coarse Aggregate #2:					

Coarse Aggregate %:	44.0%
Intermediate Aggregate %:	12.0%
Fine Aggregate #1 % of Total Fine Agg.:	100.0%
Fine Aggregate #2 % of Total Fine Agg.:	
Fine Aggregate #1 %:	44.0%
Fine Aggregate #2 %:	

Mix Proportion Calculations

Water/Cementitious Materials Ratio:	0.400
Air Content:	6.00%

	Volume (ft3)	Batch Weights SSD (lb/yd3)	Spec. Gravity	Absolute Volume (%)
Portland Cement:	2.292	449	3.140	8.487%
GGBFS:				
Fly Ash:	0.675	112	2.660	2.499%
Silica Fume:				
Other Pozzolan:				
Coarse Aggregate #1:	8.280	1,385	2.680	30.666%
Intermediate Aggregate:	2.258	376	2.670	8.363%
Fine Aggregate #1:	8.280	1,364	2.640	30.666%
Coarse Aggregate #2:				
Water:	3.596	224	1.000	13.319%
Air:	1.620			6.000%
	27.000	**3910**		**100.000%**
	Unit Weight (lb/ft^3)	**144.8**		

Admixture Information	Source/Description	oz/yd3	oz/cwt
Air Entraining Admix.:	BRETT-EUCON AEA92	19.65	3.50
Admix. #1:	BRETT-EUCON WR91	16.85	3.00
Admix. #2:			
Admix. #3:			

Combined gradation data is provided in Table 4 and Figures 7 and 8.

Table 4. Tabular Sieve Analysis Data

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REAL-TIME SMOOTHNESS IMPLEMENTATION

Combined Gradation Test Data

Project: WOODBURY/IDA COUNTY US-20
Mix ID: 16005QMC-1
Sample Comments: MIX DESIGN FROM CV
Test Date: SUPPLIER AVERAGES FROM 2016

Total Cementitious Material: 561 lb/yd^3

Agg. Ratios: 44.00% 12.00% 44.00% 100.00%

Sieve	Coarse #1	Intermediate	Fine #1		Combined % Retained	Combined % Retained On Each Sieve	Combined % Passing
2 ½"	100%	100%	100%		0%	0%	100%
2"	100%	100%	100%		0%	0%	100%
1 ½"	100%	100%	100%		0%	0%	100%
1"	94%	100%	100%		3%	3%	97%
¾"	72%	100%	100%		12%	10%	88%
½"	42%	100%	100%		26%	13%	74%
⅜"	23%	96%	100%		34%	9%	66%
#4	*2%*	18%	97%		54%	20%	46%
#8	0.4%	2.0%	82%		64%	9%	36%
#16	0.3%	1.3%	60%		73%	10%	27%
#30	0.3%	1.0%	36%		84%	11%	16%
#50	0.3%	0.8%	14%		94%	10%	6%
#100	0.3%	*0.8%*	1.5%		99%	5%	1%
#200	0.3%	0.7%	0.5%		99.6%	0.5%	0.4%

Workability Factor: **36.4**
Coarseness Factor: **54.1**

30% Coarse Sand
26% Fine Sand

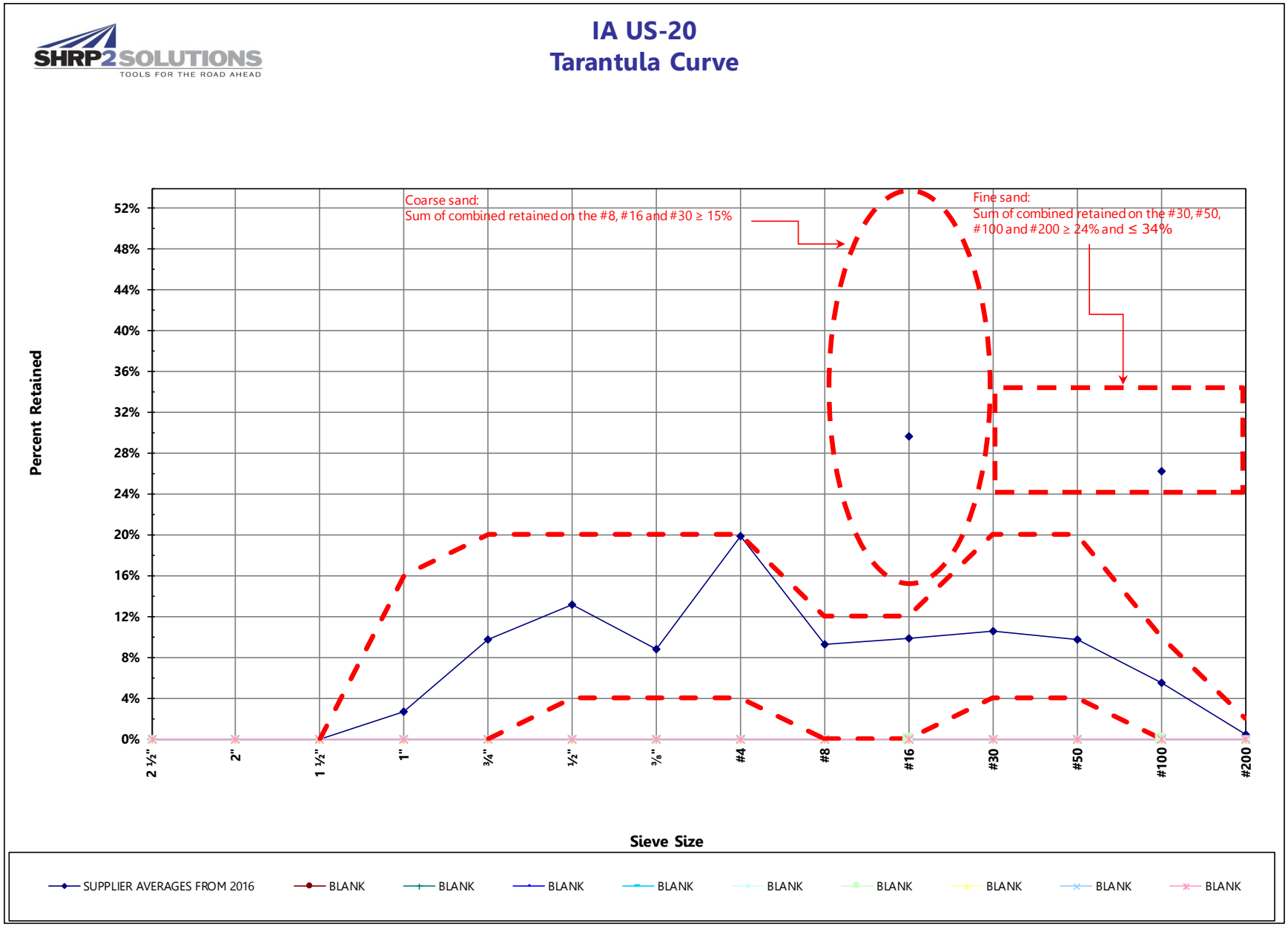

Figure 7. US-20 Combined Percent Retained (Tarantula Curve)

IA US-20

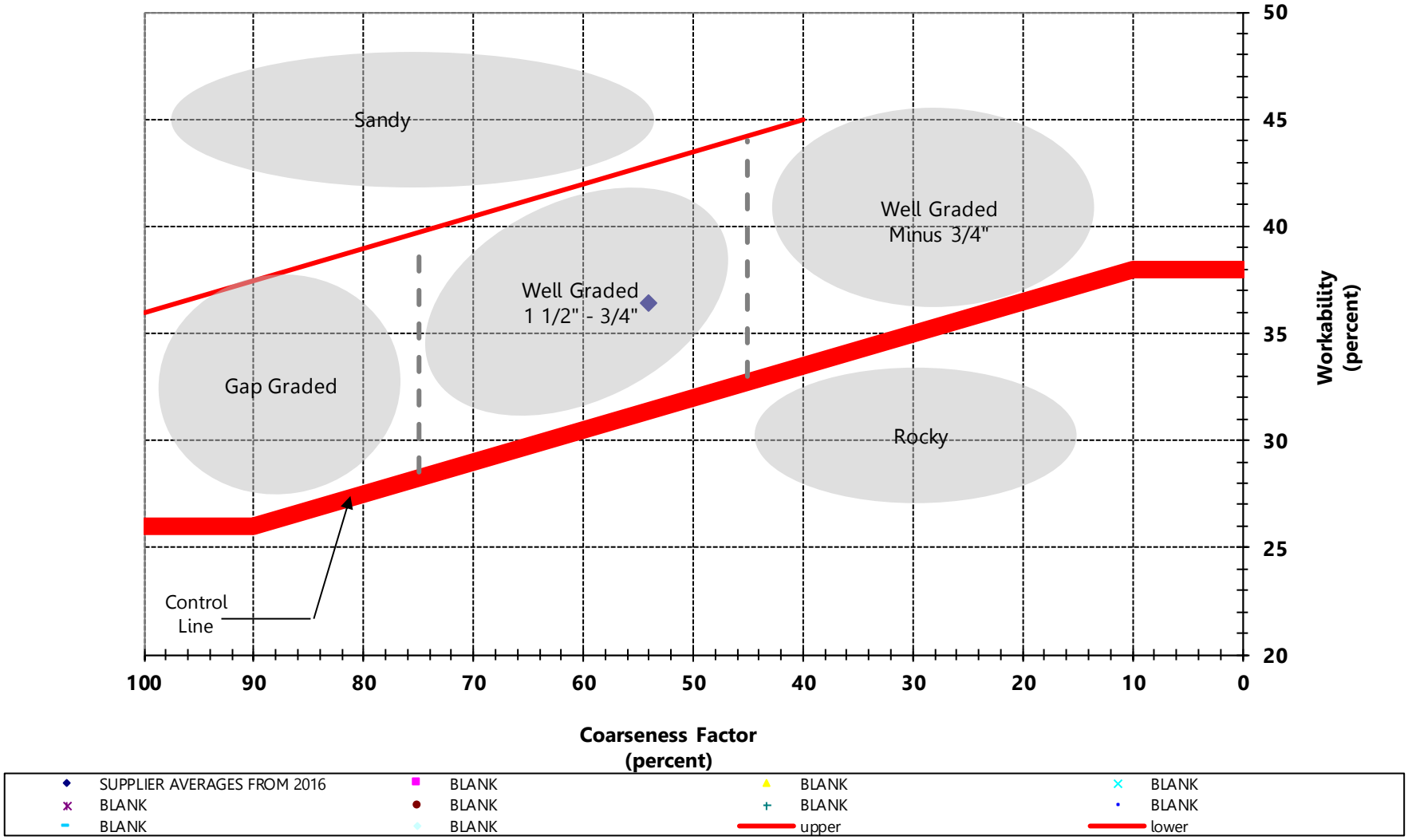

Figure 8. US-20 Combined Gradation Coarseness and Workability Factors

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

Real-time IRI measurements were approximately 10 in/mi higher than hardened IRI measurements. Establishing the relationship between real-time and hardened IRI measurement early in the equipment loan was critical in providing CVC crew members the confidence necessary to make process adjustments based on real-time smoothness feedback. IRI results for the first three days of paving are shown in Table 5.

Table 5. Tabular Results Comparing Real-Time and Hardened Profile Results

	Passing Lane			Truck Lane		
	Real-Time GSI	Hardened		Real-Time GSI	Hardened	
Date	IRI (in/mi)	MRI (in/mi)	Δ GSI-HRD (in/mi)	IRI (in/mi)	MRI (in/mi)	Δ GSI-HRD (in/mi)
08MAY2017	n/a	n/a	n/a	100	88	12
09MAY2017	60	54	6	72	62	10
11MAY2017	58	50	8	57	47	10

Looking at matched profile data from 12MAY2017 (Figure 9), it is apparent that real-time profiles and hardened profiles parallel each other, the overall IRI results for the profiles shown in Figure 9 are provided in Table 6.

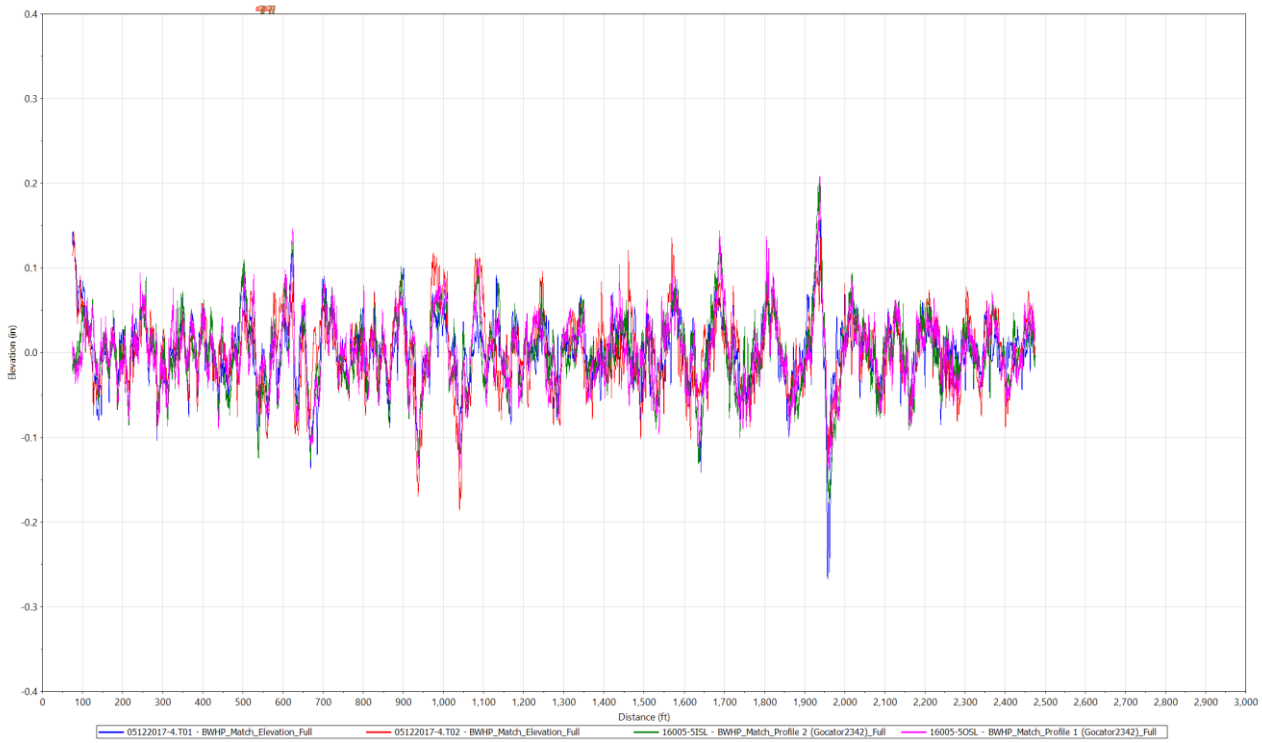

Figure 9. Real-Time and Hardened Profiles from 12MAY2017

Table 6. Overall Real-Time and Hardened IRI Values for Paving from 12MAY2017

Lane	Real-Time GSI IRI (in/mi)	Hardened MRI (in/mi)	Δ GSI-HRD (in/mi)
Passing	65	52	13
Truck	63	54	9

IRI vs. Profilograph Index (PI) Measurements

One of CVC's primary objectives of participating in the equipment loan was to evaluate how an RTS system could be used to improve the initial smoothness of concrete pavements, specifically with respect to IRI. They are accustomed to consistently earning incentives under IADOT's current zero-blanking band PI specification, but realize that the proposed switch to IRI for acceptance could negatively impact their costs (reducing earned incentives and increasing required corrective actions). The current IADOT specification pays maximum incentive for any 0.10 mile segment with a PI of 22 in/mi or less. The proposed IADOT specification would pay maximum incentive for any 0.10 mile segment with a mean ride index (MRI) of 55 in/mi or less. Using the GSI, CVC's crews were able to see in real-time the potential impact of the switch to IRI for acceptance. Figures 10A through 10D show four screen shots from the GSI display for the paving performed on 12MAY2017.

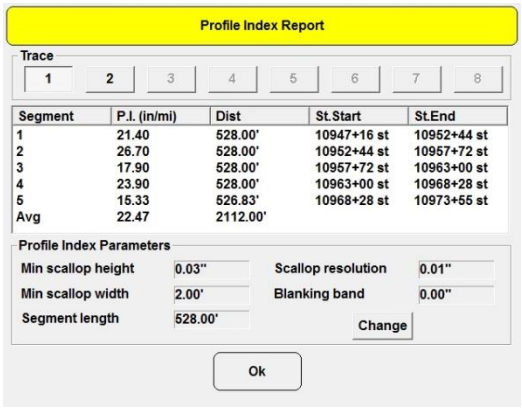

Figure 10A. GSI Screenshot: PI Report Passing Lane

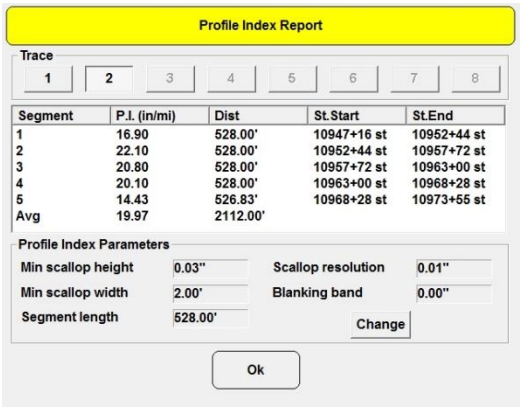

Figure 10B. GSI Screenshot: PI Report Truck Lane

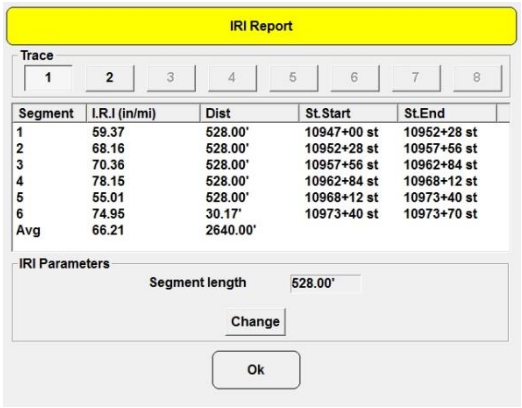

Figure 10C. GSI Screenshot: IRI Report Passing Lane

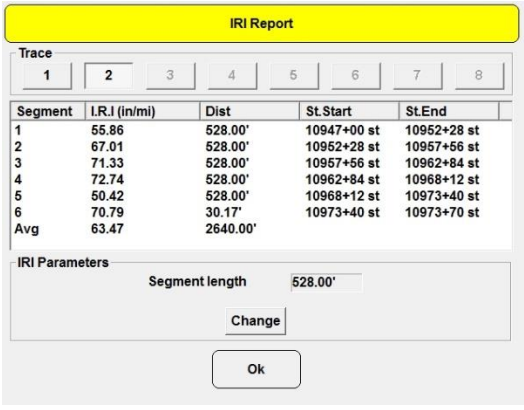

Figure 10D. GSI Screenshot: IRI Report Truck Lane

Looking at Figures 10A and 10B in real-time, CVC's crews can see that seven out of ten 0.10 mile segments are in full incentive (≤22 in/mi). Looking at Figures 10C and 10D in real-time, it is apparent that only one of ten 0.10 mile segments is in full incentive (≤55 in/mi). The difference in length between the PI and IRI reports is due to the 32 ft buffer length used for calculating PI. Had the GSI recorded a few more feet, all reports would have five full segments.

Keeping in mind that these are real-time measurements, and that the hardened results for IRI should be approximately 10 in/mi lower, it is safe to assume that 40% of segments would meet the proposed IRI criteria for full incentive and that 90% to 100% of all segments would meet the current PI criteria for full incentive. Using the real-time feedback from the GSI allowed CVC to make adjustments to their processes (mixture, paver setup and stringline tension), monitor the effect of those adjustments and further evaluate the potential impacts of IRI acceptance criteria.

Repeating Profile Features

The power spectral density analysis (PSD) from ProVAL (Figure 11) shows the following:

- Joint spacing (dowel baskets) at 20.0' c/c and subharmonics at 10.0', 6.7', 5.0' and 4.0' is more apparent in the real-time profiles than in the hardened profiles. The probable explanation for this is that hand finishing is mitigating much of this roughness.
- The repeating wavelength at 25' c/c is most likely associated with the stringline (tension, sensor adjustment, etc.). It is the most dominant wavelength in the hardened profile and is also present in the real-time profile.

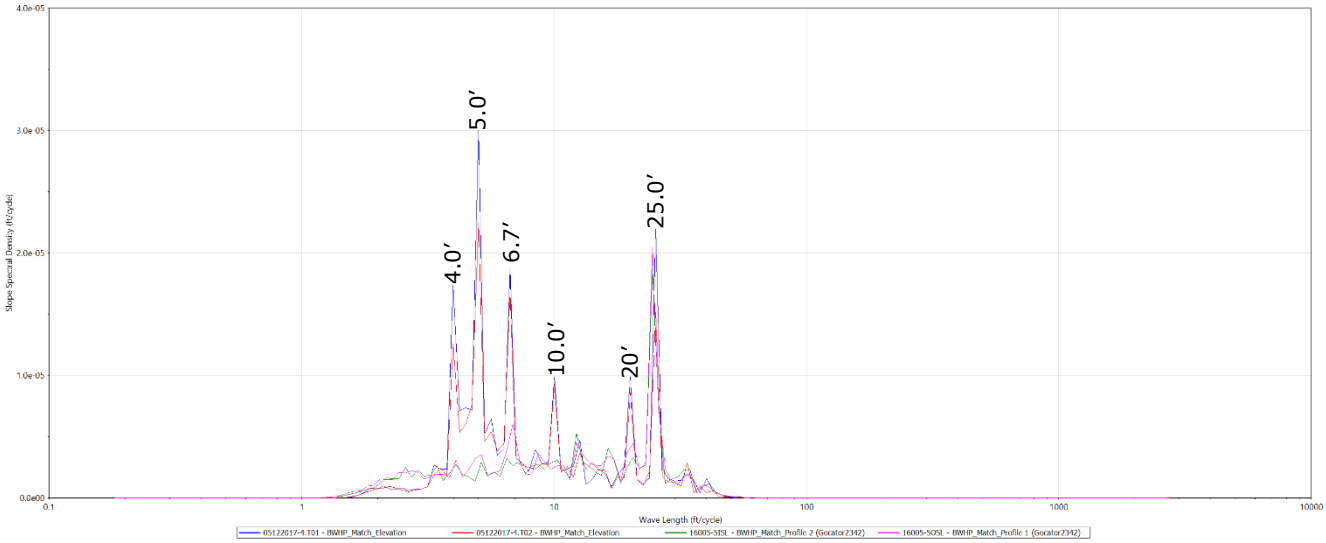

Figure 11. PSD Analysis Showing Repeating Wavelength Features at 25' and 20' (subharmonics at 10'.0', 6.7, 5.0' and 4.0')

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 values were consistently higher that hardened IRI values by approximately 10 in/mi. Establishing this relationship as early as possible is beneficial in confidently making process adjustments based on real-time smoothness feedback.
- When properly matched, the real-time and hardened profiles parallel each other with good agreement.
- RTS systems can be beneficial for estimating the impact of potential specification changes (PI to IRI), and in making adjustments to the paving process while still working under the older specification.
- Hand finishing appears to have mitigated some of the roughness associated with dowel baskets on this project.

SHRP2 Implementation Team and Contractor Observations

- An exit interview was conducted with the paving superintendent. His observations regarding real-time smoothness measurements included:
    - RTS systems provide valuable feedback and provides confidence for adjusting the paving process.
- Soon after the SHRP2 equipment loan, the contractor purchased a Gomaco GSI.