INTELLIGENT COMPACTION BRIEF
June 2016

Iowa US Highway 65 – Embankment – July 2013

DEMONSTRATION PROJECT DATES/ DURATION
June to August 2013

DEMONSTRATION PROJECT TITLE
Intelligent Compaction Demonstration for Embankment Soils on Iowa US Highway 65

DEMONSTRATION PROJECT SPONSORS
Iowa DOT
Caterpillar, Inc.

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Figure 1. Caterpillar CS74B smooth drum roller with pad foot shell kit

Introduction

This demonstration project is located on US Highway 65 near Altoona, Iowa, and was initiated as a pilot project to provide hands-on experience to the contractor with intelligent compaction (IC) technology for embankment fill construction. The project was established through a partnership between Iowa State University (ISU), the Iowa Department of Transportation (DOT), and Caterpillar, Inc. The ISU research team was present on site to conduct in situ testing beyond what was required in the project specification for demonstration purposes.

The intelligent compaction (IC) system used on this project included a Caterpillar CS74B roller with padfoot shellkit (Figure 1) equipped with the machine drive power (MDP) based measurement technology. The machine was set up with real time kinematic (RTK) global positioning system (GPS), on-board display, and data documentation/software systems. The RTK-GPS measurements were used to determine pass coverage and analyze empirical correlations between spatial IC measurement values (IC-MVs) and in situ point measurements.

In situ point testing was conducted at selected locations to develop correlations with the IC measurements. Point testing included drive core testing for dry density (γ_d) and moisture content (w), dynamic cone penetrometer (DCP) testing for dynamic penetration index (DPI), and light weight deflectometer (LWD) testing for elastic modulus (E_{LWD}). Zorn LWD testing was conducted with 200 mm diameter and 300 mm diameter plate setups. In situ testing devices are shown in Figures 2 to 4.

This document was developed as part of the Federal Highway Administration (FHWA) transportation pooled fund study TPF-5(233) –Technology Transfer for Intelligent Compaction Consortium (TTICC).

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Figure 2. DCP testing

Figure 3. LWD testing

Figure 4. Drive core testing

According to the project specifications, the quality assurance (QA) testing involved conducting field moisture and density testing at random locations. The specification requirement was to achieve a minimum dry density of 95% standard Proctor maximum dry density and moisture content within +/- 2% of the standard Proctor optimum moisture content. The specification also required that the material be placed in 8 in. lifts and a minimum of 8 roller passes be conducted to achieve the compaction.

The overall goals of the demonstration project were as follows:

- Determine project specific correlations between IC-MVs and different in-situ point measurements.
- Provide hands-on experience to the contractor and receive contractor's feedback.

IC Systems Overview

The roller used in this study is shown in Figure 1 and is equipped with MDP measurement technology. MDP technology relates to the soil properties controlling drum sinkage and uses the concept of rolling resistance to determine the stresses acting on the drum and the energy necessary to overcome the resistance to motion. MDP values can be obtained in both vibratory and static compaction operation modes. For the machine used in this study, the manufacturer reported the MDP values (that have units of kJ/s or lb-ft/s) as unit less index values over a scale of 1 to 150. Therefore, the values are reported herein as MDP* values. Additional information about MDP measurement technology is provided in White et al. (2011).

The MDP* measurements are reported at a frequency of about every 1 ft at the center of the roller drum width along with GPS coordinates and a time-stamp. An onboard display allowed the operators to view a color coded map of pass coverage and IC-MVs in real time. After downloading the IC data from the compactor, the IC results were viewed and shared using Visionlink™ software program provided by the manufacturer.

Test Results

Testing was conducted over an embankment area that has been approved by the contractor. The material consisted of light brown sandy lean clay (classified as CL). The contractor used the IC roller for compaction operations in the test area and the IC-MVs were obtained for all passes. The geo-referenced MDP* value and roller pass count value maps are shown in Figure 5. Pass coverage map showed that a majority of the map area received about 1 to 4 roller passes, while some isolated locations received higher number of passes.

The final pass map was reviewed and then in situ testing was conducted at locations selected based on the MDP* map. The 28 in situ point locations are identified on the MDP* map in Figure 5.

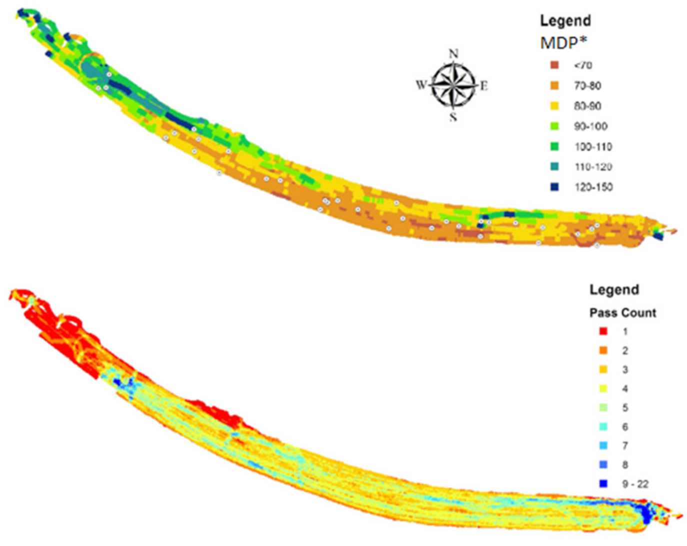

Figure 5. Color-coded geo-referenced map of MDP and pass count*

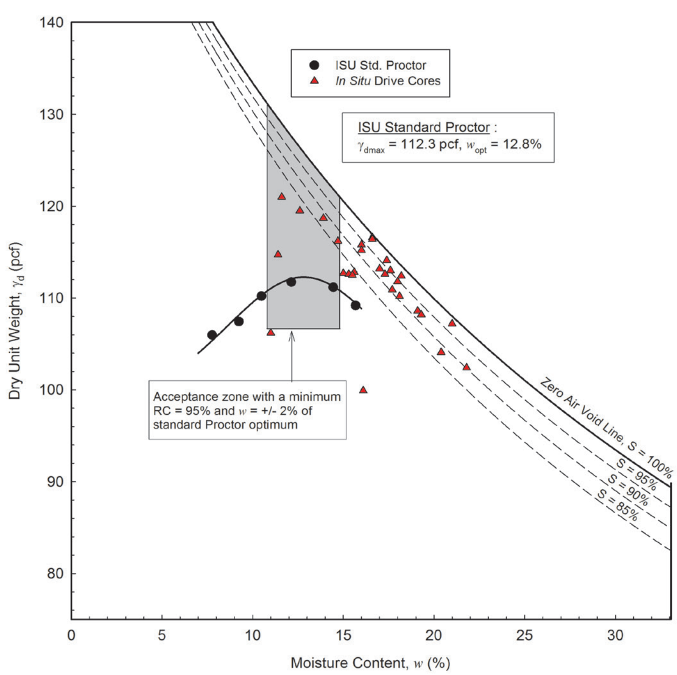

Figure 6. Standard Proctor test results and in situ drive core test results

Results from field drive core testing in comparison with laboratory standard Proctor test results are shown in Figure 6. The in situ moisture contents varied between -1.9% to +9.0% with an average of about +3.7% of the standard Proctor optimum moisture content. The relative compaction values varied between 89% and 108% with an average of about 100% of the standard Proctor maximum dry density. Out of the 28 in situ tests, only 6 met the specification limits.

MDP* results from the final pass were paired with in situ test measurements based on GPS locations for correlation analysis. Regression analysis between MDP* and in situ point measurements is shown in Figure 7. MDP* versus LWD moduli values yielded the best relationships of all in situ measurements with $R^2 > 0.6$. Relationships between MDP* and other in situ measurements yielded relatively weak relationship with $R^2 < 0.35$. Multi-variate regression analysis was attempted on this dataset to incorporate influence of moisture content on other in situ measurements, but no statistically significant relationship was found. However, past testing showed that in some cases, dry density measurements can yield better relationships with MDP* measurements when moisture content was incorporated (see White et al. 2011).

Summary of Key Findings

Some of the key findings from the in situ testing and data analysis are as follows:

- The CS74 IC system setup with RTK-GPS provided useful information to document pass coverage. The pass coverage map showed that a majority of the map area received about 1 to 4 roller passes, while some isolated locations received higher number of passes.
- Results from field drive core testing in comparison with laboratory standard Proctor test results showed that in situ moisture contents varied between -1.9% to +9.0% with an average of about +3.7% of the standard Proctor optimum moisture content, and relative compaction values varied between 89% and 108% with an average of about 100% of the standard Proctor maximum dry density. Out of the 28 in situ tests, only 6 met the specification limits.
- Regression analysis showed MDP* versus LWD moduli values showed the best relationships of all in situ measurements with $R^2 > 0.6$. Relationships between MDP* and other in situ measurements (dry density, moisture content, and DCP penetration index) yielded relatively weak relationship with $R^2 <$ 0.35.

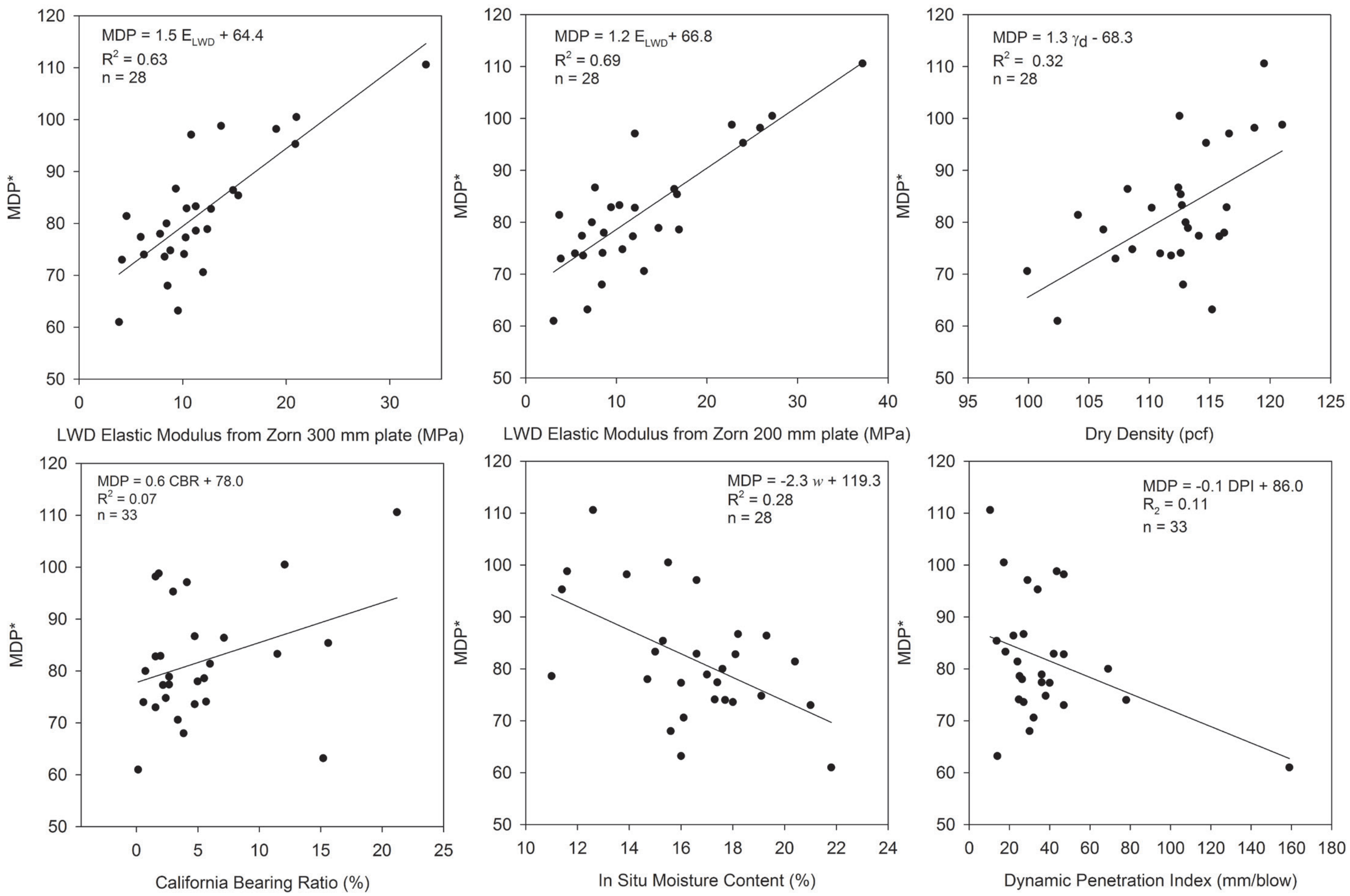

Figure 7. Correlations between MDP and in situ point measurements*

Contractor Interview

This project created an opportunity to provide the contractor with hands-on experience using the IC technologies. The following are direct quotes from the contractor about their experience using the technology on this project site:

- *"You can add a lot of road life with (road base) uniformity. States spend a lot of their transportation money on maintenance. If the base has no weaknesses, you'll only have to replace a wear course from time to time. That is a huge cost savings at a time when every dime is being watched."*
- *"Most of those passes are a waste. Many times on jobsites, we could probably get compaction densities with haul trucks. We might not even need rollers. But the specs call for eight passes, so we make them."*
- *"You can't leave technology like this on the shelf. You would have better measurements, and better roads, at a lower cost. Those are tough points to argue."*

References

White D. J., Vennapusa, P., and Gieselman, H. 2011. Field Assessment and Specification Review for Roller-Integrated Compaction Monitoring Technologies, In Special Issue on Advanced Instrumentation Techniques on Geotechnical Engineering (AITGE), *Advances in Civil Engineering*, Vol. 2011, Article ID 783836, doi:10.1155/2011/783836.