INTELLIGENT COMPACTION BRIEF
February 2012

Iowa US218—HMA Resurfacing—Aug-Sept 2009

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RESEARCH PROJECT TITLE
Iowa DOT Intelligent Compaction Research and Implementation – Phase I

SPONSOR
Iowa Department of Transportation

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MORE INFORMATION
http://www.iowadot.gov/research/pdf/newsnovember2010.pdf
http://www.ceer.iastate.edu/research/project/project.cfm?projectID=-225718242

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Objectives

The objective of this field demonstration project was to evaluate Sakai's roller-integrated compaction measurement (RICM) system on a SW880 dual smooth drum vibratory roller for use in hot-mix asphalt (HMA) construction. The following research tasks were established for the study:

- Evaluate the effectiveness of the compaction control value (CVV) RICM values in assessing the compaction quality of HMA materials.
- Develop correlations between CCV temperature, and in-situ point test measurements such as nuclear gauge total density, and falling weight deflectometer (FWD) modulus.
- Evaluate the advantages of using the technology for production compaction operations (e.g., uniformity in pass coverage).
- Obtain data to evaluate future RICM specifications.
- Develop content for future educational and training materials for Iowa DOT and contractor personnel.

Project Description

This demonstration project was one of the three projects conducted as part of this research (White et al. 2010) and was located on US218, south of I-80 in Coralville, Iowa. The project involved construction of HMA overlay over the existing PCC surface.

The HMA base course layer was compacted using two Sakai dual drum rollers in the breakdown position. Of the two rollers, one Sakai roller was equipped with the RICM system. The compaction monitoring system involved recording roller pass coverage, surface temperature, CCV, vibration settings, etc/, and displaying data in real time on the on-board display monitor located in front from the roller operator.

All the measurements were linked to a real-time kinematic (RTK) global positioning system (GPS) to provide a continuous record of the data. The ISU research team was present on-site periodically during paving operations for three days (08/31/2009 to 09/02/2009). A photo of construction operations is shown in Figure 1.

Figure 1. Paving operations on US218 project (from White et al. 2010)

On day 1, the compaction monitoring system on the roller was switched on but the on-board display monitor was closed for viewing by the operator. On days 2 and 3, the roller operator was allowed to use the on-board display to aid in "uniform" roller pass coverage. The roller operator was instructed to perform four passes (two forward and two reverse passes). The two Sakai rollers on the project were generally following each other resulting in a total of eight roller passes (note that compaction monitoring was available on only one roller).

On day 3, in-situ relative compaction using nuclear density gauge, Kuab FWD modulus testing, and asphalt surface temperature measurements using a thermal imaging camera (FLIR) and a infrared camera mounted on the FWD trailer, were obtained. Measurements were obtained on mainline and paving over the existing shoulder lane. Correlations between CCV measurements and in-situ relative compaction and FWD modulus E_{FWD} values have been developed

Test Results and Analysis

FLIR thermal images showing spatial variation in the asphalt surface temperatures are presented in Figure 2. Example roller pass coverage maps from days 1 and 2 are presented in Figure 3 and example CCV coverage maps for days 1 and 2 are presented in Figure 4. Histogram plots of roller pass coverage data, temperature, and CCV data obtained from days 1, 2, and 3 are presented in Figure 5. The histogram plots did not reveal any significant differences in the number of roller passes, temperature, and CCV from the three days. To further analyze any differences in the "uniformity" of pass coverage between days 1 to 3, geostatistical semivariograms of number of roller passes are developed as shown in Figure 6. The semivariograms indicate improved uniformity in pass coverage on day 3 compared to day 1. This is a significant finding which provides quantitative evidence of improvement in compaction operations by viewing the data in real time.

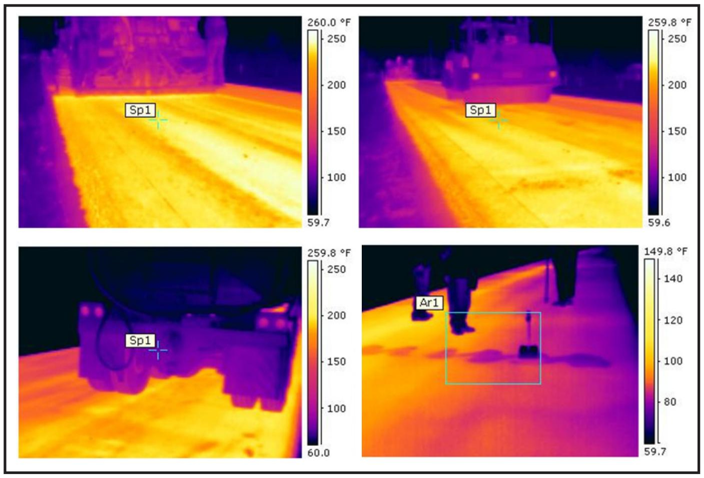

Figure 2. FLIR thermal images: in front of paver (top left), in front of break down roller (top right), behind water truck during finish rolling (bottom left), and nuclear gauge testing on the final compacted surface (bottom right) (from White et al. 2010)

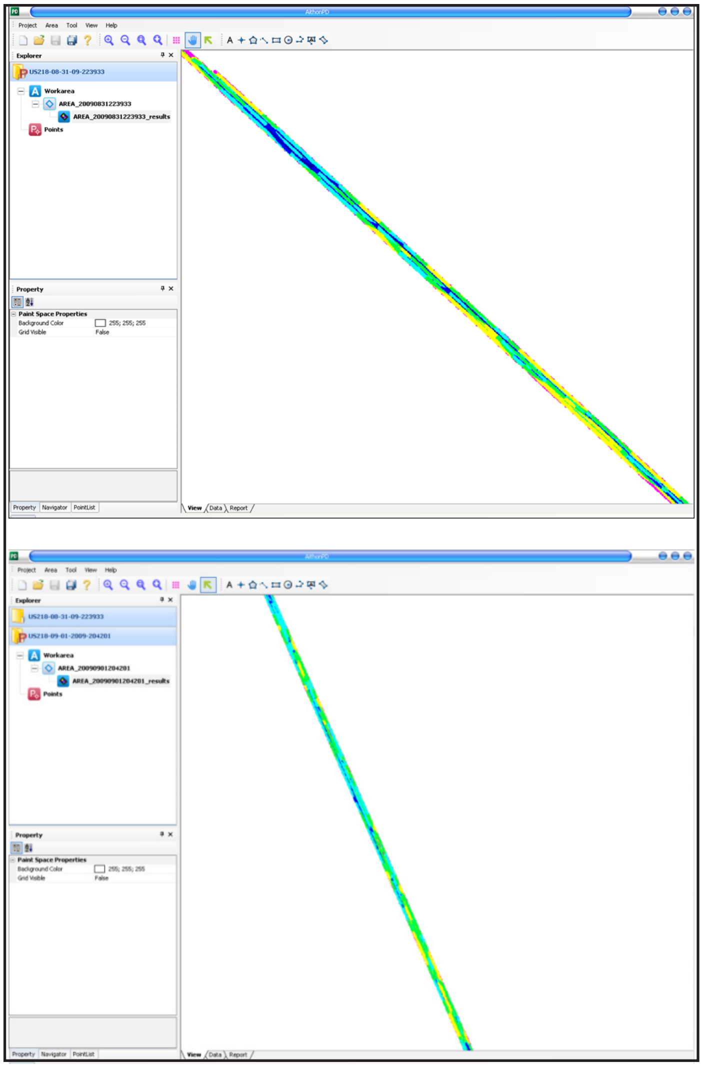

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Figure 3. Pass coverage maps from day 1 (top—between mile posts 95 and 97) and day 2 (bottom—between mile posts 92 and 95) (from White et al. 2010)

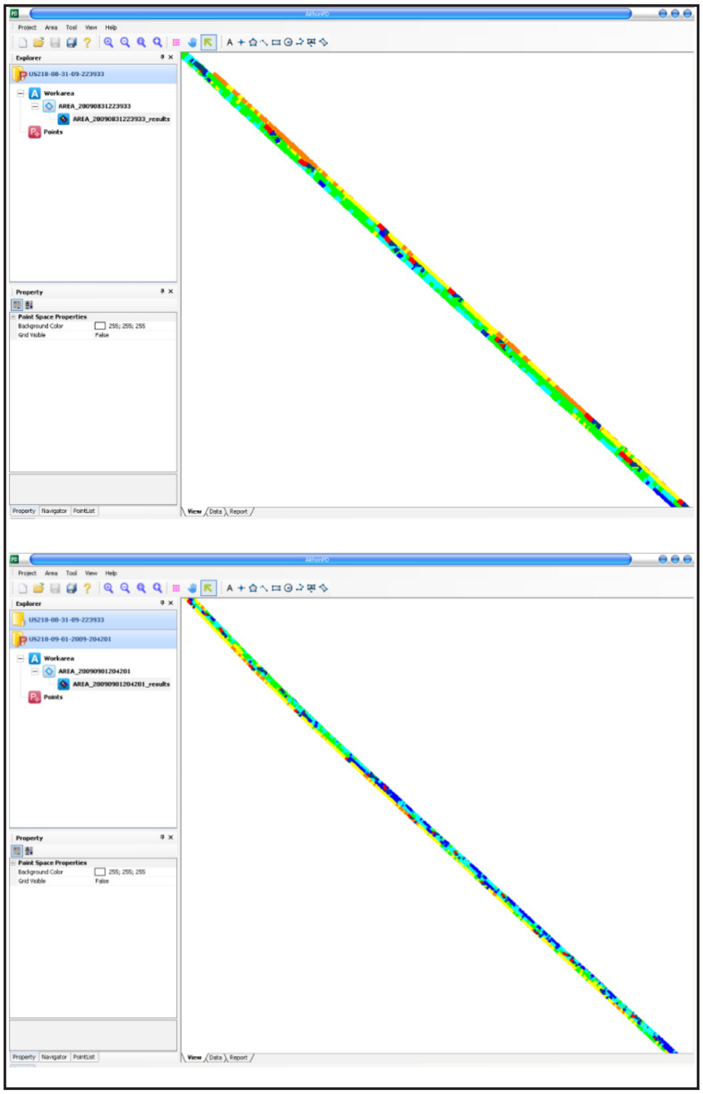

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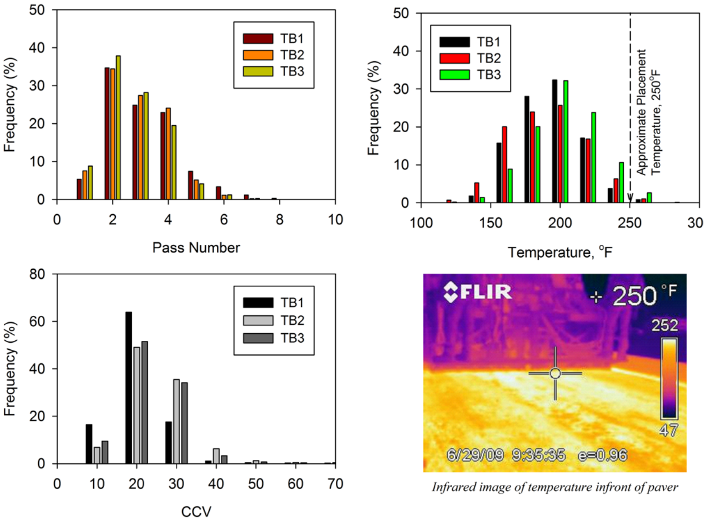
Figure 4. CCV maps from day 1 (top—between mile posts 95 and 97) and day 2 (bottom—between mile posts 92 and 95) (from White et al. 2010)



Infrared image of temperature infront of paver

Figure 5. Histogram plots of number of passes, measured temperature, and CCV measurements from the IC rollers from TBs 1, 2, and 3 (from White et al. 2010)

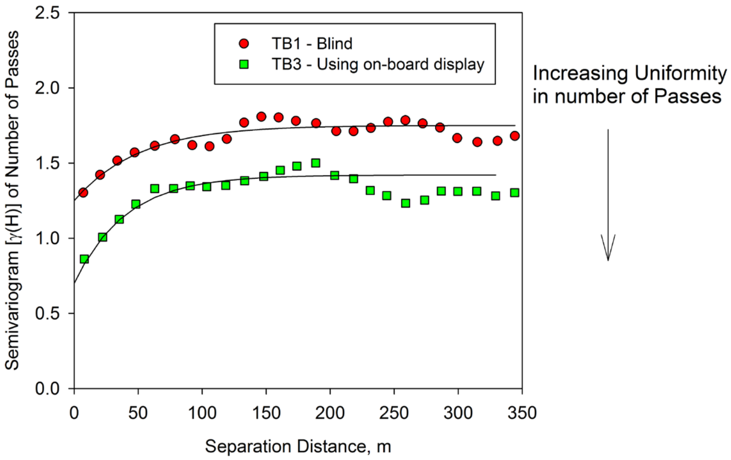


Figure 6. Comparison of semivariogram of number of roller passes from day 1 (TB1—blind study) and day 3 (TB3—with aid of on-board monitor) assessing uniformity in pass coverage (from White et al. 2010)

FLIR temperature (T_{FLIR}) and relative compaction measurements were obtained at two locations with several measurements across the pavement width (including mainline and shoulder) at each location. These results are presented in Figure 7 along with the CCV map at one test location.

Relative compaction, E_{FWD}, and T_{FLIR} in-situ test measurements obtained at several locations along a stretch of about 1.3 km on mainline and shoulder lane are compared with roller CCV measurements in Figure 8. Results presented in Figures 7 and 8 indicate that the density, modulus, and CCV were all lower on the shoulder lane compared to the mainline. This is likely because of comparatively weak support conditions under the shoulder lane compared to the mainline.

Correlations between CCV, relative compaction, and E_{FWD} are presented in Figure 9. Correlation between CCV and E_{FWD} showed strong linear regression relationship with $R^2 = 0.8$ compared to correlation between CCV and relative compaction with $R^2 = 0.4$. This is expected as CCV is a result of drum response under vibratory loading which is a measure of the stiffness and not necessarily related to the density of the material. In addition, various other factors influence both roller and in-situ test measurements which include: (a) differences in underlying support conditions; (b) differences in measurement influence depths of each device; (c) temperature at the time of the measurement; and (c) direction of roller travel.

The influence of differences in underlying support conditions is clearly reflected with data groupings in the correlations Figure 9. Further analysis revealed that CCV and E_{FWD} measurements are influenced by temperature – note that these temperature measurements are obtained at the time the in-situ test measurements were obtained while CCV were obtained at a different time.

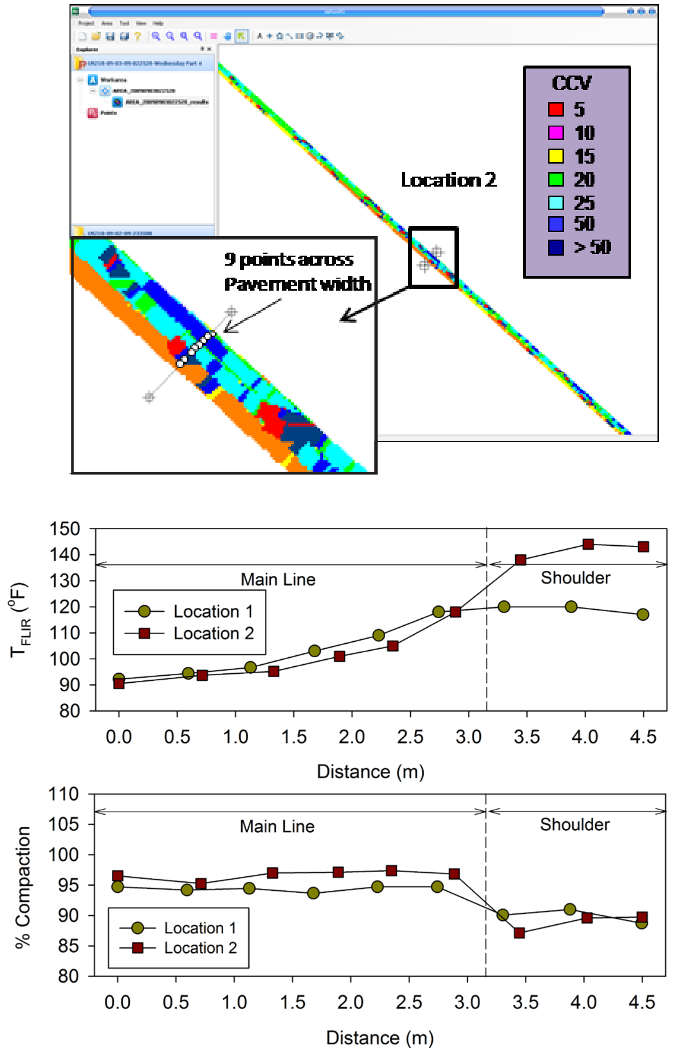


Figure 7. Comparison of semivariogram of number of roller passes from day 1 (TB1—blind study) and day 3 (TB3—with aid of on-board monitor) assessing uniformity in pass coverage (from White et al. 2010)

Summary of Key Findings

- Univariate statistics of pass count information on each day did not reveal any differences between day 1 (blind study) and days 2 and 3. Geostatistical semivariogram analysis of pass count information revealed quantitative evidence of improved spatial uniformity in pass coverage on day 3 compared to on day 1.
- Due to greater HMA layer thickness on the shoulder compared to the mainline, the surface temperature of HMA on the shoulder lane was on average about 19°F warmer than the temperature of the HMA on the mainline. The RC of the HMA layer was on average about 6% lower on the shoulder compared to the mainline.
- FWD modulus and CCV measurements on the shoulder lane were lower than on the mainline. This is likely because of weaker support conditions under the shoulder lane compared to the mainline.

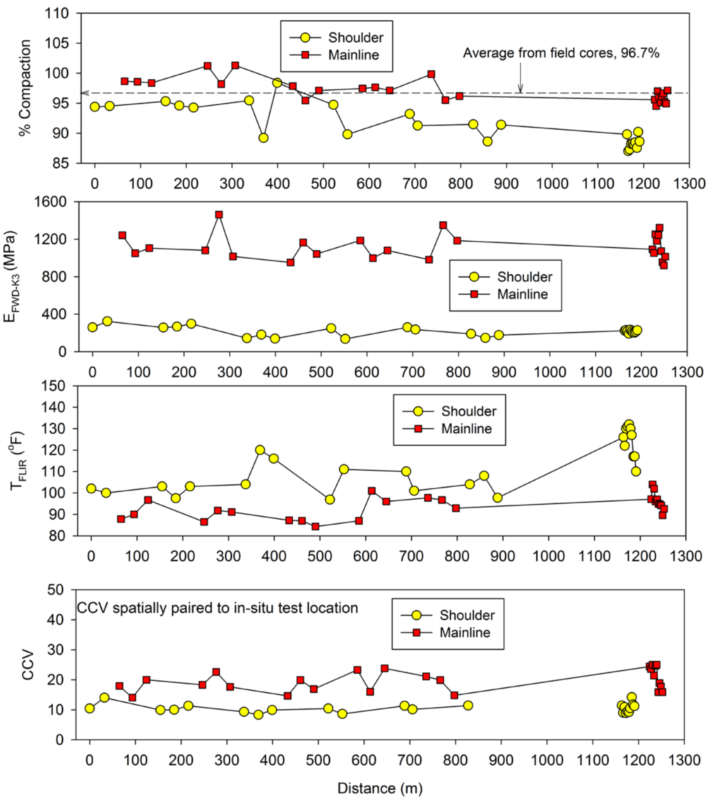


Figure 8. Comparison of CCV, percent compaction, E_{FWD-K3}, and TFLIR along shoulder and mainline (from White et al. 2010)

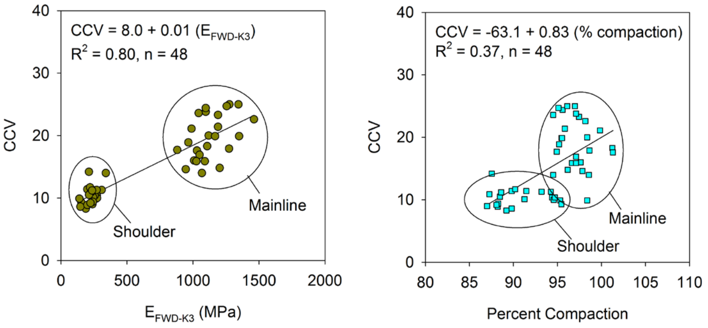


Figure 9. Correlations between CCV, E_{FWD-K3}, and percent compaction (from White et al. 2010)

- Correlation between CCV and FWD modulus showed a relatively strong linear regression relationship with $R^2 = 0.8$ compared to correlation between CCV and relative compaction with $R^2 = 0.4$. This should be expected as CCV is a result of drum response under loading which is a measure of material stiffness and not necessarily related to the density of the material. The regression relationships are influenced by differences in underlying support conditions as it was clearly reflected with data groupings (with separate groups for shoulder lane and mainline measurements) in the correlations. Results indicated that the CCV, RC, and FWD modulus measurements are influenced by temperature.

Reference

White, D.J., Vennapusa, P., and Gieselman, H. (2010). *Iowa DOT Intelligent Compaction Research and Implementation—Phase I.* Final Repoart ER10-06, Iowa State University, Ames, Iowa.