Iowa US30—Hot-Mix Asphalt Overlay—July 2010

PROJECT DATE/DURATION
July 12 to 27, 2010

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

SPONSOR
Iowa Department of Transportation

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

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Project Summary

The US30 project is about 8.1 miles long and is located between Dunlap, Iowa and Dow City, Iowa (between mile posts 38.38 and 46.12). A special provision (SP) was developed to implement roller-integrated compaction monitoring (RICM) technology on this project: "Intelligent Compaction–HMA, Harrison County, NHSN-030-1(127)--2R-43 (Effective January 20, 2010) [SP-090048]." The project involved milling the existing pavement to about 38 mm (1.5 in.), and resurfacing with 51 mm (2 in.) of hot-mix asphalt (HMA) intermediate course and 51 mm (2 in.) of HMA surface course layers. HMA resurfacing was performed in the mainline over a width of about 24 feet and over the shoulder extending about 4 feet on each side.

Compaction of the HMA layers was achieved using a Sakai SW990 smooth-drum roller in the breakdown position, followed by Hamm GRW18 pneumatic rubber-tire roller, and a Caterpillar CB-6346 smooth-drum roller for final passes. Only the Sakai SW990 smooth-drum roller was equipped with a RICM system. Sakai's RICM system recorded and displayed the spatial position of the roller (i.e., GPS northing, easting, and elevation), roller pass coverage, surface temperature, compaction control value (CCV), vibration mode, etc. in real time to the roller operator through an on-board display unit. Compaction using the SW990 roller was achieved in vibratory mode using a low amplitude setting (0.33 mm) and a frequency setting of 50 Hz (3000 vpm). Screen shots of roller pass coverage, temperature, and CCV maps from the RICM software are shown in Figures 1 to 3, respectively.

Beyond the quality control (QC) or quality assurance (QA) testing required in the project specifications, a total of fourteen production test sections (PSs) were tested

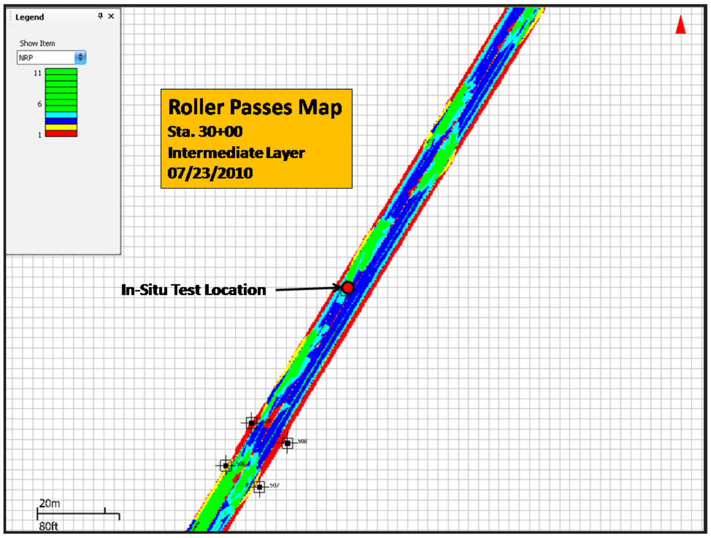

Figure 1. Roller pass coverage map at Sta. 30+00 intermediate course layer (from White et al. 2010)

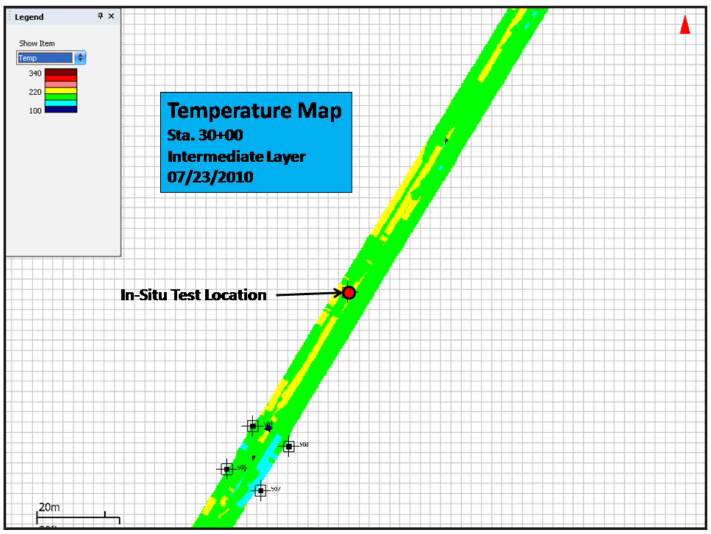

Figure 2. Surface temperature coverage map at Sta. 30+00 intermediate course layer (from White et al. 2010)

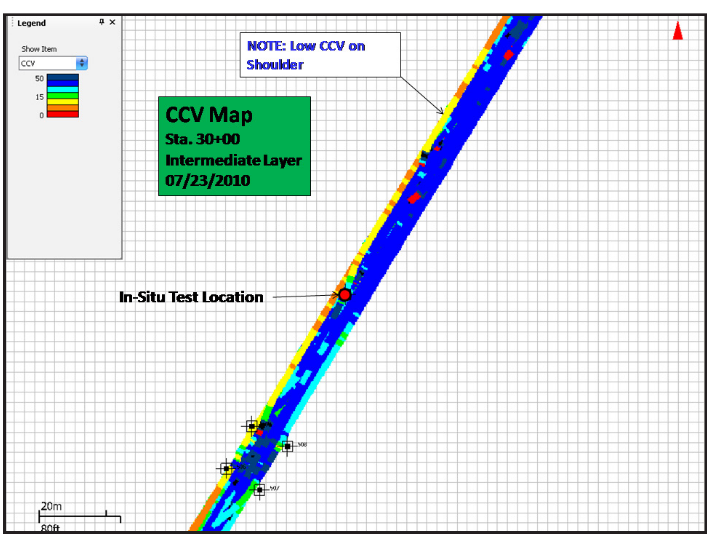

Figure 3. Roller CCV coverage map at Sta. 30+00 intermediate course layer (from White et al. 2010)

on the project site. A Troxler nuclear gauge was used to obtain percent compaction measurements on the HMA layers. HMA surface temperature measurements were obtained using a FLIR thermal camera (T_{FLIR}) and the infrared camera mounted on the RICM roller (T_{Roller}). Density and surface temperature measurements were obtained before and after multiple roller passes (e.g., 0, 1, 2, 3, etc.) to evaluate their changes with increasing passes and time. In addition, FWD tests were obtained on the existing milled asphalt base layer prior to and after placement of the intermediate layer at few test locations. FWD tests were performed to evaluate the influence of support conditions on the roller-integrated CCV measurements, which presumably have deeper influence depths (e.g., up to > 1 m).

Project Special Provisions and Costs

The SP090048 described the contractor's responsibilities to furnish the RICM rollers, data acquisition, and other key attributes related to equipment and materials, construction, data acquisition and submittals, method of measurement, and basis of payment. As part of the SP, the contractors were required to collect the RICM data for research purposes, and the data were not used for QC or QA. However, the SPs required that the RICM data be collected over a minimum of 80% of the project intermediate and surface course layers to request full payment.

Contract bid costs submitted for this project are summarized in White et al. (2011). The bid item cost (for all bidders) for implementing the SP on this project varied from about 0.7% to 3.6% of the total project cost, while the bid unit cost/mile (for all bidders) varied from about $494 to $18,541.

Summary of Key Findings

- The RICM-HMA SP-090048 was successfully implemented on the US30 Harrison County pilot project. Evaluation of RICM data coverage information indicated that the RICM data were collected over 85% of the project area on the intermediate course layer and over 95% of the project area on the surface course layers, thus conveniently exceeding the minimum 80% requirement in the SP.
- Field core density results indicated that 115 out of 117 samples exceeded the target minimum 95% compaction requirement.
- Percent compaction curves indicated that 95% compaction was generally achieved within 1 to 2 break-down roller passes at most locations, with exceptions at few locations where up to four passes or more were required (for an example, see Figure 4).

- Roller surface temperature measurements with pass generally indicated that the pass 2 measurement was lower than pass 3 (note that the rolling pattern included forward, reverse, and forward directions of travel for passes 1, 2, and 3). The temperature sensor on the roller was located on the front drum of the roller, and water sprayed on to the roller drum likely caused a reduction in the surface temperature values when the roller traveled in the reverse direction.
- Asphalt temperature cooling rate (Cγ) was modeled using an exponential statistical model from surface temperature with time measurements (see Figure 5). For cases where data up to a maximum of 35 minutes were considered, the Cγ values ranged from about -0.0090 to -0.0157 with an average of about -0.0135 and standard deviation of 0.0022.
- Correlations between CCV and asphalt density or percent compaction measurements yielded relatively low R^2 values in the range of 0.1 to 0.2 (see Figure 6). However, if the measurements for each PS were viewed separately, there was generally a trend of increasing CCV with increasing percent compaction in most sections.
- Poor correlations between density and CCV are to be expected when data are combined over multiple sections, because CCV provides a measure of ground stiffness and is strongly influenced by the conditions of the layer underneath the HMA layer and not necessarily the density of the surface layer. FWD test measurements obtained from the intermediate course layer and the underlying existing base layer confirmed that variable support conditions exist at different test locations. Correlations between the FWD modulus on intermediate course layer and base layer and CCV on the intermediate course layer yielded R^2 values in the range of 0.5 to 0.9 (Figure 7). Results presented during Phase I of this research (White et al. 2010) also corroborate this finding. This research finding is critical to understand, as it has practical consequences in terms of how roller-integrated CCV data can be used for QC or QA in future specifications.
- Correlation between T_{Roller} and T_{FILR} indicated that there was no statistically significant correlation between the two measurements; however, about 29 of the 35 measurements were close to the 1:1 line, and the measurements were, on average, comparable to each other.
- Based on field observations and conversations with the roller operator, it was understood that the roller operator targeted 3 to 4 roller passes using the breakdown roller. Roller coverage data indicated that the average number of breakdown roller passes on the project was about 3, with a standard deviation of about 1 to 2. Geostatistical analysis of pass count indicated that the sill values varied from about 2.4 to 3.6 and the range values varied from about 9 to 20 m (see Figures 8 and 9). These sill values were higher than observed in Phase I on the US218 project (~1.3) described in White et al. (2010) and on the US20 project (~0.6) described in White et al. (2011). The high sill values on the US30 project compared to the US218 and US20 projects indicates that the pass coverage was more variable on the US30 project.

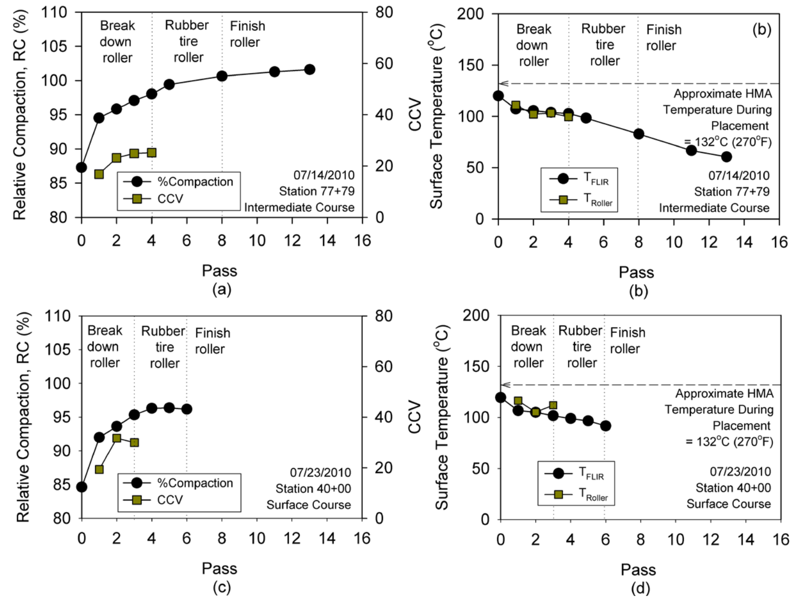

Figure 4. (a) Relative compaction versus pass count on intermediate course layer at Sta. 77+79, (b) Surface temperature versus pass count on intermediate course layer at Sta. 77+79, (c) Relative compaction versus pass count on surface course layer at Sta. 40+00, and (d) Surface temperature versus pass count on surface course layer at Sta. 40+00 (from White et al. 2010)

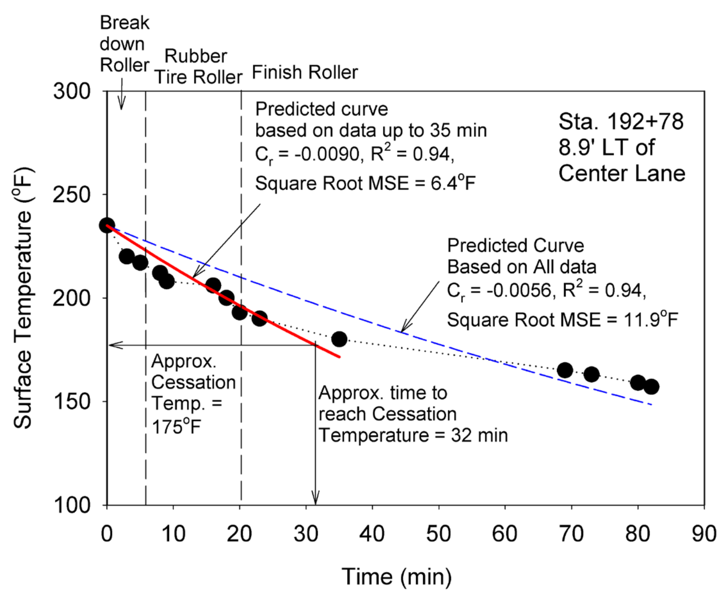

Figure 5. Surface temperature and percent compaction measurements with time at four test locations – US30 Harrison county project surface course layer (from White et al. 2010)

Field observations indicated that the number of passes made by the breakdown roller was governed heavily by the pace of the paver ahead of the breakdown roller.

- Average CCV ranged from 20 to 30 on intermediate course and 22 to 33 on surface course layers. Average surface temperature at the end of breakdown roller pass ranged from about 215°F to 225°F on surface and intermediate course layers.

References

White, D.J., Vennapusa, P., Harland, J., and Quist, S. (2011). “Iowa Roller Integrated Compaction Monitoring Technology Research and Implementation—Phase II,” ER11-01, Iowa State University, Ames, Iowa, June.

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

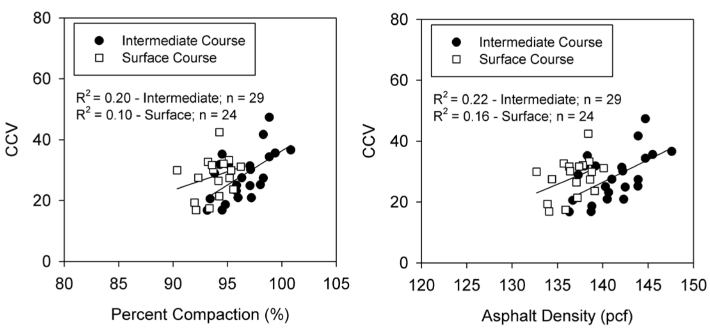

Figure 6. Correlations between in-situ HMA compaction measurements and CCV (from White et al. 2010)

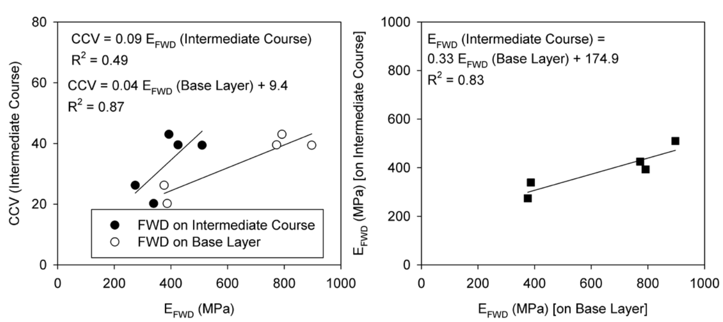

Figure 7. Correlations between CCV on intermediate course layer and FWD modulus (left) and FWD modulus on intermediate course layer and underlying base layer – US30 Harrison county project (from White et al. 2010)

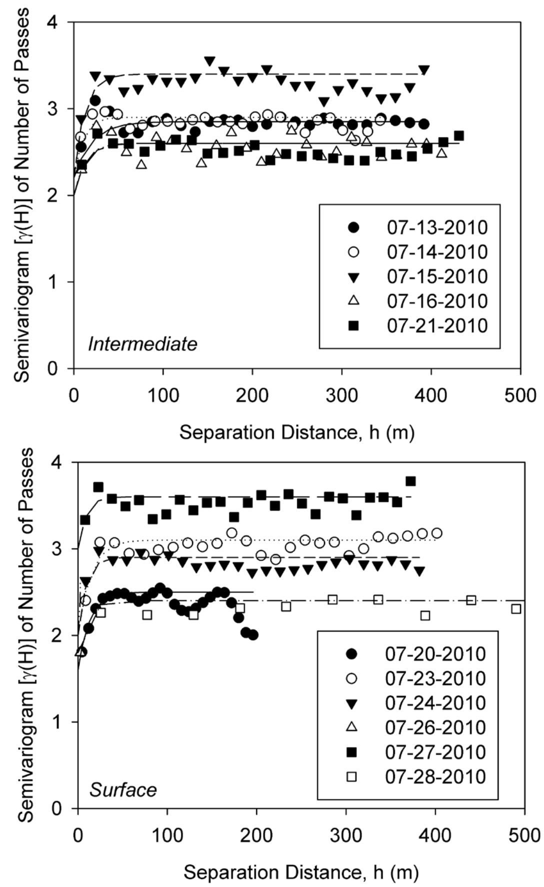

Figure 8. Semivariograms of number of roller passes on intermediate and surface course layers for each day (from White et al. 2010)

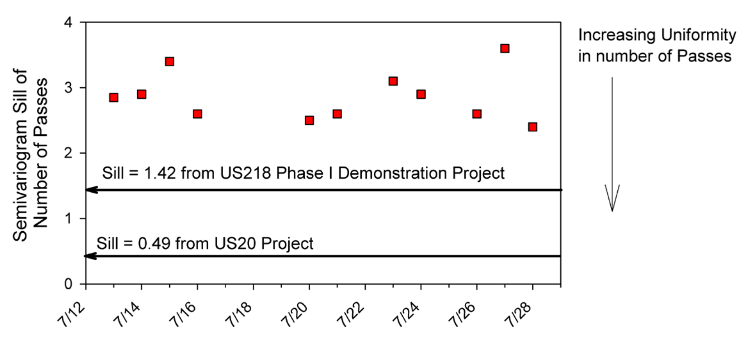

Figure 9. Variation in semivariogram sill of number of roller passes for each day (from White et al. 2010)