

Roller-Integrated Compaction Monitoring of Subbase

RESEARCH PROJECT TITLE

Central Iowa Expo Pavement Test Sections: Phase I – Foundation Construction (InTrans Project 12-433)

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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 tech brief provides a brief overview of the three roller-integrated compaction-monitoring technologies used on this project site and presents results from mapping the test sections.

Site Conditions

The project site consists of thirteen roads oriented in the North-South direction (denoted as 1st St. to 13th St.) and three roads oriented in the East-West direction (denoted as South Ave., Central Ave., and North Ave.). Re-construction occurred on all roads except 13th St., which was paved with hot-mix asphalt (HMA) earlier in 2012.

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 black polypropylene (PP) fibers and white monofilament-polypropylene (MF-PP) fibers; mechanical stabilization (mixing subgrade with existing subbase); and high-energy impact compaction. Triaxial and biaxial geogrids were used at the subgrade/subbase interface at select locations on the East-West roads. More detailed information about the different technologies are provided in individual tech briefs.

All test sections were topped with a nominal 6 in. of modified subbase material (MSB) 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 modified subbase (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 select 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 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.

Three 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
- Hamm HD120VV vibratory double smooth drum roller equipped with CMV measurement technology

All three machines were operated on this project in the CCC mode of operation. Detailed descriptions of these technologies are provided in the Phase I final report.

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*. Detailed explanation of MDP* is provided in the Phase I final report.

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). In addition, all test sections were mapped using the SV610D and HD120VV smooth drum rollers in October 2012 (about three months after construction).

Average compaction measurement values (CMV, MDP*, and CCV) from each roller for each test section are provided as bar charts in Figure 2. Spatially referenced color-coded maps of these measurements overlaid on a satellite image are shown in Figures 3 and 4.

Higher RICM 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 and HD120VV CMV) 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 October (SV610D CCV and Hamm CMV) showed high values on the fiber-reinforced (on 6th St.) and cement-stabilized subbase sections (on 6th St. and 7th St.) compared to other sections (except the cement-stabilized subgrade section).

Additional RICM testing is planned for spring 2013 after thawing and before paving. Details of correlations between the RICM values and in situ tests are discussed in the Phase I final report.



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

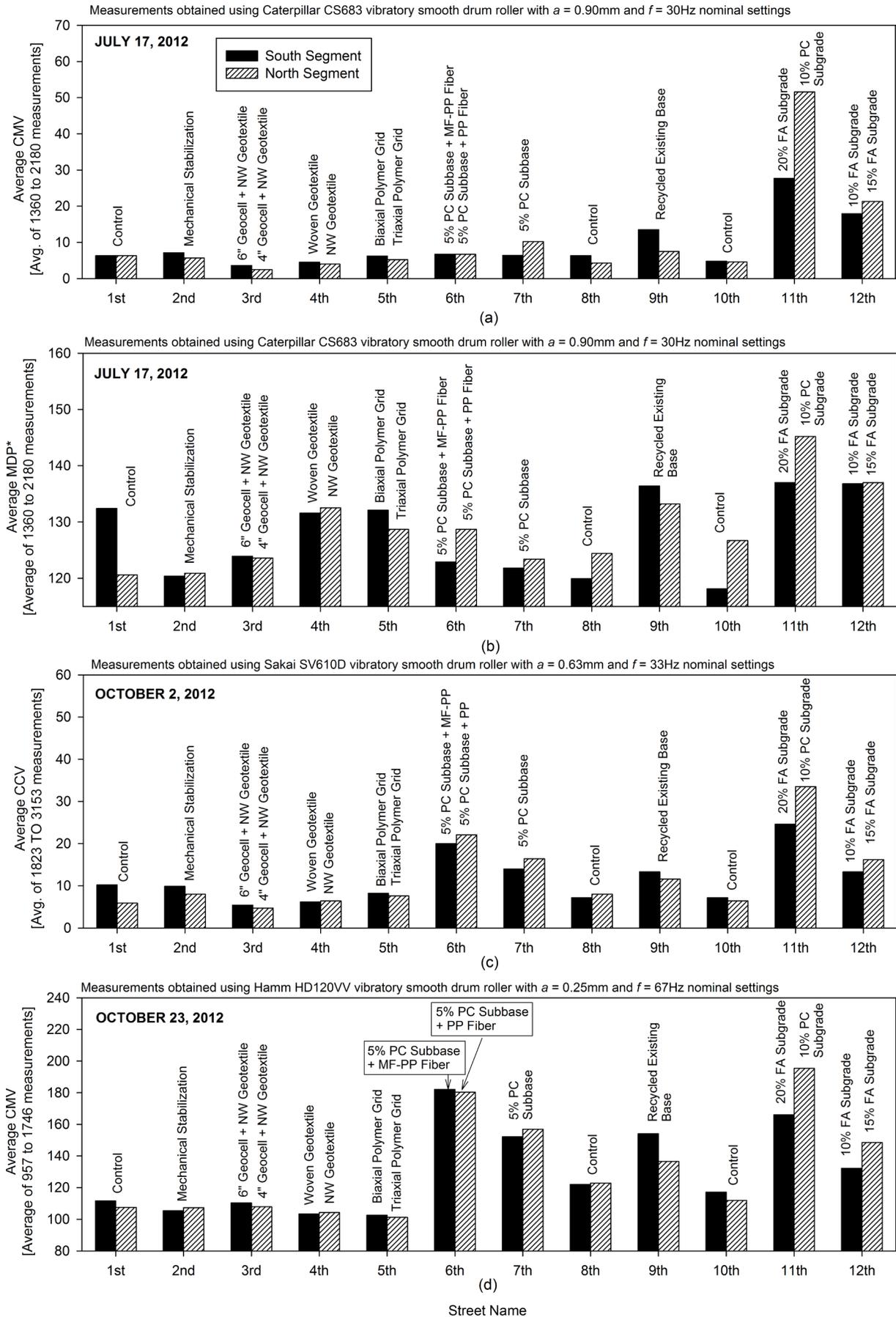


Figure 2. Average intelligent compaction measurements from (a) CS683 CMV, (b) CS683 MDP*, (c) SV610D CCV, and (d) HD120VV CMV

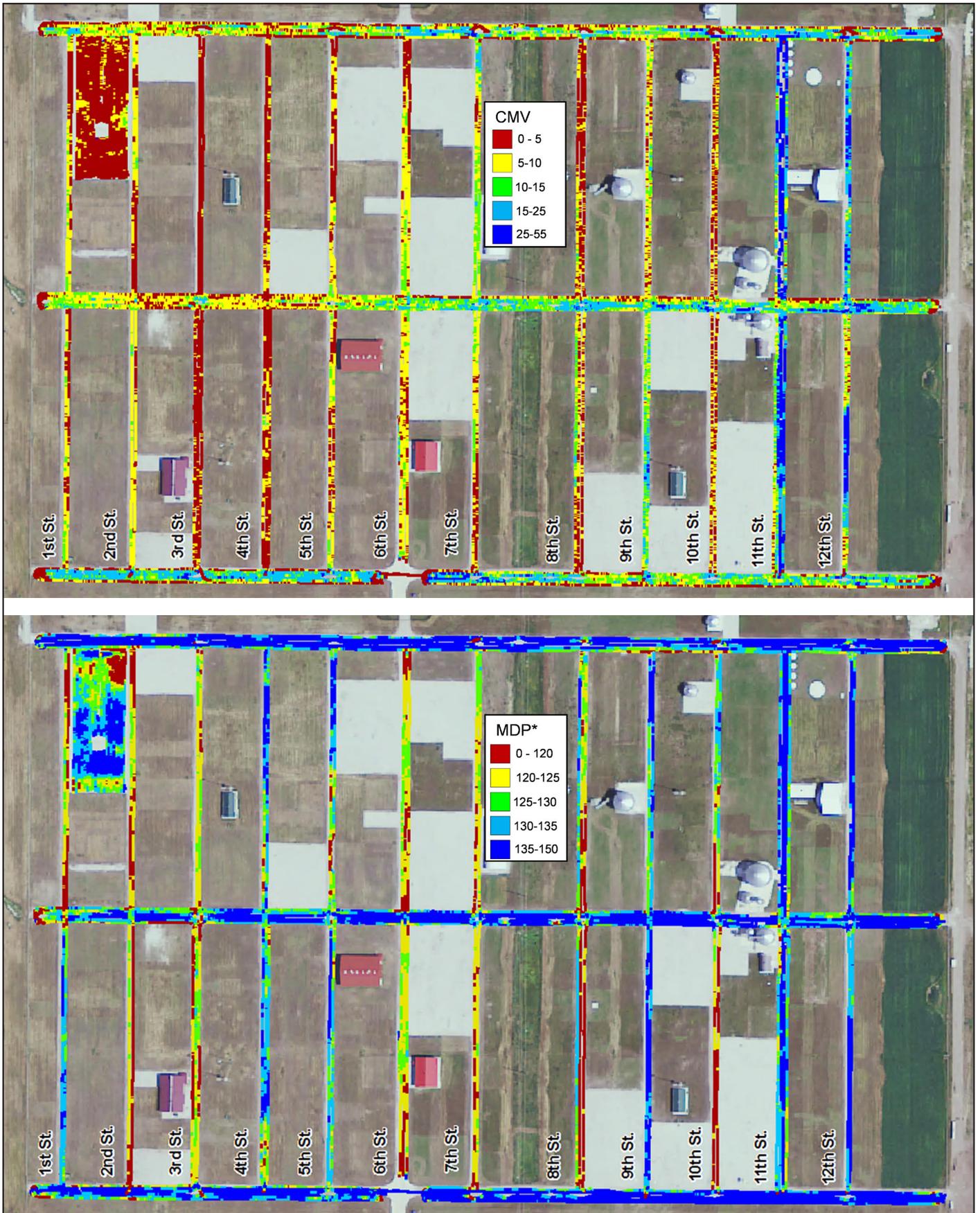


Figure 3. Spatially-referenced color-coded maps of CMV (top) and MDP* (bottom) measurements obtained using Caterpillar CS683 vibratory smooth drum roller with $a = 0.90$ mm and $f = 30$ Hz nominal settings

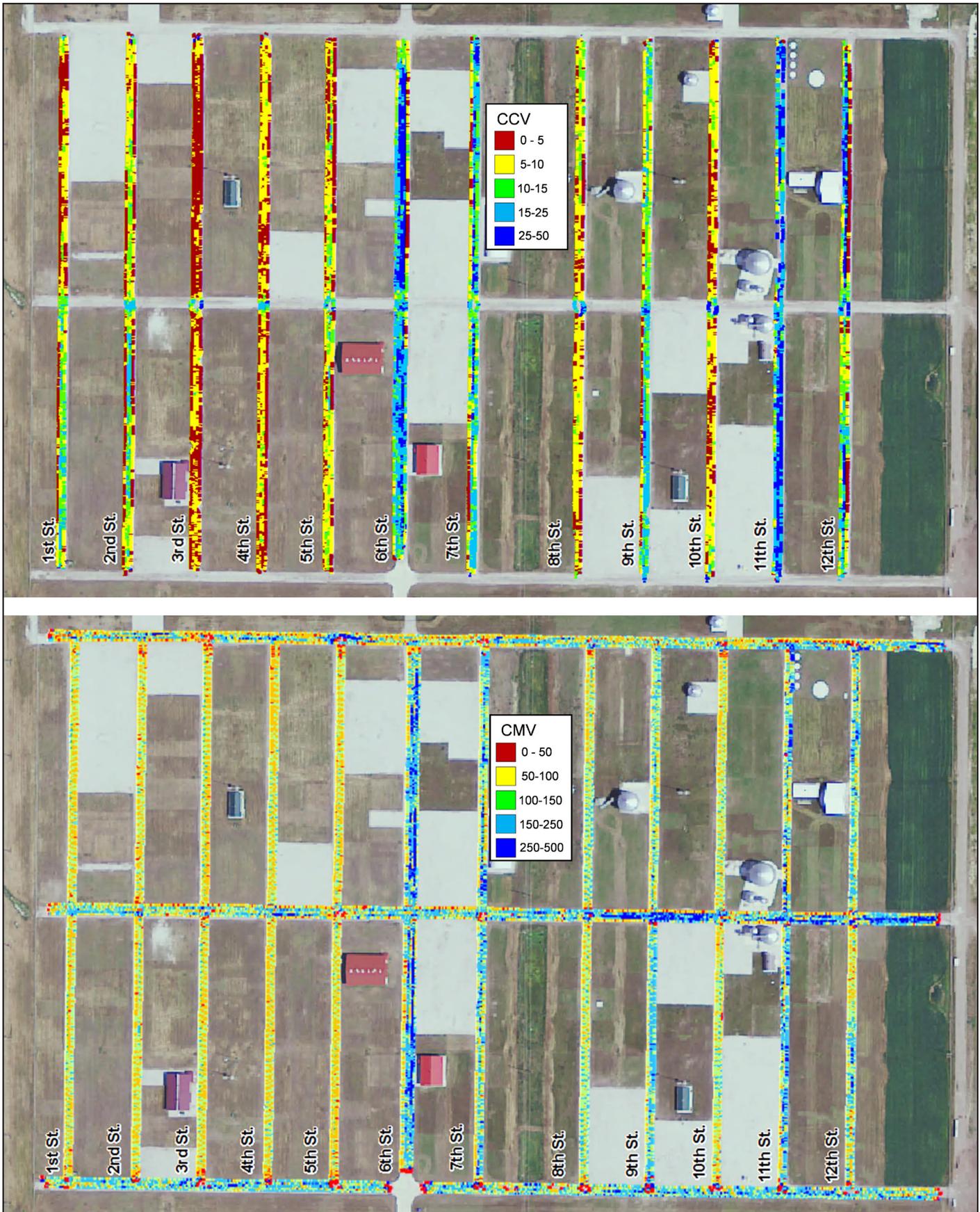


Figure 4. Spatially-referenced color-coded maps of CCV (top) obtained using Sakai SV610D vibratory smooth drum roller with $a = 0.63$ mm and $f = 33$ Hz nominal settings and CMV (bottom) obtained using Hamm HD120VV double vibratory smooth roller with $a = 0.25$ mm and $f = 67$ Hz nominal settings