NHDOT SPR2 PROGRAM
RESEARCH PROGRESS REPORT

Project # SPR 42372F		**Report Period** Year 2023 ☐ Q1 (Jan-Mar) ☐ Q2 (Apr-Jun) X Q3 (Jul-Sep) ☐ Q4 (Oct-Dec)
Project Title: Use of Drilling Parameters for Enhancing Geotechnical Site Investigations		
Project Investigator: Jean Benoit, PhD **Phone:**		**E-mail:** jean.benoit@unh.edu
Project Start Date: May 05, 2021	**Project End Date:** August 31, 2023	**Project schedule status:** **X** On schedule ☐ Ahead of schedule Behind schedule

Brief Project Description:

The standard penetration test (SPT) is a proven tool widely used in providing disturbed soil samples to aid in geotechnical site characterization and estimating soil properties for the design of DOT projects. Testing and sampling are typically done at 5 to 10 feet intervals, and thus between these samples, the use of engineering judgment identifies changes in stratigraphy and the soil's respective properties. The results from these tests are used to develop recommendations and aid in designing the NHDOT Department projects. Continuously performing the SPT is time-consuming, labor-intensive, and not well-suited for many of the soils encountered in New Hampshire and cannot be used to characterize rock. Soils containing large particles such as gravel lead to poor sampling recovery and unreliable results. A technique known as Monitoring-While-Drilling (MWD) makes use of the mechanical response of the drill rig and cutting tools while advancing a borehole. MWD can be used to explore the subsurface in any geological conditions. With such data combined with SPT testing, a continuous quantitative drilling record is produced, and the correlated parameters can be applied more reliably to the design process. Additionally, data to objectively assess site variability is obtained. The drilling parameters collected can provide quality assurance for the soil classifications provided by incomplete testing and sampling exclusively performed by the SPT.

The objectives of this research are as follows:

1. Provide MWD as a tool for geotechnical site characterization to result in a more thorough and accurate representation of subsurface conditions leading to safer and more economical designs. The MWD is an underutilized tool in the process of site characterization for infrastructure projects and is recognized by the Federal Highway Administration EDC-5: Advanced Geotechnical Methods in Exploration (A-GaME) initiative:
https://www.fhwa.dot.gov/innovation/everydaycounts/edc_5/geotech_methods.cfm

2. Support more efficient use of design and construction resources and reduce the chance of delays due to unexpected subsurface conditions. This effort will contribute to the overall goal of improving the efficiency of the NHDOT by increasing the delivery time of subsurface conditions and decreasing the time it takes to complete.

3. Provide data to other efforts: a) depth of bedrock which is of interest to other parties for mapping efforts and water quality studies, b) rock properties and joint orientations to support rock slope stability efforts with the Smart Rock technology and, c) estimates of relative permeabilities to support efforts with the Permeafor.

Scope of Work:

The proposed research will assess the use of MWD to be used on roadway and bridge foundation projects for the NHDOT. The scope of work includes the following tasks:

Task 1- UNH MWD update:
Update the existing UNH MWD system with the latest generation Lutz equipment. This will require the purchase of a new control and recording unit, junction box, and associated software.

Task 2 – MWD installation:
Install MWD system on one of the NHDOT drill rigs and perform an initial evaluation on a site with both soil and rock.

Task 3 – Torque sensor design:
Design or purchase a torque sensor to be fitted to the mechanically driven drill rig operated by the NHDOT. This design will collaborate with the Montana DOT, the University of Florida, and the Jean Lutz company.

Task 4 – MWD testing:
Using project sites determined with a NHDOT technical advisory group, drilling parameters recorded will be compared to measurements traditionally collected by SPT and the associated soil samples, along with rock cores for deep foundations. The following parameters will be collected: thrust on drilling tool, rotation rate, drilling fluid rate, advance rate, torque, fluid injection pressure, and drilling fluid return rate. In addition, other non-controlled parameters will be documented to include tool wear and changes in drilling fluid composition.

Task 5 – MWD data evaluation:
MWD data obtained in conjunction with key NHDOT projects identified as high-risk projects will be evaluated to determine direct methods to correlate values to specific design parameters and be documented for use on future NHDOT projects.

Task 6 – Collaboration with other users:
Collaborate with other DOT MWD users to develop a database of information for best practices for drilling under various soil and rock conditions.

Task 7- Final report:
Provide a final report summarizing the research and recommendations for implementing the MWD in the everyday site and soil exploration. The information will be summarized to be included in the DOT Geotechnical Manual.

Progress this Quarter (include meetings, installations, equipment purchases, significant progress, etc.):

An initial Technical Advisory Group (TAG) meeting was held over Zoom on June 16, 2021, at 10:30 am. The following items were discussed: 1) Review of the research program and implementation strategy; 2) Review of research needs; 3) Review of project.

In the second Quarter of 2022, we had an amendment to our CPA approved to obtain two newly developed torque sensors (TICOR) by Jean Lutz, capable of measuring torque directly at the top of the drill string. The TICOR sensor should also measure down pressure directly as well as rotation rate, all done wirelessly. The TICOR sensor was initially delivered to the NHDOT in the first week of November 2022. After an initial attempt to use the TICOR on December 22, 2022, in North Hampton, we identified issues in the communication between the sensor and the DIALOG tablet. The TICOR was then repaired and delivered back to UNH in mid-May 2023. The sensor was re-installed on June 8, 2023, and additional tests were performed in Durham/NH in July to implement the sensor in MWD operations. We have been communicating with Jean Lutz and identified that the TICOR was still not fully operational, with issues in the load cell that measures the down force. The TICOR was shipped back to Jean Lutz in France for further repairs.

The addition of wireless torque sensors is pertinent in this project as they provide more information to calculate compound parameters for subsurface characterization, taking advantage of the torque measurements. In July, we also purchased an instrumented drill rod manufactured by Dr. Michael Rodgers (MWD One), which has allowed us to easily obtain torque measurements with a more compact wireless device. Torque measurements from both TICOR and MWD One in Durham, NH, have been compared, and the data from both sensors at adjacent boreholes were compatible. Four 25-ft deep MWD profiles on heterogeneous glacial deposits with erratic boulders were collected in Durham on the campus of UNH. These profiles are being compared with two additional SPT tests performed at adjacent boreholes. After our initial evaluation of the instrumented drill rod by MWD One, we requested the manufacturer develop a second sensor to measure the torque and thrust at the top of the drill string. Similar to our current torque sensor by MWD One, the new sensor should also easily communicate with the Jean Lutz DIALOG system already in place. This new instrumented rod should provide more accurate thrust measurements directly at the top of the drill string and replace the TICOR sensor by Jean Lutz.

The torque sensor from MWD One was further evaluated in additional tests performed in Newington, NH, at a previous NHDOT site where SPT tests had been performed. In Newington, three 100-ft deep MWD profiles were collected across an initial layer of fine sand, followed by a 60-ft thick layer of soft clay. Given the site geology and very soft soil characteristics,

we also performed a Piezocone test at an adjacent borehole. This opportunity was also used to train NHDOT personnel to perform a CPTu test. The data collected at both sites have been used to prepare a workshop and presentation for the Northeast States Geotechnical Engineering Conference in Lake George, NY, presented by Ben Rivers and Mary Nodine (FHWA).

This Quarter, we have also updated the MWD manual with additional instructions on operating the instrumented drill rod by MWD One. These instructions should help the NHDOT personnel to collect MWD data in their drilling activities. We are waiting for more drilling opportunities to test the new instrumented drill rod with torque and thrust, which we should receive in the next Quarter. Improvements on the rotation sensor collar in the MWD drill rig recently performed by the NHDOT will allow more accurate and precise rotation measurements while drilling. Initial tests with the new collar were conducted in Seabrook, NH, by Adam Carr and Christian Buerkle on October 2, where a test demonstration was also given to Dr. Philippe Reiffsteck (Gustave Eiffel University) during his technical visit to the University of New Hampshire.

We are currently analyzing all obtained data, comparing them to results from conventional geotechnical tests. We have also recruited a MS student currently doing his project on MWD. He is currently evaluating the data collected in Newington and comparing these measurements to extensive subsurface characterization performed on soft clay at a nearby site in the past.

In parallel, we have also been working and led the MWD Users Group in collaboration with FHWA. Meetings have been held on the third Wednesdays of each month which has provided an excellent opportunity to exchange experiences, analysis approaches and testing equipment, innovations and standards with other users across the United States and worldwide. Meetings have been held since November 2021, with more than 60 participants each time. The MWD user group has discussed the implementation of a US MWD standard, as well as the diffusion of MWD knowledge to companies and organizations that are still not familiar with the technology. We have recently written an article on MWD with basic and essential knowledge of MWD, which will be published on GeoStrata later this year.

Items needed from NHDOT (i.e., Concurrence, Sub-contract, Assignments, Samples, Testing, etc…):

Additional drilling opportunities to collect MWD data from daily drilling activities in the field (drilling and coring), as well as any relevant additional testing results (SPT, grain size distribution, RQD, strength, etc.) will further advance our understanding of drilling parameters in various geological conditions. The drill rig that the NHDOT is currently planning to purchase will also be equipped with a wireless torque and thrust sensor.

Anticipated research next three (3) months:

Anticipated work for the next Quarter includes additional MWD measurements during drilling activities to be performed by the NHDOT including using the new MWD One sensor. Additional potential site locations will be determined by the NHDOT, according to their demand and availability. We will also continue to perform data analysis and evaluation. Our collaboration with other users will also continue through the MWD Users Group.

Circumstances affecting project: None.

Tasks (from Work Plan)	**Planned % Complete**	**Actual % Complete**
Task 1- UNH MWD update:	*100*	*100*
Task 2 – MWD installation:	*100*	*100*
Task 3 – Torque sensor design:	*100*	*100*
Task 4 – MWD testing:	*60*	*40*
Task 5 – MWD data evaluation:	*40*	*30*
Task 6 – Collaboration with other users:	*85*	*85*
Task 7- Final report:	*10*	*10*

Barriers or constraints to implementing research results None.