EL02-2015 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

FIELD REPORT: NEBRASKA 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:

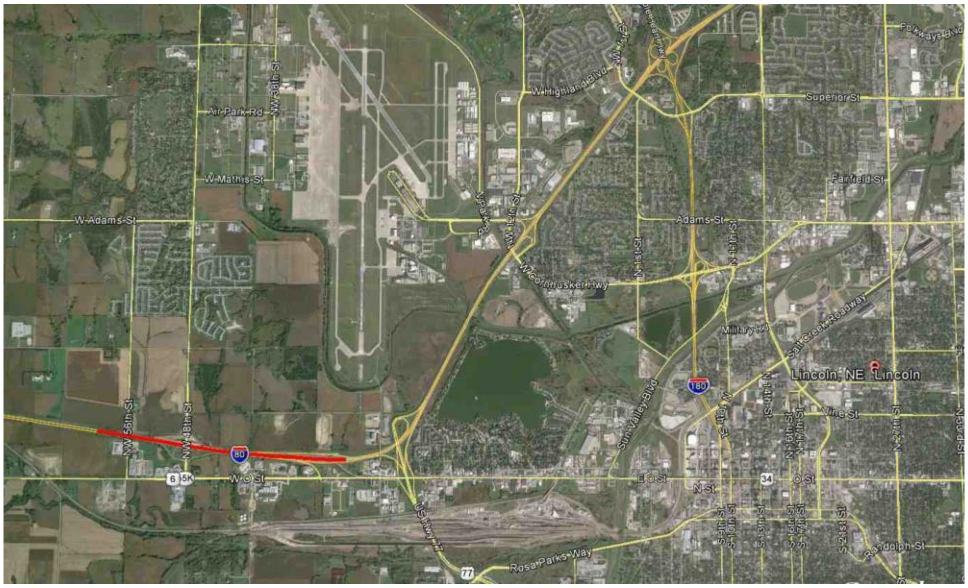
- Provide equipment (GOMACO GSI or Ames RTP) and labor for a field trial of 10 to 30 paving days
- Provide technical assistance for equipment installation start-up and operation
- On-call technical support throughout the duration of the field trial
- Planning, coordination and execution of the field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

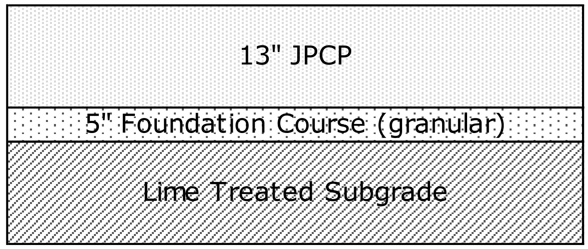
This report summarizes the activities and findings of the equipment loan conducted in Nebraska.

PROJECT DETAILS

The equipment loan was performed in May 2015 on a project in Lincoln, Nebraska. Table 1 summarizes the pertinent project details.

Table 1. Lincoln, Nebraska I-80 Project Information

<table>
<tr><th>Item</th><th>Details</th></tr>
<tr><td>Project Location</td><td>Mainline paving with gaps for entrance and exit ramps was located on westbound I-80 from just west of the US-77 interchange to approximately ½ mile west of NW 56th Street.

</td></tr>
<tr><td>Route</td><td>I-80</td></tr>
</table>

Item	Details
Agency	Nebraska Department of Roads (NDOR)
Paving Contractor	Hawkins Construction Company (HCC)
Paving Equipment	Guntert-Zimmerman S-850 paver, Leica stringless machine control and Gomaco 2600 placer/spreader
Real-Time System	Ames RTP
Typical Section	13" dowel jointed portland cement concrete pavement 
Joint Spacing	Transverse: 16.5' c/c with dowel baskets Longitudinal: spaced at 12' with inserted tie bars
Ames RTP Setup	Paver width = 24' Sensor #1 approximately 3' from the median edge of pavement and sensor #2 approximately 8' from the outside edge. Sensor locations were chosen to provide one profile near the edge of the pavement (#1) and one profile at the approximate location of the wheel path furthest from the edge of pavement (#2).
Miscellaneous Details	Initial smoothness less than 44 in/mi for 106% payment and less than 94 in/mi for 100% payment. A vibrator monitor was in use, vibrators were consistently operated in the range of 4,300 to 5,200 vpm. Burlap drag behind the trailing finishing pan. Hand finishing consisted of a 16' straightedge advanced with approximately 8' overlaps. An additional burlap drag attached to a work bridge was used prior to longitudinal tining.

IMPLEMENTATION ACTIVITIES

This equipment loan was initiated through a 30 minute briefing (Task 6.3) delivered at the annual meeting of the American Concrete Pavement Association in December of 2014. Personnel from Hawkins were in attendance and expressed an interest in participating in the equipment loan program. The project on I-80 in Lincoln, NE is their first with an IRI specification requiring initial smoothness less than 94 in/mi for full payment. As such, they had implemented new procedures and were focused on improving their initial smoothness results to.

Spring weather in the Midwest presented challenges in scheduling the equipment loan and collecting real-time profile data. Multiple rain days impacted Hawkins' schedule, resulting in only 2 days of mainline paving on the I-80 project where real-time profile data was collected. Additional real-time profile data was collected at Hawkins' Eppley Airfield project to maximize the contractor's exposure to the benefits of real-time smoothness equipment during the SHRP2 implementation team's presence in Nebraska.

This was the second equipment loan conducted and the first where the R06E team handled all of the install procedures without support from Ames Engineering. The contractor's personnel were actively involved in the operation of the RTP and utilized the real-time feedback to adjust their processes. Although weather and scheduling difficulties limited the contractor's use of the RTP to five days of paving, it was beneficial to all parties involved.

Table 2. Summary of R06E On-Site Activities

Date	On-Site Implementation Activites
05MAY2015	Install the RTP on Hawkins' S-850 paver at Eppley Airfield.
06MAY2015	Real-time profile data collection at Eppley Airfield, 9:00 am to 5:00 pm.
07MAY2015	Real-time profile data collection at Eppley Airfield, 9:00 am to 3:00 pm.
08MAY2015	Install the RTP on Hawkins' S-600 paver at I-80, Lincoln, NE.
09MAY2015	Real-time profile data collection on I-80, 12' wide median shoulder from approximately 492+50 to 454+00.
10MAY2015	Install the RTP on Hawkins' S-850 paver at I-80, Lincoln, NE.
11MAY2015	Real-time profile data collection, 7:00 am to 8:00 pm. from approximately 405+00 to 387+00 (WB lanes 2 and 3). the RTP system was restarted at approximately 403+00.
12MAY2015	RTP installation adjustment to correct sensor height.
13MAY2015	Real-time profile data collection, 6:00 am to 4:30 pm. from approximately 387+00 to 380+00 (WB lanes 2 and 3) and 416+25 to 412+50 (WB lane 3 and shoulder). NDOR and FHWA personnel visited the site to observe the RTP in use.

OBSERVATIONS, DATA and ANALYSES

Hawkins' paving operation was structured and skillful. The concrete mixture was batched at a central plant approximately 2 miles from the paving location and delivered in dump trucks. Figures 1 through 4 illustrate the installation of the RTP and different aspects of the paving equipment and processes used by Hawkins.

Figure 1. Ames RTP Mounted to G-Z S-850 Paver With a Float Pan

Figure 2. Concrete Deposited on Dowel Baskets Ahead of the Paver

Figure 3. Concrete at the Front of the Paver (relatively high head pressure)

Figure 4. Close-up of Pavement Edge

CONCRETE MIXTURE

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

Table 3. I-84 Meridian Concrete Mixture Proportions

SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

REAL-TIME SMOOTHNESS IMPLEMENTATION

Mix Design & Proect Info.

General Information

Project:	NEBRASKA I-80 LINCOLN
Contractor:	HAWKINS
Mix Description:	SLIPFORM MAINLINE
Mix ID:	N/A
Date(s) of Placement:	

Cementitious Materials	Source	Type	Spec. Gravity	lb/yd³	% Replacement by Mass
Portland Cement:	ASH GROVE		2.950	564	
GGBFS:					
Fly Ash:					
Silica Fume:					
Other Pozzolan:					
				564	**lb/yd³**
				6.0	**sacks/yd³**

Aggregate Information	Source	Type	Spec. Gravity SSD	Absorption (%)	% Passing #4
Coarse Aggregate:	MARTIN MARIETTA, WW	CRUSHED ROCK	2.660	1.2%	7%
Intermediate Aggregate:					
Fine Aggregate #1:	WESTERN, ASHLAND	NATURAL	2.620	0.5%	87%
Fine Aggregate #2:					

Coarse Aggregate %:	30.0%
Intermediate Aggregate %:	
Fine Aggregate #1 % of Total Fine Agg.:	100.0%
Fine Aggregate #2 % of Total Fine Agg.:	
Fine Aggregate #1 %:	70.0%
Fine Aggregate #2 %:	

Mix Proportion Calculations

Water/Cementitious Materials Ratio:	0.400
Air Content:	7.80%

	Volume (ft3)	Batch Weights SSD (lb/yd3)	Spec. Gravity	Absolute Volume (%)
Portland Cement:	3.064	564	2.950	11.347%
GGBFS:				
Fly Ash:				
Silica Fume:				
Other Pozzolan:				
Coarse Aggregate:	5.464	907	2.660	20.237%
Intermediate Aggregate:				
Fine Aggregate #1:	12.747	2,084	2.620	47.209%
Fine Aggregate #2:				
Water (*forced to include admix*):	3.620	226	1.000	13.407%
Air:	2.106			7.800%
	27.001	**3781**		**100.000%**
	Unit Weight (lb/ft³)	**140.0**	**Paste**	**32.553%**
			Mortar	**75.042%**

Admixture Information	Source/Description	oz/yd3	oz/cwt
Air Entraining Admix.:	MASTERAIR AE 400		
Admix. #1:	MASTERPOZZOLITH 80		
Admix. #2:			
Admix. #3:			

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

Table 4. Mix Design Submittal Sieve Analysis Data

REAL-TIME SMOOTHNESS IMPLEMENTATION

Combined Gradation Test Data

Project: NEBRASKA I-80 LINCOLN
Mix ID: MAINLINE SLIPFORM
Sample Comments: MIX DESIGN VALUES FROM HAWKINS
Test Date: MIX DESGN SUBMITTAL

Total Cementitious Material: 564 lb/yd^3

Agg. Ratios: 30.00% 0.00% 70.00% 100.00%

Sieve	Coarse	Intermediate	Fine #1	Fine #2	Combined % Retained	Combined % Retained On Each Sieve	Combined % Passing
2 ½"	100.0%		100.0%		0%	0%	100%
2"	100.0%		100.0%		0%	0%	100%
1 ½"	100.0%		100.0%		0%	0%	100%
1"	97.0%		100.0%		1%	1%	99%
¾"	86.0%		100.0%		4%	3%	96%
½"	*59.0%*		100.0%		12%	8%	88%
⅜"	*33.0%*		*94.0%*		24%	12%	76%
#4	7.3%		87.0%		37%	13%	63%
#8	*5.0%*		*65.0%*		53%	16%	47%
#16	*3.0%*		*43.0%*		69%	16%	31%
#30	2.5%		21.0%		85%	16%	15%
#50	2.3%		6.0%		95%	11%	5%
#100	*2.0%*		*2.0%*		98%	3%	2%
#200	1.9%		0.0%		99.4%	1.4%	0.6%

Workability Factor: **47.0** 48% Coarse Sand
Coarseness Factor: **45.8** 30% Fine Sand

Table 5. QC Sieve Analysis Data

REAL-TIME SMOOTHNESS IMPLEMENTATION

Combined Gradation Test Data

Project: NEBRASKA I-80 LINCOLN
Mix ID: MAINLINE SLIPFORM
Sample Comments: QC DATA
Test Date: QC TEST 24APR2014 7-3

Total Cementitious Material: 564 lb/yd^3

Agg. Ratios: 30.00% 0.00% 70.00% 100.00%

Sieve	Coarse	Intermediate	Fine #1	Fine #2	Combined % Retained	Combined % Retained On Each Sieve	Combined % Passing
2 ½"	100.0%		100.0%		0%	0%	100%
2"	100.0%		100.0%		0%	0%	100%
1 ½"	100.0%		100.0%		0%	0%	100%
1"	100.0%		100.0%		0%	0%	100%
¾"	84.6%		100.0%		5%	5%	95%
½"	*59.0%*		100.0%		12%	8%	88%
⅜"	*32.0%*		*93.0%*		25%	13%	75%
#4	4.7%		86.0%		38%	13%	62%
#8	*5.0%*		*64.0%*		54%	15%	46%
#16	*3.0%*		*43.0%*		69%	15%	31%
#30	0.7%		22.2%		84%	15%	16%
#50	0.5%		5.8%		96%	12%	4%
#100	*0.4%*		*2.0%*		98%	3%	2%
#200	0.3%		0.1%		99.8%	1.4%	0.2%

Workability Factor: **46.3** 46% Coarse Sand
Coarseness Factor: **47.1** 31% Fine Sand

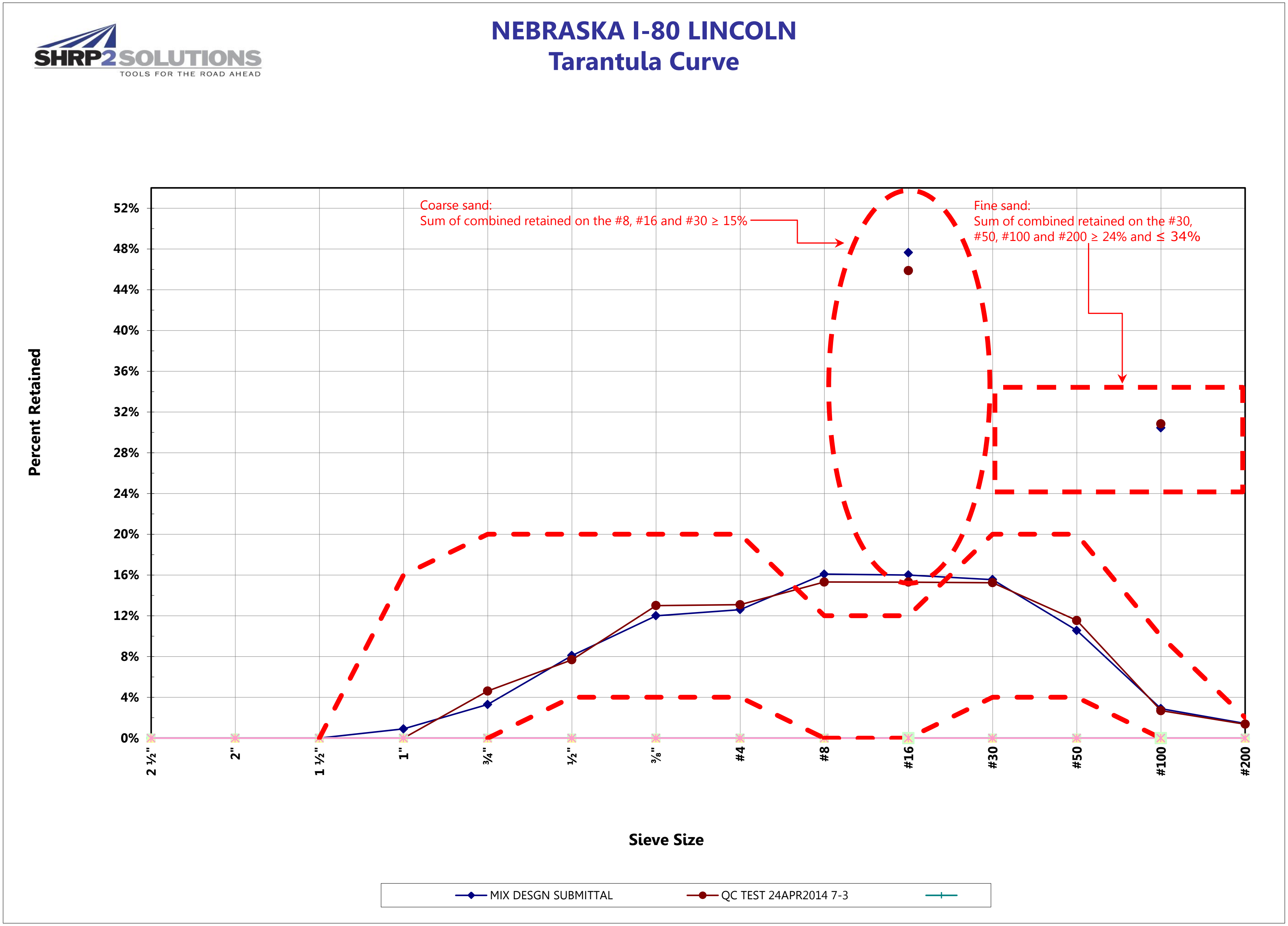


Figure 5. I-80 Combined Percent Retained (Tarantula Curve)

NEBRASKA I-80 LINCOLN

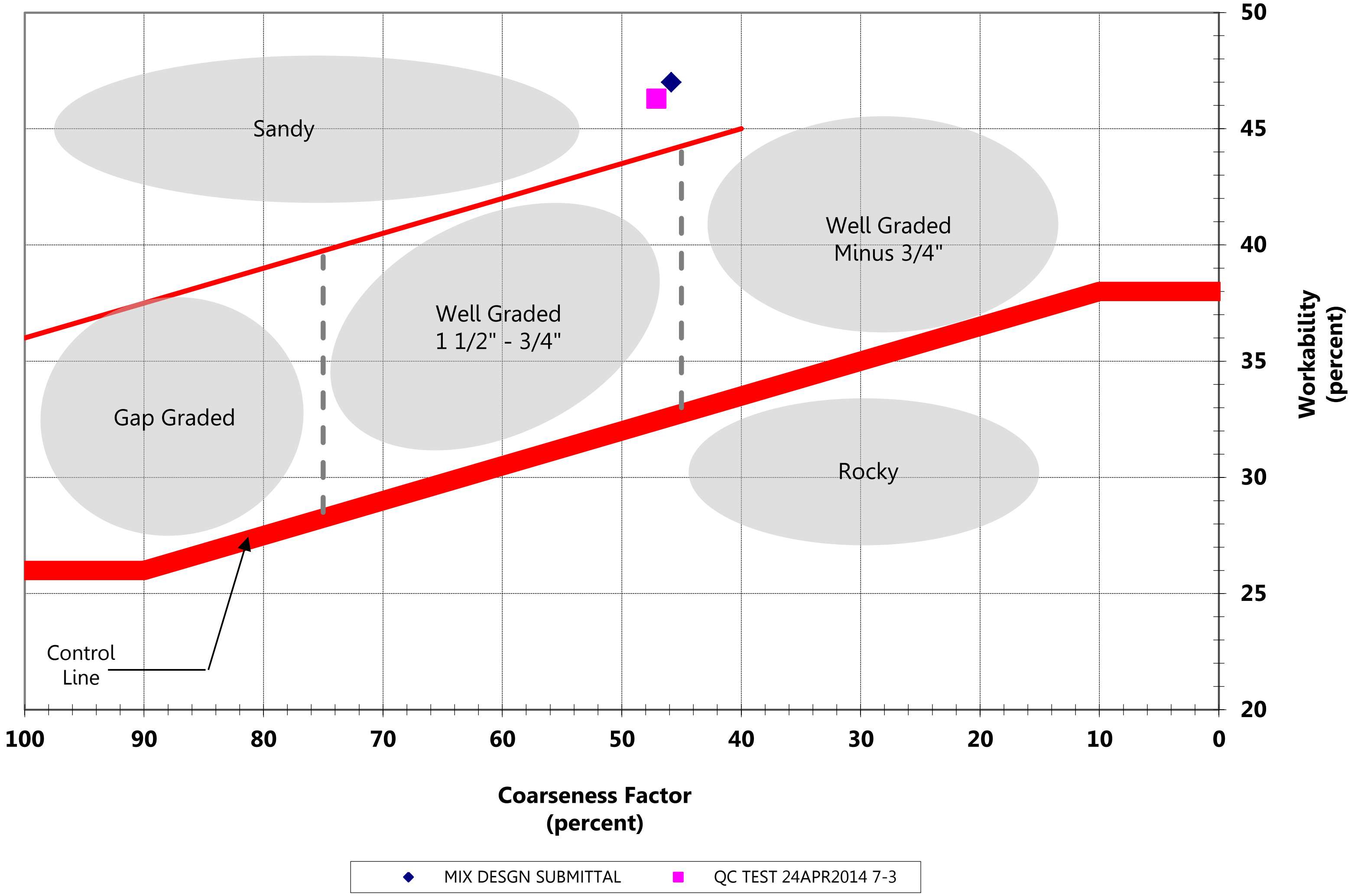


Figure 6. I-80 Combined Gradation Coarseness and Workability Factors

The mixture produced and delivered to the project by Hawkins was observed to be uniform and workable. The mixture was very responsive to vibration; consolidation was achieved with relatively low vibrator frequencies (approximately 5,000 vpm). Isolated areas of edge instability was observed, this is likely a function of the aggregate proportions (30% coarse and 70% fine), and the resulting sensitivity to vibration (Figure 7).

Figure 7. Isolated Area of Edge Instability (denoted by yellow oval)

PROFILE CHARCTERISTICS

Weather delays and conflicting project schedules limited the opportunity for extensive data collection. Therefore, it is difficult to make any statistically valid conclusions. The following information is provided to convey 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

The Ames RTP measured slightly higher roughness (localized and overall) than the hardened QC profile. This is not unexpected as finishing operations (mechanical and hand) will help remove much of the localized roughness measured behind the pan. An example from May 11th is provided in Figure 8 (yellow is hardened profile trace, blue is RTP trace and red is arbitrary action limit of 125 in/mi).

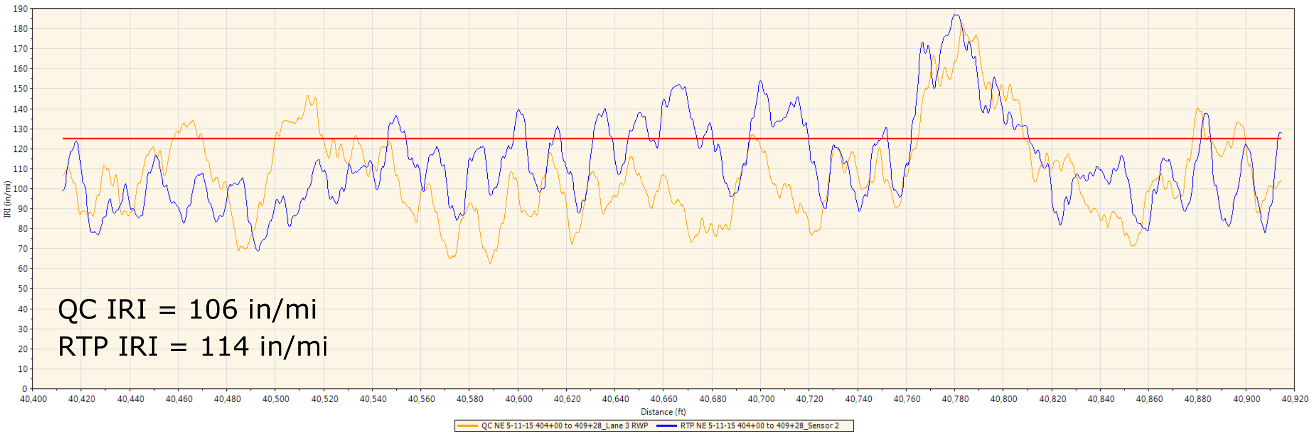


Figure 8. Comparison of Real-Time and Hardened QC IRI Results

Improvement from 5-11-15 to 5-13-15

May 11th was the first day of paving on I-80 where the RTP was used. As a matter of practice, the R06 team requests that the contractor leave their operations unchanged for the first day while they familiarize themselves with operating the RTP. The next day of paving was May 13th, and the contractor made an effort to maintain a consistent and smaller head of concrete in front of the paver than was observed on May 11th. Figure 9 shows continuous IRI results (25’ segment length) for both days (5-11 is yellow, 5-13 is blue and red is arbitrary action limit of 125 in/mi). The results from May 13th showed a 20% reduction in IRI despite the fact that it was only 400’ long.

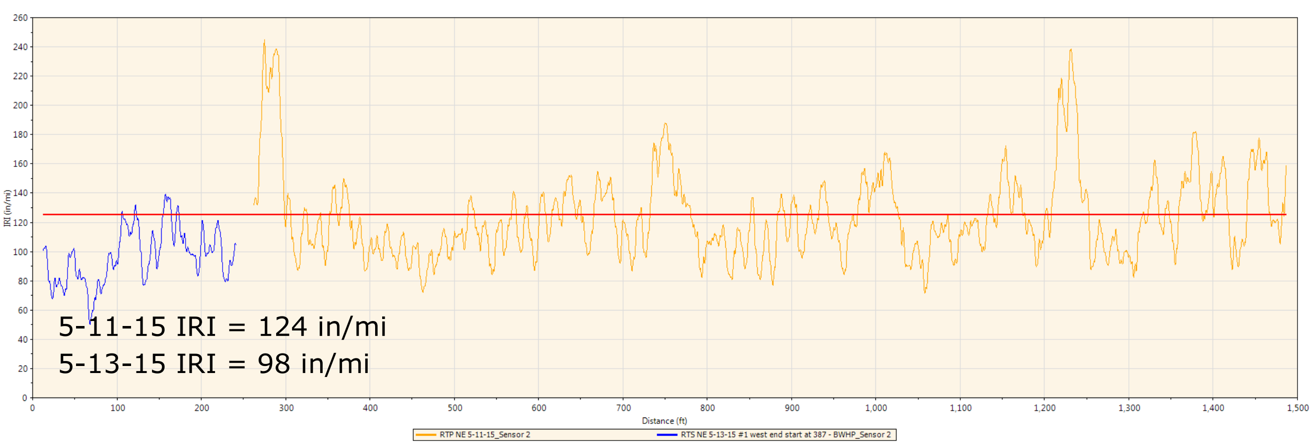


Figure 9. Comparison of Real-Time IRI Results from May 11th and May 13th

Effect of Transverse Contraction Joints

Joints (dowel baskets) were the dominant power spectral density (PSD) content in both the RTP traces and hardened profile traces, but were slightly more significant in the RTP traces, indicating that finishing operations helped to reduce the effects of the joints on roughness. The PSD plot (Figure 10) shows harmonics of the joint spacing effect, typically at 8.25′, 5.50′, 4.13′ and 3.30′.

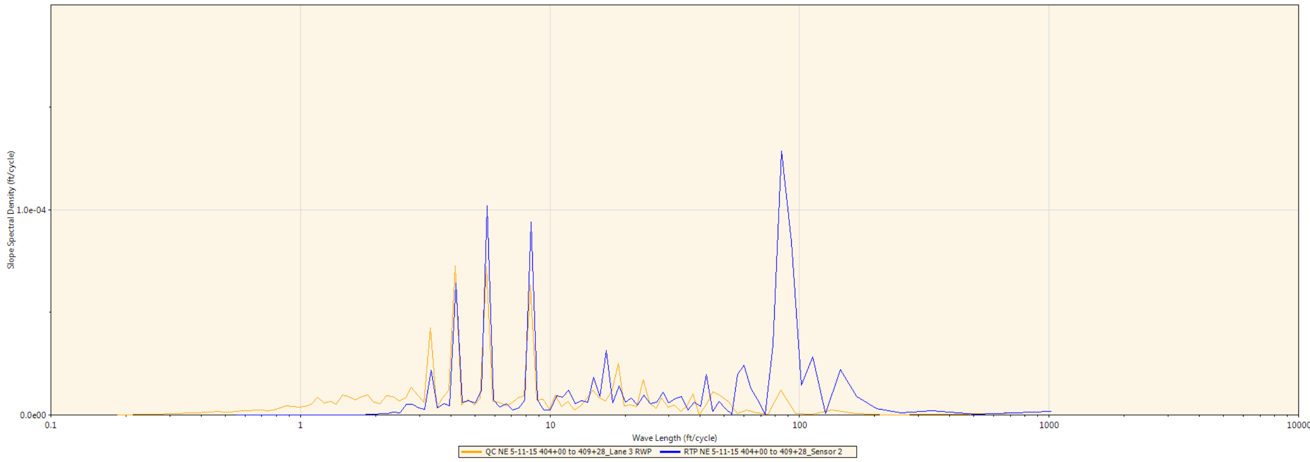


Figure 10. Power Spectral Density Analysis from May 11, 2015

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 smoothness (IRI) as measured by the Ames RTP was slightly higher than the QC hardened profile taken two days after paving.
- The contractor’s efforts to maintain a consistent and lower concrete head on May 13th resulted in a 20% reduction in IRI as compared to the previous day’s paving. The process change and resulting smoother pavement could have been achieved without real-time smoothness equipment. However, the instant feedback provided by the RTP provided positive reinforcement for the process change.
- Power spectral density plots show that transverse joints are the dominant contributor to pavement roughness.

SHRP2 Implementation Team and Contractor Observations:

- Weather delays and conflicting project schedules limited the opportunities for data collection to 5 days.
- Sensor height issues resulted in a loss of data for sensor #1 on May 11th. Care must be taken to mount the RTP sensors at the correct height and assure that they are tracking parallel to the edge of the pavement.
- Even with the limited data collection on this equipment loan, the need to have a systematic method for handling the real-time and QC profile data was apparent.
    - Someone should be assigned to be the primary caretaker of the real-time smoothness data.
    - Analysis should be done soon after paving is completed for the day (IRI and PSD).
    - Files should be named and organized in a manner that makes it easy to perform comparative analyses between real-time and hardened QC profile data.
    - Comparative analyses should be done every day.

- Software improvements are still needed and would add greater benefit to using the RTP:
    - Capability to store event markers.
    - Enhanced real-time identification of must grind locations.
    - Improved vertical scale adjustment of the real-time display.
    - Improved file exports, specifically GPS and .erd files.
- An exit interview was conducted with the paving superintendent, his observations regarding real-time smoothness measurements included:
    - The equipment is beneficial because it helps the crew "buy into" improving smoothness. They are able to see the impact of changes to the paving process. In some cases, these changes may require more effort from the crew but when the results are seen in real-time they understand why the change was made.
    - The differences between real-time IRI and the QC IRI were not a concern to the superintendent. Regardless of the number, his objective was to monitor the process and make changes to reduce the IRI.
    - Hawkins already uses an Ames lightweight profiler, they felt that the RTP software was very similar to their profiler and that implementing the system would be relatively easy.
- Upon follow-up, the contractor stated that they will be purchasing an RTP in the near future.