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CALIBRATION AND ACCURACY ASSESSMENT OF THE TDR ONE-STEP METHOD FOR QUALITY CONTROL OF COMPACTED SOILS

PROBLEM STATEMENT

Quality control of compacted fills and roadway embankments has been and remains a challenging problem. Although the most accurate measurement method for water content remains the ASTM oven-drying procedure, the procedure requires 24 hours of oven-drying before the results are available. Nuclear density and moisture gages require special certification, due to the potential hazards associated with the use of a radioactive material.

The Florida Department of Transportation has sponsored research to evaluate the Purdue Time Domain Reflectometry (TDR) method as an alternative for in-situ density and moisture measurement. The method was standardized in 2002 by ASTM under Designation D 6780. The ASTM Method calls for a two-step process that requires excavation and re-compaction of the field soil. However, a new one-step method was developed by Purdue University researchers. This method represents a breakthrough in the technology, since no excavation is needed. The procedure requires the calibration of two soils constants, f and g, to relate the dielectric constant to the bulk electrical conductivity of the soil. The field process can be completed in less than 5 minutes, which provides a significant advantage over the existing procedure. The two soil constants, f and g, are dependent on soil type, pore fluid conductivity, and water content. Determining these new soil constants for typical highway construction soils in Florida is a crucial step in the progress and eventual widespread usage of the one-step method.

OBJECTIVES

The goal of the project was to improve upon the ASTM Standard Method for TDR measurement of Soil Water Content and Density. The work relied on a new concept to obtain a simultaneous measurement of electrical resistivity in conjunction with the dielectric constant from the TDR measurement. Both measurements were then used to back calculate the water content and density in a single step that does not require excavating and re-compacting the soil. The specific objectives included the following:

- to determine the calibration constants, *c*, *d*, *f* and *g*, for typical construction materials used in Florida
- to examine the accuracy of the one-step TDR method in terms of moisture and density measurements
- to compare the TDR method with other widely accepted methods such as the nuclear gage and the sand cone methods
- to develop recommendations for implementation of the TDR one-step method in Florida

FINDINGS AND CONCLUSIONS

Soil constants “a” and “b” were found to be consistent with previous studies. In the absence of soil-specific calibration, blanket values of 1.0 and 8.5 are recommended, respectively, for “a” and “b.” Soil constant “c” is a unique point for a given soil and it is possible to catalogue “c” values based on soil type. For typical construction soils in Florida, and in the absence of soil-specific calibration data, a value of 0.01 should be used for constant “c.” Soil constant “d” demonstrated systematic change with pore fluid conductivity, with values ranging between 0.2 and 0.8. A soil-specific field calibration is required for the accurate determination of constant “d.” Soil constants “f” and “g” are calculated from constant “a,” “b,” “c,” and “d” and, as such, depend directly on their values. Soils evaluated in this study to develop these constants were exclusively poorly graded sands.

Further investigation into the effect of pore fluid conductivity on the TDR calibration revealed that the initial salt content of the soil affects calibration. A soil containing an appreciable amount of salt will alter calibration constants “c,” “d,” “f,” and “g.” Values of “c” will be slightly higher than the true calibration value, especially if the calibration is carried out at high water contents and “c” is extrapolated back onto the vertical axis of the calibration chart. It was also found that soil constant “c” may be determined accurately testing the soil at zero water content and measuring the intercept value “c.” Constant “d” is significantly affected by salt content. For a true calibration of “d” to be obtained, a soil must be washed to remove salts, since conductivity increases due to the presence of ions upon hydration. To avoid washing a soil to obtain a true calibration line, it is recommended that a single calibration point be obtained at a high water content such that the salts will be highly diluted and will have minimal effects on the calibration. As such, and if the blanket value of 0.01 for “c” is assumed, only one calibration point at the highest possible water content is needed to determine “d.”

Side-by-side tests using ASTM TDR one-step, nuclear gage, and speedy moisture methods indicate that the ASTM TDR method displays less scatter and is more accurate than both of the other methods in terms of moisture content measurement, assuming proper selection of calibration constants. Spatial analysis of the water content within a given site indicates that the site itself exhibits significant variation relative to the variation between the methods. According to the dry density results, the ASTM TDR one-step method exhibited larger scatter but consistently yielded lower densities than the nuclear density and speedy moisture measurements, and is therefore more conservative.

BENEFITS

This project has provided FDOT with state-of-the-art research on a new technique for in-situ soil measurement. The one-step TDR method eliminates the need for excavating the soil, and thus represents a non-destructive alternative to the two-step method. The use of TDR for field measurements may be preferable to current FDOT practice, namely, use of the nuclear gage and speedy moisture methods, since no safety training or certification is needed. Elimination of the nuclear source needed for the nuclear gage tests would be a significant safety and security improvement for the Department and the field operators.

This research project was conducted by Alaa Ashmawy, Ph.D., P.E. of the University of South Florida. For more information, contact David Horhota, Ph.D, P.E., Project Manager, at (352) 955-2924, david.horhota@dot.state.fl.us