Implemented Changes to FB-Deep

FDOT BDV31-977-05

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Tasks: FBDEEP Driven Pile Capacity Estimation

1. Compare FBDEEP Side, Tip and Total H-pile Predictions with DLT data for Florida soils and rock; make recommendations for improvements

2. Compare FBDEEP Side, Tip and Total Prestressed Concrete Pile Predictions with DLT data in Florida Limestone; make recommendations for improvements

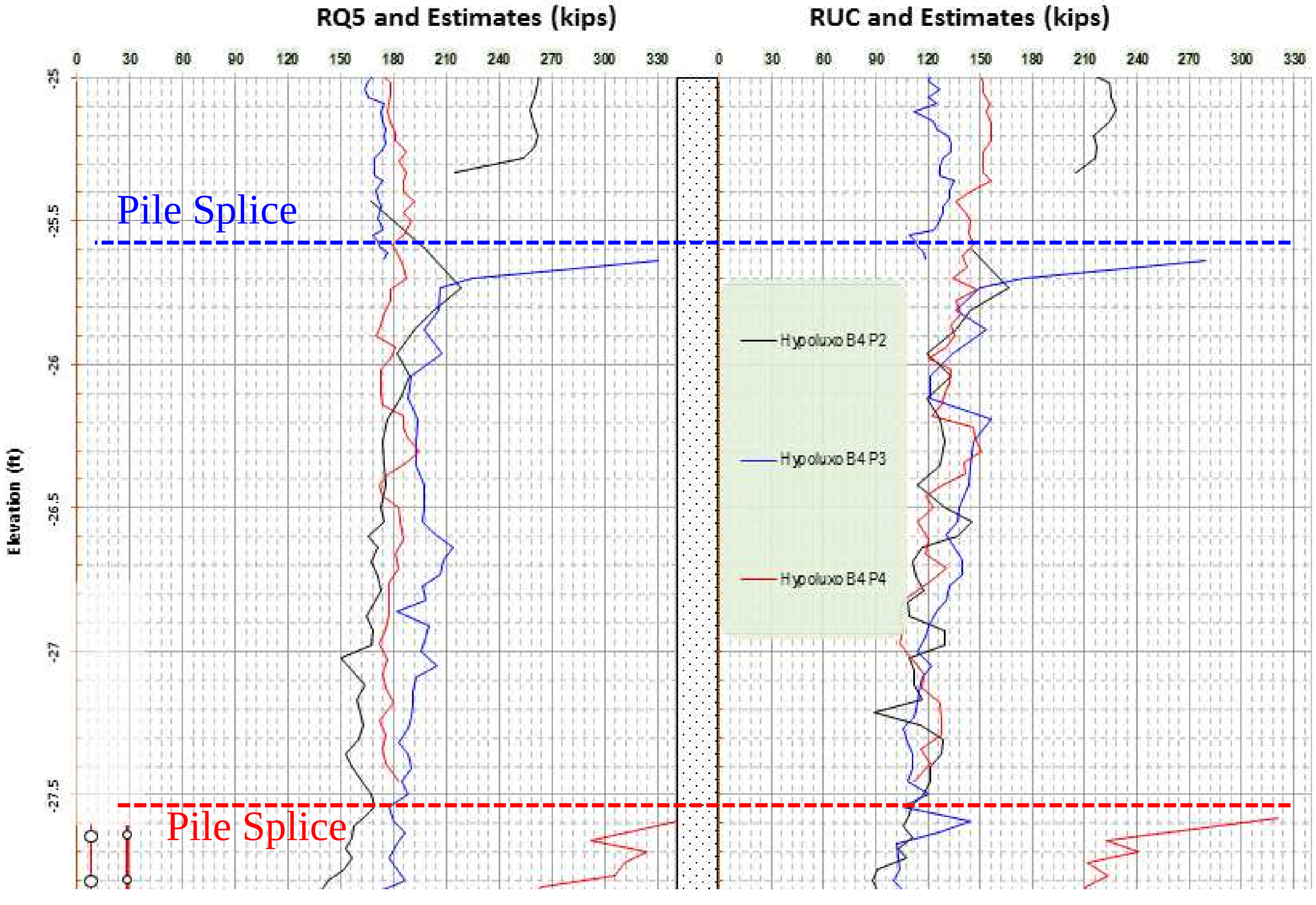
3. Compare FBDEEP Side, Tip and Total for Open Pipe Pile (24”< D< 54”) Predictions with Static and Statnamic Load Test Data; make recommendations for improvements as well as evaluate other methods (API)

H Pile Plug Conditions

Resumed driving (due to splicing) after 7 days:

Blow #0 (of the restrike) show incredible increase in Total Capacity

(Blow #0 is the soft blow in the restrike,
where the stroke height is displayed as 0 feet in Dynamic Testing software)



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Plug Conditions

During driving (EOD) the toe area may have been a half plug shape.

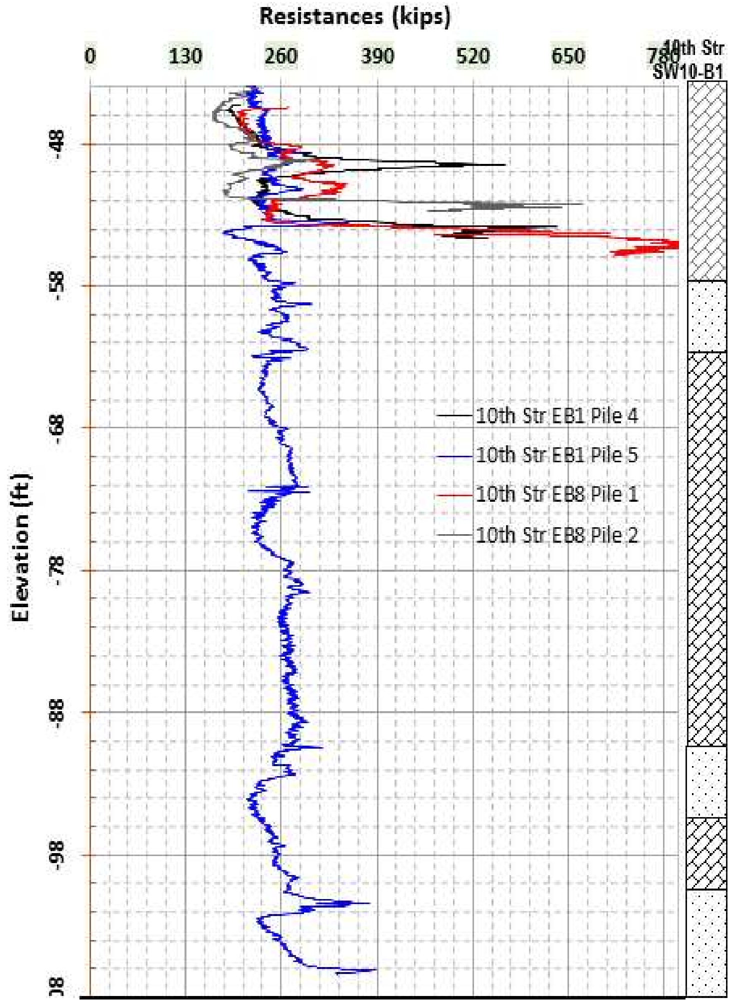
Due to setup (freeze) gains on skin frictions after a long wait time, the toe area is a full plugged box shape on BOR Blow #0,

Then the toe area is eroding away almost immediately to a half plug on the next immediate blows

→ reiterates opinions of Hannigan et al. (2006) and Holloway and Beddard (1995) that soil plug depends on hammer dynamic responses, and thus EOD DLT capacities are not the true pile capacities.

Static Load Tests in Texas (Coyle and Ungaro 1991) indicate Half Plug is the best configuration in static loading condition. This configuration is implemented on all soil types in FB-Deep

H-PILES FB-DEEP CHANGES (-CONT-)



SPT N limit: FB-Deep increase SPT N to100 for Limestone.

Change Tip Resistance Averaging to 4B below pile

FBDEEP Help – Version 2.05 H - Piles

The empirical equations for the ultimate side friction versus SPT blowcount, which are derived from the database, are as follows:

Soil Type	Soil Description	Unit Skin Friction (tsf)	SPT Blow Count Range
1	Plastic Clay	$f_s = 2 \cdot N \cdot (110 - N) / 5335.9$	$3 \le N \le 60$
2	Clay-silt-sand mixtures	$f_s = -0.0227 + 0.033 \cdot N - 4.576 \cdot 10^{-4} \cdot N^2 + 2.465 \cdot 10^{-6} \cdot N^3$	$3 \le N < 75$
3	Clean Sands	$f_s = 0.0112 \cdot N$	$3 \le N \le 60$
4	Soft limestone, very shelly sand	$f_s = 0.0076 \cdot N$	$3 \le N < 100$
5	Void	$f_s = 0.0$	n/a

The H-Pile circumference used for the skin friction calculation in all soil types (soil type 1, 2, 3, and 4, namely, clay, silt, sand , and limestone) is considering 50% plugged condition. Circumference = (3 ·Width + 2 ·Depth)

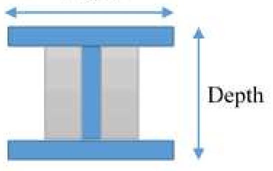


Figure 1. 50% plugged condition

The 'Width', and 'Depth' field can be seen in the 'Pile Geometry' table on the program's main screen.

END BEARING

The empirical equations (for the five soil types) for the plots of the mobilized unit end bearing capacity versus SPT blow count are presented as follows:

Soil Type	Soil Description	Unit End Bearing (tsf)	SPT Blow Count Range
1	Plastic Clay	$q_t = 0.7 \cdot N / 3$	$3 \le N \le 60$
2	Clay-silt-sand mixtures	$q_t = 1.6 \cdot N / 3$	$3 \le N < 60$
3	Clean Sands	$q_t = 3.2 \cdot N / 3$	$3 \le N \le 60$
4	Soft limestone, very shelly sand	$q_t = 3.6 \cdot N / 3$	$3 \le N < 100$
5	Void	$q_t = 0.0$	n/a

The methodology used to calculate the end bearing capacity for a given depth includes no critical depth correction, and the end bearing contribution zone of 4B below the pile tip only.

For H-Pile end bearing calculations in all soil types (soil type 1, 2, 3, and 4, namely, clay, silt, sand , and limestone), 50% plugged condition is considered. Half of the product of the user-inputted 'Width' and 'Depth' is used to calculate the pile tip area (Pile Tip Area = 0.5 x Width x Depth).

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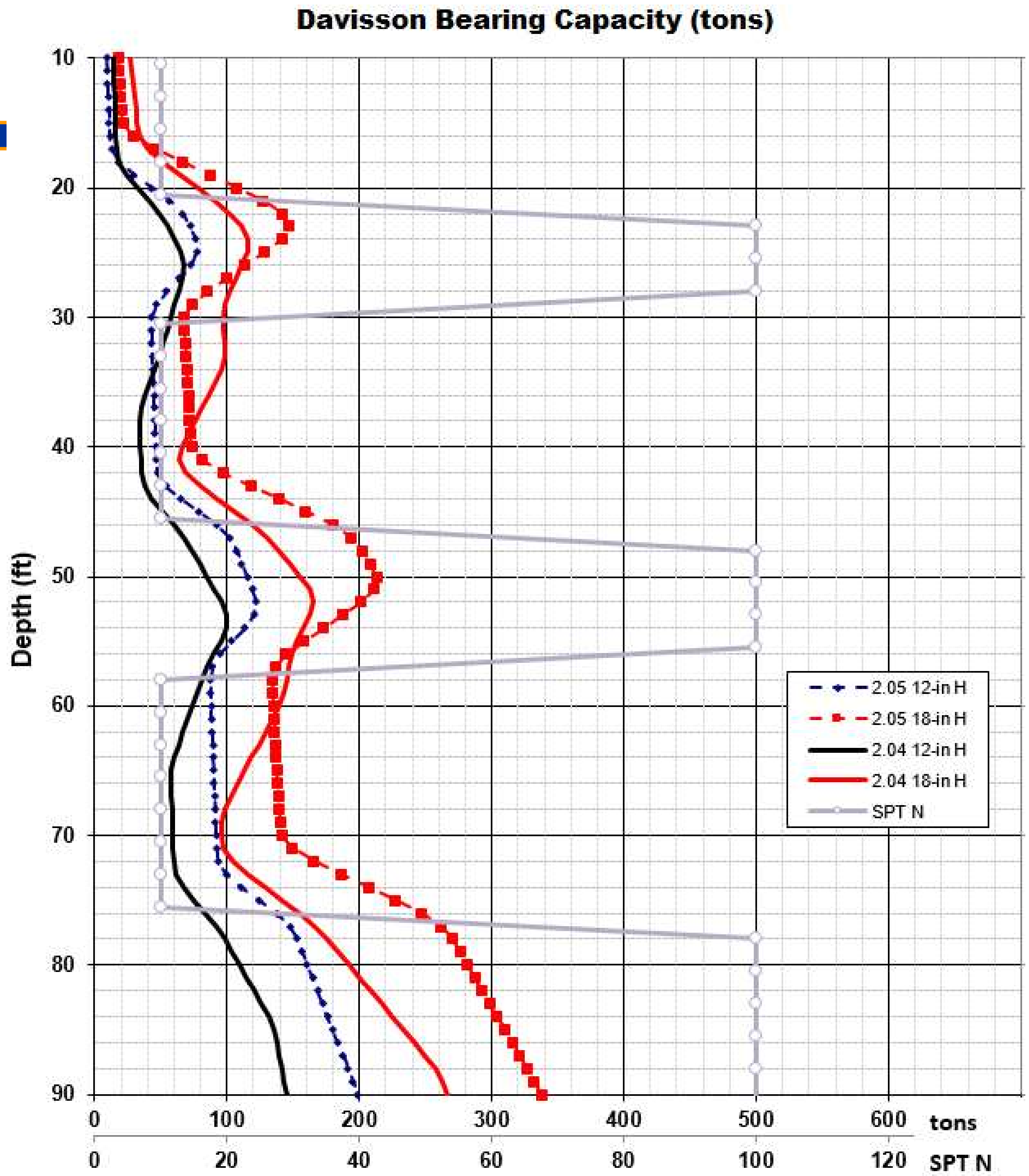
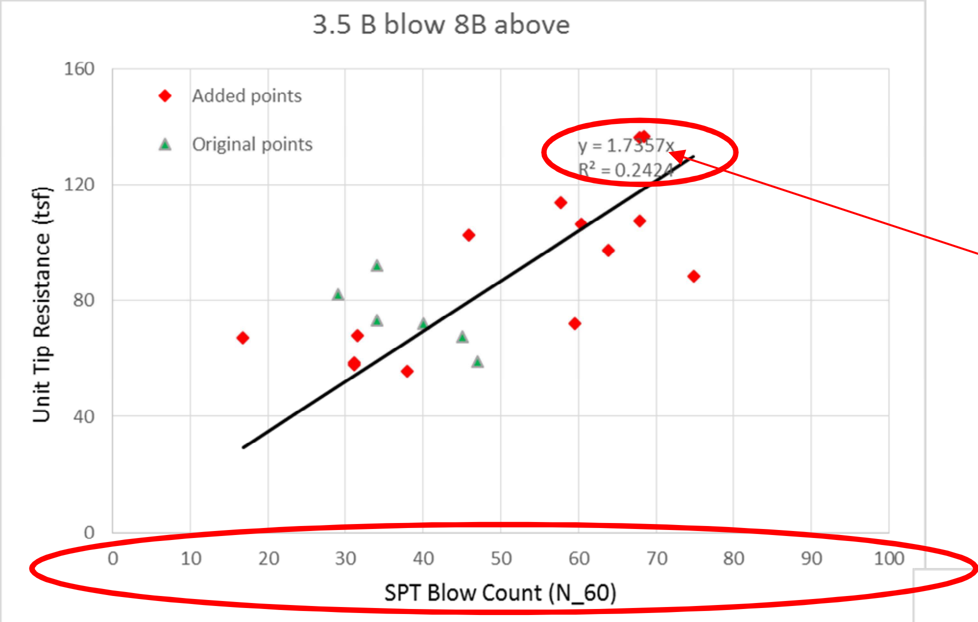
- V2.05 gives slightly higher resistances
- Actual pile behavior: H piles can punch through 2.5-ft of hard limestone (N=100), but upon a thick reliable limestone layer of 8 to 10-ft, it can get refusal, so V2.05 is still conservative, and V2.04 is definitely too conservative



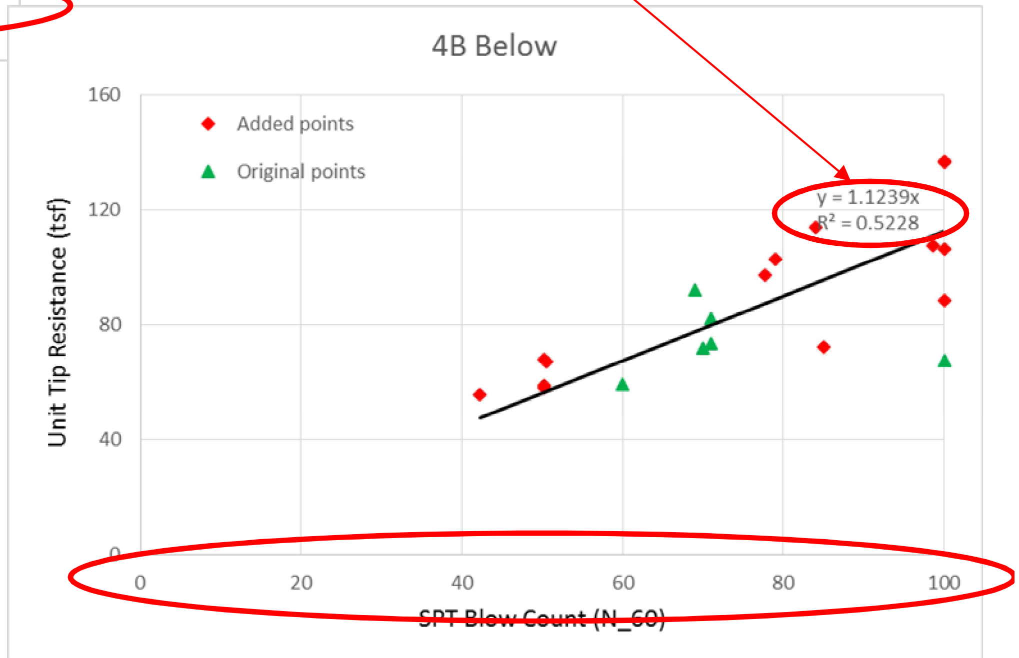
Collection of Concrete Piles in Florida Limestone Provided by Districts

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
242484-2-52-01	I-4/SR 408	58	Sand	18 & 24	90-107	112	N/A
210448-2-52-01	San Sebastian Bridge	11	Sand & Clay	24	38-111	111	N/A
211449-1-52-01	CR 229 over South Prong of St Mary's Ri	2	Sand & Clay	18	47-90	9	N/A
209293-2-52-01, 209294-1-52-01, 209294-9-52-01	SR 9B	121	Sand & Some Rock	24	45-119	183	N/A
208166-1-52-01	Plantation Oaks Boulevard over SR23	50	Sand & Rock	18	55-100	10	2
208466-2-52-01	SR 51	6	Clay & Rock	24	73-99	5	0
420809-3-52-01	I-595 Corridor Improvement Project	234	Sand & Rock	18 & 24	30-115	170	38
213304-3-52-01	I-95 Overland Bridge Replacement	133	Sand & Rock	24	22-66	5	2
406813-6-52-01	CR 245 over Olustee Creek	10	Sand & Rock	24	61-69	7	0
210687-3-52-01	SR 200 North of Callahan	11	Clay & Rock	24	36-66	25	9
429551-1-52-01	SR 200 South of Callanha	31	Sand & Rock	24	46-111	33	N/A
	I-95 over Snake Creek						4
249581-1-52-01	SR 826/836	17	Sand & Rock	24 & 30	80-110	177	20
	Total # of Soil Borings:	684	Total # of Piles with CAPWAP Data:			847	75
	Total # of Piles with Limestone Bearing Layer & BOR CAPWAP Analysis:					79	

PCP End Bearing in Competent Limestone (N >45)



$q_{tip,dav} = 3.6\ N/3 = 1.2\ N$



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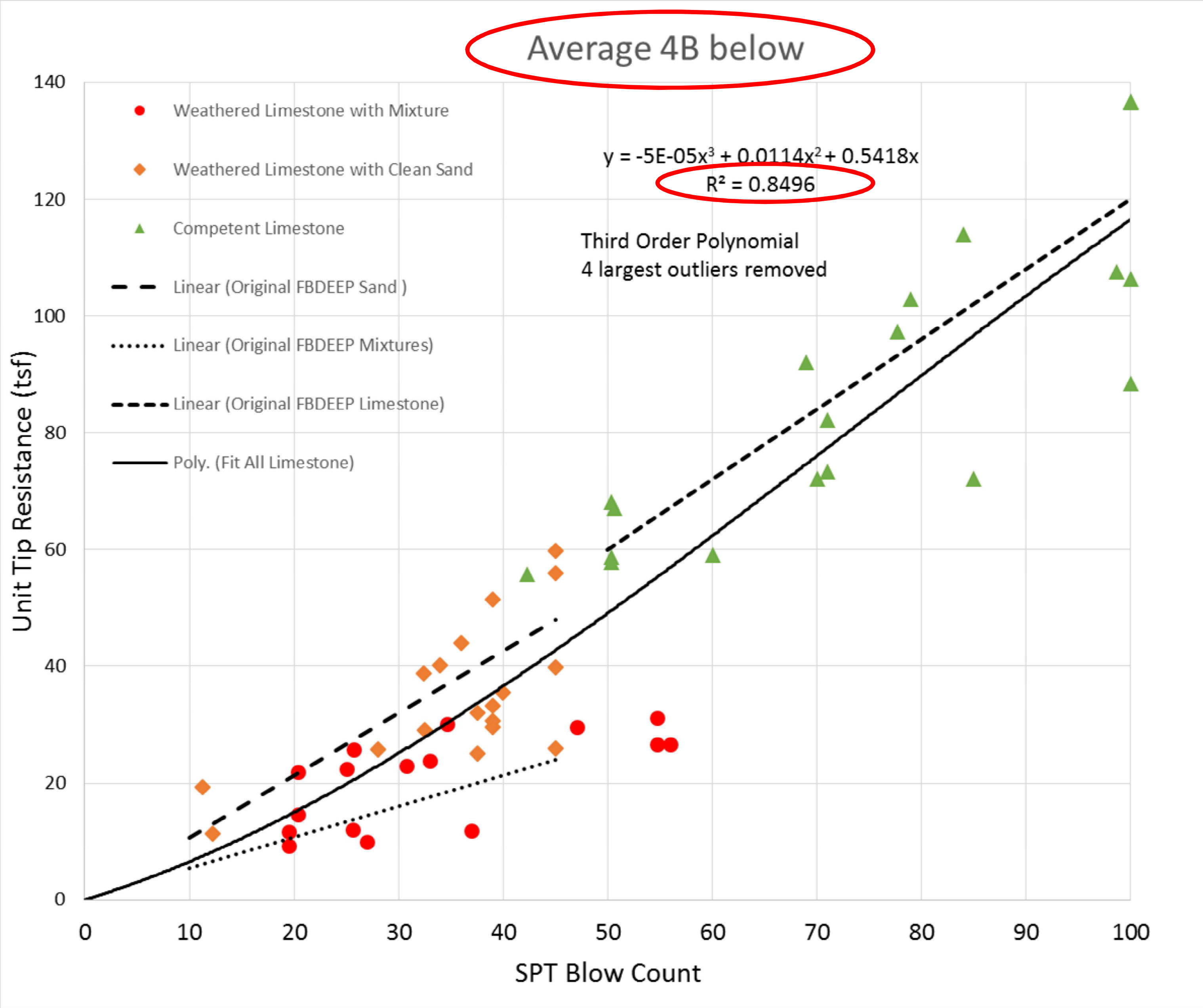
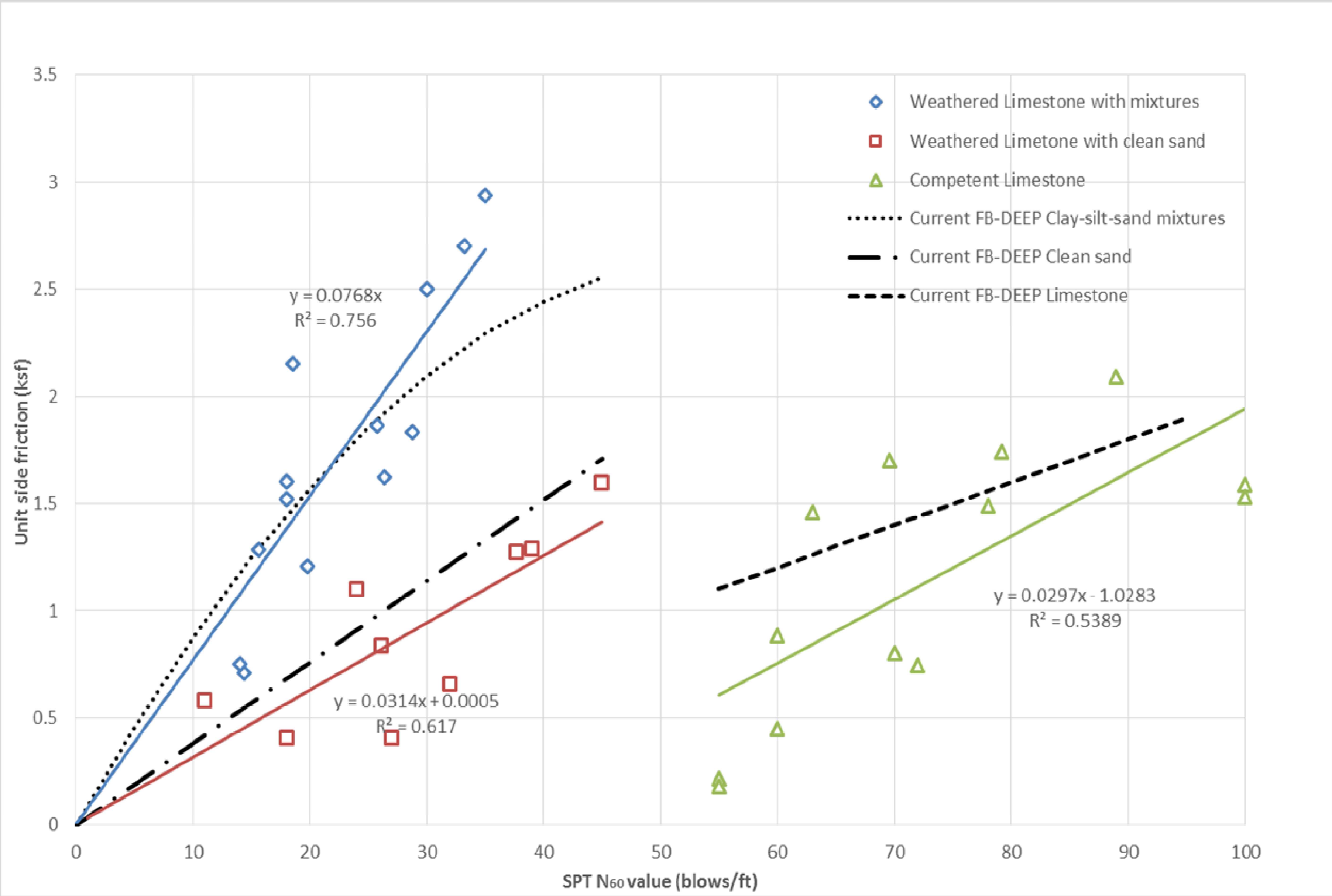
PCP End Bearing in Limestone



PCP Side Friction in Limestone



Summary of Changes to FB-Deep for PCP in Limestone

1. PCP End Bearing:

- Change Averaging from 3.5B-8B to 4B Below
- Developed New Unit Tip Resistance vs. SPT N Value
- Increase Limit of SPT N value to 100 Due to higher measured DLT tip resistances

2. PCP Side Resistance:

- PCPs in Limestone with mixed soils with N <45 is conservative (may wish to model Mixture with soil 2)
- PCP in competent Limestone, Limit of N=60 too conservative increase to N=100

FB-DEEP Help 2.05 Prestressed Concrete Piles

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SIDE FRICTION

Unit side friction at a given depth is also based on the type of soil and the corresponding SPT blowcount. The following table shows the empirically derived equations for ultimate unit side friction versus blowcount for the four soil types.

Soil Type	Soil Description	Unit Skin Friction (tsf)	SPT Blow Count Range
1	Plastic Clay	$f_s = 2 \cdot N \cdot (110 - N) / 4006.6$	$3 \le N \le 60$
2	Clay-silt-sand mixtures	$f_s = 2 \cdot N \cdot (110 - N) / 4583.3$	$3 \le N \le 60$
3	Clean Sands	$f_s = 0.019 \cdot N$	$3 \le N \le 60$
4	Soft limestone, very shelly sand	$f_s = 0.01 \cdot N$	$3 \le N \le 100$
5	Void	$f_s = 0.0$	n/a

To convert TSF to kPa multiply the f_s by 95.76.

END BEARING

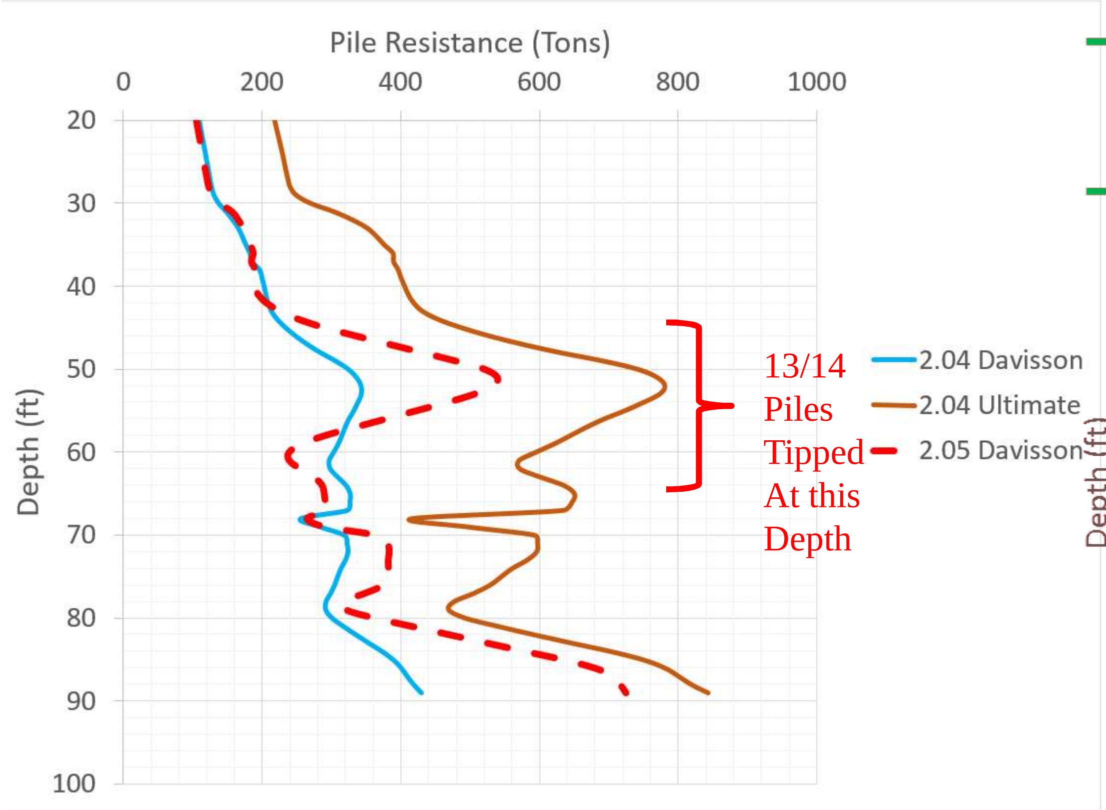
Unit end bearing at a given depth is based on the type of soil and the corresponding SPT blowcount. The following table shows the empirically derived equations for mobilized unit end bearing versus blowcount for the four soil types.

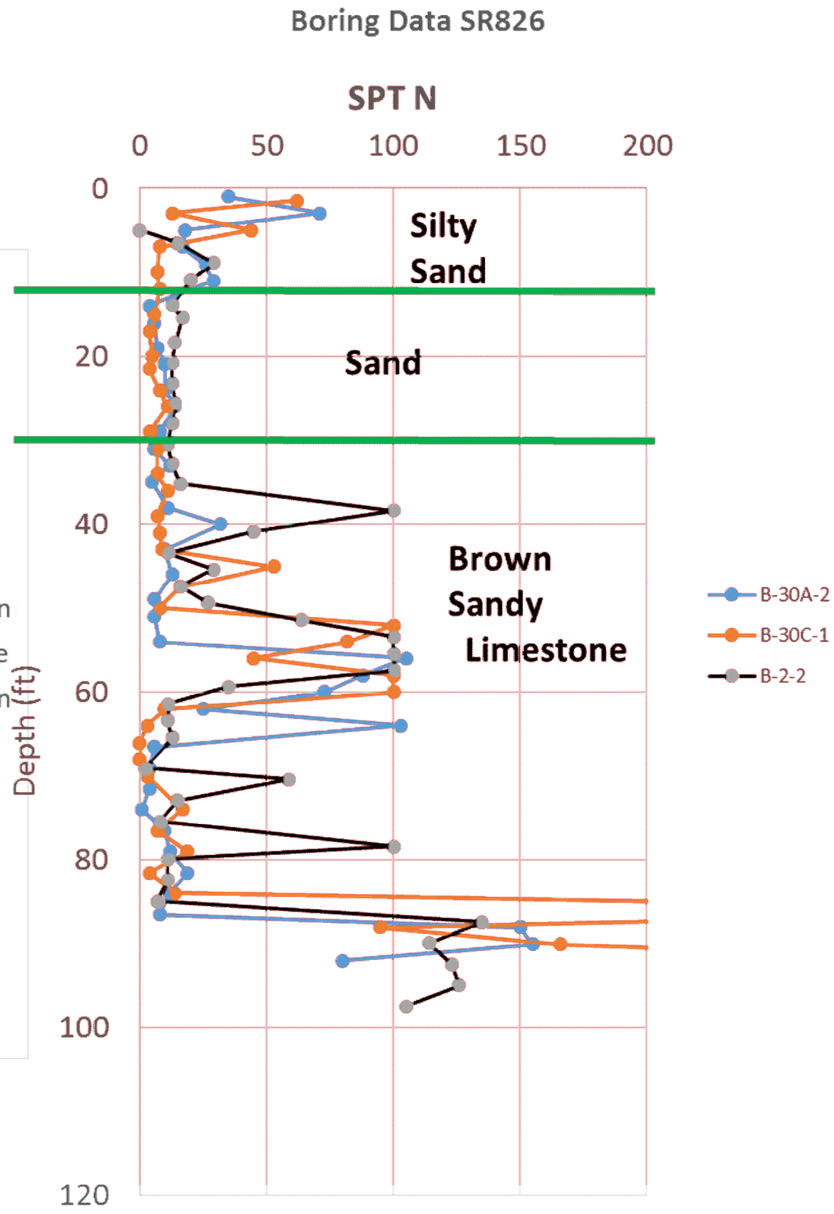
Soil Type	Soil Description	Unit End Bearing (tsf)	SPT Blow Count Range
1	Plastic Clay	$q_t = 0.7 \cdot N / 3$	$3 \le N \le 60$
2	Clay-silt-sand mixtures	$q_t = 1.6 \cdot N / 3$	$3 \le N \le 60$
3	Clean Sands	$q_t = 3.2 \cdot N / 3$	$3 \le N \le 60$
4	Soft limestone, very shelly sand	$q_t = 0.7873 \cdot N + 0.0026 \cdot N^2 + 1 \cdot 10^{-5} \cdot N^3$	$3 \le N \le 100$
5	Void	$q_t = 0.0$	n/a

To convert TSF to kPa multiply the q_t by 95.76.

The methodology used to calculate the end bearing capacity for a given depth includes the critical depth correction, and the end bearing contribution zone of 8B above and 3.5B below the pile tip is considered. Exception is when the PCP tip is in Limestone, the end bearing contribution zone of 4B below the pile tip only is considered and critical depth correction in not performed.

Impact of FB-DEEP Change – Consider SR826:
- 24" PCP Pile Tip Elevation





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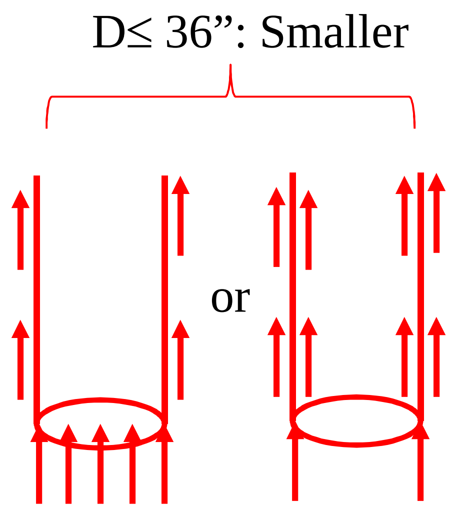
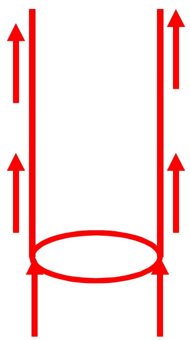
Open Diameter Pipe Piles 24”<D<54”

Current FBDEEP:



1. **D ≤ 36”**
   - **Qs = unit skin friction x A $_{\text{outside surface area}}$**
   - **Q_{tip} = smaller of unit tip resistance x$A_{\text{tip total}}$ or unit skin friction x A $_{\text{outside}}$ + unit tip resistance x A_{ring} (API Approach)**



2. **D > 36”:**
   - **Qs = unit skin friction x A $_{\text{outside surface area}}$**
   - **Q_{tip} = unit tip resistance x A_{ring}**

Should D≤ 36” Be Used for D>36”?

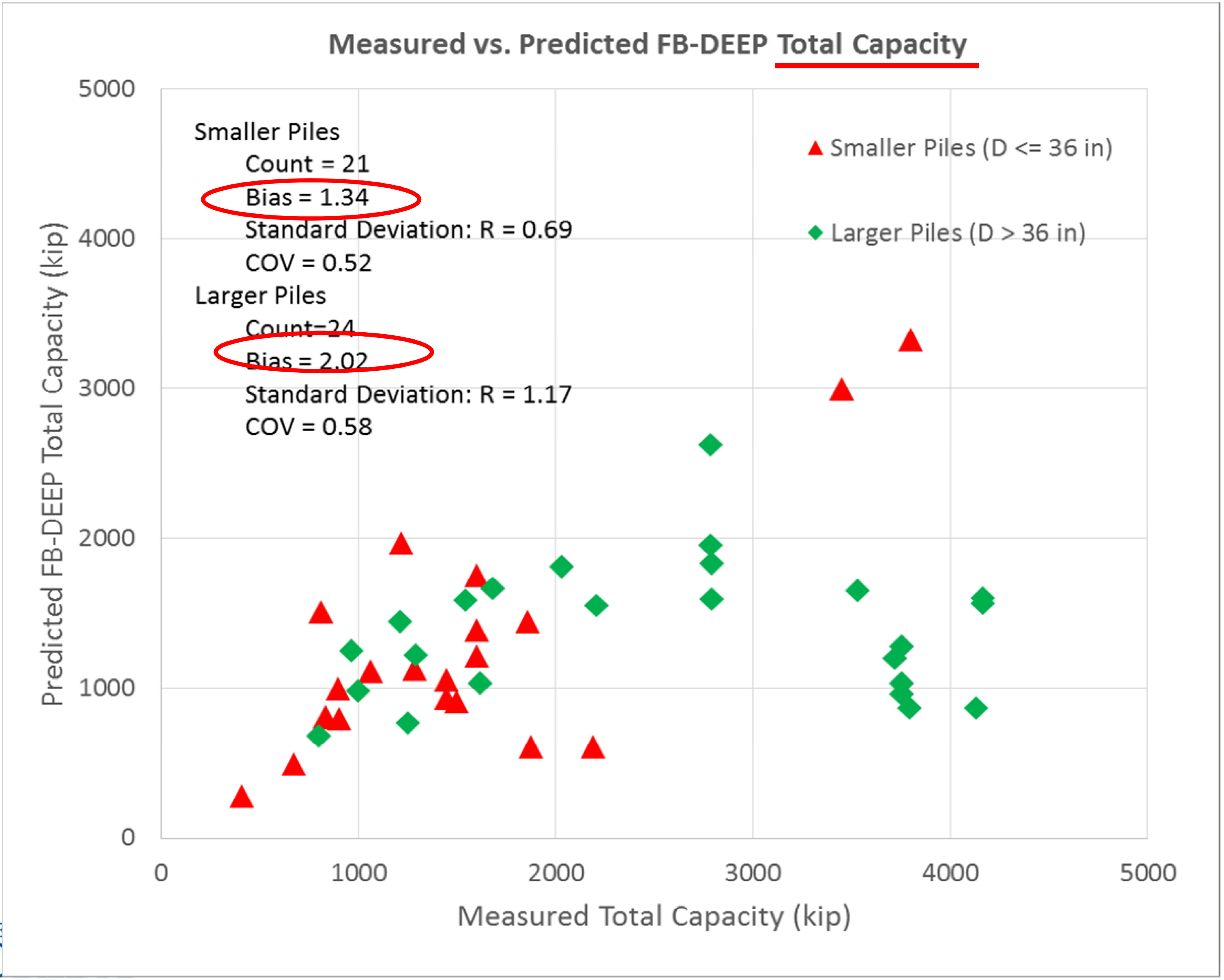
Open Diameter Pipe Piles 24”<D<54”

Project Name	Pile Name	Diam (in)	Thickness (in)	Plug %	Pile length(ft)	Pile Bottom Depth(ft)	Boring Name	Distance(ft)	Soil Type								Load Test(kips)
									Clay		Sand		Clay-Silt-Sand		Rock		
									Depth Range(ft)	Percentage	Depth Range(ft)	Percentage	Depth Range(ft)	Percentage	Depth Range(ft)	Percentage	
Louisiana Highway 1 Improvements Phase 1B, LA, USA	T-3-1	30	0.63	>0.44 WH	195.00	173.20	BR-002	80.00	34-54	11.43%			0-34&54-175	88.57%			1597.00 [1]
I-880 Port of Oakland Connector Viaduct (Caltrans Bridge No. 33-0612E), CA, USA	TP-9	42	0.63	>0.4 WH	88.30	86.30	Generalized Borin	Unknown	0-13.5&18.5-60&67-90.5	86.74%	13.5-18.5&60-67	13.26%					1253.00 [1]
							UTB-23MR	Unknown	61.25-66.50	5.52%			0-61.25&66.50-95.01	94.48%			963.40 [2]
Woodrow Wilson Bridge over Potomac River, VA & MD, USA	PL-1	54	1.00	>0.9	165.20	132.20	ID_63 UNK	Unknown	2.5-13&43-51&66-137	69.71%	0-2.5&13-41&51-57	26.64%	41-43&57-66	3.65%			2783.00 [1]
							ID_64 UNK	Unknown	0-10.2&25.5-44.5&94.5-104.7&115.5-141.7	46.30%	10.2-20.5&59.5-74.5&84.5-94.5&104.79-115.5	32.70%	20.5-25.5&44.5-59.5&74.5-84.5	21.35%			
	PL-2	42	1.00	>0.9	125.50	107.00	ID_64 UNK	Unknown	0-10.2&25.5-44.5&94.5-104.7	35.02%	10.2-20.5&59.5-74.5&84.5-94.5&104.79-112.5	38.31%	20.5-25.5&44.5-59.5&74.5-84.5	26.67%			2788.00 [1]
							ID_65 UNK	Unknown	84-108	22.22%	7-12&62-67	9.26%	0-7&12-18&23-28&38-62&67-84	54.63%	18-23&28-38	13.89%	
	PL-3	36	1.00	>0.9	96.30	78.00	ID_64 UNK	Unknown	0-10.2&25.5-44.5	34.56%	10.2-20.5&59.5-74.5	29.94%	20.5-25.5&44.5-59.5	35.50%			1597.00 [1]
							ID_65 UNK	Unknown			7-12&62-67	12.35%	0-7&12-18&23-28&38-62&67-81	65.43%	18-23&28-38	22.22%	
Berenda Slough Bridge (Clatrans Bridge No. 41-	TP-1	42	0.63		106.00	103.00	Generalized Borin	50.00			0-60.5&70.5-77	62.62%	60.5-70.5&77-107	37.38%			1618.00 [1]
Gulf Intracoastal Waterway West Closure Complex Test Site 3, LA, USA	TP-9	24	0.50	>0.5	189.83	169.92	ALGS GS-08-2U	150.00					0-177.4	100.00%			811.20 [1]
	TP-11	30	0.63	>0.5 VH	190.00	177.42	ALGS GS-08-2U	150.00					0-179.9	100.00%			1215.00 [1]
Gulf Intracoastal Waterway West Closure Complex, LA, USA	TP-3	30	0.63	>0.5 VH	160.50	141.02	ALGS GS-08-13	Unknown	0-169.3	100.00%							830.40 [1]
	TP-4	30	0.63	>0.4 WH	170.30	162.50		Unknown	0-169.3	100.00%							1060.00 [1]
	TP-5	30	0.63	>0.35 WH	161.00	140.33		Unknown	0-169.3	100.00%							899.60 [1]
	TP-6	30	0.63	>0.35 WH	150.00	140.25		Unknown	0-169.3	100.00%							830.40 [1]
Lagoon Bridge U.S.68/KY80, KY, USA	TPL-2	30	1.00	>1	97.10	80.10	B-3004 UNK	110.50	0-20.3&54.3-59.3	29.69%			20.3-54.3&59.3-85.2	70.31%			1443.00 [1]
							B-3051 UNK	52.50	18.7-24.2	6.79%					0-18.7&24.2-81	93.21%	
US Highway TH61/Mississippi River, MN,	TP-10	42	0.88	>0.3	194.00	190.00	B-09UNK	Unknown	18-64&99-13	45.26%	0-18&64-99	27.89%			139-190	26.84%	4116.00 [3]
							B-10UNK	Unknown	27-72&97-13	42.11%	0-27&72-97	27.37%			132-190	30.53%	
T.H. 36 over the St. Croix River, MN, USA	P-B-1	24	0.50	conc fill	127.70	86.90	T-205	Unknown			0-89	100.00%					1875.00 [3]
	P-B-2	24	0.63	conc fill	127.40	86.60		Unknown			0-89	100.00%					2190.00 [3]
	P-B-3	42	0.88	.7 conc fill	140.00	140.00		Unknown			0-89	62.68%			89-142	37.32%	4128.00 [3]
	P-B-4	42	0.75	.7 conc fill	140.00	140.00		Unknown			0-89	62.68%			89-142	37.32%	3750.00 [3]
TH19 over the Mississippi River, MN, USA	TP-3	42	0.88	>0.9	150.00	96.00	T12 UNK	Unknown	57-67	10.20%	0-57&67-98	89.80%					3750.00 [3]
	TP-5	42	0.88	>0.9	170.00	118.00	T12 UNK	Unknown	57-67	7.81%	0-57&67-118	84.38%			118-128	7.81%	3854.00 [3]
							T19 UNK	Unknown			0-121.8	100.00%					

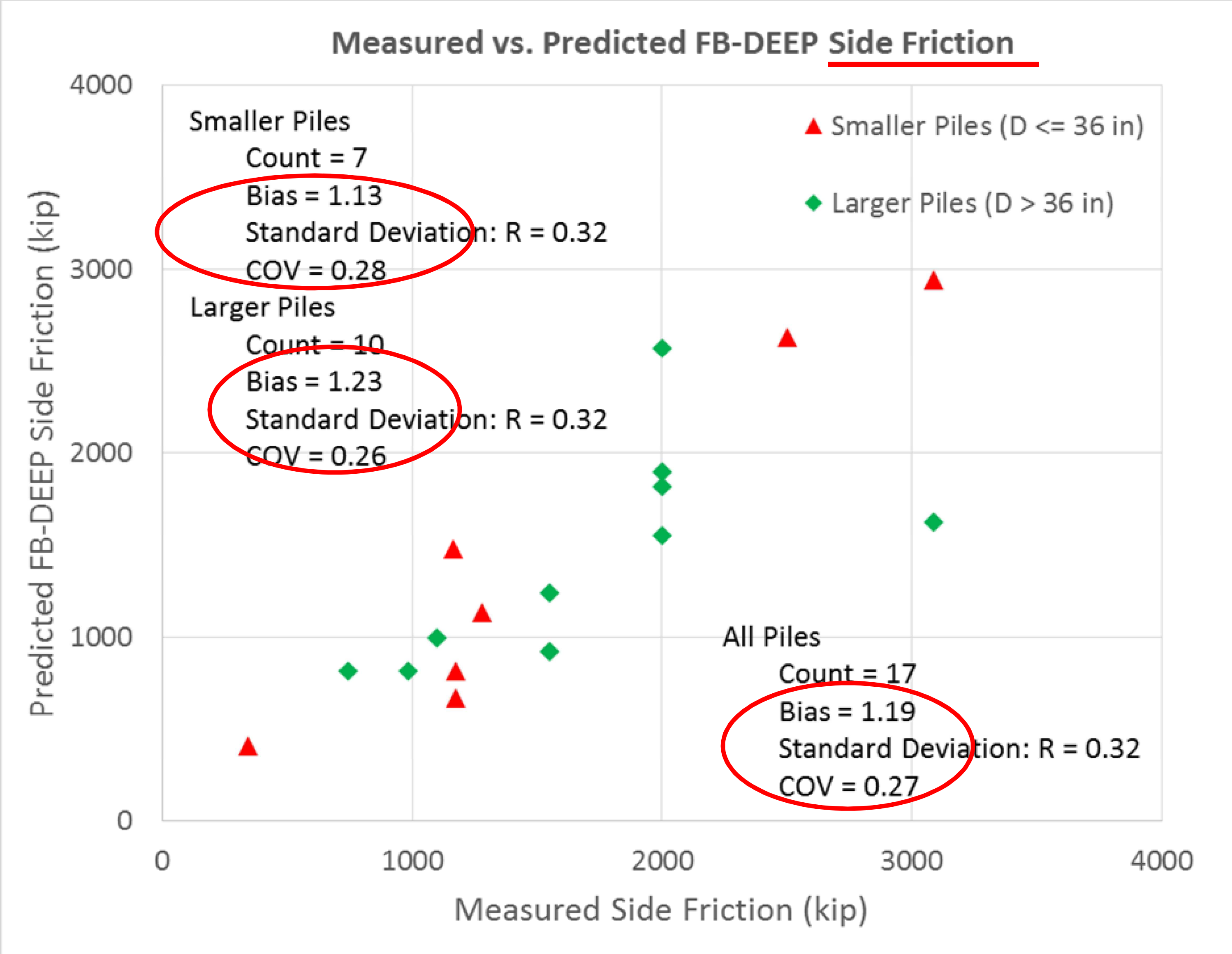
Measured vs. Predicted (Version 2.04)

Project Name	Pile Name	Diameter (in)	Boring Name	Predicted Capacity (kips)			Measured Capacity (kips)			Capwap Capacity (kips)		
				Side Friction	Tip Resistance	Total Capacity	Side Friction	Tip Resistance	Total Capacity	Side Friction	Tip Resistance	Total Capacity
Louisiana Highway 1 Improvements Phase 1B, LA, USA	T-3-1	30	BR-002	1482.00	270.00	1752.00	1163.80	433.20	1597.00	843.00	115.00	958.00
I-880 Port of Oakland Connector Viaduct (Caltrans Bridge No. 33-0612E), CA, USA	TP-9	42	Generalized Boring	754.00	15.00	769.00			1253.00			
			UTB-23MR	1234.52	18.62	1253.14			963.40			
Woodrow Wilson Bridge over Potomac River, VA & MD, USA	PL-1	54	ID_63 UNK	1900.00	52.00	1952.00	2000.00	783.00	2783.00			
			ID_64 UNK	2572.00	50.50	2622.50	2000.00	783.00	2783.00			
	PL-2	42	ID_64 UNK	1555.00	44.20	1599.20	2000.00	788.00	2788.00			
			ID_65 UNK	1816.00	17.16	1833.16	2000.00	788.00	2788.00			
	PL-3	36	ID_64 UNK	811.16	406.50	1217.66			1597.00			
			ID_65 UNK	976.40	410.40	1386.80			1597.00			
Berenda Slough Bridge (Clatrans Bridge No. 41-0009R),CA, USA	TP-1	42	B-1(Generalized Boring)	1022.84	15.74	1038.58			1618.00			
Gulf Intracoastal Waterway West Closure Complex Test Site 3, LA, USA	TP-9	24	ALGSGS-08-2U	1354.66	158.44	1513.10			811.20	1152.00	49.00	1201.00
	TP-11	30	ALGSGS-08-2U	1784.00	186.30	1970.30			1215.00	1286.00	130.00	1416.00
Gulf Intracoastal Waterway West Closure Complex, LA, USA	TP-3	30	ALGSGS-08-13U	730.00	80.64	810.64			830.40	867.00	72.00	939.00
	TP-4	30		1012.00	100.70	1112.70			1060.00	1080.00	25.00	1105.00
	TP-5	30		720.00	80.00	800.00			899.60	814.00	42.00	856.00
	TP-6	30		722.00	80.30	802.30			830.40	876.00	74.00	950.00
Lagoon Bridge U.S.68/KY80, KY, USA	TPL-2	30	B-3004 UNK	814.00	241.42	1055.42	1174.79	268.71	1443.00	593.00	74.00	667.00
			B-3051 UNK	672.00	266.40	938.40	1174.79	268.71	1443.00			
US Highway TH61/Mississippi River, MN, USA	TP-10	42	B-09UNK	1539.34	25.58	1564.92			4166.00			
			B-10UNK	1565.00	39.22	1604.22			4166.00			
T.H. 36 over the St. Croix River, MN, USA	P-B-1	24	T-205	409.58	204.46	614.04			1875.00	181.00	884.00	1065.00
	P-B-2	24		409.58	204.00	613.58	343.00	1847.00	2190.00	217.00	1029.00	1246.00
	P-B-3	42		815.40	52.74	868.14	983.00	3145.00	4128.00	797.00	2352.00	3149.00
	P-B-4	42		815.40	52.74	868.14	746.00	3044.00	3790.00	1014.00	2271.00	3285.00
TH 19 over the Mississippi River, MN, USA	TP-3	42	T12 UNK	997.72	34.78	1032.50	1100.00	2650.00	3750.00			
	TP-5	42	T12 UNK	1238.32	37.92	1276.24	1550.00	2200.00	3750.00			
			T19 UNK	924.00	42.80	966.80	1550.00	2200.00	3750.00			
T.H. 43 over the Mississippi River, MN, USA	TP-1	42	T-103	1172.61	26.35	1198.96			3720.60	1225.00	1610.00	2835.00
Port of Oakland Connector Viaduct Maritime On/Off-Ramps (Caltrans Bridge No. 33-612E), CA, USA	TP3-10NCI	42	UTB-161	666.64	13.24	679.88			800.00	655.00	296.00	951.00
	TP6-17NCI	42	UTB-24A	966.00	17.26	983.26			1000.00	806.00	246.00	1052.00
	TP9-27NCI	42	UTB-05	1204.00	17.80	1221.80			1288.00			
Legislative Route 795 section B-6 Philadelphia, PA, USA	TP-C	30	PLT-C	730.40	185.36	915.76			1499.30			
	TP-D	30	B-620	871.78	129.48	1001.26			895.78			
	TP-E	30	PLT-E	980.26	145.22	1125.48			1282.00			
Jin Mao Building, Shanghai, China	ST-1	36	Generalized Boring	2629.00	370.84	2999.84	2502.35	946.22	3447.00			
	ST-2	36		2944.30	381.80	3326.10	3085.28	566.74	3796.80			
Hokkaido, Japan	TP-1	40	B-1 Or Generalized Boring	1624.00	27.18	1651.18	3089.00	441.00	3528.00			
Chiba, Japan	TP-2	31.5	B-2(Generalized Boring)	1137.10	310.60	1447.70	1278.00	618.75	1855.00			
Kwangyang Substitute Natural Gas (SNG) Plant, KOREA	TP-2	28	BH1 Or Generalized Boring	219.00	64.00	283.00			407.00			
	TP-3	36	BH1 Or Generalized Boring	407.04	89.44	496.48			674.00			
Port of Toamasina Offshore Jetty, Republic of Madagascar	4B	40	NP-02	1532.00	23.00	1555.00			2205.00	619.35	400.00	1019.35
	12A	40	NP-04	1785.11	25.50	1810.61			2029.00	156.02	388.00	544.02
	SP05	48	BH-SP	1388.82	57.24	1446.06			1213.00	380.40	348.00	728.40

FB-DEEP (Version 2.04) Predictions



Current FB-DEEP Predictions



Modify FB-DEEP D>36” End Bearing to Same as D≤36”

Project Name	Pile Name	Diameter (in)	Boring Name	Side Friction (kips)		Tip Resistance (kips)		Total Capacity (kips)		
				Outer Skin	Inner Skin	Ring Tip	Full Tip	Outer Skin + Inner Skin + Ring	Outer Skin + Full Tip	Measured
Louisiana Highway 1 Improvements Phase 1B, LA, USA	T-3-1	30	BR-002	1482.00	1420.25	22.03	270.00	2924.28	1752.00	1597.00
I-880 Port of Oakland Connector Viaduct (Caltrans Bridge No. 33-	TP-9	42	Generalized Boring	754.00	731.56	15.00	255.81	1500.56	1009.81	1253.00
			UTB-23MR	1234.52	1197.78	18.62	317.54	2450.92	1552.06	963.40
Woodrow Wilson Bridge over Potomac River, VA & MD, USA	PL-1	54	ID_63 UNK	1900.00	1829.63	52.00	715.25	3781.63	2615.25	2783.00
			ID_64 UNK	2572.00	2476.74	50.50	694.61	5099.24	3266.61	2783.00
	PL-2	42	ID_64 UNK	1555.00	1480.95	44.20	475.42	3080.15	2030.42	2788.00
			ID_65 UNK	1816.00	1729.52	17.16	184.57	3562.68	2000.57	2788.00
	PL-3	36	ID_64 UNK	811.16	766.10	43.91	406.50	1621.17	1217.66	1597.00
			ID_65 UNK	976.40	922.16	44.33	410.40	1942.89	1386.80	1597.00
Berenda Slough Bridge (Clatrans Bridge No. 41-0009R),CA, USA	TP-1	42	B-1(Generalized Boring)	1022.84	992.40	15.74	268.43	2030.98	1291.27	1618.00
Gulf Intracoastal Waterway West Closure Complex Test Site 3, LA, USA	TP-9	24	ALGSGS-08-2U	1354.66	1298.22	12.93	158.44	2665.80	1513.10	811.20
	TP-11	30	ALGSGS-08-2U	1784.00	1709.67	15.20	186.30	3508.87	1970.30	1215.00
Gulf Intracoastal Waterway West Closure Complex, LA, USA	TP-3	30	ALGSGS-08-13U	730.00	699.58	6.58	80.64	1436.16	810.64	830.40
	TP-4	30		1012.00	969.83	8.22	100.70	1990.05	1112.70	1060.00
	TP-5	30		720.00	690.00	6.53	80.00	1416.53	800.00	899.60
	TP-6	30		722.00	691.92	6.55	80.30	1420.47	802.30	830.40
Lagoon Bridge U.S.68/KY80, KY, USA	TPL-2	30	B-3004 UNK	814.00	759.73	31.12	241.42	1604.85	1055.42	1443.00
			B-3051 UNK	672.00	627.20	34.34	266.40	1333.54	938.40	1443.00
US Highway TH61/Mississippi River, MN, USA	TP-10	42	B-09UNK	1539.34	1475.20	25.58	313.49	3040.12	1852.83	4166.00
			B-10UNK	1565.00	1499.79	39.22	480.65	3104.01	2045.65	4166.00
T.H. 36 over the St. Croix River, MN, USA	P-B-1	24	T-205	409.58	392.51	16.70	204.46	818.79	614.04	1875.00
	P-B-2	24		409.58	388.25	20.70	204.00	818.53	613.58	2190.00
	P-B-3	42		815.40	781.23	52.74	642.75	1649.37	1458.15	4128.00
	P-B-4	42		815.40	786.28	52.74	751.78	1654.42	1567.18	3790.00
TH 19 over the Mississippi River, MN, USA	TP-3	42	T12 UNK	997.72	955.91	34.78	423.87	1988.41	1421.59	3750.00
	TP-5	42	T12 UNK	1238.32	1186.43	37.92	462.14	2462.67	1700.46	3750.00
			T19 UNK	924.00	885.28	42.80	521.61	1852.08	1445.85	3750.00

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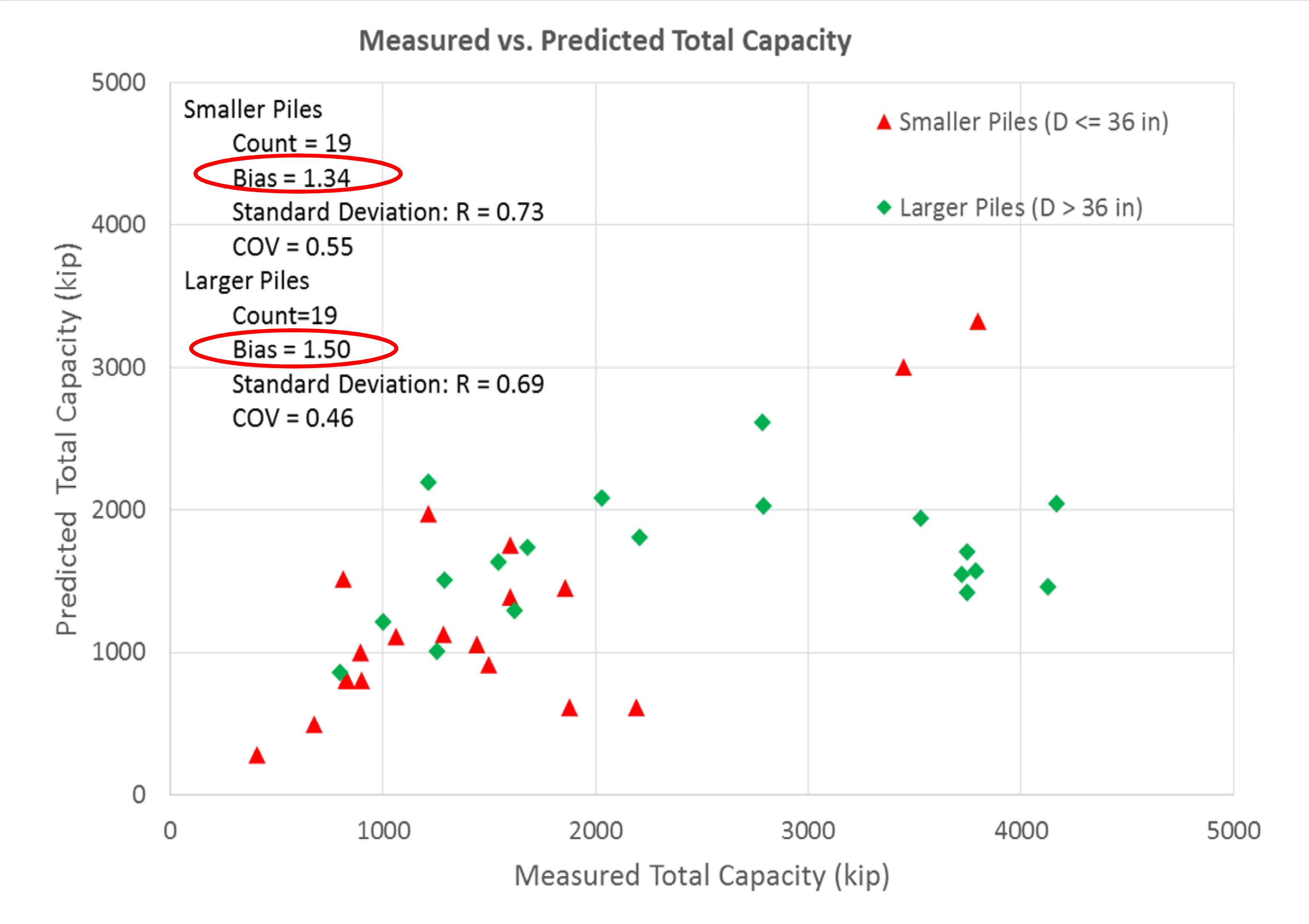
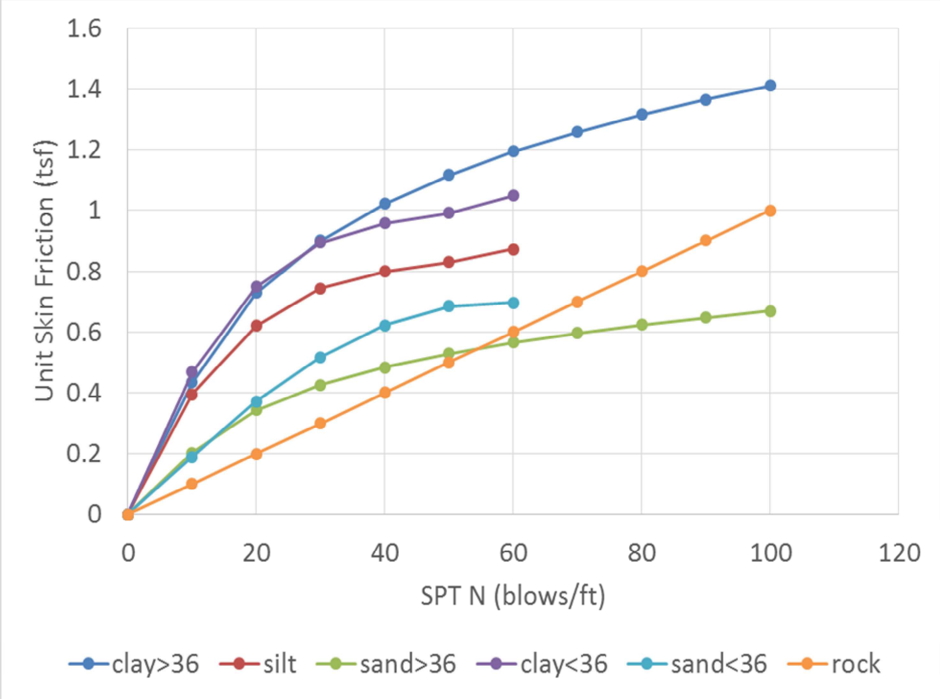
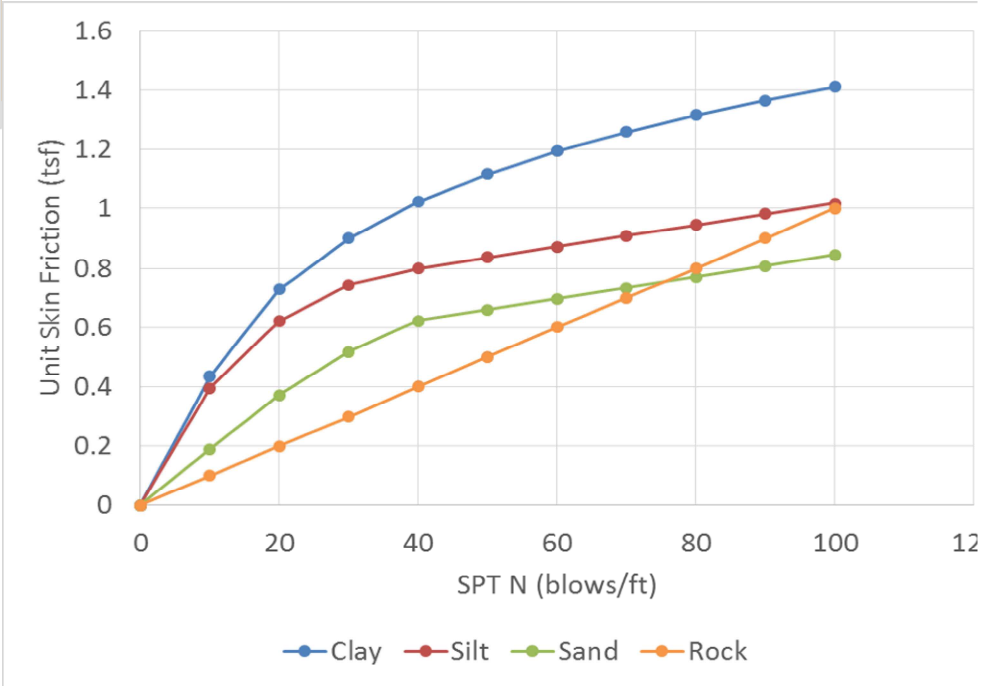
Modify FB-DEEP D>36" End Bearing to Same as D≤36"



Combine Unit Skin Friction Curves for D<36 and D>36 Steel Pipe and Extend N to 100





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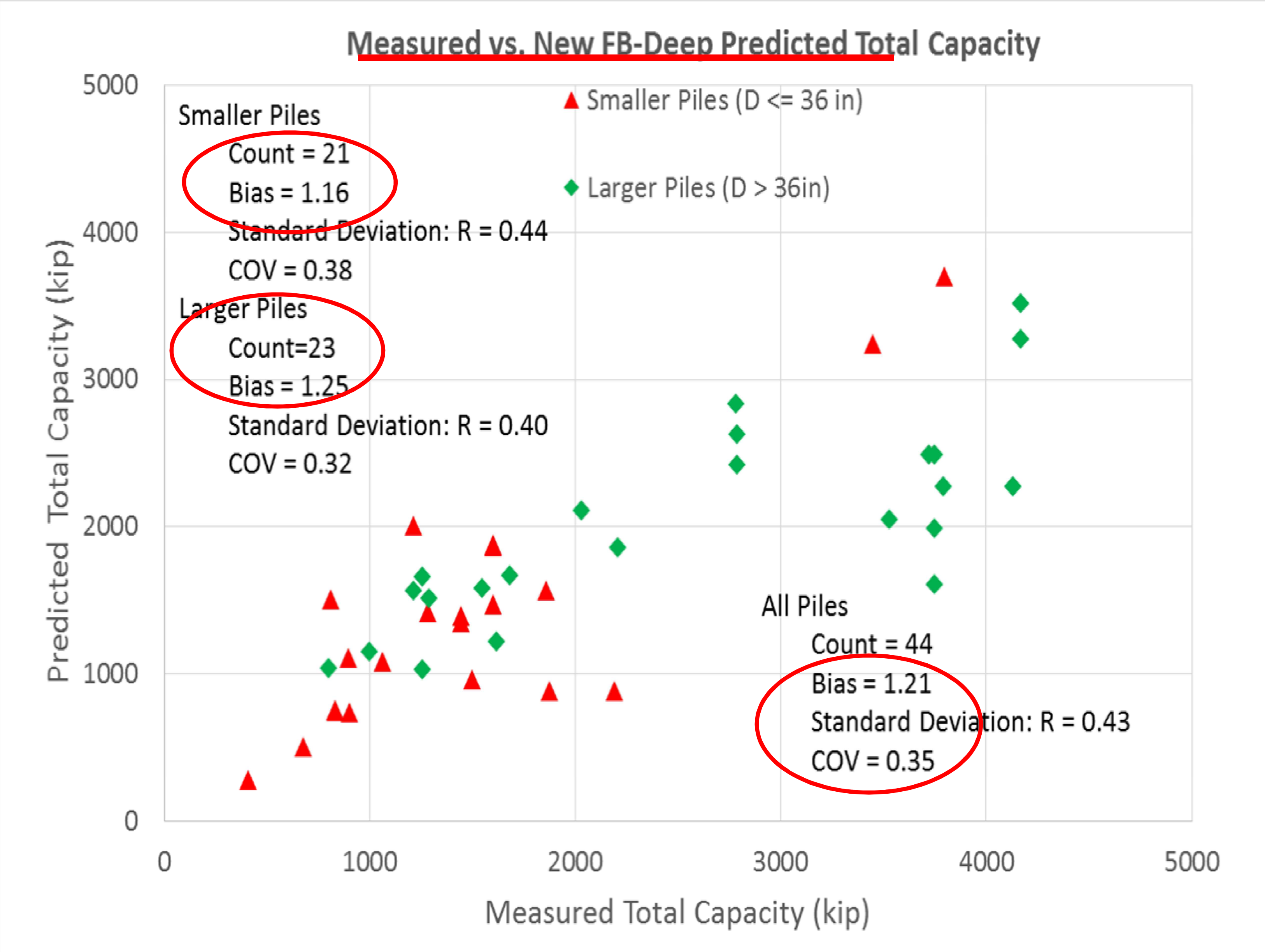
NEW FB-DEEP Version 2.05



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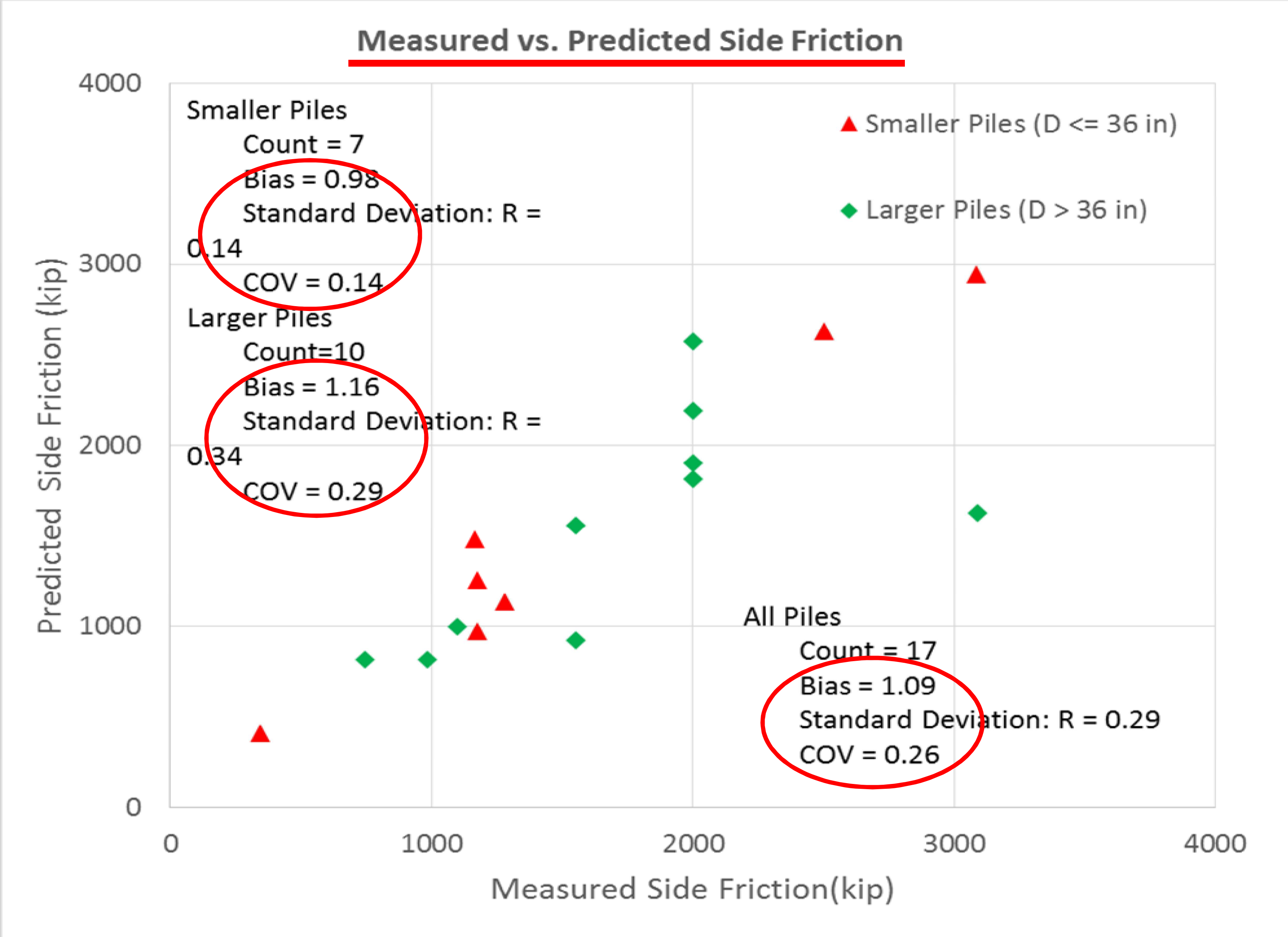
NEW FB-DEEP Version 2.05 Side Friction



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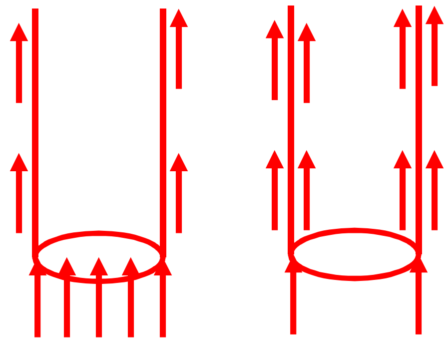
Summary of Changes to FB-DEEP's Open Pipe Pile Analysis

1. End Bearing:

- Change Analysis for D>36"
- Consider Smaller of unit tip resistance times full cross-sectional area or unit skin friction x inner surface area plus unit tip resistance x ring area



2. SPT N Value Limit:

- Raise Limit on N from 60 to 100
- Combine Steel Unit Skin Friction for D<36 and D>36

FB-DEEP Help 2.05 Steel Pipe Piles

SIDE FRICTION:

The following table shows the ultimate side friction versus SPT blowcounts for the five soil types, for steel pipe piles.

Soil Type	Soil Description	Ultimate Unit Side Friction (tsf)	SPT Blow Count Range
1	Plastic Clay	$f_s = 0.4236 \cdot ln(N) - 0.5404$	$3 \le N \le 100$
2	Clay-silt-sand mixtures, Very silty sand, silts and marls	$f_s = 0.029 + 0.045 \cdot N - 8.98 \cdot 10^{-4} \cdot N^2 + 6.371 \cdot 10^{-6} \cdot N^3$	$3 \le N < 40$
		$f_s = 0.799944 + 0.00362 \cdot (N - 40)$	$40 \le N \le 100$
3	Clean Sands	$f_s = -0.026 + 0.023 \cdot N - 1.435 \cdot 10^{-4} \cdot N^2 - 6.527 \cdot 10^{-7} \cdot N^3$	$3 \le N < 40$
		$f_s = 0.622627 + 0.003689 \cdot (N - 40)$	$40 \le N \le 100$
4	Soft limestone, very shelly sand	$f_s = 0.01 \cdot N$	$3 \le N \le 100$
5	Void	$f_s = 0.0$	n/a

*Pipe pile is assigned open-ended by default and cannot be updated by the user. The program internally checks the pile to be plugged or unplugged. The capacity is then selected as per the lower prediction between the sum of "outer" and "inner" skin friction and end bearing on the annulus (unplugged condition), and sum of "outer" skin friction and end bearing of the closed-end cross section (plugged condition).

The corrected mobilized end bearing capacity is then computed as per plugged or unplugged condition.

Thank You