

Comune di Ferrara

Provincia di Ferrara

RELAZIONE GEOLOGICA

inerente la caratterizzazione e modellazione geologica del sito (6.2.1. NTC 2018)

RELAZIONE GEOTECNICA

Relativa alle indagini, alla caratterizzazione e alla modellazione geotecnica a supporto della progettazione strutturale (6.2.2. NTC 2018) nonché relativa alla verifica delle opere di fondazione (6.4. NTC 2018)

MICROZONAZIONE SISMICA dell'area secondo gli indirizzi per gli studi di microzonazione sismica in Emilia Romagna per la pianificazione territoriale ed urbanistica, ai sensi della Delibera di Assemblea Legislativa n.112/2007 e della Delibera Giunta Regionale n. 2193/2015.



OGGETTO:

**Realizzazione del Centro Unificato dell'Emergenza
sul Territorio della Protezione Civile
in un lotto sito in via Bologna,
nella località Chiesuol Del Fosso
nel Comune di Ferrara (FE)**



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Relazione Tecnica

comprendente:

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- Tav. 2 Ubicazione indagini geognostiche
- Tav. 3 Soggiacenza falda
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- ALL. n. 1 Prove penetrometriche statiche CPTU;
- ALL. n. 2 Sondaggio a carotaggio continuo;
- ALL. n. 3 Prove di laboratorio geotecnico;
- ALL. n. 4 Verifica alla liquefazione;
- ALL. n. 5 Indagini sismiche;
- ALL. n. 6 Indagini geoelettriche.

1 PREMESSE

Nei mesi di aprile e maggio 2018 è stato eseguito il presente studio geologico, geotecnico e sismico relativo a un lotto di terreno sito in via Bologna, nei pressi della località Chiesuol del Fosso nel Comune di Ferrara (FE), che sarà interessato dalla realizzazione del Centro Unificato dell'Emergenza della Protezione Civile.

A supporto di ciò, nel sito in oggetto è stata eseguita una campagna di indagini geognostiche nei mesi di aprile e maggio 2018; questo studio si è inoltre avvalso di una ulteriore campagna di indagini geognostiche da Noi eseguita nel medesimo sito nell'ottobre del 2017. Il presente lavoro pertanto integra e approfondisce il lavoro da noi precedentemente svolto nel medesimo sito di indagine (ns. rif. 646_17).



Inquadramento geografico dell'area in oggetto.



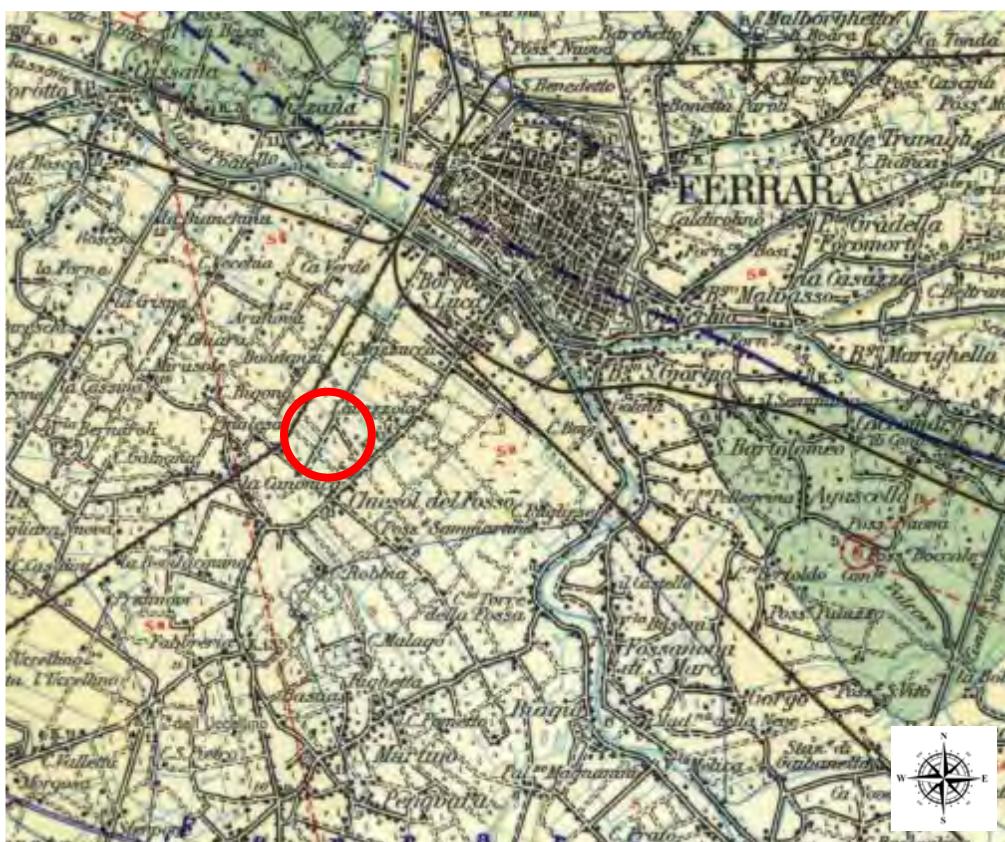
Inquadramento geografico dell'area in oggetto.

2. RELAZIONE GEOLOGICA

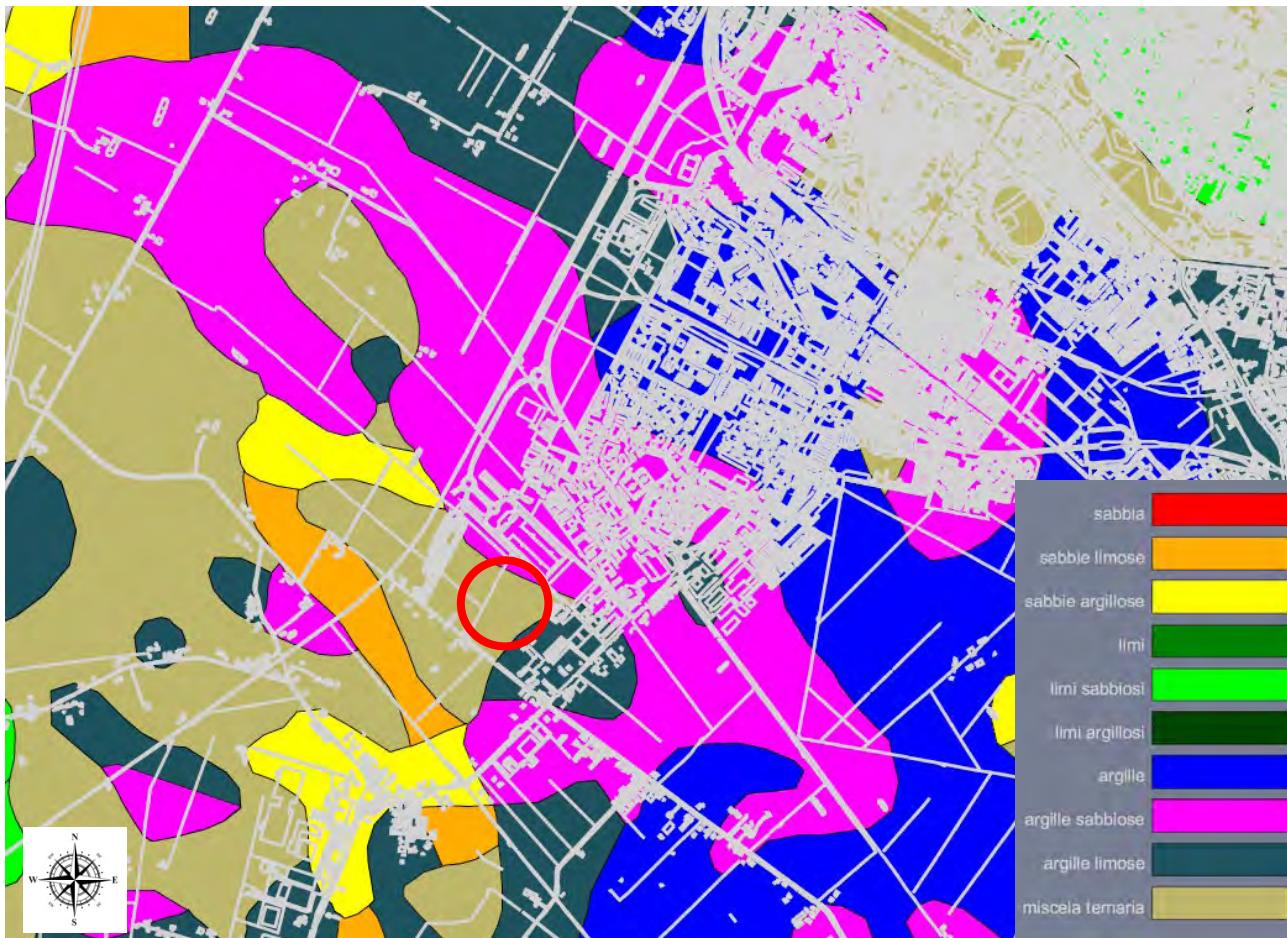
2.1 INQUADRAMENTO – GEOLOGIA E GEOMORFOLOGIA

Il lotto in oggetto è situato in un'area di pianura tra Ferrara sud e la località Chiesuol del Fosso, la quota topografica del lotto oscilla attorno ai 7.00 m s.l.m..

Dalla cartografia bibliografica, nell'area in oggetto il sottosuolo risulta caratterizzato da alternanze di terreni sabbiosi, argillosi e limosi.



Estratto della “Carta Geologica d’Italia in scala 1:100.000”; nell’area in oggetto (cerchio rosso) sono presenti terreni sabbioso-argilosì (S^a)

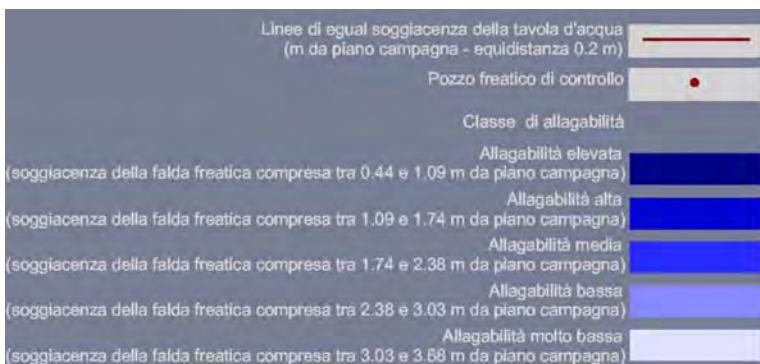
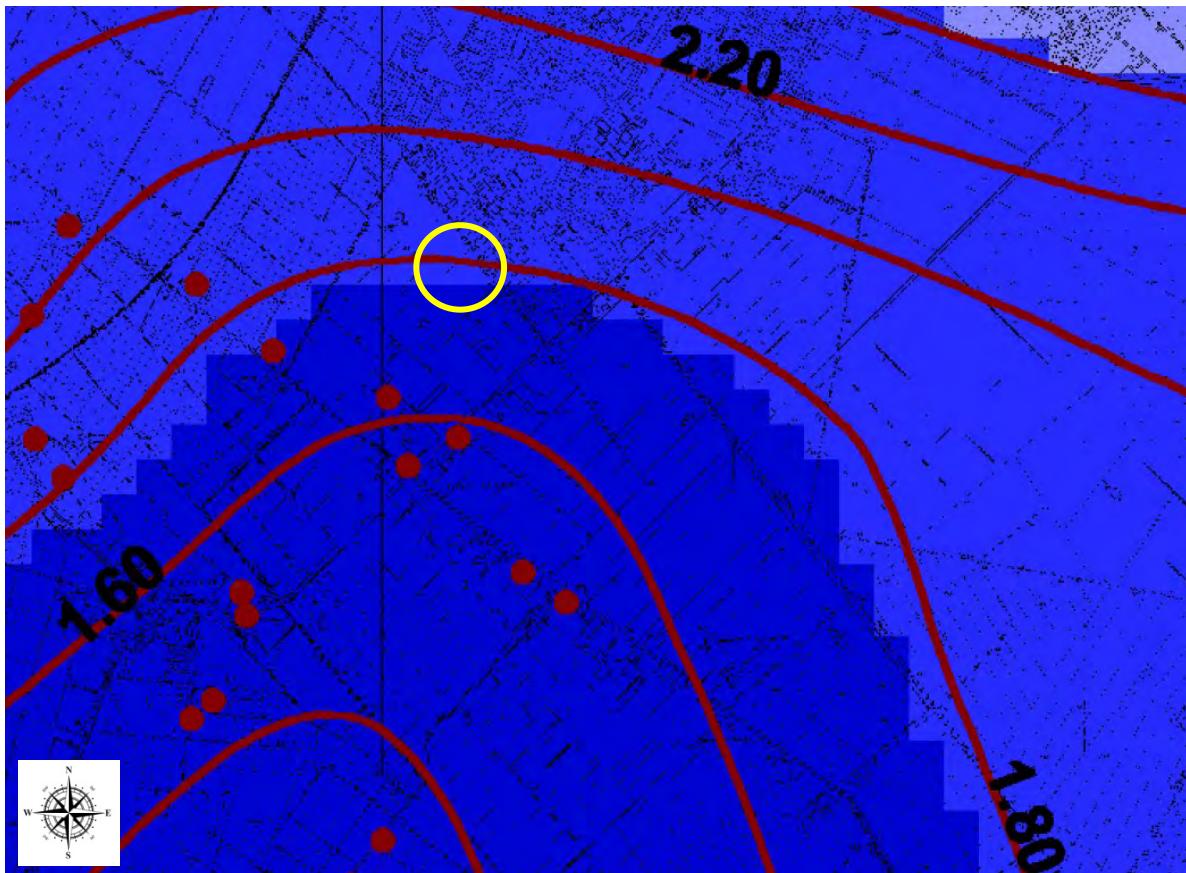


Estratto della tavola “Litologia di superficie 1/02.15” del PSC di Ferrara (2003); nell’area in oggetto (cerchio rosso) è presente una miscela ternaria di sabbie, limi e argille.

Dal punto di vista geomorfologico non si segnala la presenza di particolari morfologie né di forme di modellamento attualmente in evidente evoluzione; dalla tavole “Carta geomorfologica 1/03.03” redatta per il PSC di Ferrara nel lotto in oggetto non è segnalato il passaggio di uno dei principali paleovallei abbandonati presenti entro il territorio comunale di Ferrara.



Estratto della tavola “Carta geomorfologica 1/03.03” del PSC di Ferrara (2003); nell’area in oggetto (cerchio giallo) non è segnalato il passaggio di uno dei principali paleoalvei presenti nel territorio comunale di Ferrara.



Estratto della tavola “Minima soggiacenza della tavola d’acqua 1/03.10” del PSC di Ferrara (2003); nell’area in oggetto (cerchio giallo) la soggiacenza della falda oscilla all’incirca intorno a -1.80 m da p.c.

2.2 INDAGINI GEOTECNICHE

Nei mesi di ottobre 2017 e aprile e maggio 2018 nel lotto in oggetto sono state eseguite le seguenti indagini geotecniche:

- **n. 17 prove penetrometriche statiche con punta elettrica e piezocone CPTU;**
- **n. 1 sondaggio a carotaggio continuo.**

Nella **tavola n. 2** è riportata l'ubicazione di tutte le indagini sopracitate.

Nella tabella seguente si riportano le profondità raggiunte da ciascuna indagine geotecnica.

Indagine	Data esecuzione	Profondità (m da p.c.)
CPTU/SCPTU 1	Ottobre 2017	30.30
CPTU 2	Ottobre 2017	20.00
CPTU 3	Aprile 2018	20.30
CPTU 4	Aprile 2018	20.30
CPTU 5	Aprile 2018	20.30
CPTU 6	Aprile 2018	20.00
CPTU 7	Aprile 2018	20.00
CPTU 8	Aprile 2018	20.00
CPTU 9	Maggio 2018	20.00
CPTU 10	Maggio 2018	20.00
CPTU 11	Maggio 2018	20.00
CPTU 12	Maggio 2018	20.00
CPTU 13	Maggio 2018	20.00
CPTU 14	Maggio 2018	20.00
CPTU 15	Maggio 2018	20.00
CPTU 16	Maggio 2018	20.00
CPTU 17	Maggio 2018	20.00
Sondaggio S1	Aprile 2018	30.00

2.2.1 Prove penetrometriche CPTU e S-CPTU

La prova penetrometrica statica con punta elettrica (CPTE/U), consiste essenzialmente nella misura della resistenza alla penetrazione di una punta conica standard, connessa all'estremità inferiore di una batteria di aste cave, che viene infissa a pressione e velocità costante nel terreno tramite un dispositivo di spinta idraulico che agisce alla sommità delle aste.

La punta elettrica è strumentata con sensori elettrici e un sistema di trasmissione dei dati in superficie via cavo, che permette l'acquisizione e la registrazione dei dati quasi in continuo, ogni centimetro. I dati misurati durante la prova sono la resistenza totale alla penetrazione Q_t , la resistenza alla penetrazione della punta Q_c e la resistenza laterale del mancotto F_s ; è possibile inoltre monitorare, durante l'esecuzione della prova, alcuni parametri di controllo, quali l'inclinazione rispetto alla verticalità e la velocità di penetrazione del cono.

Una punta elettrica particolare, detta “piezocono”, è dotata anche di un dispositivo di misura della pressione, attraverso il quale viene misurata la pressione dell'acqua nei pori del terreno u (CPTU). La pressione che viene misurata è la pressione $u = u_0 + \Delta u$, dove u_0 è la pressione dovuta al livello idrostatico e Δu quella generata dallo sforzo alla penetrazione nel terreno.

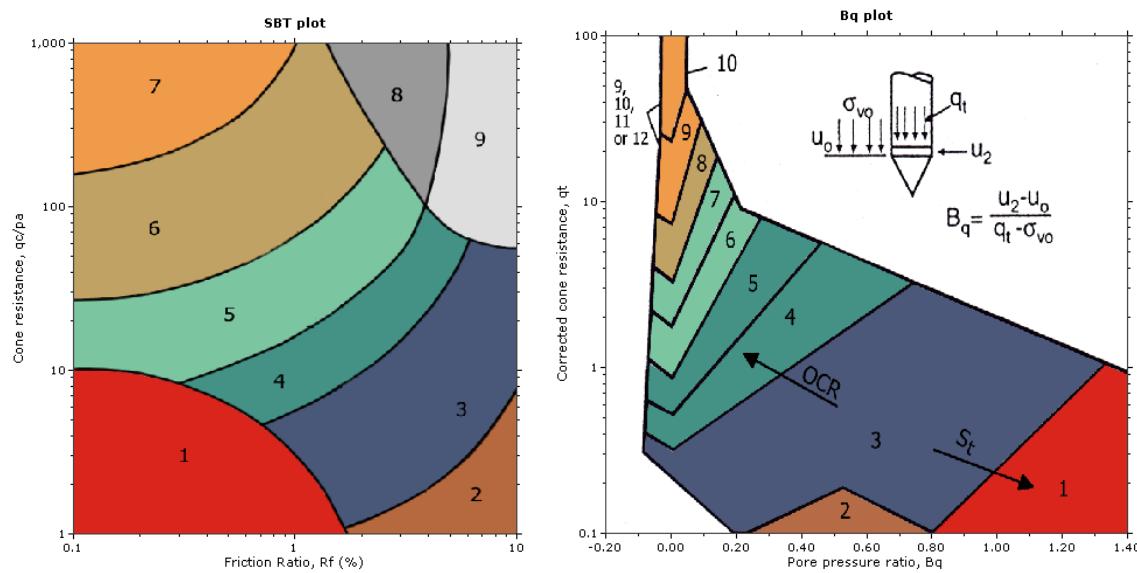
Il piezocono da Noi utilizzato è un Tecno Penta TP CPL2IN ed è dotato di un dispositivo di misura della pressione costituito da un cilindro metallico saturato con grasso, situato poco al di sopra della punta conica. Si riporta di seguito lo schema con le caratteristiche del piezocono utilizzato.

DATI STRUMENTALI DEL PIEZOCONO	
Area punta	10 cm ²
Area interna punta cono	6.6 cm ²
Angolo di apertura punta	60 °
Diametro punta conica meccanica	35.7 mm
Altezza mancotto laterale	13.37 cm
Passo	2 cm
Distanza punta/setto poroso	0.4 cm

Tab. 2.1: Caratteristiche del piezocono utilizzato.

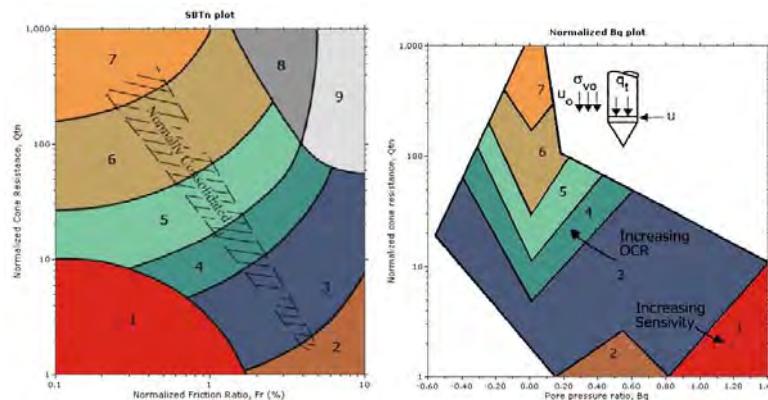
I dati acquisiti sono stati elaborati con software CPET – IT v. 1.7.4.13 prodotto da GeoLogisMiki – Geotechnical Software. I report, in cui sono riportati su grafici i dati di resistenza e pressione interstiziale misurati e l'interpretazione litostratigrafica e geotecnica delle prove, sono riportati in **allegato n. 1**.

La caratterizzazione litostatografica del terreno è stata effettuata in funzione delle carte proposte da Robertson, in cui il tipo di comportamento del terreno è definito da tre parametri: qt, resistenza alla punta corretta, Rf, Bq, nella prima carta (1986) e con i parametri normalizzati nella seconda (1990).



SBT legend

- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |



SBTn legend

- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
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La ricerca e la disponibilità di numerosi dati ottenuti in camera di calibrazione e in campagna ha prodotto numerose correlazioni tra i dati misurati in situ ed il valore dei parametri geotecnici caratteristici dei terreni. Il software utilizzato per l'elaborazione della prova utilizza le correlazioni riportate nello schema seguente.

:: Unit Weight, g (kN/m³) ::	:: Small strain shear Modulus, G₀ (MPa) ::
$g = g_w \cdot \left(0.27 \cdot \log(F_r) + 0.36 \cdot \log\left(\frac{q_t}{p_a}\right) + 1.236 \right)$ where g_w = water unit weight	$G_0 = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55I_c + 1.68}$
:: Permeability, k (m/s) ::	:: Shear Wave Velocity, Vs (m/s) ::
$I_c < 3.27$ and $I_c > 1.00$ then $k = 10^{0.952 - 3.04I_c}$	$V_s = \left(\frac{G_0}{\rho} \right)^{0.50}$
$I_c \leq 4.00$ and $I_c > 3.27$ then $k = 10^{-4.52 - 1.37I_c}$	
:: N₆₀ (blows per 30 cm) ::	:: Undrained peak shear strength, S_u (kPa) ::
$N_{60} = \left(\frac{q_t}{p_a} \right) \cdot \frac{1}{10^{1.2268 - 0.2817I_c}}$	$S_u = \frac{(q_t - \sigma_v)}{N_{60}}$ (applicable only to SBT _c : 1, 2, 3, 4 and 9 or $I_c > I_{c,max}$)
$N_{300} = Q_{60} \cdot \frac{1}{10^{1.2268 - 0.2817I_c}}$	
:: Young's Modulus, E_s (MPa) ::	:: Remolded undrained shear strength, S_{u(rem)} (kPa) ::
$(q_t - \sigma_v) \cdot 0.015 \cdot 10^{8.95I_c + 1.68}$ (applicable only to $I_c < I_{c,max}$)	$S_{u(rem)} = f_s \quad \text{(applicable only to SBTc: 1, 2, 3, 4 and 9 or } I_c > I_{c,max} \text{)}$
:: Relative Density, D_r (%) ::	:: Overconsolidation Ratio, OCR ::
$100 \cdot \sqrt{\frac{Q_{60}}{k_{DR}}} \quad \text{(applicable only to SBTc: 5, 6, 7 and 8 or } I_c < I_{c,max} \text{)}$	$k_{OCR} = \left[\frac{Q_m^{0.20}}{0.25 \cdot (10.50 + 7 \cdot \log(F_r))} \right]^{1.25} \quad \text{or user defined}$ $OCR = k_{OCR} \cdot Q_m$ (applicable only to SBT _c : 1, 2, 3, 4 and 9 or $I_c > I_{c,max}$)
:: State Parameter, ψ ::	:: In situ Stress Ratio, K_o ::
$\psi = 0.56 - 0.33 \cdot \log(Q_{60,ca})$	$K_o = 0.1 \cdot \left(\frac{q_t - \sigma_v}{\sigma_{vo}} \right)$ (applicable only to SBT _c : 1, 2, 3, 4 and 9 or $I_c > I_{c,max}$)
:: Peak drained friction angle, φ (°) ::	:: Soil Sensitivity, S_t ::
$\phi = 17.60 + 11 \cdot \log(Q_{60})$ (applicable only to SBT _c : 5, 6, 7 and 8)	$S_t = \frac{N_s}{F_r}$ (applicable only to SBT _c : 1, 2, 3, 4 and 9 or $I_c > I_{c,max}$)
:: 1-D constrained modulus, M (MPa) ::	:: Effective Stress Friction Angle, φ' (°) ::
If $I_c > 2.20$ $a = 14$ for $Q_{60} > 14$ $a = Q_{60}$ for $Q_{60} \leq 14$ $M_{CPT} = a \cdot (q_t - \sigma_v)$	$\phi' = 29.5^{\circ} \cdot B_0^{0.121} \cdot (0.256 + 0.336 \cdot B_0 + \log Q_t)$ (applicable for $0.10 < B_0 < 1.00$)
If $I_c \leq 2.20$ $M_{CPT} = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55I_c + 1.68}$	

Fig. 2.2: Correlazioni utilizzate per la stima dei parametri geotecnici.

La prova penetrometrica elettrica con piezocono sismico SCPTU consiste nell'infissione nel terreno di un piezocono standard all'interno del quale sono inseriti tre geofoni per la misura della velocità di propagazione nel terreno delle onde sismiche di taglio S e di compressione P. Le modalità esecutive della prova seguono le normative tecniche standard della classica prova con piezocono la cui infissione viene arrestata ad intervalli regolari di 1,00 metro per effettuare l'acquisizione dei dati sismici tramite sensori e sismografo.

Il sistema di energizzazione del terreno (sorgente delle onde di taglio) è costituito da una pesante traversina in ferro collegata e fissata al penetrometro in modo tale che le terminazioni della traversina siano situate ad una distanza non superiore a 3,00 metri dalla verticale di prova. Le traversine di ferro fissate alle terminazioni vengono colpiti con una mazza o un martello sufficientemente pesanti. Per la valutazione dei tempi di arrivo ad ogni metro di profondità viene utilizzato il metodo del cross-over (sovraposizione di due segnali con opposta polarizzazione) che permette di scartare i segnali non coerenti, individuare i segnali migliori su cui mediare e determinare con precisione i tempi di arrivo delle onde di taglio.

Attraverso le indagini SCPTU proposte, oltre a identificare con esattezza la litostatigrafia dei punti indagati, è stato ricavato il valore di velocità di onde S ad ogni metro di profondità, sulla base di una misura diretta e affidabile. Le misure delle velocità di onde S sono state eseguite fino alla profondità di -30.00 m.



Alcune riprese fotografiche delle prove penetrometriche CPTU eseguite in situ in data 23-24/04/2018.



Alcune riprese fotografiche delle prove penetrometriche CPTU eseguite in situ in data 23-24/04/2018.

Al termine delle prove penetrometriche sopraccitate eseguite nei mesi di ottobre 2017 e aprile e maggio 2018, dopo l'estrazione delle aste è stata eseguita la misura della falda freatica all'interno dei fori di sondaggio. Le misure eseguite hanno fornito i valori di soggiacenza riportati nella seguente tabella:

prova	Soggiacenza della falda (m da p.c.)
CPTU/SCPTU 1	-3.50 (*)
CPTU 2	-4.20 (*)
CPTU 3	-3.70
CPTU 4	-3.30
CPTU 5	-3.50
CPTU 6	-2.10
CPTU 7	-2.05
CPTU 8	-1.80
CPTU 9	-4.00
CPTU 10	-2.20
CPTU 11	-4.00
CPTU 12	-5.00
CPTU 13	-3.80
CPTU 14	-3.40
CPTU 15	-3.90
CPTU 16	-3.85
CPTU 17	-3.10
(*) misure eseguite in ottobre 2017	

2.3 CARATTERISTICHE LITOSTRATIGRAFICHE DEL SOTTOSUOLO

Dalle indagini geognostiche eseguite in situ e sulla base delle informazioni bibliografiche e di piano recepite, per l'area in oggetto si delinea uno scenario di piana alluvionale, non interessata dalla presenza di paleoalvei antichi, con una prevalenza di sedimenti fini da sabbioso-limosi ad argillosi.

Dalle indagini eseguite si evidenzia la presenza di sedimenti fini, con una prevalenza di terreni coesivi argillosi e limosi. In particolare, nel settore nord del lotto si delinea una fascia in cui si alternano depositi coesivi argillosi e talvolta torbosi e depositi incoerenti fini, sabbiosi e limosi. Al di fuori di questa fascia si denota una netta prevalenza di terreni coesivi, da argille ad argille limose e talvolta argille organiche.

La soggiacenza della falda freatica effettuate durante l'esecuzione delle prove penetrometriche, è risultata a una profondità compresa tra -5.00 ÷ -1.80 m da piano campagna. Tali misure sono comunque rappresentative dell'attuale stagione, pertanto potranno subire ulteriori oscillazioni a seconda dell'andamento della piovosità stagionale.

Si riportano nelle immagini seguenti le sezioni litostratigrafiche relative a ciascuna prova CPTU eseguita.

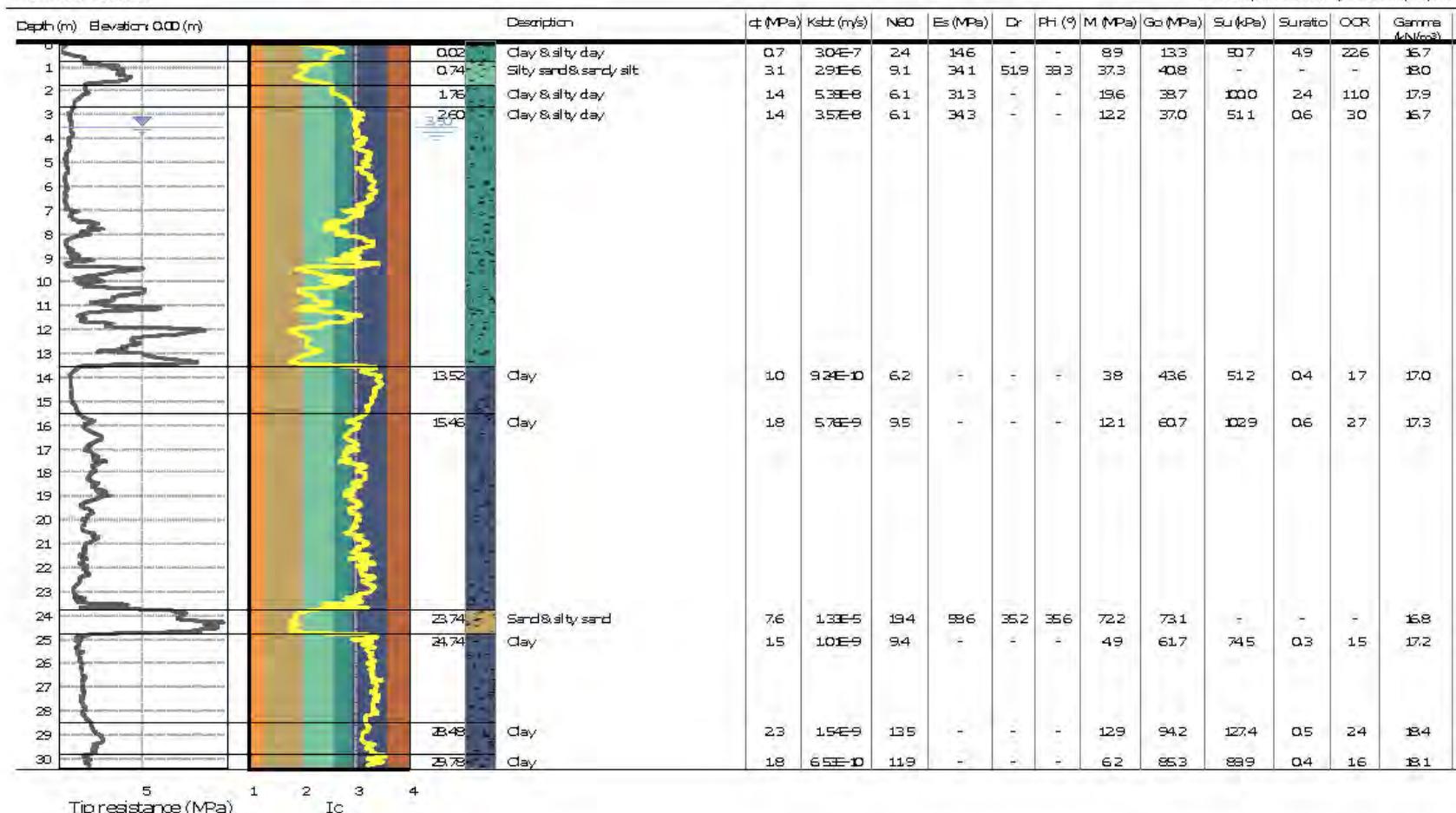
SEZIONE LITOSTRATIGRAFICA – CPTU1

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile

Location: Ferrara

CPT: CPTU 1

Total depth: 30.30 m, Date: 31/10/2017



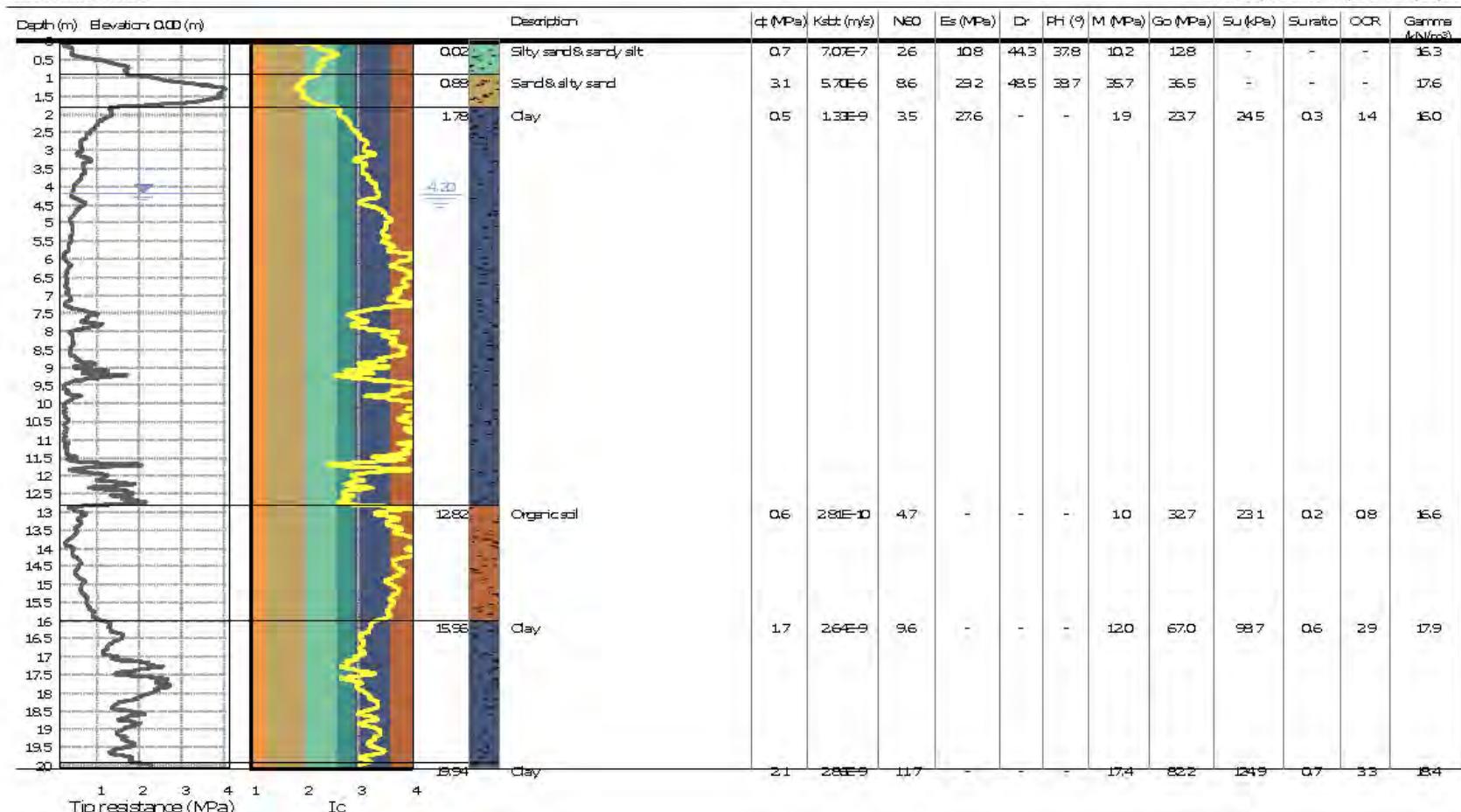
SEZIONE LITOSTRATIGRAFICA – CPTU2

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile

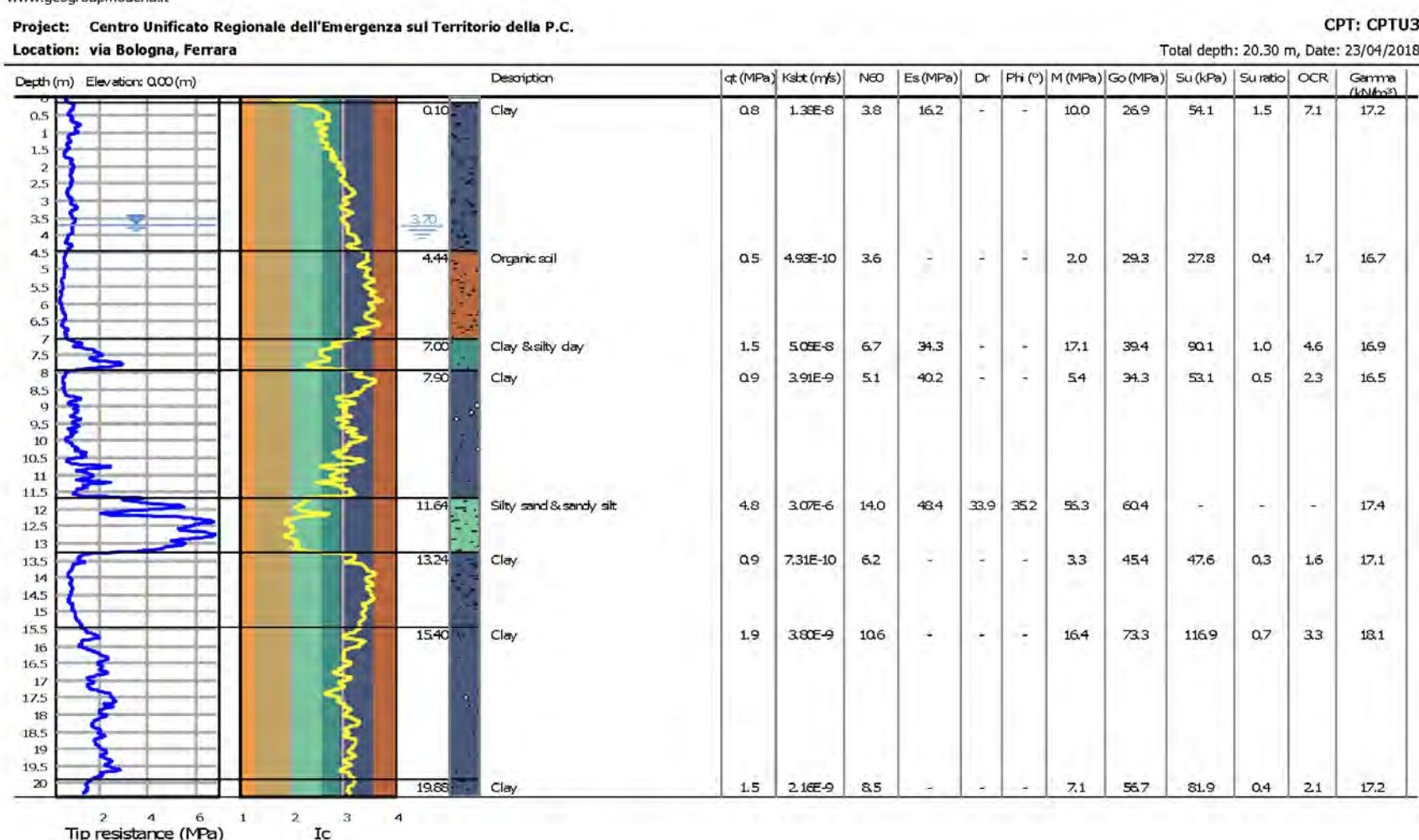
Location: Ferrara

CPT: CPTU 2

Total depth: 20.00 m, Date: 31/10/2017



SEZIONE LITOSTRATIGRAFICA – CPTU3



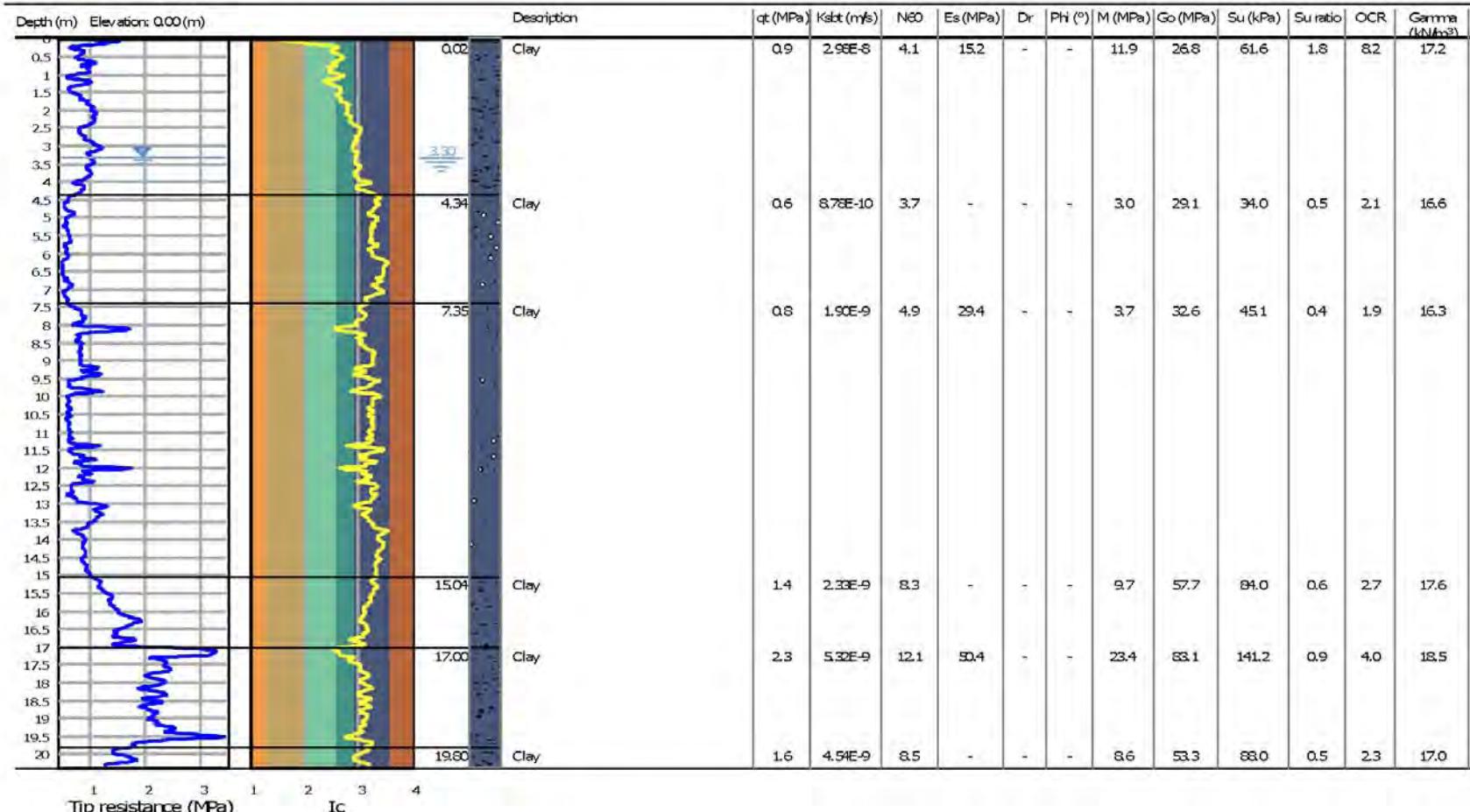
SEZIONE LITOSTRATIGRAFICA – CPTU4

Project: Centro Unificato Regionale dell'Emergenza sul Territorio della P.C.

Location: via Bologna, Ferrara

CPT: CPTU4

Total depth: 20.30 m, Date: 23/04/2018



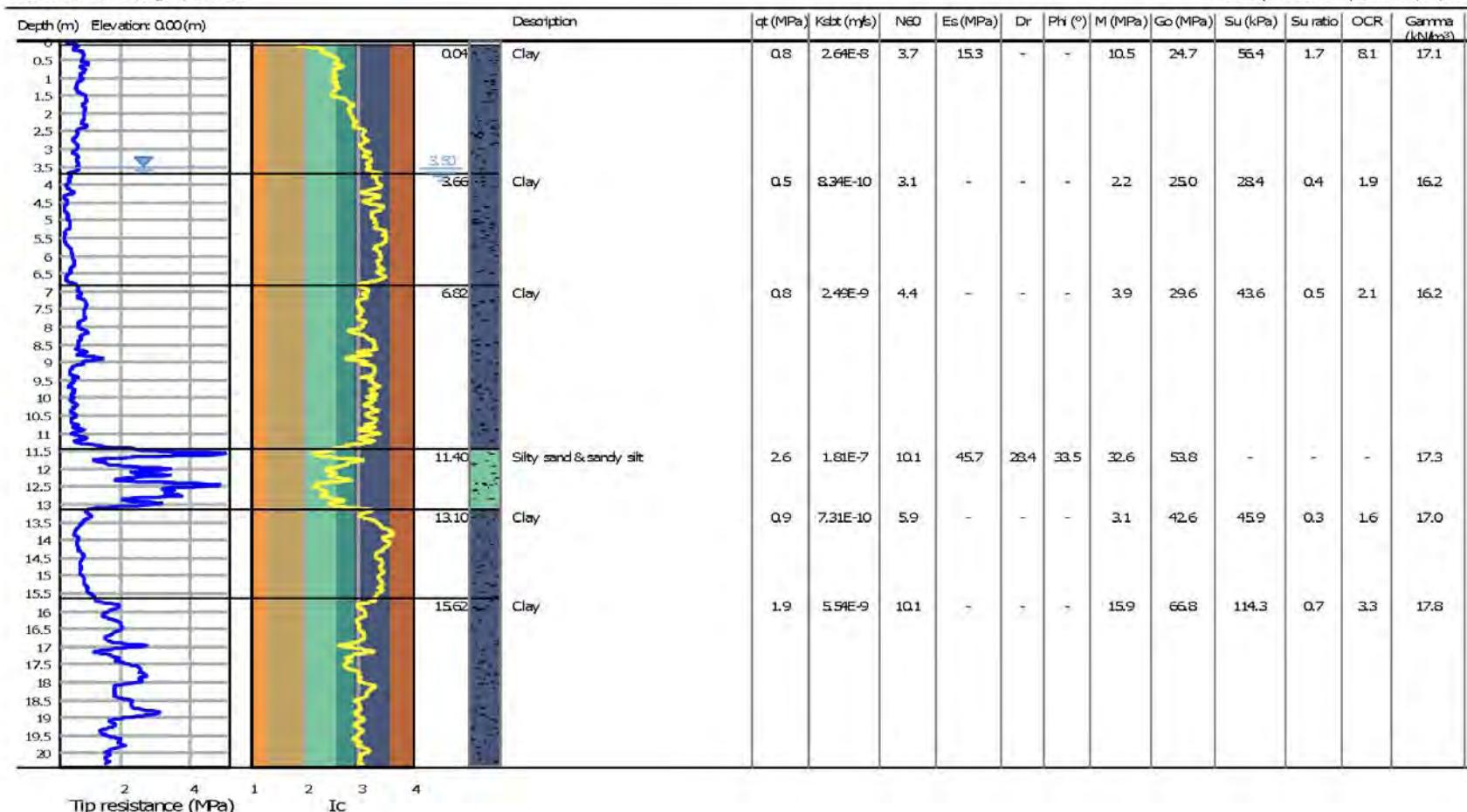
SEZIONE LITOSTRATIGRAFICA – CPTU5

Project: Centro Unificato Regionale dell'Emergenza sul Territorio della P.C.

Location: via Bologna, Ferrara

CPT: CPTU5

Total depth: 20.30 m, Date: 23/04/2018



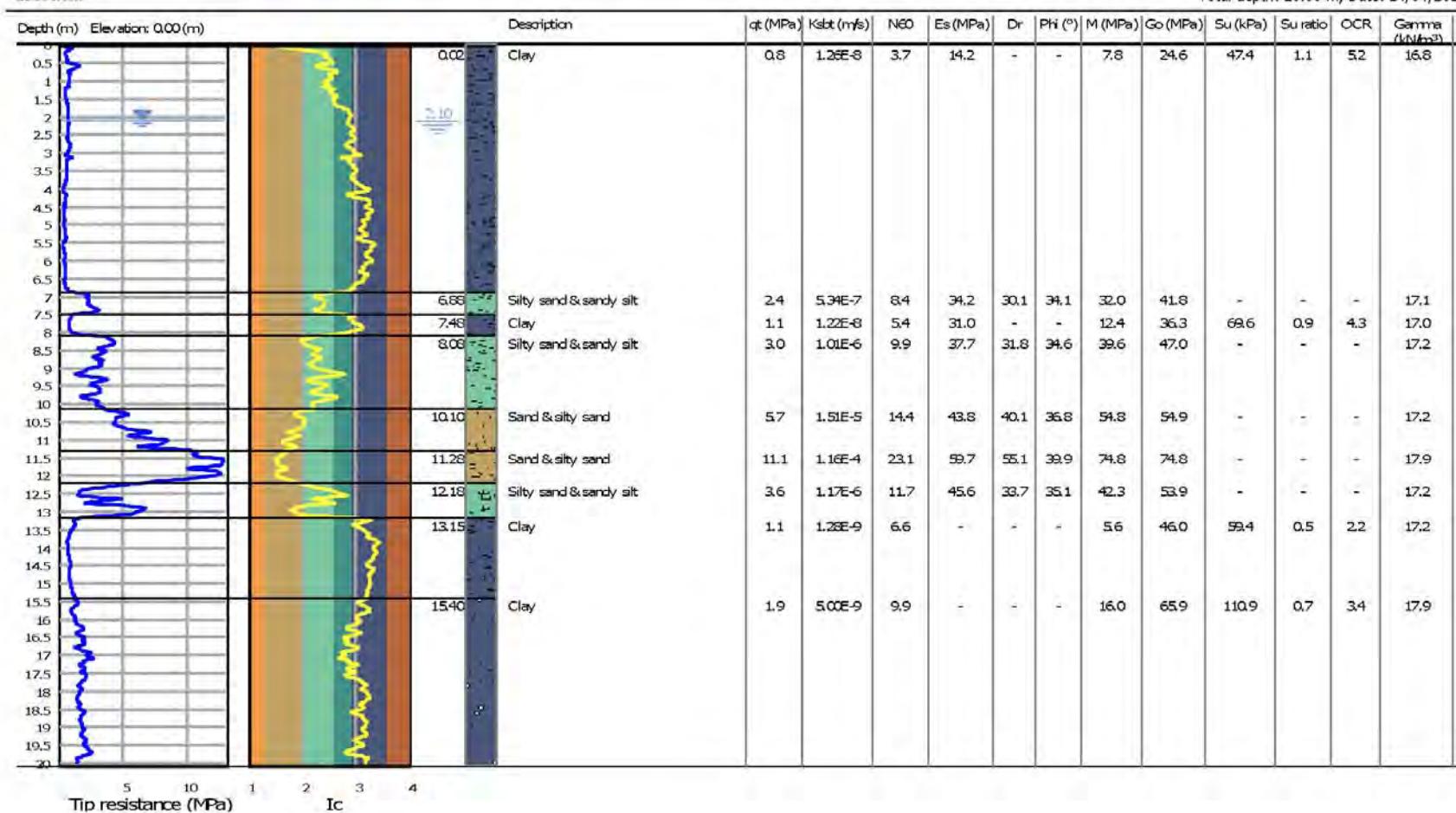
SEZIONE LITOSTRATIGRAFICA – CPTU6

Project:

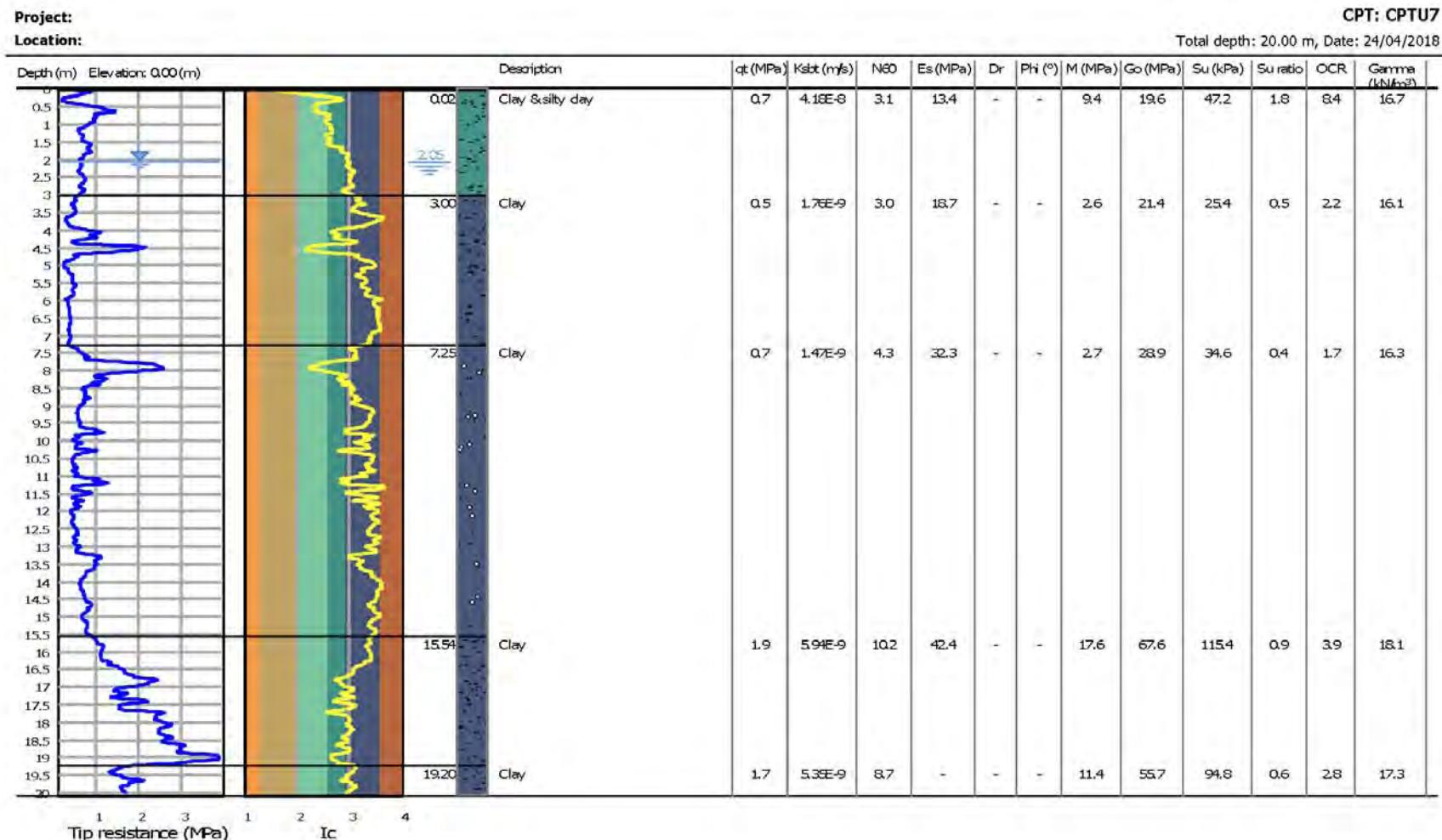
CPT: CPTU6

Location:

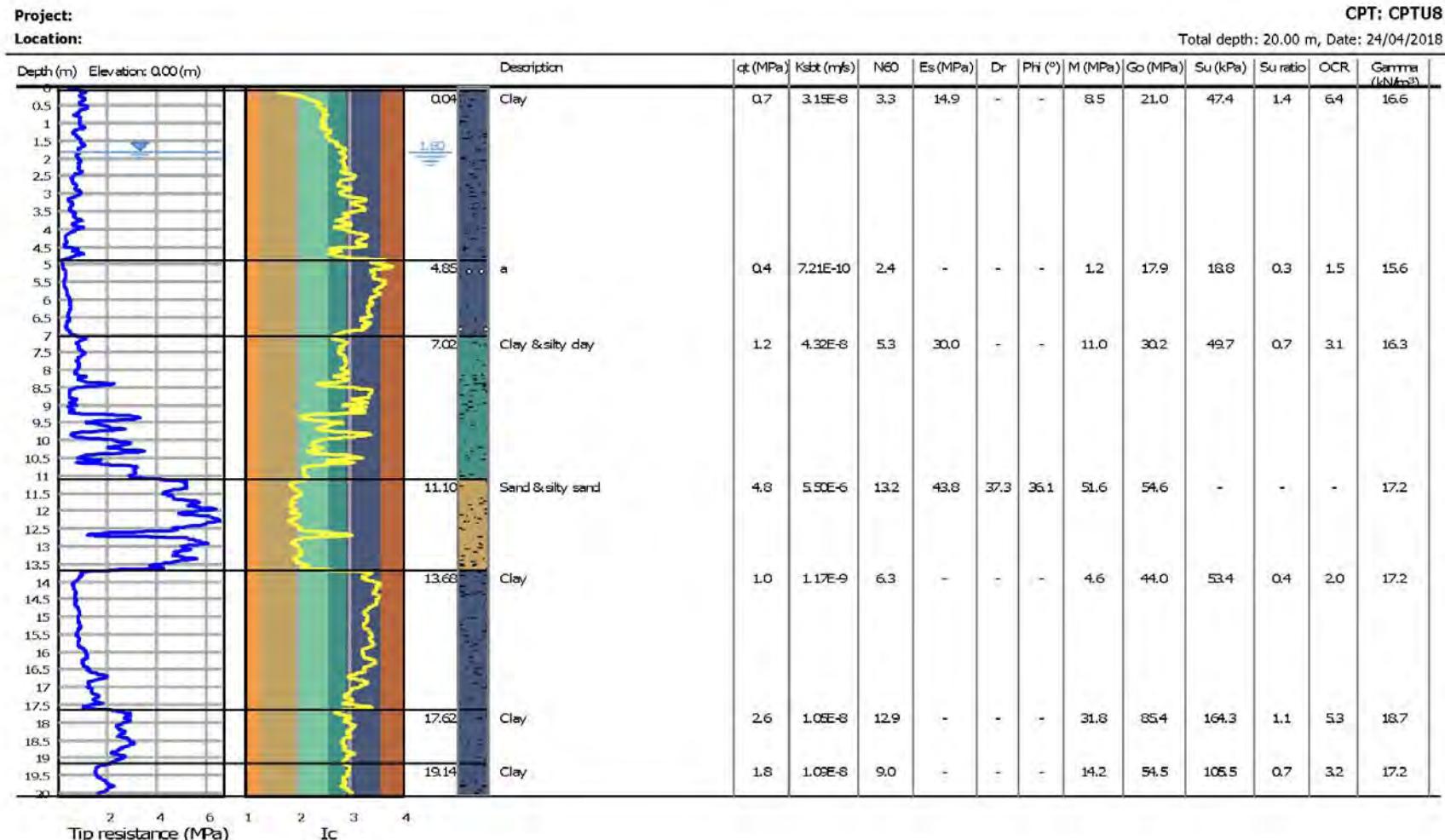
Total depth: 20.00 m, Date: 24/04/2018



SEZIONE LITOSTRATIGRAFICA – CPTU7



SEZIONE LITOSTRATIGRAFICA – CPTU8



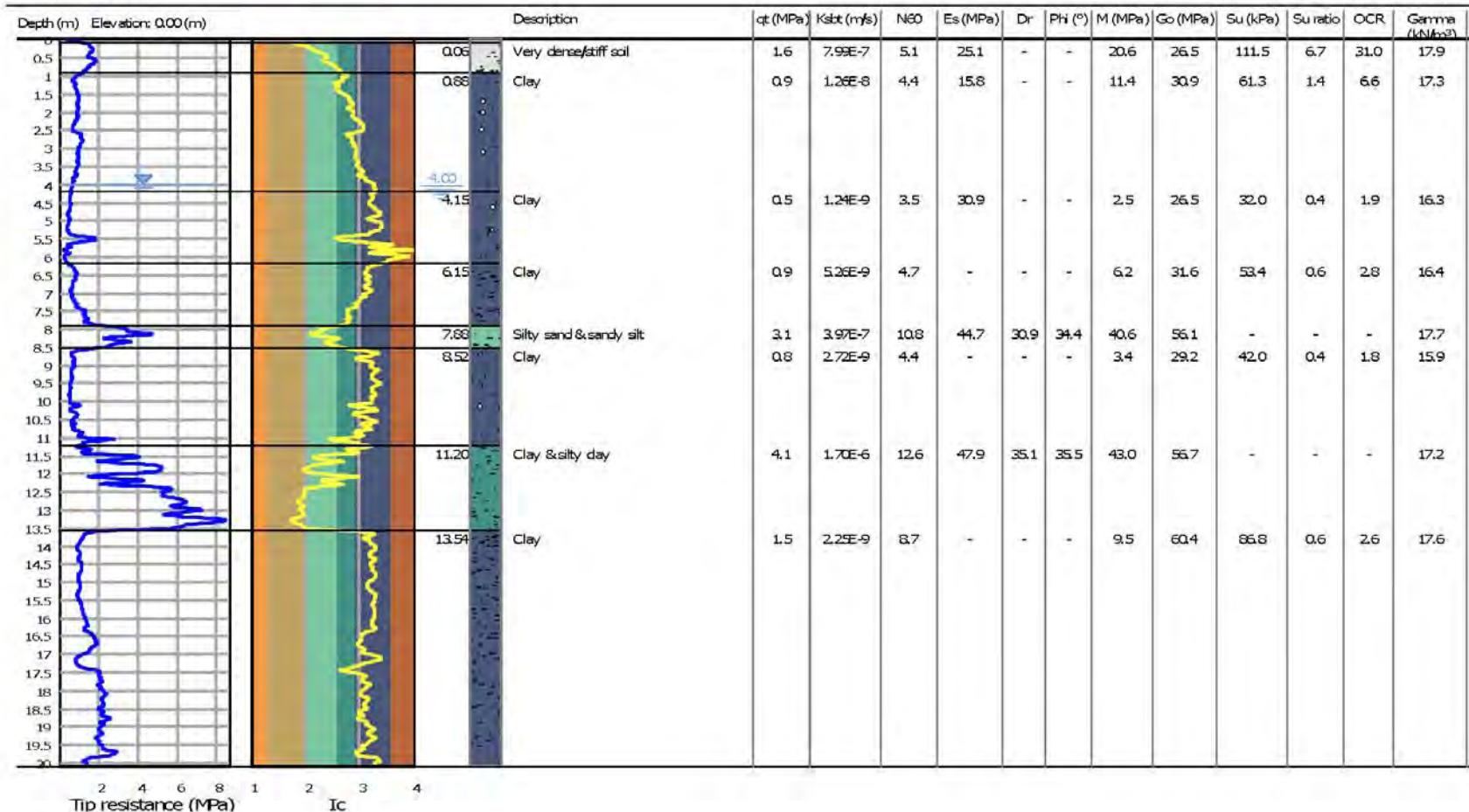
SEZIONE LITOSTRATIGRAFICA – CPTU9

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 9

Total depth: 20.00 m, Date: 14/05/2018



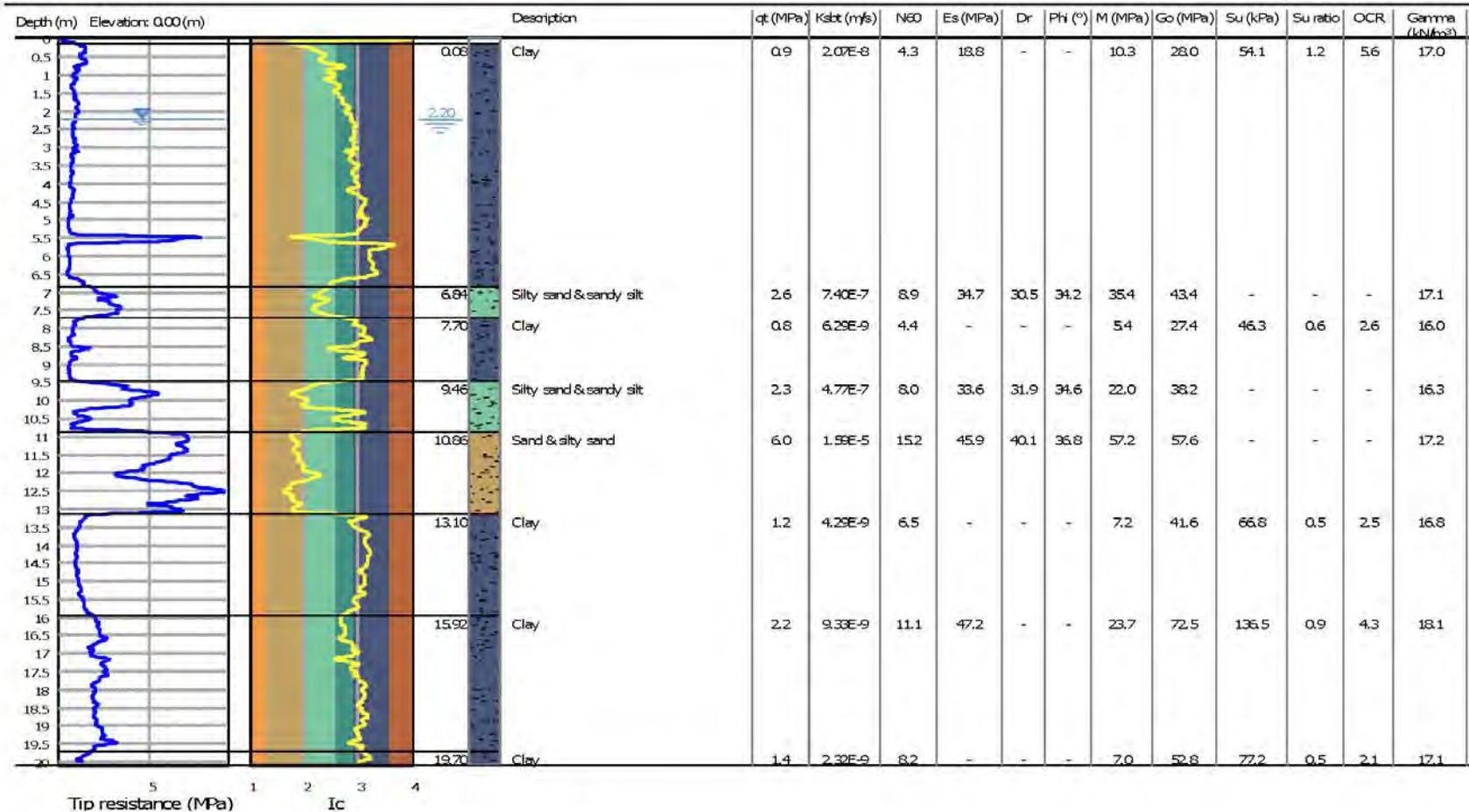
SEZIONE LITOSTRATIGRAFICA – CPTU10

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 10

Total depth: 20.00 m, Date: 14/05/2018



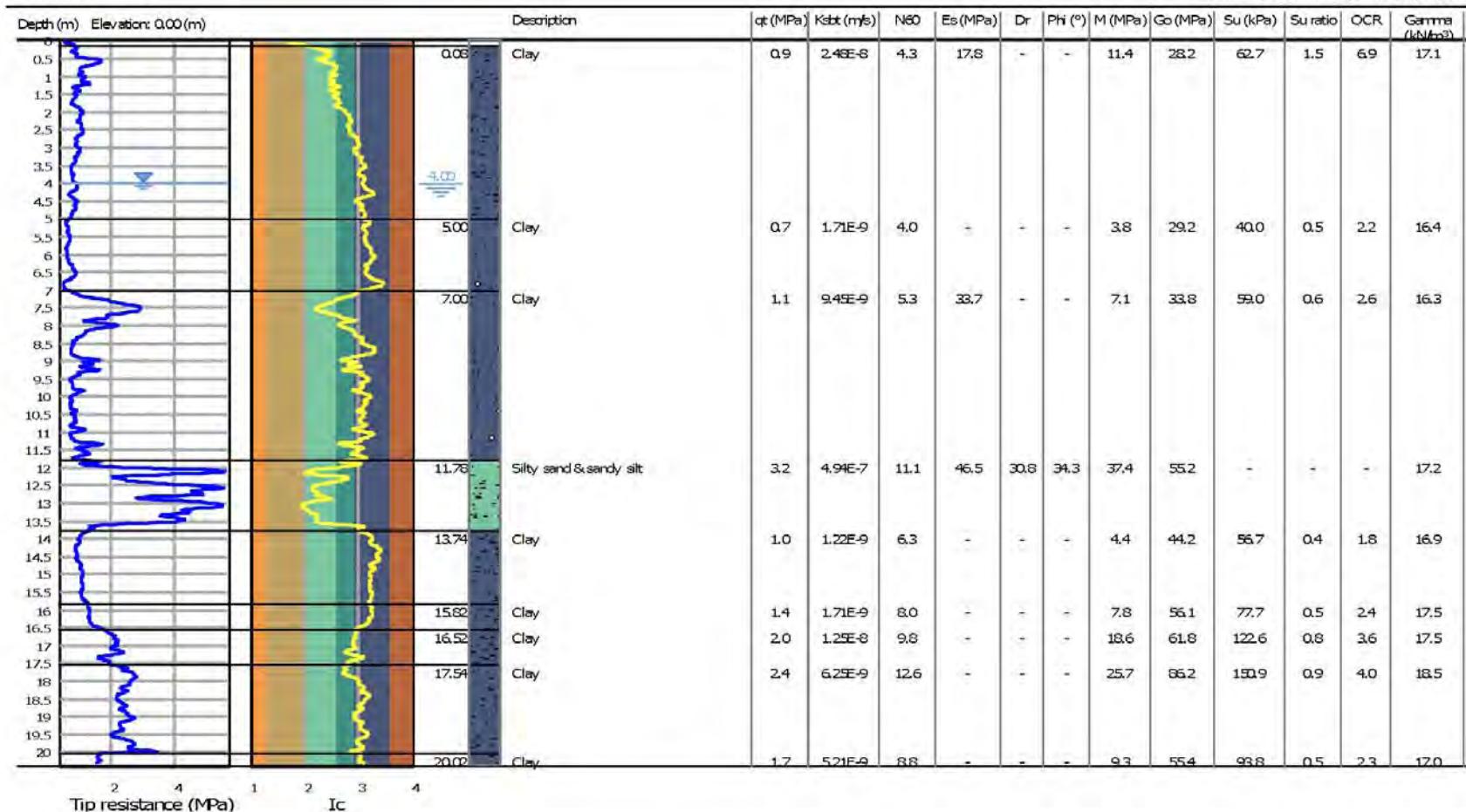
SEZIONE LITOSTRATIGRAFICA – CPTU11

Project: Centro Unificato dell'Emergenza sul Territorio

CPT: CPTU 11

Location: Ferrara

Total depth: 20.30 m, Date: 15/05/2018



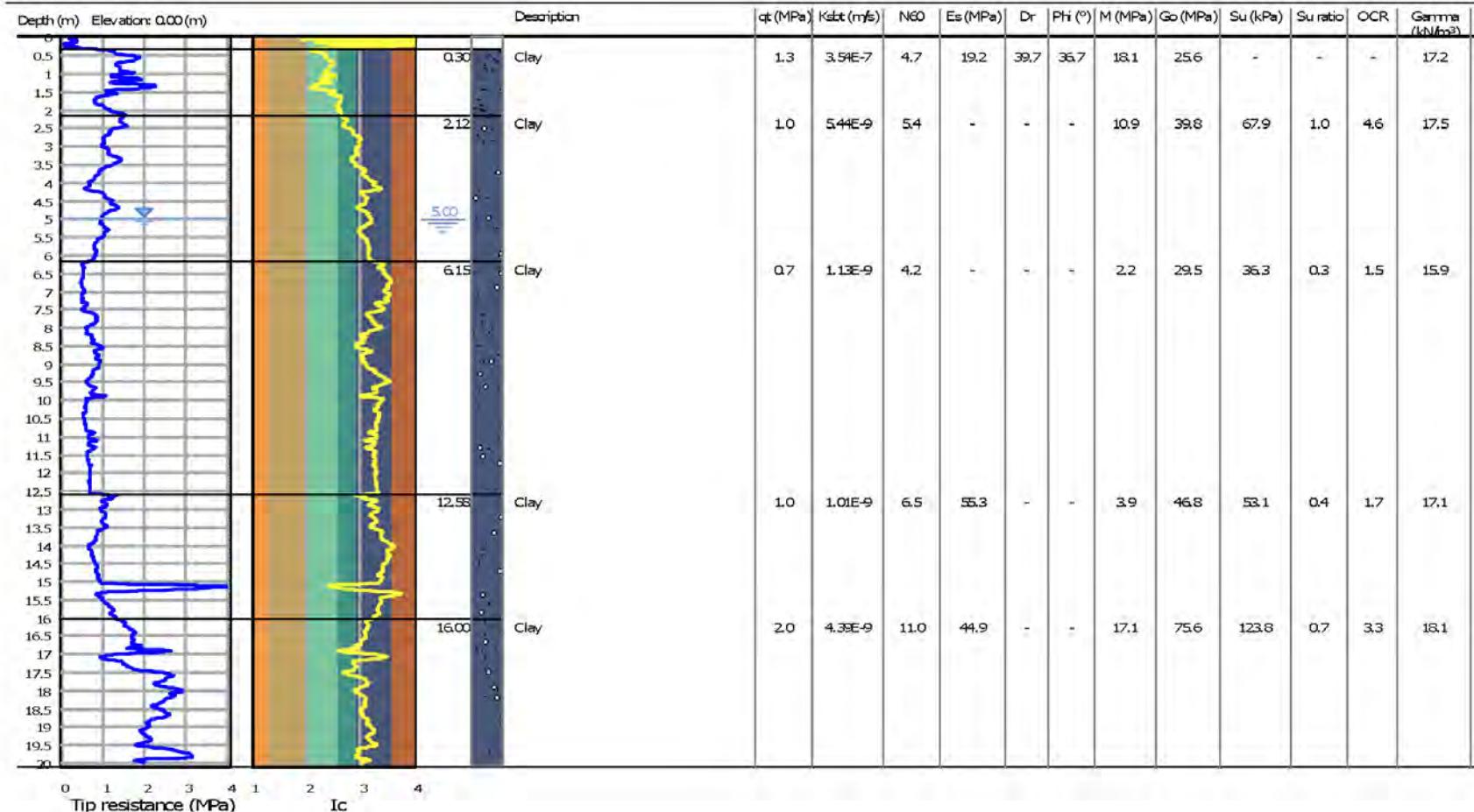
SEZIONE LITOSTRATIGRAFICA – CPTU12

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 12

Total depth: 20.00 m, Date: 16/05/2018



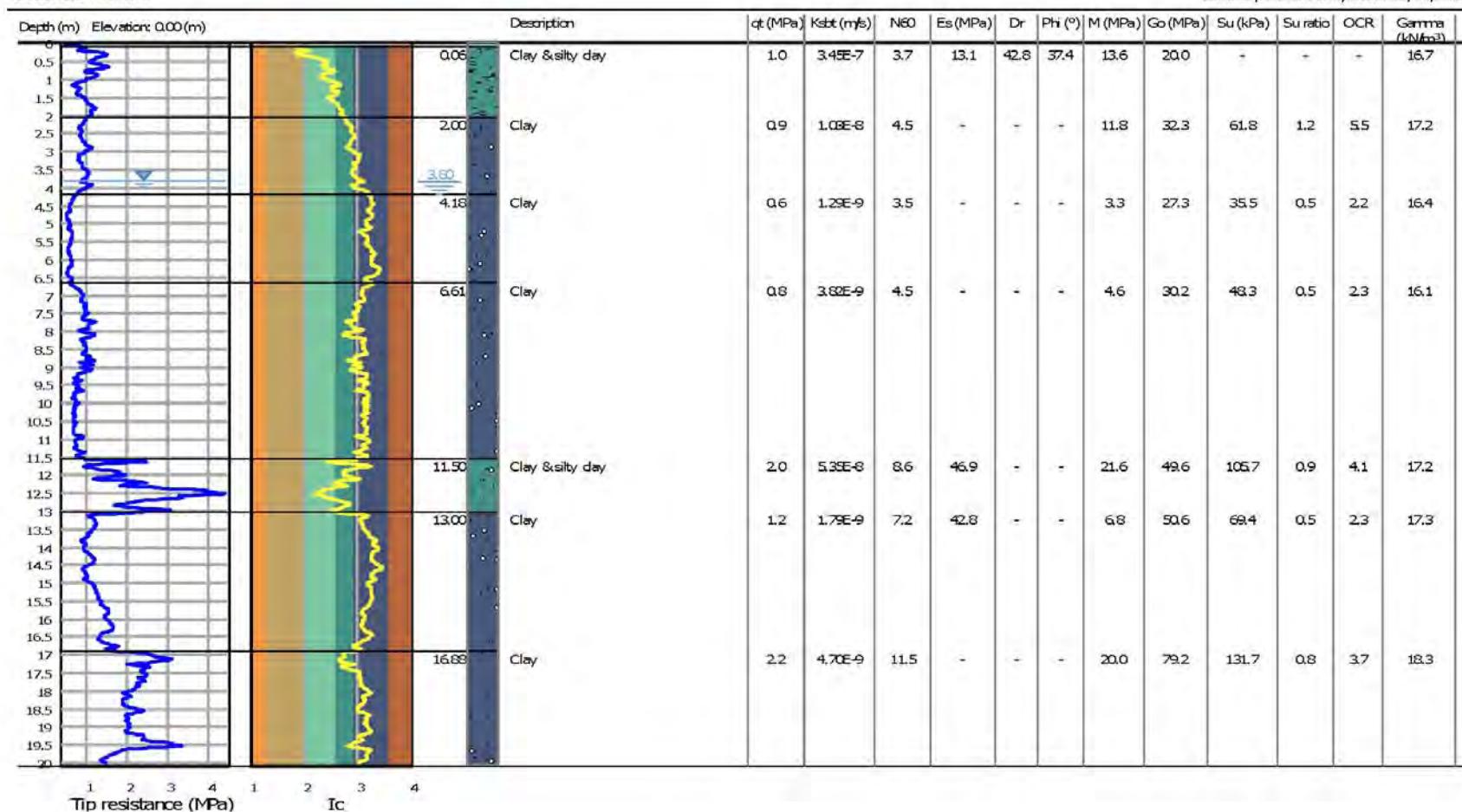
SEZIONE LITOSTRATIGRAFICA – CPTU13

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 13

Total depth: 20.00 m, Date: 15/05/2018



SEZIONE LITOESTRATIGRAFICA – CPTU14

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 14

Total depth: 20.00 m, Date: 15/05/2018

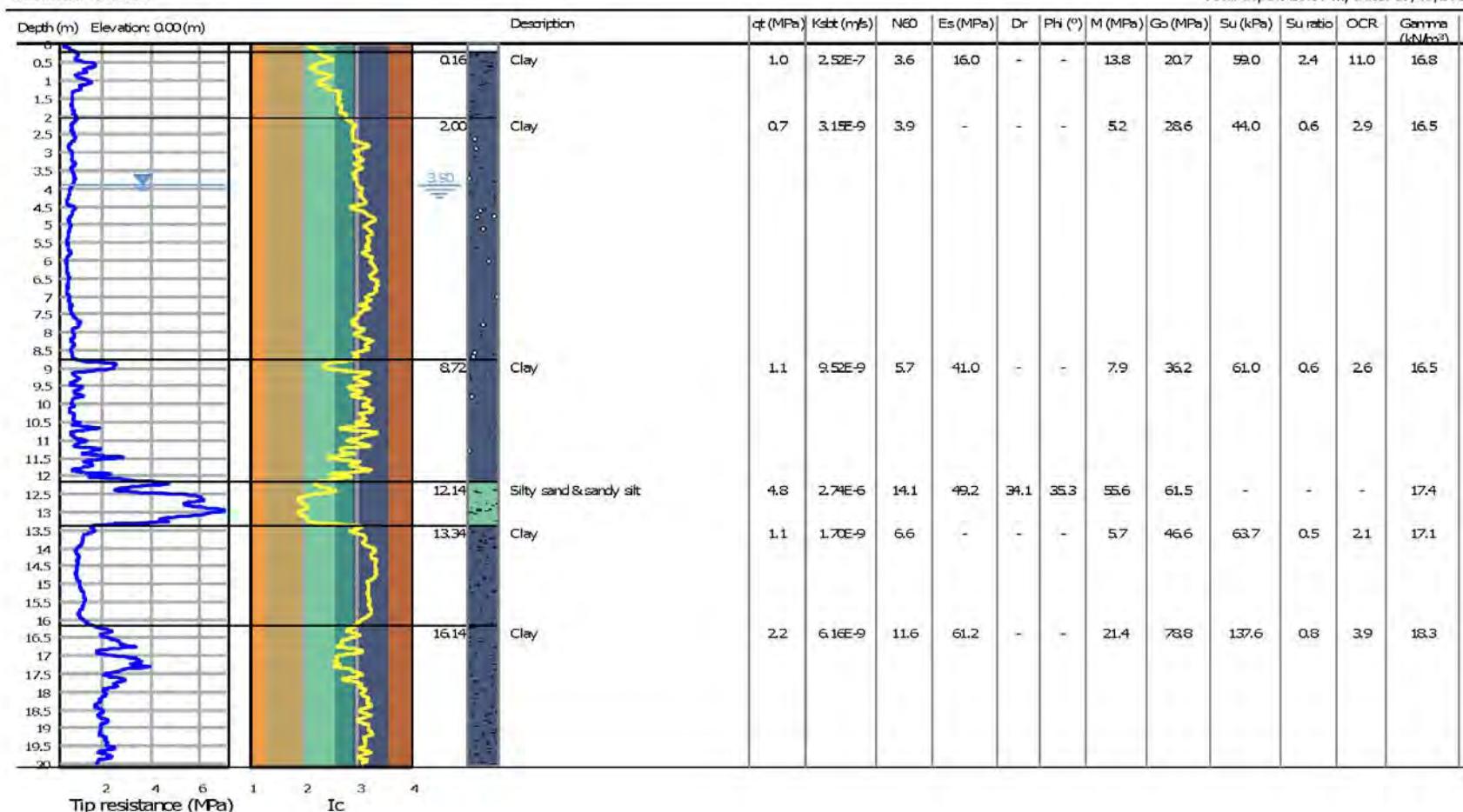
SEZIONE LITOSTRATIGRAFICA – CPTU15

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 15

Total depth: 20.00 m, Date: 17/05/2018



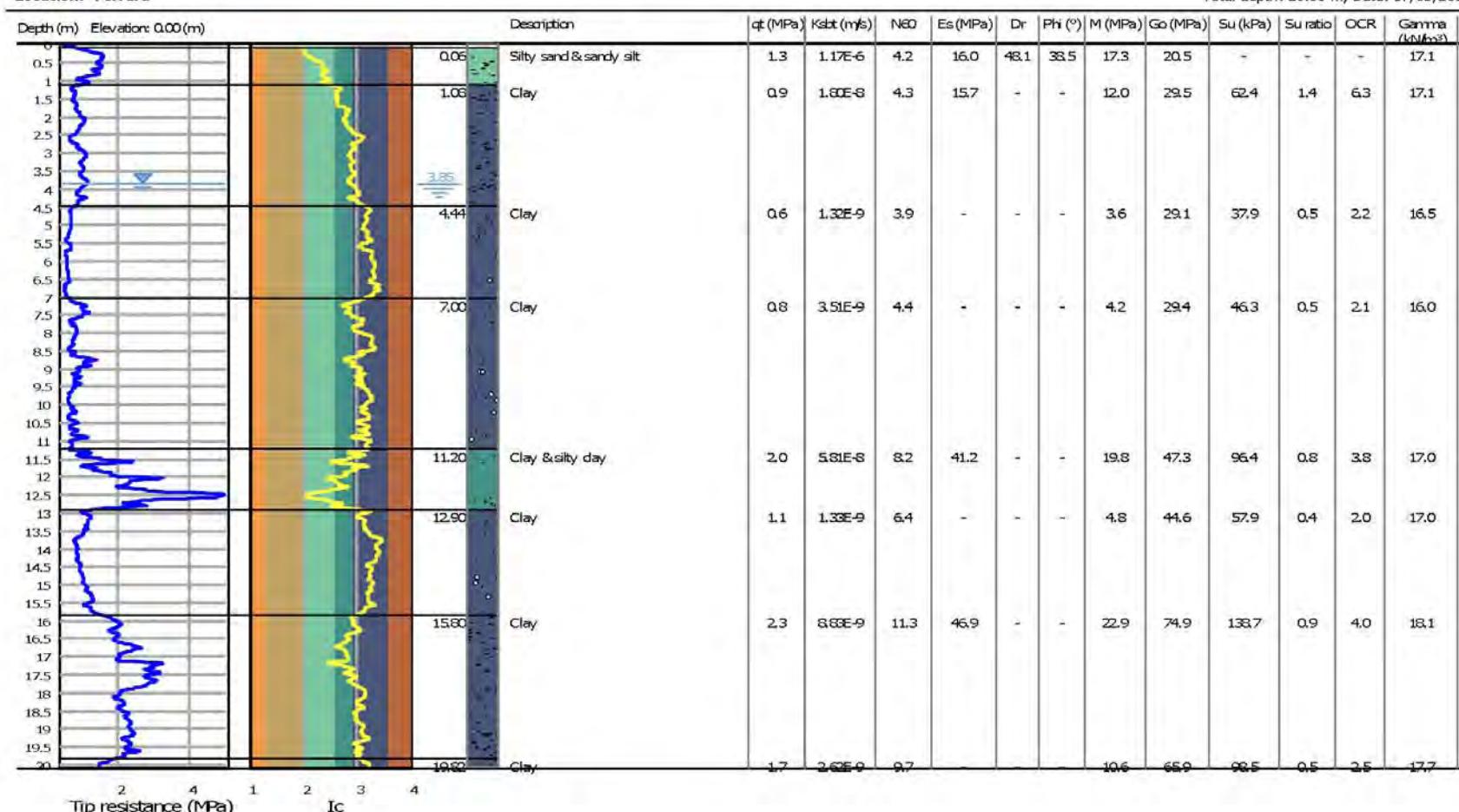
SEZIONE LITOSTRATIGRAFICA – CPTU16

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 16

Total depth: 20.00 m, Date: 17/05/2018



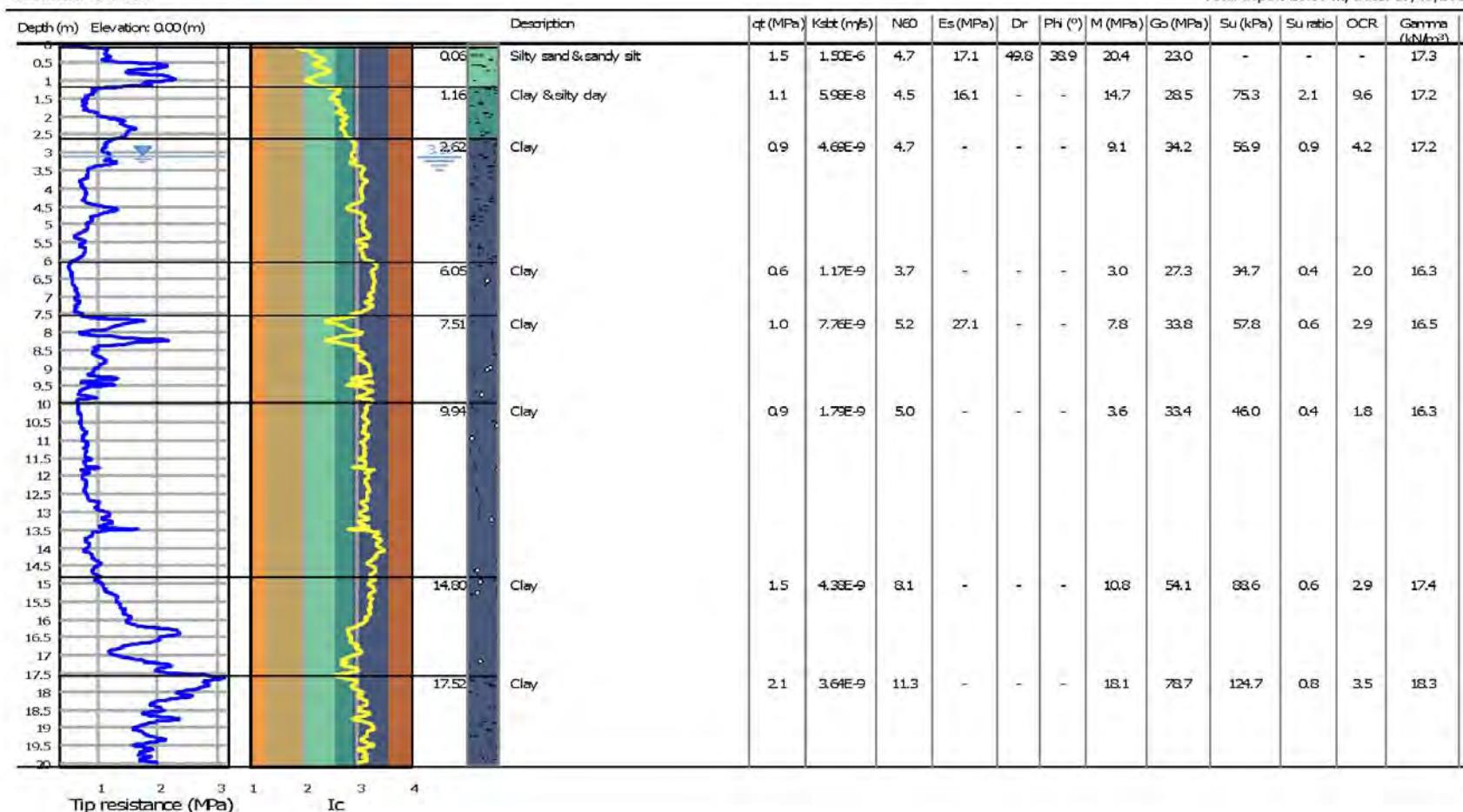
SEZIONE LITOSTRATIGRAFICA – CPTU17

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 17

Total depth: 20.00 m, Date: 17/05/2018



2.2.2 Sondaggi a carotaggio continuo

In data 26-27/04/2018 è stato eseguito n. 1 sondaggio a carotaggio continuo fino alla profondità di -30.00 m da p.c.



Riprese fotografiche dei punti di sondaggio e dell'attrezzatura di indagine

Nel corso del sondaggio eseguito, ai fini della caratterizzazione geotecnica dei terreni indagati sono stati prelevati **n. 4 campioni indisturbati di terreno**, da sottoporre a prove di laboratorio geotecnico.

Si riassumono di seguito le caratteristiche dei sondaggi a carotaggio eseguiti:

DATA ESECUZIONE	SONDAGGIO	PROFONDITÀ (*)	NOTE
26-27/04/2018	S1	-30.00	n. 4 SPT
			n. 4 campioni indisturbati
			n. 5 campioni rimaneggiati
(*) riferita alla quota di inizio dell'indagine			

CAMPIONE	tipologia	PROFONDITÀ m (*)
S1C1	Indisturbato Shelby	-3.00÷-3.60
S1C2	Indisturbato Shelby	-8.40÷-9.10
S1C3	Indisturbato Shelby	-10.50÷-11.10
S1C4	Indisturbato Shelby	-15.30÷-16.00
S1C5	Rimaneggiato	-6.00÷ -6.30
S1C6	Rimaneggiato	-9.80÷ -10.00
S1C7	Rimaneggiato	-12.30÷ -12.50
S1C8	Rimaneggiato	-16.60÷ -16.80
S1C9	Rimaneggiato	-22.30÷ -22.50
(*) riferita alla quota di inizio dell'indagine		

2.2.3 Prove penetrometriche dinamiche standard SPT in foro

Durante la perforazione, all'interno del foro di sondaggio sono state eseguite n. 4 prove penetrometriche dinamiche di tipo SPT (“Standard Penetration Test”) con punta conica chiusa al fine di determinarne i parametri geotecnici del terreno indagato; i risultati sono visibili in allegato.

La prova penetrometrica dinamica in foro SPT consiste nel far cadere, con una frequenza di 20/25 colpi al minuto, un maglio da 63,50 kg da un'altezza di 76,00 cm (standard europeo) su una batteria di aste che possiedono, nella parte terminale, un campionatore cilindrico a “punta aperta”, come in questo caso, o, in alternativa, una punta conica “chiusa”, con angolo di punta pari a 60° e avente un diametro esterno di 50,46 mm.

Nel corso della prova SPT viene registrato il numero di colpi necessario per infiggere la punta conica per **45 cm** nel terreno. Il valore di (N_{SPT30}) viene ottenuto eliminando i colpi dei primi 15 cm di infissione e sommando il valore dei colpi necessario per infiggere la punta conica nei rimanenti 30 cm di sottosuolo.

Le prove penetrometriche SPT (“Standard Penetration Test”) sono state eseguite all'interno del foro di sondaggio alle seguenti profondità (riferite alla quota di inizio indagine):

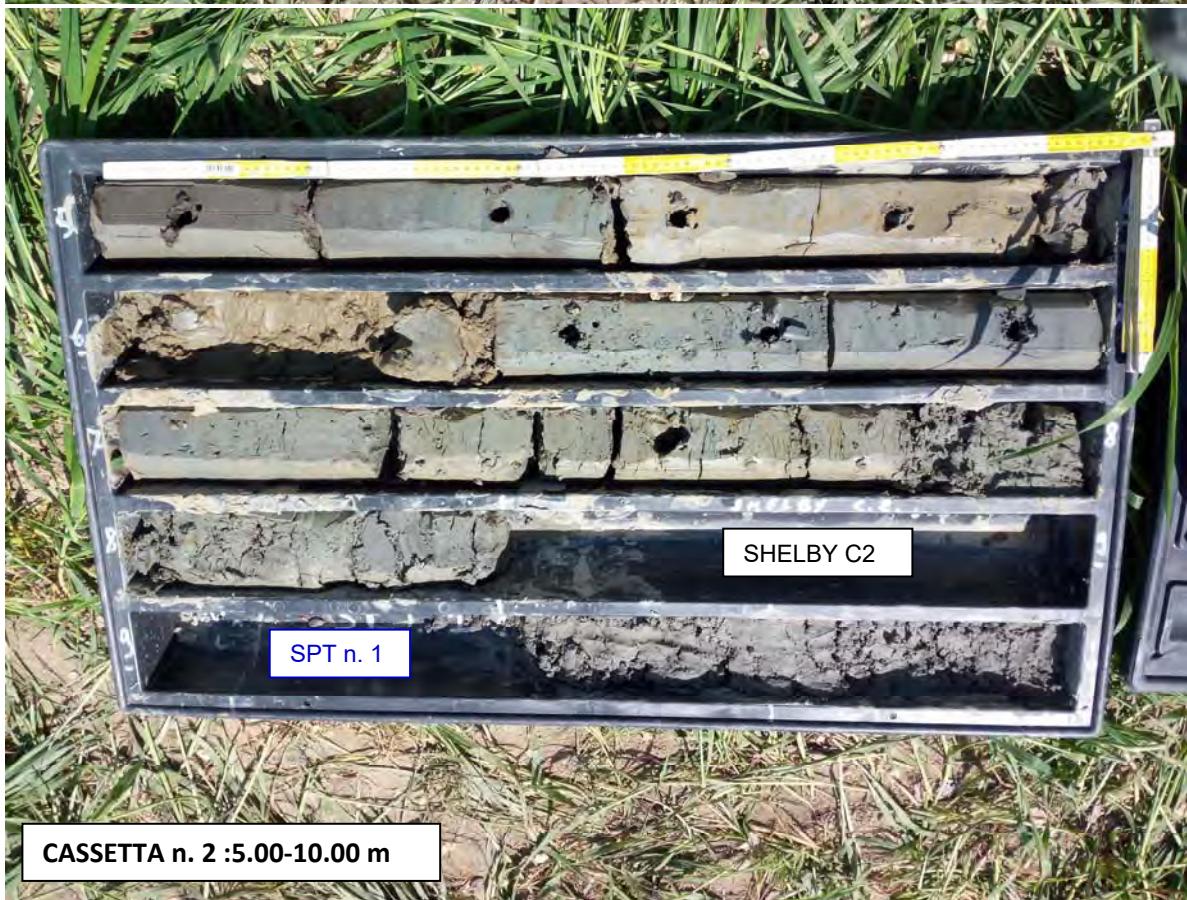
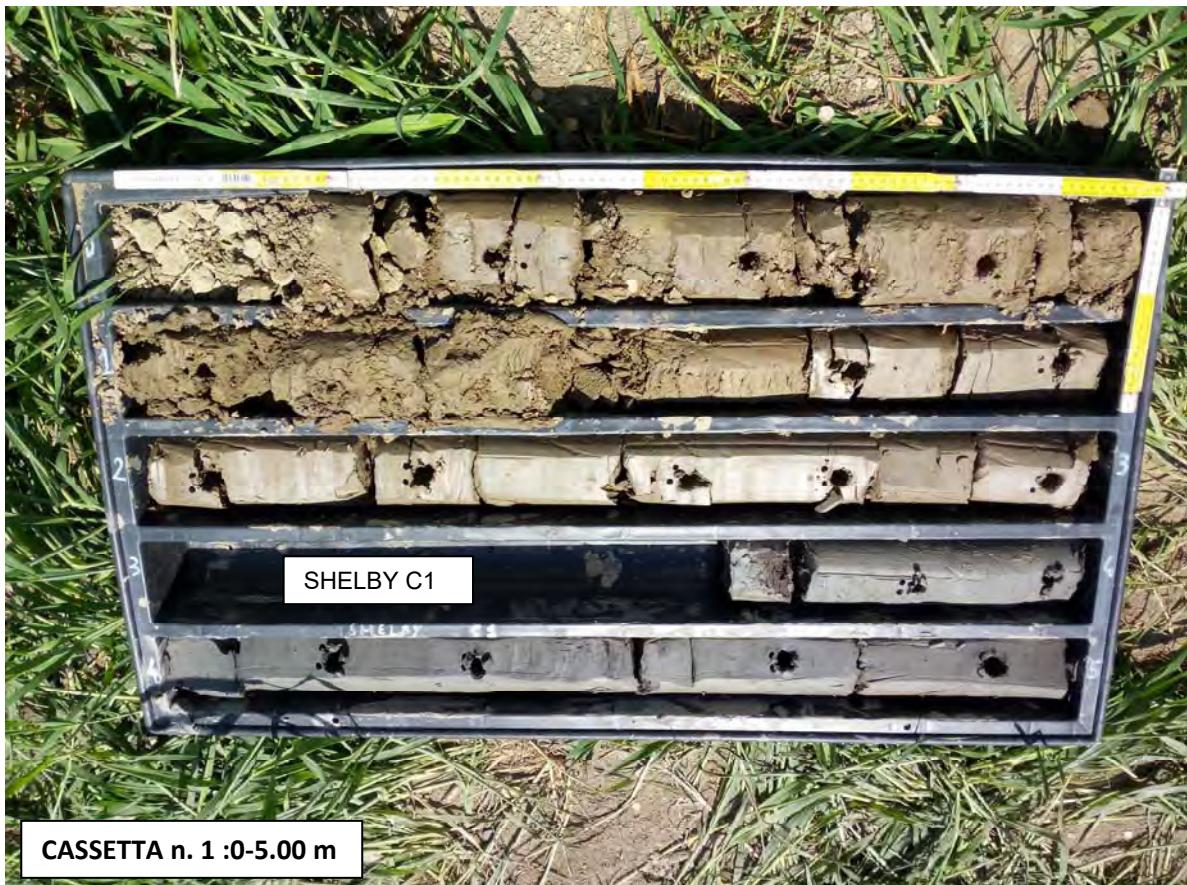
		PUNTA	PROFONDITÀ (*)	NUMERO DI COLPI			N_{SPT30}
S1	SPT 1	APERTA	-9.10 m	1	5	10	15
	SPT 2	APERTA	-11.10 m	7	12	15	27
	SPT 3	APERTA	-11.55 m	10	13	18	31
	SPT 4	APERTA	-12.70 m	12	16	20	36
(*) riferita alla quota di inizio indagine							

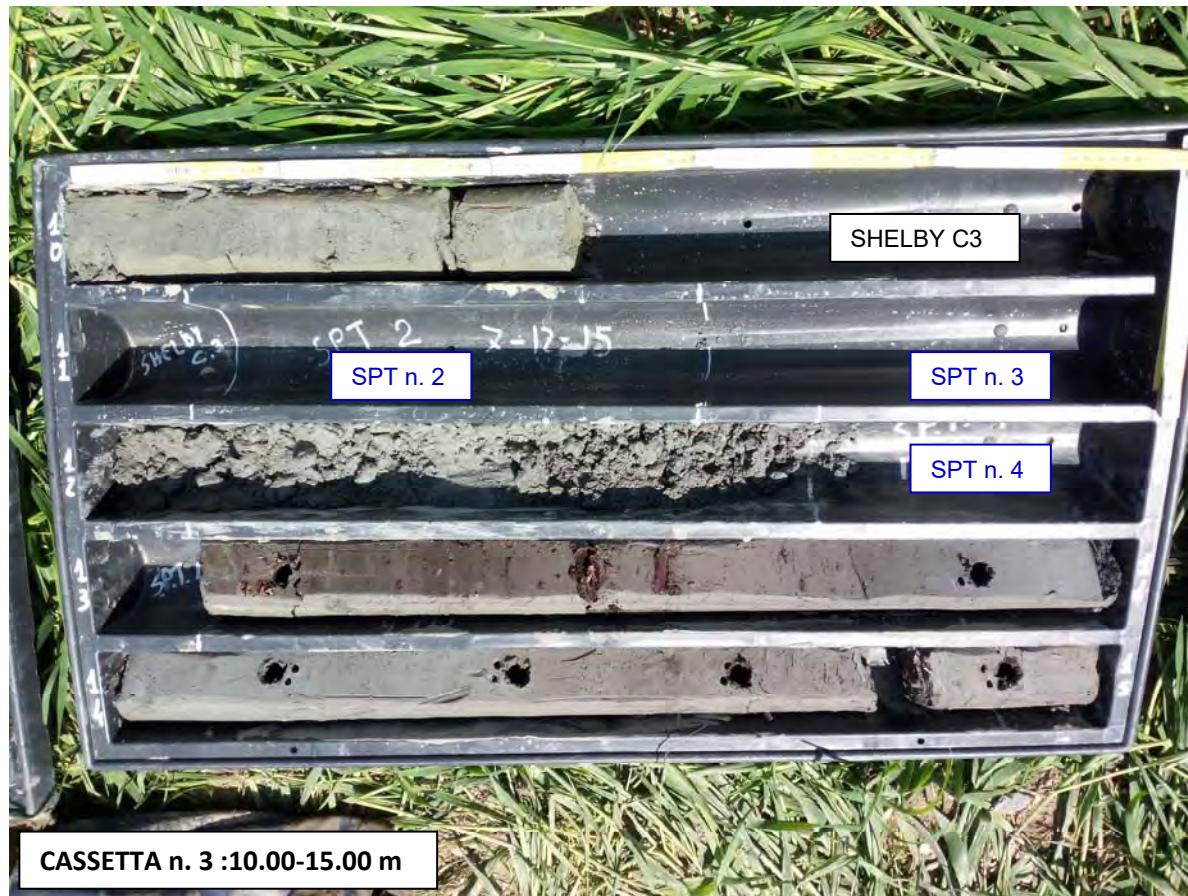
Il numero dei colpi **N**, in base alle Normative **AGI** (1977) ci dà una classifica orientativa dello stato di compattezza (addensamento) dei terreni incoerenti, come visibile nella tabella di seguito esposta:

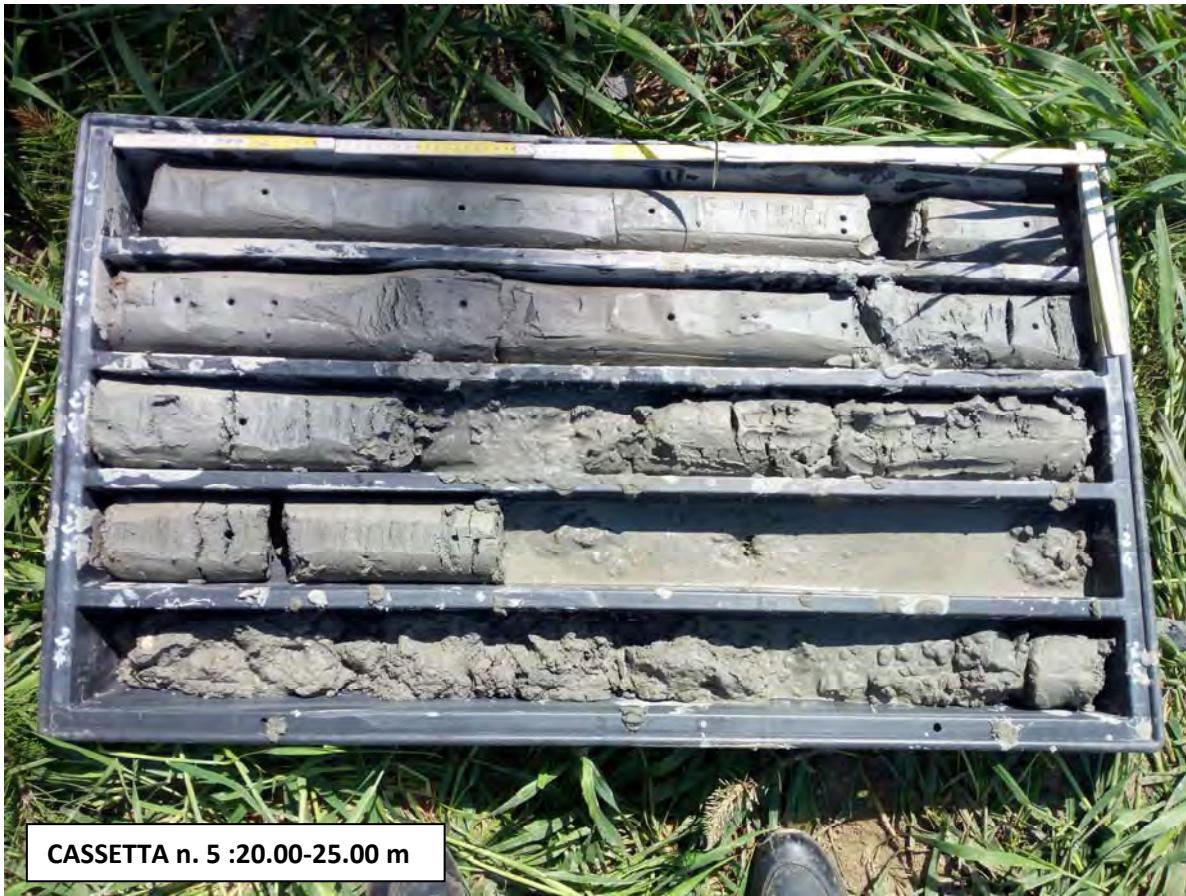
N	valutazione dello stato di addensamento
0 – 4	sciolto
4 – 10	poco addensato
10 – 30	moderatamente addensato
30 – 50	addensato
≥ 50	molto addensato

In **allegato** sono visibili i risultati ottenuti dall'elaborazione delle prove SPT ed i parametri geotecnici.

Si riportano di seguito le fotografie delle cassette catalogatrici contenenti le carote prelevate mediante il sondaggio a carotaggio S1.







CASSETTA n. 5 :20.00-25.00 m



CASSETTA n. 6 :25.00-30.00 m

2.2.4 Prove di laboratorio di geotecnica

Durante l'esecuzione del sondaggio a carotaggio continuo S1 sono stati prelevati **n. 4 campioni indisturbati di tipo Shelby e n. 5 campioni rimaneggiati**, per un totale di n. 9 campioni

Nella tabella seguente si elencano i campioni prelevati e le relative quote:

TIPOLOGIA CAMPIONE	S1	
	QUOTA PRELIEVO (m da p.c.)	
Indisturbato - Shelby	S1 C1	-3.00÷ -3.60
Indisturbato - Shelby	S1 C2	-8.40÷ -9.10
Indisturbato - Shelby	S1 C3	-10.50÷ -11.10
Indisturbato - Shelby	S1 C4	-15.30÷ -16.00
Rimaneggiato	S1 C5	-6.00÷ -6.30
Rimaneggiato	S1 C6	-9.80÷ -10.00
Rimaneggiato	S1 C7	-12.30÷ -12.50
Rimaneggiato	S1 C8	-16.60÷ -16.80
Rimaneggiato	S1 C9	-22.30÷ -22.50

Sui campioni prelevati sono state eseguite le seguenti analisi di laboratorio di geotecnica riassunte nella tabella sottostante:

SONDAGGIO S1	DESCRIZIONE DEL CAMPIONE	CARATTERISTICHE FISICHE	ANALISI GRANULOMETRICA	PROVA DI COMPRESSIONE TRIASSIALE CID	PROVA DI COMPRESSIONE TRIASSIALE UU	PROVA DI TAGLIO DIRETTO
S1 C1	x	x			x	
S1 C2	x	x		x		
S1 C3	x	x				x
S1 C4	x	x			x	
S1 C5	x	x	x			
S1 C6	x	x	x			
S1 C7	x	x	x			
S1 C8	x	x	x			
S1 C9	x	x	x			

I risultati di tutte le prove sopracitate sono riportati integralmente in allegato.

Di seguito vengono brevemente descritte le prove di laboratorio geotecnico realizzate.

2.2.4.1 Descrizione dei campioni e caratteristiche fisiche

Sulle fustelle indisturbate prelevate durante i sondaggi a carotaggio è stata eseguita una descrizione preliminare del campione ed è stata valutata la resistenza alla penetrazione in condizioni non drenate R_{PP} , misurata mediante POCKET PENETROMETER e la resistenza al taglio, sempre in condizioni non drenate R_{VT} , mediante VANE TEST. Inoltre sono state definite le caratteristiche fisiche naturali (umidità naturale, peso di volume, peso specifico e porosità).

2.2.4.2 Analisi granulometrica per setacciatura e sedimentazione

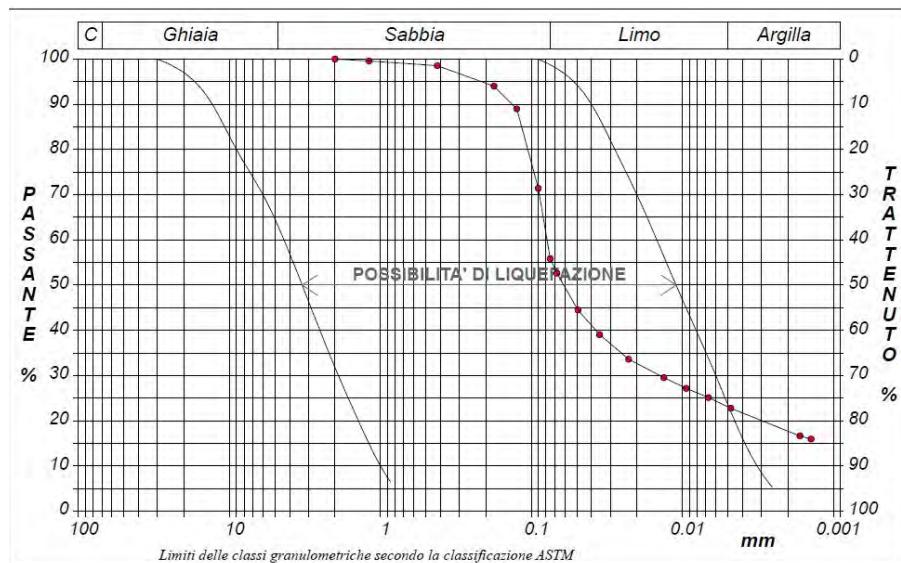
La seguente tipologia di indagine permette di determinare la distribuzione delle dimensioni delle particelle che compongono un campione di terreno e di stabilire le percentuali in peso delle varie frazioni che rientrano entro limiti prefissati (frazioni granulometriche).

I metodi utilizzati per ottenere le varie frazioni granulometriche sono principalmente due: la setacciatura e l'aerometria. L'analisi granulometrica mediante setacci con caratteristiche standardizzate è limitata alla frazione grossolana di un terreno, cioè alla percentuale trattenuta dal setaccio di luce 0.075 mm; lo strumento consiste in una serie di setacci incolonnati uno sopra l'altro, in modo tale che la luce delle maglie diminuisca dall'alto verso il basso. Per il materiale passante al setaccio inferiore, ovvero quello con luce più piccola (0.075 mm), si ricorre all'analisi per sedimentazione o aerometria. Quest'ultima tecnica viene effettuata se la parte di terreno con diametro inferiore a 0.075 mm è presente in percentuale superiore al 10%. La prova si basa sulla legge di Stokes, che permette di calcolare la velocità di sedimentazione di una particella sferica di cui si conosca il peso specifico, in un fluido di densità, viscosità e temperatura note. Il campione da analizzare viene prima di tutto trattato con acqua ossigenata, per eliminare il materiale organico, e con acido cloridrico, per disciogliere il carbonato di calcio; dopodiché viene inserito in una soluzione di acqua bidistillata ed esametafosfato di sodio al fine di evitare il processo di flocculazione, che accelererebbe la sedimentazione rendendo così inadeguata l'applicazione della Legge di Stokes. Dopo aver agitato il tutto, si può dare inizio alla prova. Ad intervalli di tempo stabiliti in base alla temperatura della soluzione, si prelevano dei campioni di terreno ad una certa profondità e, dopo averli essiccati, per ognuno di essi si calcola il peso: alla fine di un intervallo di tempo "t", le particelle con velocità di sedimentazione maggiore di " h/t " si troveranno a profondità maggiori di " h ", mentre quelle con velocità minore di " h/t ", dopo il tempo "t" si troveranno ad una profondità minore di " h ", di conseguenza, queste ultime, alla profondità " h " avranno ancora la loro concentrazione originale. Prelevato il primo campione, si lascia trascorrere un periodo di tempo "t2", dopodiché si preleva il secondo campione, sempre alla profondità " h ": quest'ultimo campione conterrà un residuo minore del precedente di una quantità uguale al peso del materiale con velocità di sedimentazione intermedia alle due scelte (" h/t " e " $h/t2$ "). I risultati sono stati

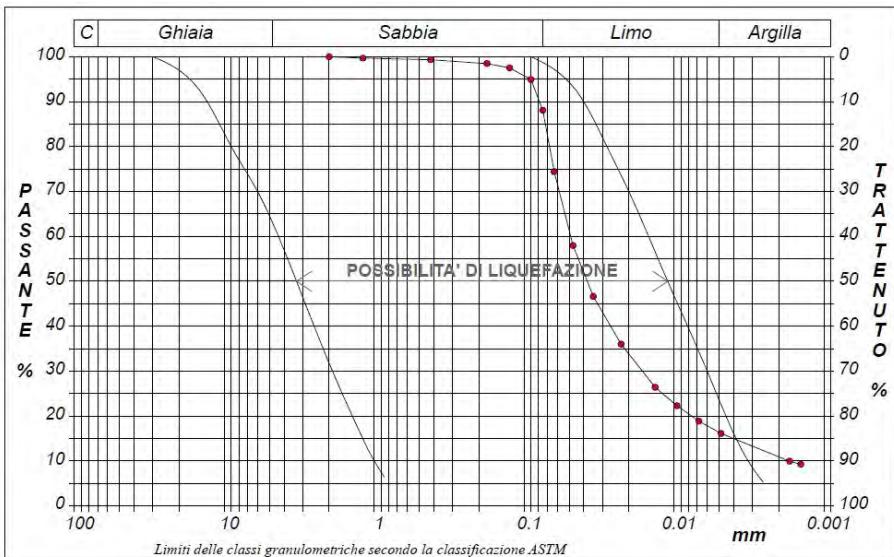
diagrammati in scala semilogaritmica, riportando in ascissa il diametro delle particelle e in ordinata le percentuali in peso delle particelle.

campione	QUOTA da p.c. :	-6.00 m ÷ 6.30 m		
S1 C5	ARGILLA (%)	LIMO (%)	SABBIA (%)	GHIAIA (%)
	23.1 %	32.8 %	44.1 %	0.0 %
Denominazione AGI: Sabbia con limo argillosa				
campione	QUOTA da p.c. :	-9.80 m ÷ -10.00 m		
S1 C6	ARGILLA (%)	LIMO (%)	SABBIA (%)	GHIAIA (%)
	16.4 %	71.7 %	11.9 %	0.0 %
Denominazione AGI: Limo argilloso sabbioso				
campione	QUOTA da p.c. :	-12.30 m ÷ -12.50 m		
S1 C7	ARGILLA (%)	LIMO (%)	SABBIA (%)	GHIAIA (%)
	15.9 %	18.2 %	65.9 %	0.0 %
Denominazione AGI: Sabbia limosa argillosa				
campione	QUOTA da p.c. :	-16.60 m ÷ -16.80 m		
S1 C8	ARGILLA (%)	LIMO (%)	SABBIA (%)	GHIAIA (%)
	22.7 %	19.9 %	57.4 %	0.0 %
Denominazione AGI: Sabbia argillosa limosa				
campione	QUOTA da p.c. :	-22.30 m ÷ -22.50 m		
S1 C9	ARGILLA (%)	LIMO (%)	SABBIA (%)	GHIAIA (%)
	9.0 %	10.5 %	80.2 %	0.0 %
Denominazione AGI: Sabbia limosa debolmente argillosa				

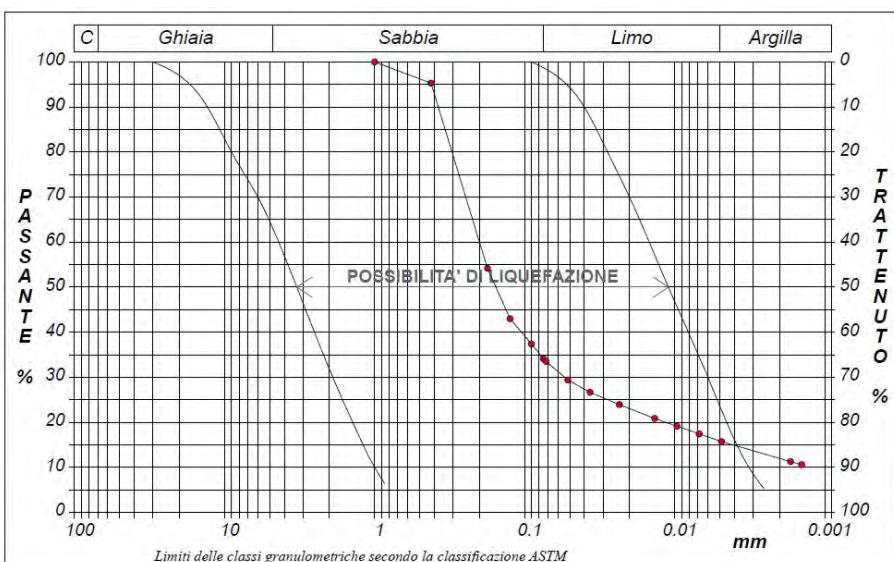
Si riportano di seguito i fusi granulometrici di ciascun campione analizzato a confronto con i fusi che delimitano la granulometria dei terreni suscettibili di liquefazione, secondo l'NTC 2018.



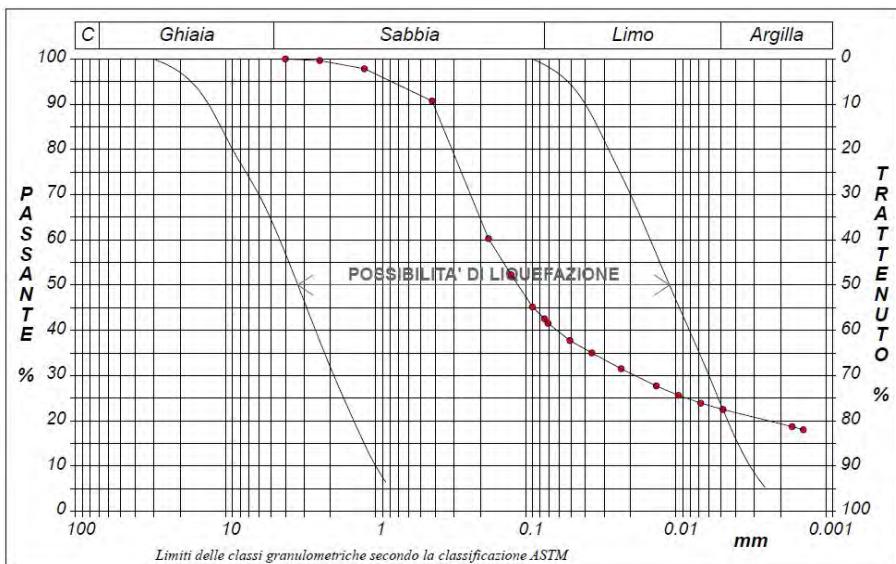
Fuso granulometrico del campione C5



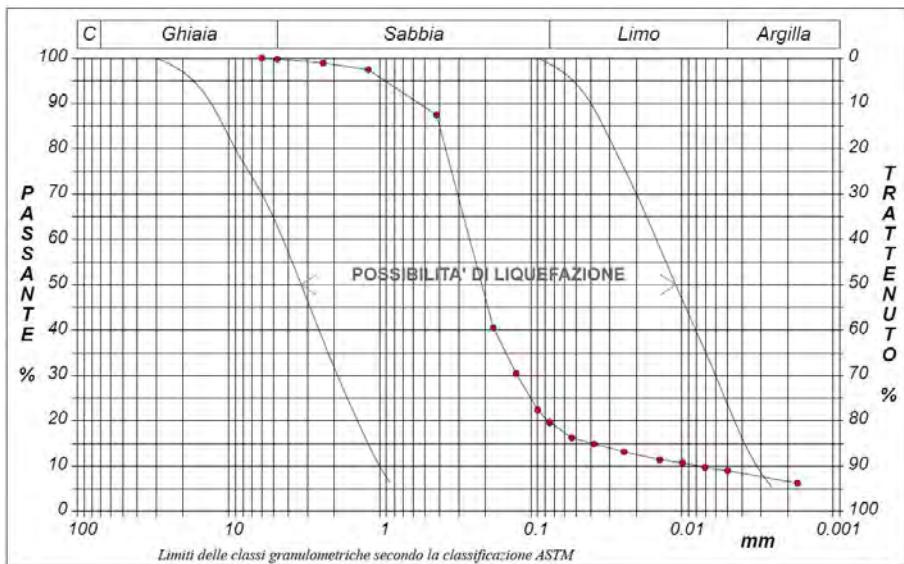
Fuso granulometrico del campione C6



Fuso granulometrico del campione C7



Fuso granulometrico del campione C8



Fuso granulometrico del campione C9

2.2.4.3 Prova di compressione triassiale consolidata – drenata TxCID (AGI 1994)

La prova di compressione triassiale TxCID permette di determinare la resistenza meccanica di un terreno in condizioni di tensione efficace.

Tenendo presente che la resistenza al taglio dipende dal livello delle tensioni applicate, vengono sottoposti a consolidazione almeno tre provini con diversi livelli di pressione di confinamento. Successivamente, si conduce a rottura i campioni considerati, favorendo il drenaggio lento del campione in modo da non generare variazioni di pressione interstiziale nei provini. Operando secondo la seguente modalità le tensioni totali ed efficaci coincidono. Si tracciano quindi i cerchi di Mohr a rottura in termini di tensioni efficaci: dagli inviluppi a rottura determinati è possibile determinare i parametri geotecnici di coesione efficace c' e φ' secondo il principio di Mohr-Coulomb.

$$\tau = c'_d + \sigma' \tan \varphi'_d$$

CAMPIONE	QUOTA (m da p.c.)	COESIONE EFFICACE (kPa)	ANGOLO DI ATTRITO EFFICACE (°)
Sondaggio S1			
S1 C2	-8.40÷ -9.10	8.2	27.2

2.2.4.4 Prova di compressione triassiale non consolidata – non drenata TxUU (ASTM D 2850)

La prova di compressione triassiale TxUU permette di determinare la resistenza al taglio non drenata c_u . La prova viene eseguita su 3 provini a differenti pressioni totali di cella. Poiché la pressione di consolidazione dei tre provini è la stessa, i cerchi di Mohr a rottura dei tre provini nel piano delle tensioni totali avranno lo stesso diametro e quindi saranno inviluppati da una retta orizzontale di equazione:

$$\tau = c_u$$

Di seguito si riportano i valori ottenuti:

CAMPIONE	QUOTA (m da p.c.)	COESIONE NON DRENATA (kPa)
Sondaggio S1		
S1 C1	-3.00÷ -3.40	59.5

2.2.4.5 Prova di taglio diretto

Al fine di calcolare **angolo di attrito interno** e **coesione efficace** del sottosuolo indagato, i campioni di terreno indisturbati e i campioni semi-disturbati sono stati sottoposti ad una **prova di resistenza al taglio** in scatola di Casagrande.

In particolare per ogni campione è stata effettuata una **prova consolidata-drenata (prova lenta CD)**: si tratta di una prova in cui una consolidazione sostanzialmente completa alla pressione di confinamento è seguita da uno sforzo assiale (di taglio) addizionale, applicato in modo tale che anche un suolo saturo a bassa permeabilità possa adattarsi completamente (interamente consolidato) alle sollecitazioni dovute agli sforzi addizionali, assiali e di taglio.

Dal campione di terreno prelevato sono stati ottenuti 3 provini, successivamente consolidati con carichi assiali diversi riportati sui certificati posti in allegato. Dopo che ogni provino ha raggiunto il consolidamento costante sotto lo sforzo assiale prestabilito, viene trasferito sull'apparecchiatura per le prove di taglio. Il provino è posto all'interno di due telai orizzontali, che possono scorrere uno rispetto all'altro, e le sollecitazioni applicate sono costituite dal carico assiale N e dalla forza di taglio T. Per queste prove è stata impostata nell'apparecchiatura una velocità di avanzamento $v = 0.004 \text{ mm/min}$.

Nel corso della prova vengono misurati gli spostamenti tra i due telai orizzontali; questi permettono di calcolare solo la deformazione media del provino che, essendo all'interno di un telaio rigido, presenta uno stato di deformazione non uniforme. Di solito i risultati delle prove vengono utilizzati per determinare i valori di coesione e angolo di resistenza al taglio in termini di tensioni efficaci, noti la resistenza al taglio disponibile e la tensione efficace normale al piano di scorrimento.

È però importante tenere presente il fatto che l'apparecchiatura non consente di controllare le condizioni di drenaggio né di misurare la pressione interstiziale, di conseguenza la prova deve essere condotta in maniera tale da garantire "a priori" le condizioni di drenaggio, per questo è importante adottare una velocità di avanzamento adeguata alla tipologia di terreno da analizzare. I risultati delle prove sono stati rappresentati in un diagramma avente in ordinate lo sforzo di taglio alla rottura ed in ascisse la tensione normale alla superficie di scorrimento. Una volta tracciata la retta che congiunge i tre punti all'interno del diagramma, si possono ricavare l'angolo d'attrito, che corrisponde alla pendenza della stessa retta rispetto all'orizzontale, e la coesione, che corrisponde al valore dell'intersezione della suddetta retta con l'asse delle ordinate.

CAMPIONE	QUOTA (m da p.c.)	COESIONE (kPa)	ANGOLO DI ATTRITO EFFICACE (°)
Sondaggio S1			
S1 C3	-10.50÷ -11.00	0.4	29.4

3 CARATTERIZZAZIONE GEOFISICA DEL SOTTOSUOLO

3.1 INDAGINI GEOFISICHE

Per la classificazione sismica e geofisica dell'area di studio, sono state eseguite in situ le seguenti indagini geofisiche:

- *n. 2 indagini sismiche con metodo MASW (eseguite in data 27/10/2017);*
- *n. 2 indagini sismiche passive con metodo Re.Mi. (eseguite in data 27/10/2017);*
- *n. 5 indagini sismiche passive Horizontal to Vertical Spectral Ratio (HVSR) – Metodo di Nakamura (eseguite in data 27/10/2017 e 27/04/2018);*
- *n. 1 prova penetrometrica statica con piezocone sismico SCPTU, spinta alla profondità di - 30.30 m da p.c., eseguita in data 31/10/2017;*
- *n. 1 indagine sismica in foro down-hole, eseguita in data 14/05/2018;*
- *n. 3 indagini tomografiche elettriche ERT (eseguite in data 14/05/2018).*

Nella **tavola n. 2** è riportata l'ubicazione di tutte le indagini sopracitate.

Per i dettagli della prova penetrometrica con sismocono SCPTU si rimanda al paragrafo 2.2.1 della presente relazione.

3.1.1 Indagine sismica con metodo MASW

Per misurare le velocità delle onde di taglio si possono eseguire prospezioni sismiche mediante stendimenti superficiali, utilizzando geofoni verticali da 4,5 Hz ed acquisendo attivamente i segnali delle onde rifratte alla superficie mediante una sorgente artificiale mette provocata. Questa tecnica, nota con la sigla **MASW** (Multichannel Analysis of Surface Waves), permette di ricostruire il profilo verticale delle Vs con procedimenti di modellazione diretta delle velocità di fase delle onde, rifratte alla superficie. Partendo dal sismogramma registrato mediante sorgente energizzante in asse con lo stendimento, viene eseguita un'analisi spettrale che ha consentito di elaborare un'immagine della distribuzione del segnale di velocità sismica in funzione delle diverse frequenze che lo compongono. Da tale elaborazione, tramite una fase di “picking” del segnale ad elevata intensità è stata ottenuta la “**curva di dispersione**”, dalla cui inversione è stato calcolato il **modello sismo-stratigrafico** espresso in termini di velocità delle onde di taglio (Vs). I dati sono stati registrati mediante un sismografo *Geode Geometrics* 24 bit con filtri disinseriti, velocità di campionamento (sample rate) di 0,2 millisecondi e lunghezza delle acquisizioni di 1 secondo. Si effettuano battute poste ad offset diversi (10 m e 15 m di distanza dal primo geofono) mediante grave da 8,0 kg di massa.

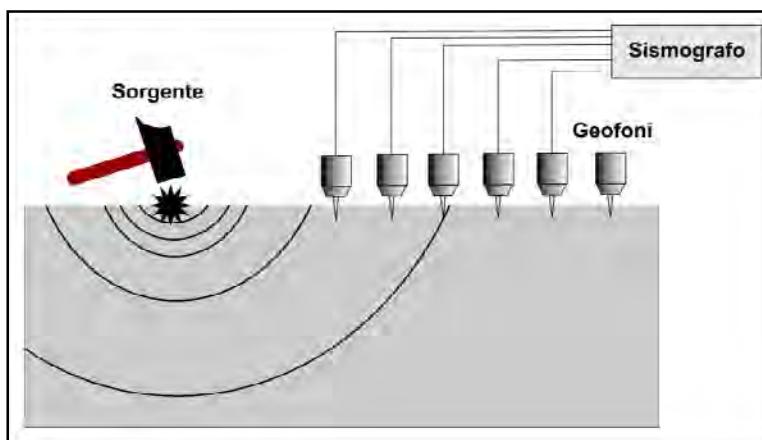


Fig. 3.1: Schema di Array lineare e punto energizzante.



Fig. 3.2: Strumentazione della Geode Geometrics utilizzata per l'esecuzione dell'indagine sismica MASW e ReMi.

3.1.2 Indagine sismica passiva con metodo dei microtremori (Re.Mi.)

La tecnica conosciuta come *Refraction Microtremors* - Re.Mi. (Louie, 2001), permette di campionare le frequenze più basse, caratterizzanti le porzioni più profonde del sottosuolo. La tecnica Re.Mi. sfrutta la capacità di poter mettere in relazione le velocità di fase e le frequenze, relative alle onde di taglio, con le forme di dispersione delle onde di superficie. I microtremori sismici naturali determinano, in corrispondenza della superficie, la formazione di onde superficiali di Rayleigh. L'indagine Re.Mi è stata eseguita mediante l'ausilio di sismografo GEODE (Geometrics) con 24 canali di acquisizione. L'array di misura è stato costituito attraverso la disposizione di n. 24 geofoni verticali con frequenza propria di vibrazione pari a 4.5 Hz, con offset geofonico pari a 5.00 m.

La tecnica Re.Mi. utilizza i microtremori naturali come sorgente sismica, trasformando i dati acquisiti da un dominio spazio/tempo a un dominio frequenza/velocità⁻¹ attraverso una trasformazione definita ρ - τ (Thorson & Claerbout, 1985) e una trasformazione di Fourier applicata nella direzione di τ . Così facendo è possibile definire lo spettro energetico relativo alle velocità di fase delle onde di Rayleigh nel dominio frequenza/velocità⁻¹. Utilizzando array lineari l'interpretazione degli spettri non risulta pertanto lineare: per ovviare al problema delle velocità apparenti, derivante dal fatto che la direzione di propagazione delle onde nelle tecniche passive non è necessariamente parallela all'array, è di comune prassi eseguire il *pick* dello spettro non al massimo dell'energia ma al minimo.

3.1.3 Indagini sismiche Horizontal to Vertical Spectral Ratio (HVSR)

La caratterizzazione sismica dei terreni tramite la tecnica di **indagine sismica passiva HVSR (Horizontal to Vertical Spectral Ratio – Metodo di Nakamura)** è finalizzata all'individuazione delle frequenze caratteristiche di risonanza di sito. Esse sono correlabili ai cambi litologici presenti sia all'interno della copertura che nell'ammasso roccioso. L'utilizzo di algoritmi di calcolo finalizzati ad una modellizzazione sintetica dello spettro H/V, permette di correlare ogni picco spettrale con le discontinuità presenti nel sottosuolo (per esempio i cambi litologici). I dati che si possono ricavare sono spessori, profondità e velocità di propagazione delle onde di taglio all'interno del sismo-strato individuato. Tramite l'elaborazione di moti superiori e l'analisi dell'andamento delle tre componenti del moto, è possibile distinguere i picchi di origine naturale da quelli generati dai moti superiori o da artefatti, al fine di garantire una corretta interpretazione dello spettro sismico registrato. La tecnica dei rapporti spettrali (HVSR) trova la sua massima applicazione negli studi di microzonazione sismica poiché fornisce un parametro fondamentale (frequenza propria di risonanza di sito) per una corretta progettazione di edifici antisismici. Negli ultimi anni si è affermata anche per la sua versatilità poiché si è dimostrato come lo spettro sismico può rappresentare un modello sismo – stratigrafico del sottosuolo.

La tecnica **HVSR** è totalmente **non invasiva, molto rapida**, si può applicare ovunque e non necessita di nessun tipo di perforazione, né di stendimenti di cavi, né di energizzazioni esterne diverse dal rumore ambientale che in natura esiste ovunque. Per l'acquisizione dei dati è stato utilizzato un "velocimetro triassiale" conforme alle norme SESAME.

I risultati che si possono ottenere da indagini sismiche HVSR sono:

- La **frequenza caratteristica di risonanza del sito** che rappresenta un parametro fondamentale per il corretto **dimensionamento degli edifici antisismici**. Si dovranno adottare adeguate precauzioni nell'edificare strutture aventi la stessa frequenza di vibrazione del terreno, per evitare l'effetto di "**doppia risonanza**", fenomeno estremamente pericoloso per la stabilità delle costruzioni.
- La **frequenza fondamentale di risonanza di un edificio**, qualora la misura venga effettuata all'interno dello stesso. In seguito sarà possibile confrontarla con quella caratteristica del sito e capire se, in caso di sisma, la costruzione potrà essere o meno a rischio.
- La **velocità media delle onde di taglio Vs** calcolata tramite un apposito codice di calcolo. È necessario, per l'**affidabilità del risultato**, conoscere la profondità di un riflettore noto dalla stratigrafia (prova penetrometrica, sondaggio, etc.) e riconoscibile nella **curva H/V**. E' possibile calcolare la **Vs30** e la relativa categoria del suolo di fondazione come esplicitamente richiesto dalle NTC 2018.
- La **stratigrafia del sottosuolo** con un *range* di indagine compreso tra 0.5 e 700 m di profondità, anche se il dettaglio maggiore si ha nei primi 100 metri. Il principio su cui si basa la tecnica **HVSR**, in termini

di **stratigrafia del sottosuolo**, è rappresentato dalla definizione di strato, inteso come unità distinta da quelle sopra e sottostanti per un **contrasto d'impedenza**, ossia per il rapporto tra i prodotti di velocità delle onde sismiche nel mezzo e densità del mezzo stesso.

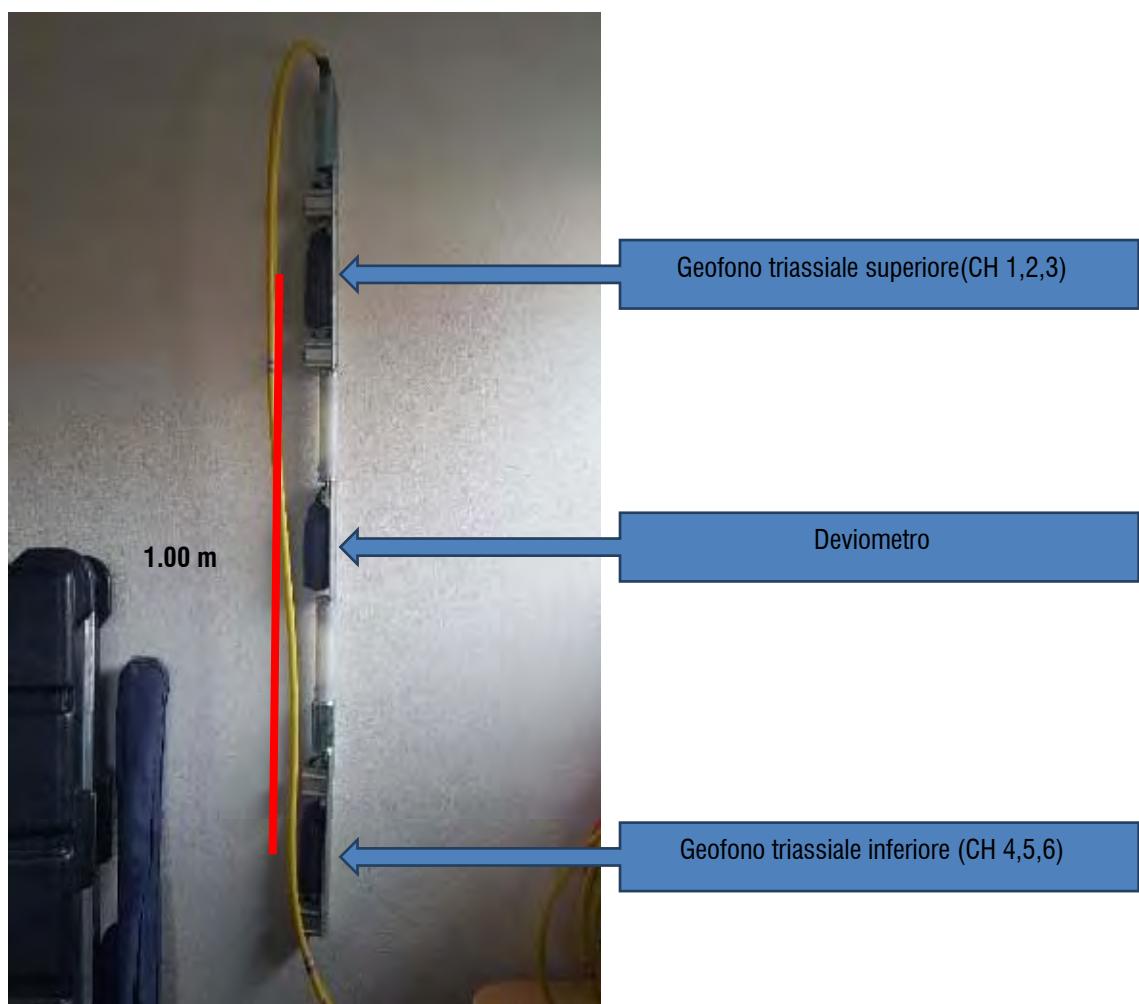
Dall'elaborazione delle indagini sismiche passive HVSR eseguite in situ sono stati individuati dei picchi H/V alle frequenze riportate nella seguente tabella:

indagine	Frequenza [Hz]
HV 1	0.83 ± 0.26
HV 2	0.88 ± 0.1
HV 3	0.73 ± 0.2
HV 1a	0.81 ± 0.26
HV 2a	0.81 ± 0.63

I picchi H/V così individuati sono di probabile origine stratigrafica, sebbene soltanto il picco rilevato dall'indagine HV 2 risulta validato dai criteri SESAME (2005).

3.1.4 Indagine sismica in foro down-hole

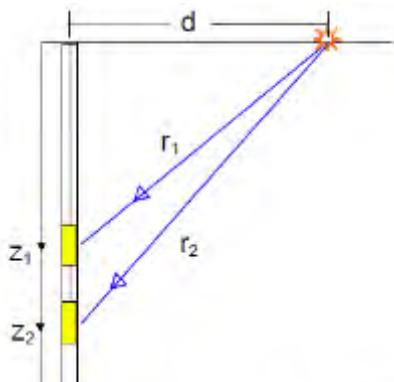
All'interno del foro di sondaggio S1 è stata eseguita una misura delle velocità delle onde di compressione P e taglio S_h secondo metodologia Down-Hole. Le misure sono state eseguite mediante doppio geofono da foro (Ambrogeo 3D Twin) dotato di n. 2 geofoni triassiali disposti a 1.00 m di distanza.



Mediante la strumentazione si eseguono misure di velocità differenziale calando lo strumento sul fondo del foro (in questo caso 30.00 m) acquisendo gli arrivi per le onde generate da uno scoppio verticale (onde P) e due scoppi orizzontali a polarità negativa e positiva (S_+ e S_-) su entrambi i geofoni, posti rispettivamente a 30.00 m e 29.00 m. Le misure vengono ripetute fino in superficie facendo avanzare i geofoni di 1.00 m per ciascuna serie di acquisizioni.

Disponendo di due punti di misura per ciascuna stazione, si rende possibile elaborare le misure e ricavare le velocità (P e S) secondo il metodo dell'intervallo. Tale metodologia, a differenza del metodo classico diretto, consente una maggiore definizione del profilo di velocità.

Si illustra successivamente il passaggi teorici del calcolo delle velocità secondo il metodo dell'intervallo:



La velocità delle onde sismiche tra due ricevitori è uguale a:

$$v = \frac{z_2 - z_1}{t_{2cor} - t_{1cor}}$$

$$t_{1cor} = \frac{z_1}{\sqrt{z_1^2 + d^2}} \cdot t_{1obs}$$

$$t_{2cor} = \frac{z_2}{\sqrt{z_2^2 + d^2}} \cdot t_{2obs}$$

Dove:

- **v** velocità (m/s);
- **z1** e **z2** sono le profondità relative dei geofoni;
- **t1_{obs}** et **t2_{obs}** sono i tempi di arrivo osservati su ciascun geofono;
- **t1_{cor}** e **t2_{cor}** sono i tempi di arrivo corretti su ciascun geofono;
- **d** distanza scoppio (in questo caso pari a 3.0 m);

I risultati dell'indagine sono riportati integralmente in allegato.

3.2 DETERMINAZIONE DEL PARAMETRO V_{s30} (§ 3.2.2 NTC 2018)

L'elaborazione delle indagini sismiche sopra citate restituisce un grafico che riporta la curva di dispersione attraverso un'immagine a colori che mostra il profilo delle velocità delle onde di Rayleigh come velocità di fase e frequenza. Si ottiene così un modello teorico dell'andamento delle Vs con la profondità. Attraverso la formula di seguito riportata si è quindi calcolato il valore di velocità equivalente delle onde S fino alla profondità di -30.00 m da p.c.:

$$V_{s,30} = \frac{30}{\sum_i \frac{h_i}{V_{si}}}$$

con:

h_i spessore dell' i -esimo strato;

V_{Si} velocità delle onde di taglio nell' i -esimo strato;

N numero di strati;

H profondità del substrato, definito come quella formazione costituita da roccia o terreno molto rigido, caratterizzata da VS non inferiore a 800 m/s.

Dall'elaborazione delle indagini sismiche eseguite e precedentemente citate sono stati ottenuti i valori di V_{s30} riportati in tabella:

INDAGINE	V_{s30} (m/s)
MASW n. 1	185
MASW n. 2	196
Re.Mi. n. 1	189
Re.Mi. n. 2	199
HVSR n. 2	185
SCPTU	181
DOWN-HOLE	190

Tuttavia, il sottosuolo indagato non risulta classificabile nelle categorie di sottosuolo previste dal § 3.2.2 delle NTC 2018, basate sul parametro V_{s30} , in quanto dalle indagini eseguite in situ è stata riscontrata una instabilità nei confronti del fenomeno della liquefazione.

Pertanto, per la definizione dell'azione sismica relativamente al sito in oggetto, si è proceduto con una specifica analisi di risposta simica locale.

3.3 AZIONE SISMICA: STUDIO DI MICROZONAZIONE SISMICA (III LIVELLO DI APPROFONDIMENTO DGR 2193/15)

Alla luce di quanto esposto nel § 3.2.2 delle NTC 2018 e in accordo con quanto esposto nella D.A.L 112/2007 e successiva D.G.R. 2193/2015 della Regione Emilia Romagna, sono stati definiti i fattori di amplificazione dell'accelerazione e delle velocità spettrali secondo uno **studio di risposta sismica locale**, secondo **III livello di approfondimento**. Per ottemperare ai riferimenti normativi citati l'analisi è stata svolta attraverso analisi numerica monodimensionale in campo lineare equivalente. Per fare ciò è stato utilizzato come strumento di lavoro il software di calcolo STRATA (University of Texas - Austin).

Ai fini della restituzione degli spettri di accelerazione, relativi allo stato limite SLV, è stata svolta la verifica dell'amplificazione del sito mediante l'utilizzo di un modello simulato in campo lineare equivalente.

Utilizzando un modello lineare equivalente è possibile ottenere una soluzione di un modello non lineare, attraverso analisi lineari complete nelle quali, al termine di ogni interazione vengono aggiornati i parametri di **rigidezza** e **smorzamento** che sono dipendenti dallo stato di deformazione del terreno. Attraverso un'iterazione di calcoli si raggiunge una convergenza prefissata a monte della fase di computazione.

Il software STRATA è in grado di valutare la risposta sismica di un deposito di terreno, considerando un profilo monodimensionale in cui si propagano linearmente le onde sismiche, in funzione dei parametri dinamici attribuiti al terreno. Il terreno viene schematizzato come un sistema di N strati orizzontali omogenei, isotropi e visco-elastici, sovrastanti un semispazio uniforme, attraversati da un treno di onde di taglio che incidono verticalmente le superfici. Ogni strato è descritto per mezzo dello spessore H , del modulo di taglio massimo G_{\max} o dalla corrispondente velocità massima V_{\max} , dal valore dello smorzamento D , dal peso dell'unità di volume γ e dalle curve di decadimento del modulo di rigidezza a taglio normalizzato ($G / G_0 \cdot \gamma$) e le corrispondenti curve dello smorzamento ($D \cdot \gamma$) con la deformazione di taglio γ . Il modello lineare visco-elastico fa riferimento al modello reologico di Kelvin-Voigt, costituito da una molla e uno smorzatore viscoso in parallelo. Tale modello è descritto quindi dalla rigidezza (**G**) e dallo smorzamento (**D**). L'onda monodimensionale viene descritta dall'equazione in cui lo spostamento provocato (u) è funzione della profondità (z) e del tempo (t):

$$u(z, t) = A \exp[i(\omega t + k^* z)] + B \exp[i(\omega t - k^* z)]$$

Nell'equazione appena presentata A e B rappresentano le corrispettive amplificazioni del tetto e della base dello strato considerato. Il fattore k^* risulta dipendente dal modulo di taglio (G), dal grado di smorzamento (D) e dalla densità del terreno (ρ). Le relazioni sono le seguenti:

$$k^* = \frac{\omega}{v_s^*}$$

$$v_s^* = \sqrt{\frac{G^*}{\rho}} \quad G^* = G \left(1 - 2D^2 + i2D \sqrt{1 - D^2} \right) \approx G(1 + i2D)$$

Dove G^* e v_s^* rappresentano il modulo di taglio e la velocità di taglio.

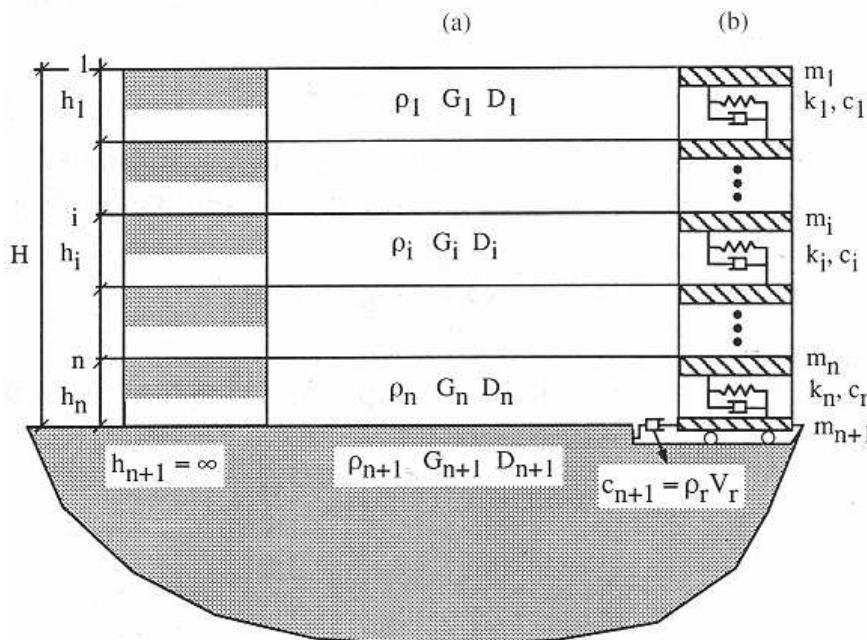


Fig. 4.5: Modello a strati continui adottato per la simulazione con il codice di calcolo STRATA.

MODELLO SIMULATO

Il modello simulato deriva dai dati ottenuti dalle prove che compongono la campagna geognostica eseguita in situ. Tale profilo approssima il comportamento del sottosuolo, dal punto di vista sismico, in corrispondenza dell'area studiata. Il profilo considerato deriva dall'interpolazione dei dati provenienti dalle indagini geofisiche eseguite e i dati, di natura bibliografica, disponibili per il sito di riferimento.

Il profilo sismico utilizzato per la modellazione della RSL deriva dall'elaborazione dell'indagine HVSR n. 2 e delle indagini di superficie eseguite (MASW, REMI). Si illustra successivamente il modello utilizzato:

Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	Poisson ratio
0.50	0.50	90	0.42
2.50	2.00	110	0.42
7.50	5.00	162	0.42
21.50	14.00	193	0.42
44.50	23.00	244	0.42
76.50	32.00	350	0.42
116.50	40.00	400	0.42
inf.	inf.	500	0.42

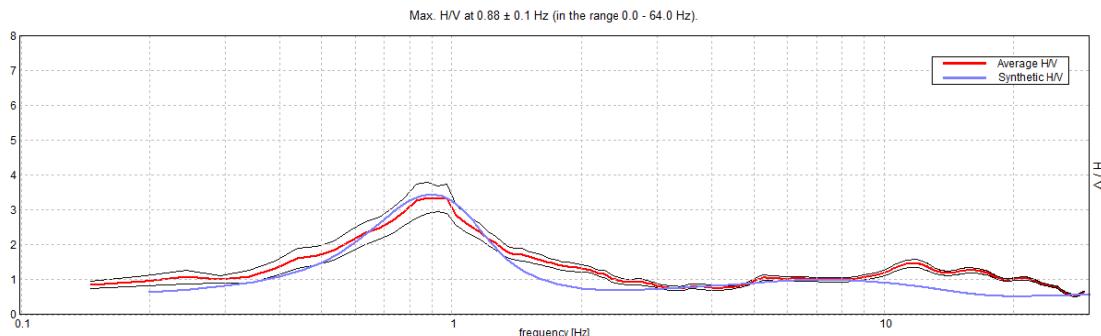


Fig. 3.6: Modello sismico utilizzato per la RSL eseguita e curva HVSR relativa al modello impiegato

Per descrivere il comportamento dinamico dei terreni costituenti il modello sono state considerate curve di decadimento dei moduli di rigidezza e smorzamento, al variare della deformazione percentuale $\gamma(\%)$. Si riportano successivamente le curve di decadimento considerate per l'esecuzione del calcolo di risposta sismica locale:

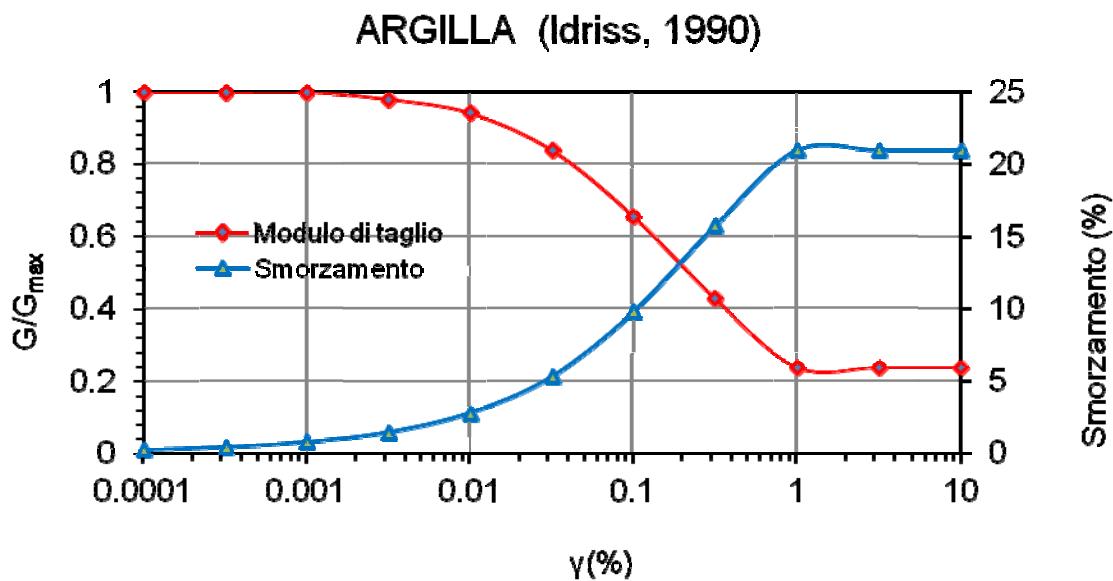


Fig. 3.7: Curva di decadimento dei moduli G/G_{\max} e D , utilizzata per descrivere il comportamento dei materiali coesivi che compongono il sottosuolo in oggetto.

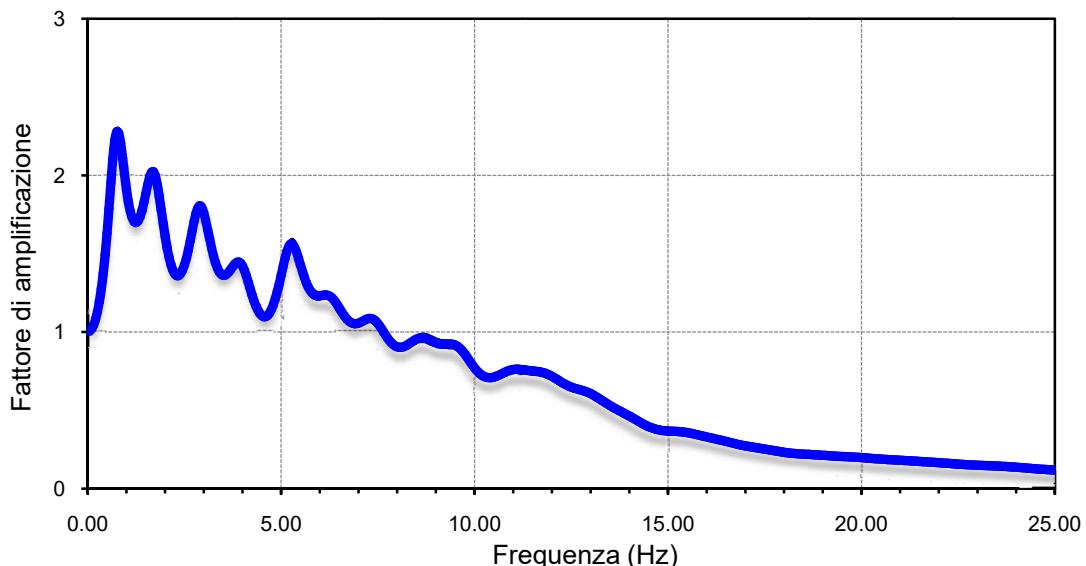
Trattandosi di una verifica a monte di una fase di verifica urbanistica, in accordo con quanto esposto nella D.G.R. 2193/15, l'analisi RSL in oggetto è stata svolta adottando come input sismico 3 accelerogrammi, corrispondenti allo stato limite SLV. I segnali di riferimento sono stati successivamente scalati per il valore di PGA_0 atteso al suolo rigido in corrispondenza dell'areale oggetto di analisi. Per fare ciò è stata considerata l'interpolazione spaziale dei valori di PGA_0 proposta da INGV per il territorio nazionale e resi disponibili per il territorio regionale sui punti di una griglia con passo 0.05 gradi.

Per il sito in oggetto, come rappresentato nella figura successivamente illustrata, tale valore è pari a **0.253 g** considerando un valore di $Cu = 2.00$ (Classe d'uso IV) e $Vn = 100$ anni per ottenere un tempo di ritorno pari a 1898 anni.

RISULTATI OTTENUTI

Sulla scorta delle verifiche svolte mediante software STRATA, in riferimento al modello considerato, è stato possibile definire, nel dominio delle frequenze, la funzione TF (Funzione di trasferimento) e rapporto spettrale di amplificazione associato. Per via grafica si inserisce successivamente la funzione di trasferimento TF ottenuta a seguito dell'analisi RSL in oggetto. Attraverso tale funzione è possibile definire il campo di frequenze entro il quale il sottosuolo, in corrispondenza del sito in oggetto, amplifica il segnale sismico, oltre che a quantificare l'amplificazione stessa.

FUNZIONE DI TRASFERIMENTO



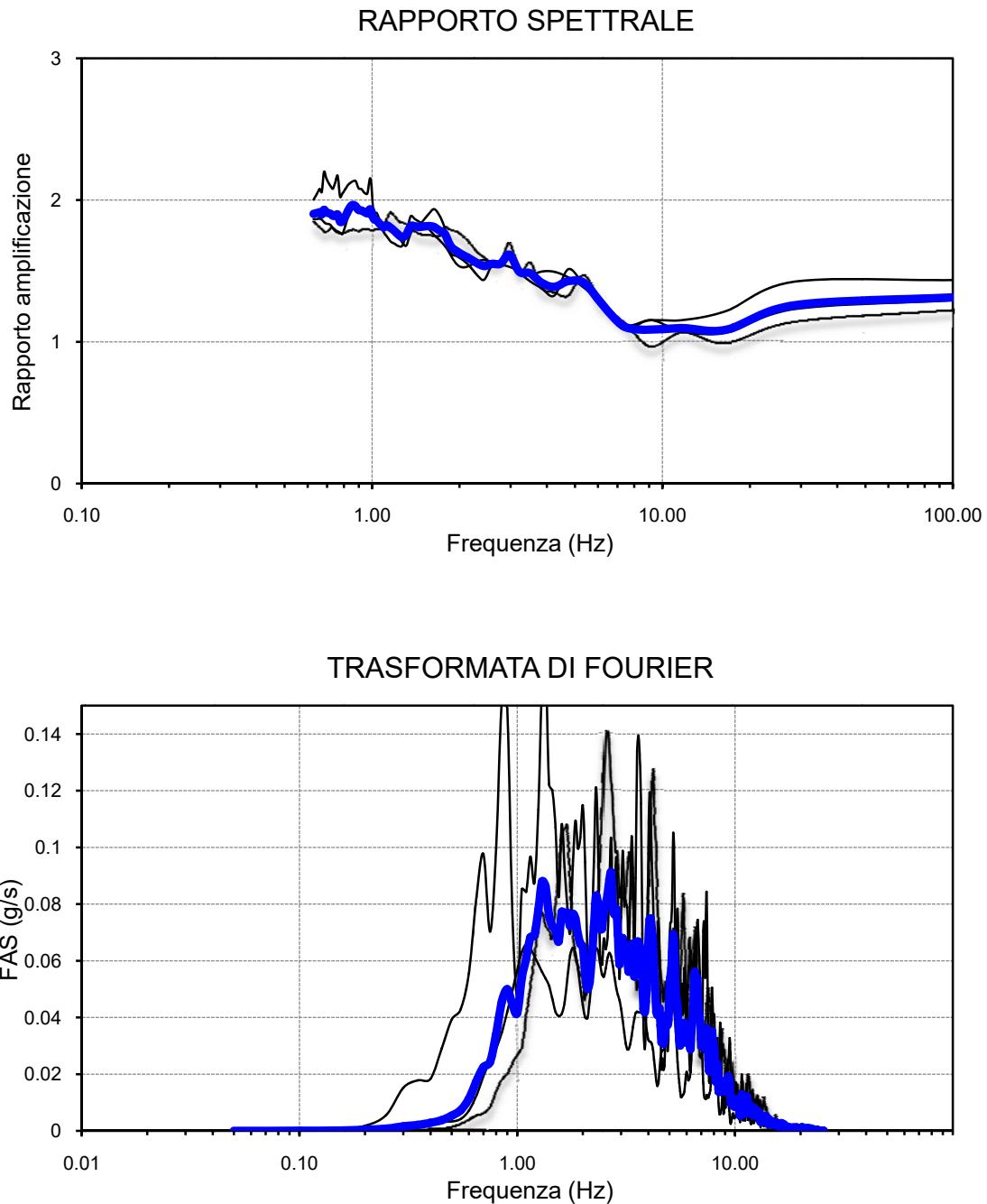


Fig. 3.9: In alto: funzione FTT, funzione FT e rapporto spettrale di amplificazione.

Definiti i parametri che descrivono il comportamento del sottosuolo nel campo elastico lineare equivalente e descritti gli accelerogrammi su suolo rigido validi per il sito in oggetto, attraverso il software STRATA sono state definite le seguenti forme spettrali, in termini accelerazione e velocità alla superficie:

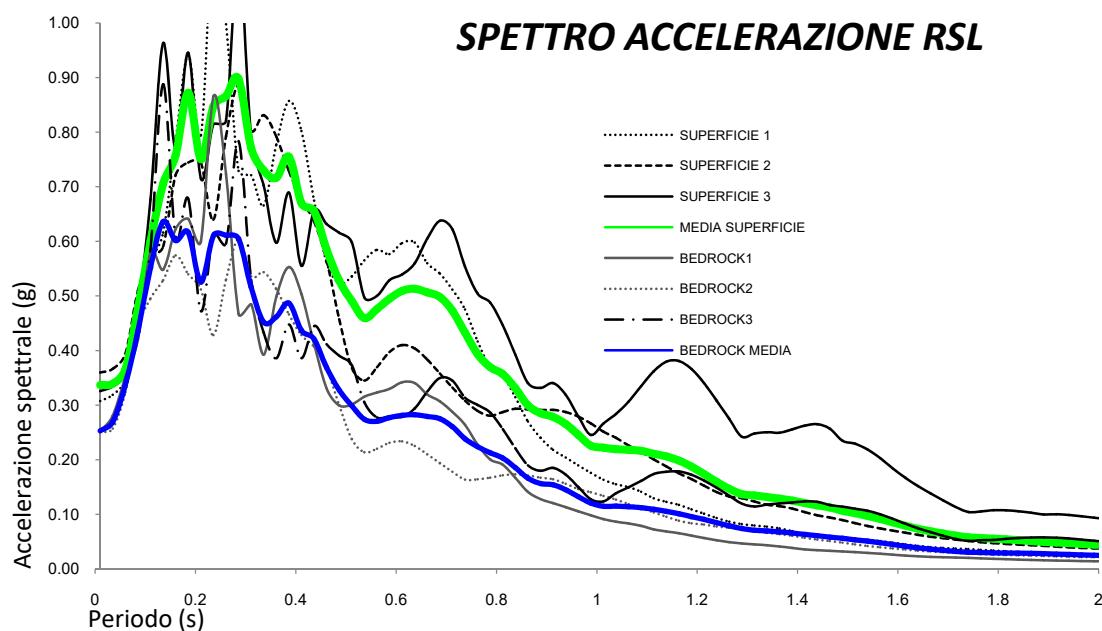


Fig. 3.10: Accelerazioni spettrali relative a un periodo di ritorno pari a 1898 anni (SLV).

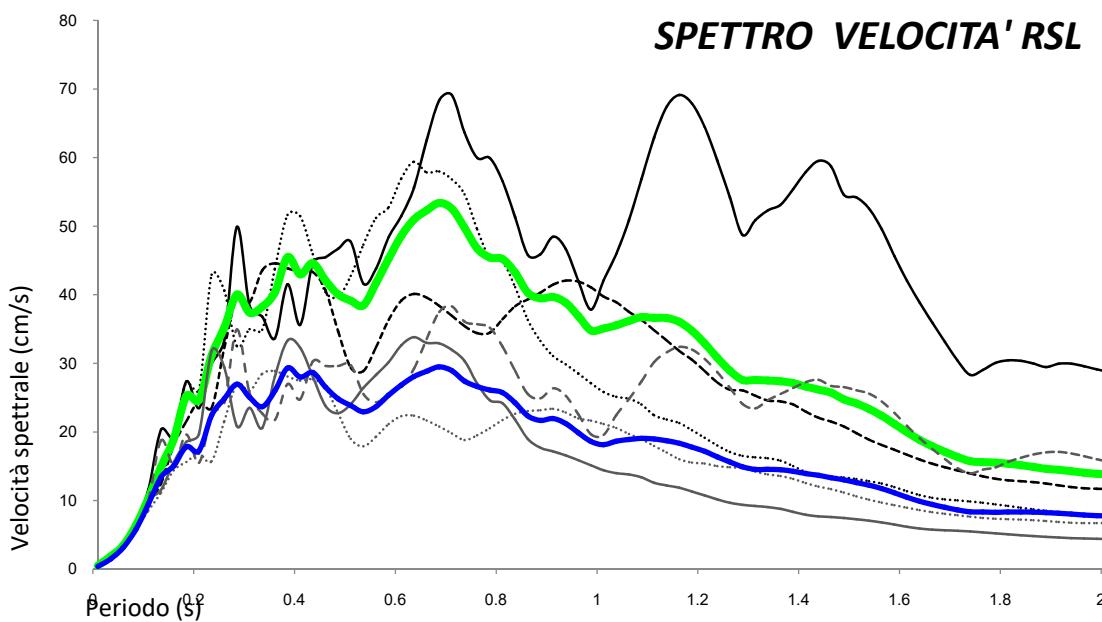
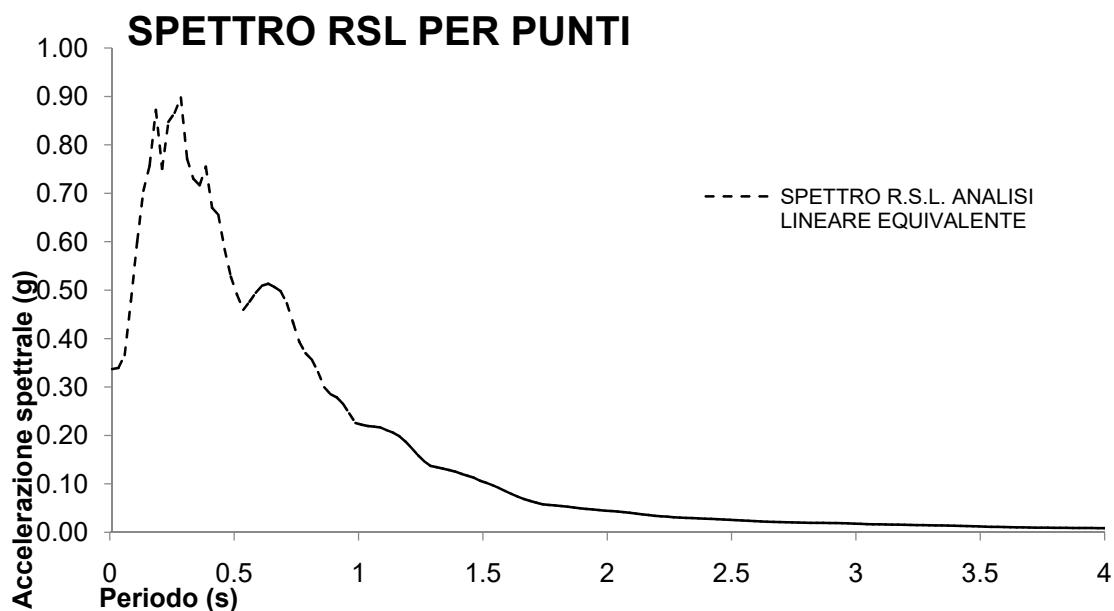


Fig. 3.11: Velocità spettrali relative a un periodo di ritorno pari a 1898 anni (SLV).

A seguito delle risultanze dello studio RSL svolto si definiscono i seguenti parametri sismici caratteristici del sito analizzato:

	F.A. S.I.					
	PGA ₀	F.A. PGA	(0.00 < T(s) < 0.50)	(0.50 < T(s) < 1.00)	(0.50 < T(s) < 1.50)	PGA _{MAX}
SLV	0.253	1.33	1.60	1.79	1.97	0.337

Tab. 3.2: Parametri che identificano lo spettro normalizzato (SLV - Tr 1898), derivato dall'analisi mediante il software di calcolo STRATA;



T (s)	Ag								
0.01	0.337	1.04	0.219	2.07	0.042	3.09	0.016	4.12	0.008
0.04	0.339	1.06	0.218	2.09	0.040	3.12	0.016	4.15	0.008
0.06	0.366	1.09	0.216	2.12	0.039	3.14	0.016	4.17	0.008
0.09	0.478	1.11	0.211	2.14	0.037	3.17	0.016	4.20	0.008
0.11	0.600	1.14	0.206	2.17	0.036	3.19	0.016	4.22	0.008
0.14	0.705	1.16	0.199	2.19	0.034	3.22	0.015	4.25	0.008
0.16	0.757	1.19	0.187	2.22	0.033	3.24	0.015	4.27	0.007
0.19	0.872	1.21	0.174	2.24	0.032	3.27	0.015	4.30	0.007
0.21	0.750	1.24	0.159	2.27	0.031	3.29	0.015	4.32	0.007
0.24	0.847	1.26	0.147	2.29	0.030	3.32	0.014	4.35	0.007
0.26	0.866	1.29	0.137	2.32	0.030	3.35	0.014	4.37	0.007
0.29	0.898	1.31	0.135	2.34	0.029	3.37	0.014	4.40	0.007
0.31	0.771	1.34	0.132	2.37	0.029	3.40	0.014	4.42	0.007
0.34	0.730	1.36	0.129	2.39	0.028	3.42	0.013	4.45	0.007
0.36	0.716	1.39	0.125	2.42	0.028	3.45	0.013	4.47	0.007
0.39	0.755	1.41	0.121	2.44	0.027	3.47	0.013	4.50	0.006
0.41	0.670	1.44	0.117	2.47	0.026	3.50	0.012	4.52	0.006
0.44	0.656	1.46	0.113	2.49	0.026	3.52	0.012	4.55	0.006
0.46	0.585	1.49	0.107	2.52	0.025	3.55	0.011	4.57	0.006
0.49	0.528	1.51	0.102	2.54	0.024	3.57	0.011	4.60	0.006

0.51	0.490	1.54	0.097	2.57	0.024	3.60	0.011	4.62	0.006
0.54	0.459	1.56	0.092	2.59	0.023	3.62	0.011	4.65	0.006
0.56	0.476	1.59	0.085	2.62	0.023	3.65	0.010	4.67	0.006
0.59	0.495	1.61	0.079	2.64	0.022	3.67	0.010	4.70	0.006
0.61	0.509	1.64	0.074	2.67	0.022	3.70	0.010	4.72	0.006
0.64	0.513	1.66	0.069	2.69	0.021	3.72	0.010	4.75	0.006
0.66	0.507	1.69	0.065	2.72	0.021	3.75	0.010	4.77	0.006
0.69	0.498	1.72	0.061	2.74	0.020	3.77	0.010	4.80	0.006
0.71	0.473	1.74	0.058	2.77	0.020	3.80	0.009	4.82	0.006
0.74	0.433	1.77	0.057	2.79	0.020	3.82	0.009	4.85	0.005
0.76	0.393	1.79	0.056	2.82	0.020	3.85	0.009	4.87	0.005
0.79	0.370	1.82	0.054	2.84	0.019	3.87	0.009	4.90	0.005
0.81	0.357	1.84	0.053	2.87	0.019	3.90	0.009	4.92	0.005
0.84	0.331	1.87	0.051	2.89	0.019	3.92	0.009	4.95	0.005
0.86	0.300	1.89	0.050	2.92	0.019	3.95	0.009	4.97	0.005
0.89	0.285	1.92	0.048	2.94	0.019	3.97	0.009	5.00	0.005
0.91	0.279	1.94	0.047	2.97	0.018	4.00	0.009		
0.94	0.265	1.97	0.046	2.99	0.018	4.02	0.009		
0.96	0.246	1.99	0.045	3.02	0.017	4.05	0.009		
0.99	0.226	2.02	0.044	3.04	0.017	4.07	0.008		
1.01	0.222	2.04	0.043	3.07	0.017	4.10	0.008		

3.4 STABILITÀ DEL SITO NEI CONFRONTI DEL FENOMENO DI LIQUEFAZIONE (APPROCCIO DGR 2193/2015)

La valutazione del fenomeno della liquefazione viene svolta attraverso il calcolo del fattore di sicurezza di ciascun livello che compone il sottosuolo analizzato nei confronti del fenomeno stesso. Il fattore di sicurezza è derivato secondo la seguente formulazione:

$$F_L(z) = \frac{CRR_{M=7.5; \sigma'_v=1atm}}{CSR} \cdot MSF \cdot K_\sigma$$

Dove:

CRR è rappresentato dal rapporto di resistenza ciclica

MSF rappresenta il fattore di scala della magnitudo che è funzione della magnitudo stessa, della PGA e del valore di CRR

K_σ è il fattore di correzione che tiene conto della pressione efficace alla profondità a cui la resistenza viene valutata

CSR è il rapporto di tensione ciclica, ovvero la tensione di taglio indotta dall'azione sismica, normalizzata rispetto alla tensione verticale efficace. Tale parametro è derivabile secondo la seguente formulazione:

$$CSR = \frac{\tau_{\text{media}}}{\sigma_{v0}} = 0.65 \cdot \frac{a_{\max}}{g} \cdot \frac{\sigma_{v0}}{\sigma_{v0}} \cdot r_d$$

i termini che compongono la seguente relazione sono rappresentati da a_{\max}/g che descrive il valore dell'accelerazione orizzontale a $T = 0.00$ s, il rapporto della tensione litostatica totale ed efficace, e il coefficiente riduttivo r_d . Quest'ultimo, in accordo con la predetta normativa è stato stimato secondo la seguente formulazione:

$$r_d = \exp[\alpha(z) + \beta(z) \cdot M]$$

$$\alpha(z) = -1.012 - 1.126 \cdot \sin\left(\frac{z}{11.73} + 5.133\right)$$

$$\beta(z) = 0.106 + 0.118 \cdot \sin\left(\frac{z}{11.28} + 5.142\right)$$

dove M rappresenta il valore di magnitudo di riferimento per il sito in analisi.

Il valore **CRR** è stato ricavato attraverso la metodologia di calcolo proposta da **Boulanger & Idriss 2014**. Per le specifiche della procedura di calcolo adottata si faccia riferimento all'allegato **A2.2** della DGR 2193/2015 della Regione Emilia Romagna.

Le verifiche sono state svolte considerando una magnitudo di riferimento **$M = 6.14$** , una accelerazione massima al suolo **$A_{\max} = 0.337$ g (calcolata secondo Approccio DGR 2193/15, III livello di approfondimento)** e con soggiacenza della falda freatica alle profondità rilevate durante l'esecuzione delle prove penetrometriche (§ 2.2.1).

A seguito dell'identificazione del fattore di sicurezza F_L è stato determinato l'indice potenziale di liquefazione IL (LPI) attraverso il quale è possibile definire l'esposizione del sito al rischio di liquefazione. Il potenziale di liquefazione LPI è stato determinato secondo la seguente formulazione:

$$I_L = \int_0^{z_{crit}} F(z) \cdot w(z) \cdot dz \quad \text{in cui} \quad w(z) = \frac{200}{z_{crit}} \cdot \left(1 - \frac{z}{z_{crit}}\right)$$

Dove $F(z)$ viene determinato secondo le formulazioni proposte da Somnez (2003)

$F(z) = 0$	per	$F_L \geq 1.2$
$F(z) = 2 \cdot 10^6 \cdot \exp(-18.427 \cdot F_L)$	per	$1.2 > F_L \geq 0.95$
$F(z) = 1 - F_L$	per	$F_L \leq 0.95$

In base al valore di LPI ottenuto è possibile fornire un'indicazione del rischio di liquefazione. In considerazione delle linee guida emesse dalla Regione Emilia Romagna, a seguito degli eventi sismici di maggio e giugno 2012, si considera la classificazione di rischio definita da **Somnez (2003)**:

INDICE DI LIQUEFAZIONE	Rischio di liquefazione
LPI=0	Nullo
0<LPI≤2	Basso
2<LPI≤5	Moderato
5<LPI≤10	Alto
15>LPI	Molto alto

A seguito della verifica, in riferimento alle verticali di prova CPTU, sono stati ottenuti i seguenti valori di LPI:

INDAGINE	INDICE DI LIQUEFAZIONE LPI	RISCHIO
CPTU 1/SCPTU	6.314	ALTO
CPTU 2	0.169	BASSO
CPTU 3	2.868	MODERATO
CPTU 4	0.358	BASSO
CPTU 5	1.319	BASSO
CPTU 6	10.573	ALTO
CPTU 7	0.206	BASSO
CPTU 8	7.132	ALTO
CPTU 9	3.017	MODERATO
CPTU 10	11.265	ALTO
CPTU 11	2.214	MODERATO
CPTU 12	0.083	BASSO
CPTU 13	0.396	BASSO
CPTU 14	0.0	BASSO
CPYU 15	1.919	BASSO
CPTU 16	0.68	BASSO
CPTU 17	0.219	BASSO

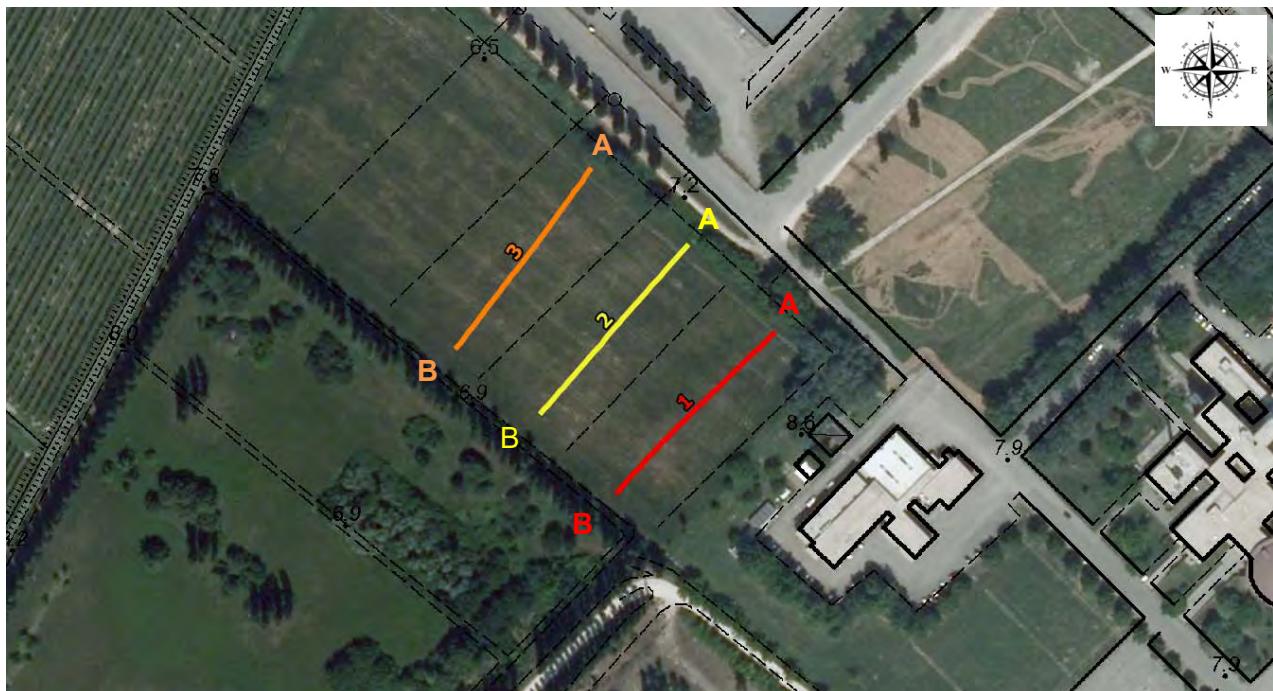
3.5 INDAGINE TOMOGRAFICA ELETTRICA

In data 14/05/2018 presso l'area di studio sono stati eseguiti n. 3 profili geoelettrici secondo metodo tomografico (ERT) con configurazione elettrodica di tipo Wenner e dipolo-dipolo.

I rilievi geofisici espletati hanno le seguenti caratteristiche:

LINEA	L _{TOT} (m)	N. Elettrodi	OFFSET _{elett.} (m)
ERT_1	94	48	2
ERT_2	94	48	2
ERT_3	94	48	2

Di seguito si riporta l'ubicazione delle indagini ERT eseguite in sito.



Metodologia d'indagine e strumentazione impiegata

La prospezione geoelettrica è un'indagine indiretta finalizzata alla definizione della resistività elettrica nel sottosuolo. È una tecnica attiva che consiste nell'immissione di corrente continua nel terreno per mezzo di due elettrodi in acciaio, detti “elettrodi di corrente” (C1-C2), e nella conseguente misurazione della differenza di potenziale (d.d.p.), mediante altri due elettrodi detti “elettrodi di tensione” (P1-P2). In superficie si determina la resistività apparente ρ_a che è calcolata dalle misure di intensità di corrente I immessa nel terreno e dalla differenza di potenziale ΔV misurata attraverso gli elettrodi di potenziale. La relazione generale, Legge di Ohm, è:

$$\rho_a = k \Delta V / I$$

dove k è il cosiddetto fattore geometrico dipendente dalla configurazione elettrodica utilizzata, cioè dalle distanze e posizioni reciproche dei 4 elettrodi (quadripolo).

Al variare del dispositivo elettrodico utilizzato, si ottiene una diversa risoluzione delle discontinuità presenti nel sottosuolo, come pure varia la profondità di investigazione a parità di lunghezza del profilo. La geoelettrica effettuata con misure multiple lungo uno stesso profilo è denominata tomografia geoelettrica (ERT) o geoelectrical profiling.

La campagna geognostica è stata espletata mediante uno strumento prodotto dalla IRIS Instruments (Francia) modello SYSCAL Pro Switch a 48 elettrodi con tomografia elettrica multi-elettrodo.



Ripresa fotografica della strumentazione utilizzata per l'acquisizione della linea tomografica.

SYSICAL Pro SPECIFICATIONS

TRANSMITTER

- Max voltage: 800V in switch mode
- Max voltage: 1 000V in manual mode
- Max current: 2.5A, typ. accuracy 0.2%
- Max power : 250W with internal DC/DC converter and 12V external battery; 1200W with external AC/DC and Motor Gene.
- Option 25mA max for readings on samples
- Pulse duration: 0.2s, 0.5s, 1s, 2s, 4s, 8s
- Internal 12V, 7Ah battery, plug for ext. batt.

RECEIVER

- Automatic ranging, 10 input channels
- Input impedance: 100 Mohm
- Max voltage channel 1: 15V
- Max voltage sum of channel 2 to 10: 15V
- Protection up to 1 000V
- Typ accuracy: 0.2%, resolution: 1 microV
- Digital rejection better than 120 db at power lines 50 and 60 Hz
- Stacking process, SP linear drift correction
- Reading of current, voltage, standard dev., 20 IP windows (preset or selectable),

Specifiche tecniche della strumentazione utilizzata.



Ripresa fotografica durante l'esecuzione di una linea geoelettrica nel sito di indagine in data 14/05/2018

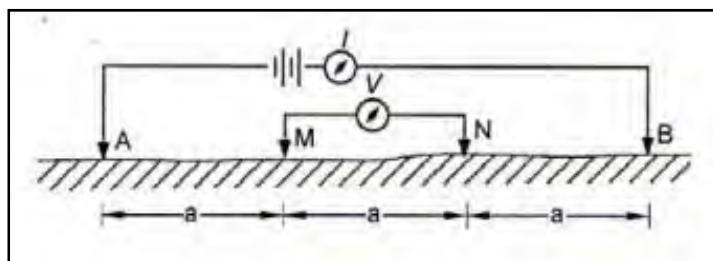
La campagna geognostica è stata espletata mediante l'esecuzione di profili elettrici superficiali con dispositivo multi-array. Si tratta di una metodologia che rappresenta l'evoluzione delle misure geoelettriche classiche, intesa ed applicata in modo tale da ottenere risoluzioni spaziali elevate. Il sistema permette di ricostruire la distribuzione spaziale, in 2 o 3 dimensioni, della resistività reale nel sottosuolo, con una risoluzione che è pari circa alla metà della distanza tra gli elettrodi. La profondità di investigazione raggiunta dal dispositivo elettrodico in fase di esecuzione dell'indagine tomografica dipende dalla profondità di penetrazione della corrente nel sottosuolo ed è legata anche al tipo di configurazione

elettrodica utilizzata. Tale profondità viene indicativamente considerata pari a circa 1/5 della lunghezza dello stendimento tomografico eseguito.

Tutti gli elettrodi, contemporaneamente infissi nel terreno mediante mazzetta e distanziati tra loro di una distanza di 2.00 m sono collegati, mediante un apposito cavo multiconduttore, allo strumento di acquisizione. La corrente viene applicata ad una coppia di elettrodi e il potenziale misurato su tutte le altre coppie disponibili utilizzando una geometria del quadripolo che dipende dalla configurazione prescelta. Si passa poi ad una seconda coppia di trasmissione e così via fino a raggiungere il numero massimo di misure indipendenti sui poli e dipoli disponibili.

Nella disposizione di **tipo Wenner** la spaziatura tra gli elettrodi di corrente A e B e tra gli elettrodi di potenziale M ed N resta fissa, ma l'intero array è traslato lungo il profilo di indagine. Sebbene sia così possibile investigare e rilevare variazioni laterali di resistività, non è altrettanto facile rilevare variazioni in profondità. L'array Wenner consente di ottenere medesimi risultati con un minor numero di misure rispetto alle altre geometrie, garantendo una buona copertura orizzontale. Il diagramma della sensitività per lo stendimento Wenner ha contorni quasi orizzontali al di sotto del centro del punto di sondaggio. In relazione a questo, lo stendimento Wenner è relativamente sensibile ai cambiamenti verticali di resistività al di sotto del centro dello stendimento, ma è meno sensibile ai cambiamenti orizzontali della resistività.

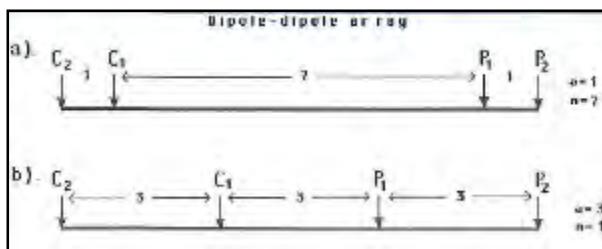
L'intensità del segnale è inversamente proporzionale al fattore geometrico $k = 2\pi a$ (piuttosto piccolo), quindi essendo il segnale molto forte, risulta andare più in profondità rispetto alle altre geometrie. La profondità di investigazione è circa la metà della spaziatura "a".



Schema di disposizione degli elettrodi di corrente e di potenziale nello stendimento di tipo Wenner.

Nella disposizione di **tipo dipolo-dipolo** la spaziatura tra gli elettrodi di corrente C1-C2 (e quelli di potenziale P1-P2) è definita "a". Il fattore "n" è il rapporto tra la distanza tra gli elettrodi C1 e P1 e la lunghezza del dipolo "a". In un sondaggio generalmente la spaziatura "a" viene mantenuta uguale alla spaziatura più piccola tra gli elettrodi, mentre il fattore "n" viene aumentato dal valore 1 al valore 6 per incrementare la profondità di investigazione. Uno svantaggio di questo stendimento è l'intensità del segnale molto bassa e che diminuisce con il cubo del fattore "n". La differenza di potenziale misurata dal resistivimetro crolla di circa 56 volte all'aumentare di "n" da 1 a 6. Per ovviare a questo problema, la

spaziatura "a" tra le coppie di dipolo C1-C2 (e P1-P2) viene aumentata all'aumentare della lunghezza dello stendimento. La figura sottostante mostra, per questo tipo di stendimento, due diversi arrangiamenti di uguale lunghezza, ma con diversi fattore "a" e "n". L'intensità di segnale dello stendi mento con "n=1" è circa 28 volte superiore a quella con "n=7". Nel diagramma di sensitività i valori maggiori di sensitività sono generalmente localizzati al di sotto del dipolo C2-C1 e del dipolo P1-P2. Questo stendimento è sensibile soprattutto ai cambiamenti di resistività al di sotto di ogni dipolo.



Schema di disposizione degli elettrodi di corrente e di potenziale nello stendimento di tipo dipolo-dipolo.

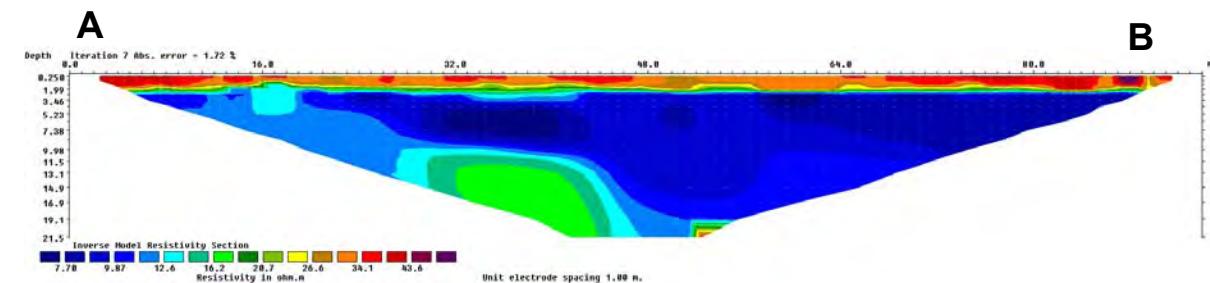
Nel caso di un suolo omogeneo ed isotropo i valori di resistività ricavati corrispondono alla resistività vera del terreno. Nella realtà, però, questo non avviene a causa dell'eterogeneità della natura del terreno e il valore di resistività misurato è detto "apparente". Esso dipende da diversi fattori quali, ad esempio, la forma e la posizione dei mezzi rispetto alla quaterna degli elettrodi di misura. È necessario, quindi, ricondurre la resistività apparente a valori "reali" del terreno attraverso la risoluzione del cosiddetto "problema inverso". Il problema inverso consiste nel ricostruire la distribuzione sconosciuta della resistività elettrica reale nel sottosuolo che ha dato origine ai dati di resistività apparente osservati in fase di acquisizione dei dati. Successivamente, quindi, ad una prima fase di verifica della coerenza dei dati acquisiti in cui è possibile evidenziare ed eliminare anomalie locali determinate da valori troppo alti o troppo bassi rispetto ai valori limitrofi, mediante un apposito algoritmo di inversione si ricostruisce la distribuzione della resistività reale del sottosuolo.

Per lo specifico caso di studio sono stati elaborati i dati con il software RES2D per l'elaborazione dei profili elettrici eseguiti e il software Prosys II della IRIS Instruments come programma di supporto. Per ogni linea geoelettrica eseguita è stato derivato il profilo di resistività reale (Ωm).

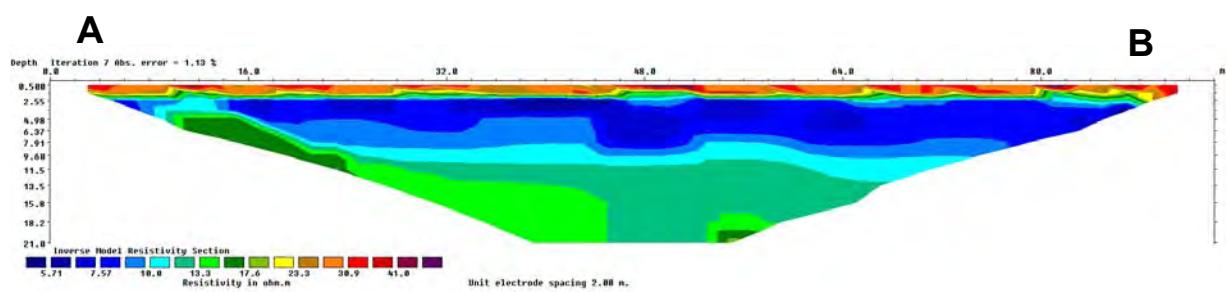
Sulla base dei valori ottenuti, è stata sviluppata la sezione invertita, rappresentativa dei valori di resistività elettrica.

Commento e interpretazione dei risultati

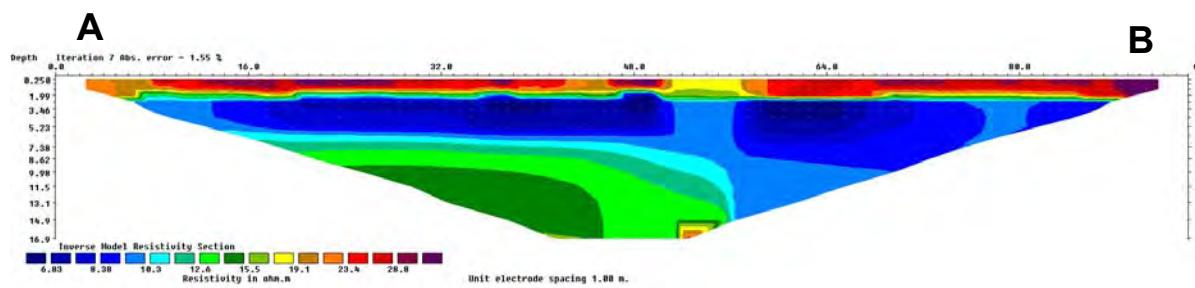
Si riportano di seguito le sezioni invertite di resistività reale risultanti da ciascuna indagine ERT eseguita.



Sezione di resistività reale relativa alla linea ERT_1



Sezione di resistività reale relativa alla linea ERT_2



Sezione di resistività reale relativa alla linea ERT_3

Dalle indagini ERT eseguite, nel sottosuolo indagato è stato misurato un range di resistività reale compreso circa tra 5÷43 Ωm.

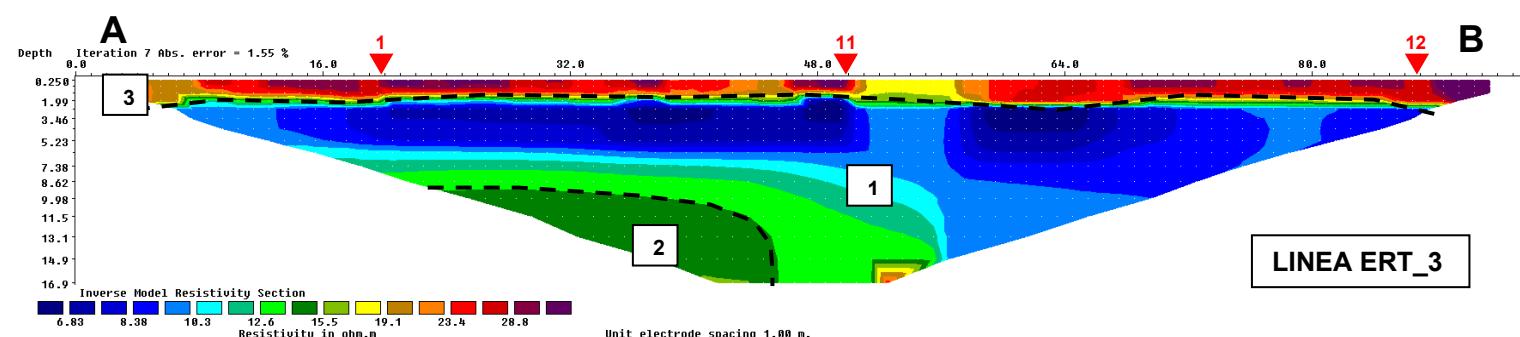
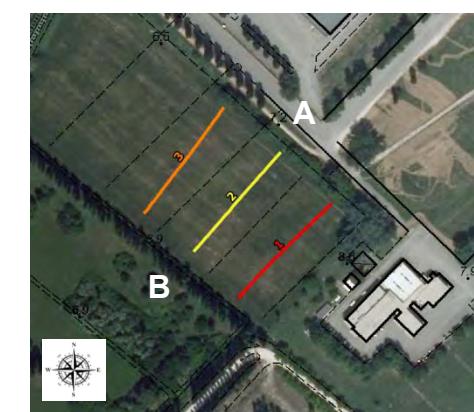
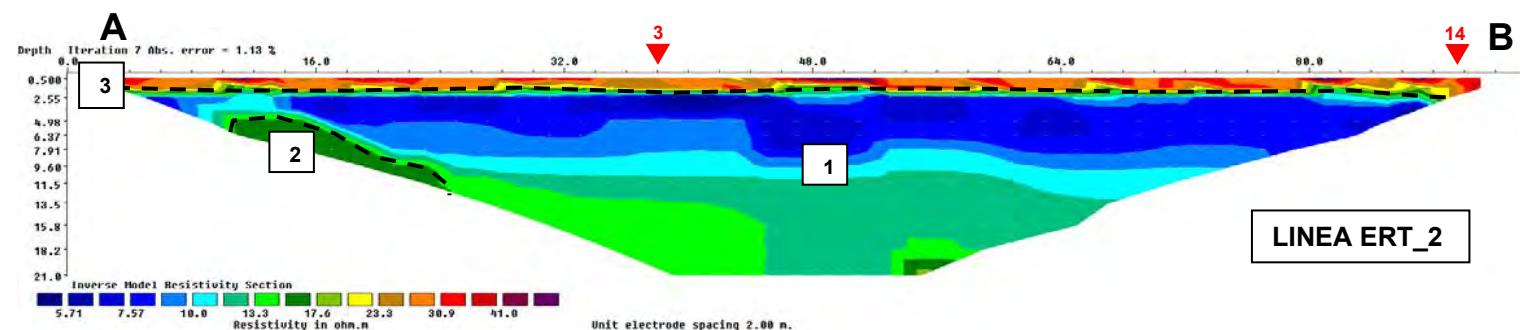
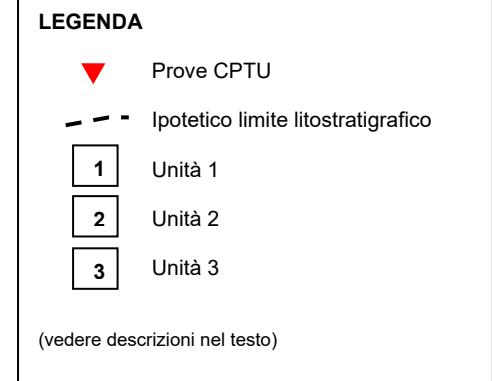
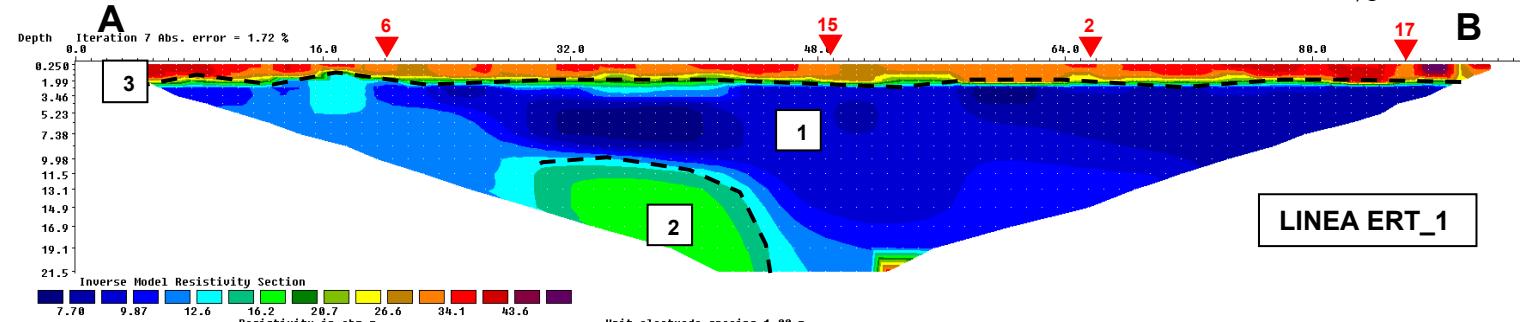
I valori di resistività reale più elevati sono stati rilevati, in tutti i profili eseguiti, in corrispondenza dei primi 2 m di spessore dal piano campagna; questi valori così distribuiti sono probabilmente dovuti al primo strato di terreno agricolo, presente al di sopra del livello della falda freatica, il quale è maggiormente soggetto ai fenomeni di essiccazione, risultando pertanto più resistivo. I valori misurati per questo livello sono nel range 20÷43 Ωm (colori dal giallo al rosso).

Dopodiché, al di sotto del primo livello di terreno agricolo, si individuano due unità principali: la prima identificata dal range di valori 5÷13 Ωm (colori dal blu al verde-acqua) e la seconda identificata dal range di valori 13÷20 Ωm. In considerazione del fatto che i terreni a comportamento coesivo (argille e limi) sono generalmente più conduttrive rispetto ai terreni incoerenti (limi, sabbie e ghiaie), si attribuisce alla prima unità a resistività minore (5÷13 Ωm) una litologia prevalentemente argillosa; per contro, alla seconda unità con valori maggiori di resistività (13÷20 Ωm) si attribuisce una litologia prevalentemente incoerente (limi e sabbie).

Nella tabella seguente si illustrano le tre principali unità litostratigrafiche identificate e interpretate sulla base dei valori d resistività reale misurati.

Unità	Resistività reale	Descrizione
Unità 1	5÷13 Ωm	Terreni prevalentemente argilosì
Unità 2	13÷20 Ωm	Terreni prevalentemente incoerenti sabbiosi e limosi – potenzialmente liquefacibile
Unità 3	20÷43 Ωm	Terreno agricolo essiccato e fessurato

Nelle figure seguenti si illustra, per ciascuna sezione ottenuta dalle tre indagini ERT, una possibile suddivisione (linea nera tratteggiata) tra le tre unità litostratigrafiche interpretate e precedentemente descritte.



4 RELAZIONE GEOTECNICA

4.1 MODELLO GEOTECNICO DEL SOTTOSUOLO

Il modello geotecnico è finalizzato a fornire tutti i dati geotecnici necessari l'intervento in oggetto. Sulla base dei dati emersi dall'elaborazione geotecnica e litostratigrafica delle indagini geotecniche eseguite in situ si può riassumere il seguente modello geotecnico schematico del terreno investigato:

MODELLO GEOTECNICO MEDIO

Strato	Profondità	Falda	Litotipo	Parametri geotecnici	
1	0.0 – 2.50 m da p.c.	-3.30 m da p.c. (livello medio)	Argilla o argilla limosa a consistenza media	γ	1800 kg/m ³ ≈ 18.00 kN/m ³
				γ'	2100 kg/m ³ ≈ 21.00 kN/m ³
				C_{uk}	0.57 kg/cm ² ≈ 57.0 kN/m ²
				C'_k	0.057 kg/cm ² ≈ 5.7 kN/m ²
				M_0	78.0 kg/cm ² ≈ 7800 kN/m ²
				G_0	290.0 kg/cm ² ≈ 29000 kN/m ²
				E_s	65.8 kg/cm ² ≈ 6580 kN/m ²
				ϕ_k	23°
2	2.50 – 8.00 m da p.c.	-3.30 m da p.c. (livello medio)	Argilla e argilla limosa a consistenza media con intercalazioni di sabbia limosa	v	0.40
				γ	1800 kg/m ³ ≈ 18.00 kN/m ³
				γ'	2100 kg/m ³ ≈ 21.00 kN/m ³
				C_{uk}	0.40 kg/cm ² ≈ 40.0 kN/m ²
				C'_k	0.04 kg/cm ² ≈ 4.0 kN/m ²
				G_0	260.0 kg/cm ² ≈ 26000 kN/m ²
				M_0	37.0 kg/cm ² ≈ 3700 kN/m ²
				E_s	56.0 kg/cm ² ≈ 5600 kN/m ²
3	8.00 – 10.00 m da p.c.	-3.30 m da p.c. (livello medio)	Limo e limo argilloso da poco consistente a mediamente consistente	ϕ_k	20°
				v	0.50
				γ	1750 kg/m ³ ≈ 17.50 kN/m ³
				γ'	2050 kg/m ³ ≈ 20.50 kN/m ³
				Dr	31%
				C_{uk}	—
				C'_k	0.082 kg/cm ² ≈ 8.2 kN/m ²
				G_0	470.0 kg/cm ² ≈ 47000 kN/m ²

4	10.00 – 11.30 m da p.c.		Sabbia limosa e argillosa mediamente addensata	γ	1850 kg/m ³ ≈ 18.50 kN/m ³			
				γ'	2150 kg/m ³ ≈ 21.50 kN/m ³			
5	11.30 – 13.15 m da p.c.		Da sabbia limosa a sabbia argillosa da mediamente addensata a poco addensata	Dr	45%			
				C'_k	0.04 kg/cm ² ≈ 4.0 kN/m ²			
6	13.15 – 17.00 m da p.c.		Argilla e argilla limosa a consistenza media con intercalazioni sabbiose	G_0	540.0 kg/cm ² ≈ 54000 kN/m ²			
				E_s	500.0 kg/cm ² ≈ 50000 kN/m ²			
8	17.00 – 20.00 m da p.c.		Argilla e argilla limosa a consistenza elevata	ϕ_k	29.4°			
				v	0.30			
Legenda								
γ = <i>peso specifico terreno naturale</i>								
γ' = <i>peso specifico terreno saturo</i>								
C_{uk} = <i>coesione non drenata caratteristica</i>								
C'_k = <i>coesione efficace caratteristica</i>								
Dr = <i>densità relativa</i>								
M_0 = <i>modulo di deformazione edometrico</i>								
E_s = <i>modulo elastico</i>								
ϕ_k = <i>angolo d'attrito caratteristico</i>								
v = <i>modulo di Poisson</i>								

4.2 VERIFICHE GEOTECNICHE

Al fine di verificare il sistema terreno-fondazione da un punto di vista geotecnico, sulla base dei dati forniti dal progettista si sono considerate delle fondazioni superficiali impostate su **plinti quadrati in c.a.** Per i calcoli si sono inoltre utilizzati i parametri meccanici desunti dalle indagini geotecniche eseguite in situ e precedentemente descritte. Si riportano di seguito i dati relativi al terreno e alle fondazioni considerate.

plinto quadrato

larghezza della base	B = 5.00 m
lunghezza della fondazione	B' = 5.00 m
profondità della quota di imposta	D = -1.50 m da p.c.

Per i parametri geotecnici del terreno si faccia riferimento al modello geotecnico riportato al paragrafo precedente.

4.2.1 VERIFICA DEI CEDIMENTI

È stato eseguito il calcolo dei cedimenti del terreno di fondazione per ciascuna prova penetrometrica CPTU, mediante il software CPET – IT v. 1.7.4.13 prodotto da GeoLogisMiki – Geotechnical Software, mediante le seguenti formule.

Per il calcolo del cedimento primario:

$$S = \sum \frac{\Delta \sigma_v}{M_{CPT}} \Delta z$$

Per il calcolo del cedimento per rifluimento viscoso (creep):

$$S = C_a \cdot \Delta z \cdot \log(t)$$

I calcoli sono stati eseguiti per ciascuna prova CPTU, considerando i seguenti dati:

Larghezza fondazione: 5.00 m

Lunghezza fondazione: 5.00 m

Piano di posa della fondazione: -1.50 m da p.c.

Carico applicato al terreno: 80 kPa.

Si riportano di seguito i risultati relativi al cedimento totale del terreno di fondazione, ottenuti per ciascuna prova CPTU:

prova	Cedimento totale [cm]
CPTU 1	3.17
CPTU 2	2.31
CPTU 3	1.80
CPTU 4	1.42
CPTU 5	2.82
CPTU 6	1.70
CPTU 7	3.65
CPTU 8	5.36
CPTU 9	1.68
CPTU 10	1.31
CPTU 11	1.18
CPTU 12	0.85
CPTU 13	1.45
CPTU 14	0.66
CPTU 15	1.52
CPTU 16	1.19
CPTU 17	1.09
Cedimento medio	1.95

4.2.2 MODULO DI SOTTOFONDO

Il modello di Winkler considera il terreno come formato da una distribuzione di vincoli semplici bilaterali elastici. La relazione che ne regola il comportamento è di tipo lineare tra il cedimento (w) e la pressione di contatto (p): $p = kw$.

Il parametro k è detto costante di sottofondo. Come è noto, k non dipende solo dal terreno ma anche dai carichi applicati, dalle proprietà del terreno, dalla forma e le dimensioni della fondazione.

Utilizzando la Formula di Bowles (1974):

$$k \text{ (kN/mc)} = 40 * Q_{lim} * F_c,$$

dove $F_c = 2.54/\text{cedimento della fondazione (cm)}$, considerando i sedimenti di riferimento calcolati ed i carichi ipotizzati e sopra riportati, si sono ottenuti i seguenti risultati per il **modulo di sottofondo** (o **costante di Winkler**):

carico applicato	Cedimento di riferimento	modulo di sottofondo (K di Winkler)
$P = 0.80 \text{ kg/cm}^2 \approx 80 \text{ kN/m}^2$	S=1.95 cm	K = 1.25 kg/cm ³

4.2.3 VERIFICA NEI CONFRONTI DEGLI SLU (6.4 NNTC 2018)

In relazione a quanto esposto nella normativa tecnica nazionale NTC 2018, si procede alla verifica nei confronti degli stati limite ultimi (SLU) di resistenza del terreno (GEO) relativamente alle opere di fondazione in oggetto, di **tipo superficiale**, fornendo il valore di resistenza offerta dal sistema geotecnico (R_d GEO). Il valore di progetto della resistenza R_d può essere determinato:

- a) in modo analitico, con riferimento al valore caratteristico dei parametri geotecnici del terreno, diviso per il valore del coefficiente parziale γ_M specificato nella Tab. 6.2.II (NNTC 2018) e tenendo conto, ove necessario, dei coefficienti parziali γ_R specificati nei paragrafi relativi a ciascun tipo di opera;
- b) in modo analitico, con riferimento a correlazioni con i risultati di prove in situ, tenendo conto dei coefficienti parziali γ_R riportati nelle tabelle contenute nei paragrafi relativi a ciascun tipo di opera;
- c) sulla base di misure dirette su prototipi, tenendo conto dei coefficienti parziali γ_R riportati nelle tabelle contenute nei paragrafi relativi a ciascun tipo di opera.

Le verifiche sono effettuate applicando la combinazione (A1+M1+R3) di coefficienti parziali prevista dall'approccio 2, tenendo conto dei valori dei coefficienti parziali riportati nelle tabelle 6.2.I, 6.2.II e 6.4.I.

Fattori correttivi sismici: Paolucci e Pecker (1997)

Per tener conto degli effetti inerziali indotti dal sisma nei riguardi della determinazione del q_{lim} vengono introdotti, all'interno della formula di Terzaghi, i fattori correttivi z:

$$z_c = 1 - 0.32 \cdot K_h \quad z_q = \left(1 - \frac{k_h}{\tan \phi}\right)^{0.35} \quad z_\gamma = z_q$$

Dove il K_h è il coefficiente sismico orizzontale. Le verifiche sono state effettuate considerando quindi i seguenti parametri sismici:

- a_{MAX} (ag/g): **0.337g** (relativa a SLV ; Tr = 1898 anni);
- coefficiente intensità sismica del terreno K_h : **0.080**

La determinazione della resistenza R_d GEO è stata svolta nella condizione sia a breve che a lungo termine per l'intervento in progetto.

La resistenza R_d calcolata in condizioni “**non drenate**” dove **Cu ≠ 0 e φ = 0**, applicando il coefficiente parziale di riduzione della coesione non drenata secondo la seguente relazione **Cud = Cuk / 1.0**, per cui si avrà **Cud = Cuk**, dove **Cud = coesione non drenata di progetto** e **Cuk = coesione non drenata caratteristica**, sarà pari a:

CONDIZIONE STATICÀ – CONDIZIONI NON DRENATE – A1+M1+R3		
Profondità di imposta	Dimensioni della fondazione	Carico limite ultimo SLU F.S. = 2.3
-1.50 m da p.c.	5.00 m x 5.00 m	1.38 kg/cm² ≈ 138 kN/m²

La resistenza Rd calcolata in condizioni “drenate” seguendo l’Approccio 2, combinazione (A1 + M1 + R3), applicando il coefficiente di riduzione parziale per la tangente dell’angolo di attrito secondo la relazione: $\text{tg } \phi'd = \text{tg } \phi'k / 1,0$, dove $\phi'd$ è l’angolo d’attrito di progetto, ne deriva, essendo $\phi'k = \phi'd$. Quindi secondo la formula di Terzaghi si ottiene, per l’intervento in progetto uno stato limite ultimo pari a:

CONDIZIONE STATICÀ – CONDIZIONI DRENATE – A1+M1+R3		
Profondità di imposta	Dimensioni della fondazione	Carico limite ultimo SLU F.S. = 2.3
-1.50 m da p.c.	5.00 m x 5.00 m	1.99 kg/cm² ≈ 199 kN/m²

CONDIZIONE PSEUDO-STATICÀ – CONDIZIONI DRENATE – A1+M1+R3		
Profondità di imposta	Dimensioni della fondazione	Carico limite ultimo SLU F.S. = 2.3
-1.50 m da p.c.	5.00 m x 5.00 m	1.86 kg/cm² ≈ 186 kN/m²

5 CONSIDERAZIONI CONCLUSIVE

Il presente studio geologico, geotecnico e sismico è stato eseguito in ottemperanza alle NNTC 2018 per caratterizzare il sottosuolo di un lotto che sarà interessato dalla realizzazione del Centro Unificato dell'Emergenza della Protezione Civile, sito in via Bologna, nei pressi della località Chiesuol del Fosso, nel Comune di Ferrara (FE).

Sulla base dei dati emersi dalle prove geotecniche eseguite in situ e in laboratorio, si fornisce per il terreno indagato il **modello geotecnico** medio riportato nel della presente relazione.

In relazione a quanto esposto nelle Nuove Norme Tecniche per le Costruzioni in zona sismica del 2018, si è proceduto alla **verifica nei confronti degli stati limite ultimi (SLU)**. Nel nostro caso specifico, per quanto riguarda le **opere di fondazione**, nelle verifiche di sicurezza agli stati limite ultimi è stato calcolato l'SLU sia a breve che a lungo termine per l'intervento in progetto, utilizzando i seguenti approcci di calcolo:

a) Approccio 2 combinazione (A1 + M1 + R3).

Si riassumono nella seguente tabella i valori di portanza del terreno di fondazione calcolati agli stati limite ultimi **SLU** relativamente alle fondazioni ipotizzate.

SLU – APPROCCIO 2 (A1 + M1 + R3) – F.S.= 2.3		
CONDIZIONI NON DRENATE	CONDIZIONI DRENATE	
	STATICHE	SISMICHE PSEUDOSTATICHE
1.38 kg/cm² ≈ 138 kN/m²	1.99 kg/cm² ≈ 199 kN/m²	1.86 kg/cm² ≈ 186 kN/m²

I cedimenti calcolati su ciascuna verticale di prova risultano modesti e ammissibili.

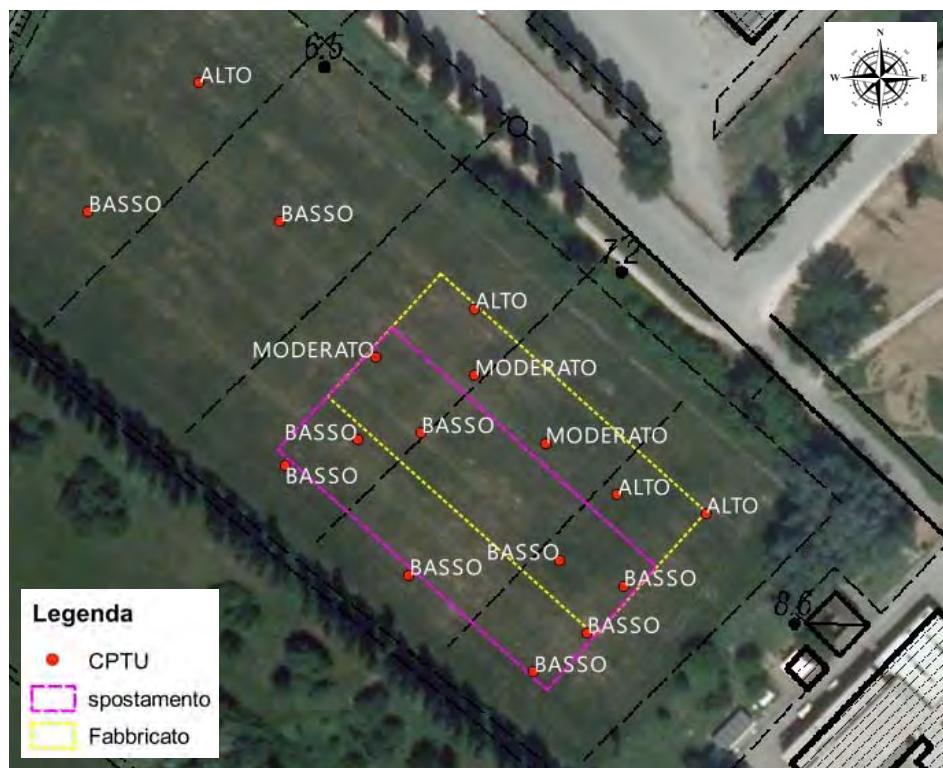
Le indagini sismiche eseguite in situ finalizzate alla **caratterizzazione sismica** del sito stesso hanno fornito i valori di Vs30 riassunti nella seguente tabella:

INDAGINE	V _s ₃₀ (m/s)
MASW n. 1	185
MASW n. 2	196
Re.Mi. n. 1	189
Re.Mi. n. 2	199
HVSR n. 2	185
SCPTU	181
DOWN-HOLE	190

La presente relazione è stata redatta in accordo con i nuovi indirizzi di Microzonazione sismica della Regione Emilia Romagna (**DGR 2193/2015**). È stata eseguita una valutazione del fattore di amplificazione e delle relative intensità spettrali secondo uno studio di III livello di approfondimento. A seguito delle risultanze dello studio RSL svolto si definiscono i seguenti parametri sismici caratteristici del sito analizzato:

	F.A. S.I.					
	PGA ₀	F.A. PGA	(0.00 < T(s) < 0.50)	(0.50 < T(s) < 1.00)	(0.50 < T(s) < 1.50)	PGA _{MAX}
SLV	0.253	1.33	1.60	1.79	1.97	0.337

Sulla base dei risultati ottenuti ed esposti nella presente relazione, che hanno integrato e approfondito il lavoro da noi precedentemente svolto nel medesimo sito di indagine (ns. rif. 646_17), si evidenzia che nel settore nordest del lotto indagato è presente una fascia di larghezza di pochi metri interessata da un rischio di liquefazione da alto a moderato, secondo la classificazione di Somnez (2003), come illustrato nella figura seguente, in cui sono illustrate anche l'ubicazione delle CPTU eseguite e i relativi rischi di liquefazione risultanti dai calcoli, e le possibili posizioni del fabbricato da realizzare.



Ubicazione delle CPTU eseguite e relativi rischi di liquefazione calcolati; i rettangoli definiscono le possibili posizioni del fabbricato da realizzare.

A disposizione per ulteriori chiarimenti cogliamo l'occasione per porgere distinti saluti.

Modena, luglio 2018

Dott. Geol. Pier Luigi Dallari



G E O G R O U P s.r.l.

Indagini geognostiche e geofisiche – geologia applicata alle costruzioni – laboratorio geotecnico –
idrogeologia – coltivazione cave – bonifiche – consolidamenti – geologia ambientale – consulenze
geologiche e geotecniche



TAVOLE

GEO GROUP SRL
C. Costa, 182, 41123 MODENA
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www.geogroupmodena.it

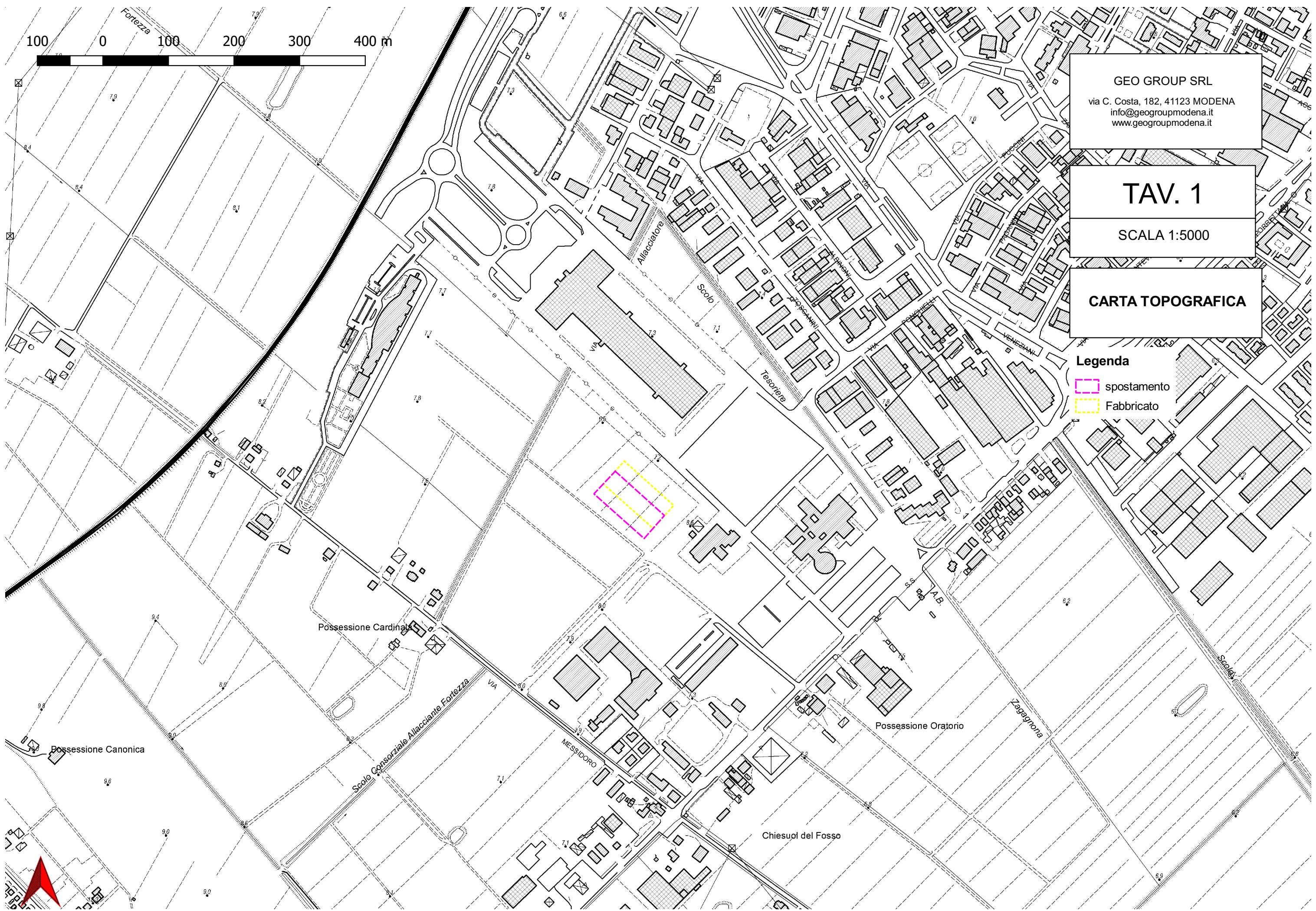
TAV. 1

SCALA 1:5000

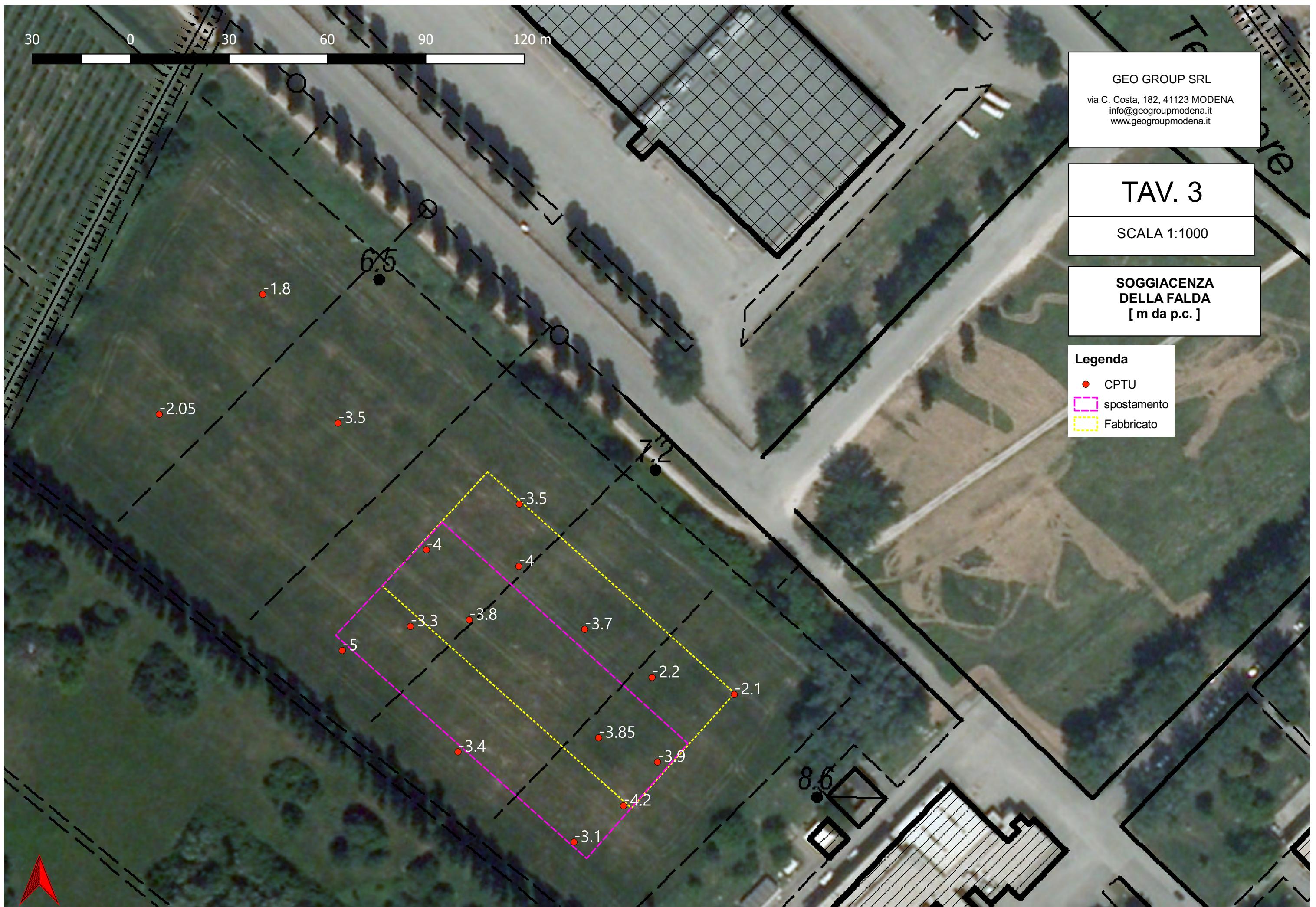
CARTA TOPOGRAFICA

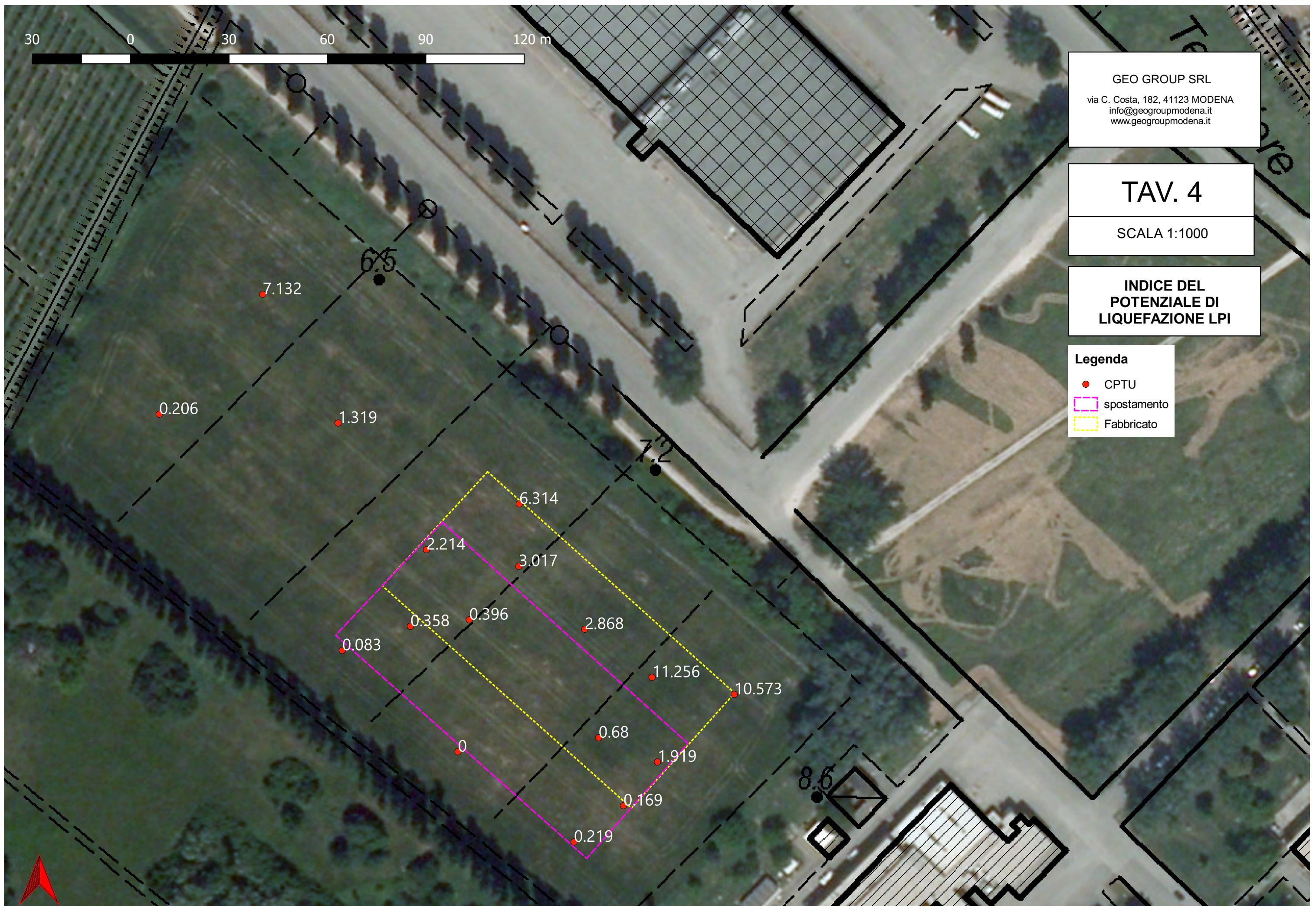
Legenda

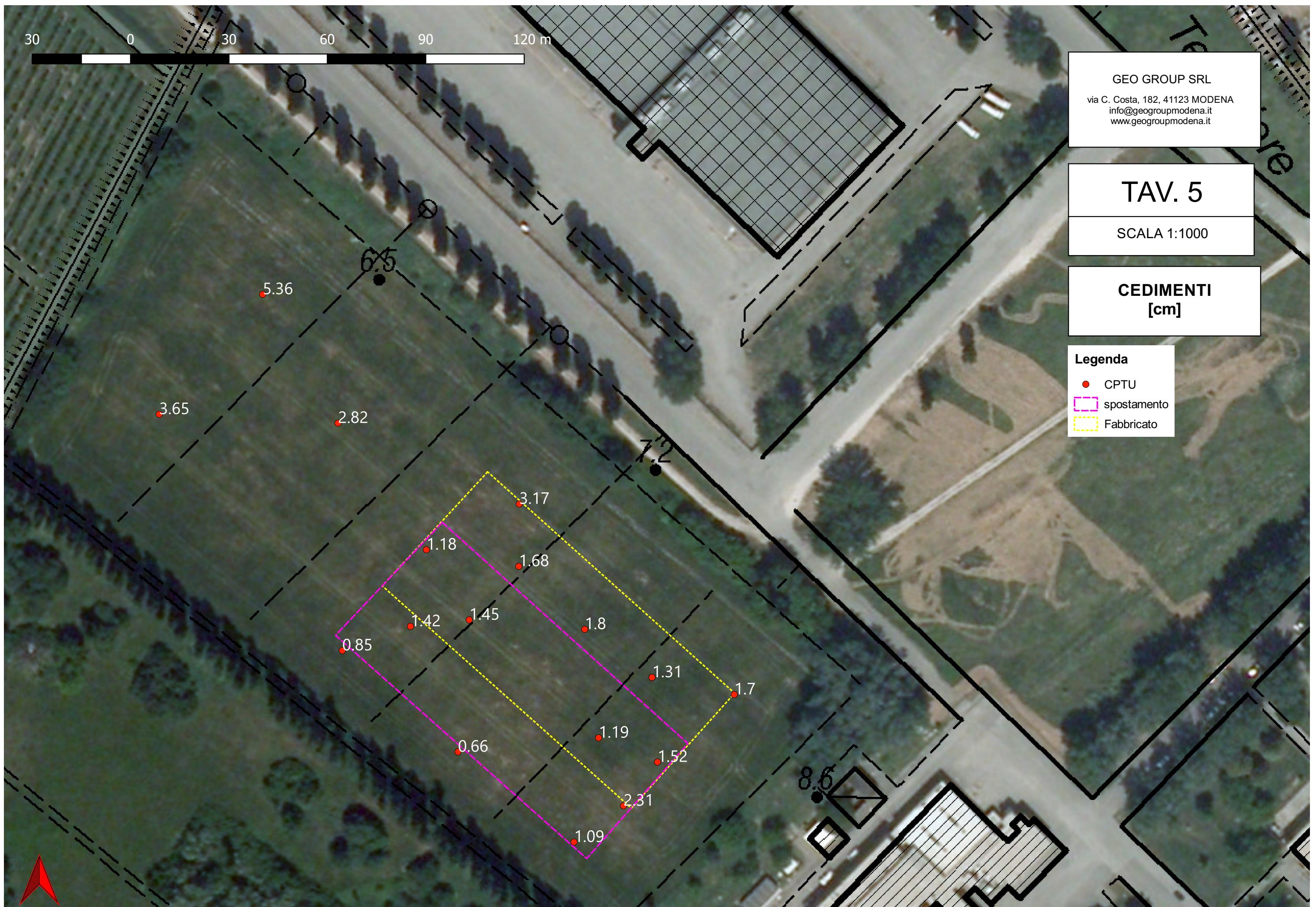
- ( spostamento
- ( Fabbricato

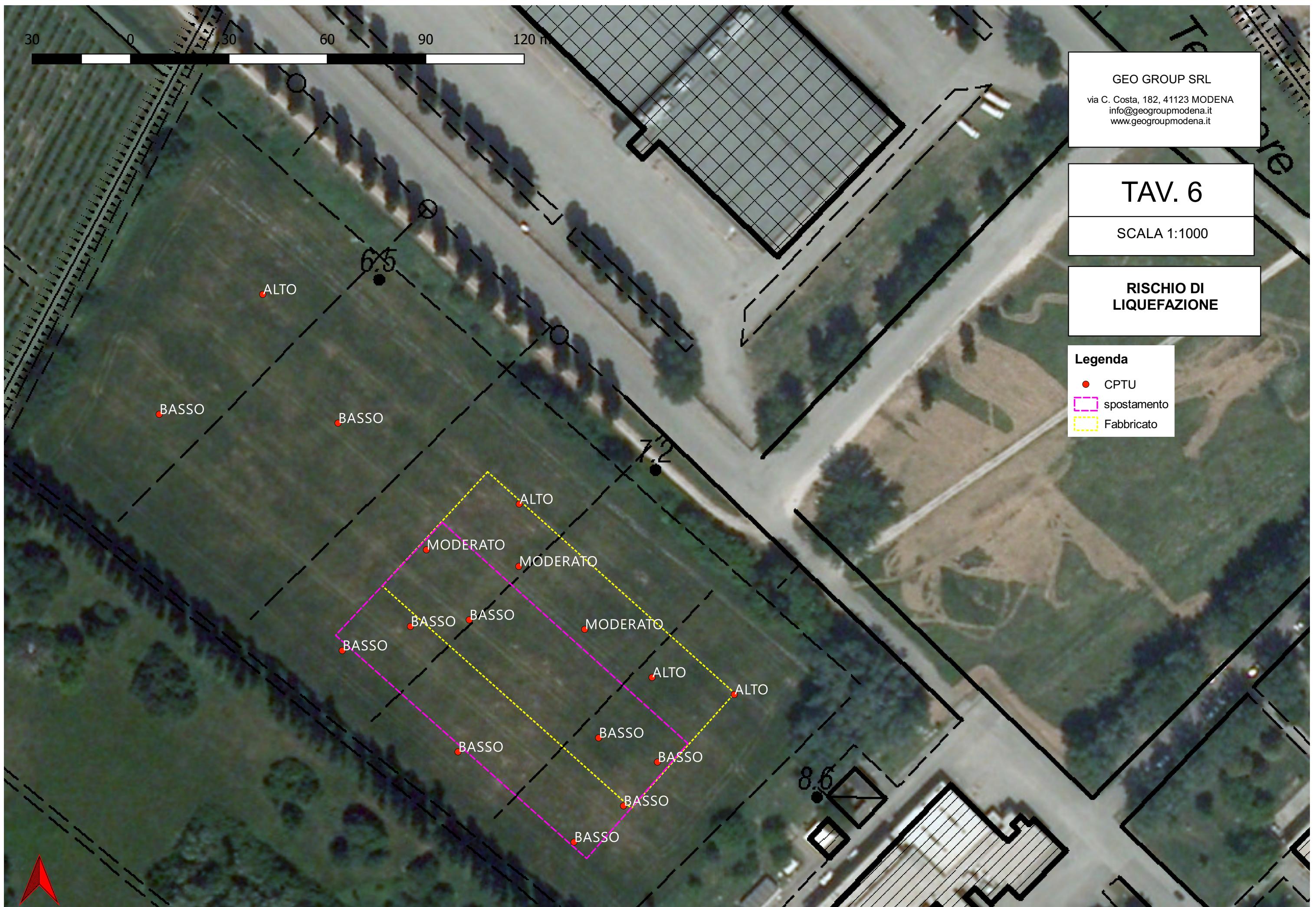












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idrogeologia – coltivazione cave – bonifiche – consolidamenti – geologia ambientale – consulenze
geologiche e geotecniche



ALLEGATO 1

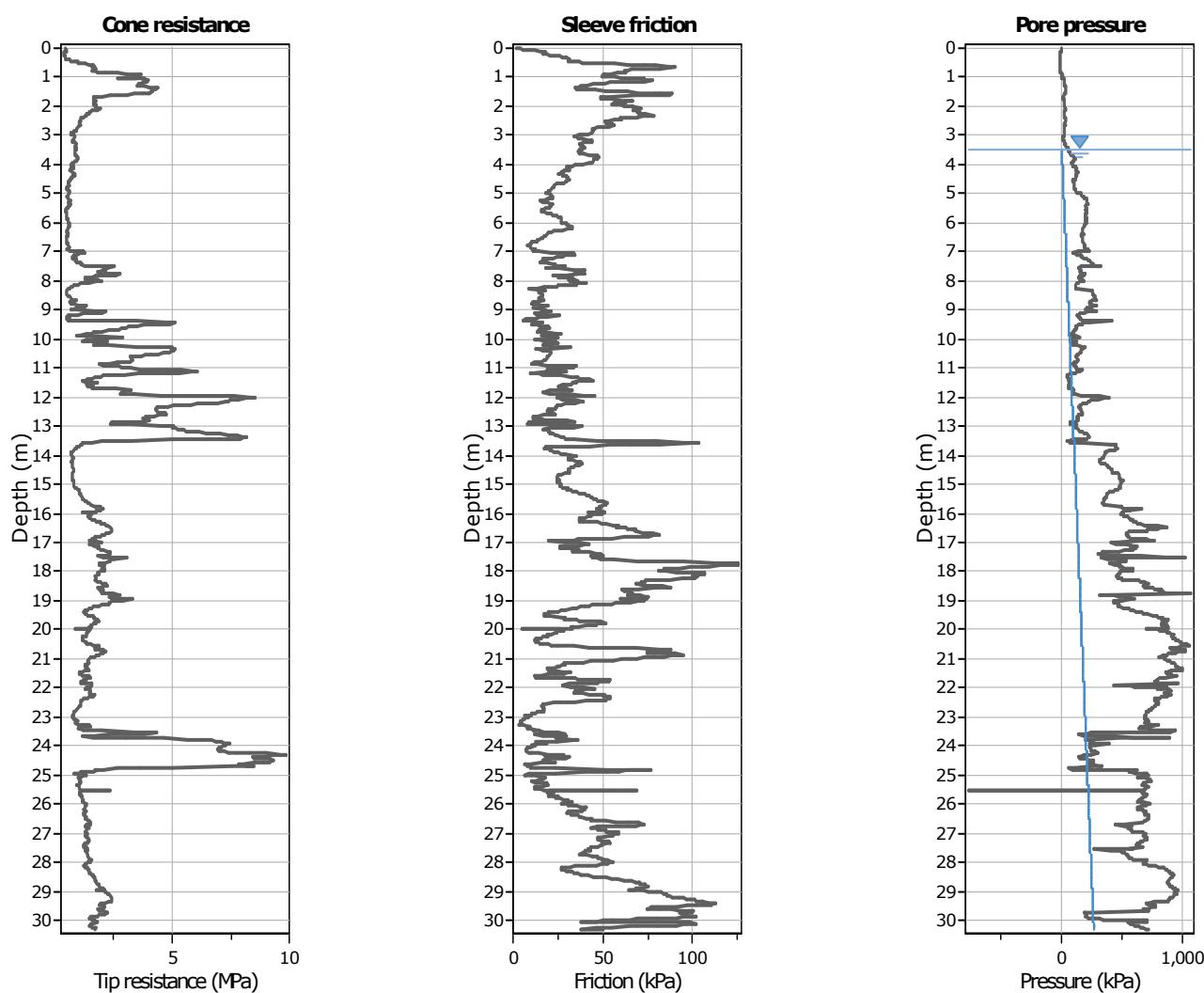
PROVE PENETROMETRICHE STATICHE CON PIEZOCONO CPTU

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile

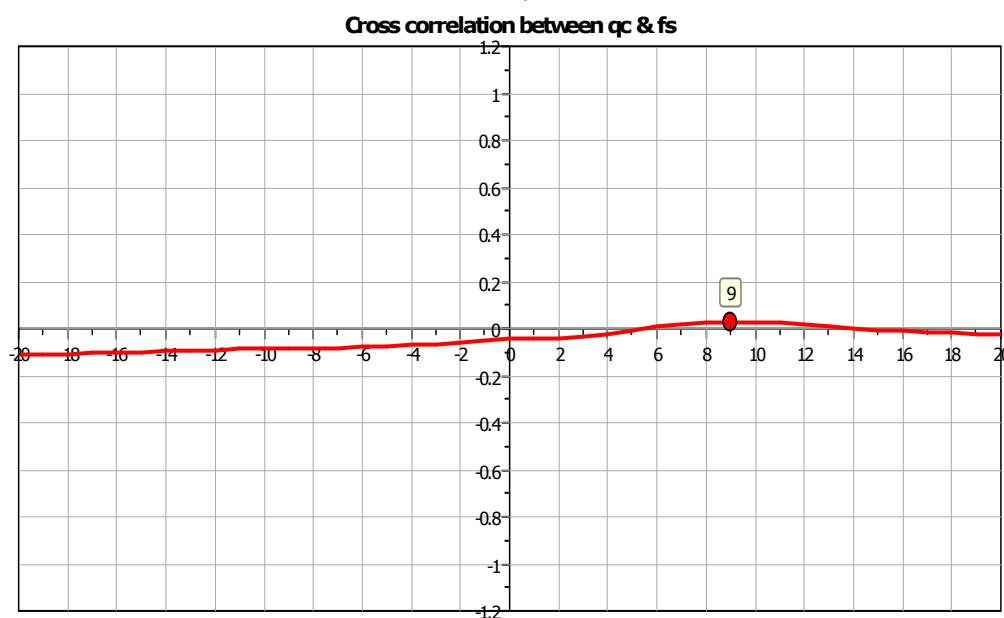
Location: Ferrara

CPT: CPTU 1

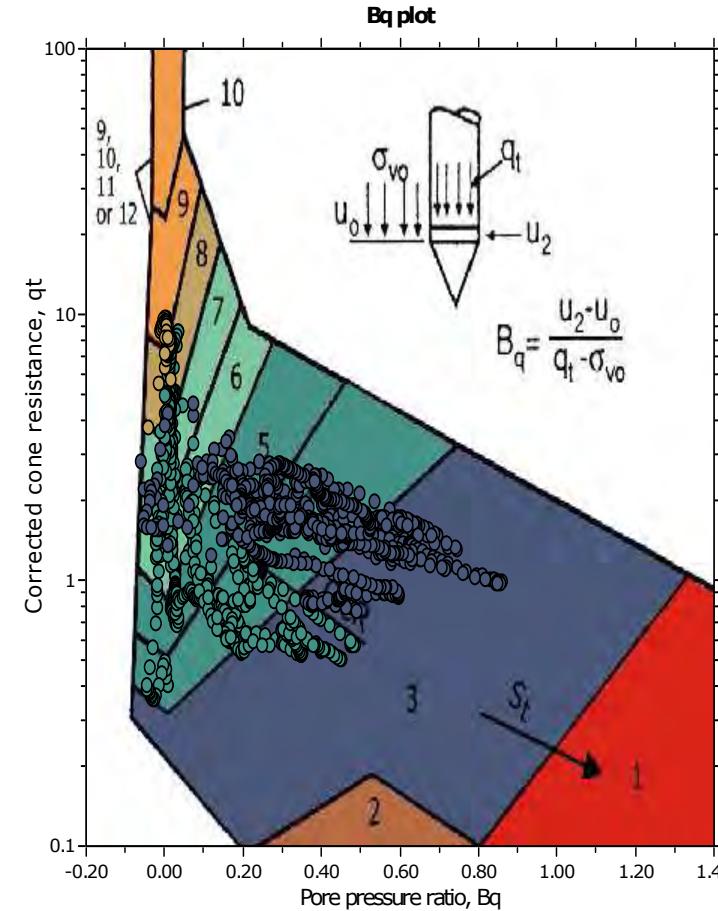
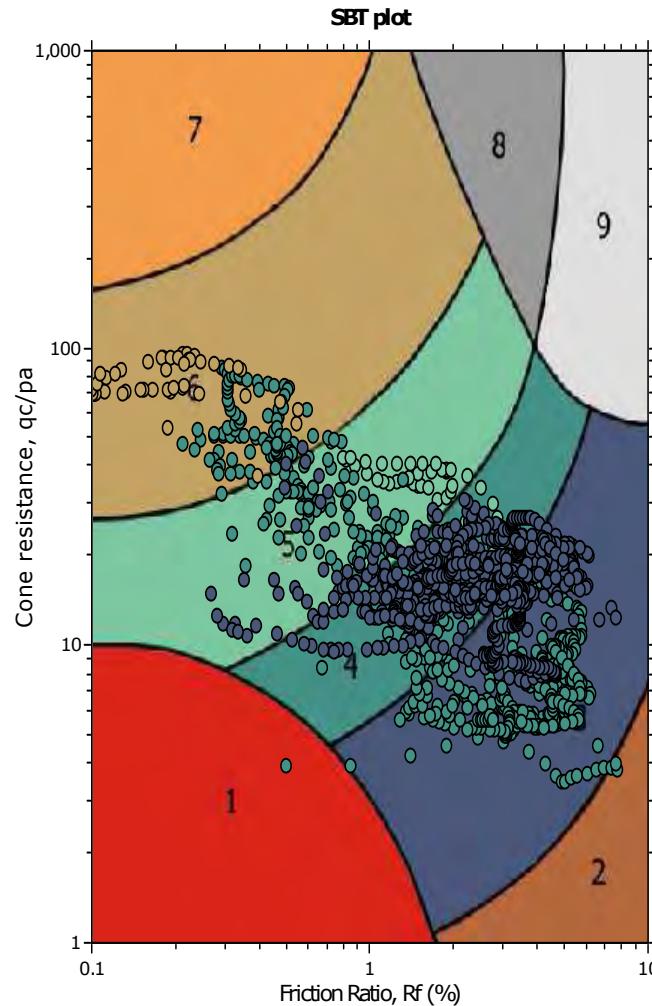
Total depth: 30.30 m, Date: 31/10/2017



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



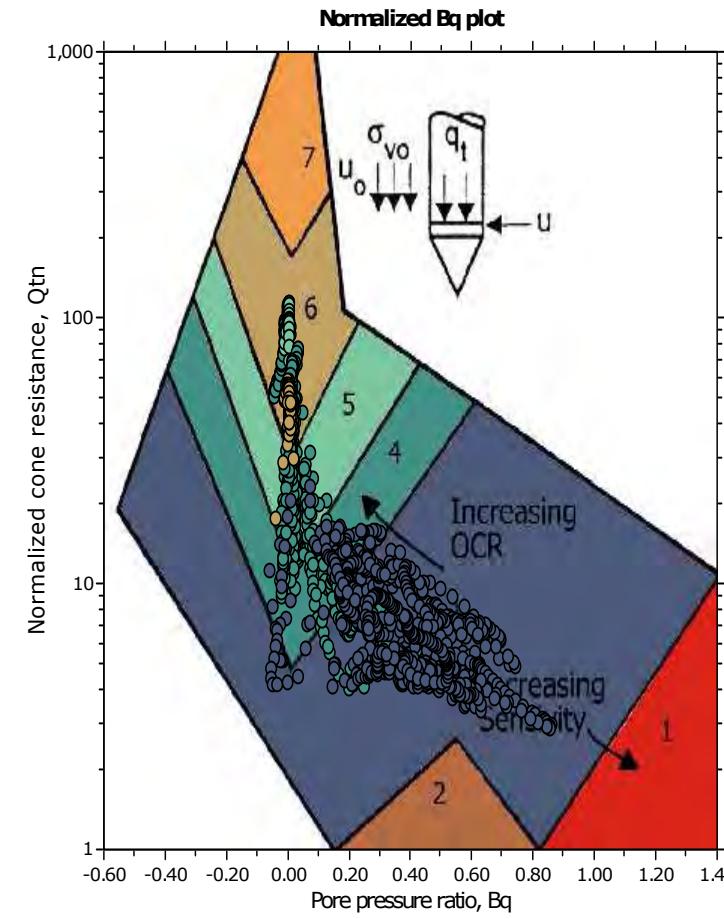
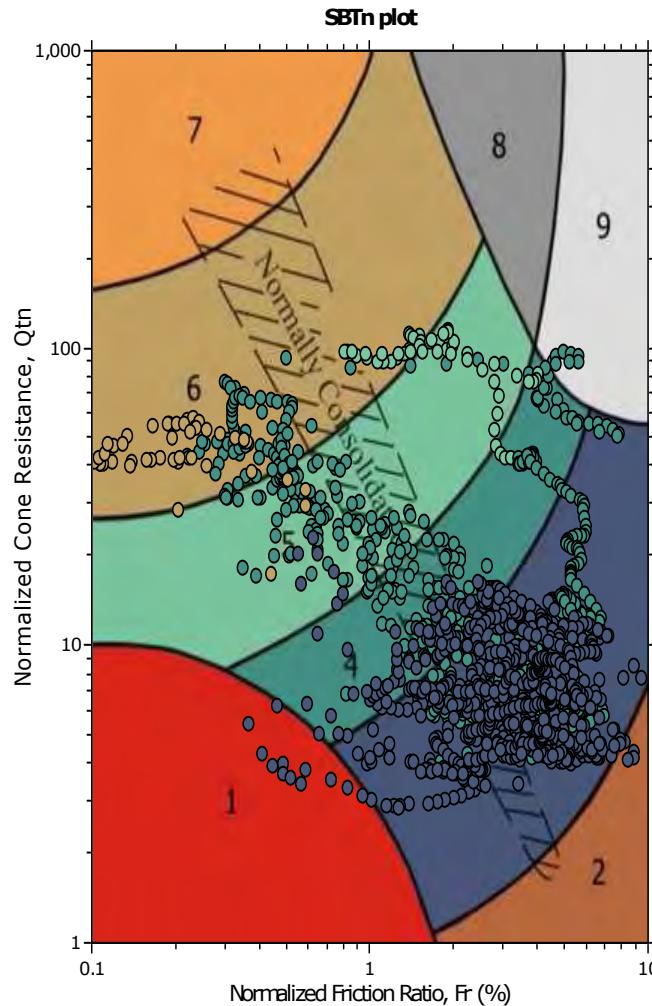
SBT - Bq plots



SBT legend

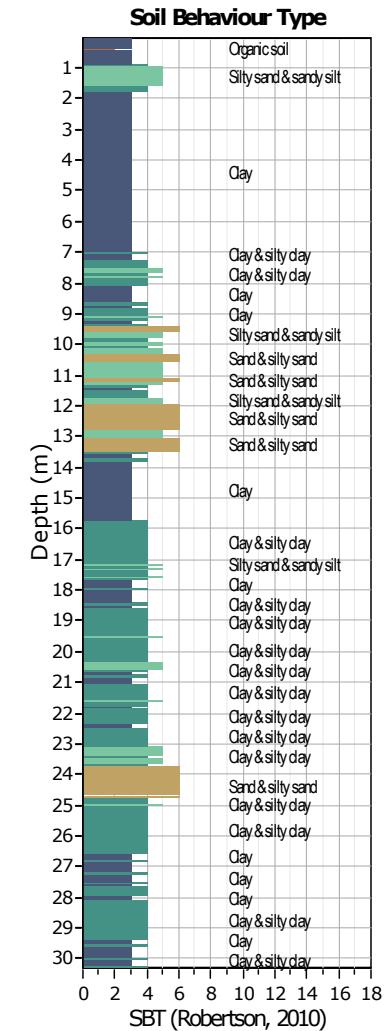
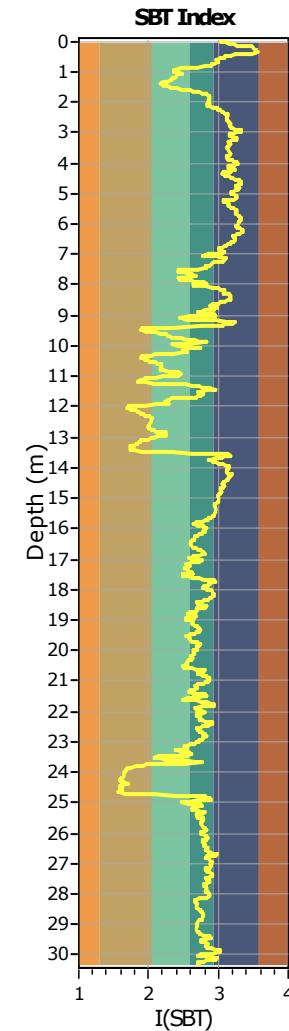
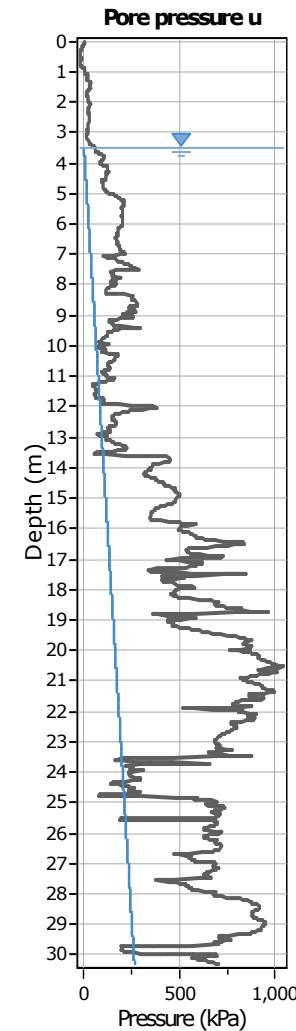
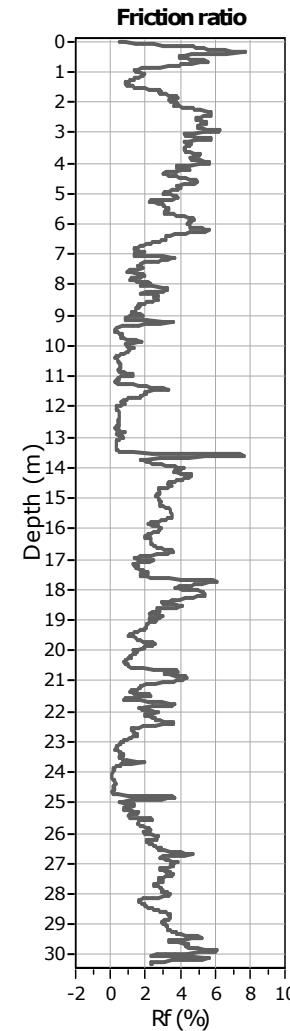
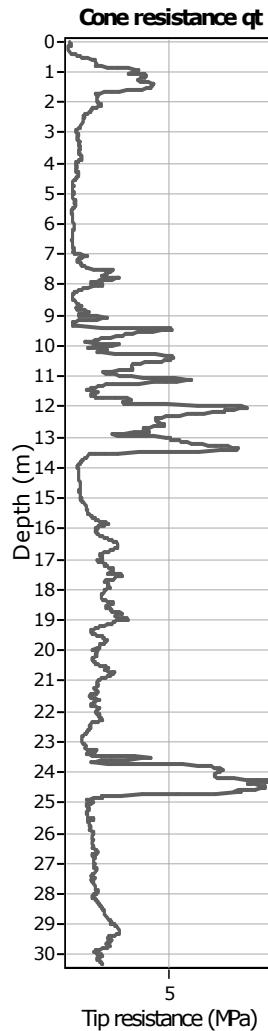
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

SBT - Bq plots (normalized)



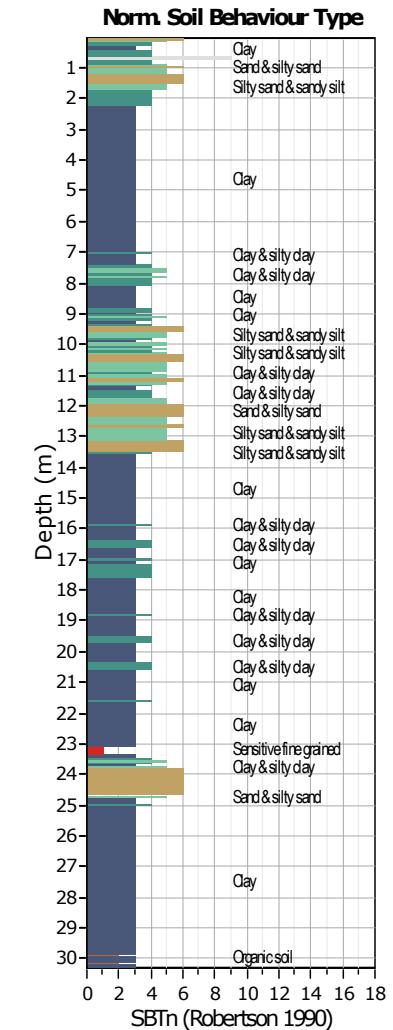
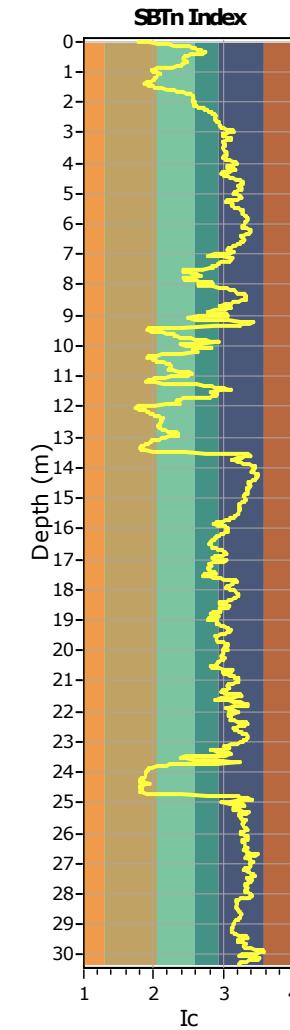
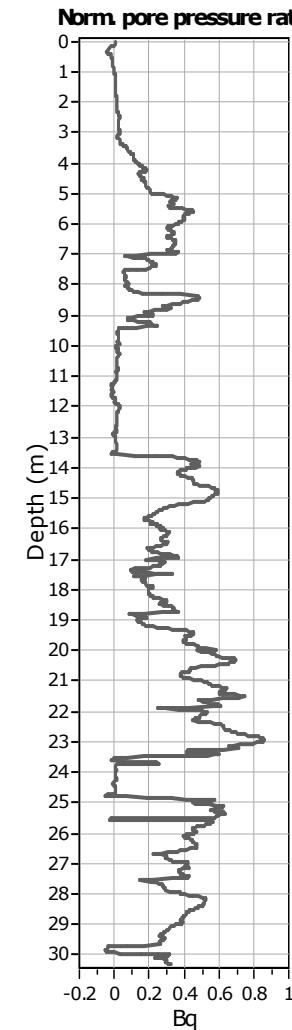
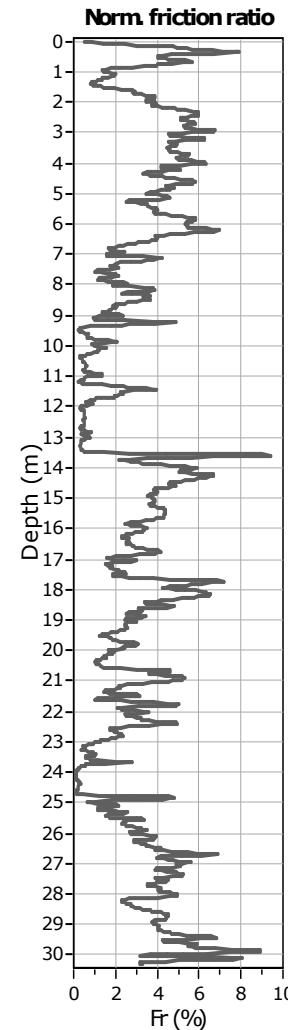
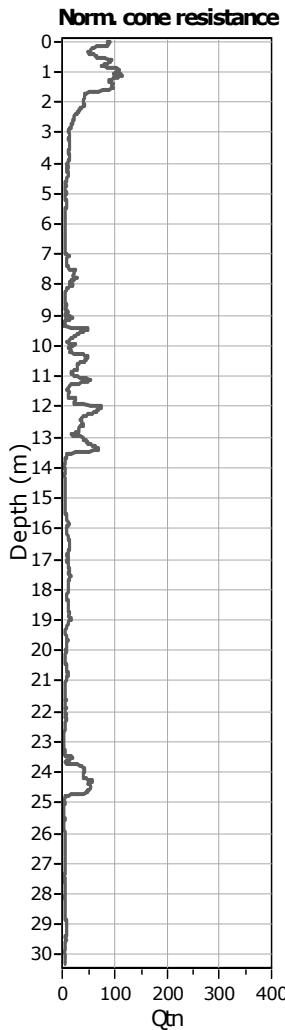
SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained



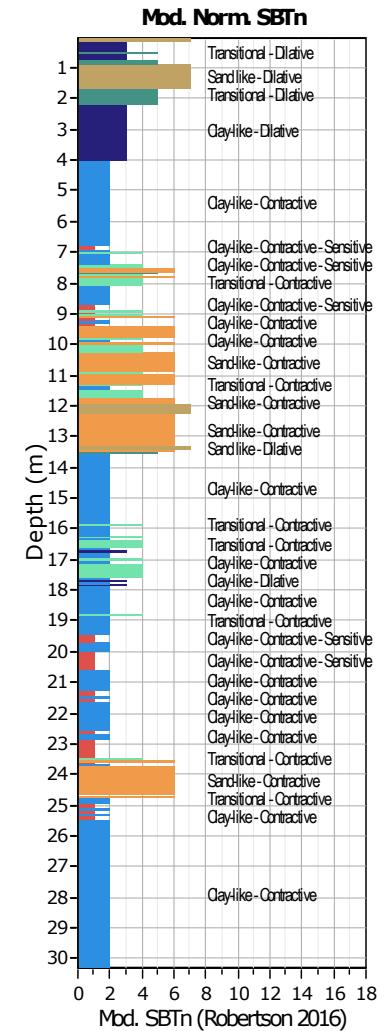
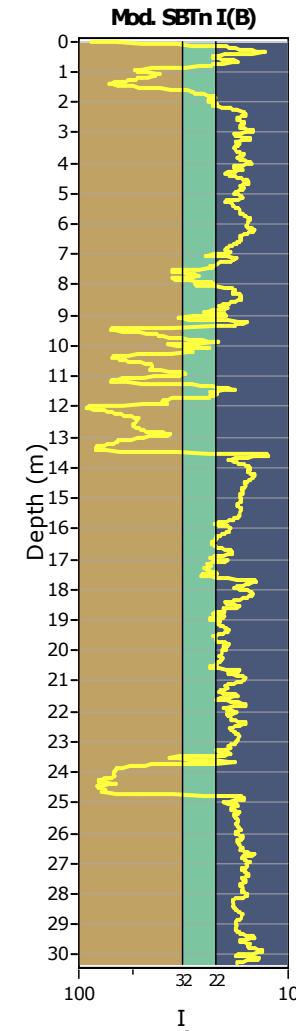
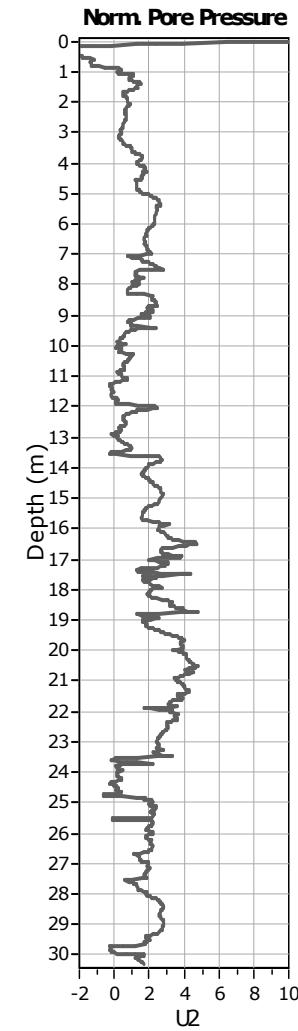
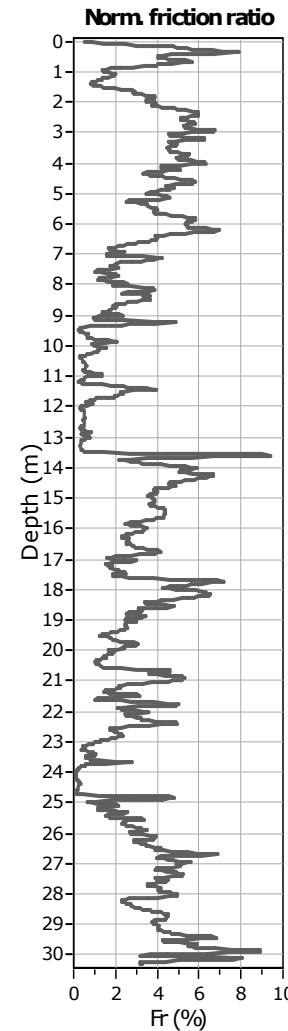
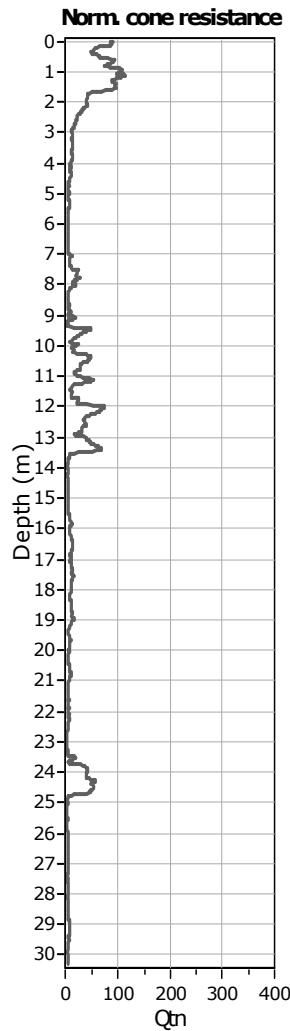
SBT legend

- | | | | | | |
|---|---------------------------|---|------------------------------|---|-----------------------------------|
| █ | 1. Sensitive fine grained | | 4. Clayey silt to silty clay | | 7. Gravely sand to sand |
| █ | 2. Organic material | | 5. Silty sand to sandy silt | | 8. Very stiff sand to clayey sand |
| █ | 3. Clay to silty clay | | 6. Clean sand to silty sand | | 9. Very stiff fine grained |



SBTn legend

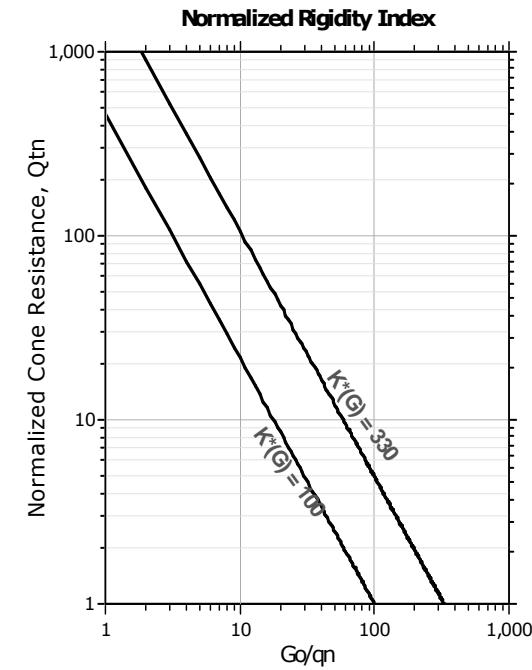
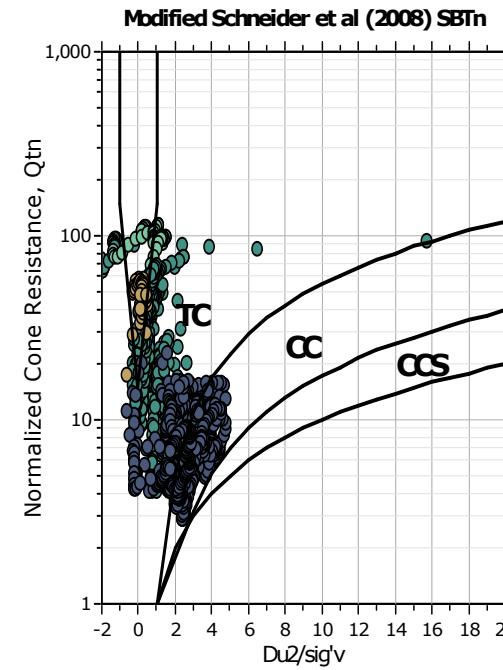
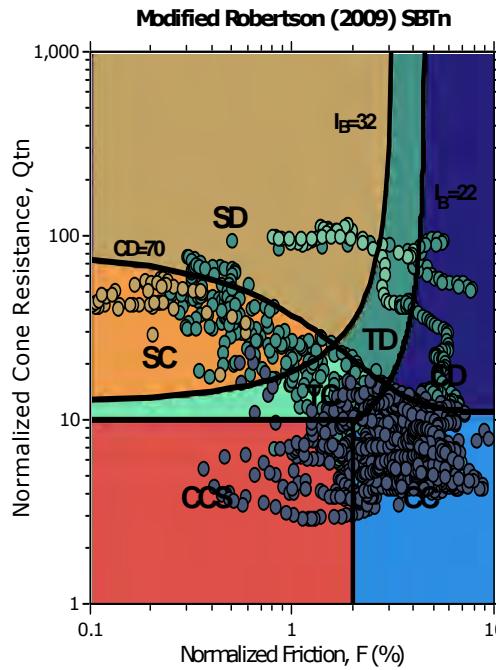
- | | | | | | |
|---|---------------------------|---|------------------------------|--|-----------------------------------|
| ■ | 1. Sensitive fine grained | ■ | 4. Clayey silt to silty clay | ■ | 7. Gravely sand to sand |
| ■ | 2. Organic material | ■ | 5. Silty sand to sandy silt | ■ | 8. Very stiff sand to clayey sand |
| ■ | 3. Clay to silty clay | ■ | 6. Clean sand to silty sand | ■ | 9. Very stiff fine grained |



Mod. SBTn legend

- | | | | | | |
|---|---|---|-----------------------------------|---|-----------------------------|
| █ | 1. CCS: ClayLike - Contractive, Sensitive | █ | 4. TC: Transitional - Contractive | █ | 7. SD: Sand-like - Dilative |
| █ | 2. CC: Clay-like - Contractive | █ | 5. TD: Transitional - Dilative | | |
| █ | 3. CD: Clay-Like: Dilative | █ | 6. SC: Sand-like - Contractive | | |

Updated SBTn plots



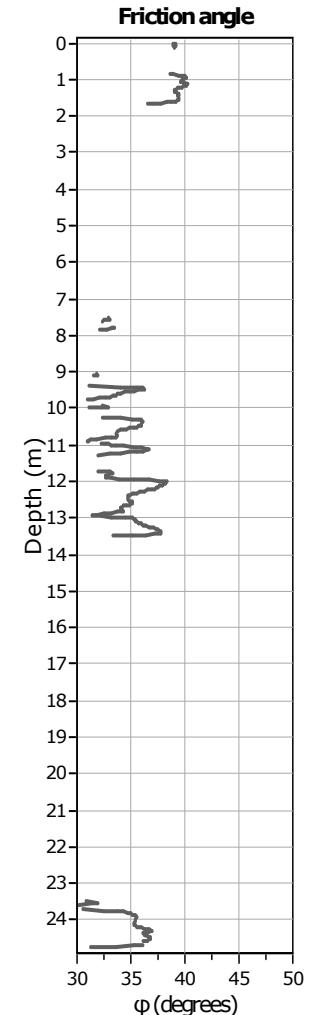
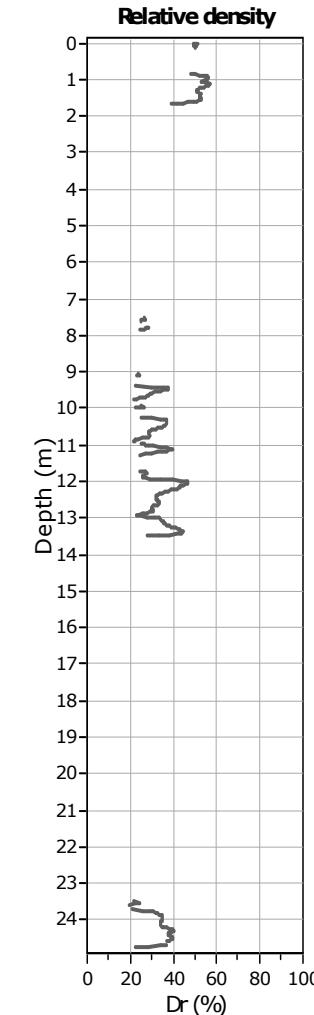
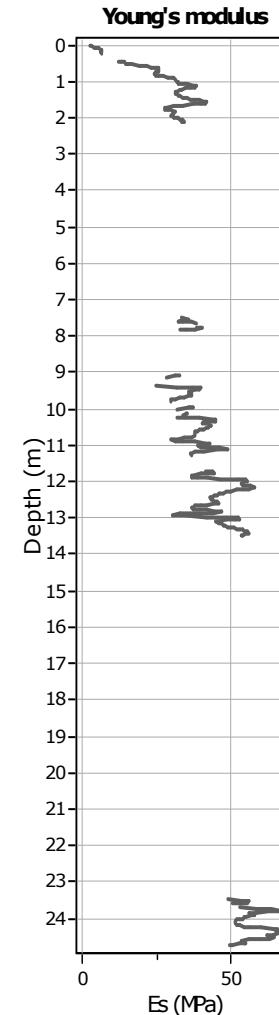
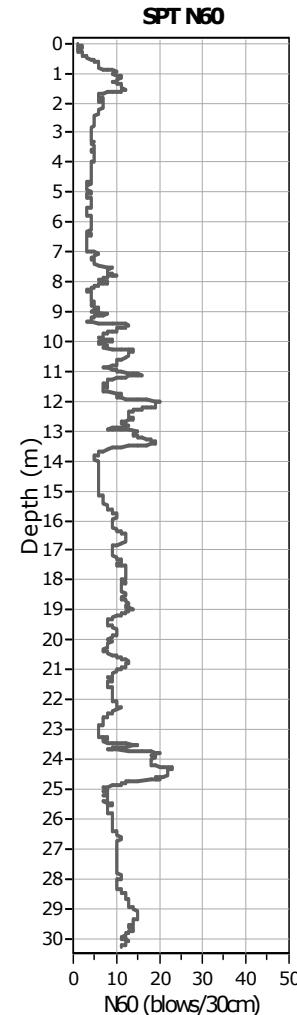
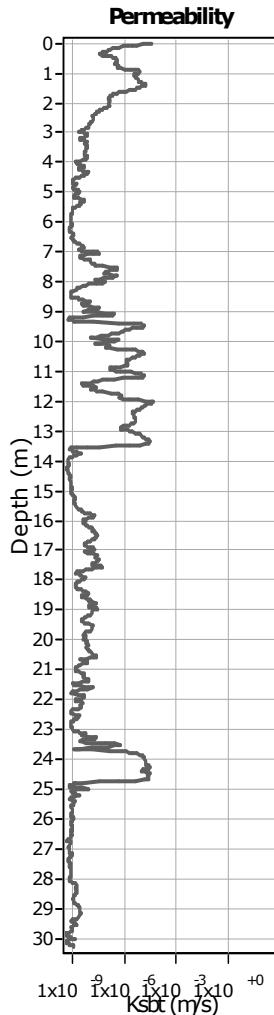
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile
Location: Ferrara

CPT: CPTU 1

Total depth: 30.30 m, Date: 31/10/2017



Calculation parameters

Permeability: Based on SBT_n

SPT N₆₀: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

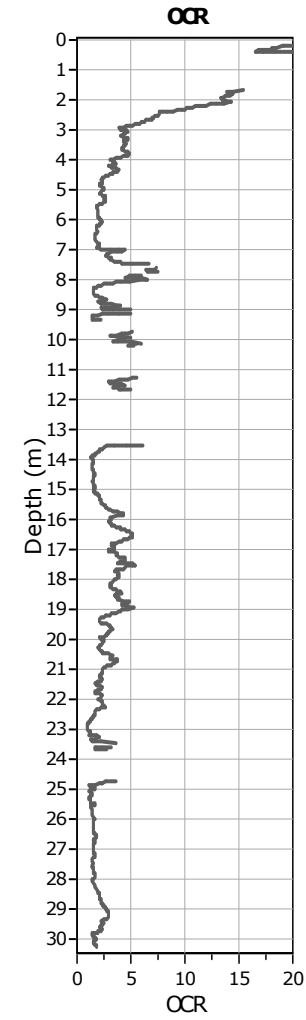
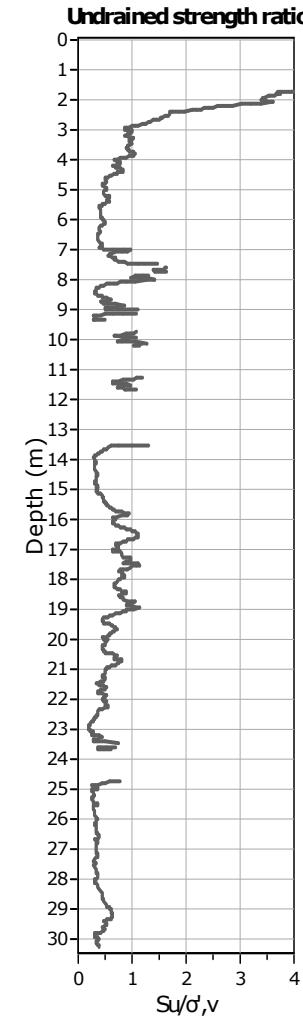
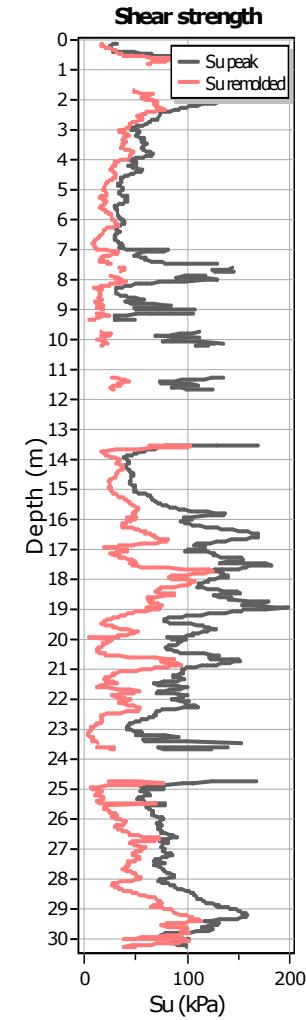
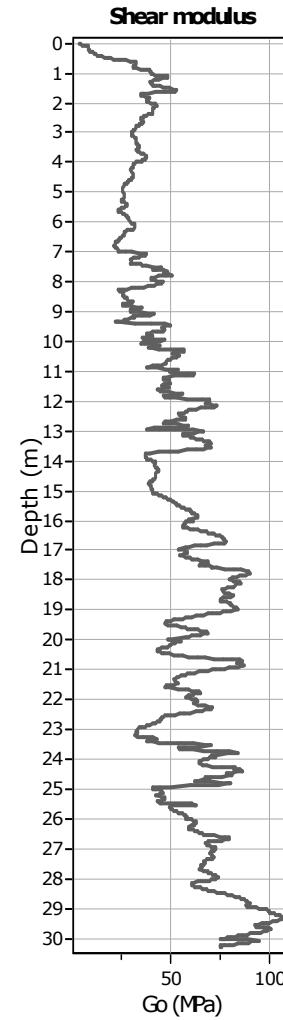
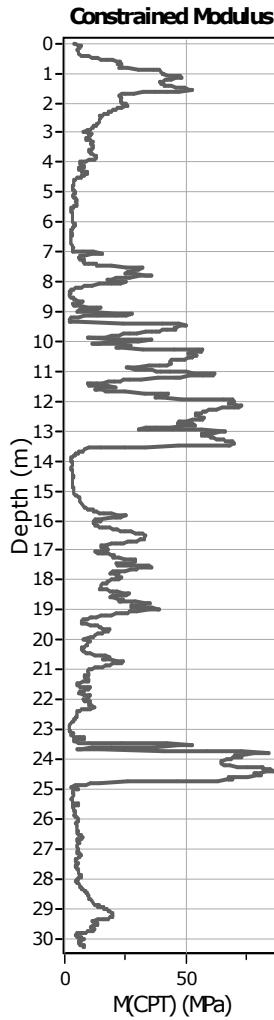
User defined estimation data

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile

Location: Ferrara

CPT: CPTU 1

Total depth: 30.30 m, Date: 31/10/2017



Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)

G_0 : Based on variable *alpha* using I_c (Robertson, 2009)

Undrained shear strength cone factor for clays, N_{kt} : 14

OCR factor for clays, N_{kt} : 0.33

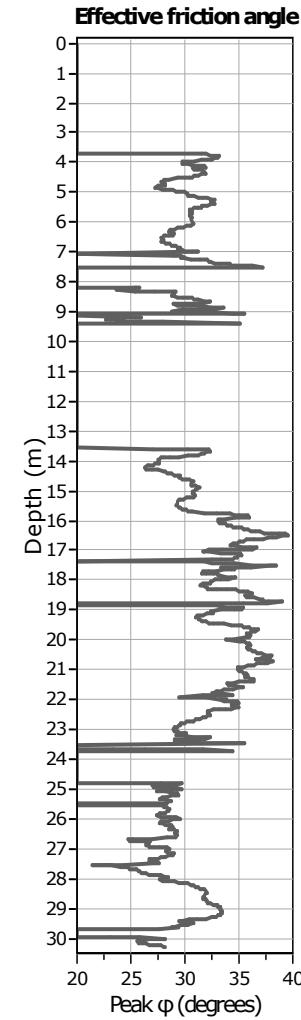
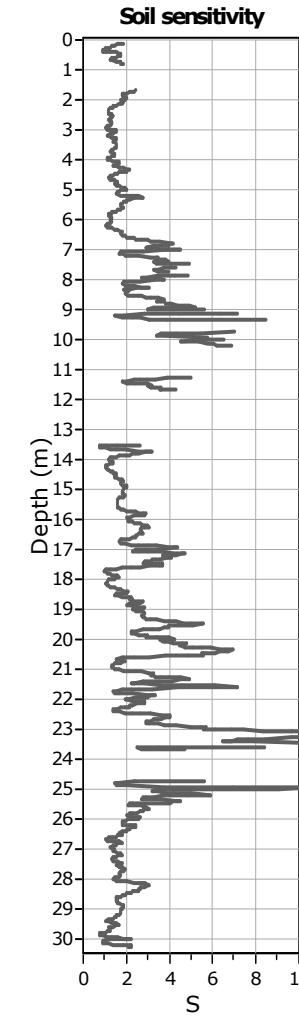
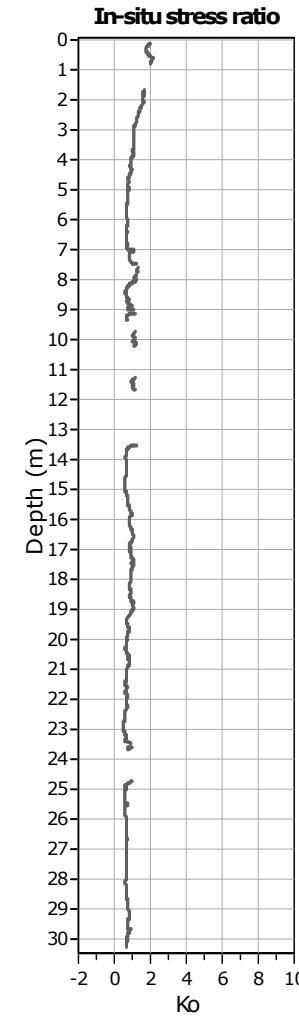
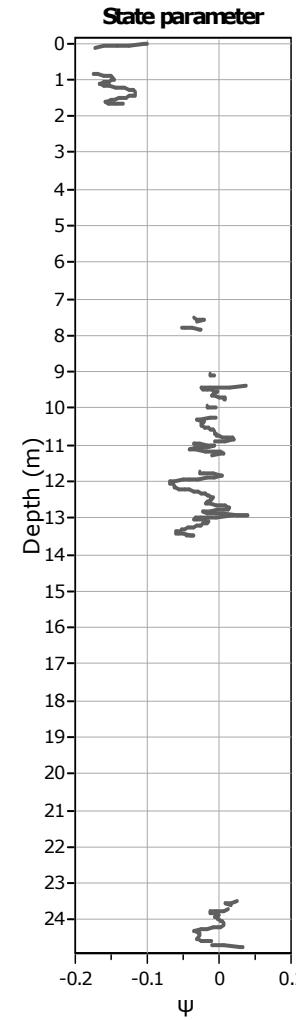
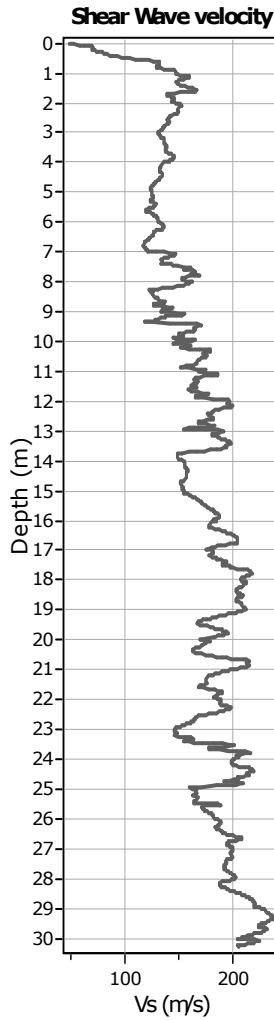
- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile

Location: Ferrara

CPT: CPTU 1

Total depth: 30.30 m, Date: 31/10/2017



Calculation parameters

Soil Sensitivity factor, N_s: 7.00

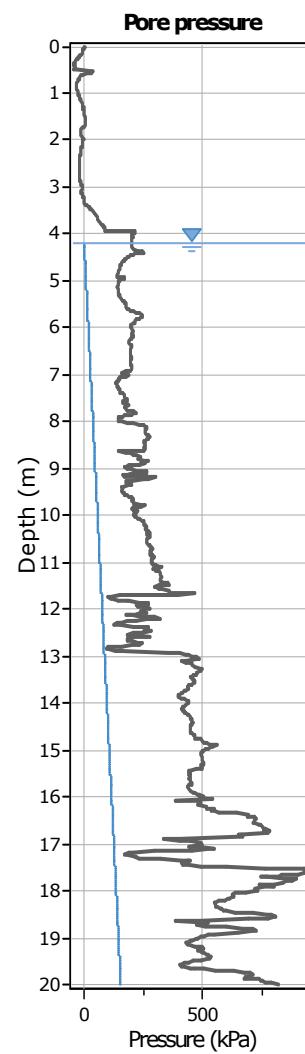
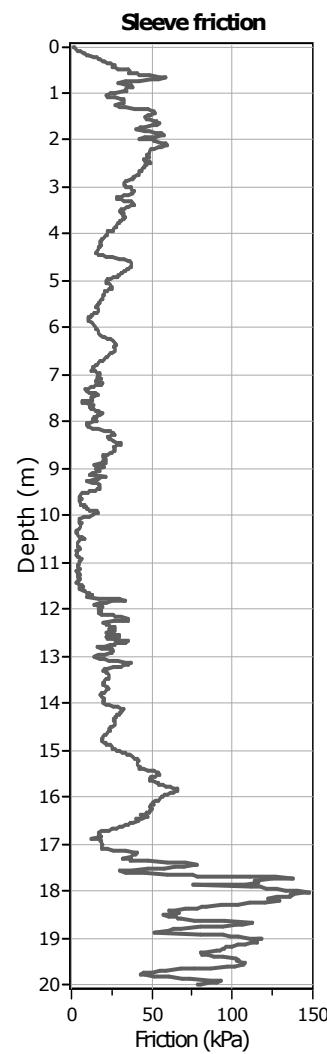
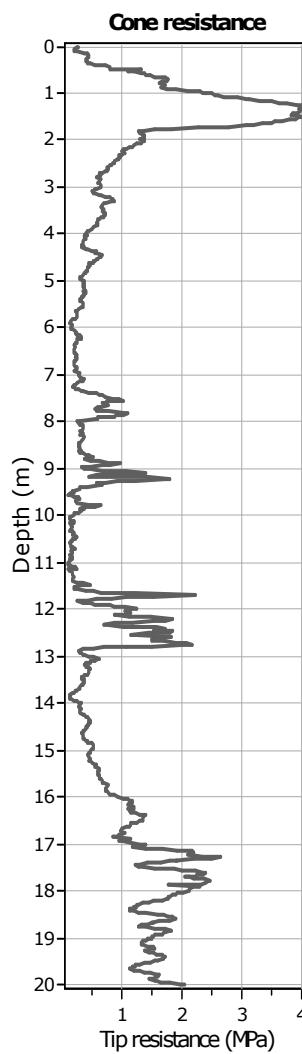
User defined estimation data

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile

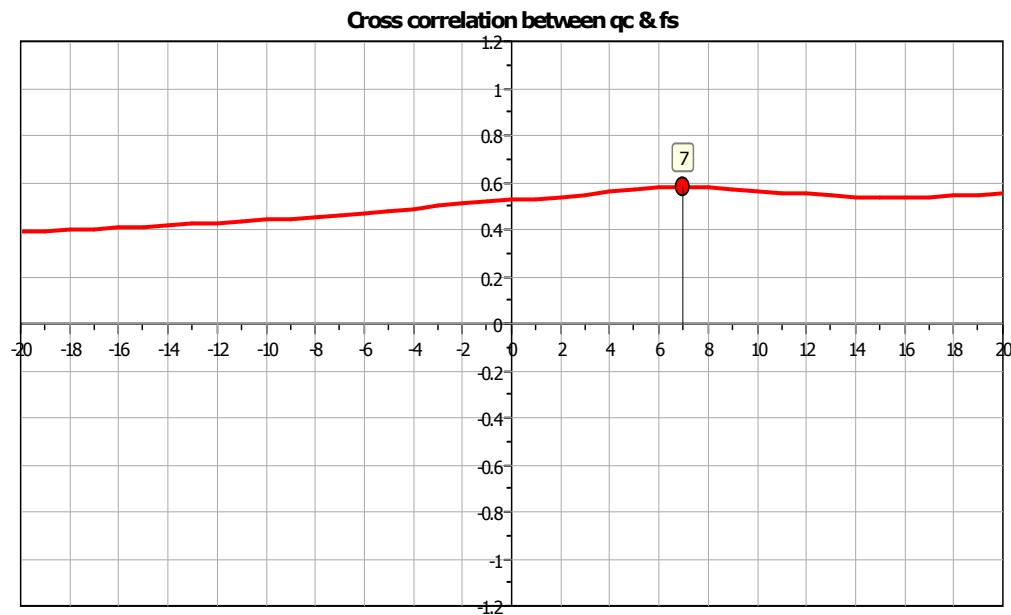
Location: Ferrara

CPT: CPTU 2

Total depth: 20.00 m, Date: 31/10/2017



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



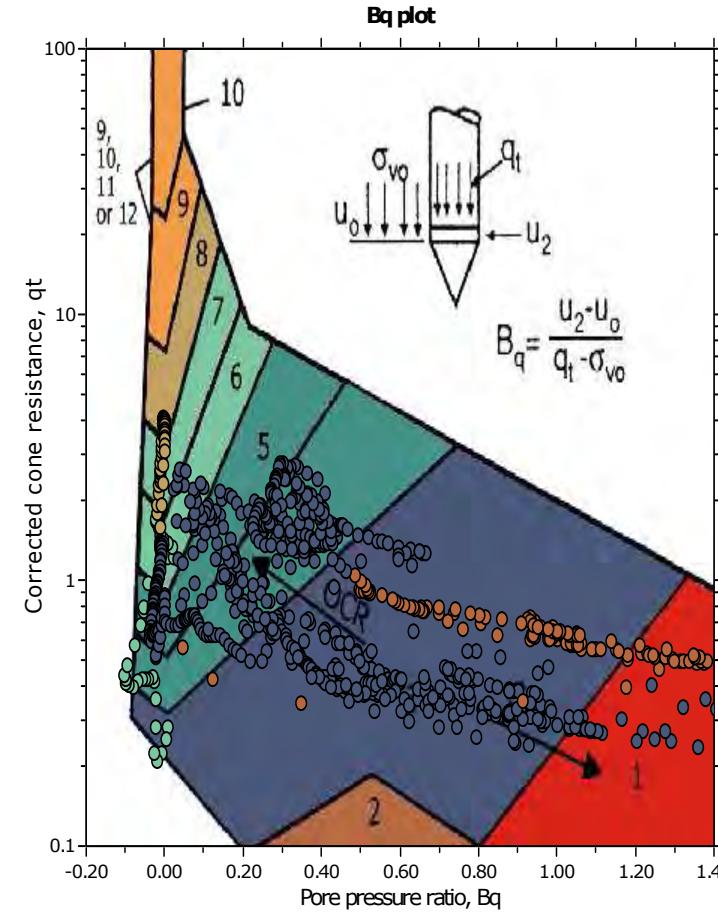
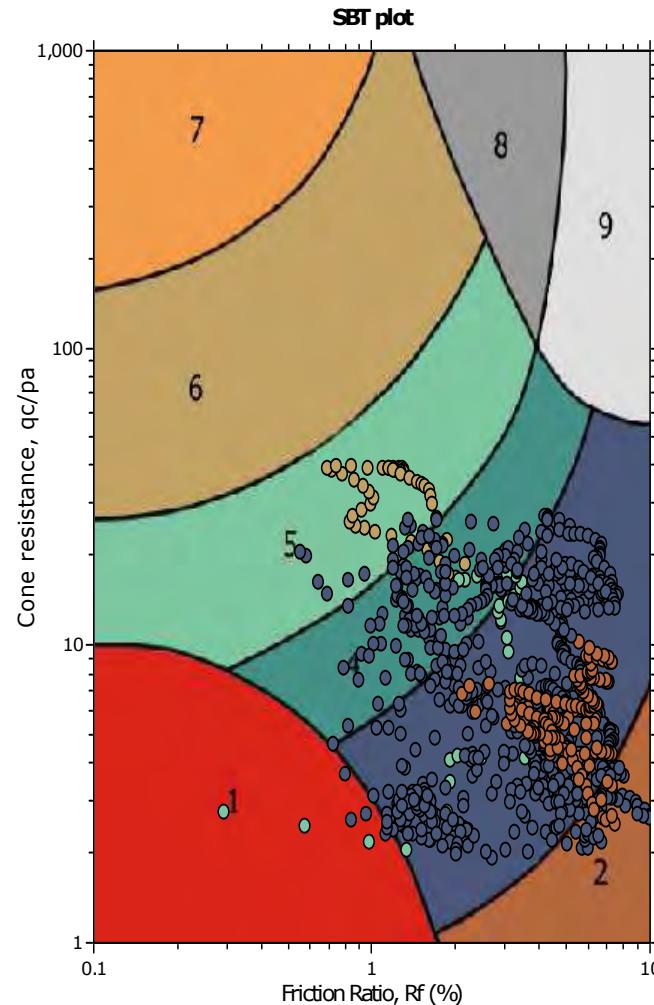
Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile

Location: Ferrara

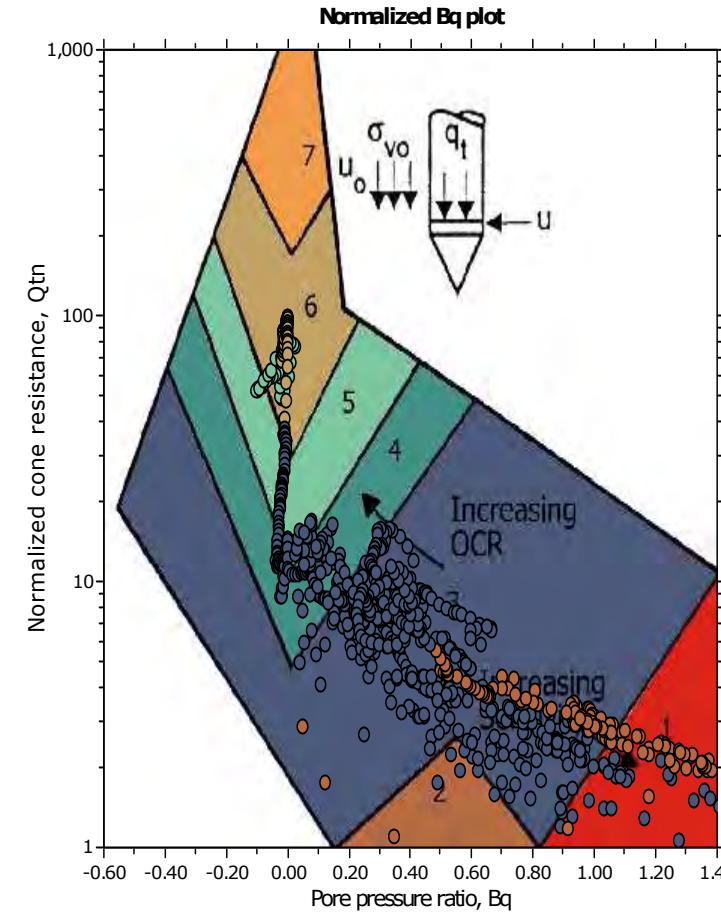
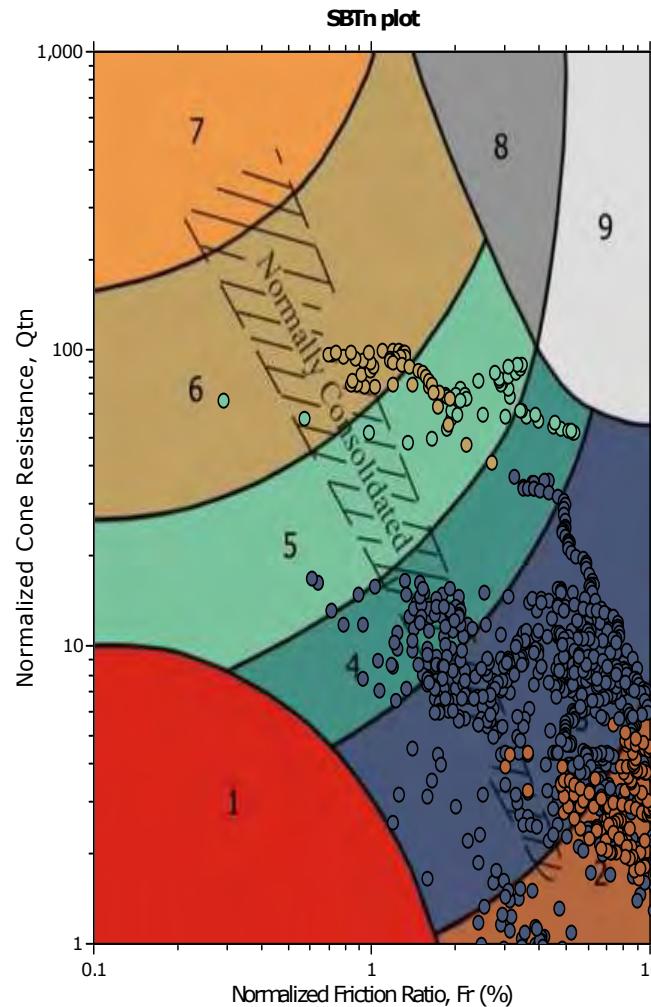
CPT: CPTU 2

Total depth: 20.00 m, Date: 31/10/2017

SBT - Bq plots



SBT - Bq plots (normalized)



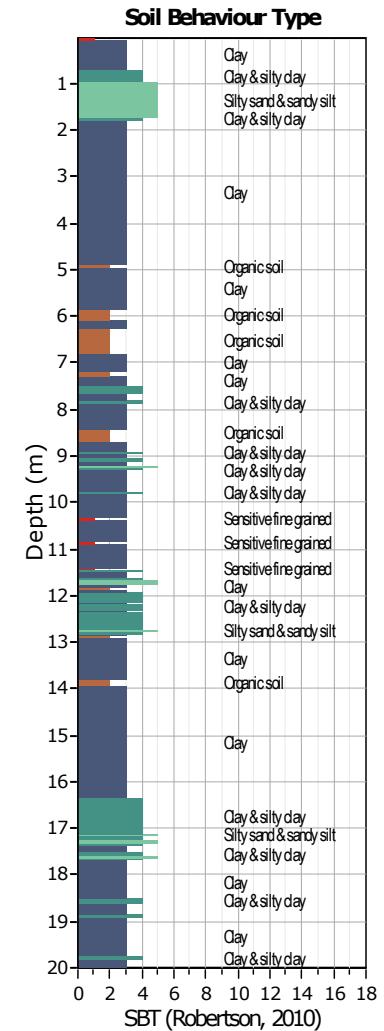
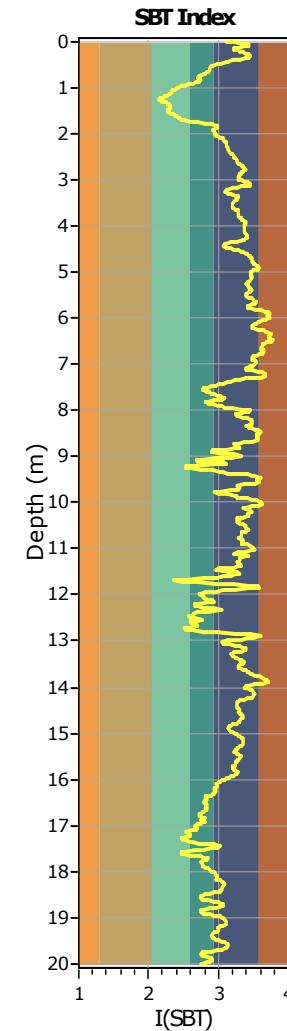
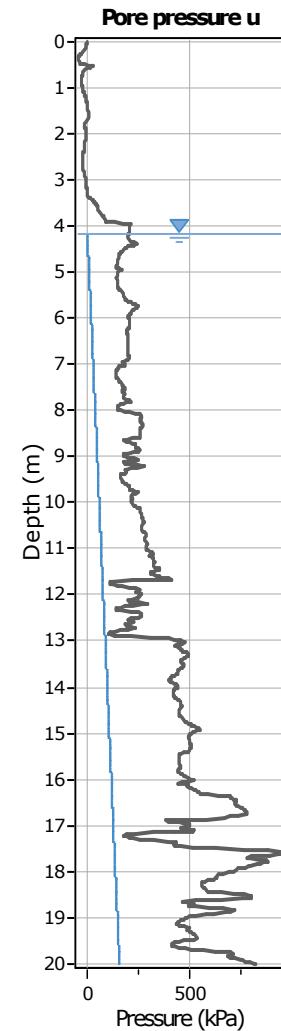
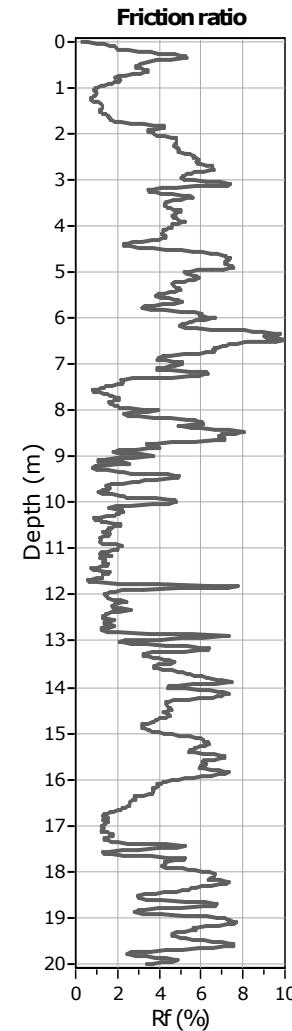
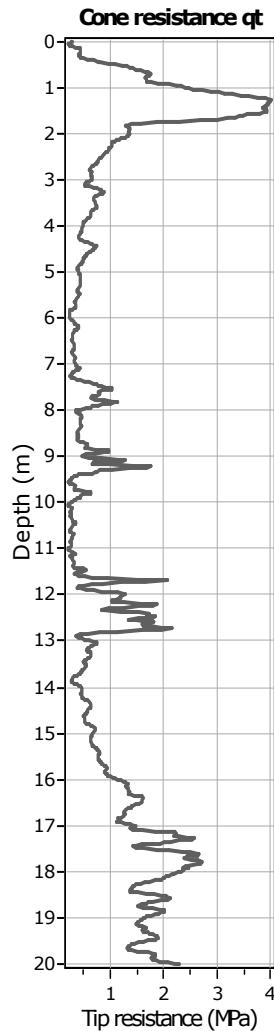
SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile
 Location: Ferrara

CPT: CPTU 2

Total depth: 20.00 m, Date: 31/10/2017



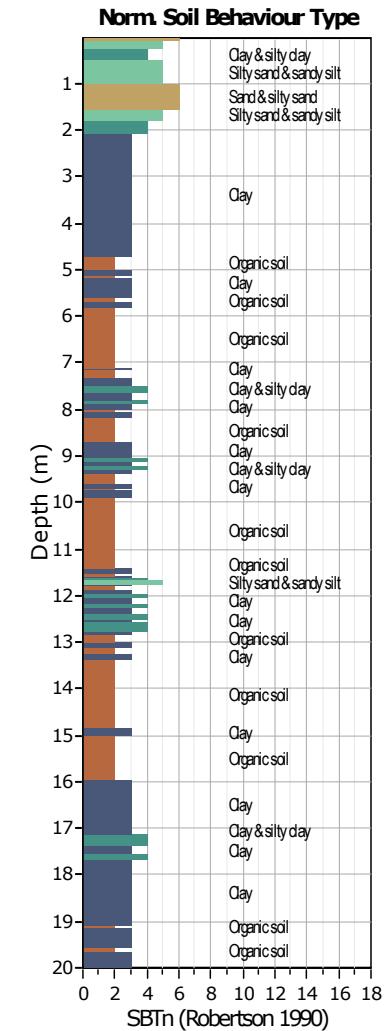
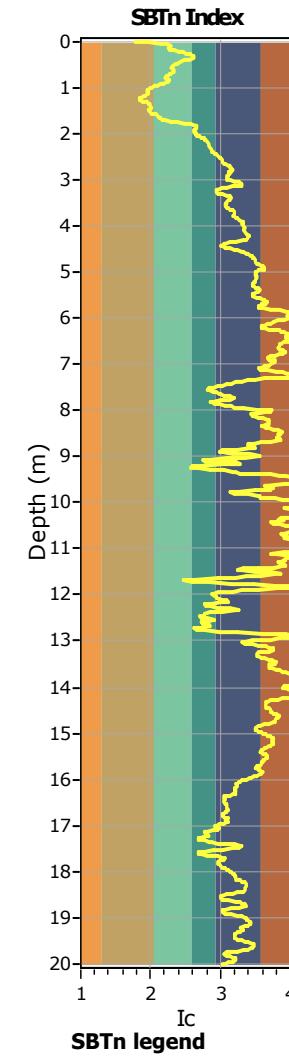
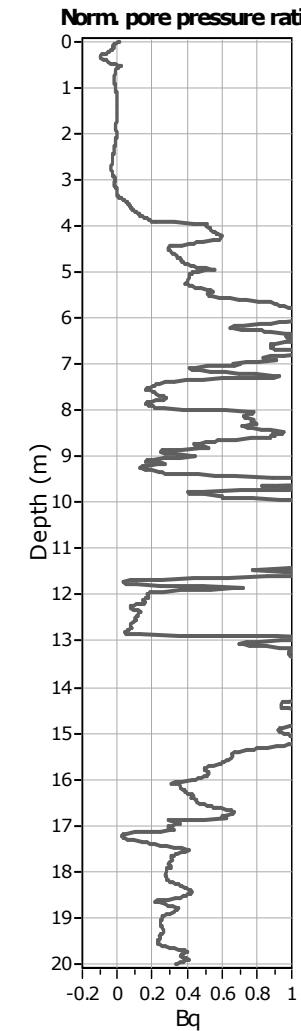
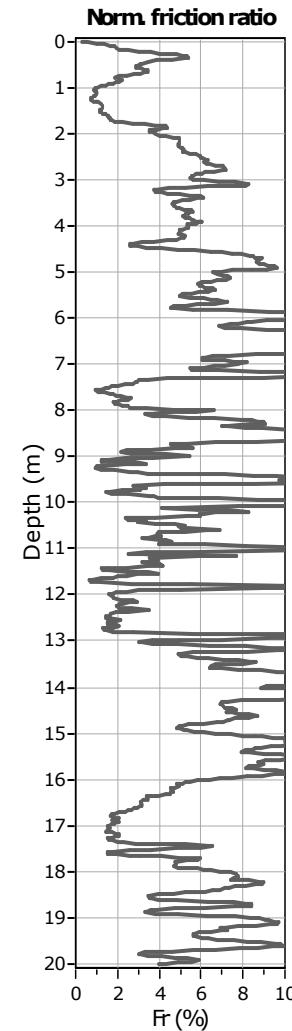
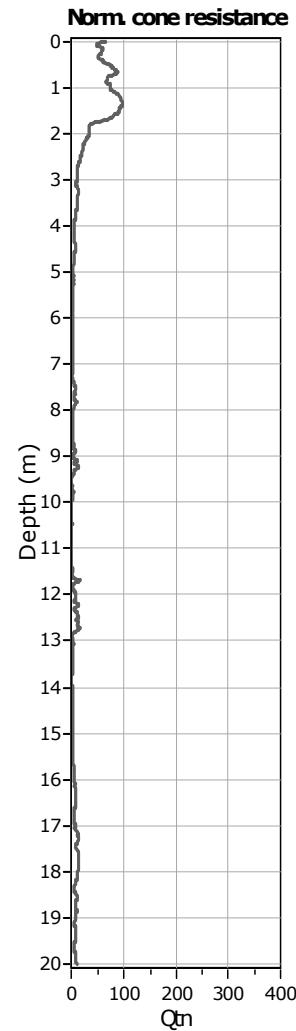
1. Sensitive fine grained	4. Clayey silt to silty clay
2. Organic material	7. Gravely sand to sand
3. Clay to silty clay	8. Very stiff sand to clayey sand
	9. Very stiff fine grained

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile

Location: Ferrara

CPT: CPTU 2

Total depth: 20.00 m, Date: 31/10/2017

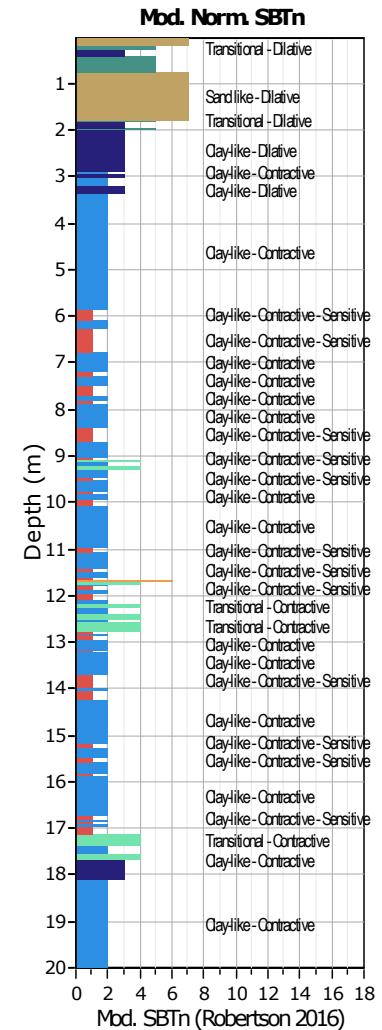
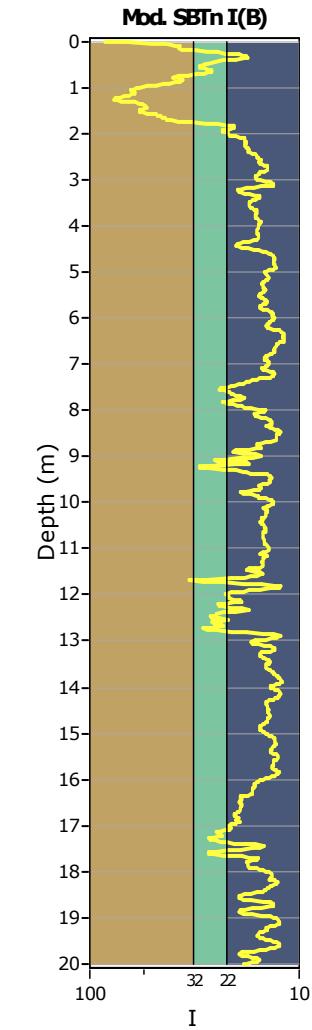
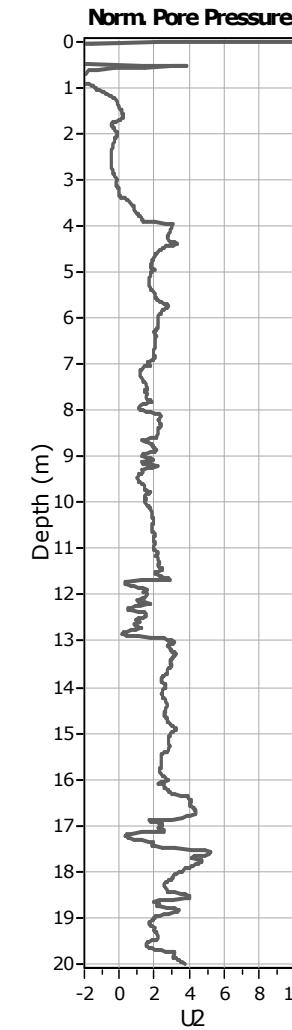
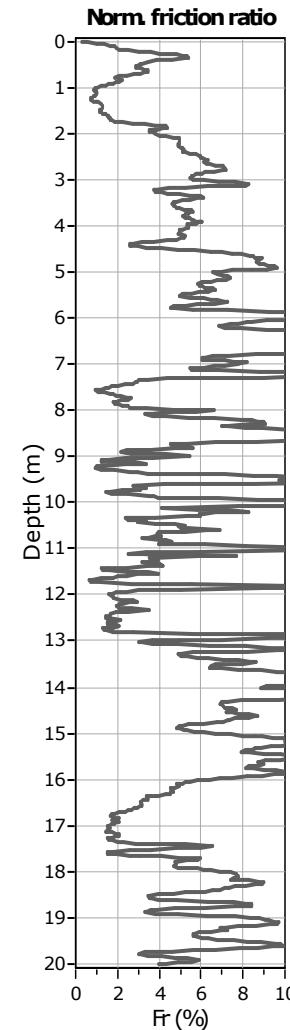
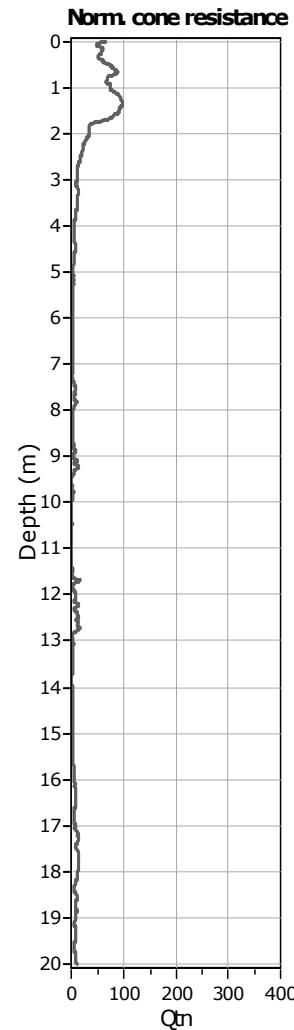


Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile

Location: Ferrara

CPT: CPTU 2

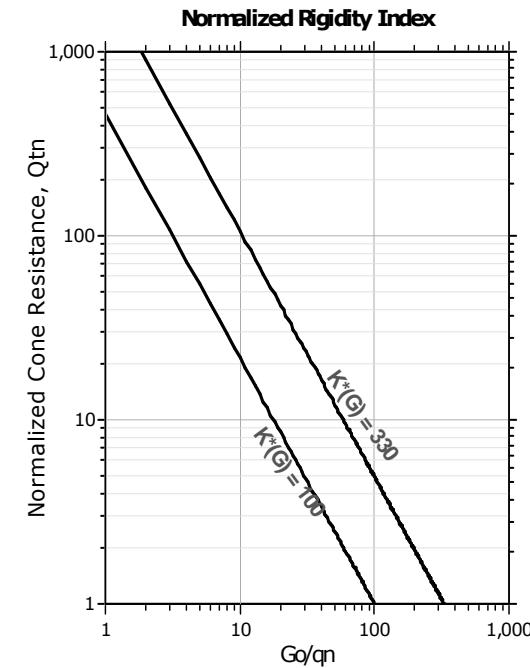
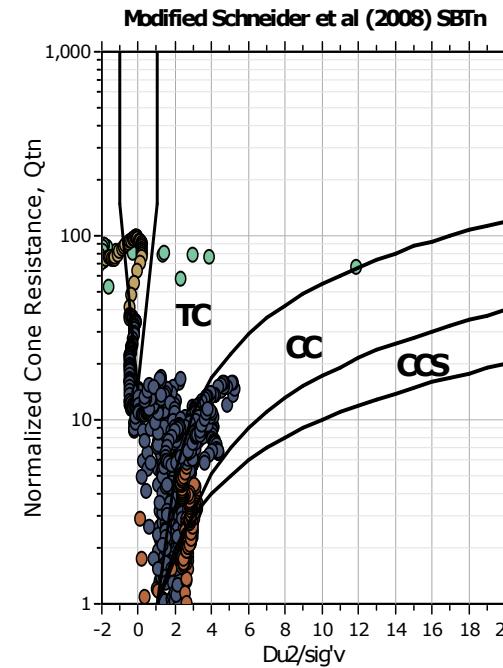
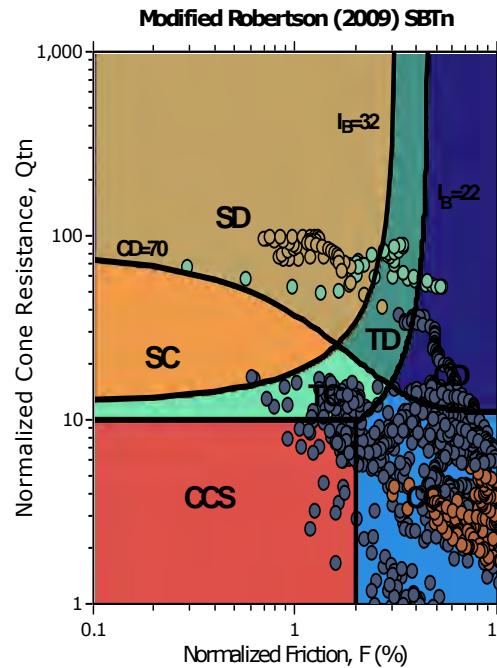
Total depth: 20.00 m, Date: 31/10/2017



Mod. SBTn legend

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. CL: Clay-like - Dilative
- 7. SD: Sand-like - Dilative
- 8. SC: Sand-like - Contractive
- 9. CL: Clay-like - Contractive

Updated SBTn plots



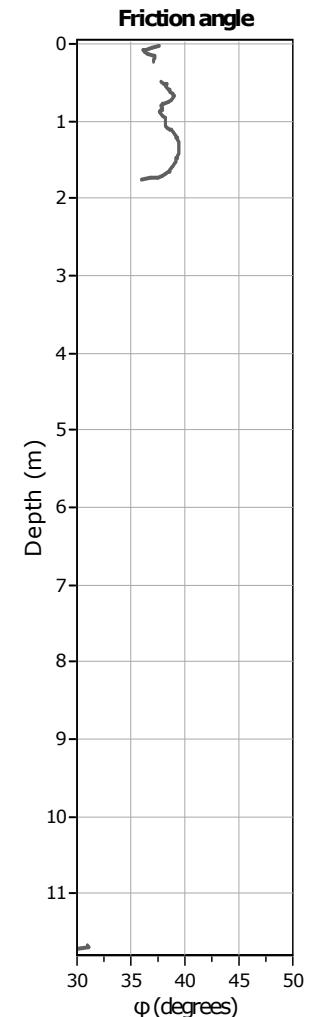
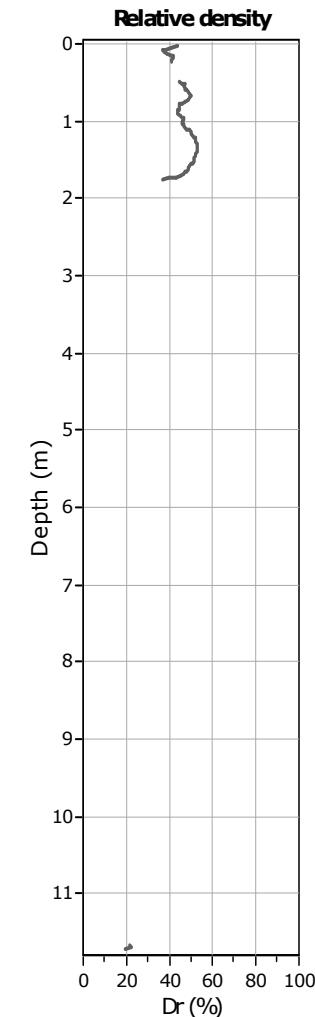
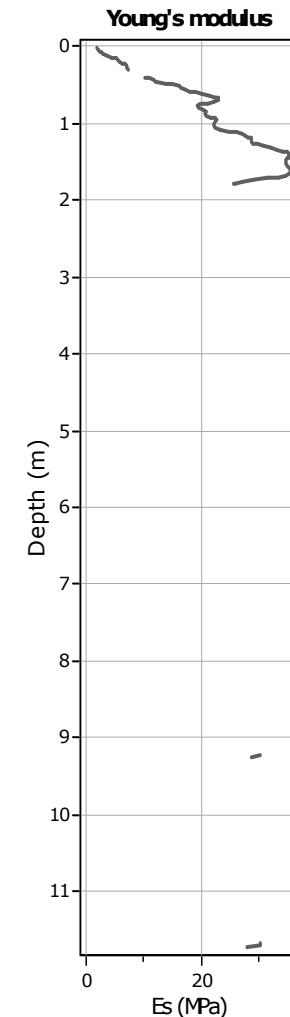
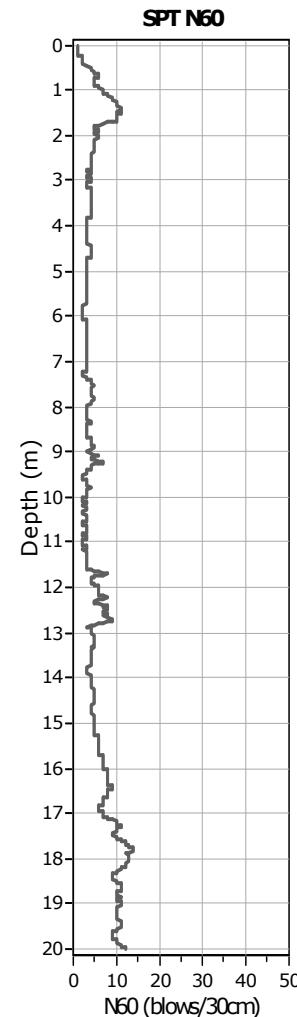
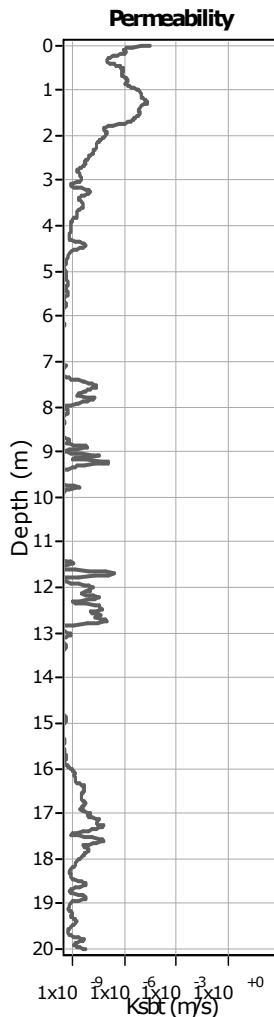
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

K(G) > 330: Soils with significant microstructure
 (e.g. age/cementation)

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile
Location: Ferrara

CPT: CPTU 2

Total depth: 20.00 m, Date: 31/10/2017



Calculation parameters

Permeability: Based on SBT_n

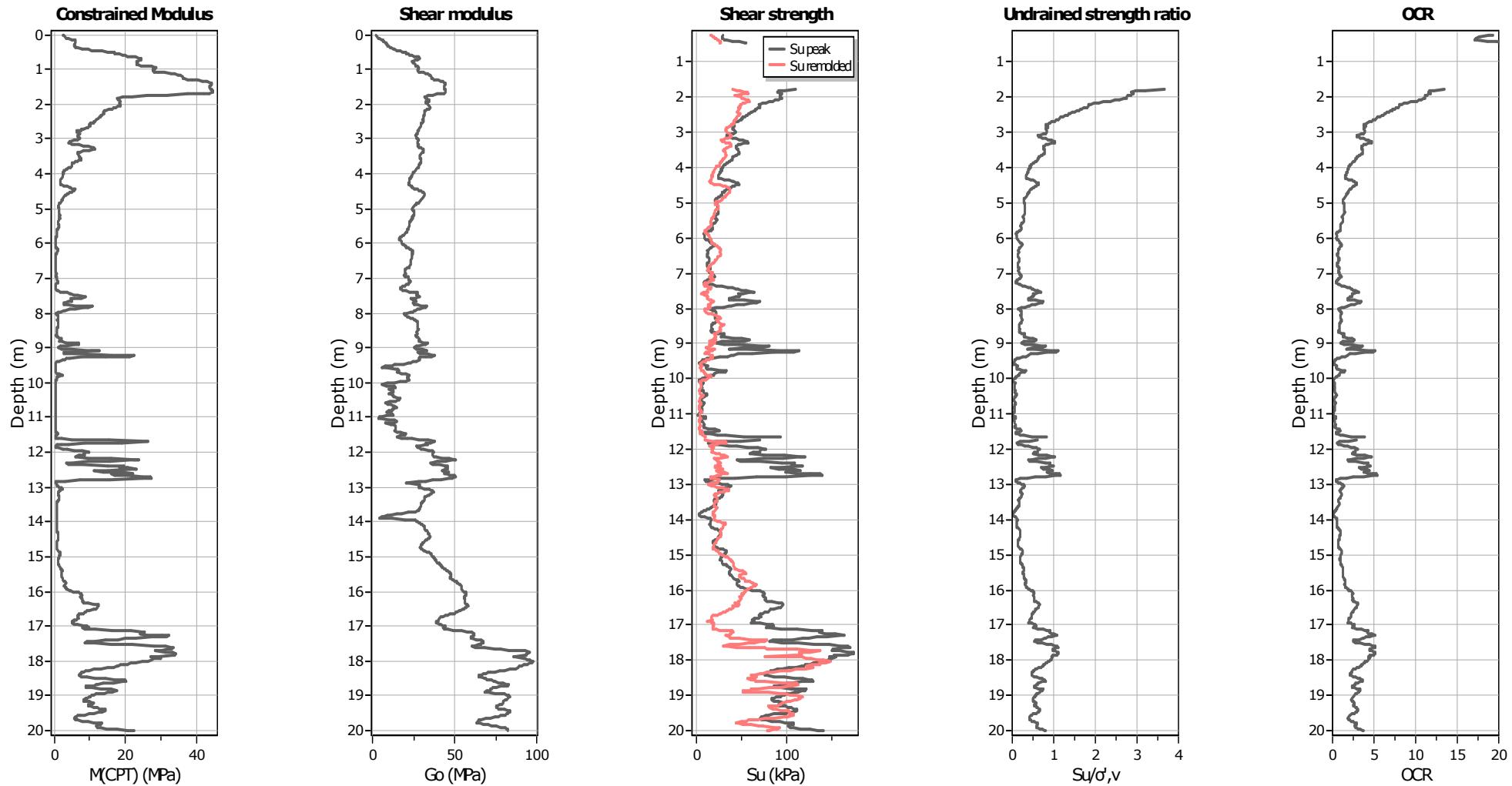
SPT N₆₀: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data



Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)

Go: Based on variable *alpha* using I_c (Robertson, 2009)

Undrained shear strength cone factor for clays, N_{kt} : 14

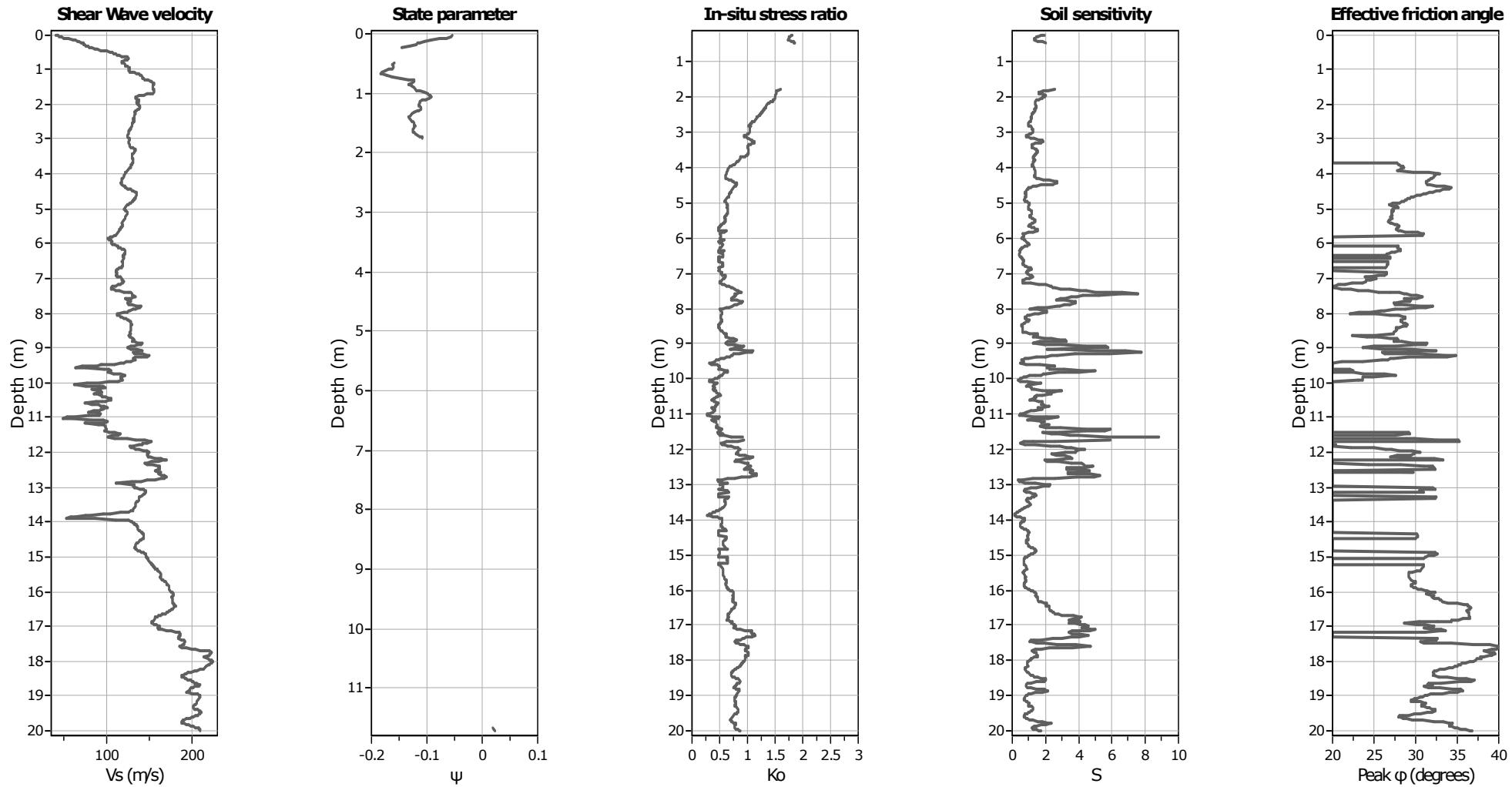
OCR factor for clays, N_{kt} : 0.33

- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato dell'Emergenza sul Territorio della Protezione Civile
Location: Ferrara

CPT: CPTU 2

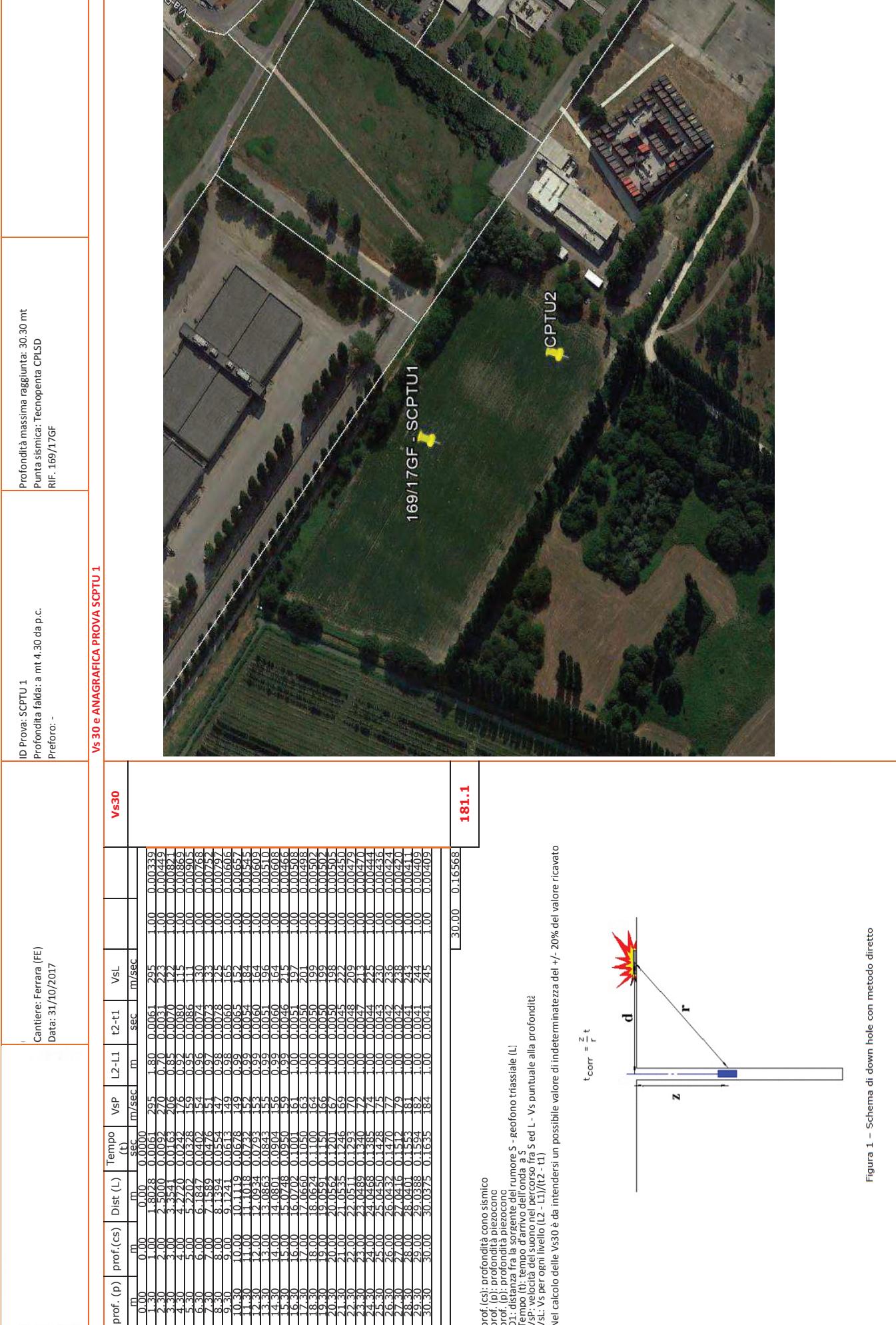
Total depth: 20.00 m, Date: 31/10/2017



Calculation parameters

Soil Sensitivity factor, N_s : 7.00

User defined estimation data



prof (cs): profondità cono sismico
 prof (p): profondità piezocrono
 prof (p): profondità piezocrono
 D: distanza fra la sorgente del rumore S - geofono triassiale [L]
 T: tempo d'arrivo dell'onda [s] Sed L - Vs puntuale alla profondità [L]
 Vs: velocità del suono nel percorso [L2 - L1]/(t2 - t1)
 Nel calcolo delle Vs30 è da intendersi un possibile valore di indeterminatezza del +/- 20% del valore ricavato

$$t_{corr} = \frac{z}{r} t$$

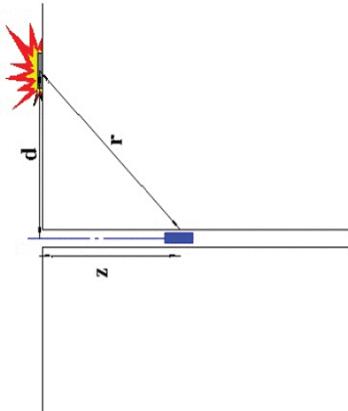
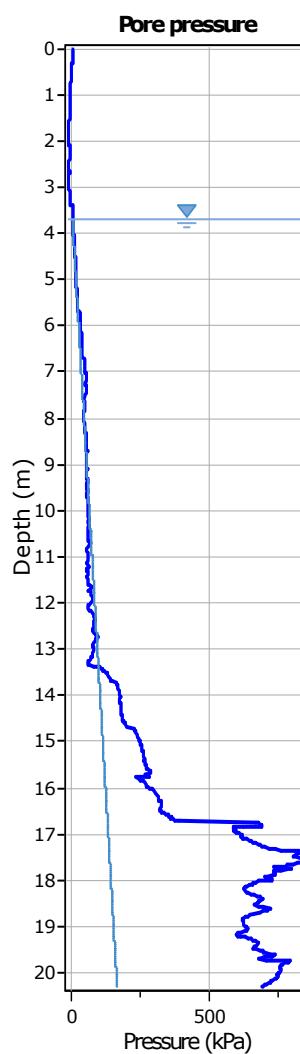
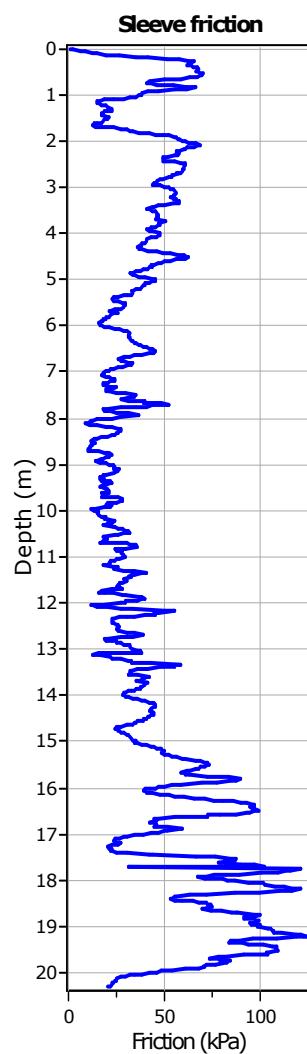
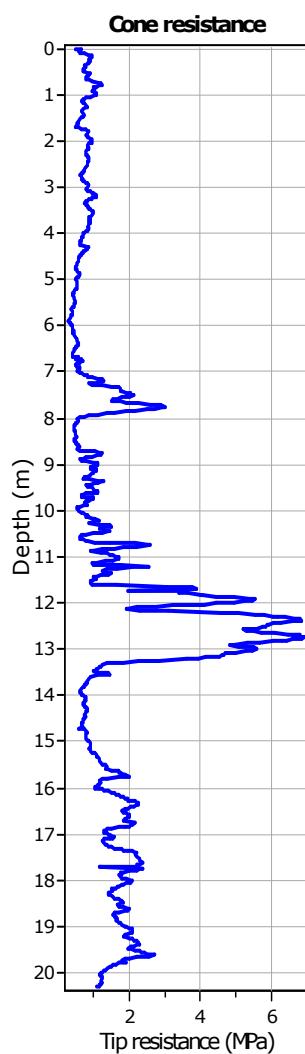
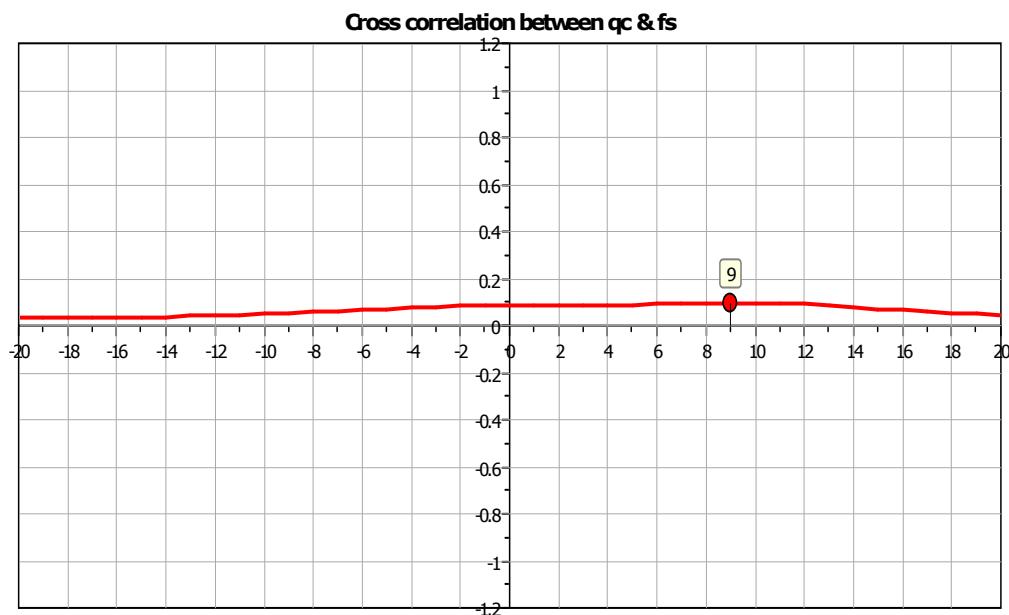


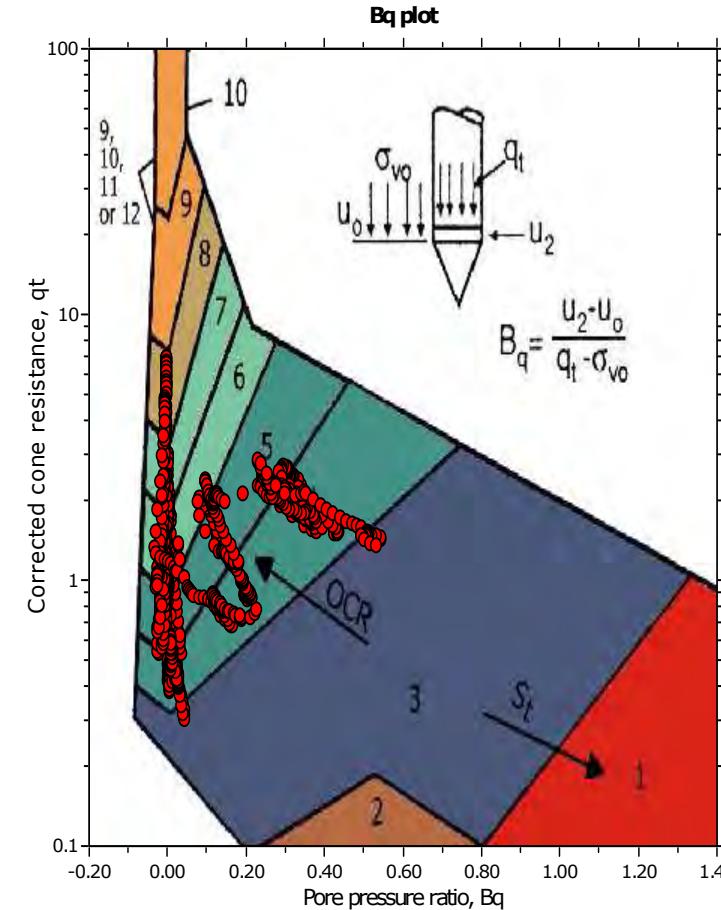
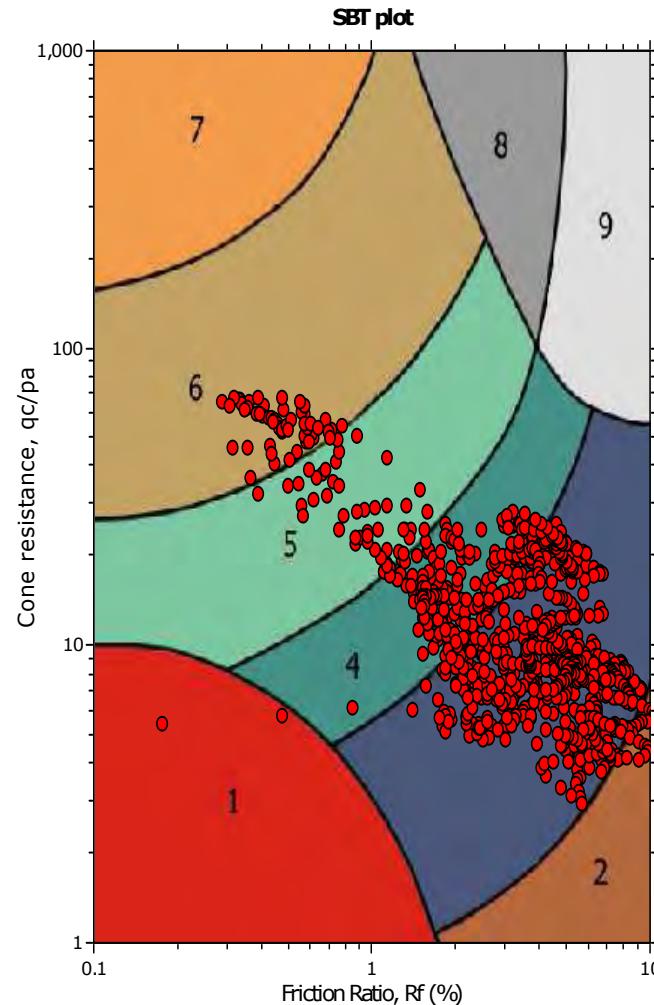
Figura 1 – Schema di down hole con metodo diretto



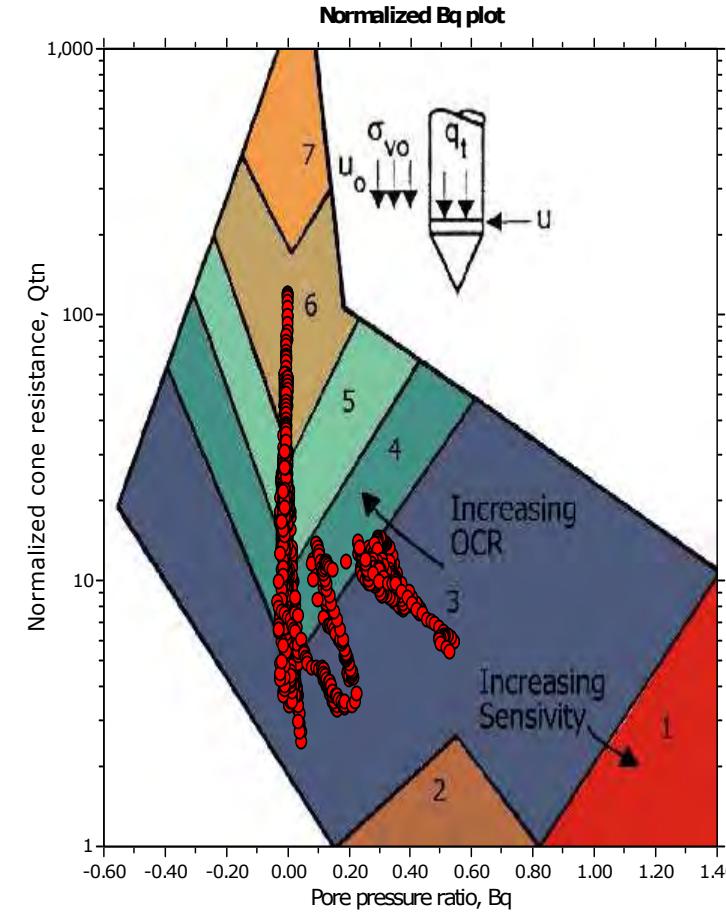
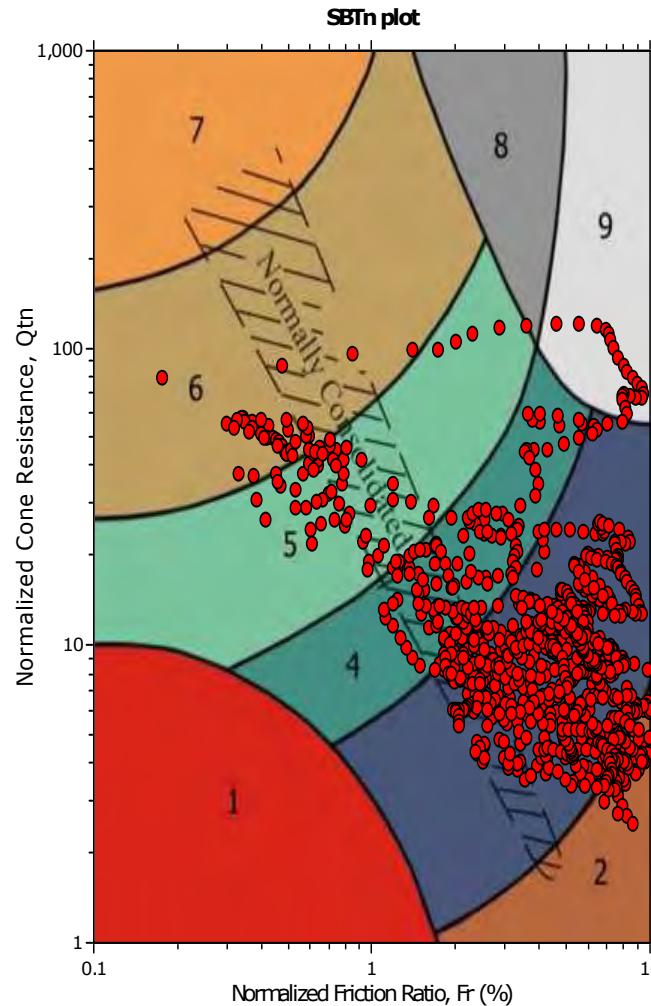
The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).

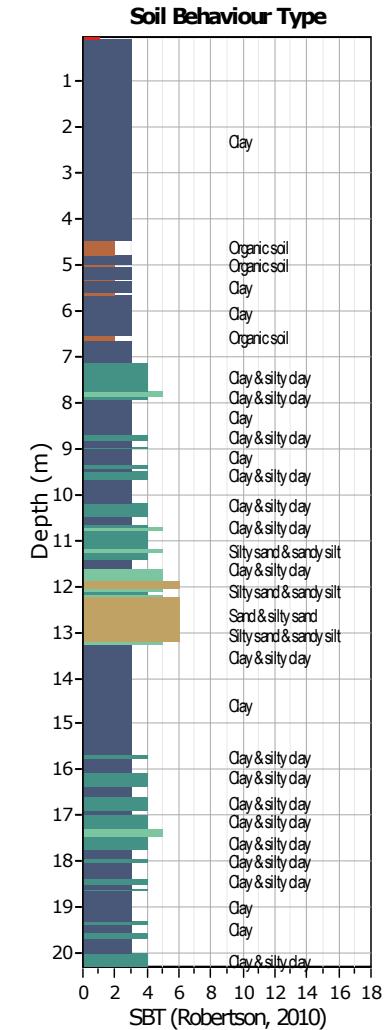
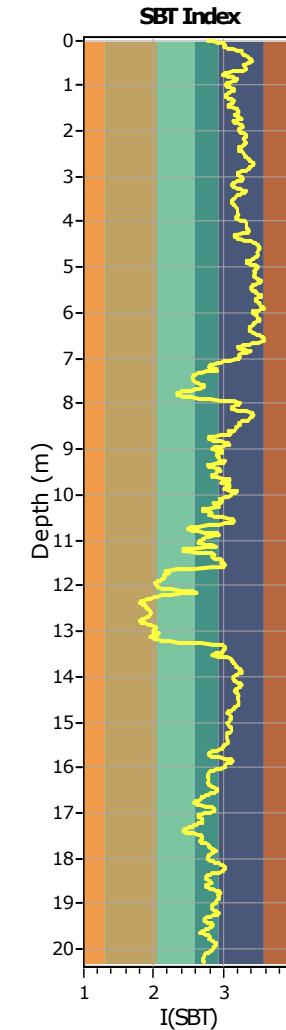
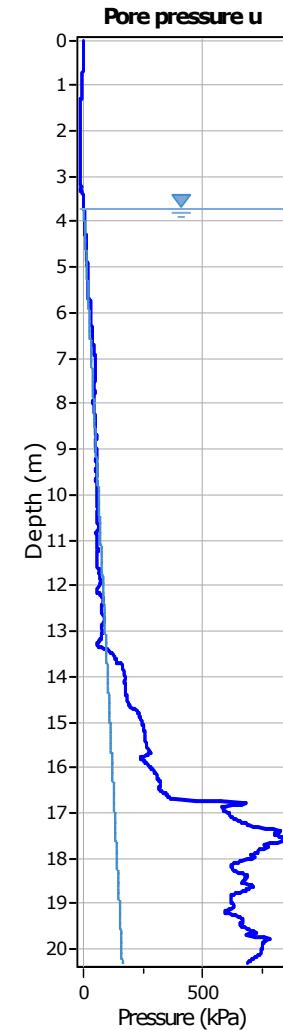
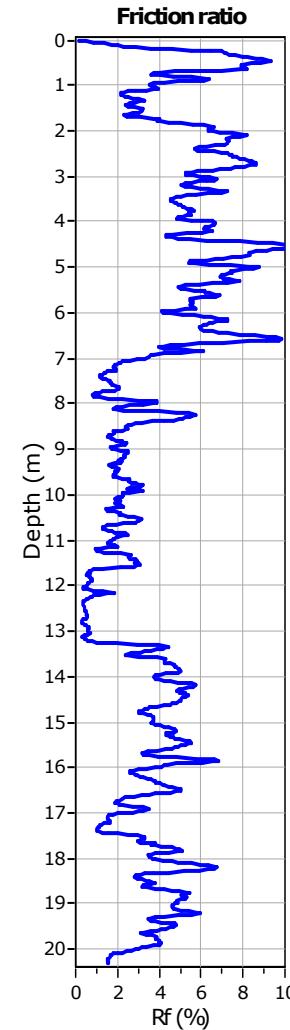
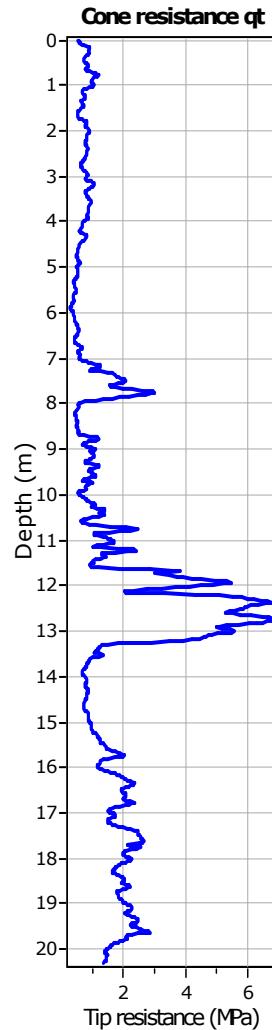


SBT - Bq plots



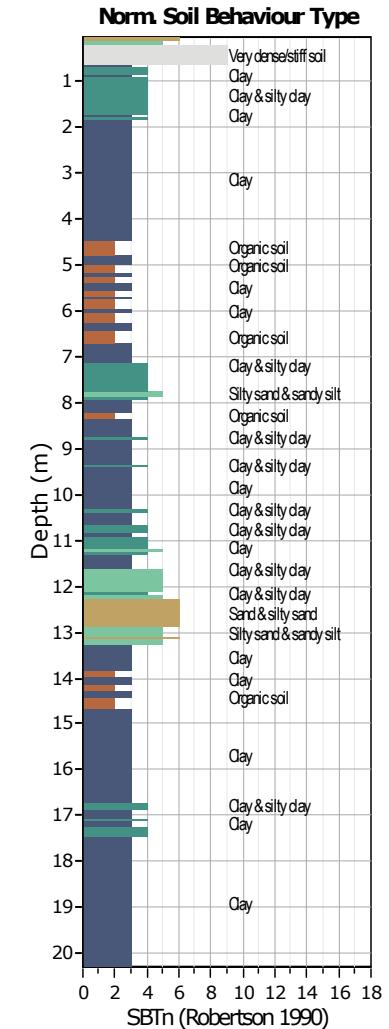
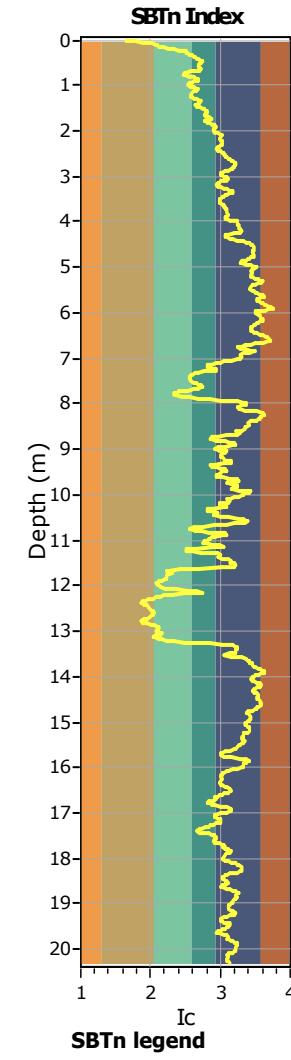
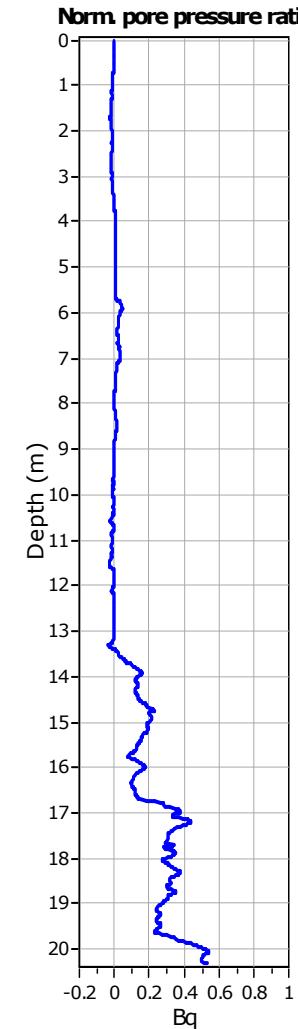
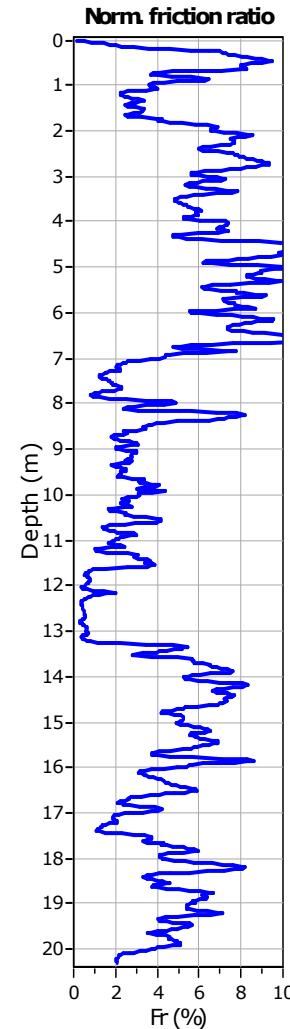
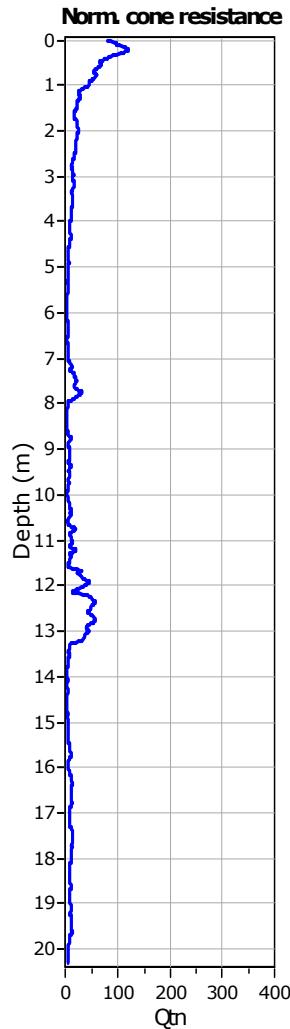
SBT - Bq plots (normalized)

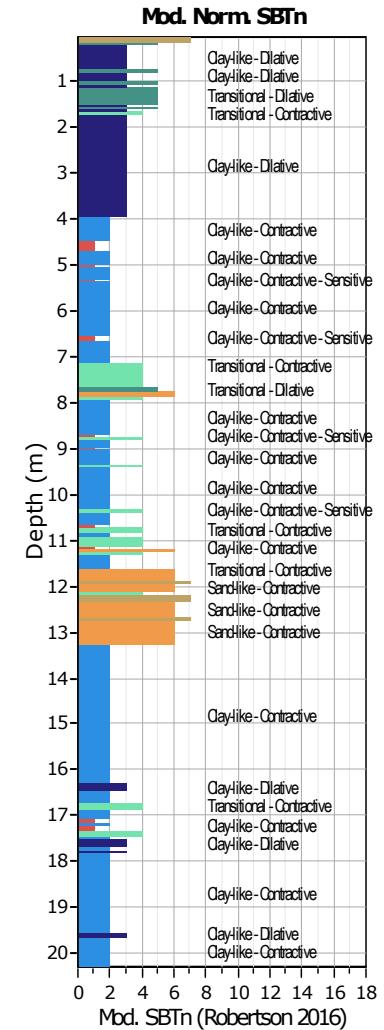
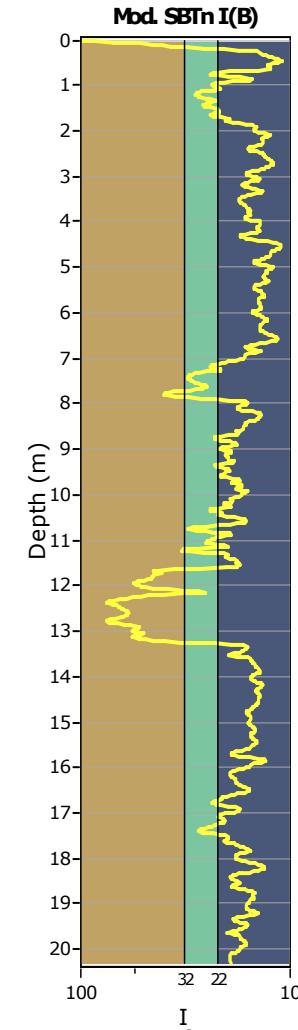
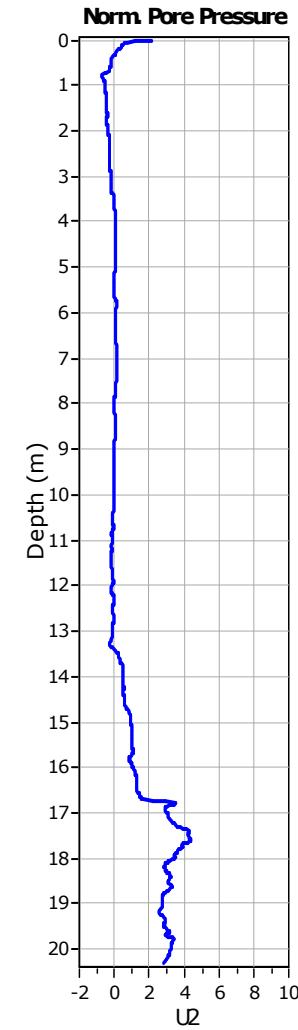
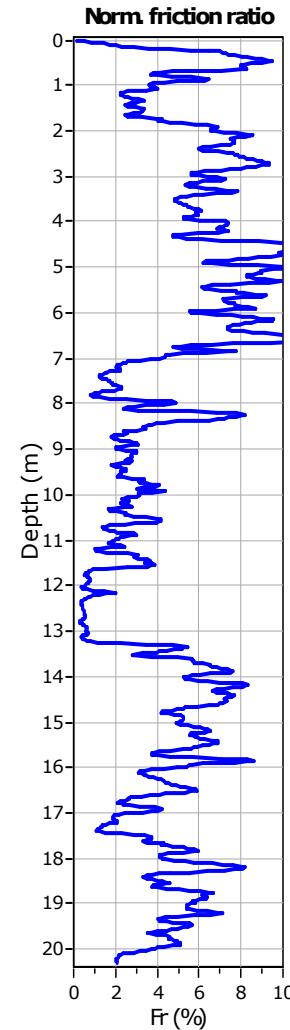
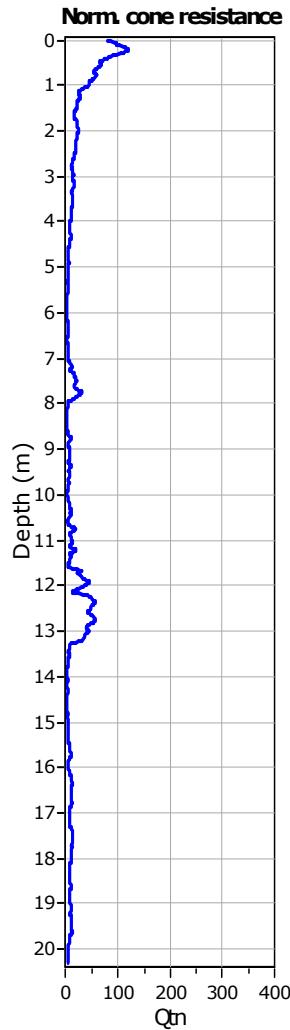




SBT legend

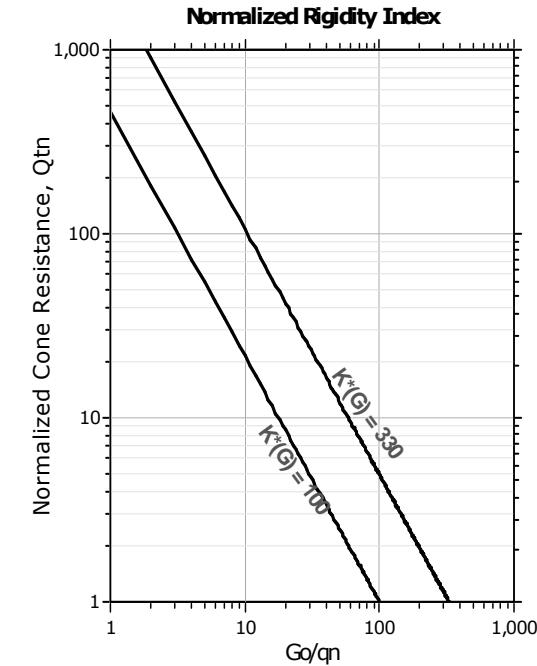
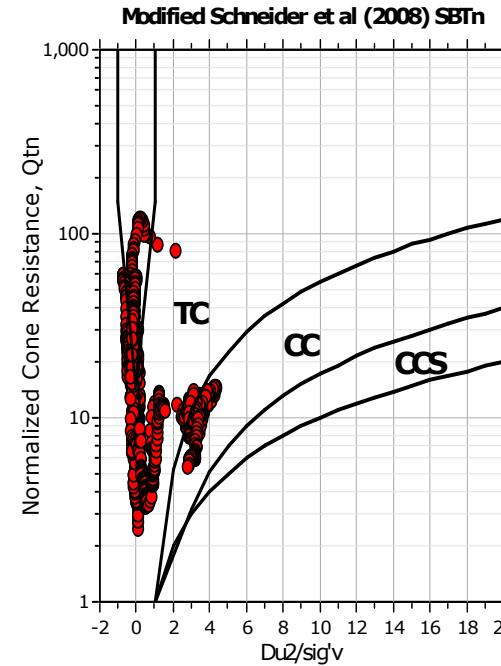
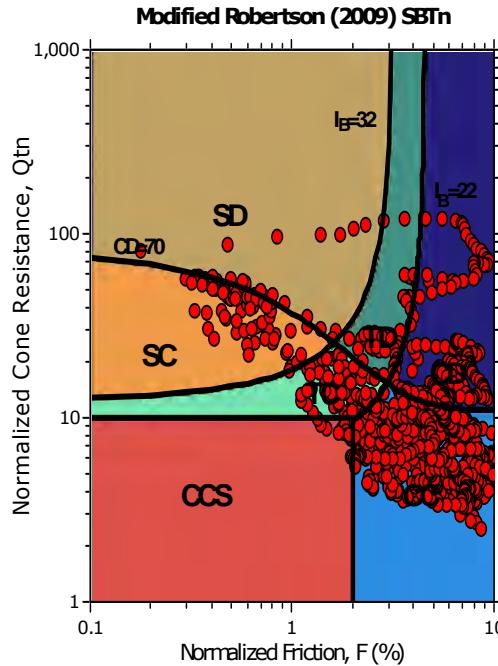
- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained



**Mod. SBTn legend**

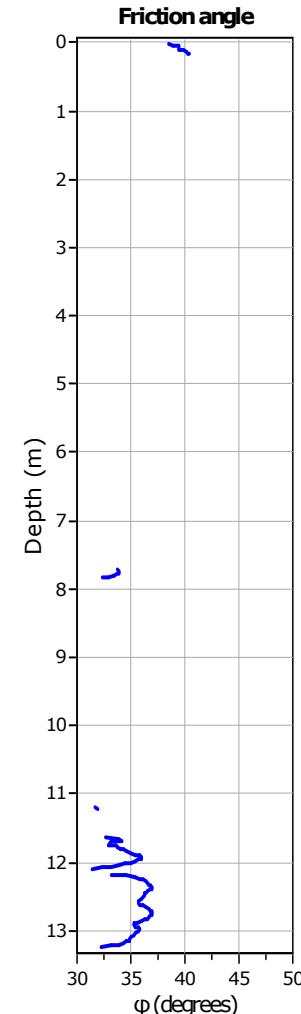
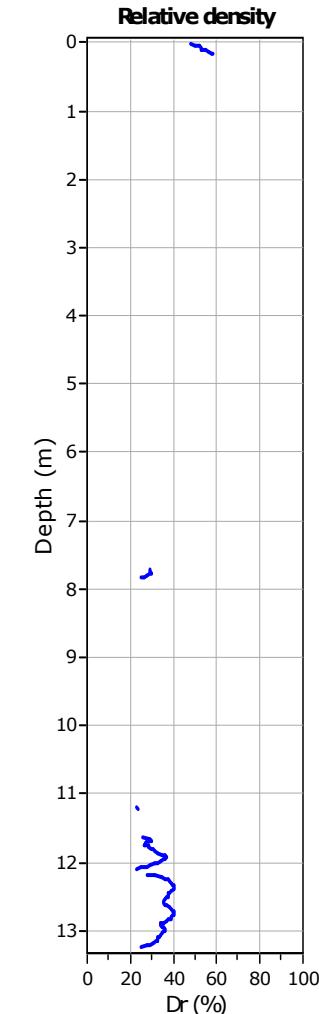
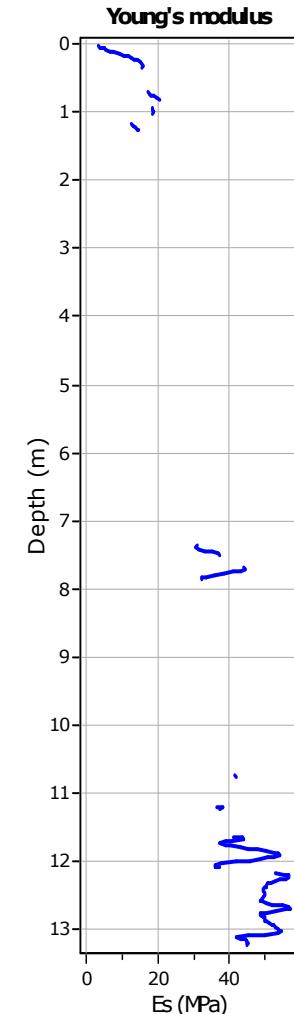
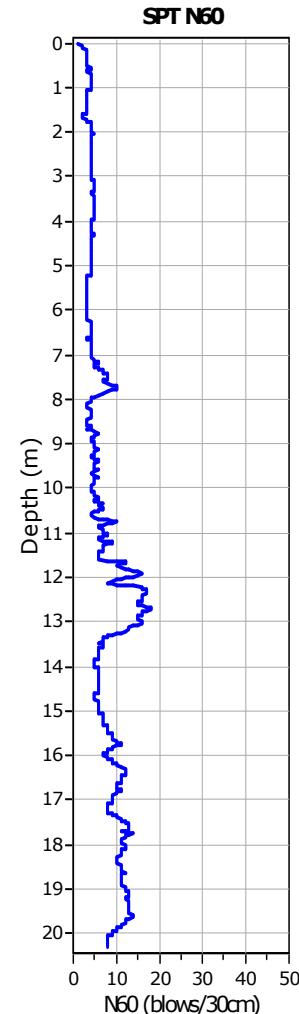
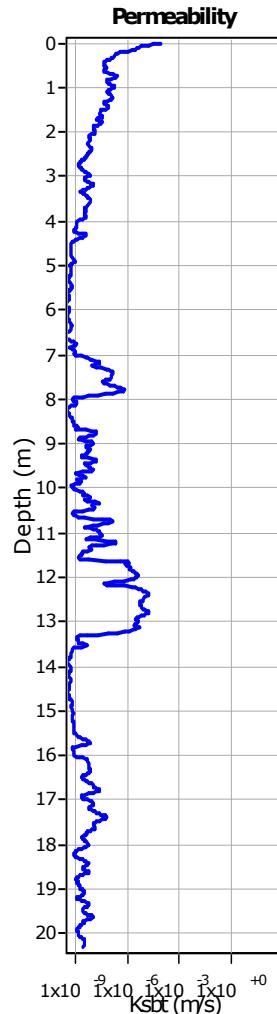
- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

Updated SBTn plots



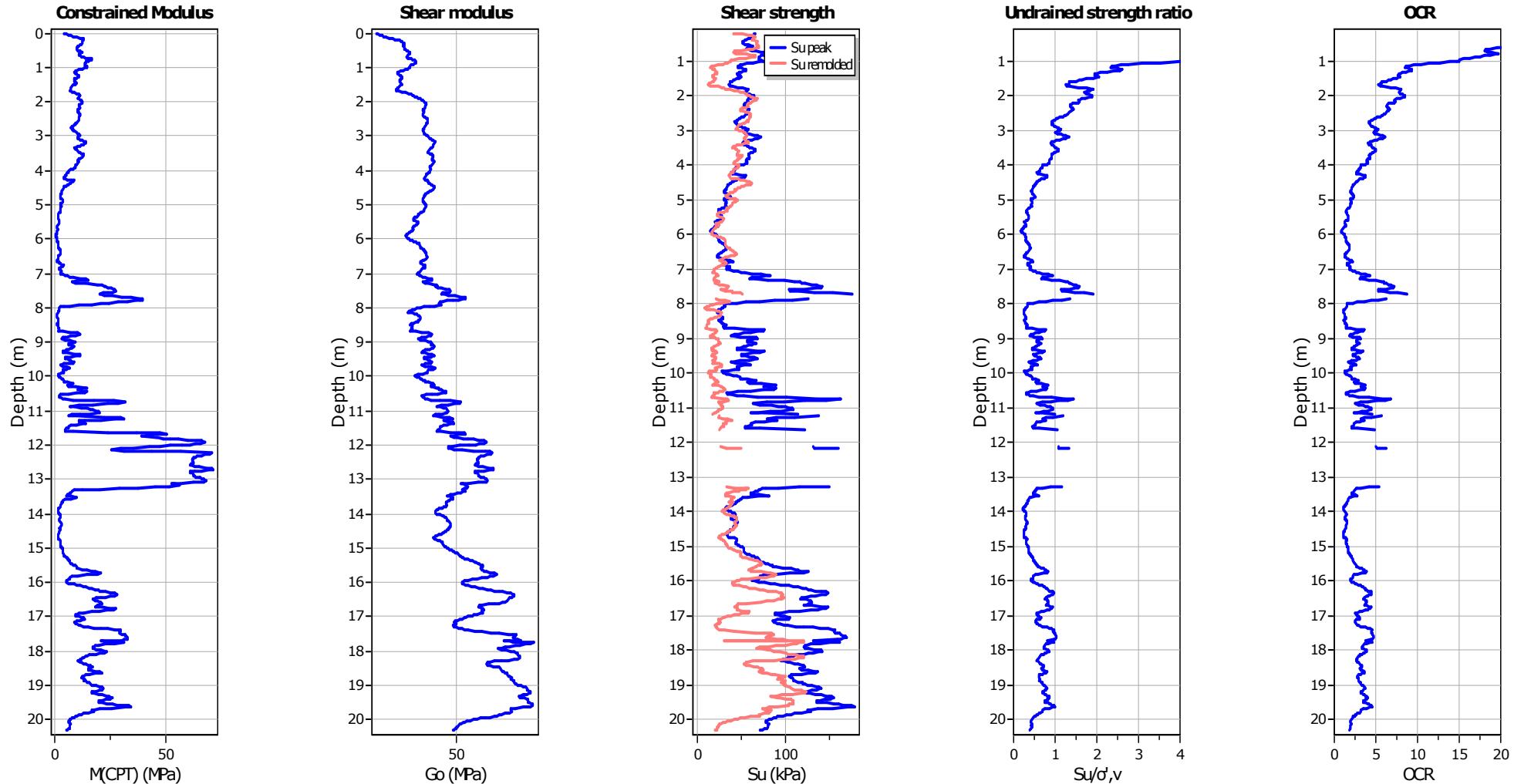
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

**Calculation parameters**

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)

G_0 : Based on variable *alpha* using I_c (Robertson, 2009)

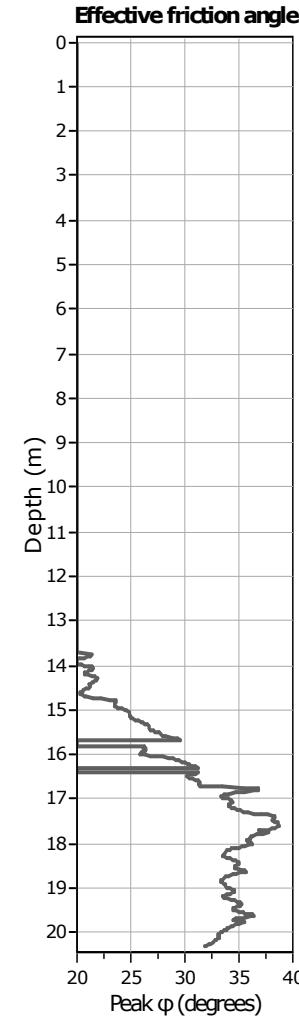
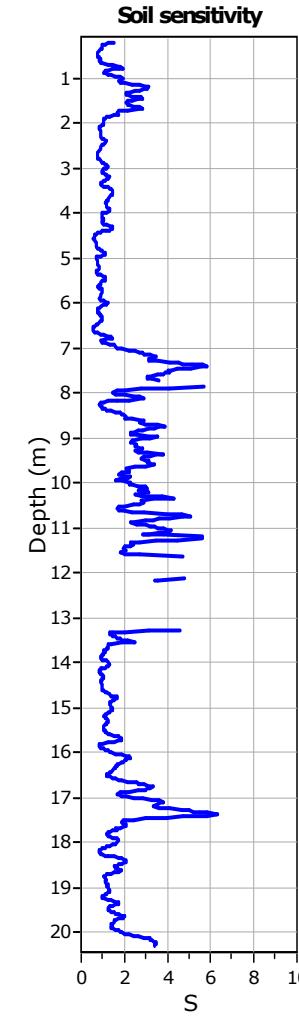
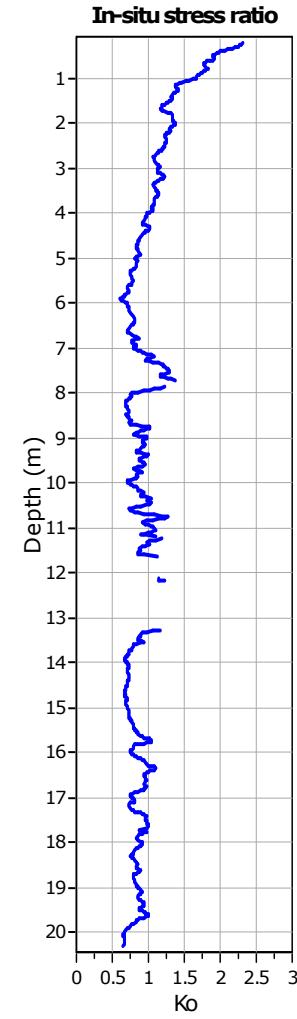
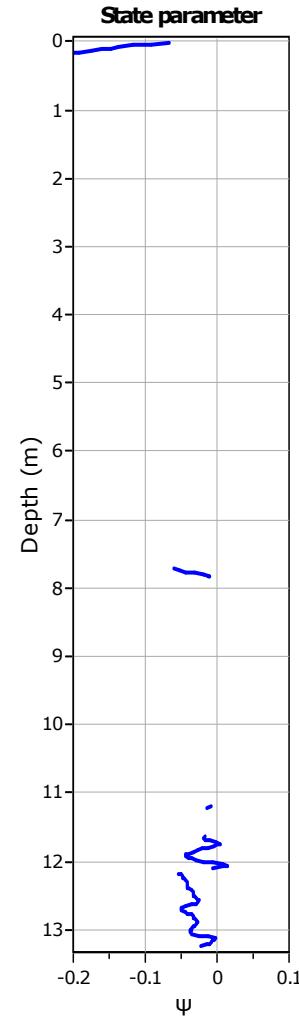
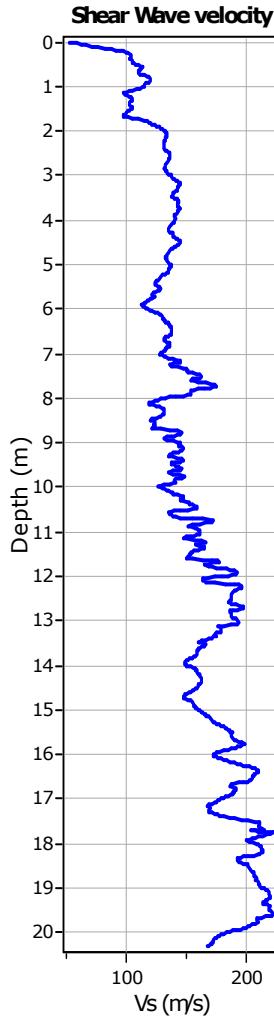
Undrained shear strength cone factor for clays, N_{kt} : 14

OCR factor for clays, N_{kt} : 0.33

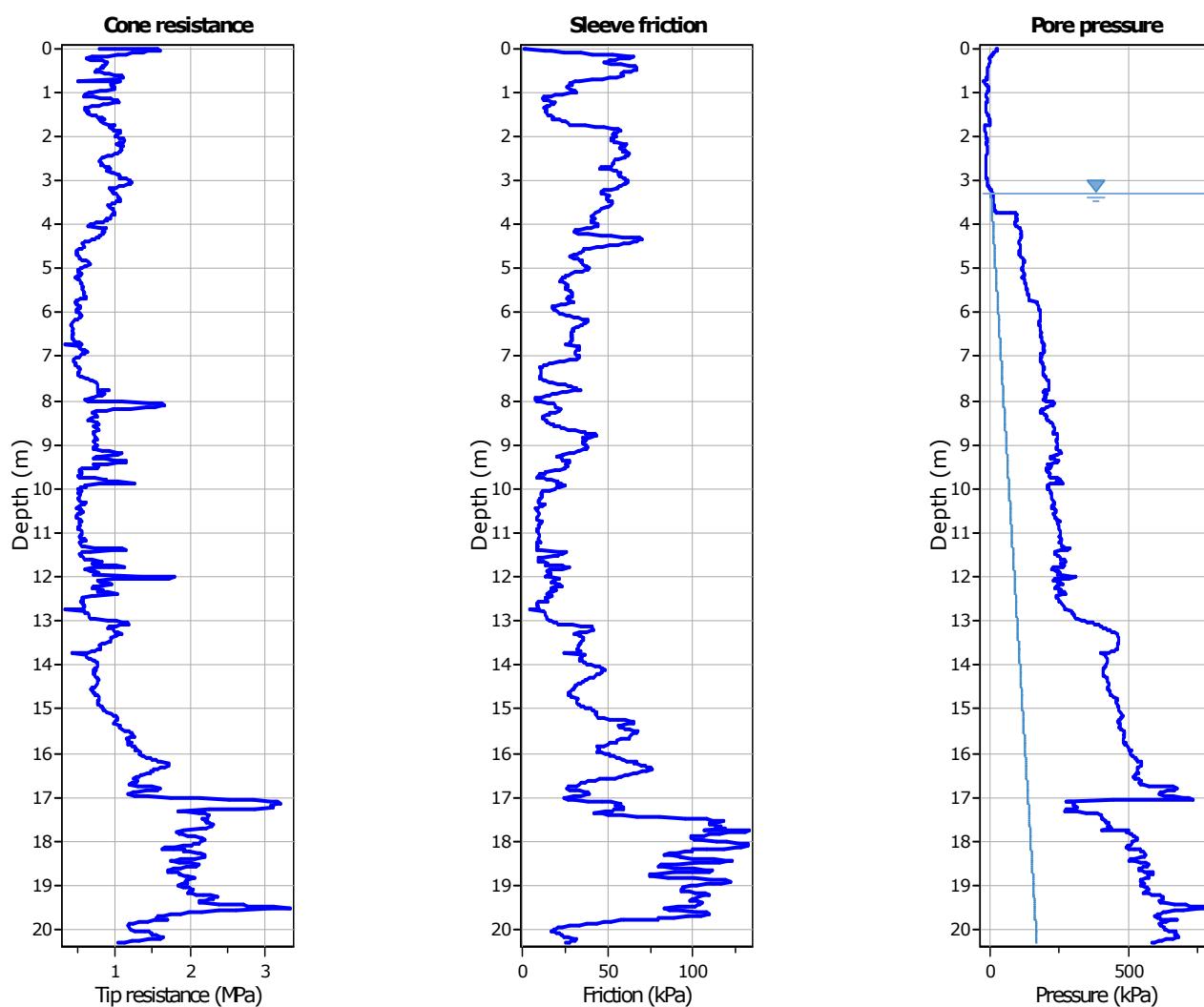
- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato Regionale dell'Emergenza sul Territorio della P.C.**Location:** via Bologna, Ferrara**CPT: CPTU3**

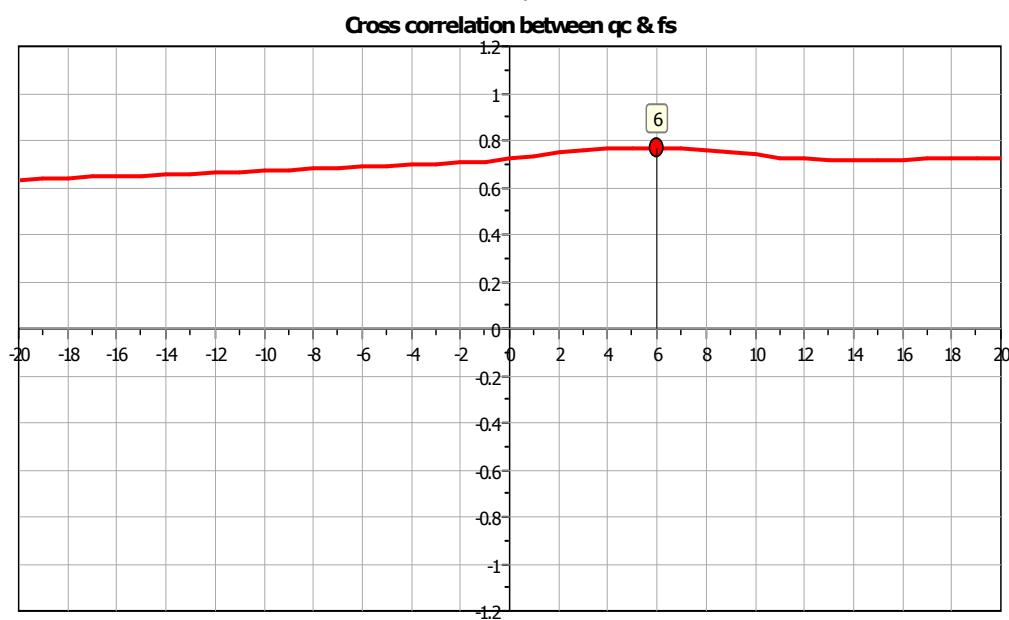
Total depth: 20.30 m, Date: 23/04/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

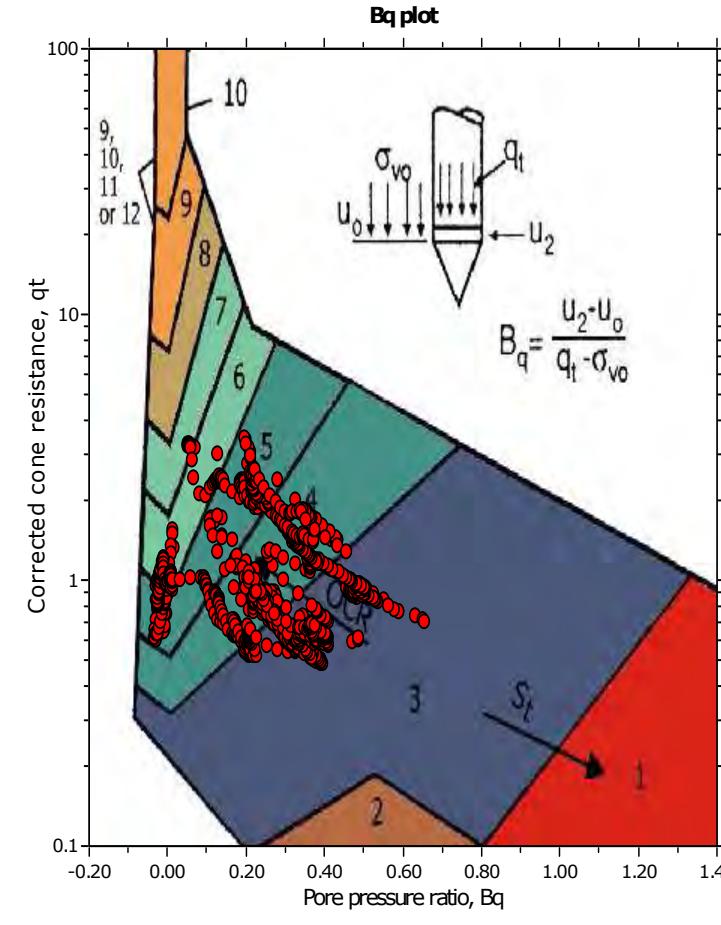
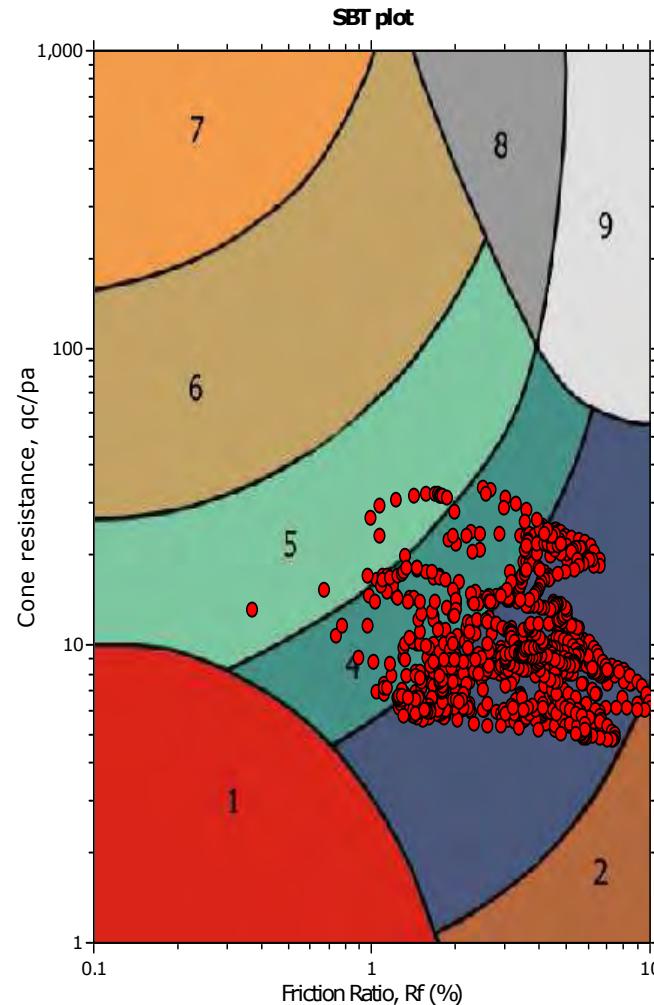
User defined estimation data



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



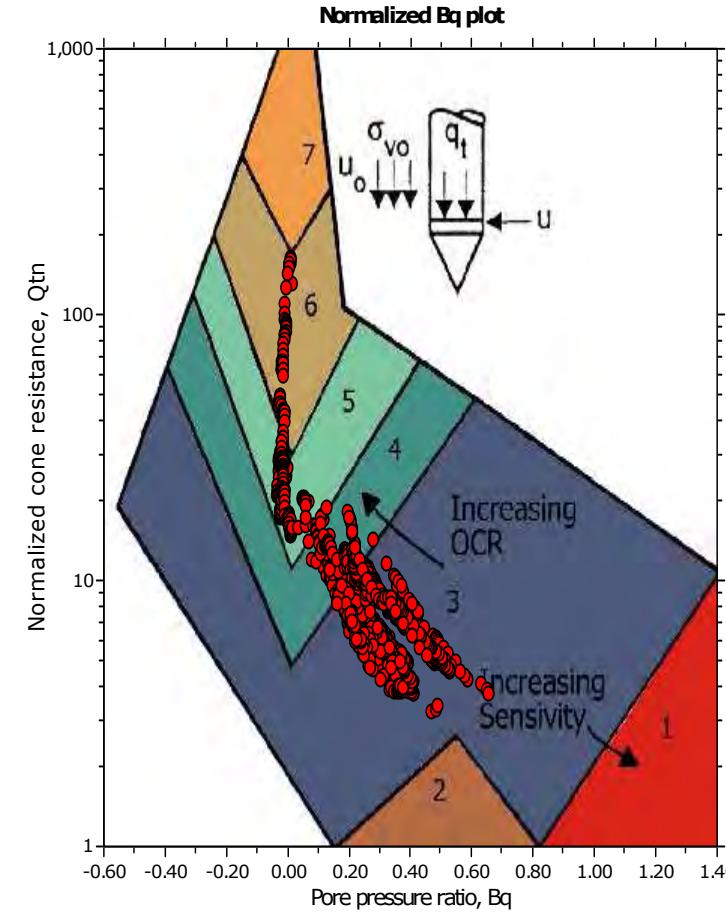
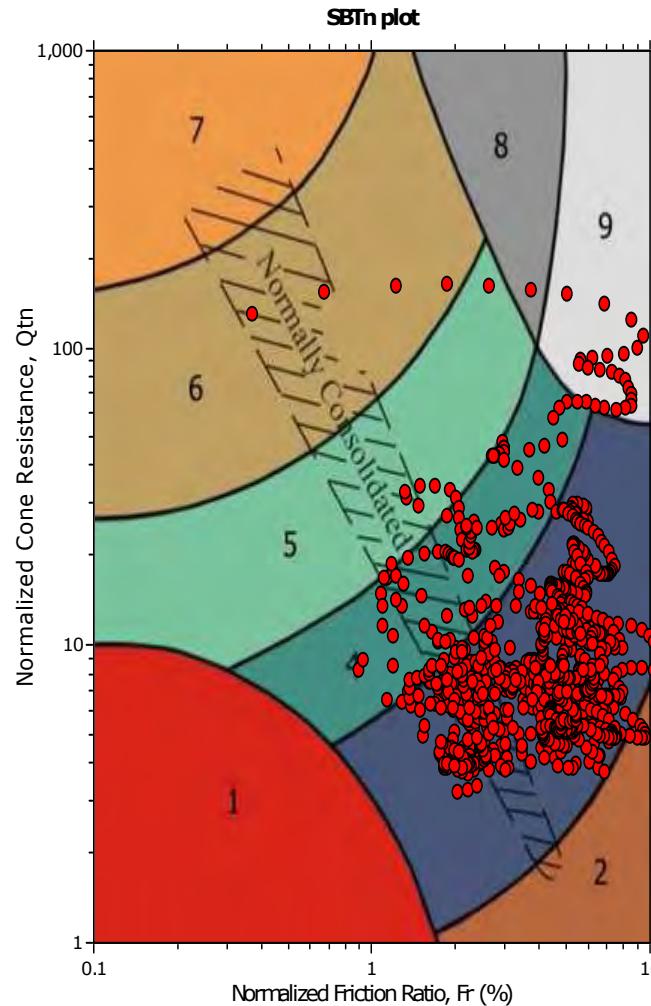
SBT - Bq plots



SBT legend

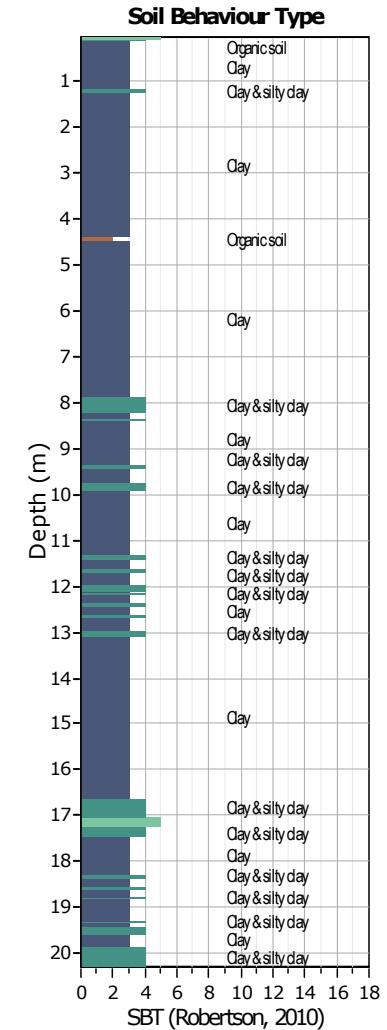
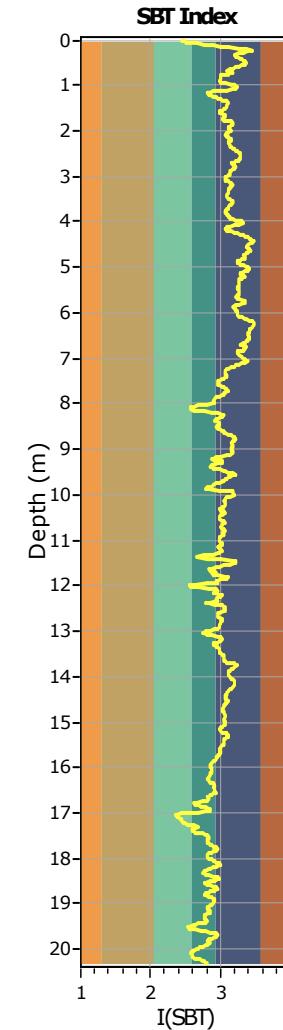
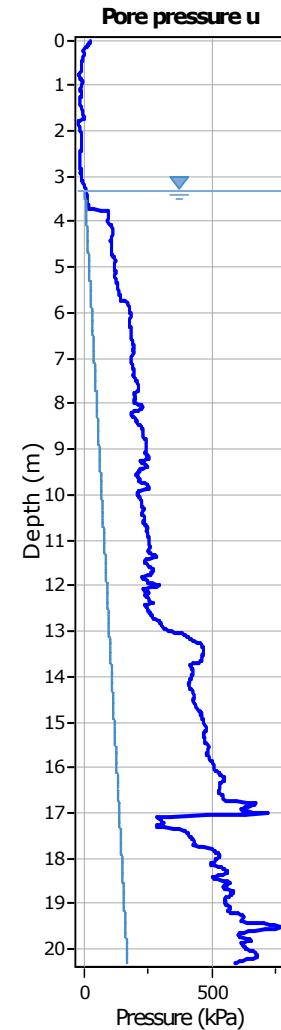
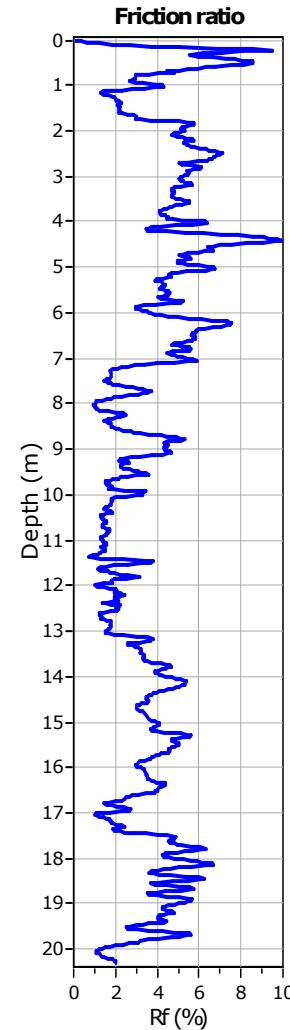
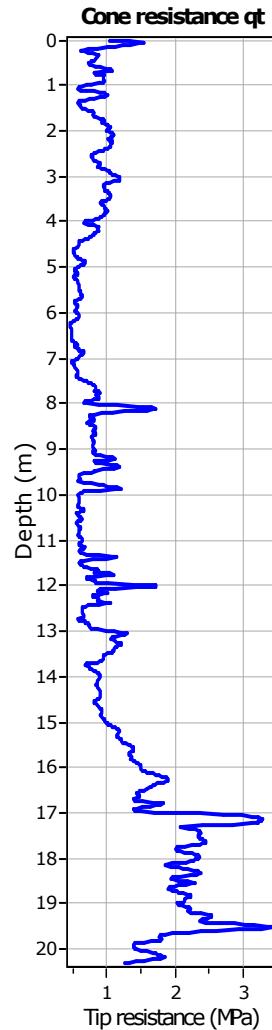
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

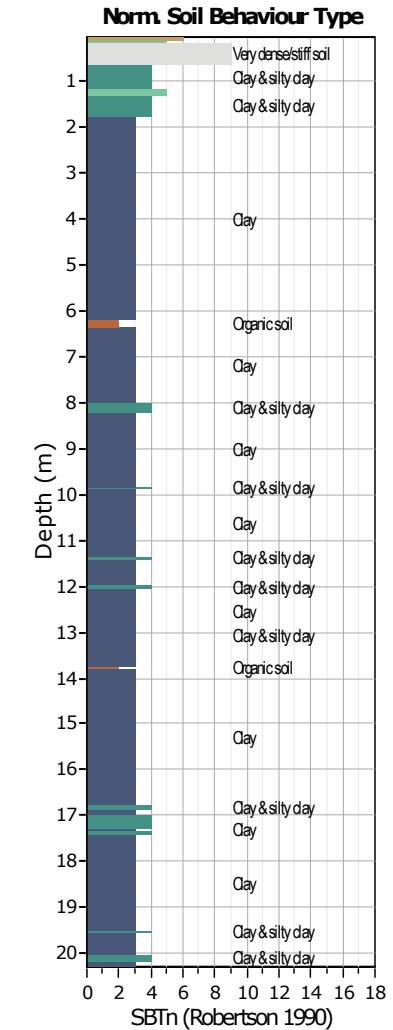
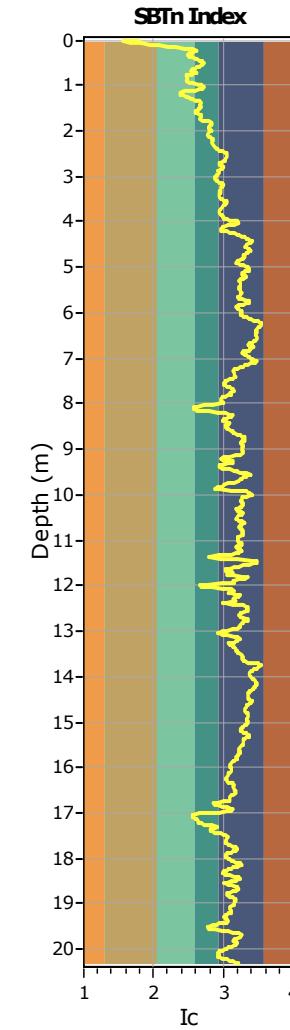
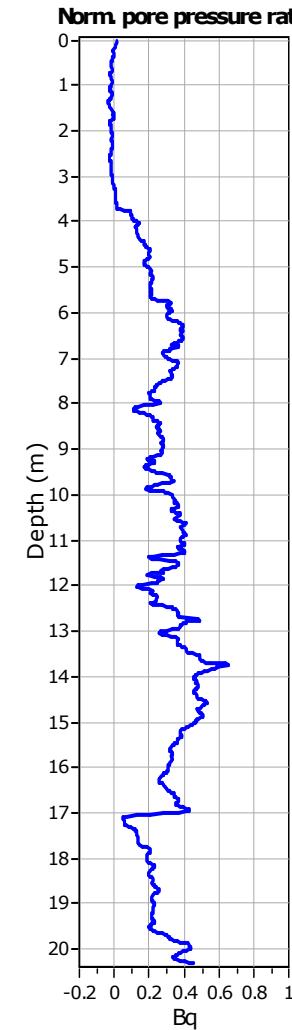
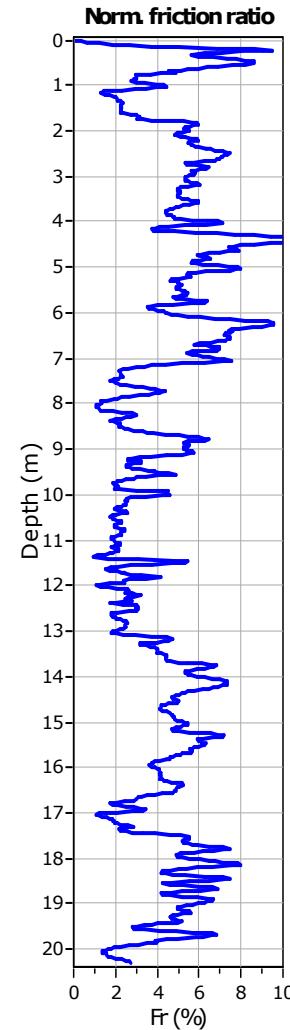
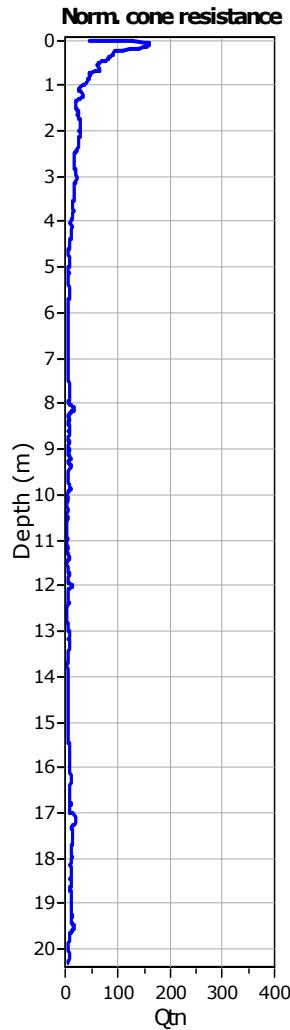
SBT - Bq plots (normalized)



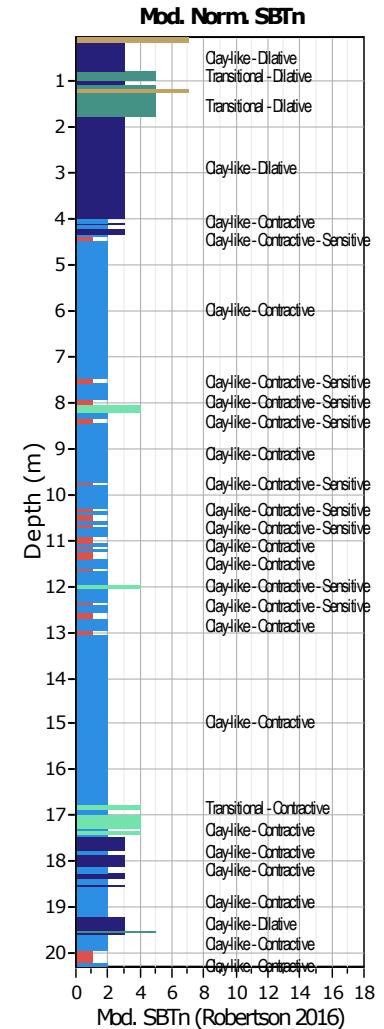
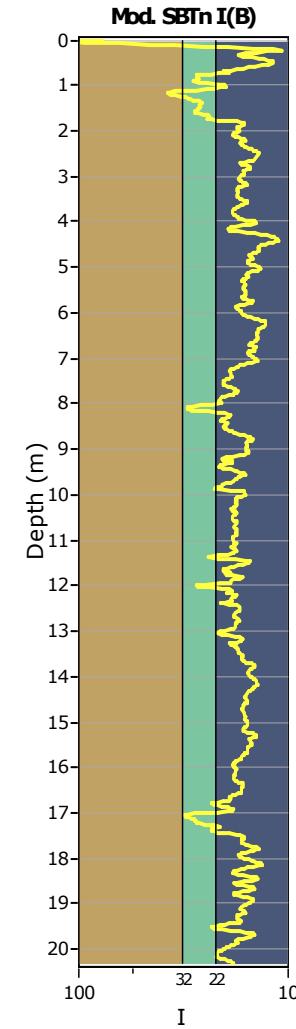
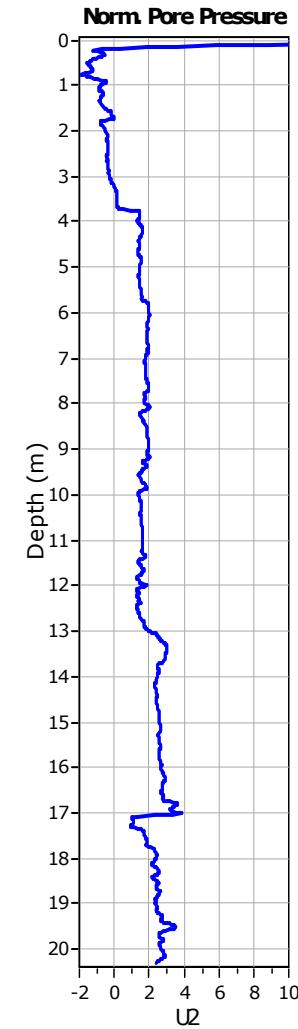
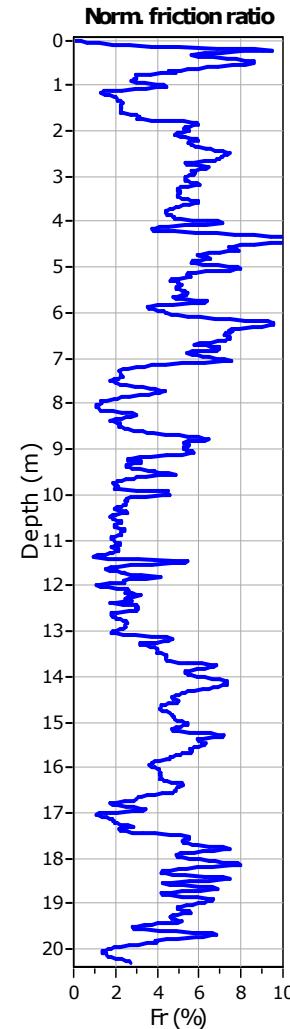
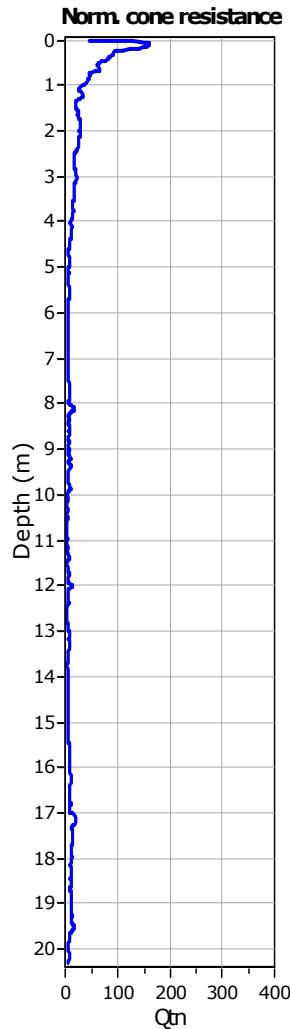
SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained





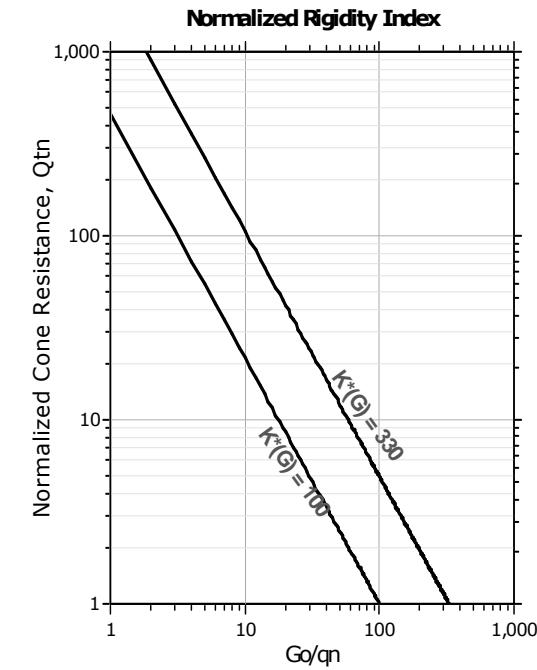
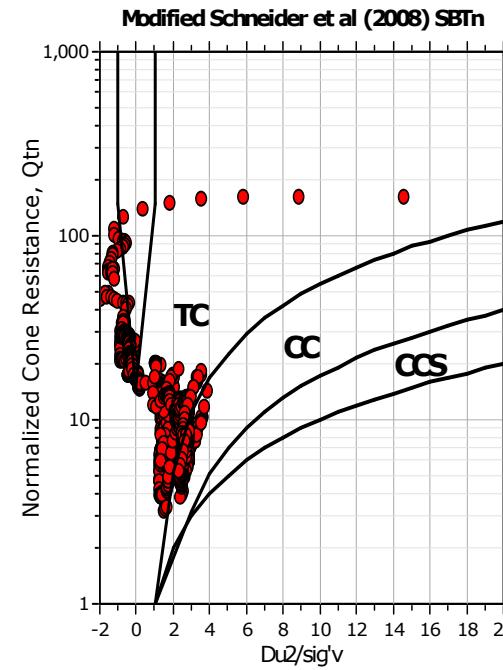
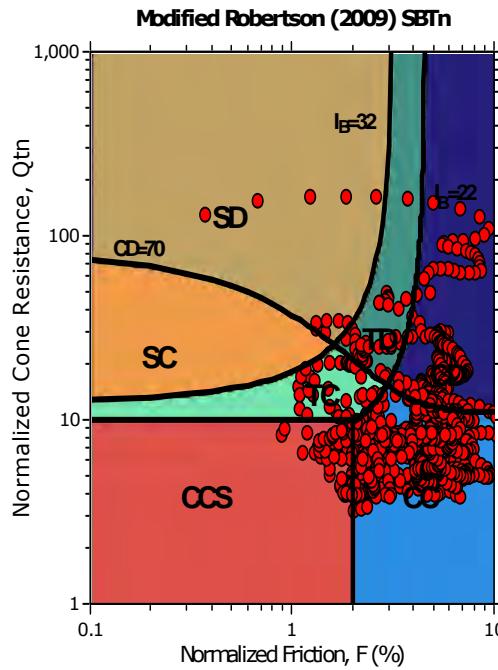
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained



Mod. SBTn legend

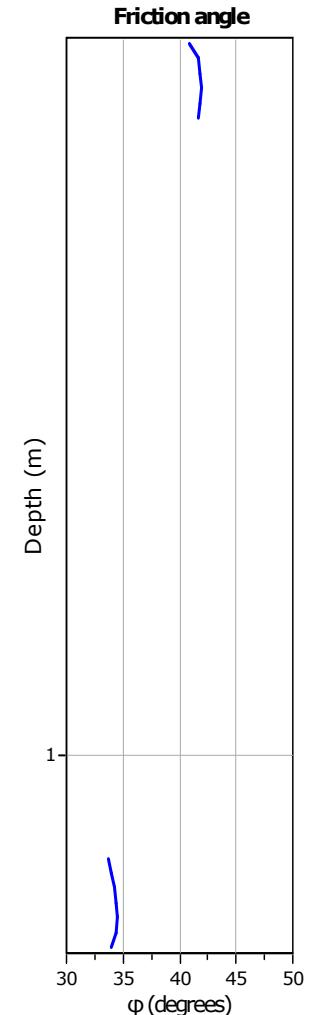
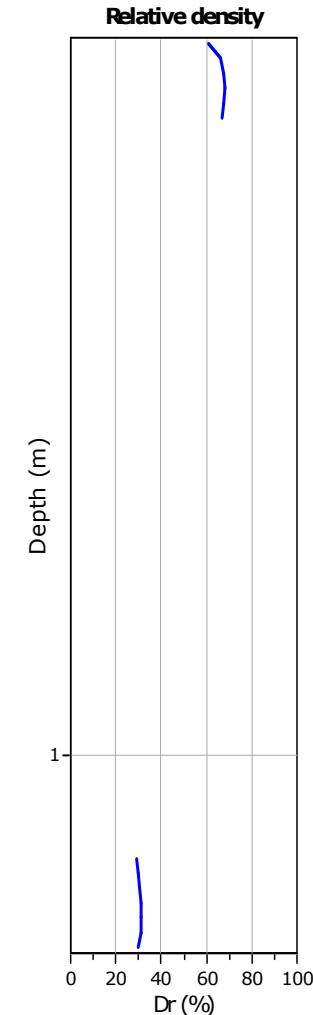
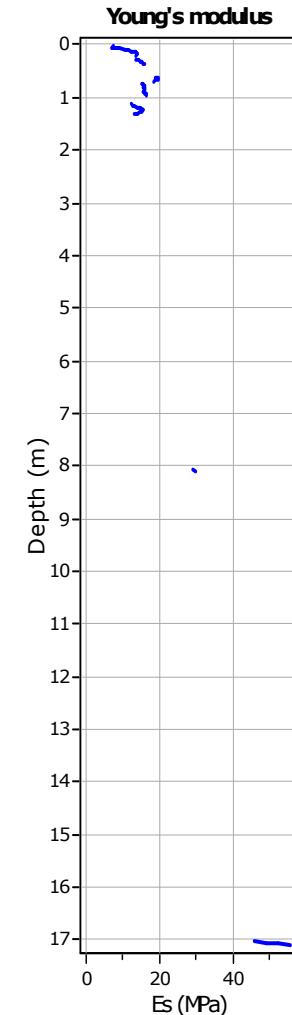
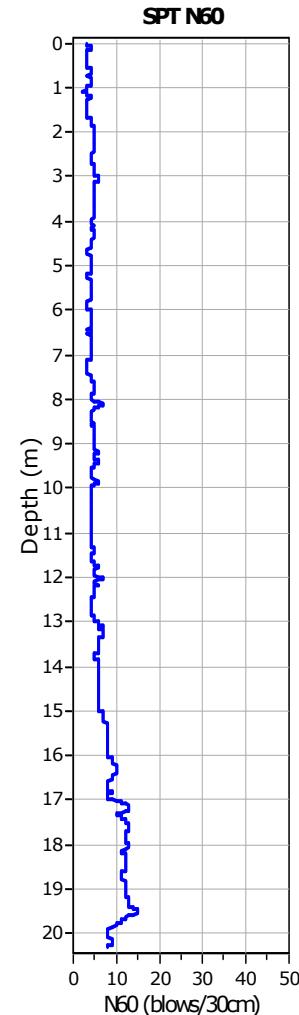
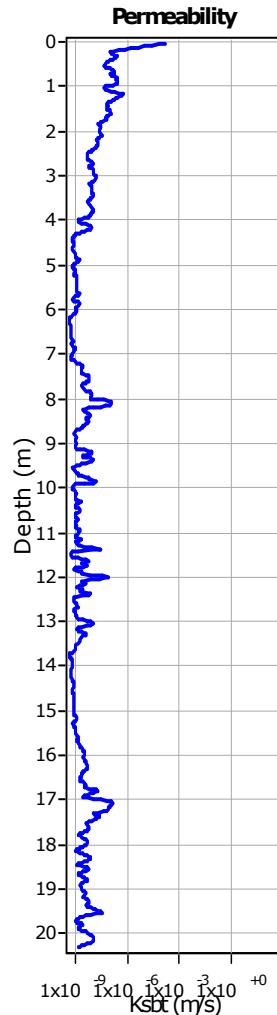
- | | | |
|---|-----------------------------------|-----------------------------|
| 1. CCS: ClayLike - Contractive, Sensitive | 4. TC: Transitional - Contractive | 7. SD: Sand-like - Dilative |
| 2. CC: Clay-like - Contractive | 5. TD: Transitional - Dilative | |
| 3. CD: Clay-Like: Dilative | 6. SC: Sand-like - Contractive | |

Updated SBTn plots



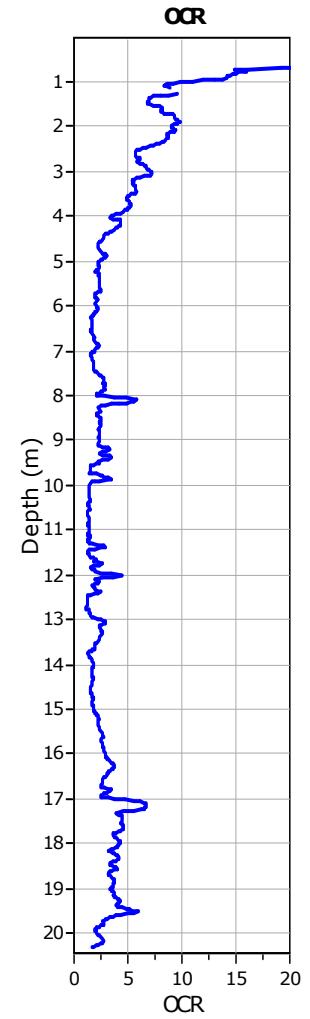
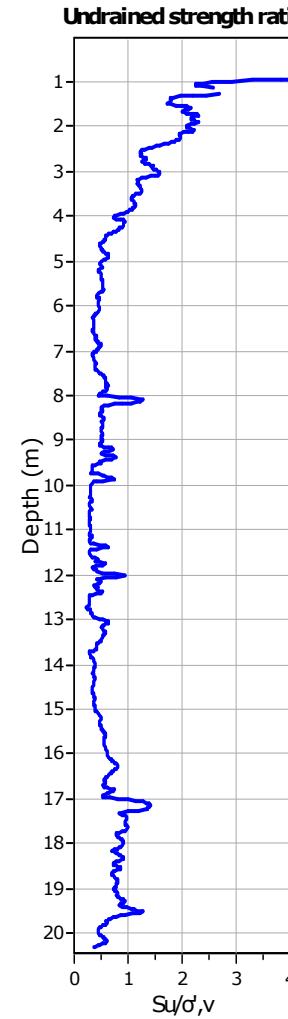
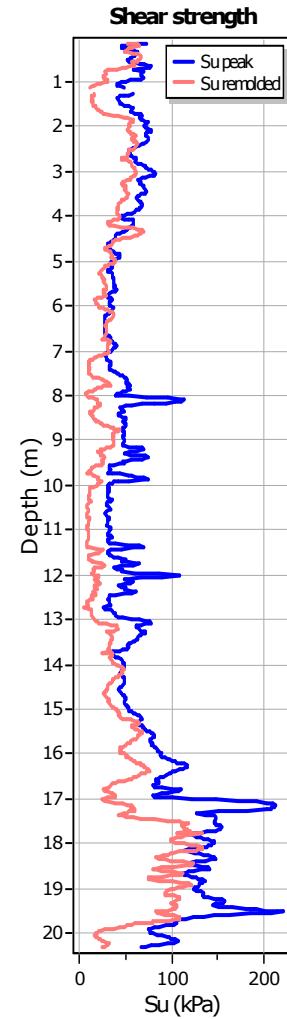
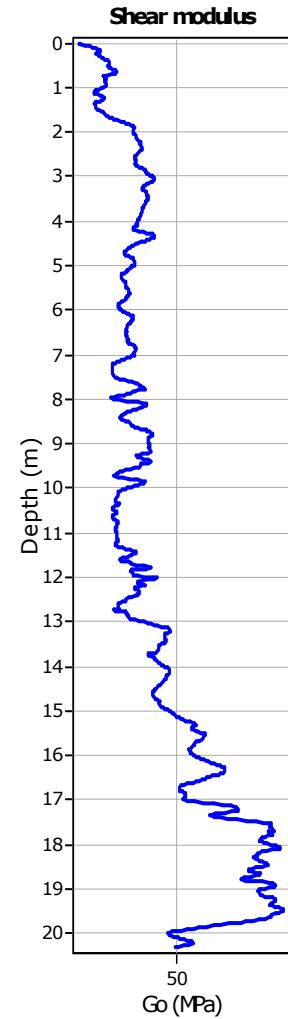
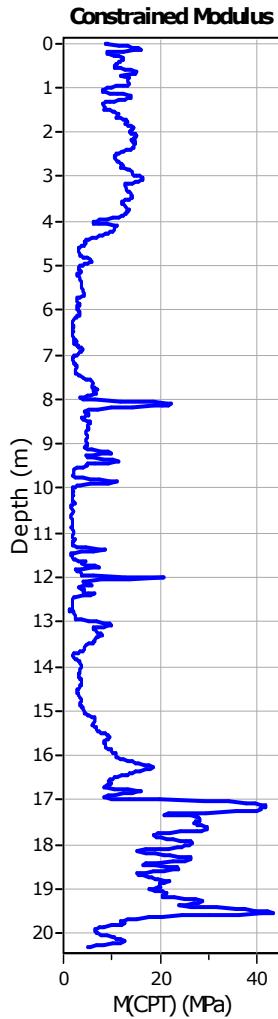
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

**Calculation parameters**

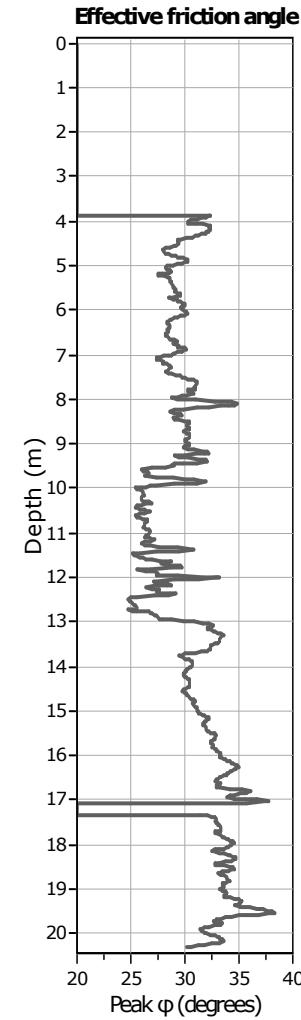
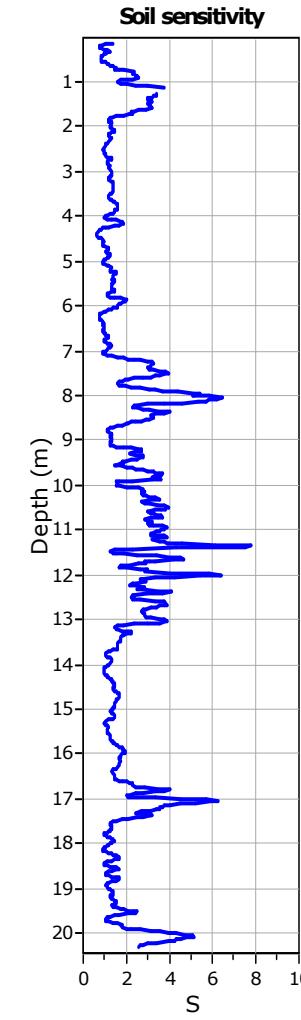
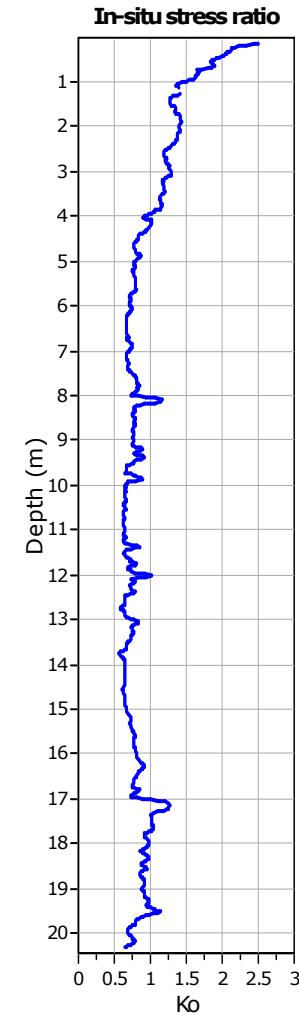
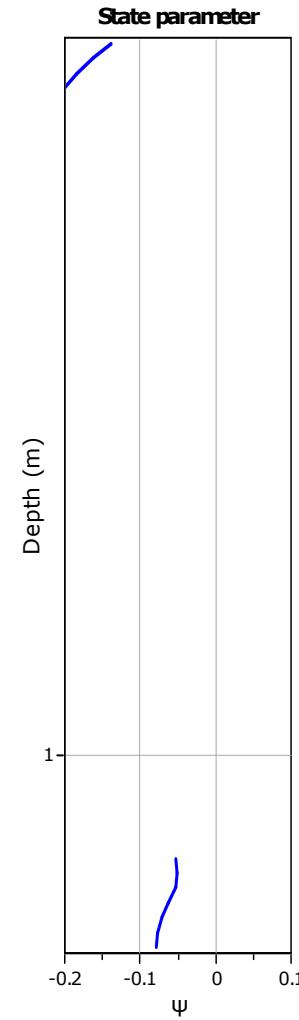
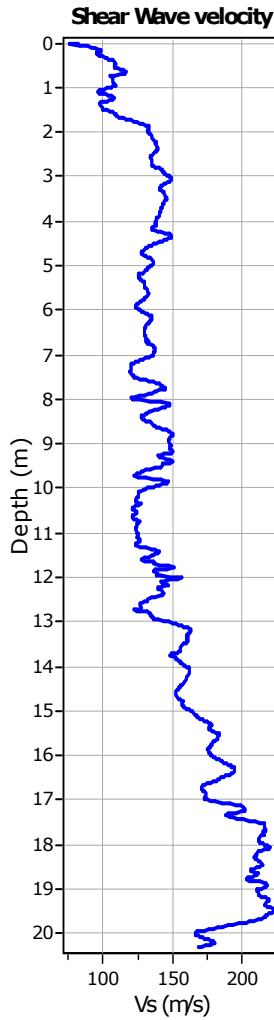
Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)

G_0 : Based on variable *alpha* using I_c (Robertson, 2009)

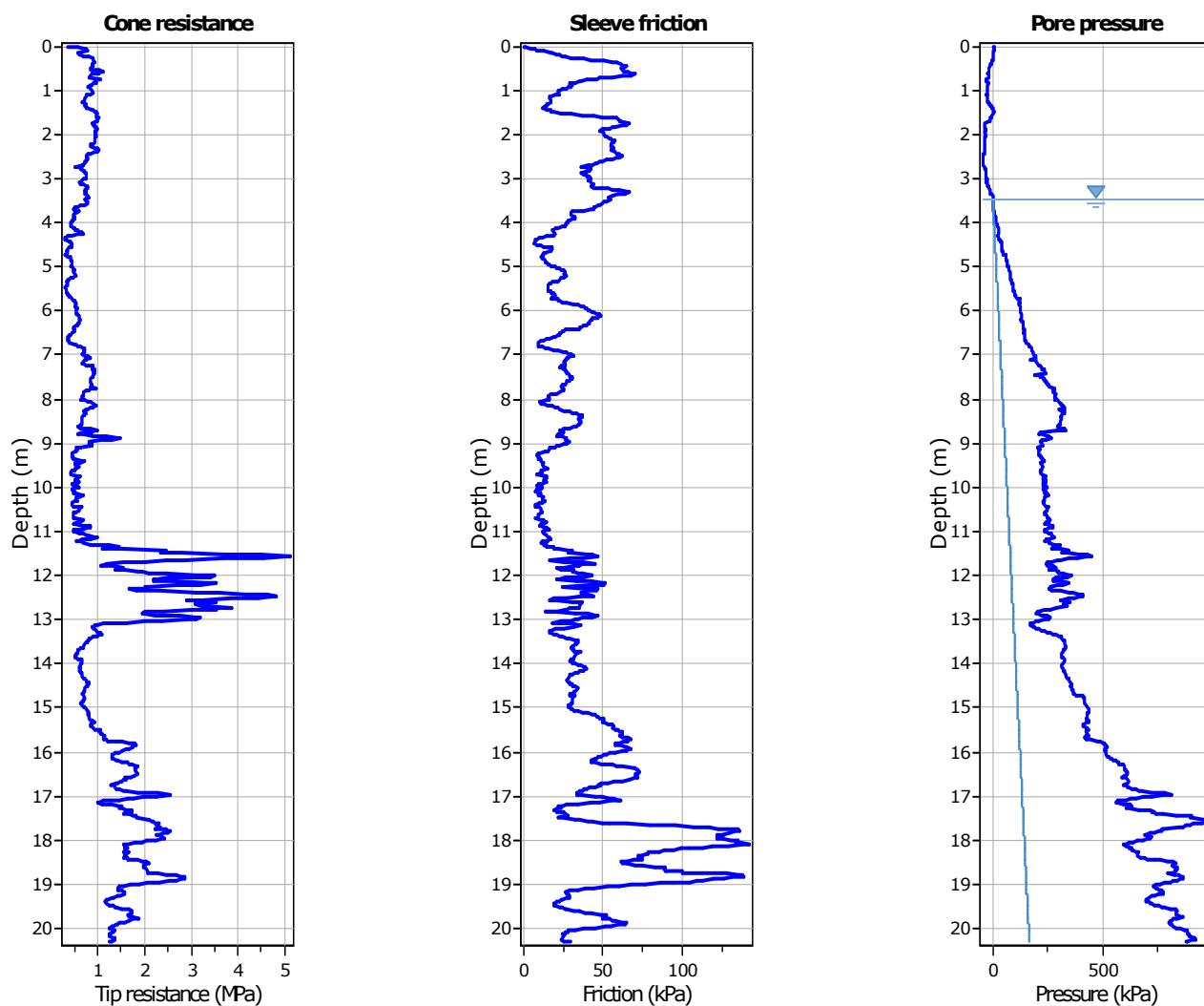
Undrained shear strength cone factor for clays, N_{kt} : 14

OCR factor for clays, N_{kt} : 0.33

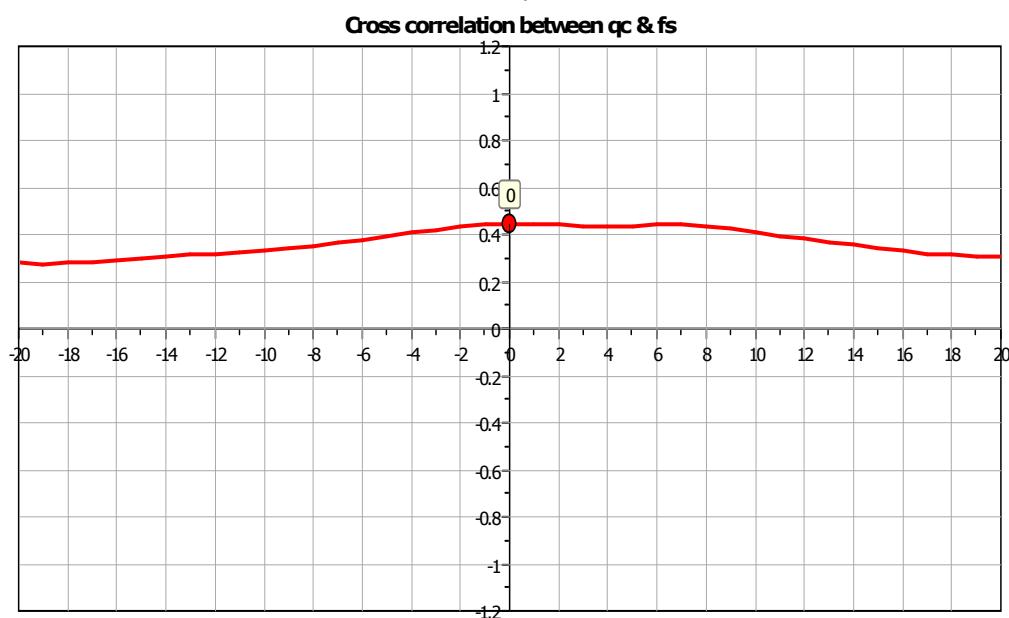
- User defined estimation data
- Flat Dilatometer Test data

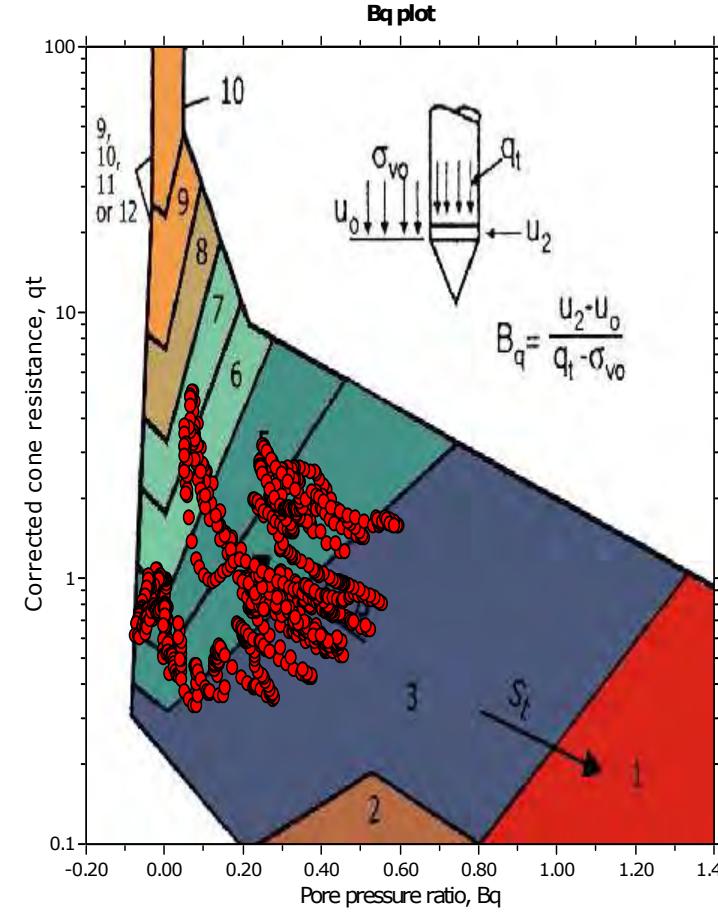
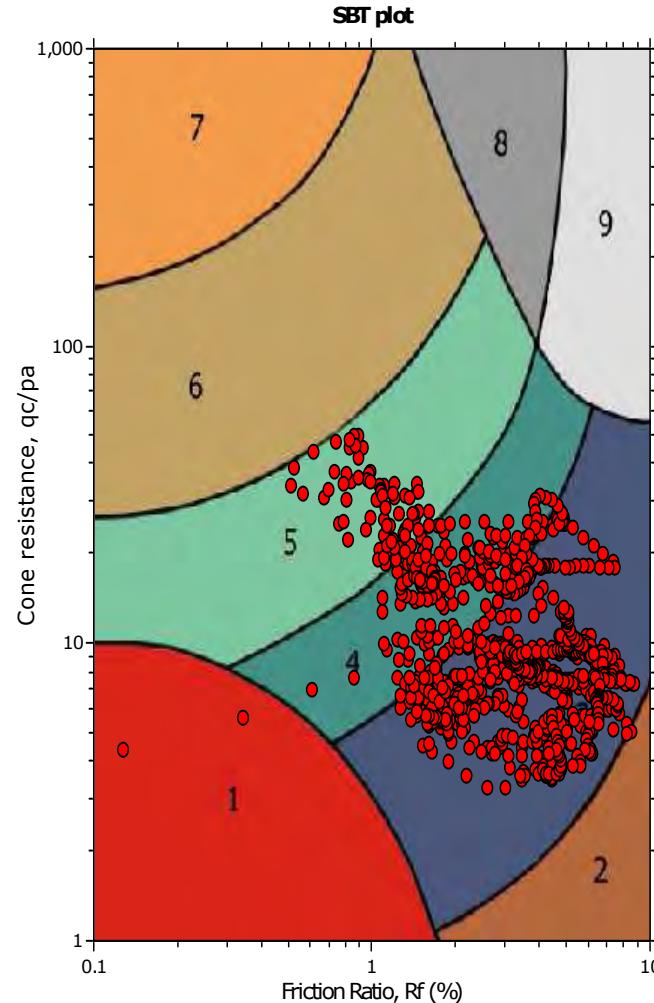
**Calculation parameters**Soil Sensitivity factor, N_s : 7.00

User defined estimation data

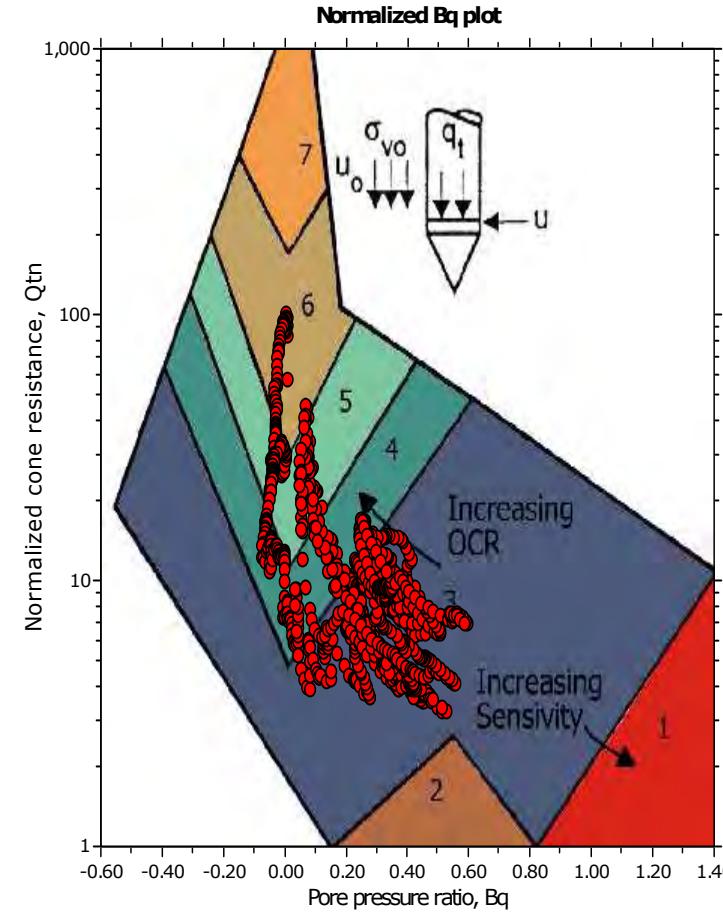
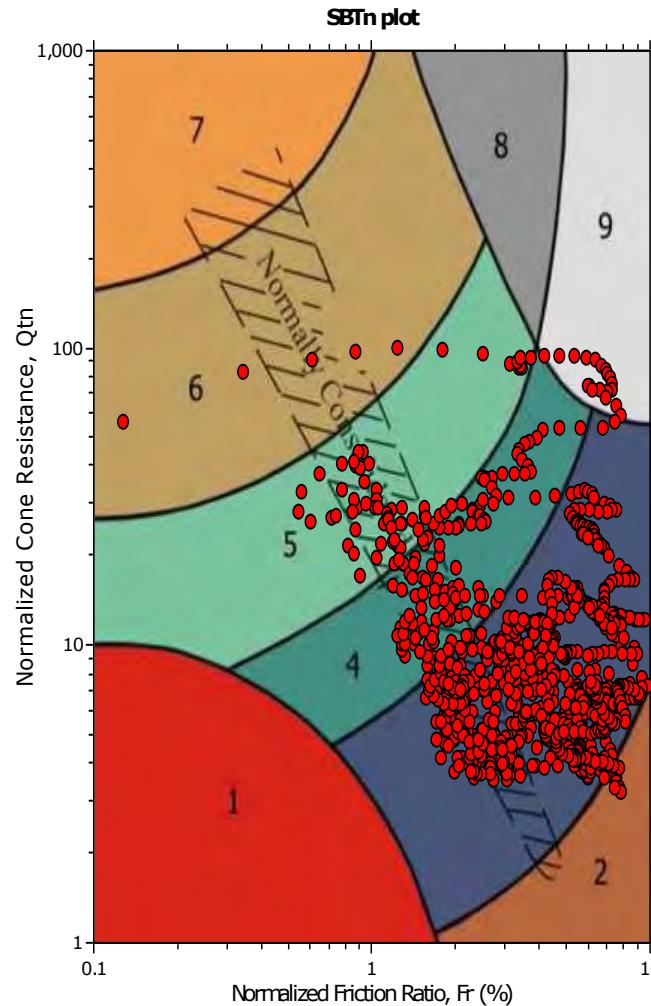


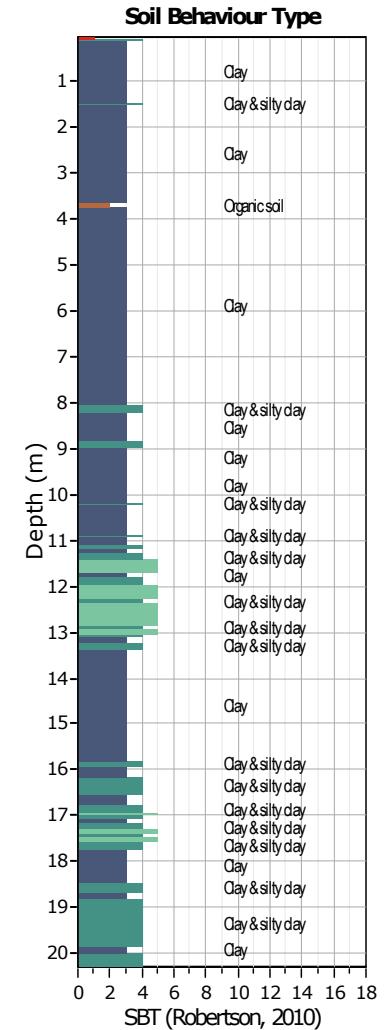
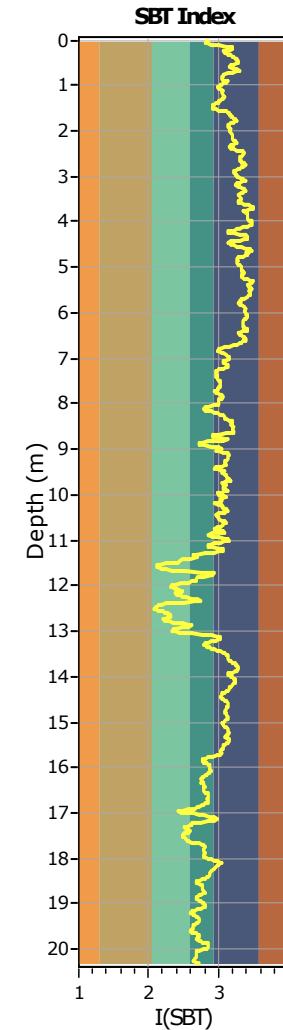
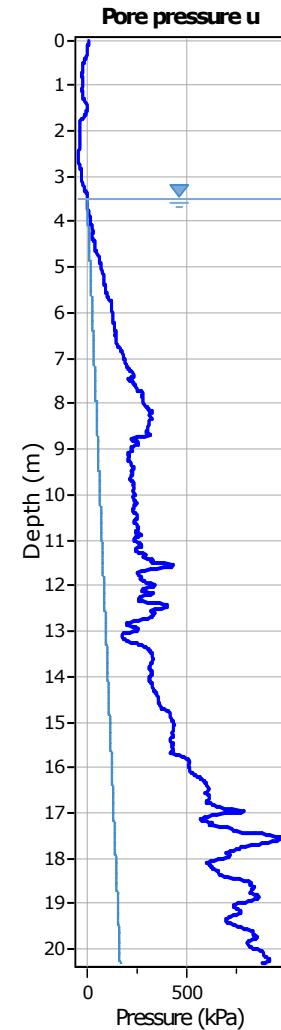
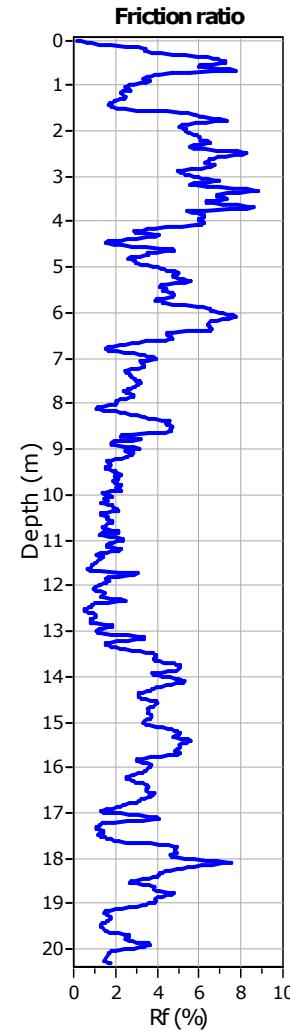
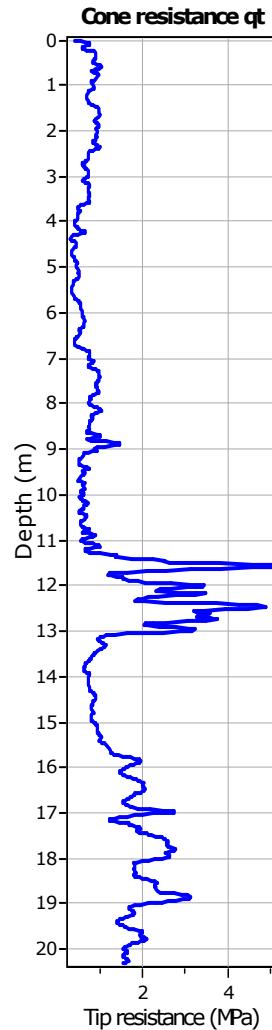
The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



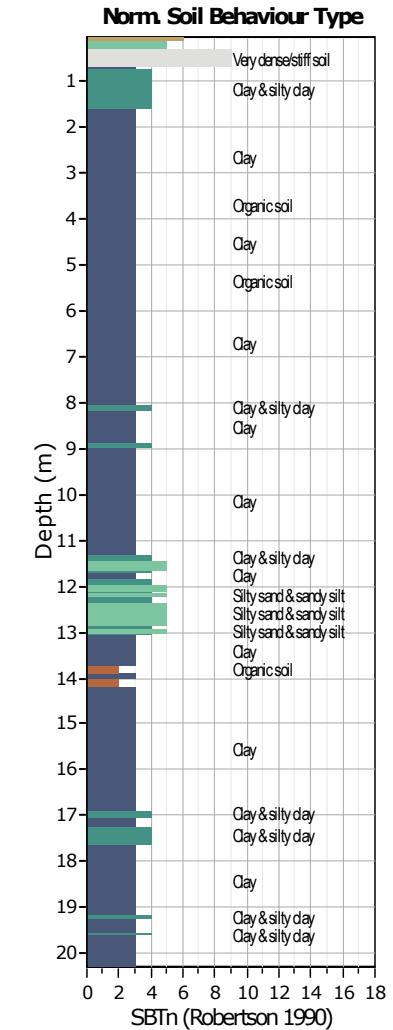
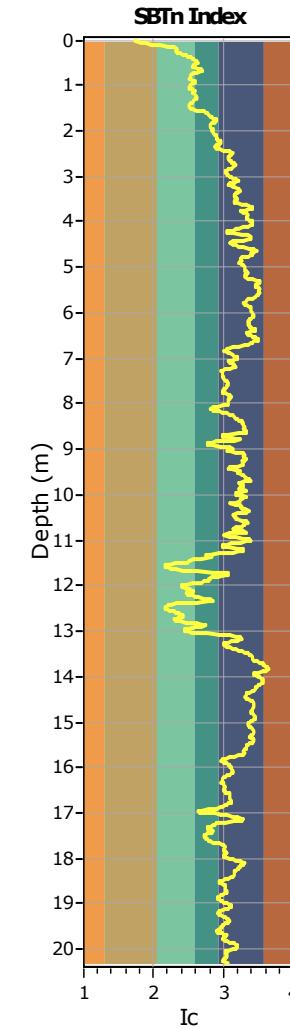
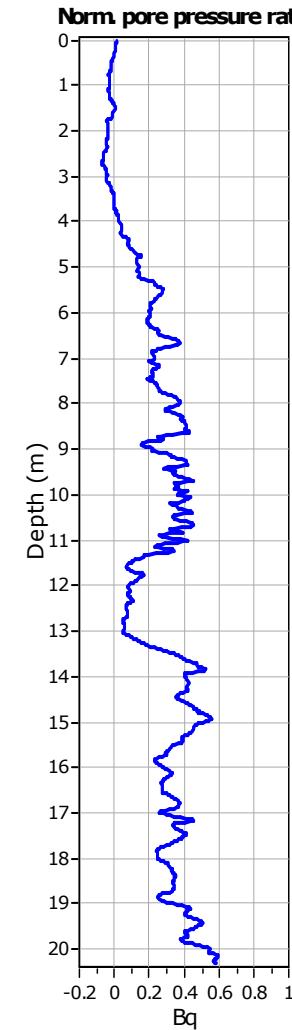
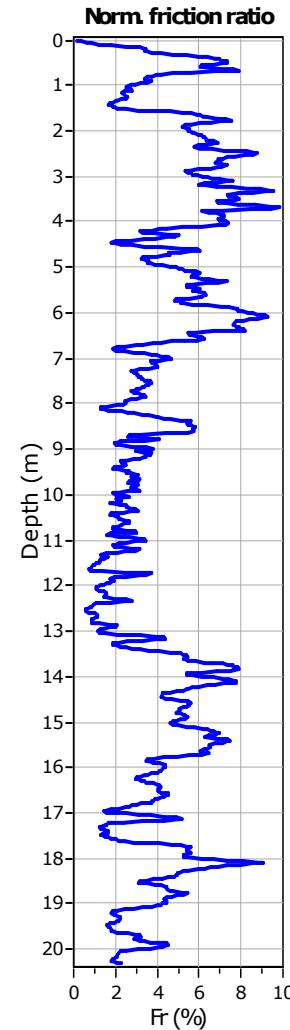
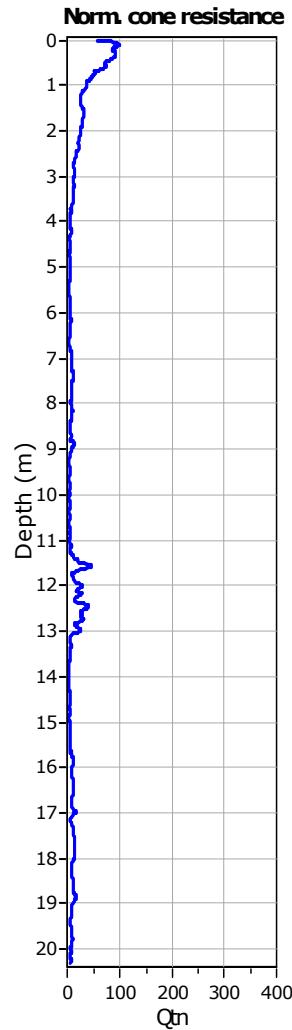
SBT - Bq plots

SBT - Bq plots (normalized)

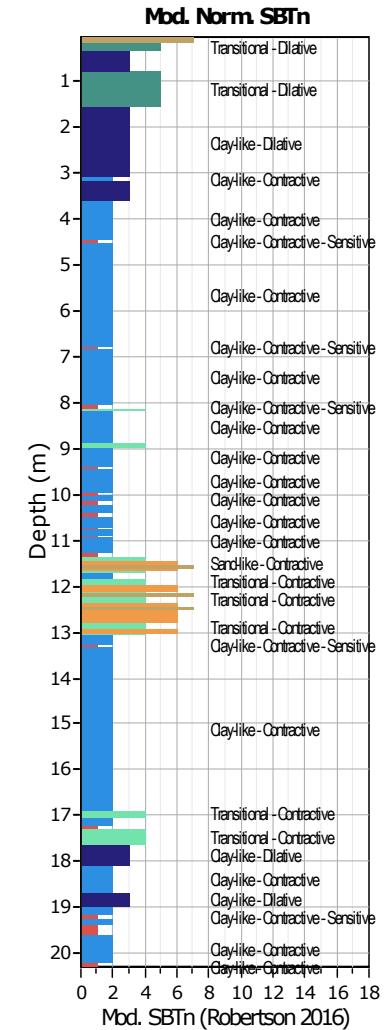
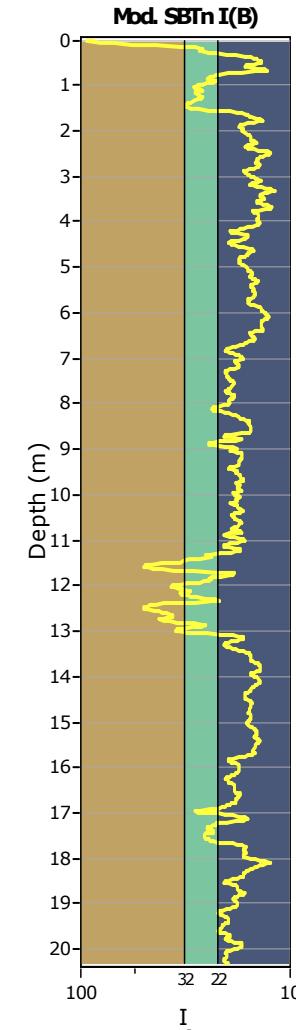
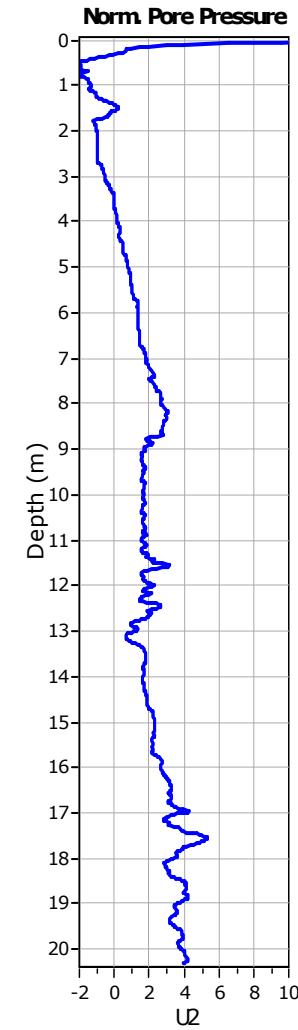
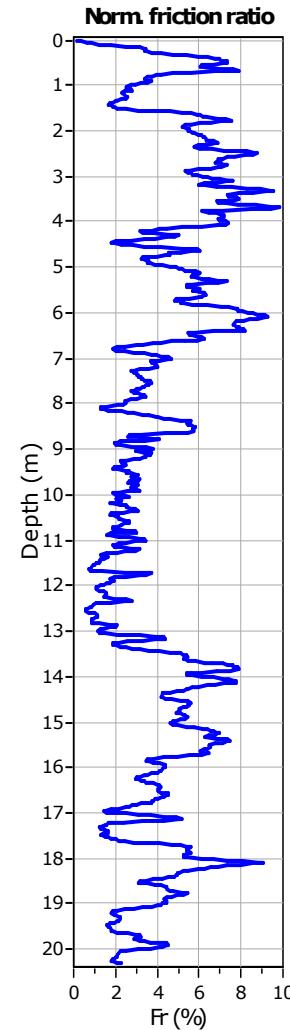
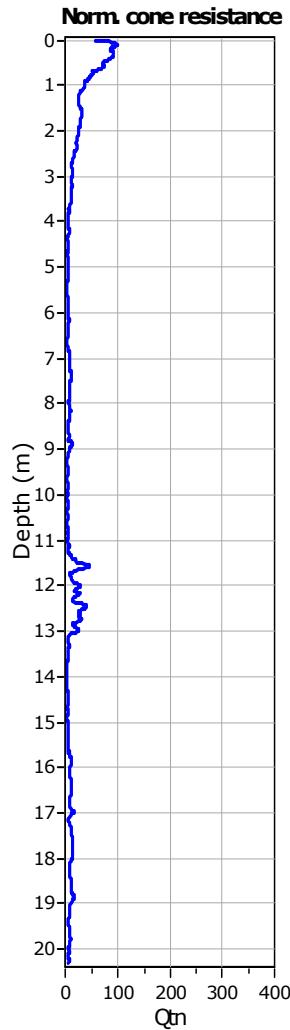


**SBT legend**

- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

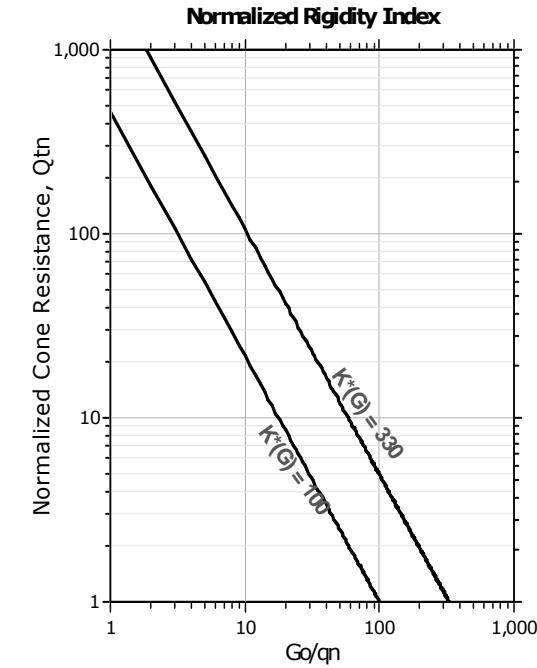
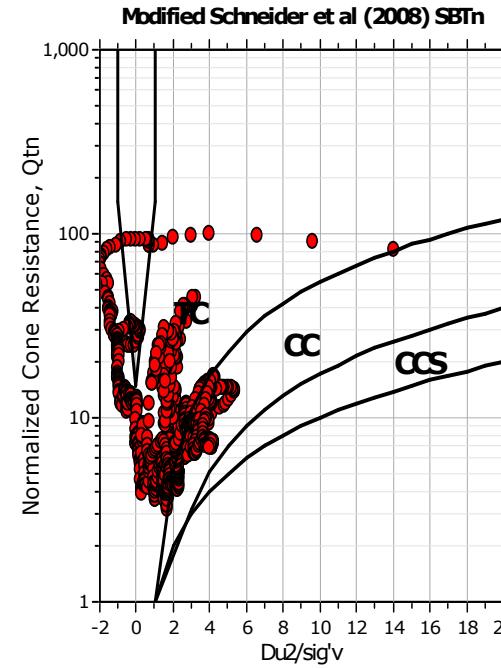
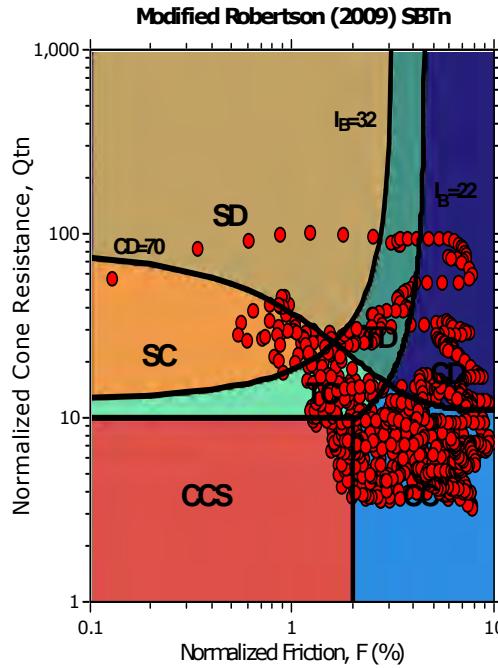
**SBTn legend**

- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

**Mod. SBTn legend**

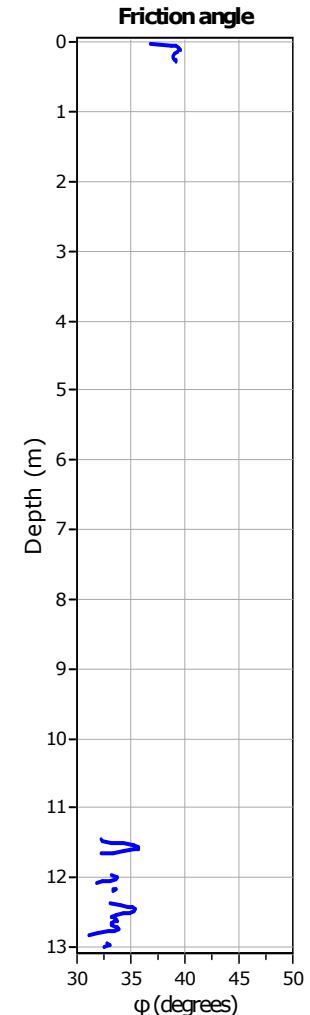
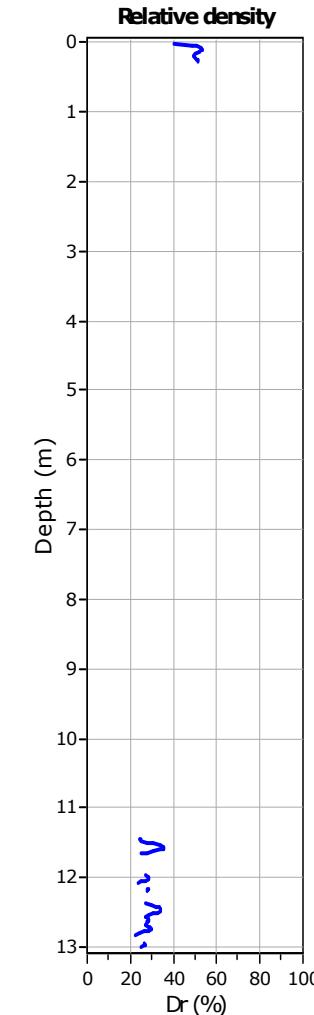
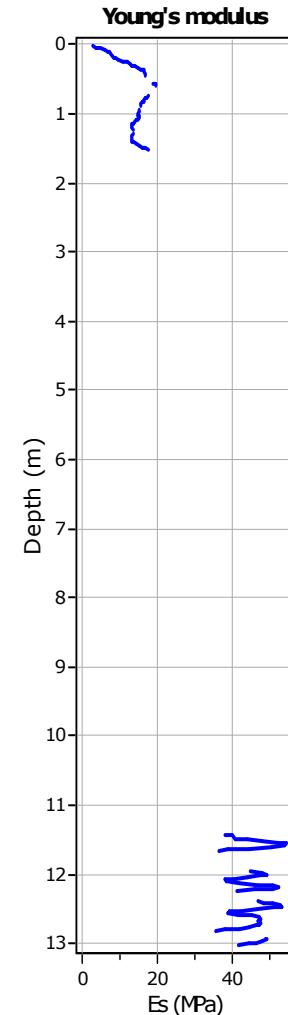
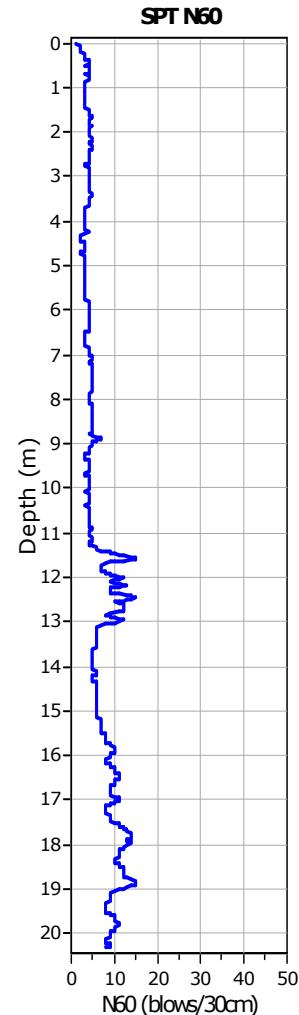
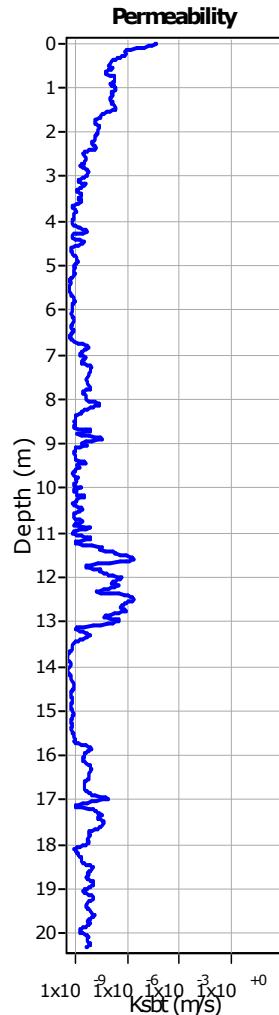
- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

Updated SBTn plots



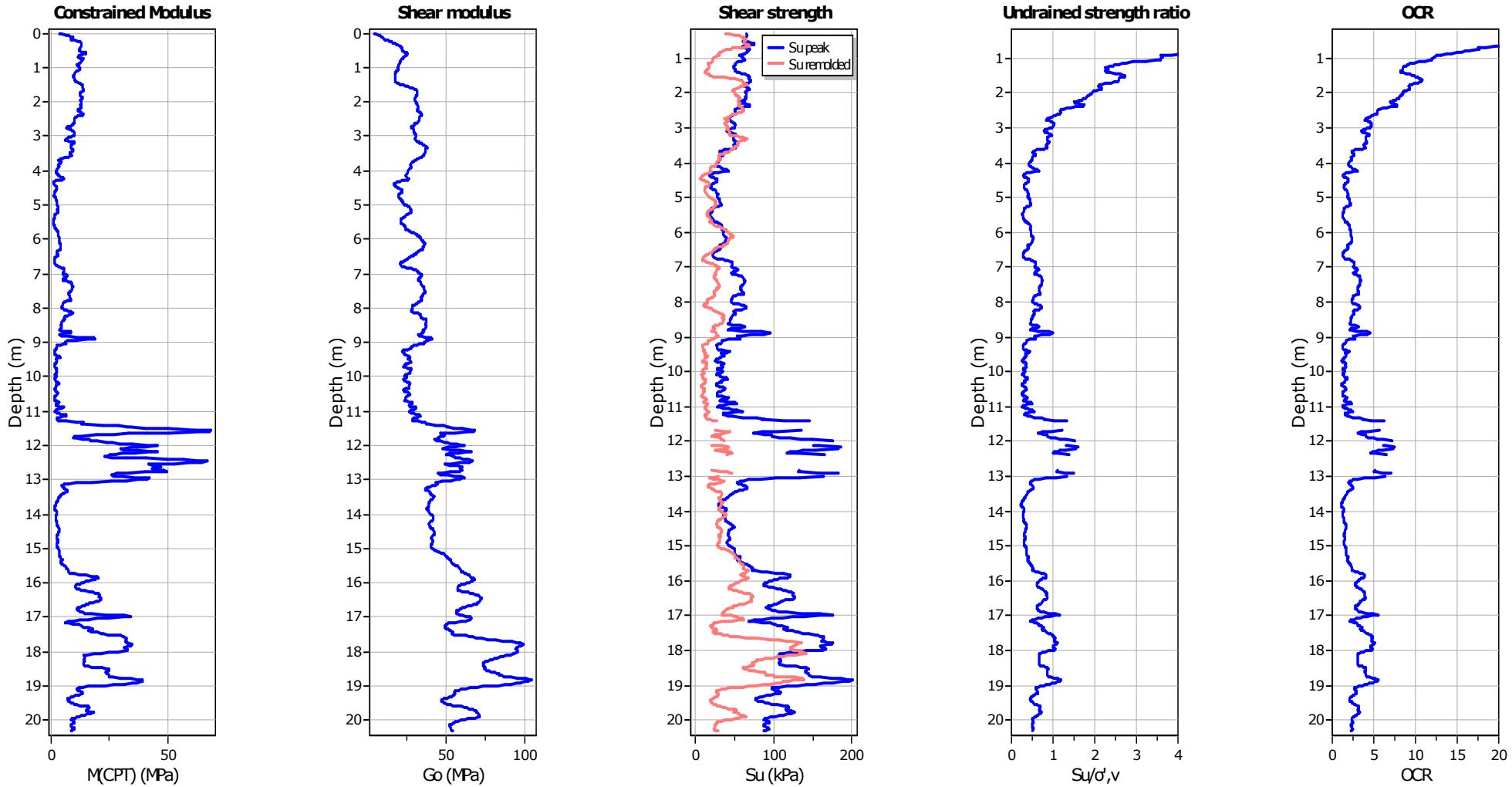
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure (e.g. age/cementation)

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

**Calculation parameters**

Constrained modulus: Based on variable *alpha* using *I_c* and *Q_{tn}* (Robertson, 2009)

Go: Based on variable *alpha* using *I_c* (Robertson, 2009)

Undrained shear strength cone factor for clays, *N_{kt}*: 14

OCR factor for clays, *N_{kt}*: 0.33

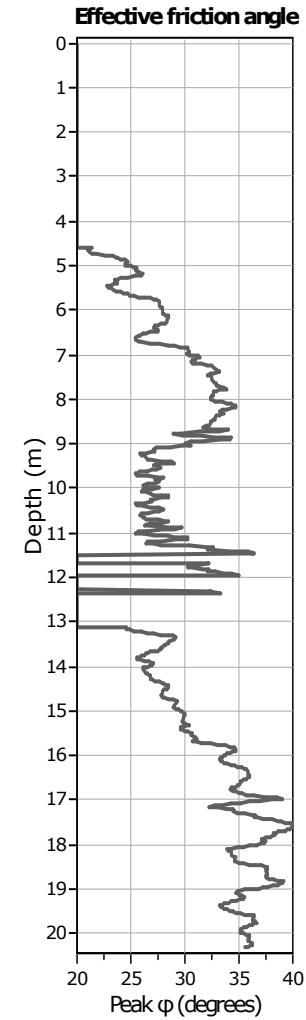
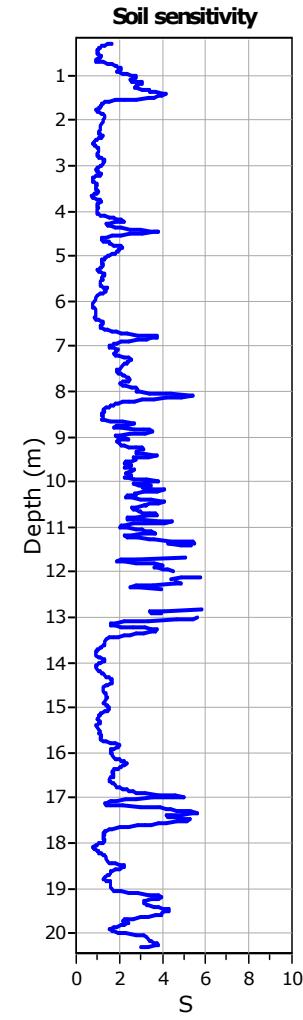
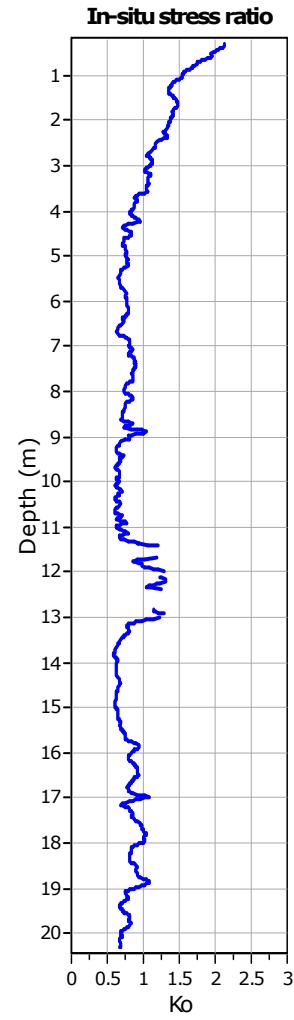
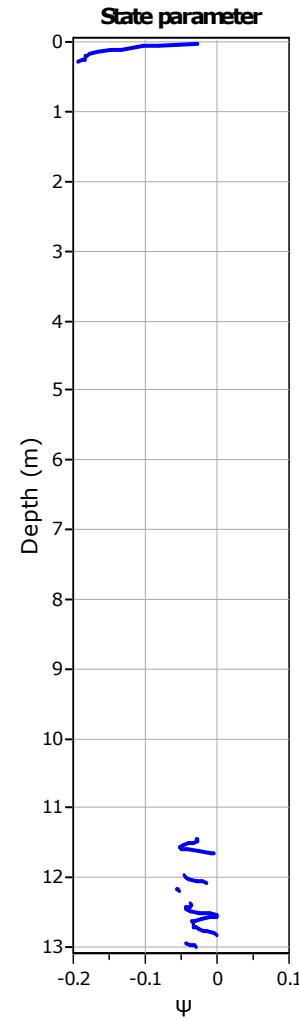
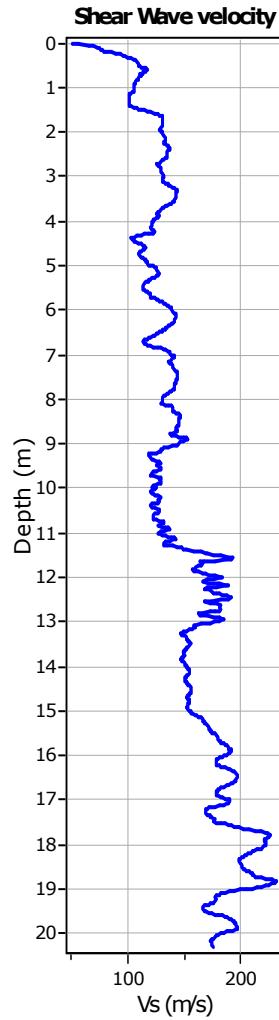
- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato Regionale dell'Emergenza sul Territorio della P.C.

Location: via Bologna, Ferrara

CPT: CPTU5

Total depth: 20.30 m, Date: 23/04/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

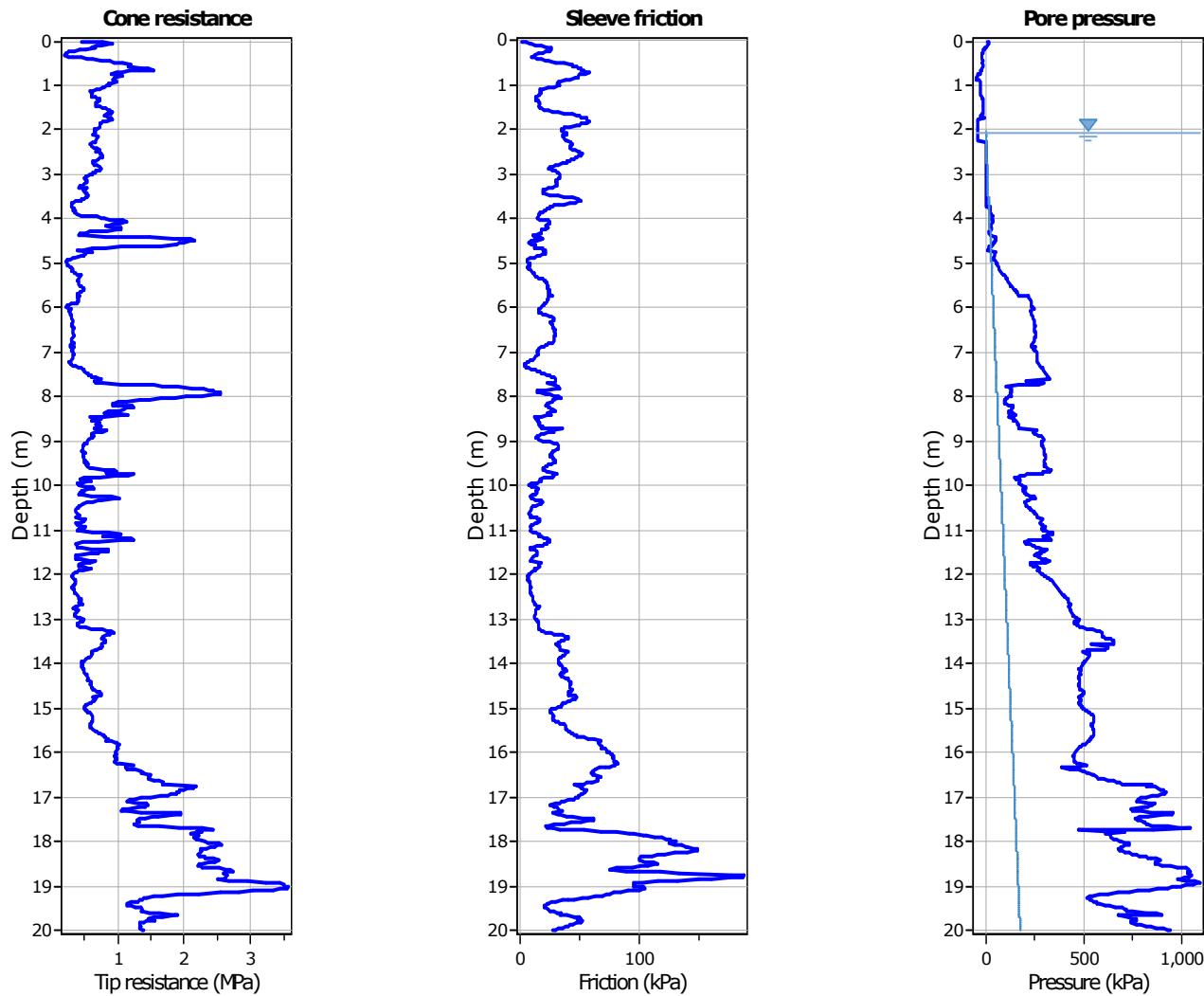
User defined estimation data

Project:

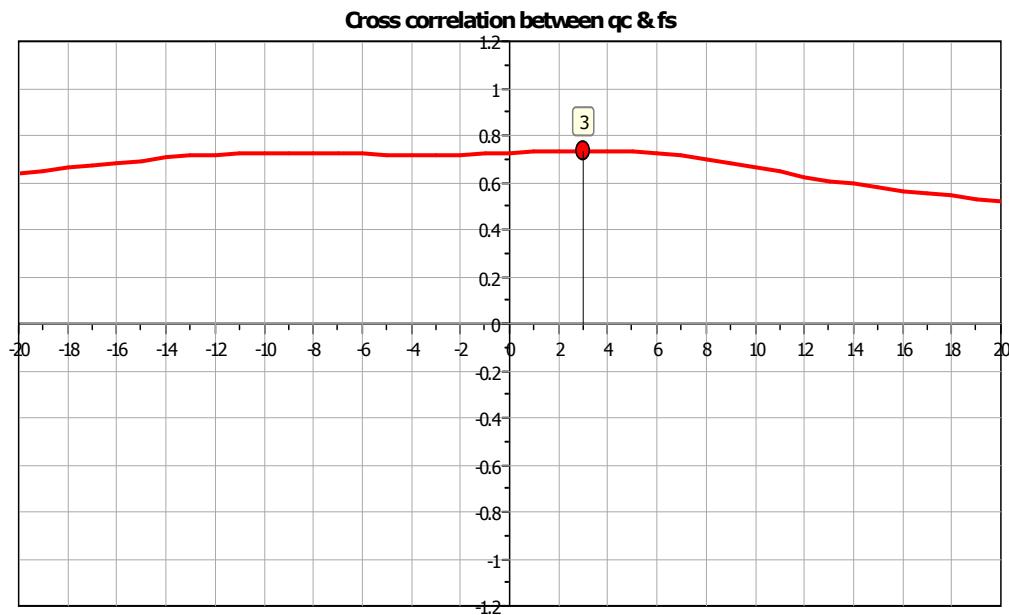
Location:

CPT: CPTU7

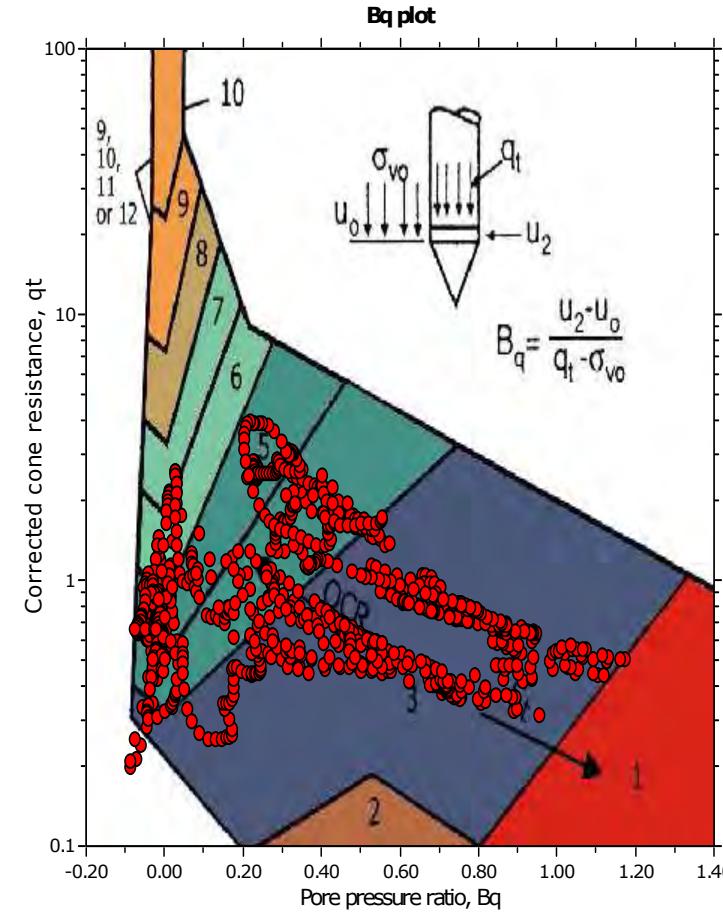
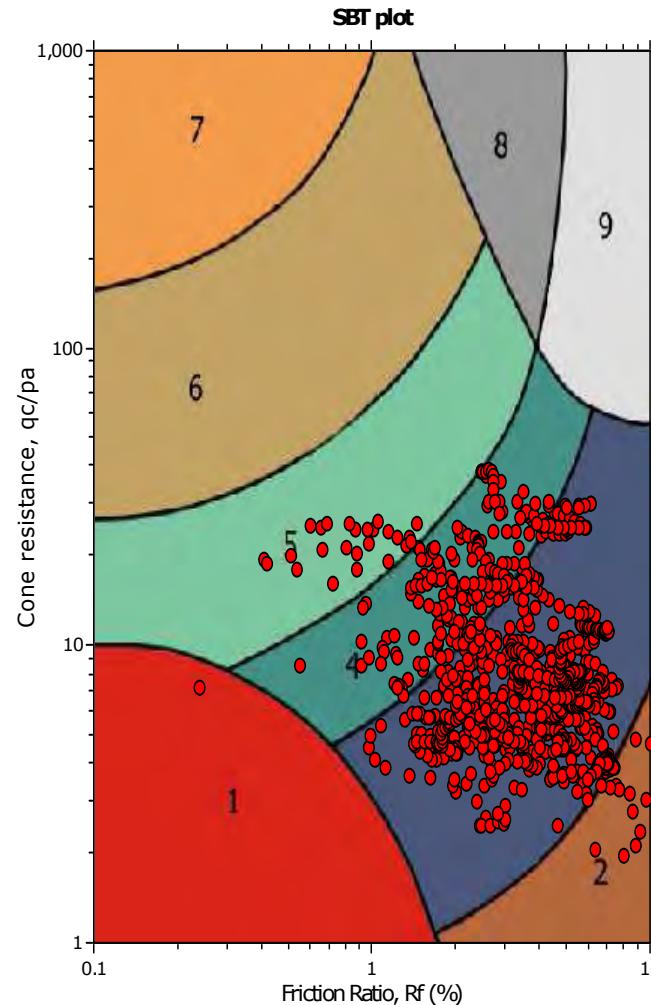
Total depth: 20.00 m, Date: 24/04/2018



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



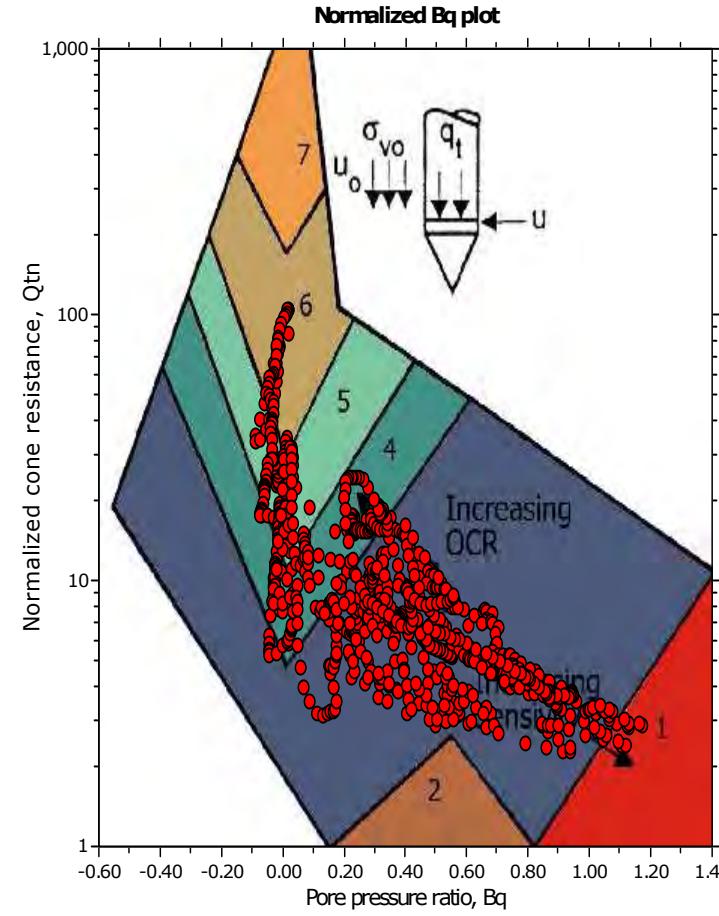
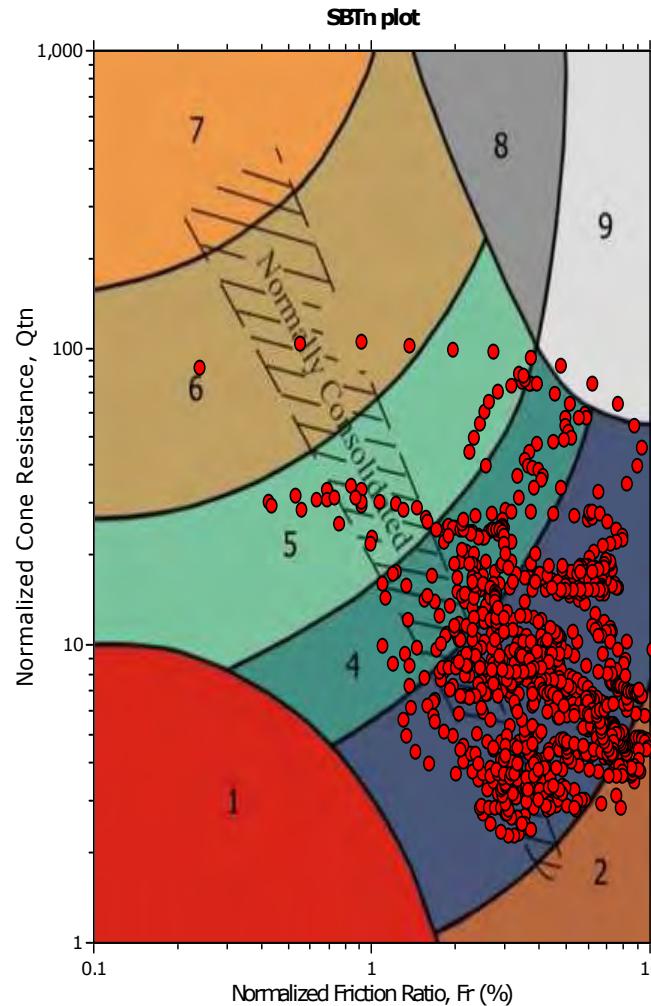
SBT - Bq plots



SBT legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

SBT - Bq plots (normalized)

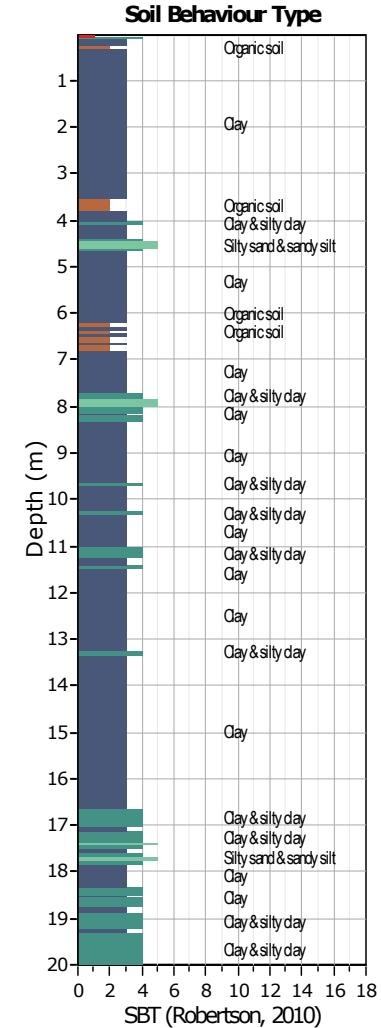
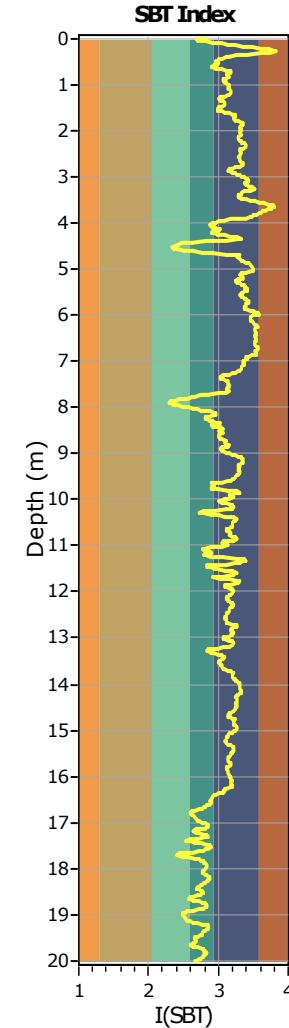
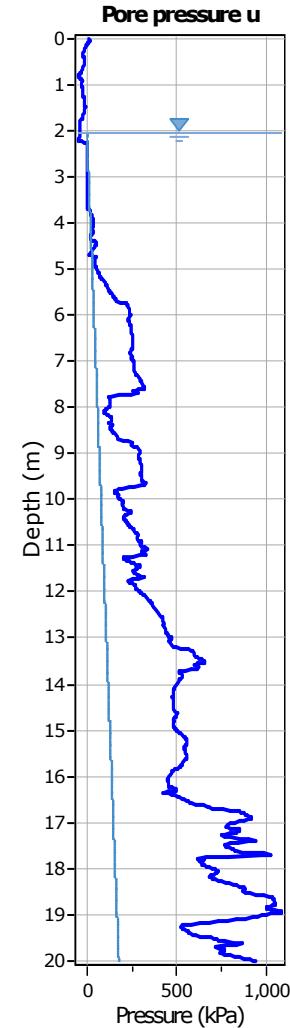
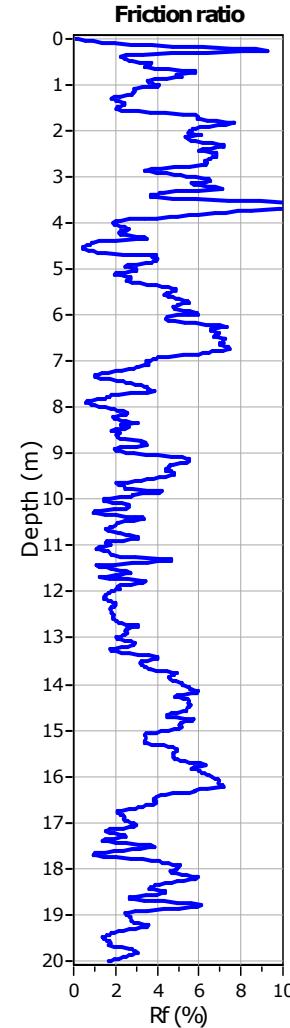
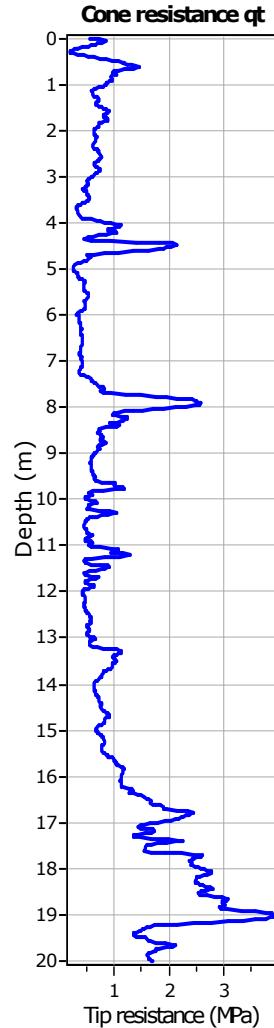


Project:

Location:

CPT: CPTU7

Total depth: 20.00 m, Date: 24/04/2018

**SBT legend**

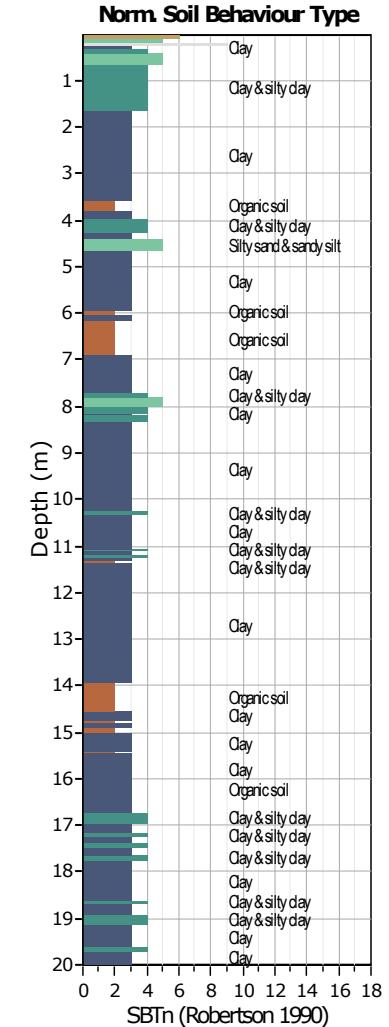
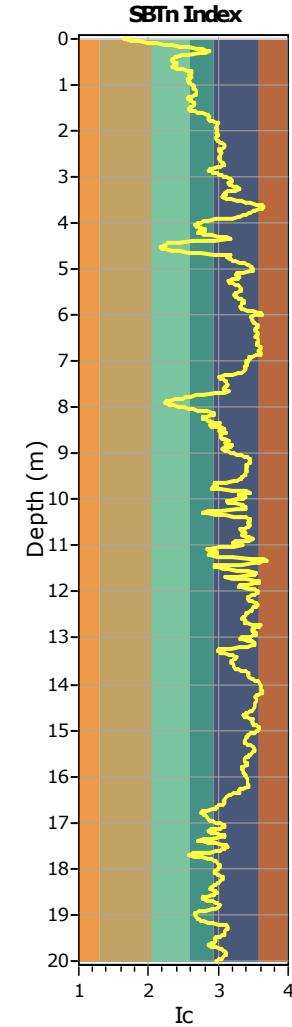
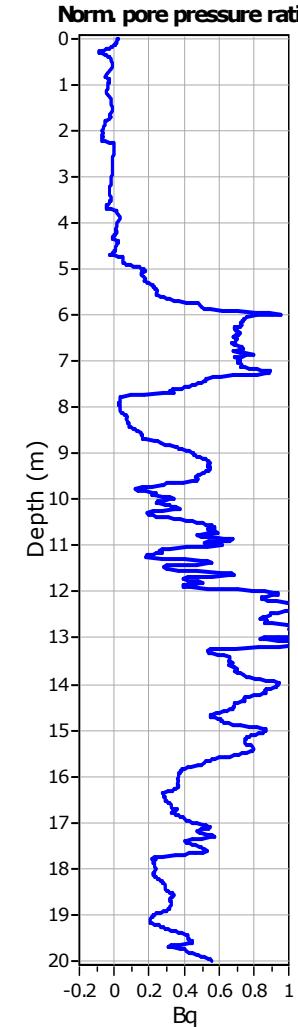
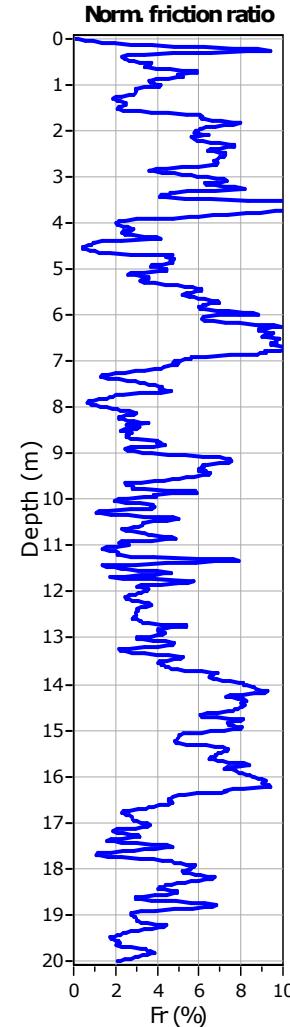
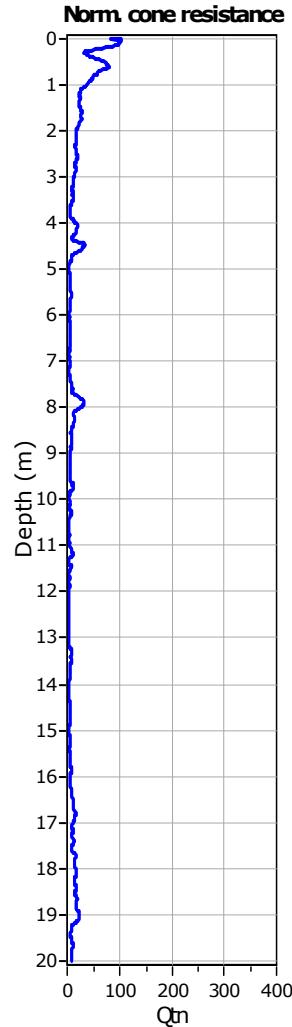
- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

Project:

Location:

CPT: CPTU7

Total depth: 20.00 m, Date: 24/04/2018

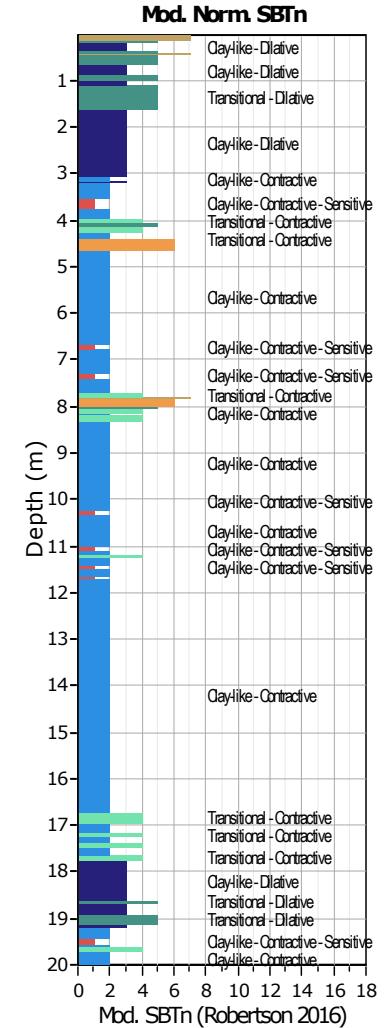
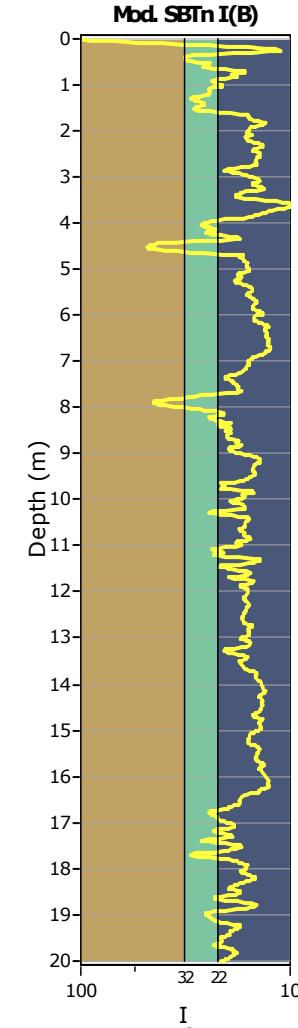
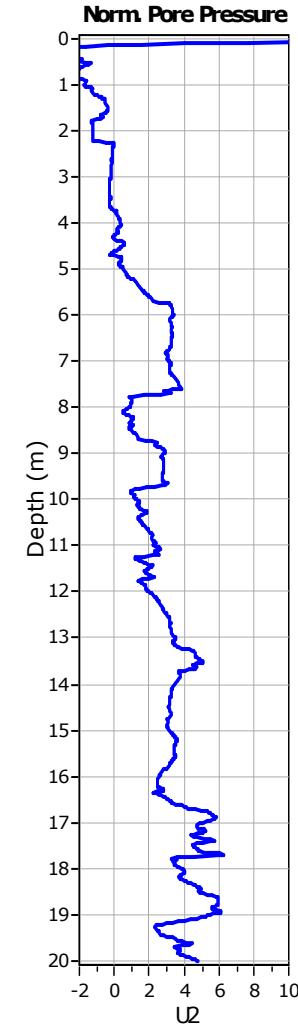
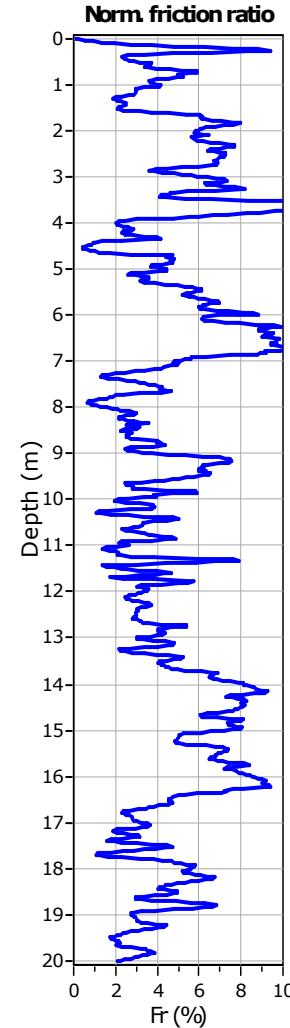
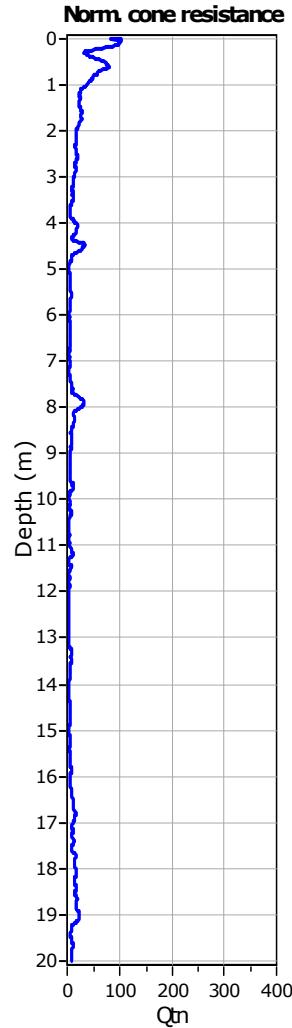


Project:

Location:

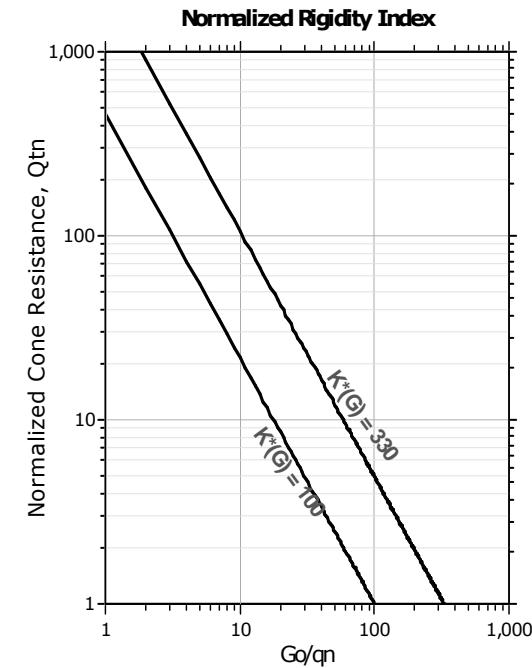
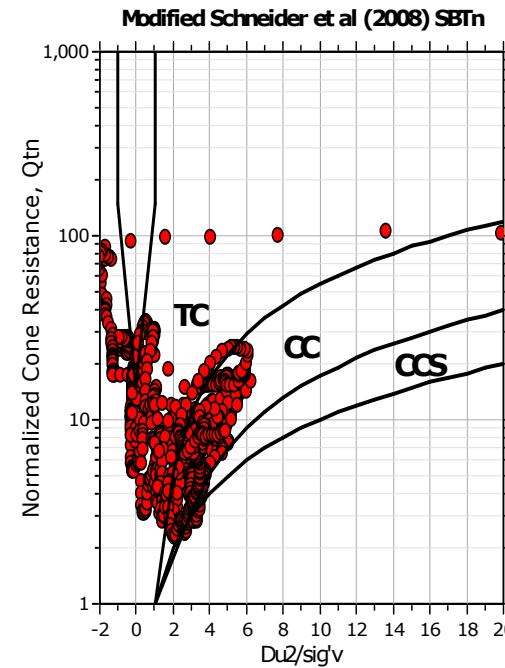
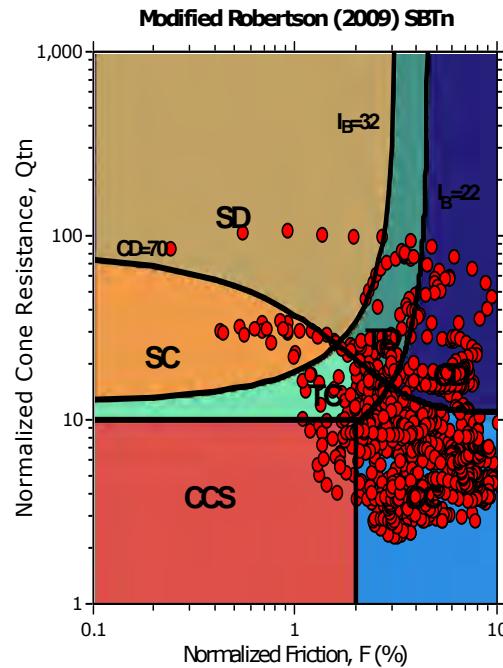
CPT: CPTU7

Total depth: 20.00 m, Date: 24/04/2018

**Mod. SBTn legend**

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

Updated SBTn plots

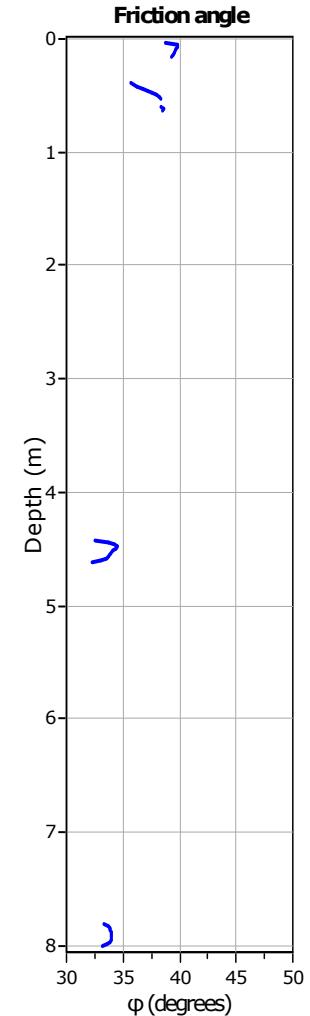
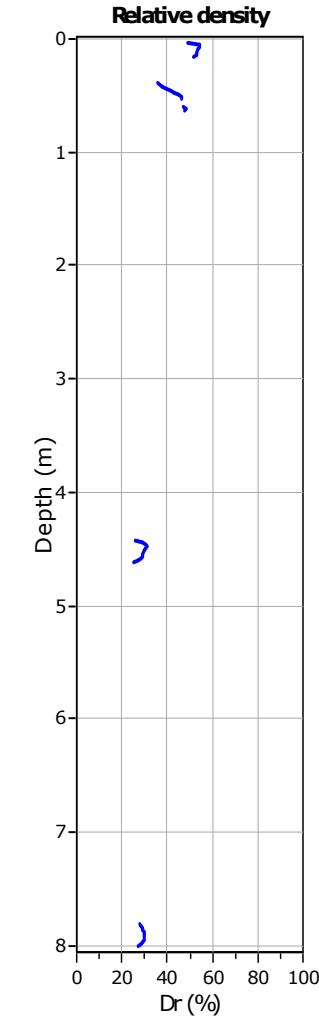
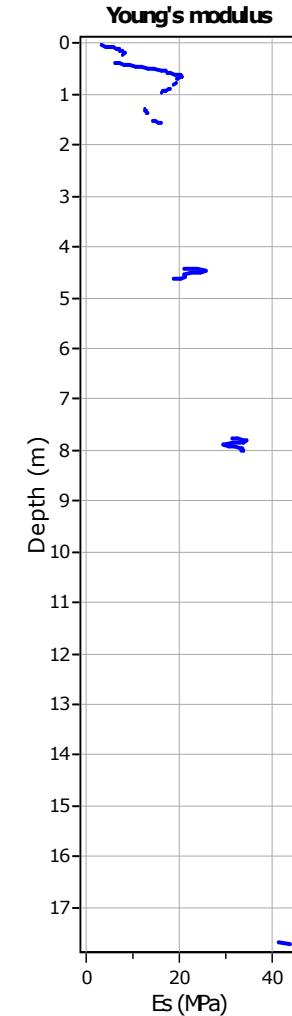
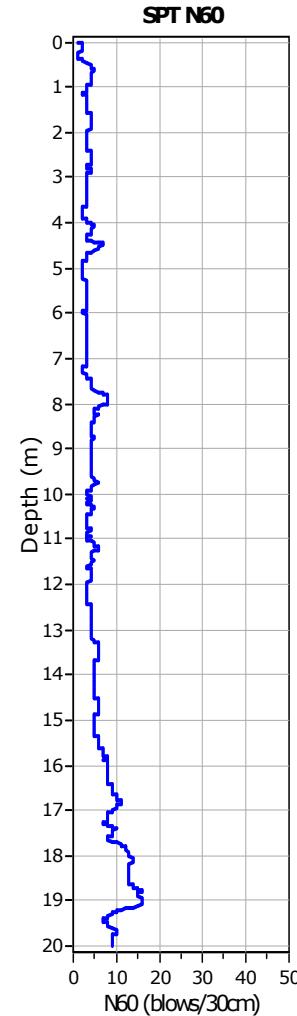
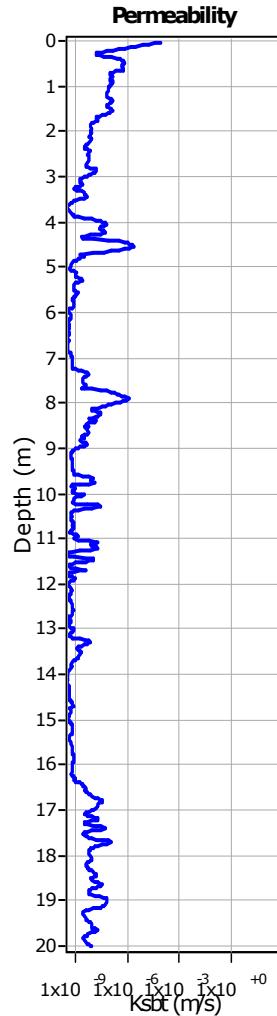


CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

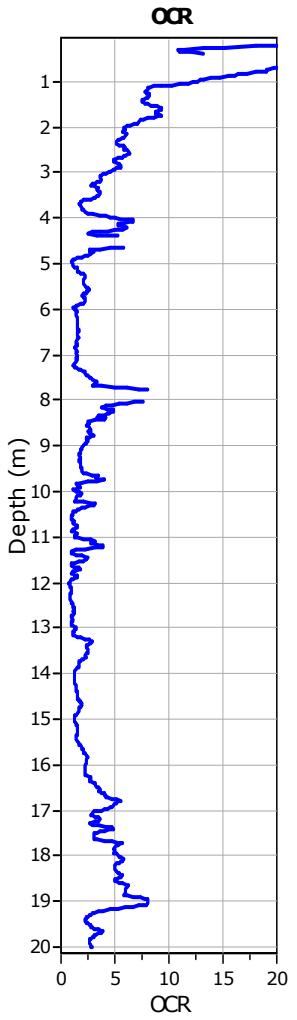
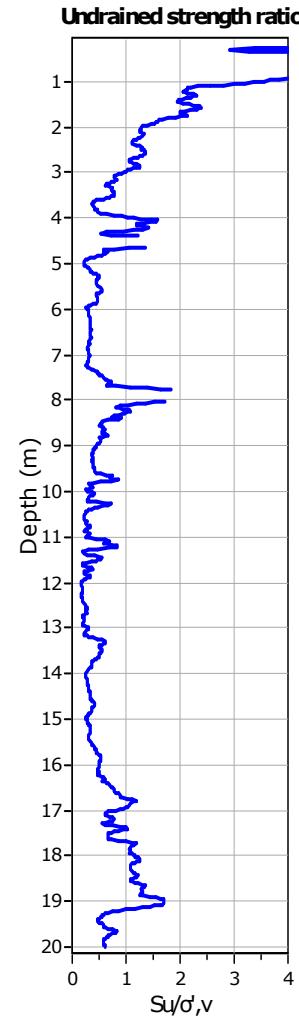
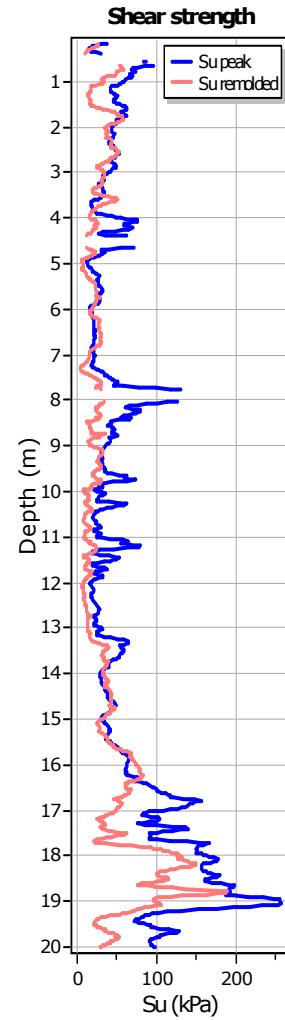
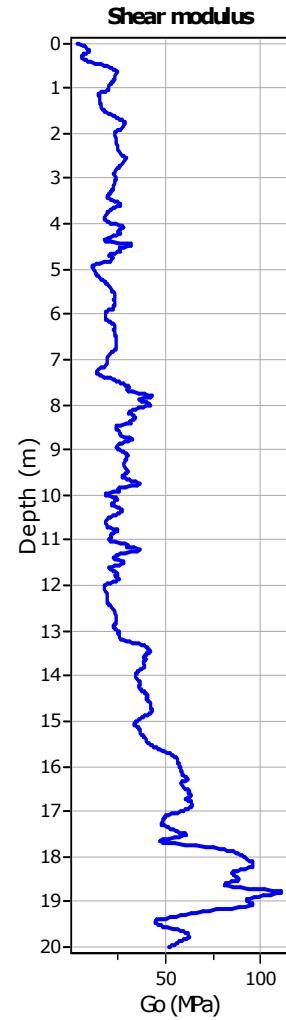
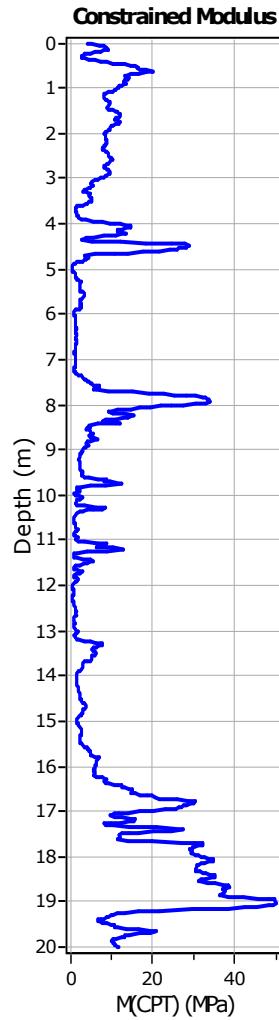
Project:**Location:****CPT: CPTU7**

Total depth: 20.00 m, Date: 24/04/2018

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

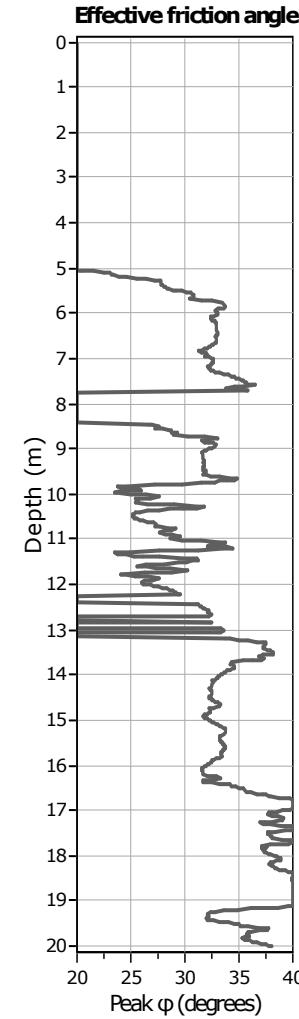
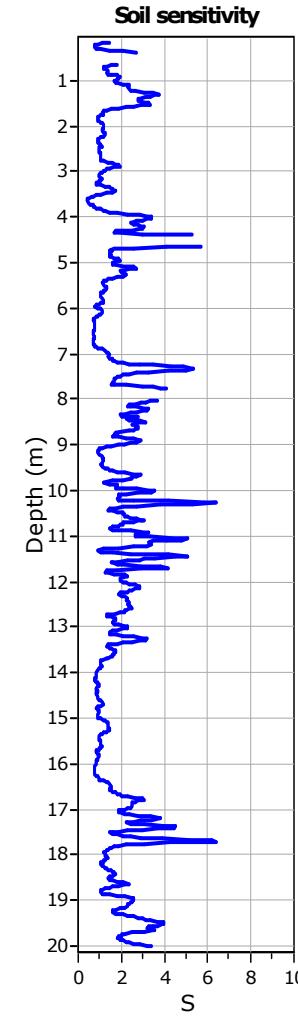
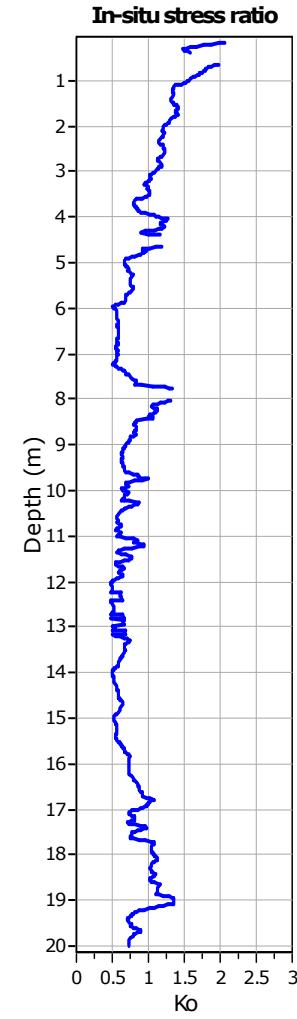
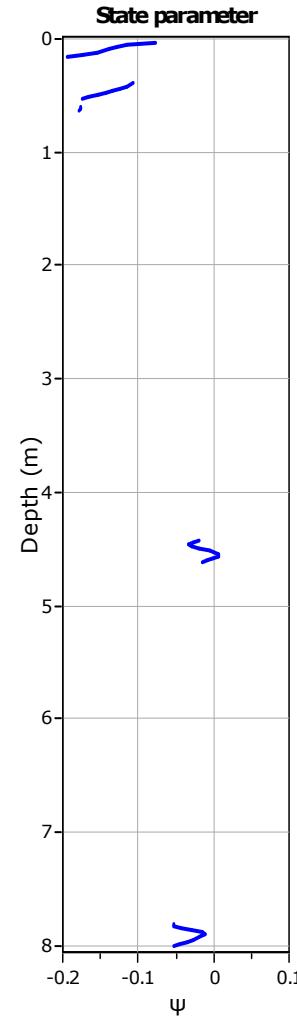
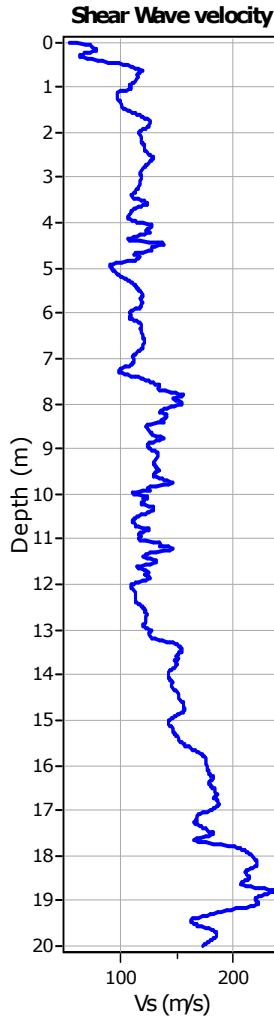
- User defined estimation data
- Flat Dilatometer Test data

Project:

Location:

CPT: CPTU7

Total depth: 20.00 m, Date: 24/04/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

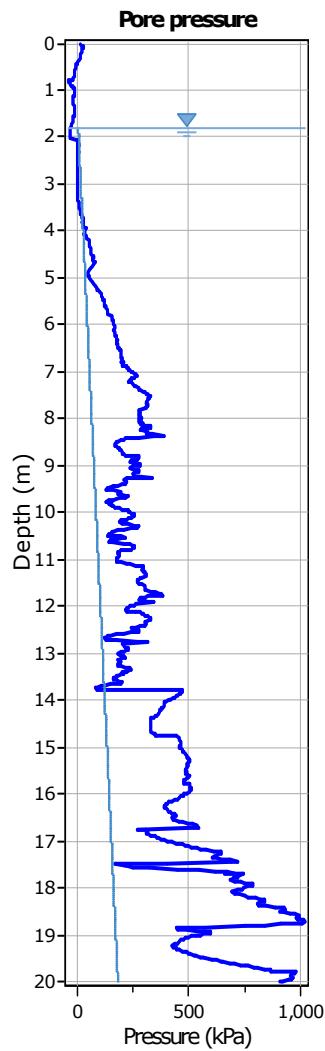
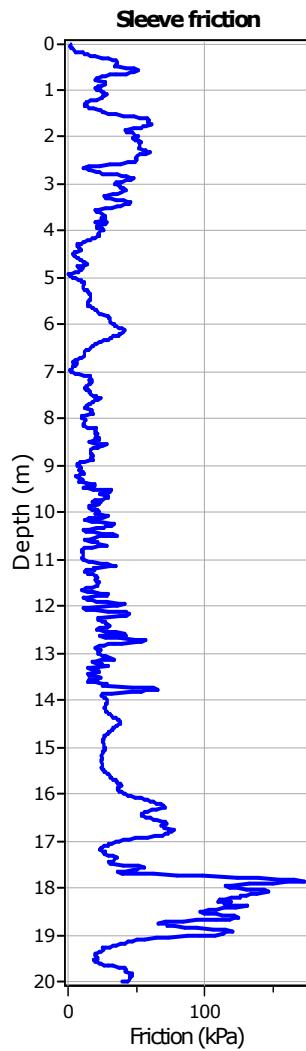
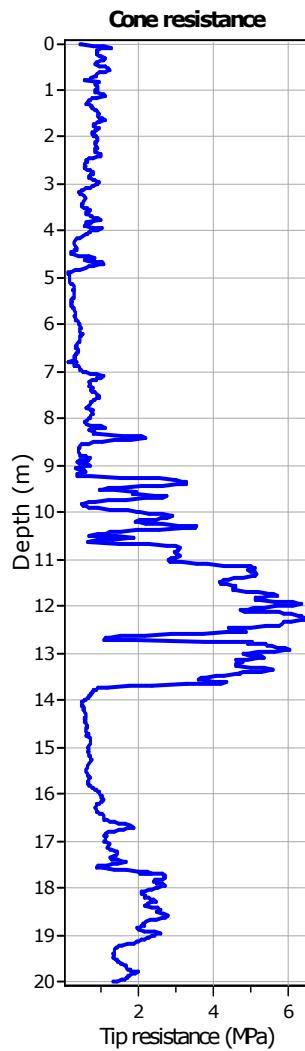
User defined estimation data

Project:

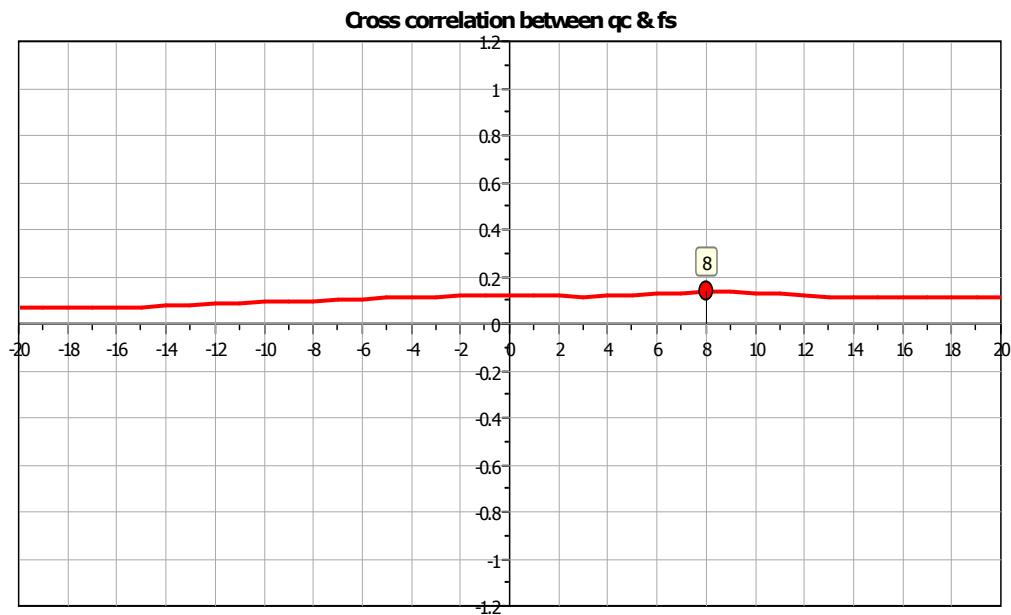
Location:

CPT: CPTU8

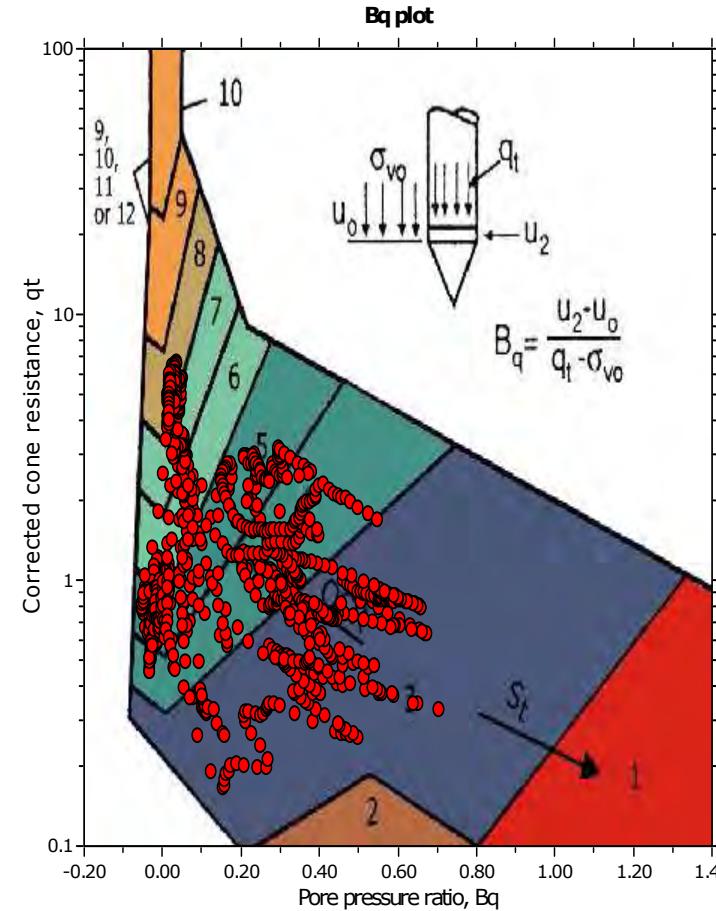
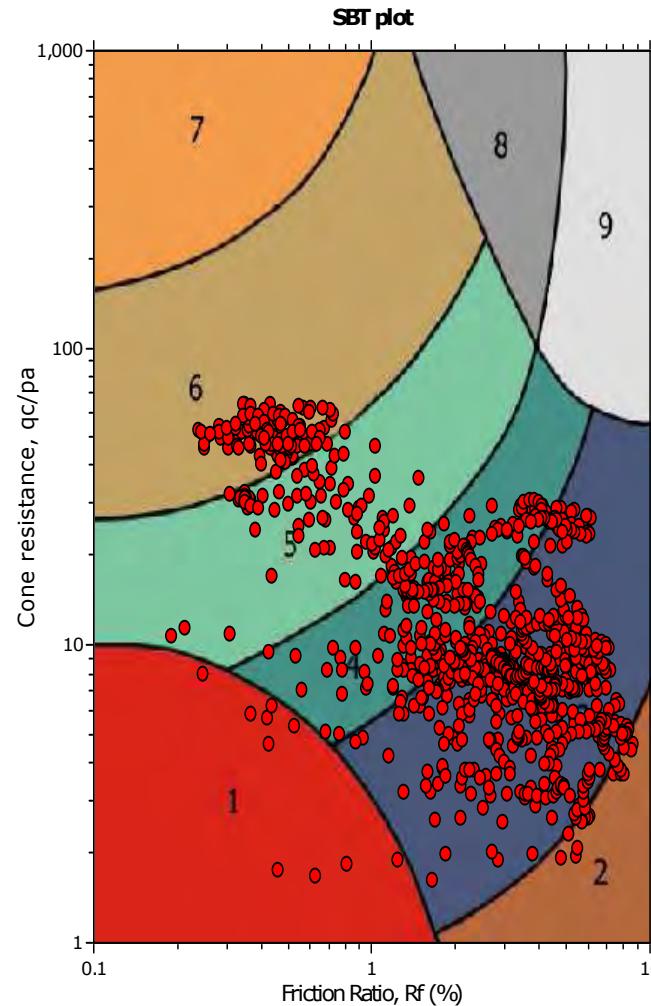
Total depth: 20.00 m, Date: 24/04/2018



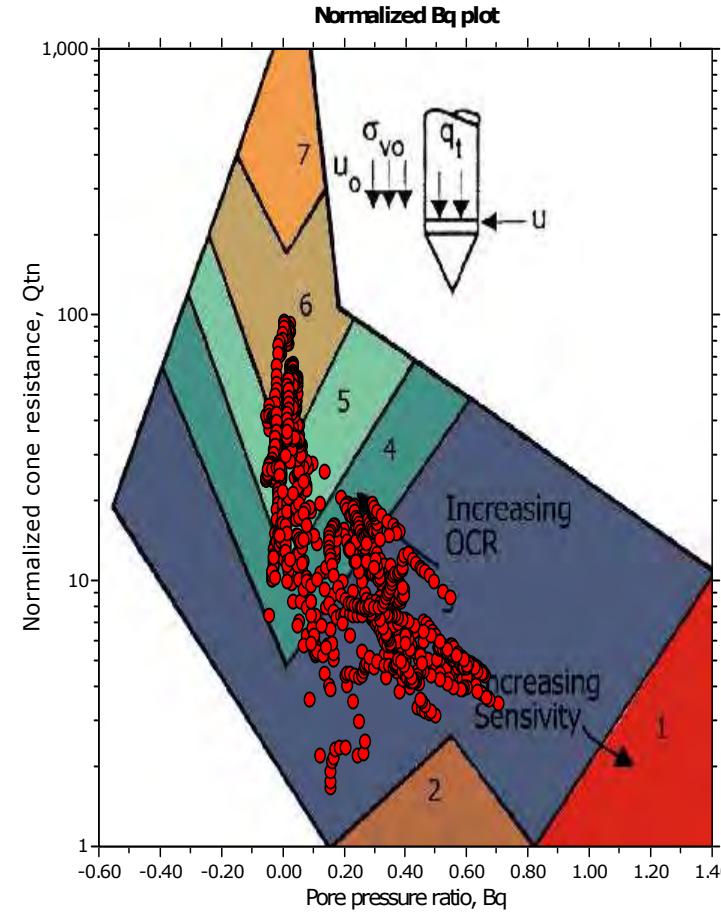
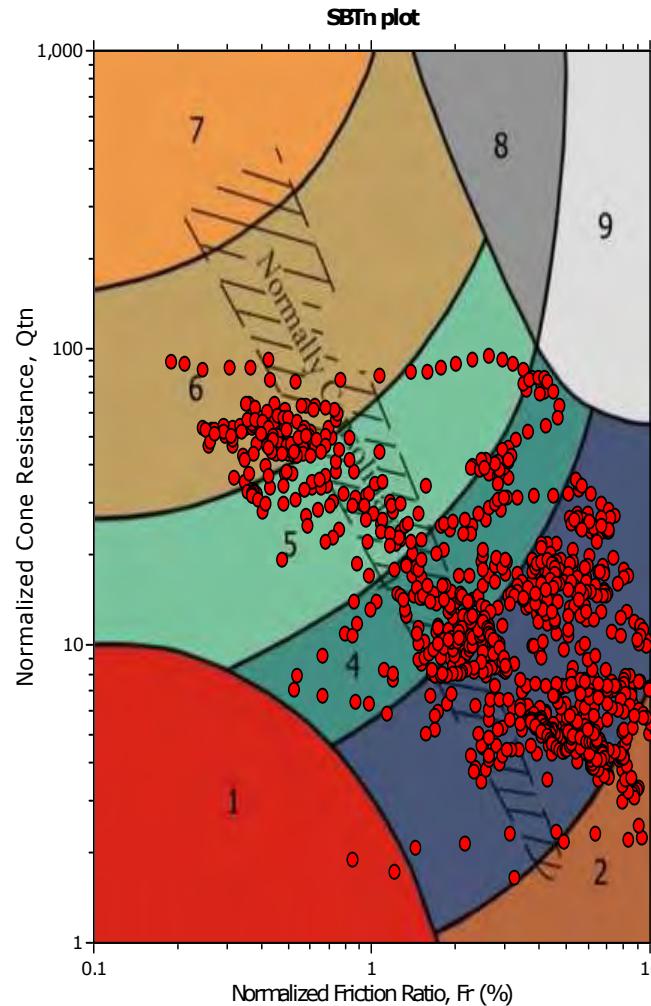
The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



SBT - Bq plots



SBT - Bq plots (normalized)



SBTn legend

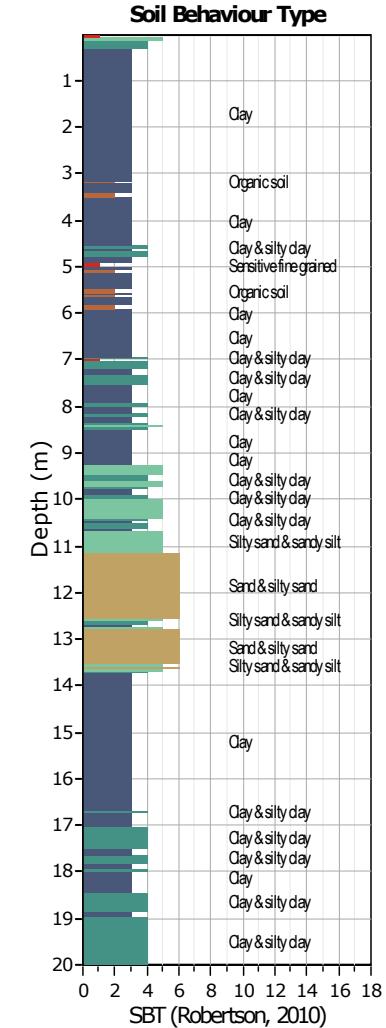
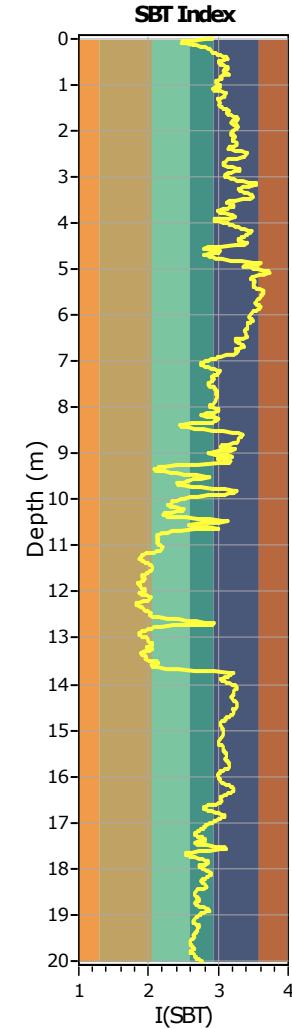
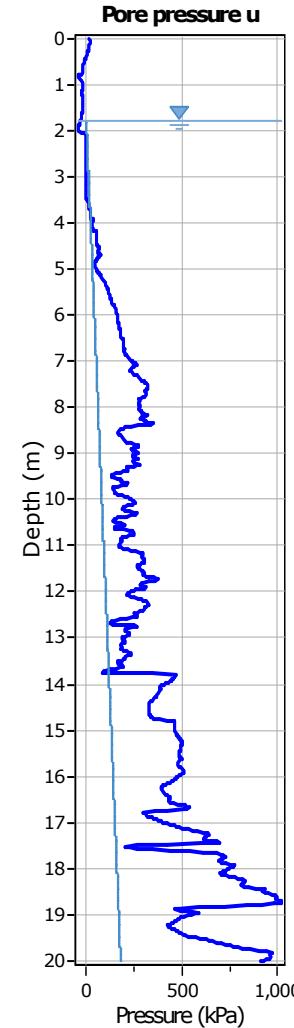
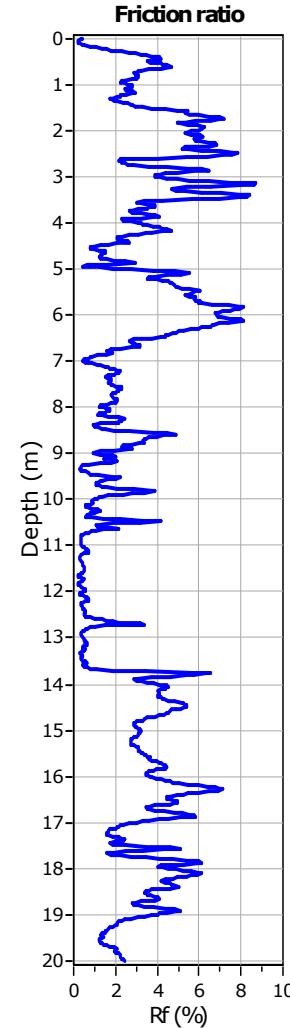
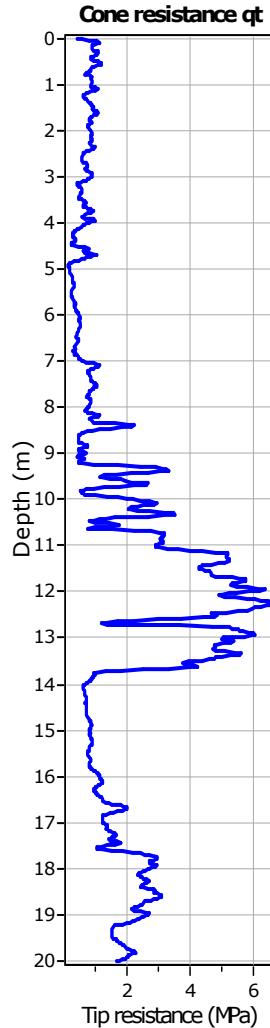
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

Project:

Location:

CPT: CPTU8

Total depth: 20.00 m, Date: 24/04/2018

**SBT legend**

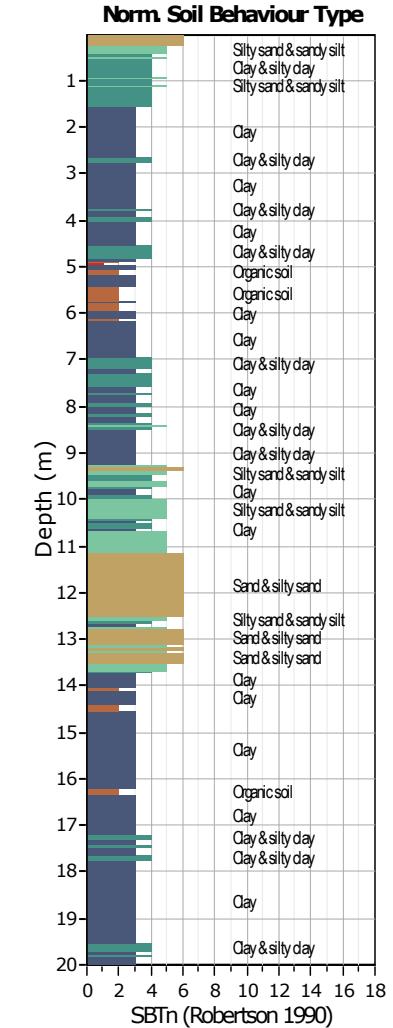
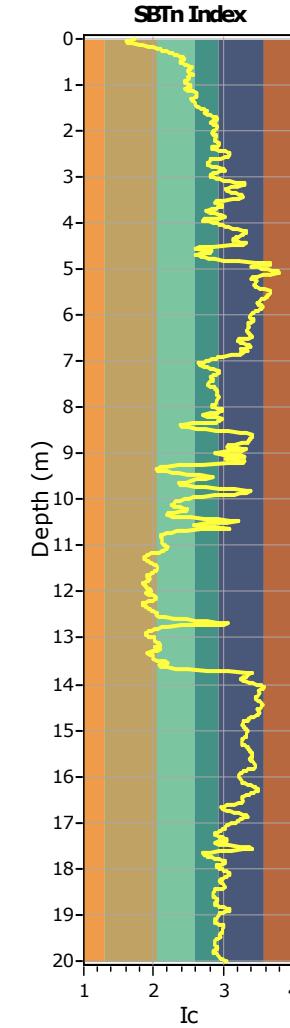
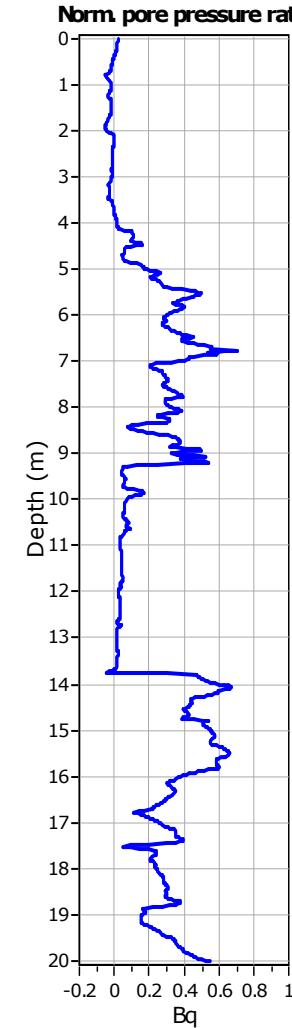
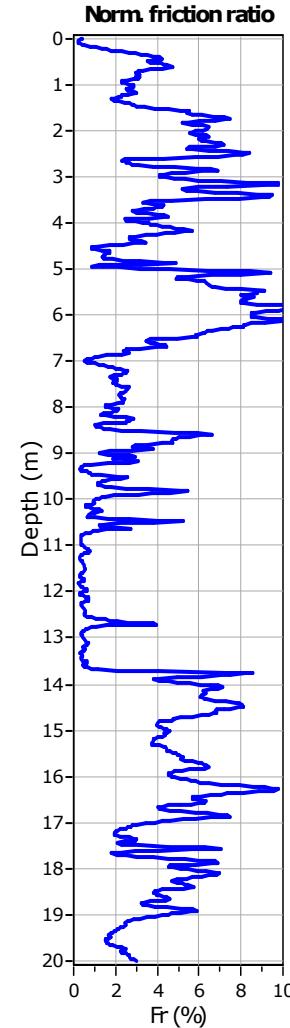
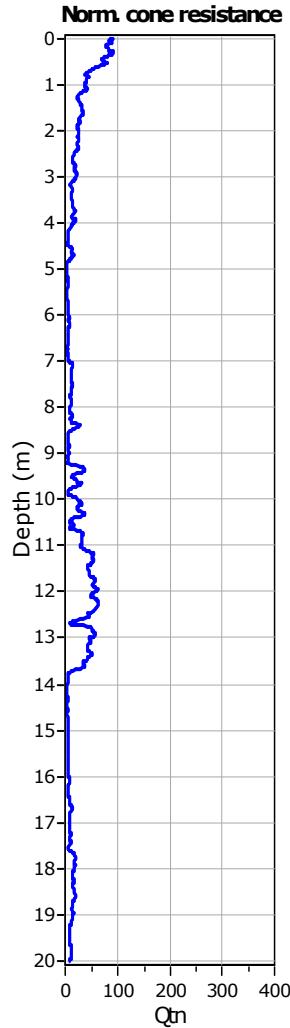
- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

Project:

Location:

CPT: CPTU8

Total depth: 20.00 m, Date: 24/04/2018

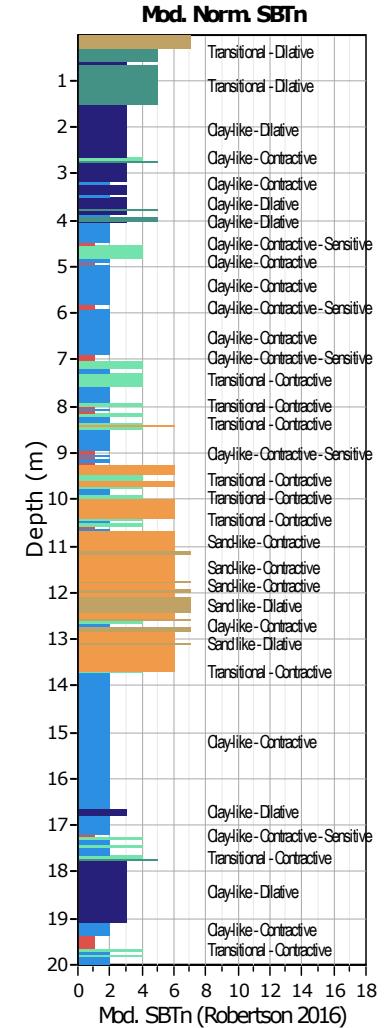
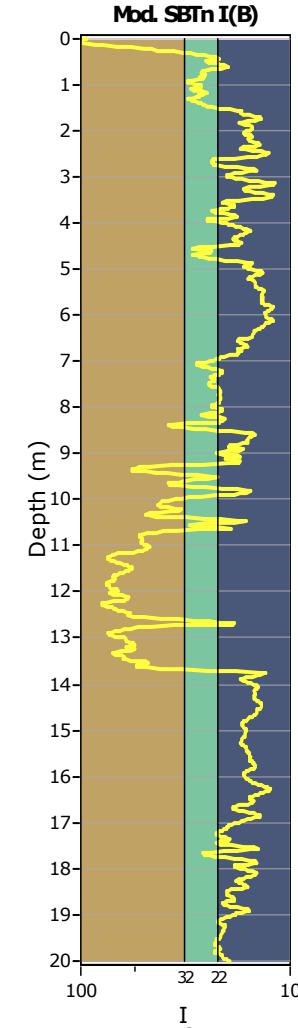
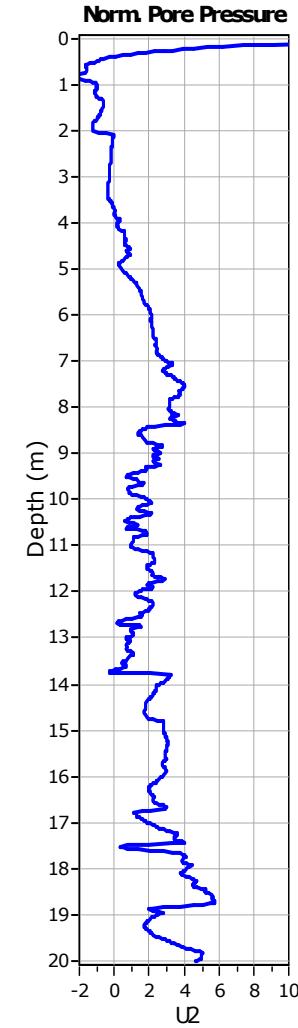
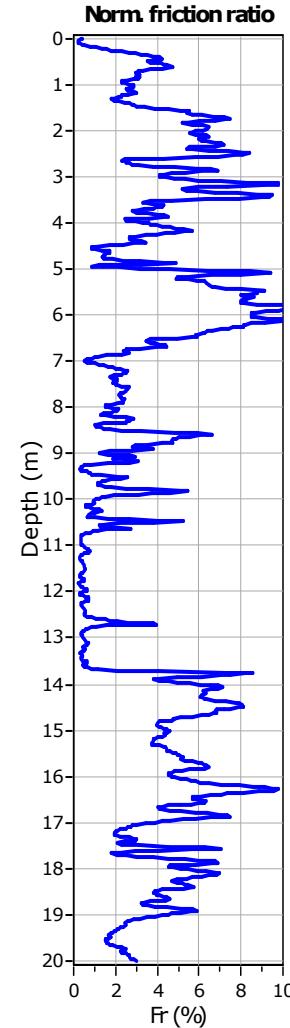
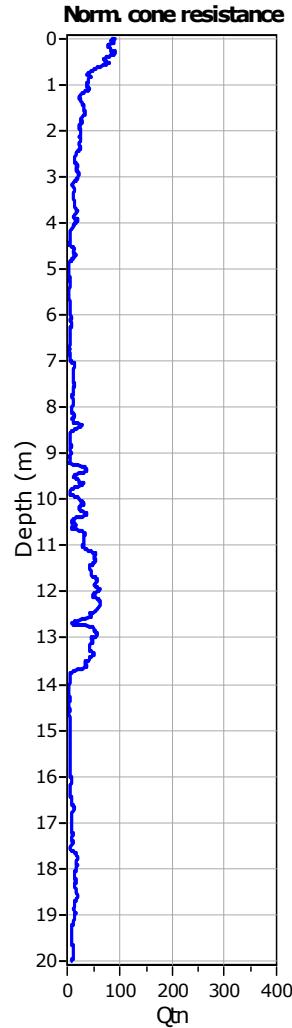


Project:

Location:

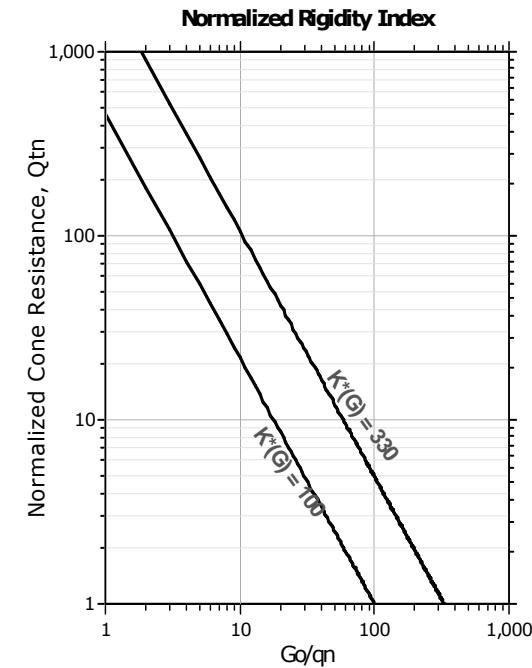
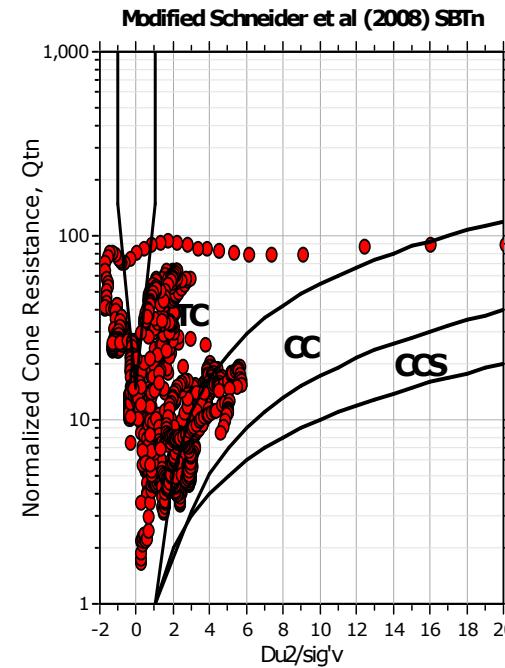
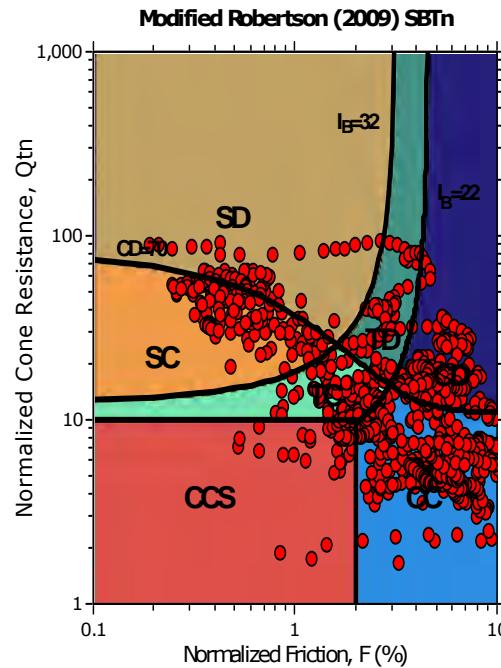
CPT: CPTU8

Total depth: 20.00 m, Date: 24/04/2018

**Mod. SBTn legend**

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

Updated SBTn plots



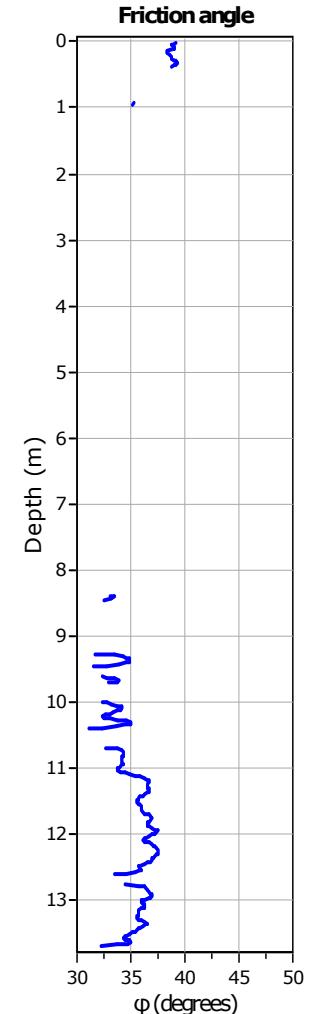
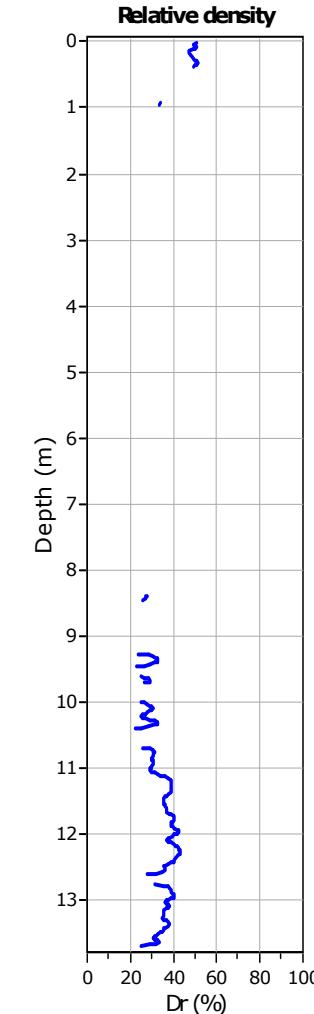
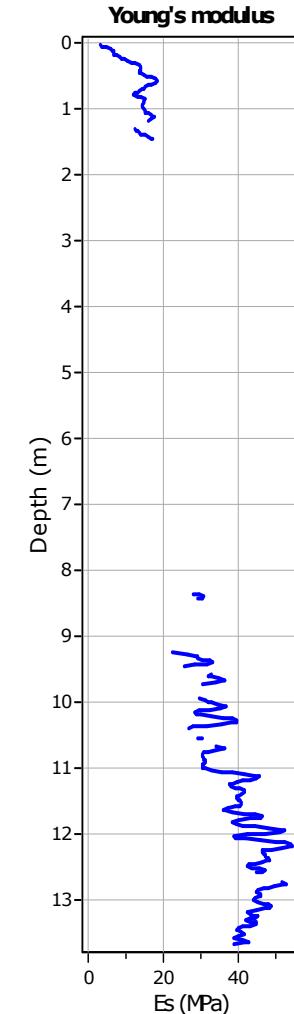
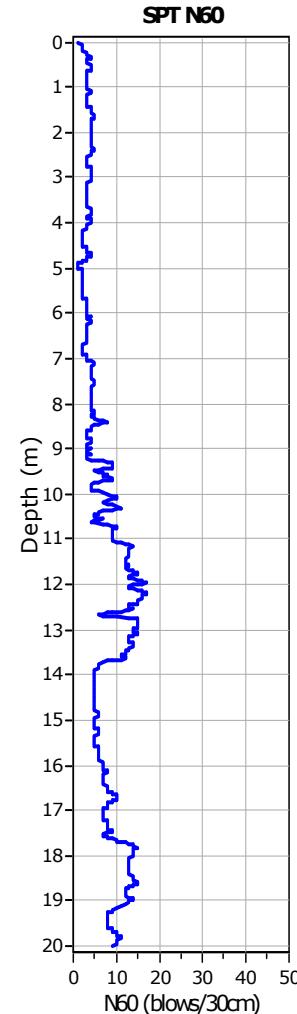
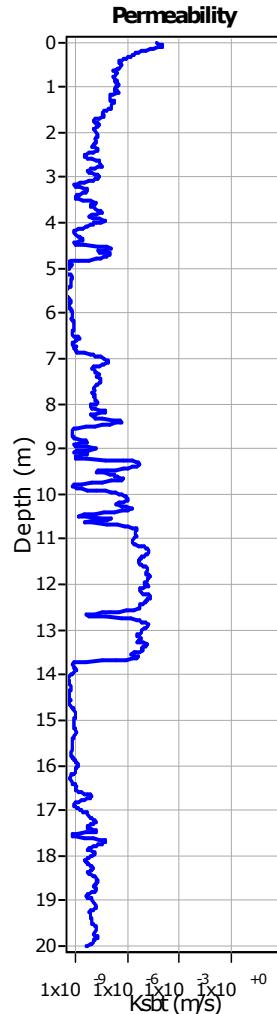
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

Project:

Location:

CPT: CPTU8

Total depth: 20.00 m, Date: 24/04/2018



Calculation parameters

Permeability: Based on SBT_n

SPT N₆₀: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

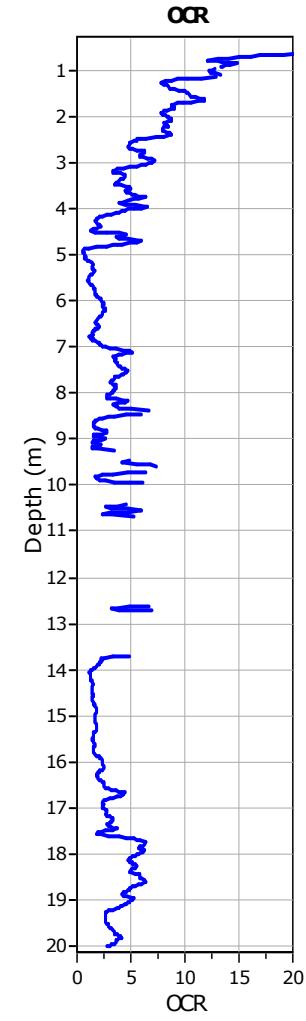
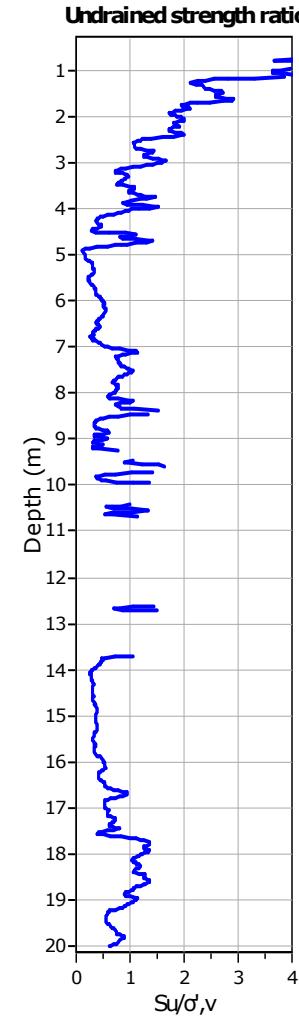
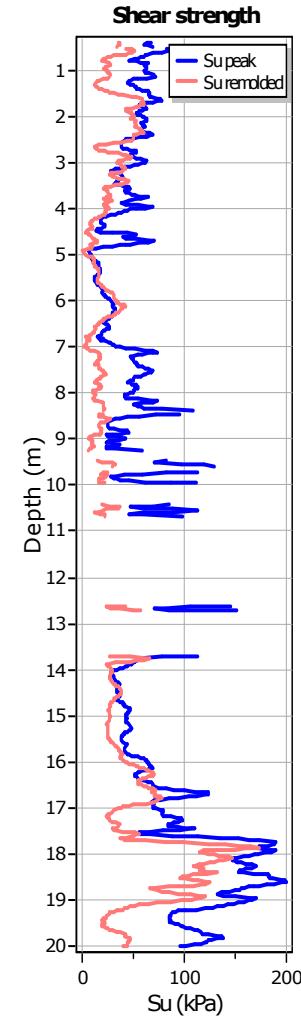
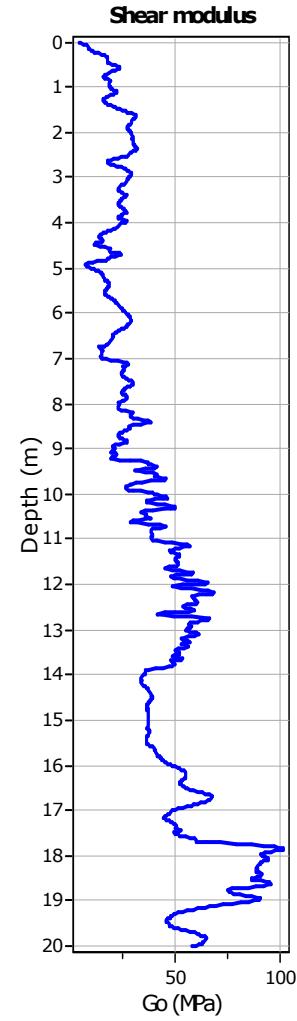
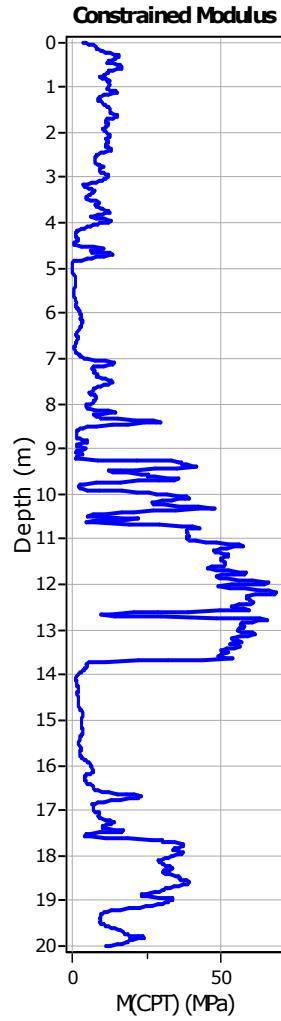
User defined estimation data

Project:

Location:

CPT: CPTU8

Total depth: 20.00 m, Date: 24/04/2018

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

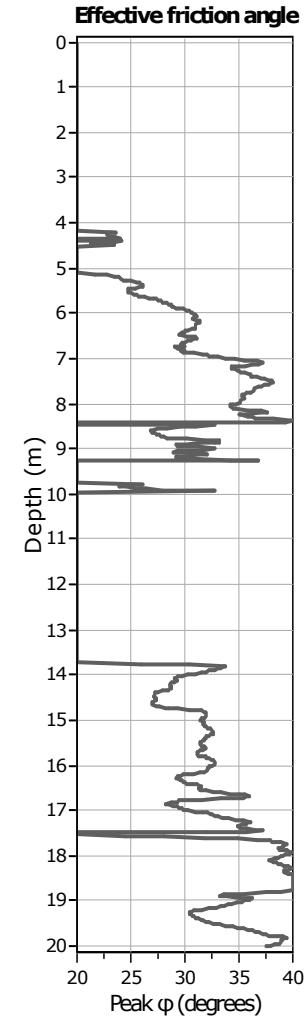
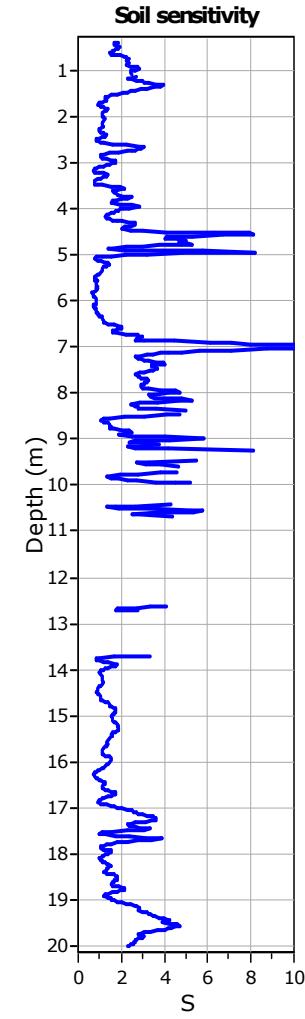
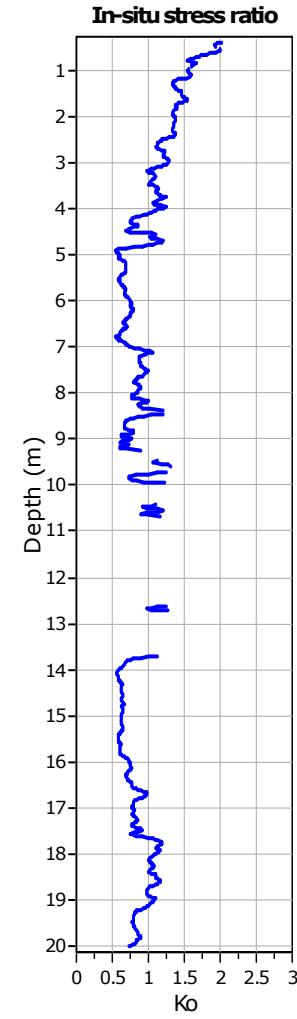
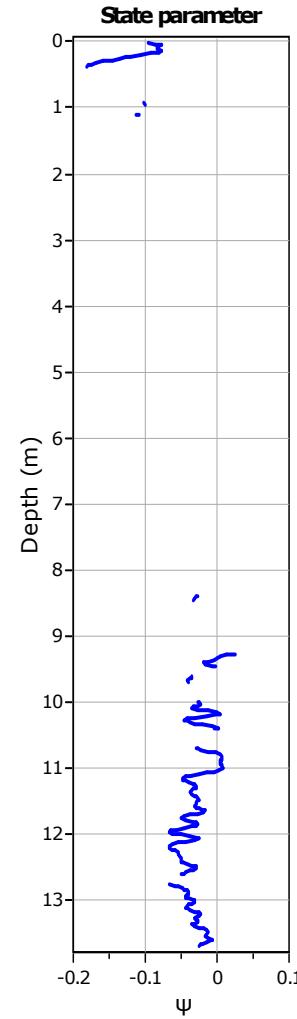
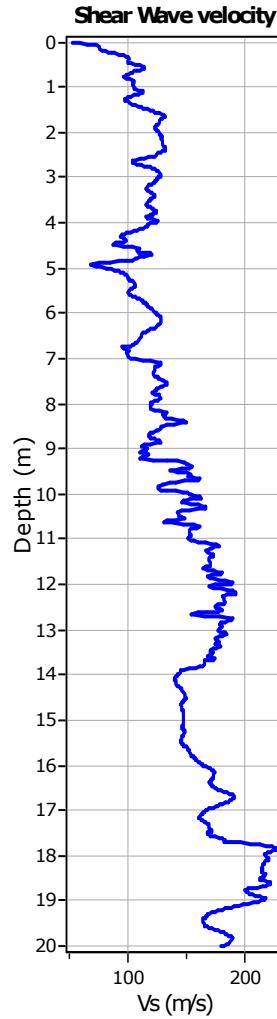
- User defined estimation data
- Flat Dilatometer Test data

Project:

Location:

CPT: CPTU8

Total depth: 20.00 m, Date: 24/04/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

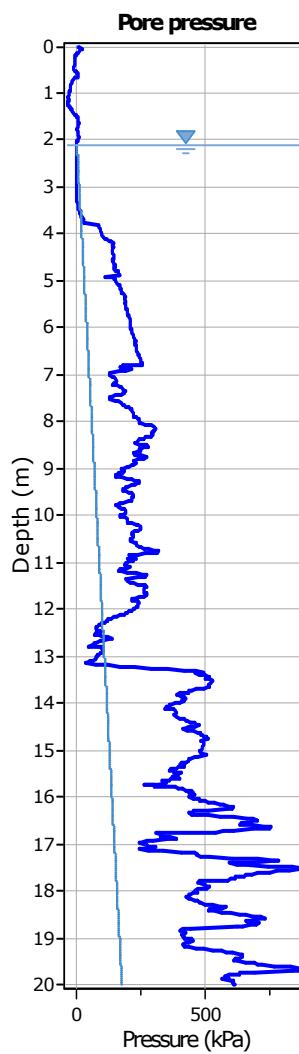
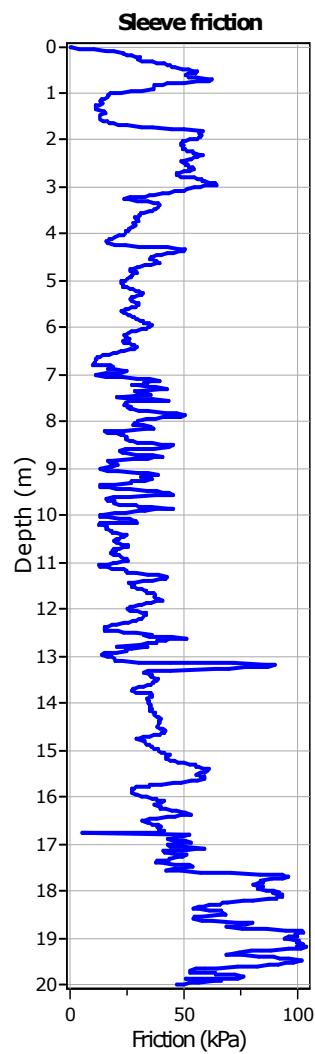
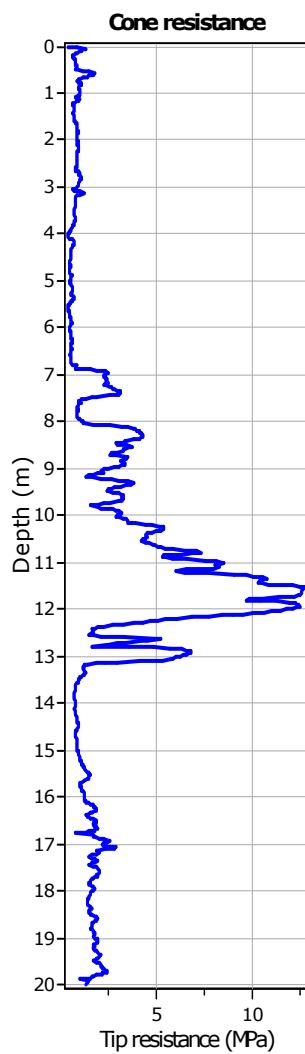
User defined estimation data

Project:

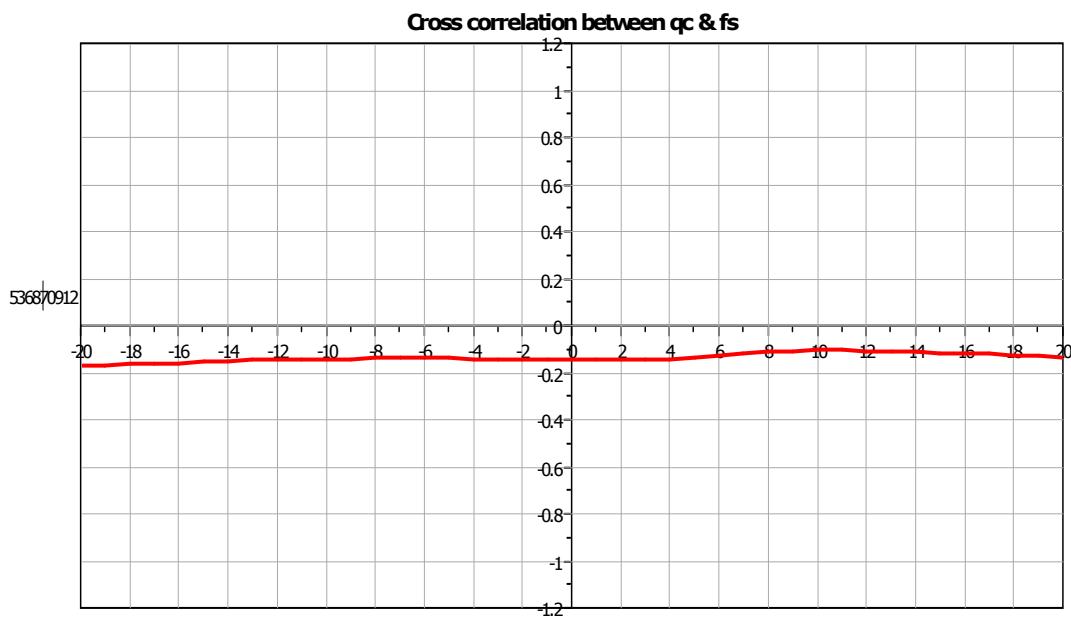
Location:

CPT: CPTU6

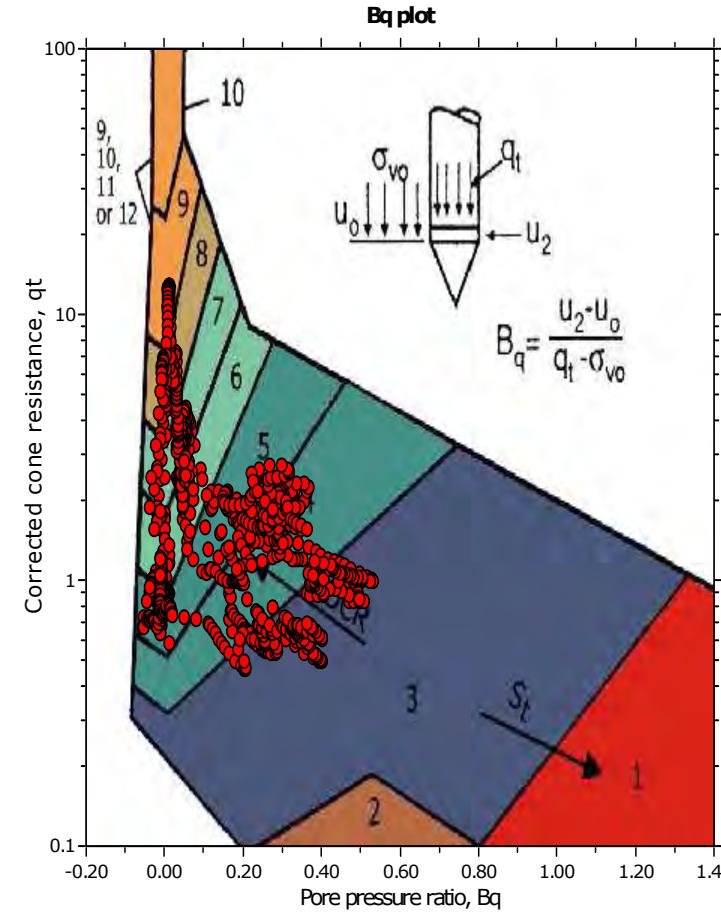
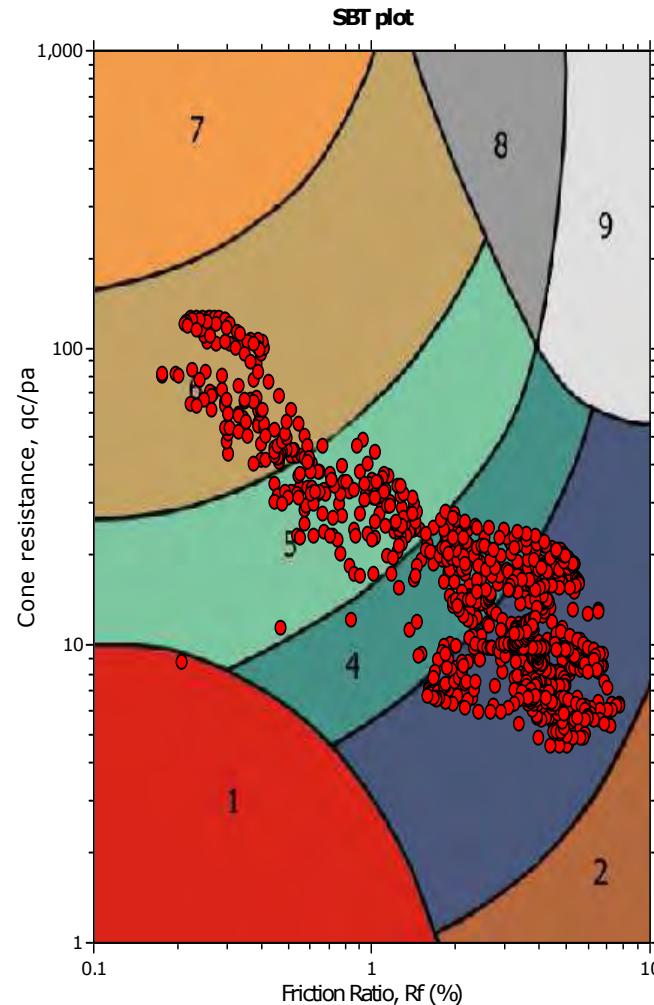
Total depth: 20.00 m, Date: 24/04/2018



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



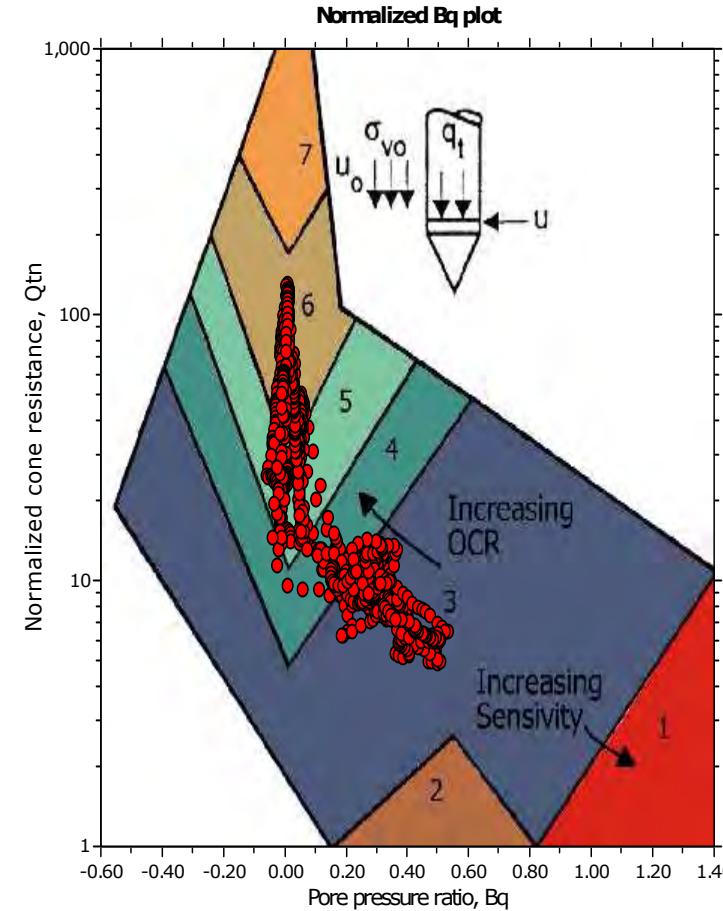
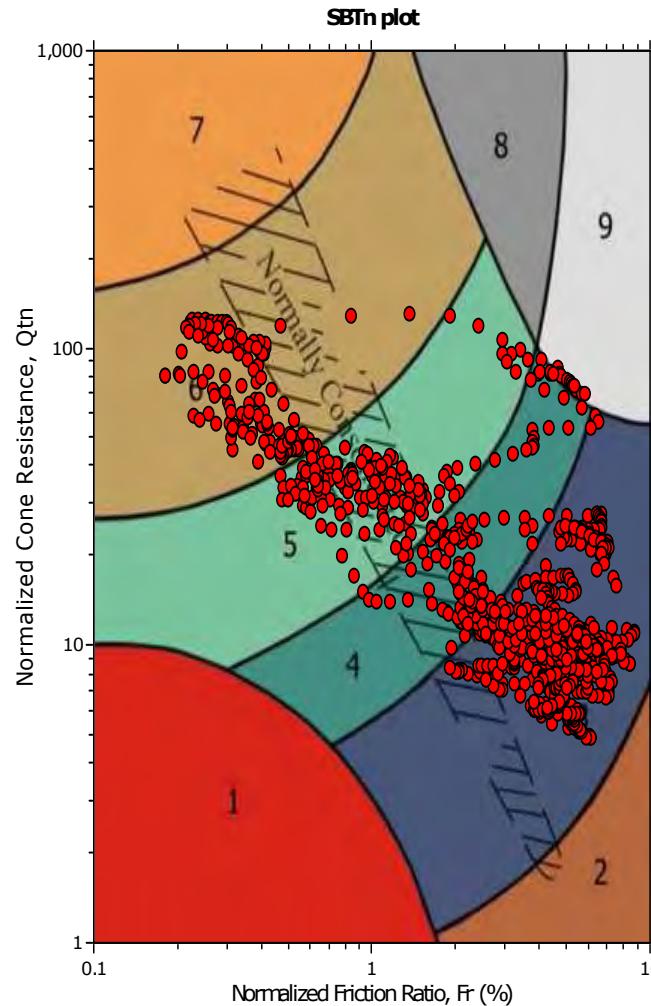
SBT - Bq plots



SBT legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

SBT - Bq plots (normalized)



SBTn legend

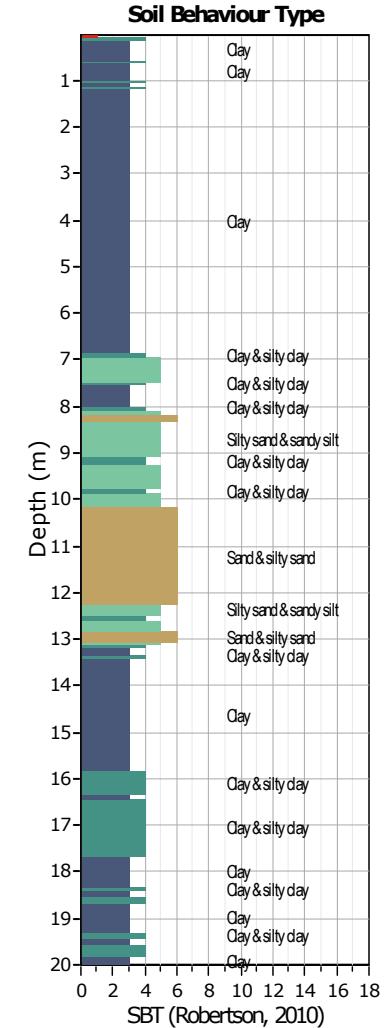
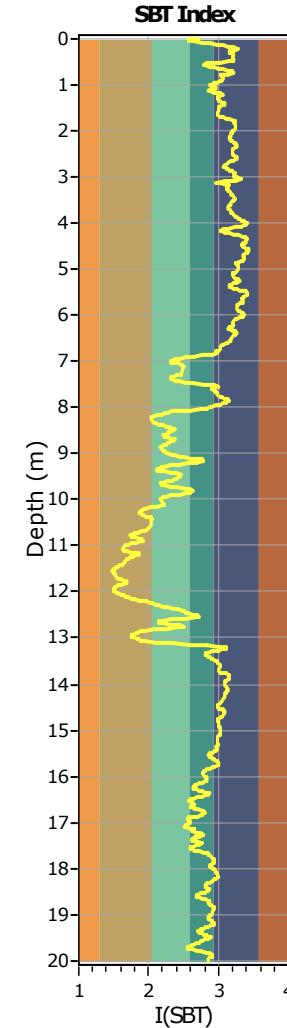
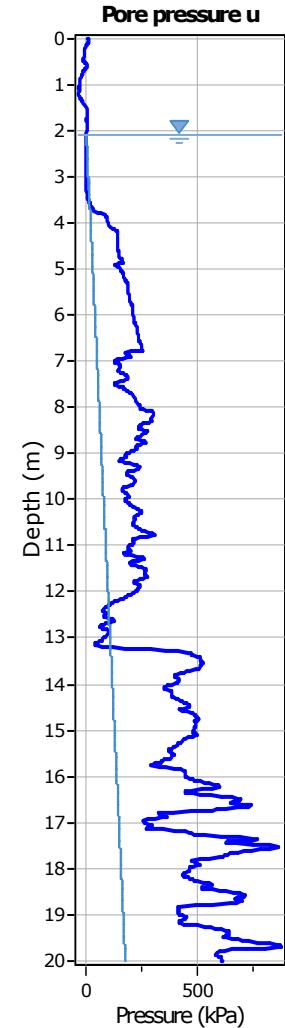
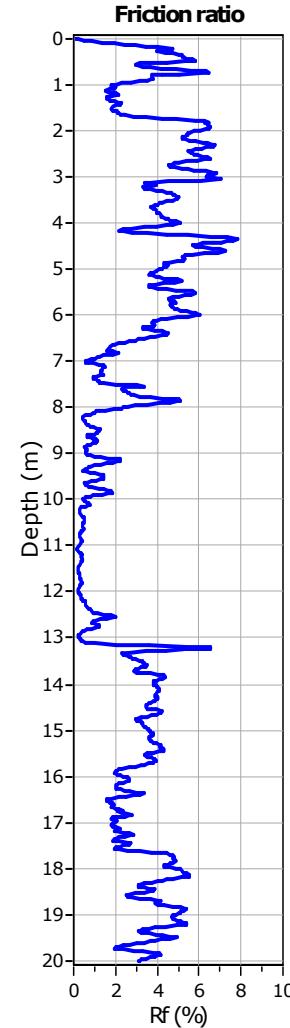
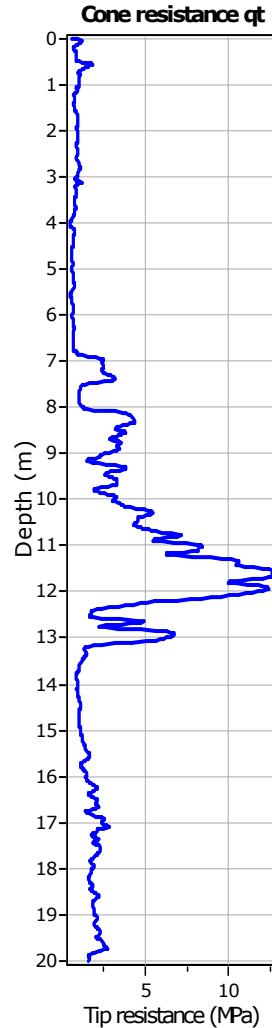
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

Project:

Location:

CPT: CPTU6

Total depth: 20.00 m, Date: 24/04/2018

**SBT legend**

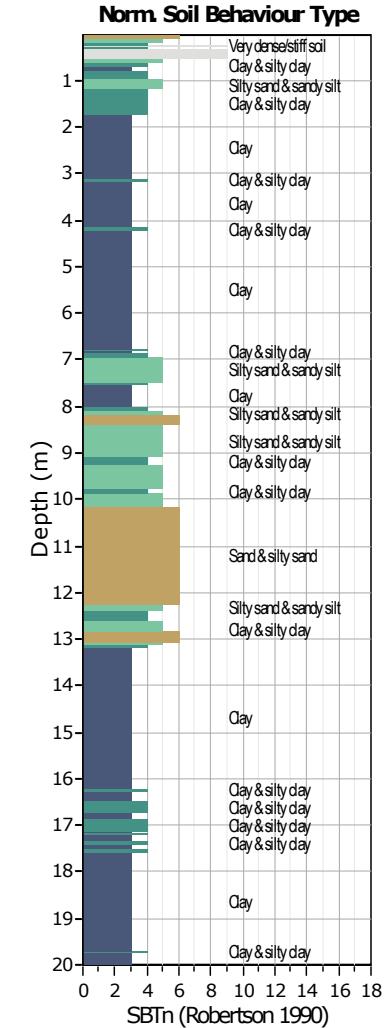
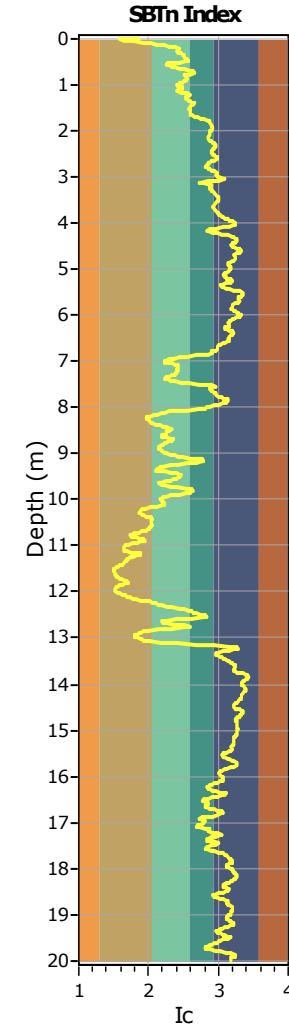
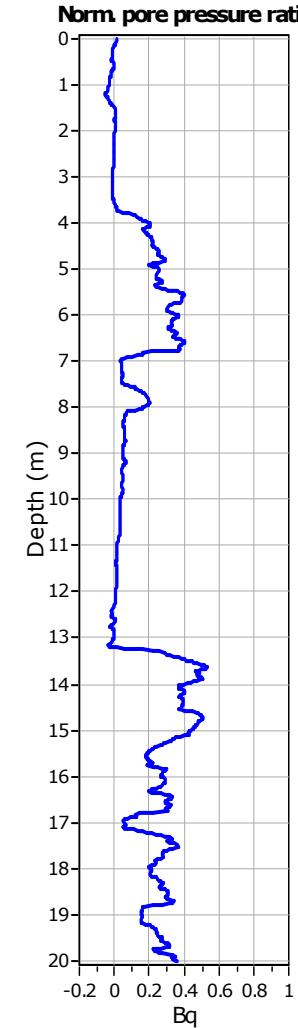
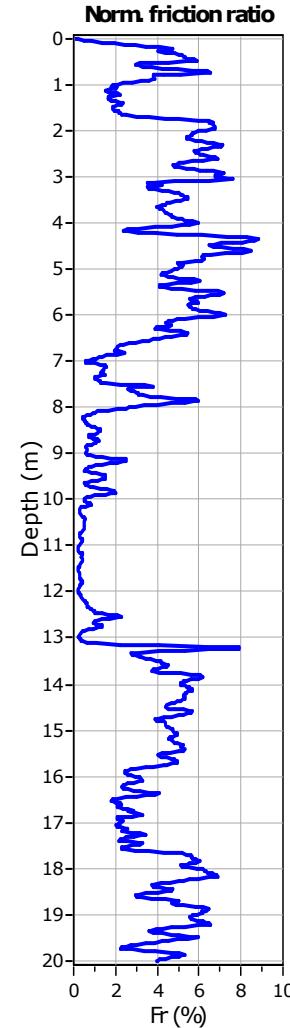
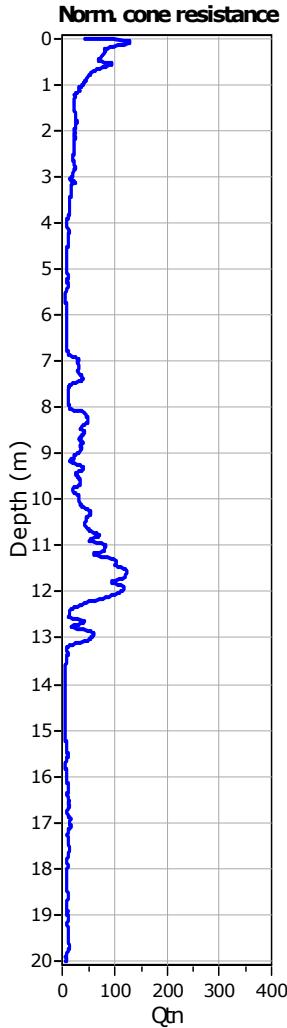
- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Project:

Location:

CPT: CPTU6

Total depth: 20.00 m, Date: 24/04/2018

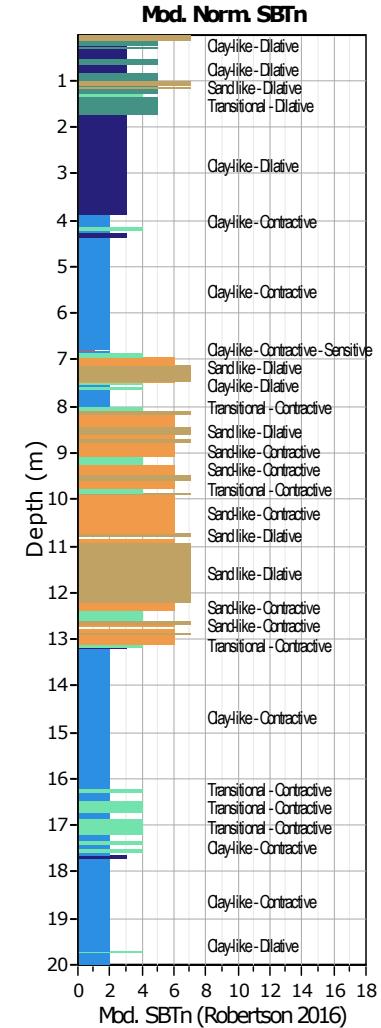
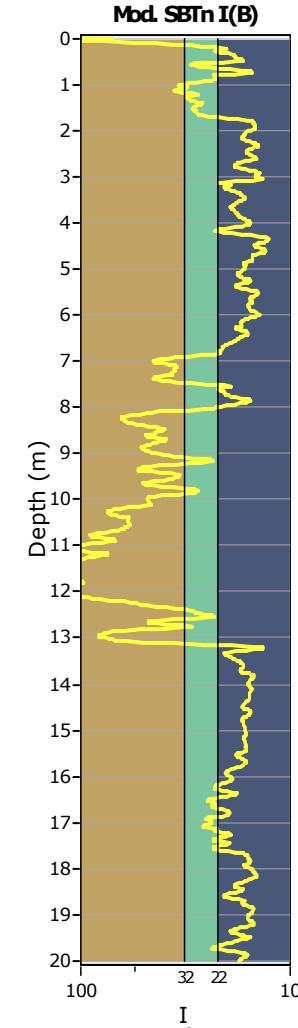
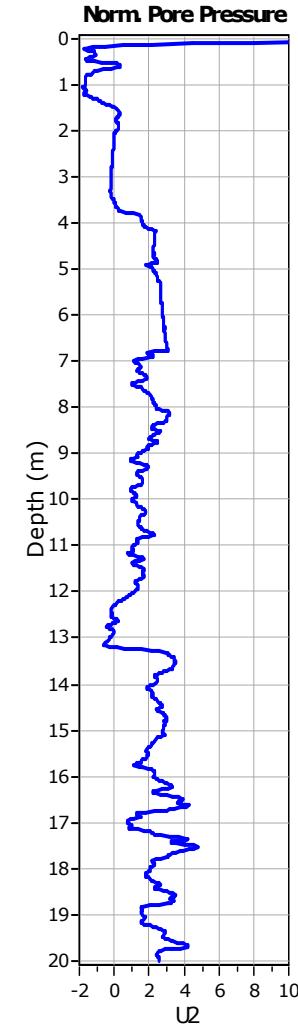
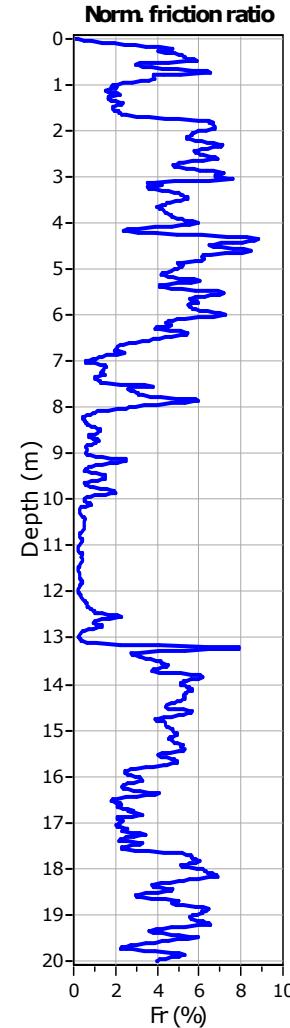
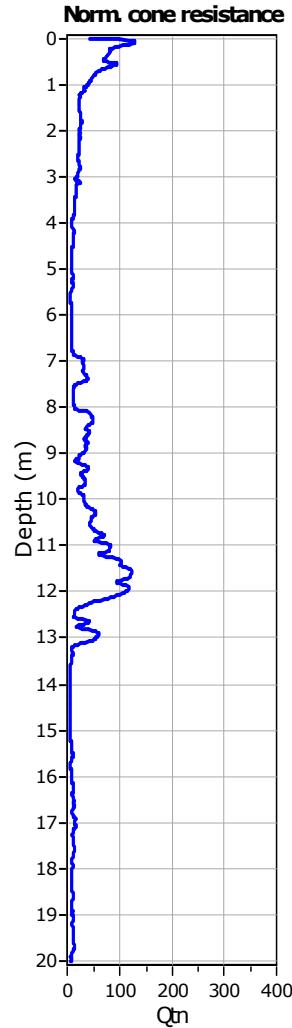


Project:

Location:

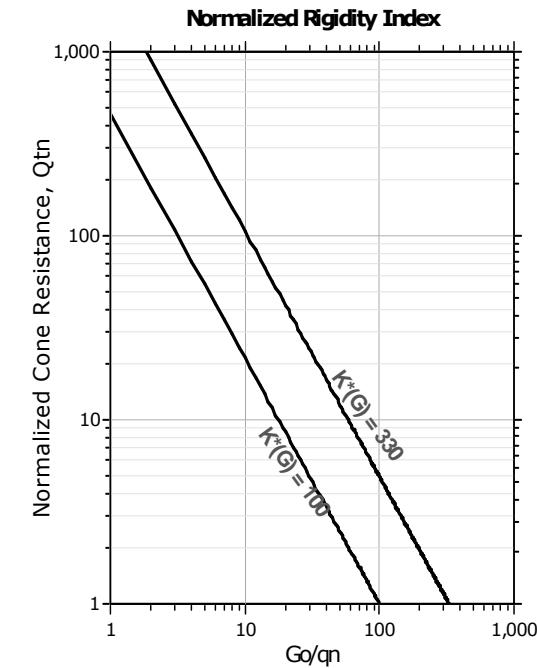
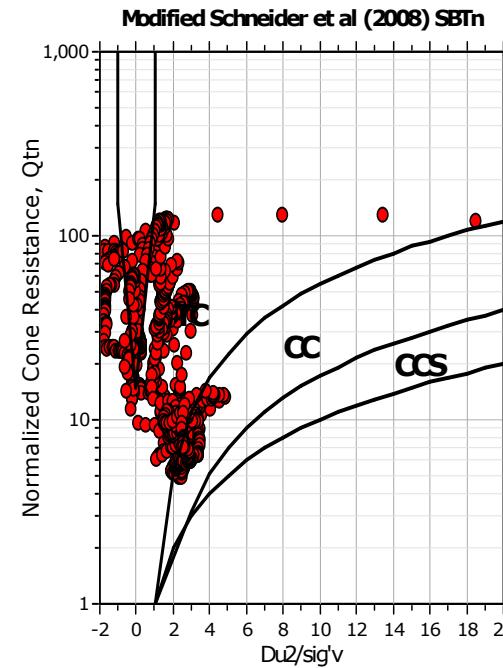
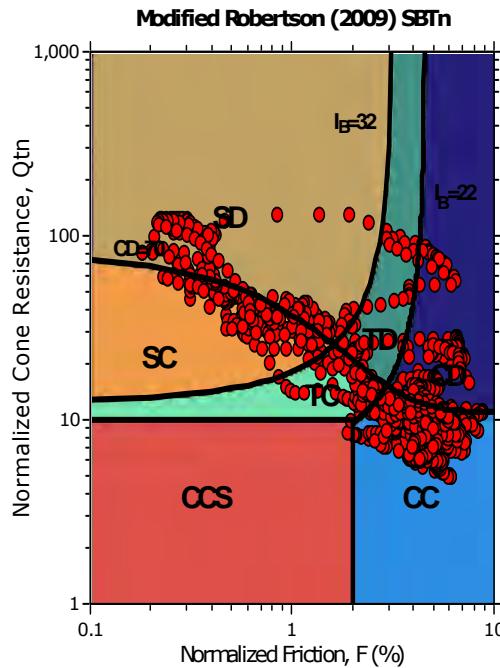
CPT: CPTU6

Total depth: 20.00 m, Date: 24/04/2018

**Mod. SBTn legend**

- | | | |
|---|-----------------------------------|-----------------------------|
| 1. CCS: ClayLike - Contractive, Sensitive | 4. TC: Transitional - Contractive | 7. SD: Sand-like - Dilative |
| 2. CC: Clay-like - Contractive | 5. TD: Transitional - Dilative | |
| 3. CD: Clay-Like: Dilative | 6. SC: Sand-like - Contractive | |

Updated SBTn plots

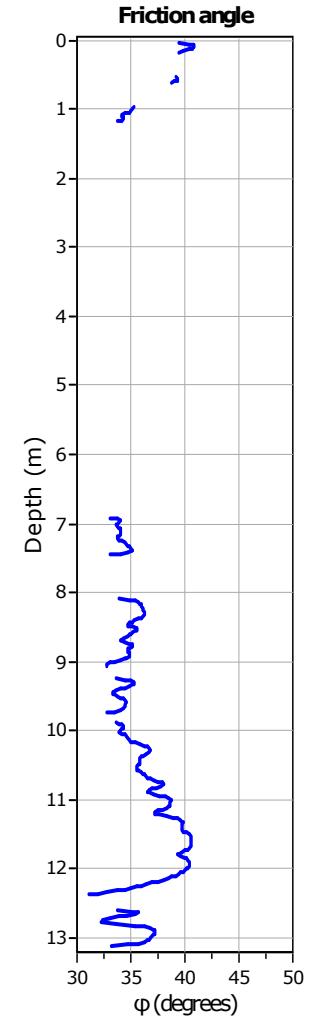
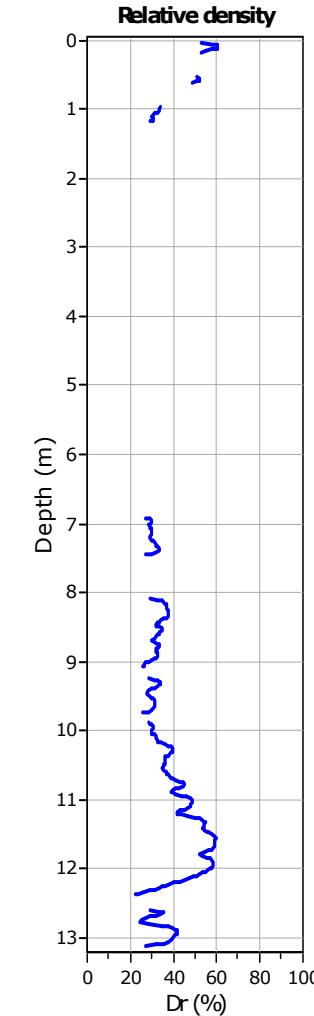
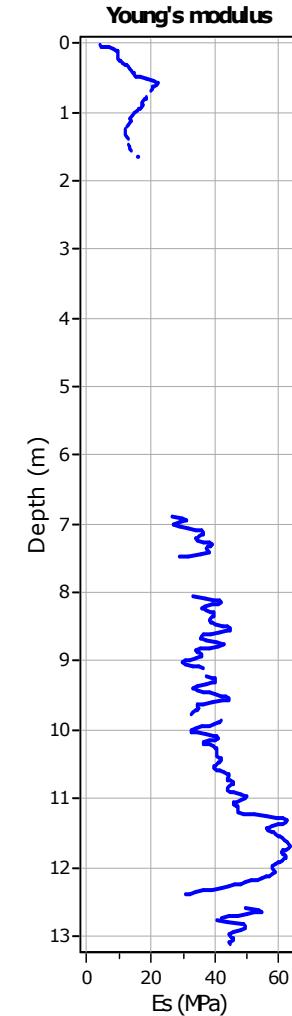
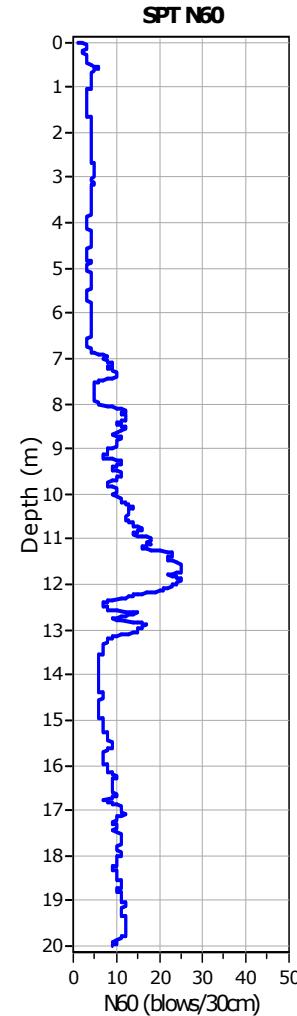
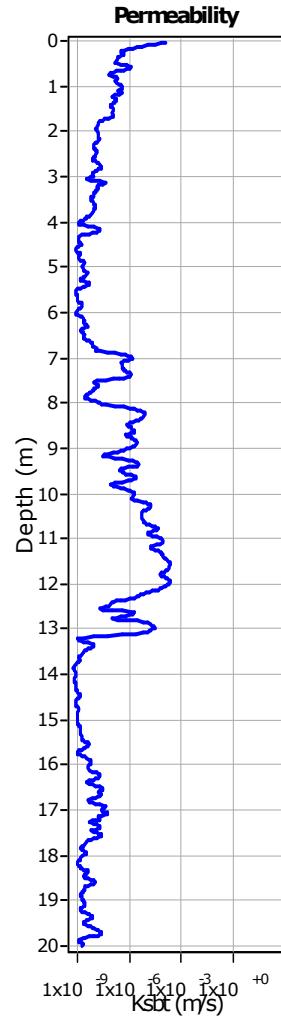


CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

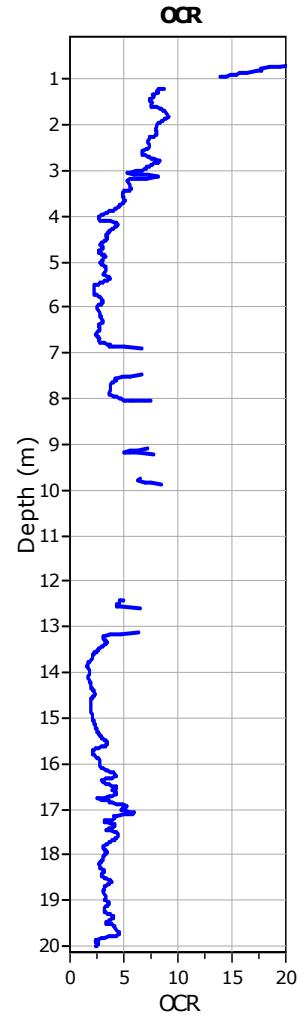
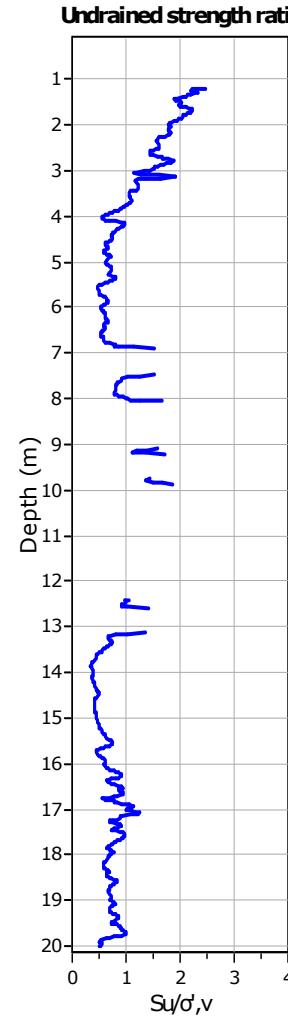
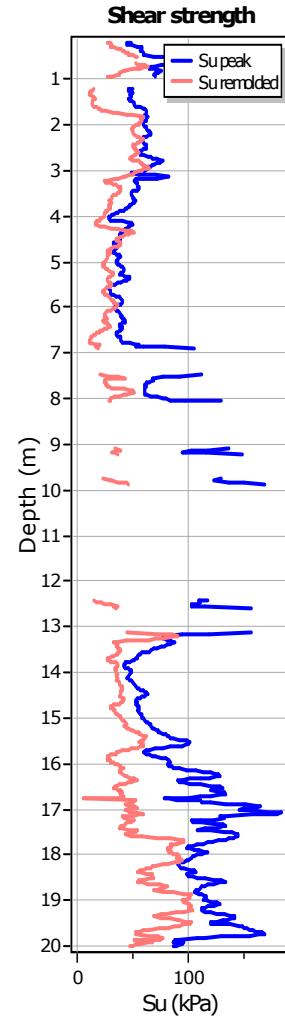
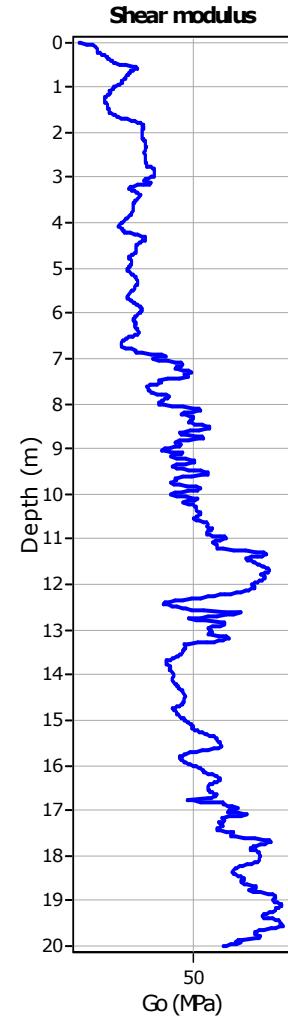
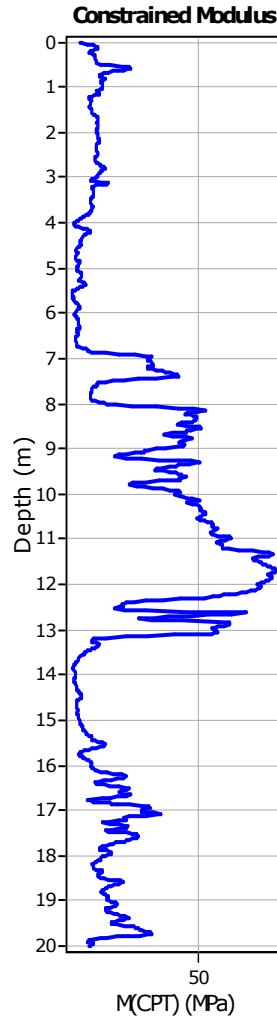
Project:**Location:****CPT: CPTU6**

Total depth: 20.00 m, Date: 24/04/2018

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

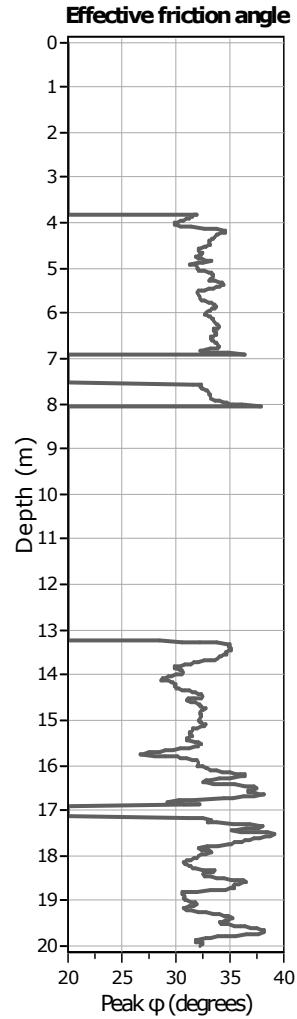
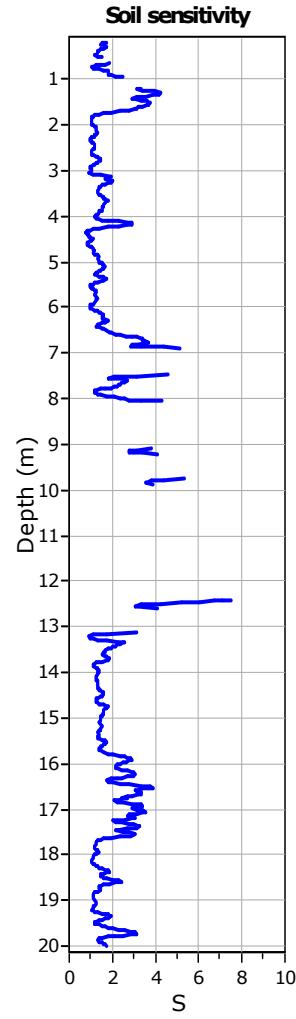
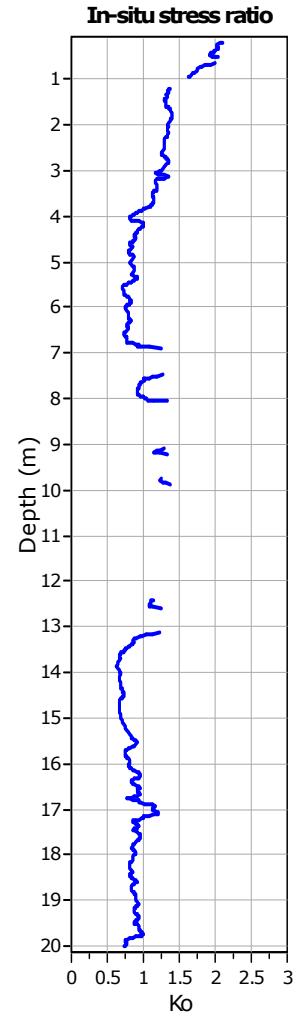
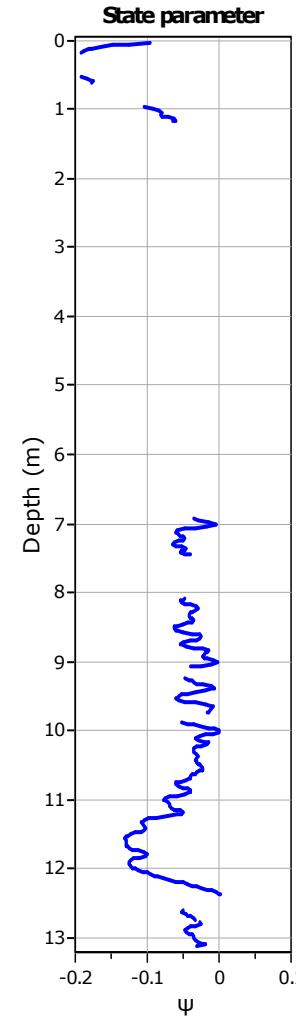
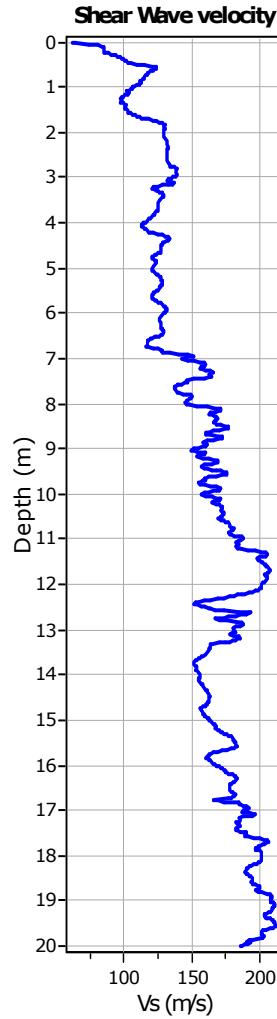
- User defined estimation data
- Flat Dilatometer Test data

Project:

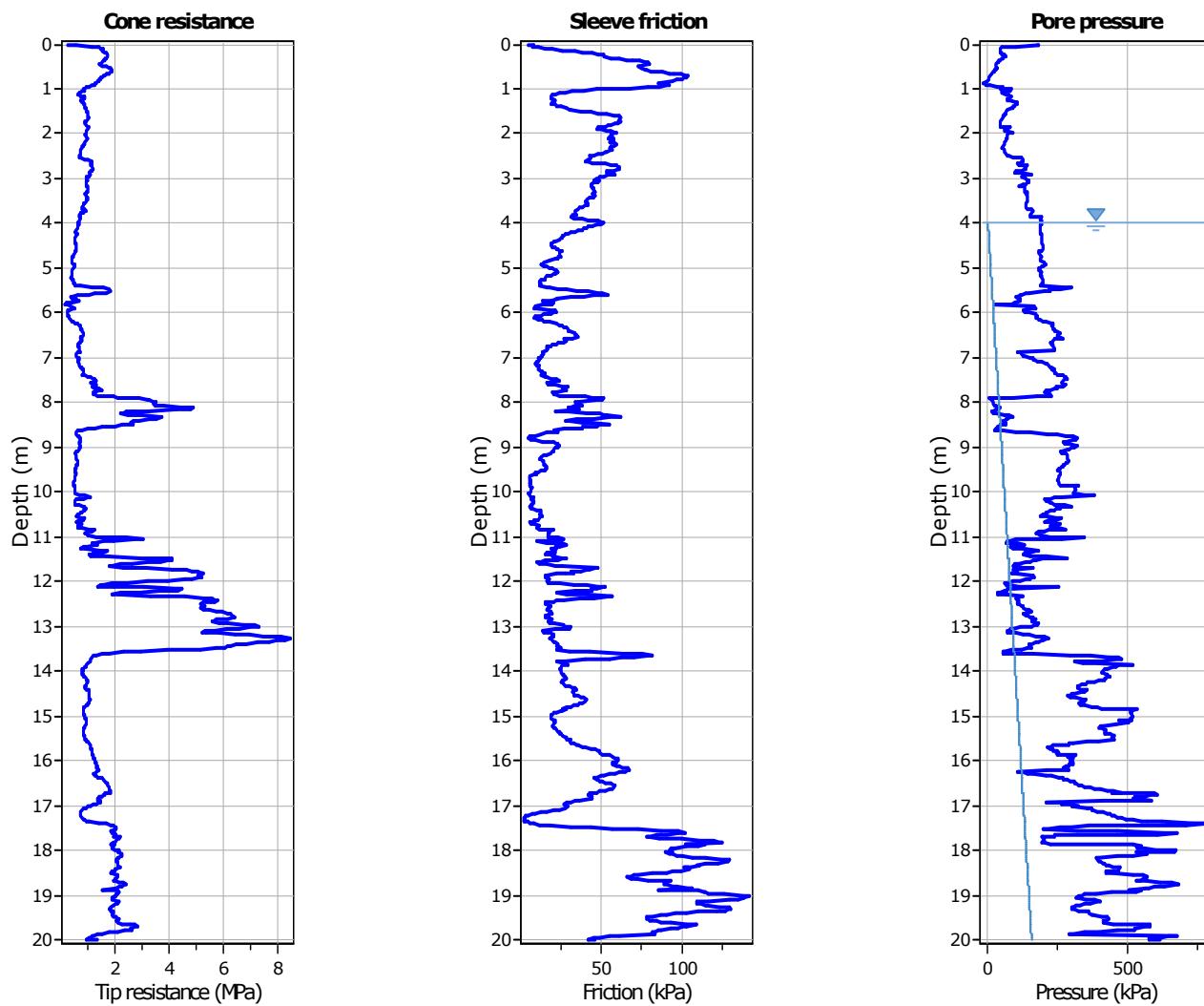
Location:

CPT: CPTU6

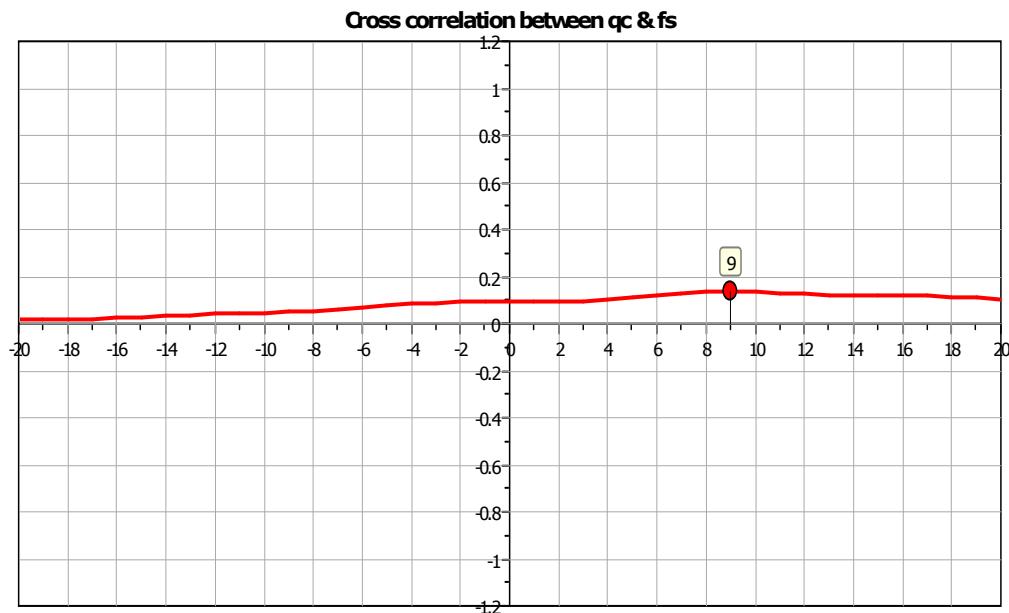
Total depth: 20.00 m, Date: 24/04/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

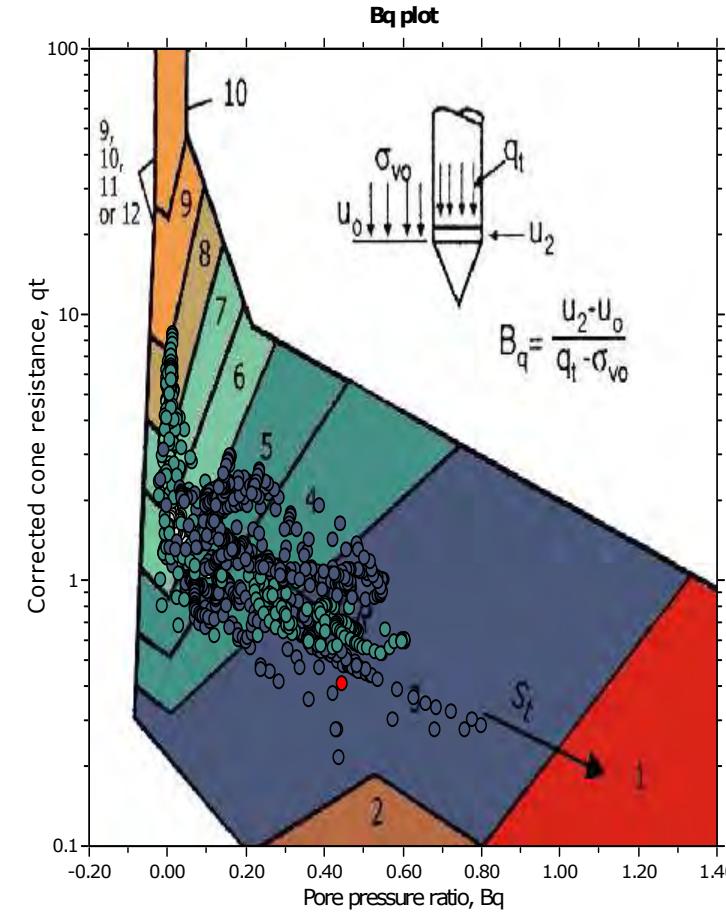
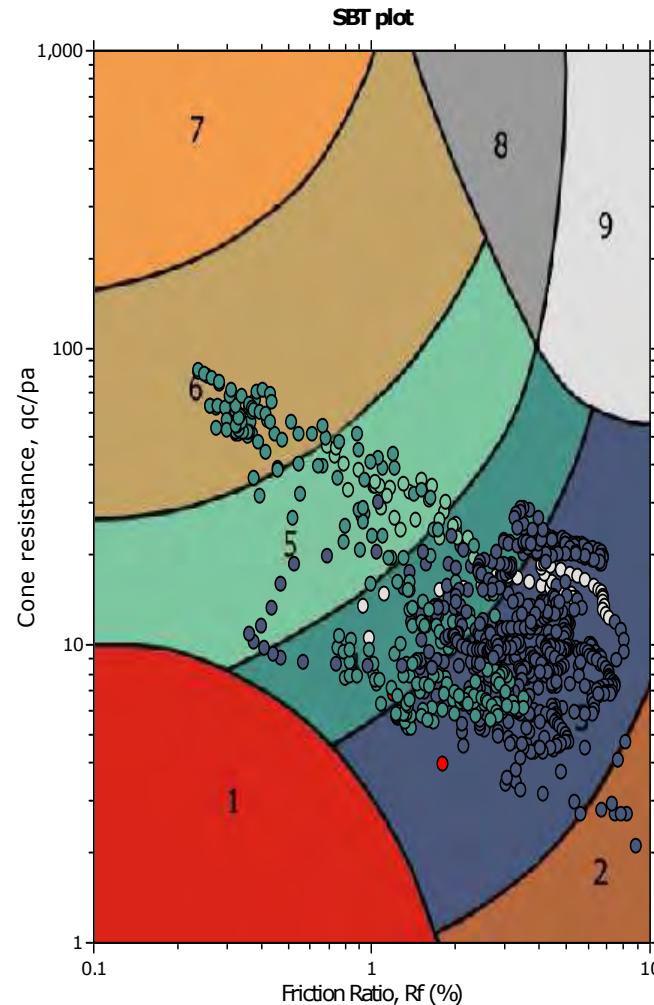
User defined estimation data



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



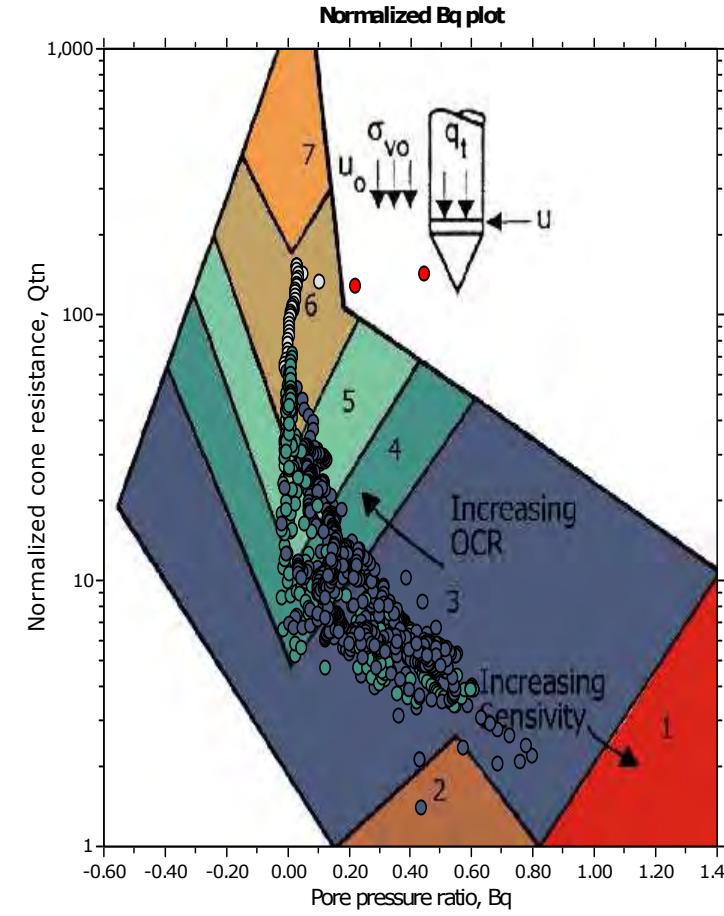
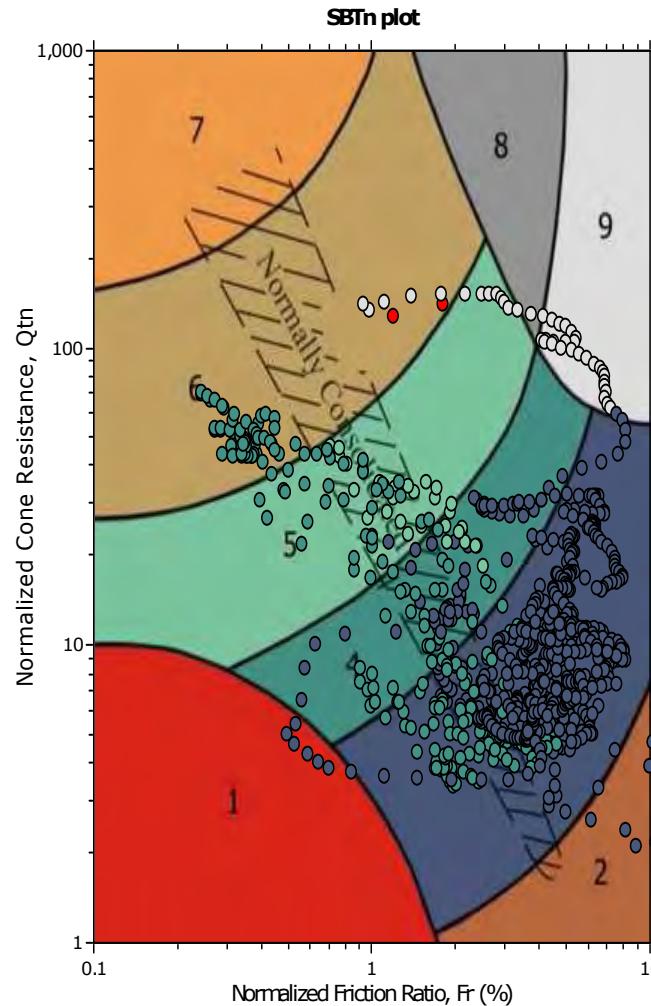
SBT - Bq plots

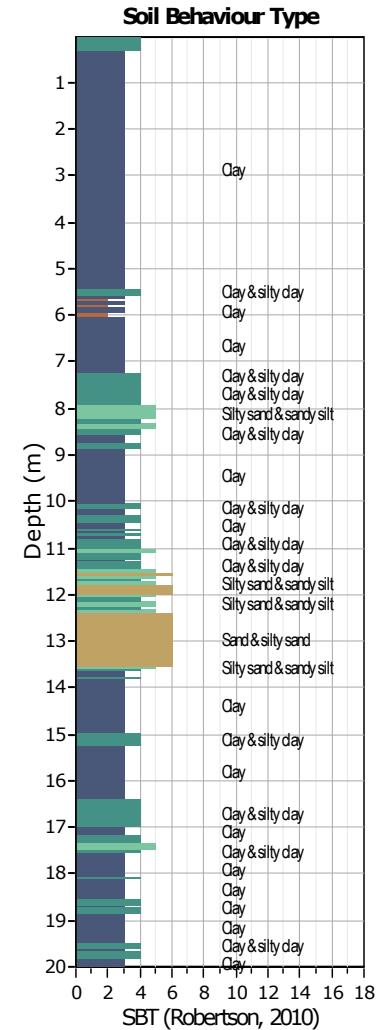
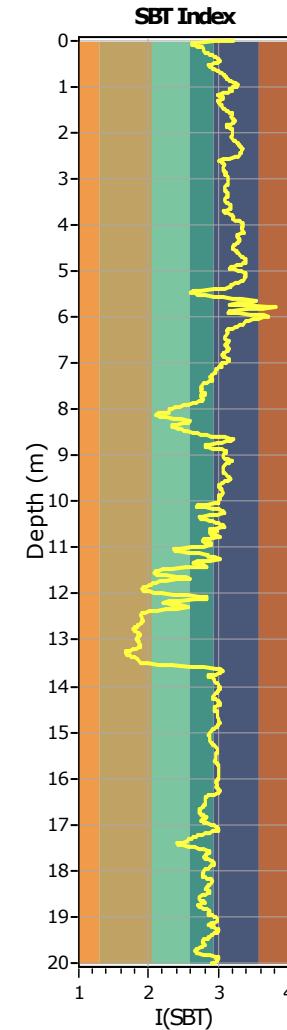
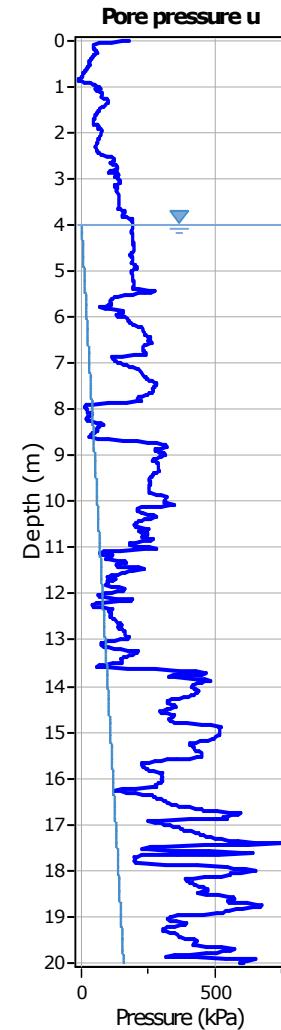
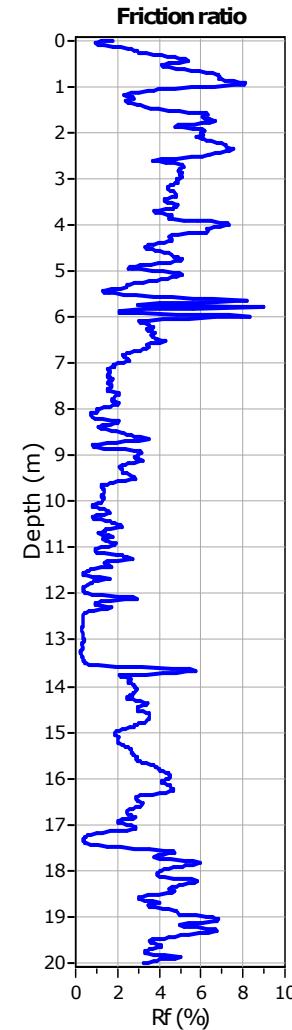
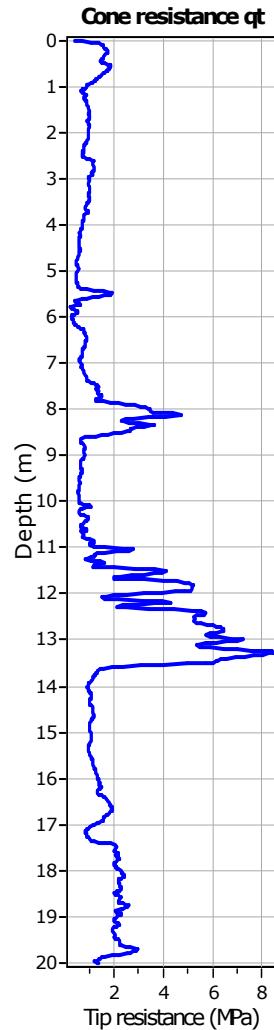


SBT legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

SBT - Bq plots (normalized)



**SBT legend**

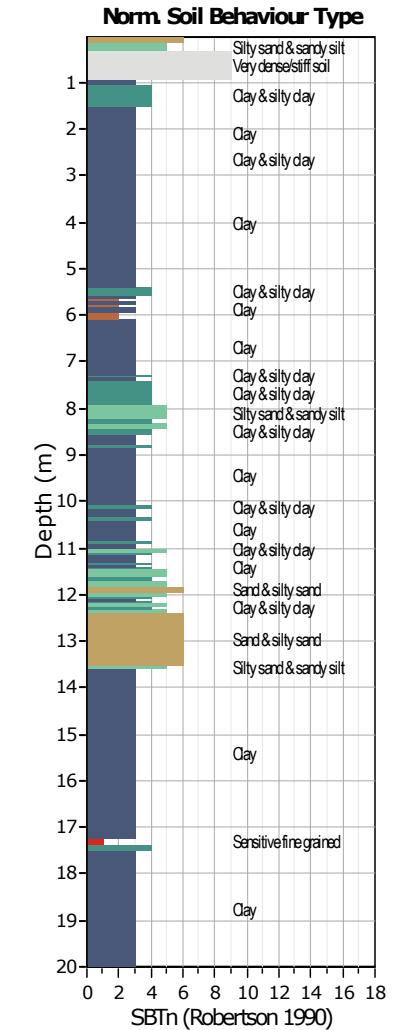
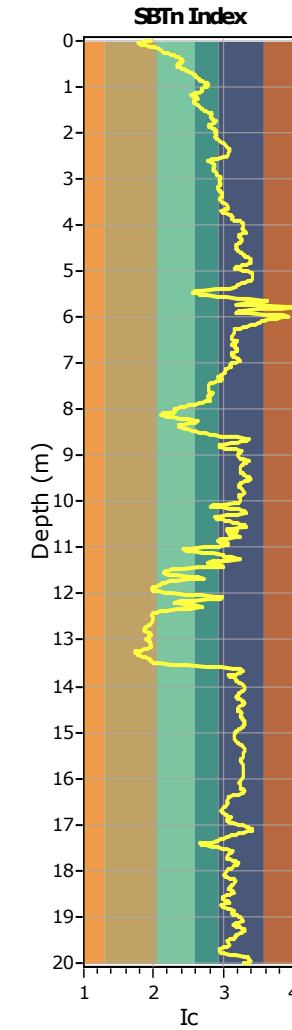
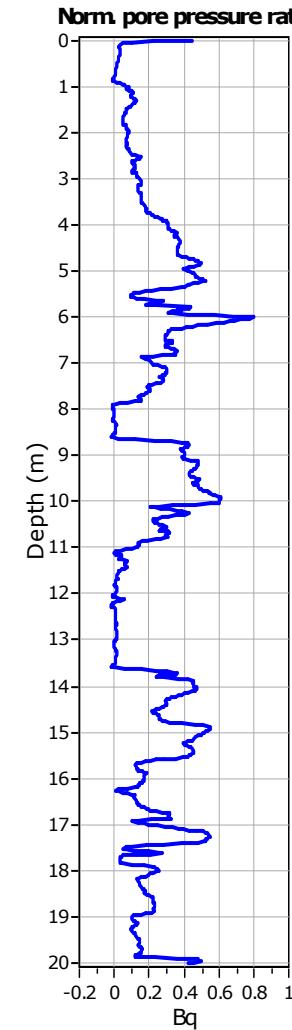
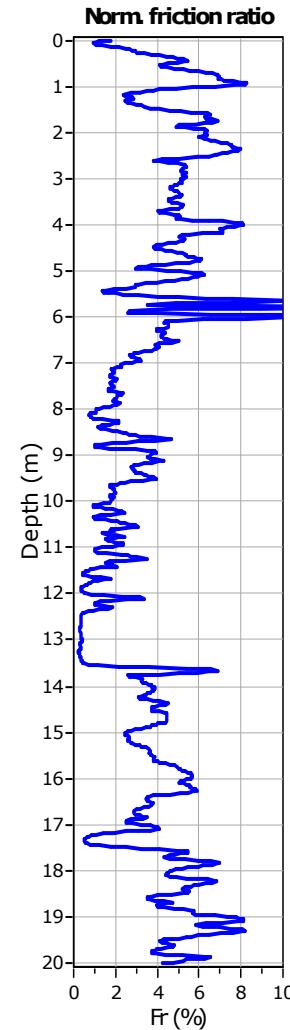
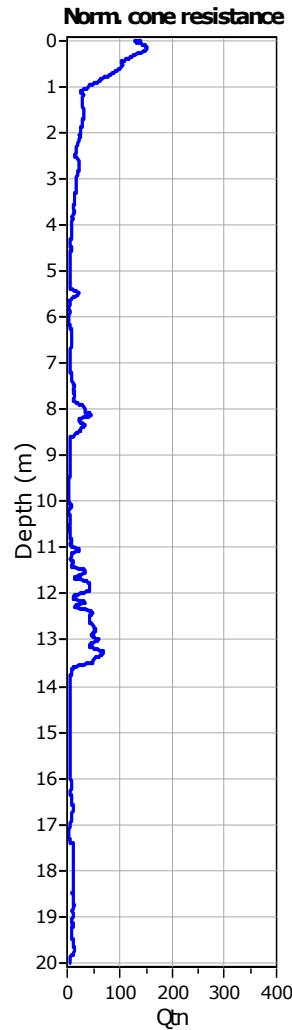
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|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 9

Total depth: 20.00 m, Date: 14/05/2018

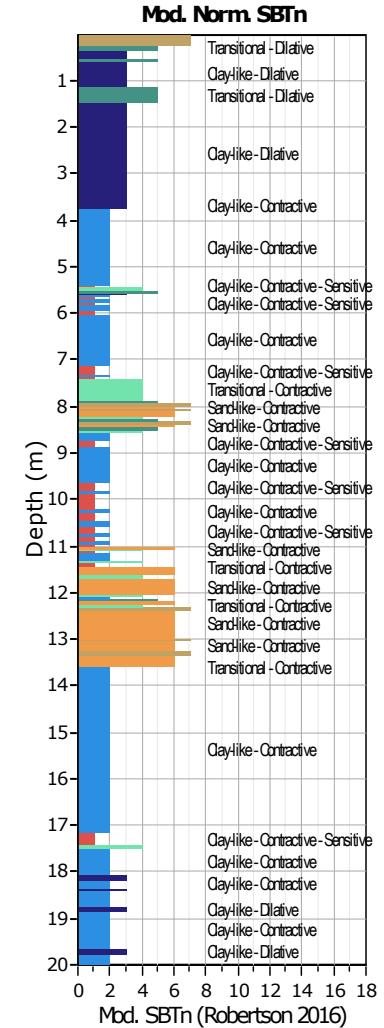
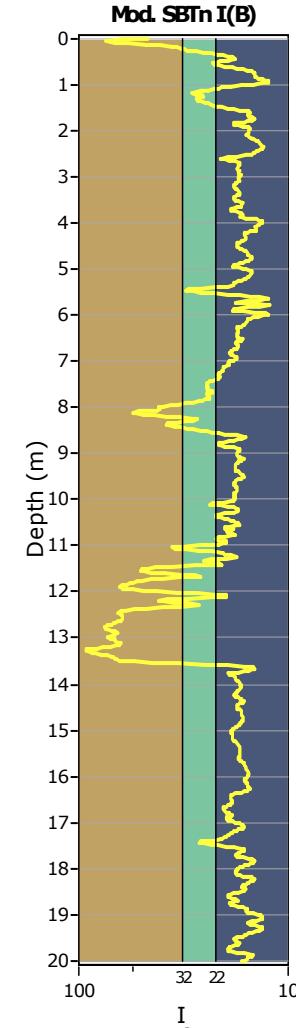
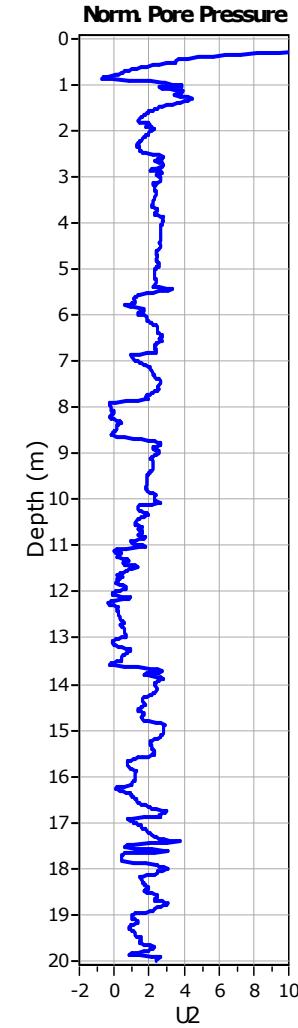
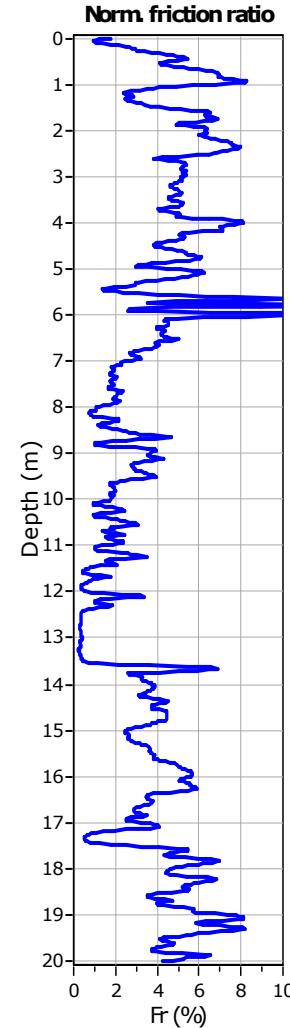
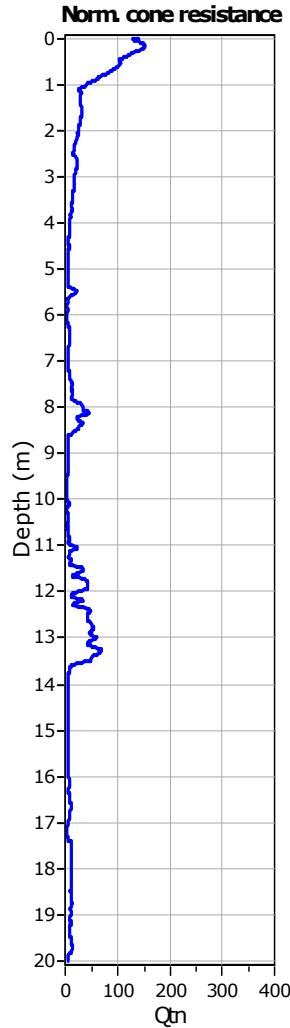


Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

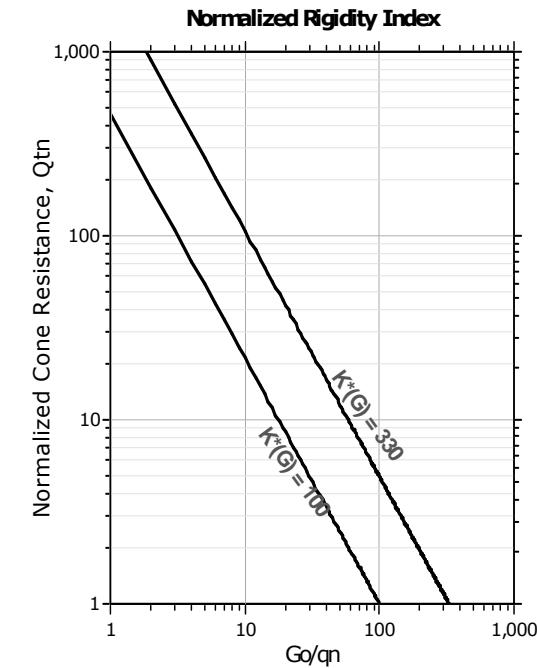
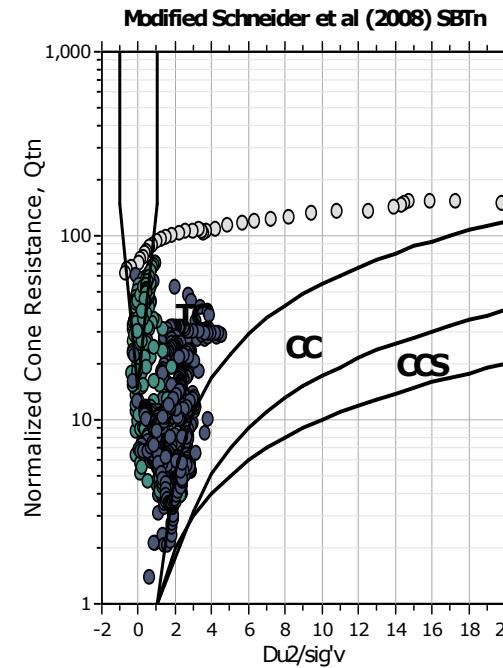
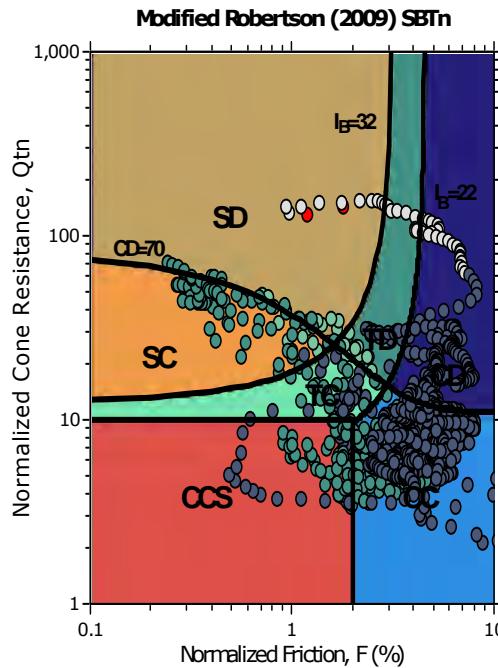
CPT: CPTU 9

Total depth: 20.00 m, Date: 14/05/2018

**Mod. SBTn legend**

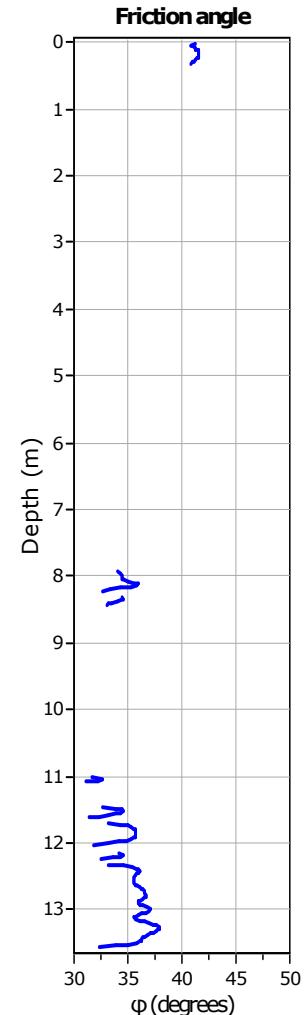
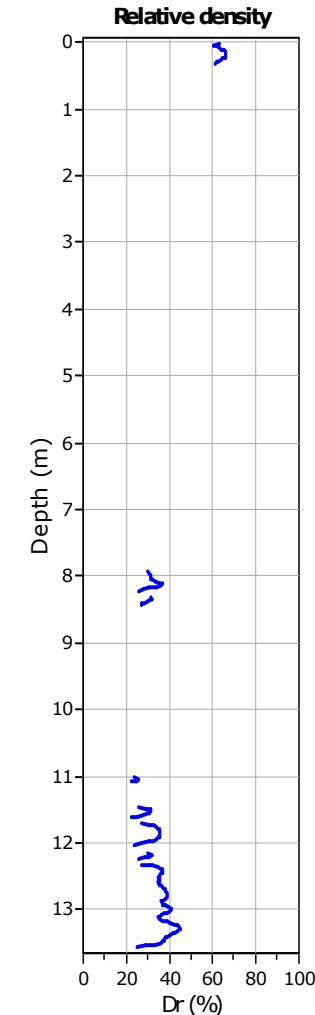
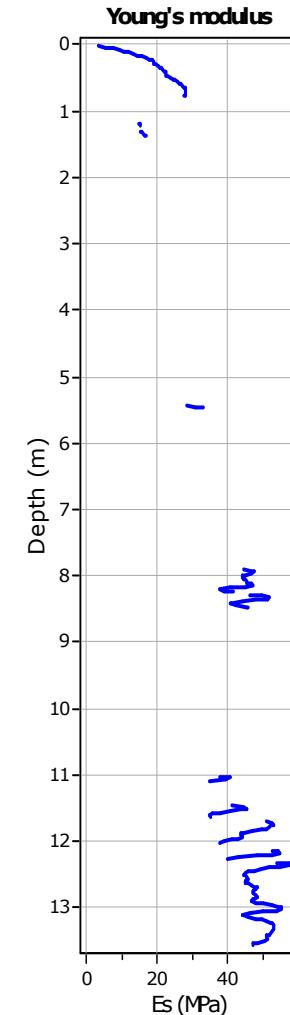
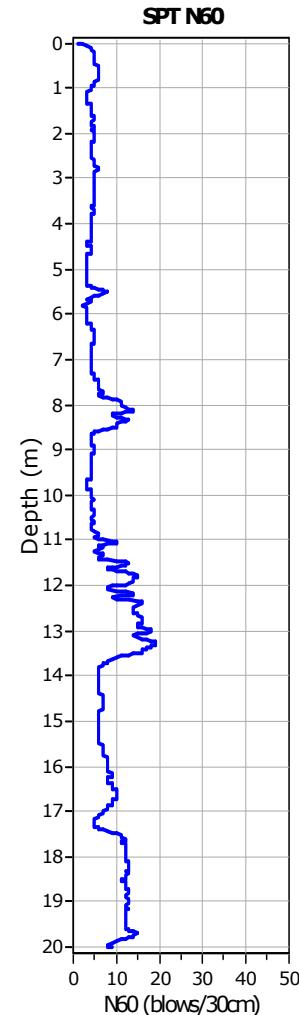
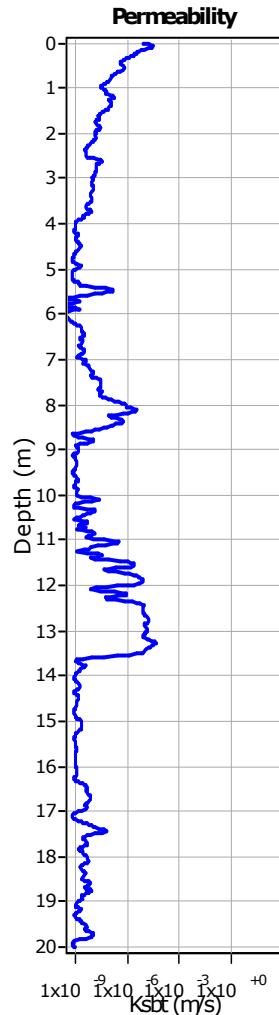
- | | | |
|---|-----------------------------------|--------------------------------|
| 1. CCS: ClayLike - Contractive, Sensitive | 4. TC: Transitional - Contractive | 7. SD: Sand-like - Dilative |
| 2. CC: Clay-like - Contractive | 5. TD: Transitional - Dilative | 8. SC: Sand-like - Contractive |
| 3. CD: Clay-Like: Dilative | 6. CL: Clay-like - Dilative | |

Updated SBTn plots



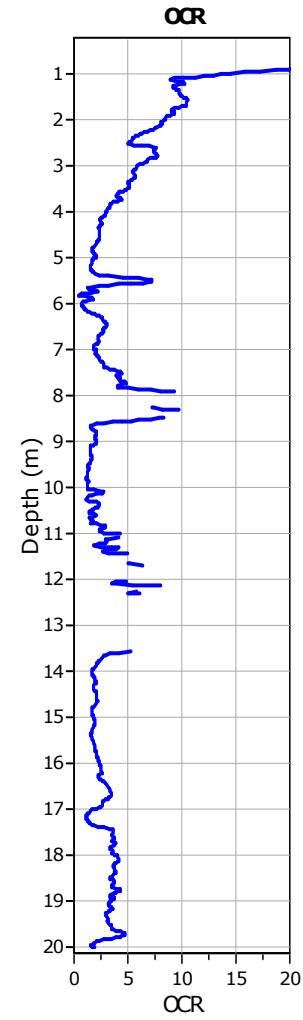
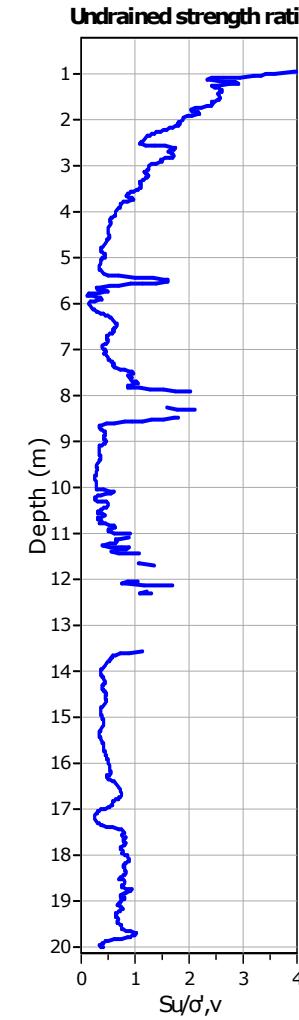
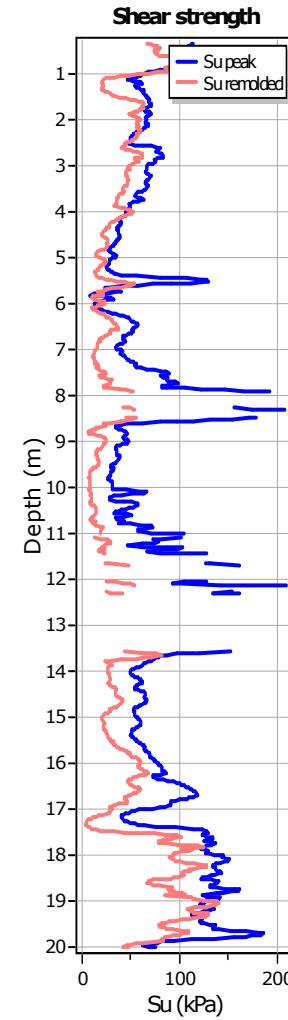
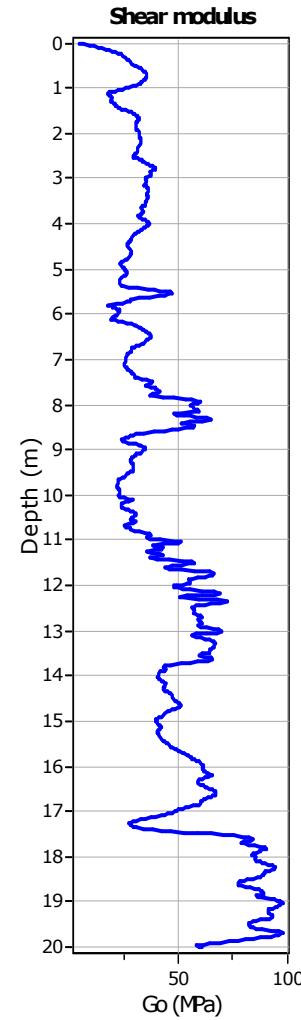
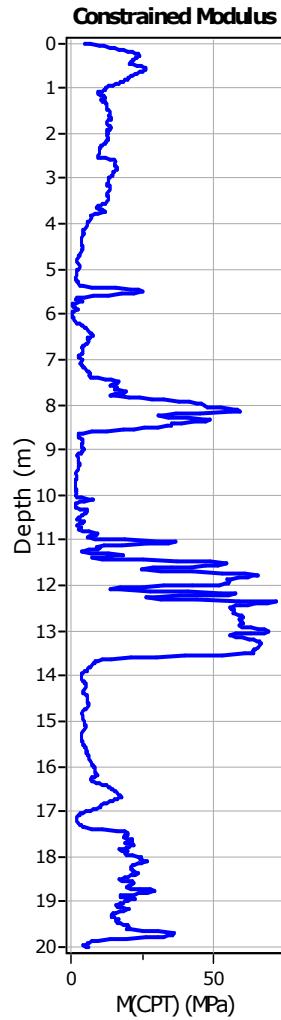
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

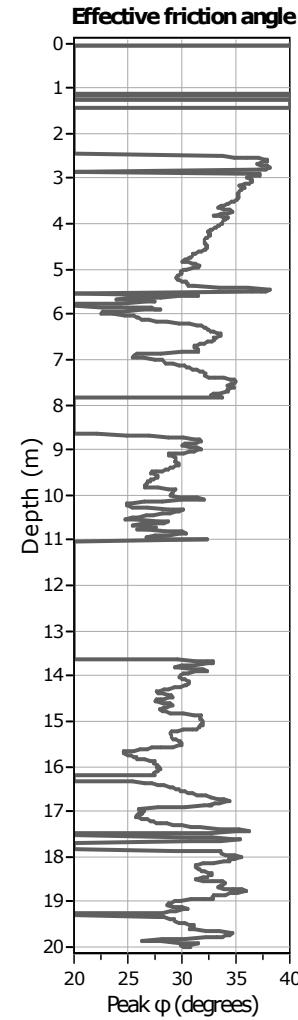
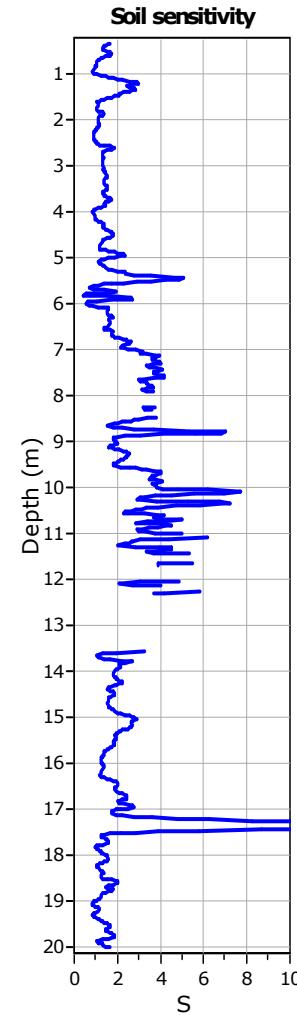
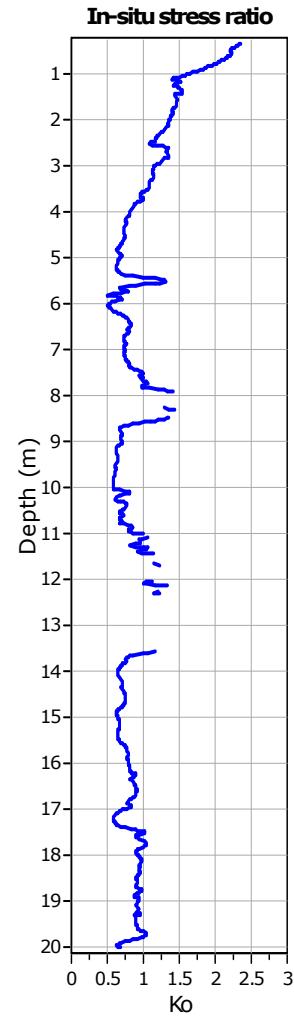
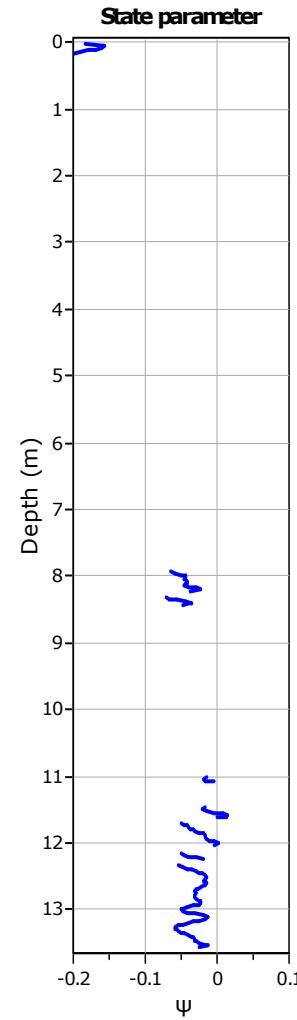
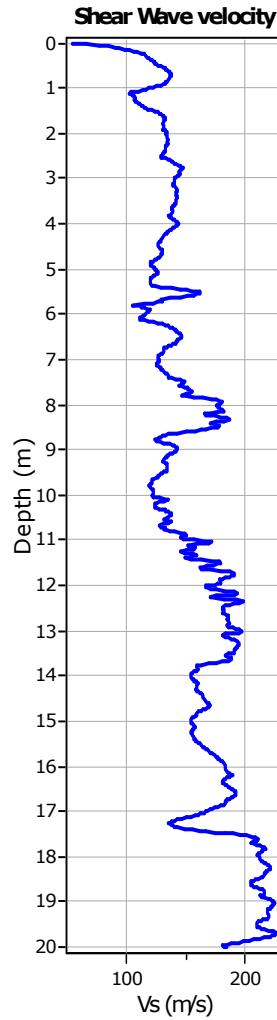
- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato dell'Emergenza sul Territorio

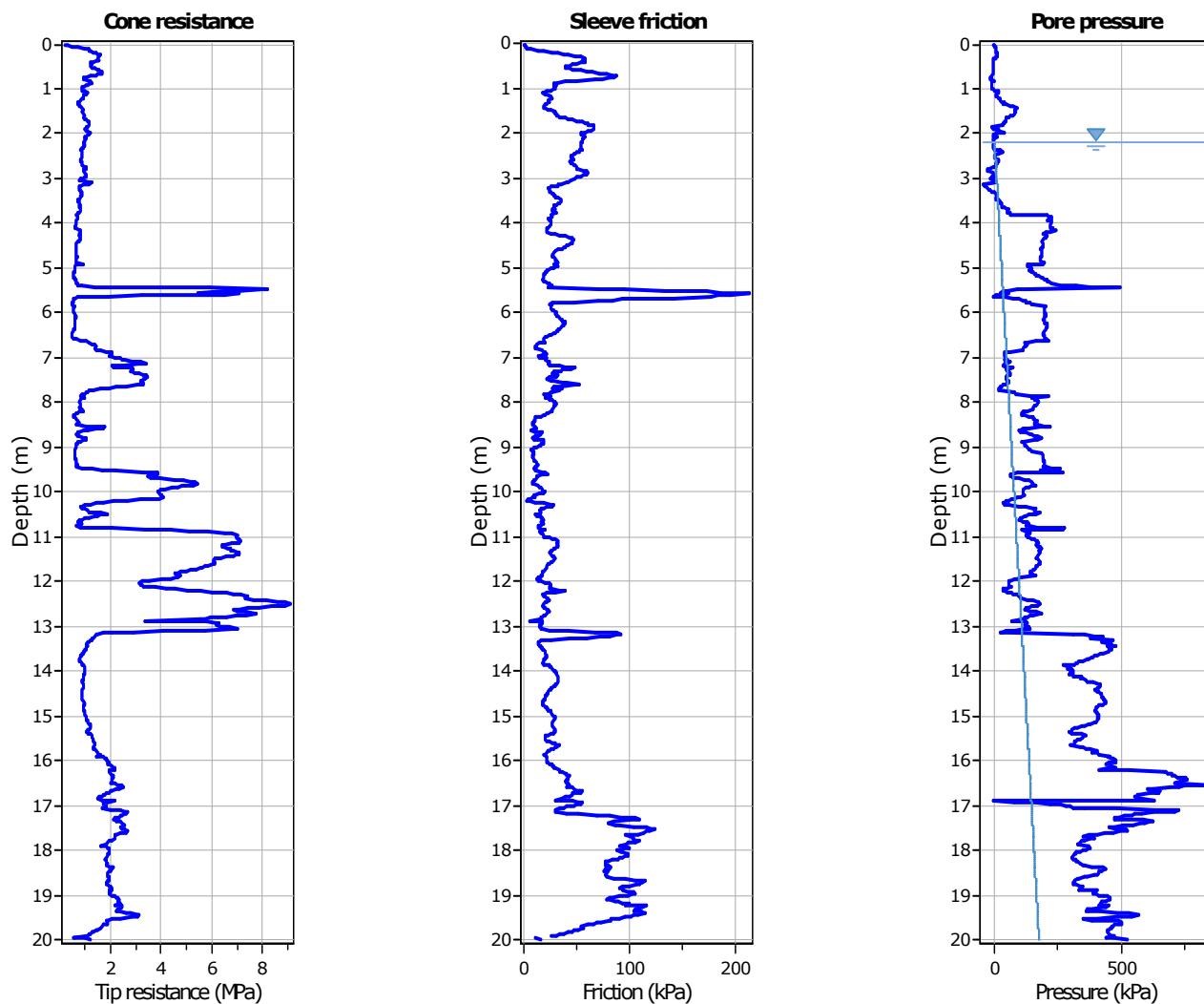
Location: Ferrara

CPT: CPTU 9

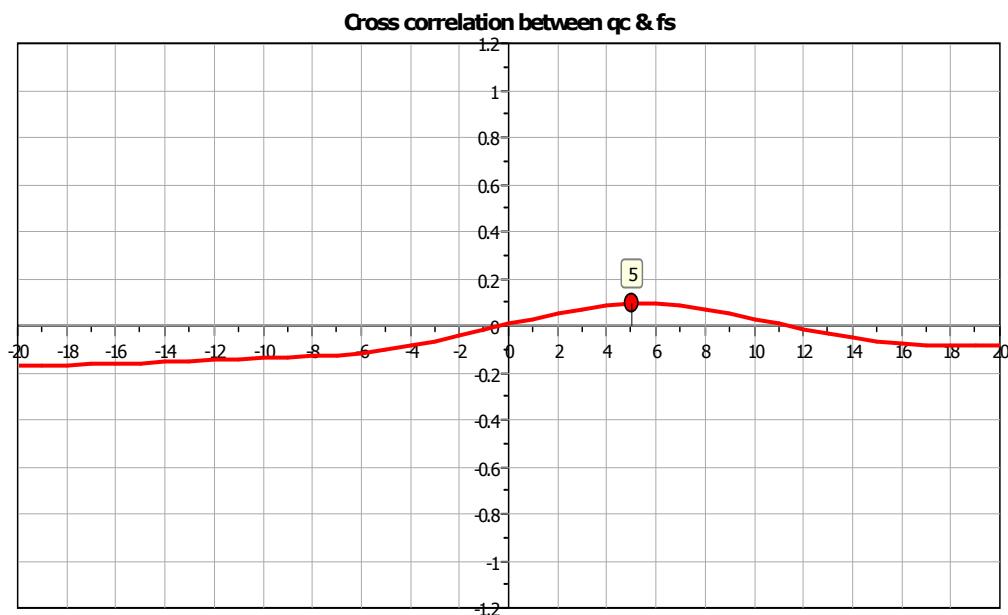
Total depth: 20.00 m, Date: 14/05/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

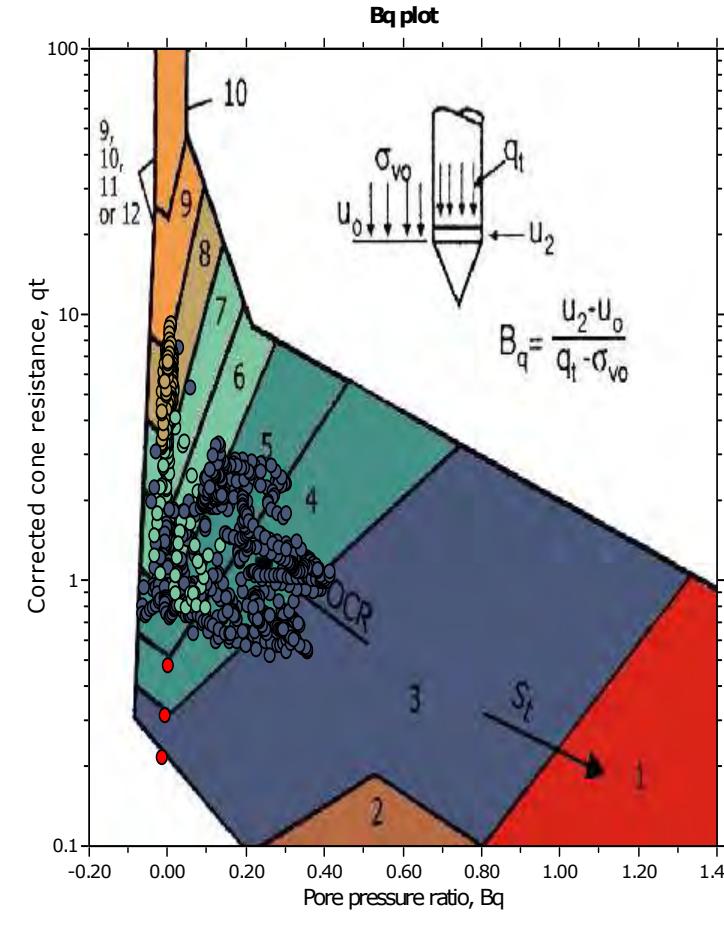
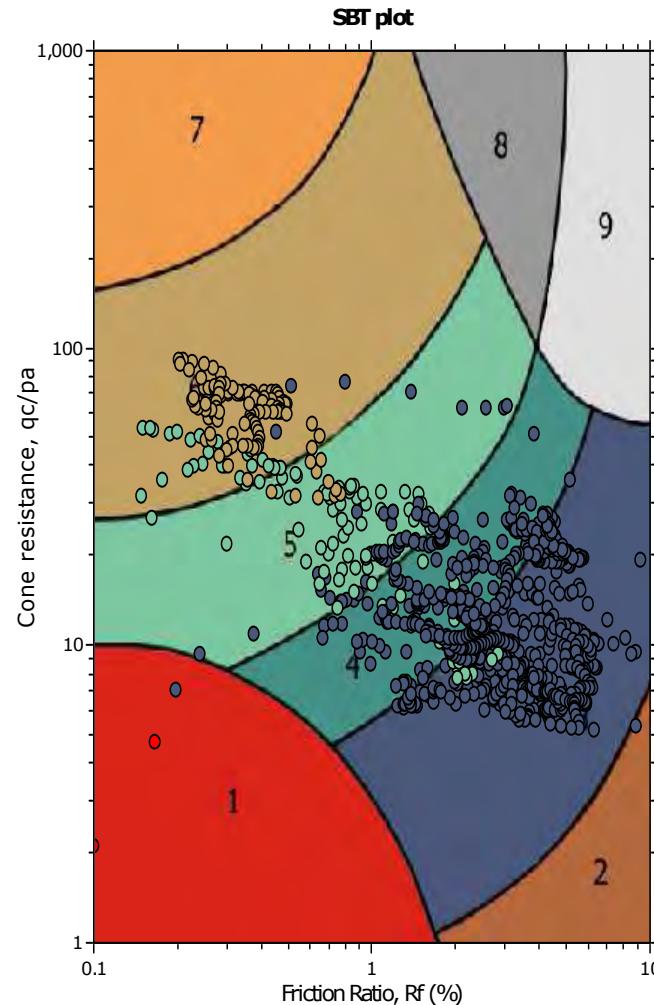
User defined estimation data



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



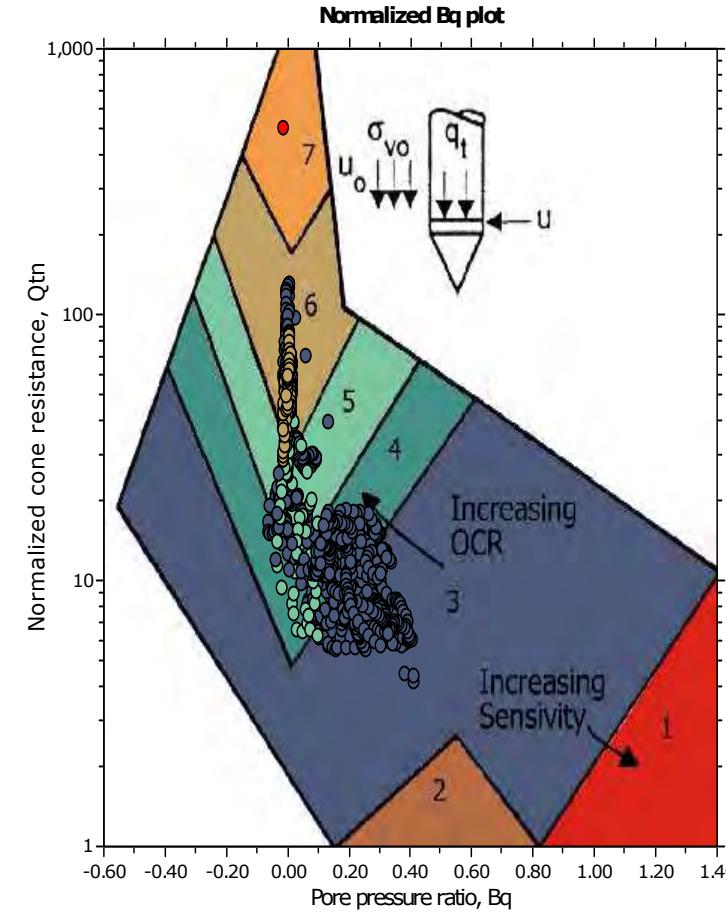
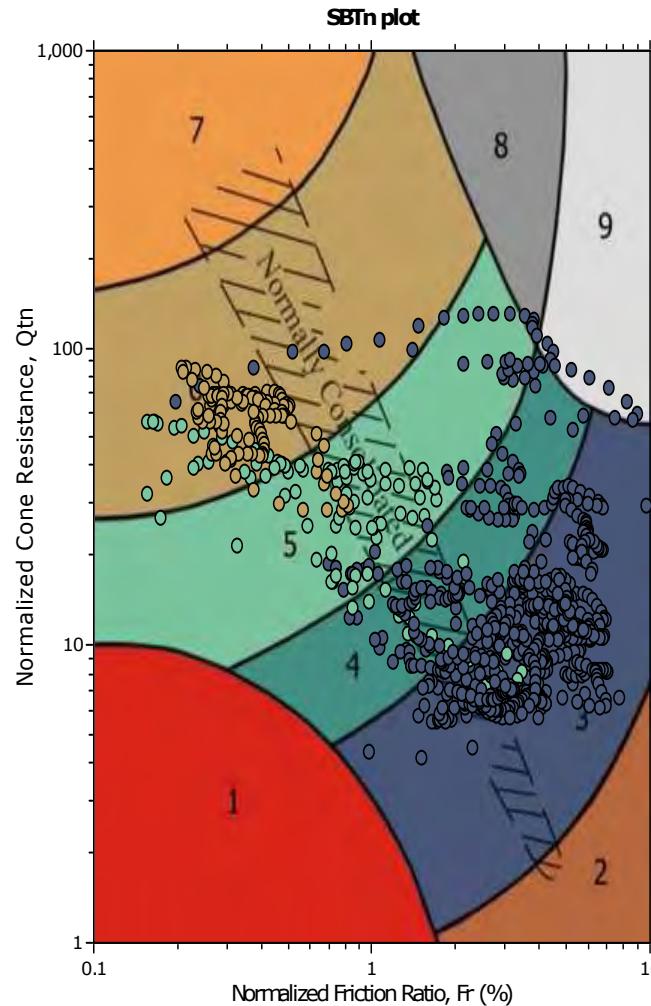
SBT - Bq plots



SBT legend

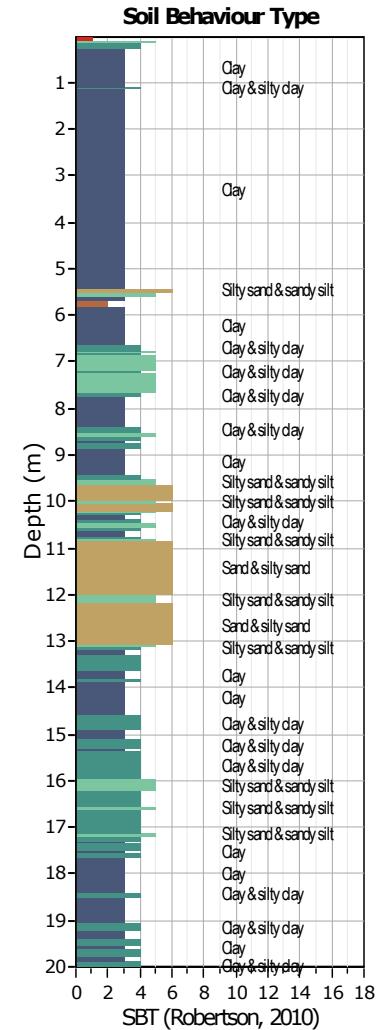
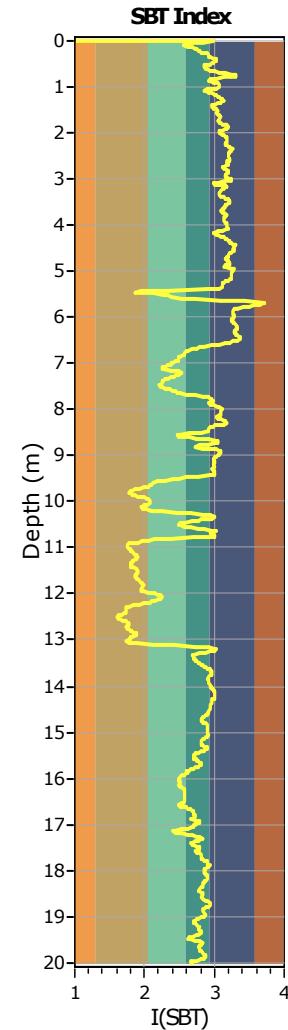
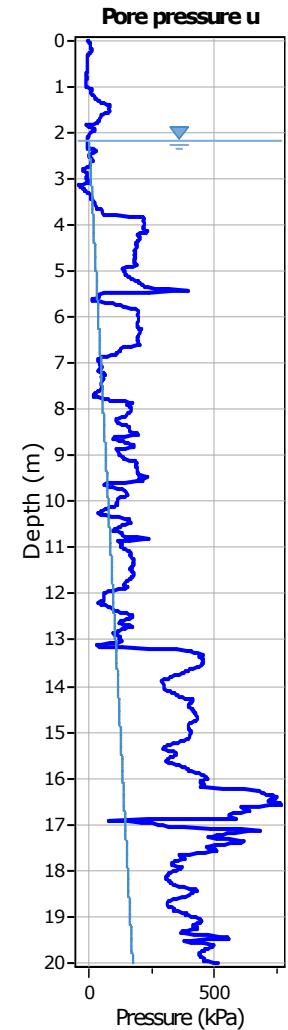
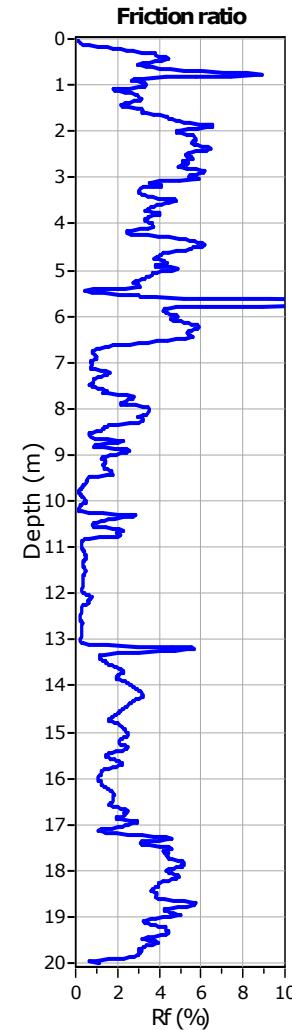
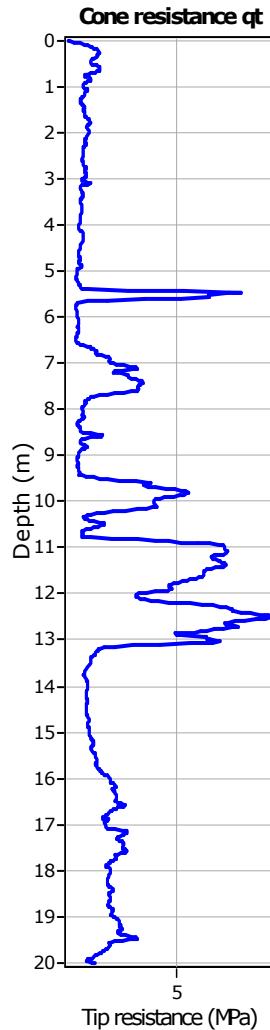
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

SBT - Bq plots (normalized)



SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

**SBT legend**

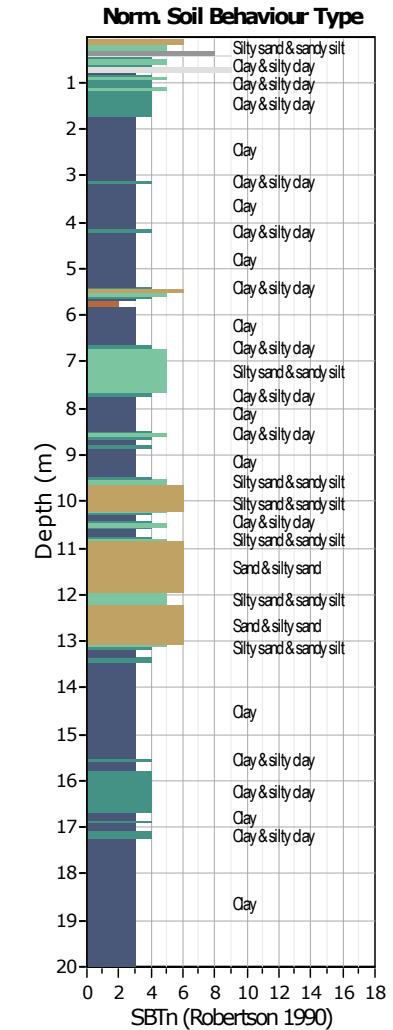
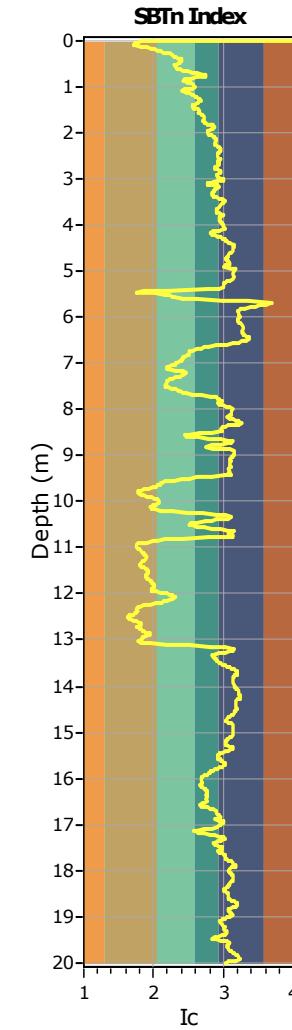
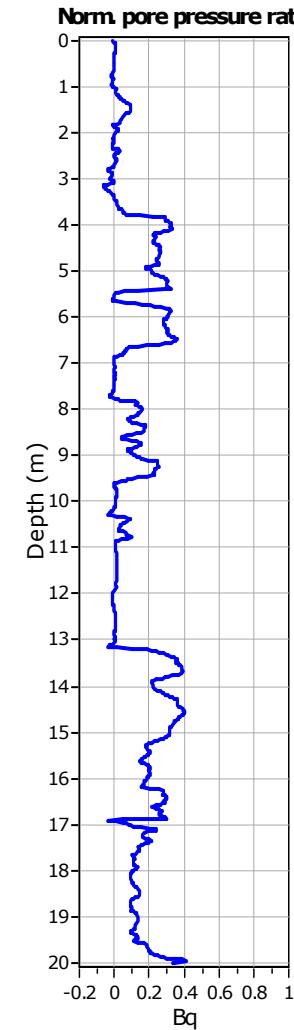
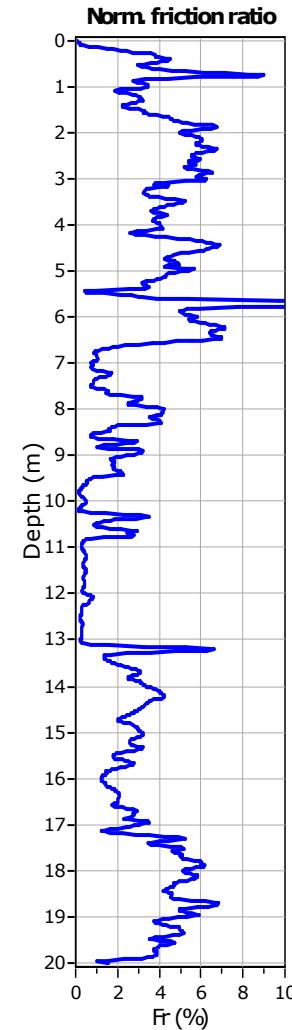
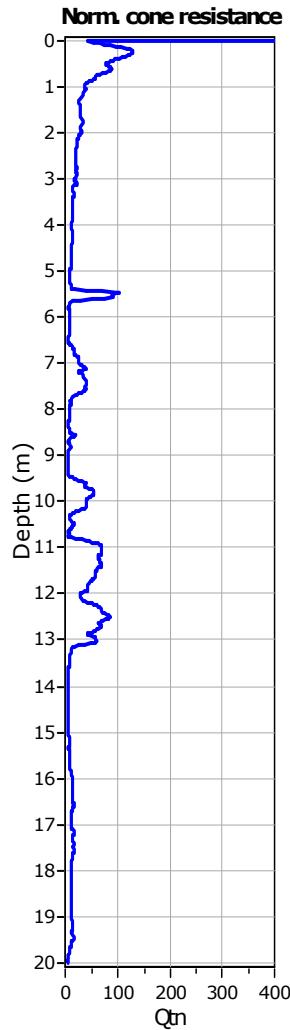
- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 10

Total depth: 20.00 m, Date: 14/05/2018

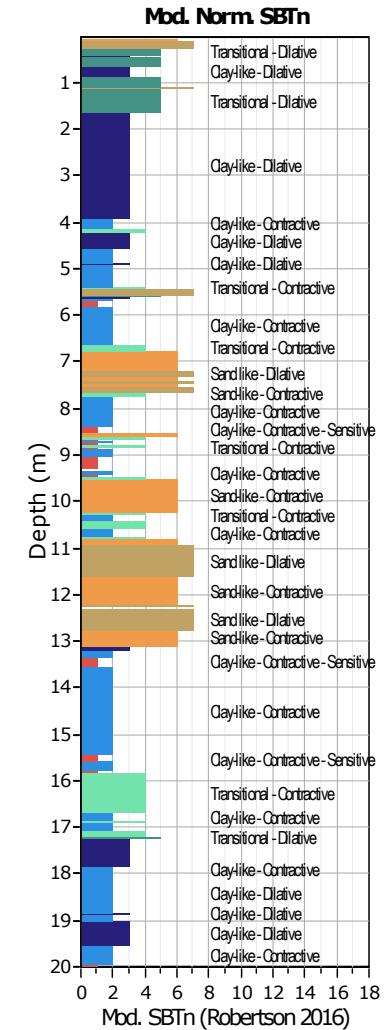
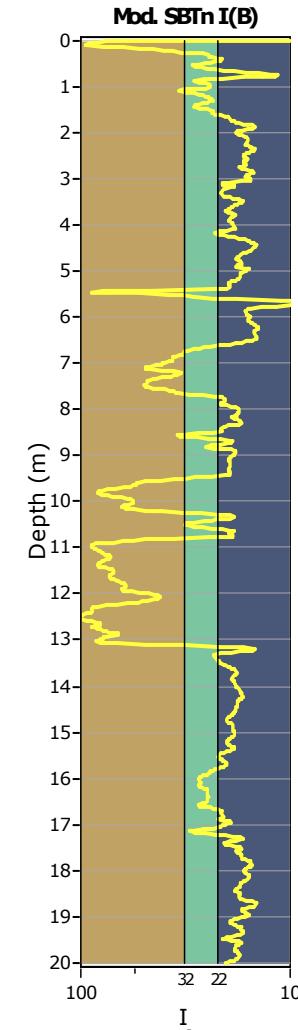
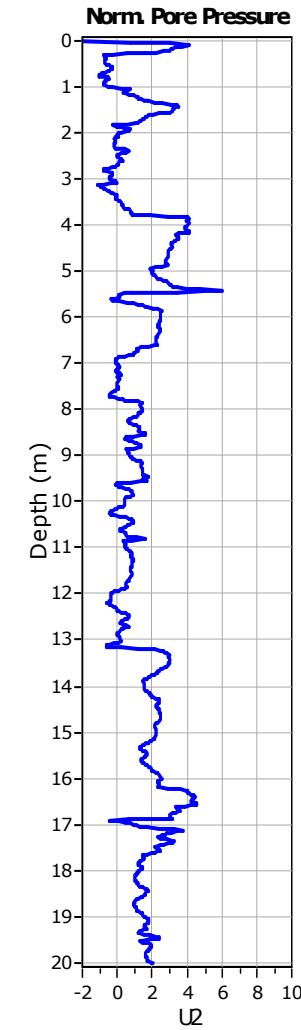
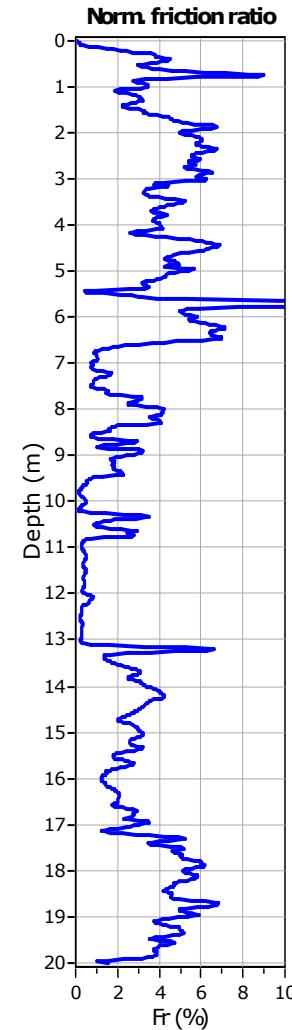
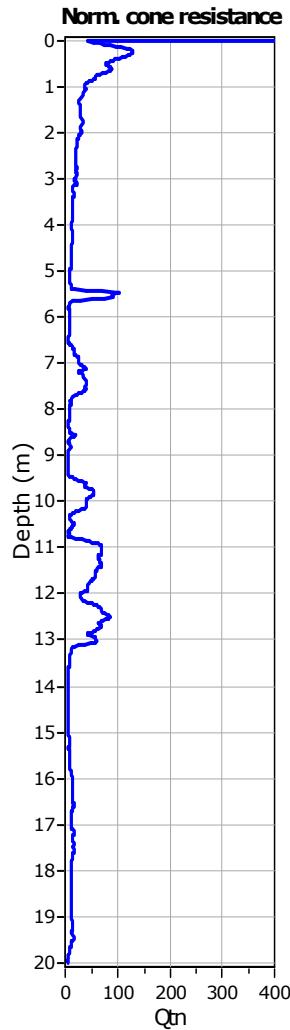


Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

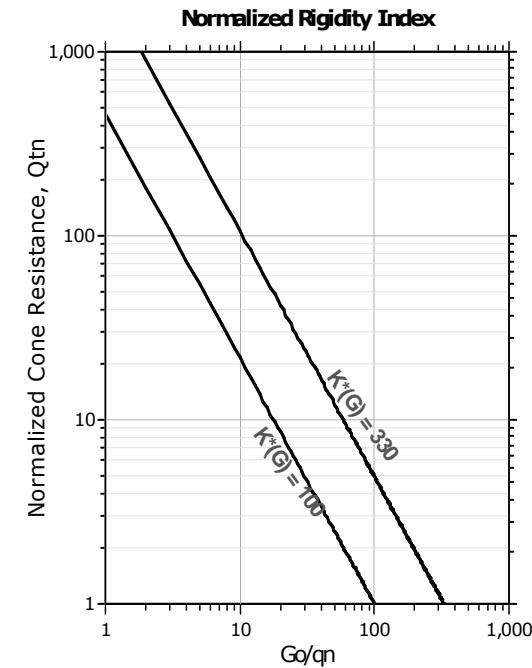
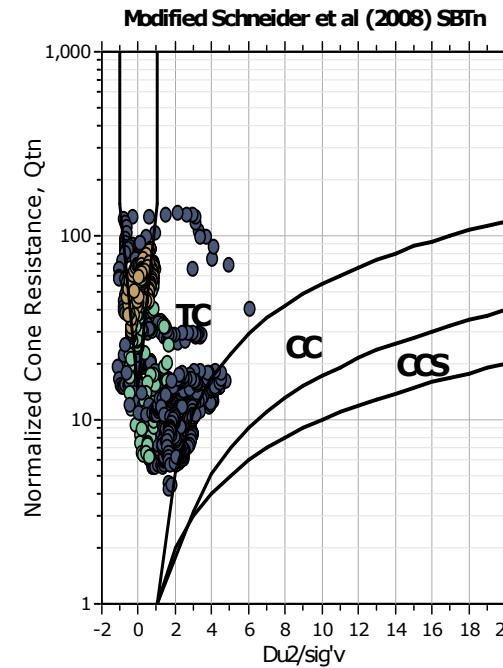
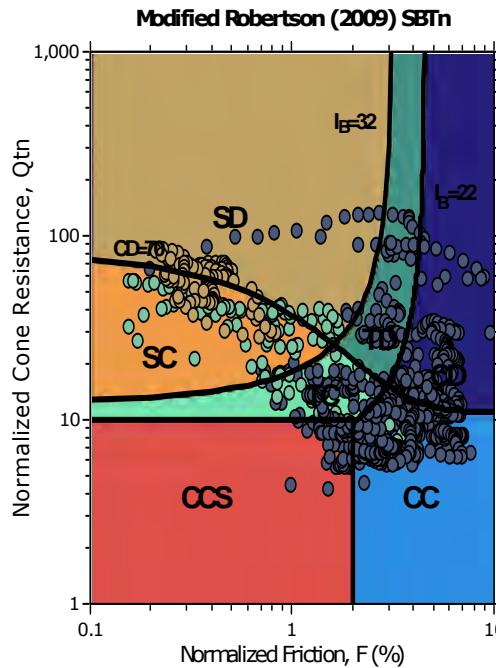
CPT: CPTU 10

Total depth: 20.00 m, Date: 14/05/2018

**Mod. SBTn legend**

- | | | |
|---|-----------------------------------|-----------------------------|
| 1. CCS: ClayLike - Contractive, Sensitive | 4. TC: Transitional - Contractive | 7. SD: Sand-like - Dilative |
| 2. CC: Clay-like - Contractive | 5. TD: Transitional - Dilative | |
| 3. CD: Clay-Like: Dilative | 6. SC: Sand-like - Contractive | |

Updated SBTn plots



CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

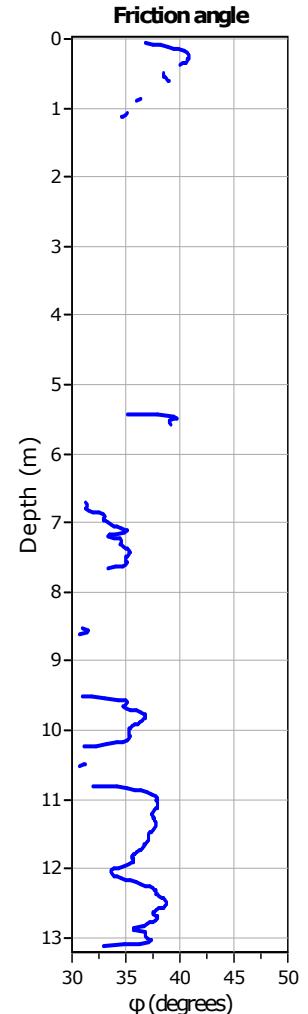
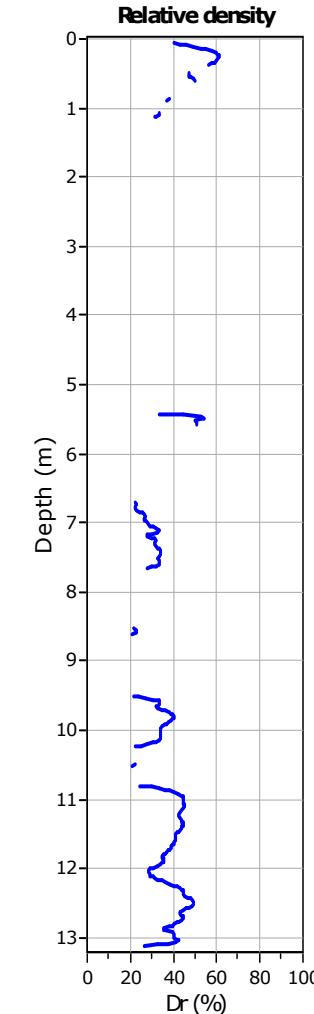
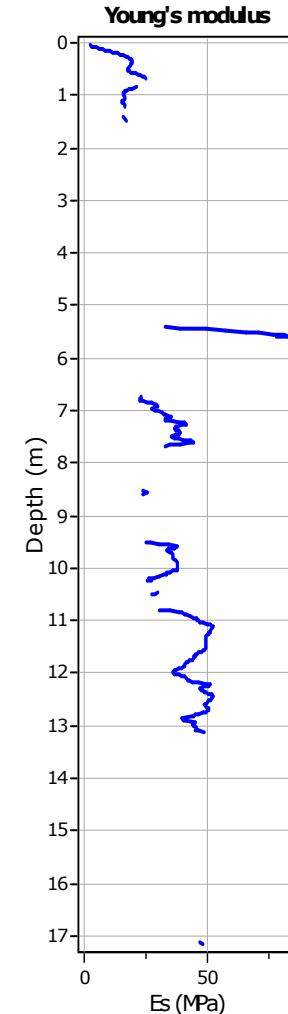
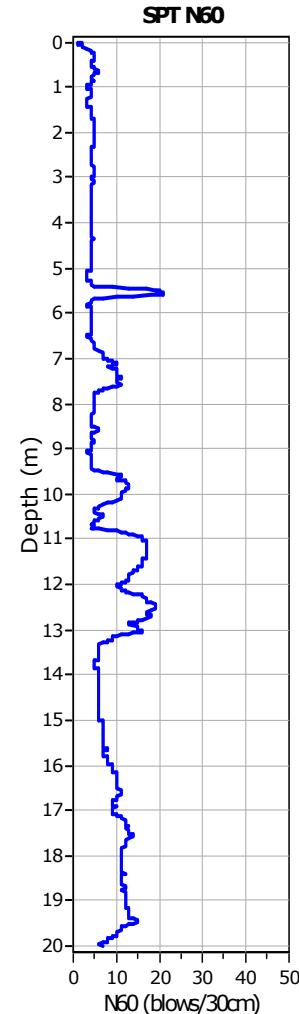
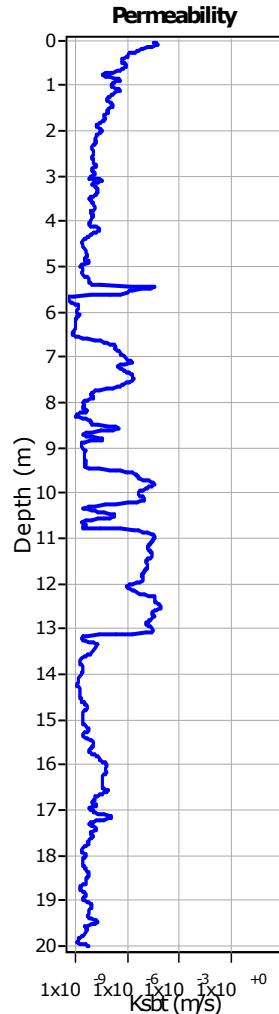
$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

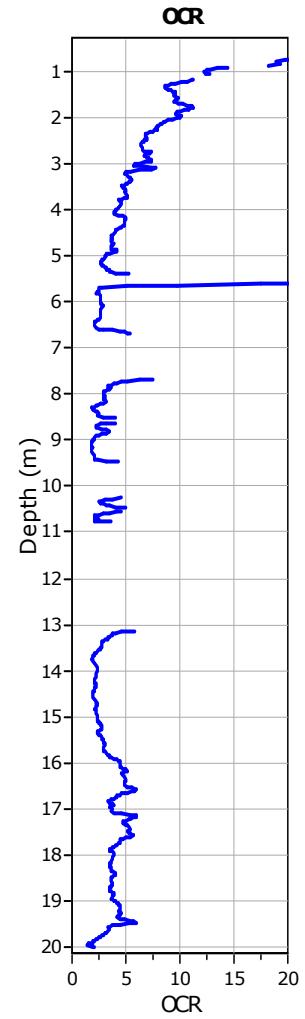
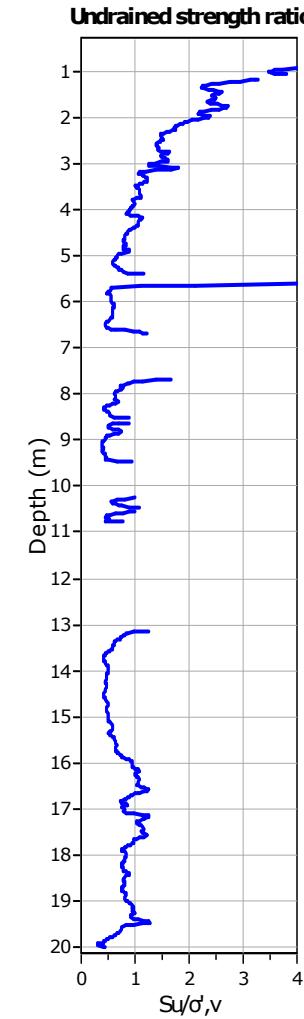
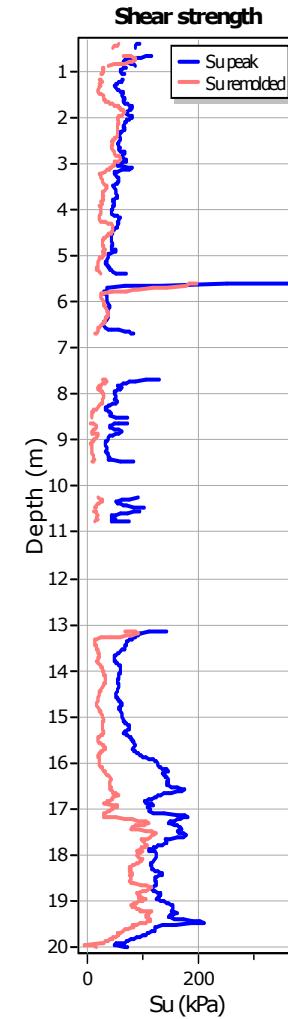
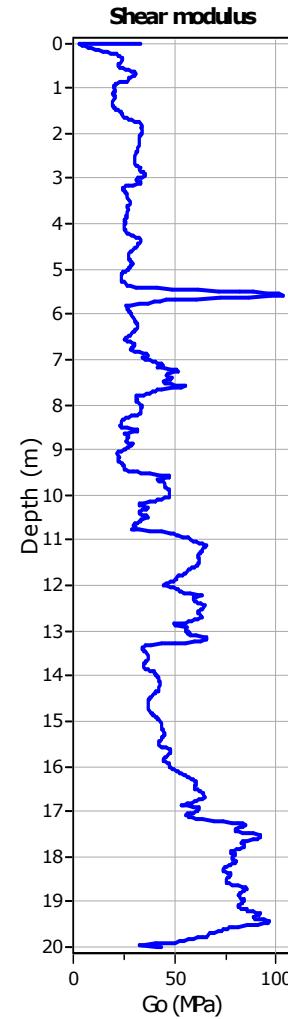
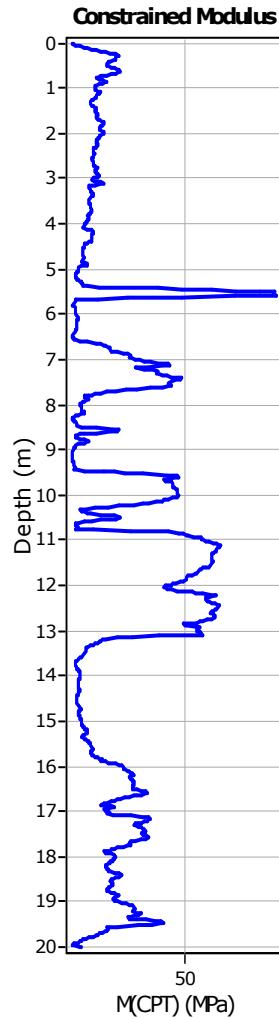
CPT: CPTU 10

Total depth: 20.00 m, Date: 14/05/2018

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

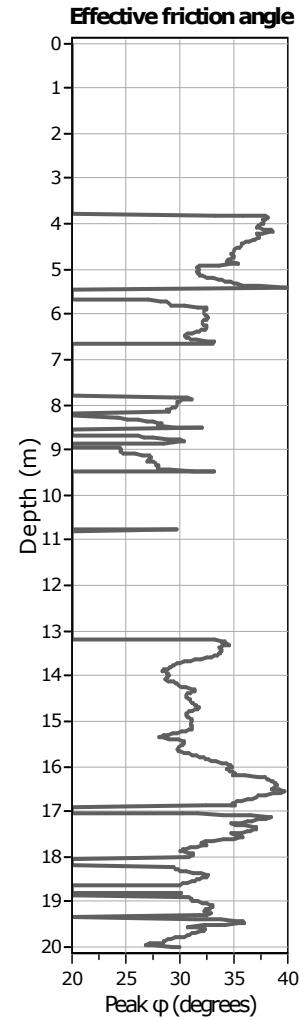
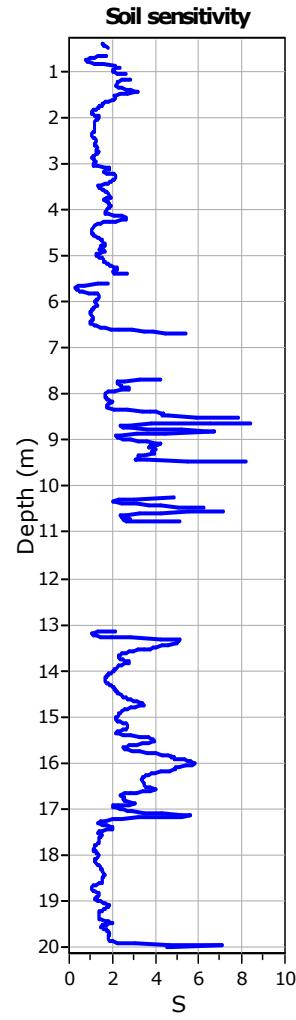
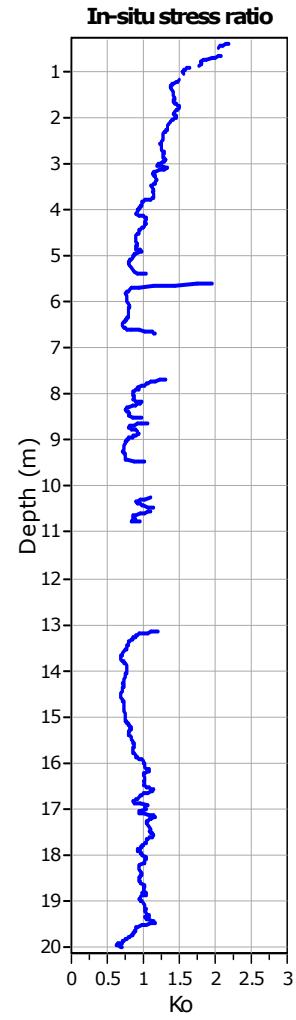
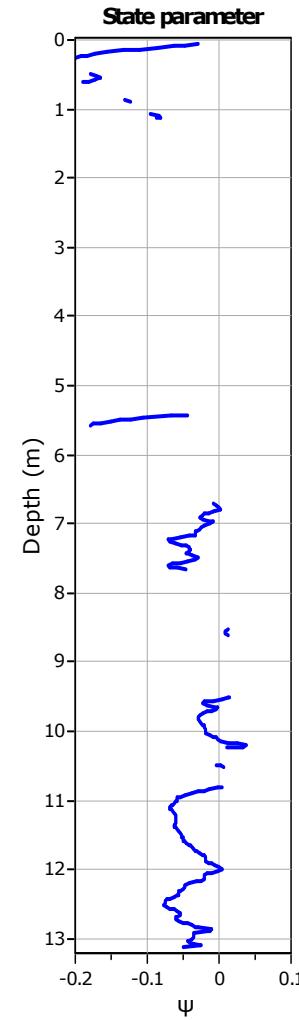
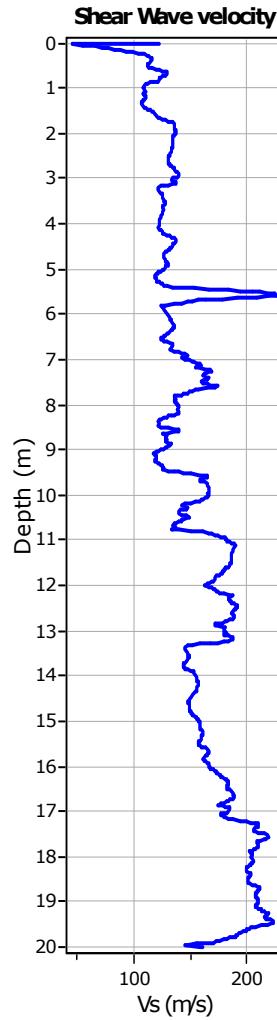
- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato dell'Emergenza sul Territorio

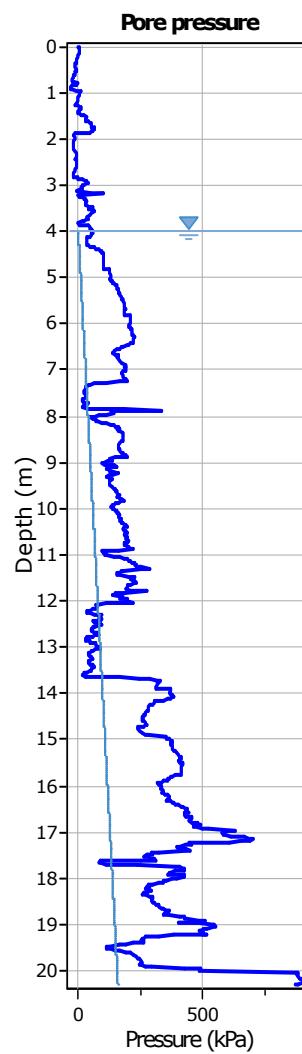
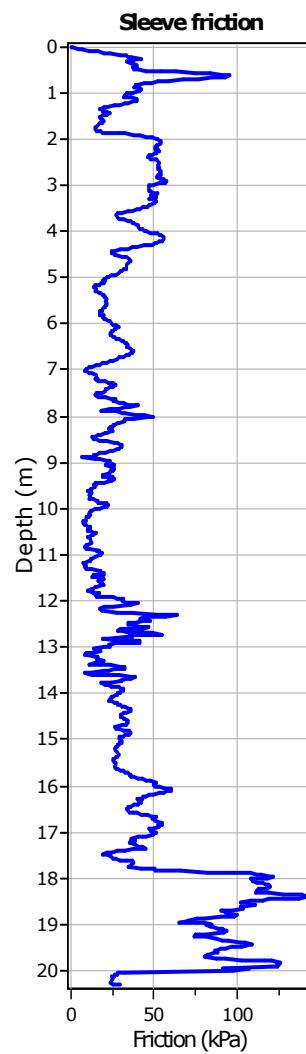
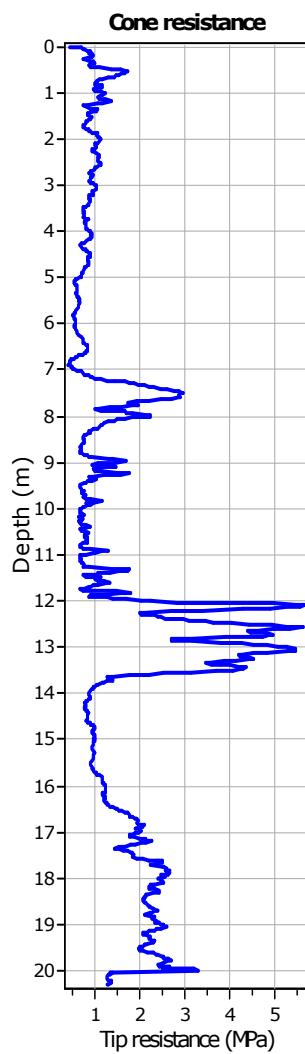
Location: Ferrara

CPT: CPTU 10

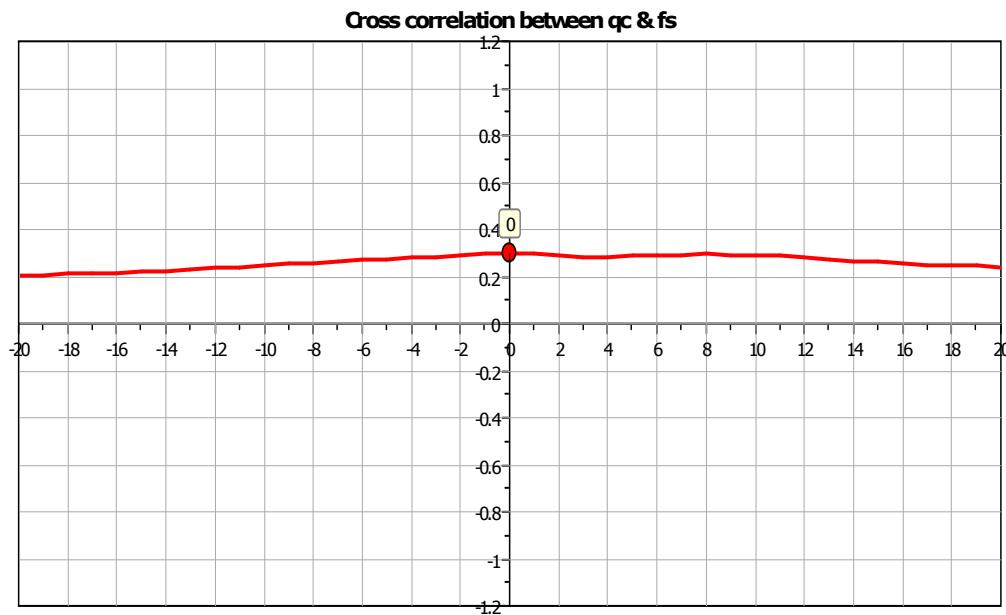
Total depth: 20.00 m, Date: 14/05/2018

**Calculation parameters**Soil Sensitivity factor, N_s : 7.00

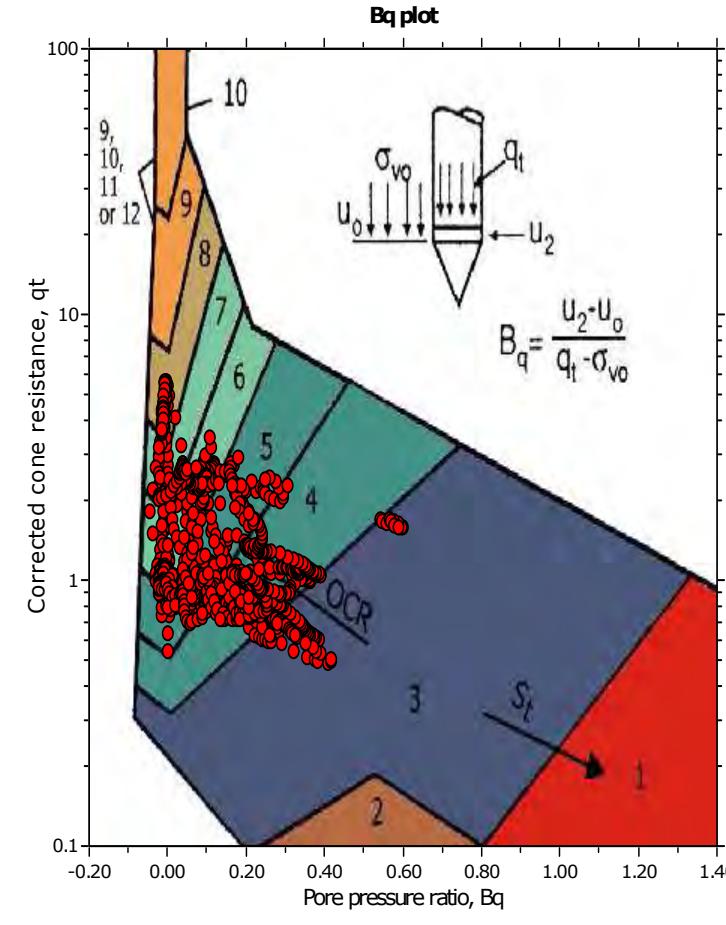
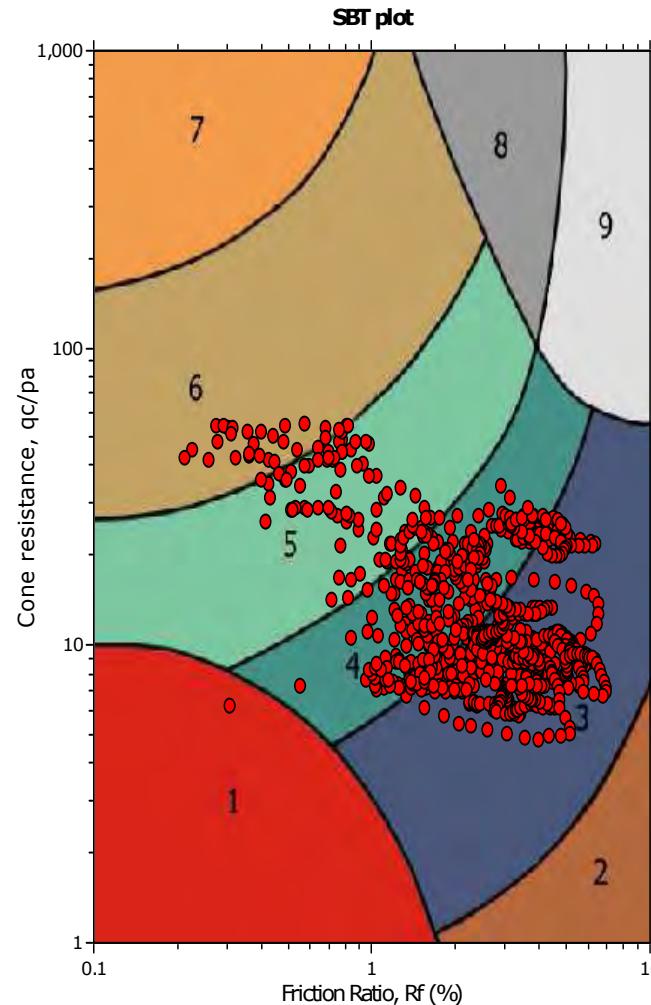
User defined estimation data



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



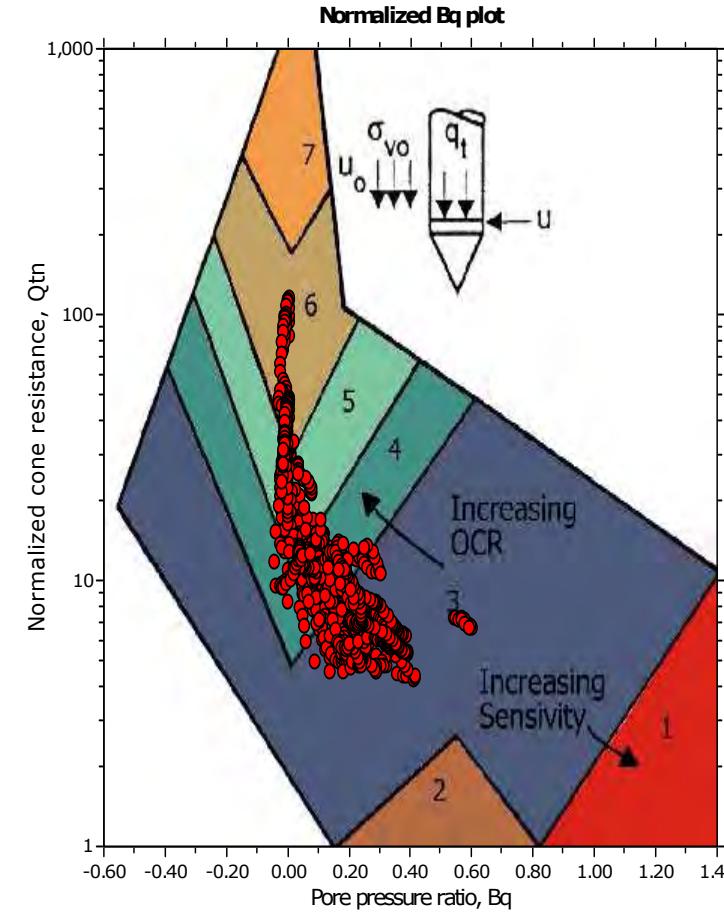
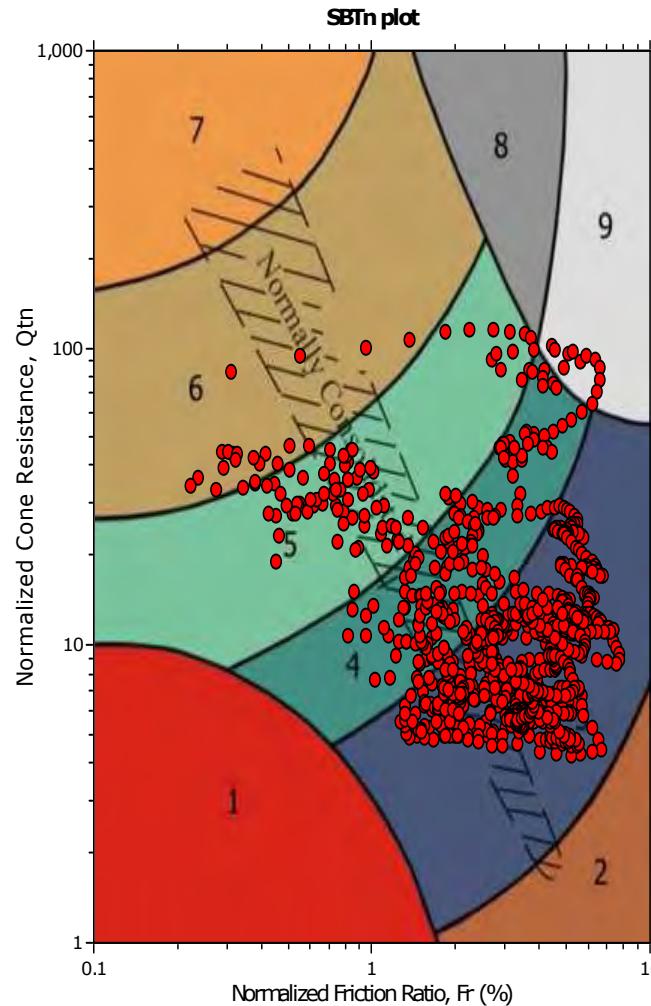
SBT - Bq plots

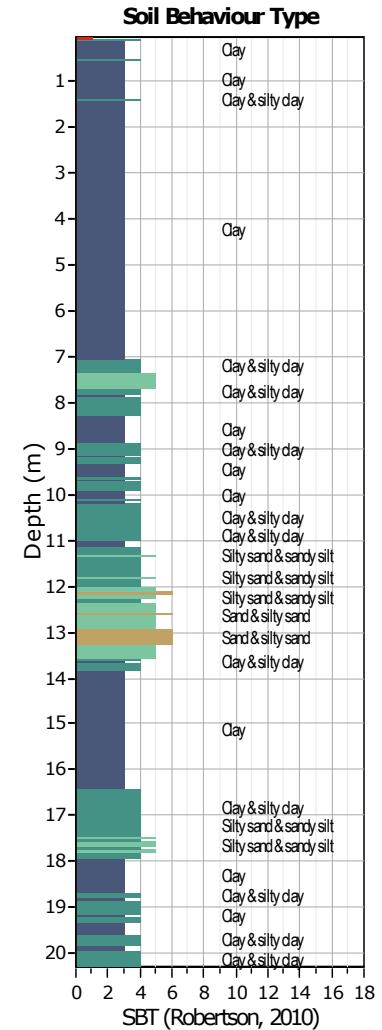
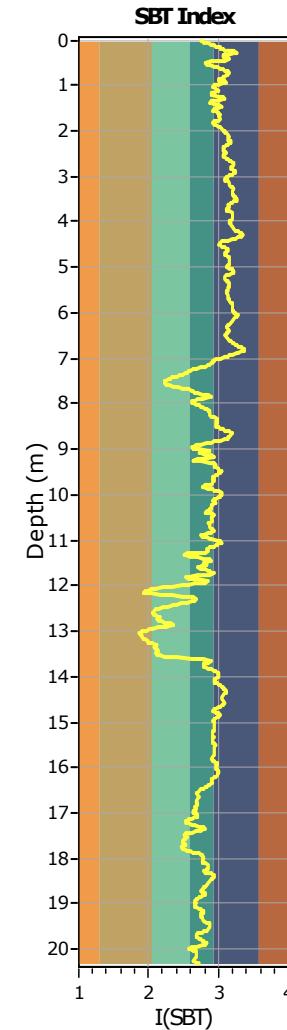
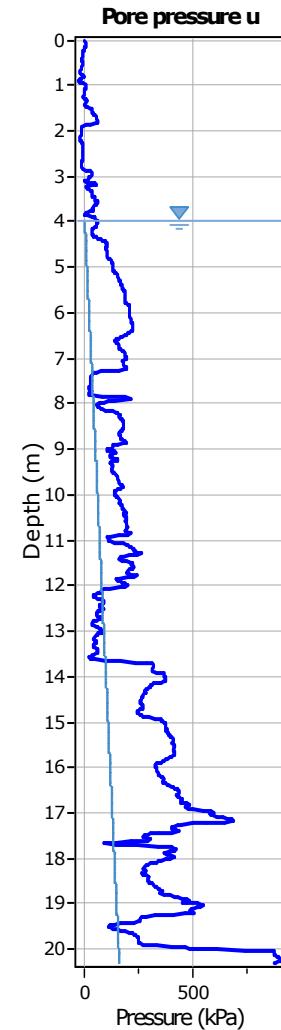
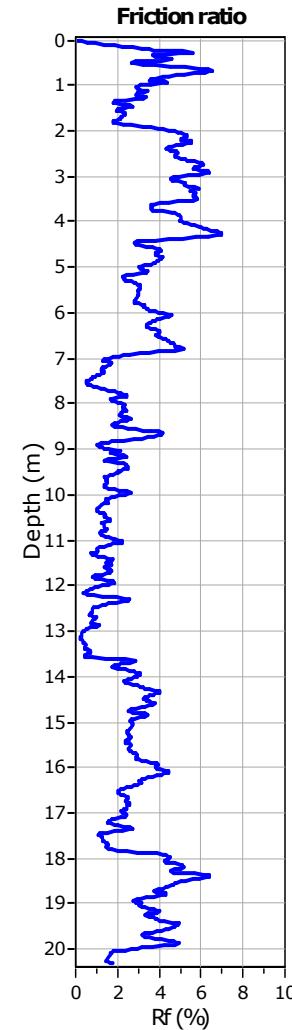
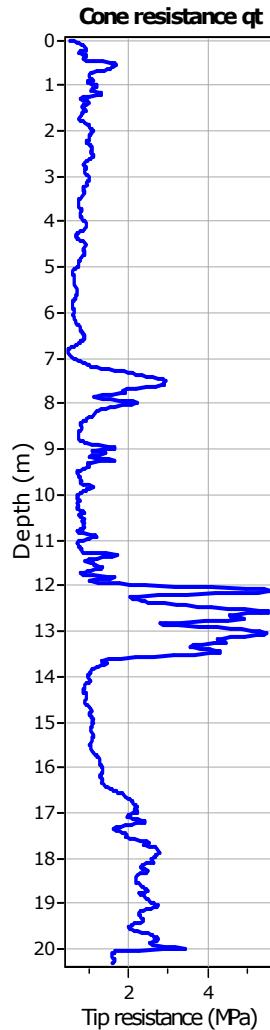


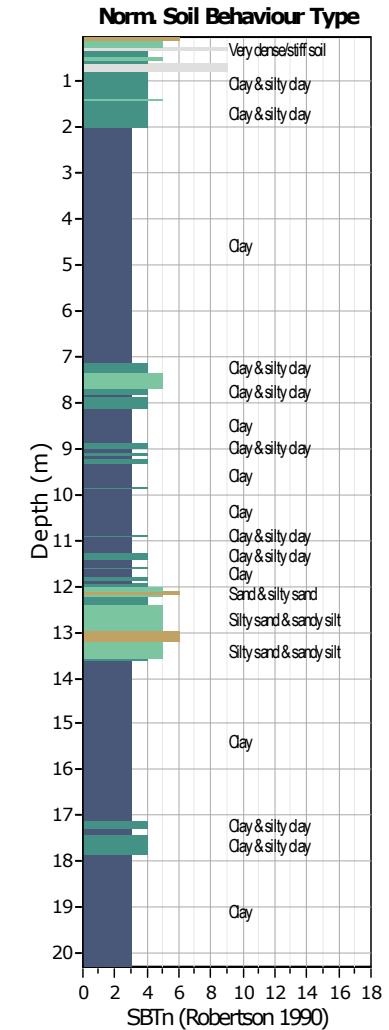
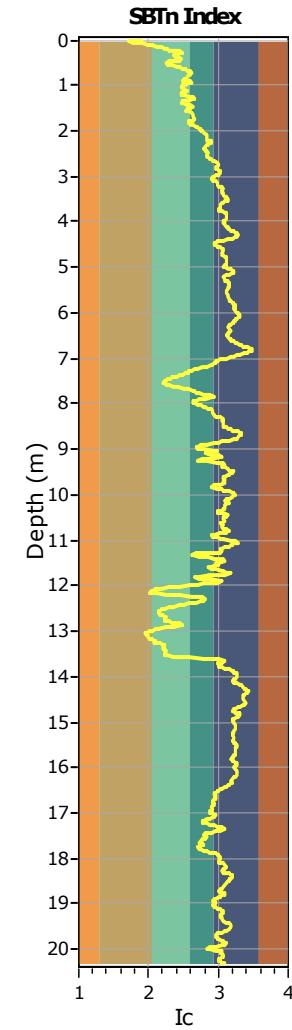
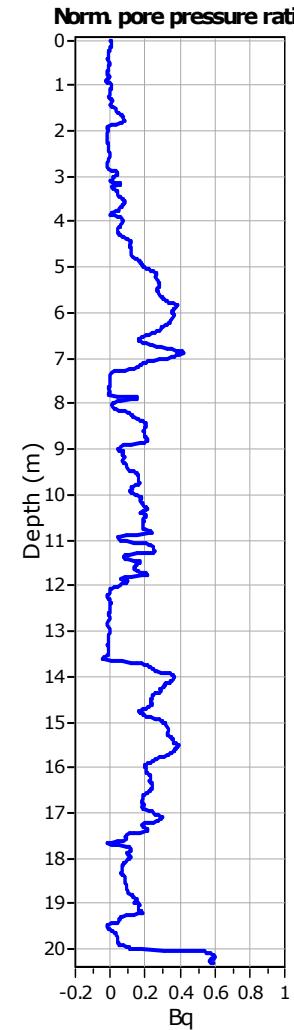
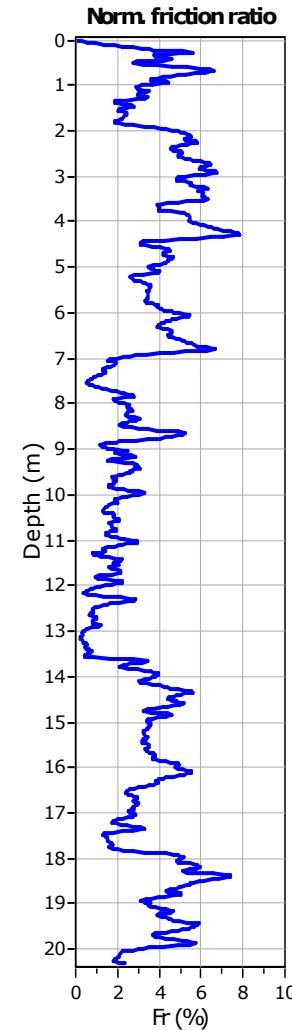
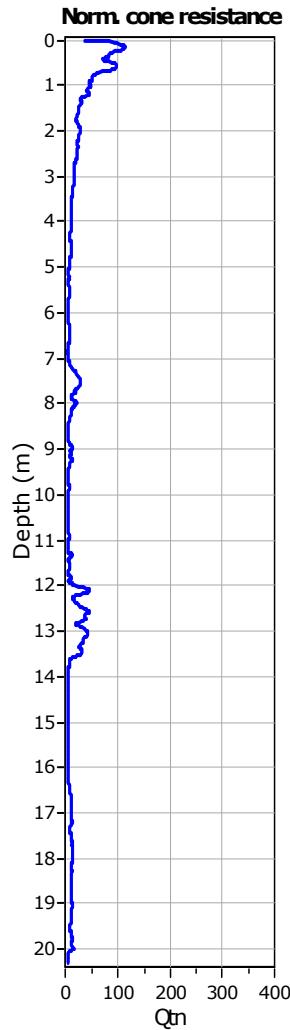
SBT legend

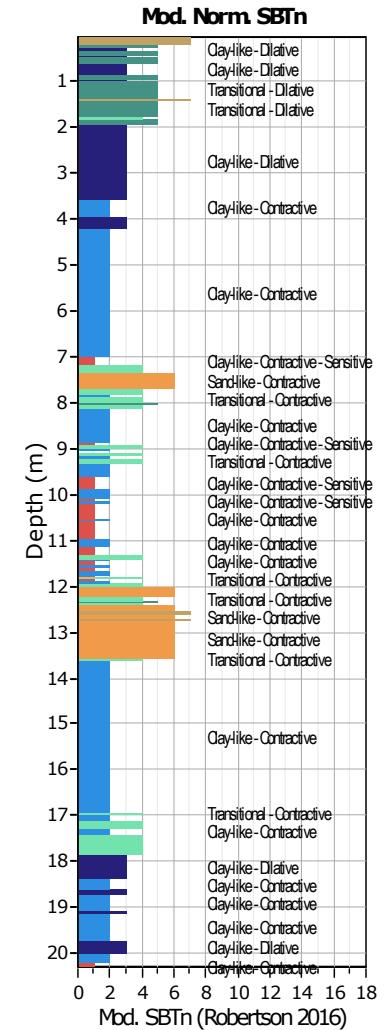
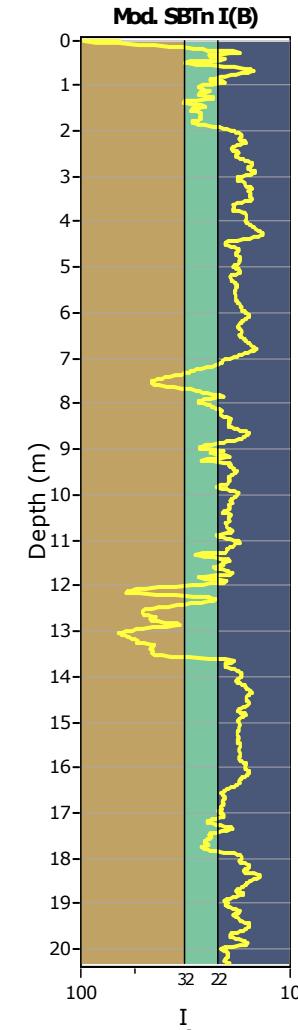
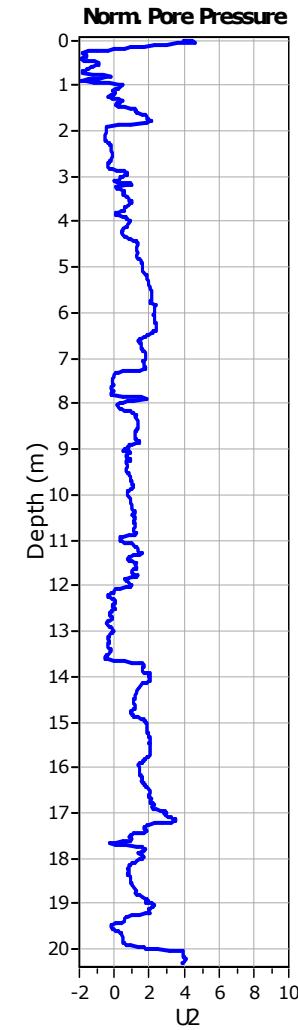
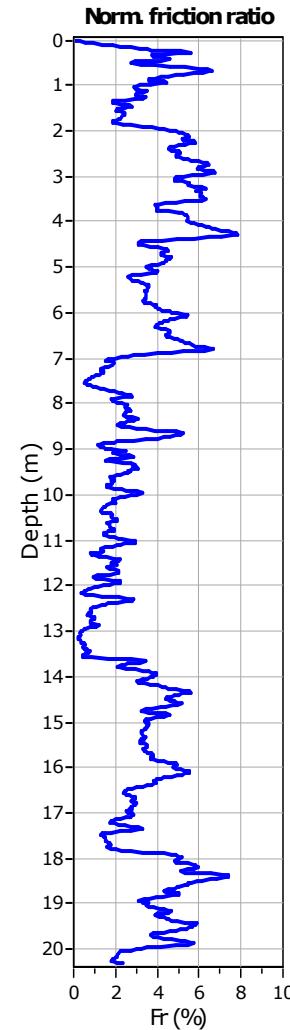
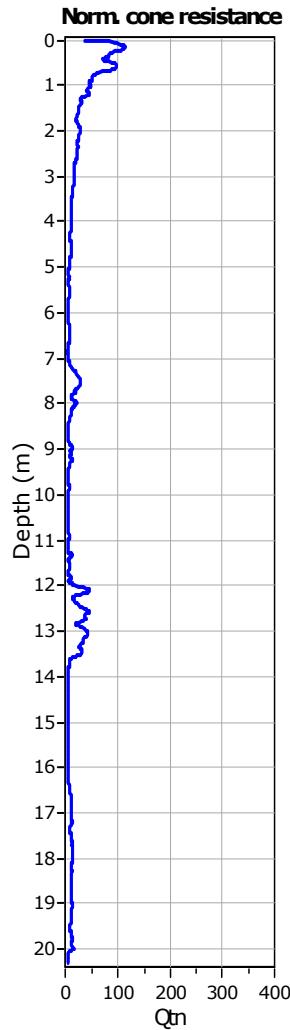
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

SBT - Bq plots (normalized)



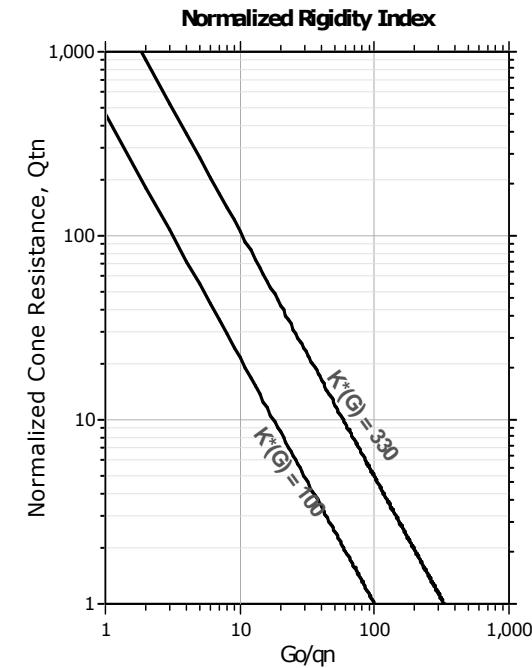
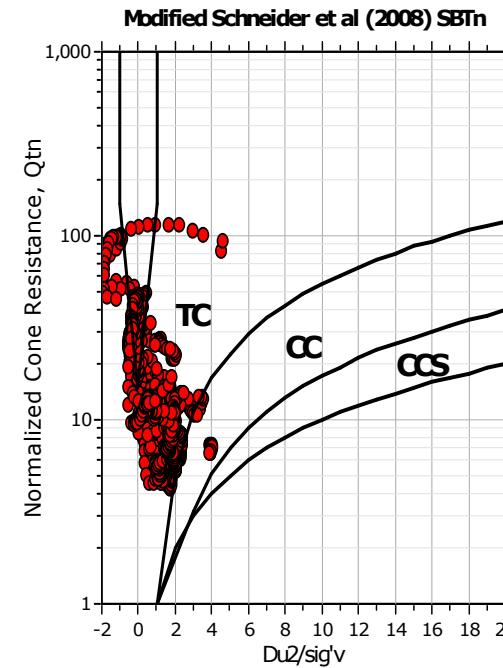
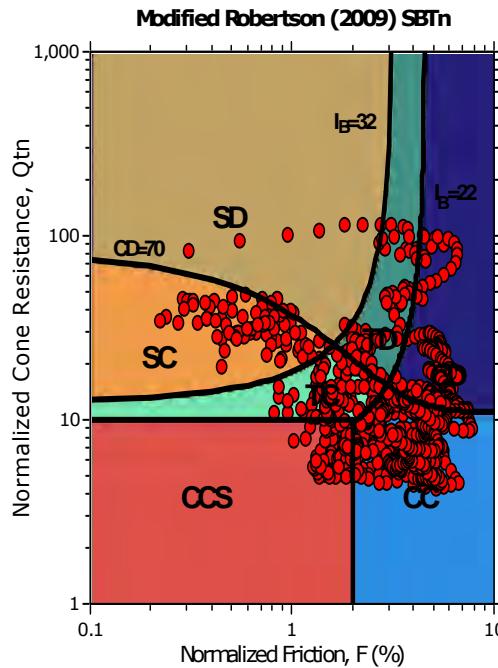




**Mod. SBTn legend**

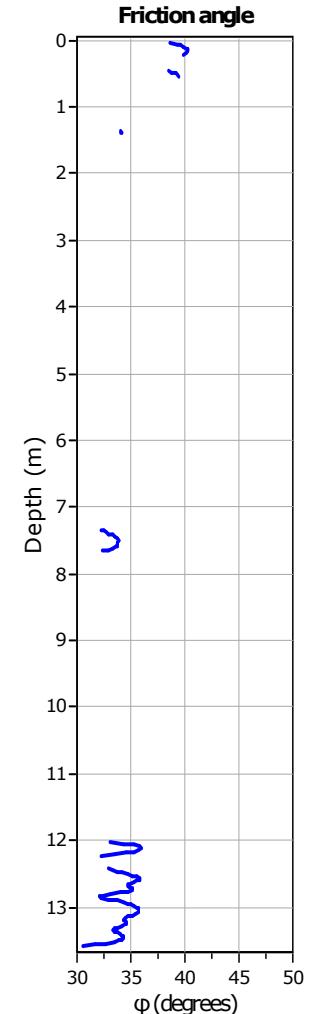
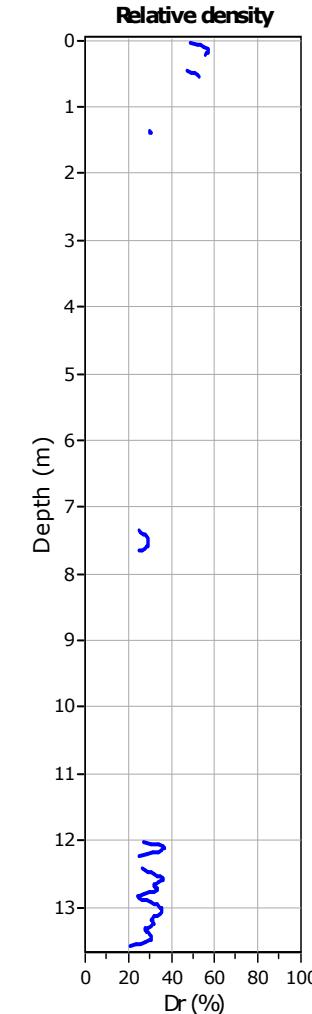
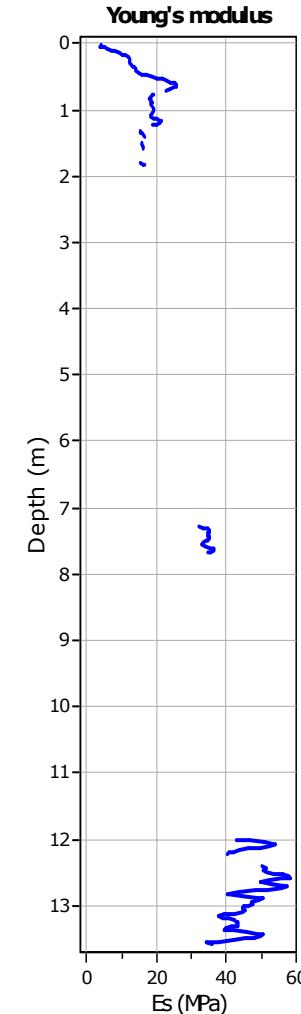
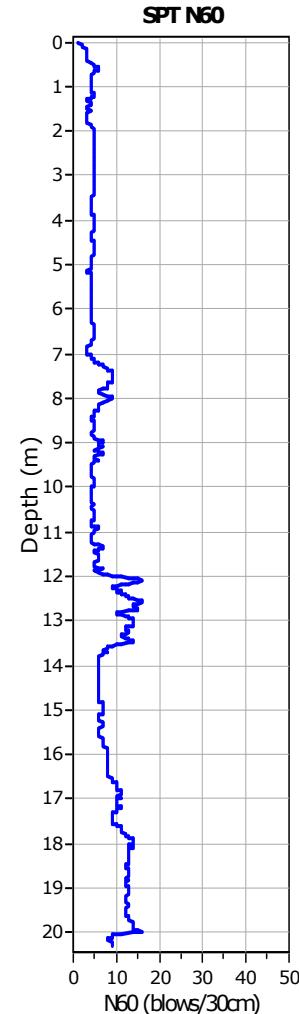
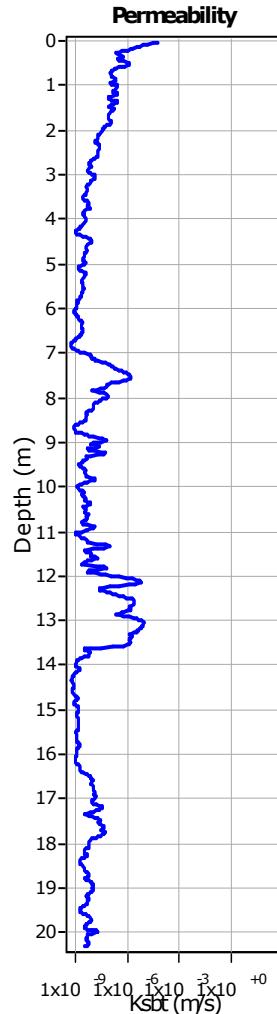
- | | | |
|---|-----------------------------------|-----------------------------|
| 1. CCS: ClayLike - Contractive, Sensitive | 4. TC: Transitional - Contractive | 7. SD: Sand-like - Dilative |
| 2. CC: Clay-like - Contractive | 5. TD: Transitional - Dilative | |
| 3. CD: Clay-Like: Dilative | 6. SC: Sand-like - Contractive | |

Updated SBTn plots



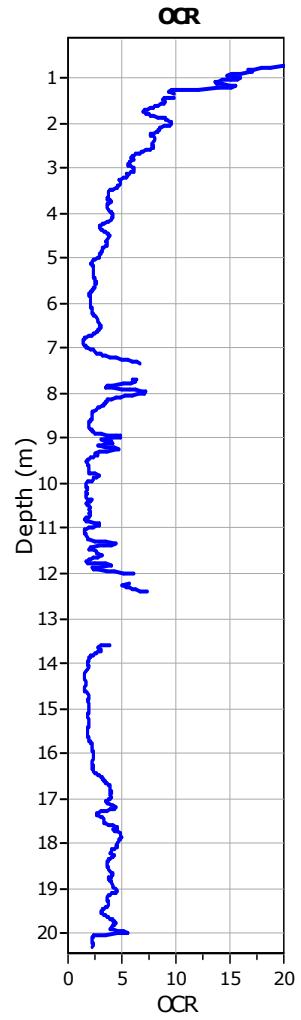
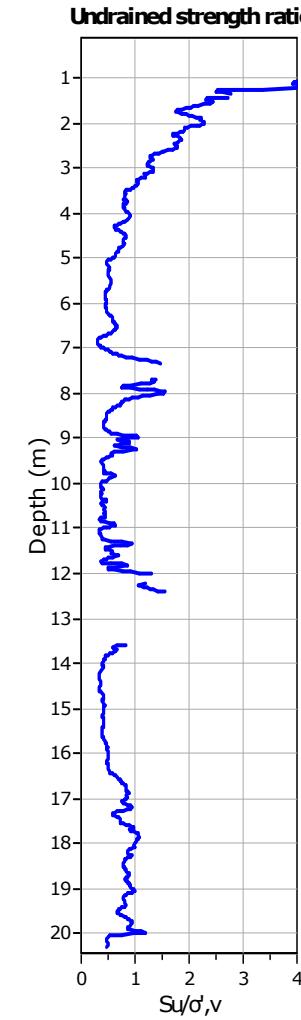
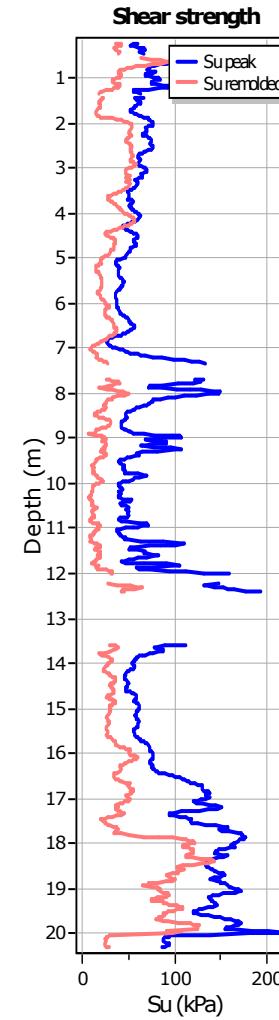
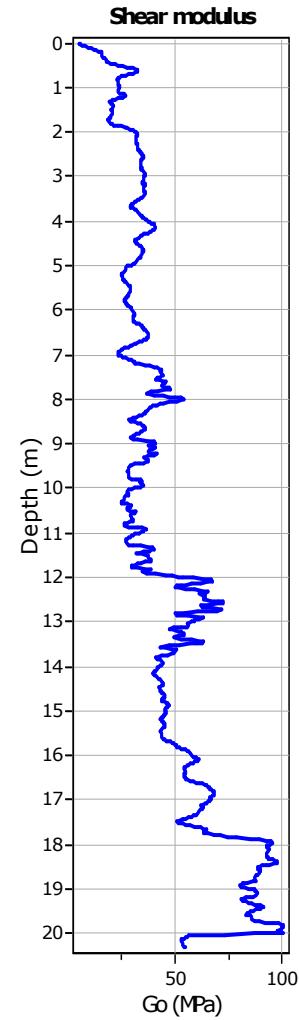
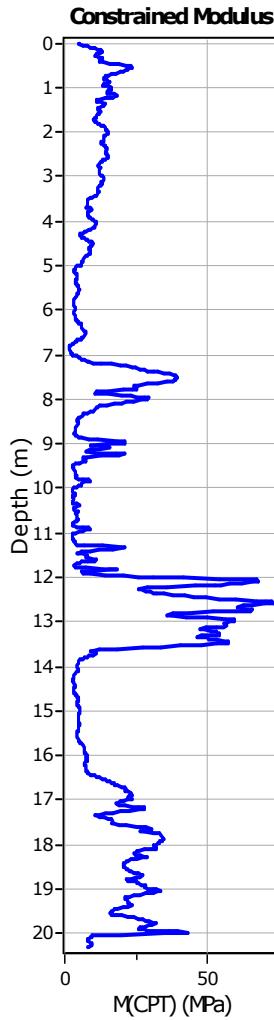
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure (e.g. age/cementation)

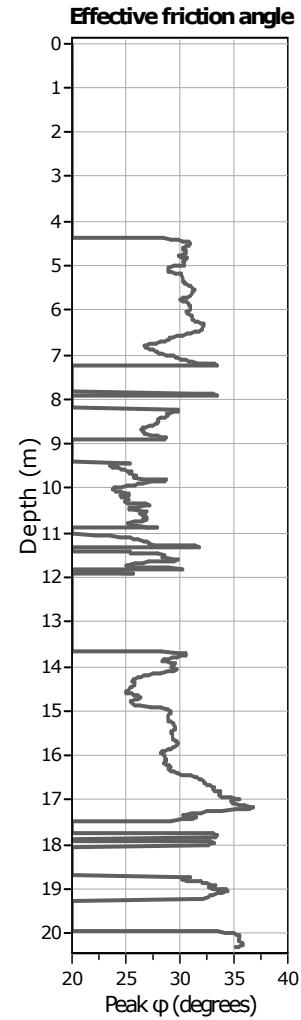
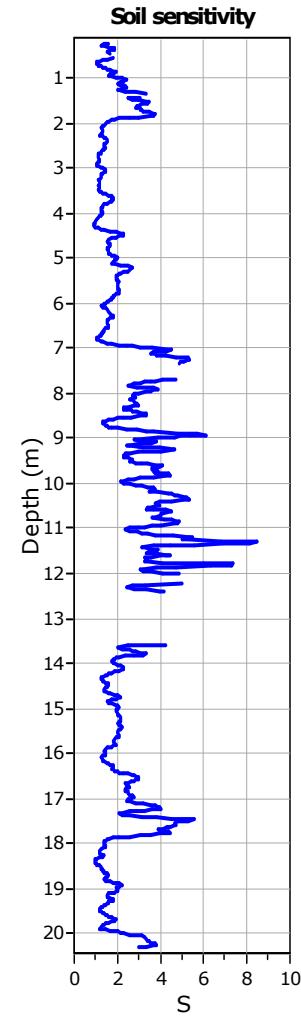
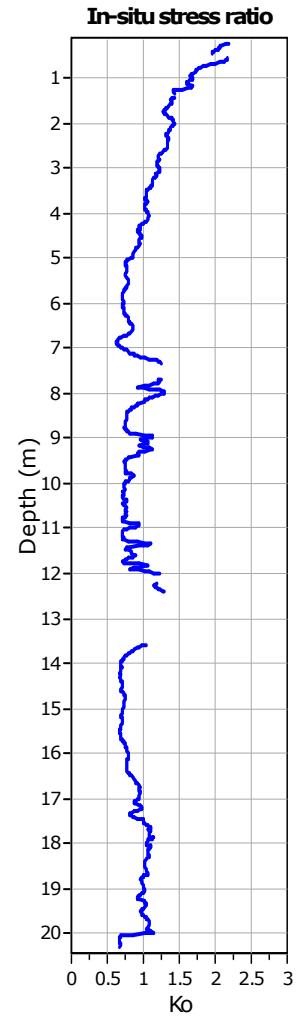
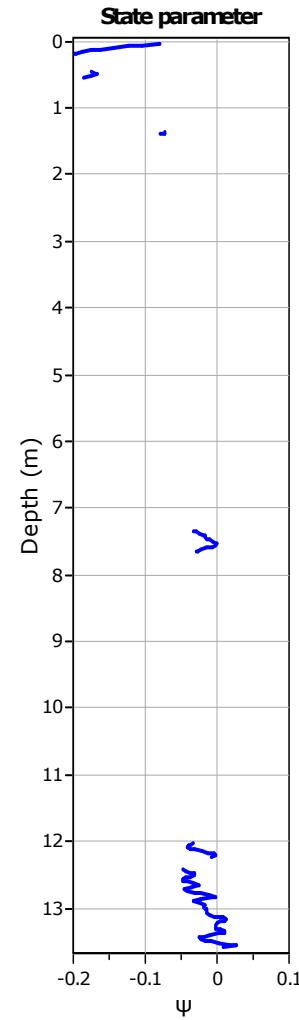
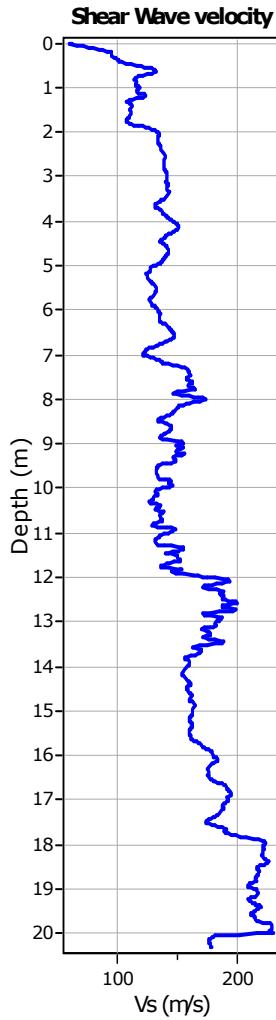
**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

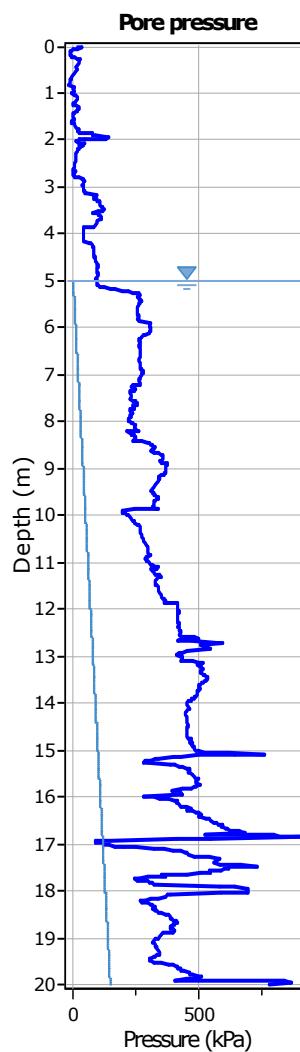
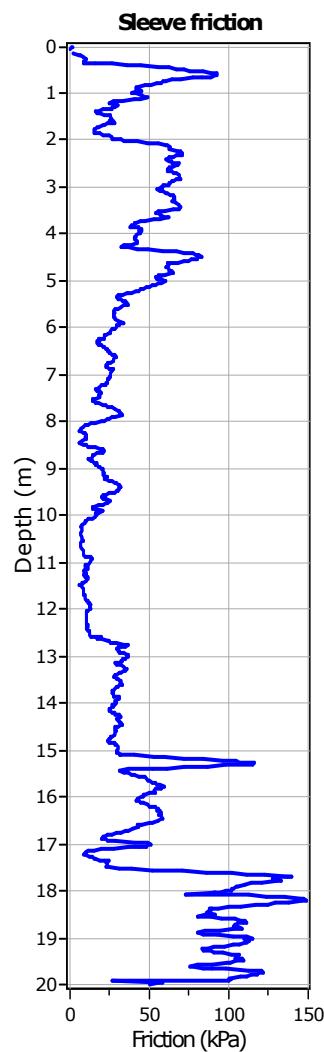
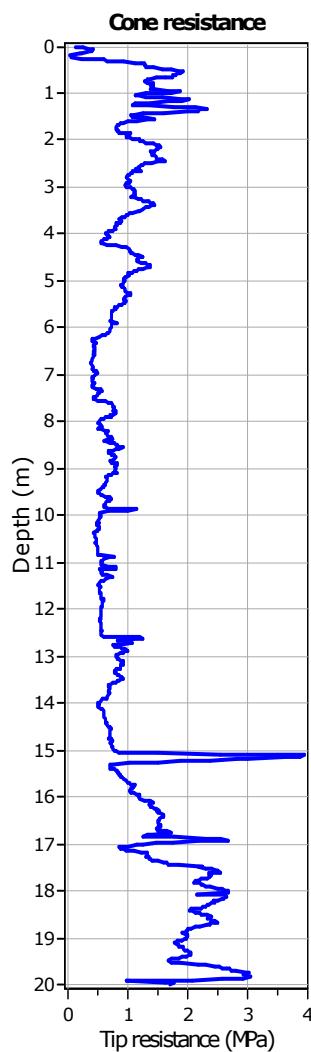
User defined estimation data

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

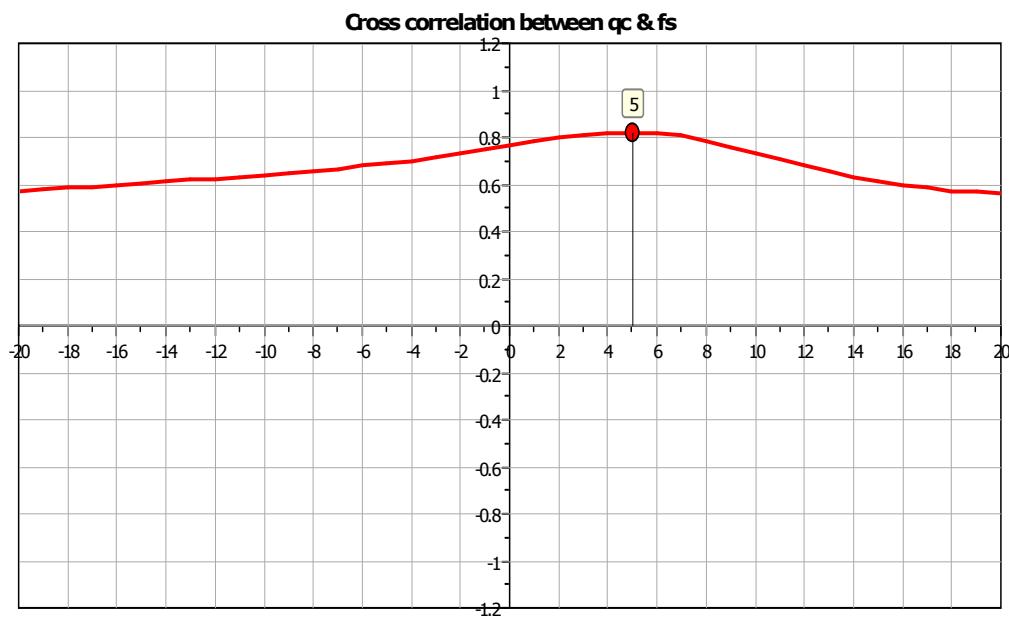
- User defined estimation data
- Flat Dilatometer Test data

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

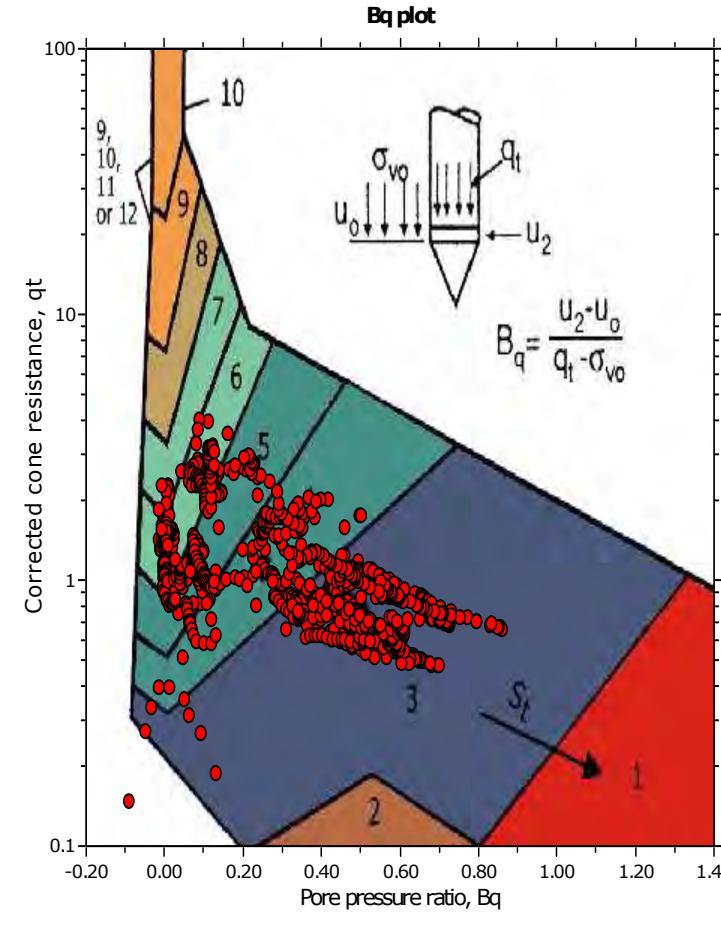
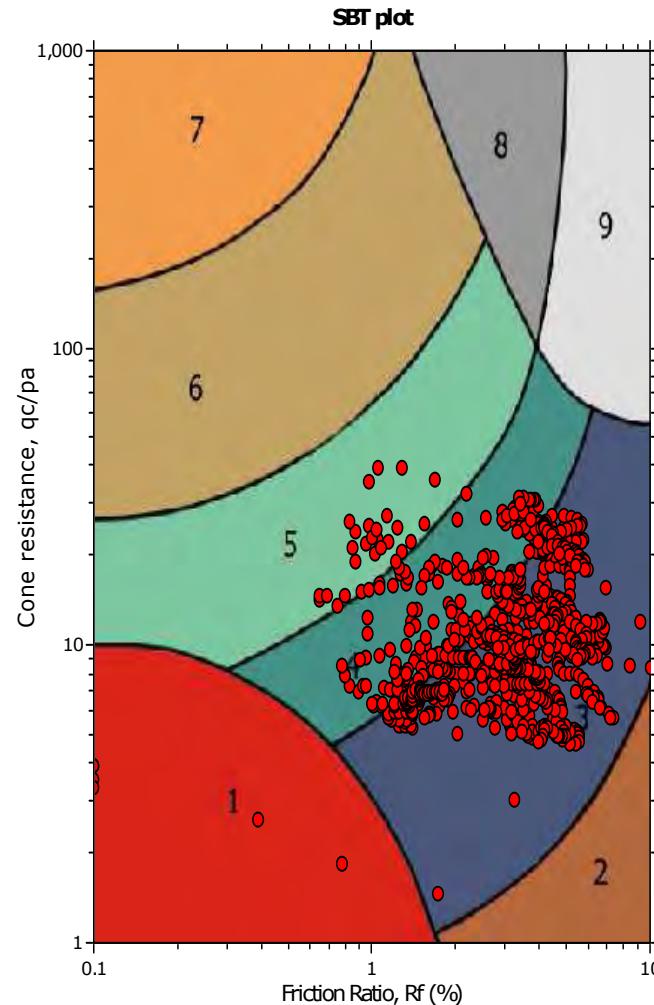
User defined estimation data



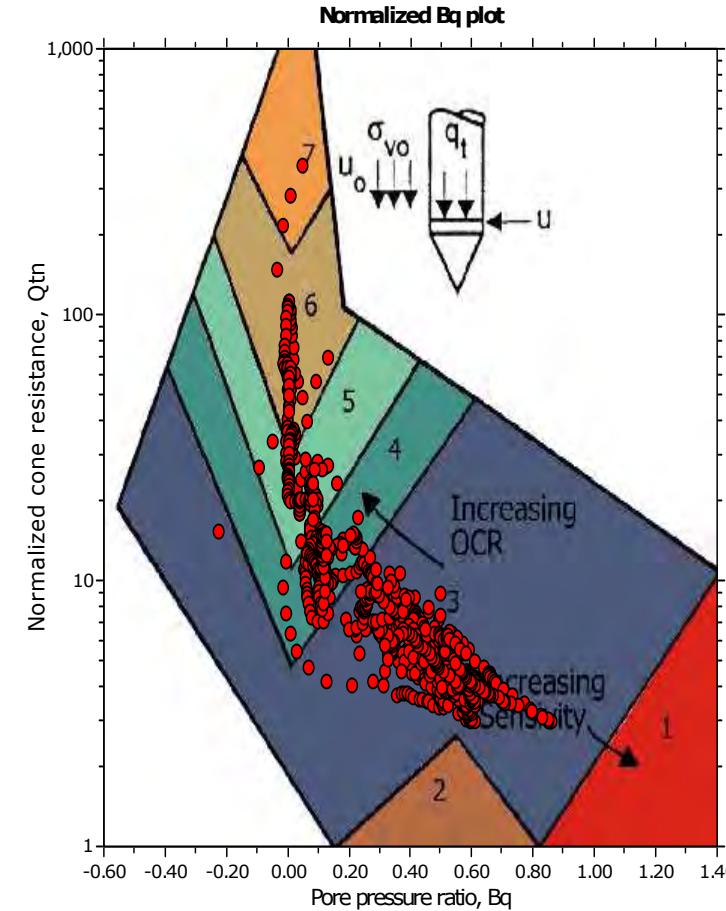
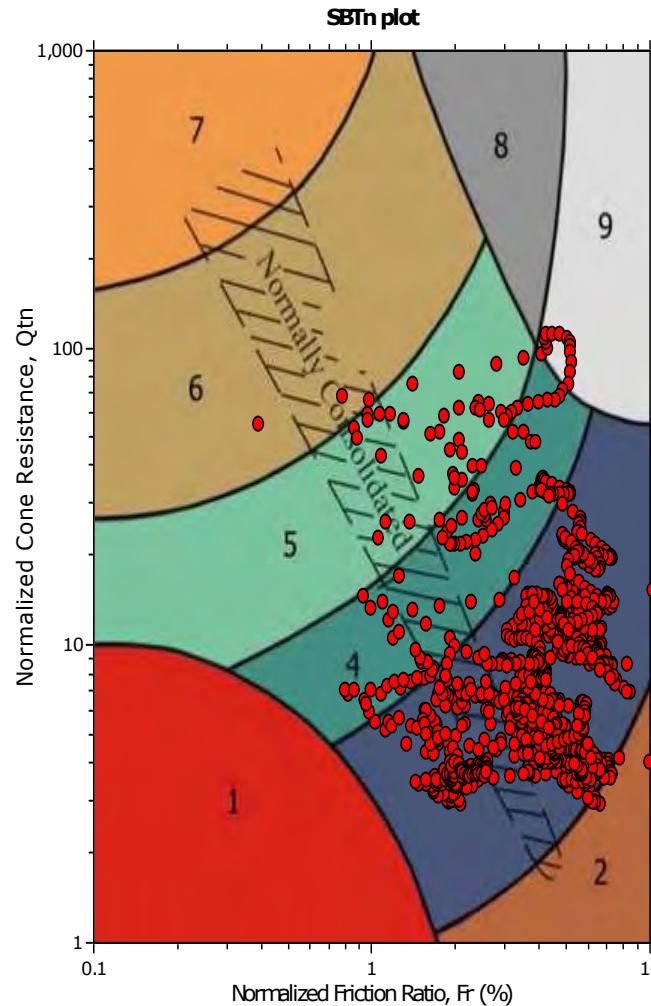
The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



SBT - Bq plots

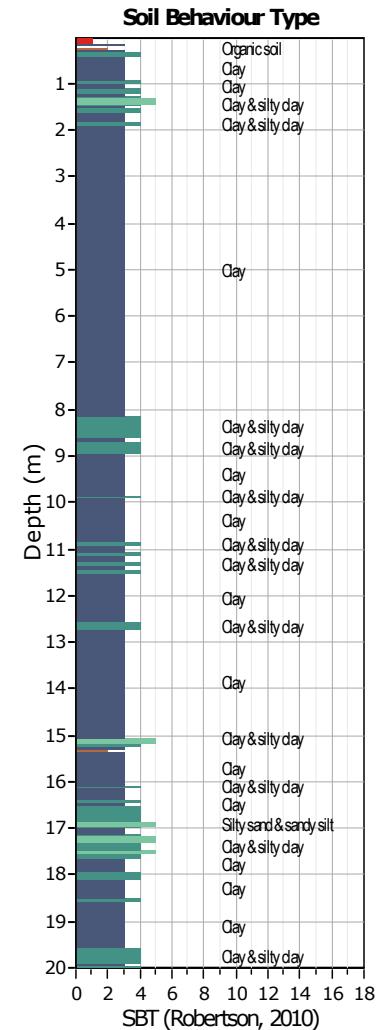
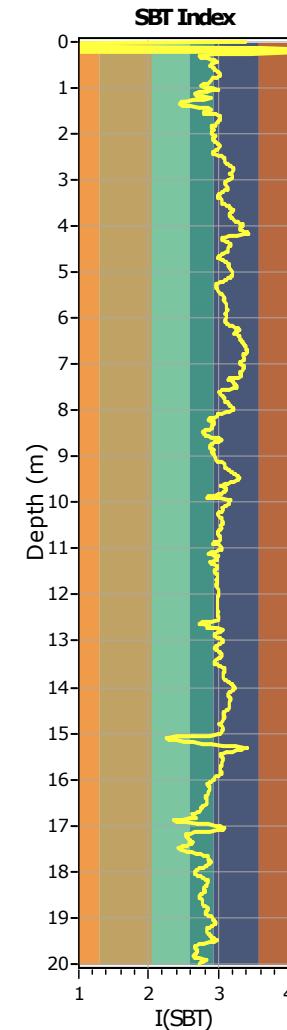
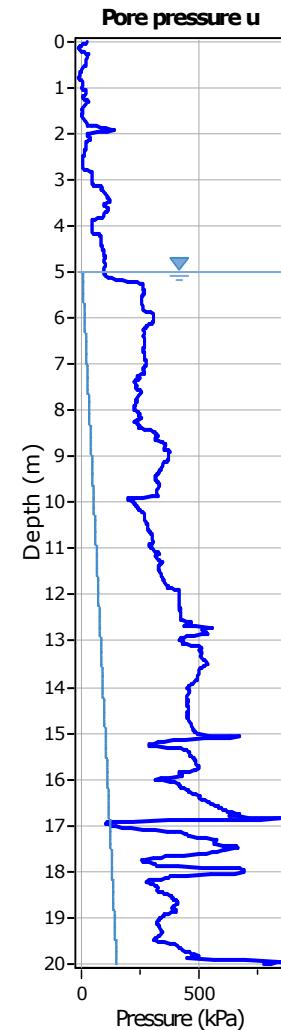
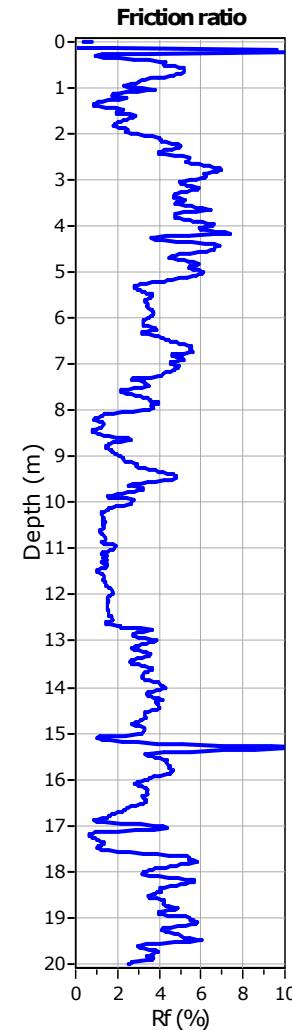
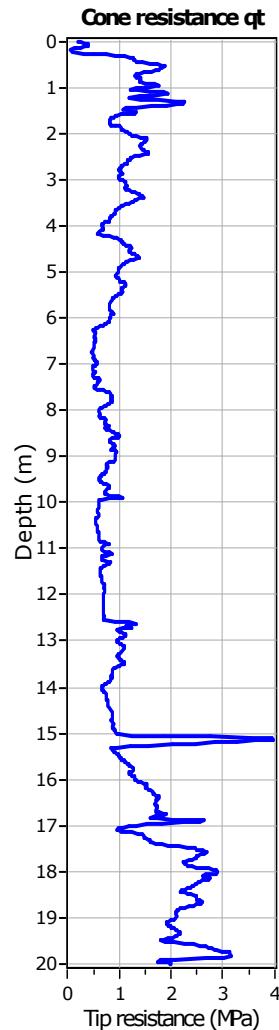


SBT - Bq plots (normalized)



SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained



SBT legend

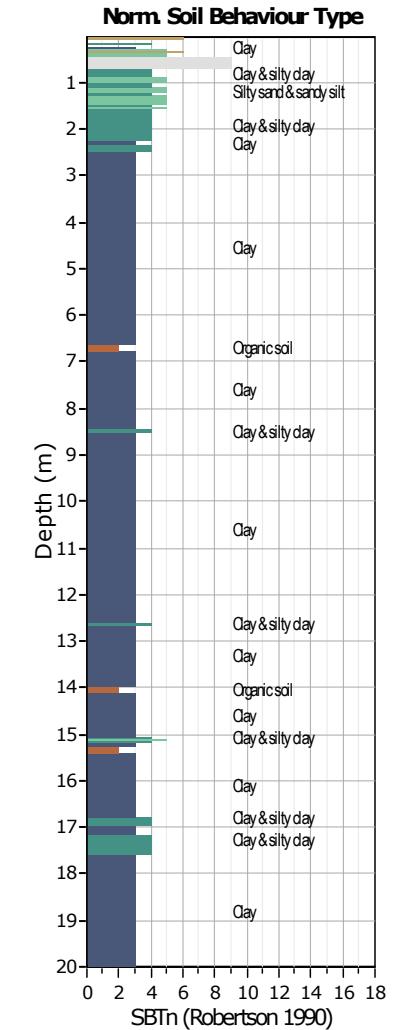
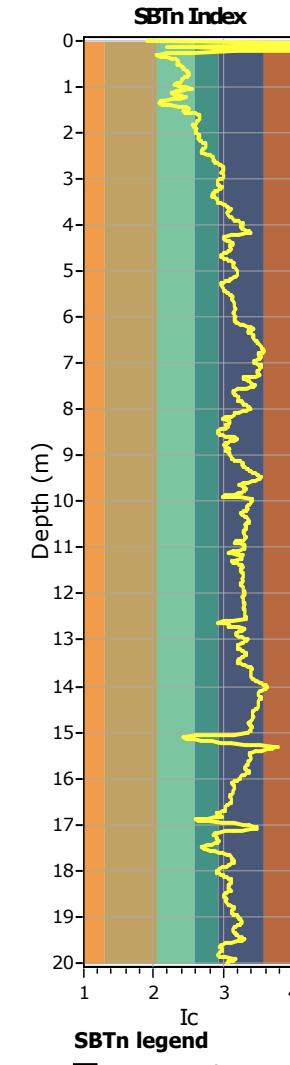
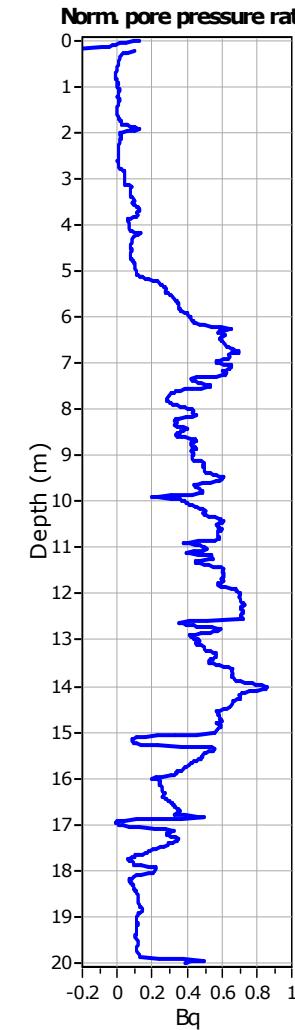
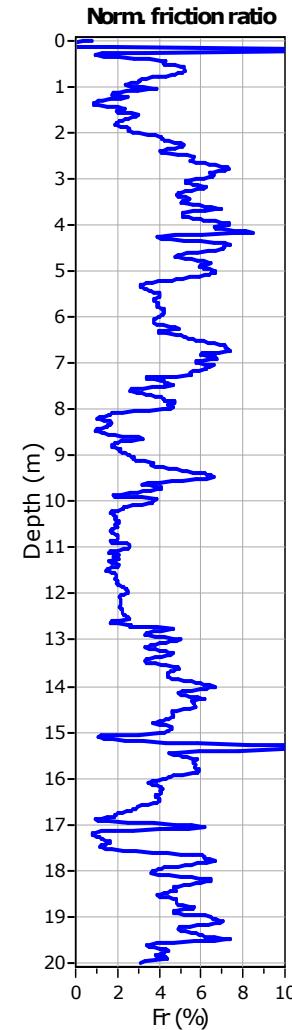
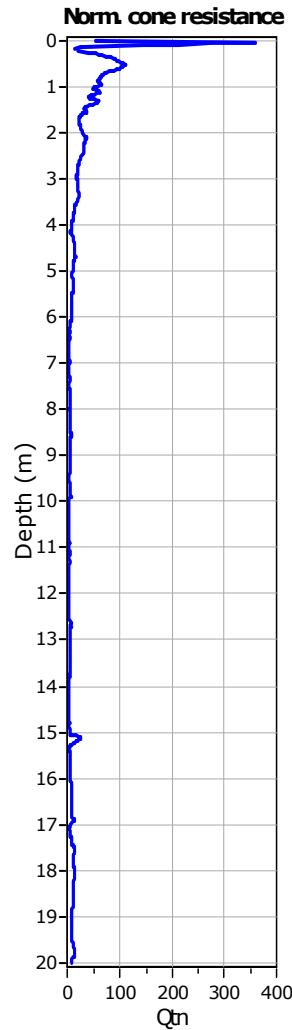
- | | | | | | |
|---|---------------------------|---|------------------------------|---|-----------------------------------|
| █ | 1. Sensitive fine grained | | 4. Clayey silt to silty clay | | 7. Gravely sand to sand |
| █ | 2. Organic material | | 5. Silty sand to sandy silt | | 8. Very stiff sand to clayey sand |
| █ | 3. Clay to silty clay | | 6. Clean sand to silty sand | | 9. Very stiff fine grained |

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 12

Total depth: 20.00 m, Date: 16/05/2018



- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand

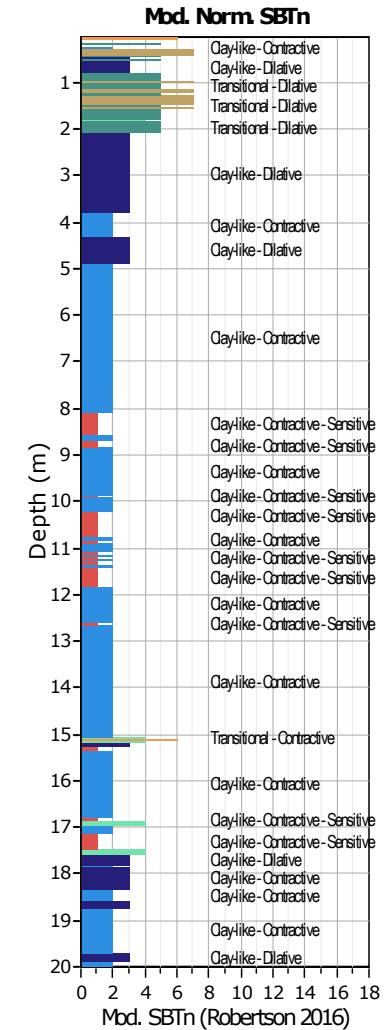
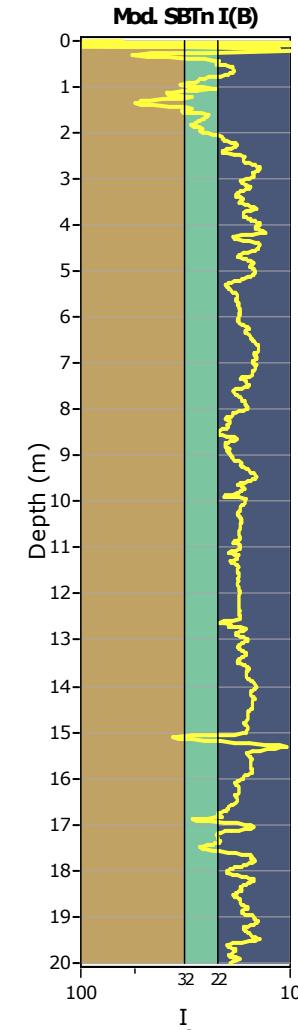
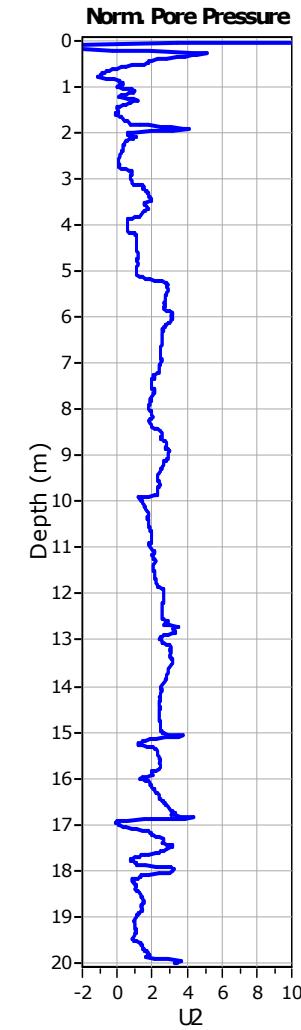
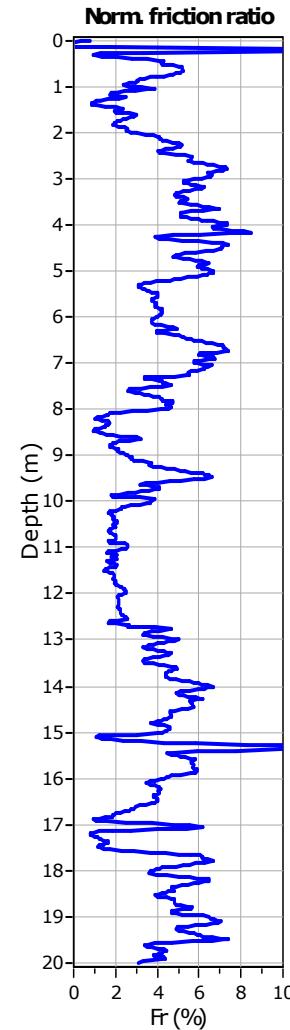
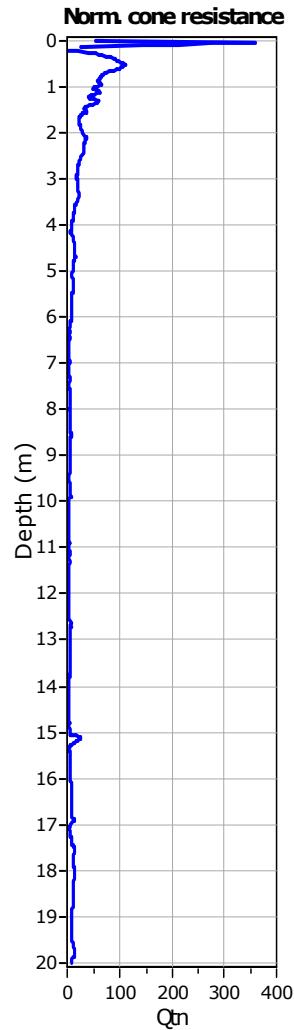
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

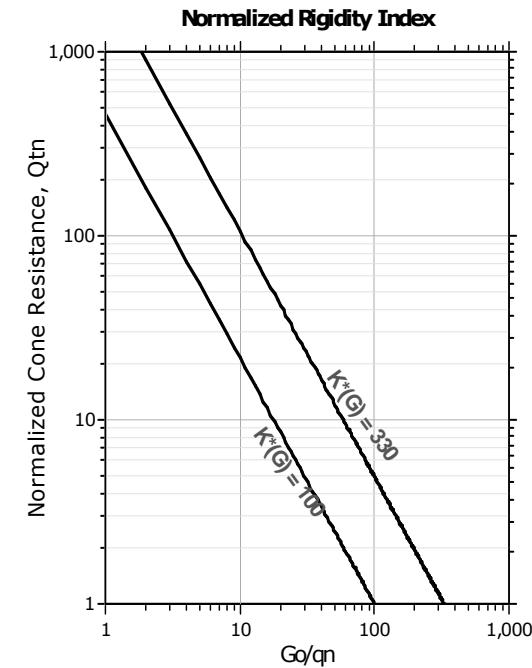
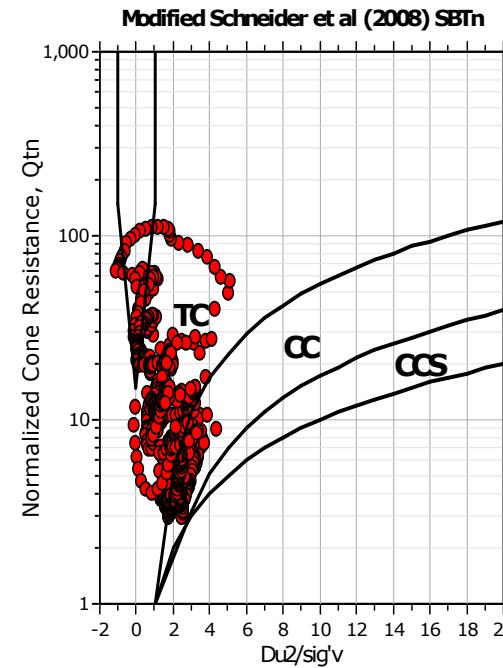
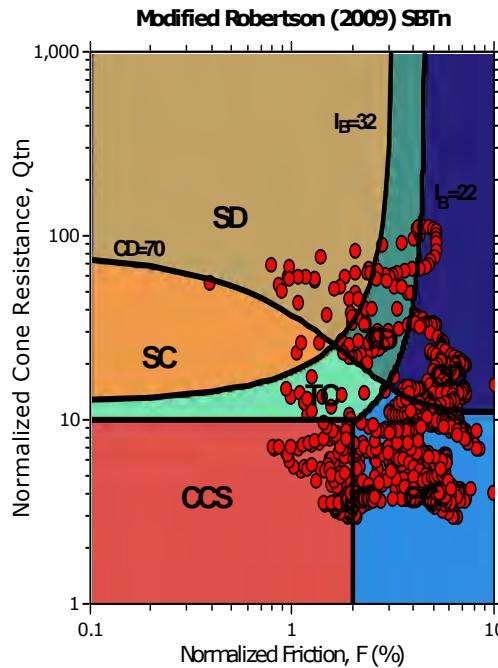
CPT: CPTU 12

Total depth: 20.00 m, Date: 16/05/2018

**Mod. SBTn legend**

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

Updated SBTn plots

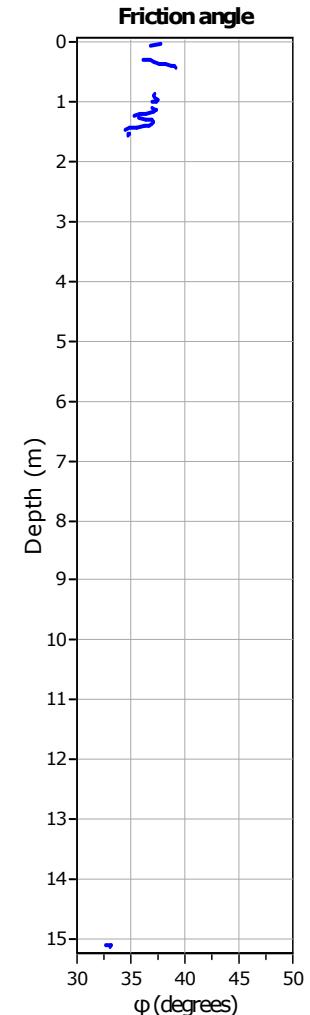
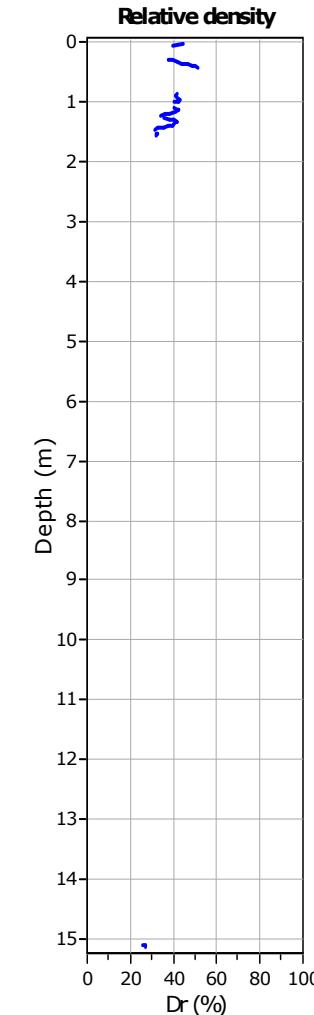
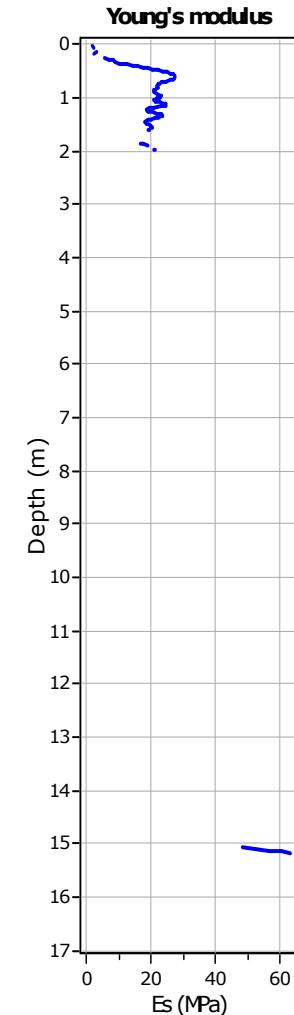
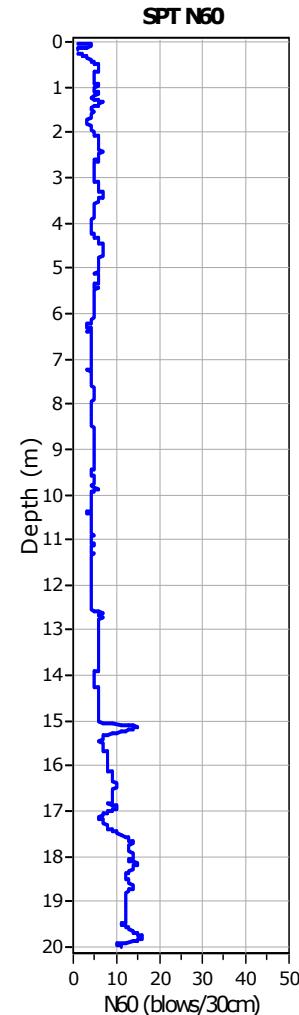
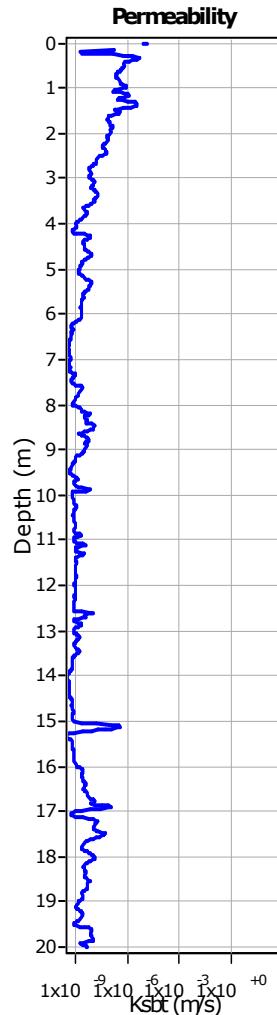


CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

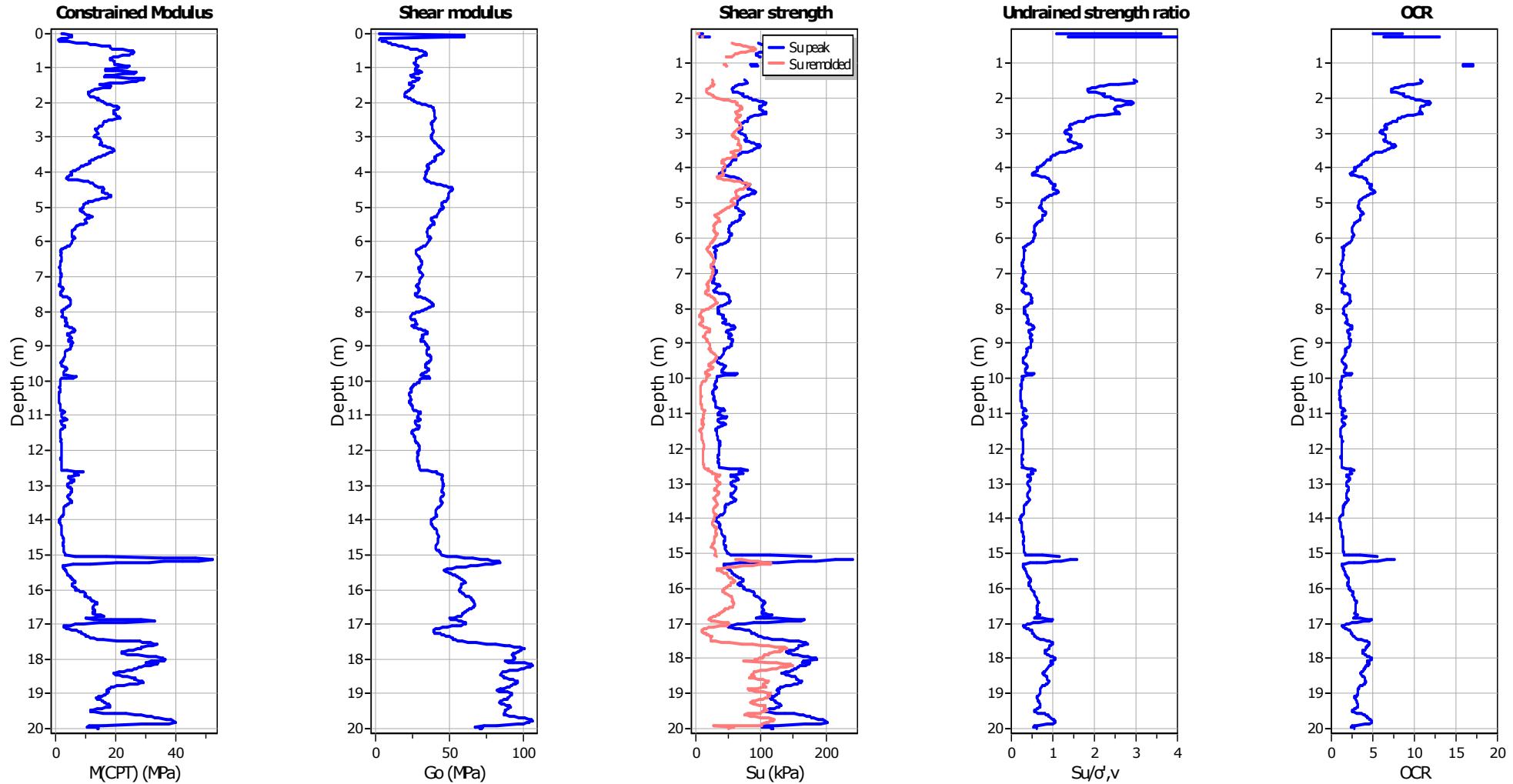
Project: Centro Unificato dell'Emergenza sul Territorio**Location:** Ferrara**CPT: CPTU 12**

Total depth: 20.00 m, Date: 16/05/2018

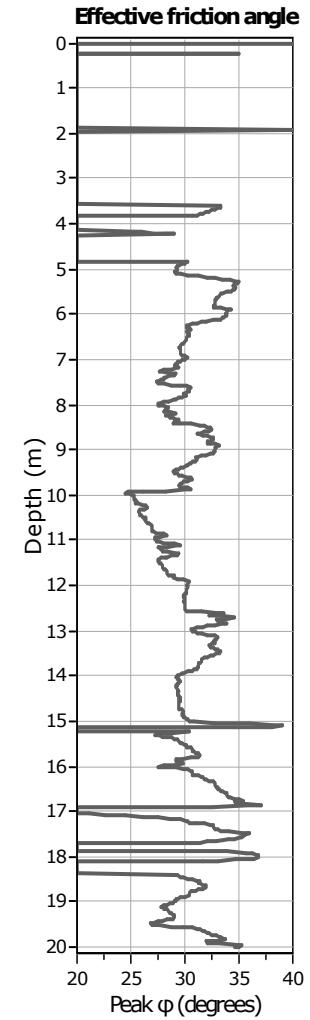
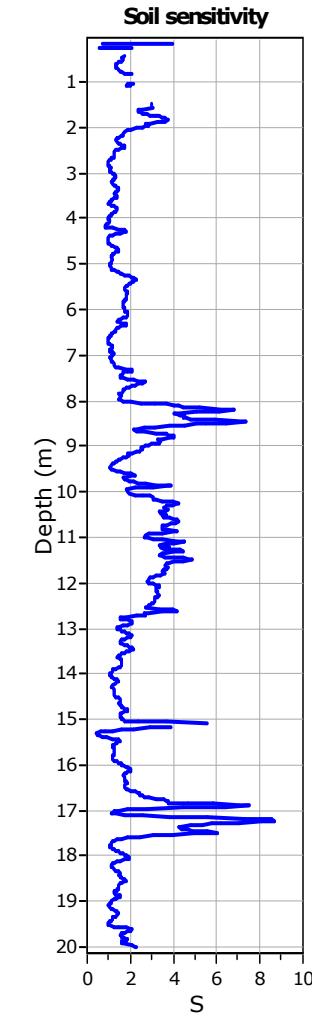
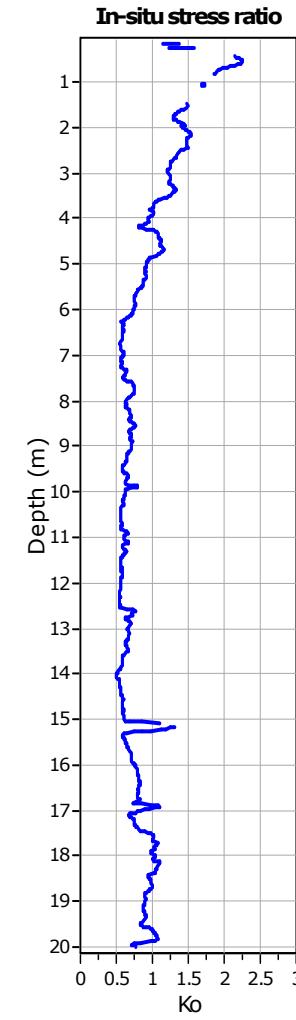
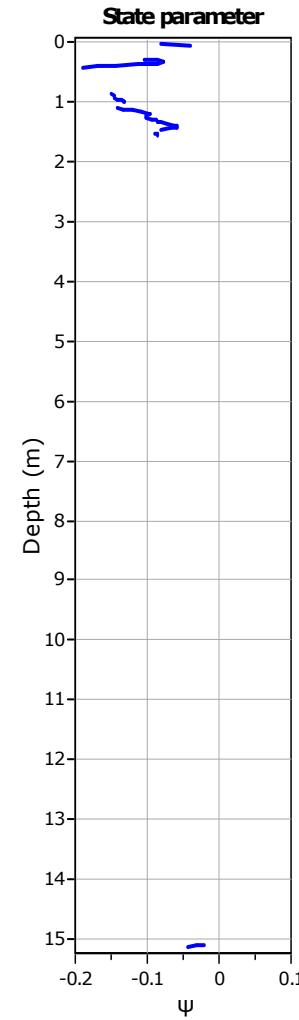
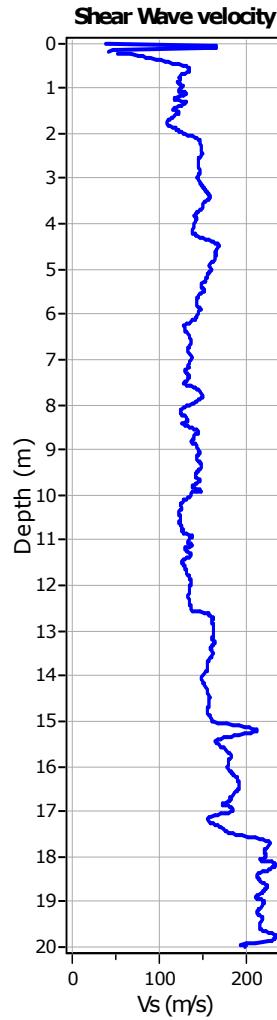
**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

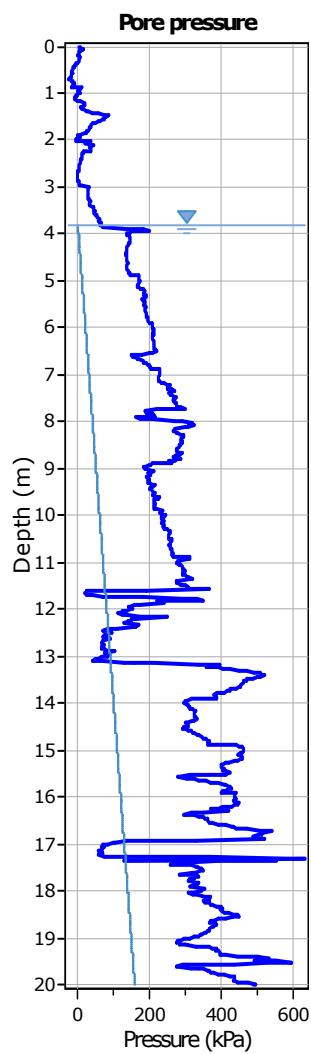
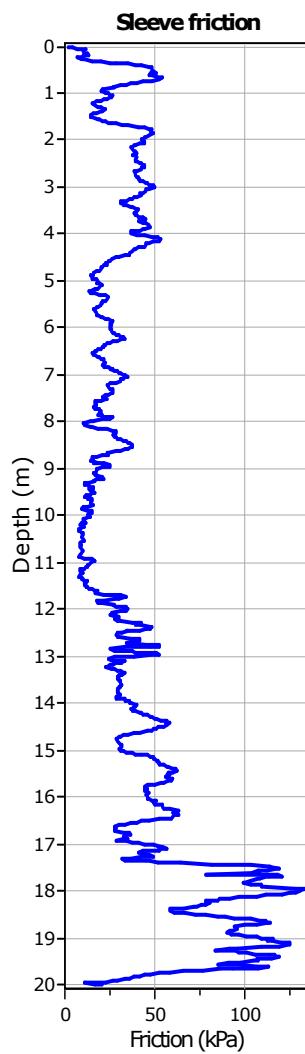
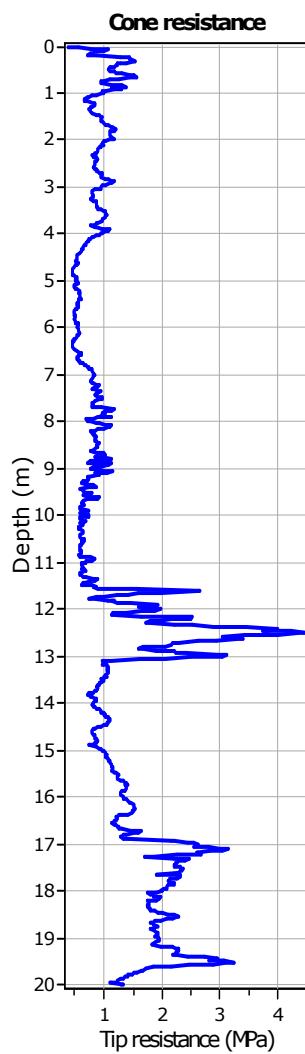
**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

- User defined estimation data
- Flat Dilatometer Test data

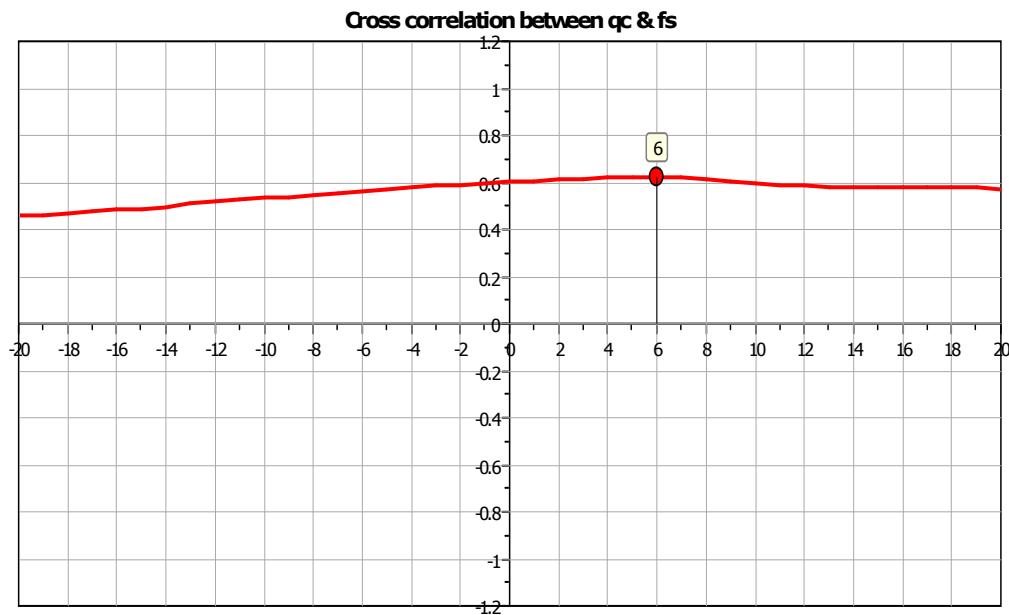
**Calculation parameters**

Soil Sensitivity factor, Ns: 7.00

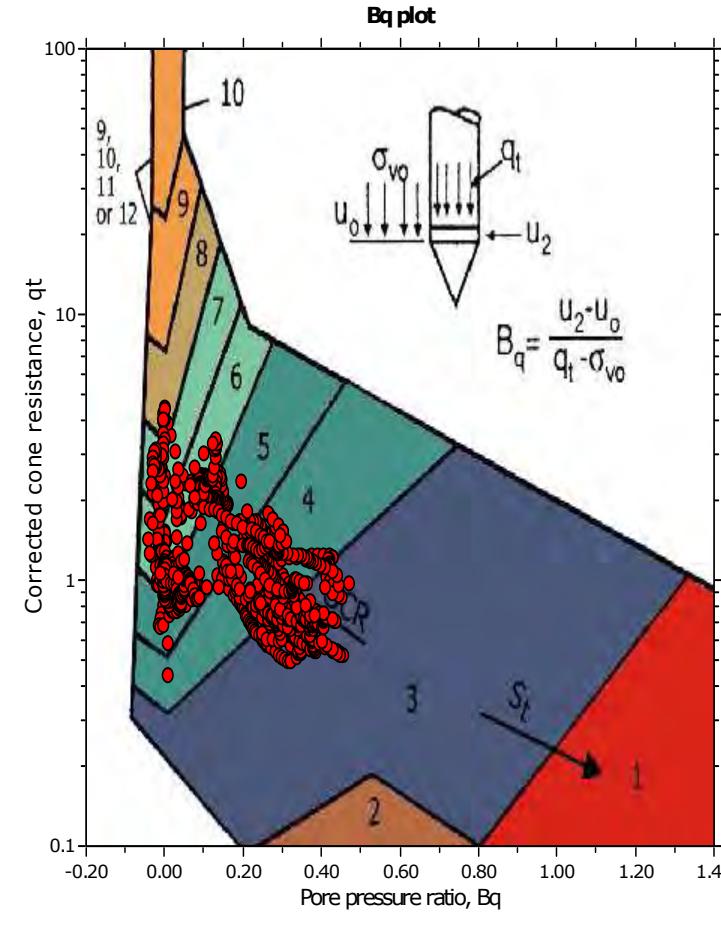
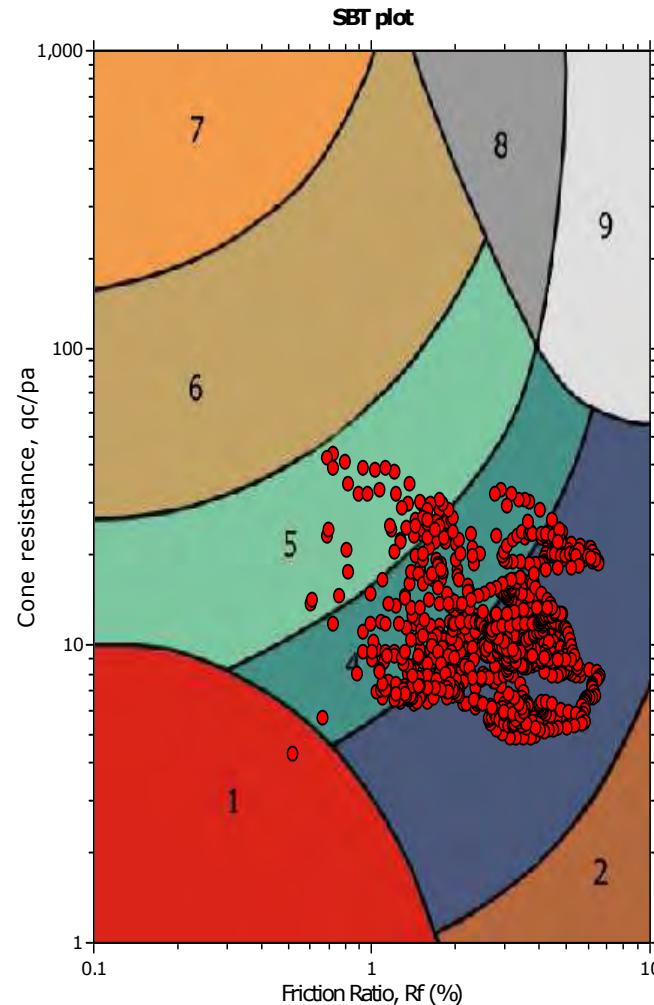
User defined estimation data



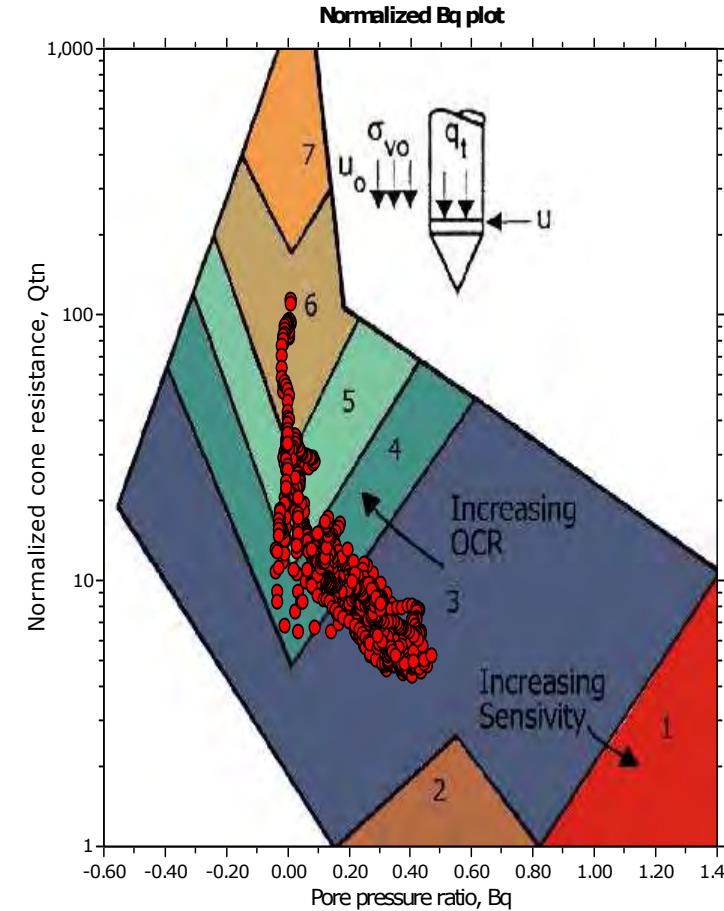
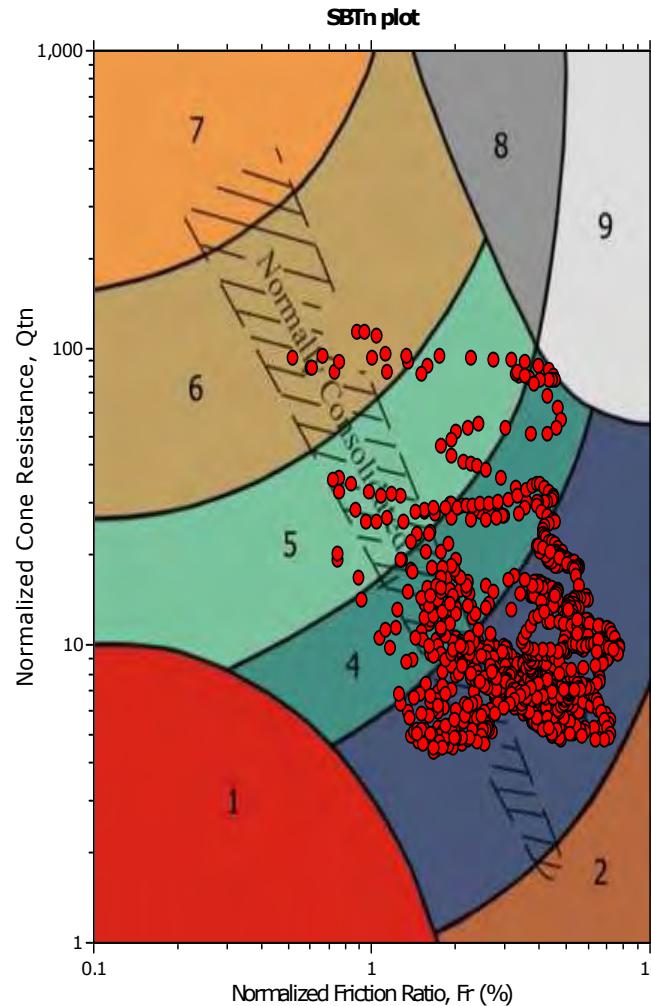
The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



SBT - Bq plots



SBT - Bq plots (normalized)



SBTn legend

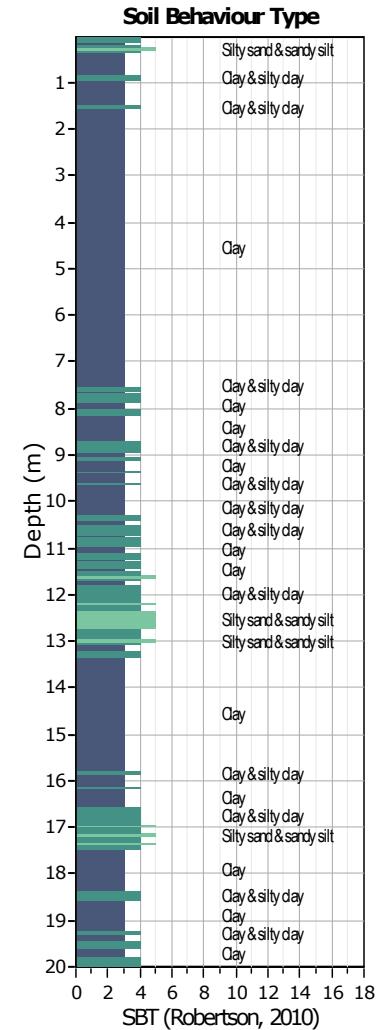
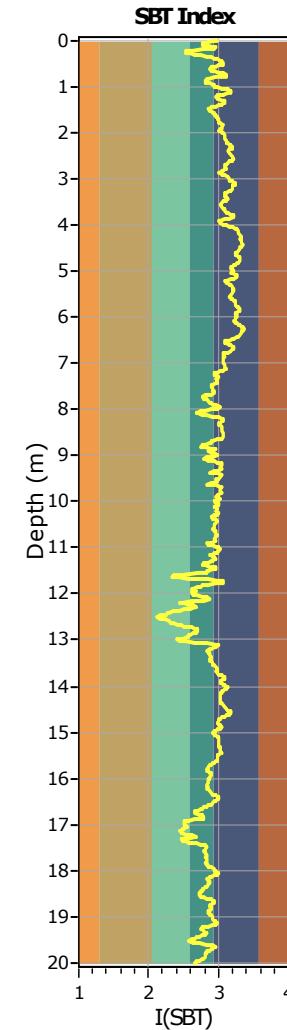
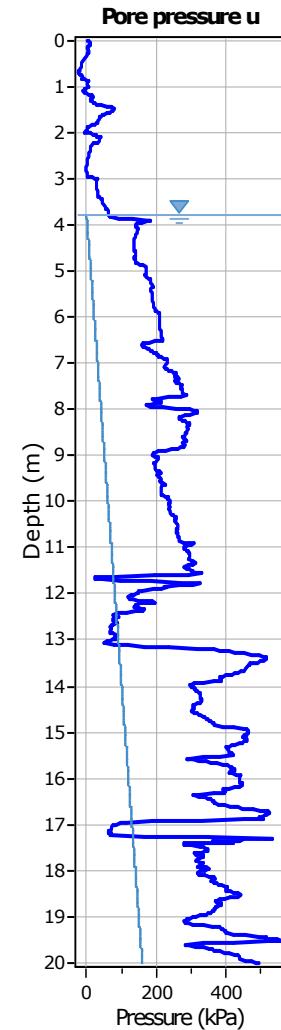
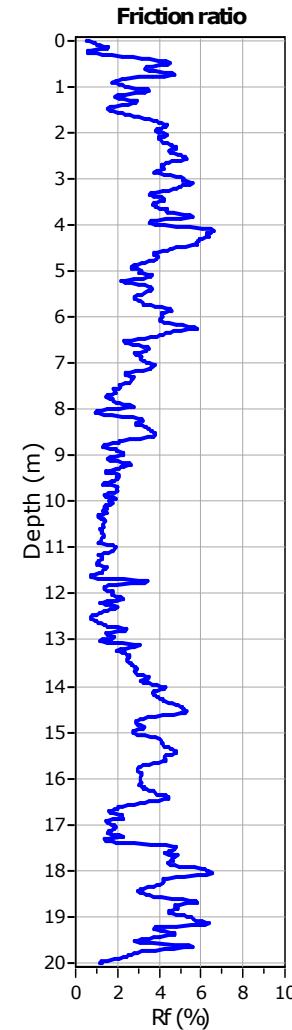
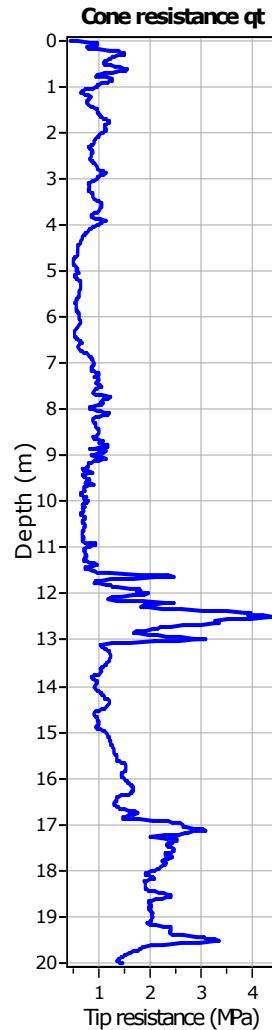
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 13

Total depth: 20.00 m, Date: 15/05/2018

**SBT legend**

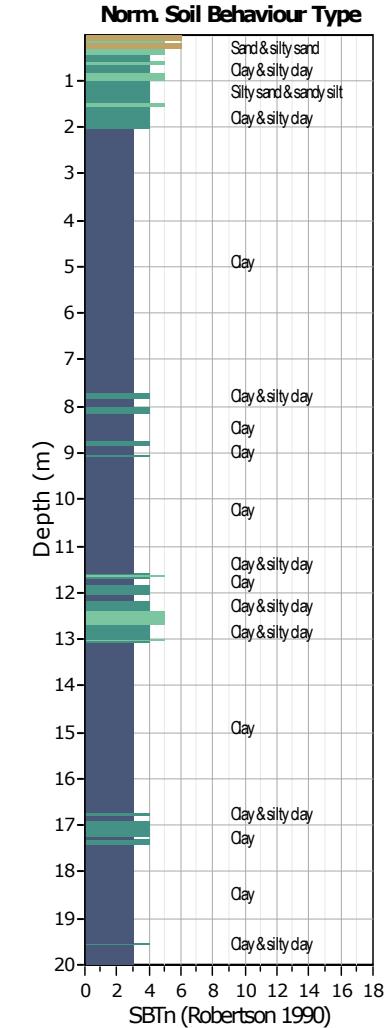
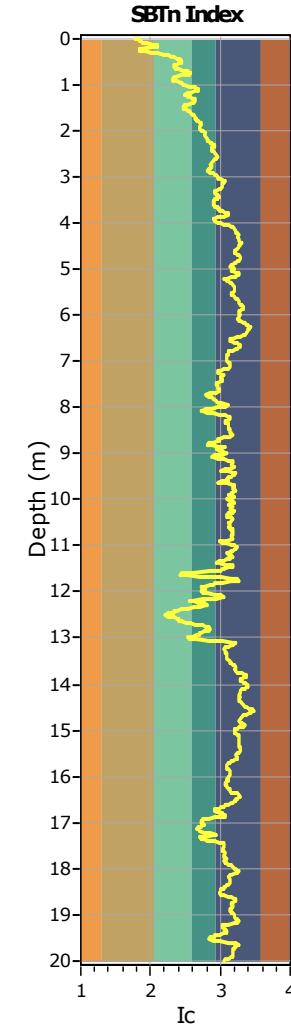
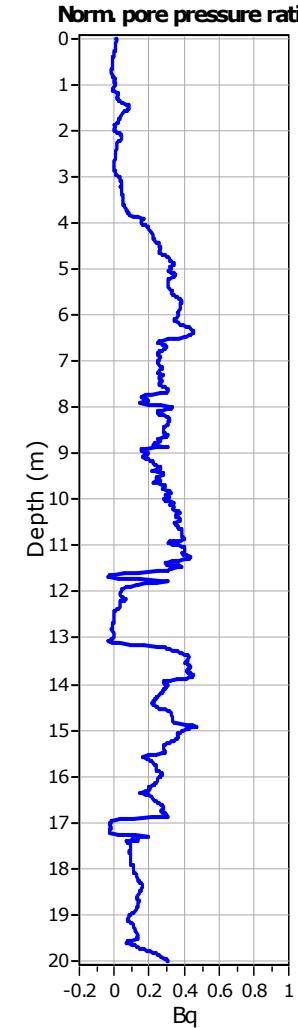
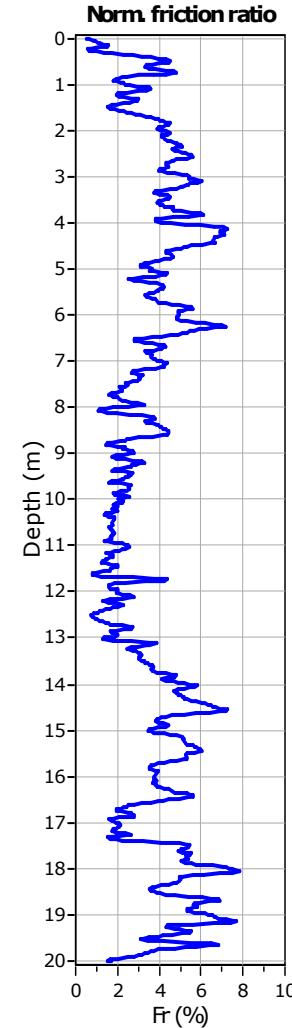
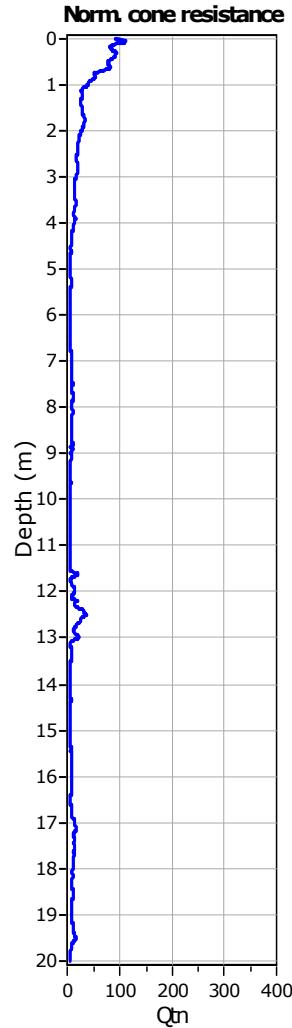
- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 13

Total depth: 20.00 m, Date: 15/05/2018

**SBTn legend**

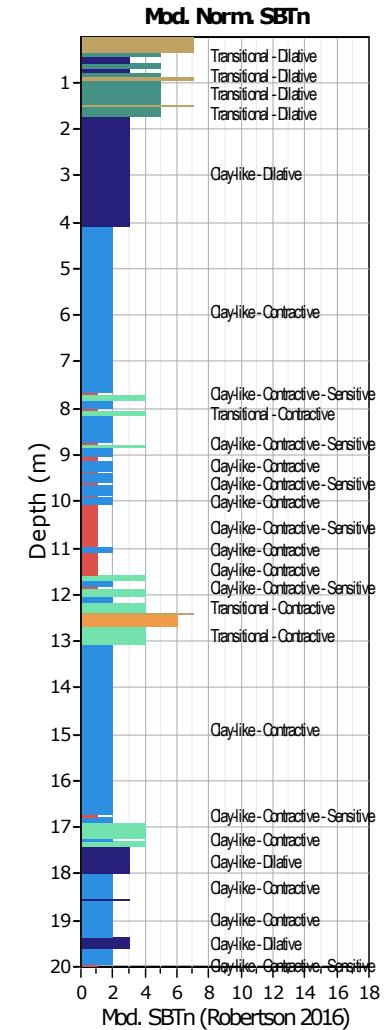
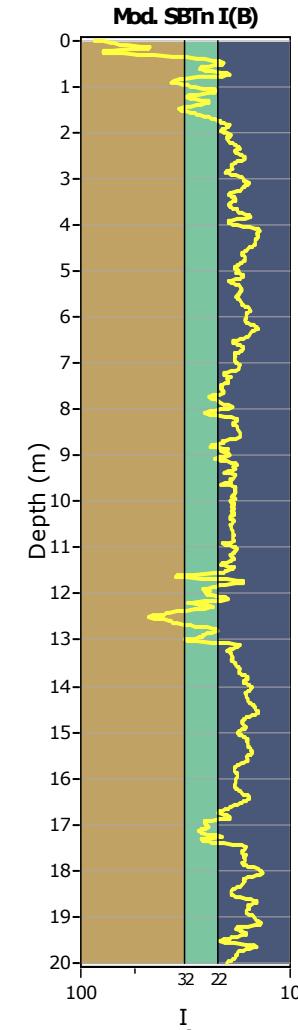
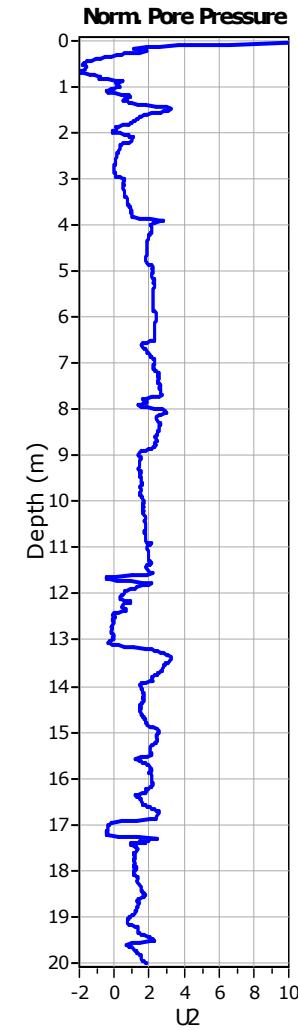
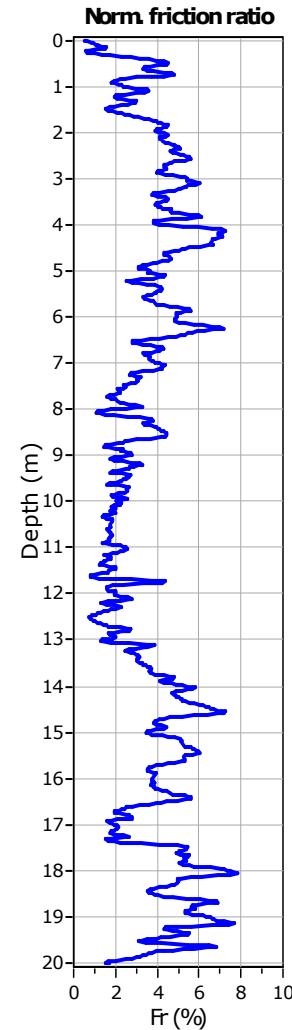
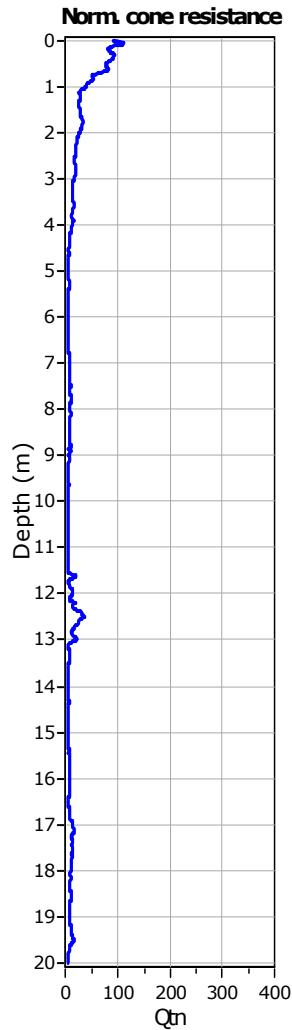
- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

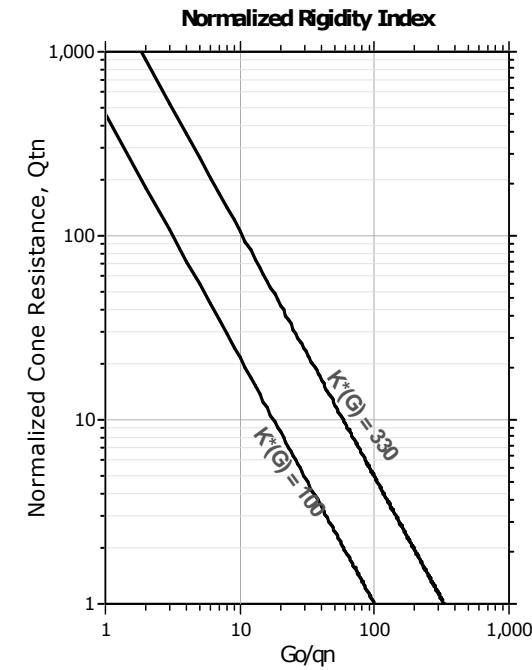
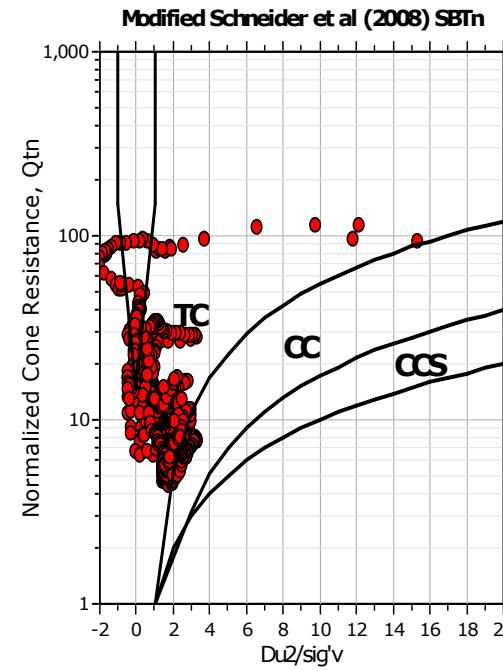
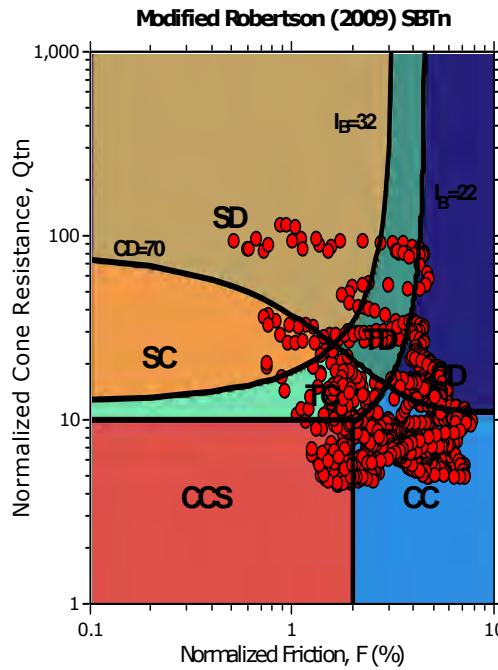
CPT: CPTU 13

Total depth: 20.00 m, Date: 15/05/2018

**Mod. SBTn legend**

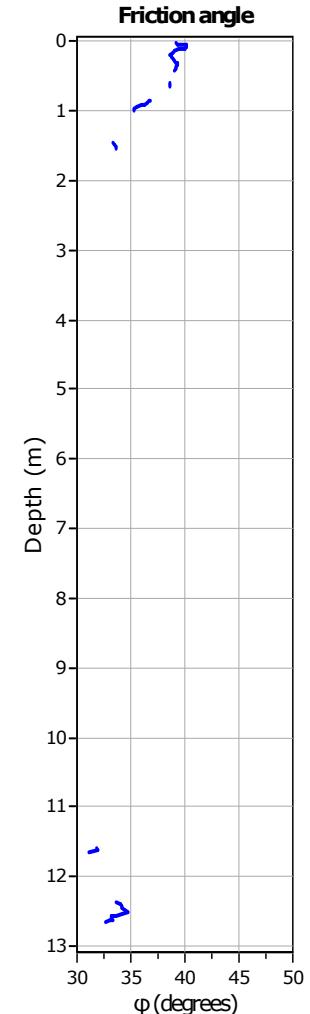
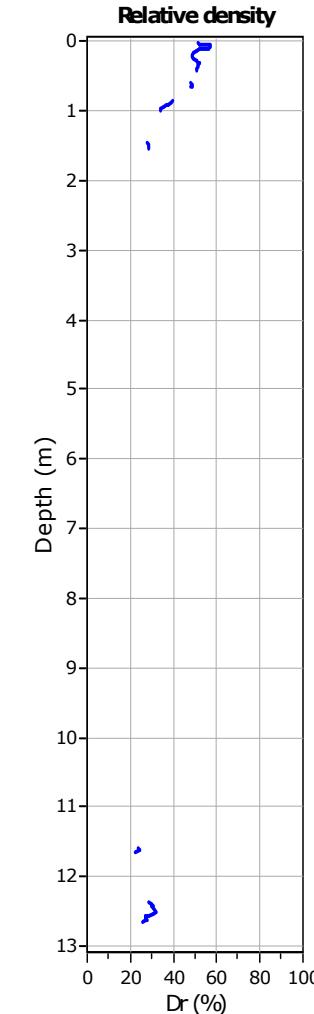
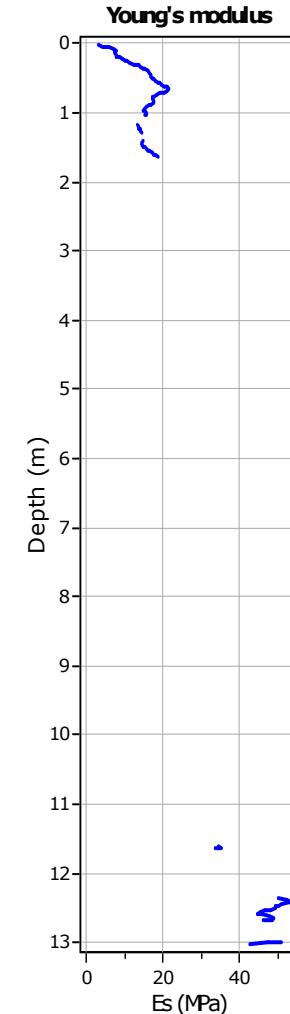
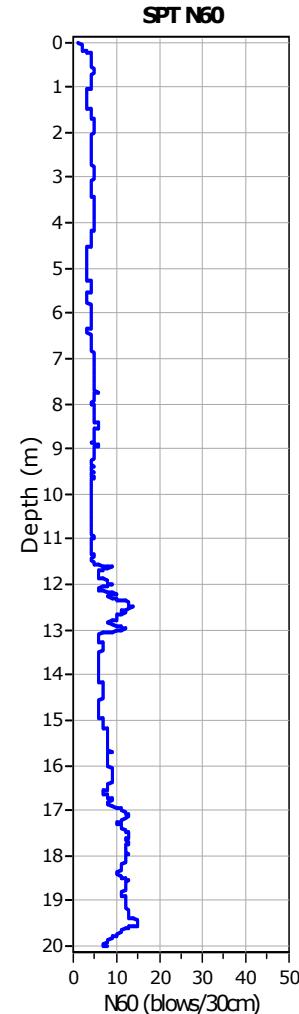
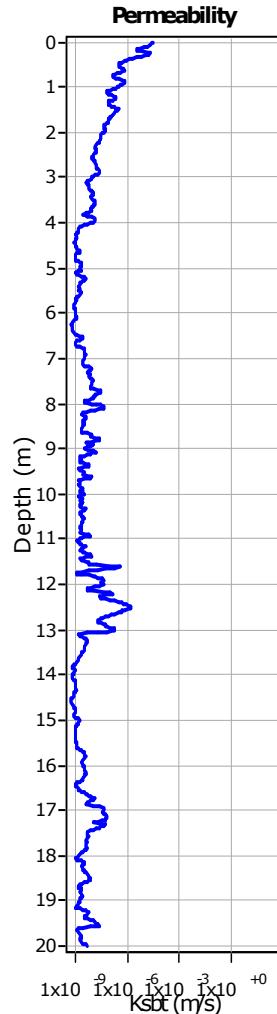
- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

Updated SBTn plots



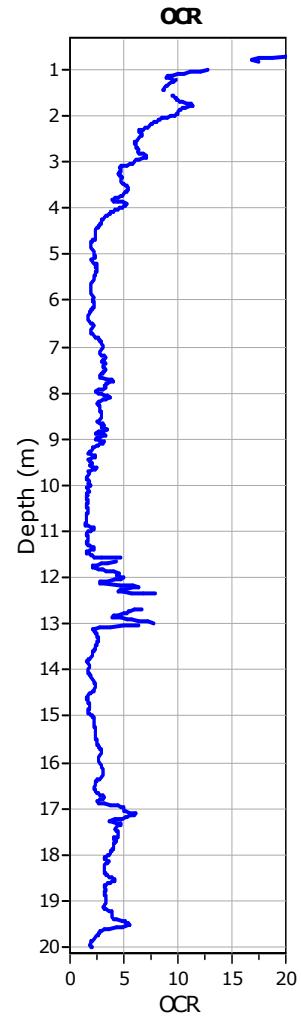
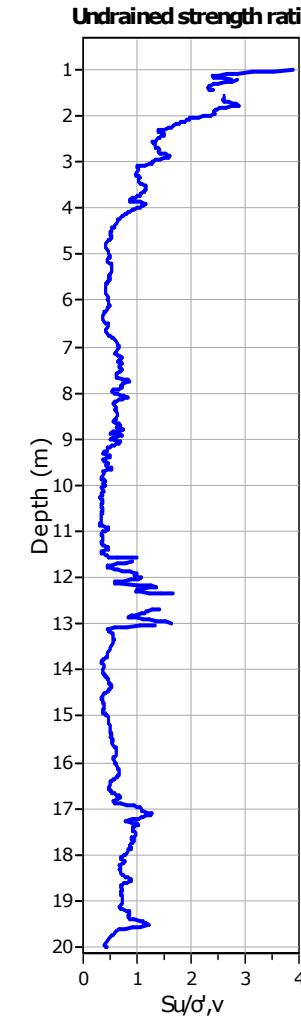
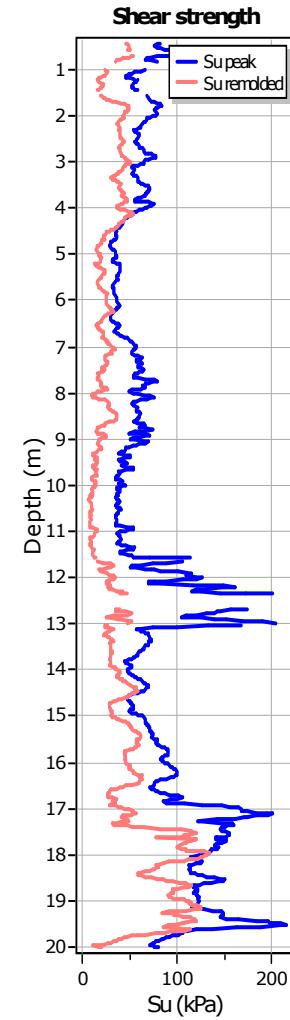
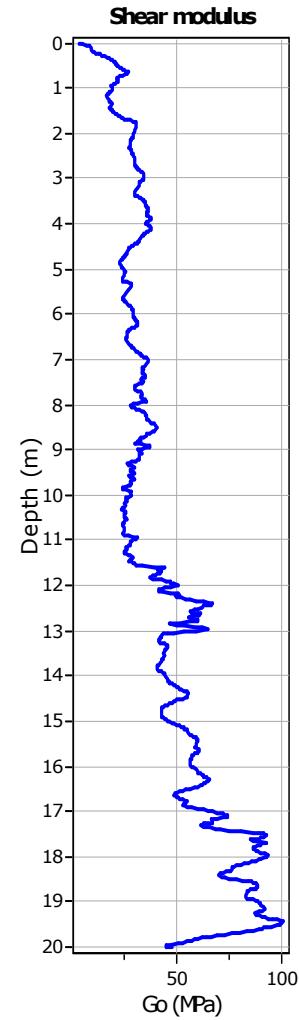
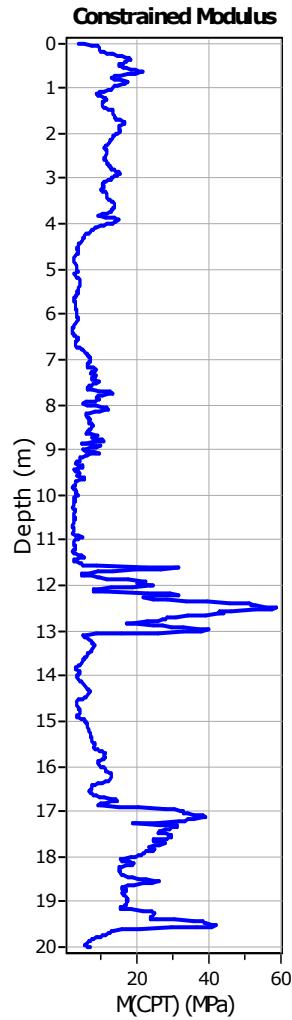
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure (e.g. age/cementation)

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

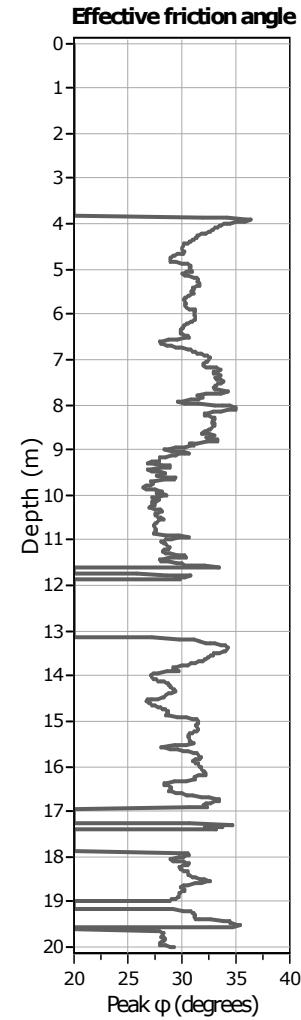
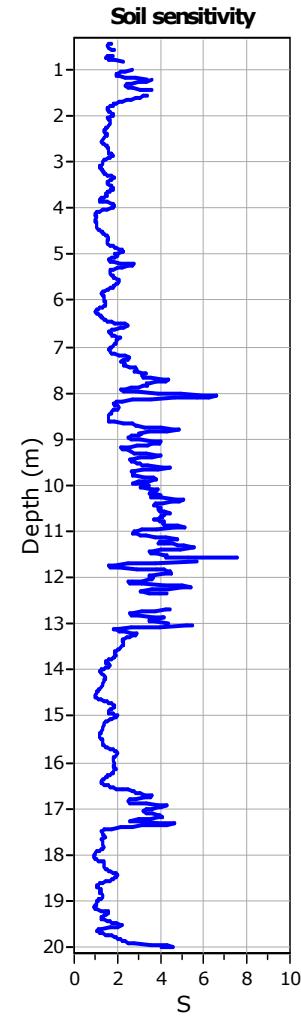
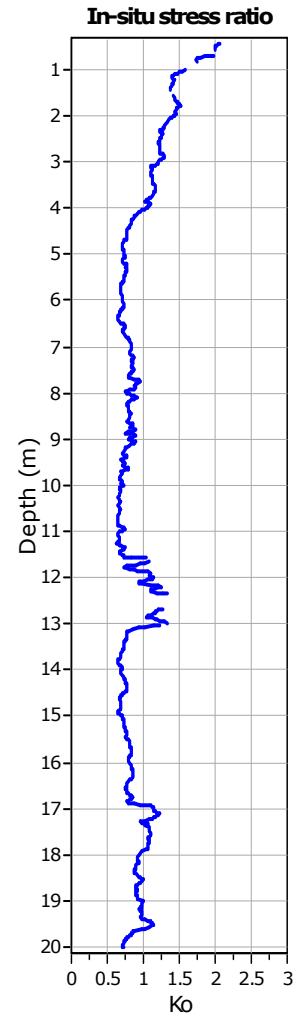
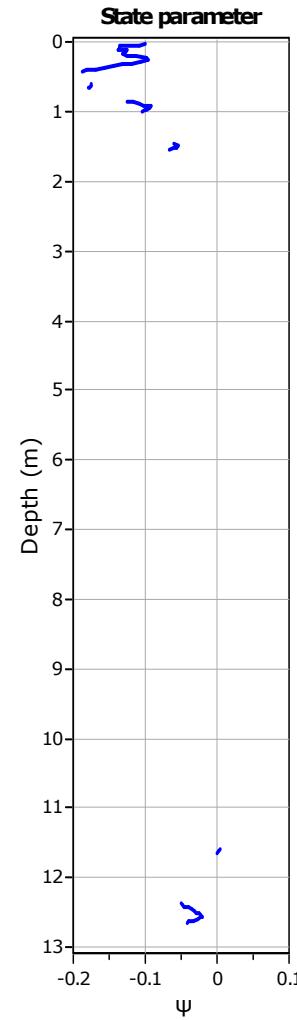
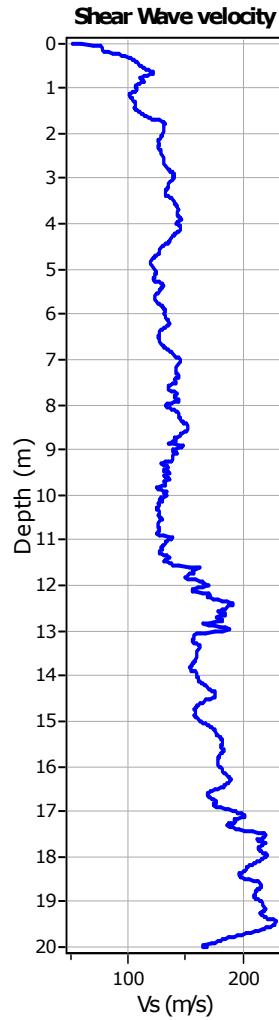
- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato dell'Emergenza sul Territorio

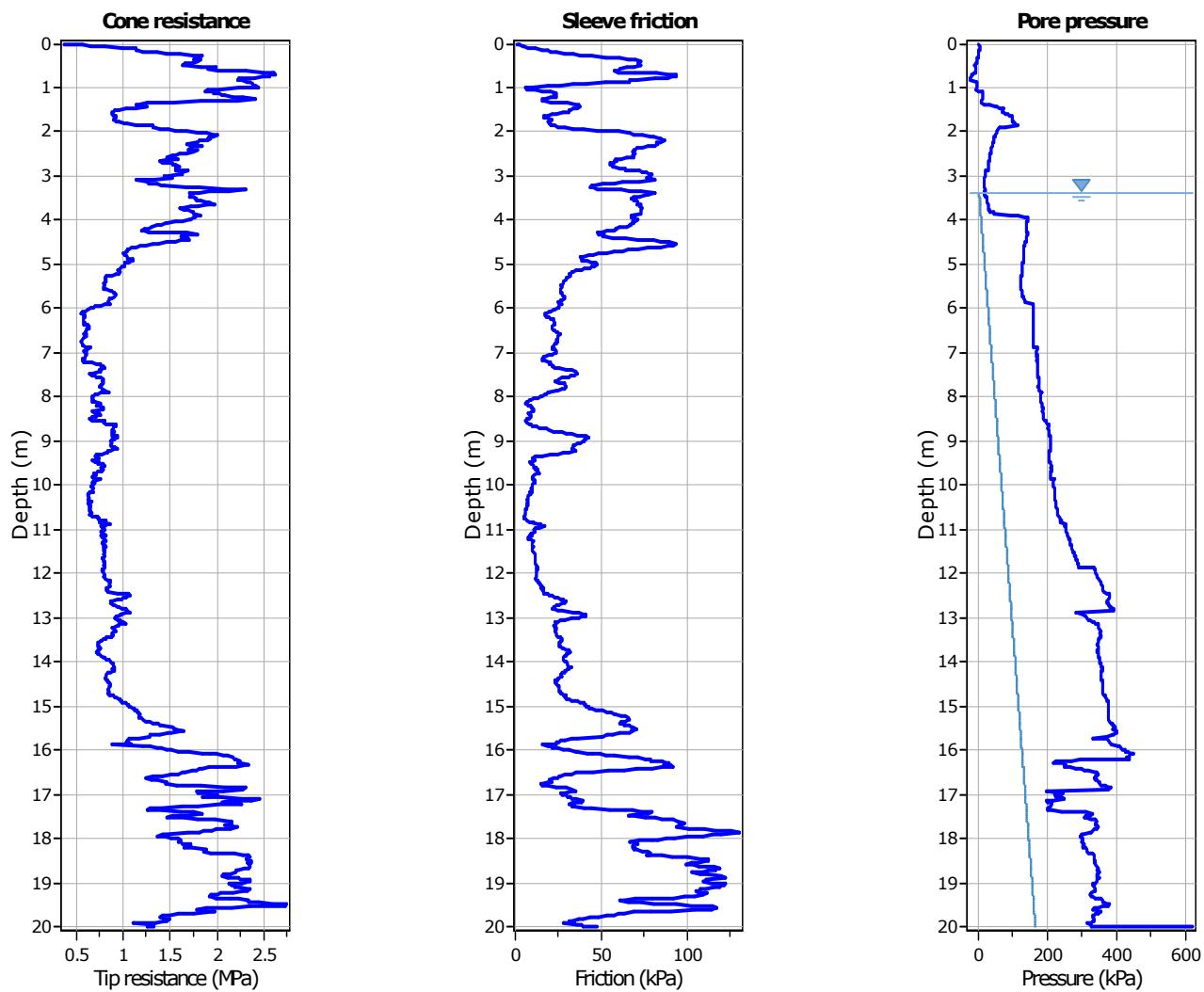
Location: Ferrara

CPT: CPTU 13

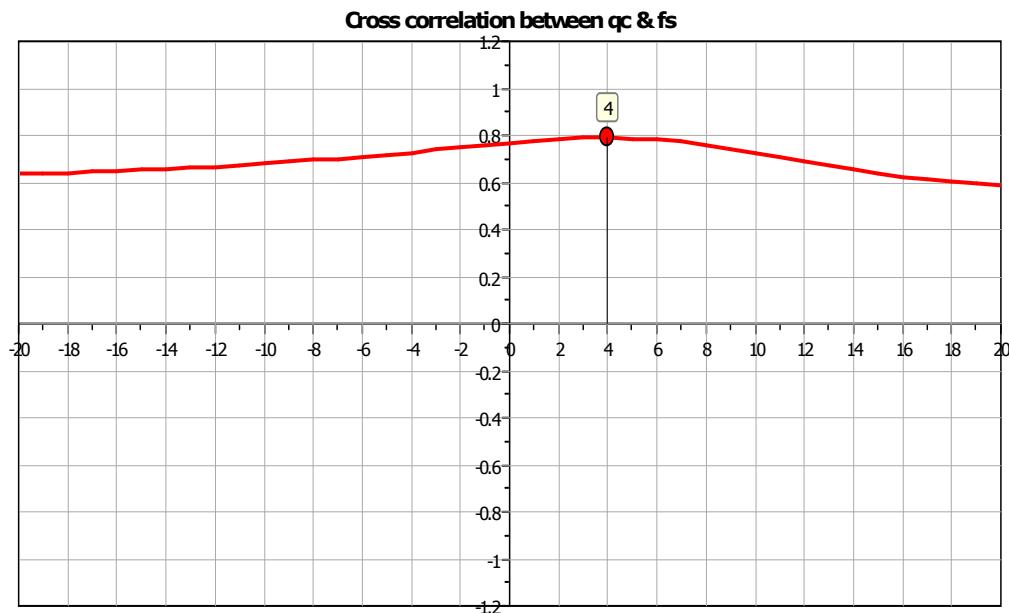
Total depth: 20.00 m, Date: 15/05/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

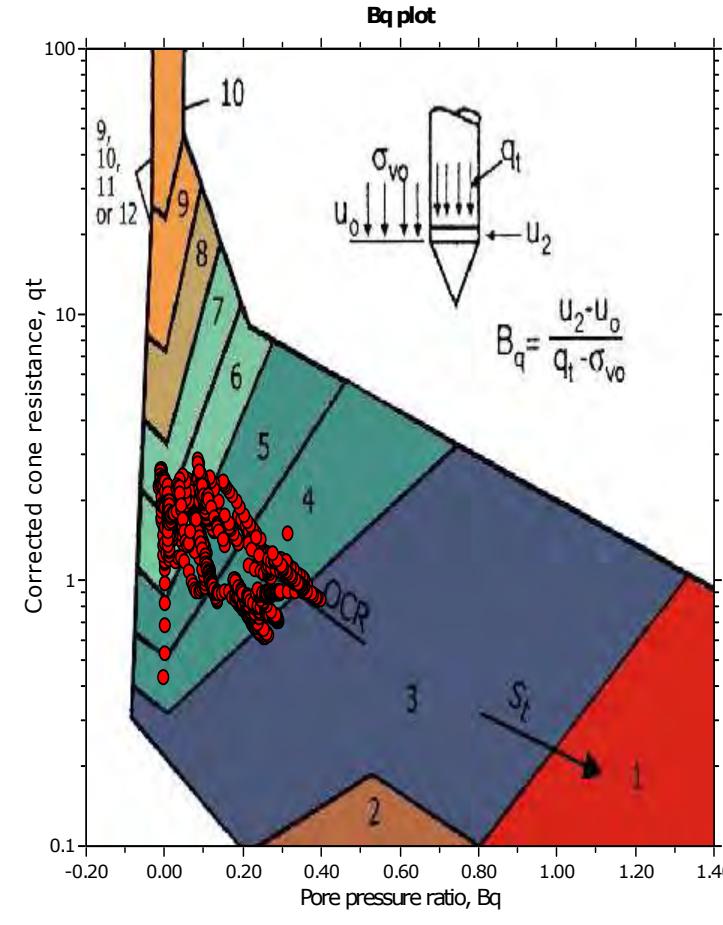
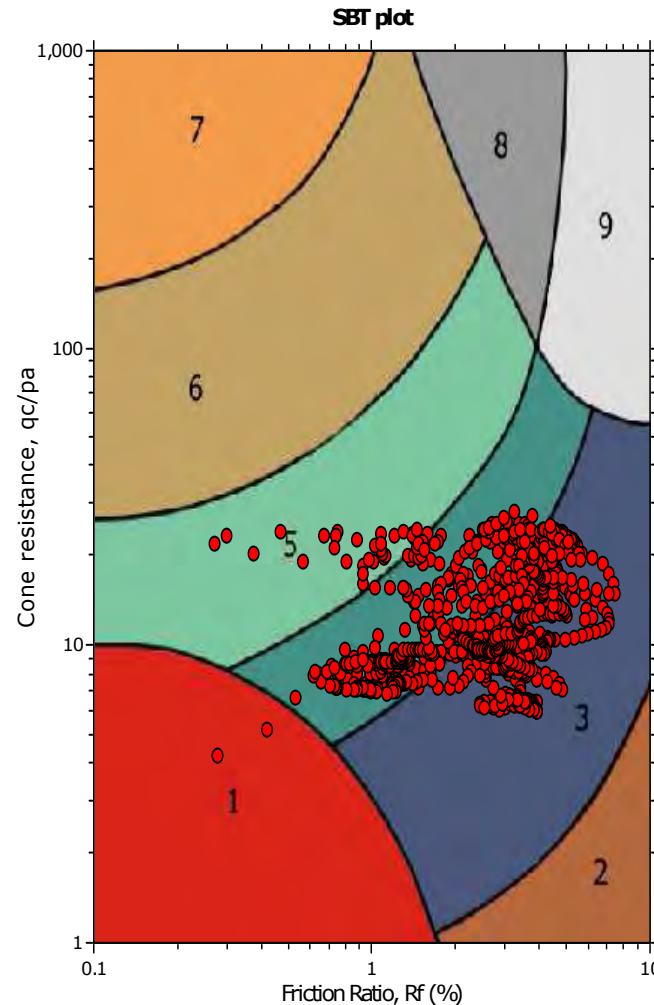
User defined estimation data



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



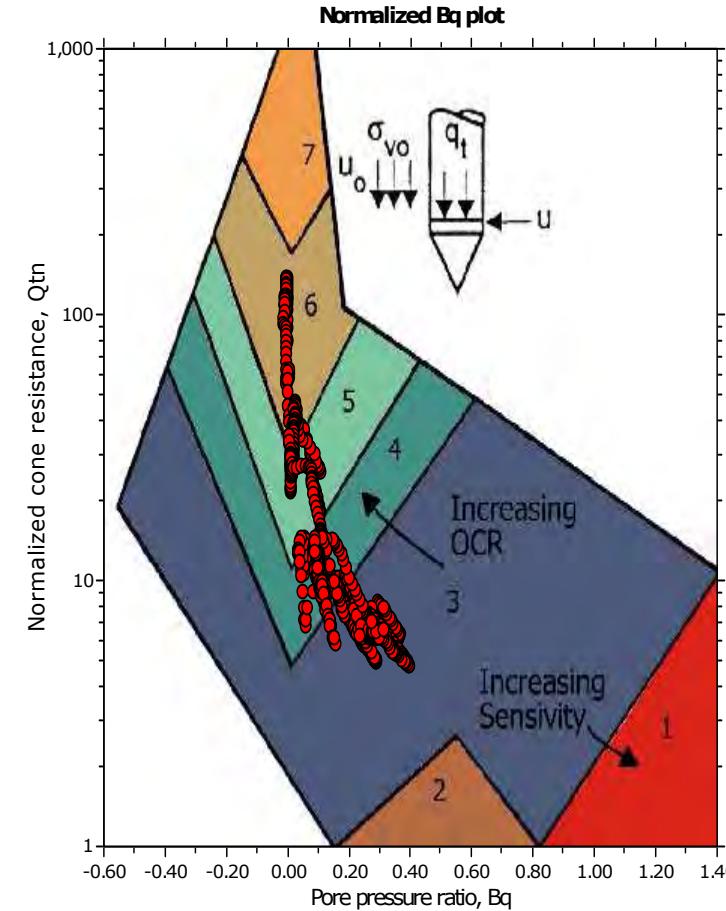
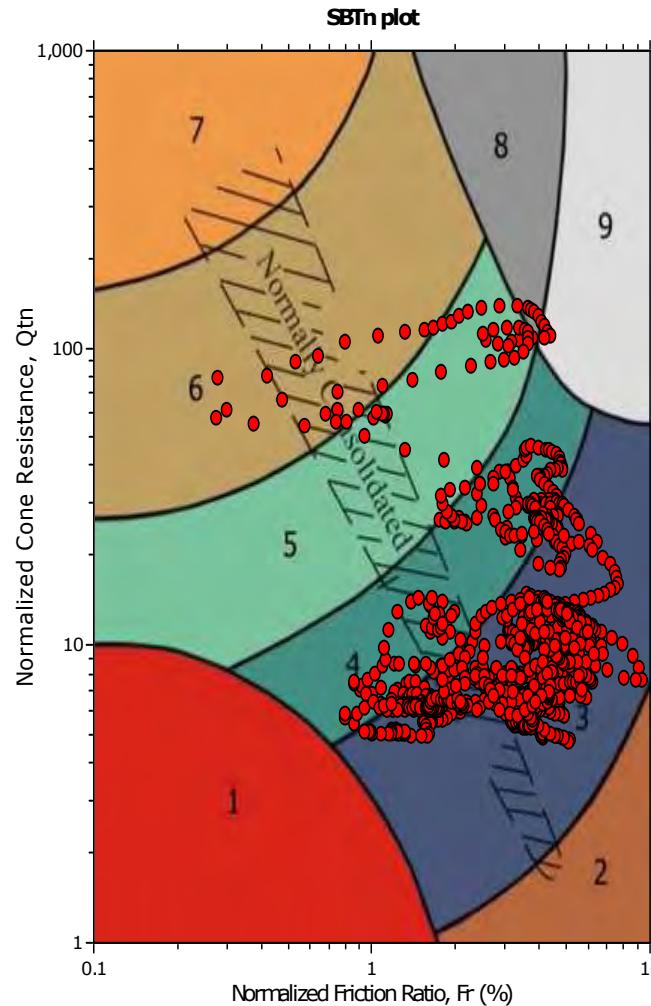
SBT - Bq plots



SBT legend

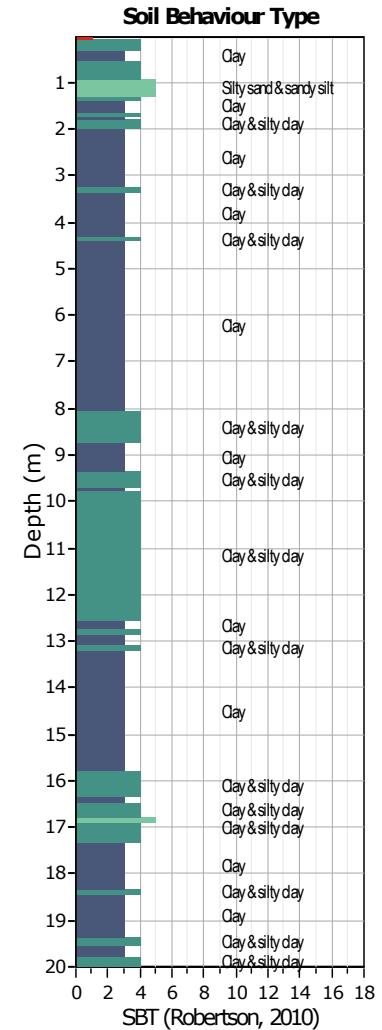
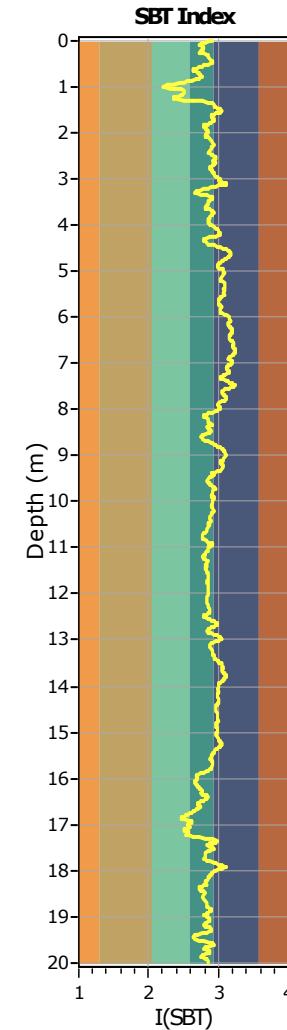
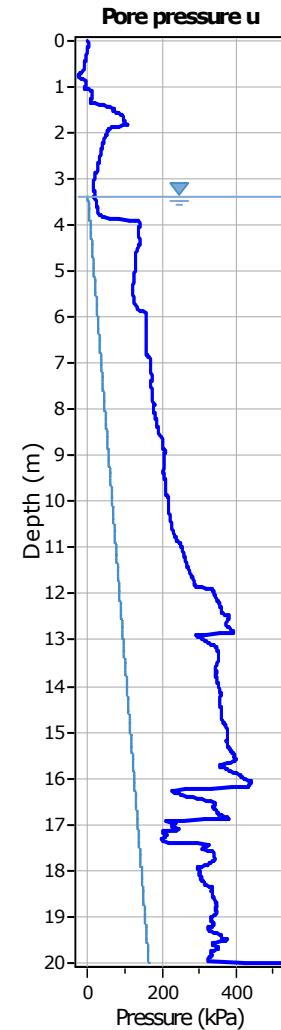
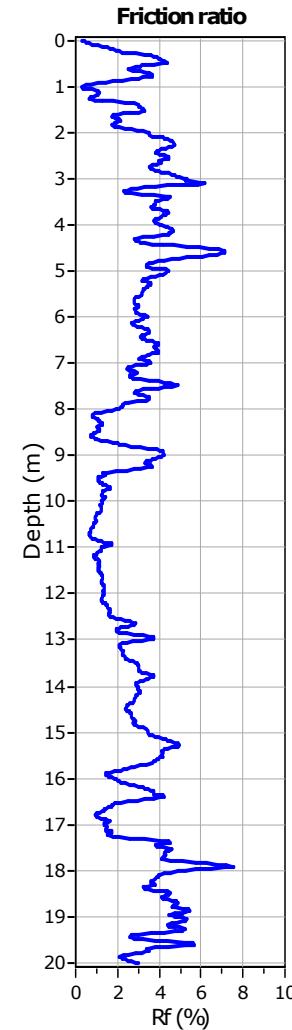
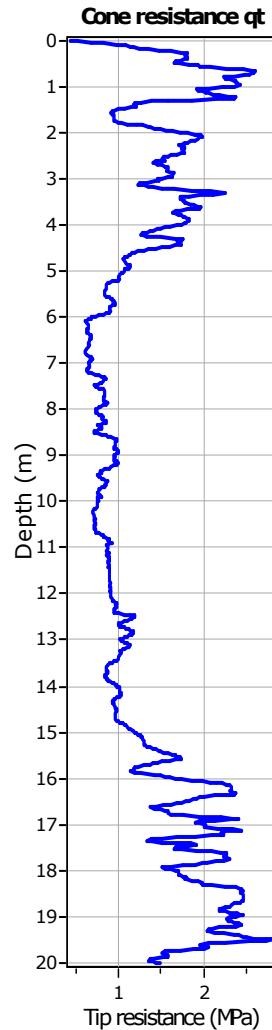
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

SBT - Bq plots (normalized)

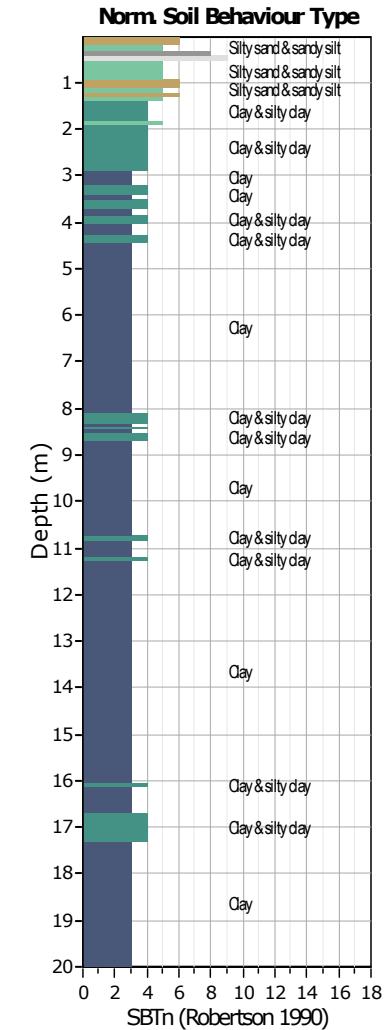
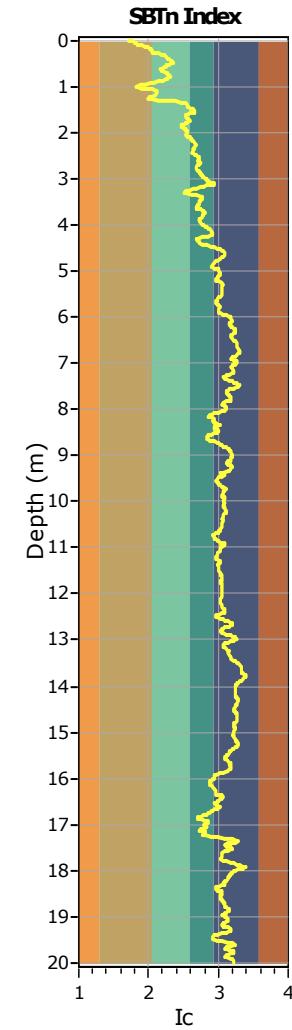
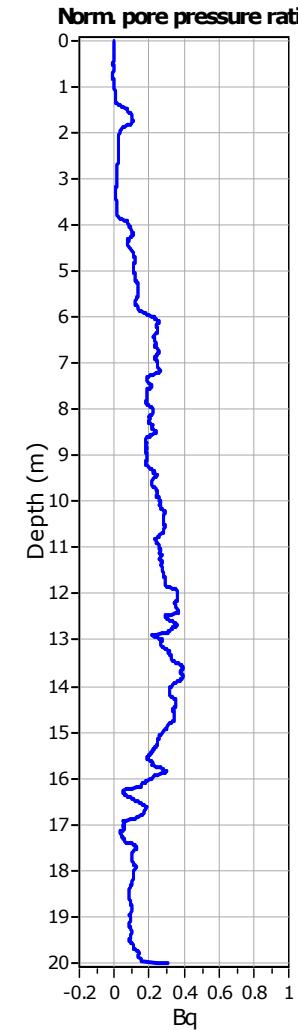
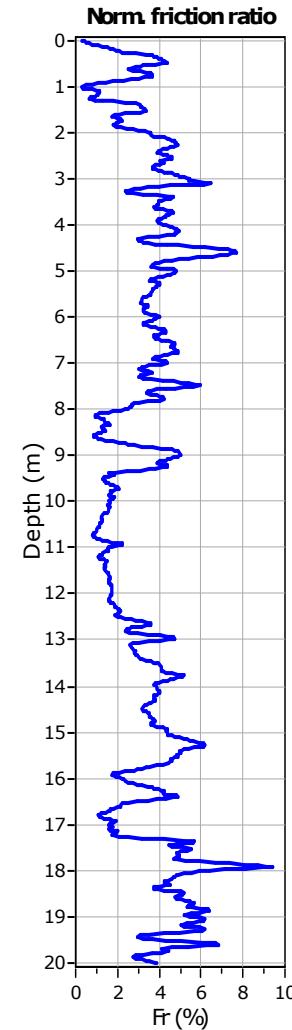
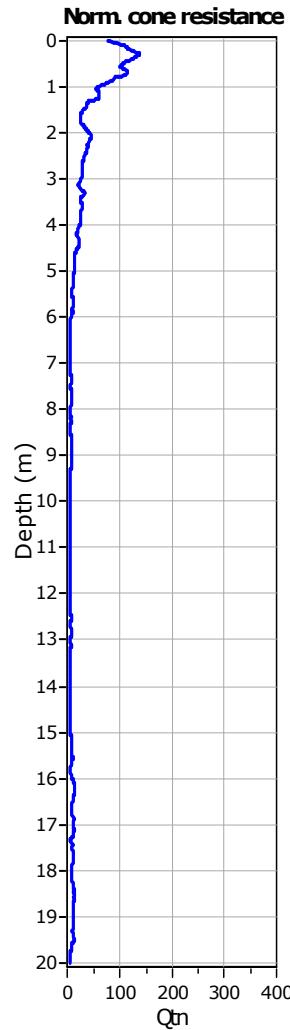


SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	6. Clean sand to silty sand
3. Clay to silty clay	8. Very stiff sand to clayey sand	9. Very stiff fine grained

**SBT legend**

- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

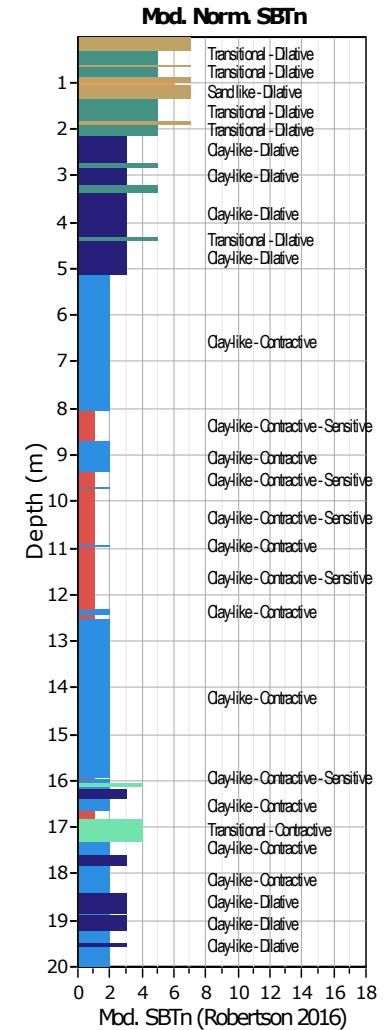
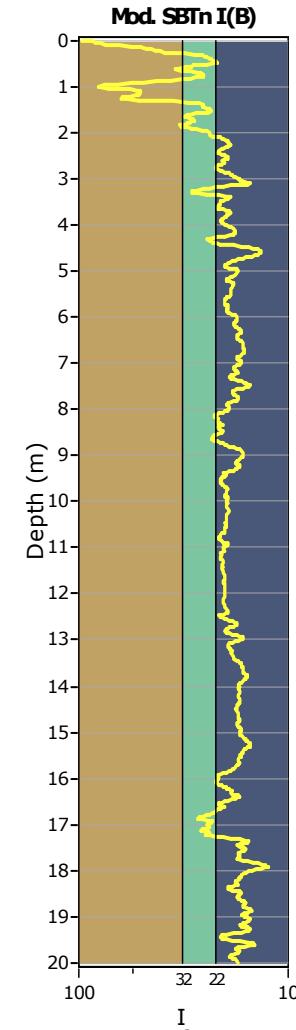
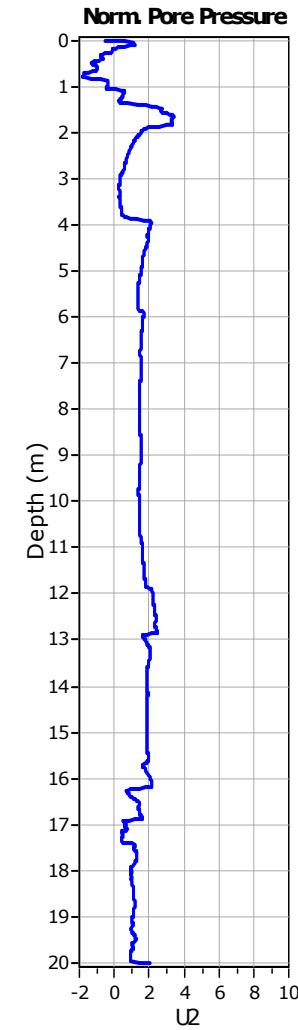
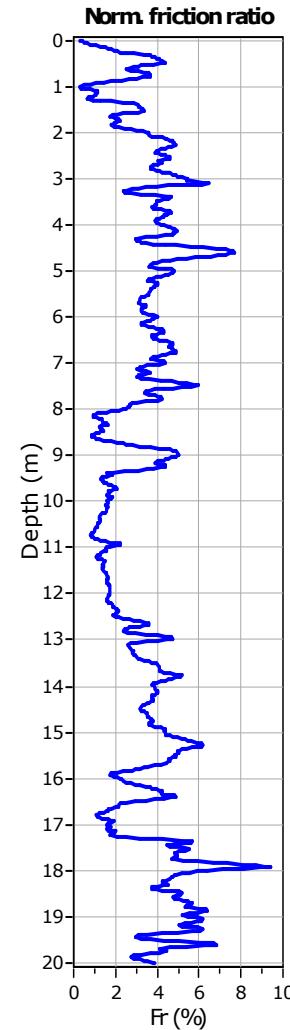
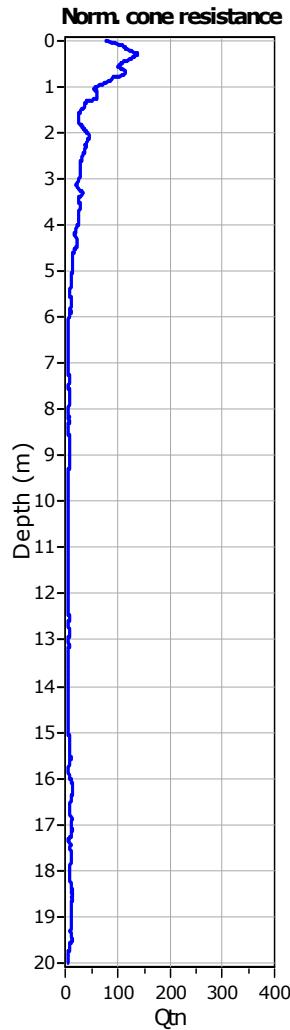


Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

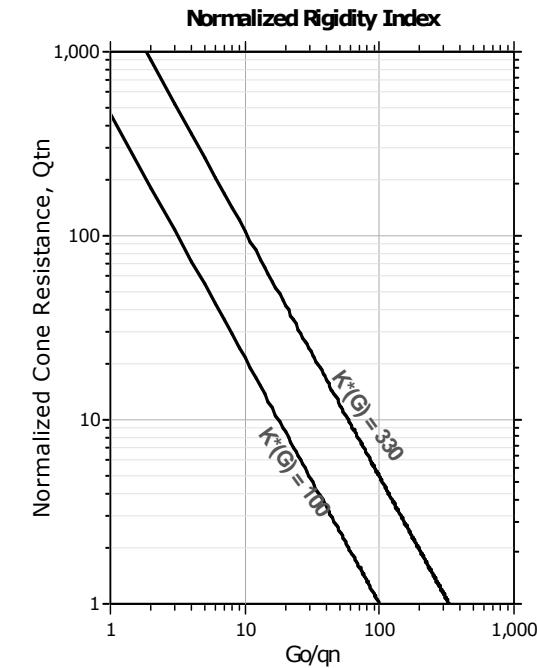
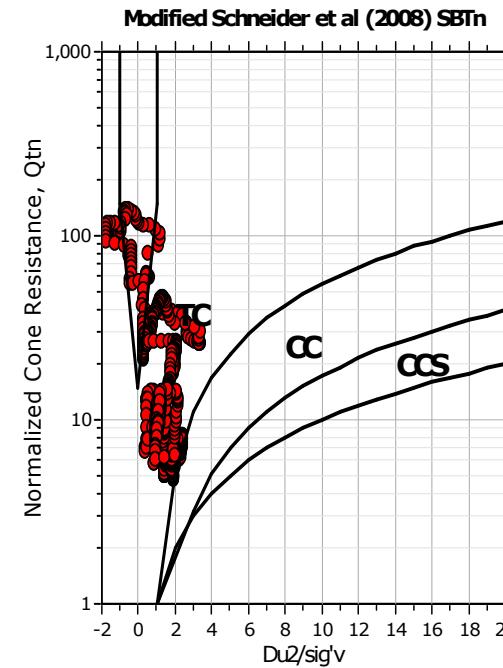
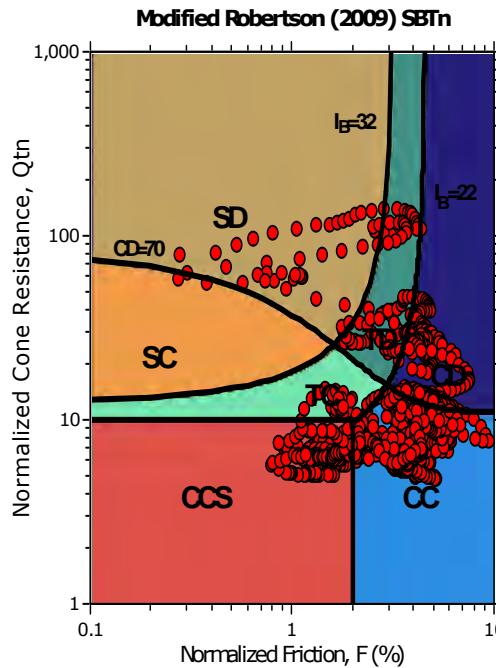
CPT: CPTU 14

Total depth: 20.00 m, Date: 15/05/2018

**Mod. SBTn legend**

- | | | |
|---|-----------------------------------|--------------------------------|
| 1. CCS: ClayLike - Contractive, Sensitive | 4. TC: Transitional - Contractive | 7. SD: Sand-like - Dilative |
| 2. CC: Clay-like - Contractive | 5. TD: Transitional - Dilative | 6. SC: Sand-like - Contractive |
| 3. CD: Clay-Like: Dilative | | |

Updated SBTn plots



CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

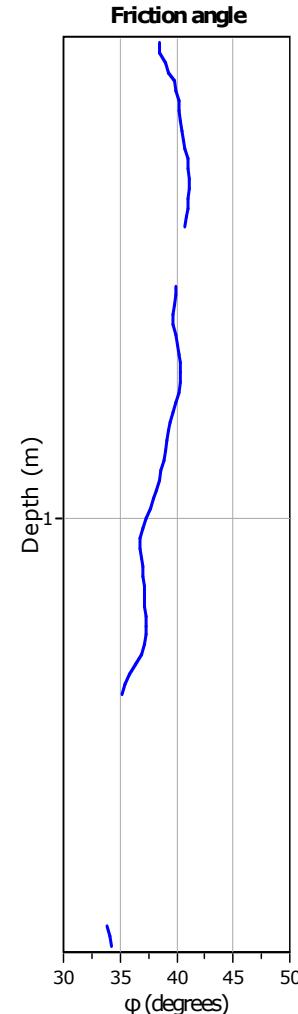
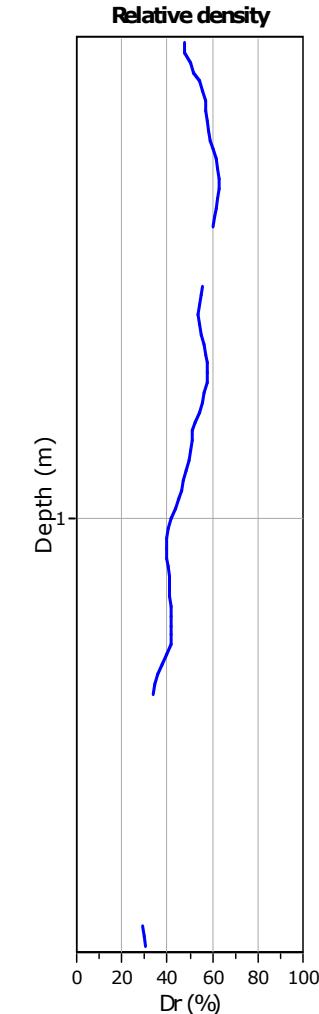
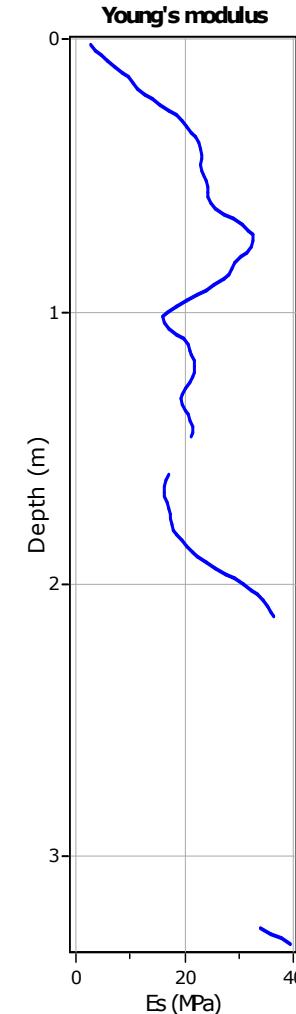
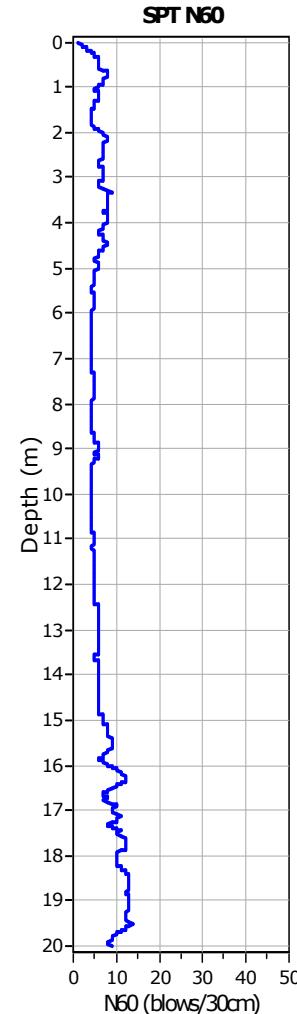
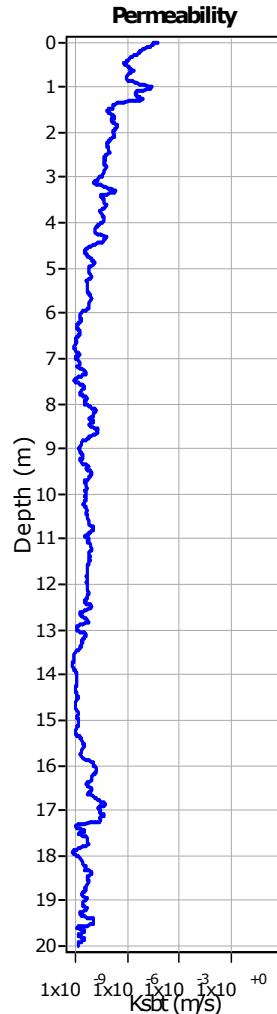
$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

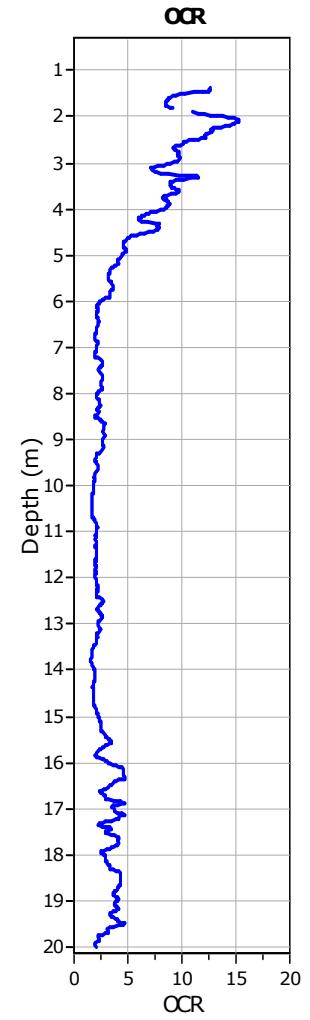
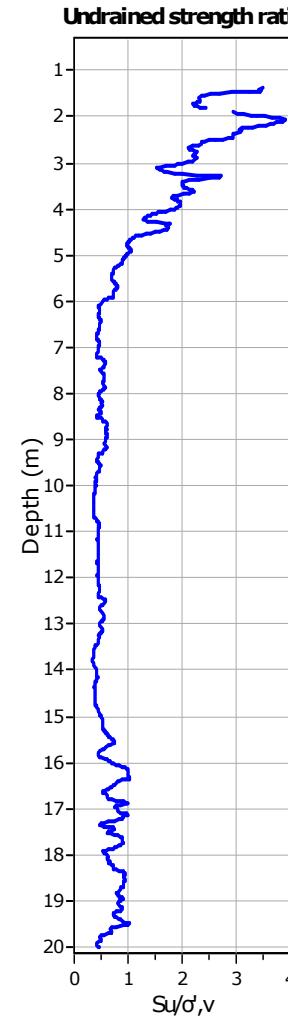
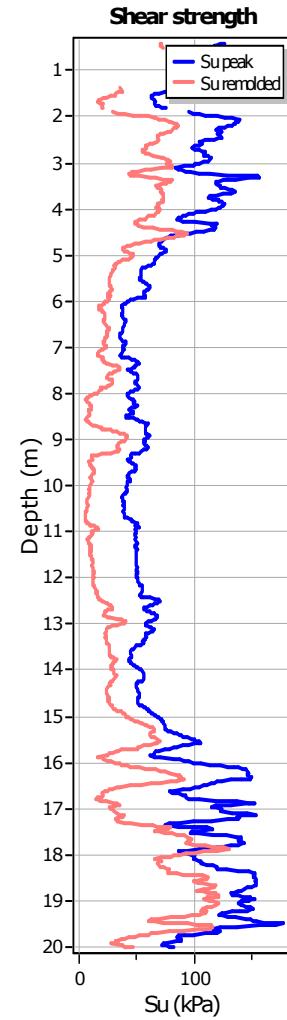
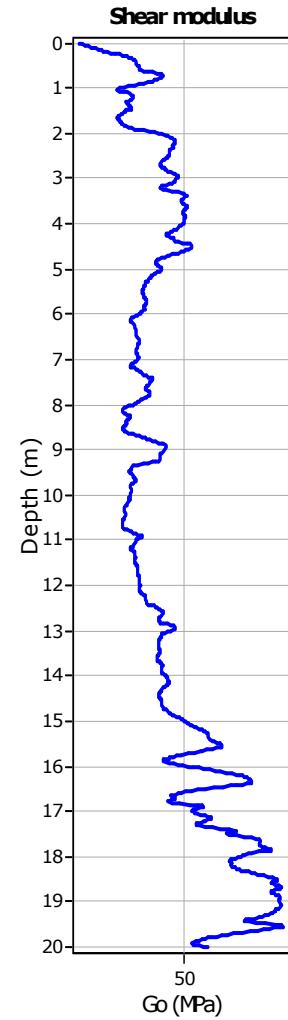
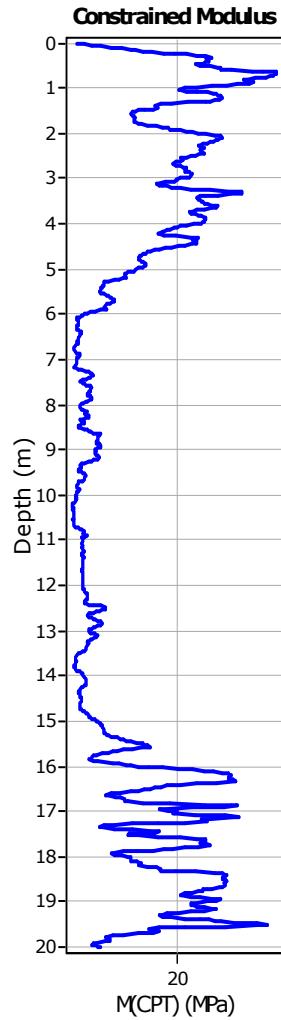
CPT: CPTU 14

Total depth: 20.00 m, Date: 15/05/2018

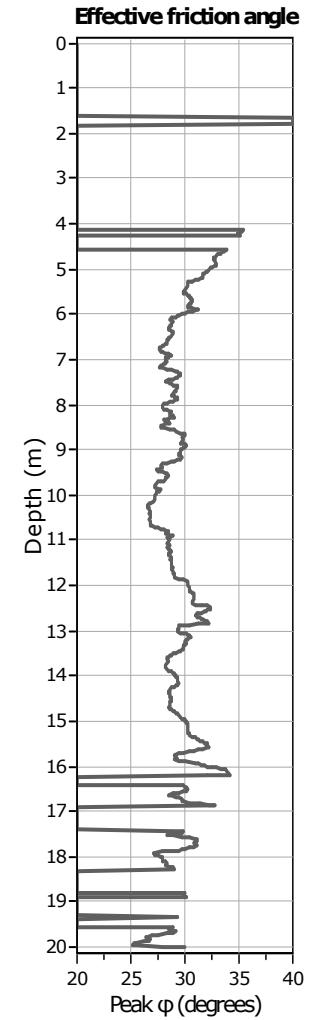
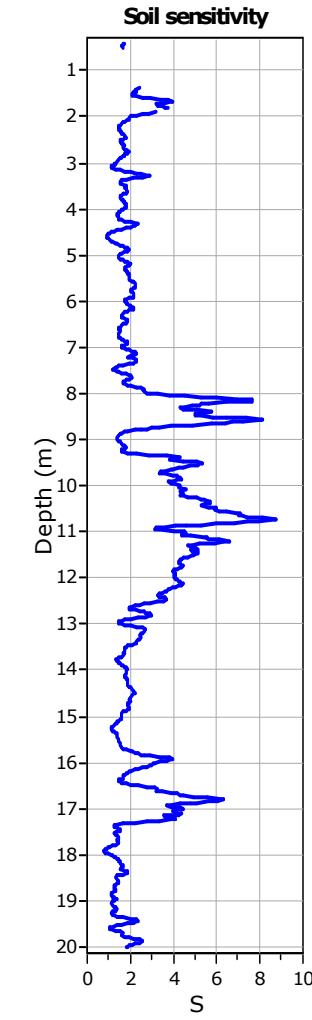
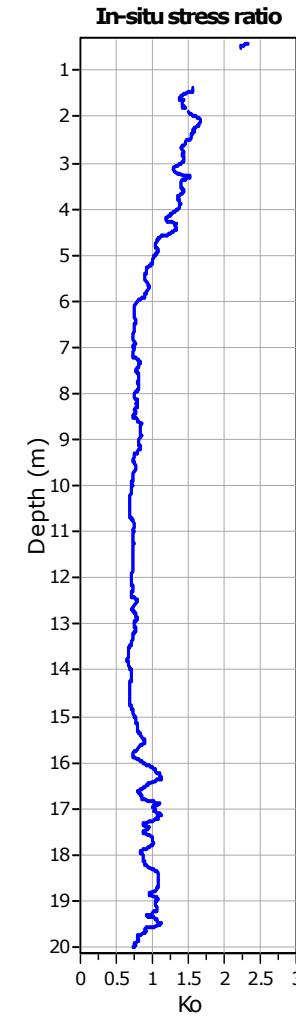
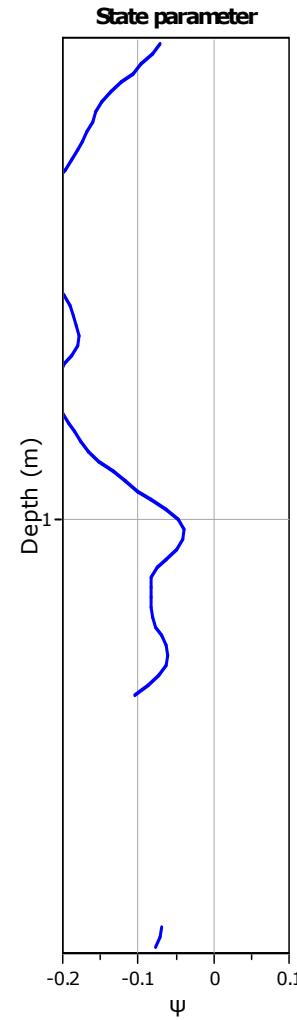
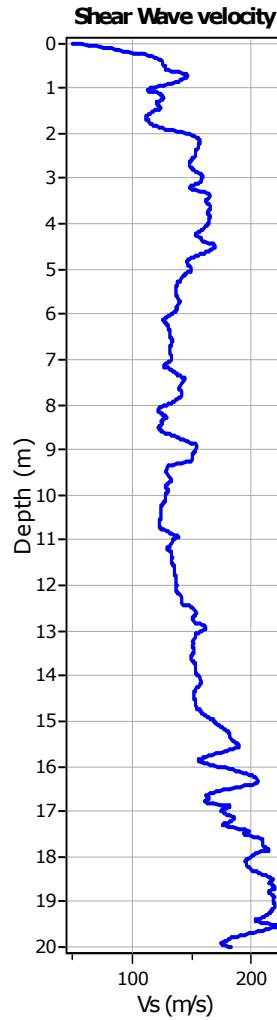
**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

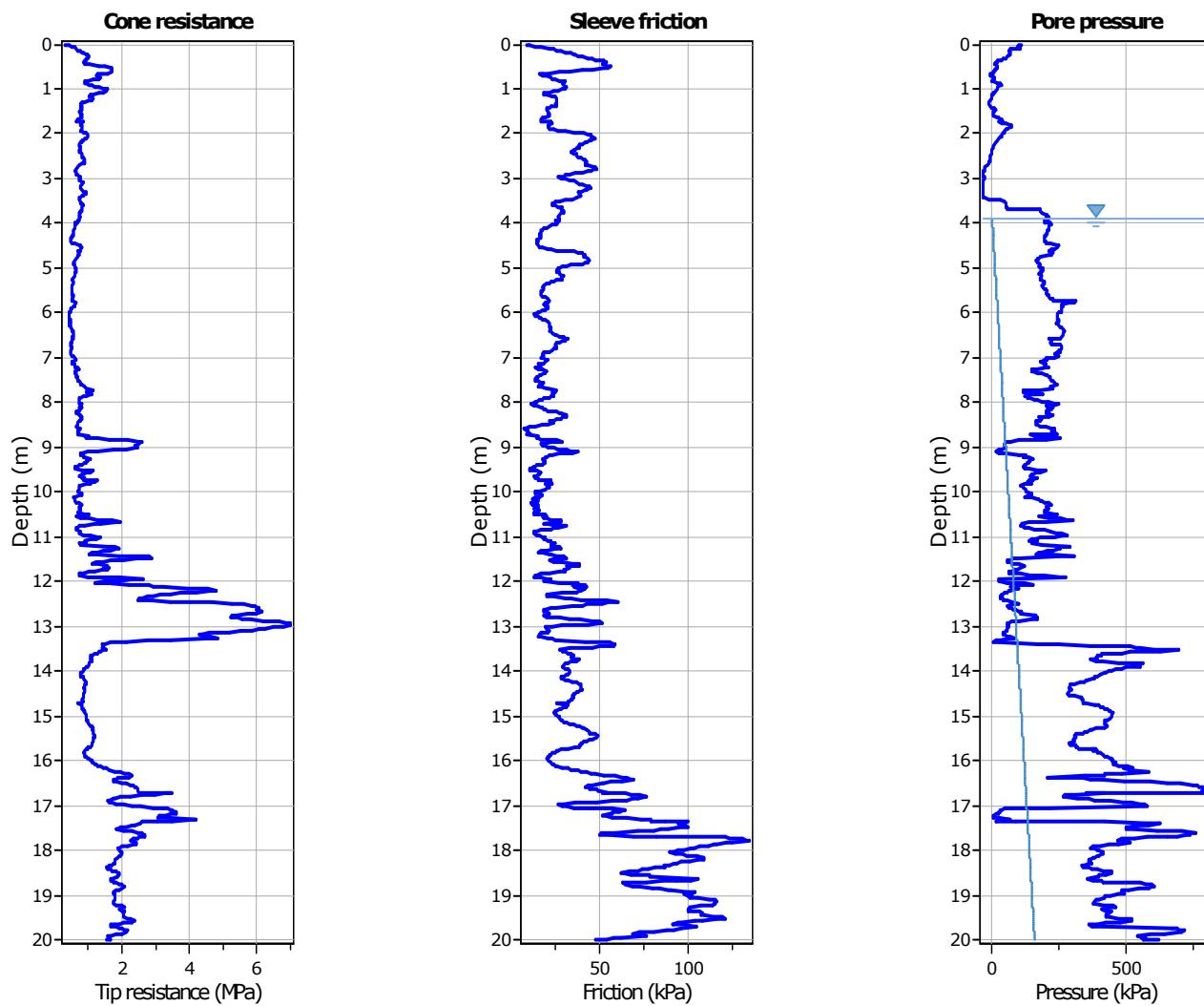
User defined estimation data

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

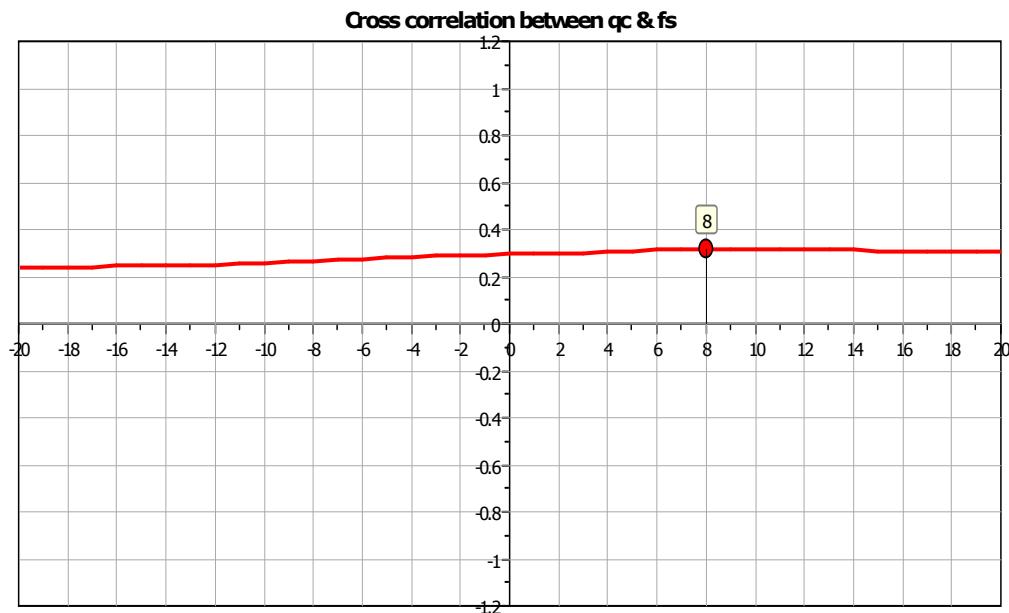
- User defined estimation data
- Flat Dilatometer Test data

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

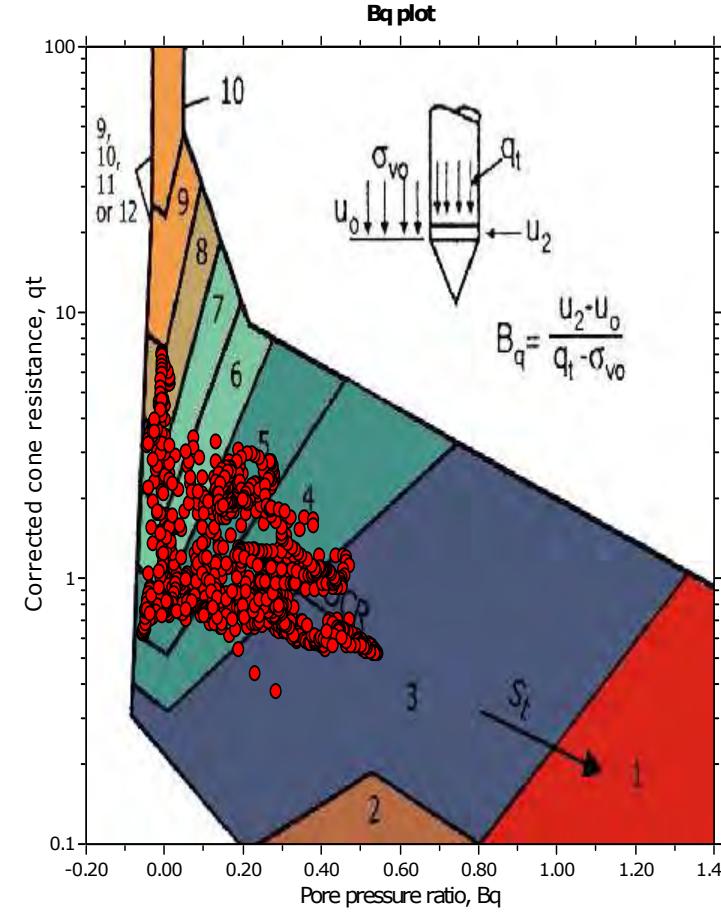
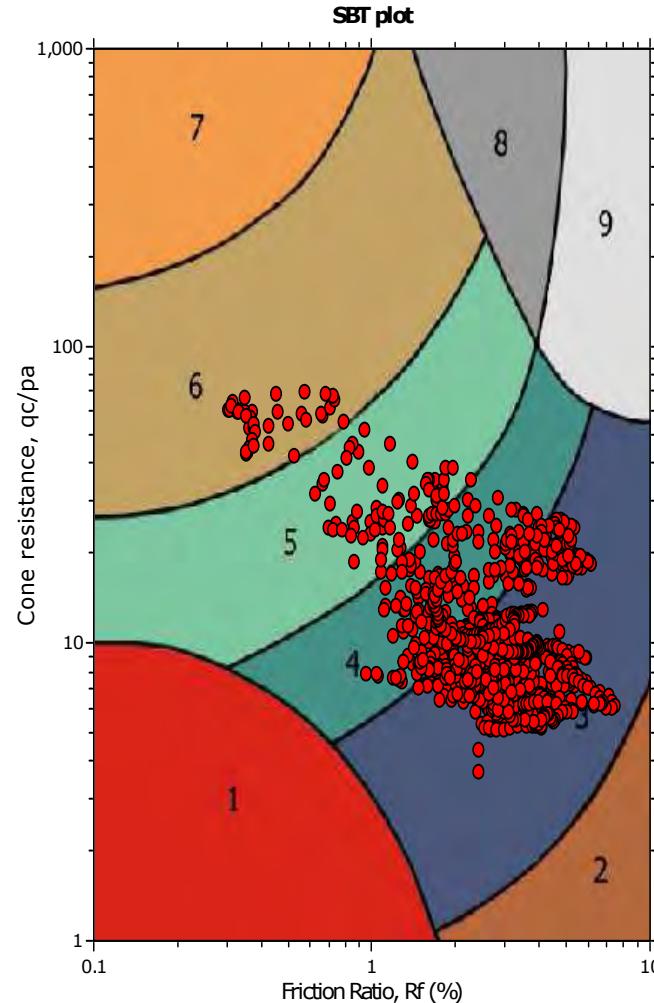
User defined estimation data



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



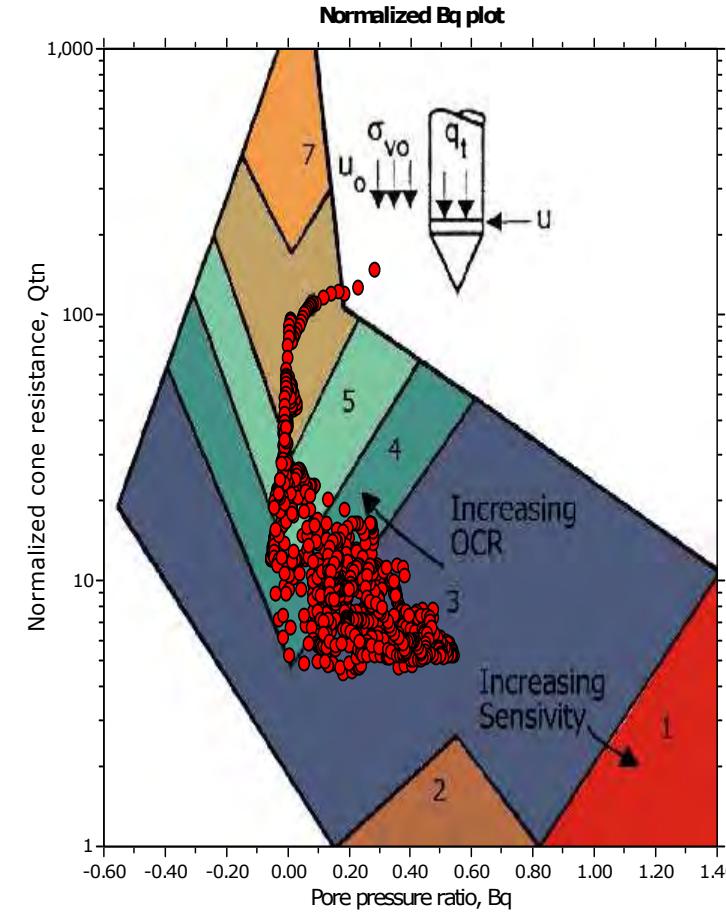
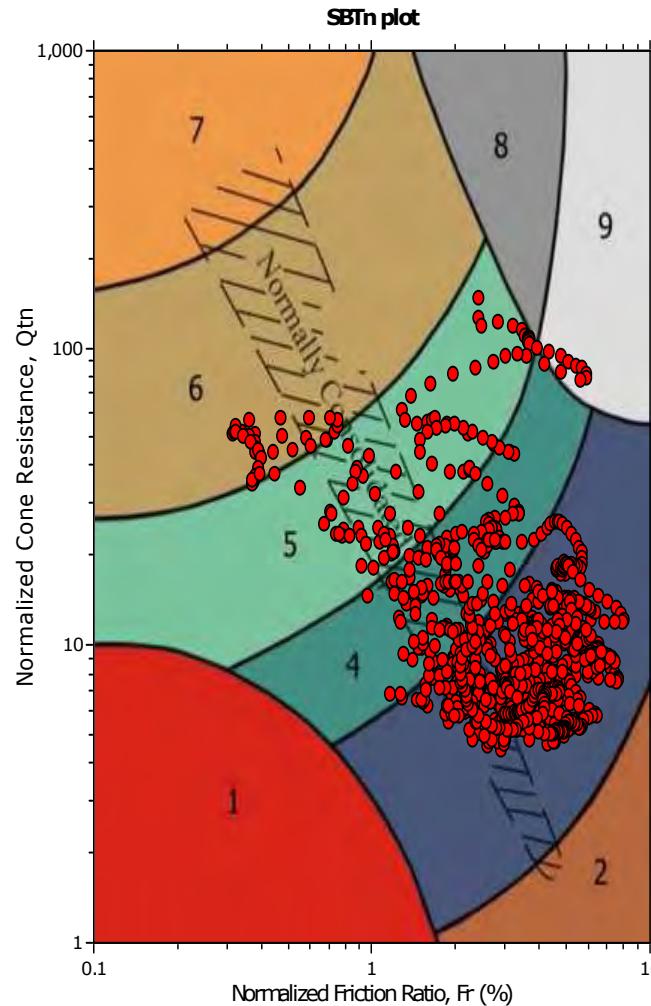
SBT - Bq plots



SBT legend

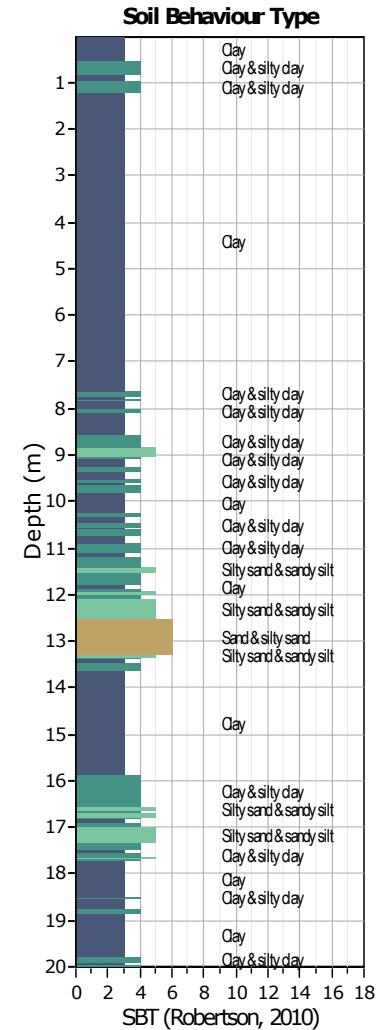
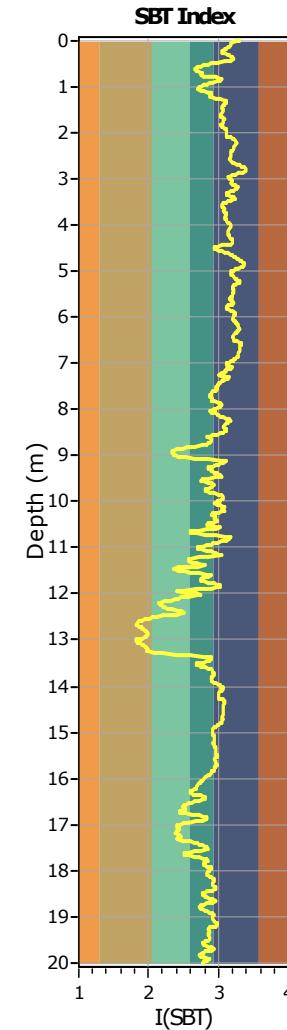
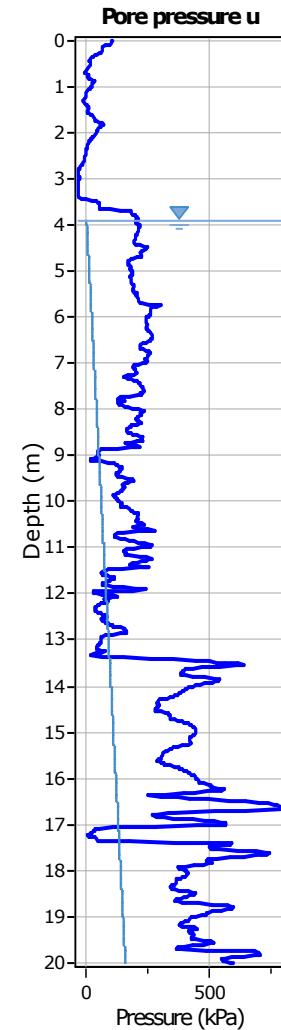
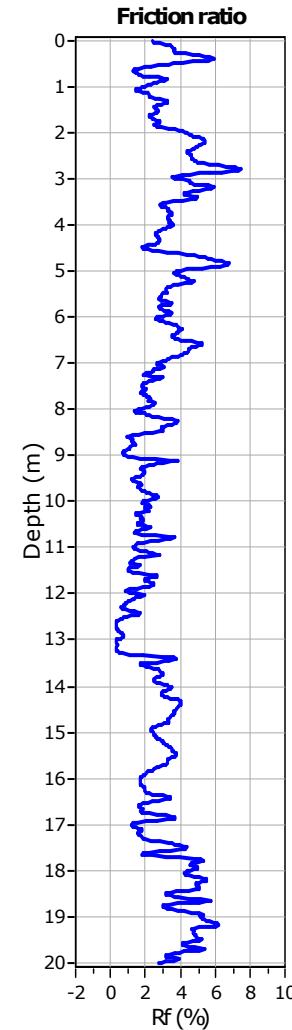
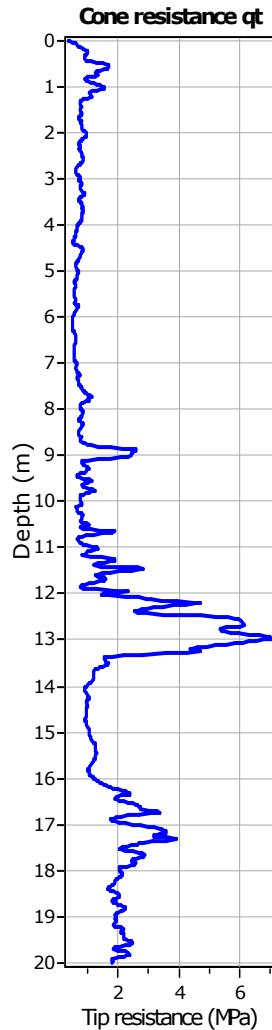
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

SBT - Bq plots (normalized)

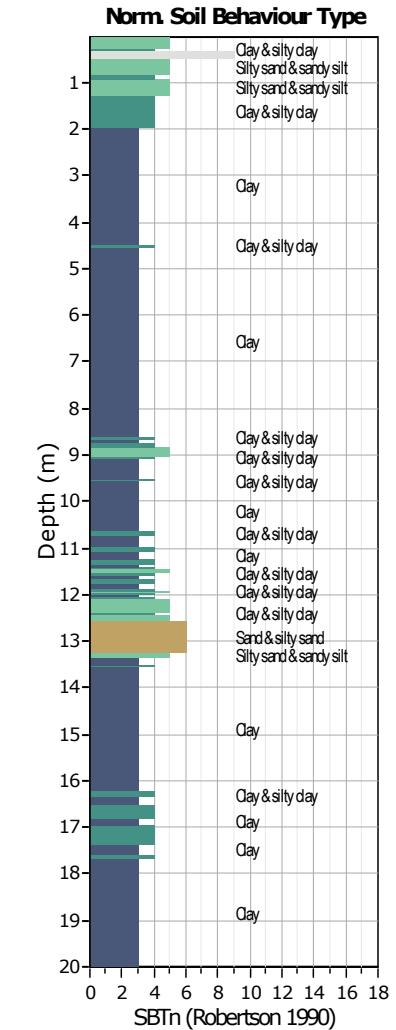
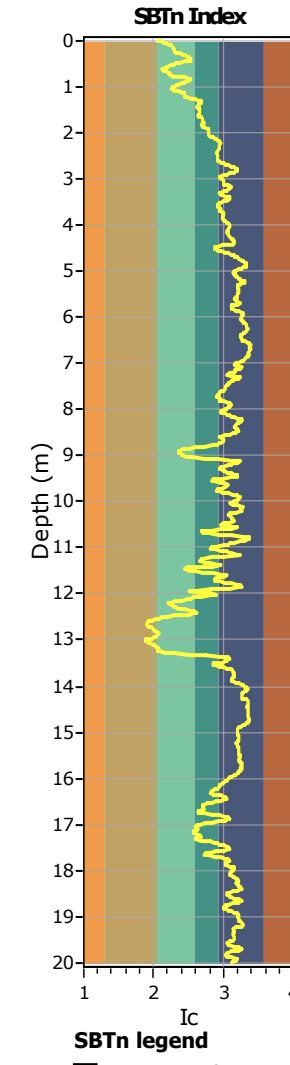
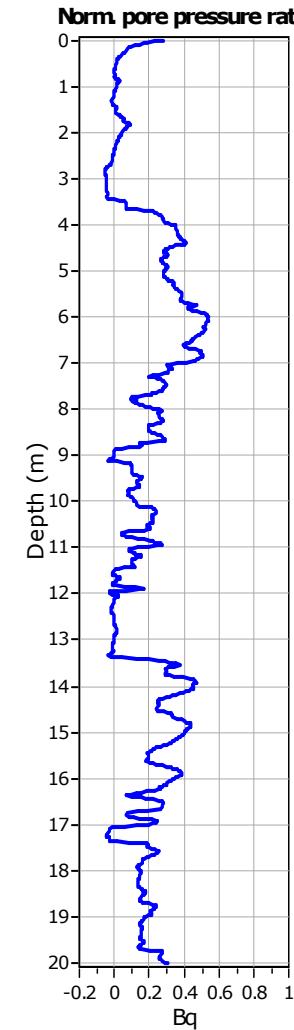
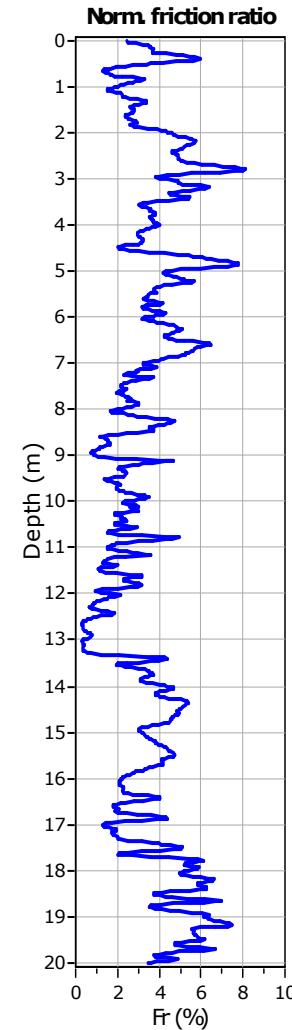
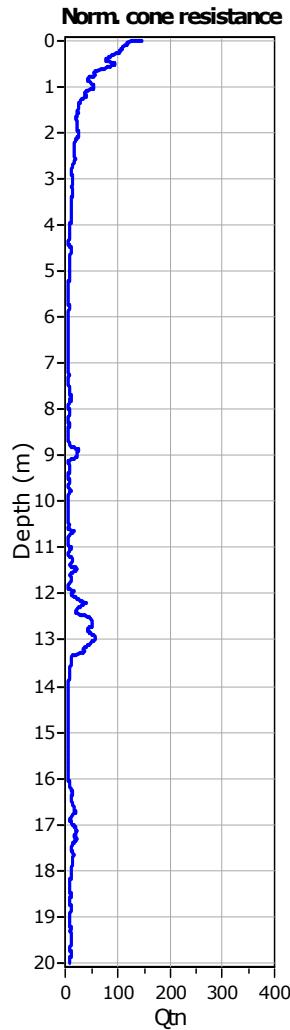


SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

**SBT legend**

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

**SBTn legend**

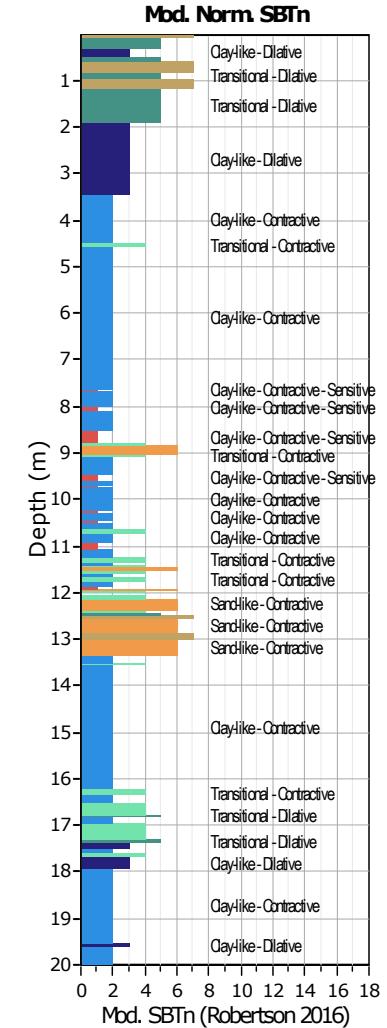
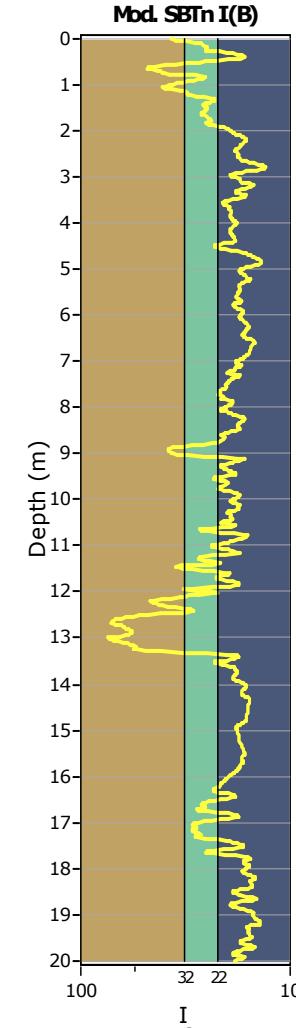
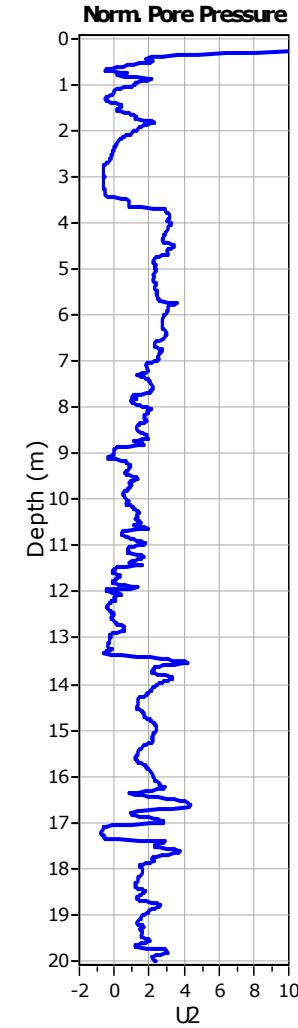
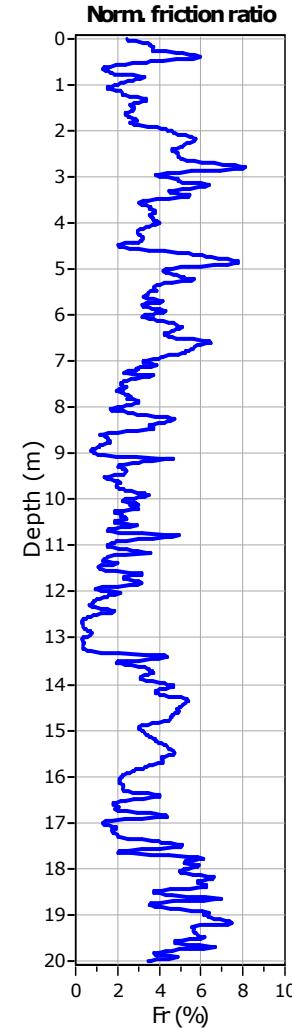
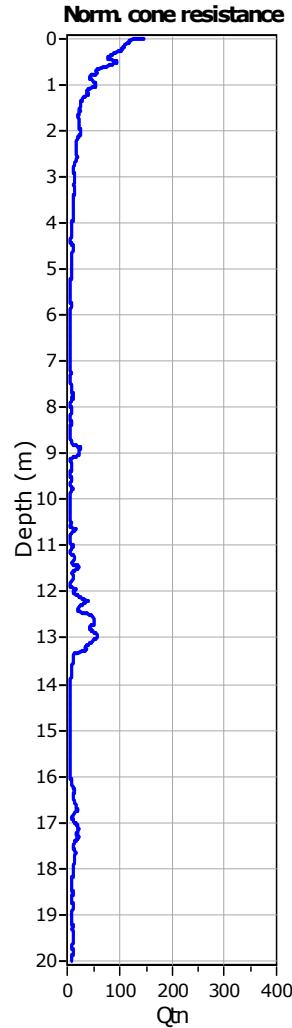
- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

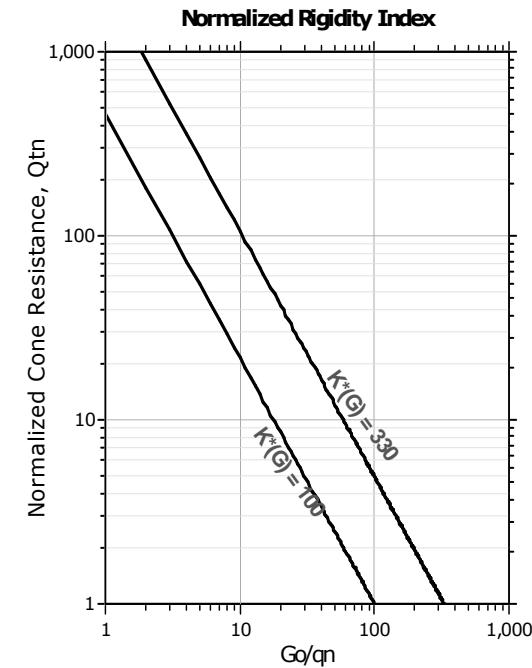
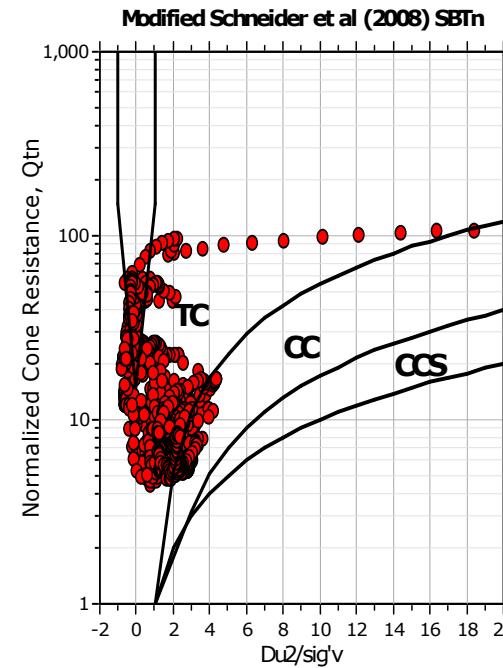
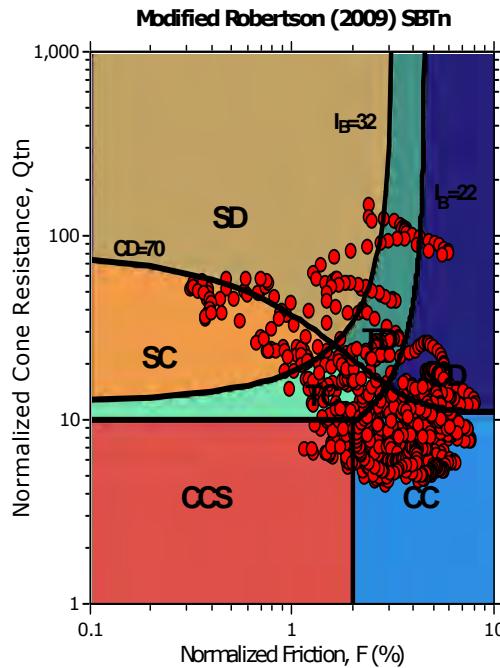
CPT: CPTU 15

Total depth: 20.00 m, Date: 17/05/2018

**Mod. SBTn legend**

- | | | |
|---|-----------------------------------|--------------------------------|
| 1. CCS: ClayLike - Contractive, Sensitive | 4. TC: Transitional - Contractive | 7. SD: Sand-like - Dilative |
| 2. CC: Clay-like - Contractive | 5. TD: Transitional - Dilative | 8. SC: Sand-like - Contractive |
| 3. CD: Clay-Like: Dilative | 6. CL: Clay-like - Dilative | 9. DL: Dilatant - Dilative |

Updated SBTn plots



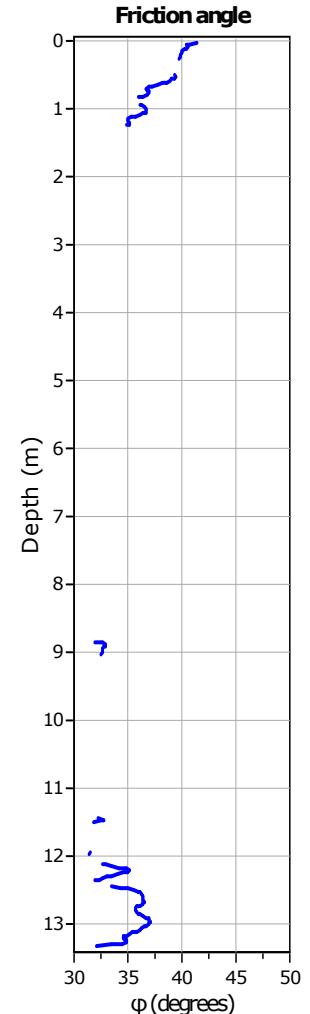
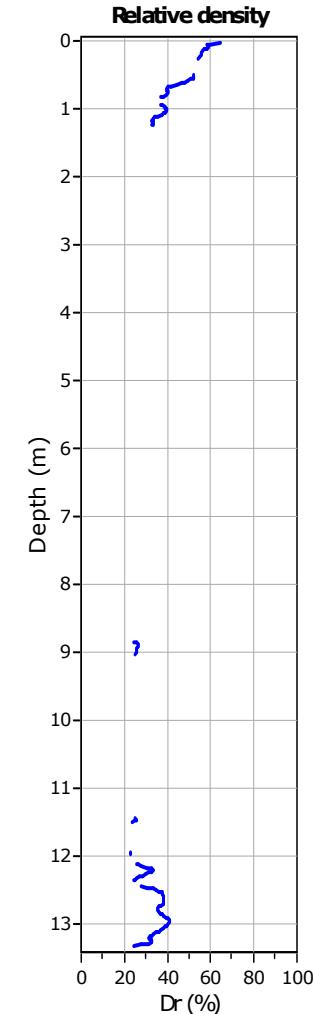
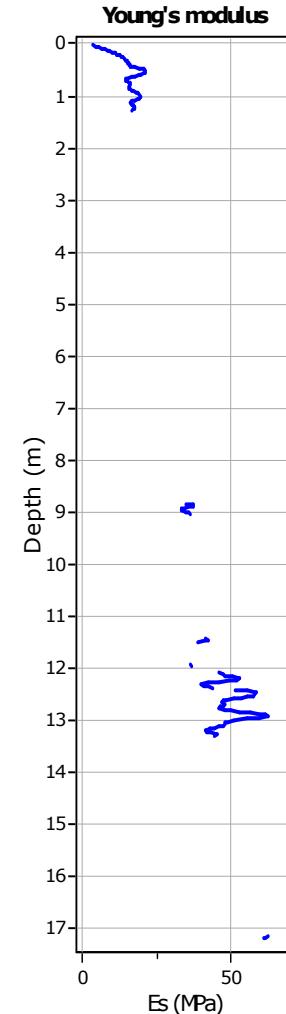
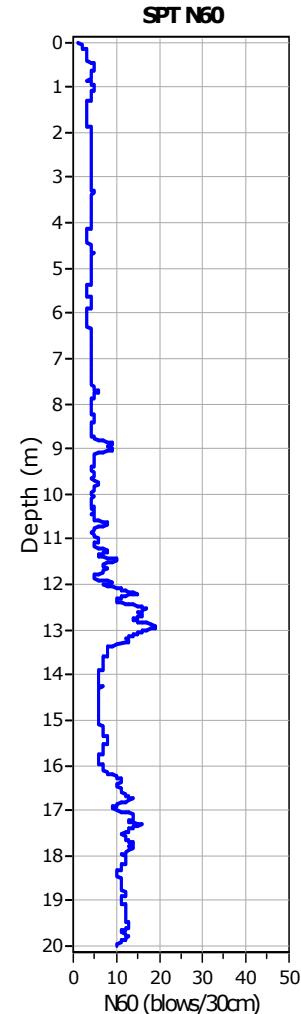
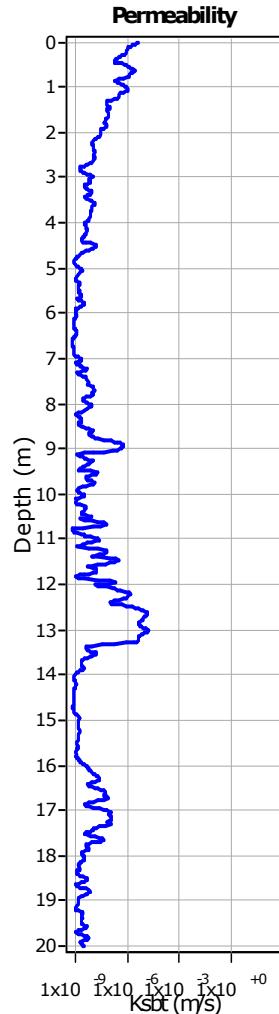
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

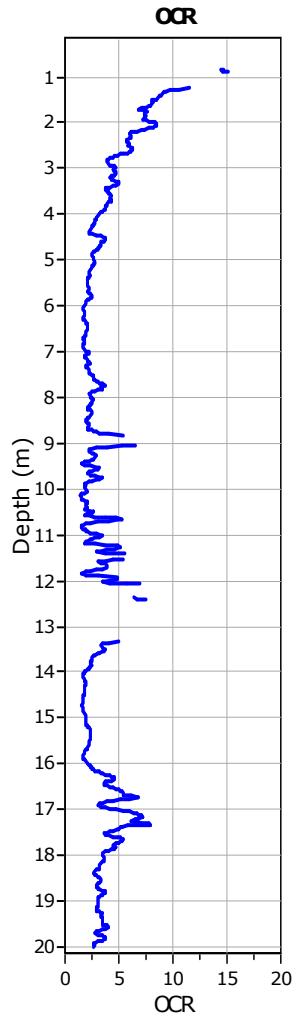
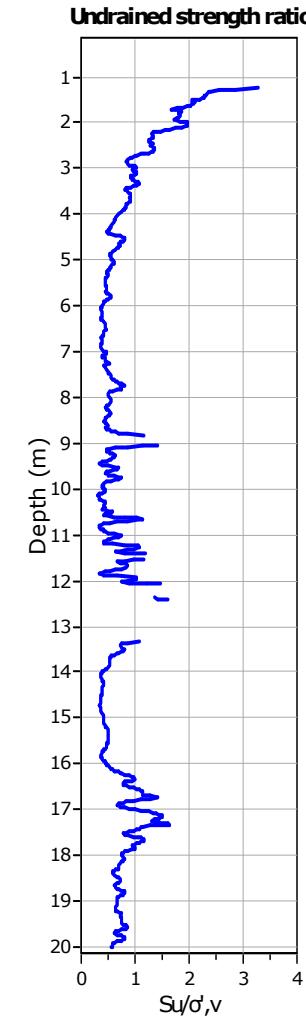
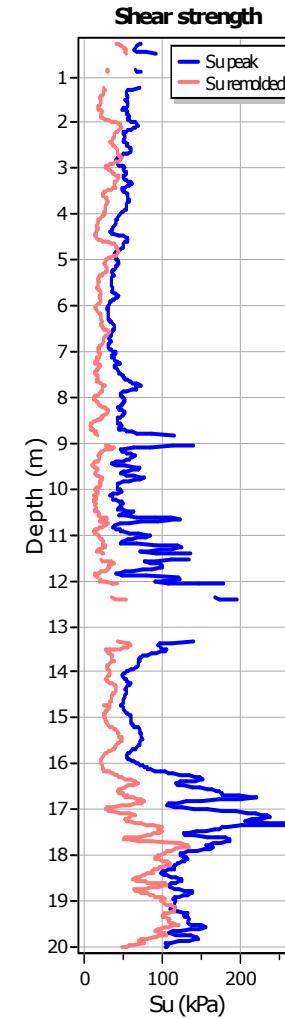
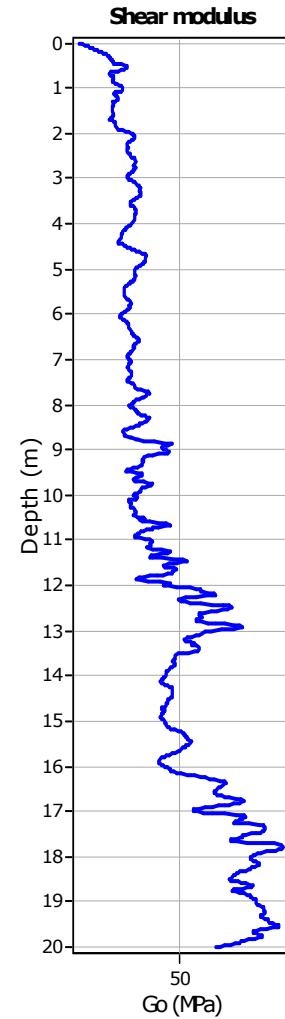
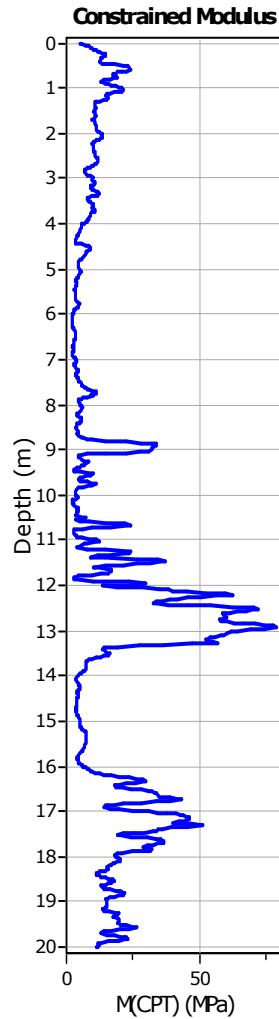
CPT: CPTU 15

Total depth: 20.00 m, Date: 17/05/2018

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

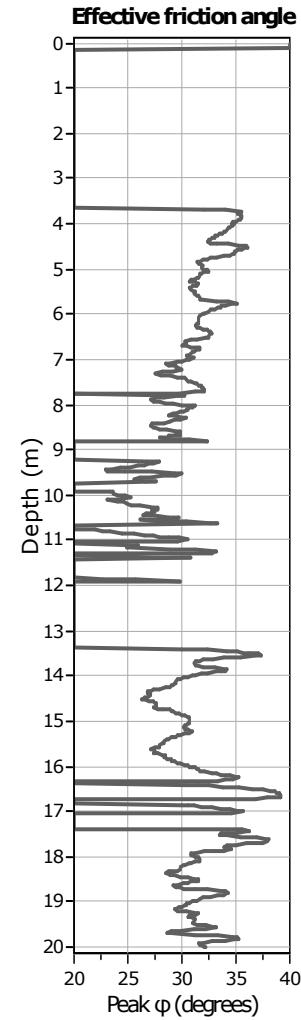
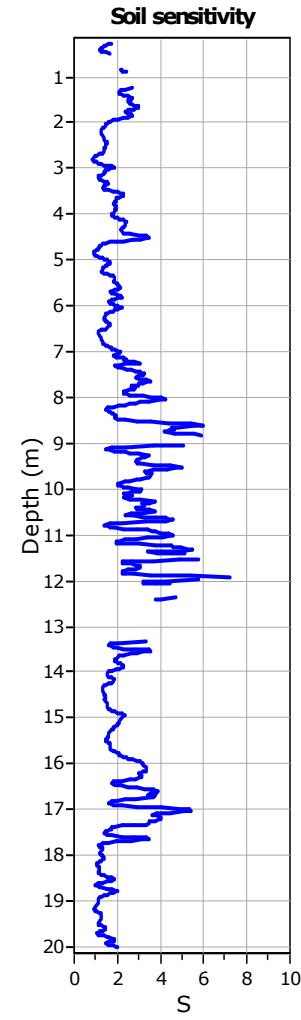
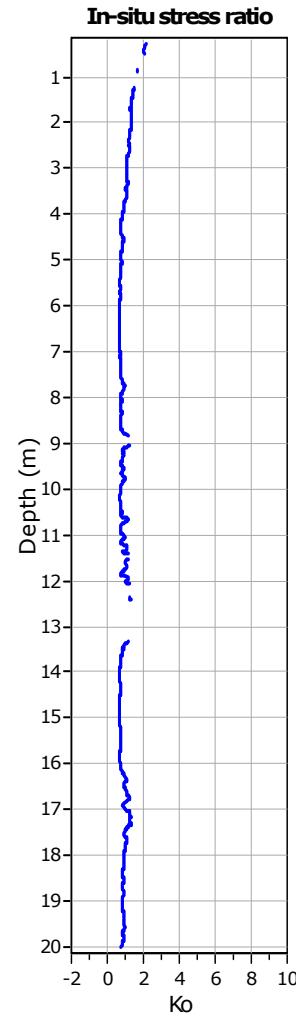
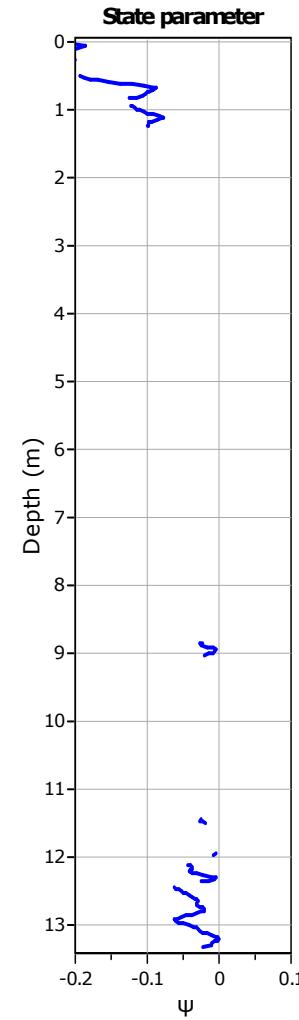
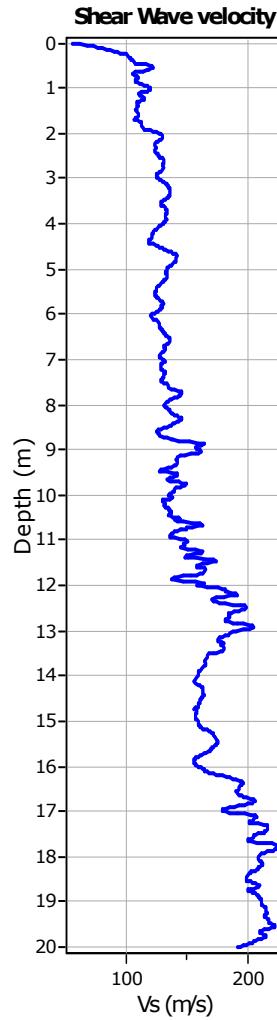
- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 15

Total depth: 20.00 m, Date: 17/05/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

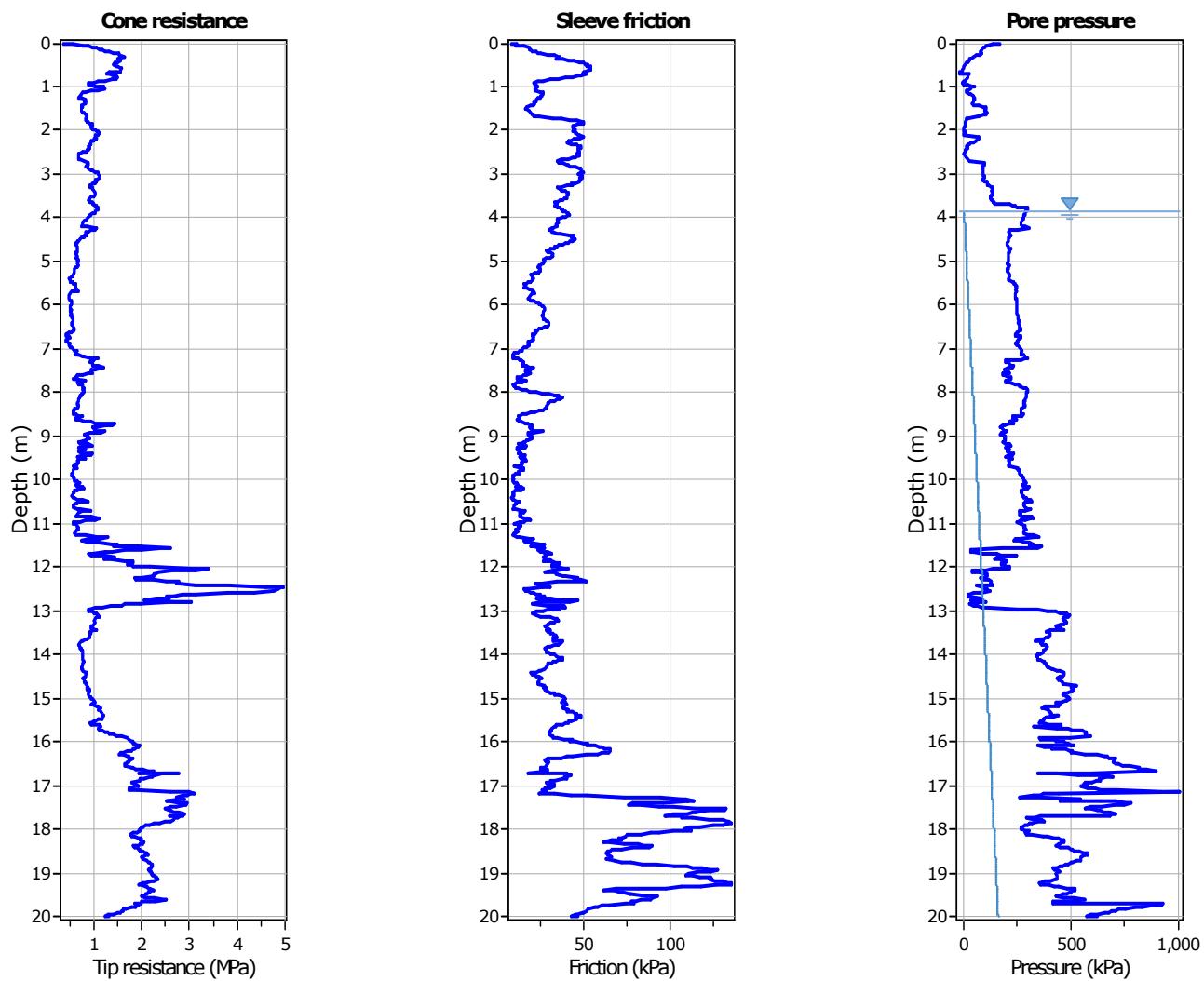
User defined estimation data

Project: Centro Unificato dell'Emergenza sul Territorio

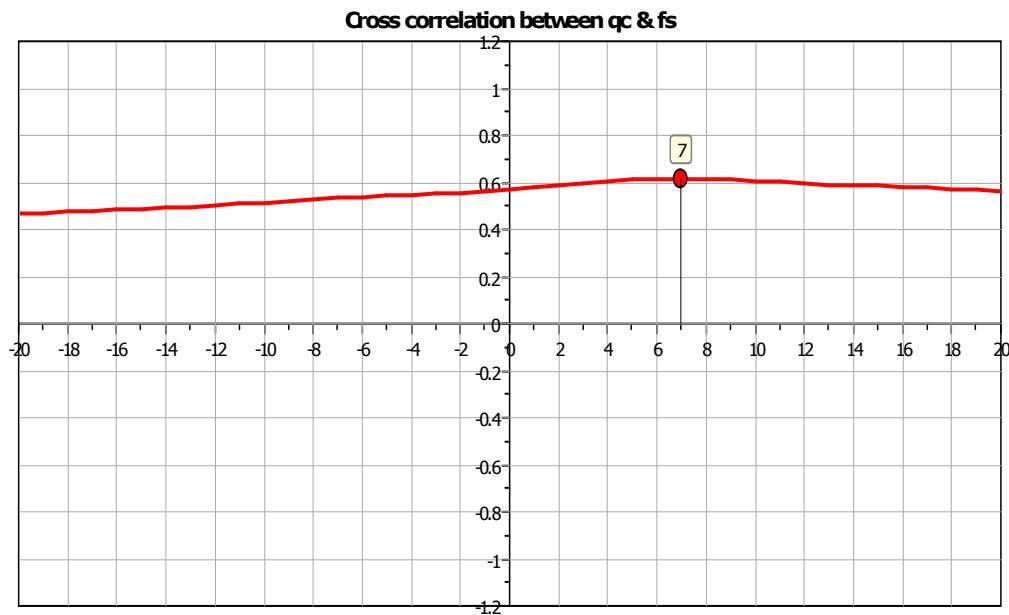
Location: Ferrara

CPT: CPTU 16

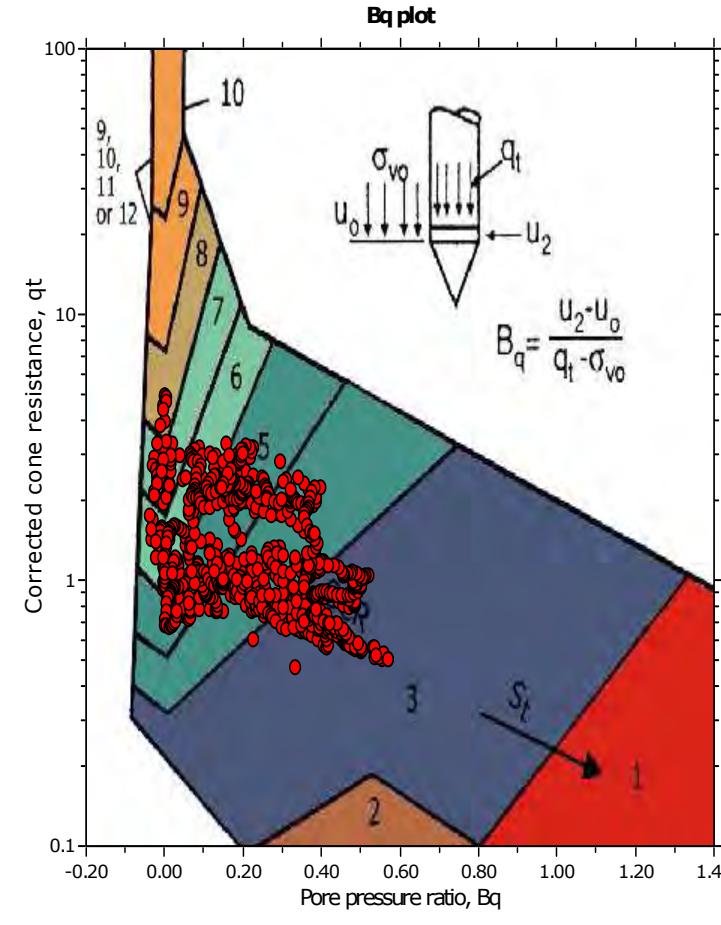
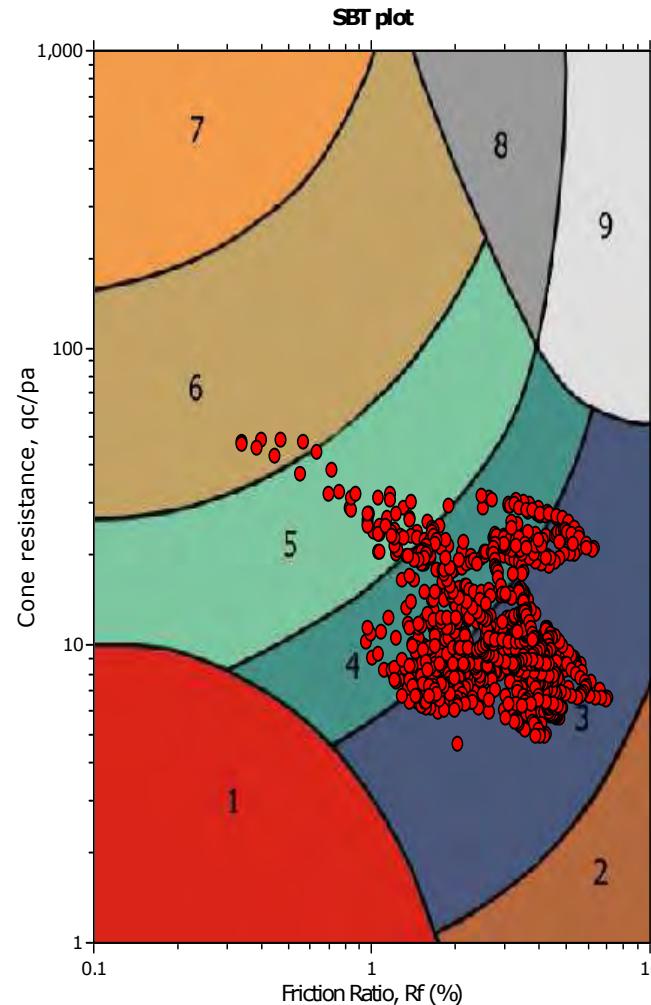
Total depth: 20.00 m, Date: 17/05/2018



The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



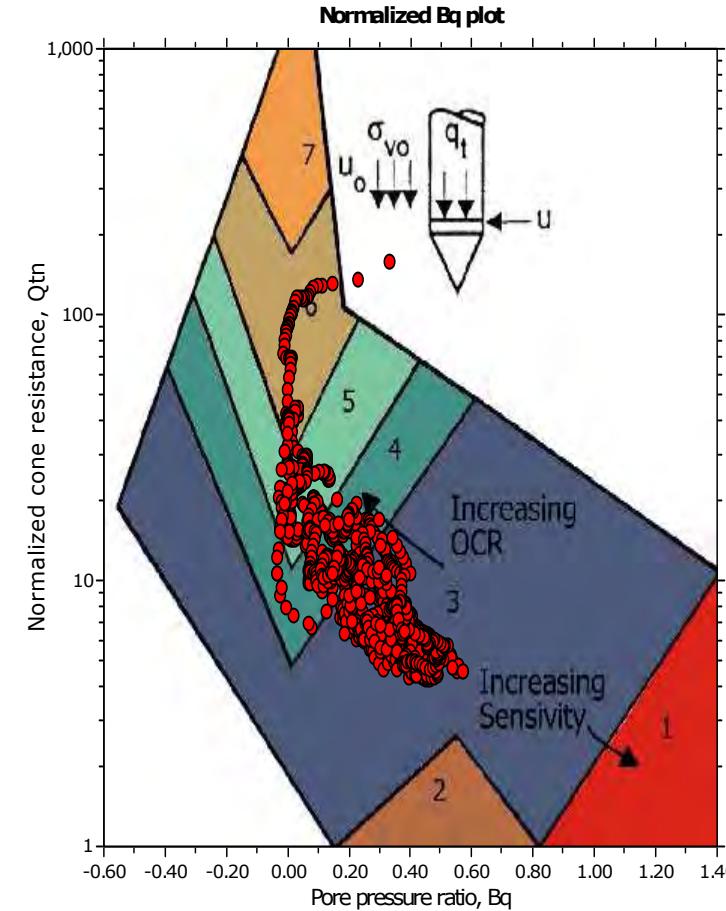
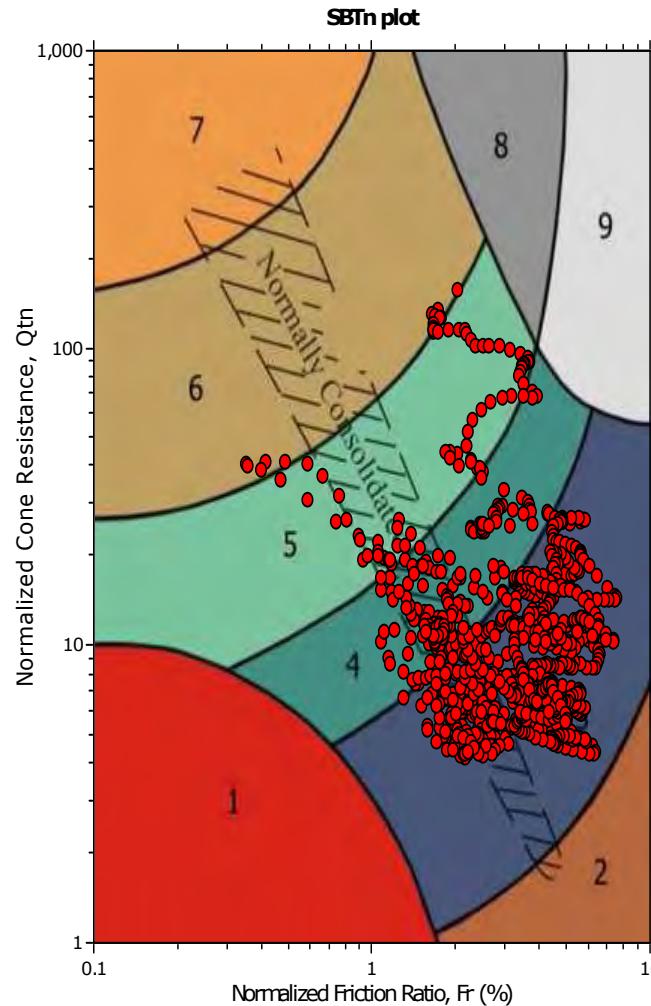
SBT - Bq plots



SBT legend

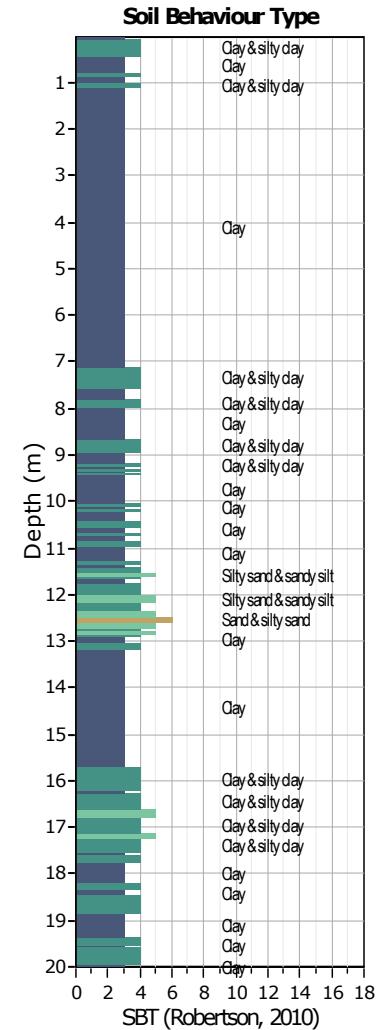
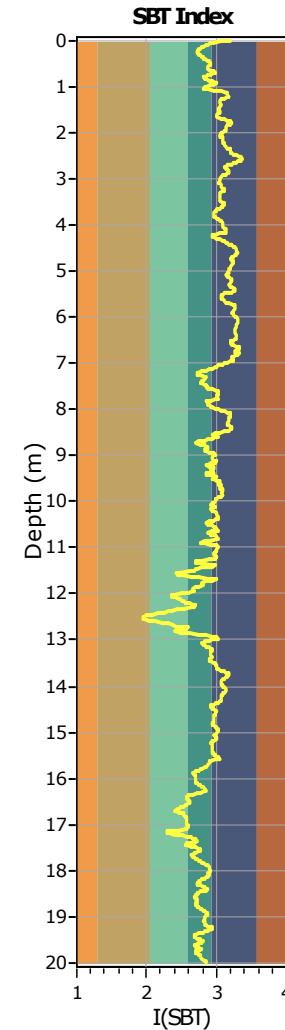
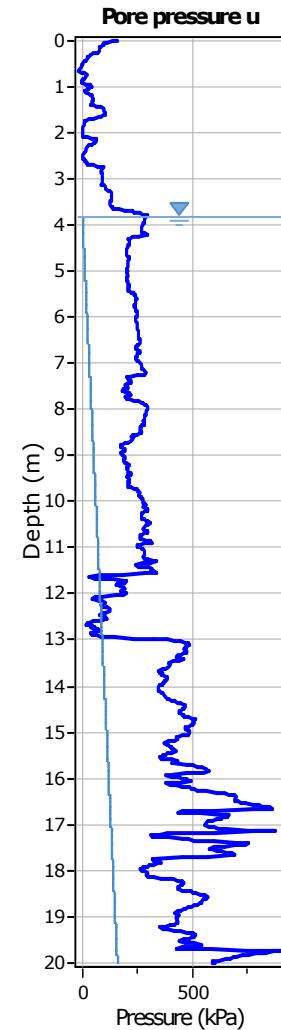
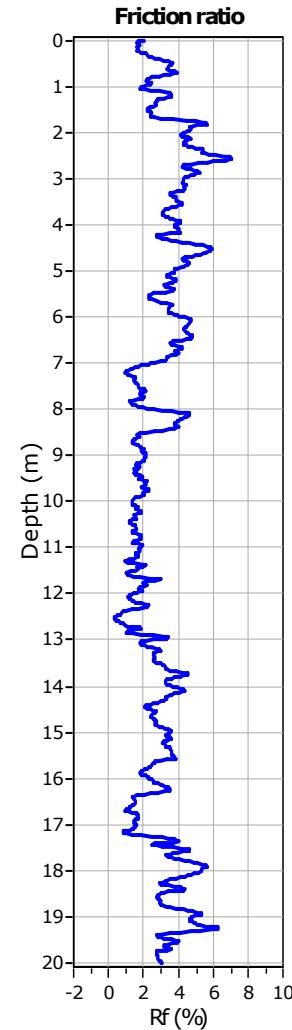
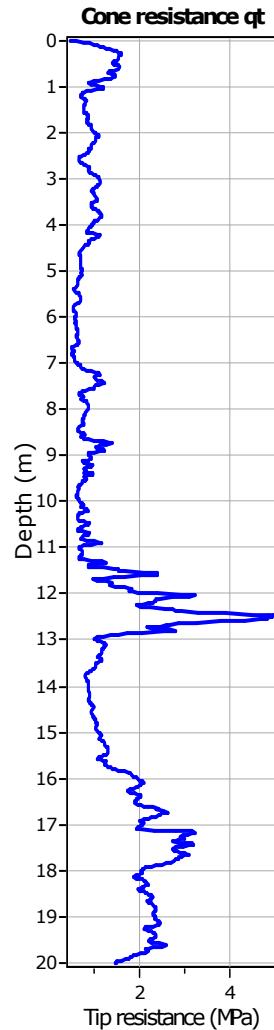
1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

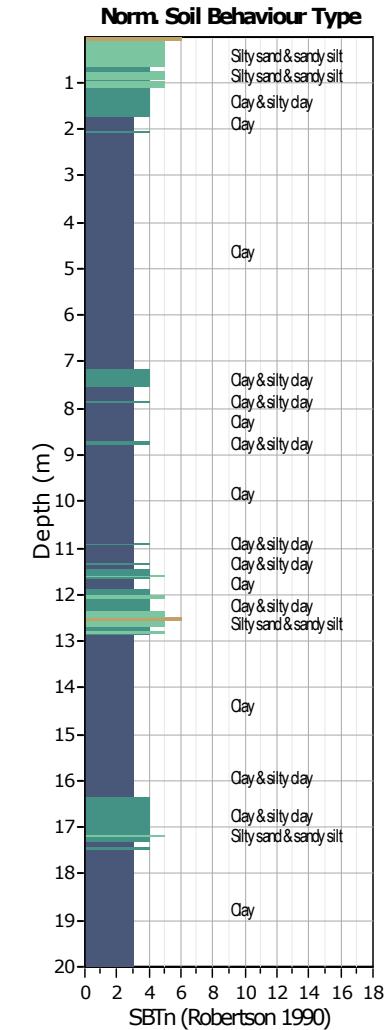
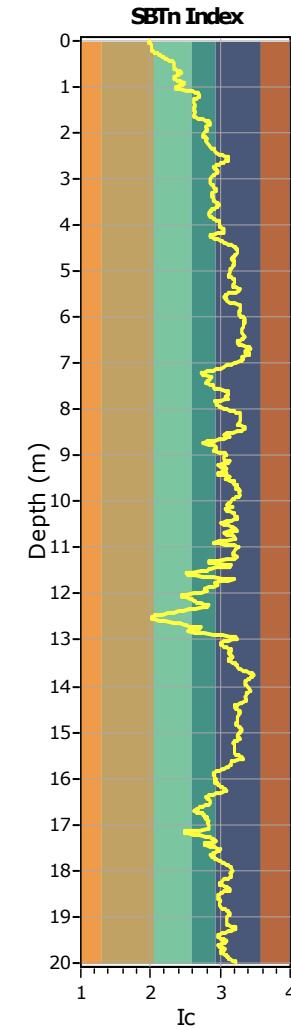
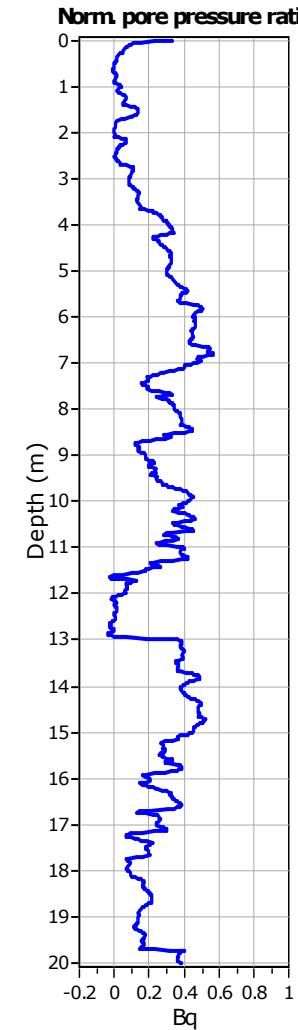
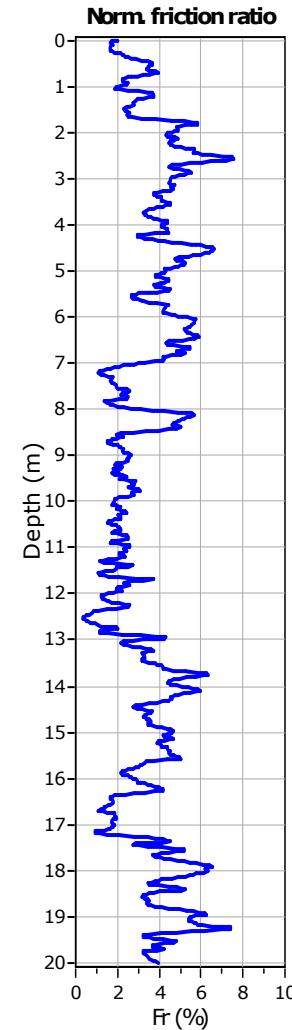
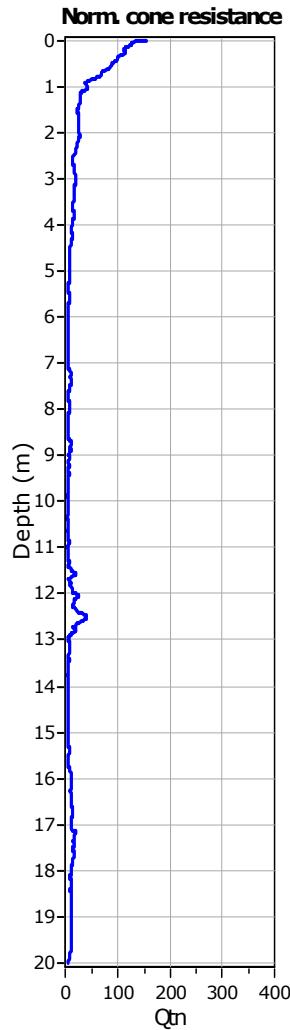
SBT - Bq plots (normalized)



SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to clayey sand
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained



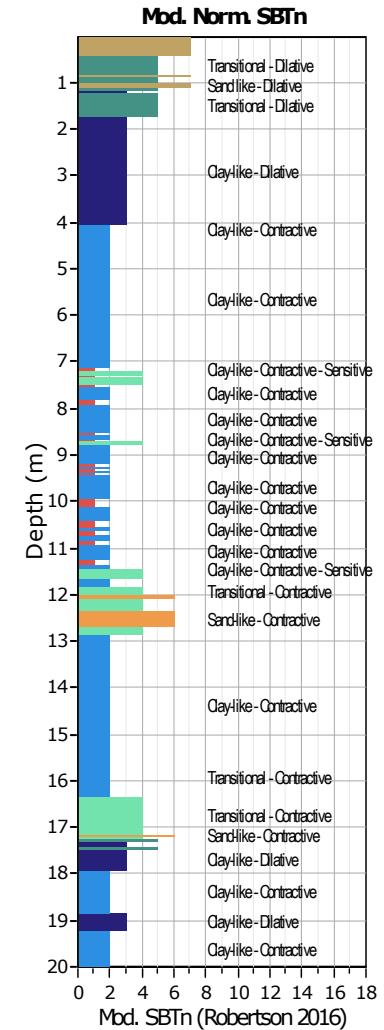
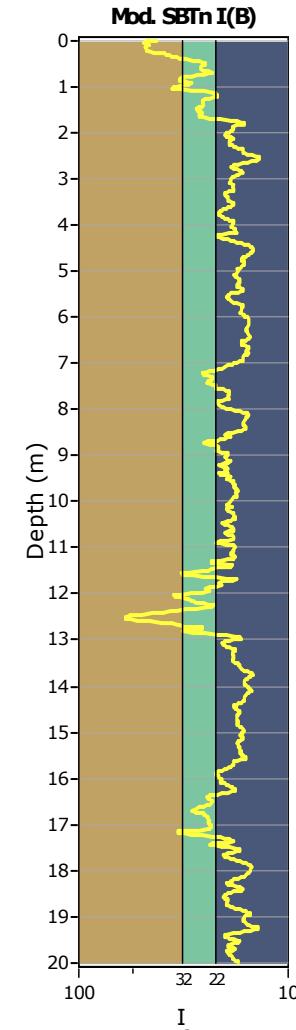
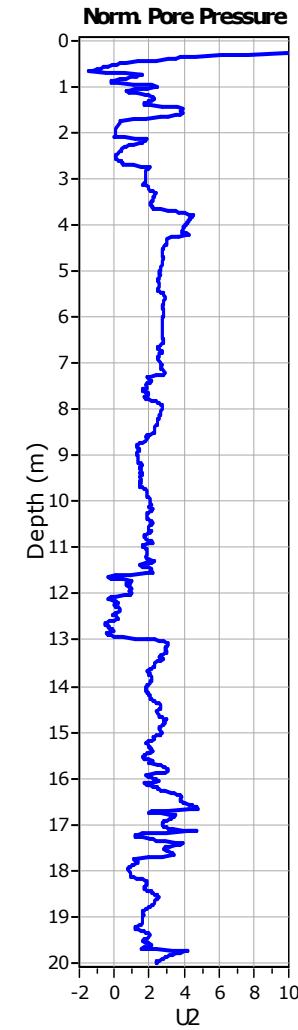
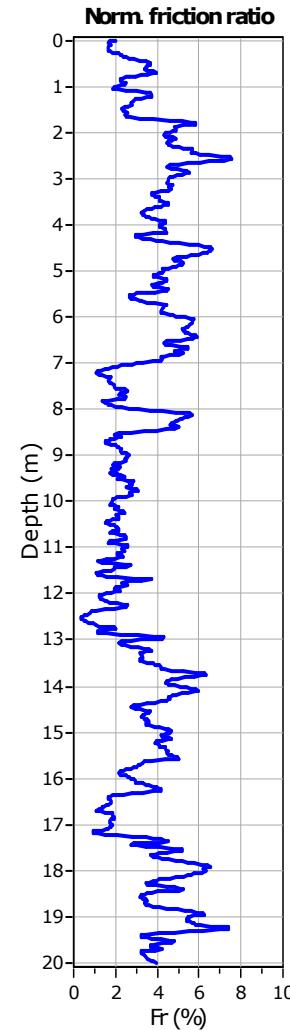
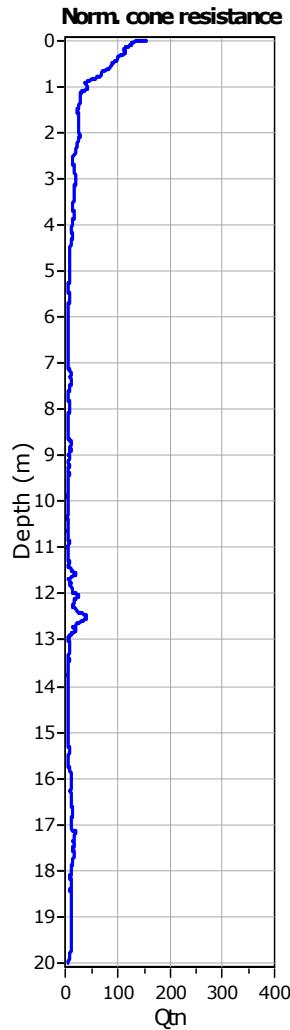


Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

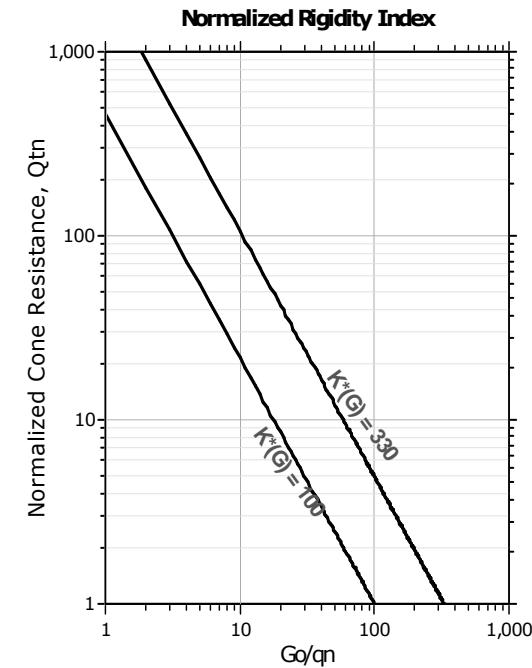
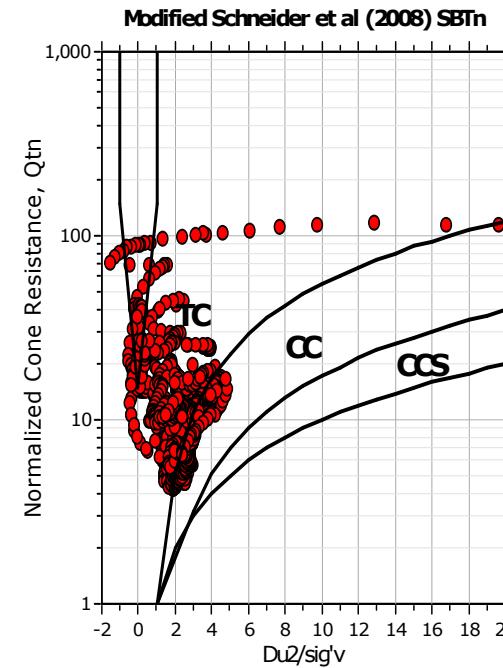
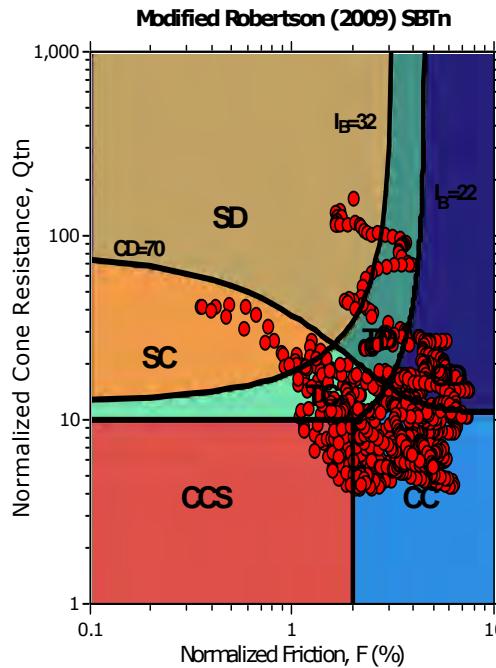
CPT: CPTU 16

Total depth: 20.00 m, Date: 17/05/2018

**Mod. SBTn legend**

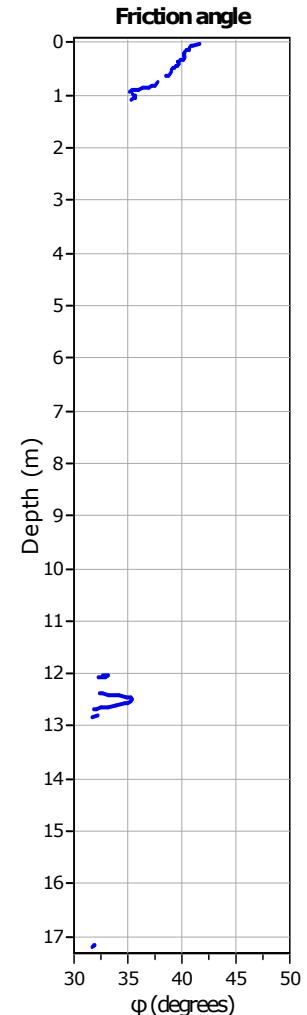
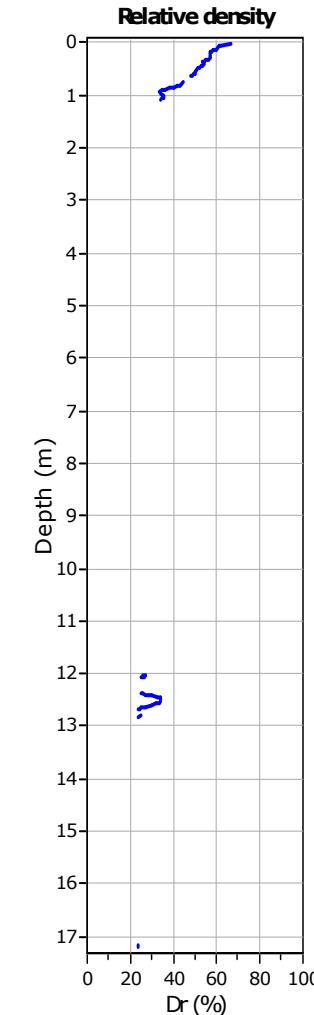
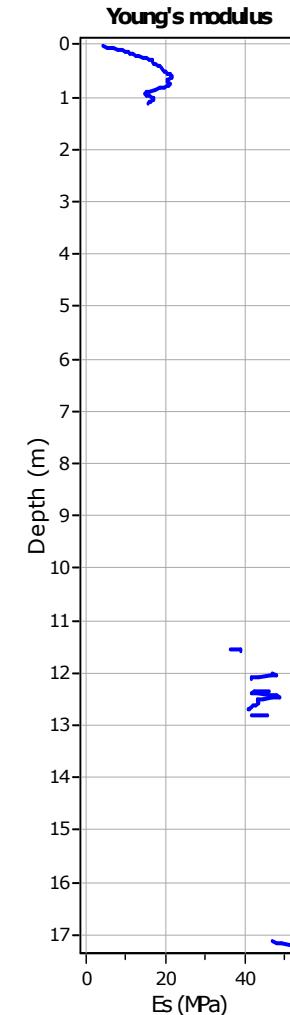
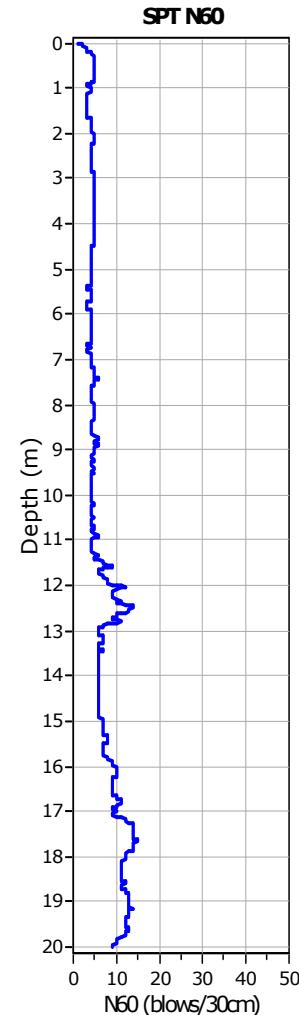
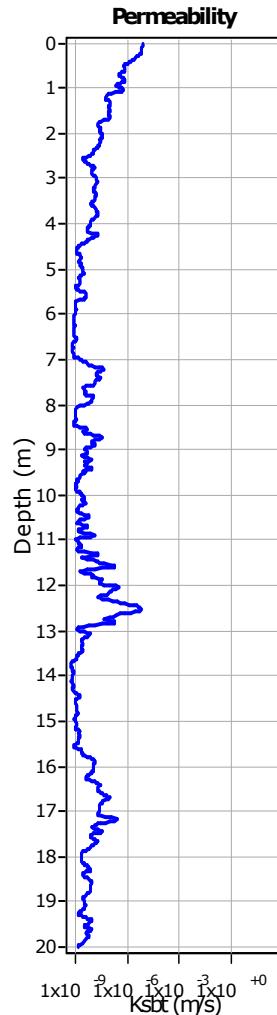
- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

Updated SBTn plots



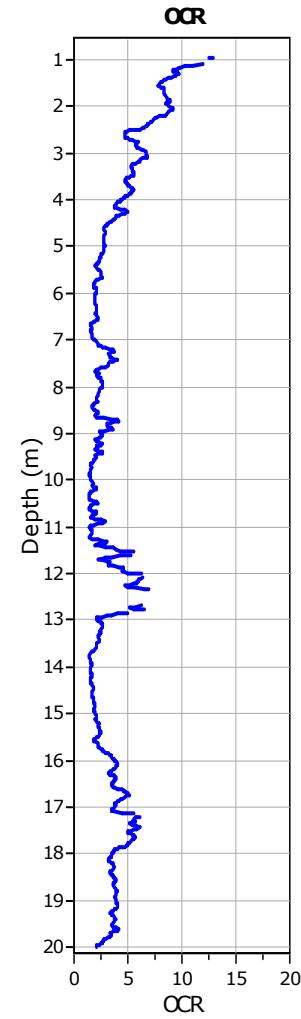
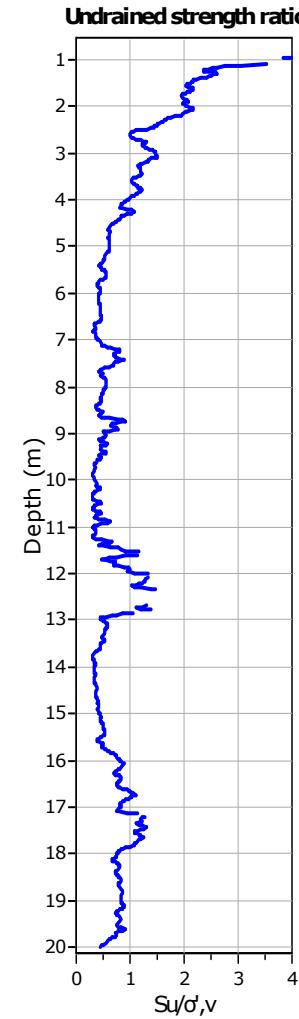
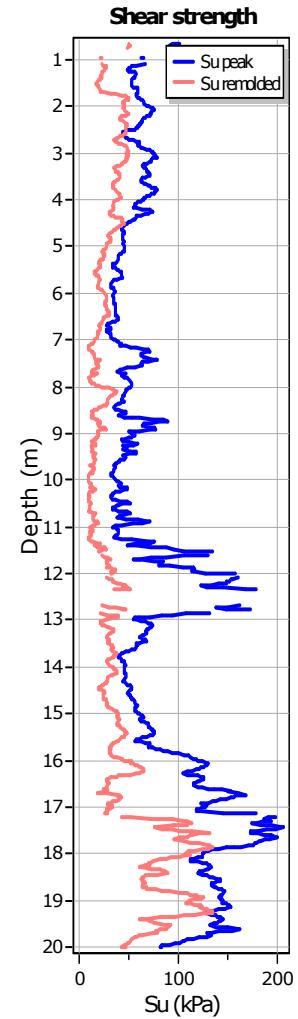
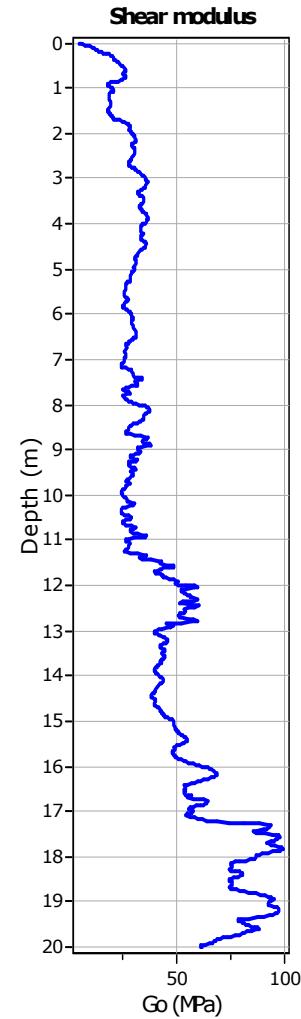
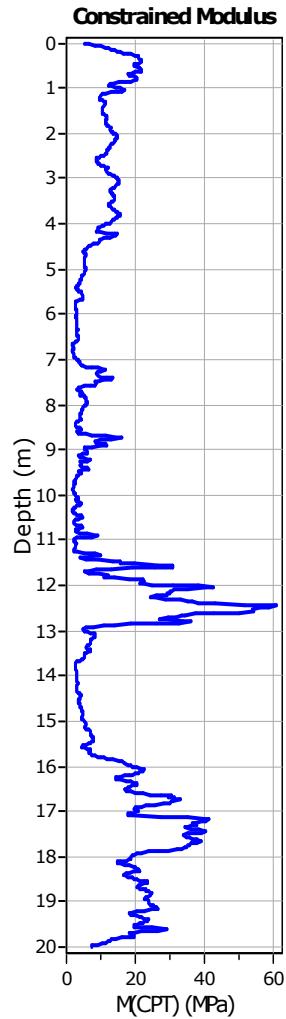
CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
 TD: Transitional - Dilative
 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

$K(G) > 330$: Soils with significant microstructure
 (e.g. age/cementation)

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

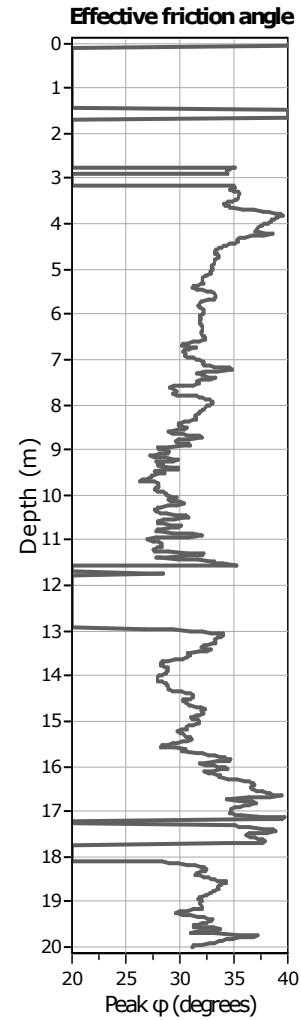
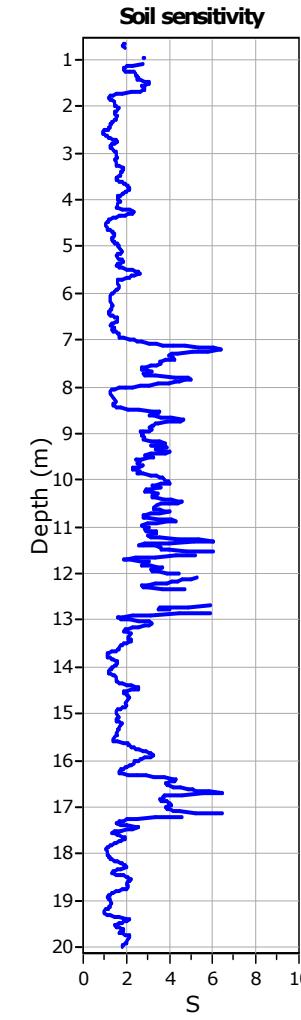
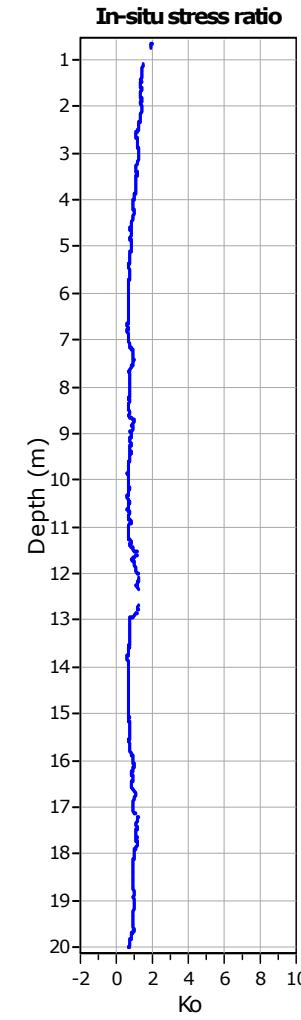
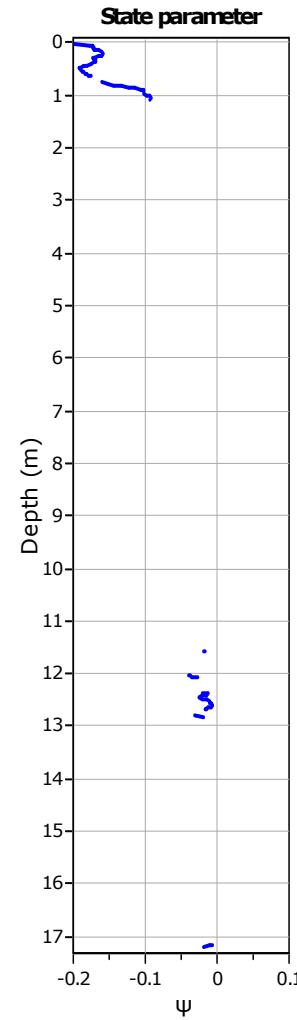
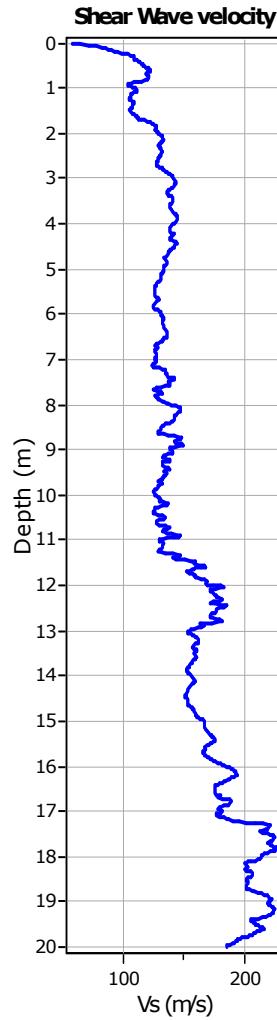
User defined estimation data

**Calculation parameters**Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)Go: Based on variable *alpha* using I_c (Robertson, 2009)Undrained shear strength cone factor for clays, N_{kt} : 14OCR factor for clays, N_{kt} : 0.33

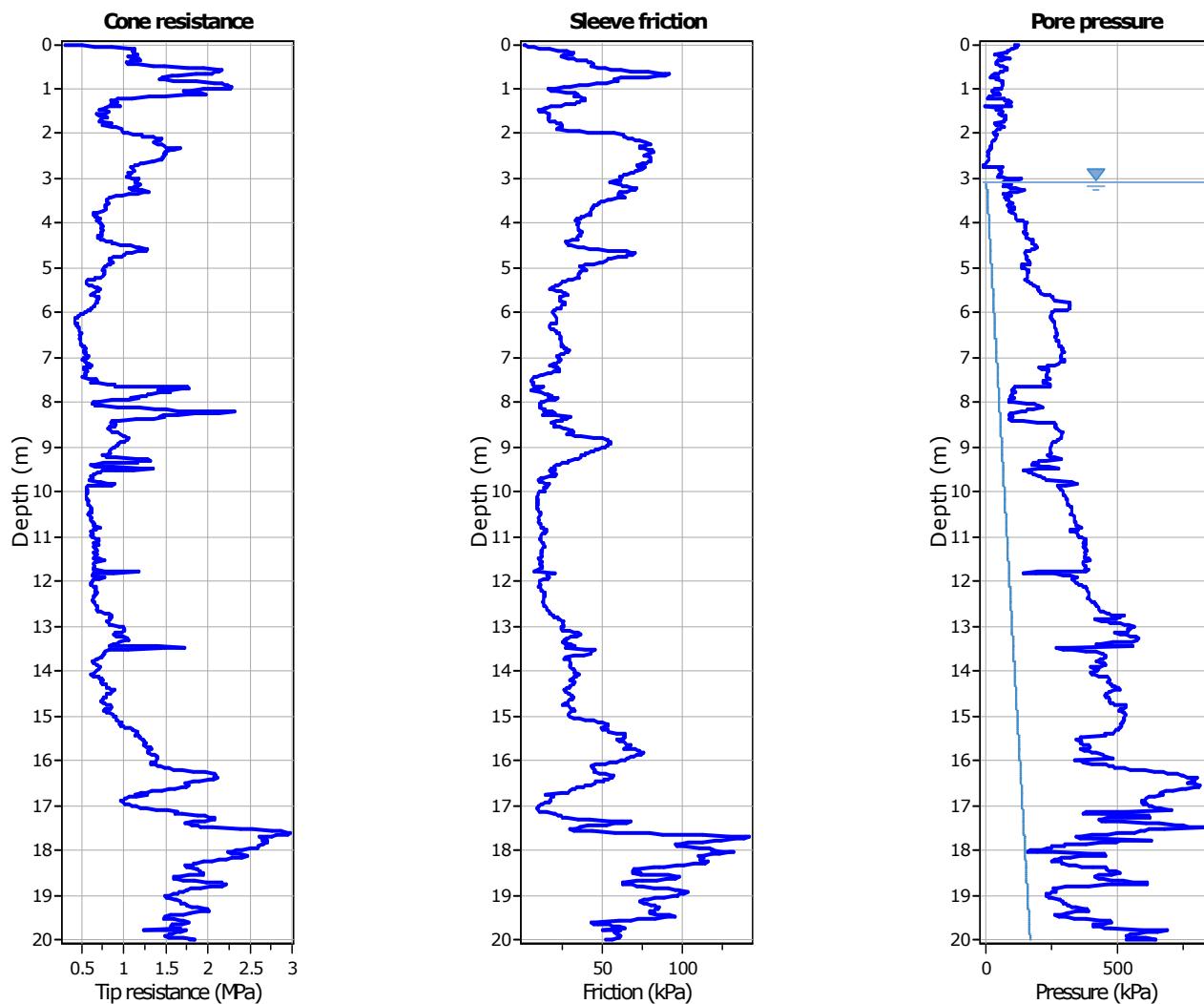
- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato dell'Emergenza sul Territorio**Location:** Ferrara**CPT: CPTU 16**

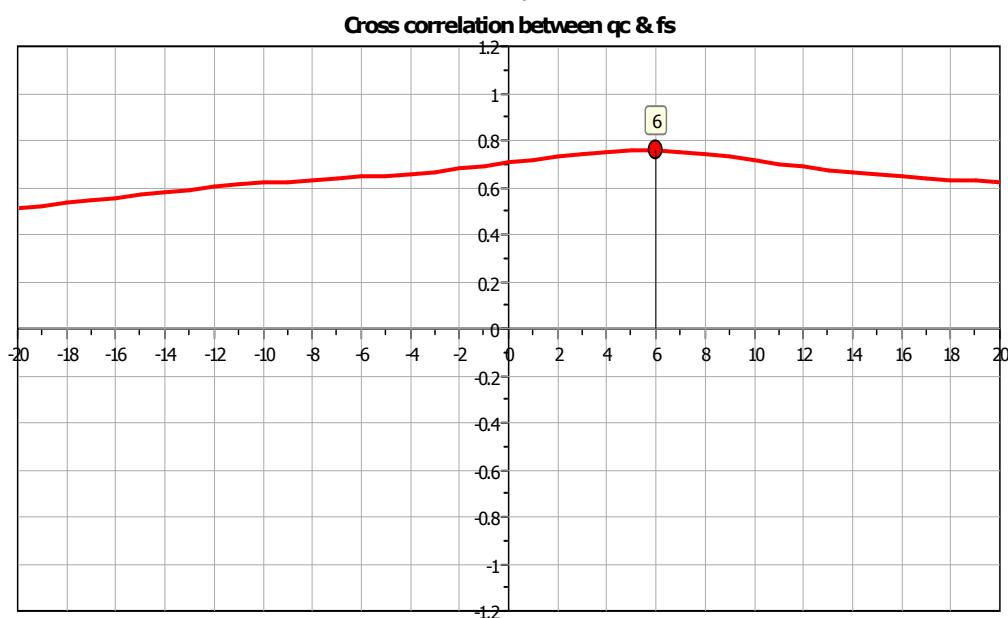
Total depth: 20.00 m, Date: 17/05/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

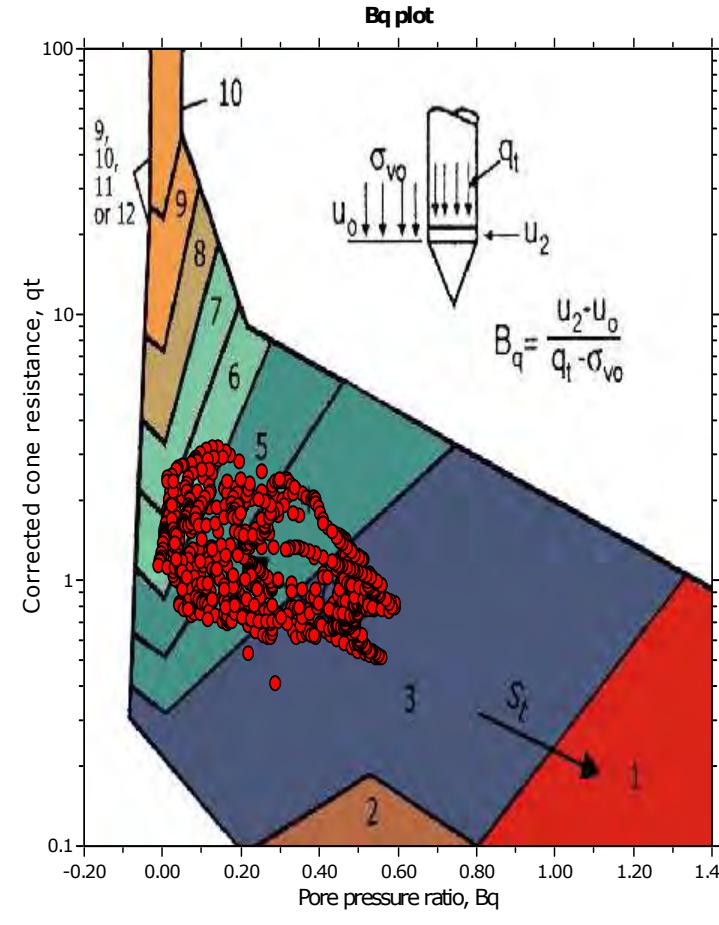
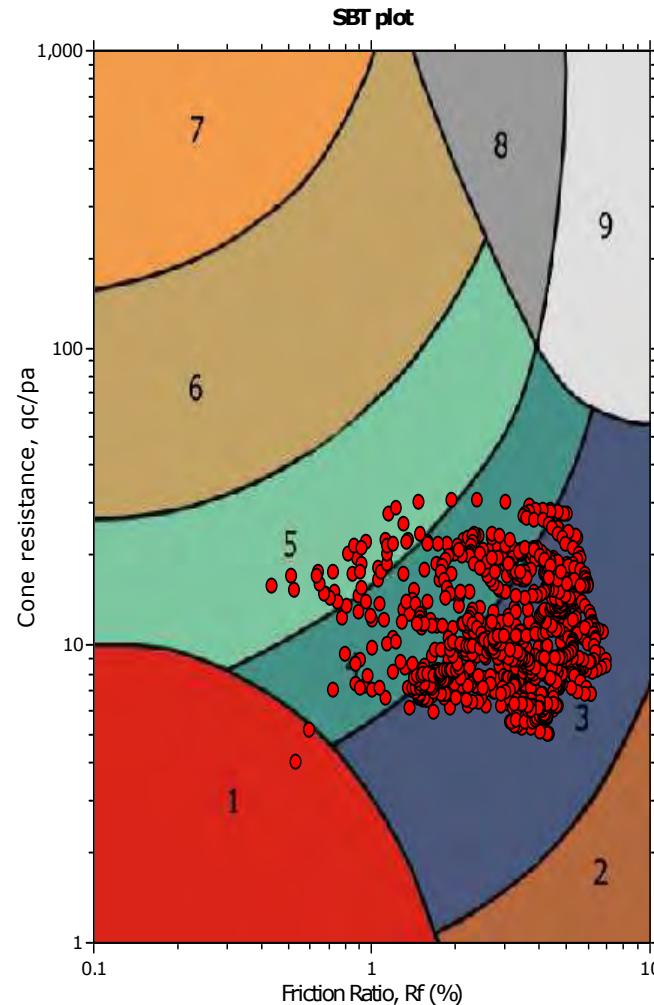
User defined estimation data



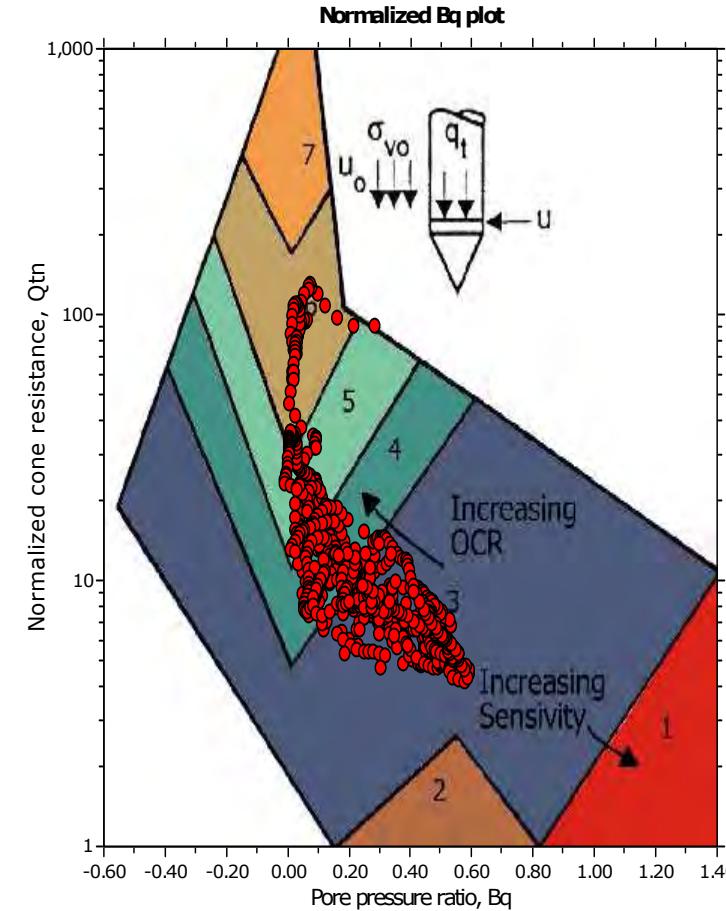
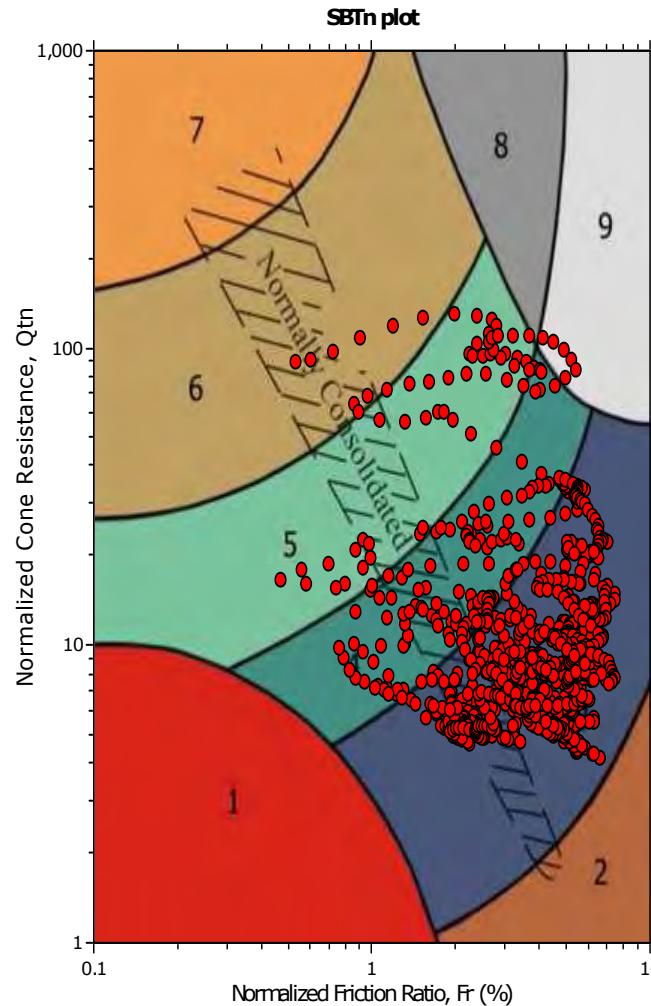
The plot below presents the cross correlation coefficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two successive CPT measurements).



SBT - Bq plots

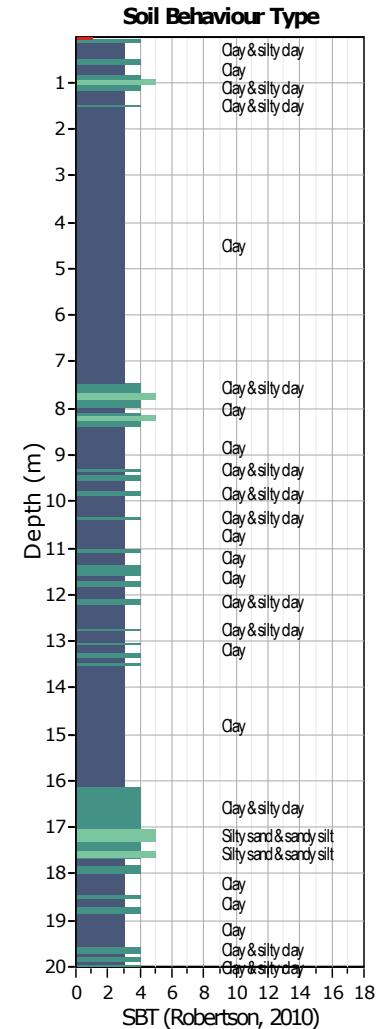
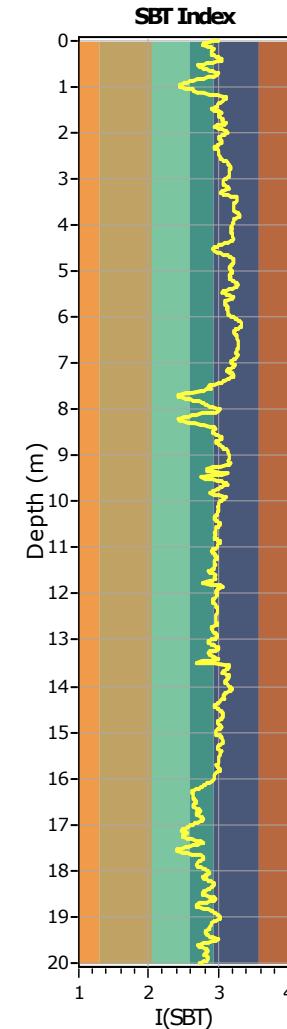
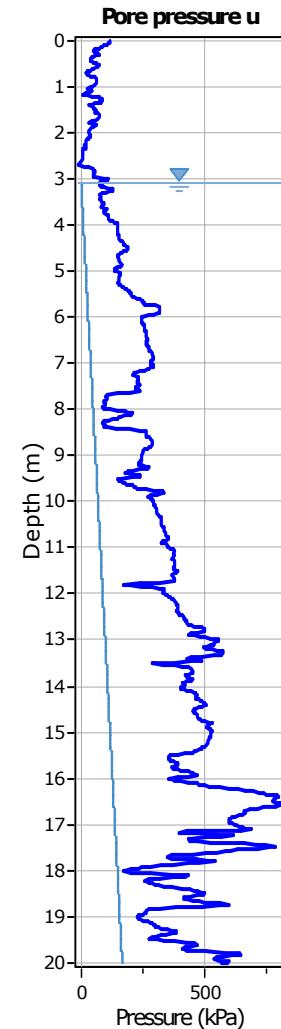
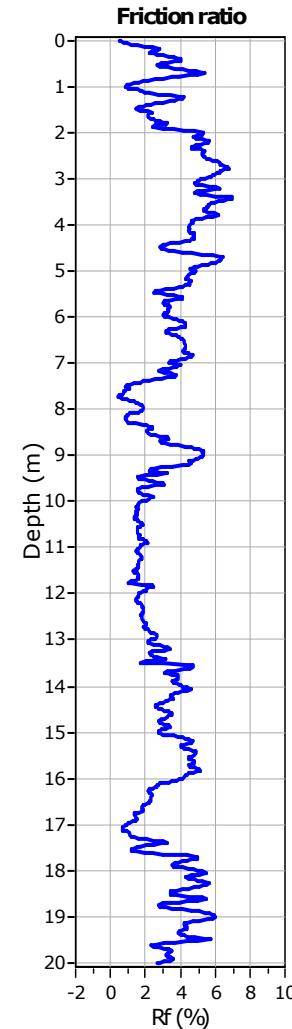
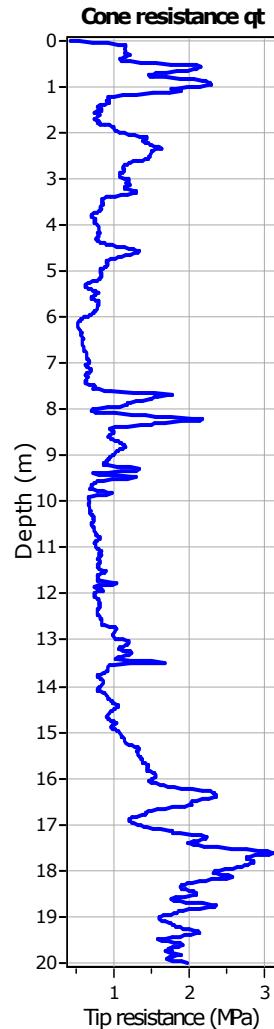


SBT - Bq plots (normalized)

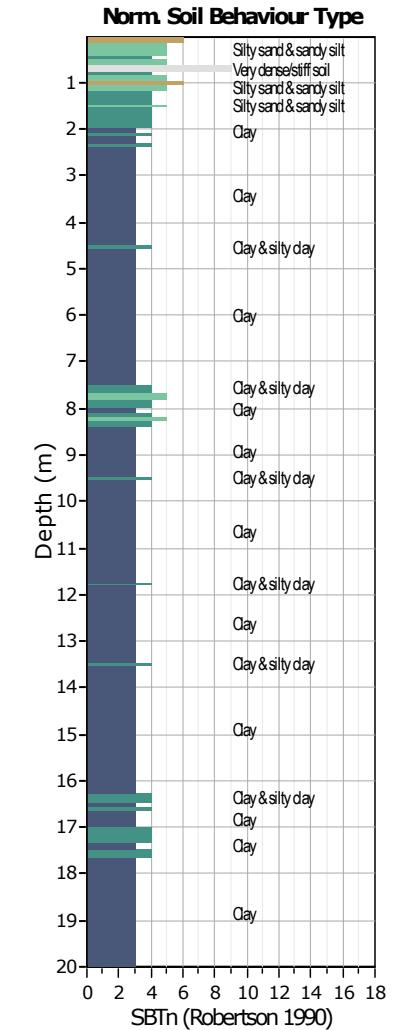
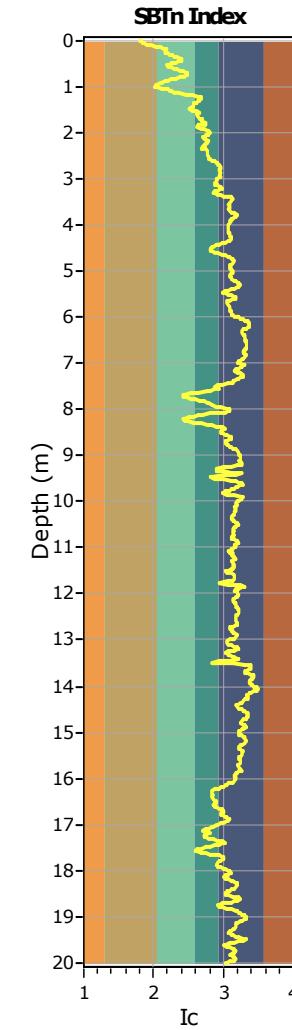
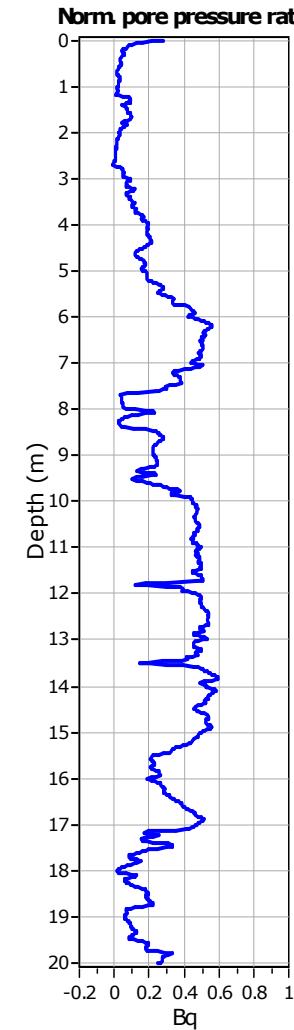
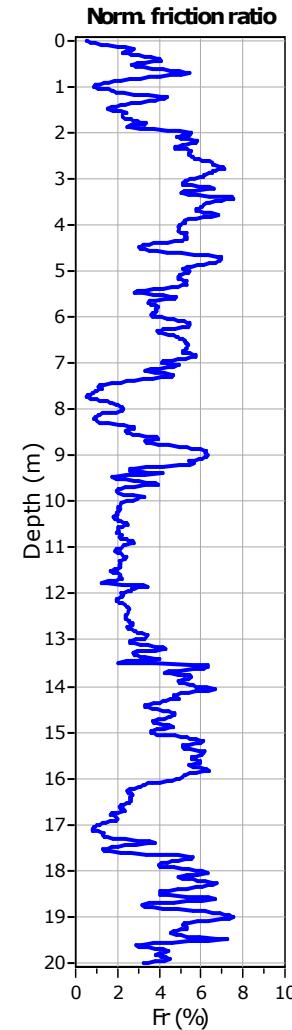
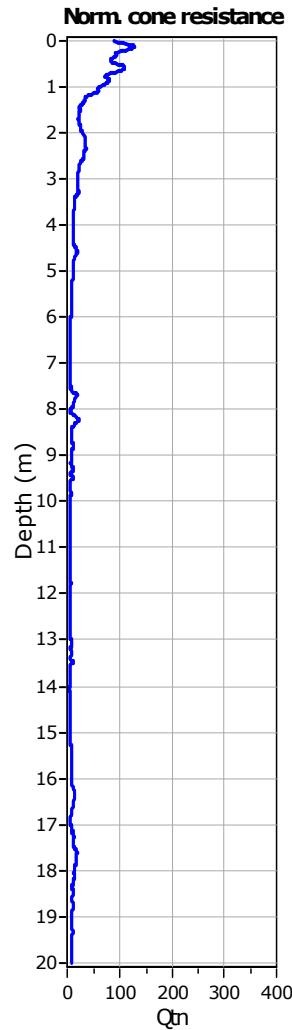


SBTn legend

1. Sensitive fine grained	4. Clayey silt to silty clay	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	6. Clean sand to silty sand
3. Clay to silty clay		8. Very stiff sand to clayey sand
		9. Very stiff fine grained

**SBT legend**

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

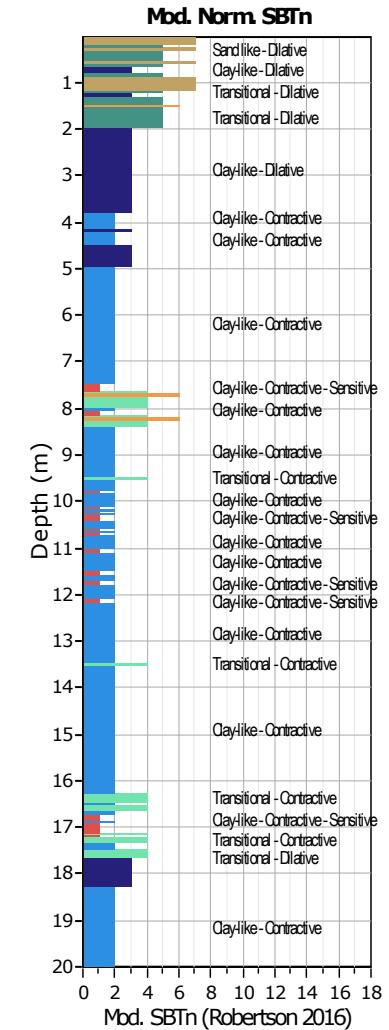
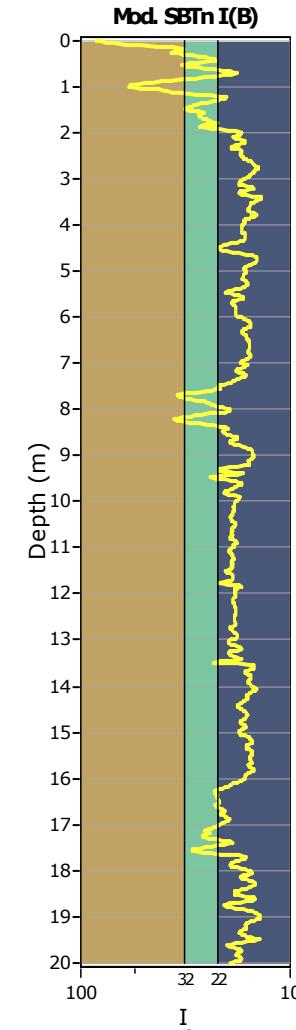
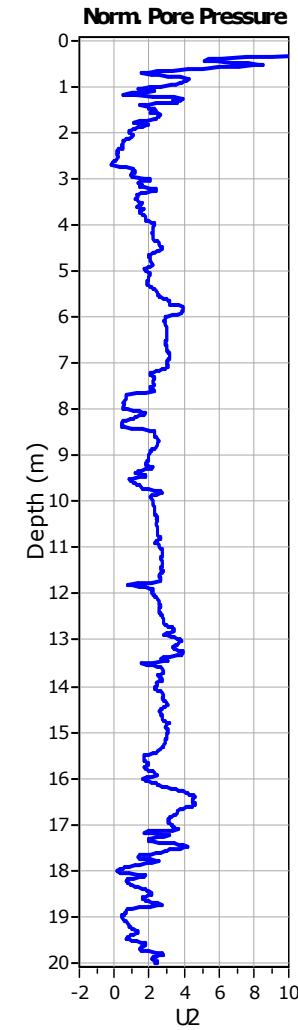
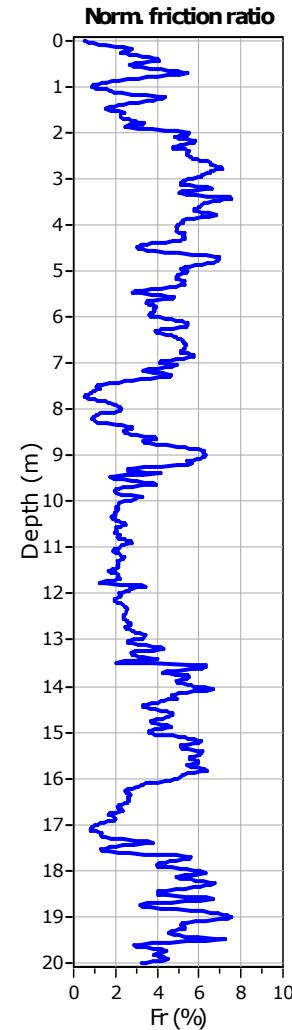
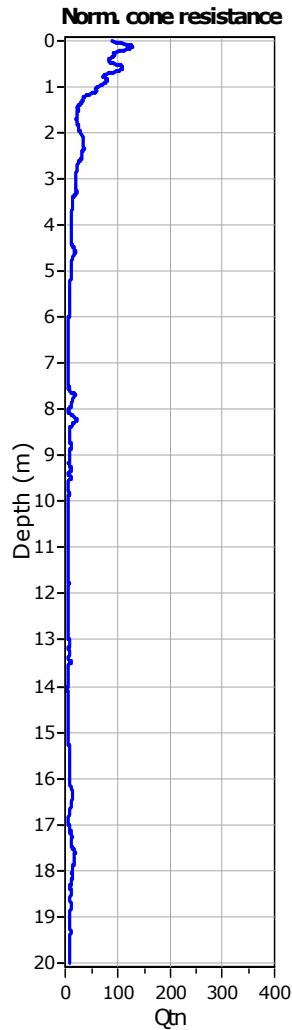


Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

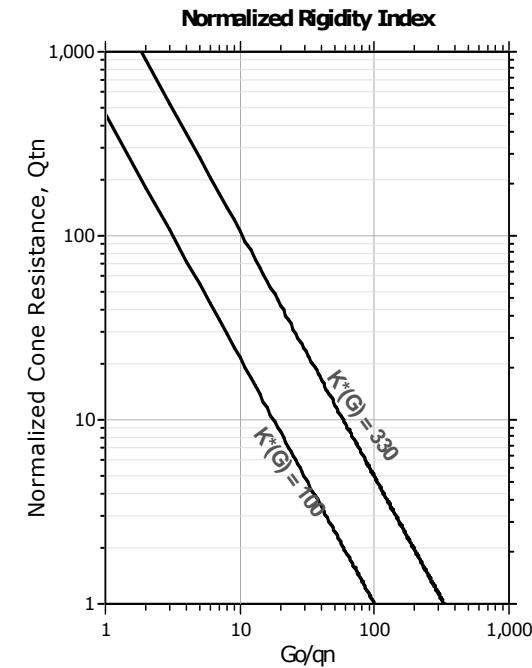
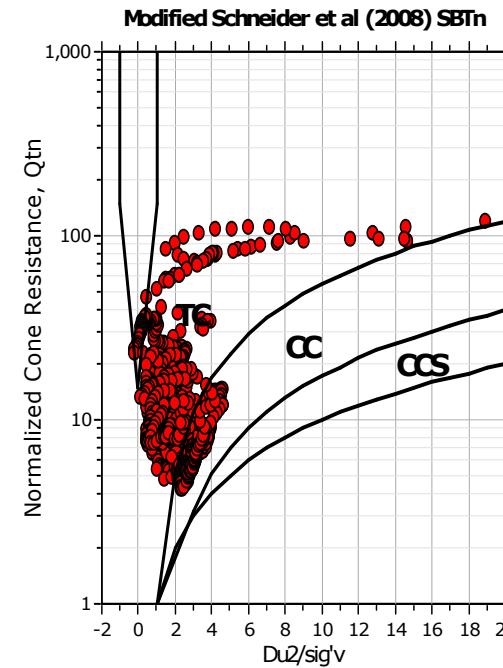
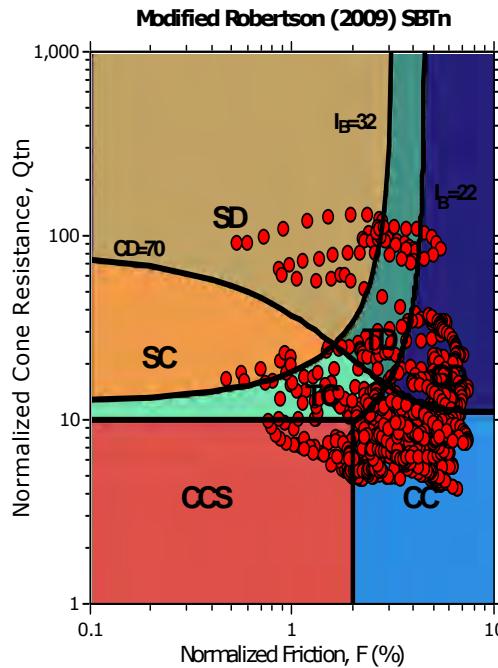
CPT: CPTU 17

Total depth: 20.00 m, Date: 17/05/2018

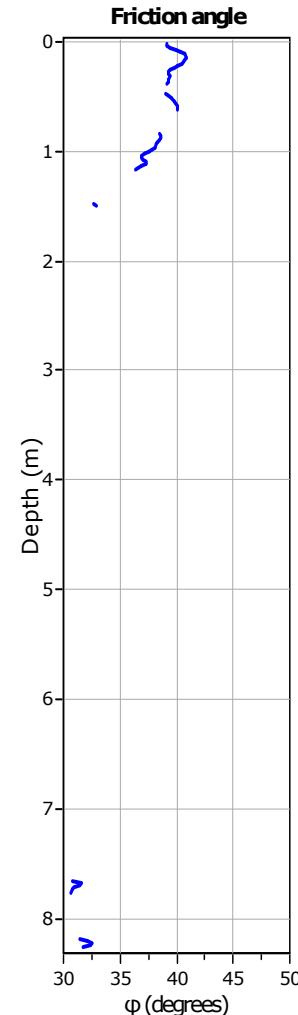
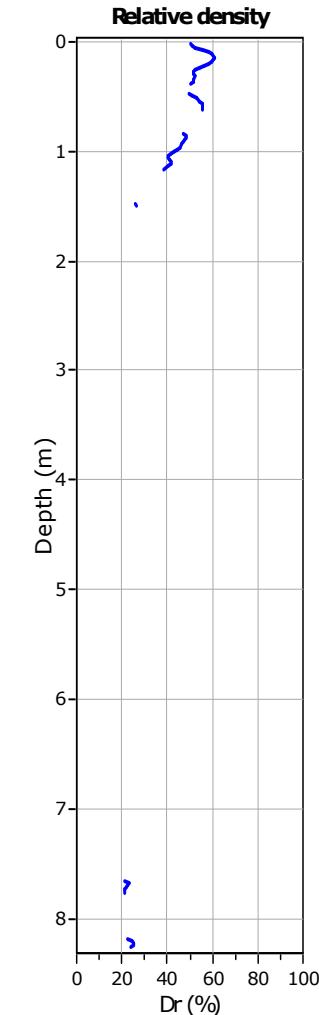
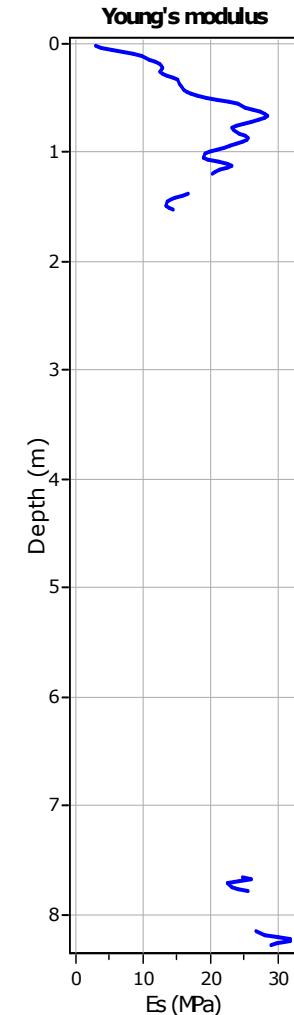
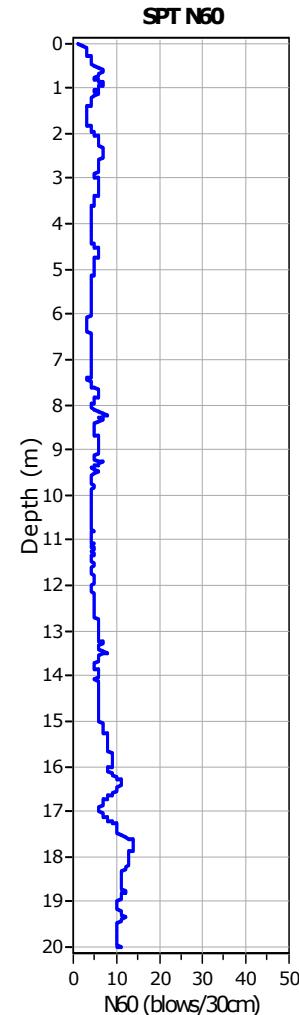
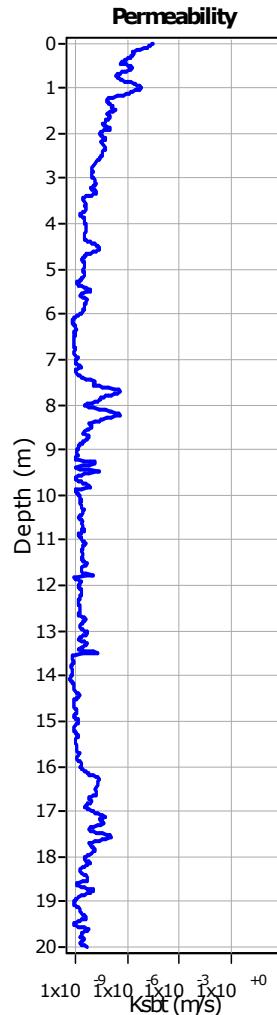
**Mod. SBTn legend**

- | | | |
|---|-----------------------------------|--------------------------------|
| 1. CCS: ClayLike - Contractive, Sensitive | 4. TC: Transitional - Contractive | 7. SD: Sand-like - Dilative |
| 2. CC: Clay-like - Contractive | 5. TD: Transitional - Dilative | 8. SC: Sand-like - Contractive |
| 3. CD: Clay-Like: Dilative | 6. CL: Clay-Like | |

Updated SBTn plots

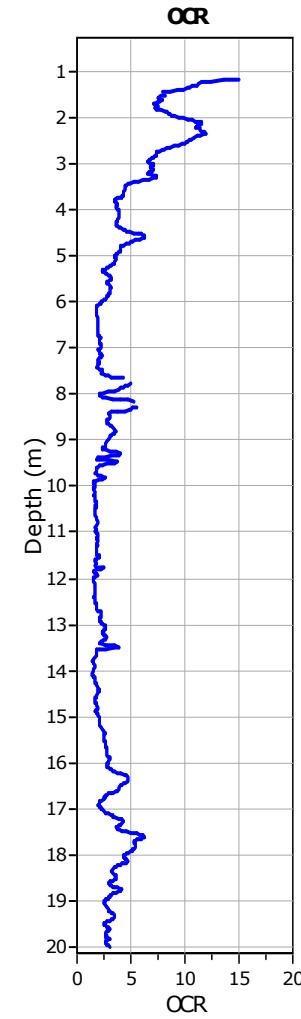
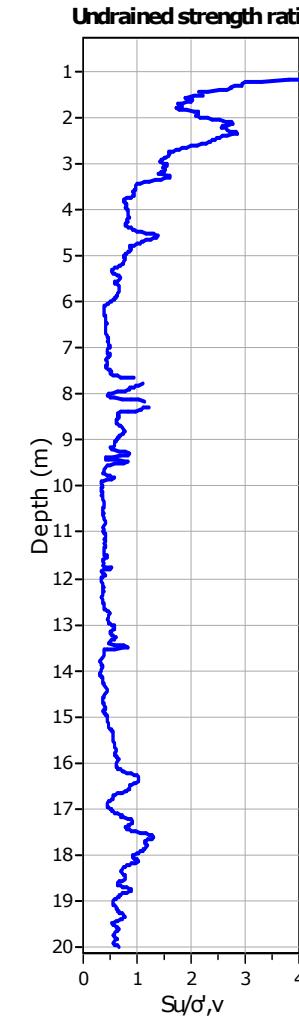
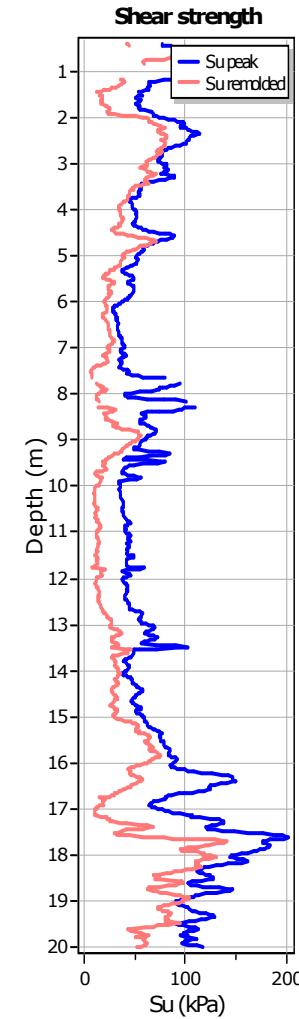
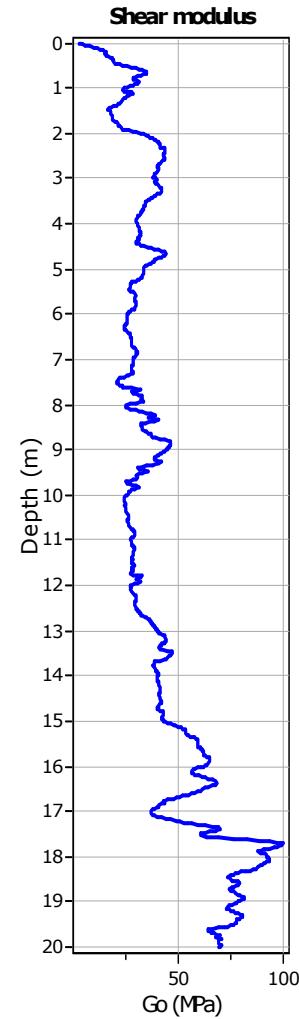
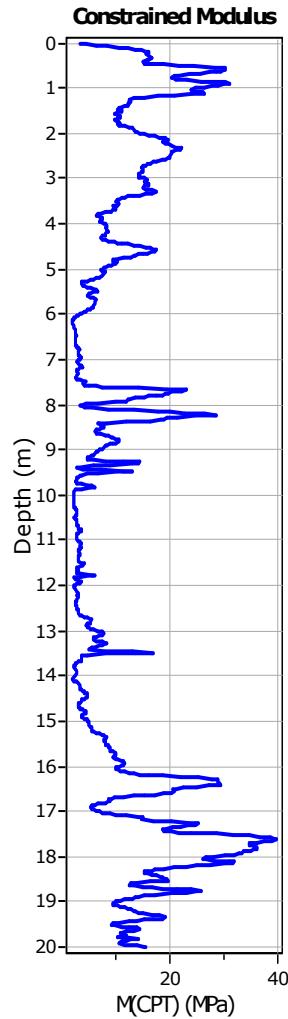


CCS: Clay-like - Contractive - Sensitive
 CC: Clay-like - Contractive
 CD: Clay-like - Dilative
 TC: Transitional - Contractive
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 SC: Sand-like - Contractive
 SD: Sand-like - Dilative

**Calculation parameters**Permeability: Based on SBT_nSPT N₆₀: Based on I_c and q_tYoung's modulus: Based on variable alpha using I_c (Robertson, 2009)Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

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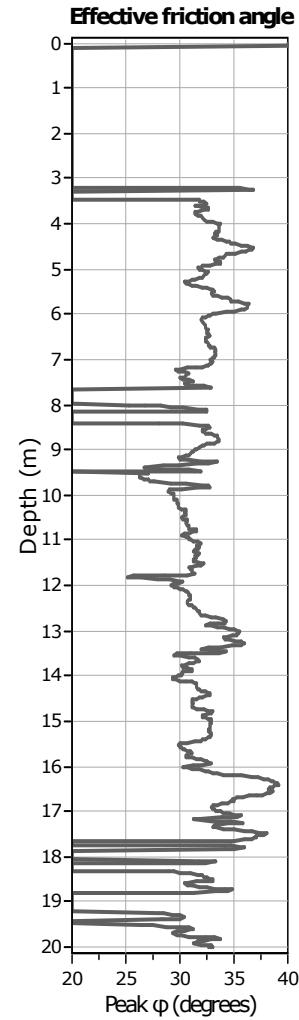
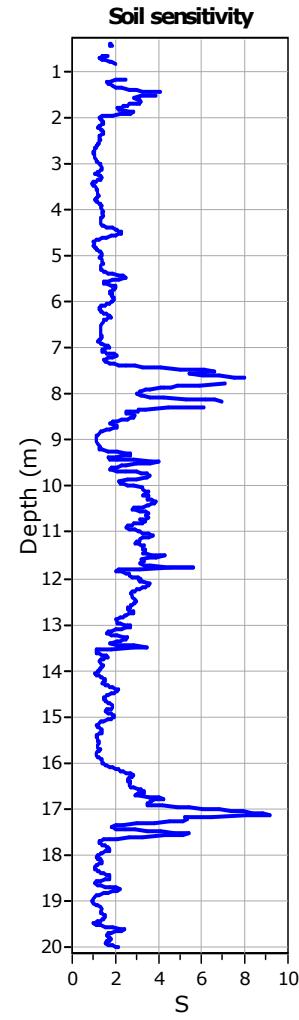
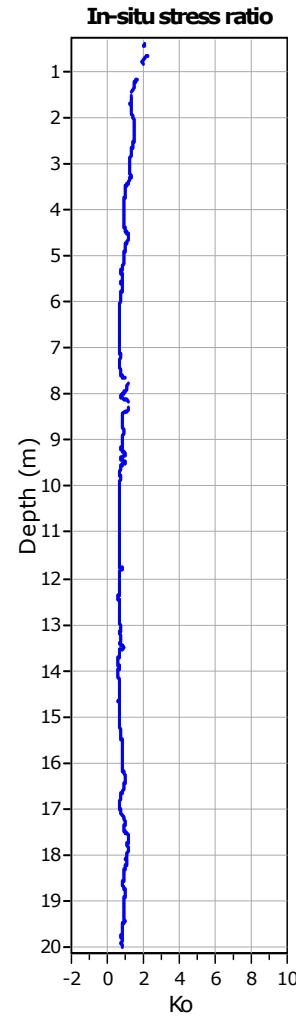
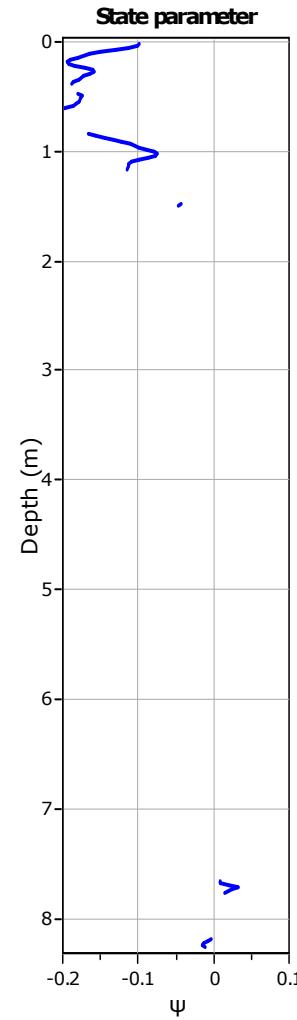
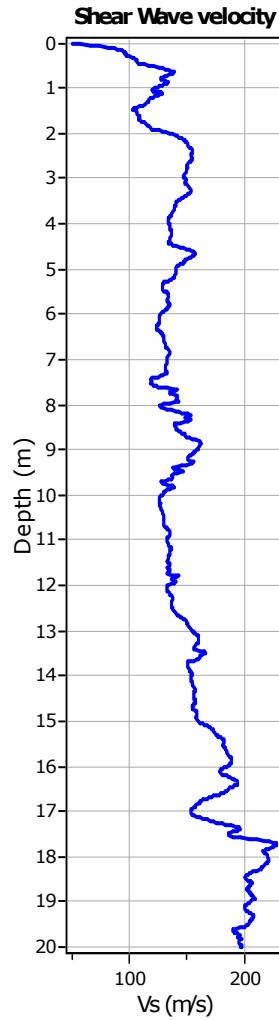
- User defined estimation data
- Flat Dilatometer Test data

Project: Centro Unificato dell'Emergenza sul Territorio

Location: Ferrara

CPT: CPTU 17

Total depth: 20.00 m, Date: 17/05/2018

**Calculation parameters**Soil Sensitivity factor, N_s: 7.00

User defined estimation data

G E O G R O U P s.r.l.

Indagini geognostiche e geofisiche – geologia applicata alle costruzioni – laboratorio geotecnico –
idrogeologia – coltivazione cave – bonifiche – consolidamenti – geologia ambientale – consulenze
geologiche e geotecniche



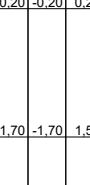
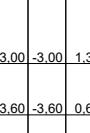
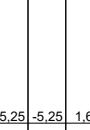
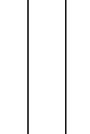
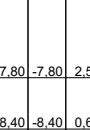
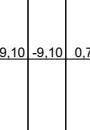
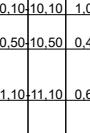
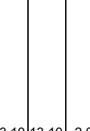
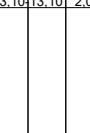
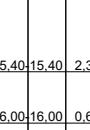
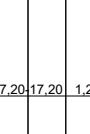
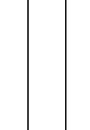
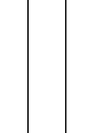
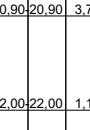
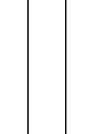
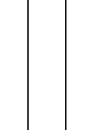
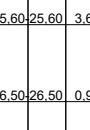
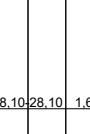
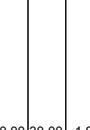
ALLEGATO 2

SONDAGGIO A CAROTAGGIO CONTINUO

Committente: Centro Unificato Reg. dell'Emergenza sul Territorio della Protezione Civile	Sondaggio: S1
Riferimento: 218/18	Data: 26-27/04/2018
Coordinate:	Quota: piano campagna
Perforazione: Sondaggio a carotaggio continuo	

GEO GROUP srl

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email : geo.group@libero.it

metri batt.	LITOLOGIA	prof. m	Quota m	Spess. m	DESCRIZIONE	Campioni	RP	S.P.T.			
								VT	m	S.P.T.	
1		0.20	-0.20	0.20	Terreno vegetale Limo e limo argilloso, con orizzonti argillosi, colore da marrone chiaro a nocciola, mediamente consistente e plastico		4.2 4 2.3 2.1 1.3 2.5 2.5 2.5 2.1 2.2 2.1	0.9 17.5 0.6 0.3 0.9 0.7 0.7 0.8 0.8 1.1			
2		1.70	-1.70	1.50	Argilla e argilla debolmente limosa di colore nocciola, con striature grigie, mediamente consistente						
3		3.00	-3.00	1.30	Shelby C1	1) She < 3,00 3,60					
4		3.60	-3.60	0.60	Argilla e argilla debolmente limosa, di colore da grigio-marrone a grigio-nera, con intercalazioni torbose, da poco consistente a mediamente consistente		0.9 1.1 1.1 1.1 1.1 1.1	0.4 0.4 0.5 0.6 0.6 0.5			
5		5.25	-5.25	1.65			1.4 1.1 1.5	0.4 0.4 0.4			
6					Da argilla debolmente limosa a argilla limosa, colore da grigio-azzurra a grigia, con striature nocciola, da poco consistente a mediamente consistente; intercalazione di limo e/o limo debolmente argilloso di colore nocciola, molle e plastico, tra 6.00÷6.40 m		1.8 1.1 1.6	0.4 0.3 0.3			
7							1.5	0.4			
8		7.80	-7.80	2.55	Limo e limo debolmente argilloso, colore grigio, molle e plastico	2) She < 8,40 9,10					
9		8.40	-8.40	0.60	Shelby C2						
10		9.10	-9.10	0.70	Limo e limo debolmente argilloso, colore grigio, molle e plastico						
11		10.10	-10.10	1.00	Sabbia argillosa, fine, colore grigio e grigio-nocciola, mediamente addensata	3) She < 10,50 11,10					
12		10.50	-10.50	0.40	Shelby C3						
13		11.10	-11.10	0.60	Da sabbia limosa a sabbia debolmente limosa, da fine a medio-fine, colore grigio, poco addensata						
14		13.10	-13.10	2.00			1.2	0.4			
15		15.40	-15.40	2.30	Argilla e argilla debolmente limosa, di colore da grigio-marrone a grigio-nera, con intercalazioni torbose, da poco consistente a mediamente consistente		1.0 1.8 1.7 1.5 1.1	0.5 0.7 0.6 0.6 15.3			
16		16.00	-16.00	0.60	Shelby C4	4) She < 15,30 16,00	1.7	0.6			
17		17.20	-17.20	1.20	Sabbia limosa di colore grigio, poco addensata						
18					Da argilla a argilla debolmente limosa di colore grigio, con striature nocciola, mediamente consistente e plastica		2.8	1.2			
19							1.1 2.7 2.7 3.0	0.5 1.1 1.1 1.2			
20							2.7 2.2 2.5 3	1.0 0.9 1.1			
21		20.90	-20.90	3.70	Da argilla limosa e limo argilloso di colore grigio-marrone, da poco consistente a molle e plastico		2.3 1.5 1.6 2.2 1.6 1.2 0.5 0.5 0.9 1	0.8 1.2 0.9 0.7 0.7 1.2 0.5 0.2 0.4 0.3			
22		22.00	-22.00	1.10	Da sabbia argillosa a sabbia limosa, da fine a media, di colore grigio, da mediamente addensata a sciolta; livello di sabbia debolmente limosa, medio-fine, sciolta tra 23,40÷24,00 m		1.4 0.6	0.3 0.1			
23							0.7	1.8			
24											
25		25.60	-25.60	3.60	Argilla, colore da grigio-scuro a grigio-nero, consistente		0.5 1.1 0.9	1 0.9 1			
26		26.50	-26.50	0.90			2.5 1.3 1.8 2	0.85 1 0.5			
27					Limo e limo argilloso, di colore grigio, con orizzonti argillosi, da poco consistente a mediamente consistente		0.7	0.5			
28		28.10	-28.10	1.60			1.1 1.1 2.1 1	0.4 0.8 0.4 0.5			
29					Argilla e argilla debolmente limosa, di colore grigio, con abbondanti striature nocciola, da mediamente consistente a molto consistente, con intercalazioni di limo argilloso molle e plastico (tra 28,70÷29,00 m)		0.9 1.3 3 3 0.4 0.4 0.5 2.1	0.5 0.4 1.2 1.2 0.3 0.2 0.2 1			
30		30.00	-30.00	1.90			1.2 2.7 3.4	1.2 1.2 1.2			

PROVA PENETROMETRICA DINAMICA

Committente:	
Cantiere:	
Località:	

Caratteristiche Tecniche-Strumentali Sonda: CAMPIONATORE RAYMOND FORO

Rif. Norme	DIN 4094
Peso Massa battente	63.5 Kg
Altezza di caduta libera	0.76 m
Peso sistema di battuta	4.2 Kg
Diametro punta conica	50.46 mm
Area di base punta	20 cm ²
Lunghezza delle aste	1 m
Peso aste a metro	10 Kg/m
Profondità giunzione prima asta	0.99 m
Avanzamento punta	0.30 m
Numero colpi per punta	N(30)
Coeff. Correlazione	0.926
Rivestimento/fanghi	No

PROVE PENETROMETRICHE DINAMICHE CONTINUE (DYNAMIC PROBING) DPSH – DPM (... scpt ecc.)

Note illustrative - Diverse tipologie di penetrometri dinamici

La prova penetrometrica dinamica consiste nell'infiggere nel terreno una punta conica (per tratti consecutivi δ) misurando il numero di colpi N necessari.

Le Prove Penetrometriche Dinamiche sono molto diffuse ed utilizzate nel territorio da geologi e geotecnici, data la loro semplicità esecutiva, economicità e rapidità di esecuzione.

La loro elaborazione, interpretazione e visualizzazione grafica consente di "catalogare e parametrizzare" il suolo attraversato con un'immagine in continuo, che permette anche di avere un raffronto sulle consistenze dei vari livelli attraversati e una correlazione diretta con sondaggi geognostici per la caratterizzazione stratigrafica.

La sonda penetrometrica permette inoltre di riconoscere abbastanza precisamente lo spessore delle coltri sul substrato, la quota di eventuali falde e superfici di rottura sui pendii, e la consistenza in generale del terreno.

L'utilizzo dei dati, ricavati da correlazioni indirette e facendo riferimento a vari autori, dovrà comunque essere trattato con le opportune cautele e, possibilmente, dopo esperienze geologiche acquisite in zona.

Elementi caratteristici del penetrometro dinamico sono i seguenti:

- peso massa battente M
- altezza libera caduta H
- punta conica: diametro base cono D, area base A (angolo di apertura α)
- avanzamento (penetrazione) δ
- presenza o meno del rivestimento esterno (fanghi bentonitici).

Con riferimento alla classificazione ISSMFE (1988) dei diversi tipi di penetrometri dinamici (vedi tabella sotto riportata) si rileva una prima suddivisione in quattro classi (in base al peso M della massa battente) :

- tipo LEGGERO (DPL)
- tipo MEDIO (DPM)
- tipo PESANTE (DPH)
- tipo SUPERPESANTE (DPSH)

Classificazione ISSMFE dei penetrometri dinamici:

Tipo	Sigla di riferimento	peso della massa M (kg)	prof.max indagine battente (m)
Leggero	DPL (Light)	$M \leq 10$	8
Medio	DPM (Medium)	$10 < M < 40$	20-25
Pesante	DPH (Heavy)	$40 \leq M < 60$	25
Super pesante (Super Heavy)	DPSH	$M \geq 60$	25

penetrometri in uso in Italia

In Italia risultano attualmente in uso i seguenti tipi di penetrometri dinamici (non rientranti però nello Standard ISSMFE):

- DINAMICO LEGGERO ITALIANO (DL-30) (MEDIO secondo la classifica ISSMFE)
massa battente M = 30 kg, altezza di caduta H = 0.20 m, avanzamento δ = 10 cm, punta conica ($\alpha=60-90^\circ$), diametro D 35.7 mm, area base cono A=10 cm² rivestimento / fango bentonitico : talora previsto;
- DINAMICO LEGGERO ITALIANO (DL-20) (MEDIO secondo la classifica ISSMFE)
massa battente M = 20 kg, altezza di caduta H=0.20 m, avanzamento δ = 10 cm, punta conica ($\alpha= 60-90^\circ$), diametro D 35.7 mm, area base cono A=10 cm² rivestimento / fango bentonitico : talora previsto;
- DINAMICO PESANTE ITALIANO (SUPERPESANTE secondo la classifica ISSMFE)
massa battente M = 73 kg, altezza di caduta H=0.75 m, avanzamento δ =30 cm, punta conica ($\alpha = 60^\circ$), diametro D = 50.8 mm, area base cono A=20.27 cm² rivestimento: previsto secondo precise indicazioni;
- DINAMICO SUPERPESANTE (Tipo EMILIA)
massa battente M=63.5 kg, altezza caduta H=0.75 m, avanzamento δ =20-30 cm, punta conica conica ($\alpha = 60^\circ-90^\circ$) diametro D = 50.5 mm, area base cono A = 20 cm², rivestimento / fango bentonitico : talora previsto.

Correlazione con Nspt

Poiché la prova penetrometrica standard (SPT) rappresenta, ad oggi, uno dei mezzi più diffusi ed economici per ricavare informazioni dal sottosuolo, la maggior parte delle correlazioni esistenti riguardano i valori del numero di colpi Nspt ottenuto con

la suddetta prova, pertanto si presenta la necessità di rapportare il numero di colpi di una prova dinamica con Nspt. Il passaggio viene dato da:

$$Nspt = \beta_t N$$

Dove:

$$\beta_t = \frac{Q}{Q_{SPT}}$$

in cui Q è l'energia specifica per colpo e Qspt è quella riferita alla prova SPT.

L'energia specifica per colpo viene calcolata come segue:

$$Q = \frac{M^2 \cdot H}{A \cdot \delta \cdot (M + M')}$$

in cui

M = peso massa battente;

M' = peso aste;

H = altezza di caduta;

A = area base punta conica;

δ = passo di avanzamento.

Valutazione resistenza dinamica alla punta Rpd

Formula Olandesi

$$Rpd = \frac{M^2 \cdot H}{[A \cdot e \cdot (M + P)]} = \frac{M^2 \cdot H \cdot N}{[A \cdot \delta \cdot (M + P)]}$$

Rpd = resistenza dinamica punta (area A);

e = infissione media per colpo (δ / N);

M = peso massa battente (altezza caduta H);

P = peso totale aste e sistema battuta.

Metodologia di Elaborazione.

Le elaborazioni sono state effettuate mediante un programma di calcolo automatico Dynamic Probing della *GeoStru Software*.

Il programma calcola il rapporto delle energie trasmesse (coefficiente di correlazione con SPT) tramite le elaborazioni proposte da Pasqualini 1983 - Meyerhof 1956 - Desai 1968 - Borowczyk-Frankowsky 1981.

Permette inoltre di utilizzare i dati ottenuti dall'effettuazione di prove penetrometriche per estrapolare utili informazioni geotecniche e geologiche.

Una vasta esperienza acquisita, unitamente ad una buona interpretazione e correlazione, permettono spesso di ottenere dati utili alla progettazione e frequentemente dati maggiormente attendibili di tanti dati bibliografici sulle litologie e di dati geotecnici determinati sulle verticali litologiche da poche prove di laboratorio eseguite come rappresentazione generale di una verticale eterogenea disuniforme e/o complessa.

In particolare consente di ottenere informazioni su:

- l'andamento verticale e orizzontale degli intervalli stratigrafici,
- la caratterizzazione litologica delle unità stratigrafiche,
- i parametri geotecnici suggeriti da vari autori in funzione dei valori del numero dei colpi e delle resistenza alla punta.

Valutazioni statistiche e correlazioni

Elaborazione Statistica

Permette l'elaborazione statistica dei dati numerici di Dynamic Probing, utilizzando nel calcolo dei valori rappresentativi dello strato considerato un valore inferiore o maggiore della media aritmetica dello strato (dato comunque maggiormente utilizzato); i valori possibili in immissione sono :

Media

Media aritmetica dei valori del numero di colpi sullo strato considerato.

Media minima

Valore statistico inferiore alla media aritmetica dei valori del numero di colpi sullo strato considerato.

Massimo

Valore massimo dei valori del numero di colpi sullo strato considerato.

Minimo

Valore minimo dei valori del numero di colpi sullo strato considerato.

Scarto quadratico medio

Valore statistico di scarto dei valori del numero di colpi sullo strato considerato.

Media deviata

Valore statistico di media deviata dei valori del numero di colpi sullo strato considerato.

Media + s

Media + scarto (valore statistico) dei valori del numero di colpi sullo strato considerato.

Media - s

Media - scarto (valore statistico) dei valori del numero di colpi sullo strato considerato.

Distribuzione normale R.C.

Il valore di Nspt,k viene calcolato sulla base di una distribuzione normale o gaussiana, fissata una probabilità di non superamento del 5%, secondo la seguente relazione:

$$Nspt_{,k} = Nspt_{,medio} - 1.645 \cdot (\sigma_{Nspt})$$

dove sNspt è la deviazione standard di Nspt

Distribuzione normale R.N.C.

Il valore di Nspt,k viene calcolato sulla base di una distribuzione normale o gaussiana, fissata una probabilità di non superamento del 5%, trattando i valori medi di Nspt distribuiti normalmente:

$$Nspt_{,k} = Nspt_{,medio} - 1.645 \cdot (\sigma_{Nspt}) / \sqrt{n}$$

dove n è il numero di letture.

Pressione ammissibile

Pressione ammissibile specifica sull'interstrato (con effetto di riduzione energia per svergolamento aste o no) calcolata secondo le note elaborazioni proposte da Herminier, applicando un coefficiente di sicurezza (generalmente = 20-22) che corrisponde ad un coefficiente di sicurezza standard delle fondazioni pari a 4, con una geometria fondale standard di larghezza pari a 1 mt. ed immorsamento d = 1 mt..

Correlazioni geotecniche terreni incoerenti

Liquefazione

Permette di calcolare utilizzando dati Nspt il potenziale di liquefazione dei suoli (prevolentemente sabbiosi).

Attraverso la relazione di SHI-MING (1982), applicabile a terreni sabbiosi, la liquefazione risulta possibile solamente se Nspt dello strato considerato risulta inferiore a Nspt critico calcolato con l'elaborazione di SHI-MING.

Correzione Nspt in presenza di falda

Nspt corretto = $15 + 0.5 \times (Nspt - 15)$

Nspt è il valore medio nello strato

La correzione viene applicata in presenza di falda solo se il numero di colpi è maggiore di 15 (la correzione viene eseguita se tutto lo strato è in falda) .

Angolo di Attrito

- Peck-Hanson-Thornburn-Meyerhof 1956 - Correlazione valida per terreni non molli a prof. < 5 mt.; correlazione valida per sabbie e ghiaie rappresenta valori medi. - Correlazione storica molto usata, valevole per prof. < 5 mt. per terreni sopra falda e < 8 mt. per terreni in falda (tensioni < 8-10 t/mq)
- Meyerhof 1956 - Correlazioni valide per terreni argilosì ed argilosì-marnosi fessurati, terreni di riporto sciolti e coltri detritiche (da modifica sperimentale di dati).
- Sowers 1961)- Angolo di attrito in gradi valido per sabbie in genere (cond. ottimali per prof. < 4 mt. sopra falda e < 7 mt. per terreni in falda) $\sigma > 5$ t/mq.
- De Mello - Correlazione valida per terreni prevalentemente sabbiosi e sabbioso-ghiaiosi (da modifica sperimentale di dati) con angolo di attrito < 38° .
- Malcev 1964 - Angolo di attrito in gradi valido per sabbie in genere (cond. ottimali per prof. > 2 m. e per valori di angolo di attrito < 38°).
- Schmertmann 1977- Angolo di attrito (gradi) per vari tipi litologici (valori massimi). N.B. valori spesso troppo ottimistici poiché desunti da correlazioni indirette da Dr %.
- Shioi-Fukuni 1982 (ROAD BRIDGE SPECIFICATION) Angolo di attrito in gradi valido per sabbie - sabbie fini o limose e limi siltosi (cond. ottimali per prof. di prova > 8 mt. sopra falda e > 15 mt. per terreni in falda) $\sigma > 15$ t/mq.
- Shioi-Fukuni 1982 (JAPANESE NATIONALE RAILWAY) Angolo di attrito valido per sabbie medie e grossolane fino a ghiaiose .
- Angolo di attrito in gradi (Owasaki & Iwasaki) valido per sabbie - sabbie medie e grossolane-ghiaiose (cond. ottimali per prof. > 8 mt. sopra falda e > 15 mt. per terreni in falda) $s > 15$ t/mq.
- Meyerhof 1965 - Correlazione valida per terreni per sabbie con % di limo < 5% a profondità < 5 mt. e con % di limo > 5% a profondità < 3 mt.
- Mitchell e Katti (1965) - Correlazione valida per sabbie e ghiaie.

Densità relativa (%)

- Gibbs & Holtz (1957) correlazione valida per qualunque pressione efficace, per ghiaie Dr viene sovrastimato, per limi sottostimato.
- Skempton (1986) elaborazione valida per limi e sabbie e sabbie da fini a grossolane NC a qualunque pressione efficace, per ghiaie il valore di Dr % viene sovrastimato, per limi sottostimato.
- Meyerhof (1957).
- Schultze & Menzenbach (1961) per sabbie fini e ghiaiose NC , metodo valido per qualunque valore di pressione efficace in depositi NC, per ghiaie il valore di Dr % viene sovrastimato, per limi sottostimato.

Modulo Di Young (E_y)

- Terzaghi - elaborazione valida per sabbia pulita e sabbia con ghiaia senza considerare la pressione efficace.
- Schmertmann (1978), correlazione valida per vari tipi litologici .
- Schultze-Menzenbach , correlazione valida per vari tipi litologici.
- D'Appollonia ed altri (1970) , correlazione valida per sabbia, sabbia SC, sabbia NC e ghiaia
- Bowles (1982), correlazione valida per sabbia argillosa, sabbia limosa, limo sabbioso, sabbia media, sabbia e ghiaia.

Modulo Edometrico

- Begemann (1974) elaborazione desunta da esperienze in Grecia, correlazione valida per limo con sabbia, sabbia e ghiaia
- Buismann-Sanglerat , correlazione valida per sabbia e sabbia argillosa.
- Farrent (1963) valida per sabbie, talora anche per sabbie con ghiaia (da modifica sperimentale di dati).
- Menzenbach e Malcev valida per sabbia fine, sabbia ghiaiosa e sabbia e ghiaia.

Stato di consistenza

- Classificazione A.G.I. 1977

Peso di Volume Gamma

- Meyerhof ed altri, valida per sabbie, ghiaie, limo, limo sabbioso.

Peso di volume saturo

- Terzaghi-Peck 1948-1967

Modulo di poisson

- Classificazione A.G.I.

Potenziale di liquefazione (Stress Ratio)

- Seed-Idriss 1978-1981 . Tale correlazione è valida solamente per sabbie, ghiaie e limi sabbiosi, rappresenta il rapporto tra lo sforzo dinamico medio τ e la tensione verticale di consolidazione per la valutazione del potenziale di liquefazione delle sabbie e terreni sabbio-ghiaiosi attraverso grafici degli autori.

Velocità onde di taglio Vs (m/sec)

- Tale correlazione è valida solamente per terreni incoerenti sabbiosi e ghiaiosi.

Modulo di deformazione di taglio (G)

- Ohsaki & Iwasaki – elaborazione valida per sabbie con fine plastico e sabbie pulite.
- Robertson e Campanella (1983) e Imai & Tonouchi (1982) elaborazione valida soprattutto per sabbie e per tensioni litostatiche comprese tra 0,5 - 4,0 kg/cmq.

Modulo di reazione (K_o)

- Navfac 1971-1982 - elaborazione valida per sabbie, ghiaie, limo, limo sabbioso .

Resistenza alla punta del Penetrometro Statico (Q_c)

- Robertson 1983 Q_c

Correlazioni geotecniche terreni coesivi

Coesione non drenata

- Benassi & Vannelli- correlazioni scaturite da esperienze ditta costruttrice Penetrometri SUNDA 1983.
- Terzaghi-Peck (1948-1967), correlazione valida per argille sabbiose-siltose NC con Nspt <8 , argille limose-siltose mediamente plastiche, argille marnose alterate-fessurate.
- Terzaghi-Peck (1948). Cu min-max.
- Sanglerat , da dati Penetr. Statico per terreni coesivi saturi , tale correlazione non è valida per argille sensitive con sensitività > 5, per argille sovraconsolidate fessurate e per i limi a bassa plasticità.
- Sanglerat , (per argille limose-sabbiose poco coerenti), valori validi per resistenze penetrometriche < 10 colpi, per resistenze penetrometriche > 10 l'elaborazione valida è comunque quella delle "argille plastiche " di Sanglerat.
- (U.S.D.M.S.M.) U.S. Design Manual Soil Mechanics Coesione non drenata per argille limose e argille di bassa media ed alta plasticità , (Cu-Nspt- grado di plasticità).
- Schmertmann 1975 Cu (Kg/cmq) (valori medi), valida per **argille e limi argillosi** con Nc=20 e Qc/Nspt=2.
- Schmertmann 1975 Cu (Kg/cmq) (valori minimi), valida per argille NC .
- Fletcher 1965 - (Argilla di Chicago) . Coesione non drenata Cu (Kg/cmq), colonna valori validi per argille a medio-bassa plasticità .
- Houston (1960) - argilla di media-alta plasticità.
- Shioi-Fukuni 1982 , valida per suoli poco coerenti e plastici, argilla di media-alta plasticità.
- Begemann.
- De Beer.

Resistenza alla punta del Penetrometro Statico (Q_c)

- Robertson 1983 Q_c

Modulo Edometrico-Confinato (M_o)

- Stroud e Butler (1975) - per litotipi a media plasticità, valida per litotipi argillosi a media-medio-alta plasticità - da esperienze su argille glaciali.
- Stroud e Butler (1975), per litotipi a medio-bassa plasticità (IP< 20), valida per litotipi argillosi a medio-bassa plasticità (IP< 20) - da esperienze su argille glaciali .
- Vesic (1970) correlazione valida per argille molli (valori minimi e massimi).
- Trofimenkov (1974), Mitchell e Gardner Modulo Confinato -M_o (Eed) (Kg/cmq)-, valida per litotipi argillosi e limosi-argilosì (rapporto Qc/Nspt=1.5-2.0).

- Buismann- Sanglerat, valida per argille compatte (Nspt <30) medie e molli (Nspt <4) e argille sabbiose (Nspt=6-12).

Modulo Di Young (E_Y)

- Schultze-Menzenbach - (Min. e Max.), correlazione valida per limi coerenti e limi argilosì con I.P. >15
- D'Appollonia ed altri (1983) - correlazione valida per argille sature-argille fessurate.

Stato di consistenza

- Classificazione A.G.I. 1977

Peso di Volume

- Meyerhof ed altri, valida per argille, argille sabbiose e limose prevalentemente coerenti.

Peso di volume saturo

- Meyerhof ed altri.

PROVA ... Nr.1

Strumento utilizzato... CAMPIONATORE RAYMOND FORO
Prova eseguita in data 26/04/2018
Falda rilevata

Tipo elaborazione Nr. Colpi: Massimo

Profondità (m)	Nr. Colpi
9.15	1
9.30	5
9.45	10

STIMA PARAMETRI GEOTECNICI PROVA Nr.1

TERRENI COESIVI

Coesione non drenata (Kg/cm²)

	Nspt	Prof. Strato (m)	Terzaghi-Peck	Sanglerat	Terzaghi-Peck (1948)	U.S.D.M. S.M	Schmertmann 1975	SUNDA (1983) Benassi e Vannelli	Fletcher (1965) Argilla di Chicago	Houston (1960)	Shioi - Fukui 1982	Begeman	De Beer
[1] -	13.89	9.45	0.94	1.74	0.50	0.55	1.37	0.00	1.21	1.53	0.70	1.10	1.74

Modulo Edometrico (Kg/cm²)

	Nspt	Prof. Strato (m)	Stroud e Butler (1975)	Vesic (1970)	Trofimenkov (1974), Mitchell e Gardner	Buisman-Sanglerat
[1] -	13.89	9.45	63.73	--	143.46	138.90

Modulo di Young (Kg/cm²)

	Nspt	Prof. Strato (m)	Schultze	Apollonia
[1] -	13.89	9.45	139.34	138.90

Peso unità di volume

	Nspt	Prof. Strato (m)	Correlazione	Peso unità di volume (t/m ³)
[1] -	13.89	9.45	Meyerhof ed altri	2.05

Peso unità di volume saturo

	Nspt	Prof. Strato (m)	Correlazione	Peso unità di volume saturo (t/m ³)
[1] -	13.89	9.45	Meyerhof ed altri	2.25

Velocità onde di taglio

	Nspt	Prof. Strato (m)	Correlazione	Velocità onde di taglio (m/s)
[1] -	13.89	9.45		0

TERRENI INCOERENTI

Densità relativa

	Nspt	Prof. Strato (m)	Gibbs & Holtz 1957	Meyerhof 1957	Schultze & Menzenbach (1961)	Skempton 1986
[1] -	13.89	9.45	35.28	66.37	66.34	40.96

Angolo di resistenza al taglio

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Peck-Hanson-Thornburn-Meyerhoff 1956	Sowers (1961)	Malcev (1964)	Meyerhoff (1965)	Schmertmann (1977) Sabbie	Mitchell & Katti (1981)	Shioi-Fukuni 1982 (ROAD BRIDGE SPECIFICATION)	Japanese National Railway	De Mello	Owasaki & Iwasaki	
[1] -	13.89	9.45	13.89	30.97	23.97	31.89	30.07	35.09	37.29	30-32	29.43	31.17	39.35	31.67

Modulo di Young (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Terzaghi	Schmertmann (1978) (Sabbie)	Schultze-Menzenbach (Sabbia ghiaiosa)	D'Appollonia ed altri 1970 (Sabbia)	Bowles (1982) Sabbia Media
[1] -	13.89	9.45	13.89	266.02	111.12	164.60	284.17	144.45

Modulo Edometrico (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Buisman-Sanglerat (sabbie)	Begemann 1974 (Ghiaia con sabbia)	Farrent 1963	Menzenbach e Malcev (Sabbia media)
[1] -	13.89	9.45	13.89	83.34	56.00	98.62	99.95

Classificazione AGI

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Classificazione AGI
[1] -	13.89	9.45	13.89	Classificazione A.G.I. 1977	MODERATAMENTE ADDENSATO

Peso unità di volume

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Gamma (t/m ³)
[1] -	13.89	9.45	13.89	Meyerhof ed altri	1.85

Peso unità di volume satura

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Gamma Sastro (t/m ³)
[1] -	13.89	9.45	13.89	Terzaghi-Peck 1948-1967	1.94

Modulo di Poisson

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Poisson
[1] -	13.89	9.45	13.89	(A.G.I.)	0.33

Modulo di deformazione a taglio dinamico (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Ohsaki (Sabbie pulite)	Robertson e Campanella (1983) e Imai & Tonouchi (1982)
[1] -	13.89	9.45	13.89	771.00	623.88

Velocità onde di taglio

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Velocità onde di taglio (m/s)
[1] -	13.89	9.45	13.89	Ohta & Goto (1978) Limi	145.54

Modulo di reazione Ko

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Ko
[1] -	13.89	9.45	13.89		---

Qc (Resistenza punta Penetrometro Statico)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Qc (Kg/cm ²)
[1] -	13.89	9.45	13.89		---

PROVA ... Nr.2

Strumento utilizzato...
 Prova eseguita in data
 Falda rilevata

CAMPIONATORE RAYMOND FORO

26/04/2018

Tipo elaborazione Nr. Colpi: Massimo

Profondità (m)	Nr. Colpi
11.25	7
11.40	12
11.55	15

STIMA PARAMETRI GEOTECNICI PROVA Nr.2**TERRENI COESIVI****Coesione non drenata (Kg/cm²)**

	Nspt	Prof. Strato (m)	Terzaghi-Peck	Sanglerat	Terzaghi-Peck (1948)	U.S.D.M. S.M.	Schmertmann 1975	SUNDA (1983) Benassi e Vannelli	Fletcher (1965) Argilla di Chicago	Houston (1960)	Shioi - Fukui 1982	Begeman	De Beer
[1] -	25.002	11.55	1.69	3.13	1.00	0.95	2.48	0.00	2.07	2.57	1.25	2.72	3.13

Modulo Edometrico (Kg/cm²)

	Nspt	Prof. Strato (m)	Stroud e Butler (1975)	Vesic (1970)	Trofimenkov (1974), Mitchell e Gardner	Buisman-Sanglerat
[1] -	25.002	11.55	114.71	--	256.80	250.02

Modulo di Young (Kg/cm²)

	Nspt	Prof. Strato (m)	Schultze	Apollonia
[1] -	25.002	11.55	267.12	250.02

Peso unità di volume

	Nspt	Prof. Strato (m)	Correlazione	Peso unità di volume (t/m ³)
[1] -	25.002	11.55	Meyerhof ed altri	2.12

Peso unità di volume satura

	Nspt	Prof. Strato (m)	Correlazione	Peso unità di volume satura (t/m ³)
[1] -	25.002	11.55	Meyerhof ed altri	2.22

Velocità onde di taglio

	Nspt	Prof. Strato (m)	Correlazione	Velocità onde di taglio (m/s)
[1] -	25.002	11.55		0

TERRENI INCOERENTI**Densità relativa**

	Nspt	Prof. Strato (m)	Gibbs & Holtz 1957	Meyerhof 1957	Schultze & Menzenbach (1961)	Skempton 1986
[1] -	25.002	11.55	40.37	74.43	73.84	51.23

Angolo di resistenza al taglio

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Peck-Hanson-Thornburn-Meyerhoff 1956	Sowers (1961)	Malcev (1964)	Meyerhof (1965)	Schmertmann (1977) Sabbie	Mitchell & Katti (1981)	Shioi-Fukuni (ROAD BRIDGE SPECIFICATION)	Japanese National Railway	De Mello	Owasaki & Iwasaki	
[1] -	25.002	11.55	20.001	32.71	25.71	33.6	30.1	37.07	38.42	30-32	32.32	33	41.76	35

Modulo di Young (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Terzaghi	Schmertmann (1978) (Sabbie)	Schultze-Menzelbach (Sabbia ghiaiosa)	D'Appollonia ed altri 1970 (Sabbia)	Bowles (1982) Sabbia Media
[1] -	25.002	11.55	20.001	319.22	160.01	236.71	330.01	175.01

Modulo Edometrico (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Buisman-Sanglerat (sabbie)	Begemann 1974 (Ghiaia con sabbia)	Farrent 1963	Menzenbach e Malcev (Sabbia media)
[1] -	25.002	11.55	20.001	120.01	68.55	142.01	127.20

Classificazione AGI

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Classificazione AGI
[1] -	25.002	11.55	20.001	Classificazione A.G.I.	MODERATAMENTE ADDENSATO

Peso unità di volume

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Gamma (t/m ³)
[1] -	25.002	11.55	20.001	Meyerhof ed altri	1.99

Peso unità di volume saturo

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Gamma Saturo (t/m ³)
[1] -	25.002	11.55	20.001	Terzaghi-Peck 1948-1967	2.39

Modulo di Poisson

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Poisson
[1] -	25.002	11.55	20.001	(A.G.I.)	0.31

Modulo di deformazione a taglio dinamico (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Ohsaki (Sabbie pulite)	Robertson e Campanella (1983) e Imai & Tonouchi (1982)
[1] -	25.002	11.55	20.001	1086.18	779.57

Velocità onde di taglio

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Velocità onde di taglio (m/s)
[1] -	25.002	11.55	20.001	Ohta & Goto (1978) Limi	161.13

Modulo di reazione Ko

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Ko
[1] -	25.002	11.55	20.001		---

Qc (Resistenza punta Penetrometro Statico)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Qc (Kg/cm ²)
[1] -	25.002	11.55	20.001		---

PROVA ... Nr.3

Strumento utilizzato...
 Prova eseguita in data
 Falda rilevata

CAMPIONATORE RAYMOND FORO
 26/04/2018

Tipo elaborazione Nr. Colpi: Massimo

Profondità (m)	Nr. Colpi
11.75	10
11.90	13

STIMA PARAMETRI GEOTECNICI PROVA Nr.3**TERRENI COESIVI****Coesione non drenata (Kg/cm²)**

	Nspt	Prof. Strato (m)	Terzaghi-Peck	Sanglerat	Terzaghi-Peck (1948)	U.S.D.M. S.M	Schmertmann 1975	SUNDA (1983) Benassi e Vannelli	Fletcher (1965) Argilla di Chicago	Houston (1960)	Shioi - Fukui 1982	Begeman	De Beer
[1] -	28.706	12.05	1.94	3.59	1.00	1.08	2.85	0.00	2.34	2.95	1.44	3.28	3.59

Modulo Edometrico (Kg/cm²)

	Nspt	Prof. Strato (m)	Stroud e Butler (1975)	Vesic (1970)	Trofimenkov (1974), Mitchell e Gardner	Buisman-Sanglerat
[1] -	28.706	12.05	131.70	--	294.58	287.06

Modulo di Young (Kg/cm²)

	Nspt	Prof. Strato (m)	Schultze	Apollonia
[1] -	28.706	12.05	309.72	287.06

Peso unità di volume

	Nspt	Prof. Strato (m)	Correlazione	Peso unità di volume (t/m ³)
[1] -	28.706	12.05	Meyerhof ed altri	2.15

Peso unità di volume satura

	Nspt	Prof. Strato (m)	Correlazione	Peso unità di volume satura (t/m ³)
[1] -	28.706	12.05	Meyerhof ed altri	2.33

Velocità onde di taglio

	Nspt	Prof. Strato (m)	Correlazione	Velocità onde di taglio (m/s)
[1] -	28.706	12.05		0

TERRENI INCOERENTI**Densità relativa**

	Nspt	Prof. Strato (m)	Gibbs & Holtz 1957	Meyerhof 1957	Schultze & Menzenbach (1961)	Skempton 1986
[1] -	28.706	12.05	41.54	76.37	75.72	53.88

Angolo di resistenza al taglio

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Peck-Hanson-Thornburn-Meyerhoff 1956	Sowers (1961)	Malcev (1964)	Meyerhof (1965)	Schmertmann (1977) Sabbie	Mitchell & Katti (1981)	Shioi-Fukuni 1982 (ROAD BRIDGE SPECIFICATION)	Japanese National Railway	De Mello	Owasaki & Iwasaki	
[1] -	28.706	12.05	21.853	33.24	26.24	34.12	30.1	37.61	38.69	30-32	33.11	33.56	42.31	35.91

Modulo di Young (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Terzaghi	Schmertmann (1978) (Sabbie)	Schultze-Menzenbach (Sabbia ghiaiosa)	D'Appollonia ed altri 1970 (Sabbia)	Bowles (1982) Sabbia Media
[1] -	28.706	12.05	21.853	333.68	174.82	258.57	343.90	184.26

Modulo Edometrico (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Buisman-Sanglerat (sabbie)	Begemann 1974 (Ghiaia con sabbia)	Farrent 1963	Menzenbach e Malcev (Sabbia media)
[1] -	28.706	12.05	21.853	131.12	72.35	155.16	135.46

Classificazione AGI

	Nspt	Prof. Strato	Nspt corretto per	Correlazione	Classificazione AGI
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		(m)	presenza falda		
[1] -	28.706	12.05	21.853	Classificazione A.G.I. 1977	MODERATAMENTE ADDENSATO

Peso unità di volume

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Gamma (t/m ³)
[1] -	28.706	12.05	21.853	Meyerhof ed altri	2.03

Peso unità di volume satura

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Gamma Satura (t/m ³)
[1] -	28.706	12.05	21.853	Terzaghi-Peck 1948-1967	2.44

Modulo di Poisson

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Poisson
[1] -	28.706	12.05	21.853	(A.G.I.)	0.31

Modulo di deformazione a taglio dinamico (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Ohsaki (Sabbie pulite)	Robertson e Campanella (1983) e Imai & Tonouchi (1982)
[1] -	28.706	12.05	21.853	1180.47	822.91

Velocità onde di taglio

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Velocità onde di taglio (m/s)
[1] -	28.706	12.05	21.853	Ohta & Goto (1978) Limi	164.96

Modulo di reazione Ko

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Ko
[1] -	28.706	12.05	21.853		---

Qc (Resistenza punta Penetrometro Statico)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Qc (Kg/cm ²)
[1] -	28.706	12.05	21.853		---

PROVA ... Nr.4

Strumento utilizzato...
Prova eseguita in data
Falda rilevata

CAMPIONATORE RAYMOND FORO
26/04/2018

Tipo elaborazione Nr. Colpi: Massimo

Profondità (m)	Nr. Colpi
12.85	12
13.00	16
13.15	20

STIMA PARAMETRI GEOTECNICI PROVA Nr.4

TERRENI COESIVI

Coesione non drenata (Kg/cm²)

	Nspt	Prof. Strato (m)	Terzaghi- Peck	Sanglerat	Terzaghi- Peck (1948)	U.S.D.M. S.M	Schmertm ann 1975	SUNDA (1983)	Fletcher (1965)	Houston (1960)	Shioi - Fukui 1982	Begeman	De Beer
[1] -	33.336	13.15	2.25	4.17	0.00	1.24	3.32	0.00	2.66	3.45	1.67	3.86	4.17

Modulo Edometrico (Kg/cm²)

	Nspt	Prof. Strato (m)	Stroud e Butler (1975)	Vesic (1970)	Trofimenkov (1974), Mitchell e Gardner	Buisman-Sanglerat

[1] -	33.336	13.15	152.95	--	341.80	333.36
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Modulo di Young (Kg/cm²)

	Nspt	Prof. Strato (m)	Schultze	Apollonia
[1] -	33.336	13.15	362.96	333.36

Peso unità di volume

	Nspt	Prof. Strato (m)	Correlazione	Peso unità di volume (t/m ³)
[1] -	33.336	13.15	Meyerhof ed altri	2.23

Peso unità di volume satura

	Nspt	Prof. Strato (m)	Correlazione	Peso unità di volume satura (t/m ³)
[1] -	33.336	13.15	Meyerhof ed altri	2.48

Velocità onde di taglio

	Nspt	Prof. Strato (m)	Correlazione	Velocità onde di taglio (m/s)
[1] -	33.336	13.15		0

TERRENI INCOERENTI
Densità relativa

	Nspt	Prof. Strato (m)	Gibbs & Holtz 1957	Meyerhof 1957	Schultze & Menzenbach (1961)	Skempton 1986
[1] -	33.336	13.15	41.89	76.9	76.47	56.93

Angolo di resistenza al taglio

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Peck-Hanson-Thornburn-Meyerhoff 1956	Sowers (1961)	Malcev (1964)	Meyerhof (1965)	Schmertmann (1977) Sabbie	Mitchell & Katti (1981)	Shioi-Fukuni 1982 (ROAD BRIDGE SPECIFICATION)	Japanese National Railway	De Mello	Owasaki & Iwasaki	
[1] -	33.336	13.15	24.168	33.91	26.91	34.77	29.95	38.25	38.77	30-32	34.04	34.25	42.62	36.99

Modulo di Young (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Terzaghi	Schmertmann (1978) (Sabbie)	Schultze-Menzenbach (Sabbia ghaiosa)	D'Appollonia ed altri 1970 (Sabbia)	Bowles (1982) Sabbia Media
[1] -	33.336	13.15	24.168	350.91	193.34	285.88	361.26	195.84

Modulo Edometrico (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Buisman-Sanglerat (sabbie)	Begemann 1974 (Ghiaia con sabbia)	Farrent 1963	Menzenbach e Malcev (Sabbia media)
[1] -	33.336	13.15	24.168	145.01	77.11	171.59	145.79

Classificazione AGI

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Classificazione AGI
[1] -	33.336	13.15	24.168	Classificazione A.G.I. 1977	ADDENSATO

Peso unità di volume

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Gamma (t/m ³)
[1] -	33.336	13.15	24.168	Meyerhof ed altri	2.07

Peso unità di volume satura

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Gamma Satura (t/m ³)
[1] -	33.336	13.15	24.168	Terzaghi-Peck 1948-1967	2.48

Modulo di Poisson

	Nspt	Prof. Strato	Nspt corretto per	Correlazione	Poisson
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		(m)	presenza falda		
[1] -	33.336	13.15	24.168	(A.G.I.)	0.31

Modulo di deformazione a taglio dinamico (Kg/cm²)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Ohsaki (Sabbie pulite)	Robertson e Campanella (1983) e Imai & Tonouchi (1982)
[1] -	33.336	13.15	24.168	1297.66	875.12

Velocità onde di taglio

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Velocità onde di taglio (m/s)
[1] -	33.336	13.15	24.168	Ohta & Goto (1978) Limi	170.72

Modulo di reazione Ko

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Ko
[1] -	33.336	13.15	24.168		---

Qc (Resistenza punta Penetrometro Statico)

	Nspt	Prof. Strato (m)	Nspt corretto per presenza falda	Correlazione	Qc (Kg/cm ²)
[1] -	33.336	13.15	24.168		---

G E O G R O U P s.r.l.

Indagini geognostiche e geofisiche – geologia applicata alle costruzioni – laboratorio geotecnico –
idrogeologia – coltivazione cave – bonifiche – consolidamenti – geologia ambientale – consulenze
geologiche e geotecniche



ALLEGATO 3

PROVE DI LABORATORIO GEOTECNICO

laboratorio

**geoTecnico terre - rocce - aggregati - prove cicliche e dinamiche -
prove geotecniche in situ - geochemica ambientale -
proprietà geofisiche - prove non distruttive - misura del Radon**



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I.s.r. di Carbone Andrea & C.



Geotest S.r.l. - Molli (PZ) - Italy has been resulted in compliance with the standard
UNI EN ISO 9001:2008 for the following field of activities: Provision of geotechnical tests -
Classification EA (European co-operation for Accreditation): 35

QUADRO RIASSUNTIVO PROVE GEOTECNICHE DI LABORATORIO

Committente: **GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena**

Cantiere: **Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara**

Verbale n.: **116** del **07/05/2018** Data emissione certificati **21/05/2018**

N° d'ordine	Rif. interno	Sondaggio	Campione	Classe campione (AGI)	Profondità		γ_s	Granulometria				Parametri meccanici		
					da metri	a metri		(%)	(%)	(%)	(%)	(kPa)	(°)	(kPa)
1	256-18	S1	C1	Q5	3,00	3,40	•	•	•	•	•	•	•	59,5
2	257-18	S1	C2	Q5	8,40	8,80	•	•	•	•	•	8,2	27,2	•
3	258-18	S1	C3	Q3	10,50	11,00	•	•	•	•	•	0,4	29,4	•
4	259-18	S1	C4	Q5	15,30	15,85	•	•	•	•	•	•	•	81,6
5	260-18	S1	C5	Q2	6,00	6,30	2,61	0,0	44,1	32,8	23,1	•	•	•
6	261-18	S1	C6	Q2	9,80	10,00	2,62	0,0	11,9	71,7	16,4	•	•	•
7	262-18	S1	C7	Q2	12,30	12,50	2,61	0,0	65,9	18,2	15,9	•	•	•
8	263-18	S1	C8	Q2	16,60	16,80	2,58	0,0	57,4	19,9	22,7	•	•	•
9	264-18	S1	C9	Q2	22,30	22,50	2,59	0,3	80,2	10,5	9,0	•	•	•

γ_s = Peso specifico - G = Ghiaia - S = Sabbia - L = Limo - A = Argilla - C', ϕ' = Coesione e angolo di resistenza al taglio (tensioni efficaci da TRXCIU o Taglio Diretto) - C_u = Coesione non drenata (da TriassialeUU)

IL DIRETTORE DEL LABORATORIO

dott. Carbone Raffaele

laboratorio



geoTecnico terre - rocce - aggregati - prove cicliche e dinamiche - prove geotecniche in situ - geochemica ambientale - prospezioni geofisiche - prove non distruttive - misura del Radon

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DEFINIZIONI ADOTTATE PER LA DESCRIZIONE DEI CAMPIONI

CONSERVAZIONE ED APERTURA DEI CAMPIONI

Dopo il controllo dei dati identificativi, i campioni ricevuti sono stati ricoverati in camera climatica in cui temperatura e umidità relativa vengono mantenute costanti rispettivamente a 20°C e oltre 85 %.

Per ogni campione aperto sono stati rilevati i dati identificativi (sondaggio e numero d'ordine progressivo). Il modulo di prova è stato quindi compilato con data di consegna, data di apertura e con ogni altra informazione disponibile riguardo le modalità di campionamento. Per tutti i campioni in fustella esaminati è stata adottata l'estruzione orizzontale: con un estrusore pneumatico, provvisto di variatore di pressione e di teste intercambiabili in funzione del diametro interno del carotiere, il campione è stato estratto in una singola corsa e depositato su un banco posto allo stesso livello del bordo della fustella; dopo una cauta scorticazione del terreno per liberarlo dal velo costituito dal fango di perforazione è stata ottenuta una ripresa fotografica.

DESCRIZIONE GEOTECNICA DEI TERRENI

La descrizione del campione, riportata sul "Modulo Riassuntivo", raccoglie tutte le indicazioni desunte dall'osservazione delle caratteristiche del campione immediatamente dopo la sua estruzione e scorticazione. Sono state in primo luogo descritte le caratteristiche generali del campione, evidenziando ad esempio la eventuale presenza di discontinuità, fratture o rammollimenti di alcune parti del campione stesso. Il campione è stato quindi descritto evidenziando le parti aventi caratteristiche omogenee, nel seguito chiamate "**settori**". Ogni singolo settore è stato analizzato a partire dalla testa del campione, secondo il seguente ordine: delimitazione del settore, natura del materiale, colore, struttura (se riconoscibile), consistenza (se misurabile) e nell'eventualità, presenza di materiale organico vegetale, reattività con acido cloridrico, strutture subordinate, discontinuità, torba e/o fossili. Per i campioni rimaneggiati la descrizione è stata di norma adeguata alle caratteristiche del campione e limitata alle informazioni relative a natura del terreno, colore, reattività con acido cloridrico ed eventuali presenze di strutture subordinate e/o torba o fossili.

I limiti spaziali del settore sono stati espressi in metri, attribuendo alla testa del campione la profondità reale di campionamento.

La natura del terreno è stata descritta con riferimento alle dimensioni dei grani ed alle percentuali dei diversi tipi di materiali presenti, così come determinati visivamente dall'Operatore e successivamente tramite verifica con le analisi granulometriche secondo lo schema e le definizioni delle Raccomandazioni AGI (AGI, 1977). Al materiale è stato attribuito il nome della percentuale più rilevante seguita da specificazioni per indicare le frazioni minoritarie. **Per la ghiaia è stato descritto l'assortimento, il grado di arrotondamento, la forma e la dimensione maggiore (Lmax) espressa in millimetri;** mentre per la sabbia è stato descritto l'assortimento e, per la frazione avente grani ben osservabili ad occhio nudo, è stato anche riportato il grado di arrotondamento.

Per descrivere l'assortimento sono stati utilizzati i termini fine (f), media (m), grossolana (g), medio fine (m/f), medio grossolana (m/g) ed eterogenea.

Per il grado di arrotondamento sono stati usati i termini arrotondata, subarrotondata, subangolare, angolare con riferimento alle fig. 1 (Rittenhouse, 1943) per la sabbia e alla fig. 1 per la ghiaia e i ciottoli (Pettijohn, 1949).

Per la forma sono stati usati i termini discoidale, sferoidale, lamellare, allungata con riferimento allo schema di fig. 1 (Gnaccolini, 1978), in cui la dimensione dell'elemento di dimensione maggiore (Lmax) è espressa in centimetri.

Il colore fondamentale o i colori fondamentali (se più di uno, ma distribuiti senza una struttura particolare)

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sono stati descritti con l'ausilio della Tavola dei colori Munsell (Munsell, 1975) fornendo il nome e la sigla.

La struttura del settore, cioè l'organizzazione macroscopica delle particelle costituenti il materiale, è stata individuata, quando evidente, con riferimento ai seguenti tipi:

Struttura omogenea: consiste in materiale con organizzazione indifferenziata delle particelle.

Struttura a livelli: consiste nella presenza di livelli (spessore di materiale maggiore di 6 mm) che si alternano nel settore. I livelli possono essere descritti come da schema di fig. 1.

Struttura laminata: consiste nella presenza di laminazioni e livelli (rispettivamente con spessore di materiale inferiore o superiore a 6 mm) che si alternano nel settore. Queste possono essere descritte come da schema di fig. 1 con il termine "*in alternanza*".

Struttura caotica: è individuata da segni evidenti di rimescolamento legato a fenomeni naturali.

Struttura scagliosa: è individuata dall'attitudine del materiale a sfaldarsi secondo "scaglie".

L'assenza di indicazioni segnala una struttura omogenea del materiale.

La consistenza è stata descritta per i soli terreni fini sulla base dei risultati del Penetrometro Tascabile condotti sulle teste del campione o sui fianchi previamente scorticati.

Il materiale organico è stato descritto mediante i termini resti vegetali e torba cioè materiale vegetale in variabile stato di decomposizione. Di quest'ultimo sono stati indicati: tessitura: fibrosa o amorfica a seconda che sia stato riconosciuto o meno il tessuto vegetale originario; consistenza: compatta o spugnosa a seconda che possa essere stata o meno manipolata; colore: ricavato dal confronto con le tavole "Munsell Soil Color Chart".

Per qualificare un terreno contenente percentuali variabili di torba è stato utilizzato il termine "torboso". Si è, infine, fatto uso del termine "frustolo" per indicare l'eventuale struttura irregolare della torba.

I fossili sono stati descritti con riferimento al colore ed alla loro integrità o fratturazione.

La reazione all'acido cloridrico è stata descritta con i termini "debolmente reagente con HCl", "reagente con HCl", "fortemente reagente con HCl". Le classi corrispondono rispettivamente ad una debole reazione, ad una reazione evidente e ad una reazione molto intensa. L'assenza di indicazioni segnala la mancata reazione del materiale con HCl.

Le strutture subordinate sono state classificate come livelli, laminazioni, lenti, noduli, granuli, identificabili all'interno del settore per diversa granulometria, reazione con HCl o colore. I termini "livelli" e "laminazioni" sono stati utilizzati per indicare rispettivamente spessori di materiale superiori e inferiori a 6 mm relativi all'intera sezione del campione. La geometria della loro disposizione è stata descritta con riferimento allo schema di fig. 1. Il termine "lenti" è stato utilizzato per descrivere materiali con geometria lentiforme; il termine "noduli" per materiali subsferoidali di diametro superiore a 2 mm; il termine "granuli" per materiali subsferoidali di diametro inferiore a 2 mm. La descrizione dei materiali subordinati, quando significativa, è stata eseguita con le stesse modalità previste per il settore.

Le discontinuità sono state segnalate con il termine "frattura", con indicazione dell'eventuale assenza di scabrezza.

Di ogni materiale subordinato è stato indicato l'intervallo di profondità all'interno del quale è stato osservato. Nel caso fosse presente in tutto lo strato considerato, è stato utilizzato il termine "sparso". Del materiale subordinato è stata indicata anche la frequenza con gli aggettivi "raro", "qualche" e "frequente". Di ogni campione è stata ottenuta documentazione fotografica per meglio evidenziare i tipi di materiali esaminati e le eventuali anomalie strutturali. Le fotografie sono completate con i dati identificativi, una scala cromatica e un riferimento dimensionale.

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.97 00000	SABBIA ARROTONDATA	.63 00000
.95 00000		.61 00000
.93 00000		.59 00000
.91 00000		.57 00000
.89 00000		.55 00000
.87 00000	SABBIA SUBANGOLARE	.53 00000
.85 00000		.51 00000
.83 00000		.49 00000
.81 00000	SABBIA ANGOLARE	.47 00000
.79 00000		.45 00000
.77 00000		
.75 00000	SABBIA ANGOLARE	
.73 00000		
.71 00000		
.69 00000		
.67 00000		
.65 00000	SABBIA ANGOLARE	

Fig. 1/1 - Classificazione delle sabbie in relazione al grado di arrotondamento (Rittenhouse, 1943)

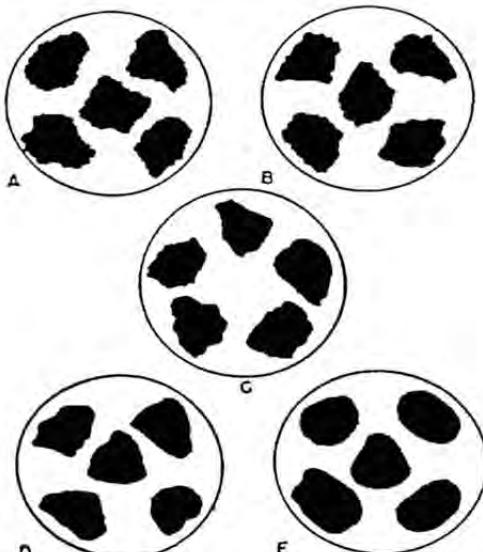


Fig. 1/2 - Classificazione della ghiaia e dei ciottoli in relazione al grado di arrotondamento:

A = Angolare B = Subangolare,
C = Subarrotondata D E = Arrotondata

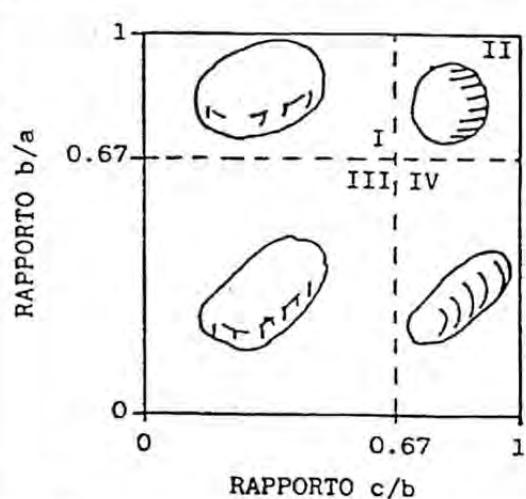


Fig. 1/3 - Classificazione della ghiaia e dei ciottoli in funzione della forma (Gnaccolini, 1978): a, b, c d sono le dimensioni caratteristiche dei grani.

I = discoidali II = sferoidali
III = lamellari IV = allungati

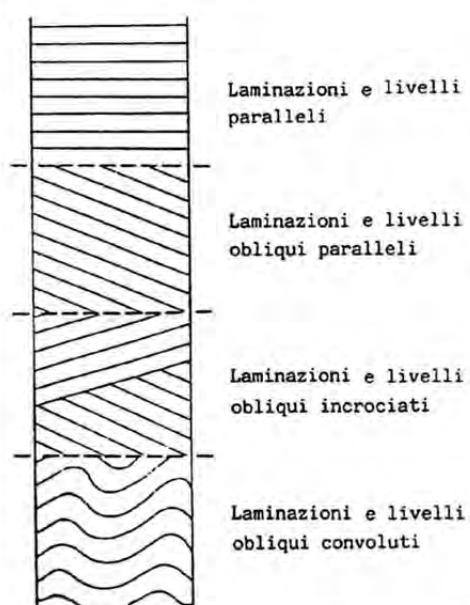


Fig. 1/4
- Schema per la descrizione dei livelli e delle laminazioni.

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SONDAGGIO: S1

CAMPIONE: C1

PROFONDITA': m 3,00-3,40

MODULO RIASSUNTIVO

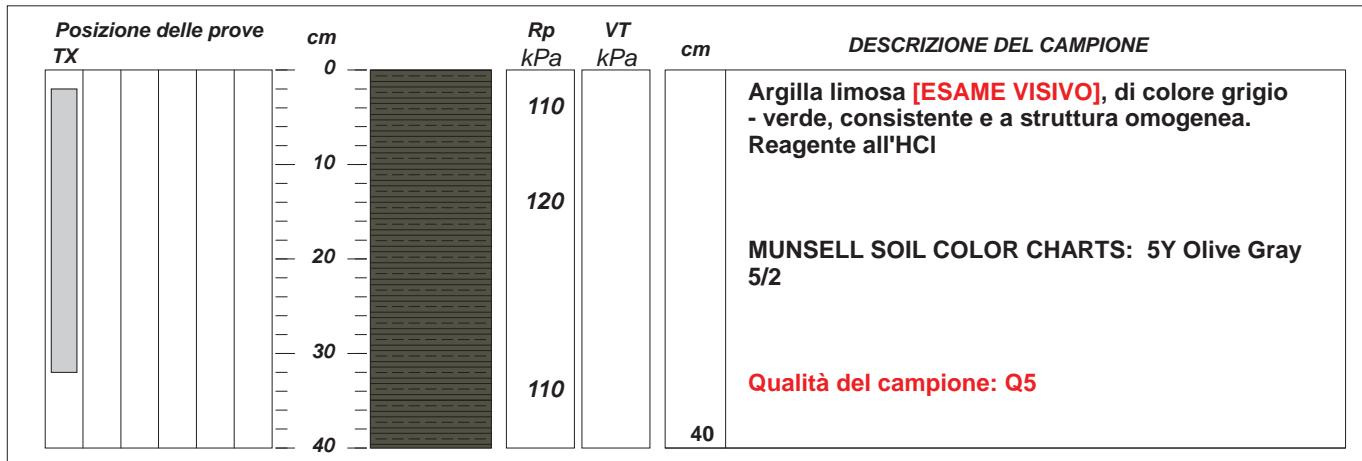
CARATTERISTICHE FISICHE

<i>Umidità naturale</i>	37,5	%
<i>Peso di volume</i>	17,4	kN/m ³
<i>Peso di volume secco</i>	12,7	kN/m ³
<i>Peso di volume saturo</i>	0,0	kN/m ³

COMPRESIONE TRIASSIALE U.U.

<i>Coesione: (c_u)</i>	59,5	kPa
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FOTOGRAFIA



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VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 08/05/18
Apertura campione: 07/05/18 Fine analisi: 09/05/18

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SONDAGGIO: S1

CAMPIONE: C1

PROFONDITA': m 3,00-3,40

PROVA DI COMPRESSIONE TRIASSIALE U.U.

Modalità di prova: Norma ASTM D 2850

TABELLA RIASSUNTIVA DEI DATI DELLA PROVA

PROVINO	1	2	3	PROVINO	1	2	3
Condizioni	Indisturbato	Indisturbato	Indisturbato	Pressioni iniziali			
Caratteristiche iniziali dei provini							
Massa (g)	154,44	154,22	154,71	Pressione di cella (kPa)	400	500	600
Altezza (cm)	7,62	7,62	7,62	Back pressure (kPa)	300	300	300
Diametro (cm)	3,81	3,81	3,81	Pressione efficace (kPa)	100	200	300
Sezione (cm ²):	11,40	11,40	11,40	Valori finali o a rottura			
Volume (cm ³)	86,87	86,87	86,87	Deformazione verticale (%)	4,7	6,3	10,1
Peso di volume (kN/m ³)	17,4	17,4	17,5	$\sigma_1 - \sigma_3$ (kPa)	111	117	128
Umidità (%)	37,6	37,2	37,7	Pressione interstiziale (kPa)	328	391	446
Peso specifico	0,00	0,00	0,00	$(\sigma_1 + \sigma_3) / 2$ (kPa)	156	259	364
Peso di volume secco (kN/m ³)	12,7	12,7	12,7	$(\sigma_1 - \sigma_3) / 2$ (kPa)	56	59	64
Grado di saturazione (%)							

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CAMPIONE: C1

PROFONDITA': m 3,00-3,40

PROVA DI COMPRESSIONE TRIASSIALE U.U.

Modalità di prova: Norma ASTM D 2850

P n	Dimensioni		Caratteristiche fisiche			Pressione			Valori finali o a rottura				
	H _o cm	ϕ cm	γ kN/m ³	γ _s %	w %	S _o %	σ ₃ kPa	u _o kPa	σ' ₃ kPa	δ _f %	σ _t -σ ₃ kPa	σ _t +σ ₃ 2 kPa	σ _t -σ ₃ 2 kPa
1	7,62	3,81	17,4	0,00	37,6	0,0	400	300	100	4,7	111	156	56
2	7,62	3,81	17,4	0,00	37,2	0,0	500	300	200	6,3	117	259	59
3	7,62	3,81	17,5	0,00	37,7	0,0	600	300	300	10,1	128	364	64

H_o ϕ - Altezza e diametro provini
w - Umidità dei provini

γ γ_s - Peso di volume e peso specifico
S_o - Grado di saturazione iniziale

σ₃ - Pressione di cella
u_o - Back pressure

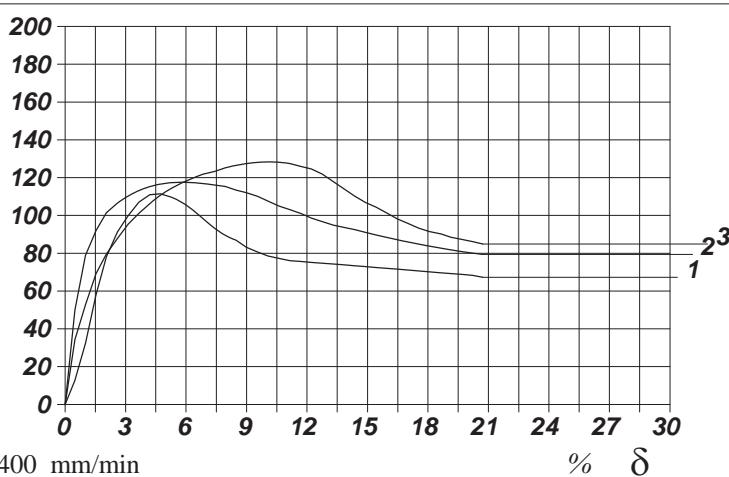
δ_f - Deformazione a rottura
σ_t σ₃ - Tensioni totali

σ_t-σ₃
kPa

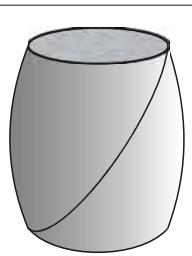
Diagramma

Tensione totale -
- Deformazione

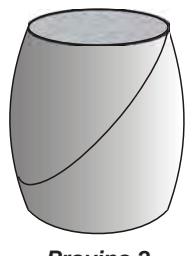
Velocità di deformazione: 0,400 mm/min



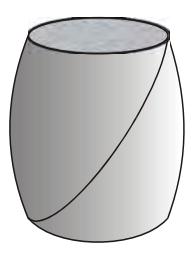
Tipo di rottura



Provino 1



Provino 2

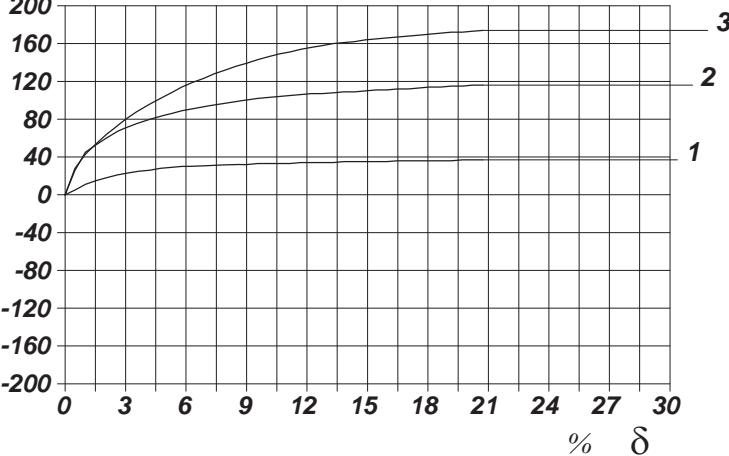


Provino 3

ΔV
%

Diagramma

Pressione interstiziale -
- Deformazione



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CAMPIONE: C1

PROFONDITA': m 3,00-3,40

PROVA DI COMPRESSIONE TRIASSIALE U.U.

Modalità di prova: Norma ASTM D 2850

PROVINO 1				PROVINO 2				PROVINO 3			
δ mm	δ %	σ _I -σ ₃ kPa	Δv kPa	δ mm	δ %	σ _I -σ ₃ kPa	Δv kPa	δ mm	δ %	σ _I -σ ₃ kPa	Δv kPa
0,37	0,49	12,7	5,0	0,37	0,49	49,9	25,8	0,37	0,49	34,3	27,8
0,77	1,01	32,3	11,0	0,77	1,01	78,9	45,0	0,77	1,01	52,8	43,1
1,17	1,54	58,1	15,0	1,17	1,54	92,0	53,0	1,17	1,54	69,2	54,0
1,56	2,05	78,2	18,0	1,56	2,05	101,5	60,0	1,56	2,05	79,7	64,0
1,98	2,60	91,3	21,0	1,98	2,60	106,6	67,0	1,98	2,60	87,8	73,0
2,38	3,12	99,8	23,0	2,38	3,12	110,2	72,0	2,38	3,12	95,3	82,0
2,79	3,66	107,1	25,0	2,79	3,66	113,1	76,0	2,79	3,66	101,1	89,0
3,20	4,20	110,9	26,0	3,20	4,20	115,2	80,0	3,20	4,20	106,2	96,0
3,60	4,72	111,4	28,0	3,60	4,72	116,7	83,0	3,60	4,72	110,6	102,0
4,01	5,26	109,7	29,0	4,01	5,26	117,4	86,0	4,01	5,26	114,4	108,0
4,41	5,79	106,9	30,0	4,41	5,79	117,4	89,0	4,41	5,79	117,0	114,0
4,82	6,33	103,0	30,0	4,82	6,33	117,4	91,0	4,82	6,33	119,8	119,0
5,22	6,85	98,1	31,0	5,22	6,85	116,8	93,0	5,22	6,85	121,9	123,0
5,64	7,40	93,3	31,0	5,64	7,40	116,1	95,0	5,64	7,40	123,2	128,0
6,05	7,94	89,5	32,0	6,05	7,94	115,4	97,0	6,05	7,94	125,2	132,0
6,46	8,48	86,9	32,0	6,46	8,48	113,4	99,0	6,46	8,48	126,5	136,0
6,85	8,99	83,3	32,0	6,85	8,99	112,1	100,0	6,85	8,99	127,4	139,0
7,28	9,55	80,6	33,0	7,28	9,55	110,1	102,0	7,28	9,55	128,2	143,0
7,67	10,07	78,6	33,0	7,67	10,07	107,5	103,0	7,67	10,07	128,3	146,0
8,09	10,62	77,3	33,0	8,09	10,62	104,9	104,0	8,09	10,62	128,2	149,0
8,49	11,14	76,1	33,0	8,49	11,14	103,0	105,0	8,49	11,14	127,4	151,0
8,91	11,69	75,7	34,0	8,91	11,69	101,1	106,0	8,91	11,69	126,0	154,0
9,31	12,22	75,2	34,0	9,31	12,22	98,6	107,0	9,31	12,22	124,6	156,0
9,72	12,76	74,8	34,0	9,72	12,76	96,7	107,0	9,72	12,76	121,9	158,0
10,14	13,31	74,3	34,0	10,14	13,31	94,9	108,0	10,14	13,31	117,9	160,0
10,54	13,83	73,8	35,0	10,54	13,83	93,7	109,0	10,54	13,83	114,0	161,0
10,95	14,37	73,4	35,0	10,95	14,37	92,5	109,0	10,95	14,37	110,2	162,0
11,35	14,90	72,9	35,0	11,35	14,90	91,0	110,0	11,35	14,90	107,0	164,0
11,76	15,43	72,5	35,0	11,76	15,43	89,5	111,0	11,76	15,43	104,4	165,0
12,16	15,96	72,0	35,0	12,16	15,96	88,2	111,0	12,16	15,96	101,3	166,0
12,56	16,48	71,6	36,0	12,56	16,48	87,2	112,0	12,56	16,48	98,2	167,0
12,97	17,02	71,1	36,0	12,97	17,02	86,0	112,0	12,97	17,02	95,7	168,0
13,37	17,55	70,6	36,0	13,37	17,55	84,8	113,0	13,37	17,55	93,3	169,0
13,77	18,07	70,2	36,0	13,77	18,07	83,6	114,0	13,77	18,07	91,5	170,0
14,21	18,65	69,7	36,0	14,21	18,65	82,8	114,0	14,21	18,65	90,2	171,0
14,59	19,15	69,3	36,0	14,59	19,15	81,7	115,0	14,59	19,15	88,5	172,0
15,02	19,71	68,8	37,0	15,02	19,71	80,8	115,0	15,02	19,71	87,3	172,0
15,41	20,22	68,3	37,0	15,41	20,22	80,1	116,0	15,41	20,22	86,1	173,0
15,79	20,72	67,3	37,0	15,79	20,72	79,4	116,0	15,79	20,72	84,9	174,0

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C2

PROFONDITA': m 8,40-8,80

MODULO RIASSUNTIVO

CARATTERISTICHE FISICHE

<i>Umidità naturale</i>	23,2	%
<i>Peso di volume</i>	19,8	kN/m ³
<i>Peso di volume secco</i>	16,1	kN/m ³
<i>Peso di volume saturo</i>	0,0	kN/m ³

COMPRESIONE TRIASSIALE C.I.D.

<i>Coesione: (c_d)</i>	8,2	kPa
<i>Angolo di attrito interno: (ϕ_d)</i>	27,2	°

FOTOGRAFIA



Posizione delle prove TX	cm	Rp kPa	VT kPa	cm	DESCRIZIONE DEL CAMPIONE
	0				
	10				
	20				
	30				
	40				

257-18 SGEO - Laboratorio 6.1 - 2018

IL DIRETTORE DEL LABORATORIO
dott. geol. CARBONE Raffaele
Raffaele Carbone

CERTIFICATO DI PROVA N°: 01244 Pagina 1/6
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 09/05/18
Apertura campione: 07/05/18 Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C2

PROFONDITA': m 8,40-8,80

PROVA DI COMPRESSIONE TRIASSIALE C.I.D.

Modalità di prova: Norma Raccomandazioni A.G.I. - 1994

TABELLA RIASSUNTIVA DEI DATI DELLA PROVA

PROVINO	1	2	3	PROVINO	1	2	3
Condizioni	Indisturbato	Indisturbato	Indisturbato	Pressioni iniziali			
Caratteristiche iniziali dei provini							
Massa (g)	175,51	174,88	175,32	Pressione di cella (kPa)	400	500	600
Altezza (cm)	7,62	7,62	7,62	Back pressure (kPa)	300	300	300
Diametro (cm)	3,81	3,81	3,81	Pressione efficace (kPa)	100	200	300
Sezione (cm ²)	11,40	11,40	11,40	Valori finali o a rottura			
Volume (cm ³)	86,87	86,87	86,87	Deformazione verticale (%)	4,0	6,5	8,6
Peso di volume (kN/m ³)	19,8	19,7	19,8	$\sigma_1 - \sigma_3$ (kPa)	195	365	530
Umidità (%)	23,2	23,5	22,9	Pressione interstiziale (kPa)	300	300	300
Peso specifico	0,00	0,00	0,00	$(\sigma_1 + \sigma_3) / 2$ (kPa)	198	383	565
Peso di volume secco (kN/m ³)	16,1	16,0	16,1	$(\sigma_1 - \sigma_3) / 2$ (kPa)	98	183	265
Grado di saturazione (%)				Calcolo della velocità di prova			
Parametri di saturazione							
Coefficiente B	0,98	0,99	0,98	T100 (minuti)	10,2	24,5	38,0
Caratteristiche dopo la consolidazione				Deformazione stimata (%)	4	7	9
Altezza (cm)	7,59	7,58	7,56	Velocità di prova (mm/min)	0,019	0,014	0,011
Variazione altezza (%)	-0,4	-0,5	-0,8	Velocità di prova (mm/min)			
Volume (cm ³)	85,18	84,77	84,18				
Variazione volume (%)	-2,0	-2,4	-3,1				
Peso di volume (kN/m ³)	20,6	20,5	20,7				
Umidità (%)	25,40	25,30	24,26				
Grado di saturazione (%)							
Caratteristiche dopo la rottura							
Altezza (cm)	6,13	6,12	6,11				
Volume (cm ³)	87,00	86,20	85,33				
Peso di volume (kN/m ³)	20,8	20,6	20,6				
Umidità (%)	24,21	23,82	22,37				
Grado di saturazione (%)							

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VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

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RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C2

PROFONDITA': m 8,40-8,80

PROVA DI COMPRESSIONE TRIASSIALE C.I.D.

Modalità di prova: Norma Raccomandazioni A.G.I. - 1994

P	Dimensioni		Caratteristiche fisiche				Consolidazione					Valori finali o a rottura					
	n	H _o cm	ϕ cm	γ kN/m ³	γ _s %	w _o %	S _o %	σ ₃ kPa	u _o kPa	σ' ₃ kPa	ΔV/V %	ΔH/H %	w _f %	δ _f %	σ _I -σ ₃ kPa	σ _I +σ ₃ 2 kPa	σ _I -σ ₃ 2 kPa
1	7,62	3,81	19,8	0,00	23,2	0,0		400	300	100	2,0	0,4	24,2	4,0	195	198	98
2	7,62	3,81	19,7	0,00	23,5	0,0		500	300	200	2,4	0,5	23,8	6,5	365	383	183
3	7,62	3,81	19,8	0,00	22,9	0,0		600	300	300	3,1	0,8	22,4	8,6	530	565	265

H_o ϕ - Altezza e diametro provini
w_o w_f - Umidità iniziale e finale

γ γ_s - Peso di volume e peso specifico
S_o - Grado di saturazione iniziale

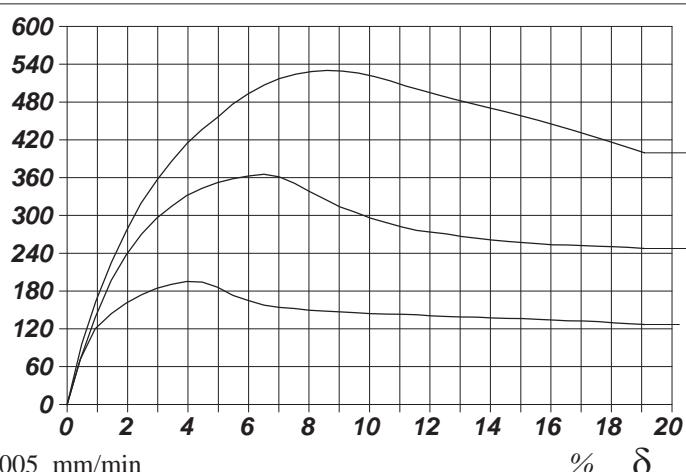
ΔH ΔV - Variaz. di altezza e volume
σ₃/u_o - Press. di cella/Back pressure

δ_f - Deformazione a rottura
σ_I σ₃ - Tensioni totali

σ_I-σ₃
kPa

Diagramma

Tensione efficace -
- Deformazione

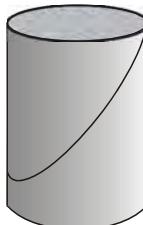


Velocità di deformazione: 0,005 mm/min

Tipo di rottura



Provino 1



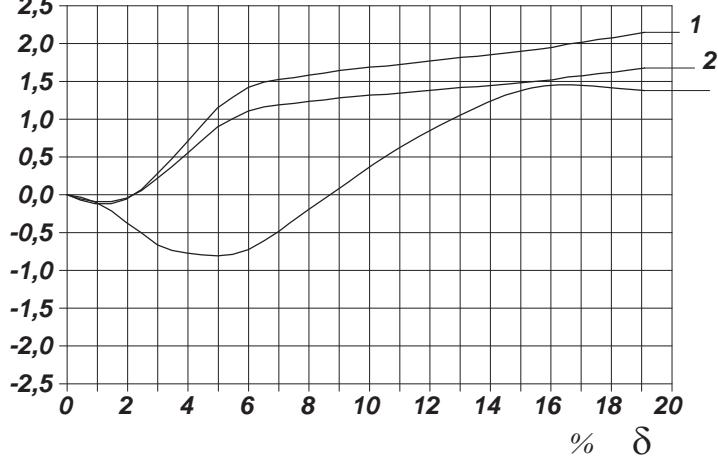
Provino 2



Provino 3

ΔV
%

Diagramma
Variazione di volume -
- Deformazione



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VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

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RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C2

PROFONDITA': m 8,40-8,80

PROVA DI COMPRESSIONE TRIASSIALE C.I.D.

Modalità di prova: Norma Raccomandazioni A.G.I. - 1994

PROVINO 1				PROVINO 2				PROVINO 3			
δ mm	δ %	σ _I -σ ₃ kPa	ΔV %	δ mm	δ %	σ _I -σ ₃ kPa	ΔV %	δ mm	δ %	σ _I -σ ₃ kPa	ΔV %
0,33	0,44	71,4	-0,07	0,33	0,44	71,3	-0,05	0,37	0,49	95,6	-0,04
0,71	0,93	120,0	-0,12	0,71	0,93	137,8	-0,09	0,73	0,96	164,2	-0,10
1,11	1,46	143,8	-0,12	1,11	1,46	196,8	-0,09	1,12	1,47	225,8	-0,21
1,49	1,95	161,0	-0,06	1,49	1,95	237,4	-0,05	1,49	1,96	275,6	-0,37
1,88	2,46	174,1	0,07	1,88	2,46	270,4	0,05	1,86	2,44	319,1	-0,50
2,25	2,96	184,3	0,27	2,25	2,96	295,7	0,21	2,28	2,99	357,7	-0,67
2,63	3,45	190,5	0,47	2,63	3,45	314,3	0,37	2,64	3,46	386,5	-0,74
3,01	3,95	195,2	0,69	3,01	3,95	331,5	0,54	3,03	3,98	415,0	-0,77
3,41	4,48	194,3	0,93	3,41	4,48	343,1	0,72	3,40	4,46	436,5	-0,79
3,79	4,98	186,1	1,15	3,79	4,98	352,1	0,90	3,79	4,97	455,9	-0,81
4,18	5,48	173,0	1,29	4,18	5,48	358,3	1,01	4,17	5,47	476,6	-0,79
4,57	5,99	165,1	1,42	4,57	5,99	362,4	1,11	4,57	6,00	493,3	-0,72
4,96	6,51	157,7	1,49	4,96	6,51	365,4	1,16	4,97	6,52	507,0	-0,61
5,35	7,01	154,1	1,53	5,35	7,01	361,4	1,19	5,35	7,02	517,2	-0,48
5,73	7,52	152,3	1,55	5,73	7,52	351,1	1,21	5,77	7,57	524,5	-0,32
6,11	8,01	149,6	1,58	6,11	8,01	337,9	1,24	6,16	8,08	528,5	-0,17
6,47	8,50	148,4	1,61	6,47	8,50	326,5	1,26	6,55	8,60	530,1	-0,02
6,88	9,03	147,1	1,64	6,88	9,03	313,5	1,28	6,93	9,09	529,3	0,11
7,25	9,51	145,8	1,67	7,25	9,51	305,6	1,30	7,33	9,62	526,0	0,26
7,64	10,03	144,3	1,69	7,64	10,03	295,9	1,32	7,72	10,13	520,8	0,40
8,04	10,55	143,5	1,70	8,04	10,55	288,7	1,33	8,14	10,68	513,8	0,55
8,43	11,07	143,2	1,73	8,43	11,07	281,9	1,35	8,54	11,21	505,4	0,68
8,81	11,56	142,4	1,75	8,81	11,56	276,4	1,37	8,94	11,74	498,3	0,79
9,18	12,05	140,7	1,77	9,18	12,05	273,4	1,38	9,35	12,27	491,4	0,90
9,57	12,56	139,6	1,80	9,57	12,56	270,7	1,40	9,75	12,80	484,7	1,02
9,94	13,05	138,8	1,82	9,94	13,05	266,5	1,42	10,16	13,34	478,1	1,11
10,33	13,55	138,5	1,83	10,33	13,55	263,8	1,43	10,59	13,90	471,5	1,22
10,71	14,06	137,3	1,86	10,71	14,06	261,1	1,45	11,04	14,48	464,6	1,32
11,11	14,58	136,5	1,88	11,11	14,58	258,8	1,47	11,53	15,14	456,8	1,39
11,48	15,07	136,1	1,90	11,48	15,07	256,8	1,48	11,99	15,73	449,2	1,44
11,88	15,59	134,8	1,93	11,88	15,59	255,2	1,50	12,38	16,25	442,1	1,45
12,24	16,06	134,2	1,95	12,24	16,06	253,4	1,52	12,73	16,70	435,5	1,45
12,62	16,56	132,9	2,00	12,62	16,56	253,1	1,56	13,06	17,14	429,1	1,44
13,01	17,07	132,4	2,02	13,01	17,07	252,3	1,58	13,39	17,57	422,9	1,43
13,39	17,58	131,5	2,05	13,39	17,58	251,3	1,60	13,69	17,97	416,9	1,42
13,79	18,09	129,4	2,08	13,79	18,09	250,3	1,62	13,99	18,36	411,1	1,40
14,16	18,58	128,1	2,11	14,16	18,58	249,2	1,65	14,27	18,72	405,3	1,39
14,55	19,10	126,8	2,15	14,55	19,10	247,5	1,68	14,55	19,09	399,6	1,38

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COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

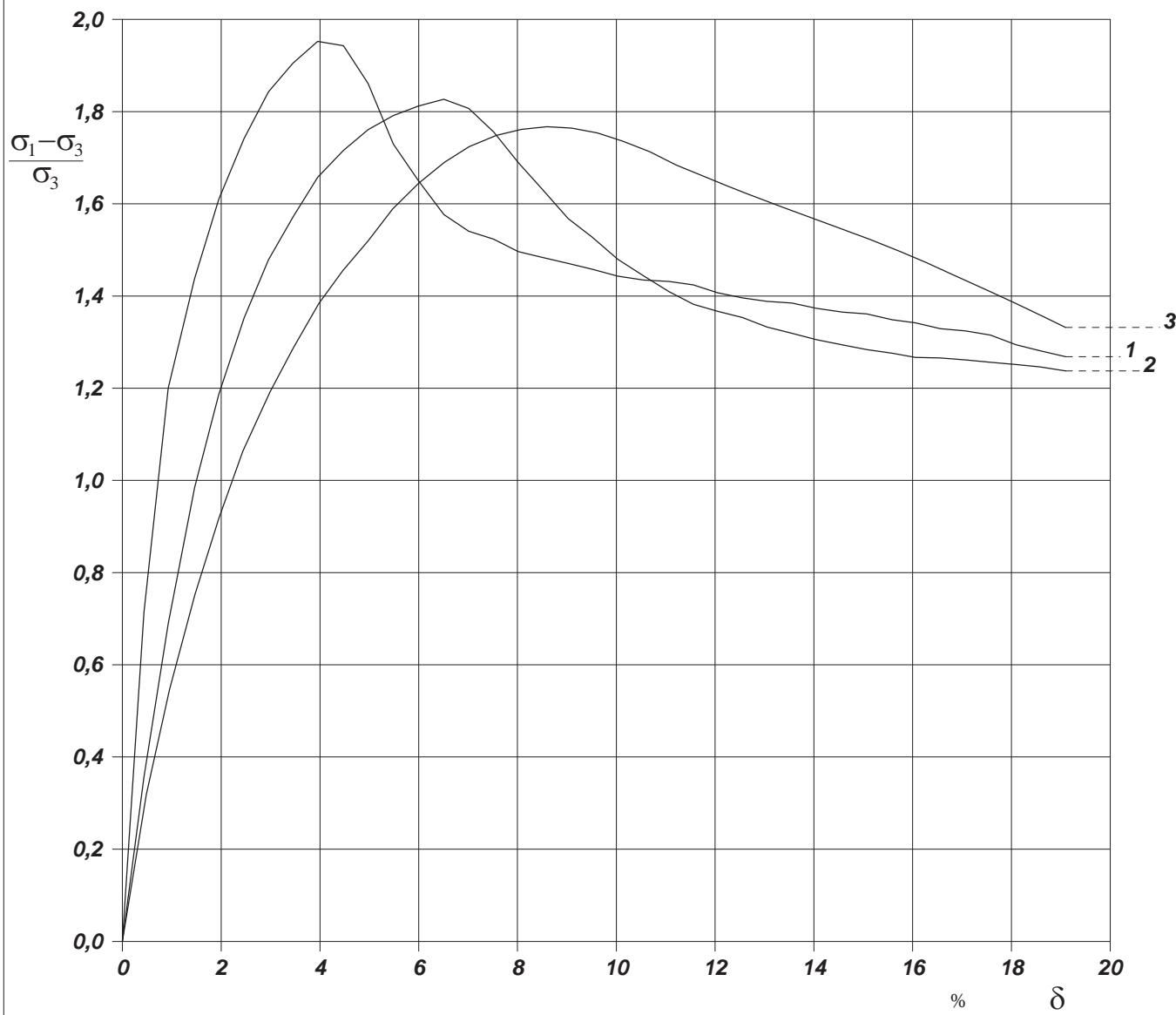
CAMPIONE: C2

PROFONDITA': m 8,40-8,80

PROVA DI COMPRESSIONE TRIASSIALE C.I.D.

Modalità di prova: Norma Raccomandazioni A.G.I. - 1994

Diagramma Sforzi principali efficaci - Deformazione



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RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C2

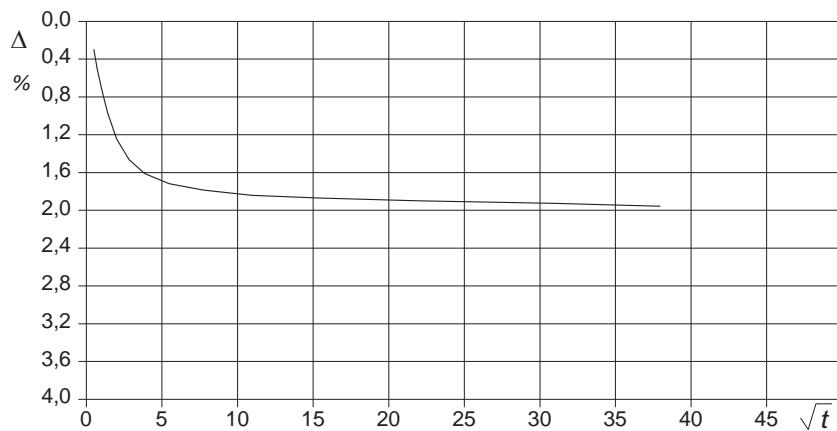
PROFONDITA': m 8,40-8,80

PROVA DI COMPRESSIONE TRIASSIALE - FASE DI CONSOLIDAZIONE

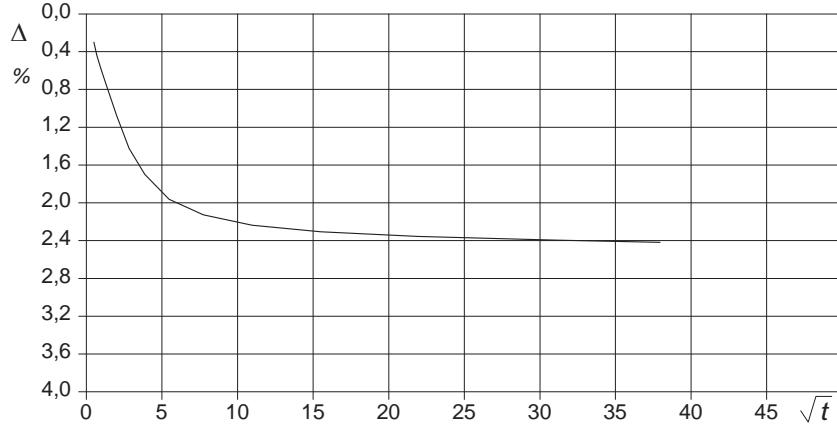
Modalità di prova: Norma Raccomandazioni A.G.I. - 1994

DIAGRAMMI TEMPO - VARIAZIONE DI VOLUME

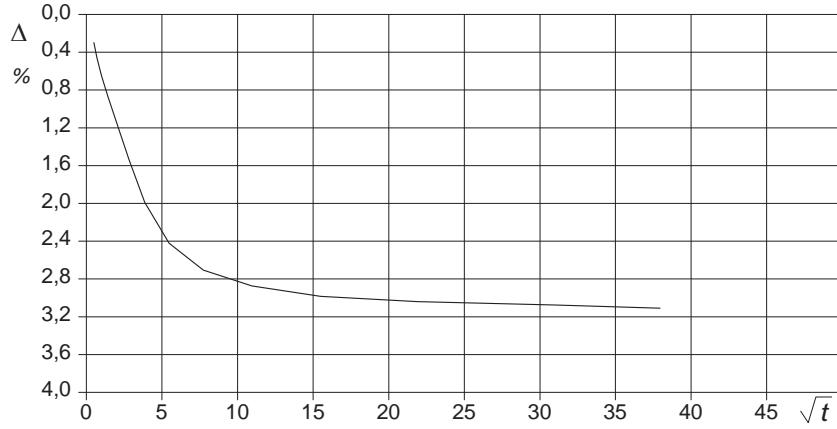
PROVINO 1	
Pressione (kPa)	100
Altezza (cm)	7,62
Fattore F	15,758
T ₁₀₀ (min)	10,2
Deformaz. stimata (%)	4
Veloc. stimata (mm/min)	0,019



PROVINO 2	
Pressione (kPa)	200
Altezza (cm)	7,62
Fattore F	15,758
T ₁₀₀ (min)	24,5
Deformaz. stimata (%)	7
Veloc. stimata (mm/min)	0,014



PROVINO 3	
Pressione (kPa)	300
Altezza (cm)	7,62
Fattore F	15,758
T ₁₀₀ (min)	38,0
Deformaz. stimata (%)	9
Veloc. stimata (mm/min)	0,011



257-18 Velocità stimata di prova = (H · DefV) / (100 · F · T₁₀₀) - Velocità media di prova (mm/min): 0,005

SGEO - Laboratorio 6.1 - 2018

L'ESPONENTE
dott. Geol. MAURIZIO SUSY
Susy Mario

IL DIRETTORE DEL LABORATORIO
dott. GeoL CARBONE Raffaele
Raffaele

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VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

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RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 **CAMPIONE:** C2 **PROFONDITA':** m 8,40-8,80

PROVA DI COMPRESSIONE TRIASSIALE - FASE DI CONSOLIDAZIONE

Modalità di prova: Norma Raccomandazioni A.G.I. - 1994

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RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C3

PROFONDITA': m 10,50-11,00

MODULO RIASSUNTIVO

CARATTERISTICHE FISICHE

<i>Umidità naturale</i>	21,4	%
<i>Peso di volume</i>	17,9	kN/m ³
<i>Peso di volume secco</i>	14,7	kN/m ³
<i>Peso di volume saturo</i>	0,0	kN/m ³

TAGLIO DIRETTO

<i>Coesione:</i>	0,4	kPa
<i>Angolo di attrito interno:</i>	29,4	°

FOTOGRAFIA



Posizione delle prove TD	cm	Rp kPa	VT kPa	cm	DESCRIZIONE DEL CAMPIONE
					cm
	0	20			Sabbia (m) [ESAME VISIVO], di colore grigio, con qualche elemento cristallino di colore argento, privo di consistenza e a struttura omogenea. Reagente all'HCl
	10	20			MUNSELL SOIL COLOR CHARTS: Gley 1 Very Dark Greenish Gray 10GY
	20				Provini per la prova di Taglio Diretto ricostituiti al peso di volume di 17,9 kN/m ³
	30				Qualità del campione: Q3
	40	10			
	50				

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VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 08/05/18
Apertura campione: 07/05/18 Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

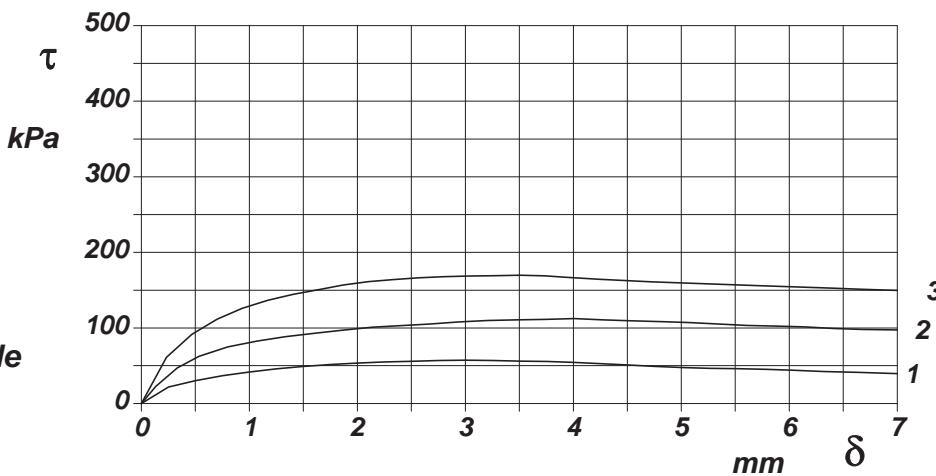
SONDAGGIO: S1 **CAMPIONE:** C3 **PROFONDITA': m** 10,50-11,00

PROVA DI TAGLIO DIRETTO

Modalità di prova: Norma ASTM D 3080

Provino n°:	1	2	3
Condizione del provino:	Ricostituito	Ricostituito	Ricostituito
Tempo di consolidazione (ore):	24	24	24
Pressione verticale (kPa):	100,0	200,0	300,0
Umidità iniziale e umidità finale (%):	21,5 23,8	21,8 23,3	20,9 22,5
Peso di volume (kN/m³):	17,9	17,9	17,9
Tipo di prova: Consolidata - lenta	Velocità di deformazione: 0,004 mm / min		

DIAGRAMMA

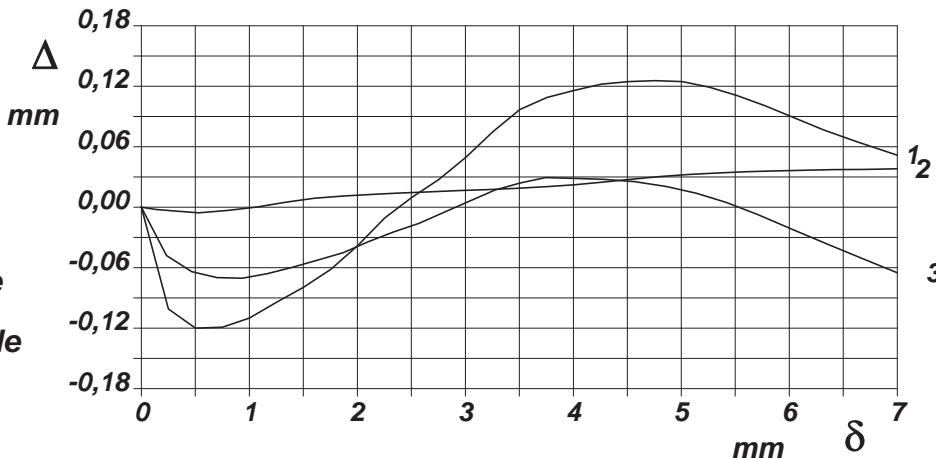


Deformazione orizzontale

Tensione

Deformazione orizzontale

DIAGRAMMA



Deformazione verticale

Deformazione orizzontale

Provini ricostituiti al peso di volume di 17,9 kN/m³

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VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 **Inizio analisi:** 08/05/18
Apertura campione: 07/05/18 **Fine analisi:** 15/05/18

COMMITTENTE: **GEO GROUP S.r.l.** - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 **CAMPIONE:** C3 **PROFONDITÀ': m** 10,50-11,00

PROVA DI TAGLIO DIRETTO

Modalità di prova: Norma ASTM D 3080

CERTIFICATO DI PROVA N°: 01245 Pagina 3/4
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 08/05/18
Apertura campione: 07/05/18 Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 **CAMPIONE:** C3 **PROFONDITA': m** 10,50-11,00

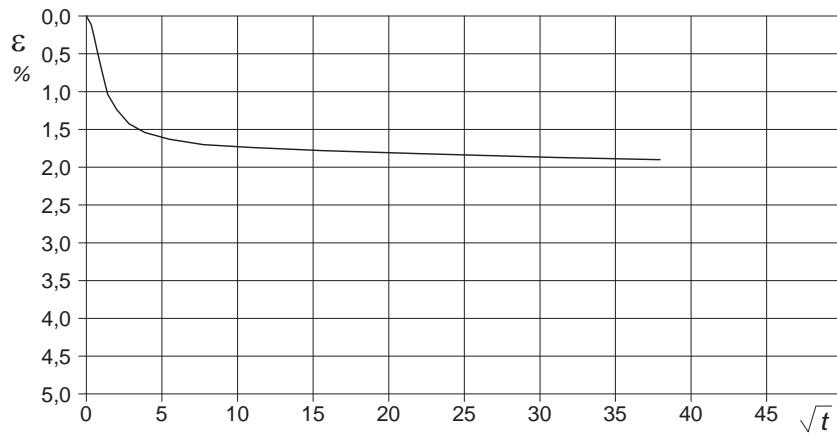
PROVA DI TAGLIO DIRETTO - FASE DI CONSOLIDAZIONE

Modalità di prova: Norma ASTM D 3080

**Diagramma
TEMPO - CEDIMENTO**

PROVINO 1

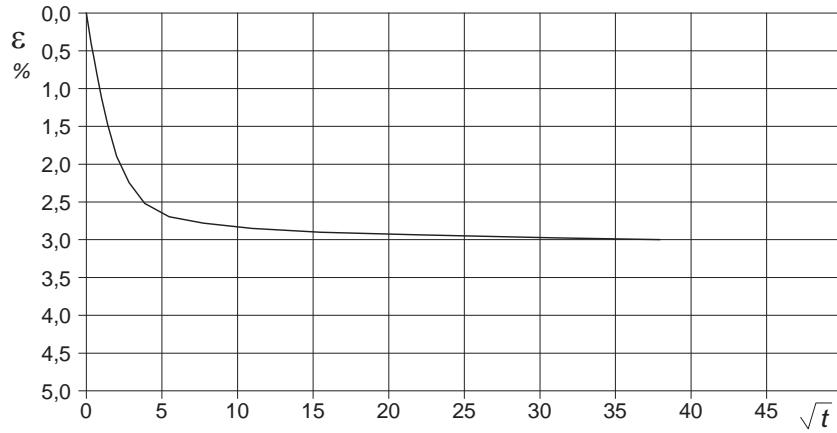
Pressione (kPa)	100
Altezza iniziale (cm)	2,000
Altezza finale (cm)	1,962
Sezione (cm ²):	36,00
T ₁₀₀ (min)	6,0
Df (mm)	3
Vs (mm/min)	0,050



**Diagramma
TEMPO - CEDIMENTO**

PROVINO 2

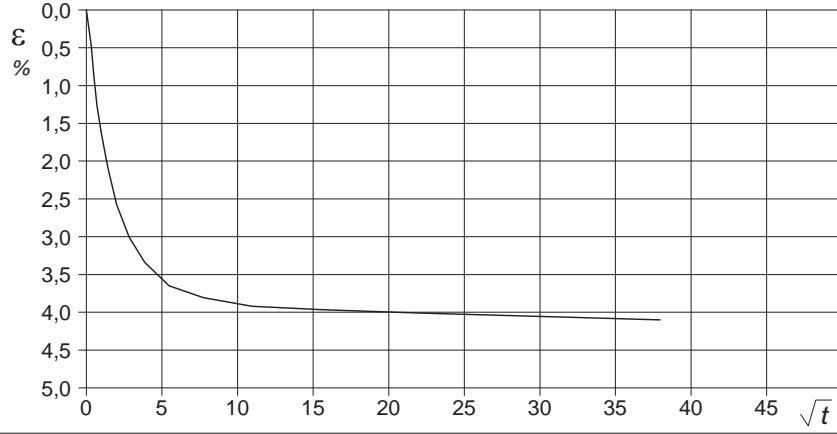
Pressione (kPa)	200
Altezza iniziale (cm)	2,000
Altezza finale (cm)	1,940
Sezione (cm ²):	36,00
T ₁₀₀ (min)	10,5
Df (mm)	4
Vs (mm/min)	0,038



**Diagramma
TEMPO - CEDIMENTO**

PROVINO 3

Pressione (kPa)	300
Altezza iniziale (cm)	2,000
Altezza finale (cm)	1,918
Sezione (cm ²):	36,00
T ₁₀₀ (min)	10,3
Df (mm)	3
Vs (mm/min)	0,029



Vs = Velocità stimata di prova Df = Deformazione a rottura stimata

tf = 10 x T₁₀₀ Vs = Df / tf

CERTIFICATO DI PROVA N°: 01245 Pagina 4/4

VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 **Inizio analisi:** 08/05/18
Apertura campione: 07/05/18 **Fine analisi:** 15/05/18

COMMITTENTE: **GEO GROUP S.r.l.** - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 **CAMPIONE:** C3 **PROFONDITÀ': m** 10,50-11,00

PROVA DI TAGLIO DIRETTO - FASE DI CONSOLIDAZIONE

Modalità di prova: Norma ASTM D 3080

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C4

PROFONDITA': m 15,30-15,85

MODULO RIASSUNTIVO

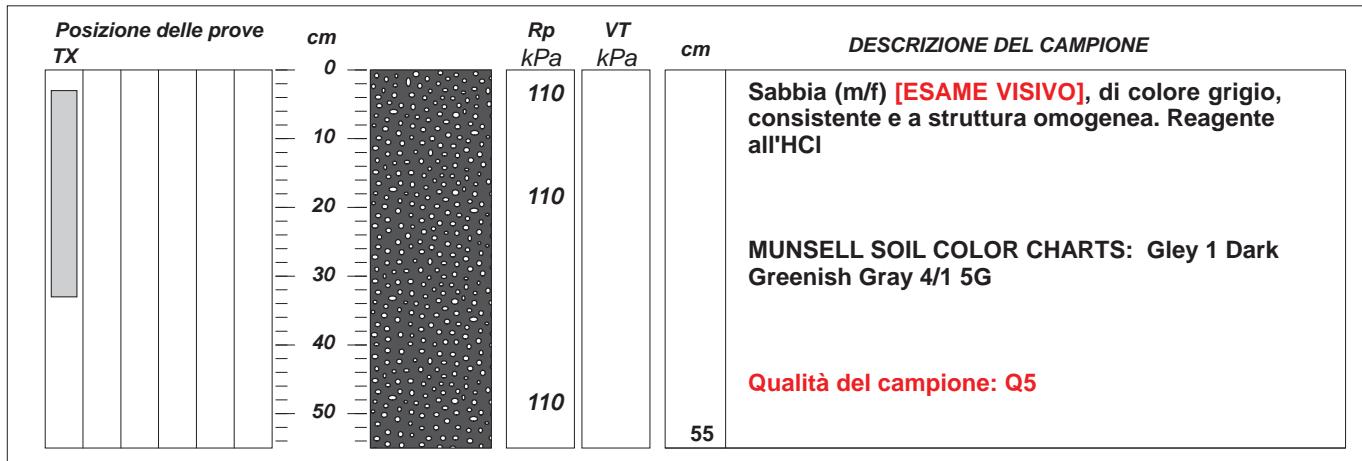
CARATTERISTICHE FISICHE

<i>Umidità naturale</i>	28,2	%
<i>Peso di volume</i>	18,6	kN/m³
<i>Peso di volume secco</i>	14,5	kN/m³
<i>Peso di volume saturo</i>	0,0	kN/m³

COMPRESIONE TRIASSIALE U.U.

<i>Coesione: (c_u)</i>	81,6	kPa
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FOTOGRAFIA



CERTIFICATO DI PROVA N°: 01246 Pagina 1/3
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 16/05/18
Apertura campione: 07/05/18 Fine analisi: 17/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 CAMPIONE: C4 PROFONDITA': m 15,30-15,85

PROVA DI COMPRESSIONE TRIASSIALE U.U.

Modalità di prova: Norma ASTM D 2850

TABELLA RIASSUNTIVA DEI DATI DELLA PROVA

PROVINO	1	2	3	PROVINO	1	2	3
Condizioni	Indisturbato	Indisturbato	Indisturbato	Pressioni iniziali			
Caratteristiche iniziali dei provini							
Massa (g)	164,57	164,89	164,73	Pressione di cella (kPa)	500	600	700
Altezza (cm)	7,62	7,62	7,62	Back pressure (kPa)	300	300	300
Diametro (cm)	3,81	3,81	3,81	Pressione efficace (kPa)	200	300	400
Sezione (cm ²):	11,40	11,40	11,40	Valori finali o a rottura			
Volume (cm ³)	86,87	86,87	86,87	Deformazione verticale (%)	9,6	12,9	11,2
Peso di volume (kN/m ³)	18,6	18,6	18,6	$\sigma_1 - \sigma_3$ (kPa)	152	162	175
Umidità (%)	28,1	28,7	27,7	Pressione interstiziale (kPa)	346	322	319
Peso specifico	0,00	0,00	0,00	$(\sigma_1 + \sigma_3) / 2$ (kPa)	276	381	488
Peso di volume secco (kN/m ³)	14,5	14,5	14,6	$(\sigma_1 - \sigma_3) / 2$ (kPa)	76	81	88
Grado di saturazione (%)							

CERTIFICATO DI PROVA N°: 01246 Pagina 2/3
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

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RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C4

PROFONDITA': m 15,30-15,85

PROVA DI COMPRESSIONE TRIASSIALE U.U.

Modalità di prova: Norma ASTM D 2850

P n	Dimensioni		Caratteristiche fisiche			Pressione			Valori finali o a rottura				
	H _o cm	ϕ cm	γ kN/m ³	γ _s	w	S _o %	σ ₃ kPa	u _o kPa	σ' ₃ kPa	δ _f %	σ _t -σ ₃ kPa	σ _t +σ ₃ 2 kPa	σ _t -σ ₃ 2 kPa
1	7,62	3,81	18,6	0,00	28,1	0,0	500	300	200	9,6	152	276	76
2	7,62	3,81	18,6	0,00	28,7	0,0	600	300	300	12,9	162	381	81
3	7,62	3,81	18,6	0,00	27,7	0,0	700	300	400	11,2	175	488	88

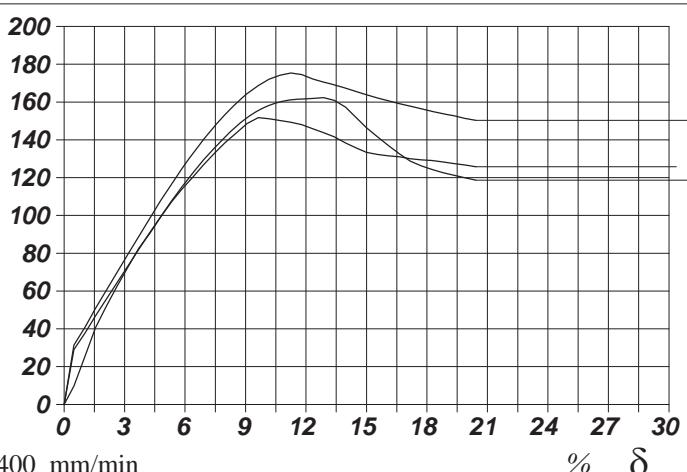
H_o ϕ - Altezza e diametro provini
w - Umidità dei provini

γ γ_s - Peso di volume e peso specifico
S_o - Grado di saturazione iniziale

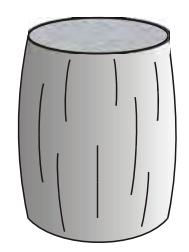
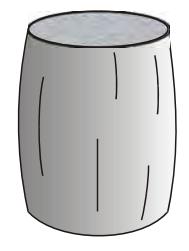
σ₃ - Pressione di cella
u_o - Back pressure

δ_f - Deformazione a rottura
σ_t σ₃ - Tensioni totali

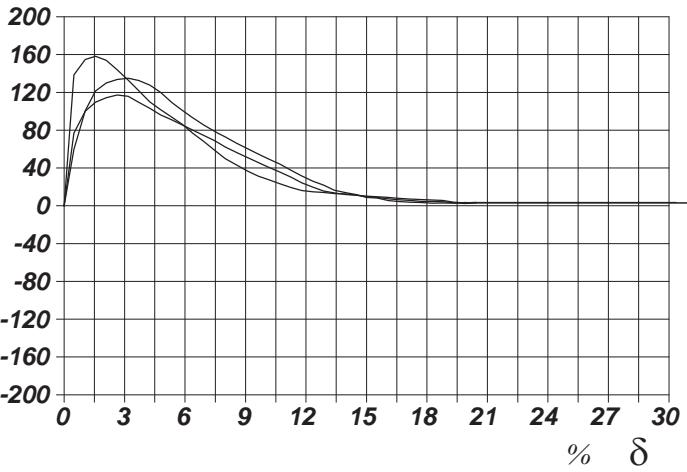
σ_t-σ₃
kPa



Tipo di rottura



ΔV
%



CERTIFICATO DI PROVA N°: 01246 Pagina 3/3
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

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RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C4

PROFONDITA': m 15,30-15,85

PROVA DI COMPRESSIONE TRIASSIALE U.U.

Modalità di prova: Norma ASTM D 2850

PROVINO 1				PROVINO 2				PROVINO 3			
δ mm	δ %	σ _I -σ ₃ kPa	Δv kPa	δ mm	δ %	σ _I -σ ₃ kPa	Δv kPa	δ mm	δ %	σ _I -σ ₃ kPa	Δv kPa
0,37	0,49	9,7	77,0	0,37	0,49	28,9	59,5	0,37	0,49	31,4	138,6
0,80	1,05	25,9	100,1	0,80	1,05	38,0	100,6	0,80	1,05	41,1	154,9
1,19	1,56	40,6	109,6	1,19	1,56	46,9	121,6	1,19	1,56	50,8	158,2
1,59	2,09	51,9	114,3	1,59	2,09	55,8	130,0	1,59	2,09	60,4	154,0
2,01	2,63	62,6	117,3	2,01	2,63	64,5	133,7	2,01	2,63	69,9	144,0
2,42	3,17	72,8	115,9	2,42	3,17	73,3	135,1	2,42	3,17	79,4	133,0
2,81	3,69	82,5	109,7	2,81	3,69	82,1	132,7	2,81	3,69	88,9	122,0
3,24	4,25	90,5	103,2	3,24	4,25	90,9	127,7	3,24	4,25	98,5	110,0
3,65	4,78	99,0	96,3	3,65	4,78	99,4	120,1	3,65	4,78	107,7	101,7
4,07	5,34	107,3	91,1	4,07	5,34	107,6	109,5	4,07	5,34	116,6	93,8
4,47	5,86	114,1	85,6	4,47	5,86	115,4	101,2	4,47	5,86	125,0	86,3
4,88	6,40	120,4	80,1	4,88	6,40	122,6	92,9	4,88	6,40	132,9	76,6
5,27	6,92	126,8	74,5	5,27	6,92	129,4	85,7	5,27	6,92	140,2	68,4
5,69	7,46	133,0	69,0	5,69	7,46	135,7	78,8	5,69	7,46	147,1	58,8
6,09	7,99	138,7	62,1	6,09	7,99	141,8	72,9	6,09	7,99	153,6	49,8
6,52	8,55	143,7	56,2	6,52	8,55	147,2	66,2	6,52	8,55	159,4	43,2
6,92	9,08	148,6	51,4	6,92	9,08	151,8	60,8	6,92	9,08	164,4	37,0
7,34	9,63	151,8	45,8	7,34	9,63	155,7	54,8	7,34	9,63	168,7	31,4
7,74	10,16	151,2	40,5	7,74	10,16	158,3	49,3	7,74	10,16	172,1	27,5
8,16	10,71	150,3	35,6	8,16	10,71	160,0	44,0	8,16	10,71	174,2	23,2
8,57	11,25	149,4	30,3	8,57	11,25	161,0	37,8	8,57	11,25	175,4	19,4
8,98	11,79	148,0	24,3	8,98	11,79	161,6	31,5	8,98	11,79	174,5	16,1
9,41	12,35	145,8	19,6	9,41	12,35	162,0	26,0	9,41	12,35	172,2	14,8
9,81	12,87	143,8	15,6	9,81	12,87	162,4	21,9	9,81	12,87	170,6	14,2
10,21	13,40	141,6	13,6	10,21	13,40	160,9	16,4	10,21	13,40	169,0	12,9
10,63	13,95	138,4	11,9	10,63	13,95	157,4	14,0	10,63	13,95	167,5	12,6
11,03	14,48	135,8	11,2	11,03	14,48	151,9	11,9	11,03	14,48	165,5	11,2
11,43	15,00	133,4	10,2	11,43	15,00	146,4	8,8	11,43	15,00	164,0	9,5
11,84	15,54	132,4	9,5	11,84	15,54	141,7	8,2	11,84	15,54	162,2	8,8
12,26	16,09	131,5	8,8	12,26	16,09	137,0	5,4	12,26	16,09	160,7	7,4
12,68	16,64	131,0	7,7	12,68	16,64	132,6	4,4	12,68	16,64	159,1	6,4
13,09	17,17	130,0	7,0	13,09	17,17	128,7	3,7	13,09	17,17	157,9	5,7
13,51	17,73	129,4	6,7	13,51	17,73	126,2	3,4	13,51	17,73	156,3	4,6
13,90	18,25	129,1	6,0	13,90	18,25	124,4	2,7	13,90	18,25	155,0	4,6
14,32	18,79	128,3	5,6	14,32	18,79	122,7	3,1	14,32	18,79	154,0	4,2
14,73	19,32	127,5	3,9	14,73	19,32	121,3	2,7	14,73	19,32	152,8	3,2
15,15	19,88	126,7	3,2	15,15	19,88	119,9	3,4	15,15	19,88	151,4	2,5
15,56	20,42	125,8	3,5	15,56	20,42	118,7	3,1	15,56	20,42	150,4	2,8

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C5

PROFONDITA': m 6,00-6,30

MODULO RIASSUNTIVO

CARATTERISTICHE FISICHE

Peso specifico	2,61
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ANALISI GRANULOMETRICA

Ghiaia	%
Sabbia	44,1
Limo	32,8
Argilla	23,1

FOTOGRAFIA



Posizione delle prove	cm	Rp kPa	VT kPa	cm	DESCRIZIONE DEL CAMPIONE
	0				Sabbia (m) argillosa con limo, di colore grigio. Reagente all'HCl
	5				MUNSELL SOIL COLOR CHARTS: Gley 1 Dark Greenish Gray 4/1 10GY
	10				
	15				
	20				
	25				
	30				
					Qualità del campione: Q2

CERTIFICATO DI PROVA N°: 01247 Pagina 1/1
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 17/05/18
Apertura campione: 08/05/18 Fine analisi: 18/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 **CAMPIONE:** C5 **PROFONDITA': m** 6,00-6,30

PESO SPECIFICO DEI GRANULI

Modalità di prova: Norma ASTM D 854

$$\gamma_s = \text{Peso specifico dei granuli (media delle due misure)} = 2,61$$

$$\gamma_{sc} = \text{Peso specifico dei granuli corretto a } 20^\circ = 2,61$$

Metodo: A B

Capacità del picnometro: 100 ml

Temperatura di prova: 20,8 °C

Dimensione massima delle particelle: 2,00 mm

Disaerazione eseguita per bollitura e sotto vuoto

CERTIFICATO DI PROVA N°: 01248 Pagina 1/1
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 08/05/18
Apertura campione: 08/05/18 Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

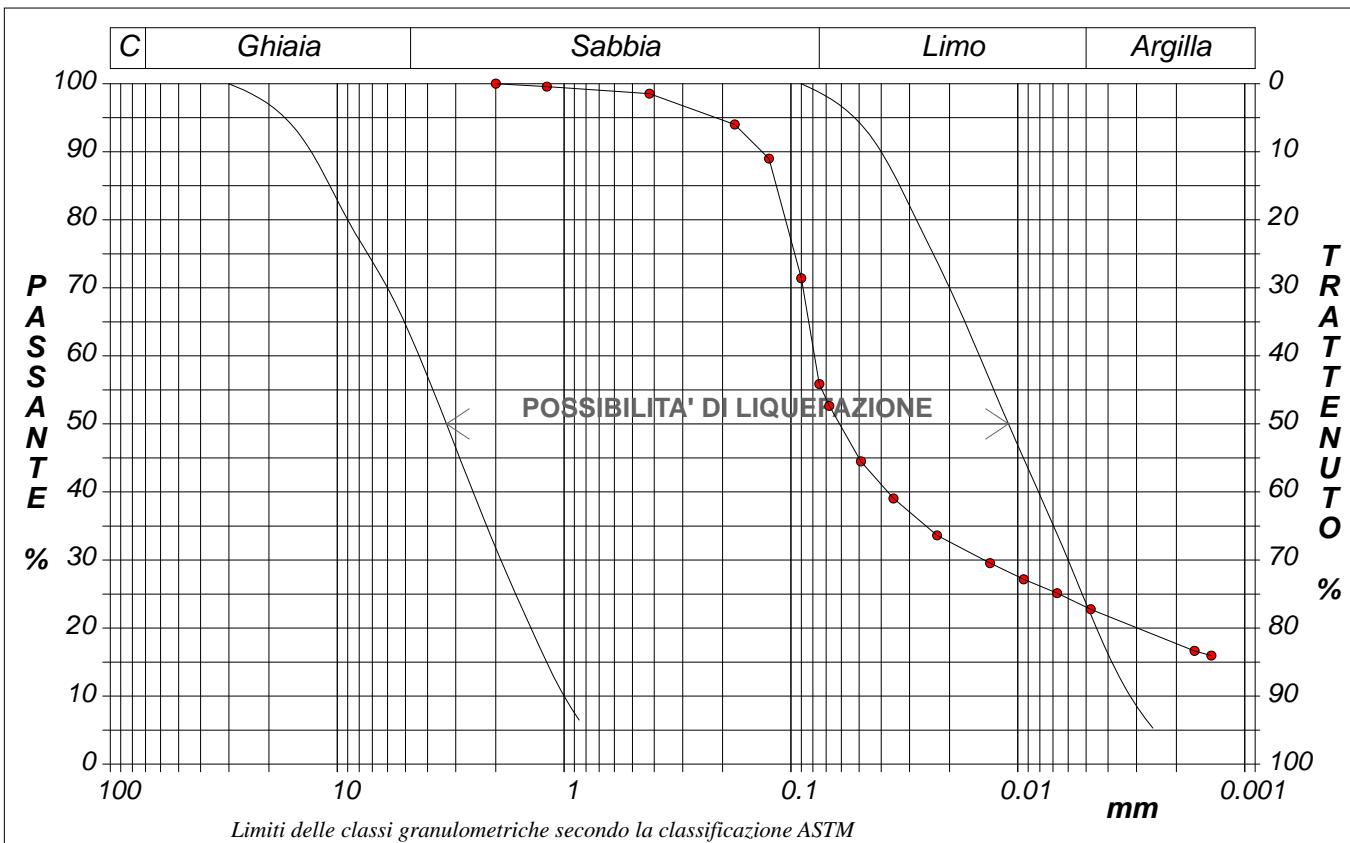
CAMPIONE: C5

PROFONDITA': m 6,00-6,30

ANALISI GRANULOMETRICA

Modalità di prova: Norma ASTM D 422

Ghiaia	0,0 %	Passante setaccio 10 (2 mm)	100,0 %	D ₁₀	0,00031 mm	
Sabbia	44,1 %	Passante setaccio 40 (0.42 mm)	98,3 %	D ₃₀	0,01407 mm	
Limo	32,8 %	Passante setaccio 200 (0.075 mm)	55,9 %	D ₅₀	0,06106 mm	
Argilla	23,1 %			D ₆₀	0,07873 mm	
Coefficiente di uniformità		251,14	Coefficiente di curvatura	8,02	D ₉₀	0,13409 mm



Diametro mm	Passante %								
2,0000	100,00	0,0900	71,41	0,0227	33,62	0,0017	16,64		
1,1900	99,58	0,0750	55,86	0,0133	29,55	0,0014	15,96		
0,4200	98,54	0,0678	52,64	0,0094	27,17				
0,1770	94,00	0,0491	44,49	0,0067	25,13				
0,1250	88,99	0,0353	39,06	0,0048	22,76				

CERTIFICATO DI PROVA N°: 01248

Allegato 1

VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18

Inizio analisi: 08/05/18

Apertura campione: 08/05/18

Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C5

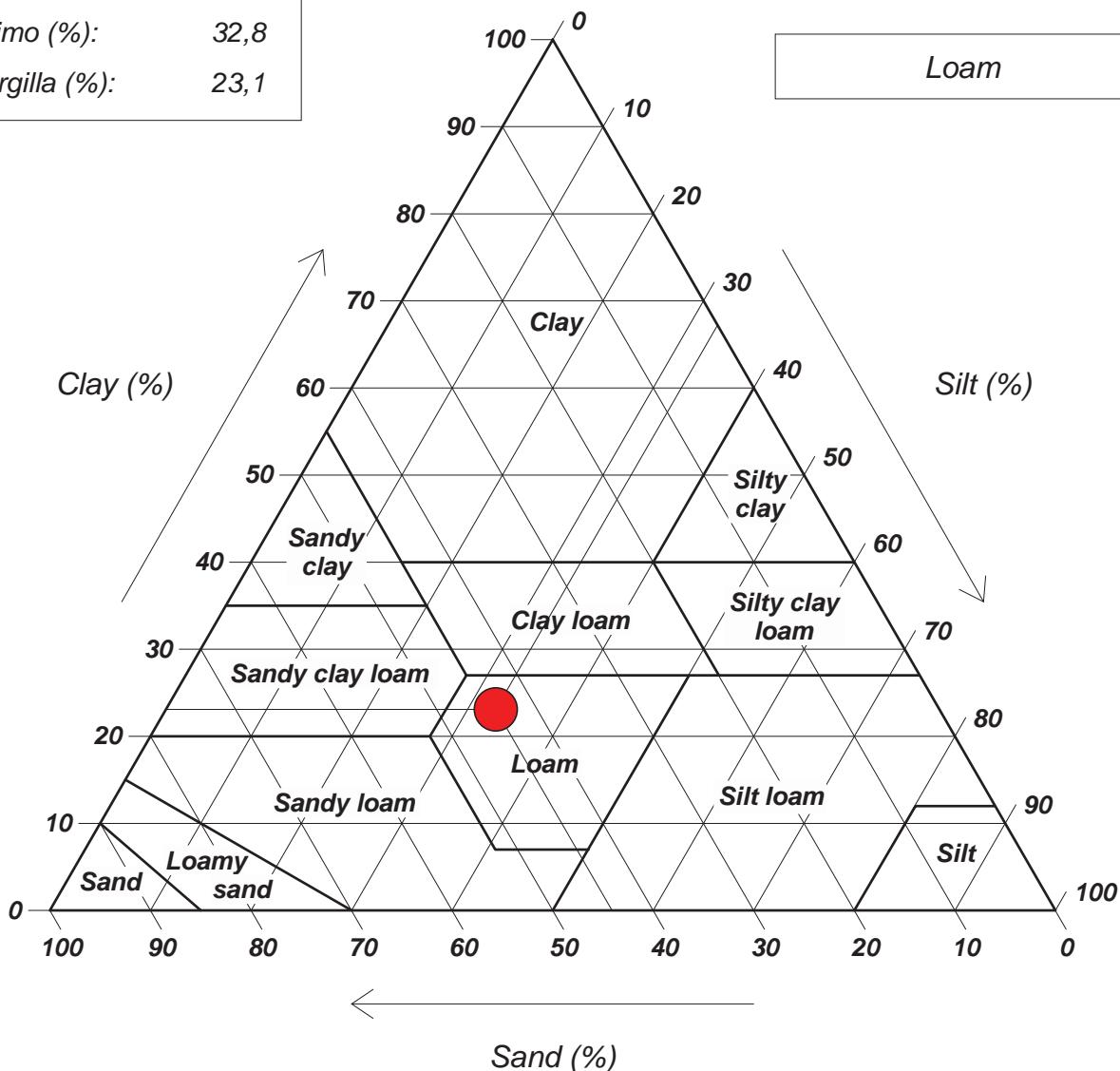
PROFONDITA': m 6,00-6,30

ANALISI GRANULOMETRICA - GRAFICO TRIANGOLARE

Modalità di prova: Norma ASTM D 422

Sabbia (%):	44,1
Limo (%):	32,8
Argilla (%):	23,1

Diagramma U.S.D.A.



COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C6

PROFONDITÀ: m 9,80-10,00

MODULO RIASSUNTIVO

CARATTERISTICHE FISICHE

Peso specifico

2,62

ANALISI GRANULOMETRICA

Ghiaia	%
Sabbia	11,9 %
Limo	71,7 %
Argilla	16,4 %

FOTOGRAFIA



Posizione delle prove	cm	Rp kPa	VT kPa	cm	DESCRIZIONE DEL CAMPIONE
	0				Limo argilloso e sabbioso (m/f), di colore grigio. Reagente all'HCl
	5				
	10				MUNSELL SOIL COLOR CHARTS: Gley 1 Dark Greenish Gray 4/1 10GY
	15				
	20				Qualità del campione: Q2

CERTIFICATO DI PROVA N°: 01249 Pagina 1/1
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 17/05/18
Apertura campione: 08/05/18 Fine analisi: 18/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 **CAMPIONE:** C6 **PROFONDITA': m** 9,80-10,00

PESO SPECIFICO DEI GRANULI

Modalità di prova: Norma ASTM D 854

$$\gamma_s = \text{Peso specifico dei granuli (media delle due misure)} = 2,62$$

$$\gamma_{sc} = \text{Peso specifico dei granuli corretto a } 20^\circ = 2,62$$

Metodo: A B

Capacità del picnometro: 100 ml

Temperatura di prova: 20,7 °C

Dimensione massima delle particelle: 2,00 mm

Disaerazione eseguita per bollitura e sotto vuoto

CERTIFICATO DI PROVA N°: 01250 Pagina 1/1
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 08/05/18
Apertura campione: 08/05/18 Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

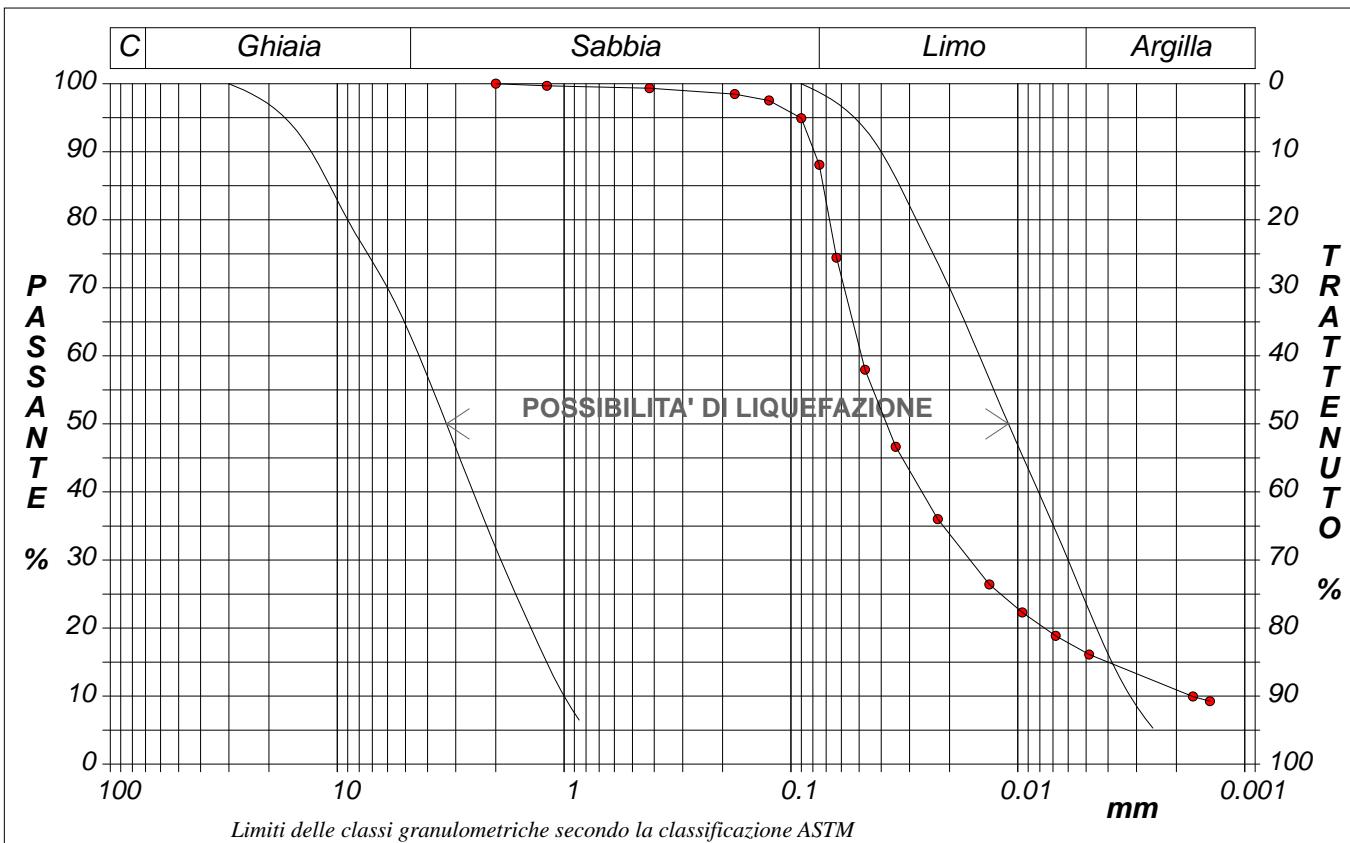
CAMPIONE: C6

PROFONDITA': m 9,80-10,00

ANALISI GRANULOMETRICA

Modalità di prova: Norma ASTM D 422

Ghiaia	0,0 %	Passante setaccio 10 (2 mm)	100,0 %	D ₁₀	0,00171 mm	
Sabbia	11,9 %	Passante setaccio 40 (0.42 mm)	99,3 %	D ₃₀	0,01624 mm	
Limo	71,7 %	Passante setaccio 200 (0.075 mm)	88,1 %	D ₅₀	0,03787 mm	
Argilla	16,4 %			D ₆₀	0,04885 mm	
Coefficiente di uniformità		28,64	Coefficiente di curvatura	3,17	D ₉₀	0,07893 mm



Diametro mm	Passante %								
2,0000	100,00	0,0900	94,92	0,0225	36,01	0,0017	9,95		
1,1900	99,69	0,0750	88,09	0,0134	26,41	0,0014	9,26		
0,4200	99,33	0,0630	74,42	0,0095	22,29				
0,1770	98,48	0,0471	57,96	0,0068	18,86				
0,1250	97,53	0,0345	46,64	0,0049	16,12				

CERTIFICATO DI PROVA N°: 01250

Allegato 1

VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18

Inizio analisi: 08/05/18

Apertura campione: 08/05/18

Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C6

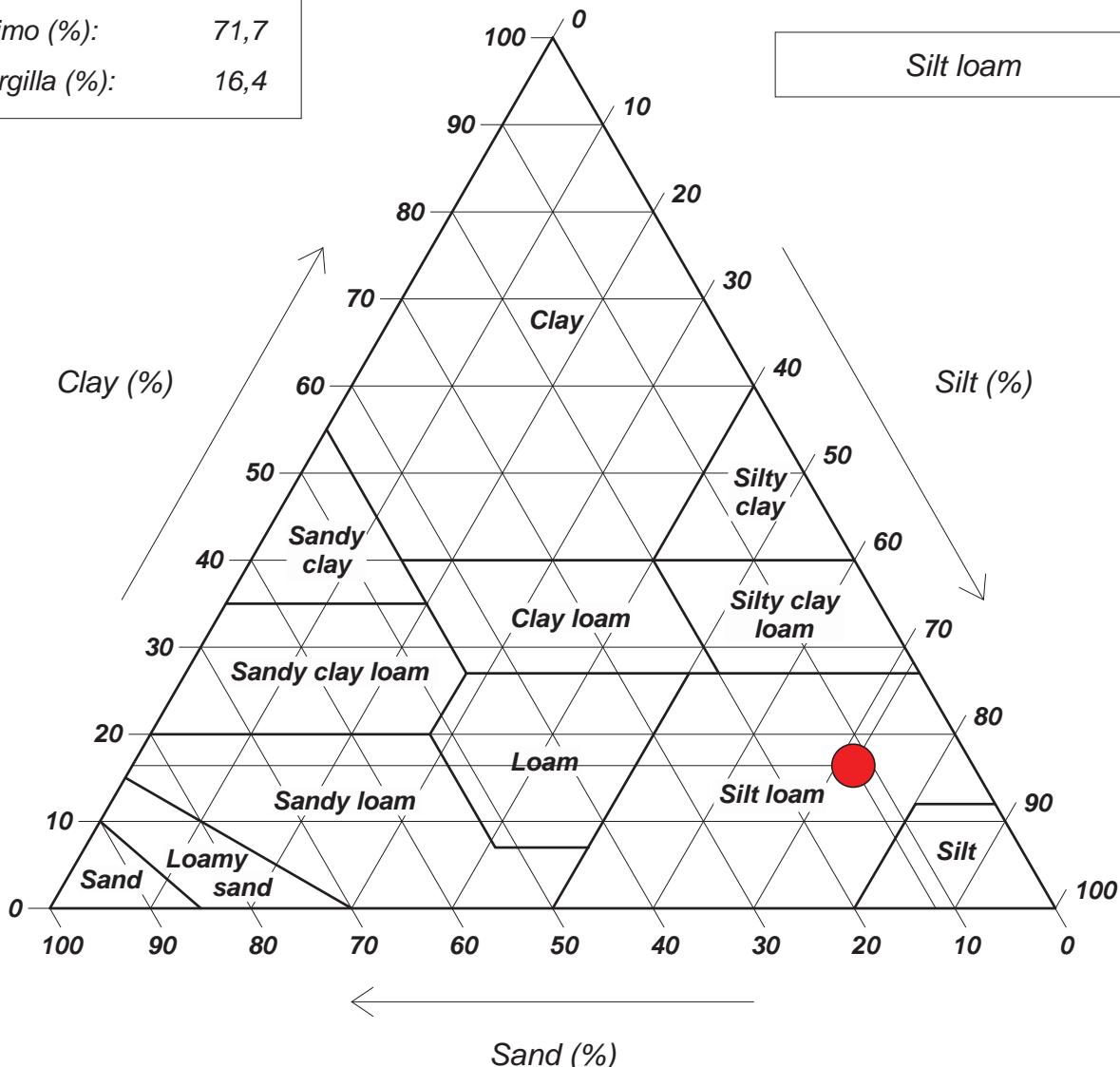
PROFONDITA': m 9,80-10,00

ANALISI GRANULOMETRICA - GRAFICO TRIANGOLARE

Modalità di prova: Norma ASTM D 422

Sabbia (%):	11,9
Limo (%):	71,7
Argilla (%):	16,4

Diagramma U.S.D.A.



COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C7

PROFONDITA': m 12,30-12,50

MODULO RIASSUNTIVO

CARATTERISTICHE FISICHE

Peso specifico	2,61
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ANALISI GRANULOMETRICA

Ghiaia	%
Sabbia	65,9
Limo	18,2
Argilla	15,9

FOTOGRAFIA



Posizione delle prove	cm	Rp kPa	VT kPa	cm	DESCRIZIONE DEL CAMPIONE
	0				Sabbia (m/f) limosa e argillosa, di colore grigio. Reagente all'HCl
	5				MUNSELL SOIL COLOR CHARTS: Gley 1 Dark Greenish Gray 4/1 10GY
	10				
	15				
	20				Qualità del campione: Q5

CERTIFICATO DI PROVA N°: 01251 Pagina 1/1
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 17/05/18
Apertura campione: 08/05/18 Fine analisi: 18/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 **CAMPIONE:** C7 **PROFONDITA': m** 12,30-12,50

PESO SPECIFICO DEI GRANULI

Modalità di prova: Norma ASTM D 854

$$\gamma_s = \text{Peso specifico dei granuli (media delle due misure)} = 2,61$$

$$\gamma_{sc} = \text{Peso specifico dei granuli corretto a } 20^\circ = 2,61$$

Metodo: A B

Capacità del picnometro: 100 ml

Temperatura di prova: 20,5 °C

Dimensione massima delle particelle: 1,00 mm

Disaerazione eseguita per bollitura e sotto vuoto

CERTIFICATO DI PROVA N°: 01252 Pagina 1/1
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 08/05/18
Apertura campione: 08/05/18 Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

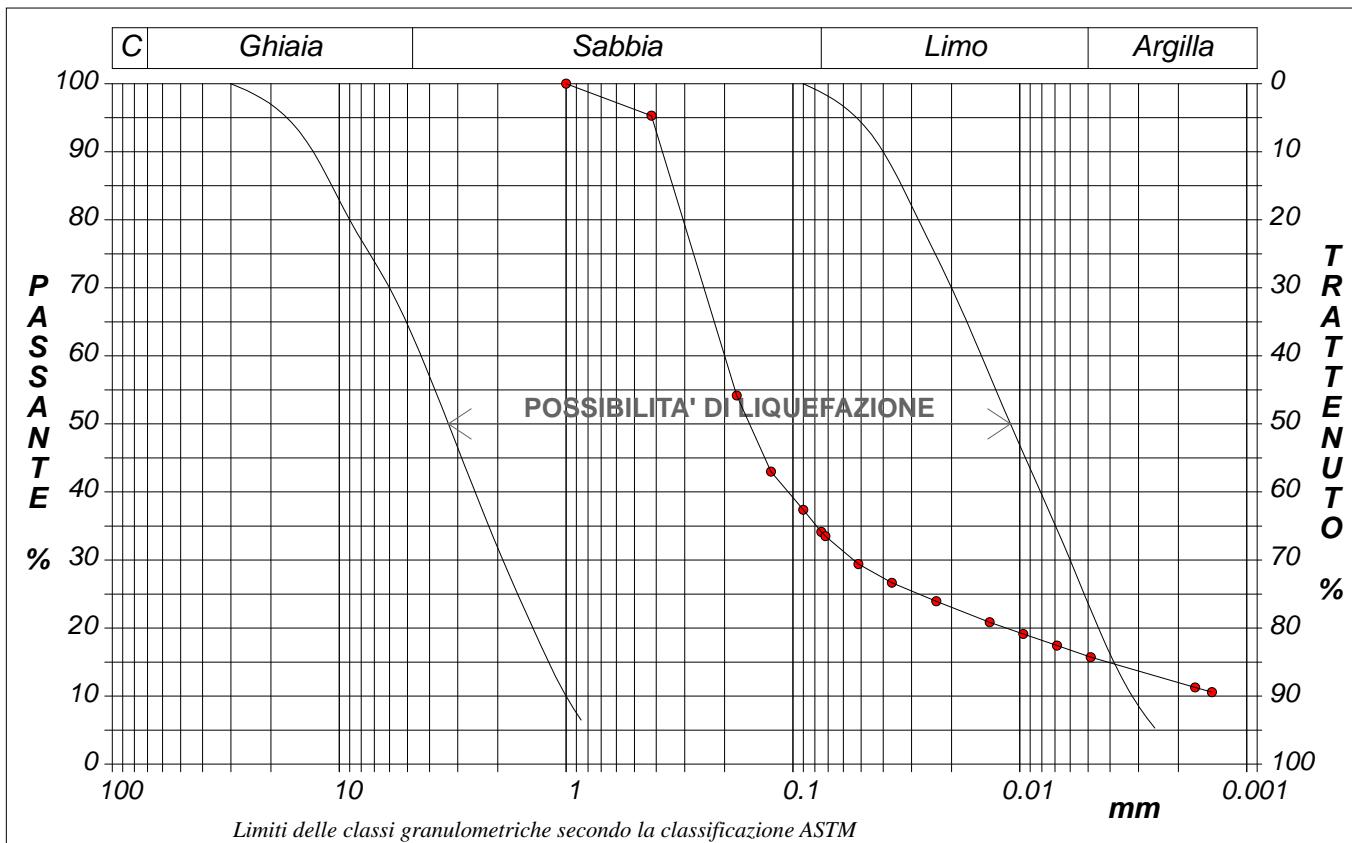
RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 CAMPIONE: C7 PROFONDITA': m 12,30-12,50

ANALISI GRANULOMETRICA

Modalità di prova: Norma ASTM D 422

Ghiaia	0,0 %	Passante setaccio 10 (2 mm)	100,0 %	D ₁₀	0,00123 mm	
Sabbia	65,9 %	Passante setaccio 40 (0.42 mm)	93,0 %	D ₃₀	0,05402 mm	
Limo	18,2 %	Passante setaccio 200 (0.075 mm)	34,1 %	D ₅₀	0,15540 mm	
Argilla	15,9 %			D ₆₀	0,20000 mm	
Coefficiente di uniformità		163,08	Coefficiente di curvatura	11,90	D ₉₀	0,37571 mm



Diametro mm	Passante %								
1,0000	100,00	0,0750	34,13	0,0136	20,85	0,0014	10,60		
0,4200	95,30	0,0719	33,50	0,0097	19,14				
0,1770	54,19	0,0514	29,40	0,0069	17,44				
0,1250	43,00	0,0366	26,67	0,0049	15,73				
0,0900	37,39	0,0233	23,93	0,0017	11,28				

CERTIFICATO DI PROVA N°: 01252

Allegato 1

VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18

Inizio analisi: 08/05/18

Apertura campione: 08/05/18

Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C7

PROFONDITA': m 12,30-12,50

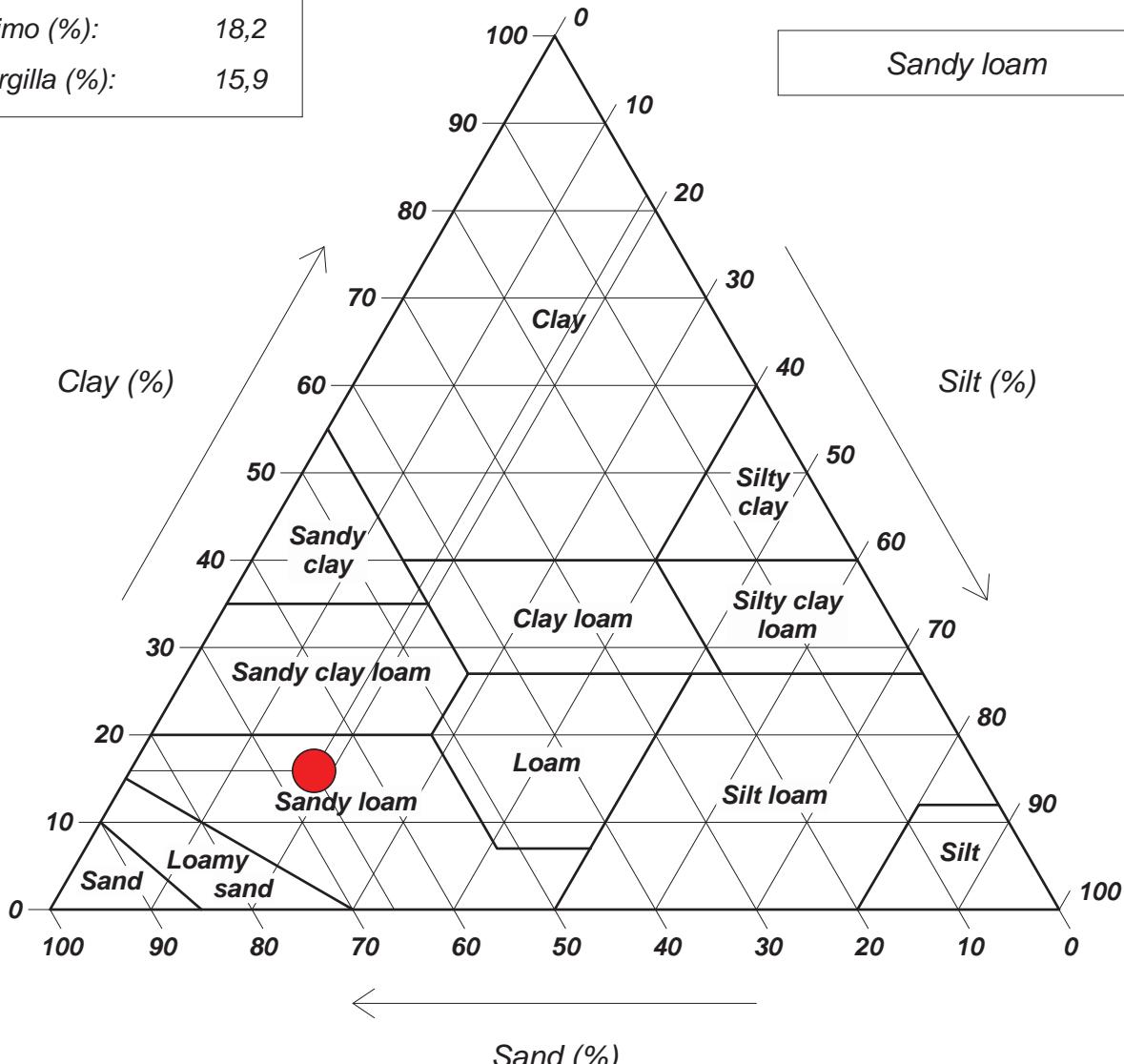
ANALISI GRANULOMETRICA - GRAFICO TRIANGOLARE

Modalità di prova: Norma ASTM D 422

Sabbia (%):	65,9
Limo (%):	18,2
Argilla (%):	15,9

Diagramma U.S.D.A.

Sandy loam



COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C8

PROFONDITA': m 16,60-16,80

MODULO RIASSUNTIVO

CARATTERISTICHE FISICHE

Peso specifico	2,58
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ANALISI GRANULOMETRICA

Ghiaia	%
Sabbia	57,4
Limo	19,9
Argilla	22,7

FOTOGRAFIA



Posizione delle prove	cm	Rp kPa	VT kPa	cm	DESCRIZIONE DEL CAMPIONE
	0				Sabbia (m) argillosa e limosa, di colore grigio. Reagente all'HCl
	5				MUNSELL SOIL COLOR CHARTS: Gley 1 Dark Greenish Gray 4/1 10GY
	10				
	15				Qualità del campione: Q2
	20				

CERTIFICATO DI PROVA N°: 01253 Pagina 1/1
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 17/05/18
Apertura campione: 08/05/18 Fine analisi: 18/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 CAMPIONE: C8 PROFONDITA': m 16,60-16,80

PESO SPECIFICO DEI GRANULI

Modalità di prova: Norma ASTM D 854

$$\gamma_s = \text{Peso specifico dei granuli (media delle due misure)} = 2,58$$

$$\gamma_{sc} = \text{Peso specifico dei granuli corretto a } 20^\circ = 2,58$$

Metodo: A B

Capacità del picnometro: 100 ml

Temperatura di prova: 20,6 °C

Dimensione massima delle particelle: 4,00 mm

Disaerazione eseguita per bollitura e sotto vuoto

CERTIFICATO DI PROVA N°: 01254

Pagina 1/1

VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18

Inizio analisi: 08/05/18

Apertura campione: 08/05/18

Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

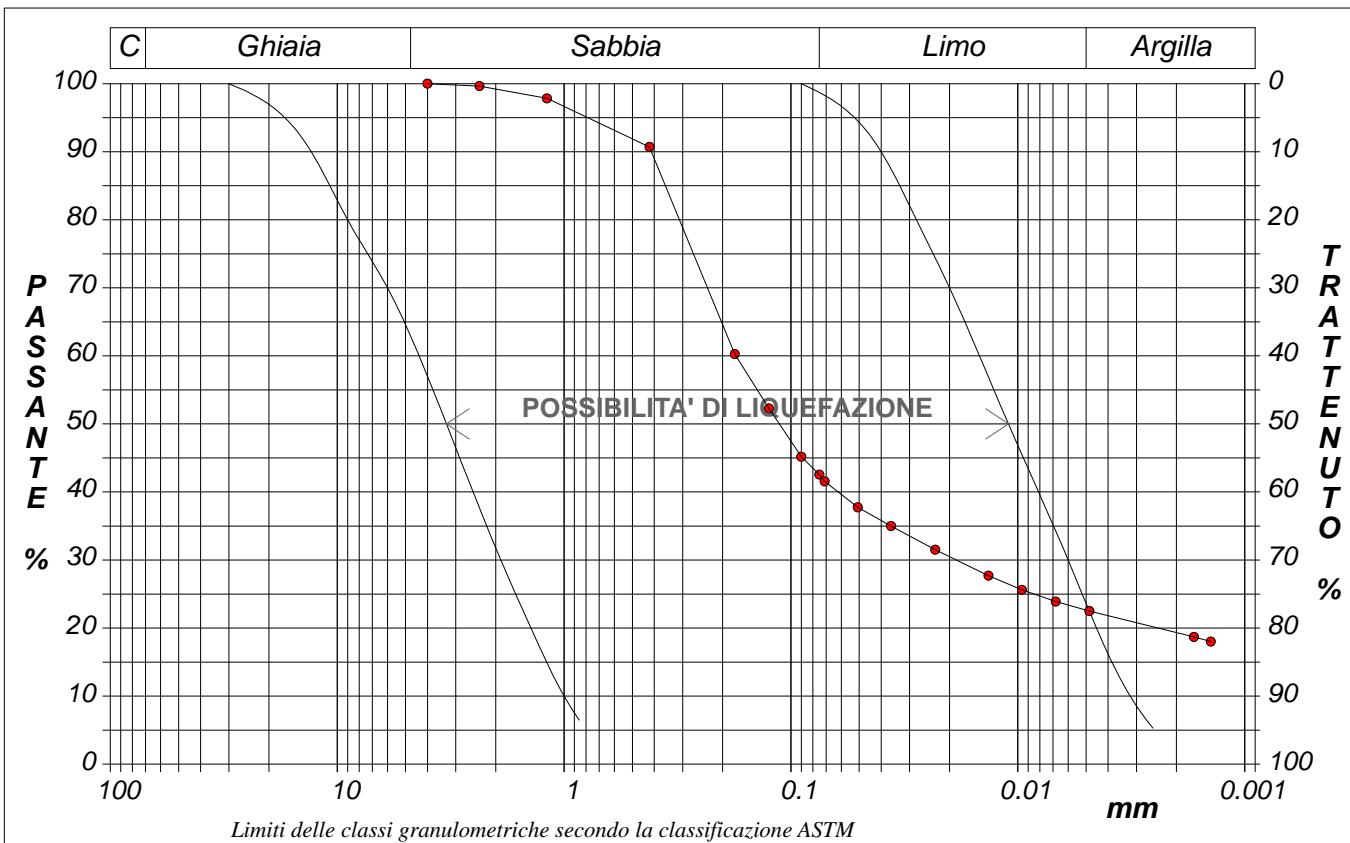
CAMPIONE: C8

PROFONDITA': m 16,60-16,80

ANALISI GRANULOMETRICA

Modalità di prova: Norma ASTM D 422

Ghiaia	0,0 %	Passante setaccio 10 (2 mm)	99,2 %	D ₁₀	0,00020 mm	
Sabbia	57,4 %	Passante setaccio 40 (0.42 mm)	89,0 %	D ₃₀	0,01864 mm	
Limo	19,9 %	Passante setaccio 200 (0.075 mm)	42,6 %	D ₅₀	0,11249 mm	
Argilla	22,7 %			D ₆₀	0,17493 mm	
Coefficiente di uniformità		892,00	Coefficiente di curvatura	10,13	D ₉₀	0,41164 mm



Diametro mm	Passante %								
4,0000	100,00	0,1250	52,28	0,0362	34,98	0,0048	22,51		
2,3600	99,64	0,0900	45,18	0,0231	31,52	0,0017	18,70		
1,1900	97,85	0,0750	42,55	0,0135	27,71	0,0014	18,01		
0,4200	90,71	0,0710	41,57	0,0096	25,63				
0,1770	60,27	0,0508	37,76	0,0068	23,90				

CERTIFICATO DI PROVA N°: 01254

Allegato 1

VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18

Inizio analisi: 08/05/18

Apertura campione: 08/05/18

Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C8

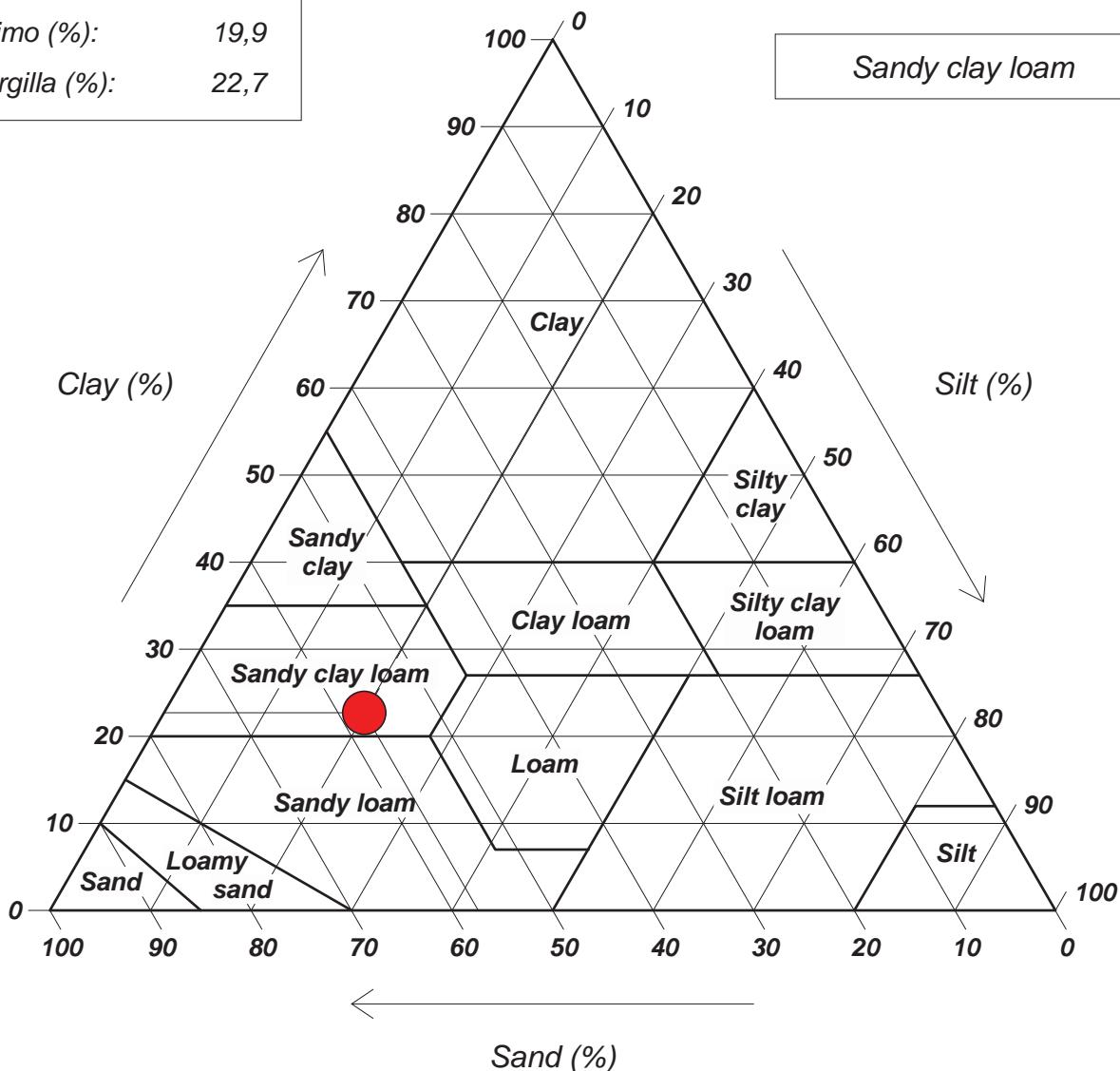
PROFONDITA': m 16,60-16,80

ANALISI GRANULOMETRICA - GRAFICO TRIANGOLARE

Modalità di prova: Norma ASTM D 422

Sabbia (%):	57,4
Limo (%):	19,9
Argilla (%):	22,7

Diagramma U.S.D.A.



COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C9

PROFONDITA': m 22,30-22,50

MODULO RIASSUNTIVO

CARATTERISTICHE FISICHE

Peso specifico	2,59
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ANALISI GRANULOMETRICA

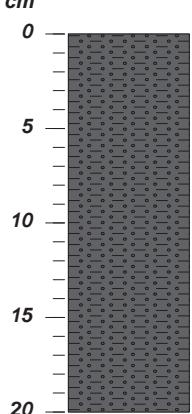
Ghiaia	0,3	%
Sabbia	80,2	%
Limo	10,5	%
Argilla	9,0	%

FOTOGRAFIA



Posizione delle prove

cm



Rp
kPa

VT
kPa

cm

DESCRIZIONE DEL CAMPIONE

Sabbia (m) limosa debolmente argillosa, di colore grigio. Reagente all'HCl

MUNSELL SOIL COLOR CHARTS: Gley 1 Dark Greenish Gray 4/1 10GY

Qualità del campione: Q2

CERTIFICATO DI PROVA N°: 01255 Pagina 1/1
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 17/05/18
Apertura campione: 08/05/18 Fine analisi: 18/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1 **CAMPIONE:** C9 **PROFONDITA': m** 22,30-22,50

PESO SPECIFICO DEI GRANULI

Modalità di prova: Norma ASTM D 854

$$\gamma_s = \text{Peso specifico dei granuli (media delle due misure)} = 2,59$$

$$\gamma_{sc} = \text{Peso specifico dei granuli corretto a } 20^\circ = 2,59$$

Metodo: A B

Capacità del picnometro: 100 ml

Temperatura di prova: 20,6 °C

Dimensione massima delle particelle: 6,00 mm

Disaerazione eseguita per bollitura e sotto vuoto

CERTIFICATO DI PROVA N°: 01256 Pagina 1/1
VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18 Inizio analisi: 08/05/18
Apertura campione: 08/05/18 Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

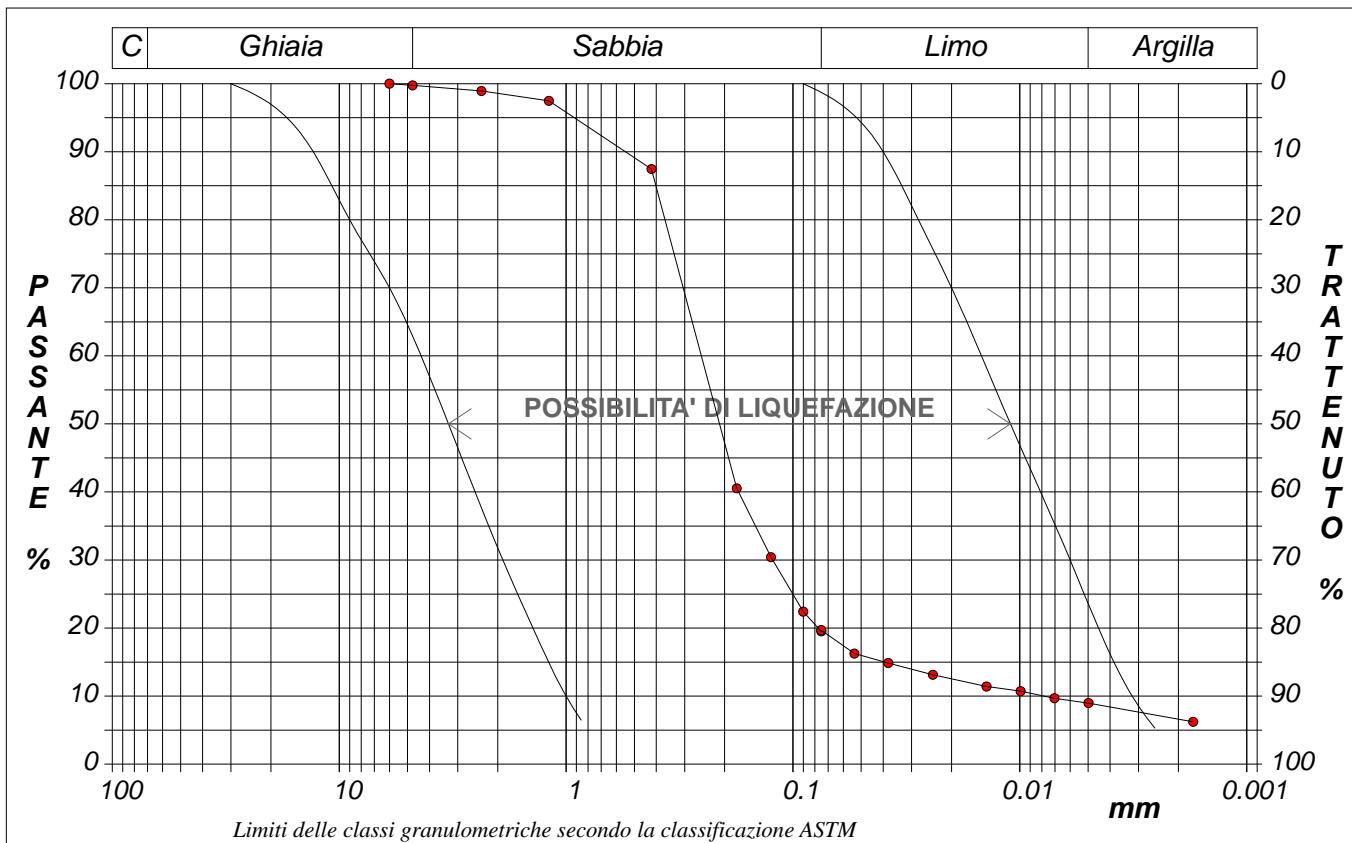
CAMPIONE: C9

PROFONDITA': m 22,30-22,50

ANALISI GRANULOMETRICA

Modalità di prova: Norma ASTM D 422

Ghiaia	0,3 %	Passante setaccio 10 (2 mm)	98,6 %	D ₁₀	0,00781 mm	
Sabbia	80,2 %	Passante setaccio 40 (0.42 mm)	84,8 %	D ₃₀	0,12288 mm	
Limo	10,5 %	Passante setaccio 200 (0.075 mm)	19,5 %	D ₅₀	0,21072 mm	
Argilla	9,0 %			D ₆₀	0,25334 mm	
Coefficiente di uniformità		32,43	Coefficiente di curvatura	7,63	D ₉₀	0,54740 mm



Diametro mm	Passante %								
6,0000	100,00	0,1770	40,53	0,0536	16,25	0,0070	9,68		
4,7500	99,75	0,1250	30,42	0,0380	14,87	0,0050	8,99		
2,3600	98,93	0,0900	22,42	0,0242	13,14	0,0017	6,22		
1,1900	97,47	0,0751	19,71	0,0140	11,41				
0,4200	87,45	0,0750	19,52	0,0099	10,72				

CERTIFICATO DI PROVA N°: 01256

Allegato 1

VERBALE DI ACCETTAZIONE N°: 116 del 07/05/18

DATA DI EMISSIONE: 21/05/18

Inizio analisi: 08/05/18

Apertura campione: 08/05/18

Fine analisi: 15/05/18

COMMITTENTE: GEO GROUP S.r.l. - Via per Modena, 12 - Castelnuovo Rangone - 41051 Modena

RIFERIMENTO: Località Chiesuol del Fosso - Via Bologna - Comune di Ferrara

SONDAGGIO: S1

CAMPIONE: C9

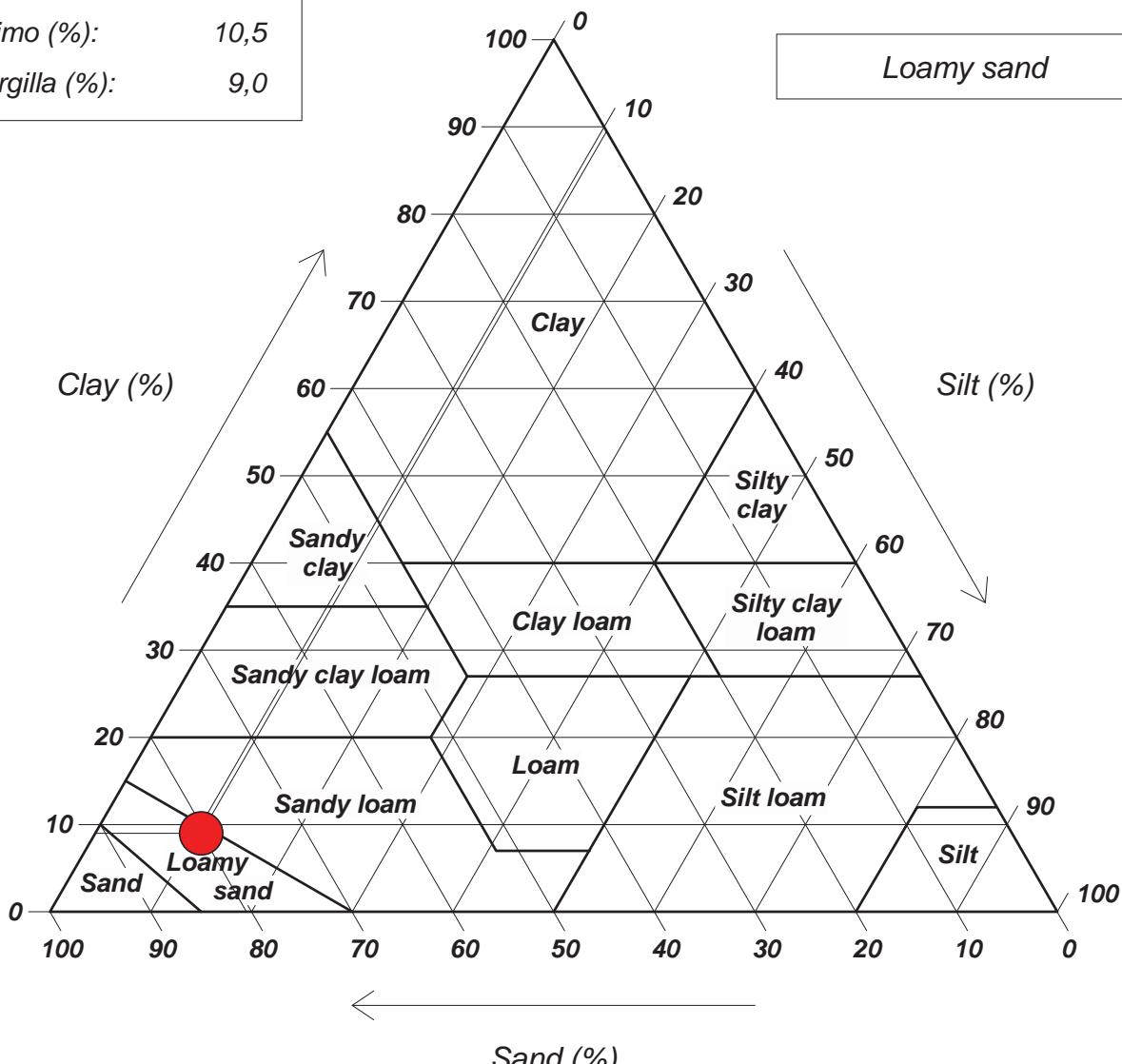
PROFONDITA': m 22,30-22,50

ANALISI GRANULOMETRICA - GRAFICO TRIANGOLARE

Modalità di prova: Norma ASTM D 422

Sabbia (%):	80,5
Limo (%):	10,5
Argilla (%):	9,0

Diagramma U.S.D.A.



G E O G R O U P s.r.l.

Indagini geognostiche e geofisiche – geologia applicata alle costruzioni – laboratorio geotecnico –
idrogeologia – coltivazione cave – bonifiche – consolidamenti – geologia ambientale – consulenze
geologiche e geotecniche



ALLEGATO 4

INDAGINI SISMICHE



GEO GROUP s.r.l.

Sede Legale: via C. Costa, 182 – 41124 Modena

Sede operativa: via per Modena, 12 – 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

p.IVA e C.F. 02981500362 – www.geogroupmodena.it - e-mail: info@geogroupmodena.it

ANALISI SISMICA DI SITO SECONDO METODOLOGIA ReMi

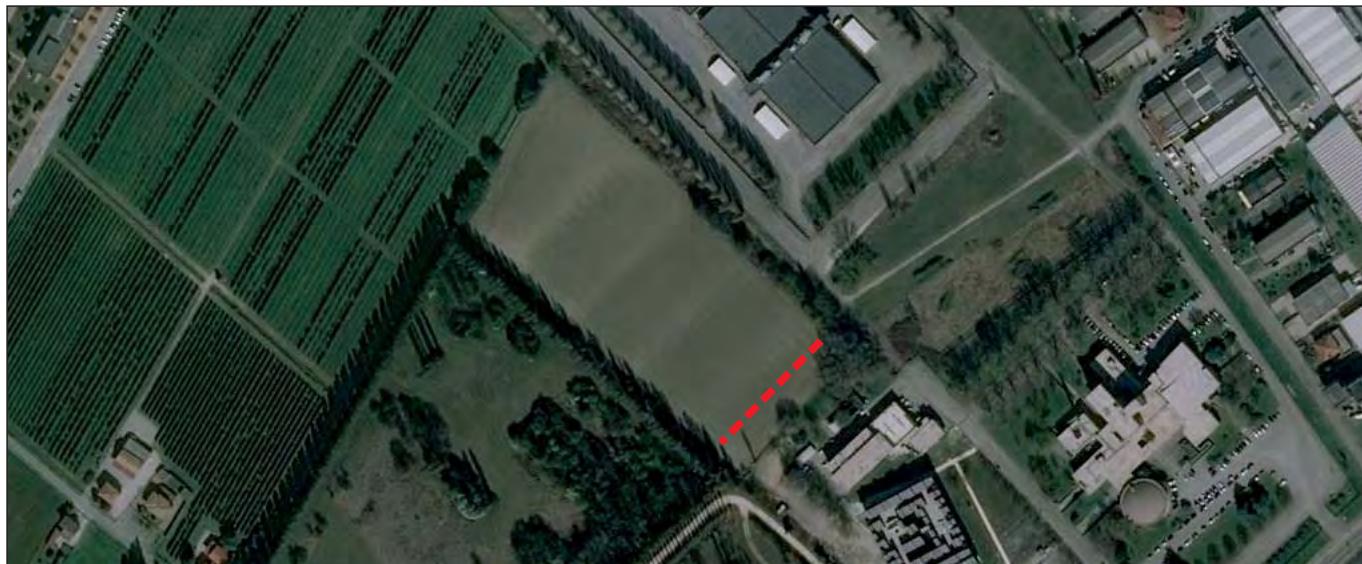
Cantiere: Ferrara (FE), Via Bologna n. 534

Data: 27/10/2017

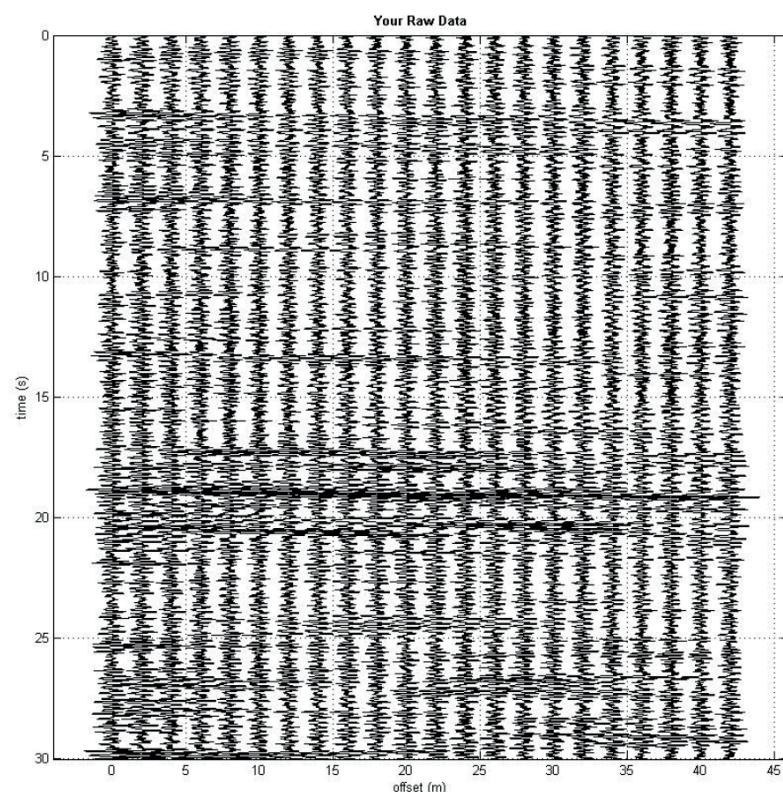
Lavoro: Studio di microzonazione sismica

Responsabile: Dott. Geol. Pier Luigi Dallari

**Re.Mi. 1
Rif. 646/17**



UBICAZIONE DELLO STENDIMENTO SISMICO IMPIEGATO





GEO GROUP s.r.l.

Sede Legale: via C. Costa, 182 – 41124 Modena

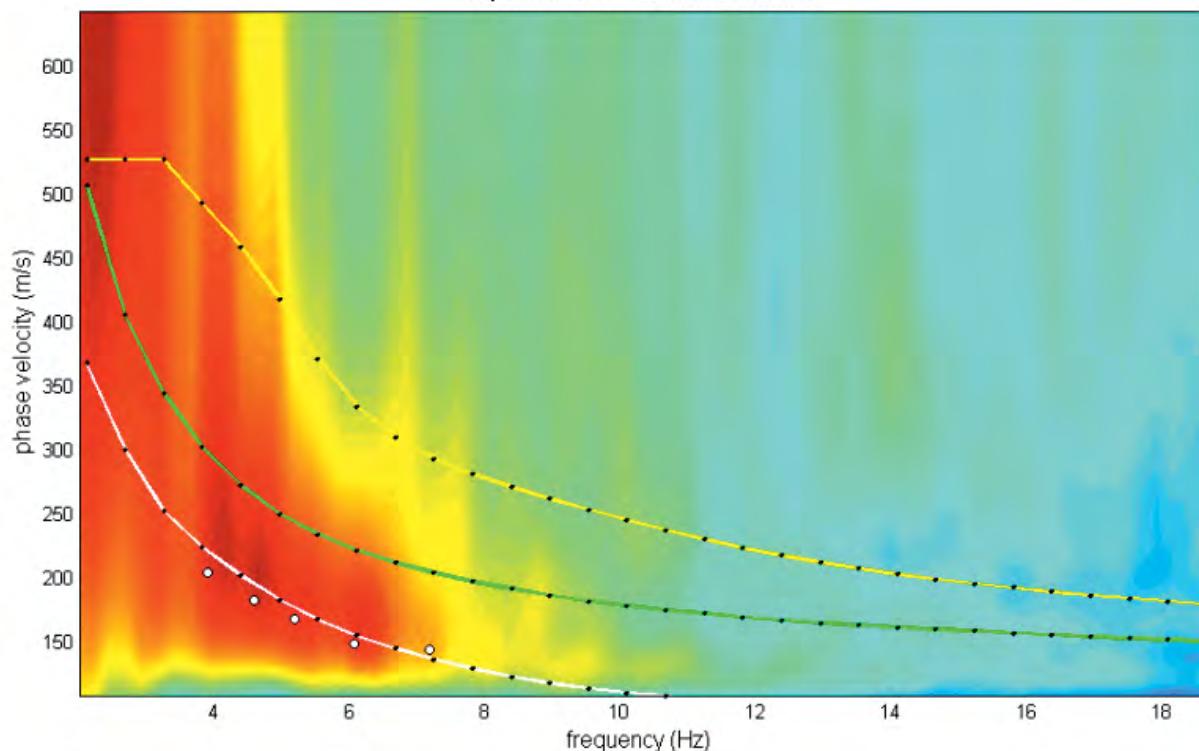
Sede operativa: via per Modena, 12 – 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

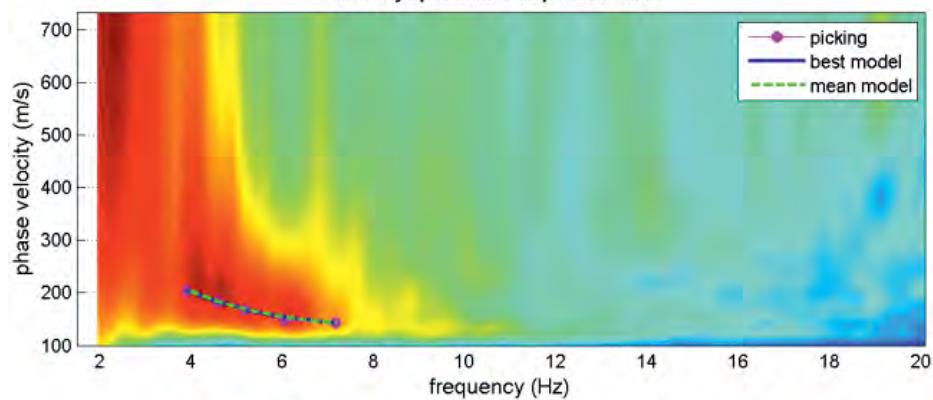
p.IVA e C.F. 02981500362 – www.geogroupmodena.it - e-mail: info@geogroupmodena.it

SPETTRO RELATIVO ALLE VELOCITA' DI FASE, REGISTRATE NEL DOMINIO DELLE FREQUENZE

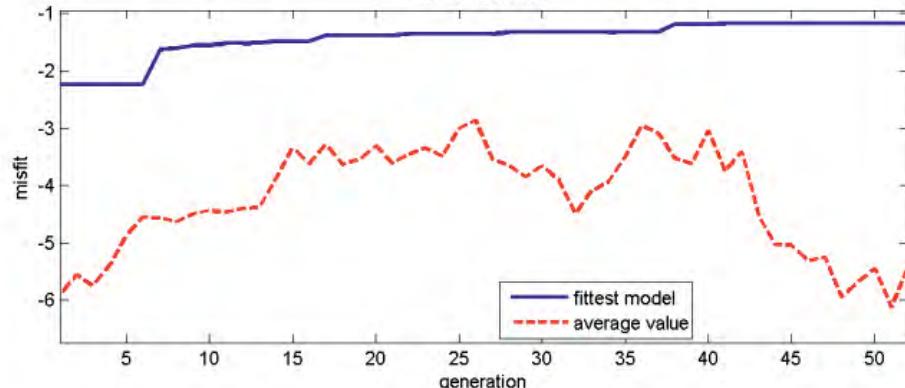
dispersion curves - model: model.mod



velocity spectrum & dispersion curve



misfit evolution





GEO GROUP s.r.l.

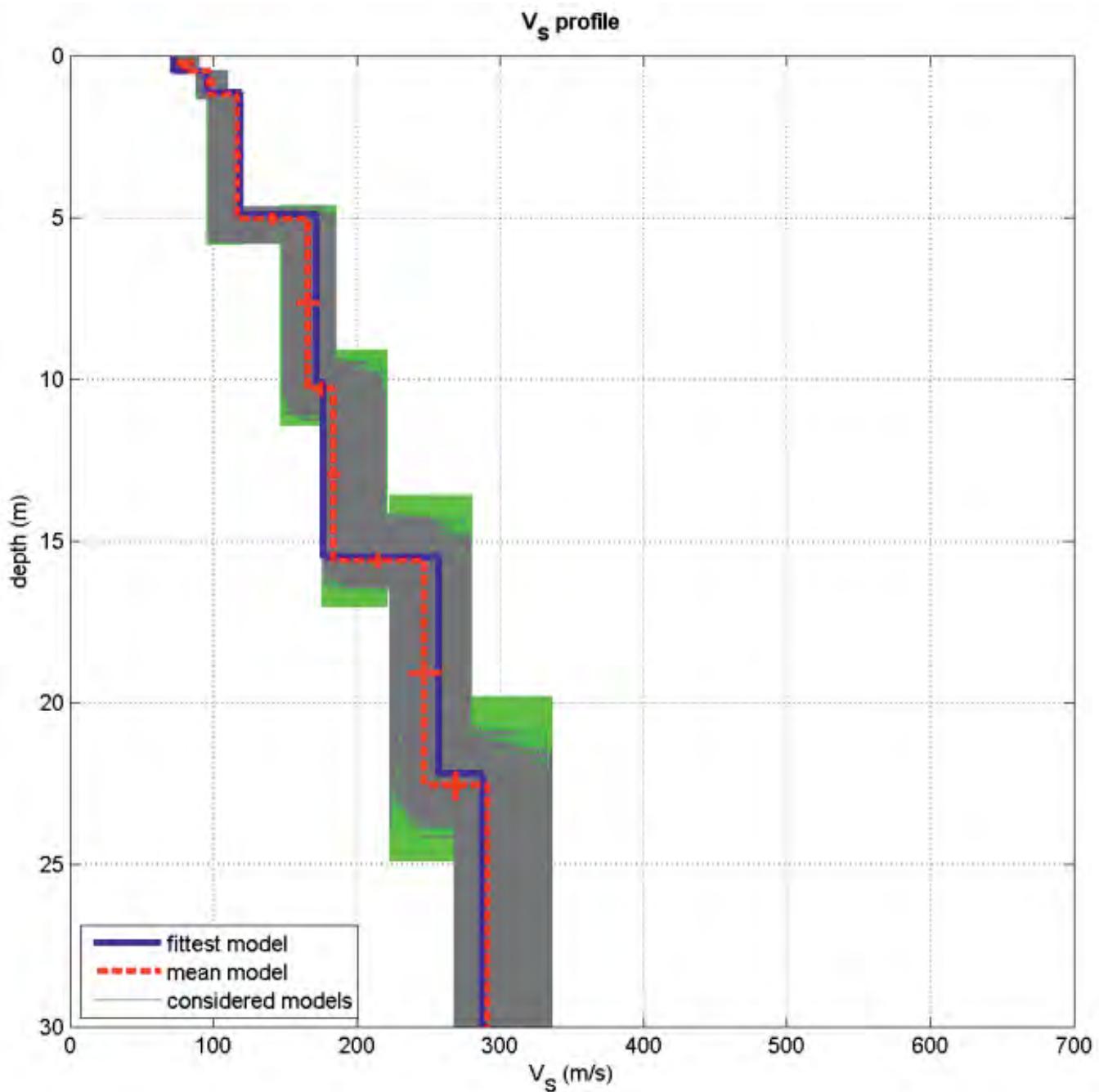
Sede Legale: via C. Costa, 182 – 41124 Modena

Sede operativa: via per Modena, 12 – 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

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MODELLO Vs30 DERIVATO DALL'INDAGINE ReMI ESEGUITA



BEST MODEL
V_{s30} = 189 m/s



GEO GROUP s.r.l.

Sede Legale: via C. Costa, 182 – 41124 Modena

Sede operativa: via per Modena, 12 – 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

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ANALISI SISMICA DI SITO SECONDO METODOLOGIA ReMi

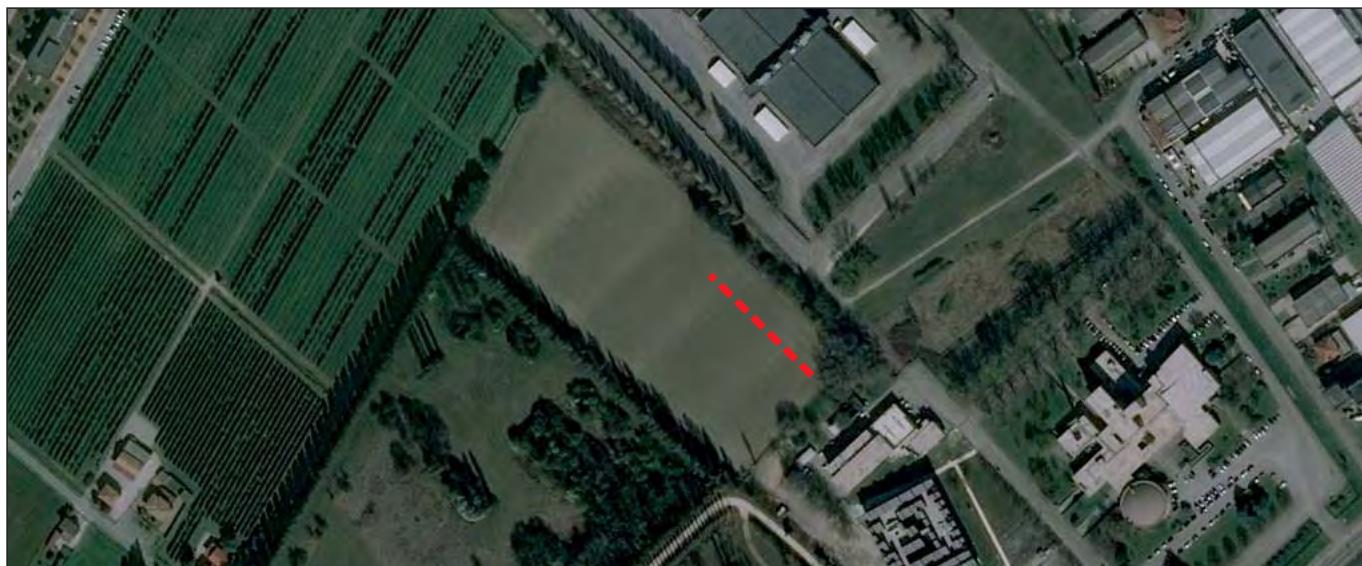
Cantiere: Ferrara (FE), Via Bologna n. 534

Data: 27/10/2017

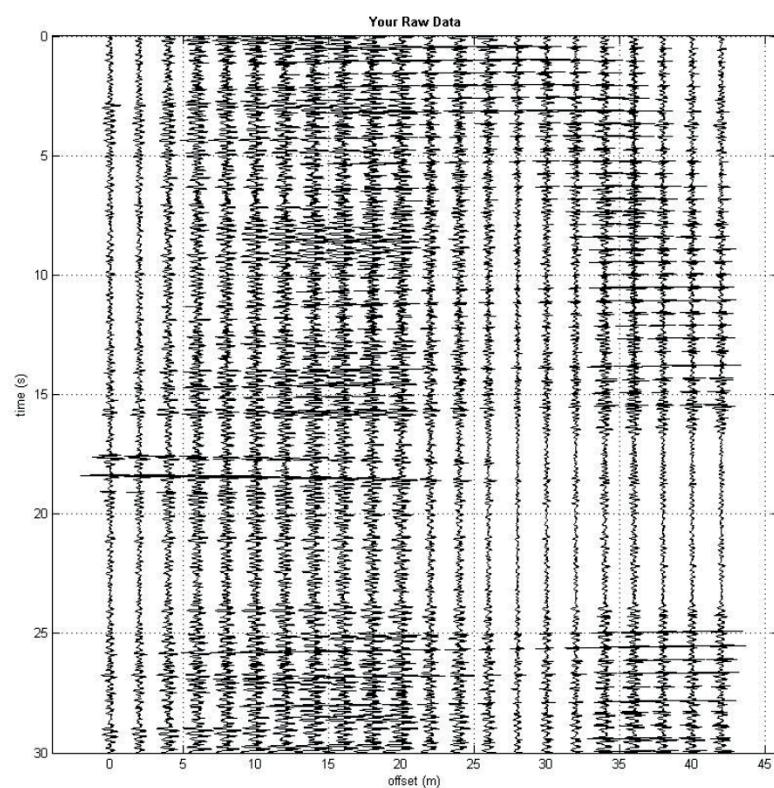
Lavoro: Studio di microzonazione sismica

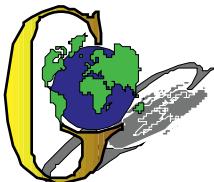
Responsabile: Dott. Geol. Pier Luigi Dallari

**Re.Mi. 2
Rif. 646/17**



UBICAZIONE DELLO STENDIMENTO SISMICO IMPIEGATO





GEO GROUP s.r.l.

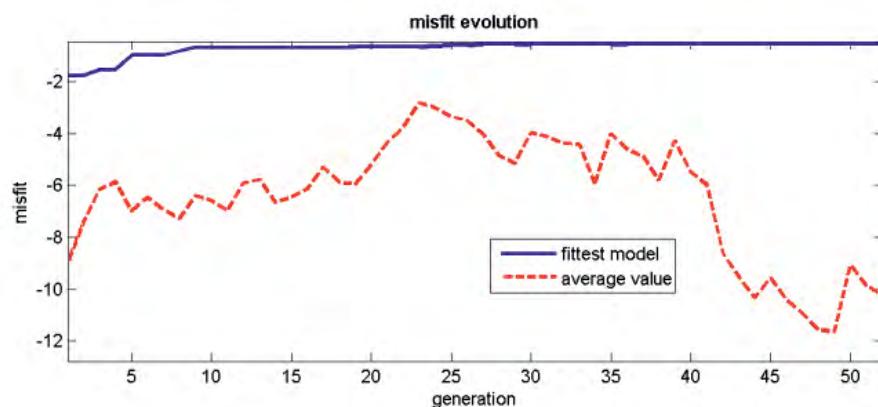
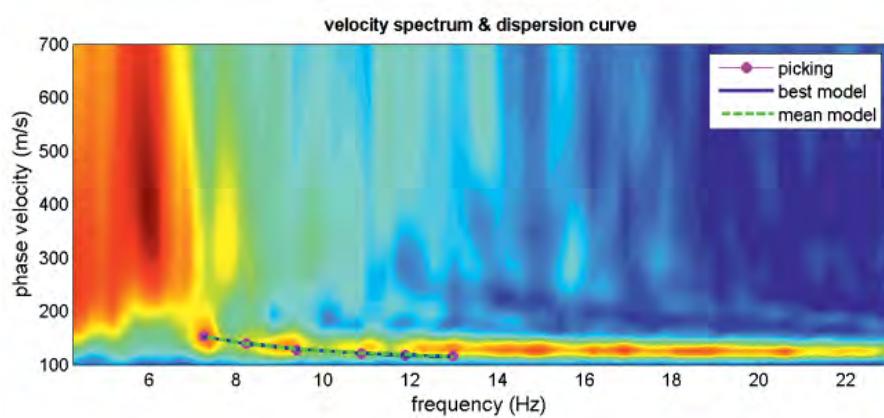
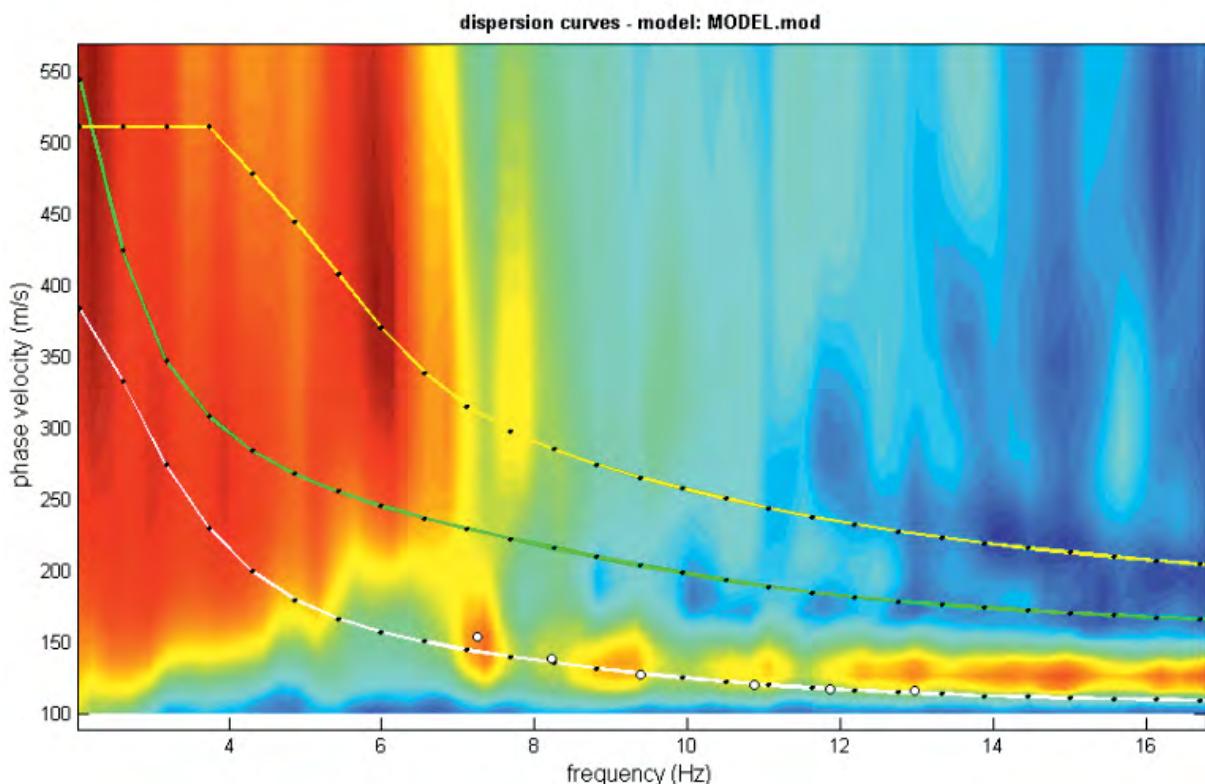
Sede Legale: via C. Costa, 182 – 41124 Modena

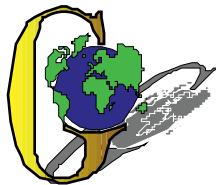
Sede operativa: via per Modena, 12 – 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

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SPETTRO RELATIVO ALLE VELOCITA' DI FASE, REGISTRATE NEL DOMINIO DELLE FREQUENZE





GEO GROUP s.r.l.

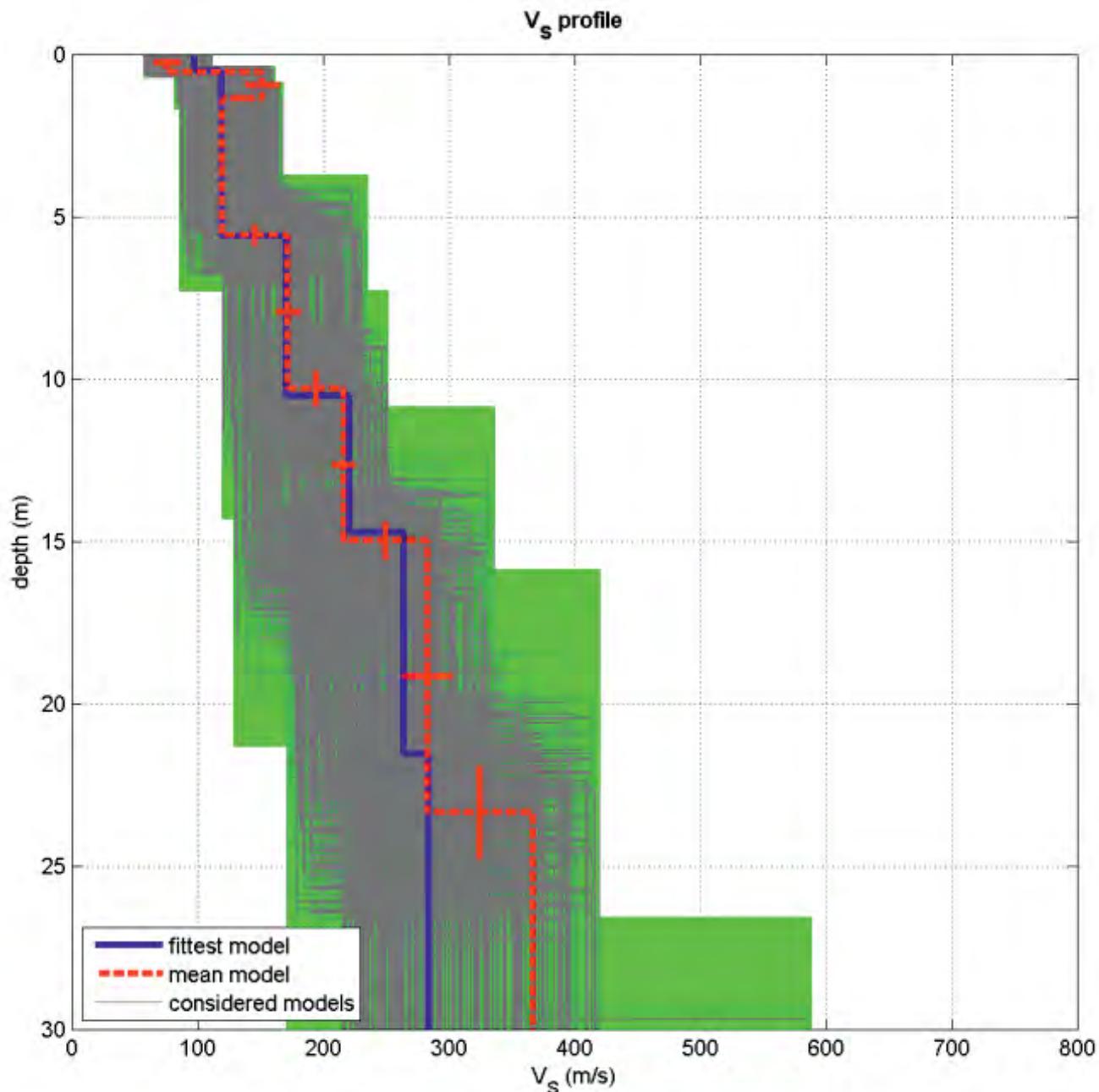
Sede Legale: via C. Costa, 182 – 41124 Modena

Sede operativa: via per Modena, 12 – 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

p.IVA e C.F. 02981500362 – www.geogroupmodena.it - e-mail: info@geogroupmodena.it

MODELLO Vs30 DERIVATO DALL'INDAGINE ReMI ESEGUITA



BEST MODEL
V_s30 = 189 m/s



GEO GROUP s.r.l.

Sede Legale: via C. Costa, 182 – 41124 Modena

Sede operativa: via per Modena, 12 – 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

p.IVA e C.F. 02981500362 – www.geogroupmodena.it - e-mail: info@geogroupmodena.it

ANALISI SISMICA DI SITO SECONDO METODOLOGIA M.A.S.W.

Cantiere: Ferrara (FE), Via Bologna n. 534

Lavoro: Studio di microzonazione sismica

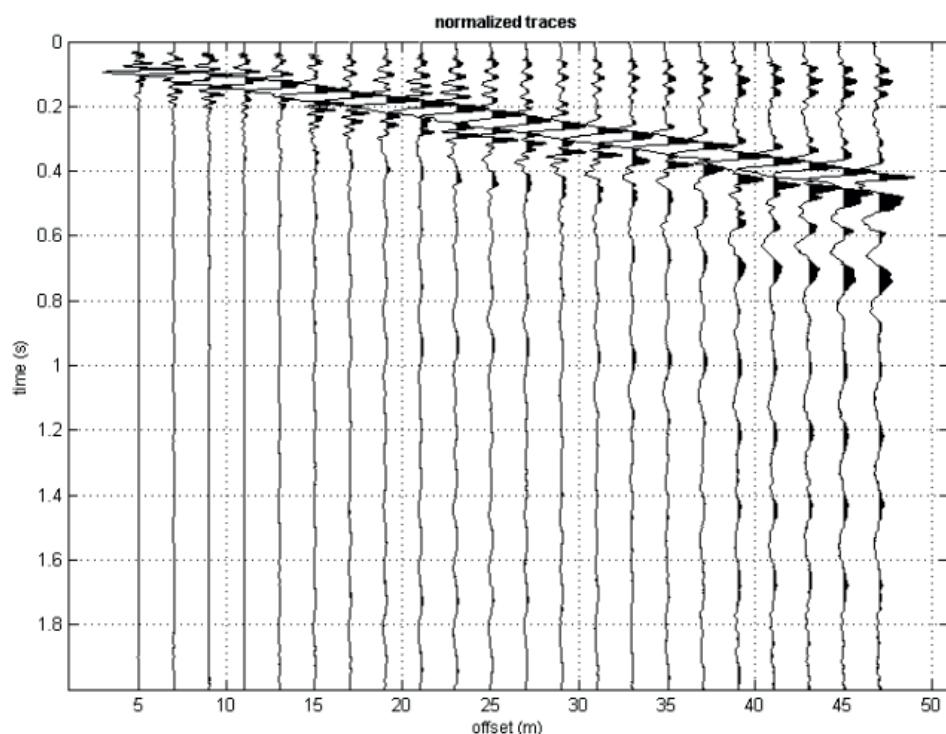
Data: 27/10/2017

Responsabile: Dott. Geol. Pier Luigi Dallari

**MASW n. 1
Rif. 646/17**



UBICAZIONE DELLO STENDIMENTO SISMICO IMPIEGATO





GEO GROUP s.r.l.

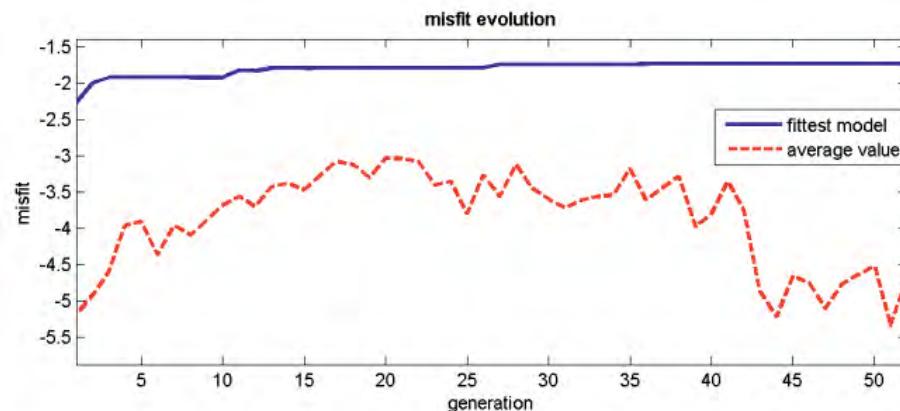
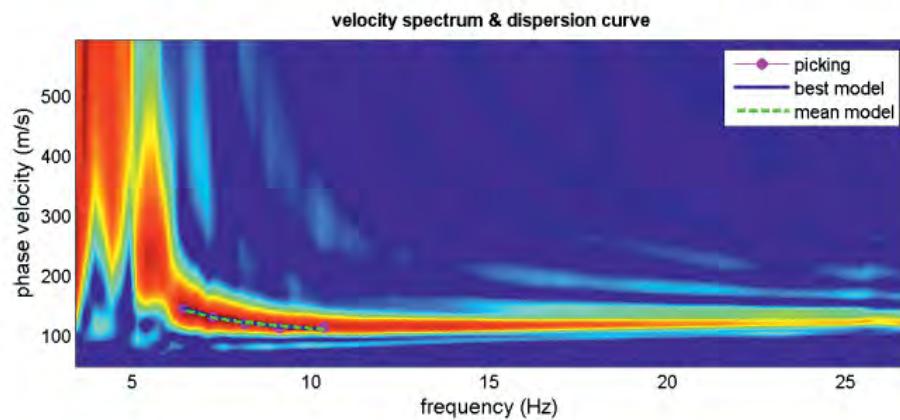
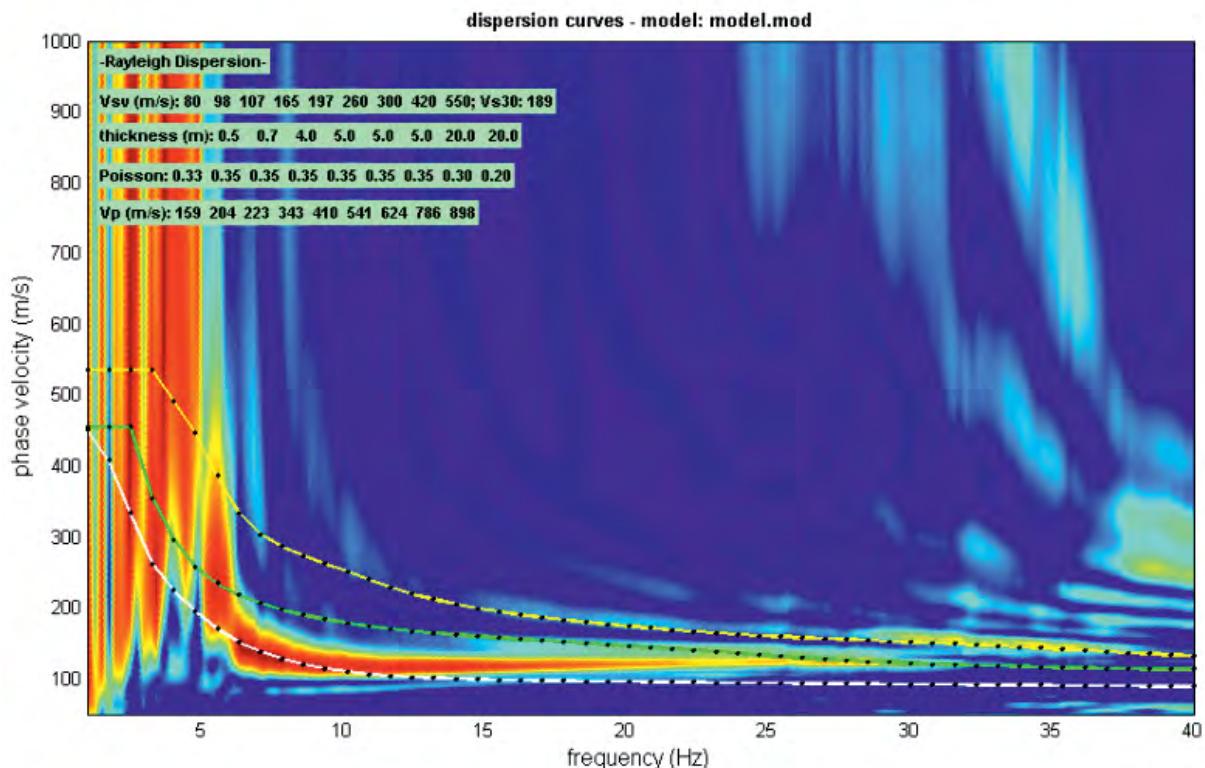
Sede Legale: via C. Costa, 182 - 41124 Modena

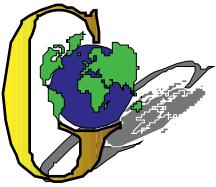
Sede operativa: via per Modena, 12 - 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

p.IVA e C.F. 02981500362 - www.geogroupmodena.it - e-mail: info@geogroupmodena.it

SPECTRUM RELATIVO ALLE VELOCITA' DI FASE, REGISTRATE NEL DOMINIO DELLE FREQUENZE





GEO GROUP s.r.l.

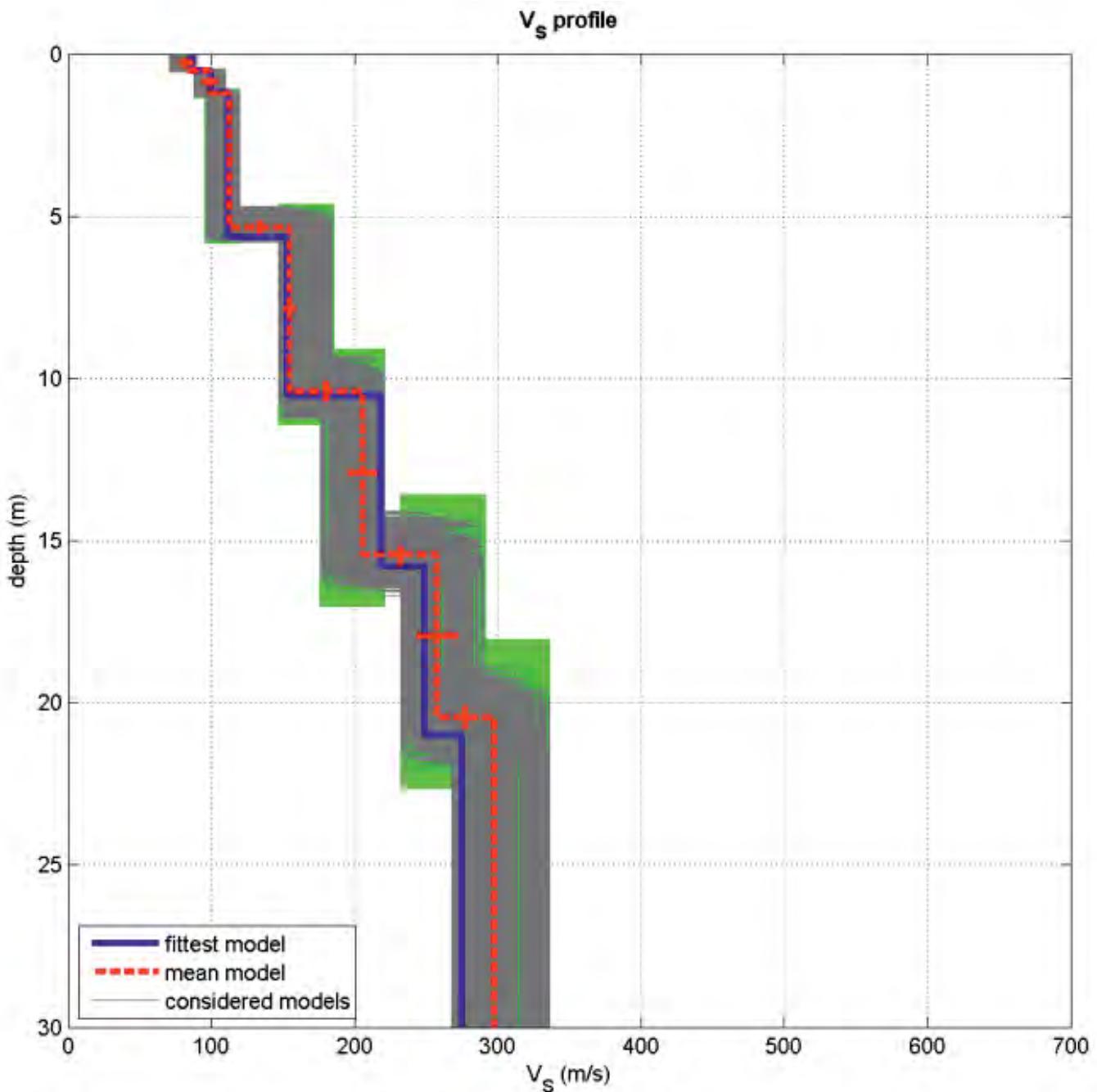
Sede Legale: via C. Costa, 182 - 41124 Modena

Sede operativa: via per Modena, 12 - 41051 Castelnuovo Rangone (MO)

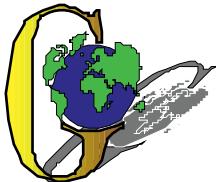
Tel. 059-39.67.169 - Fax . 059-53.32.019

p.IVA e C.F. 02981500362 - www.geogroupmodena.it - e-mail: info@geogroupmodena.it

MODELLO Vs30 DERIVATO DALL'INDAGINE MASW ESEGUITA



BEST MODEL
V_{s30} = 185 m/s



GEO GROUP s.r.l.

Sede Legale: via C. Costa, 182 – 41124 Modena

Sede operativa: via per Modena, 12 – 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.16.9 - Fax . 059-53.32.019

p.IVA e C.F. 02981500362 – www.geogroupmodena.it - e-mail: info@geogroupmodena.it

ANALISI SISMICA DI SITO SECONDO METODOLOGIA M.A.S.W.

Cantiere: Ferrara (FE), Via Bologna n. 534

Lavoro: Studio di microzonazione sismica

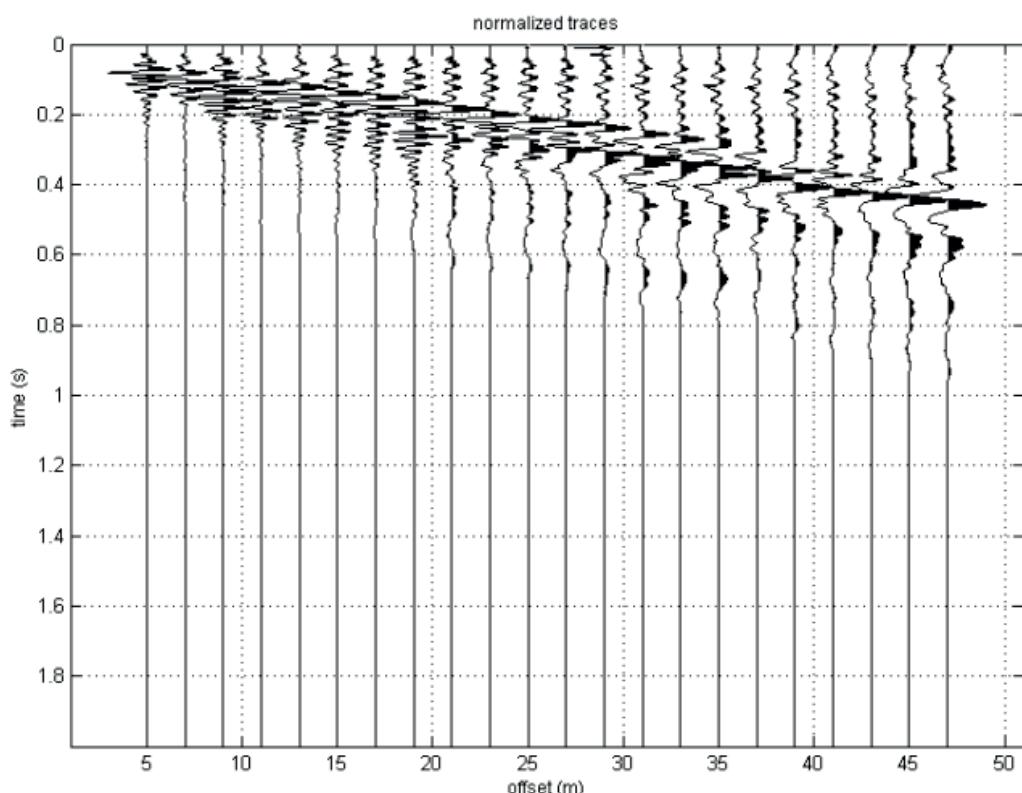
Data: 27/10/2017

Responsabile: Dott. Geol. Pier Luigi Dallari

**MASW n. 2
Rif. 646/17**



UBICAZIONE DELLO STENDIMENTO SISMICO IMPIEGATO





GEO GROUP s.r.l.

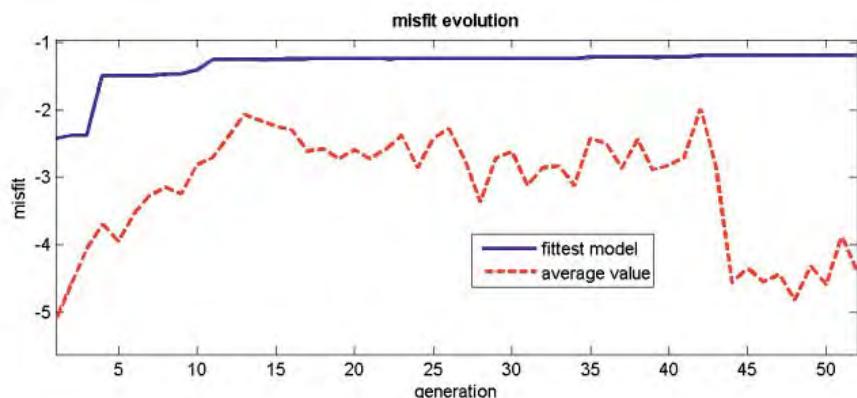
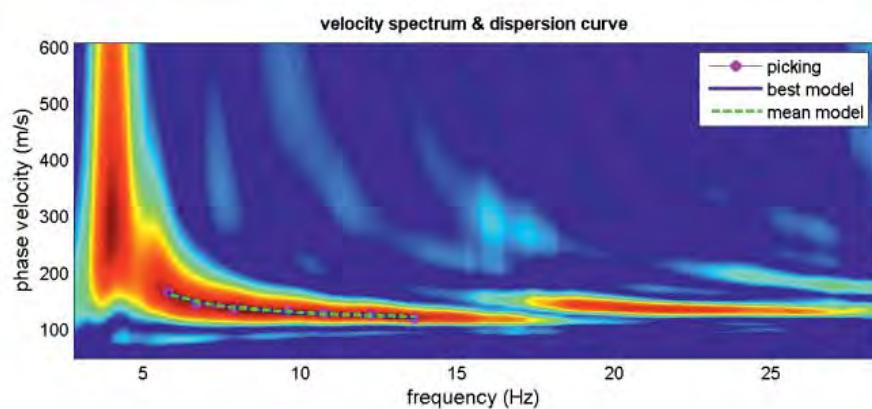
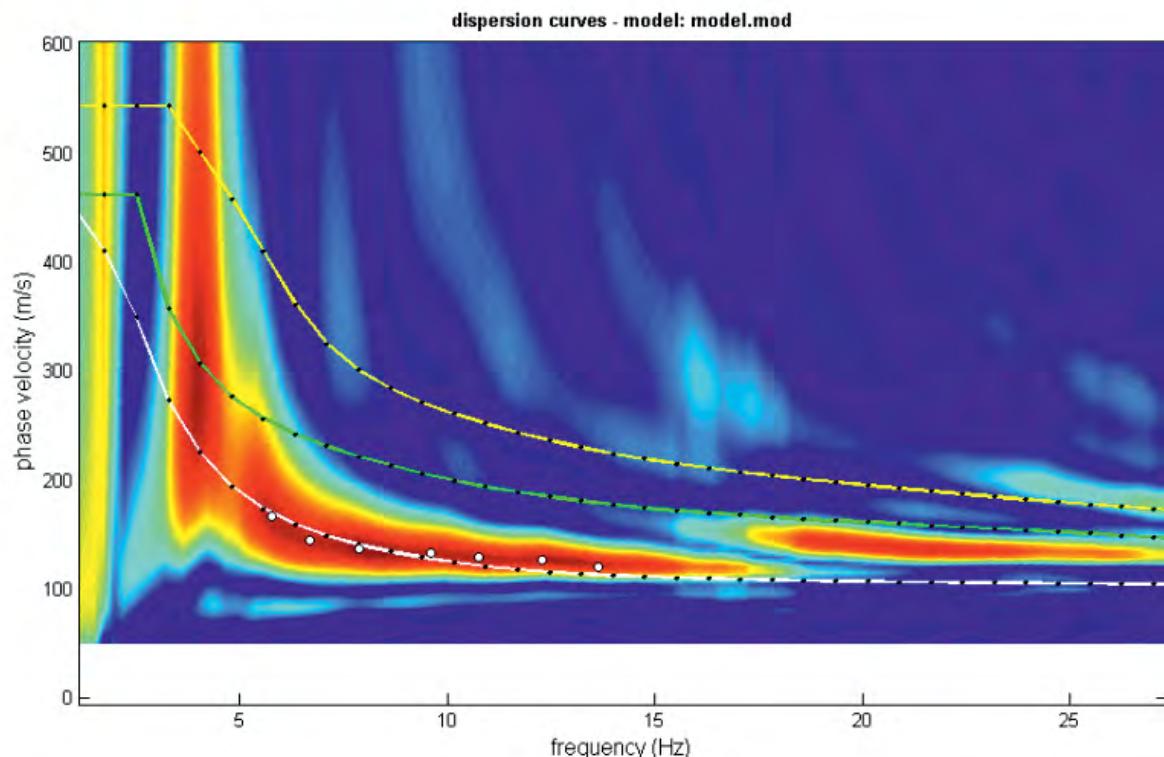
Sede Legale: via C. Costa, 182 - 41124 Modena

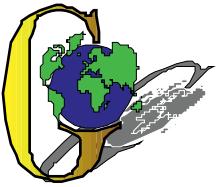
Sede operativa: via per Modena, 12 - 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

p.IVA e C.F. 02981500362 - www.geogroupmodena.it - e-mail: info@geogroupmodena.it

SPECTRUM RELATIVE TO PHASE VELOCITIES REGISTERED IN THE FREQUENCY DOMAIN





GEO GROUP s.r.l.

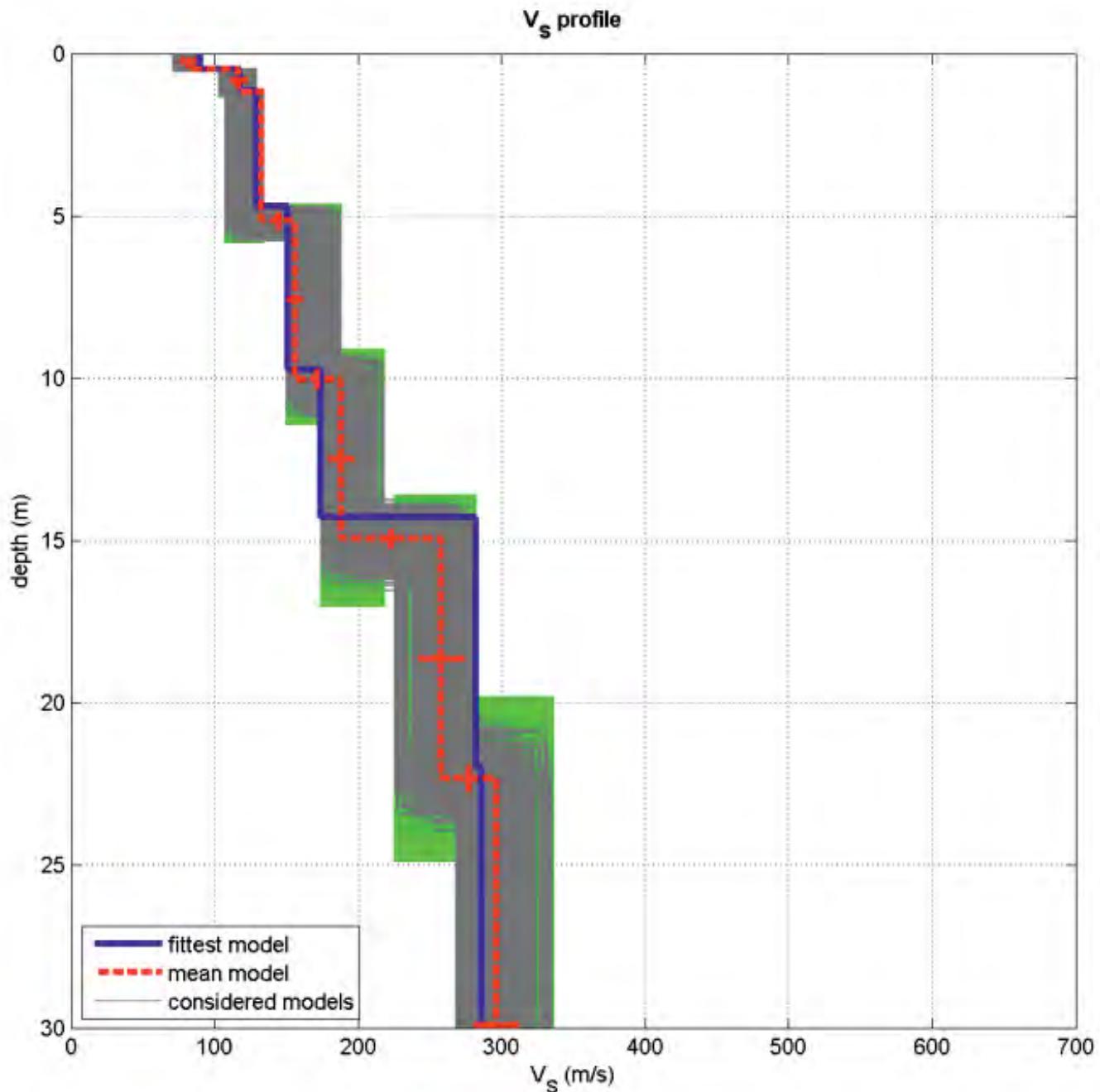
Sede Legale: via C. Costa, 182 - 41124 Modena

Sede operativa: via per Modena, 12 - 41051 Castelnuovo Rangone (MO)

Tel. 059-39.67.169 - Fax . 059-53.32.019

p.IVA e C.F. 02981500362 - www.geogroupmodena.it - e-mail: info@geogroupmodena.it

MODELLO Vs30 DERIVATO DALL'INDAGINE MASW ESEGUITA



BEST MODEL
V_{s30} = 196 m/s

1, 01

Instrument: EXT- 24 bit USB

Data format: 16 byte

Full scale [mV]: n.a.

Start recording: 27/10/17 10:55:04 End recording: 27/10/17 11:15:04

Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN

GPS data not available

Trace length: 0h20'00". Analysis performed on the entire trace.

Sampling rate: 200 Hz

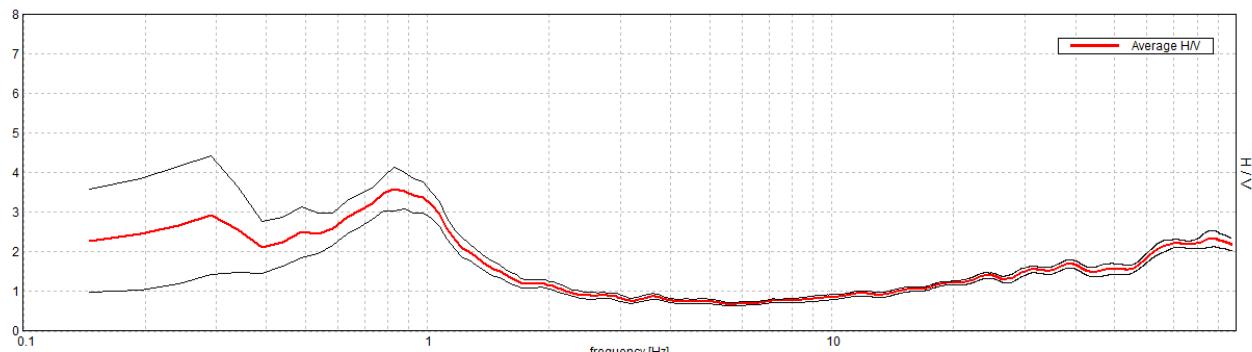
Window size: 20 s

Smoothing type: Triangular window

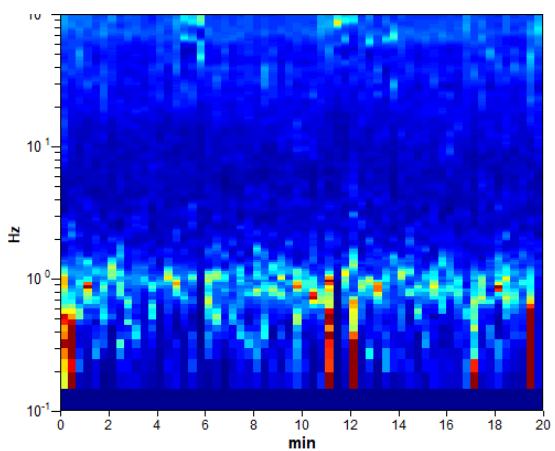
Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

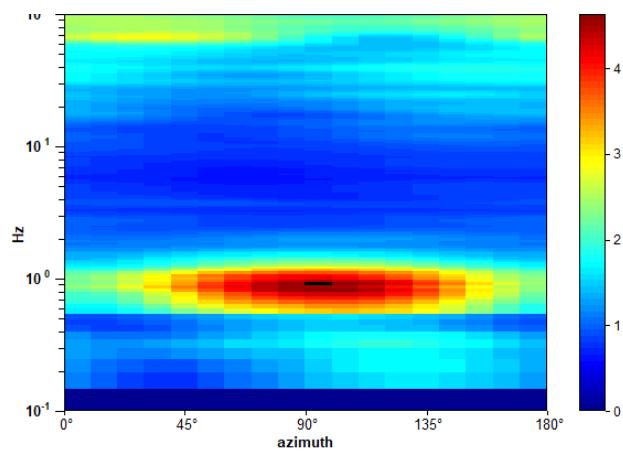
Max. H/V at 0.83 ± 0.26 Hz. (In the range 0.0 - 64.0 Hz).



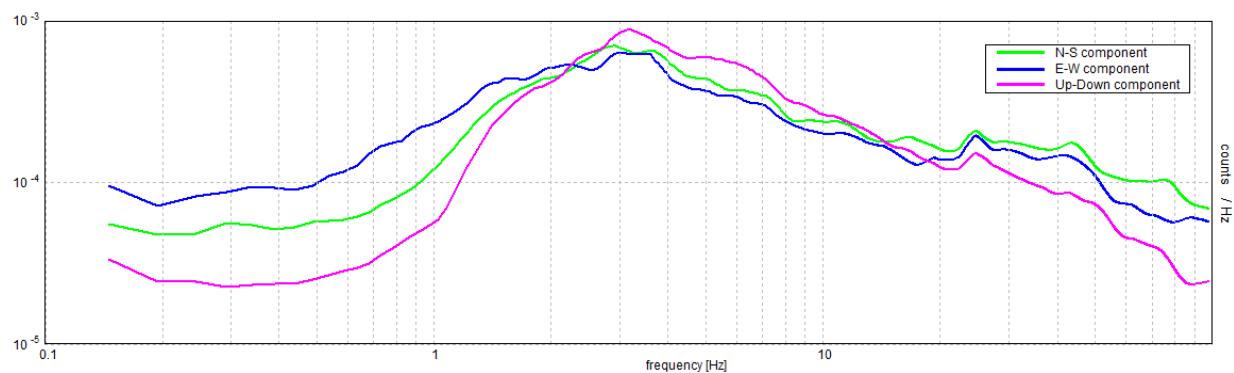
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.83 ± 0.26 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

$f_0 > 10 / L_w$	$0.83 > 0.50$	OK	
$n_c(f_0) > 200$	$996.1 > 200$	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$	Exceeded 0 out of 26 times	OK	

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

Exists f^- in $[f_0/4, f_0]$ $A_{H/V}(f^-) < A_0 / 2$			NO
Exists f^+ in $[f_0, 4f_0]$ $A_{H/V}(f^+) < A_0 / 2$	1.367 Hz	OK	
$A_0 > 2$	$3.58 > 2$	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	$ 0.3121 < 0.05$		NO
$\sigma_f < \varepsilon(f_0)$	$0.25907 < 0.12451$		NO
$\sigma_A(f_0) < \theta(f_0)$	$0.5444 < 2.0$	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{\log H/V}(f)$	standard deviation of $\log A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$

Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
$\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

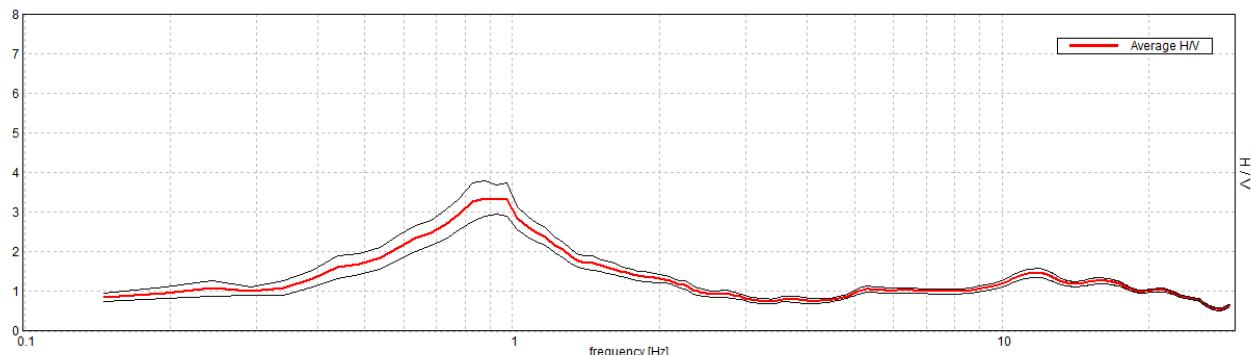
1, 02

Instrument: EXT- GEMINI 3D L
Data format: 16 byte
Full scale [mV]: n.a.
Start recording: 27/10/17 11:22:51 End recording: 27/10/17 11:42:51
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

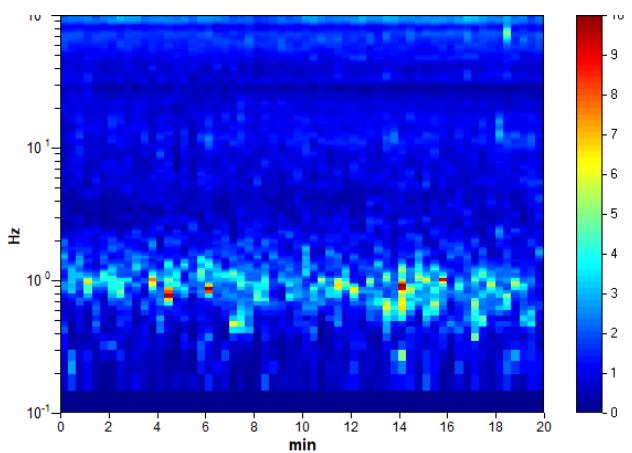
Trace length: 0h20'00". Analysis performed on the entire trace.
Sampling rate: 200 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

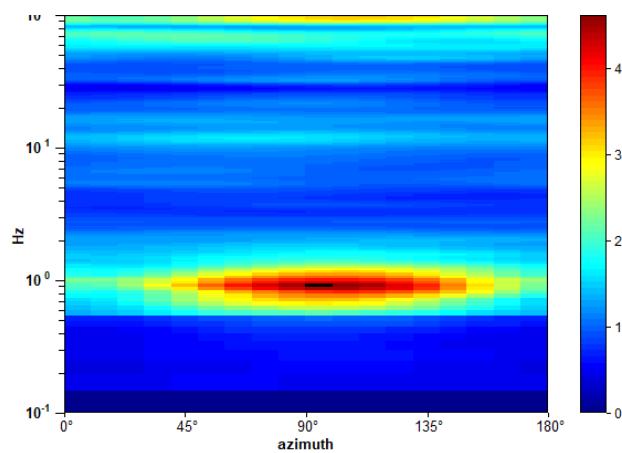
Max. H/V at 0.88 ± 0.1 Hz (in the range 0.0 - 64.0 Hz).



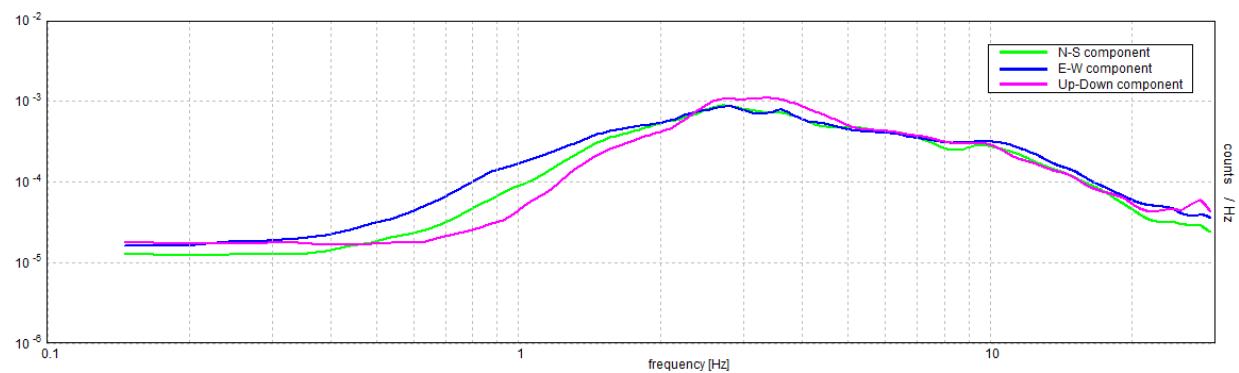
H/V TIME HISTORY



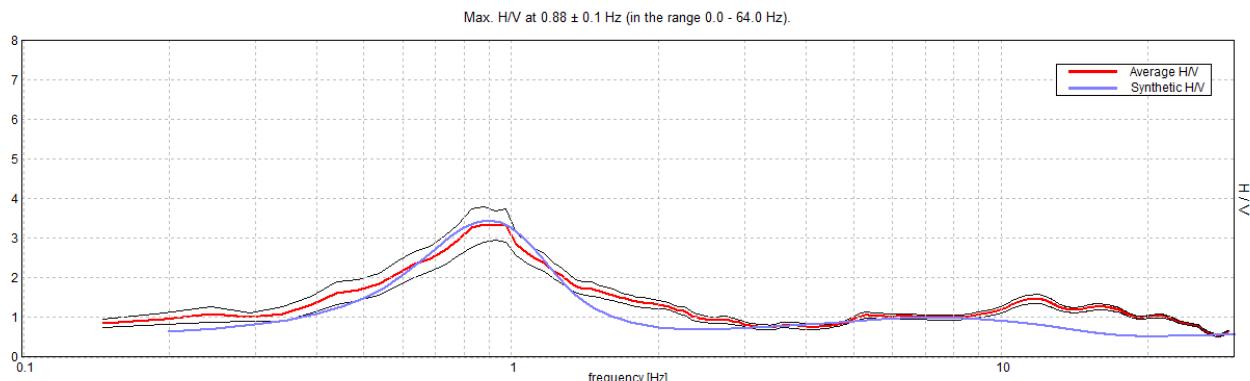
DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA

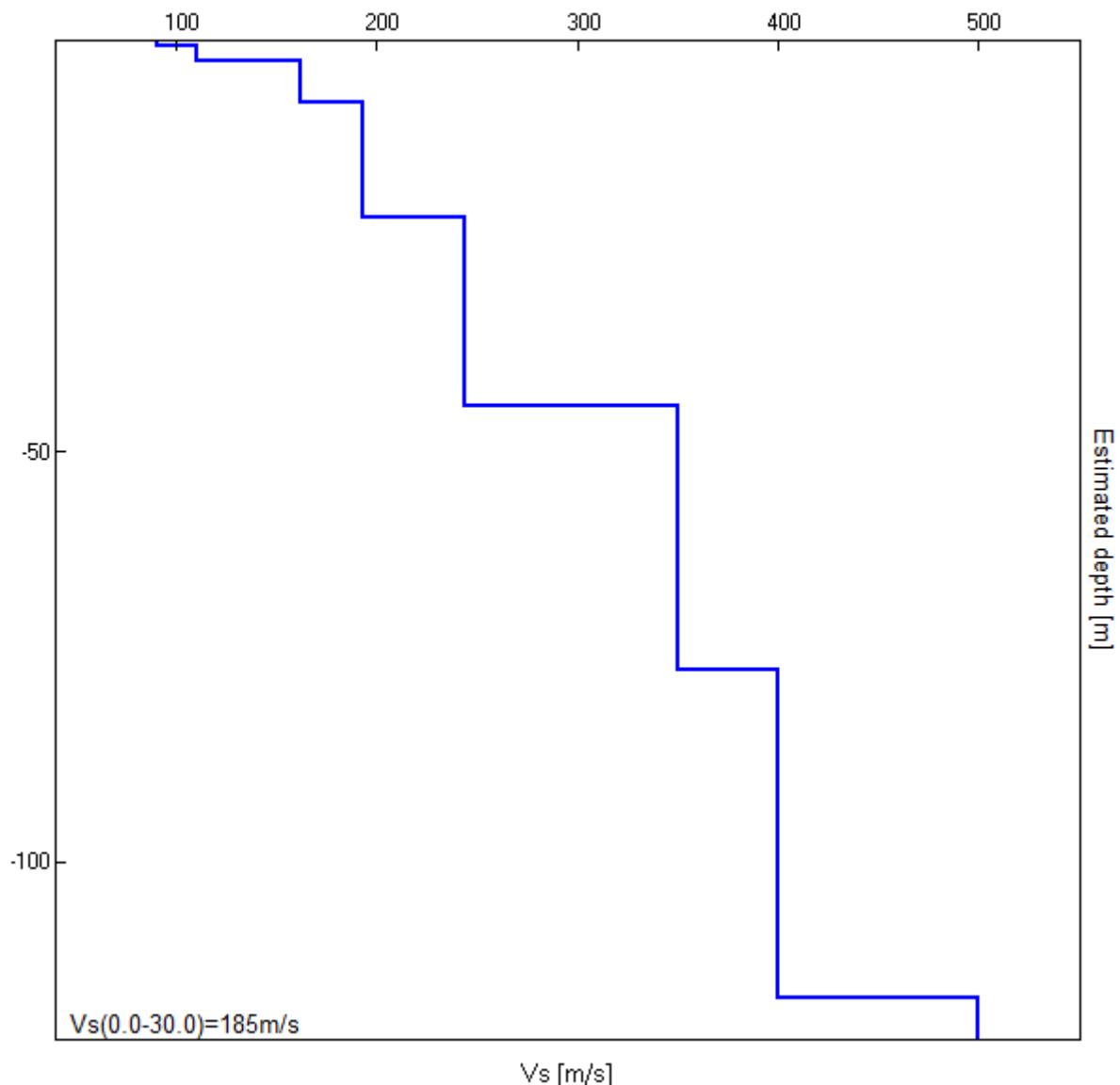


EXPERIMENTAL vs. SYNTHETIC H/V



Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	Poisson ratio
0.50	0.50	90	0.42
2.50	2.00	110	0.42
7.50	5.00	162	0.42
21.50	14.00	193	0.42
44.50	23.00	244	0.42
76.50	32.00	350	0.42
116.50	40.00	400	0.42
inf.	inf.	500	0.42

$$Vs(0.0-30.0)=185 \text{ m/s}$$



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.88 ± 0.1 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

$f_0 > 10 / L_w$	$0.88 > 0.50$	OK	
$n_c(f_0) > 200$	$1054.7 > 200$	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$	Exceeded 0 out of 28 times	OK	

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

Exists f^- in $[f_0/4, f_0]$ $A_{H/V}(f^-) < A_0 / 2$	0.439 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ $A_{H/V}(f^+) < A_0 / 2$	1.514 Hz	OK	
$A_0 > 2$	$3.34 > 2$	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	$ 0.11763 < 0.05$		NO
$\sigma_f < \varepsilon(f_0)$	$0.10339 < 0.13184$	OK	
$\sigma_A(f_0) < \theta(f_0)$	$0.446 < 2.0$	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{\log H/V}(f)$	standard deviation of $\log A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$

Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
$\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

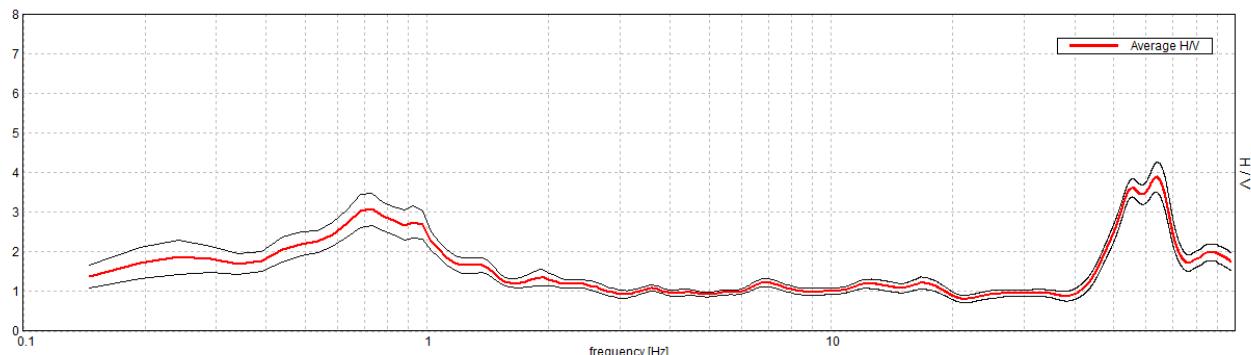
FERRARA, HV 3

Instrument: EXT- GEMINI 3D L
 Data format: 16 byte
 Full scale [mV]: 51
 Start recording: 27/10/17 12:27:02 End recording: 27/10/17 12:47:02
 Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
 GPS data not available

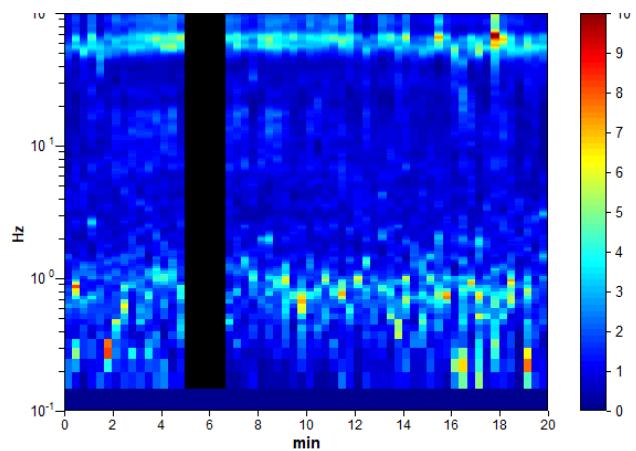
Trace length: 0h20'00". Analyzed 92% trace (manual window selection)
 Sampling rate: 200 Hz
 Window size: 20 s
 Smoothing type: Triangular window
 Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

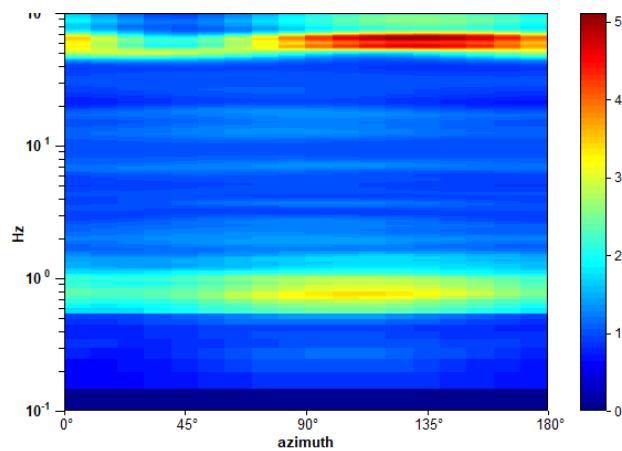
Max. H/V at 0.73 ± 0.2 Hz. (In the range 0.0 - 30.0 Hz).



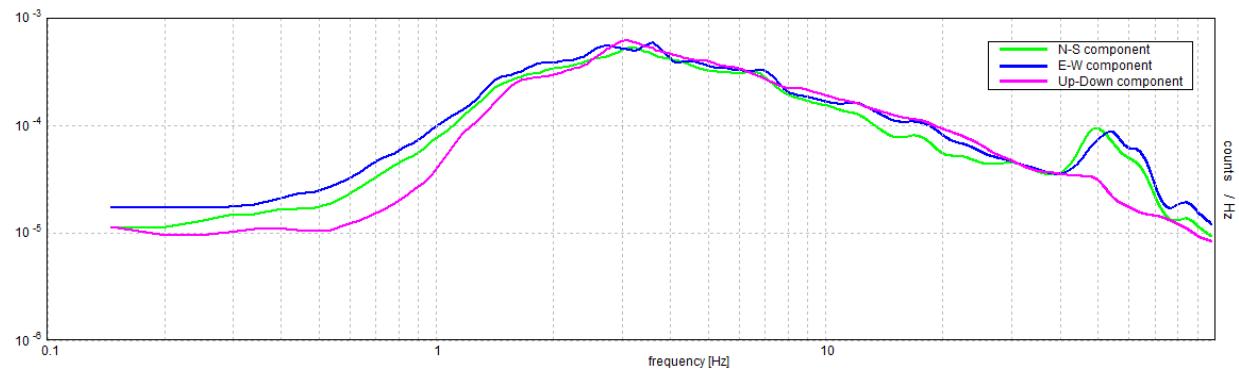
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.73 ± 0.2 Hz (in the range 0.0 - 30.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

$f_0 > 10 / L_w$	$0.73 > 0.50$	OK	
$n_c(f_0) > 200$	$805.7 > 200$	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$	Exceeded 0 out of 24 times	OK	

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

Exists f^- in $[f_0/4, f_0]$ $A_{H/V}(f^-) < A_0 / 2$			NO
Exists f^+ in $[f_0, 4f_0]$ $A_{H/V}(f^+) < A_0 / 2$	1.465 Hz	OK	
$A_0 > 2$	$3.07 > 2$	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	$ 0.27132 < 0.05$		NO
$\sigma_f < \varepsilon(f_0)$	$0.19872 < 0.10986$		NO
$\sigma_A(f_0) < \theta(f_0)$	$0.4086 < 2.0$	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{\log H/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$

Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
$\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

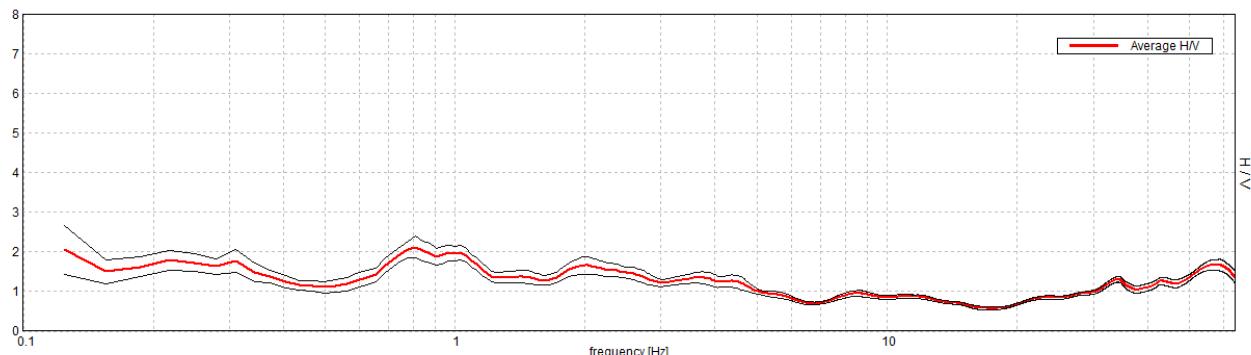
FERRARA CERPIC, HV 1A

Instrument: TE3-0303/01-17
 Data format: 16 byte
 Full scale [mV]: 51
 Start recording: 27/04/18 11:16:37 End recording: 27/04/18 11:36:37
 Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
 GPS data not available

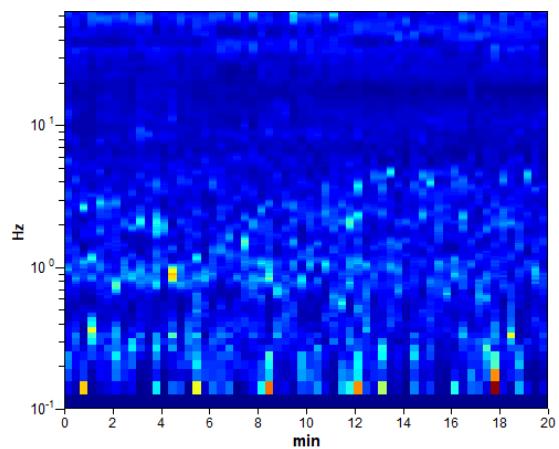
Trace length: 0h20'00". Analysis performed on the entire trace.
 Sampling rate: 128 Hz
 Window size: 20 s
 Smoothing type: Triangular window
 Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

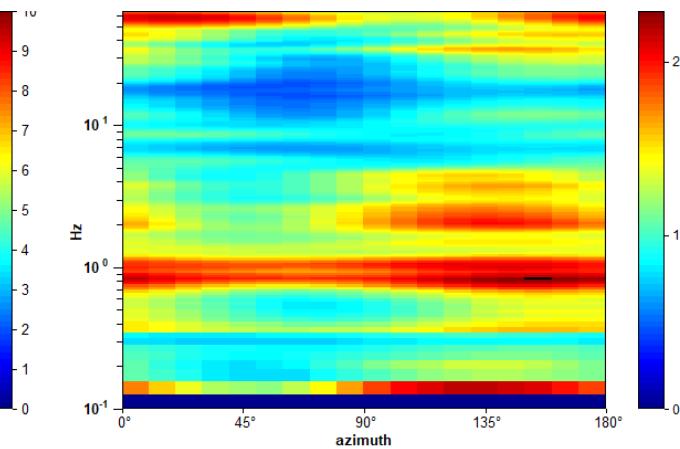
Max. H/V at 0.81 ± 0.26 Hz. (In the range 0.0 - 30.0 Hz).



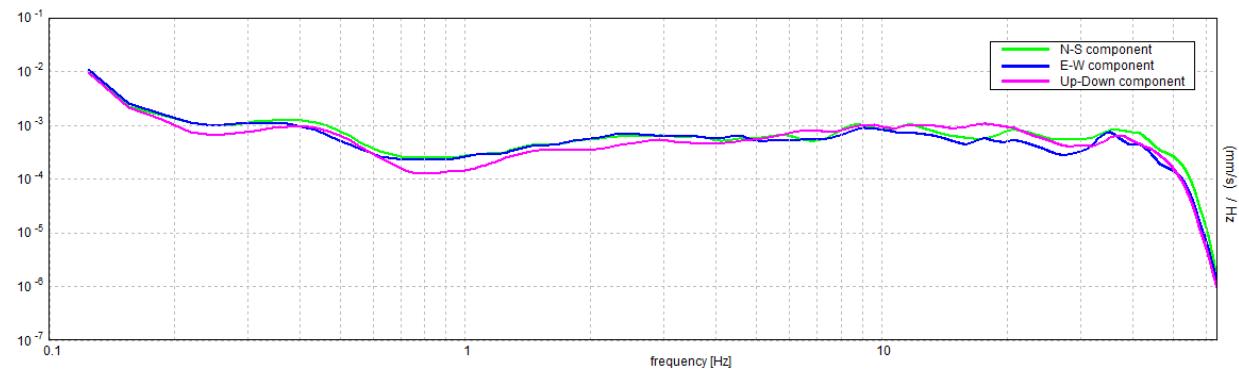
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.81 ± 0.26 Hz (in the range 0.0 - 30.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

$f_0 > 10 / L_w$	$0.81 > 0.50$	OK	
$n_c(f_0) > 200$	$975.0 > 200$	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$	Exceeded 0 out of 40 times	OK	

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

Exists f^- in $[f_0/4, f_0]$ $A_{H/V}(f^-) < A_0 / 2$			NO
Exists f^+ in $[f_0, 4f_0]$ $A_{H/V}(f^+) < A_0 / 2$			NO
$A_0 > 2$	$2.12 > 2$	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	$ 0.32598 < 0.05$		NO
$\sigma_f < \varepsilon(f_0)$	$0.26486 < 0.12188$		NO
$\sigma_A(f_0) < \theta(f_0)$	$0.2683 < 2.0$	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{\log H/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$

Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
$\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

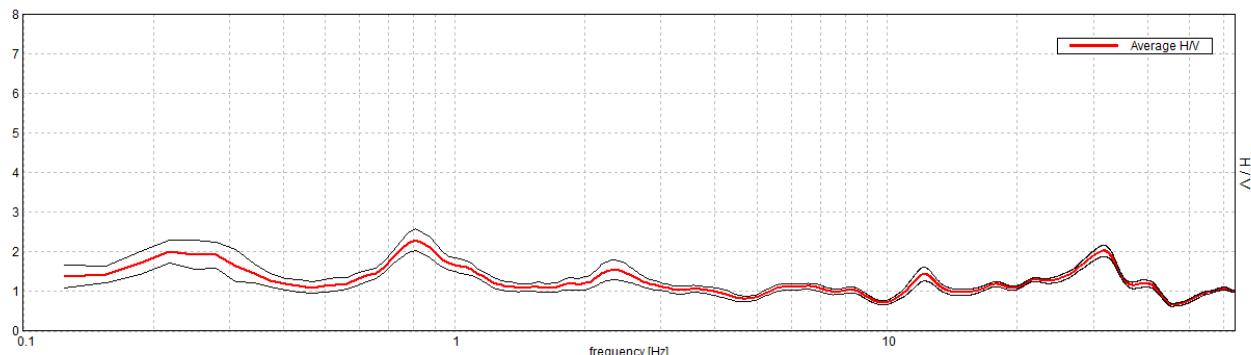
FERRARA CERPIC, HV 2A

Instrument: TE3-0303/01-17
 Data format: 16 byte
 Full scale [mV]: 51
 Start recording: 27/04/18 11:41:59 End recording: 27/04/18 12:01:59
 Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
 GPS data not available

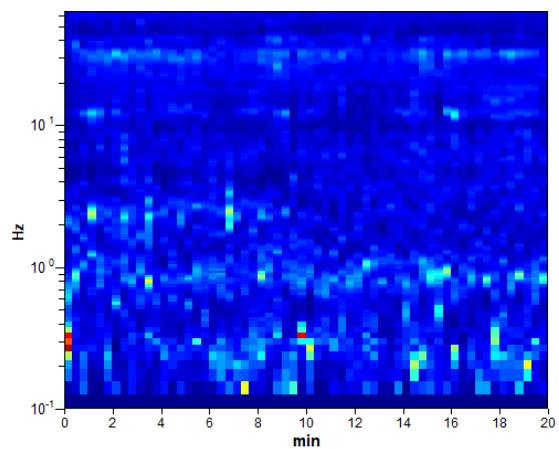
Trace length: 0h20'00". Analysis performed on the entire trace.
 Sampling rate: 128 Hz
 Window size: 20 s
 Smoothing type: Triangular window
 Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

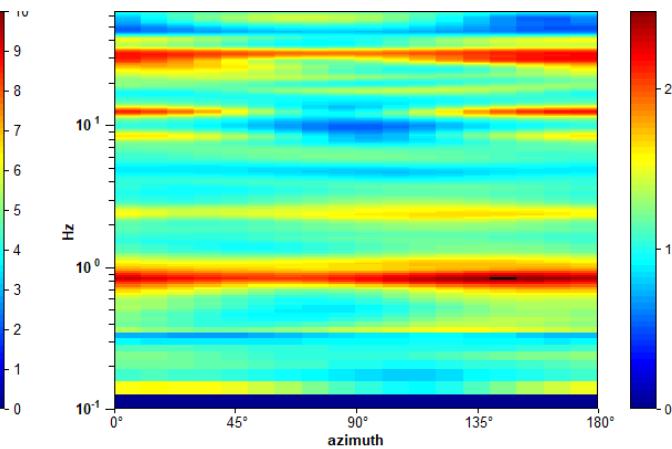
Max. H/V at 0.81 ± 0.63 Hz. (In the range 0.0 - 30.0 Hz).



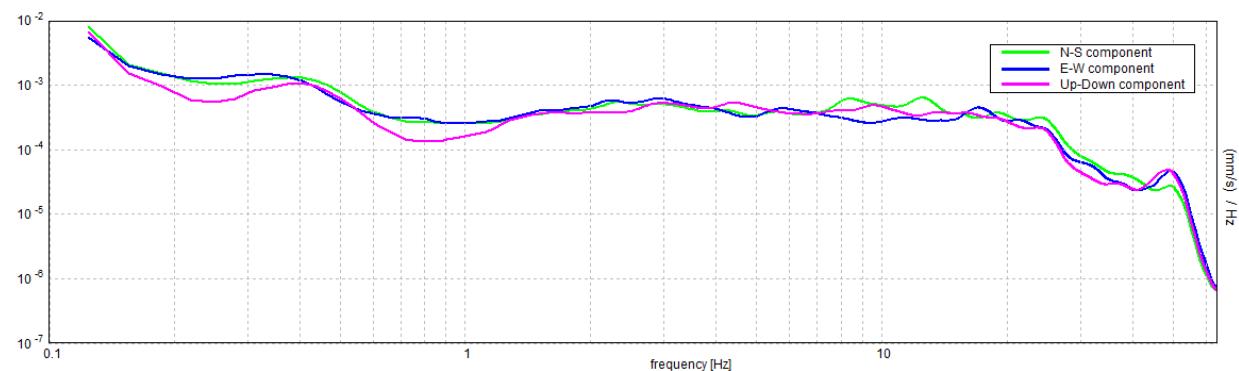
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.81 ± 0.63 Hz (in the range 0.0 - 30.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	$0.81 > 0.50$	OK	
$n_c(f_0) > 200$	$975.0 > 200$	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$	Exceeded 0 out of 40 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ $A_{H/V}(f^-) < A_0 / 2$	0.5 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ $A_{H/V}(f^+) < A_0 / 2$	1.313 Hz	OK	
$A_0 > 2$	2.31 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	$ 0.77635 < 0.05$		NO
$\sigma_f < \varepsilon(f_0)$	$0.63078 < 0.12188$		NO
$\sigma_A(f_0) < \theta(f_0)$	$0.2698 < 2.0$	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{\log H/V}(f)$	standard deviation of $\log A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
$\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

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DI GESTIONE QUALITÀ
CERTIFICATO DA DNV
= ISO 9001 =

INDAGINE SISMICA IN FORO DOWN-HOLE DOWN-HOLE – ELABORAZIONE INTERVALLO

Cantiere	Ferrara, CERPIC
Data esecuzione indagini	14/05/2018
Committente	
Operatori	Dott. geol. Gabriele Ghirardini, dott. Emanuele Paganelli
Responsabile	Dott. geol. Pier Luigi Dallari
Elaborazione	Dott. geol. Gabriele Ghirardini
STRUMENTAZIONE	
Strumentazione impiegata	GEODE GEOMETRICS 24ch
Energizzatore	Massa battente da 5 kg
Sensoristica	Doppia terna geofonica Ambrogeo Twin3d
Distanza battute P e S	Onde P: 3.00 m ; Onde S: 3.00 m
Acquisizioni	Battuta P / Battuta S+ / Battuta S-
Foro di Sondaggio	S1

INDAGINE SISMICA IN FORO DOWN-HOLE DOWN-HOLE – ELABORAZIONE INTERVALLO

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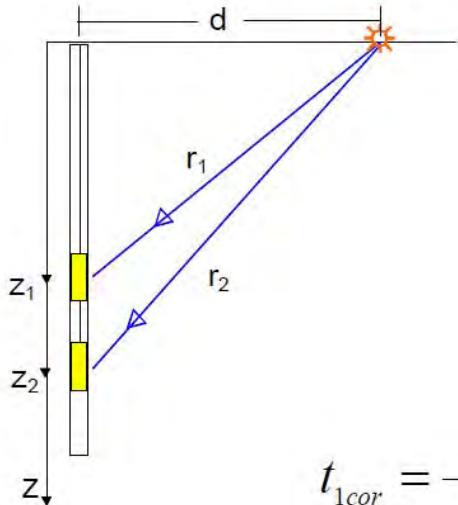
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CENNI TEORICI – ELABORAZIONE INTERVALLO



La velocità delle onde sismiche tra due ricevitori è uguale a:

$$v = \frac{z_2 - z_1}{t_{2COR} - t_{1COR}}$$

$$t_{1cor} = \frac{z_1}{\sqrt{z_1^2 + d^2}} \cdot t_{loss}$$

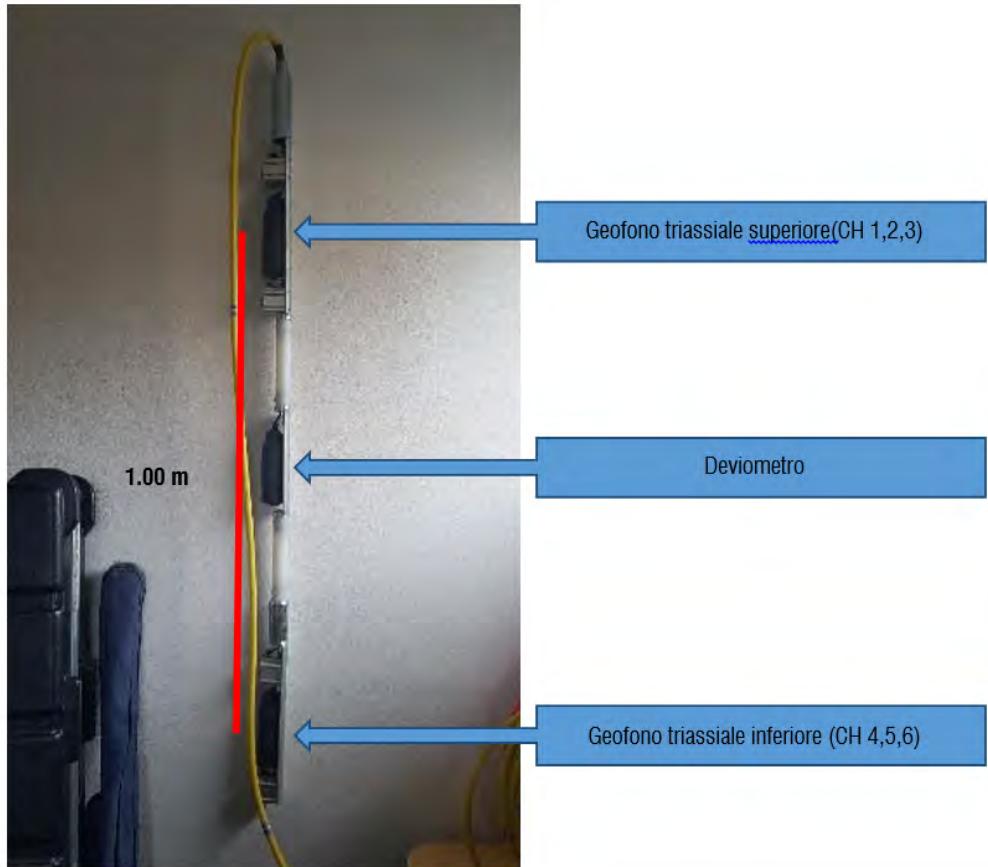
$$t_{2cor} = \frac{z_2}{\sqrt{z_2^2 + d^2}} \cdot t_{loss}$$

Nel presente caso:

Z= 1.00 m (interdistanza fissa geofoni)

dP= 3.00 m

dS= 3.00 m



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INDAGINE SISMICA IN FORO DOWN-HOLE

DOWN-HOLE – ELABORAZIONE INTERVALLO

ONDE P												
FILE	m	m	m	ms	ms	ms	ms	s	s	s	m/s	
	Z	Z1	Z2	T1 obs	T2 obs	T1 cor	T2 cor	T1	T2	ΔT	V	
269	1.5	2	1	9.78	10.47	3.09	5.81	0.00309	0.00581	0.00272	368	
266	2.5	3	2	9.98	10.12	5.54	7.16	0.00554	0.00716	0.00162	617	
263	3.5	4	3	8.53	9.36	6.03	7.49	0.00603	0.00749	0.00146	687	
260	4.5	5	4	11.92	12.27	9.54	10.52	0.00954	0.01052	0.00099	1015	
257	5.5	6	5	12.27	12.62	10.52	11.29	0.01052	0.01129	0.00077	1305	
254	6.5	7	6	8.94	9.32	8.00	8.57	0.00800	0.00857	0.00057	1754	
251	7.5	8	7	12.62	13.10	11.60	12.27	0.01160	0.01227	0.00067	1501	
248	8.5	9	8	12.83	13.45	12.01	12.76	0.01201	0.01276	0.00075	1339	
245	9.5	10	9	13.24	13.94	12.56	13.35	0.01256	0.01335	0.00079	1263	
242	10.5	11	10	14.49	15.53	13.88	14.98	0.01388	0.01498	0.00110	906	
239	11.5	12	11	16.29	17.05	15.72	16.54	0.01572	0.01654	0.00082	1212	
236	12.5	13	12	15.81	16.29	15.34	15.87	0.01534	0.01587	0.00053	1870	
233	13.5	14	13	16.29	17.19	15.87	16.81	0.01587	0.01681	0.00094	1069	
230	14.5	15	14	13.94	14.63	13.63	14.35	0.01363	0.01435	0.00072	1398	
227	15.5	16	15	14.91	15.81	14.62	15.54	0.01462	0.01554	0.00092	1088	
224	16.5	17	16	14.49	15.25	14.24	15.02	0.01424	0.01502	0.00078	1288	
221	17.5	18	17	15.74	16.29	15.50	16.07	0.01550	0.01607	0.00057	1761	
218	18.5	19	18	16.43	16.99	16.21	16.78	0.01621	0.01678	0.00058	1737	
215	19.5	20	19	21.08	21.49	20.82	21.25	0.02082	0.02125	0.00043	2325	
212	20.5	21	20	22.05	22.60	21.81	22.37	0.02181	0.02237	0.00057	1764	
209	21.5	22	21	21.15	21.63	20.94	21.43	0.02094	0.02143	0.00049	2023	
206	22.5	23	22	23.09	23.64	22.88	23.44	0.02288	0.02344	0.00056	1776	
203	23.5	24	23	24.13	24.68	23.93	24.49	0.02393	0.02449	0.00056	1779	
200	24.5	25	24	27.94	28.42	27.72	28.22	0.02772	0.02822	0.00049	2027	
197	25.5	26	25	28.50	28.98	28.30	28.79	0.02830	0.02879	0.00049	2033	
194	26.5	27	26	29.42	29.85	29.23	29.67	0.02923	0.02967	0.00044	2266	
191	27.5	28	27	29.35	29.78	29.17	29.61	0.02917	0.02961	0.00044	2273	
188	28.5	29	28	29.68	30.10	29.51	29.94	0.02951	0.02994	0.00043	2330	
185	29.5	30	29	30.20	30.65	30.04	30.50	0.03004	0.03050	0.00046	2182	

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INDAGINE SISMICA IN FORO DOWN-HOLE

DOWN-HOLE – ELABORAZIONE INTERVALLO

ONDE SH													
		m	m	m	ms	ms	ms	ms	s	s	s	m/s	
FILE +	FILE -	Z	Z1	Z2	T1 obs	T2 obs	T1 cor	T2 cor	T1	T2	ΔT	V	
270	271	1.5	2	1	21.84	26.21	6.91	14.54	0.00691	0.01454	0.00763	131	
267	268	2.5	3	2	26.76	33.49	14.84	23.68	0.01484	0.02368	0.00884	113	
264	265	3.5	4	3	40.90	46.80	28.92	37.44	0.02892	0.03744	0.00852	117	
261	262	4.5	5	4	48.53	56.57	38.82	48.51	0.03882	0.04851	0.00968	103	
258	259	5.5	6	5	56.99	63.99	48.87	57.23	0.04887	0.05723	0.00837	120	
255	256	6.5	7	6	61.56	66.97	55.06	61.56	0.05506	0.06156	0.00649	154	
252	253	7.5	8	7	67.04	71.96	61.62	67.38	0.06162	0.06738	0.00576	174	
249	250	8.5	9	8	72.10	78.41	67.51	74.39	0.06751	0.07439	0.00688	145	
246	247	9.5	10	9	76.12	83.61	72.21	80.08	0.07221	0.08008	0.00787	127	
243	244	10.5	11	10	86.18	93.80	82.55	90.49	0.08255	0.09049	0.00795	126	
240	241	11.5	12	11	93.52	99.56	90.22	96.59	0.09022	0.09659	0.00636	157	
237	238	12.5	13	12	100.32	105.24	97.32	102.54	0.09732	0.10254	0.00522	192	
234	235	13.5	14	13	104.27	111.34	101.60	108.87	0.10160	0.10887	0.00727	138	
231	232	14.5	15	14	103.65	109.68	101.35	107.55	0.10135	0.10755	0.00620	161	
228	229	15.5	16	15	109.89	113.49	107.76	111.55	0.10776	0.11155	0.00379	264	
225	226	16.5	17	16	118.27	121.88	116.24	120.03	0.11624	0.12003	0.00378	264	
222	223	17.5	18	17	122.30	127.01	120.44	125.28	0.12044	0.12528	0.00484	206	
219	220	18.5	19	18	124.03	128.12	122.34	126.55	0.12234	0.12655	0.00421	238	
216	217	19.5	20	19	131.24	135.68	129.63	134.18	0.12963	0.13418	0.00454	220	
213	214	20.5	21	20	139.14	143.23	137.60	141.79	0.13760	0.14179	0.00419	239	
210	211	21.5	22	21	144.00	149.20	142.55	147.83	0.14255	0.14783	0.00528	189	
207	208	22.5	23	22	145.59	148.57	144.25	147.32	0.14425	0.14732	0.00307	326	
204	205	23.5	24	23	133.11	137.27	131.99	136.21	0.13199	0.13621	0.00422	237	
201	202	24.5	25	24	143.93	148.64	142.82	147.58	0.14282	0.14758	0.00476	210	
198	199	25.5	26	25	145.25	149.60	144.22	148.61	0.14422	0.14861	0.00440	227	
195	196	26.5	27	26	146.35	150.24	145.39	149.32	0.14539	0.14932	0.00394	254	
192	193	27.5	28	27	150.27	154.85	149.35	153.97	0.14935	0.15397	0.00462	217	
189	190	28.5	29	28	154.65	159.01	153.77	158.17	0.15377	0.15817	0.00440	227	
186	187	29.5	30	29	159.05	163.50	158.21	162.69	0.15821	0.16269	0.00448	223	

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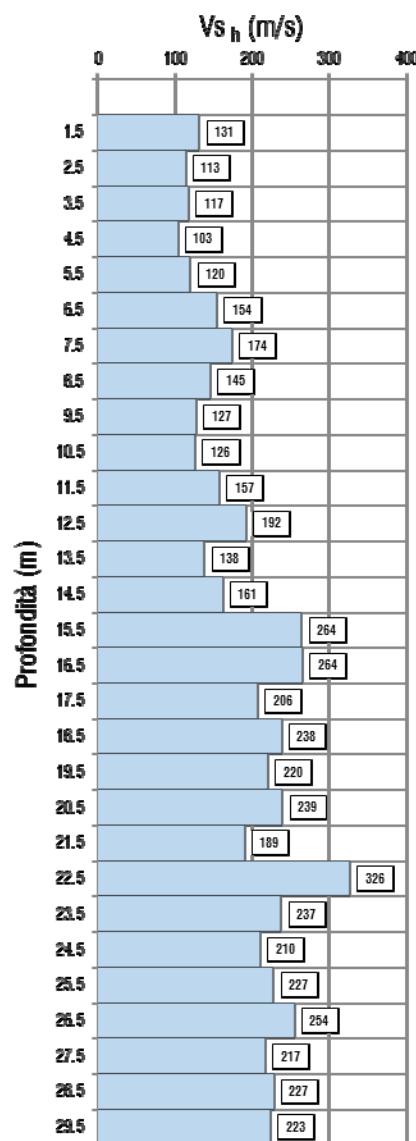
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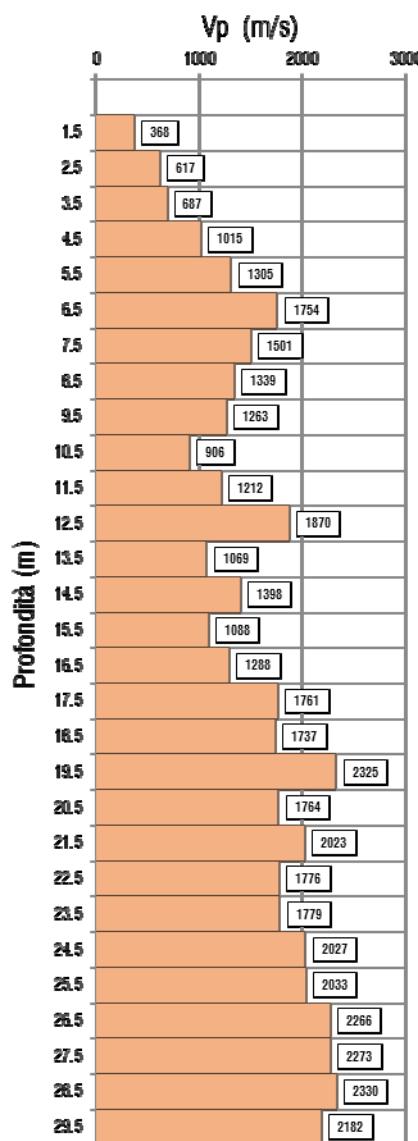


INDAGINE SISMICA IN FORO DOWN-HOLE DOWN-HOLE – ELABORAZIONE INTERVALLO Risultati interpretazione

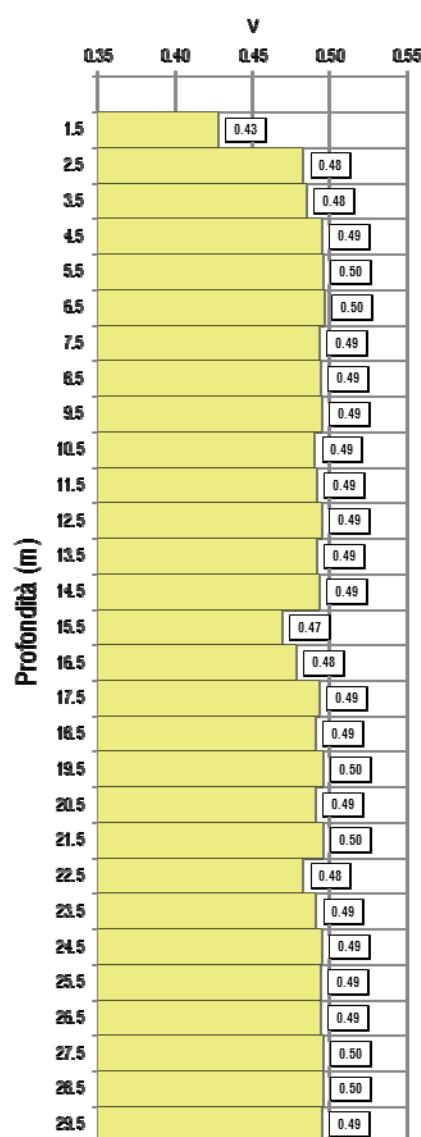
Onde Sh



Onde P



Poisson



$$Vs_{30} = 190 \text{ m/s}$$

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G E O G R O U P s.r.l.

Indagini geognostiche e geofisiche – geologia applicata alle costruzioni – laboratorio geotecnico –
idrogeologia – coltivazione cave – bonifiche – consolidamenti – geologia ambientale – consulenze
geologiche e geotecniche

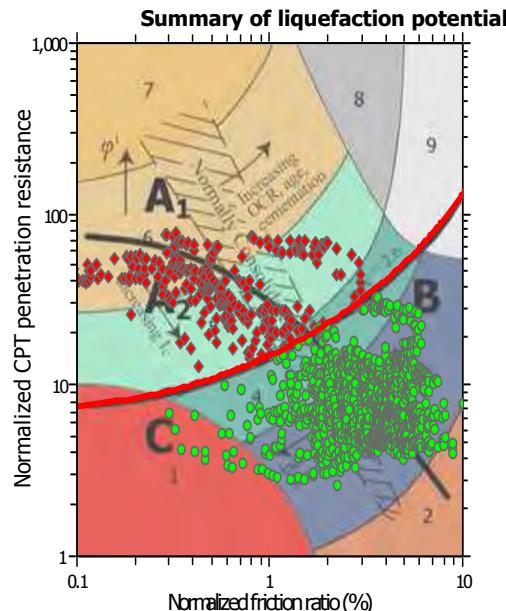
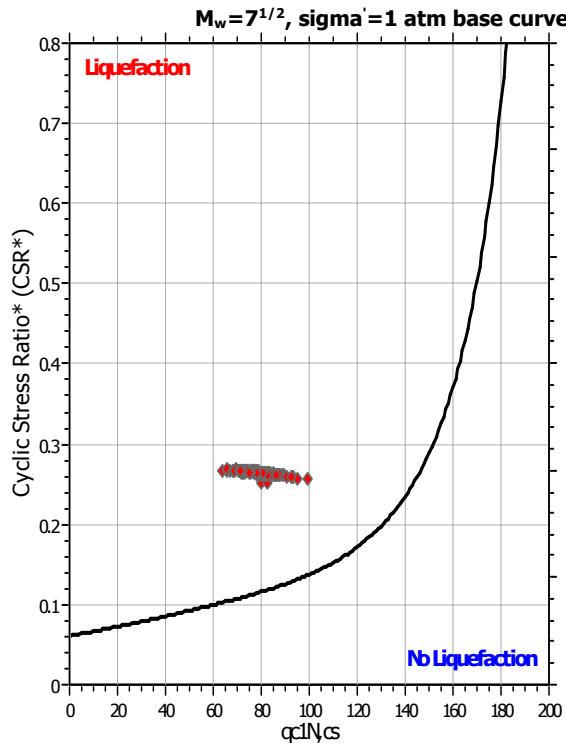
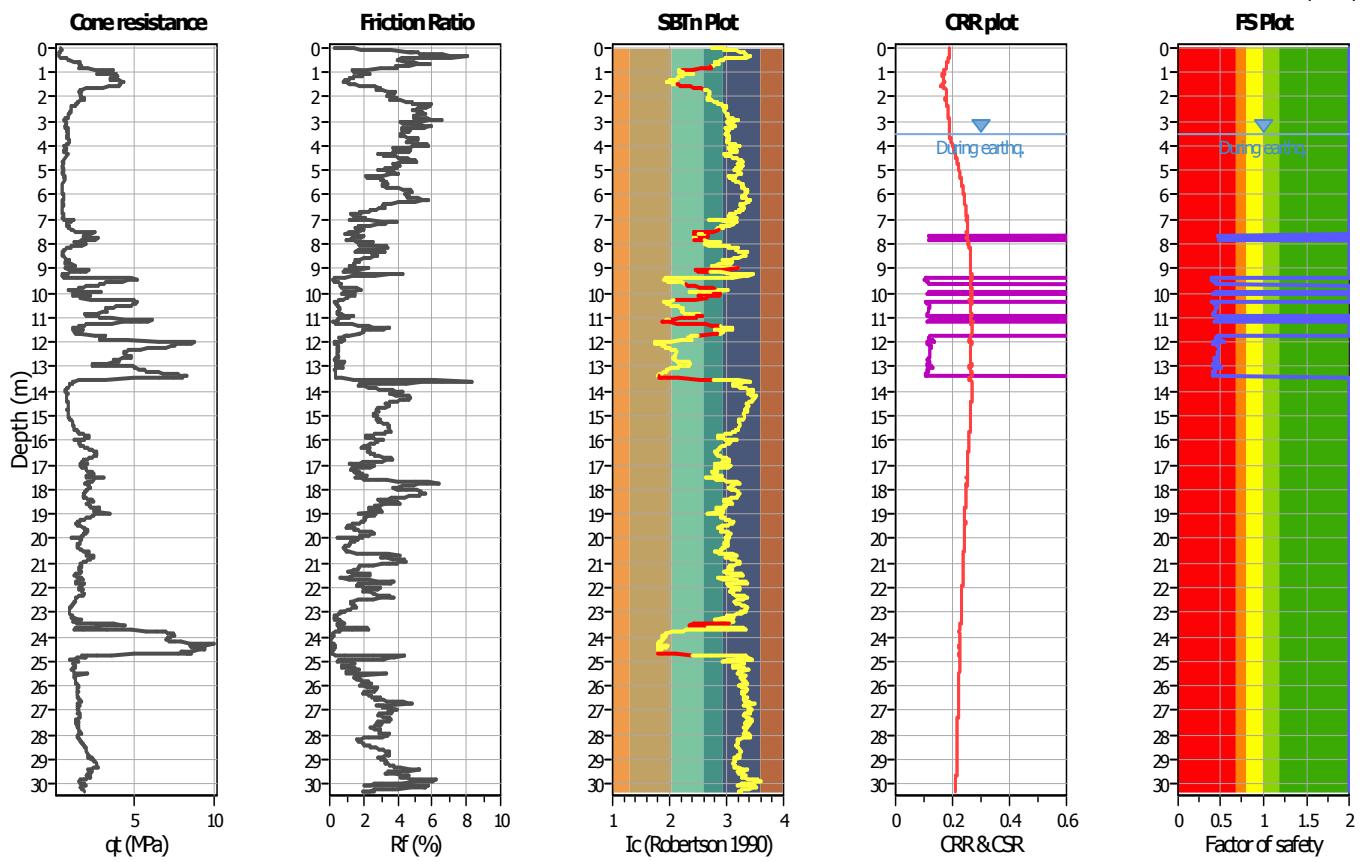


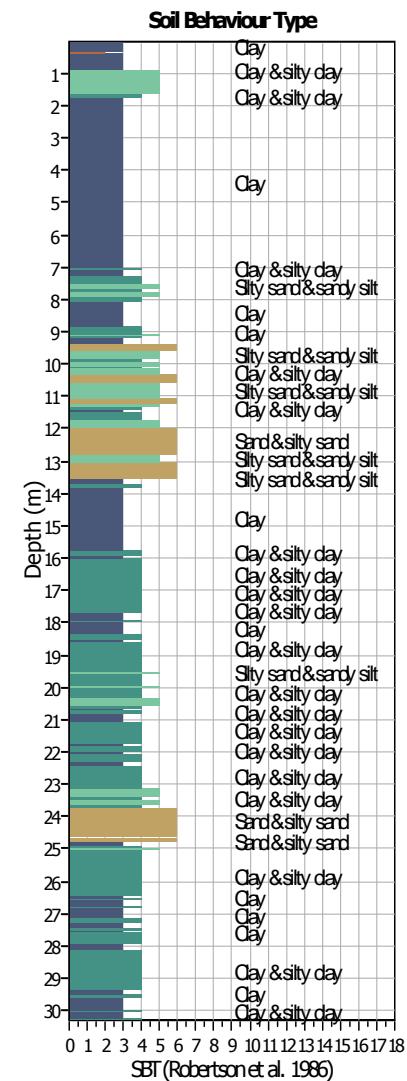
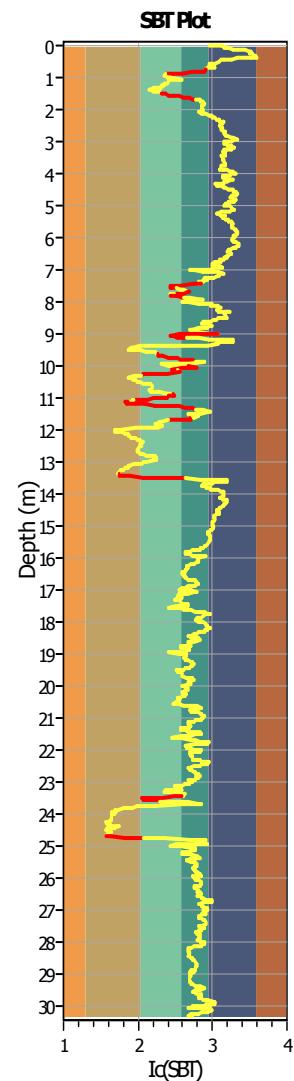
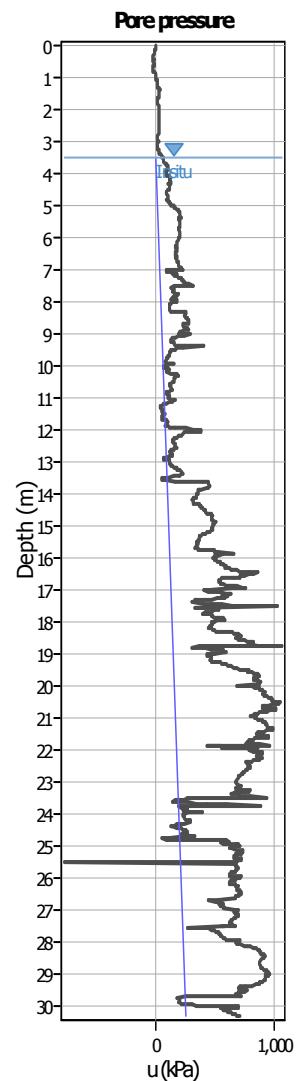
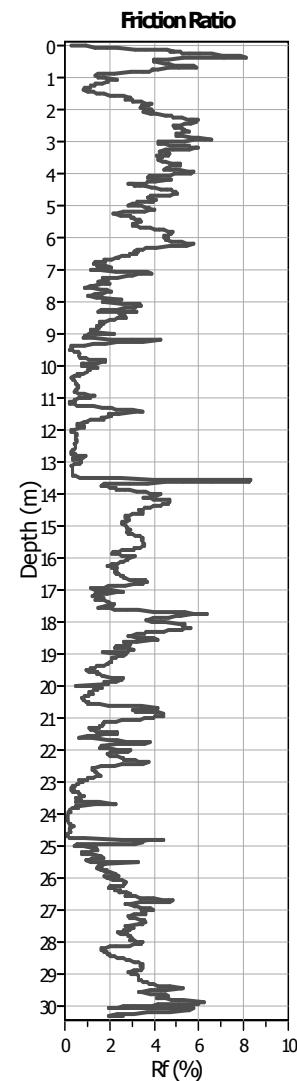
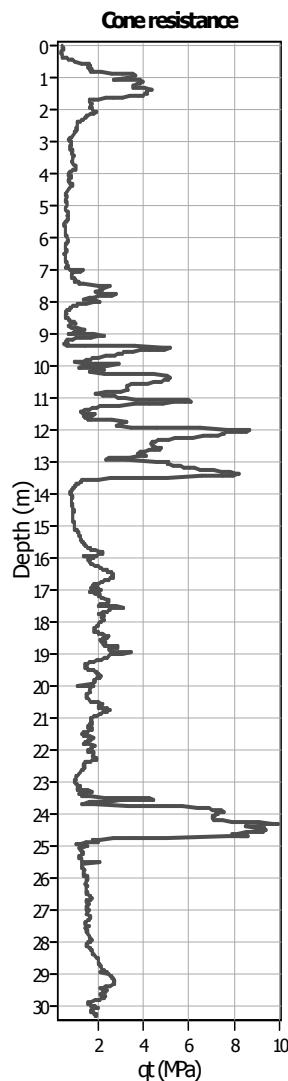
ALLEGATO 5

VERIFICA ALLA LIQUEFAZIONE

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 1
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.50 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	20.00 m
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



CPT basic interpretation plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in-situ): 3.50 m

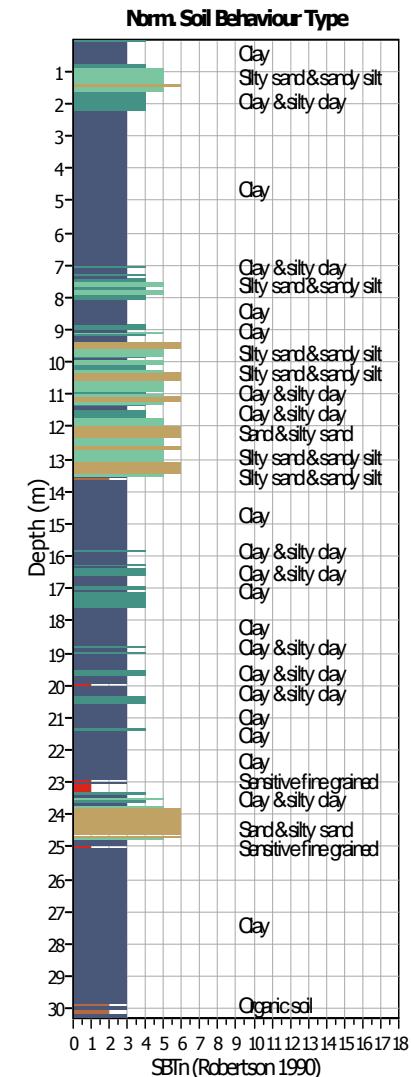
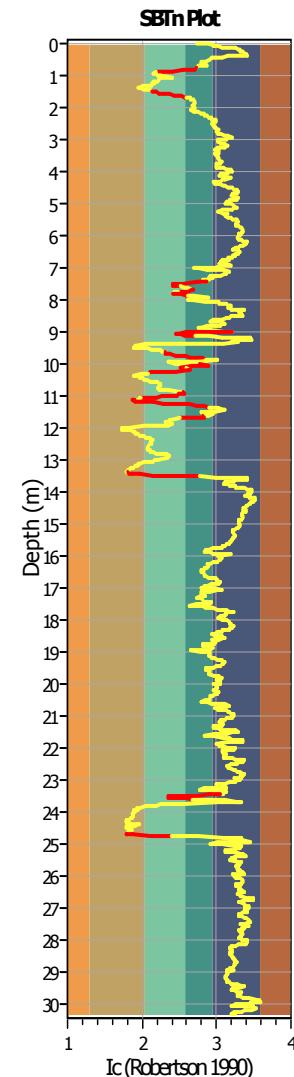
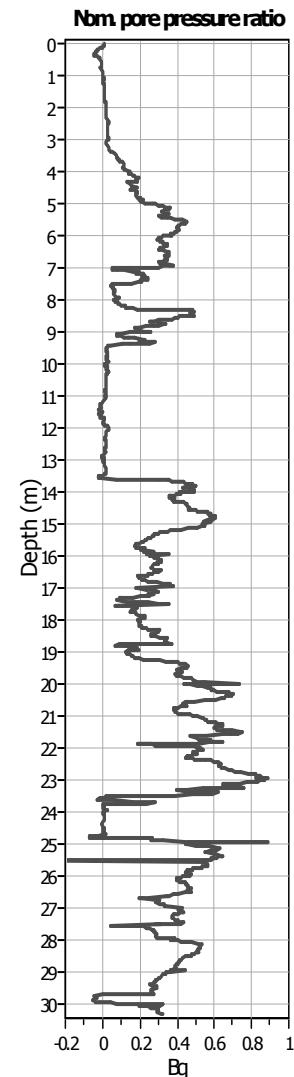
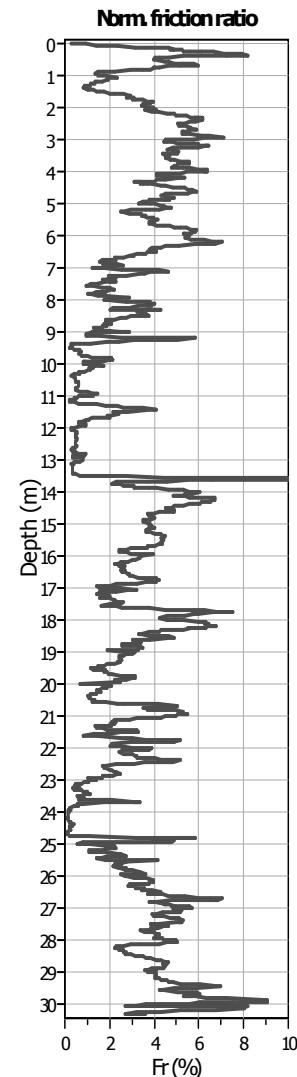
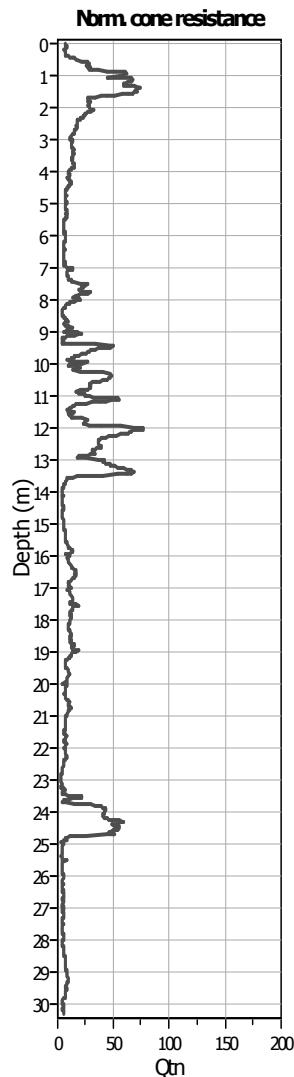
Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied:
 K_0 applied:
 Clay like behavior applied:
 Limit depth applied:
 Limit depth:

N/A
 Yes
 Yes
 Sands only
 Yes
 20.00 m

SBT legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to
- 9. Very stiff fine grained

CPT basic interpretation plots (normalized)**Input parameters and analysis data**

Analysis method: B&I (2014)
Fines correction method: B&I (2014)
Points to test: Based on Ic value
Earthquake magnitude M_w : 6.14
Peak ground acceleration: 0.34
Depth to water table (in situ): 3.50 m

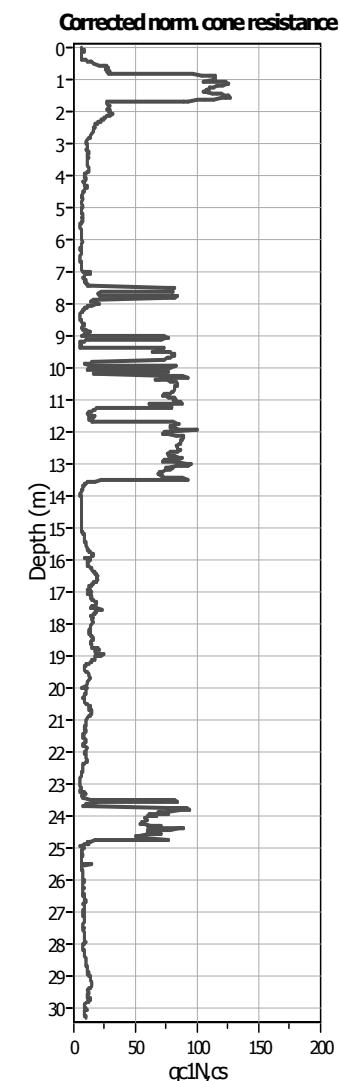
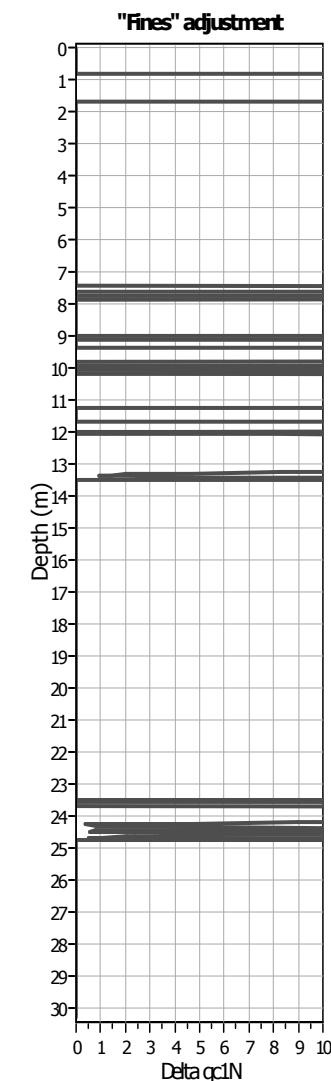
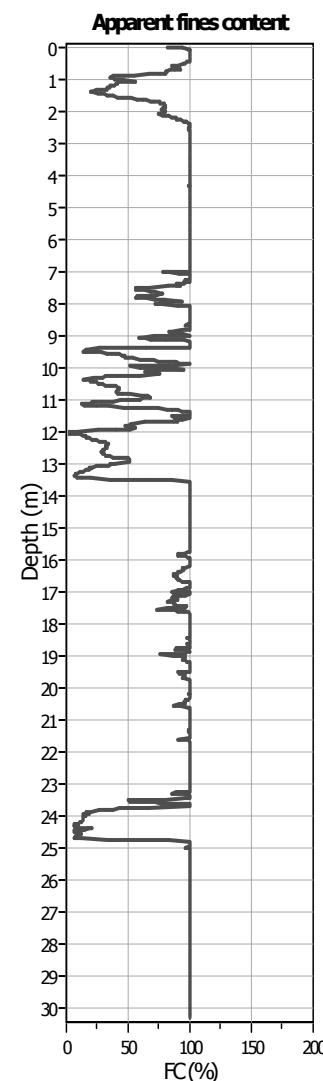
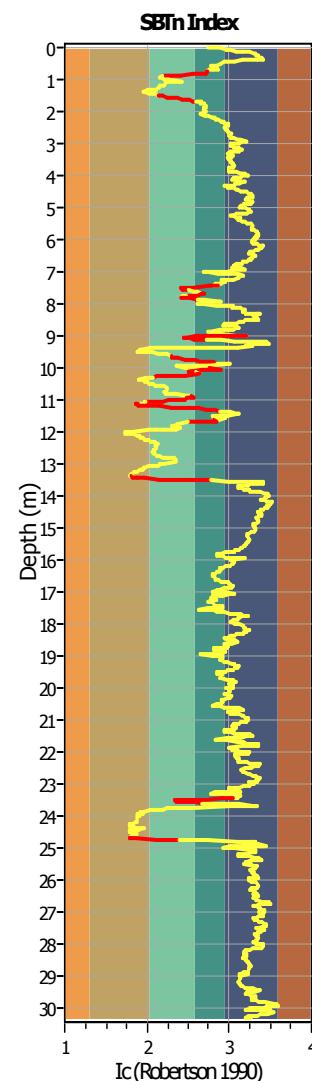
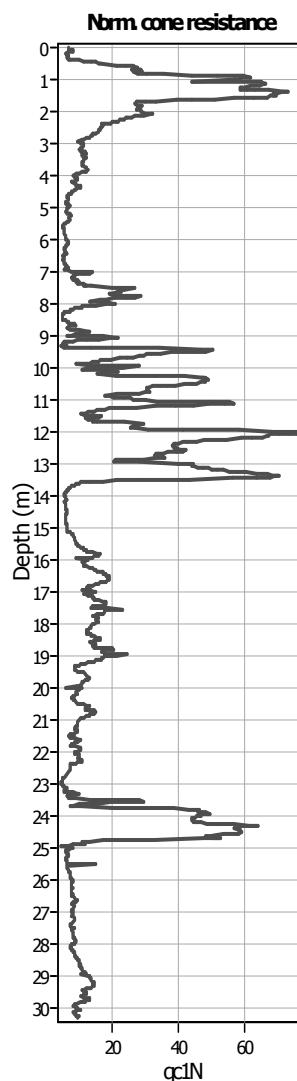
Depth to GWT (erthq.): 3.50 m
Average results interval: 1
Ic cut-off value: 2.60
Unit weight calculation: Based on SBT
Use fill: No
Fill height: N/A

Fill weight:
Transition detect. applied:
 K_0 applied:
Clay like behavior applied:
Limit depth applied:
Limit depth:

N/A
Yes
Yes
Sands only
Yes
20.00 m

SBTn legend

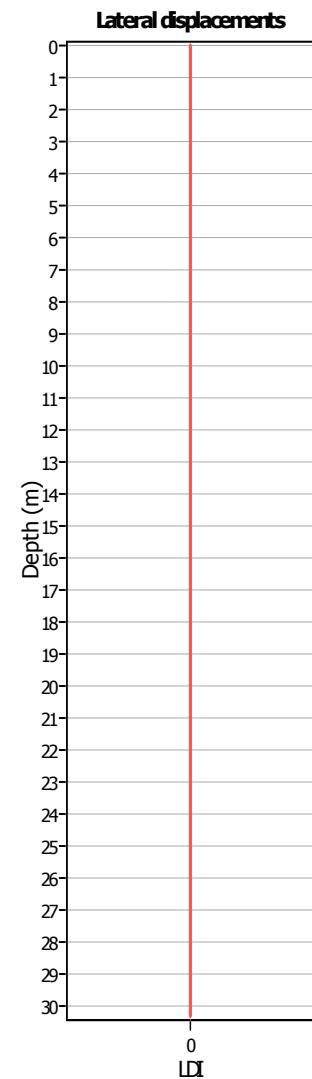
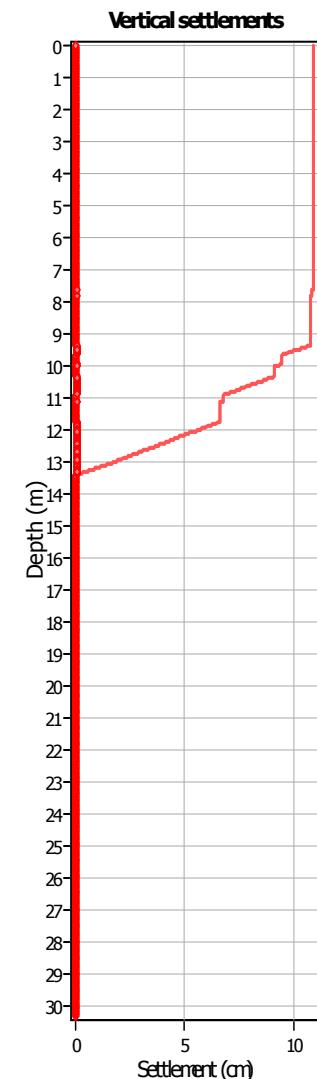
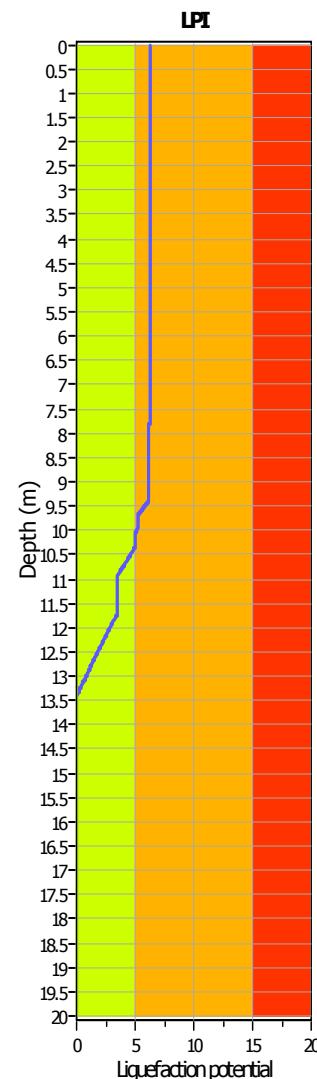
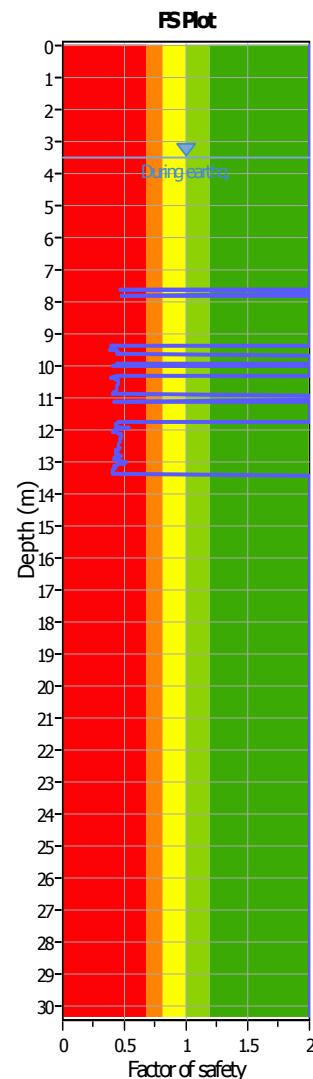
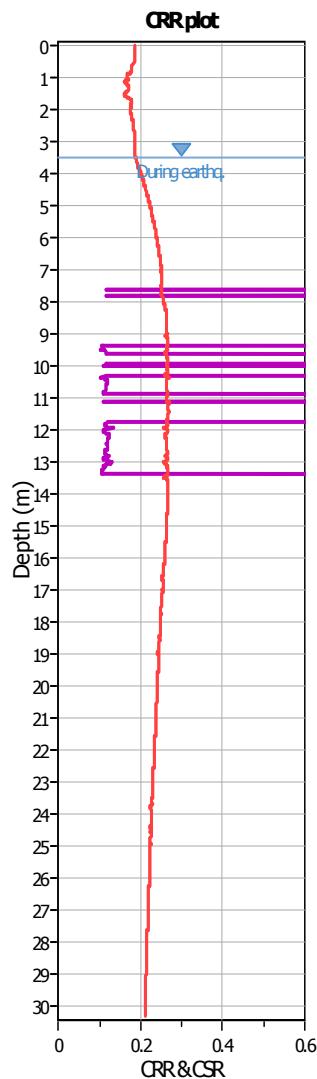
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: Yes
 Limit depth: 20.00 m

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

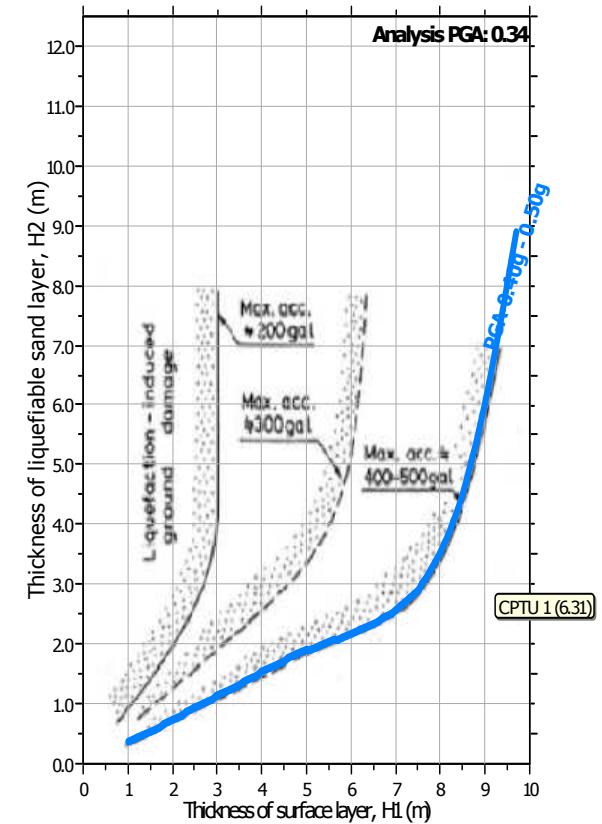
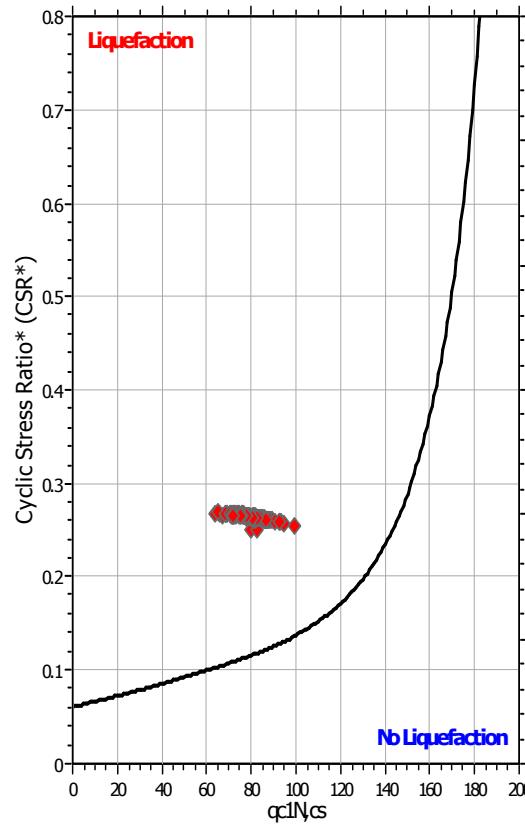
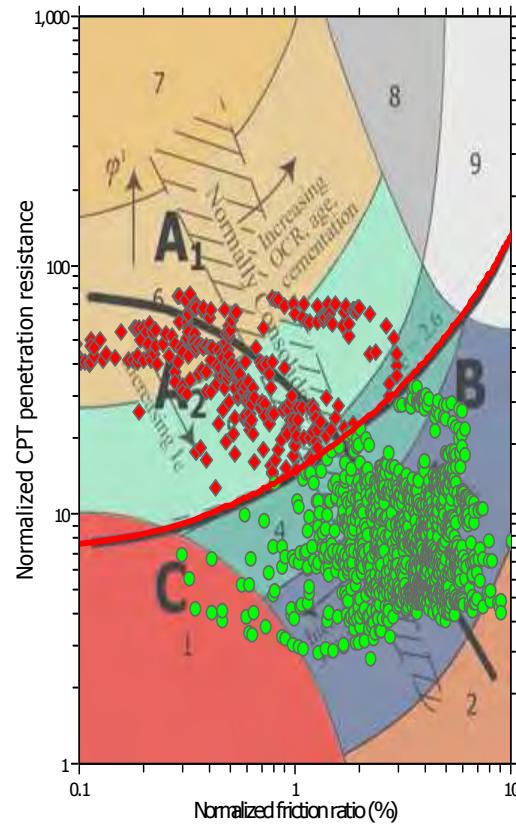
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: Yes
 Limit depth: 20.00 m

F.S. color scheme

Red	Almost certain it will liquefy
Orange	Very likely to liquefy
Yellow	Liquefaction and no liq. are equally likely
Green	Unlike to liquefy
Light Green	Almost certain it will not liquefy

LPI color scheme

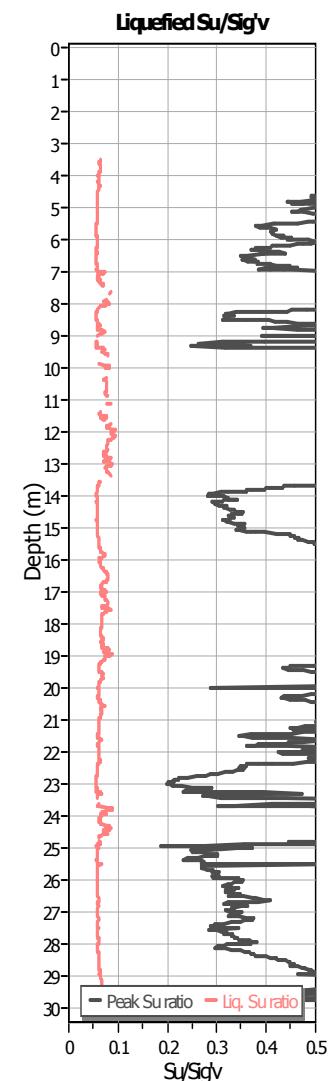
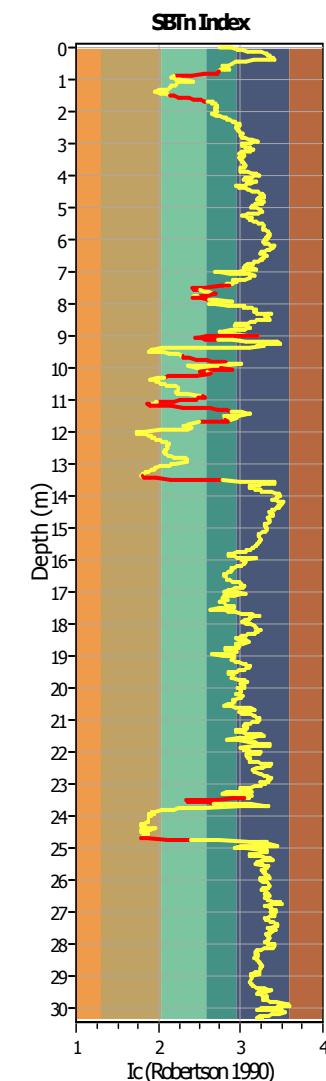
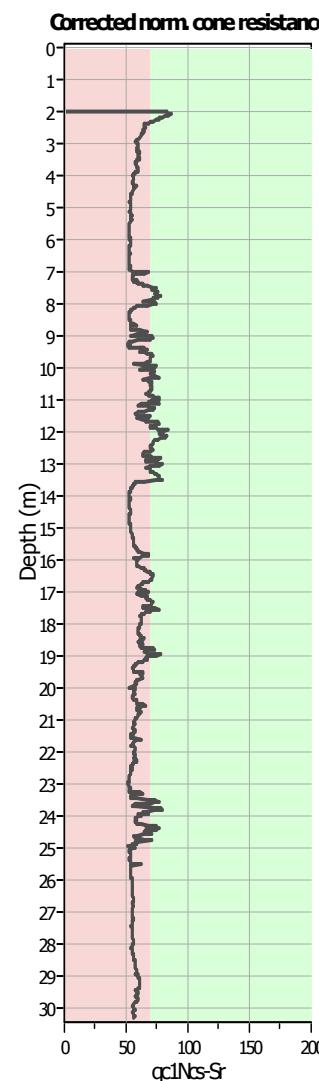
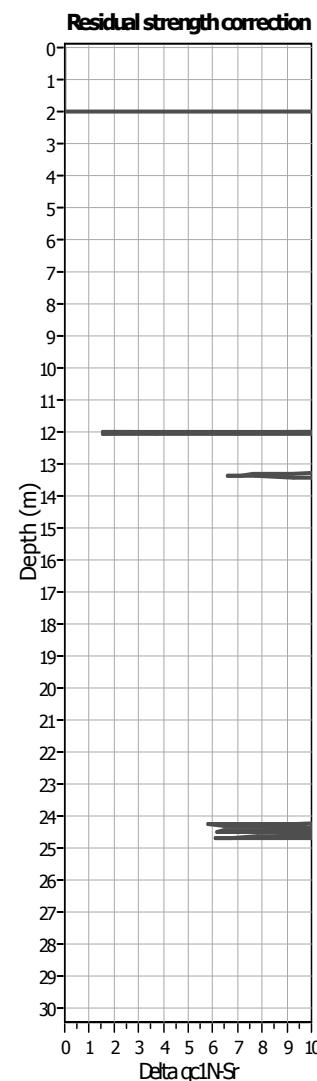
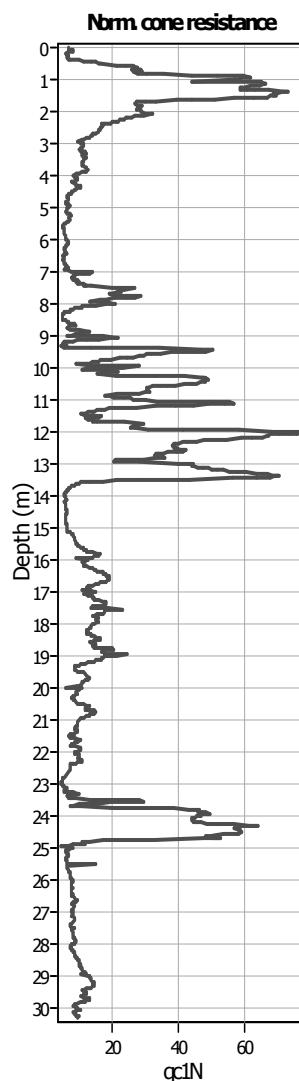
Red	Very high risk
Orange	High risk
Yellow	Medium risk
Green	Low risk

Liquefaction analysis summary plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: Yes
 Limit depth: 20.00 m

Check for strength loss plots (Idriss & Boulanger (2008))**Input parameters and analysis data**

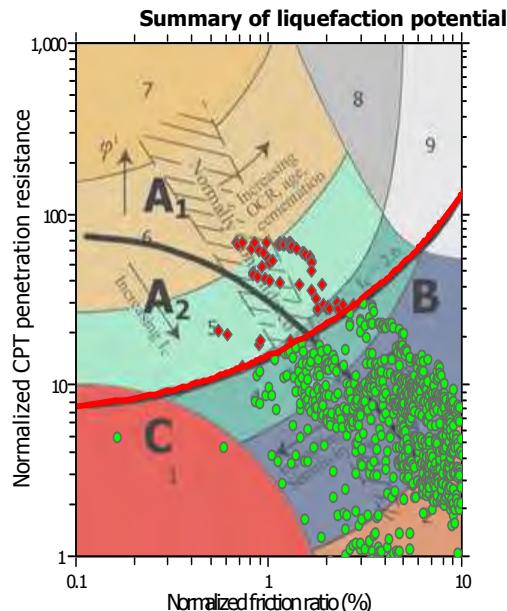
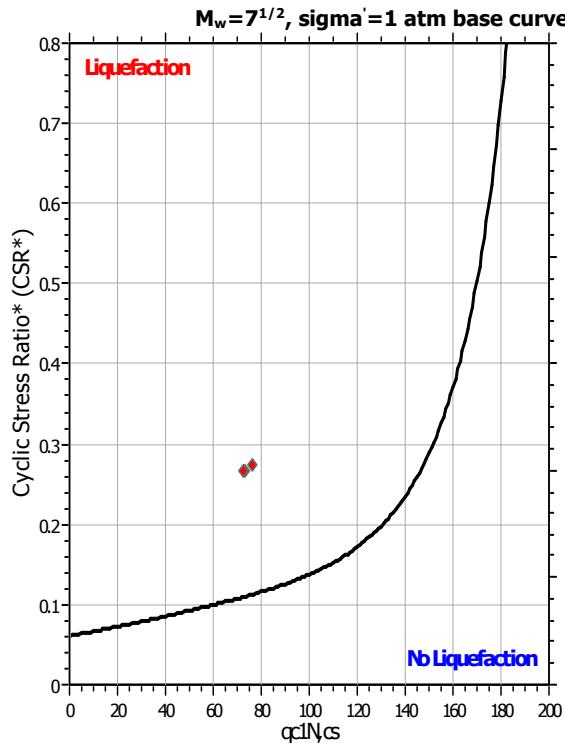
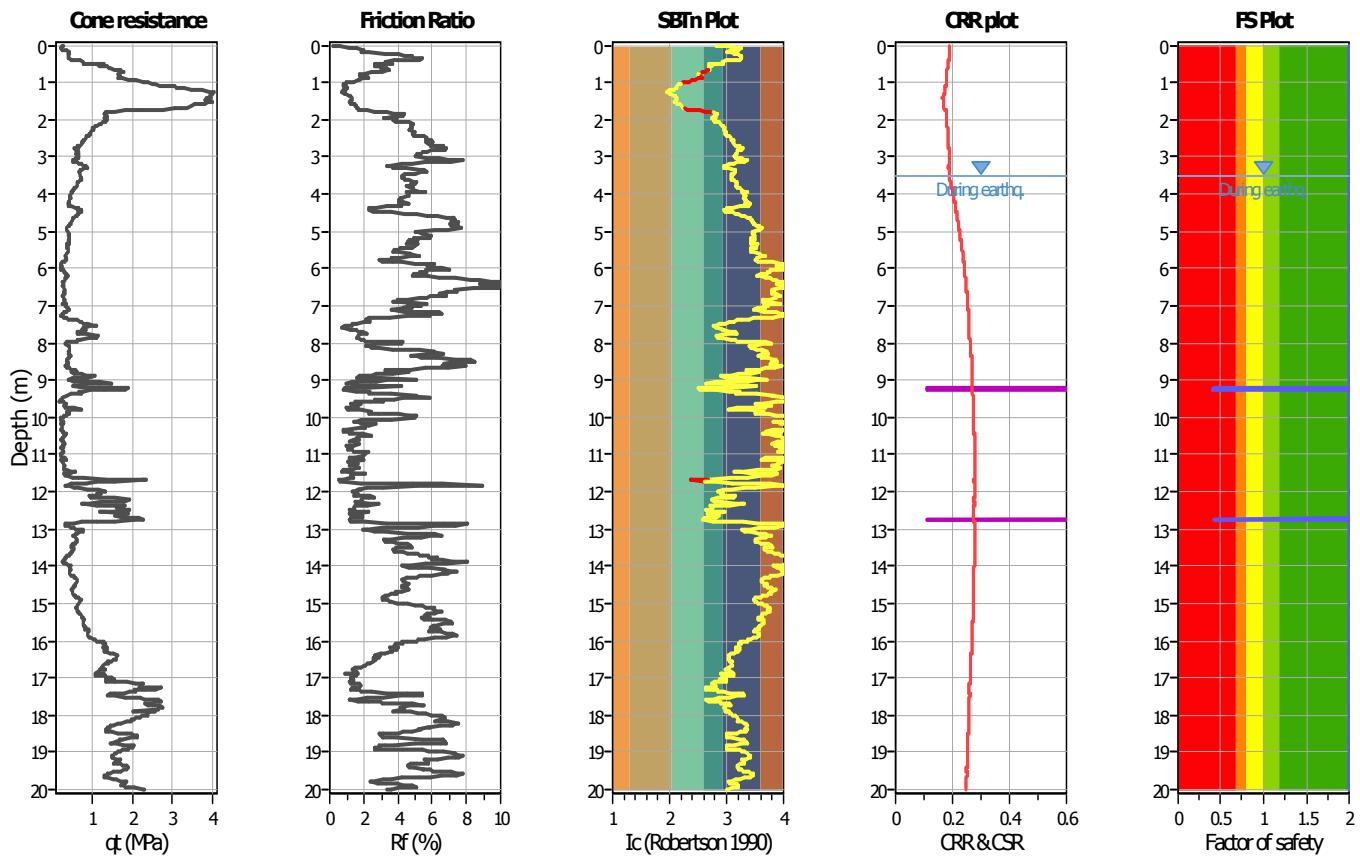
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

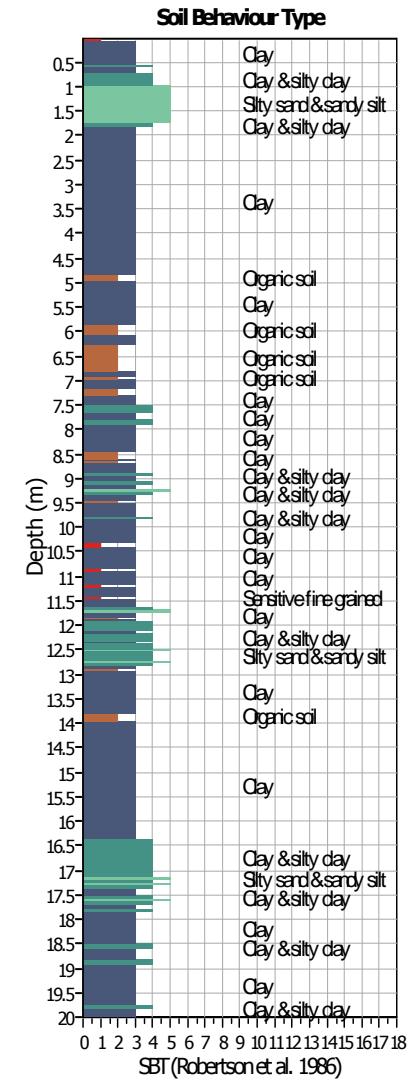
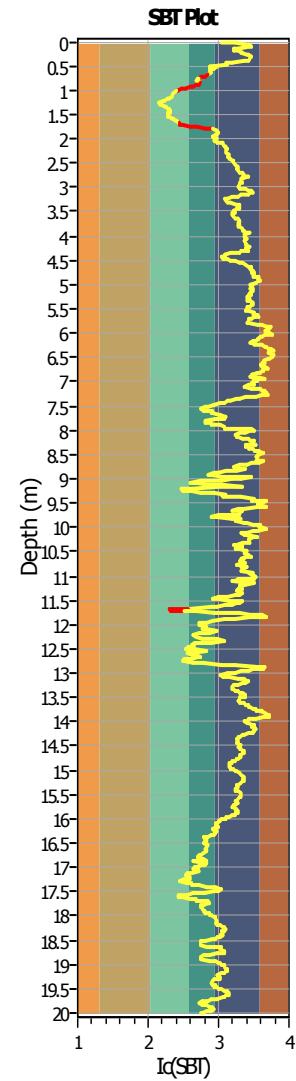
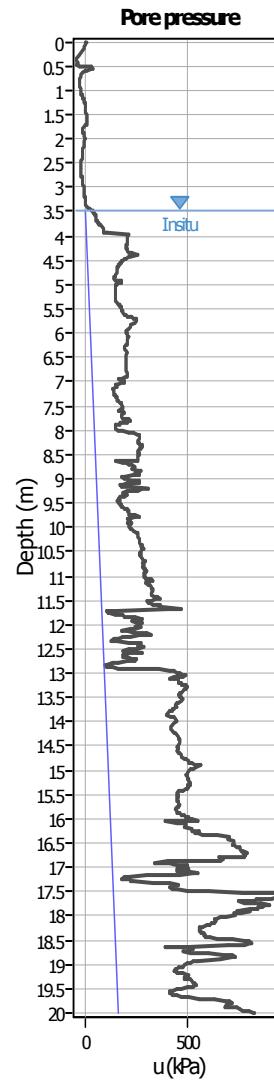
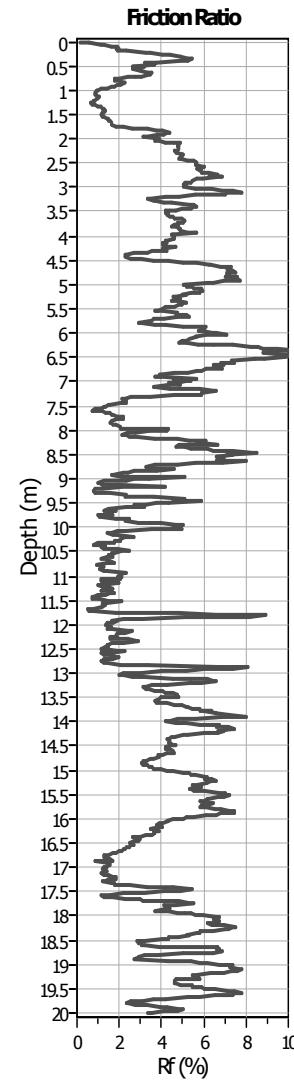
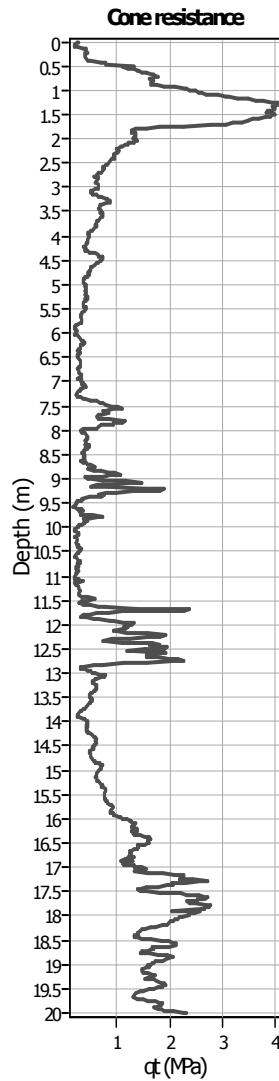
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: Yes
 Limit depth: 20.00 m

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 2
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.50 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	20.00 m
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

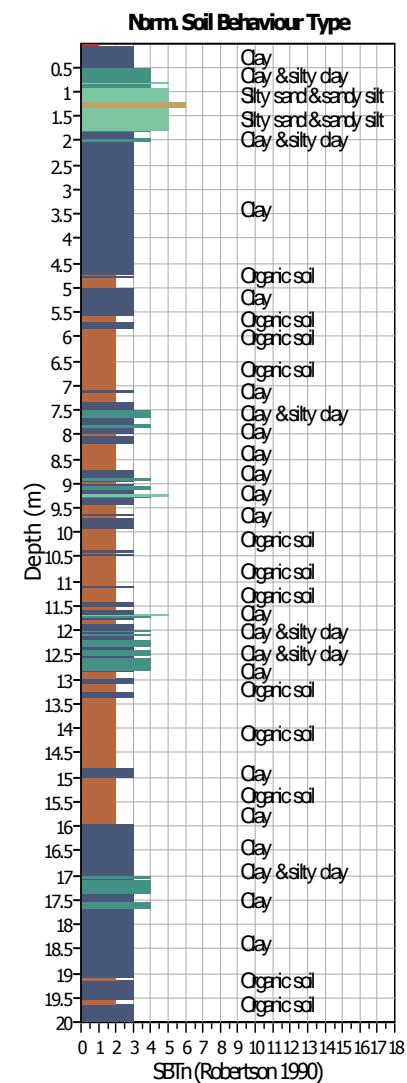
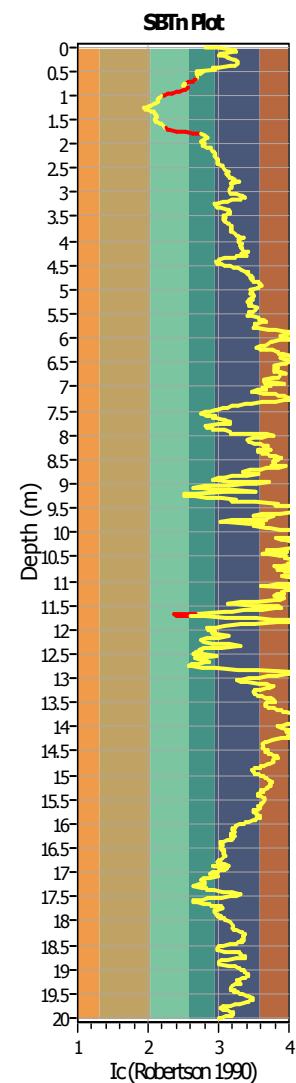
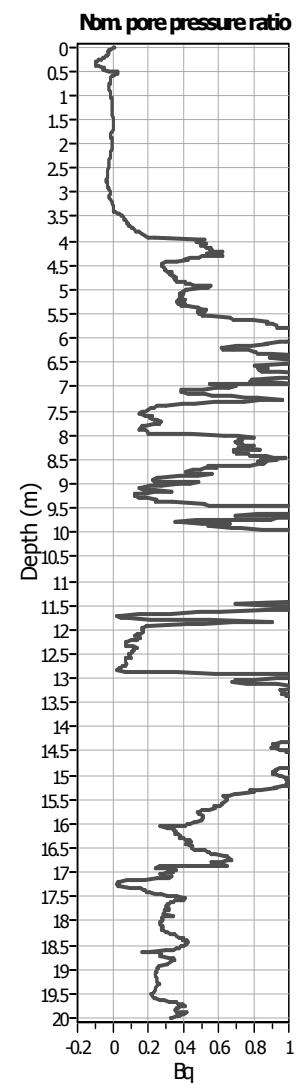
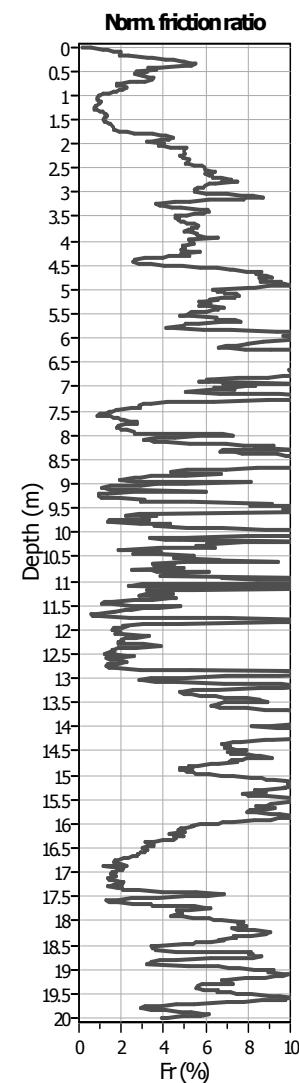
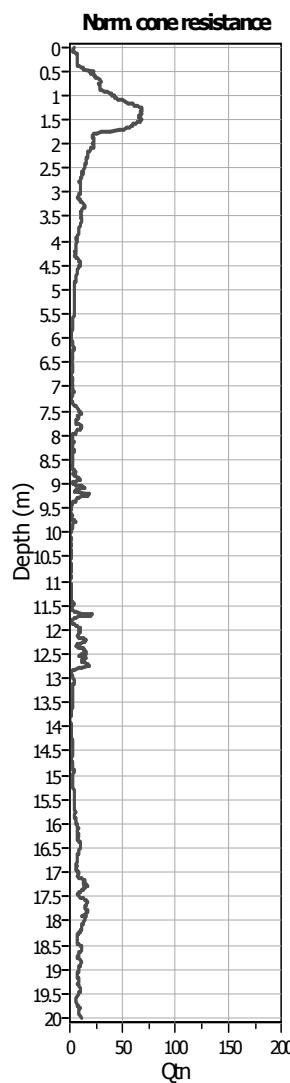
Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: Yes
 Limit depth: 20.00 m

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)



Input parameters and analysis data

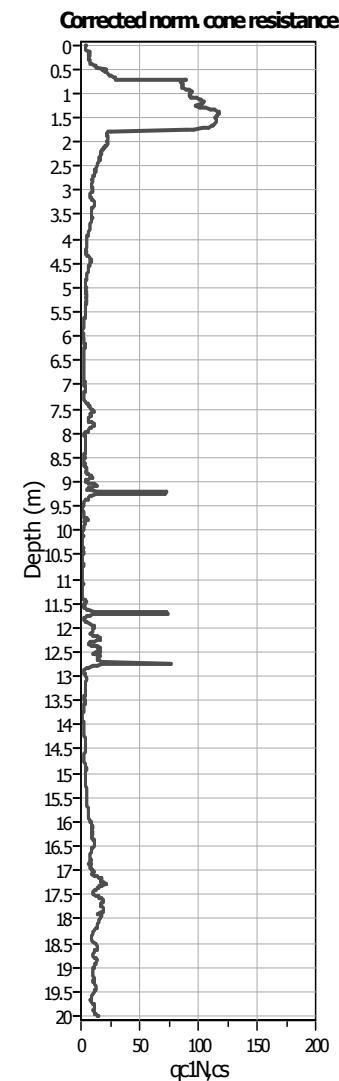
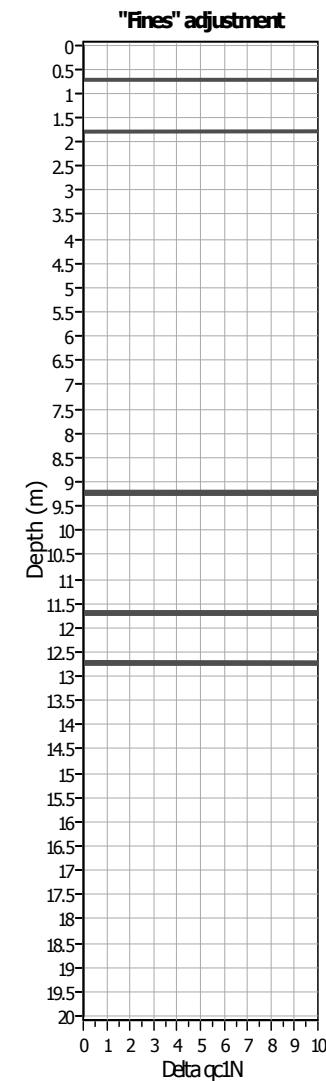
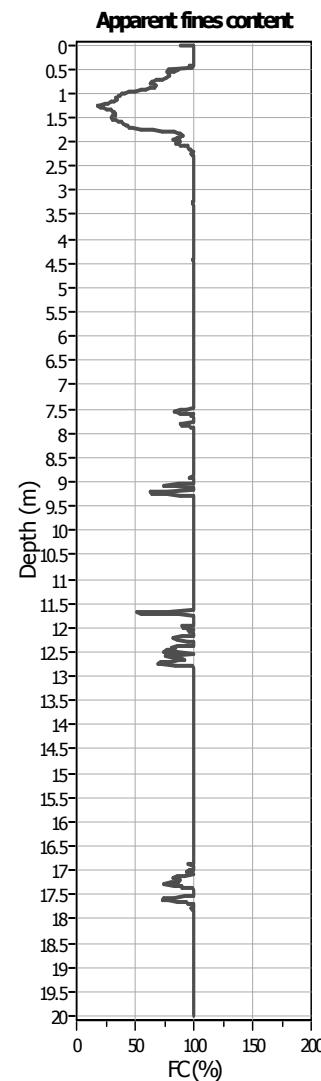
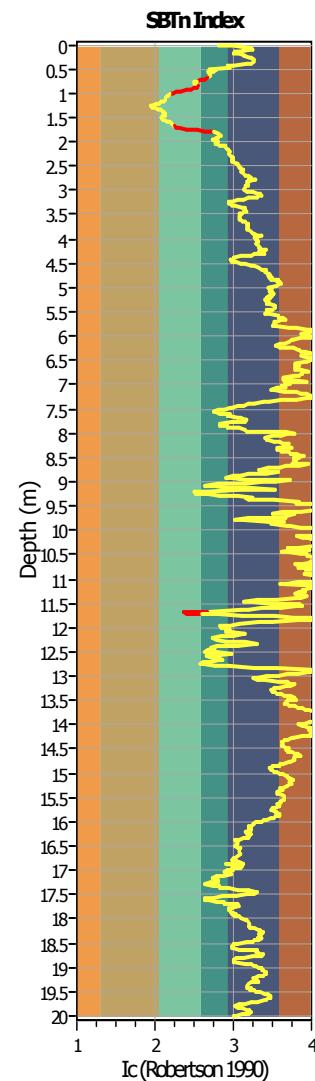
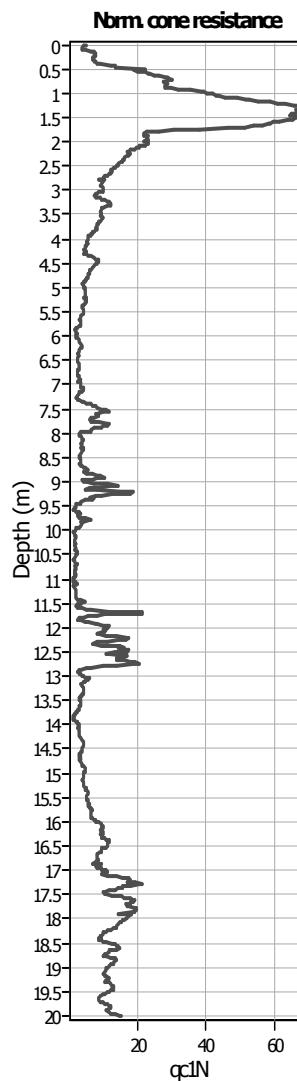
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: Yes
 Limit depth: 20.00 m

SBTn legend

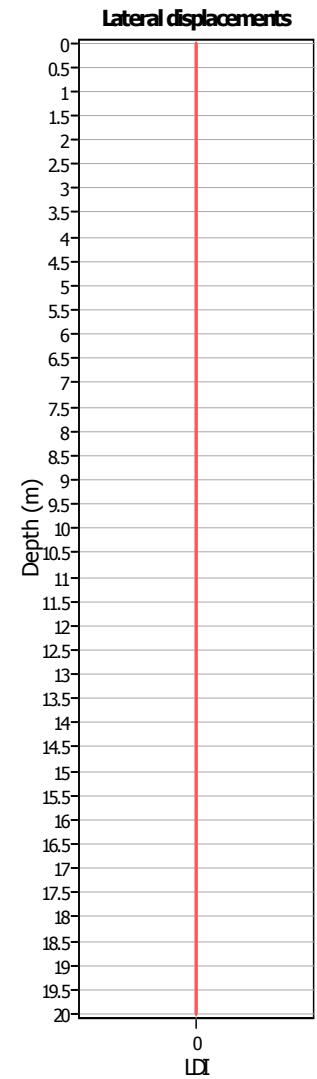
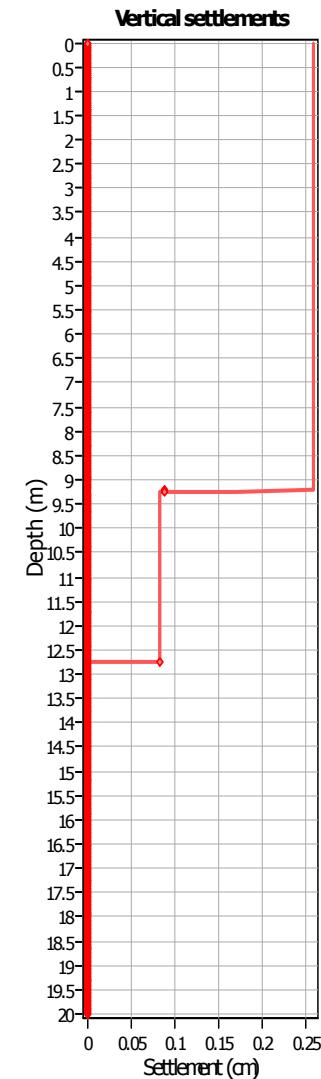
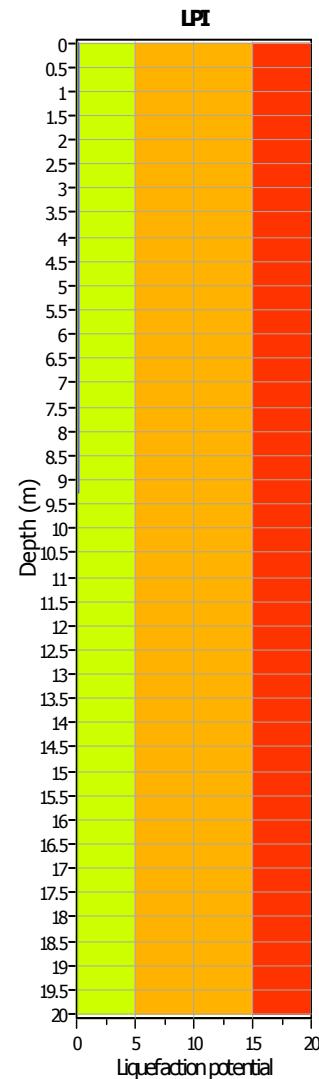
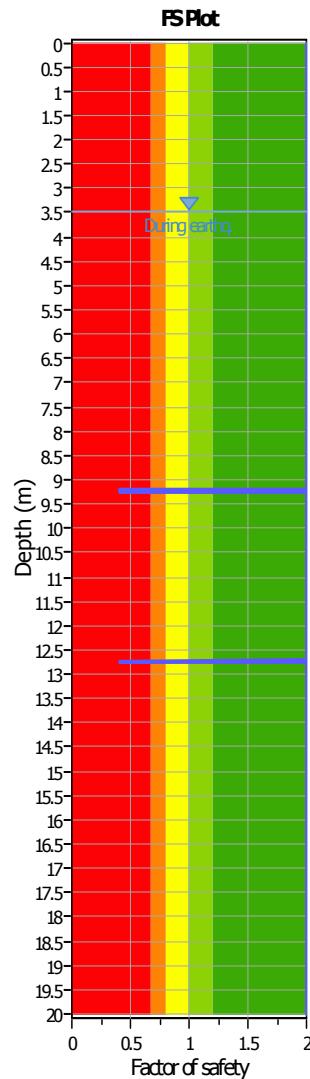
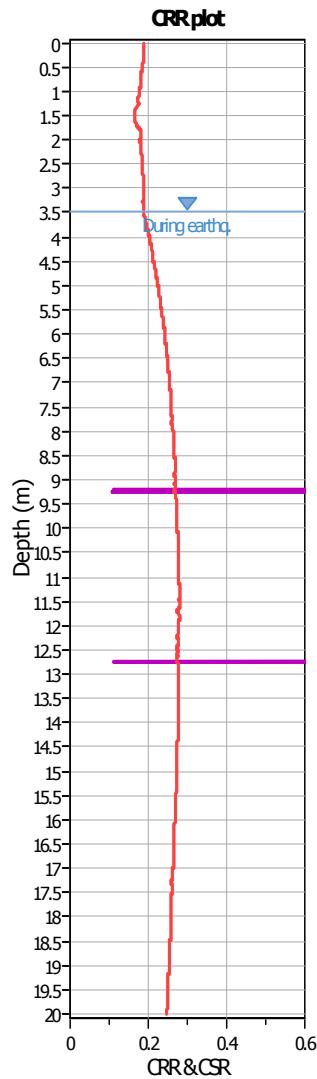
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: Yes
 Limit depth: 20.00 m

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

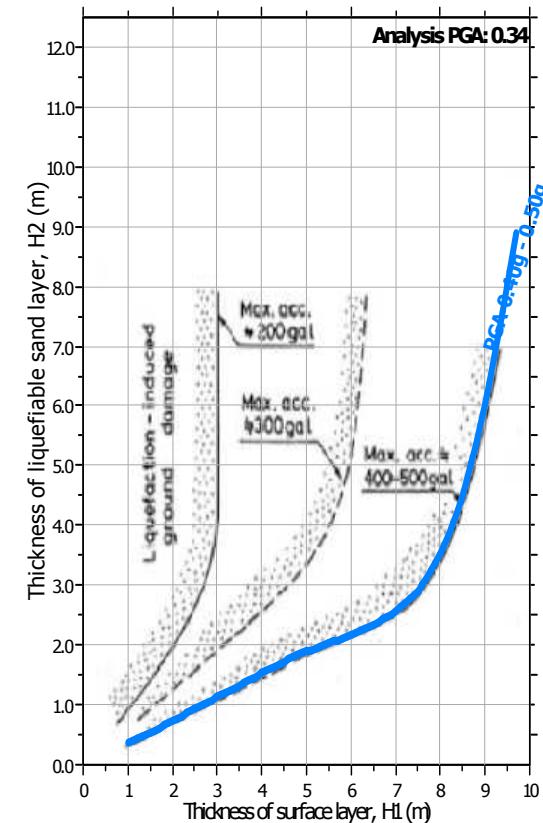
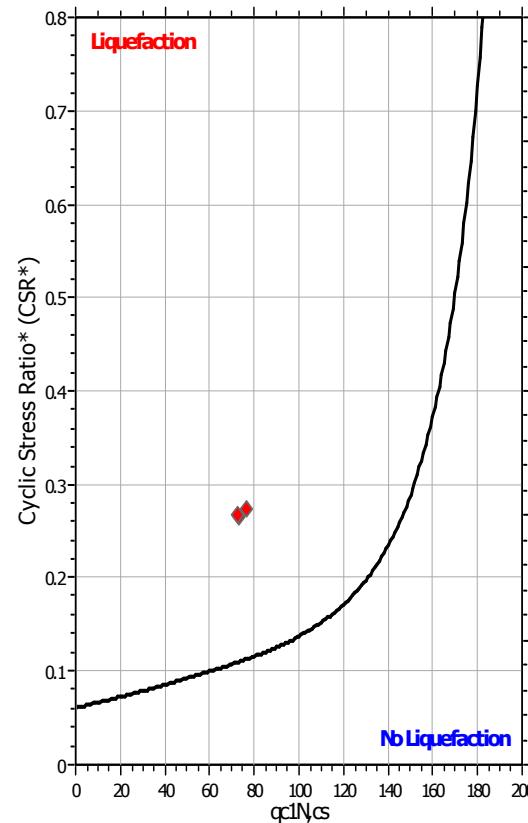
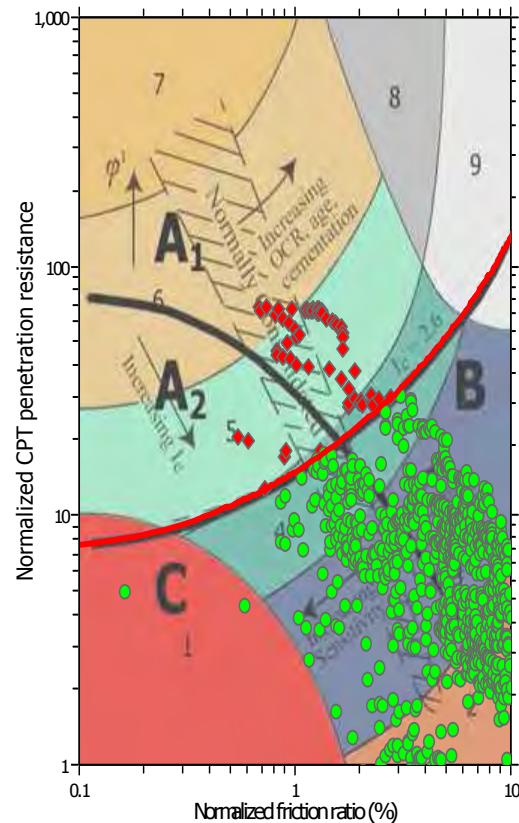
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: Yes
 Limit depth: 20.00 m

F.S. color scheme

- █ Almost certain it will liquefy
- █ Very likely to liquefy
- █ Liquefaction and no liq. are equally likely
- █ Unlike to liquefy
- █ Almost certain it will not liquefy

LPI color scheme

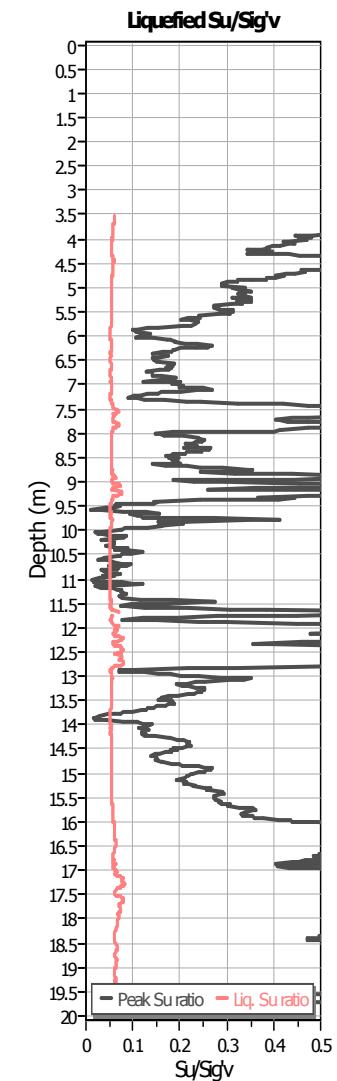
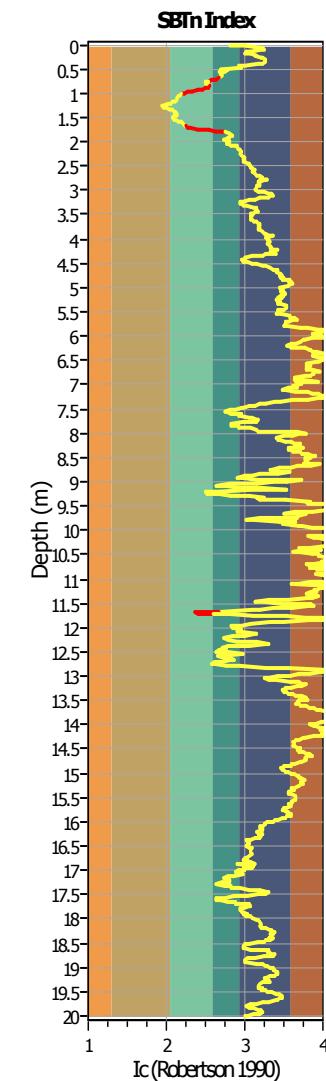
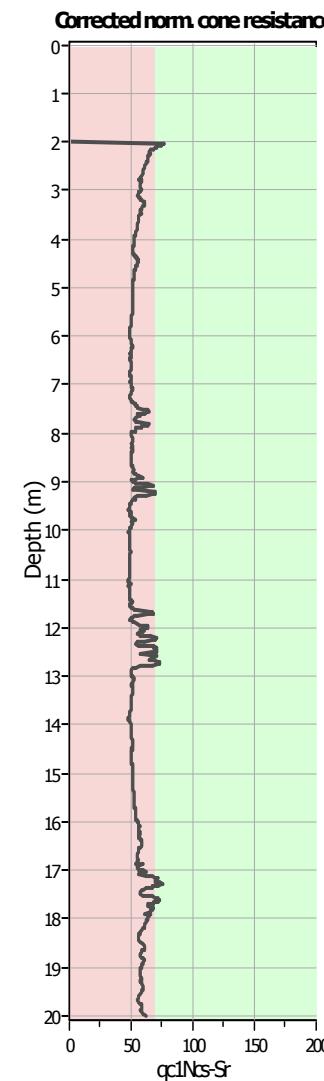
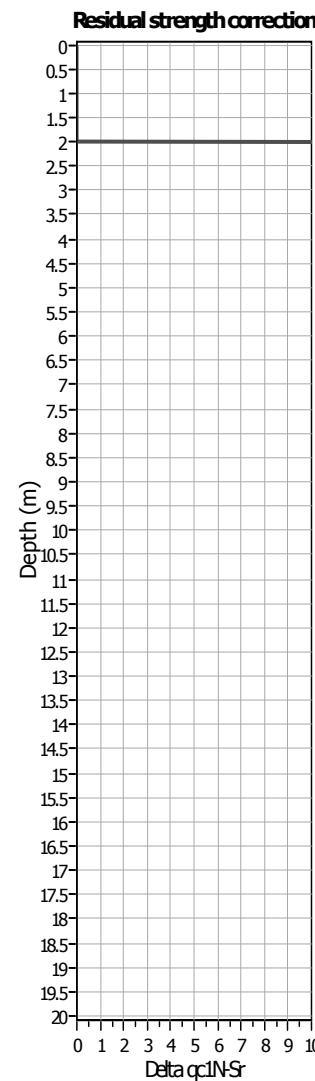
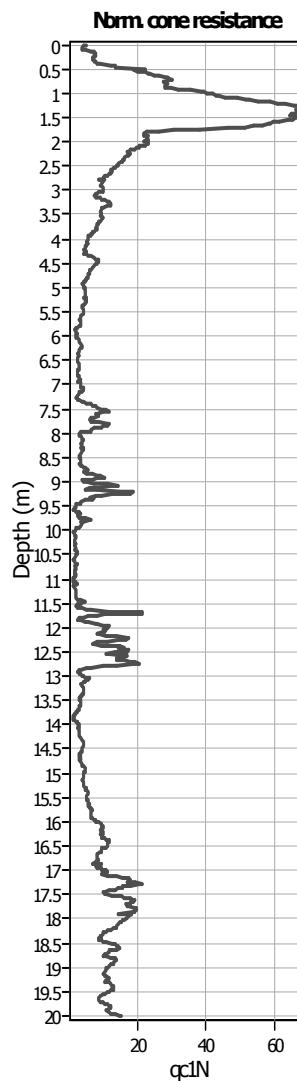
- █ Very high risk
- █ High risk
- █ Moderate risk
- █ Low risk

Liquefaction analysis summary plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A
 Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: Yes
 Limit depth: 20.00 m

Check for strength loss plots (Idriss & Boulanger (2008))

**Input parameters and analysis data**

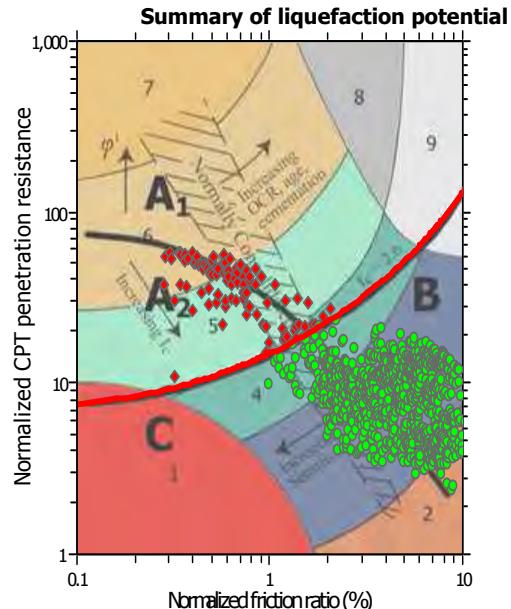
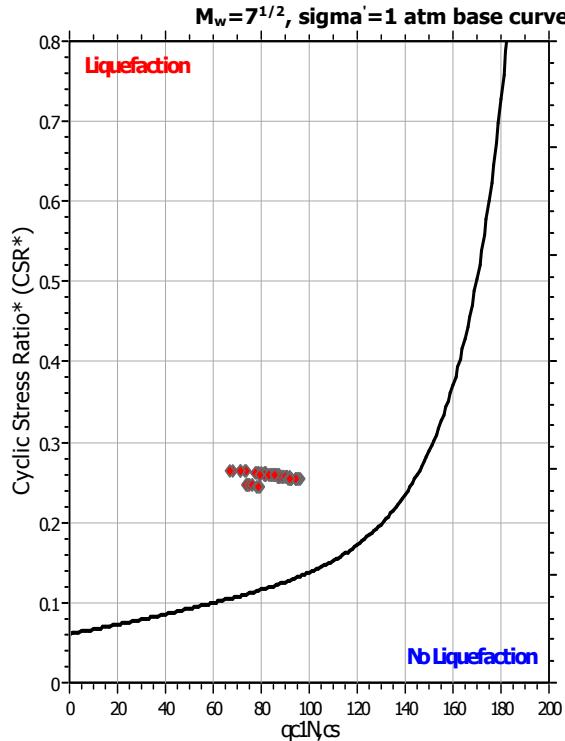
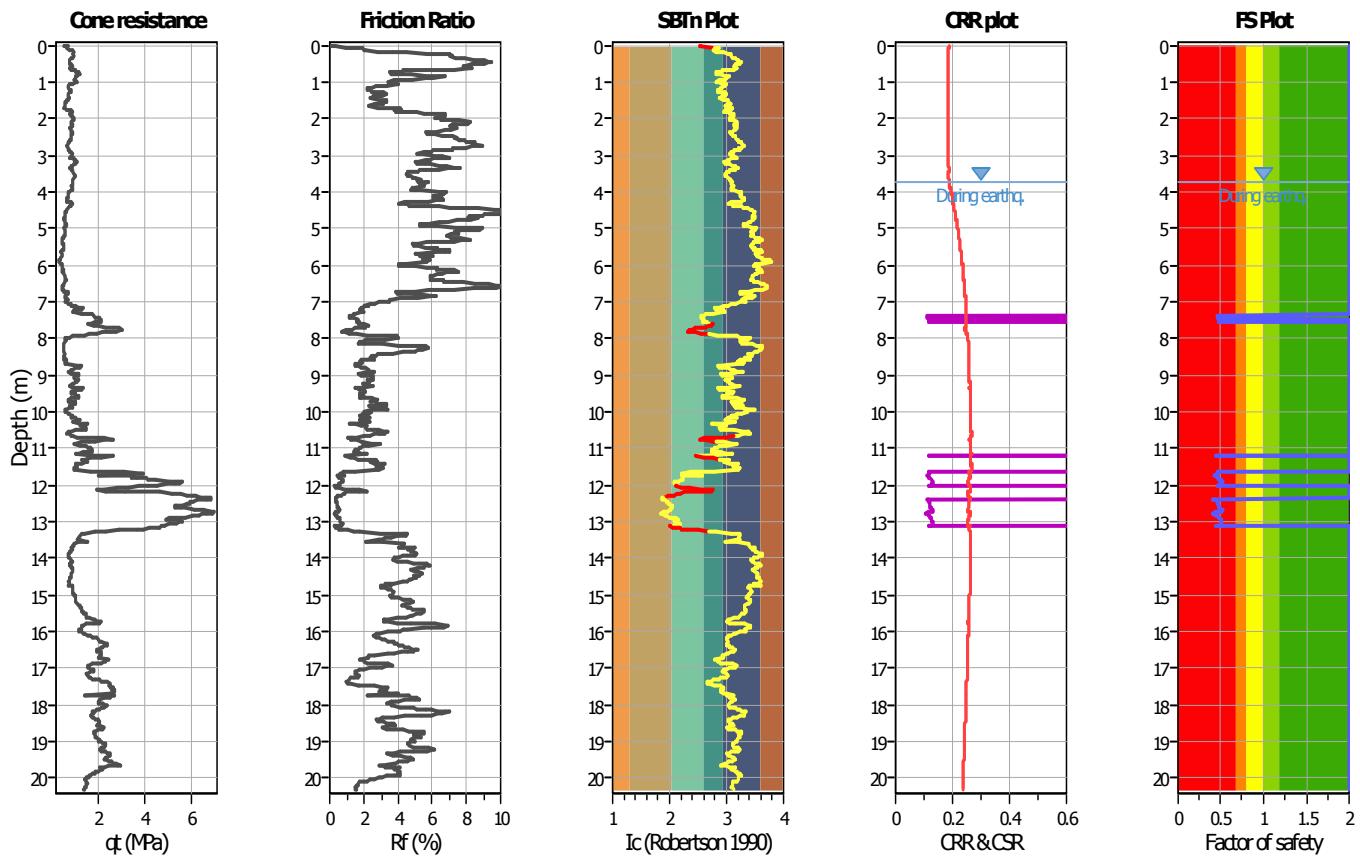
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

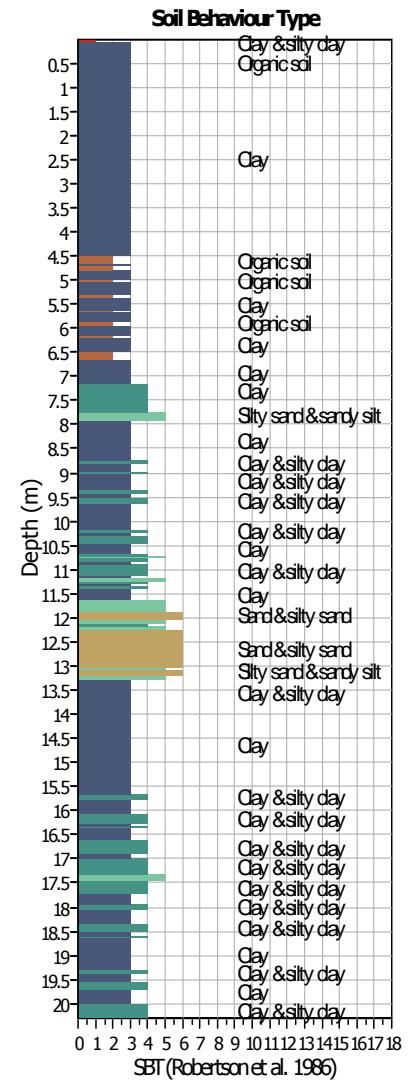
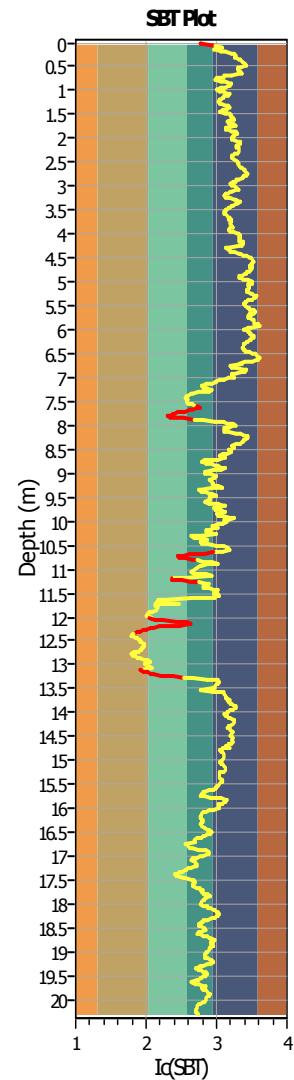
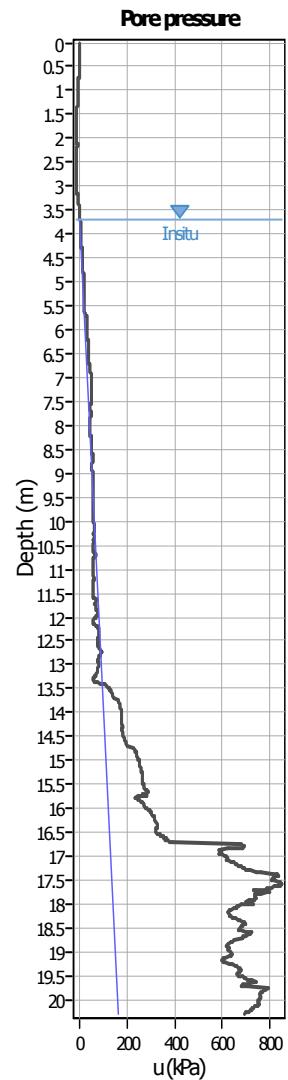
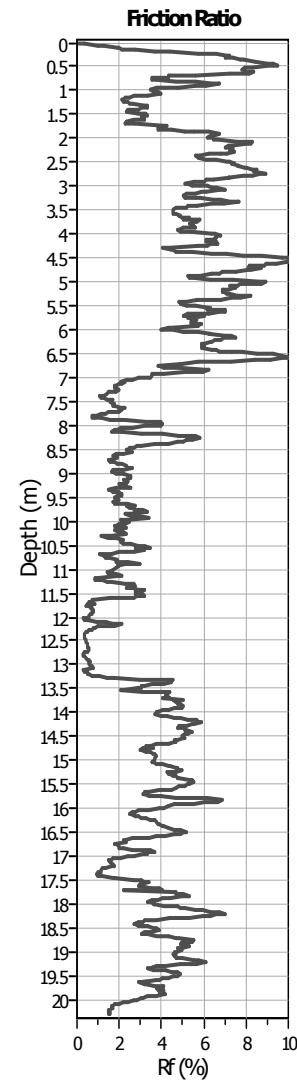
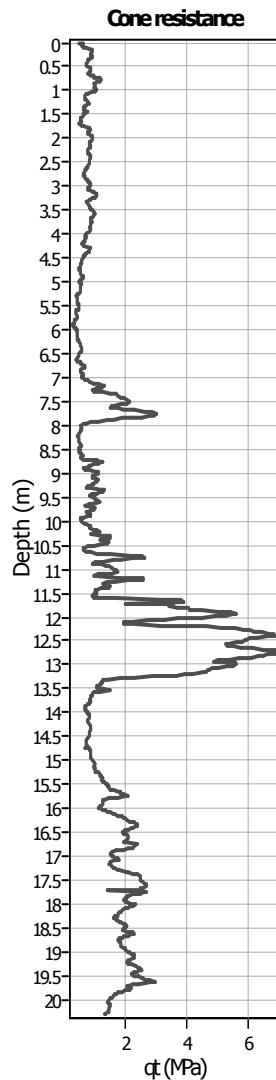
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: Yes
 Limit depth: 20.00 m

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato Regionale dell'Emergenza sul **Location : via Bologna, Ferrara**
CPT file : CPTU3
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.70 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.70 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in-situ): 3.70 m

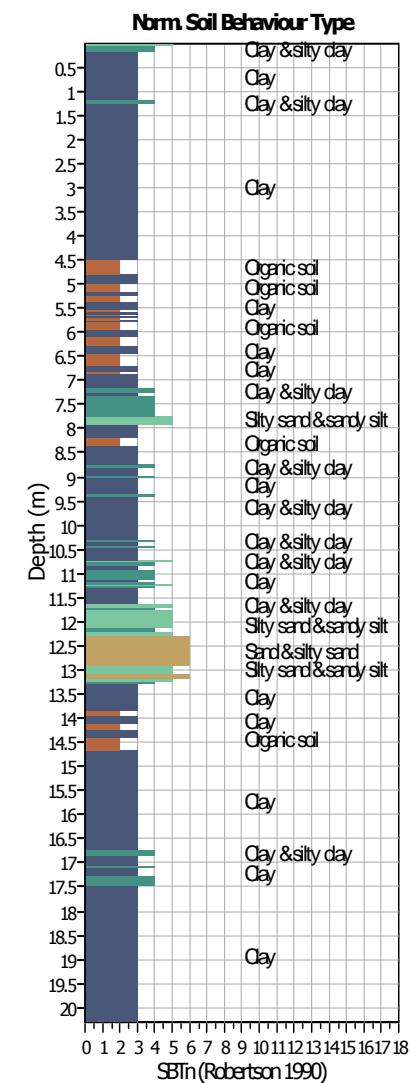
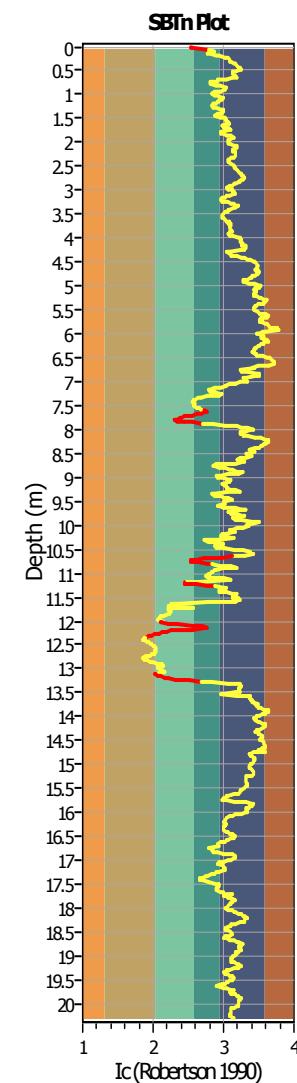
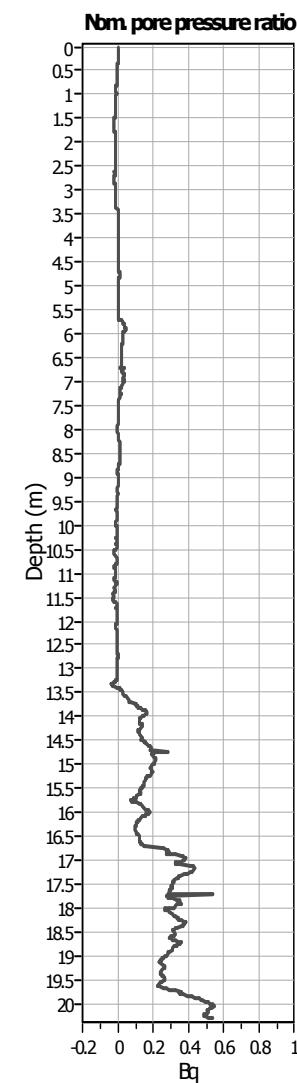
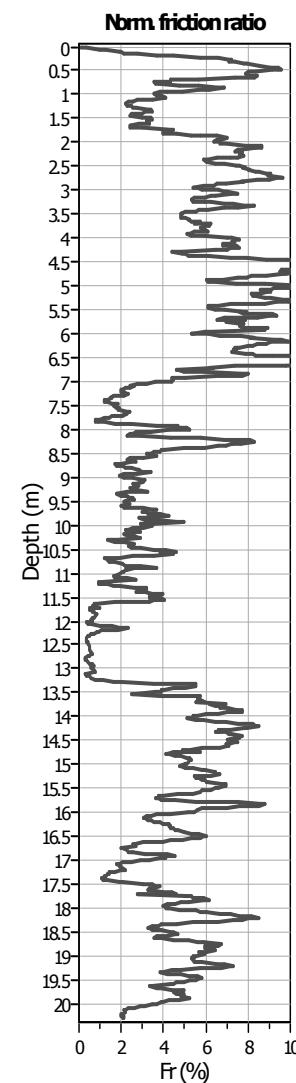
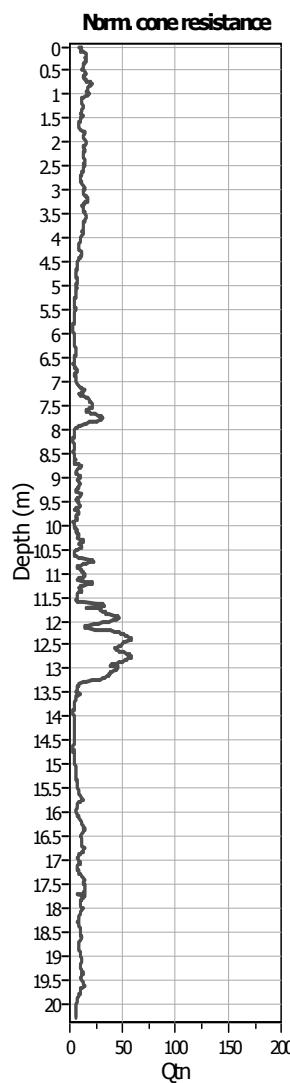
Depth to GWT (erthq.): 3.70 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)



Input parameters and analysis data

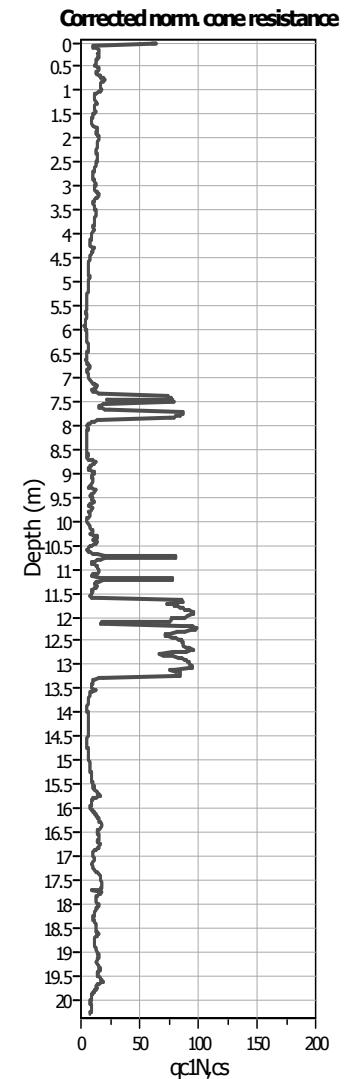
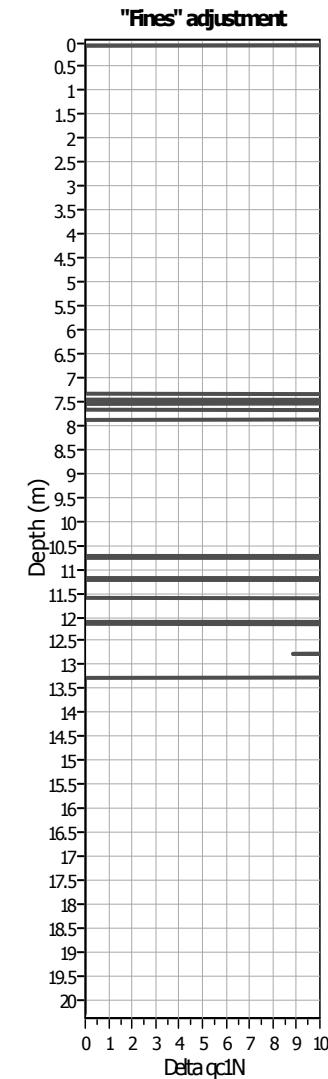
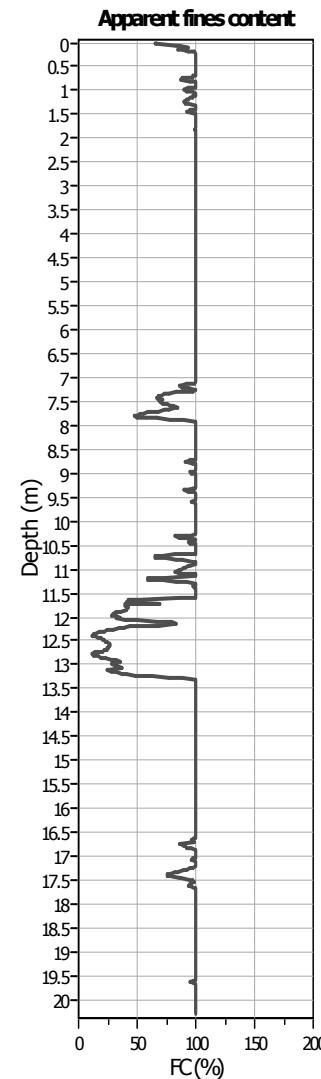
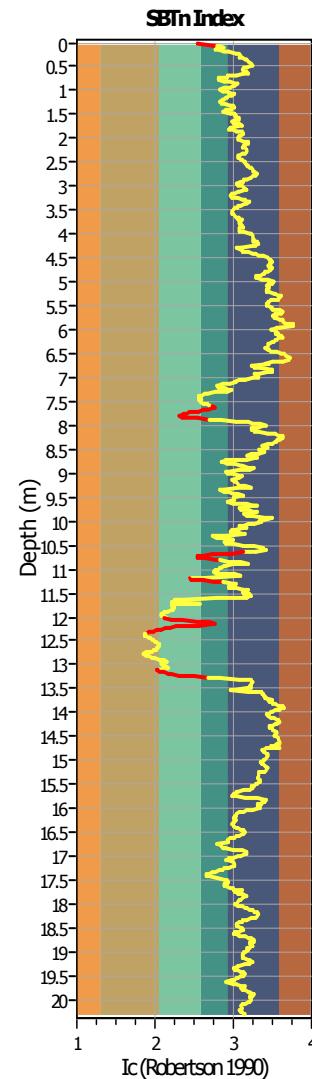
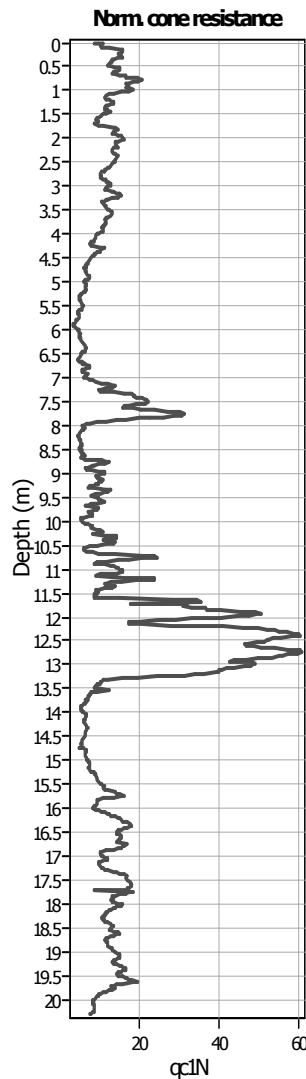
Analysis method:	B&I (2014)
Fines correction method:	B&I (2014)
Points to test:	Based on Ic value
Earthquake magnitude M_w :	6.14
Peak ground acceleration:	0.34
Depth to water table (insitu):	3.70 m

Depth to GWT (erthq.):	3.70 m	Fill weight:
Average results interval:	1	Transition detect. applied:
Ic cut-off value:	2.60	K_o applied:
Unit weight calculation:	Based on SBT	Clay like behavior applied:
Use fill:	No	Limit depth applied:
Fill height:	N/A	Limit depth:

N/A
Yes
Yes
Sands only
No
N/A

SBTn legend

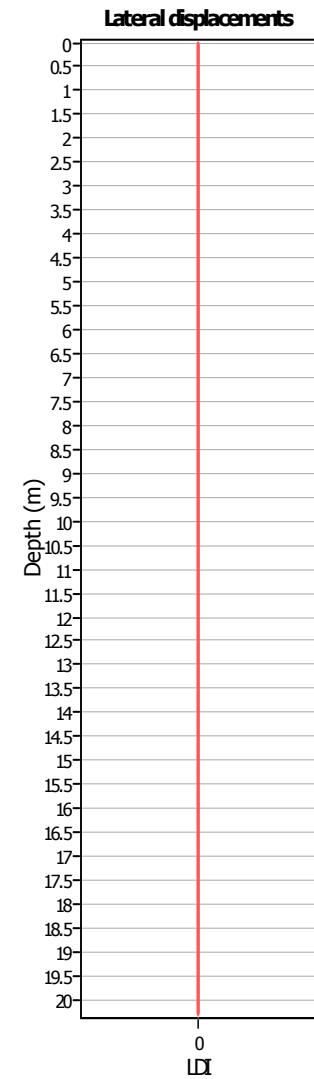
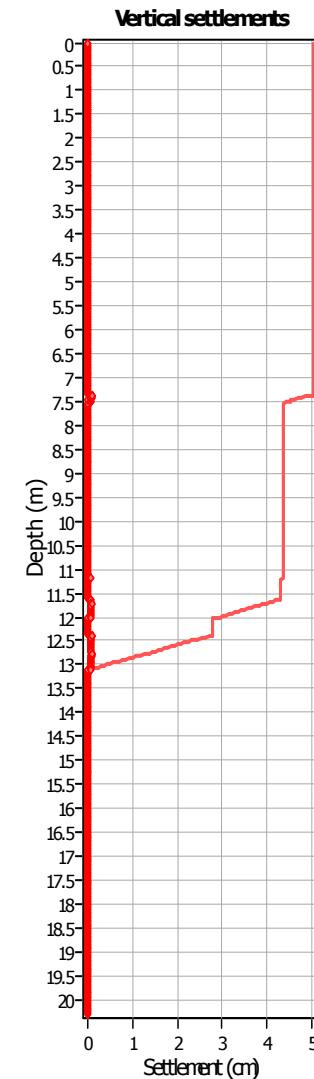
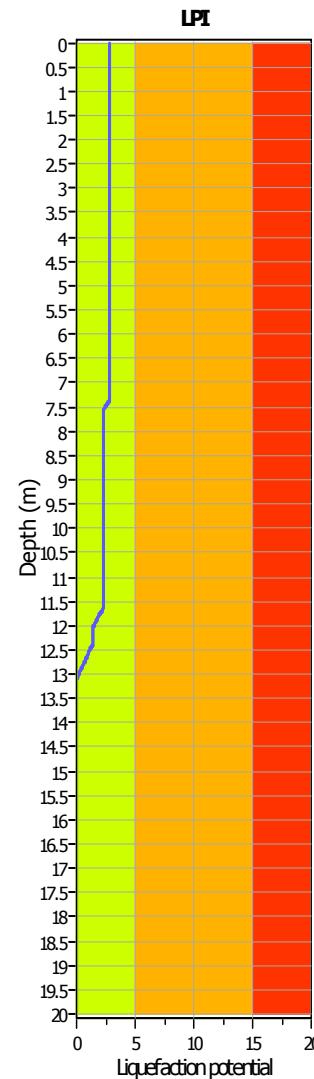
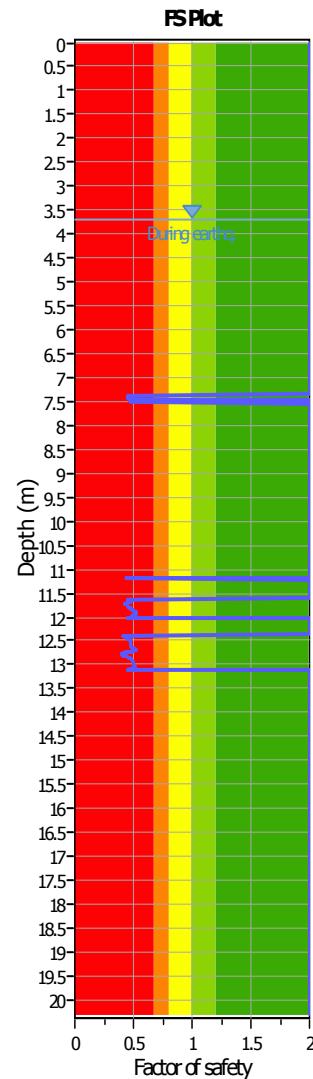
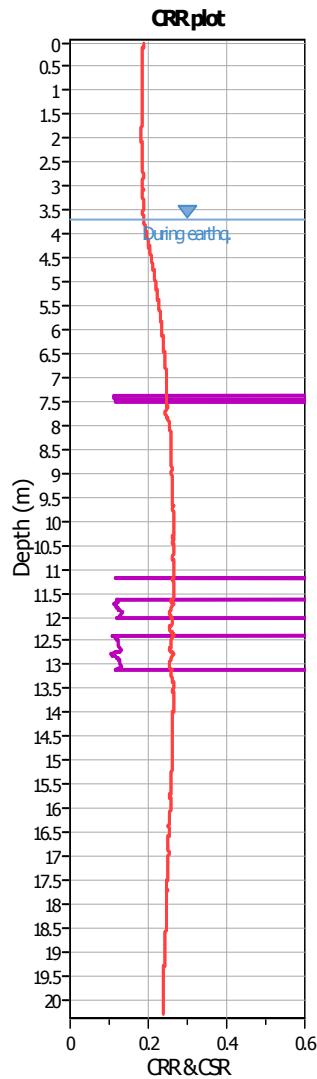
- | | | | | | |
|--------------------------------------|---------------------------|---|-----------------------------|--|----------------------------|
| █ | 1. Sensitive fine grained | | 4. Clayey silt to silty | | 7. Gravely sand to sand |
| █ | 2. Organic material | | 5. Silty sand to sandy silt | | 8. Very stiff sand to |
| █ | 3. Clay to silty clay | | 6. Clean sand to silty sand | | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.70 m

Depth to GWT (erthq.): 3.70 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.70 m

Depth to GWT (earthq.): 3.70 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

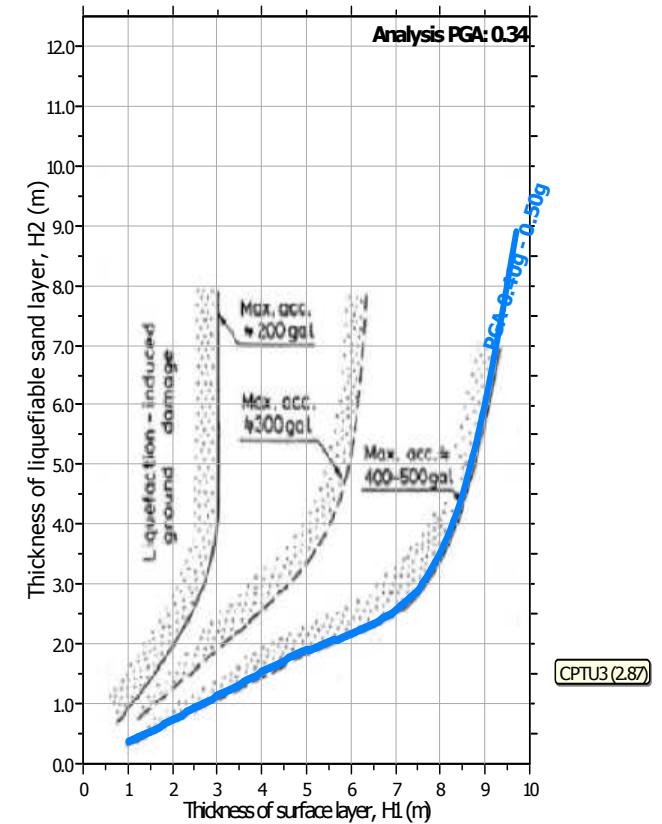
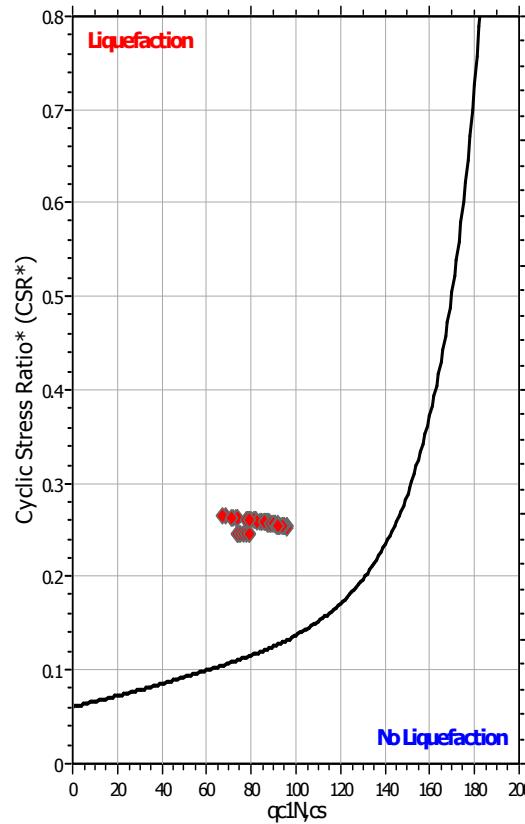
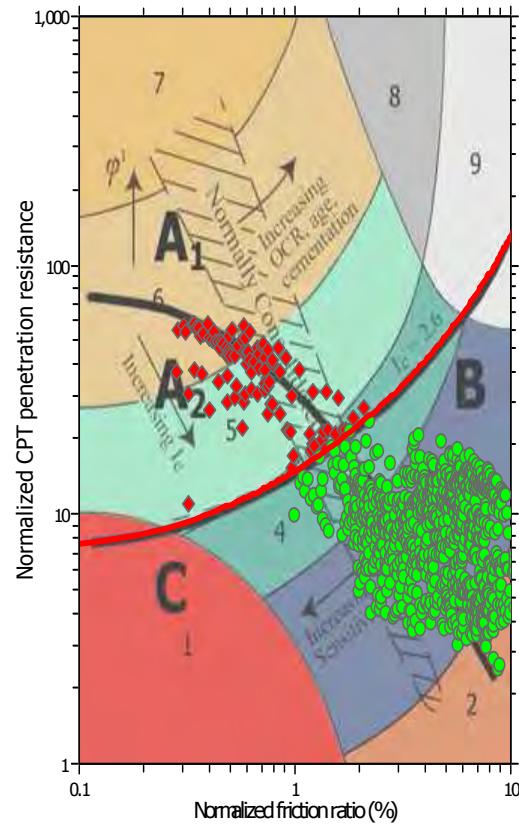
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

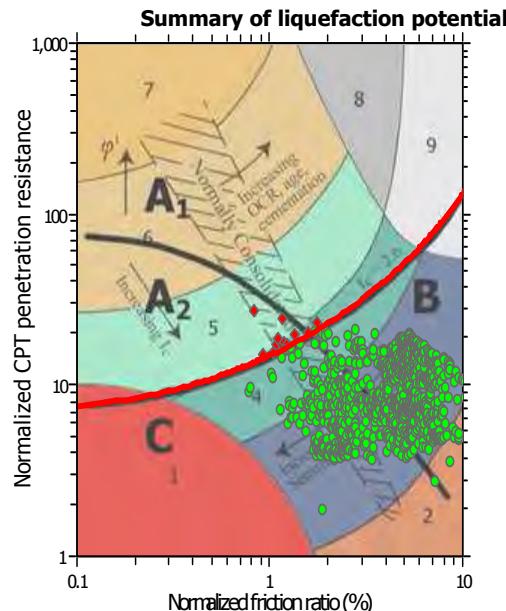
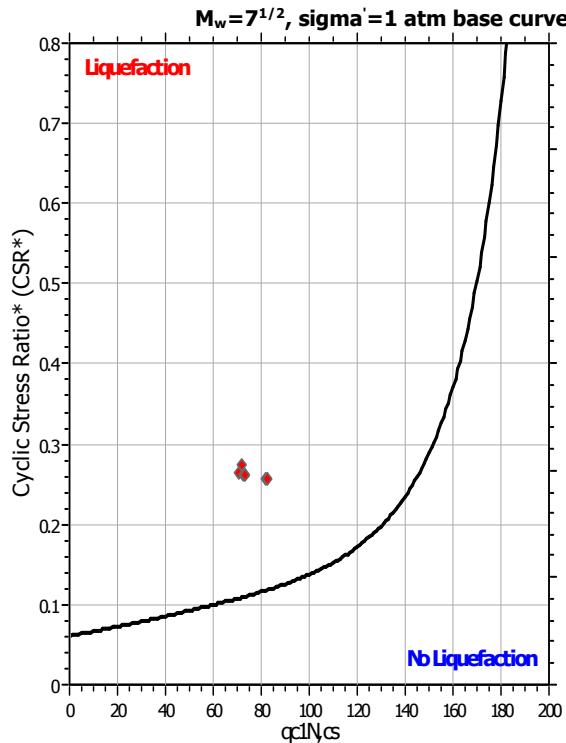
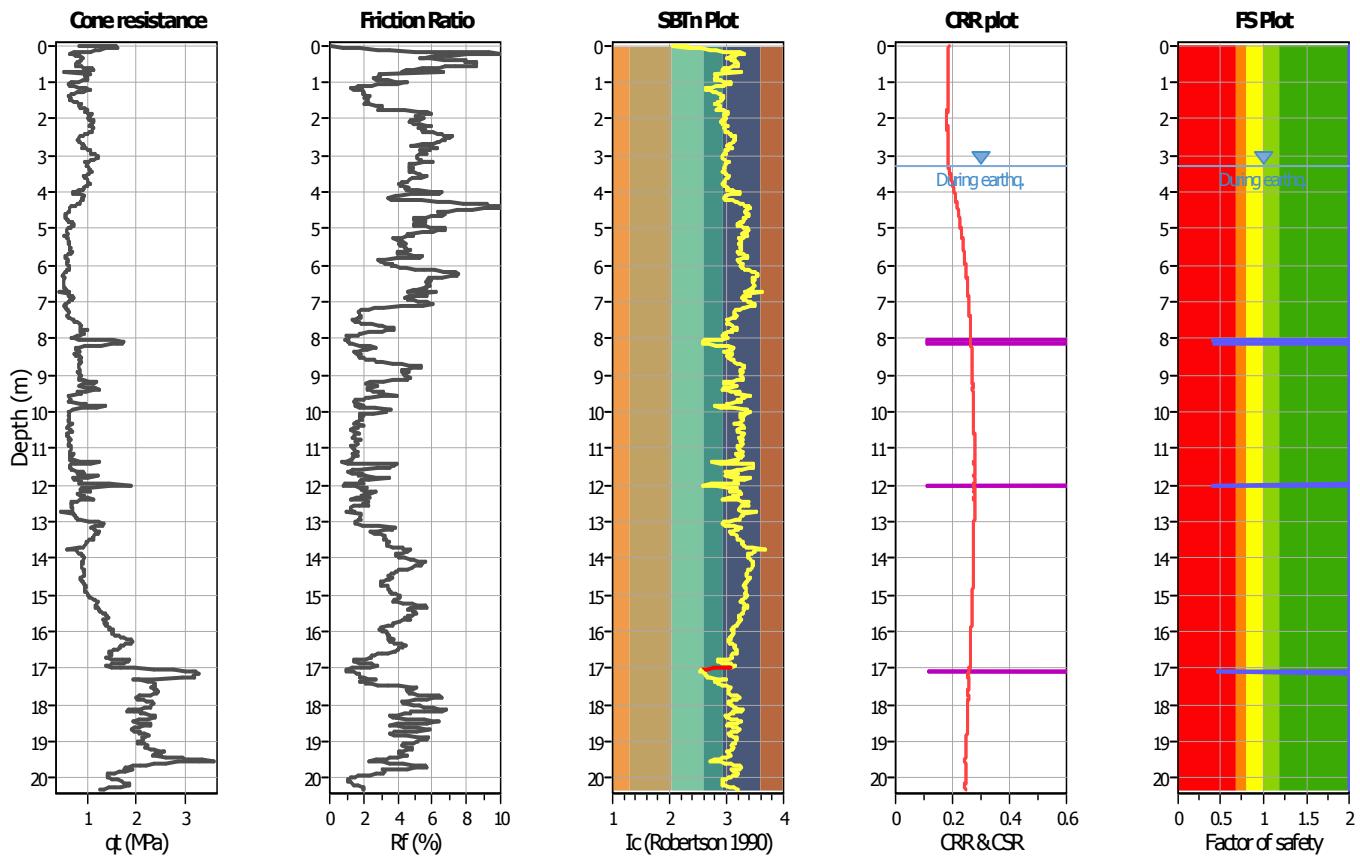
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.70 m

Depth to GWT (erthq.): 3.70 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

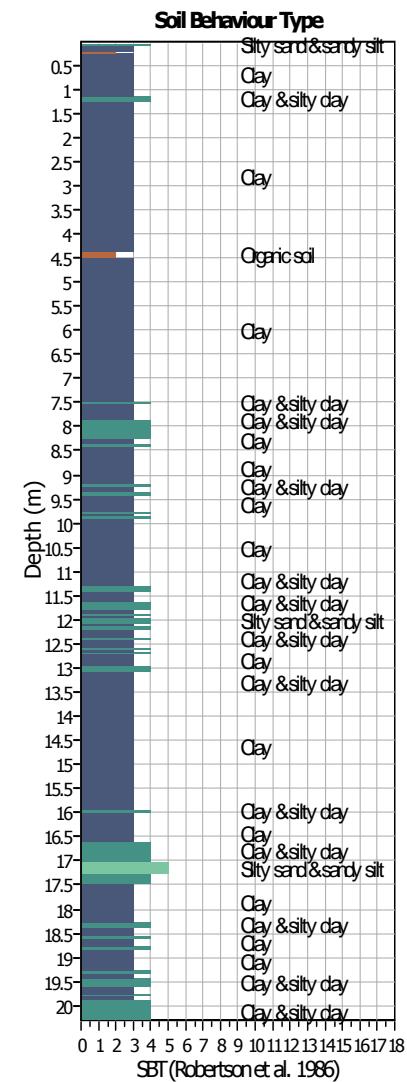
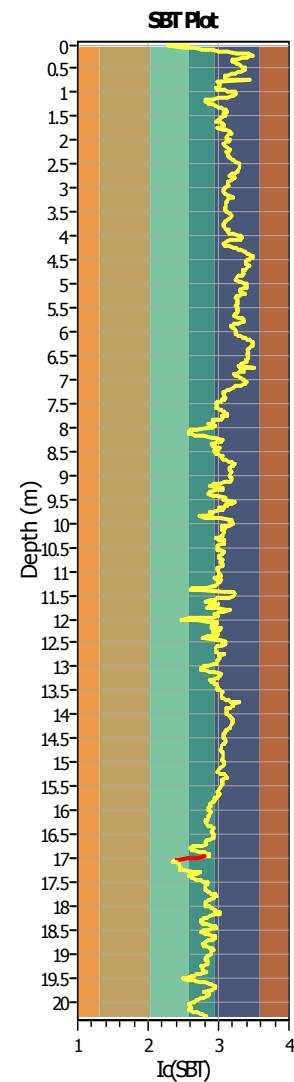
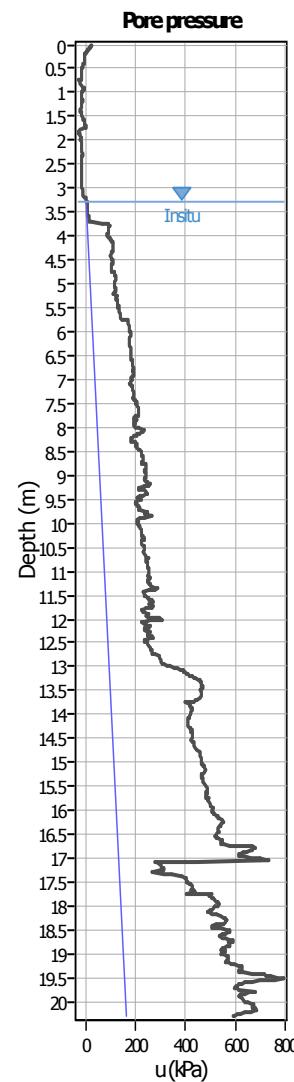
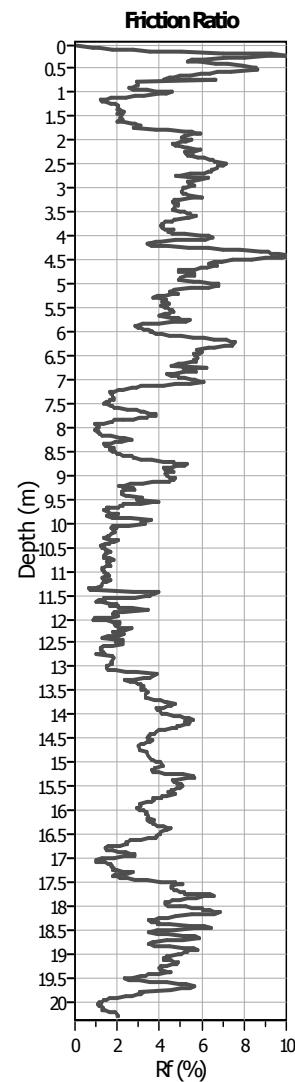
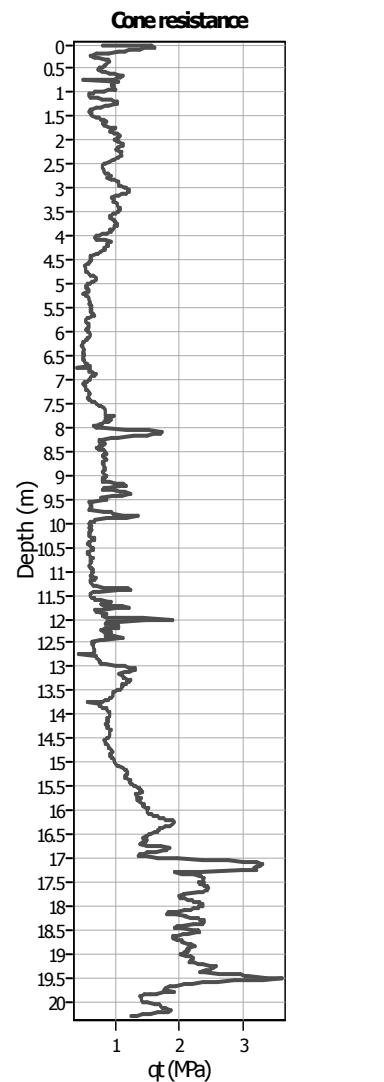
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato Regionale dell'Emergenza sul **Location : via Bologna, Ferrara**
CPT file : CPTU4
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.30 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.30 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

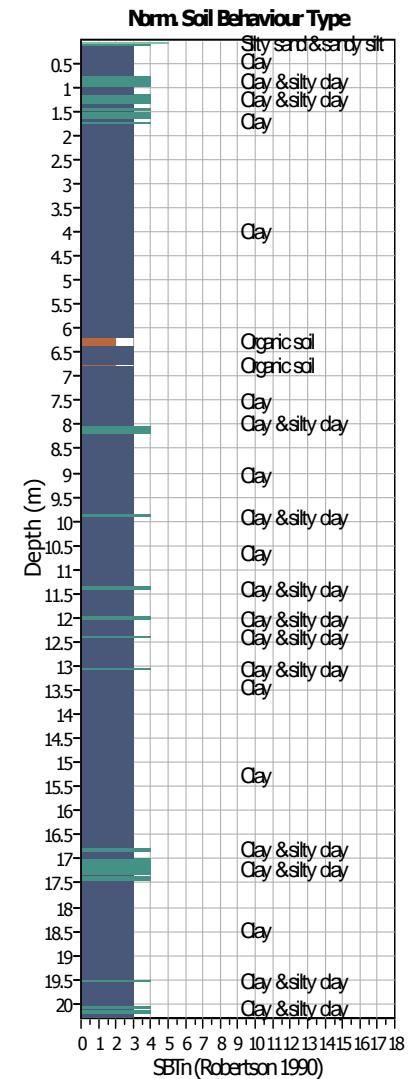
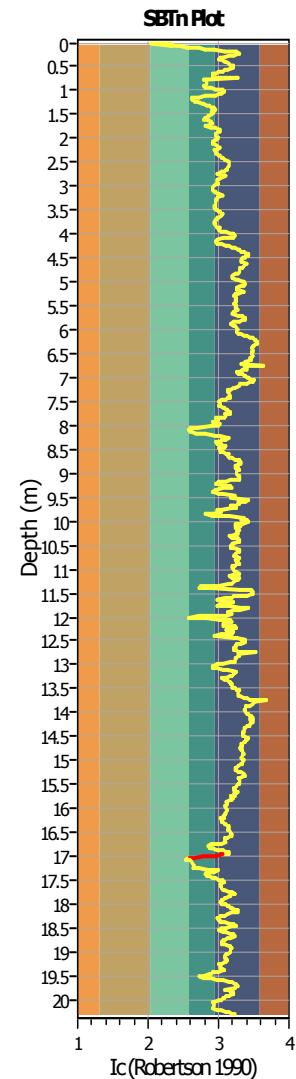
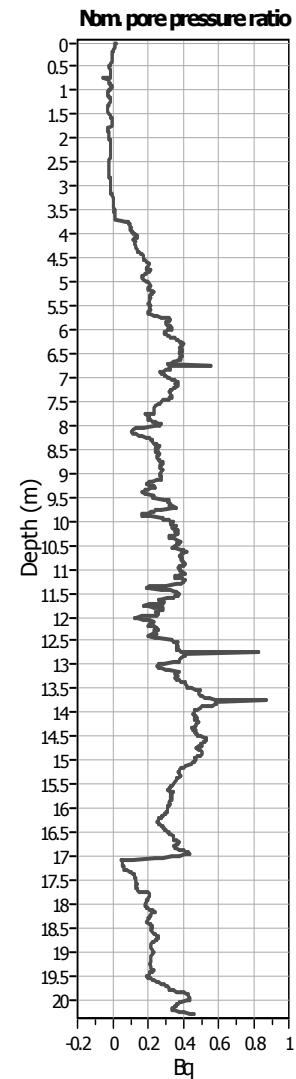
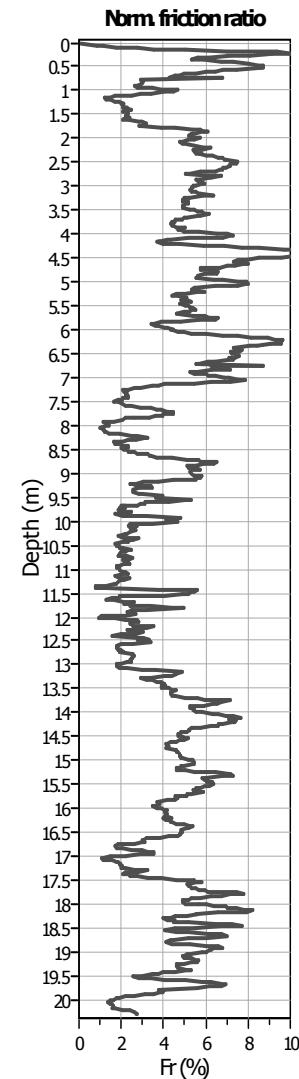
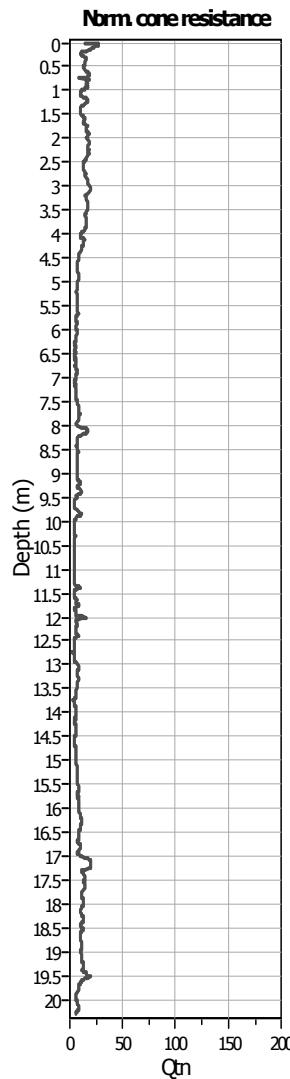
Analysis method: B&I (2014)
Fines correction method: B&I (2014)
Points to test: Based on Ic value
Earthquake magnitude M_w : 6.14
Peak ground acceleration: 0.34
Depth to water table (in situ): 3.30 m

Depth to GWT (erthq.): 3.30 m
Average results interval: 1
Ic cut-off value: 2.60
Unit weight calculation: Based on SBT
Use fill: No
Fill height: N/A

Fill weight:
Transition detect. applied: Yes
 K_0 applied: Yes
Clay like behavior applied: Sands only
Limit depth applied: No
Limit depth: N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)**Input parameters and analysis data**

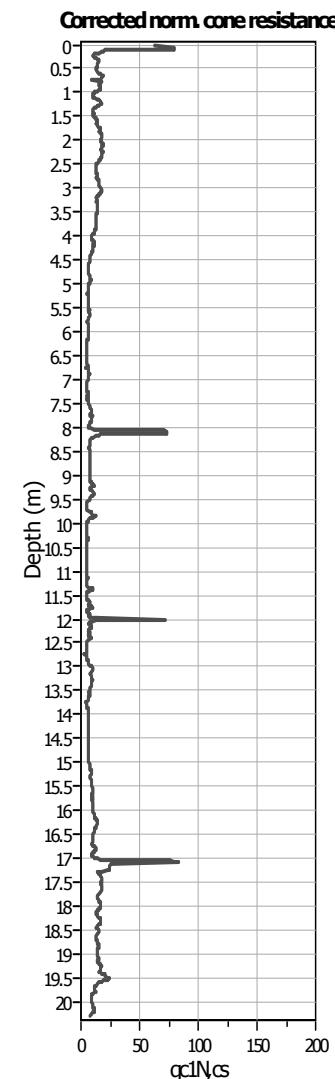
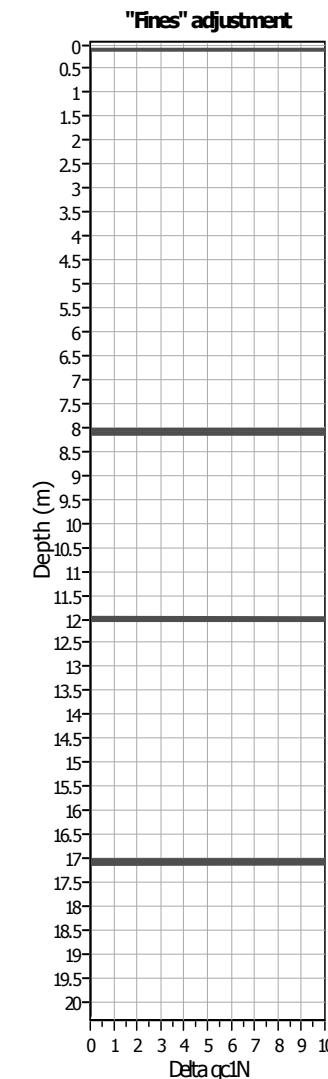
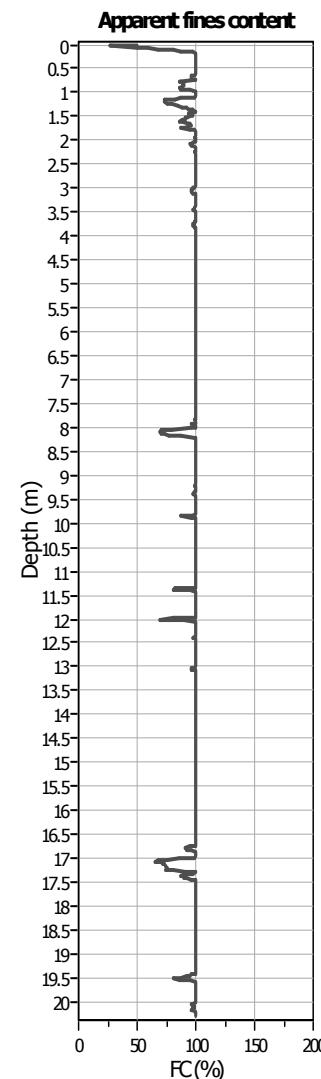
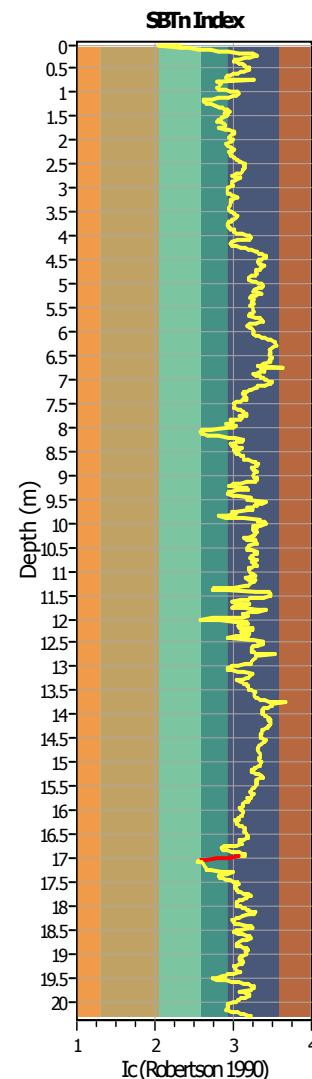
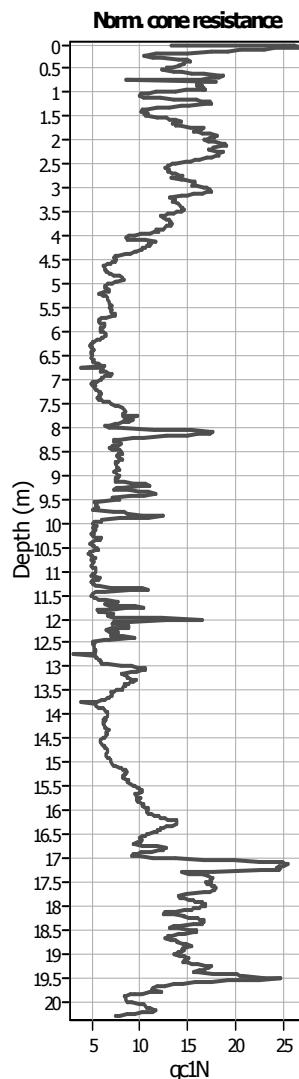
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.30 m

Depth to GWT (erthq.): 3.30 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBTn legend

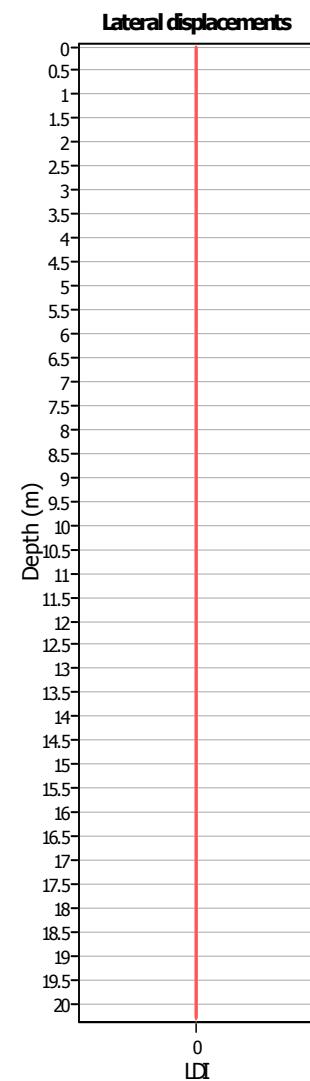
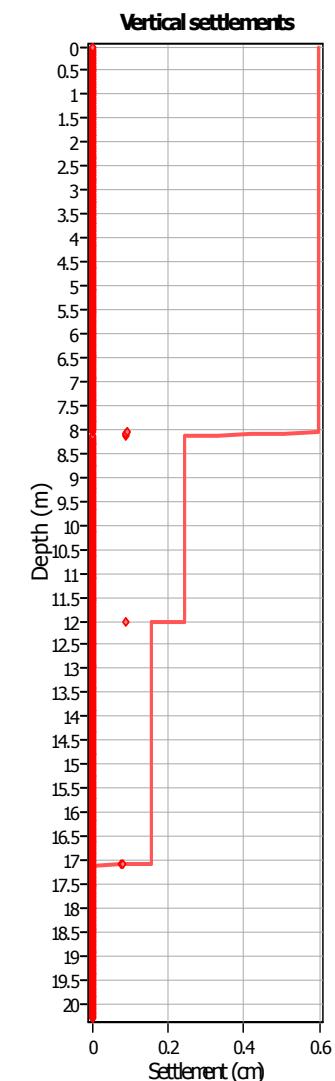
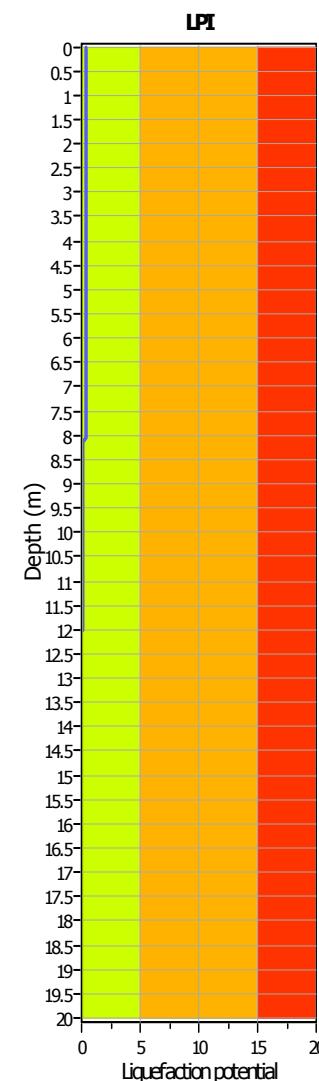
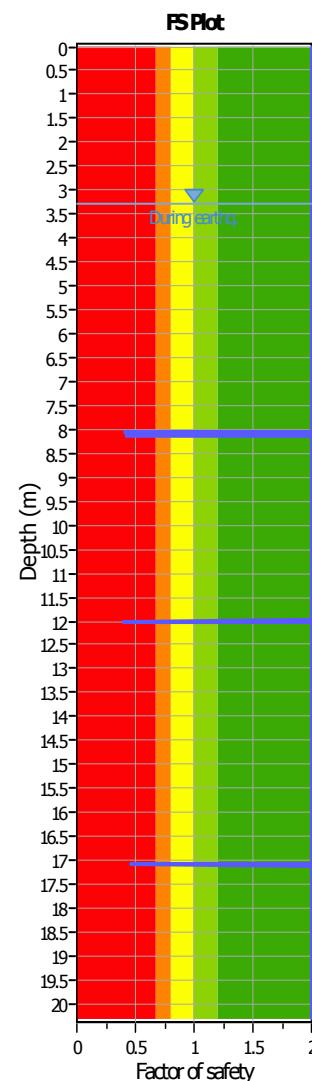
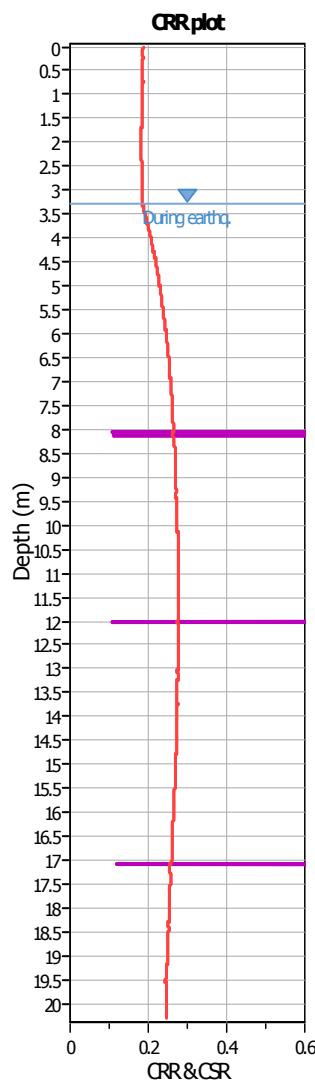
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.30 m

Depth to GWT (erthq.): 3.30 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.30 m

Depth to GWT (erthq.): 3.30 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

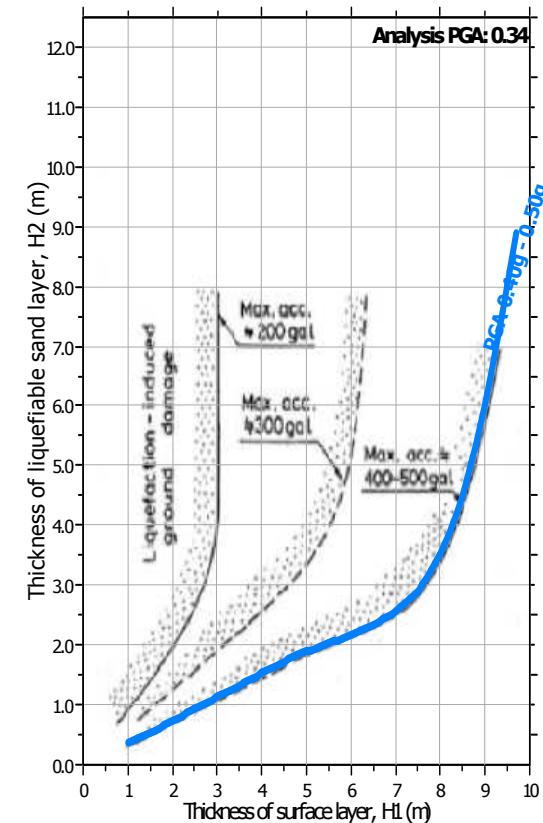
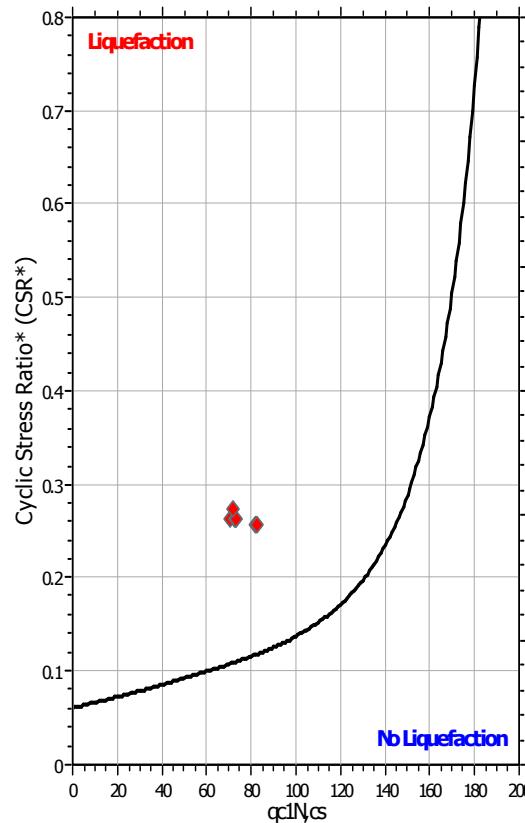
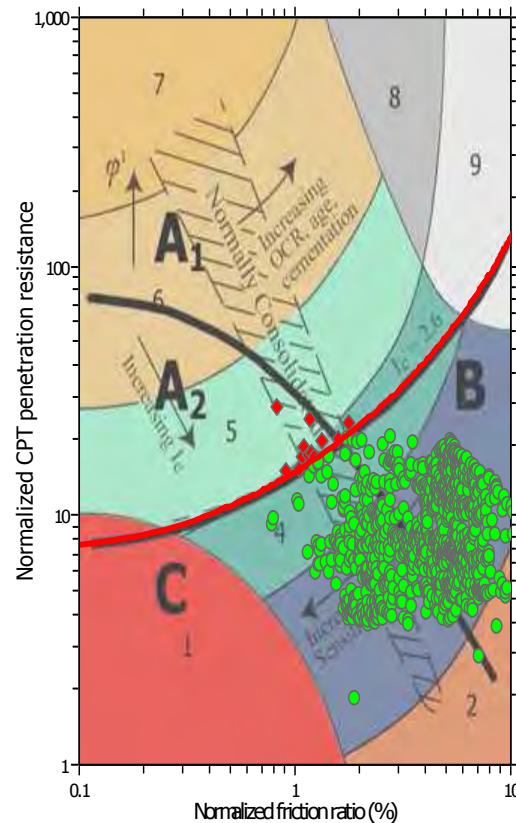
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

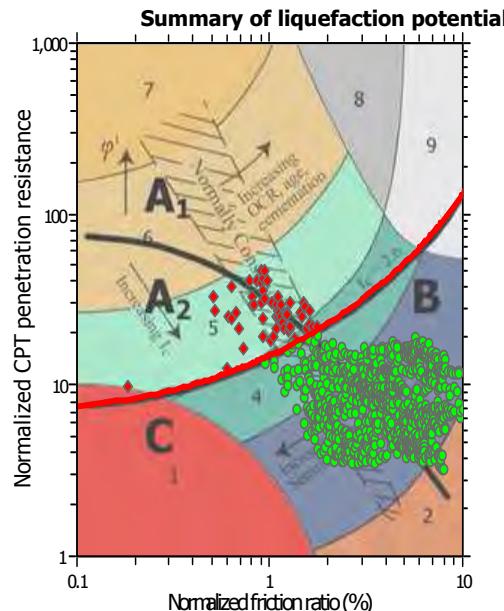
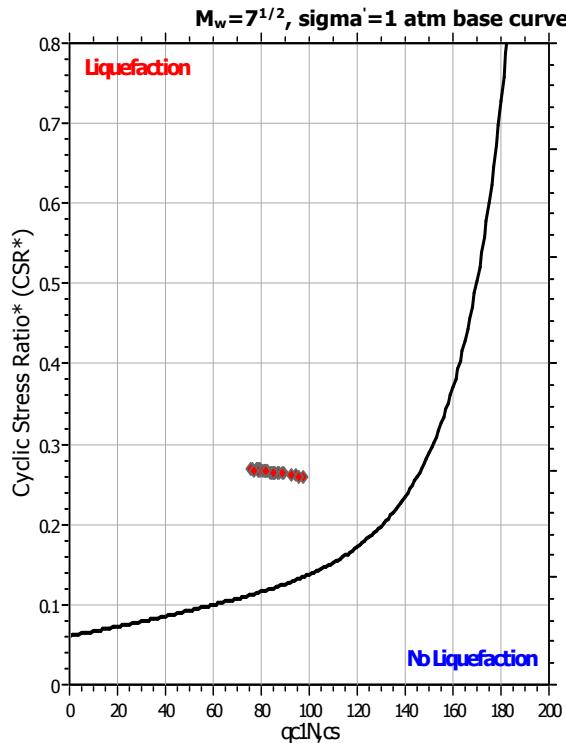
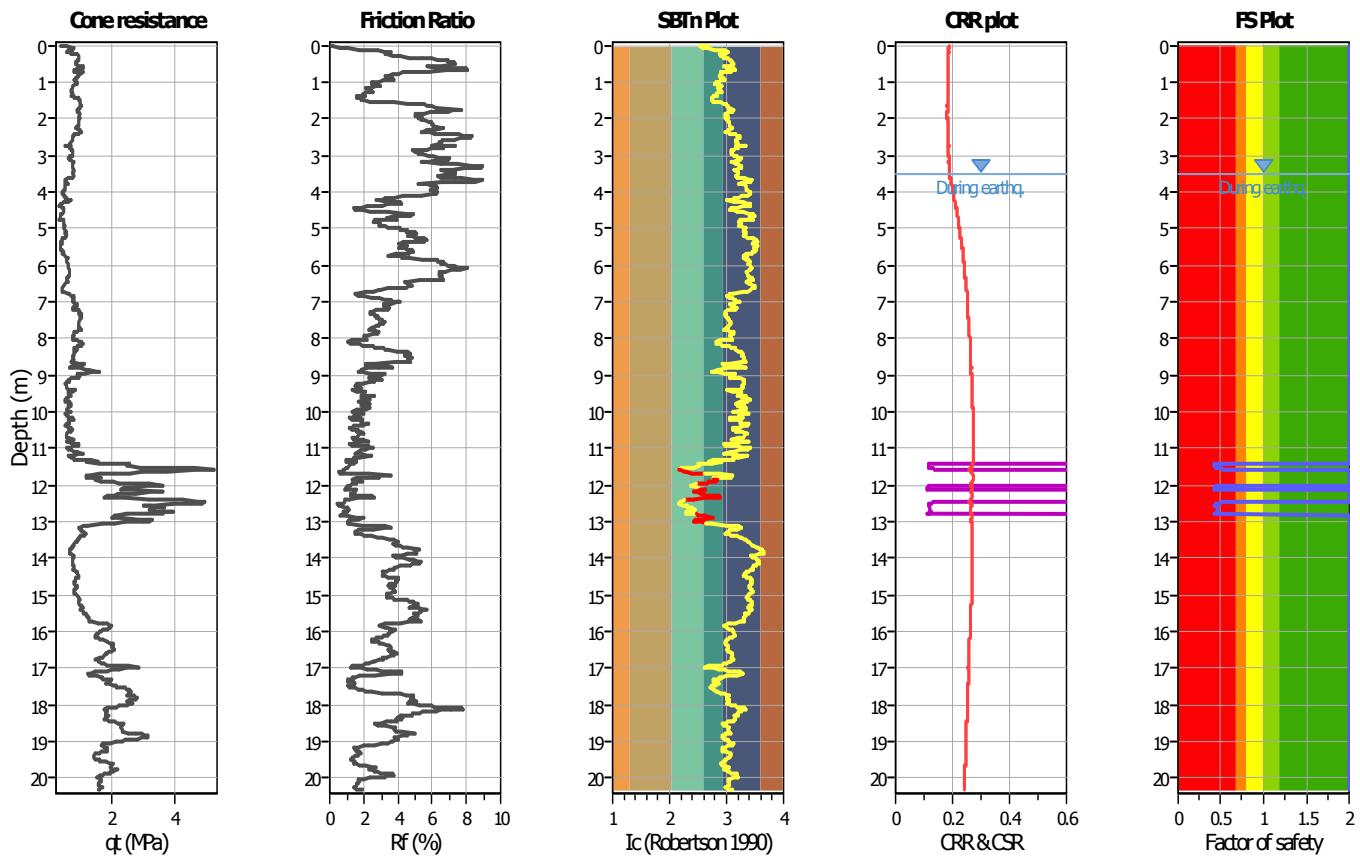
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.30 m

Depth to GWT (erthq.): 3.30 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

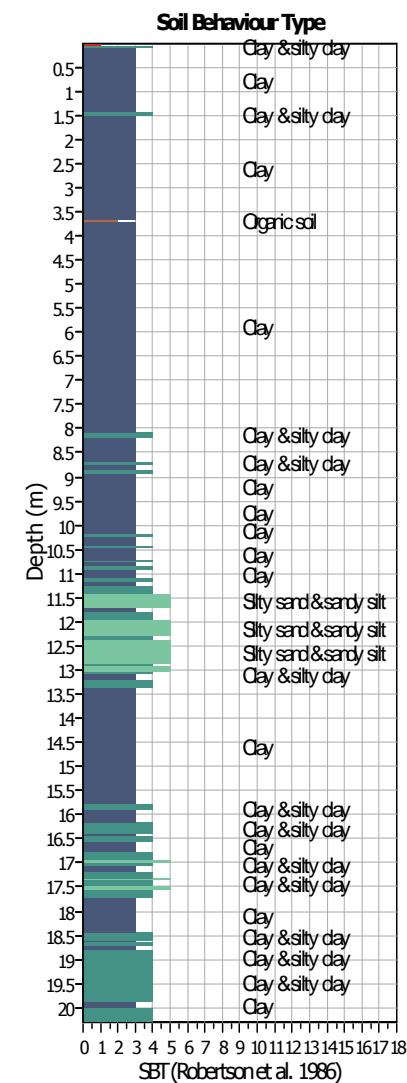
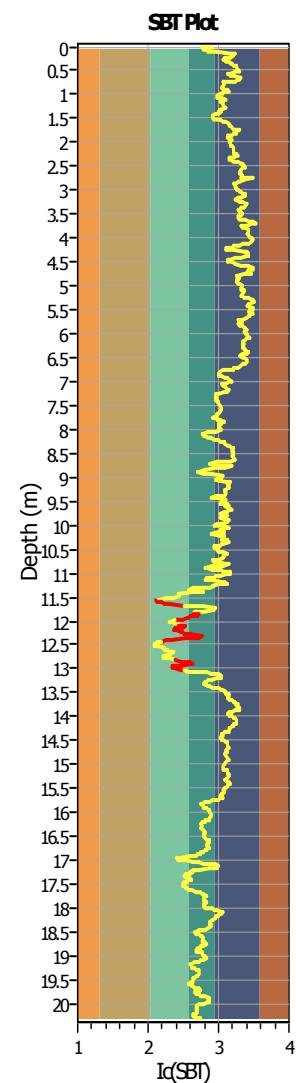
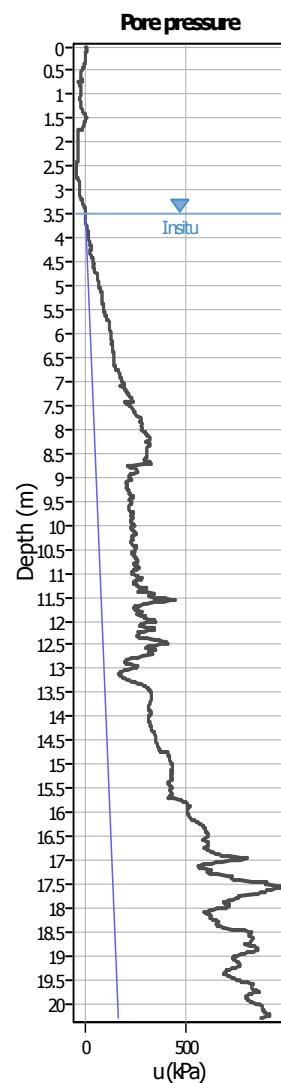
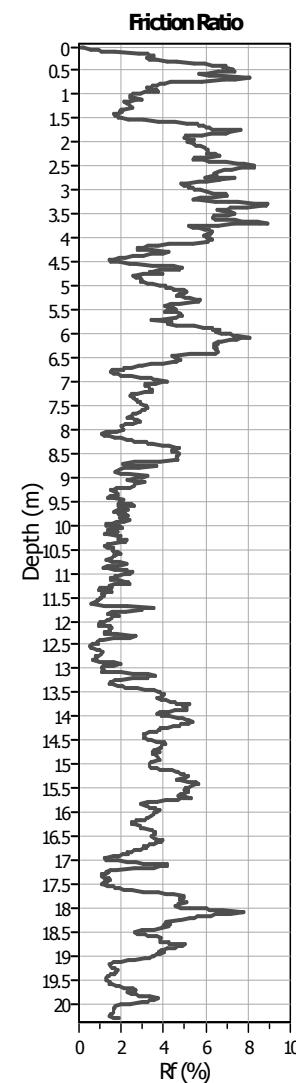
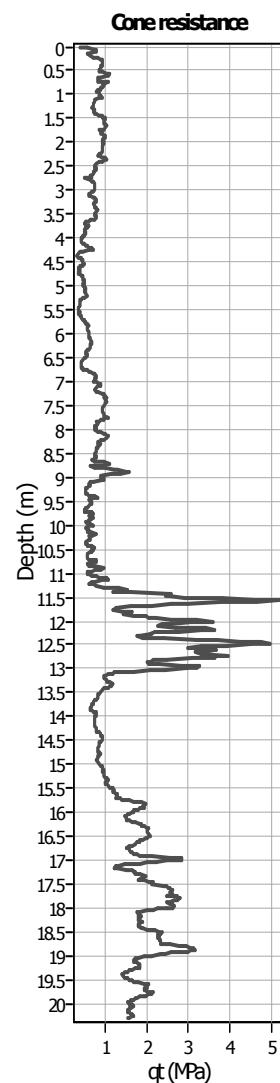
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato Regionale dell'Emergenza sul **Location : via Bologna, Ferrara**
CPT file : CPTU5
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.50 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

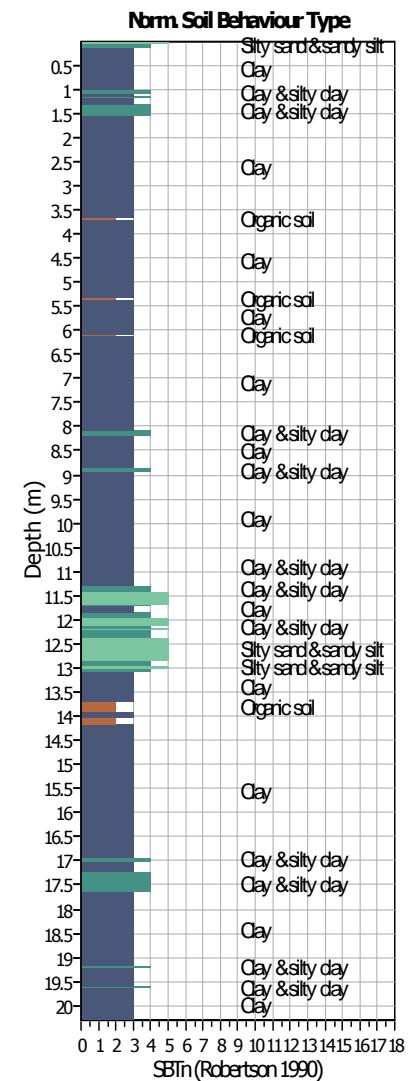
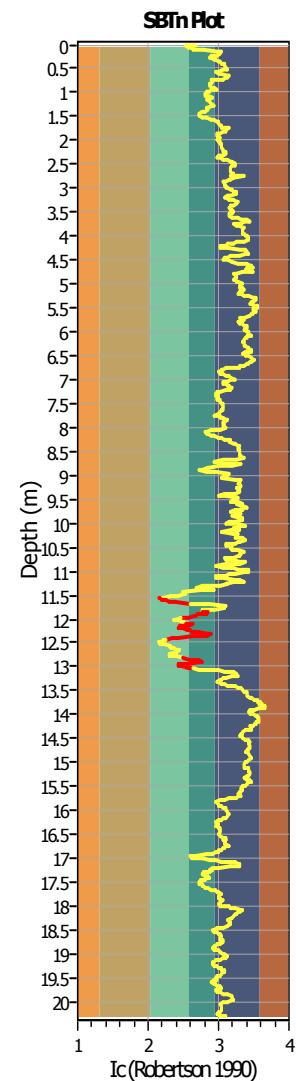
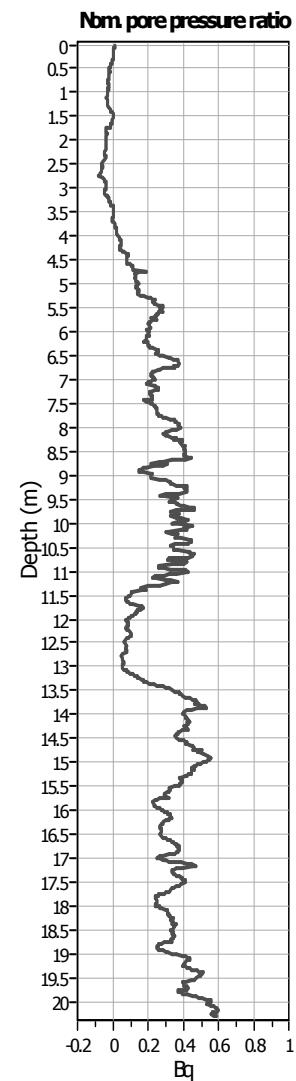
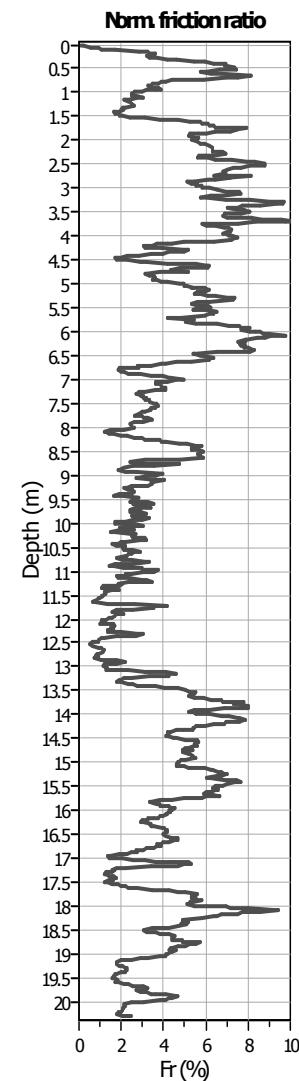
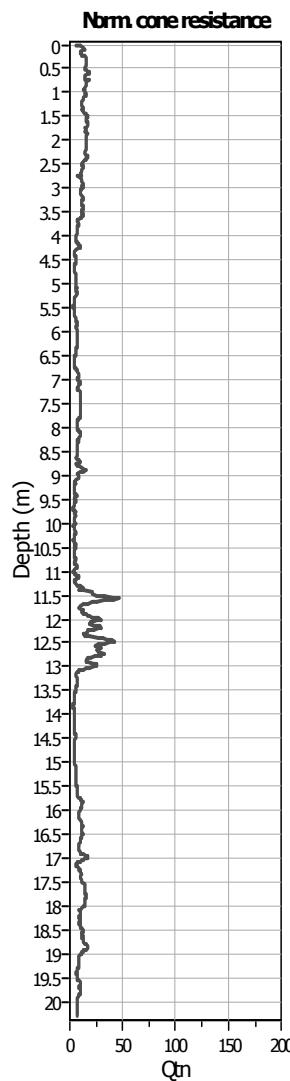
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)**Input parameters and analysis data**

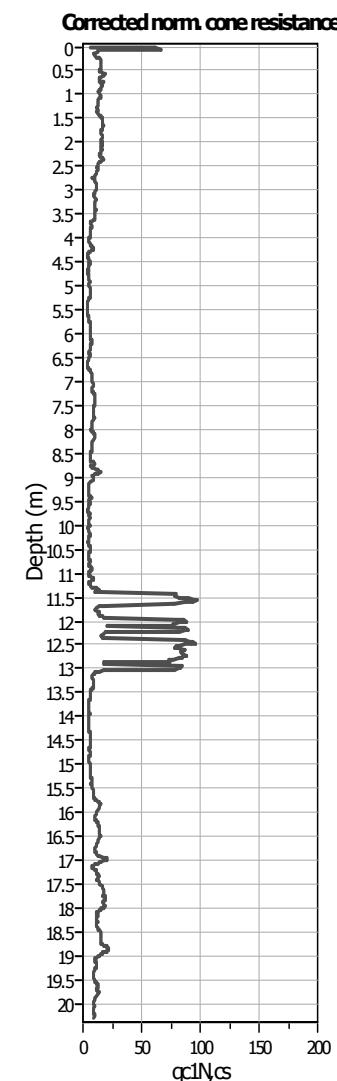
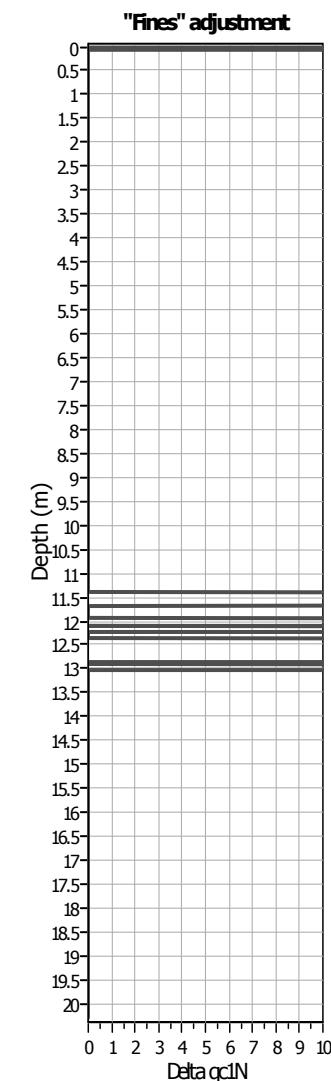
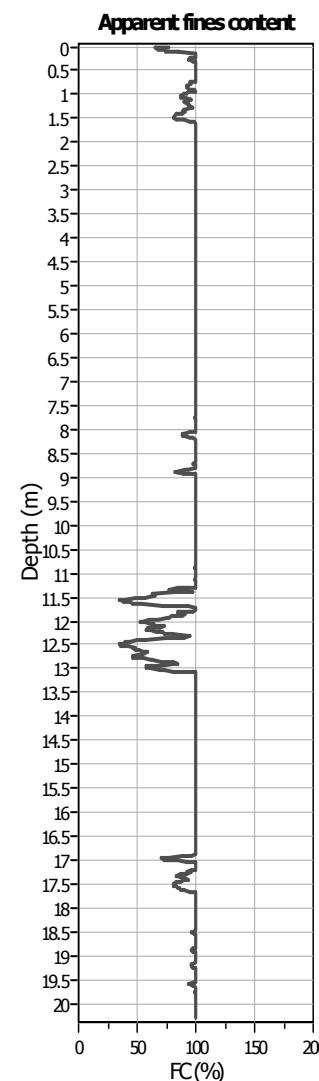
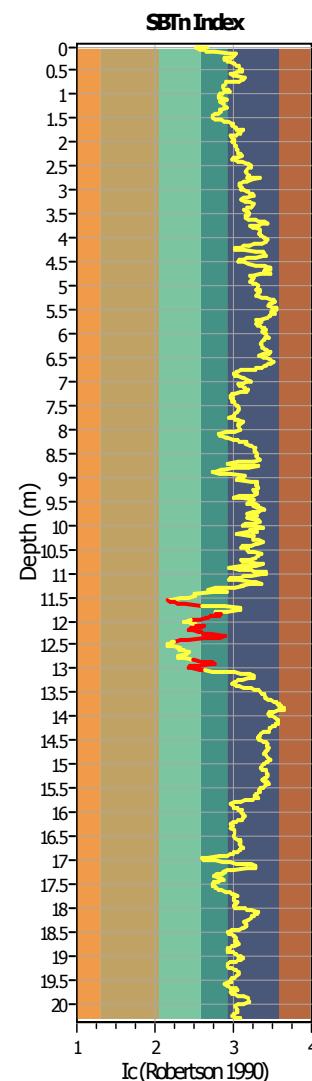
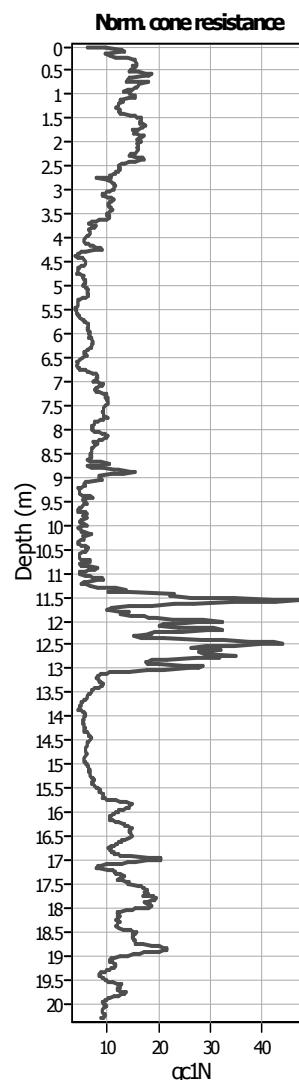
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBTn legend

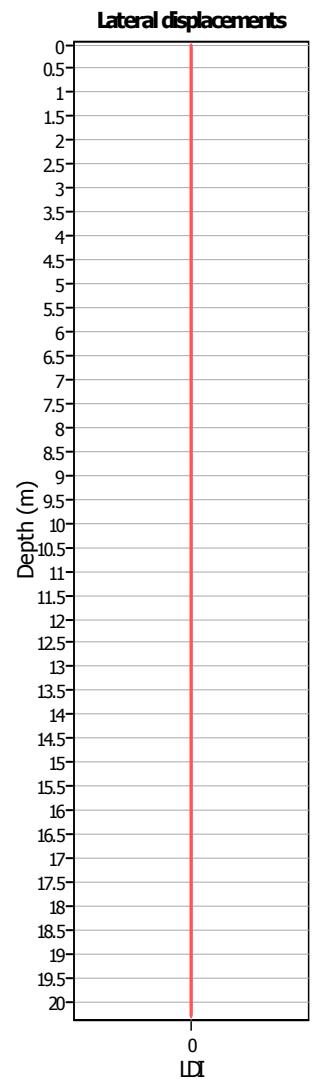
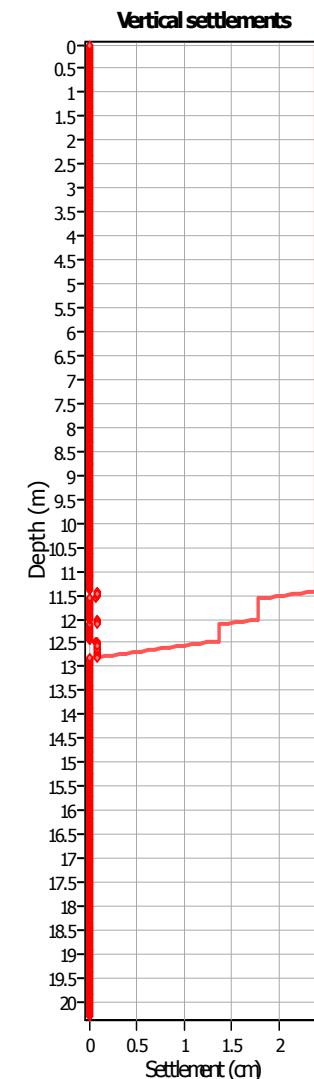
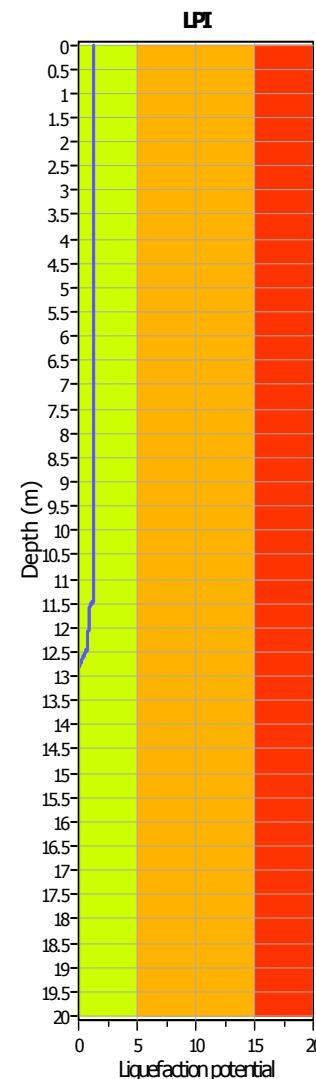
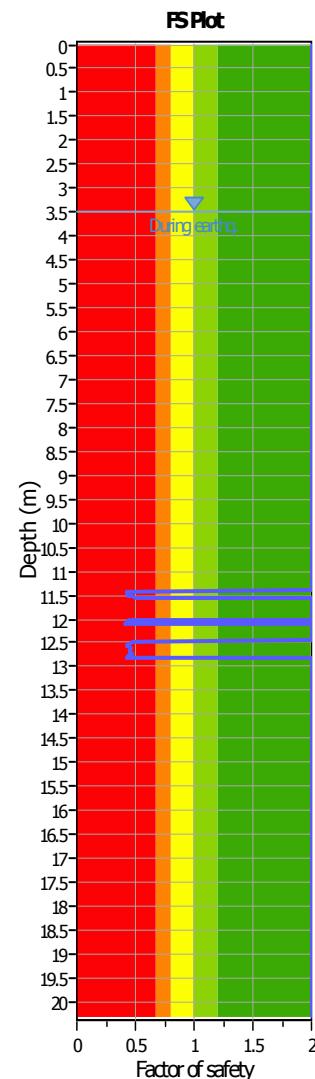
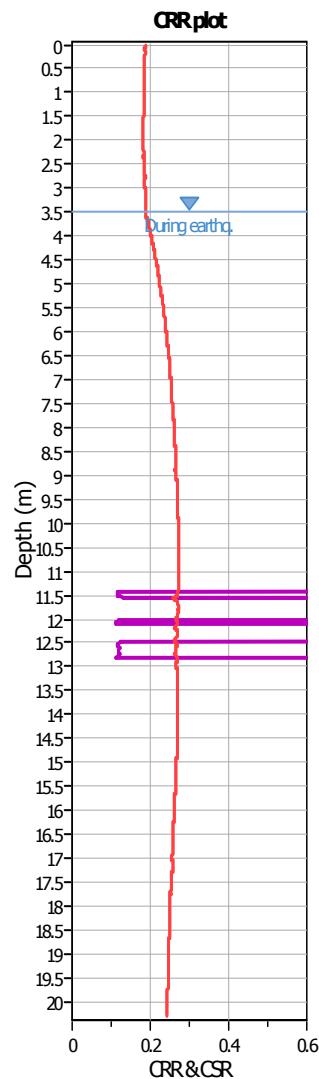
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (earthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied:
 K_0 applied:
 Clay like behavior applied:
 Limit depth applied:
 Limit depth:

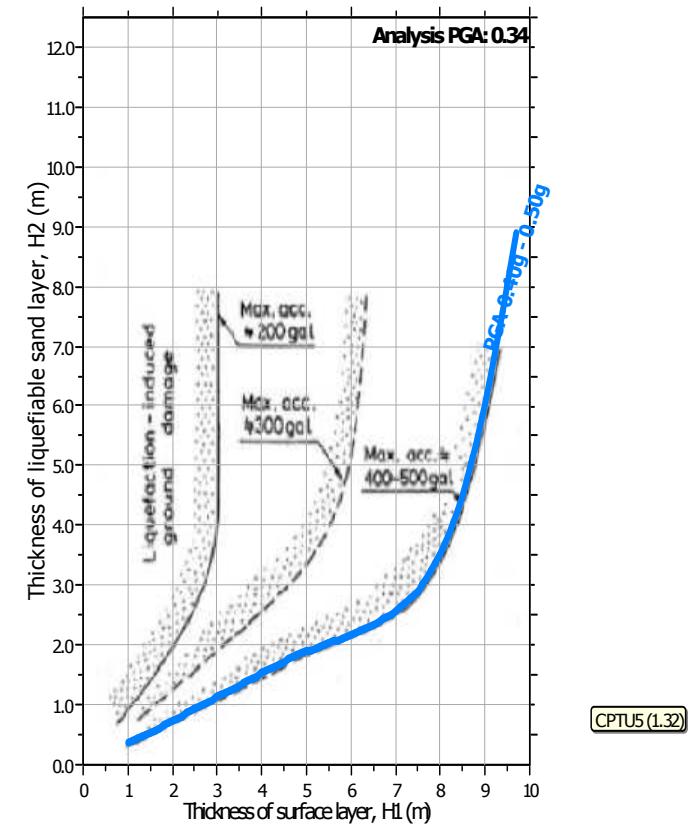
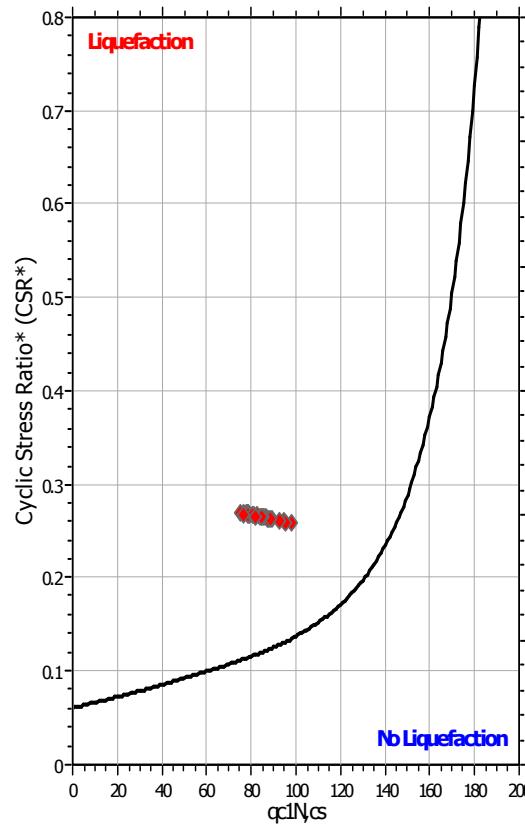
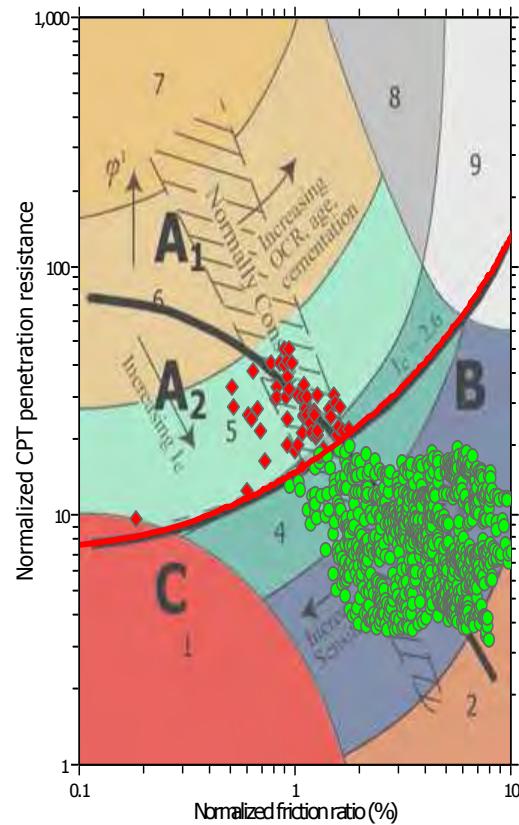
N/A
 Yes
 Yes
 Sands only
 No
 N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

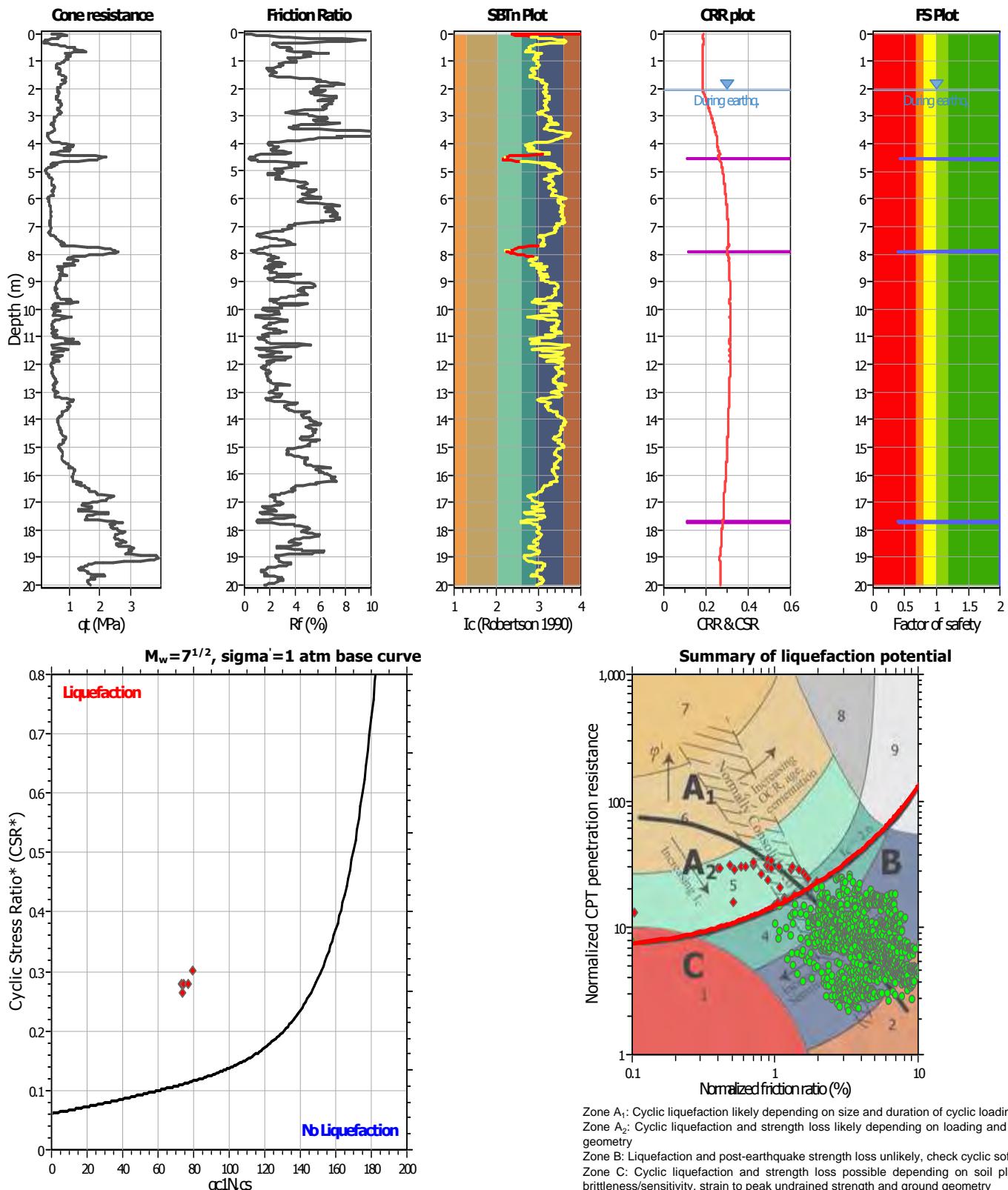
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.50 m

Depth to GWT (erthq.): 3.50 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

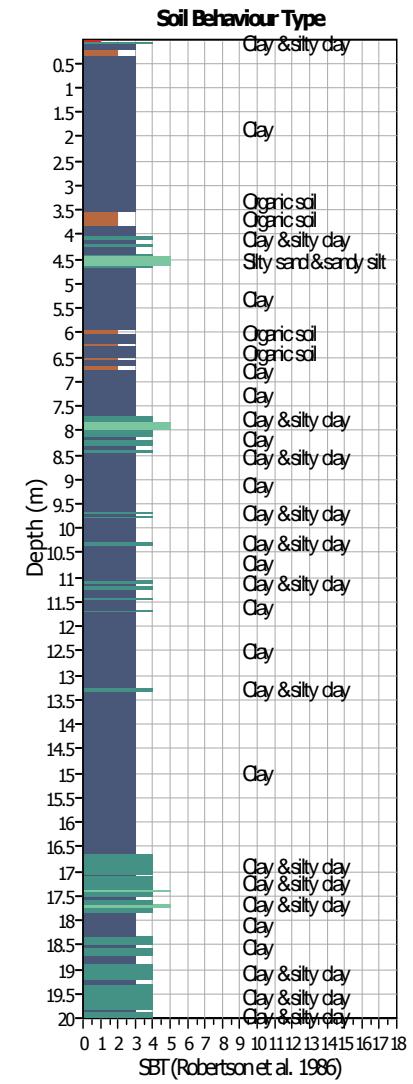
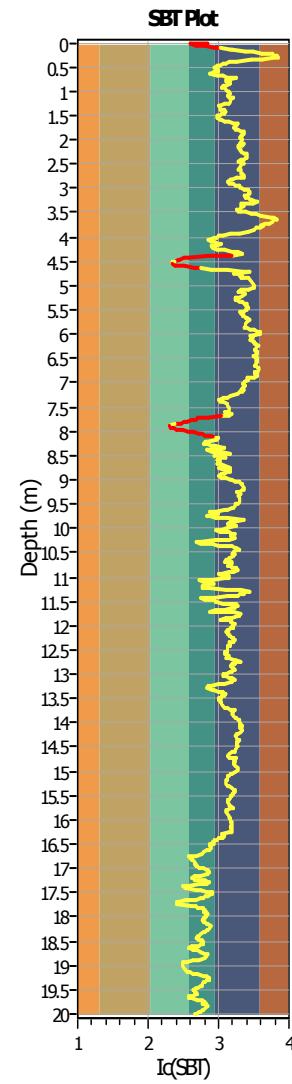
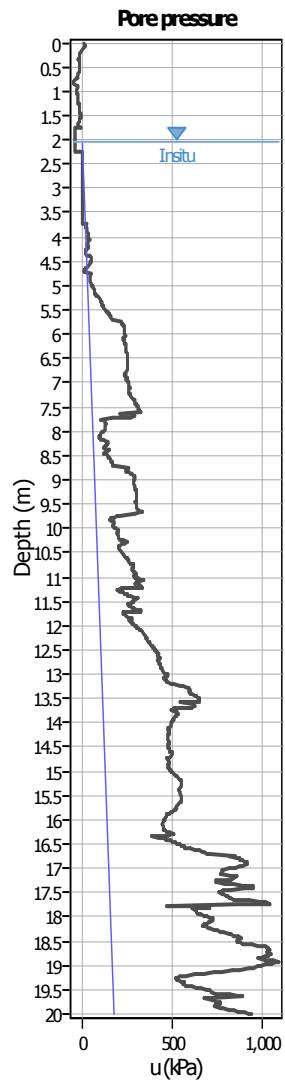
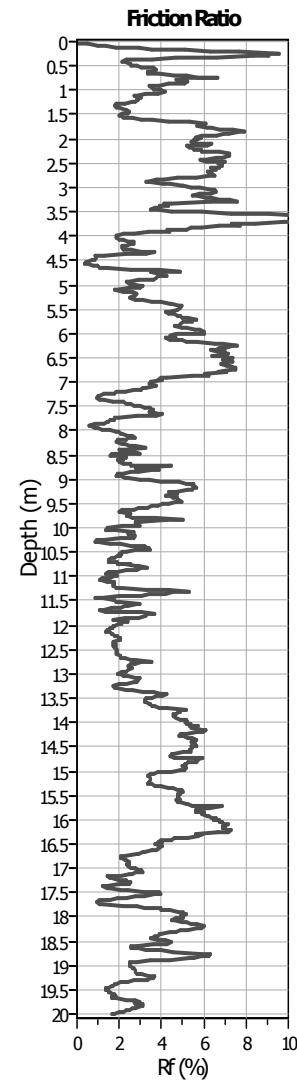
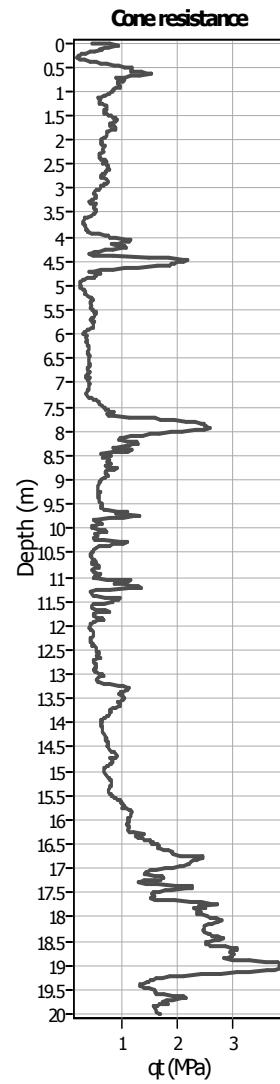
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title :
CPT file : CPTU7
Location :
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.05 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	2.05 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in-situ): 2.05 m

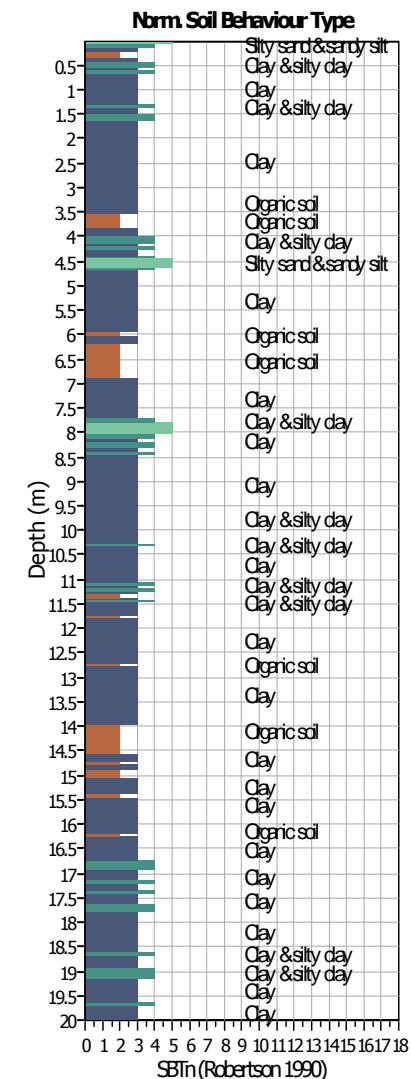
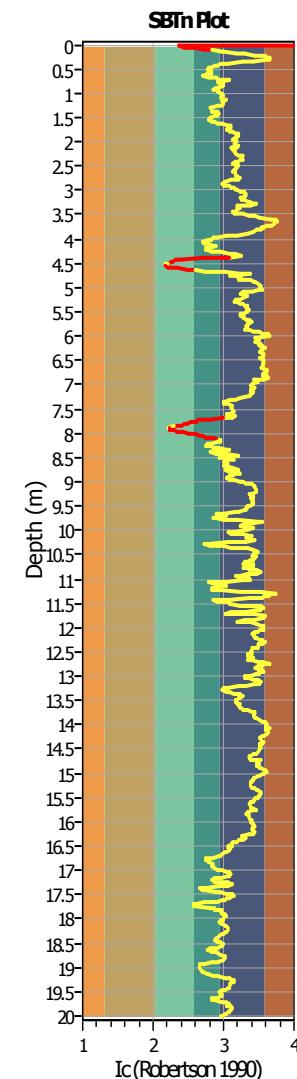
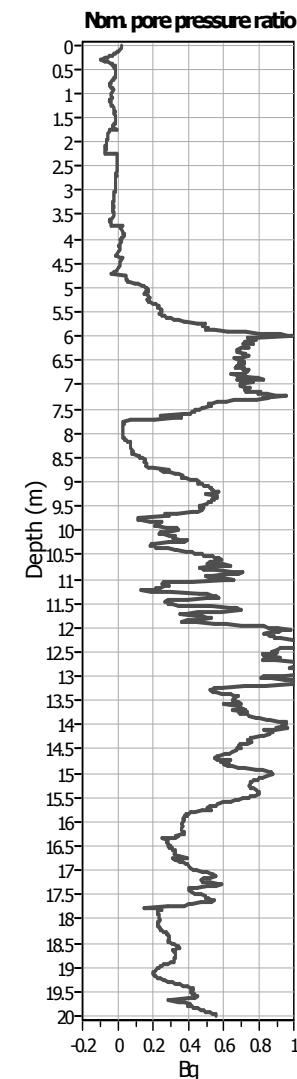
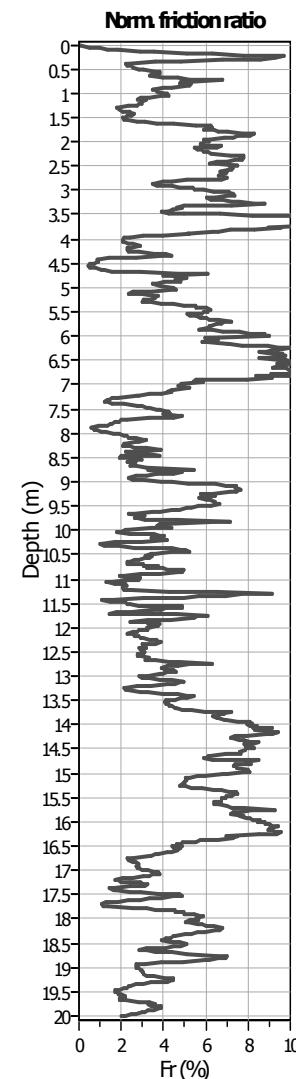
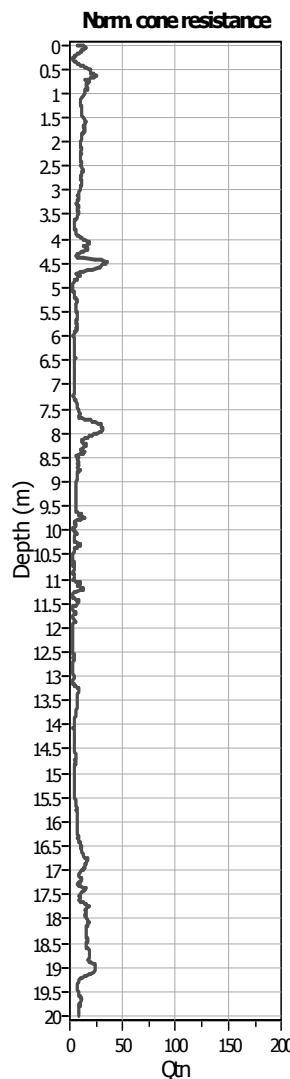
Depth to GWT (erthq.): 2.05 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBT legend

1. Sensitive fine grained	4. Clayey silt to silty	7. Gravely sand to sand
2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to
3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained

CPT basic interpretation plots (normalized)



Input parameters and analysis data

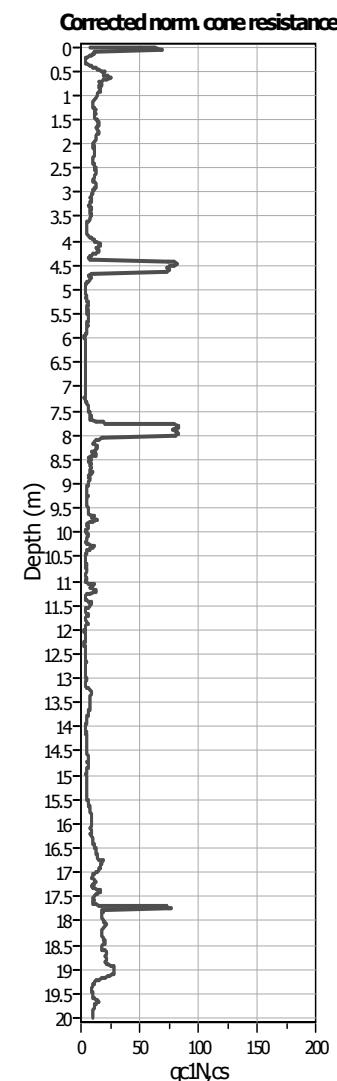
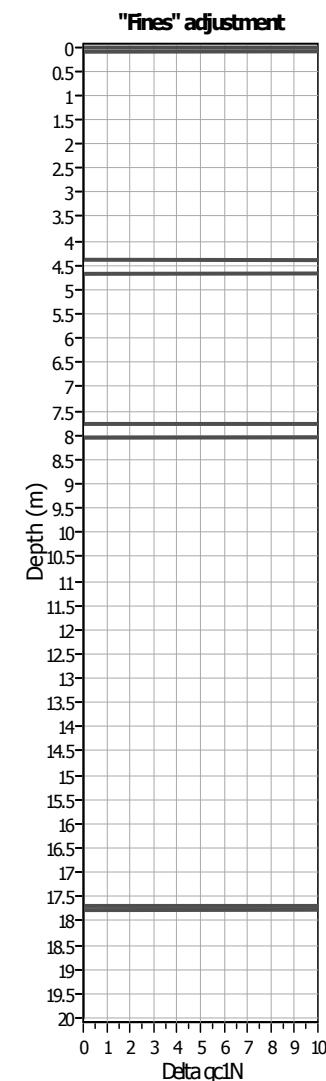
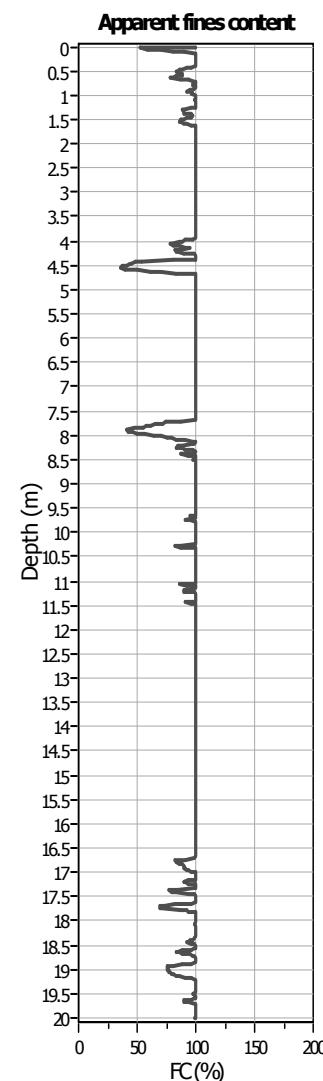
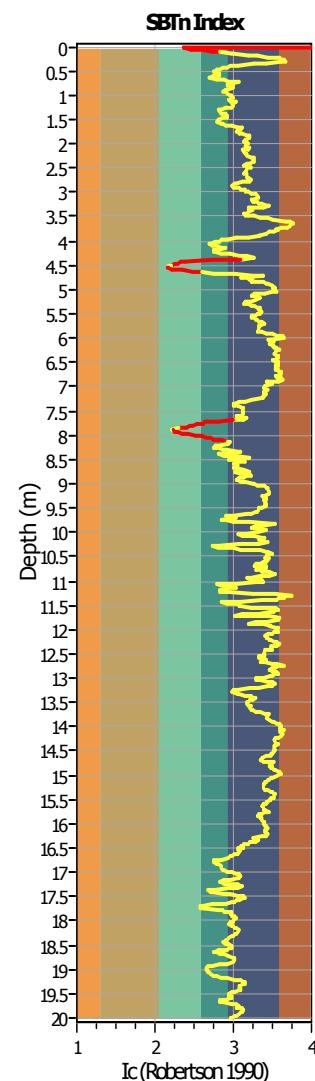
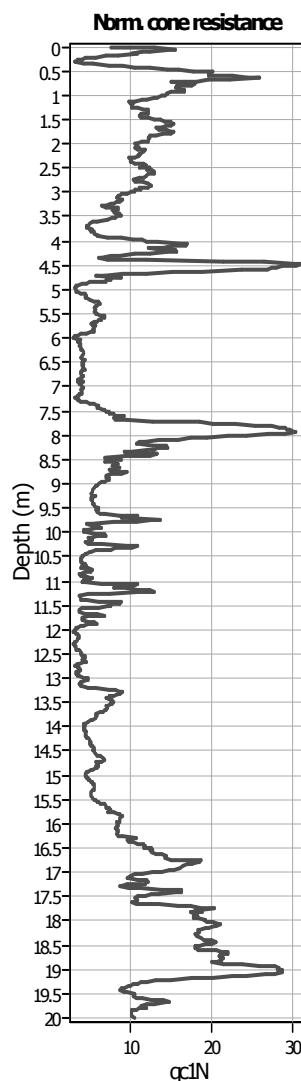
Analysis method:	B&I (2014)
Fines correction method:	B&I (2014)
Points to test:	Based on Ic value
Earthquake magnitude M_w :	6.14
Peak ground acceleration:	0.34
Depth to water table (insitu):	2.05 m

Depth to GWT (erthq.):	2.05 m	Fill weight:
Average results interval:	1	Transition detect. applied:
Ic cut-off value:	2.60	K_o applied:
Unit weight calculation:	Based on SBT	Clay like behavior applied:
Use fill:	No	Limit depth applied:
Fill height:	N/A	Limit depth:

N/A
Yes
Yes
Sands only
No
N/A

SBTn legend

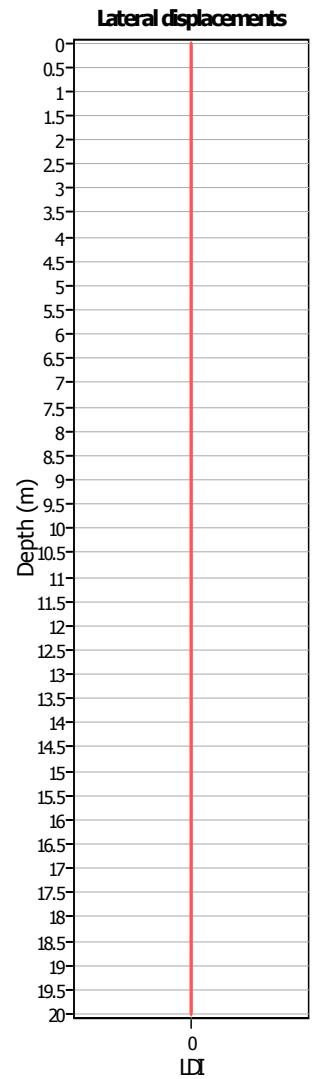
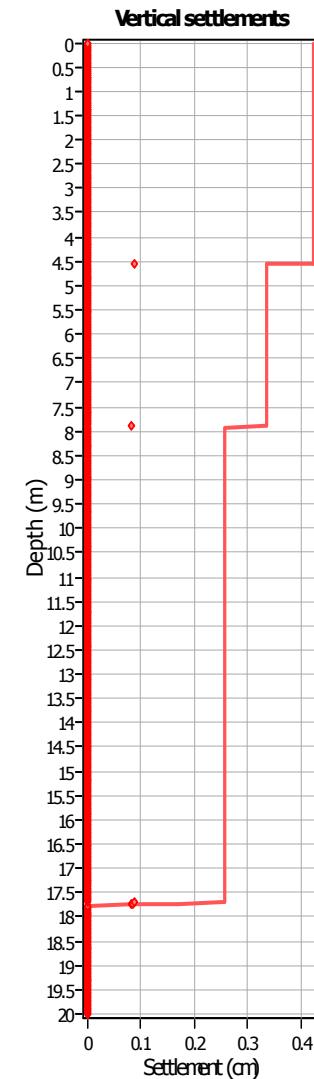
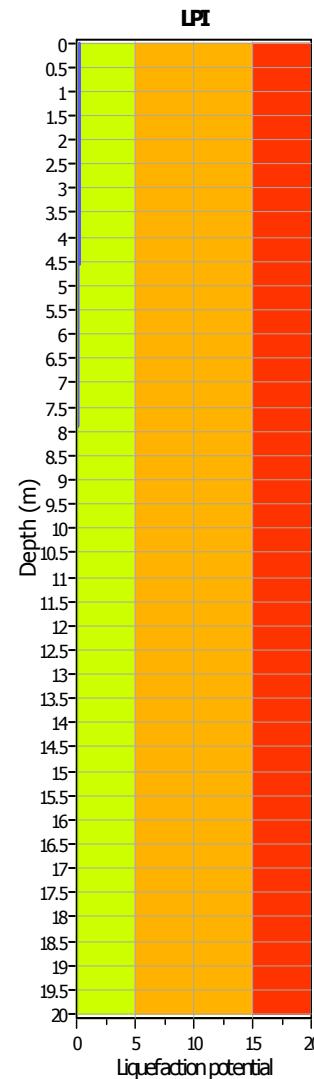
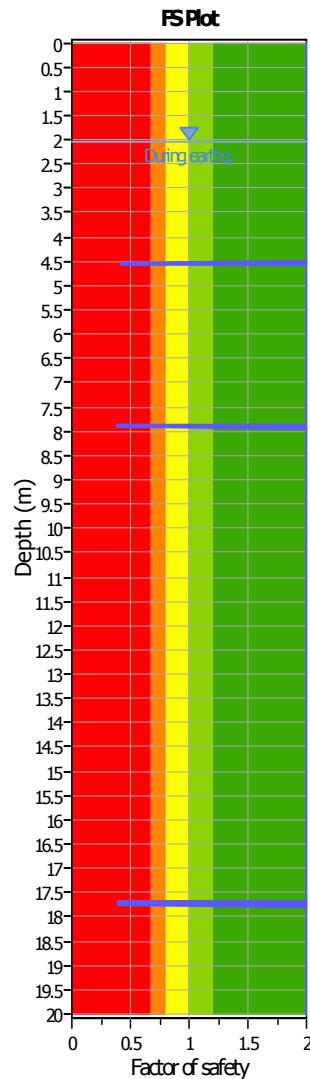
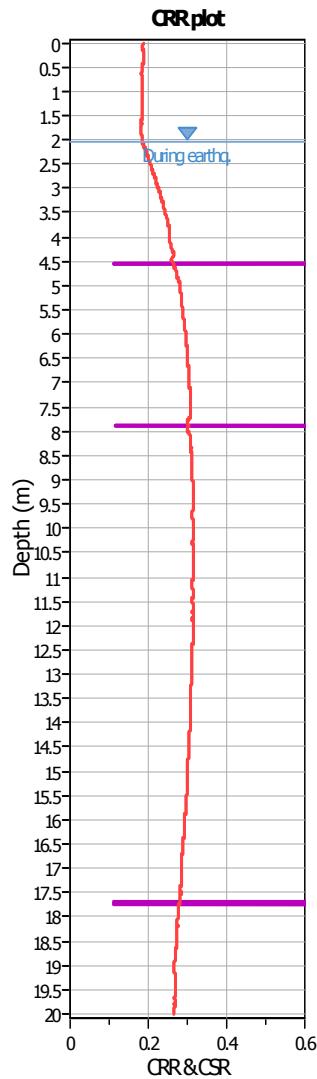
- | | | | | | |
|--------------------------------------|---------------------------|---|-----------------------------|--|----------------------------|
| █ | 1. Sensitive fine grained | | 4. Clayey silt to silty | | 7. Gravely sand to sand |
| █ | 2. Organic material | | 5. Silty sand to sandy silt | | 8. Very stiff sand to |
| █ | 3. Clay to silty clay | | 6. Clean sand to silty sand | | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.05 m

Depth to GWT (erthq.): 2.05 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.05 m

Depth to GWT (erthq.): 2.05 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

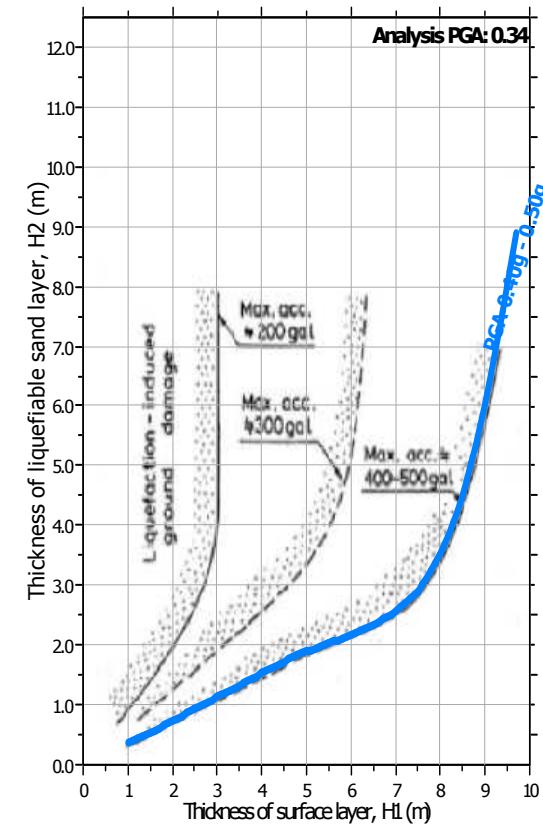
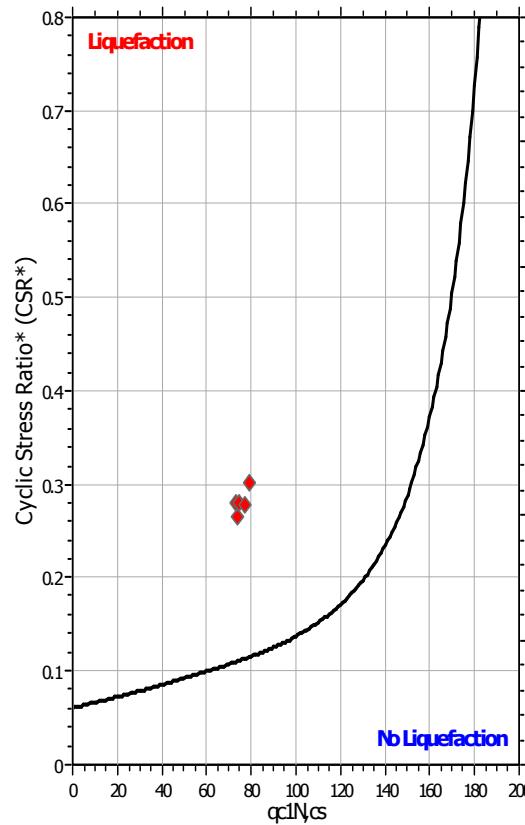
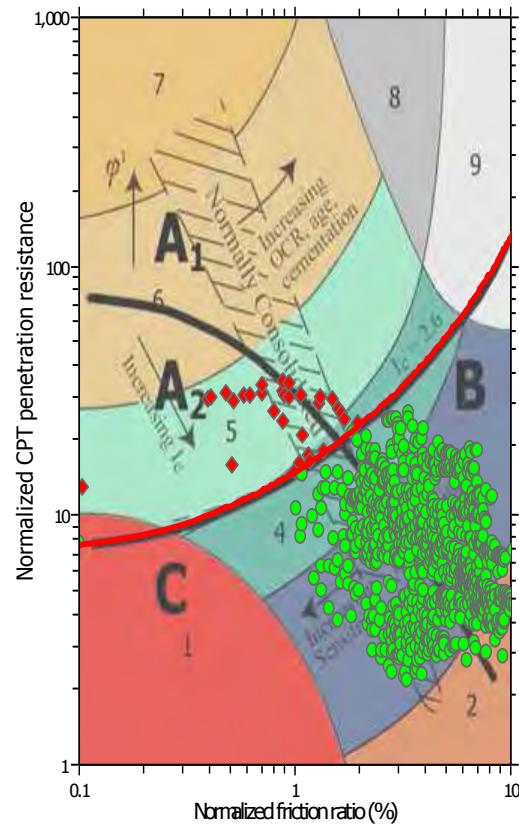
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

- █ Almost certain it will liquefy
- █ Very likely to liquefy
- █ Liquefaction and no liq. are equally likely
- █ Unlike to liquefy
- █ Almost certain it will not liquefy

LPI color scheme

- █ Very high risk
- █ High risk
- █ Moderate risk
- █ Low risk

Liquefaction analysis summary plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.05 m

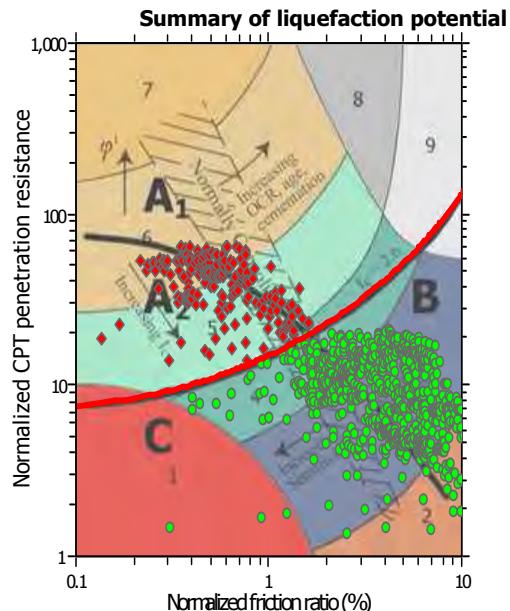
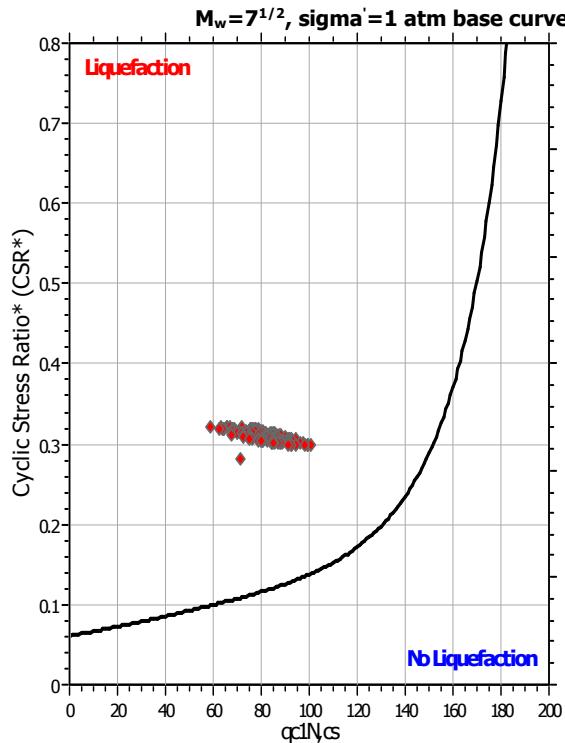
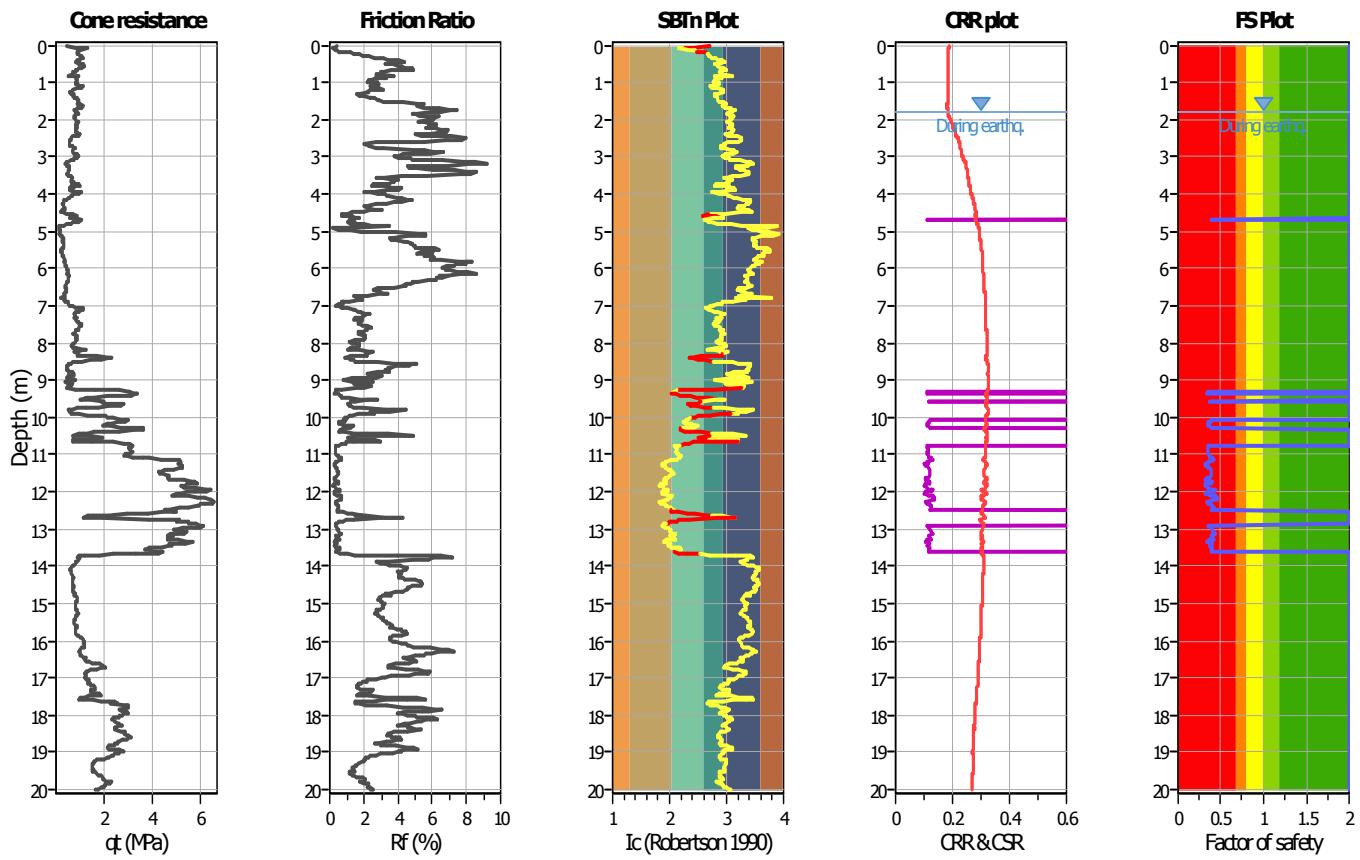
Depth to GWT (erthq.): 2.05 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

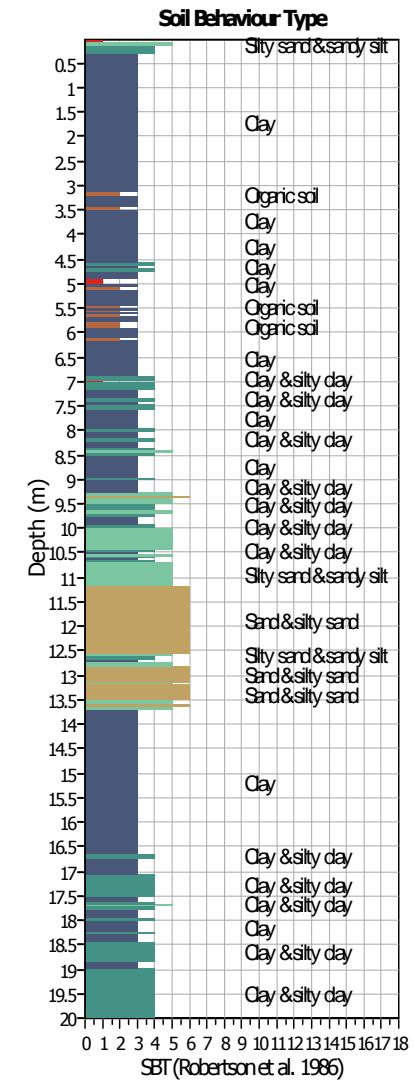
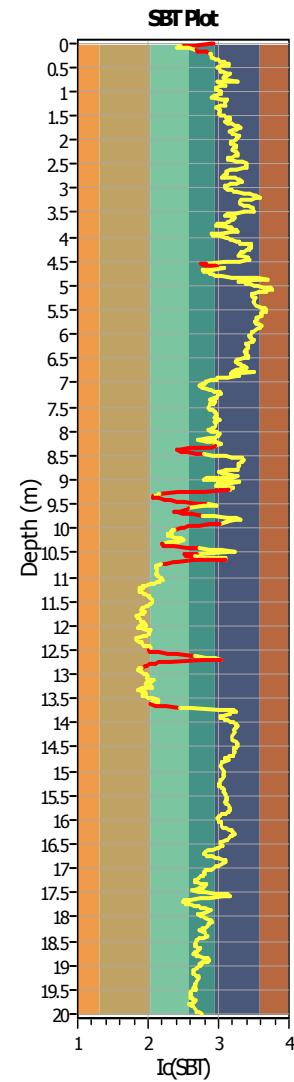
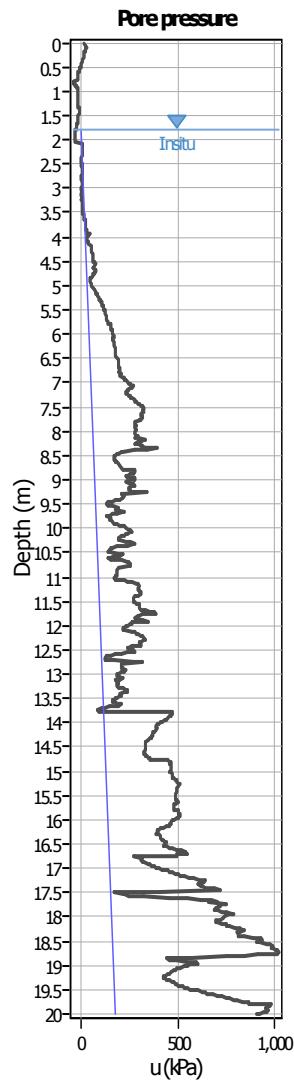
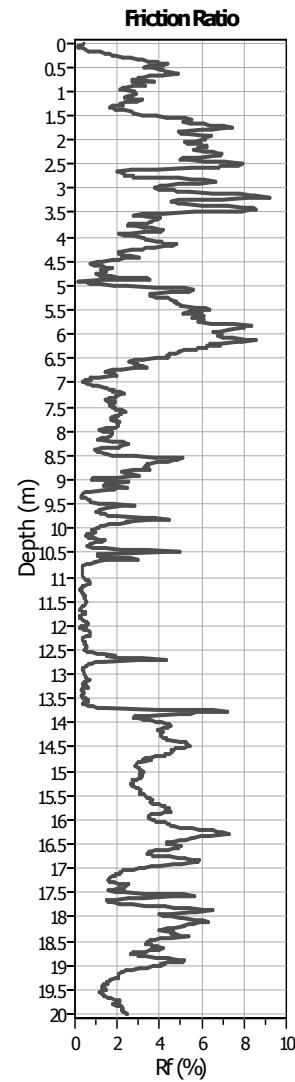
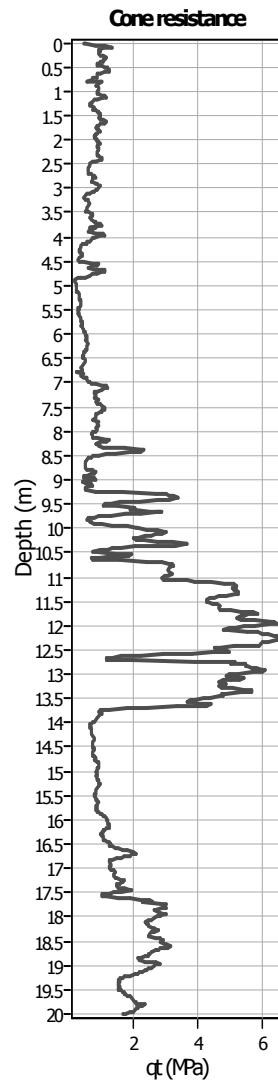
LIQUEFACTION ANALYSIS REPORT
Project title :
CPT file : CPTU8

Location :
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.80 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.80 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

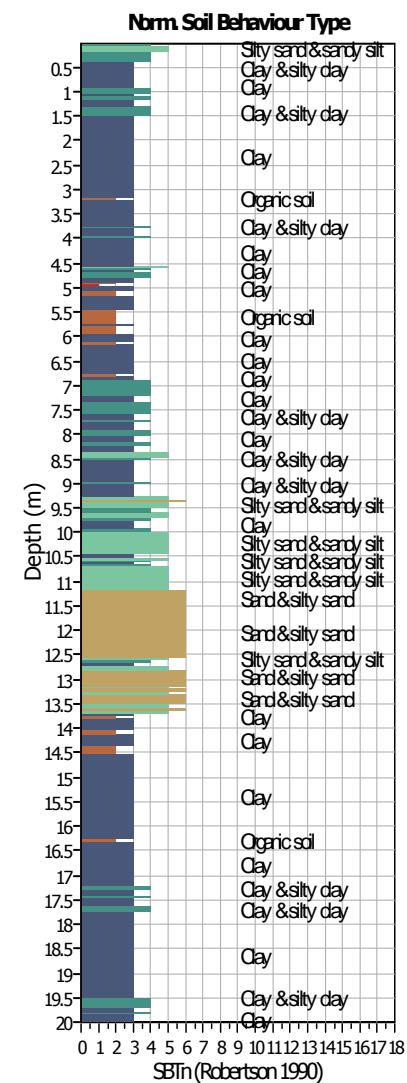
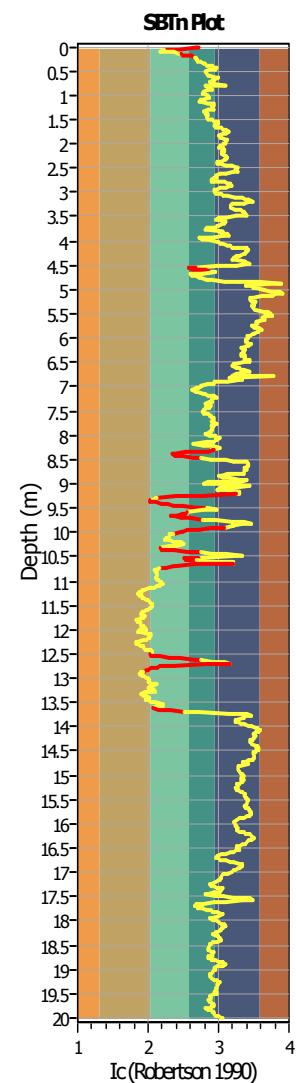
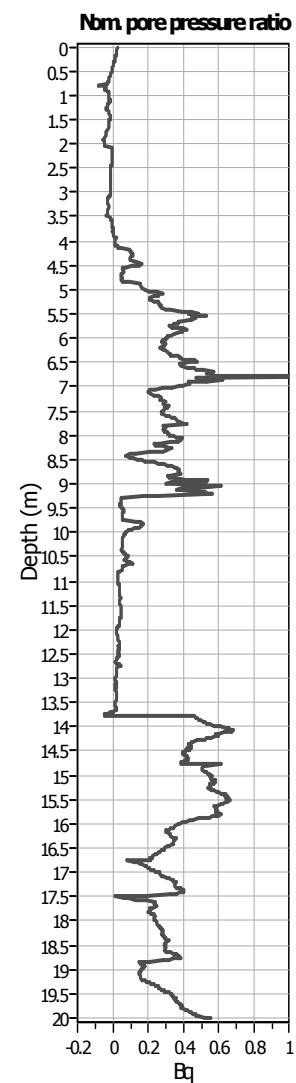
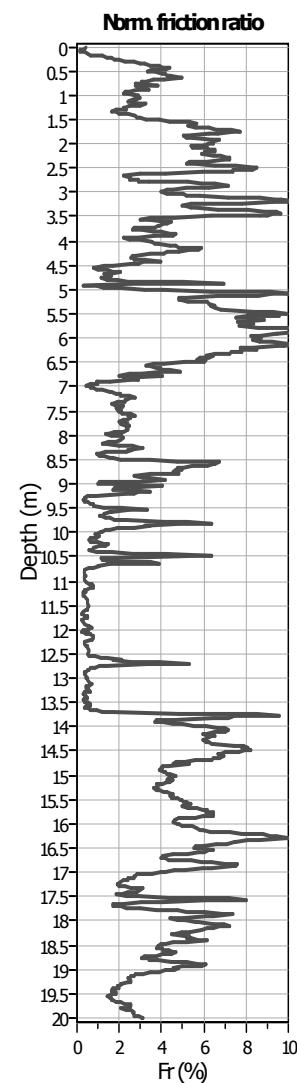
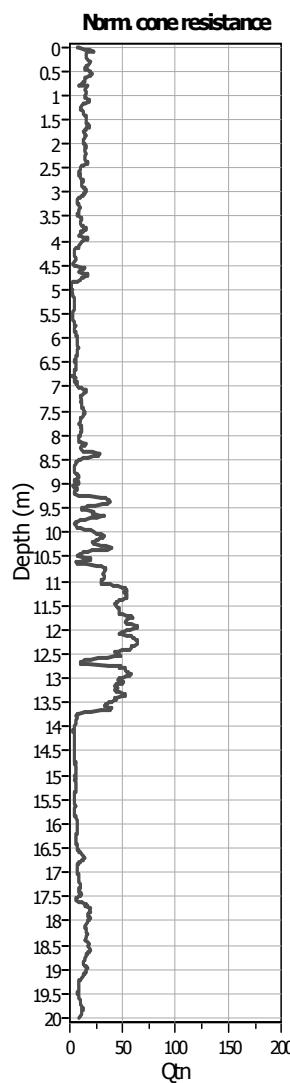
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 1.80 m

Depth to GWT (erthq.): 1.80 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)**Input parameters and analysis data**

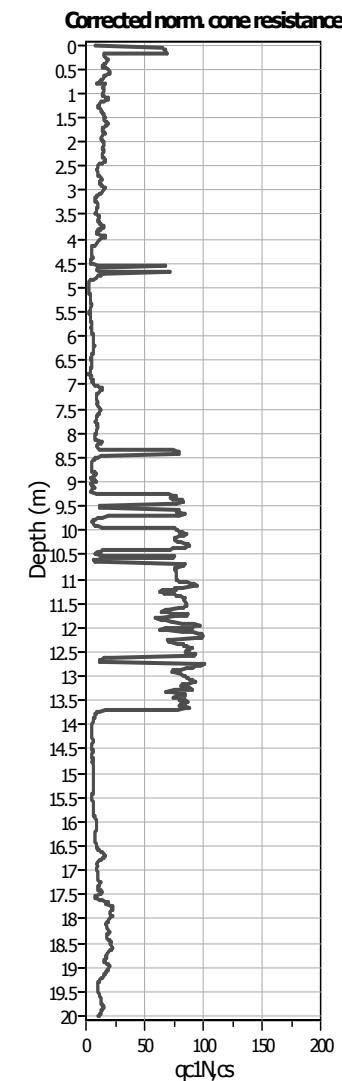
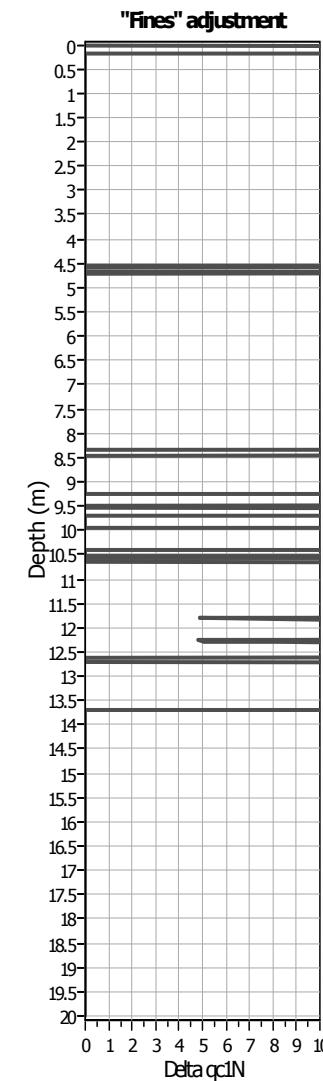
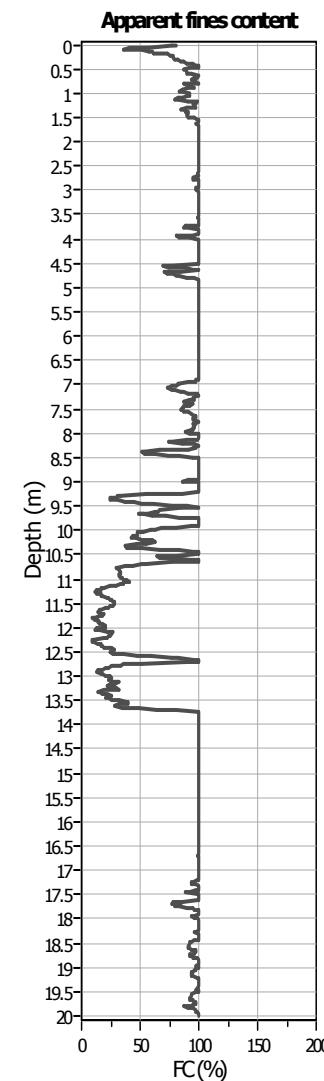
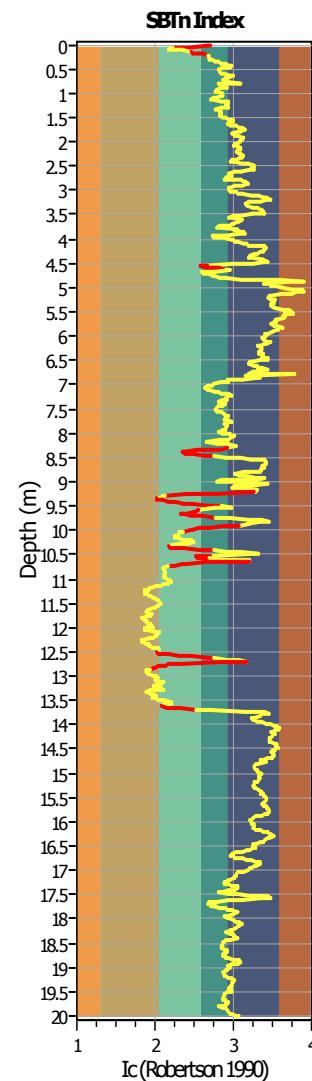
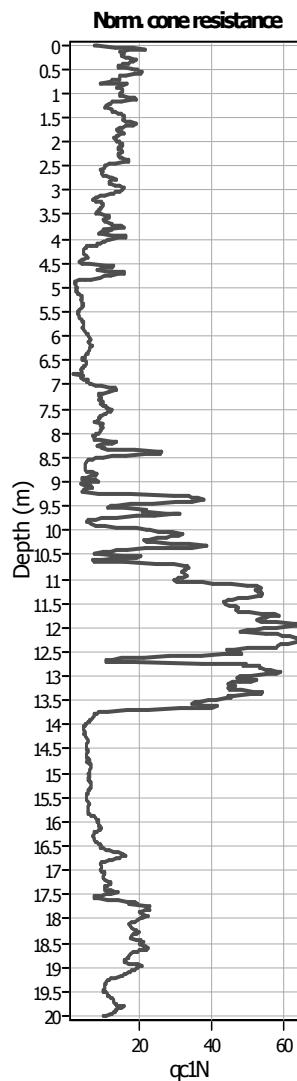
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 1.80 m

Depth to GWT (erthq.): 1.80 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBTn legend

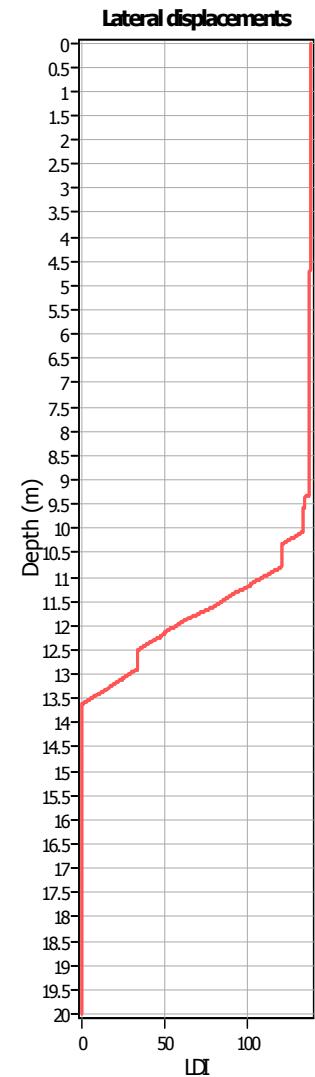
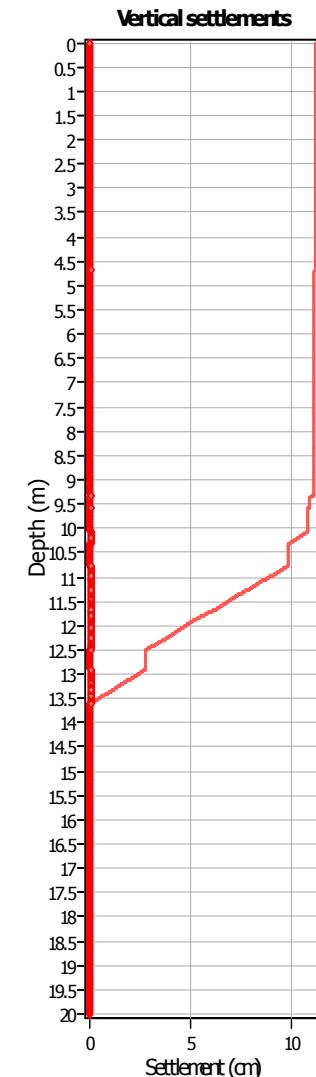
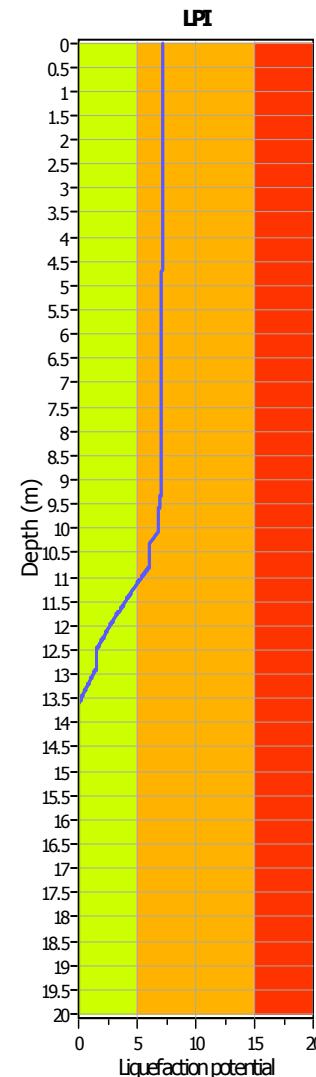
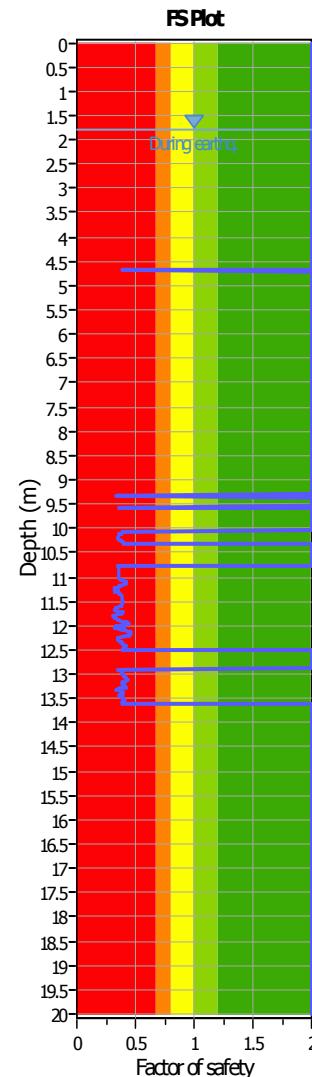
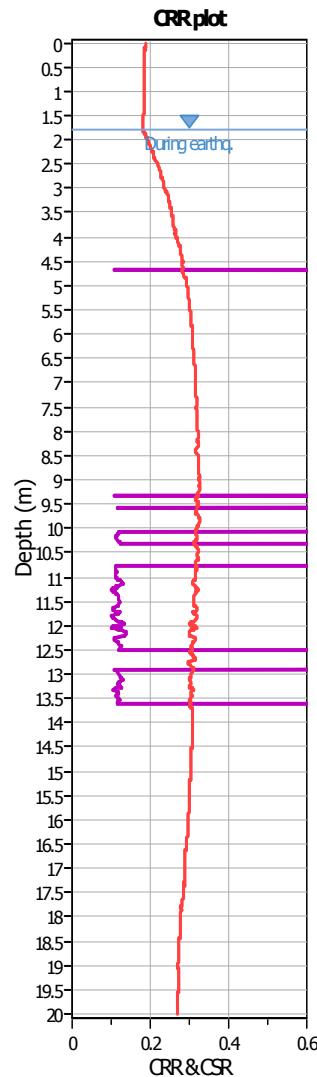
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 1.80 m

Depth to GWT (erthq.): 1.80 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 1.80 m

Depth to GWT (erthq.): 1.80 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied:
 K_0 applied:
 Clay like behavior applied:
 Limit depth applied:
 Limit depth:

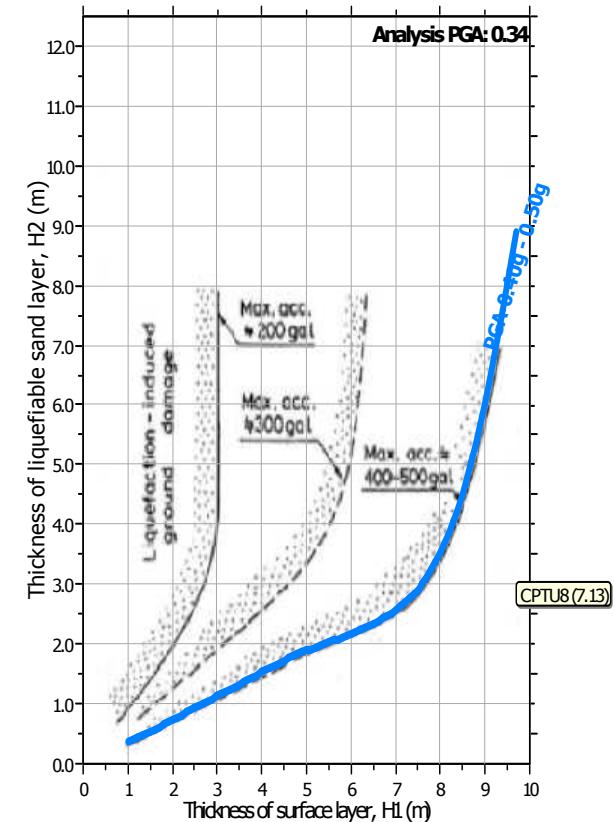
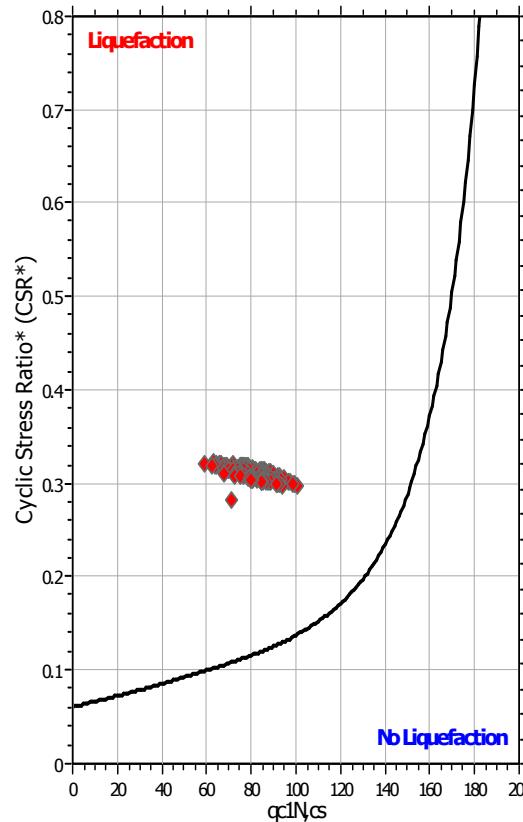
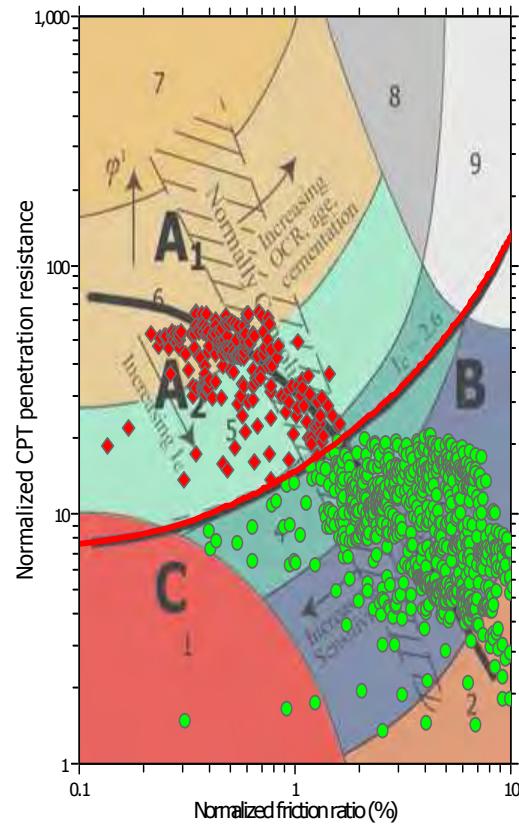
N/A
 Yes
 Yes
 Sands only
 No
 N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

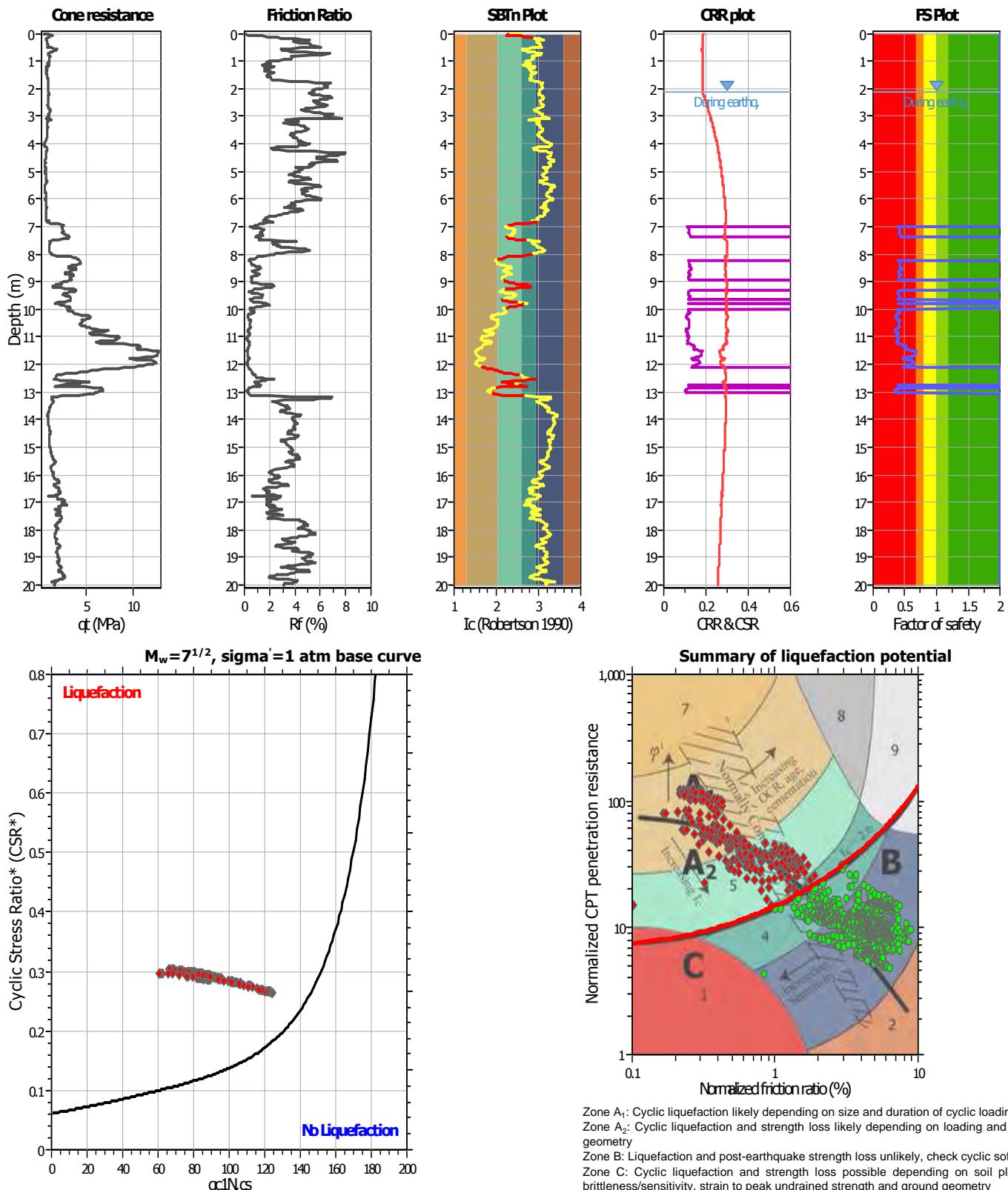
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 1.80 m

Depth to GWT (erthq.): 1.80 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

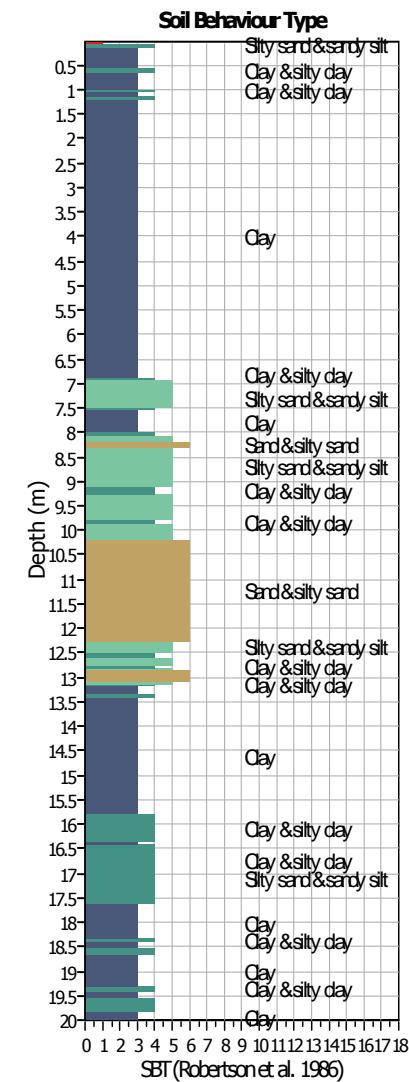
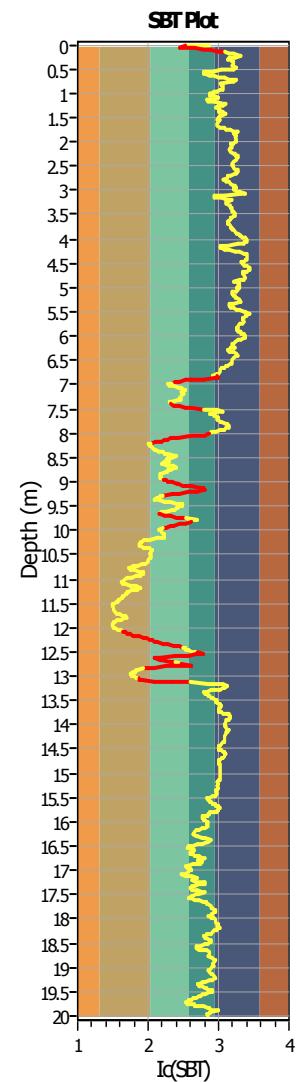
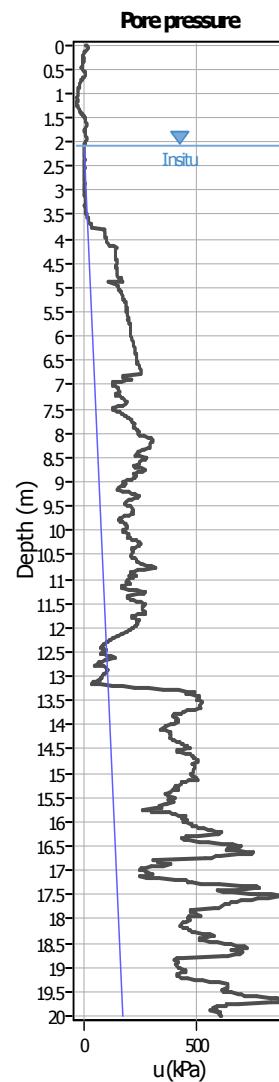
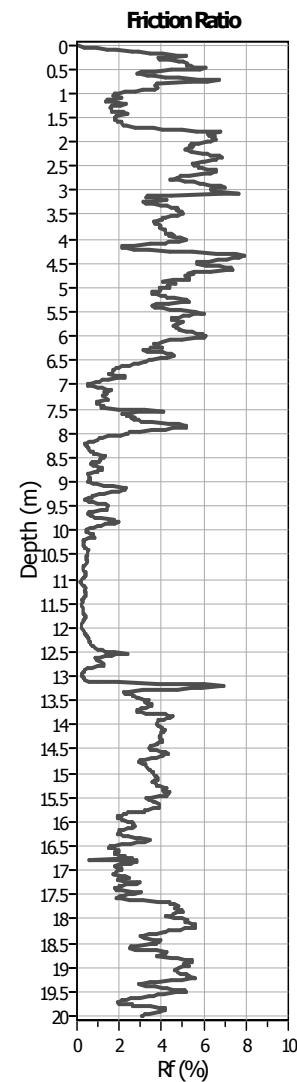
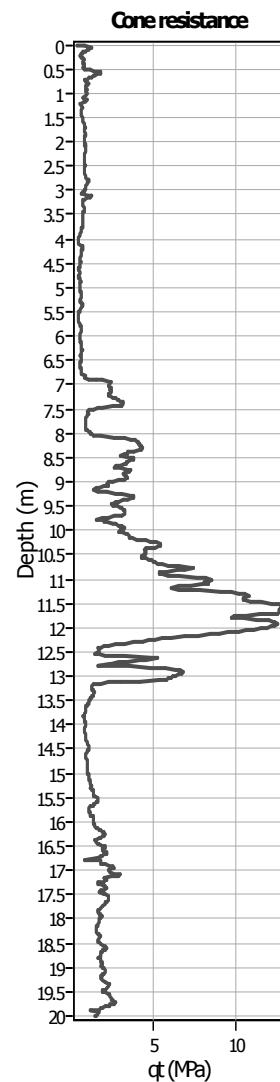
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title :
CPT file : CPTU6
Location :
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.10 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	2.10 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

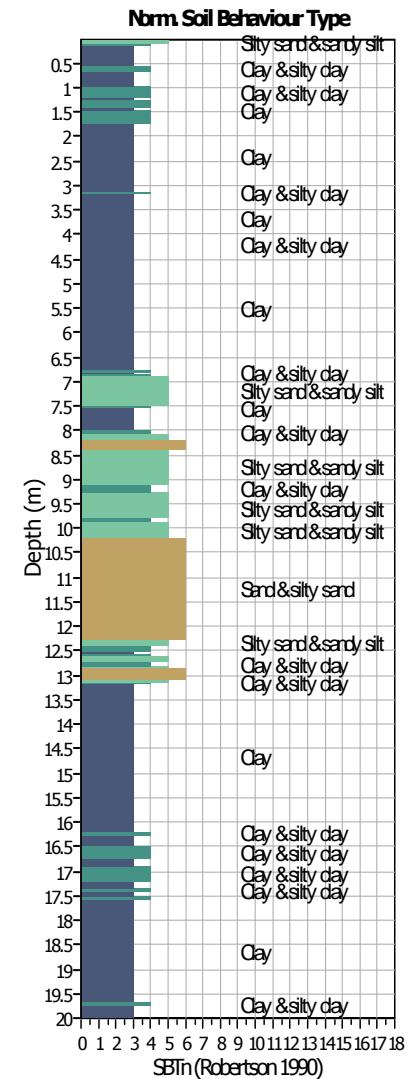
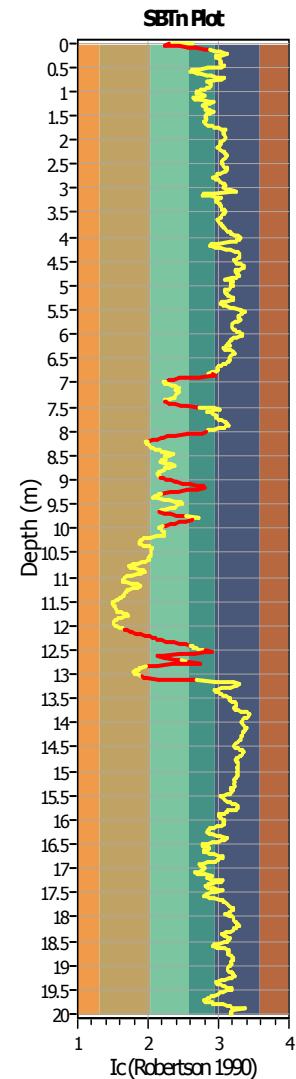
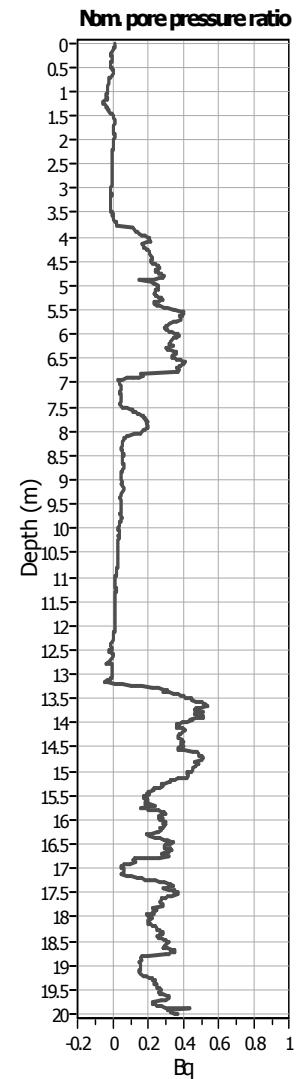
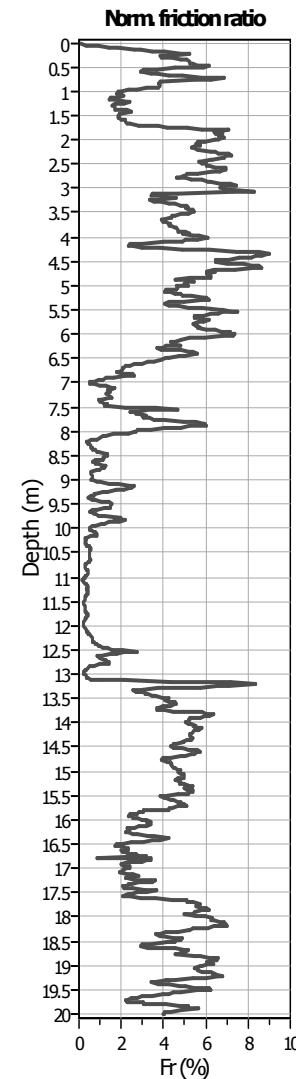
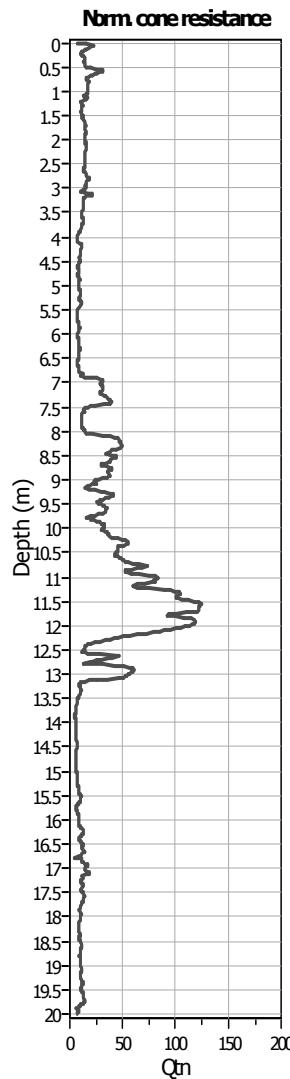
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.10 m

Depth to GWT (erthq.): 2.10 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravelly sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)**Input parameters and analysis data**

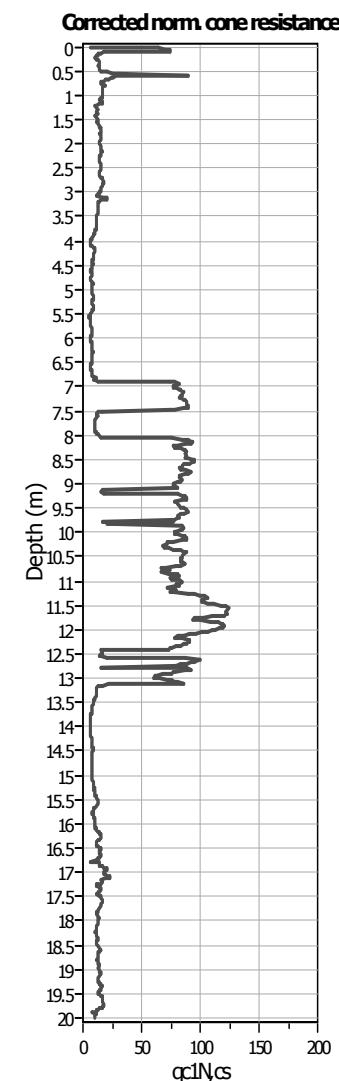
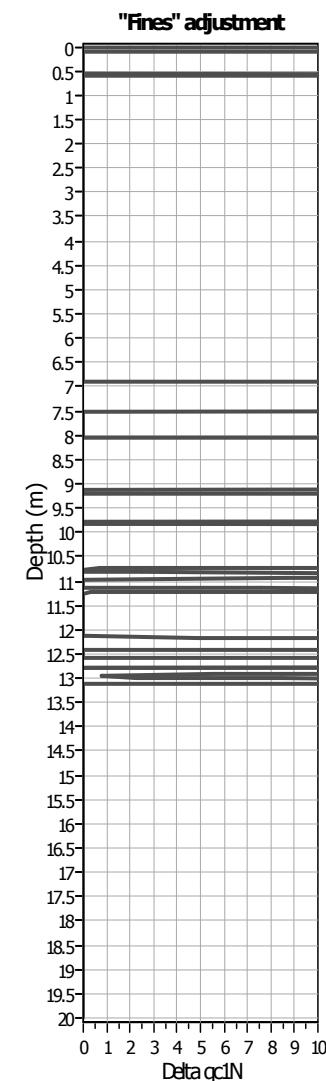
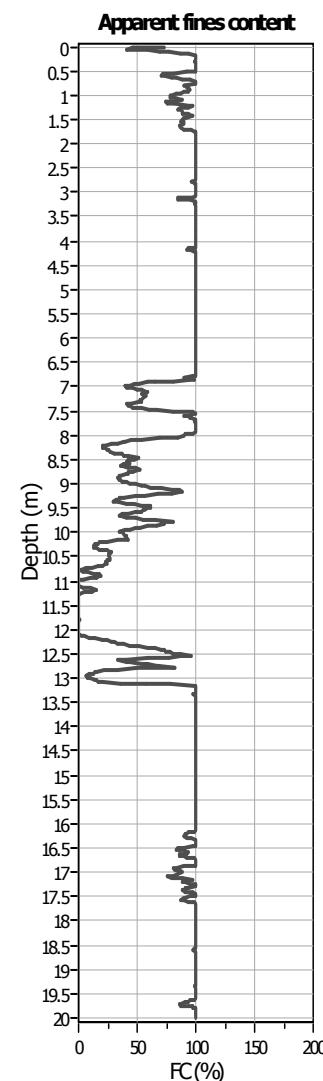
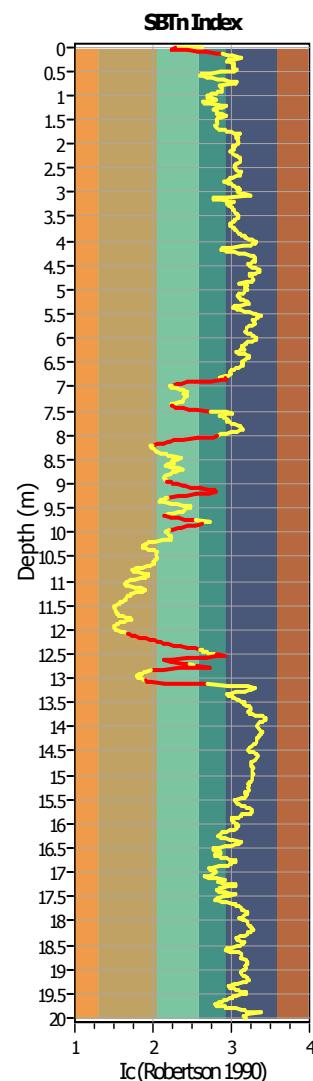
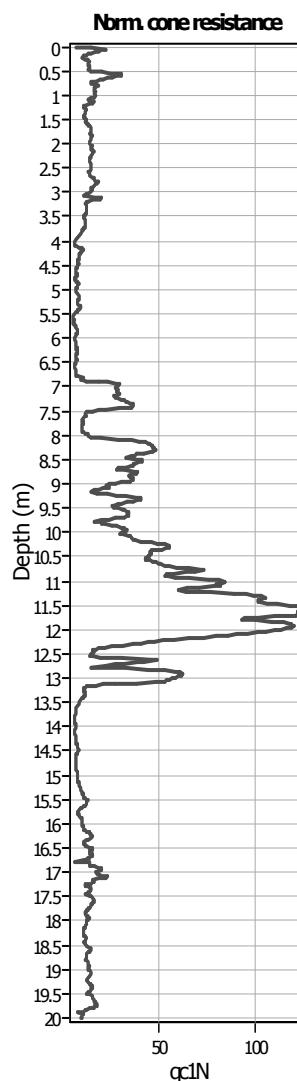
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.10 m

Depth to GWT (erthq.): 2.10 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBTn legend

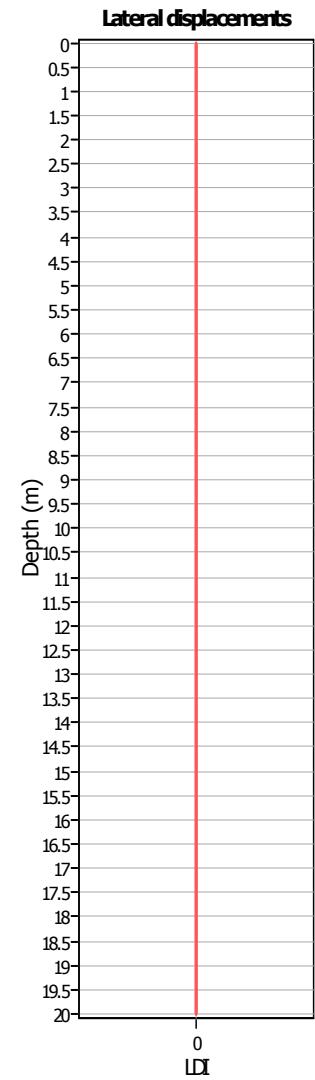
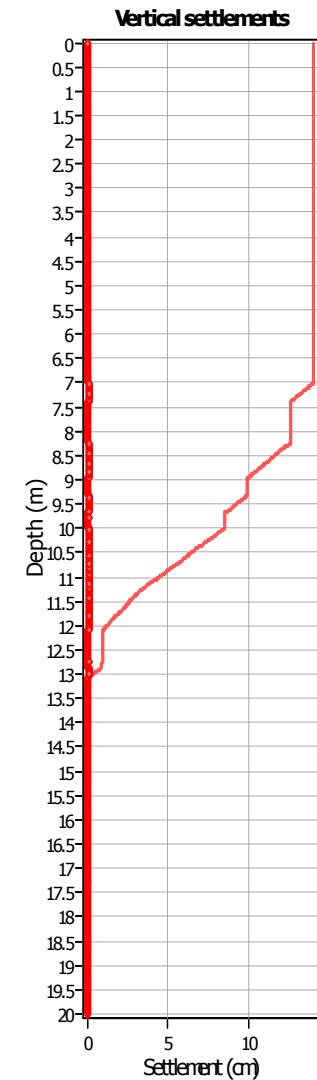
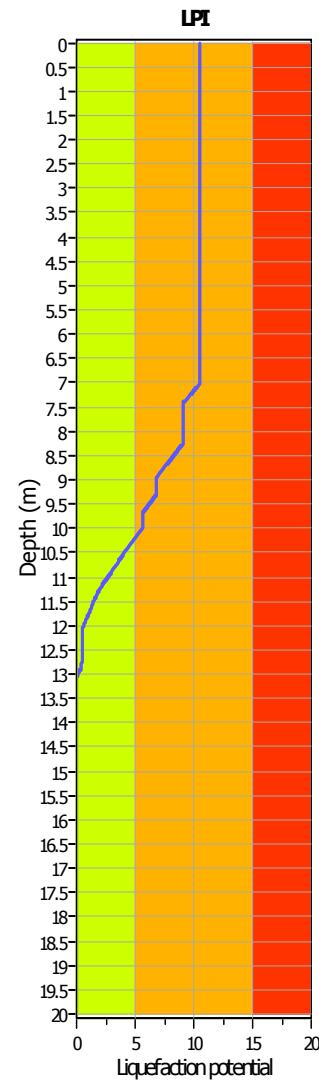
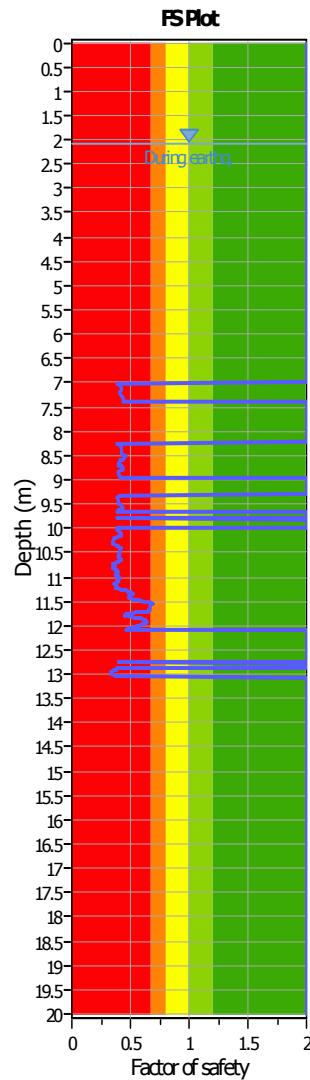
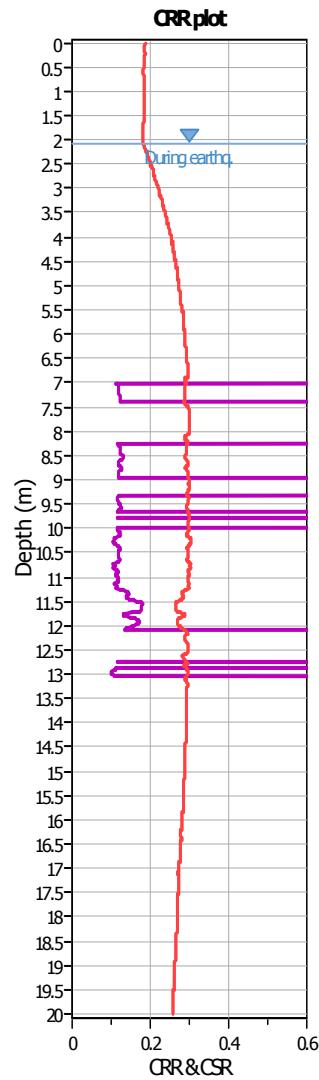
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.10 m

Depth to GWT (erthq.): 2.10 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.10 m

Depth to GWT (erthq.): 2.10 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

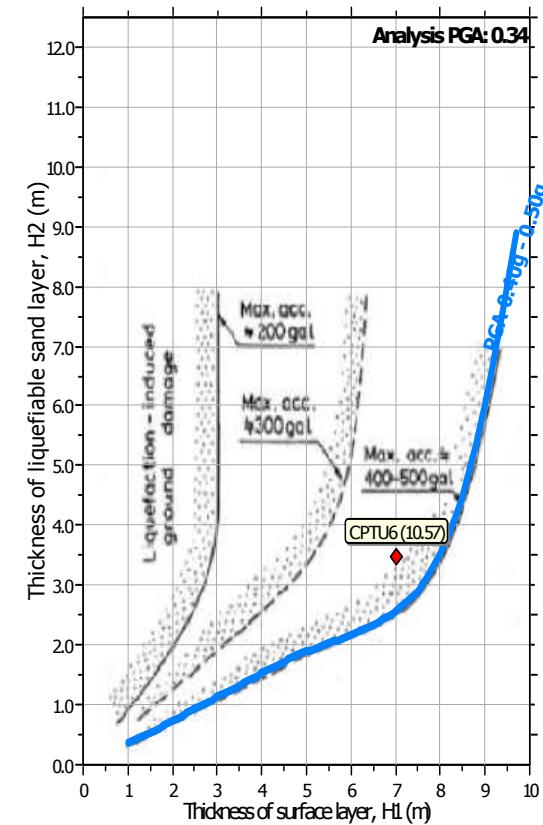
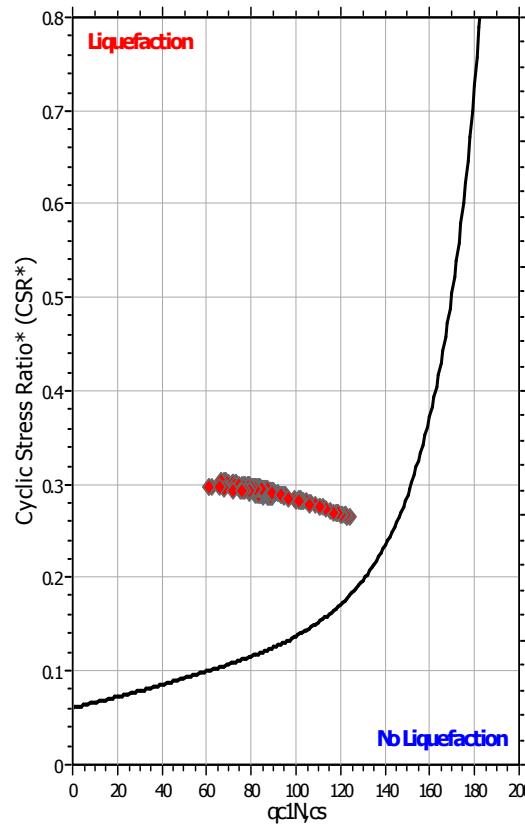
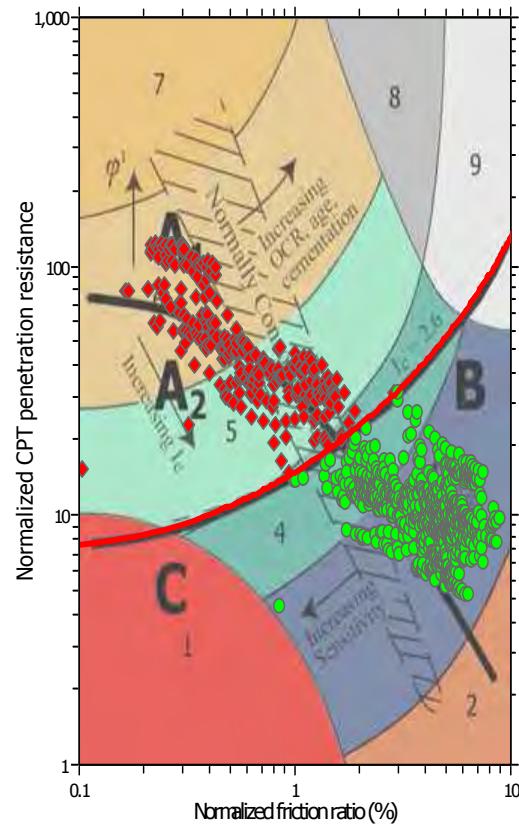
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

- █ Almost certain it will liquefy
- █ Very likely to liquefy
- █ Liquefaction and no liq. are equally likely
- █ Unlike to liquefy
- █ Almost certain it will not liquefy

LPI color scheme

- █ Very high risk
- █ High risk
- █ Moderate risk
- █ Low risk

Liquefaction analysis summary plots**Input parameters and analysis data**

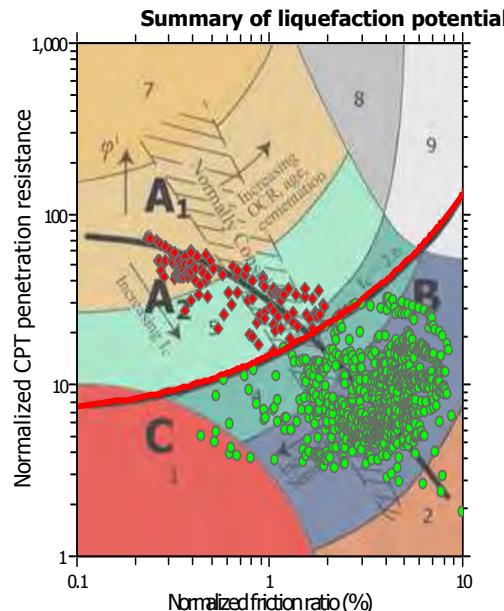
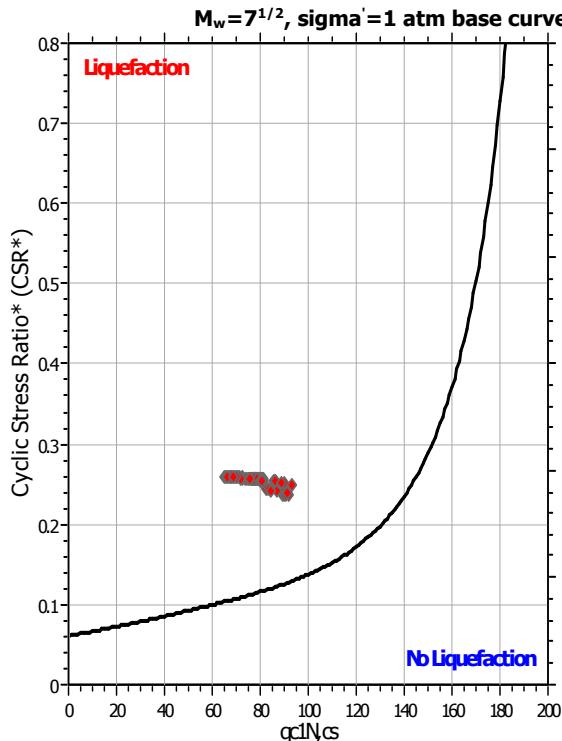
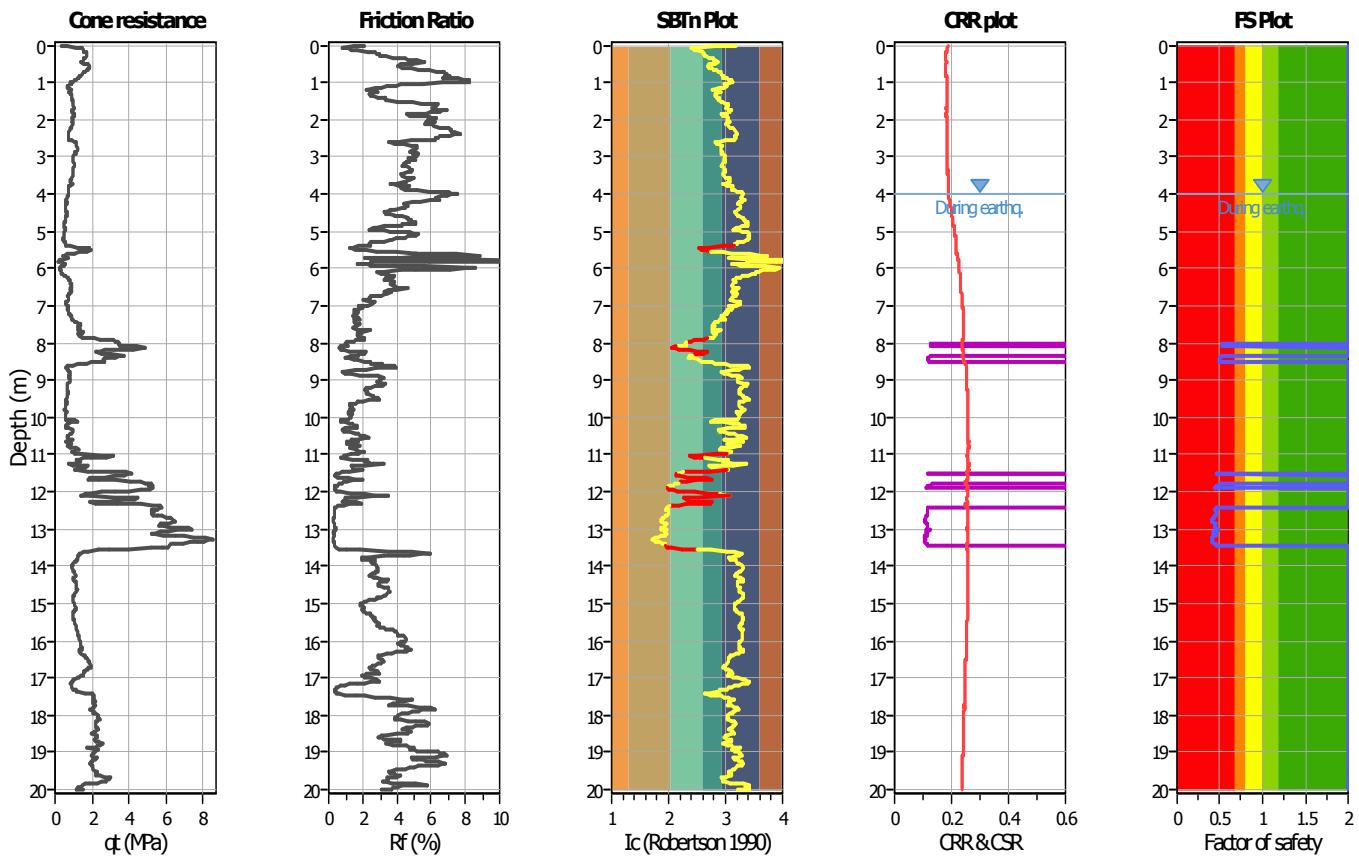
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.10 m

Depth to GWT (erthq.): 2.10 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

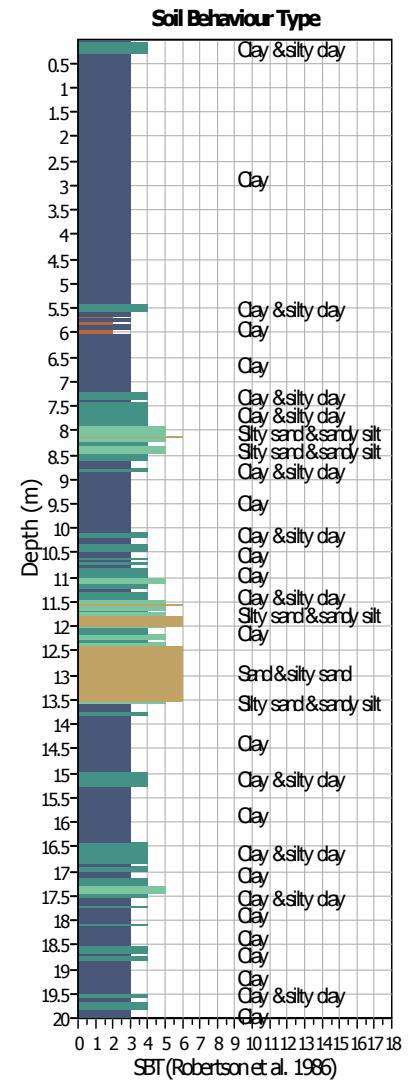
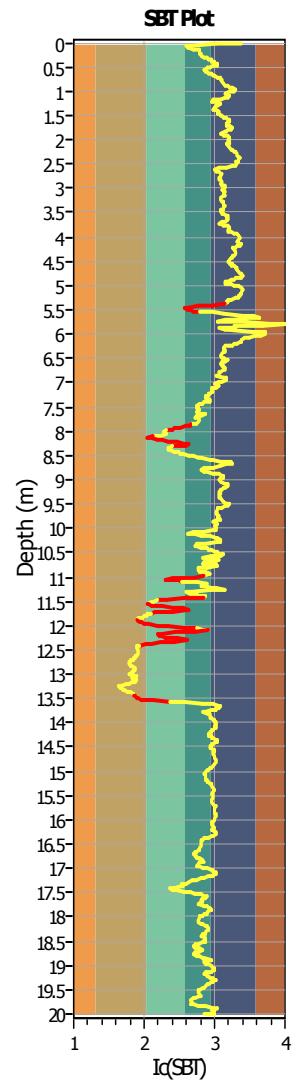
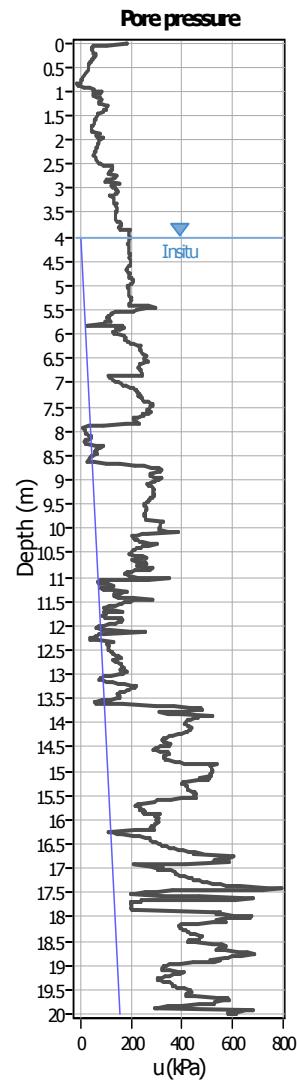
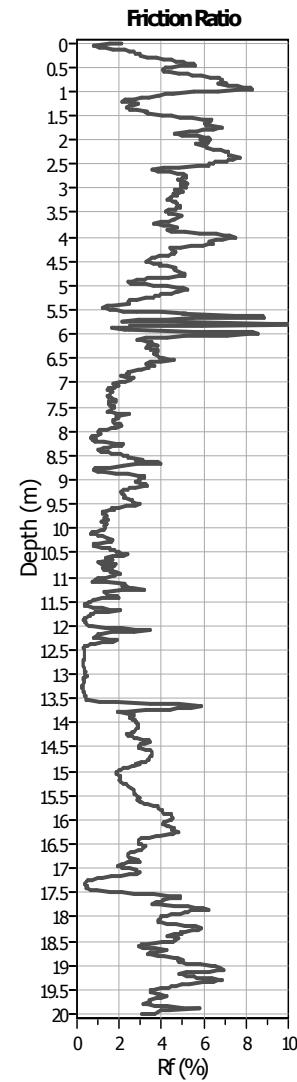
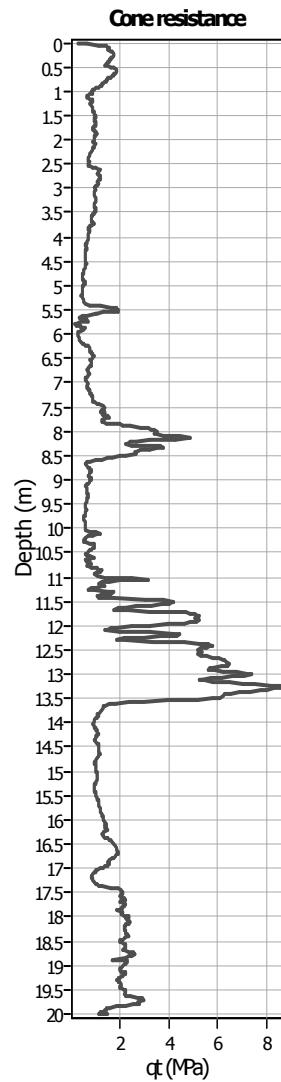
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 9
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	4.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	4.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 4.00 m

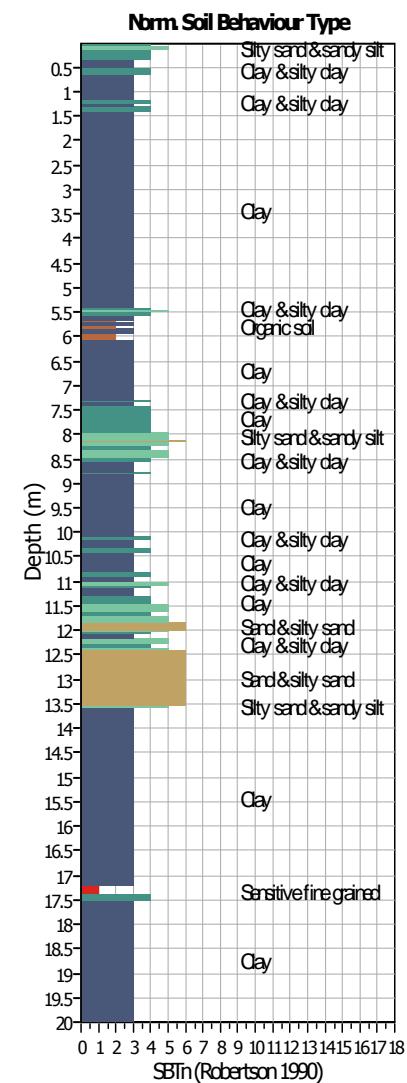
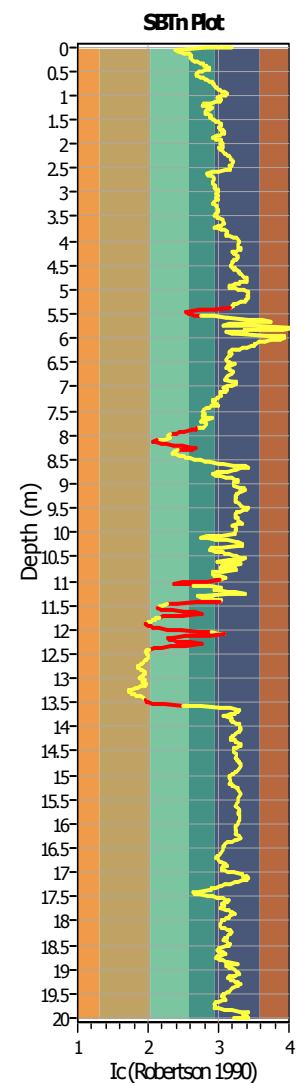
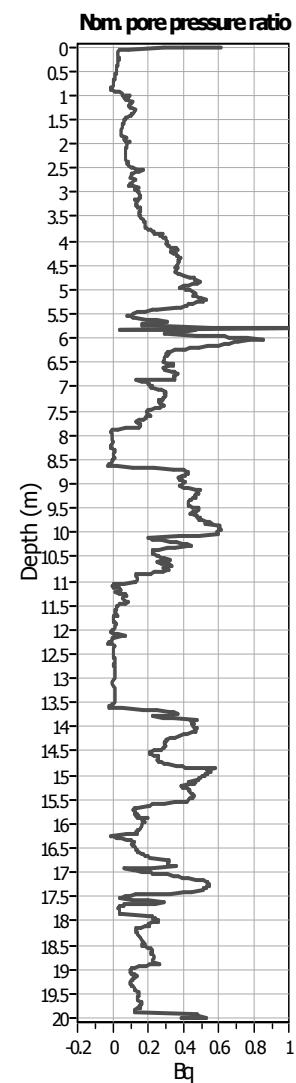
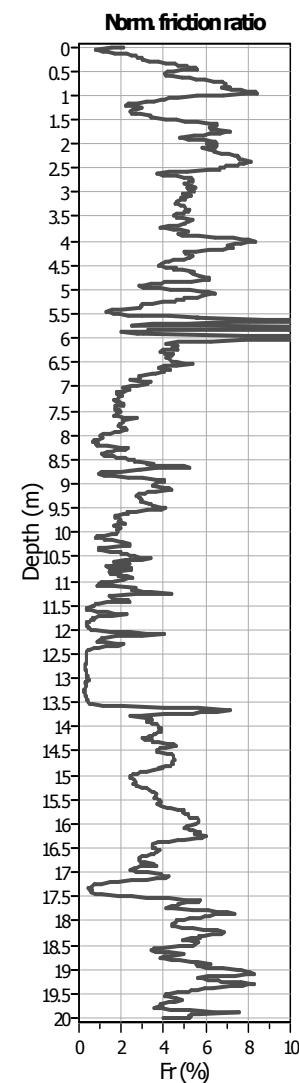
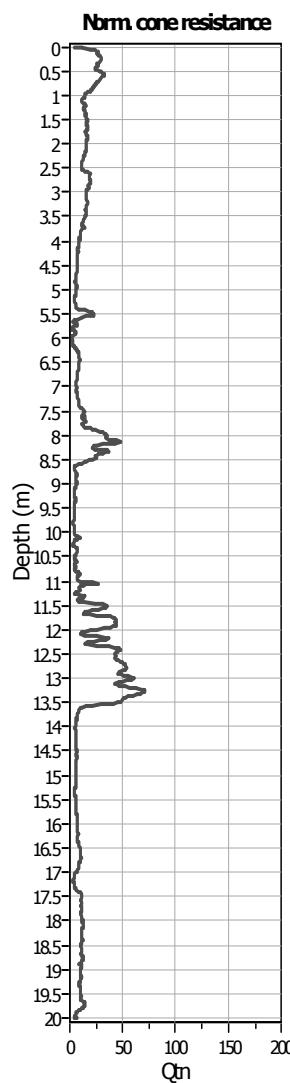
Depth to GWT (erthq.): 4.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)



Input parameters and analysis data

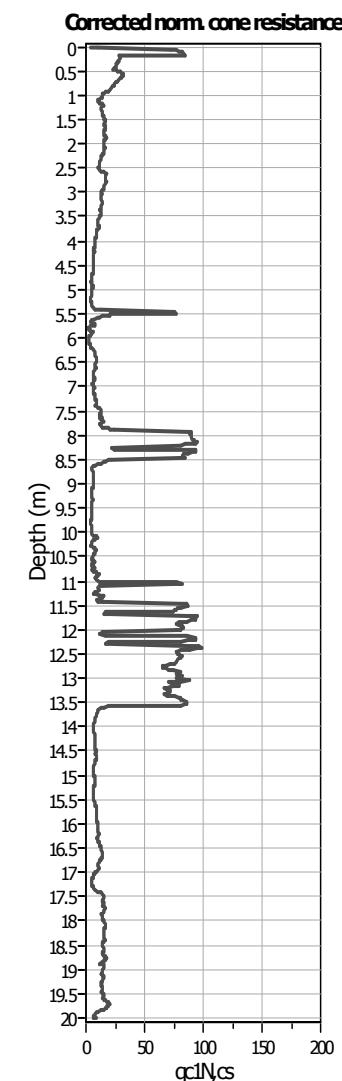
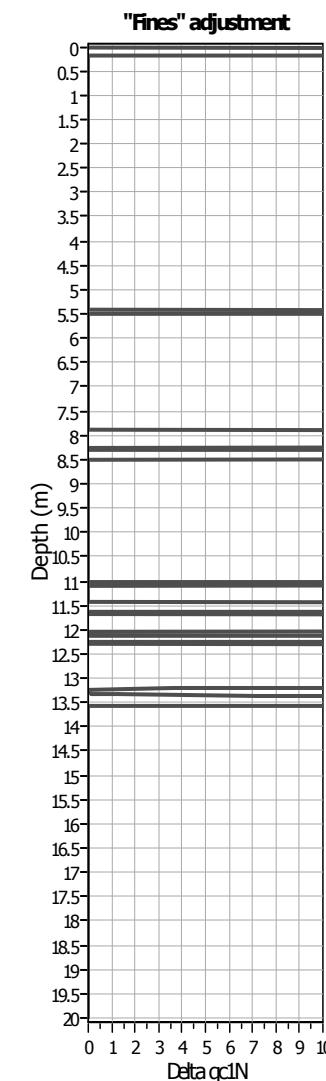
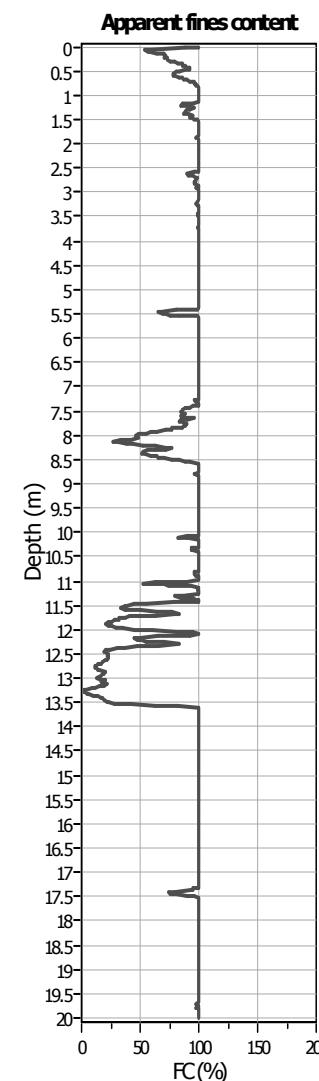
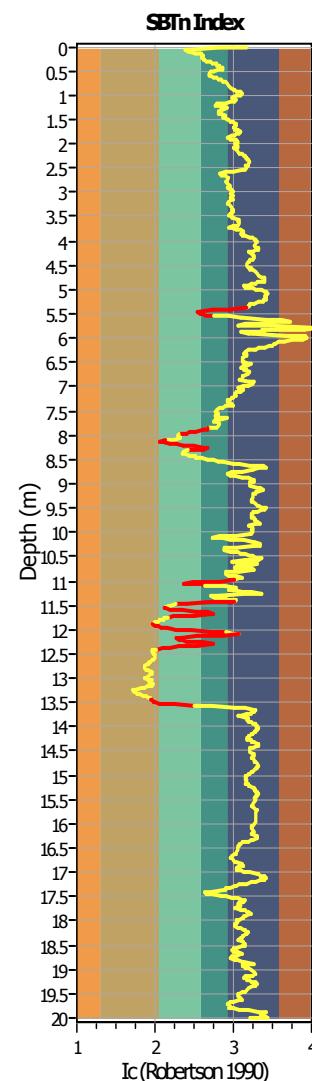
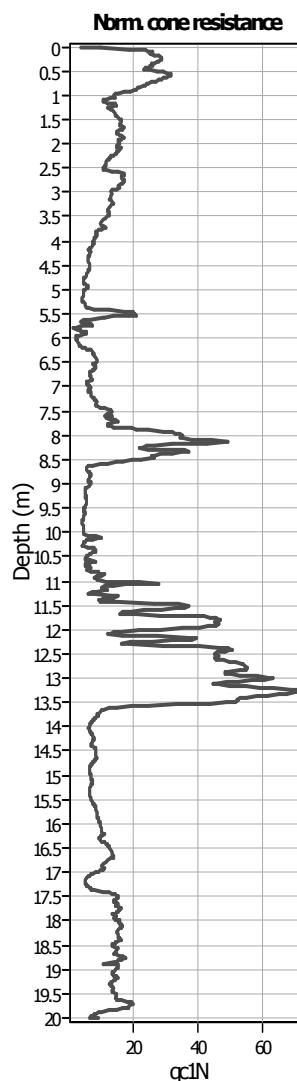
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 4.00 m

Depth to GWT (erthq.): 4.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBTn legend

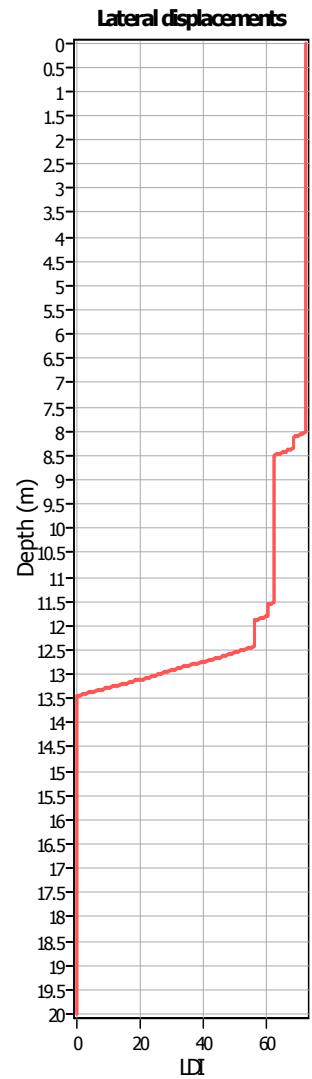
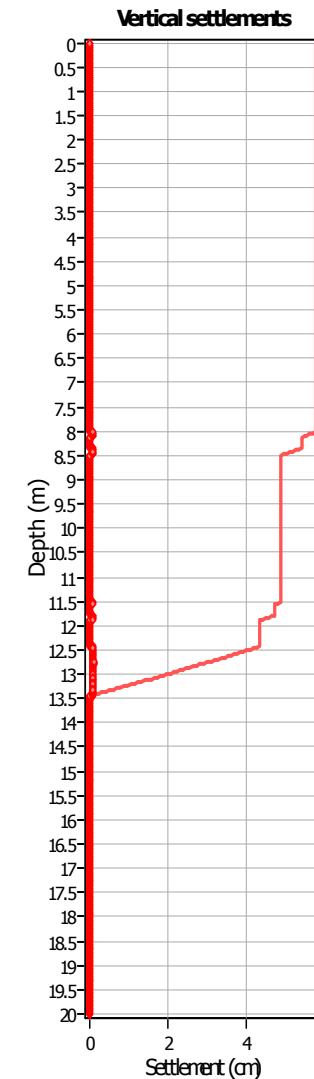
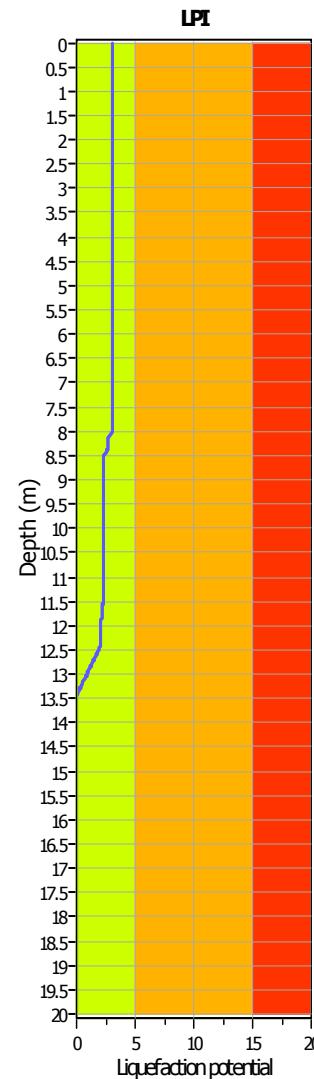
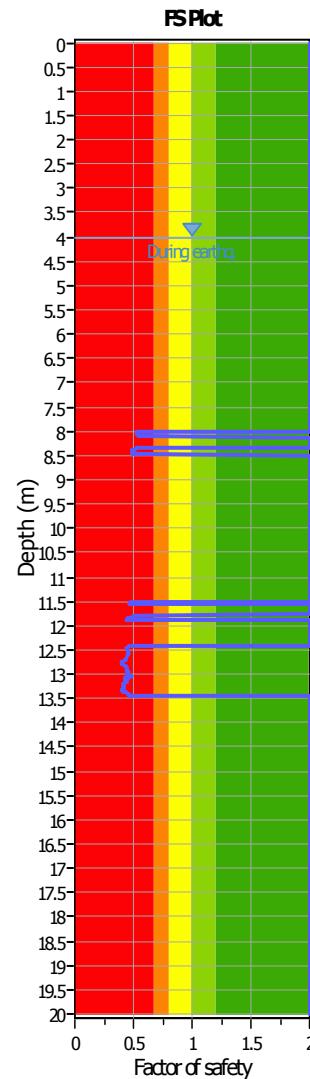
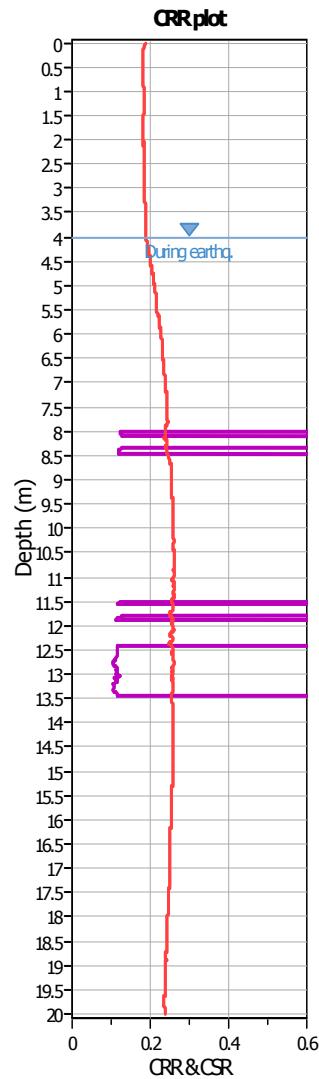
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 4.00 m

Depth to GWT (erthq.): 4.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 4.00 m

Depth to GWT (erthq.): 4.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

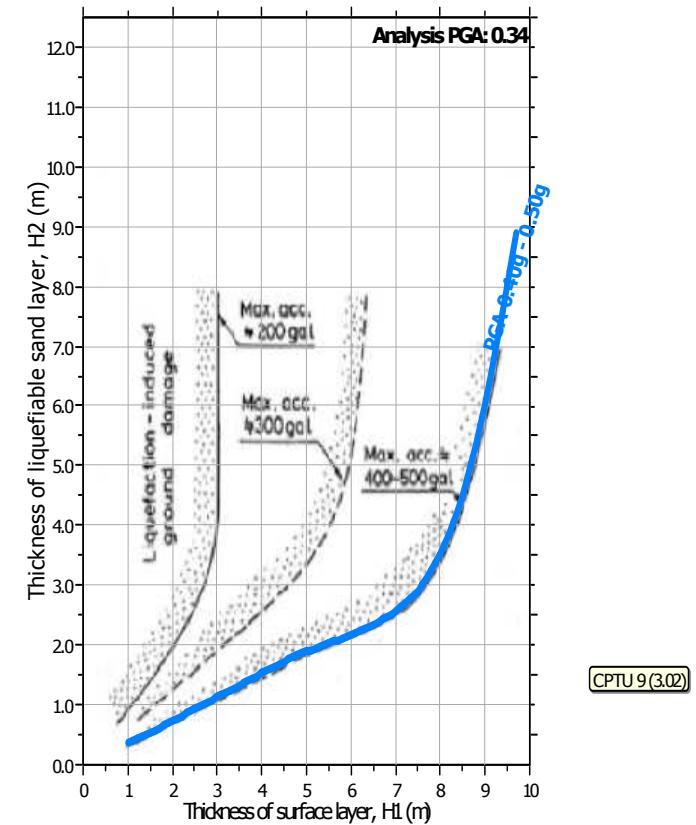
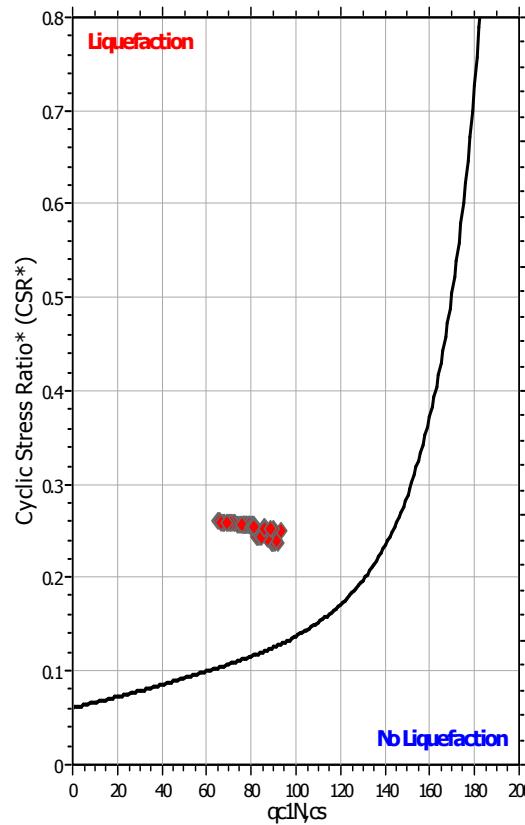
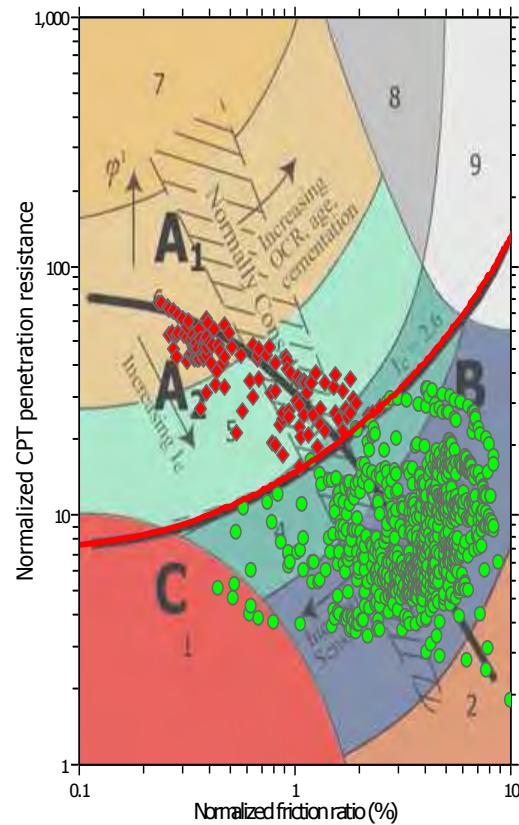
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

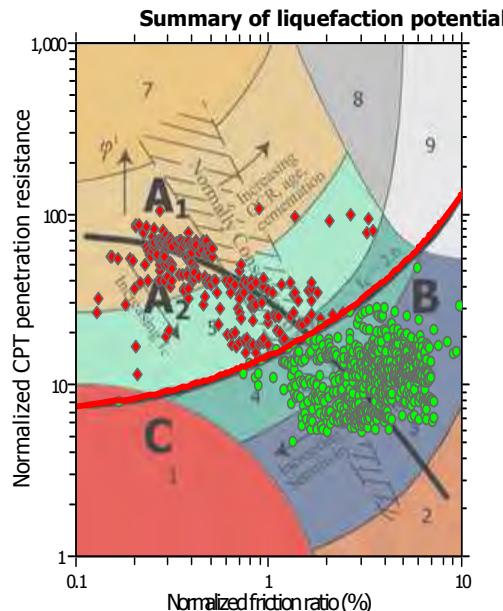
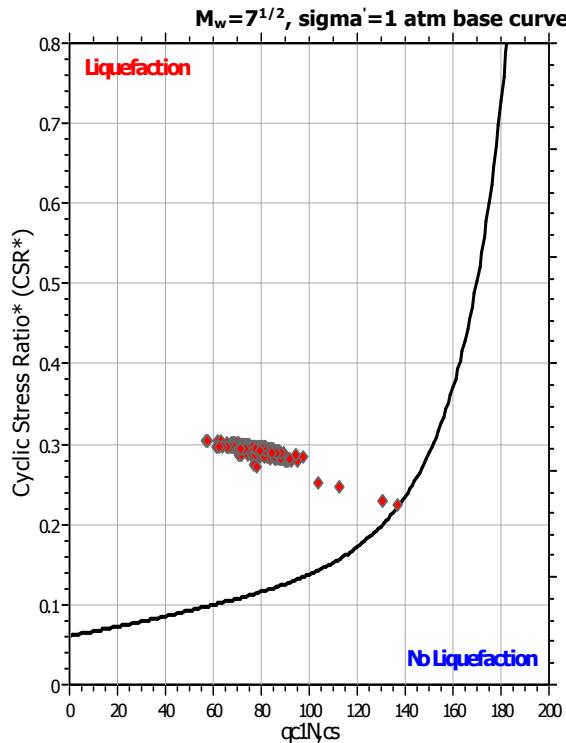
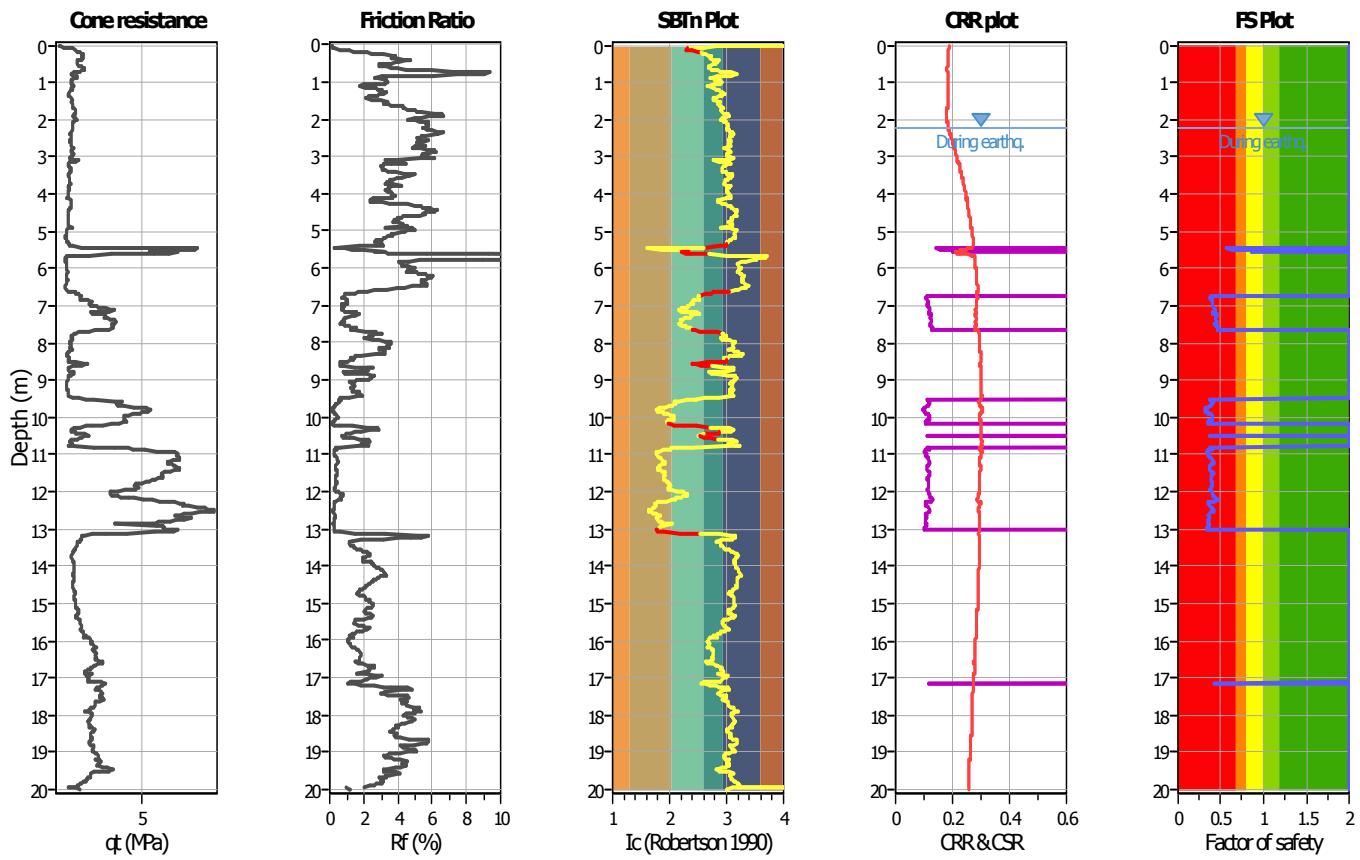
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in-situ): 4.00 m

Depth to GWT (erthq.): 4.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

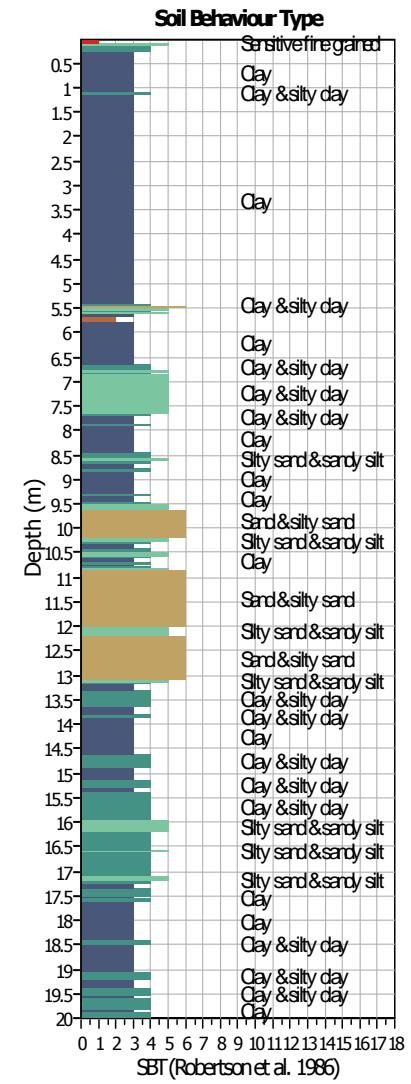
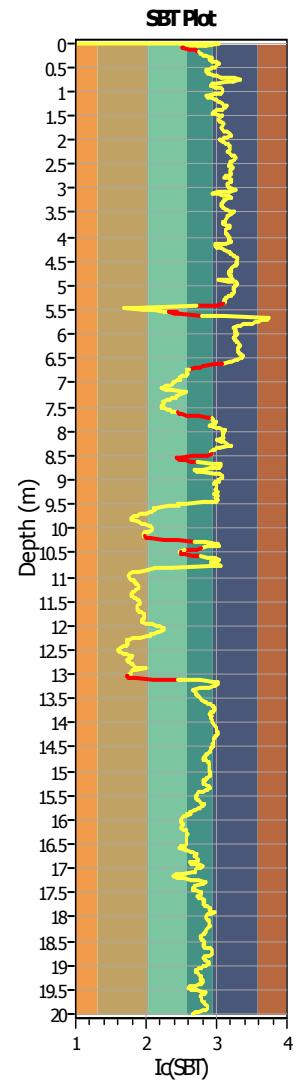
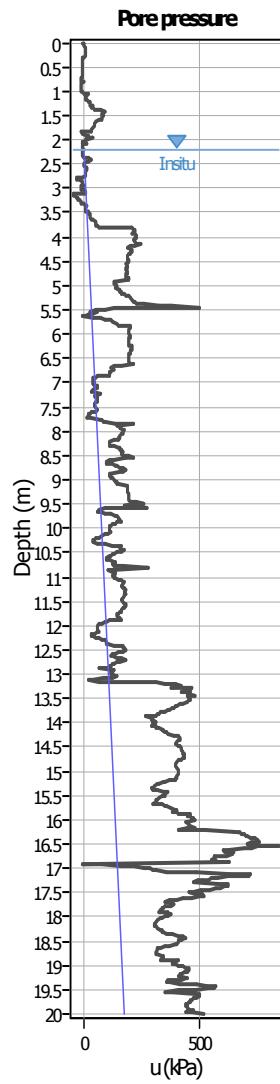
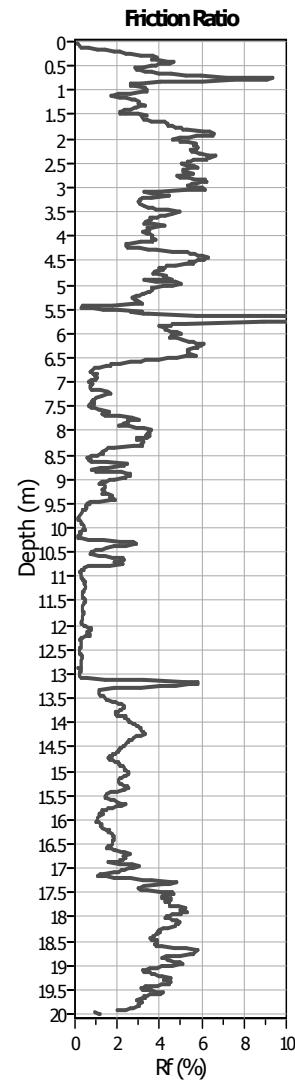
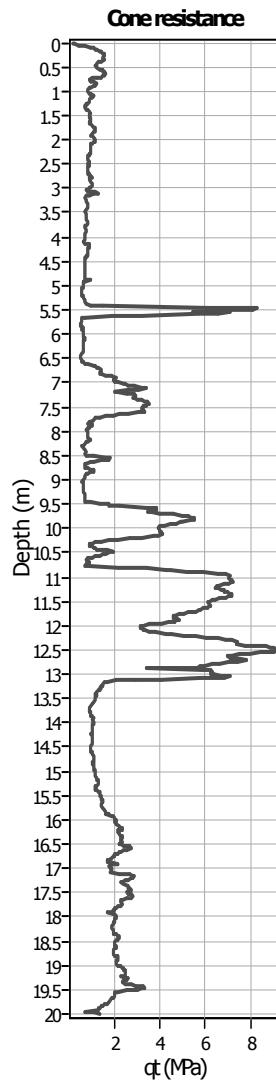
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 10
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.20 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	2.20 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

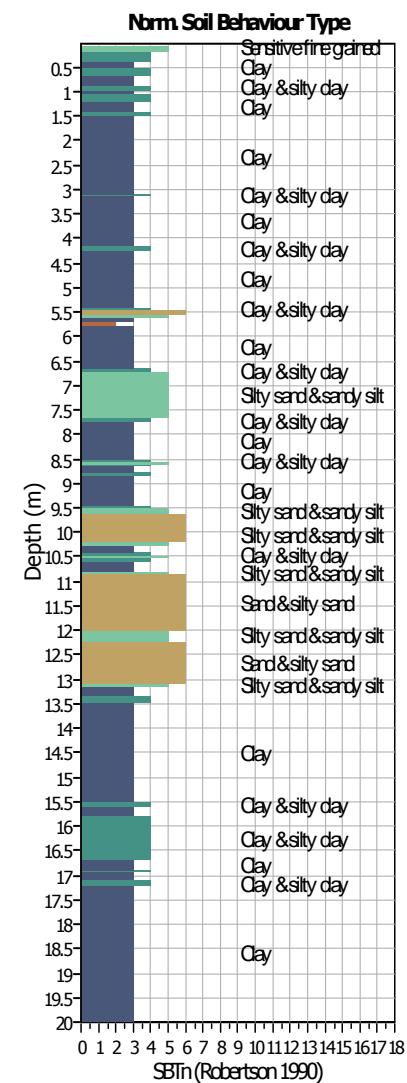
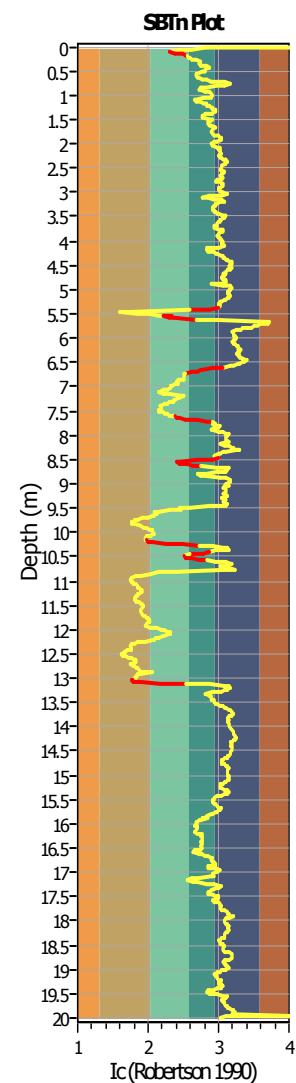
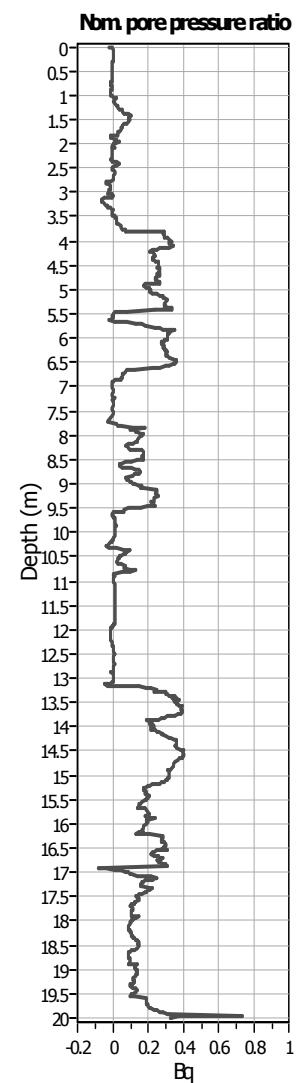
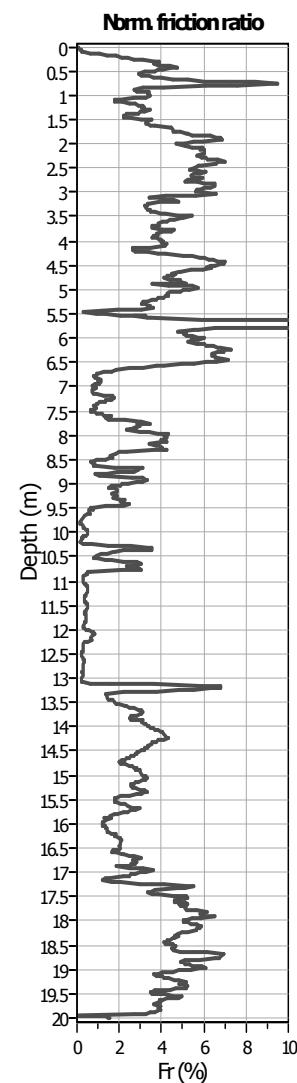
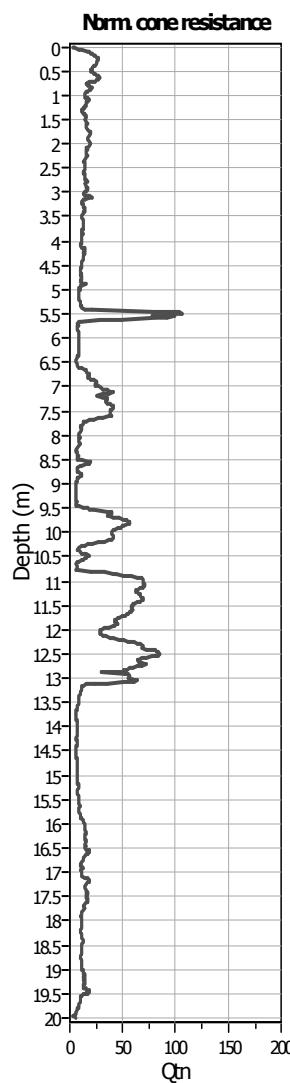
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.20 m

Depth to GWT (erthq.): 2.20 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)**Input parameters and analysis data**

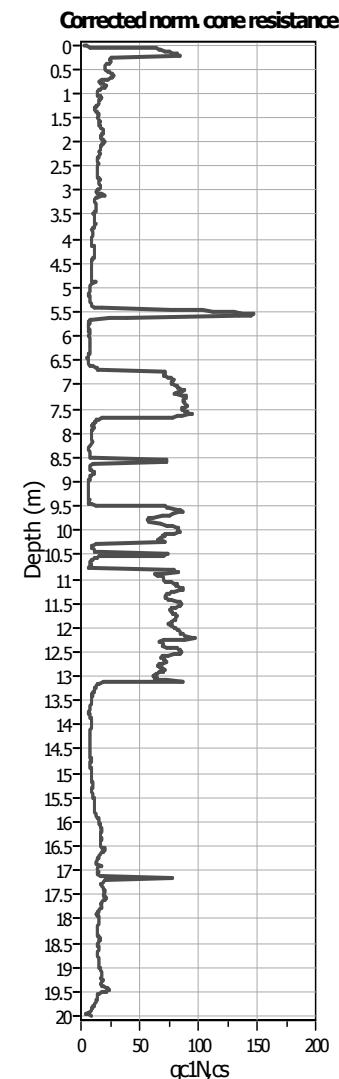
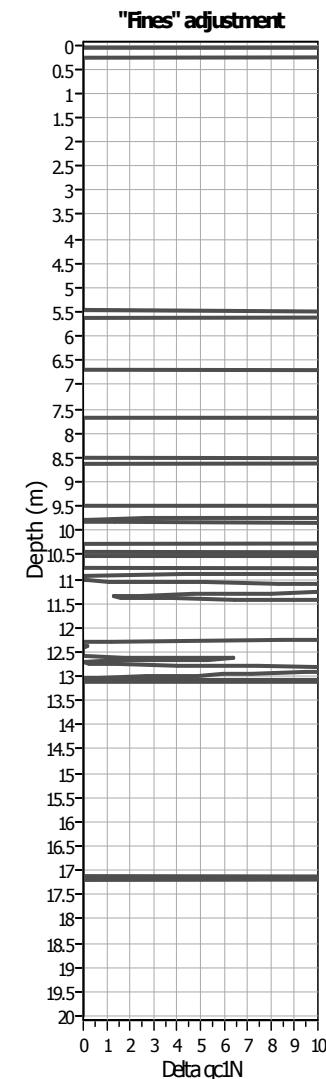
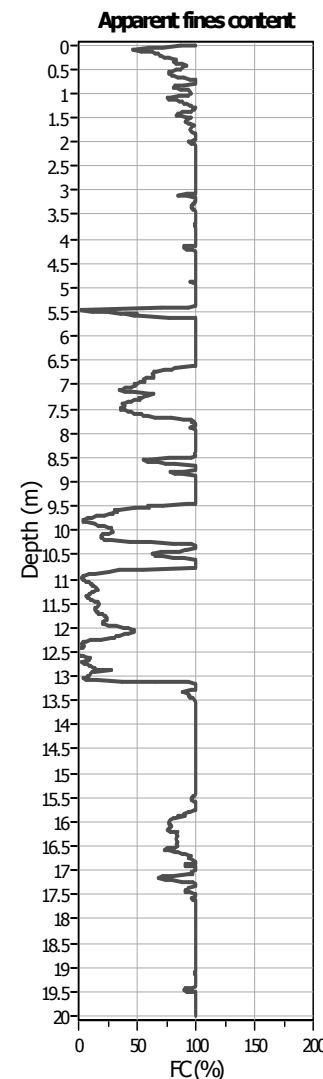
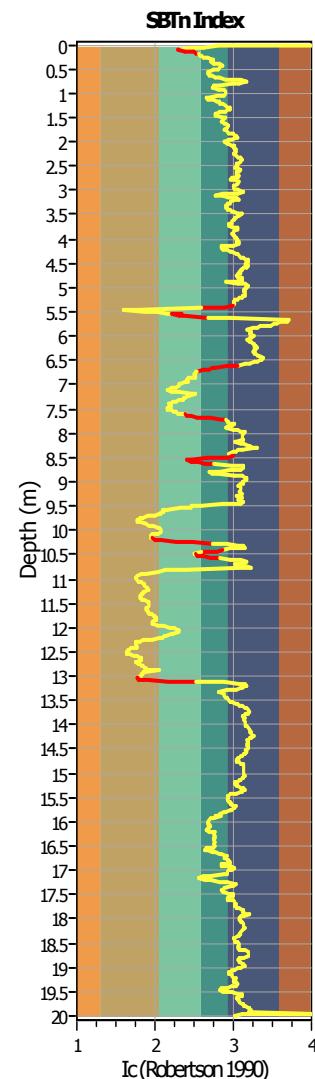
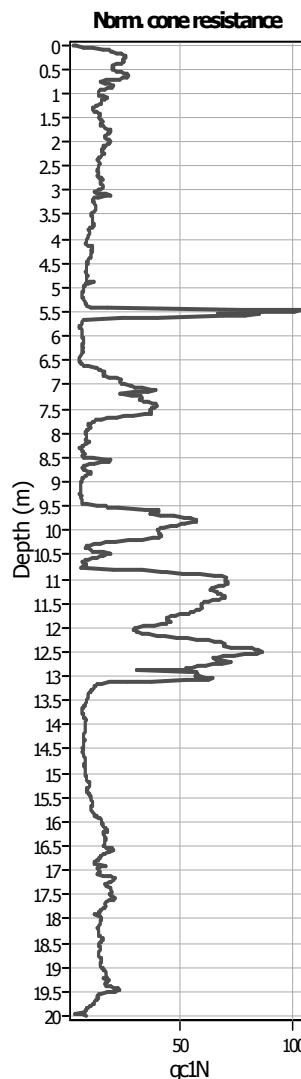
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.20 m

Depth to GWT (erthq.): 2.20 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBTn legend

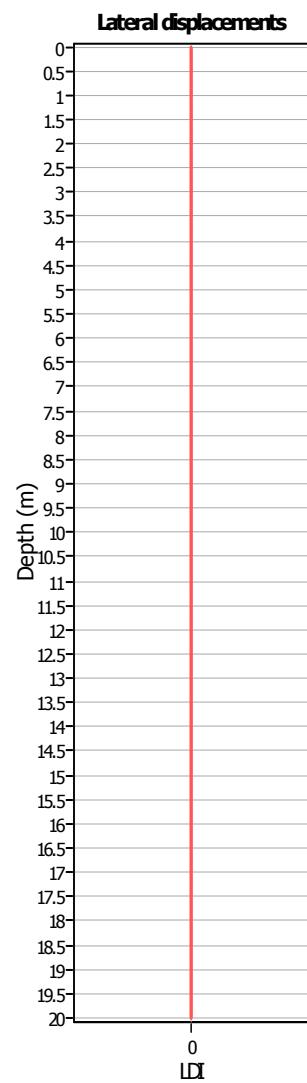
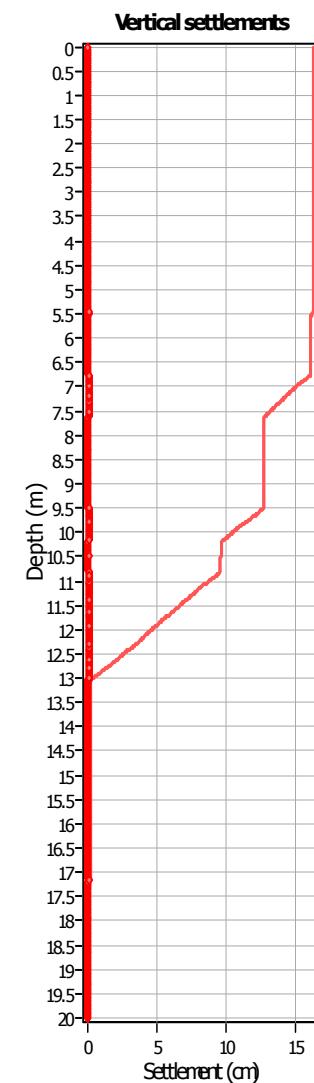
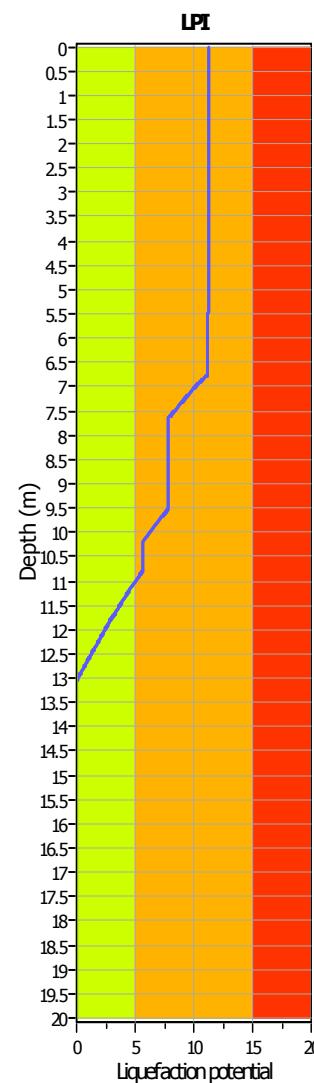
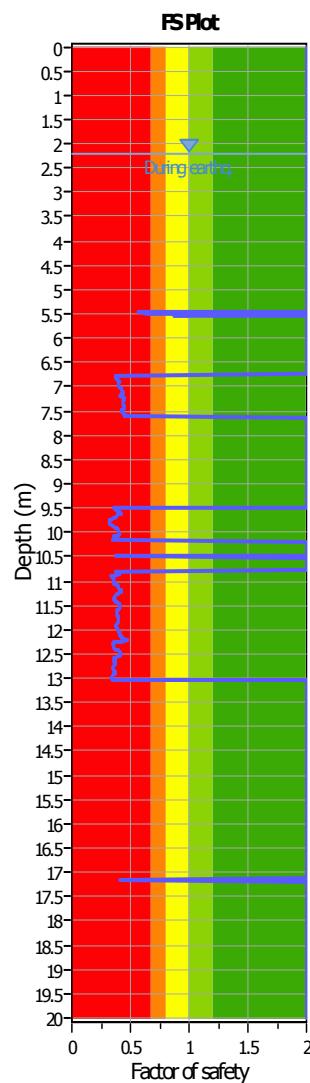
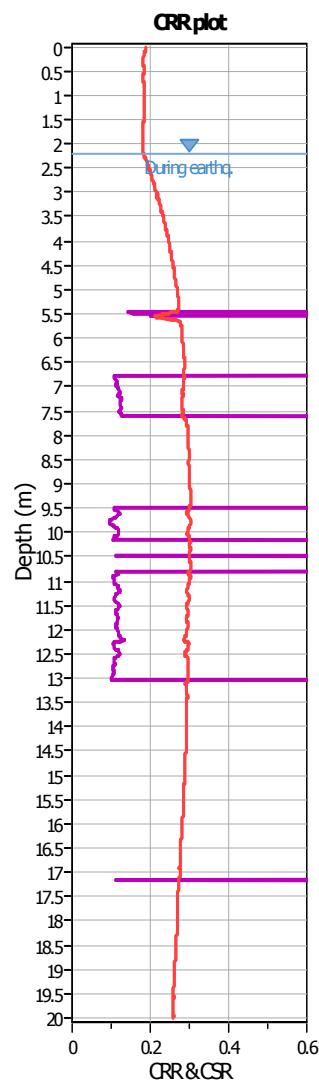
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|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.20 m

Depth to GWT (erthq.): 2.20 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.20 m

Depth to GWT (erthq.): 2.20 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

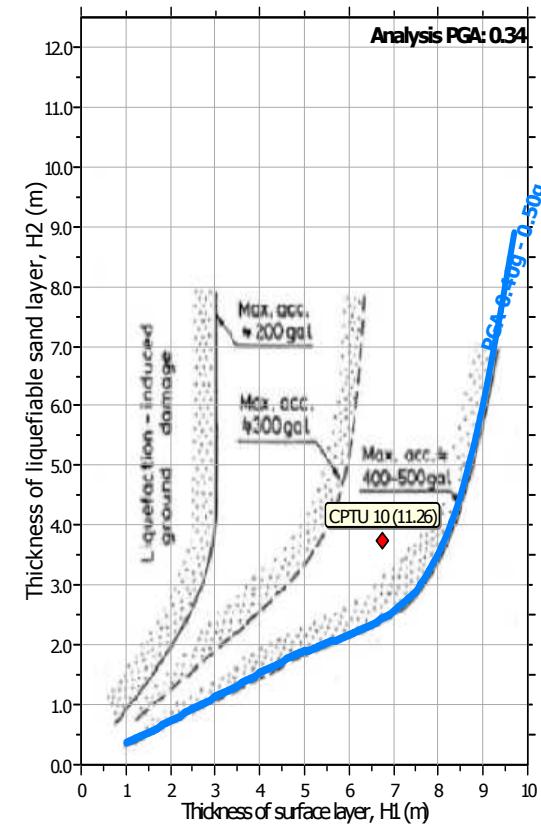
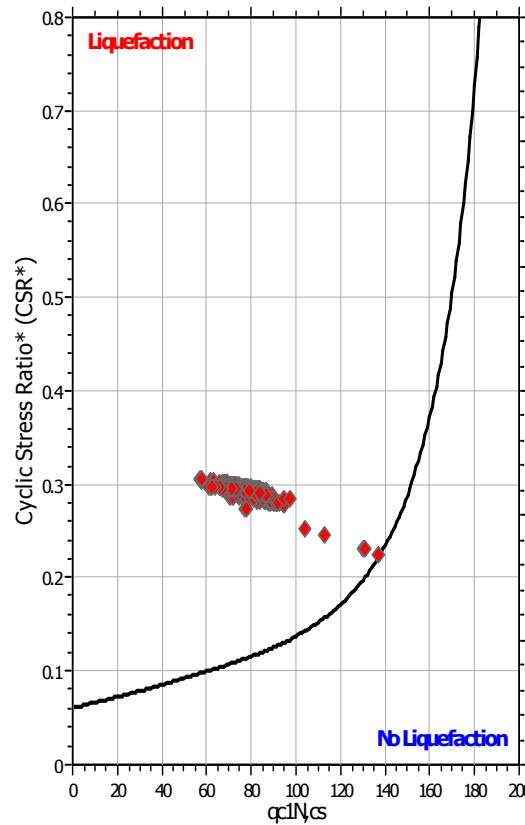
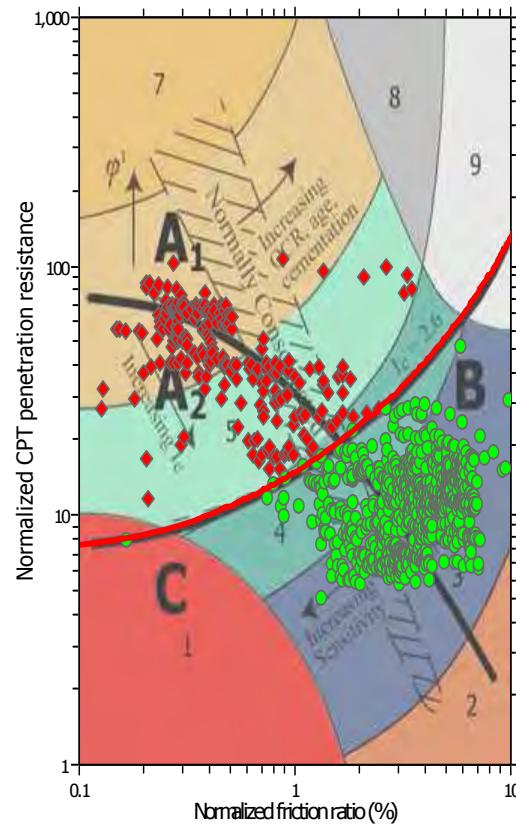
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

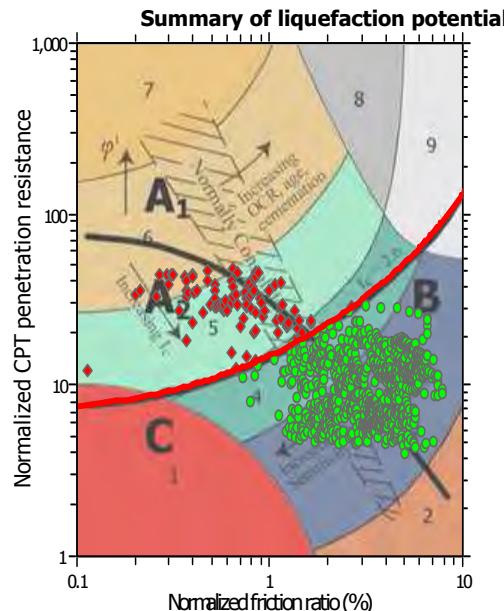
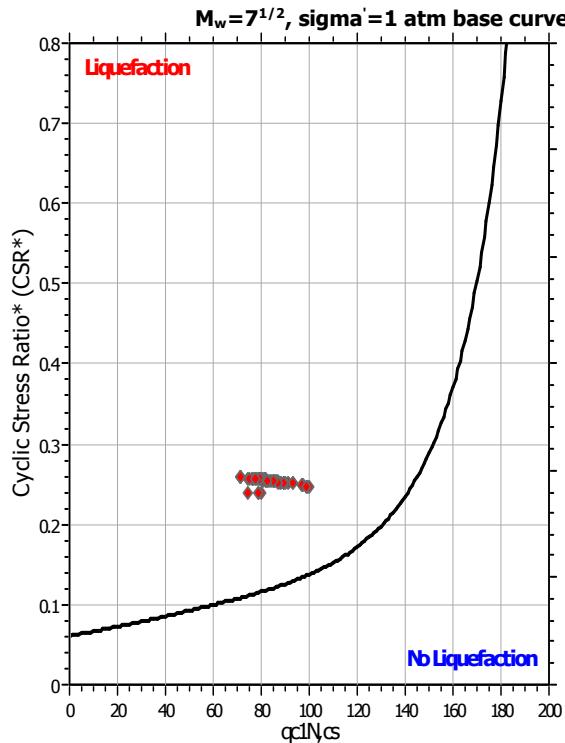
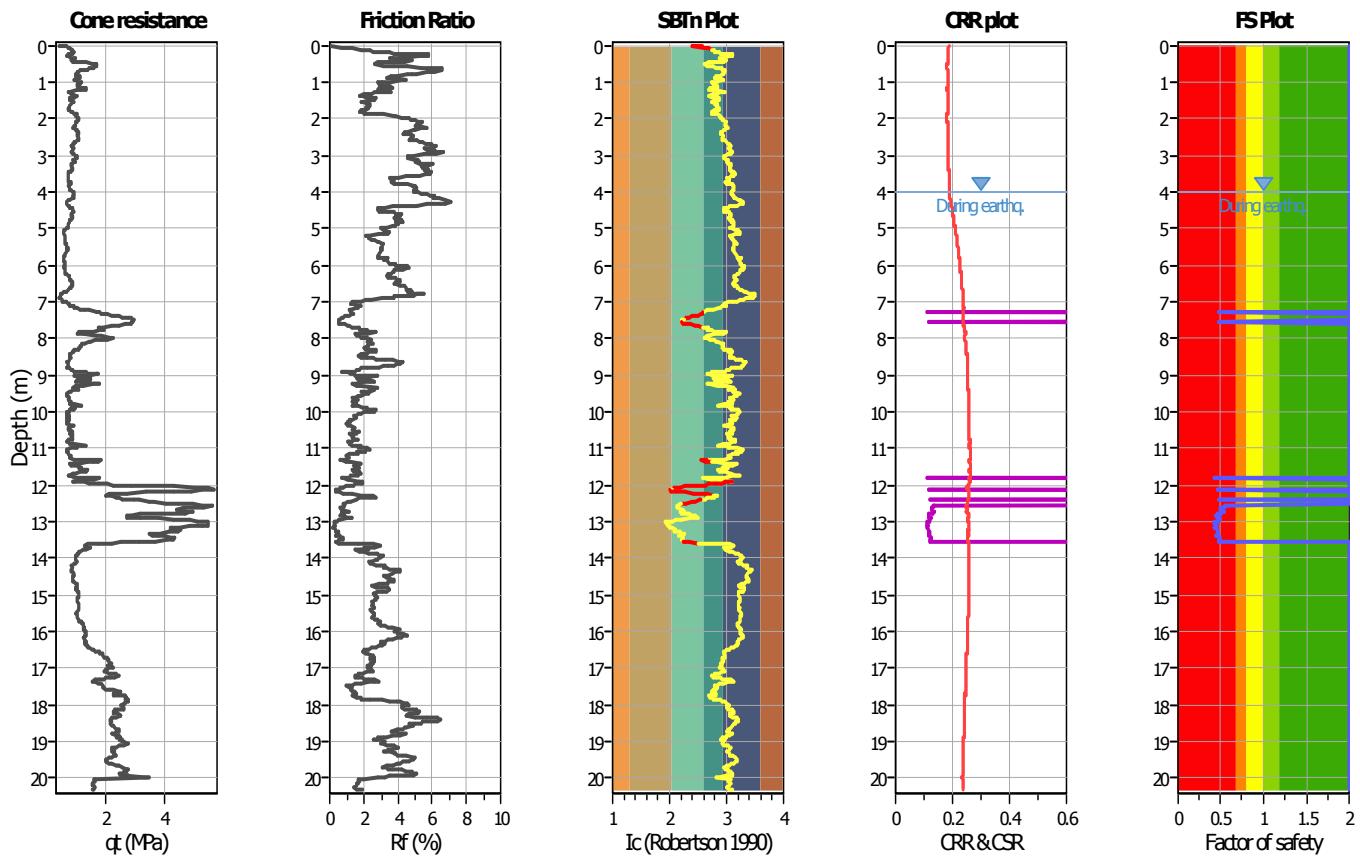
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 2.20 m

Depth to GWT (erthq.): 2.20 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

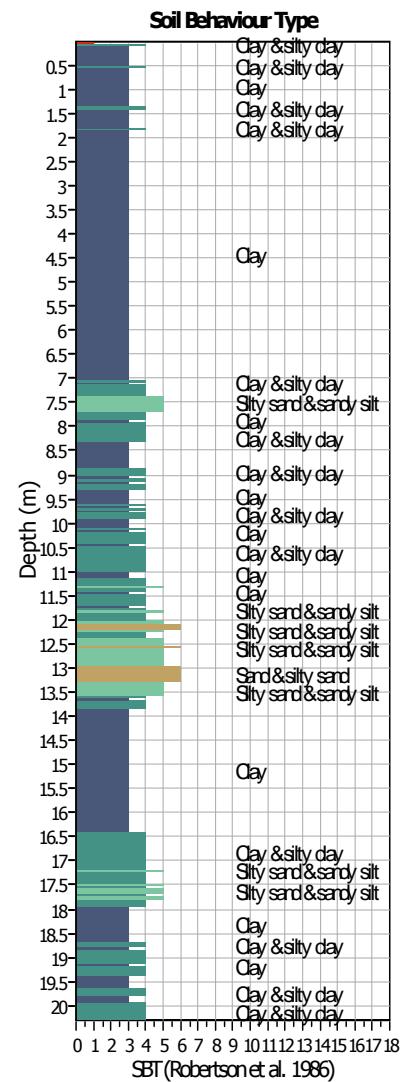
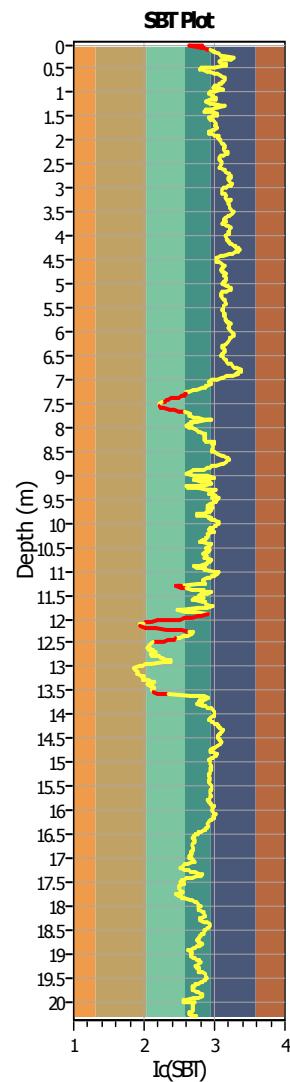
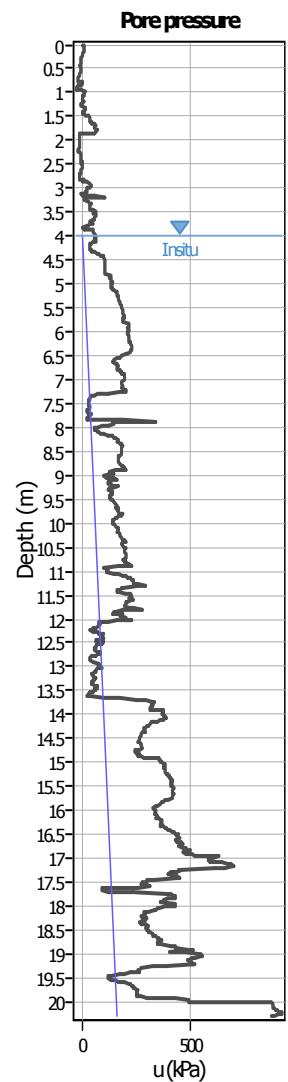
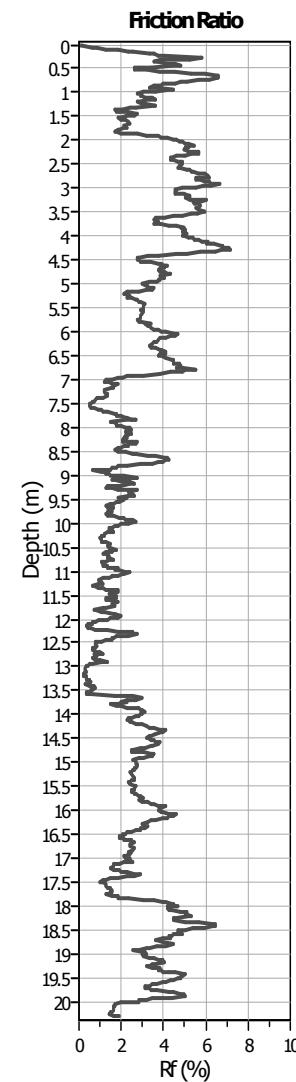
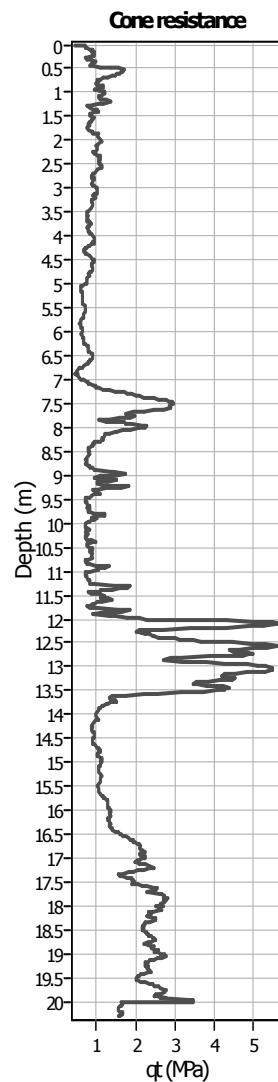
LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 11
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	4.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	4.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



Input parameters and analysis data

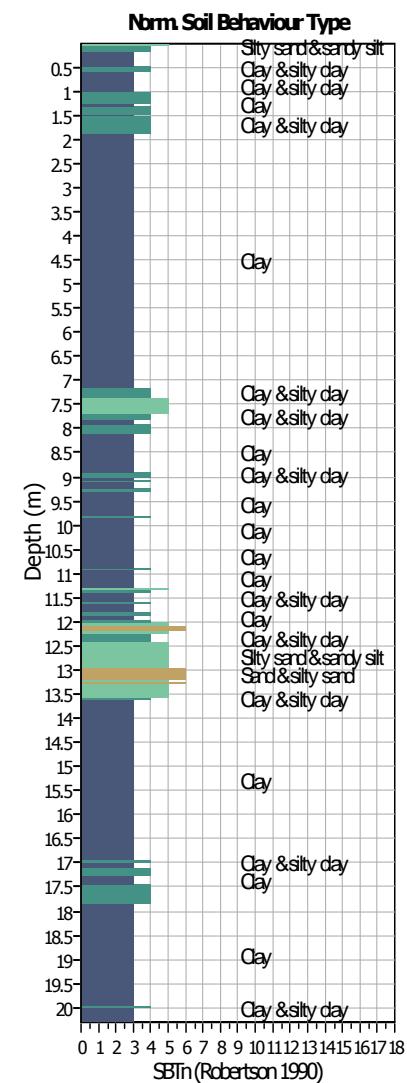
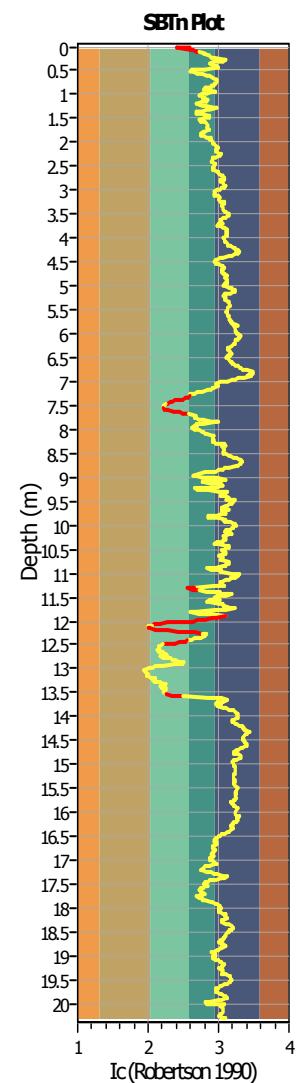
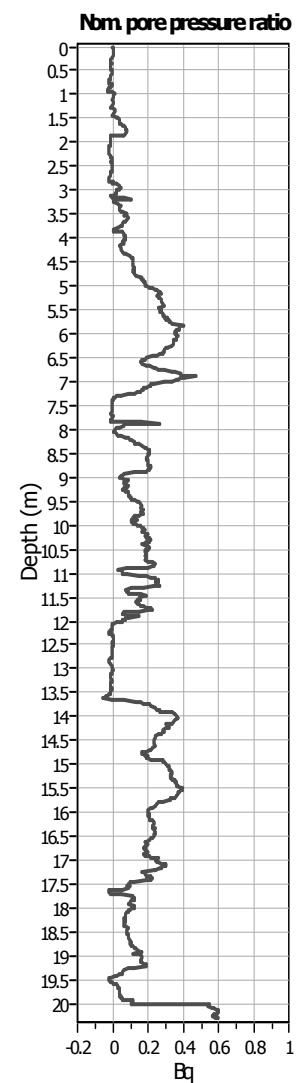
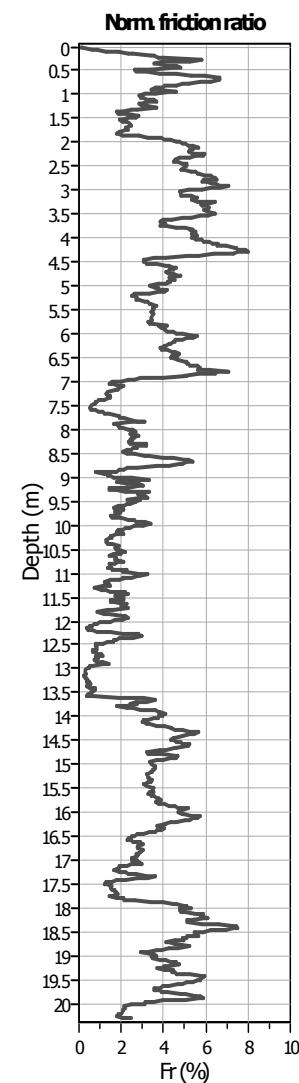
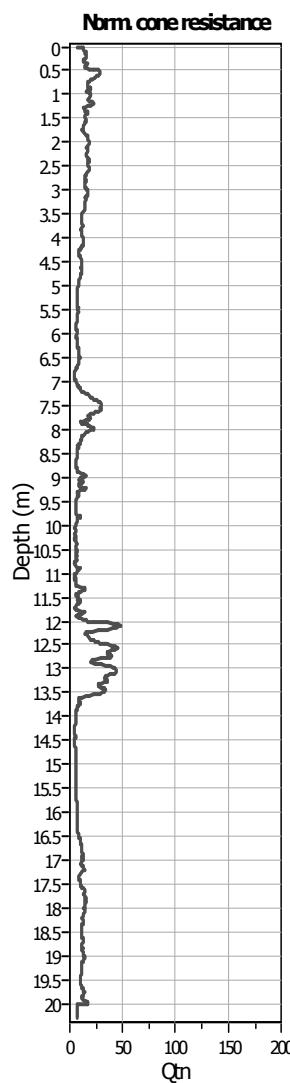
Analysis method:	B&I (2014)
Fines correction method:	B&I (2014)
Points to test:	Based on Ic value
Earthquake magnitude M_w :	6.14
Peak ground acceleration:	0.34
Depth to water table (insitu):	4.00 m

Depth to GWT (erthq.): 4.00 m
Average results interval: 1
Ic cut-off value: 2.60
Unit weight calculation: Based on SBT
Use fill: No
Fill height: N/A

Fill weight:	N/A
Transition detect. applied:	Yes
K_o applied:	Yes
Clay like behavior applied:	Sands only
Limit depth applied:	No
Limit depth:	N/A

SBT legend

- | | | | | | |
|---|---------------------------|---|-----------------------------|---|----------------------------|
| █ | 1. Sensitive fine grained | █ | 4. Clayey silt to silty | █ | 7. Gravely sand to sand |
| █ | 2. Organic material | █ | 5. Silty sand to sandy silt | █ | 8. Very stiff sand to |
| █ | 3. Clay to silty clay | █ | 6. Clean sand to silty sand | █ | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)**Input parameters and analysis data**

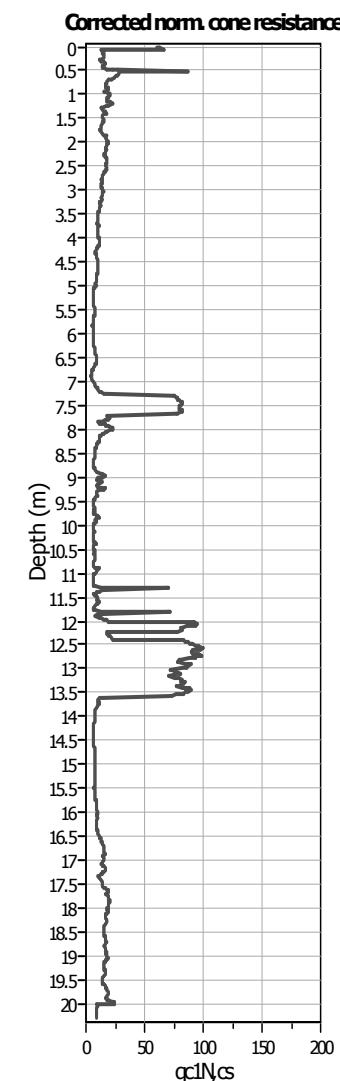
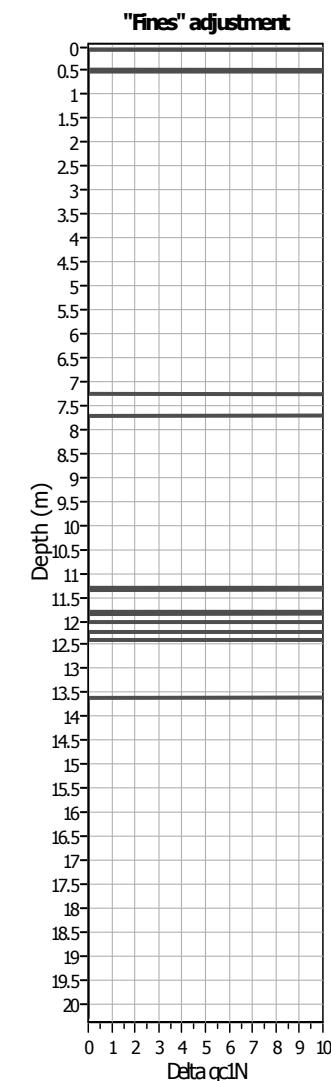
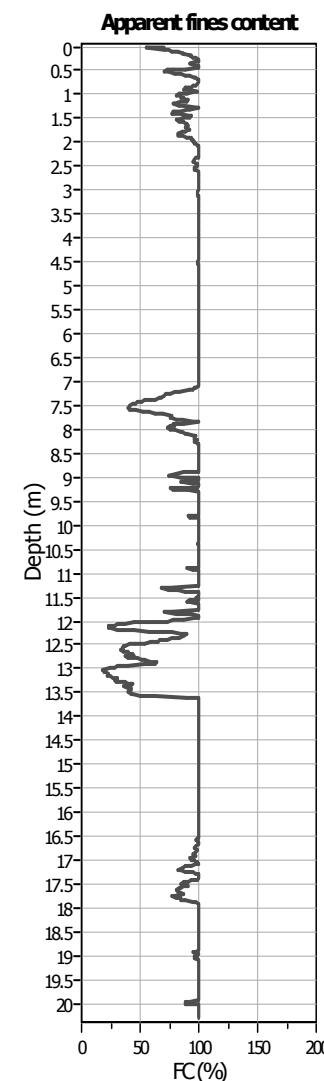
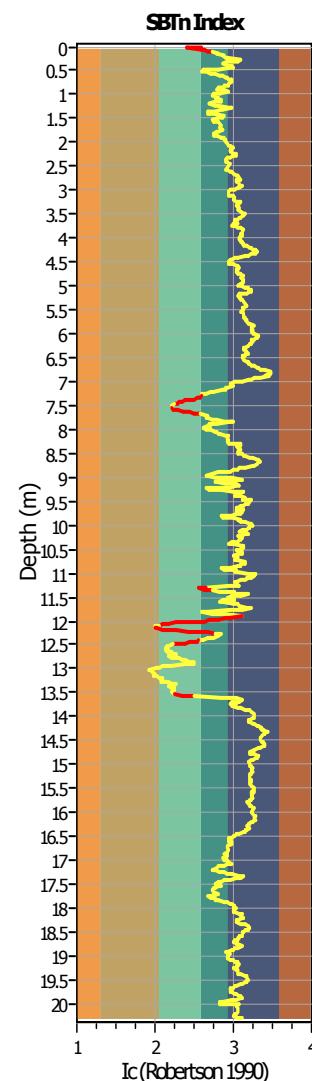
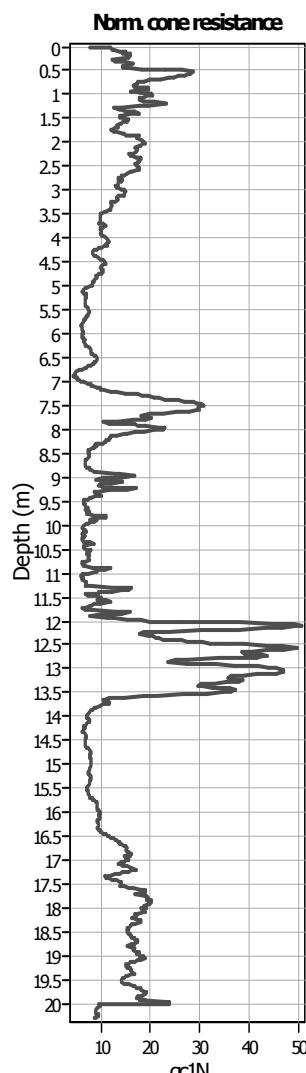
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 4.00 m

Depth to GWT (erthq.): 4.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

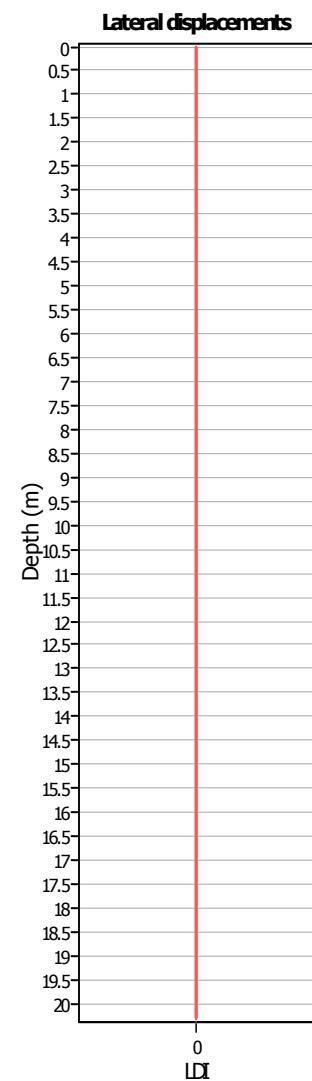
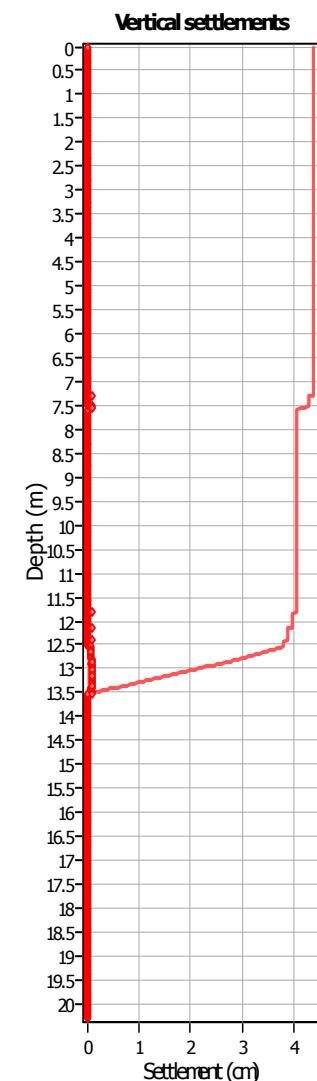
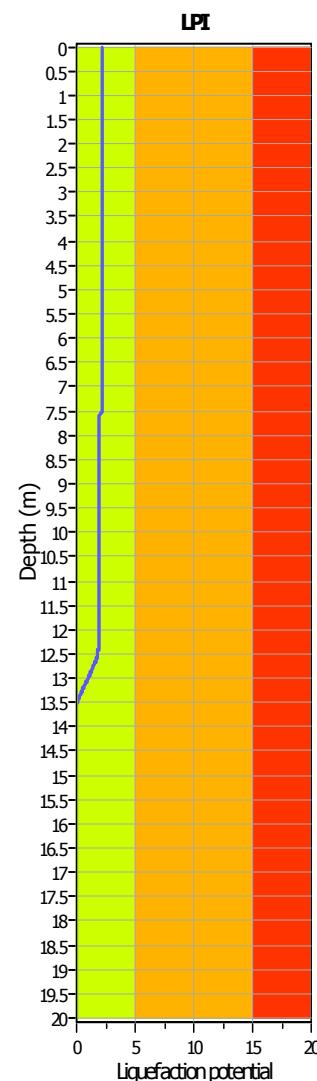
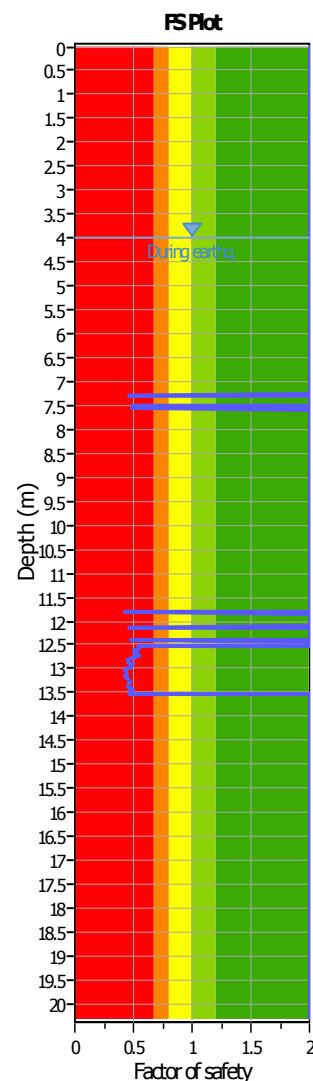
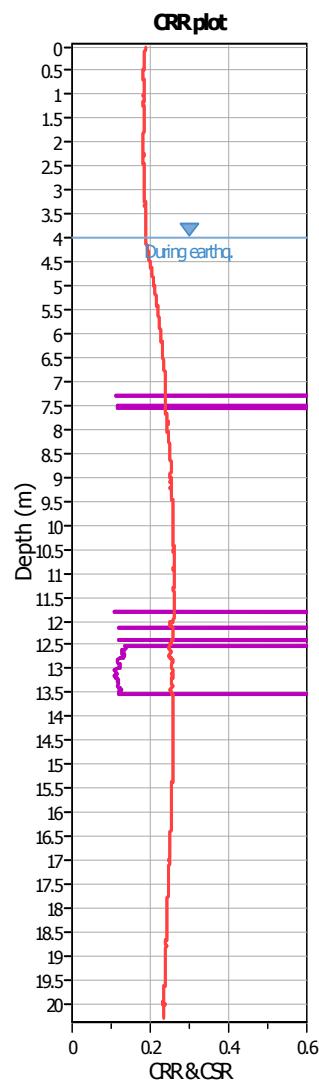
SBTn legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 4.00 m

Depth to GWT (erthq.): 4.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A
 Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 4.00 m

Depth to GWT (erthq.): 4.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied:
 K_0 applied:
 Clay like behavior applied:
 Limit depth applied:
 Limit depth:

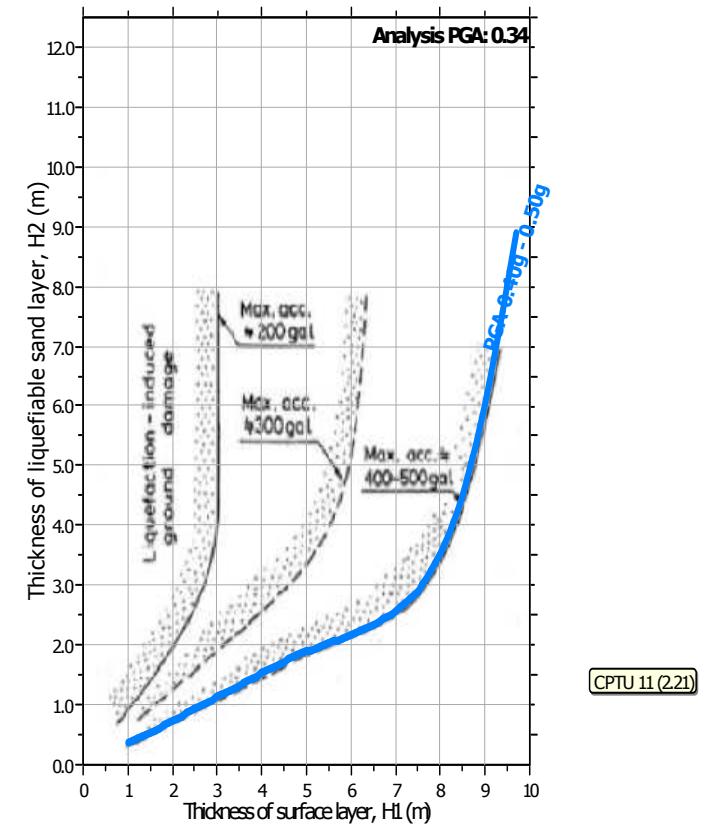
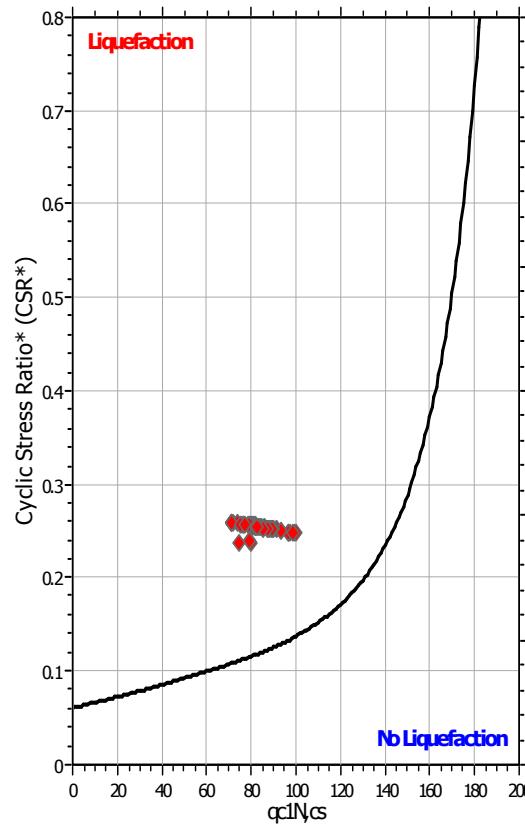
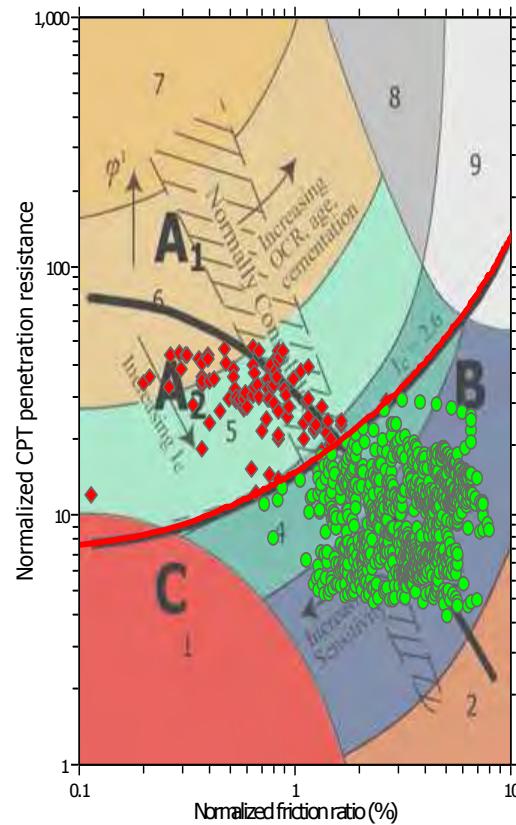
N/A
 Yes
 Yes
 Sands only
 No
 N/A

F.S. color scheme

Very high risk
 Very likely to liquefy
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Low risk

Liquefaction analysis summary plots**Input parameters and analysis data**

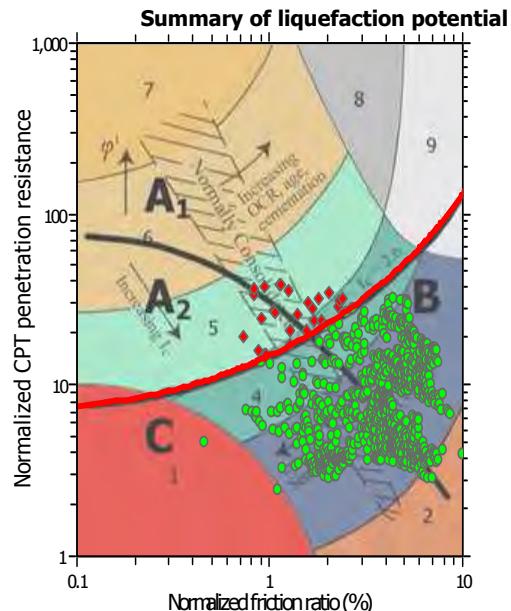
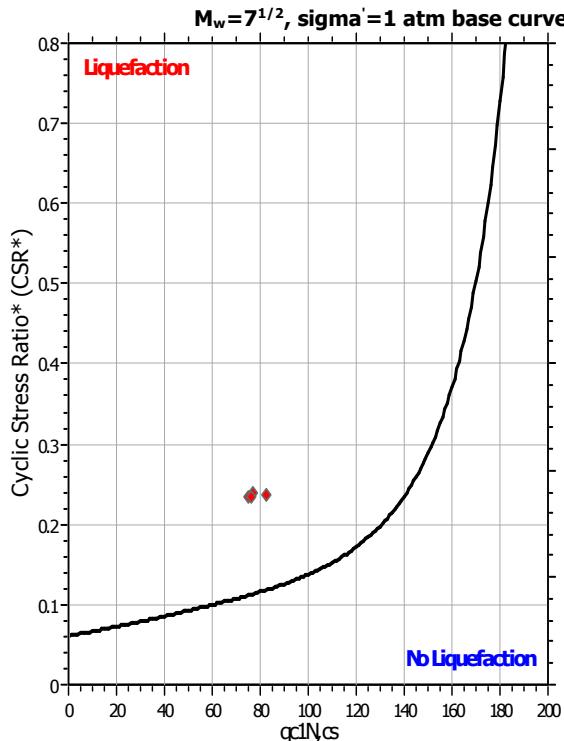
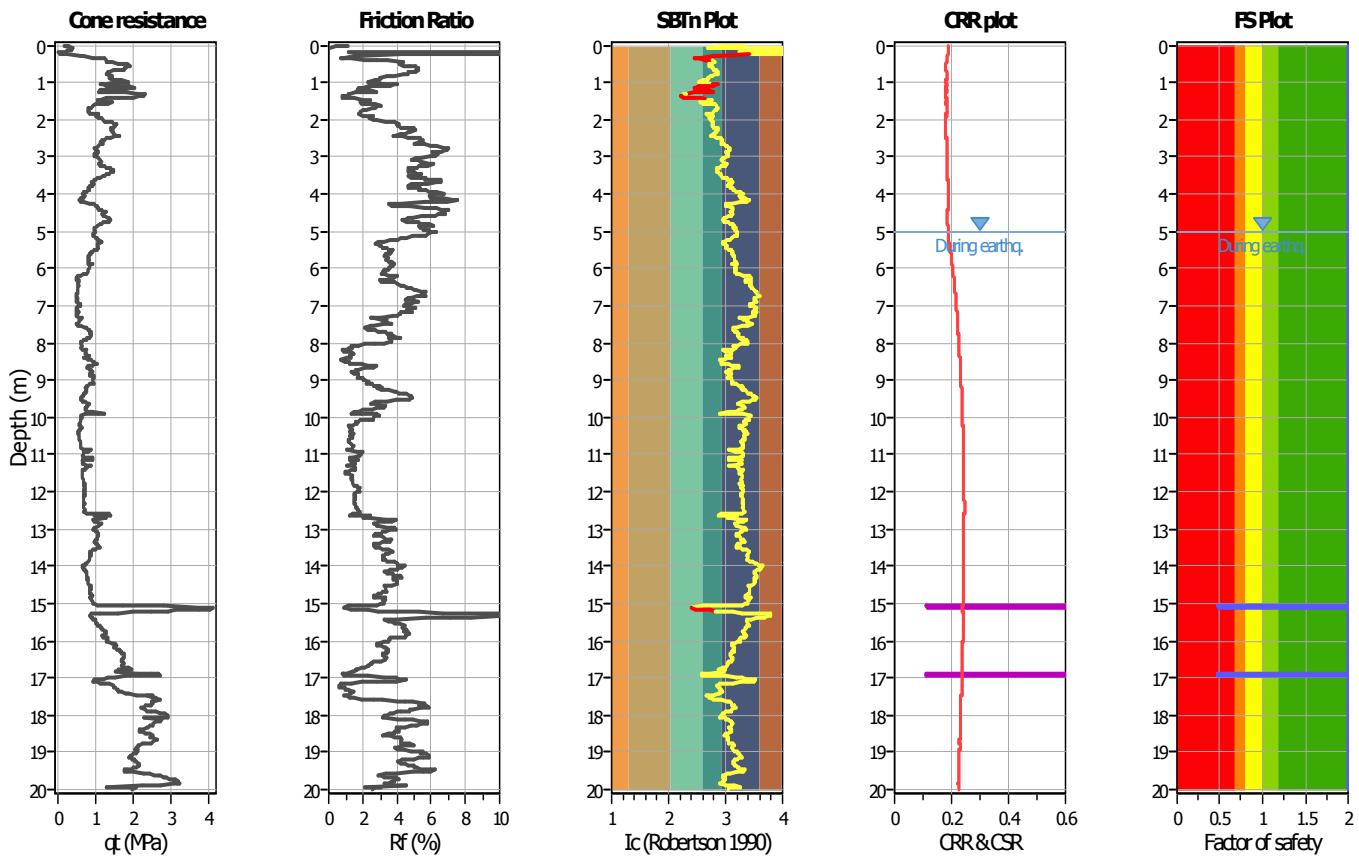
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 4.00 m

Depth to GWT (erthq.): 4.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

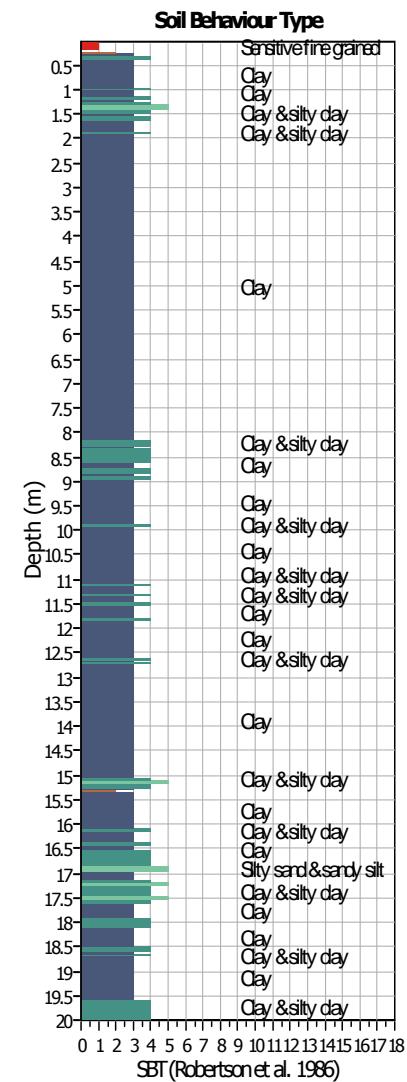
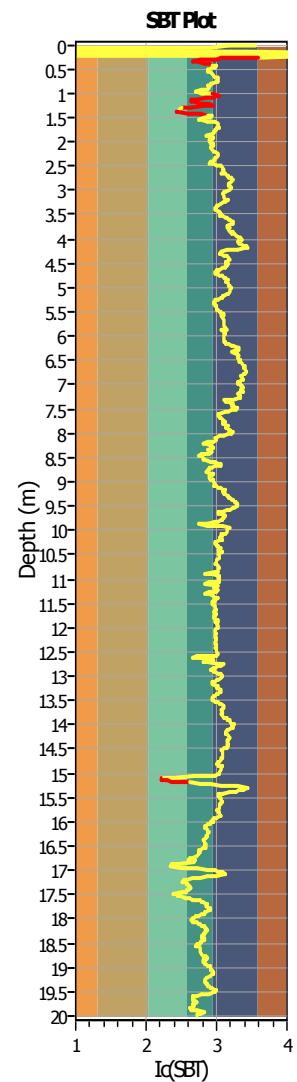
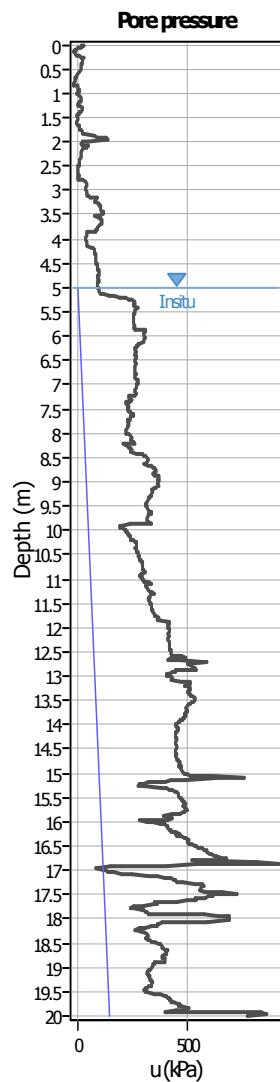
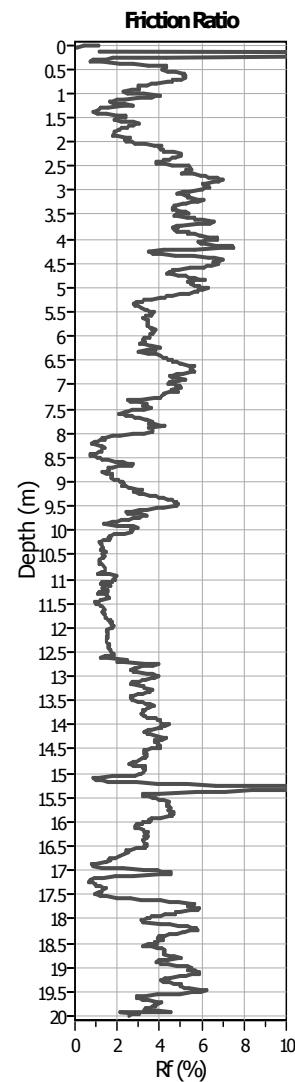
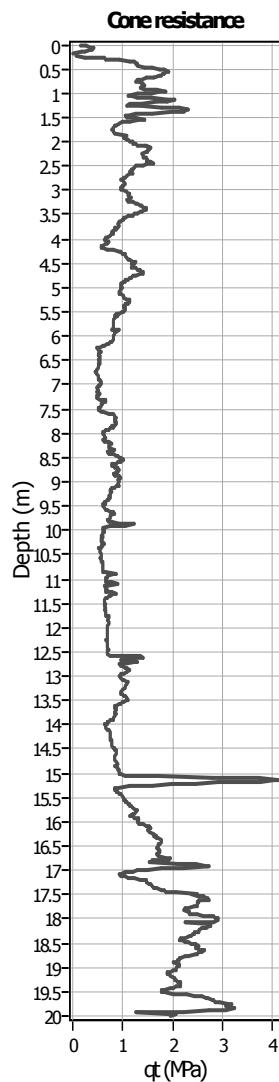
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 12
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	5.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	5.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 5.00 m

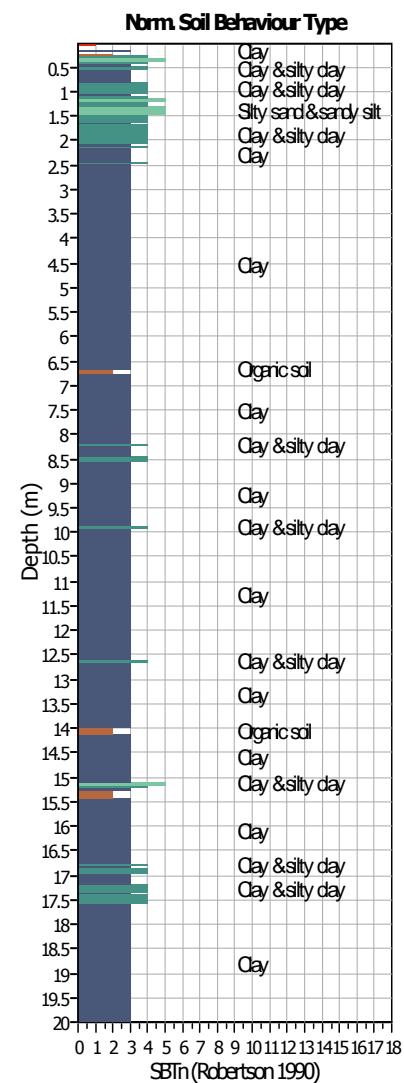
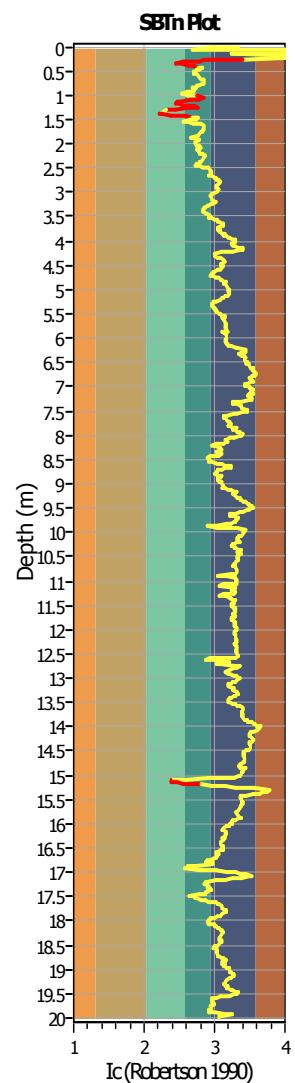
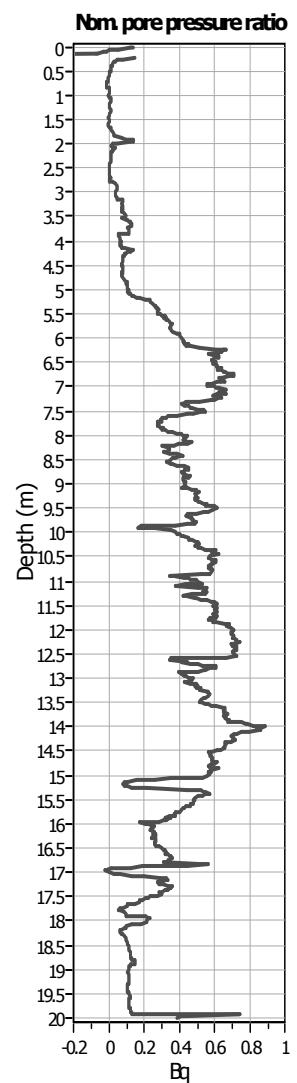
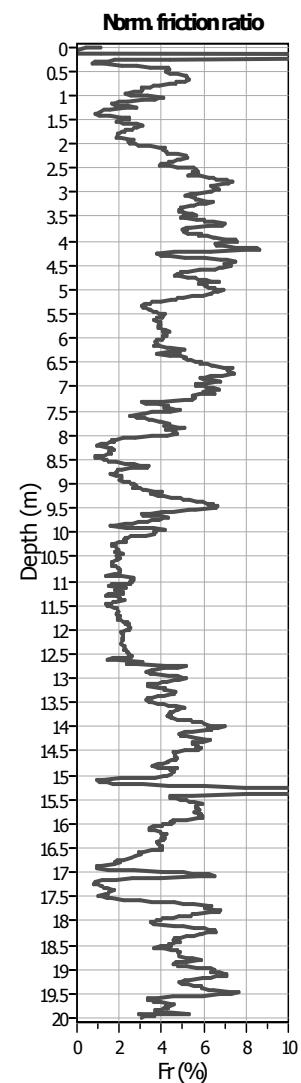
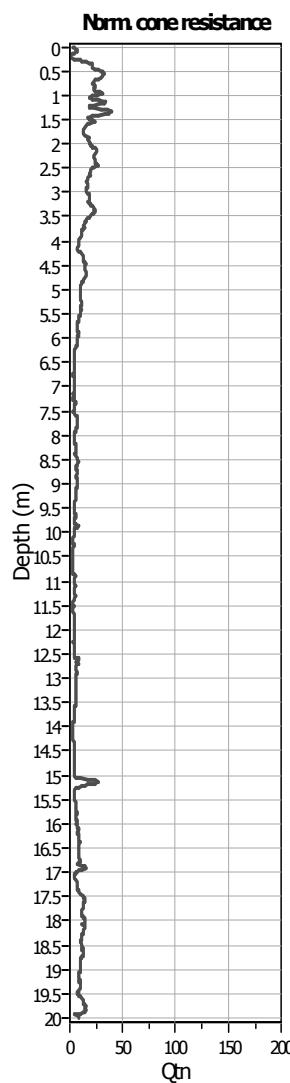
Depth to GWT (erthq.): 5.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)



Input parameters and analysis data

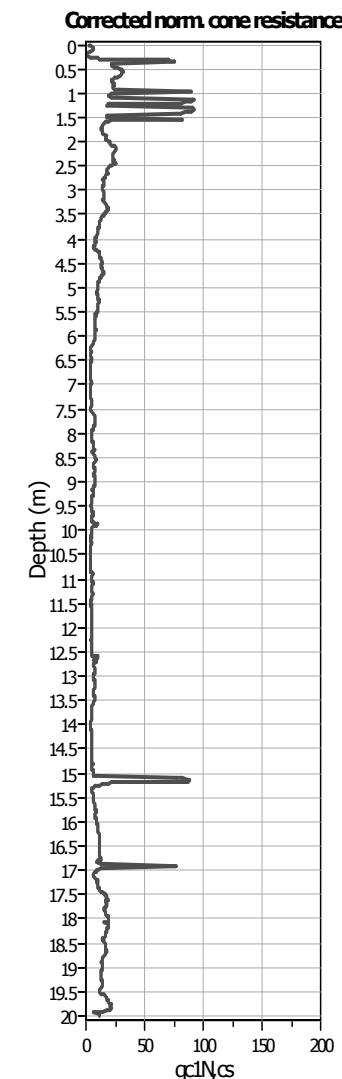
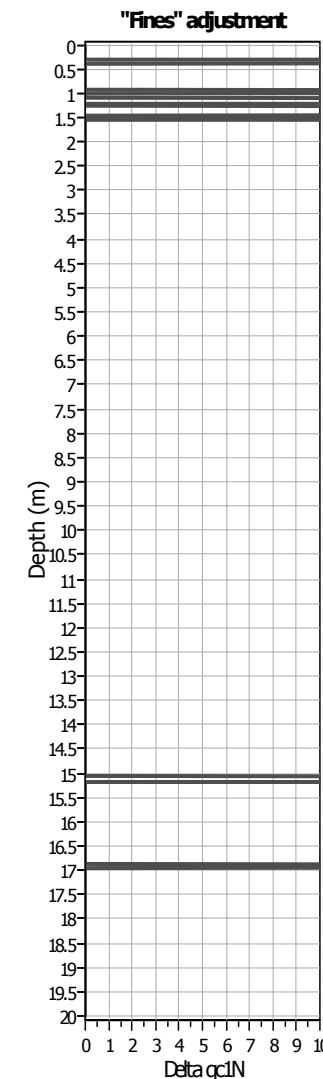
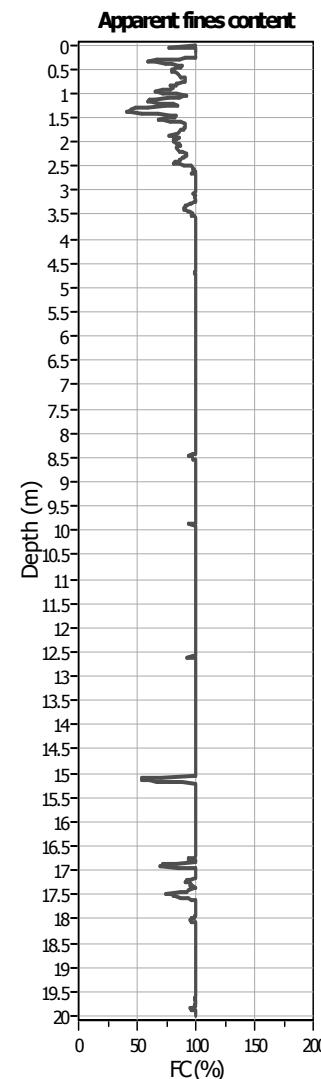
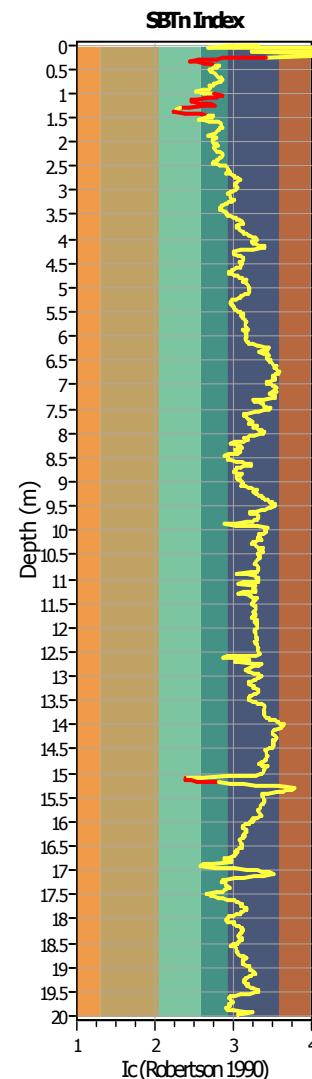
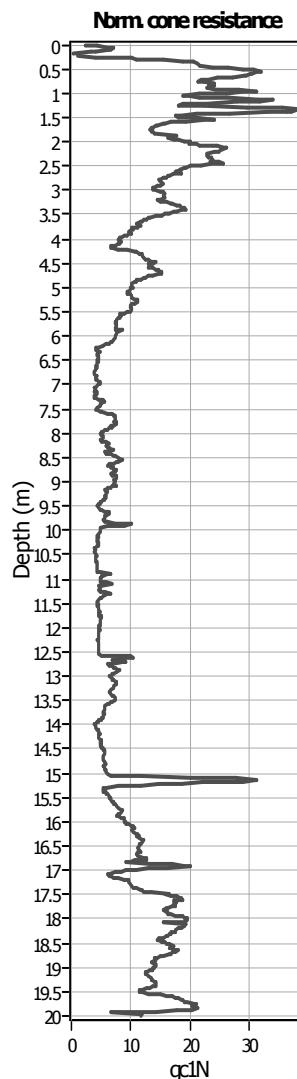
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 5.00 m

Depth to GWT (erthq.): 5.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBTn legend

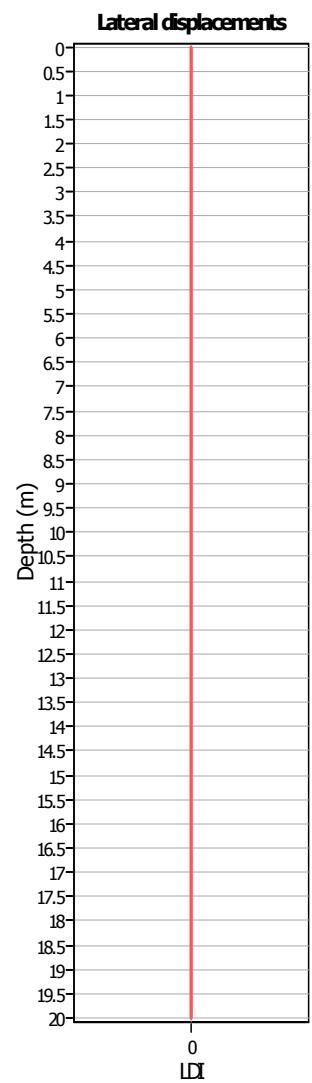
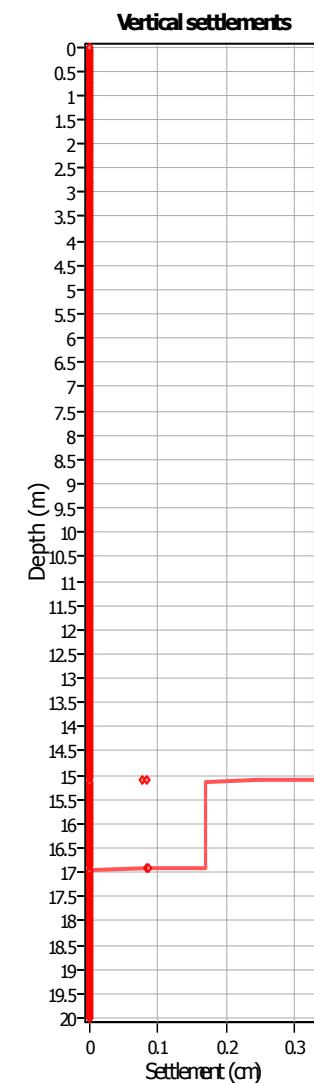
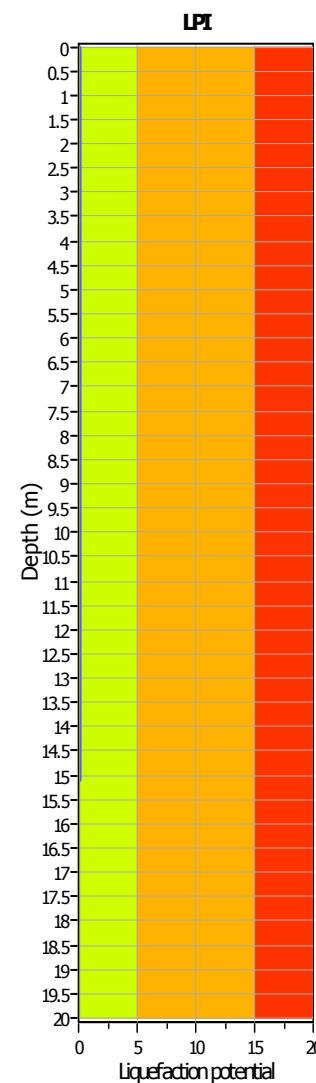
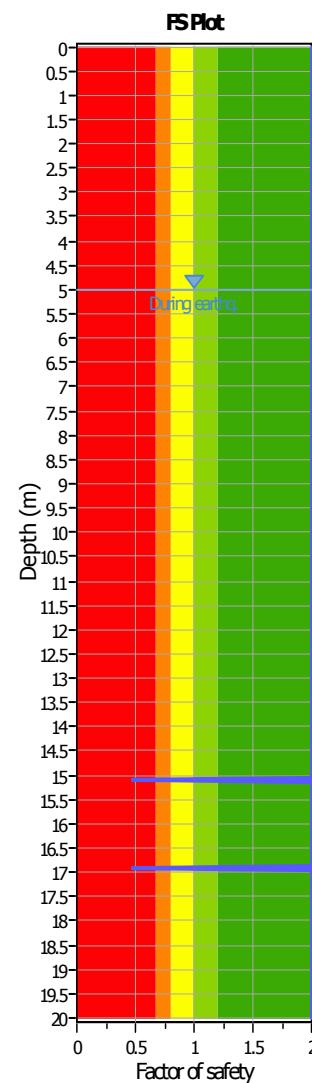
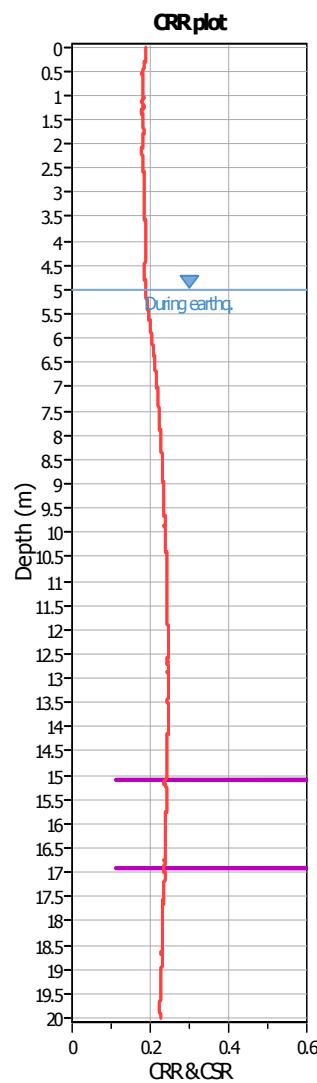
- | | |
|---------------------------|------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty sand |
| 2. Organic material | 5. Silty sand to sandy silt |
| 3. Clay to silty clay | 6. Clean sand to silty sand |
| | 7. Gravely sand to sand |
| | 8. Very stiff sand to |
| | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 5.00 m

Depth to GWT (erthq.): 5.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 5.00 m

Depth to GWT (erthq.): 5.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

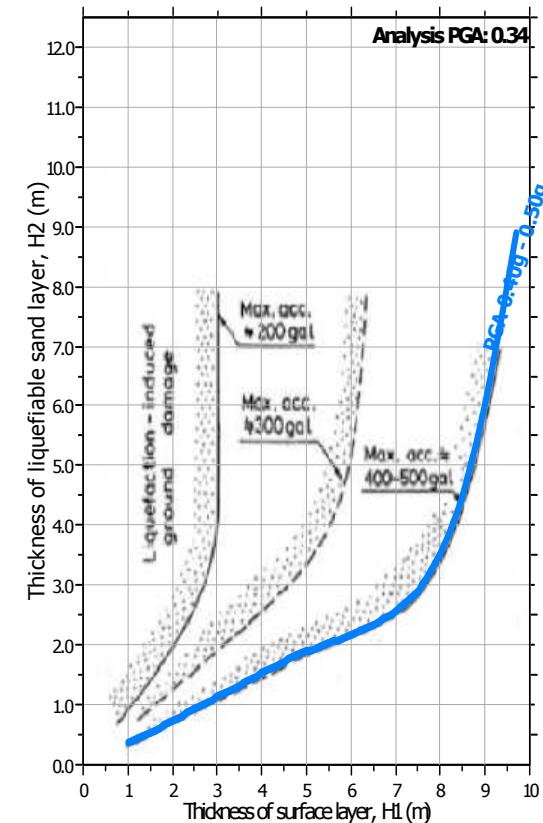
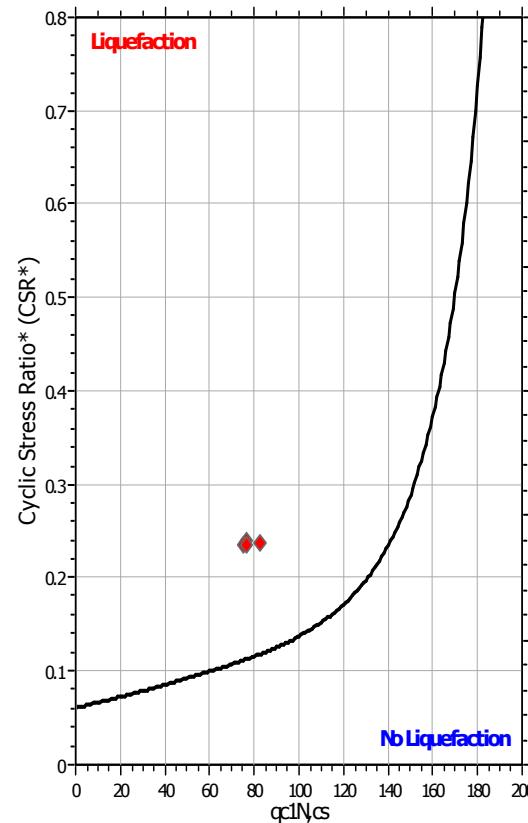
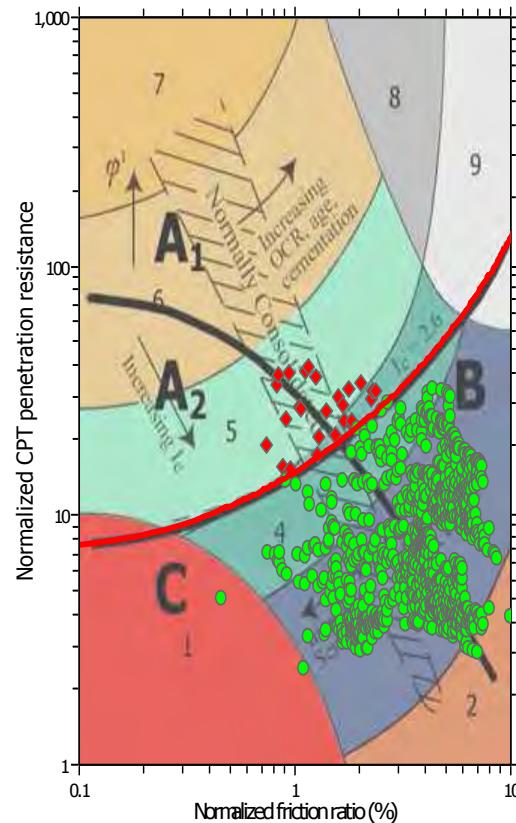
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

Red	Almost certain it will liquefy
Orange	Very likely to liquefy
Yellow	Liquefaction and no liq. are equally likely
Green	Unlike to liquefy
Light Green	Almost certain it will not liquefy

LPI color scheme

Red	Very high risk
Orange	High risk
Yellow	Medium risk
Light Green	Low risk

Liquefaction analysis summary plots**Input parameters and analysis data**

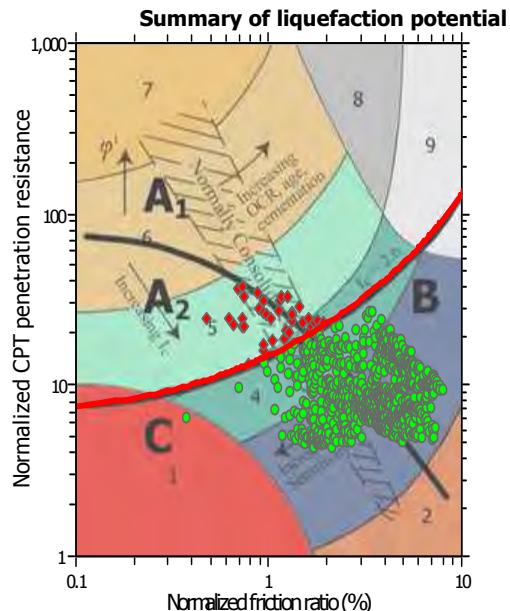
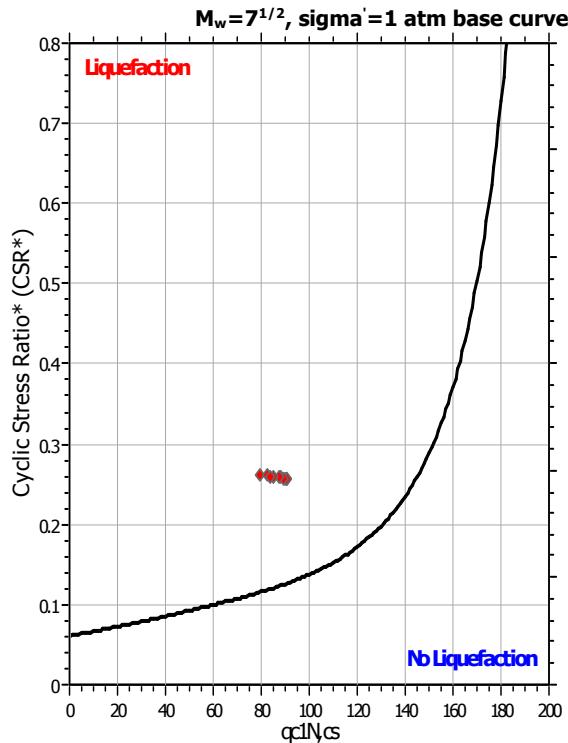
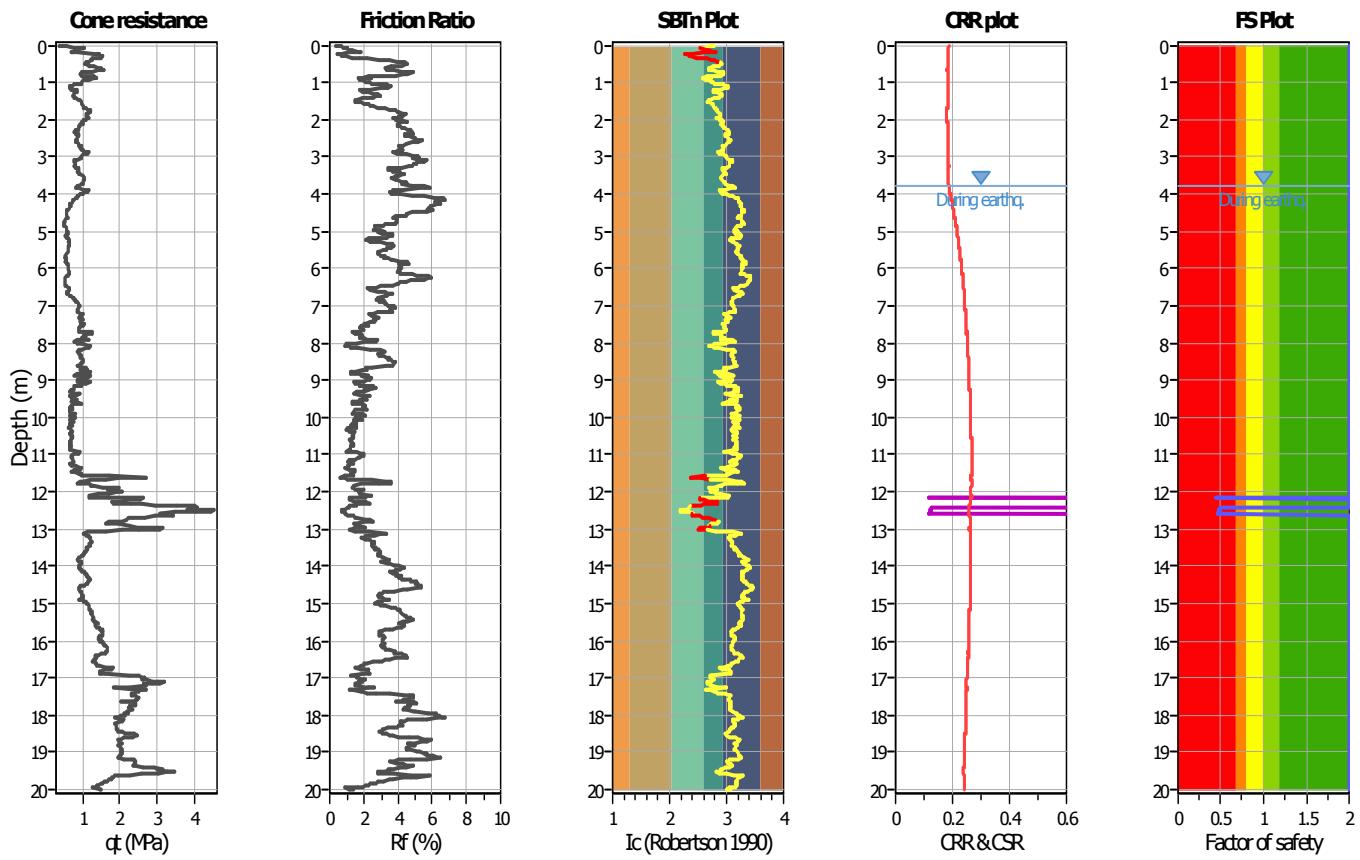
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 5.00 m

Depth to GWT (erthq.): 5.00 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

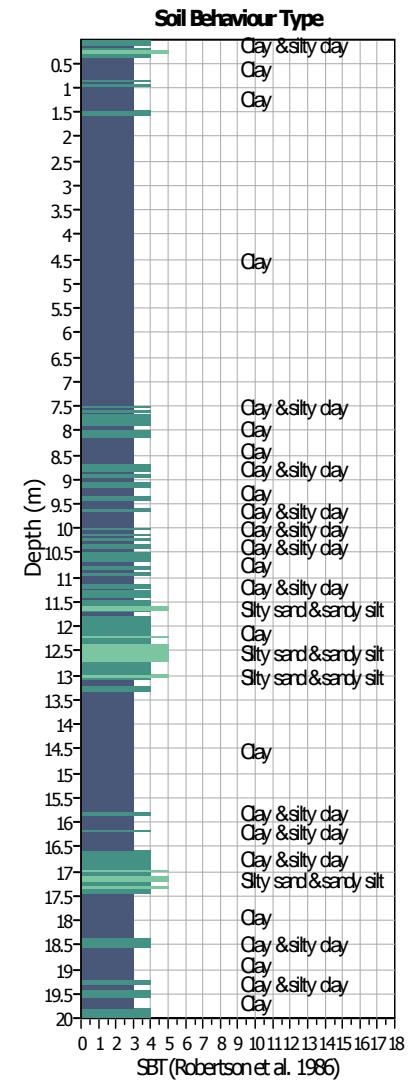
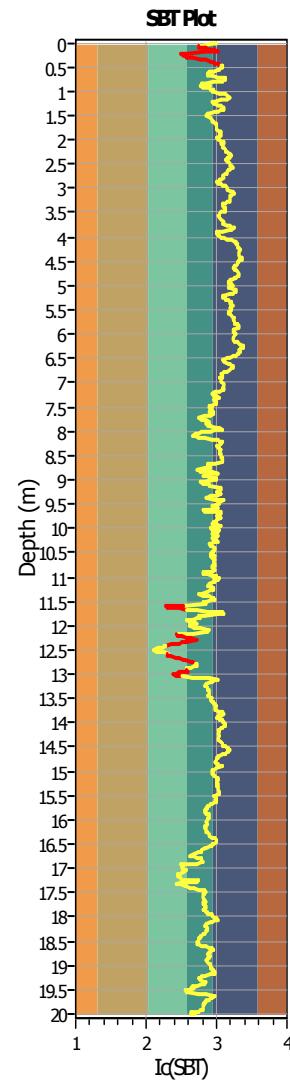
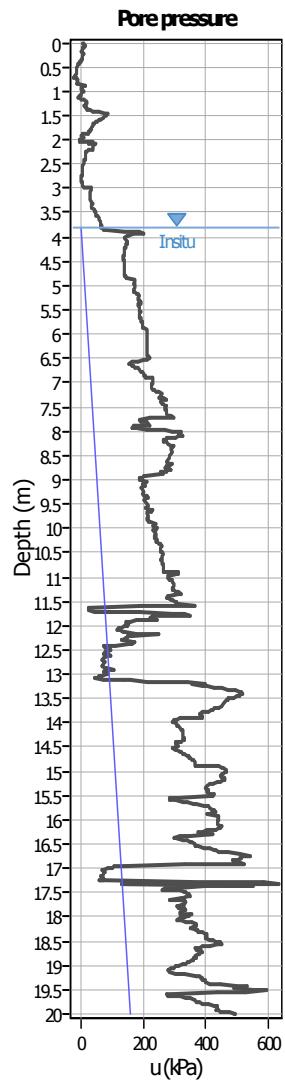
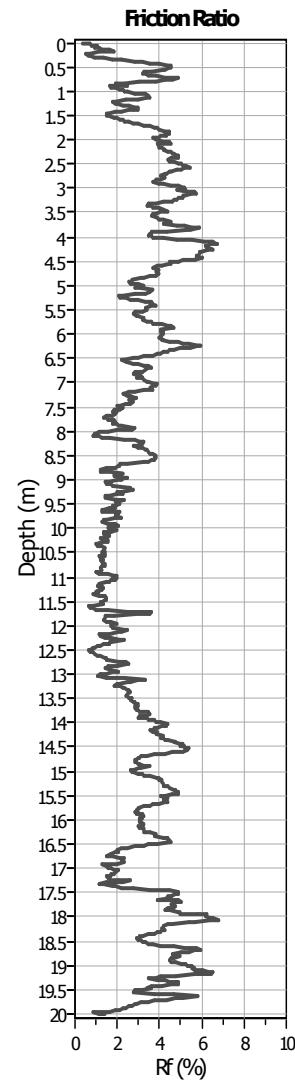
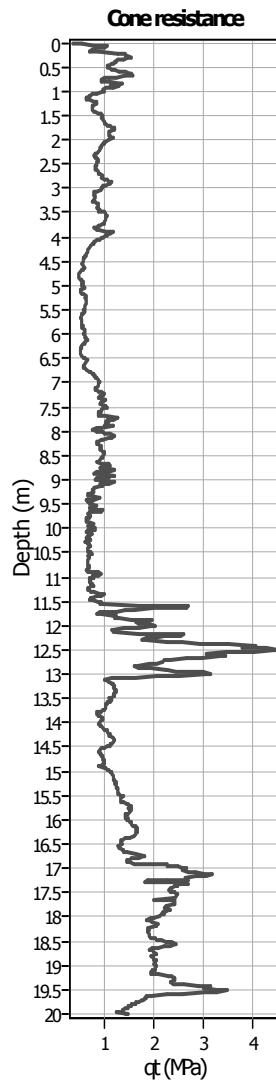
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 13
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.80 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.80 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

Analysis method: B&I (2014)
Fines correction method: B&I (2014)
Points to test: Based on Ic value
Earthquake magnitude M_w : 6.14
Peak ground acceleration: 0.34
Depth to water table (in situ): 3.80 m

Depth to GWT (erthq.): 3.80 m
Average results interval: 1
Ic cut-off value: 2.60
Unit weight calculation: Based on SBT
Use fill: No
Fill height: N/A

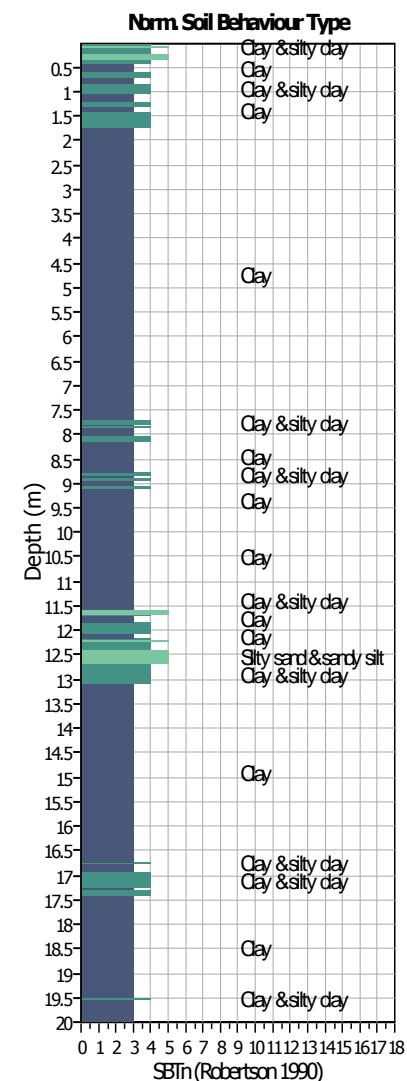
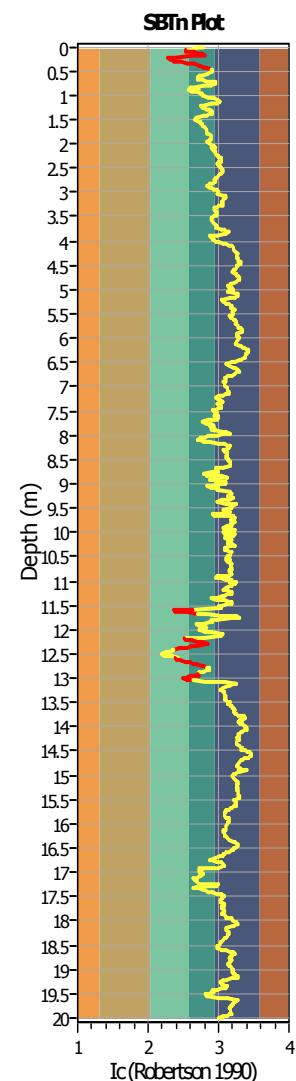
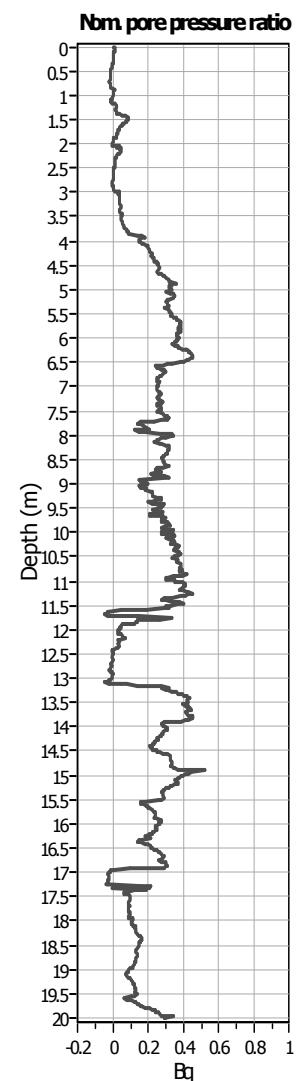
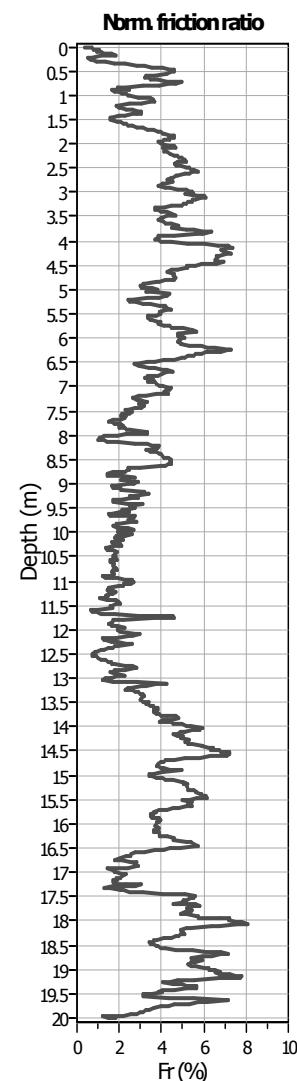
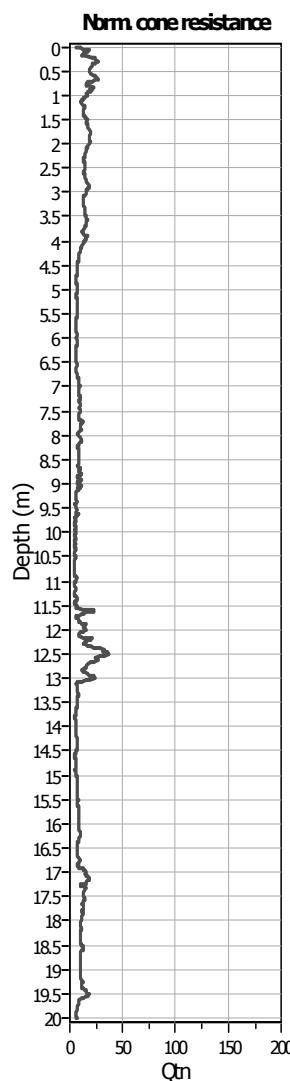
Fill weight:
Transition detect. applied:
 K_0 applied:
Clay like behavior applied:
Limit depth applied:
Limit depth:

N/A
Yes
Yes
Sands only
No
N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)



Input parameters and analysis data

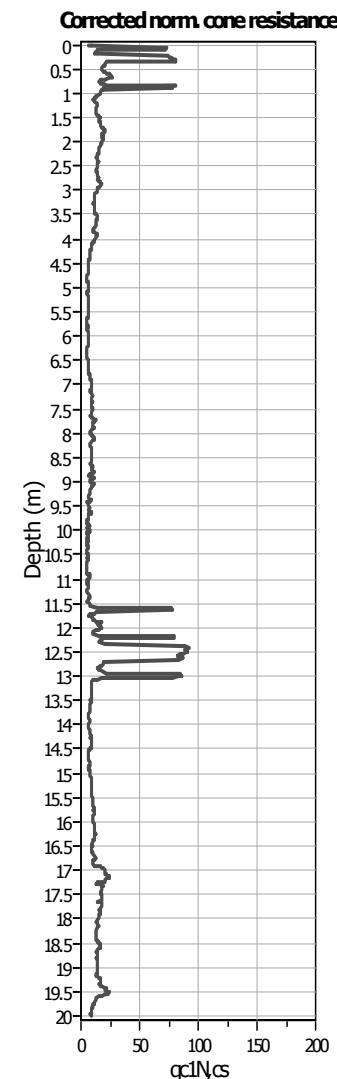
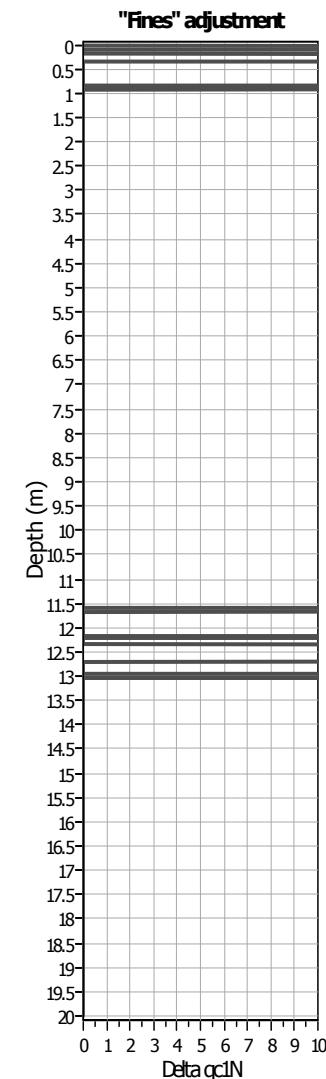
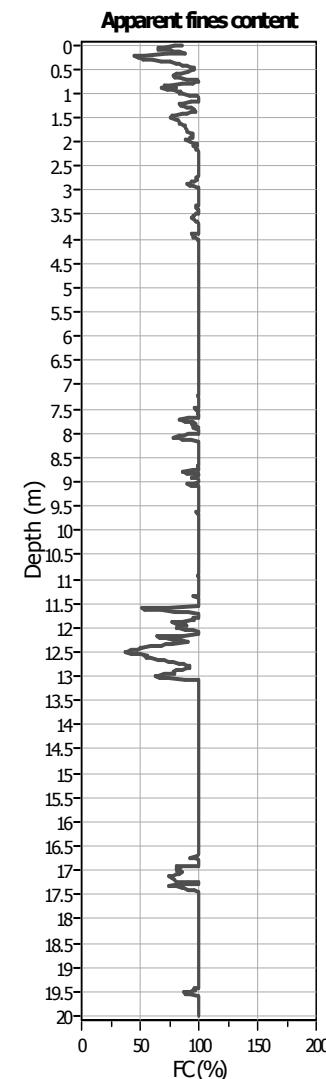
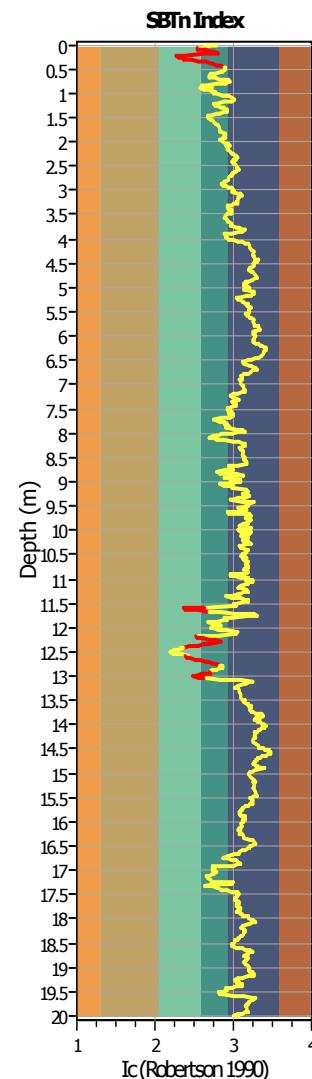
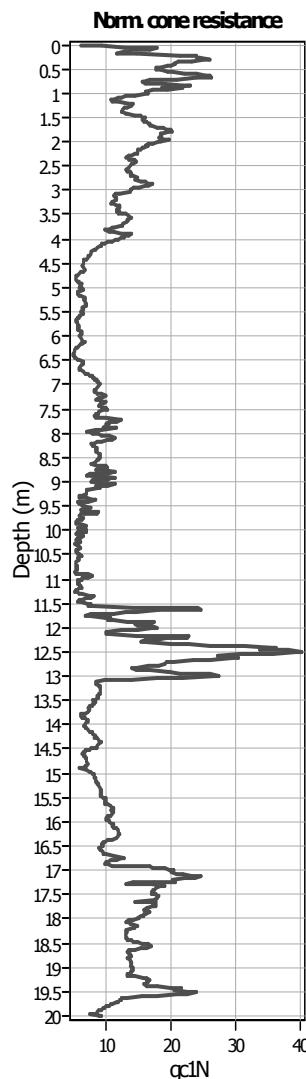
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.80 m

Depth to GWT (erthq.): 3.80 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBTn legend

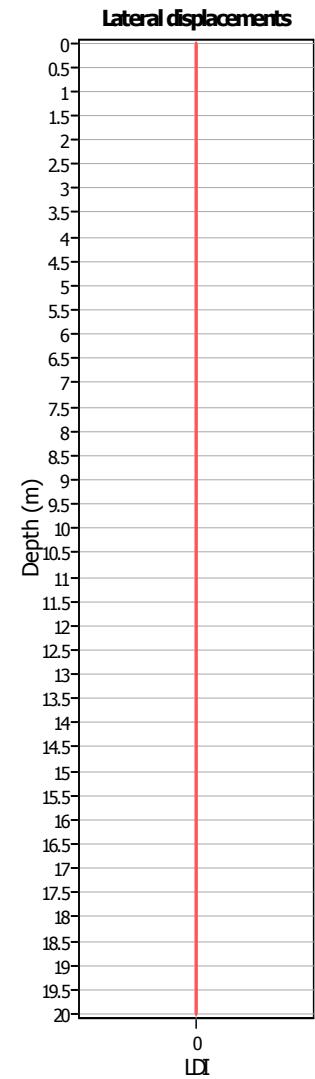
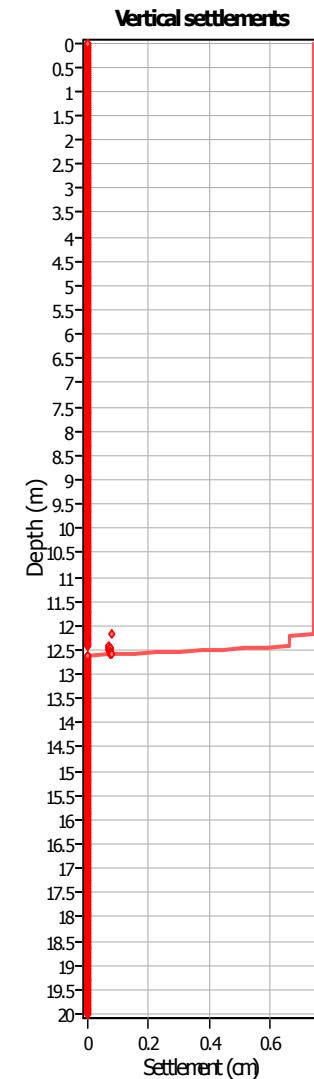
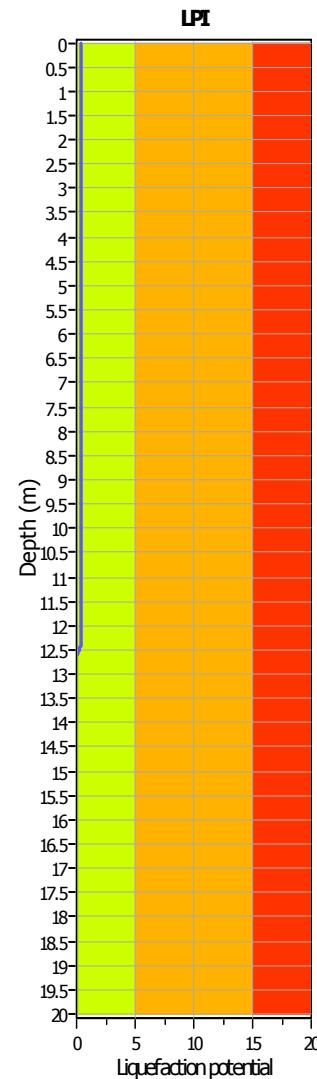
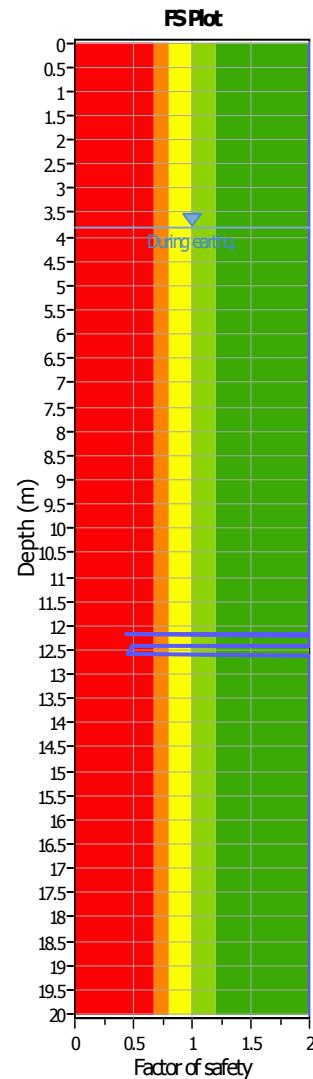
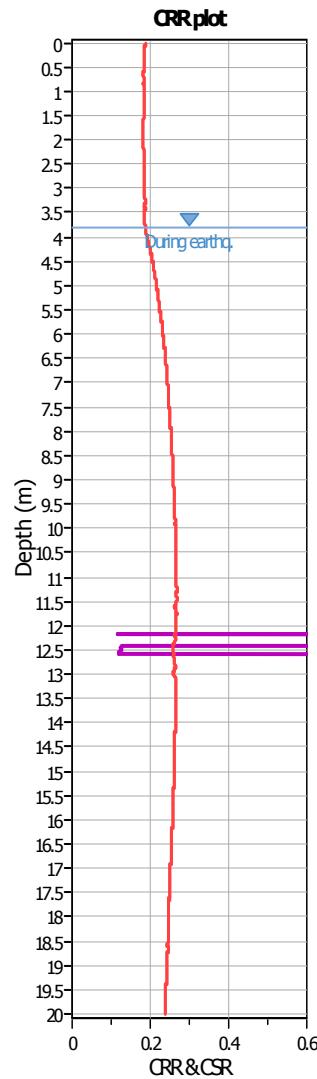
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.80 m

Depth to GWT (erthq.): 3.80 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.80 m

Depth to GWT (earthq.): 3.80 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

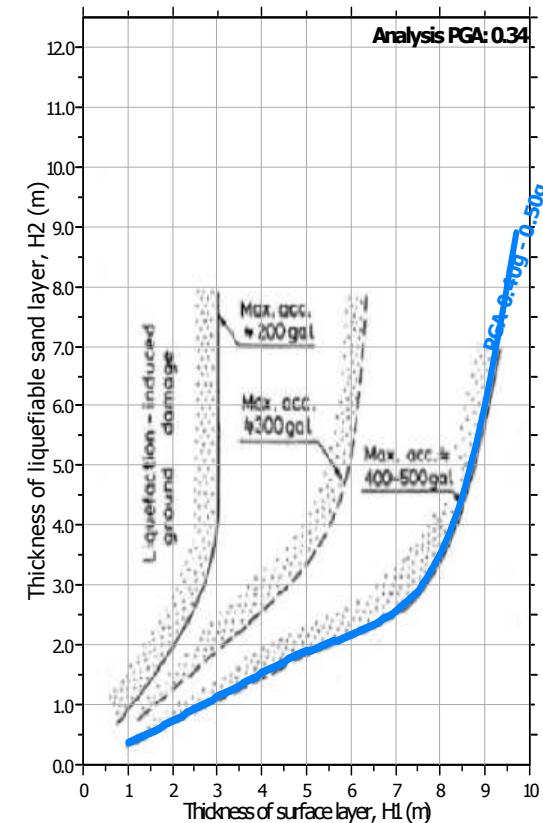
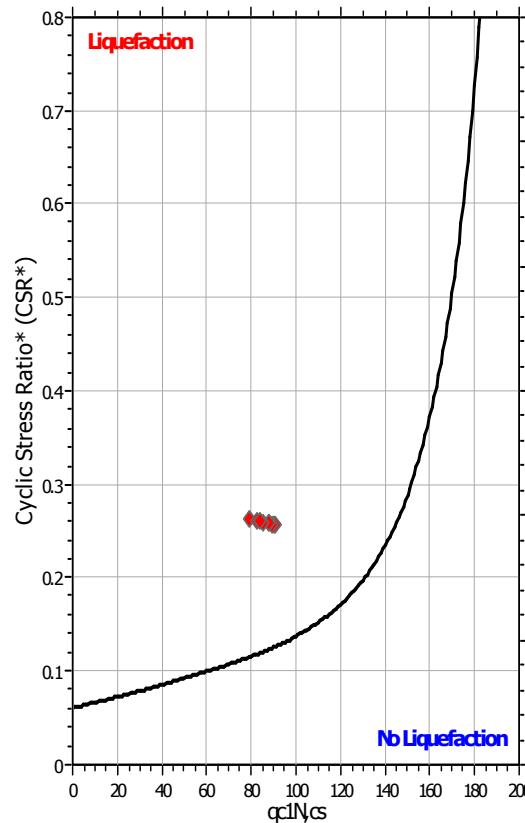
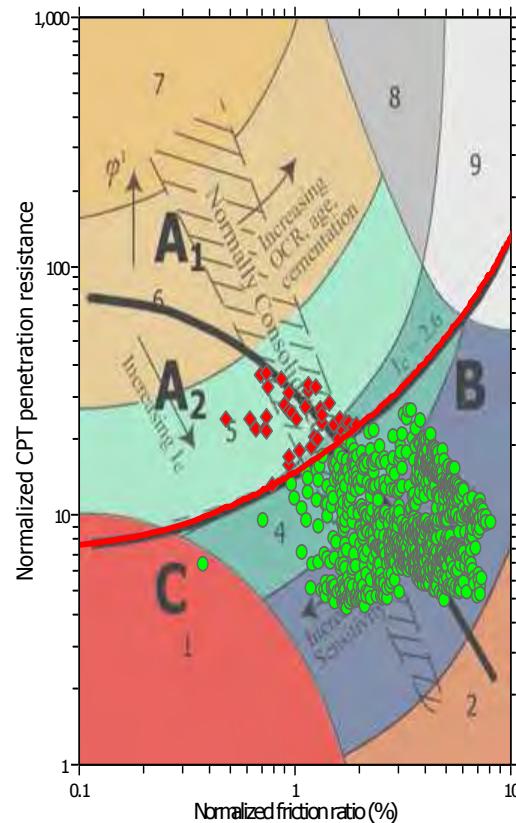
Fill weight: N/A
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

- █ Almost certain it will liquefy
- █ Very likely to liquefy
- █ Liquefaction and no liq. are equally likely
- █ Unlike to liquefy
- █ Almost certain it will not liquefy

LPI color scheme

- █ Very high risk
- █ High risk
- █ Moderate risk
- █ Low risk

Liquefaction analysis summary plots**Input parameters and analysis data**

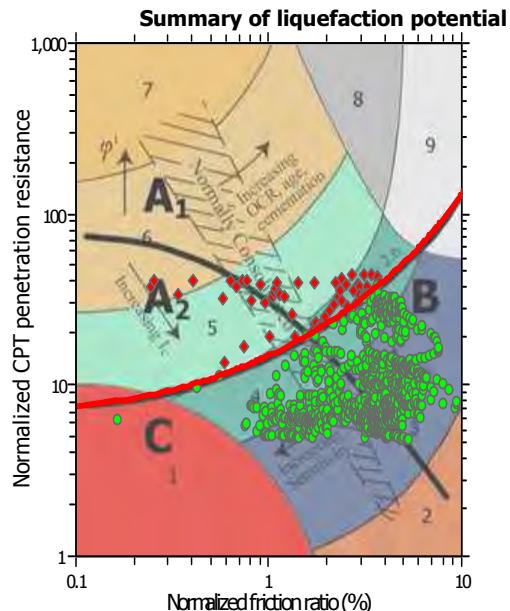
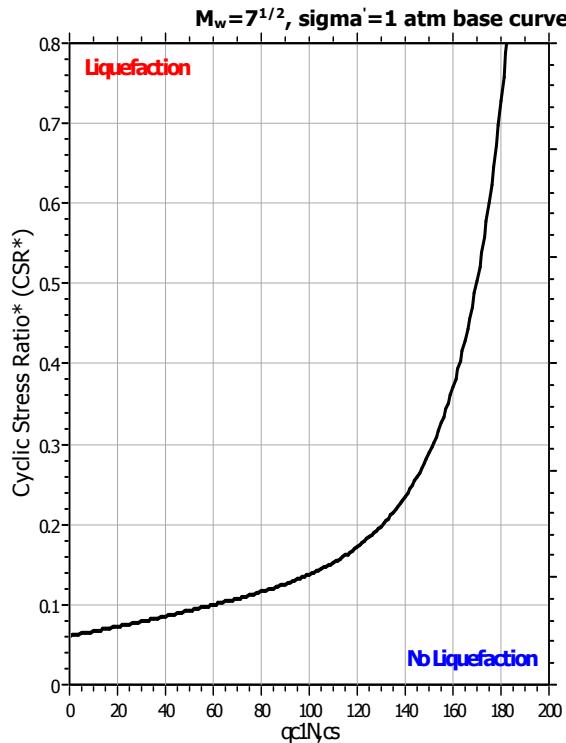
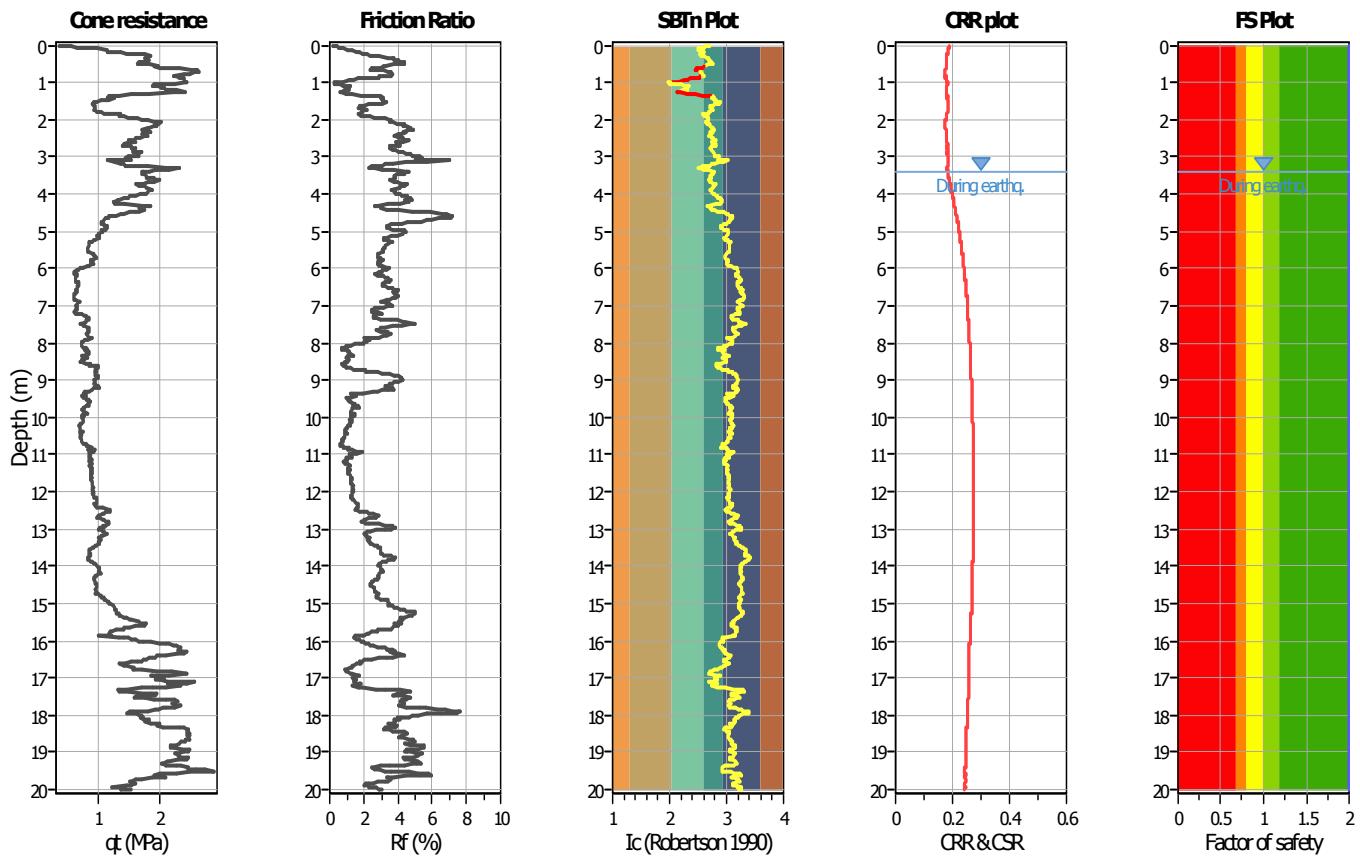
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.80 m

Depth to GWT (erthq.): 3.80 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

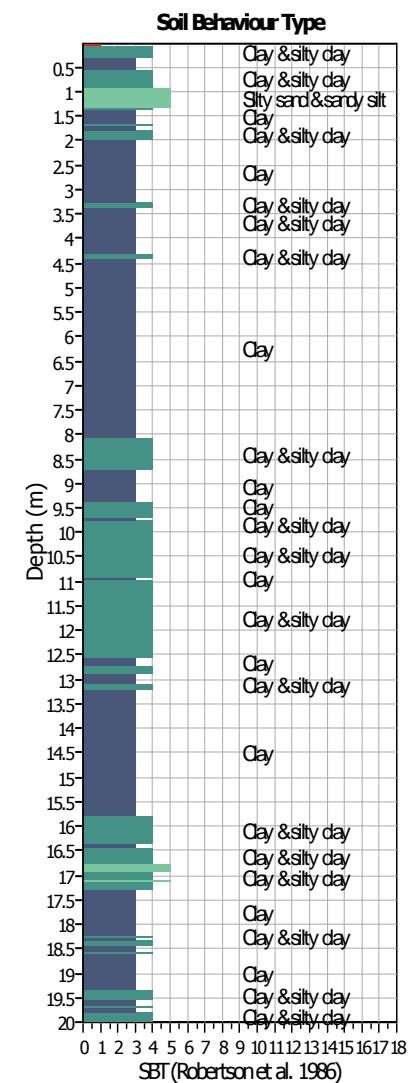
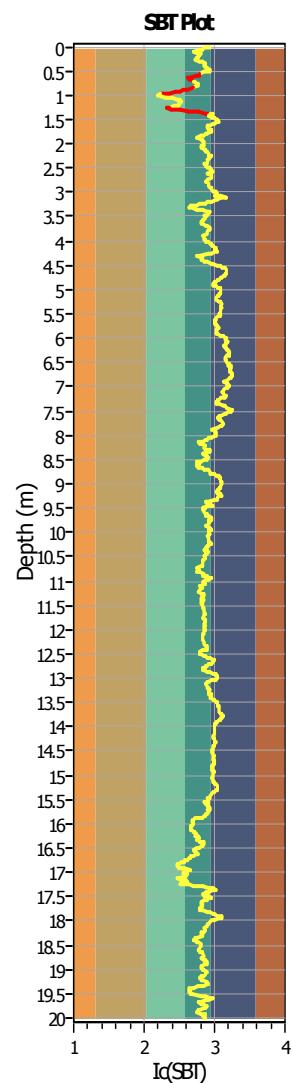
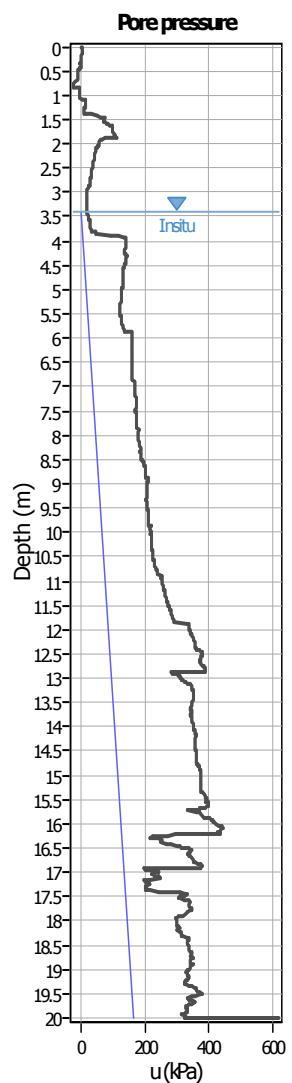
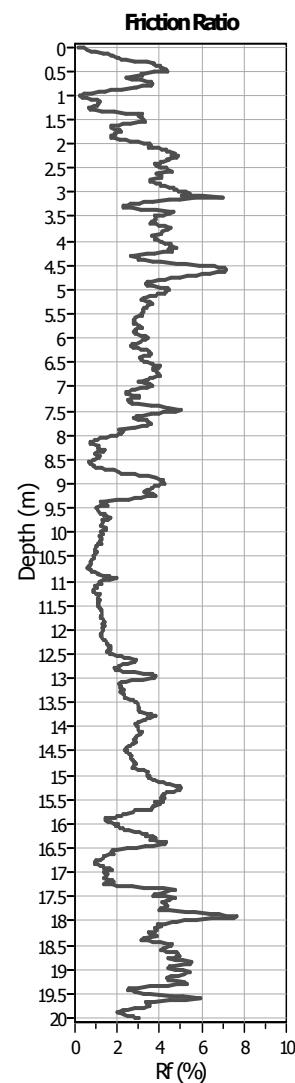
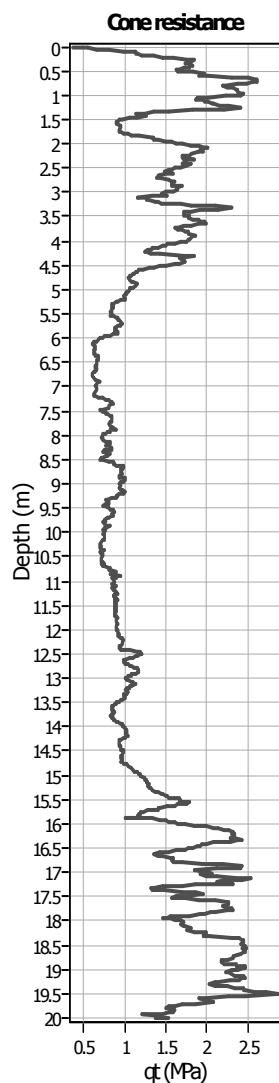
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 14
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.40 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.40 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on I_c value
 Earthquake magnitude M_w: 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in-situ): 3.40 m

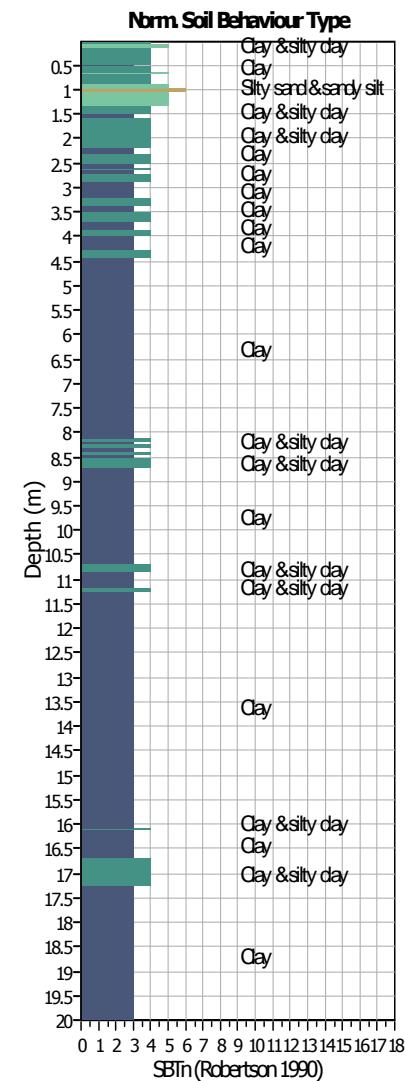
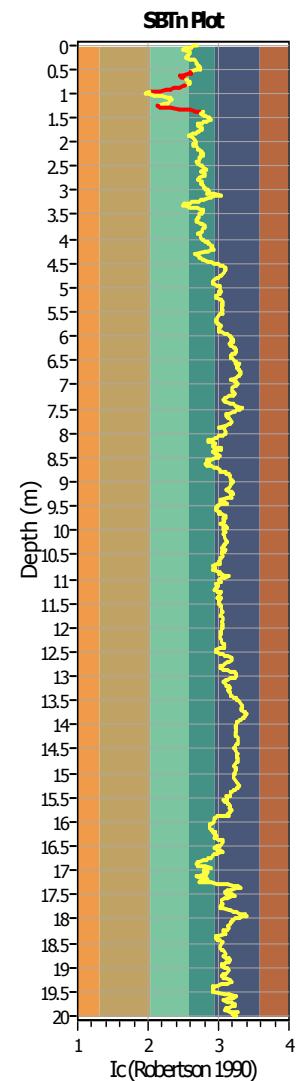
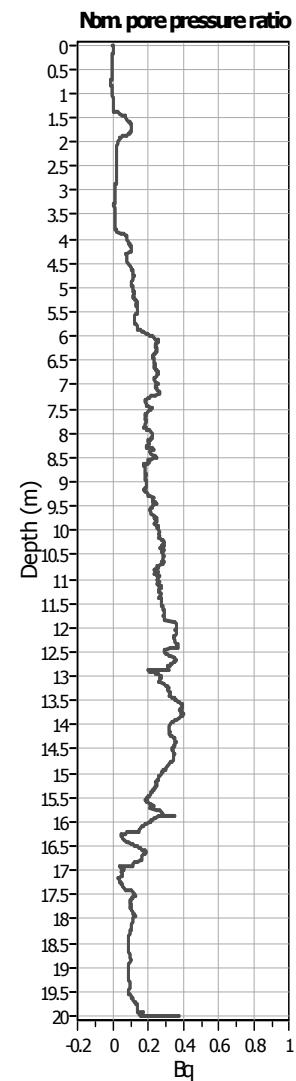
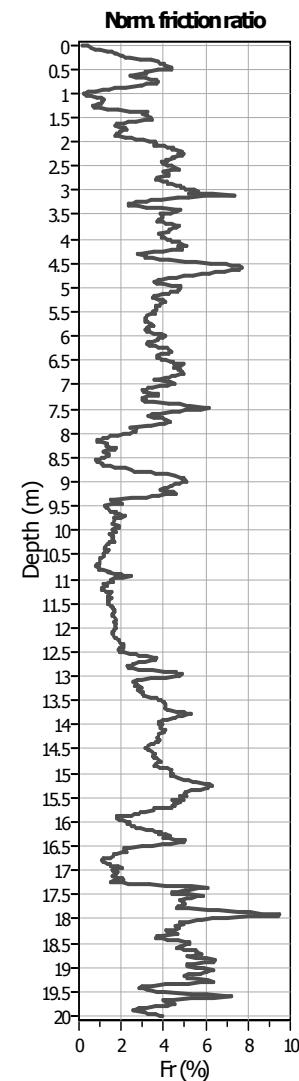
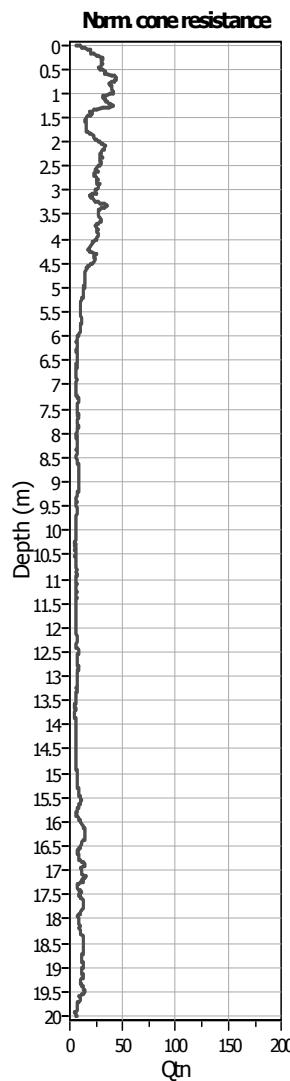
Depth to GWT (erthq.): 3.40 m
 Average results interval: 1
 I_c cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_o applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)



Input parameters and analysis data

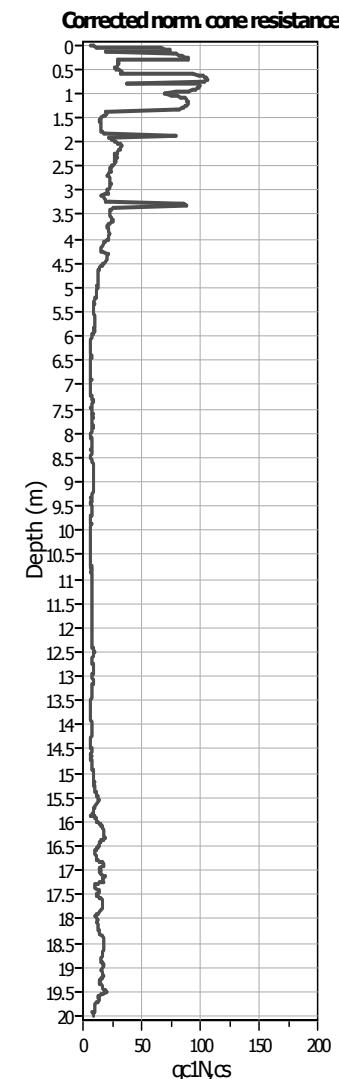
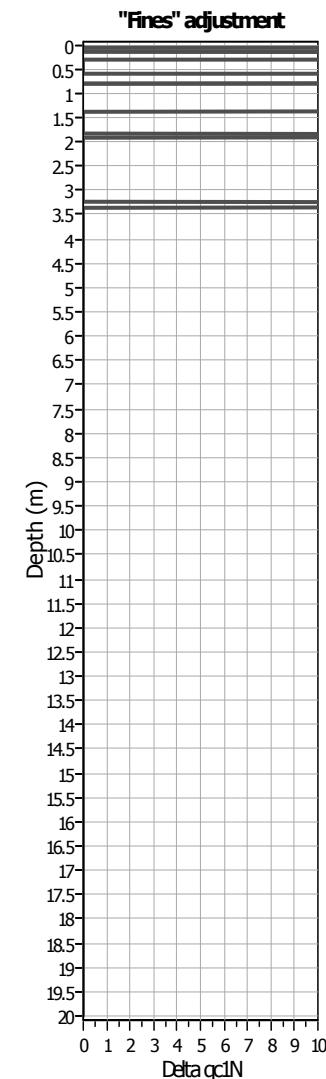
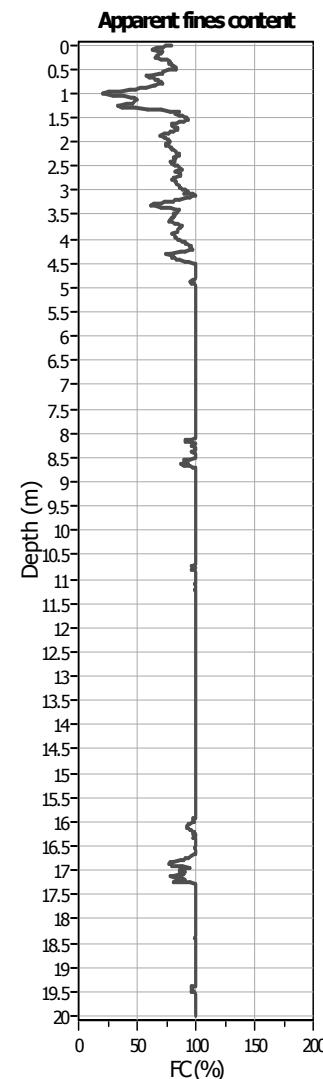
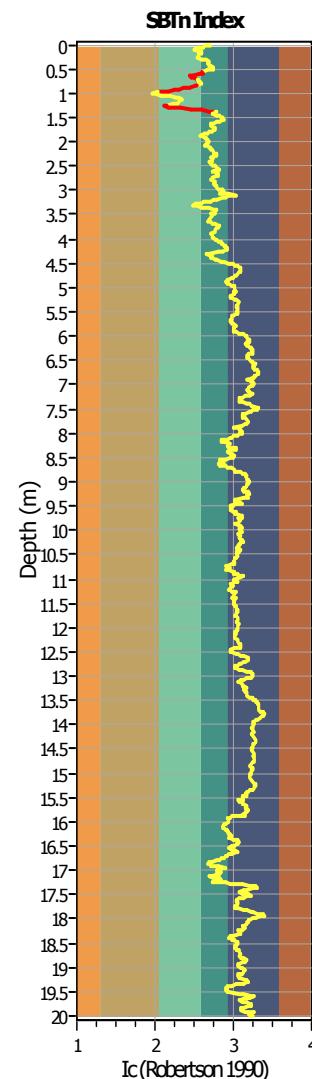
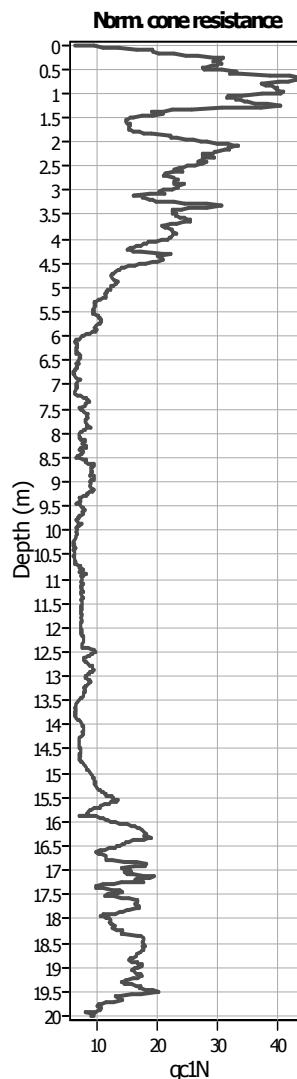
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.40 m

Depth to GWT (erthq.): 3.40 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBTn legend

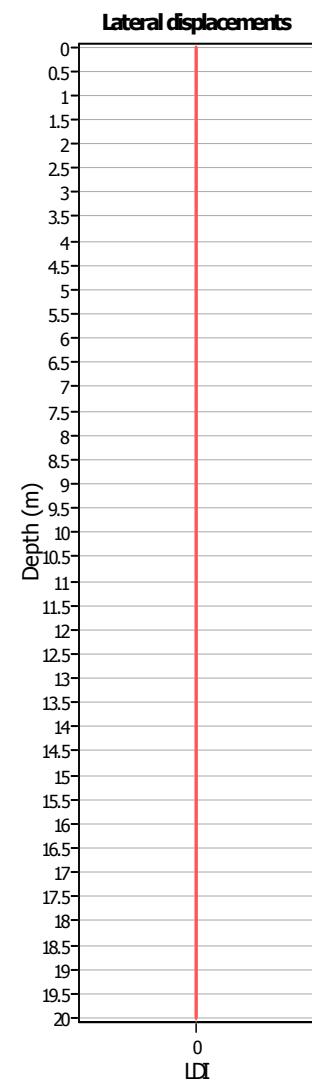
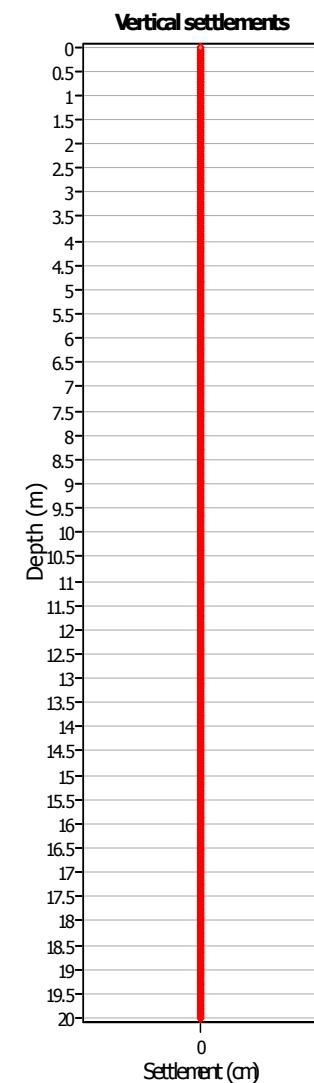
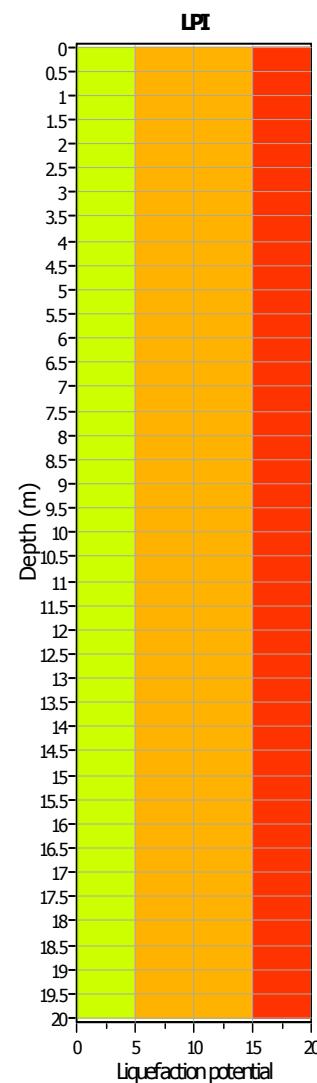
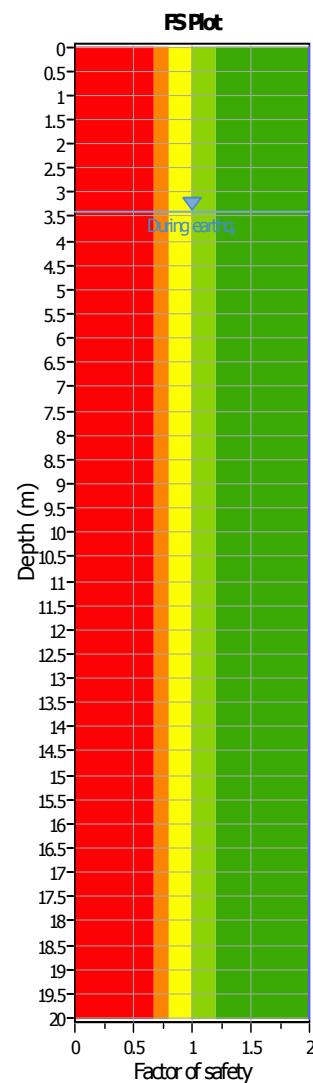
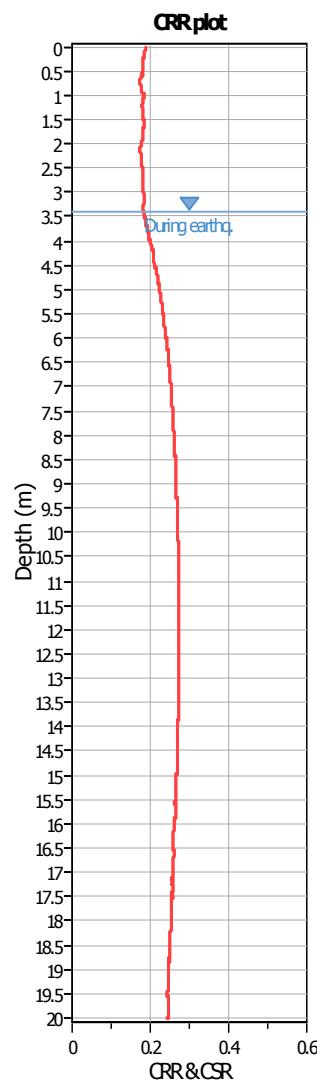
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.40 m

Depth to GWT (erthq.): 3.40 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.40 m

Depth to GWT (earthq.): 3.40 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied:
 K_0 applied:
 Clay like behavior applied:
 Limit depth applied:
 Limit depth:

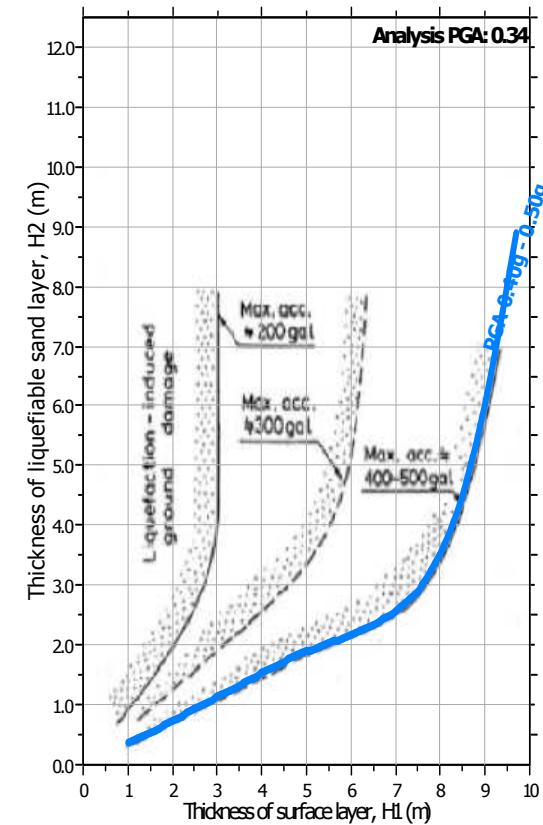
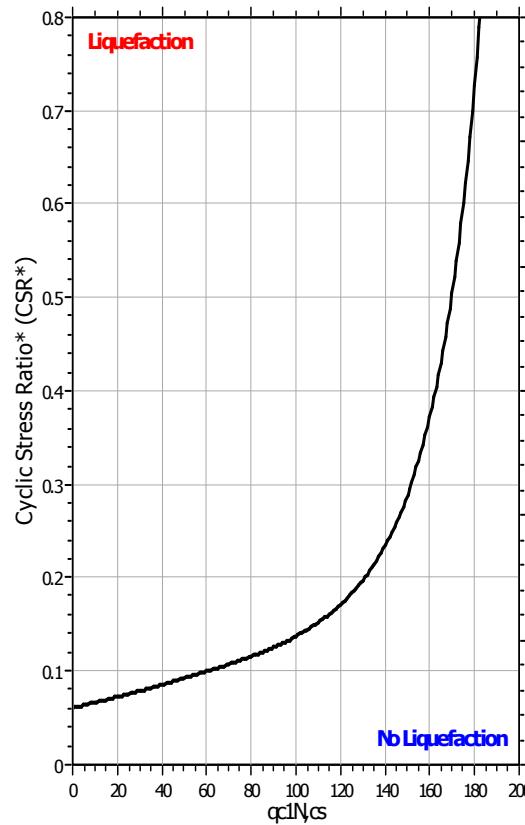
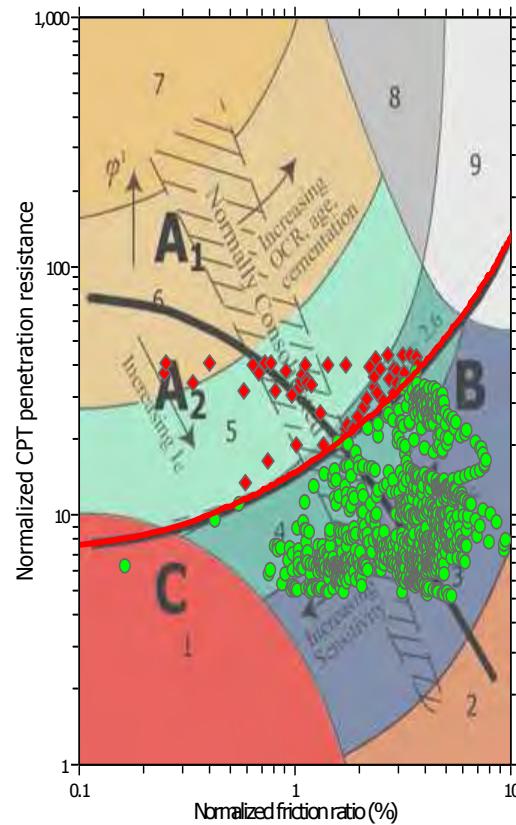
N/A
 Yes
 Yes
 Sands only
 No
 N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

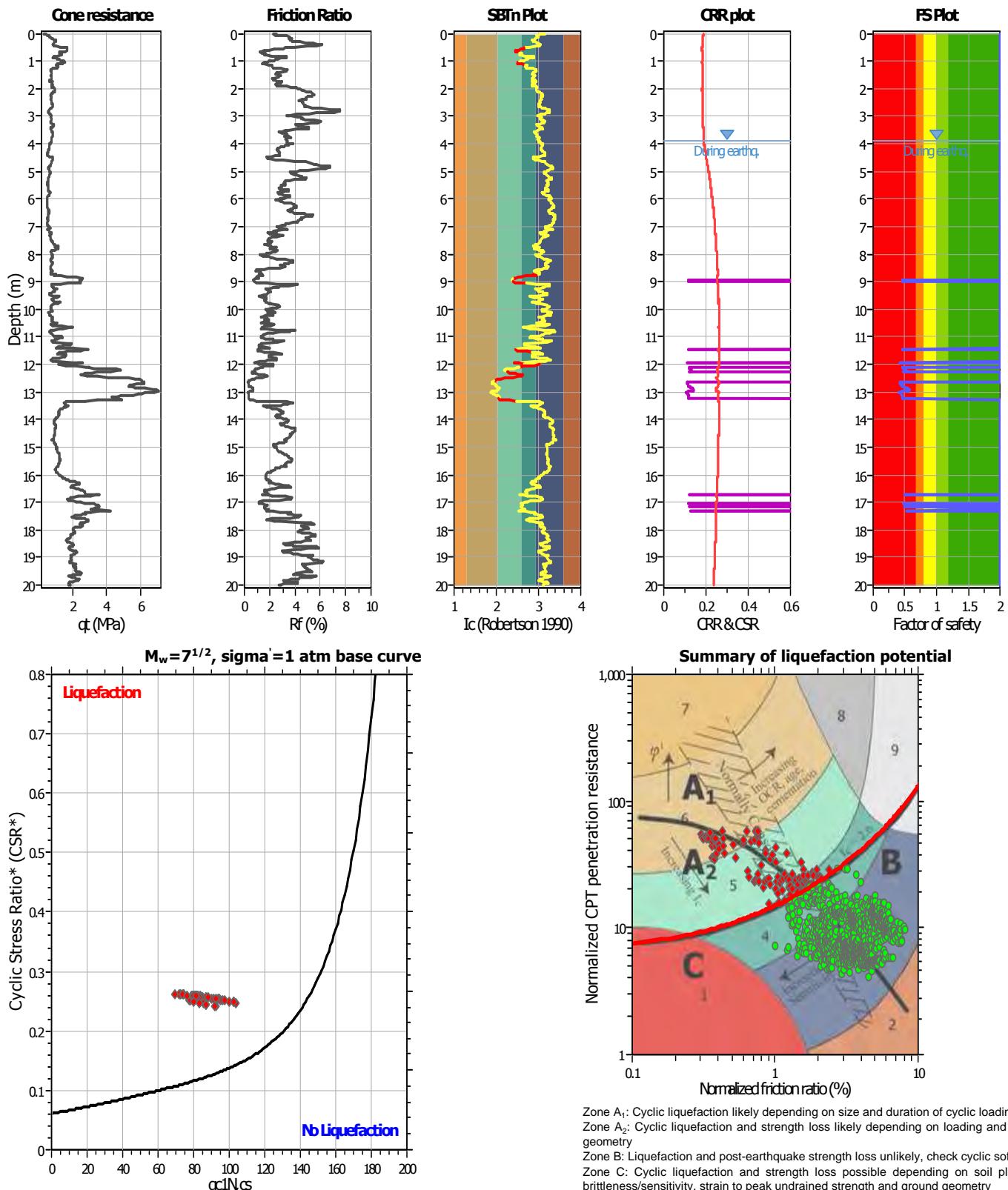
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.40 m

Depth to GWT (erthq.): 3.40 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

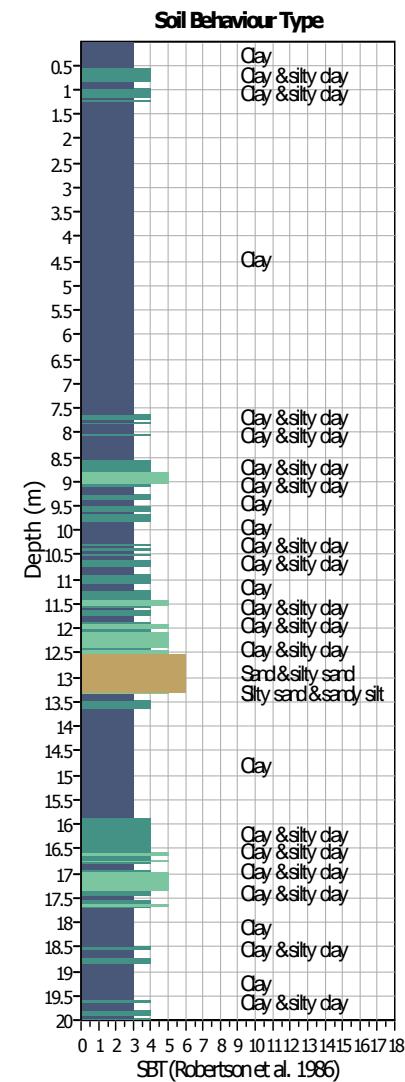
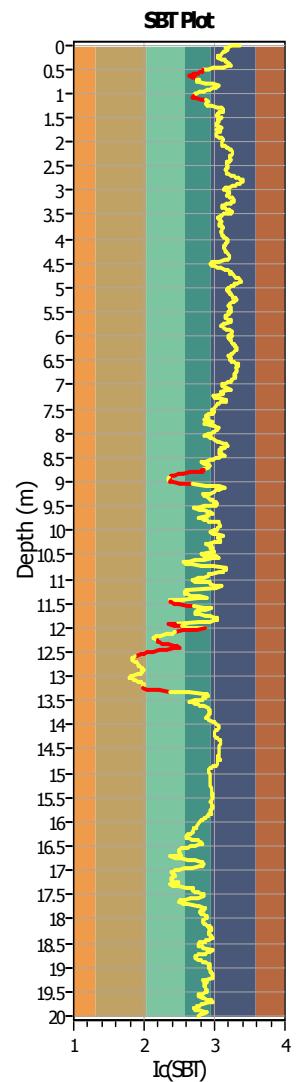
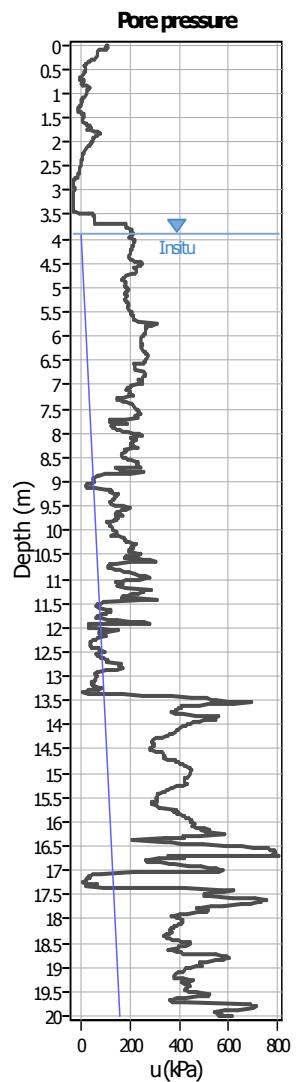
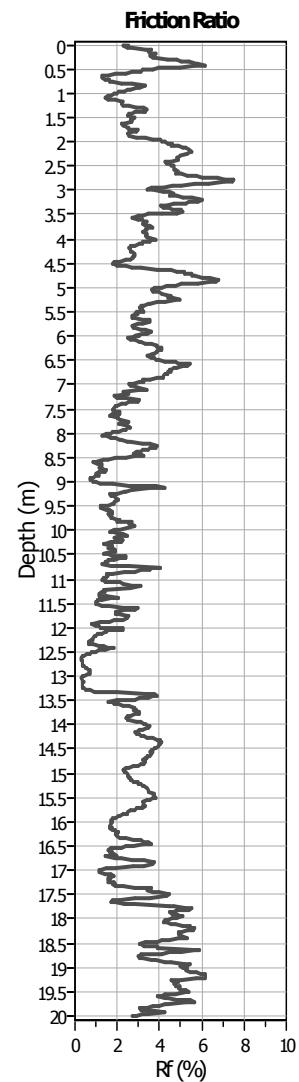
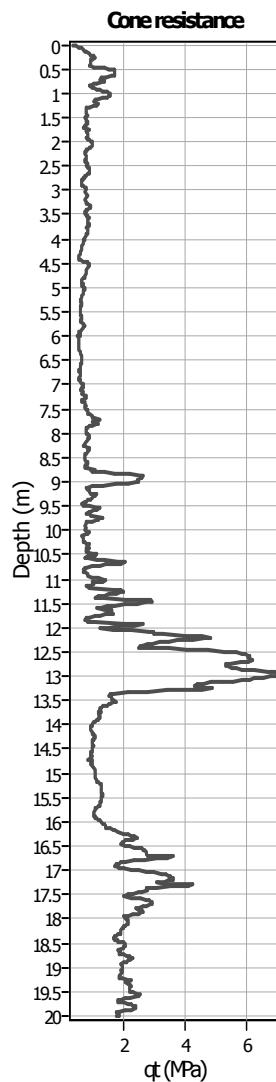
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 15
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.90 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.90 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.90 m

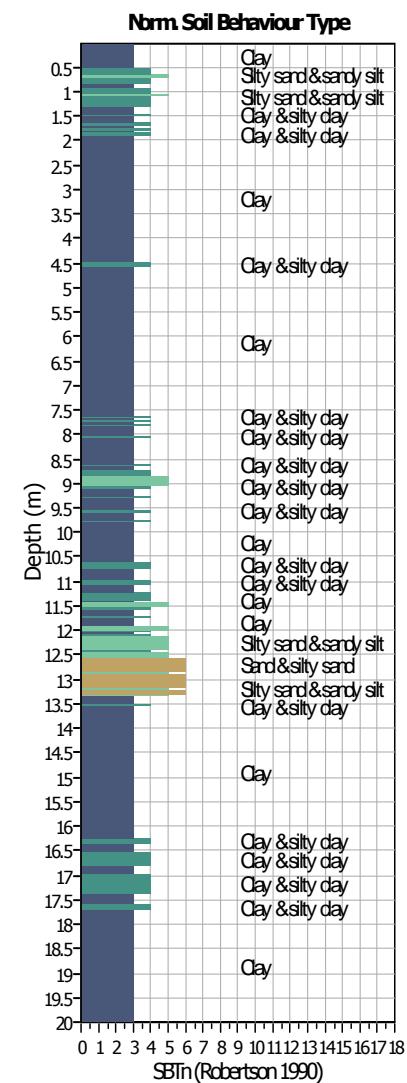
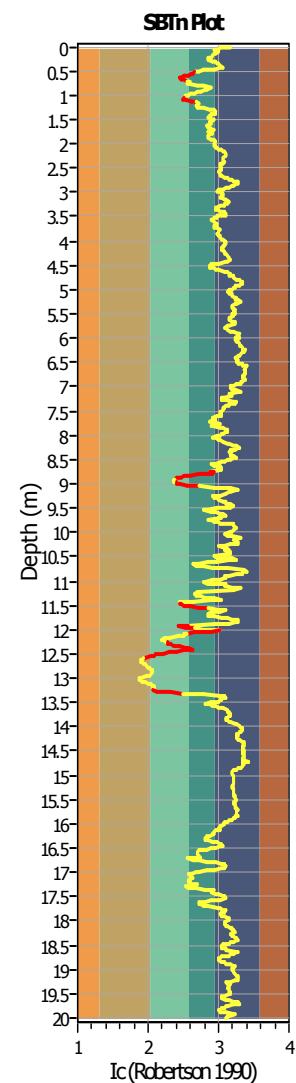
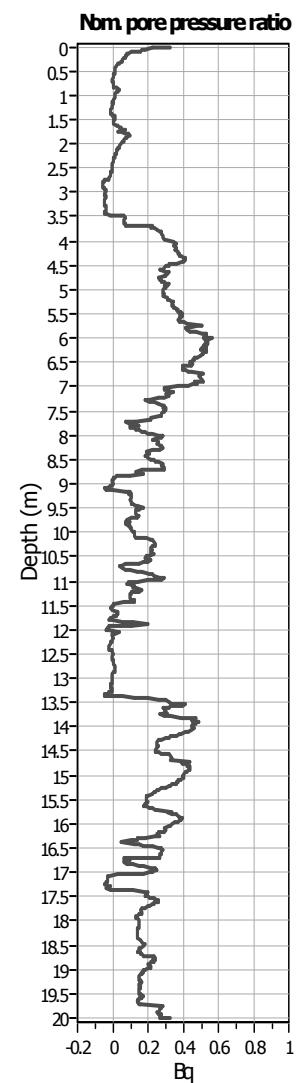
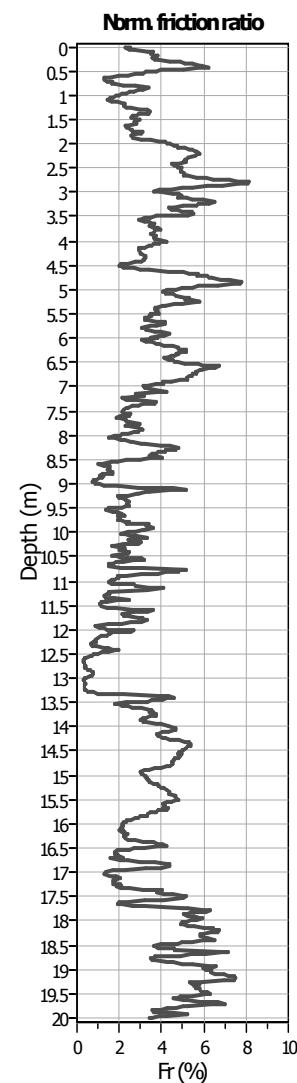
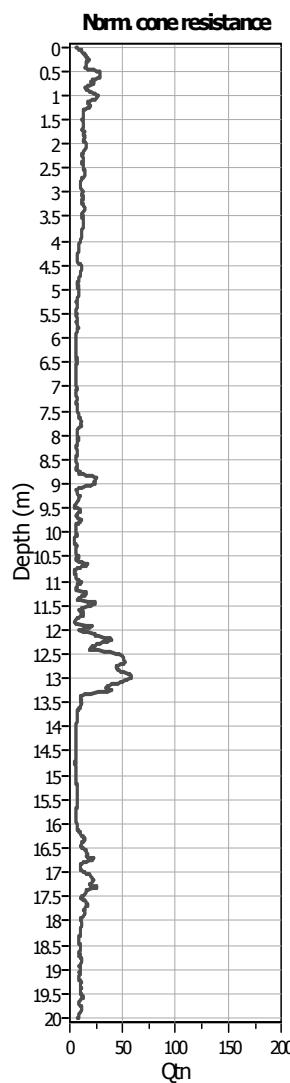
Depth to GWT (erthq.): 3.90 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)



Input parameters and analysis data

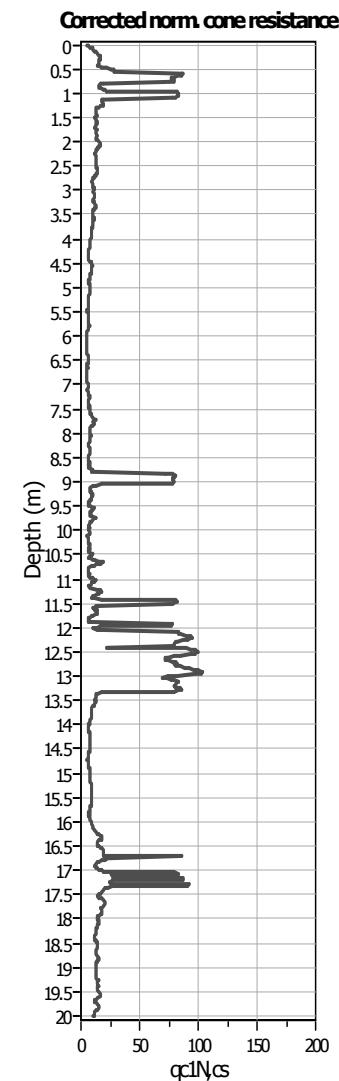
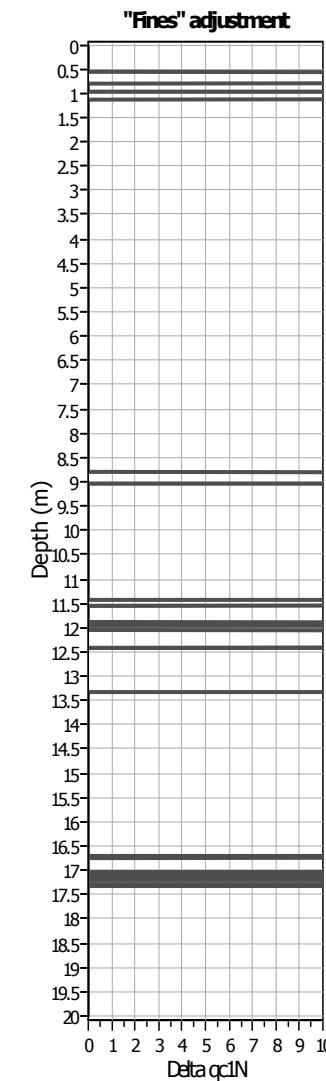
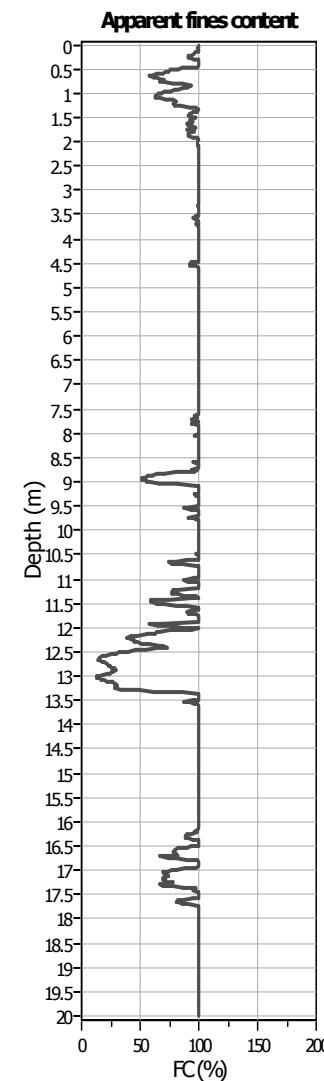
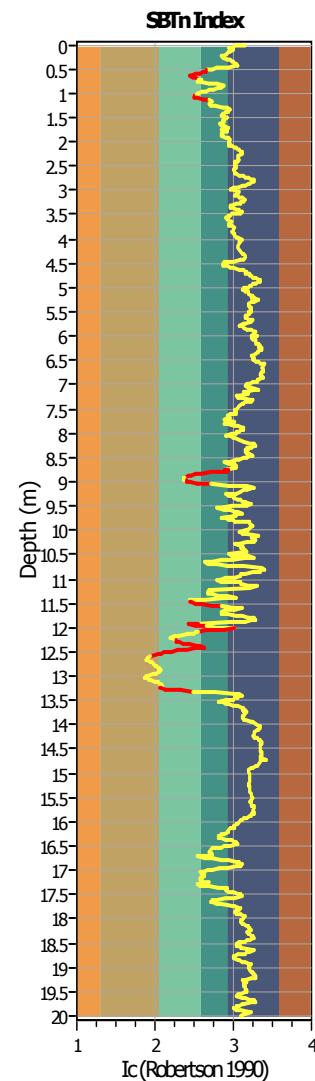
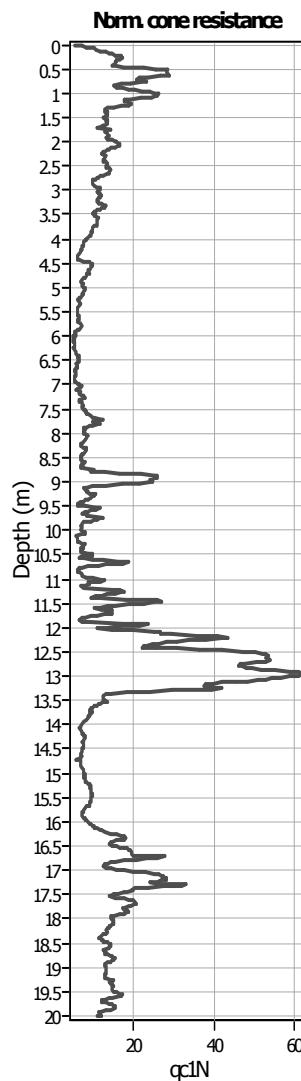
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.90 m

Depth to GWT (erthq.): 3.90 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: N/A
 K_0 applied: Yes
 Clay like behavior applied: Yes
 Limit depth applied: Sands only
 Limit depth: No
 N/A

SBTn legend

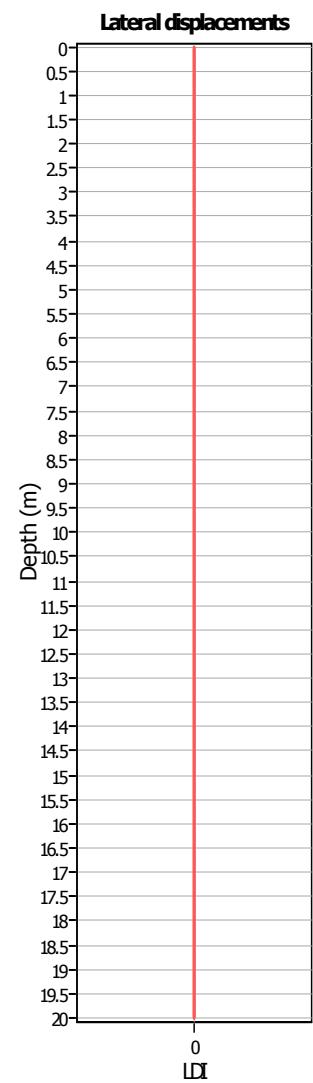
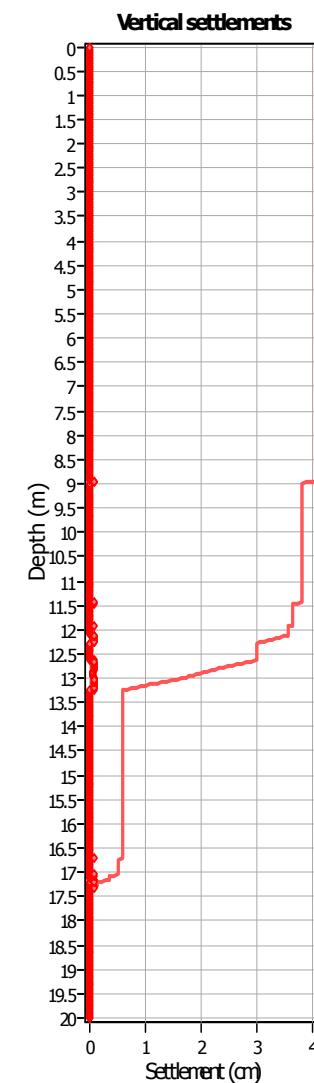
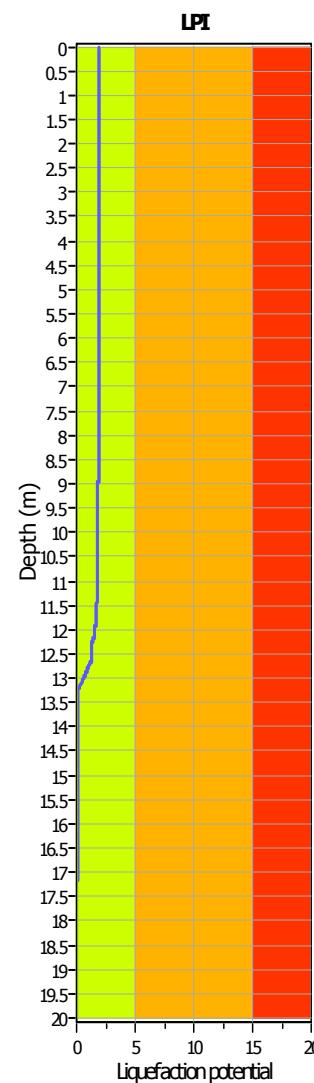
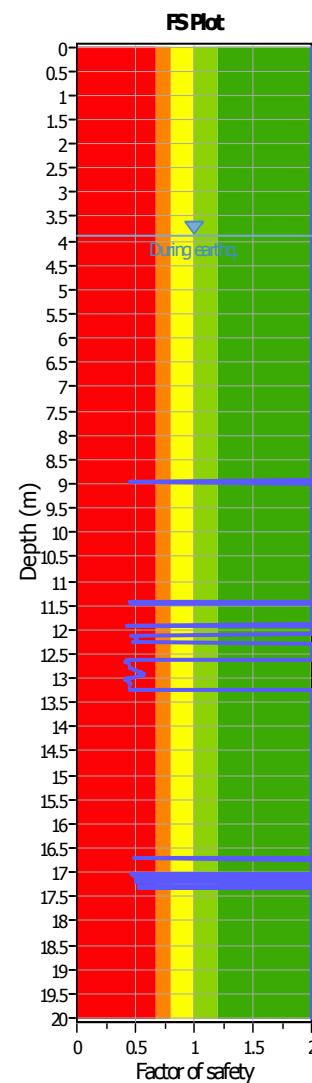
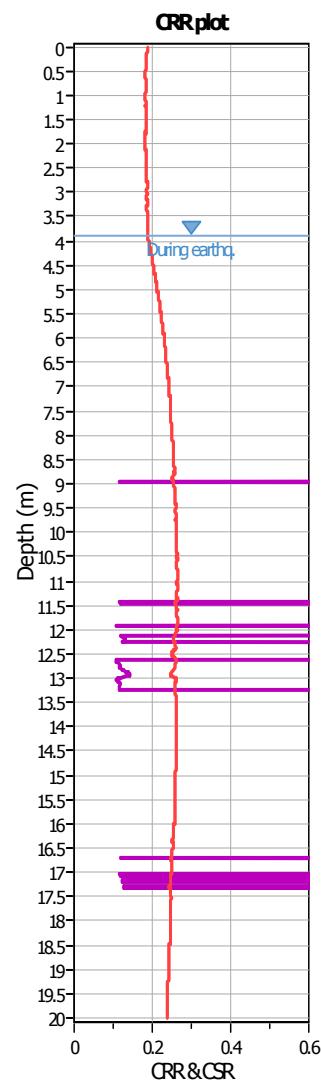
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.90 m

Depth to GWT (erthq.): 3.90 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.90 m

Depth to GWT (erthq.): 3.90 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

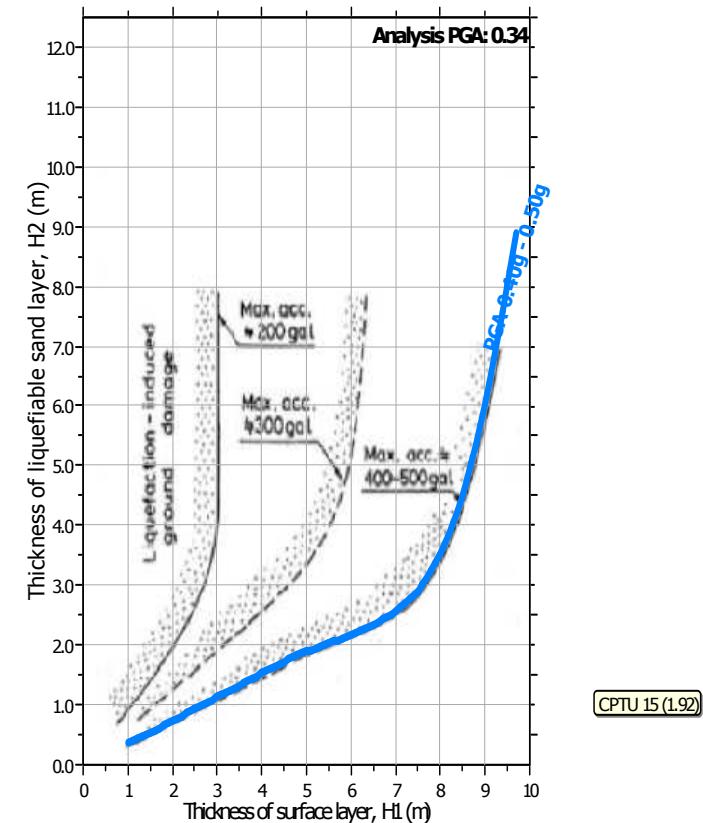
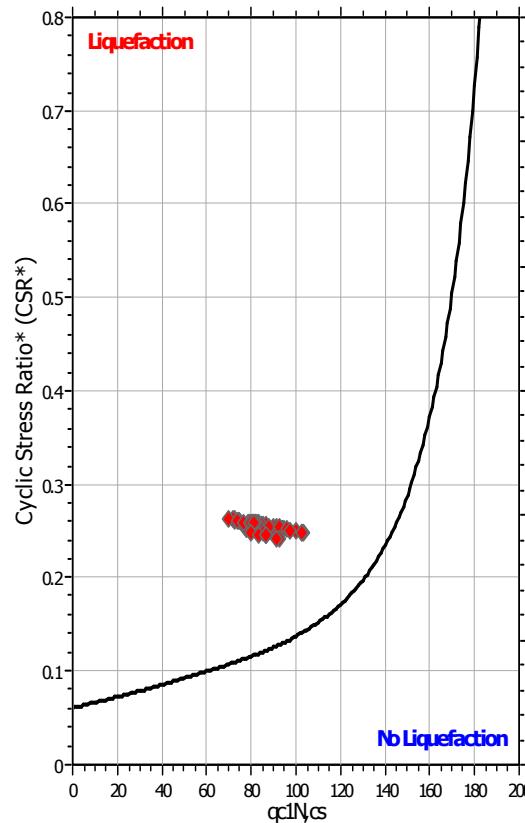
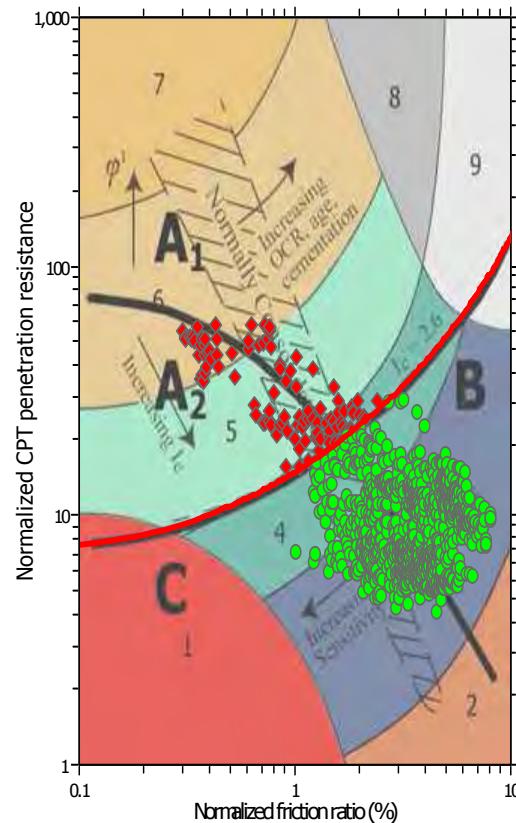
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

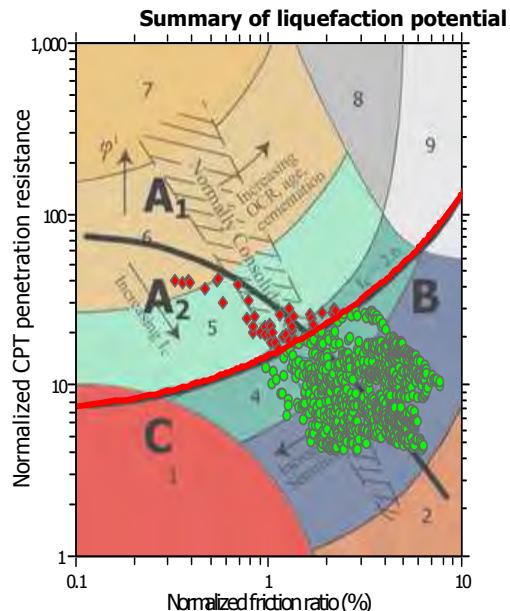
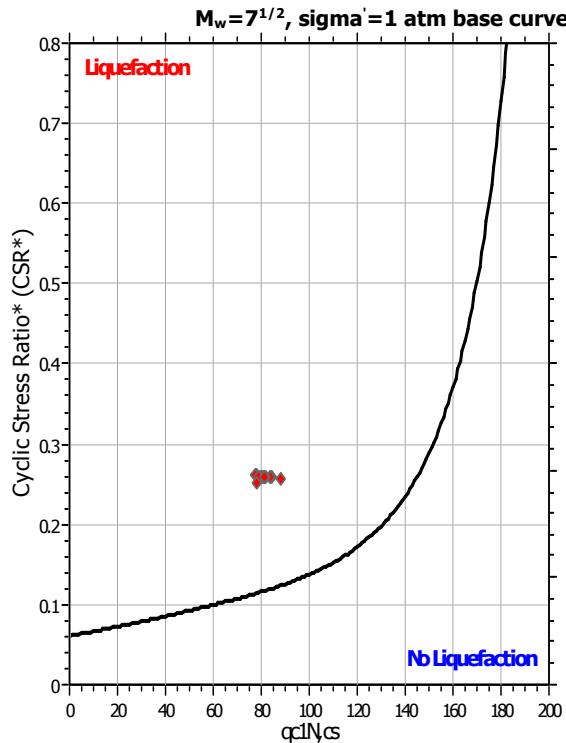
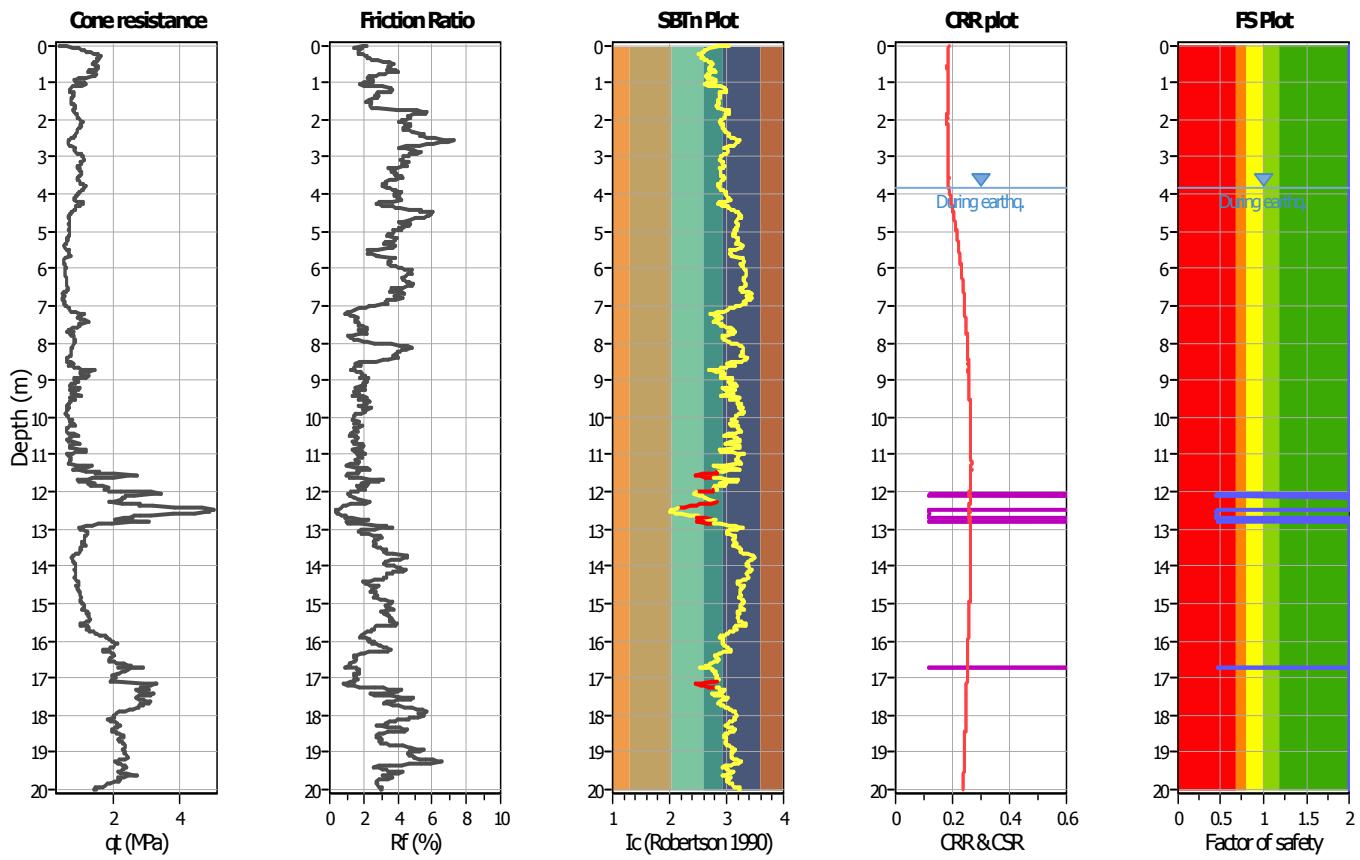
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.90 m

Depth to GWT (erthq.): 3.90 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

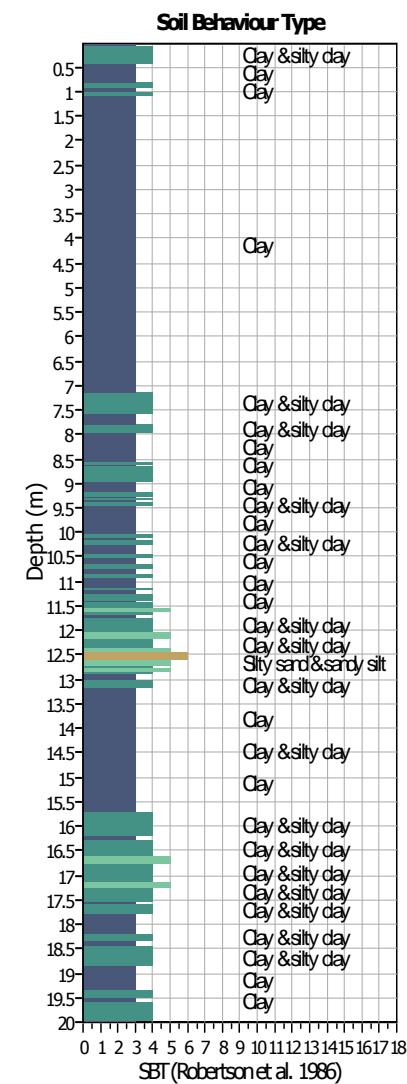
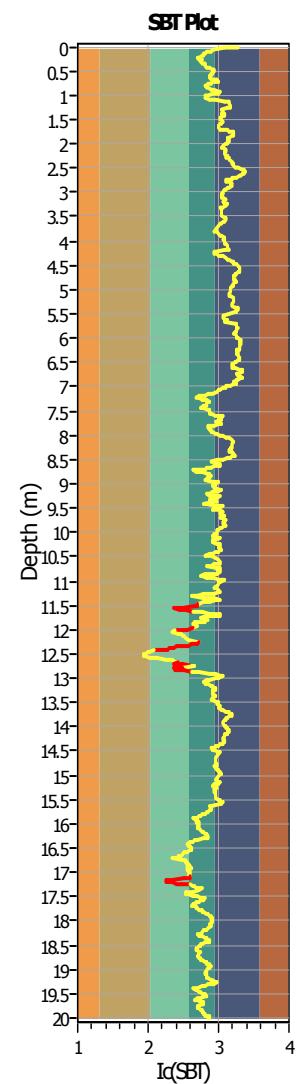
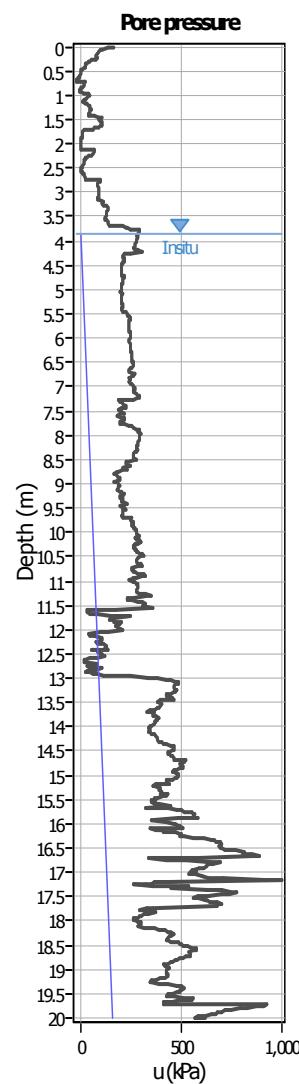
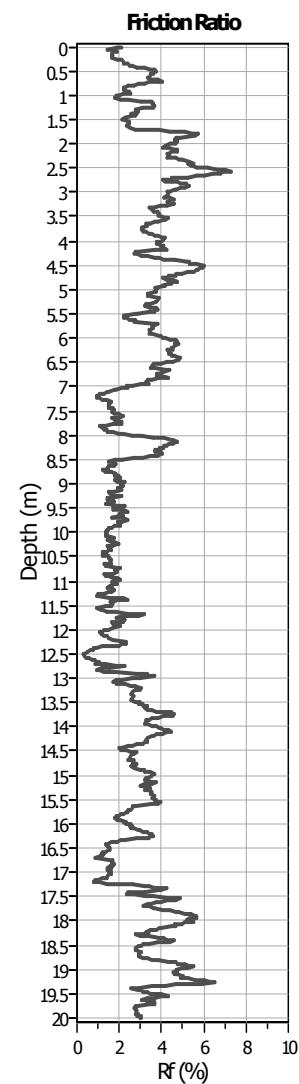
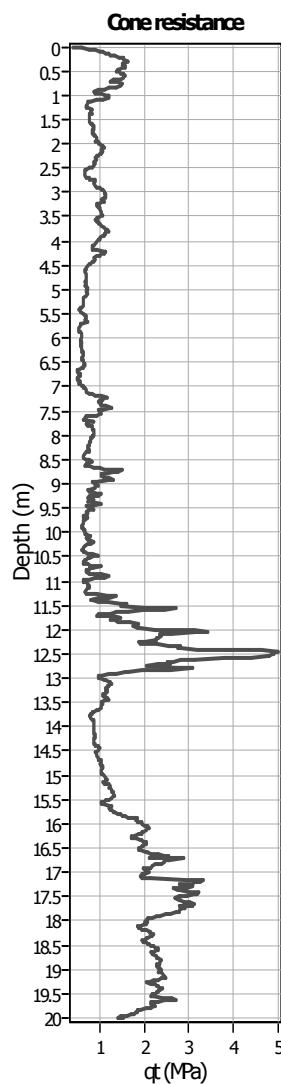
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 16
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.85 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.85 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots**Input parameters and analysis data**

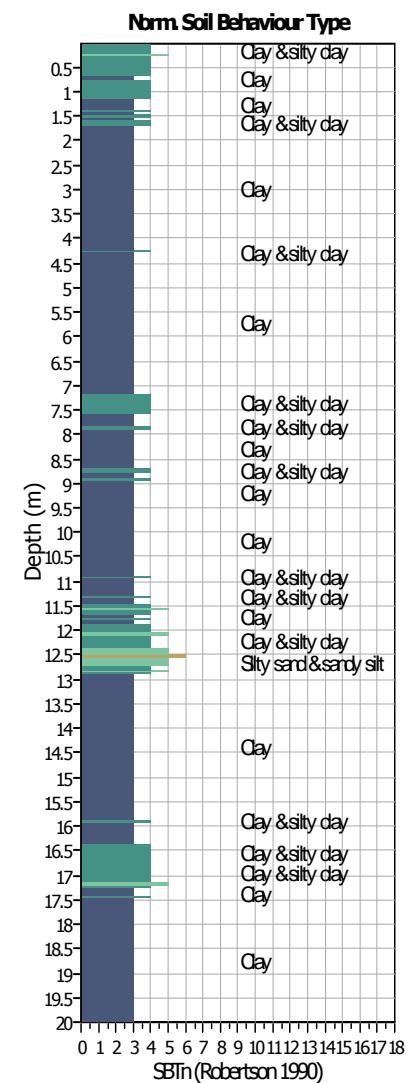
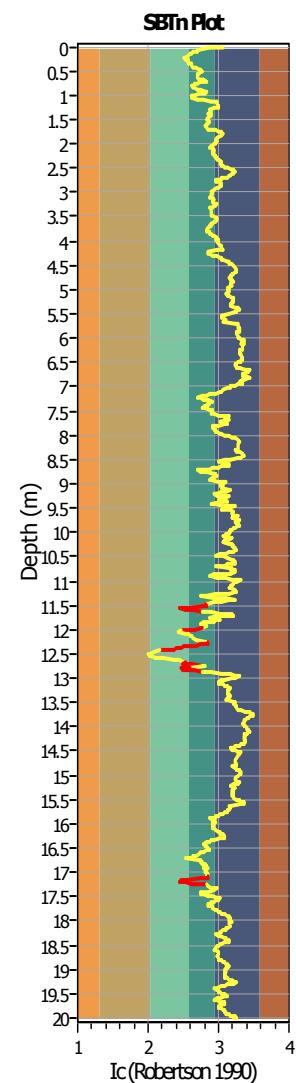
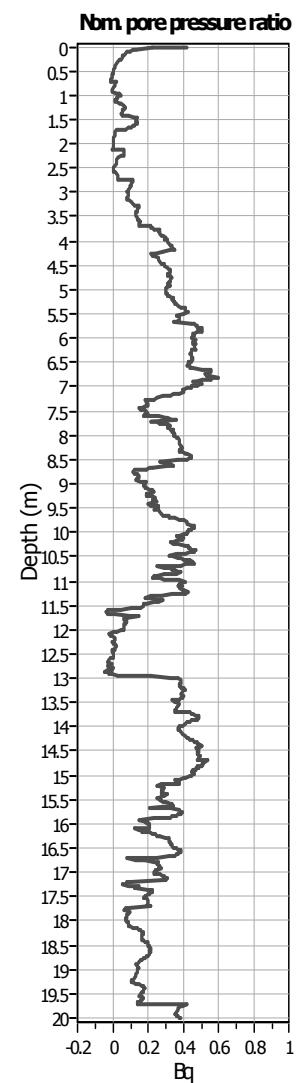
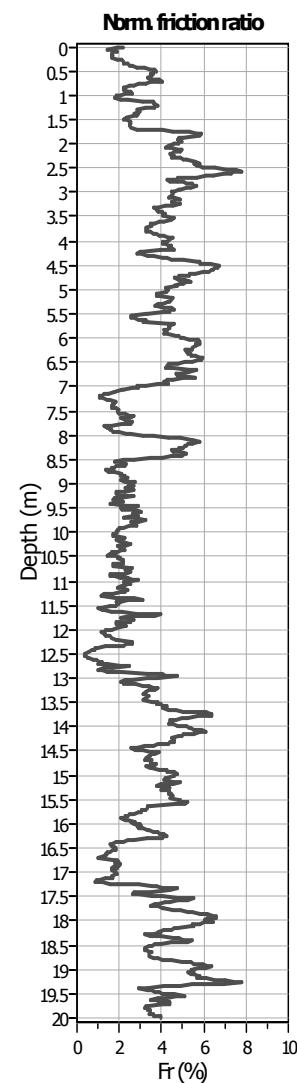
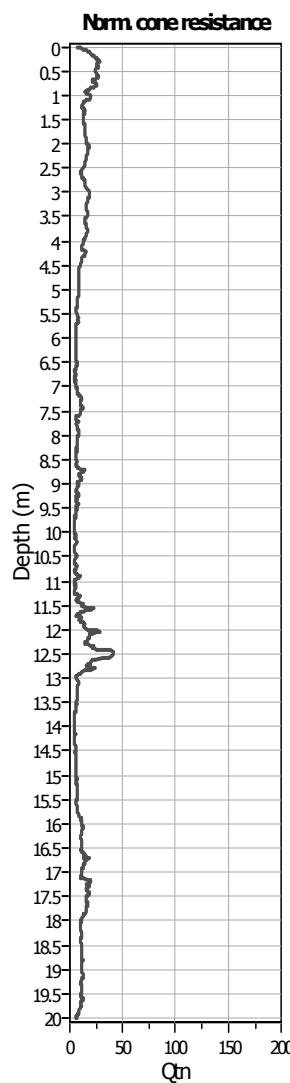
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.85 m

Depth to GWT (erthq.): 3.85 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBT legend

- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)**Input parameters and analysis data**

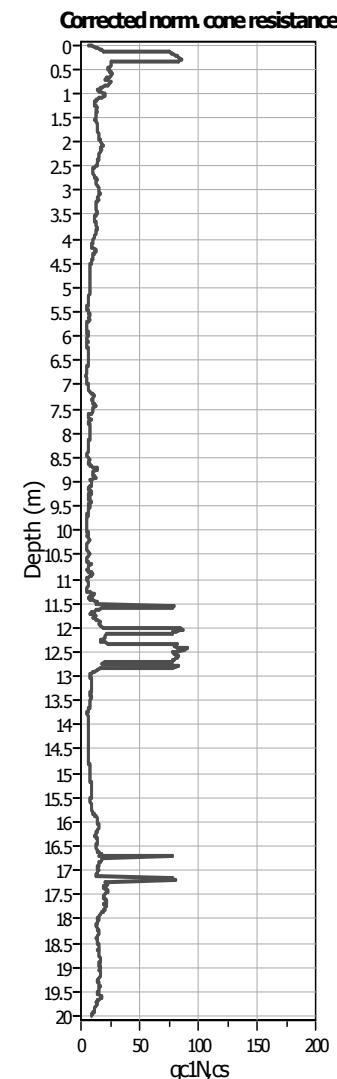
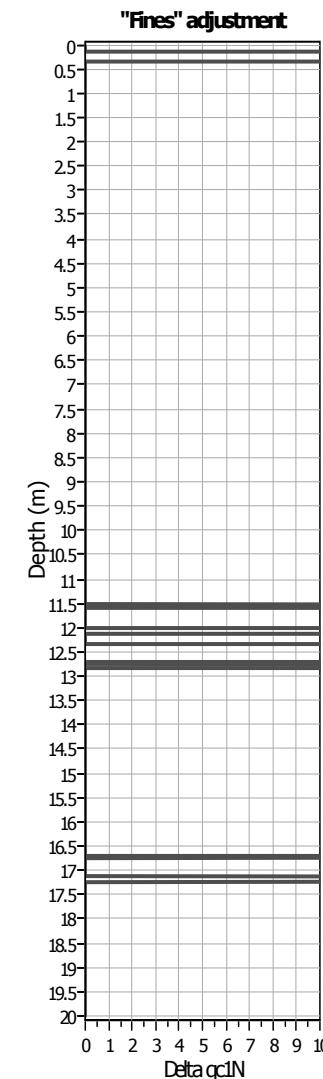
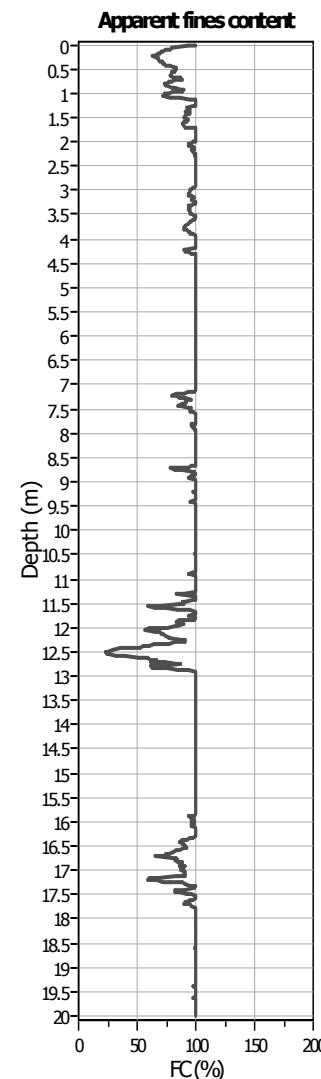
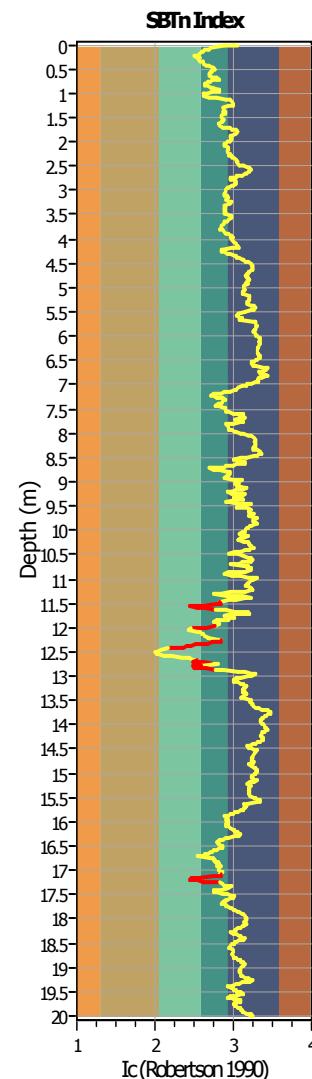
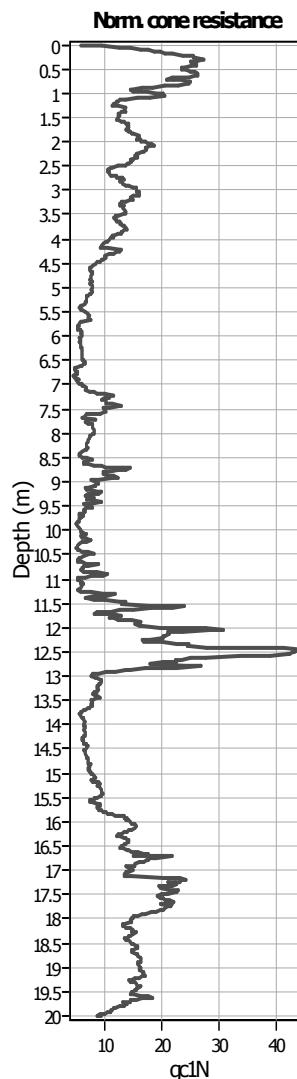
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.85 m

Depth to GWT (erthq.): 3.85 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

SBTn legend

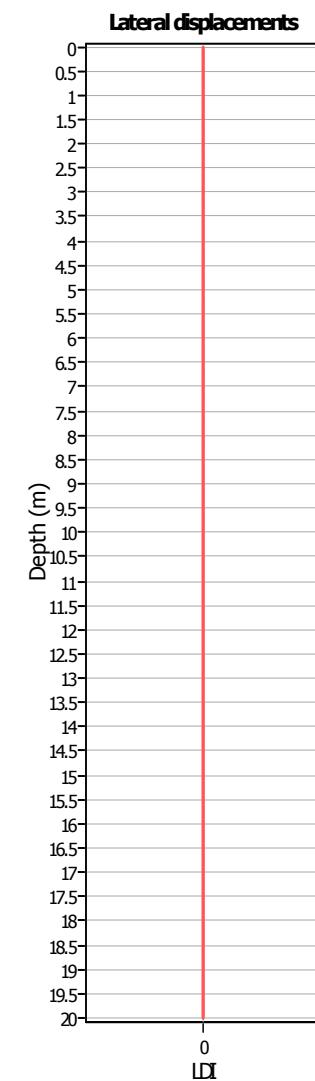
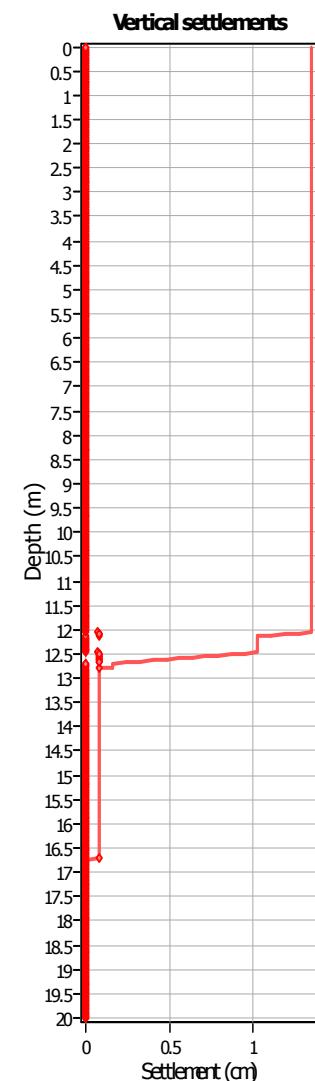
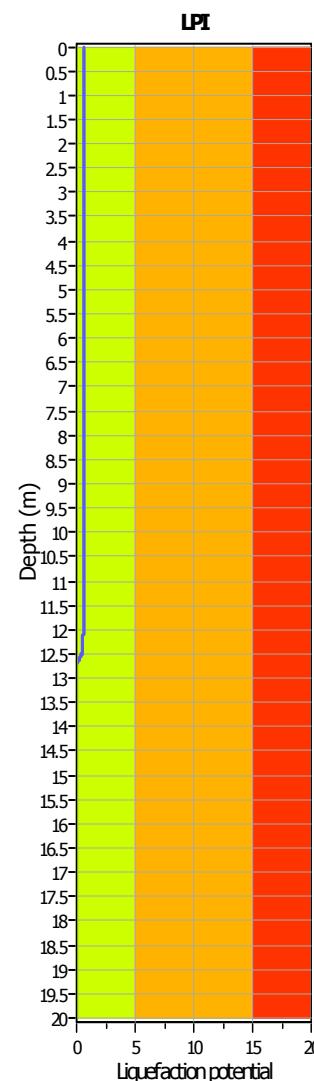
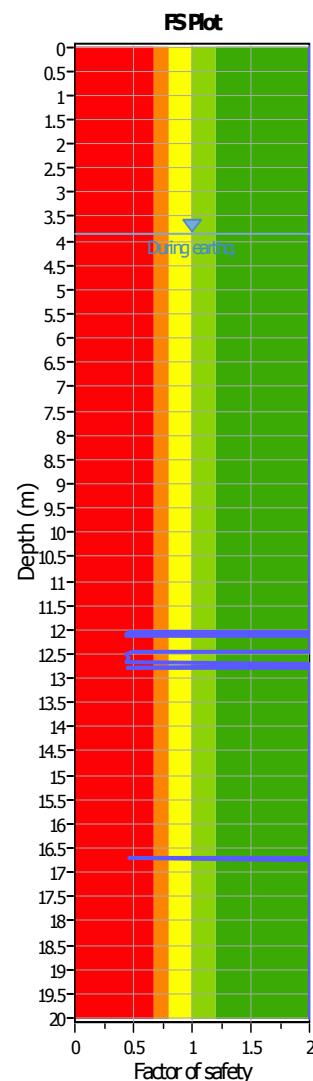
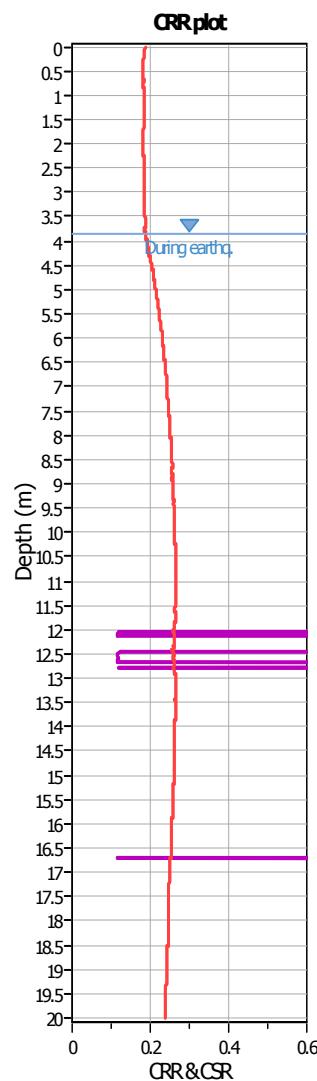
- | | | |
|---------------------------|-----------------------------|----------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.85 m

Depth to GWT (erthq.): 3.85 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.85 m

Depth to GWT (erthq.): 3.85 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

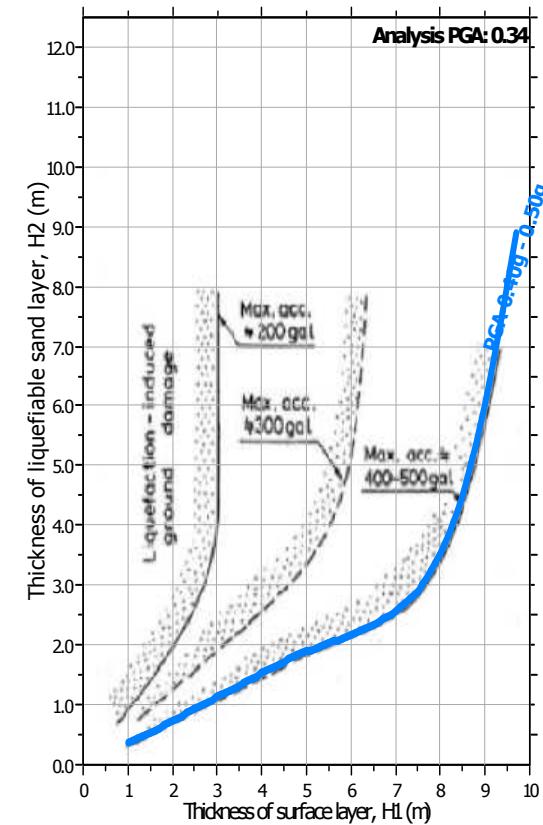
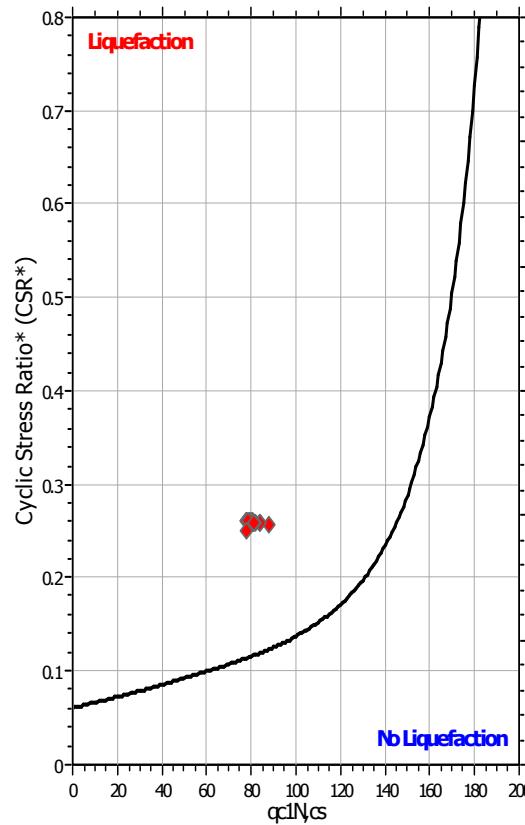
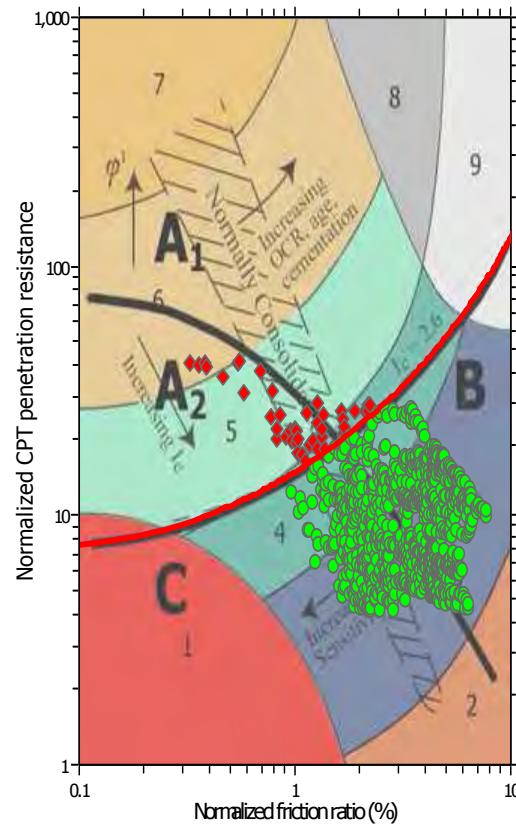
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

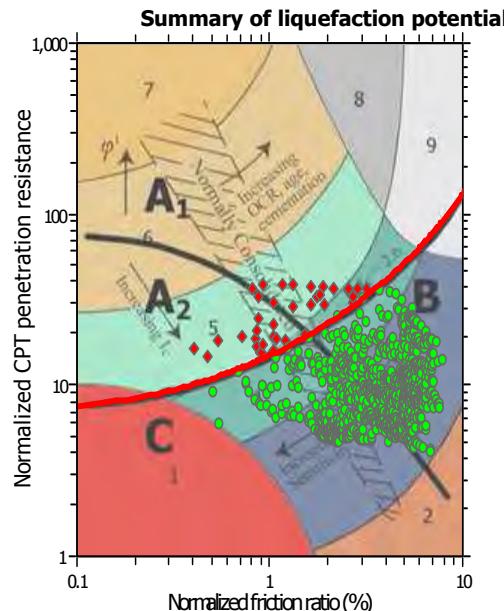
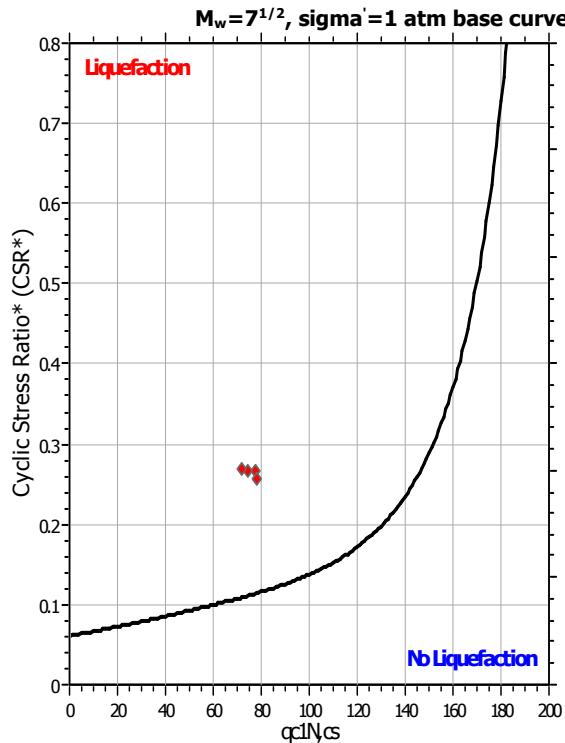
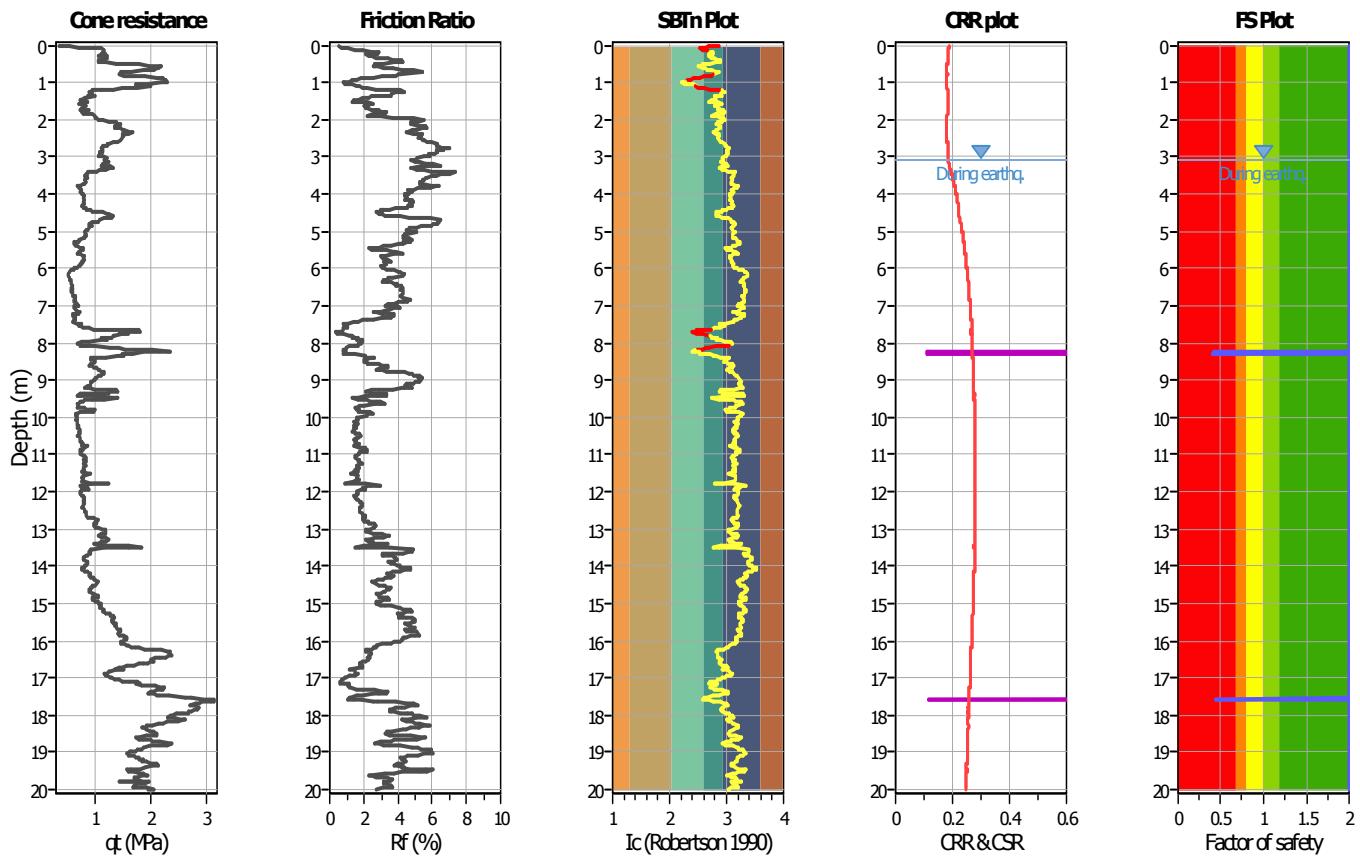
Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.85 m

Depth to GWT (erthq.): 3.85 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

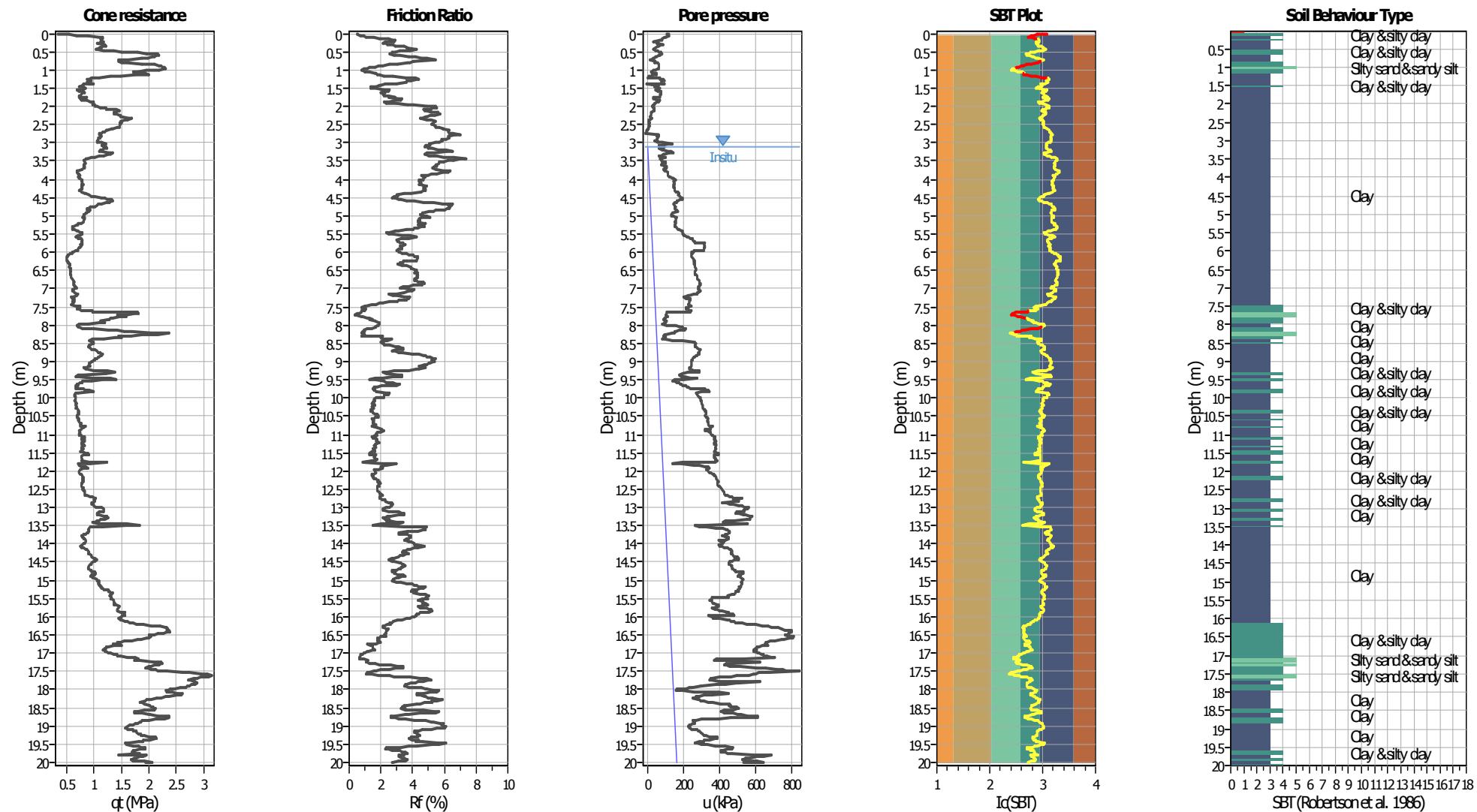
LIQUEFACTION ANALYSIS REPORT
Project title : Centro Unificato dell'Emergenza sul Territorio Location : Ferrara
CPT file : CPTU 17
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.10 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.10 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	1	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.34	Unit weight calculation:	Based on SBT	K_o applied:	Yes		



Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



Input parameters and analysis data

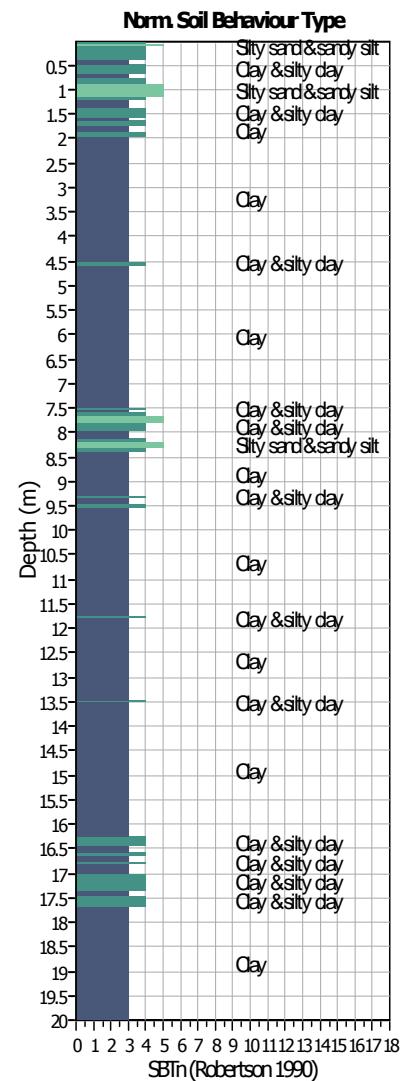
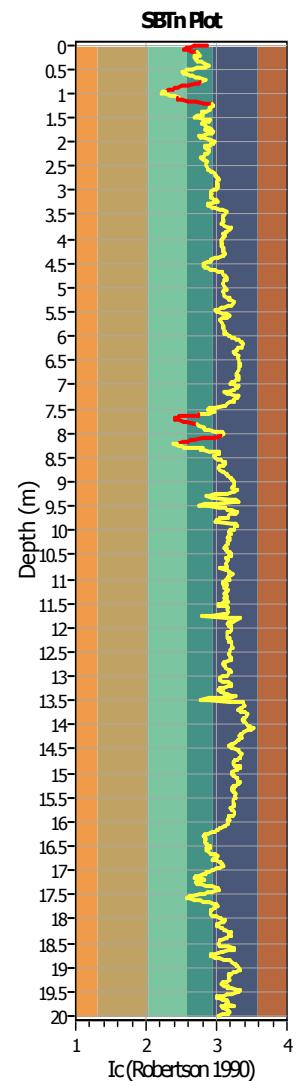
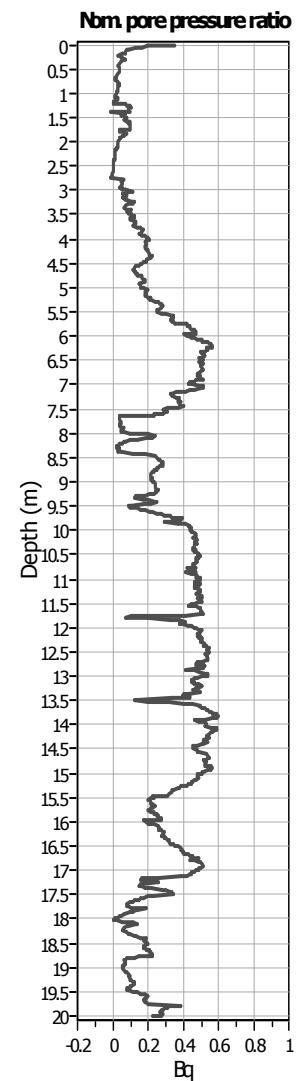
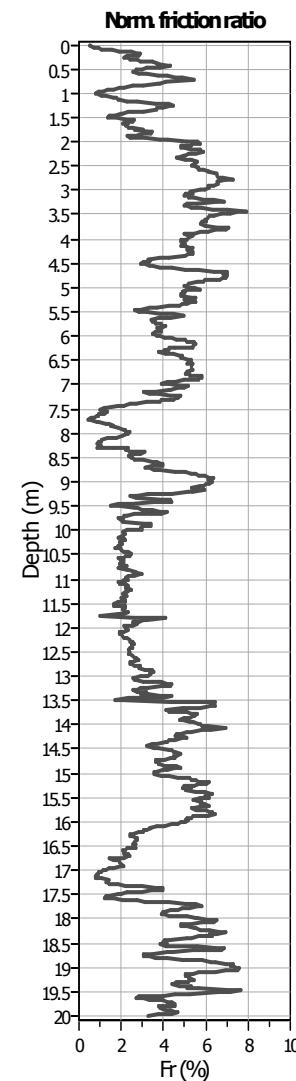
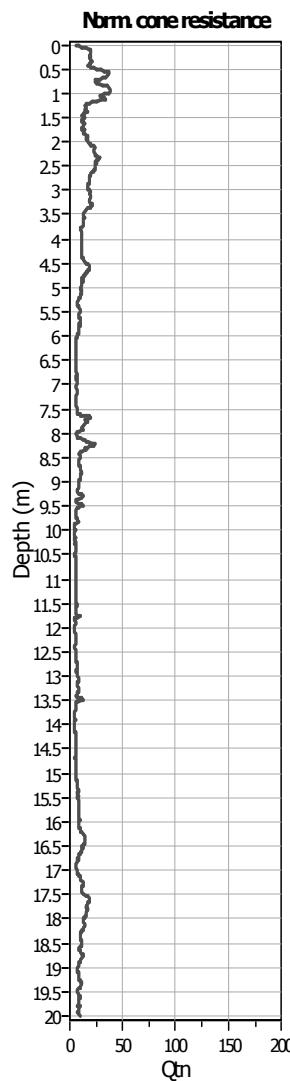
Analysis method:	B&I (2014)
Fines correction method:	B&I (2014)
Points to test:	Based on Ic value
Earthquake magnitude M_w :	6.14
Peak ground acceleration:	0.34
Depth to water table (insitu):	3.10 m

Depth to GWT (erthq.):	3.10 m	Fill weight:	N/A
Average results interval:	1	Transition detect. applied:	Yes
Ic cut-off value:	2.60	K_o applied:	Yes
Unit weight calculation:	Based on SBT	Clay like behavior applied:	Same
Use fill:	No	Limit depth applied:	No
Fill height:	N/A	Limit depth:	N/A

SBT legend

- | | | | | | |
|--------------------------------------|---------------------------|---|-----------------------------|---|----------------------------|
| █ | 1. Sensitive fine grained | █ | 4. Clayey silt to silty | █ | 7. Gravely sand to sand |
| █ | 2. Organic material | █ | 5. Silty sand to sandy silt | █ | 8. Very stiff sand to |
| █ | 3. Clay to silty clay | █ | 6. Clean sand to silty sand | █ | 9. Very stiff fine grained |

CPT basic interpretation plots (normalized)



Input parameters and analysis data

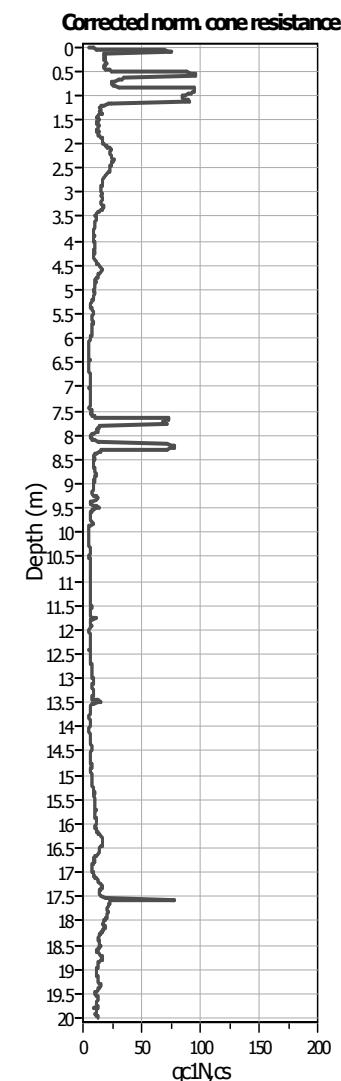
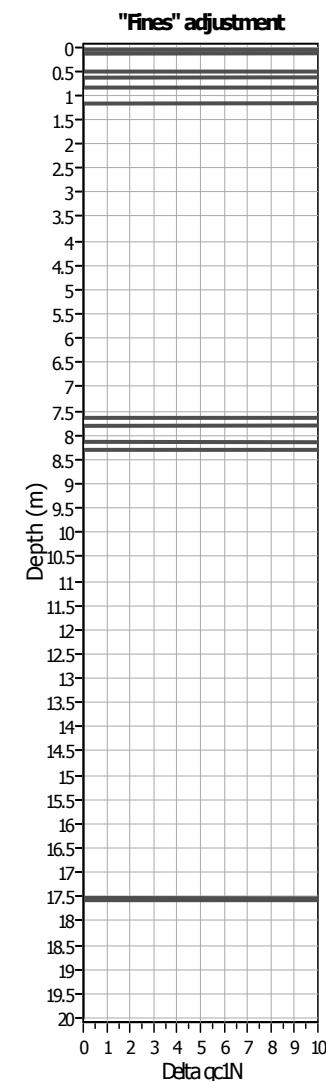
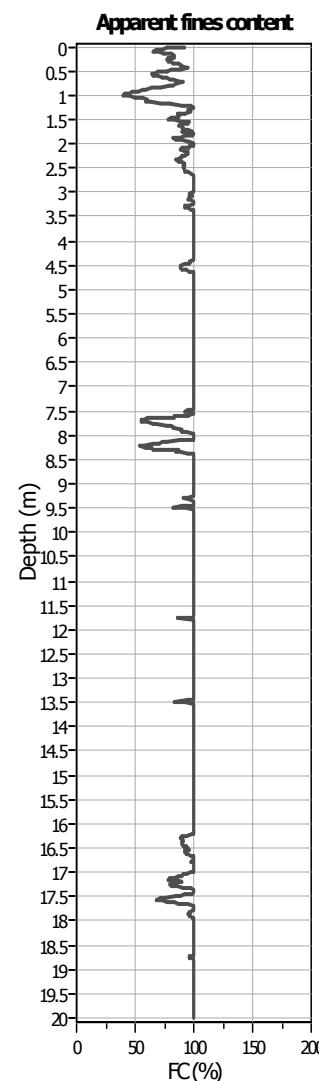
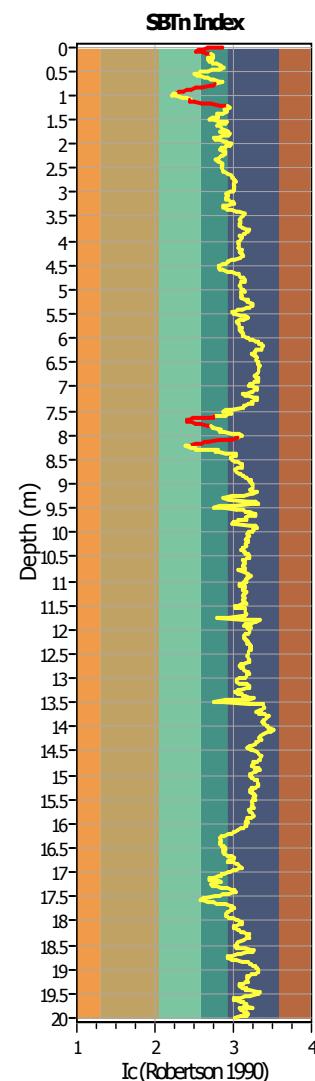
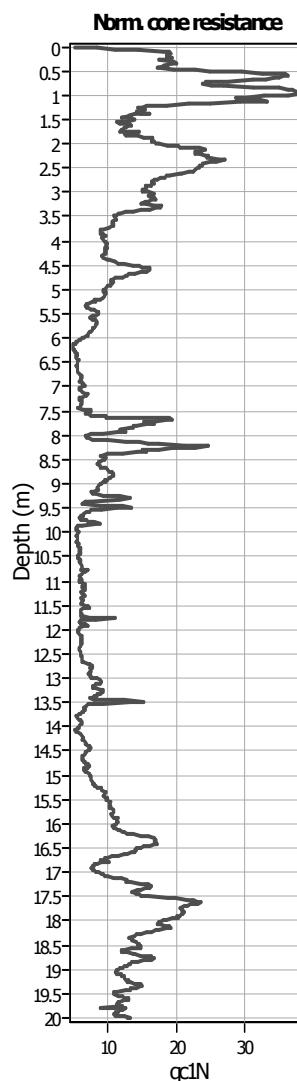
Analysis method:	B&I (2014)
Fines correction method:	B&I (2014)
Points to test:	Based on Ic value
Earthquake magnitude M_w :	6.14
Peak ground acceleration:	0.34
Depth to water table (insitu):	3.10 m

Depth to GWT (erthq.):	3.10 m	Fill weight:
Average results interval:	1	Transition detect. applied:
Ic cut-off value:	2.60	K_g applied:
Unit weight calculation:	Based on SBT	Clay like behavior applied:
Use fill:	No	Limit depth applied:
Fill height:	N/A	Limit depth:

N/A
Yes
Yes
Sands only
No
N/A

SBTn legend

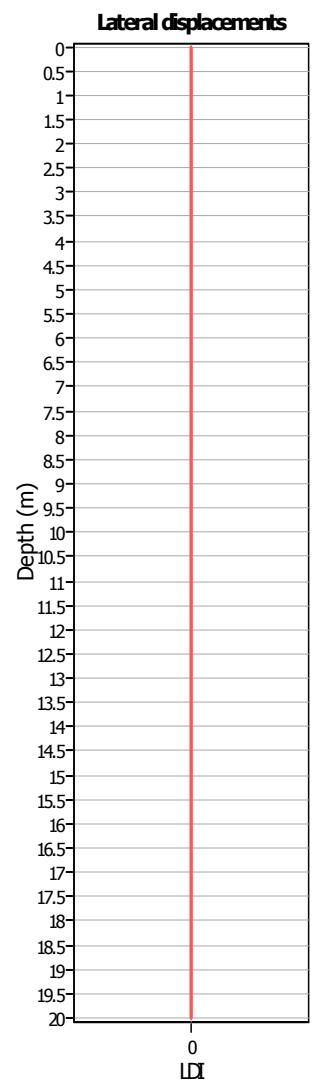
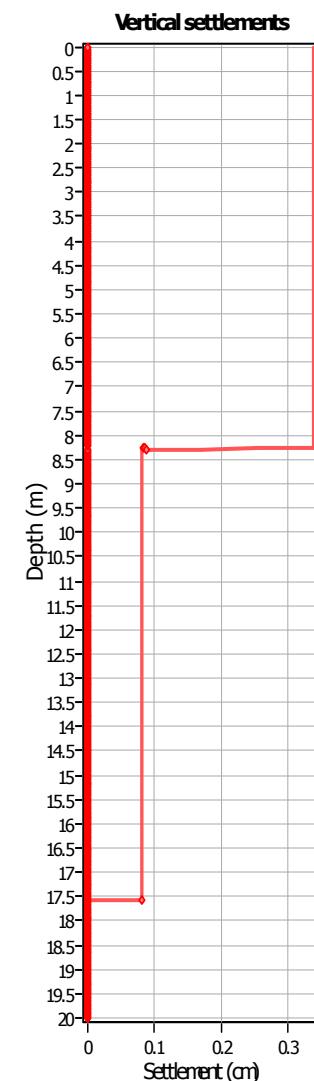
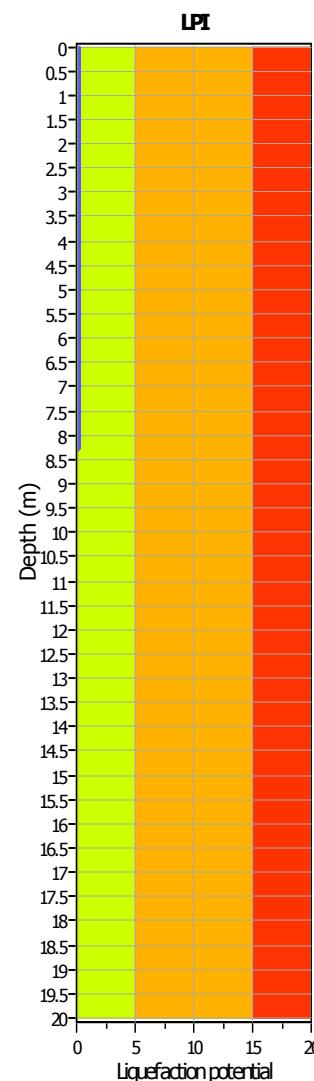
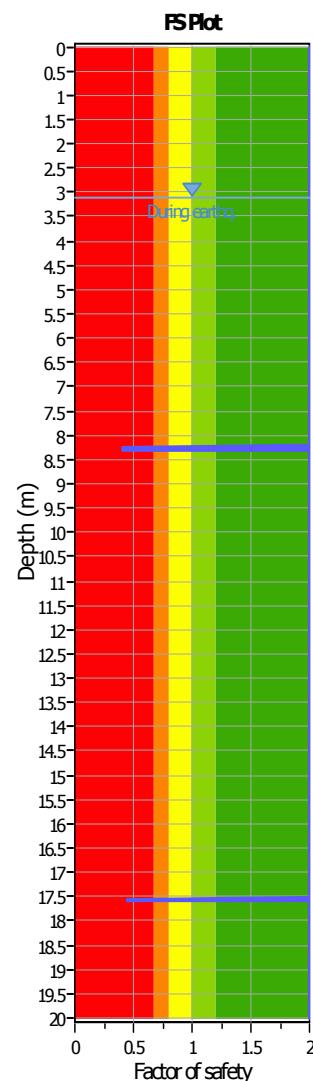
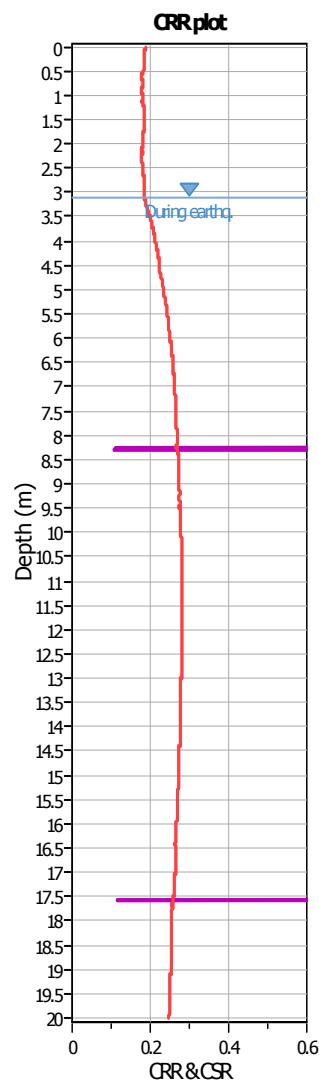
- | | | | | | |
|--------------------------------------|---------------------------|--|-----------------------------|---|----------------------------|
| █ | 1. Sensitive fine grained | █ | 4. Clayey silt to silty | █ | 7. Gravely sand to sand |
| █ | 2. Organic material | █ | 5. Silty sand to sandy silt | █ | 8. Very stiff sand to |
| █ | 3. Clay to silty clay | █ | 6. Clean sand to silty sand | █ | 9. Very stiff fine grained |

Liquefaction analysis overall plots (intermediate results)**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.10 m

Depth to GWT (erthq.): 3.10 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

Liquefaction analysis overall plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.10 m

Depth to GWT (erthq.): 3.10 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight:
 Transition detect. applied:
 K_0 applied:
 Clay like behavior applied:
 Limit depth applied:
 Limit depth:

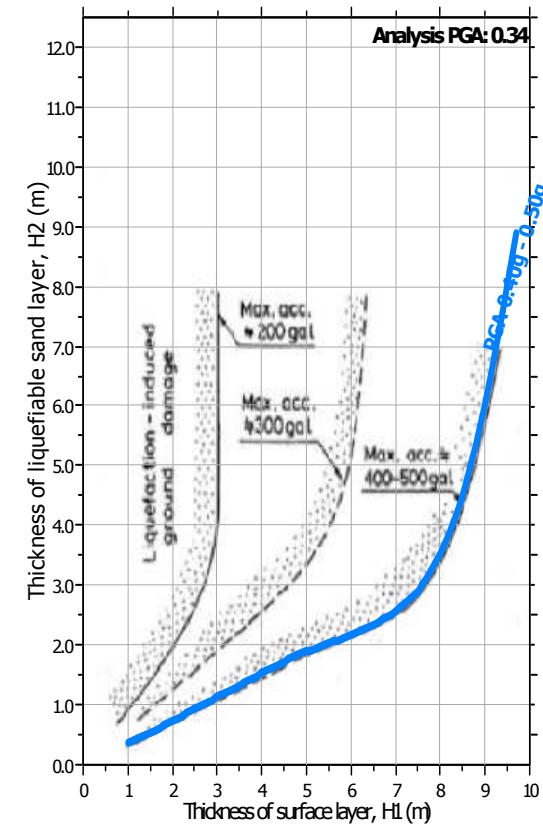
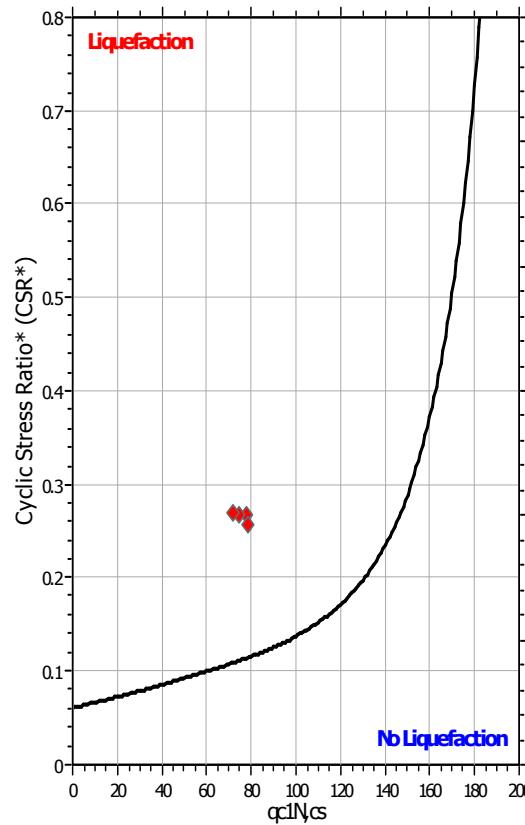
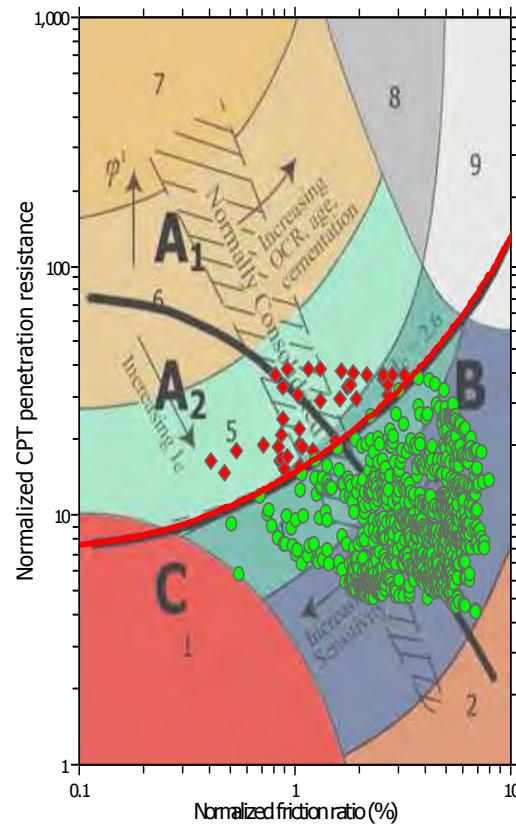
N/A
 Yes
 Yes
 Sands only
 No
 N/A

F.S. color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

LPI color scheme

Very high risk
 High risk
 Liquefaction and no liq. are equally likely
 Unlike to liquefy
 Almost certain it will not liquefy

Liquefaction analysis summary plots**Input parameters and analysis data**

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 6.14
 Peak ground acceleration: 0.34
 Depth to water table (in situ): 3.10 m

Depth to GWT (erthq.): 3.10 m
 Average results interval: 1
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

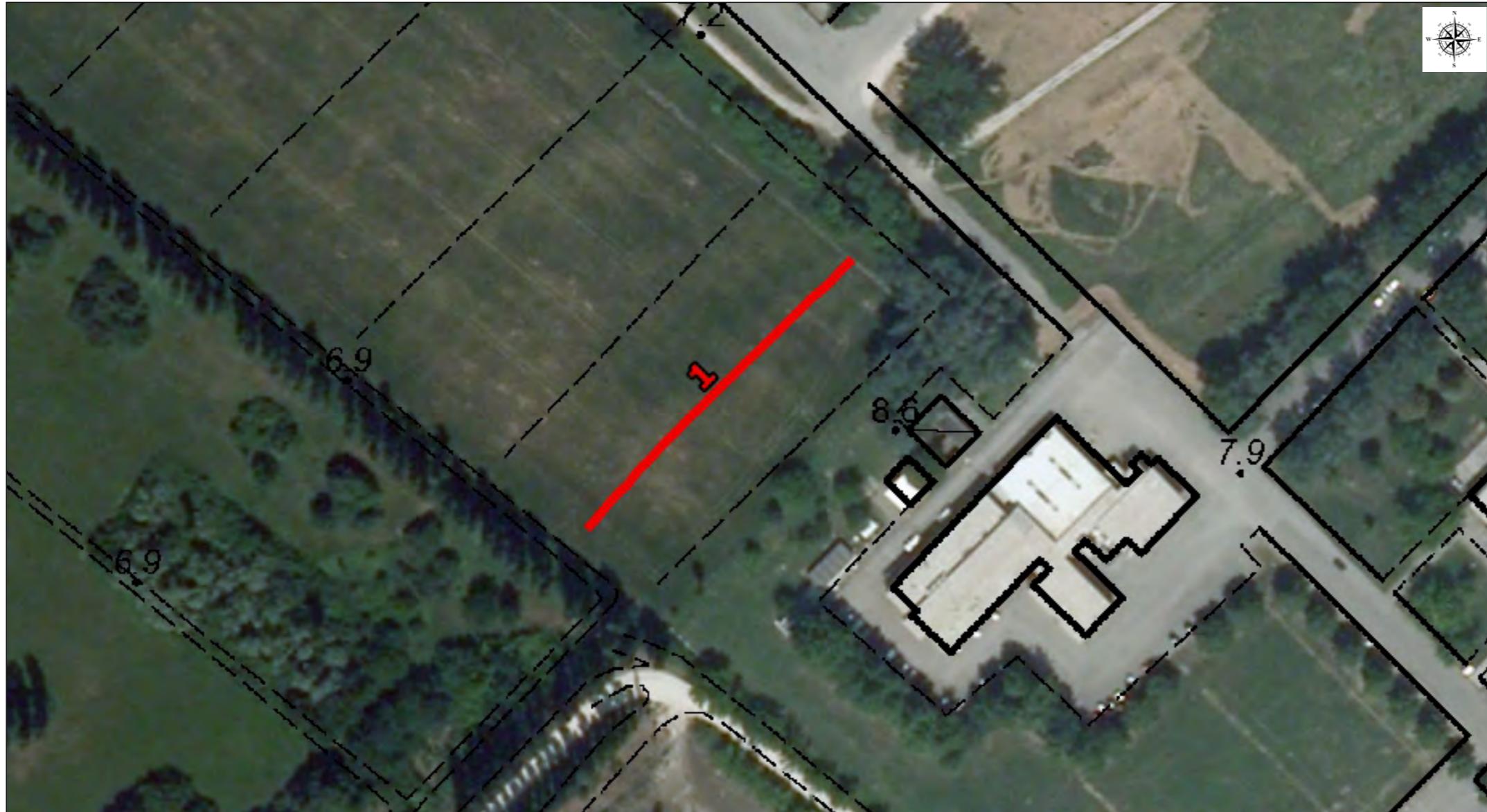
Fill weight:
 Transition detect. applied: Yes
 K_0 applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

G E O G R O U P s.r.l.

Indagini geognostiche e geofisiche – geologia applicata alle costruzioni – laboratorio geotecnico –
idrogeologia – coltivazione cave – bonifiche – consolidamenti – geologia ambientale – consulenze
geologiche e geotecniche



ALLEGATO 6
INDAGINE TOMOGRAFICA ELETTRICA ERT



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182, via C. Costa 41100 Modena
Tel. 059/3967169 - Fax. 059/5960176
e-mail: info@geogroupmodena.it

SEZIONE GEOELETTRICA

ERT 1

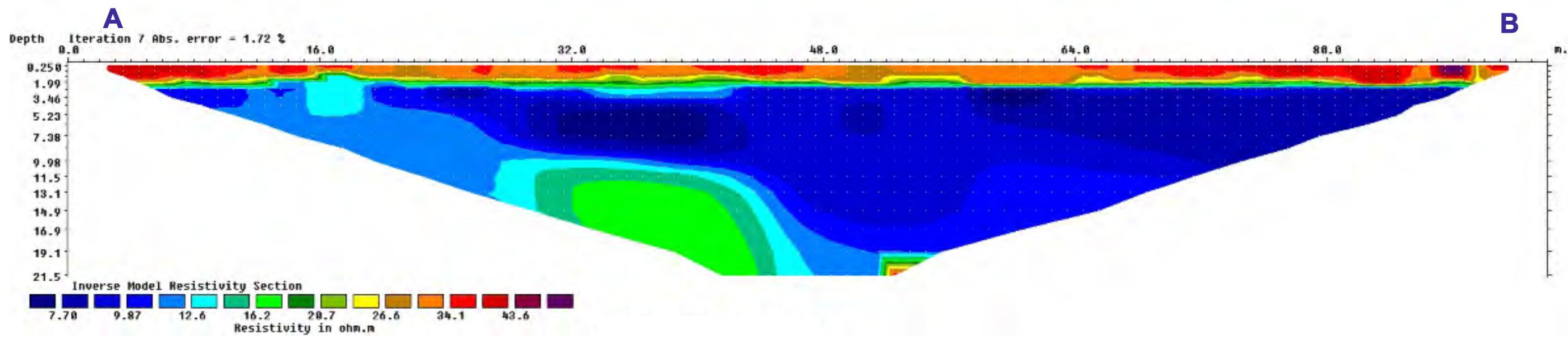
SCALA GRAFICA

FERRARA (FE)
RIF. 218/18

Caratteristiche stendimento:

- 48 elettrodi
- offset 2 m
- lunghezza totale 94 m

Sequenza:
- dipolo-dipolo





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Tel. 059/3967169 - Fax. 059/5960176
e-mail: info@geogroupmodena.it

SEZIONE GEOELETTRICA

ERT 2

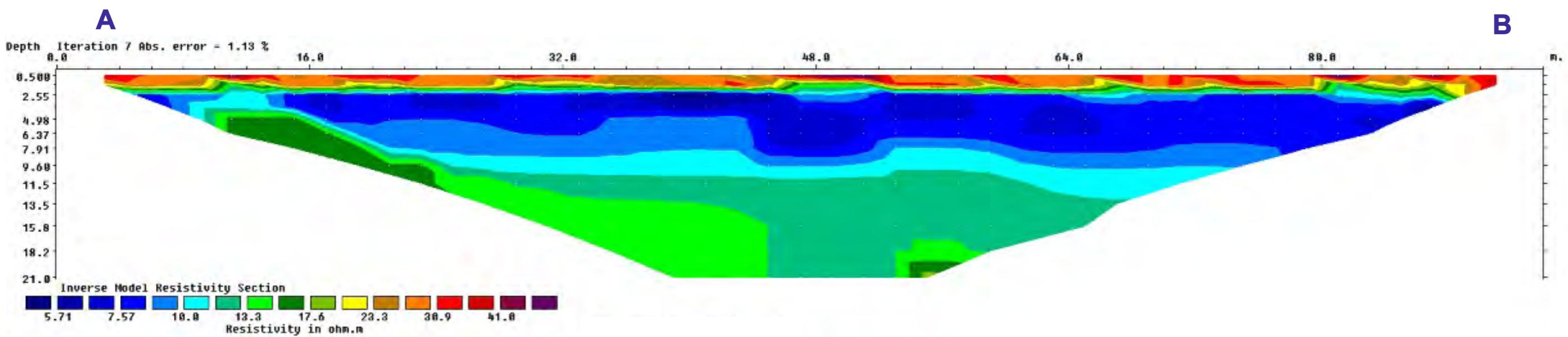
SCALA GRAFICA

FERRARA (FE)
RIF. 218/18

Caratteristiche stendimento:

- 48 elettrodi
- offset 2 m
- lunghezza totale 94 m

Sequenza:
- dipolo-dipolo





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e-mail: info@geogroupmodena.it

SEZIONE GEOELETTRICA

ERT 3

SCALA GRAFICA

FERRARA (FE)
RIF. 218/18

Caratteristiche stendimento:

- 48 elettrodi
- offset 2 m
- lunghezza totale 94 m

Sequenza:
- wenner

