INTELLIGENT COMPACTION BRIEF
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Iowa US30—Cohesive Embankment—July 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 the machine-drive power (MDP) based Caterpillar compaction value roller-integrated compaction measurement (RICM) system on CP56 padfoot roller for use in embankment construction with cohesive soils. The following research tasks were established for the study:

- Evaluate the effectiveness of the RICM values in assessing the compaction quality of cohesive subgrade materials.
- Develop correlations between RICM values and in situ test measurements such as dry density, moisture content, elastic modulus, and shear strength.
- Evaluate the advantages of using the technology for production compaction operations.
- 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 three projects conducted as part of this research (White et al. 2010) and was located on US30 between Colo, Iowa and State Center, Iowa. The project involved adding two lanes to the existing highway to make it a four-lane divided highway. Grading work typically included construction of embankment and subgrade layers with “select clay” subgrade treatment in the top 0.76 m (2.5 ft) of the final subgrade elevation. The soils on site consisted of dark clays at the surface underlain by sandy to silty clay soils derived from glacial deposits (Figure 1). Fill materials were obtained from on-site borrow and cut areas along the project alignment. Fill materials were classified as sandy clay (SC) and lean clay to silt (CL-ML). Project specifications required that the moisture content of the material be within ±2% of standard Proctor optimum moisture content.

The project involved construction and testing of one calibration test bed (TB), two spatial areas TBs and one production

Figure 1. Construction operations and in situ soil conditions (from White et al. 2010)

TB with multiple lifts wherein MDP-based RICM values (hereafter referred to as MDP$_{40}$; see White et al. 2010 for description) and in situ point-MVs were obtained. Compaction on the TBs was mostly achieved using the CP56 padfoot roller equipped with the RICM system. Compaction was also achieved using pull-behind sheepsfoot rollers and construction traffic in production areas. In situ light weight deflectometer (LWD), dynamic cone penetrometer (DCP), and nuclear gauge (NG) tests were conducted on each TB. LWD and DCP tests are shown in Figure 2. Correlations between MDP$_{40}$ and in situ point-MVs were developed for each TB by matching the GPS referenced in situ point-MV locations with the spatially nearest GPS-referenced MDP$_{40}$ measurements. Data obtained from each TB were analyzed separately to develop correlations. In the end, data obtained from all the test beds were combined to develop site-wide correlations over a wide measurement range.

Figure 2. Light weight deflectometer test (left) and dynamic cone penetrometer test (right) (from White et al. 2010)

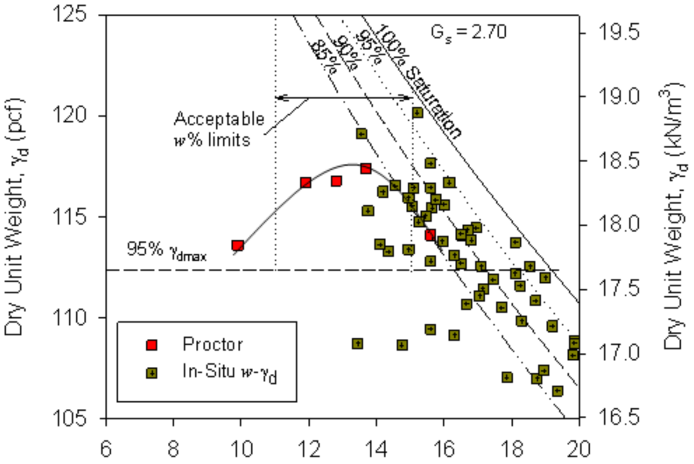


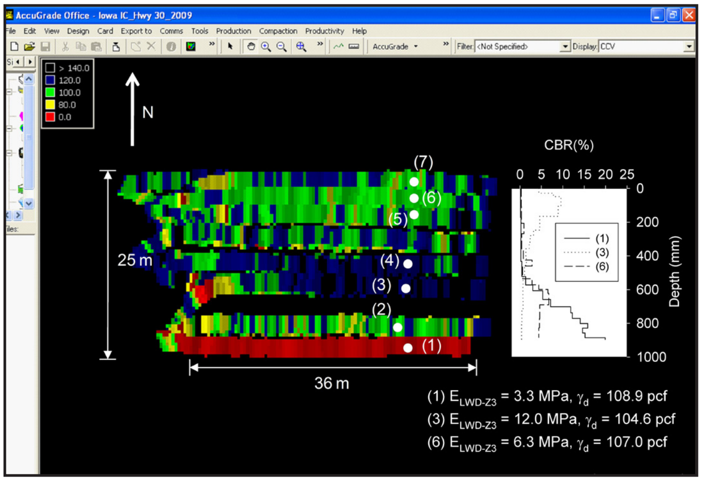
Figure 3. In situ moisture and dry unit weight measurements in comparison with laboratory standard Proctor test data (from White et al. 2010)

Summary of Key Findings

The moisture content of the subgrade materials was generally wet of optimum (about 5% wet of standard Proctor optimum moisture content) and the relative compaction of the materials varied on average (per test bed) from 90% to 97% of standard Proctor maximum dry unit weight (γ_{dmax}) (Figure 3). The material was in wet conditions due to frequent rain events at the time of project demonstration. MDP$_{40}$ compaction curves were affected by roller "off-tracking", i.e., roller operator not maintaining the same track as the previous pass.

MDP$_{40}$ data were able to delineate soft and stiff areas as verified by in situ point-MVs (Figure 4).

Spatial visualization of MDP$_{40}$ maps from multiple lifts in a production area TB indicated that a "soft" zone with relatively low MDP$_{40}$ values on lift 1 reflected through the successive lifts 2, 3, 4, and 5 with similarly low MDP$_{40}$ values in that zone (Figure 5). Geostatistical semivariogram analysis on MDP$_{40}$ measurements on lifts 1 to 5 indicated that the variability reduced and the spatial continuity of the measurements improved from lifts 1 to 5, as demonstrated by a decrease in the sill and an increase in the range values (Figure 6).



(1) E_{LWD-Z3} = 3.3 MPa, γ_d = 108.9 pcf
(3) E_{LWD-Z3} = 12.0 MPa, γ_d = 104.6 pcf
(6) E_{LWD-Z3} = 6.3 MPa, γ_d = 107.0 pcf

Figure 4. MDP40 final pass map from TB2 with in situ test results at selected point test locations (from White et al. 2010)

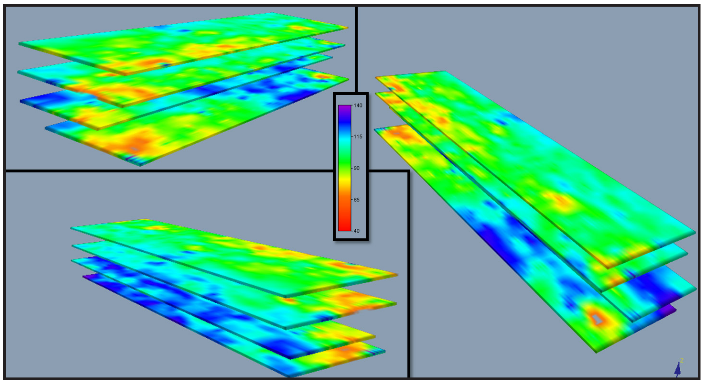


Figure 5. Three-dimensional spatial visualization of MDP measurements on lifts 2 to 5 (note: vertical elevation between each lift exaggerated for clarity) (from White et al. 2010)

Regression analysis results indicated better correlations between MDP_{40} and LWD modulus and California bearing ratio (CBR) determined from DCP compared to dry density measurements. Combining data from all test beds, MDP_{40} vs. LWD modulus and CBR yielded a non-linear power relationship with $R^2 > 0.50$ (Figure 7). MDP_{40} vs. dry density did not yield a statistically significant relationship (Figure 7). MDP_{40} measurements were somewhat sensitive to moisture content (MDP_{40} decreased with increasing moisture content). Correlation between MDP_{40} and moisture content yielded a linear relationship with $R^2 = 0.20$.

Multivariate non-linear regression analysis was performed to assess the influence of including a moisture content parameter in predicting MDP_{40} from LWD modulus measurements (Figure 7). This analysis showed $R^2 = 0.71$, which is a slight improvement over the simple regression model without the moisture content parameter ($R^2 = 0.63$). A similar analysis was performed to predict MDP_{40} from CBR measurements, but it did not show any improvement in the R^2 value (Figure 8). The MDP_{40} vs. dry density dataset combined with moisture content did not show a statistically significant relationship.

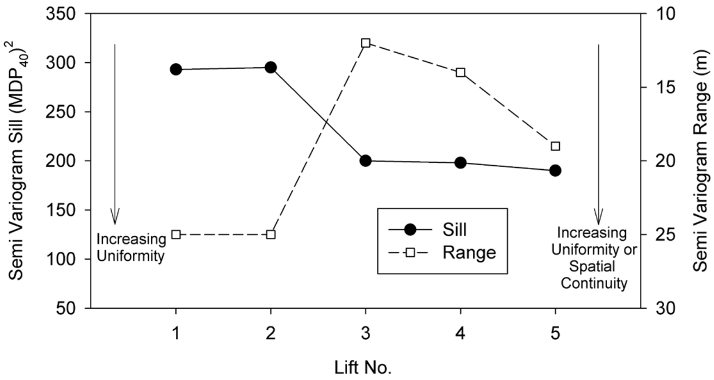


Figure 6. Semi variogram sill and range values on lifts 1 to 5 (from White et al. 2010)

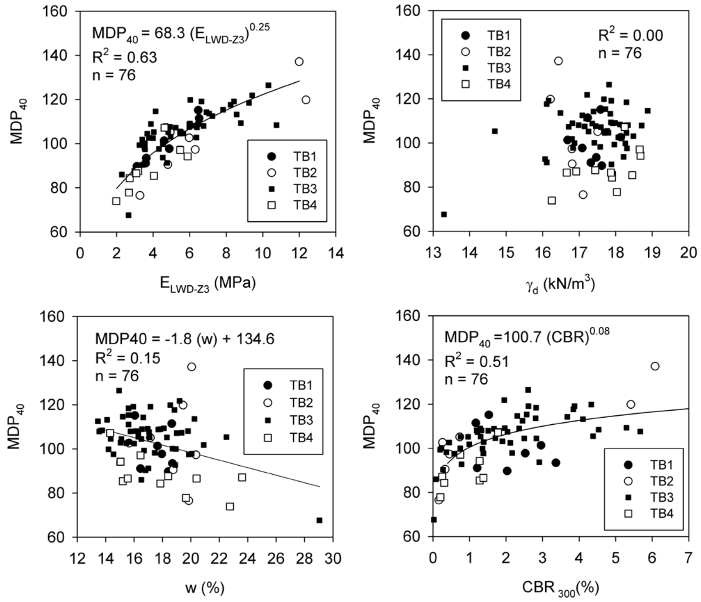


Figure 7. Correlations between MDP_{40} and point-MVs from all test beds (from White et al. 2010)

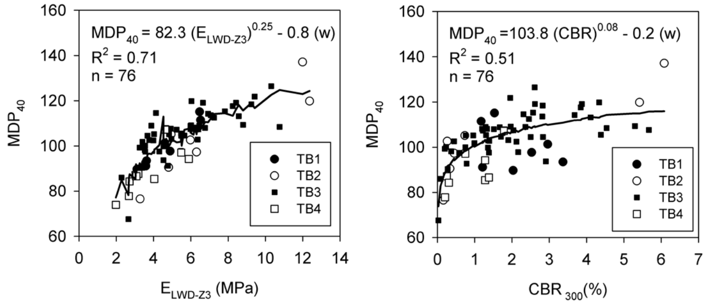


Figure 8. Multivariate non-linear regression analysis results (from White et al. 2010)

Reference

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.