

CPT'10



**Session Report 3:
CPT Applications**

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Purposes

Conduct a brief summary of CPT applications

Organise topics in main themes

Summarise main issues in each theme

Emphasise current practice

Envisage possible trends

Select needs for future research

Main themes

	Papers
1. Site characterization	10
2. Soil properties	9
3. Foundations design	13
4. Soil liquefaction	9
5. Geo- environmental investigation	10

Site characterization



Profiling

Benefiting from the experience on natural soils

Majority of papers: CPTU

Few contributions: Seismic measurements

- ✓ Extending this experience by evaluating soil improvement after ground treatment
- ✓ Probabilistic analysis to optimize site characterization

Site characterization



Soil improvement (9 papers)

✓ Evaluating in situ conditions prior and after
ground improvement

Dynamic compaction & soil mixture (Ku & Juang,
Squeglia & Lo Presti, Ozer et al, Skutnik et
al Bates & Merfield, Sinha et al)

✓ Methods for assessing the degree of
compaction in grained soils

In situ tests (*Agrawal et al*)

Mini-cone calibration chamber (*Squeglia & Lo
Presti*)

Site characterization



Probabilistic Analysis

- ✓ determine vertical and horizontal distances required for a given project (Ng & Zhou)
- ✓ define minimum stretches necessary to assess the probability of failure of embankments on soft ground (*Noss et al*)

Probabilistic Analysis in Engng Practice
Data (number and spatial intervals) to perform
robust statistical analysis

Prediction of soil properties



Majority of papers: CPTU on soft clay deposits
Routine methods for estimation of S_u , OCR (σ'_p), C_h

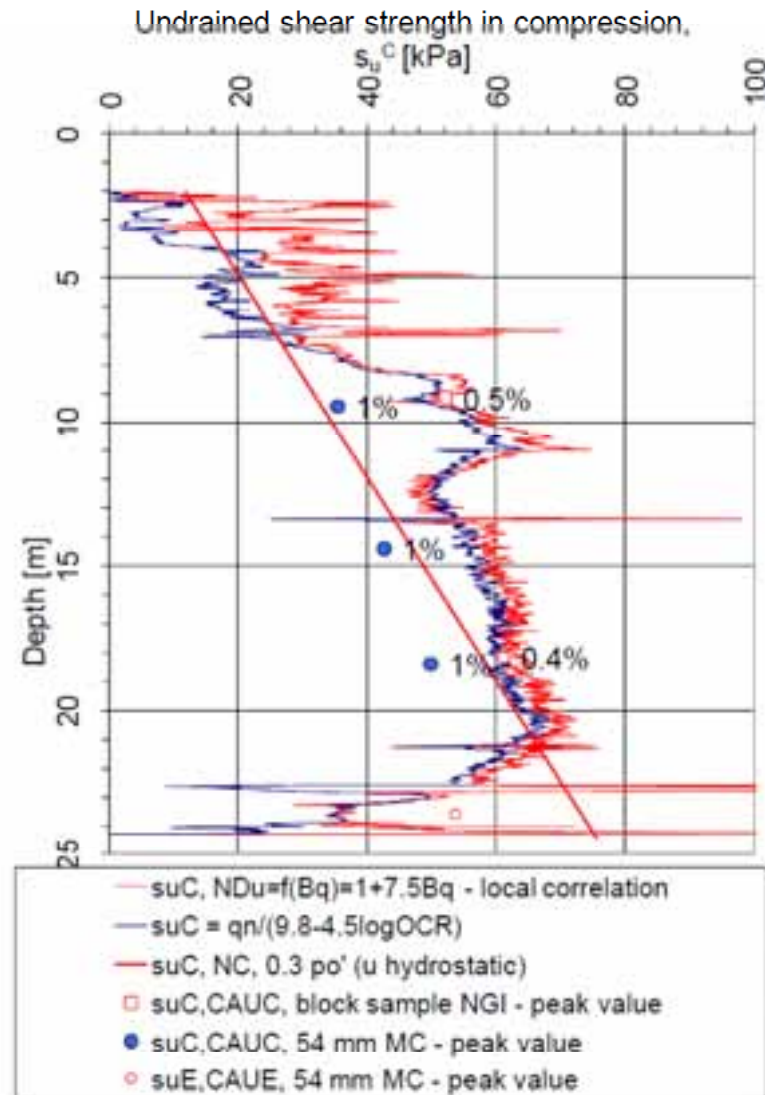
Best practice should account for both
established and locally based correlations
Need for good quality sample

Benefits in combining different testing
techniques

Comparisons to vane and dilatometer

*(Farrar; Steiner; Camp et al; Sunitsakul et al, Torum et al
Sotil et al, Ozer et al., Gadeikis et al, Karan et al)*

Prediction of soil properties



. Interpretation of undrained shear strength in quick clay (Torum et al)

Prediction of soil properties

Data Set	Independent Variables	R^2 (%)	Equation (From the model given in Equation 1, and regression output by using Microsoft EXCEL, the linear regression can be back transformed to):
A	(σ_{vs}/P_a)	87.5	$\frac{\sigma'_p}{P_a} = 0.932 \left(\frac{\sigma_{vs}}{P_a} \right)^{0.892}$
B	(q_t/P_a)	88.1	$\frac{\sigma'_p}{P_a} = 0.290 \left(\frac{q_t}{P_a} \right)^{0.863}$
C	$((q_t - \sigma_{vs})/P_a)$	82.9	$\frac{\sigma'_p}{P_a} = 0.429 \left(\frac{q_t - \sigma_{vs}}{P_a} \right)^{0.798}$
D	$(\sigma_{vs}/P_a), (q_t/P_a)$	90.8	$\frac{\sigma'_p}{P_a} = 0.478 \left(\frac{\sigma_{vs}}{P_a} \right)^{0.438} \left(\frac{q_t}{P_a} \right)^{0.469}$
E	$(\sigma_{vs}/P_a), ((q_t - \sigma_{vs})/P_a)$	90.9	$\frac{\sigma'_p}{P_a} = 0.632 \left(\frac{\sigma_{vs}}{P_a} \right)^{0.565} \left(\frac{q_t - \sigma_{vs}}{P_a} \right)^{0.342}$
F	$(q_t/P_a), ((q_t - \sigma_{vs})/P_a)$	90.4	$\frac{\sigma'_p}{P_a} = 0.192 \left(\frac{q_t}{P_a} \right)^{1.953} \left(\frac{q_t - \sigma_{vs}}{P_a} \right)^{-1.046}$
G	$(\sigma_{vs}/P_a), (q_t/P_a), \text{ and } ((q_t - \sigma_{vs})/P_a)$	90.7	$\frac{\sigma'_p}{P_a} = 0.960 \left(\frac{\sigma_{vs}}{P_a} \right)^{0.756} \left(\frac{q_t}{P_a} \right)^{-0.693} \left(\frac{q_t - \sigma_{vs}}{P_a} \right)^{0.842}$

Linear regression for normalized preconsolidation pressure (*Ozer et al*)

Prediction of soil properties



COMPARE - COMBINE - CONVERT

- a) Comparisons - better understanding of both
- b) Combined independent measurements for new correlations
- c) Convert database from one test to another
- d) ~~Use methods from one test with results from other~~

Comparison between static q_c and dynamic q_d

cone penetration resistance (*Gadeikis et al*)

granular materials the static cone penetration is a function of D_r , σ_v , σ_h , whereas the dynamic cone is a function of: (1) soil properties, (2) hammer mass and height of fall and (3) rod geometry

Shallow and deep foundations



- ✓ CPT-based pile bearing capacity methods
- ✓ Estimation of the entire load-settlement
- ✓ Prediction the driving force of piles

- ✓ Response of shallow foundations

Deep foundations

- ✓ CPT-based pile bearing capacity methods
 - Conventional axial pile load testing
 - Direct and indirect methods
- 1. CFA pile load tests in **silty clay** soils (*Pardoski*).
- 2. Tapered precast concrete pile test in a **soft lacustrine** deposit overlaying a dense alluvial layer (*Togliani*)
- 3. Bored pile load tests carried out in **unsaturated and collapsible porous** clay (*Cunha & Stewart*) - LCPC
- 4. Precast concrete plies - Axial pile load tests in **silt-clay residual** soil using an axisymmetric finite element model. (*Prakoso & Hadiwardoyo*)

Reasonable predictions of bearing capacity

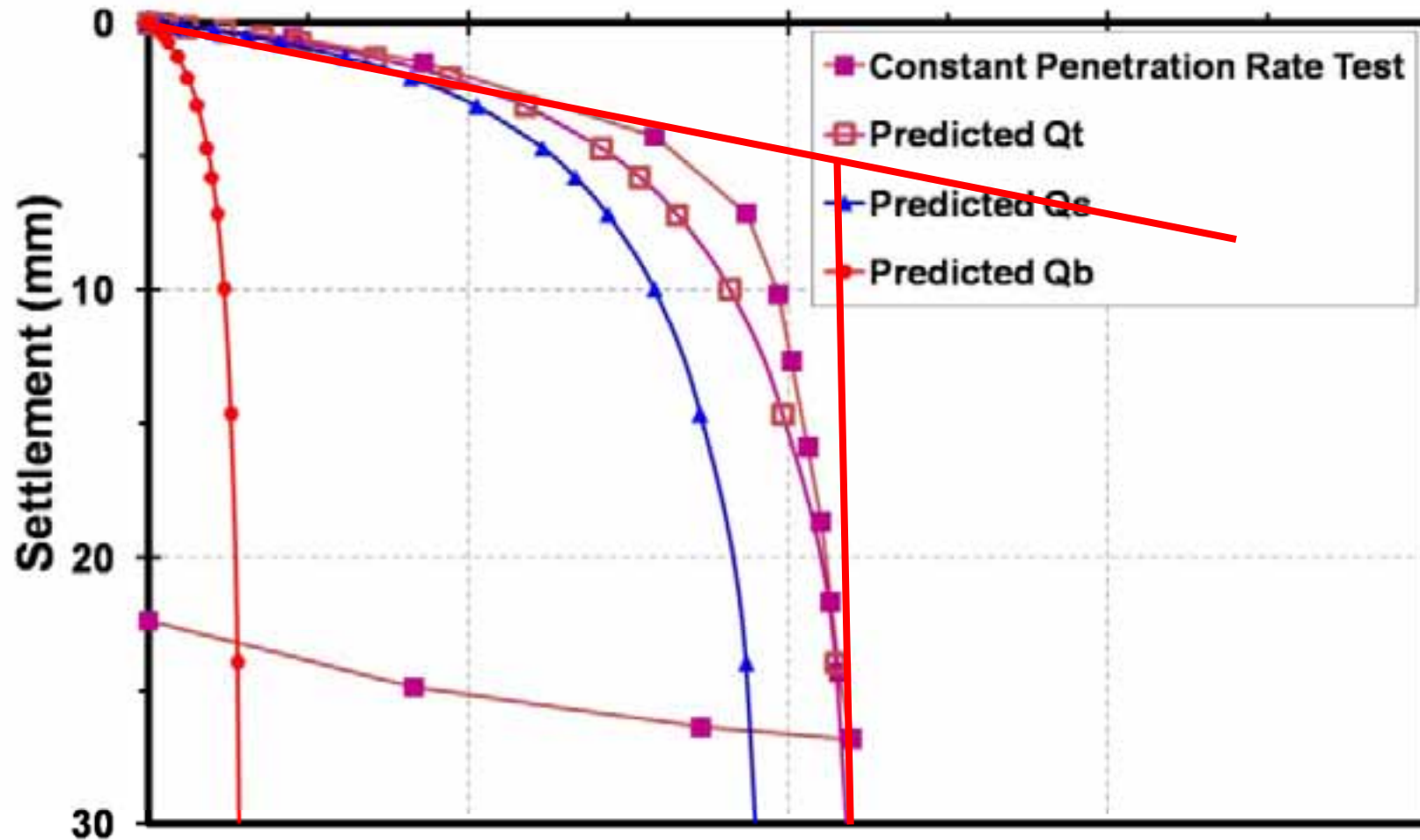
Deep foundations



Predictions extrapolated to environments outside the data base to which methods were calibrated

- ✓ Load tests - axial compression (case studies)
- ✓ Attempts to predict mechanism (*Schneider et al*)
- ✓ Statistical analysis supporting correlations and soil variability (scatter in pile capacity)
- ✓ Finite element analysis (*Tolooiyan & Gavin, Prakoso & Hadiwardoyo*)

Deep foundations



SCPT: estimation of the entire load-settlement (*Niazi et al*)

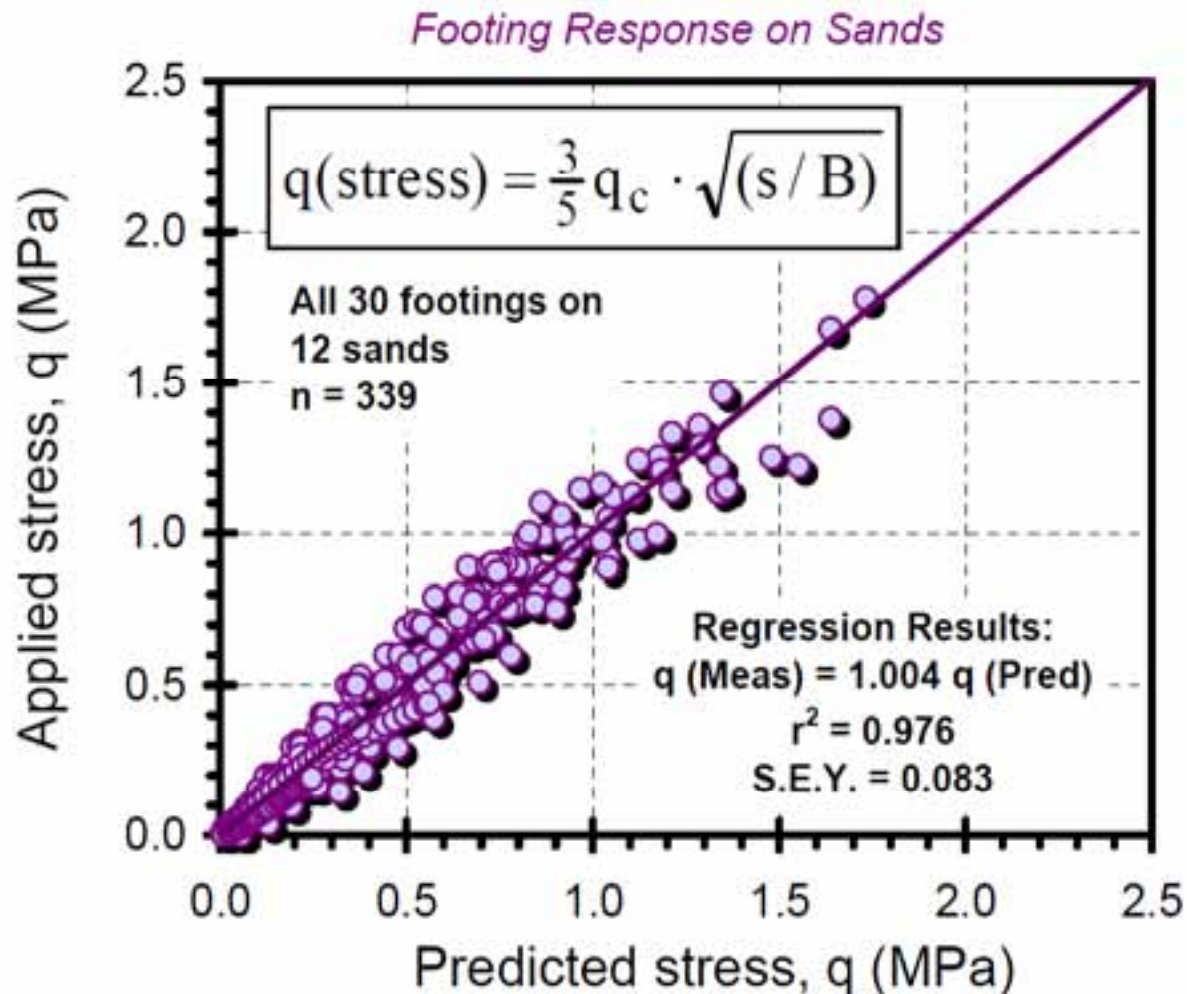
Shallow foundations

Strength & stress history from piezocone test applied to the design of shallow bridge foundations (Bentler et al)

Settlement estimation of multiples footings in sand by 3D non-linear finite element analysis Schmertmann's framework where the elastic modulus of each individual layer is obtained from representative cone resistance (Lee et al)

Cone Loading Test (CLT) - conceived to estimate settlements. The cone is loaded in a minimum of ten successive steps lasting 60 s each, or at constant very slow speed. Scale and form effects (Reiffsteck et al)

Shallow foundations



Applied vs. predicted stresses CPT-based approach (*Mayne & Illingworth*)

Soil liquefaction



CPT-based simplified models for liquefaction evaluation: CSR vs q_t

adjust predictions to non-plastic silt soils with large fines content (*Baxter et al, Juang et al*)
need for local correlations (*Pease, Ozocak & Sert*)
cyclic pore pressure and dissipation tests (*Bol et al, Pehlivan et al*)

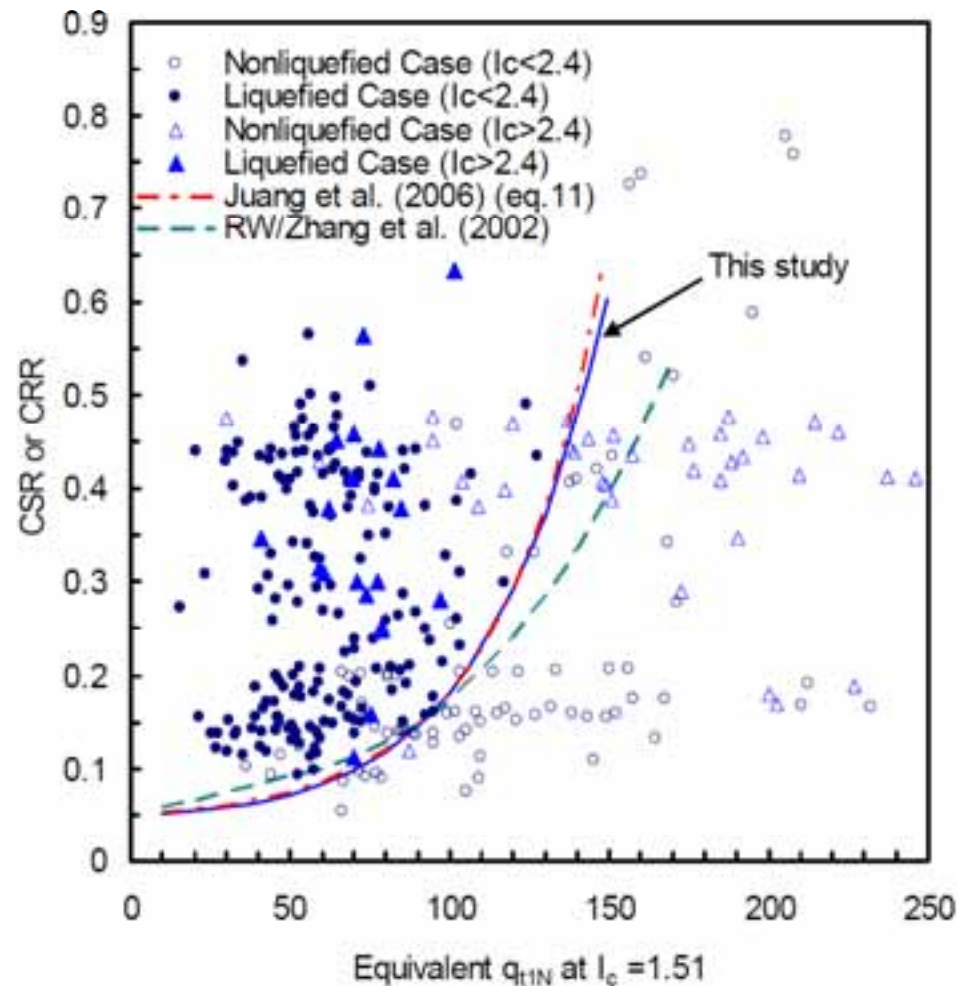
no state parameters type of approach

Comparisons of CPT and DMT sensitivity to stress history and aging in sand. (*Marchetti*)

Soil liquefaction

CPT-based simplified models for liquefaction

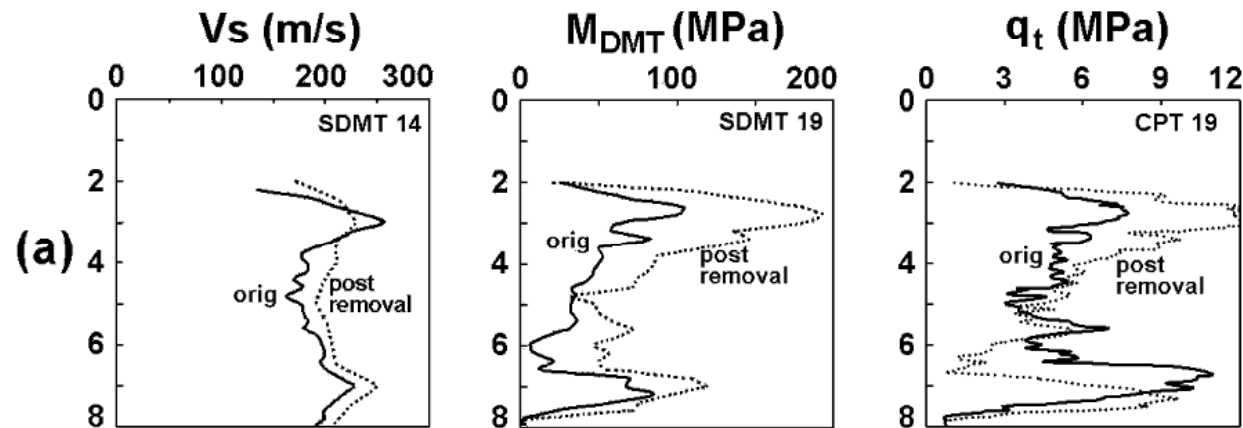
.Tuang et al



Soil liquefaction

Comparisons of CPT and DMT sensitivity.

Marchetti

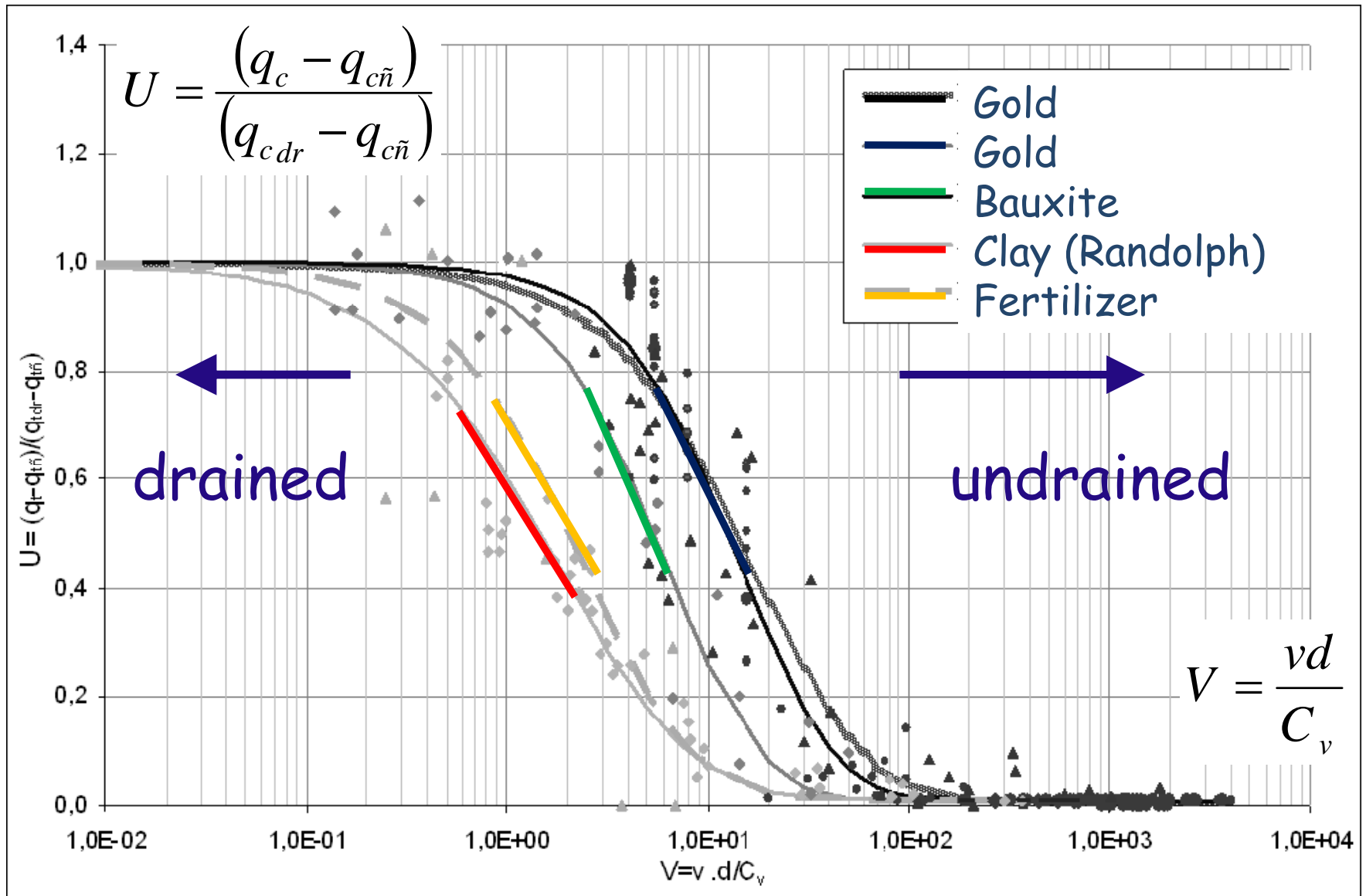


This case study comprises with existing experience?

Is G_0 an useful measured for assessing parameters controlling liquefaction?

Is the DMT a better test?

Geo-environmental investigation: taling minerals



Geo-environmental investigation



- ✓ investigation of mineral tailings
- ✓ profiling capability in contaminated areas
- ✓ geo-environmental applications

Diversity of techniques

hydraulicPunch technology (HP)
direct push injection logging (DPIL),
direct push permeameter (DPP)
electrical conductivity (EC)
fluorescence violet laser technology ROST
ultra-violet optical screening technology (UVOST)
ultraviolet induced fluorescence (UVIF)
ultraviolet optical screening tool (UVOST)

Geo-environmental investigation

Technique	Application	Authors
CPTU	inspect the in situ wall-backfill of a deep soil-bentonite barrier	<i>Jones & Taylor</i>
CPT and HP (hydraulicPunch) technology	ground plume trichloroethylene (TCE).	<i>Osborne</i>
CPT, direct push injection logging (DPIL), direct push permeameter (DPP) and electrical conductivity (EC)	hydrostratigraphic and permeability profiling	<i>Quinnan et al</i>
high-resolution piezocone (HRP)	measure hydraulic conductivity	<i>Kram et al</i>
Fluorescence violet laser technology (ROST, UVOST, UVIF)	LNAPL, multiple contaminant sources	<i>Laber Patton et al Smith & Gleason</i>

Conclusive Remarks.



1. Research *vs* application: mechanical properties assessed from combination of results from different sensors incorporated to the CPT. Reported applications are concentrated on CPT and CPTU, with few references to SCPT and no reference to CPMT
2. Best practice for assessing soil parameters comes from a combination of established and locally developed correlations. Established correlations define the order of magnitude of a given parameter whereas local correlations can fine tune this estimation to a more accurate value.

Conclusive Remarks.



3. Foundation design: (i) established methods, (ii) take advantage of scale effects and (b) investigate pile-soil interaction mechanism
4. Liquefaction: combined effects of relative density, stress and strain history, aging and soil structure. Parameters sensitivity. Methods reported to adjust predictions in non-plastic silt soils with large fines content.
5. Geo-environmental investigation: Devices methods still under improvement, but field has matured with the cone penetrometer being recognized as an useful, cost-effective technique.

Thank you!

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