Pile Design and Soil Characterization by CPTu Data-Urmiyeh Lake Causeway Site

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Contents:

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Tehran, November 2-3, 2010

4th ICGESM
Tehran, November 2-3, 2010

Laboratory Tests Problems

- Preparing undisturbed sample is very difficult
- Compressing and shearing of soil during sampling and soil disturbance
- Soil relaxation and changing in sample volume
- Omitting of confinement pressure
- Loading of samples in lab in a different condition from Site
- Size effect and size limits
- Sample transportation and maintenance
- Non continues data and measurements

In Situ Tests

- Overcome sampling difficulties
- Simple performance and fast
- Economical
- Provides continues records with depth
- Generally applicable for Foundation Engineering

Laboratory and In-Situ testings approaches are complement in Geotechnical Engineering Practice

1-In-Situ Testing in Geotechnical Engineering

Types of In Situ Tests

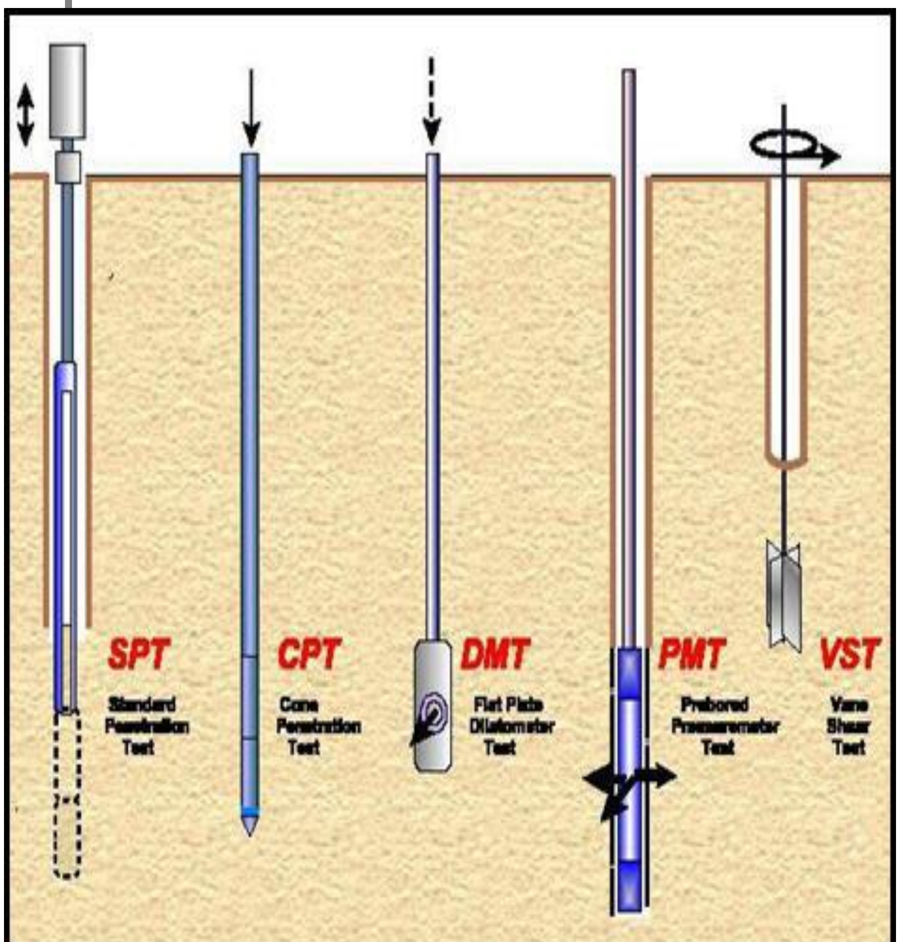

Fig.1-Type of In-Situ Tests

- Standard Penetration Test (S.P.T)
- Cone Penetration Test (C.P.T)
- Piezo Penetrometer (CPTu)
- Dilatometer (DMT)
- Persumeter (PMT)
- Vane Shear test (VST)
- Plate Load Test (PLT)

1-In-Situ Testing in Geotechnical Engineering

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The applicability and usefulness of in-situ tests

Group	Device	Soil Parameters													Ground Type						
		Soil type	Profile	u	$*\varphi'$	s_u	I_D	m_v	c_v	k	G_0	σ_h	OCR	σ-ε	Hard rock	Soft rock	Gravel	Sand	Silt	Clay	Peat
Penetrometers	Dynamic	C	B	-	C	C	C	-	-	-	C	-	C	-	-	C	B	A	B	B	B
	Mechanical	B	A/B	-	C	C	B	C	-	-	C	C	C	-	-	C	C	A	A	A	A
	Electric (CPT)	B	A	-	C	B	A/B	C	-	-	B	B/C	B	-	-	C	C	A	A	A	A
	Peizocone (CPTU)	A	A	A	B	B	A/B	B	A/B	B	B	B/C	B	C	-	C	-	A	A	A	A
	Seismic (SCPT/SCPTU)	A	A	A	B	A/B	A/B	B	A/B	B	A	B	B	B	-	C	-	A	A	A	A
	Flat dilatometer (DMT)	B	A	C	B	B	C	B	-	-	B	B	B	C	C	C	-	A	A	A	A
	Standard penetration test (SPT)	A	B	-	C	C	B	-	-	-	C	-	C	-	-	C	B	A	A	A	A
	Resistivity probe	B	B	-	B	C	A	C	-	-	-	-	-	-	-	C	-	A	A	A	A
Pressuremeters	Pre-bored (PBP)	B	B	-	C	B	C	B	C	-	B	C	C	C	A	A	B	B	B	A	B
	Self boring (SBP)	B	B	A[1]	B	B	B	B	A[1]	B	A[2]	A/B	B	A/B[2]	-	B	-	B	B	A	B
	Full displacement (FDP)	B	B	-	C	B	C	C	C	-	A[2]	C	C	C	-	C	-	B	B	A	A
Others	Vane	B	C	-	-	A	-	-	-	-	-	-	B/C	B	-	-	-	-	-	A	B
	Plate load	C	-	-	C	B	B	B	C	C	A	C	B	B	B	A	B	B	B	A	A
	Screw plate	C	C	-	C	B	B	B	C	C	A	C	B	-	-	-	-	A	A	A	A
	Borehole permeability	C	-	A	-	-	-	-	B	A	-	-	-	-	A	A	A	A	A	A	B
	Hydraulic fracture	-	-	B	-	-	-	-	C	C	-	B	-	-	B	-	-	-	-	A	C
	Crosshole/downhole/surface seismic	C	C	-	-	-	-	-	-	-	A	-	B	-	A	A	A	A	A	A	A

Applicability: A = high, B = moderate, C = low, - = none

$*\varphi'$ = Will depend on soil type; [1] = Only when pore pressure sensor fitted; [2] = Only when displacement sensor fitted.

Soil parameter definitions: u = *In situ* static pore pressure; φ' = effective internal friction angle; s_u = undrained shear strength; I_D = density index; m_v = constrained modulus; c_v = coefficient of consolidation; k = coefficient of permeability; G_0 = shear modulus at small strains; σ_h = horizontal stress; OCR = overconsolidation ratio; σ-ε = stress-strain relationship

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2-CPT and CPTu

Cone Penetrometer (CPTu) Probes

Fig.2-Type of CPT and CPTu Probes

- **Electronic Steel Probes with 60° Apex Tip**
- **ASTM D 5778 Procedures**
- **H No Boring, No Samples, No Cuttings, No Spoil**
- **Hydraulic Push at 20 mm/s**
- **Continuous readings of stress, friction, pressure**

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Terminology of Cone Penetrometer

- Cone penetrometer come in a range of sizes with the 10 cm^2 and 15 cm^2 probes the most common and specified in most standards.

- CPT's can be performed to depths exceeding 100m in soft soils and with large capacity pushing equipment.

Test Procedures

-Pre-drilling

-Verticality

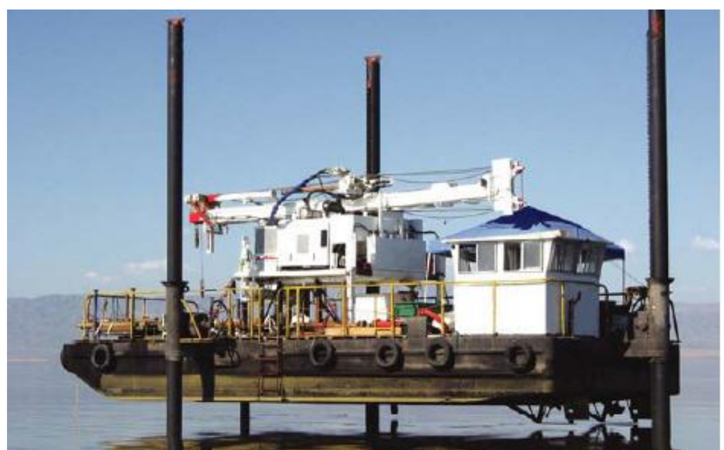
-Rate of Penetration= 2 cm/sec

Fig.3 Range of CPT probes (from left: 2 cm^2, 10 cm^2, 15 cm^2, 40 cm^2)

2-CPT and CPTu

Cone Trucks

Fig.4-Different Types of Cone Trucks



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Standards and References:

1) ***ASTM****: Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils (1995)*

2) **SWEDISH GEOTECHNICAL SOCIETY (SGF):** *Recommended Standard for Cone Penetration Test* (1993)

3) **NORWEGIAN GEOTECHNICAL SOCIETY (NGF)**: *Guideline for Cone Penetration Tests(1994)*

4) ISSMFE: *International Reference Test Procedure Cone Penetration Test (CPT) (1989)*

5) DUTCH STANDARD: *Determination of the Cone Resistance and Sleeve Friction of Soil NEN5140* (1996)

Conferences and Issues

*1-**ESOPT**(European Symposium)*

*2-**ISOPT**(International Symposium)*

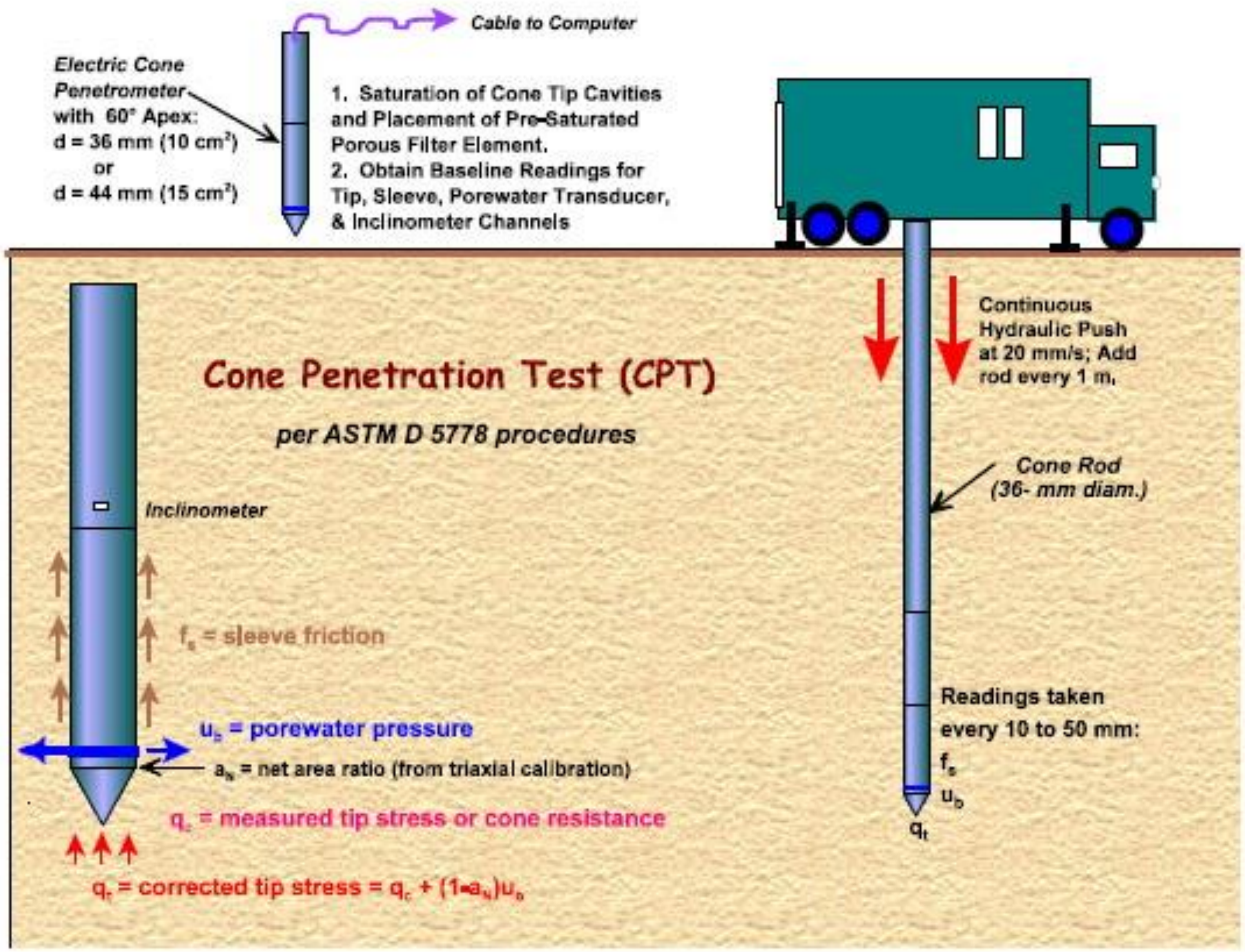
***3-CPT`95-** International Symposium on Cone Penetration Testing, Linkoping, Sweden*

***4- Site Characterization**, 2006*

***5-CPT`10-**Second International Symposium on Cone Penetration Testing, California, USA, May 2010*

2-CPT and CPTu

CPTu Performance



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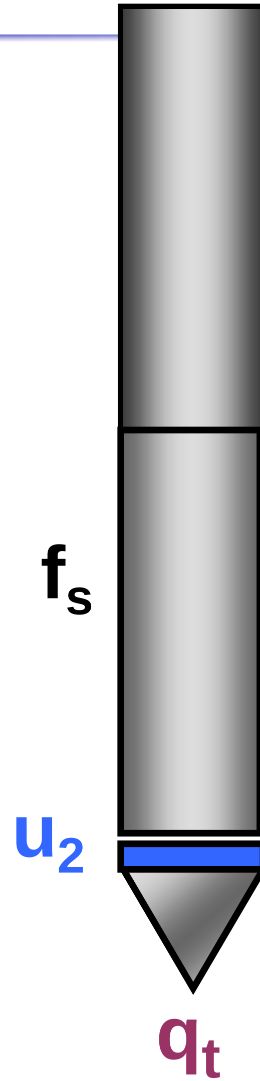
2-CPT and CPTu

CPTu data



Cone Resistance (q_t)

Friction Resistance (f_s)

Pore Pressure (u_2)

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2-CPT and CPTu

Typical CPTu Profile

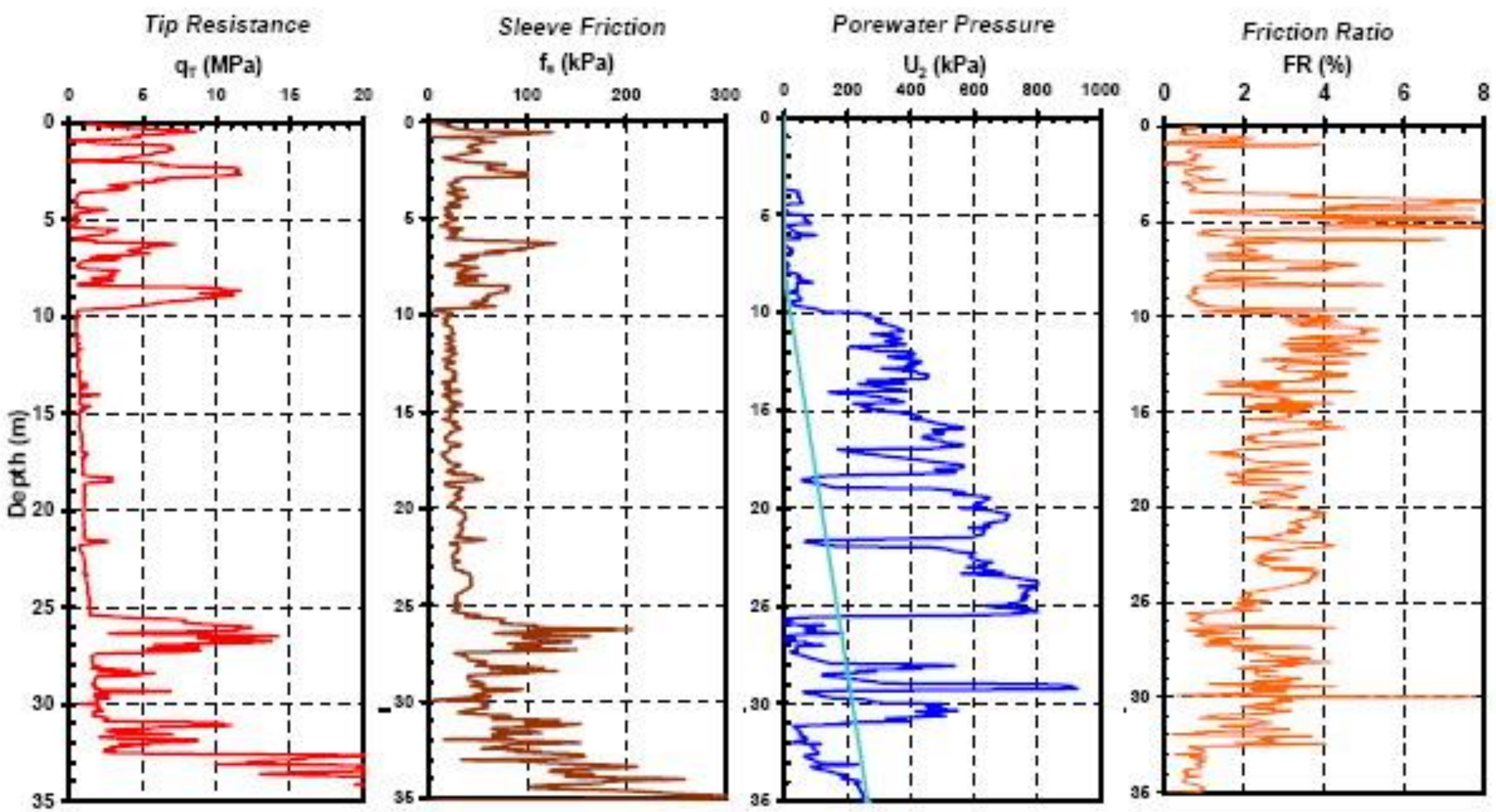

Fig.5: CPTu Profile

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The Advantages and Disadvantageous of CPTu Test

Advantages of CPT:

- Fast and continuous profiling
- Repeatable and reliable data (not operator-dependent)
- Economical and productive
- Strong theoretical basis for interpretation

Disadvantage of CPT:

- High capital investment
- Requires skilled operators
- No soil sample
- Penetration can be restricted in gravel/cemented layers

CPT and CPTu Interpretation

Soil Type	D_r	Ψ	K_o	OCR	S_t	s_u	ϕ'	E,G*	M	G_0*	k	c_h
Sand	2-3	2-3		5			2-3	2-3	2-3	2-3	3	3-4
Clay			2	1	2	1-2	4	3-4	2-3	3-4	2-3	2-3

1=high, 2=high to moderate, 3=moderate, 4=moderate to low, 5=low reliability, Blank=no applicability, * improved with SCPT

Where:

D_r	Relative density	ϕ'	Friction angle
Ψ	State Parameter	K_0	In-situ stress ratio
E, G	Young's and Shear moduli	G_0	Small strain shear moduli
OCR	Over consolidation ratio	M	Compressibility
s_u	Undrained shear strength	S_t	Sensitivity
c_h	Coefficient of consolidation	k	Permeability

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Applications of CPT and CPTu Data in Pile Design

Because of similarities between the cone penetrometer and a pile, the **penetrometer can be considered as a model pile.** Several methods have been proposed to predict the pile capacity from CPT and CPTU data.

1- Direct approaches:

$$\begin{cases} fs \Rightarrow rs \\ qc \Rightarrow rt \end{cases}$$

2- Indirect approaches:

$$qc\ fs \Rightarrow C,\phi \Rightarrow q_{ult}$$

3-Pile Design by CPT and CPTu

CPT Based methods in Pile Design

No.	Method	Reference
1	"Dutch" CPT	Van Mierlo and Koppejan, 1952
2	Begmann	Begemann, 1963
3	Mohan and Kumar	Mohan and Kumar, 1963
4	Senneset	Senneset, 1974
5	Rodin et al.	Rodin, Cobett, Sherwood, and Thorburn, 1974
6	Meyerhof	Meyerhof, 1956; 1976; 1983
7	Schmertmann and Nottingham	Nottingham, 1975; Schmertmann, 1978
8	European	De Ruiter and Beringen, 1979
9	Tumay and Fakhroo	Tumay and Fakhroo, 1981
10	French; LCPC (Laboratoire Central des Ponts et Chausees)	Bustamante and Gianeselli, 1982
11	Zhou et al.	Zhou et al., 1982
12	Gwizdala	Gwizdala, 1984
13	Van Impe	Van Impe, 1988
14	The New Euro Code	"Eurocode 7-Part 1" (ENV 1997-1993) and French Highway Administration (MELT, 1993) Frank, 1994

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3-Pile Design by CPT and CPTu

Summary of Currently Used CPT and CPTu Methods

Current CPT & CPTu Methods	Unit Toe Resistance r_t	Unit Shaft Resistance r_s	Note
Schmertmann & Nottingham(1978)	$r_t = C_t q_{ca}$	$r_s = C_s q_c$ $r_s = K f_s$	C_s= 0.8~1.8% Clay & Sand K=0.8~2 Sand , K=0.2~1.25 Clay
Beringen & De Ruiter (1979)	$r_t = N_c S_u$	$r_s = C_s q_c$ & $r_s = K f_s$ $r_s = \alpha S_u$	K=1 , C=0.3% sand α=1 for NC , α=0.5 for OC Clay
Bustamante & Gianeselli (1982)	$r_t = C_t q_{ca}$	$r_s = C_s q_c$	C_t=0.4~0.55 C_s=0.3%
Tumay & Fakhroo (1982)	$r_t = C_t q_{ca}$	$r_s = k f_s$	C_s= 0.8~1.8% Clay & Sand $k = 0.5 + 9.5e^{(-0.009 f_s)}$
Eslami & Fellenius (1997)	$r_t = C_t q_{Eg}$	$r_s = C_s q_{Eg}$	C_t=1 C_s=(0.3~8)%

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3-Pile Design by CPT and CPTu

Schmertmann method, 1978

The Schmertmann and Nottingham method is based on a summary of the work on model and full-scale piles presented by Nottingham (1975) and Schmertmann (1978).

$$r_t = C_{OCR} . q_c$$

$$r_s = K . f_s$$

$$r_s = C . q_c$$

The extent of the influence zone depends on the trend of the qc values and follows recommendations by Begemann (1963), who based the one extent on an assumed logarithmic spiral failure pattern for the pile toe.

3-Pile Design by CPT and CPTu

European method , 1978

The European method (DeRuiter and Beringen 1979) is based on experience gained from offshore construction in the North Sea. For unit toe resistance of a pile in sand, the method is the same as the Schmertmann and Nottingham method. In clay, the unit toe resistance is determined from total stress analysis

$$r_t = N_c . S_u$$

$$S_u = {q_c}/{N_k}$$

$$r_s = \alpha . S_u$$

3-Pile Design by CPT and CPTu

French method, 1982

The *French method (Bustamante and Gianeselli 1982) is* based on experimental work by Laboratoire Central des Pontset Chausees (LCPC). The sleeve friction, *fs, is neglected and* the unit toe and unit shaft resistances are both determined from the average cone resistance, *qc*. analysis

3-Pile Design by CPT and CPTu

Tumay and Fakhroo method, 1982

The *Tumay and Fakhroo method (Tumay and Fakhroo 1981)* is based on an experimental study in clay soils in Louisiana. The unit toe resistance is determined the same way as in the Schmertmann and Nottingham method

$$\boxed{K = 0.5 + 9.5e^{-0.09 f_s}}$$

3-Pile Design by CPT and CPTu

Eslami-Fellenius method, 1997

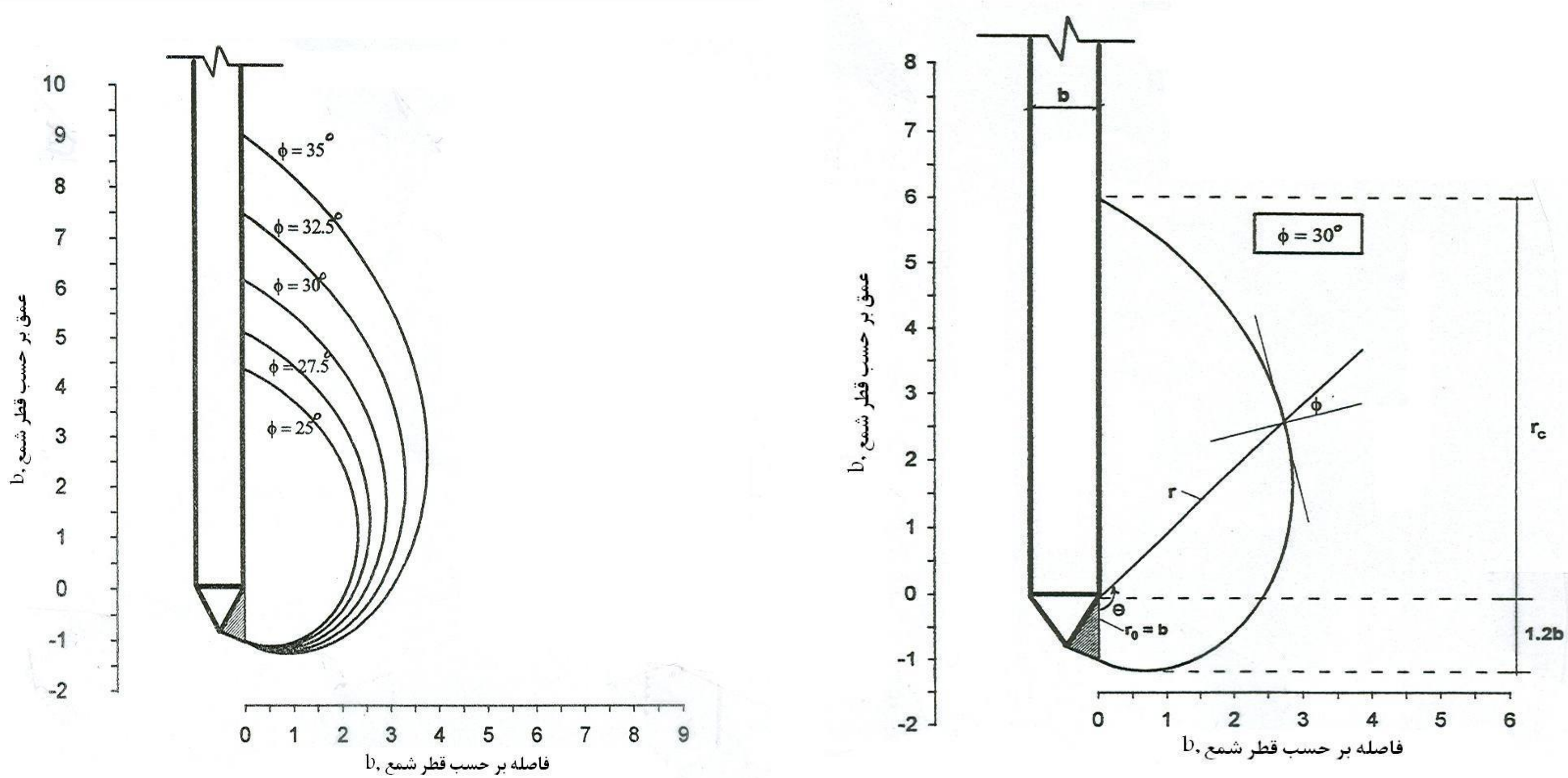
The Eslami and Fellenius CPTu method (1997) has been developed based on the piezocone. In contrast to the five other methods, the data are unfiltered and no minimum path is used. Instead, the potential disproportionate influence of odd “peaks and troughs” is reduced by means of employing the geometric average of the cone point resistance as opposed to the arithmetic average used by the current CPT methods.

$$r_t = C_t \cdot q_{Eg}$$

$$r_s = C_s \cdot q_E$$

3-Pile Design by CPT and CPTu

Influence and Failure Zone



Geometric average of cone resistance *qc for different size zones*

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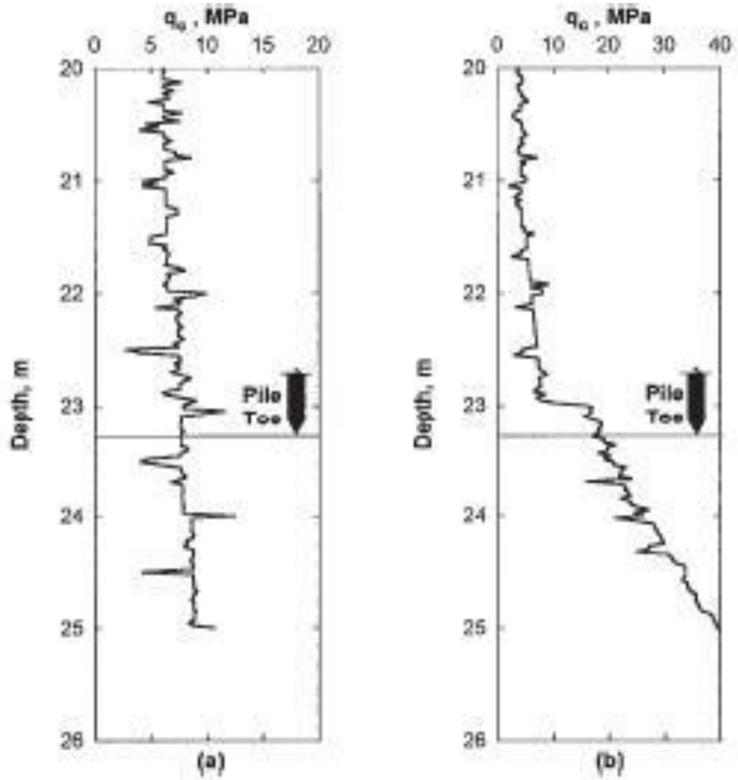
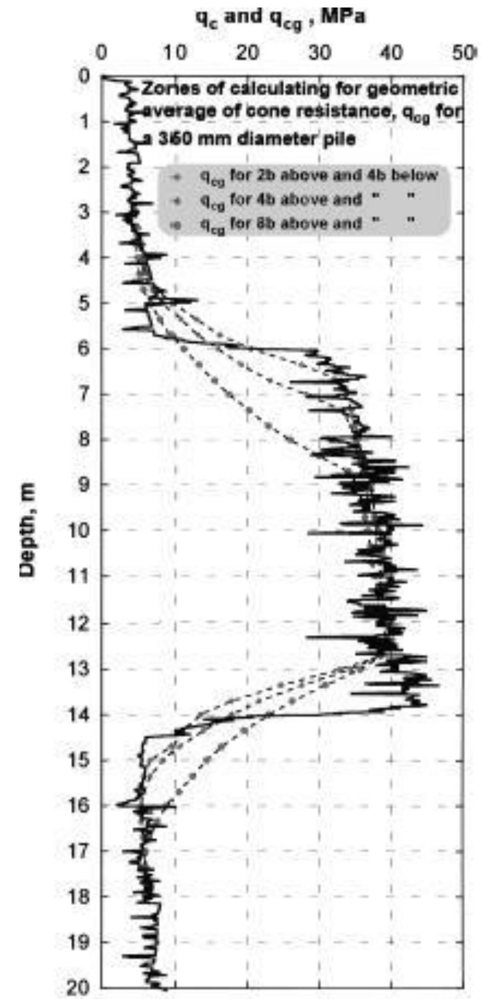
3-Pile Design by CPT and CPTu

Data Processing and Scale Effect





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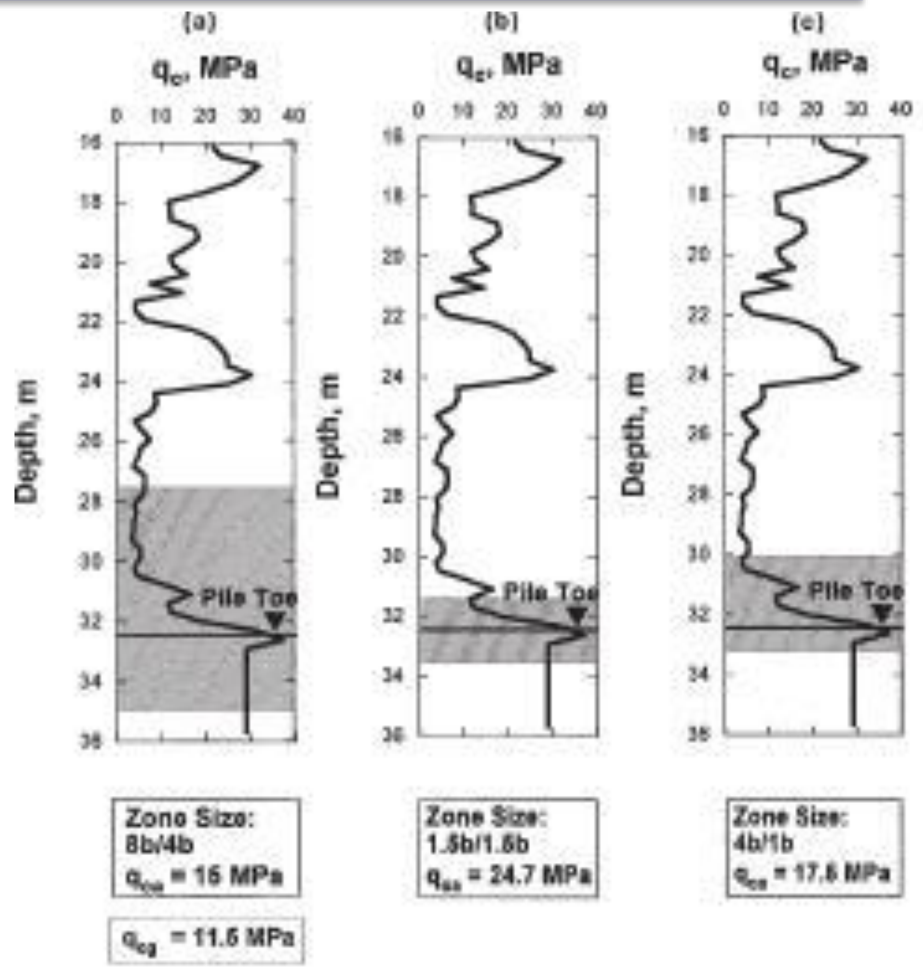
3-Pile Design by CPT and CPTu

Data Processing and Scale Effect (Count.)



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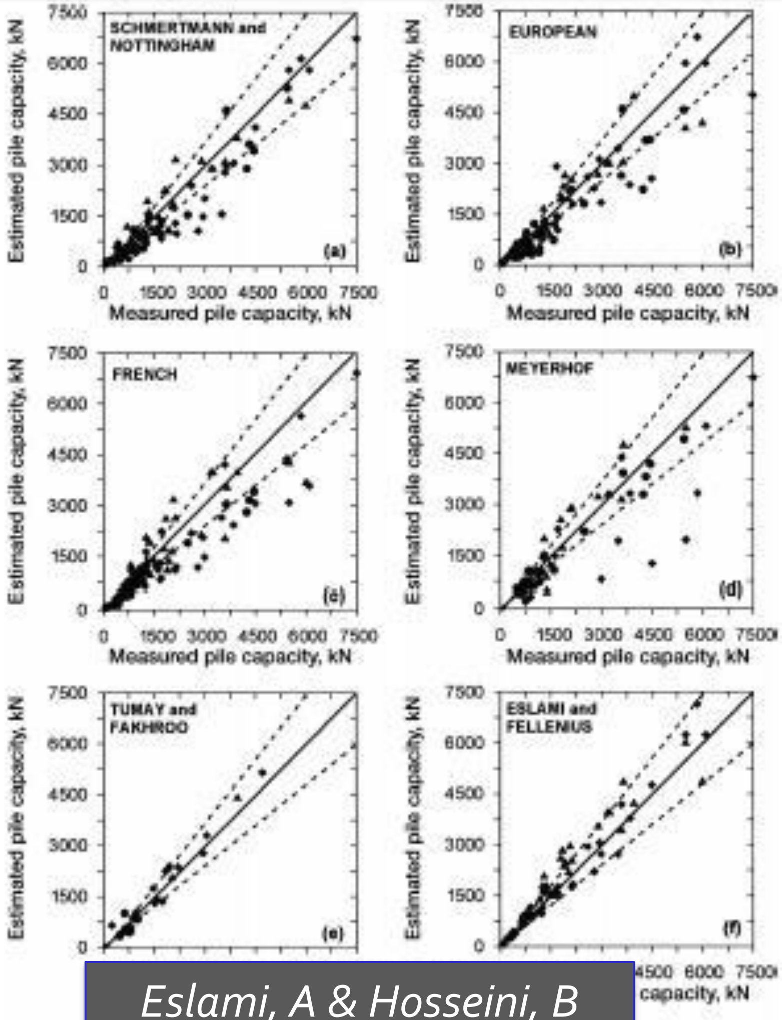
3-Pile Design by CPT and CPTu

Data Base Including 102 Pile Case Histories

Predictive Methods Comparison



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Generals

- The major application of the CPT is for *soil profiling and soil type*.

- Typically, the cone resistance, (qt) is high in sands and low in clays, and the friction ratio (Rf = fs/qt) is low in sands and high in clays.

- CPT charts cannot be expected to provide accurate predictions of soil type based on grain size distribution but provide a guide to the mechanical characteristics of the soil, or the *soil behavior type*.

4-Soil Profiling by Cone Penetrometer

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Begemann,1963

Begemann,1963 pioneered soil profiling from the CPT, showing that, while Coarse grained soils generally demonstrate larger values of cone resistance, q_c, and sleeve friction, f_s, than do fine grained soils, the soil type is not a strict function of either cone resistance or sleeve friction, but of the combination of the these values

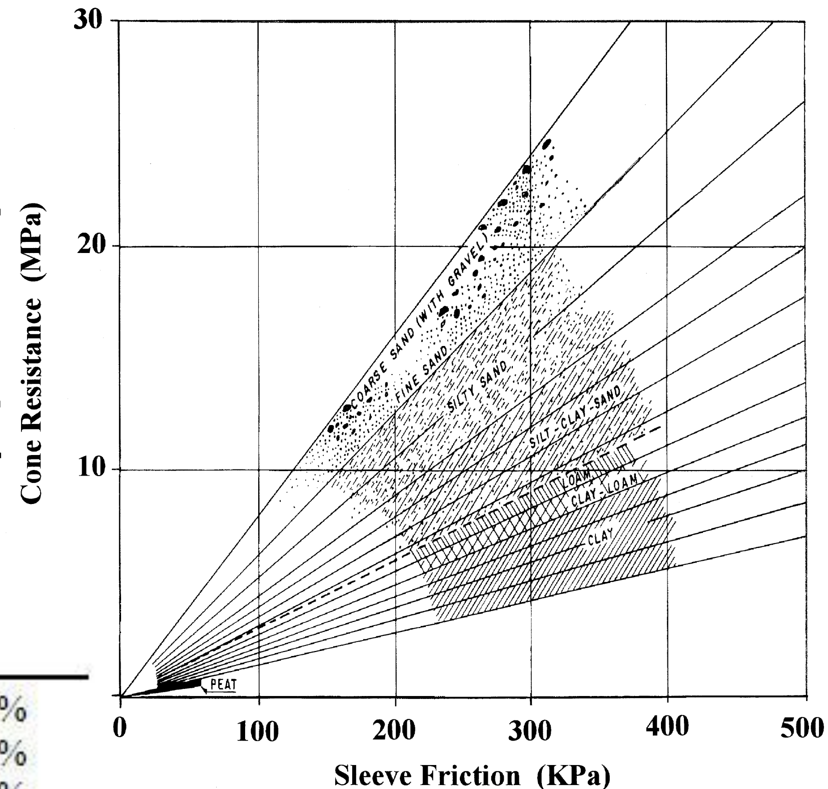

Fig-6:The Begemann original profiling chart

Soil Type as a Function of Friction Ratio (Begemann)

Coarse sand with gravel through fine sand	1.2 %	-	1.6 %
Silty sand	1.6 %	-	2.2 %
Silty sandy clayey soils	2.2 %	-	3.2 %
Clay and loam, and loam soils	3.2 %	-	4.1 %
Clay	4.1 %	-	7.0 %
Peat			>7 %

Sanglerat et al., 1974

Sanglerat et al., proposed the chart shown in the Figure presenting data from an 80 mm diameter research penetrometer. The chart plots the cone resistance (logarithmic scale) versus the friction ratio (linear scale).

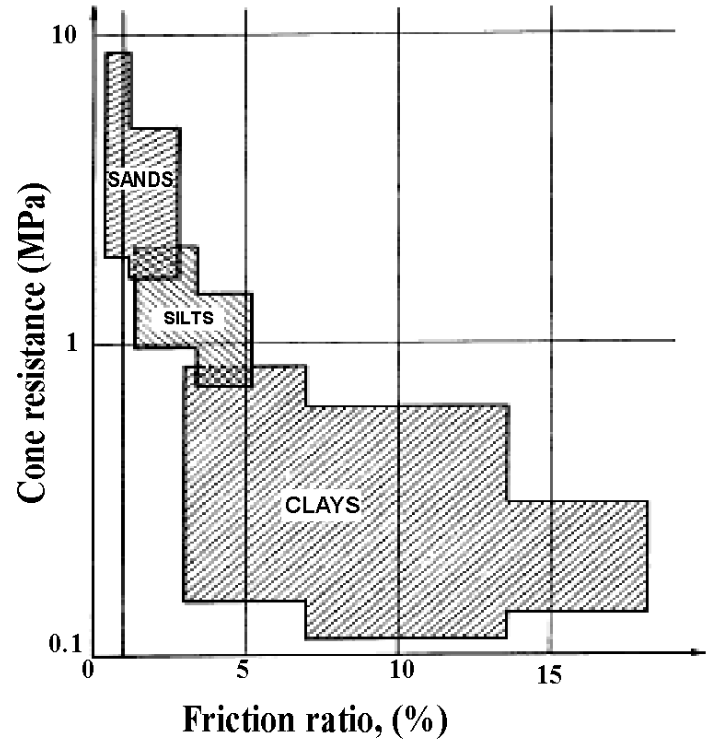

Fig.7 Plot of data from research penetrometer (Sanglerat et al.)

Schmertmann, 1978

Schmertmann,1978 proposed the soil profiling chart shown in the Figure. The chart is based on results from mechanical cone data in "North Central Florida" and incorporates Begemann's CPT data and indicates zones of common soil type.

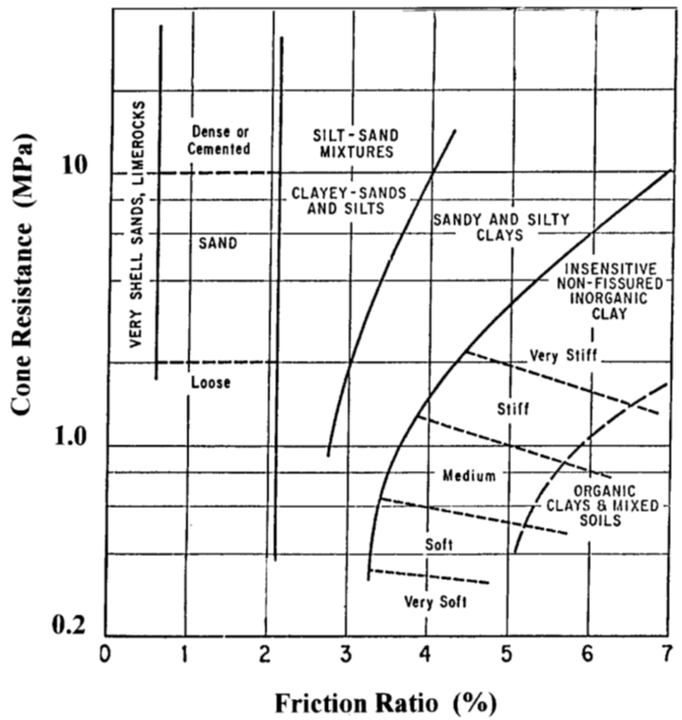

Fig.8-The Schmertmann profiling chart (Schmertmann)

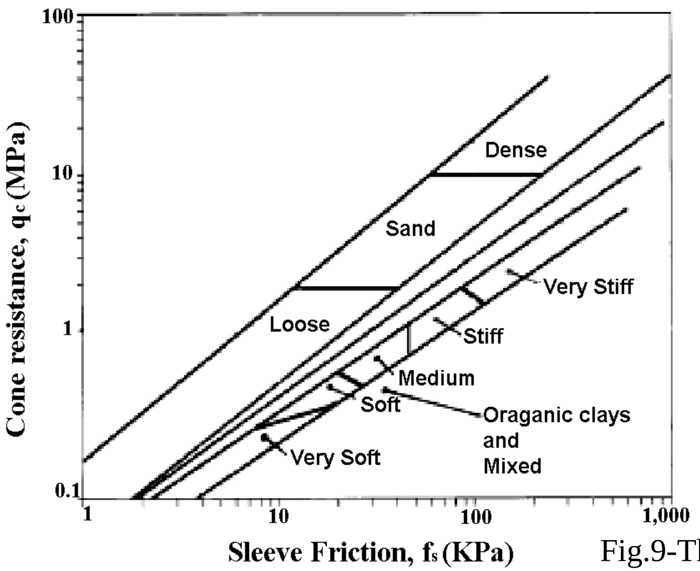

Fig.9-The Schmertmann profiling chart converted to a Begemann type profiling chart

4-Soil Profiling by Cone Penetrometer

Searle, 1979

Searle presented a CPT profiling chart shown in the Fig. Also this chart is based on mechanical cone penetrometer data. In addition to separation on soil type, the chart details areas for relative density, undrained shear strength, and friction angle, suggesting that, these values are functions of both cone resistance and friction ratio.

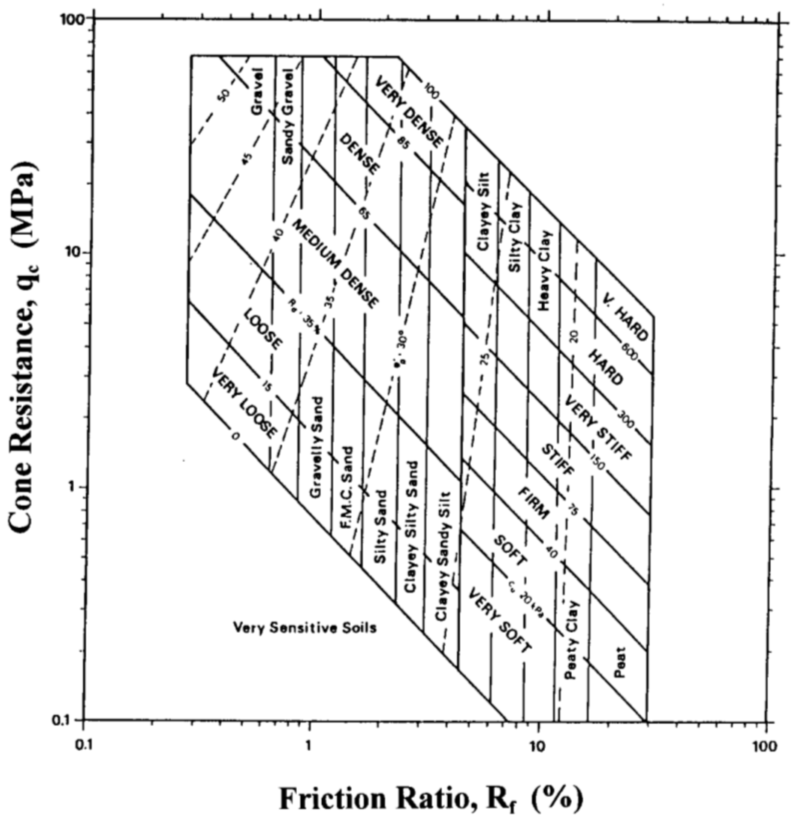

Fig.10:Profiling chart per Searle

4-Soil Profiling by Cone Penetrometer

Douglas and Olsen, 1981

Douglas and Olsen, 1981 were the first to propose a soil profiling chart based on tests with the electrical cone penetrometer. They published the chart shown in the Figure, which appends classification per the unified soil classification system to the soil type zones.

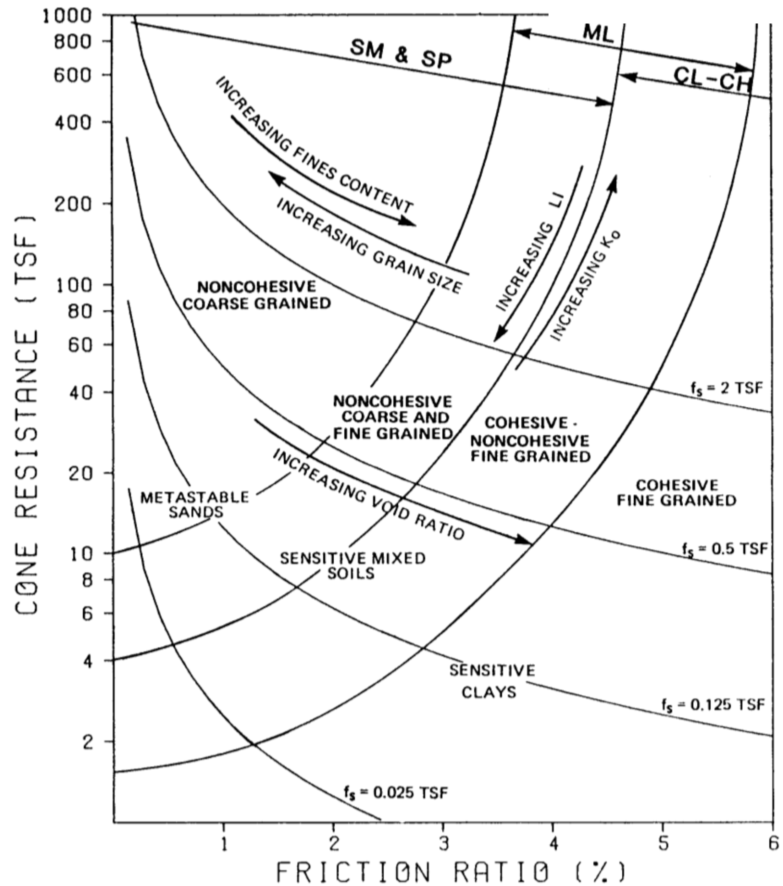

Fig.11:Profiling chart per Douglas and Olsen

4-Soil Profiling by Cone Penetrometer

Vos, 1982

Vos, 1982, suggested using the electrical cone penetrometer for Dutch soils to identify soil types from the friction ratio, as shown below. The percentage values are similar but not identical to those recommended by Begemann

Soil Type as a Function of Friction Ratio (Vos)

Coarse sand and gravel	<0.5%		
Fine sand	1.0 %	-	1.5 %
Silt	1.5 %	-	3.0 %
Clay	3.0%	-	5.0%
Clay	4.1 %	-	7.0 %
Peat			>5 %

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4-Soil Profiling by Cone Penetrometer

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Jones and Rust, 1982

Jones and Rust, 1982 developed the soil profiling chart shown in the Fig. 7, which is based on the piezocone using the measured total cone resistance and the measured *excess* pore water pressure mobilized during cone advancement. The chart presents the excess pore water pressure plotted against net cone resistance, in which total overburden stress subtracted from total cone resistance.

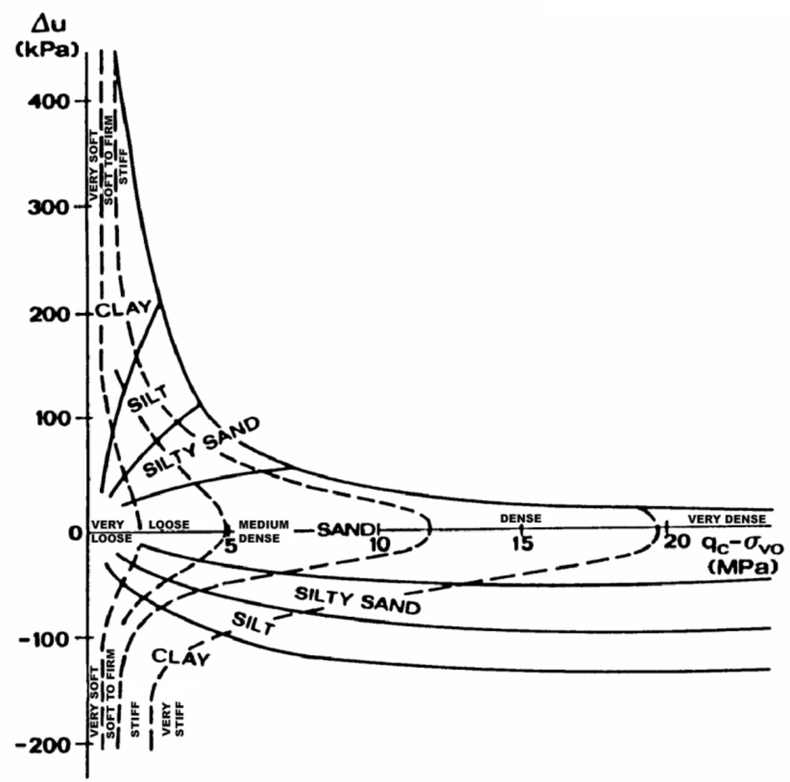

Fig.12:Profiling chart per Jones and Rust

4-Soil Profiling by Cone Penetrometer

Robertson and Campanella, 1982

Robertson and Campanella proposed the profiling chart shown in Fig which is very similar to that shown in the Fig. (Douglas and Olsen)

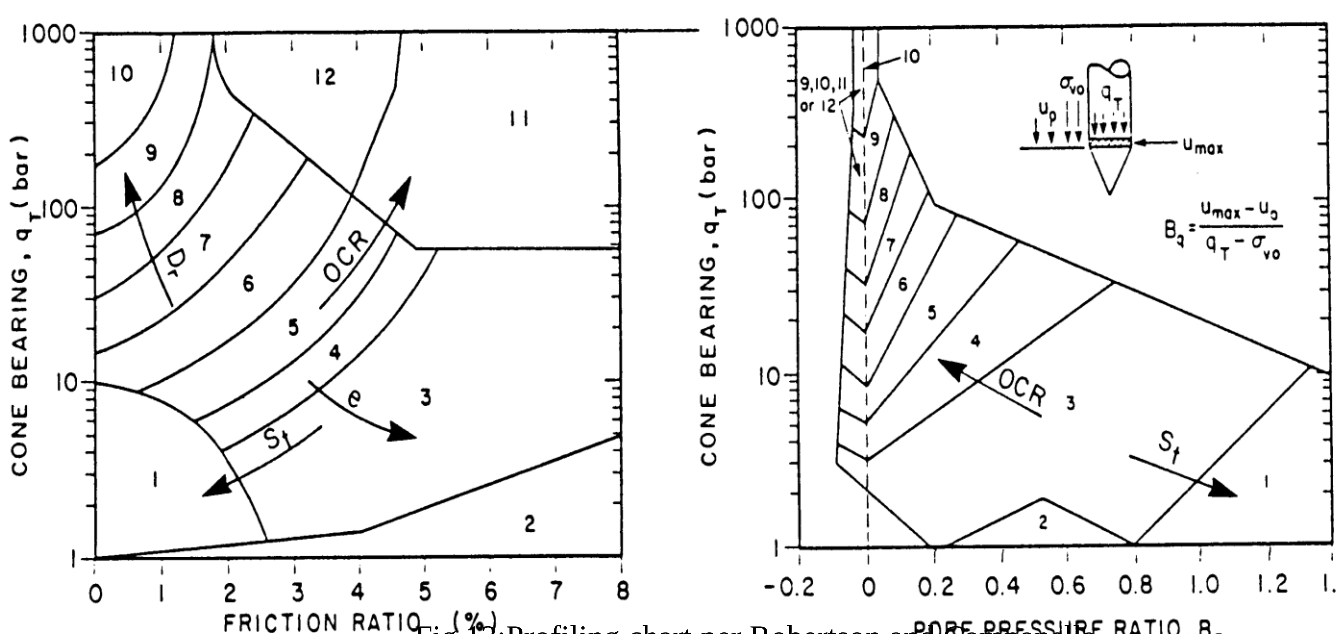

Fig.13:Profiling chart per Robertson and Campanella

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4-Soil Profiling by Cone Penetrometer

Senneset et al., 1989

Senneset et al., 1989 produced a soil classification chart based on plotting corrected cone resistance, q_t , against pore pressure ratio, B_q, as shown in Fig. The chart is limited to the area where q_t is smaller than 16 MPa. It identifies limits of density and consistency (dense, stiff, soft, etc.) that appear to be somewhat lower than those normally applied in North American practice

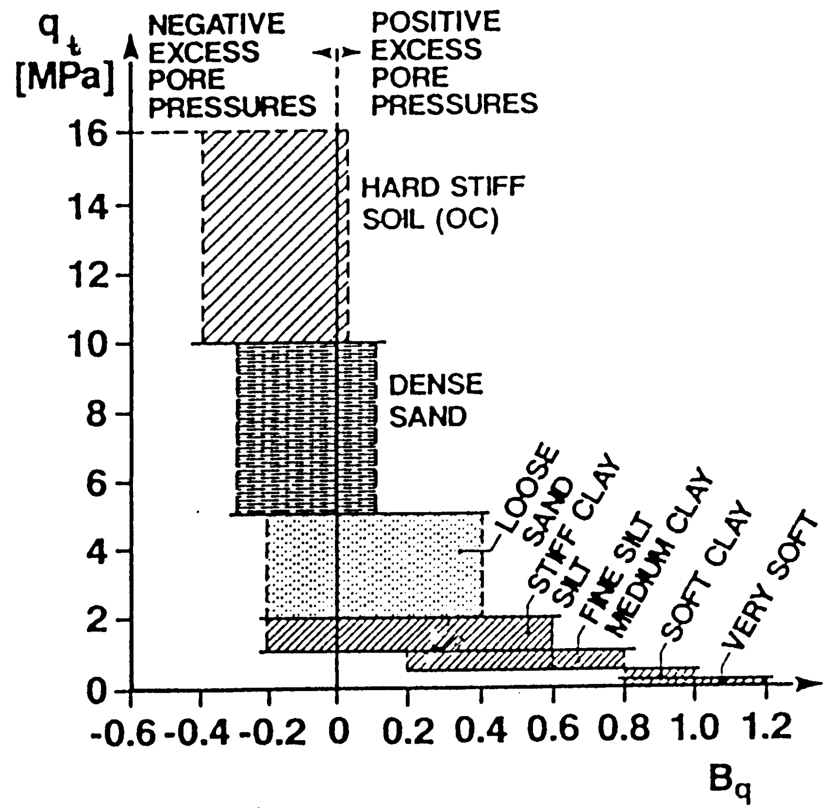

Fig.14:Profiling chart per Senneset et al.

4-Soil Profiling by Cone Penetrometer

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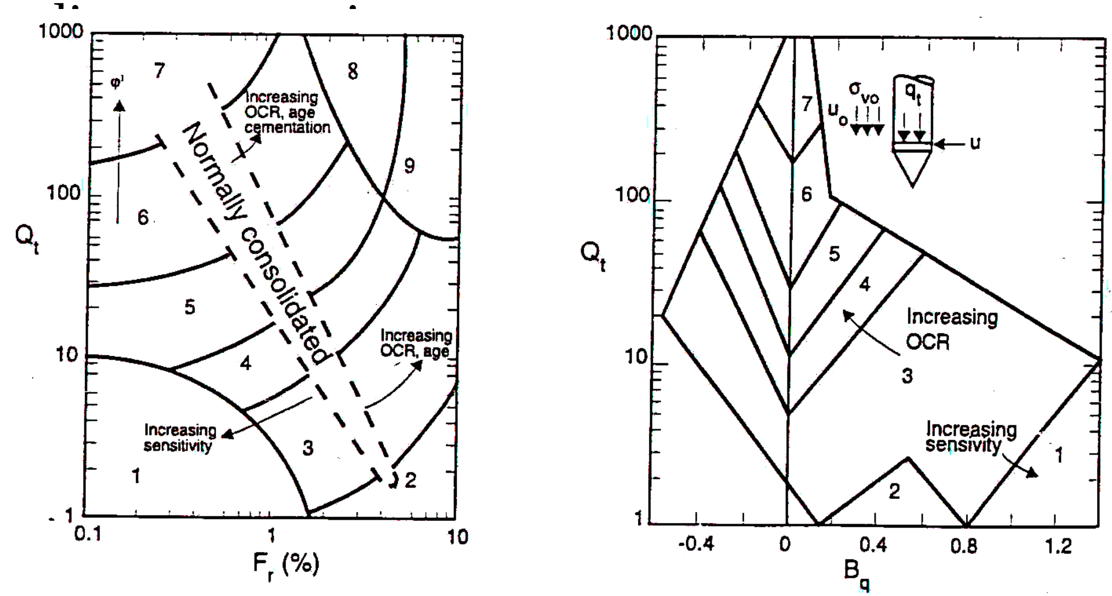
Robertson, 1990

Robertson et al., and **Campanella and Robertson** were the first to present a chart based on the piezocone with the cone resistance corrected for pore pressure at the shoulder acc



$Q_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}}$ $B_q = \frac{u_2 - u_o}{q_t - \sigma_{vo}}$ $F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$

Fig.15:Profiling chart per Robertson

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Larsson and Mulabdic , 1991

Larsson and Mulabdic, 1991 investigated sensitive clay soils using piezocone data. The data contain a maximum cone stress, q_t,of about 4 Mpa with a large number of data points smaller than q_t =1 MPa. Such soils are very difficult to positively identify from cone data as to their being clay or slit. Larsson and Mulabdic studied the data in terms of q_t versus B_{q}.

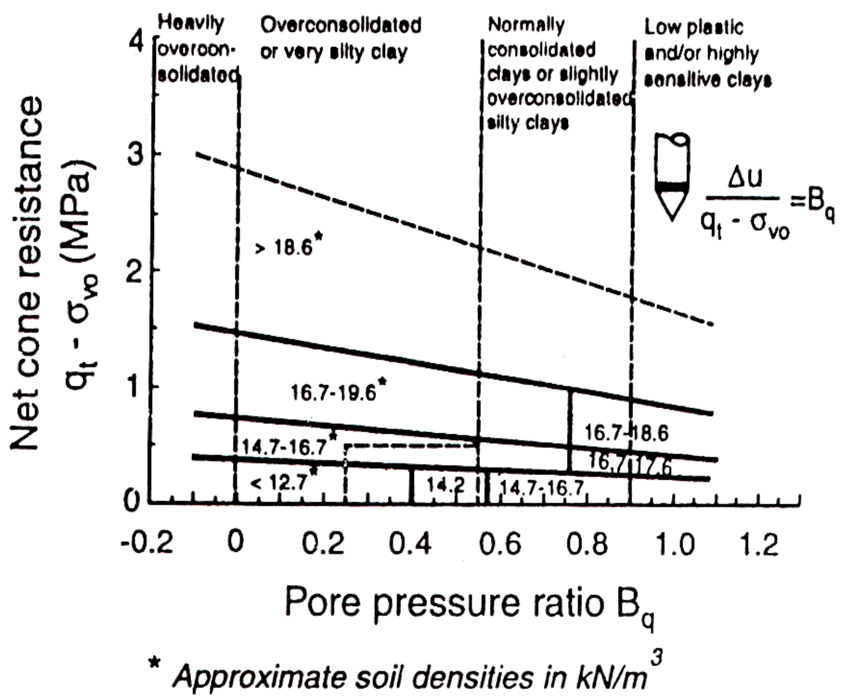


Fig.16:Profiling chart per Larson and Mulabdic

4-Soil Profiling by Cone Penetrometer

Jefferies and Davies, 1991

Jefferies and Davies, 1991 proposed a soil profiling chart for use with piezocone data, plotting a "corrected cone resistance" versus the "normalized friction ratio "as shown in Fig... The "corrected cone resistance" is the normalized cone resistance, Q_{cnrm},

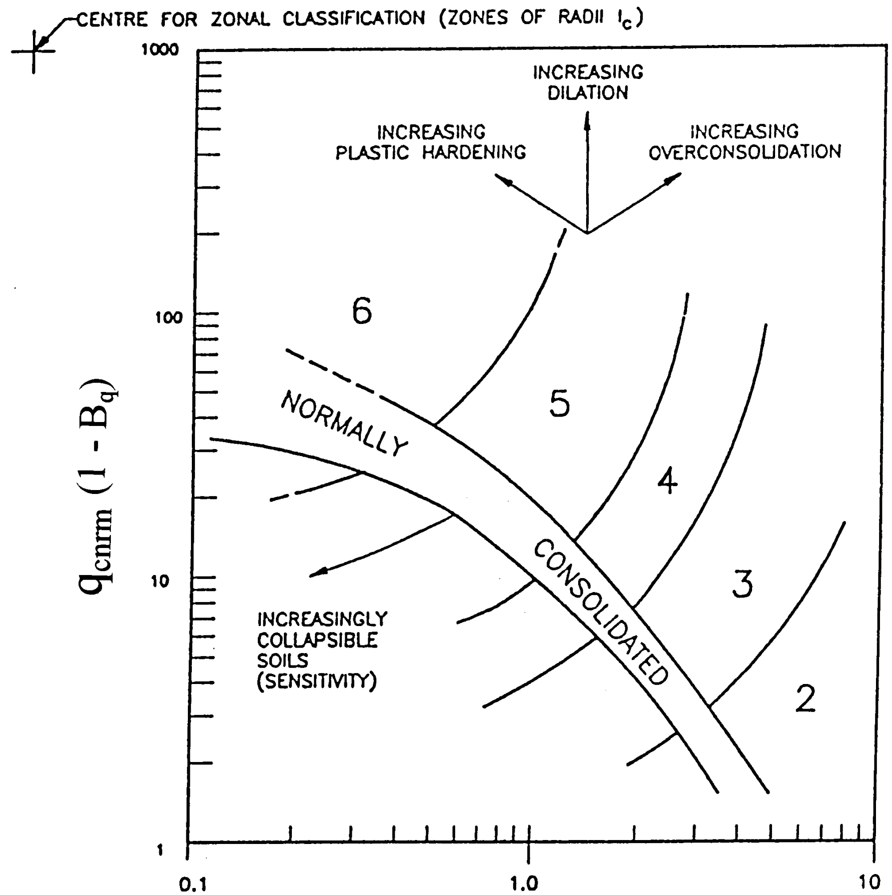


Fig.17:Profiling chart per Jefferies and Davies

4-Soil Profiling by Cone Penetrometer

4th ICGESM
Tehran, November 2-3, 2010

Olsen and Mitchell, 1995

Olsen and Mitchell, 1995 proposed a soil profiling chart shown in Fig.15, plotting “normalized cone resistance, q_{fc1e},”versus the friction ratio, R_f. The normalized cone resistance is determined.

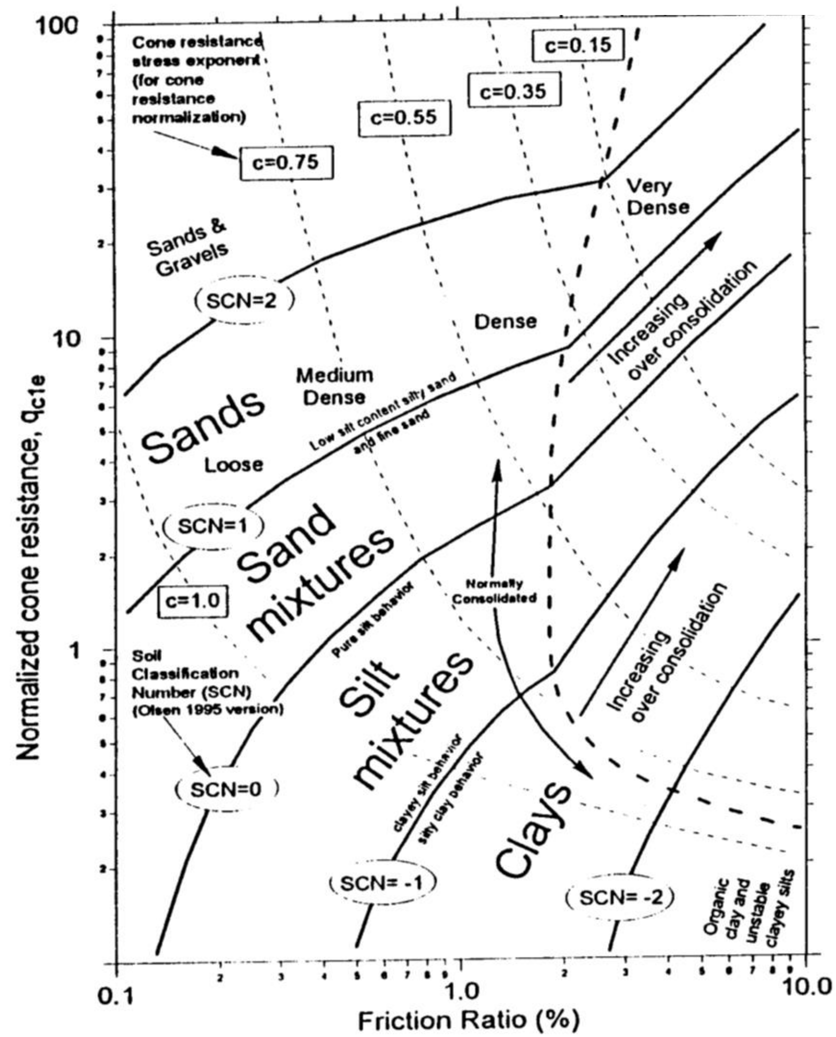
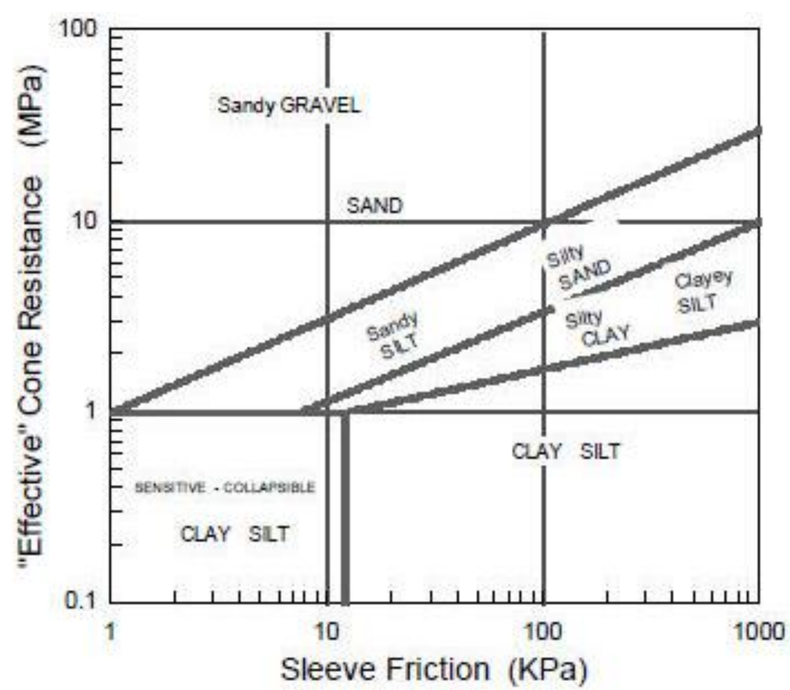


Fig.18:Profiling chart per Olsen and Mitchell

4-Soil Profiling by Cone Penetrometer

Eslami and Fellenius, 2004

Eslami and Fellenius, 2004 developed a soil profiling method when investigating the use of cone penetrometer data in pile design. A database have been compiled consisting of CPT and CPTu data associated with results of boring, sampling, laboratory testing, and routine soil characteristics of cases from 18 sources reporting data from 20 sites in 5 countries.



$$q_E = (q_t - u_2)$$

5-UniCone Program

Background

UniCone is a program for processing and reporting results of cone penetrometer tests (CPT and CPTU) and for soil profiling and pile capacity analysis. The program processes CPT and CPTU data obtained by any method and instrument. The data can be converted to User's choice of units regardless of what system of units used in recording the original data. The data (qc, qt, fs, u, and Rf) can be displayed on screen in tables and graphs, alone of with soil profile interpretation.

The tables can be printed out in hard copy or to file and the diagrams can be sized to desired scale and produced on hard copy of "clipped" for pasting into a document.

5-UniCone Program

UniCone Application

Pile Design (CPT/CPTu)

- Meyerhof (1976)
- Schmertmann (1978)
- European (1979)
- LCPC (French,1982)
- Tummay-Fakhroo (1982)
- Eslami-Fellenius (1997)

Soil Profiling (CPT/CPTu)

- Robertson (1990)
- Eslami-Fellenius (2004)

5-UniCone Program

4th ICGESM
Tehran, November 2-3, 2010

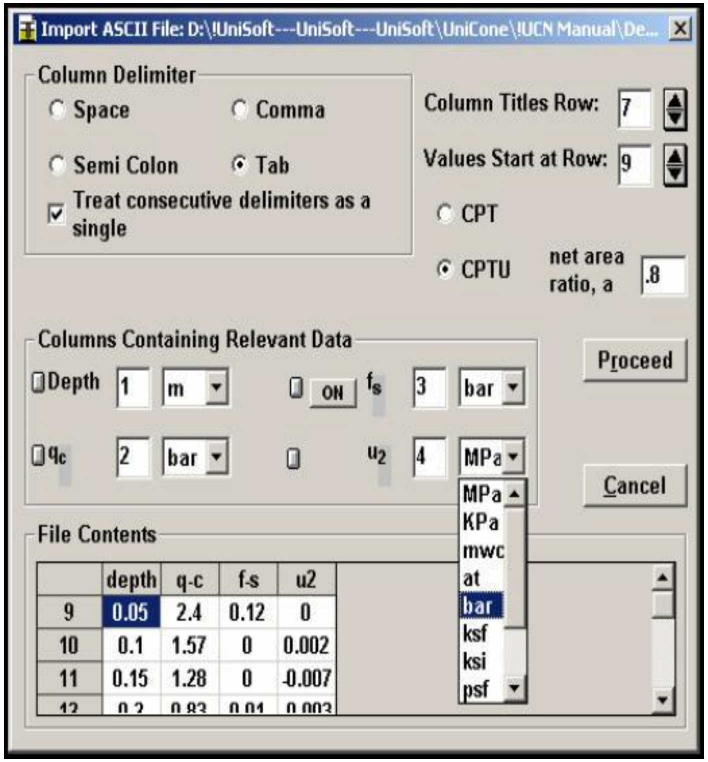
Input Data

<u>Parameters achieved From CPT/CPTu test:</u> including**: Cone resistance (qc), Sleeve Friction (fs), u2(Pore Pressure on Shoulder)**

<u>Pile Properties:</u> Including: Pile Material (Concrete or Steel), Construction Type (Driven or Cast In place), Cross Section (Circular,….), Pile Dimension (Diameter and embedment length)

<u>Soil Layers properties:</u> type of soil (Clay or Sand), thickness of layers, Over Consolidation Ratio, Ground Water Level.

<u>Text Explanations: (Optional)</u>



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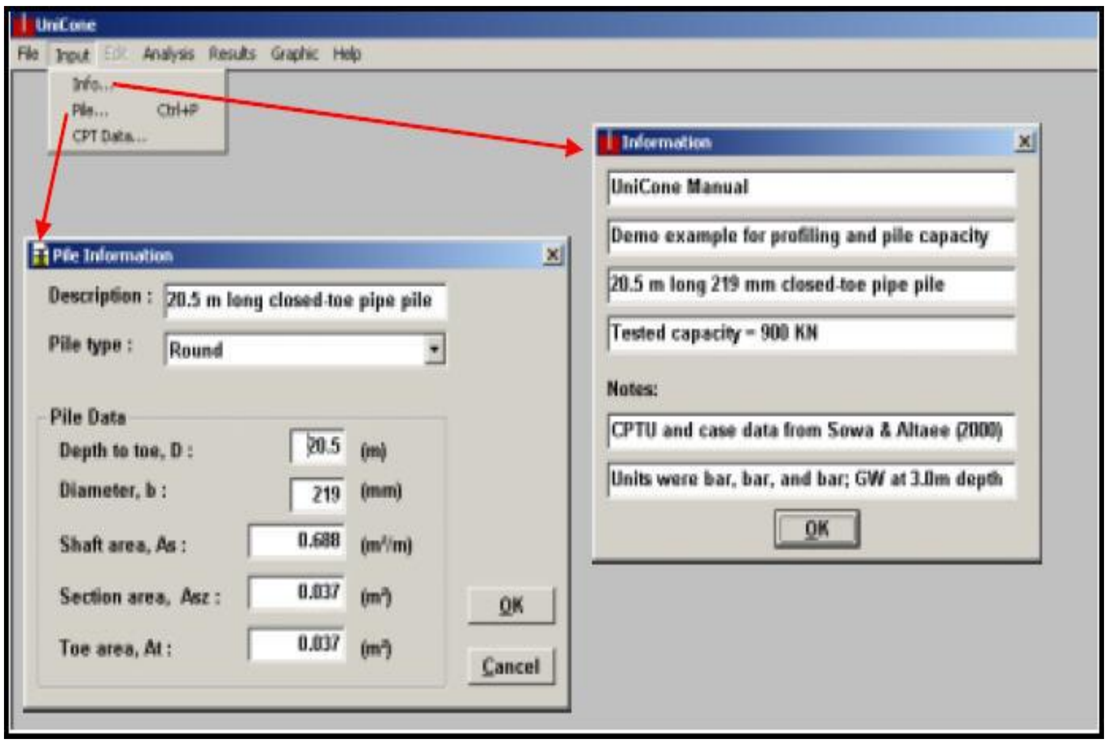
5-UniCone Program

Entering Input Data For Pile Properties



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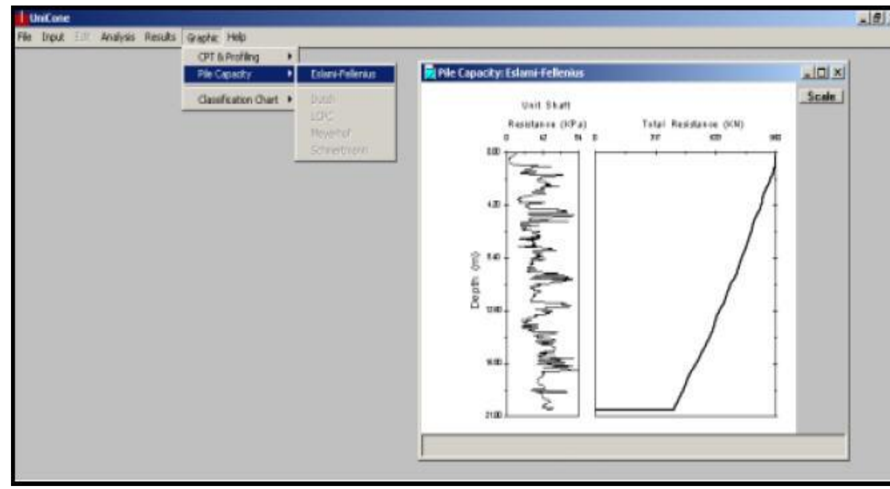
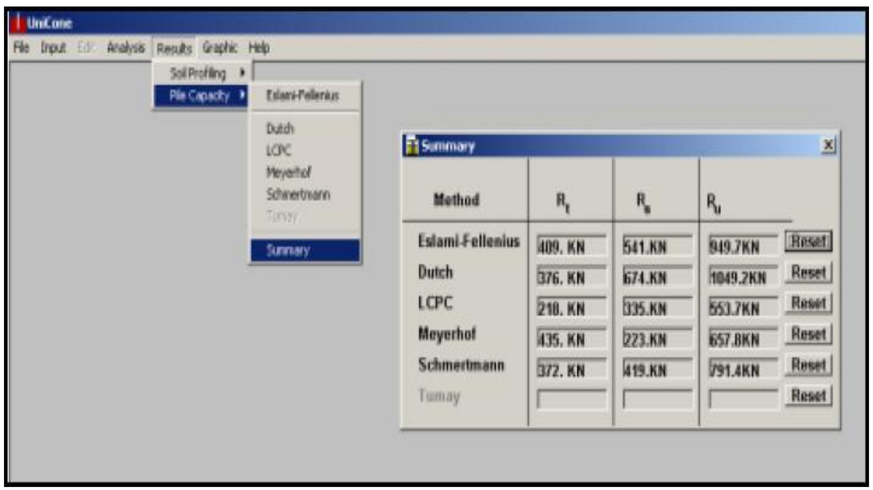
5-UniCone Program

Pile Capacity Calculation





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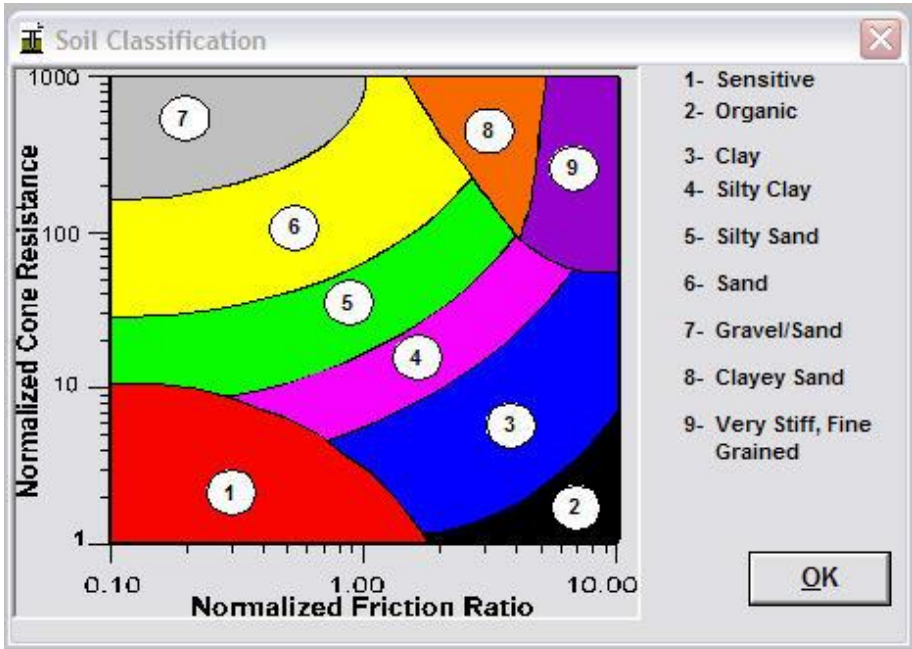
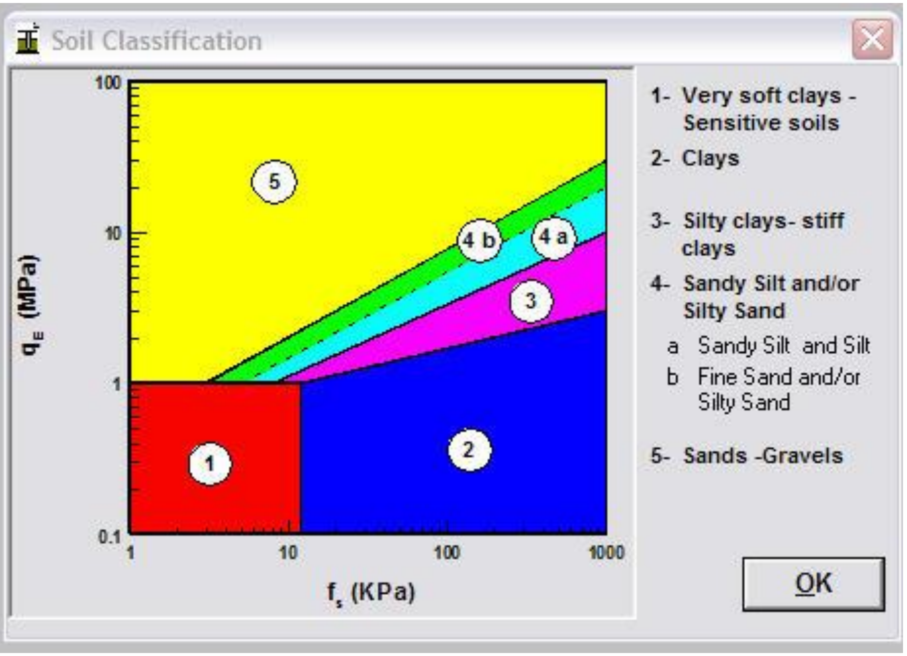
5-UniCone Program

Soil Profiling





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5-UniCone Program

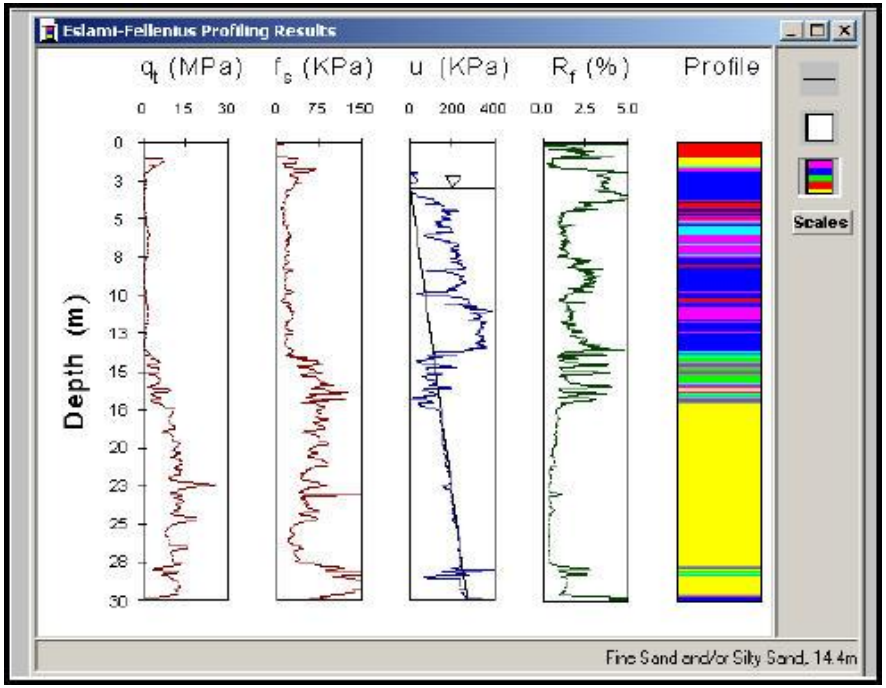
Soil Profiling

Soil Profiling Results: Eslami-Fellenius

Soil Profiling Results: Eslami-Fellenius

	Depth	qt	fs	u2	qE	Rf	Soil Type
	m	MPa	KPa	KPa	MPa	%	
330	16.500	2.5	57.0	133.0	2.3	2.3	Silty Clay
331	16.550	3.7	62.0	110.7	3.6	1.7	Silty Sand to Silt
332	16.600	3.8	70.0	64.8	3.7	1.8	Silty Sand to Silt
333	16.650	5.1	52.0	83.2	5.0	1.0	Fine Sand and/or Silty Sand
334	16.700	6.8	54.0	12.2	6.8	0.8	Sand
335	16.750	6.6	75.0	12.7	6.6	1.1	Fine Sand and/or Silty Sand
336	16.800	5.8	127.0	1.4	5.8	2.2	Silty Sand to Silt
337	16.850	3.6	114.0	24.0	3.6	3.2	Silty Sand to Silt
338	16.900	2.8	82.0	76.1	2.7	2.9	Silty Clay
339	16.950	3.2	95.0	90.5	3.1	3.0	Silty Clay
340	17.000	2.8	66.0	92.4	2.7	2.4	Silty Clay
341	17.050	4.3	44.0	114.3	4.2	1.0	Fine Sand and/or Silty Sand
342	17.100	5.6	63.0	39.8	5.6	1.1	Fine Sand and/or Silty Sand
343	17.150	6.0	77.0	41.8	6.0	1.3	Fine Sand and/or Silty Sand
344	17.200	7.0	75.0	59.1	6.9	1.1	Sand
345	17.250	7.4	76.0	45.7	7.3	1.0	Sand
346	17.300	7.4	83.0	59.1	7.3	1.1	Sand
347	17.350	8.5	88.0	83.5	8.4	1.0	Sand
348	17.400	10.1	85.0	101.9	10.0	0.8	Sand

Plot Values



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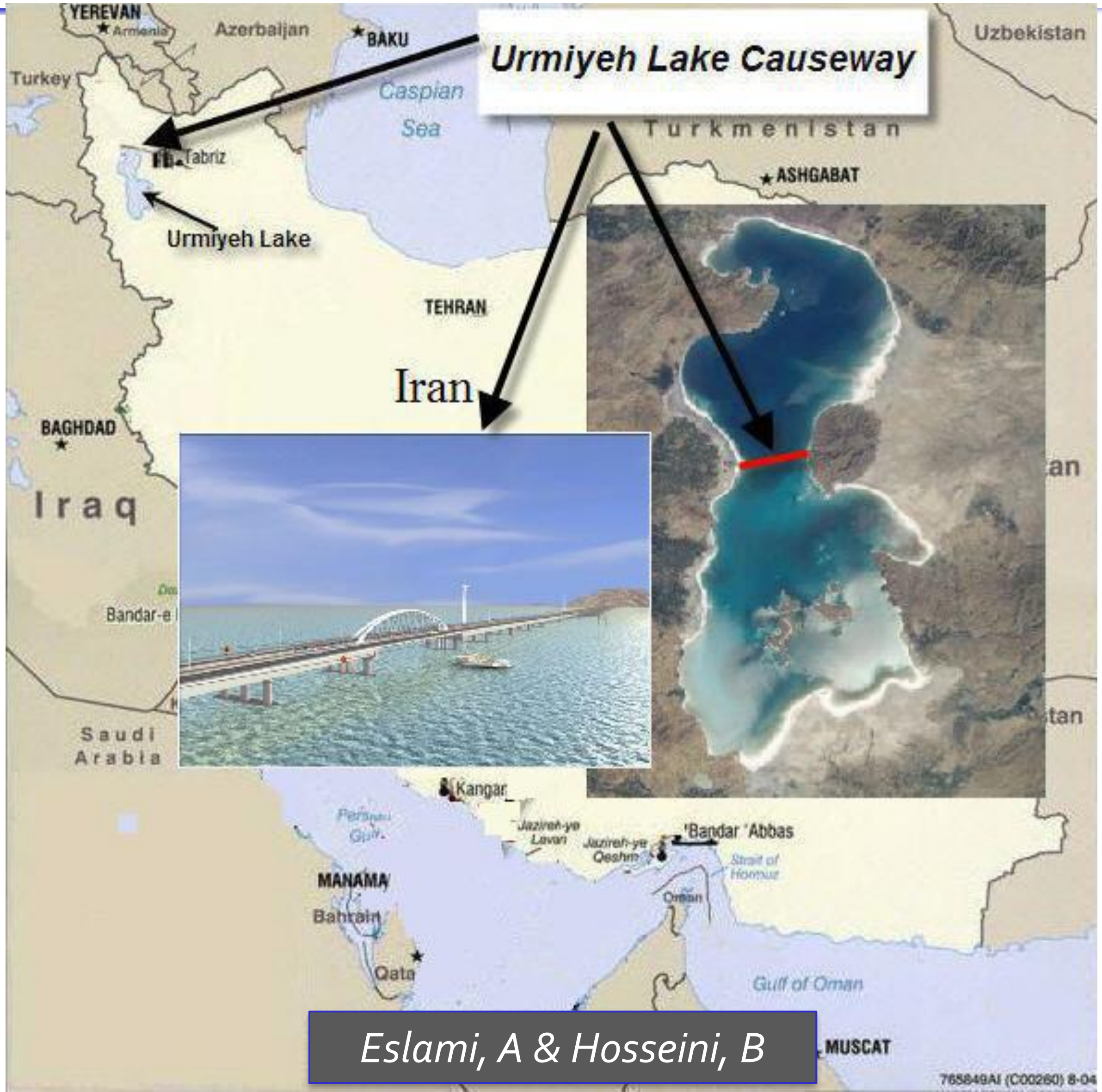
6-Case History: Urmiyeh Lake Causeway Site



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6-Case History: Urmiyeh Lake Causeway Site

History

- In early 1980, construction of a highway, the Tabriz-Urmiyeh, began for the purpose of connecting west part of Iran to Turkey.
- The new road would shorten the distance between Tabriz and Urmiyeh cities in north-eastern of Iran by about 130 km, resulting in improved access and efficient transit between Iran and Europe through Turkey.
- The highway will cross the Urmiyeh Lake, an inland lake surrounded by mountains.
- The lake area is approximately 5,500 km^2, the length is about 140 km and the width ranges from 15 through 50 km. The average depth of the lake is about 7 m and the maximum depth is about 12 m.

6-Case History: Urmiyeh Lake Causeway Site

Location of Urmiyeh Causeway on the lake

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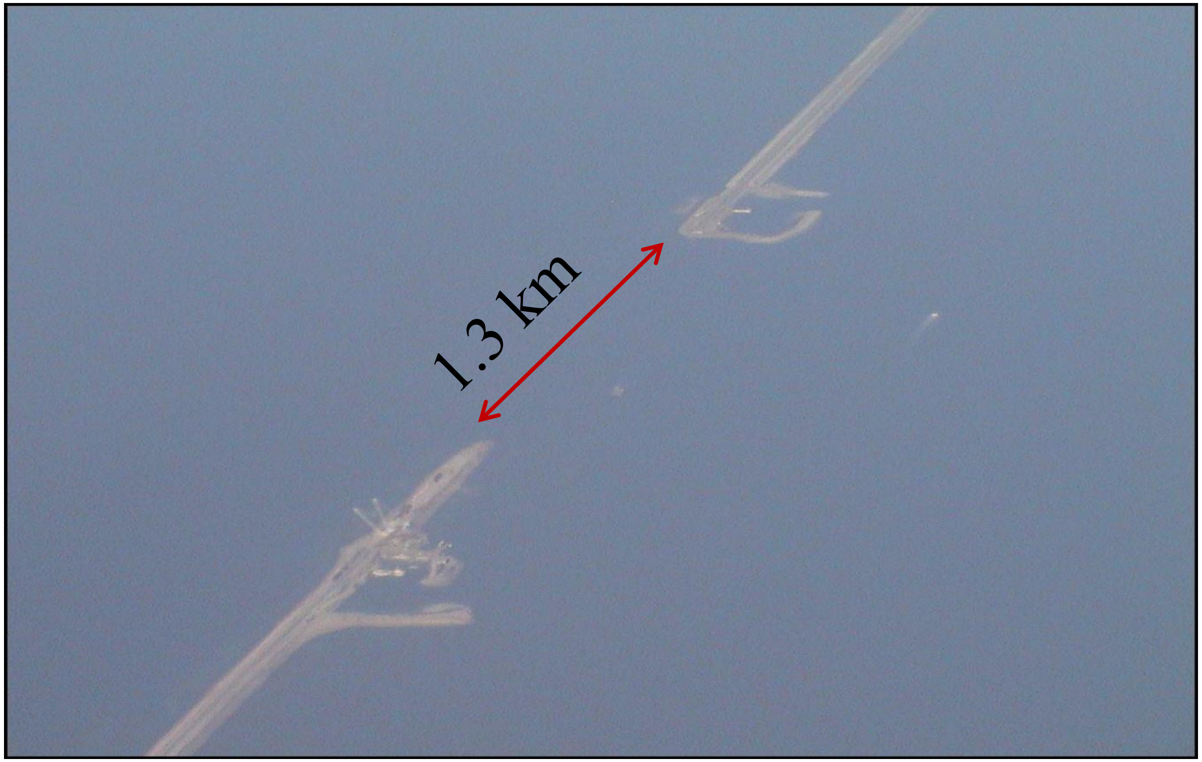
6-Case History: Urmiyeh Lake Causeway Site

Open Gap Between two Fills



6-Case History: Urmiyeh Lake Causeway Site

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Tehran, November 2-3, 2010

Bridge Longitudinal View

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6-Case History: Urmiyeh Lake Causeway Site

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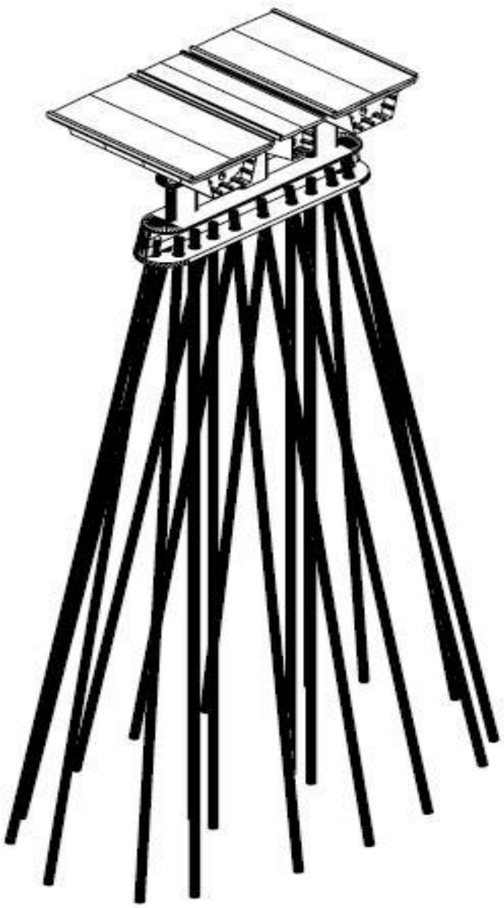
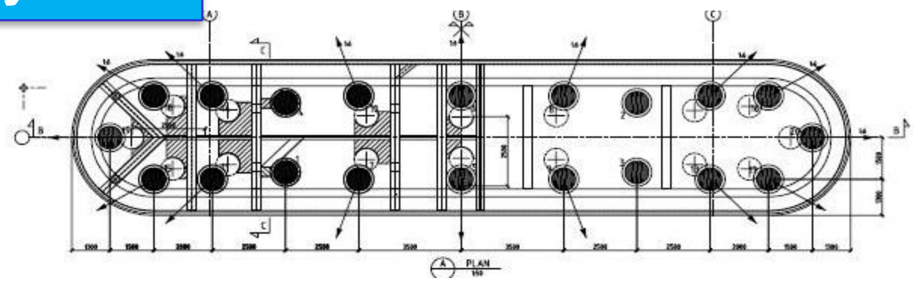
Bridge Pier Foundation System





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6-Case History: Urmiyeh Lake Causeway Site

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Geotechnical Investigation

The CPTu was the major geotechnical tool and source of useful subsoil data in this project.

CPTu soundings were performed in 12 locations, along the bridge route, down to 100 m below the lake-bed.

In order to study in more details Robertson (1990) and Eslami-Fellenius (2004) methods were selected.

UniCone Program was applied to evaluate SBT of Soils based on 2 mentioned method

6-Case History: Urmiyeh Lake Causeway Site

4th ICGESM
Tehran, November 2-3, 2010

Structural Elements

A bridge with the length of 1,260 m, comprising of 19 spans is considered.

The main span is in the form of an overhead tied arch structure in the length of 100 m, and the side spans are in form of flat deck system.

The bridge abutments land on the adjacent embankment in a manner ensuring adequate continuity for road and railway traffic in the abutment areas. In construction of the bridge, more than 400 piles having a total length of 32 km have been driven.

Design of the piles compiled different methods such as static analysis, 2 pile loading tests, 8 dynamic testing and correlations to in situ tests, such as cone penetration test (CPTu).

6-Case History: Urmiyeh Lake Causeway Site

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Tehran, November 2-3, 2010

Pile Properties

Case No	Pile Name	Pile Shape	Pile Size			Measured	Type of Test
			Length (m)	Diameter (mm)	Thickness (mm)	R_u (KN)	
1	UCA4	Circular	66	813	38.1	5400	Dynamic Test Pile driving Analyzer
2	UCA5	Circular	66	813	38.1	4700	
3	UCA7	Circular	66	813	38.1	5500	
4	UCB3	Circular	75	813	38.1	7300	
5	UCB4	Circular	75	813	38.1	5500	
6	UCB5	Circular	75	813	38.1	7000	
7	UCB7	Circular	75	813	38.1	6300	
8	UCB8	Circular	75	813	38.1	8000	
9	UCA4-C	Circular	30	356	12	760	Pile Load Test
10	UCA5-T	Circular	70	305	16	3200	

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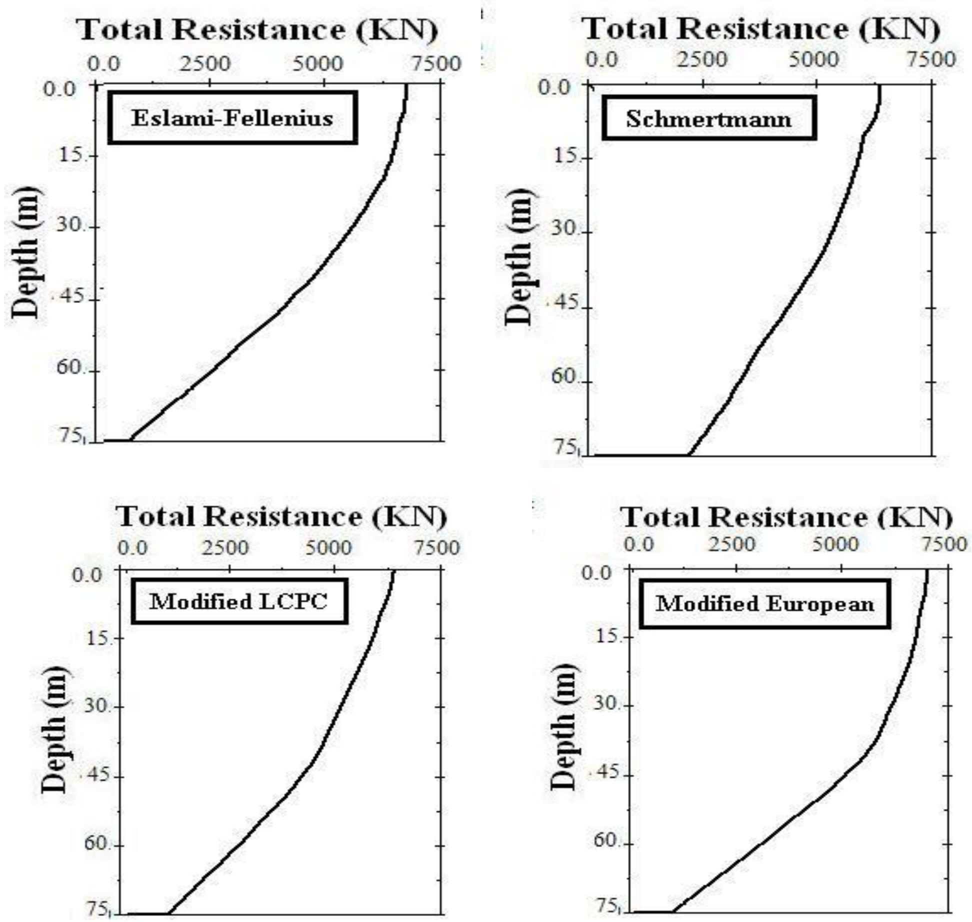
6-Case History: Urmiyeh Lake Causeway Site

Pile Capacity by Different CPT/CPTu Methods



Total capacity graphs for case No.7 by for 4 different CPT methods

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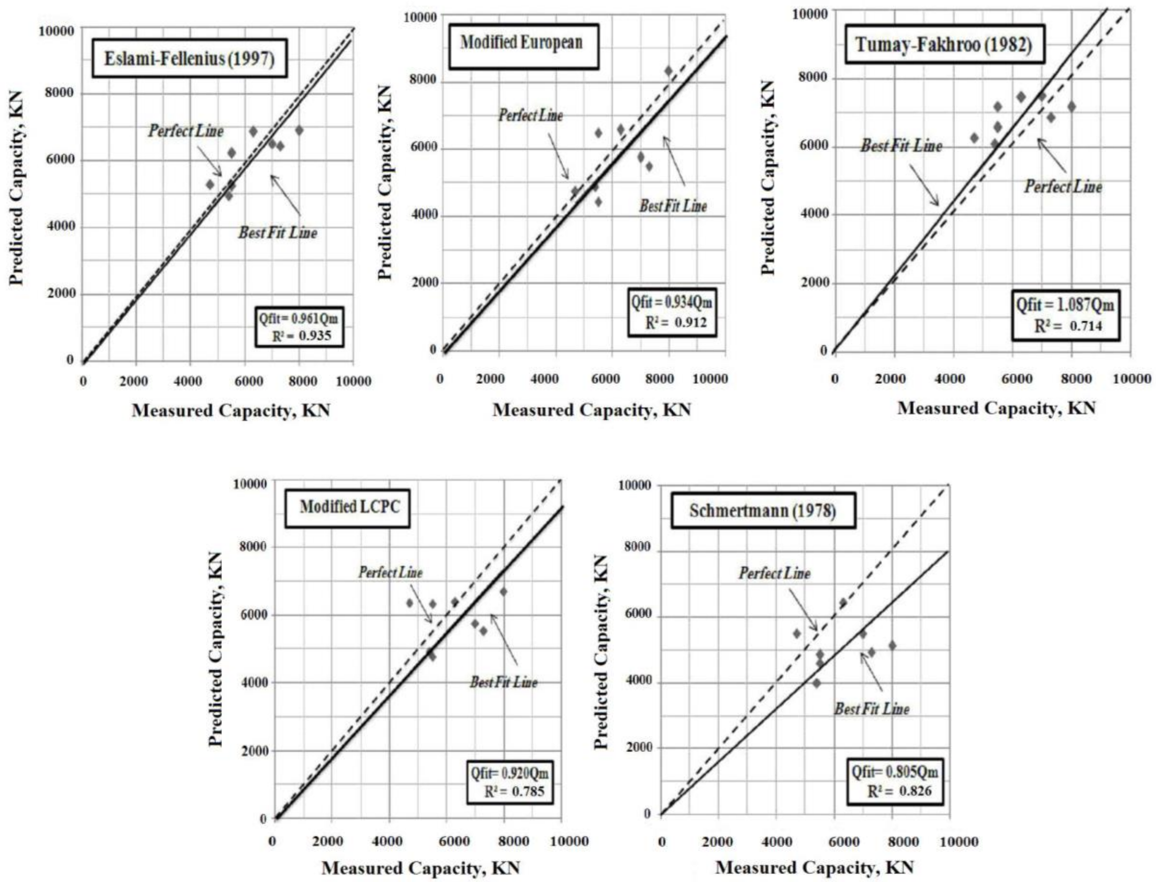
6-Case History: Urmiyeh Lake Causeway Site

Evaluation CPT/CPTu Methods Based on Dynamic Tests



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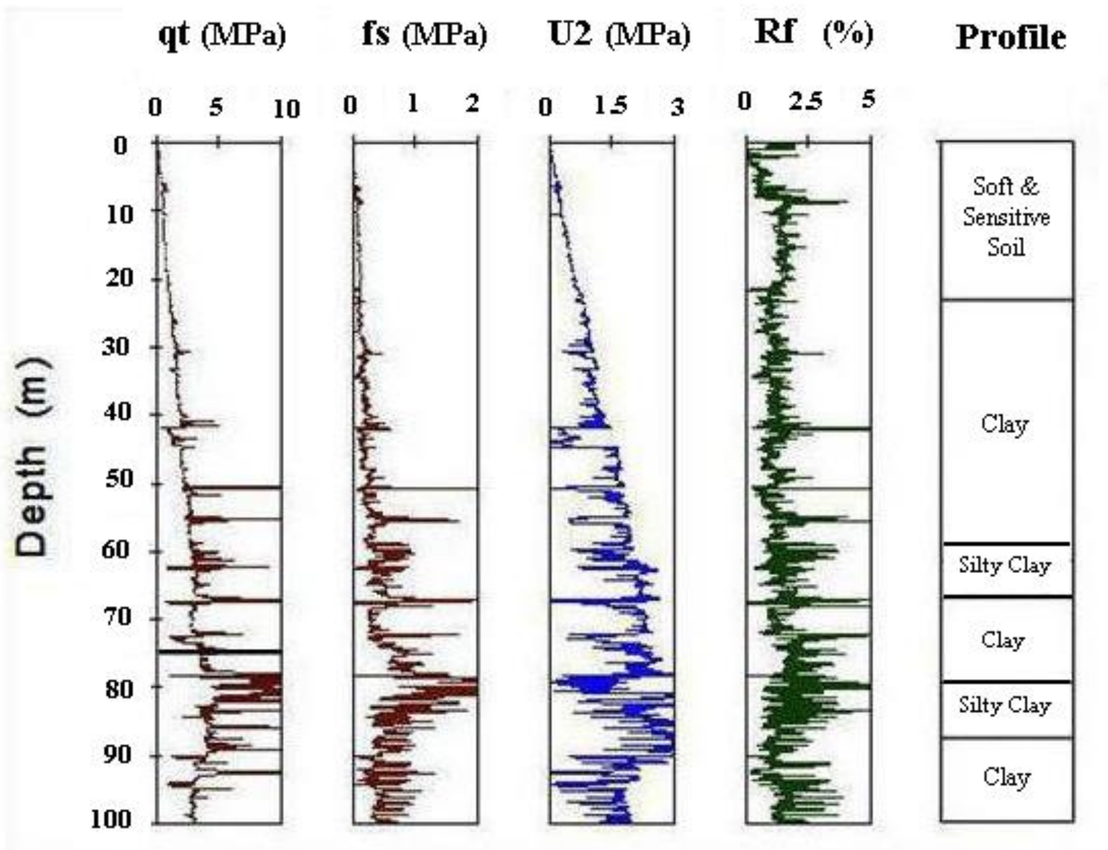
7-Charactrization of Surprising Soil

Soil Profiling

Because of specific soft and sensitive deposits in sub layers for the Urmiyeh Lake which makes it unique and in order to classify these surprising soils, the Robertson (1990) [9] and Eslami-Fellenius (2004)] methods were applied.



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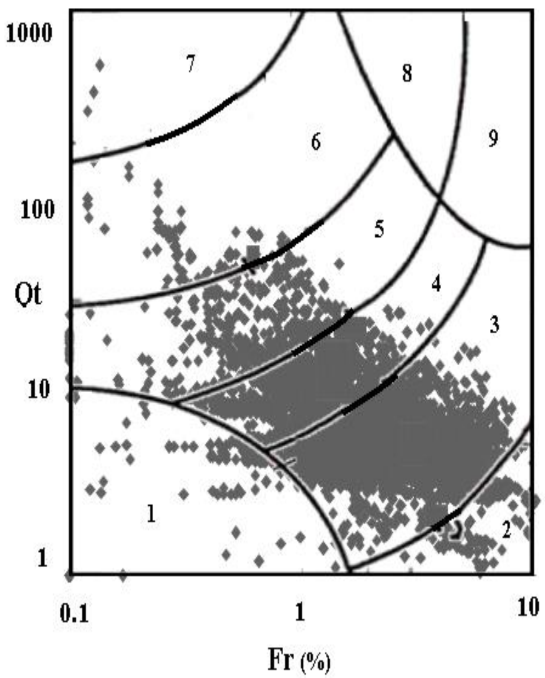
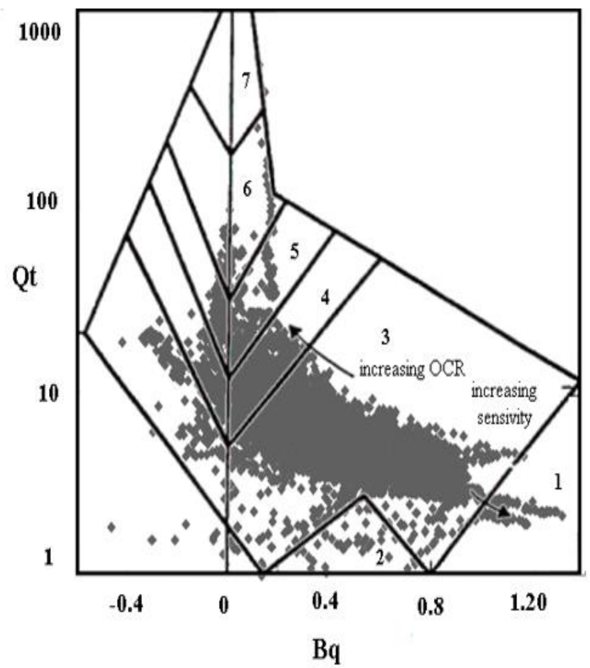
7-Charactrization of Surprising Soil

Soil Profiling

Robertson, (1990)





Zone	Soil Behavior Type
1	Sensitive, fine grained
2	Organic soils – peats
3	Clays – silty clay to clay
4	Silt mixtures – clayey silt to silty clay
5	Sand mixtures – silty sand to sandy silt
6	Sands – clean sand to silty sand
7	Gravelly sand to dense sand
8	Very stiff sand to clayey sand*
9	Very stiff, fine grained*

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7-Charactrization of Surprising Soil

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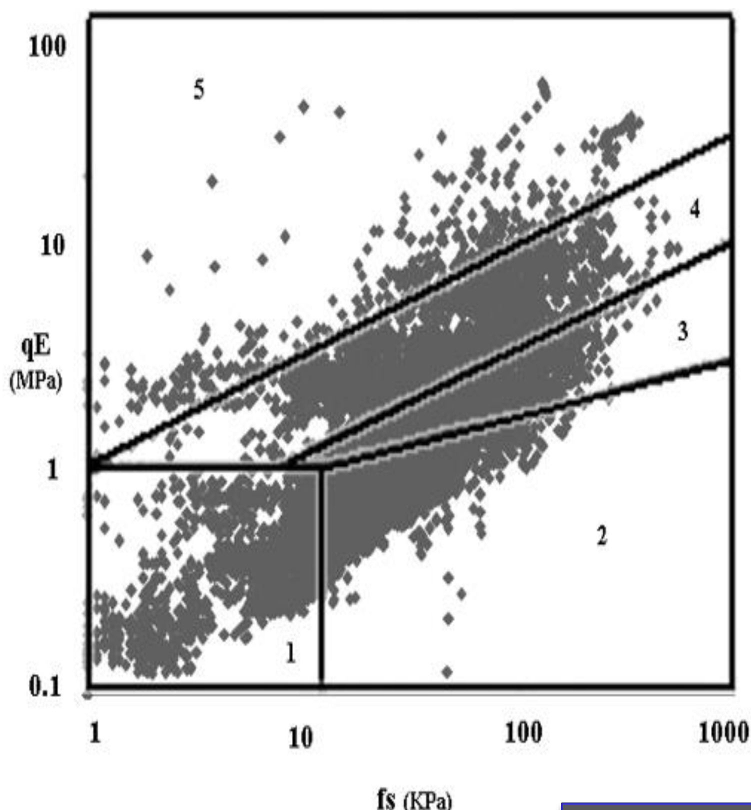
Tehran, November 2-3, 2010

Soil Profiling

Eslami-Fellenius, (2004)



1. Sensitive and Collapsible Clay and/or Silt
2. Clay and/or Silt
3. Silty Clay and/or Clayey Silt
4. Sandy Silt and/or Silty Sand
5. Sand and/or Sandy Gravel

Eslami, A & Hosseini, B

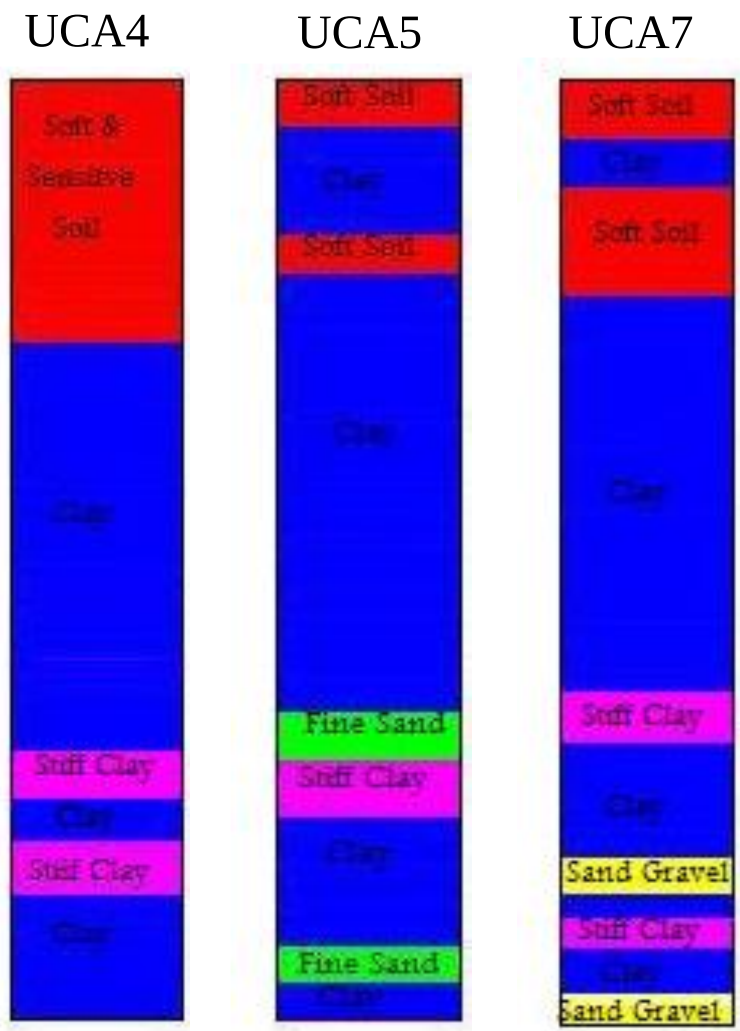
7-Charactrization of Surprising Soil

Soil Profiling

As illustrated in previous Figures Robertson (1990) charts, orientation of data shows that the layers **consist of clays (clay to silty clay), silt mixtures (silty clay to clayey silt), sand mixtures (sandy silt to silty sand), sand (silty sand to clean sand) and sensitive clay.** Considering Eslami-Fellenius (2004) chart, orientation of the data shows that the most of the layers **consist of sensitive and collapsible clay, silt, clay and silt and some other type of soil like silty clay and clayey silt, sandy silt and silty sand.**

7-Charactrization of Surprising Soil

Soil Profiling



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7-Charactrization of Surprising Soil

Sensivity

In order to determine the sensivity of soil layers, based on CPTu data, sensivity of layers was evaluated using Schmertmann proposed method (1978):

$$S_t = N_s / R_f$$

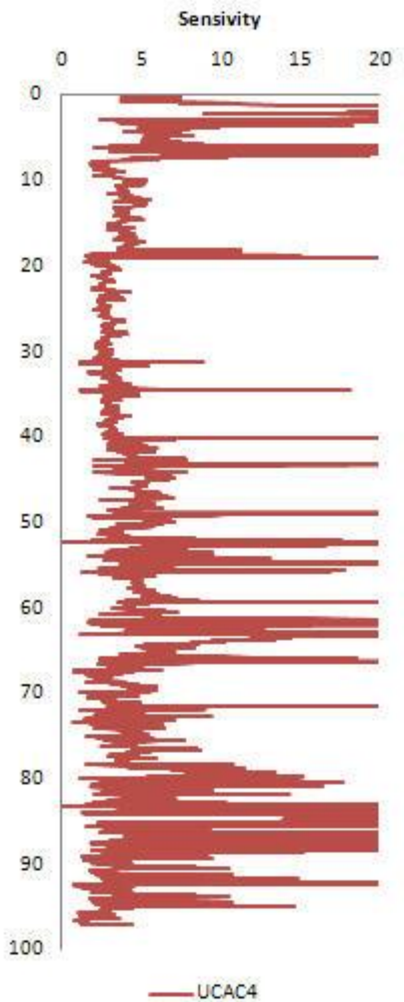
where S_t = sensivity, N_s = empirical coefficient and R_f = friction ratio.

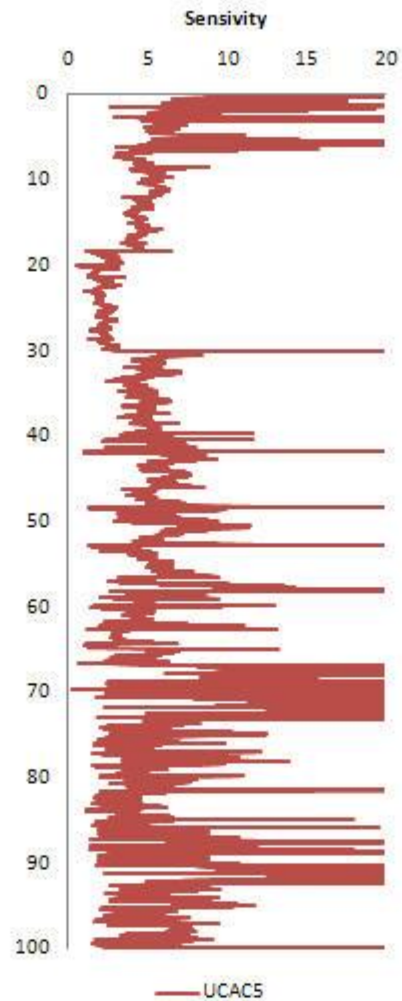
Based on a suggestion by Rad and Lunne (1986) [12] the N_s value ranges from 5 to 9 with average value of 7.5. The average value was considered for determination of soil layers sensivity.

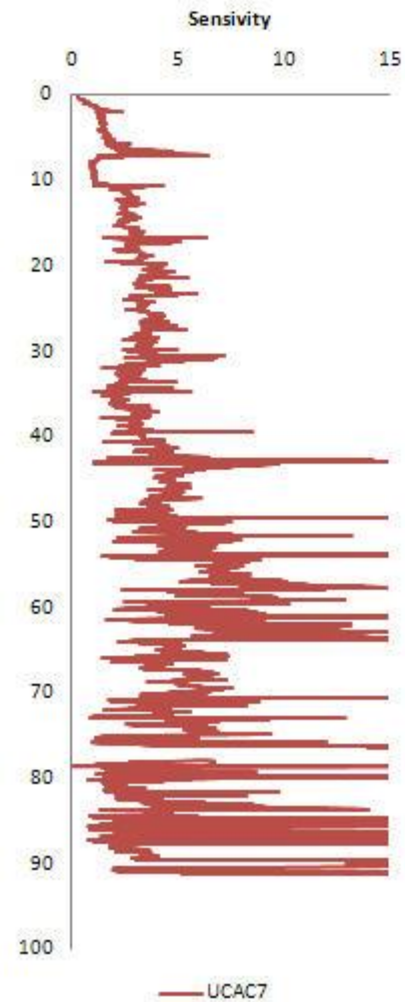
7-Charactrization of Surprising Soil

4th ICGESM
Tehran, November 2-3, 2010

Sensivity







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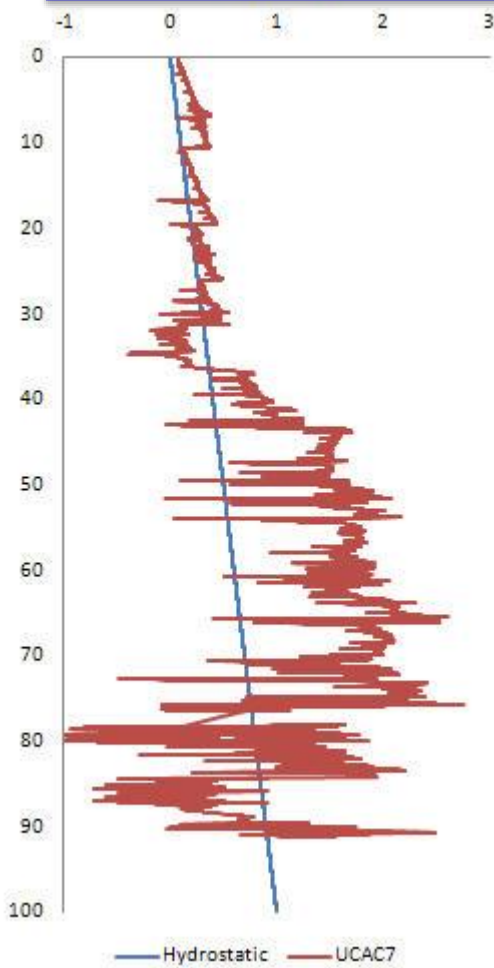
Excess Pore Pressure

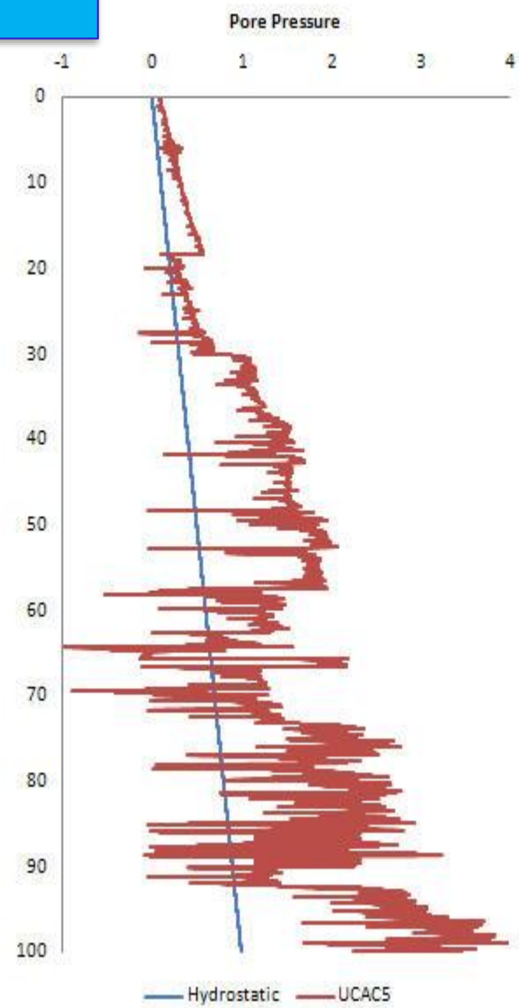
In order to evaluate the water pore pressure condition in sub soil layers, the value of u_2 versus depth as presented in next Figure.

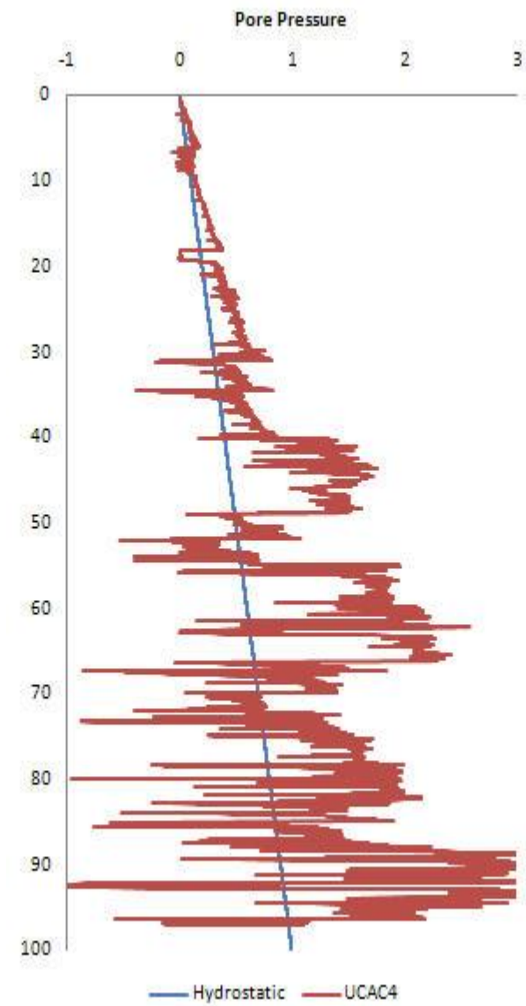
As it is illustrated the pore pressure is greater 2 to 3 times hydrostatic pressure.

7-Charactrization of Surprising Soil

Pore Pressure







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8-Conclusions

4th ICGESM
Tehran, November 2-3, 2010

1-The cone penetration test ***(CPT/CPTu) is simple, fast, and relatively economical, supplies continuous records with depth,*** and allows a variety of sensors to be incorporated with the penetrometer.

2-The advantage of using CPT data for pile design, is that dependency on “undisturbed” sampling and subsequent conventional laboratory testing are avoided. Moreover, it is not necessary to furnish intermediate parameters, such as earth pressure and bearing capacity coefficients, *Ks and Nq.*
The penetrometer can be considered as a model pile.

8-Conclusions

3-Cone penetration test (CPT) allows for the soil type to be determined from the measured values of cone resistance (qt) and sleeve friction (fs). By ***piezocone (CPTu), the reliability of the determination of soil type also improved by pore pressure (u) measurement.***

4-Among broad site investigation efforts for construction of ***1260 m long Urmiyeh Lake Causeway***, ***The CPTu soundings have been realized a valuable tool for site characterization and pile design.***

8-Conclusions

4th ICGESM
Tehran, November 2-3, 2010

John. H. Schmertmann (CPT`95):

We found it necessary to use a system approach to sell the CPT to predicting engineers. One might also consider ***it is a "carrot and stick" approach. The carrot of better engineering and possibly better profits, the stick of the potential of loss of consulting work if you don`t have the CPT available.***

Some years ago one of Swedish Geotechnical Institute (SGI) members, Dr Eskill Sellegren, published a paper with the title:

"CPT- The Geotechnician`s Sound of Music"