Florida SR 9B – Granular Layered Embankment and Geosynthetic Reinforcement – May 2011

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Geotechnical Solutions for Soil Improvement, Rapid embankment Construction, and Stabilization of the Pavement Working Platform (SHRP 2 Project R02) – Compaction "Roadeo" Field Demonstration

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MORE INFORMATION
http://www.ceer.iastate.edu/research/project/project.cfm?projectID=-159867489

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Project Description

This field demonstration project was conducted on the Florida State Road (SR) 9B construction project in Jacksonville, Florida from May 16 through May 19, 2011. A Caterpillar CS74 vibratory smooth drum self-propelled roller was used on the project. The machine was set up with a roller-integrated compaction monitoring (RICM) system.

Four test beds (TBs) were evaluated using the on-site granular embankment fill material. TBs 1 and 2 involved constructing and testing sections with different types of geosynthetic reinforcement materials. TBs 3 and 4 involved mapping project production areas and selecting test locations based on the color-coded on-board computer display in the roller for in situ testing.

Field testing involved obtaining RICM measurements during the compaction and mapping process and point tests including the following: dynamic cone penetrometer (DCP), static cone penetrometer test (CPT), static plate load test (PLT), falling weight deflectometer (FWD), light weight deflectometer (LWD), nuclear gauge (NG), and sand cone density. In addition, all test sections of TB1 were instrumented with piezoelectric earth pressure cells (EPCs) to monitor in-ground total vertical and horizontal stresses before, during, and after compaction.

Project Objectives

- Evaluate the use of RICM technology with on-board computer display for compacted fill quality control (QC) and quality assurance (QA) testing
- Evaluate compaction influence depth under the RICM roller
- Evaluate differences in engineering properties between different types of geosynthetic and geocell reinforced fill test sections along with unreinforced fill test section using different QC/QA testing methods
- Evaluate differences in the in-ground dynamic stresses under the roller between different test sections

- Provide researchers and practitioners with hands-on experience using RICM technology and various QC/QA testing technologies and geosynthetic/geocell reinforcement products

This tech brief presents results of some key findings from the TB1 test area and TBs 3 and 4 production areas. (Detailed results are available in White et al. 2012 and Vennapusa and White 2014).

RICM System Overview

The Caterpillar CS74 roller was equipped with compaction meter value (CMV) and machine drive power (MDP) measurement systems.

CMV is an index parameter (measure of non-linearity) computed as the ratio of drum acceleration amplitude of the first harmonic divided by the acceleration amplitude at the fundamental (eccentric excitation) frequency. This value requires only the measurement of vertical drum acceleration.

MDP relates to the soil properties controlling drum sinkage and uses the concepts of rolling resistance and sinkage to determine the stresses acting on the drum and the energy necessary to overcome the resistance to motion. MDP is a relative value referencing the material properties of a calibration surface. Positive MDP values indicate material that is softer than the calibration surface, while negative MDP values indicate material that is stiffer than the calibration surface.

The MDP values obtained from the CS74 machine used in this study were scaled by the manufacturer to range between 1 (high machine resistance) and 150 (low machine resistance) and these re-scaled values are noted as MDP* in this brief.

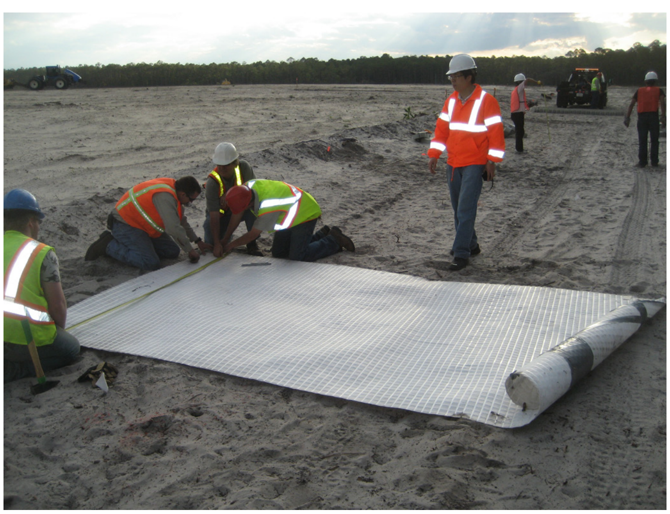
More information about CMV and MDP* measurements is provided in White et al. 2012.

Test Beds and Material Properties

TB1 involved constructing a test area about 6.2 m wide by 75 m long with six test sections incorporating one control section and several different geosynthetic reinforcement materials into one or two layers of poorly graded sand (A-3 or SP) embankment fill material as follows (Figure 1): biaxial geogrid (BX), nonwoven geotextile geocomposite (C30), polypropylene woven fabric (PPWF), 100 mm geocell (GC100), and 150 mm geocell (GC150) materials.

(a)

(b)



(c)

(d)

Figure 1. Geosynthetic reinforcement used on TB1: (a) BX geogrid, (b) GC100/150, (c) C30, and (d) PPWF

Figure 2. TB3 with RAP surfacing (top) and TB4 with embankment sand fill (bottom)

TB3 involved testing a production area with 30 to 120 mm thick recycled asphalt pavement (RAP) surfacing over natural (uncompacted) sand subgrade, which was constructed to serve as a haul road for construction traffic at the site (Figure 2). Plan dimensions of the test area were about 10 m wide by 95 m long. The area was mapped in four roller lanes in low amplitude (a = 0.90 mm), high amplitude (a = 1.80 mm), and static modes. The vibration frequency was set at 30 Hz and the machine was operated at a nominal speed of 4.5 km/h. LWD and DCP tests were conducted at 11 to 12 test locations in the area that were selected using CMV and MDP* color-coded maps on the screen. Test locations were then selected at three to four locations in the low, medium, and high CMV or MDP* values. The RAP material was visually classified as well-graded sand with gravel.

TB4 consisted of a production embankment fill area with A-3 or SP material (Figure 2). Pull-behind scrapers were used for hauling fill material in this area. Compaction occurring under scraper tires and other construction traffic was considered acceptable on this project (i.e., no compactors were used). Plan dimensions of the TB4 area was about 12.5 m wide by 65 m long. The area was mapped in four roller lanes in low amplitude, high amplitude, and static modes. LWD and DCP tests were conducted at 10 test locations in the area.

Field Test Results

Test Bed 1 – Geosynthetic Reinforced Test Sections

On TB1, MDP* and CMV measurements were obtained for multiple passes by operating the machine in opposite travel directions. Results from two passes are shown in Figure 3 for MDP* and Figure 4 for CMV.

These results indicated that both MDP* and CMV RICM measurements are influenced by the roller direction of travel. The MDP* data are reported at the center of the drum. However, the measurements represent the mechanical performance of the whole roller, which are affected by the roller-soil interaction at the front drum and the rear tires.

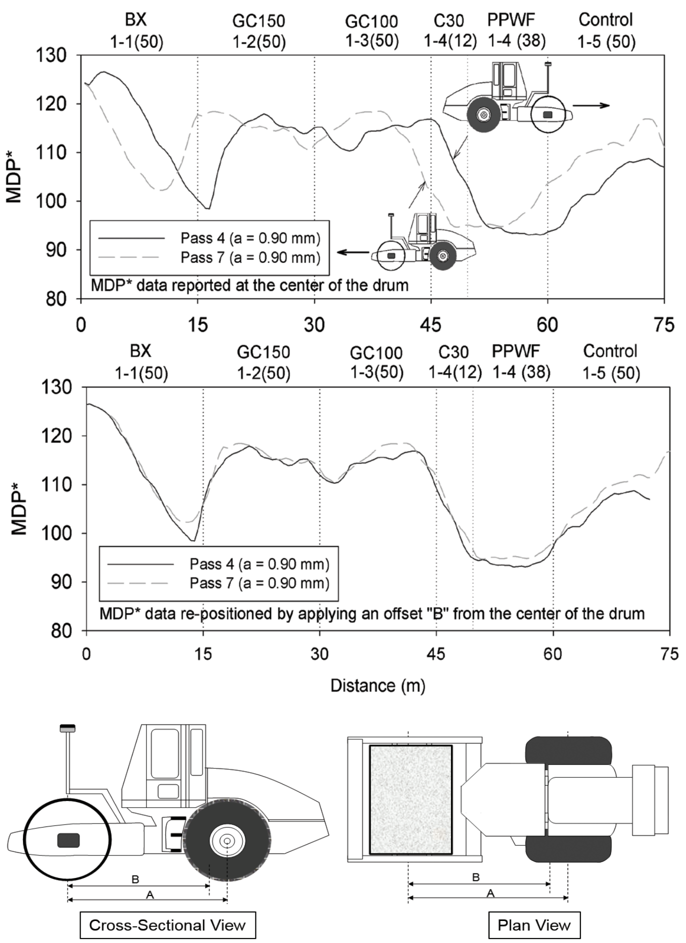
To assess the amount of influence that the front drum versus the rear tire has on the MDP* measurements, the data obtained from the two passes were repositioned to match the sharp transitions or peaks observed along the TB (Figure 3).

The offset distance for repositioning was observed to be about 2.60 m behind the drum center. Note that this offset calculation inherently assumes that the subsurface conditions under the full length of the roller are the same in both directions of travel when the drum is positioned at a point, which is not true given that each section along this TB has distinctly different reinforcement systems. For example, if the roller is traveling from left to right (0 m to 75 m) and the drum center is positioned at 30 m (BX/GC150 transition), the rear tire is in the BX section. In contrary, if the roller is traveling from right to left (75 m to 0 m), the rear tire is in the GC150 section.

Further research is warranted to clearly identify and characterize the relative influence of the front drum versus the rear tires on MDP* measurements and this is an important aspect to further evaluate, because it directly affects how QC/QA test measurements should be obtained to conduct calibration tests and establish target values for acceptance.

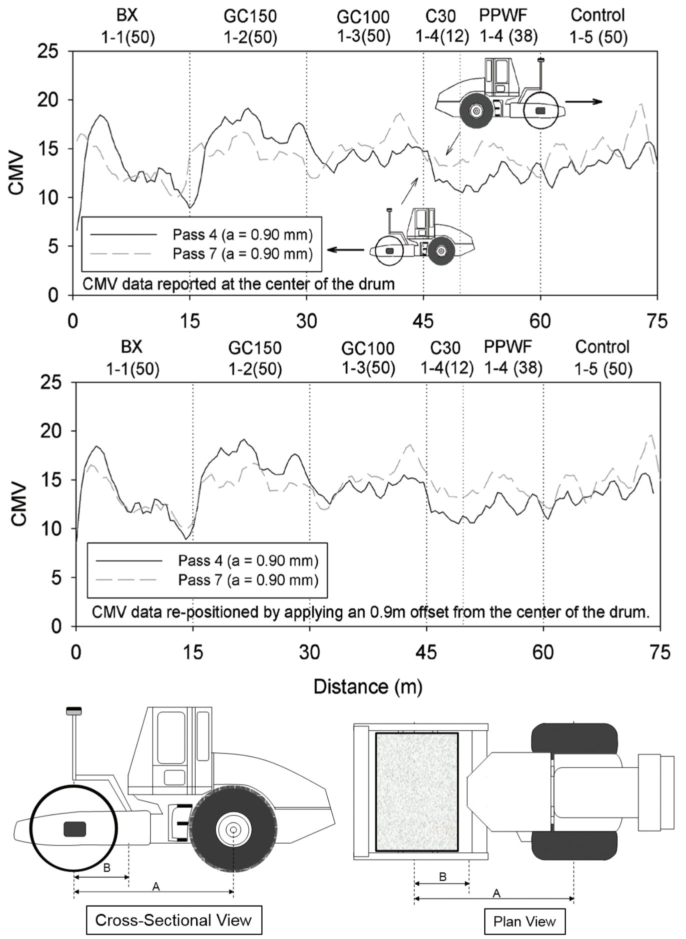
Using a similar procedure explained above for MDP* measurements, the offset distance for CMV measurements was obtained as 0.9 m. Unlike MDP* measurements, the CMV measurements are based purely on drum/soil interaction with minimal influence of rear tires. However, the offsetting occurs because the CMV at a given point indicates an average value over a roller travel length of about 0.5 sec (Geodynamik ALFA-030 undated). The roller travel speed for passes 4 and 7 was about 5.0 km/h. Therefore, the travel distance in 0.5 sec was about 0.7 m, which is very close to the calculated 0.9 m offset distance.

Comparison of RICM measurements between different test sections revealed that the average MDP* was about 1.07 times higher in the geocell sections compared to the control section. The BX section average MDP* was about the same, while the C30 and PPWF section average MDP*s were about 0.90 to 0.95 times the control section average MDP*.



A = 2.90 m = Length between wheel bases
B = 2.60 m = Offset length used to adjust MDP* position depending on the direction of travel

Figure 3. MDP measurements for two passes in opposite directions before and after offsetting measurement positions and roller schematic showing measurement offset*



A = 2.90 m = Length between wheel bases
B = 0.90 m = Offset length used to adjust CMV position depending on the direction of travel

Figure 4. CMV measurements for two passes in opposite directions before and after offsetting measurement positions and roller schematic showing the measurement offset

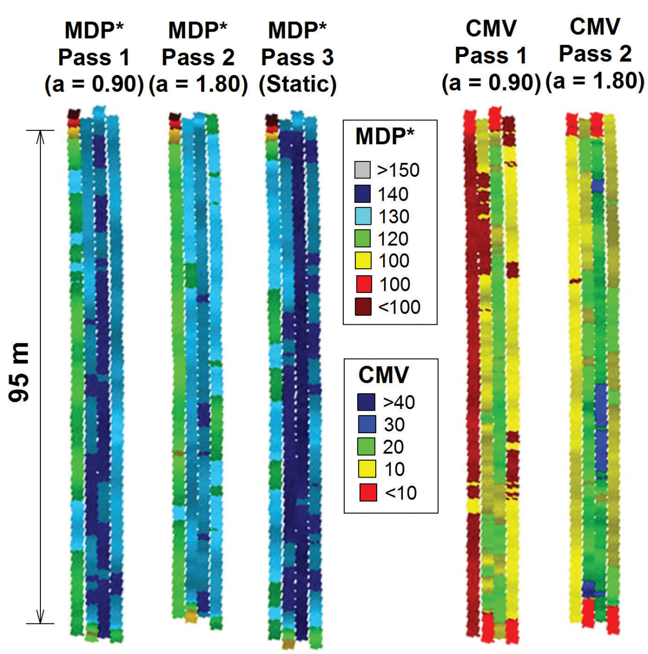


Figure 5. MDP and CMV maps at different amplitude settings on TB3*

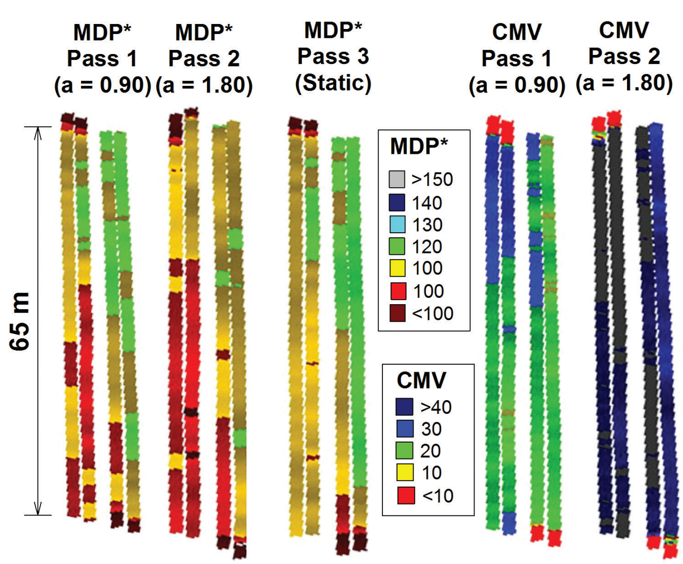


Figure 6. MDP and CMV maps at different amplitude settings on TB4*

In contrary to the MDP* measurements, CMV measurements were generally lower in the reinforced sections than in the control section with the exception of measurements in the GC100 section. The BX section showed the lowest values compared to all other reinforced sections.

Test Beds 3 and 4 – Production Areas

CMV and MDP color-coded maps from TBs 3 and 4 are presented in Figures 5 and 6, respectively.

On average, MDP* values were higher in TB3 than in TB4. CMV measurements were higher in TB4. These differences between CMV and MDP* measurements on the two test sections are attributed to the differences between their measurement influence depths (MIDs). MID is further explained through correlation analysis below.

Representative DCP-CBR and cumulative blows profiles from each test section are shown in Figure 7. The DCP profile from TB3 shows a thin stiff crust at the surface (CBR > 40) with the RAP material and a relatively uniform CBR with depth (CBR~10) in the underlying natural sand subgrade. The DCP profile from TB4 shows increasing CBR with depth. This trend is due to increasing confinement with depth.

Weighted average CBR up to a depth of 300 mm (CBR_{300}) and 800 mm (CBR_{800}) below the surface were calculated from each test location for correlation analysis. On TB4, these measurements were calculated by excluding data from the first drop (considering the drop as the seating drop over loose surface material), as well as including data from the first drop.

Correlations between LWD modulus (E_{LWD}) and CBR measurements and roller CMV and MDP* measurements are presented in Figure 8.

Regression relationships and the corresponding statistics (i.e., coefficient of determination (R^2) value, standard error, and number of measurements (n)) are also presented in the figure. The statistical relationship between CMV and E_{LWD} yielded a linear regression model with R^2 = 0.66 for TB3 (Figure 8a).

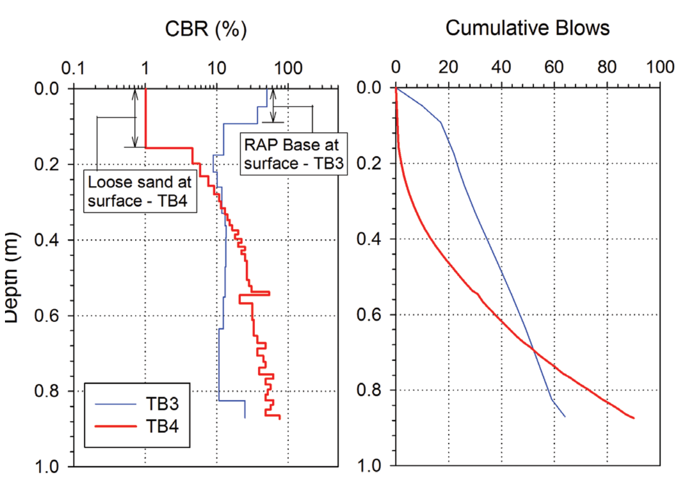


Figure 7. Sample DCP-CBR profiles from TB3 and TB4

The TB4 data did not follow the same trend as the TB3 data. Similarly, the relationship between CMV and CBR_{300} showed that the TB4 data did not follow the same trend as the TB3 data. CMV versus CBR_{300} for TB3 data yielded a non-linear relationship with R^2 = 0.77 (Figure 8c). There was no statistically significant relationship for the TB4 E_{LWD} and CBR_{300} data with CMV.

The relationship between CMV and CBR_{800} yielded a non-linear exponential model with R^2 = 0.77, including data from both test beds (Figure 8e). The CBR_{800} data calculated excluding first-blow DCP data, correlated better with CMVs than data calculated including first-blow DCP data. This suggests that CMV measurements are not particularly sensitive to loose sand at the surface.

MDP* versus E_{LWD} and MDP* versus CBR_{300} relationships (Figures 8b and 8d) yielded a non-linear hyperbolic model with R^2 = 0.65 and 0.86, respectively, including data from both test beds. The CBR_{300} data calculated, including first-blow DCP data, correlated better with MDP* than data calculated excluding first-blow DCP data. This suggests that MDP* values are sensitive to loose material at the surface.

The hyperbolic relationship between CBR_{300} and MDP* suggests that the MDP* values are more sensitive to changes in CBR_{300} up to about 7 than at values less than 7. The relationship between MDP* and CBR_{800} yielded a linear regression model with R^2 = 0.83 for TB4 (Figure 8f). TB3 data did not follow the same trend as TB4 data.

Summary of Key Findings

- Color-coded display with 100% coverage of compaction area was effective in selecting "soft" and "stiff" areas for spot testing.
- RICM measurements generally were better correlated with LWD and DCP-CBR spot test measurements than with NG density measurements (see White et al. 2012 for results).
- MDP* measurements were influenced by the direction of travel. This is because the MDP* measurements represent the mechanical performance of the whole roller, which are affected by the roller-soil interaction at the front drum and the rear tires, and the results are only reported at the center of the drum. The offset distance for MDP* measurements is observed to be about 2.60 m behind the drum center. This is an important aspect to further evaluate because it directly affects how QC/QA test measurements should be obtained to conduct calibration tests and establish target values for acceptance.
- CMV measurements were also influenced by the direction of travel. The offsetting occurs because the CMV at a given point indicates an average value over a roller travel length corresponding to a measurement interval of about 0.5 sec.
- CMV has a deeper measurement influence depth (up to 1 m) than MDP* (< 0.5 m). The stiff surface layer of RAP material on TB3 influenced MDP* measurements more than CMV measurements.

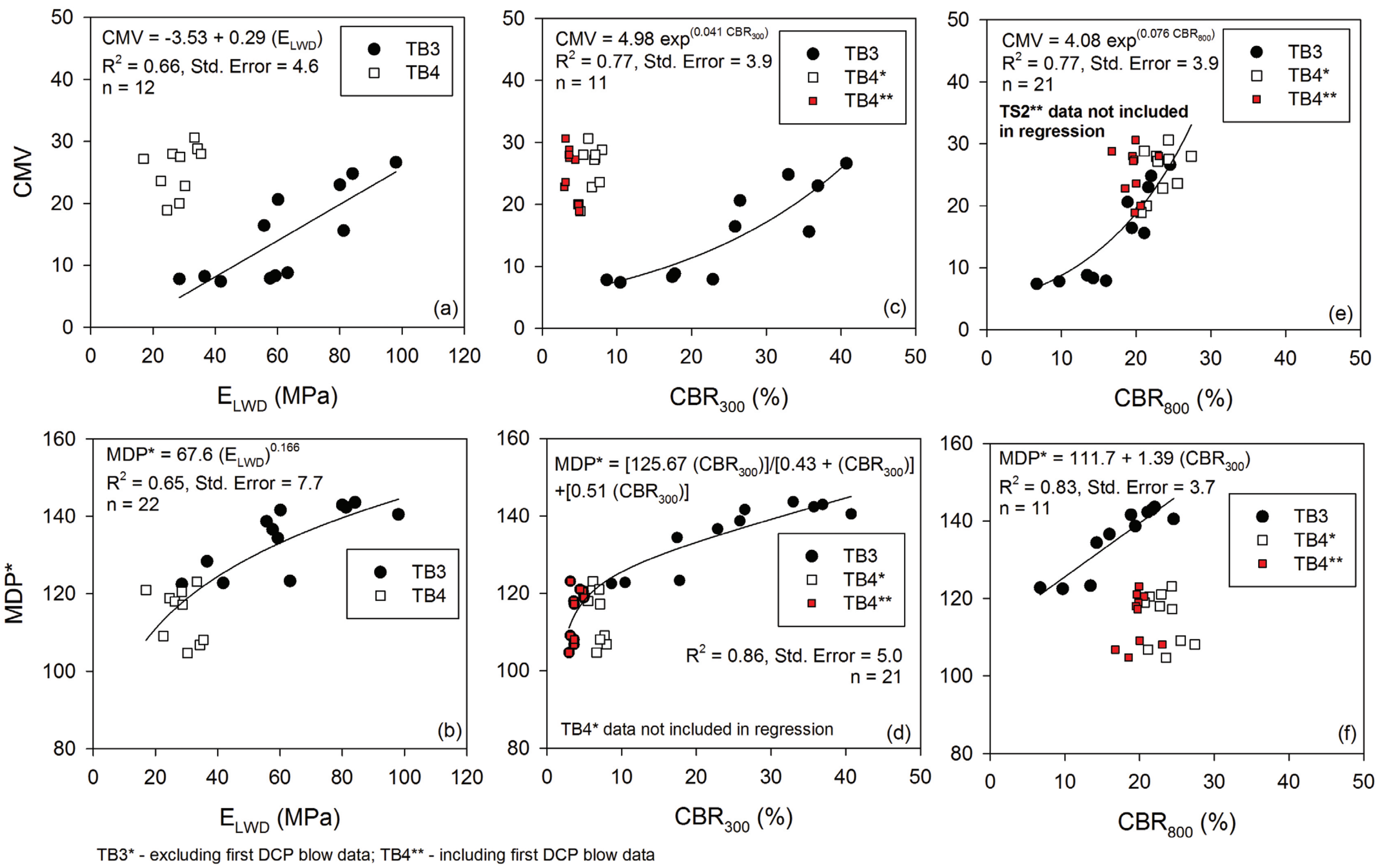


Figure 8. Regression relationships between (a) CMV and E_{LWD} (b) MDP and E_{LWD} (c) CMV and CBR_{300} (d) MDP* and CBR_{300} (e) CMV and CBR_{800} and (f) MDP* and CBR_{800}*

- When data from TBs 3 and 4 are combined, MDP* correlated well with E_{LWD} and CBR_{300} (which represents the material properties in the top 300 mm). The data did not follow the same trend when MDP* data was correlated with CBR_{800} (which represents the material properties in the top 800 mm).
- When data from TBs 3 and 4 are combined, CMV correlated well with CBR_{800}. The data did not follow the same trend when CMV was correlated with E_{LWD} and CBR_{300}.
- CBR_{800} correlated better with CMV measurements when the first DCP drop was excluded (considering it as a seating drop) for TB4 data, where the material was loose at the surface due to no confinement, than when the first DCP drop was included. On the other hand, CBR_{300} data correlated better with MDP measurements when the first DCP drop was included for TB4 data. This suggests that the MDP* measurements are influenced by the loose sand at the surface, while CMV is not.

References

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