



www.cproadmap.org

August 2016

ROAD MAP TRACK 8

PROJECT TITLE

Real-Time Smoothness Measurements for Portland Cement Concrete Pavements

TECHNICAL WRITER

Gary Fick

EDITOR

Sabrina Shields-Cook

SPONSORS

Federal Highway Administration
National Concrete Consortium

MORE INFORMATION

Gary Fick
trinity construction management services, inc.
gfick@trinity-cms.com

The Long-Term Plan for Concrete Pavement Research and Technology (CP Road Map) is a national research plan developed and jointly implemented by the concrete pavement stakeholder community. Publications and other support services are provided by the Operations Support Group and funded by the Federal Highway Administration.

Moving Advancements into Practice (MAP) Briefs describe innovative research and promising technologies that can be used now to enhance concrete paving practices. The August 2016 MAP Brief provides information relevant to Track 8 of the CP Road Map: Concrete Pavement Construction, Reconstruction, and Overlays.

This MAP Brief is available at www.cproadmap.org/publications/MAPbriefAugust2016.pdf.

“Moving Advancements into Practice”

MAP Brief August 2016

Best practices and promising technologies that can be used now to enhance concrete paving

Real-Time Smoothness Measurements for Portland Cement Concrete Pavements

Introduction

Pavement smoothness is one of the most important factors affecting user (driver) satisfaction. As far back as the AASHTO Road Test it has been recognized that road users judge the quality of a road primarily based on its ride quality.

However, initial smoothness of a portland cement concrete pavement (PCCP) also has a direct impact on the life of the pavement. According to the findings of Perera, et al. (2005), “... pavements that are built smoother will provide a longer service life before reaching a terminal roughness value, compared to pavements having a lower initial smoothness level.”

Therefore, from both a user and a life-cycle cost perspective, it is desirable to construct smooth PCCP. The use of real-time smoothness equipment can assist the contractor in improving the initial smoothness of PCCP.

Real-Time Smoothness (RTS) Systems

There are currently two systems commercially available for measuring PCCP smoothness in real-time: Ames Real-Time Profiler (RTP), and Gomaco Smoothness Indicator (GSI). The Ames unit is a laser-based sensor combined with a ruggedized

laptop (figure 2). The Gomaco unit uses sonic sensors and a dedicated computer (figure 3). Both are configured similarly with sensors mounted to the back of the paver to measure the pavement profile and send it to the data collection hardware and software for processing and display in real-time (figure 1).

The primary difference between the systems is the sensor technology used, the GSI uses acoustic (ultrasonic) sensors and the RTP uses lasers. When mounted to the back of the paver, both systems capture profile data by measuring the height of the sensor relative to the fresh pavement directly behind the paver (typically 6 in. to 12 in. behind the pan or trailing pan).

Both systems use a combination of height, slope, and distance data that is continuously fed to the software where it is converted to a real-time profile and smoothness statistics (IRI, PI, must grinds, and localized roughness). Distance data is collected using a calibrated bicycle wheel, a wheel mounted to a paver track, or an internal encoder

Each of these systems underwent a thorough independent evaluation as part of the SHRP2 R06E project *Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction* (Rasumssen et al. 2013). Findings from



Figure 1. Diagram of a real-time smoothness system

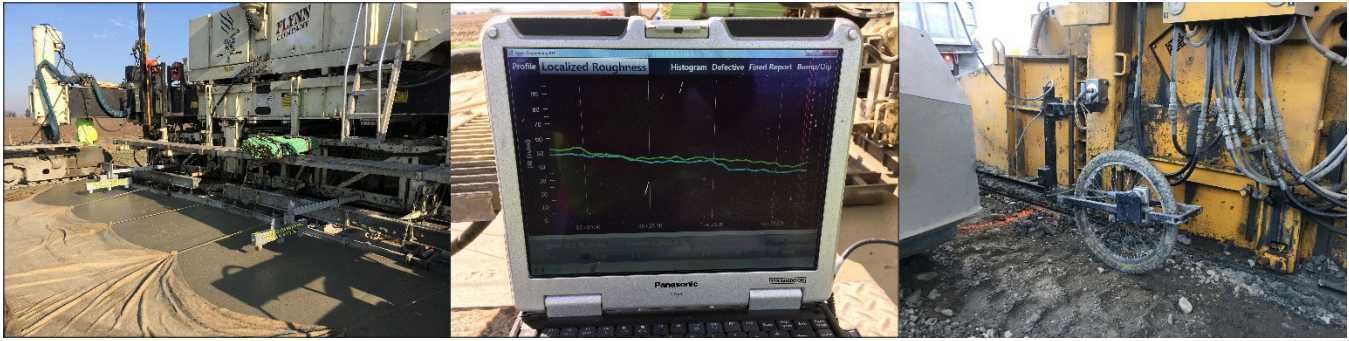


Figure 2. Ames RTP system installed on a paver (from the left: RTP sensors mounted at the back of the paver, computer showing real-time smoothness information, and bicycle wheel collecting distance data)

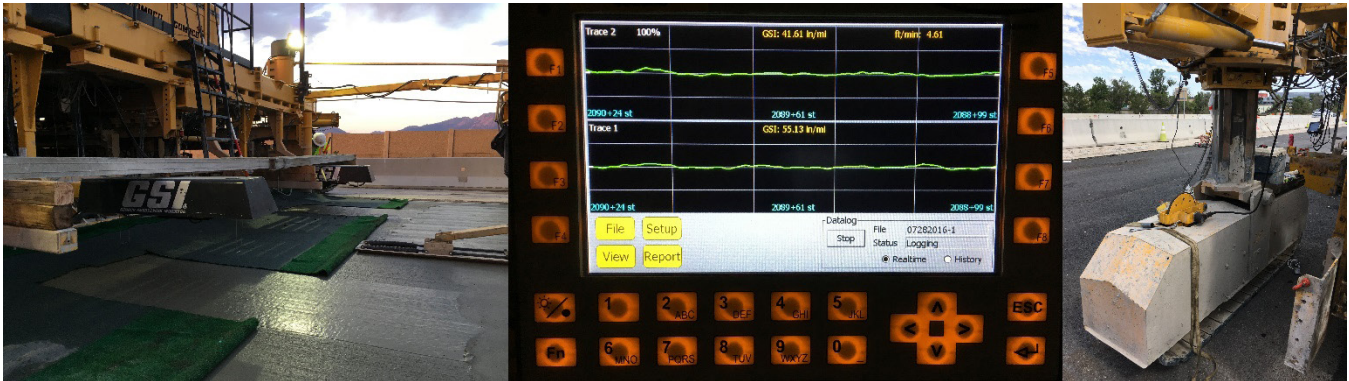


Figure 3. Gomaco GSI system installed on a paver (from the left: GSI sensors mounted at the back of the paver, computer showing real-time smoothness information, and wheel mounted to the paver track collecting distance data)

this project concluded that both systems demonstrated their value as a quality control (QC) tool for the contractor in assessing initial pavement smoothness and providing real-time feedback for process adjustments.

Based on these findings, the Federal Highway Administration (FHWA) nominated this technology for SHRP2 implementation funding. In cooperation with FHWA, The National Concrete Pavement Technology Center (CP Tech Center) has been involved in furthering the implementation of real-time smoothness by exposing contractors to the technology through equipment loans and workshops designed to help contractors realize the benefits of this tool for improving the initial smoothness of PCCP.

Benefits of Using Real-Time Smoothness Systems

When properly implemented into the contractor's paving operation, real-time smoothness systems provide valuable feedback that allows the contractor to adjust their processes to improve the initial smoothness characteristics (overall smoothness and localized roughness) of the new PCCP.

While profilographs and lightweight inertial profilers have traditionally been used for quality control and quali-

ty assurance (acceptance level) smoothness measurements, the paver must have adequate strength and all sawing must be completed before they can be operated on the pavement surface, resulting in a minimum 12- to 24-hour delay in the feedback on smoothness numbers. Real-time smoothness systems provide the same profile information as the profilograph and inertial profiler, but in real-time during paving. It should be noted that these systems are not intended for, and should not be used for, acceptance measurements. (See Real-Time IRI vs. Hardened IRI page 4 for further details).

However, having this information in real-time allows the contractor to make process adjustments sooner and allows for corrections to be made during finishing, providing the contractor the opportunity to construct smoother pavements.

The primary process adjustments that can be validated by use of these systems include but are not limited to:

- Tuning the paver—there are numerous adjustments and operational characteristics of slipform pavers that impact pavement smoothness (see the following section for more detail).

Mixture adjustments aimed at improving the overall workability and/or edge stability.

In addition, localized roughness caused by major profile

events (e.g., loss of vertical control, paver stops, etc.) resulting in dips and bumps that need to be corrected by hand finishing can be identified using real-time smoothness systems. The effectiveness of the correction made by hand finishing is a matter of workmanship, there is no real-time verification for this process.

The power of these systems to improve the initial smoothness of PCC pavements lies in the timely use of profile information. No improvement to smoothness occurs by installing a system on a paver; improvements are only possible when the crew members embrace the technology and act on the feedback provided in real-time.

Using Real-Time Smoothness Systems

Through the experience gained from the equipment loans, the CP Tech Center team has developed recommendations for contractors who are interested in using these systems. This four step implementation process includes:

1. Establish a baseline—monitor the process.
 - a. Install a real-time smoothness system.
 - b. Monitor results for 1 to 2 days.
 - c. Keep processes static, but make ordinary adjustments (mixture, vibrators, paving speed, head, etc.).
 - d. Observe typical responses to the ordinary adjustments and make notes or add event markers in the RTS.
2. Eliminate large events—actively utilize the real-time system to reduce the impact of major profile features.
 - a. Stringline/stringless interference.
 - b. Paver stops.
 - c. Padline issues.
 - d. Other mixture or process impacts.
3. Fine-tune the paving process—utilize the real-time feedback when making intentional adjustments to the processes.
 - a. Paver adjustments.
 - i. Maintaining/adjusting concrete head in the grout box.
 - ii. Adjusting the angle of attack of the paver—setting the longitudinal profile of the slipform mold as flat as practical relative to the roadway profile.
 - iii. Hydraulic and stringless sensitivities.
 - iv. Vibrators (height and frequency).
 - v. Paving speed.
 - b. Concrete mixture adjustments to improve overall workability, finishing properties and/or edge stability.
 - i. Aggregate proportions.
 - ii. Admixture dosages.
 - iii. Water:cementitious materials (w/cm) ratio (note: w/cm ratio should never be adjusted above the approved mix proportions).

- iv. Total mass of cementitious materials.
- v. Ratio of supplementary cementitious materials to portland cement.

4. Identify repeating profile features using the power spectral density analysis (PSD) in ProVAL and use the real-time system to mitigate the roughness from these features. The PSD function of road profiles is a statistical representation of the importance of various wavelengths. It provides valuable information regarding what repeating wavelengths are contributing to pavement roughness.
 - a. Doweled joints.
 - b. Dumping/Spreading loads.
 - c. CRCP bar supports.

Lessons Learned from Real-Time Smoothness Equipment Loans

Six real-time smoothness equipment loans have been completed by the CP Tech Center as part of the SHRP2 Technology Implementation program. A sampling of the lessons learned from utilization of the real-time smoothness systems on these projects in Idaho, Iowa, Nebraska, Michigan, Pennsylvania, and Texas shows the potential benefit of utilizing real-time profile feedback.

Pennsylvania

The Gomaco GSI was utilized in this real-time smoothness equipment loan in October/November of 2015 on the northbound lanes of I-81 near Pine Grove, PA (figure 4). Paving was 24 ft. wide and consisted of two typical sections: 8 in. thick JPCP unbonded overlay and 13 in. thick JPCP reconstruction sections.



Figure 4. Paving on I-81 in central Pennsylvania

Real-Time IRI vs. Hardened IRI

It should be noted that for multiple reasons, and in almost all cases, the IRI measured by real-time smoothness equipment will be higher than when the hardened slab is measured by an inertial profiler. This difference does not invalidate the real-time measurements, users should simply focus on making the real-time IRI lower and the hardened IRI will follow (initial pavement smoothness is improved). The project on I-81 provided good examples of the properties of real-time and hardened profiles.

Figure 5 shows the profile data for a section of I-81 from September 28, 2015, where the real-time IRI is 20 in./mile greater than the hardened IRI measured using a lightweight inertial profiler. Even though the IRI results between real-time and hardened profiles are different, the data shows that they parallel each other closely, indicating that the difference is not entirely due to RTP measurement error.

Building upon the previous observations a power-spectral-density (PSD) plot from 28SEP2015 (figure 6) shows differences between the wavelengths contributing to roughness in the passing lane for the GSI real-time data and hardened data. Peaks shown in PSD plots identify the wavelengths associated with pavement roughness and do not correlate directly to IRI values. The following observations can be made from this PSD analysis:

- i. Shorter wavelength roughness in the hardened profile is likely from macrotexture (burlap drag and tining) applied behind the GSI sensors.
- ii. Real-time roughness at the 5 ft. wavelength was significantly reduced by hand finishing.

- iii. Joint spacing had a 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.
- iv. The source of roughness present in the hardened profile at longer wavelengths needs additional investigation.

For this project, the majority of the differences between real-time and hardened profiles can be attributed to hand finishing, measurement error and slab curling/warping. Each project is unique, these differences should be analyzed to help identify areas for improvement on a project-by-project basis.

Idaho

Taking place in April of 2015, this equipment loan utilized an Ames RTP on I-84 in Boise, Idaho. The typical section was 12 in. thick JPCP, paving was 24 ft. wide (figure 7).

Truck Load Influence

On April 21, the RTP picked up a ~10.5 ft. feature that was determined to be related to concrete load spacing, which averaged 10.6 ft. (with a standard deviation of 2 ft.). This feature was also reflected in the hardened profile, and was more dominant than the joint spacing in the PSD plot. This content was not noticeable for any of the other days of paving.

A PSD analysis from first part of April 21 is provided in figure 8.

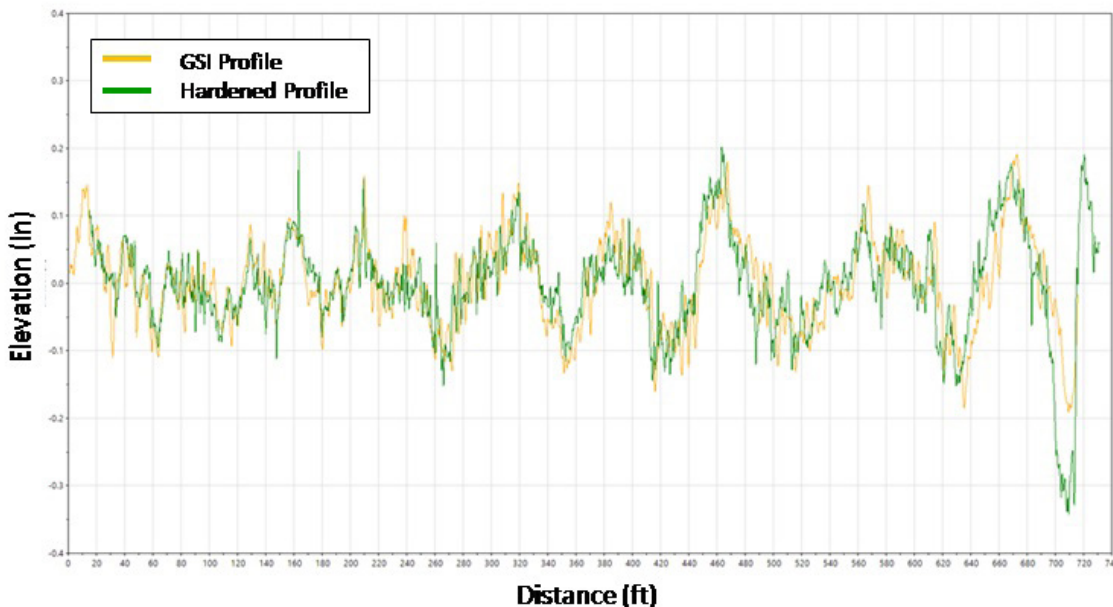


Figure 5. Comparison of real-time profile (GSI) and hardened profile (I-81)

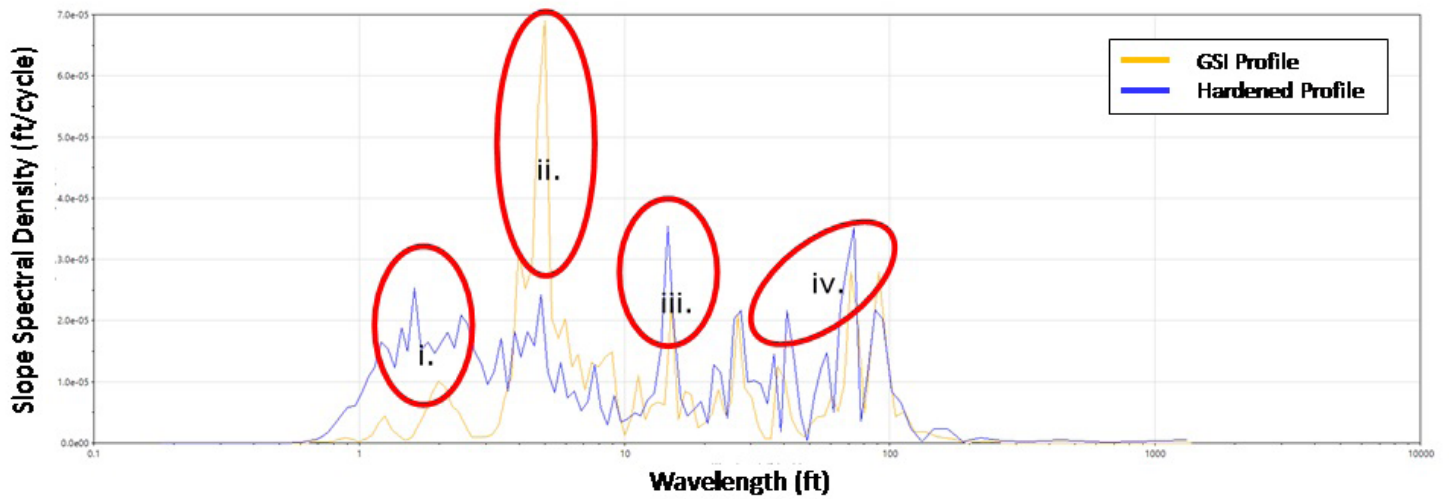


Figure 6. PSD analysis of real-time profile (GSI) and hardened profile



Figure 7. Paving on I-84 in Boise, Idaho

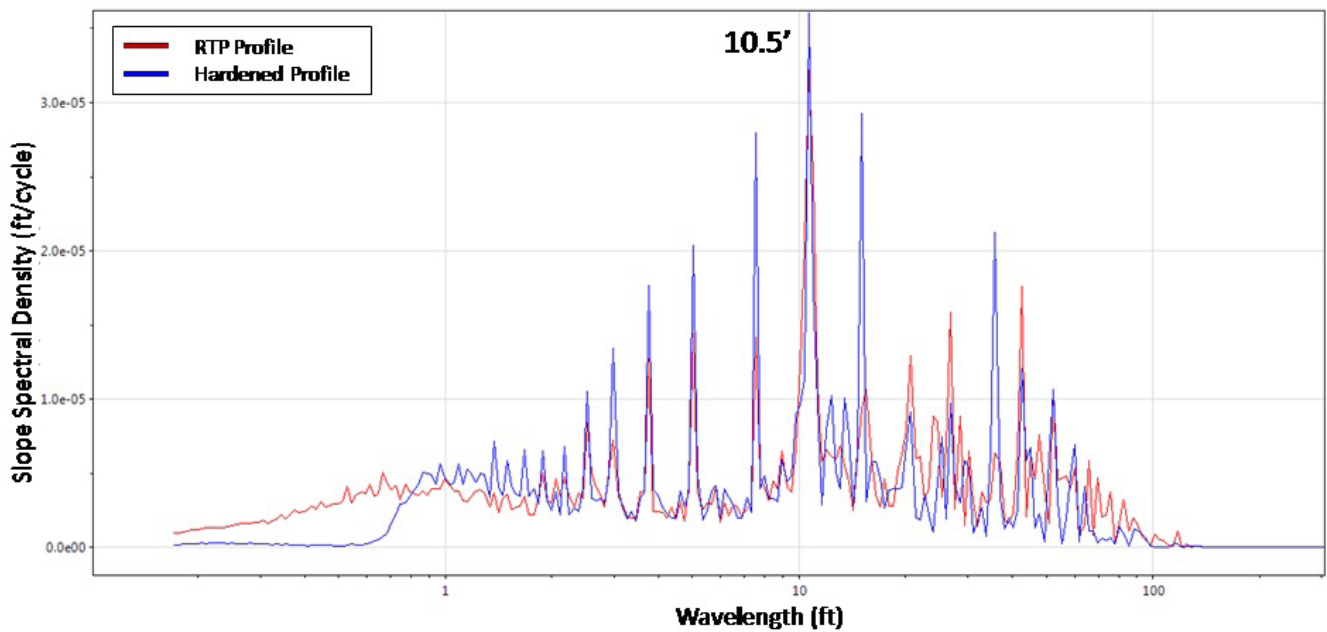


Figure 8. PSD analysis of real-time profile (GSI) and hardened profile

Nebraska

A project on I-80 on the west side of Lincoln, Nebraska utilized an Ames RTP for a real-time smoothness equipment loan. The typical section consisted of 13 in. thick JPCP, paving was 24 ft. wide (figure 9).

Influence of Concrete Head

May 11 was the first day of paving on I-80 where the RTP was used. As a matter of practice, the CP Tech Center team requested that the contractor leave their operations unchanged for the first day while they familiarized themselves with operating the RTP. The next day of paving was May 13, 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 11.

Figure 10 shows continuous IRI results (25 ft. segment length) for both days (the red line is an arbitrary action limit of 125 in./mi). The results from May 13 showed a 20% reduction in IRI despite the fact that it was only 400 ft. long.



Figure 9. Paving on I-80 in Lincoln, Nebraska

Conclusion

Given that concrete pavements that are constructed smoother stay smoother longer, efforts should be taken to improve the initial smoothness of newly constructed PCCP. The use of real-time smoothness equipment during construction provides valuable information to the contractor regarding initial smoothness; and, because the feedback is instantaneous, this gives them confidence (lowers the risk) to adjust their processes to achieve smoother PCCP. Ultimately, the use of tools such as RTS will help contractors and agencies save money and improve user satisfaction.

For more information, contact:

- Gary Fick, trinity construction management services, inc., g fick@trinity-cms.com
- David Merritt, The Transtec Group, Inc., dmerritt@thetranstecgroup.com
- Stephen Cooper, Federal Highway Administration, Stephen.J.Cooper@dot.gov

References

1. Perera R., Kohn S., and Tayabji S. 2005. "Achieving a High Level of Smoothness in Concrete Pavements without Sacrificing Long-Term Performance." Soil and Materials Engineers, Inc. Final Report for FHWA project No. DTFH61-01-C-00030, FHWA.
2. Rasmussen R., Torres H., Sohaney R., Karamihas S., Fick G. 2013. "Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction." The Transtec Group, Inc. Final Report for SHRP2 project No. R06E, TRB.

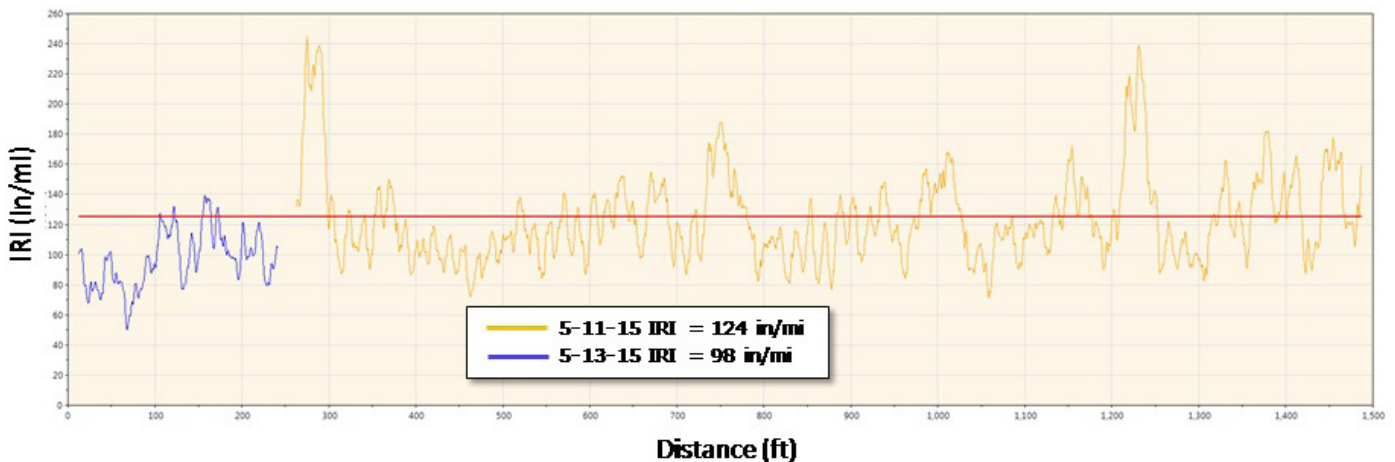


Figure 10. IRI localized roughness (25 ft. base length) showing smoother pavement related to a smaller and more consistent head of concrete