Measuring While Drilling for Florida Site Investigation (FLMWD) BDV31-820-006

FDOT GRIP Meeting

Project Manager: David Horhota, Ph.D., P.E.
UF PI: Michael McVay, Ph.D.
UF Co-PI: Michael Rodgers, Ph.D.

August 18th, 2017

Topics Covered

- Introduction
- Background
- Objectives
- Tasks 1 – 3
- Remaining Work
  - Tasks 4 – 7

Introduction

- Generally, a foundation engineer has to consider multiple layers of soil and rock, with limited in situ or laboratory data available for design
- In Florida, the lack of laboratory data is often a result of poor recoveries experienced during standard rock coring procedures
- New methods should be developed to provide an increase in usable design data
  - Lead to a better understanding of spatial variability

Background

- Interest is growing worldwide for measuring while drilling, MWD, applications
- A large amount of data can be obtained from continuously taking measurements during drilling
  – MWD practices developed for drilled shaft monitoring provided 20 times the amount of usable data, in a third of the sampled locations, compared to the extensive site investigation performed at Kanapaha.
- An ISO standard has already been established for MWD monitoring systems and procedures
  – Measuring in situ rock strength is a new application

Background

- BDV31-977-20 took the first steps in our understanding and delineation of MWD practices for measuring in situ rock strength during drilling
  - Construction monitoring technique
  - MWD implemented post design phase
- Integrate the same approach into SPT coring and drilling procedures used as a site investigation tool.
  - MWD implemented prior to the design phase
  - Provides a significant increase in design data

Objectives

- The objective of this research is to investigate the viability of developing MWD practices for standard Florida site investigation.
- The same methods implemented in BDV31-977-20 will be used to develop the new MWD technique for SPT practices.
- The MWD procedure will include using two drilling tools.
  - Standard core barrel
  - Tri-cone roller bit

Objectives

- Developing the method using both drilling tools will provide continuous MWD while the hole is being advanced and during standard coring procedures
- The focus of developing the method will be assessing rock strength anytime rock layers are encountered
- Investigate quantifying drilling/coring procedures
  - Are we influencing poor recoveries?
  - Can we improve drilling techniques to extract more intact core samples for lab testing?

Task Outline

1. Surveying district SPT drillers
2. SPT rig investigation and instrumentation
3. Controlled field testing with Gatorock
4. Full scale field testing at various Florida sites
5. Field testing analysis
6. Draft final report and closeout teleconference
7. Final report

Surveying District SPT Drillers (Task 1)

- A SPT drilling/coring survey was presented to SPT rig operators from multiple districts
- Provide a better understanding of typical coring and drilling procedures
- Included questions on typical drilling equipment, coring equipment, and procedures.
- The procedure results were used to provide variations in the drilling plan for Task 3

Survey Results

- This is very much a feel based procedure!
- Slightly higher rotational speeds are used with a core barrel compared to a tri-cone bit
  - Generally 3rd gear is used with variable throttle
- Penetration rates are purely feel based
  - Can use feed rate settings which regulate the thrust pressure (F/A)
    - Thrust pressures should be 150 – 200 psi based on survey results
  - Penetration rates are always variable
- Low flowrates when coring
- High flowrates when using a tri-cone bit
- 1” – 4” diameter cores are typically extracted
  - 2.4” according to SFH handbook
- Double wall diamond studded core barrel

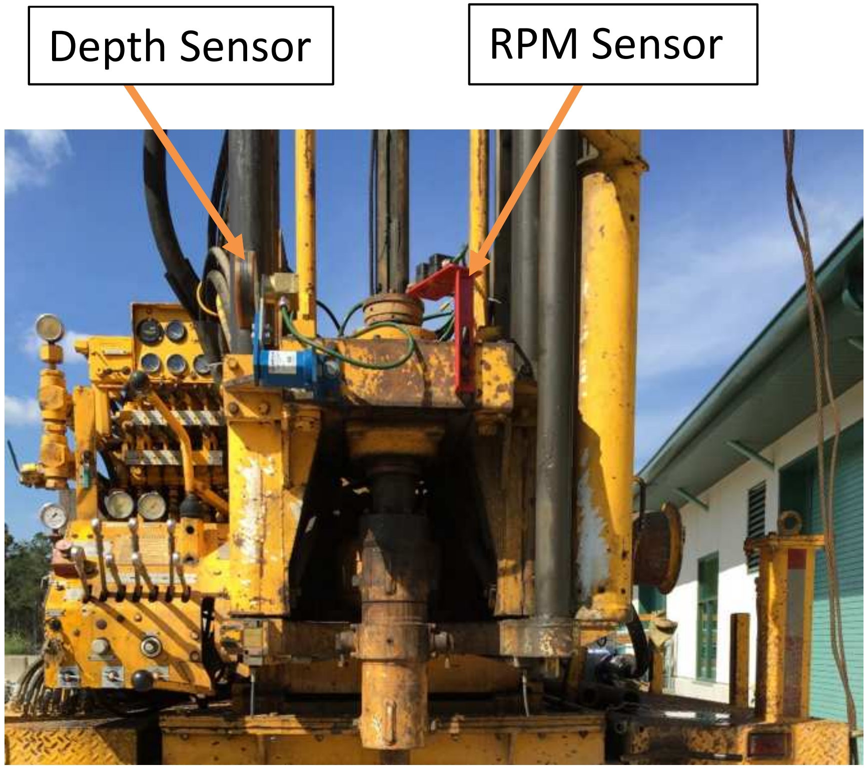
SPT Rig Investigation and Instrumentation (Task 2)

- Real time measurements of:
  1. Torque
  2. Crowd
  3. Rotational speed
  4. Penetration rate
  5. Flow rate and circulation pressure
     - Monitored for the first time
  6. Bit diameter
     - Fixed drilling parameter
- Provides an ISO MWD Category A – Class 1 monitoring system
- Conducted with the SMO’s CME-75 SPT rig

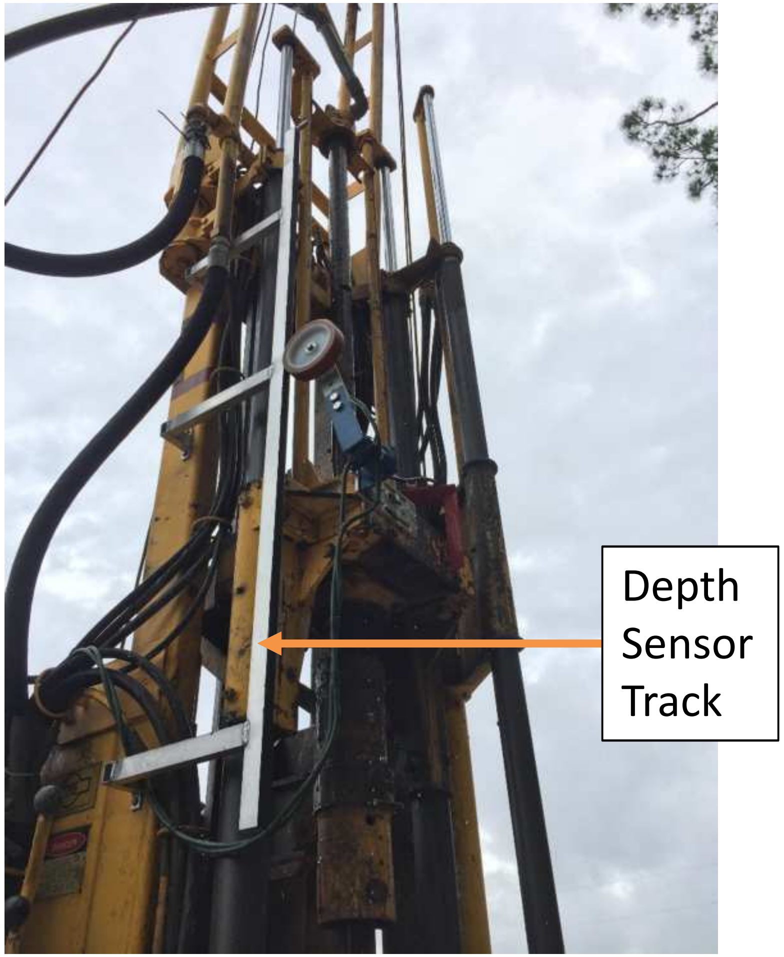
Drill Rig Instrumentation

- Rotational speed, penetration rate, flow rate, and circulation pressure are tied into the main junction box
  - Permanent junction box
- Torque and crowd are tied into a smaller junction box via a wireless data transmitter attached to an instrumented drill rod
  - Breakaway junction box
  - Conversion modules provide compatibility w/ the DIALOG (DAQ)
- All drilling parameters are monitored and recorded via the DIALOG (DAQ)
  - Plotted versus depth
  - Provides average readings every 2 cm of penetration

Penetration Rate and Rotation Speed



Modified Depth Sensor

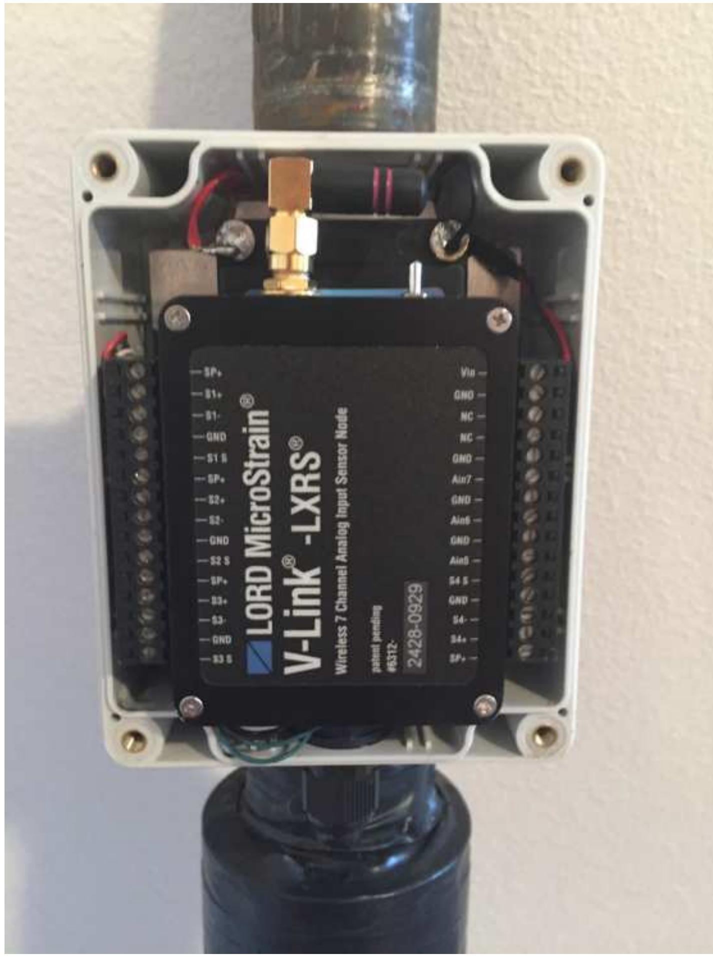


Flowrate and Pressure

Instrumented Drill Rod

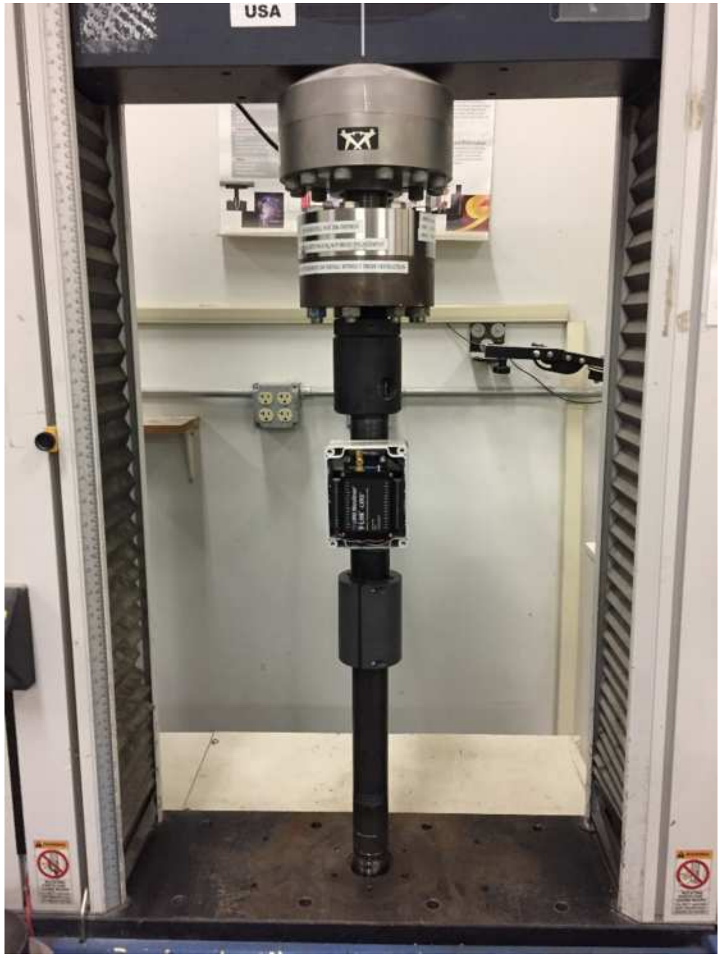
- Torque rosettes and T-element strain gauges every 90 degrees
- Full bridge to compensate for bending and temperature
  - Moisture protected coating
- IP 65 waterproof housing for the wireless data transmitter
  - Reduced antenna length
- External battery
  - Improved the battery life by a factor of 10
  - Can monitor all week without having to charge the battery

Instrumented Drill Rod

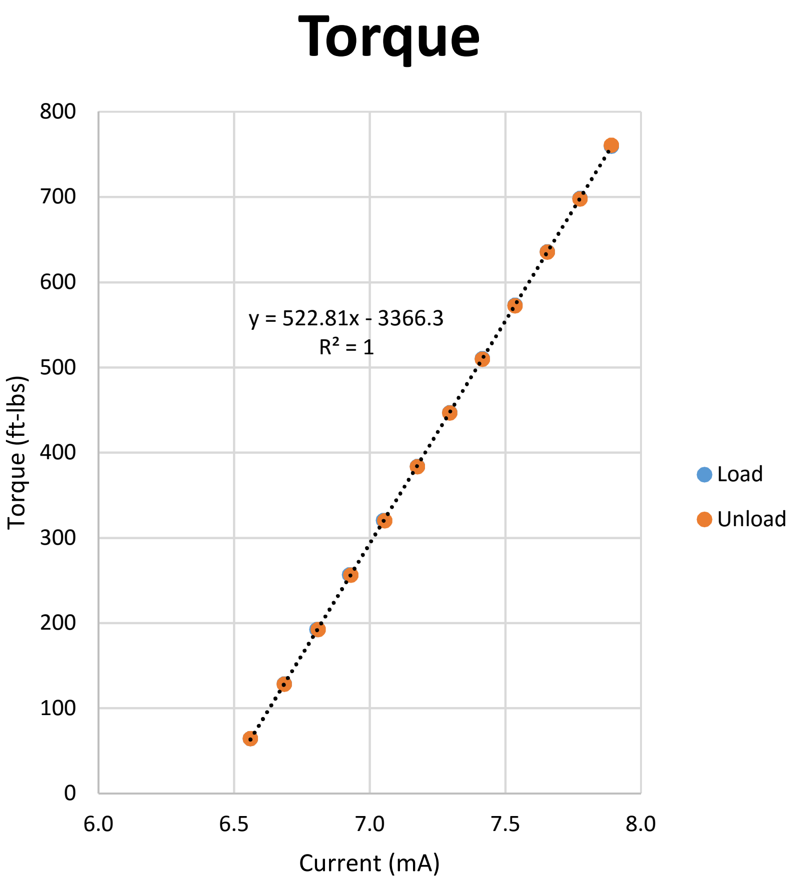


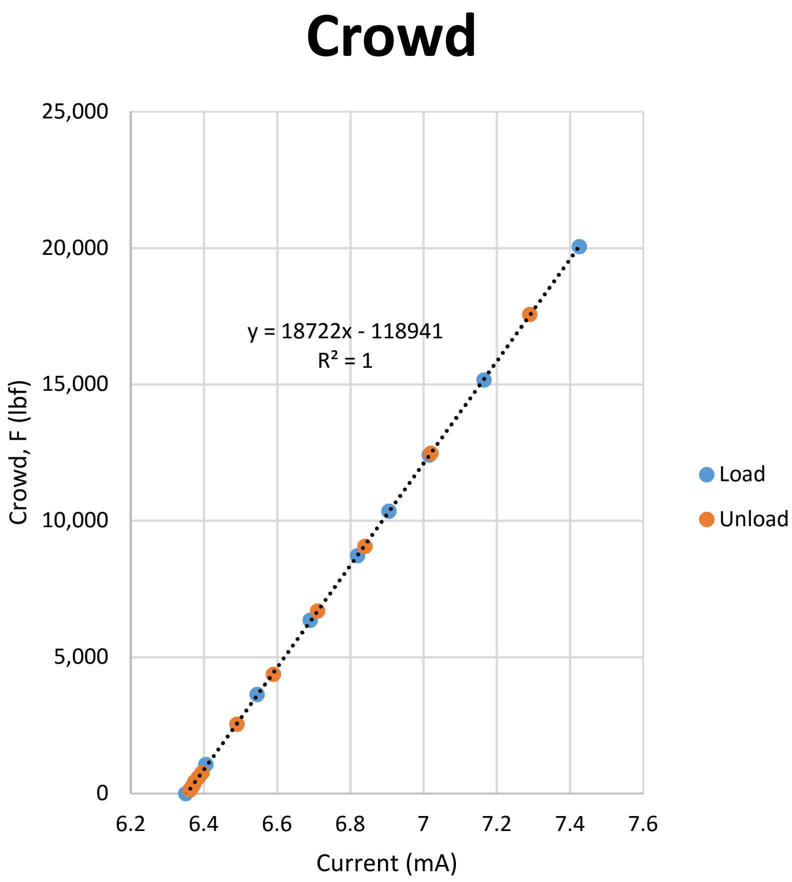
Torque Calibration

Crowd Calibration



Calibration Curves





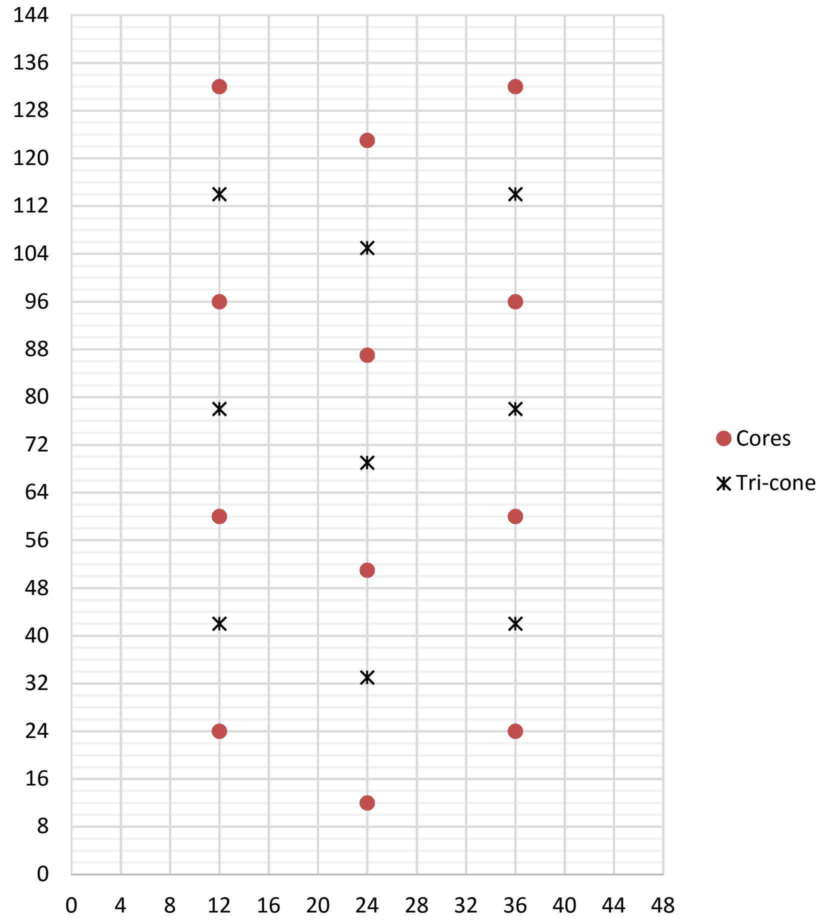
Real Time Monitoring

Controlled Field Testing with Gatorock (Task 3)

- A full scale drilling investigation is in progress using Gatorock in the field at Kanapaha
  - Multiple 4’x 4’ x 12’ trenches were excavated
  - Each trench was backfilled with a different strength of Gatorock and allowed to cure for 28 days
- Provides benchmark compressive strength values to develop drilling equations
- Investigate how variable drilling parameters influence the drilling procedure and core recoveries without drastic changes in rock strength

Creating Gatorock Slabs

Drilling Plan



Core Barrel

- 12 cores per slab
  - Approximately 4’ length
  - 10 – 12 samples per core for qu testing
  - 2 – 3 qt tests
- 2 rotational speeds
  - 75 and 125 rpm
    - 150 rpm was also investigated
- 3 feed rates
  - Regulated thrust pressures of 125, 155, 185 psi
- 3 flow settings
  - Flowrate is dependent on flow setting and rpm throttle
  - Higher flowrates can be achieved with lower flow settings and more rpm throttle

Tri-cone Roller Bit

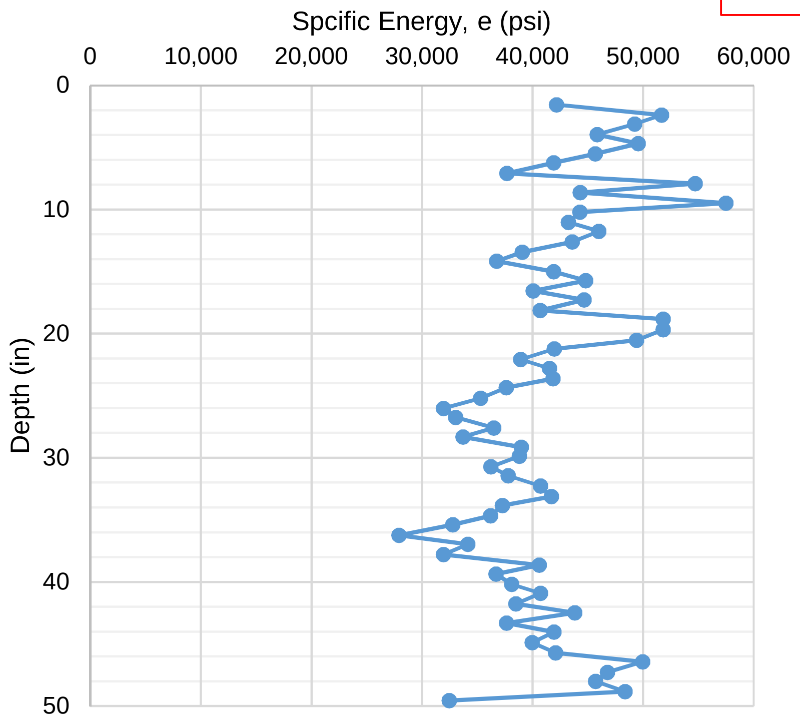
- 9 drillings per slab
  - Adjacent cores on two sides of the tri-cone drilling
  - Field cores will be used as strength reference
  - Cast cylinders are showing lower strengths
- 3 rotational speeds
  - 75, 125, and 150 rpms
  - 175 rpm was investigated
    - Crowd spikes at higher rotational speeds
    - More vibration at higher rotational speeds
- 3 feed rates
  - Thrust pressures of 125, 155, 185 psi
- 3 flow settings
  - Same as the core barrel

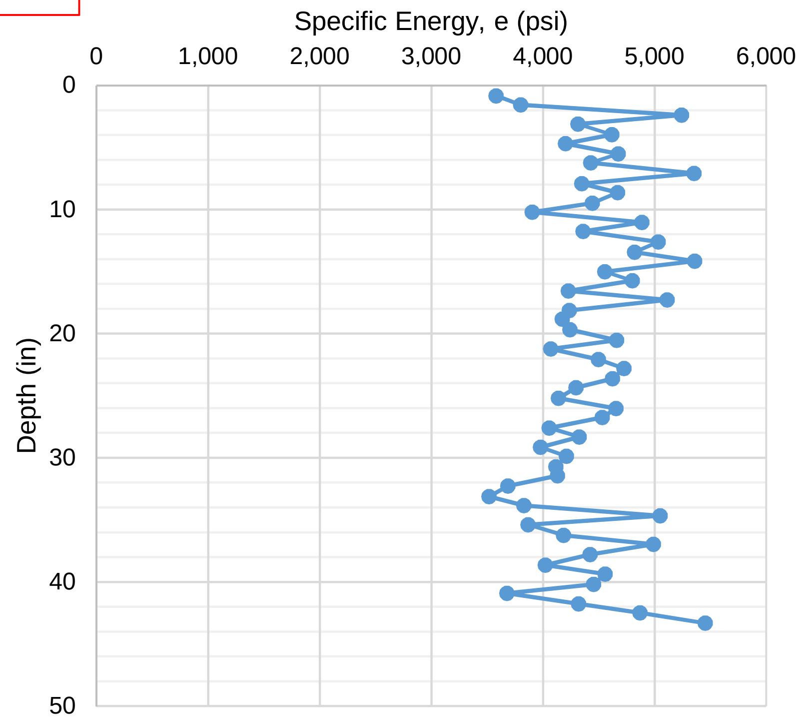
Specific Energy Comparison

Core Barrel

Tri-cone Bit

S1-H11 (1.88" Core) ← Adjacent Drillings → S1-H9 (2.88" Tri-cone)





Core Barrel Comparison

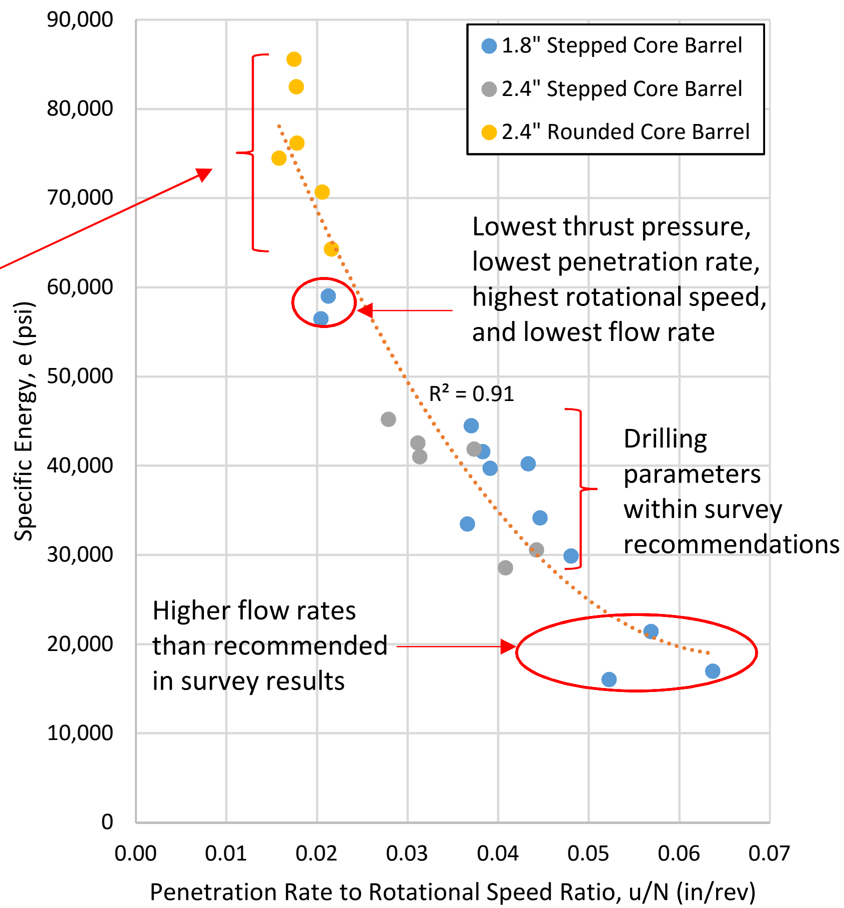
- 3 double wall core barrels were compared
- All with diamond studded cutting surfaces
  - Based on survey results
- 2 different cutting surface configurations
  - Stepped
  - Rounded
- 3 different methods of fluid injection

1.9” Stepped   2.4” Stepped   2.4” Rounded

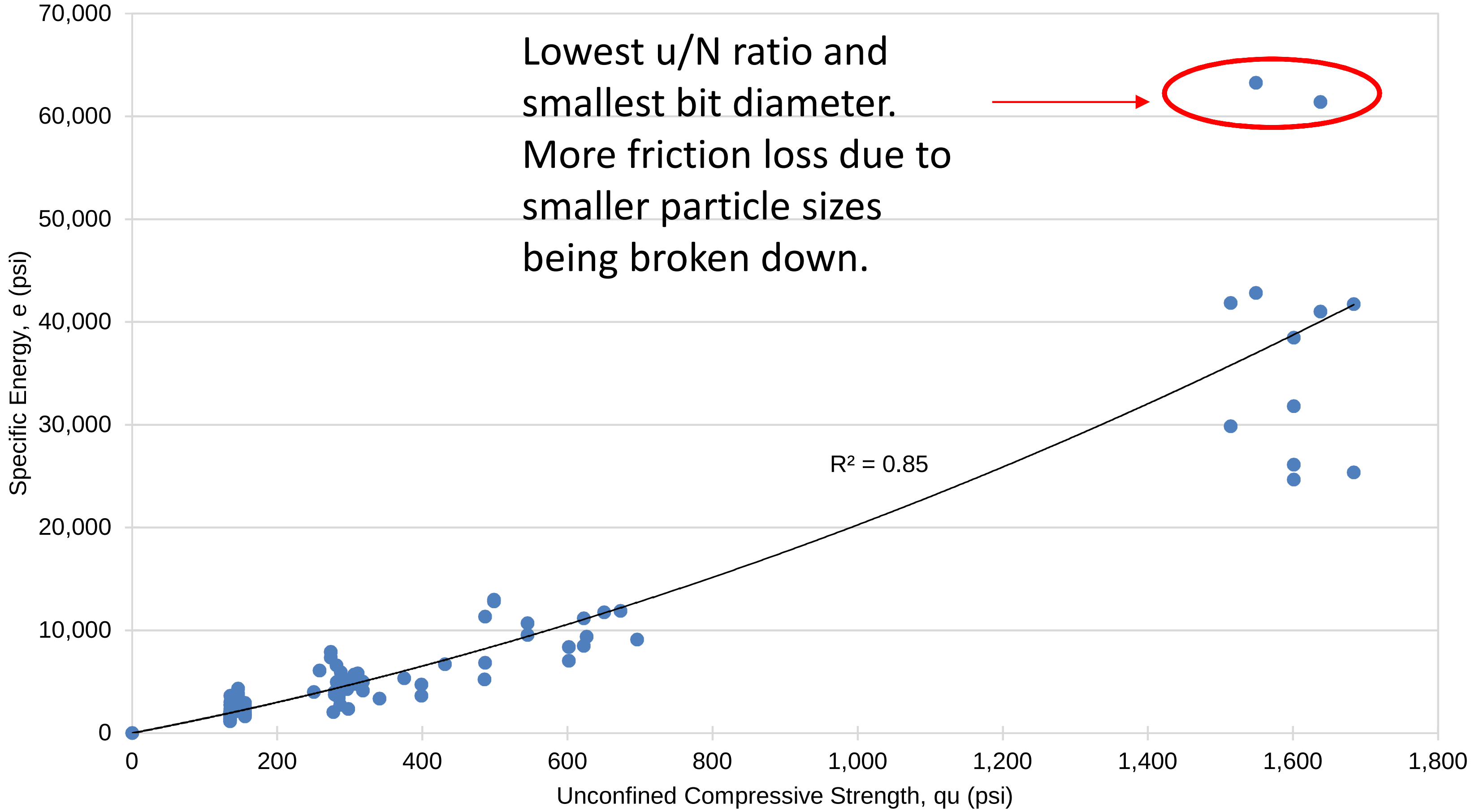
Core Barrel Comparison

- 2.4” rounded core barrel is less mechanically efficient
  - Slower penetration rate under the same regulated thrust pressure and RPMs
  - Friction loss due to smaller particle sizes being broken down?
    - Will be investigated
  - Will likely require a unique equation to relate specific energy with UCS
- Stepped core barrels show similar mechanical efficiency
  - Higher penetration rate under the same regulated thrust pressure and RPMs
  - Changes in bit diameter have a negligible effect on specific energy prediction
- Increasing the flow rate improves the mechanical efficiency
  - Less friction loss due to rock cuttings being flushed out quicker

UCS ≈ 1,700 psi for all data points

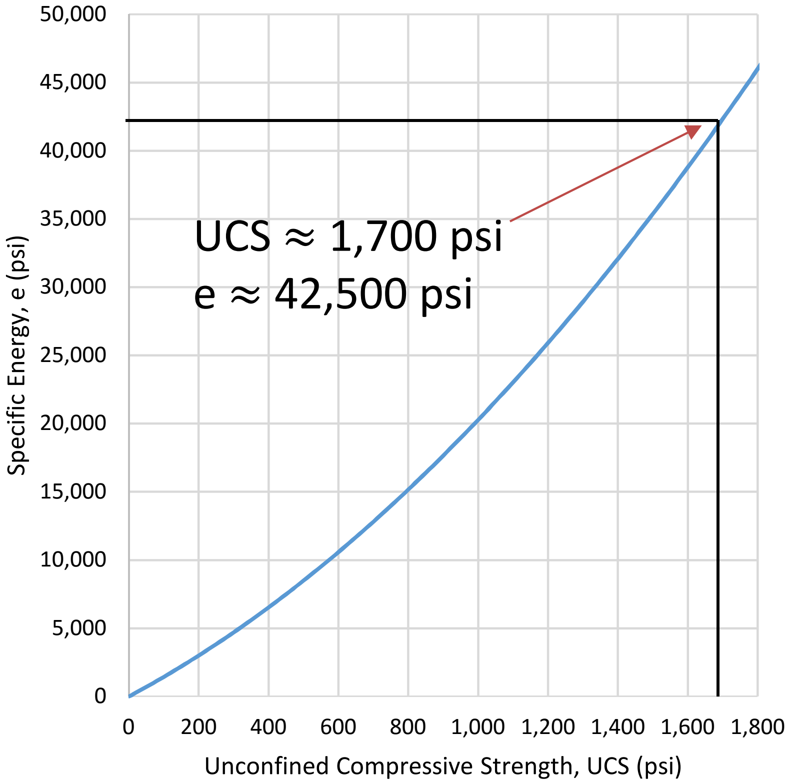


Drilled Shaft - Rock Auger Equation

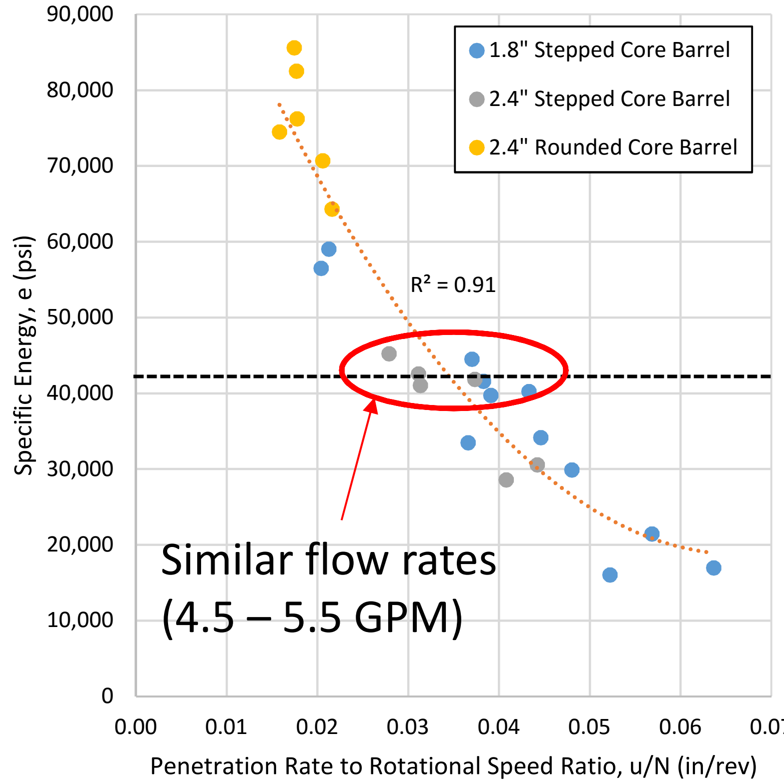


Using the Rock Auger Equation

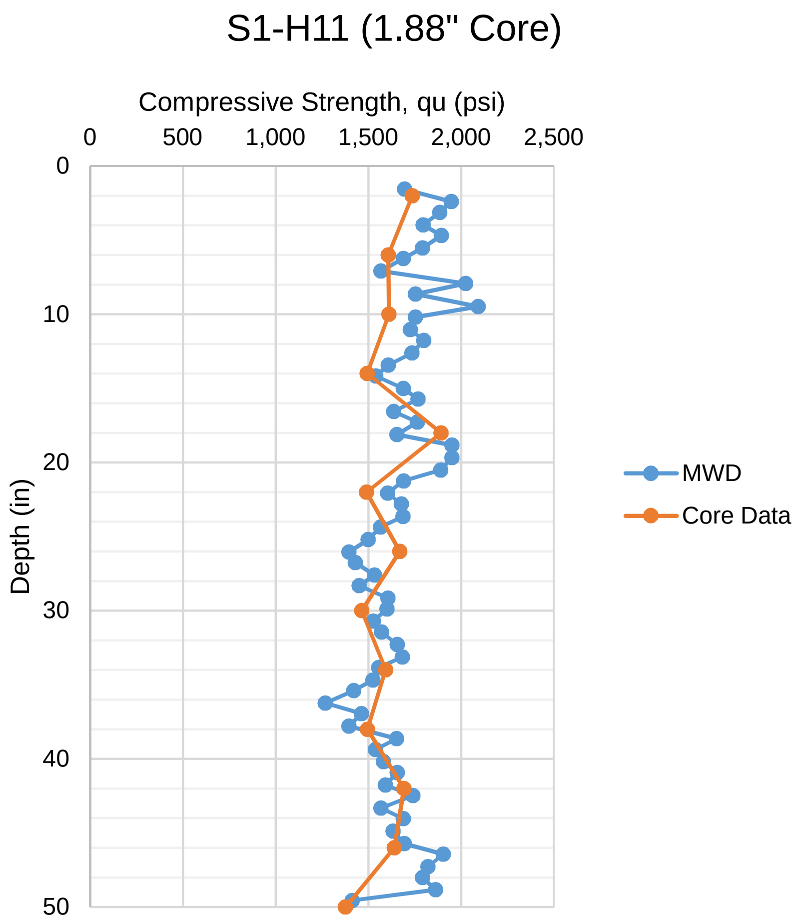
Rock Auger



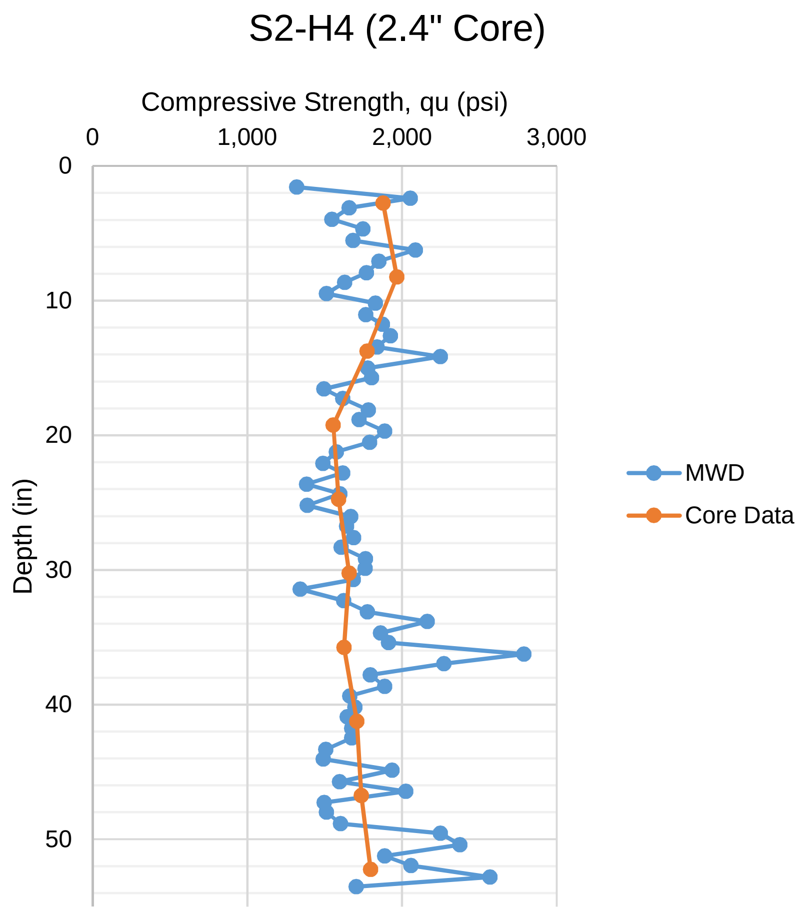
Core Barrel



Strength Comparison With Core Data



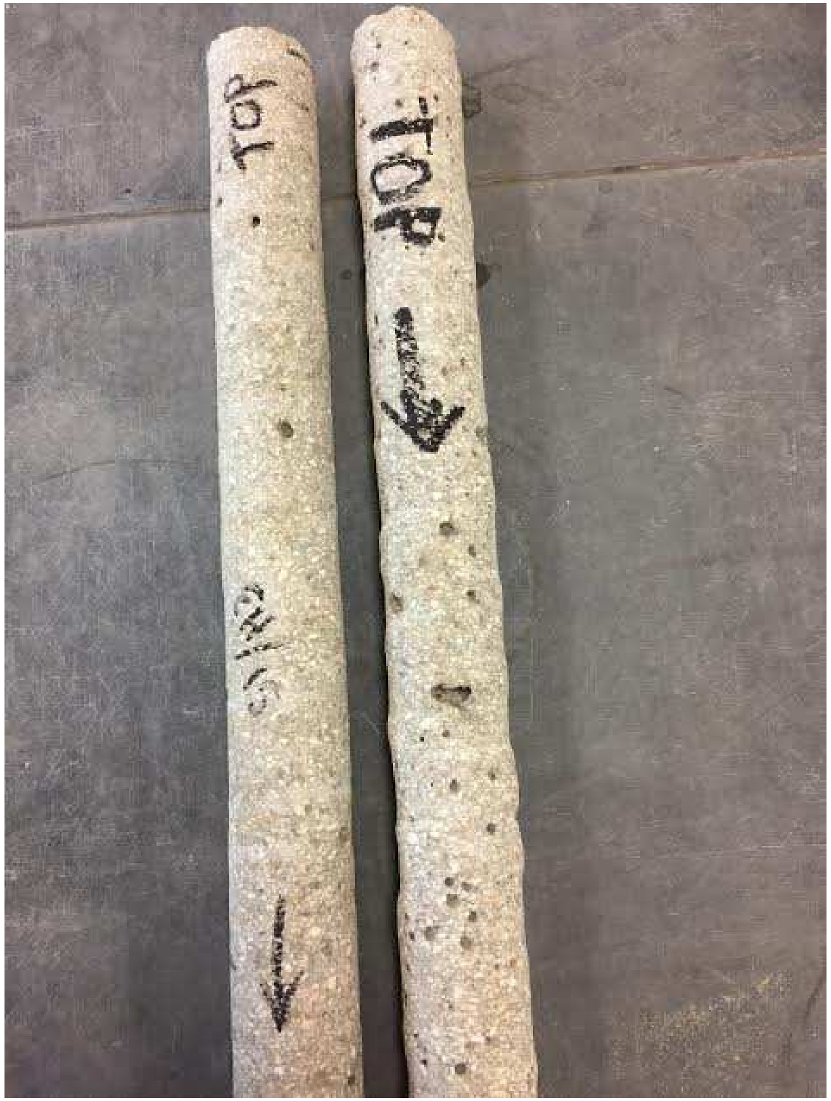
UCS_{MWD} = 1,674 psi
UCS_{Cores} = 1,597 psi



UCS_{MWD} = 1,766 psi
UCS_{Cores} = 1,729 psi

Effects of Flowrate

- Left Core – 4.8 GPM
  - Rotational speed = 75 rpm
- Right Core – 8.1 GPM
  - Rotational speed = 150 rpm
- Right core appears to be fairly weathered
  - Recovered within 2 feet of the left core.
- Core data showed 130 psi decrease in compressive strength (right core)
- Did the increased flow rate and higher rotational speed cause a decrease in core strength?



Full Scale Field Testing at Various Florida Sites (Task 4)

- Four natural occurring sites will be monitored (MWD) during core extraction
- The project manager will choose the designated sites
- During the drilling and coring process, the same drilling parameters will be continuously measured
- The core results, tested at the SMO, will be compared to the MWD results

Field Testing Analysis (Task 5)

- Analysis of the field testing, Tasks 3 and 4, will be conducted similar to BDV31-977-20
- Effects of the variable drilling parameters will be investigated.
- The final analysis will include developing drilling equations for both bit types
- Each equation will provide direct correlation between the specific energy required to excavate the hole and unconfined compressive strength
  - Similar to BDV31-977-20

Tasks 6 and 7

- Task 6
  - Draft final report
  - Closeout meeting
- Task 7
  - Final Report

Project Benefits

- MWD will provide a significant increase in usable data obtained during a standard site investigation at a degree of precision that could not be achieved using any current method
- This will provide a better understanding of spatial variability
- Lead to a reduction in future construction costs as MWD will provide more reliable data to build on
- This research will take the next step in our understanding and delineation of MWD practices for measuring in situ rock strength during drilling

Questions?