Two Non-Destructive Approaches for Assessment of Field Lift Thickness

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Introduction

The placement of soil in uniform lifts at the specified thickness is a crucial component during earthwork construction. However, it can be extremely difficult for inspectors and field engineers to monitor the lift thickness of soil during earthwork construction without continuous surveying. Technologies such as, Continuous Compaction Control (CCC) has been utilized to monitor the compaction process in real-time through instrumentation of a compaction roller which includes a RTK-GPS receiver mounted on the compaction roller. To date, little research has been performed evaluating the accuracy and implementation of CCC technology for lift thickness control during active earthwork construction. In this study a test pad was constructed where a single lift of soil was placed with varying lift thicknesses to determine lift thickness measurements at pre-determined locations using CCC technology. In parallel, lift thickness measurements were also made with the MIT SCAN T3 thickness scanner as an accurate tool for nondestructive determination of material thickness. Lift thickness measurements were validated using physical lift thickness measurements made with a caliper and steel ruler.

Figure 1. Caterpillar CS56B Compaction Roller with RTK-GPS Receiver

Figure 2. MIT SCAN T3 Lift Thickness Scanner

Test Pad Construction

A test pad was constructed that was approximately 38 m long by 18.5 m wide with two 18.4 m by 18.4 m grids within the test pad. Within each grid, 41 Within each grid 41 steel reflectors, with a nominal diameter of 30 cm, were placed in a gridded pattern, as shown in Figures X and X. Prior to the placement of the steel reflectors the test pad was proof rolled with a Caterpillar CS56B smooth drum compaction roller that was instrumented with a MS972 RTK-GPS receiver in order to obtain elevation readings along the test pad.

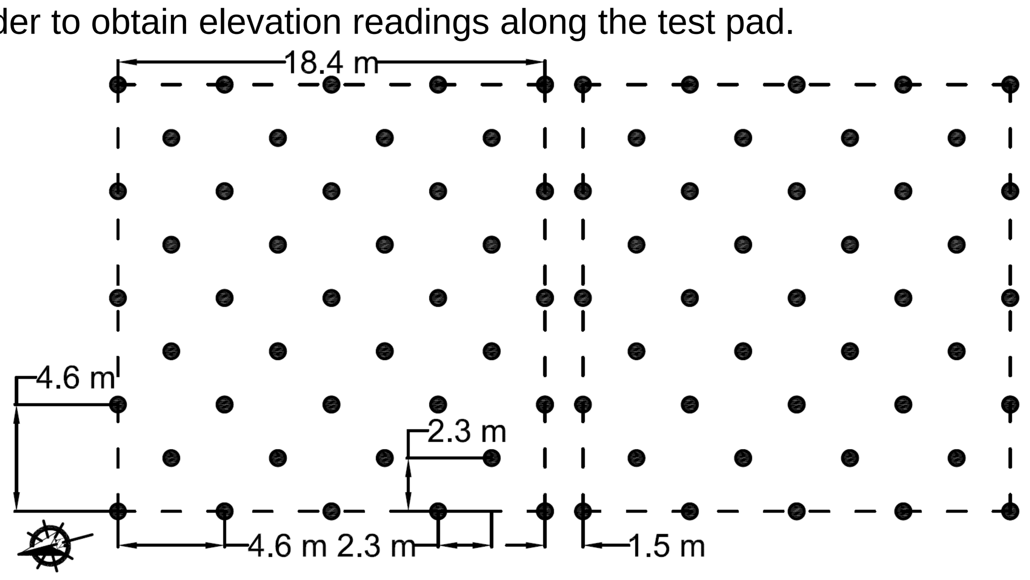

Figure 3. Proposed Test Pad/Disk Configuration

Figure 4. Constructed Test Pad/Disk Configuration

Upon completion of securing the steel reflectors to the foundation of the test pad, a lift of soil was placed along the test pad. The northern grid received an approximate 0.33 m (12 in) loose lift and the southern grid received an approximate 0.22 m (8 in) loose lift. The test pad was then compacted and proof rolled utilizing the same compaction roller to obtain elevation readings along the test pad after the placement of the lift of soil.

Figure 5. Grading lift of soil along Test Pad

Figure 6. Compacting lift of soil along Test Pad

Once the lift of soil was placed and compacted, nondestructive lift thickness measurements were collected at each steel reflector location utilizing the MIT SCAN T3. Physical lift thickness measurements were also collected by digging down to each steel reflector and measuring the lift thickness utilizing a 30 cm dial caliper and 91 cm steel ruler.

Figure 7. Utilizing dial caliper to measure physical lift thickness

Figure 8. Utilizing steel ruler to measure physical lift thickness

Compaction Roller RTK-GPS Results

Given that the elevation readings measured by the CCC RTK GPS receiver are near continuous in nature, an interpolation technique was needed in order to estimate the elevation readings at the 82 predetermined steel reflector locations. Inverse Distance Weighting (IDW) was chosen as the interpolation technique of choice for this study. The equation for IDW can be defined as:

$$\hat{v} = \sum_{i=1}^{n} \frac{\frac{1}{d_i^p} v_i}{\frac{1}{d_i^p}}$$

$\hat{v}$- estimation point of interest, e.g. reflector location

v_i - i[th] sampled value used to estimate $\hat{v}$, e.g. CCC RTK GPS elevation reading

d_i- i[th] euclidean distance between the point of interest and the i[th] sampled value

p - power weighting function value

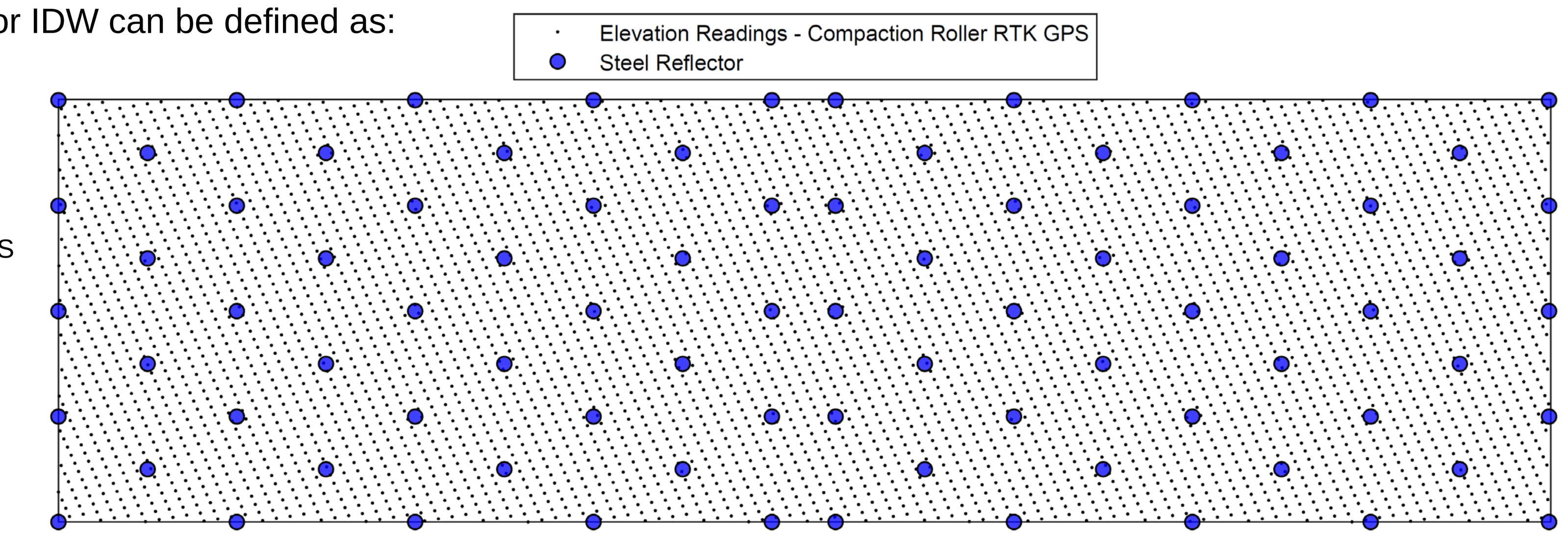

Figure 9. Comparison between steel reflector locations and elevation readings locations from CCC RTK GPS receiver

Given that a search radius *d* and power weighting value *p* need to be assigned in order to utilize IDW a sensitivity analysis was conducted in order to determine the combination of *d* and *p* that resulted in the lowest error in thickness measurements produced by the CCC RTK GPS receiver. Based on the sensitivity analysis, the optimum combination of *d* and *p* values resulted in a *d* value of 1.75 m and *p* value of 0.026; producing a mean absolute error (MAE) of 1.65 cm when compared against physical lift thickness measurements

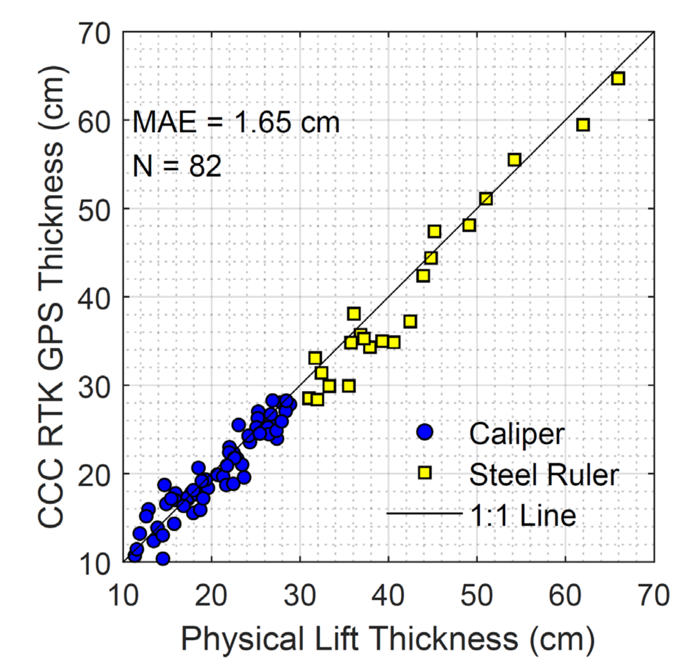

Figure 10. Lift Thickness Comparison between CCC RTK GPS Lift Thickness Measurements and Physical Lift Thickness Measurements

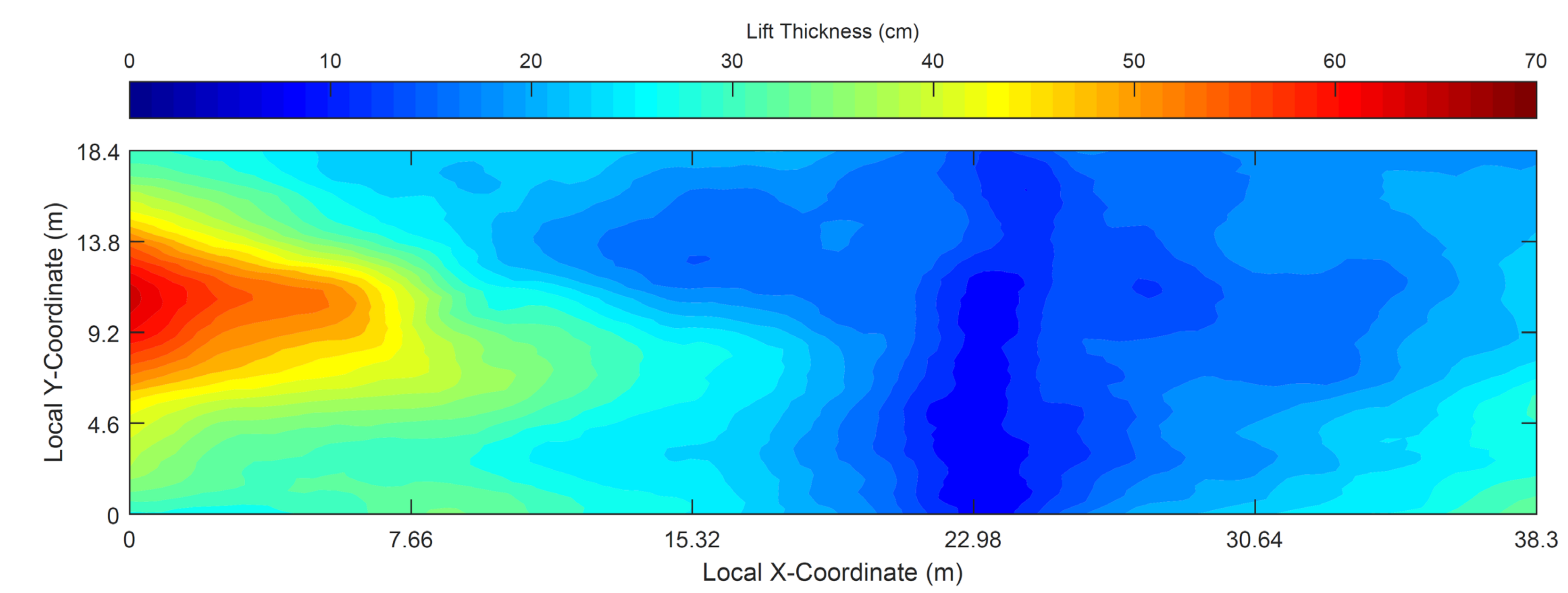

Figure 11. Lift Thickness Heat Map utilizing Elevation Readings from CCC RTK-GPS and IDW interpolation with *d* = 1.75 m and *p* = 0.026

MIT SCAN T3 Results

At each steel reflector location 5 measurements were taken with the MIT SCAN T3. Table 1 provides summary statistics of the variation in measurements taken utilizing the MIT SCAN T3 at a given locations. Based on the results presented in Table 1, the measurement variation for the MIT SCAN T3 for a given location was significantly and consistently low when examining the mean and median values for both coefficient of variation (COV) and the range. Overall the MIT SCAN T3 performed considerable well, producing an MAE of 0.39 cm when compared against physical lift thickness measurements.

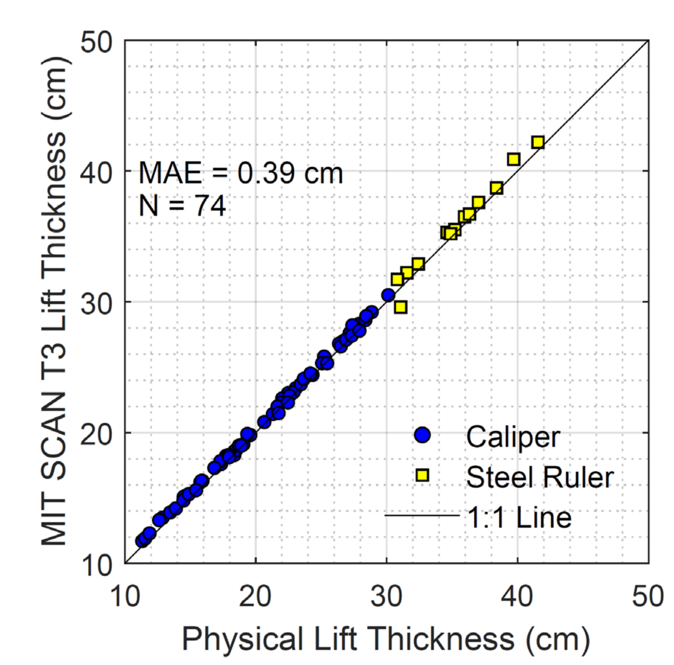

Figure 12. Lift Thickness Comparison between MIT SCAN T3 Thickness Measurements and Physical Lift Thickness Measurements

Table 1. Summary Statistics of Sample Variation Utilizing MIT SCAN T3

	5 Sample σ (mm)	5 Sample COV (%)	5 Sample Range (mm)
Minimum	0	0	0
Maximum	8	20	20
Mean	0.65	2.7	1.5
Median	0.55	2.5	1

Conclusions

Overall, both technologies in an aggregate sense were able to produce MAE values of less than 2 cm when compared against physical lift thickness measurements. On a point-by-point basis, there were instances where the use of IDW as the interpolation technique produced lift thickness measurements errors greater than ± 4 cm from the elevation readings produced by the CCC RTK-GPS. This finding warrants further investigation into more sophisticated interpolation techniques (e.g. kriging). The MIT SCAN T3 was found to be very accurate, with measured thicknesses being limited to the size of the reflector used; also of course, this device was only able to determine the lift thickness at discrete locations.

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