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

GRIP Meeting

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Project Objectives

1. Investigate the viability of developing MWD practices for in situ soil assessment in support of conventional site characterization methods
2. Investigate multiple drill bit types to determine which bit provides the best sensitivity for the delineating Florida soils and provides an efficient drilling rate
3. Identify optimal drilling parameter ranges and develop a standard drilling procedure for the new test method
4. Investigate various independent and compound drilling parameters while maintaining the optimal parameter ranges to begin building an operational index to classify soil and rock types
5. Investigate the effect of eccentric drill string rotation on in situ strength assessment
6. Develop correlations between the measured drilling response and soil and rock properties commonly used in geotechnical design

Project Tasks

- Task 1 - Drill Rig Instrumentation, Site Reconnaissance, and Preliminary Development
- Task 2 - Drill Bit Selection and Method Development
- Task 3a - Operational Index Development
- Task 3b - Eccentric Rotation Investigation at Deeper Drilling Depths
- Task 4 - Developing Correlation Between MWD and Engineering Parameters
- Tasks 5a, 5b, and 5c - Consultant Implementation of MWD for Geotechnical Site Characterization
- Task 6a - Draft Final
- Task 6b - Closeout Meeting
- Task 7 - Final Report

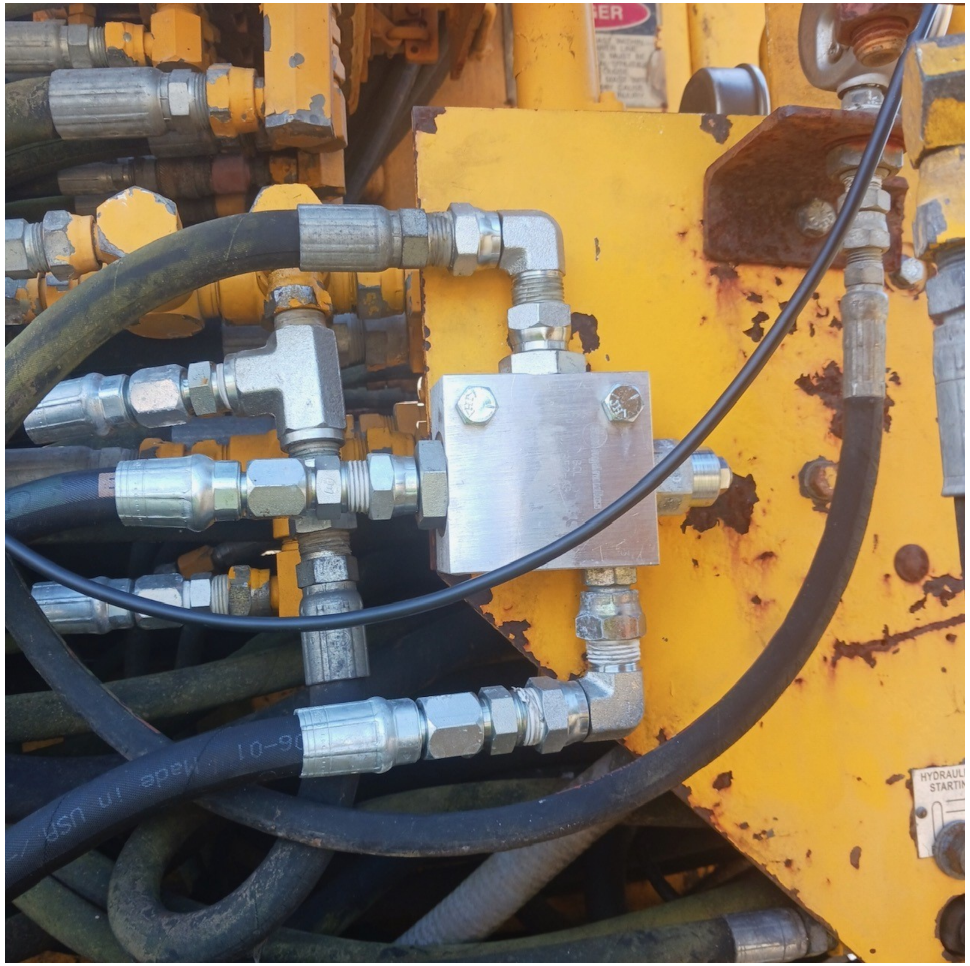
Task 1 – Drill Rig Instrumentation, Site Reconnaissance, and Preliminary Development

- Four Gatorock slabs were cast to assist in developing correlations between drilling parameters and qu and qt 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

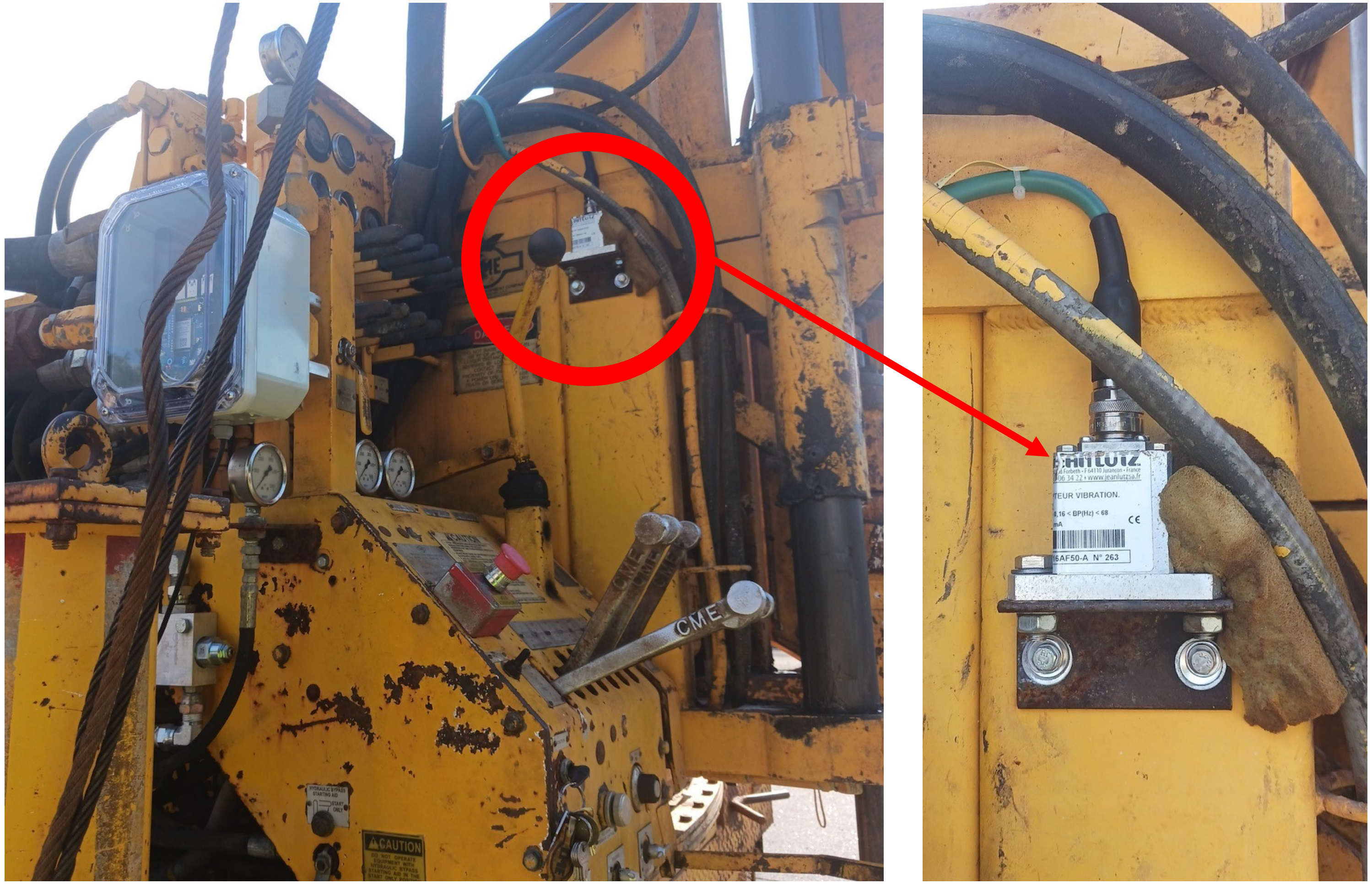
Task 1 – Drill Rig Instrumentation - Depth Sensor

Task 1 – Drill Rig Instrumentation - RPM Sensor

Task 1 – Drill Rig Instrumentation
Hydraulic Flow Control Valve and Drill Rig Vibration Sensor

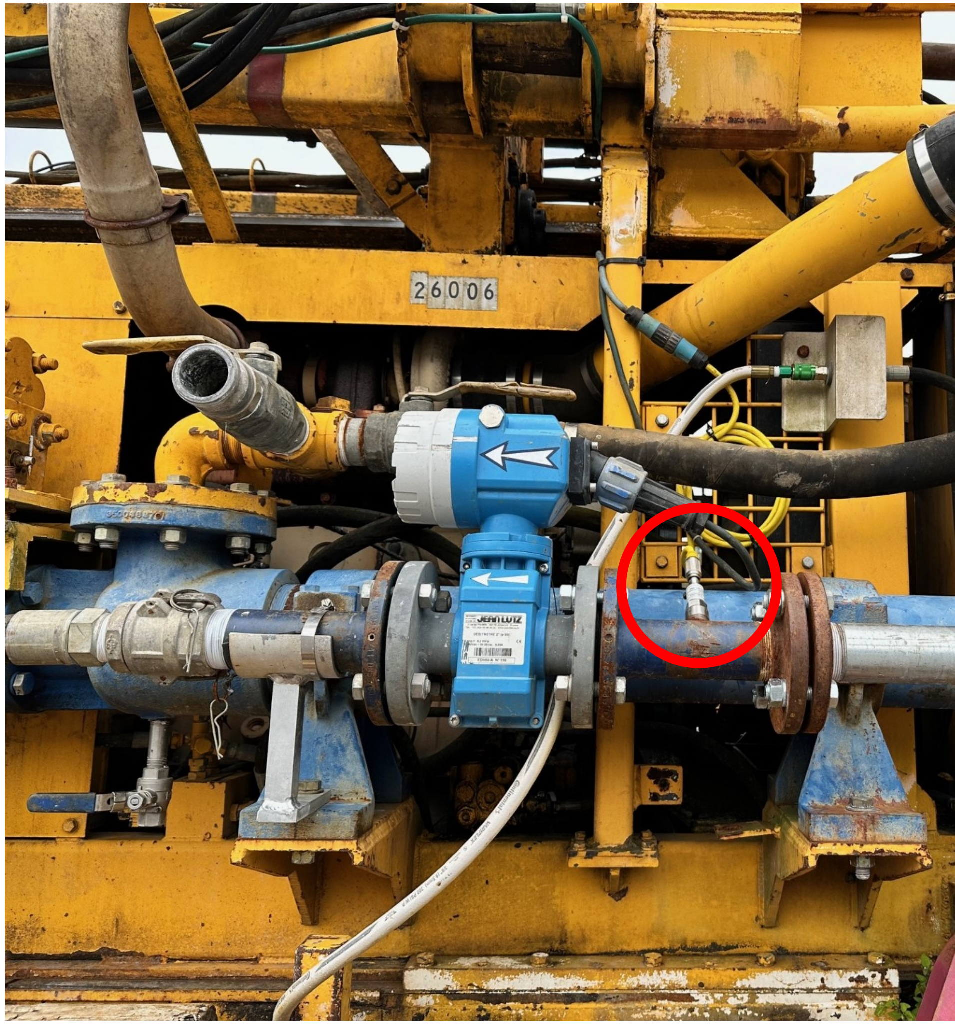


More control of penetration rate



Measure drilling vibrations on the drill rig

Task 1 – Drill Rig Instrumentation - Flow Meter & Pressure Transducer



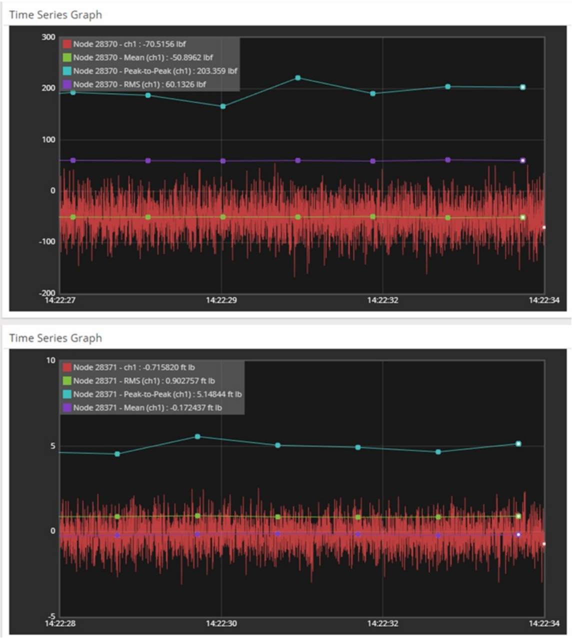
Task 1 – Drill Rig Instrumentation

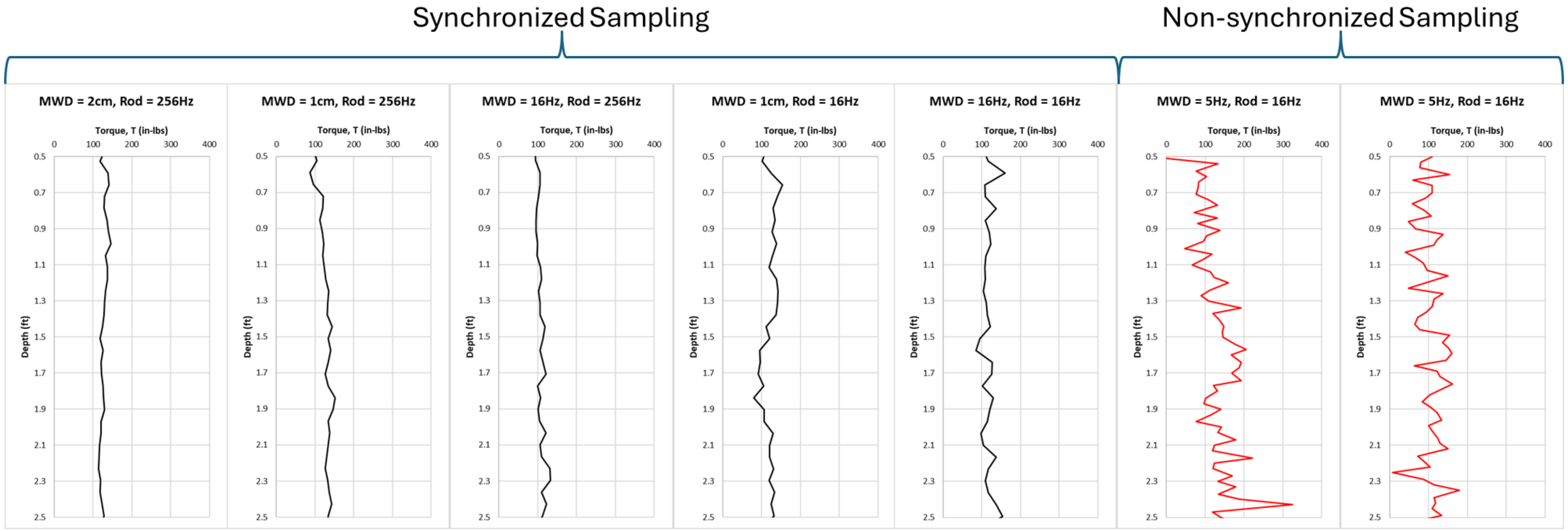
- New wireless drill rod transducer measures torque, crowd, and 3-axis vibration in the drill string
- Begins sampling drill rod data after the MWD system is powered on

<u>Old System Requirements</u>

- External computer
  - Daily shunt calibrations and logging procedures
- External base station
- Conversion module box
- Auxiliary junction box
- Additional cabling
- **Not viable for implementation**
  - FHWA (TN), MDOT, MTDOT

Sampling Rates and System Compatibility





- MWD = 2cm: MWD system continuously collects data that is averaged every 2 centimeters of penetration
- MWD = 1cm: MWD system continuously collects data that is averaged every centimeter of penetration
- MWD = 16Hz: MWD system takes an average every 1/16th of a second
- Rod = 256Hz: Drill rod records 256 samples per seconds and transmits 16 samples every 1/16th of a second
- Rod = 16Hz: Drill rod records 16 samples per seconds and transmits 1 samples every 1/16th of a second
- MWD = 5Hz: MWD system records a value every 200 milliseconds
- Rod = 16Hz: Drill rod records 16 samples per seconds and transmits 1 sample every 1/16th of a second

Candidate Sites for MWD Development

- Kanapaha (Sand, Clay, Chert boulders, weak weathered Ocala limestone)
- Trenton (SP, SM, SC)
- US 301 (SP, SP-SM, and organics)
- CR-250 (Sand, Sandy Clay, Clay, and a wide range of low strength Ocala limestone)
- CR-349 (SC, CH)
- Caryville (Limestone and various soil types near the surface)
- Little River (SP, SM, SP-SM, ML, MH, CL, CH, Cemented Clays, Limestone, Dolomite)
- Marianna – FDOT maintenance yard – (SC)
- Cottondale (SP-SM)
- I-75 NB Rest Area (SP, SP-SM, SC, CH)
- Kingsley (SM, SP-SM)
- Perry (Clayey material and a wide range of limestone strengths – nearly the full Florida unconfined compressive strength, qu, range)
- Bell (SC and weak weathered high porosity Ocala limestone)

MWD Drill Bits

- Surveys were given to FL Geotechs that do site investigation work for FDOT
- Develop method to embrace the current FL drilling practice and tooling

- Tri-cone roller bits and drag bits were identified in majority of surveys
  - Drag bit depicted was chosen for versatility in sand/clay/rock
- PDC bit is UF research recommendation
- Drill bit diameter = 2-7/8”
  - Based on survey responses

Steel Tooth Tri-cone Roller Bit

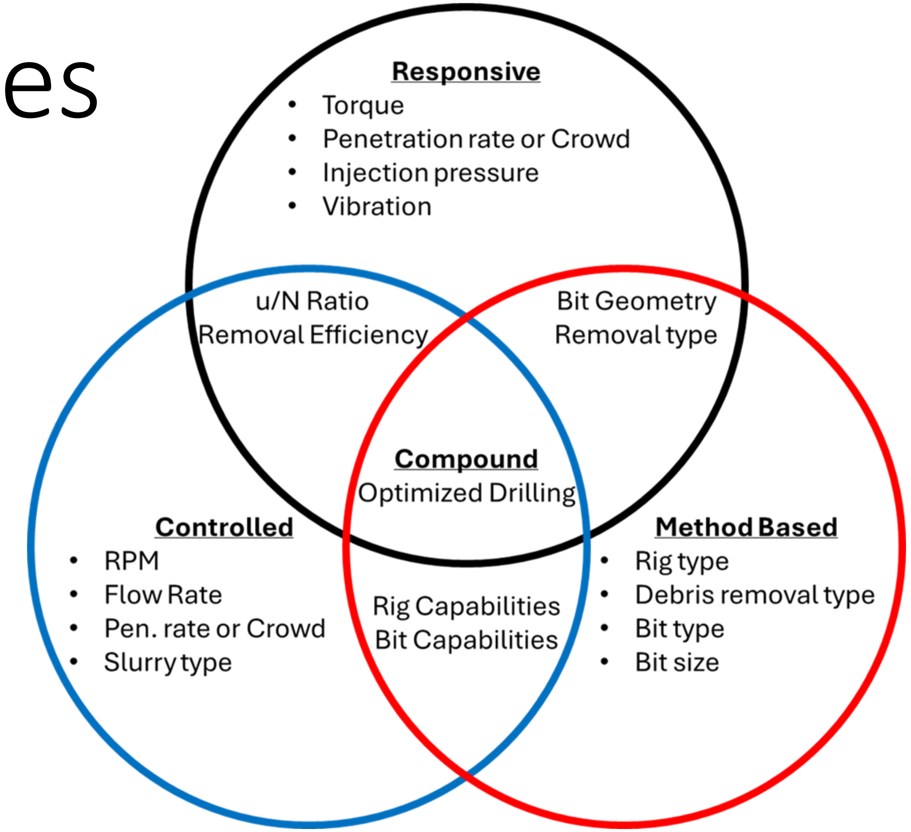
Infinity PDC Bit

3 Chevron Stepped Drag bit

Task 2 – Drill Bit Selection and Method Development

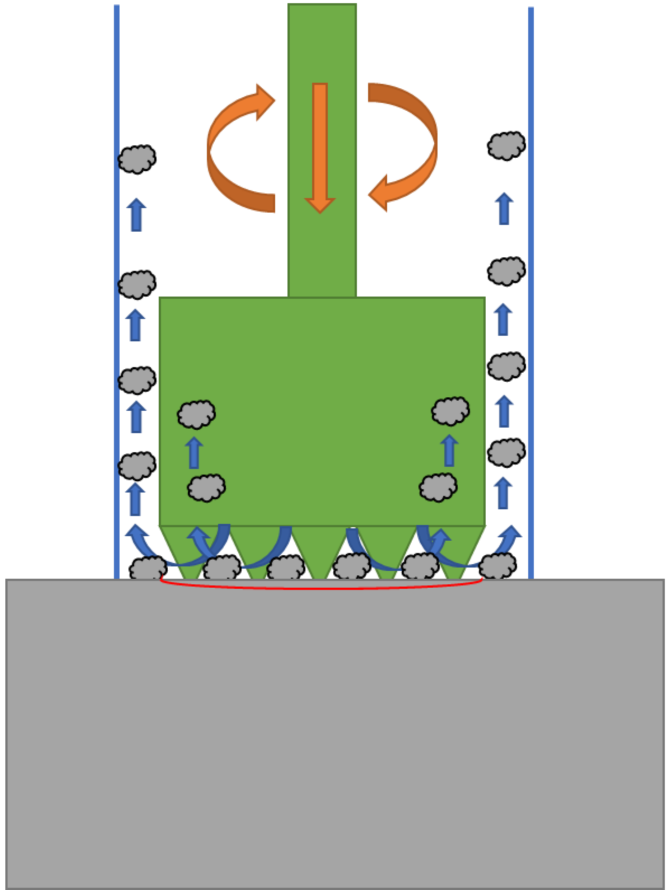
- Which drilling tool provides…
  - Best sensitivity for the delineation of various Florida soils
  - Ideal penetration rate to ensure the method is efficient
- Investigating three potential drilling tools:
  - Tri-cone roller bit, a PDC bit, and a stepped drag bit
  - Each of these drilling tools are 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

Develop Efficient Drilling Guidelines



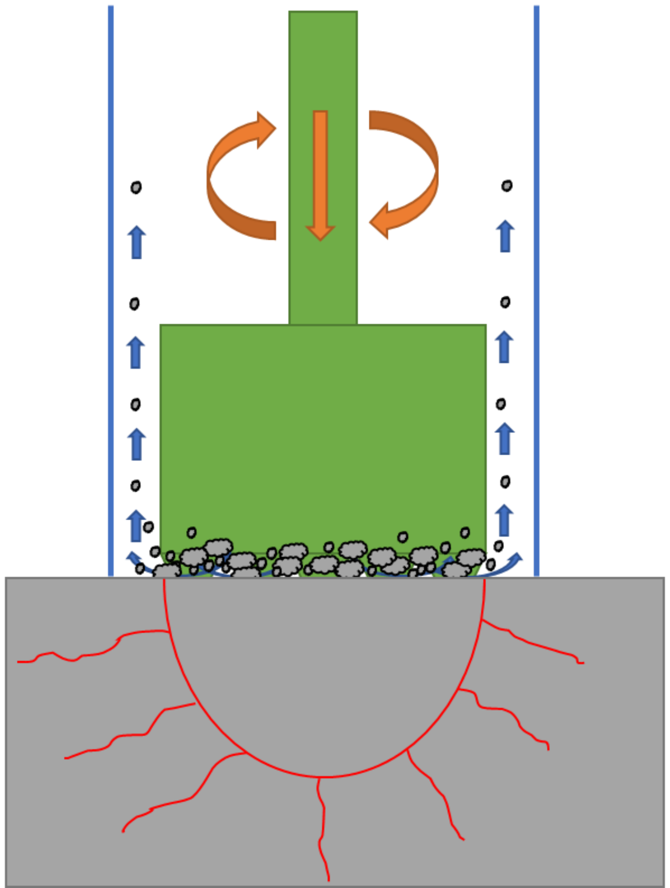
Optimized Drilling

- **Proper indentation and cutting → optimized penetration per rotation**
- **Efficient removal of drilled debris → Larger soil/rock particles removed → minimal energy**
- **Minimal disturbance to soil/rock prior to strength assessment → Optimized core REC and RQD**
- **In situ strength assessment viable via MWD**



Drilling Disturbance

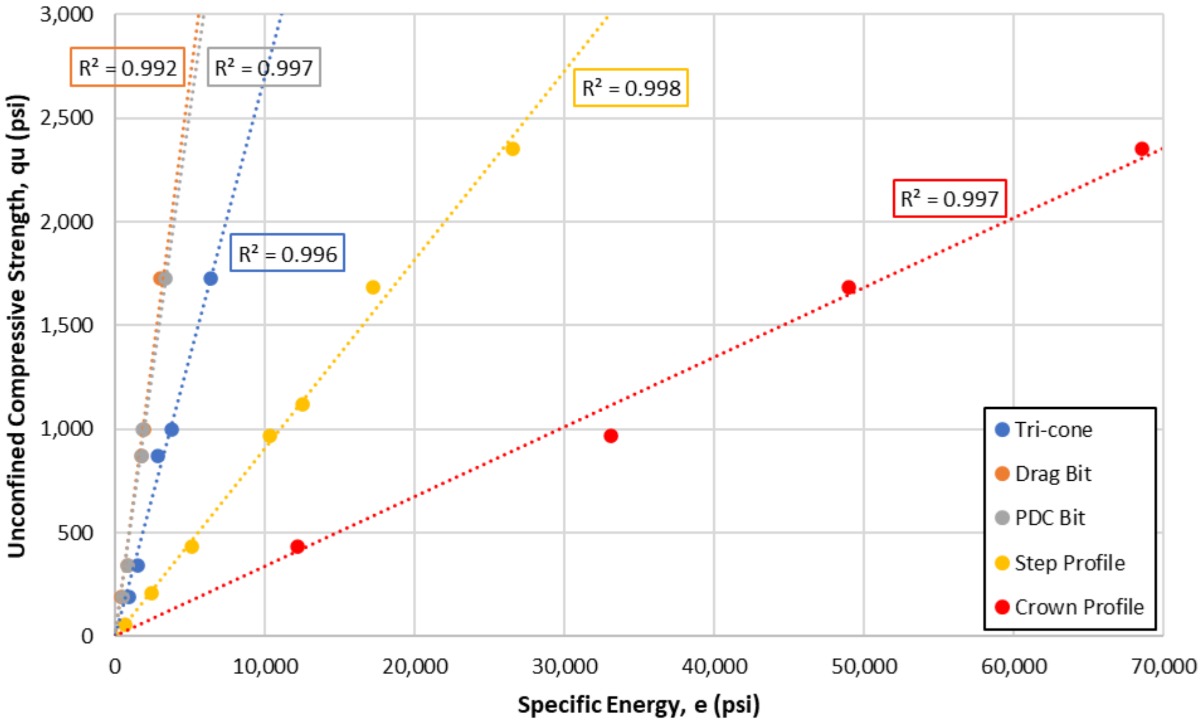
- **Overcrowding the bit → Increased torque**
- **Inefficient flushing → accumulation of drilled debris → smaller soil/rock particles removed**
- **Increased frictional resistance → High energy**
- **Increased bit wear and drill rig wear**
- **Disturbed soil/rock prior to strength assessment**
- **In situ strength assessment NOT viable via MWD**



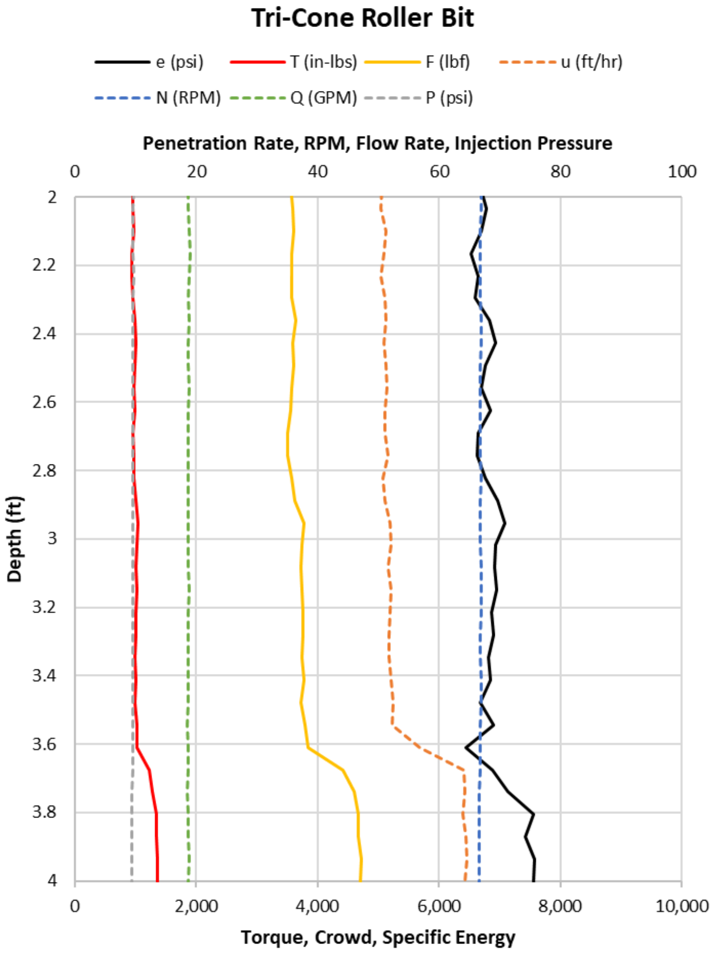
Optimized

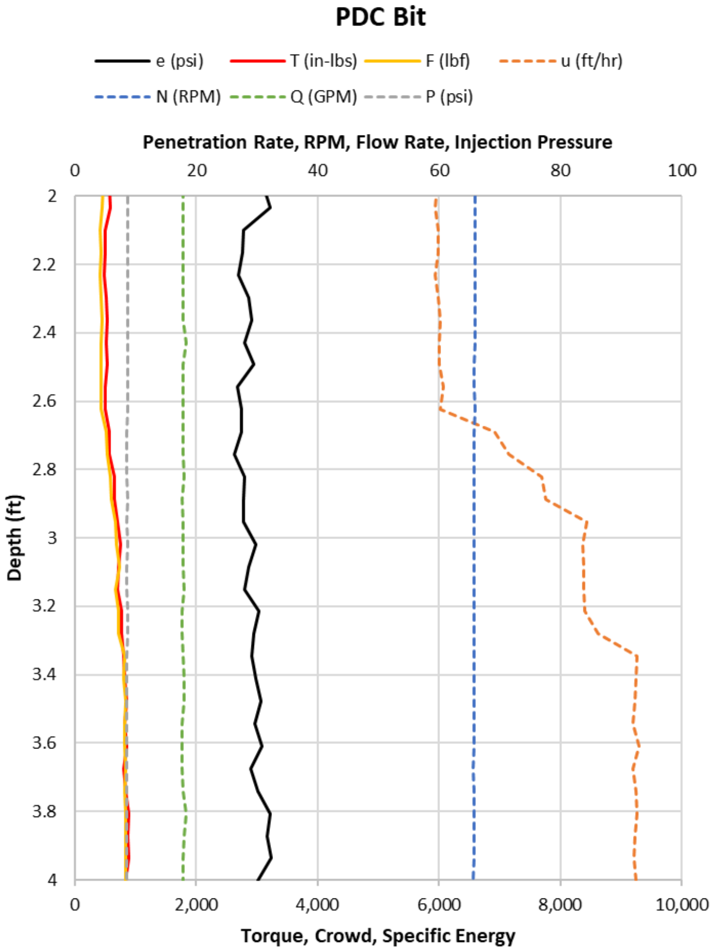
Disturbed

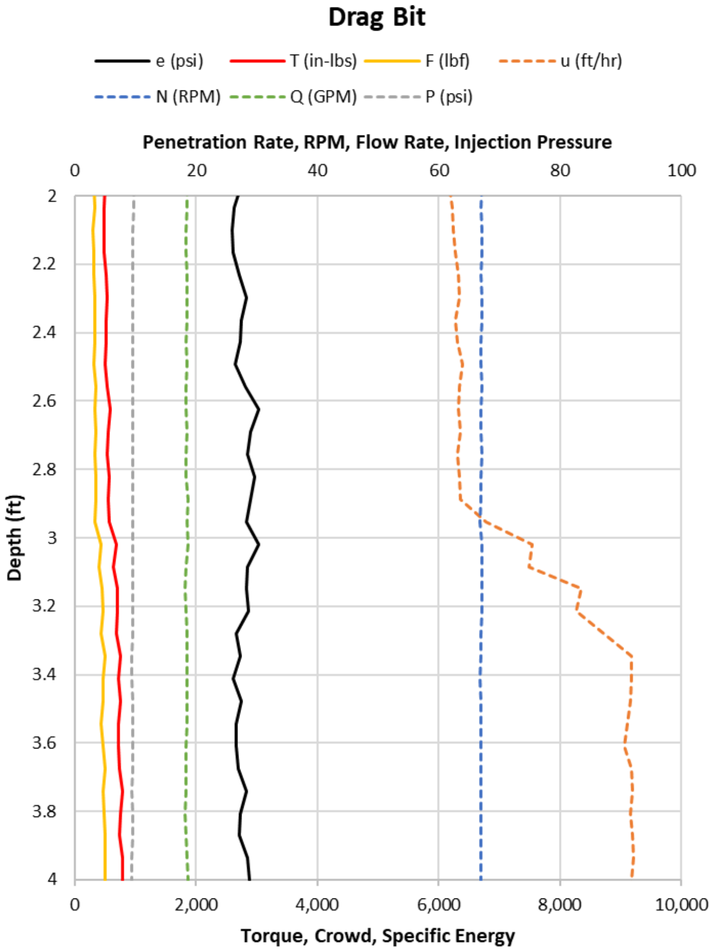
UCS vs Specific Energy for Five FL Drilling Tools



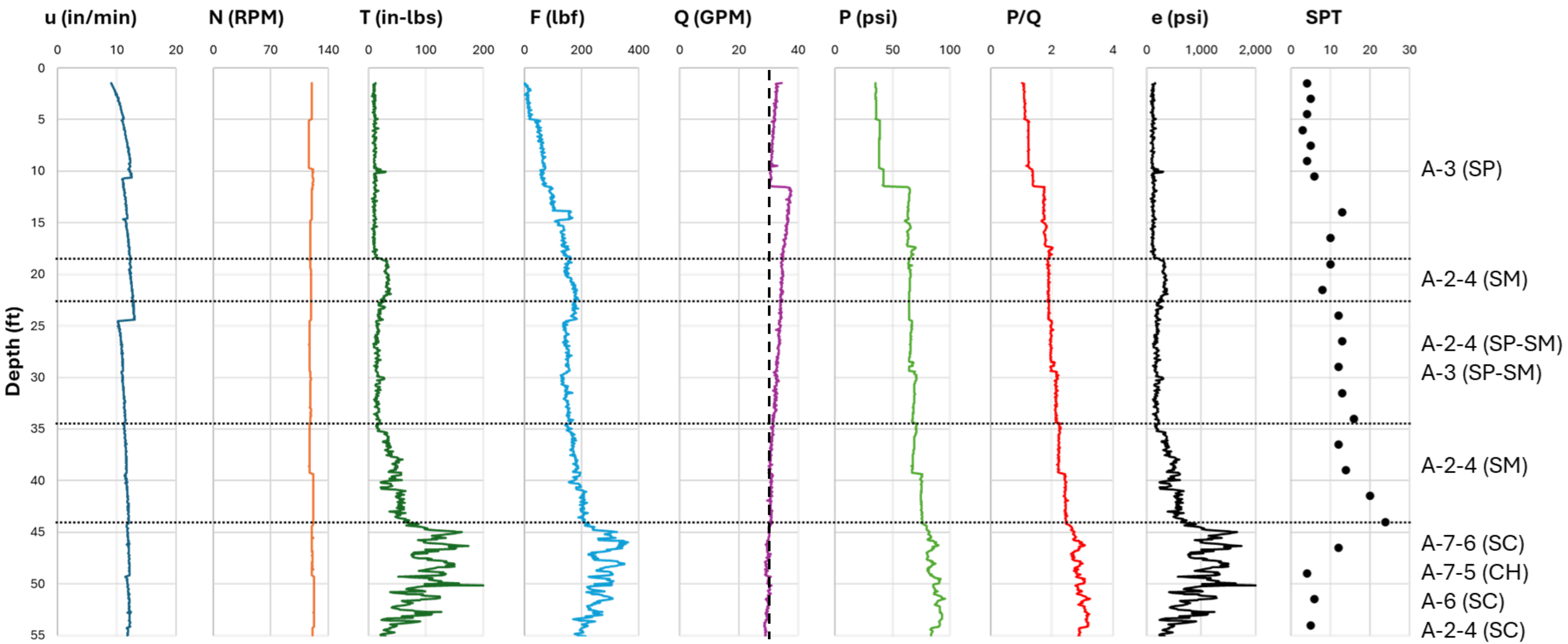
Task 2 – Drill Bit Selection and Method Development







MWD Soil Assessment – Trenton, FL – Drag Bit

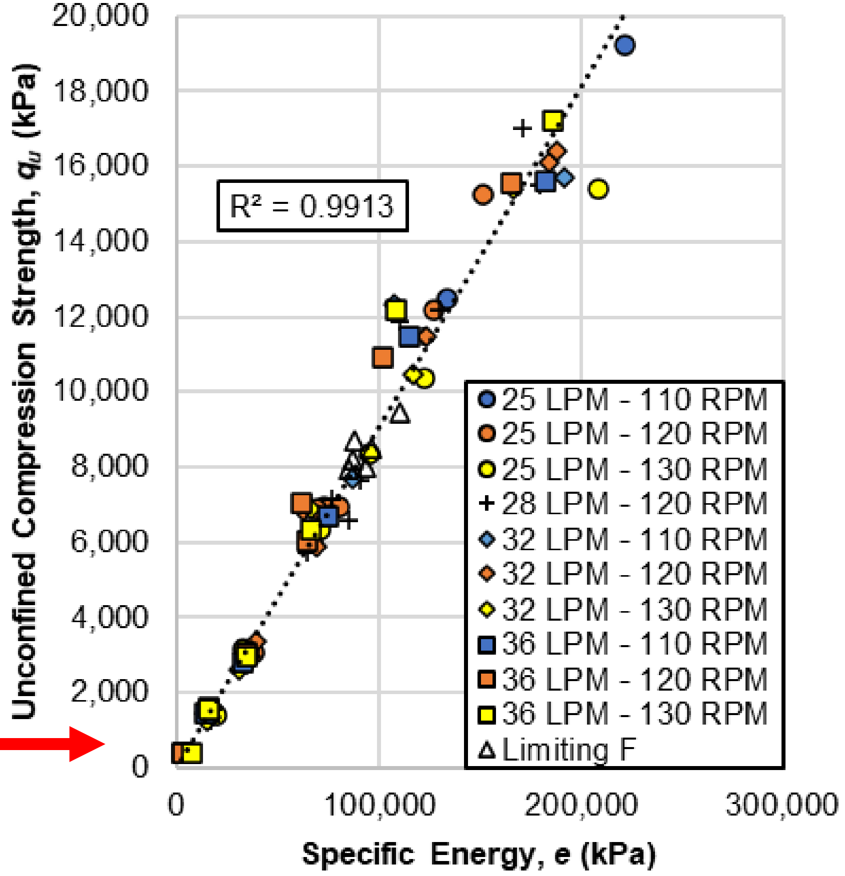


Task 3a – Operational Index Development

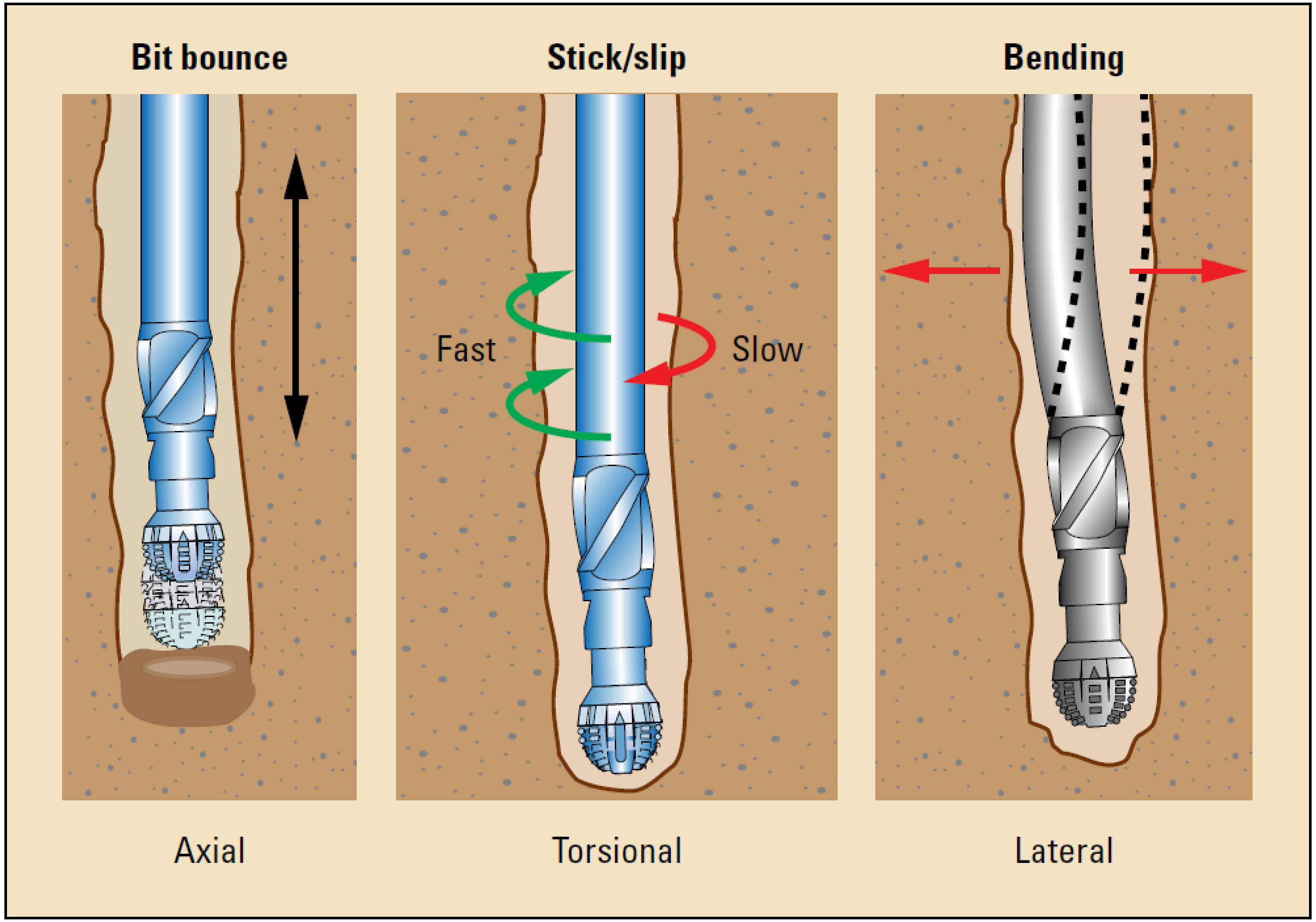
- Once the optimum drilling tool has been selected for the new MWD method, an operational drilling index will be developed
- The operational drilling index will comprise multiple independent and compound drilling parameters that when considered in combination, directly identify the soil type encountered
  - Individual drilling parameters
  - Compound parameters can be generated from other parameters
  - Waveform parameters can be extracted from T, F, and 3-axis vibration
  - ML will be utilized to assist in developing the operational index

How does this work?

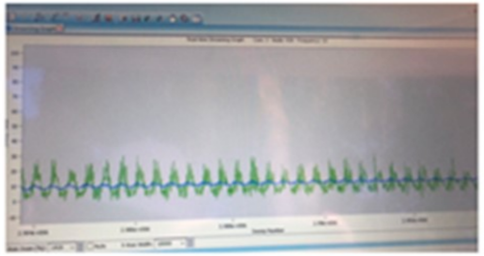
- Individual parameters will be used by drillers to maintain efficient drilling
  - Develop drilling procedures and guidelines – Task 2
  - Validates the recorded data
- Individual, compound, and waveform parameters used to identify materials
  - Operational index
- Compound parameters will be used to generate geotechnical design parameters using relationships unique to each material type
  - Specific energy vs. unconfined compression strength for coring limestone
- For soil assessment, SPT, CPT, DMT, VIP, and lab testing will be required near each MWD drilling location for development

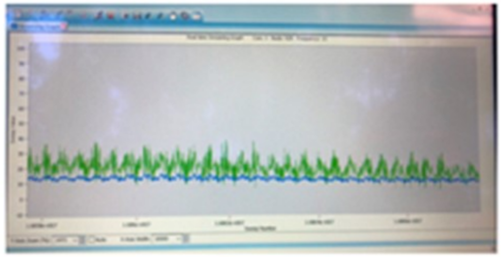


Drilling Vibration



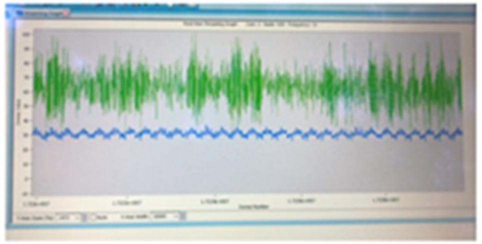
Schlumberger (2010)

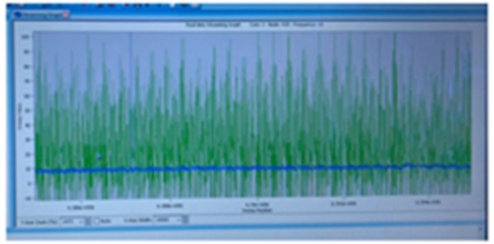




Extremely Soft Limestone
γ_d = 100 pcf
w% = 22%

Fresh Limestone
γ_d = 110-130 pcf
w% = 7-20%

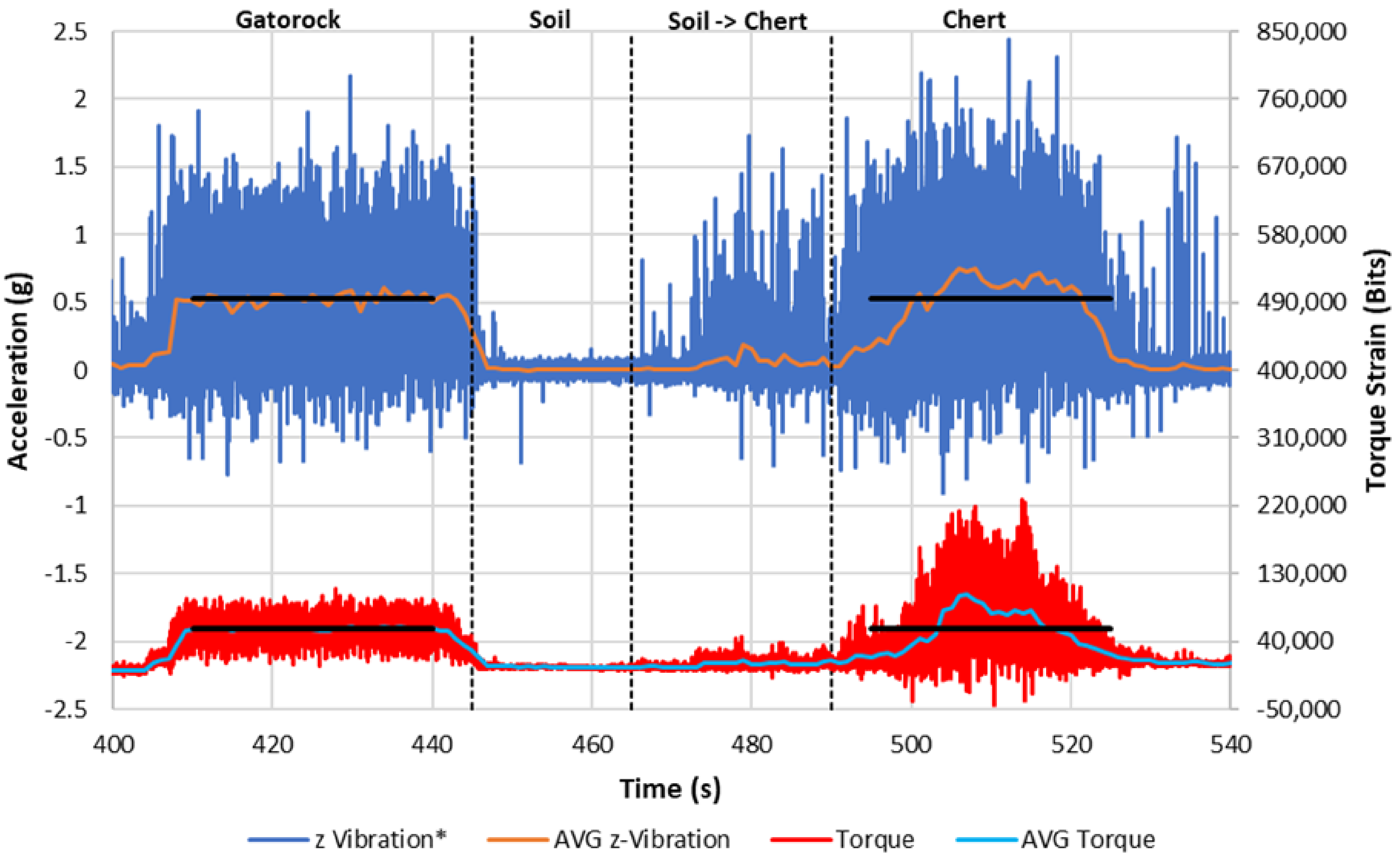




Banded Limestone/Dolestone
γ_d = 130-150 pcf
w% = 4-12%

Banded Limestone/Chert
γ_d = 140-145 pcf
w% = 4-5%

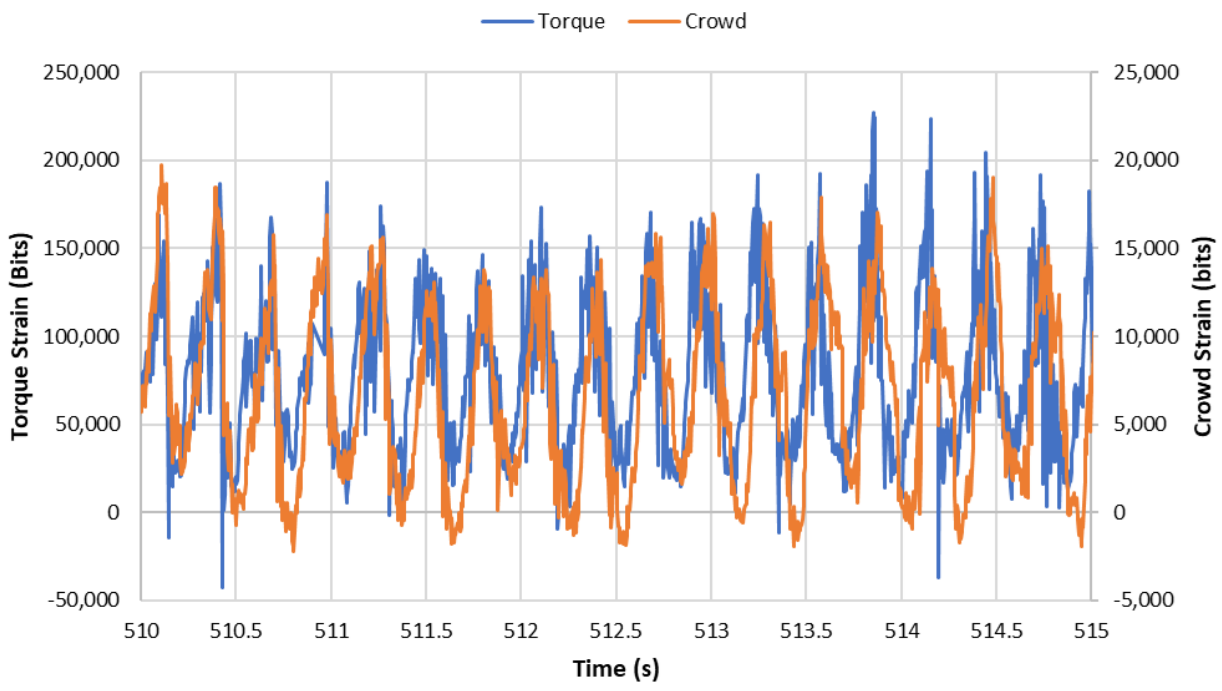
Time-referenced Data for 2K PSI Gatorock, Soil, and Chert



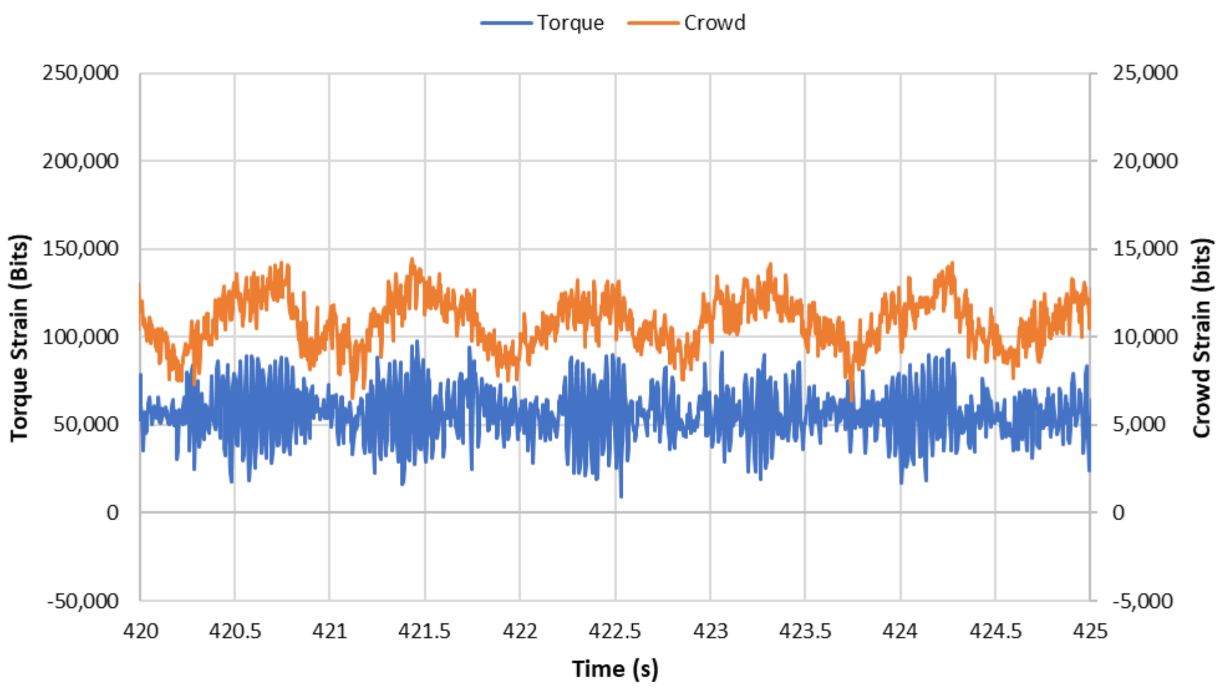
Torque and Crowd Strain Wave Comparison

Chert vs. 2,000 psi Gatorock

Chert Strain Waves



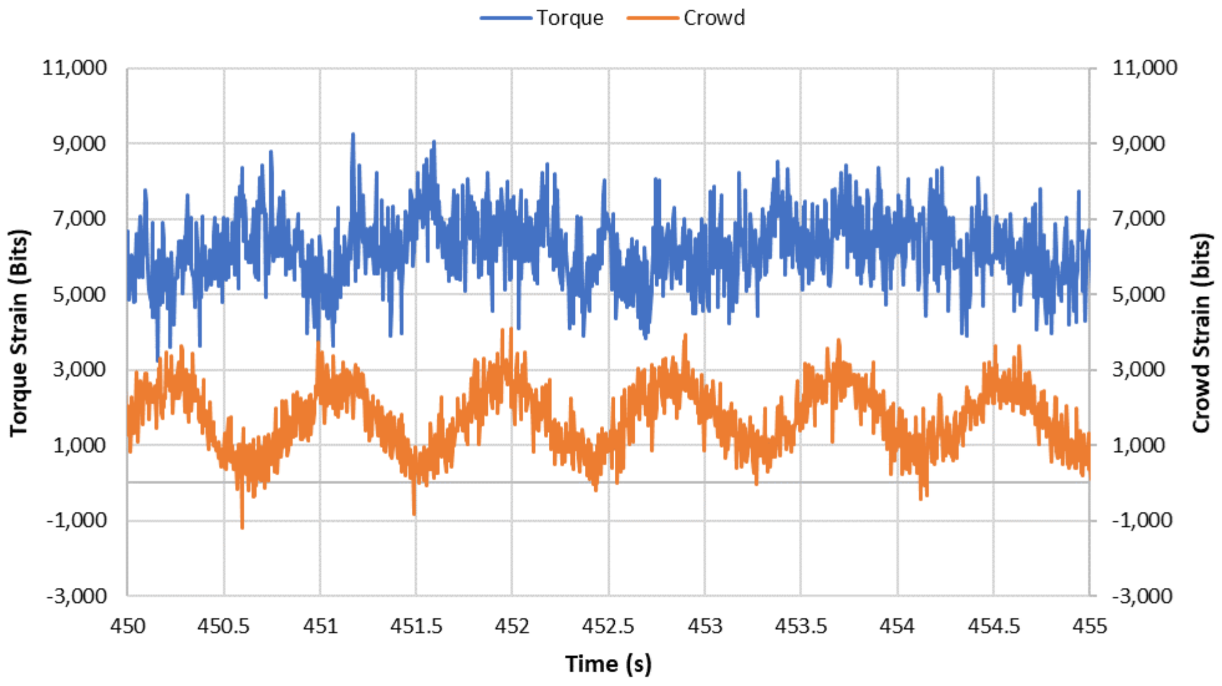
2,000 psi Gatorock Strain Waves



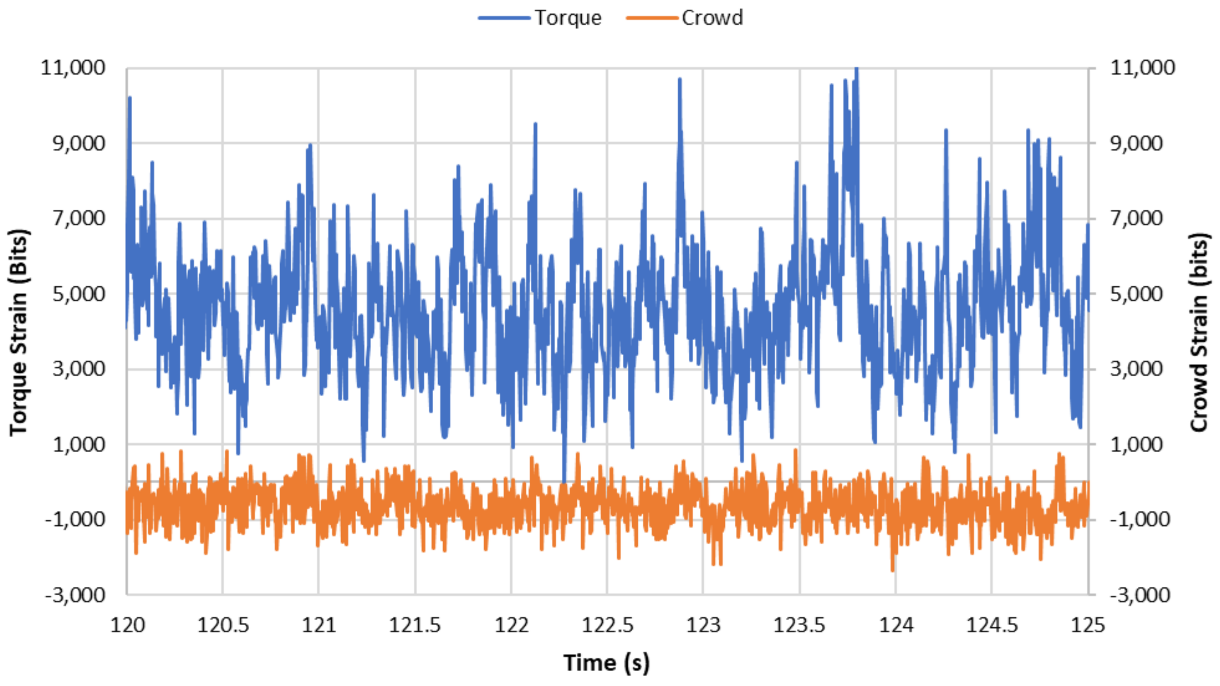
Torque and Crowd Strain Wave Comparison

Soil vs. 56 psi Gatorock

Soil Strain Waves



56 psi Gatorock Strain Waves



Derived Wave Parameters

- **RMS** is calculated by accumulating the mean squared of each chunk, dividing by the number of chunks in the window, and taking the square root.

$$RMS(F) = \sqrt{\sum_{j=0}^{J-1} \frac{\sum_{n=0}^{N-1} F_j(n)^2}{K}}$$

- **Crest Factor** is calculated by taking the absolute maximum value from the window and dividing by the RMS of the window.

$$CrestFactor(F) = \max(|\max(F_0, \ldots, F_{J-1})|, |\min(F_0, \ldots, F_{J-1})|)/RMS(F)$$

- **Peak to Peak** is calculated by subtracting the smallest value from the window from the largest value.

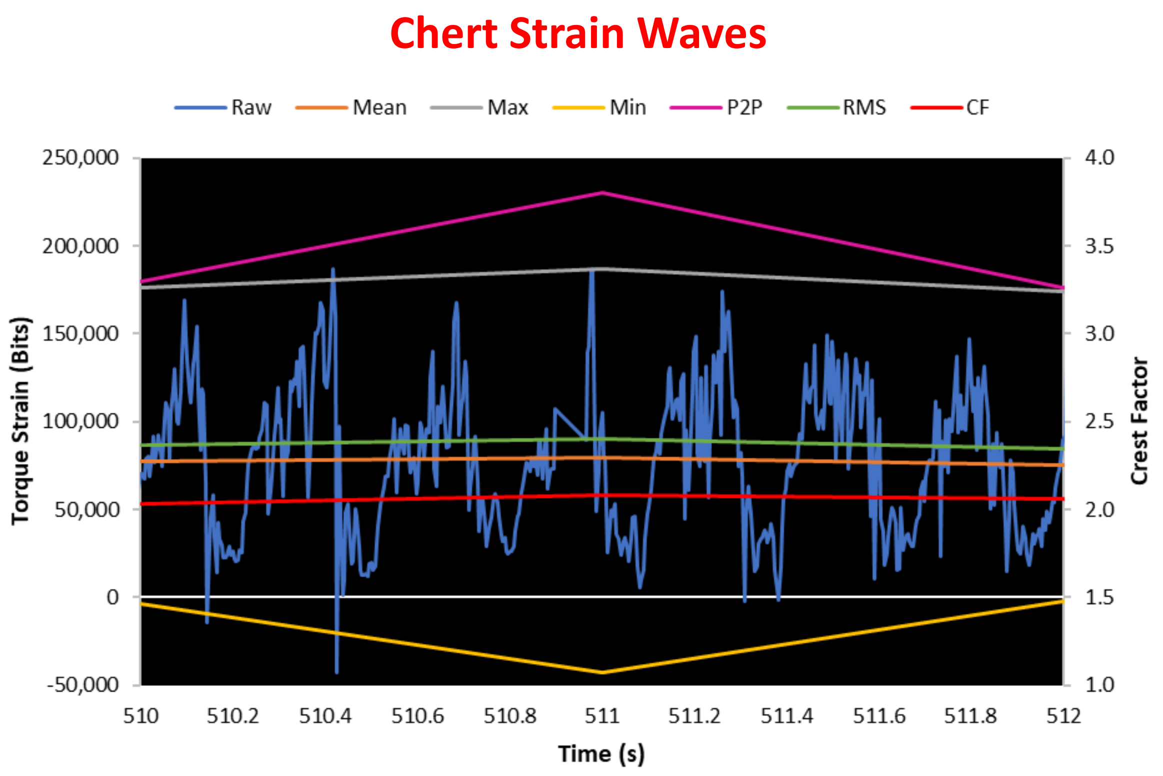
$$PeakToPeak(F) = \max(F_0, \ldots, F_{J-1}) - \min(F_0, \ldots, F_{J-1})$$

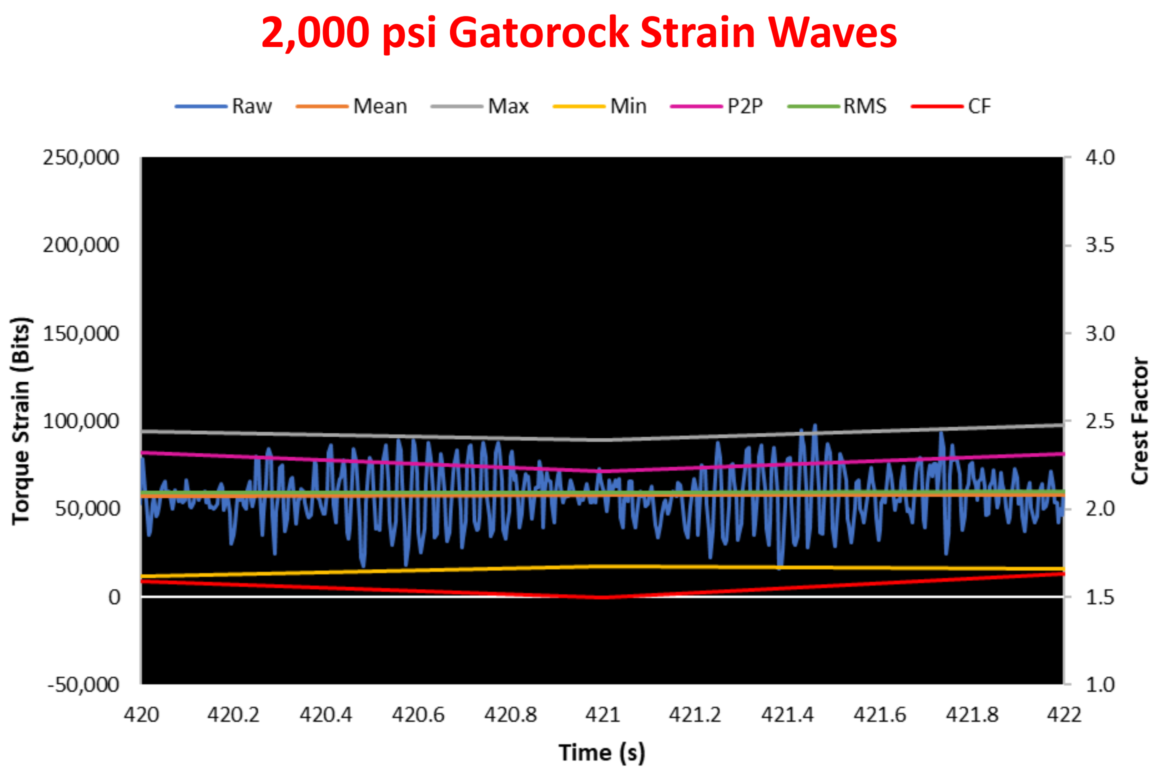
- **Velocity** – IPS or m/s

$$IPS_{RMS}(F) = \sqrt{\sum_{j=0}^{J-1} \frac{\sum_{n=0}^{N-1} \left(\int CSI(F_j)(n)\right)^2}{K}} \cdot 386.2197$$

Strain Wave Characteristics Comparison

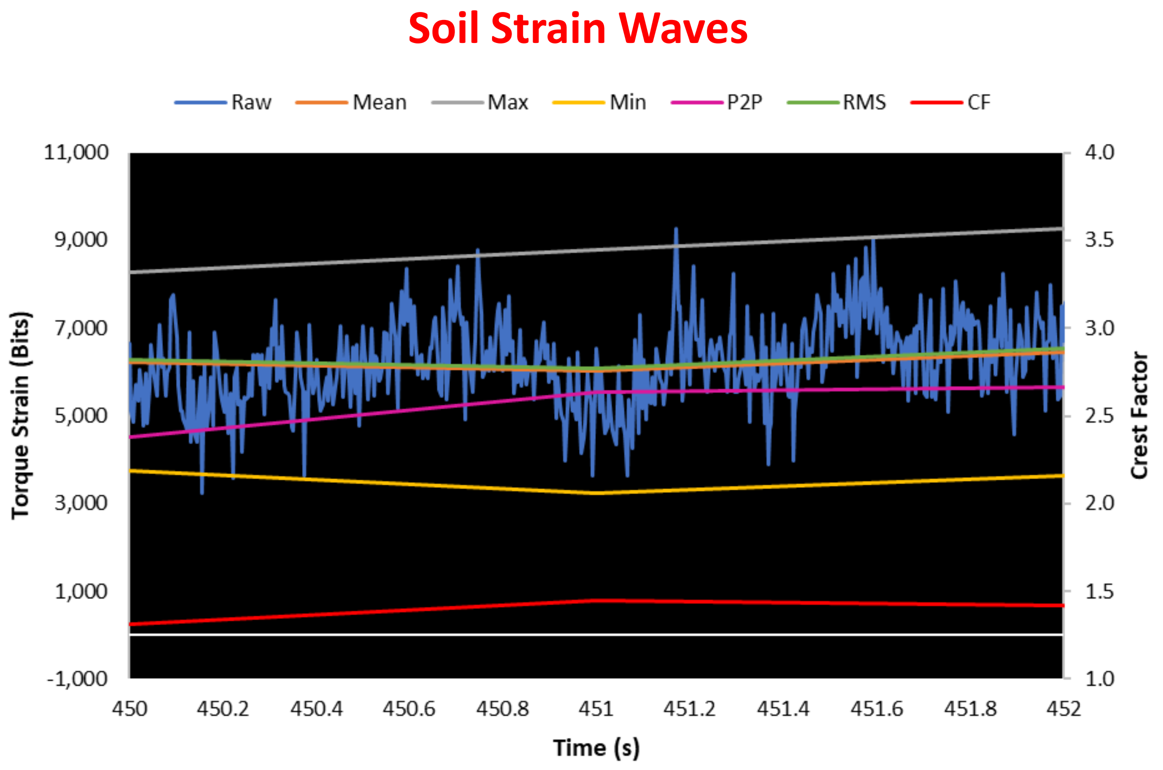
Chert vs. 2,000 psi Gatorock

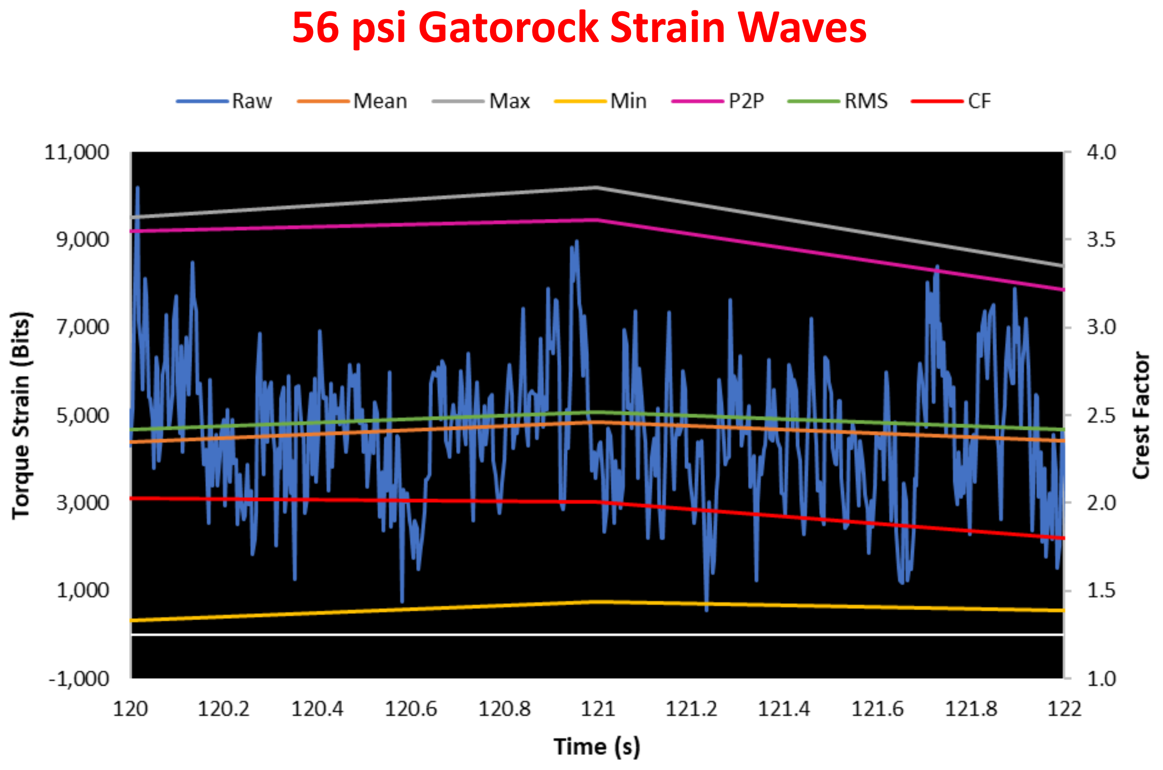




Strain Wave Characteristics Comparison

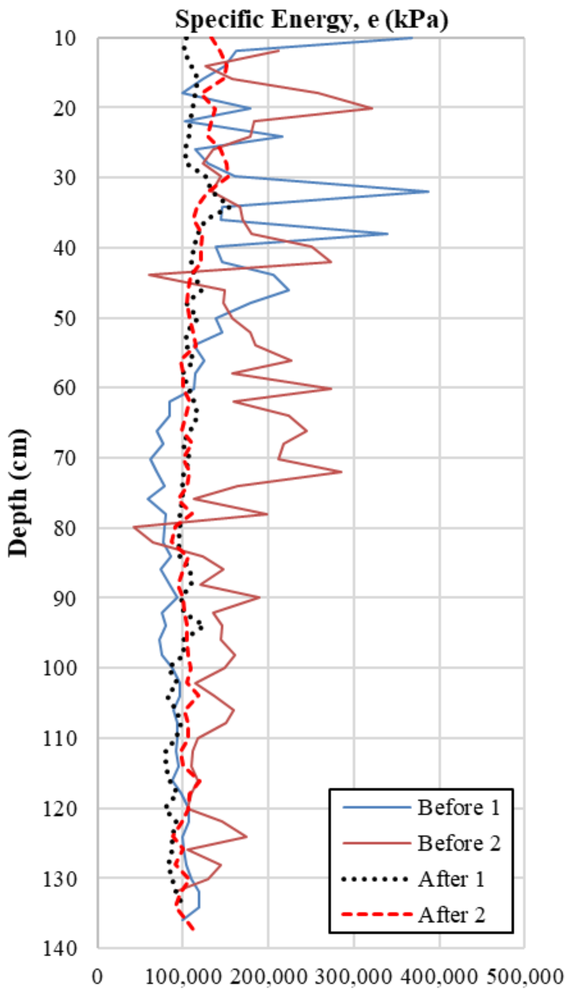
Soil vs. 56 psi Gatorock

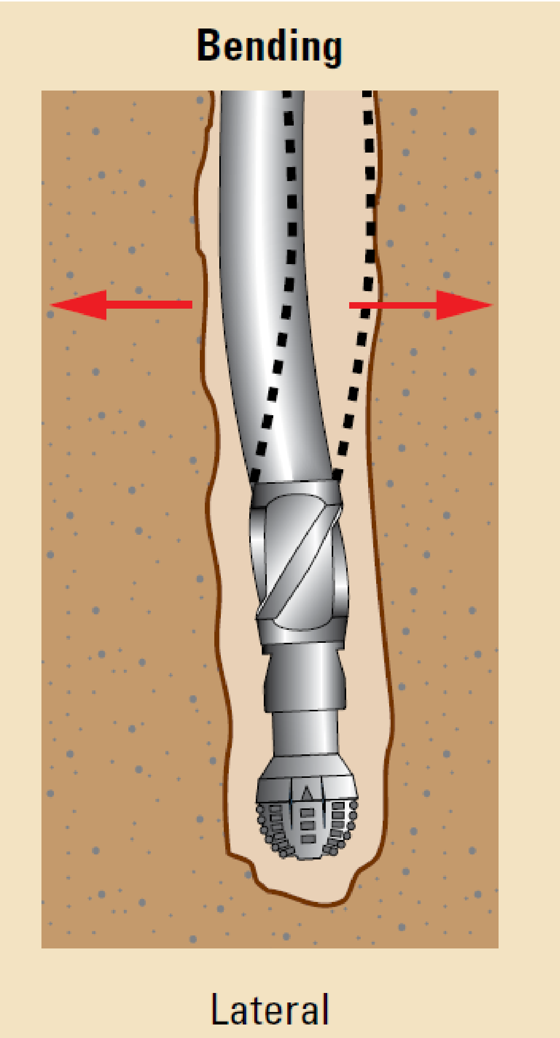




Task 3b – Eccentric Rotation Investigation at Deeper Drilling Depths

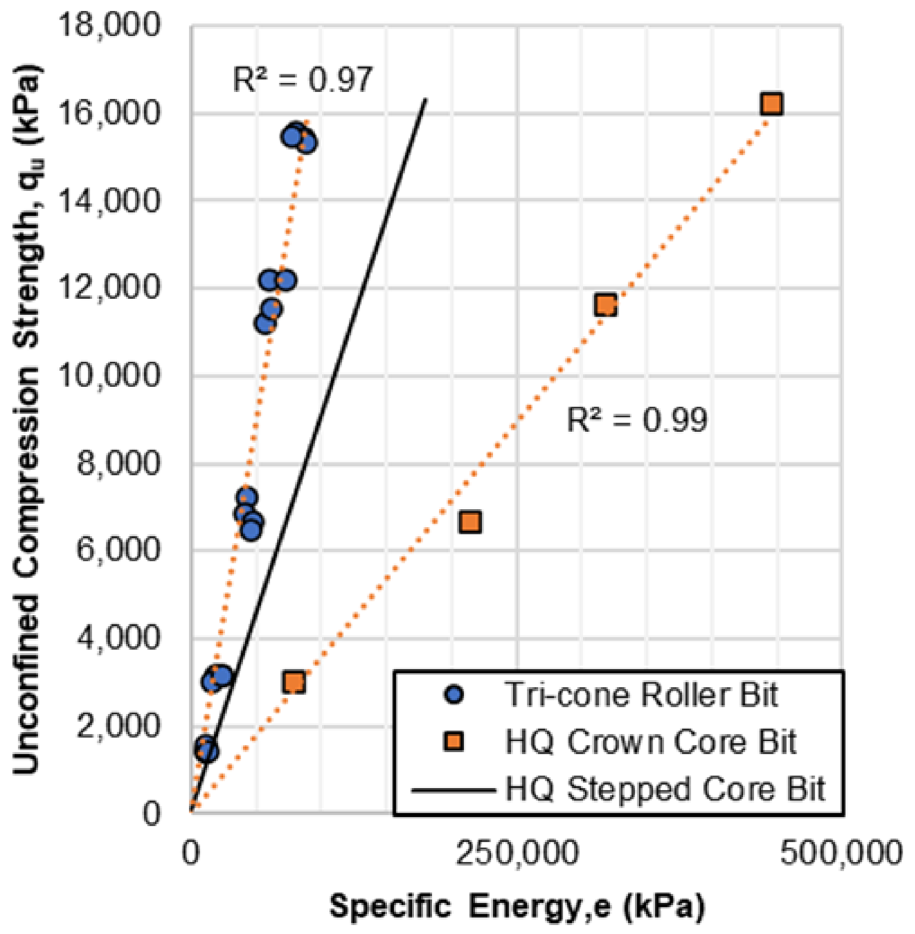
- FDOT Project BDV31-977-125 indicated eccentric rotation and excessive vibration may be induced at greater drilling depths due to the slenderness of the drill string, regardless of the rotary head's condition
- The new MWD method should be assessed based on the depth of drilling and potential effects 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
  - Waveform analysis will help identify this
- 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





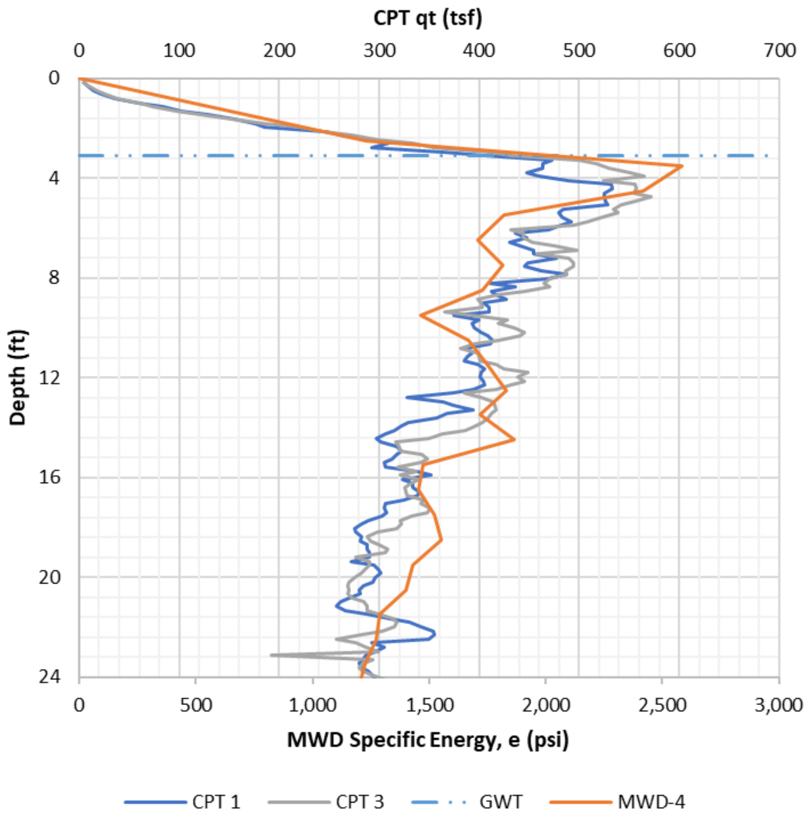
Task 4 – Developing Correlation Between MWD and Engineering Parameters

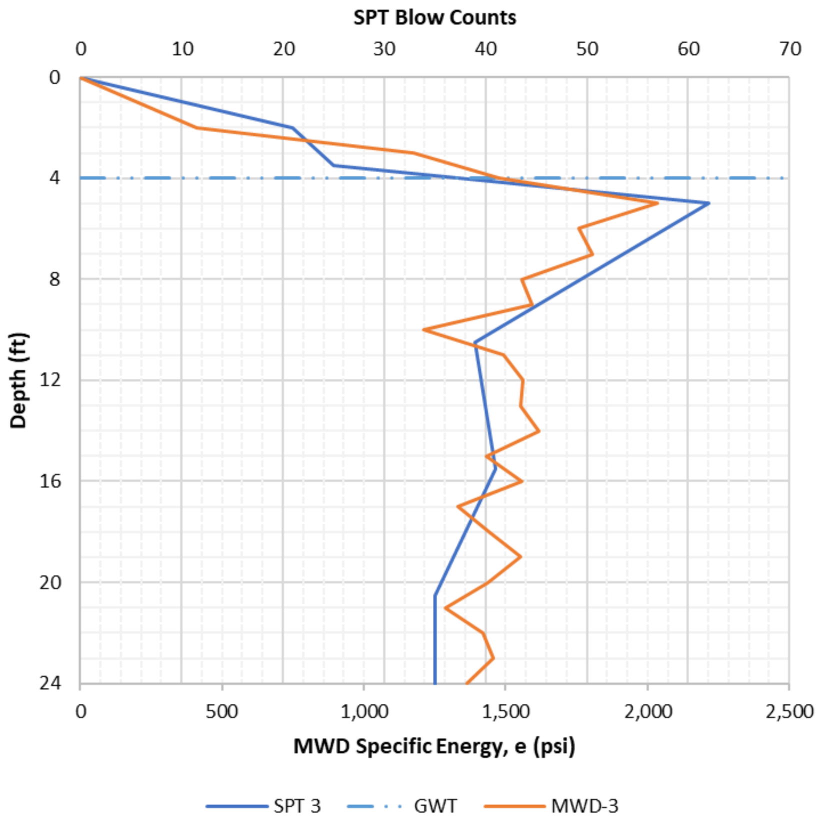
- Once the operational limits and the operational index has been developed, correlations between MWD parameters and the engineering parameters of will be investigated
- It is expected that the unique mechanical behavior and properties of various in situ soils and rock will produce a unique drilling response that will be captured by MWD
- Certain MWD parameters will be used to identify the soil and rock type encountered
  - i.e., operational index
- Certain compound drilling parameters will be used to determine the engineering parameters of the soil or rock type identified
  - e.g., specific energy
- 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 tension strengths of rock/IGM



MWD Compared to Conventional Methods

- One of the biggest challenges for developing MWD in-situ soil assessment will be relating drilling parameters to conventional soil engineering parameters commonly used in design
- We are already seeing agreement between MWD and conventional site investigation methods that are commonly used for soil characterization and design – encouraging!

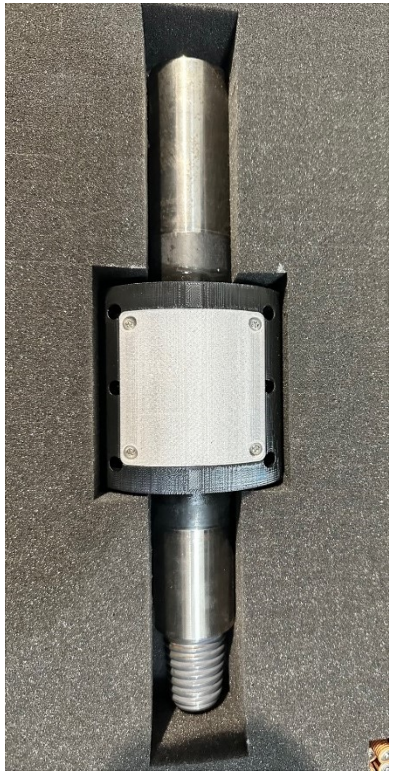




Rodgers, Horhota, and Jones (2024)

-Project Amendment-
Task 5 - Florida Consultant MWD

- Three FL consultants will engage in MWD site investigation
- UF research team will provide assistance and guidance
  - Instrumentation, method development, and data reduction
- UF research team will provide wireless drill rod transducers to measure mechanical torque



Questions?