Center for Transportation Infrastructure Systems

Continuous Moisture Measurement during Pavement Foundation Construction

Technical Memorandum 1

Task 1: Expected Research Benefits and Potential Implementation Steps

by

Mark Baker
Soheil Nazarian

Conducted for

National Road Research Alliance

March 2021
Rev: May 2021

Center for Transportation Infrastructure Systems
The University of Texas at El Paso
El Paso, TX 79968
(915) 747-6925

Expected Research Benefits and Potential Implementation Steps

Project Abstract

Accurate and timely moisture measurement of earthwork during compaction of foundation layers is crucial to proper construction and long-term durability of the pavement structures. Since the traditional methods for measuring moisture are point specific, expensive, and/or time-consuming, it is desirable to explore new devices that can provide the full coverage of the spatial variation of moisture.

This project will document the current state of knowledge concerning field moisture measurement during pavement foundation construction. This project will also provide critical information about the state of the art and the state of practice related to the most effective moisture measurement devices suitable for improving compaction near structures such as retaining walls and bridge abutments. Finally, this project will demonstrate a prototype device in appearance and mobility capable of continuously measuring moisture during pavement foundation construction.

Objective of Project

The objective of this study is to demonstrate a prototype/breadboard of a device that can continuously measure moisture during pavement foundation construction, similar to the Asphalt Rolling Density Meter (https://www.geophysical.com/products/pavescan-rdm) used for asphalt layer.

Benefit to Taxpayers of the NRRA Member States

Earthwork and unbound aggregates, collectively called compacted geomaterials, are a significant portion of the construction of pavements. Much of the distress observed in pavements, particularly in flexible pavements, can be traced to problems in those materials. Good pavement performance can only be assured with appropriate process control to ensure the geomaterials used are similar to the one selected, proper processing of the material to ensure that the material is uniformly mixed and contains an appropriate amount of moisture before compaction, and adequate compaction equipment to ensure proper density and stiffness.

The primary tool for quality management is currently the nuclear density/moisture gauge (NDG). Despite the importance of moisture content at the time of compaction to the quality of the final product, several highway agencies do not impose or enforce limits on moisture content in their specifications. According to White et al. (2016),[1] four out of nine NRRA member states do not impose a limit on moisture content at all on granular materials while three other members require moisture limits depending on the type of project or the method of compaction. They also indicated that in a typical project as high as 50% of the field moisture content measurements could be outside the normally acceptable moisture content variations. Since the measurement of moisture content and dry density does not directly tie the construction quality with the mechanistic-empirical design processes, in-situ modulus-based devices that estimate the stiffness parameters of a constructed pavement structure are emerging. Such stiffness parameters are more representative of the pavement performance predicted during the mechanistic-empirical based design process, but there are also more sensitive to the variation in the moisture content of the layer.

---

[1] White D., Li S., and Vennapusa P. (2016), "Embankment Quality and Assessment of Moisture Control Implementation," Report IHRB Project TR-677, Center for Earthworks Engineering Research, Iowa State University, 225 p.

The proposed technology will contribute to uniform and higher quality foundation layers as both process control and a quality control tool. A more uniform and stronger foundation should result in a longer-lasting pavement that will require less maintenance and rehabilitation throughout its life cycle.

Initial Projection of Expected Benefits

The initial benefits can be summarized in the following items:

- More informed quality management of the earthwork by measuring a significant parameter, moisture content.
- Lower life-cycle cost in terms of less frequent maintenance and rehabilitation by improving the uniformity and quality of the pavement foundation
- Less risk to the owner agencies by covering the entire project as opposed to spot testing
- A tool to help contractors produce a quality product and improve their productivity with less dispute

Expected Technical Outcomes

The following list summarizes the expected outcomes of this research:

- A methodology for quantifying the moisture content of the earthwork during construction in a continuous manner.
- Lab and field prototypes/breadboards for measuring moisture.
- A thorough evaluation of the developed prototype equipment
- Test procedures for performing the proposed tests

Summary of Research Methodology

The proposed technology is based on the measurement of complex resistivity (CR) of geomaterials as a function of frequency, electric current, and measurement geometry to characterize moisture content and degree of saturation. Complex resistivity measures ionic conduction and polarization along adsorbed water at grain boundaries, ionic conduction through free pore fluid, and polarization at the air-water interface. Currently marketed DC-resistivity equipment could be used with little material calibration if enough additional measurements are made to distinguish residual moisture on fines, saturation variations, and void changes in compaction. This would require measuring a) material resistivity in the dry state, b) resistivity of the water added, and then c) pre- and d) post-compaction resistivity. Our proposed CR at intermediate frequencies gives simpler field procedures, distinguishes saturated and unsaturated cases with an enhanced polarization signal with partial saturation from charges blocked from the movement at air-water interfaces, and minimizes the need to measure soil resistivity before watering, and the water resistivity.

Research Implementation Steps

The research team will implement the research plan through the following major steps.

Step 1. The research team will systematically evaluate the laboratory prototype of the proposed equipment using laboratory and small-scale specimens prepared from diverse geomaterials.

Step 2. The research team will develop a field version of the equipment for continuous moisture measurement and evaluate its performance

Step 3: The research team will demonstrate the field prototype of the device to the representatives of the NRRA member states.

Step 4: The research team will coherently synthesize the results to demonstrate the strength and shortcomings of the proposed methodology and prototypes along with the path forward with regards to addressing the shortcomings toward the development of a final ruggedized, field-implementable product.

Quantification of Benefits of Project

Even though the qualification of the benefits of incorporating moisture measurement in the process control for earthwork has been carried out routinely, objective quantification of the benefits is rather difficult because such activity has rarely been carried out in the field.

Quantifying the possible improvement in the quality of the road network due to incorporating moisture control in the process control will be provided in consultation with the project panel and the MnDOT and other NRRA states' geotechnical and pavement engineers. As mentioned above, only two NRRA member states always monitor or enforce limits on the moisture content.