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OFFICE OF TRANSPORTATION SYSTEM MANAGEMENT

TECHNICAL SUMMARY

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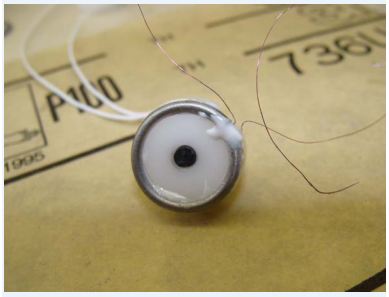
PROJECT COST:
$65,289



The button heat pulse sensor takes in situ readings without requiring soil sample preparation, but is not yet rugged enough for field use.

Alternative Devices for Measuring Soil Moisture

What Was the Need?

To construct a stable, supportive pavement foundation, engineers must ensure that the moisture content of the soil is near its optimum value when compacted. To determine this optimum value for a specific soil, MnDOT uses the AASHTO T99 laboratory procedure in which soil samples with varying moisture levels are compacted and measured for density.

Many state transportation agencies use nuclear density gauges to compare the field moisture content and density of soils to the laboratory-estimated optimum values. MnDOT uses the sand cone test, which avoids exposing workers to radioactive materials but requires time-consuming drying and weighing of soil samples. State departments of transportation nationwide are actively looking for alternative devices that can measure moisture content quickly and safely in the field.

The DOT600 continues to show promise as an effective, accurate tool for determining soil moisture content in the field. With further development, it could be a viable alternative to the more labor-intensive methods MnDOT currently uses.

For several years, MnDOT has been working with Campbell Scientific to develop and refine the DOT600, a portable device that uses soil electrical properties to determine moisture content. A previous MnDOT project found that the DOT600 showed promise as an alternative field device. Its outputs correlated well with measures of soil stiffness and of matric suction, a measure of the energy state of water molecules in the pores between soil particles.

What Was Our Goal?

Building on previous research results, this project evaluated the DOT600 alongside three other devices for measuring soil moisture content. The project's goal was to evaluate the proficiency of the four instruments at accurately determining the moisture contents of three soils commonly used in Minnesota road construction projects.

What Did We Do?

Researchers evaluated four devices:

- **DOT600:** This field device determines moisture content of a soil sample using the principle of dielectric permittivity. The soil sample is compacted in a cylindrical chamber, and the oscillation frequency of an electronic circuit beneath the sample is measured. As water content increases, the period of oscillation increases.
- **Button heat pulse sensor:** An emerging tool in agricultural applications, this field device estimates moisture content by measuring temperature rise in the soil.
- **Exudation pressure device:** This device determines the moisture state of a sample based on the compressive force (exudation pressure) required to exude water from a soil sample. MnDOT uses an exudation pressure of 240 psi during pavement design to determine the design moisture content. A sample that requires more pressure to exude water is considered dry, and one that requires less pressure is wet compared to the design moisture. The resistance value, R-value, of a sample at the design moisture with 240 psi exudation pressure is used during pavement design.

continued

"This project evaluated four different approaches for determining the moisture content of soils during construction. With modifications, all four have potential for future applications."

—John Nieber,
Professor, University of Minnesota Department of Bioproducts and Biosystems Engineering

"Our goal is to deploy a field device for measuring moisture content that enhances the ability of our inspectors to be effective with reduced resources and greater responsibilities."

—John Siekmeier,
MnDOT Research Engineer

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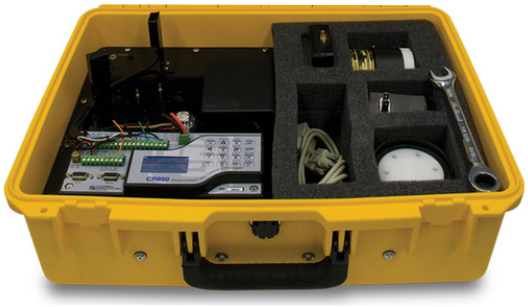

To use the DOT600 (left), a soil sample is placed in the device's compaction chamber and compacted to a selected pressure. The device uses the soil's electrical properties to calculate its moisture content. A ruggedized field device (right) is being developed.

- **WP4C dewpoint potentiometer:** This laboratory device estimates the matric suction of a soil sample by measuring the dewpoint temperature inside the sample chamber.

Researchers evaluated these devices by comparing their measured values against both pressure plate generated matric suction values and water content values for each point on the AASHTO T99 curve.

What Did We Learn?

Of the four devices, the DOT600 and the exudation pressure device showed the strongest potential as a field test for moisture content and have the potential to become a new standard. Detailed results include the following:

- The DOT600's sensor output period (frequency) values showed a strong correlation with water content. Therefore, the DOT600 could be used to compare field conditions to the optimum moisture content estimated in the laboratory.
- For two of the three soils tested, the moisture contents of samples that met the exudation pressure of 240 psi were very close to the AASHTO T99 optimum moisture content. This was not the case for the third soil.
- The button heat pulse sensor showed a strong correlation between measured temperature rise and water content, but the device is not rugged enough to withstand field conditions.
- The WP4C may be a viable option for laboratory measurement of the matric suction of soils that reach optimum moisture content at suctions above 250 kPa. It did not accurately measure matric suction for any of the soil samples in the wet range (0 to 200 kPa).

What's Next?

With further development, the DOT600 and exudation pressure device could provide viable methods for MnDOT, local agencies and consultants to assess soil moisture content safely and effectively in the field. MnDOT is in discussions with Campbell Scientific about modifying the DOT600 to meet customer needs. As resources permit, MnDOT plans to continue modifying the exudation pressure test, ultimately building a prototype for pilot testing on construction sites.

This Technical Summary pertains to Report 2013-28, "Performance-Based Measurement of Optimum Moisture for Soil Compaction," published November 2013. The full report can be accessed at http://www.lrrb.org/PDF/201328.pdf.