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

FDOT GRIP Meeting Thursday, August 15, 2024, 2:00 to 2:45 PM

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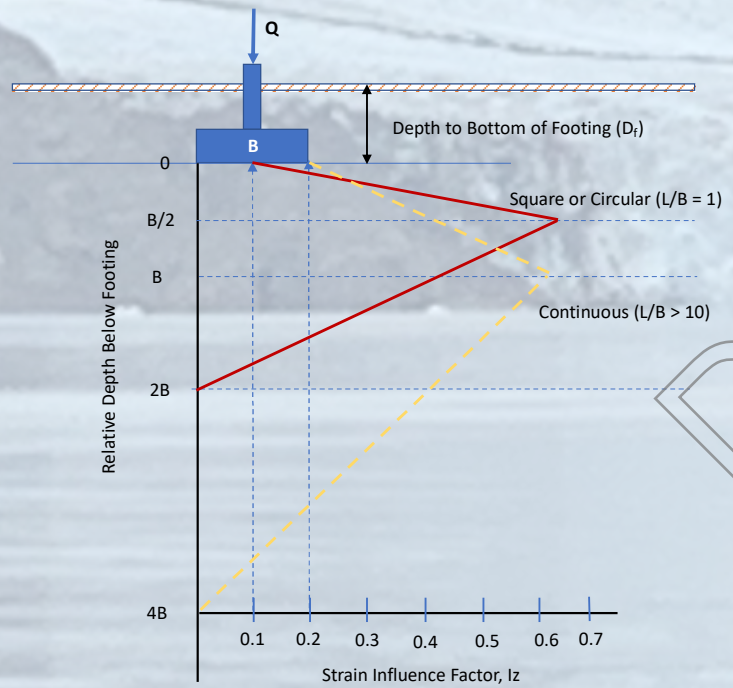
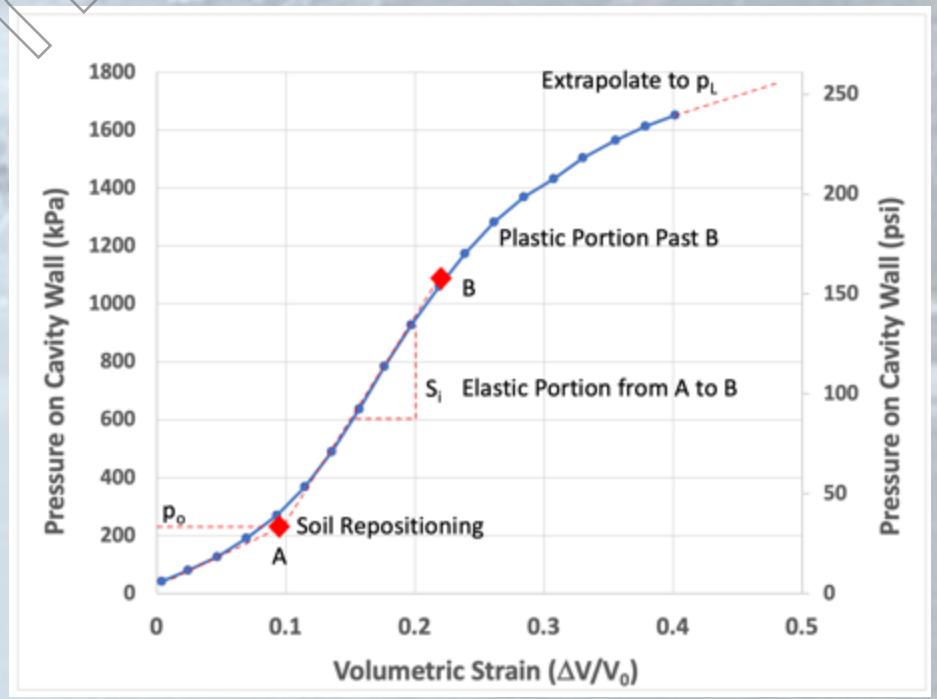
FDOT GRIP 2024 Meeting Outline

1. Introduction & Overview
2. Objective
3. Task Results to Date
    1. **Literature- Completed**
    2. **SMO Testing – Completed**
    3. ***Site Selection, Site Visits, and Procurement of Site Data – Completed***
    4. ***PPMT, TEXAM, SSMini, CPT, DMT, SPT, and Field Plate Load Testing – 98% Completed***
    5. ***Analyzing the Modulus Effects on Foundation Settlement and Bearing Capacity – In Progress***
    6. Extrapolation of Design Procedure Data with Design Flow Chart using Florida Site Conditions
    7. Draft Final Report and Closeout Teleconference
    8. Final Report
4. Project Timeline
5. 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 are we doing this?

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

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

  - New PPMT data are being compared to existing PMT data
  - To determine PENCEL PMT affect on the Briaud 2007 settlement prediction method.
  - Potential pile foundation sites will be re-evaluated using digital PENCEL PMT data to determine if they would enable shallow footings to be used.

- The research report will contain 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

- Engineers now use PMT testing for more designs
  - Traditional uses were for lateral loads on structures
  - High-quality PMT stress-strain data gives engineers confidence to use it in other areas especially for shallow footings
- Methods to predict elastic moduli and settlement of sands indicate:
  - Several PMT elastic moduli approaches are available
  - DMT elastic moduli approaches to predict both bearing capacity and settlement are available
  - CPT correlations between qc and elastic moduli are used
  - SPT Correlation to elastic moduli are available
- Case Histories from Shallow Footings in Chicago, Virginia and Florida were reviewed
- Numerous Correlations were reviewed by UCF

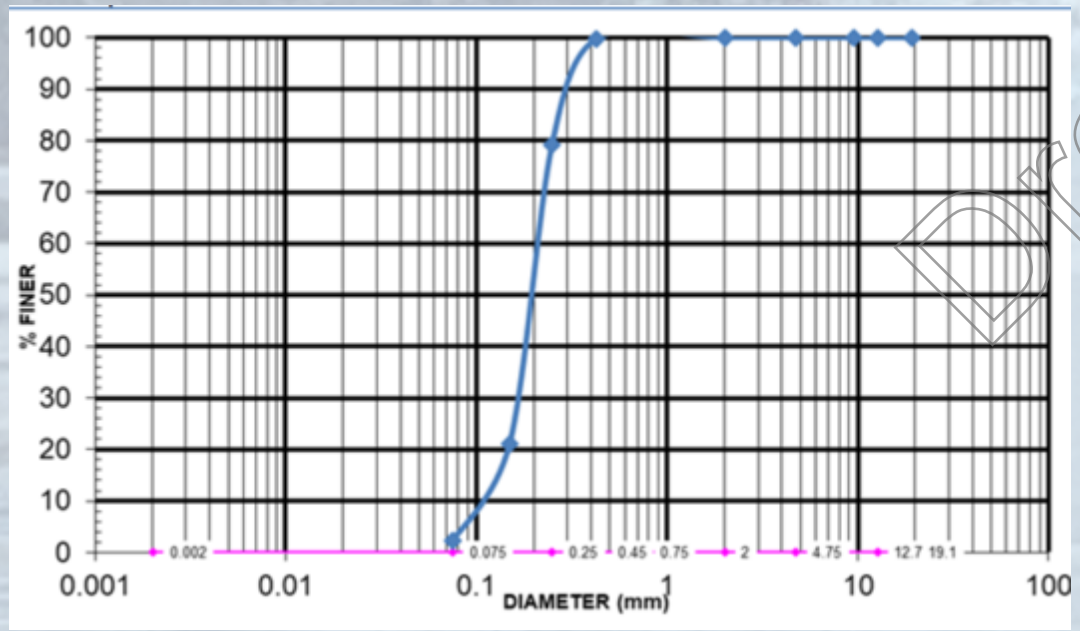
Task 2-SMO Testing- In situ tests to determine E

- 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*

Index Test Results

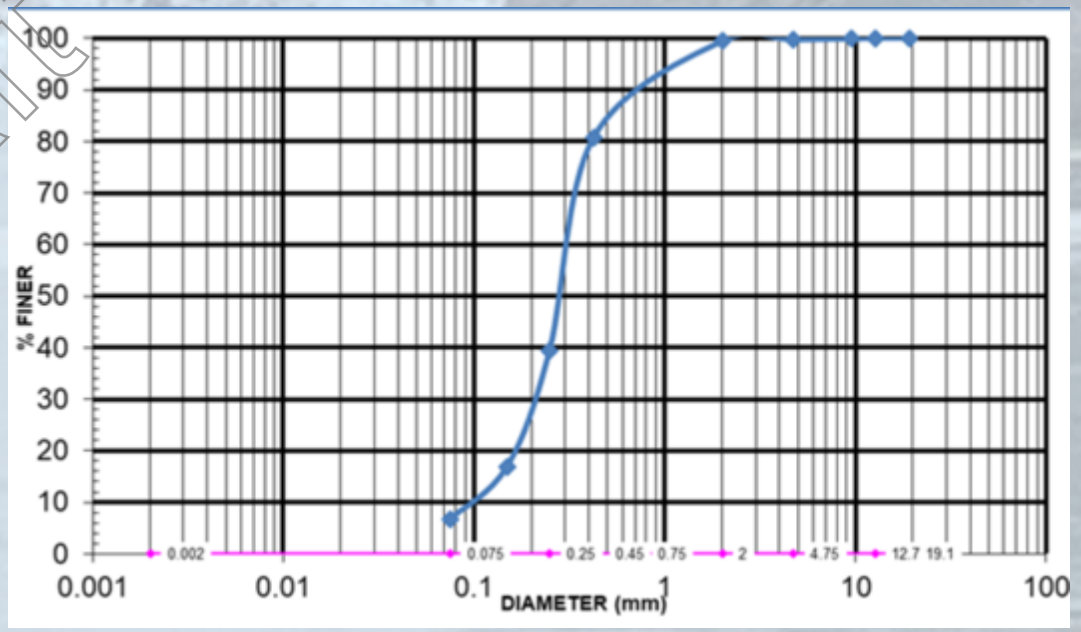
Material	γ_{dmax} (pcf)	Moisture (%)	% Compaction Density (pcf) 90	95	100	LBR
Starvation Hill	114	11	103	108	114	32
Osteen	106	14	96	101	106	20

- SP sand
- 2.2% passing #200



Osteen

- SP-SM silty sand
- 6.8% passing #200



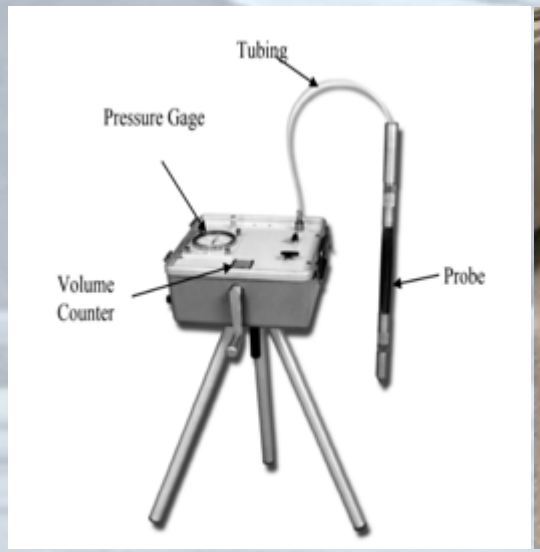
Starvation Hill

Summary of SMO Testing

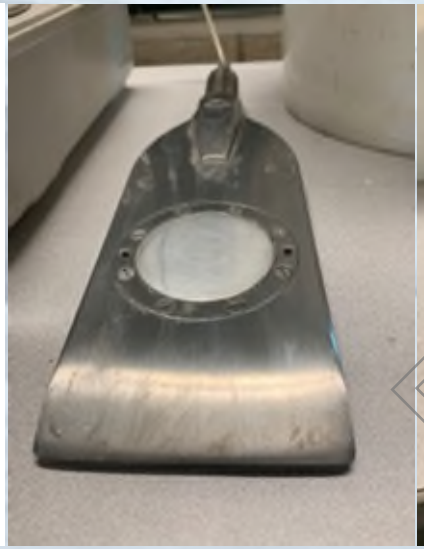
Site	PPMT Tests	SSMini Tests	CPT Soundings	DMT Tests	Plate Tests
SMO Starvation Hill 90 %	18	6	3	12	3
SMO Starvation Hill 95 %	6	8	3	12	3
SMO Starvation Hill 100 %	10	8	3	12	3
Subtotal	*34*	*22*	*9*	*36*	*9*
SMO Osteen 90 %	8	8	3	9	4
SMO Osteen 95 %	6	8	3	9	5
SMO Osteen 100 %	6	8	3	9	3
Subtotal	*20*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

Instruments

PENCEL PMT



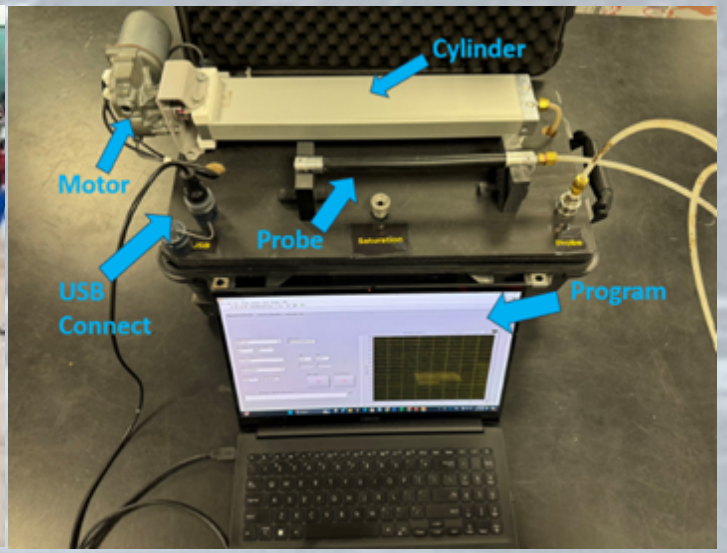
DMT



CPT

Plate

SSMini PMT

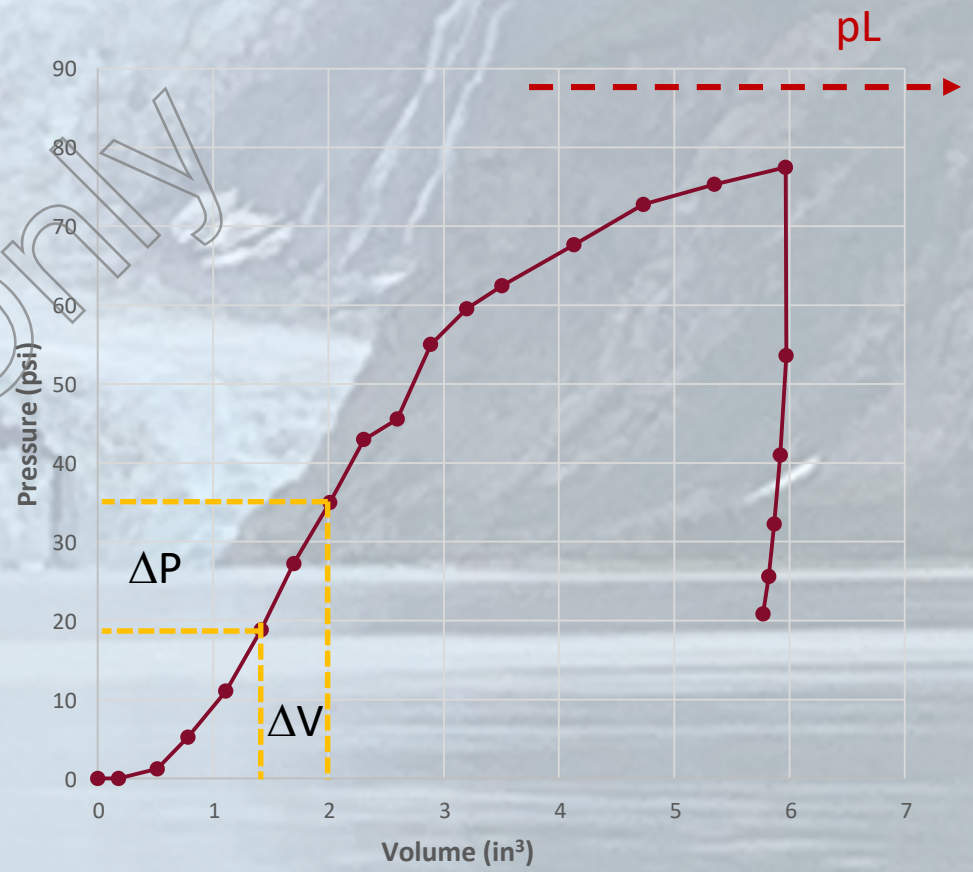


Task 2 Objective

- Compare in-situ stiffness and strength parameters from PPMT, DMT, CPT, *SSMini PMT* and plate bearing tests using 90%, 95%, and 100% modified Proctor densities on two SP sands in SMO Test Pits

PENCEL Pressuremeter Output

- Relevant parameters: E_{PMT} and p_L
- $E_{PMT} = 2 * (1 + \nu) \left[(\Delta P) / (\frac{\Delta V / V_0}{V_m}) \right]$
- p_L determined through extrapolation



Dilatometer Output

- Relevant parameter: E_{DMT}
- $E_{DMT} = 34.7 * (p_1 - p_0)$

FDOT	State Materials Office Geotechnical Unit	ASTM D6635 Dilatometer Field Data & Interpreted Soil Properties	Worksheet Revised By:	D. Jameson
			Revised Date:	Nov. 2022
			Sounding #: 90% DMT 1	

Field Data and Preliminary Calculations

Depth			Gauge Readings				Corrected Readings			Dilatometer Index			
Z_m (m)	Depth (ft)	Elev. (ft)	Thrust (lbf)	A (bars) [10]	B (bars) [11]	C (bars)	p_o (bars) [12]	p_1 (bars) [13]	p_2 (bars) [14]	E_D (bars) [15]	I_D [16]	K_D [17]	U_D [18]
0 [39]	0	7.00	0	0.18	0.41	0.00	*Initial gauge readings @ atmospheric pressure*						
0.3048	1	6.00	460	0.30	2.10	0.00	0.42	1.67	0.00	43.36	3.01	8.18	0.000
0.6096	2	5.00	949	0.55	3.00	0.00	0.63	2.57	0.00	67.04	3.05	6.23	0.000
0.9144	3	4.00	1738	1.15	4.70	0.00	1.18	4.27	0.00	107.12	2.62	7.30	0.000
1.2192	4	3.00	1958	1.20	5.10	0.00	1.21	4.67	0.00	119.87	2.85	5.62	0.000

Cone Penetrometer Output

- Relevant parameter: q_c
- Given directly from test data
- Can be correlated into E_{CPT}
  - $E_{CPT} = 2$ to $4 * q_c$ (NC sand)
  - $E_{CPT} = 1.3$ to $1.9 * \mathrm{q_c}$ (Silty sand)

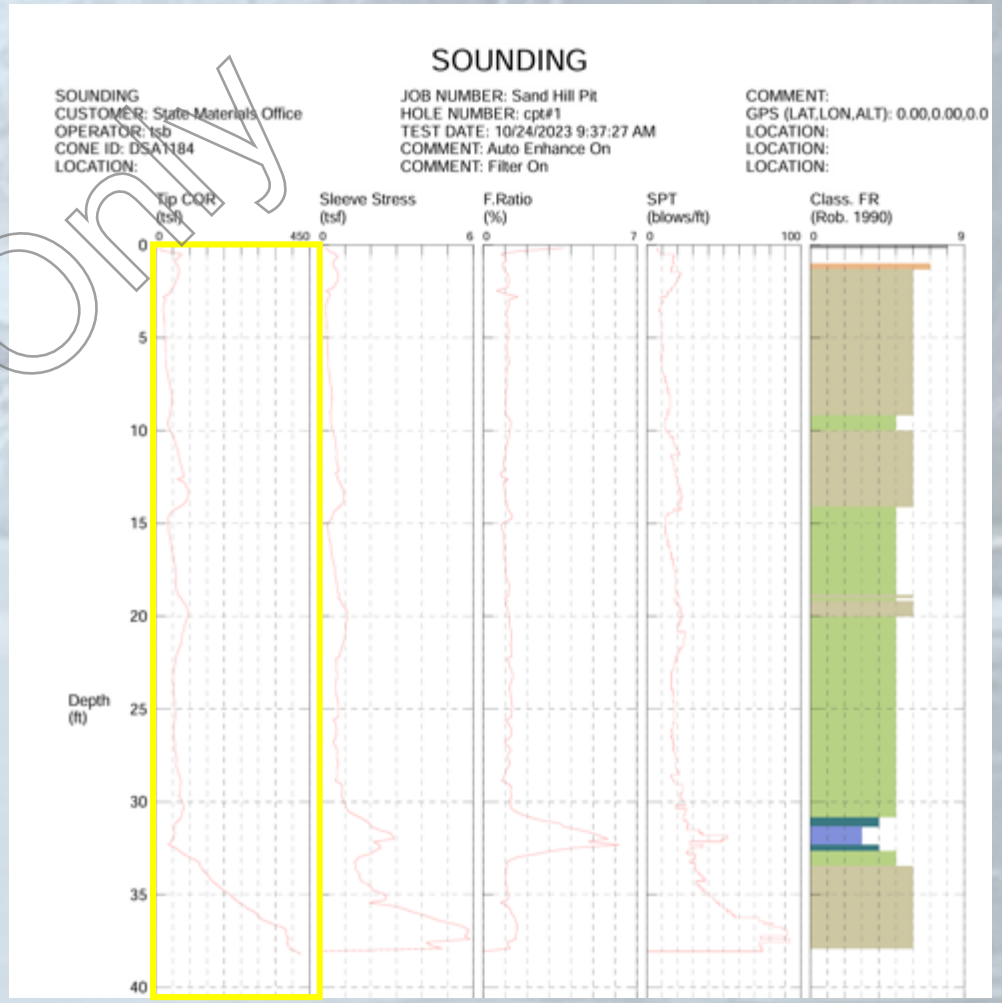
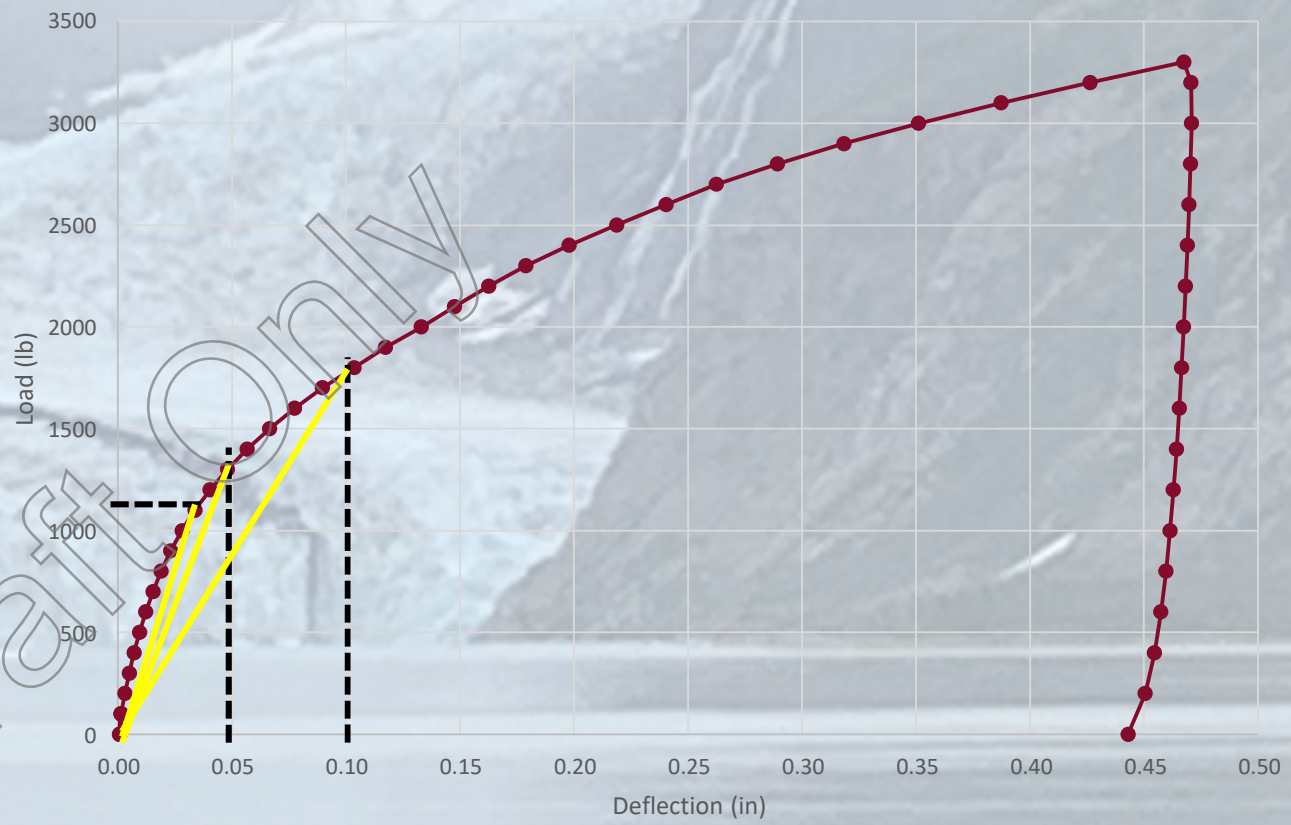


Plate Bearing Output

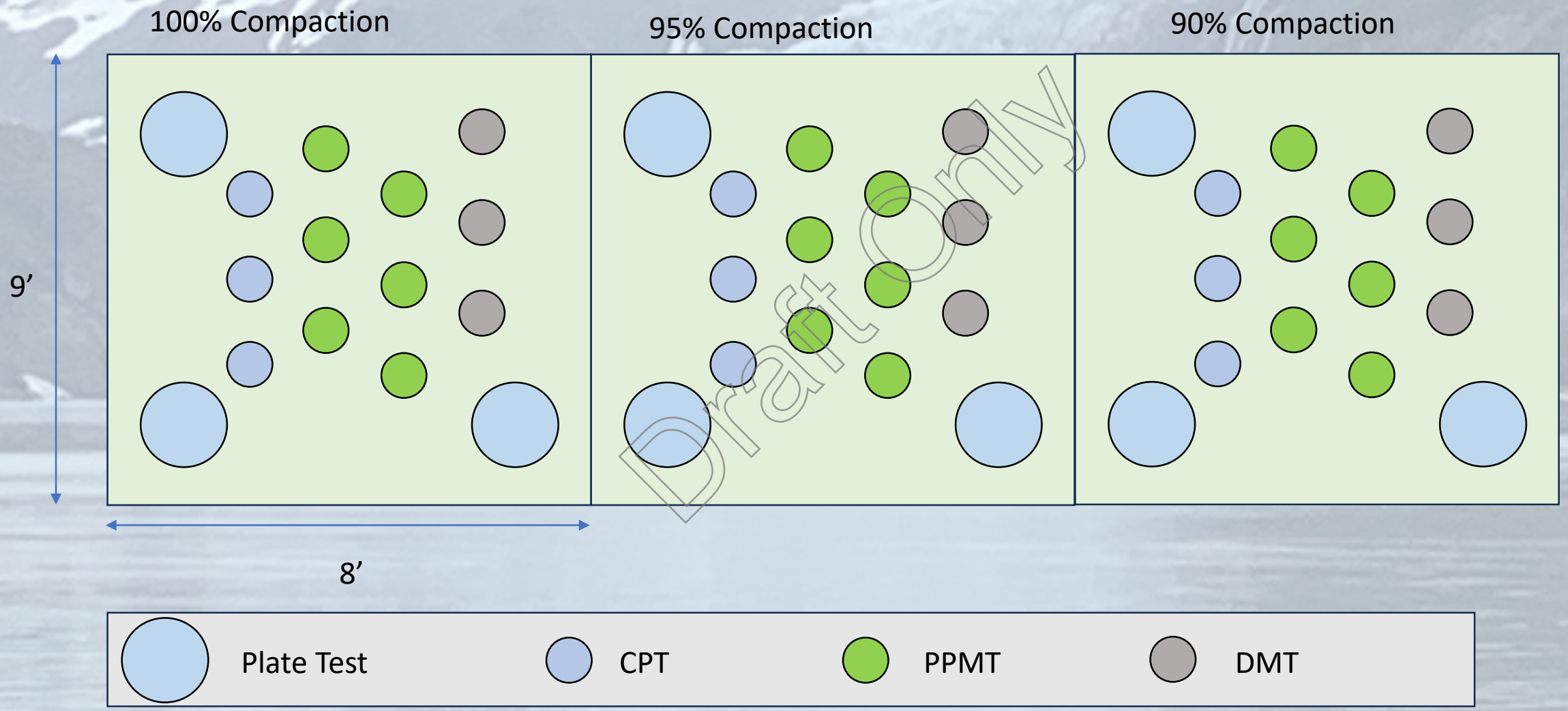
- Relevant parameters: K, E
- Three methods to find K:
  - 0.05” deflection (Bowles 1982)
  - 0.1” deflection
  - 10 psi pressure (Yoder and Witczak 1959)
- $E = \frac{K\pi R(1-\mu^2)}{2}$



Task 2 - Testing Program

Test Pit Preparation

Test Pit Testing Layout



In-situ Testing

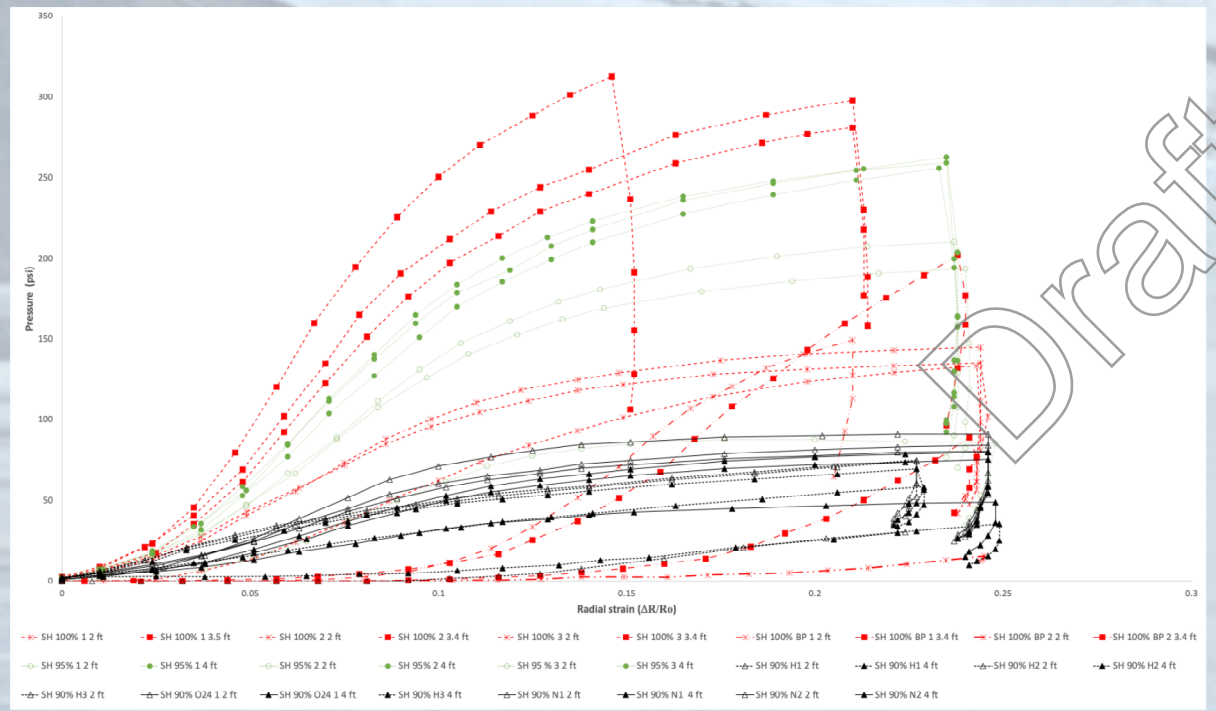
Instrument	# of Tests	Depths (ft)
PPMT	36	2,4
DMT	84	1,2,3,4
CPT	18	Cont. 0-5
Plate	20	Surface

Task 2 Analysis

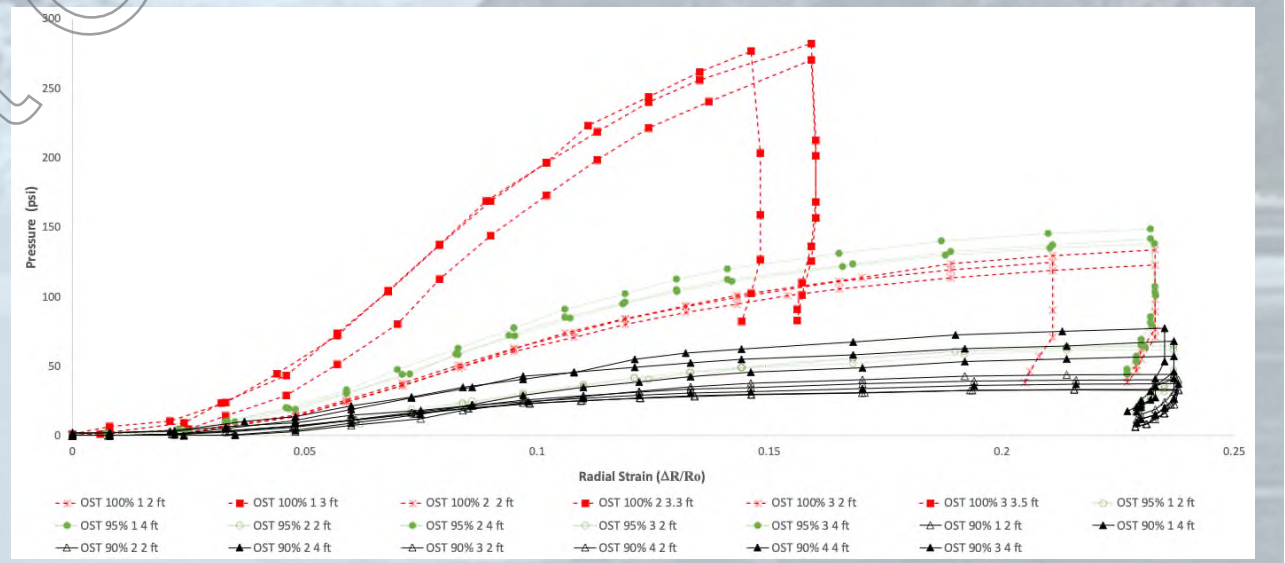
Correlations, data reduction, error

PPMT Results

Starvation Hill

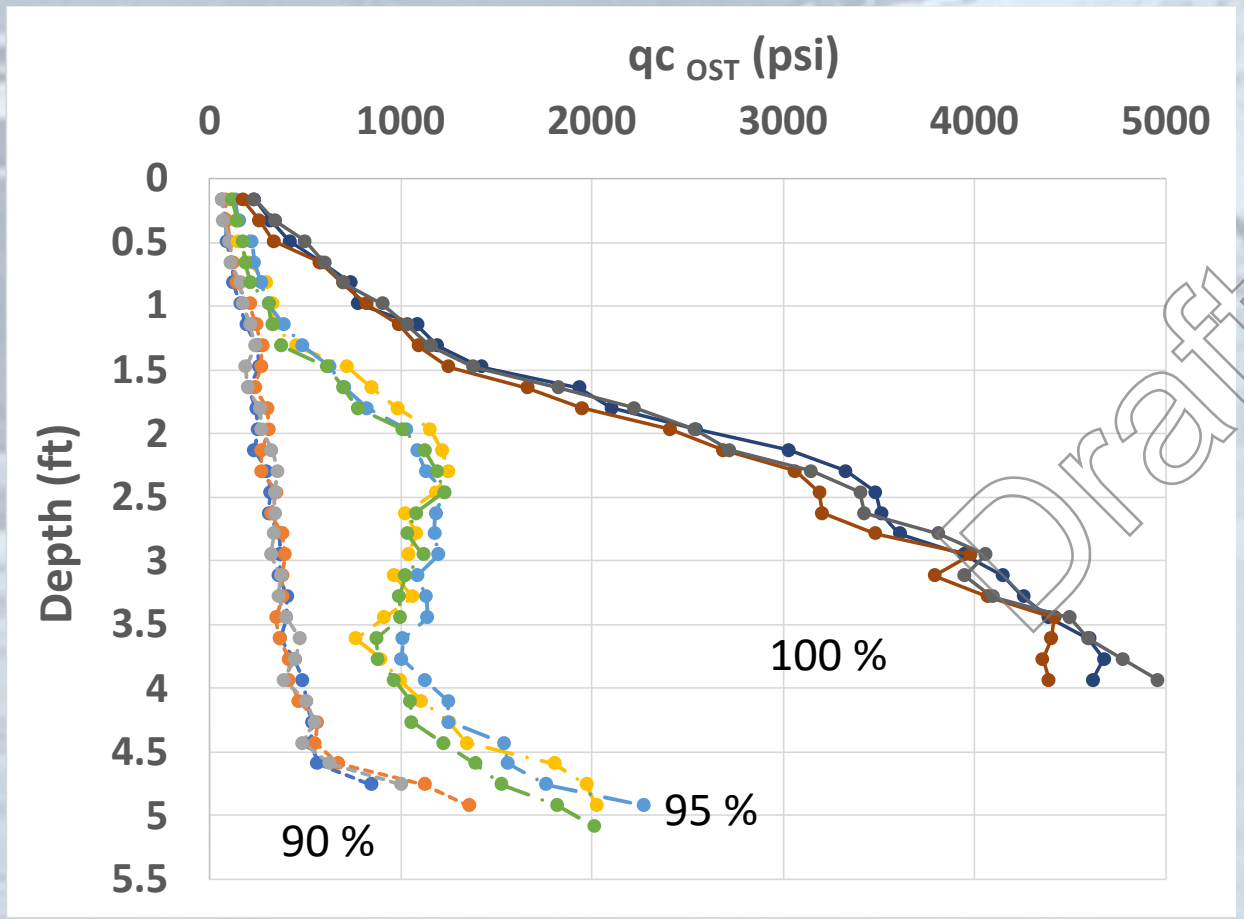


Osteen

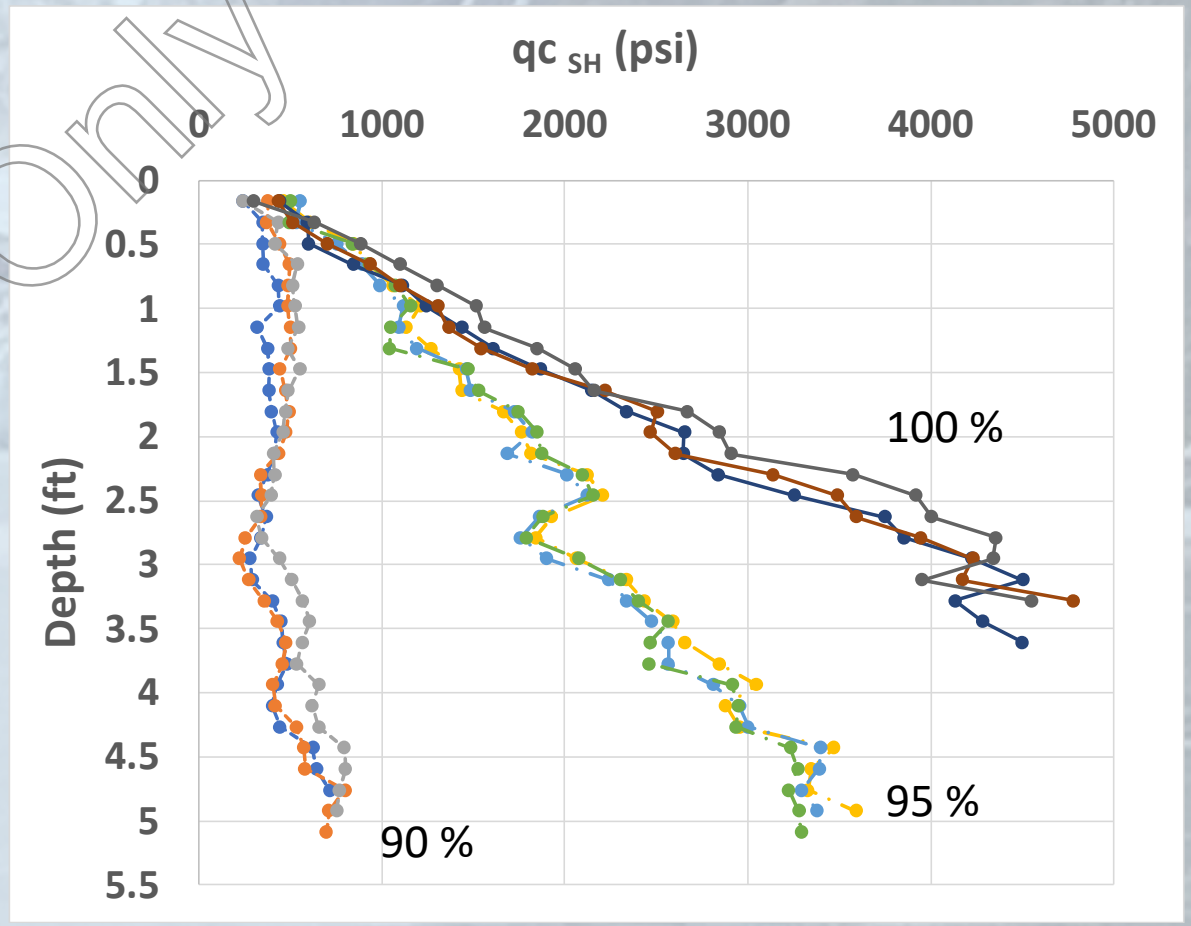


CPT Results

Osteen Pit

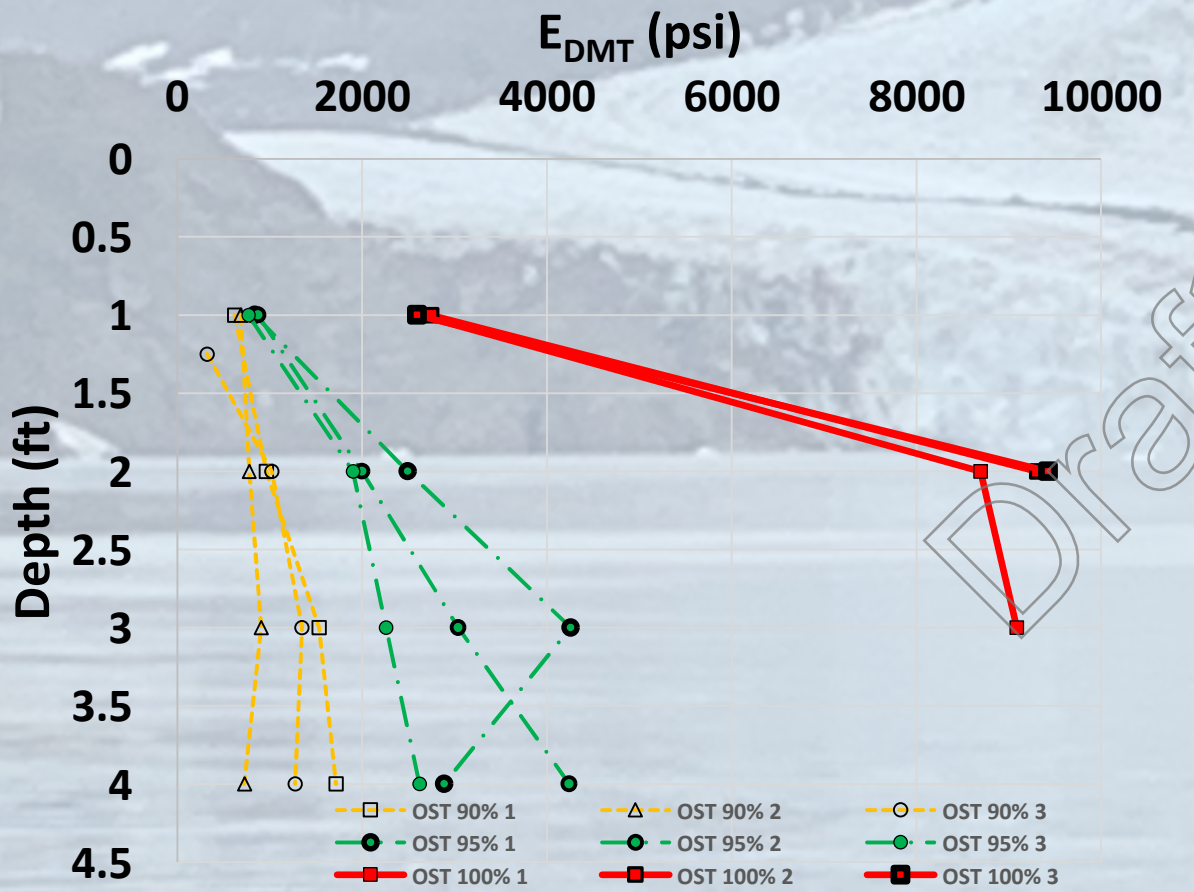


Starvation Hill Pit



DMT Results

Osteen Pit



Starvation Hill Pit

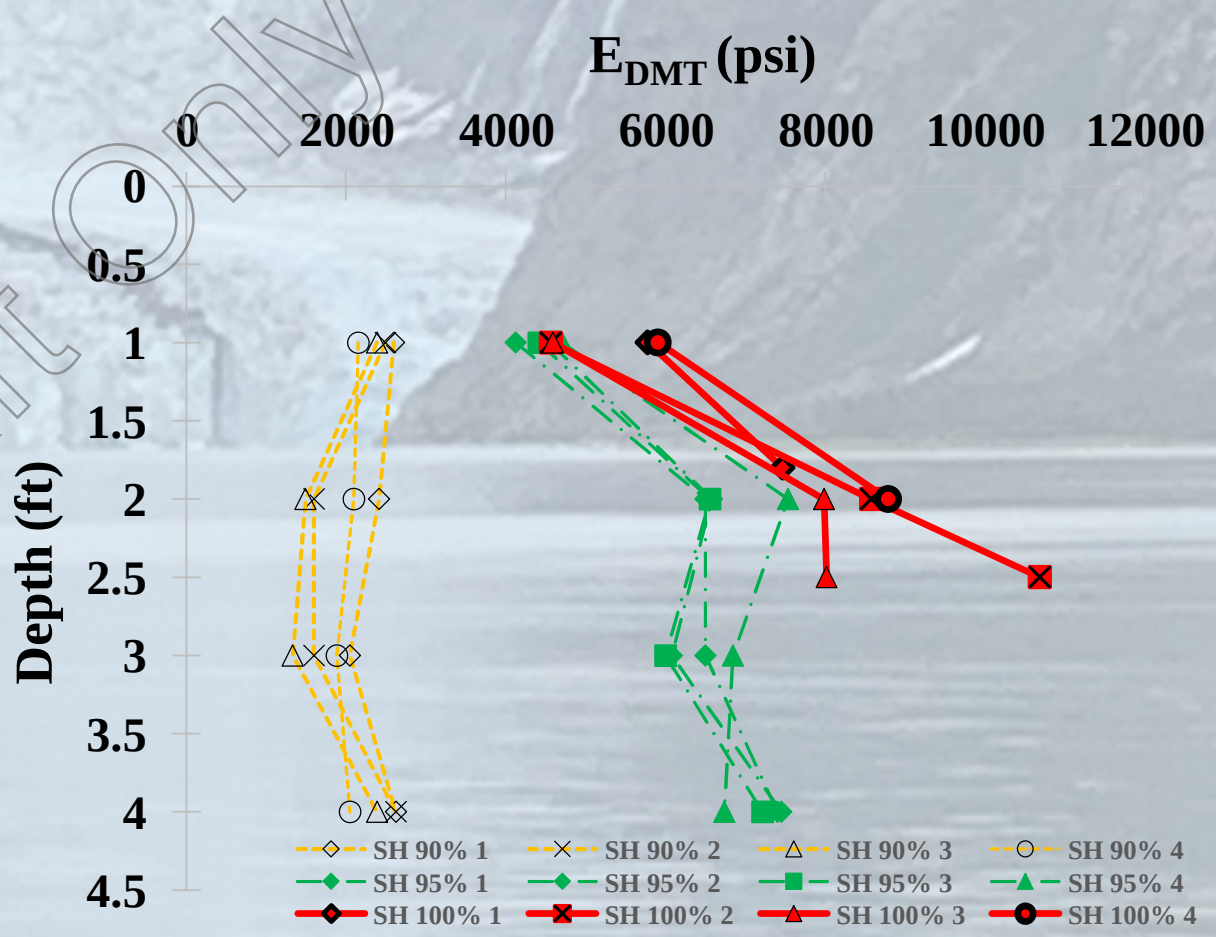
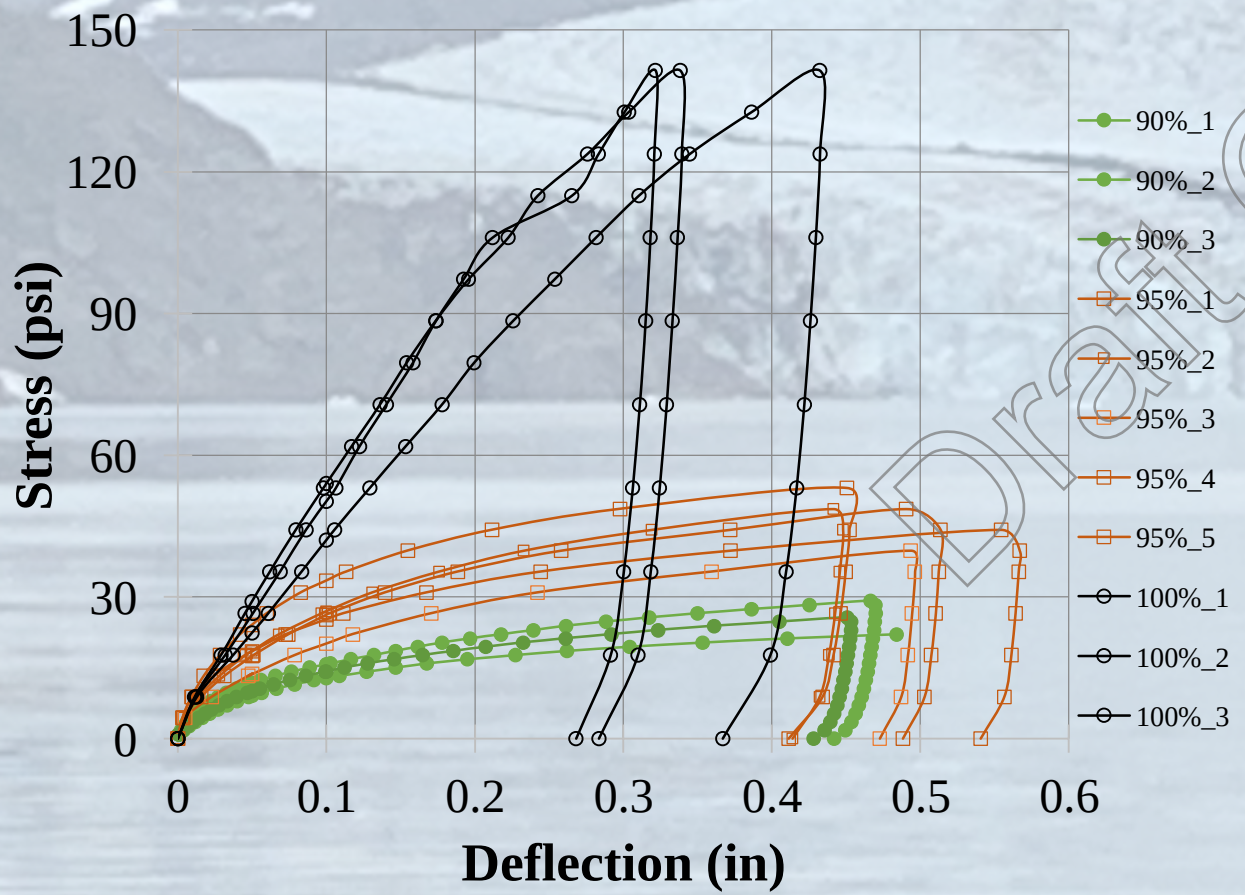
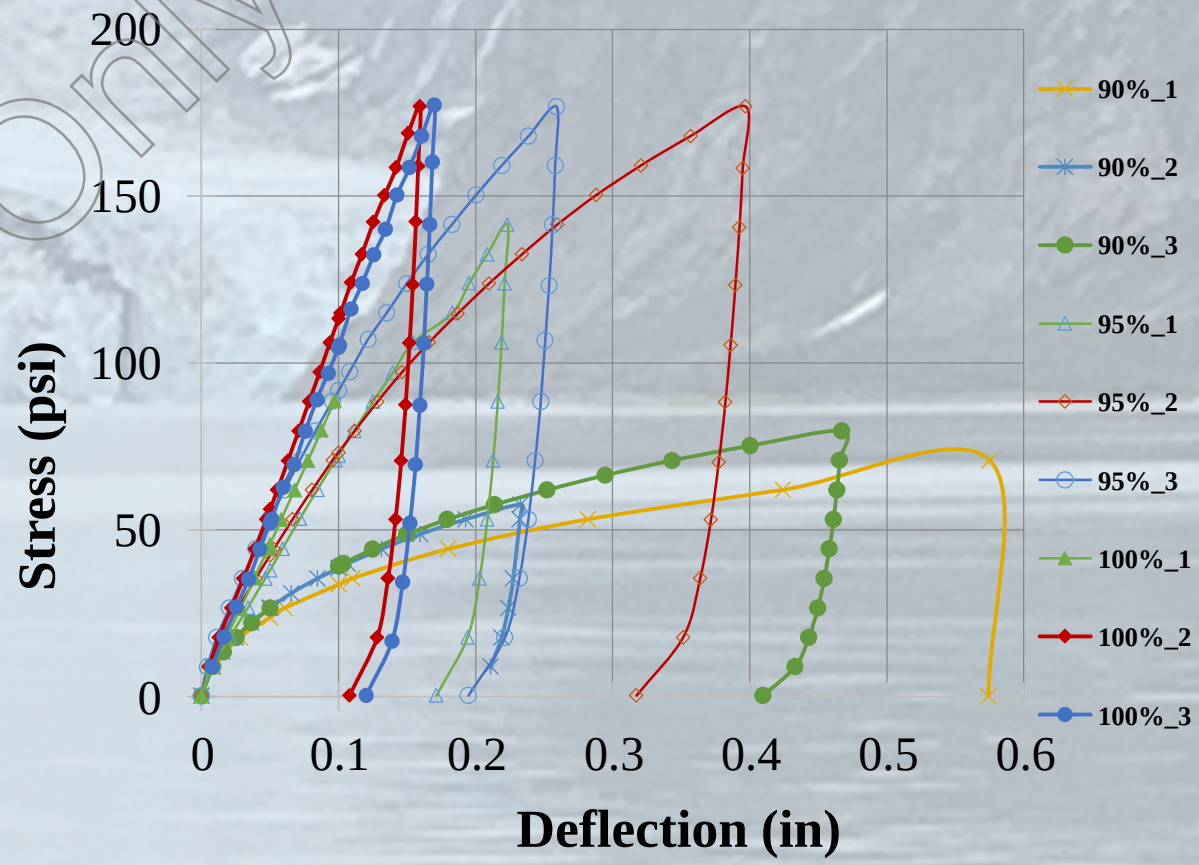


Plate Testing Results

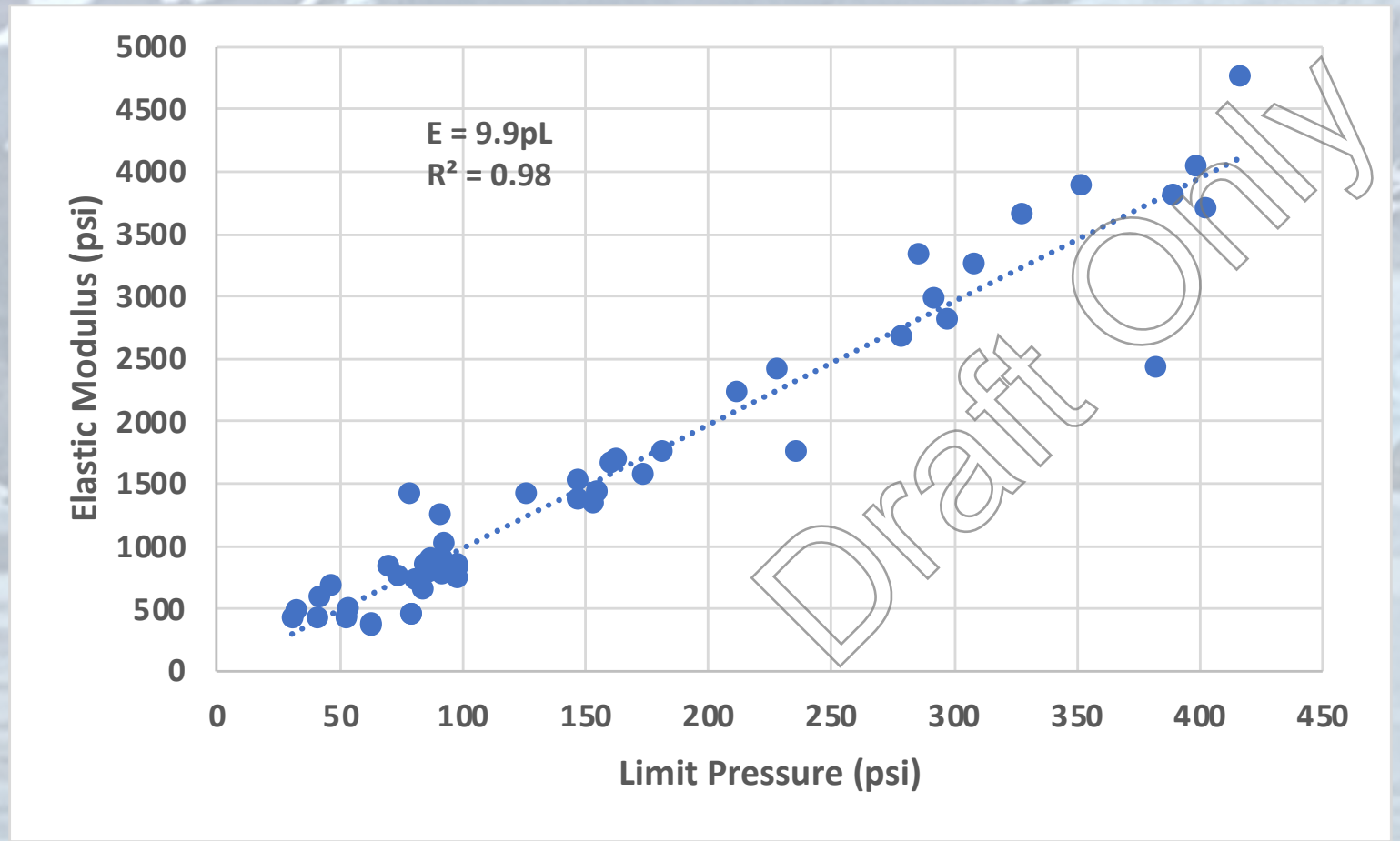
Osteen Pit



You're Starvation Pit



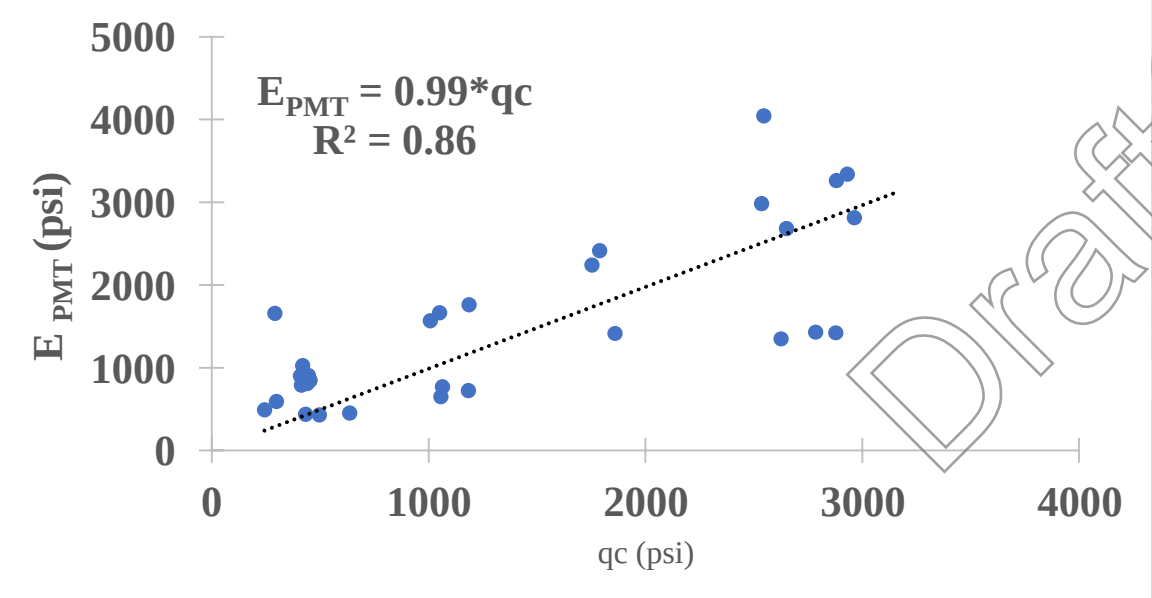
PPMT Data Quality SMO Pits
54 tests - SP Sands



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

PPMT-CPT Comparison

q_c versus E_{PMT}

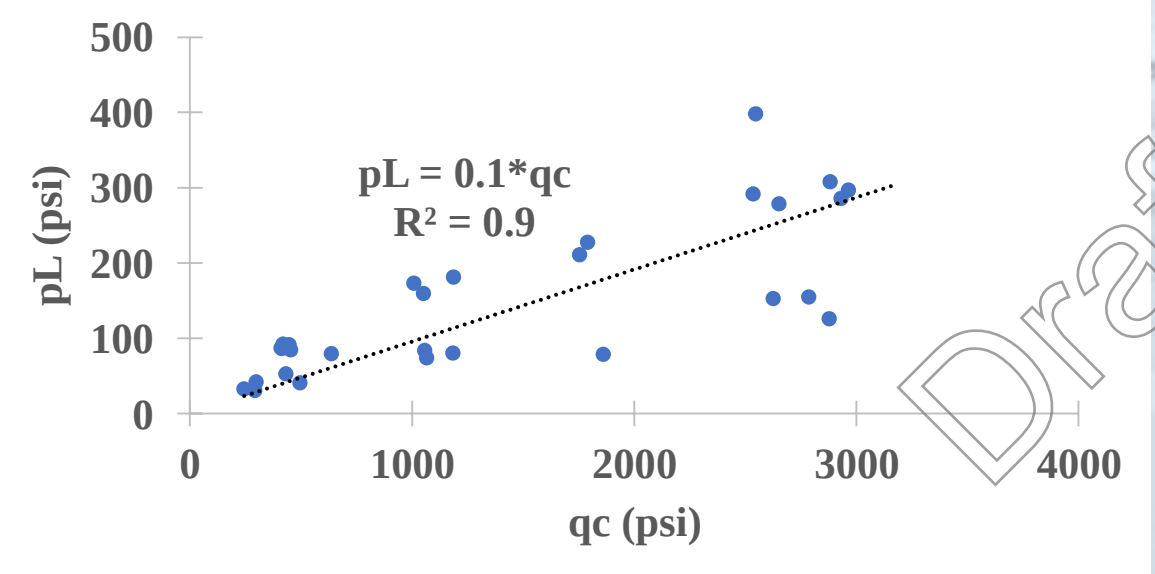


Takeaways

- Strong correlation
- E_{PMT} ~ 1.0 qc
- Literature suggests E_{PMT} = 2.5 qc
- qc influenced by bottom of test pit

PPMT-CPT Comparisons

p_L versus q_c

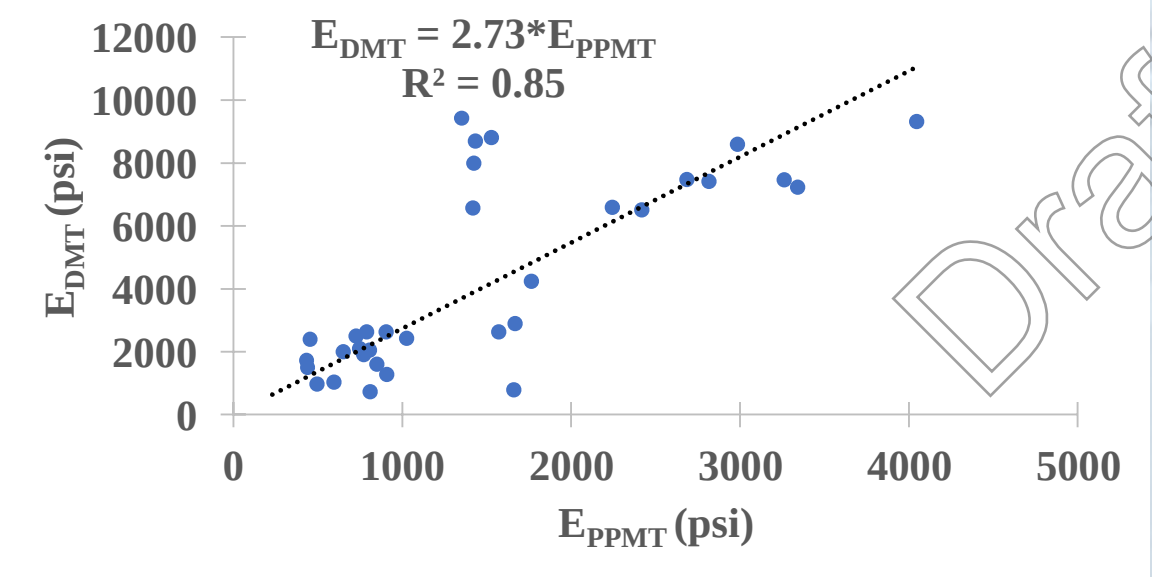


Takeaways

- $p_L \sim 0.1\ q_c$
- Strong correlation

PPMT-DMT Comparisons

Average E_{DMT} versus E_{PPMT}

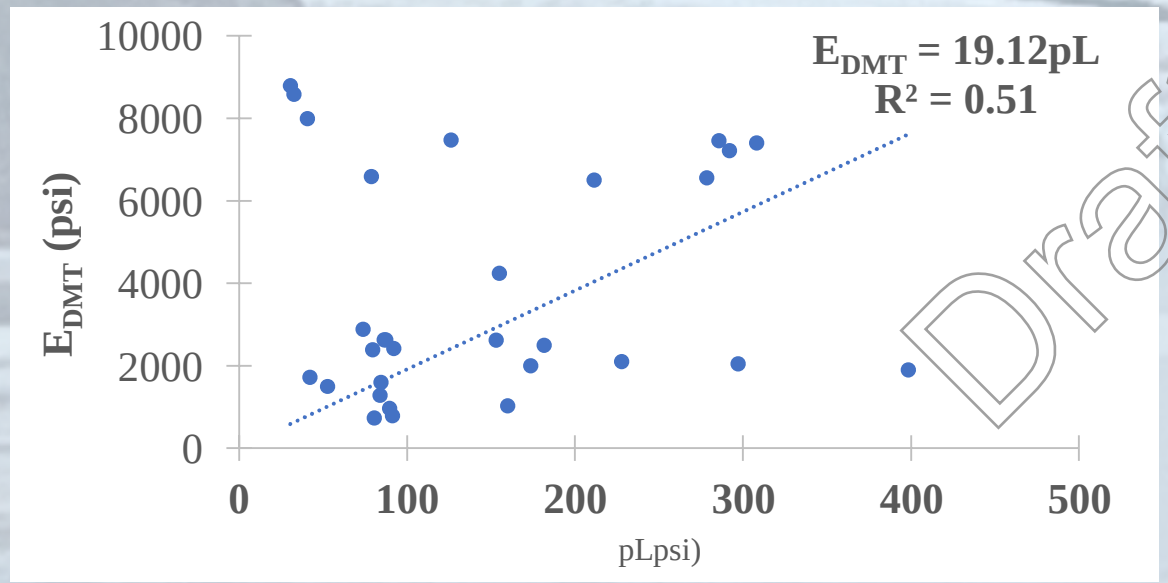


Takeaways

- E_{DMT} ~ 2.75 E_{PPMT}

PPMT-DMT_{ave} Comparisons

E_{DMT} versus p_L

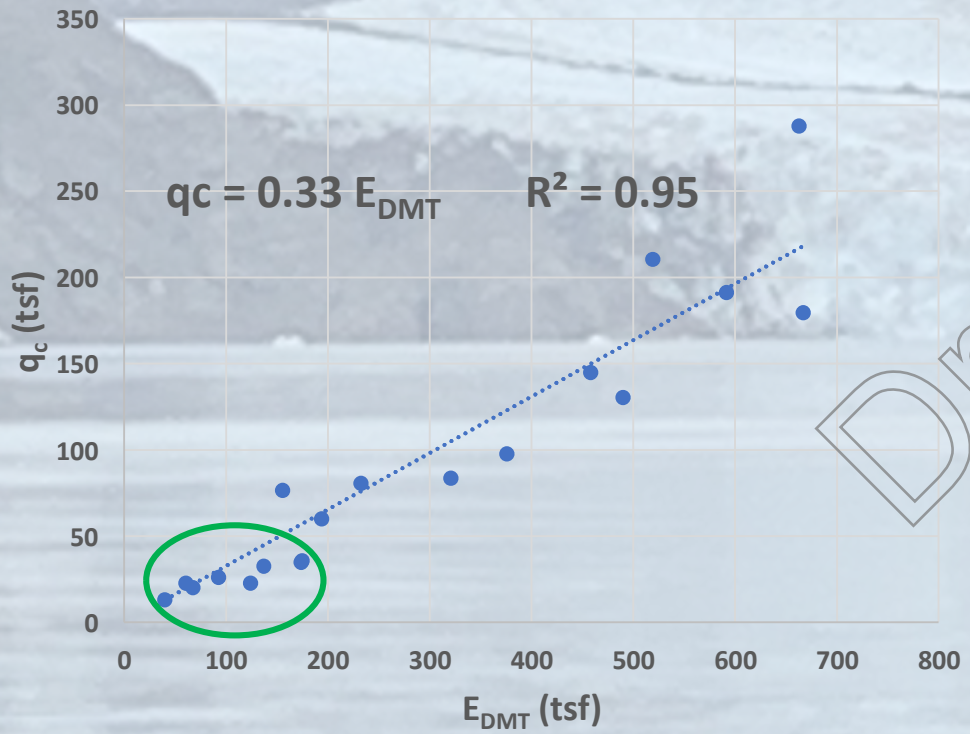


Takeaways

- E_{DMT} ~ 19 times p_L
- Weaker correlation

CPT-DMT Comparisons

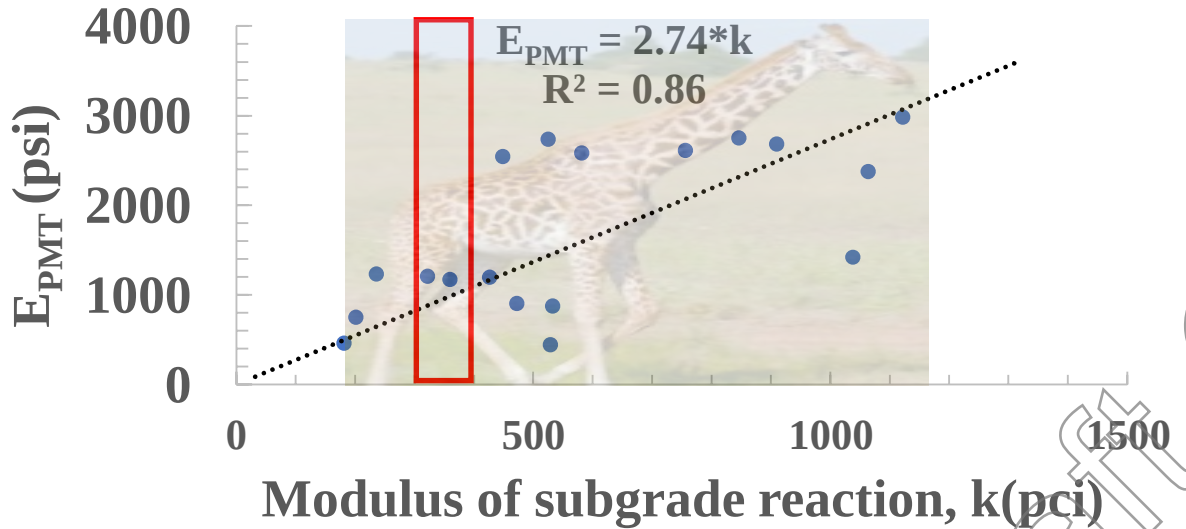
q_c versus E_{DMT}

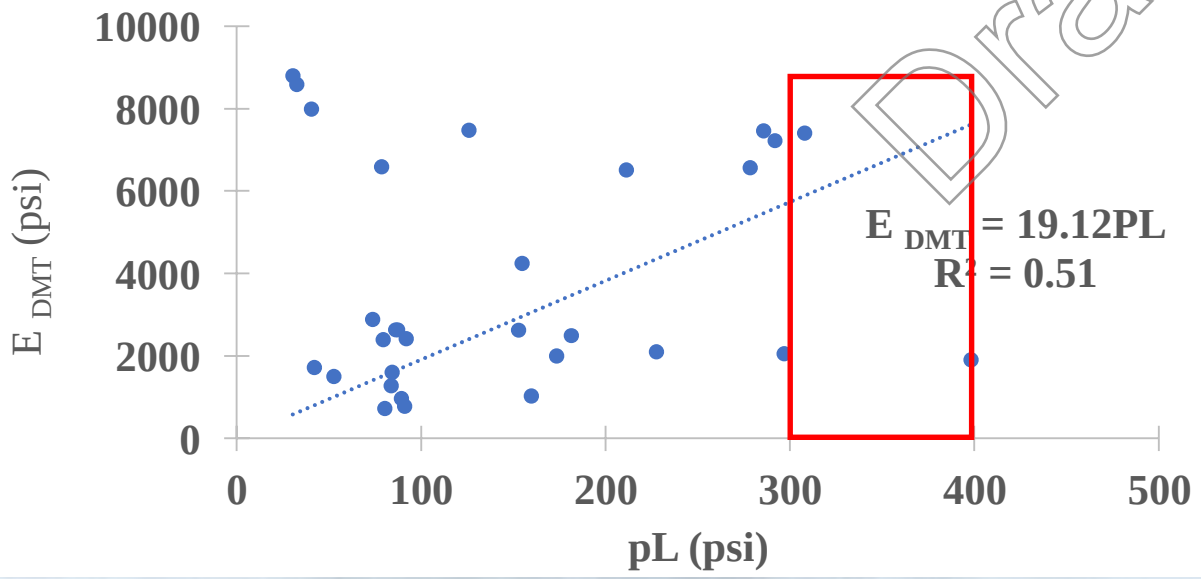


Takeaways

- q_c ~ 0.33 times E_{DMT} (18 data points)
- Mayne and Liao 2004 say 0.2 for similar soil
- Strong correlation
- Less certainty at higher values

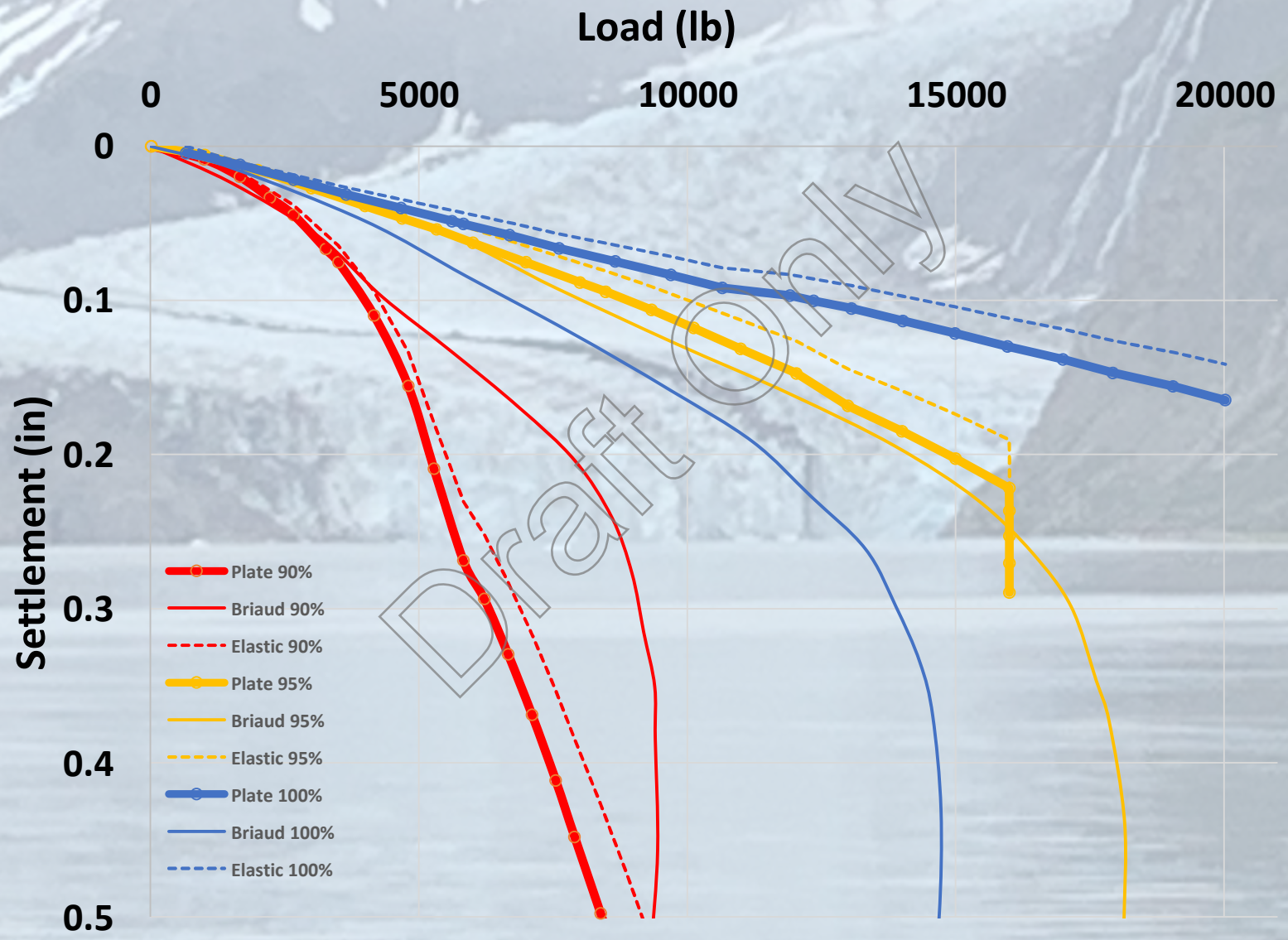
Plate Bearing Comparisons



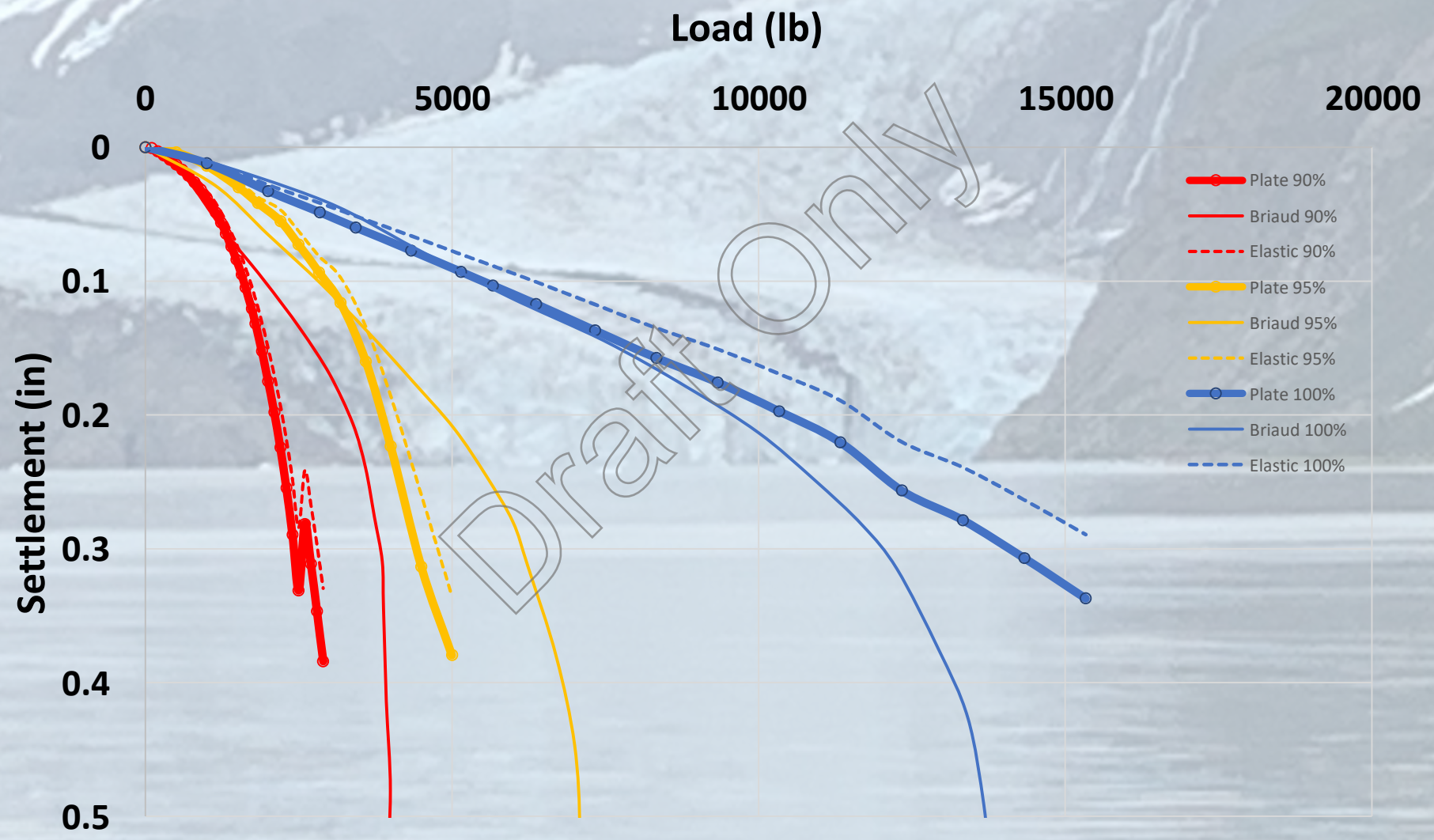


- Literature SP K 300-400 pci
- Correlation Good
- I see a Giraffe

You're Starving Settlement – Ave. Plate vs. PPMT



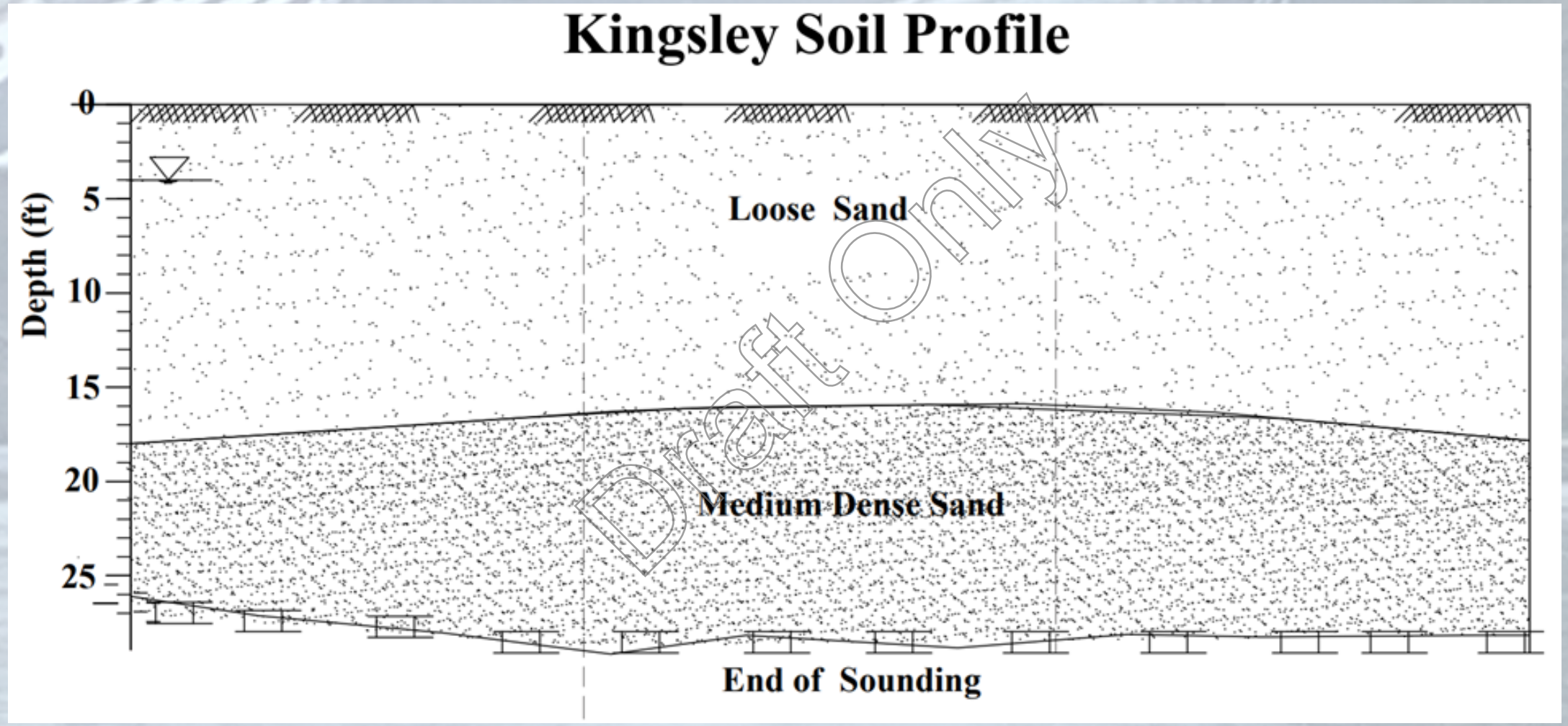
Osteen Settlement – Ave. Plate vs. PPMT



Task 2 Conclusions

- Stiffness and strength parameters from PPMT, DMT, CPT, and Plate tests suggests 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 Field Sites Soil Profiles



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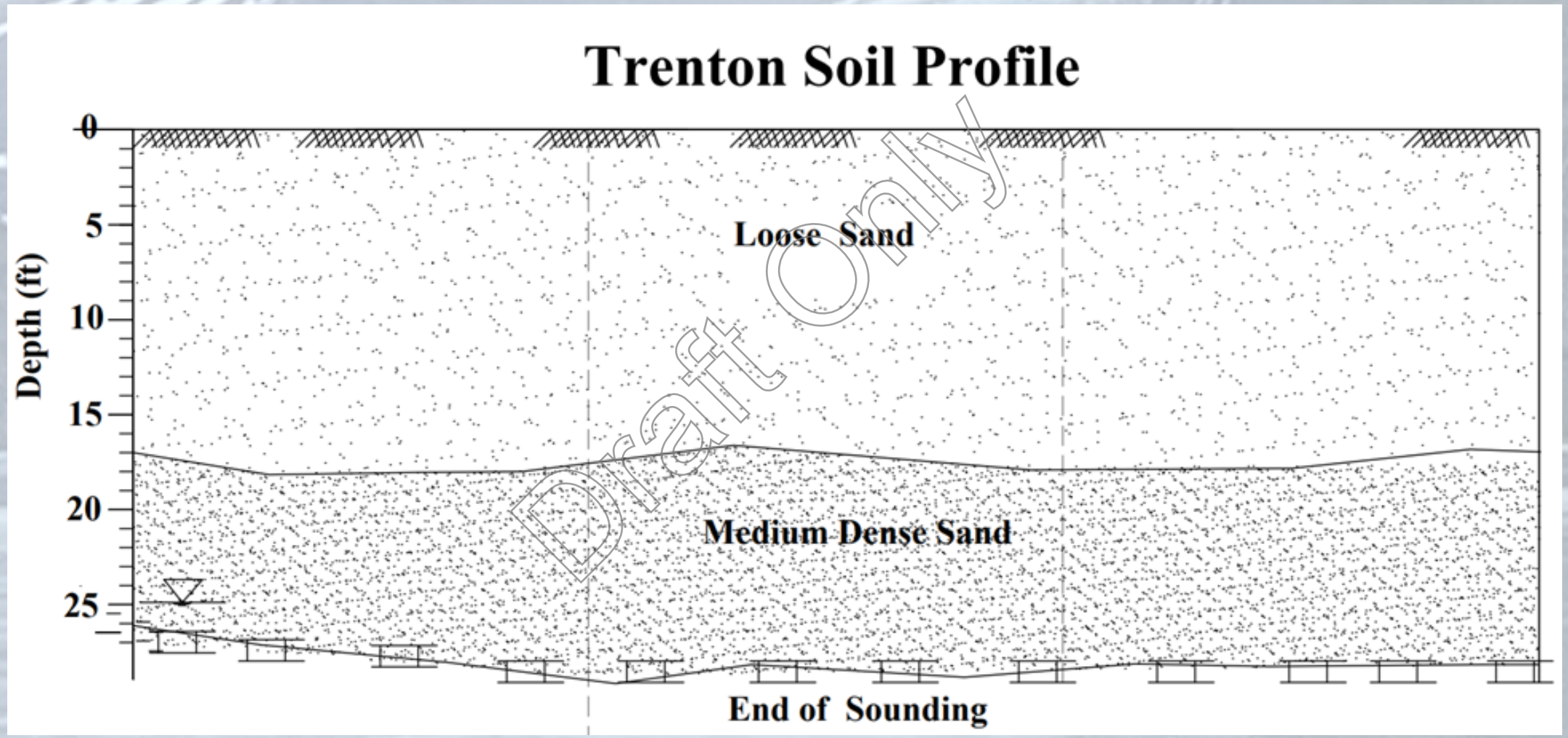

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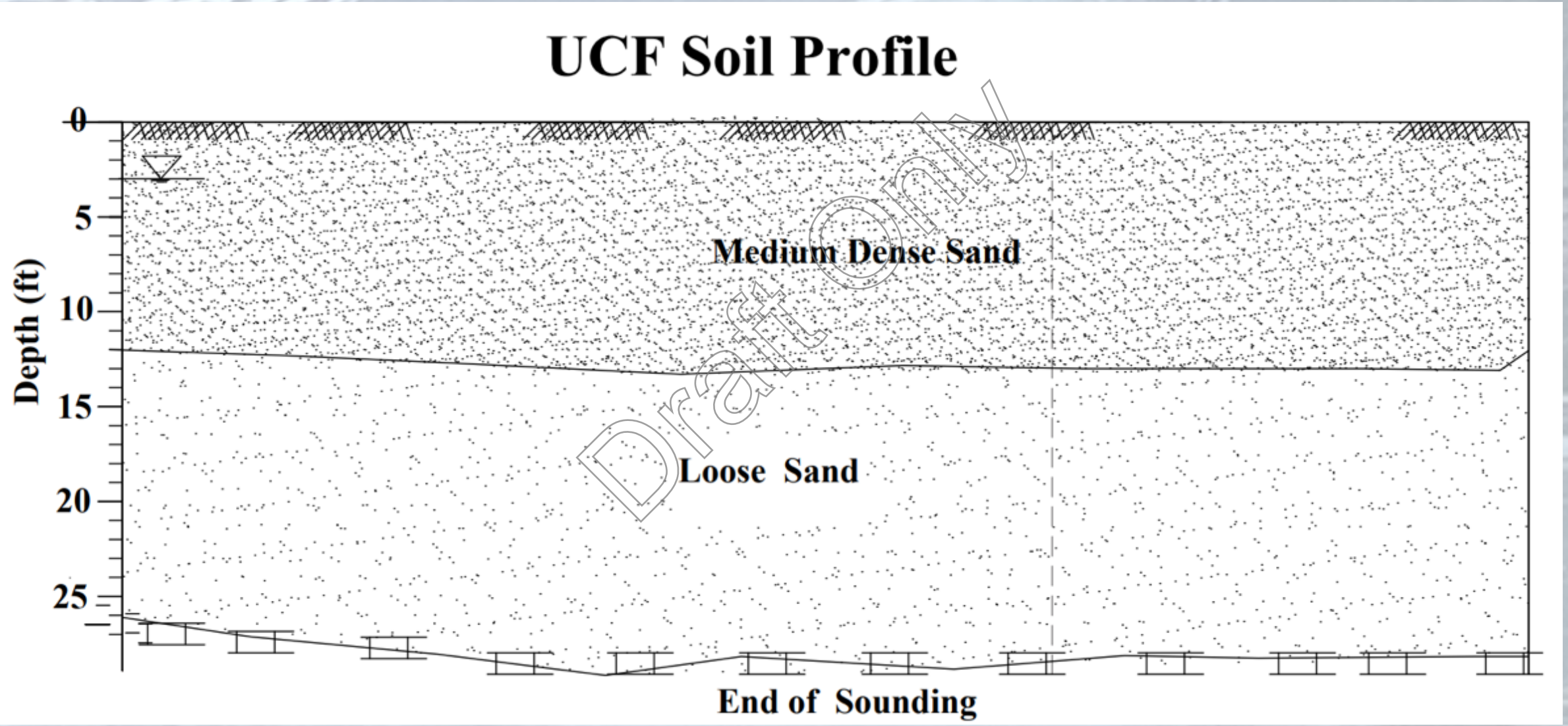
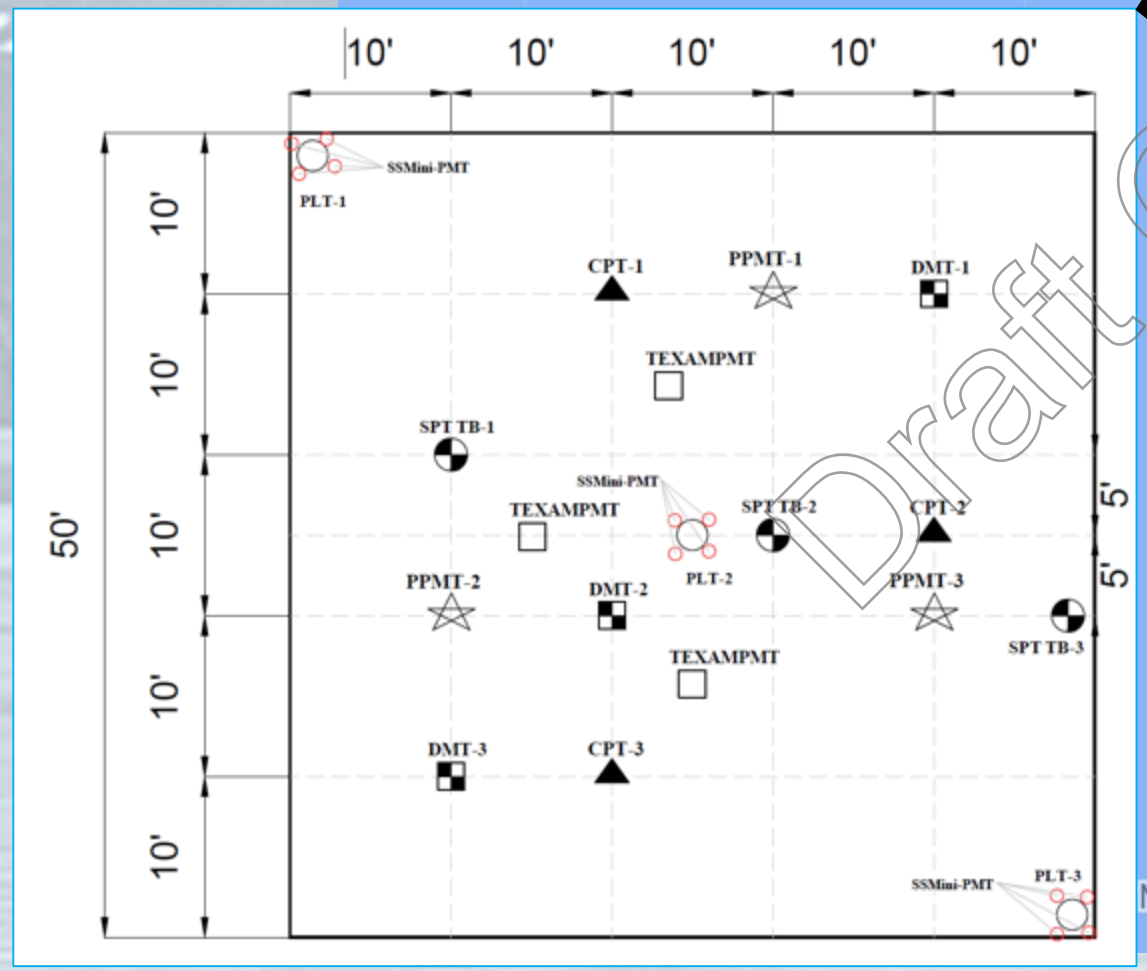


Task 4 Field Testing

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

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

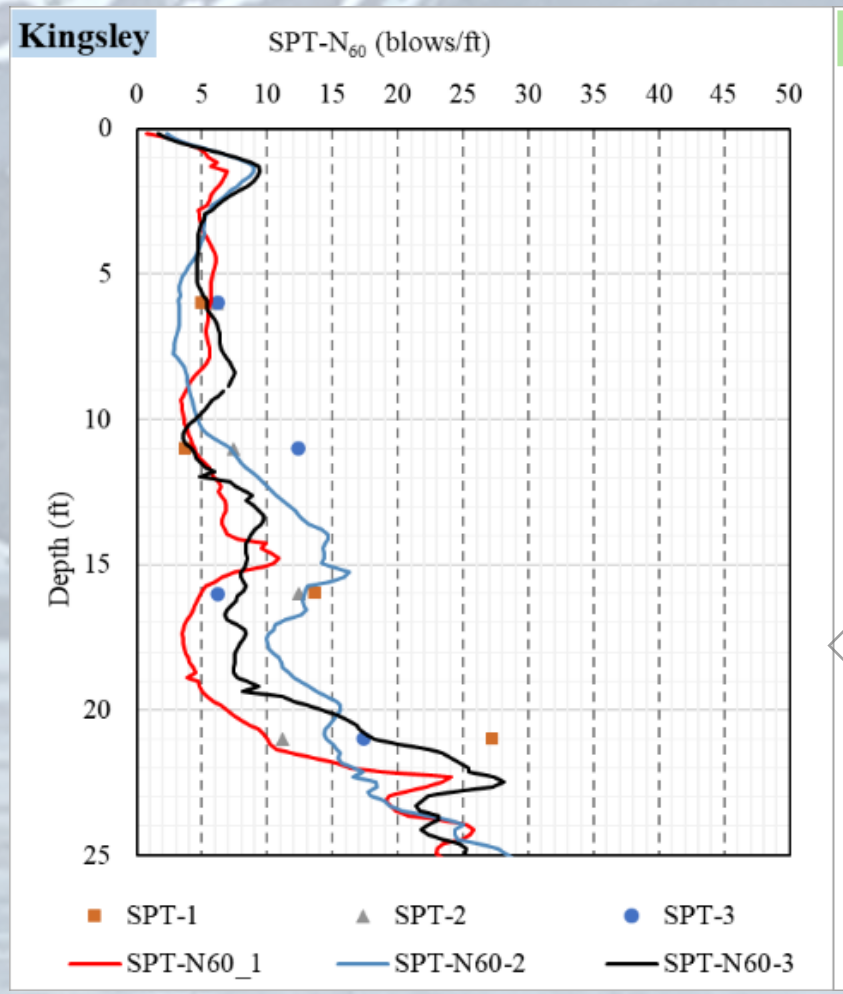

10'
10'
10'
10'
10'
50'
10'
10'
10'
10'
10'
5'
5'
SSMini-PMT
PLT-1
CPT-1
PPMT-1
DMT-1
TEXAMPMT
SPT TB-1
SSMini-PMT
TEXAMPMT
SPT TB-2
CPT-2
PLT-2
PPMT-2
DMT-2
PPMT-3
SPT TB-3
TEXAMPMT
DMT-3
CPT-3
SSMini-PMT
PLT-3

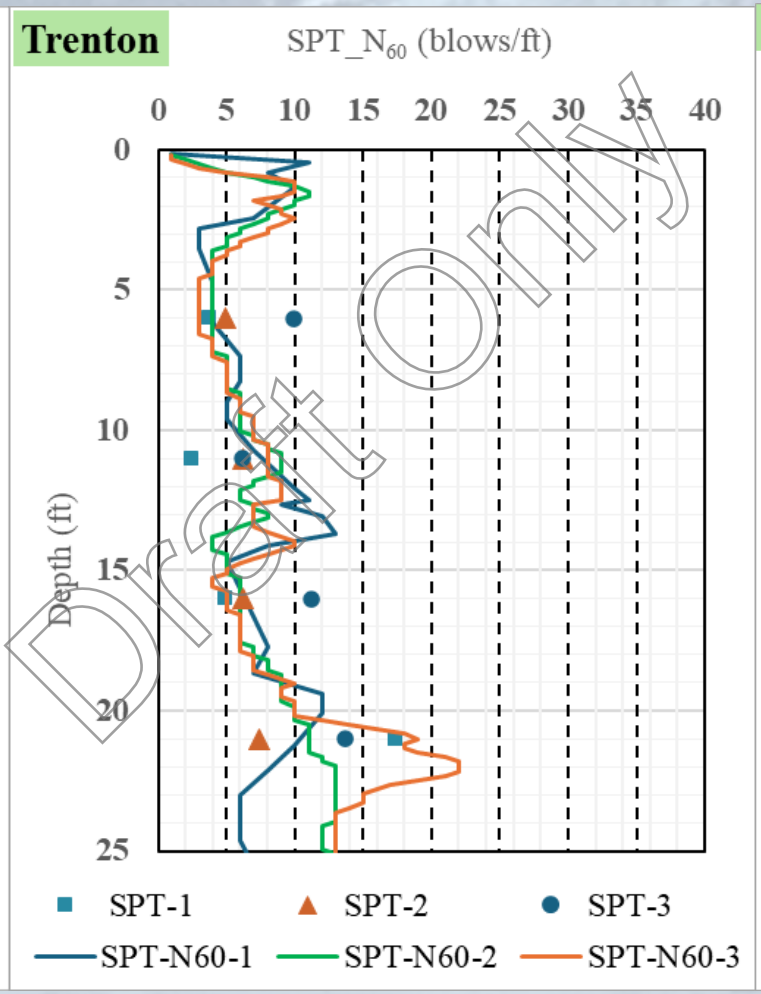
Enterprise
Dothan
Brunswick
Valdosta
Mobile
Crestview
Pensacola
Destin
Tallahassee
Jacksonville
Gulf Shores
Panama City Beach
Panama City
St. Augustine
Palm Coast
Daytona Beach
Ocala
The Villages
Sanford
Orlando
Spring Hill
Kissimmee
Melbourne
Tampa
Clearwater
FLORIDA
St. Petersburg
Sarasota
Port St. Lucie
West Palm Beach
Fort Myers
Naples
Fort Lauderdale
Miami
Homestead
Everglades National Park
Key West
Maps

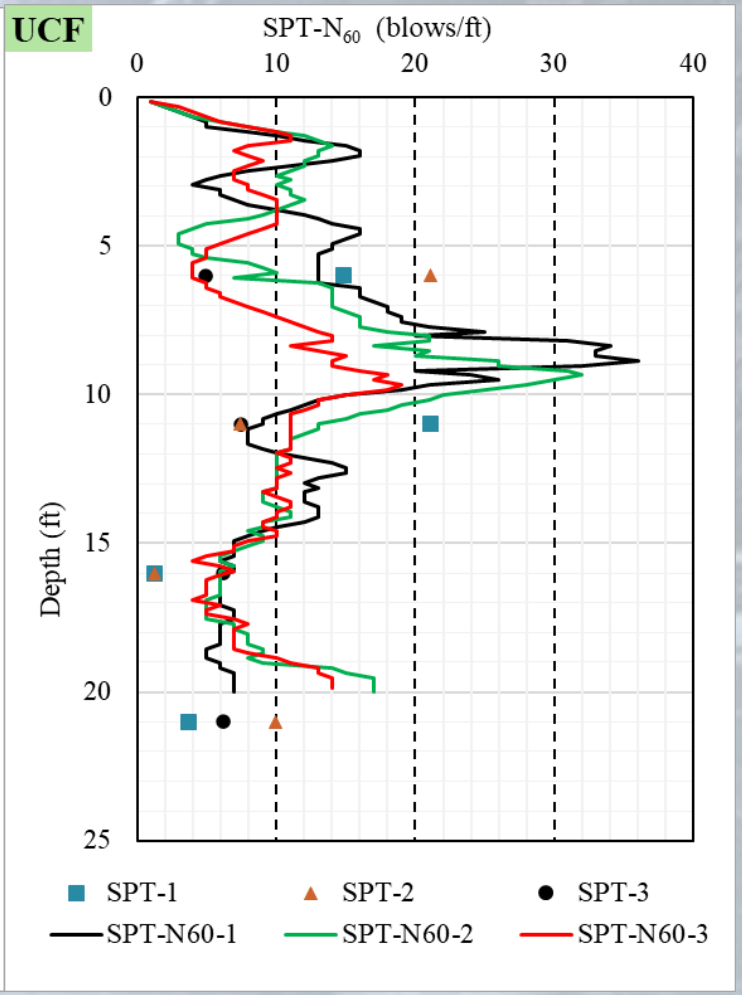
Overview of A Lot of Field Testing

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**

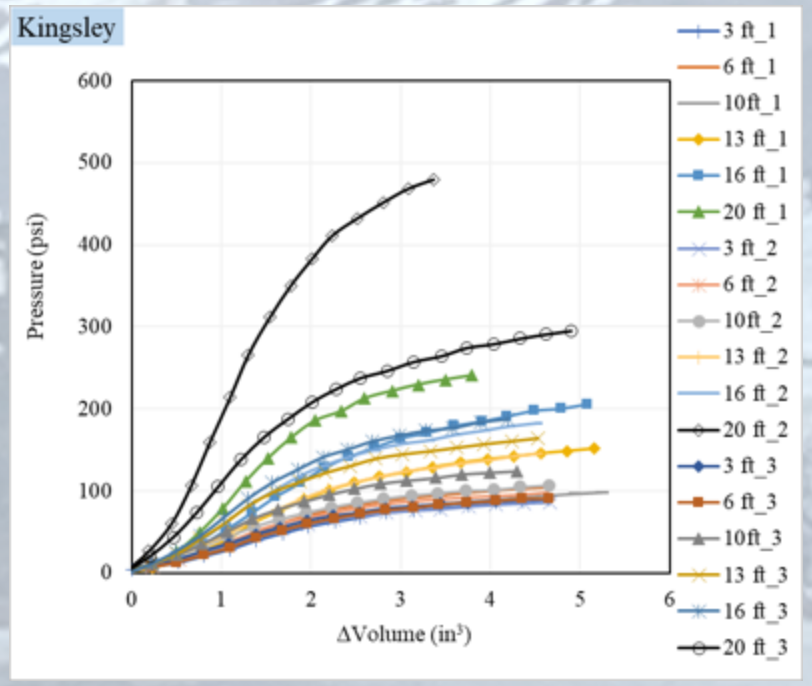
Task 4 CPT-SPT Soil Profiles

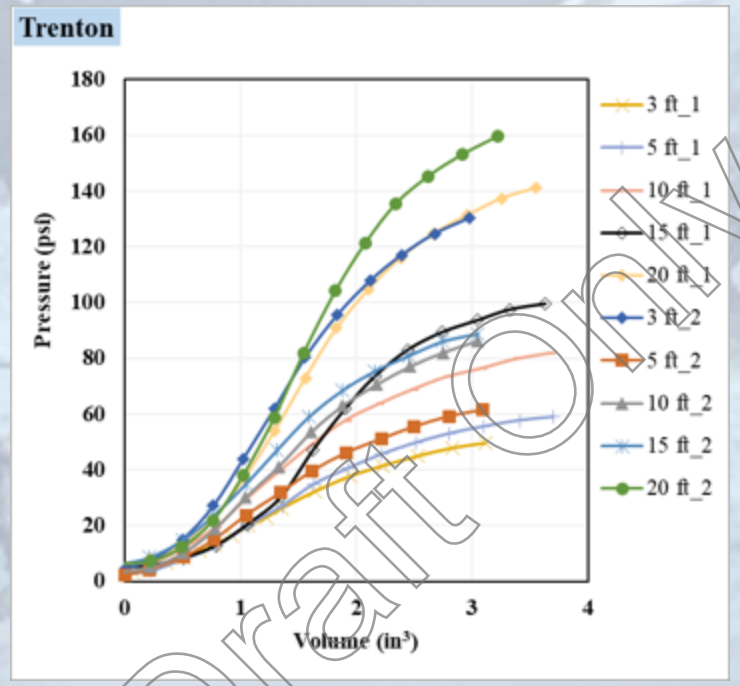


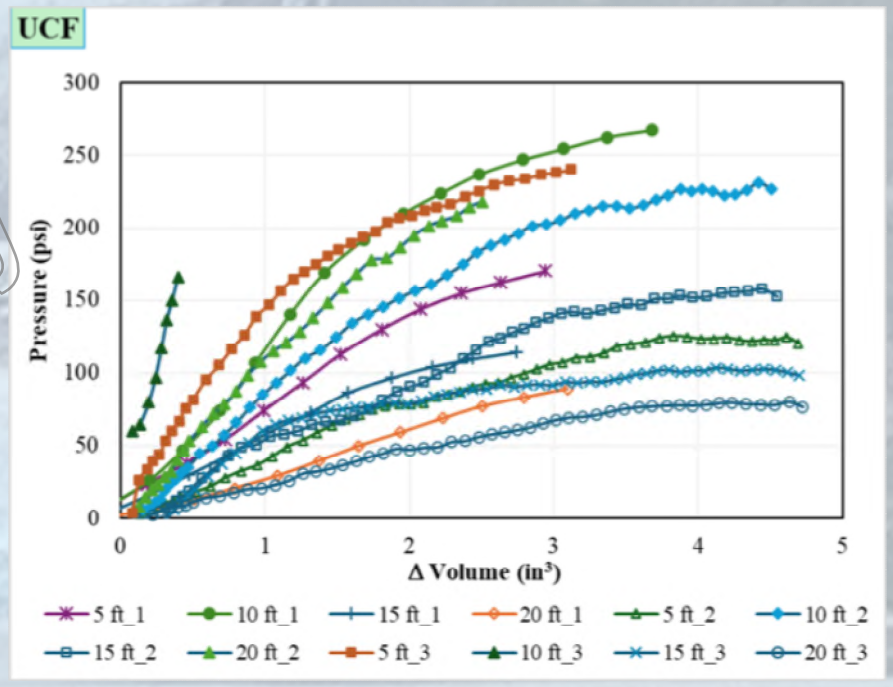


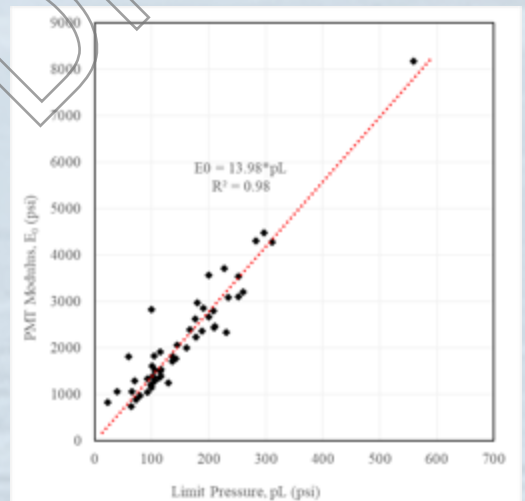


Task 3 PENCEL PMT Data

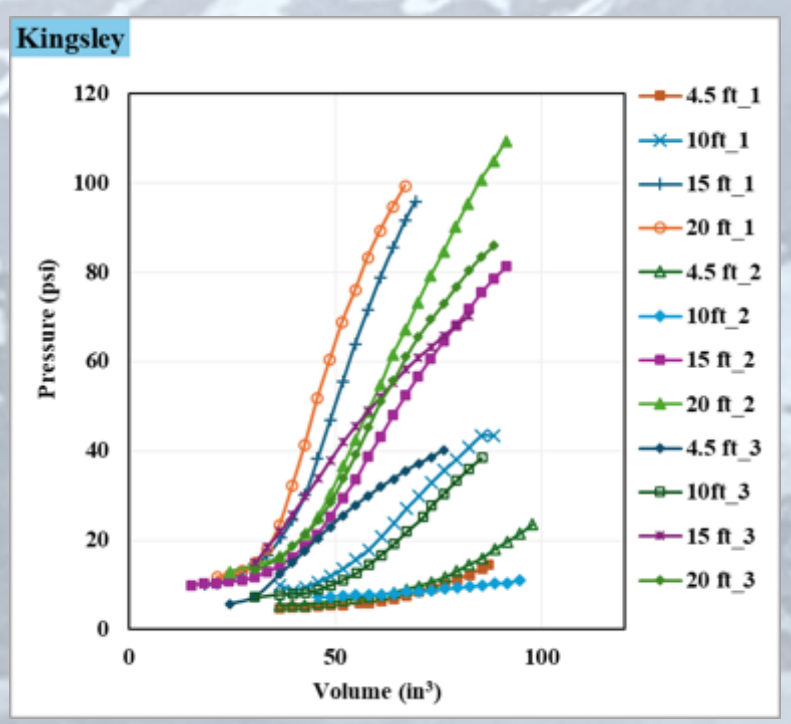


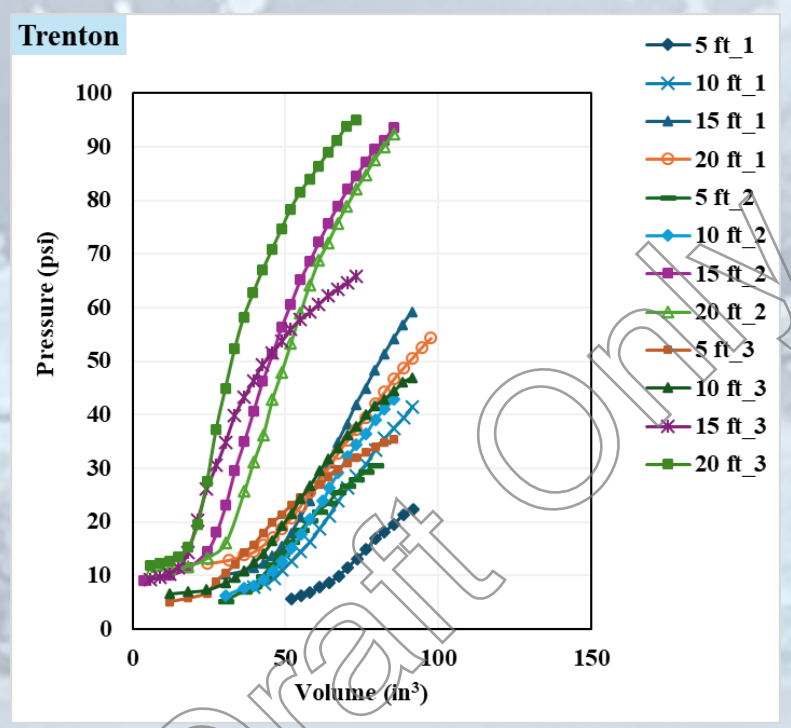


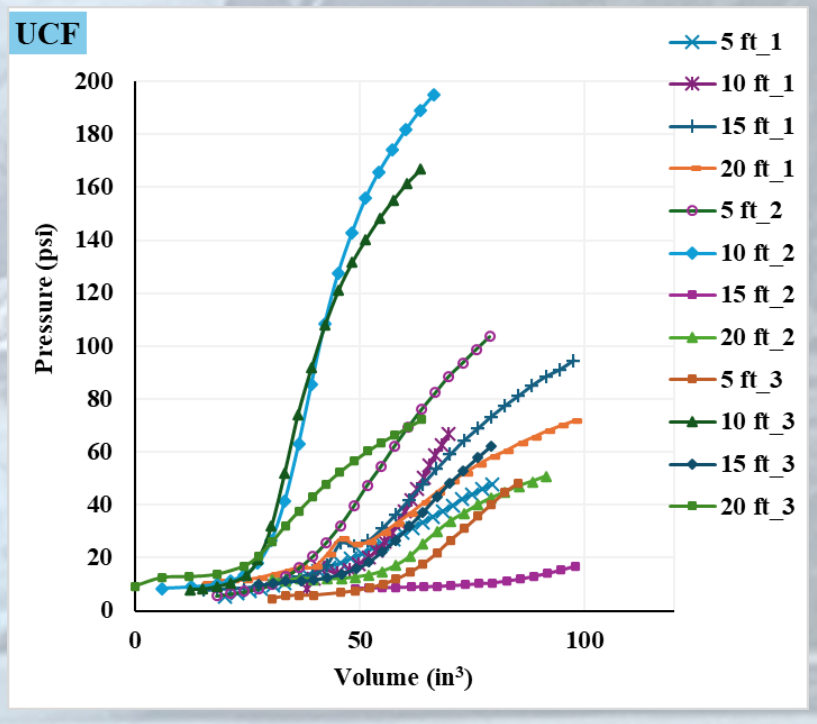


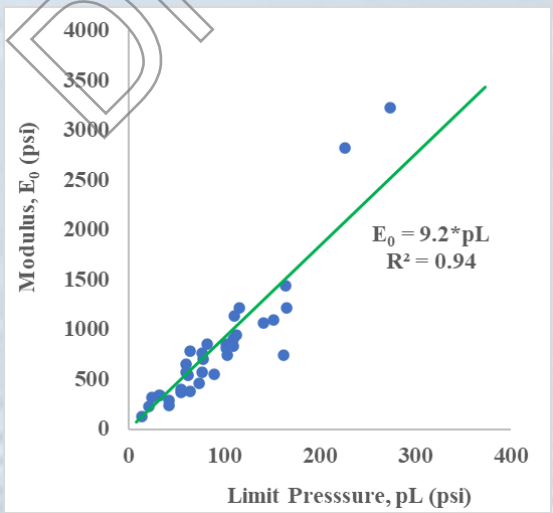


Task 3 TEXAMe PMT

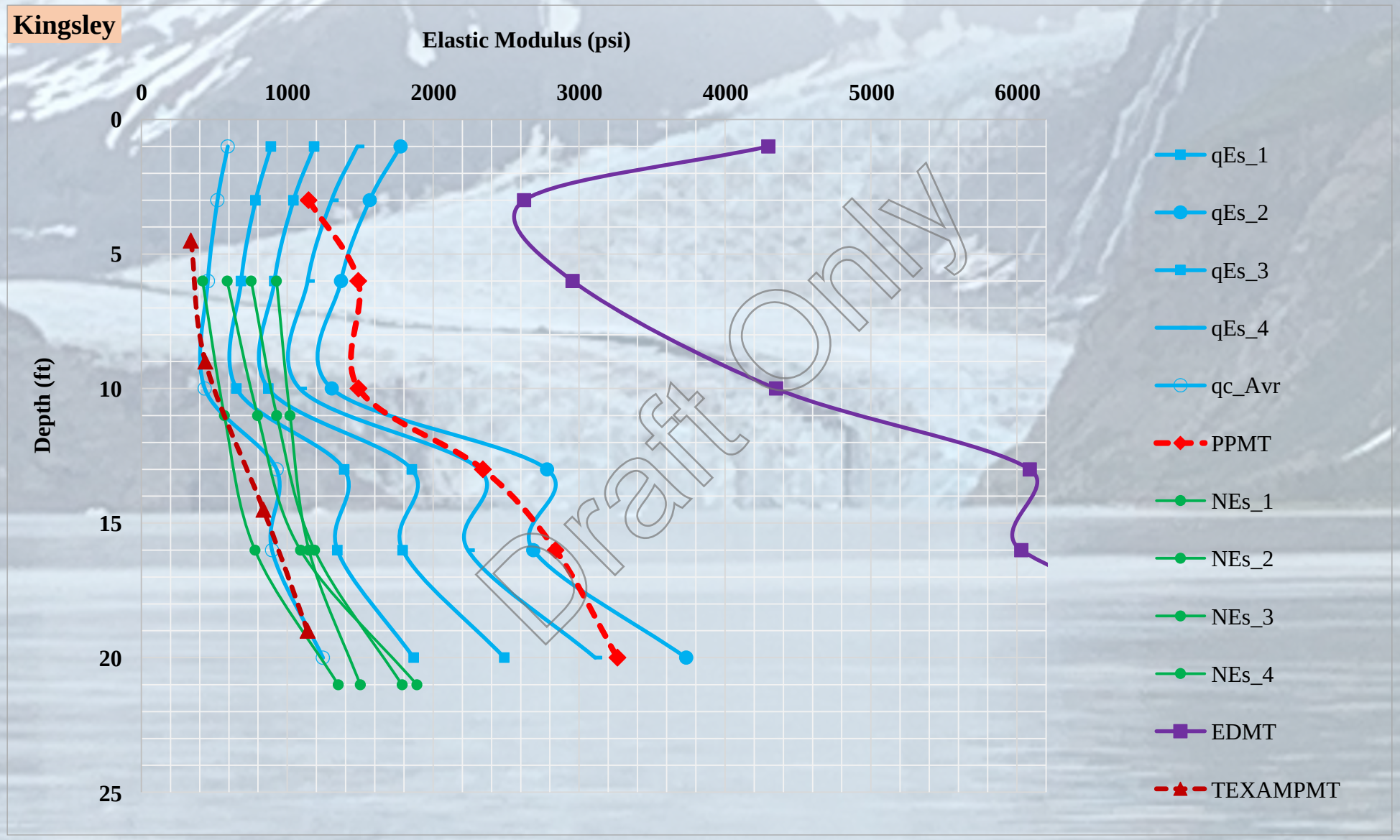






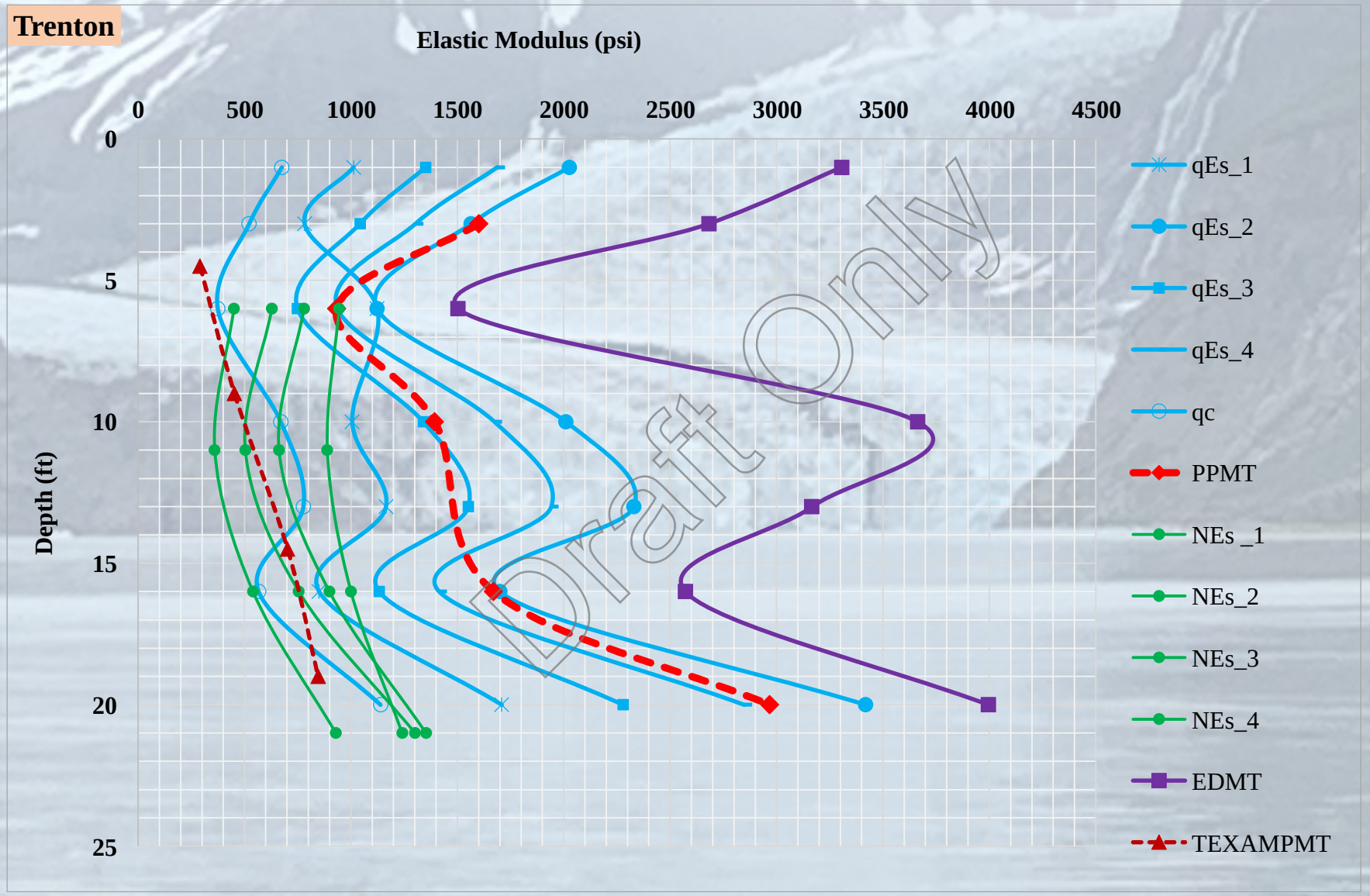


Task 4 - All Tests- Kingsley



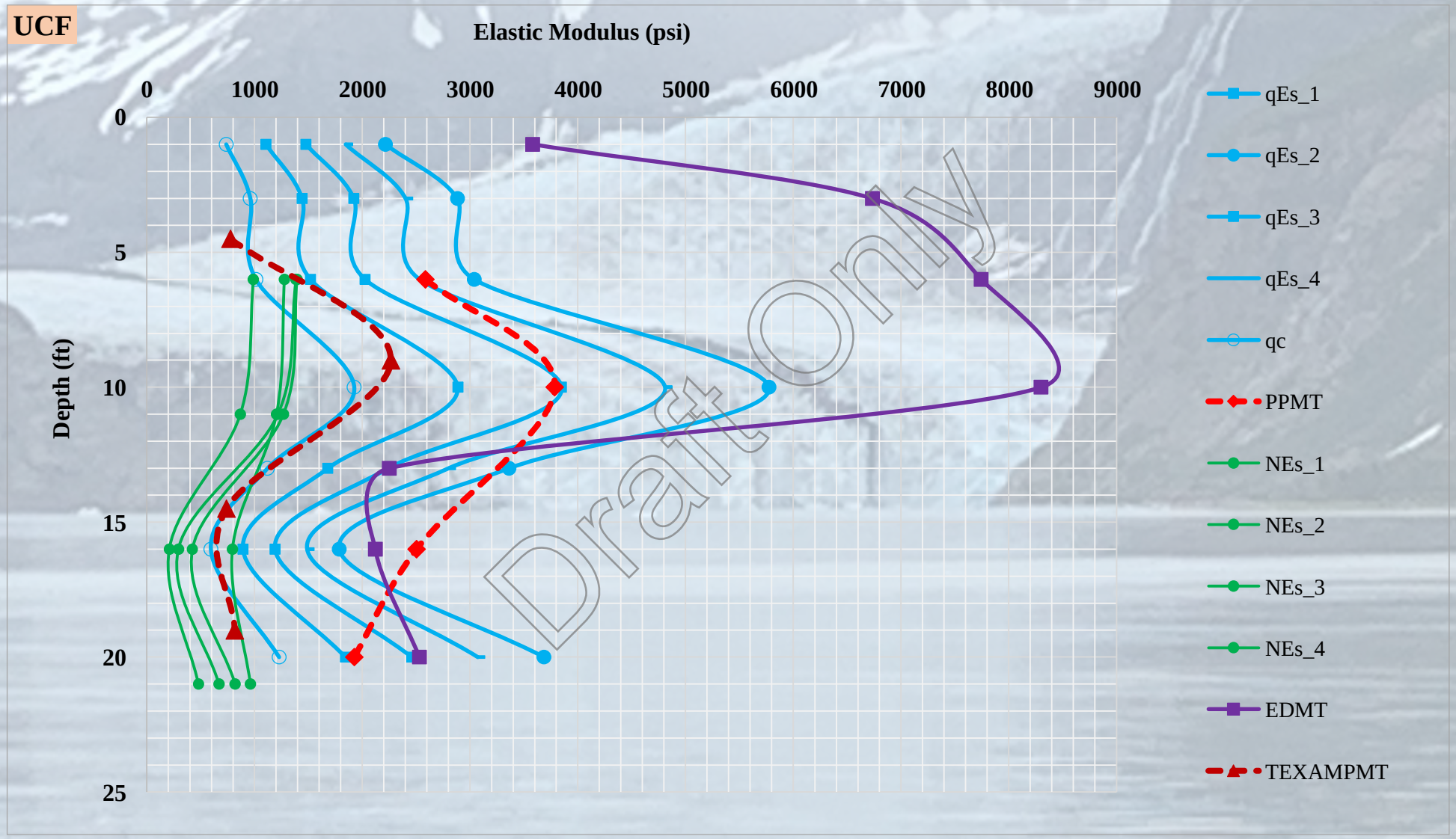
Moduli Trends are Similar from PPMT, TEXAM, CPT and DMT Data

Task 4 - All Tests-Trenton



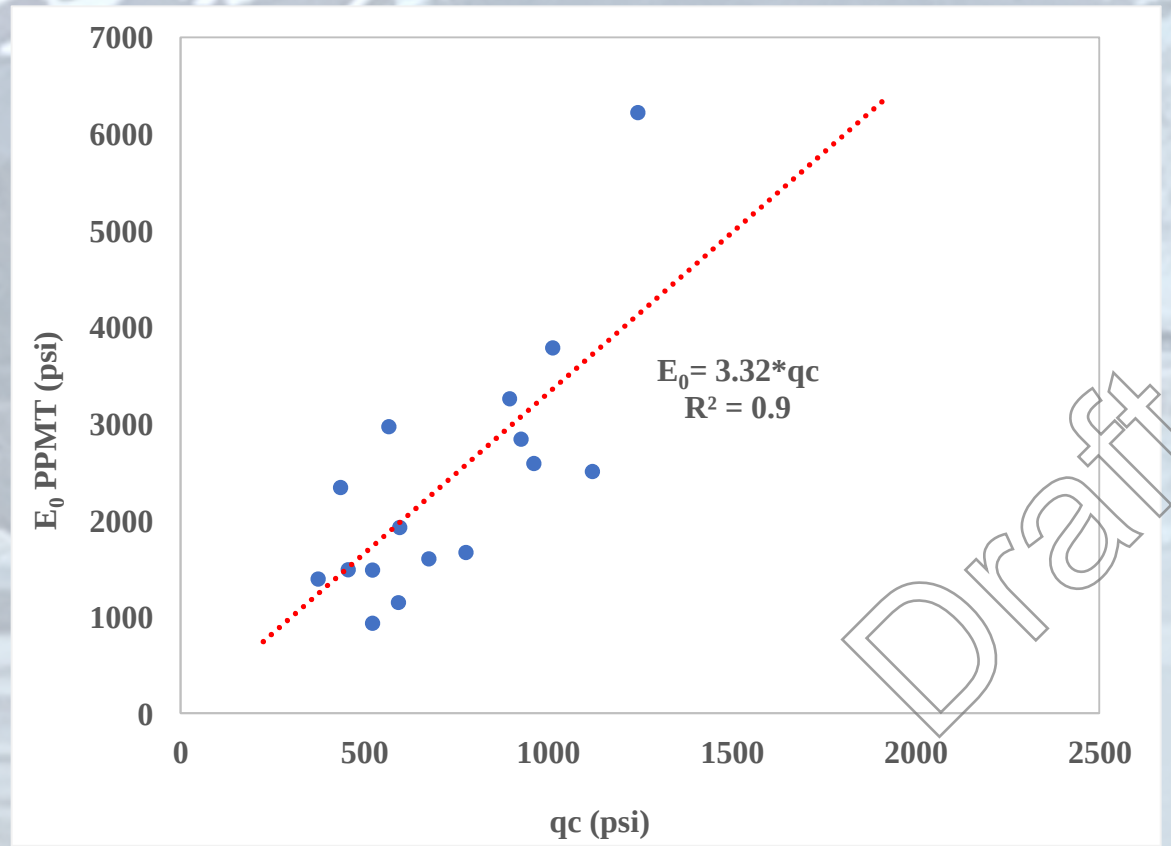
Moduli Trends are Similar from PPMT, TEXAM, CPT and DMT Data

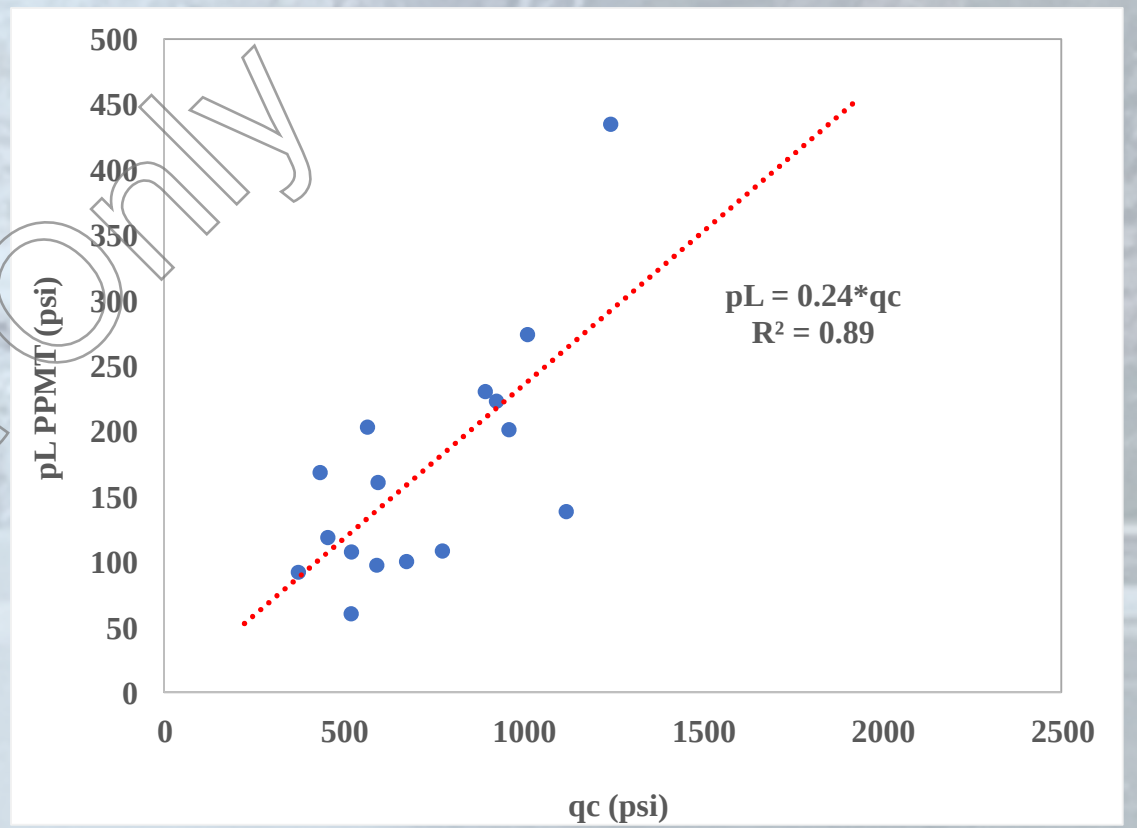
Task 4 - All Tests - UCF



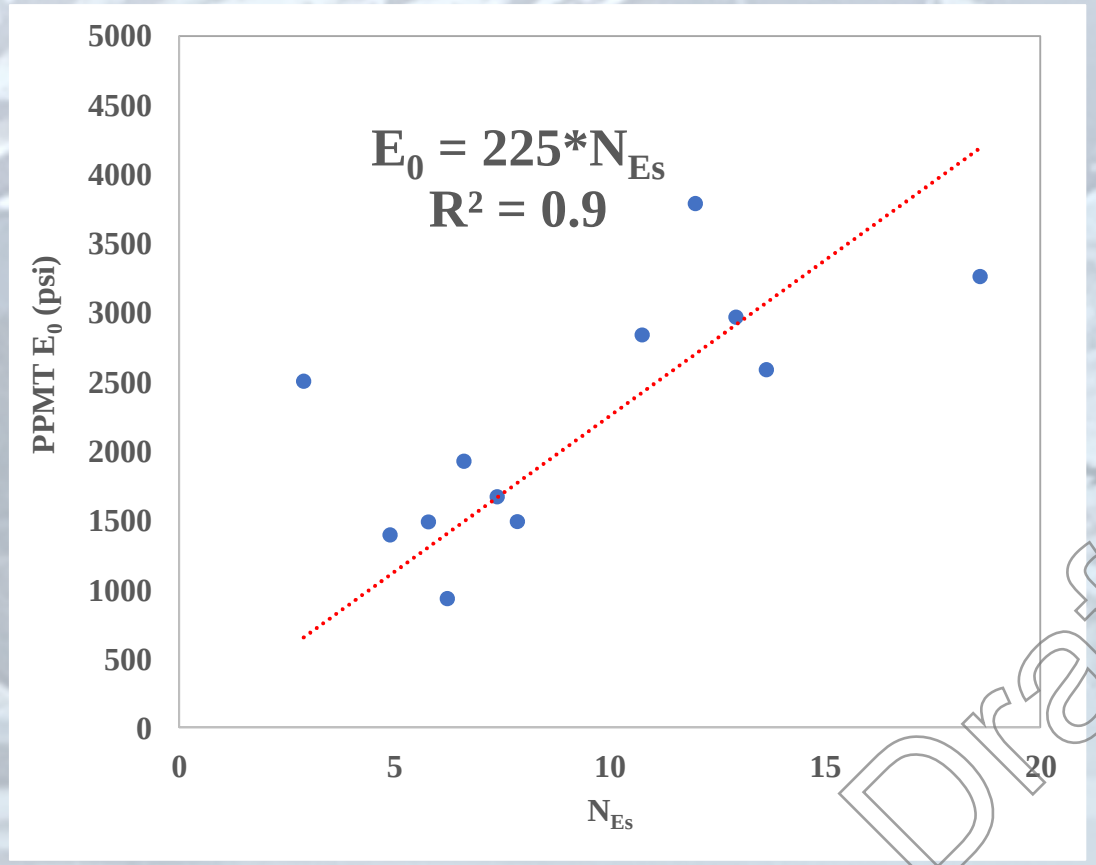
Moduli Trends are Similar from PPMT, TEXAM, CPT and DMT Data

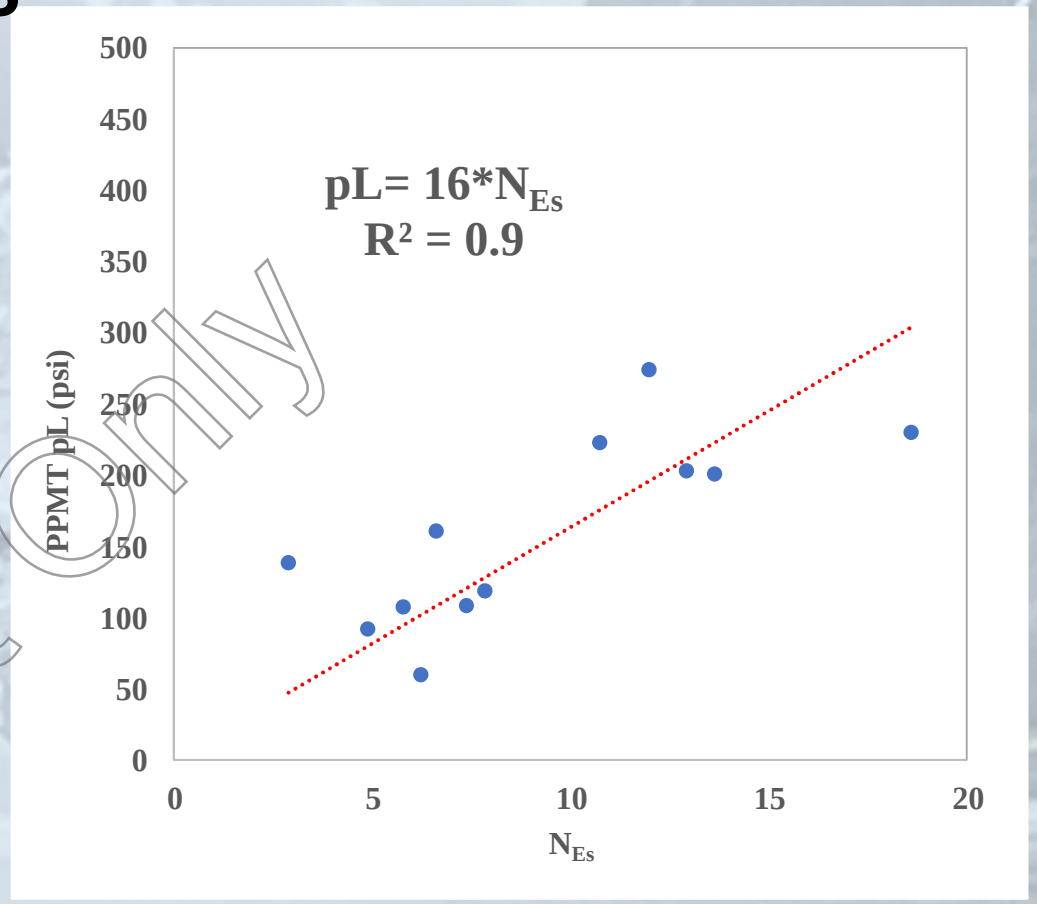
PPMT CPT Correlations





PPMT SPT N_{ES} Correlations

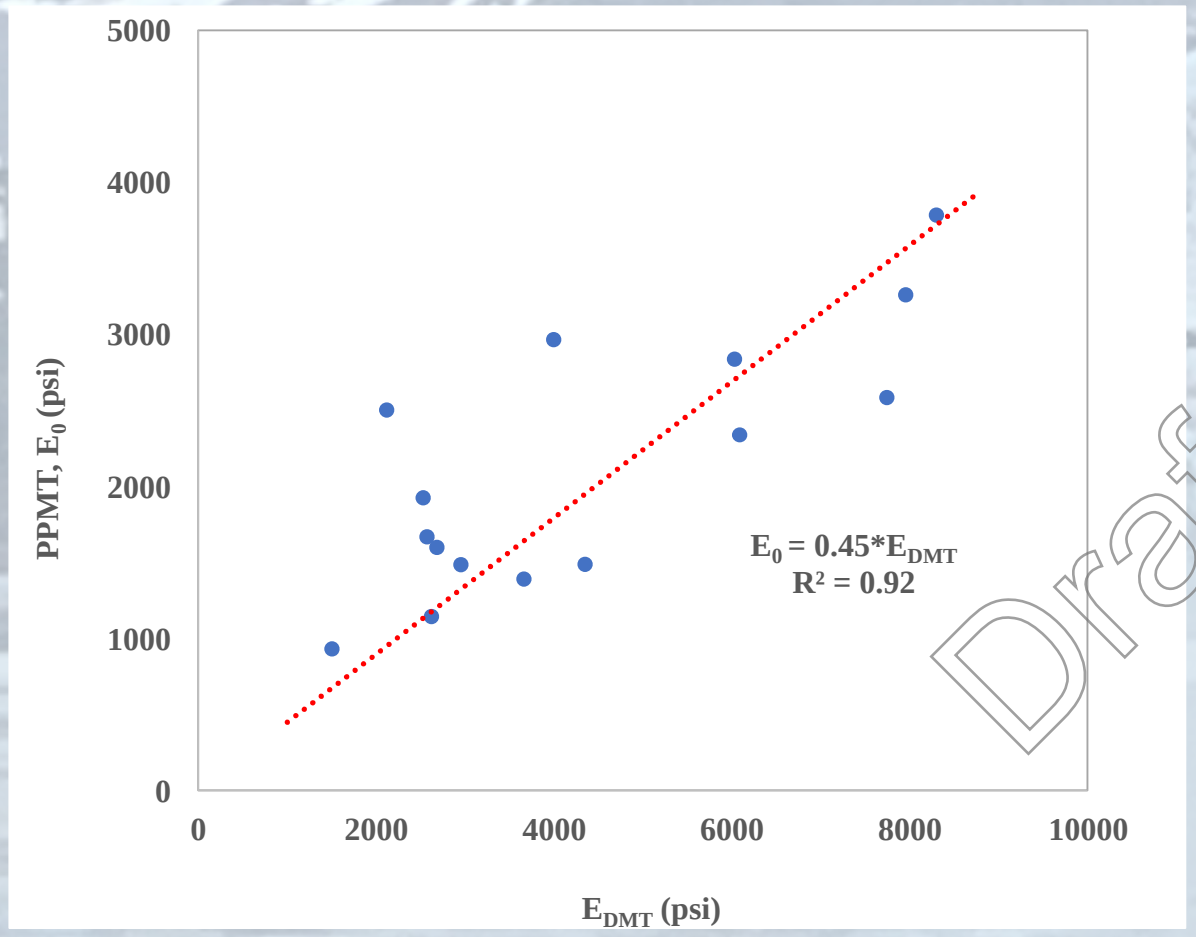


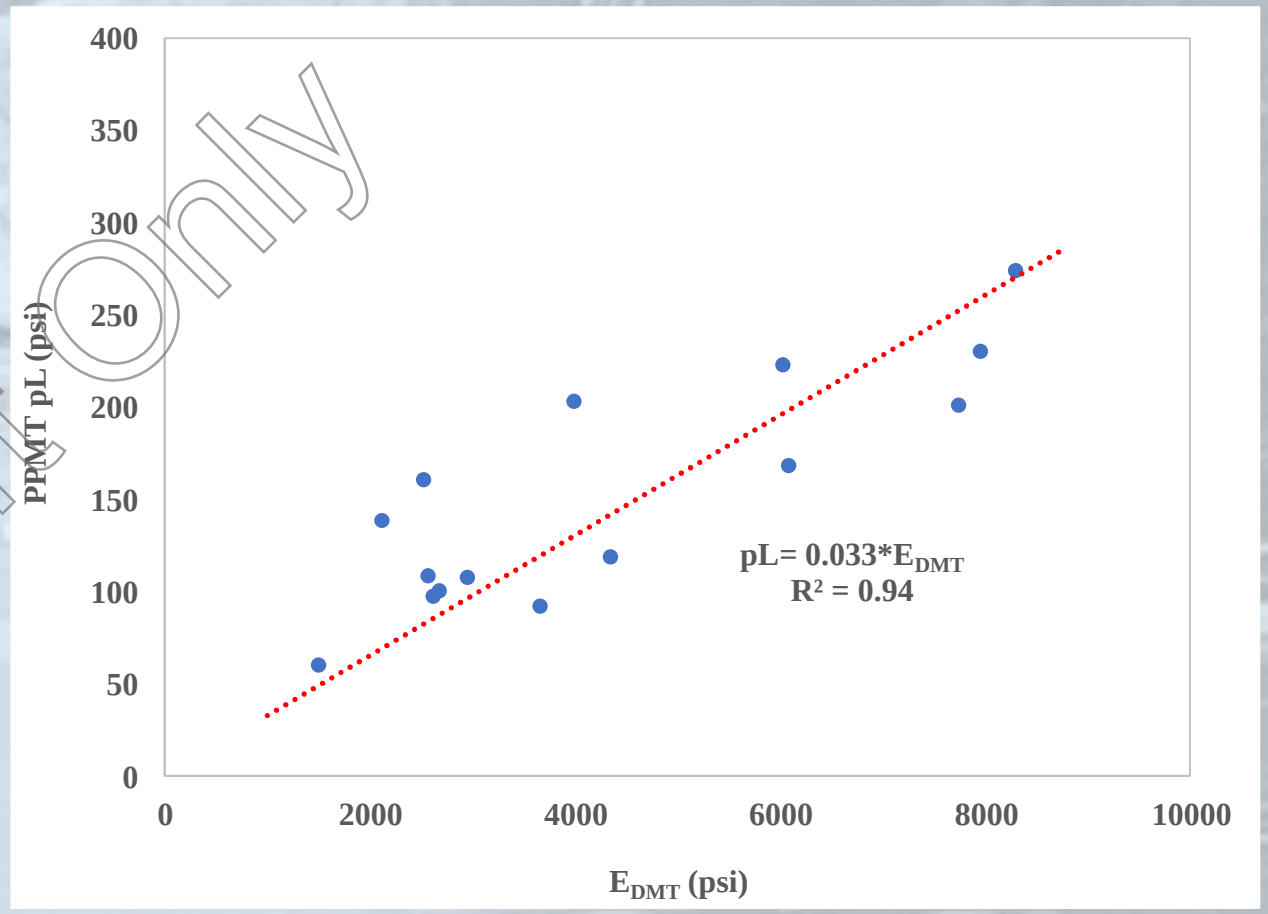


Literature Says:

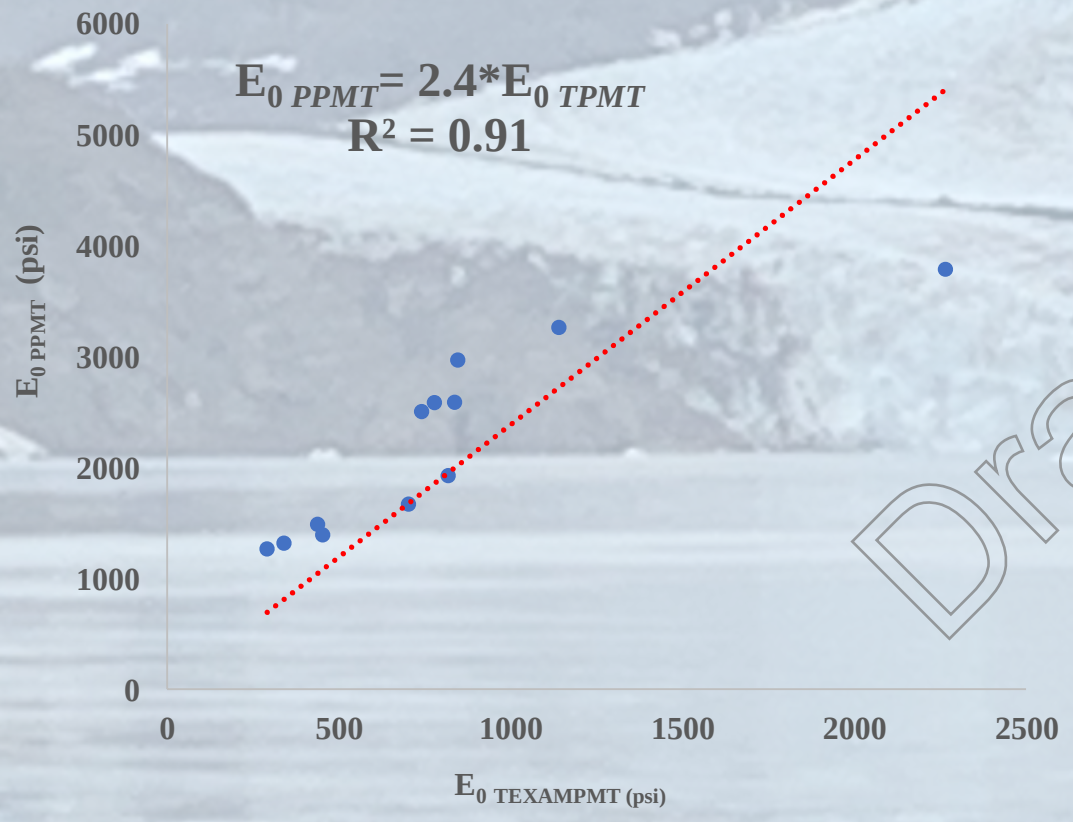
E = 40 (N+5) (psi) for Silty Sands !!!!

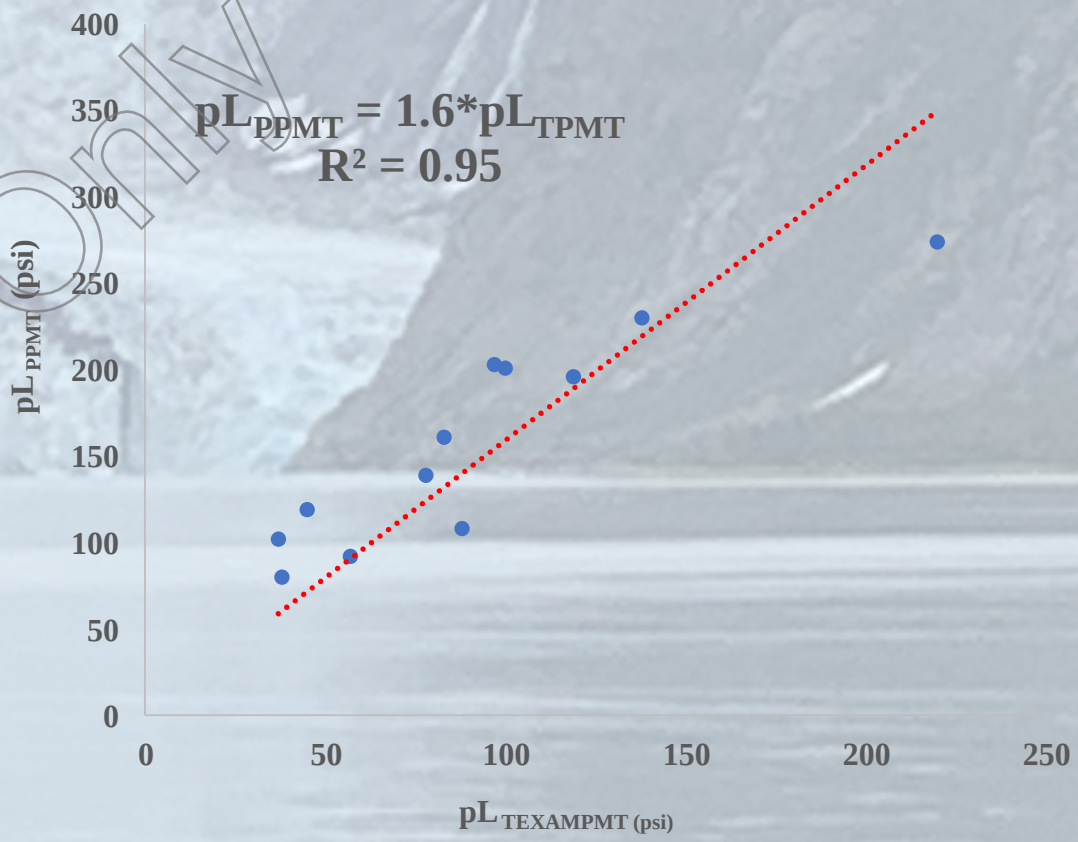
PPMT DMT Correlations





PPMT - TEXAM Correlations





Task 4 Summary

- *Moduli Trends are Similar from PPMT, TEXAM, CPT and DMT Data*

PPMT	Factor	Test Stiffness
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*

Questions

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