VARIABLE RATE CONE PENETRATION TESTING

PEER Transportation Systems Research Program

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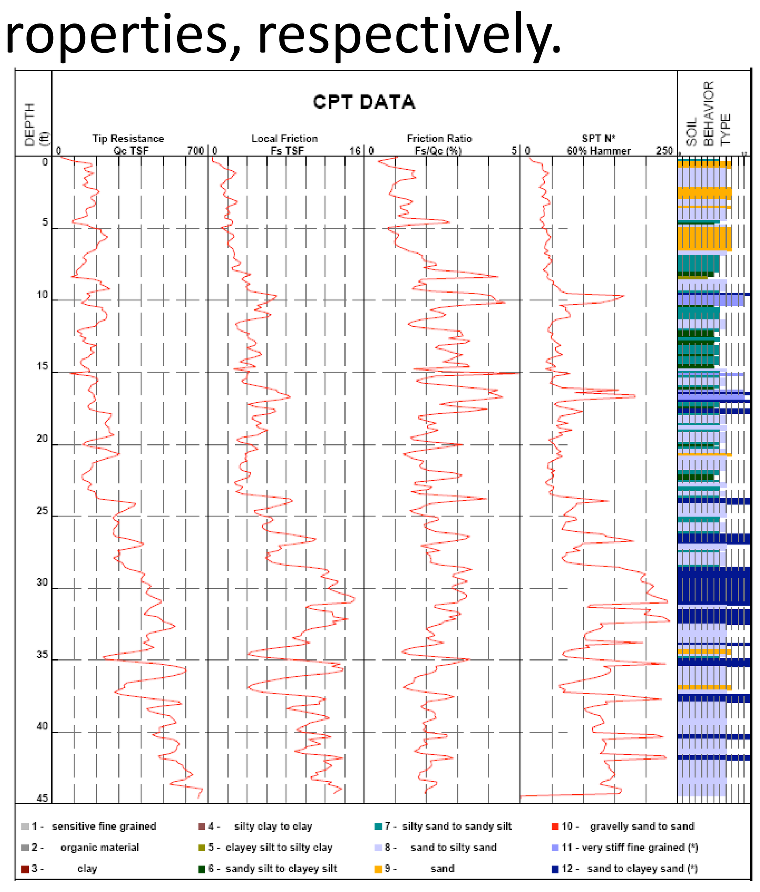
Introduction

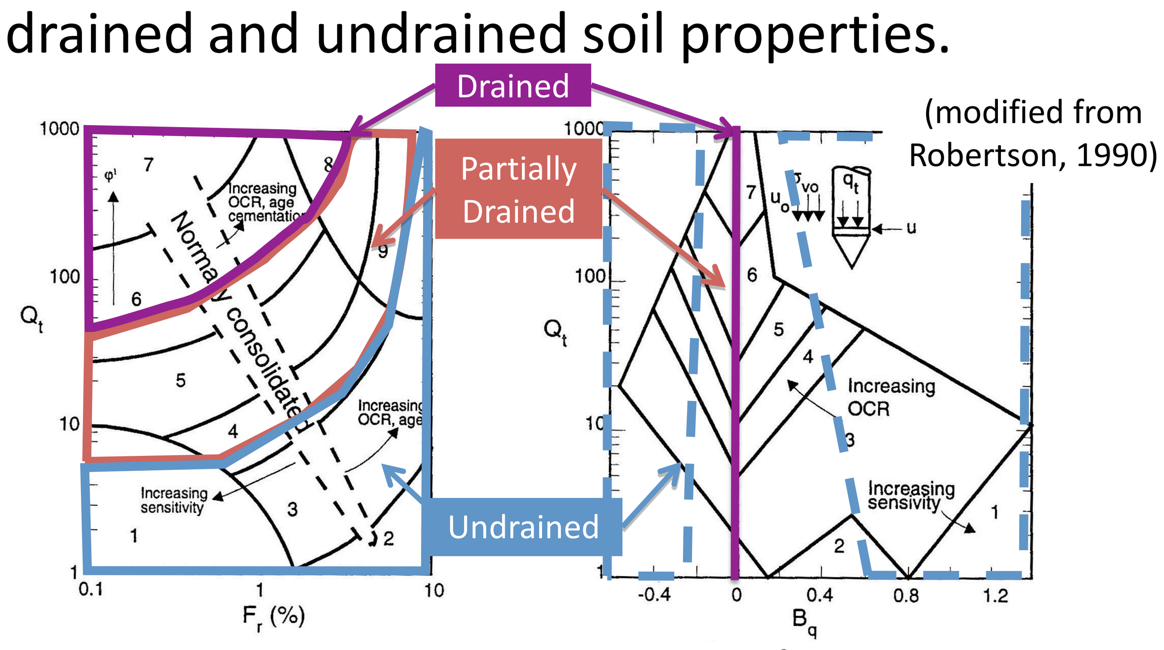
Interpreting properties of sandy clays, clayey sands, and silty soils (intermediate soils) with the cone penetration test is complicated since partially drained conditions likely exist at the standard penetration rate of 2 cm/sec. Drained or undrained conditions are required to reliably estimate drained and undrained soil properties, respectively.



Courtesy of Tom Holzer

A typical CPT log showing variations of soil types.

Soil classification charts can indicate whether soil is sand-like, clay-like, or in between, yet they do not provide guidance on determining drained and undrained soil properties.

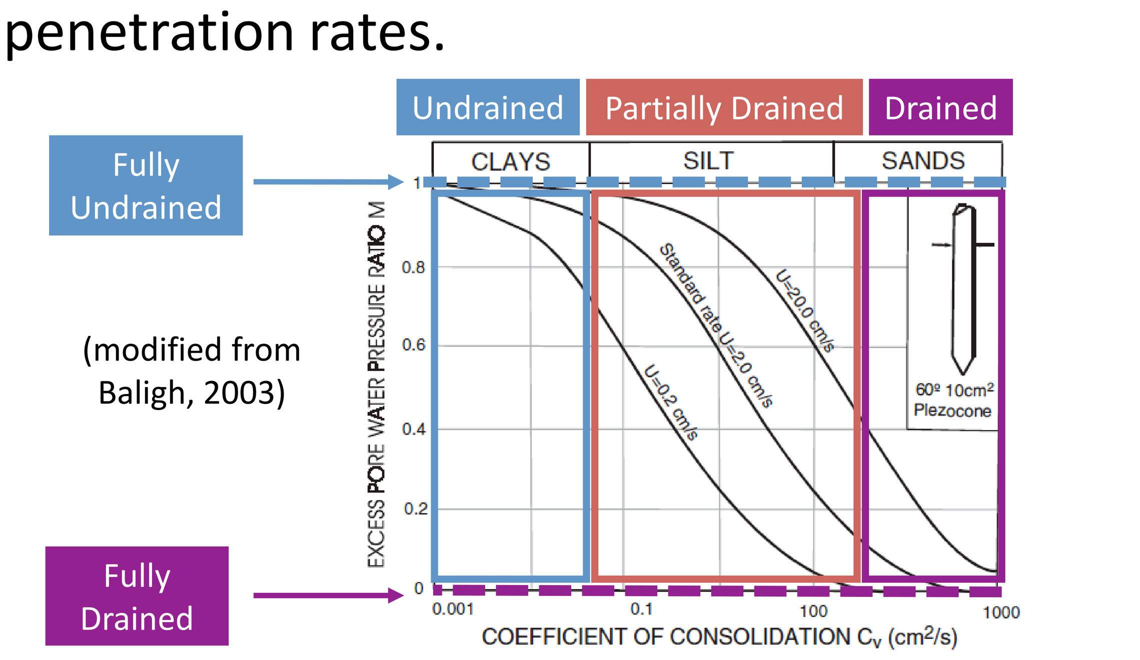


$$Q = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}} \quad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}} \quad F_r = \frac{f_s}{q_t - \sigma_{vo}}$$

Soil classification chart for cone penetration at the ASTM standard penetration rate of 2 cm/sec.

Research Approach

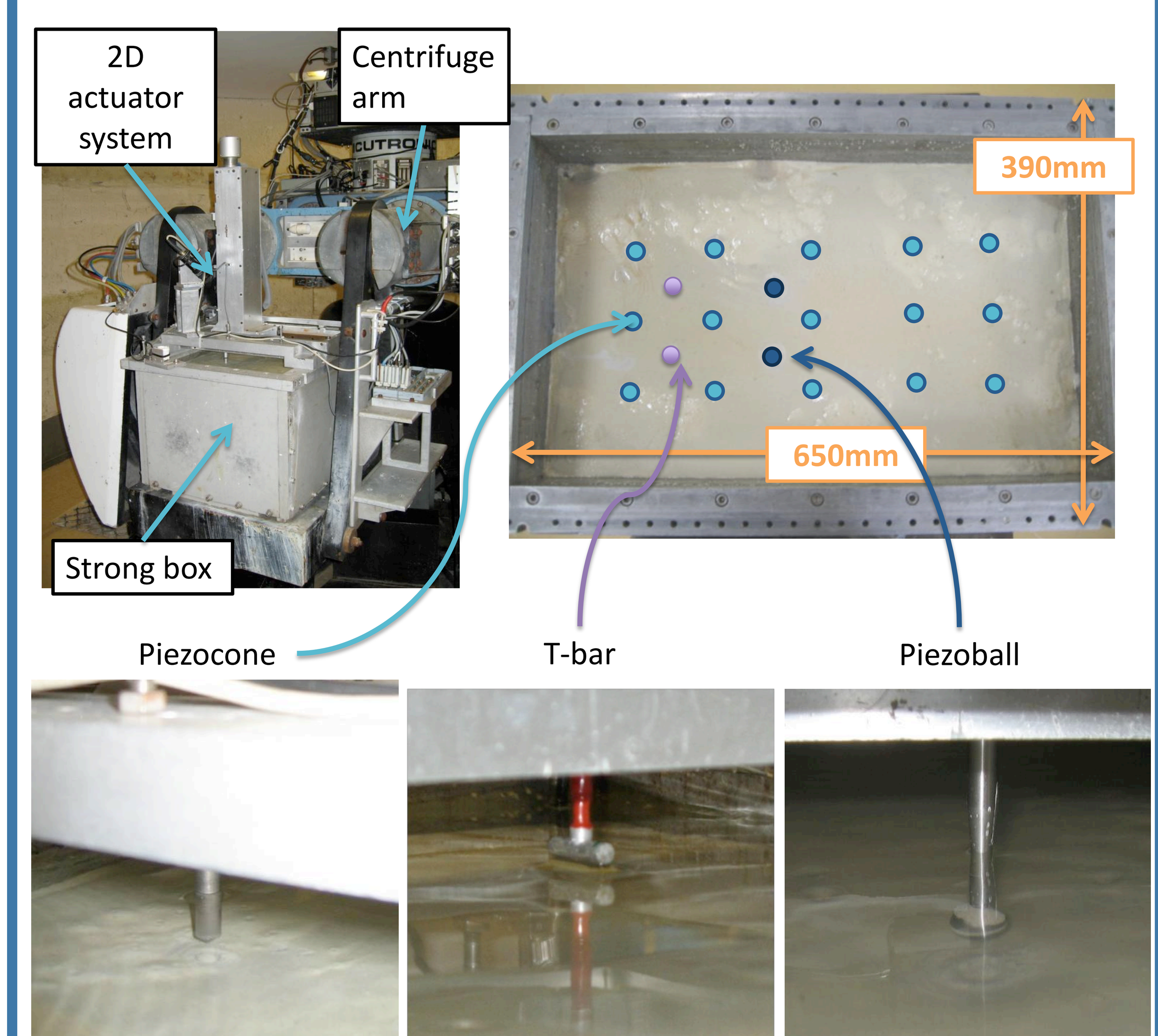
Drainage conditions during cone penetration can be controlled by varying the penetration rate (Jaeger, 2008). Drained conditions can be achieved at slow penetration rates, while undrained conditions can be achieved at fast penetration rates.



Numerical simulation of the effect of cone penetration rate on excess pore pressure ratios generated in varying soil types.

Centrifuge Experiment

A centrifuge experiment was performed at 100g in a normally consolidated intermediate soil mixture consisting of 75% sand, 25% kaolin (PI=9.5%, ϕ'=28°) at the University of Western Australia. 19 in-flight in situ tests were performed to investigate variable penetration rate in situ tests within intermediate soils.

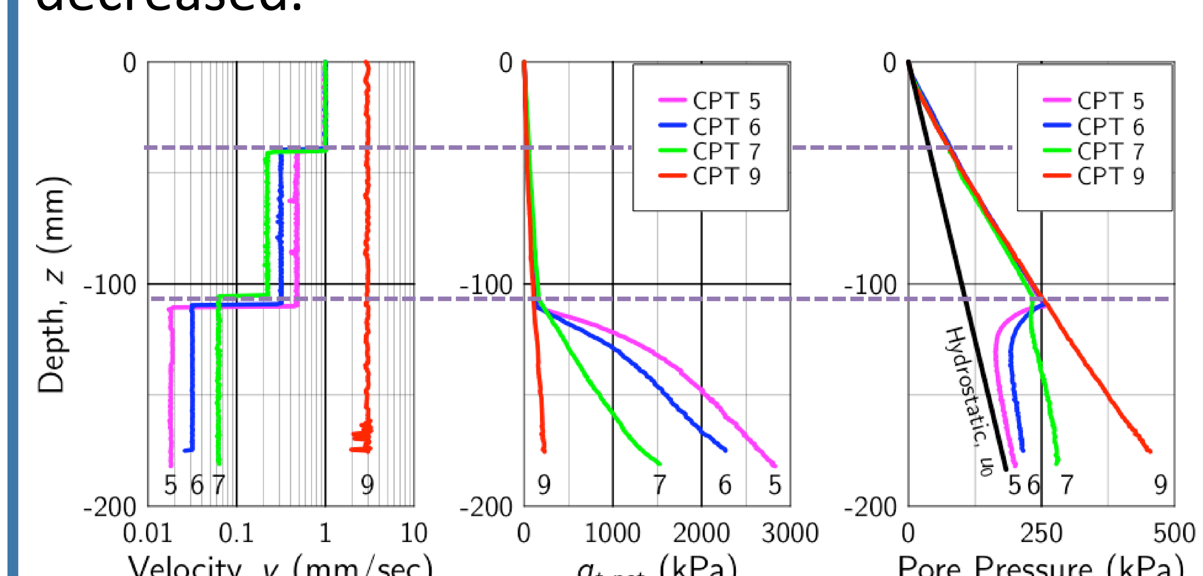


Probe	Rates (mm/sec)	Test Types	Number of Tests
CPT	0.003 - 3.0	Variable Rate	13
		Twitch	2
		Dissipation	8
T-bar	1.0 - 3.0	Cyclic	2
Ball	1.0 - 3.0	Dissipation	1
		Cyclic	1

Summary of in-flight in situ tests performed in the centrifuge experiment at UWA.

Experimental Results

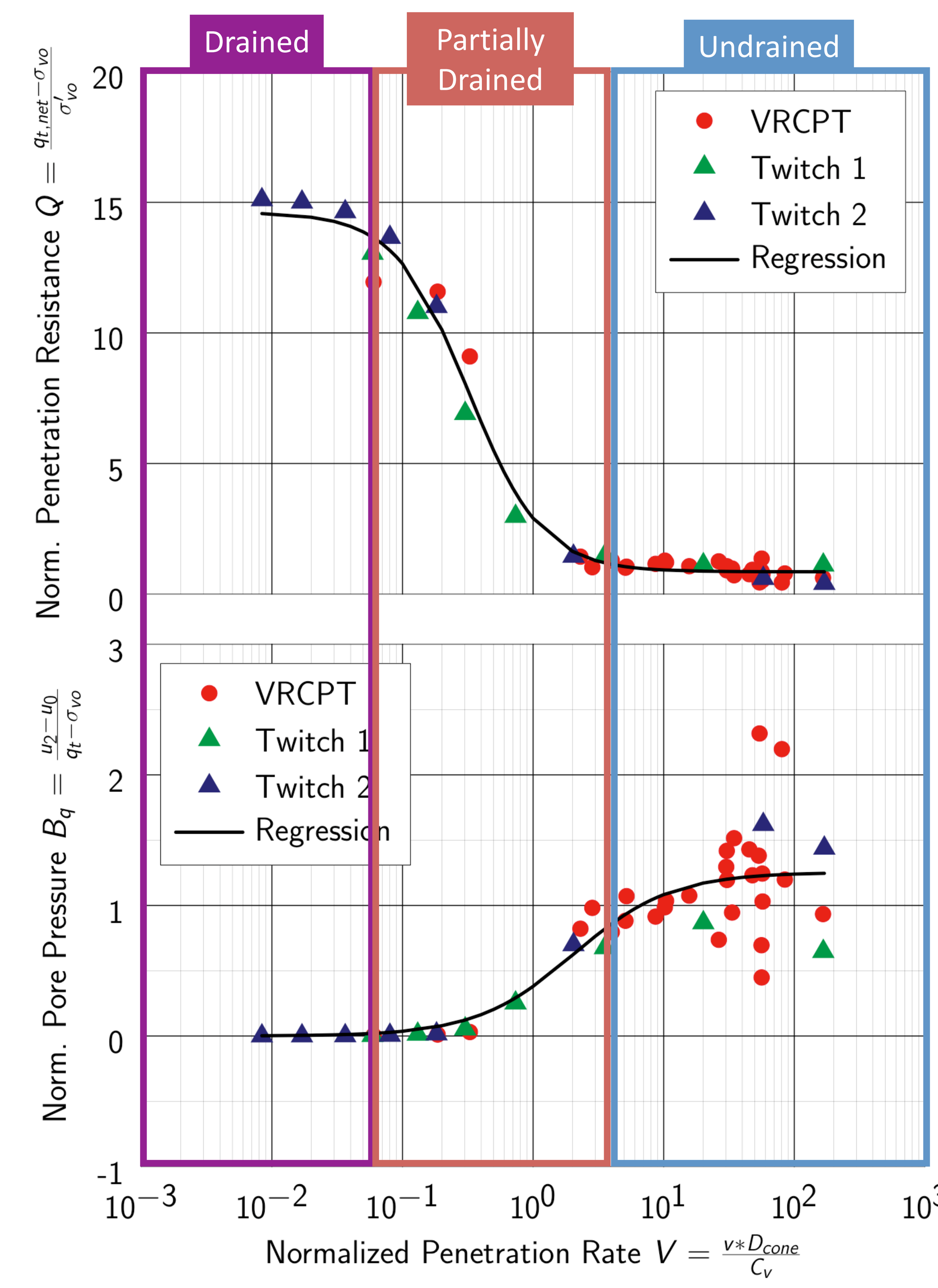
Four cone penetration test profiles from this experiment illustrate the effects of penetration rate on penetration resistance and pore pressure generation. CPT 9 is pushed rapidly to create undrained conditions. CPTs 5, 6, and 7 are initially undrained and become partially drained beyond 110 mm depth when the penetration rates are decreased.



Four cone penetration tests at varying rates illustrate the effect of penetration rate on cone penetration resistance and pore pressures.

Analysis of Results

Normalization of penetration resistance and penetration rate accounts for tests at different depths and allows different soils to be compared. Drained conditions (B_q=0) are created during slow penetration and undrained conditions are created during fast penetration.



Normalized penetration rate versus normalized penetration resistance (Q) and pore pressure parameter (B_q)

Continuing Activities

Interpreting soil properties of intermediate soils from cone penetration testing is problematic. Variable penetration rate cone penetration testing (VPRCPT) can control drainage conditions in intermediate soils. We are currently performing additional tests at the model scale and developing field testing capabilities. In the next year we will complete testing at several field sites that consist of thick deposits of intermediate soils. To compliment this we are also performing numerical simulations of VPRCPT in intermediate soils using the MIT-S1 model (Pestana, 1994).

Acknowledgements

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