EL03-2015 Implementation Assistance Program

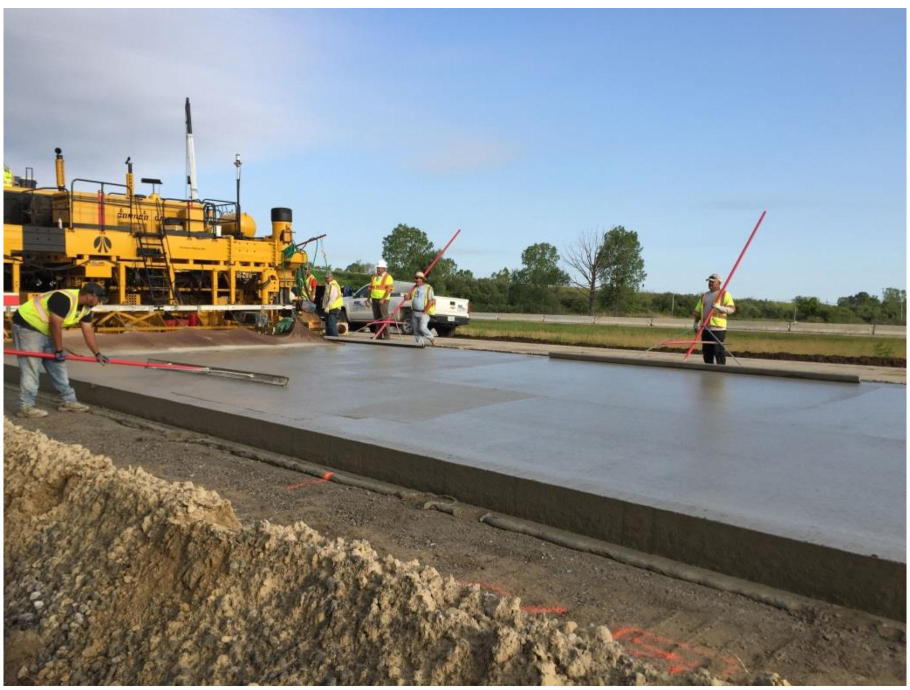
Tools to Improve PCC Pavement Smoothness During Construction (R06E)

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

SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

National Concrete Pavement Technology Center



FIELD REPORT: MICHIGAN 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

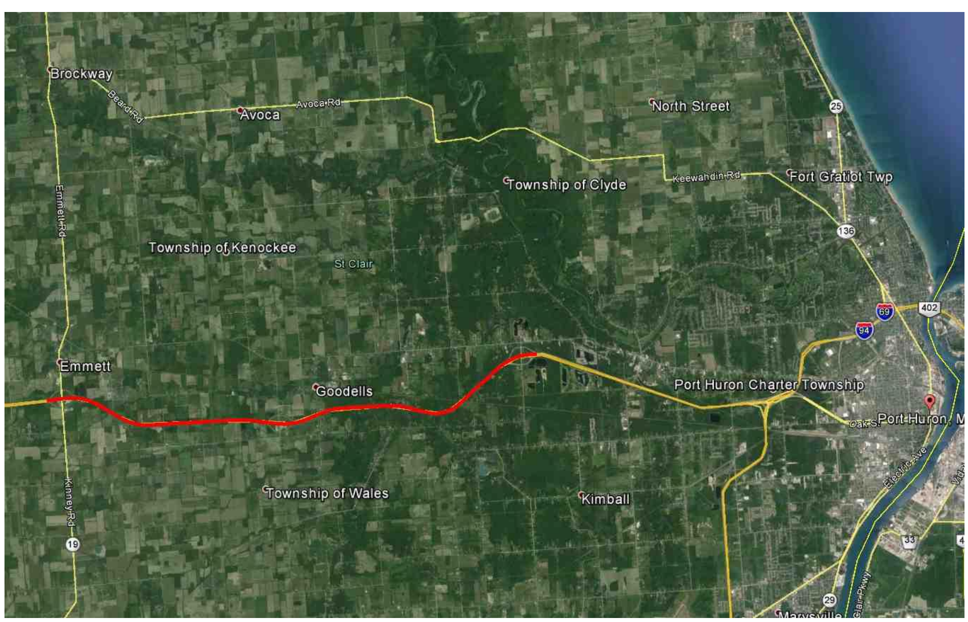
This report summarizes the activities and findings of the equipment loan conducted in Nebraska.

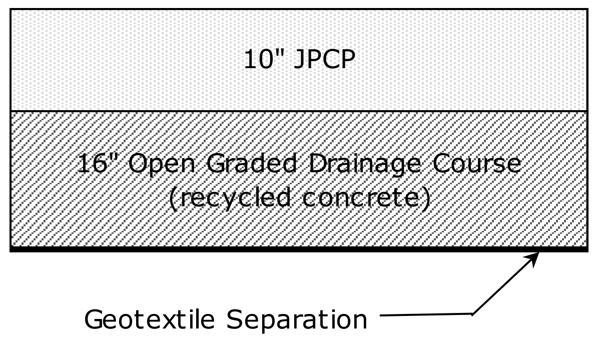
PROJECT DETAILS

The equipment loan was performed in July 2015 on a project west of Port Huron, Michigan. Table 1 summarizes the pertinent project details.

Table 1. Michigan I-69 Project Information

Item	Details
Project Location	Mainline paving with gaps for entrance and exit ramps was located on northbound I-69 from just south of the Goodells interchange to approximately 1 ½ mile south of the Taylor Dr. interchange.



Item	Details
Route	I-69
Agency	Michigan DOT (MDOT)
Paving Contractor	Ajax Construction Company (AJAX)
Paving Equipment	Gomaco 2800 paver with DBI and Trimble stringless machine control
Real-Time System	Ames RTP
Typical Section	10″ dowel jointed portland cement concrete pavement 
Joint Spacing	Transverse: 14′ c/c with inserted dowels Longitudinal: spaced at 12′ and 14′ with inserted tie bars
Ames RTP Setup	Paver width = 24′ (14′ truck lane and 10′ tied shoulder) Sensor #1 approximately 6.5′ from the outside edge of pavement and sensor #2 approximately 3′ from the longitudinal joint between lanes. Sensor locations were limited by available mounting locations. Note: The contractor was also using a Gomaco GSI which was provided by Gomaco, and not part of the scope of this SHRP2 Implementation Assistance.
Miscellaneous Details	Initial smoothness less than 71 in/mi for 100% payment, must correct bumps and dips greater than 0.3″ in 25′. A vibrator monitor was in use, vibrators were consistently operated at approximately 5,000 vpm. Burlap drag behind the trailing finishing pan. Hand finishing consisted of a 10′ straightedge advanced with approximately 1′ overlaps and a 16′ straightedge advanced with approximately 8′ overlaps. An additional burlap drag attached to a work bridge was used prior to curing and final texturing.

IMPLEMENTATION ACTIVITIES

This equipment loan arose as a result of a 30 minute briefing (Task 6.3) delivered at the annual meeting of the American Concrete Pavement Association (ACPA) in December of 2014. The local ACPA chapter executive solicited interest from member contractors and AJAX expressed interest in utilizing the Ames RTP. This was the first project that AJAX had performed under MDOT's new acceptance limit of 70 in/mi. The previous limit for full pay had been 75 in/mi.

Spring and early summer weather in eastern Michigan presented challenges in scheduling the equipment loan and collecting real-time profile data. Multiple rain days and the July 4th holiday impacted the paving schedule and limited the collection of real-time smoothness data to 3 days of paving. Future equipment loans for 2015 were all scheduled to be done with the Gomaco GSI, therefore the Ames RTP was left with AJAX for their continued use from July 11, 2015 through October 5, 2015.

Table 2. Summary of R06E On-Site Activities

Date	On-Site Implementation Activites
01JUL2015	Install the RTP on AJAX Gomaco 2800 paver with DBI.
02JUL2015	Real-time profile data collection.
06JUL2015	Real-time profile data collection.
10JUL2015	Real-time profile data collection.

OBSERVATIONS, DATA and ANALYSES

AJAX's paving operation was highly organized, efficient and quality oriented. The concrete mixture was batched at a central plant located at an interchange within the project limits, haul distances ranged from approximately 0.1 mile to 2.5 miles. The fresh concrete was delivered in dump trucks and agitors. Figures 1 through 4 illustrate different aspects of the paving equipment and processes used by AJAX.

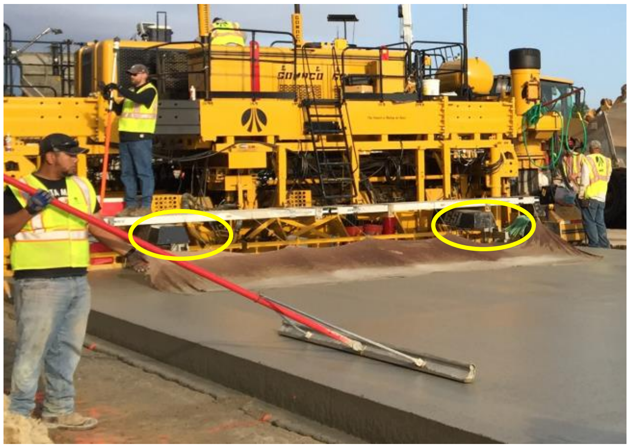


Figure 1. Ames RTP Mounted to Gomaco 2800 paver with DBI (yellow ovals, note that GSI sensors are mounted adjacent to the RTP).

Figure 2. Concrete Deposited on Grade Ahead of the Paver

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

Figure 4. DBI Section of the Paver Showing the Oscillating Finisher

CONCRETE MIXTURE

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

Table 3. I-69 Concrete Mixture Proportions

SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

REAL-TIME SMOOTHNESS IMPLEMENTATION

Mix Design & Proect Info.

General Information

Project:	MICHIGAN I-69
Contractor:	AJAX
Mix Description:	SLIPFORM MAINLINE
Mix ID:	437315-02
Date(s) of Placement:	

Cementitious Materials	Source	Type	Spec. Gravity	lb/yd^3	% Replacement by Mass
Portland Cement:	ST. MARY'S	1	3.150	375	
GGBFS:	ST. MARY'S	100	2.900	125	25.00%
Fly Ash:	HEADWATERS	F	2.360		
Silica Fume:					
Other Pozzolan:					
				500	**lb/yd^3**
				5.3	**sacks/yd^3**

Aggregate Information	Source	Type	Spec. Gravity SSD	Absorption (%)	% Passing #4
Coarse Aggregate:	PRESQUE ISLE 71-047	CRUSHED ROCK	2.568	n/a	n/a
Intermediate Aggregate:	PRESQUE ISLE 71-047	CRUSHED ROCK	2.554	n/a	n/a
Fine Aggregate #1:	MID-MICHIGAN 74-051	NATURAL	2.640	n/a	n/a
Fine Aggregate #2:					

Coarse Aggregate %:	26.8%
Intermediate Aggregate %:	31.0%
Fine Aggregate #1 % of Total Fine Agg.:	100.0%
Fine Aggregate #2 % of Total Fine Agg.:	
Fine Aggregate #1 %:	42.2%
Fine Aggregate #2 %:	

Mix Proportion Calculations

Water/Cementitious Materials Ratio:	0.420
Air Content:	6.80%

	Volume (ft3)	Batch Weights SSD (lb/yd3)	Spec. Gravity	Absolute Volume (%)
Portland Cement:	1.908	375	3.150	7.066%
GGBFS:	0.691	125	2.900	2.558%
Fly Ash:			2.360	
Silica Fume:				
Other Pozzolan:				
Coarse Aggregate:	5.146	825	2.568	19.058%
Intermediate Aggregate:	5.952	949	2.554	22.044%
Fine Aggregate #1:	8.102	1,335	2.640	30.009%
Fine Aggregate #2:				
Water (*forced to include admix*):	3.365	210	1.000	12.464%
Air:	1.836			6.800%
	27.000	**3818**		**100.000%**
	Unit Weight (lb/ft^3)	**141.4**	**Paste**	**28.889%**
			Mortar	**#VALUE!**

Admixture Information	Source/Description	oz/yd3	oz/cwt
Air Entraining Admix.:	PREMEIRE CONAIR 260	7.50	1.50
Admix. #1:	PREMEIRE OPTIFLOW 50	15.00	3.00
Admix. #2:	PREMEIRE PROLONG L		
Admix. #3:			

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

Table 4. Mix Design Submittal Sieve Analysis Data

REAL-TIME SMOOTHNESS IMPLEMENTATION

Combined Gradation Test Data

Project: MICHIGAN I-69
Mix ID: MAINLINE SLIPFORM
Sample Comments: MIX DESIGN VALUES FROM AJAX
Test Date: MIX DESGN SUBMITTAL

Total Cementitious Material: 564 lb/yd^3

Agg. Ratios:	26.80%	31.00%	42.20%		100.00%

Sieve	Coarse	Intermediate	Fine #1	Fine #2	Combined % Retained	Combined % Retained On Each Sieve	Combined % Passing
2 ½"	100.0%	100.0%	100.0%		0%	0%	100%
2"	100.0%	100.0%	100.0%		0%	0%	100%
1 ½"	94.2%	100.0%	100.0%		2%	2%	98%
1"	30.0%	100.0%	100.0%		19%	17%	81%
¾"	8.2%	98.6%	100.0%		25%	6%	75%
½"	2.2%	77.8%	100.0%		33%	8%	67%
⅜"	1.4%	51.6%	100.0%		41%	8%	59%
#4	1.2%	10.4%	98.6%		55%	13%	45%
#8	1.2%	4.2%	85.4%		62%	7%	38%
#16	1.2%	3.0%	68.6%		70%	7%	30%
#30	1.2%	2.4%	50.2%		78%	8%	22%
#50	1.2%	2.2%	27.2%		88%	10%	12%
#100	1.0%	2.0%	7.6%		96%	8%	4%
#200	0.9%	1.9%	1.2%		98.7%	2.8%	1.3%

Workability Factor: **37.7** 23% Coarse Sand

Coarseness Factor: **66.5** 29% Fine Sand

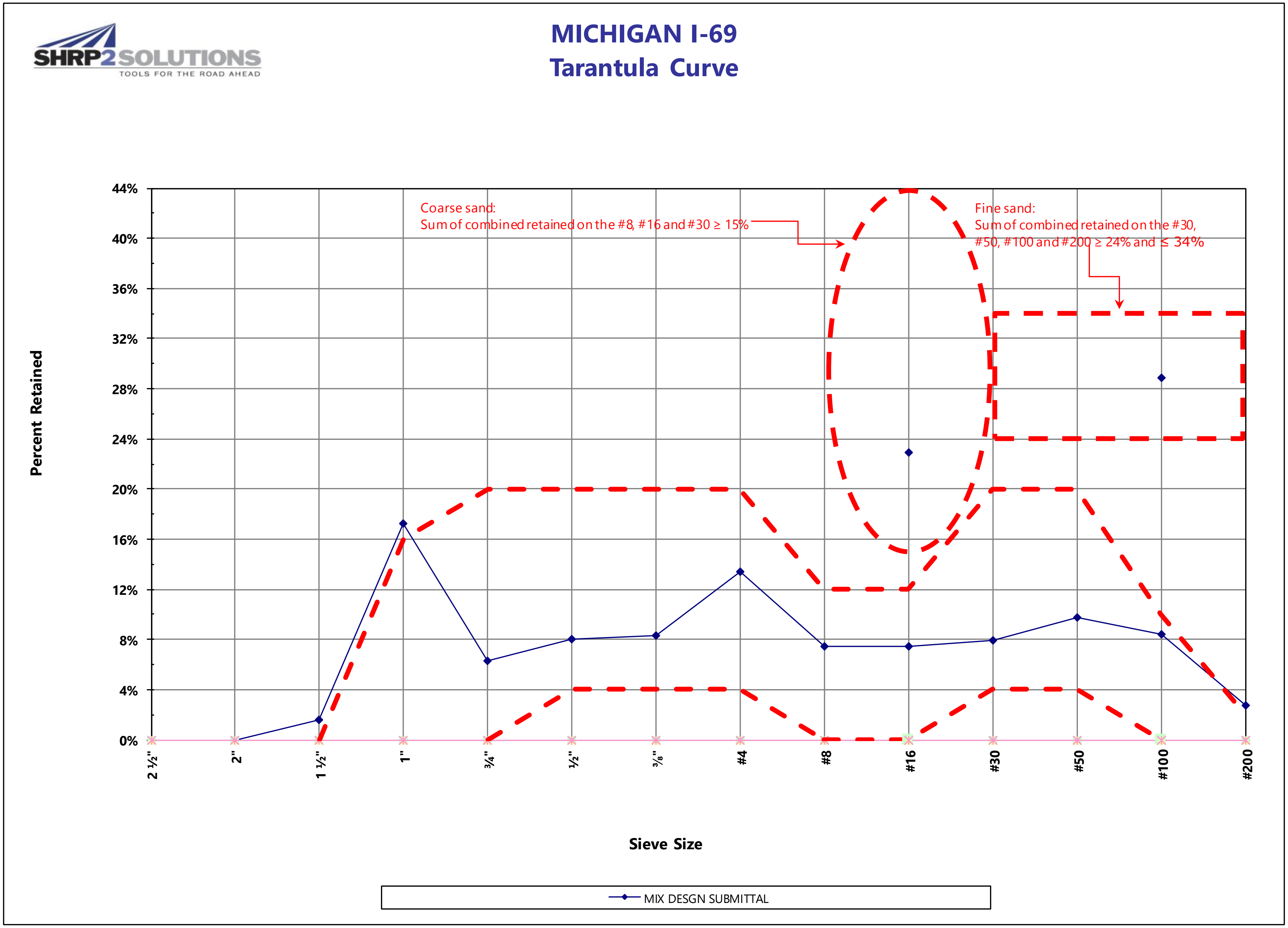


Figure 5. I-69 Combined Percent Retained (Tarantula Curve)

MICHIGAN I-69

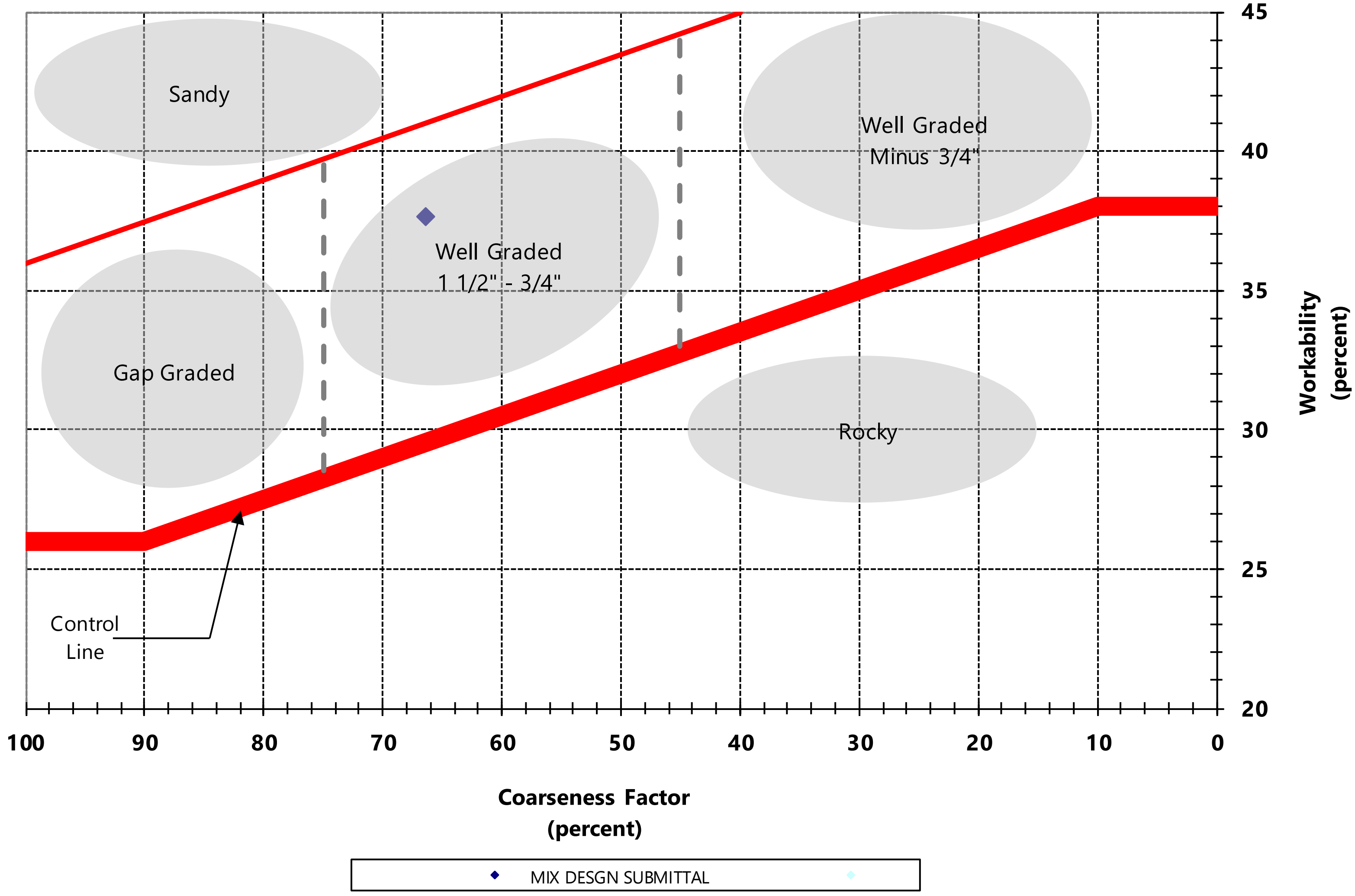


Figure 6. I-69 Combined Gradation Coarseness and Workability Factors

The quality and uniformity of the concrete mixture delivered by AJAX was observed to be excellent. Edge stability, edge slump and finishing characteristics were excellent as well (Figure 7). Consolidation was achieved with vibrator frequencies of approximately 5,000 vpm.

Figure 7. Stable Edges and No Surface Voids Directly Behind the Paver

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

Overall IRI results for the Ames RTP and hardened QC were very similar, more so than we have previously observed (Table 5).

Table 5. Summary of Overall IRI Results

Date	Hardened QC IRI (in/mi)	Real-Time RTP IRI (in/mi)	Length (ft)
02JUL2015	78	80	2,600
06JUL2015	70	70	2,300
10JUL2015	72	67	4,700
Weighted Average	73	72	

Figure 8 shows a section of real-time and hardened QC profile data from 7-2-15. This graphic illustrates the following about real-time vs. hardened QC profile data:

- In general, profile characteristics (e.g. bumps and dips) captured in real-time are reflected in the hardened QC profile. The magnitude of the localized roughness is typically lower in the hardened QC profile due to hand finishing.
- The areas bounded by yellow ovals indicate where hand finishing significantly changed the profile characteristics.

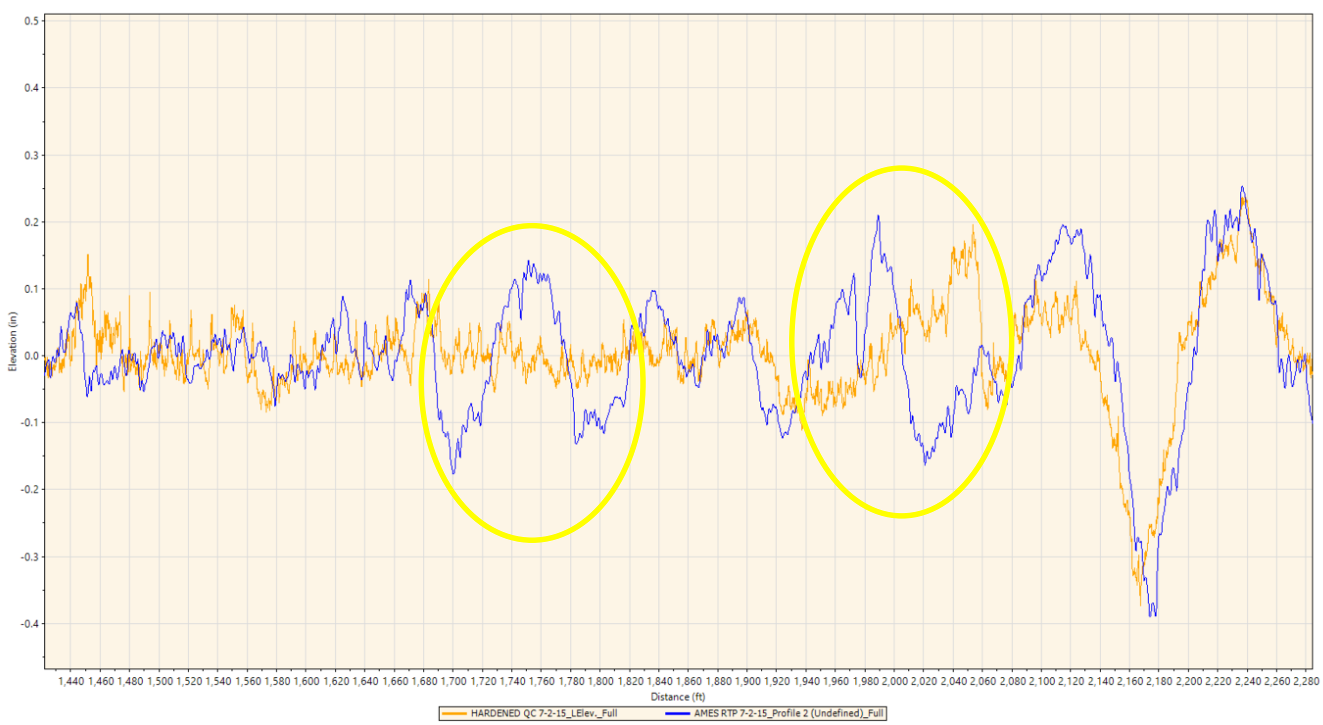


Figure 8. 800' Section of Real-Time and Hardened QC Profile from July 2, 2015

Repeating Profile Characteristics

A power spectral density (PSD) analysis was applied to all of the profile data collected, the results were similar for all three days of data. The predominant feature is the joint spacing at 14' and corresponding harmonics at 7', 4.7, and 3.5'. Figure 9 shows the PSD from 7-2-15 which is representative of all three days. It is interesting to note that the harmonic at 7' is the most predominant wavelength contributing to roughness in the hardened profile, while the real-time PSD shows the 14' and 4.7' wavelengths as primary contributors to roughness.

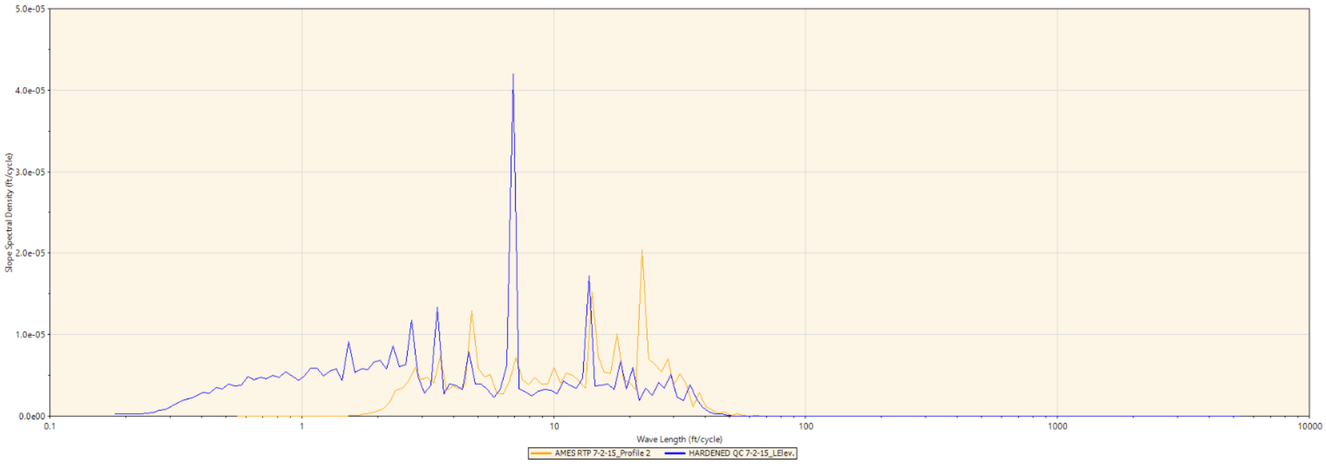


Figure 9. Power Spectral Density Analysis from July 2, 2015

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 nearly equal to the IRI obtained from the hardened profiles.
- 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 3 days.
- Software improvements were implemented on this project, the addition of event markers provides added functionality for correlating smoothness results with multiple factors such as changes in the mixture, paver stops, cross-slope adjustments, etc. The capability to import these event markers in to ProVAL would be beneficial.
- An exit interview was conducted with the paving superintendent, and his observations regarding real-time smoothness measurements included:
    - They see the benefit of utilizing real-time smoothness equipment, but it will take additional training and more experience to fully realize the potential.
    - The current MDOT specification does not offer any smoothness incentive. AJAX is balancing the cost of real-time smoothness systems with the objective of making marginal improvements in smoothness (75 in/mi to 70 in/mi). An incentive for smoothness would make the investment in a real-time system easily justifiable.
    - AJAX has been using a Gomaco GSI for approximately 1 year, they noted that the Ames RTP provides very similar feedback and both systems have positives and negatives.
- Upon follow-up, the contractor purchased a Gomaco GSI system.