Progress Report, GRIP MEETING 2018

Project: Comparison of Standard Penetration Test (SPT) N-value with Alternative Field Test Methods in Determining Moduli for Settlement Predictions

PRESENTED BY

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Outline

Selected Topics:

- Project Overview
- Soil Profile
- Class “A” Prediction Models
- Design Calculations: Boussinesq Analysis, Horizontal Deformation Analysis
- Summary of Correlations and Settlement Methods
- Sensor Installation
- Survey Results

UCF Geotechnical Research Test Site

Goals

- To identify the most appropriate correlations with SPT-N to obtain accurate modulus values compared to current practice of using general correlations identified in various textbooks
- Identify supplemental field test methods that may yield more accurate moduli correlation than those from SPT-N correlations
- Perform analysis based on results using actual field settlement measurements under controlled conditions.
- Conduct additional laboratory testing

Tasks

- Conduct a review of literature related to current methods for modulus and for immediate settlement predictions
- Survey of practitioners and district engineers
- Study previous research report – differentiate different layers and identify two or three locations for field testing
- Perform Conical Load tests (Schmertmann, 1993)
  - Measurements using settlement plates and spider magnet rings at intermediate layers
  - Pore pressure transducers and Shelby tube samples for silty layers

Tasks - Continued

- Conduct additional CPT, DMT, PMT and seismic geophysical

– Perform related Index testing (at UCF and SMO) on soil samples with significant fines
  - – Consolidation tests
  - – Triaxial tests
  - – Atterberg Limits
  - – Specific Gravity

- Analysis of data

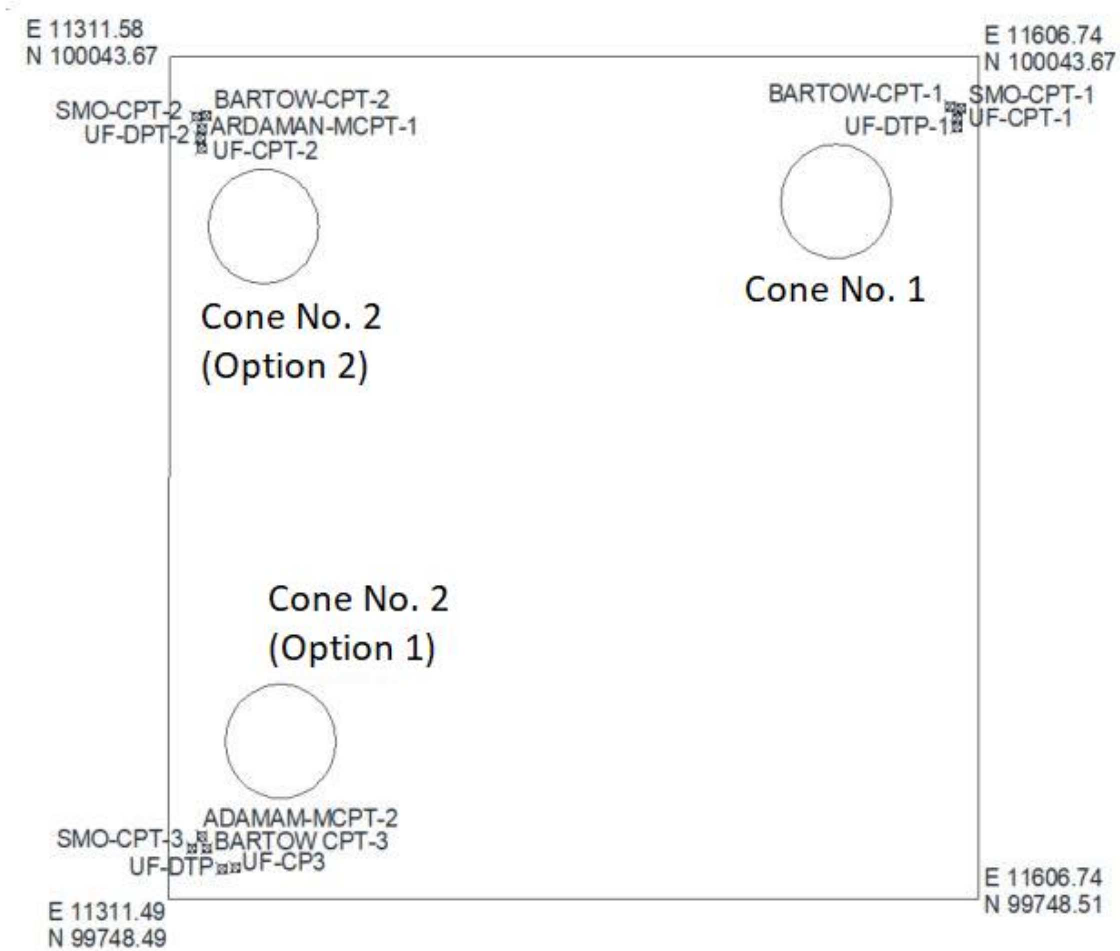
- Progress updates and Reporting per FDOT requirements

- Implementation

Plan View

Summary of instrumentation from FDOT (2003) for the proposed test sites

Proposed Location No.	CPT	SPT	DMT	PMT	Total
1	3	3	2	-	8
2 (Option No. 1)	4	-	-	-	4
2 (Option No. 2)	4	-	-	-	4
Total	11	3	2	-	16



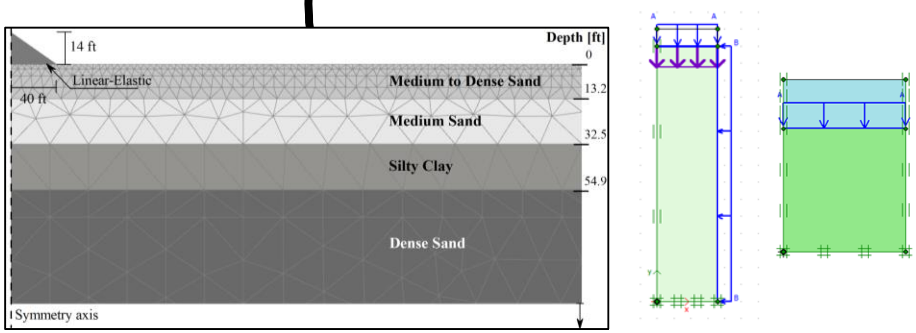
Research Approach

Field performance

Field tests,
soil samples

Laboratory and Field Tests

Calibration of
soil parameters

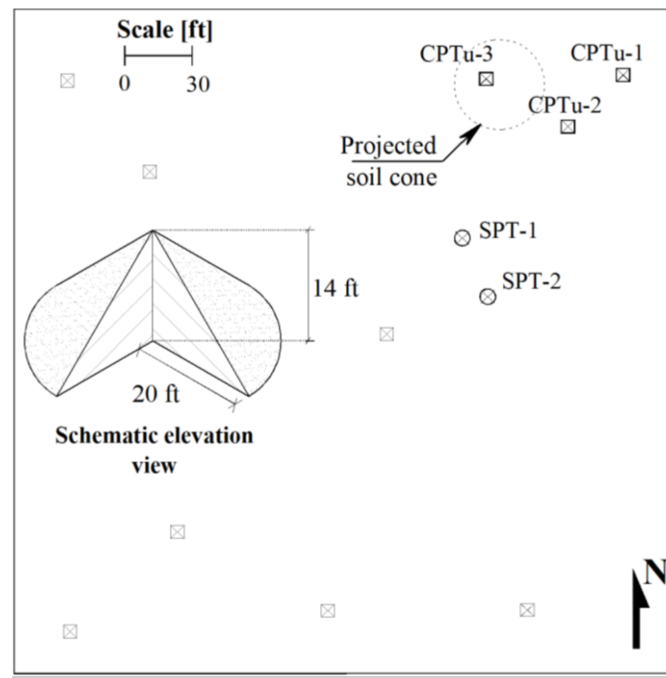


Numerical Models

Comparisons

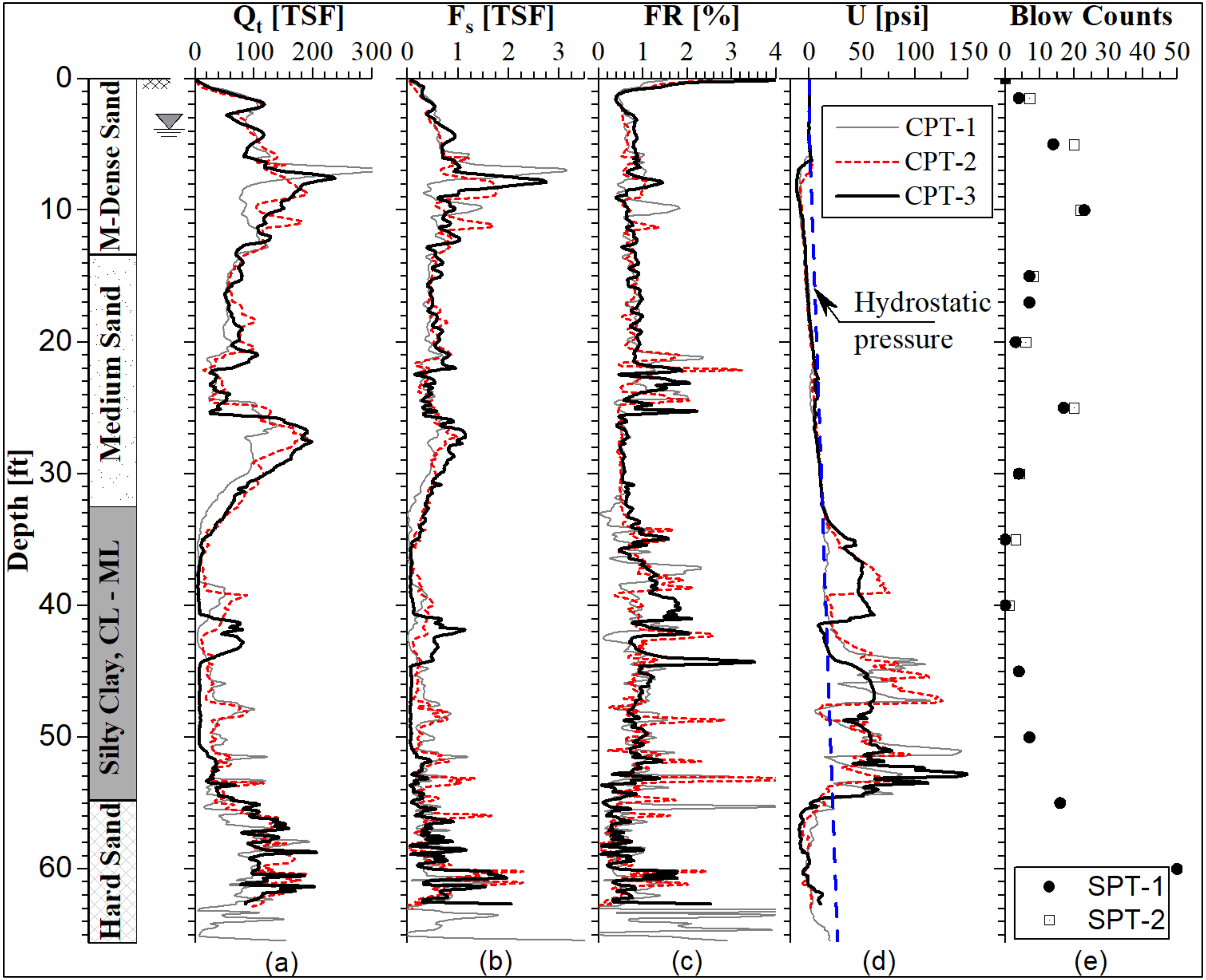
Conical Load Test No. 1: Plan View

Estimated Aug.-Sept. 2018: Conical Load Test No. 1



UCF RESEARCH SITE

Summarized Soil Profile



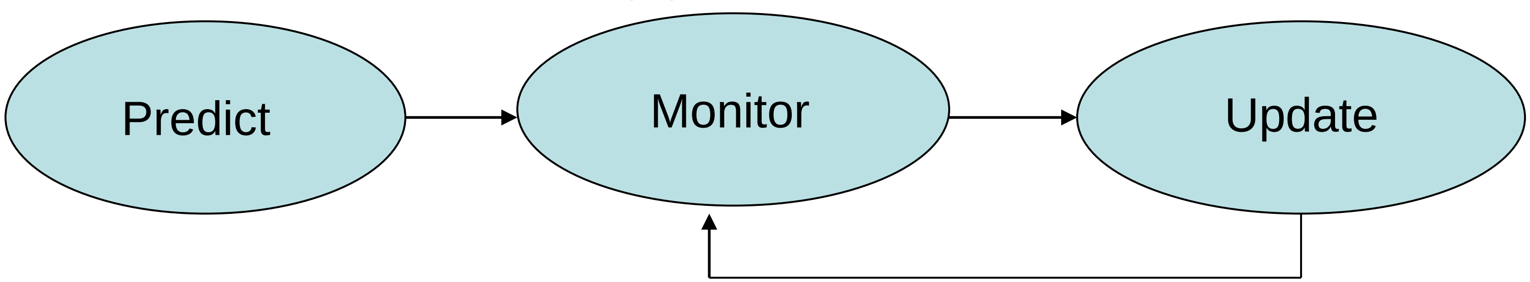
"Predictions in Soil Engineering", Lambe (1973), Geotechnique

"Predicting constitutes and integral component -the very heart- of the practice of civil engineering"

Classification of prediction

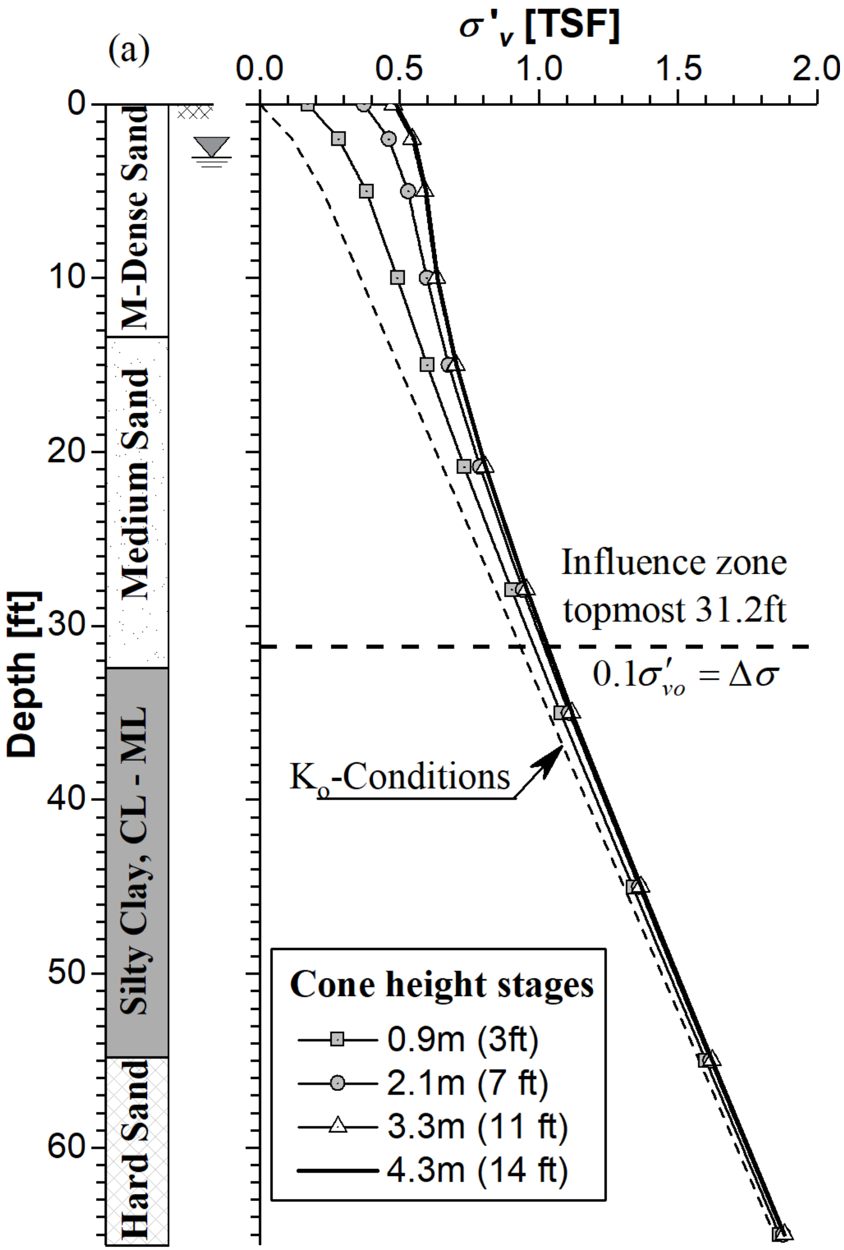
Prediction type	When prediction made	Results at time prediction made
A	Before event	—
B	During event	Not known
B1	During event	Known
C	After event	Not known
C1	After event	Known

Approach

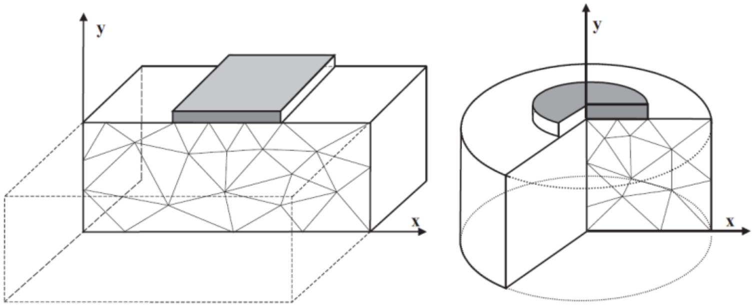


"Accurate predictions in geotechnical engineering are a results of compensating errors"
Elio D'Appolonia, Ph.D., P.E., NAE, a giant of geotechnical and foundation engineering

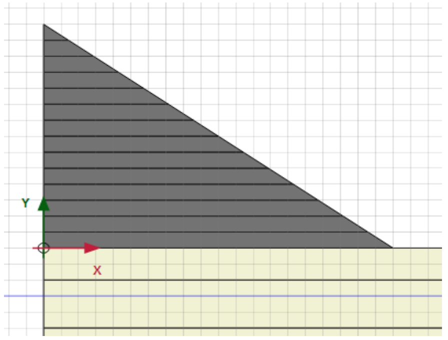
Preliminary Analyses: Boussinesq Analyses



Plane strain vs. axisymmetric



Cone modeling (axisymmetric conditions)



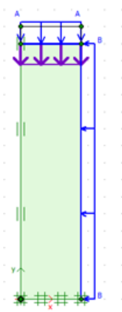
Conclusion from vertical stress analyses:

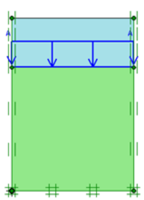
- Influence zone 30ft.

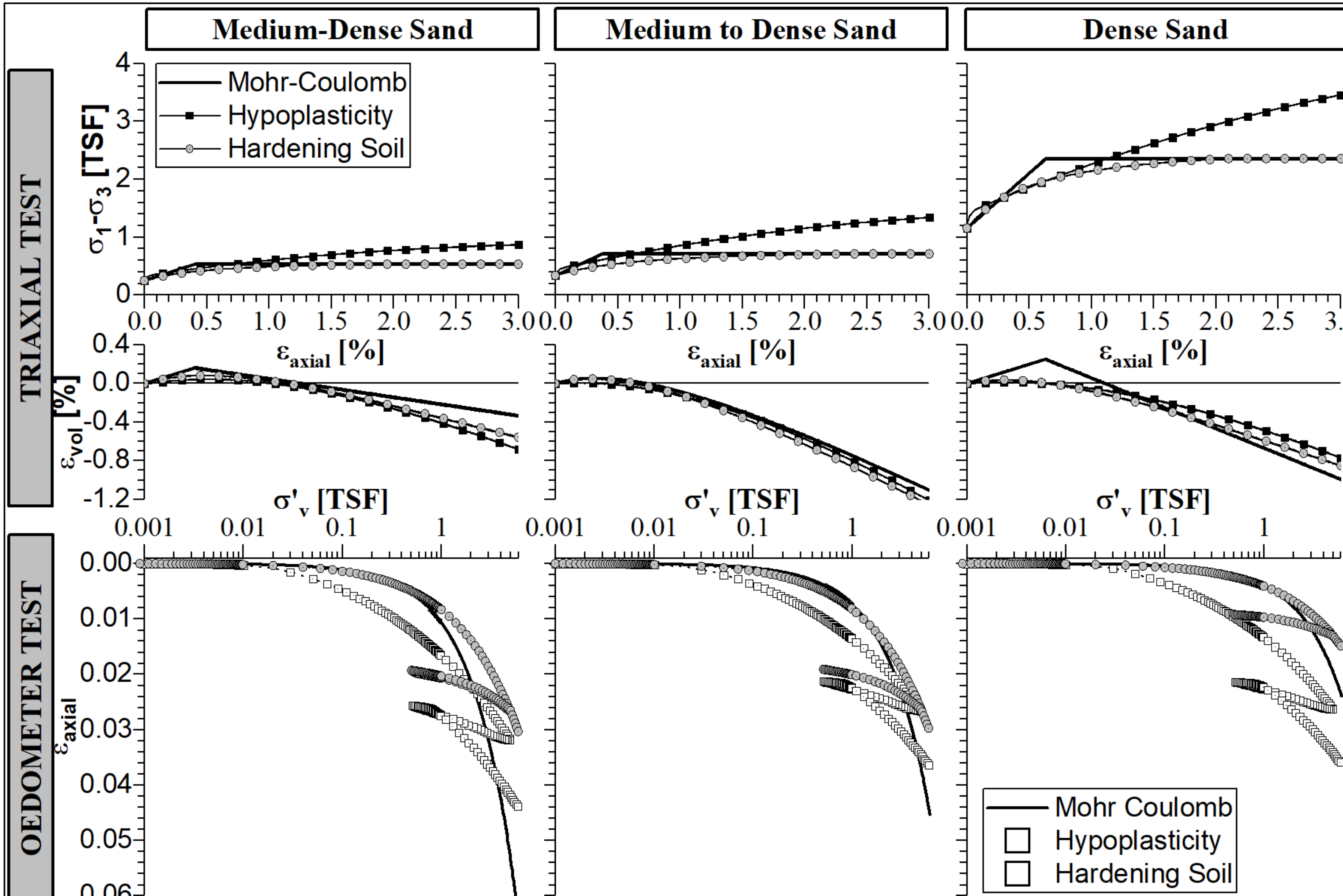
(i.e., we might not stress the silty clay)

Calibration of Soil Parameters

- Simulations at element-scale level, sandy soils at UCF site
- Goal? Simulate soil behavior (compressibility and shearing at element-scale level) … then (crossing our fingers) … capture observed behavior in the field and in the lab.
- Feedback loop (recalibrate soil parameters as more information is obtained)

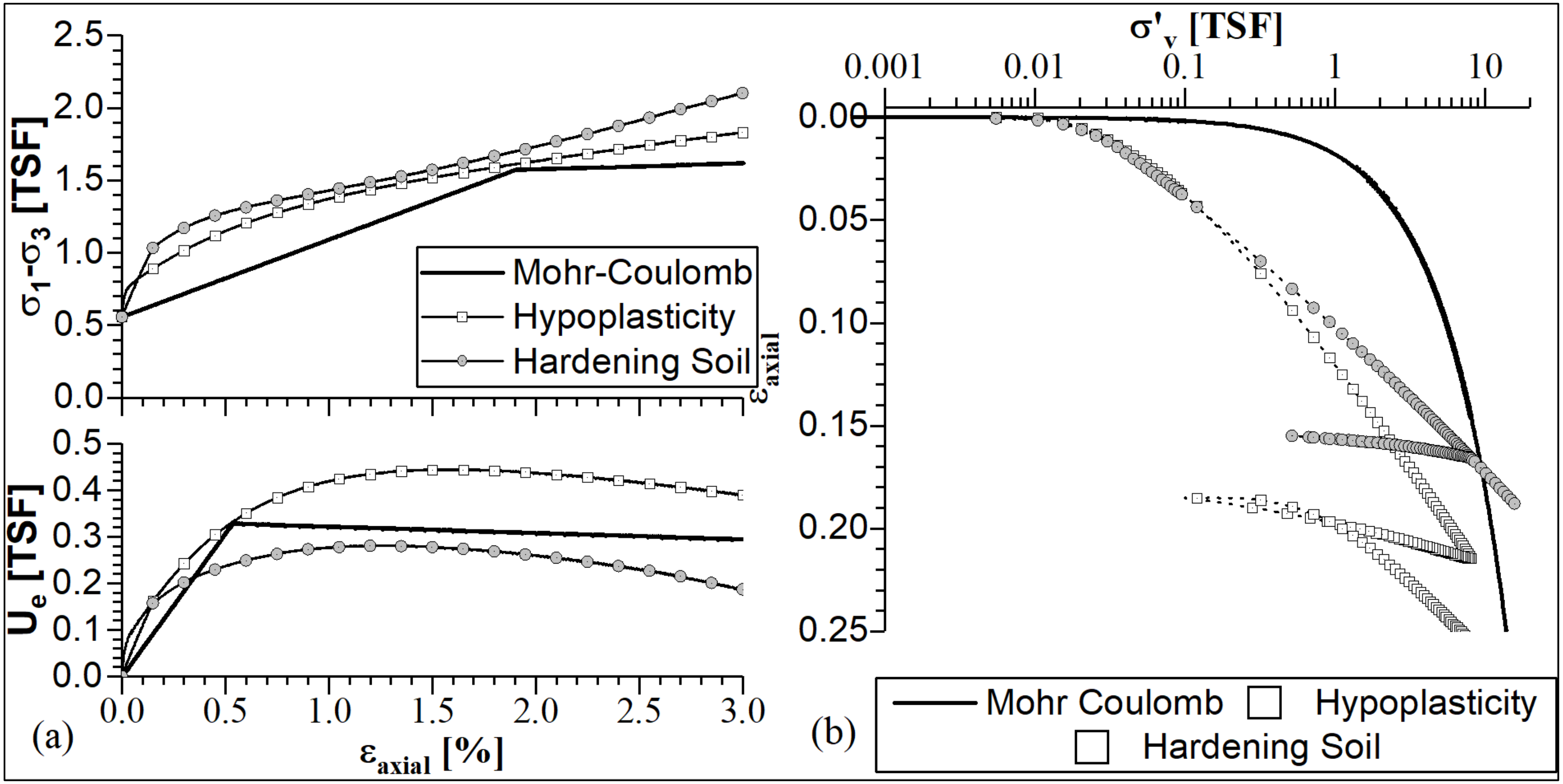






Calibration of Soil Parameters

- Simulations at element-scale level, silty clay layer at UCF site

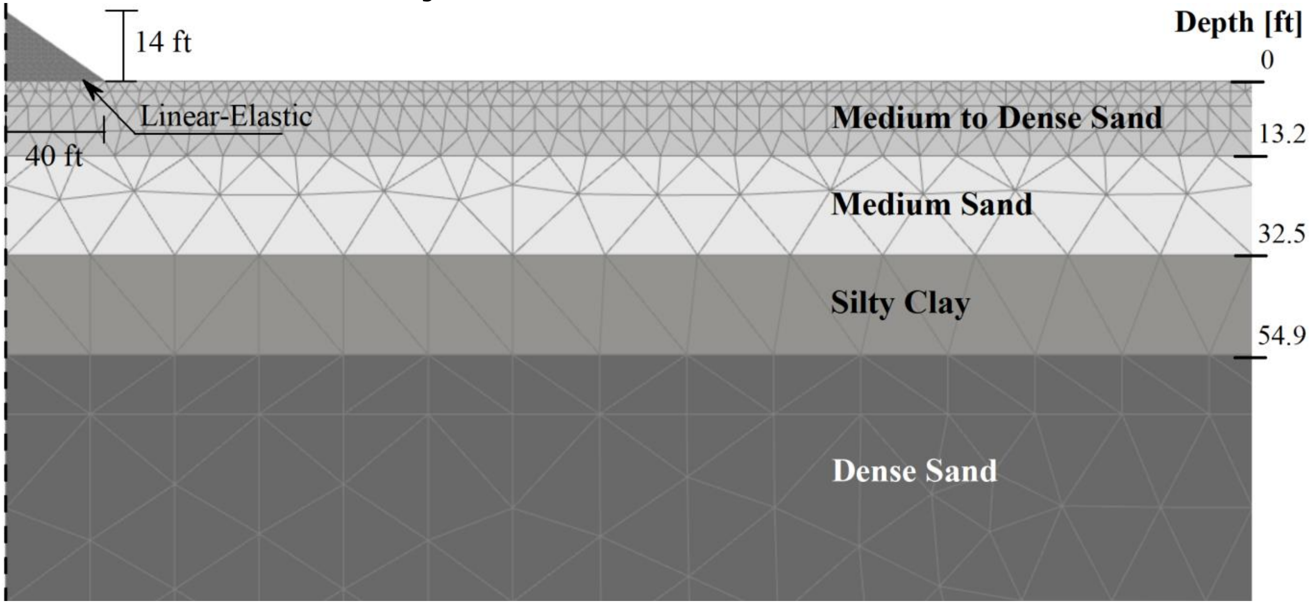


Triaxial

Oedometer

Numerical Model Layout: Constitutive Soil Parameters

Numerical Model Plaxis 2D



(Example of soil parameters for med.-dense sand)

Mohr-Coulomb Model

Parameter	Unit	Value
E’	ksf	146
v		0.3
G	ksf	56
E_{oed}	ksf	197
C_{ref}	psf	21
φ	deg	30
ψ	deg	5

Hardening Soil Model

Parameter	Unit	Value
E_{50}^{ref}	ksf	150
E_{oed}^{ref}	ksf	150
E_{ur}^{ref}	ksf	450
e_{init}		0.8
m		0.3
C_{ref}	psf	21
φ	deg	30
ψ	deg	5

Hypoplasticity Soil Model

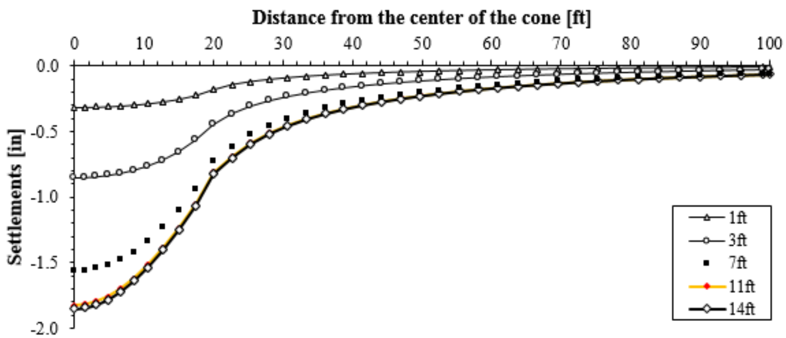
Parameter	Unit	Value
φ_c	deg	31
h_s	-	4177
n	-	0.28
e_{d0}	-	0.58
e_{c0}	-	1.096
e_{i0}	-	1.315
α	-	0.25
β	-	1.4
R	-	1E-4
m_R	-	5
m_T	-	2
χ	-	1
β_R	-	0.4

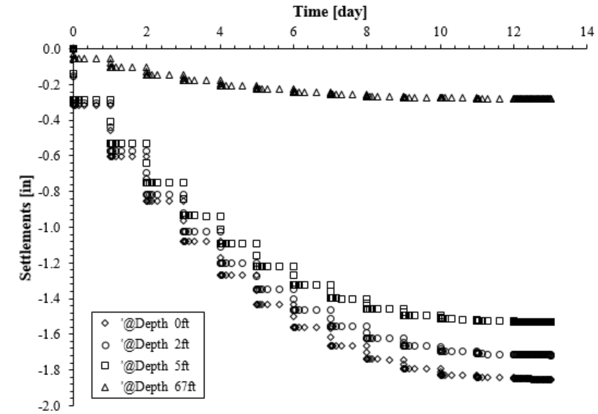
Results of Class A Prediction Models

Settlement versus distance

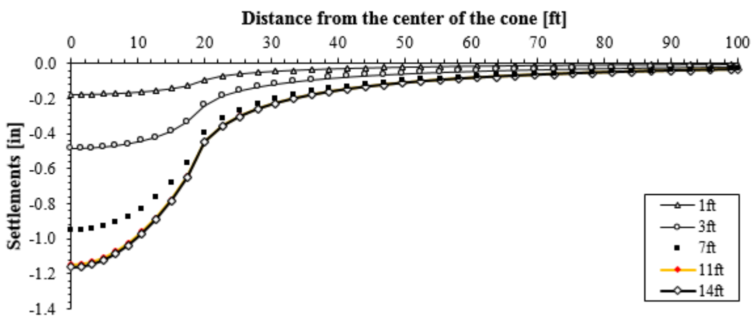
Settlement versus time

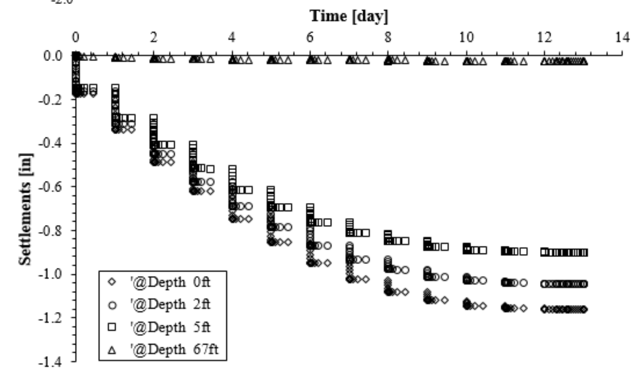
MC Results



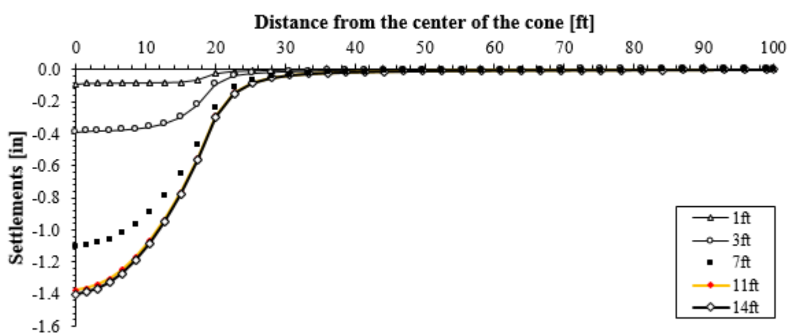


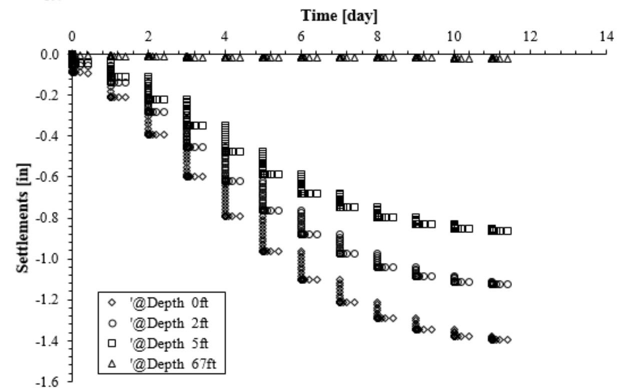
Hardening Soil Results





Hypoplasticity Results

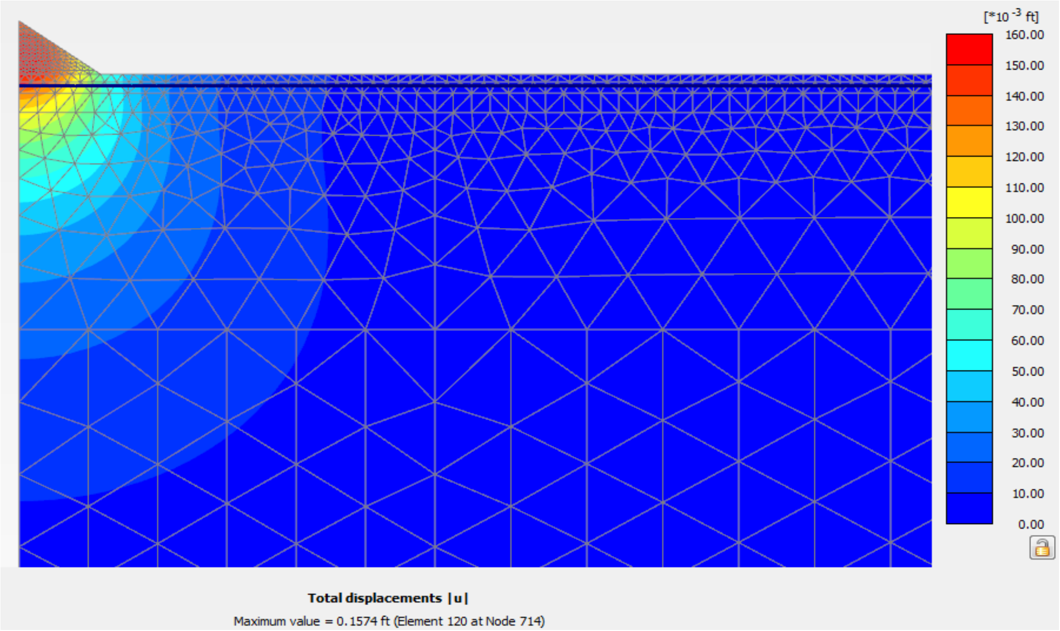




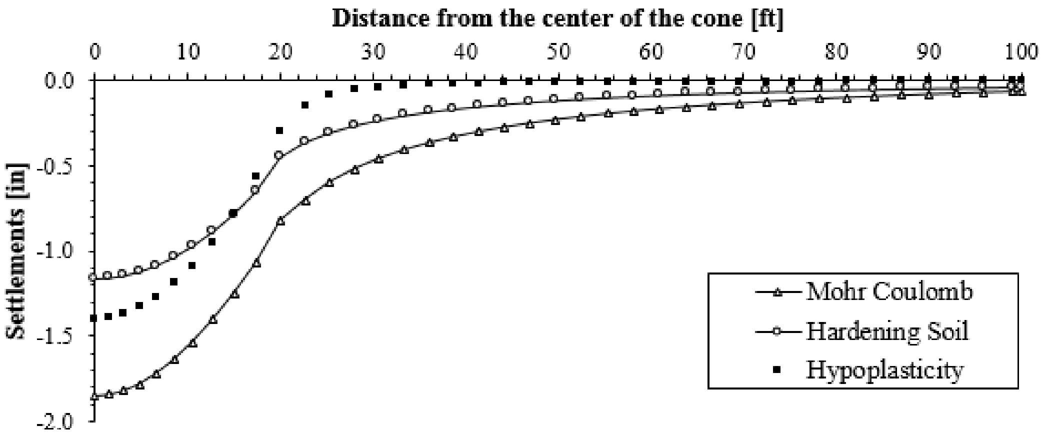
Conclusions: About 2-inch settlement expected. About 50 ft horiz. influence zone

Class A Prediction Models: Calibration of Soil Parameters

Typical settlement contour

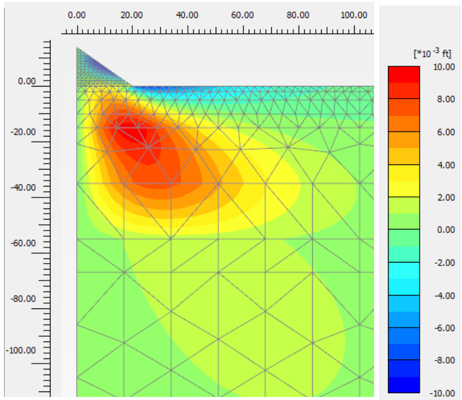


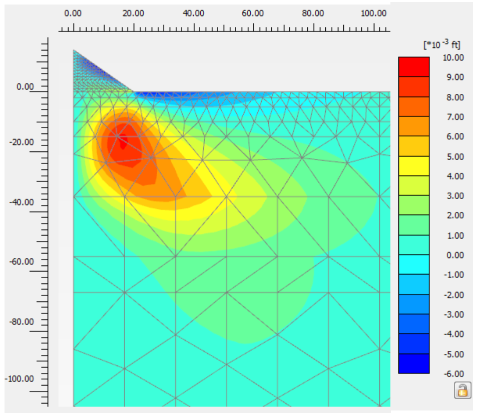
Summary of preliminary settlements < 2".

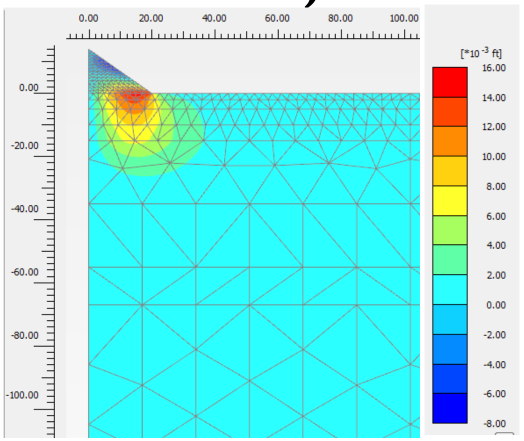


Very small excess pore water pressure is expected

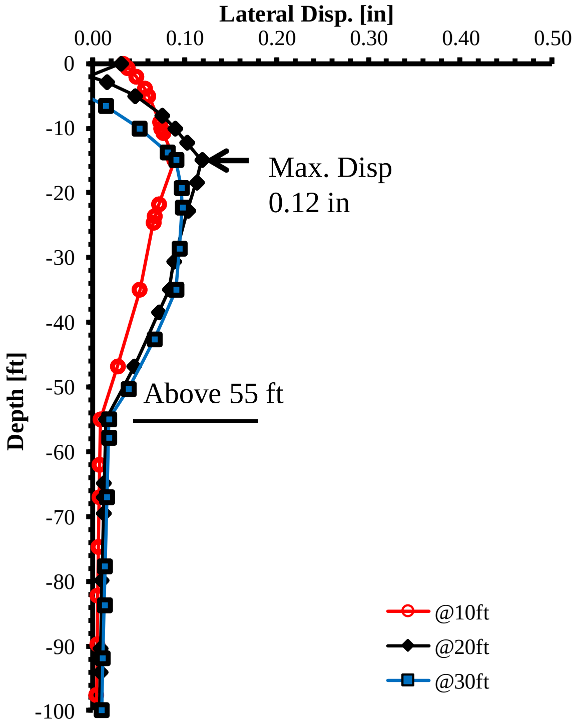
Horizontal Deformation Contours (Finite Element Model)



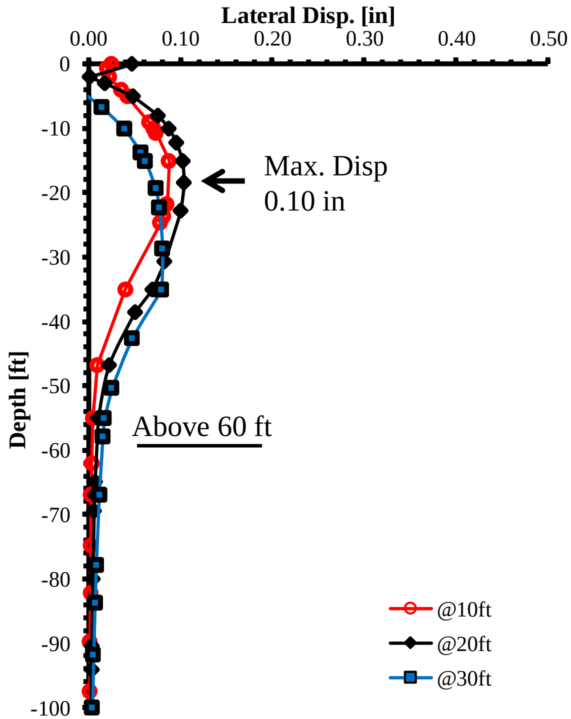




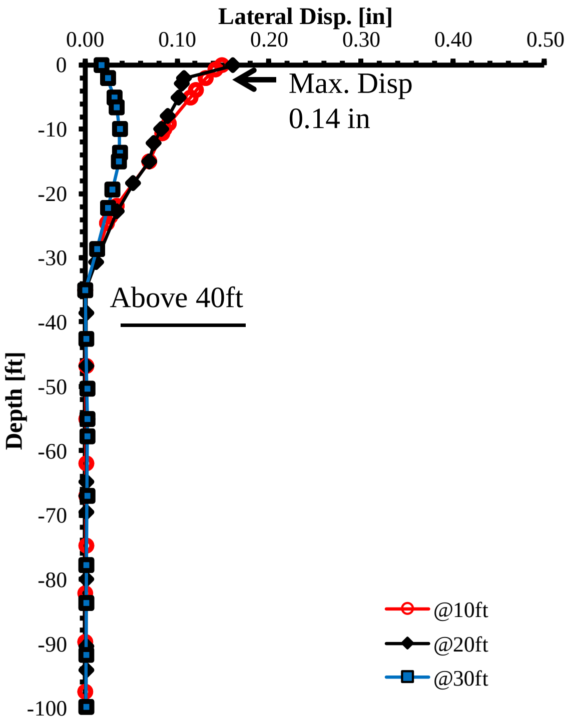
Max. Horiz. Displ. = 0.15 inches (1/8”). Anchor zone above 60 ft



Mohr-Coulomb



Hardening Soil



Hypoplasticity Model

Summary of Correlations of Elastic Modulus with SPT, CPT, DMT, PMT

SOIL	SPT	CPT
Dry Sand	**Schultze and Melzer (1965)**	**Schultze and Melzer (1965)**
Sand	**Trofnnenkov (1974)** **Webb (1969)** **Chaplin (1963)** **Denver (1982)** **Clayton et al. (1985)** **Papadopoulos (1982)**	**Buisman (1940)** **Trofunenkov (1964)** **De Beer (1967)** **Bachelier and Parez (1965)** **Vesic (1970)** **Sanglerat et al. (1972)** **DeBeer (1974b)** **Trofunenkov (1974)** **Thomas (1968)** **Schmertmann (1970)**
Sand with fines	**Kulhawy and Mayne (1990)** **Webb (1969)**	
Clean NC Sand	**Kulhawy and Mayne (1990)**	E=2 to 4 qc **Vesic (1970)**
Clean OC Sand	**Kulhawy and Mayne (1990)** **Bowles (1996)**	**Bowles (1996)**
Gravelly sand	**Bowles (1996)**	
Young Uncemented silica sand		**CPT Guide-2015**
Clayey sand	**Bowles (1996)**	**Bowles (1996)** **Bachelier and Parez (1965)**
Silty sand		E=1 to 2 q_c **Bachelier and Parez (1965)**
Submerged fine to medium sand	**Webb (1969)**	
Submerged sand	**Bowles (1996)**	**Webb (1969)** **Bowles (1996)**
Submerged clayey sand		**Webb (1969)**
Silt with sand to gravel with sand	**Begemann (1974)**	
Gravel		**Gielly et al. (1969)** **Sanglerat et al. (1972)**
Sands, Sandy gravels	**(FHWA-IF-02-034)**	**Bogdanovic' (1973)**
Silty saturated sands		**Bogdanovic' (1973)**
Sand and silty saturated sands with silt		**Bogdanovic' (1973)**

Total No. of Studies: 30

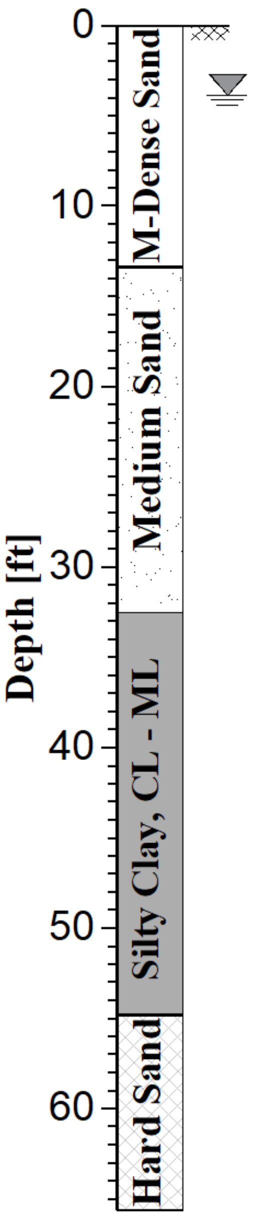
Only the authors are shown, the correlation equations are shown in deliverable document

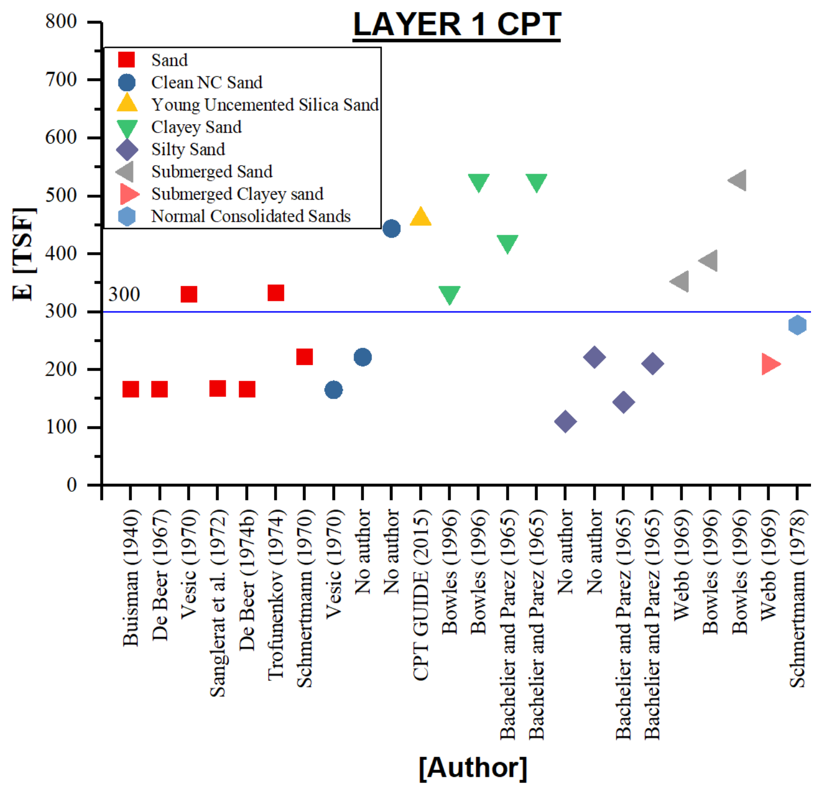
Summary of Correlations of Elastic Modulus with SPT, CPT, DMT, PMT

SOIL	SPT	CPT
NC Sands	**Bowles (1996)**	**Schmertmann et al. (1978)** **Bowles (1996)**
Silts, sandy silts, slightly cohesive mixtures	**(FHWA-IF-02-034)** **Bowles (1996)**	**Bowles (1996)**
Clean fine to medium sands and slightly silty sands	**(FHWA-IF-02-034)**	
Coarse sands and sands with little gravel	**(FHWA-IF-02-034)**	
Non-specified	**Farrent (1963)**	
Soft clay		**Bowles (1996)** **Bachelier and Parez (1965)**
Soft silty clay		**Meigh and Corbett (1969)**
Low Plasticity Clays (CL)		**Gielly et al. (1969)** **Sanglerat et al. (1972)**
Low Plasticity Silts (ML)		**Gielly et al. (1969)** **Sanglerat et al. (1972)**
Highly plastic silts and Clays (MH,CH)		**Gielly et al. (1969)** **Sanglerat et al. (1972)**
Organic silts (OL)		**Gielly et al. (1969)** **Sanglerat et al. (1972)**
Peat and organic clay (Pt, OH)		**Gielly et al. (1969)** **Sanglerat et al. (1972)**
Clayey silts		**Bogdanovic' (1973)**
Clays		**Trofunenkov (1974)**

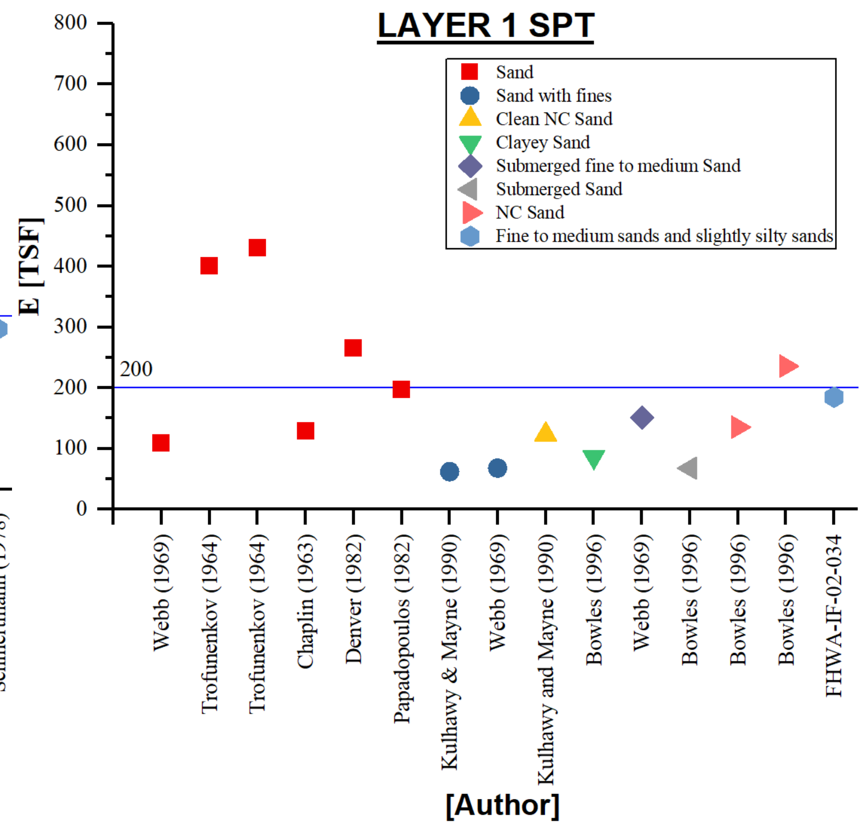
Preliminary Results: Elastic Modulus Statistical Distribution

Layer 1: Medium to dense sand





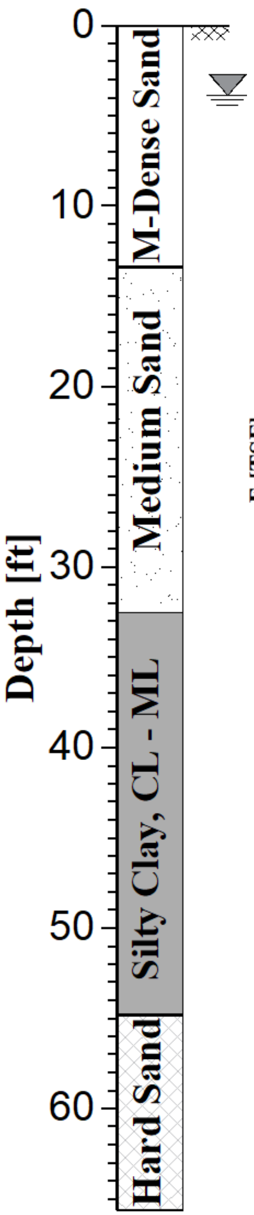
N total	Mean	Standard Deviation	Minimum	Median	Maximum
24	300	134	111	250	527

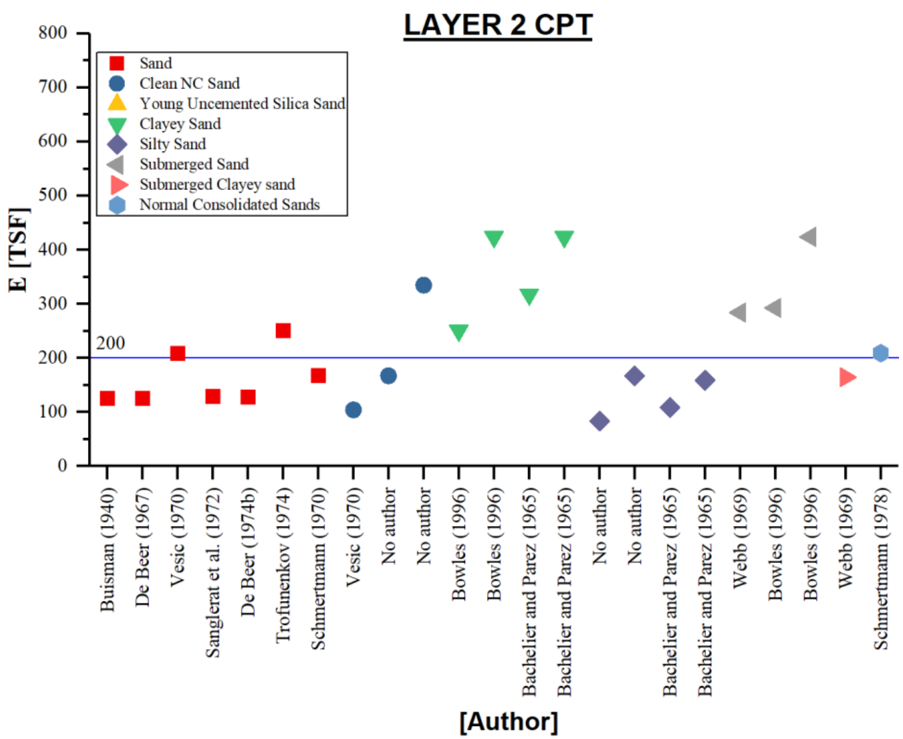


N total	Mean	Standard Deviation	Minimum	Median	Maximum
15	200	115	62	135	431

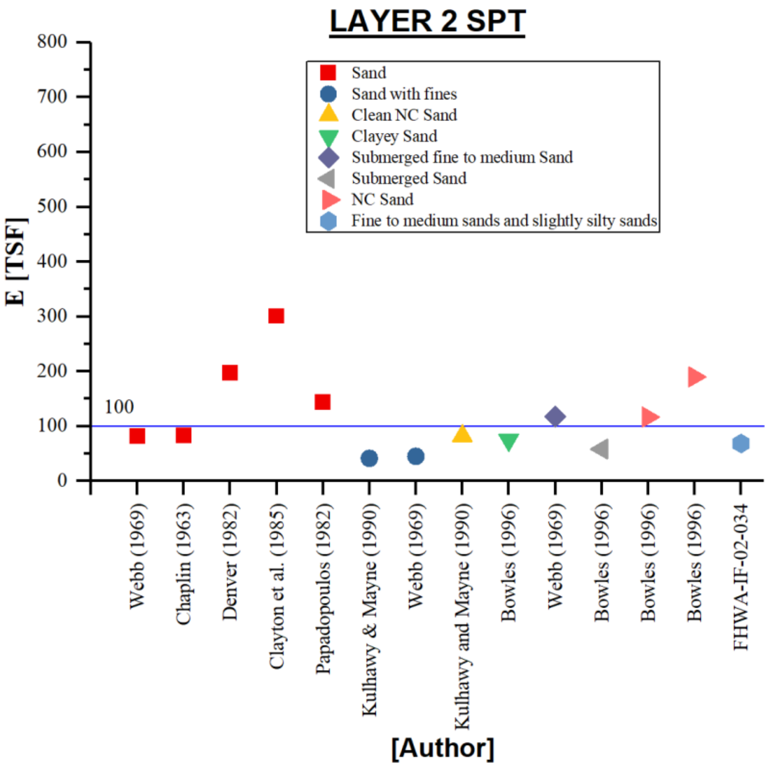
Preliminary Results: Elastic Modulus Statistical Distribution

Layer 2: Medium sand





N total	Mean	Standard Deviation	Minimum	Median	Maximum
23	200	107	84	167	424



N total	Mean	Standard Deviation	Minimum	Median	Maximum
14	100	72	41	83	301

Summary of Methods for Calculation of Elastic Settlement

Total No. of Studies: 32

Elastic half-space method $s_e = \frac{[q_0(1-\nu^2)\sqrt{A'}]}{144 E_s \beta_z}$

Hough method (1959) $s_e = \sum_{i=1}^{n} \Delta H_i \; ; \; \Delta H_i = H_c (\frac{1}{C'}) log \left[\frac{(\sigma_0^{'} + \Delta\sigma_v^{'})}{\sigma_0^{'}}\right]$

D'Appolonia Method (1968) $\Delta \mathrm{H} = \left(\frac{\Delta\sigma_v \mathrm{B}_f}{M}\right) \mu_0 \mu_1$

Schmertmann Method (1970) $s = C_1 C_2 q \sum_{i=1}^{n} (I_z / E_s) z_i$

Equivalent Linear Model by Oweiss (1979) $s = qB \sum_{i=1}^{n} (\psi_i / E_i)$

Tschebotarioff (1953, 1971) $s = (0.867\ qbC_s)/E$ (square footings)

$s = [(2.0qb)/\ E]\log\ [1 + (1.154H)/b]$ (strip footings)

Canadian Foundation Manual (1975) $\varepsilon_z = q_z/E_s$ $s = \sum \varepsilon_z \cdot h_z$

Bowles (1987) $s = (q_0 B i_c)/E_s$

Papadopoulos (1992) $s = q_0 B' \frac{1-\mu^2}{E_s} m I_s I_F$ $s = \left[\frac{qB}{Es}\right] f$

Mayne & Poulos (1999) $s = \frac{q \cdot d \cdot I_G \cdot I_F \cdot I_E \cdot (1-\nu^2)}{E_0}$

Summary of Methods for Calculation of Elastic Settlement

Semi-empirical approaches based on SPTs

Terzaghi and Peck (1967)

$s = (8q/N)(C_w C_d)$ (for $B \leq 4ft$)

$s = (12q/N)[B/(B+1)]^2 C_w C_d$ (for $B > 4ft$)

$s = (12q/N) C_w C_d$ (for rafts)

General form: $s = (3q/N)[2B/(B+1)]^2 C_w C_d$

Meyerhof (1965)

$s = 4q/N$ (for $B \leq 4ft$)

$s = [6q/N][B/(B+1)]^2$ (for $B > 4ft$)

$s = 6q/N$ (for rafts)

Teng (1962)

$s = [q/(720(N_c - 3))][2B/(B+1)]^2 [1/(C_w)(C_d)]$

Alpan (1964)

$s = s_0 [2B/(B+1)]^2 m'/12$

Peck and Bazaraa (1969)

$s = [(16q)/3N_c][C_d C_w]$ (for $B \leq 4ft$)

$s = [(8q)/N_c][B/(B+1)]^2 [C_d C_w]$ (for $B > 4ft$)

$S = [8q/N_c][C_d C_w]$ (for rafts)

Webb (1969)

$s = \Sigma_i^n (\sigma_{zi}/E)\Delta z_i$

Parry (1971)

$s = \alpha [qB/N_m][C_d C_w C_t]$

Schultze and Sherif (1973)

$s = (QF_c)/(N^{0.87} C_d)$

Summary of Methods for Calculation of Elastic Settlement

Peck et al. (1974)

$s = (q)/(0.11\ N_c\ C_w)$ (for medium sized footings (B> 2ft))

$s = (q)/(0.22\ N_c\ C_w)$ (for rafts)

Meyerhof (1974)

$s=[(q)(B)^{1/2}/(2N)]\ [C_d]$

$s=[(q)(B)^{1/2}/(N)]\ [C_d]$ (for very fine or silty submerged sand)

Arnold (1980)

$s=43.06B\sum_{z=0}^{2B} \Delta z\left[\alpha ln\left(1/(1-Iq/Q)\right)\right]/[1+(3.281B)^m]^2$

Burland and Burbidge (1985)

$s = 0.14\ C_sC_IIc\ (B/B_r)^{0.7}\ (q'/\sigma_r)B_r$ for NC soils

$s = 0.047\ C_sC_IIc\ (B/B_r)^{0.7}\ (q'/\sigma_r)B_r$ for OC soils and $q' \leq \sigma'_c$,

$s = 0.14\ C_sC_IIc\ (B/B_r)^{0.7}\ [(q'-0.67\ \sigma'_c)/\sigma_r)$ for OC soils and $q' > \sigma'_c$

Berardi et al. (1991)

$$s_0 = I_s \frac{qB}{E'}$$

Anagnostopoulos, Papadopoulos and Kavvadas (1991)

$s = [0.57\ (q)^{0.94}(B)^{0.90}]/N^{0.87}$ for $0< N<10$

$s = [0.35\ (q)^{1.01}(B)^{0.69}]/N^{0.94}$ for $10 < N< 30$

$s = [604\ (q)^{0.90}(B)^{0.76}]/N^{2.82}$ for $N > 30$

$s = [1.90\ (q)^{0.77}(B)^{0.45}]/N^{1.08}$ for $B\leq 3m$

$s = [1.64\ (q)^{1.02}(B)^{0.59}]/N^{1.37}$ forB> 3m

Summary of Methods for Calculation of Elastic Settlement

Semi-empirical approaches based on CPTs

DeBeer and Martens (1957) $s=(2.3/C)\log[(p'_0 + \Delta p')/p'_0]\,H$

Meyerhof (1965) $s = (q\,B)/(2q_c)$

DeBeer (1965)

$$s = \sum_{i=1}^{N} 1.535\left(\frac{\sigma'_{v0}}{q_{ci}}\right)\log\left[\frac{(\sigma'_{v0i} + \Delta\sigma'_v)}{\sigma'_{v0i}}\right]\Delta h_i$$

Robertson (1991) $s=[I_s q_{net} B][(1-\mu^2)/E']$

Semi-empirical approaches based on PMTs

Menard and Rousseau (1962)

$$s = \frac{2}{9E_m} q * B_0\left[\lambda_d \frac{B}{B_0}\right]^\alpha + \frac{\alpha}{9E_m} q * \lambda_c B \text{ or } s = \frac{q*}{9E_m}\left[2B_0\left(\lambda_d \frac{B}{B_0}\right)^\alpha + \alpha\lambda_c B\right]$$

Briaud (1992)

$$s = I_0 I_1 (1 - \upsilon^2) q (B/E)$$

Semi-empirical approaches based on DMTs

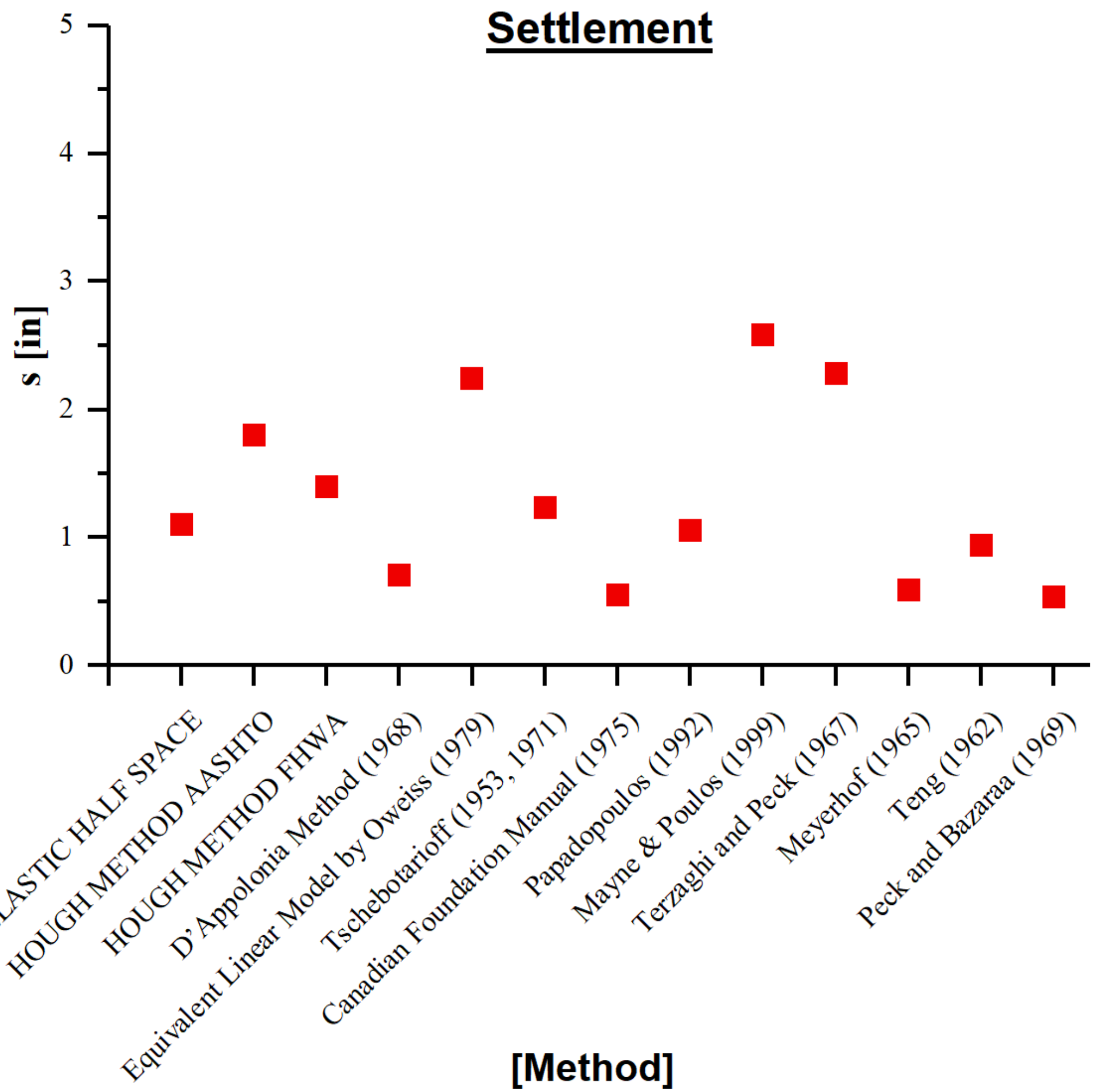
Schmertmann (1986)

$$s = \sum_{i=1}^{n}\left(\frac{\Delta\sigma_v' \cdot h_i}{M_i}\right)$$

Leonards & Frost (1988)

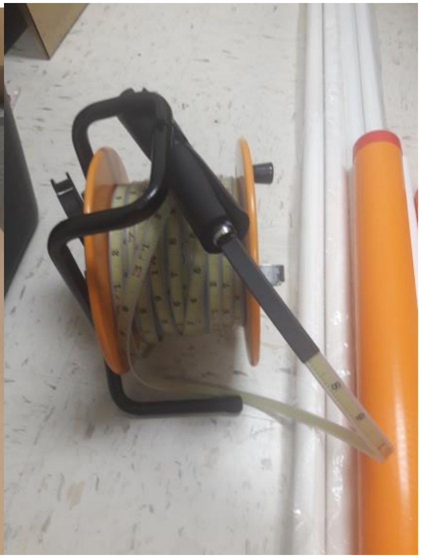
$$s = C_1 q_{net} \sum_{0}^{D} I_Z \Delta_Z \left[\frac{R_Z(OC)}{E_Z(OC)} + \frac{R_Z(NC)}{E_Z(NC)}\right]$$

Summary of Methods for Calculation of Elastic Settlement



(About 2 inches, but pending to be refined)

Sensors



Settlement Plates:

- 2 steel 24” square x ¼” settlement plates
- 6 pc. 1.5”x5ft steel rods
- 4 steel couplers
- 2 steel pipe caps

Magnetic Extensometers:

- 15 spider magnets
- 6 pc. Flush coupled PVC access tube 10ft length 1”
- 3 Datum ring magnet
- Switch probe 100 ft tape

Sensors

Piezometers:

- 3 pc. 100 psi piezometer – 60 ft length blue cable
- 2 pc. 100 psi piezometer – 80 ft length blue cable
- 225 galvanized aircraft cable
- GK-404 handheld readout
- 16 channel datalogger

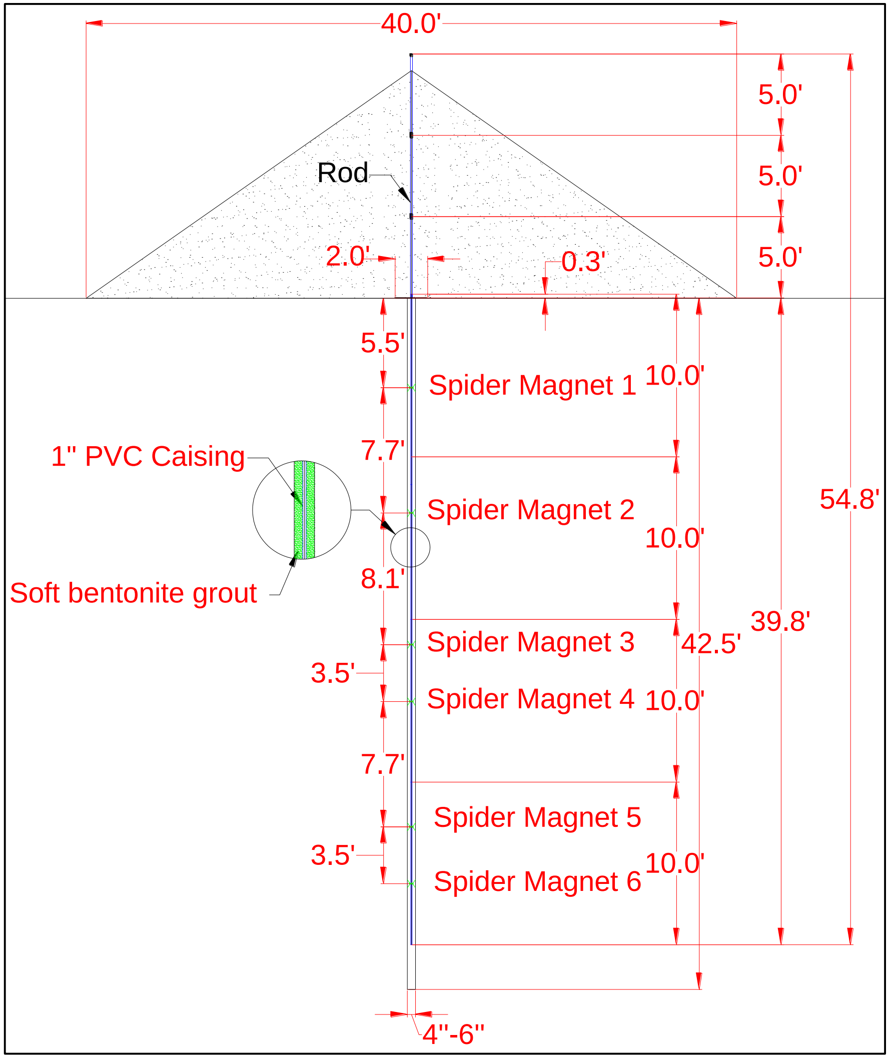
Inclinometers:

- Inclinometer probe
- 100ft control cable
- 6 pc. 2.75” glue-snap inclinometer casing 10ft length+1pc 5ft length
- Cable reel and case
- Cable pulley
- Nautiz X8 handheld

Reading Frequency Plan

Sensor	Frequency	Notes
Settlement Plate	Readings at each increment of loading (every 3”, 6 times per day) until the loading process is completed.	Readings using a surveyor level and reference level installed before loading.
Magnetic Extensometers	Readings at each increment of loading (every 6”, 6 times per day) until the loading process is completed.	Readings at the same time as the settlement plate.
Inclinometer	1-2 readings per day	This process is done manually.
Piezometers	Readings up to 16 channels, every 30 seconds for 6-7 days without changing the batteries.	Continuous reading with the data logger.

MAGNETIC EXTENSOMETER

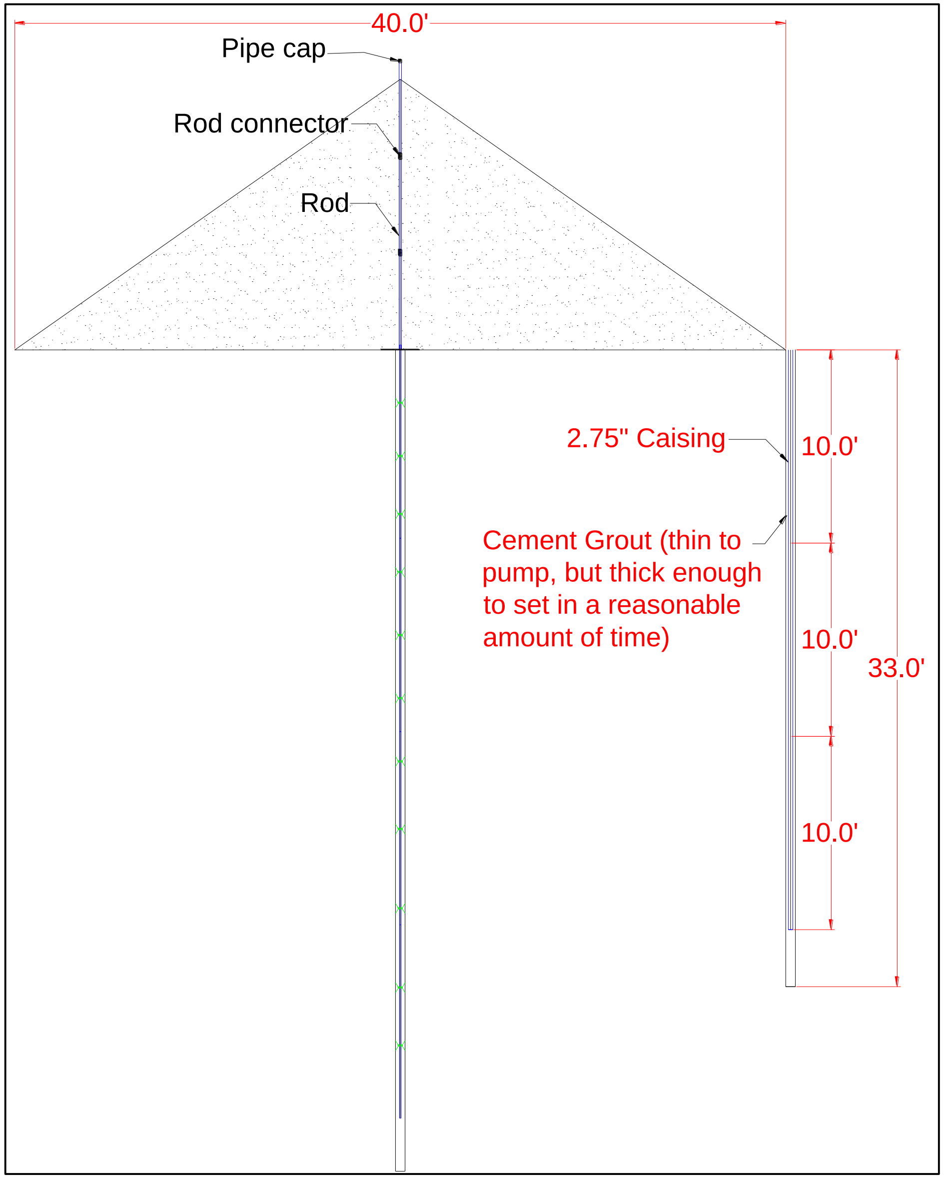


Procedure for installation in boreholes

- Drill the borehole (using bentonite or a casing).
- Grout the borehole with soft bentonite grout.
- Prepare the access tube arranging the casings in the correct order with the anchors (Spider magnets attached).
- Cement the end cap at the bottom section of the access tube (casing).
- To hold the anchors at the right position (e.g., electrical tape is used).
- Using a single layer of masking tape around the cable 1 ft above the hook to prevent pull-pin prematurely pulled.
- If borehole is grouted after the casing is placed, the tremie pipe should be taped to the bottom access tube.
- If it is expected that the borehole is filled with water or if the borehole is pre-grouted, the access tube has to be filled with clean water.
- Special care is needed to avoid that the pull-cables get coiled.
- Once the access tube is lowered, using the reed switch probe the position of the anchors is verified.

- If hole is grouted, typical grout: 43 kg cement, 2kg bentonite and 40 kg of water.
- For cased boreholes the casing is removed at this point, making sure to not pull out the access tubing.
- The magnetic spider anchors are released at this point beginning with the top anchor.

INCLINOMETER



Procedure for installation in boreholes

- Drill the Borehole as vertical as possible (within a degree is suggested).

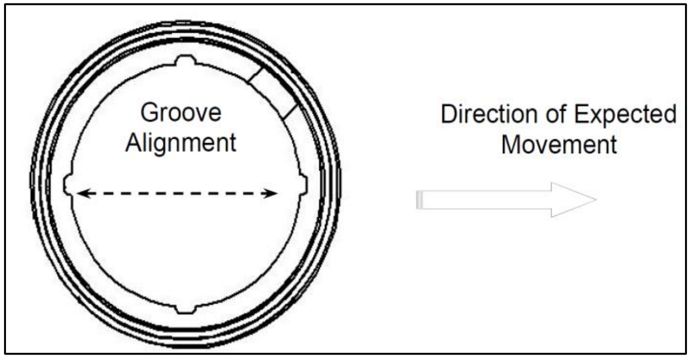
> 6.1.3 Create the borehole using procedures to keep it aligned within the range of the readout equipment. Extend the borehole at least 5 m (16 ft) beyond the zone of expected movement. It may be necessary to use casing, hollow-stem augers, or drilling mud to keep the hole open and stable. Flush the hole until clear of drilling cuttings.

- Flush the borehole clean.
- Verify that the borehole is open to the bottom.
- Check the depth before installing the casing. (grout valves or external weights may require a deeper borehole)
- Install the end cap applying ABS cement **(not PVC cement)** type 771 or 773. The PVC cleaner helps to soften the ABS.
- Lower the casing with the end cap into the hole. (If applicable, attach a grout tremie line)
- With the help of the clamps, assemble the next section using the ABS on **the male end only**. (This is to avoid grooves blocking). The dummy probe can help to verify the alignment of the grooves running it to the bottom of the hole. If the probe does not pass, jump tracks or returns in another set of grooves, the problem needs to be rectified pulling the casing. It is suggested to use tape to seal the couplings specially when grout is used to seal the casing in the hole.

INCLINOMETER

Procedure for installation in boreholes

- Control that the grooves are aligned in the direction of the expected movement (See figure below)



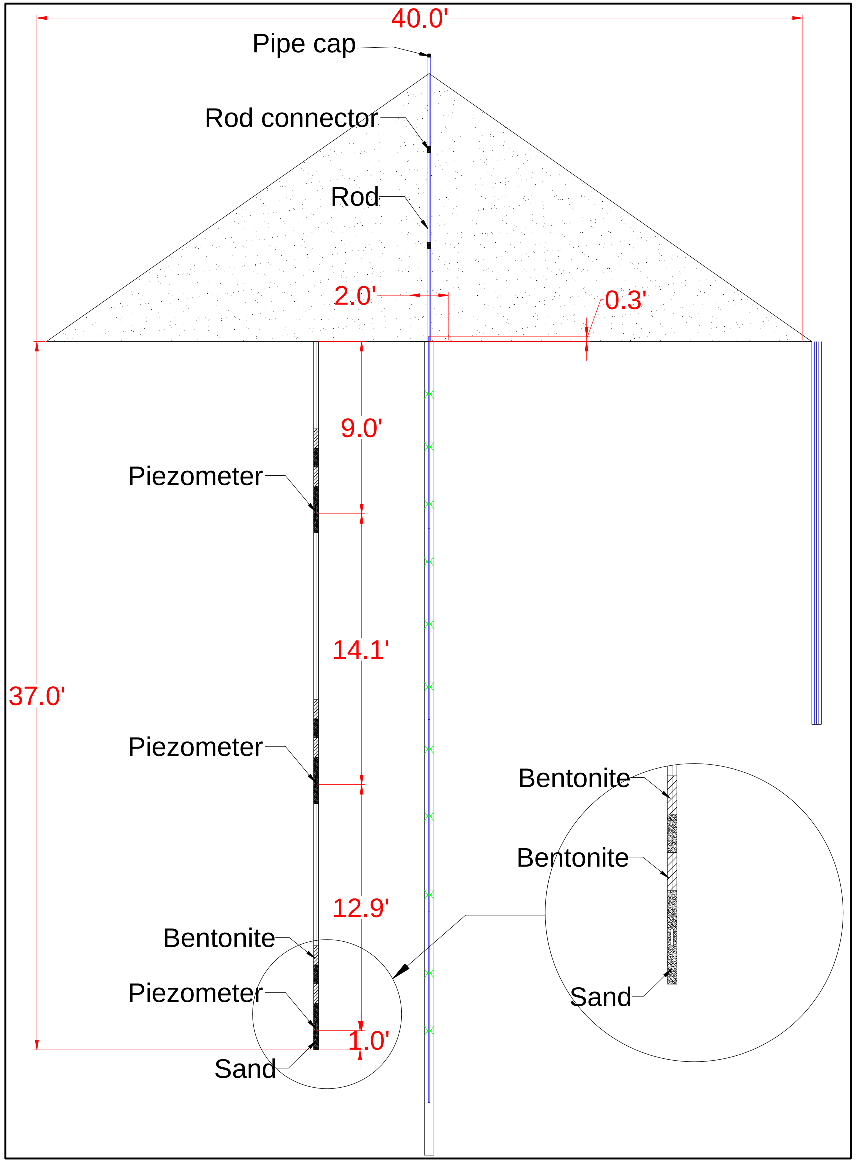
- To avoid buoyancy the casing can be filled with clean water.
- Backfill the annular space between the borehole and the casing. A cement grout is suggested in the ASTM D6230 and the GEOKON manual
- During the grouting process, the casing becomes buoyant, therefore, it is recommended to insert drilling rods inside the casing to hold it or anchor the bottom of the casing. (Never apply a downforce to the top of the casing, never use the drilling rig as a reaction force).

As a reference for the borehole diameter the following table is presented:

Q (Standard)				
SIZE	CORE DIAMETER		HOLE DIAMETER	
	Metric (mm)	U.S. (in)	Metric (mm)	U.S. (in)
BQ	36.4	1-7/16	60.0	2-23/64
NQ	47.6	1-7/8	75.7	2-63/64
HQ	63.5	2-1/2	96.0	3-25/32
PQ	85.0	3-11/32	122.6	4-53/64

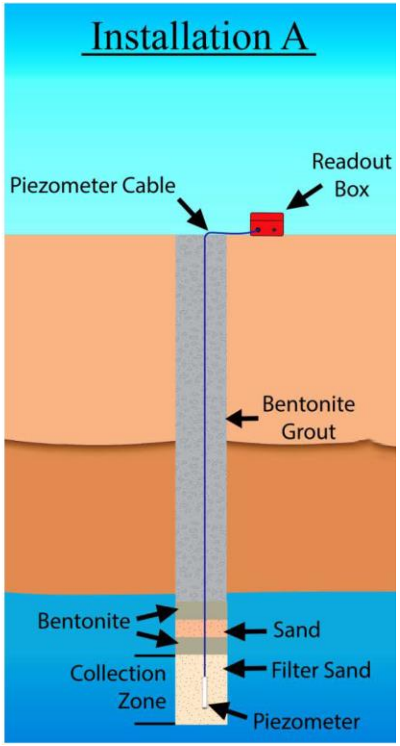
Installation Method

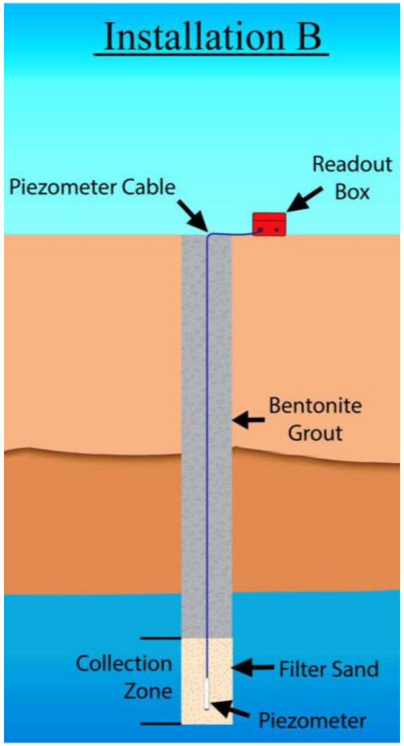
PIEZOMETER



Procedure for installation in boreholes (GEOKON)

- Extend the borehole 6 to 12 inches below the proposed location. A material that degrades rapidly such as Revert™ should be used to drill, mud is not suggested.
- Backfill the borehole with clean sand to a point six inches below the desired tip location of the deeper Piezometer.
- Lower the piezometer into position.
- Three installation methods to isolate the monitored zone are proposed:





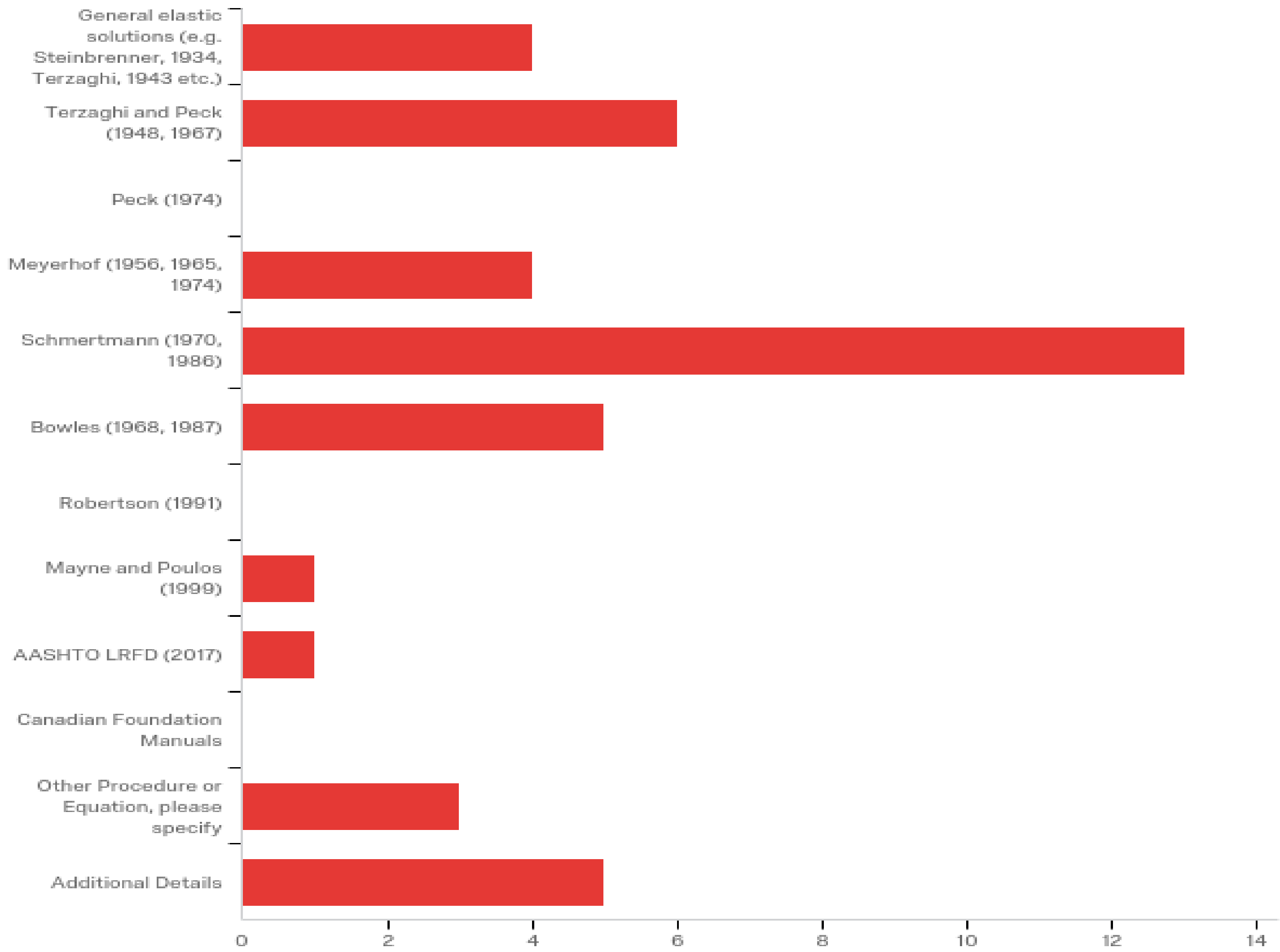
PIEZOMETER

If multiple piezometers are to be used in a single hole, the bentonite and sand should be tamped in place below and above the upper piezometers, as well as at intervals between the piezometer zones. When using tamping tools special care should be taken to ensure that the piezometer cable jackets are not cut during installation, as this could introduce a possible pressure leak in the cable.

Installation C:

- With the care that fines will not migrate through the filter, the piezometer can be placed in contact with most materials where it is not necessary to provide sand zones (only a canvas bas is suggested). In this case the borehole can be grouted using a bentonite cement grout that mimics the surrounding soil.

Q1: For the design of shallow foundations, which procedure or equation do you most often use for the calculation of immediate settlement in Florida soils? Please select all that apply and provide any relevant information about reference manuals or links in the last box below.



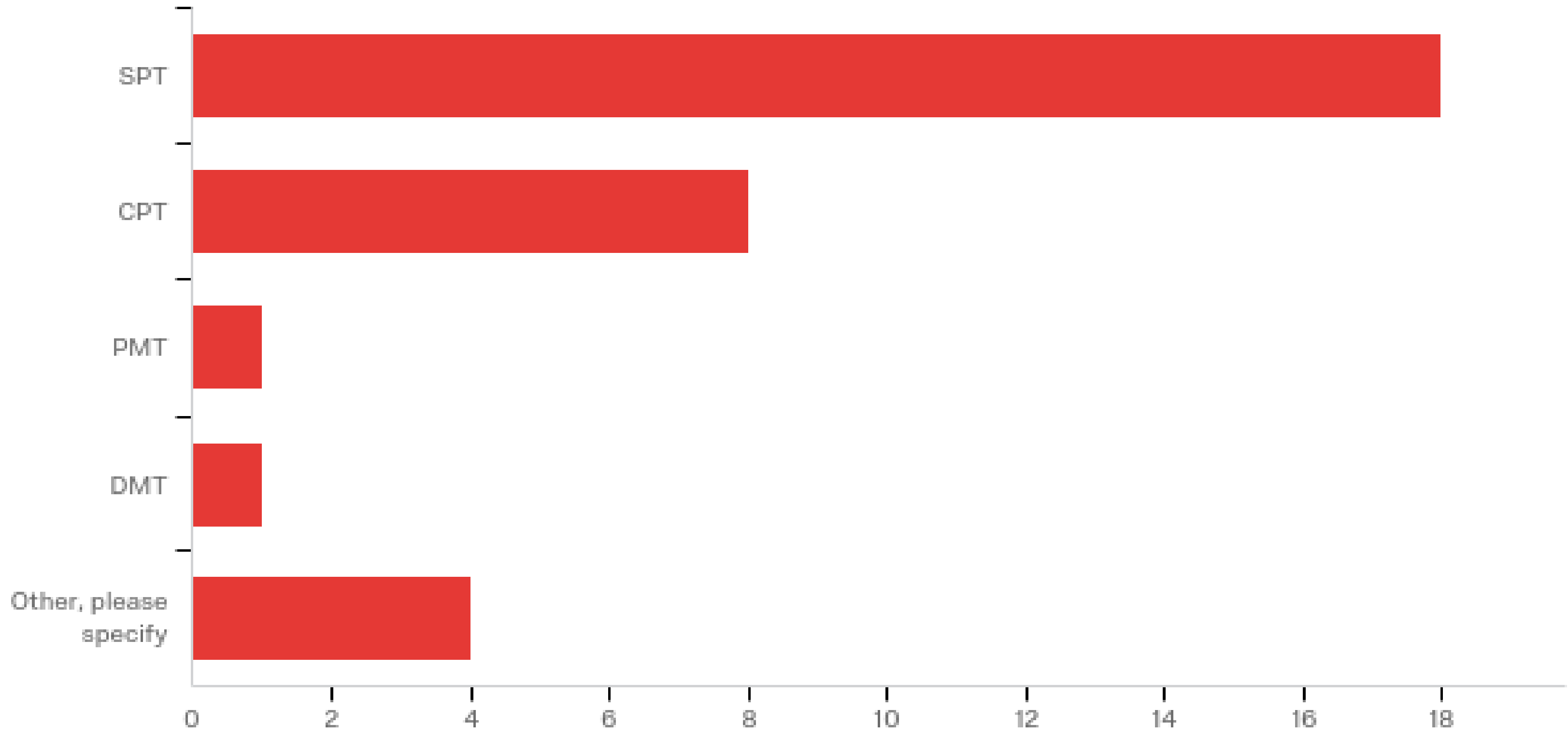
Q2: Which correlations and/or values do you use for elastic modulus of the soil in the methods specified in Question 1? Please enter text below or provide information about reference manuals with pages or relevant links.

Selected Answers-

- Bowles formulas
- Soils and Foundations FHWA HI-88-009 Figure 13
- E = 8N (tsf)
- SPT and CPT correlations and data from pressuremeter testing
- Correlations presented in the FB-MultiPier Soil Parameter Tables
- M = 30*Nmanual (tsf): Schmertmann, J.H. (1988)
- Please see FHWA-IF-02-034, Table 28 and Table 29
- Young's Modulus (elastic modulus) (1984) by Robertson and Campanella
- GeoStudio 2007 Sigma/W for further settlement analysis for larger structures, which does require Elastic Modulus as input

Survey Results

Q3: Do you use any specific correlations for elastic modulus of the soil with field tests? Please select all that apply.



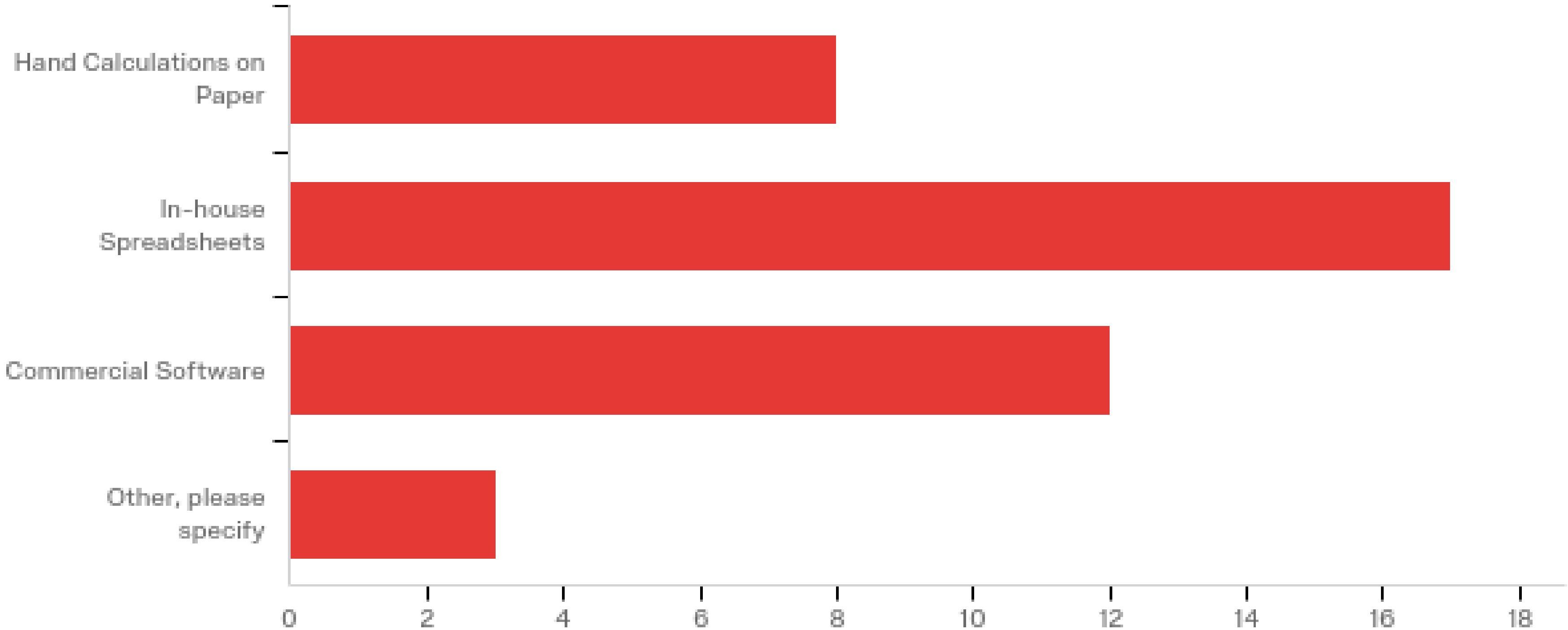
Survey Results

Q4: For those identified in Question 3, please provide information about any reference, or manuals with page numbers, or relevant links in the box below. If more than one is identified, which do you use with greatest confidence?

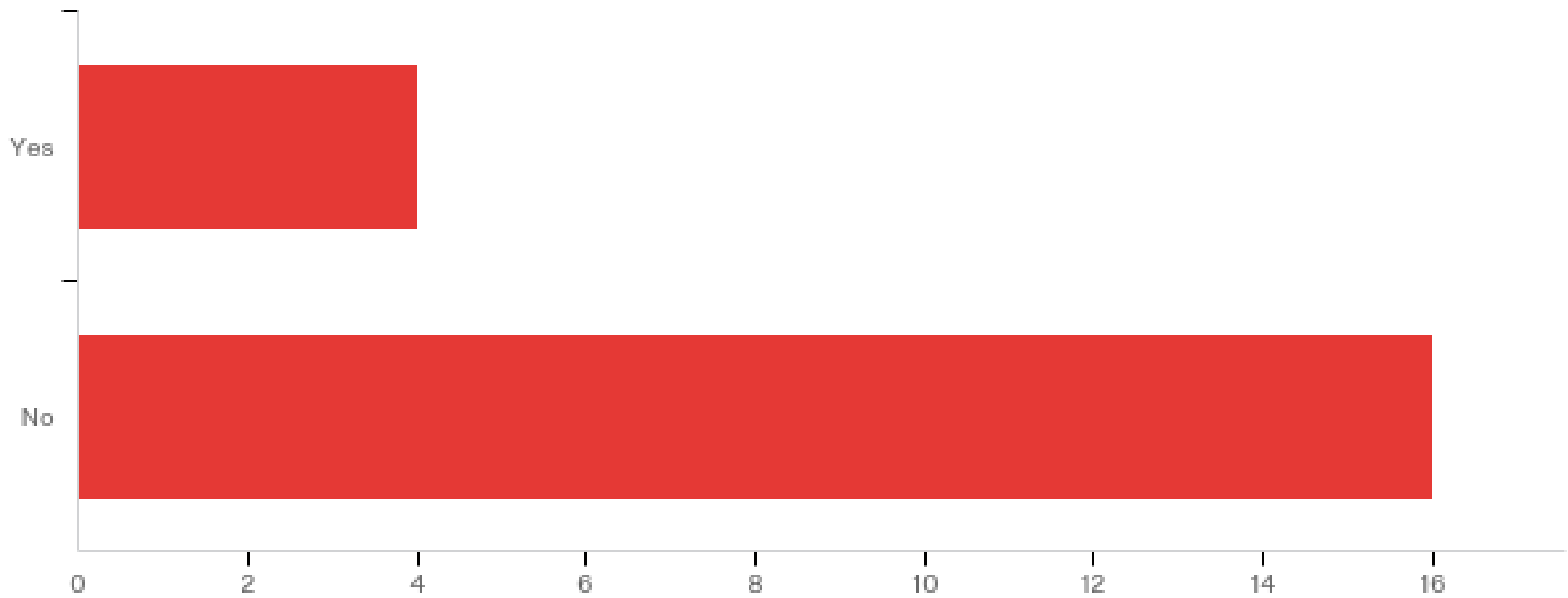
Selected Answers:

- Bowles P. 189
- Soils and Foundations FHWA HI-88-009 Figure 13 (page 170)
- SPT and CPT data
- E=(100,000*OCR^0.5)+24000N60 (sands) E=(50,000*OCR^0.5)+12000N60 (clayey, silty sands)
- AASHTO recommendations
- For SPT, please see FHWA-IF-02-034, Table 28 and Table 29
- EM 1110-1-1904
- Using the Bowles 1996 Foundation Analysis and Design (5th Edition) tables, we converted the soil density descriptions to approximate SPT N-values

Q5: Which of the following approaches do you use to perform your calculations of immediate settlement?



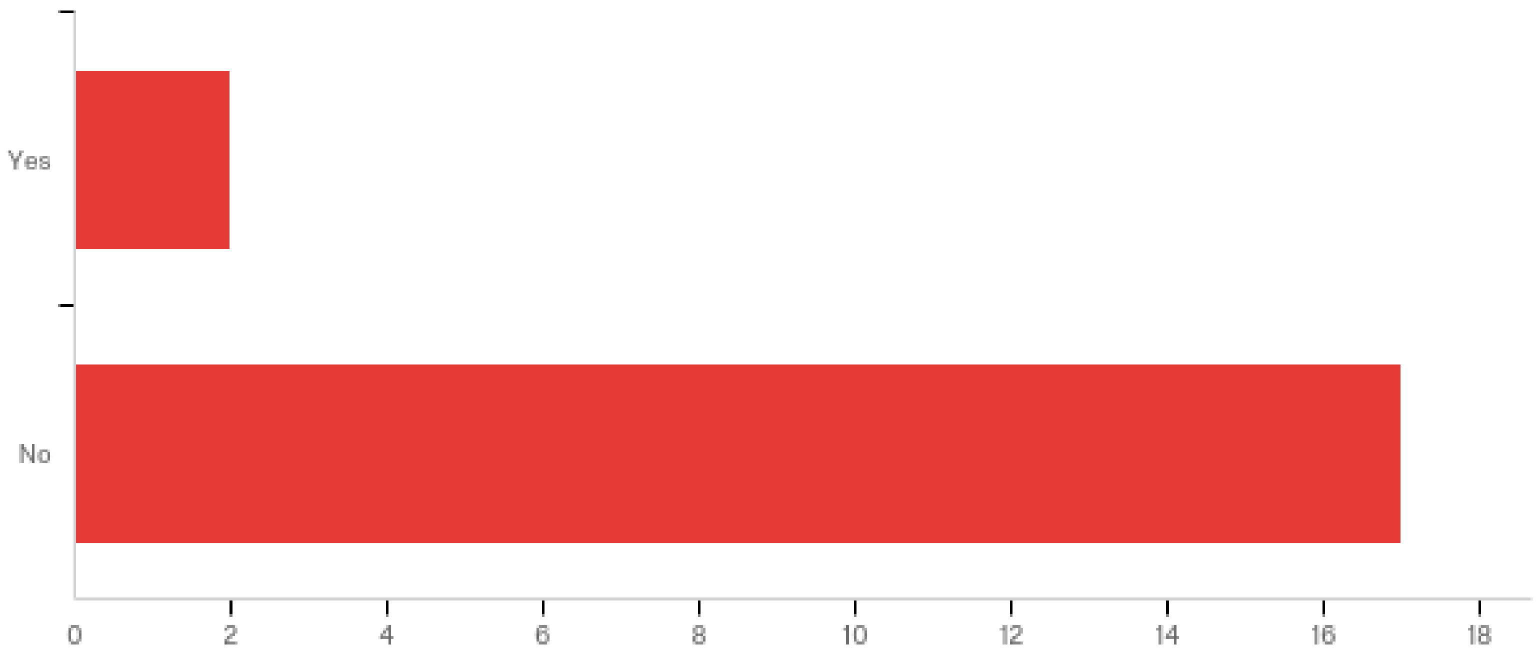
Q6: Do you perform any additional laboratory and/or field tests to check your selection of elastic modulus and immediate settlement values? If the answer is Yes, please provide information about the tests performed in the last box below.



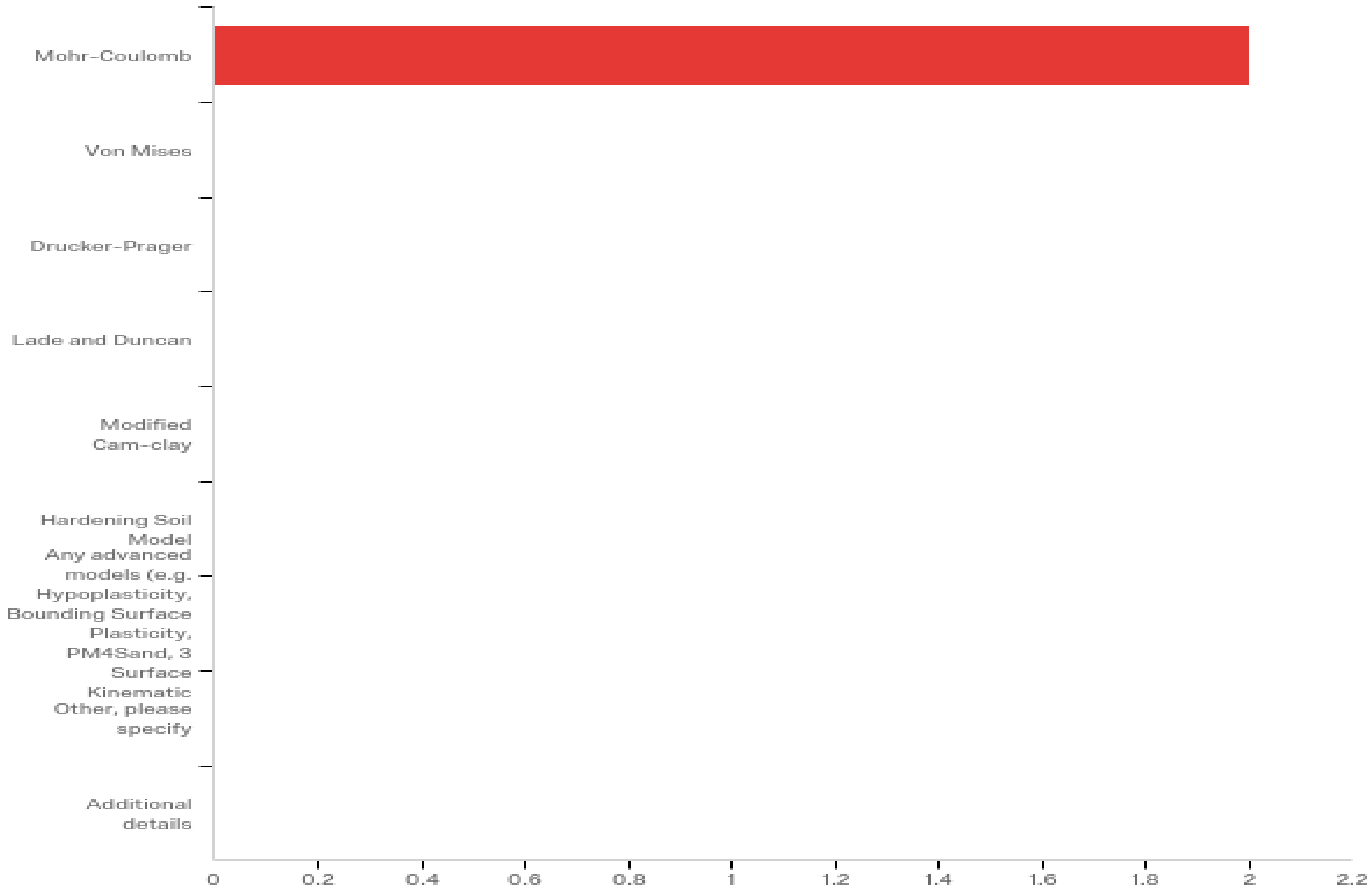
Q7. If the answer to Question 6 is Yes, please provide information about the tests performed in the box below.

Unconfined Compression
Settlement performance from survey data and static load test data
On occasion, we perform DMT. Not very often, though. Often difficult to convince clients to pay for it.

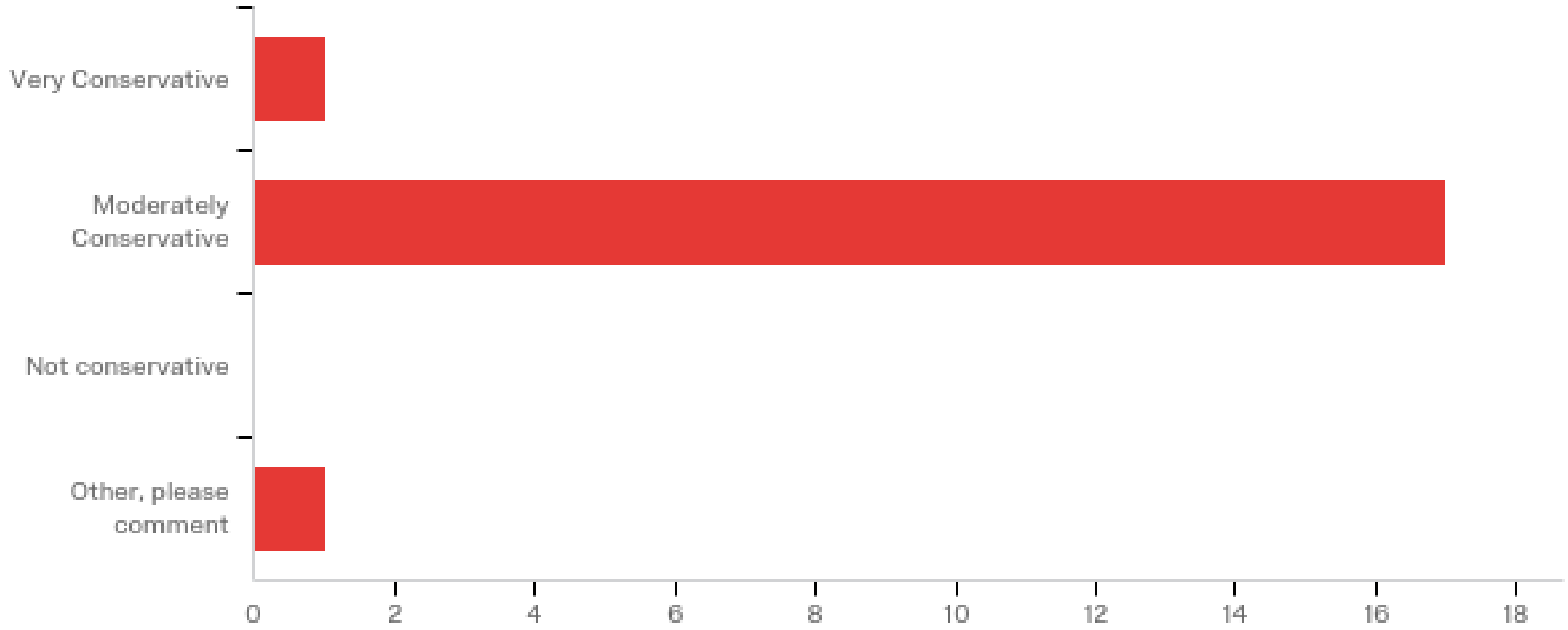
Q8. Do you run any numerical models to calculate or verify your immediate settlement (e.g. finite elements, finite difference, discrete elements)?



Q9. If the answer to Question 8 is Yes, please select the type of constitutive soil model used and provide any details in the text box below.



Q10: Do you feel that the existing method you use to calculate elastic modulus and immediate settlement is conservative?



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