Assessing Axial Capacities of Auger Cast Piles from Measuring While Drilling BDV31-977-125

GRIP Meeting

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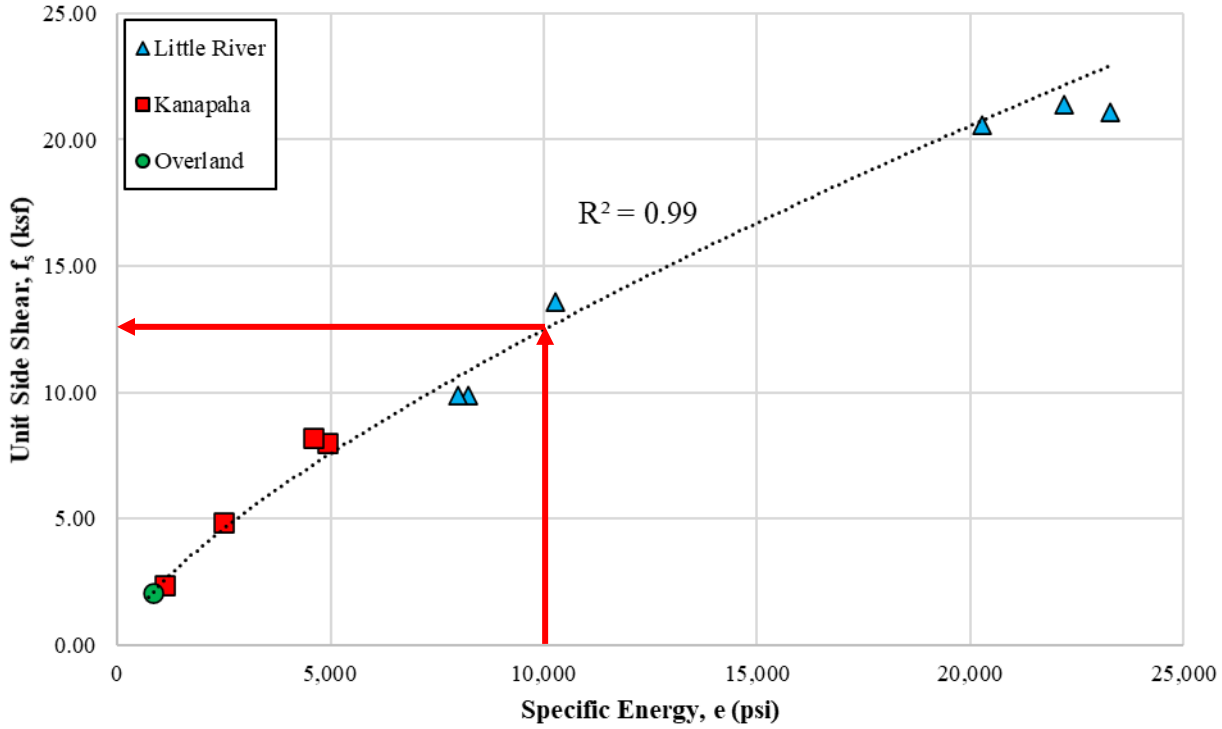
Outline

- Introduction
- Project Background
- Project Objectives
- Tasks and Deliverables
- Current work
- Future work

Introduction

- The FDOT has developed and applied measuring while drilling (MWD) of drilled shafts to assess axial shaft capacity quality control.
  - Little River, Kanapaha, Overland, Selmon Expy, and CR-250
- The process involves monitoring the torque, crowd, penetration rate, and rotational speed in real time to obtain specific energy per 1” of penetration which is then correlated to measured shaft side shear from static load tests, rock strength (qu), and SPT N values
- The developed specific energy-side shear correlation is subsequently used for quality assurance (shaft capacities) during the installation of production shafts
  - “qu vs. e” is established or verified on a site-to-site basis

Specific energy – side shear relationship for drilled shafts using rock augers



Project Background

- Recently, the FDOT has allowed the use of auger cast (ACIP) piles for bridge piers at I-395 in Miami, West Palm-Boca Raton and Delray, as well as other sites
- Like drilled shafts, ACIP piles require QA/QC of their axial capacities during production pile installation
- ACIP Piles employ an auger bit to remove limestone similar to drilled shafts → It is believed MWD could be used for ACIP axial capacity QA/QC
  - Assess specific energy on at least a 1” scale on planned load tests
  - Establish correlation for ACIP Piles
- Established correlations could then be used as a new method of ACIP QA/QC for production piles
- Since a large amount of data is being collected, LRFD phi assessment of different design methods should be revisited and LRFD for standard design as well as MWD approach should be assessed

Project Objectives

- Establish side shear vs. MWD specific energy correlations on a number of sites using ISO compliant MWD on ACIP Pile installations for load tested piles
- Validate MWD correlations and developed QA/QC procedures on production piles at each of the sites
- Based on pile load tests and recovered field cores/laboratory strength testing, reassess LRFD phi factors for Auger Cast Piles in South Florida
- Use the MWD specific energy vs. pile side shear correlations from load tests to establish LRFD phi factors for future south Florida axial pile capacity QA/QC

Tasks and Deliverables

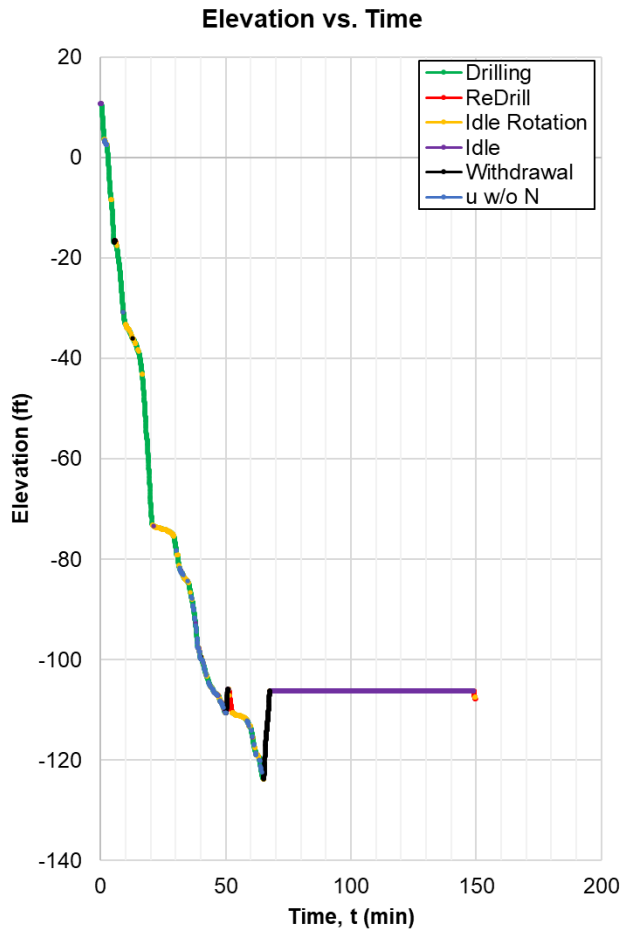
- Deliverable 1 - Establish MWD Data Reduction Criteria and Procedures for ACIP Pile Drill Rigs. (Task 1)
- Deliverable 2 - MWD Specific Energy vs. ACIP Pile Side Shear Relationships (Task 2)
- Deliverable 3 - MWD Correlation Validation for ACIP Production Pile QA/QC (Task 3)
- Deliverable 4 - LRFD Phi Assessment of FDOT Design Methods of ACIP Piles in South Florida (Task 4)
- Deliverable 5 - LRFD Phi Assessment of MWD Specific Energy for ACIP Pile Axial Capacity QA/QC (Task 5)
- Deliverable 6a - Draft Final (Task 6)
- Deliverable 6b - Closeout Meeting (Task 6)
- Deliverable 7 - Final Report (Task 7)

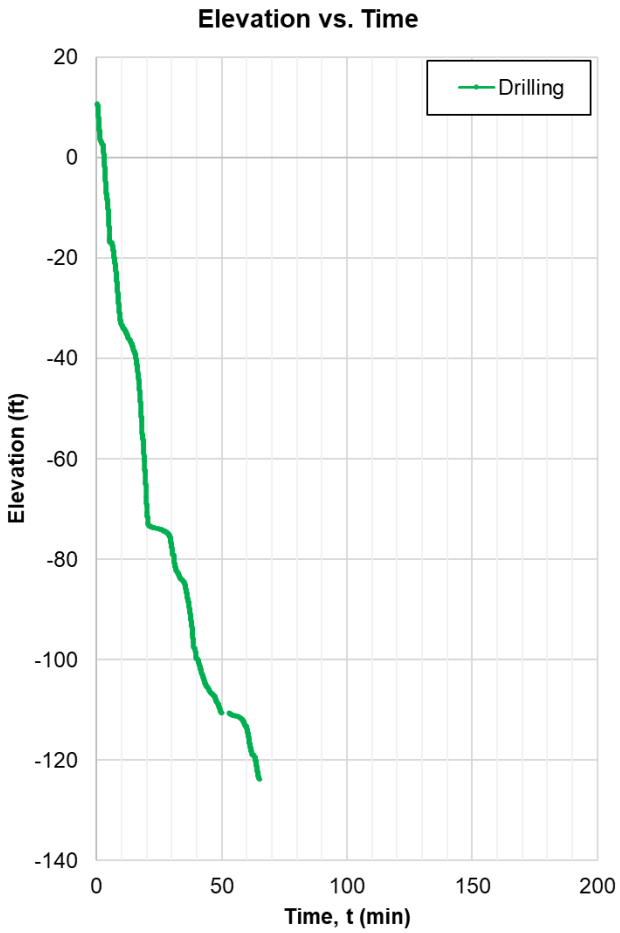
Task 1 – Establish MWD Data Reduction Criteria and Procedures for ACIP Drill Rigs

- The monitoring systems onboard the ACIP pile drill rigs, and the format in which the drilling parameters may be recorded and reported was unknown
  - Time or depth referenced?
- New raw data processing criteria and procedures were developed to produce a workable spreadsheet in which specific energy, rock strength, and shaft capacity may be assessed
- Processing the raw data required a program to be written in which the time-referenced-data is transformed into depth-referenced-data for compatibility with the specific energy equation
  - This increased the complexity of post processing due to the large number of time-referenced raw data points
  - The research effort first focused on properly reducing the raw data in a workable format prior to the assessment of MWD specific energy

Establishing Valid Drilling Data

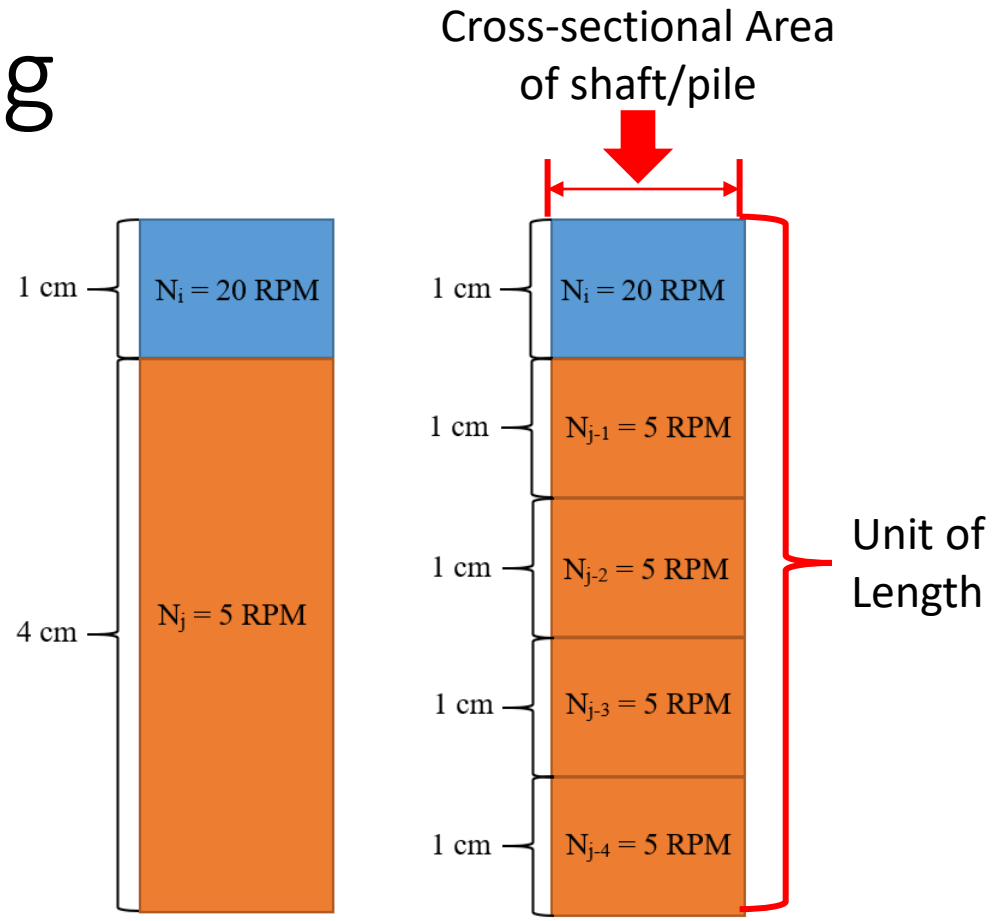
- The drilling operations can include 6 different types of drilling
- **Drilling**
  - Penetration, rotation, torque, and crowd are applied simultaneously
- Withdrawal
  - Auger is being withdrawn (moving upward not downward)
- Re-drill
  - Re-drilling a segment that has been previously drilled (occurs after withdrawal)
- Idle Rotation
  - Rotation is occurring without penetration
- Idle
  - The auger is at rest
- u w/o N
  - Penetration is occurring without rotation (possible void or depth sensor malfunction)
- Only **drilling** data is considered valid and used for specific energy and strength assessment
- Once the valid drilling data points have been established then proper averaging must take place





Proper Averaging

- In rock drilling, specific energy is defined as the energy required to remove/excavate a unit volume of rock
- In order to properly average specific energy over a specified length equal individual lengths of measure must be used
  - Length of shaft segment
  - Volume removed (L_{Shaft} x $A_{X\text{-}sect}$)
- Must use weighted averaging
  - Proportional to the depth increment achieved
  - Cannot be achieved using the time-referenced measurements alone



Incorrect Averaging:

$$N_{avg} = \frac{N_i + N_j}{n} = \frac{20\ RPM + 5\ RPM}{2} = 12.5\ RPM$$

Correct Weighted Averaging:

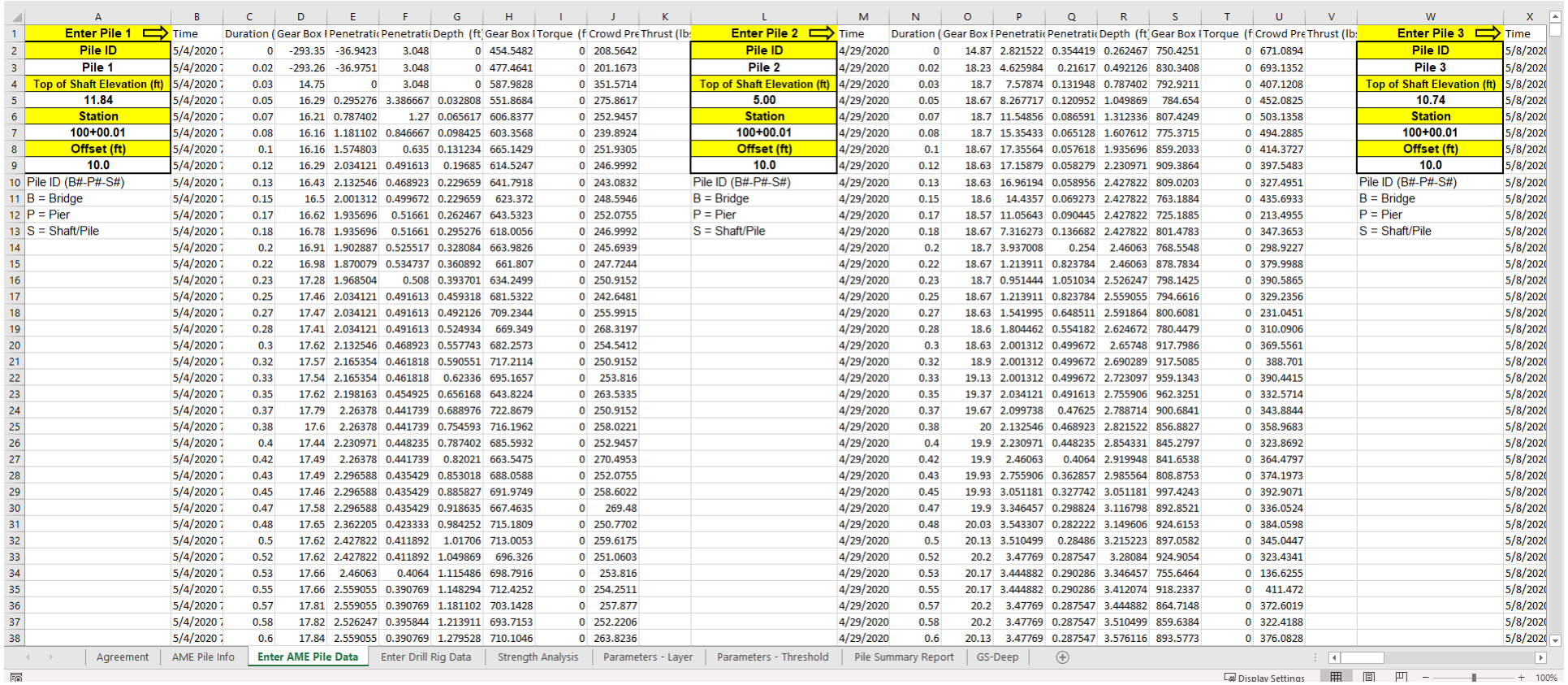
$$N_{avg} = \frac{N_i + N_{j1} + N_{j2} + N_{j3} + N_{j4}}{n} = \frac{20+5+5+5+5}{5} = 8\ RPM$$

ACIP Analysis Program

- Easy to use and navigate
  - Used simple Microsoft Excel format
- Quickly assess layering within the pile
  - Can assess up to 30 layers within the pile at a time
- Quickly assess rock strengths and pile capacity
  - Automatically provides qu, fs, and capacity for the whole pile and within defined layers
- Capable of assessing time-referenced and depth-referenced data
- Quickly adjust analyses based on the drill rig used
- Track drilling operations and efficiency
  - Provides a pile summary report and plots drilling operations vs. time
- Assist in developing a “drilling index” to automatically discern soil from rock
  - Can analyze individual and compound drilling parameters based on layering or specific energy requirements
- Compare multiple piles
  - Can load 10 piles into spreadsheet at a time for quick analyses of a pile group
  - Produces a data page that can be quickly dropped into GeoStat for further analyses

Enter AME Pile Data

Can enter in ACIP MWD data for up to 10 piles



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	Enter Pile 1 ⇨	Time	Duration (	Gear Box I	Penetrati	Penetrati	Depth (ft	Gear Box I	Torque (f	Crowd Pre	Thrust (lb	Enter Pile 2 ⇨	Time	Duration (	Gear Box I	Penetrati	Penetrati	Depth (ft	Gear Box I	Torque (f	Crowd Pre	Thrust (lb	Enter Pile 3 ⇨	Time
2	Pile ID	5/4/2020 7	0	-293.35	-36.9423	3.048	0	454.5482	0	208.5642		Pile ID	4/29/2020	0	14.87	2.821522	0.354419	0.262467	750.4251	0	671.0894		Pile ID	5/8/202(
3	Pile 1	5/4/2020 7	0.02	-293.26	-36.9751	3.048	0	477.4641	0	201.1673		Pile 2	4/29/2020	0.02	18.23	4.625984	0.21617	0.492126	830.3408	0	693.1352		Pile 3	5/8/202(
4	Top of Shaft Elevation (ft)	5/4/2020 7	0.03	14.75	0	3.048	0	587.9828	0	351.5714		Top of Shaft Elevation (ft)	4/29/2020	0.03	18.7	7.57874	0.131948	0.787402	792.9211	0	407.1208		Top of Shaft Elevation (ft)	5/8/202(
5	11.84	5/4/2020 7	0.05	16.29	0.295276	3.386667	0.032808	551.8684	0	275.8617		5.00	4/29/2020	0.05	18.67	8.267717	0.120952	1.049869	784.654	0	452.0825		10.74	5/8/202(
6	Station	5/4/2020 7	0.07	16.21	0.787402	1.27	0.065617	606.8377	0	252.9457		Station	4/29/2020	0.07	18.7	11.54856	0.086591	1.312336	807.4249	0	503.1358		Station	5/8/202(
7	100+00.01	5/4/2020 7	0.08	16.16	1.181102	0.846667	0.098425	603.3568	0	239.8924		100+00.01	4/29/2020	0.08	18.7	15.35433	0.065128	1.607612	775.3715	0	494.2885		100+00.01	5/8/202(
8	Offset (ft)	5/4/2020 7	0.1	16.16	1.574803	0.635	0.131234	665.1429	0	251.9305		Offset (ft)	4/29/2020	0.1	18.67	17.35564	0.057618	1.935696	859.2033	0	414.3727		Offset (ft)	5/8/202(
9	10.0	5/4/2020 7	0.12	16.29	2.034121	0.491613	0.19685	614.5247	0	246.9992		10.0	4/29/2020	0.12	18.63	17.15879	0.058279	2.230971	909.3864	0	397.5483		10.0	5/8/202(
10	Pile ID (B#-P#-S#)	5/4/2020 7	0.13	16.43	2.132546	0.468923	0.229659	641.7918	0	243.0832		Pile ID (B#-P#-S#)	4/29/2020	0.13	18.63	16.96194	0.058956	2.427822	809.0203	0	327.4951		Pile ID (B#-P#-S#)	5/8/202(
11	B = Bridge	5/4/2020 7	0.15	16.5	2.001312	0.499672	0.229659	623.372	0	248.5946		B = Bridge	4/29/2020	0.15	18.6	14.4357	0.069273	2.427822	763.1884	0	435.6933		B = Bridge	5/8/202(
12	P = Pier	5/4/2020 7	0.17	16.62	1.935696	0.51661	0.262467	643.5323	0	252.0755		P = Pier	4/29/2020	0.17	18.57	11.05643	0.090445	2.427822	725.1885	0	213.4955		P = Pier	5/8/202(
13	S = Shaft/Pile	5/4/2020 7	0.18	16.78	1.935696	0.51661	0.295276	618.0056	0	246.9992		S = Shaft/Pile	4/29/2020	0.18	18.67	7.316273	0.136682	2.427822	801.4783	0	347.3653		S = Shaft/Pile	5/8/202(
14		5/4/2020 7	0.2	16.91	1.902887	0.525517	0.328084	663.9826	0	245.6939			4/29/2020	0.2	18.7	3.937008	0.254	2.46063	768.5548	0	298.9227			5/8/202(
15		5/4/2020 7	0.22	16.98	1.870079	0.534737	0.360892	661.807	0	247.7244			4/29/2020	0.22	18.67	1.213911	0.823784	2.46063	878.7834	0	379.9988			5/8/202(
16		5/4/2020 7	0.23	17.28	1.968504	0.508	0.393701	634.2499	0	250.9152			4/29/2020	0.23	18.7	0.951444	1.051034	2.526247	798.1425	0	390.5865			5/8/202(
17		5/4/2020 7	0.25	17.46	2.034121	0.491613	0.459318	681.5322	0	242.6481			4/29/2020	0.25	18.67	1.213911	0.823784	2.559055	794.6616	0	329.2356			5/8/202(
18		5/4/2020 7	0.27	17.47	2.034121	0.491613	0.492126	709.2344	0	255.9915			4/29/2020	0.27	18.63	1.541995	0.648511	2.591864	800.6081	0	231.0451			5/8/202(
19		5/4/2020 7	0.28	17.41	2.034121	0.491613	0.524934	669.349	0	268.3197			4/29/2020	0.28	18.6	1.804462	0.554182	2.624672	780.4479	0	310.0906			5/8/202(
20		5/4/2020 7	0.3	17.62	2.132546	0.468923	0.557743	682.2573	0	254.5412			4/29/2020	0.3	18.63	2.001312	0.499672	2.65748	917.7986	0	369.5561			5/8/202(
21		5/4/2020 7	0.32	17.57	2.165354	0.461818	0.590551	717.2114	0	250.9152			4/29/2020	0.32	18.9	2.001312	0.499672	2.690289	917.5085	0	388.701			5/8/202(
22		5/4/2020 7	0.33	17.54	2.165354	0.461818	0.62336	695.1657	0	253.816			4/29/2020	0.33	19.13	2.001312	0.499672	2.723097	959.1343	0	390.4415			5/8/202(
23		5/4/2020 7	0.35	17.62	2.198163	0.454925	0.656168	643.8224	0	263.5335			4/29/2020	0.35	19.37	2.034121	0.491613	2.755906	962.3251	0	332.5714			5/8/202(
24		5/4/2020 7	0.37	17.79	2.26378	0.441739	0.688976	722.8679	0	250.9152			4/29/2020	0.37	19.67	2.099738	0.47625	2.788714	900.6841	0	343.8844			5/8/202(
25		5/4/2020 7	0.38	17.6	2.26378	0.441739	0.754593	716.1962	0	258.0221			4/29/2020	0.38	20	2.132546	0.468923	2.821522	856.8827	0	358.9683			5/8/202(
26		5/4/2020 7	0.4	17.44	2.230971	0.448235	0.787402	685.5932	0	252.9457			4/29/2020	0.4	19.9	2.230971	0.448235	2.854331	845.2797	0	323.8692			5/8/202(
27		5/4/2020 7	0.42	17.49	2.26378	0.441739	0.82021	663.5475	0	270.4953			4/29/2020	0.42	19.9	2.46063	0.4064	2.919948	841.6538	0	364.4797			5/8/202(
28		5/4/2020 7	0.43	17.49	2.296588	0.435429	0.853018	688.0588	0	252.0755			4/29/2020	0.43	19.93	2.755906	0.362857	2.985564	808.8753	0	374.1973			5/8/202(
29		5/4/2020 7	0.45	17.46	2.296588	0.435429	0.885827	691.9749	0	258.6022			4/29/2020	0.45	19.93	3.051181	0.327742	3.051181	997.4243	0	392.9071			5/8/202(
30		5/4/2020 7	0.47	17.58	2.296588	0.435429	0.918635	667.4635	0	269.48			4/29/2020	0.47	19.9	3.346457	0.298824	3.116798	892.8521	0	336.0524			5/8/202(
31		5/4/2020 7	0.48	17.65	2.362205	0.423333	0.984252	715.1809	0	250.7702			4/29/2020	0.48	20.03	3.543307	0.282222	3.149606	924.6153	0	384.0598			5/8/202(
32		5/4/2020 7	0.5	17.62	2.427822	0.411892	1.01706	713.0053	0	259.6175			4/29/2020	0.5	20.13	3.510499	0.28486	3.215223	897.0582	0	345.0447			5/8/202(
33		5/4/2020 7	0.52	17.62	2.427822	0.411892	1.049869	696.326	0	251.0603			4/29/2020	0.52	20.2	3.47769	0.287547	3.28084	924.9054	0	323.4341			5/8/202(
34		5/4/2020 7	0.53	17.66	2.46063	0.4064	1.115486	698.7916	0	253.816			4/29/2020	0.53	20.17	3.444882	0.290286	3.346457	755.6464	0	136.6255			5/8/202(
35		5/4/2020 7	0.55	17.66	2.559055	0.390769	1.148294	712.4252	0	254.2511			4/29/2020	0.55	20.17	3.444882	0.290286	3.412074	918.2337	0	411.472			5/8/202(
36		5/4/2020 7	0.57	17.81	2.559055	0.390769	1.181102	703.1428	0	257.877			4/29/2020	0.57	20.2	3.47769	0.287547	3.444882	864.7148	0	372.6019			5/8/202(
37		5/4/2020 7	0.58	17.82	2.526247	0.395844	1.213911	693.7153	0	252.2206			4/29/2020	0.58	20.2	3.47769	0.287547	3.510499	859.6384	0	322.4188			5/8/202(
38		5/4/2020 7	0.6	17.84	2.559055	0.390769	1.279528	710.1046	0	263.8236			4/29/2020	0.6	20.13	3.47769	0.287547	3.576116	893.5773	0	376.0828			5/8/202(

Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | Strength Analysis | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

AME Pile Info

- Based on pile selected (discussed later) it will automatically import the data into the Pile Info tab
  - Can scroll through organized raw data for pile selected
- Pile info tab also allows depth referenced data to be dropped into the spreadsheet for analysis

	A	B	C	D	E	F	G	H	I	J
1			Time	Duration (min)	Depth (ft)	Rotational Speed (RPM)	Penetration Rate (ft/min)	Torque Pressure (psi)	Crowd Pressure (psi)	
2	Input		3/25/2020 10:19:59 PM	0.00	0.00	0.0	0.00	132	-355	
3	Engineer		3/25/2020 10:20:00 PM	0.02	0.00	0.0	0.00	129	-369	
4	Michael Rodgers		3/25/2020 10:20:01 PM	0.03	0.00	0.0	0.00	114	-357	
5	Location		3/25/2020 10:20:02 PM	0.05	0.00	0.0	0.00	117	-367	
6	Miami, Florida		3/25/2020 10:20:03 PM	0.07	0.00	0.0	0.00	90	-373	
7	Project		3/25/2020 10:20:04 PM	0.08	0.00	0.0	0.00	127	-372	
8	ACIP MWD		3/25/2020 10:20:05 PM	0.10	0.00	0.0	0.00	134	-368	
9	Drill Bit Diameter (in)		3/25/2020 10:20:06 PM	0.12	0.00	0.0	0.00	116	-352	
10	30.0		3/25/2020 10:20:07 PM	0.13	0.00	0.0	0.00	135	-343	
11			3/25/2020 10:20:08 PM	0.15	0.00	0.0	0.00	123	-338	
12	Do Not Input		3/25/2020 10:20:09 PM	0.17	0.00	0.0	0.00	141	-343	
13	Pile ID		3/25/2020 10:20:10 PM	0.18	0.00	0.0	0.00	115	-355	
14	Sample Data Set		3/25/2020 10:20:11 PM	0.20	0.00	0.0	0.00	129	-368	
15	Top of Pile Elevation (ft)		3/25/2020 10:20:12 PM	0.22	0.00	0.0	0.00	1,681	-364	
16	10.74		3/25/2020 10:20:13 PM	0.23	0.00	0.0	0.00	954	-366	
17	Station		3/25/2020 10:20:14 PM	0.25	0.00	0.0	0.00	1,034	-355	
18	100+00.01		3/25/2020 10:20:15 PM	0.27	0.00	1.2	0.00	1,467	-347	
19	Offset (ft)		3/25/2020 10:20:16 PM	0.28	0.00	12.0	0.00	1,222	-349	
20	10		3/25/2020 10:20:17 PM	0.30	0.00	12.0	0.00	1,286	-358	
21	Pile Length (ft)		3/25/2020 10:20:18 PM	0.32	0.00	15.6	0.00	1,592	-375	
22	134.48		3/25/2020 10:20:19 PM	0.33	0.00	24.0	0.00	1,471	-369	
23	Pile Length (in)		3/25/2020 10:20:20 PM	0.35	0.00	25.2	0.03	1,733	-352	
24	1,613.78		3/25/2020 10:20:21 PM	0.37	0.03	24.0	0.46	1,565	-346	
25	Area of Excavation (ft^2)		3/25/2020 10:20:22 PM	0.38	0.10	28.8	1.84	1,641	-312	
26	4.91		3/25/2020 10:20:23 PM	0.40	0.16	32.4	3.12	1,628	-292	
27	Area of Excavation (in^2)		3/25/2020 10:20:24 PM	0.42	0.20	31.2	3.44	1,760	-260	
28	706.86		3/25/2020 10:20:25 PM	0.43	0.26	33.6	3.54	1,560	-272	
29			3/25/2020 10:20:26 PM	0.45	0.36	32.4	3.87	1,767	-276	
30			3/25/2020 10:20:27 PM	0.47	0.43	31.2	4.23	1,646	-263	
31			3/25/2020 10:20:28 PM	0.48	0.49	34.8	4.53	1,901	-245	

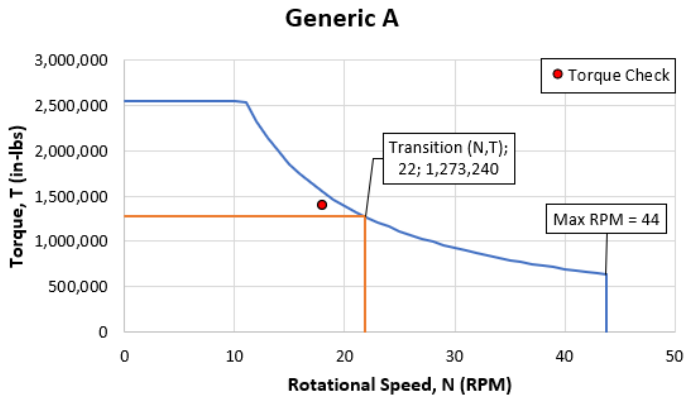
Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | Strength Analysis | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

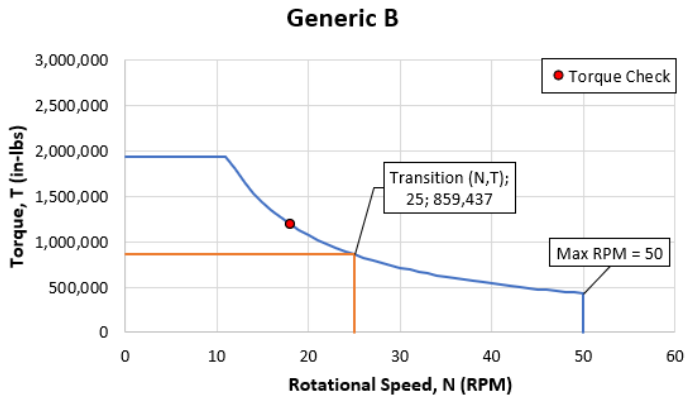
Enter Drill Rig Data

Torque Specifications									
Drill Rig	Rig Type	Maximum Operating Pressure, OP_{Max} (psi)	Hydraulic Motor Displacment, V_g (in^3/rev)		Hydraulic Flow Rate, Q (in^3/min)	Gear Case Reduction		# of Motors	Select Drill Rig (1 or 2)
			Max	Min		Gear 1	Gear 2		
1	Generic A	5,000	10.00	5.00	35,000	160.0	80.0	2	2
2	Generic B	4,500	9.00	4.00	30,000	150.0	75.0	2	

Crowd Specifications		
Specifications	Drill Rig 1	Drill Rig 2
F_{Max} (lbf)	78,683	89,924
OP_{Max} (psi)	5,000	4,500
Baseline Pressure, BP (psi)	0	0
Crowd Conversion Coefficient, K_F (lbf/psi)	15.74	19.98

Drill Rig	Gear	N_{min} (RPM)	N_{max} (RPM)	T_{min} (in-lbs)	T_{max} (in-lbs)	Torque Check - Drill Rig 1		Torque Check - Drill Rig 2	
						N (RPM)	P (psi)	N (RPM)	P (psi)
1	1	11	22	1,273,240	2,546,479				
	2	22	44	636,620	1,273,240	18	4,500	18	4,500
2	1	11	25	859,437	1,933,733	T (in-lbf)	T (ft-lbf)	T (in-lbf)	T (ft-lbf)
	2	22	50	429,718	966,866	1,392,606	116,050.5	1,193,662	99,471.8





Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | Strength Analysis | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

Strength Analysis Tab – Specific Energy

Pile	Pile Segment	ΔZ Increment (cm)
5	8	1
e Threshold (psi)	e Reduction (psi/ft)	MWD Assessment
0	0.0	ISO Class 1

Specific Energy, e (psi) - All Data

Mean	Median	Standard Deviation	Coefficient of Variation	Maximum	Minimum	Count
3,095	2,134	7,286	2.35	280,309	603	3,702

Pile Information

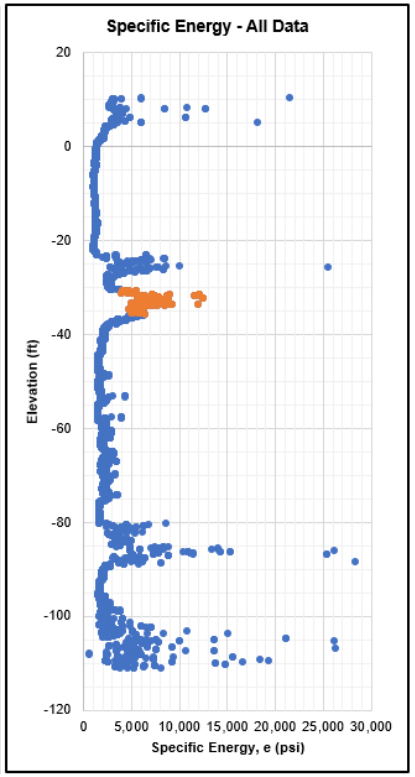
Pile ID	Pile Elevations (ft)		Pile Length (ft)	Layer Elevations (ft)		Drill Bit Diameter (ft)
	Top of Pile	Bottom of Pile		Top	Bottom	
Pile 5	10.29	-111.20	121.49	-30.7	-35.7	2.5

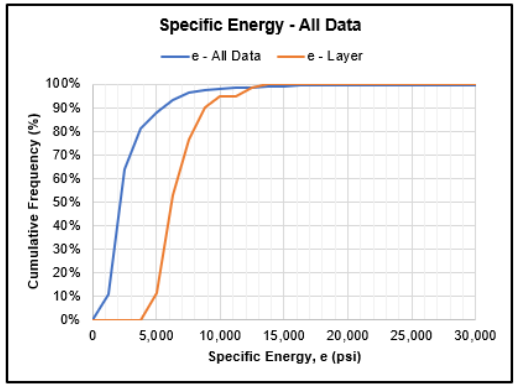
Pile Segments and Elevations

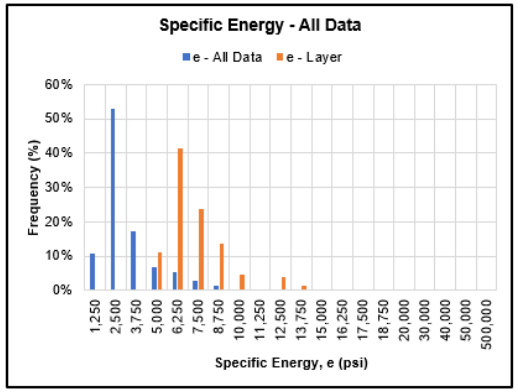
Pile Segment	Elevation 1 (ft)	Elevation 2 (ft)
1	3.60	-0.7
2	-0.7	-5.7
3	-5.70	-10.7
4	-10.7	-15.7
5	-15.70	-20.7
6	-20.7	-25.7
7	-25.70	-30.7
8	**-30.7**	**-35.7**
9	-35.70	-40.7
10	-40.7	-45.7
11	-45.70	-50.7
12	-50.7	-55.7
13	-55.70	-60.7
14	-60.7	-65.7
15	-65.70	-70.7
16	-70.7	-75.7

Specific Energy, e (psi) - All Data - Layer Analysis

Mean	Median	Std. Dev.	CV	Maximum	Minimum	Count
1,812	1,928	355	0.20	2,322	1,329	131
1,267	1,271	64	0.05	1,436	1,104	153
1,128	1,116	38	0.03	1,264	1,072	152
1,263	1,244	55	0.04	1,410	1,184	153
1,271	1,286	118	0.09	1,567	1,108	152
2,996	2,229	2,203	0.74	10,068	1,063	152
3,862	2,903	4,165	1.08	47,387	2,398	153
6,586	**6,033**	**1,784**	**0.27**	**12,529**	**3,947**	**152**
3,213	2,550	1,250	0.39	6,450	2,034	153
1,881	1,951	219	0.12	2,295	1,509	152
1,753	1,652	295	0.17	2,723	1,473	152
1,911	1,790	503	0.26	4,418	1,465	153
1,953	1,857	537	0.27	3,986	1,475	152
2,305	2,242	399	0.17	3,207	1,794	153
2,302	2,244	385	0.17	3,481	1,756	152
2,382	2,323	321	0.13	3,531	1,748	152







Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | Strength Analysis | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

Strength Analysis Tab – Specific Energy

Pile	Pile Segment	ΔZ Increment (cm)
9	8	1
e Threshold (psi)	e Reduction (psi/ft)	MWD Assessment
0	0.0	ISO Class 1

Specific Energy, e (psi) - All Data

Mean	Median	Standard Deviation	Coefficient of Variation	Maximum	Minimum	Count
3,727	2,376	11,105	2.98	488,901	969	3,699

Pile Information

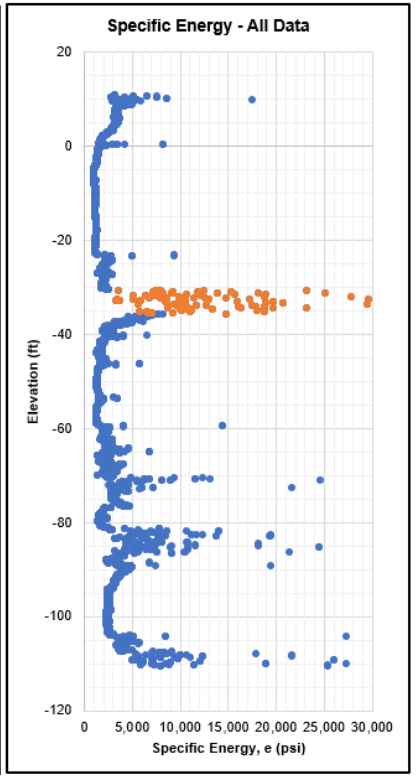
Pile ID	Pile Elevations (ft)		Pile Length (ft)	Layer Elevations (ft)		Drill Bit Diameter (ft)
	Top of Pile	Bottom of Pile		Top	Bottom	
Pile 9	10.86	-110.63	121.49	-30.7	-35.7	2.5

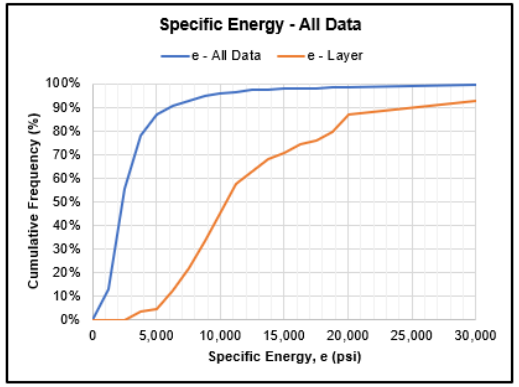
Pile Segments and Elevations

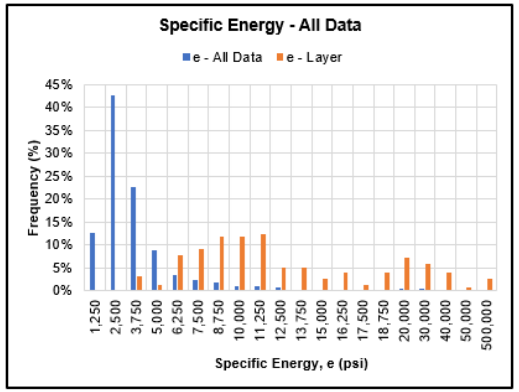
Pile Segment	Elevation 1 (ft)	Elevation 2 (ft)
1	3.6	-0.7
2	-0.7	-5.7
3	-5.7	-10.7
4	-10.7	-15.7
5	-15.7	-20.7
6	-20.7	-25.7
7	-25.7	-30.7
8	**-30.7**	**-35.7**
9	-35.7	-40.7
10	-40.7	-45.7
11	-45.7	-50.7
12	-50.7	-55.7
13	-55.7	-60.7
14	-60.7	-65.7
15	-65.7	-70.7
16	-70.7	-75.7
Soil	-5.0	-20

Specific Energy, e (psi) - All Data - Layer Analysis

Mean	Median	Std. Dev.	CV	Maximum	Minimum	Count
2,210	1,943	916	0.41	8,251	1,497	131
1,276	1,296	146	0.11	1,509	1,011	152
1,131	1,160	96	0.08	1,264	969	153
1,198	1,195	43	0.04	1,305	1,108	152
1,253	1,258	50	0.04	1,347	1,156	152
1,966	1,963	1,167	0.59	9,420	1,114	153
2,063	2,014	327	0.16	3,558	1,455	152
15,797	**10,541**	**23,714**	**1.50**	**238,445**	**3,295**	**153**
3,950	3,461	1,789	0.45	14,874	1,973	152
1,822	1,803	291	0.16	3,409	1,309	152
1,623	1,398	698	0.43	5,769	1,257	153
1,596	1,492	418	0.26	3,427	1,311	152
1,764	1,309	1,575	0.89	14,407	1,236	153
2,523	2,308	837	0.33	6,814	1,685	152
3,357	2,471	9,269	2.76	116,196	1,432	152
5,047	3,551	6,260	1.24	59,907	2,591	153
1,187	1,202	90	0.08	1,347	969	457





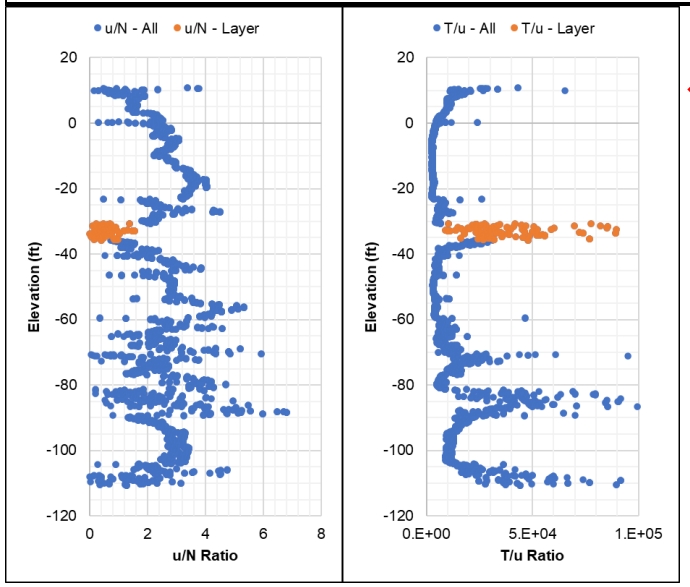


Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | Strength Analysis | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

Parameters – Layer

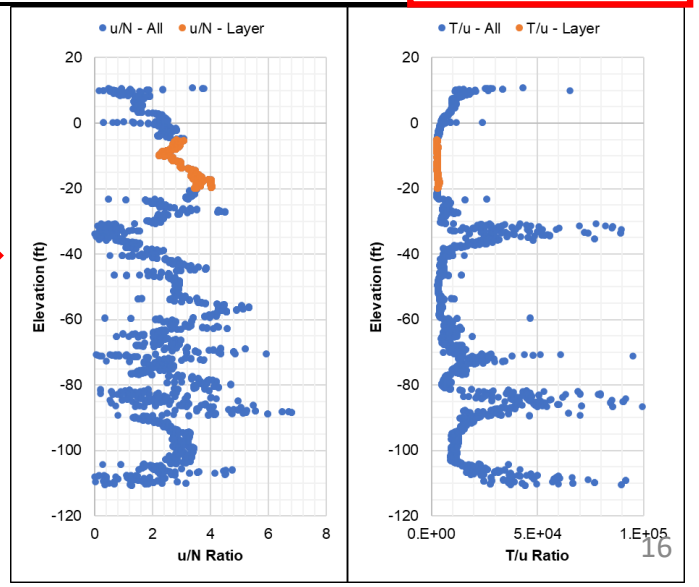
Rock Layer

Summary of Statistics - Layer						
Statistics	N (RPM)	T (in-lbs)	u (in/min)	F (lbf)	Compound u/N	Compound T/u
Mean	37.6	605,640	20.4	25,345	0.56	46,852
Median	38.4	583,913	19.3	23,527	0.49	30,684
Stand. Dev.	5.2	99,246	11.4	9,809	0.32	62,421
CV	0.14	0.16	0.56	0.39	0.58	1.33
Maximum	46.8	878,595	56.7	50,508	1.56	604,163
Minimum	25.2	436,783	0.8	1,380	0.02	9,127
Count	153	153	153	153	153	153



Soil Layer

Summary of Statistics - Layer						
Statistics	N (RPM)	T (in-lbs)	u (in/min)	F (lbf)	Compound u/N	Compound T/u
Mean	45.8	405,382	140.8	21,108	3.10	2,857
Median	46.8	381,140	141.7	20,575	2.96	2,761
Stand. Dev.	3.1	83,881	17.2	2,207	0.50	314
CV	0.07	0.21	0.12	0.10	0.16	0.11
Maximum	50.4	580,784	165.4	26,287	4.05	3,872
Minimum	37.2	299,165	111.4	17,663	2.22	2,415
Count	457	457	457	457	457	457



- Low u/N ratio and high T/u ratio are indicative of rock layering
- High u/N ratio and Low T/u ratio are indicative of soil layering
- This information will be used to build a “drilling index” to distinguish soil from rock automatically – Similar to CPT

Strength Analysis – Specific Energy – Above Threshold

Pile	Pile Segment	ΔZ Increment (cm)
9	8	1
e Threshold (psi)	e Reduction (psi/ft)	MWD Assessment
2,000	0.0	ISO Class 1

Specific Energy, e (psi) - Above Threshold - Entire Pile

Mean	Median	Standard Deviation	Coefficient of Variation	Maximum	Minimum	Count
5,309	3,195	14,204	2.68	488,901	2,002	2,194

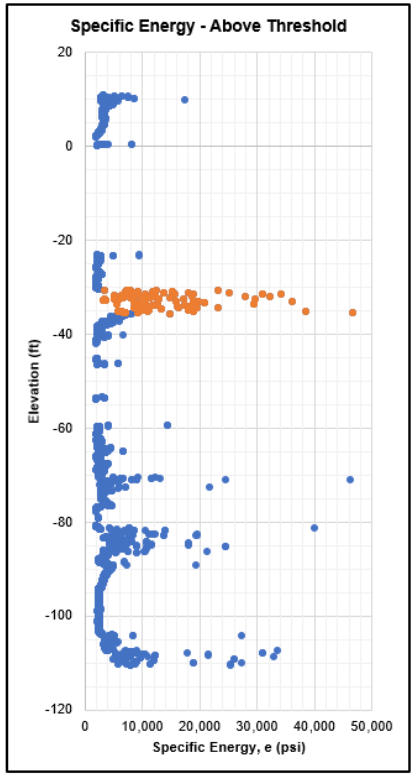
Pile Information

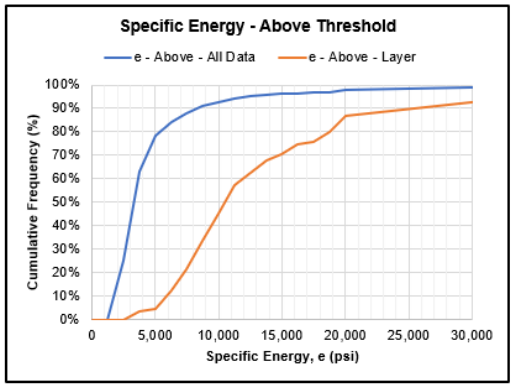
Pile ID	Pile Elevations (ft)		Pile Length (ft)	Layer Elevations (ft)		Drill Bit Diameter (ft)
	Top of Pile	Bottom of Pile		Top	Bottom	
Pile 9	10.86	-110.63	121.49	-30.70	-35.70	2.50

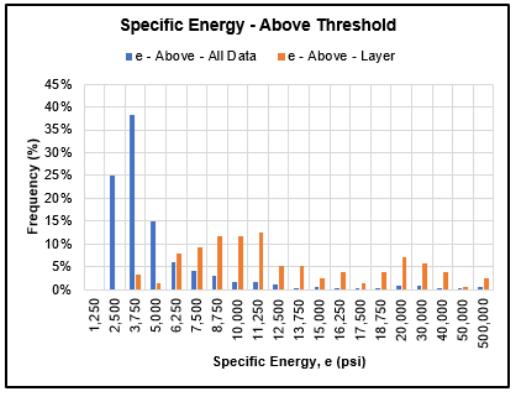
Pile Segments and Elevations

Specific Energy, e (psi) - Above Threshold - Layer Analysis

Pile Segment	Elevation 1 (ft)	Elevation 2 (ft)	Mean	Median	Std. Dev.	CV	Maximum	Minimum	Count
1	3.6	-0.7	2,786	2,527	1,115	0.40	8,251	2,026	59
2	-0.7	-5.7	0	0	0	0.00	0	0	0
3	-5.7	-10.7	0	0	0	0.00	0	0	0
4	-10.7	-15.7	0	0	0	0.00	0	0	0
5	-15.7	-20.7	0	0	0	0.00	0	0	0
6	-20.7	-25.7	2,779	2,458	1,266	0.46	9,420	2,101	72
7	-25.7	-30.7	2,289	2,292	295	0.13	3,558	2,014	77
8	**-30.7**	**-35.7**	**15,797**	**10,541**	**23,714**	**1.50**	**238,445**	**3,295**	**153**
9	-35.7	-40.7	3,990	3,558	1,785	0.45	14,874	2,162	149
10	-40.7	-45.7	2,201	2,133	240	0.11	3,409	2,015	38
11	-45.7	-50.7	3,548	3,388	1,425	0.40	5,769	2,179	12
12	-50.7	-55.7	2,741	3,111	678	0.25	3,427	2,047	13
13	-55.7	-60.7	3,498	2,487	3,078	0.88	14,407	2,192	29
14	-60.7	-65.7	2,689	2,401	862	0.32	6,814	2,013	121
15	-65.7	-70.7	3,717	2,567	10,279	2.77	116,196	2,015	123
16	-70.7	-75.7	5,047	3,551	6,260	1.24	59,907	2,591	153
Soil	-5.0	-20	0	0	0	0.00	0	0	0







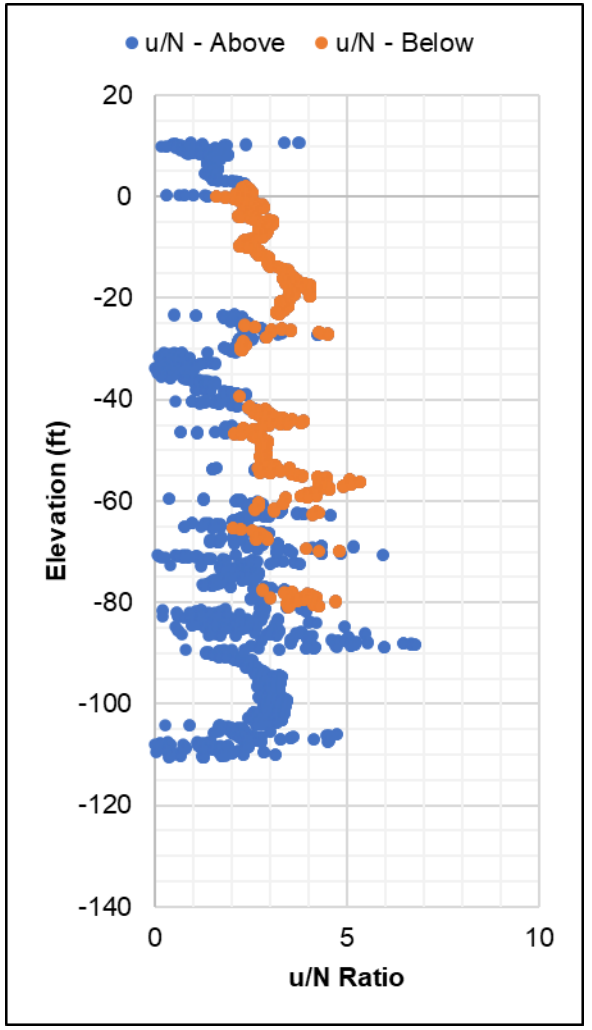
Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | **Strength Analysis** | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

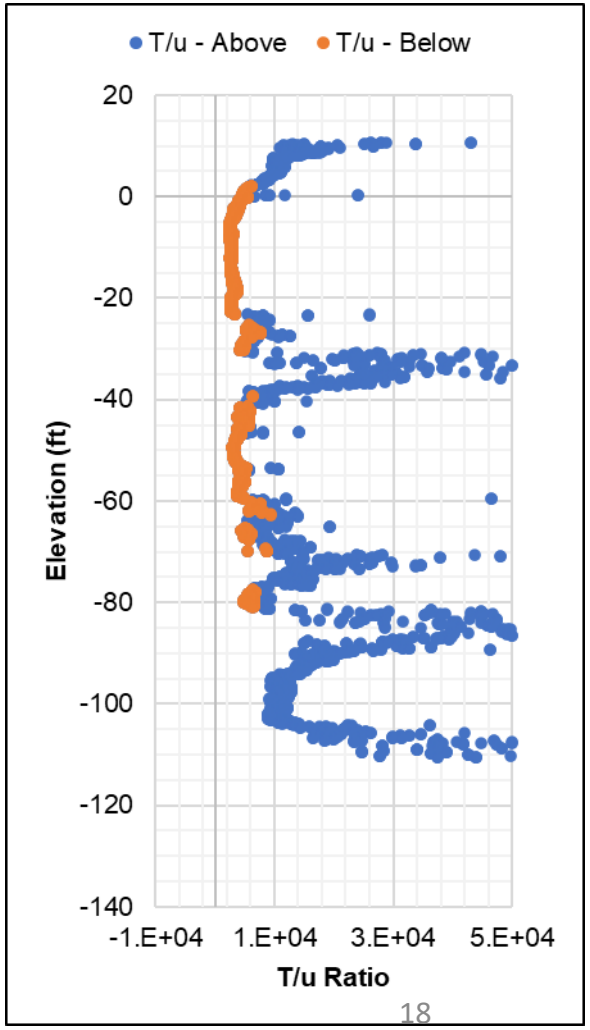
Parameters – Threshold

Summary of Statistics - Above Specific Energy Threshold						
Statistics	N (RPM)	T (in-lbs)	u (in/min)	F (lbf)	Compound u/N	Compound T/u
Mean	29.1	859,247	58.7	9,837	2.18	24,699
Median	28.8	771,657	57.5	8,912	2.14	12,660
Stand. Dev.	8.7	381,776	24.2	13,988	1.05	76,760
CV	0.30	0.44	0.41	1.42	0.48	3.11
Maximum	48.0	2,675,698	110.6	58,724	6.79	2,291,507
Minimum	1.2	293,652	0.4	-27,167	0.02	4,812
Count	2,194	2,194	2,194	2,194	2,194	2,194

Summary of Statistics - Below Specific Energy Threshold						
Statistics	N (RPM)	T (in-lbs)	u (in/min)	F (lbf)	Compound u/N	Compound T/u
Mean	41.5	488,242	127.5	17,561	3.13	3,946
Median	43.2	463,630	126.0	18,928	2.95	3,639
Stand. Dev.	6.1	127,655	22.3	6,576	0.66	1,270
CV	0.15	0.26	0.17	0.37	0.21	0.32
Maximum	50.4	1,060,084	165.4	54,495	5.33	9,308
Minimum	22.8	293,630	63.0	-1,816	1.59	2,415
Count	1,505	1,505	1,505	1,505	1,505	1,505

- This information will be used to build a “drilling index” to distinguish soil from rock automatically – Similar to CPT





Strength Analysis – Unconfined Compressive Strength

Pile	Pile Segment	ΔZ Increment (cm)
9	8	1
e Threshold (psi)	e Reduction (psi/ft)	MWD Assessment
2,000	0.0	ISO Class 1

Pile Segments and Elevations

Pile Segment	Elevation 1 (ft)	Elevation 2 (ft)
1	3.6	-0.7
2	-0.7	-5.7
3	-5.7	-10.7
4	-10.7	-15.7
5	-15.7	-20.7
6	-20.7	-25.7
7	-25.7	-30.7
8	**-30.7**	**-35.7**
9	-35.7	-40.7
10	-40.7	-45.7
11	-45.7	-50.7
12	-50.7	-55.7
13	-55.7	-60.7
14	-60.7	-65.7
15	-65.7	-70.7
16	-70.7	-75.7
Soil	-5.0	-20

Unconfined Compressive Strength, q_u (psi) - Above Threshold - Entire Pile

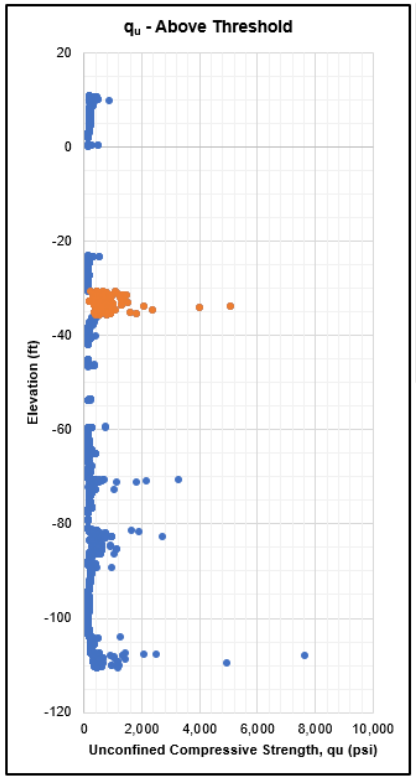
Mean	Median	Standard Deviation	Coefficient of Variation	Maximum	Minimum	Count
295	212	327	1.11	7,632	137	2,194

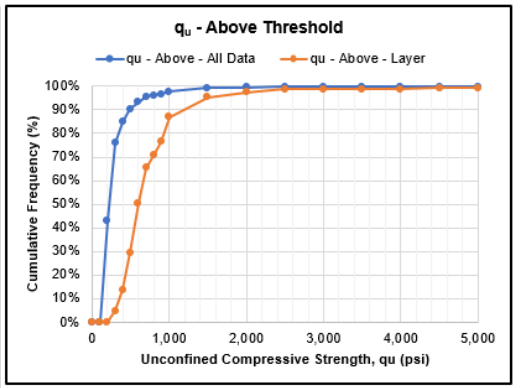
Unconfined Compressive Strength, q_u (psi) - Above Threshold - Layer Analysis

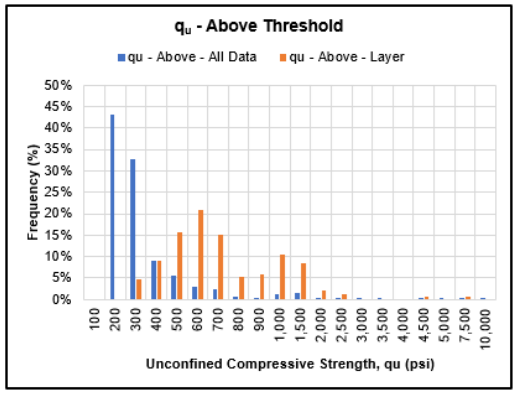
Mean	Median	Std. Dev.	CV	Maximum	Minimum	Count
185	171	63	0.34	488	139	59
0	0	0	0.00	0	0	0
0	0	0	0.00	0	0	0
0	0	0	0.00	0	0	0
0	0	0	0.00	0	0	0
184	166	70	0.38	545	144	72
156	156	19	0.12	234	138	77
739	**598**	**564**	**0.76**	**5,063**	**218**	**153**
255	234	99	0.39	788	148	149
150	146	15	0.10	225	138	38
231	224	83	0.36	359	149	12
183	207	42	0.23	226	140	13
221	168	156	0.71	768	149	29
180	163	51	0.28	415	138	121
211	173	285	1.35	3,286	138	123
299	233	237	0.79	2,150	175	153
0	0	0	0.00	0	0	0

Pile Information

Pile ID	Pile Elevations (ft)		Pile Length (ft)	Layer Elevations (ft)		Drill Bit Diameter (ft)
	Top of Pile	Bottom of Pile		Top	Bottom	
Pile 9	10.86	-110.63	121.49	-30.70	-35.70	2.50







Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | **Strength Analysis** | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

*Uses drilled shaft rock auger equation developed in Rodgers et al. (2018a, b) to estimate qu

Strength Analysis – Side Shear and Shaft Capacity

Pile	Pile Segment	ΔZ Increment (cm)
9	8	1
e Threshold (psi)	e Reduction (psi/ft)	MWD Assessment
2,000	0.0	ISO Class 1

Pile Segments and Elevations

Pile Segment	Elevation 1 (ft)	Elevation 2 (ft)
1	10.9	-0.7
2	-0.7	-5.7
3	-5.7	-10.7
4	-10.7	-15.7
5	-15.7	-20.7
6	-20.7	-25.7
7	-25.7	-30.7
8	**-30.7**	**-35.7**
9	-35.7	-40.7
10	-40.7	-45.7
11	-45.7	-50.7
12	-50.7	-55.7
13	-55.7	-60.7
14	-60.7	-65.7
15	-65.7	-70.7
16	-70.7	-75.7
17	-75.7	-80.7
18	-80.7	-85.7
19	-85.7	-90.7
20	-90.7	-95.7
21	-95.7	-100.7
22	-100.7	-105.7
23	-105.7	-110.7

Side Shear and Shaft Capacity - Above Threshold - Entire Pile

e (psi)	qu (psi)	f_s (ksf)	L_{pile} (ft)	L_{rock} (ft)	P (kips)	*f_s (ksf)
5,309	295	8.3	121.5	72.0	4,719	4.9

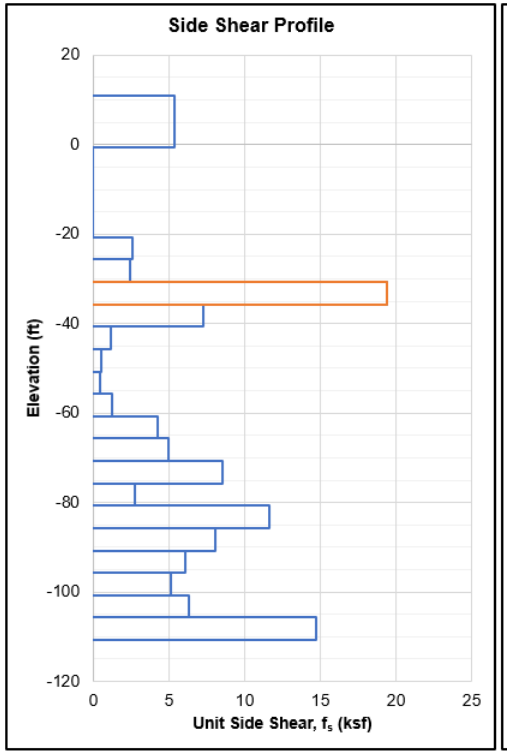
Side Shear and Shaft Capacity - Above Threshold - Layer Analysis

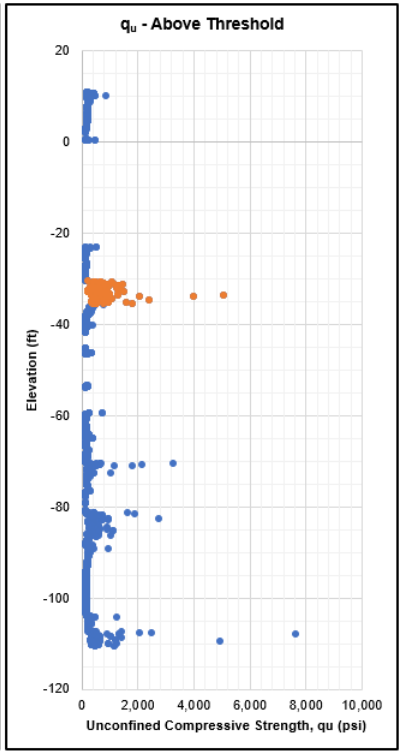
Count	e_{AVG} (psi)	$q_{u\text{-}AVG}$ (psi)	$f_{s\text{-}AVG}$ (ksf)	L_{rock} (ft)	P (kips)	*f_s (ksf)
278	3,555	232	6.8	9.1	488.4	5.4
0	0	0	0.0	0.0	0.0	0.0
0	0	0	0.0	0.0	0.0	0.0
0	0	0	0.0	0.0	0.0	0.0
0	0	0	0.0	0.0	0.0	0.0
72	2,779	184	5.5	2.4	102.6	2.6
77	2,290	156	4.8	2.5	94.3	2.4
153	**15,798**	**739**	**19.4**	**5.0**	**766.2**	**19.4**
149	3,991	256	7.4	4.9	285.6	7.3
38	2,202	150	4.6	1.2	45.0	1.1
12	3,549	231	6.8	0.4	21.0	0.5
13	2,742	183	5.5	0.4	18.5	0.5
29	3,498	221	6.5	1.0	48.3	1.2
121	2,689	180	5.4	4.0	168.7	4.3
123	3,718	211	6.2	4.0	195.4	5.0
153	5,047	299	8.5	5.0	335.9	8.5
71	3,008	199	5.9	2.3	108.7	2.8
145	8,033	444	12.2	4.8	456.3	11.6
152	4,428	279	8.1	5.0	315.6	8.0
152	3,080	205	6.1	5.0	239.0	6.1
153	2,510	170	5.1	5.0	202.9	5.1
152	3,311	215	6.3	5.0	248.4	6.3
151	13,552	560	14.9	5.0	578.1	14.7

*fs = Adjusted side shear based on cumulative length of rock socket

Pile Information

Pile ID	Pile Elevations (ft)		Pile Length (ft)	Layer Elevations (ft)		Drill Bit Diameter (ft)
	Top of Pile	Bottom of Pile		Top	Bottom	
Pile 9	10.86	-110.63	121.49	-30.70	-35.70	2.50





Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | **Strength Analysis** | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

*Uses drilled shaft side shear equation developed in Rodgers et al. (2019) to estimate f_s

Strength Analysis – Side Shear and Shaft Capacity

Pile	Pile Segment	ΔZ Increment (cm)
9	Upper	1
e Threshold (psi)	e Reduction (psi/ft)	MWD Assessment
2,000	0.0	ISO Class 1

Pile Segments and Elevations

Pile Segment	Elevation 1 (ft)	Elevation 2 (ft)
1	10.9	-0.7
2	-0.7	-5.7
3	-5.7	-10.7
4	-10.7	-15.7
5	-15.7	-20.7
6	-20.7	-25.7
7	-25.7	-30.7
8	-30.7	-35.7
9	-35.7	-40.7
10	-40.7	-45.7
11	-45.7	-50.7
12	-50.7	-55.7
13	-55.7	-60.7
14	-60.7	-65.7
15	-65.7	-70.7
16	-70.7	-75.7
17	-75.7	-80.7
18	-80.7	-85.7
19	-85.7	-90.7
20	-90.7	-95.7
21	-95.7	-100.7
22	-100.7	-105.7
23	-105.7	-110.7
Upper	**10.9**	**-70.7**
Lower	-70.7	-110.70

Side Shear and Shaft Capacity - Above Threshold - Entire Pile

e (psi)	qu (psi)	f_s (ksf)	L_{pile} (ft)	L_{rock} (ft)	P (kips)	*f_s (ksf)
5,309	295	8.3	121.5	72.0	4,719	4.9

Side Shear and Shaft Capacity - Above Threshold - Layer Analysis

Count	e_{AVG} (psi)	$q_{u\text{-}AVG}$ (psi)	$f_{s\text{-}AVG}$ (ksf)	L_{rock} (ft)	P (kips)	*f_s (ksf)
278	3,555	232	6.8	9.1	488.4	5.4
0	0	0	0.0	0.0	0.0	0.0
0	0	0	0.0	0.0	0.0	0.0
0	0	0	0.0	0.0	0.0	0.0
0	0	0	0.0	0.0	0.0	0.0
72	2,779	184	5.5	2.4	102.6	2.6
77	2,290	156	4.8	2.5	94.3	2.4
153	15,798	739	19.4	5.0	766.2	19.4
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38	2,202	150	4.6	1.2	45.0	1.1
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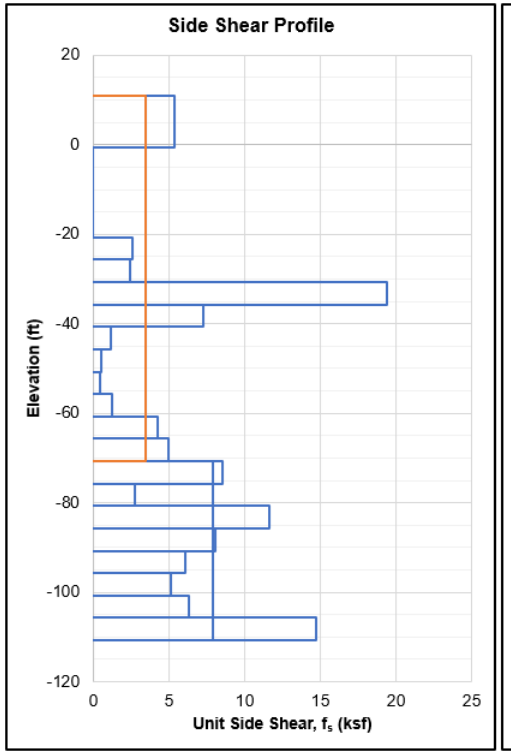
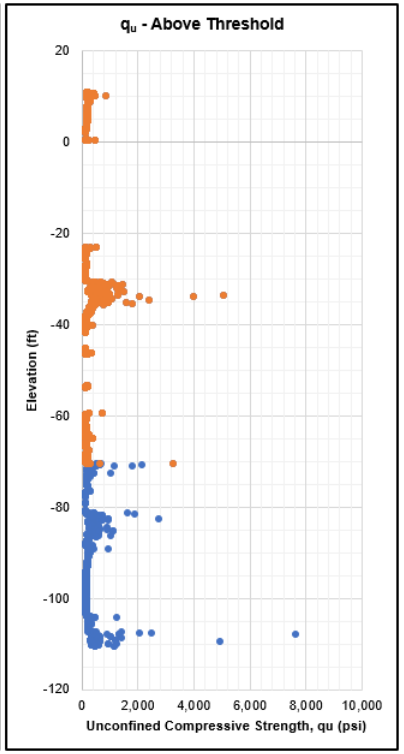
152	3,080	205	6.1	5.0	239.0	6.1
153	2,510	170	5.1	5.0	202.9	5.1
152	3,311	215	6.3	5.0	248.4	6.3
151	13,552	560	14.9	5.0	578.1	14.7
1,065	**5,092**	**287**	**8.1**	**34.9**	**2,234.0**	**3.5**
1,129	5,514	302	8.5	37.0	2,484.9	7.9

*fs = Adjusted side shear based on cumulative length of rock socket

Pile Information

Pile ID	Pile Elevations (ft)		Pile Length (ft)	Layer Elevations (ft)		Drill Bit Diameter (ft)
	Top of Pile	Bottom of Pile		Top	Bottom	
Pile 9	10.86	-110.63	121.49	10.86	-70.70	2.50

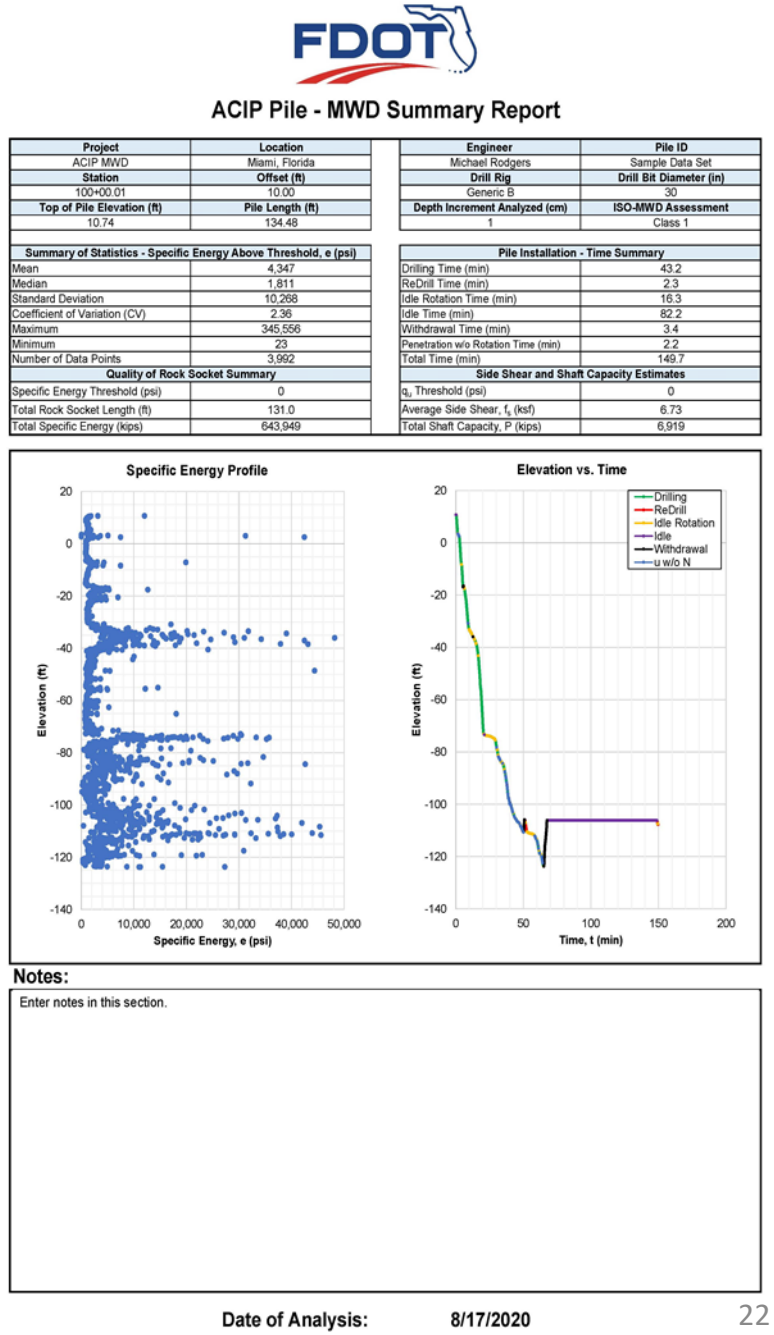




Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | Strength Analysis | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

Pile Summary Report

- Project
- Location
- Engineer
- Pile ID
- Station
- Offset
- Top of Pile Elevation
- Drill Rig Identification
- Pile Diameter
- Pile Length
- Depth Increment Analyzed
- ISO-MWD Assessment Class
- Summary of Statistics for Specific Energy Above the e Threshold
  - Mean, median, standard deviation, CV, maximum, minimum, and number of data points
- Quality of Rock Socket Summary
  - Specific energy threshold value, total rock socket length based on the e Threshold, and the total specific energy based on the e Threshold
- Pile Installation Time Summary
- Side Shear and Shaft Capacity Estimates



FDOT

ACIP Pile - MWD Summary Report

Project	Location	Engineer	Pile ID
ACIP MWD	Miami, Florida	Michael Rodgers	Sample Data Set
Station	**Offset (ft)**	**Drill Rig**	**Drill Bit Diameter (in)**
100+00.01	10.00	Generic B	30
Top of Pile Elevation (ft)	**Pile Length (ft)**	**Depth Increment Analyzed (cm)**	**ISO-MWD Assessment**
10.74	134.48	1	Class 1

Summary of Statistics - Specific Energy Above Threshold, e (psi)	
Mean	4,347
Median	1,811
Standard Deviation	10,268
Coefficient of Variation (CV)	2.36
Maximum	345,556
Minimum	23
Number of Data Points	3,992
Quality of Rock Socket Summary	
Specific Energy Threshold (psi)	0
Total Rock Socket Length (ft)	131.0
Total Specific Energy (kips)	643,949

Pile Installation - Time Summary	
Drilling Time (min)	43.2
ReDrill Time (min)	2.3
Idle Rotation Time (min)	16.3
Idle Time (min)	82.2
Withdrawal Time (min)	3.4
Penetration w/o Rotation Time (min)	2.2
Total Time (min)	149.7
Side Shear and Shaft Capacity Estimates	
q_t Threshold (psi)	0
Average Side Shear, f_s (ksf)	6.73
Total Shaft Capacity, P (kips)	6,919

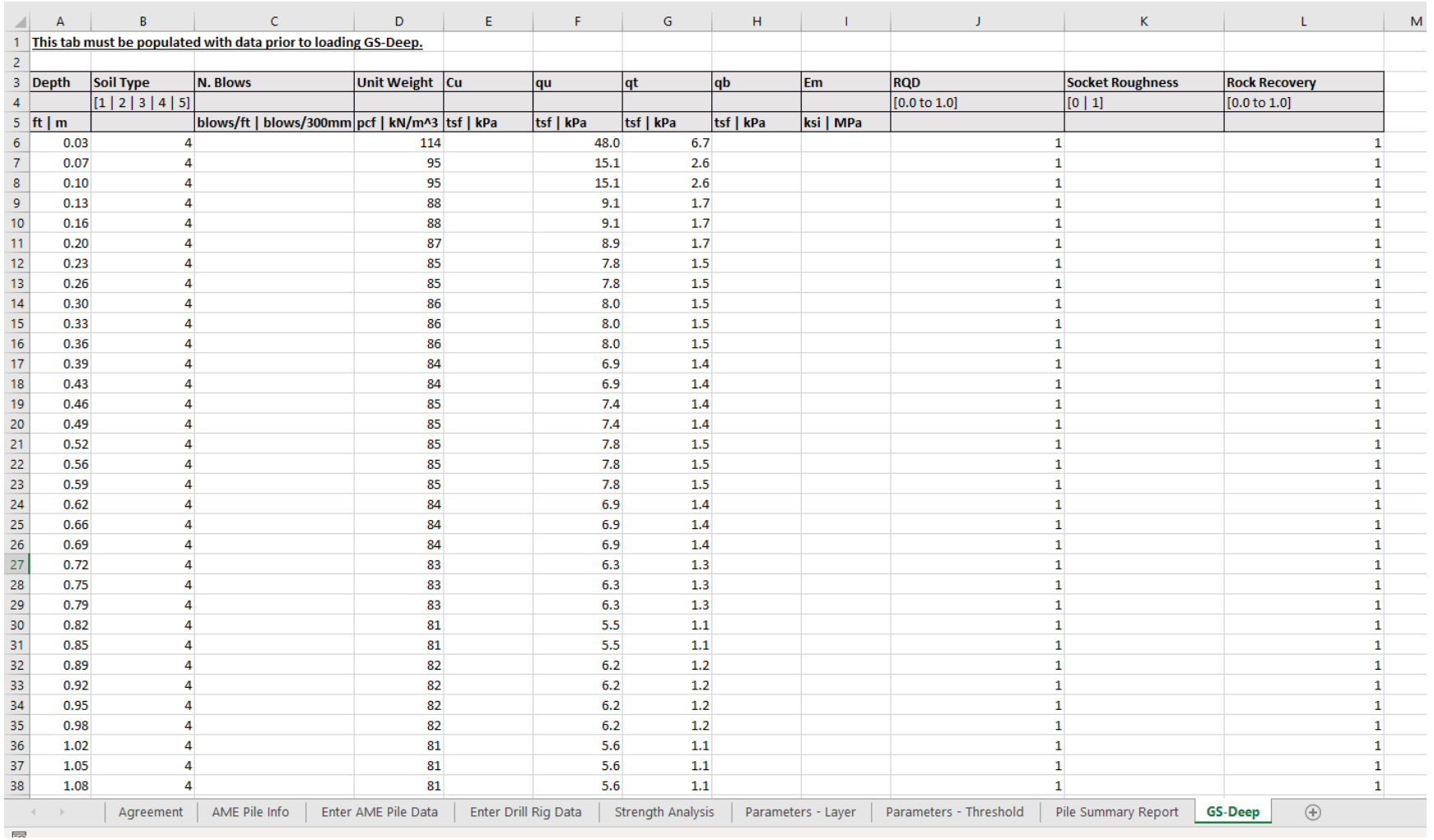
Notes:

Enter notes in this section.

Date of Analysis: 8/17/2020

GeoStat Analyses

- Automatically populates rock strength data for Geostat (GS-Deep) Analyses



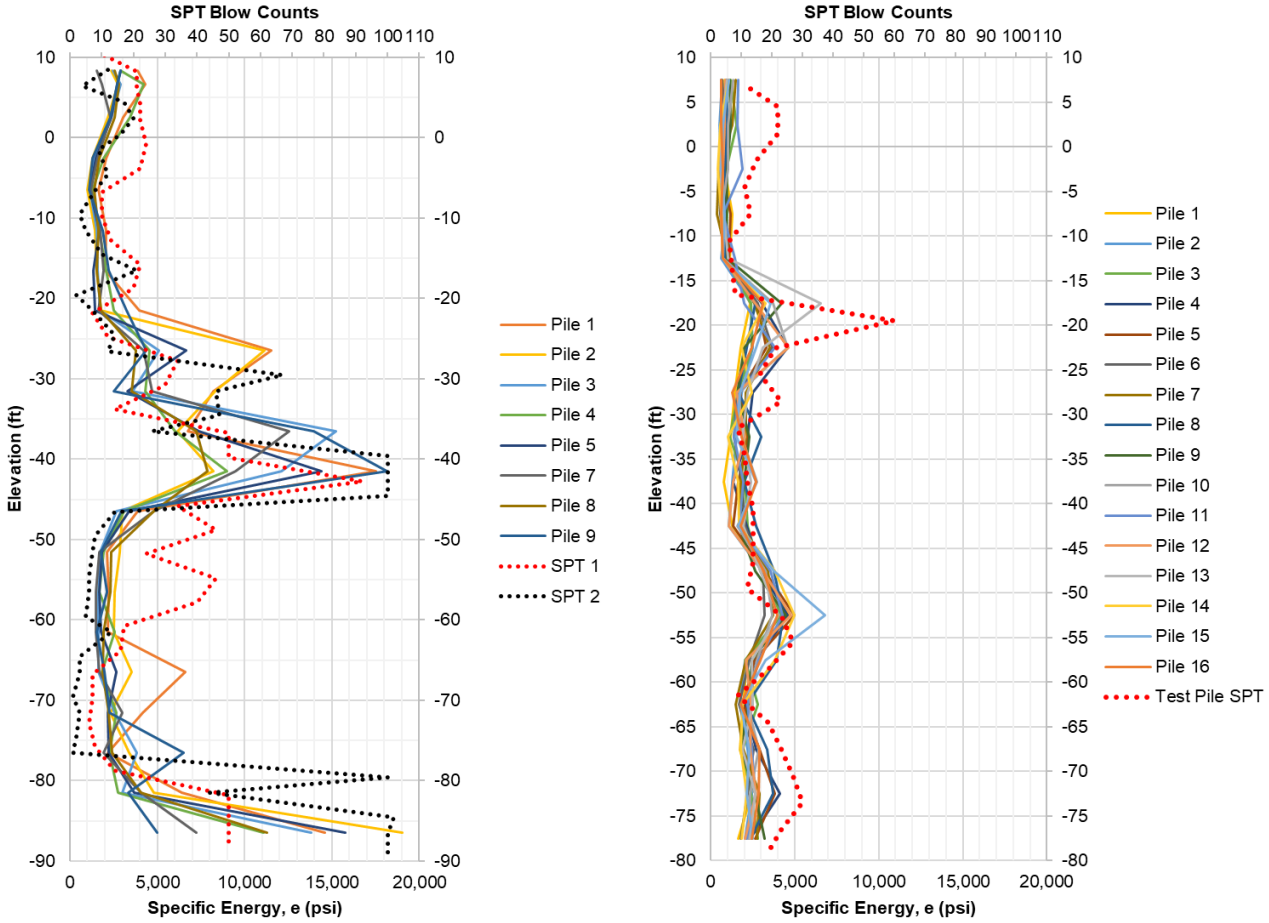
This tab must be populated with data prior to loading GS-Deep.

Depth	Soil Type	N. Blows	Unit Weight	Cu	qu	qt	qb	Em	RQD	Socket Roughness	Rock Recovery
	[1 | 2 | 3 | 4 | 5]								[0.0 to 1.0]	[0 | 1]	[0.0 to 1.0]
ft | m		blows/ft | blows/300mm	pcf | kN/m^3	tsf | kPa	tsf | kPa	tsf | kPa	tsf | kPa	ksi | MPa			
0.03	4		114		48.0	6.7			1		1
0.07	4		95		15.1	2.6			1		1
0.10	4		95		15.1	2.6			1		1
0.13	4		88		9.1	1.7			1		1
0.16	4		88		9.1	1.7			1		1
0.20	4		87		8.9	1.7			1		1
0.23	4		85		7.8	1.5			1		1
0.26	4		85		7.8	1.5			1		1
0.30	4		86		8.0	1.5			1		1
0.33	4		86		8.0	1.5			1		1
0.36	4		86		8.0	1.5			1		1
0.39	4		84		6.9	1.4			1		1
0.43	4		84		6.9	1.4			1		1
0.46	4		85		7.4	1.4			1		1
0.49	4		85		7.4	1.4			1		1
0.52	4		85		7.8	1.5			1		1
0.56	4		85		7.8	1.5			1		1
0.59	4		85		7.8	1.5			1		1
0.62	4		84		6.9	1.4			1		1
0.66	4		84		6.9	1.4			1		1
0.69	4		84		6.9	1.4			1		1
0.72	4		83		6.3	1.3			1		1
0.75	4		83		6.3	1.3			1		1
0.79	4		83		6.3	1.3			1		1
0.82	4		81		5.5	1.1			1		1
0.85	4		81		5.5	1.1			1		1
0.89	4		82		6.2	1.2			1		1
0.92	4		82		6.2	1.2			1		1
0.95	4		82		6.2	1.2			1		1
0.98	4		82		6.2	1.2			1		1
1.02	4		81		5.6	1.1			1		1
1.05	4		81		5.6	1.1			1		1
1.08	4		81		5.6	1.1			1		1

Agreement | AME Pile Info | Enter AME Pile Data | Enter Drill Rig Data | Strength Analysis | Parameters - Layer | Parameters - Threshold | Pile Summary Report | GS-Deep

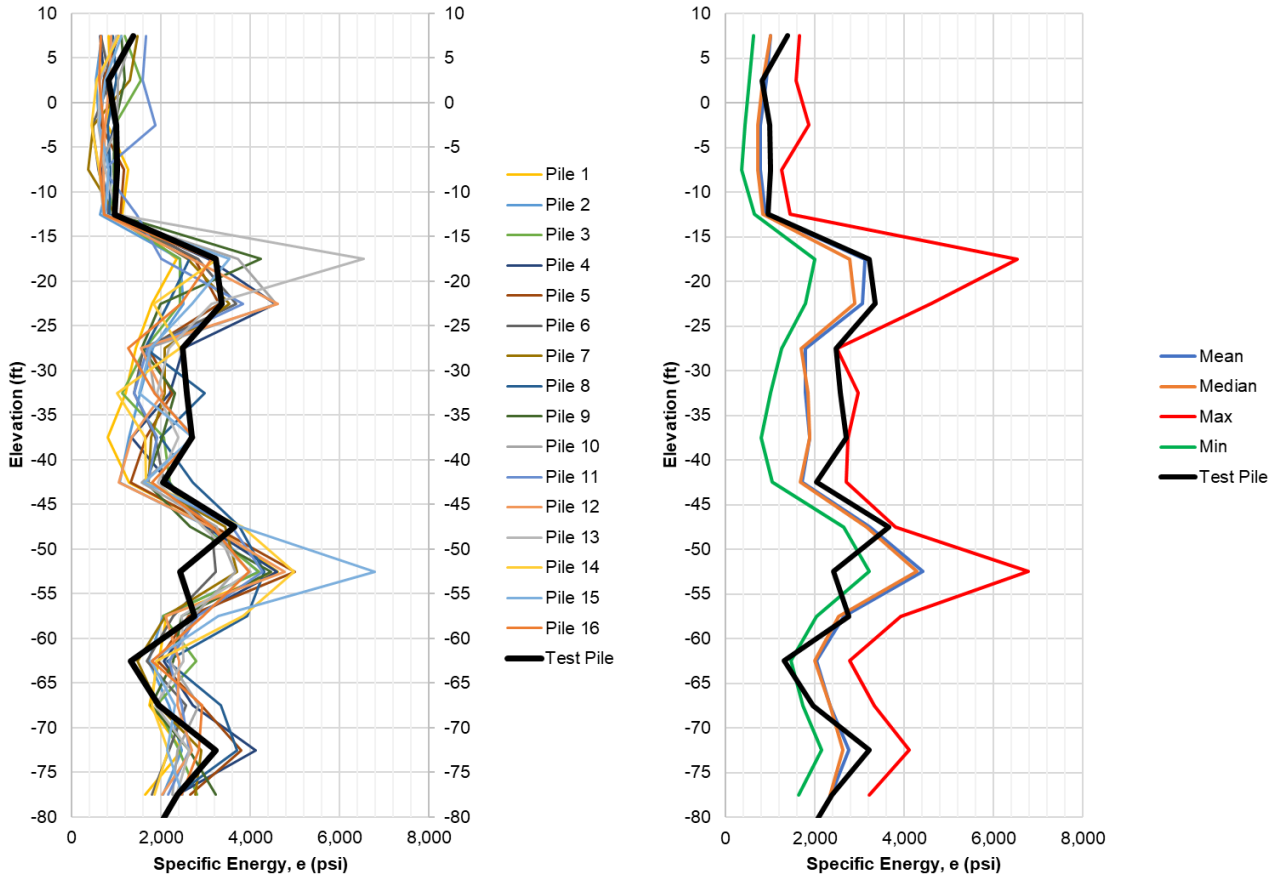
MWD “e” versus SPT “N”

- Compare MWD specific energy to SPT blow count profile
  - Drilling resistance vs. driving resistance
  - SPT blow counts obtained within the ACIP pile group or within proximity (≈50 ft)
- MWD profiles resemble the SPT profiles
  - Indicates MWD layering is correct
- Layering and strengths are different for each pile group
  - Separated by ≈ 2,200 feet



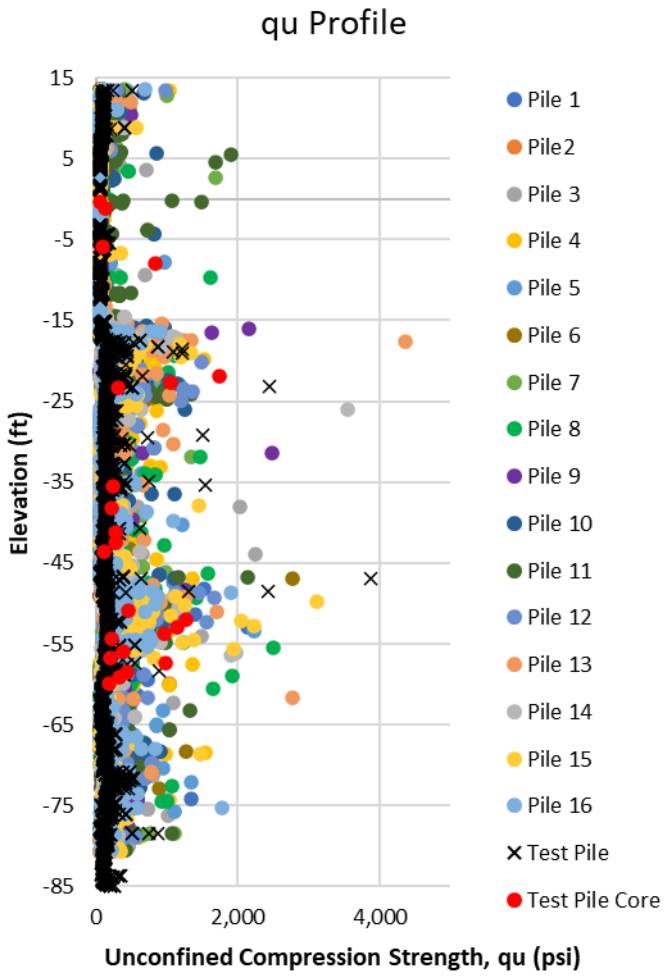
Variability Over Short Distances

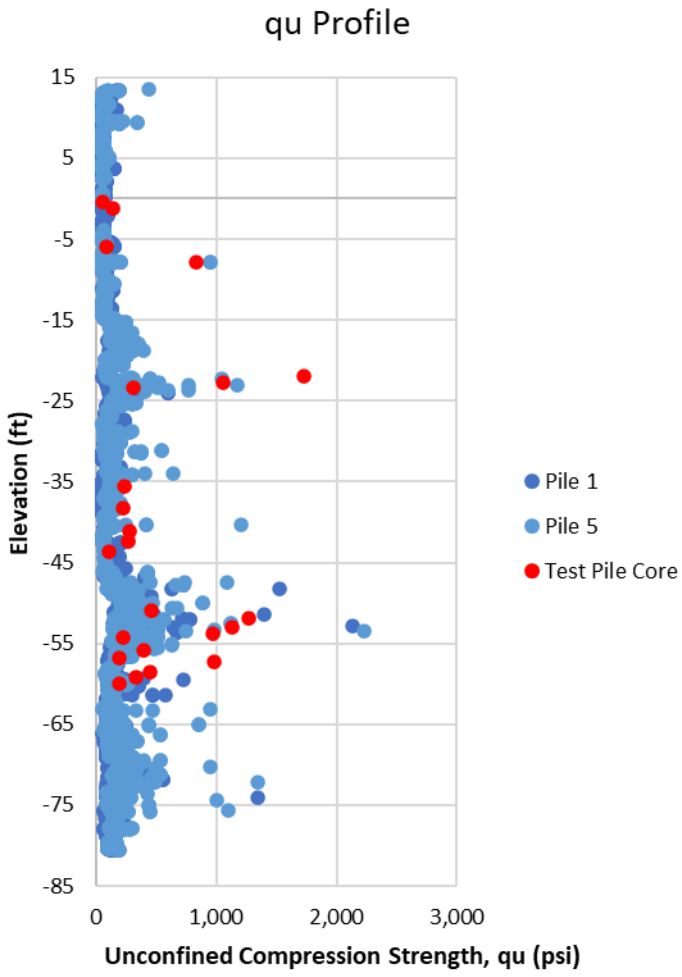
- Compare MWD “e” from pile group to load test MWD within proximity
  - Load test MWD 50’ to 85’ from adjacent pile group
- Variability observed within the 25’ by 25’ pile group
- Load test MWD shows similar layering as pile group MWD but does not always follow the average



MWD versus Core Strengths (qu)

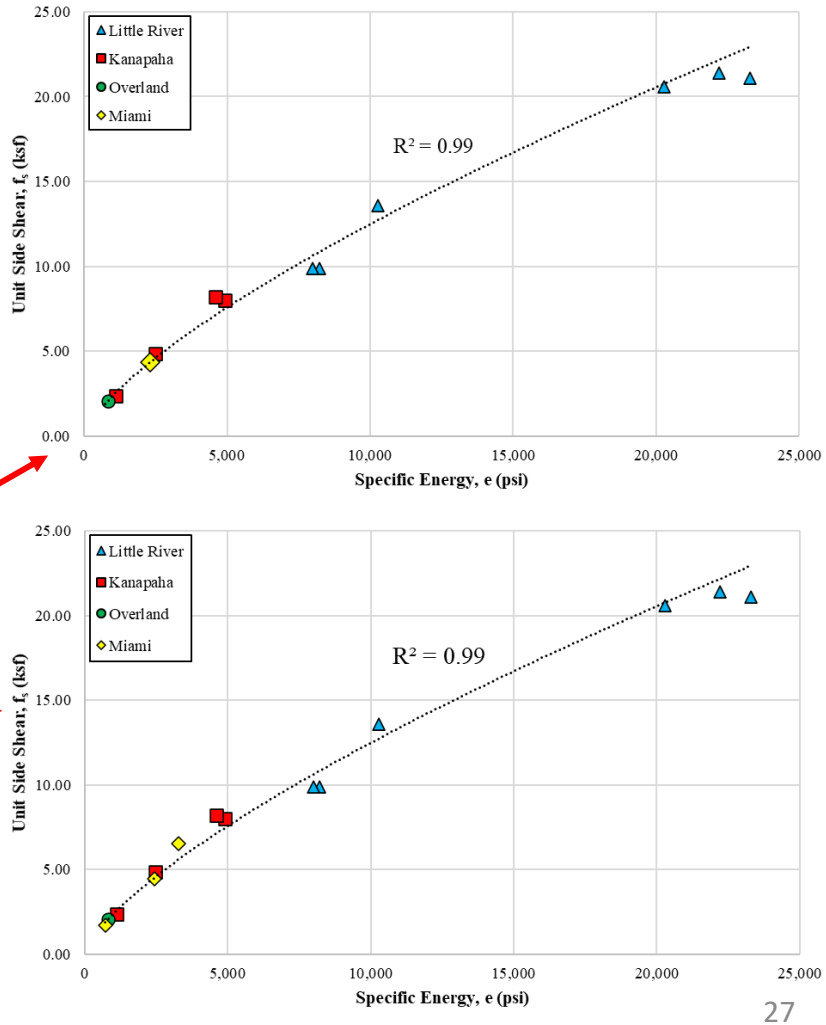
- Rock cores tested in unconfined compression (qu) are compared to MWD qu estimates.
  - ≈ 40,000 MWD qu strength assessments within 25’ by 25’ pile group
  - 23 core samples collected
- Some piles more closely resemble the core strength layering
  - Piles 1 and 5 separated by 7.5’ center to center





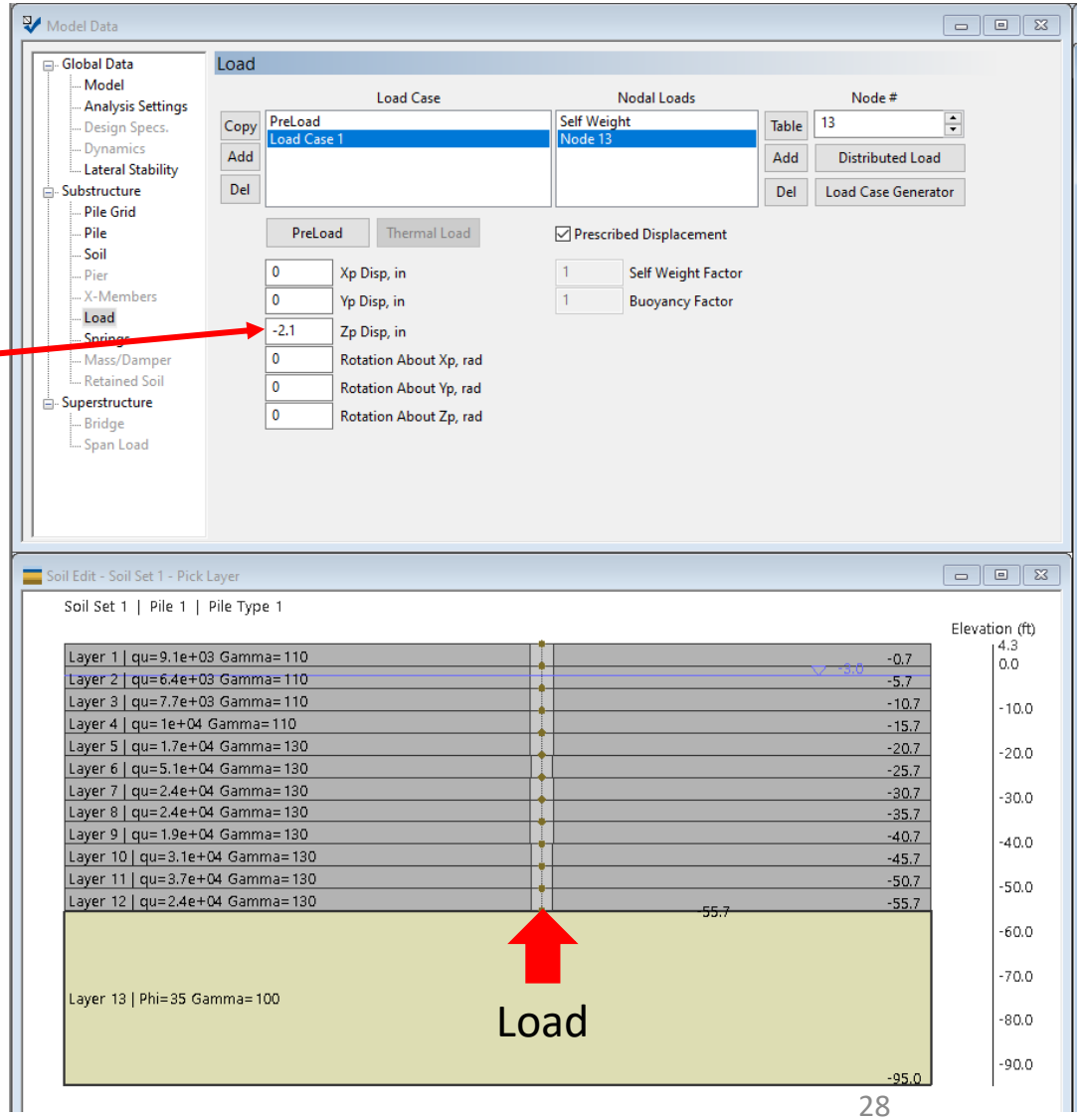
MWD “e” versus Load Test Side Shear

- Recently obtained 1st mobilized load test with MWD data
  - Pile segments above load cell were fully mobilized
    - 2.1” of displacement
  - Allows MWD to be directly compared to load test results to build or verify correlation
- Highly non-linear rigidity observed in pile and reported in load test results
- Difficult to compare smaller layers
  - Need to analyze the load test in larger layers to compensate for the highly non-linear rigidity
- Can compare whole upper pile segment to MWD
- Can break load test results into 3 larger layers w/ similar pile geometries for comparison with MWD
  - Komurka and Robertson (2020)
- Indicates drilled shaft rock auger equation may be valid for ACIP piles that use rock augers
  - Potential state-wide correlation for rock augers



Load Test MultiPier Simulation using MWD Data

- Modeled the Test Pile in MultiPier using MWD strengths (q_u and f_s) for each of the load test layers
  - Loaded the pile tip to simulate a load cell at midspan
  - Modeled pile diameters for each segment based on TIP results
- Used a prescribed displacement of 2.1”
  - Actual load test mobilized 2.1”
- Modeled pile was fully mobilized by a load of P = 2,128 kips
- Load test reported the pile displaced ½ - inch (0.35” to 0.84”@ LTA, 0.14” to 0.62” @ TOP) in 10 minutes while sustaining a load of 2,148 kips → Likely mobilized entire pile
  - P = 2,253 kips → 2.1” of displacement
  - 1.3” of displacement in 10 min under final load
- Supports the use of the drilled shaft rock auger equation for ACIP piles in rock



Remaining Tasks

- Continue to establish the MWD specific energy vs. ACIP pile side shear relationship
- Validate the MWD correlation for ACIP production pile QA/QC
- LRFD phi assessment of FDOT design methods of ACIP piles in South Florida
- LRFD phi assessment of MWD specific energy for ACIP pile axial capacity QA/QC
- Draft Final
- Closeout Meeting
- Final Report

Questions?

- Komurka V. and Robertson S. 2020. Results and lessons learned from converting strain to internal force in instrumented static loading tests using the incremental rigidity method. ASCE Geo-Congress, GSP 315.
- Rodgers M., McVay M., Ferraro C., Horhota D., Tibbetts C., Crawford S. 2018a. Measuring Rock Strength While Drilling Shafts Socketed Into Florida Limestone. ASCE Journal of Geotechnical and Geoenvironmental Engineering, 144(3). doi:10.1061/(ASCE)GT.1943-5606.0001847.
- Rodgers M., McVay M., Horhota D., Hernando J. 2018b. Assessment of Rock Strength from Measuring While Drilling Shafts in Florida Limestone. Canadian Geotechnical Journal, 55(8): 1154-1167. doi:10.1139/cgj-2017-0321.
- Rodgers M., McVay M., Horhota D., Sinnreich J., Hernando J. 2019. Assessment of Shear Strength from Measuring While Drilling Shafts in Florida Limestone. Canadian Geotechnical Journal. doi:10.1139/cgj-2017-0629.
- Teale, R. 1965. The concept of specific energy in rock drilling. International Journal of Rock Mechanics and Mining Science, 2(1), 57–73.