Measuring While Drilling in Florida Soils for Geotechnical Site Characterization BED31-977-03

GRIP Meeting

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August 11, 2022

Introduction

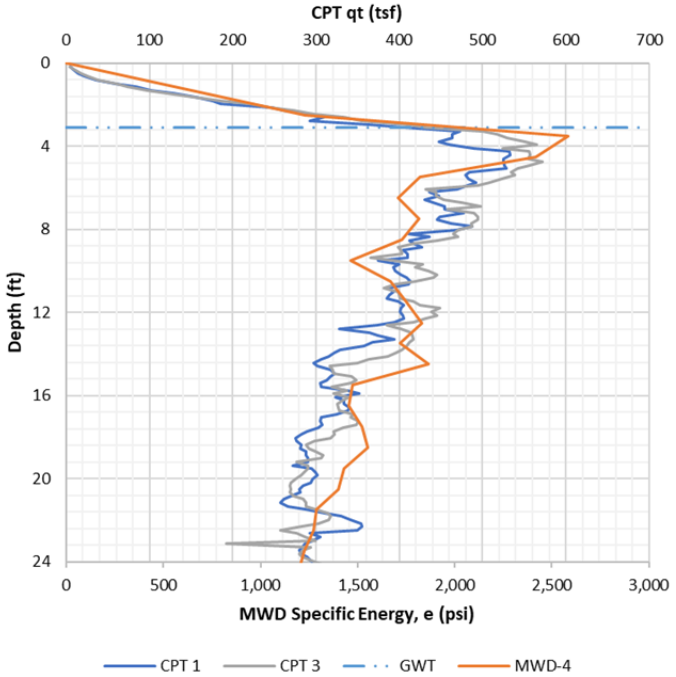
- The FDOT has developed and applied measuring while drilling (MWD) for the assessment of in situ rock strength for bored piles (ACIP piles and drilled shafts) and site investigation purposes (rock coring)
- The completed work has produced significant advancements in geotechnical exploration, a better understanding of Florida's highly variable geology, and improvements in deep foundation design and construction
- In situ soil classification and geo-mechanical property assessment via MWD have not been addressed by the FDOT
- This limits the use of MWD, and the many benefits associated with the new method, from being applied to numerous geotechnical applications in which the soil-structure interaction is the main focus of design

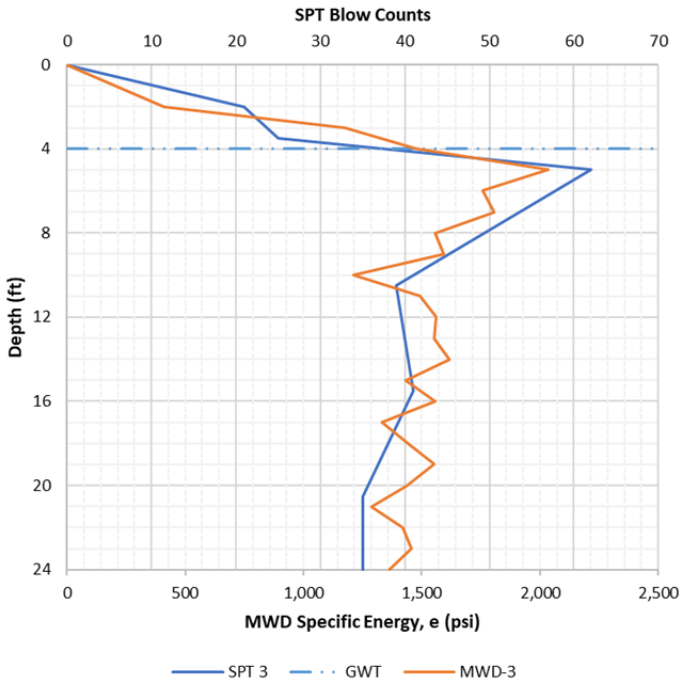
Site Investigation MWD – Geotechnical Design

Bored Pile MWD – Construction QA/QC

Introduction

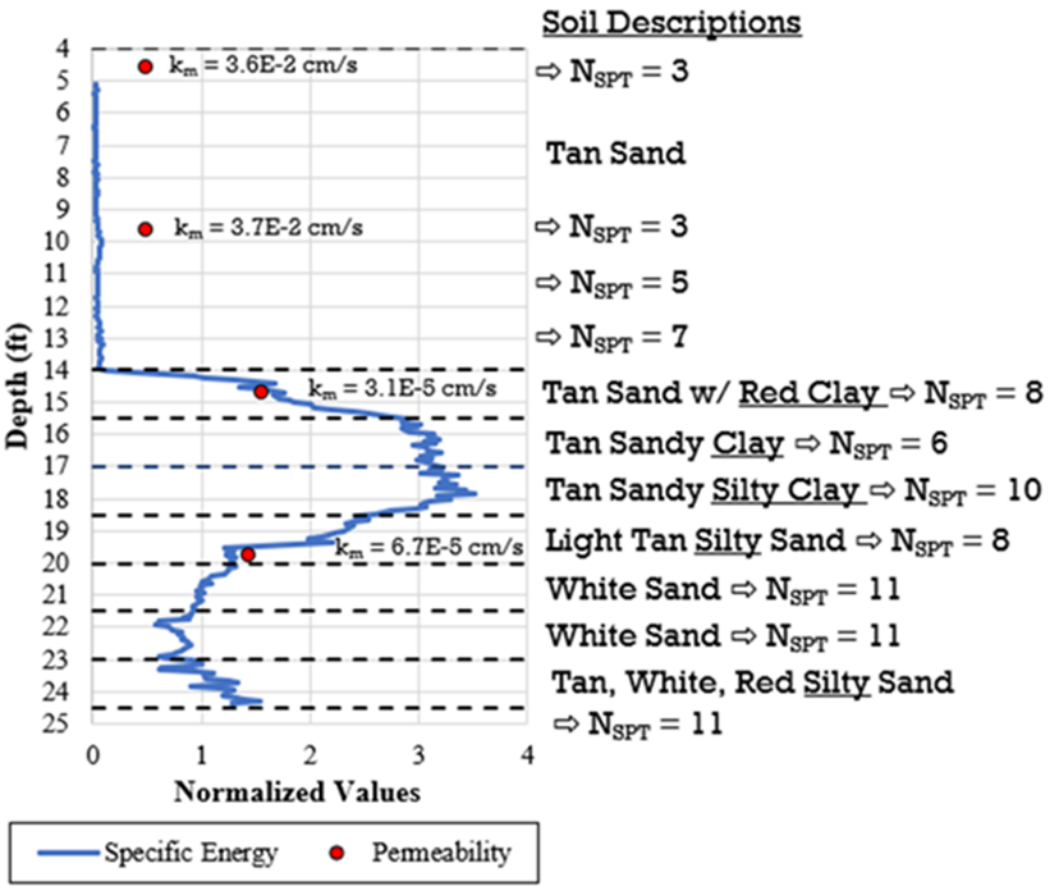
- Driven piles are used throughout the state of Florida, with the piles often driven into variable layers of soil with unique properties that provide the capacity of the foundation element
- Driven piles are often designed using Standard Penetration Test (SPT) and/or Cone Penetration Test (CPT) data
  - SPT is typically only performed every 2.5 feet for bridge structures, which produces a low-resolution profile of the strata encountered
  - CPT provides a much higher resolution profile than SPT but is vulnerable to termination when rock or stiff IGM or soil layers are encountered
- MWD is capable of producing high resolution profiling like CPT and has the ability to penetrate rock like SPT
- Therefore, developing MWD as a new method of in situ soil assessment would combine the benefits of both conventional methods and greatly improve the practice





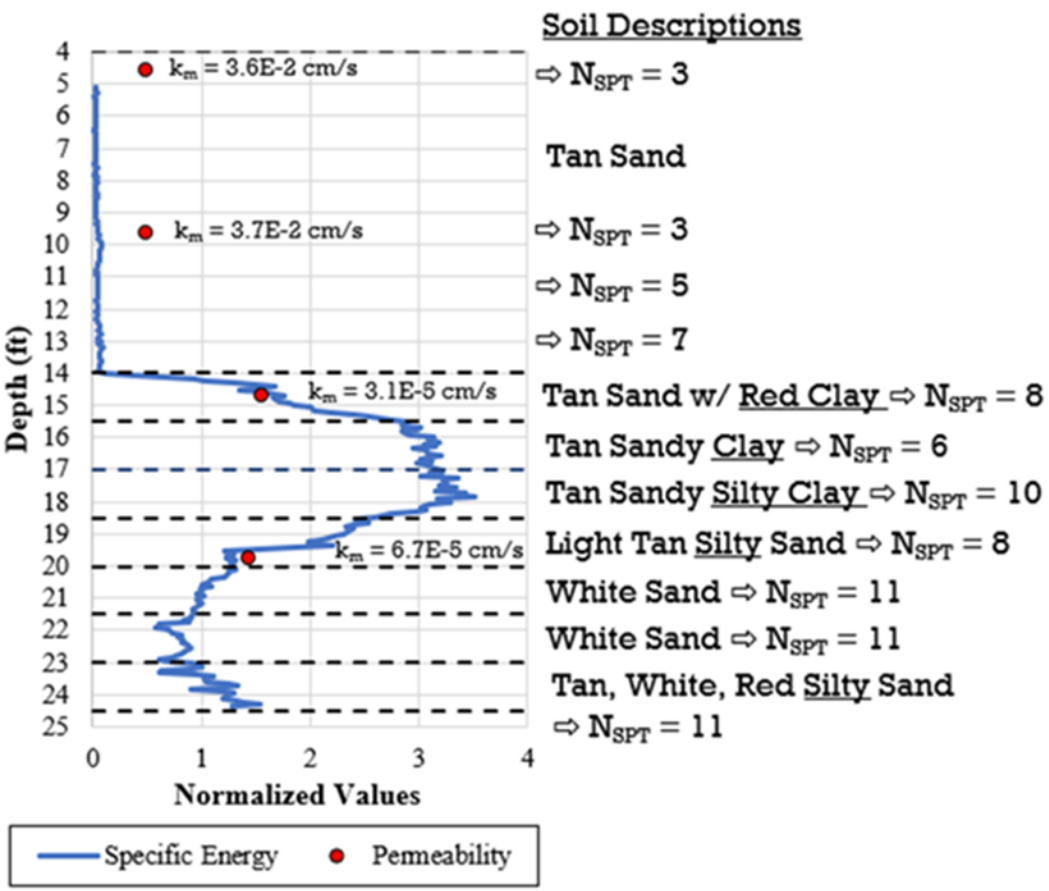
Project Background

- A brief investigation was completed during BDV31-820-006 that indicated the proposed MWD approach is promising
- The intent of the study was to investigate MWD as a quick method of identifying and assessing changes in soil layering as a potential supplement to SPT and CPT testing
- During the investigation, MWD was conducted using a tri-cone roller bit
- The monitored drilling took place from a depth of five to 25 feet, with the entire drilling investigation taking approximately 10 minutes to complete (very efficient)
- The results from MWD were then compared to SPT blow counts, soil descriptions, Vertical In situ Permeameter (VIP) permeability results (FDOT FM 5-614), and soil classifications, each of which was completed in close proximity to the MWD borehole location
- MWD indicated low specific energy in cohesionless soil with low SPT blow counts
- MWD indicated increased specific energy in cohesive soil with higher SPT blow counts
- MWD injection pressure increased in lower permeable soils
  - Agreed with comparative permeability tests conducted using the VIP (FM5-614) – Not Depicted



Project Background

- The brief study indicated that MWD was capable of identifying material layer changes and that the MWD results were consistent with the SPT blow counts, material descriptions, VIP permeability results, and soil classifications
- The results suggested that a new quick method of soil assessment may be possible via MWD
  - MWD required far less time to characterize the soil compared to the work that went into performing SPT testing every 2.5 feet, collecting soil samples to be tested in the lab, and VIP permeability testing
- In addition to the soil assessment investigation discussed, prior MWD investigations have shown that several individual and compound drilling parameters may be indicative of changes in soil and/or rock types
- Based on these prior MWD observations, it is believed that various soil types may be classified, and their geo-mechanical properties assessed in situ by building an operational index similar to CPT soil identification
  - The index would logically consider a variety of individual and compound drilling parameters to identify various soil types, essentially combining the benefits of SPT and CPT into one efficient method of soil assessment
- Once the operational index has been developed, independent and compound drilling parameters will be used to relate the drilling response to strength characteristics of the geomaterial encountered
  - Relating MWD parameters to soil engineering parameters to support geotechnical design



Project Objectives

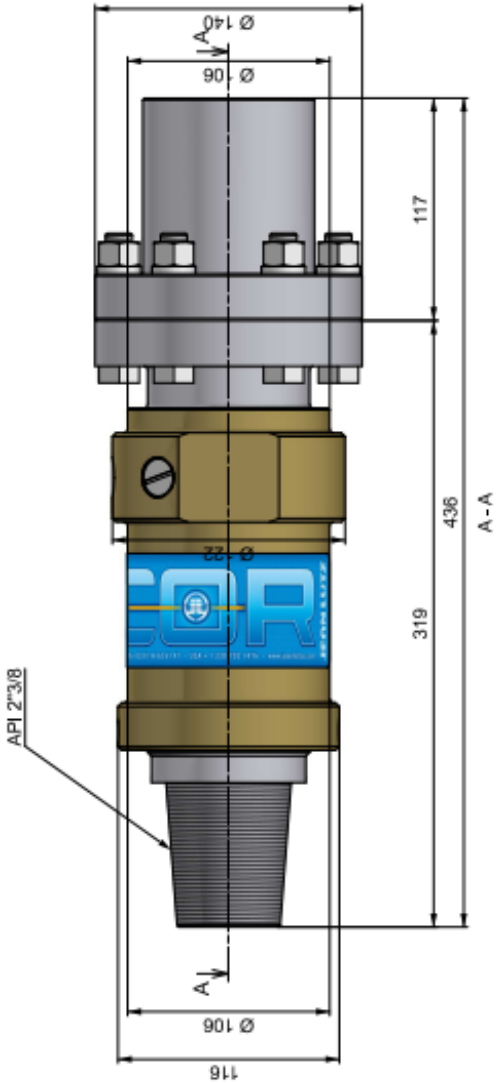
- Investigate the viability of developing MWD practices for in situ soil assessment in support of conventional site characterization methods
- Investigate multiple drill bit types to determine which bit type provides the best sensitivity for the delineation of various Florida soils and also provides an efficient drilling rate
- Identify optimal drilling parameter ranges and develop a standard drilling procedure for the new test method
- Investigate various independent and compound drilling parameters while maintaining the optimal parameter ranges to begin building an operational index in order to classify and assess various soil types
- Investigate the effect of eccentric drill string rotation on in situ strength assessment
- Develop correlations between the measured drilling response and soil properties commonly used in the design of deep foundations

Tasks and Deliverables

- Deliverable 1 – Drill Rig Instrumentation, Site Reconnaissance, and Preliminary Development (Task 1)
- Deliverable 2 – Drill Bit Selection and Method Development (Task 2)
- Deliverable 3a - Operational Index Development (Task 3)
- Deliverable 3b - Eccentric Rotation Investigation at Deeper Drilling Depths (Task 3)
- Deliverable 4 - Developing Correlation Between MWD and Engineering Parameters (Task 4)
- Deliverable 5a - Draft Final (Task 5)
- Deliverable 5b - Closeout Meeting (Task 5)
- Deliverable 6 - Final Report (Task 6)

Task 1 – Drill Rig Instrumentation, Site Reconnaissance, and Preliminary Development

- Much of the anticipated drill rig instrumentation was completed in FDOT Project BDV31-820-006
- New instrumented drill rods will need to be developed and a new depth sensor type that may be more universal will be explored during this project
- In addition, a new flow meter that allows the fluid density of the slurry, and potentially viscosity and temperature, to be measured will be integrated into the existing MWD system as well as a new sensor to measure vibration (frequency and amplitude)
- Each of these new sensors will be vital to developing a reliable method of MWD soil assessment
- A Jean Lutz TICOR sensor will also be purchased which has the capabilities to measure torque, crowd, rotational speed, inclination, and hammer energy all from a single instrument and location
  - Greatly simplifies drill rig instrumentation and supports implementation of the research
  - Currently, torque measurements are provided by a UF custom-built instrumented drill rod which hinders implementation because the custom sensor is not commercially available
  - The TICOR would resolve the commercialization issue and facilitate implementation



Task 1 – Drill Rig Instrumentation, Site Reconnaissance, and Preliminary Development

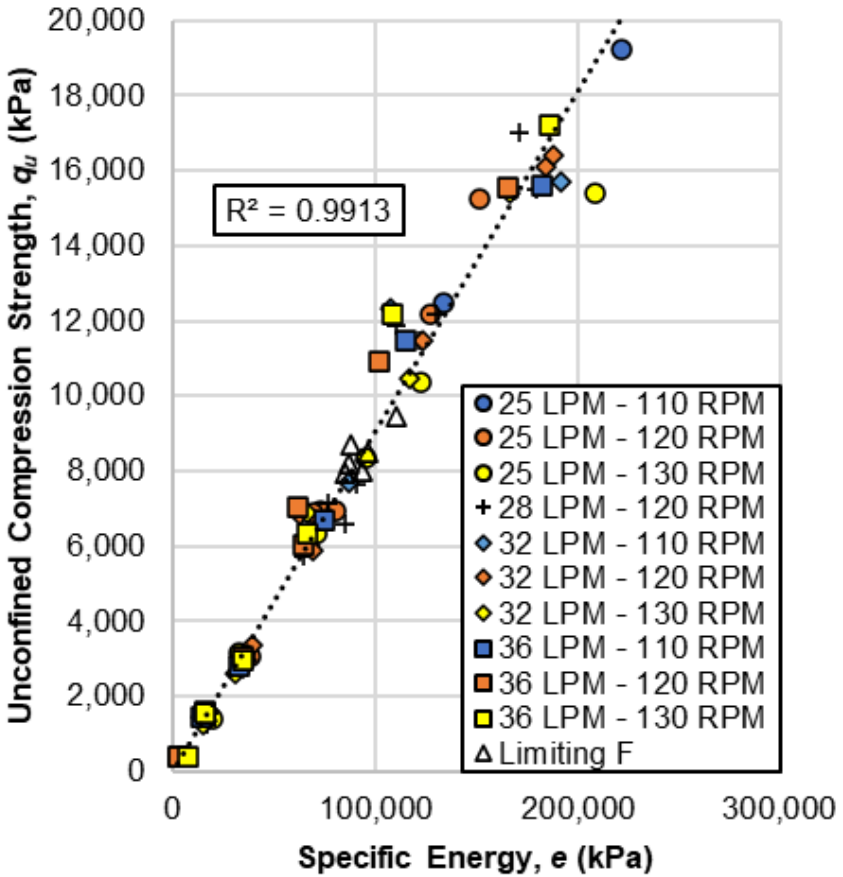
- Four Gatorock slabs will be cast to assist in developing correlations between drilling parameters and unconfined compression strength and splitting tensile strength using the bit selected in Task 2
  - The slabs will also assist in determining an upper penetration rate limitation while drilling within the developed operational limits
- UF researchers will work closely with the FDOT State Materials office to identify ten candidate sites that will be ideal for development of the new MWD method
  - Ideal soil sites will contain multiple soil types in which thicker (≈10-feet or greater) uniform layers of each soil type are present
  - Sites in which prior MWD bored pile work and load tests have been conducted in layers of limestone are also ideal (e.g., CR 250)
- Preliminary drilling will take place as part of the instrumentation calibration in which the initial results will be used to provide insight for the development that takes place in Task 2
- UF researchers will contact Geotechnical firms that routinely perform SPT drilling in the State of Florida to inquire about the type of tooling used
  - This will ensure the tooling proposed for Task 2 is representative of the practice
  - The proposed tooling may be modified based on the responses

Task 2 – Drill Bit Selection and Method Development

- One of the main components of the project will be determining which drilling tool provides the best sensitivity for the delineation of various Florida soil types as well as an ideal rate of penetration to ensure the method is efficient
- This will require investigating three potential drilling tools: a tri-cone roller bit, a PDC bit, and a stepped drag bit
  - Each of these drilling tools are commonly used to advance boreholes during SPT and rock coring procedures
- Survey results from BDV31-820-006 and manufacturer recommendations will provide the initial drilling parameter ranges implemented during drilling for this investigation
- Optimal parameter ranges will then be dialed-in and identified for each drilling tool
- Once the optimal parameter ranges are identified, the drilling results will be analyzed, and a recommended drill bit will be selected for further development

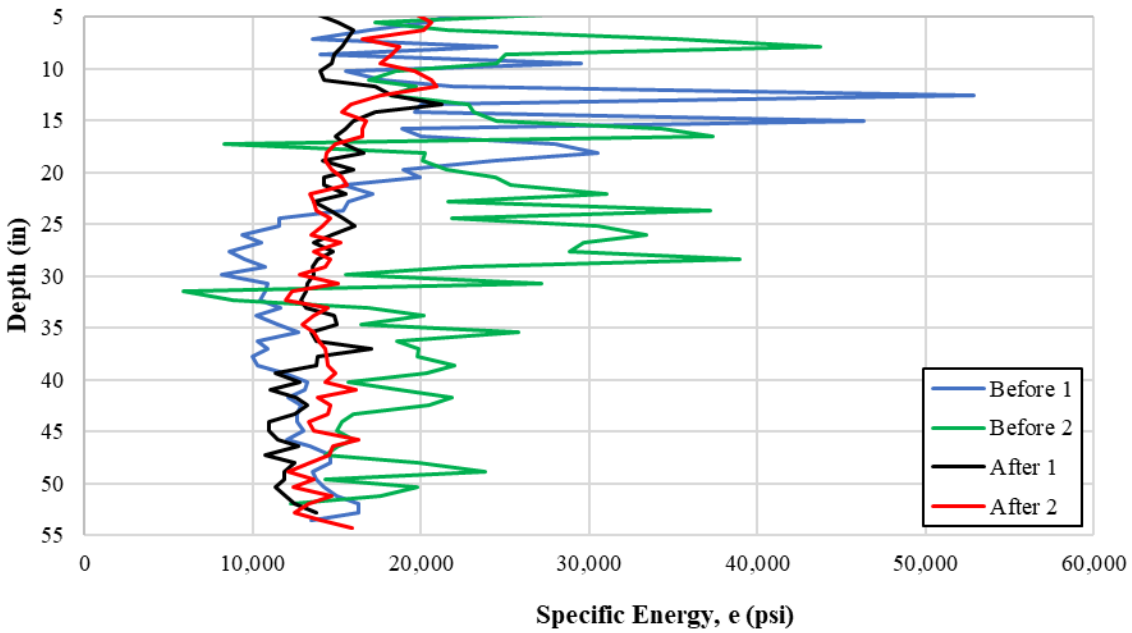
Task 3a – Operational Index Development

- Once the optimum drilling tool has been selected for the new MWD method, additional drilling locations identified in Task 1 will be required to further develop the operational drilling index
- The operational drilling index will comprise multiple independent and compound drilling parameters that when considered in combination, directly identify the soil type encountered
- It is likely that specific energy will be used to assess the strength of each soil type identified by the operational index
- Additional compound parameters commonly used to assess drilling resistance will also be considered (e.g., Somerton Index, Drillability Strength (Ds), etc.)
- During this portion of the study, SPT, CPT, and lab testing will be required in close proximity to each MWD drilling location
- VIP testing will also be completed in close proximity to the MWD drilling locations at select depths to provide a comparable measurement of soil hydraulic conductivity



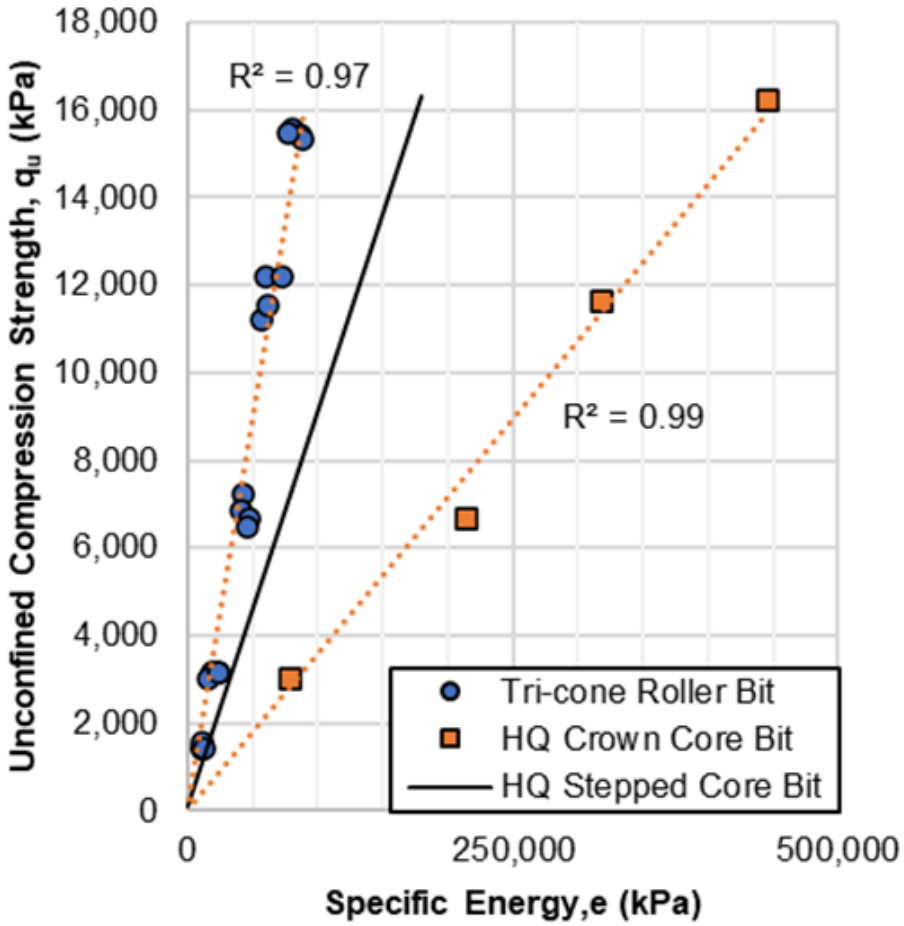
Task 3b – Eccentric Rotation Investigation at Deeper Drilling Depths

- Recent discoveries from FDOT Project BDV31-977-125 indicate that eccentric rotation and excessive vibration may be induced at greater drilling depths due to the slenderness of the drill string, regardless of the rotary head's condition
- The new MWD method should be assessed based on the depth of drilling and potential effects of eccentric rotation
- If eccentric rotation becomes problematic at a certain drilling depth, this portion of the study will be used to quantify the effects
- The operational limits of the drilling tool previously identified in Task 2 and further investigated in Task 3a may need to be adjusted to mitigate the effects of eccentric rotation at greater depths
- Once the investigation is complete, and the operational limits of the drilling tool have been defined, the research can then move forward to Task 4, which focuses on developing engineering parameters from MWD



Task 4 – Developing Correlation Between MWD and Engineering Parameters

- Once the operational limits of the drilling tool selected have been established and the operational index has been developed, correlations between MWD parameters and the engineering parameters of Florida soils and rock will be investigated
- It is expected that the unique mechanical behavior and properties of various in situ soils and rock will produce a unique drilling response that will be captured by MWD
- Certain MWD parameters will be used to identify the soil and rock type encountered (i.e., operational index) and certain compound drilling parameters (e.g., specific energy) will be used to determine the engineering parameters of the soil or rock type identified
- It is anticipated that unique correlations will be developed between MWD compound parameters and the in situ density, internal friction angle, and undrained shear strength of soils and unconfined compression and split tensile strengths of rock/IGM



Project Benefits - Qualitative

- Increased knowledge for all geotechnical MWD applications
- Provides highly detailed records of geological formations
  - **Soil** and rock
- Delineate soil from rock
- Proper assessment of site variability (CV)
- Develop new site investigation method
  - SPT and CPT are predominately used
  - MWD combines the best of both methods
- Investigate new MWD technology
  - Vibration sensor – prior work indicates this will be largely beneficial for the delineation of soil types, soil and rock, and various types of rock
  - TICOR – new sensor type developed to meet the needs of MWD for site investigation – was developed based on our prior work and the interest we have built for MWD worldwide – will support implementation efforts
- New method will be applicable to driven and bored pile design
  - Prior work was only applicable to bored pile design in limestone
- Provide recommendations for MWD technical specifications used in future work
  - Updated specifications for FM 5-625
  - Provide guidance for national MWD specifications

Project Benefits - Quantitative

- Increase the number of strength assessments collected throughout a site during routine investigation by an order of magnitude or more
  - Data collected at each site can be used for geostatistical analyses (GeoStat) to properly assess spatial variability
- Provide insight on the significant future savings from taking the MWD approach
  - MWD site investigation vs. SPT and CPT approach
  - Reduced mobilization costs – only need one truck to get the same benefits as CPT and SPT (2 trucks)
  - Reduced site investigation time as MWD provides all necessary data
- Provide higher resolution strength profiles with the ability to penetrate rock
  - More data collected per linear foot with early termination less likely
- Investigate the effects of more MWD parameters than any prior MWD project
- Acquire more soil/rock properties than prior MWD projects

Project Timeline

Deliverable # / Description of Deliverable as provided in the scope (included associated task #)	Anticipated Date of Deliverable Submittal (month/year)	TO BE COMPLETED BY RESEARCH CENTER (performance monitoring)
Kick-off Teleconference	(04/2022)	
Deliverable (1): Drill Rig Instrumentation, Site Reconnaissance, and Preliminary Development. (Task 1)	(09/2022)	
Deliverable (2): Drill Bit Selection and Method Development. (Task 2)	(03/2023)	
Deliverable (3a): Operational Index Development. (Task 3)	(07/2023)	
Deliverable (3b): Eccentric Rotation Investigation at Deeper Drilling Depths. (Task 3)	(09/2023)	
Deliverable (4): Developing Correlation Between MWD and Engineering Parameters. (Task 4)	(11/2023)	
Deliverable (5a): Draft Final Report. (Task 5)	(12/2023)	
Deliverable (5b): Closeout Teleconference. (Task 5)	(03/2024)	
Deliverable (6): Final Report. (Task 6)	(03/2024)	

Questions?