Progress Report, GRIP MEETING 2019

Project Title: 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
- Field conical load tests
- Field tests results
- Work yet to be accomplished

Project Goals: Reminder

Improve settlement estimation for local soil conditions

- Load testing under stress-controlled conditions to assess:
  - Conical load weight/pressure vs time
  - Settlement vs time

Identify most appropriate correlations, based on SPT-N and CPTu, to accurately obtain soil modulus values

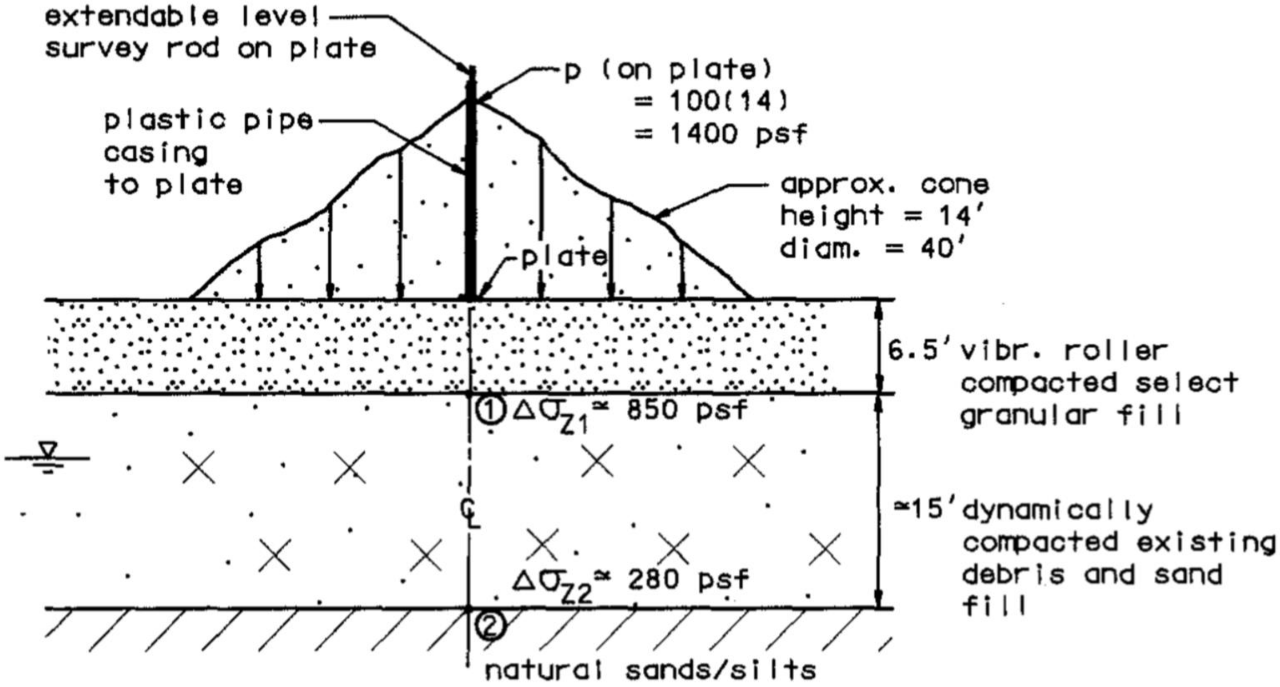
- Literature review of commonly used correlations

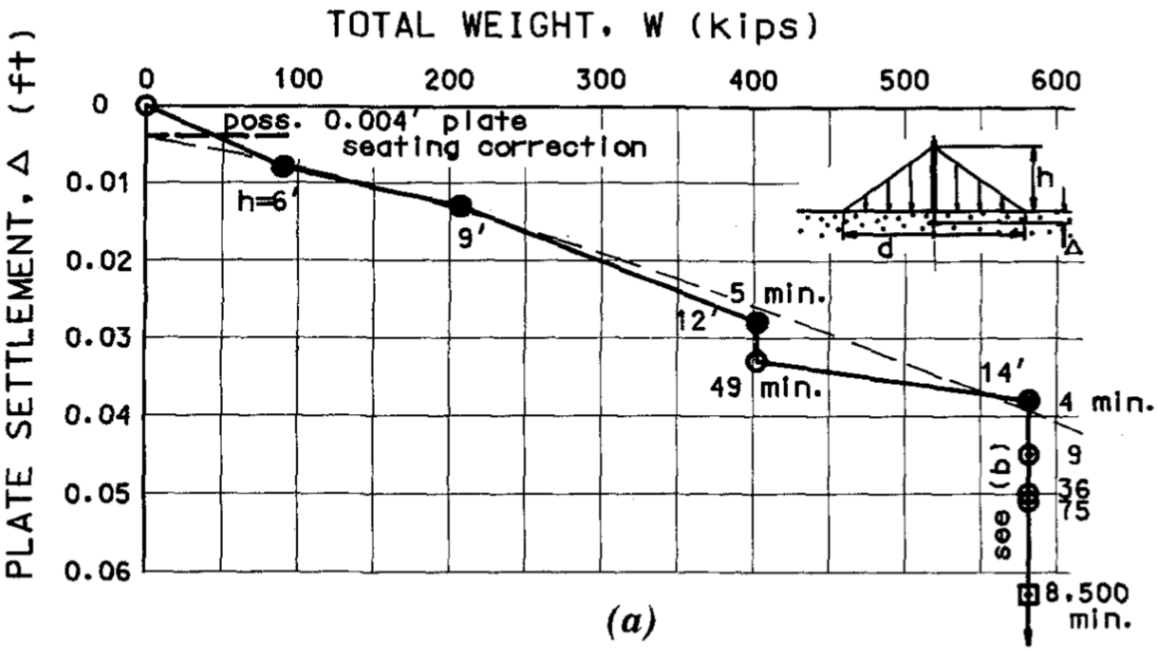
Technical review of immediate settlement estimation methods

Final recommendations for: E and Si

- Analysis based on laboratory and field load testing results

Conical Load Tests (Schmertmann, 1993)



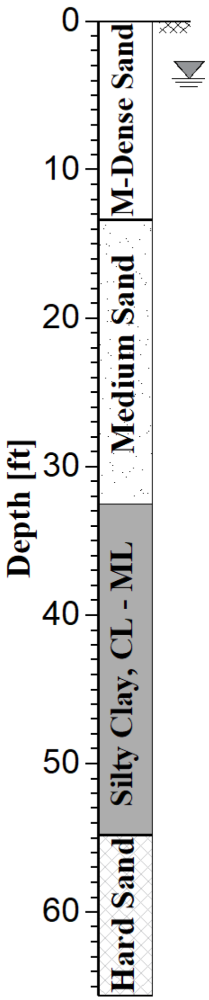


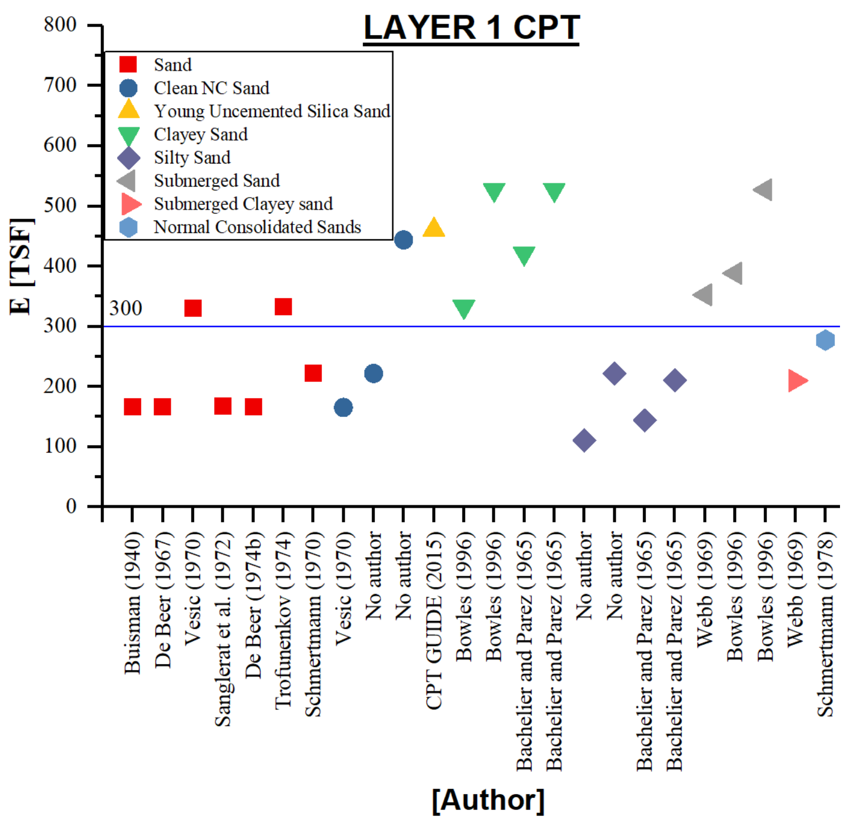
(a)

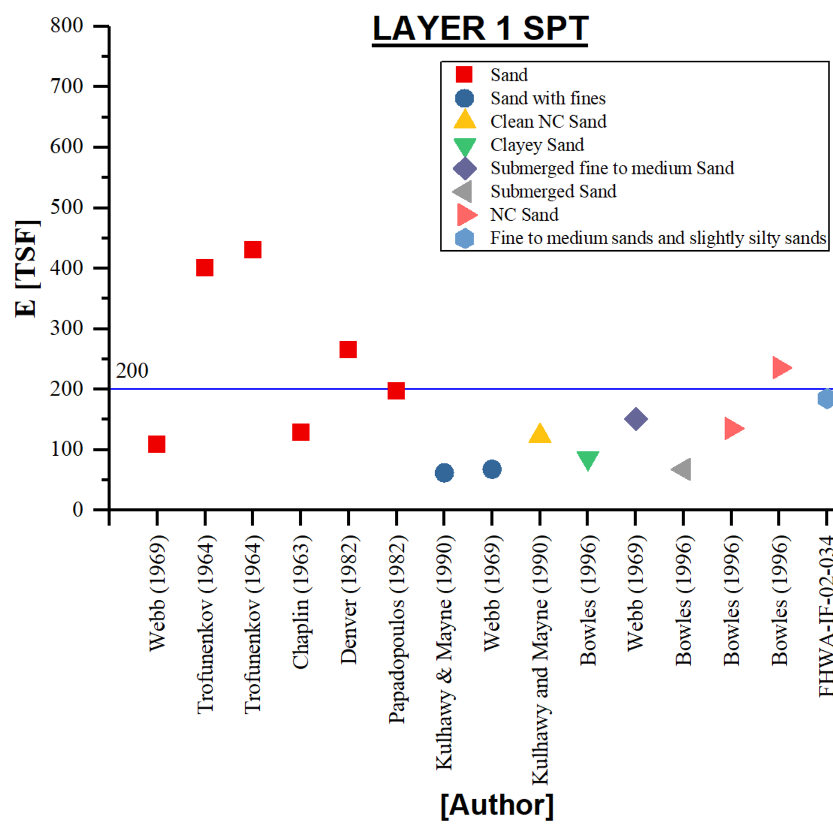
Elastic modulus calculation before tests (Class "A" predictions)

- Review of technical literature on methods for modulus and for immediate settlement predictions.

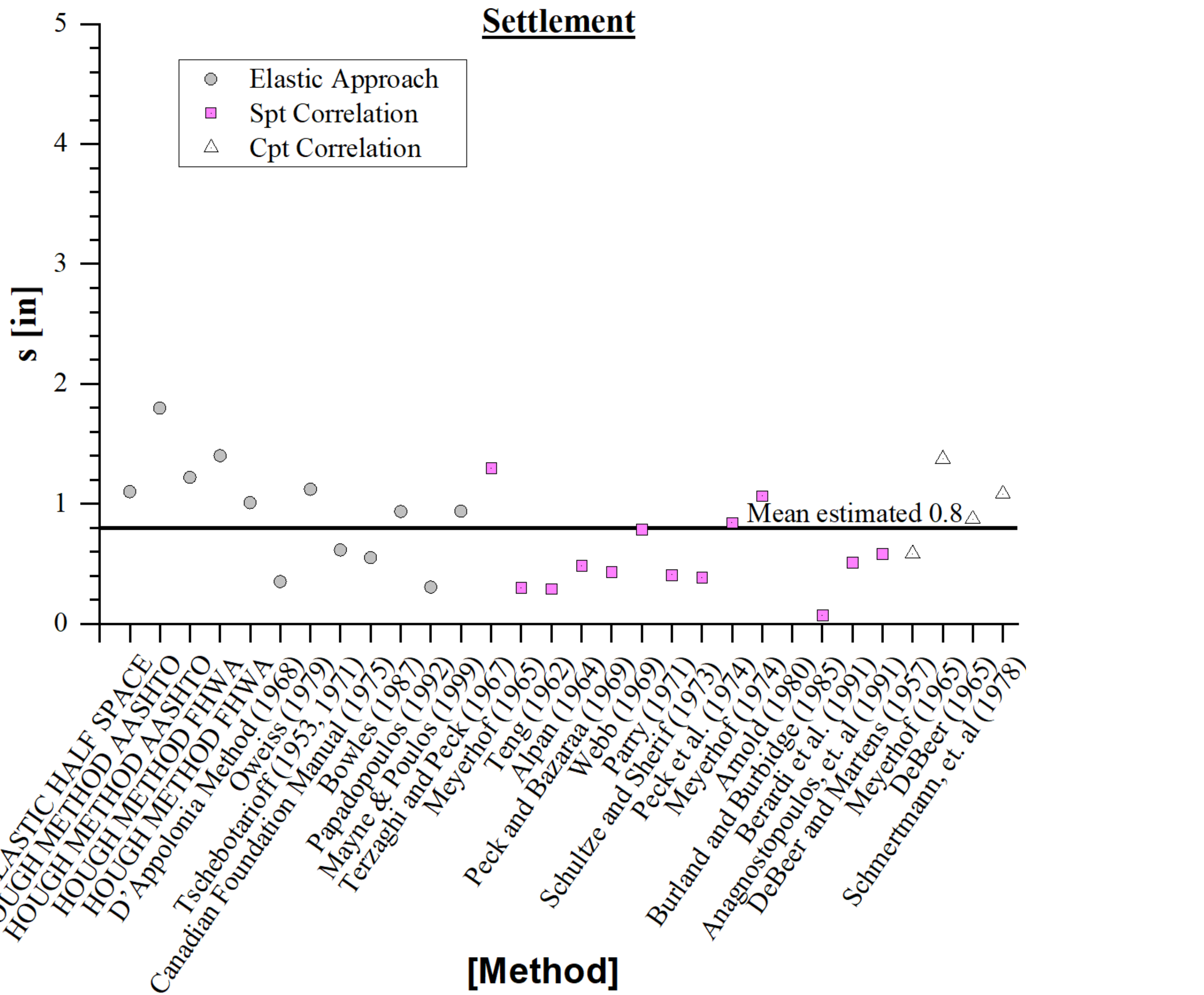
Layer 1: Medium to dense sand





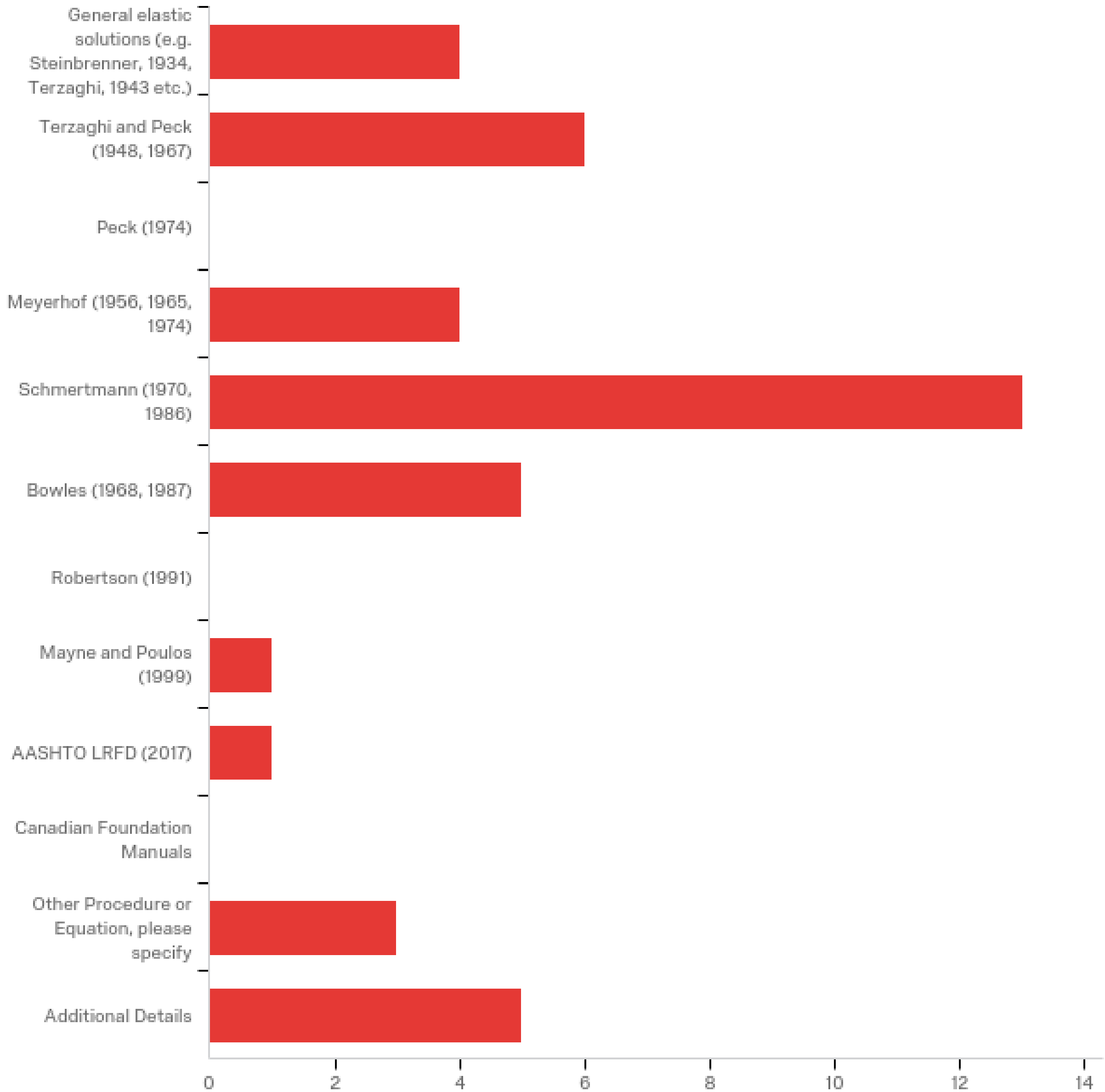


Immediate settlement calculation before tests (Class "A" predictions)



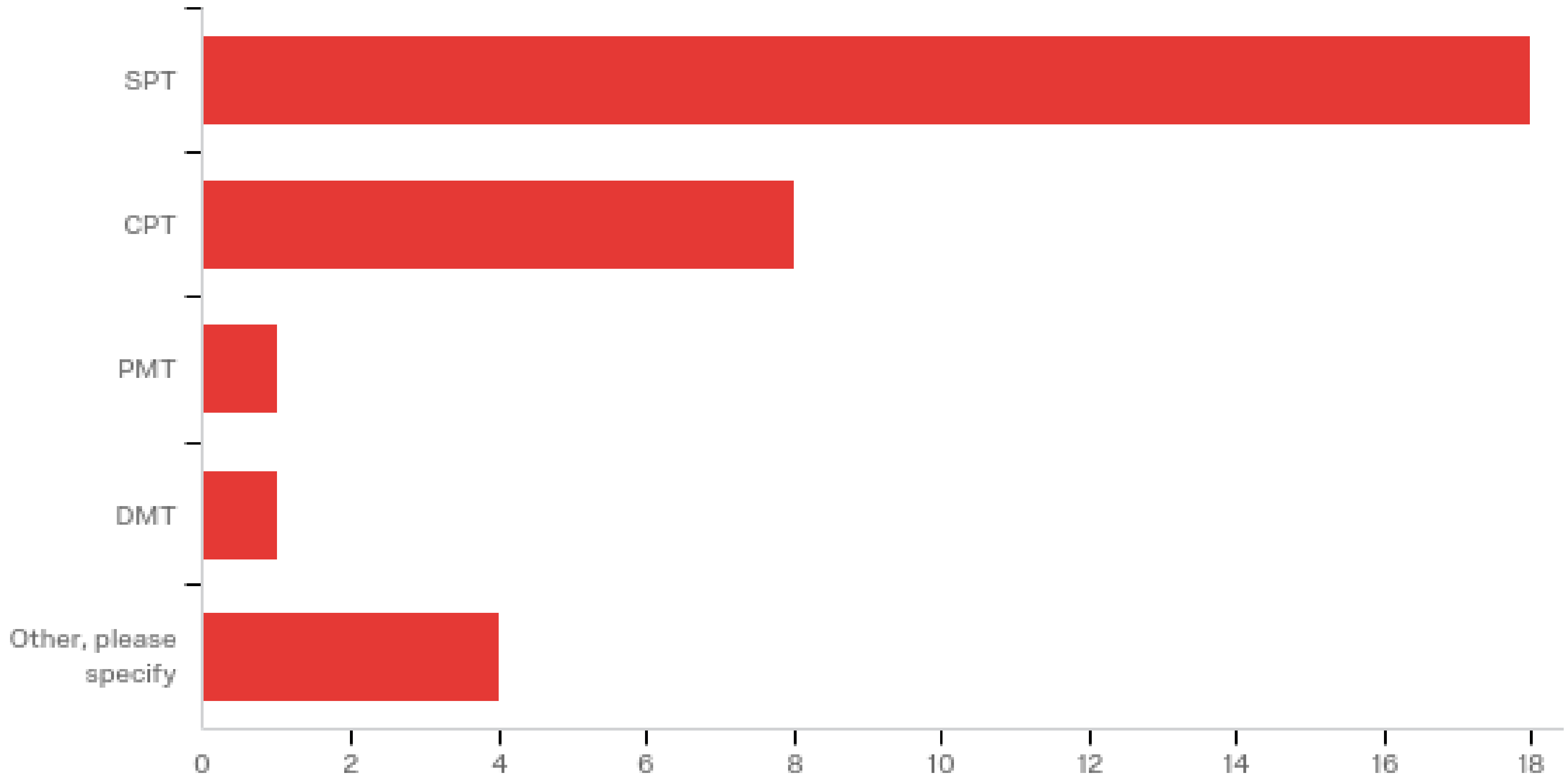
Survey to practitioners about commonly used methods

Q1: Procedure or equation most often used for immediate settlement calculation in Florida soils:



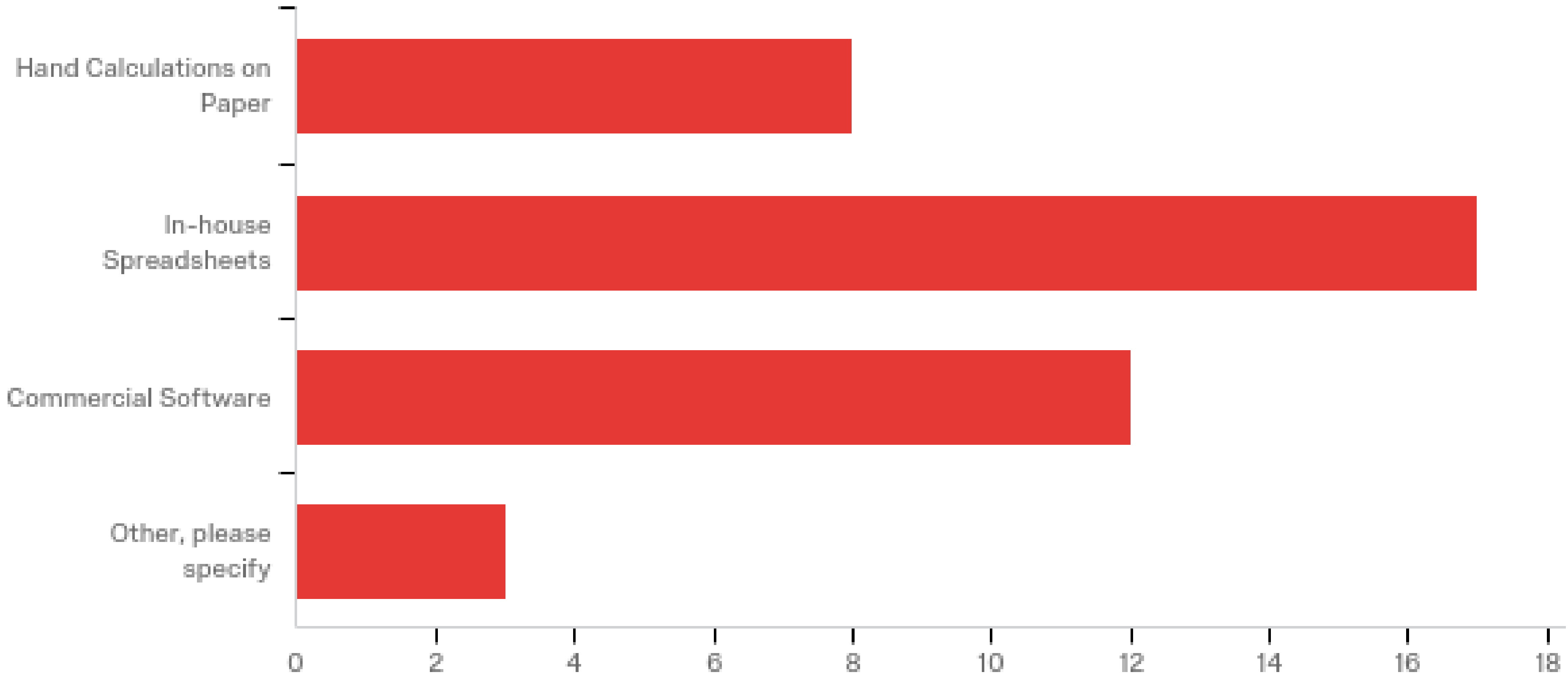
Survey to practitioners about commonly used methods

Q3: Correlations for elastic modulus estimation of the soil with field tests:



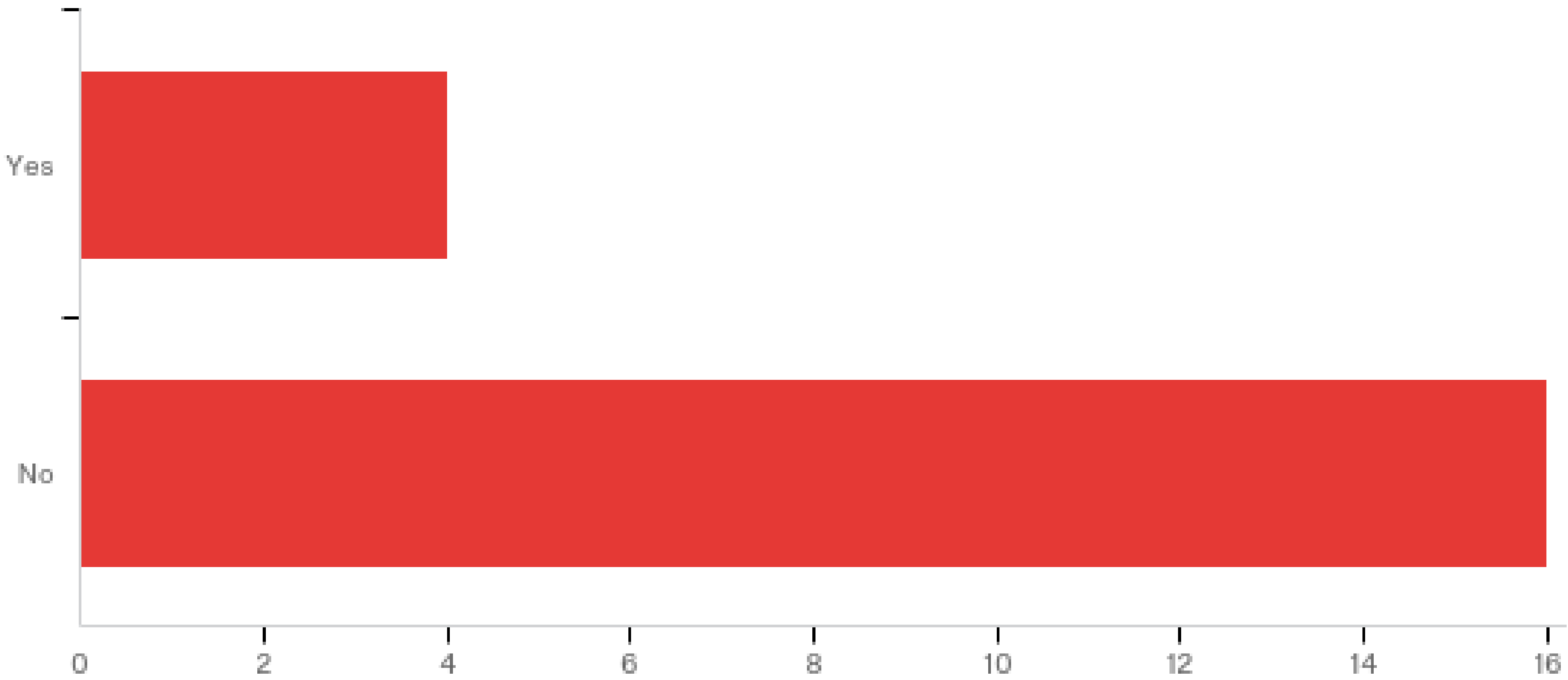
Survey to practitioners about commonly used methods

Q5: Approaches used to perform calculations of immediate settlement:



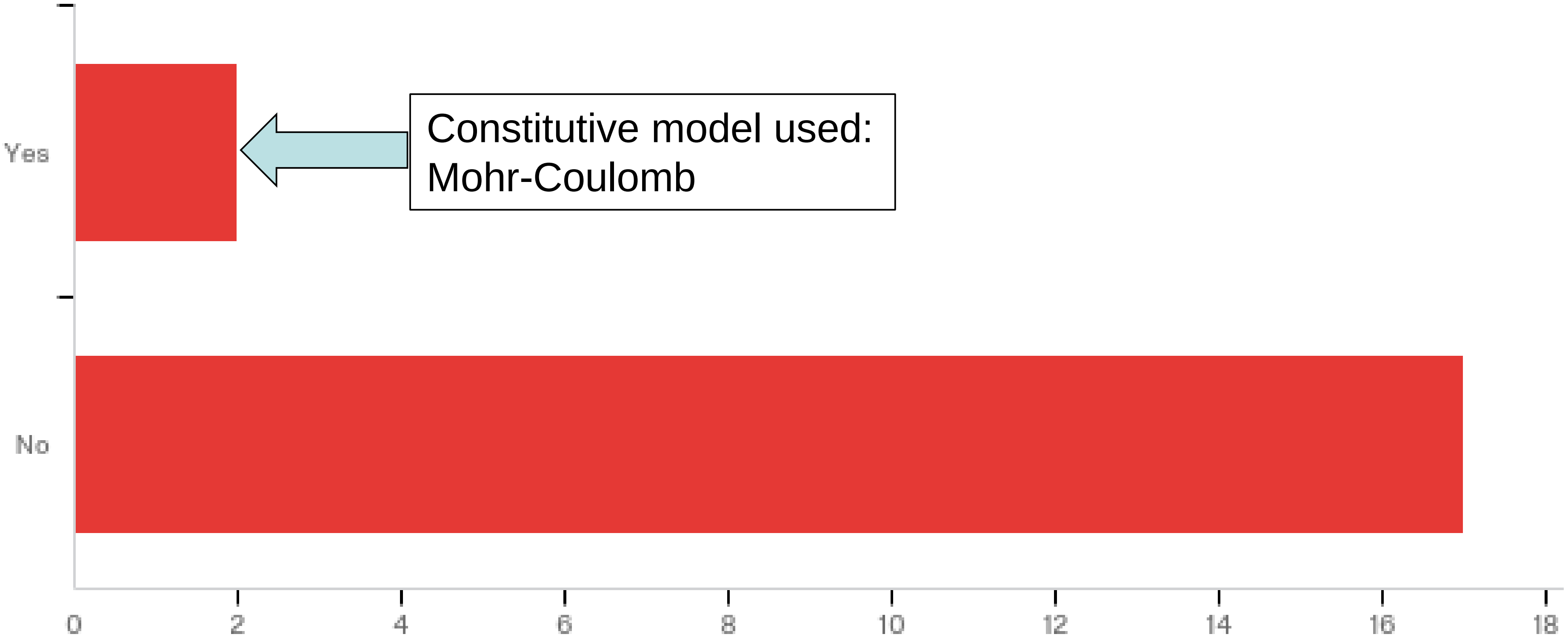
Survey to practitioners about commonly used methods

Q6: Number of practitioners that perform additional laboratory and/or field tests to check the selection of elastic modulus and immediate settlement values:



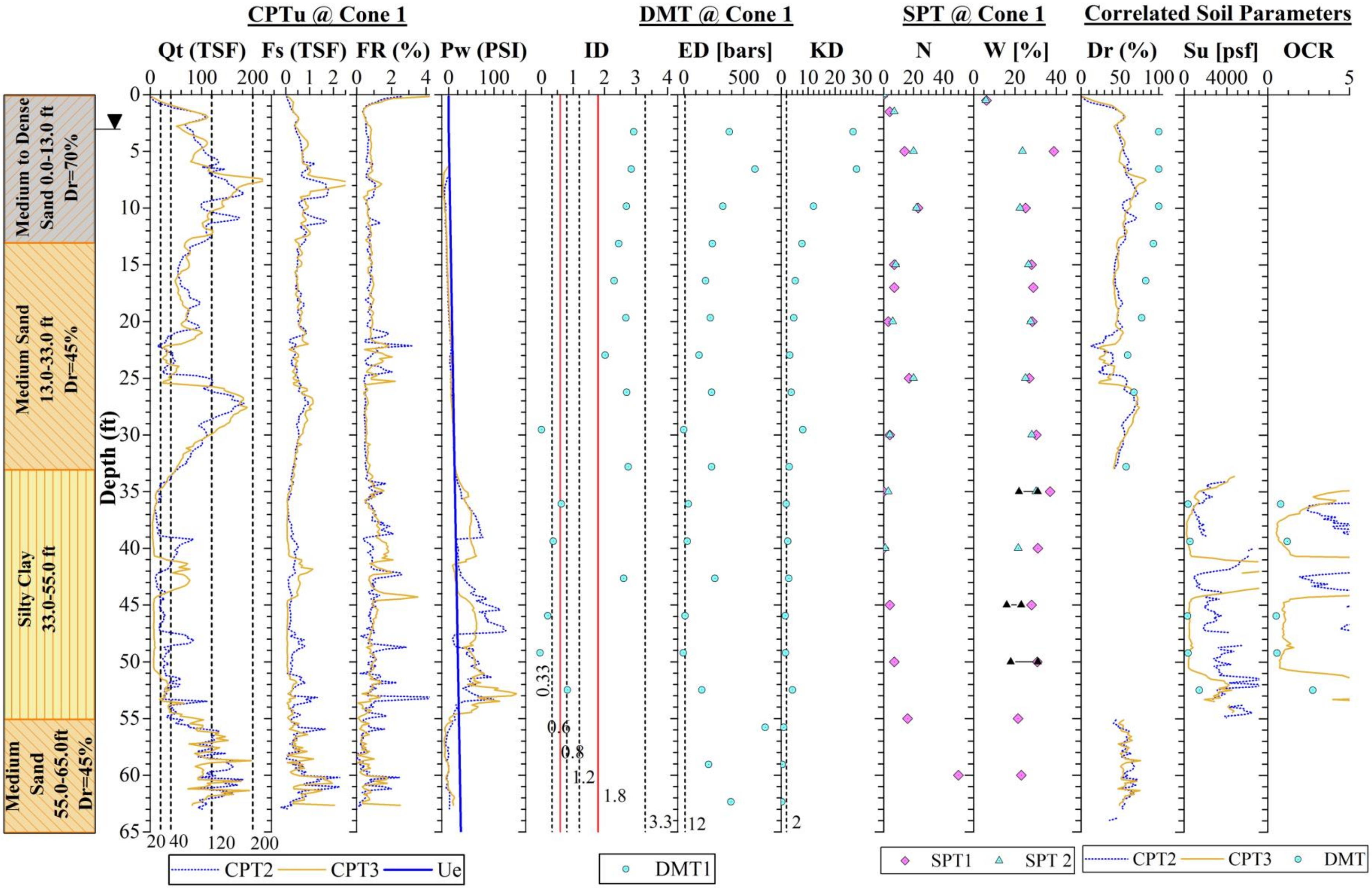
Survey to practitioners about commonly used methods

Q8. Number of practitioners who run numerical models to calculate or verify immediate settlement:



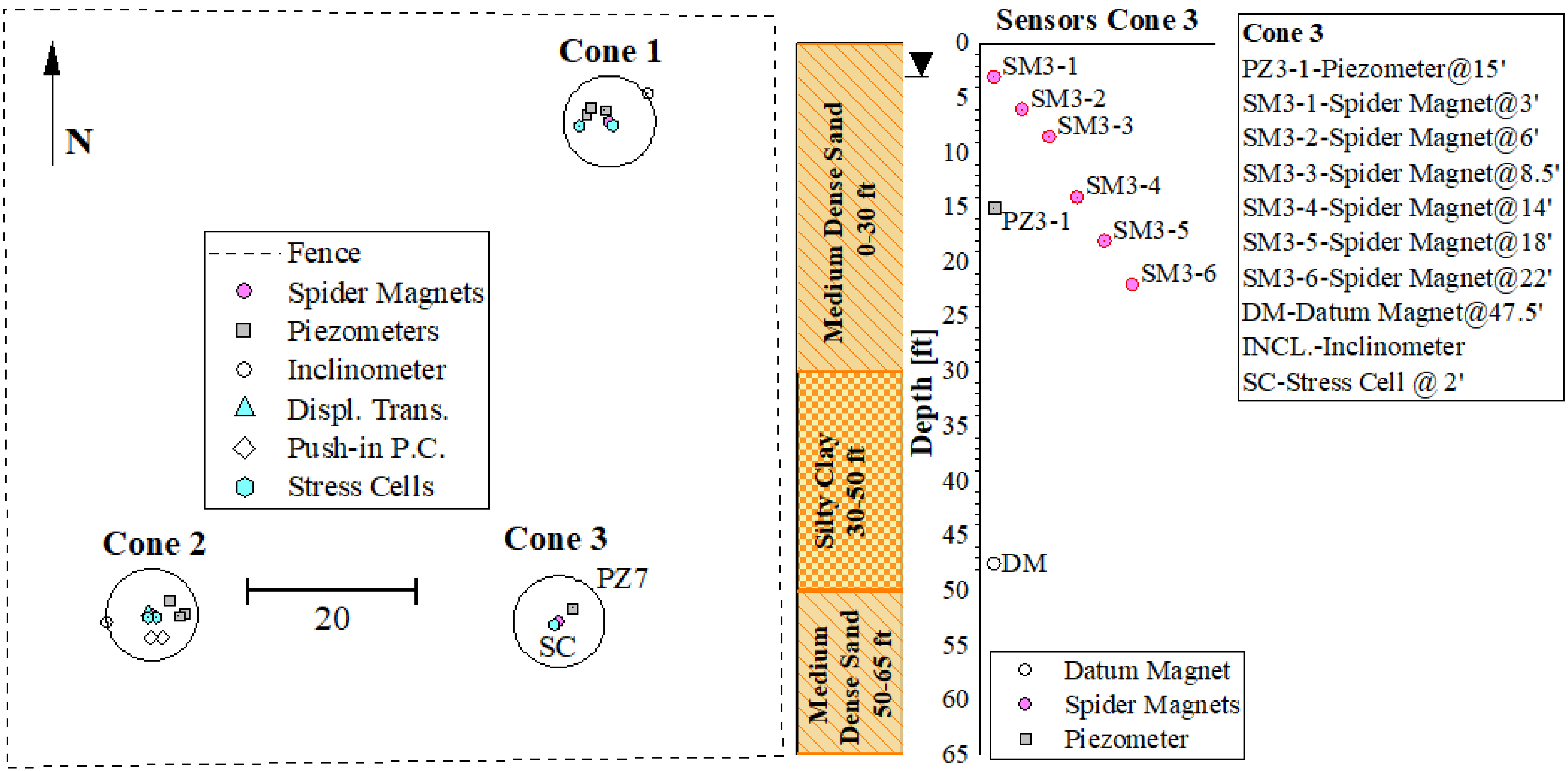
Field tests at UCF site

Summarized soil profile at the project site



Field tests at UCF site: conical load test

Instrumentation layout



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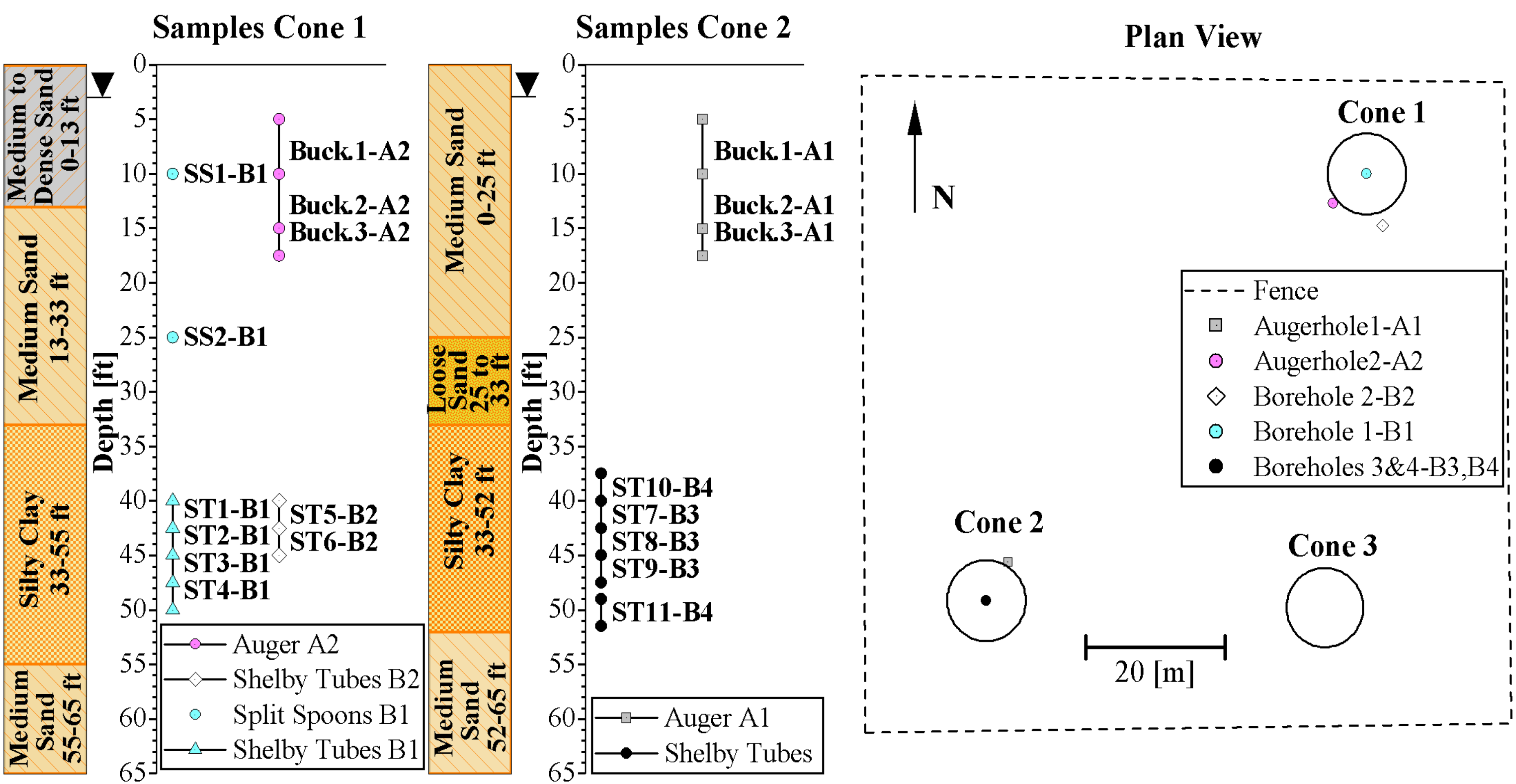
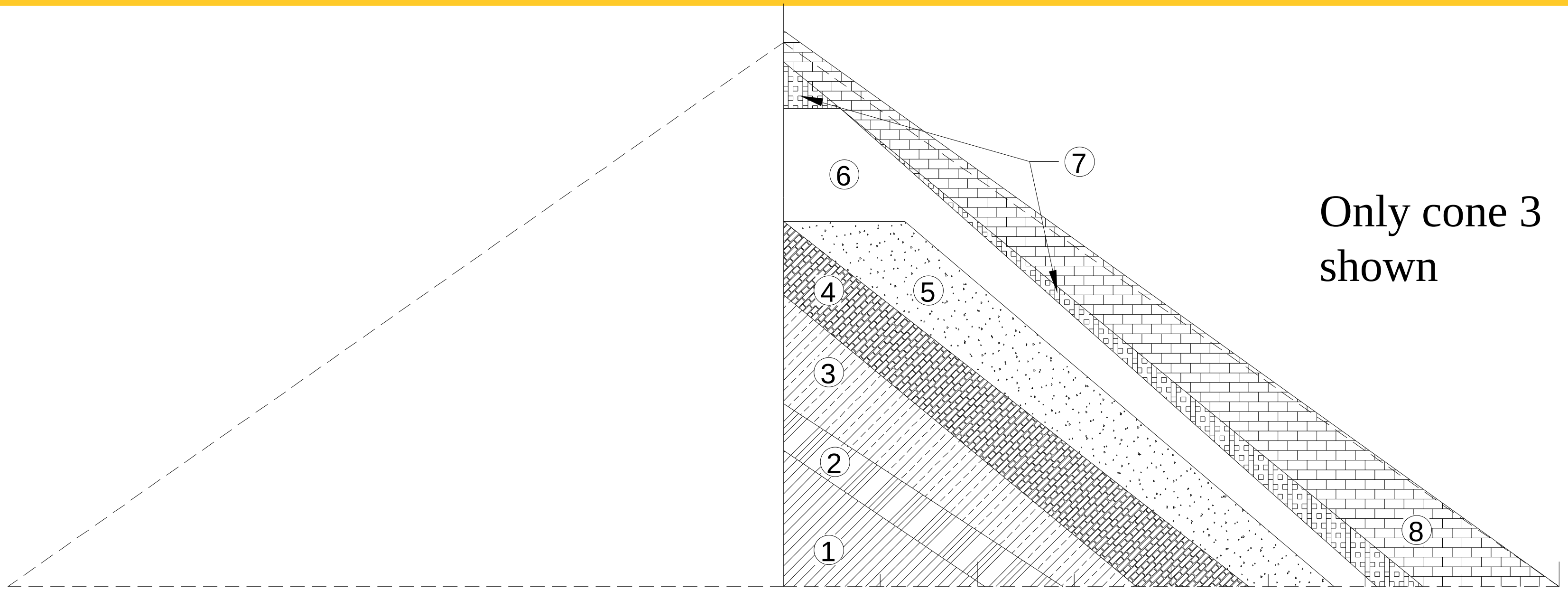
Laboratory Tests (Currently being performed at UCF lab)

Sampling summary and conical load test locations



Field tests at UCF site: Conical load tests

Field tests at UCF site: Conical load tests

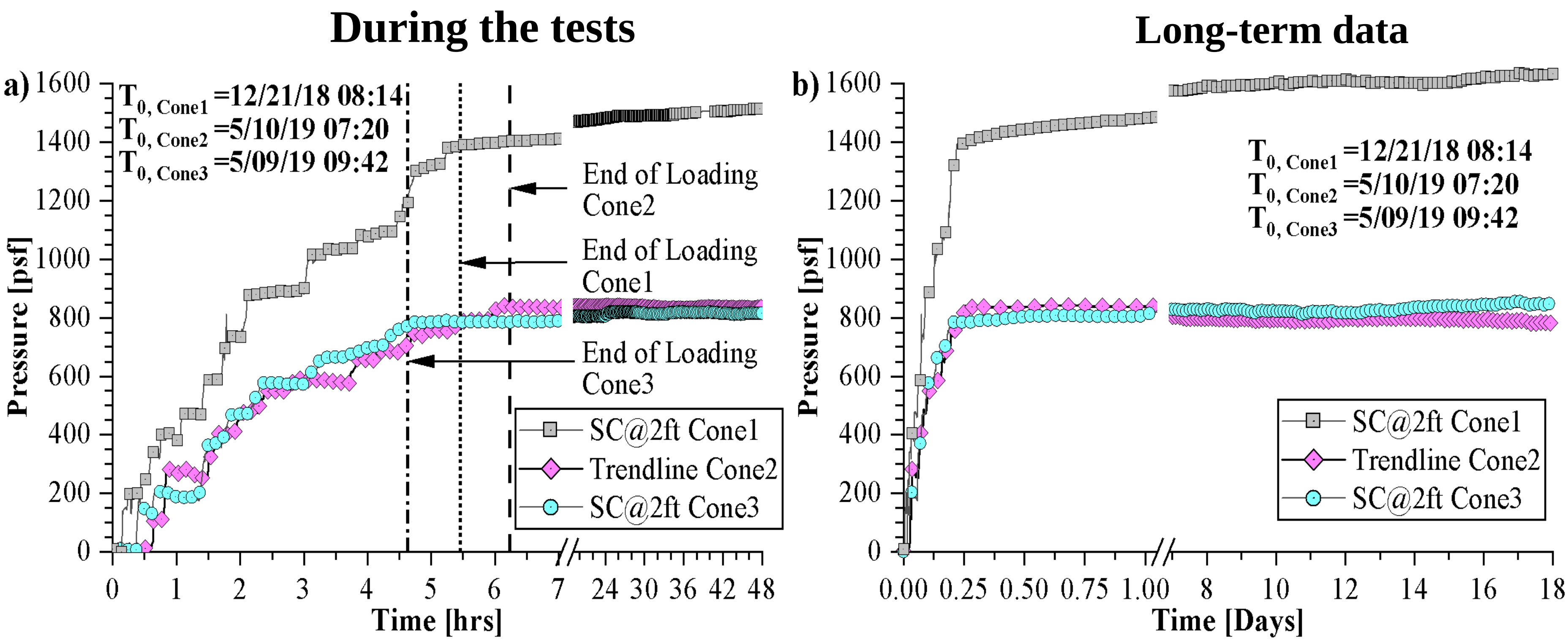


Only cone 3 shown

Dimensions monitored at each loading stage to compute soil volume and weight

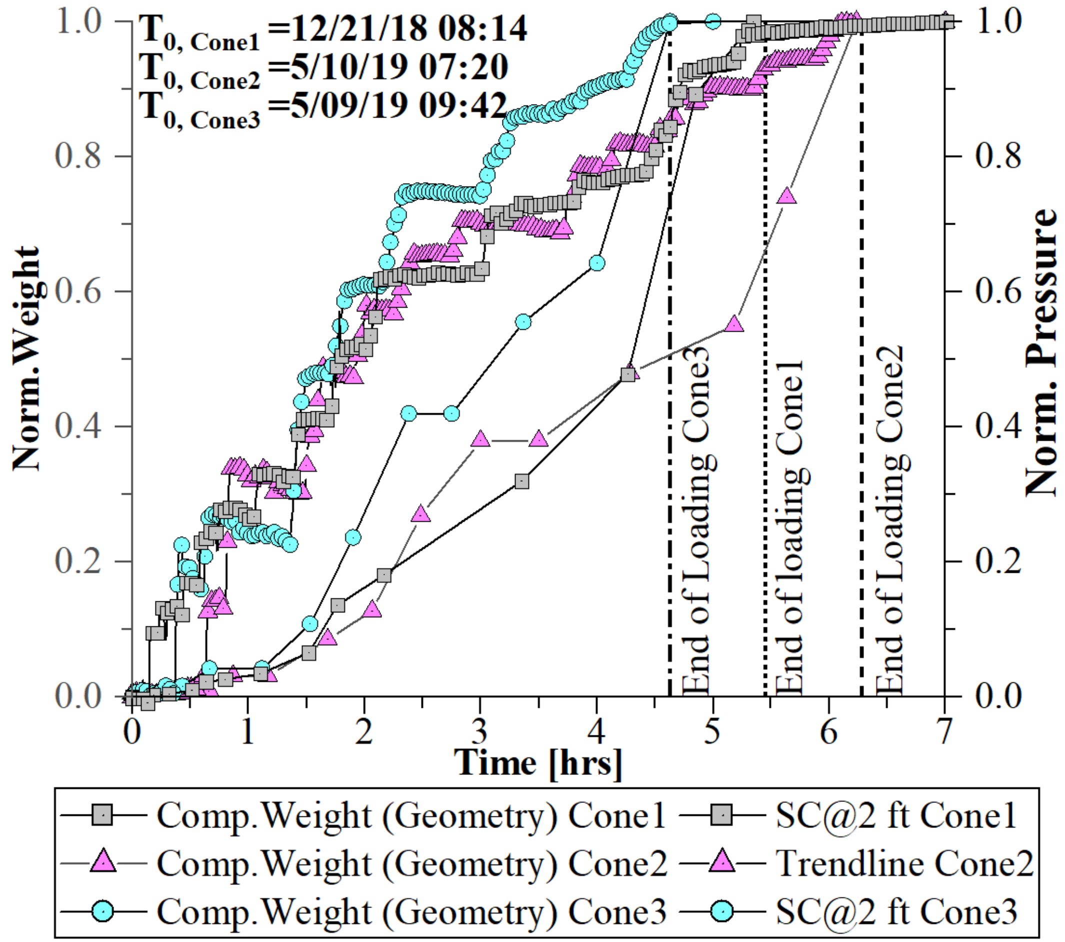
FINAL					
Bottom Radius	Top radius	High	Volume		Weight
[ft]	[ft]	[ft]	[ft^3]	[m^3]	[kip]
0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.0	3.5	99.6	2.8	8.7
7.2	0.0	4.7	255.1	7.2	22.2
7.2	0.0	4.7	255.1	7.2	22.2
9.1	0.0	7.5	650.4	18.4	56.6
12	0.0	9.4	1413.7	39.9	123.0
14.2	3.1	9.4	2512.1	70.9	218.6
14.2	3.1	9.4	2512.1	70.9	218.6
15.3	1.5	12.3	3326.2	93.9	289.4
16.5	0.0	13.5	3848.8	108.7	334.8
20	0.0	14.3	5990.0	169.1	521.1

Results field tests: Stress cells vs time



- SCs near the cone centerline are shown
- Higher soil unit weight at cone 1 than cones 2-3 (**100pcf vs 87pcf** measured with ASTM sand cone test)
- Higher water content of the loading material at cone 1 than cones 2-3 (10% vs 6%)
- Final cone volumes (7335, 5734, and 5990 ft^3 at cones 1 to 3, respectively)
- Slightly larger long-term variation at cone 1 because of rainy season

Results field tests: Normalized weights and pressures vs time



- Differences between normalized weights and pressures for each test show the stiffness effect of the conical loading material (deformable body)
- Differences in loading rates for all tests were negligible
- Stress redistributions and soil "arching" in conical soil arrangement were identified. Stiffness of the applied load needs to be studied

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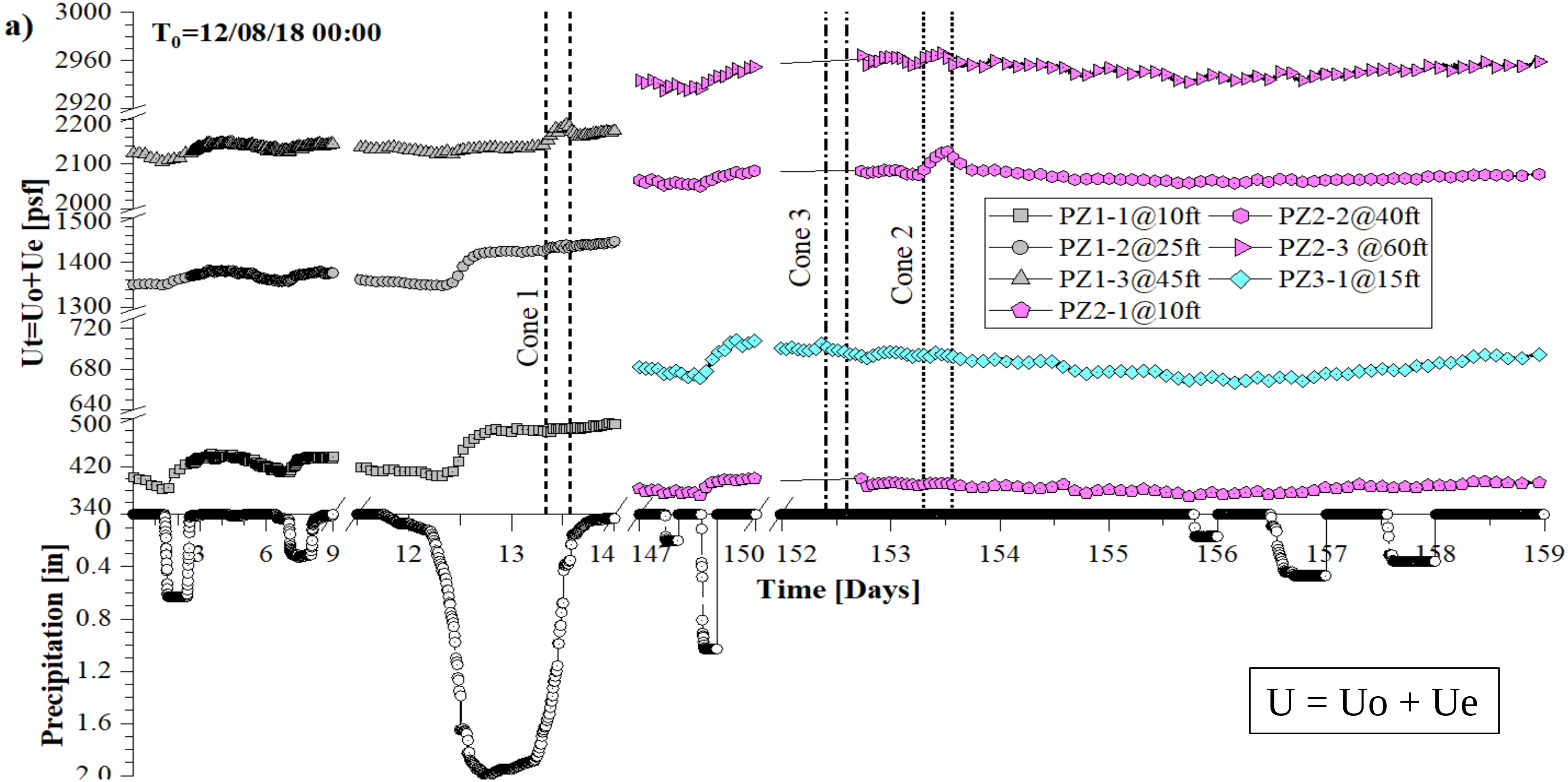
Results field tests: Porewater pressures (long-term)



- U = Uo + Ue and water table fluctuation correlated with precipitation data using 7 piezometers and measurement of conical load-induced excess PWP
- The data allowed: 1) identification of water table versus time, 2) check soil type at the piezometer location (k value), 3) assess excess porewater pressure (are settlements immediate or consolidation or secondary compression?), and 4) verify possible downward flow with deep piezometers

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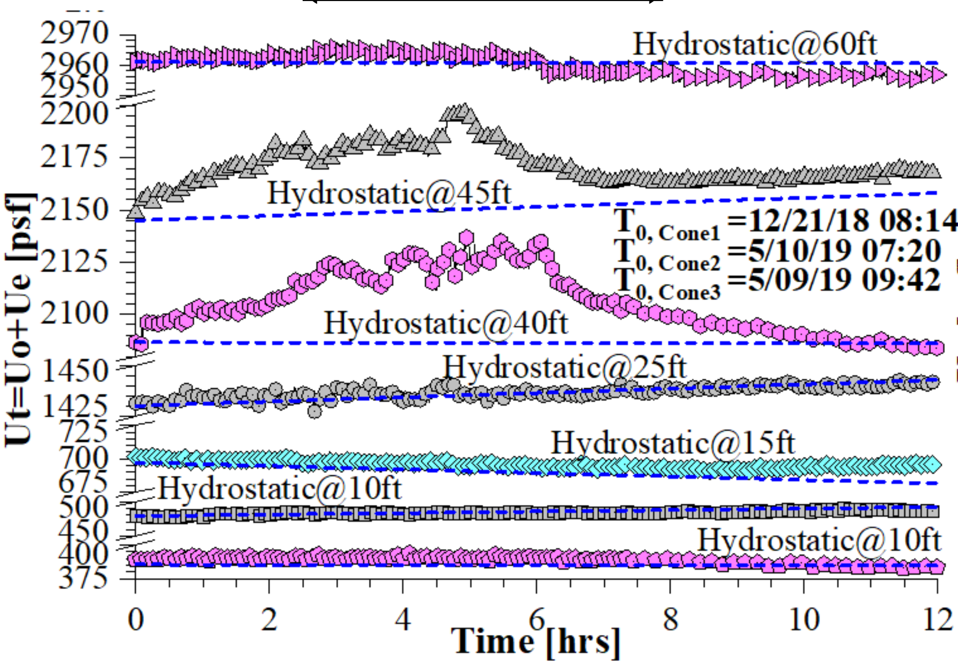
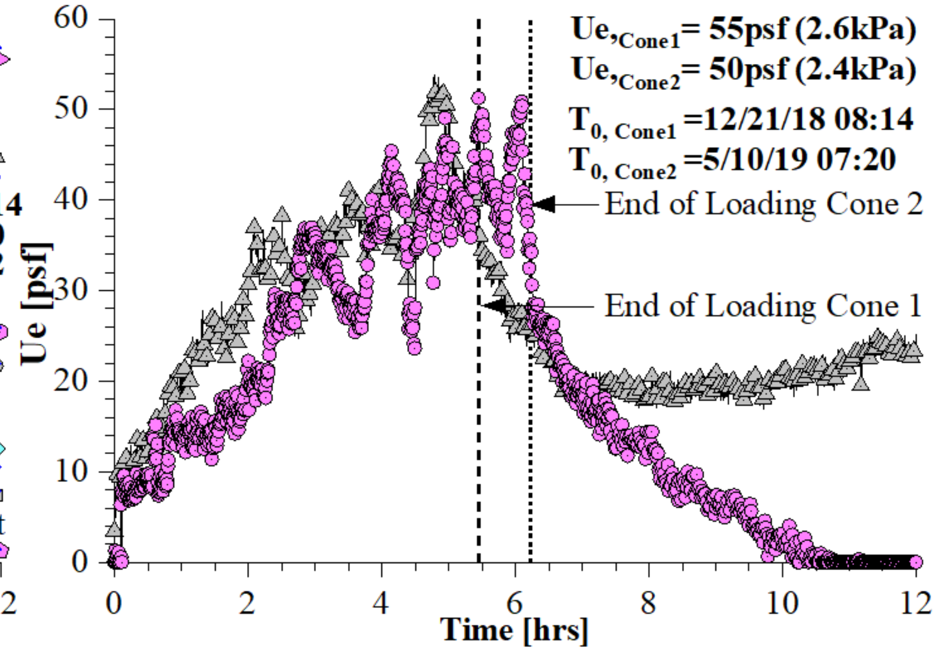
Results field tests: Porewater pressures vs time (short-term)

TOTAL POREWATER PRESSURE (DURING TEST)

EXCESS POREWATER PRESSURE (DURING TEST)





- Negligible excess porewater pressures everywhere even at the fine soil layer No. 3… thus immediate settlement (S_i) was measured.
- Excess PWP dissipate after test is completed
- Confirmation that about 40 ft was the influence zone from preliminary calculations using Boussinesq analyses as conical load-induced excess porewater pressures were small. (Observe small excess PWP at PZ1-3 and PZ2-2 installed in the silty clay layer)

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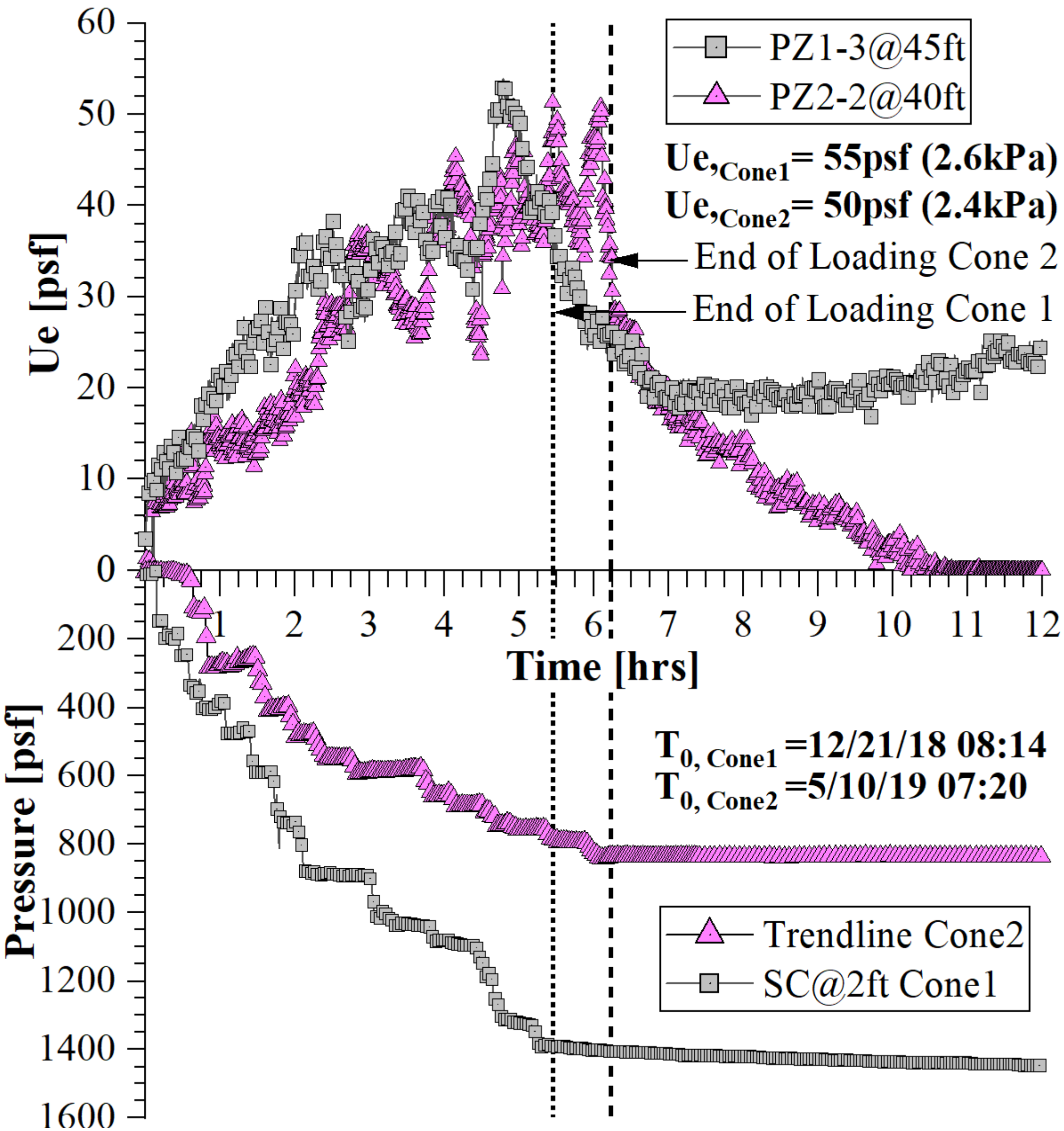
Results field tests: Measured Excess PWP and Earth Pressures at Ground Surface



- *Ue* are less than 10% of the vertical effective stress at their specific locations. Negligible *Ue* at 40 ft.
- Conical loading increases = EPWP build up
- Conical loading finished = EPWP dissipate… does it cause S_c?

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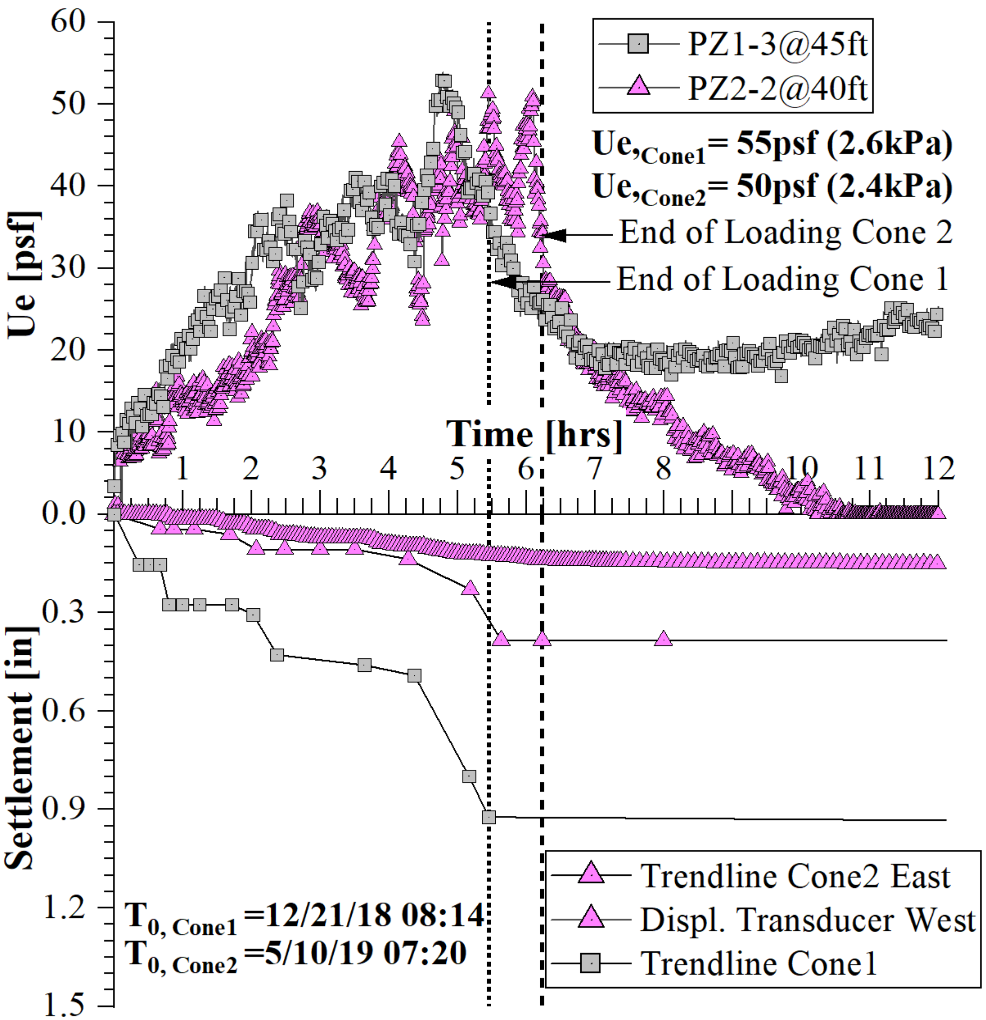
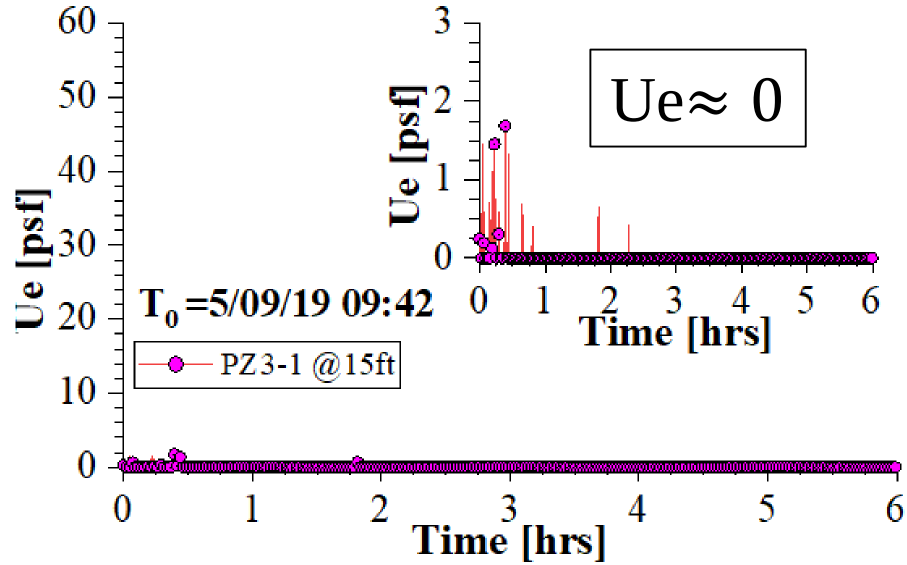
Results field tests: Measured Excess PWP and Settlement at Ground Surface

Typical piezometers at the silty clay layer (@40ft)



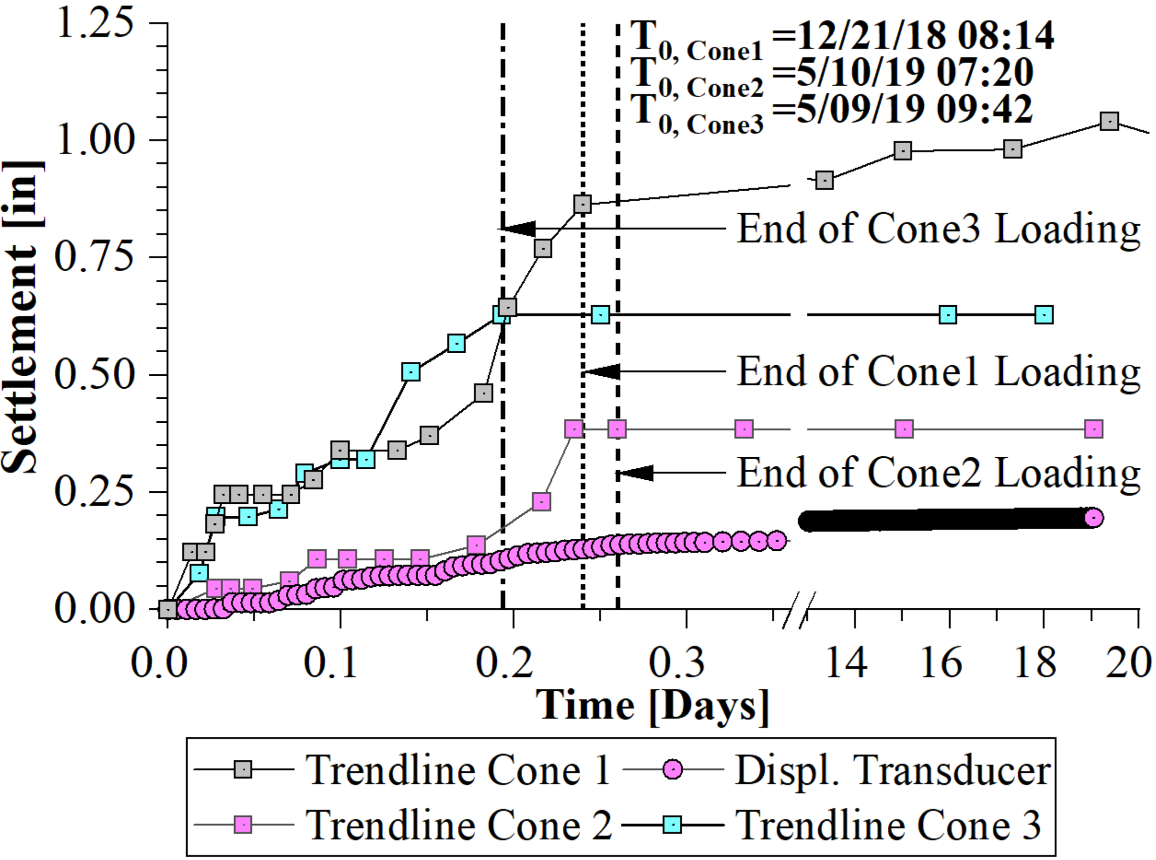
Typical piezometers at the sandy layers (below 40ft)



- Remember: $S_{total} = S_i + S_c + S_s$

- S_c? Nope!
- S_s? Nope!
- S_i? Yup!

Results field tests: Ground surface settlement (long-term)



Cone 1: $S_i \approx$ 0.75" to 1"
Cones 2-3: $S_i \approx$ 0.4" to 0.6"
(Settlement magnitudes explained from unit weight and volume of loading material, and slightly different soil conditions found at the project site)

- Negligible long-term settlement data, negligible S_c after EPWP build-up and dissipation, zero S_s was measured (i.e., only S_i was measured!)

- For an influence zone of 40 ft, computed axial strains (ε_a) mobilized by conical load are about 0.1 to 0.2% (important because E is a function of strains mobilized!)

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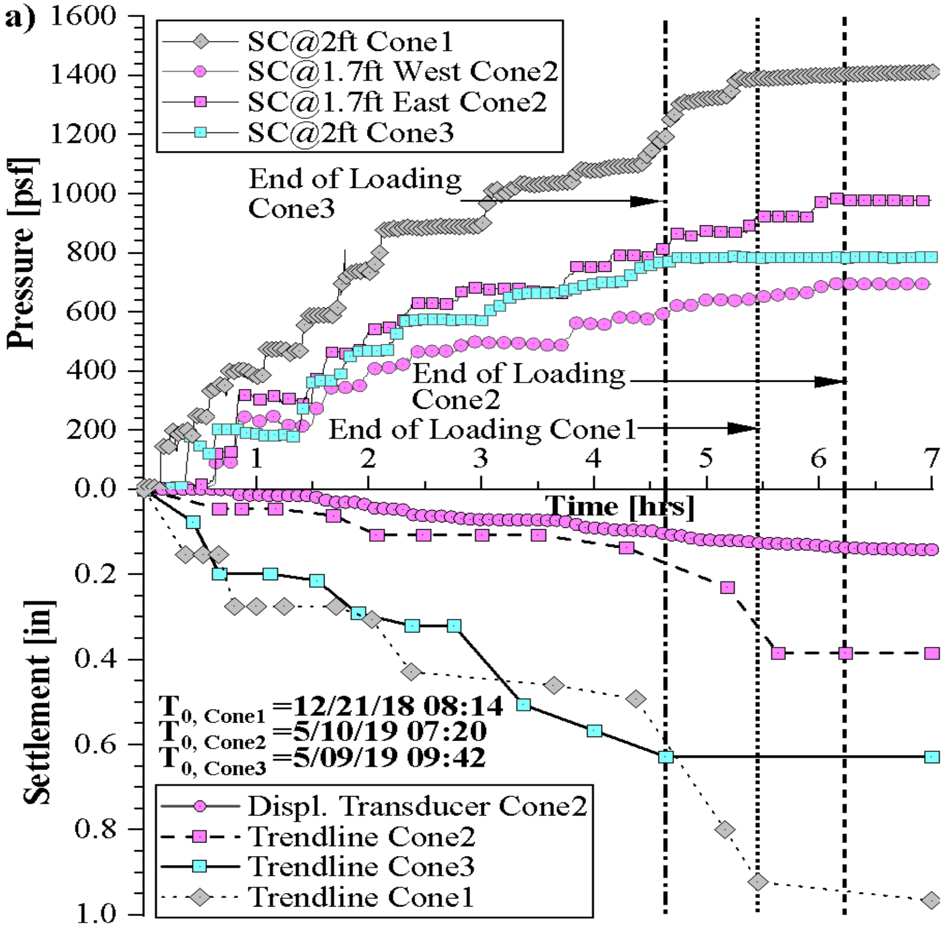
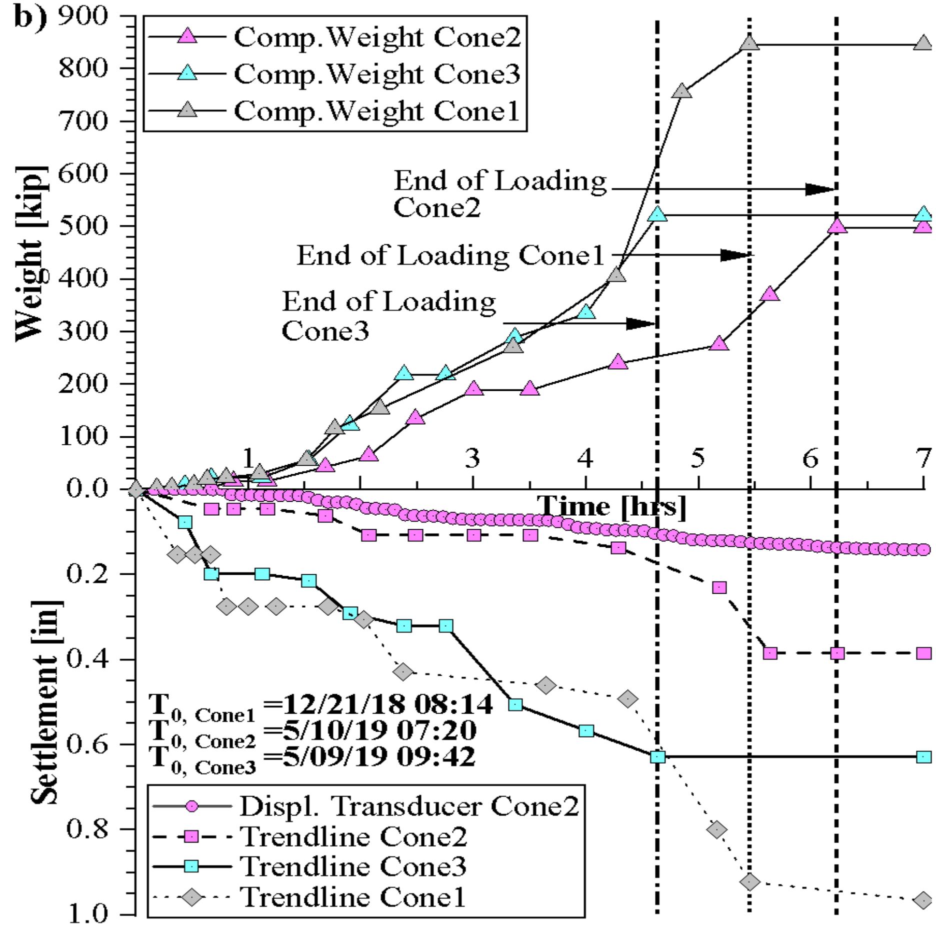
Results field tests: settlement, pressure, and weights vs time

Pressure & Settlement vs Time



Weight & Settlement vs Time



- Settlement variations better described by pressure with SCs than weights
- As expected… larger weights and pressures in conical loads caused larger settlements
- Stiffness of conical loading can be evaluated with stress cell pressure readings, and not with weights as Schmertmann did.

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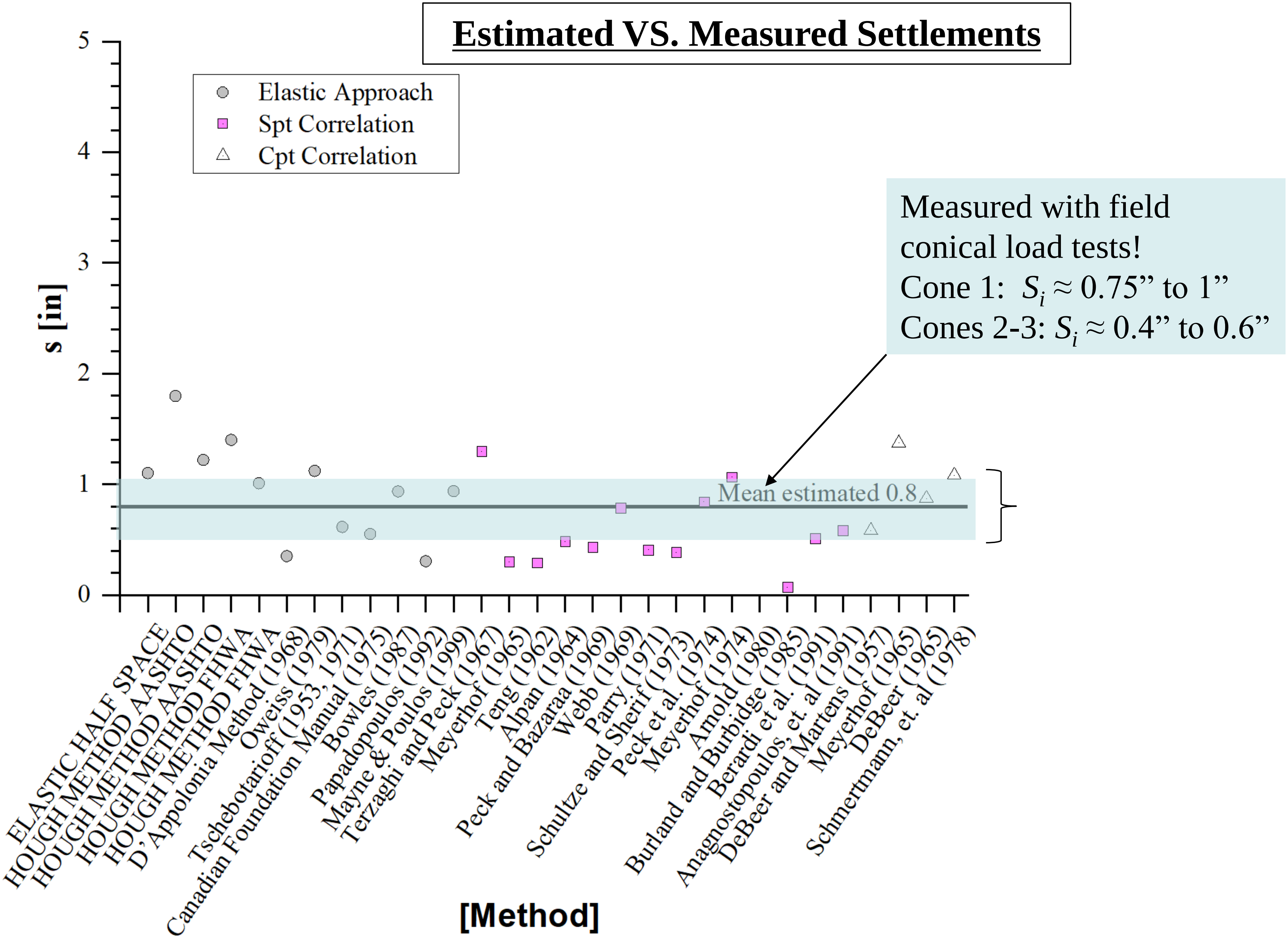
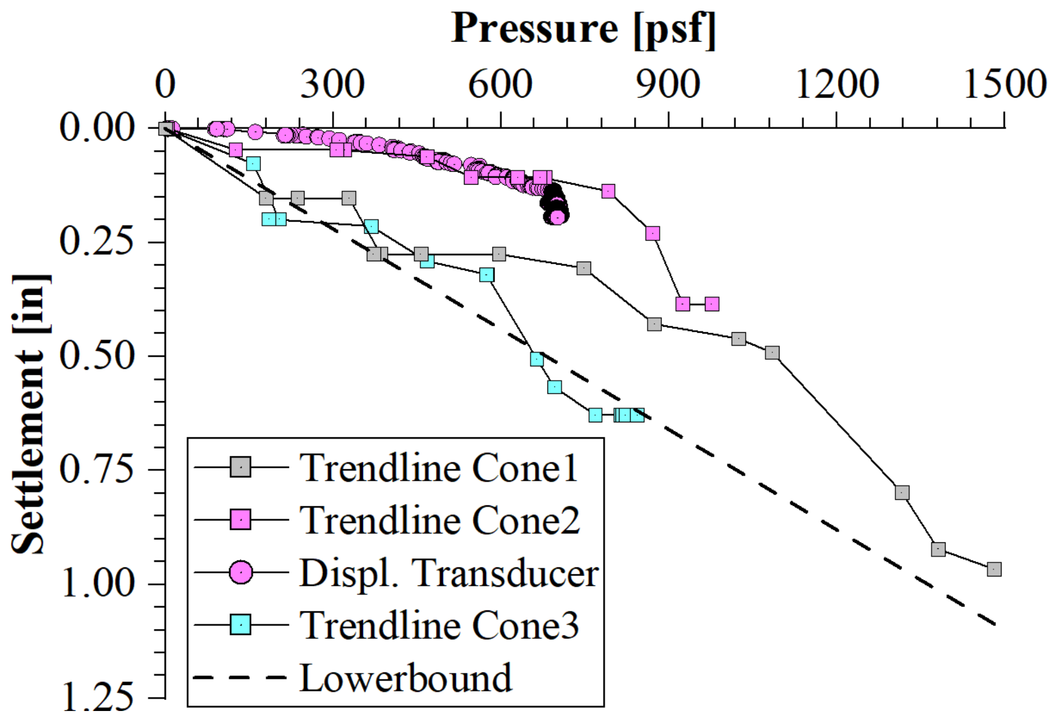
Preliminary conclusions about results



Preliminary conclusions about results

Settlement vs Pressure



- Stiffness parameters can be extracted from these figures:

Initial approach:

- ➢ $P = k \cdot S_i$
- ➢ P is the maximum measured pressures
- ➢ S_i measured at Cones 1 through 3:

k_1= 1500 psf/in; k_2= 2800 psf/in; k_3= 1300 psf/in (most conservative)

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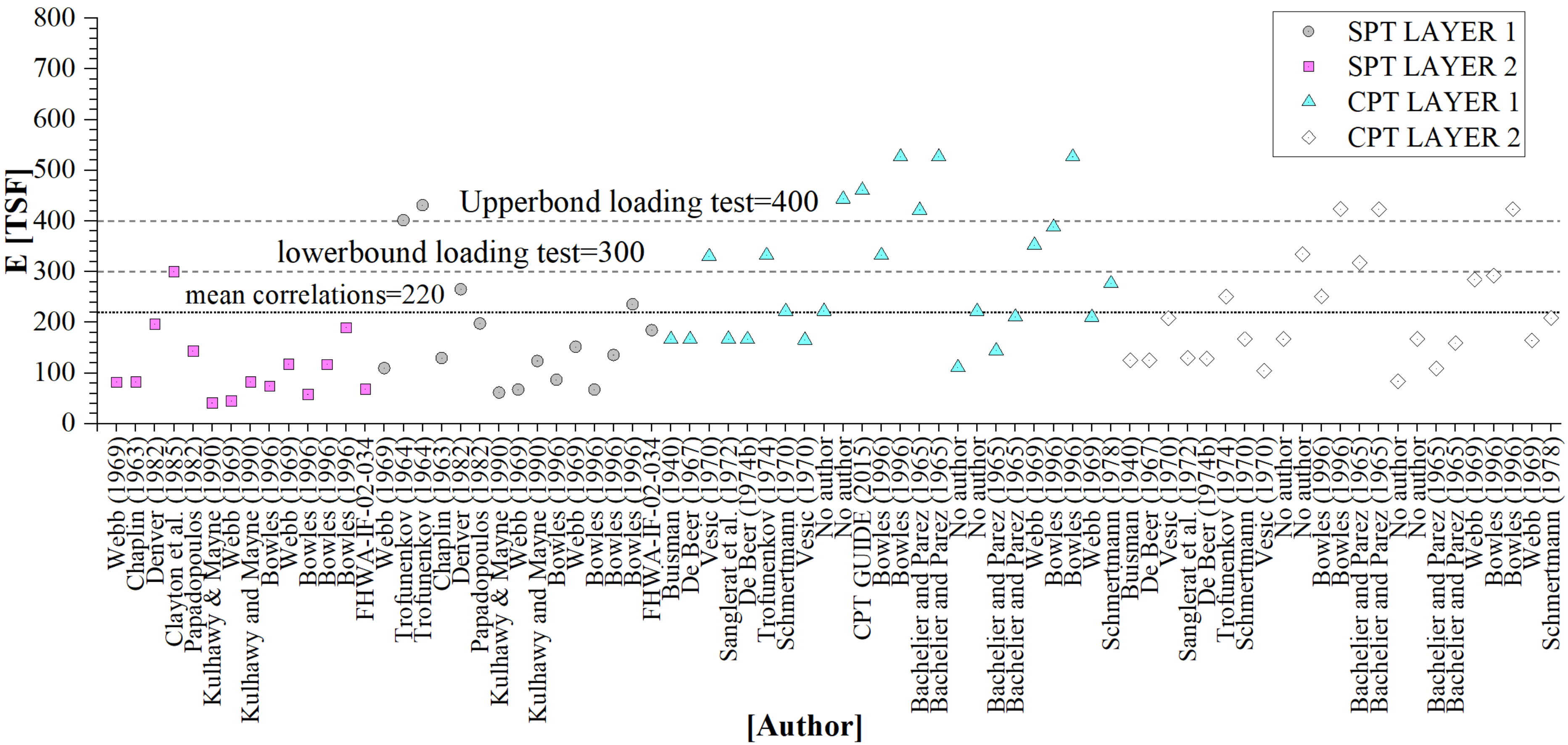
Preliminary conclusions about results

Estimated *E* values with SPT/CPT correlations Vs. *E* measured with conical load tests



- Young's modulus initial approach assuming uniaxial (vertical) strain (ε_a) mobilized by conical loading:

$$\sigma_a = E \cdot \varepsilon_a; \qquad Conical\ load\ pressure = E \cdot \frac{S_i}{H}$$

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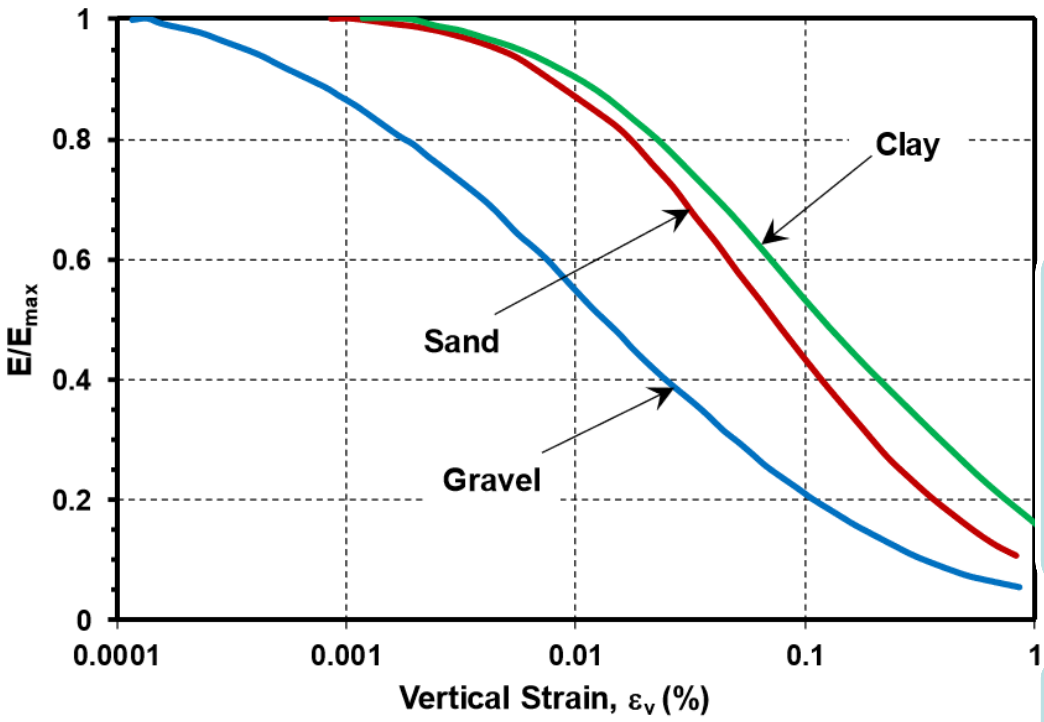
The future…

<u>Soil modulus is a function of mobilized axial strains… for our conical load test: $\varepsilon_v \approx 0.1\%$</u>



Determine E_{max} from field test results, lab measurements or correlations

Compute first order approximation of settlement and best estimate of vertical strains of your project (for our conical load tests $\varepsilon_v \approx 0.1\%$)

Find best E-ε_v relationship for your soils based on stiffness degradation curves (hopefully measured in the lab or via published E-ε_v relationships: Vucetic, Dobry, Hardin, Drnevich, Seed, Kramer, Rollins, EPRI, etc.)

With corrected E estimate a new settlement and a new vertical strain and repeat steps

What's coming next…

- Finalize laboratory testing at UCF lab:
  - Consolidation tests (CRS and classical oedometer tests)
  - Triaxial tests, mainly: CKoD-TXC and TXE tests
  - Atterberg limits, hydrometers, specific gravity tests

In progress

- Finalize numerical simulations and comparisons with measured data

In progress

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