

Boone County Research Test Sections—Stabilized Pavement Foundations—Summer 2012

PROJECT DATE

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RESEARCH PROJECT TITLE

Boone County Expo Research
Phase I – Granular Road Compaction and
Stabilization (InTrans Project 373342403)

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MORE INFORMATION

[http://www.ceer.iastate.edu/research/
project/project.cfm?projectId=-373342403](http://www.ceer.iastate.edu/research/project/project.cfm?projectId=-373342403)

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The Iowa Department of Transportation (DOT) worked with its research partners to design comparative pavement foundation test sections at the Central Iowa Expo Site in Boone, Iowa. The project was constructed from May through July 2012. Sixteen 700 ft long test sections were constructed on 4.8 miles of roadway with the following goals:

- Construct a test area that will allow long-term performance monitoring
- Develop local experience with new stiffness measurement technologies to assist with near-term implementation
- Increase the range of stabilization technologies to be considered for future pavement foundation design to optimize the pavement system

This brief provides an overview of the three roller-integrated compaction-monitoring technologies used on this project site, and presents results from mapping the test sections in comparison with in situ modulus measurements.

Site Conditions

The project site consists of thirteen roads oriented in the North-South direction (denoted as 1st St. to 12th St.) and three roads oriented in the East-West direction (denoted as South Ave., Central Ave., and North Ave.). Construction of test sections required removal of the existing chip seal surface and subbase and 6 to 12 in. of subgrade. The subgrade consisted primarily of wet soils classified as CL or A-6(5). Pore water pressure measurements from cone penetration tests (CPT) indicated ground water elevations generally at depths of about 3 to 6 ft below the original grade across the site and at depths of about 12 ft or greater in areas close to drainage features.

Sixteen test sections were constructed on the North-South roads, which involved using: woven and non-woven (NW) geotextiles at subgrade/subbase interface; triaxial and biaxial geogrids at subgrade/

subbase interface; 4 in. and 6 in. geocells in the subbase layer with non-woven geosynthetics at subgrade/subbase interface; portland cement (PC) and fly ash (FA) stabilization of subgrade; PC stabilization of recycled subbase; PC + fiber stabilization of recycled subbase with polypropylene (PP) fibers and monofilament-polypropylene (MF-PP) fibers; mechanical stabilization (mixing subgrade with existing subbase); and high-energy impact compaction. Triaxial and biaxial geogrids were used at subgrade/subbase interface at select locations on the East-West roads. More detailed information about the different technologies are provided in project report (White et al. 2013).

All test sections were topped with a nominal 6 in. of modified subbase (MSB) material classified as GP-GM or A-1-a (7% fines content). One exception was the 6 in. geocell section that required 7 in. of subbase. Crushed limestone was used in the MSB layer on all North-South roads, and a mixture of recycled concrete and recycled asphalt was used in the MSB layer on all East-West roads. A few test sections (6th St., 7th St., and 9th St.) consisted of 6 in. of recycled subbase material classified as SM or A-1-a (14% fines content) between the subbase and subgrade layers.

Roller-Integrated Compaction-Monitoring Technologies

Roller-integrated compaction monitoring (RICM) (i.e., intelligent compaction or continuous compaction control) is the recording and color-coded, real-time display of integrated measurement parameter values on rollers including roller operation parameters, position, roller-ground interaction parameter values, and/or temperature. Intelligent Compaction (IC) technologies consist of machine-integrated sensors and control systems that provide a record of drum-soil interaction

and automatically adjust vibration amplitude and/or frequency and/or speed using drum feedback during the compaction process.

Without the automatic feedback system, the technology is commonly referred to as continuous compaction control (CCC). Although most RICM technologies are vibratory-based systems applied to self-propelled smooth drum rollers, RICM technologies have also been applied to vibratory double drum asphalt compactors and self-propelled padfoot machines.

Four rollers equipped with different RICM systems were used on this project (Figure 1):

- Caterpillar CS683 vibratory smooth drum roller equipped with compaction meter value (CMV) and machine drive power (MDP) measurement technologies
- Sakai SV610D vibratory smooth drum roller equipped with continuous compaction value (CCV) measurement technology
- Caterpillar CS74 vibratory smooth drum roller equipped with CMV and MDP measurement technologies
- Hamm HD120VV vibratory double smooth drum roller equipped with CMV measurement technology

All four machines were operated on this project in the CCC mode of operation. Detailed descriptions of these technologies are provided in the project report (White et al. 2013).

In brief, CMV is an index parameter computed as the ratio of drum acceleration amplitude of the first harmonic divided by the acceleration amplitude at the fundamental frequency. The ratio is multiplied by a constant (typically 300, but depends on the manufacturer). CMV requires only the measurement of vertical drum acceleration. Another index parameter, CCV, is similar to CMV. However, in addition to using the fundamental and first harmonic, CCV uses the first sub-harmonic and higher-order harmonics.

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 values can be obtained in both vibratory and static compaction operation modes. The MDP values reported on this project are shown as MDP*. A detailed explanation of MDP* is provided in the project report (White et al. 2013).

Falling Weight Deflectometer Testing

Falling weight deflectometer (FWD) tests were conducted using a Kuab FWD setup with an 11.81 in. diameter loading plate by applying one seating drop and four loading drops. The applied loads varied from about 5,000 to 15,000 lb in the four loading drops. The actual applied forces were recorded using a load cell, and deflections were recorded using seismometers mounted on the device, per ASTM D4694-09.



Figure 1. (top to bottom) Caterpillar CS683 smooth drum roller, Sakai SV610D smooth drum roller, Caterpillar CS74 smooth drum roller, and Hamm HD120VV double smooth drum roller (courtesy of Hamm-Writgen Group)

Elastic modulus values from the FWD tests (ESB-FWD) were determined using the following equation:

$$E = \frac{(1 - \eta^2) \sigma_0 r}{D_0} \times F \quad (1)$$

where, E = elastic modulus (psi), D_0 = measured deflection under the plate (in.), η = Poisson's ratio (assumed as 0.4), σ_0 = applied stress (psi), r = radius of the plate (in.), and F = shape factor depending on stress distribution (assumed as 2).

To compare ESB-FWD from different test locations at the same applied contact stress and to perform correlations, the deflection values at each test location were normalized to a 14,000 lb load.

Subbase Layer Mapping

The subbase layer on each test section was mapped using the CS683 smooth drum roller on July 17, 2012 (shortly after construction), using the SV610D and HD120VV smooth drum rollers in October 2012 (about three months after construction), and using the CS683 and CS74 smooth drum rollers in April 2013 (during the spring/thaw).

Average ESB-FWD values from July 2012, October 2012, and April 2013, are shown in Figure 2. Spatially referenced color-coded maps of RICM measurements overlaid on a satellite image are shown in Figures 3 and 6.

Higher RICM values and FWD modulus values were observed in the chemically-stabilized sections (on both north and south sections of 6th St., 11th St., and 12th St.) compared to other sections. The variability observed in RICM values across the site from different machines was not similar due to differences in the vibration settings and effects of aging. Measurements obtained in October (SV610D CCV, HD120VV CMV, and FWD measurements) showed higher values on the cement-stabilized subbase and fiber-reinforced sections (on 6th St. and 7th St.) compared to other sections (except the cement- and fly ash-stabilized subgrade sections on 11th St.). Measurements obtained in April 2013 (during spring/thaw) showed lower modulus values in all test sections, compared to October and July 2012 testing.

Correlations between CS683 and CS74 RICM values (CMV and MDP*) and E_{SB-FWD} values are provided in Figure 7. Correlation between SV610D CCV and E_{S-FWD} values are provided in Figure 8. Regression analysis indicated linear relationships for CMV and CCV, and non-linear regression relationships for MDP*. The R^2 values for CMV and CCV correlations were > 0.7 , and higher than for correlations for MDP* ($R^2 \leq 0.50$).

Reference

White, D.J., Becker, P., Vennapusa, P. (2013). *Boone County Expo Research Phase I – Granular Road Compaction and Stabilization*, Final Report, Iowa Department of Transportation, Ames, Iowa (in preparation). < <http://ceer.iastate.edu/research/project/project.cfm?projectID=-275497063> >

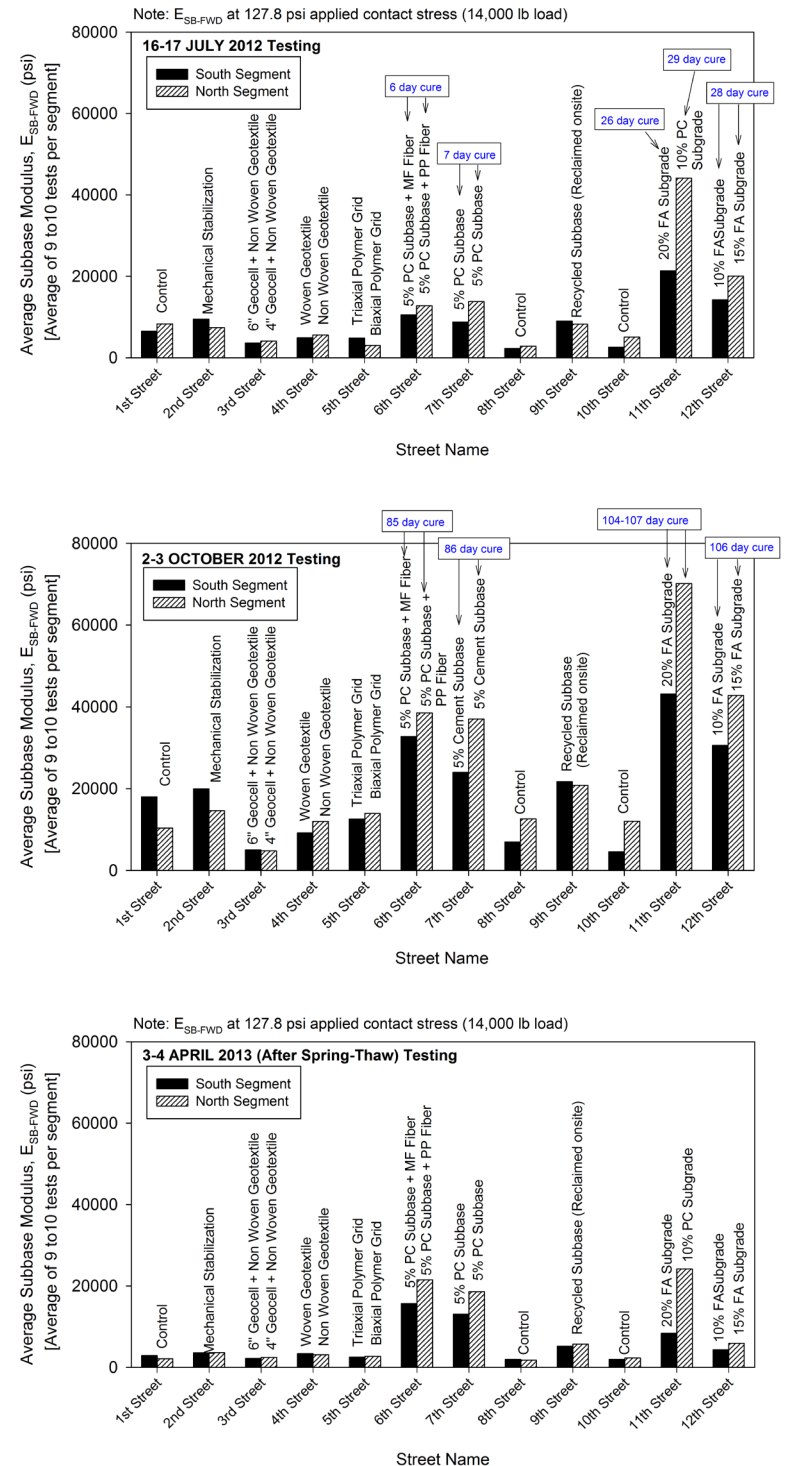


Figure 2. Average FWD modulus measurements from July 2012 (shortly after construction), October 2012 (three months after construction), and April 2013 (during spring/thaw – fourteen months after construction)

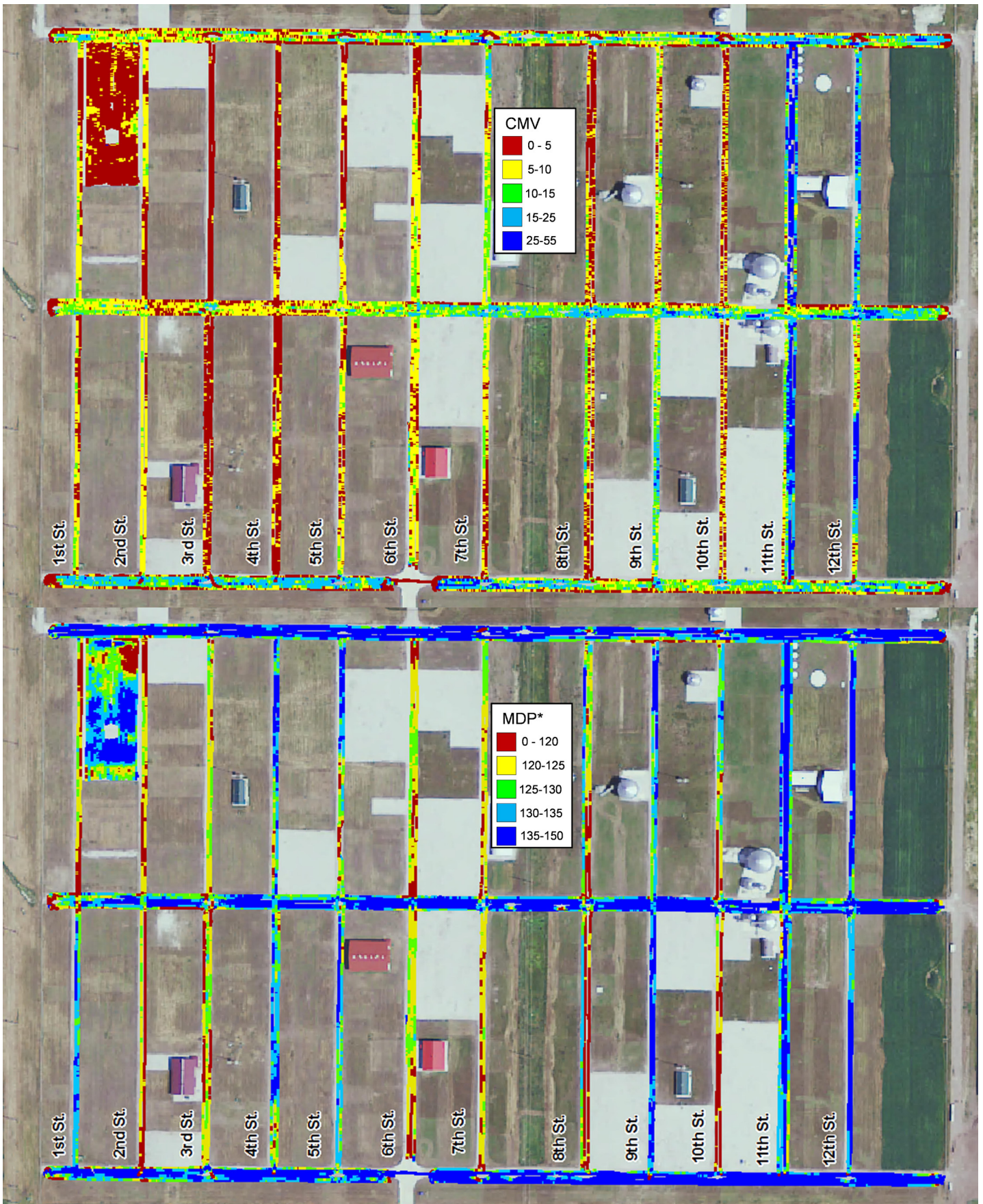


Figure 3. Spatially referenced color coded maps of CMV (top) and MDP* (bottom) measurements obtained using Caterpillar CS683 vibratory smooth drum roller with $a = 0.85$ mm and $f = 30$ Hz nominal settings (July 2012 – shortly after construction)

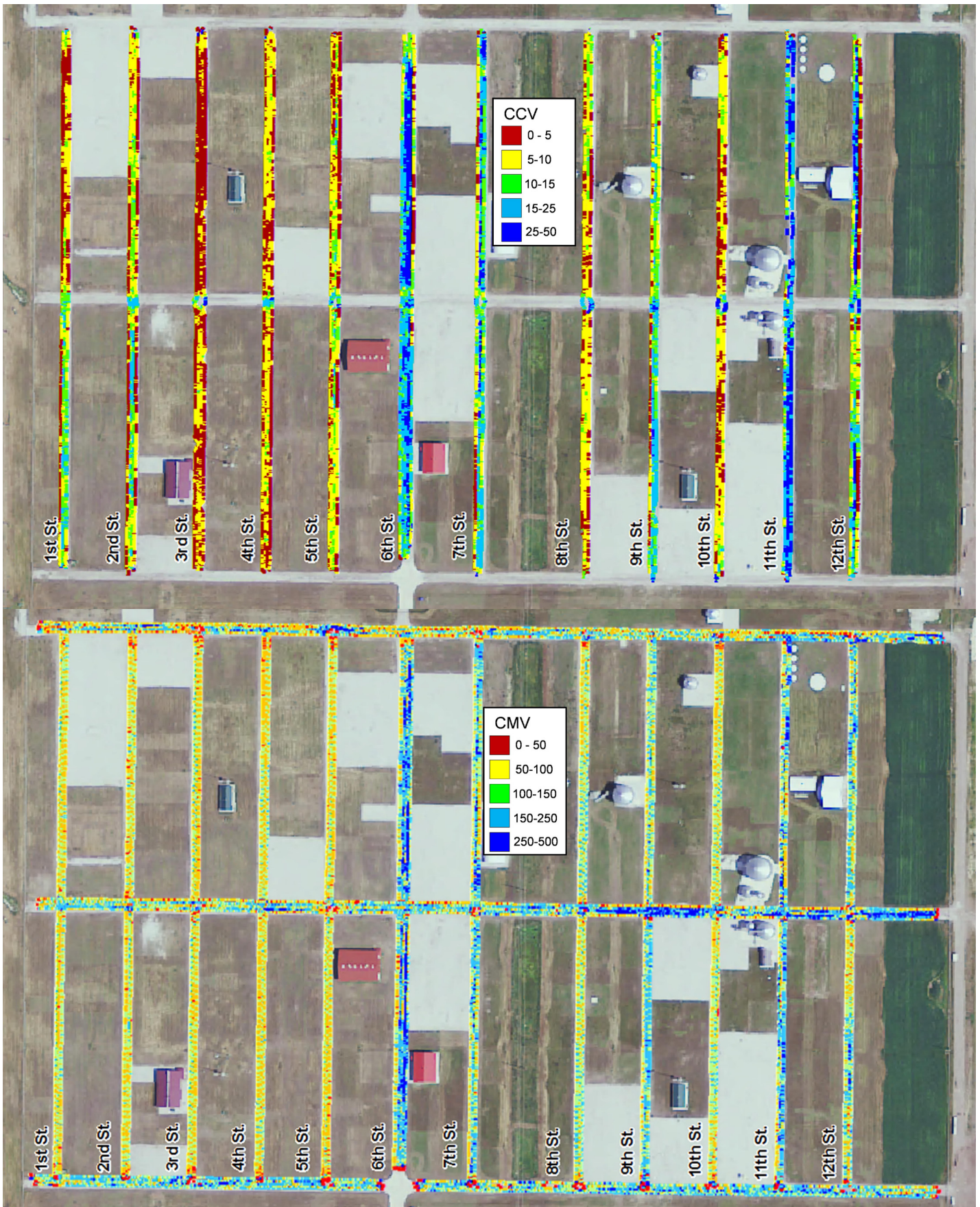


Figure 4. Spatially-referenced color-coded maps of CCV (top) obtained using Sakai SV610D vibratory smooth drum roller with $a = 0.63$ mm and $f = 33$ Hz nominal settings and CMV (bottom) obtained using Hamm HD120VV double vibratory smooth roller with $a = 0.25$ mm and $f = 67$ Hz nominal settings

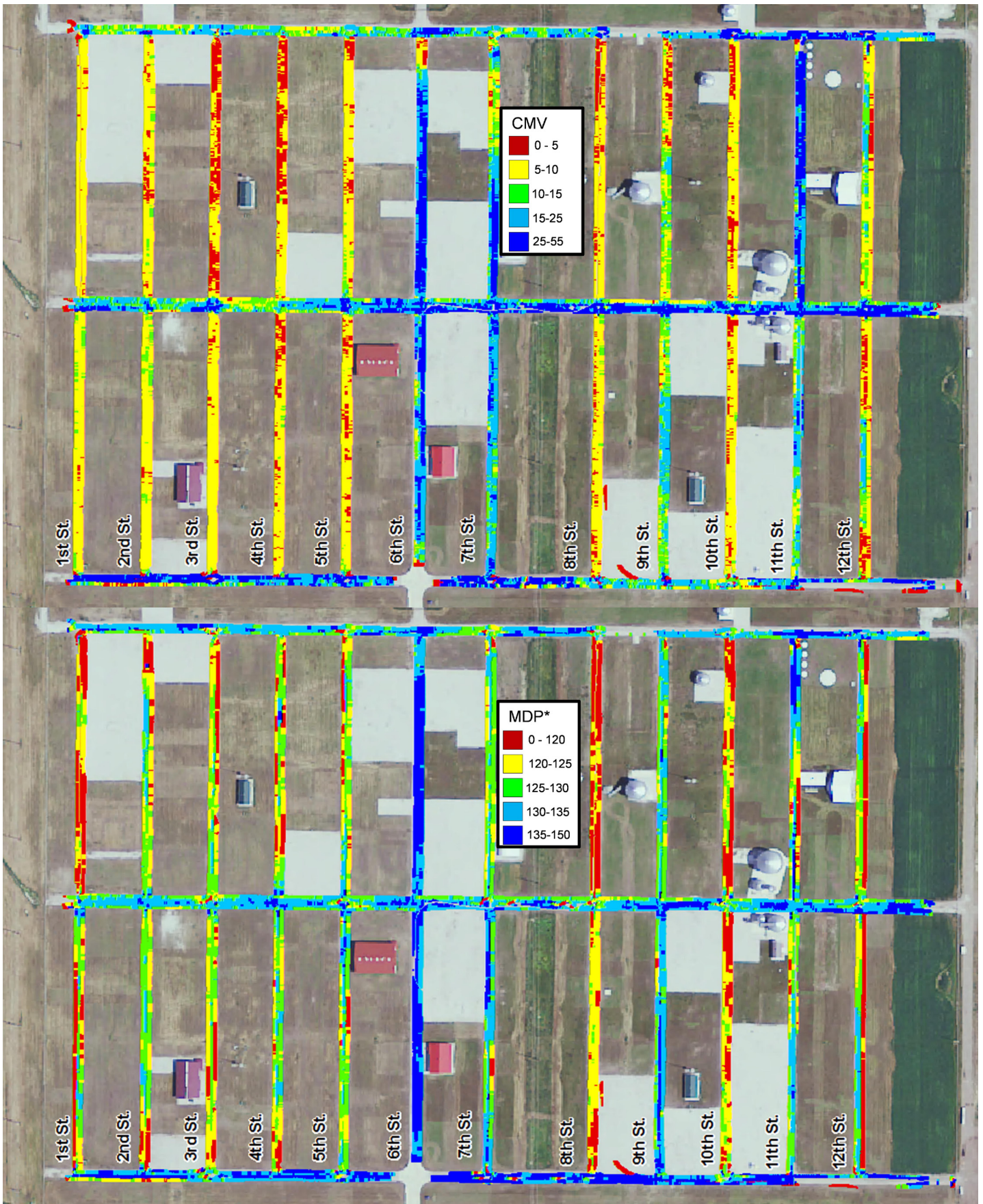


Figure 5. Spatially referenced color coded maps of CMV (top) and MDP* (bottom) measurements obtained using Caterpillar CS74 vibratory smooth drum roller with $a = 0.85$ mm and $f = 30$ Hz nominal settings (April 2013 – during spring/thaw)

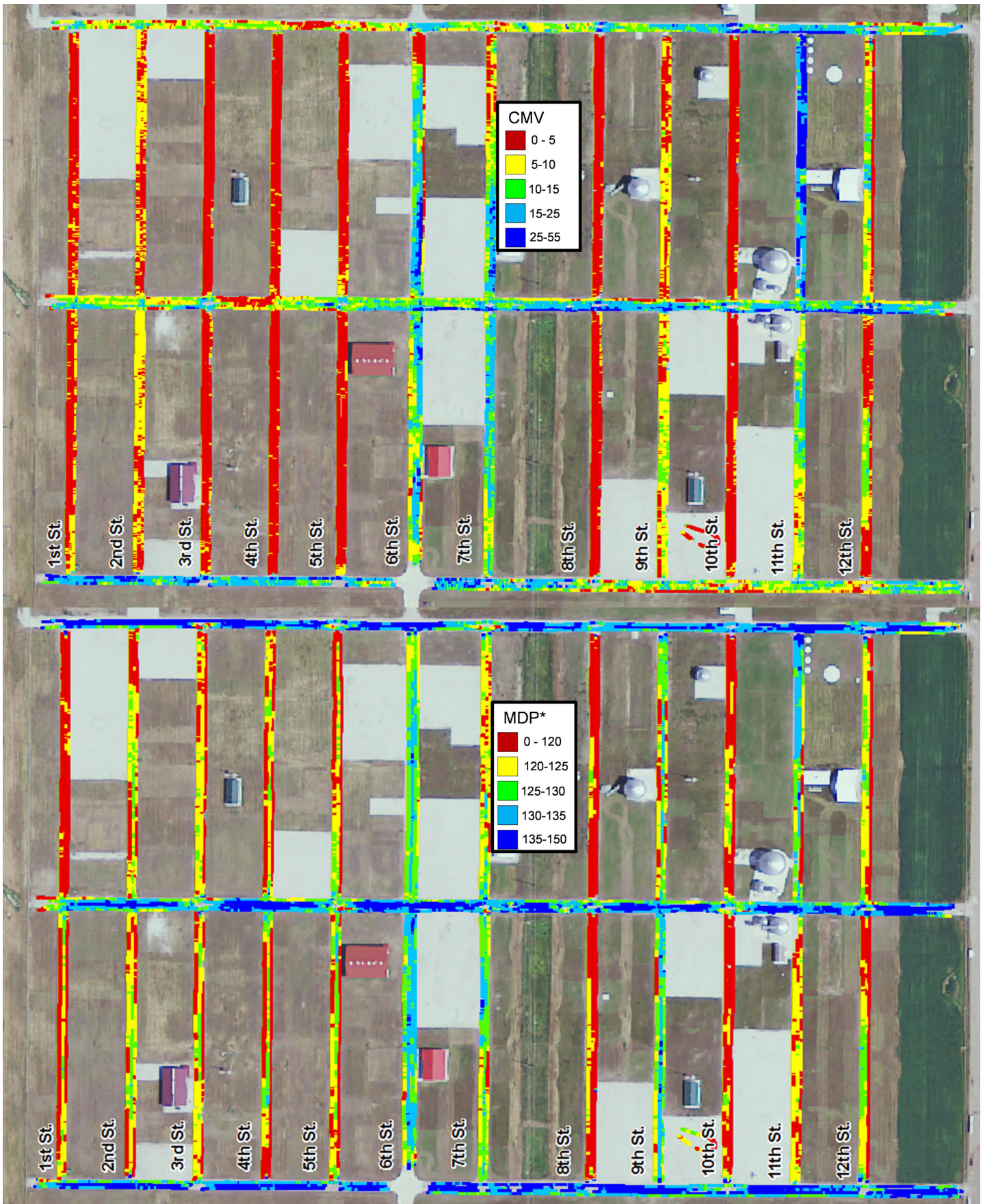


Figure 6. Spatially referenced color coded maps of CMV (top) and MDP* (bottom) measurements obtained using Caterpillar CS683 vibratory smooth drum roller with $a = 0.85$ mm and $f = 30$ Hz nominal settings (April 2013 – during spring/thaw)

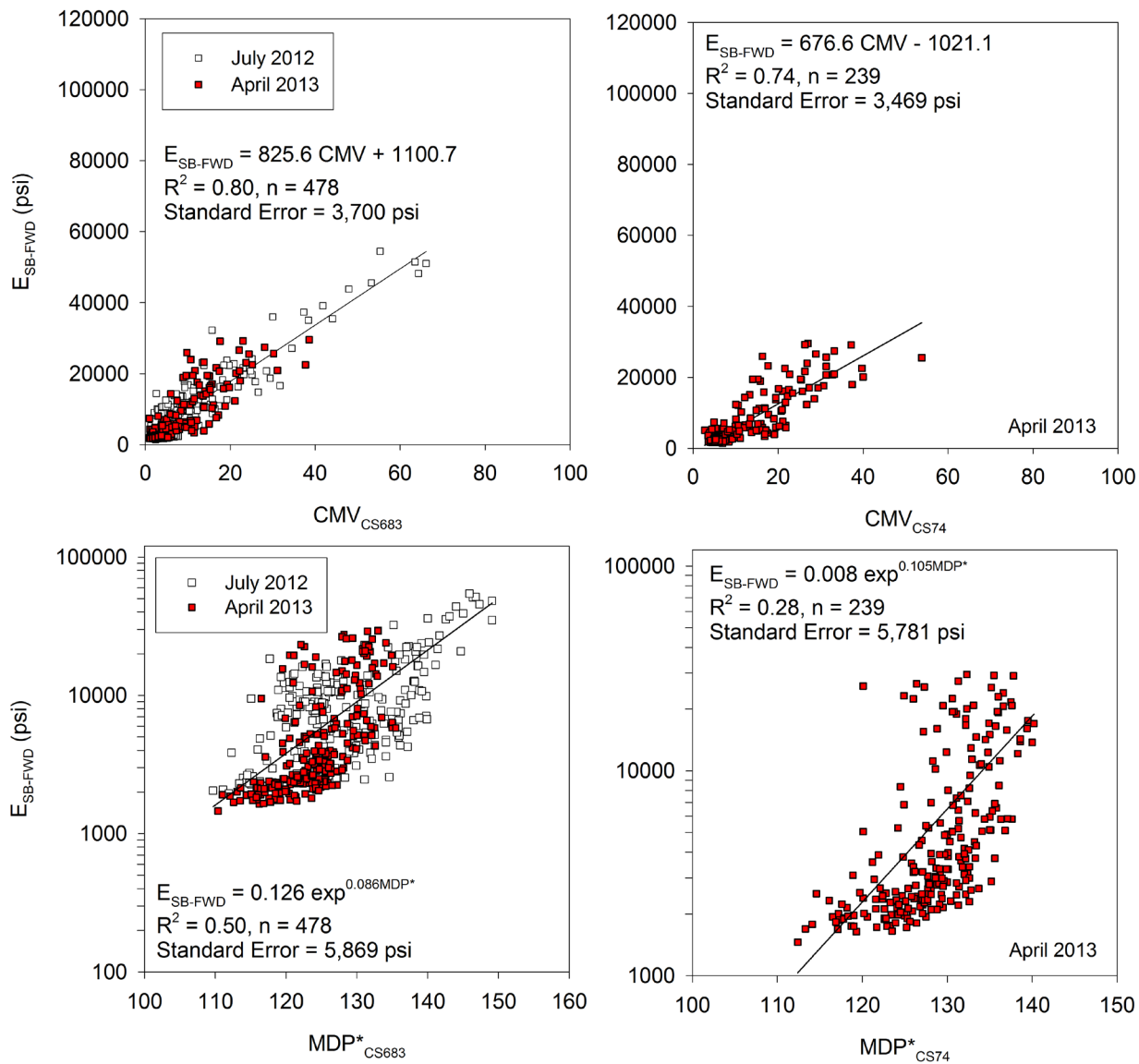


Figure 7. Correlations between RICM values from CS683 and CS74 rollers, and FWD modulus values

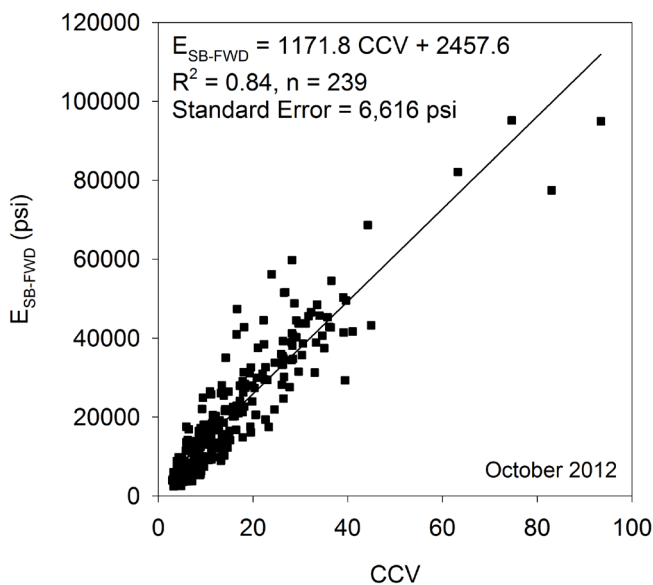


Figure 8. Correlations between RICM values from Sakai SV610D roller and FWD modulus values