Civil & Coastal Engineering

Evaluation of Static Resistance of Deep Foundation

FDOT Contract No.: BDV31-977-05

Project Managers:

Rodrigo Herrera, PE

Principal Investigator:

Mike McVay, PhD (Phase I)
Jae H. Chung, PhD (Phase II)

Primary Researchers:

John Schwartz III, PhD student
Lin Huang, MS student

GATOR Engineering

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Project Overview
Scope & Supporting Tasks

Civil & Coastal Engineering

Phase I

Task 1.1 to 1.4

- Data Collection, Data Analysis, and Development of Improved Predictions of Driven Piles (H, Pipe, and PCP) and Drilled Shafts with Casing Embedded in Limestone
- Upload Collected Data to FDOT/UF Geotechnical Database (In Progress)

Phase II

Task 2.1 to 2.5

- Implement New Equations in FB-Deep
- Release New Version of FB-Deep

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Project Overview
Scope & Supporting Tasks

Civil & Coastal Engineering

Phase I

Task 1.1: Collect Data form DOTs, Consultants, & Contractors (Completed)

- Driven Pile Data
  - H, PCPs in Limestone, Steel Pipe, & Concrete Cylinder
  - Geotechnical & Foundation Certification Reports
  - In Situ (SPT, Lab Test Data, etc.)
  - Dynamic Load Test (PDA & CAPWAP)
- Drilled Shafts with Steel Casing in Florida Limestone (Task 1.4)
  - Geotechnical & Foundation Certification Reports
  - In Situ (SPT, Lab Test Data, etc.)
  - Load Test (Static & Statnamic)

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Project Overview
Scope & Supporting Tasks

Civil & Coastal Engineering

Phase I

Task 1.2: Evaluate Pile Side Resistance & End Bearing
(Steel H Piles Completed; PCPs Ongoing)

- Recorded SPT Blow Count & Estimated/Measured Pile Capacity (Dynamic Testing -CAPWAP)
- Develop Relationship between N Values vs. Side & Tip Resistance for All Soil Types
- Develop Method to Delineate between Weathered and Competent Limestone (Ongoing)
- Develop Relationship between N Values vs. Side &Tip Resistance for both Weathered and Competent Limestone

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Project Overview
Scope & Supporting Tasks

Phase I

Task 1.3: Evaluate Pile Side Resistance & End Bearing of Steel Pipe Piles & Concrete Cylinder Piles (In Progress)

- Recorded SPT Blow Count & Estimated/Measured Pile Capacity (Dynamic Load Test)
- Investigate Different Methods of Evaluating Total Side Resistance (IFR & API)
- Develop Relationship between N Value for Open & Closed Ended Piles in All Soil Types
  - Unit Side Resistance
  - Unit End Bearing

Phase I
Task 1.1: Data Collection

Driven Piles

Contacted DOTs, Consultants, & Contractors

- Florida
- Other States (Louisiana, Texas, California, etc.)

Open Ended Pipe Piles & Concrete Cylinder Piles

- Published Papers
- FDOT/FHWA Deep Foundation Load Test Database (DFLTD)

Drilled Shaft

Existing Database

- FDOT

Phase I

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Task 1.1: Data Collection - Steel H Piles

Florida DOTs, Consultants, & Contractors

Site Information		Insitu Information		Pile Information			
Project Number (Financial)	Project Site	# of Soil Borings	Predominant Soil Type	Dimensions (in)	Length (ft)	# of Piles with CAPWAP	# of BOR CAPWAP Analyses
208466-2-52-01	SR 51 from Taylor County Line to Dixie County Line	66	Sand & Rock	14 x 89	60 - 120	3	1
221754-1-52-01	CR 146 over Aucilla River	9	Sand, Clay & Rock	14 x 117	150 - 220	5	0
422796-1-52-01 & 422796-2-52-01	Widening I 95 (SR 9) over Hallandale Beach Boulevard Bridge	5	Sand & Rock	18 x 135	90 - 116	8	5
	Widening I 95 (SR 9) over Hollywood Boulevard (SR 820)	3	Sand & Rock	18 x 135	90 - 115	11	3
	Widening I 95 (SR 9) over Stirling Road (SR 848)	3	Sand & Rock	18 x 135	110 - 168	5	4
	Widening I 95 (SR 9) over Pembroke Road Bridge	3	Sand & Rock	19 x 135	85	9	6
403984-1-52-01	Eller Drive Overpass (SR 862)	29	Sand & Rock	14 x 73	90 - 140	3	0
242484-2-52-01	I-4 (SR 408)/SR 408 interchange (Widening at Church Street Viaduct; Phase 1)	29	Sand & Clay	14 x 89 & 12 x 53	90 - 140	37	5
	I-4 (SR 408)/SR 408 interchange (Widening over Robinson Street; Phase 2)	1	Sand	14 x 89	100 - 150	14	1
	I-4 (SR 408)/SR 408 interchange (Widening over South Street; Phase 3)	2	Sand & Clay	12 x 53	150	3	0
	Ramp E (Phase 4)	3	Sand & Clay	14 x 89	150	3	0
	Ramp F2 (Phase 5)	5	Sand	14 x 89	105 - 135	3	0
	Ramps D & D1 (Phase 6)	20	Sand & Clay	12 x 53	90 - 115	18	1
	Anderson Street Overpass & Ramp F1 (Phase 7)	7	Sand & Clay	14 x 89	---	4	1
	Ramp C (Phase 8)	12	Sand	14 x 89	---	12	0
238429-3-52-01	US 27 (SR 50) Interchange at SR 50	7	Sand	14 x 73	99 - 120	33	18
	Total # of Soil Borings	**204**		**Total # of CAPWAP Analyses**		**171**	**45**

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Phase I

Task 1.1: Data Collection - PCPs

Florida DOTs, Consultants, & Contractors

Site Information		Insitu Information		Pile Information		
Project Number (Financial)	Project Site	# of Soil Borings	Predominant Soil Type	Dimensions (in)	Length (ft)	# of Piles with CAPWAP
242484-2-52-01	I-4/SR 408	58	Sand	18 & 24	90 - 107	112
210448-2-52-01	San Sebastian Bridge	11	Sand & Clay	24	38 - 111	111
211449-1-52-01	CR 229 over South Prong of St. Mary's River	2	Sand & Clay	18	47 - 90	14
209293-2-52-01, 209294-1-52-01, 209294-9-52-01	SR 98	121	Sand & Some Rock	24	45 - 119	183
208166-1-52-01	Plantation Oaks Boulevard over SR 23	50	Sand & Rock	18	55 - 100	11
208466-2-52-01	SR 51	6	Clay & Rock	24	73 - 99	5
420809-3-52-01	I-595	234	Sand & Rock	18 & 24	30 - 115	170
213304-3-52-01	I-95 Overland Bridge Replacement	133	Sand & Rock	24	22 - 66	5
406813-6-52-01	CR 245 over Olustee Creek	10	Sand & Rock	24	61 - 69	7
210687-3-52-01	SR 200 North of Callahan	11	Clay & Rock	24	36 - 66	25
429551-1-52-01	SR 200 South of Callahan	31	Sand & Rock	24	46 - 111	33
422796-1-52-01 & 422796-2-52-01	I-95 over Snake Creek	5	Sand & Rock	18	55 - 80	8
	Total # of Soil Borings:	**672**			**Total # of Piles with CAPWAP Data:**	**684**
					Total # of Piles with Limestone Bearing Layer:	**264**
					Total # of BOR CAPWAP Analyses on Piles with Limestone Bearing Layer:	**65**

Phase I

Task 1.1: Data Collection – Steel Pipe Piles

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Florida DOTs, Consultants, & Contractors

Site Information		Insitu Information		Pile Information			
Project Number (Financial)	Project Site	# of Soil Borings	Predominant Soil Type	Dimensions (in)	Tip	Length (ft)	# of Piles with CAPWAP
211449-1-52-01	CR 229 Temporary Bridge over South Prong of St. Mary's River (FPID: 432823-2-H2-01)	2	Sand	24	Closed	85	2
212594-1-52-01	Lessie Road over Little St. Mary's River	4	Sand	24	Closed	55 - 105	10
220773-4-52-01	SR 79 over Reedy Branch	12	Sand & Rock	24	Closed	40 - 180	10
407167-1-52-01	SR 79 over Holmes Creek	13	Sand & Rock	24	Closed	84 - 129	14
222334-1-52-01	CR 166 over Alligator Creek	7	Sand & Rock	20	Closed	65 - 85	1
422908-1-52-01	SR 10 (US 90) over Camp Branch	6	Sand	24	Closed	120 - 180	3
424301-1-52-01	SR 30 (US 98) E.B. over East Pass	11	Sand	30	Open	55 - 90	21
424460-1-52-01	Rum Road over Parrot Creek	4	Sand, Clay, & Rock	24	Open	50 - 75	1
420809-3-52-01	I-595 Corridor Improvement Project from I-75 to East of SR 7	23	Sand & Rock	12 ¾, 18, & 24	Closed	79 - 130	13
258660-2-52-01	I-275 (SR 93) from Hillsborough Ave. to Yukon St. (NB & SB I-275 (SR 93) over Yukon Street)	4	Sand & Rock	18	Open	80 - 225	1
	Total # of Soil Borings:	**86**				**Total # of Piles with CAPWAP Data:**	**76**

Phase I
Task 1.1: Data Collection
Steel Pipe Piles

Published Papers

Site Information		Insitu	Pile Information			
Reference	Project Site	Predominant Soil Type	Dimensions (in)	Tip	Length (ft)	# of Load Tests
Goble & Rausche (1980)	Well Conductor Pipe (Gulf of Mexico)	X	24	Open	480	3
Jardine et al (1998)	Leman Field, southern North Sea	Sand	26	Open	125	1
Kolk et al (2005)	Eemshaven, The Netherlands	Sand	30	Open	100 - 153	10
Reese et al (1976)	Mustang Island (Texas, USA)	Sand	24	Open	69	3
Richard (2010)	southeastern Louisiana (3 Test Sites)	Clay	18, 20, 30, & 54	Open	80 - 182	32
McCammon et al (1970)	Lower Arrow Lake (British Columbia, Canada)	Sand, Silt, & Clay	24	Open & Closed	149 - 150 & 100 - 158	7
Kusakabe et al (1989)	Hokkaido, Japan	Sand & Silt	40	Open	135	1
	Chiba, Japan	Sand, Silt, & Clay	32	Open	158	1
	Chiba, Japan	X	14	Open	49	1
	Port Said, Egypt	X	28	Open	167	1
Olson et al (2004)	California DOT (Statewide)	Sand	10 - 72	Open & Closed	24 - 114	89
					Total # of Load Tests:	**149**

Phase I

Task 1.1: Data Collection
Steel Pipe & Concrete Cylinder Piles

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Published Papers, FHWA, DFLTD, & FDOT

Site Information		Insitu	Pile Information			
Reference	Project Site	Predominant Soil Type	Dimensions (in)	Tip	Length (ft)	# of Load Tests
Pump et al (1998)	Jin Mao Building (Shanghai, China)	Sand, Silt, & Clay	36	Open	259	2
Tveldt & Fredriksen (2003)	Drammen	Sand	32	Open	49 & 82	4
Hu (2007)	West Palm Beach & Fort Myers	Sand	17, 52, & 76	X	X	X
FHWA Deep Foundation Load Test Database (DFLTD)	Bayshore Freeway (CA)	Sand & Clay	24	Open	52 - 73	3
	West Seattle Freeway Main Span (WA)	Sand, Soilt, & Clay	24	Open	147 - 214	2
	Stillwater Bridge over St. Croix River (MN)	X	24	Open	120	X
	NNO (Nano, Japan)	X	31 ½	X	36	X
McVay et al (2004) *Steel Pipe Piles	Woodrow Wilson Bridge over Potomac River (VA & MD)	Sand, Silt, & Clay	36, 42, & 54	Open	96 - 164	3
McVay et al (2004) *Concrete Pipe Piles	St.Georges Island Bridge Replacement (FL)	Sand & Rock	54	Open	80	4
	Herbert C. Bonner Bridge (a.k.a. Bridge Over Oregon Inlet) (NC)	Sand & Silt	66	Open	131	X
	Chesapeake Bay Bridge-Tunnel (VA)	Sand, Silt, & Clay	54 & 66	Open	128 - 204	6
	I-664 Bridge (VA)	Clay	54	Open	48 - 133	9
					Total # of Load Tests:	**33**

Phase I
Task 1.4: Data Collection
Drilled Shaft with Casing Embedded in Limestone

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FDOT

~ 60 Shafts with No Casing and/or No Casing Embedment in Limestone

Site Information		Insitu	Shaft Information				
Project Number	Project Site	# of Soil Borings	Dimensions (in)	Length (ft)	# of Load Test	# of Viable Shafts	Comments
10130-1544	Gandy Bridge	116	48	43 - 83	6	4	possibly five test shafts available, but questionable due to length of casing in limestone
53020-3540	Victory Bridge	28	48	69 - 100	6	3	
250445-1-52-01	Jewfish Creek	98	48	45 - 67	2	1	of two possible shafts, only one had at least 3 ft of casing-limestone overlap
10190-1416	Lee Roy Selmon	504	48	47 - 80	13	1	
416361-2-52-01	Lee Roy Selmon Crosstown Expressway Bridge Widening and Deck Replacement	247	48	47 - 83	5	1	
10150-3543/3546	Hillsborough Avenue	31	30 & 48	65 - 79	2	2	old report (UF hard copy)
*	Barnett Bank Headquarters Building	15	28 & 36	58 - 90	2	1	casing on test shaft was intended to be temporary but left in place
86180-1522	17th Street	95	48	40 - 100	3	3	discrepancy between FDOT and contractor reports regarding lengths of casing in limestone
413485-1-31-01	CR 12A Bridge Replacement	4	48	20 - 68	*	*	need to determine if casings present and in limestone
	Total # of Soil Borings:	**1138**		**Total # of Load Tests:**		**16**	

* No Data Found

Phase I

Task 1.2: Steel H Pile Analyses Convert Data to Usable Format

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SPT Data

- Enter data into "Insitu Excel 2.01 Application"
  - Convert to XML
  - Upload to FDOT Database

Dynamic Data

- Enter Dynamic Data into Microsoft Excel
- Convert Dynamic Data into XML Format
  - Modified "SoilComplete" GUI to Include Pile Driving Data (Recently Completed)
  - Upload to Database

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Phase I

Task 1.2: Evaluate Static Capacity of Steel H Piles

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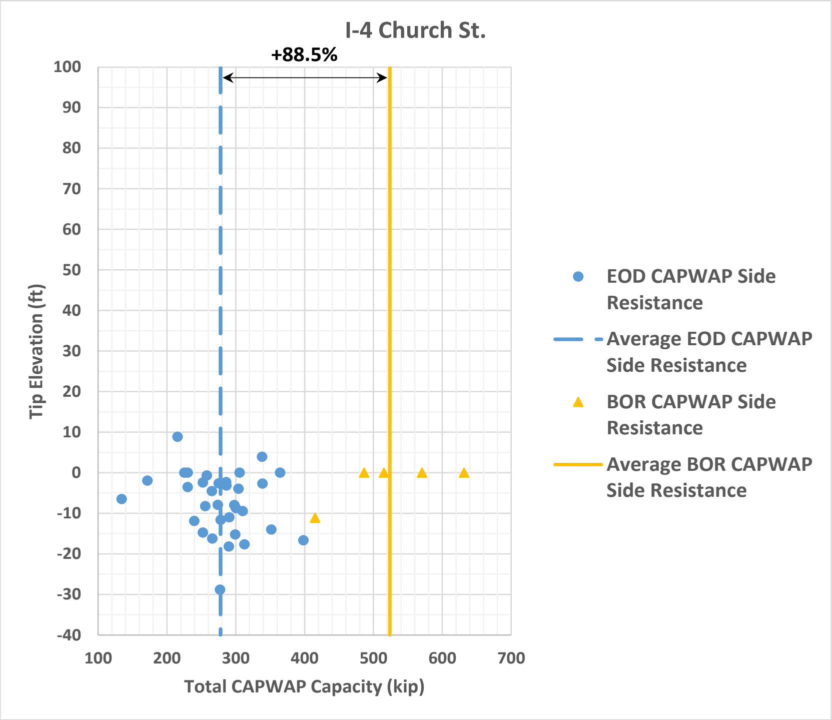
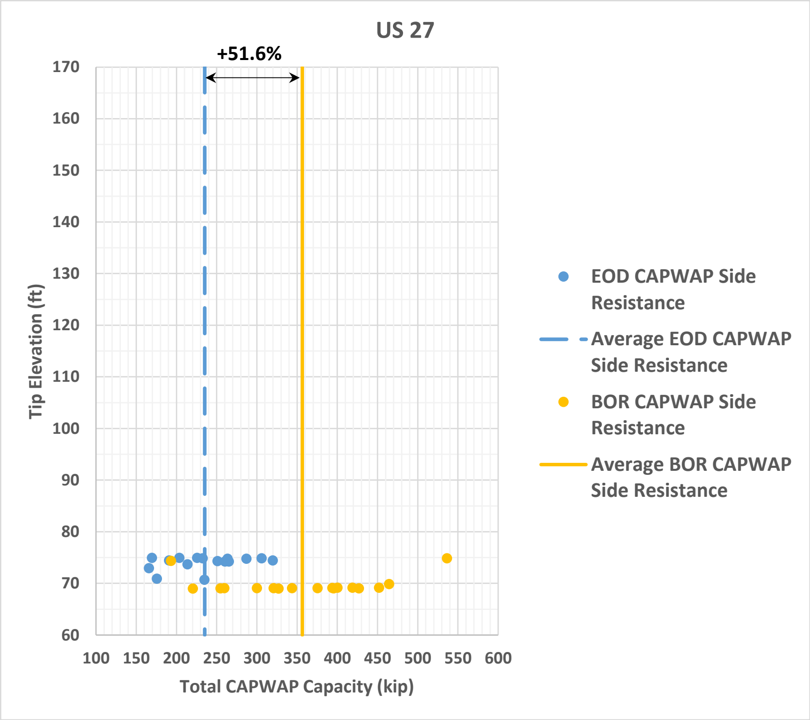
End of Drive (EOD) vs. Beginning of Re-Strike (BOR)

- Consider Pile Set-Up & Relaxation
- BOR only to Develop Unit Side Resistance Relationships
- EOD and Some BOR to Develop Unit End Bearing Relationship





Phase I

Task 1.2: Evaluate Static Capacity of Steel H Piles

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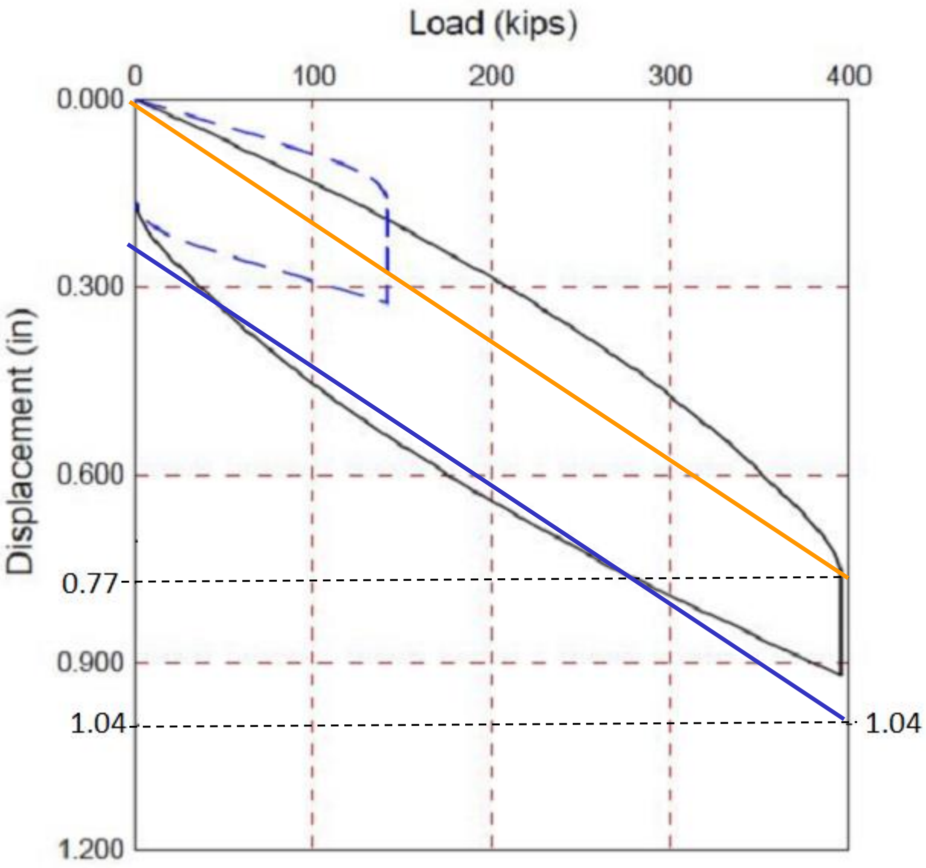
Ultimate Capacity vs. Davisson Capacity

– Consider CAPWAP Simulated Load Test Curves during BOR



$$\Delta L = \frac{PL}{AE}$$

$$\Delta OS = \frac{B}{120} + 0.15\ (in)$$

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Phase I

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Task 1.2: Develop Relationship for Unit Side Resistance of Steel H Piles

Analysis Methods

First Three Methods Based on Nearest Boring(s)

- First Approach
  - Considered Every Blow Count along Each CAPWAP Pile Section
  - No Clear Trend - Too much Variability with Reported SPT Data
- Second Approach
  - Averaged Blow Counts along Each Pile Section, i.e., “Single Section”
  - Started Seeing Trend (Unit Side Resistance Increase with SPT Blow Count)
  - Still too much Variability with SPT Data (Only Averaged Two or Three Blow Counts along Each Pile Section)
- Third Approach
  - Averaged Blow Counts & Unit Side Resistance along Consecutive CAPWAP Pile Section , i.e., “Section Pairs”
  - More Pronounced Trend
  - Trend Improves as Average Length Increases

Phase I

Task 1.2: Develop Relationship for Unit Side Resistance of Steel H Piles

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Analysis Methods

- Fourth Approach
  - Defined Soil Layers Across Sites & Averaged along Layers
    - Blow Counts from All Borings on Site
    - Unit Side Resistance
  - Grouped Soil Types following Current FB-Deep Schema (USCS)
    - Soil Type 1: Plastic Clay
      Includes: CH & OH
      "Clay"
    - Soil Type 2: Clay-Silt-Sand Mixtures; Very Silty Sand; Silts & Marls
      Includes: GC, SC, ML, & CL (also Included SP-SM, SP-SC, etc.)
      "Mixed"
    - Soil Type 3: Clean Sands
      Includes: GW, GP, GM, SW, SP, & SM
      "Sand"
    - Soil Type 4: Soft Limestone; Hard Limestone; Very Shelly Sands
      Includes: Limestone & Very Shelly Sand
      "Rock"

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Phase I

Task 1.2: Develop Relationship for Unit Side Resistance of Steel H Piles

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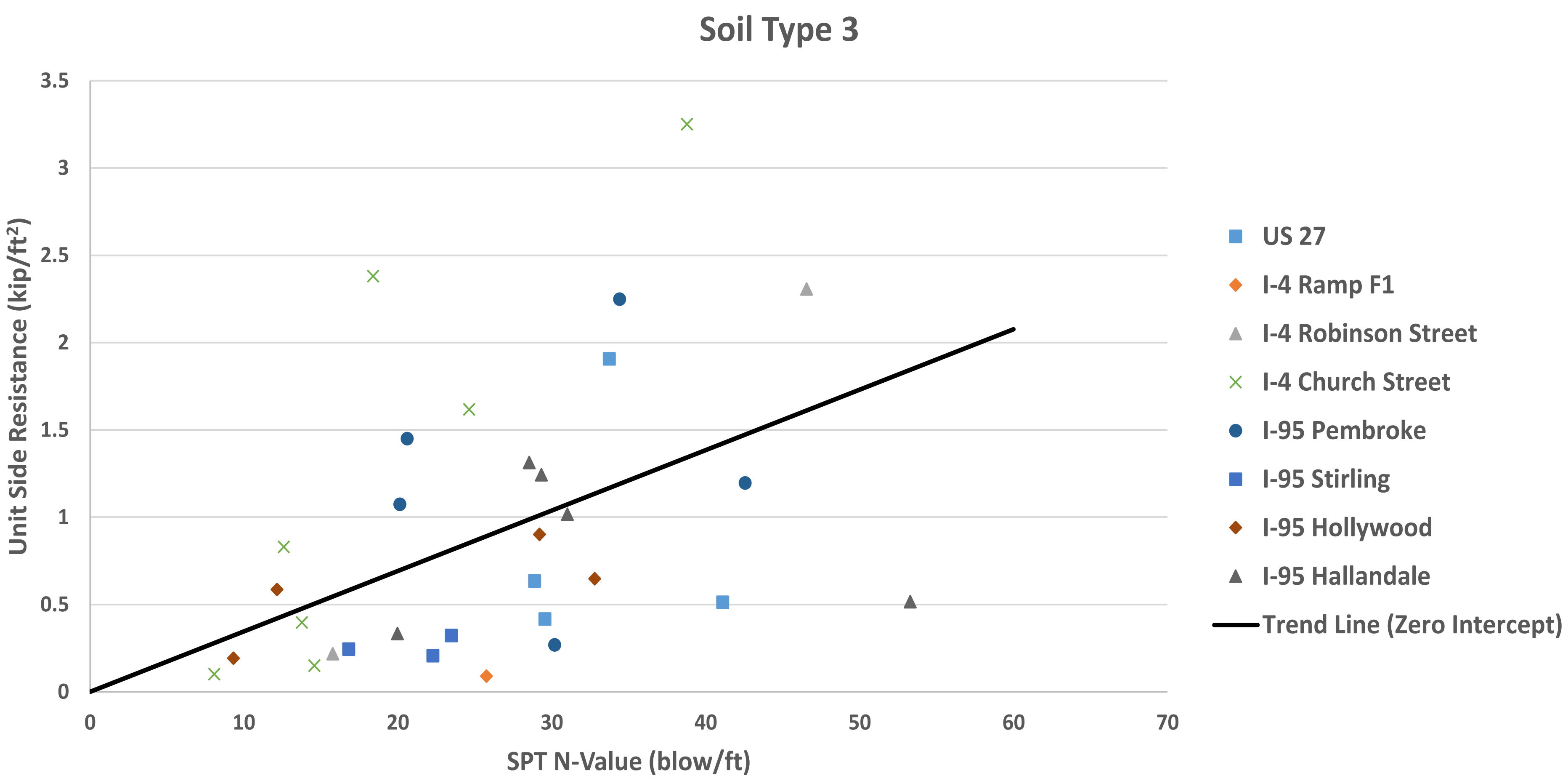

Phase I

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Task 1.2: Develop Relationship for Unit Side Resistance of Steel H Piles

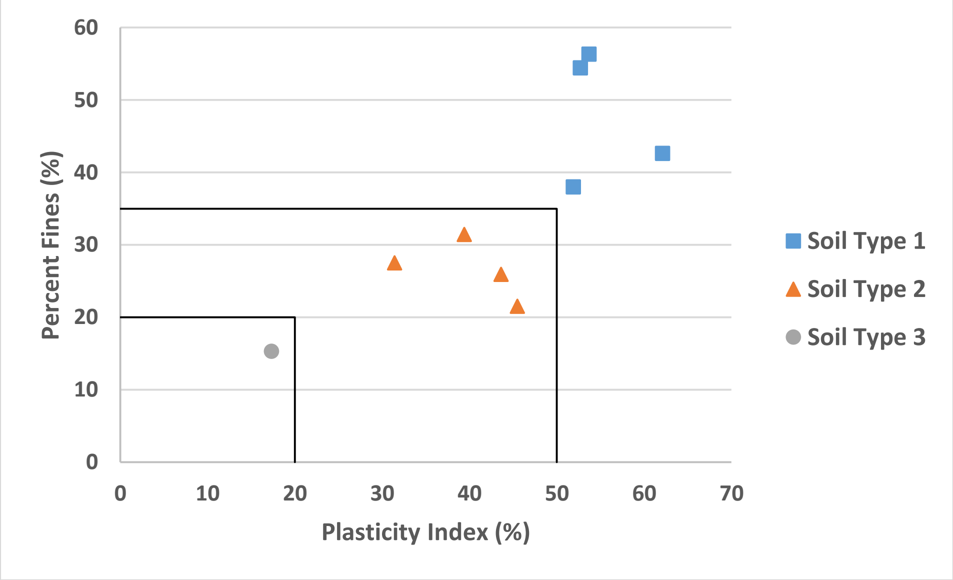
Analysis Methods

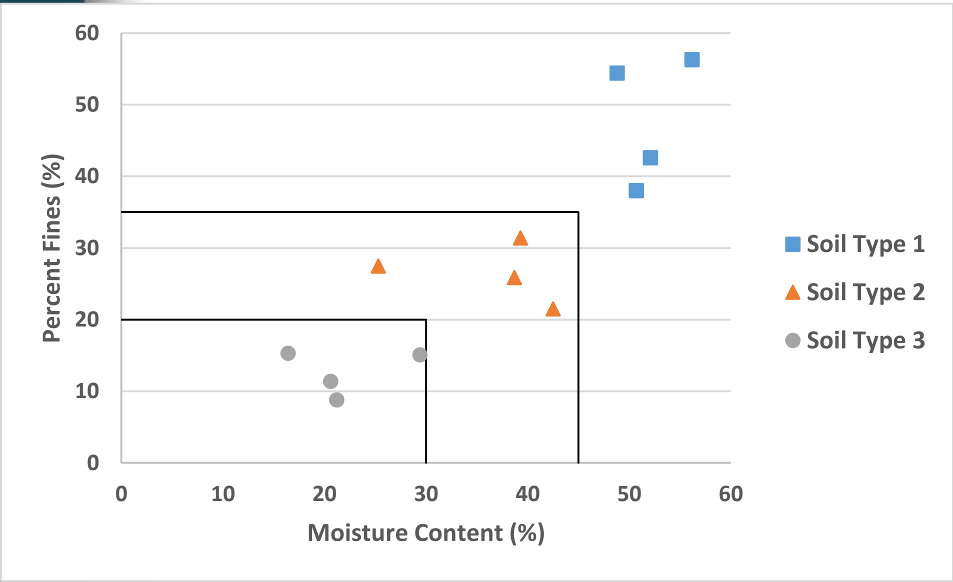
- Fifth Approach (Final)
  - Defined Soil Layers Across Sites & Averaged along Layers
    - Blow Counts from All Borings on Site
    - Unit Side Resistance
  - What about Dual Soil Classifications like SP-SM, SP-SC, etc. with Larger Percent Fines (-200%), Moisture Content (MC), and/or Plasticity Index & Liquid Limit (PI & LL Respectively)?
  - Grouped Soil Types Considering Laboratory Test Data (-200%, MC, PI, & LL), Magnitude of Unit Side Resistance Reported, & Unified Soil Classification System (USCS)

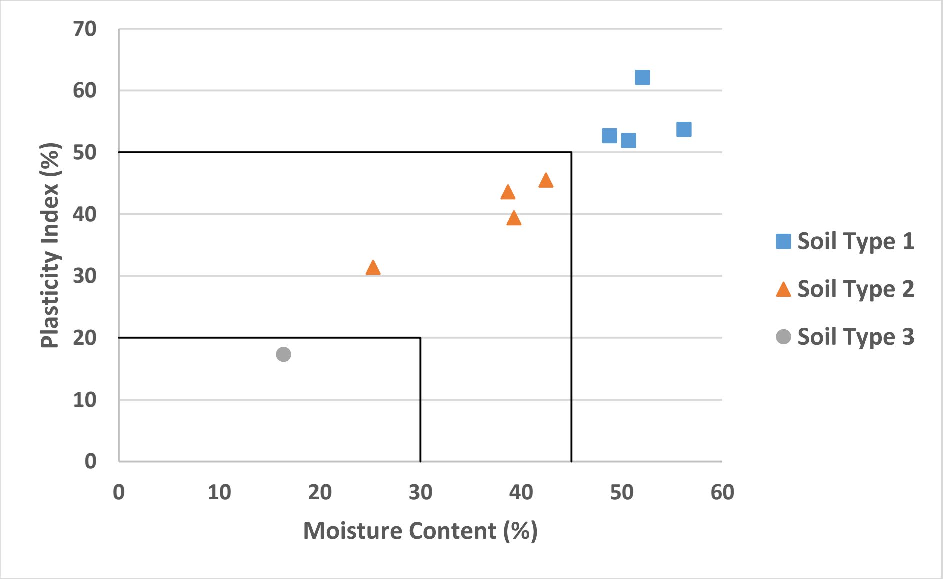
Soil Type 1	**Soil Type 2**	**Soil Type 3**
Fines > 35%	20% < Fines < 35%	Fines < 20%
MC > 45%	30% < MC < 45%	MC < 30%
PI > 50%	20% < PI < 50%	PI < 20%
LL > 90%	40% < LL < 90%	LL < 40%

Phase I

Task 1.2: Develop Relationship for Unit Side Resistance of Steel H Piles







Phase I

Task 1.2: Develop Relationship for Unit Side Resistance of Steel H Piles

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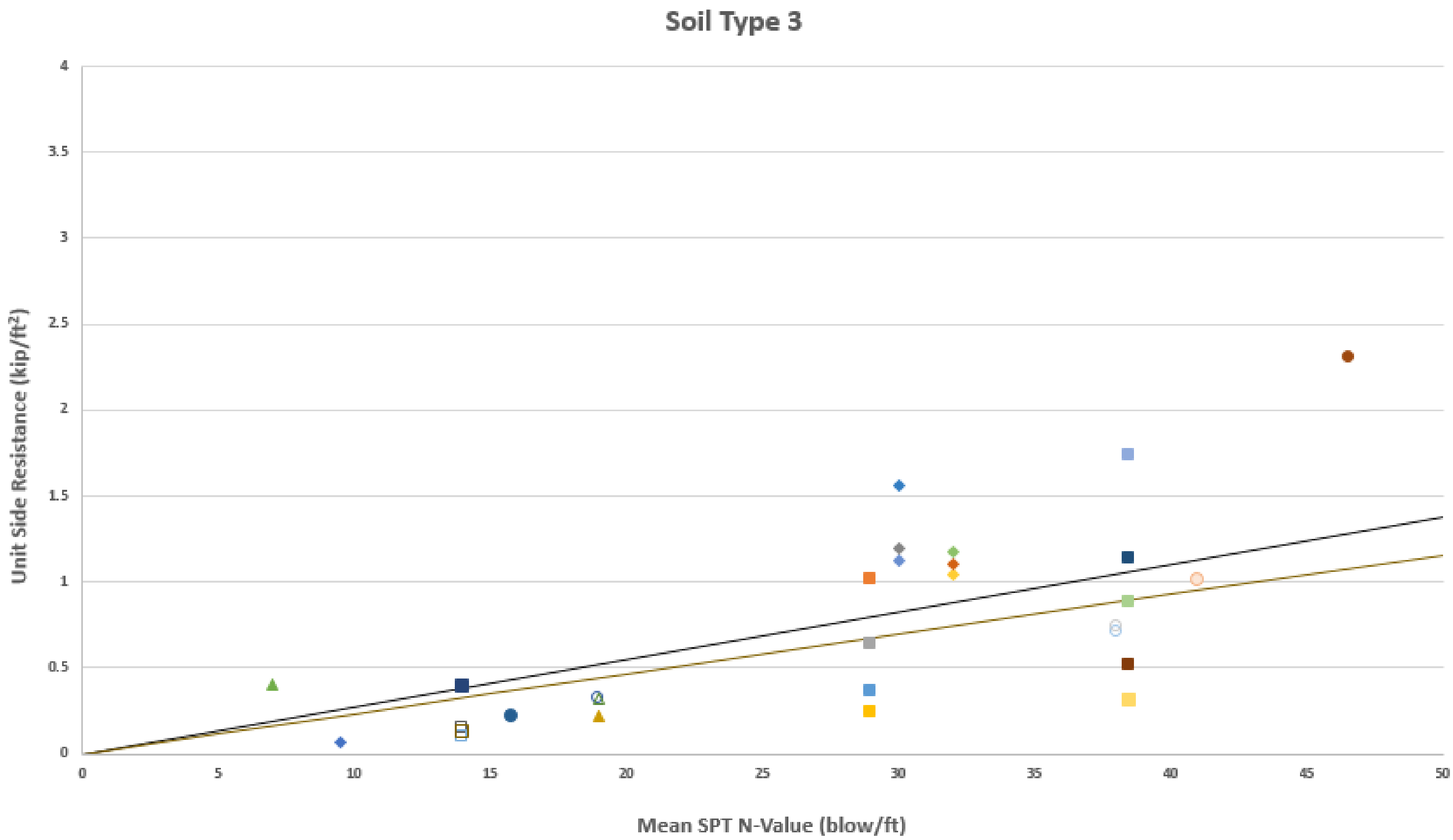

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Task 1.2: Develop Relationship for Unit Side Resistance of Steel H Piles

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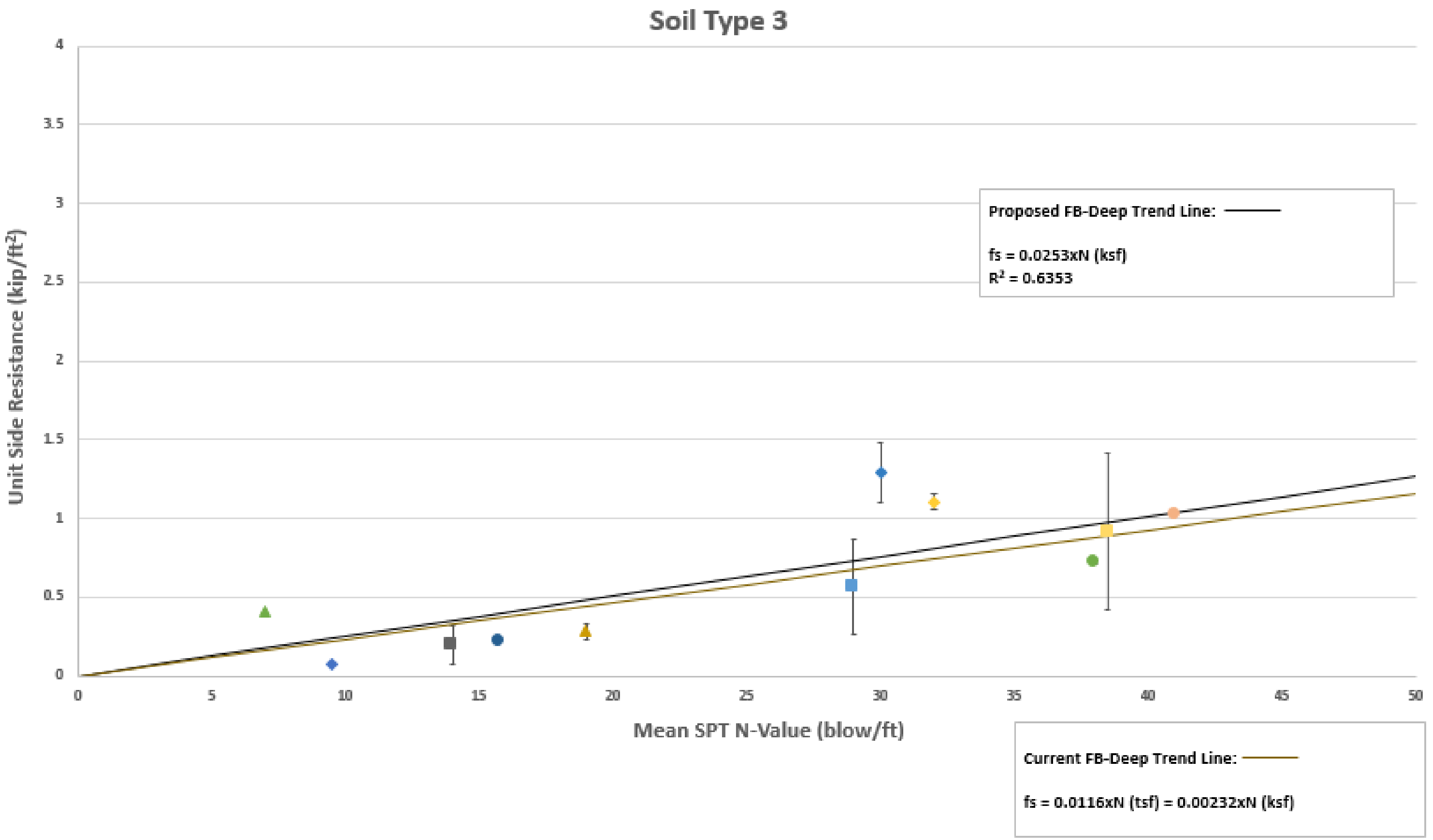

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Task 1.2: Develop Relationship for Unit Side Resistance of Steel H Piles

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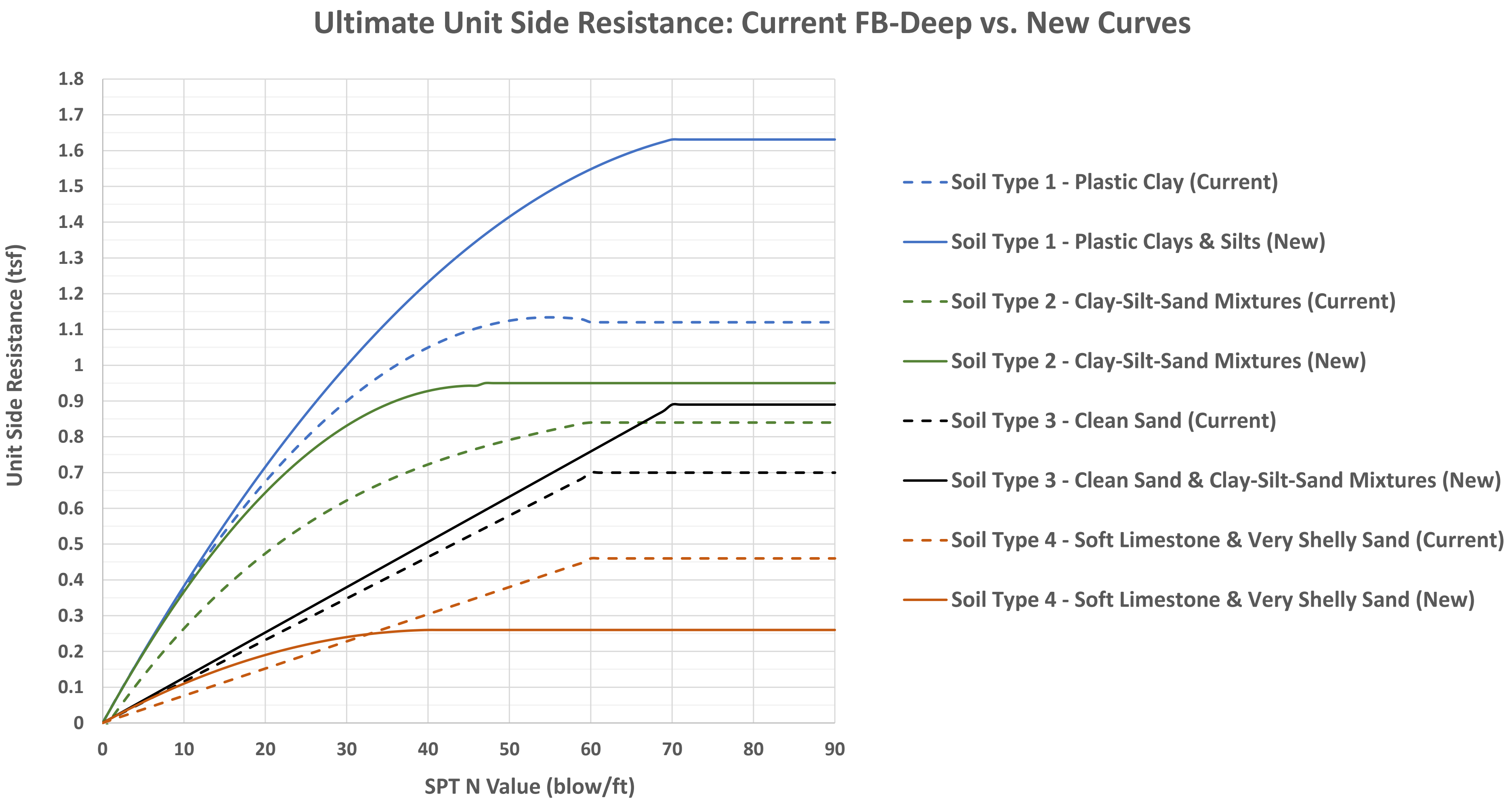

Phase I

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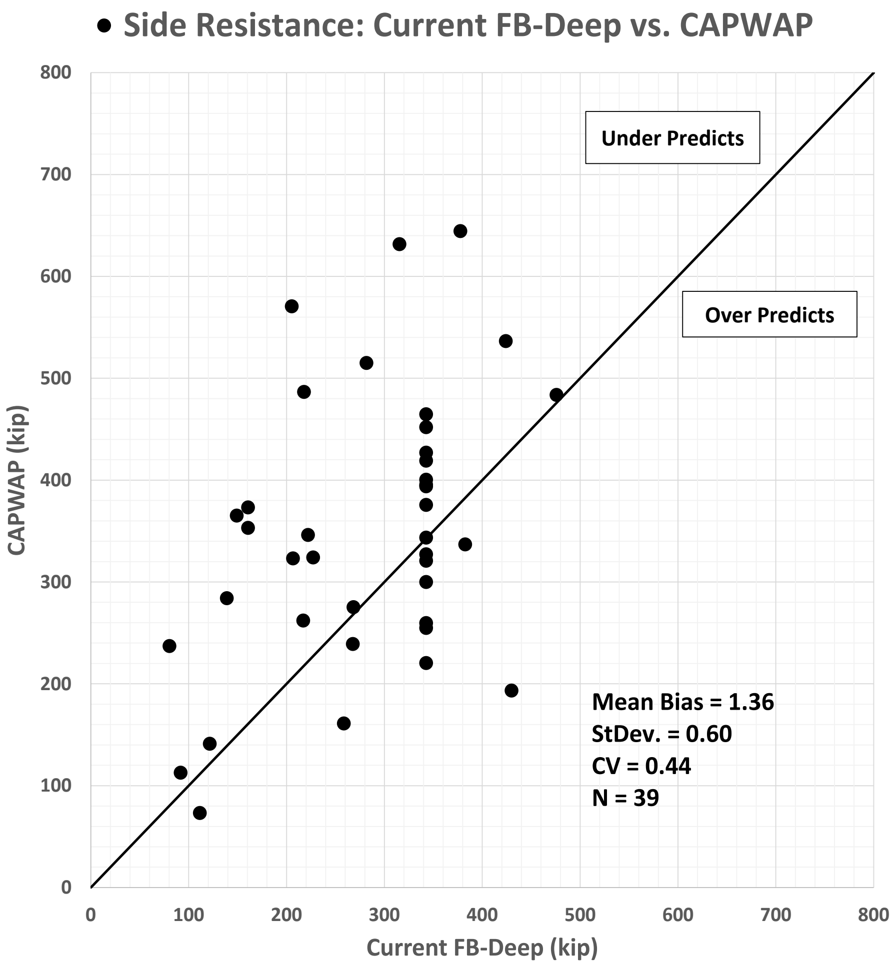
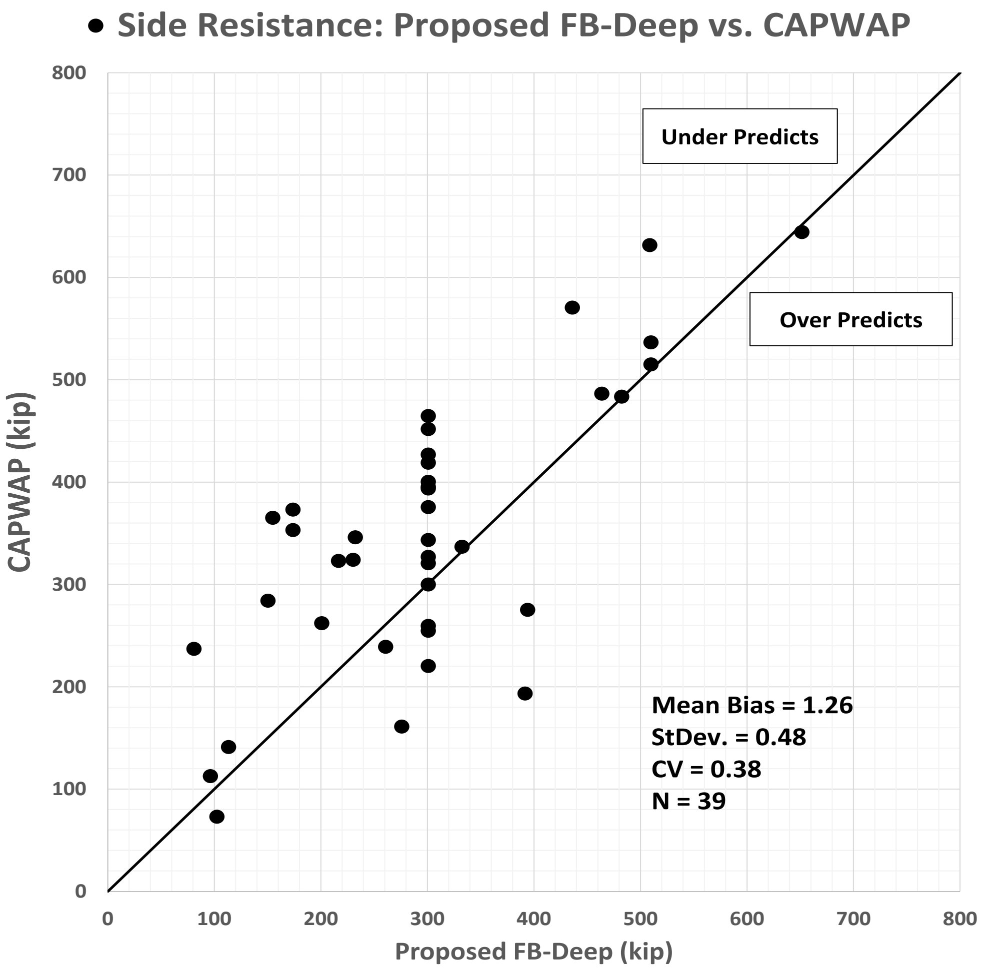
Task 1.2: Side Resistance of Steel H Piles Current FB-Deep vs. Proposed





Phase I

Task 1.2: Develop Relationship for Unit End Bearing of Steel H Piles

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- A total of 52 piles were identified;
- 25 for clean sand (SW, SP);
- 14 for clay-silt-sand mixtures (SC, SM, etc.);
- 13 for limestone;
- 0 for plastic clay (CH, CL);
- 38 piles on BOR blows;
- 14 piles on EOD blows.

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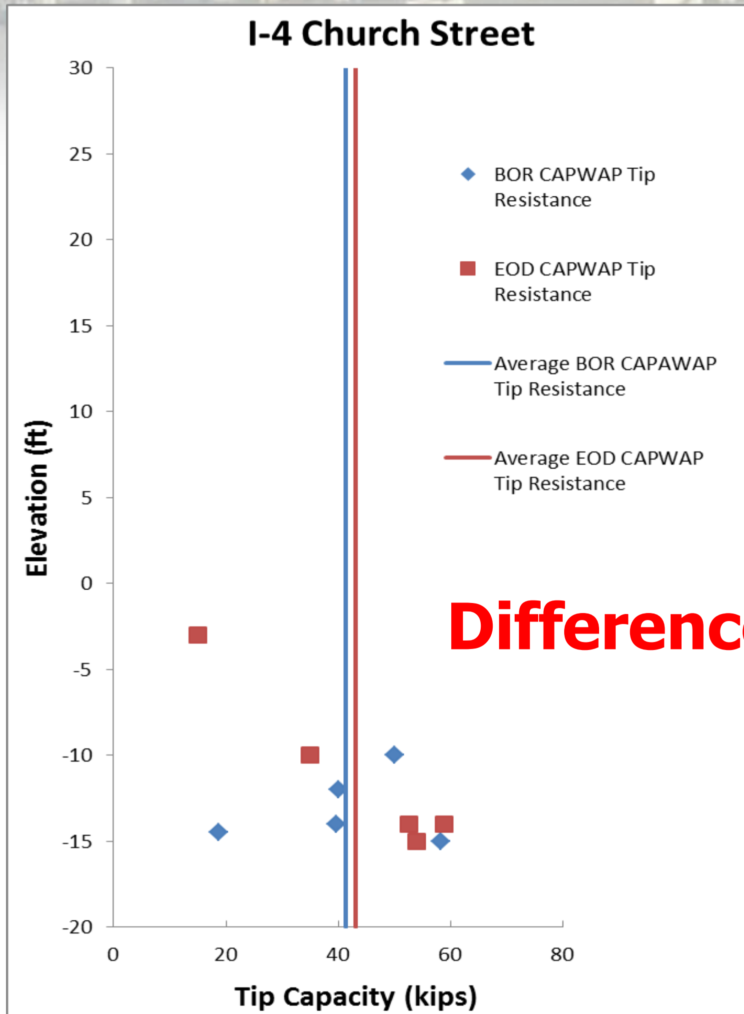
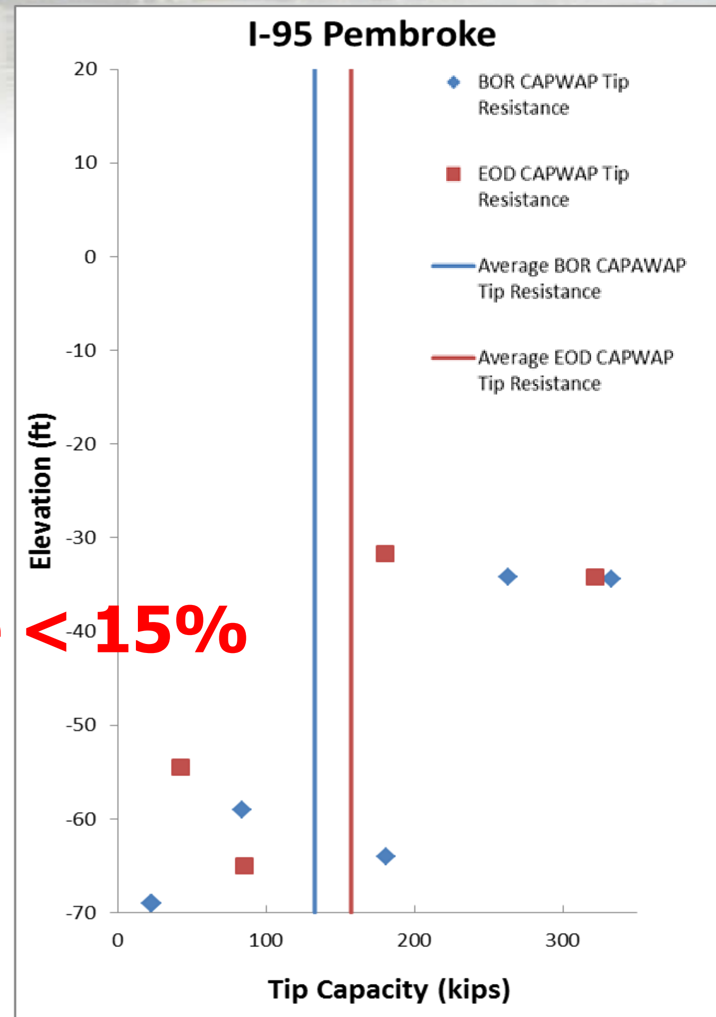
Task 1.2: Develop Relationship for Unit End Bearing of Steel H Piles





Difference <15%

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Task 1.2: Develop Relationship for Unit End Bearing of Steel H Piles

- Three methods were considered for end Bearing:
  - (1) 4B below the pile tip;
  - (2) 8B below the pile tip;
  - (3) 8B above and 3.5B below the pile tip.

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Task 1.2: Develop Relationship for Unit End Bearing of Steel H Piles

Project Site	Pile #	Tip Bearing (kips)	Tip Elevation (ft)	CAPWAP qt (tsf)	Box Area (ft2)	True Area (ft2)	Method #1	Method #2	Method #3	Soil Type	Nearest Boring
I-4 Ramp F1	Pier F1-1 Pile 5 - Setcheck	107.1	-10	39.35	1.36	0.18	44	47	32	Sand	AS-101&102&103
I-95 Hollywood	Pier 3-SB Pile 2	41	-78	13.91	1.47	0.28	23	23	27	Sand	BH-1 & BH-3
	Pier 3-SB Pile 2-SectionTest	57		13.91	1.47	0.28	23	23	27		
I-95 Pembroke	End Bent 1 Pile 3	42	-54.5	9.70	2.16	0.28	27	23	20	Sand	BP-1
	Pier 2 Pile 2	85	-65	20.00	2.16	0.28	21	50	40	Sand	
	Pier 2 Pile 3R	22	-69	5.11	2.16	0.28	20	21	20	Sand	BP-1
	Pier 2 Pile 3 Restrike	23		5.11	2.16	0.28	20	21	20		
	Pile 2 Pile 4 Restrike	23	-69	5.33	2.16	0.28	20	21	20	Sand	BP-1
	Pier 3 Pile 2 Restrike	84	-59	19.47	2.16	0.28	41	31	24	Sand	BP-2
	Pier 4 Pile 3 Restrike	181	-64	41.96	2.16	0.28	20	35	33	Sand	BP-1&BP-2
US 27	Bent 3 Pile 16 Set CheTest	185.7	75	68.22	1.36	0.15	39	35	41	Sand	B-2
	End Bent 1 Pile 12	58.1	67	21.07	1.38	0.15	31	32	32	Sand	B-1&SE-1
	Pier 2 Pile 1 3HR	141.2	70	51.22	1.38	0.15	32	35	36	Sand	B-3
	Pier 2 Pile 2 4.5 HR	92.4	69	33.52	1.38	0.15	32	35	34	Sand	B-3
	Pier 2 Pile 3 6HR	131.8	88.5	47.81	1.38	0.15	38	35	36	Sand	B-3
	Pier 2 Pile 4 7HR	120.8	70	43.82	1.38	0.15	32	35	36	Sand	B-3
	Pier 2 Pile 5 2HR	125.3	70	45.45	1.38	0.15	32	35	36	Sand	B-3
	Pier 2 Pile 6 1DR	113.7	70	41.24	1.38	0.15	32	35	36	Sand	B-3
	Pier 2 Pile 8 1DR	90.5	69.5	32.83	1.38	0.15	32	35	36	Sand	B-3
	Pier 2 Pile 9 1DR	137.4	69.5	49.84	1.38	0.15	32	35	36	Sand	B-3
	Pier 2 Pile 10 1DR	135.1	69.5	49.01	1.38	0.15	32	35	36	Sand	B-3
	Pier 2 Pile 11 1DR	139.2	69.5	50.49	1.38	0.15	30	36	38	Sand	B-2&B-3
	Pier 2 Pile 12 1DR	118.7	70	43.06	1.38	0.15	30	36	38	Sand	B-2&B-3
	Pier 2 Pile 13 1DR	155.2	69.5	56.30	1.38	0.15	30	36	38	Sand	B-2&B-3
	Pier 2 Pile 14 1DR	99.7	69.5	36.17	1.38	0.15	30	36	38	Sand	B-2&B-3
	Pier 2 Pile 15 2DR	157	69.5	56.95	1.38	0.15	30	36	38	Sand	B-2&B-3
	Pier 2 Pile 16 1DR	109.2	59	39.61	1.38	0.15	43	48	43	Sand	B-2&B-3
	Pier 2 Pile 17 2DR	154.6	69.5	56.08	1.38	0.15	30	36	38	Sand	B-2&B-3

Phase I

Civil & Coastal Engineering

Task 1.2: Develop Relationship for Unit End Bearing of Steel H Piles

Project Site	Pile #	Tip Bearing (kips)	Tip Elevation (ft)	CAPWAP qt (tsf)	Box Area (ft2)	True Area (ft2)	Method #1	Method #2	Method #3	Soil Type	Nearest Boring
I-4 Ramp D1	Pier 5 Pile 1	57.6	-27	21.16	1.36	0.18	37	41	52	Mixture	D-106
	Pier 8 Pile 33	50	-18	18.37	1.36	0.18	50	56	54	Mixture	D-112
	Pier 12 Pile 41	55	-7	20.21	1.36	0.18	57	46	55	Mixture	D1-104
	Pier 16, Pile 15 - Setcheck	65	-10	23.88	1.36	0.18	75	68	44	Mixture	D1-101
I-4 Church Street	Pier 1 Pile 3	59	-14	29.50	1.00	0.11	75	N/A	68	Mixture	CSV-1
	Pier 3 Pile 1	52.6	-14	26.30	1.00	0.11	55	N/A	48	Mixture	CSV-2
	Pier 4 Pile 1	15	-3	7.50	1.00	0.11	50	N/A	34	Mixture	CVS-4
	Pier 5 Pile 1	54	-15	27.00	1.00	0.11	60	N/A	53	Mixture	CVS-4&CVS-6
	Pier 11 WB Pile 3	35	-10	17.50	1.00	0.11	74	65	42	Mixture	B-8&B-9
	Pier 2 EB/ Pile 2	50	-10	25.00	1.00	0.11	53	52	57	Mixture	CSV-2
	Pier 13 WB Pile 1 Restrike	40	-12	20.00	1.00	0.11	77	72	48	Mixture	B-8
	Pier 14 Pile 1 - Stest	18.7	-14.5	9.35	1.00	0.11	55	55	42	Mixture	B-7&CSV-14
	Pier 16 Pile 1 - Stest	39.7	-14	19.85	1.00	0.11	55	54	52	Mixture	CSV-16
	Pier 16 Pile 3 - Stest	58.4	-15	29.20	1.00	0.11	98	98	70	Mixture	B-6
Project Site	Pile #	Tip Bearing (kips)	Tip Elevation (ft)	qt (tsf)	Box Area (ft2)	True Area (ft2)	Method #1	Method #2	Method #3	Soil Type	Nearest Boring
I-95 Hallandale	End Bent 1 Pile 3	142	-60	32.92	2.16	0.28	34	35	33	Limestone	BH-1
	Pier 2 Pile 4	88	-72	20.4	2.16	0.28	38	35	36	Limestone	BH-1&BH-2
	Pier 3 Pile 2 sc	95	-66	22.02	2.16	0.28	26	33	36	Limestone	BH-1&BH-3
	Pier 3 Pile 4	108	-67	25.035	2.16	0.28	38	40	42	Limestone	BH-2&BH-4
	Pier 4 Pile 4 sec	49	-68	11.5	2.16	0.28	36	47	57	Limestone	BH-3&BH-5
I-95 Pembroke	End Bend 5 Pile 2	180	-31.72	42.00	2.16	0.28	37	33	34	Limestone	BP-1&BP-2&BP-3
	Pier 3 Pile 4	322	-34.16	74.5	2.16	0.28	45	47	45	Limestone	BP-1&BP-3
	Pier 3 Pile 4 Restrike	263	-34.16	60.96	2.16	0.28	45	47	45	Limestone	BP-1&BP-3
	Pier 4 Pile 4 Restrike	333	-34.4	77.185	2.16	0.28	50	55	58	Limestone	BP-3
SR 51	EB 3 Temp Pile 1 RestTest	220.4	-25	80.965	1.36	0.18	69	55	57	Limestone	B-1
CR 146 Aucilla River	Bent 6 Pile 1	244.3	-10	89.745	1.36	0.18	65	65	70	Limestone	B-6
Eller Driver	Pier 7L Pile 48	201.6	-37.5	73.125	1.38	0.18	60	60	55	Limestone	TB-7L
	Pier 8R Pile 50	124.1	-117.98	45.59	1.36	0.18	52	52	50	Limestone	TB-7L&TB-8L
	Pier 9Rt Pile 32	200	-60	73.47	1.36	0.18	55	57	57	Limestone	TB-9R

Phase I

Task 1.2: Develop Relationship for Unit End Bearing of Steel H Piles

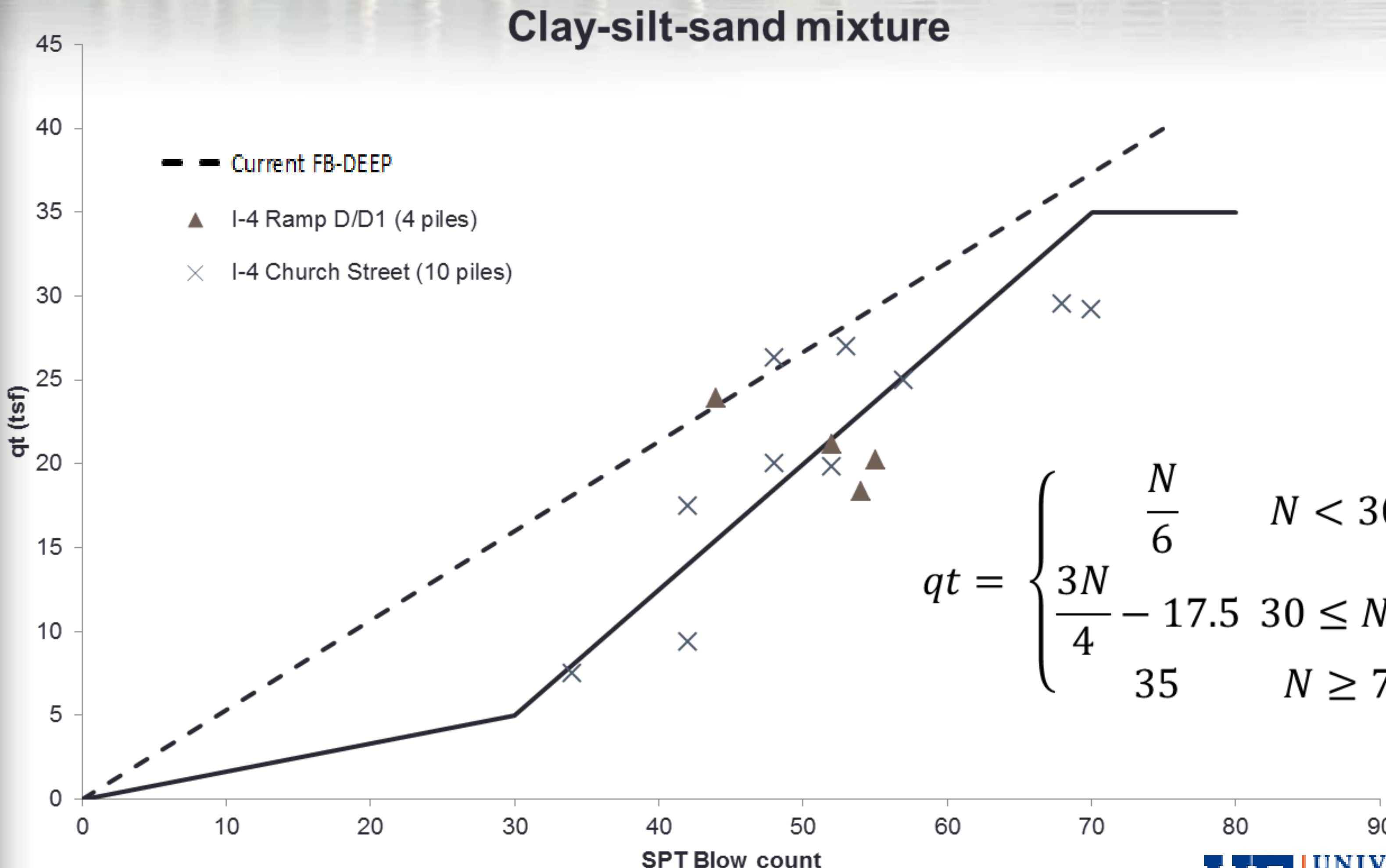
R-Square	Method #1	Method #2	Method #3
Clay-silt-sand mixtures	0.11	0.15	0.67
Clean Sands	0.09	0.26	0.90
Soft limestone	0.14	0.82	0.77

- Based on the above analyses, Method 3 - 8B above and 3.5B below resulted in the highest correlation

Phase I

Task 1.2: Develop Relationship for Unit End Bearing of Steel H Piles

Civil & Coastal Engineering



$$qt = \begin{cases} \frac{N}{6} & N < 30 \\ \frac{3N}{4} - 17.5 & 30 \leq N < 70 \\ 35 & N \geq 70 \end{cases}$$

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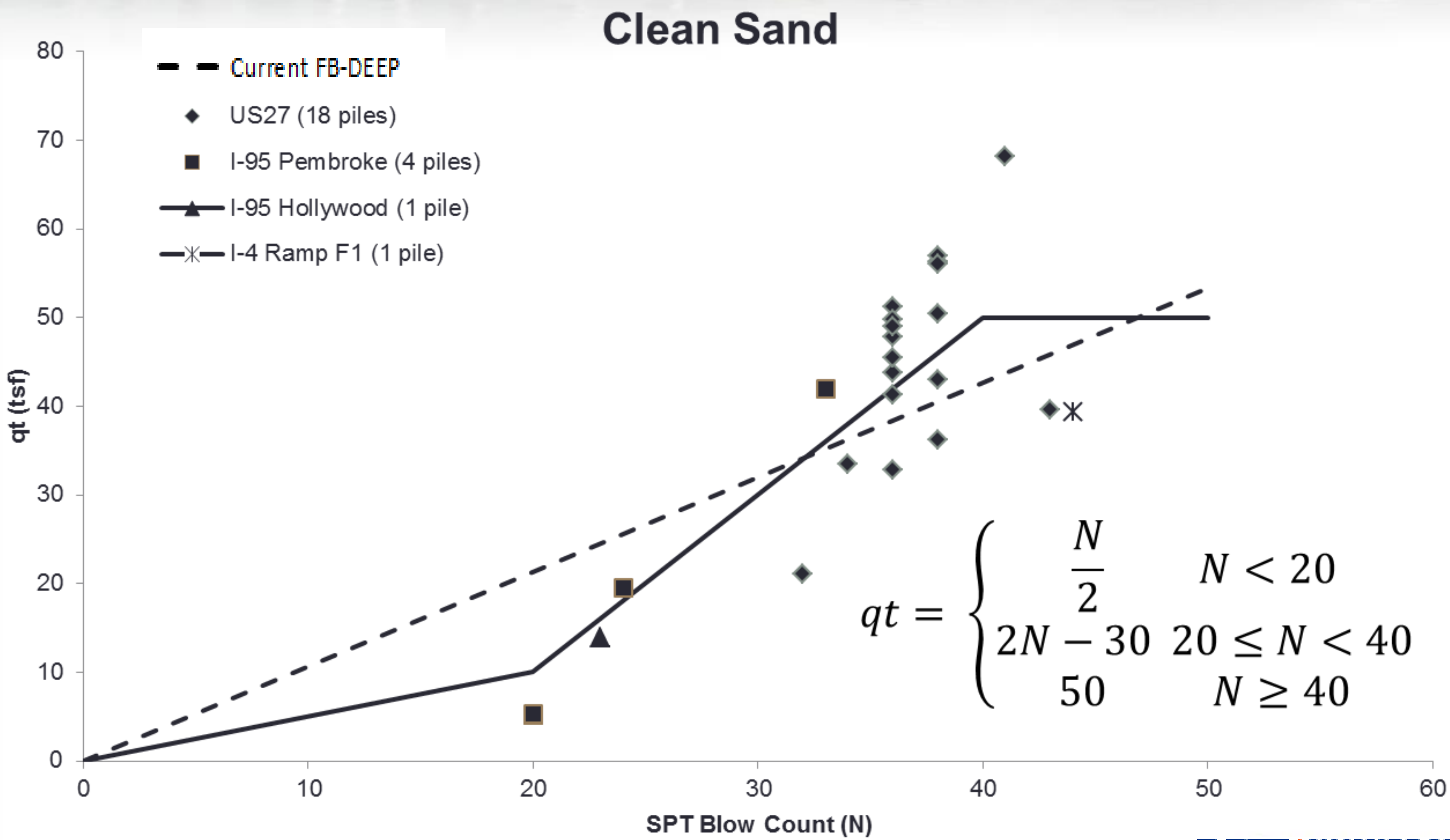
Phase I

Task 1.2: Develop Relationship for Unit End Bearing of Steel H Piles

Civil & Coastal Engineering



$$qt = \begin{cases} \frac{N}{2} & N < 20 \\ 2N - 30 & 20 \leq N < 40 \\ 50 & N \geq 40 \end{cases}$$

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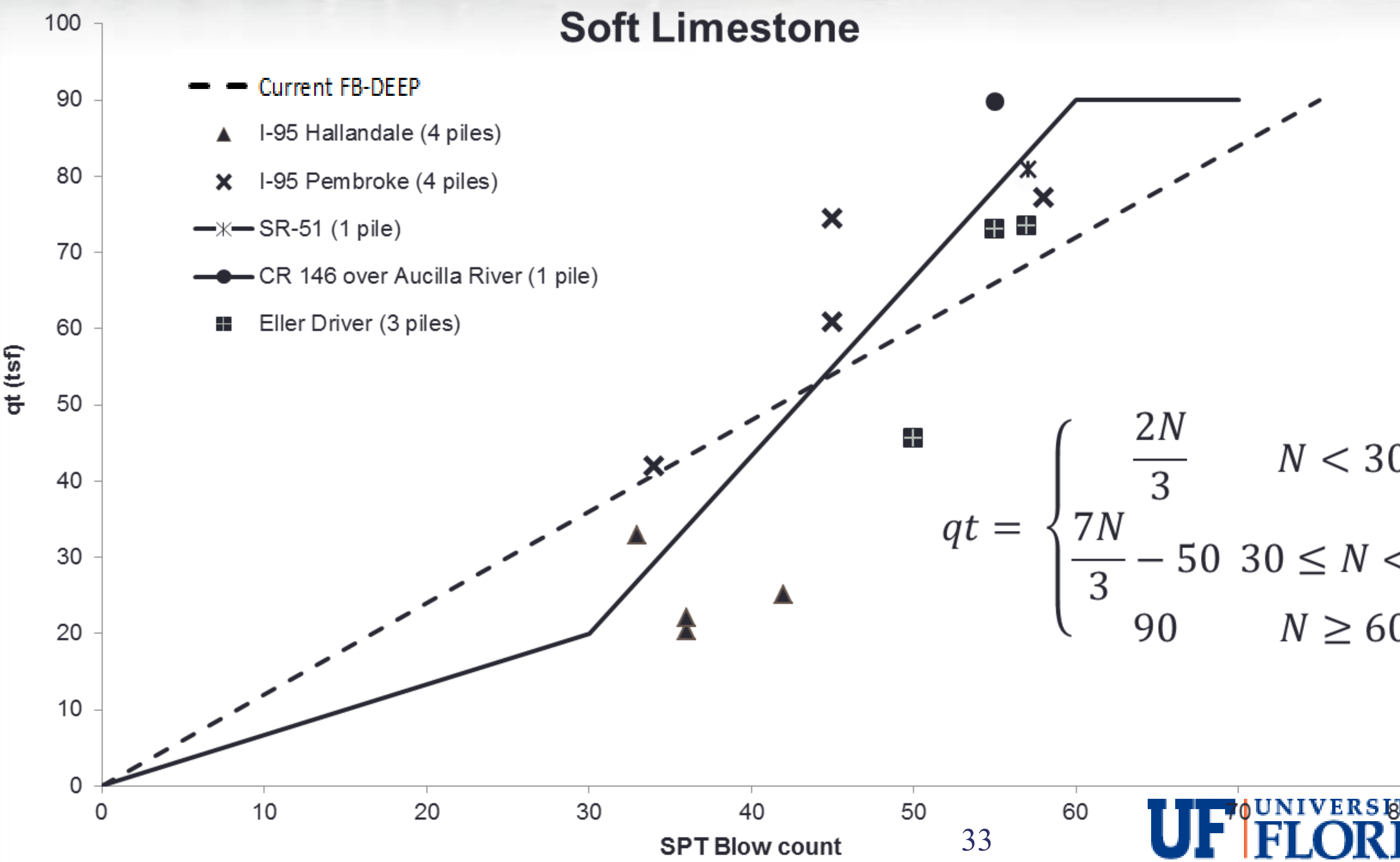
Phase I

Task 1.2: Develop Relationship for Unit End Bearing of Steel H Piles

Civil & Coastal Engineering



$$qt = \begin{cases} \frac{2N}{3} & N < 30 \\ \frac{7N}{3} - 50 & 30 \le N < 60 \\ 90 & N \ge 60 \end{cases}$$

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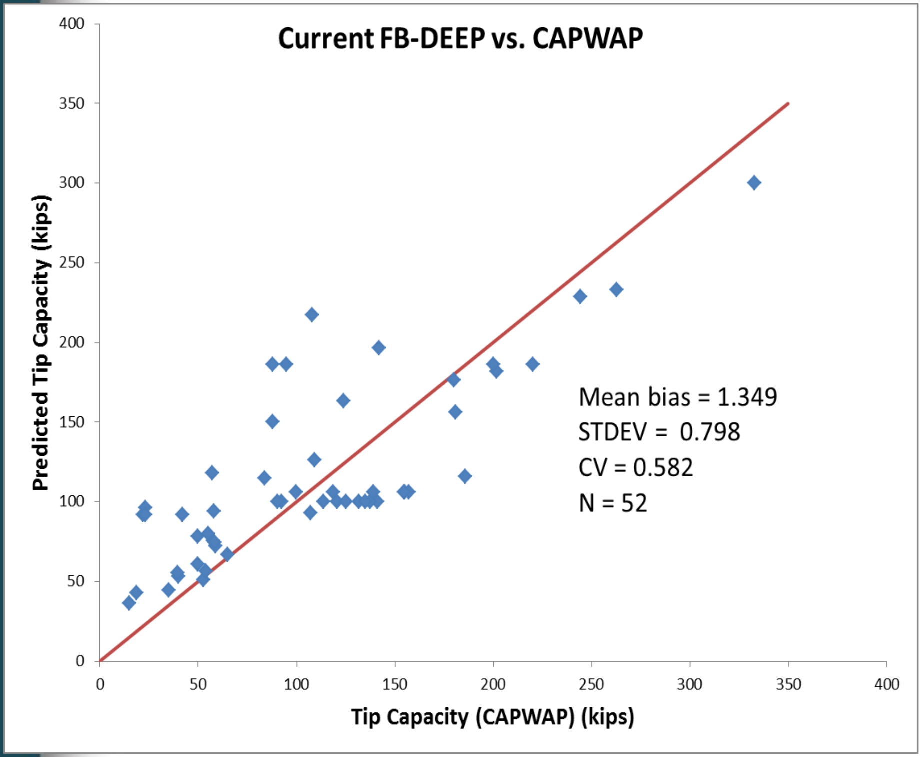
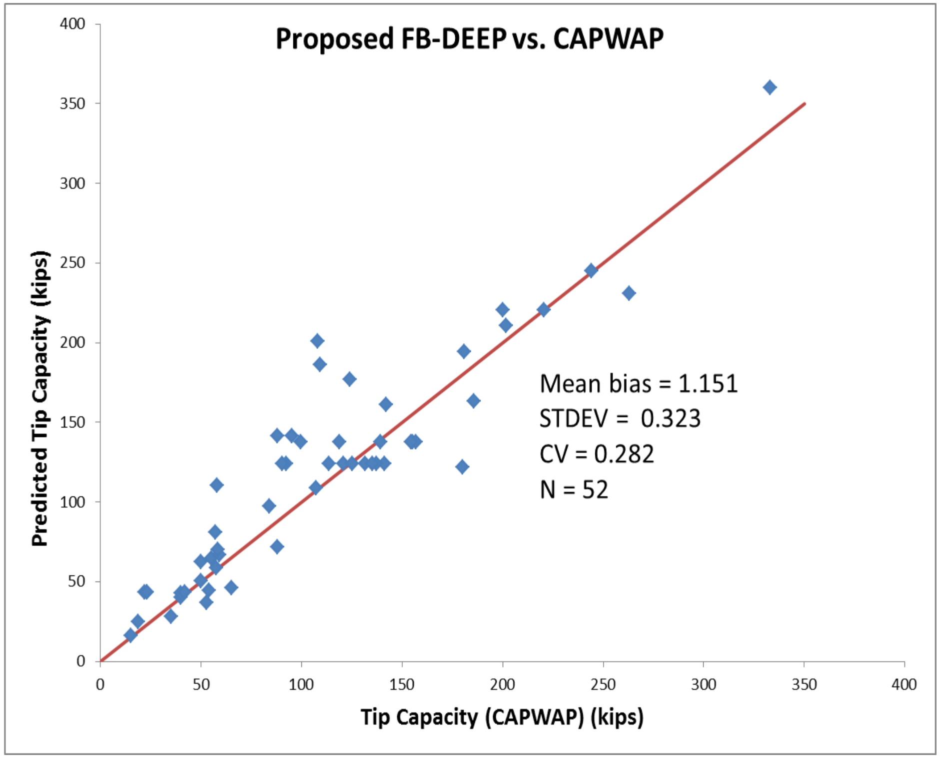
Phase I

Task 1.2: End Bearing of Steel H Piles Current FB-Deep vs. Proposed



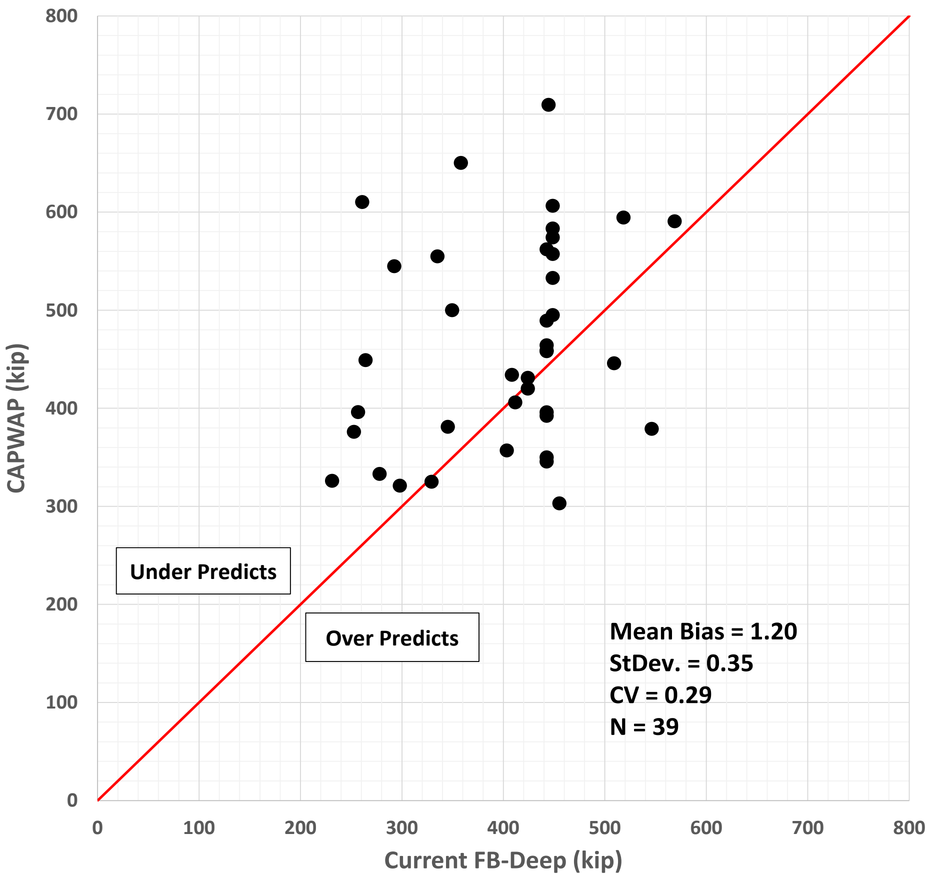


Phase I

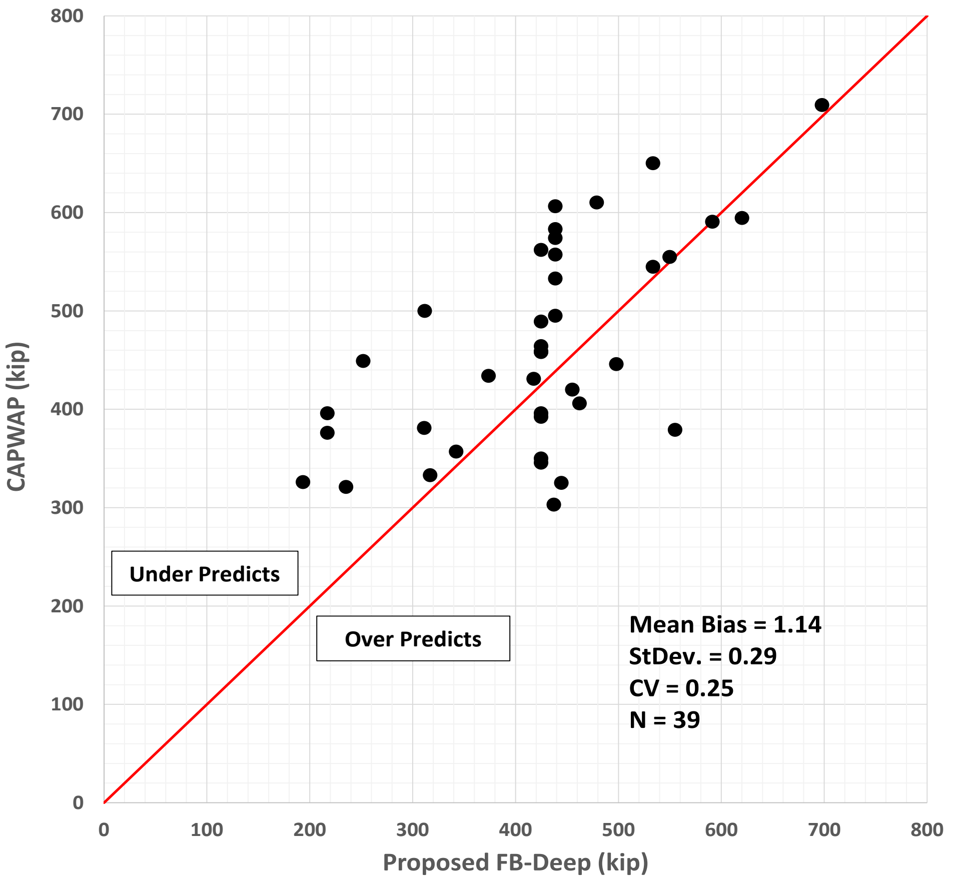
Task 1.2: Total Capacity of Steel H Piles Current FB-Deep vs. Proposed

Civil & Coastal Engineering

- Total Capacity: Current FB-Deep vs. CAPWAP



- Total Capacity: Proposed FB-Deep vs. CAPWAP



Phase I

Task 1.4: Develop Relationship for Unit Side Resistance between Casing & Limestone Interface

Phase I

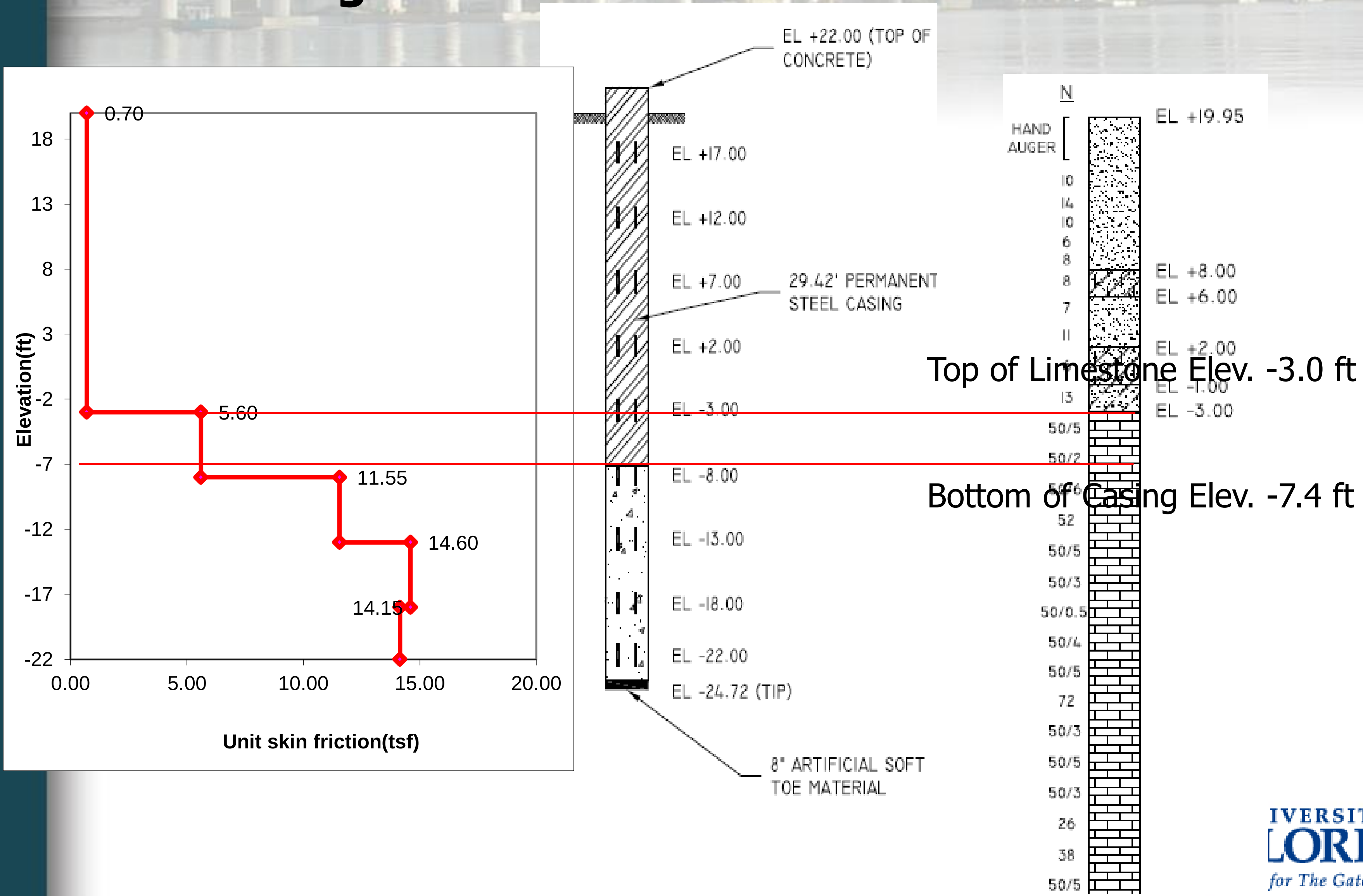
Task 1.4: Unit Side Resistance between Casing & Limestone Interface

- 16 drilled shafts with casing into limestone;
- 9 Osterberg, 7 Statnamic;
- Reported thickness of the steel casings were approximately 1 inch;
- The average limestone elevation was determined from the Geotechnical reports;

Phase I

Task 1.4: Unit Side Resistance between Casing & Limestone Interface

Civil & Coastal Engineering



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Phase I

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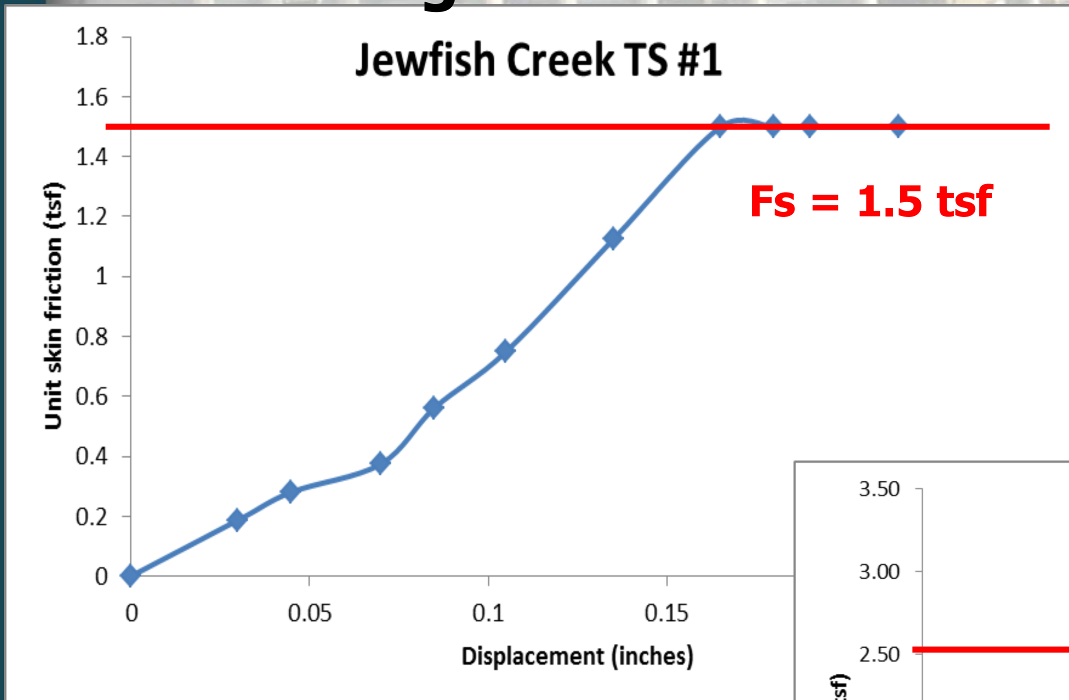
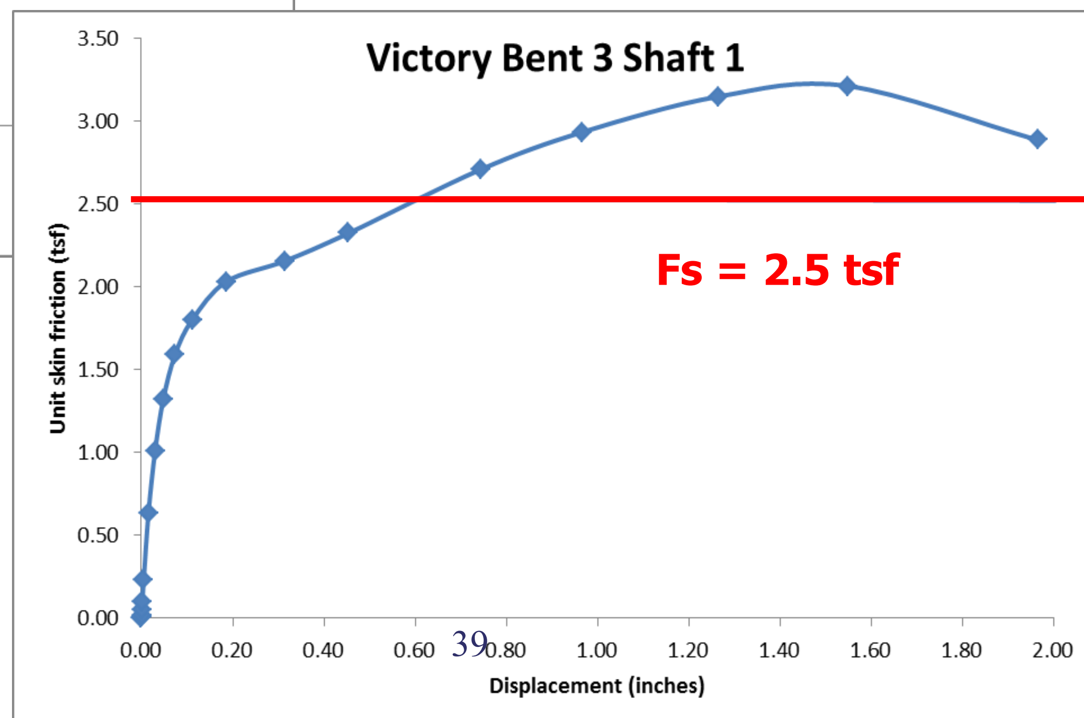
Task 1.4: Unit Side Resistance between Casing & Limestone Interface





Phase I

Civil & Coastal Engineering

Task 1.4: Unit Side Resistance between Casing & Limestone Interface

Project Name	Load Test Shaft	Load Test method	Top of LS (ft)	Bottom of Casing (ft)	Overlap (ft)	Diameter (ft)	fs (tsf)	Qu (tsf)	Qt (tsf)	REC (%)	RQD (%)
Gandy Bridge	Pier 26 Shaft 2*	O-cell	-9.00	-11.50	2.50	4	0.75	49.30	5.50	100	60
	Pier 52 Shaft 3	Statnamic	-23.00	-24.00	1.00	4	2.40	50.00	11.70	95	52
	Pier 91 Shaft 4	O-cell	-40.50	-43.00	2.50	4	1.69	42.22	7.00	80	45
	Pier 26 Shaft 1	Statnamic	-8.00	-8.94	0.94	4	2.30	141.00	11.50	100	65
Victory Bridge	Bent 3 Shaft 2*	O-cell	39.40	37.37	2.03	4	2.80	81.40	16.37	97	25
	Bent 3 Shaft 1*	O-cell	39.00	38.00	1.00	4	2.50	125.60	15.57	77	25
	Test Shaft #5	Statnamic	31.00	26.00	5.00	4	2.80	60.00	44.00	92	30
Hillsborough Avenue	Pier 4 Shaft 4-1	O-cell	-32.80	-37.80	5.00	4	0.65	11.40	4.75	85	40
	Pier 4 Shaft 4-2	O-cell	-37.80	-41.50	3.70	4	1.17	45.10	1.87	95	30
	Pier 5 Shaft 10	Statnamic	-35.00	-45.33	10.33	4	1.06	44.00	4.46	90	35
Lee Roy Selmon	Test Shaft #3*	Statnamic	-3.00	-7.40	4.40	4	2.40	54.00	12.50	100	40
17th Street	LTSO-1	O-cell	-61.35	-70.54	9.19	4	0.91	94.50	22.50	30	20
	LTSO-2	O-cell	-52.00	-70.54	18.54	4	0.23	23.00	16.00	23.5	22
Apalachicola River	Pier # 59, TS #8*	O-cell	-22.00	-25.00	3.00	9	0.82	10.00	2.20	60	60
Jewfish Creek	Test Shaft #1*	Statnamic	-10.50	-12.50	2.00	4	1.50	25.20	7.50	75	75
	Test Shaft #2*	Statnamic	-11.00	-13.50	2.50	4	0.75	37.60	7.30	70	70

Phase I

Task 1.4: Unit Side Resistance between Casing & Limestone Interface

Unit skin friction of uncased shafts

- The rock's cohesion, c, was found based on the rock strengths
  - $Cohesion, c = \frac{1}{2}\sqrt{q_u}\sqrt{q_t}$
- then the estimated unit skin friction (FDOT), f_{su}^*, for uncased shafts was found
- $$f_{su}^* = \frac{1}{2}\sqrt{q_u}\sqrt{q_t}(REC)$$

Phase I

Task 1.4: Unit Side Resistance between Casing & Limestone Interface

Civil & Coastal Engineering

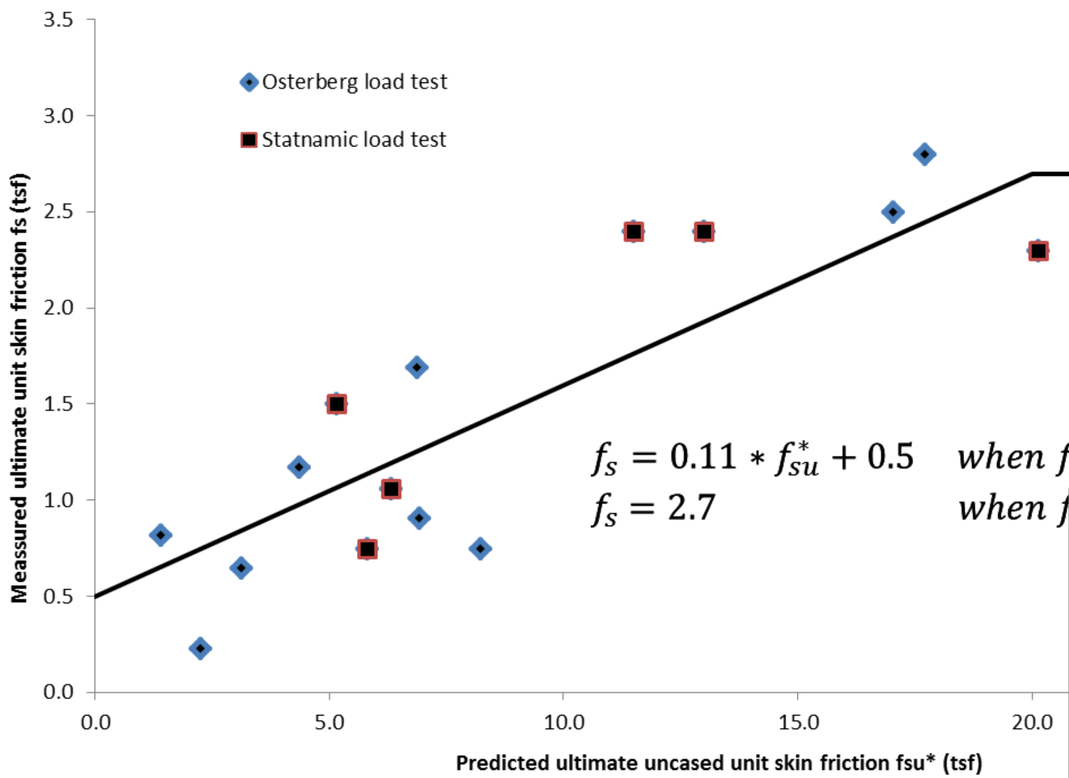


Figure (a). Measured unit skin friction f_s versus predicted f_{su}^* for Cased Drilled shaft Segments

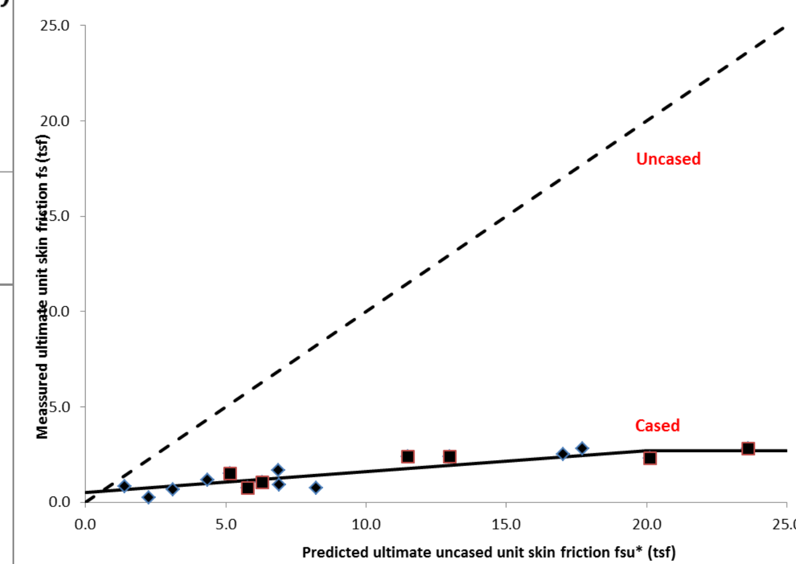


Figure (b). Comparison of uncased and cased drilled shaft segments

Thank You

Questions?