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Implementation Report

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More Info:

The research is documented in Report FHWA/MT-25-001/10118-877

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ORGANIZATION AND ANALYSIS OF MEASUREMENT WHILE DRILLING (MWD) DATA

https://www.mdt.mt.gov/research/projects/mwd.aspx

Introduction and Purpose

The design and construction of any foundation, especially deep foundations in transportation infrastructure projects, requires reliable information about subsurface conditions. This usually includes not only information about the different soil/rock layers and their strength properties but also their variability across a project site. For example, Rodgers et al. (2018)[1] reported that the stratigraphy and strength characteristics of the subsurface underneath two separate bridge piers at a project site varied significantly. Their study indicated that the mean unconfined compressive strengths (UCS) of the bearing material from two individual borings spaced only 5 meters (16.4 ft) apart at a drilled shaft site in Fort Lauderdale, Florida, were about 50 percent different. This example illustrates that it is critical to obtain accurate strength properties to reduce uncertainty in the design stage. Having a means of estimating the strength of subsurface geomaterials at every location and at every depth of interest in a project would be of high value. This is where estimating (correlating) the strength data from parameters that can be continuously measured during the drilling operation at a site would become extremely valuable.

The scope of the MDT MWD research project comprised collection and organization of data onto a portal, data review and quality control, and analysis of relationships between MWD drilling parameters and rock properties. MWD data have been collected at MDT project sites with proposed cuts, embankment fills, culverts, and bridge foundations. The primary focus of this effort is within intermediate geomaterials (IGM's) which are prevalent throughout Montana and which exhibit strength properties for both a stiff soil and a soft rock, making strength interpretation, subsurface modeling and design a challenge. Collected MWD data have been assembled into a comprehensive online database for collaboration with a research team. The challenges for MWD technology include a combination of organizing large amounts of collected data and correlating these data to desired subsurface characteristics, such as subsurface soil and rock strength parameters.

Our initial approach was investigation of traditional linear correlations between individual MWD drilling parameters and rock properties such as SPT blow count for hollow stem auger data and UCS (unconfined compressive strength) or unit weight for rock core data. In addition to individual MWD data types (depth, rotation rate, rotation torque, down pressure and advance rate) we also included the calculated compound parameter specific energy.

Based on poor, single parameter, linear correlation results using MWD data from multiple boreholes, we extended our correlation analysis to exponential fitting with no improvement in correlations. To further investigate correlations, we implemented a multiple linear regression (MLR) approach using all possible combinations of the six inputs. Correlation results improved for a number of combinations of inputs but still resulted in weak predictive models. Finally, because of poor linear correlation model predictive results, we turned to a nonlinear approach by implementing a feedforward neural network. The neural network (NN) approach investigated all combinations of MWD drilling parameters as inputs, used one hidden layer with varying numbers of neurons, and a single neuron output layer for predicting either SPT blow count, UCS or unit weight. Using a nonlinear approach greatly improved the predictive power of the MWD inputs for rock properties as discussed in the final report.

Implementation Summary

MDT recognizes the potential benefits of implementing a comprehensive MWD program; however, at this time it is not clear if commitment to the extra resources required and training of personnel will result in a net benefit for implementing the program.

Implementation Recommendations

RECOMMENDATION 1:

Have the driller/engineer (D/E) actively involved with the MWD process from beginning to end and preferably do the actual drilling. It is important that the D/E be able to implement and modify on-site drilling parameters that will ensure the highest quality data. In addition, the D/E should be actively involved in the data processing and analysis phase. Being involved in data analysis will create an active feedback-loop to further optimize the drilling process.

MDT RESPONSE:

The technical panel pointed out difficulties associated with having a dedicated driller/engineer. As it is, turnover among drillers is high and continually replacing drillers trained specifically for MWD would be difficult.

RECOMMENDATION 2:

Collecting data samples for laboratory testing will always be a part of the drilling process. However, we suggest that drilling a second adjacent borehole using continuous drilling for collecting MWD data will greatly improve MWD data quality and make data processing and data quality control much easier.

MDT RESPONSE:

The technical panel suggested that it would be difficult to convince conventional drillers that a second continuous drilling borehole is needed unless the driller was actively involved with data quality and analysis. Furthermore, MDT cannot justify the additional time, budget, and resources that would be required to perform a second borehole.

RECOMMENDATION 3:

The chosen modeling approach (linear, nonlinear) will require continuous updating as new MWD data are collected. It is likely that over time, specific data subsets for different geologic settings will need to be created for optimal modeling results.

MDT RESPONSE:

After presentation and discussion of the recommendations, MDT indicated that there would be a pause on the MWD program possibly to be revisited in the future. In the event the program continues, a significant concern of MDT for implementing Recommendation 3 is that of using and updating the custom developed software and how to maintain the software on existing platforms.

[1] Rodgers M, McVay M, Ferraro C, Horhota D, Tibbetts C, Crawford S. Measuring Rock Strength While Drilling Shafts Socketed into Florida Limestone. J Geotech Geoenvironmental Eng [Internet]. 2018a Mar 23 [cited 2021 Jun 22];144(3):04017121. Available from: https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29GT.1943-5606.0001847 [ascelibrary.org]

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