BED Two 28 977-01
Using the PENCEL PMT to Evaluate Shallow Foundations at Florida's Fine Sand Sites

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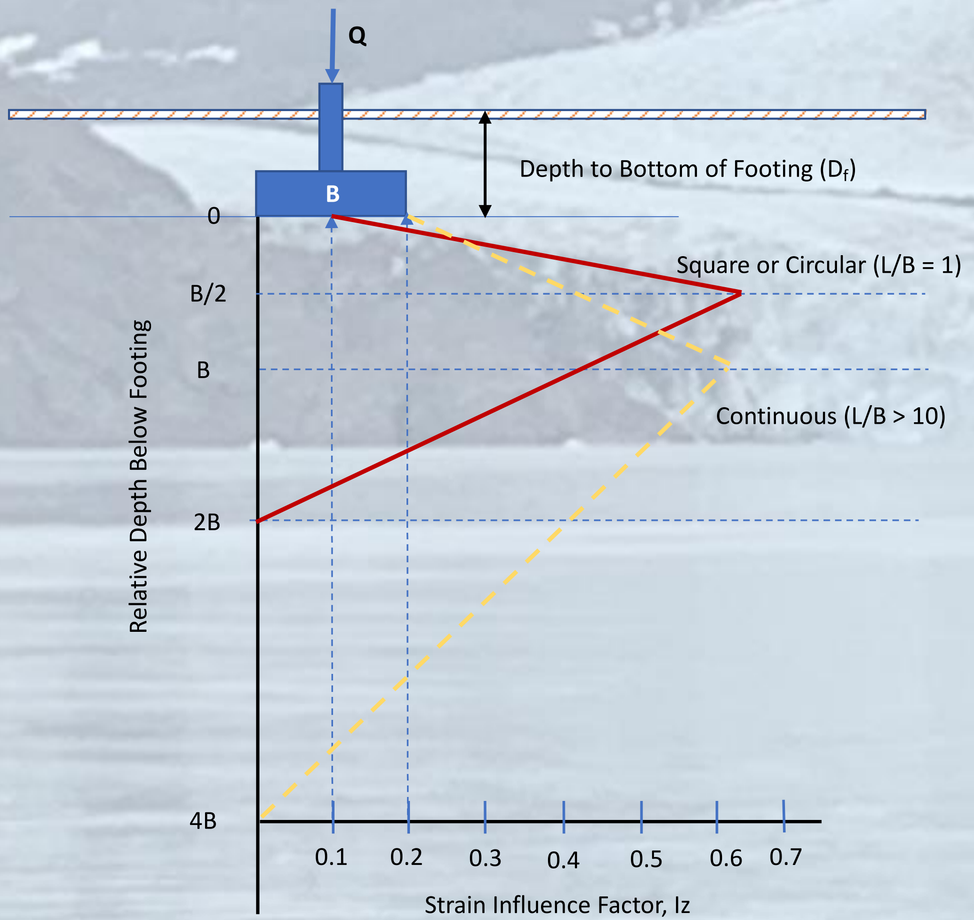
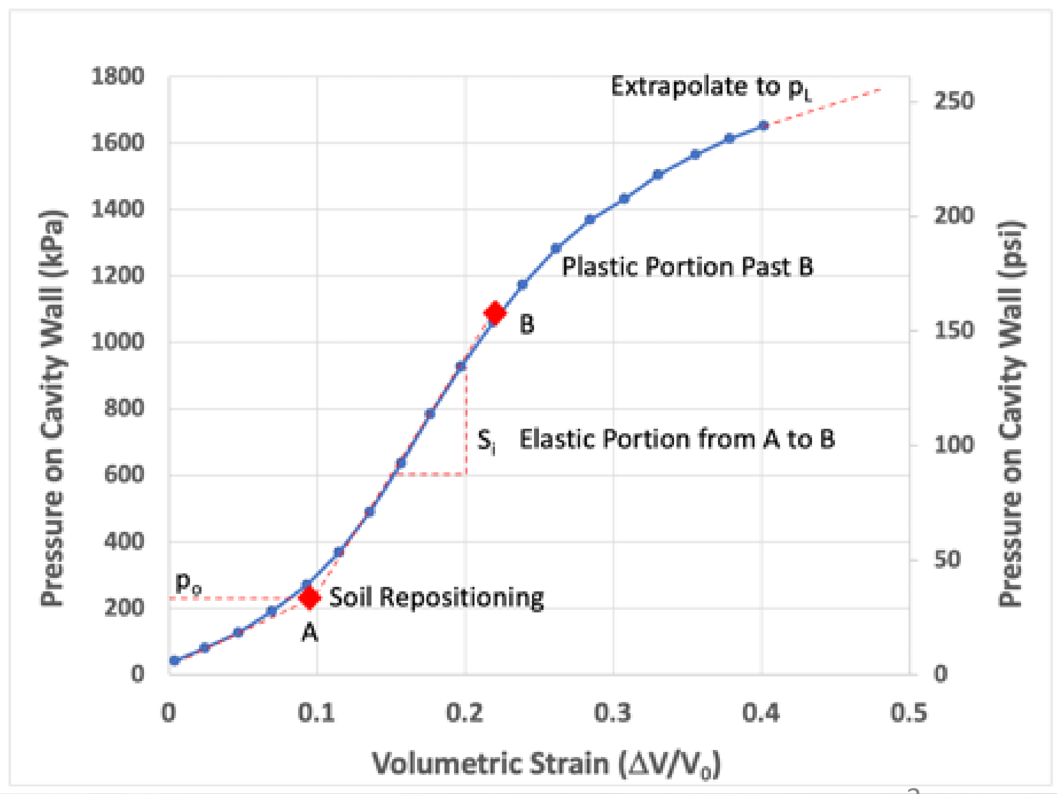
FDOT GRIP 2025 Outline

1. Introduction & Overview
2. Objective
3. Tasks
    1. Literature and Historical Review
    2. SMO Testing with PENCEL PMT, CPT, CPT, SSMini PMT, and Plate Bearing
    3. Site Selection, Site Visits, and Procurement of Site Data
    4. *PPMT, TEXAM, SSMini, CPT, DMT, SPT, and Field Plate Load Testing*
    5. Analyzing the Modulus Effects on Foundation Settlement and Bearing Capacity
    6. Extrapolation of Design Procedure Data with Design Flow Chart using Florida Site Conditions
    7. Conclusions
    8. Recommendations
4. Closing Slide

Introduction

- When Shallow Foundations are used, the zone of soil affected is typically within the top 25 to 25 feet.
- PENCEL PMT stress-strain curve components are easy to interpret and use in footing designs





Why did we do this?

- To make the Geotechnical community comfortable with the easier to use PENCEL PMT

- Data from this work complements the existing data used in Briaud's 2007 Settlement of Sands prediction method.

- The research report contains specific guidelines/ recommendations for consulting engineers to follow when using PMT data to design shallow footings.

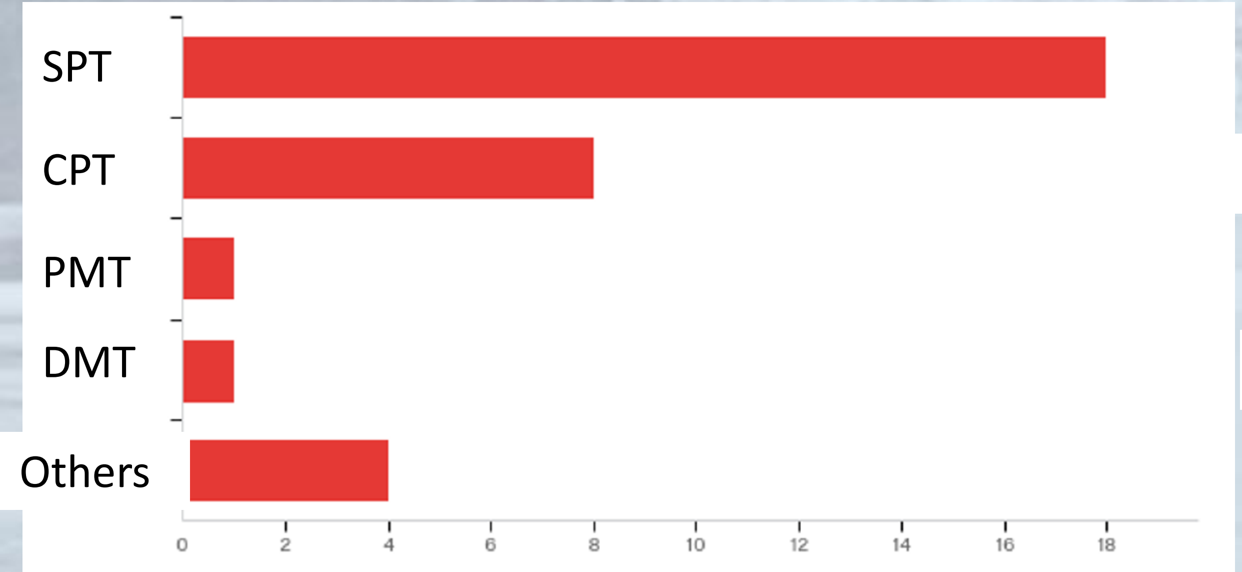
Objective

- ***To improve the geotechnical engineer's confidence in using PENCEL PMT data to safely design shallow footings placed on Florida fine sands.***

Task 1 Literature and Historical Review

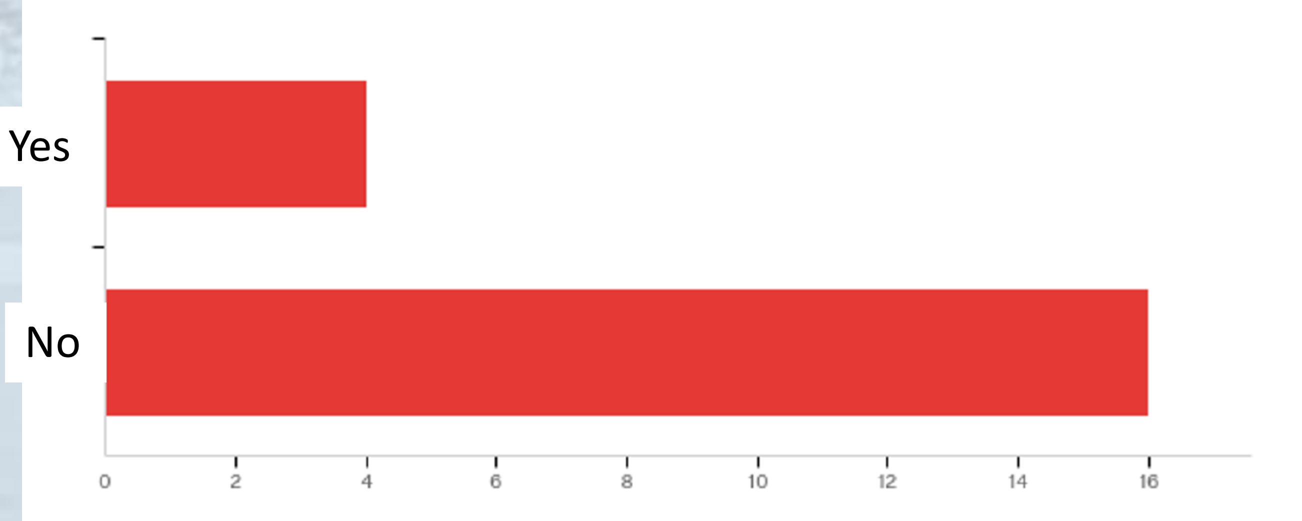
Survey of Florida Field Tests (BDV24-977-29 Chopra & Arboleda-Monsalve, 2020)

Do you use Specific correlations for the elastic modulus of the soil with field tests? Please select all that apply



16 of 32 use SPT
50%

Do you perform any additional laboratory and/or field tests to check your selection of elastic modulus and immediate settlement values?



4 of 20 use Lab Tests to Supplement
20%

Task 2-SMO Testing- In situ tests to determine E

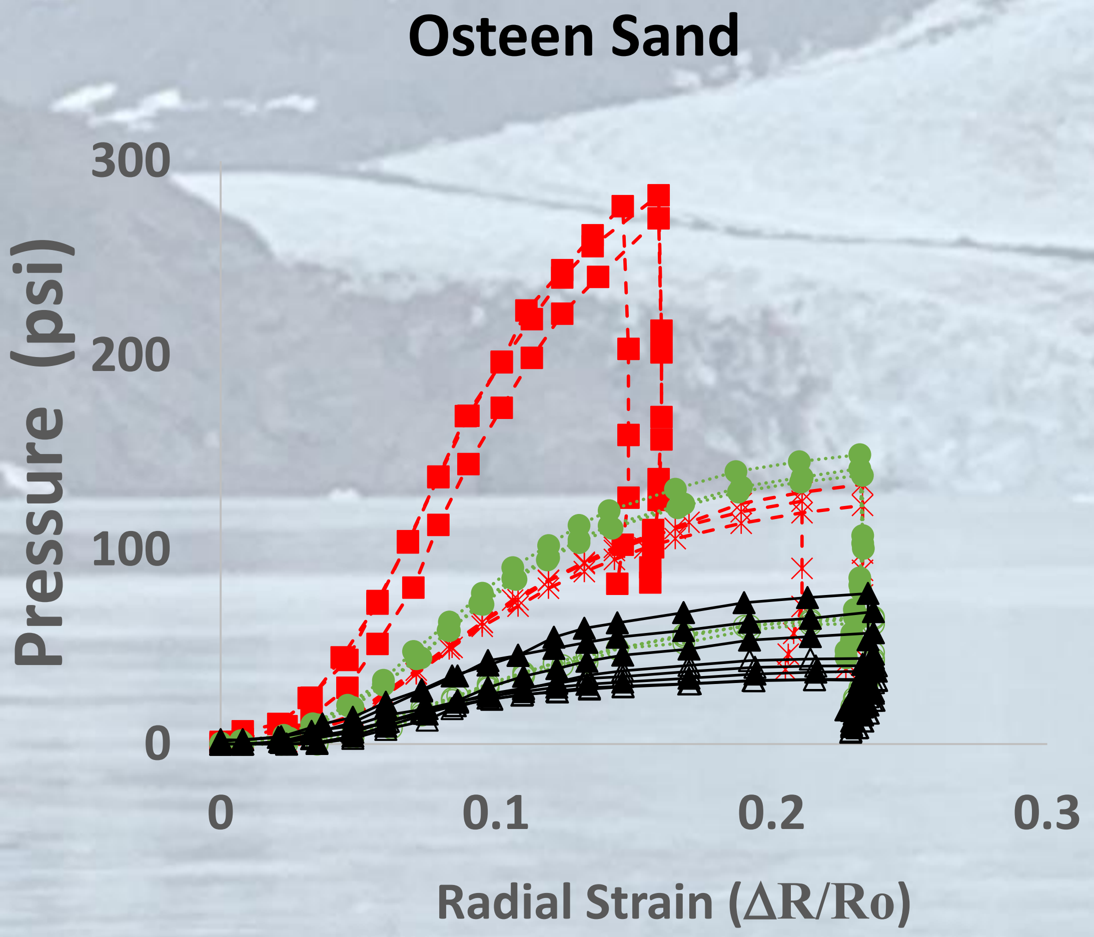
- Both Indoor SMO Pits used
  - Compacted to about 5 ½ feet
- Two SP sands
  - *Starvation Hill Pit- Stronger SP*
  - *Osteen Pit- Weaker SP*
- NDG-to ensure uniform compaction
  - 90, 95, 100 % Modified Proctor Densities
- PPMT-mostly pushed
- CPT
- DMT
- Plate Loading
- *SSMini PMT added to help with Plate Evaluations*

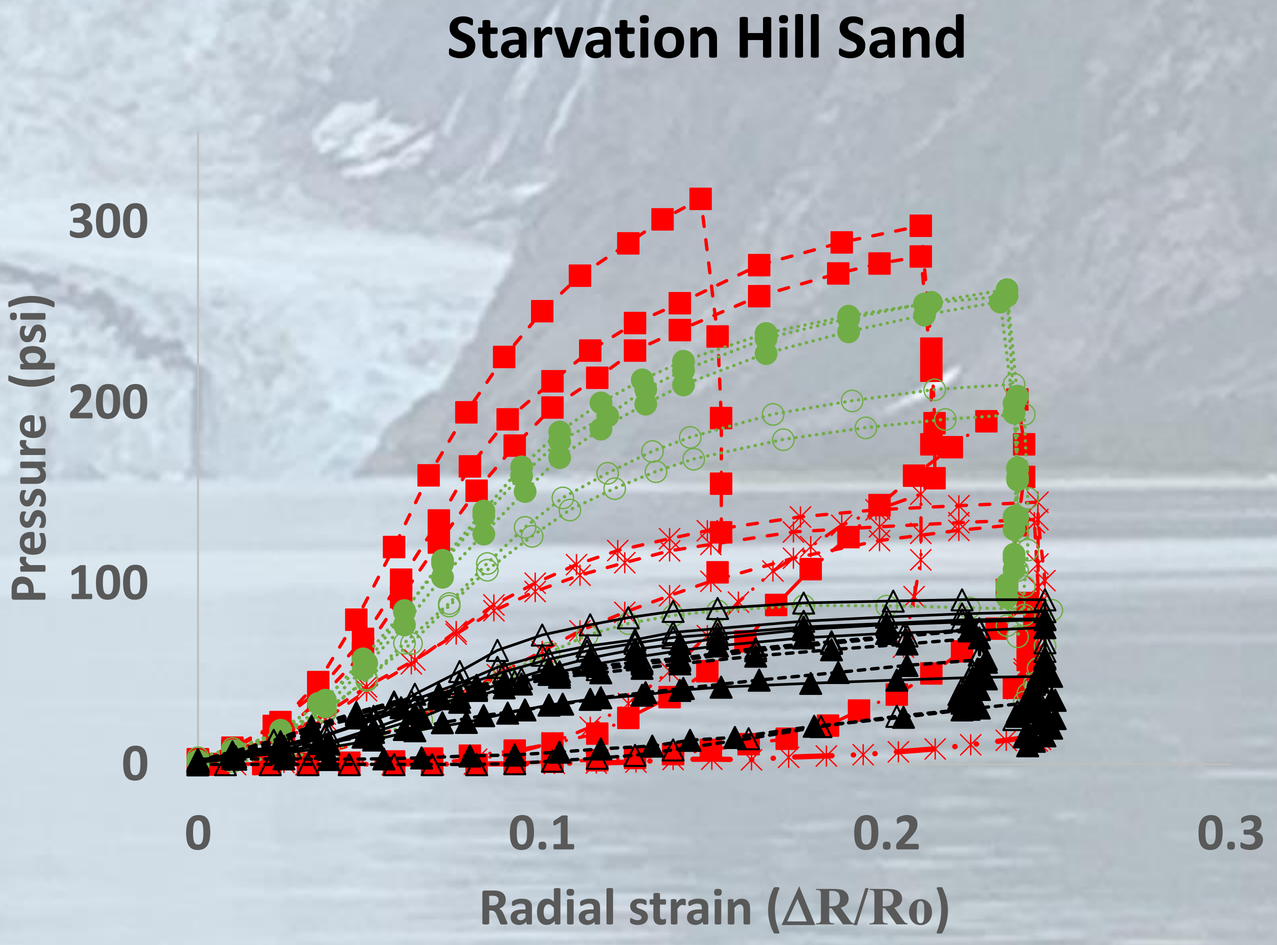
Summary of SMO Testing

Site	PPMT Tests	SSMini Tests	CPT Soundings	DMT Tests	Plate Tests
SMO Starvation Hill 90 %	18	6	3	12	3
SMO Starvation Hill 95 %	6	8	3	12	3
SMO Starvation Hill 100 %	10	8	3	12	3
Subtotal	*34*	*22*	*9*	*36*	*9*
SMO Osteen 90 %	8	8	3	9	4
SMO Osteen 95 %	6	8	3	9	5
SMO Osteen 100 %	6	8	3	9	3
Subtotal	*20*	*24*	*9*	*27*	*12*
Total	**54**	**46**	**18**	**63**	**21**

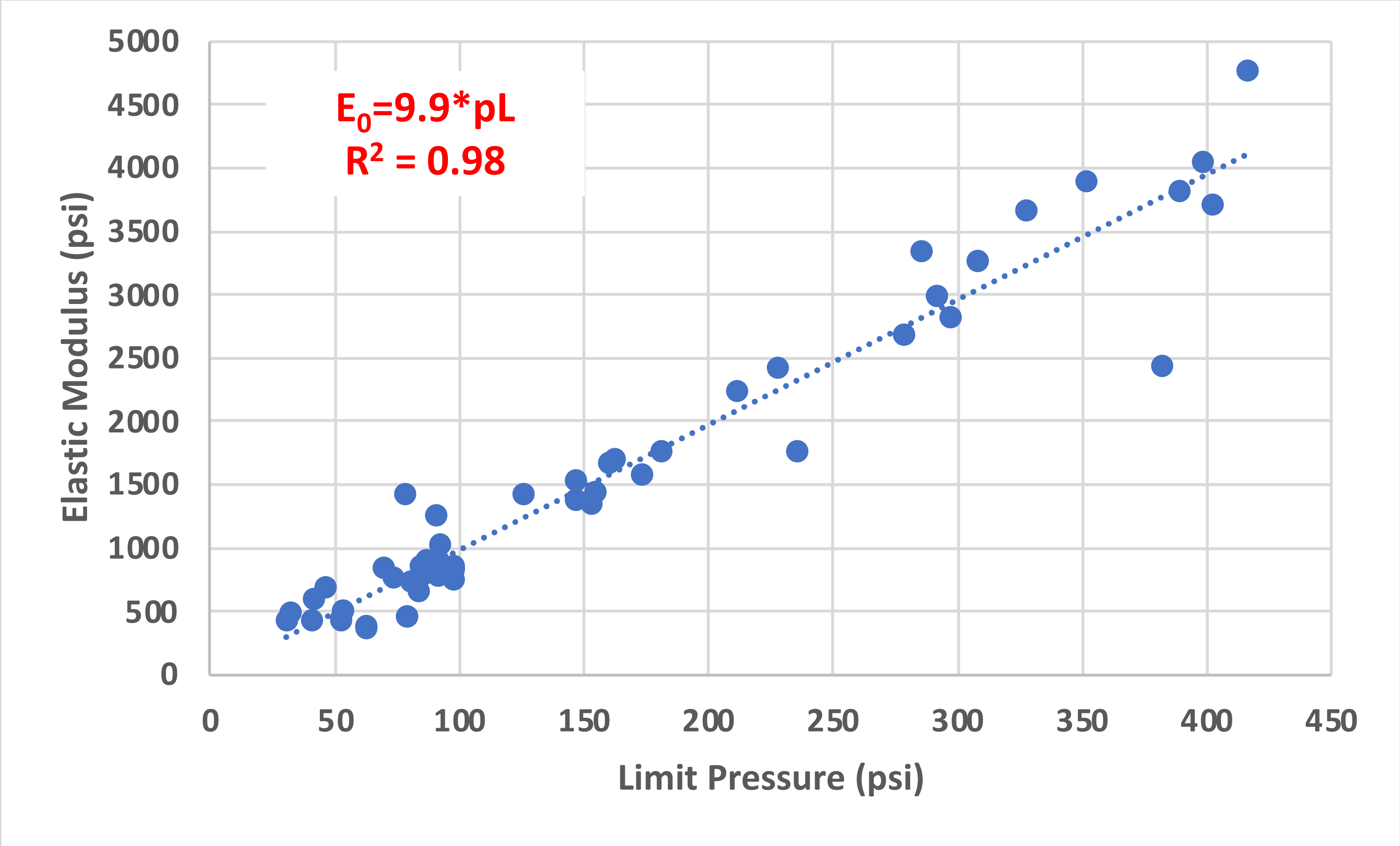
Note, there are about the same number of PENCEL & SSMini Tests as DMT Tests

Task 2 PPMT Results @ 100, 95 & 90 % RC



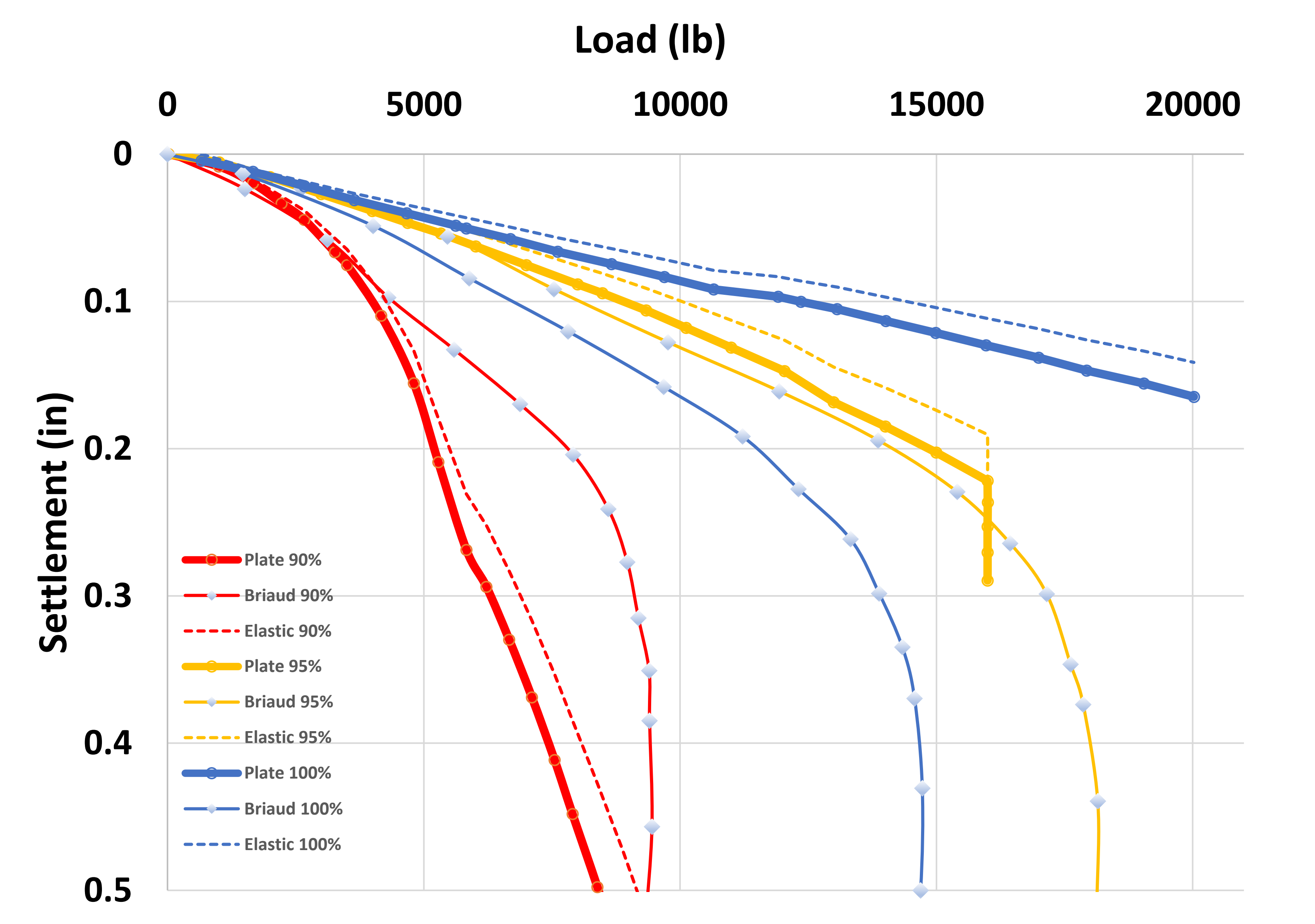


Task 2
PPMT Data Quality SMO Pits
54 tests - SP Sands

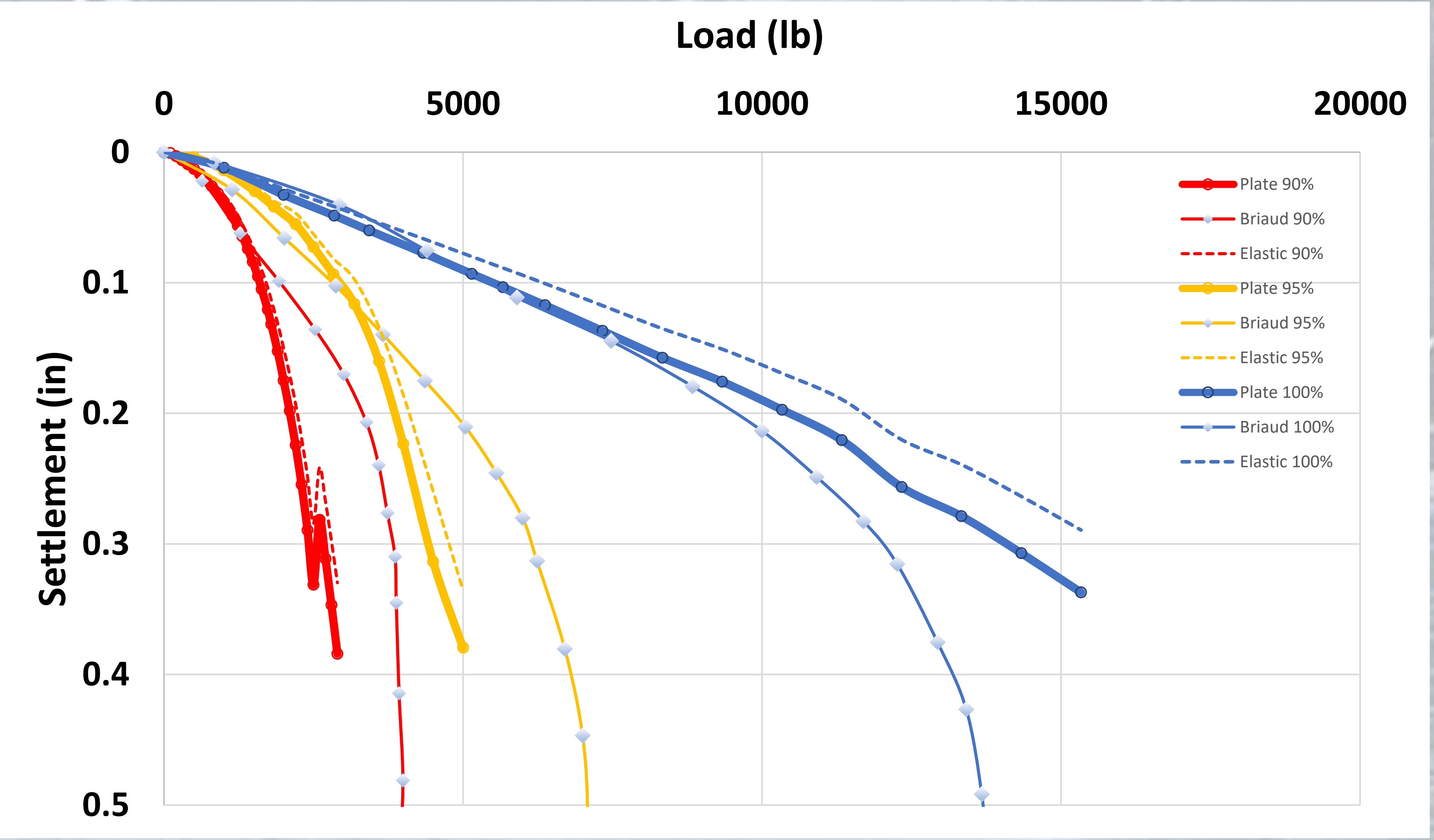


- ***PPMT produces reliable data***
- ***E_{PPMT} is ~10 times p_L***
- ***Relationship consistent with literature: E_{PMT} ~ 6 to 16 times p_L***
- ***Useful for QC of PMT test results***

Task 2 Starvation Hill Settlement Measured Plate vs. PPMT Predictions



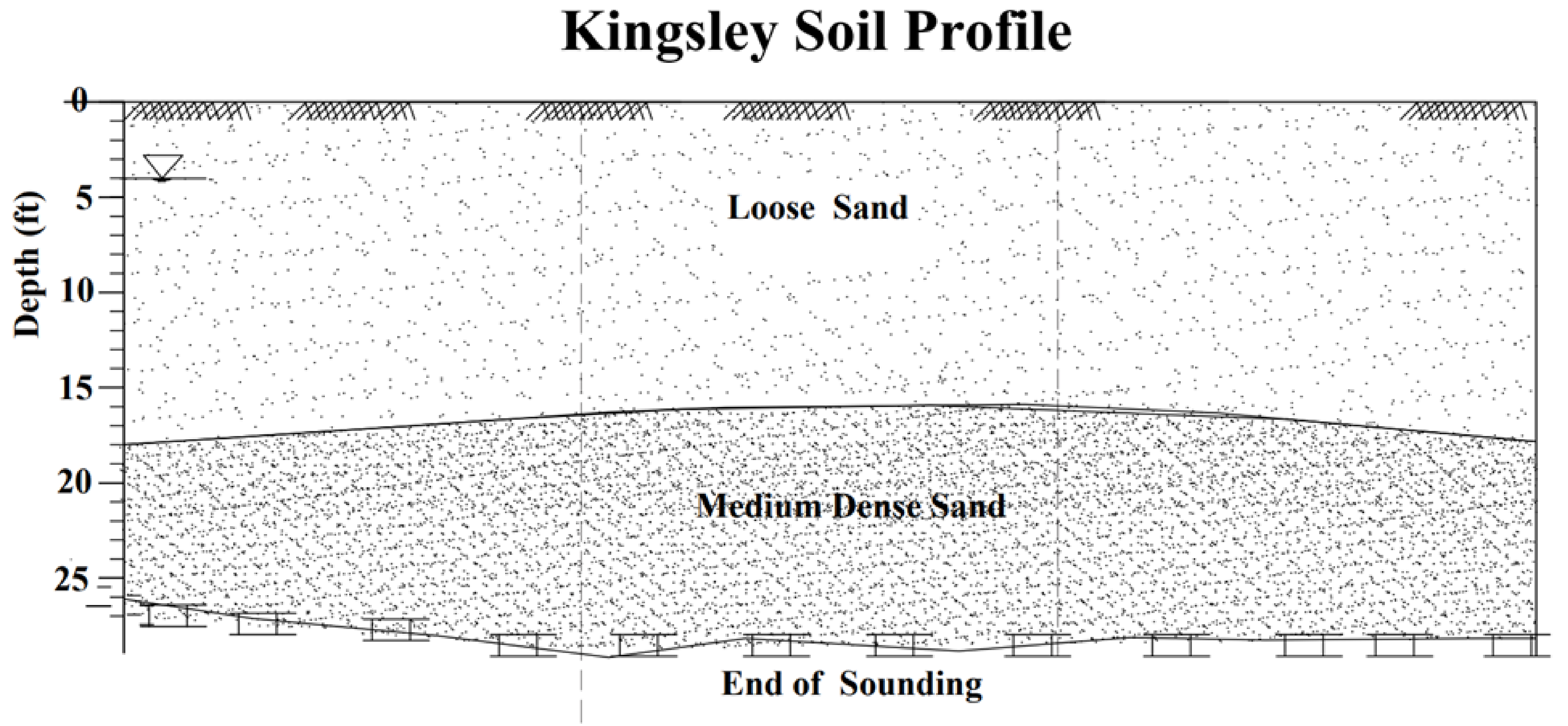
Task 2 Osteen Settlement Measured Plate vs. PPMT Predictions



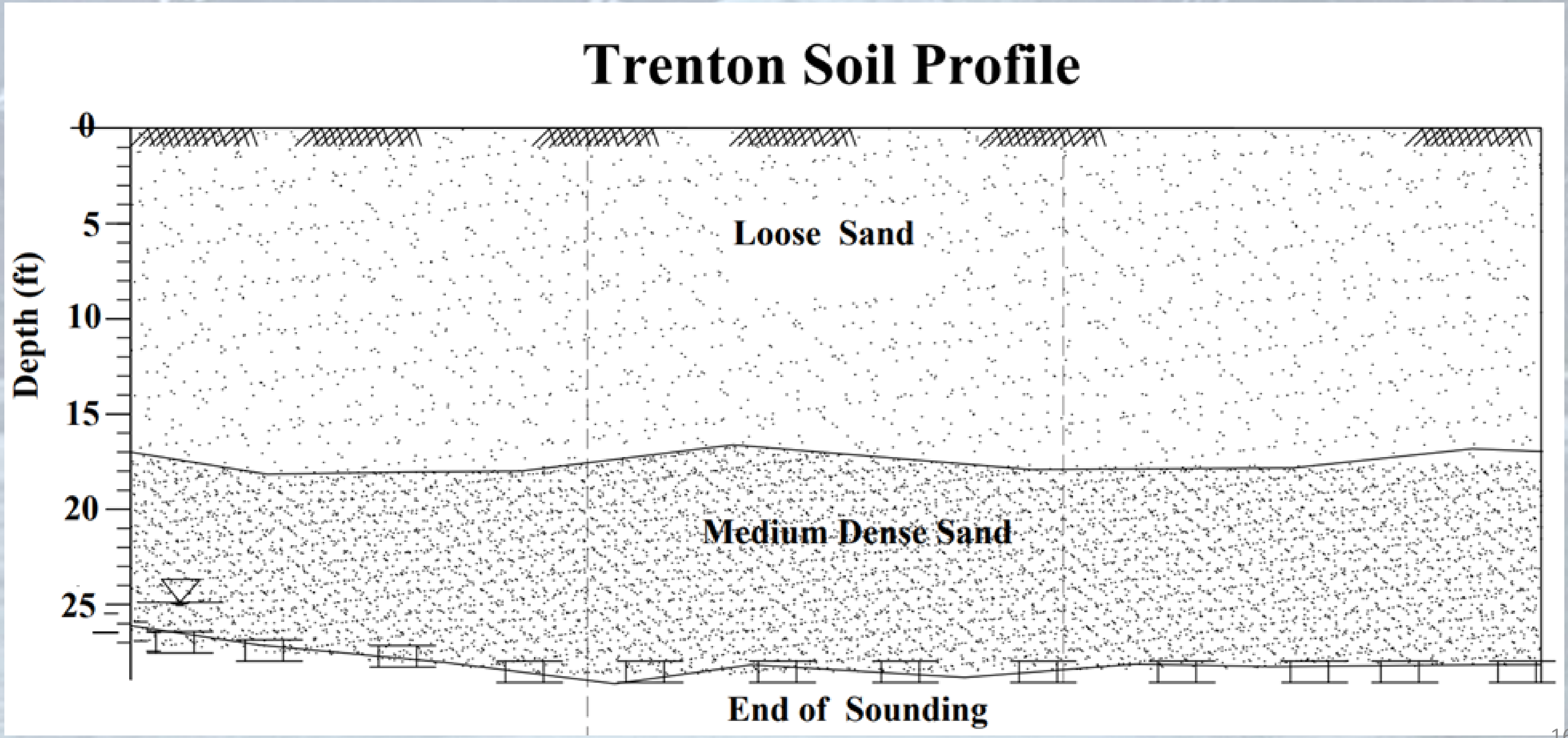
Task 2 Conclusions

- PPMT testing produced an excellent E_0/pL relationship
- Stiffness & strength parameters from PPMT, DMT, CPT, and Plate tests suggest strong correlations with each other
- Relationships are consistent for 90%, 95%, and 100% relative compaction in both Florida sands, with 95% and 100% being the most closely related

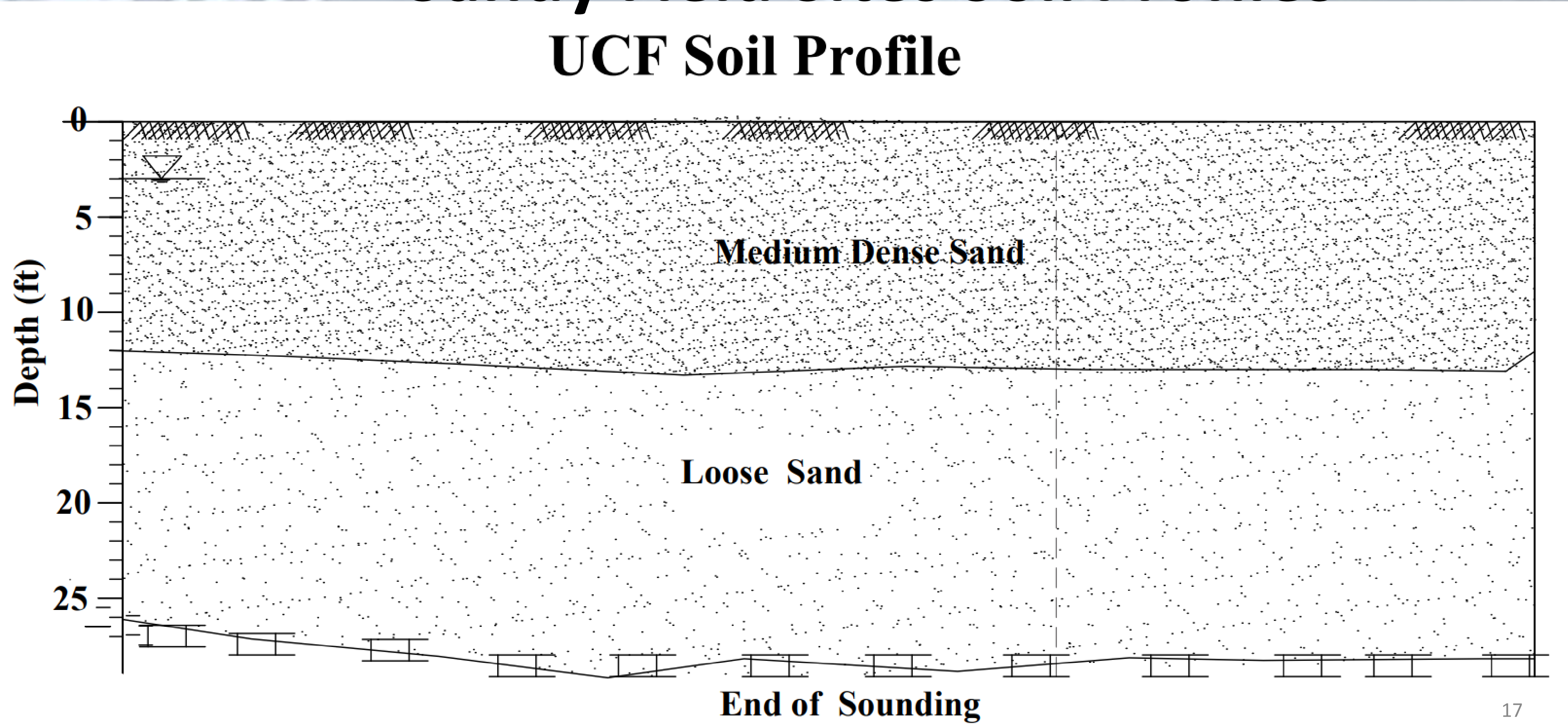
Task 3
Sandy Field Sites Soil Profiles



Task 3
Sandy Field Sites Soil Profiles



Task 3
Sandy Field Sites Soil Profiles



Task 4 Field Testing

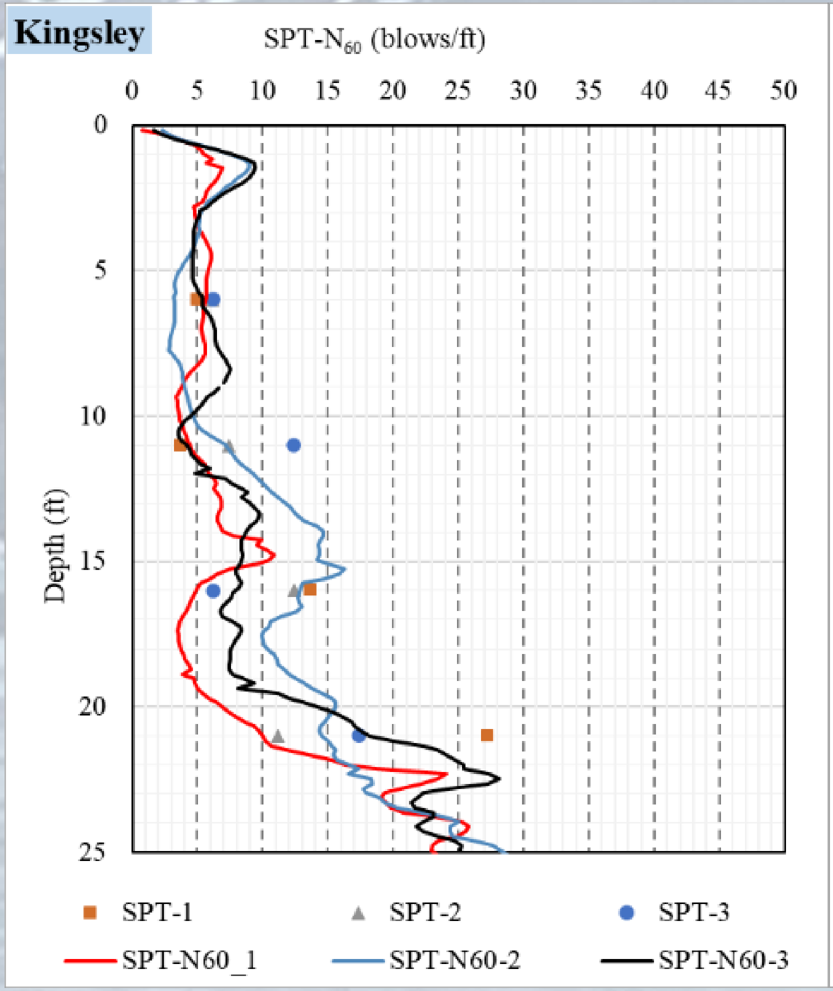
- Equipment Used
  - PENCEL PMT
  - TEXAM PMT
  - SSMini PMT
  - CPT
  - DMT
  - SPT
  - Plate

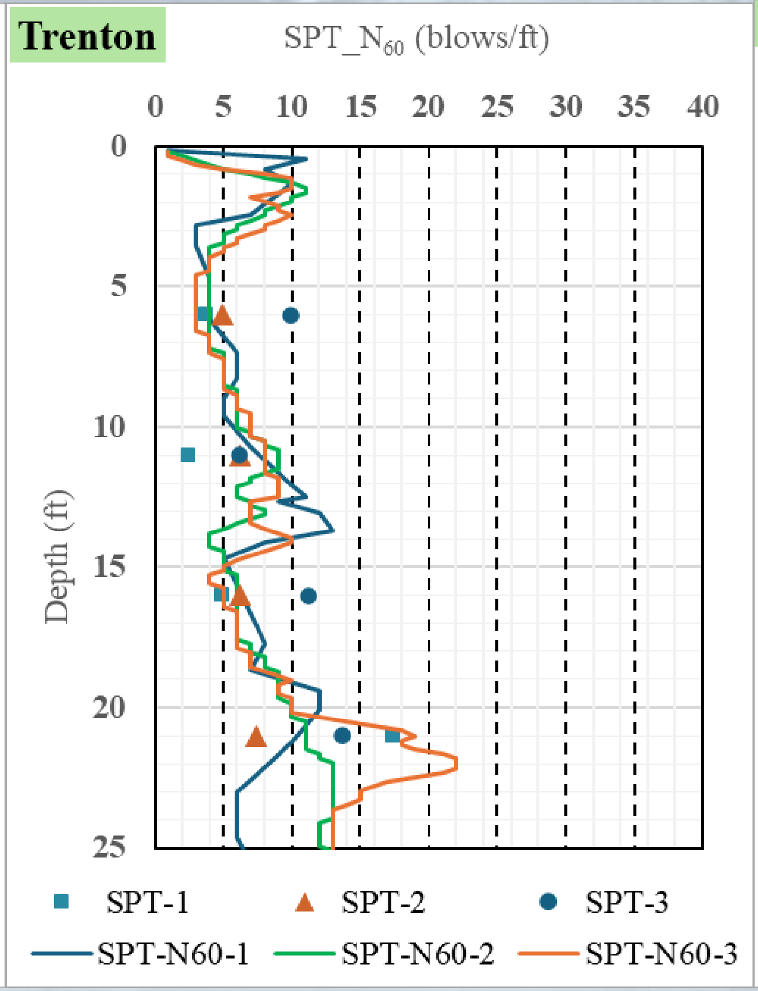
- Results
  - PENCEL PMT E_0, pL
  - TEXAM PMT E_0, pL
  - SSMini PMT E_0, pL
  - DMT Ed
  - CPT qc
  - SPT N_{ES} Blows/Foot
  - Plate k (pci)

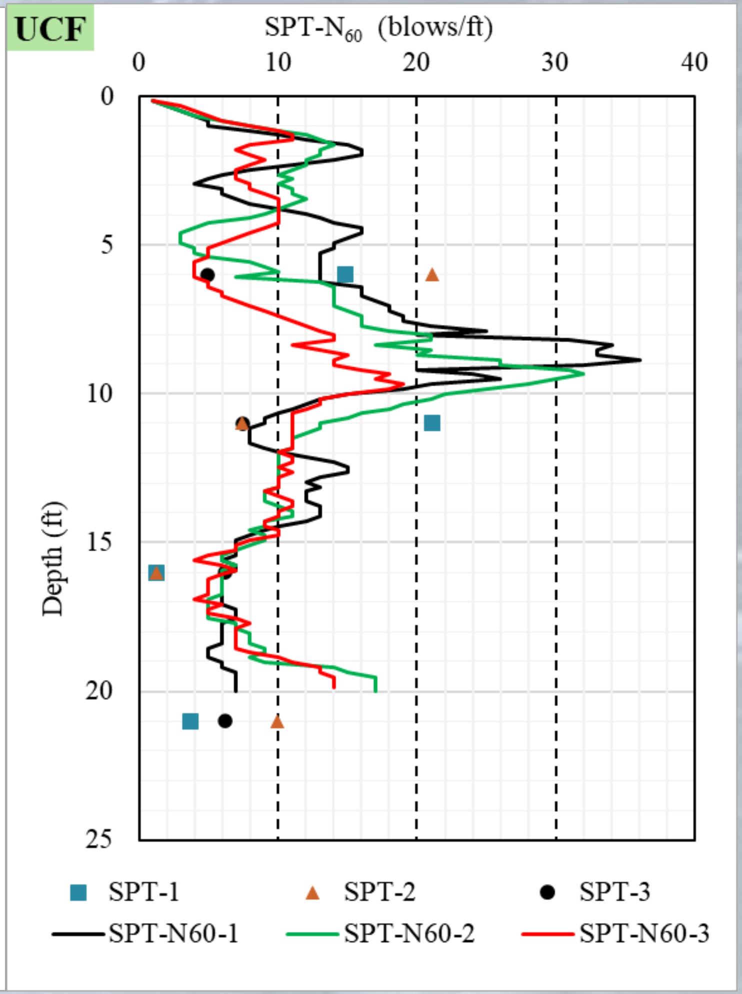
Overview of A Lot of Field Testing

Site	PPMT Tests	SSMini Tests	TEXAMe Tests	SPT Borings	CPT Soundings	DMT Tests	Plate Tests
FDOT Kingsley Field Site	20	12	12	3	3	110	3
FDOT Trenton Field Site	20	12	12	3	3	93	3
UCF Field Site	11	12	12	3	3	93	3
Total	**51**	**36**	**36**	**9**	**9**	**296**	**9**

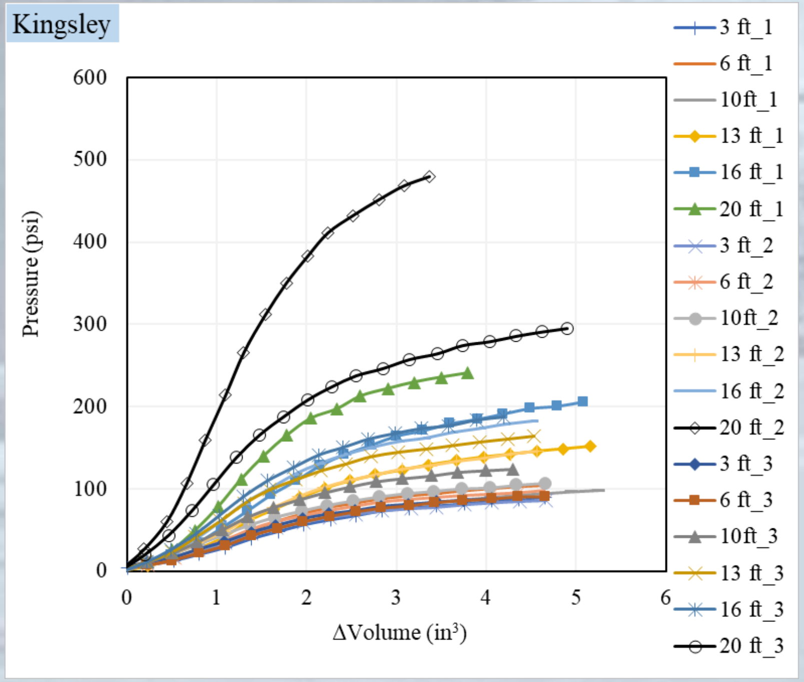
Task 4
CPT plus SPT N Profiles

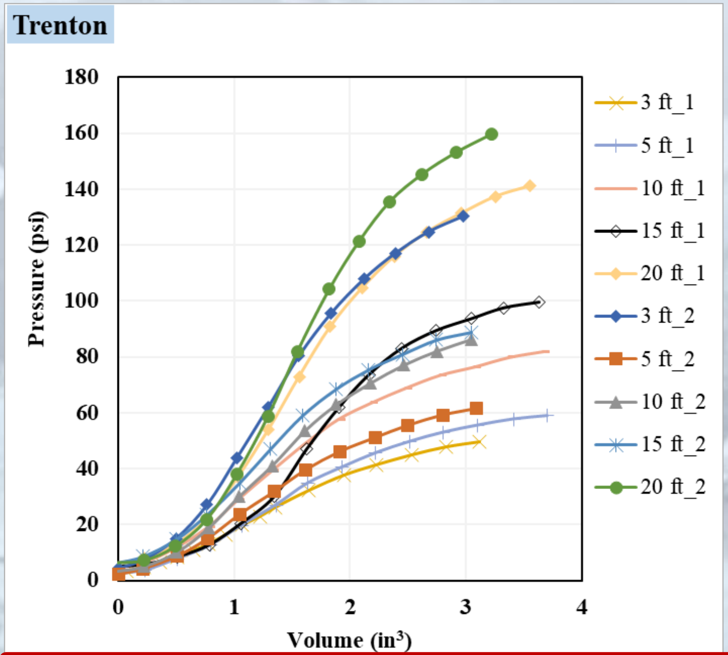


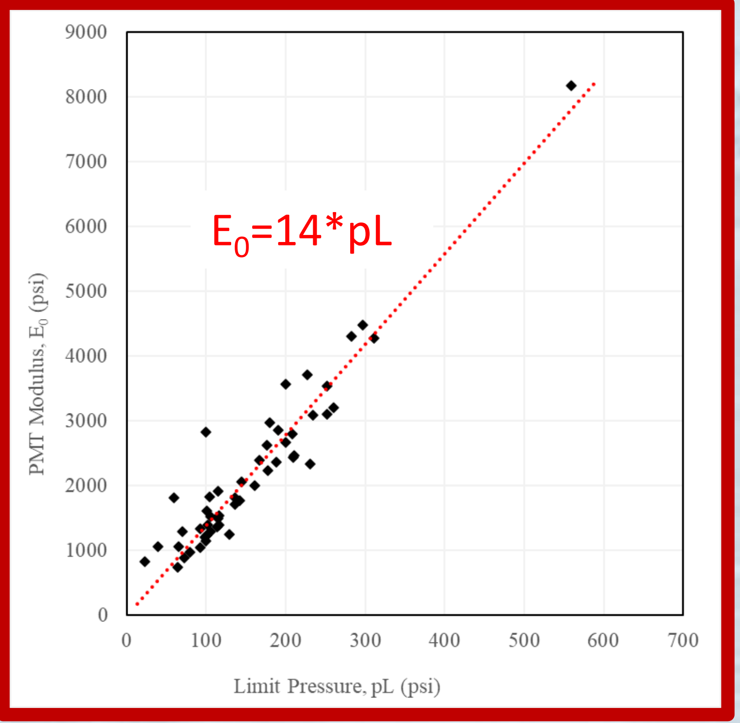


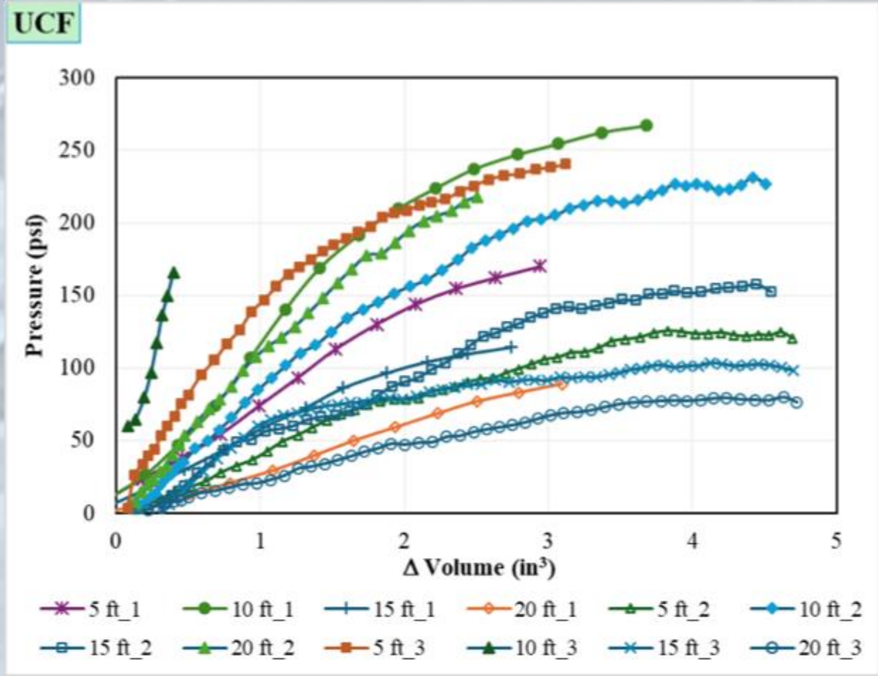


Task 4 PENCEL PMT Data

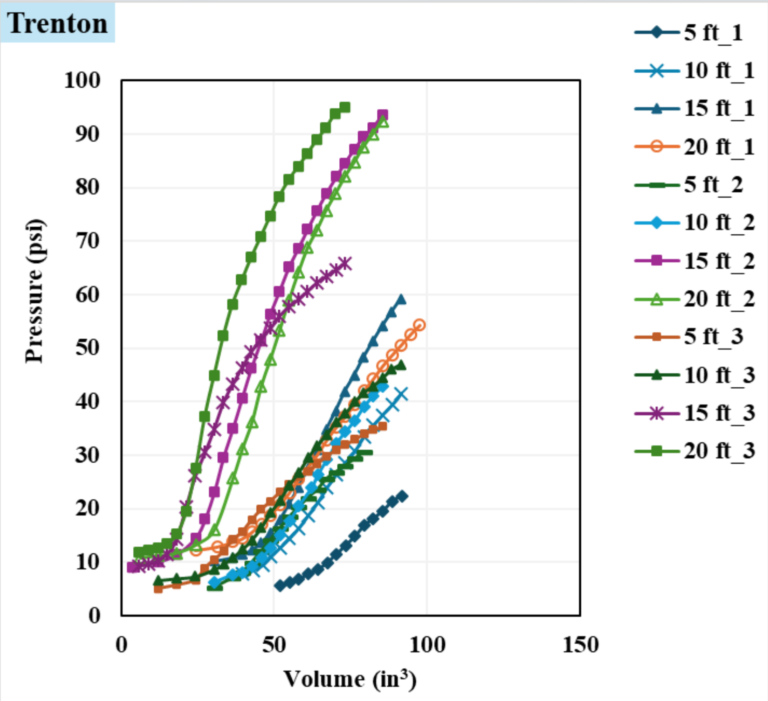


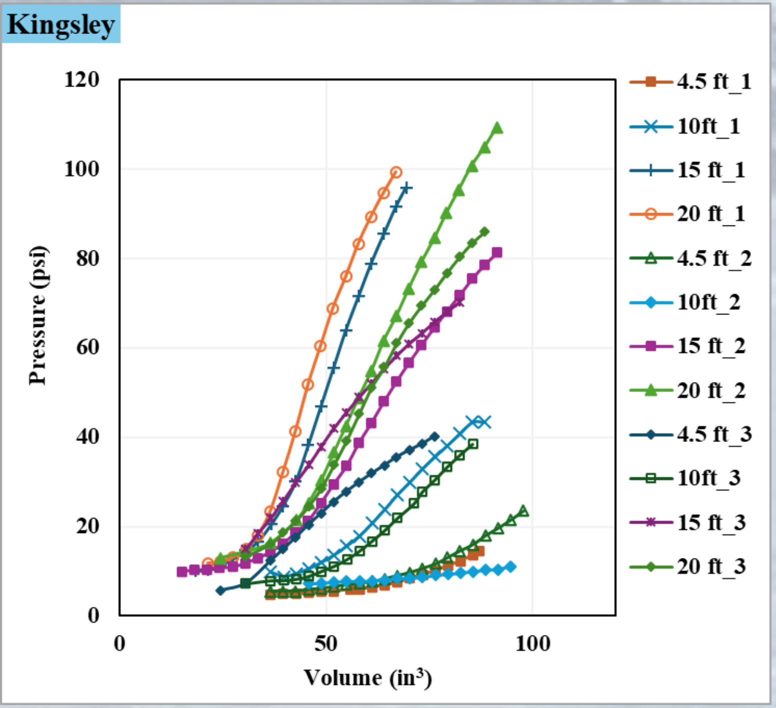


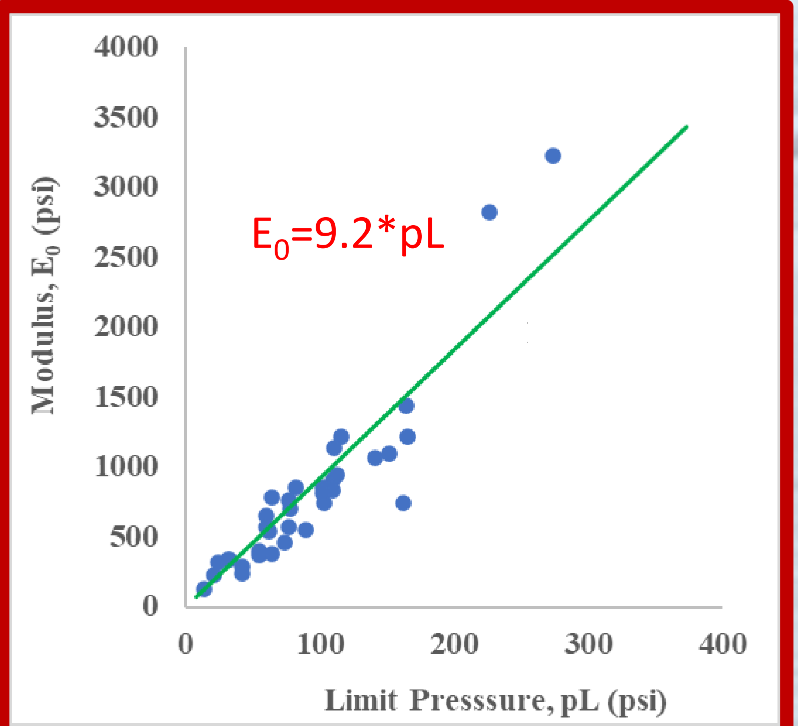


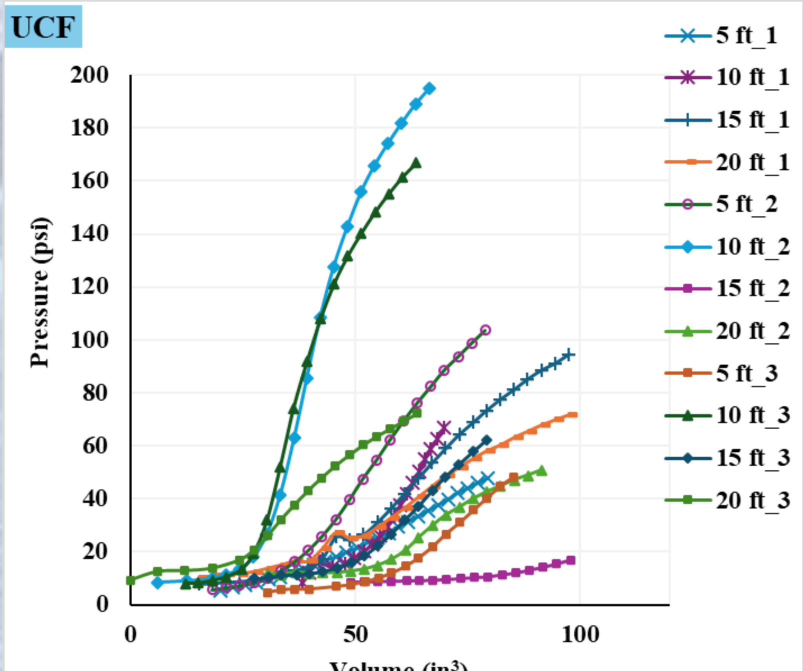


Task 4 TEXAMe PMT

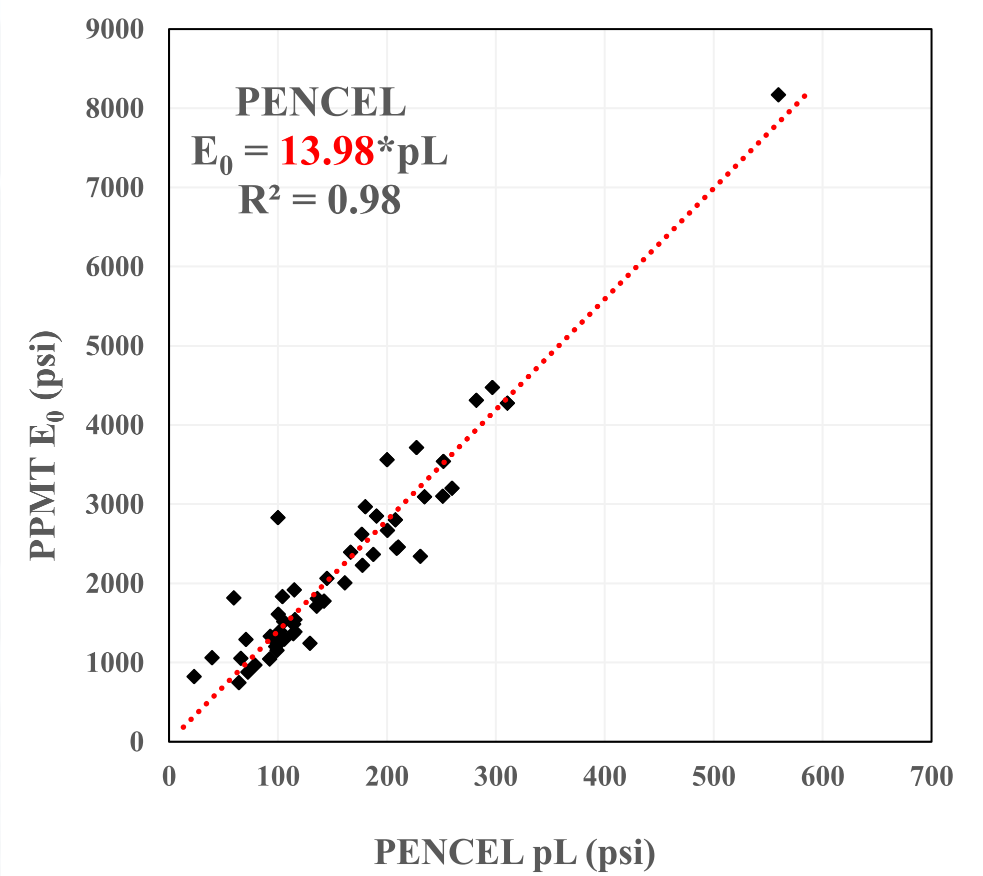


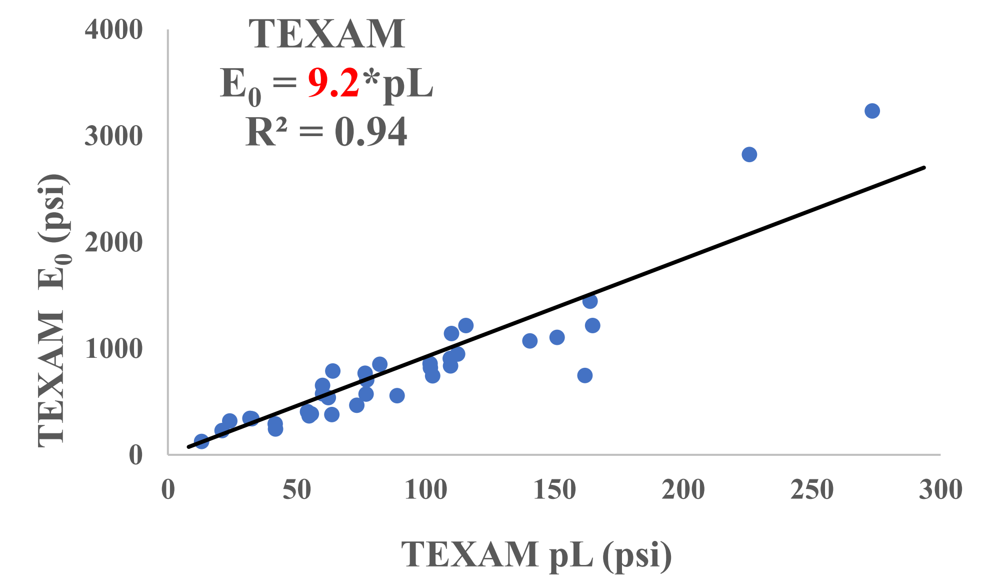


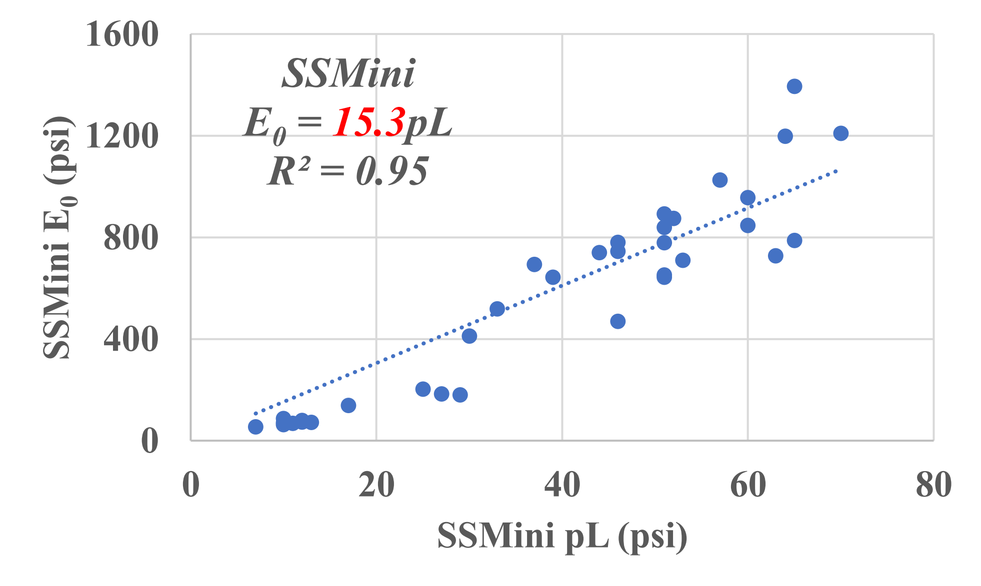




Task 4 Consistent E_0/pL Ratios from all PMT testing



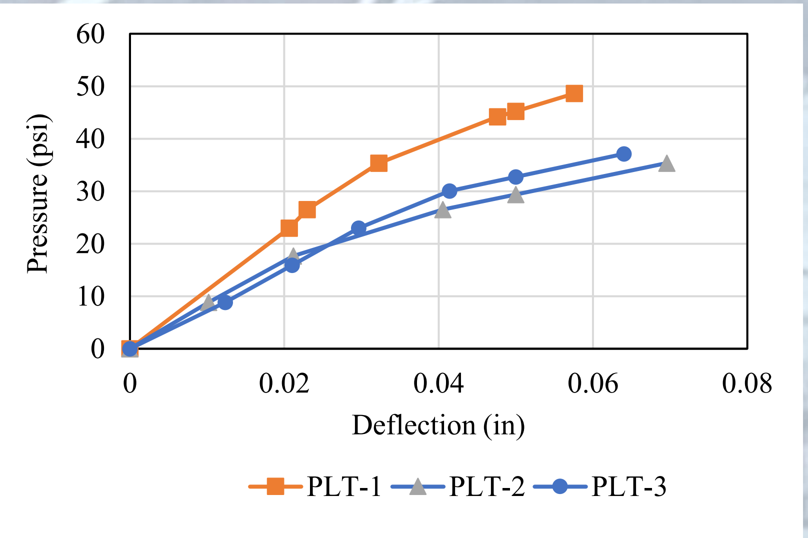




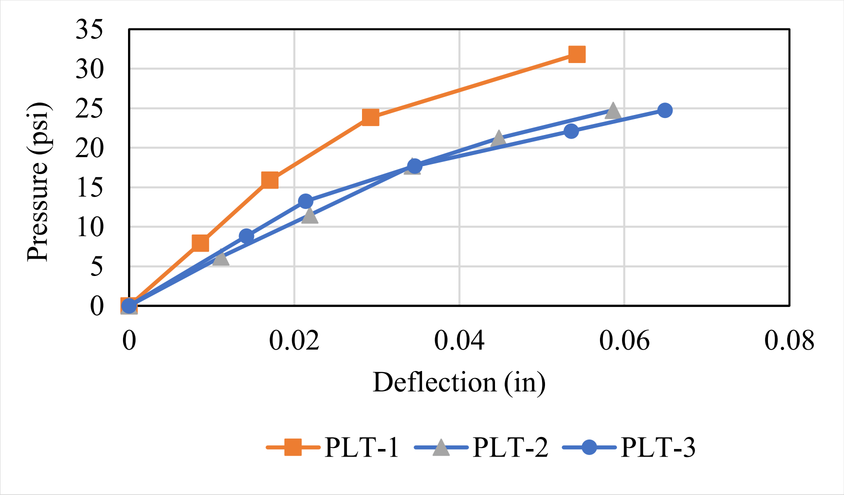
Borehole Prep is Critical

Task 4 Plate Bearing Results

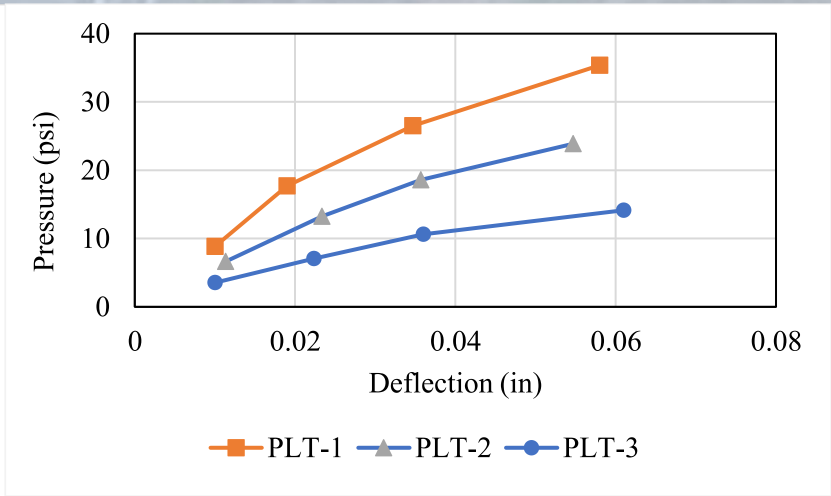
Kingsley



Trenton



UCF



Site	Test #	E_{PLT} (psi)	k (pci)
Kingsley	1	6409	1260
	2	4163	819
	3	4106	808
Trenton	1	4314	848
	2	3192	628
	3	3011	592
UCF	1	4579	901
	2	3196	629
	3	1783	351

Task 4
SPT, CPT, DMT, PMT Correlations

Literature E & SPT-N 16 different correlations

Webb (1969) Young's modulus of the soil from the uncorrected SPT blow counts, N for saturated silty sands, clayey sands, and sands with intermediate fine contents, respectively.

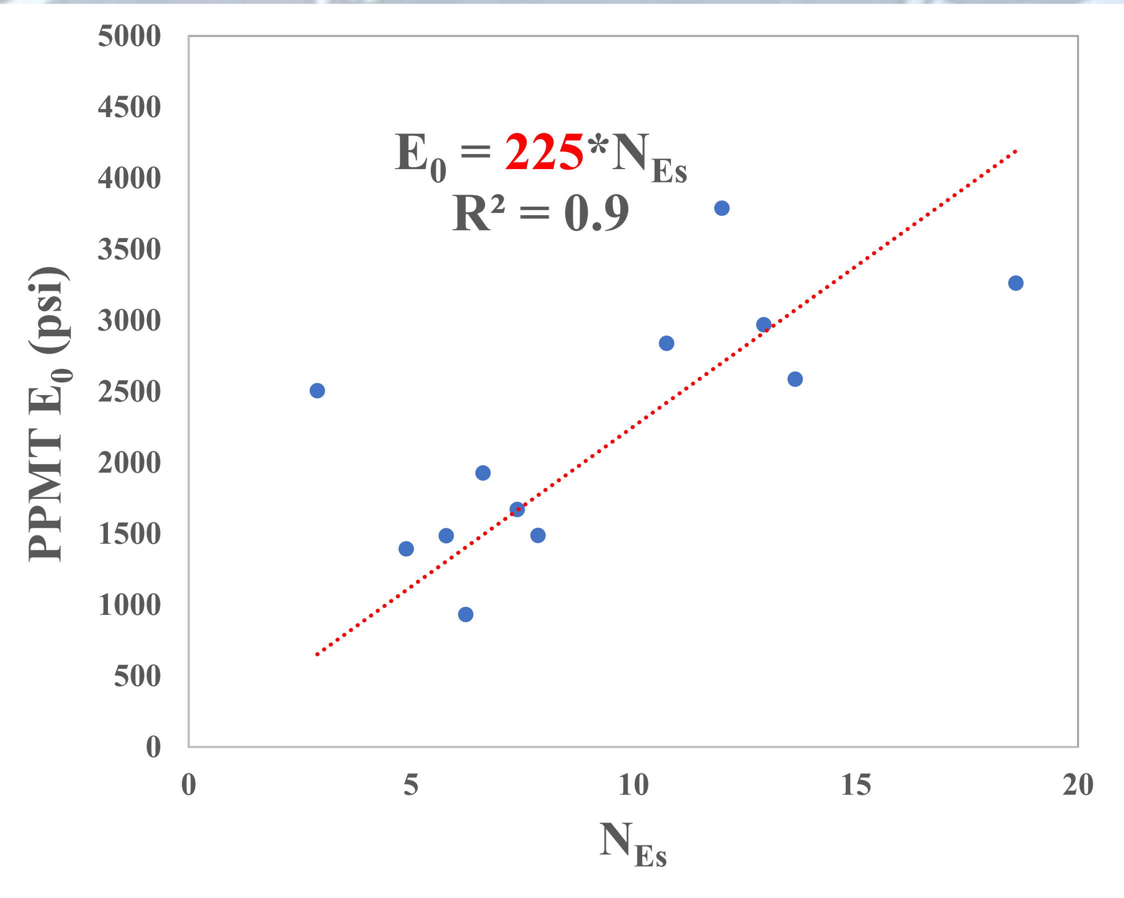
$$E = 5(N + 15)$$
$$E = 3.33\ (N + 5)$$
$$E = 4(N + 12)$$

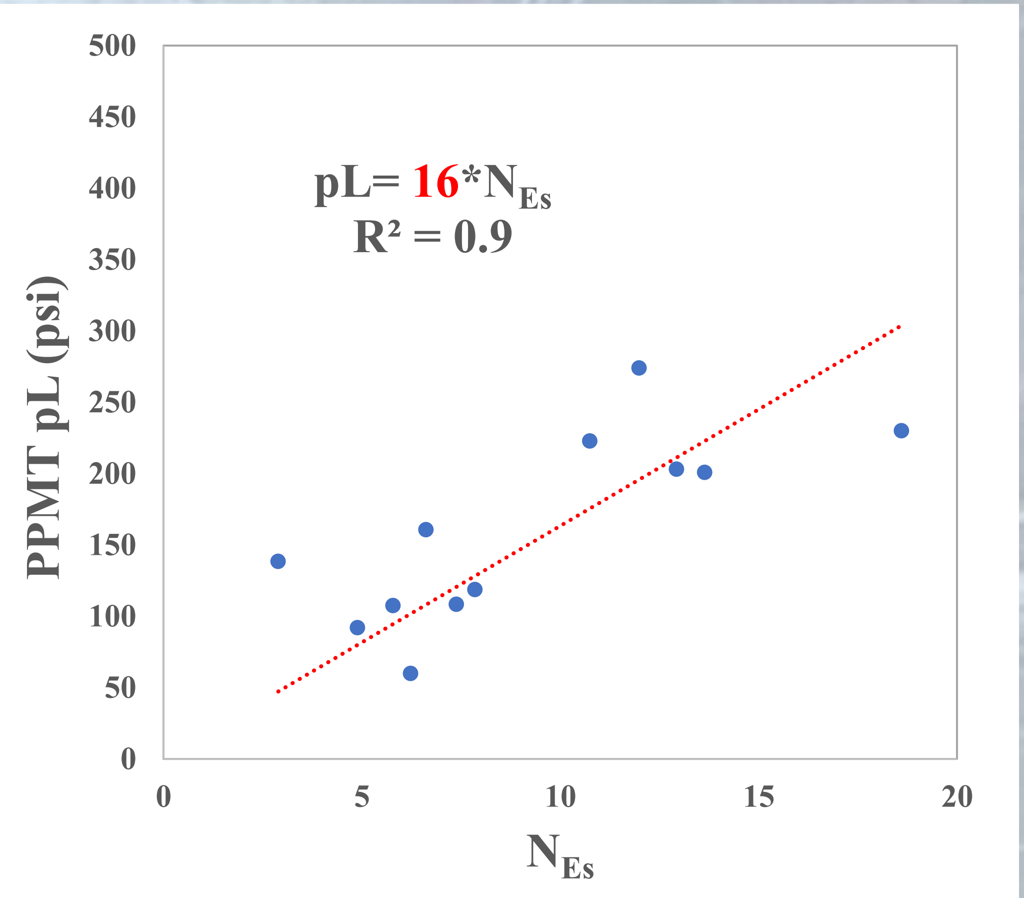
Papadopoulos (1992) $Es = 2.5\ qc$ and $Es = 7.5 + 0.8N\ (MPa)$

Trofimenkov (1974):
E_s= (350 to 500)logN, kg/cm^2
Webb (1969):
E=4(N + 12), ton/ft^2
Chaplin (1963):
$E_s^{4/3}$ = (44N), tsf
Denver (1982):
E_s= 7(N)$^{0.5}$, MPa
Clayton et al. (1985):
E_s= 3.5N to 40N, MPa
Papadopoulos and Anagnostopoulos (1987):
E_s= 7.5 + 0.8N, MPa

Sand with fines	**Kulhawy and Mayne (1990):** E/Pa=5N_{60} **Webb (1969):** E = 3.33 (N + 5), tons/ft^2 (Clayey saturated sands)
Submerged fine to medium sand	**Webb (1969):** E=5(N+15), tons/ft^2
Sands, Sandy gravels	**(FHWA-IF-02-034):** E=1,200 $(N_1)_{60}$, kPa
NC Sands	**Bowles (1996):** E_s=500(N_{55}+15), kPa =7,000$\sqrt{N_{55}}$ =6,000N_{55}
Clean fine to medium sands and slightly silty sands	**(FHWA-IF-02-034):** E=700 $(N_1)_{60}$, kPa

Task 4 PPMT SPT N_{ES} Correlations





Task 4
E_{PPMT} vs. SPT-N and E_{SPT} Correlations (from 3 Field sites)

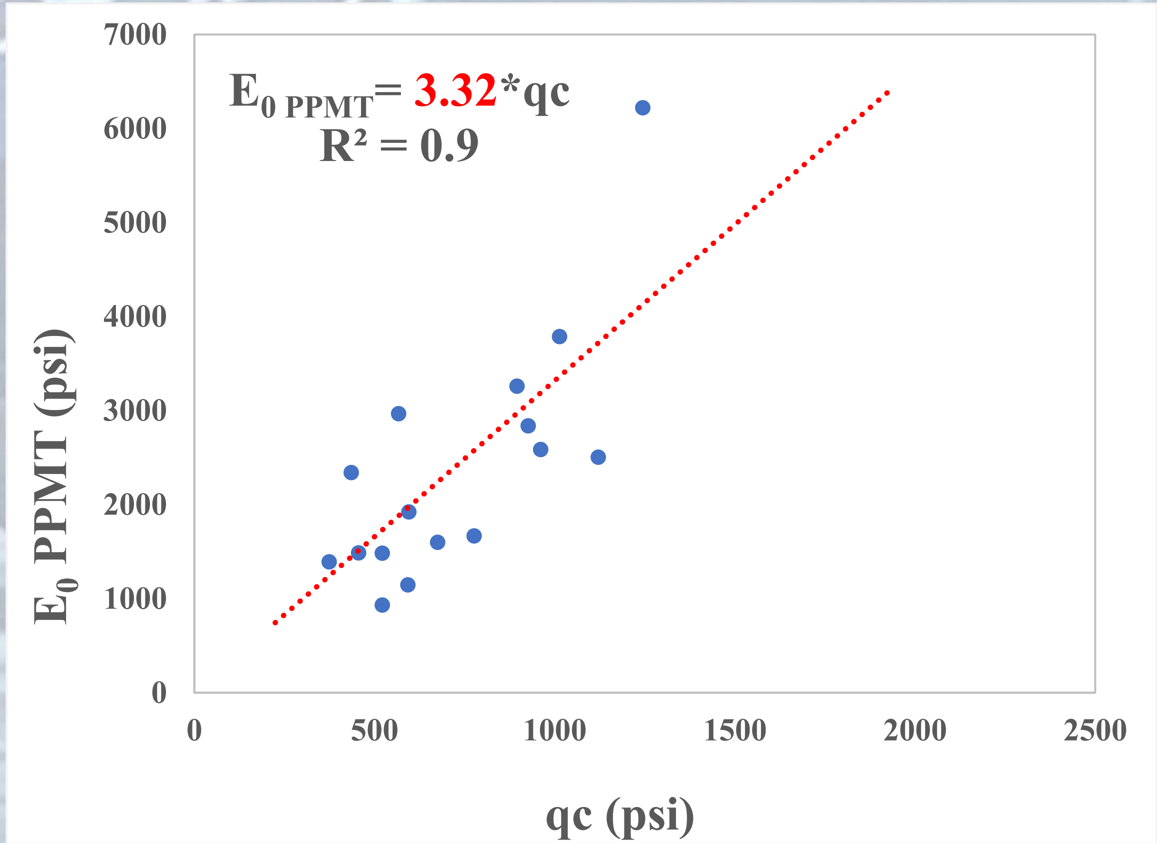
Site	Depth (ft)	SPT-N	E_{PPMT}/SPT-N (psi)
Kingsley	6	5	297.2
	10	6	248.2
	16	9	315.4
	20	15	217.5
Trenton	6	5	186.6
	10	4	348.3
	16	6	278.3
	20	10	296.8
UCF	6	11	235.2
	10	10	378.8
	16	2	1252.5
	20	5	385.2
Average			**370**

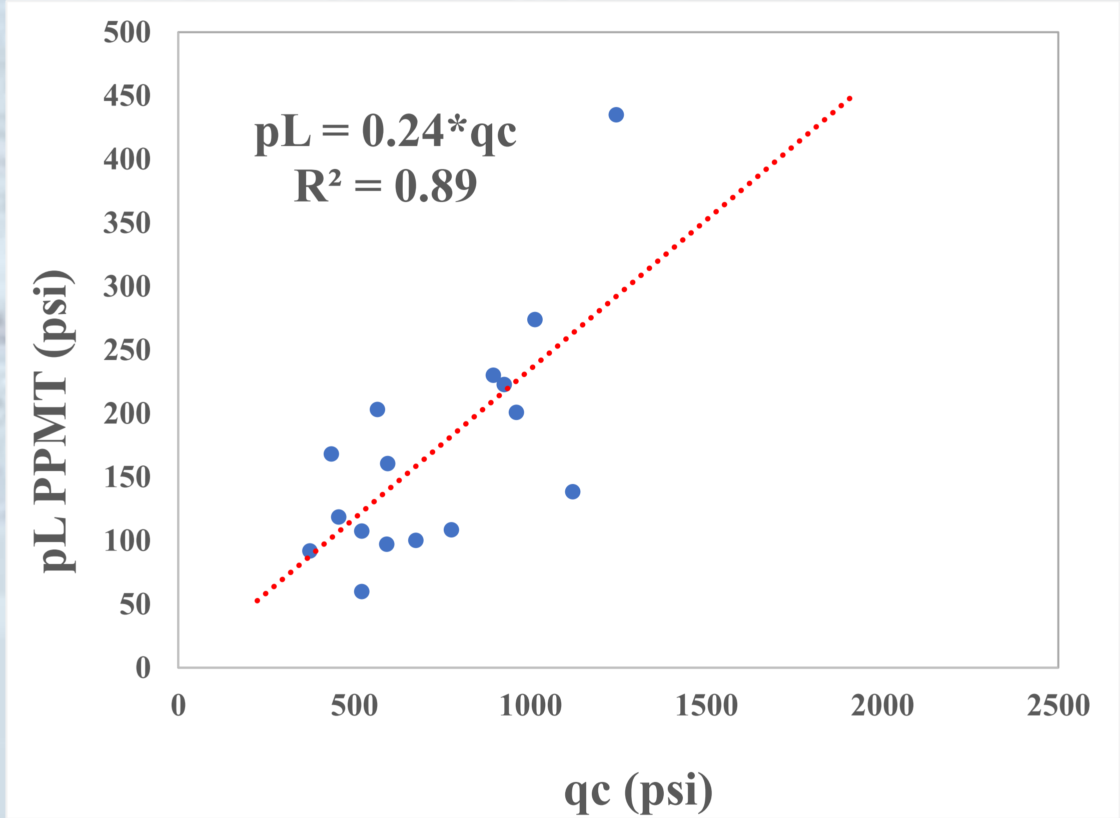
= 290 w/o 16' UCF ratio

Site	Depth (ft)	Modulus (psi)		$E_{PPMT}/E_{\_SPTN}$
		PPMT	SPT	
Kingsley	6	1486	928	1.6
	10	1489	1090	1.4
	16	2839	1317	2.2
	20	3262	1963	1.7
Trenton	6	933	976	1
	10	1393	769	1.8
	16	1670	982	1.7
	20	2968	1435	2.1
UCF	6	2587	1867	1.4
	10	3788	1539	2.5
	16	2505	502	5
	20	1926	852	2.3
Average				**2**

= 1.8 w/o 16' UCF ratio

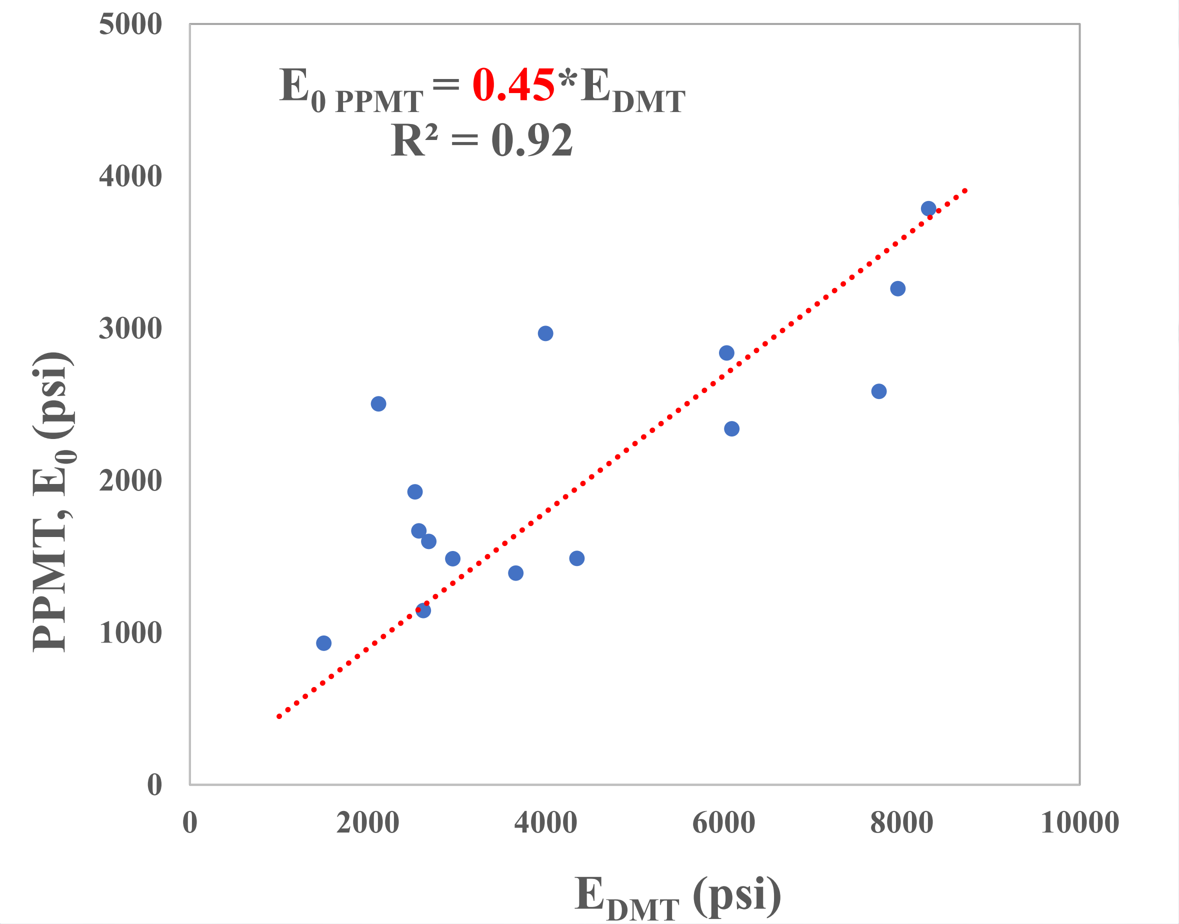
Task 4 PPMT CPT Correlations

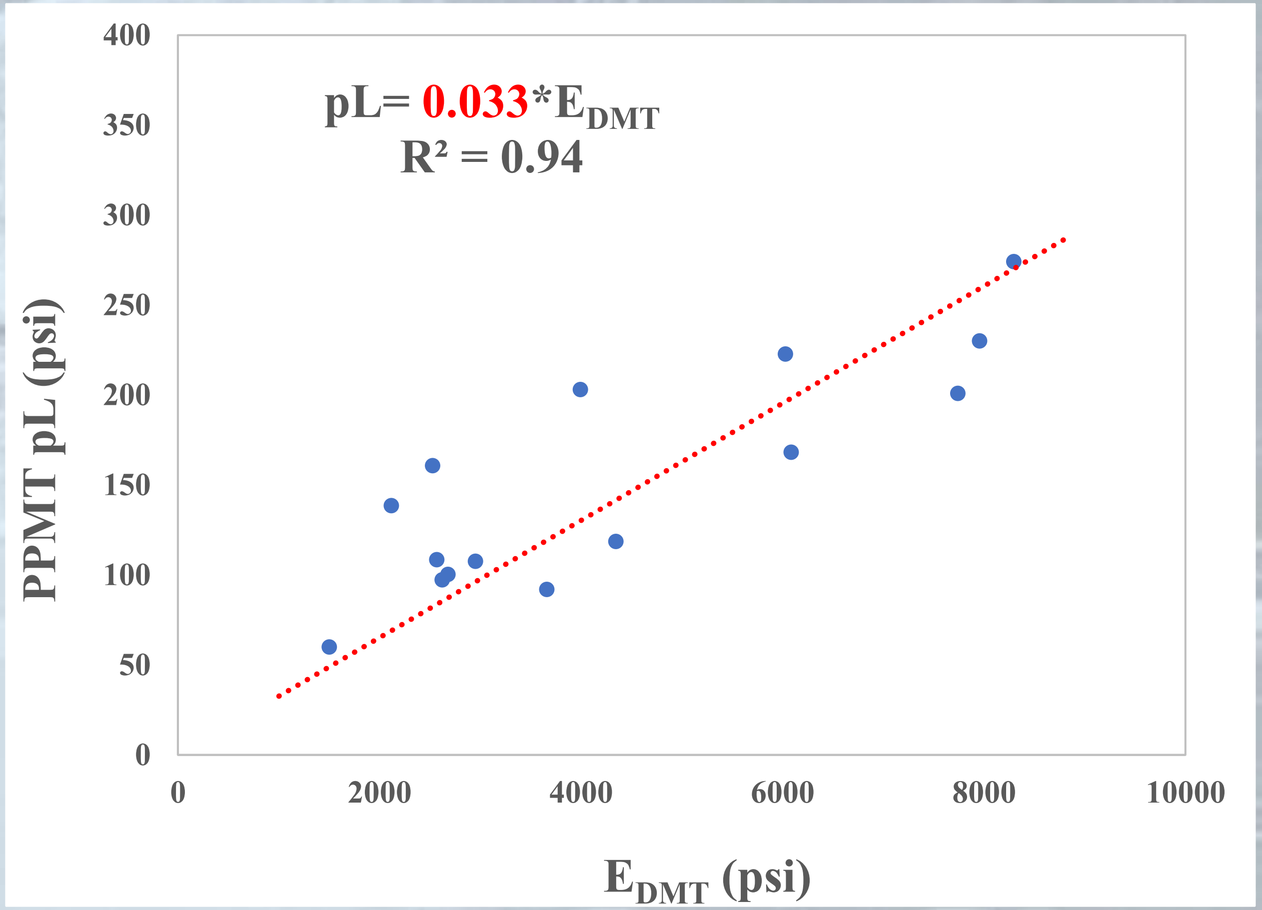




Recall Literature says E=2.5 to 3.5 qc

Task 4 PPMT DMT Correlations

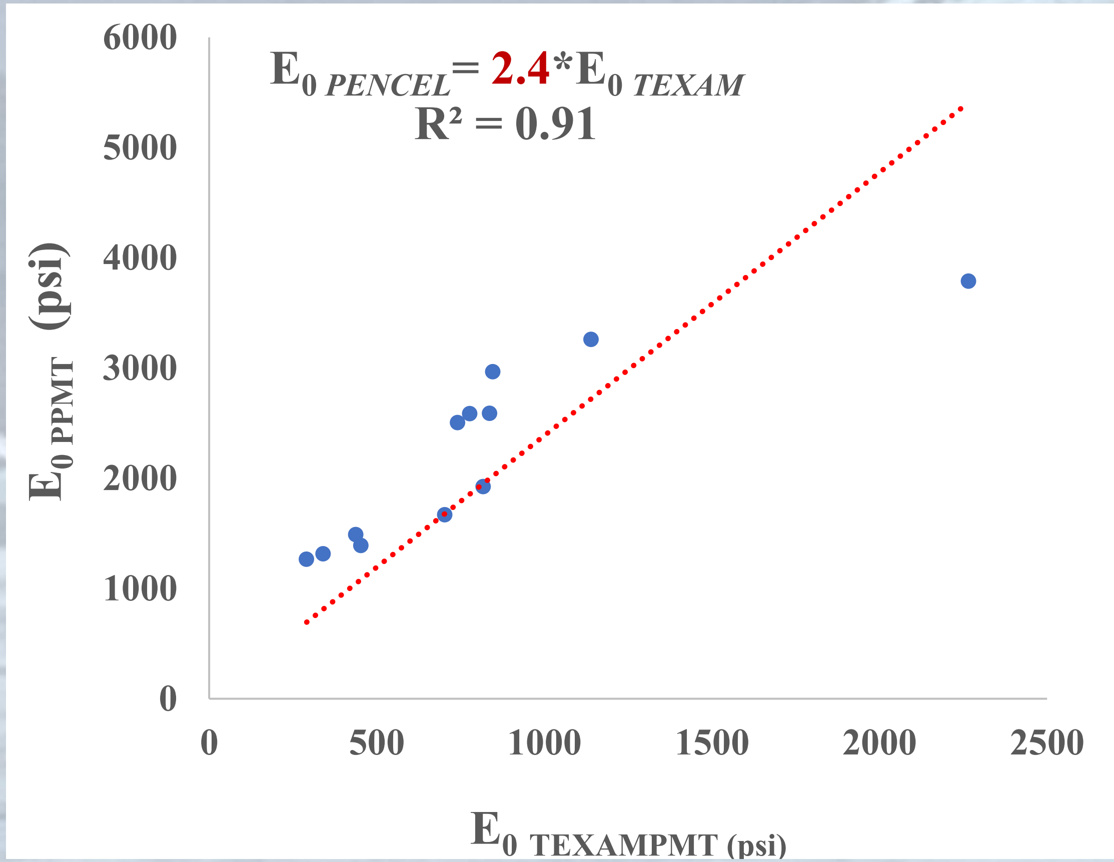


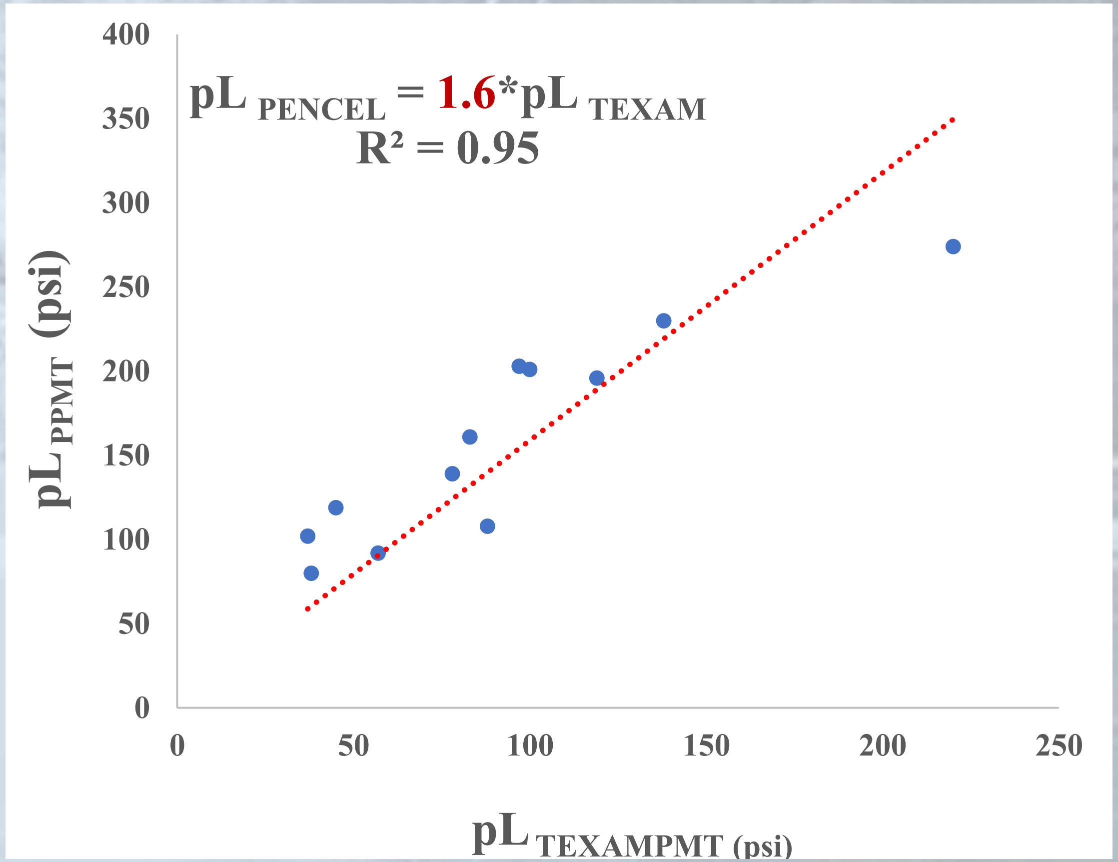


$Eo_{\ PPMT} \simeq 1/2\ E_{\ DMT}$

$pL_{\ PPMT} \simeq 1/30\ E_{\ DMT}$

Task 4 PENCEL - TEXAM Correlations Loose To Medium Dense Fine Sands





Borehole Preparation Produces Differences

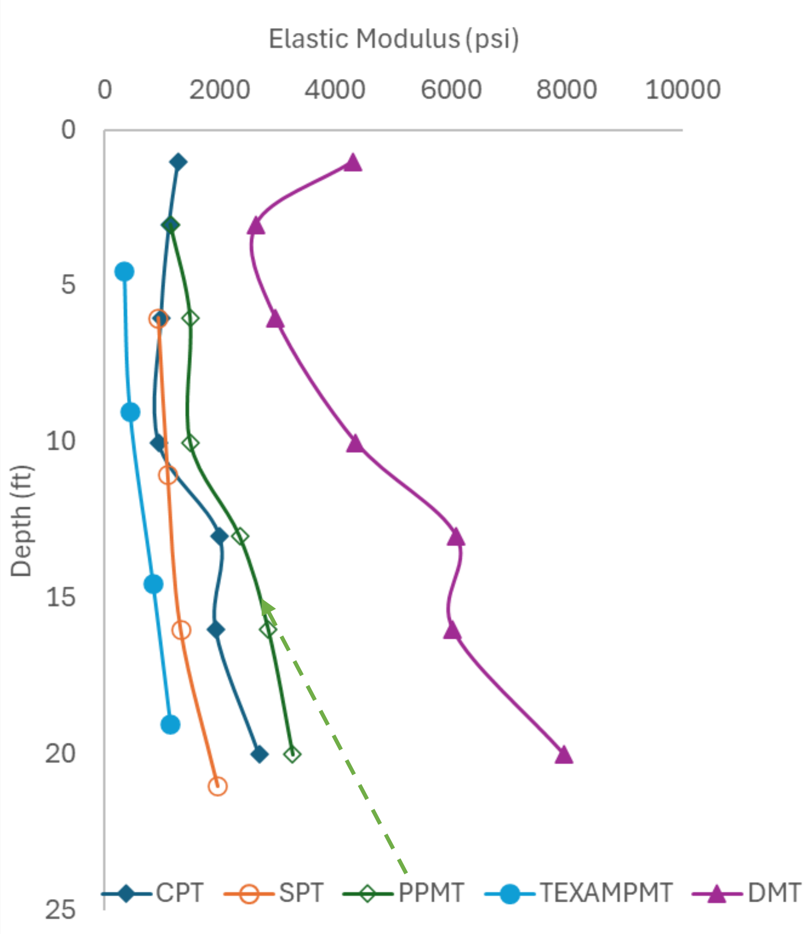
Task 4 Summary

PPMT	Factor	Test Modulus
E_0	2.4	TEXAM
	0.45	DMT
	3.32	CPT
	225	SPT
	2.74	*Plate*
pL	0.95	TEXAM
	0.033	DMT
	0.24	CPT
	16	SPT
	19	*Plate*

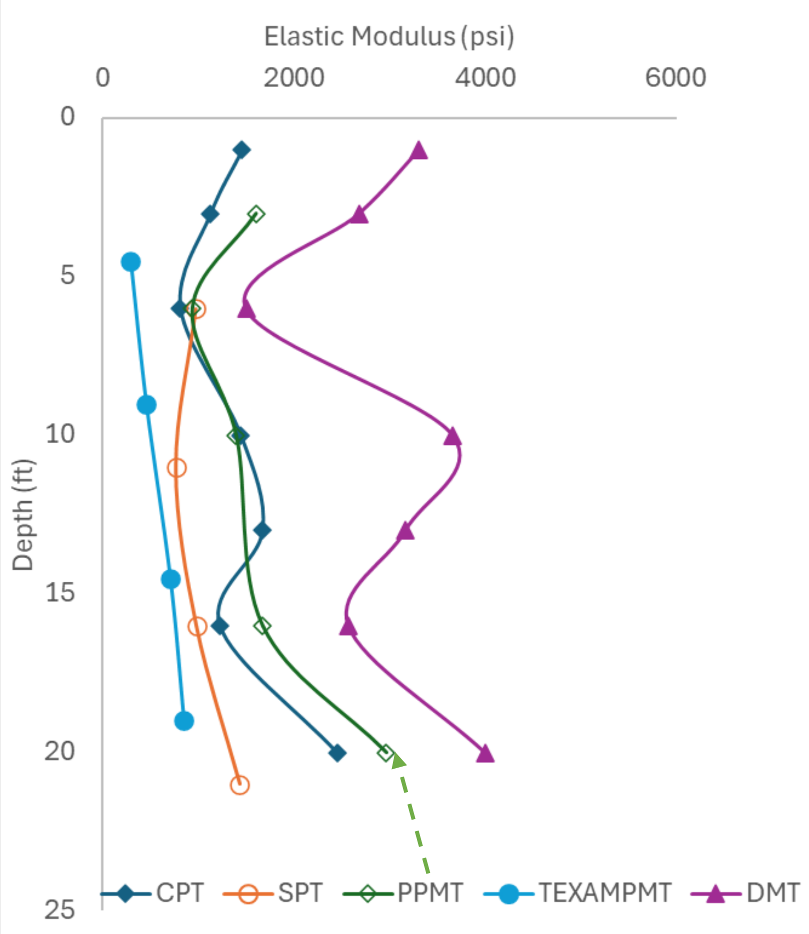
- *Moduli Trends are Similar between PPMT, TEXAM, CPT, and DMT Data,*
- *SPT correlation much higher*
- *Plate difficult to visualize vs depth*

Task 5 Comparison of Elastic Moduli versus depth: All sites

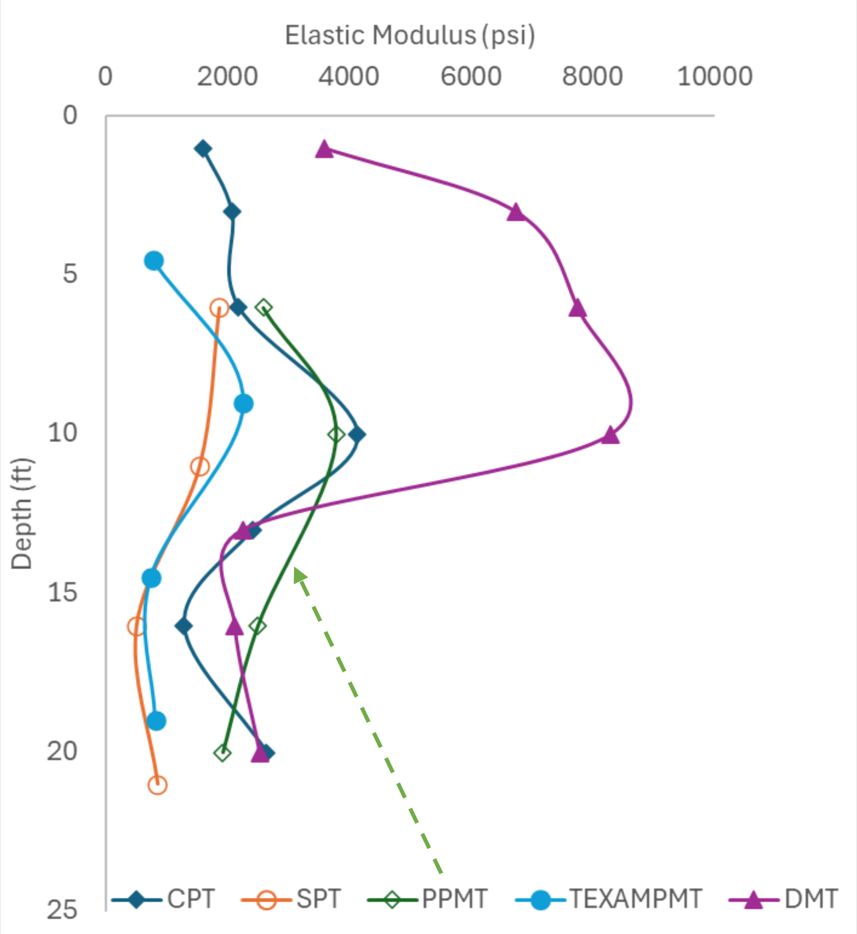
Kingsley



Trenton



UCF



Task 5

Overall Summary of Elastic Moduli

Site	Es (psi)				
	Borehole	Depth (ft)			
		5	10	15	20
Kingsley	SPT	980	1083	1200	1760
	CPT	1167	1083	2900	3583
	PPMT	1317	1489	2633	3263
	TEXAM	335	439	837	1140
	DMT	2700	4047	6183	8357
Trenton	SPT	1083	813	932	1283
	CPT	867	1800	1333	2983
	PPMT	949	1507	1797	2817
	TEXAM	291	452	703	846
	DMT	1568	2063	2155	4003
UCF	SPT	1730	1550	810	830
	CPT	2117	7200	2100	3367
	PPMT	2587	3626	2505	1926
	TEXAM	778	2266	741	818
	DMT	7128	9444	1861	2592

Overall Comparison of Elastic Moduli Compared to SPT Moduli

Site	Comparison to SPT Moduli				
	Borehole	Depth (ft)			
		5	10	15	20
Kingsley	SPT	0%	0%	0%	0%
	CPT	19%	0%	142%	104%
	PPMT	34%	37%	119%	85%
	TEXAM	-66%	-59%	-30%	-35%
	DMT	176%	274%	415%	375%
Trenton	SPT	0%	0%	0%	0%
	CPT	-20%	121%	43%	133%
	PPMT	-12%	85%	93%	120%
	TEXAM	-73%	-44%	-25%	-34%
	DMT	45%	154%	131%	212%
UCF	SPT	0%	0%	0%	0%
	CPT	22%	365%	159%	306%
	PPMT	50%	134%	209%	132%
	TEXAM	-55%	46%	-9%	-1%
	DMT	312%	509%	130%	212%

Lots of numbers! Main Point: SPT moduli are LOWER, unless there is a testing problem

Task 5 Elastic Modulus from SSMini PMT

Summary of Plate, SSMini, CPT, and DMT moduli

Site	Borehole Vicinity	SSMini E (psi) 0 to 1 ft	CPT E (psi) 0 to 1 ft	DMT E (psi) 0 to 1 ft	Plate E (psi) 0 to 1 ft
Kingsley	1	703	1066	3075	6409
	2	716	1373	3216	4163
	3	794	1400	4323	4636
	Average	**738**	**1280**	**3538**	**5069**
Trenton	1	612	1589	2898	4314
	2	1033	1494	3303	3192
	3	1039	1292	3012	3011
	Average	**895**	**1458**	**3071**	**3506**
UCF	1	177	1671	5543	4579
	2	73	1697	5195	3196
	3	64	1410	5149	1783
	Average	**105**	**1593**	**5296**	**3186**

Overall Comparison of Plate, CPT, DMT to SSMini moduli

Site	Borehole Vicinity	SSMini E (psi) 0 to 1 ft	CPT E (psi) 0 to 1 ft	DMT E (psi) 0 to 1 ft	Plate E (psi) 0 to 1 ft
Kingsley	1	100%	52%	337%	812%
	2	100%	92%	349%	481%
	3	100%	76%	444%	484%
	Average	**100%**	**73%**	**379%**	**587%**
Trenton	1	100%	160%	374%	605%
	2	100%	45%	220%	209%
	3	100%	24%	190%	190%
	Average	**100%**	**63%**	**243%**	**292%**
UCF	1	*100%*	844%	3032%	2487%
	2	*100%*	2225%	7016%	4278%
	3	*100%*	2103%	7945%	2686%
	Average	**100%**	**1417%**	**4944%**	**2934%**

Lots of numbers! Main Point, SSMini Moduli compared to upper 1 foot data from DMT & CPT are lower unless there is a testing problem (UCF Water Table)

Summary of Settlement Prediction Approaches

Task 5

Settlement Prediction Approaches		
Number	Reference	Comments
1	AASHTO, 2017	Analytical
2	Berardi et al., 1991	
3	Bowles, 1987	
4	Hough, 1959	
5	Mayne & Poulos, 1999	
6	Oweis, 1979	
7	Papadopoulos, 1992	
8	Poulos & Davis, 1974	
9	Schmertmann, 1970	
10	Schmertmann, et al., 1979	
11	Tschebotarioff, 1973	
12	Webb, 1970	
13	Menard & Rousseau, 1962	Empirical-PMT
14	Briaud, 2007	
15	Alpan, 1964	Empirical-SPT
16	Anagnostopoulos et al., 1991	
17	Burland et al., 1985	
18	Meyerhof, 1965	
19	Meyerhof, 1974	
20	Parry, 1985	
21	Peck et al., 1974	
22	Peck & Bazaara, 1969	
23	Schultze & Sharif, 1973	
24	Teng, 1962	
25	Terzaghi, 1968	
26	DeBeer, 1970	Elastic-CPT
27	DeBeer & Martens, 1957	
28	Meyerhof, 1965	
29	Leonards & Frost, 1988	Empirical -DMT
30	Schmertmann, 1986	

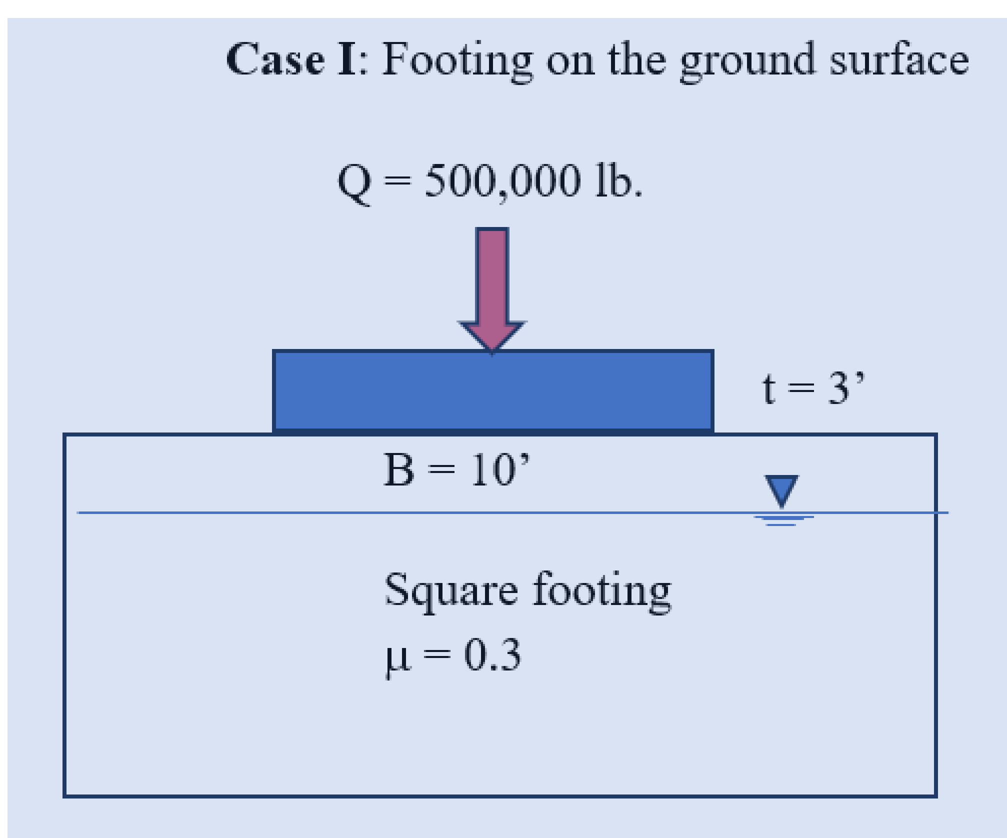
Summary of Bearing Capacity Prediction Approaches

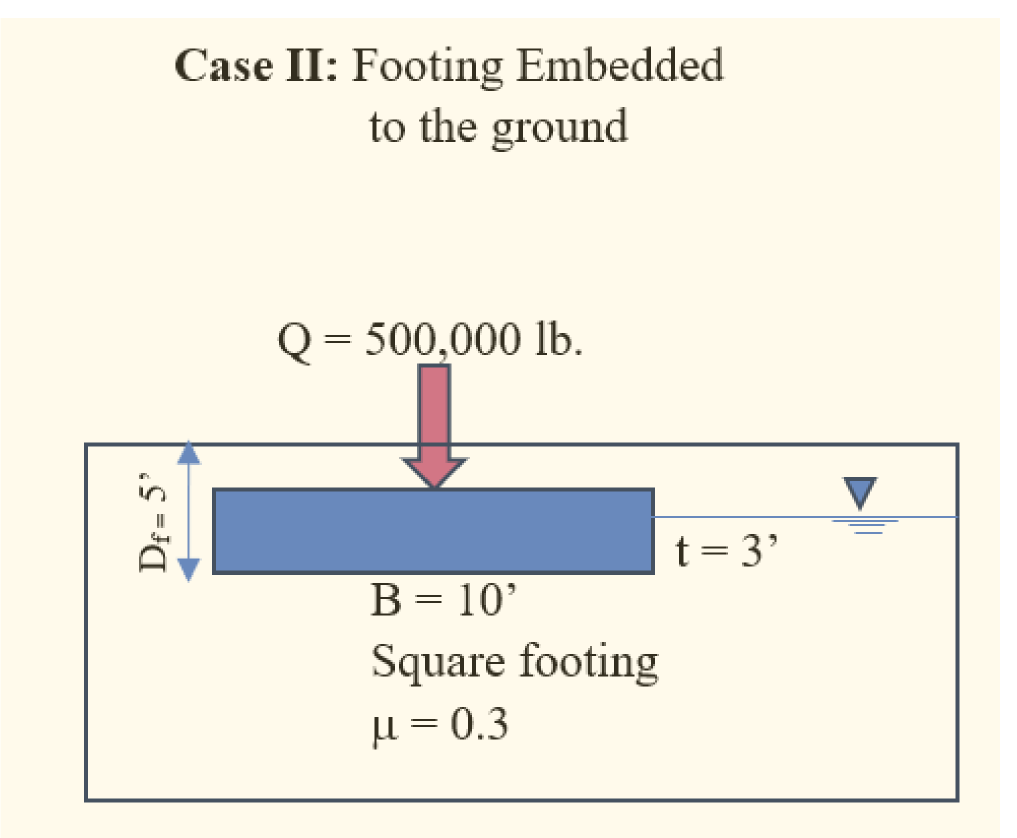
Bearing Capacity Prediction Approaches		
Number	Reference	Comments
1	DeBeer, 1970	Empirical -DMT
2	Hanna & Meyerhof, 1981	
3	Hansen, 1970	
4	Meyerhof, 1963	
5	Terzaghi, 1943	
6	Vesic, 1973	
7	Briaud, 1992	PMT Based
8	Menard, 1963	
9	Bowles, 1996	SPT-Based
10	Meyerhof, 1956	
11	Parry, 1977	
12	Teng, 1962	
13	Schmertmann, 1978	

Assumed Footing Arrangement

(for comparison purposes only)

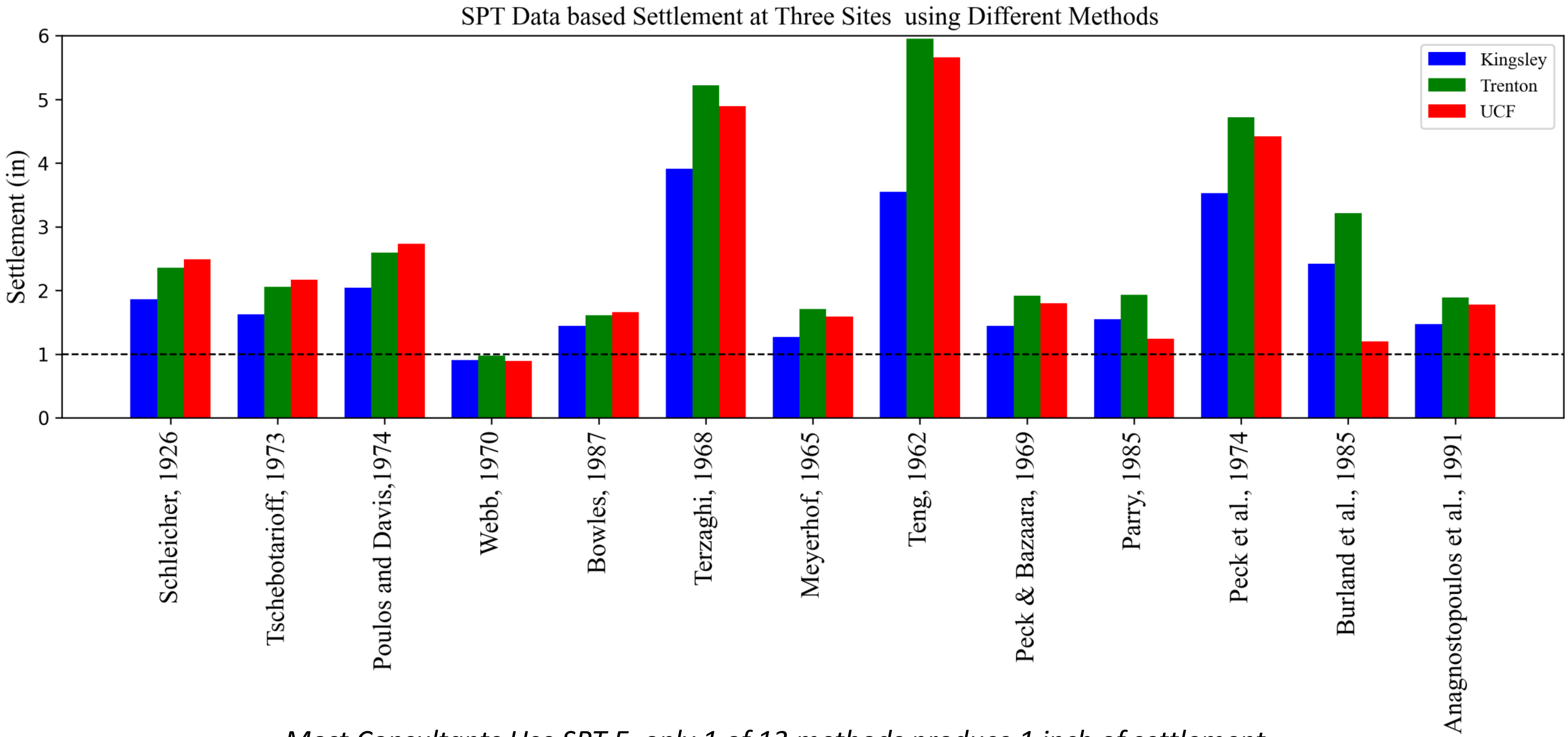
Task 5





Settlement based on SPT data

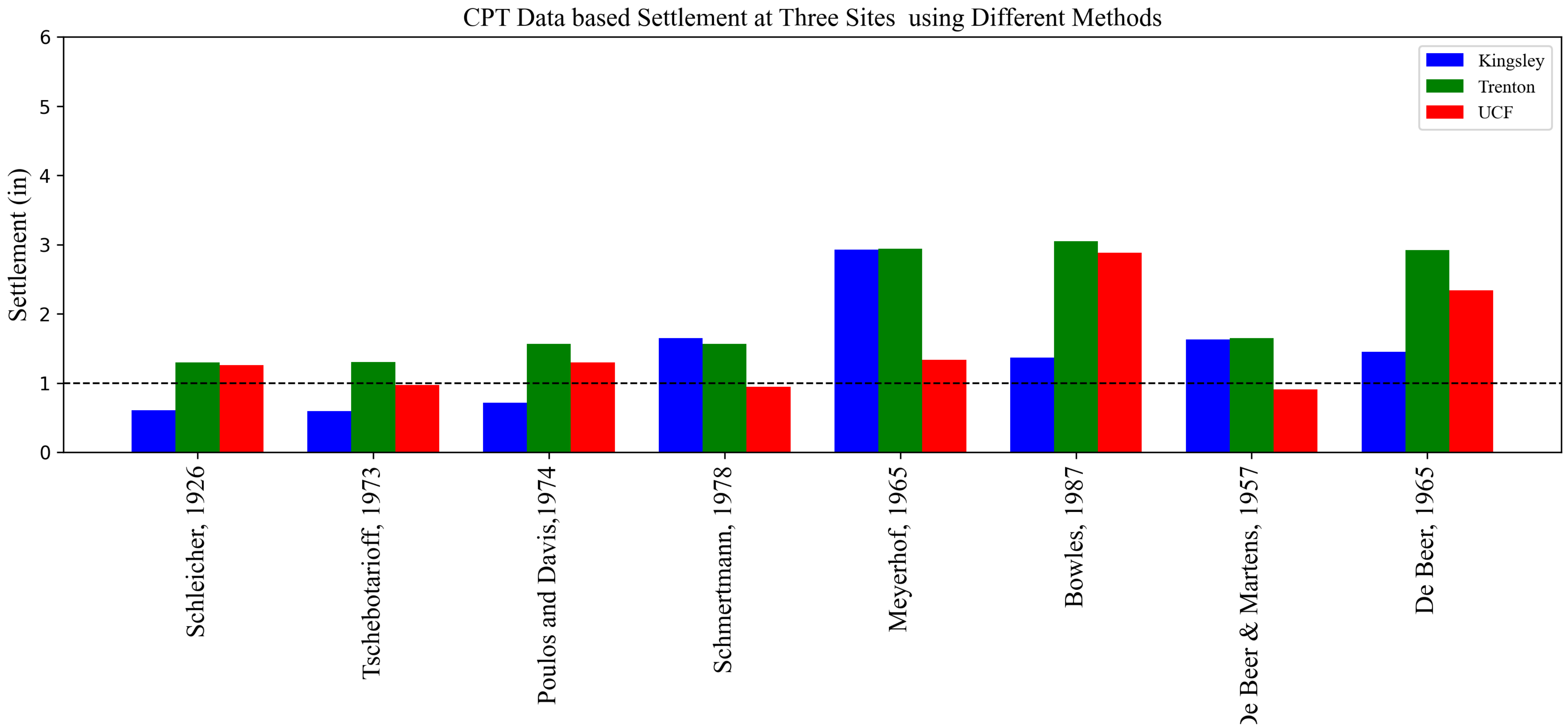
Task 5



Most Consultants Use SPT E, only 1 of 13 methods produce 1 inch of settlement

Settlement from CPT

Task 5

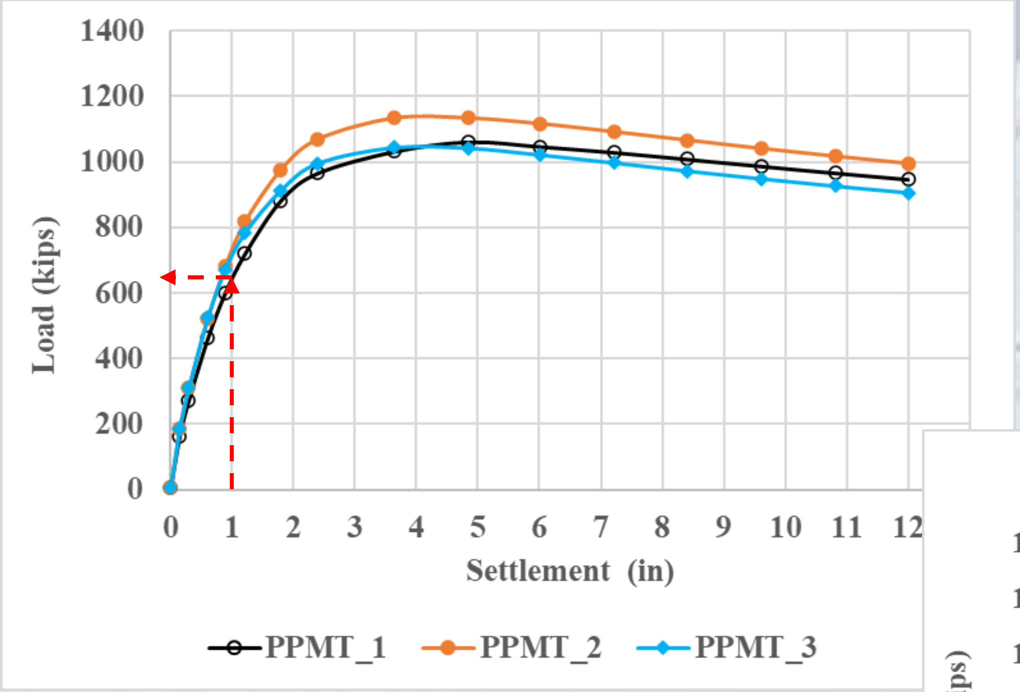


Note the variability of the CPT predictions at each site at least ½ predict over 1 inch

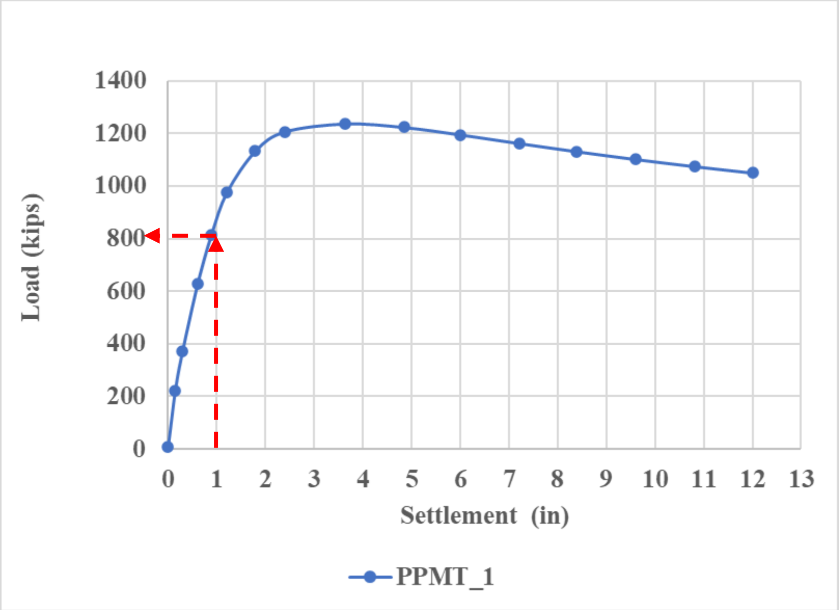
Settlement Predictions from Pushed-in PPMT: Briaud (2007)

Task 5

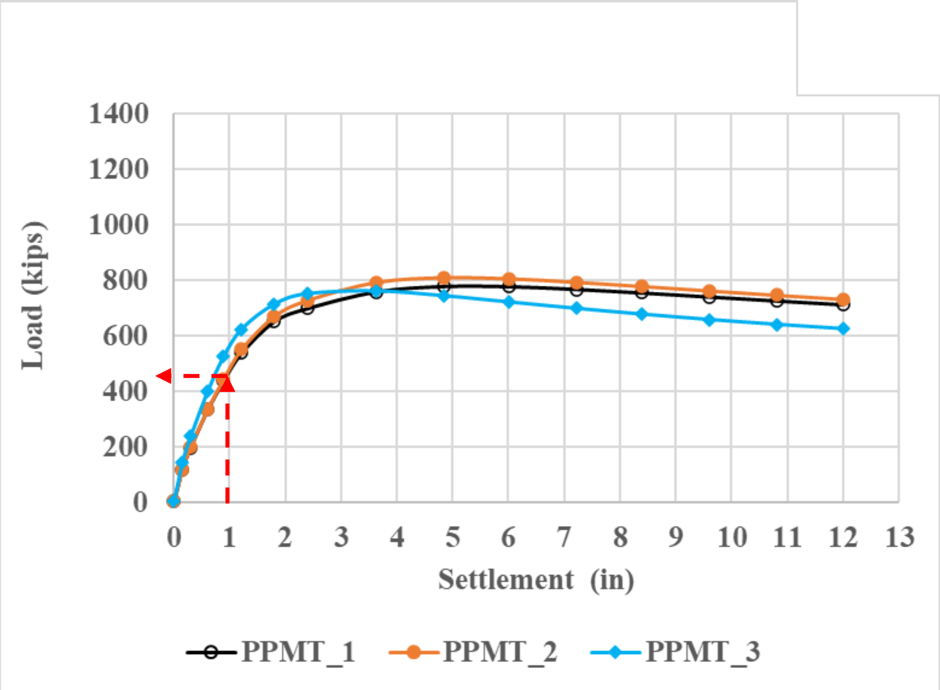
Kingsley



UCF



Trenton



1-inch settlement
@ Kingsley = 650 Kips
@ Trenton = 450 to 575 Kips
@ UCF = 800 Kips

1-inch settlement vs 500 Kips
@ Kingsley Footing OK
@ Trenton Marginal Footing
@ UCF Footing Ok

Summary of Settlement Predictions from Pushed-in PMT

Task 5

Settlement using pressuremeter modulus					
Approach	**Site**	**Depth of influence**	**Borehole**	**Se (in) (Menard α=1)**	**Se (in) (Menard α=0.5)**
Ménard, 1967	Kingsley	Entire field-testing depth	K_PPMT_1	0.78	0.40
			K_PPMT_2	0.84	0.43
			K_PPMT_3	0.79	0.41
	Trenton		T_PPMT_1	1.27	0.66
			T_PPMT_2	0.90	0.46
			T_PPMT_3	1.04	0.54
			T_PPMT_4	0.84	0.43
	UCF		UCF_PPMT_1	0.49	0.25
			UCF_PPMT_2	0.57	0.30
			UCF_PPMT_3	0.37	0.19
Briaud, 2007	Kingsley	2B square footing	K_PPMT_1	0.30	
			K_PPMT_2	0.24	
			K_PPMT_3	0.24	
	Trenton		T_PPMT_1	0.45	
			T_PPMT_2	0.45	
			T_PPMT_3	0.35	
	UCF		UCF_PPMT_1	0.20	
			UCF_PPMT_2	*	
			UCF_PPMT_3	*	

Ménard, 1967
For 500 Kips on 10 by 10 footing, only Trenton had values near 1”

Briaud, 2007
For 500 Kips on 10 by 10 footing, no values near 1”

Summary of Settlement from TEXAM PMT

Task 5

Settlement using TEXAM pressuremeter modulus				
Approach	Site	Depth of influence	Borehole	Se (in)
Ménard, 1967	Kingsley	Thickness of Test depth	K_TEXAM_1	1.47
			K_TEXAM_2	2.24
			K_TEXAM_3	1.35
	Trenton		T_TEXAM_1	1.62
			T_TEXAM_2	1.61
			T_TEXAM_3	1.97
	UCF		UCF_TEXAM_1	1.07
			UCF_TEXAM_2	0.68
			UCF_TEXAM_3	0.65
J.-L. Briaud, 2007	Kingsley	2B square footing	K_ TEXAM _1	3.4
			K_ TEXAM _2	The ultimate bearing capacity is less than 500 kips
			K_ TEXAM _3	
	Trenton		T_ TEXAM _1	The ultimate bearing capacity is less than 500 kips
			T_ TEXAM _2	
			T_ TEXAM _3	
	UCF		UCF_ TEXAM _1	5
			UCF_ TEXAM _2	1.6
			UCF_ TEXAM _3	1.3

Ménard, 1967 & Briaud 2007 For 500 Kips on 10 by 10 footing, most had values greater 1”

Summary of Settlement Predictions from DMT

Task 5

Settlement using DMT modulus				
Approach	**Site**	**Depth of influence**	**Borehole**	**Se (in)**
Schmertmann, 1986	Kingsley	Thickness of Test depth	K_DMT_1	0.15
			K_DMT_2	0.15
			K_DMT_3	0.09
	Trenton		T_DMT_1	0.21
			T_DMT_2	0.17
			T_DMT_3	0.26
	UCF		UCF_DMT_1	0.16
			UCF_DMT_2	0.17
			UCF_DMT_3	0.25
Leonards & Frost, 1988	Kingsley	Thickness of compressible layer	K_DMT_1	0.27
			K_DMT_2	0.06
			K_DMT_3	0.02
	Trenton		T_DMT_1	0.77
			T_DMT_2	0.75
			T_DMT_3	0.74
	UCF		UCF_DMT_1	0.86
			UCF_DMT_2	3.55
			UCF_DMT_3	1.21

Schmertmann, 1986
For 500 Kips on 10 by 10 footing, most predictions much less than 1”

Leonard & Frost, 1988
For 500 Kips on 10 by 10 footing, only UCF had values greater than 1”

Summary of Predicted Settlements

Task 5

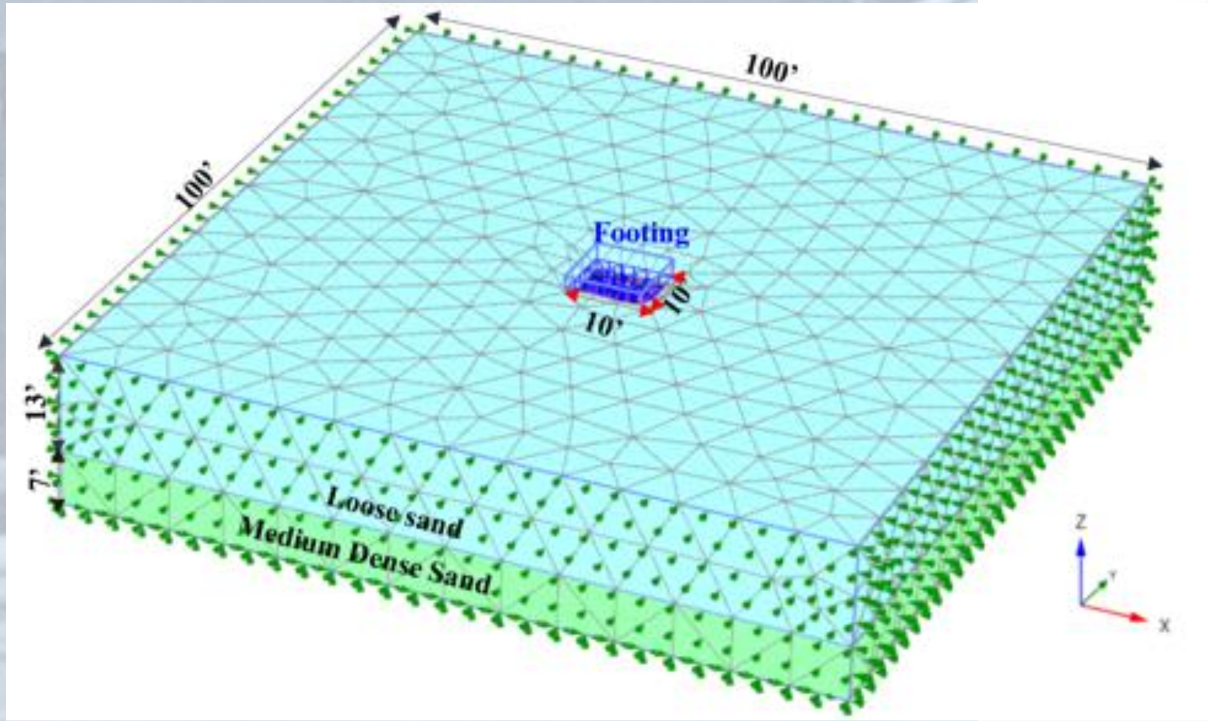
Test	Site	Mean Settlement (in)	Difference (in)	Difference (%)
PPMT	Kingsley	0.53	0	0
	Trenton	0.76	0	0
	UCF	0.41	0	0
DMT	Kingsley	0.12	-0.41	-77%
	Trenton	0.48	-0.28	-37%
	UCF	1	0.59	144%
CPT	Kingsley	0.94	0.41	77%
	Trenton	1.69	0.93	122%
	UCF	1.36	0.95	232%
TEXAM PMT	Kingsley	1.69	1.16	219%
	Trenton	1.73	0.97	128%
	UCF	0.8	0.39	95%
SPT	Kingsley	1.96	1.43	270%
	Trenton	2.57	1.81	238%
	UCF	2.48	2.07	505%
Overall		1.23	0.84	160%

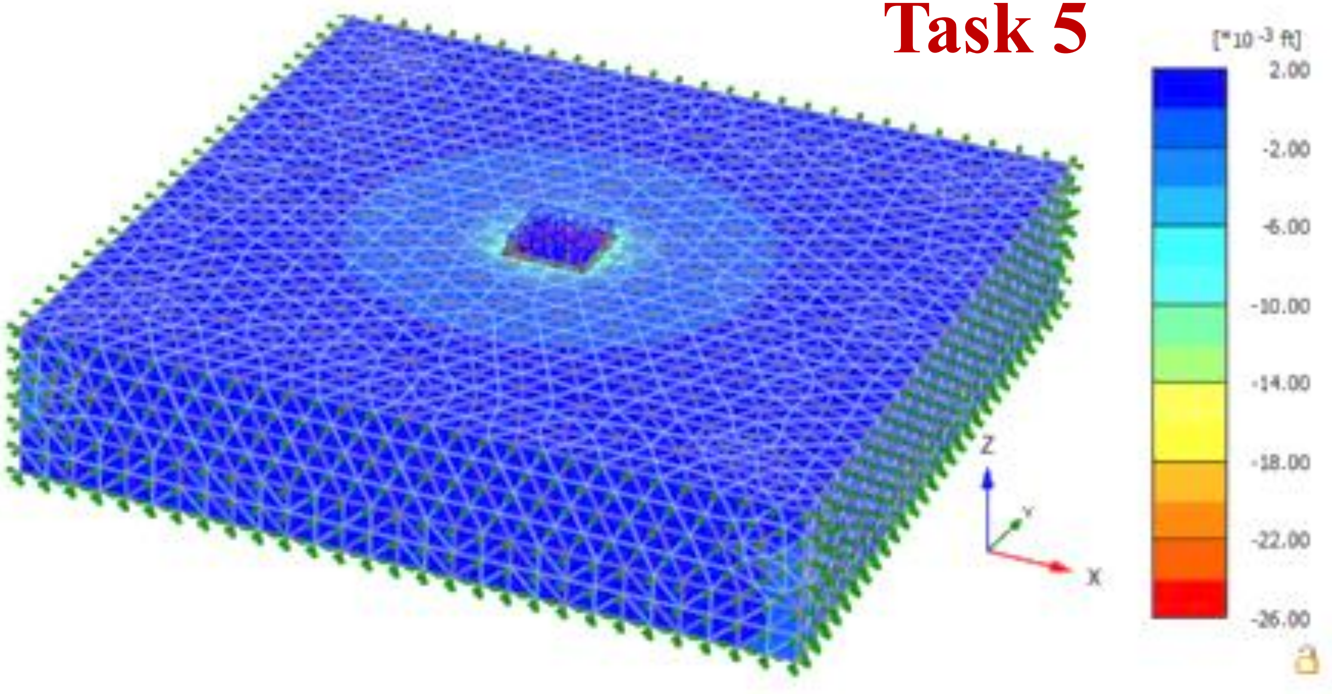
1-inch boundary

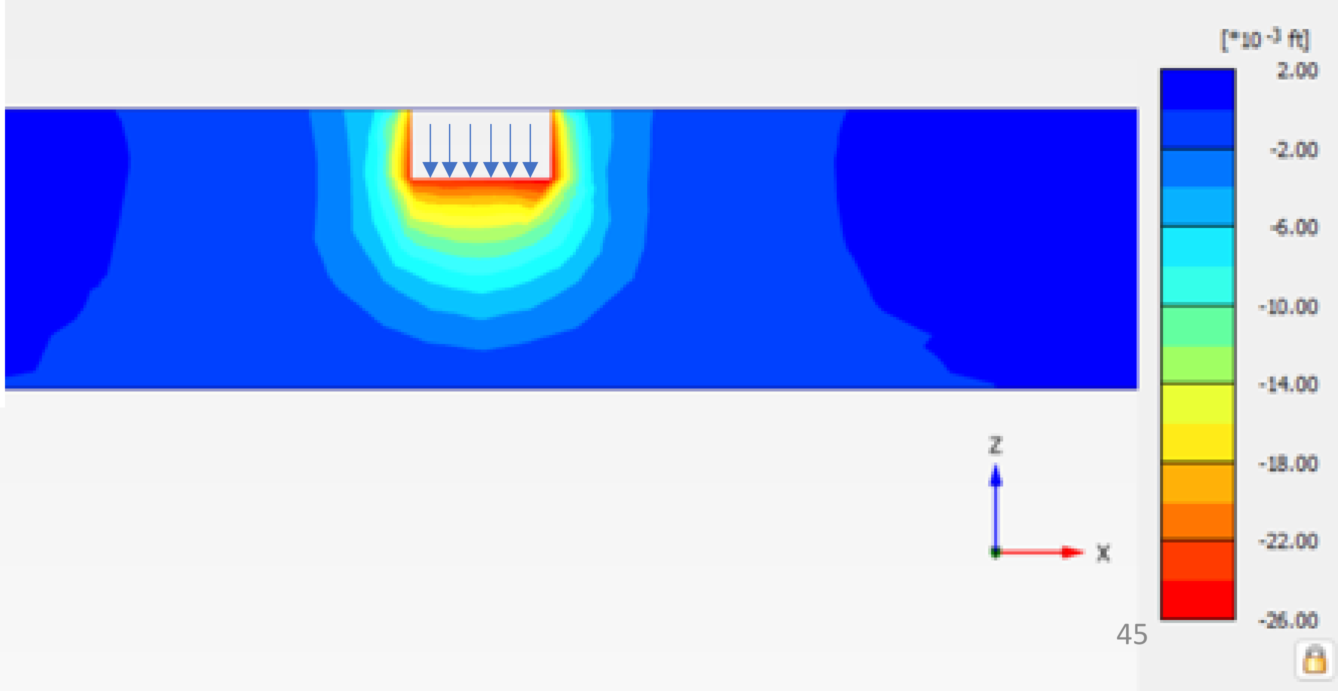
Pushed-in PENCEL PMT produces excellent data and moduli for settlement predictions

FEM
Numerical Method

Task 5



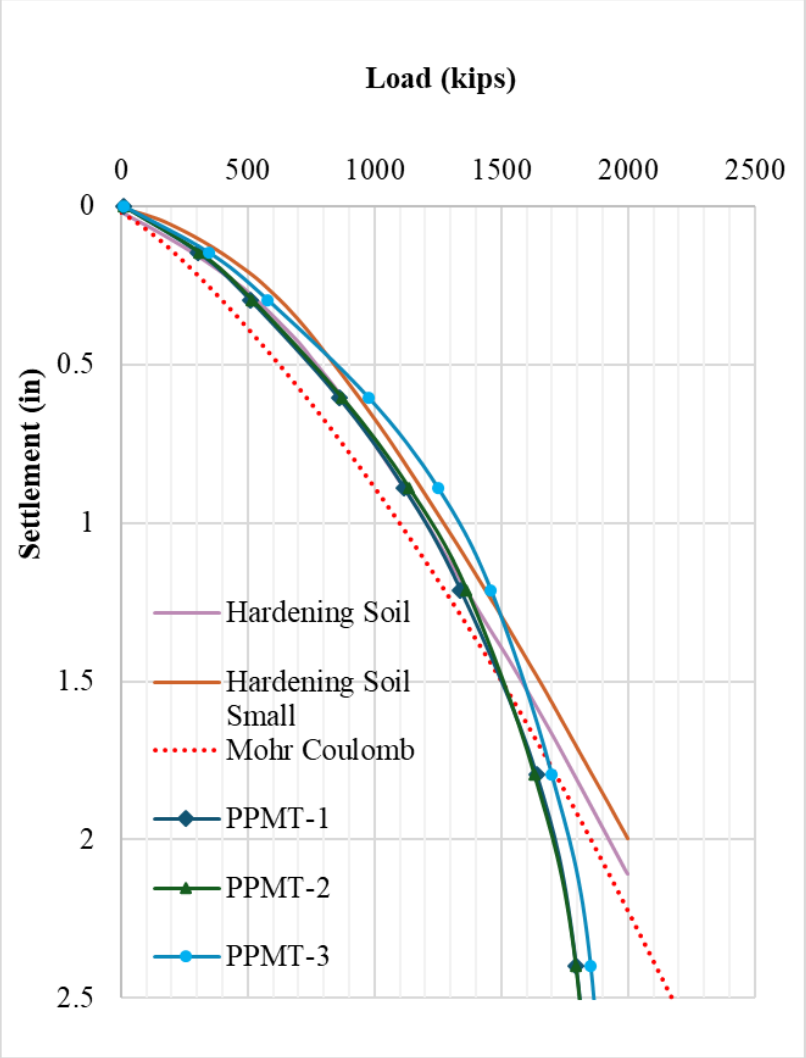




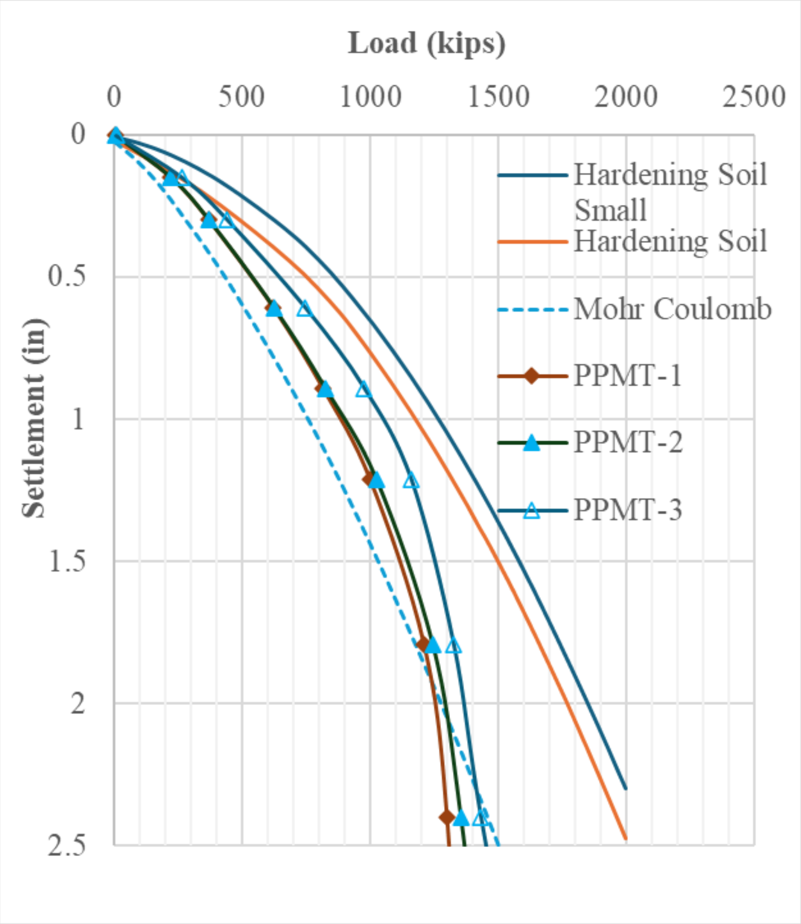
FEM Model versus Pushed-In PENCEL PMT Briaud Predictions

Task 5

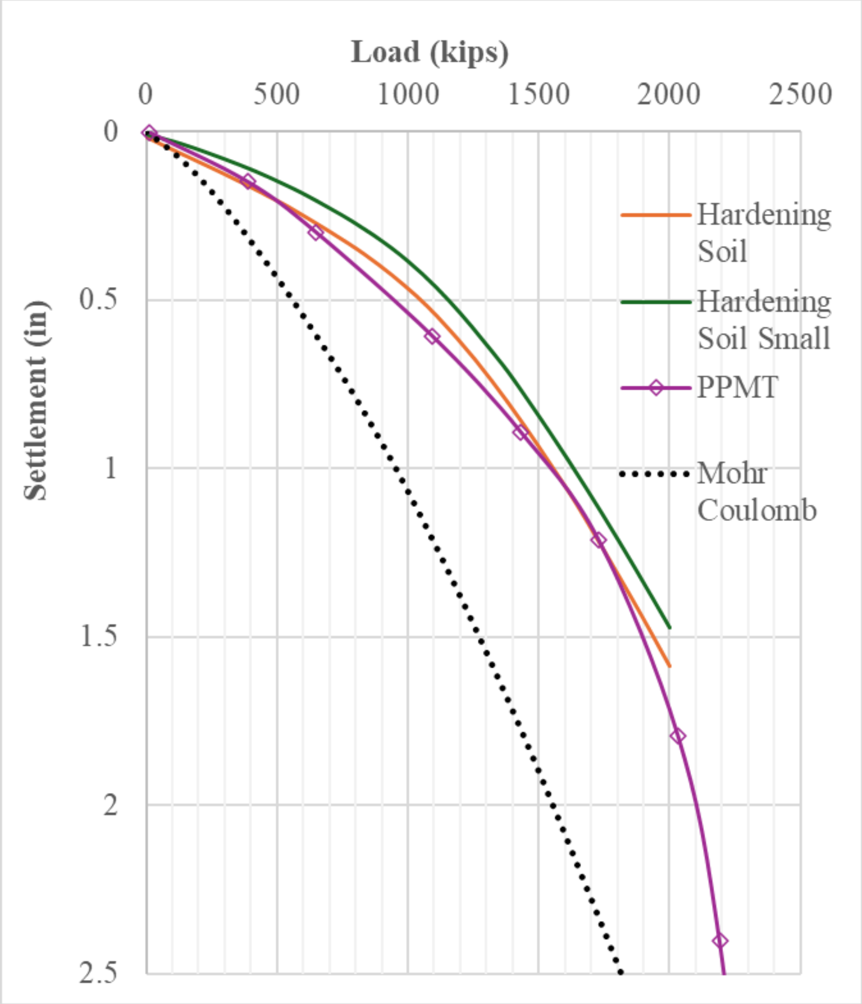
Kingsley



Trenton



UCF



Bearing Capacity Predictions

Task 5

Site	Bearing Capacity (q_{ult}) (psi)							
	(1) Terzaghi 1943	(2) Meyerhof 1963	(3) Vesic 1973	(4) Hansen 1970	(5) De Beer 1970	(6) Hanna & Meyerhof 1981	(7)-PPMT Menard 1962	(8)-PPMT Briaud 2007
Kingsley	141	225	185	159	171	171	270	144
Trenton	141	225	154	159	171	171	249	131
UCF	177	318	365	217	234	234	360	186
Site	(9)-TEXAM Menard 1962	(10)-TEXAM Briaud 2007	(11)-SPT Bowles 1996	(12)-SPT Parry 1977	(13)-SPT Meyerhof 1956	(14)-SPT Teng 1962	(15)-CPT Meyerhof 1956	(16)-CPT Schmertmann 1979
Kingsley	91	47	67	89	32	52	1591	158
Trenton	114	59	48	73	23	47	1536	153
UCF	200	104	55	167	26	101	3027	274

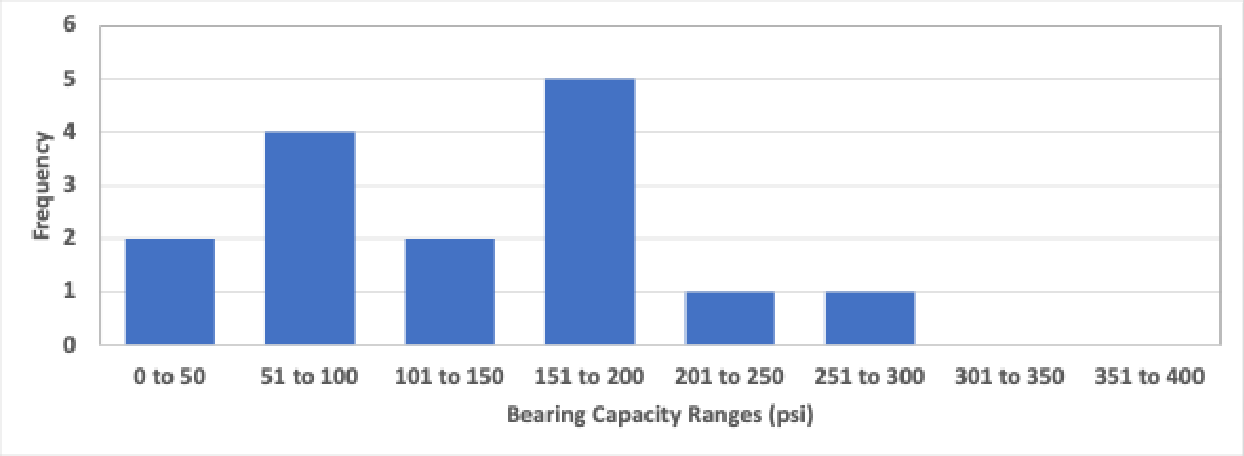
Average Bearing Capacity (q_{ult}) (psi)	
Kingsley	**131**
Trenton	**128**
UCF	**201**

Averages Exclude Outlier

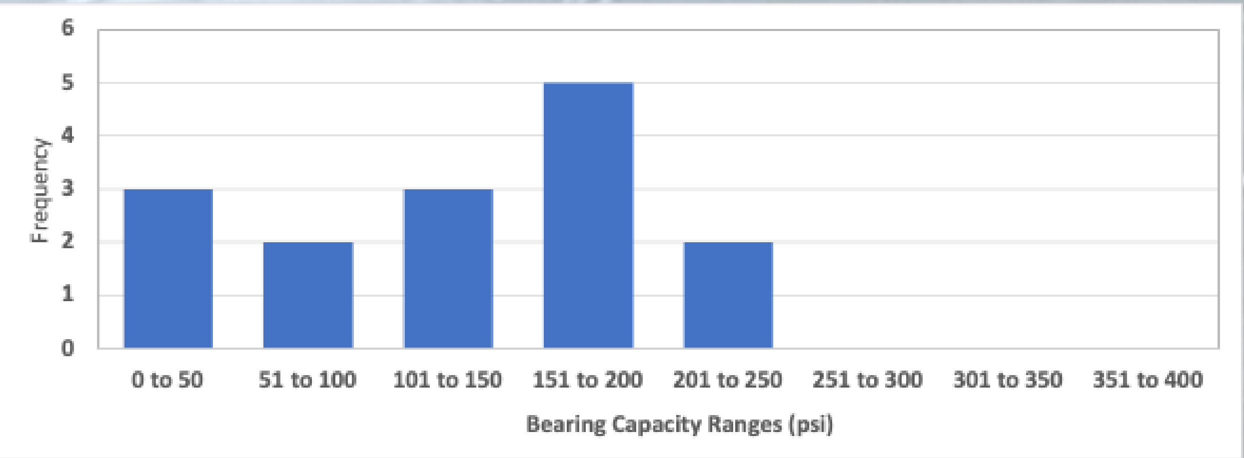
Bearing Capacity Predictions Frequency Diagrams

Task 5

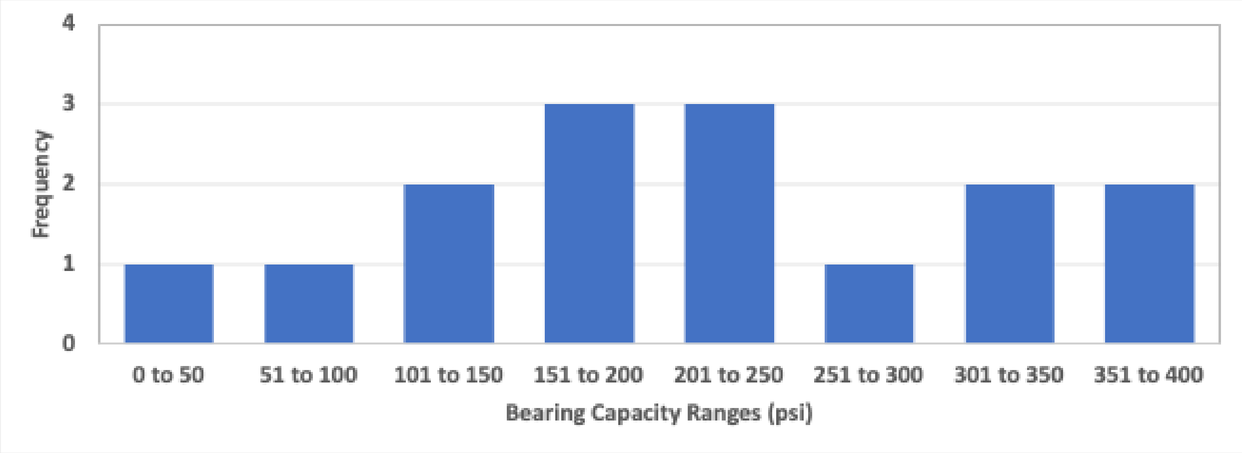
Kingsley



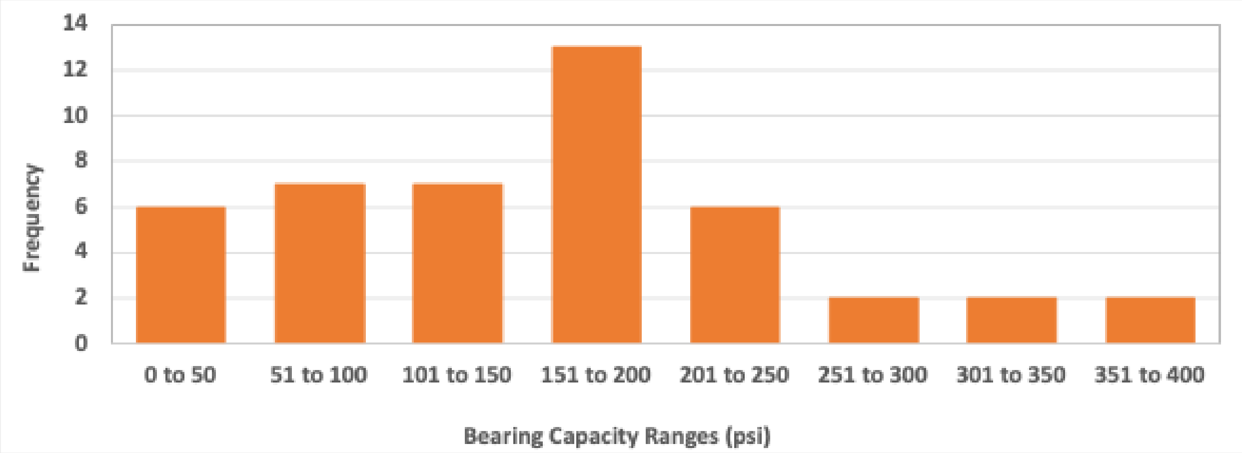
Trenton



UCF



Overall- Three sites



150-200 psi [10 to 15 tsf] most frequently estimated

Task 5: Summary and Discussion

Elastic Settlement:

- For an assumed 10’ by10’ foundation loaded with 500 kips:
  - ✓ Settlements ranging from 0.09” to 9.73”
  - ✓ SPT data produced the highest settlement
  - ✓ CPT and TEXAM PMT settlements were the second and third-highest
  - ✓ Pushed-in PPMT test data yielded very consistent settlement predictions.
    - ➢ **Average settlement 0.24” to 0.76” with the smallest standard deviations**

Task 5: Summary and Discussion
Elastic Settlement…..

- 30 different settlement prediction methods were used:
  - 12 were based on analytical methods (Es found based on CPT correlations)
  - 28 methods based on direct input data from SPT, CPT, DMT, and PMT data
- 3 Numerical approaches (HS, HSS, and MC) were used
  - No single parameter was predicted from PPMT data and, therefore, has no bias towards PPMT data
  - Model input parameters were determined using CPT data
  - PPMT testing produces consistent and very similar settlement results to the three numerical approaches
  - CPT testing produced consistent & similar settlement predictions compared to the numerical method and the PPMT

Task 5: Summary and Discussion
Bearing Capacity

- 13 different Ultimate bearing capacity predictions were used:
  - The pushed in PPMT testing, based on Briaud's (2007) approach, produces very reasonable bearing capacity predictions
  - All SPT-based predictions produce much lower quality values than the average predicted values.
  - The PMT approaches showed variability in results, as the Ménard (1962) values were higher than the Briaud (2007) values

Task 6: Overview

- Predicted settlements in Florida's fine sands derived using the pushed-in PPMT data were consistent and closely aligned with the predictions computed using three numerical approaches
- Five case studies by ECS showed that PMT settlement predictions were close to measured (monitored) settlements

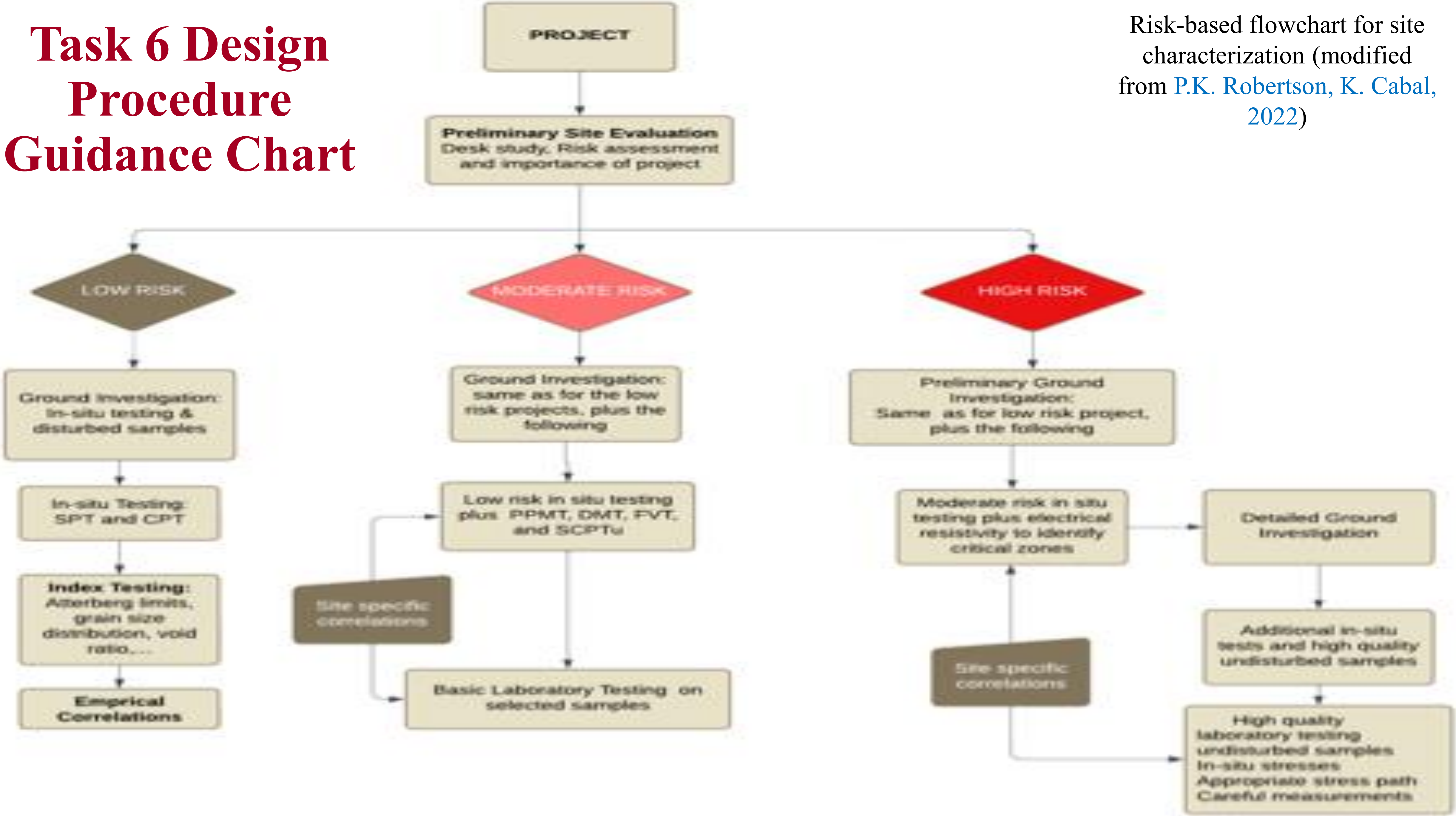
Task 6
Design Procedure Guidance Table

- Pushed-in PPMT testing can be conducted at any depth that Cone Penetrometers can be pushed in
- Industry suggests N < ≅ to 20 to 25 blows per foot (*Prevents Probe Damage*)
- Suitable in cohesionless soil
- Project Risk & Geological Complexity Controls Use

Project Importance (or) Risk Level	Geological Complexity		
	High	Moderate	Low
High	PPMT	PPMT	PPMT
Moderate	PPMT	PPMT	Conventional in-situ tests
Low	PPMT	PPMT	Conventional in-situ tests

Task 6 Design Procedure Guidance Chart

Risk-based flowchart for site characterization (modified from P.K. Robertson, K. Cabal, 2022)



Recommended Spacing and Depth of Soundings for the Pushed-in PPMT

- Depends on the uniformity of the soil horizontally and vertically (uniform, variable) and project type (multi-story buildings, dams, embankments, roadways, pipelines, …)
- 15 to 60 feet is recommended for critical structures
- 3 feet vertical spacing with the following total depths are recommended:
  - ➢ 2B for a square or circular footing (L=B)
  - ➢ 4B for strip footing (L/B>10)
  - ➢ Interpolate for footing shapes with 1<L/B<=10

Task 6 Conclusions For Florida Fine Sands

- Literature and Research supports the use of Pushed-In PENCEL Pressuremeter testing in Florida Fine Sands to predict settlement & BC
- FDOT SMO test pit testing showed that PENCEL PMT, DMT, CPT, and Plate bearing tests can be compared.
- TEXAM, PENCEL, and SSMini PMT testing consistently produced E_0/pL ratios between 10 and 17
  - This indicates that this ratio is an excellent test quality control method.
- Field Testing showed that the moduli from Pushed-PPMT tests produced realistic settlement & BC predictions

Task 6 Conclusions For Florida Fine Sands (Cont.)

- Field Testing also showed that moduli from all field testing can be used for settlement and bearing capacity predictions.
- TEXAM and PENCEL PMT data correlated well but showed that TEXAM testing produced lower moduli than PENCEL testing
  - Attributed to borehole preparation and disturbance.
- PENCEL and TEXAM limit pressures compared well
- DMT moduli are ≈ 2 ¼ times higher than Pushed-In PPMT moduli.
- Moduli predicted from CPT point bearing require multiplying factors near 3 to be compared to Pushed-in PPMT moduli
- Moduli predicted from SPT Equivalent Safety Hammer N-values require large multiplying factors to be compared to Pushed-in PPMT moduli

Task 6 Conclusions For Florida Fine Sands(Cont.)

- To allow plate bearing data to be useful, SSMini PMT tests were performed in 12-inch pin holes.
- Settlement predictions based on Pushed-in PPMT, TEXAM PMT, DMT, CPT qc moduli correlations and SPT N_{ES} moduli correlations showed Pushed-in PPMT data produced the most consistent and reliable results.
- Bearing capacity predictions based on Pushed-in PPMT, TEXAM PMT, DMT, CPT qc moduli correlations and SPT N_{ES} moduli correlations showed Pushed-in PPMT data produced the most consistent and reliable results.
- Briaud (2007) provided a reliable method to predict settlement of shallow footings in Florida fine SP sands.

Task 6 Conclusions For Florida Fine Sands (Cont.)

- Both the Design Procedure Guidance Table & Design Procedure Guidance Chart can be used by geotechnical engineers as engineering decision guides for using Pushed-in PENCEL PMT testing.

Task 6 Recommendations For Florida Fine Sands

- It is acceptable to use pushed-in PENCEL PMT tests to determine the stress-strain behavior, $E_{0,}$ & pL in loose to medium dense Florida fine sands.
- Both the Design Procedure Guidance Table and Chart should be used by geotechnical engineers to guide them as to when to use Pushed-in PENCEL PMT testing.
- Use the E_0/pL ratio in each soil at a site to check the quality of the PENCEL PMT data.
- SSMini PMT testing is a fast and reliable way to produce compaction strengths and stiffnesses for comparisons to plate bearing moduli of subgrade reactions.

Special Note

- Update FM Pressuremeter FDOT 2024 Soils and Foundation Handbook pages 36 (text) and 47 (drawing).
- https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/materials/geotechnical/sfh2024.pdf

Questions

To the Best State Materials Gang in the Land: Thank you