Indiana SR 25 – Granular and Non-Granular Embankment Subgrade Fill – August 2010

PROJECT DATE
August 16 to 18, 2010

RESEARCH PROJECT TITLE
Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base, and Asphalt Pavement Materials (FHWA DTFH61-07-C-R0032)

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Federal Highway Administration

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MORE INFORMATION
http://www.ceer.iastate.edu/research/project/project.cfm?projectID=-373342403

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).

Figure 1. Caterpillar CS56 smooth drum with padfoot shell kit (left) and Caterpillar CS563E smooth drum roller (right) (from White et al. 2011)

Project Description

This demonstration was conducted on State Route (SR) 25 in West Lafayette, Indiana. The machine configurations and roller-integrated compaction measurement (RICM) systems used on this project included a Caterpillar CS56 smooth drum roller with a padfoot shell kit (here after referred to as padfoot roller) and a Caterpillar CS563E smooth drum vibratory roller (Figure 1). Both were equipped with machine drive power (MDP) technology (reported as MDP* and see White et al. 2011 for description of MDP*). Both machines were also equipped with a real-time kinematic (RTK) global positioning system (GPS) and on-board display and documentation systems.

The project involved construction and testing of six test beds consisting of cohesive and granular embankment fill materials. The MDP* values were evaluated by conducting field testing in conjunction with in situ dry density (γd) and moisture content (w) determined from nuclear gauge (NG), California bearing ratio (CBR) determined from dynamic cone penetrometer (DCP), and dynamic modulus determined from light weight deflectometer (LWD).

Field Study Goals

- Document machine vibration amplitude influence on compaction efficiency
- Develop correlations between MDP* measurement values to in situ point measurements (point-MVs)
- Compare roller-integrated compaction monitoring (RICM) results to traditional compaction operations
- Study RICM measurement values in production compaction operations
- Evaluate RICM measurement values in terms of alternative specification options

An open house was conducted near the end of the field investigation to disseminate results from current and previous IC projects.

Materials

The cohesive embankment fill material on the project was classified as sandy lean clay (CL) or A-7-6 (13) soil and the granular embankment fill material was classified as poorly graded sand with silt (SP-SM) or A-3 soil.

Field Test Results and Observations

Six test beds (TBs) were evaluated as part of this study. TBs 1 and 2 consisted of granular embankment fill calibration test areas, TBs 3 and 6 consisted of granular embankment fill production areas, and TBs 4 and 5 consisted of cohesive embankment fill calibration areas. Results from selected test beds (TB5 cohesive embankment fill and TBs 3 and 6 granular fill) are presented in this Tech Brief.

In addition, a contractor representative was trained on-site to perform compaction operations on TB6 and his interview responses from after the roller operations are also summarized in this Tech Brief.

TB5 Cohesive Embankment Fill Test Strip

This test bed consisted of a 48 m long test strip with compacted cohesive fill and visually showed rutting or sinkage under construction traffic loading (Figure 2). The test bed area was mapped using one roller pass in the low amplitude setting. The MDP* values varied from about 65 to 145 along the test strip. LWD modulus (E_{LWD-Z3}) measurements were obtained at 72 locations along the test strip at relative dense point-point spacing (~0.65 m). MDP* values in comparison with E_{LWD-Z3} values are presented in Figure 3. Both MDP* and E_{LWD-Z3} measurements tracked well on this test strip.

Figure 2. TB5 cohesive embankment fill test strip (from White et al. 2011)

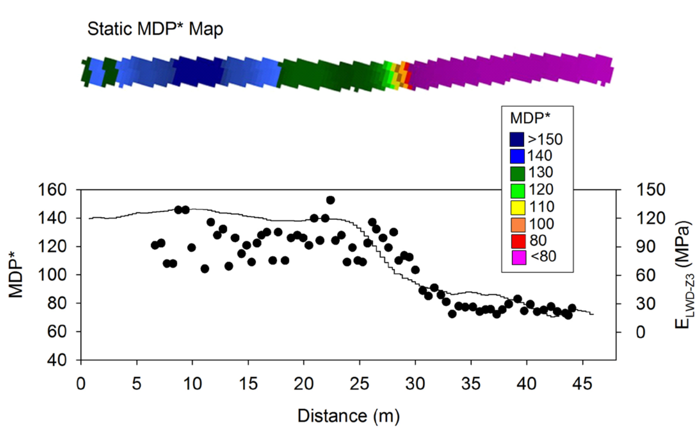

Figure 3. Comparison between MDP and E_{LWD-Z3} on TB5 test strip (from White et al. 2011)*

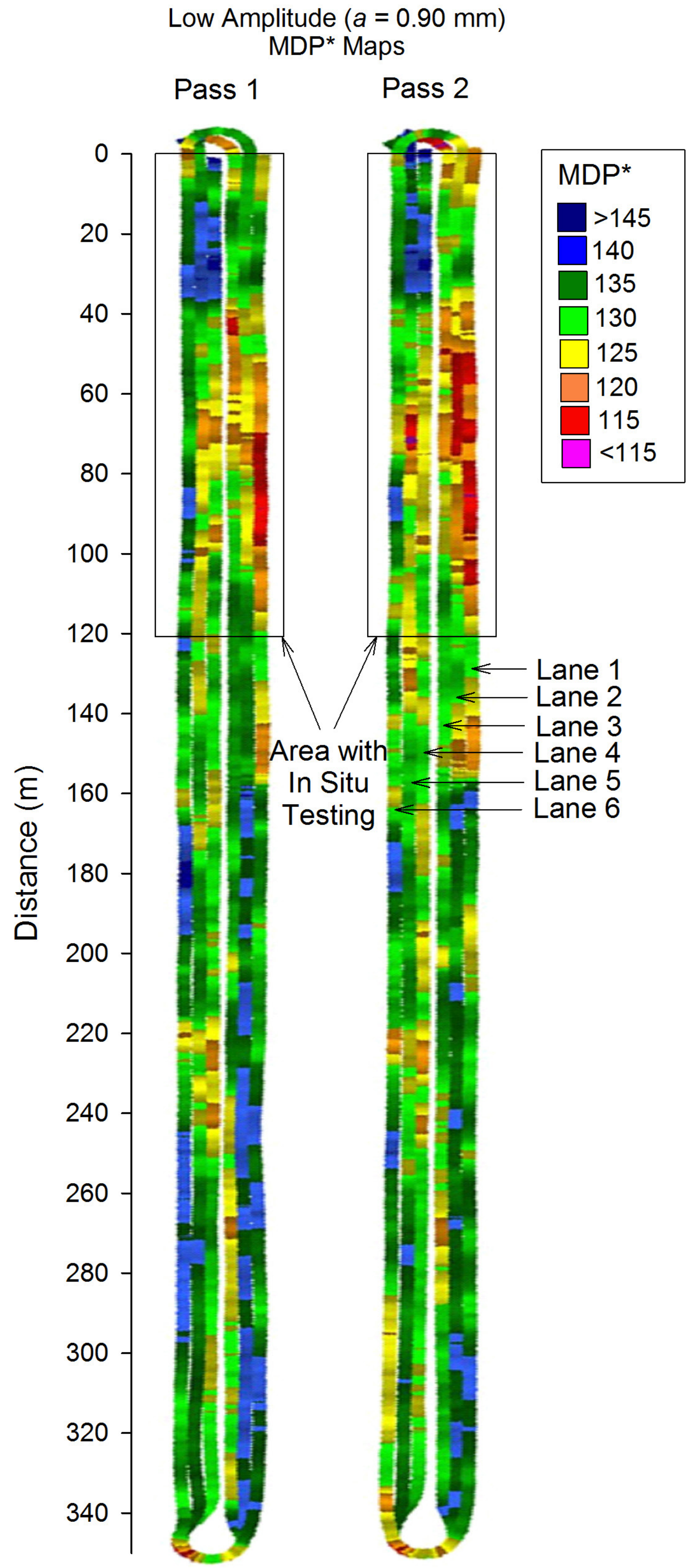

Figure 4. MDP maps from two passes on TB3 granular embankment fill production area (from White et al. 2011)*

TBs 3 and 6 Granular Embankment Fill Production Areas

TBs 3 and 6 consisted of two lifts in a production area with granular embankment fill (Lift 1 for TB3 and Lift 2 for TB6). Lift 1 was mapped using two roller passes and LWD tests were performed in a selected area with high, medium, and low MDP* values using the on-board display. Tests were performed at 20 locations with relatively high MDP* values, 16 locations with medium range MDP* values, and 28 test locations with relatively low MDP* values. DCP tests were also performed at 7 selected locations. After compaction and testing on Lift 1 (TB3), Lift 2 (TB6) was placed and compacted using four roller passes in low amplitude mode by the contractor.

The roller operator was trained on-site to make use of the on-board display unit and was instructed to perform four roller passes over the production area. After the final pass, LWD tests were performed at 42 test locations across the production area. Test locations were selected based on the IC display to capture high, medium, and low values. In addition, DCP and NG tests were performed at 7 selected locations.

Spatial MDP* maps from TB3 (Lift 1) for the two passes are presented in Figure 4. MDP* plots with distance along each roller lane in comparison with LWD modulus measurements are presented in Figure 5. Spatial MDP* and roller pass coverage maps from TB6 (Lift 2) for the four passes are presented in Figure 6. The LWD values generally tracked well with variations in the MDP* values on both Lift 1 and Lift 2, except at some locations on lanes 2 and 6 on TB3 (Lift 1).

The moisture content of the fill material varied from about 3.5% to 5.1%, which was about -9 to -11% of standard Proctor optimum moisture content, and the relative compaction of the fill material varied from about 95% to 110% with an average of about 97% of standard Proctor maximum density.

Regression Analysis

Relationships between MDP* obtained from the smooth drum roller in low amplitude settings and in situ point-MVs from TBs 1, 3, and 6 are presented in Figure 7. All relationships showed significant scatter with R^2 values < 0.4. Comparatively, correlation between MDP* and $E_{LWD\text{-}Z3}$ showed a better relationship with R^2 = 0.38 compared to dry density (γ_d) and CBR.

Relationships between MDP* obtained from the padfoot roller in static mode and in situ point-MVs from TBs 4 and 5 are presented in Figure 8. Correlation between MDP* and $E_{LWD\text{-}Z3}$ showed a power relationship with R^2 = 0.75, while correlations with γ_d and CBR point measurements did not show a statistically significant relationship. Note that measurements were obtained over a wide range of MDP* measurements (75 to 140) in correlation with $E_{LWD\text{-}Z3}$, while the MDP* measurements ranged only within a narrow range in correlation with γ_d and CBR (80 to 110).

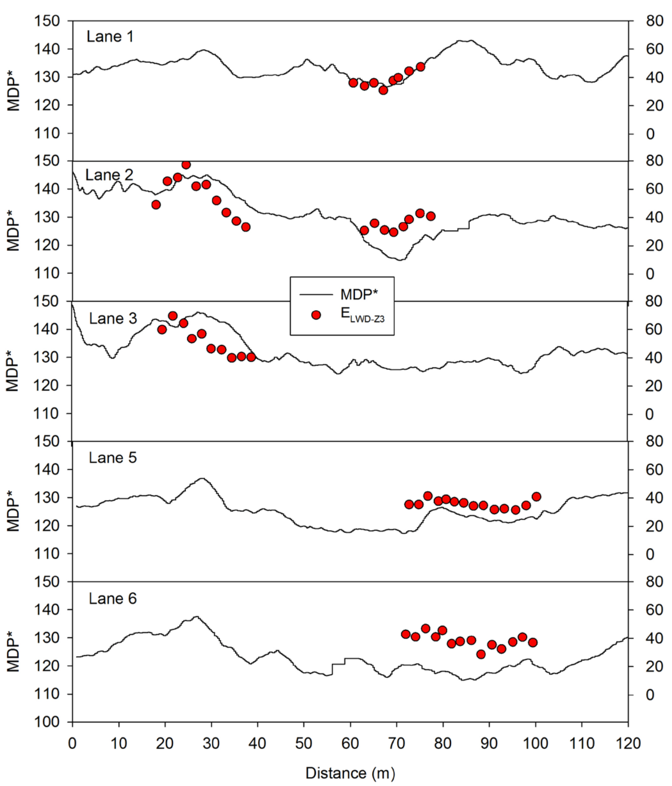

Figure 5. Comparison between MDP and LWD modulus measurements from multiple lanes on TB3 (from White et al. 2011)*

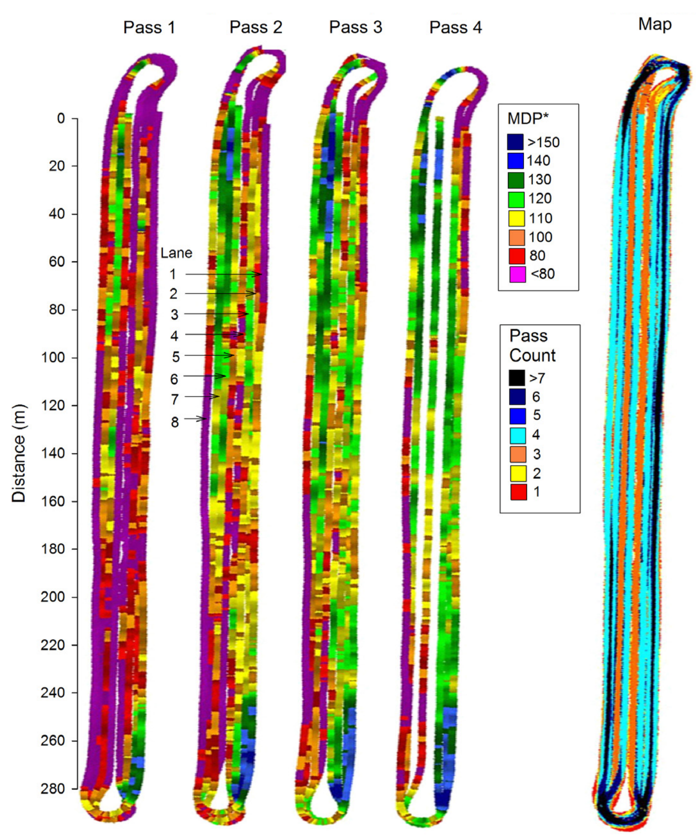

Figure 6. MDP maps from four passes and pass count map on TB6 granular embankment fill production area (from White et al. 2011)*

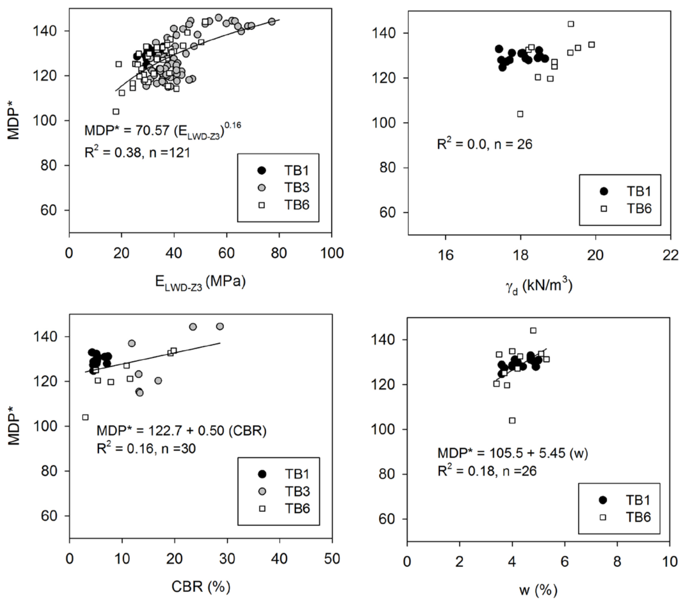

Figure 7. Correlations between MDP and in situ test measurements from TBs 1, 3, and 6 granular embankment fill compacted in low amplitude settings (from White et al. 2011)*

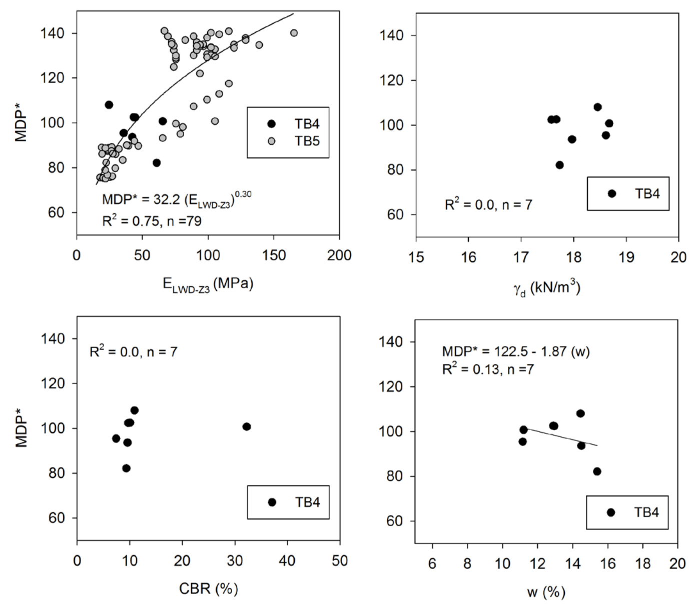

Figure 8. Correlations between MDP and in situ test measurements from TBs 4 and 5 cohesive embankment fill compacted in static mode (from White et al. 2011)*

Contractor Interview

A contractor representative was trained on-site to make use of the on-board computer display during compaction operations on TB6 using the CS563 roller. After the roller operations, the research team interviewed him with the following questions and his responses are summarized below.

Question: What to do you think about how the process worked and what information from the display was valuable and not valuable?

> **Response:** The on-board display monitor was helpful to keep track of the number of roller passes. Also, by experience, I know that there would be areas that are relatively softer than other areas just because there was no construction traffic on it.

Question: Did the IC values you see on the monitor confirm what you would expect from experience?

> **Response:** Yes. If you hit a thick lift spot, the IC values went down and if you hit a relatively thin lift spot, the IC values went up.

Question: What did you think about the display? Did you use the display much during compaction operations?

> **Response:** The display worked well. But when you do your first pass, it's all red, so you cannot see the roller icon very well. It's a bit distracting as the screen moves when the station passes.

Question: Would you give a thumbs up or a thumps down for the technology?

> **Response:** I would give thumbs up and it would be good for us to use it more.

Reference

White, D. J., and Vennapusa, P., Gieselman, H. 2011. *Accelerated Implementation of Intelligent Compaction Monitoring Technology for Embankment Subgrade Soils, Aggregate Base, and Asphalt Pavement Materials.* TPF-5(128) – SR-25. West Lafayette, Indiana, Report submitted to The Transtec Group, FHWA, April.