NHDOT SPR2 PROGRAM
RESEARCH PROGRESS REPORT

Project # SPR 42372F		**Report Period** Year 2023 ☐ Q1 (Jan-Mar) ☐ Q2 (Apr-Jun) ☐Q3 (Jul-Sep) X 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 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 that would be capable of measuring torque directly at the top of the drill string, all done wirelessly. We evaluated two torque sensors: the TICOR sensor, developed by Jean Lutz, and the instrumented drill rod, manufactured by MWD One. Wireless torque sensors are pertinent in this project as they provide more information to calculate compound parameters for subsurface characterization, taking advantage of the torque measurements.

The TICOR sensor was designed to measure torque, down force and rotation rate. The TICOR sensor was initially delivered to the NHDOT in November 2022. After an initial attempt to use the TICOR in North Hampton on December 22, 2022, 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 France in September 2023 for further repairs.

In July 2023, we also purchased an instrumented drill rod manufactured by Dr. Michael Rodgers (MWD One), allowing us to obtain torque measurements easily 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. After our initial evaluation of the instrumented drill rod by MWD One, we purchased a second unit that wirelessly measures the torque and thrust at the top of the drill string. The new sensor was tested in late November in Loudon, NH. Similar to our current torque sensor by MWD One, the new sensor also easily communicates with the Jean Lutz DIALOG system already in place. This new instrumented rod provides more accurate thrust measurements and replaces the initially tested TICOR sensor by Jean Lutz.

Following the data collection this Summer in Durham and Newington, NH, the MWD One sensors were used in two sites this Quarter. Additional MWD data has been collected this Quarter in Seabrook and Loudon, NH, where SPT testing in adjacent boreholes was also performed. The data from Q4 were successfully collected by Adam Carr and Christian Buerkle (NHDOT). Improvements on the rotation sensor collar in the MWD drill rig performed by the NHDOT in the last Quarter allowed more accurate and precise rotation measurements.

We are currently analyzing all obtained data, comparing them to results from conventional geotechnical tests. We have also

recruited an MS student who recently finished his project on MWD. He evaluated the data collected in Newington and compared measurements to the additional SPT and CPT testing performed at the site. His project was defended at UNH on December 14, 2023, and the obtained results will be incorporated into our comprehensive report to be submitted to the NHDOT by Summer 2024. His work demonstrates that compound parameters are helpful in delineating soil stratigraphy, but more information is still needed to properly classify the identified layers. In his defense, the question of how the water table level can influence water pressure measurements was raised, and how the response might vary for cohesive or non-cohesive soils below or above the water table.

In the first week of October, Dr. Philippe Reiffsteck (University Gustave Eiffel) did a technical visit to the University of New Hampshire, when we were collecting data in Seabrook. During Dr. Reiffsteck's visit, several portable MWD profiles were obtained in Franklin and Enfield, NH. The portable MWD results will be compared to standardized lightweight dynamic penetrometer (PANDA) measurements from the same testing locations. While the portable MWD cannot be used to drill through rock easily, it can be an alternative to perform shallow subsurface characterization without mobilizing extensive drilling equipment.

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.

Our recently written article on MWD with basic and essential knowledge of MWD was published in GeoStrata in the December-January issue. Recent MWD results obtained in this research, as well as relevant information about MWD implementation and analysis, have also been discussed as part of GeoStrata Extra which consisted of an interview of Prof. Jean Benoît conducted by Mary Nodine (FHWA) on December 12, 2023. The interview is expected to be online in the next few weeks.

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:	*70*	*50*
Task 5 – MWD data evaluation:	*40*	*30*
Task 6 – Collaboration with other users:	*85*	*85*
Task 7- Final report:	*20*	*20*

Barriers or constraints to implementing research results None.