MONTANA
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Research

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Project Summary Report
FHWA/MT-25-001/10118-877

ORGANIZATION AND ANALYSIS OF MEASUREMENT WHILE DRILLING (MWD) DATA

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

Introduction

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. 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. Fortunately, Measurement While Drilling (MWD) technology has shown potential to improve the characterization of the variability of soil/rock layers and strength characteristics.

One of the main goals of this study was to investigate the data collected through the MWD program at MDT, develop correlations between measured data and strength of the soil/ rock layers and finally evaluate the influence of different measured parameters on the correlations. The primary focus of this effort was within sedimentary intermediate geomaterials (IGM's), such as sandstone, claystone, siltstone, and mudstone 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.

What We Did

The research project was accomplished through the following Tasks:

Task 1: Organization and preprocessing of collected data

To develop correlations, the collected (raw) data were preprocessed. This preprocessing step is complicated due to the large amount of collected data, the noisy nature of the MWD data, and different formats usually used to assemble data from different sources. Preprocessing of MWD and drilling data were accomplished in Task 1 of this project.

As part of Task 1, all available MWD and drilling data from available projects were organized and uploaded to a GIS-based interactive map on a website portal. The GIS portal provides access to available data files via templates for entering MWD and drilling data. A program called *SiteTools* was originally planned for data analysis and quality control but was not implemented due to ongoing development problems. The research team at Montana Tech developed their own set of analysis tools instead.

Task 2: Investigating the correlations between MWD and the substrata strength using traditional methods

Initial analyses consisted of plotting target parameters (SPT blow count, UCS, and unit weight) against six individual MWD parameters: depth, down pressure, rotation torque, rotation speed, moving speed and the compound parameter specific energy. Best fit linear regression lines were calculated and the coefficients of determination (R^2) were recorded for each MWD parameter. We also explored correlation results using a best fit exponential curve and tabulated those R^2 values as well.

Based on poor results from single parameter linear and exponential correlations, the research team then explored multiple parameter linear correlations and multiple parameter nonlinear (neural network) correlations to improve modeling predictive capability. Multiple parameter linear correlation explored all possible combination of inputs and produced better predictability results using the correlation coefficient R^2. Using a multiple parameter nonlinear approach (artificial neural networks), predictability significantly improved; especially for predicting SPT blow count values.

Task 3: Development of final deliverables

As specified in the contract, the research team prepared a final report, a final presentation, a project poster, a project summary report, a performance measures report and an implementation report based on discussions after the final presentation.

The final report describes in detail results from each of the modeling approaches and which data were used for analysis.

What We Found

Our analysis target parameters were SPT blow count, UCS (unconfined compressive strength) and unit weight. The six modeling inputs used are listed in the previous section. We achieved best results for SPT blow count prediction followed by predictions for unit weight and lowest performance for UCS prediction.

Single parameter linear and exponential correlations showed poor predictive capability with R^2 values ranging from approximately 0.01 to 0.5 for SPT blow counts, 0.01 to 0.25 for UCS and 0.01 to 0.3 for unit weight. Most of the values were much lower than 0.5.

Multiple parameter linear modeling results produced R^2 values ranging from approximately 0.2 to 0.6 for SPT blow counts, 0.01 to 0.2 for UCS and 0.01 to 0.2 for unit weight. Many values were lower than 0.3.

Multiple parameter nonlinear (neural network) modeling results produced R^2values ranging from approximately 0.6 to 0.9 for SPT blow counts, 0.3 to 0.7 for UCS and 0.6 to 0.8 for unit weight for much improved predictive capability. Figure 1 is an example plot showing best R^2 results for SPT blow count prediction with a subset of inputs from 100 iterations plotted against the number of neurons in the neural network hidden layer.

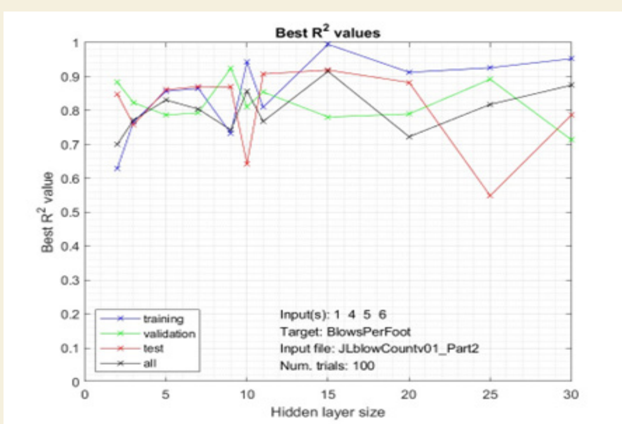

Figure 1: An example plot showing best R^2 results for predicting SPT blow counts using the subset of inputs depth, rotation speed, moving speed and the compound parameter specific energy.

Importantly, the multiple input modelling helps indicate which of the MWD inputs are most important for prediction of the targets. Interestingly, measuring depth as an input proved to be a high value input for modelling.

What The Researchers Recommend

Based on the findings from this research, the following recommendations are made:

1. Successful correlation of MWD data to geotechnical parameters requires careful preprocessing of MWD data and quality control/editing of drilling data such as UCS or SPT blow count. In addition, any correlations developed will be site specific and closely correlated with the local geology.
2. The geology at MWD sites for the Montana project consisted of intermediate geomaterials (IGMs) categorized as extremely weak rock (35 to 150 psi) and very weak rock (150 to 725 psi). These weak materials present a challenge to the MWD drilling process and ultimately data analysis and correlation development.
3. Future MWD work should focus on controlling the drilling environment to achieve optimized drilling parameters for highest drilling efficiency and optimal core recovery to achieve high quality MWD and drilling data. This approach may require dedicated MWD drillers adhering to standards developed by organizations involved. In addition, drilling a second adjacent borehole specifically for MWD data collections should be explored.
4. Our work with MWD data from IGMs indicates that the relationship between MWD drilling parameters and correlations with geotechnical parameters is likely nonlinear.

More Info:

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

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