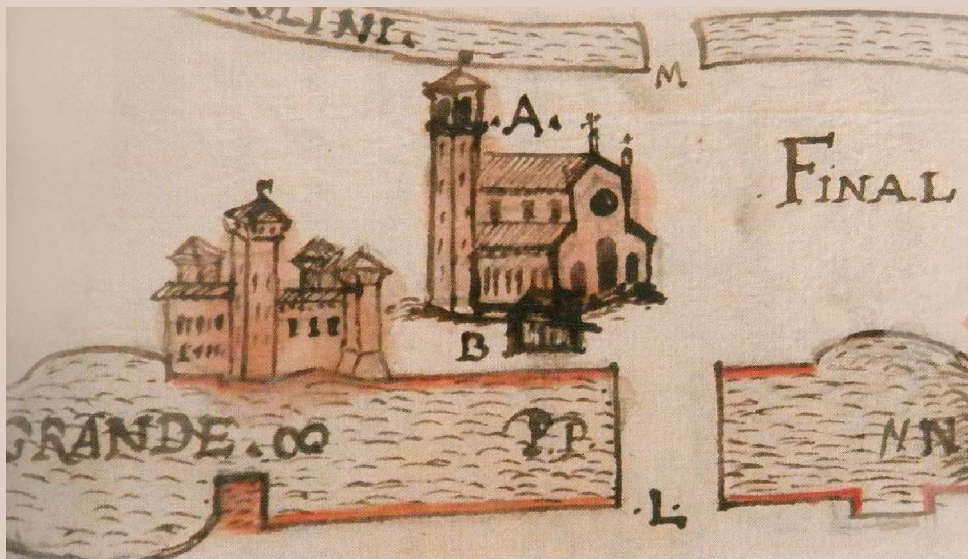


LAVORI DI RIPRISTINO CON MIGLIORAMENTO SISMICO DELLA CHIESA DEI SANTI FILIPPO E GIACOMO (DUOMO) DI FINALE EMILIA DANNEGGIATA DAL SISMA DEL 20/29 MAGGIO 2012 – ID 2163 - CIG: 6489971D7B CUP: I79G13000680005

PROGETTO ESECUTIVO



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P.I Emanuela Becchi

OPERE GENERALI

INTEGRAZIONE INDAGINE GEOLOGICA



PARTE D'OPERA	DISCIPLINA	DOC. E PROG.	FASE REV.
0001	XX	RG01	3 0

Cartella	File name	Prot.	Scala	Formato
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0	EMISSIONE PER GARA DI APPALTO	MARZO 2018	Geo Group	M.Goldoni M.Goldoni
REV.	DESCRIZIONE	Data	REDATTO	VERIFICATO APPROVATO

Comune di Finale Emilia Provincia di Modena

RELAZIONE TECNICA



OGGETTO:

**Integrazione alla relazione Rif. 371/15
inerente lo studio del terreno di fondazione
della "Chiesa dei Santi Filippo e Giacomo"
di Finale Emilia (MO)**

DUOMO DI FINALE EMILIA



Dott. Geol. Pier Luigi Dallari

Giugno 2016
INT. Rif. 371/15

ASSOCIATO



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GEOTECNICA ITALIANA



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**AZIENDA CON SISTEMA
DI GESTIONE QUALITÀ
CERTIFICATO DA DNV
= ISO 9001 =**

Relazione Tecnica

comprendente

OGGETTO

Integrazione alla relazione Rif. 371/15 inerente lo studio del terreno di fondazione della "Chiesa dei Santi Filippo e Giacomo" di Finale Emilia (MO)

LOCALITÀ

Via C. Battisti
Comune di Finale Emilia
Provincia di Modena

A cura di:



GEO GROUP s.r.l.

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ALLEGATI

ALL. n. 1 Verifica della suscettibilità alla liquefazione;

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1. PREMESSE

Su indicazione dei progettisti, nel mese di Giugno 2016 è stata redatta la presente integrazione alla relazione Rif. n. 371/15 (Luglio 2015) a cura di Geo Group S.r.l., inerente lo studio del terreno di fondazione della "Chiesa dei Santi Filippo e Giacomo" sita in Via C. Battisti nel Comune di Finale Emilia (MO). Le predette integrazioni concernono l'aggiornamento dell'analisi di risposta sismica locale RSL e delle relative verifiche a liquefazione, considerando un valore di Vita Nominale inferiore a quanto precedentemente considerato ai fini della redazione del documento datato Luglio 2015.

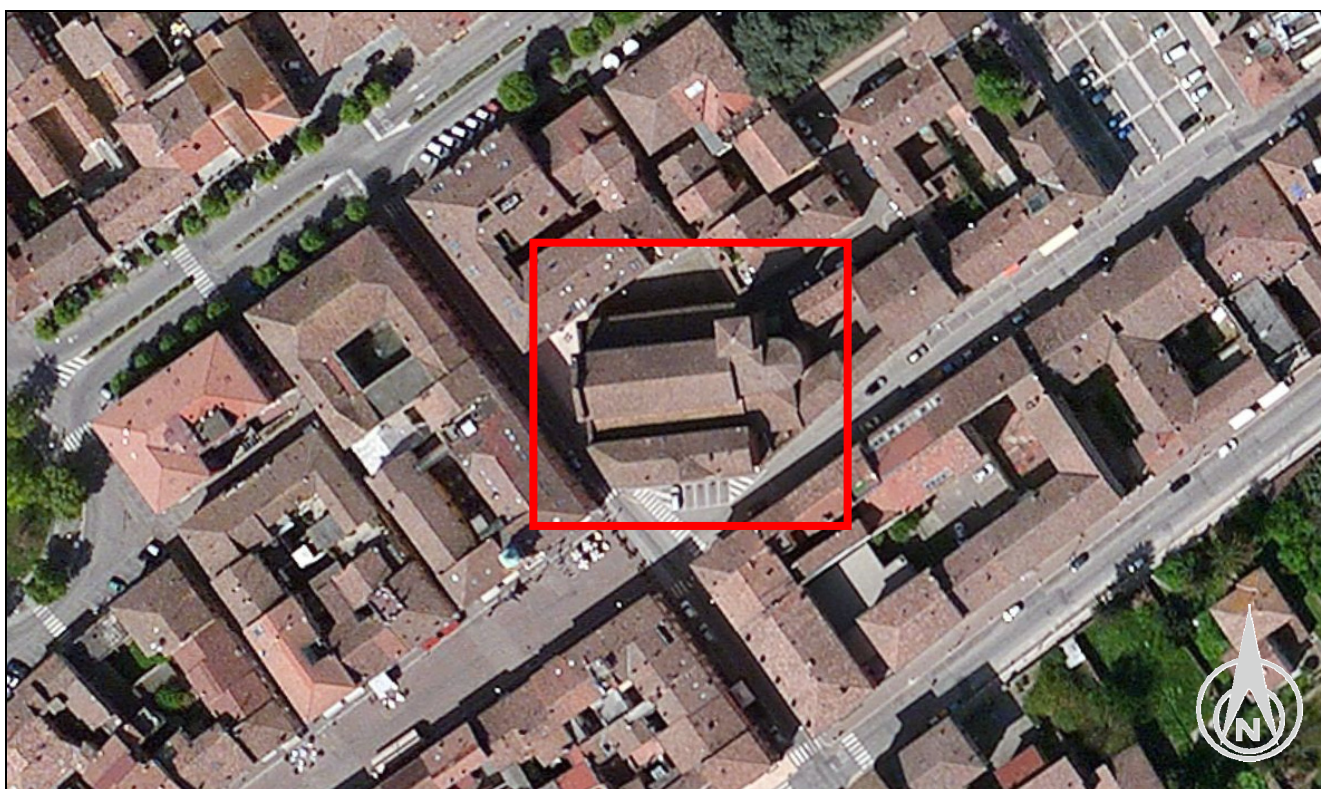


Fig. 1.1 – Inquadramento geografico dell'area di interesse; immagine tratta da *Bing Maps*.

Le coordinate geografiche relative al sito in oggetto sono le seguenti:

SITO IN ESAME	
COORDINATE GEOGRAFICHE ED 50	
LATITUDINE	LONGITUDINE
44,833333	11,297174

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2. AZIONE SISMICA DI RIFERIMENTO

2.1 APPROCCIO SEMPLIFICATO NNTC 2008

Si procede a identificare l'azione sismica di riferimento alla progettazione, considerando le indicazioni fornite dai progettisti.

Sulla base della nuova normativa sismica per gli edifici (D.M. 14 Gennaio 2008), secondo le indagini geofisiche eseguite in sito si classifica il terreno di fondazione del lotto in oggetto, come appartenente alla **categoria C**, corrispondente a depositi di terreni a grana grossa mediamente addensati o terreni a grana fine di media consistenza con spessori superiori a 30 metri, caratterizzati da un graduale miglioramento delle proprietà meccaniche con la profondità e da valori di Vs30 compresi tra 180 m/s e 360 m/s (ovvero $15 < NSPT_{30} < 50$ nei terreni a grana grossa e $70 < cu_{30} < 250$ KPa nei terreni a grana fine).

Sulla scorta dei contenuti del D.M. 14/01/2008 è stato definito un parametro di accelerazione massima attesa a_g in relazione a un tempo di riferimento T_R stimato pari a 712 anni, considerando una classe d'uso pari a III ($Cu=1.5$) e una vita nominale pari a 50 anni.

Per l'area in oggetto, identificata dalle seguenti coordinate geografiche (ED50): Latitudine: 44,833333° e Longitudine: 11,297174°, tale parametro è risultato pari ad $a_{g \text{ attesa}} = 0.176g$.

Stato Limite	Tr [anni]	a_g [g]	Fo	Tc' [s]
Operatività (SLO)	45	0,048	2,492	0,265
Danno (SLD)	75	0,062	2,503	0,275
Salvaguardia vita (SLV)	712	0,176	2,559	0,274
Prevenzione collasso (SLC)	1462	0,235	2,494	0,283
Periodo di riferimento per l'azione sismica:	75			

Ai fini della definizione dell'azione sismica, determinata la pericolosità sismica di base, occorre valutare gli **effetti di sito** mediante specifiche analisi di risposta sismica locale.

Per la definizione dell'azione sismica, sulla base di quanto previsto dalle N.N.T.C., si può fare riferimento ad un approccio semplificato che **si basa sull'individuazione della categoria di sottosuolo e le condizioni topografiche del sito**, in funzione delle quali si definiscono l'entità dell'amplificazione stratigrafica e topografica.

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Si ricava quindi il **fattore stratigrafico S_s** , caratteristico del sito secondo le N.N.T.C. - D.M. 14/01/2008, mediante la seguente relazione, valida suoli in classe **C**:

$$1.00 \leq S_s = 1.70 - (0.60 \cdot F_o \cdot a_g/g) \leq 1.50 \quad (4.1.1)$$

dove:

- F_o = fattore che quantifica l'amplificazione spettrale massima, su sito di riferimento rigido orizzontale, ed ha valore minimo pari a 2.2; per il sito oggetto di studio tale valore, calcolato mediante l'utilizzo di apposito software, risulta pari a **2.559**;
- a_g/g = accelerazione orizzontale del sito, con tempo di ritorno pari a **712** anni/accelerazione di gravità;
- S_s = coefficiente di amplificazione stratigrafica o fattore stratigrafico, calcolato tramite la relazione 4.1.1; per il sito oggetto di studio risulta pari a **1.43**.

Per l'area studiata, sita in una zona di pianura e appartenente quindi alla categoria topografica **T1**, si ottiene un fattore topografico S_T pari a **1.0**.

$$A_{max} = S_s \cdot S_T \cdot a_g = 1.43 \cdot 1.0 \cdot 0.176 g = 0.251 g$$

2.2 STUDIO DI RISPOSTA SISMICA LOCALE

In accordo con le indicazioni dei progettisti è stata eseguita nuovamente l'analisi di risposta sismica locale RSL, considerando come riferimento un valore di $C_u = 1.5$ e $V_n = 50$. Per l'accurata descrizione del modello simulato durante l'analisi RSL, così come le curve di decadimento del modulo di taglio iniziale e del dumping, si faccia riferimento alla relazione redatta da Geo Group s.r.l. Rif. 371/15. Gli accelerogrammi impiegati per la precedente analisi sono stati scalati per il valore di $a_g = 0.176g$ attesa al suolo rigido.

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.

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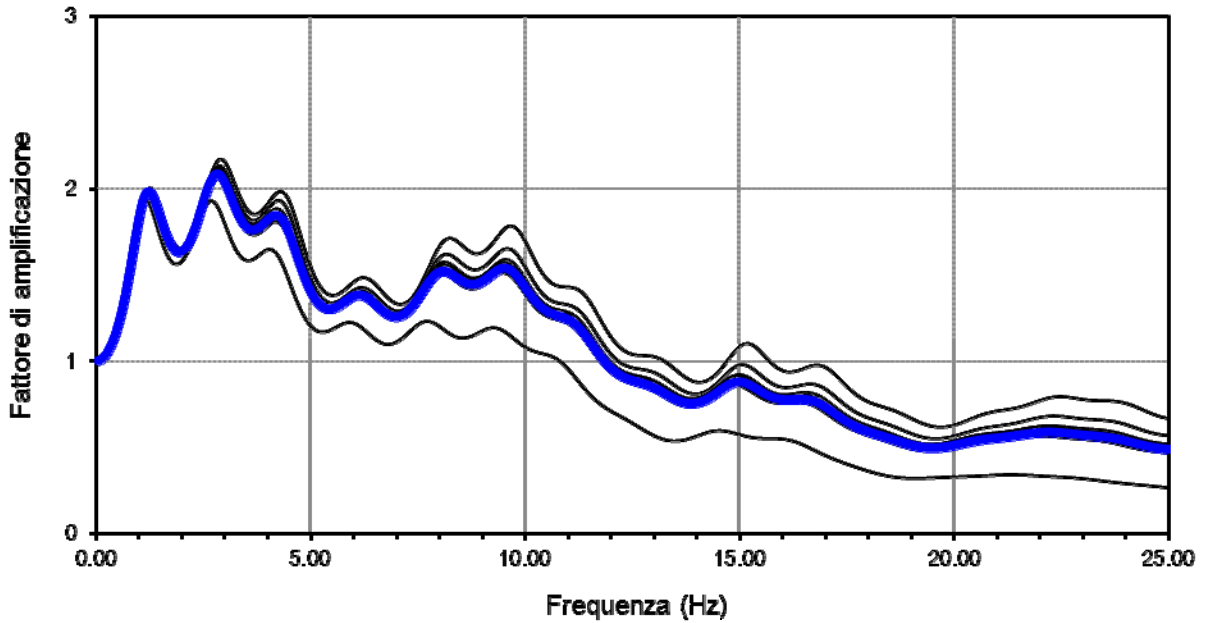
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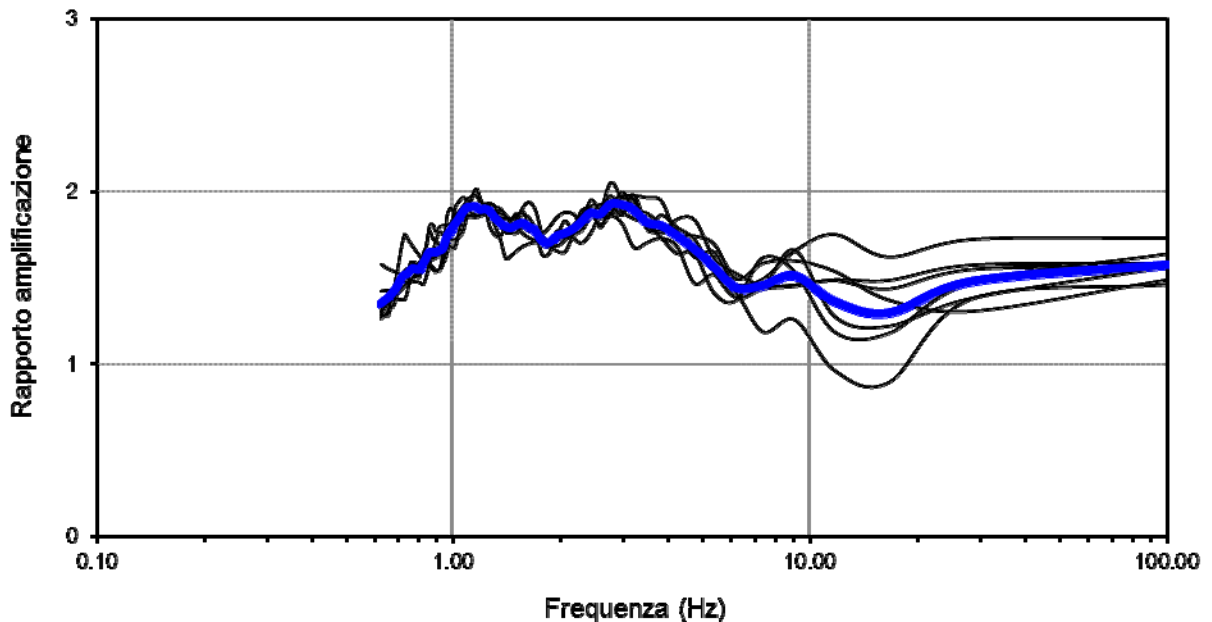


Attraverso tale funzione è possibile definire il campo di frequenze entro il quale il sottosuolo, in corrispondenza del sito in oggetto, amplifica il segnale sismico, oltre che a quantificare l'amplificazione stessa.

FUNZIONE DI TRASFERIMENTO



RAPPORTO SPETTRALE



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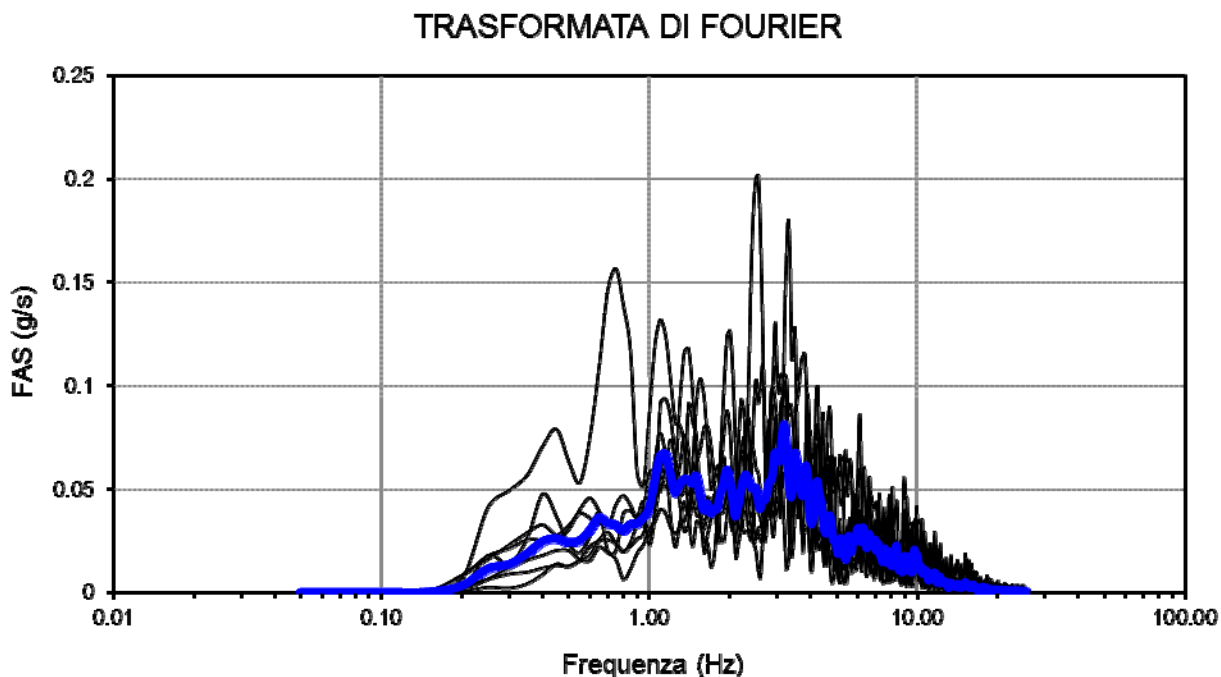


Fig.

2.1: 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:

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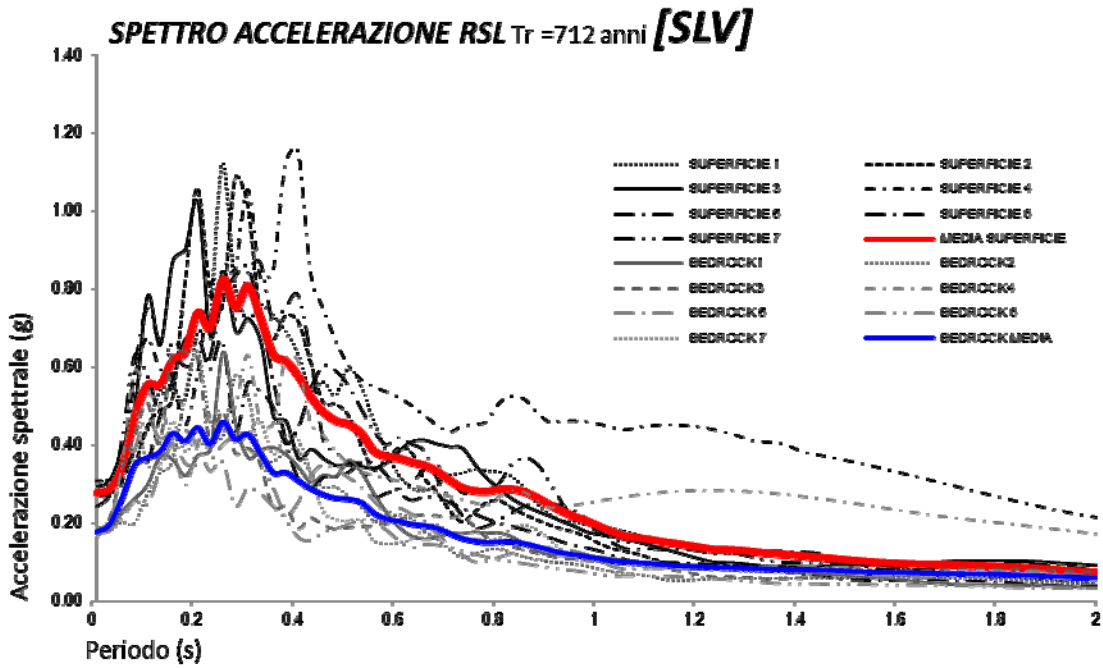


Fig. 2.2: Accelerazioni spettrali relative a un periodo di ritorno pari a 712 anni (SLV).

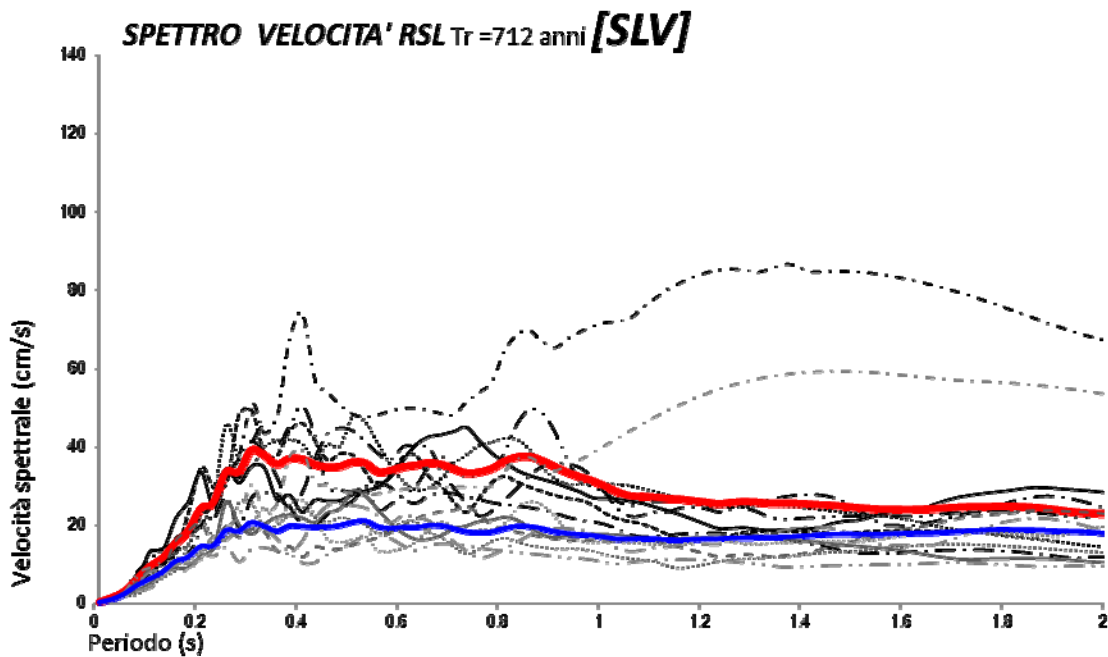


Fig. 2.3: Velocità spettrali relative a un periodo di ritorno pari a 712 anni (SLV).

Dati i valori di accelerazione ottenuti dal calcolo eseguito, è stato definito lo spettro normalizzato per lo stato limite considerato. Così facendo è stato ottenuto lo spettro a probabilità uniforme, sulla base dei risultati ottenuti mediante il software STRATA.

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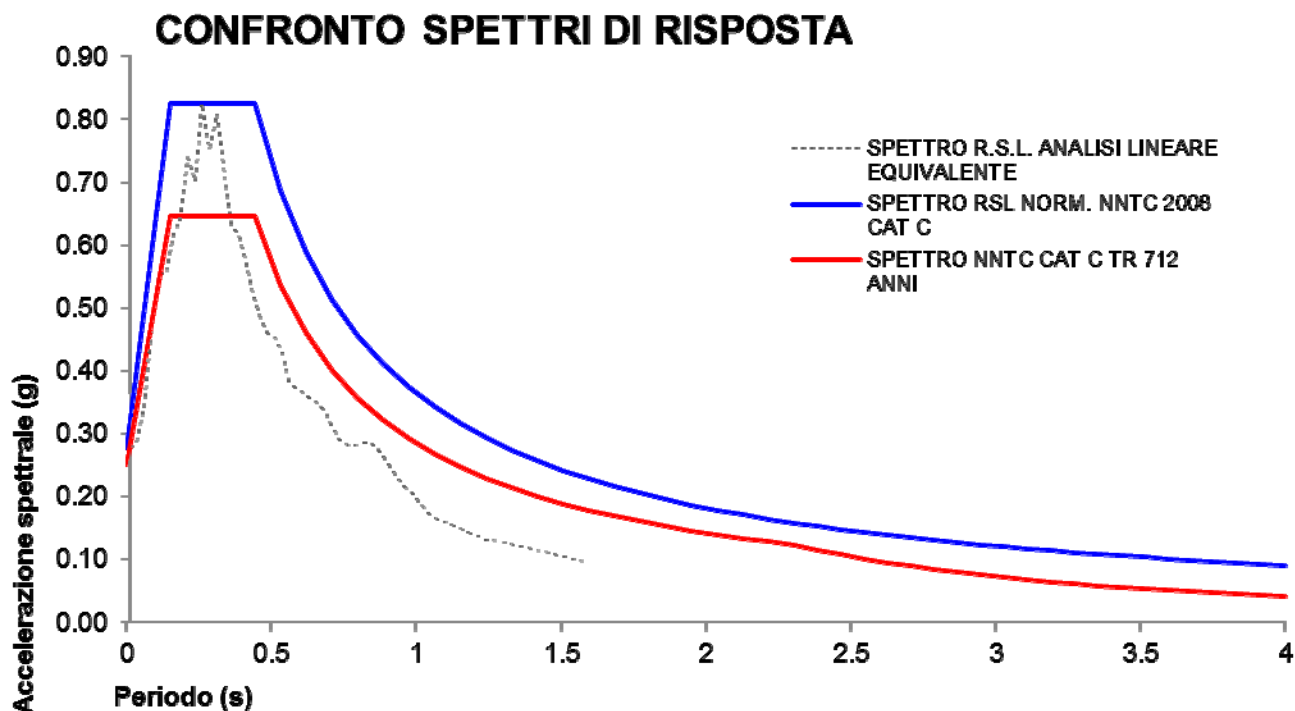


Fig. 2.4: Confronto tra lo spettro di accelerazione calcolato secondo NTC (CAT. C-SLV) (in rosso o) e lo spettro di accelerazione normalizzato ottenuto dal calcolo mediante software STRATA (in blu) (SLV).

Da quanto è possibile osservare nelle figure appena riportate, lo spettro calcolato per una categoria di sottosuolo C, sottostima l'azione sismica per il sito in oggetto nella prima porzione dello spettro considerato (Intervallo T(s) compreso tra 0.00 s e 0.440 s). Considerando quindi gli spettri derivanti dall'analisi RSL è possibile definire un'azione sismica maggiore rispetto a quella identificata dall'approccio semplificato NNTC.

Poiché lo spettro generato a seguito dell'analisi svolta non è normalizzato secondo i parametri spettrali NNTC, si propone successivamente una normalizzazione dello spettro RSL calcolato. I parametri che identificano lo spettro normalizzato RSL sono i seguenti:

	Tr	Ag (g)	S	n	T*	f ₀	T _c (Sec)	T _b (Sec)	T _d (Sec)	Amax (g)
SLV	712	0.176	1.57	1	0.274	2.981	0.441	0.147	2.306	0.277

T (s)	Ag
0.000	0.277
0.147	0.825
0.441	0.825
0.530	0.687
0.619	0.588
0.707	0.514

T (s)	Ag
2.386	0.153
2.467	0.148
2.548	0.143
2.628	0.138
2.709	0.134
2.790	0.130

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0.796	0.457	2.870	0.127
0.885	0.411	2.951	0.123
0.974	0.374	3.032	0.120
1.063	0.343	3.112	0.117
1.151	0.316	3.193	0.114
1.240	0.293	3.274	0.111
1.329	0.274	3.354	0.108
1.418	0.257	3.435	0.106
1.506	0.242	3.516	0.104
1.595	0.228	3.597	0.101
1.684	0.216	3.677	0.099
1.773	0.205	3.758	0.097
1.862	0.195	3.839	0.095
1.950	0.187	3.919	0.093
2.039	0.178	4.000	0.091
2.128	0.171		
2.217	0.164		
2.306	0.158		

Tab. 5.1: Spettro NNTC normalizzato derivante dall'analisi RSL svolta.

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3. VERIFICA DEL FENOMENO DELLA LIQUEFAZIONE

A seguito dell'identificazione della nuova azione sismica, relativa a un valore di $C_u=1.5$ e un valore di $V_n = 50$ anni, è stata eseguita la verifica della suscettibilità del sito al fenomeno di liquefazione. Le metodologie impiegate per l'esecuzione delle verifiche sono analoghe a quelle adottate per le precedenti verifiche (Rif. 371/15).

Le verifiche eseguite per le n. 2 verticali di prova CPTU sono state svolte considerando l'azione sismica derivata sia secondo approccio semplificato ($A_{max}= 0.25$ g), sia sulla scorta dei risultati ottenuti a seguito dell'analisi RSL eseguita ($A_{max}=0.28$ g), utilizzando una magnitudo di riferimento pari a 6.14 e considerando una soggiacenza della falda freatica pari a -1.80 m da p.c., in accordo con quanto rilevato durante l'esecuzione delle indagini.

Si illustrano successivamente i risultati, espressi nei termini di indice potenziale di liquefazione LPI, ottenuti considerando le metodologie di calcolo secondo *Robertson e Wide* (1998) e *Boulanger e Idriss* (2008).

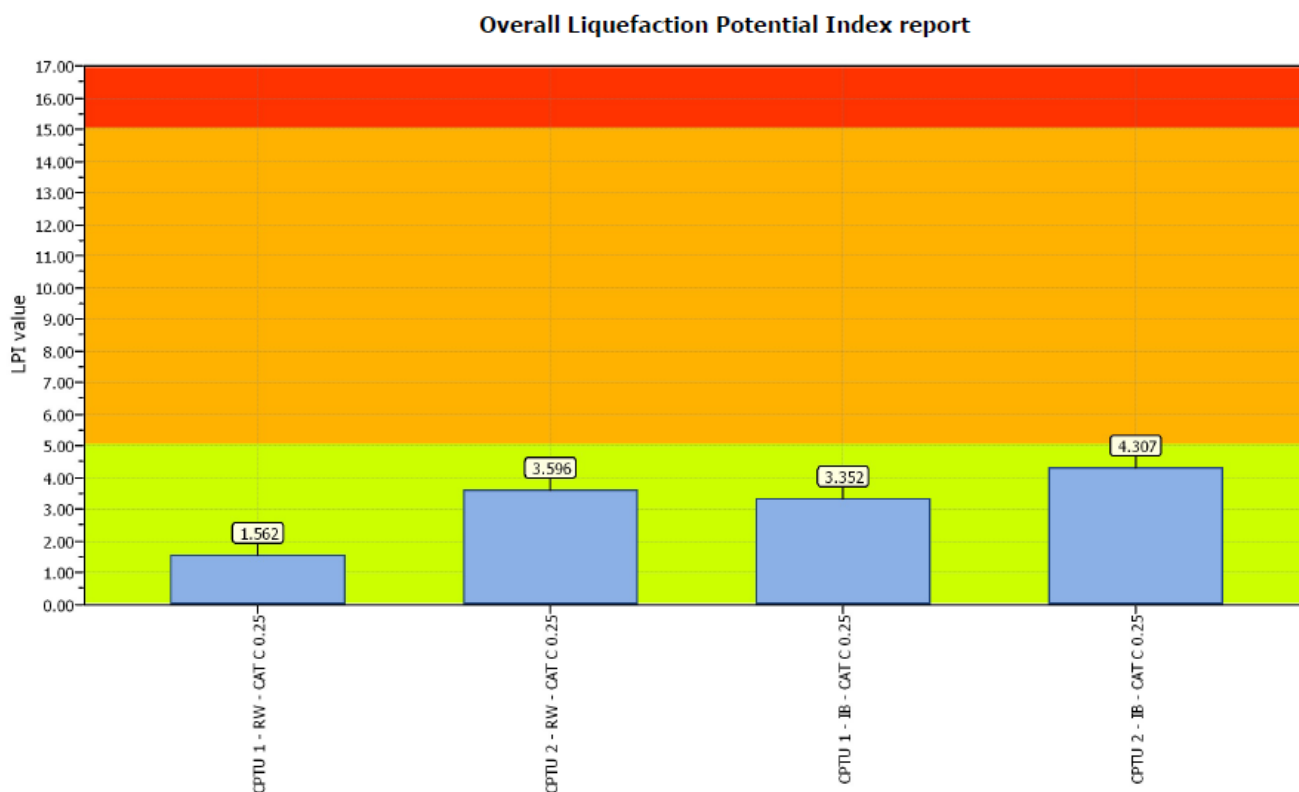


Fig. 3.1: Indici potenziali di liquefazione calcolati per l'azione sismica derivata da approccio semplificato NNTC 2008

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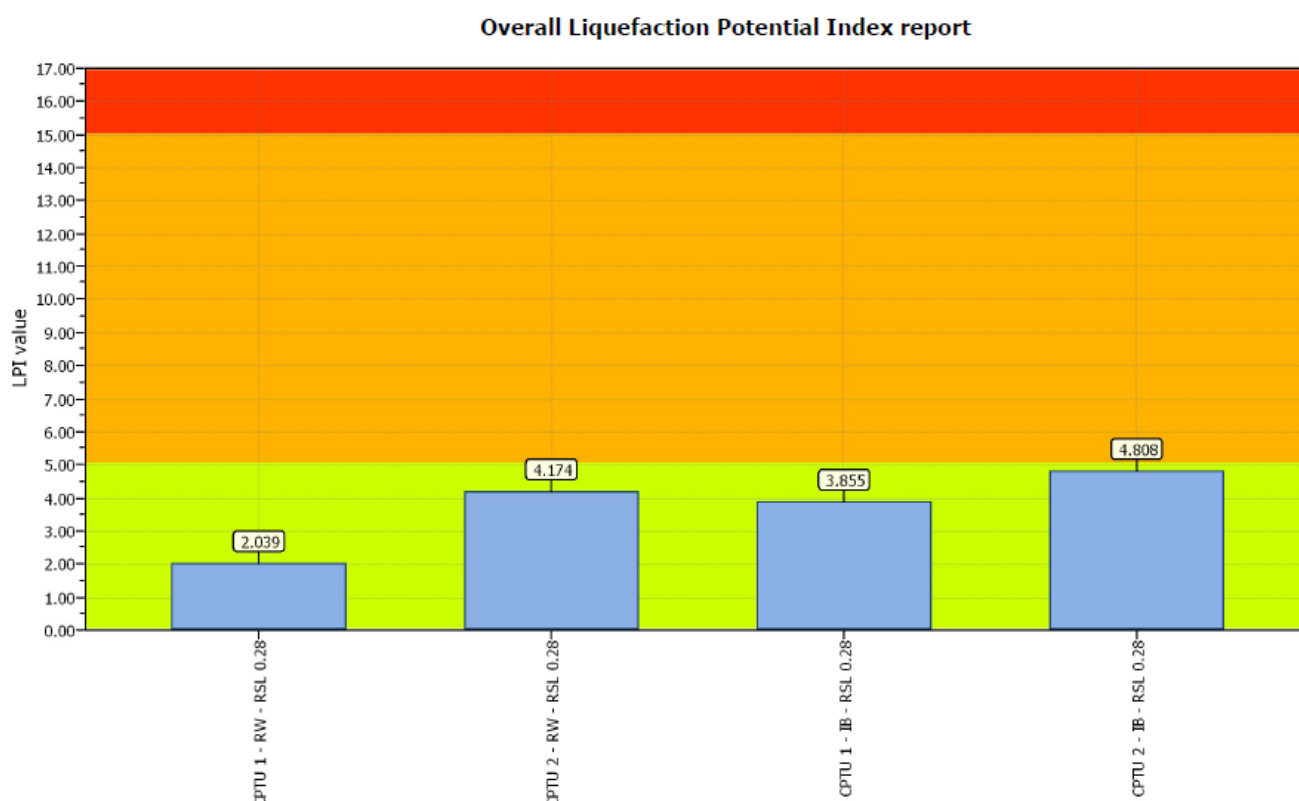


Fig. 3.2: Indici potenziali di liquefazione calcolati per l'azione sismica derivata secondo i risultati ottenuti dall'analisi RSL eseguita

Considerando le classificazioni di rischio proposte da Iwasaki e Somnez, il rischio di liquefazione derivato risulta variabile da "basso" a "moderato".



4. CONCLUSIONI

La presente relazione integra e aggiorna quanto verificato e illustrato nella precedente relazione da noi redatta nel mese di Luglio 2015 (Rif. 371/15), nella quale è contenuta la caratterizzazione geologica, geotecnica e sismica del volume significativo di sottosuolo in riferimento alla Chiesa dei Santi Filippo e Giacomo, sita in Via C. Battisti nel Comune di Finale Emilia.

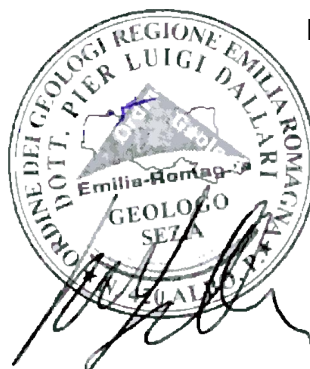
La seguente integrazione è stata resa necessaria a seguito della comunicazione da parte dei progettisti di una variazione del periodo di riferimento da considerare per la determinazione dell'azione sismica di progetto.

Sulla scorta di ciò è stata verificata nuovamente l'analisi RSL, congiuntamente alla verifica della suscettività del sito ai fenomeni di liquefazione secondo l'azione sismica di riferimento desunta alla luce dei nuovi parametri progettuali.

In accordo con quanto precedentemente illustrato, considerando un periodo di ritorno pari a 712 relativo allo stato limite di salvaguardia della vita SLV, il sito risulta esposto al fenomeno di liquefazione secondo una classe di rischio variabile da "basso" a "moderato". Si rammenta che, in accordo con il paragrafo 7.11.3.4.3 della normativa tecnica nazionale NNTC 2008, *l'adeguatezza del margine di sicurezza nei confronti della liquefazione deve essere valutata e motivata dal progettista*. Detto ciò, ogni valutazione riguardante la necessaria realizzazione di interventi di consolidamento e mitigazione dei fenomeni di liquefazione rimane a carico del progettista.

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

Modena, 9 Giugno 2016



Dott. Geol. Pier Luigi Dallari

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ALLEGATO N° 1

***VERIFICA DELLA SUSCETTIBILITÀ
DEL SITO AL FENOMENO DELLA
LIQUEFAZIONE***



LIQUEFACTION ANALYSIS REPORT

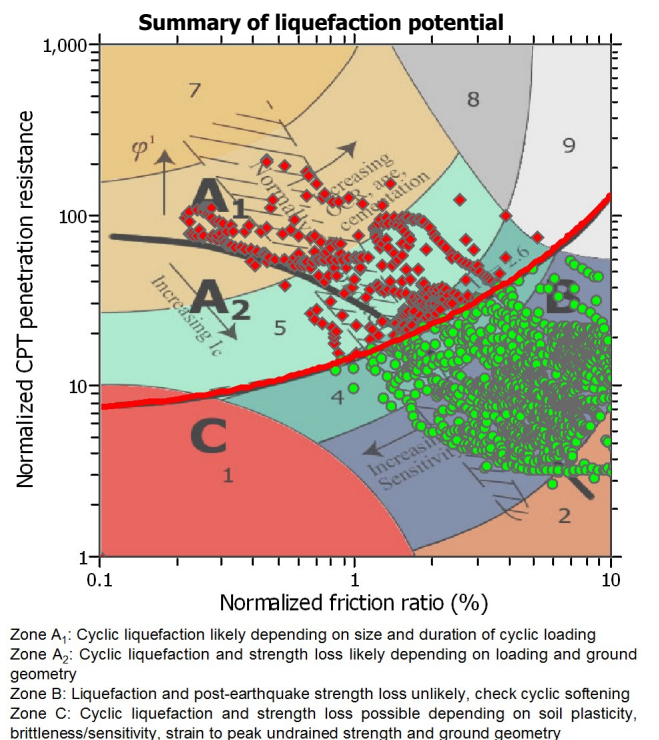
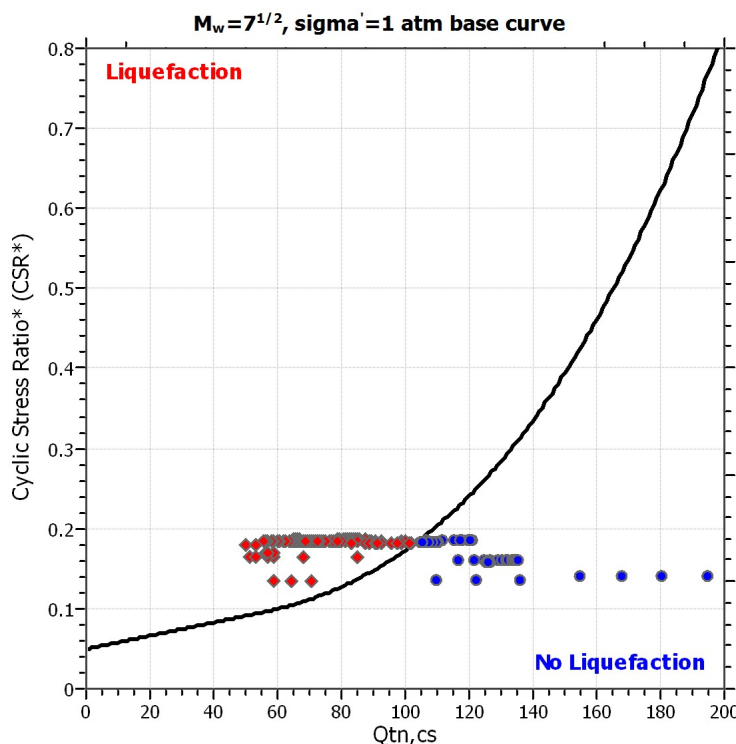
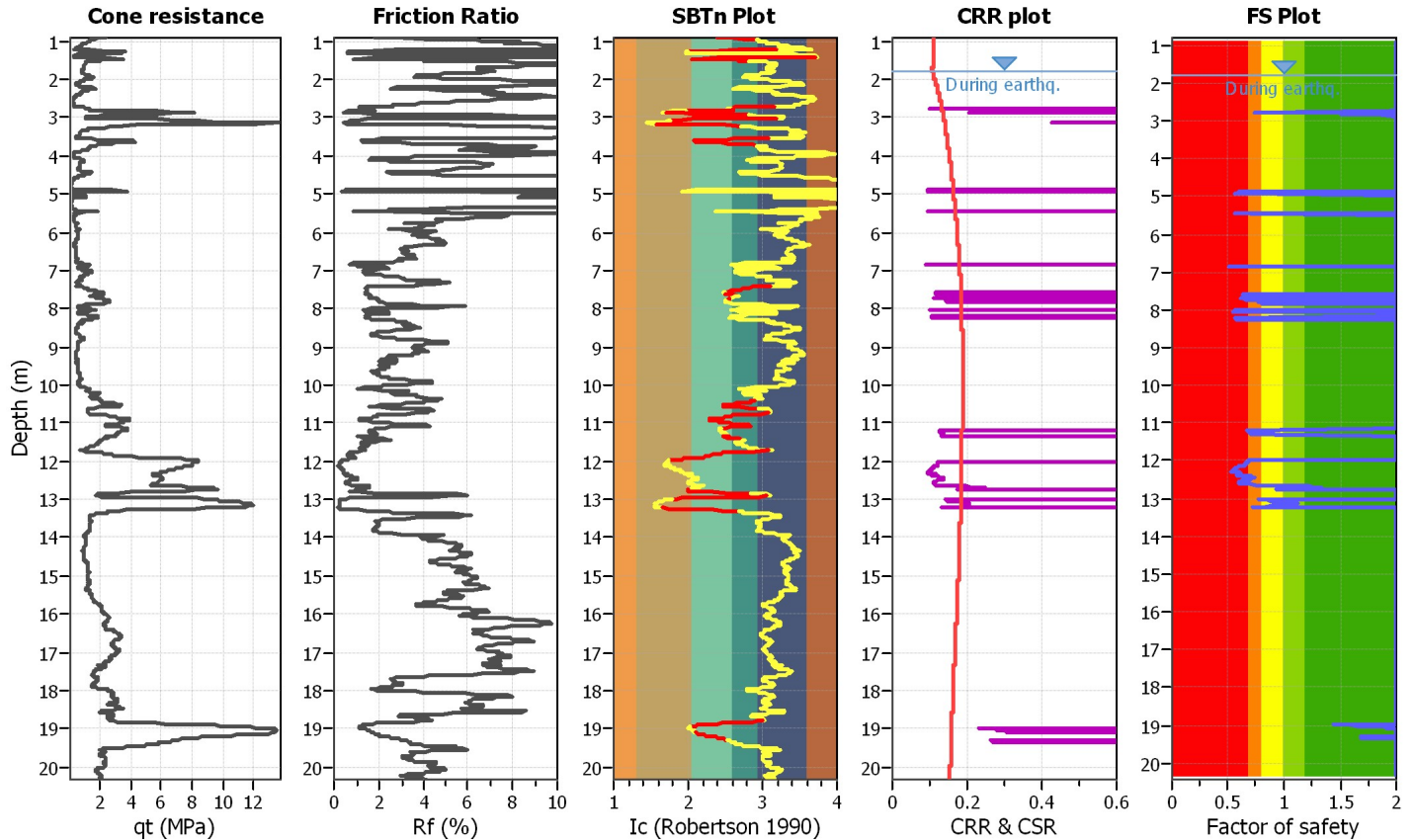
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Location : Duomo, Finale Emilia

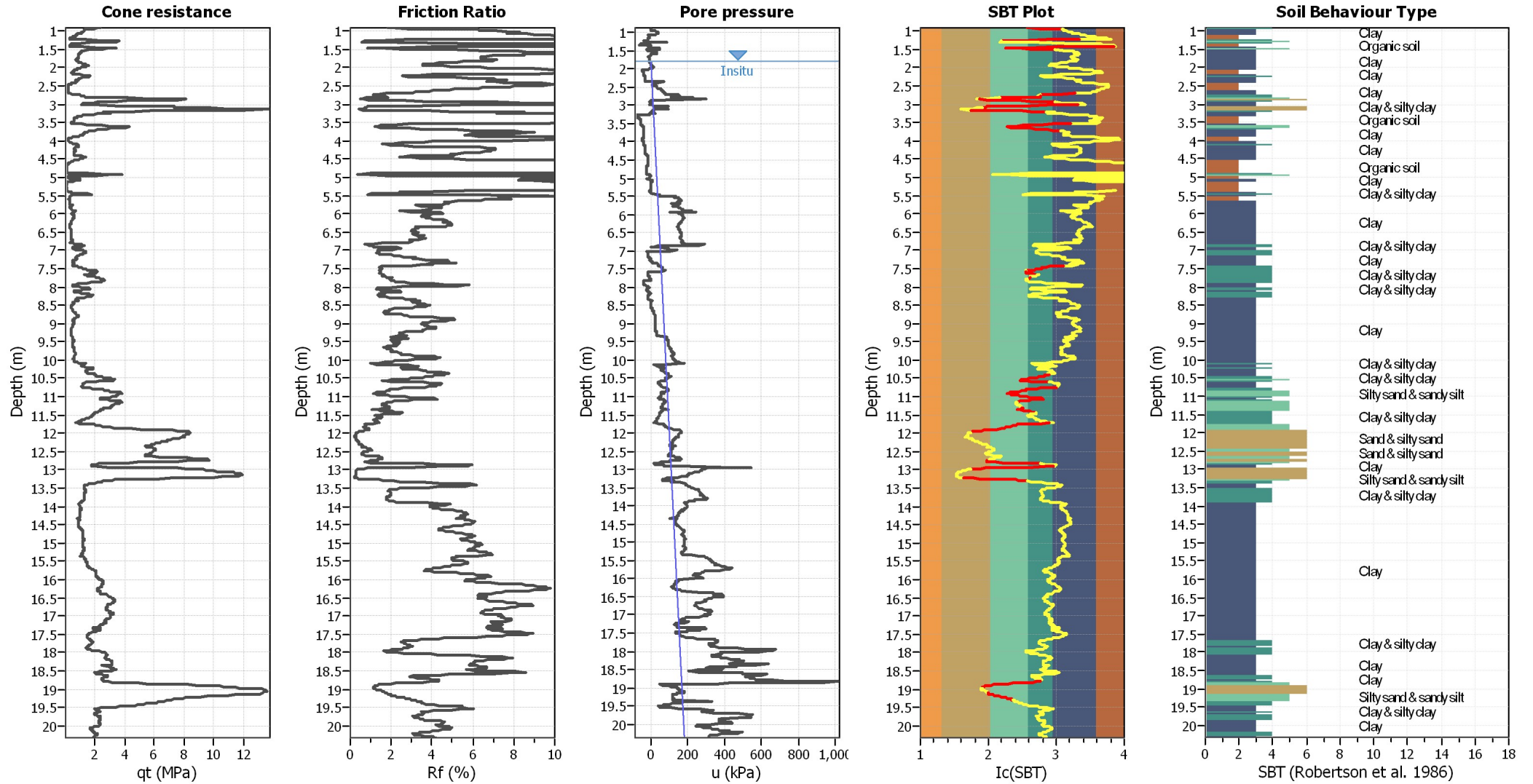
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Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	1.80 m	Use fill:	No	Clay like behavior	
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	1.80 m	Fill height:	N/A	applied:	Sands only
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth applied:	Yes
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	Limit depth:	20.00 m
Peak ground acceleration:	0.28	Unit weight calculation:	Based on SBT	K_g applied:	Yes	MSF method:	Method based



CPT basic interpretation plots



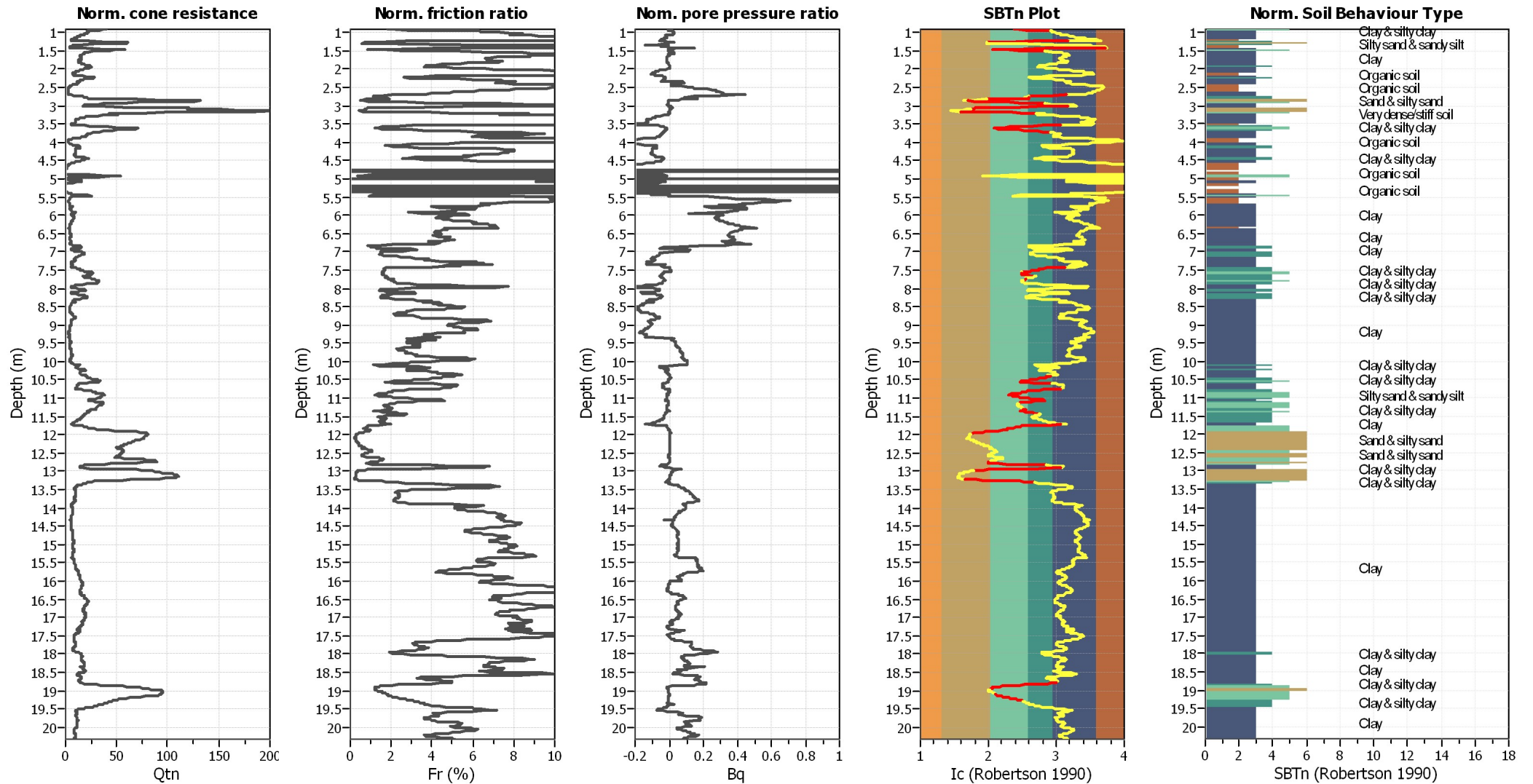
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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)



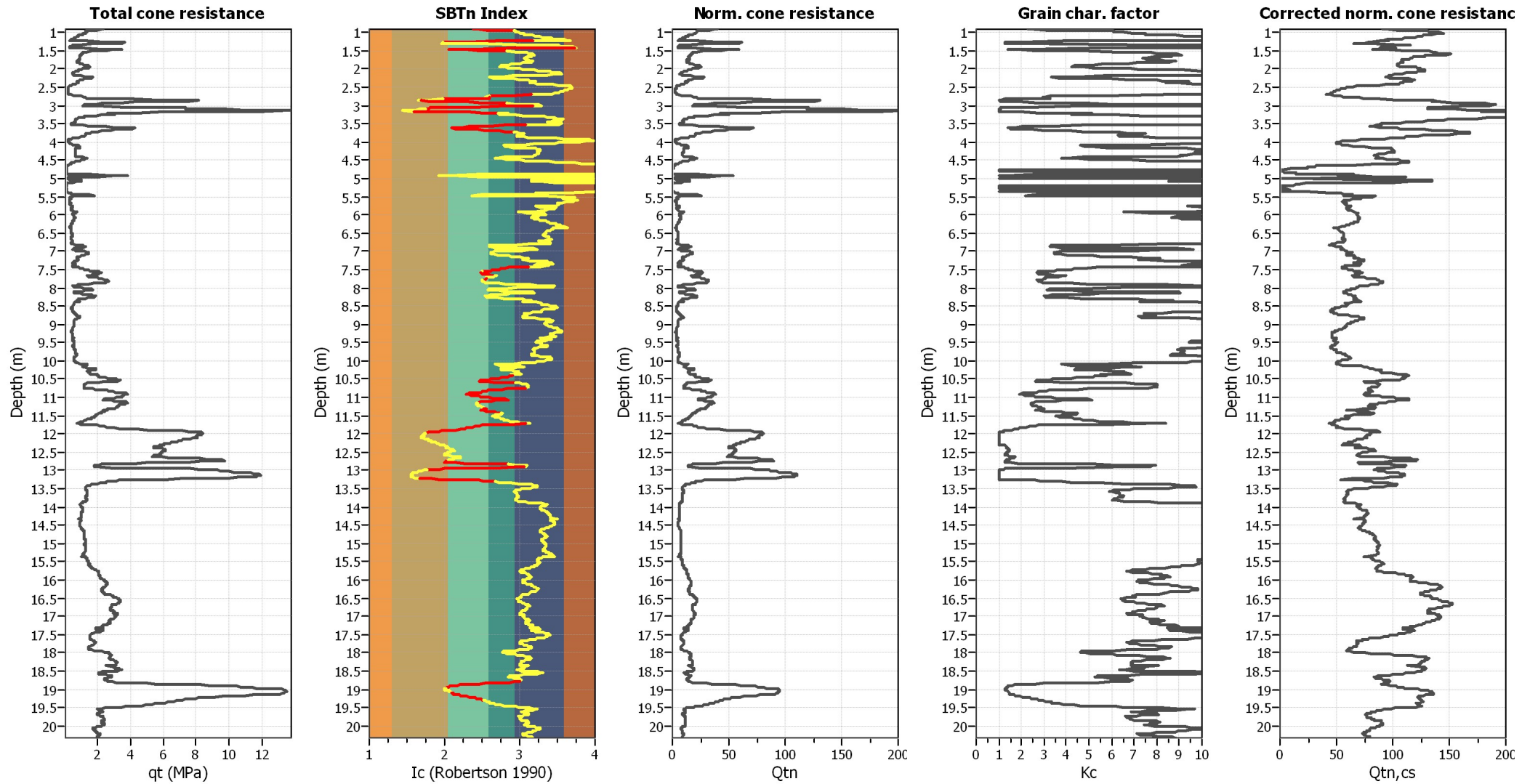
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_v applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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

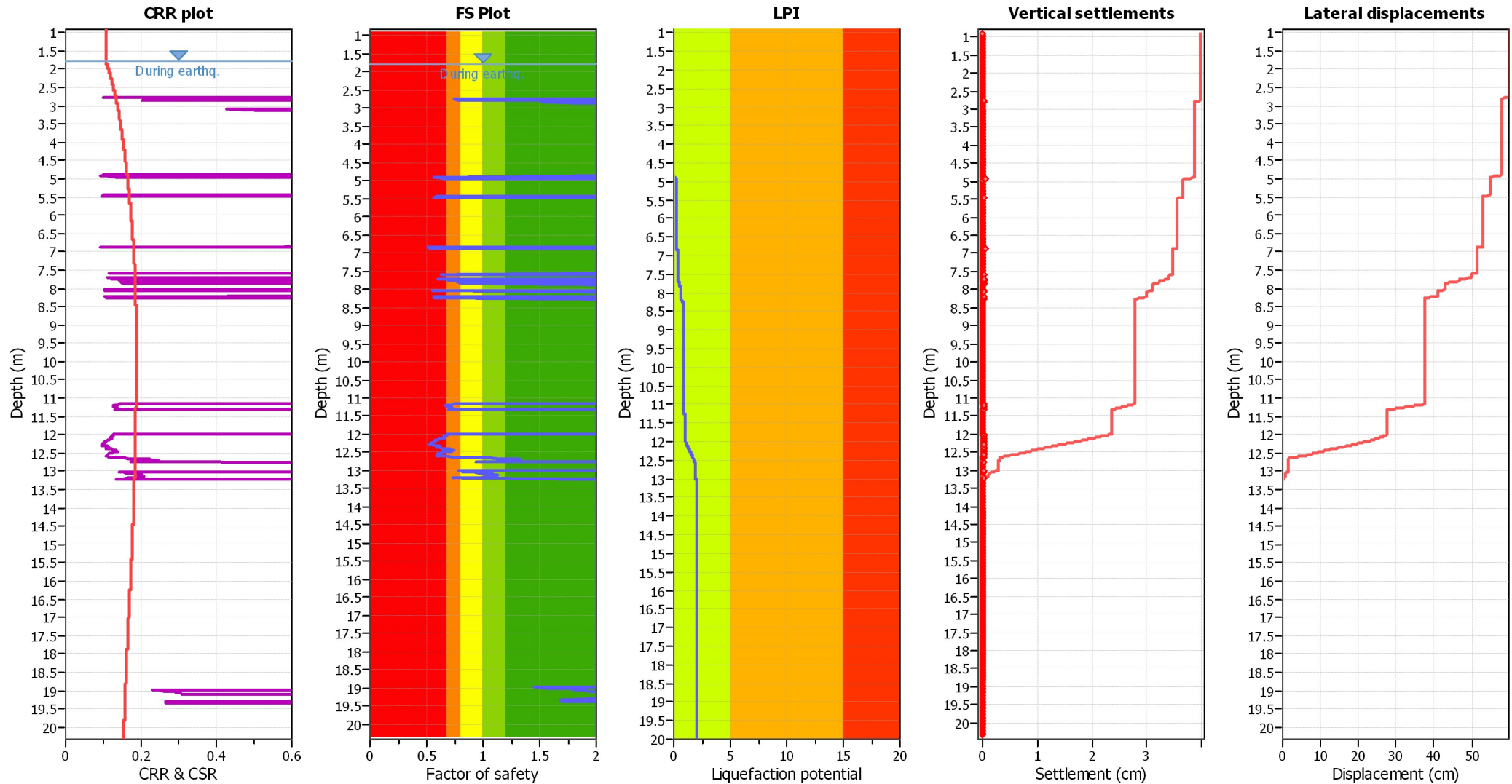
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _c applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{σ} applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

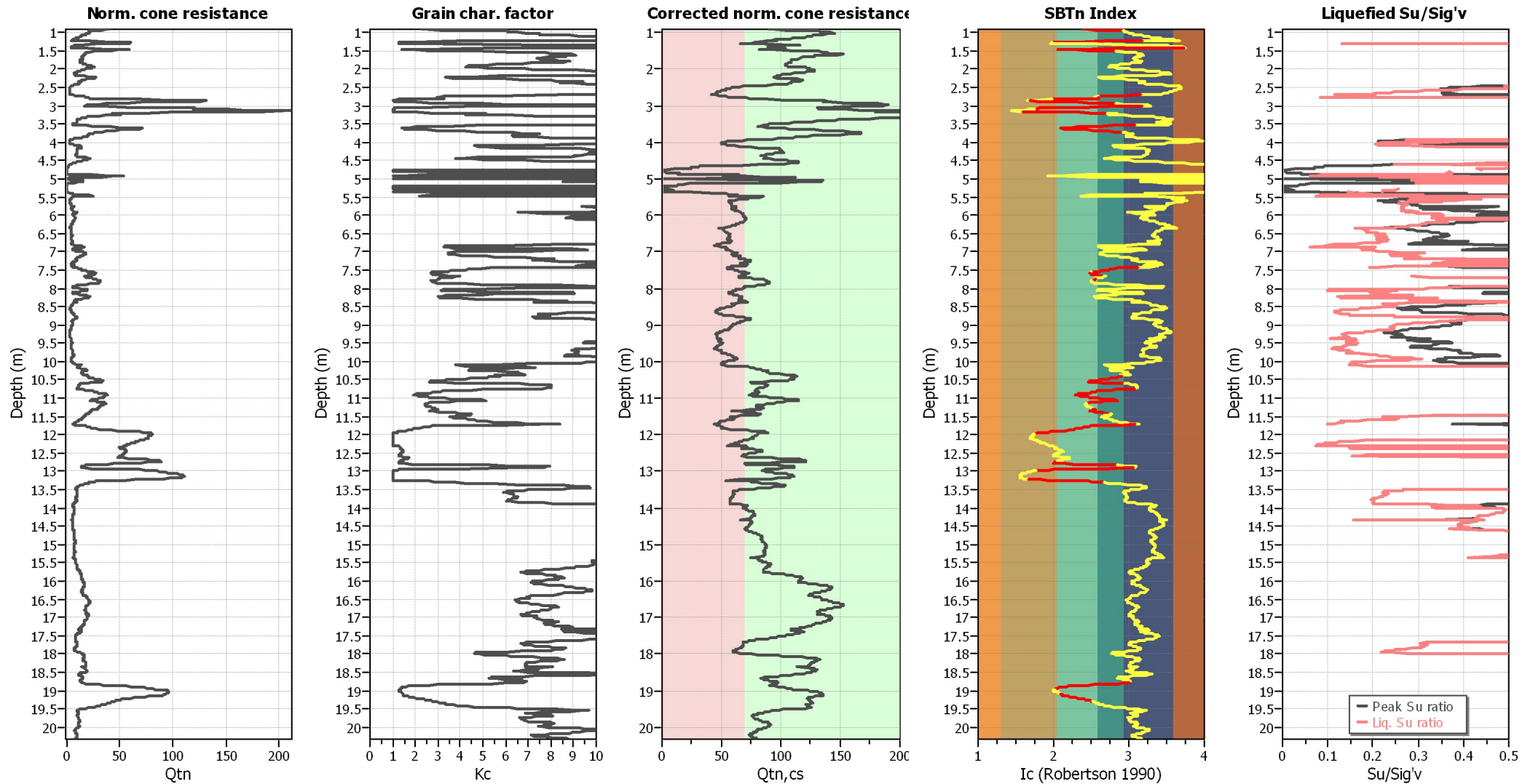
F.S. color scheme

- 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
- Low risk

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _{cs} applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m



LIQUEFACTION ANALYSIS REPORT

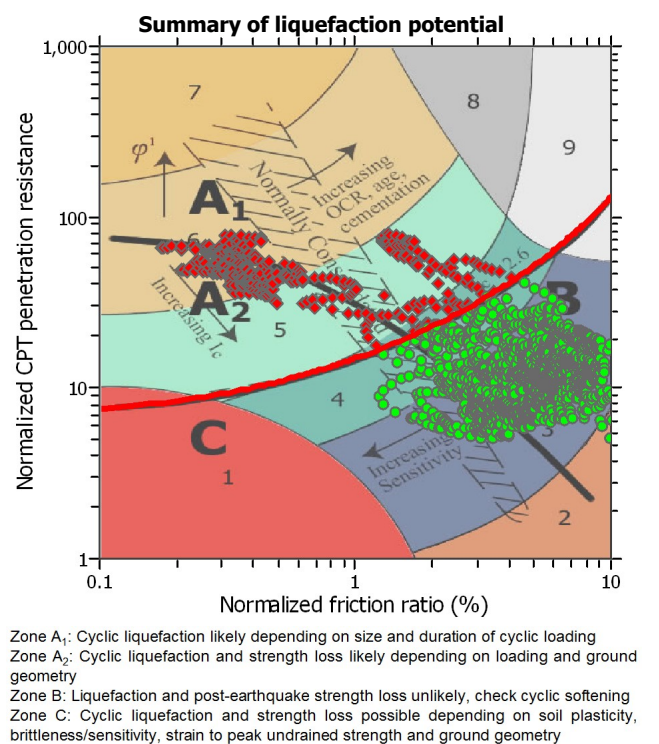
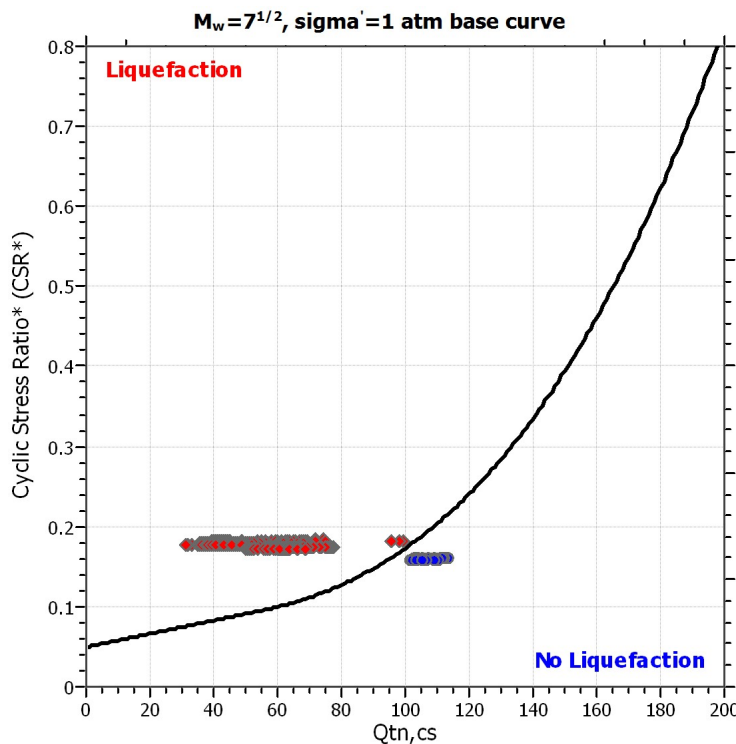
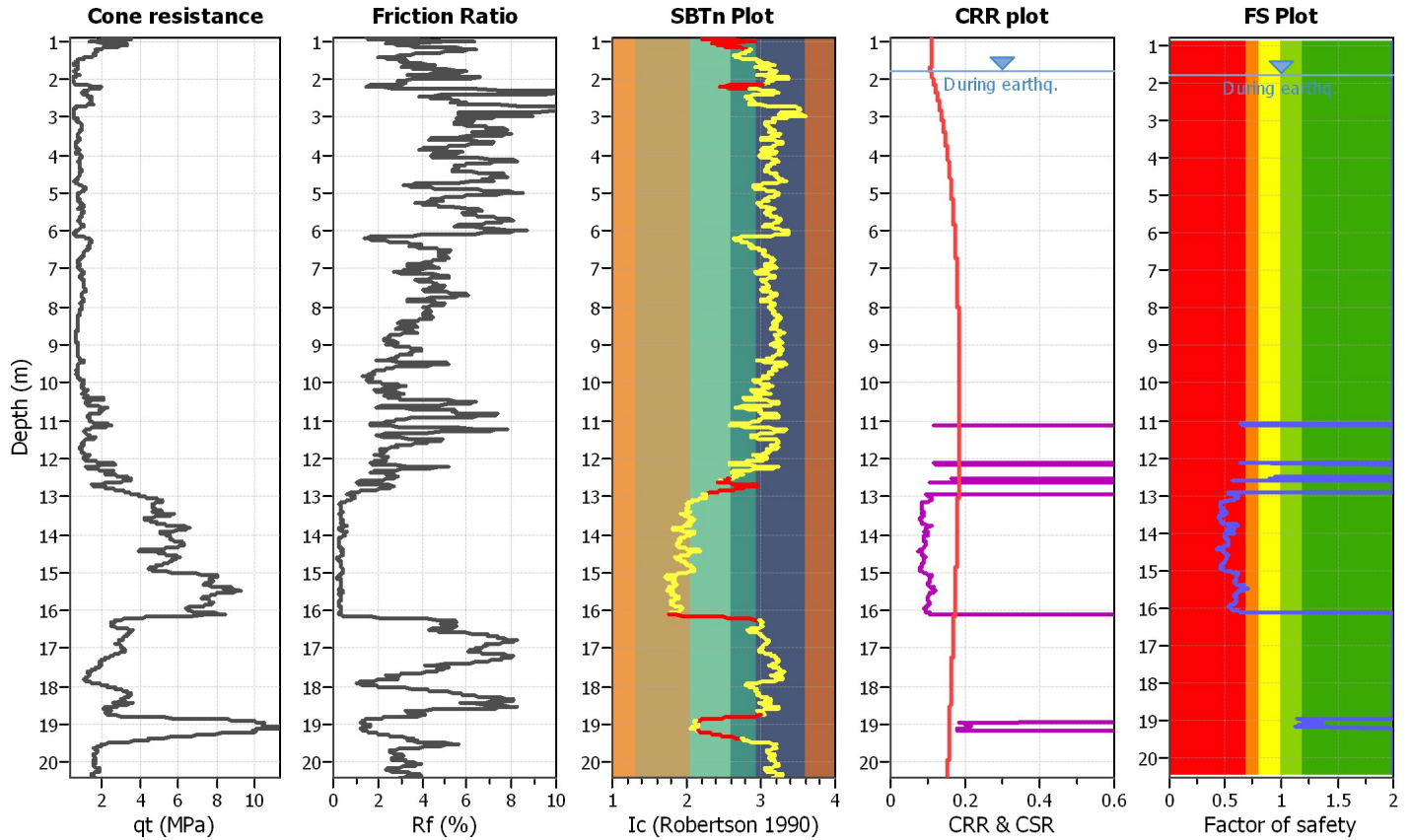
Project title : Studio del terreno di fondazione

Location : Duomo, Finale Emilia

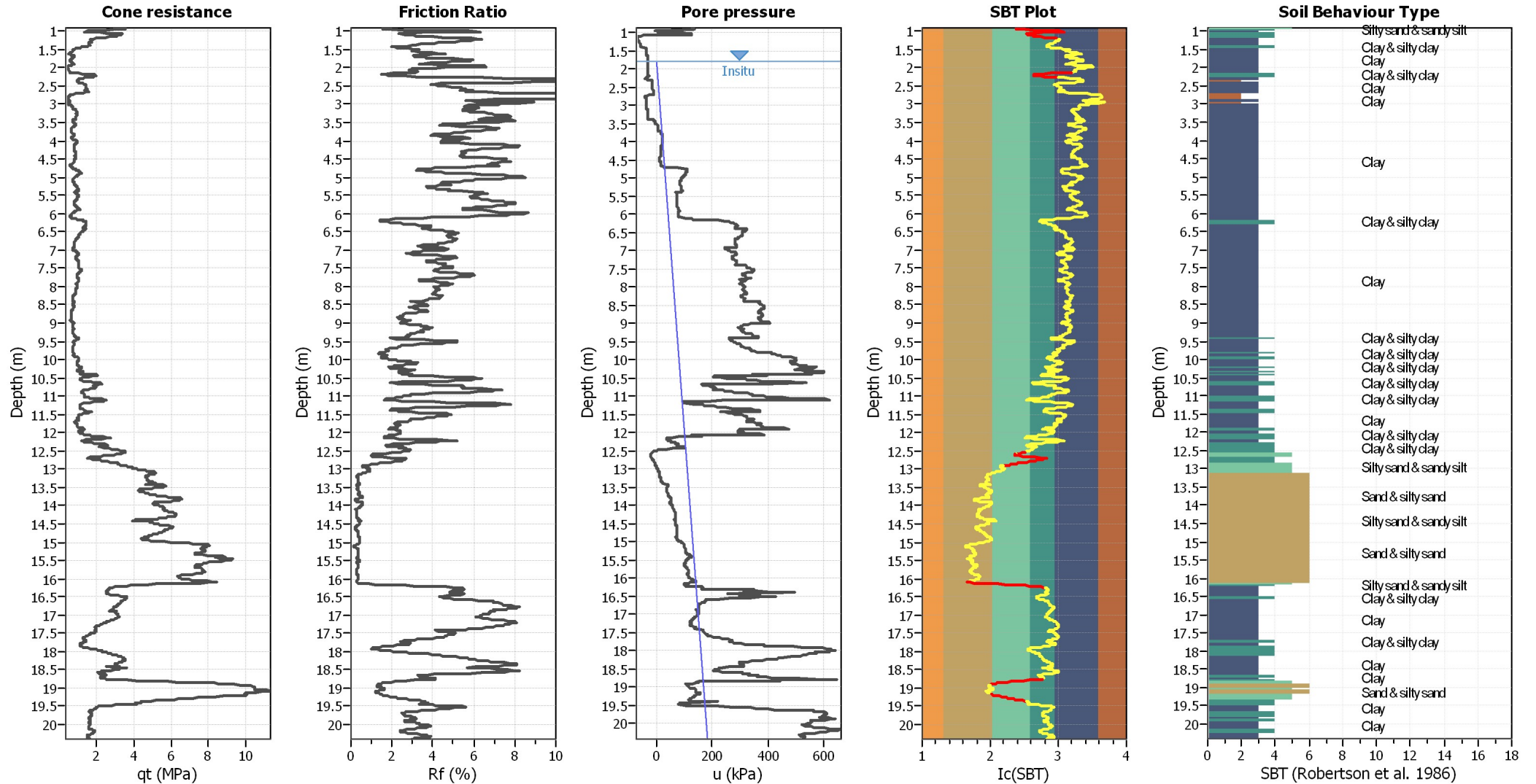
CPT file : CPTU 2 - RW - RSL 0.28

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	1.80 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	1.80 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	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 based
Peak ground acceleration:	0.28	Unit weight calculation:	Based on SBT	K_g applied:	Yes		



CPT basic interpretation plots



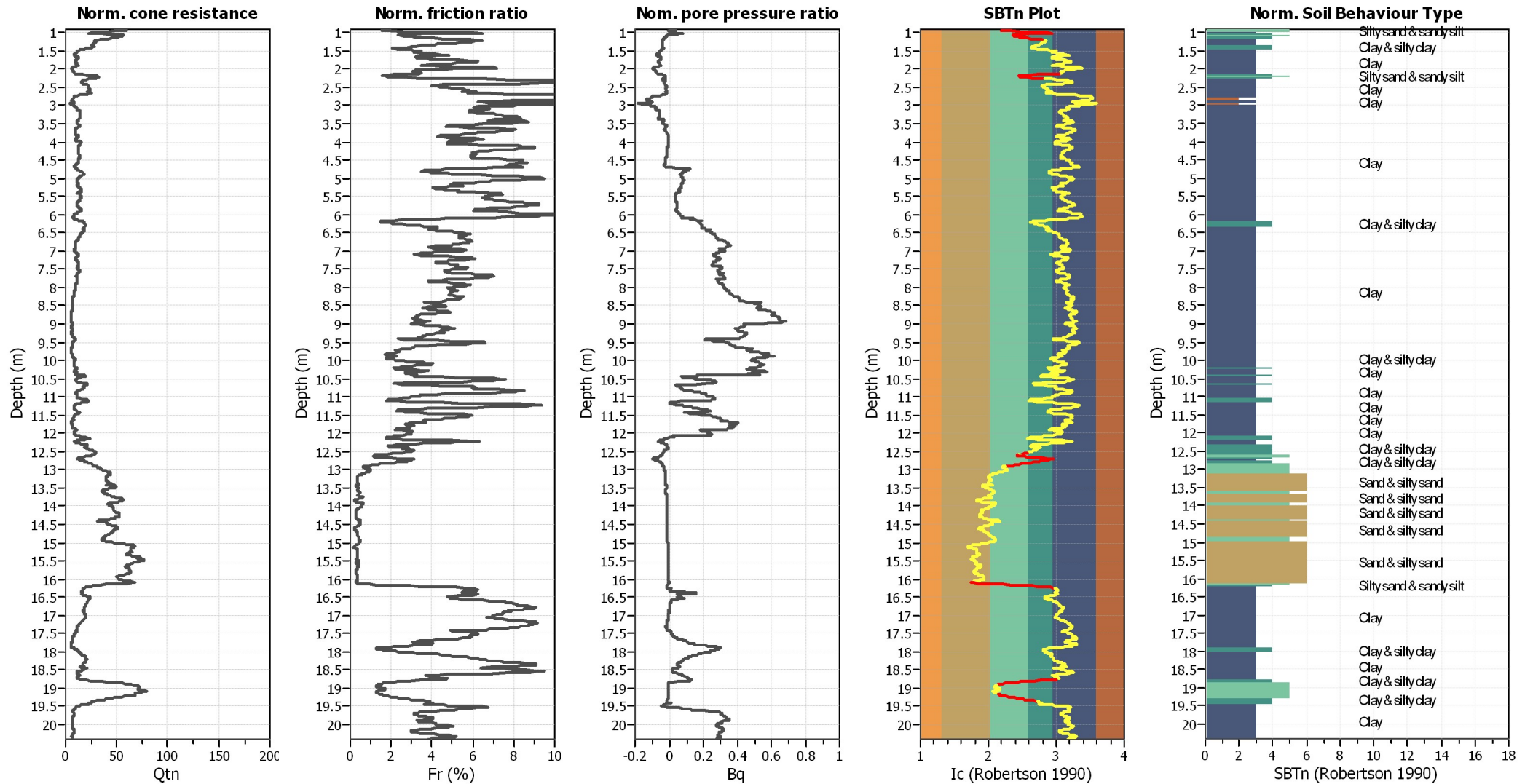
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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)



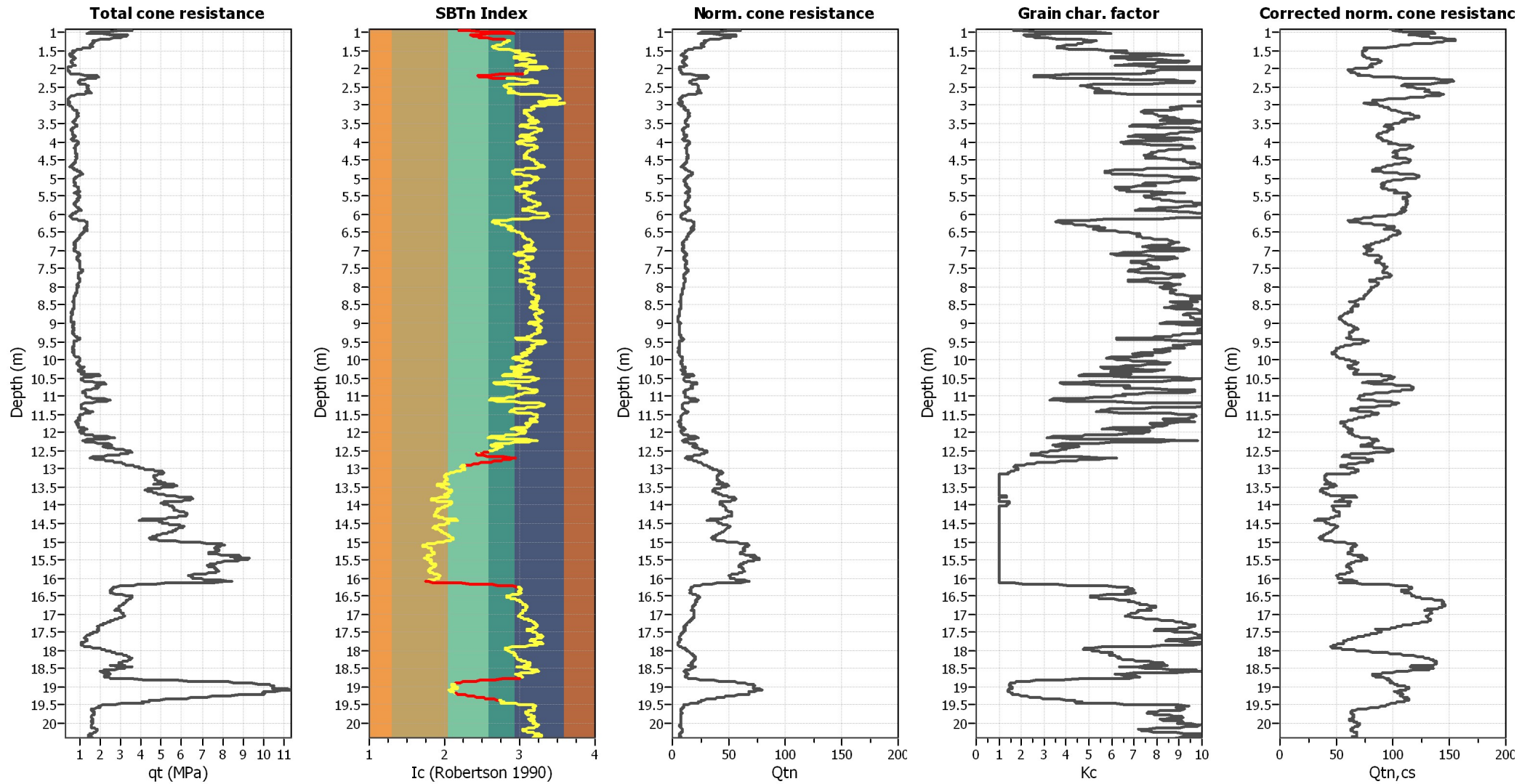
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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

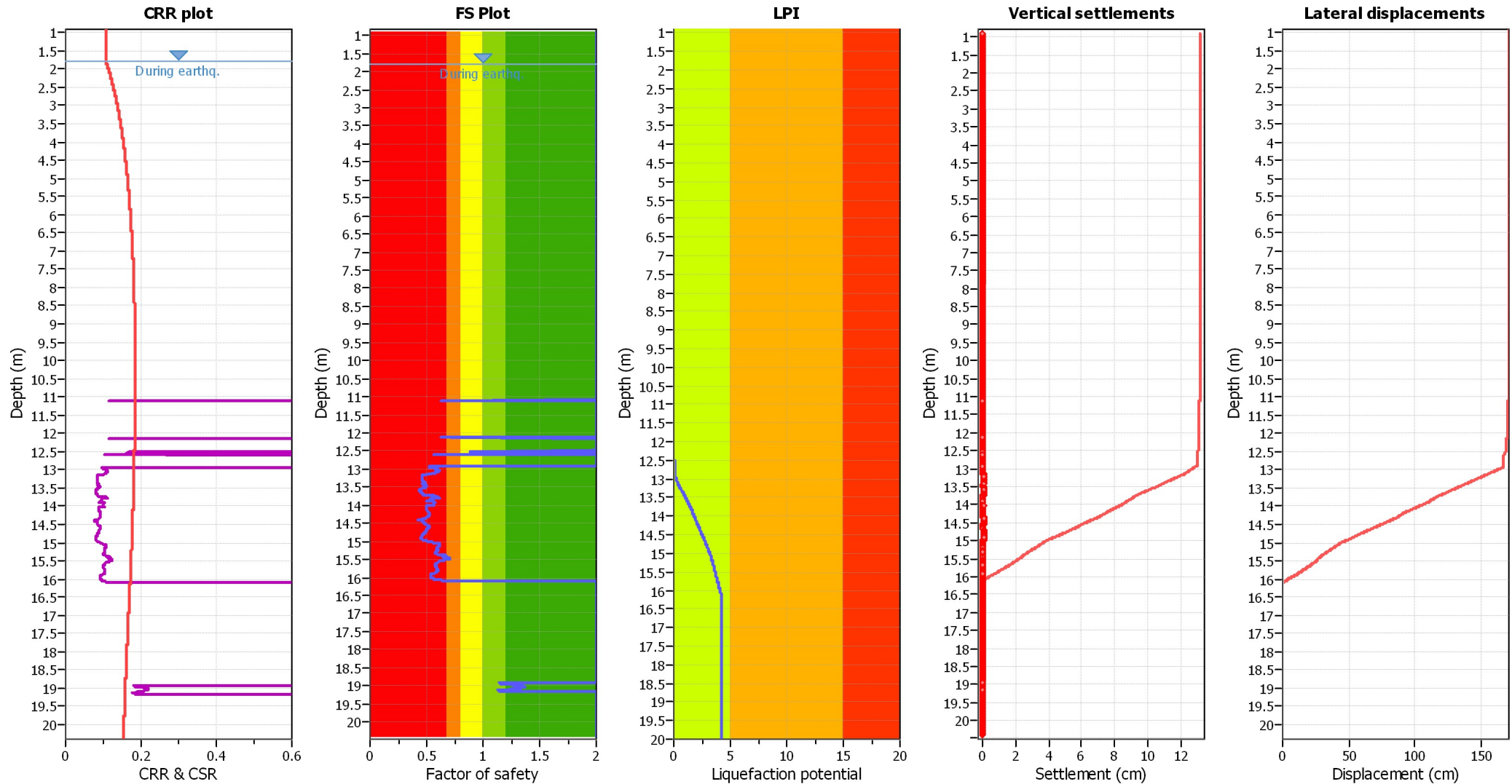
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _c applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_0 applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

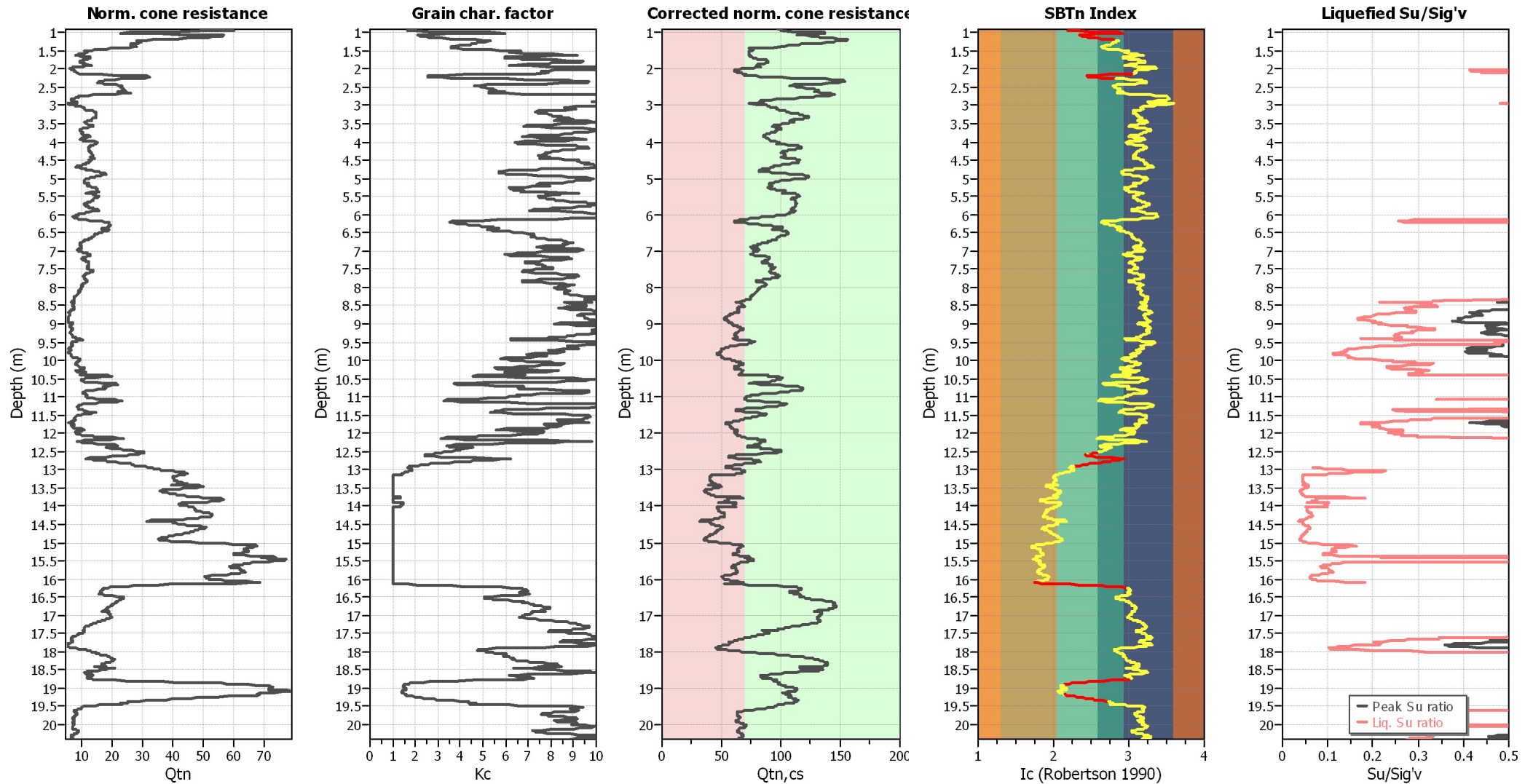
F.S. color scheme

- 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
- Low risk

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{cs} applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m



LIQUEFACTION ANALYSIS REPORT

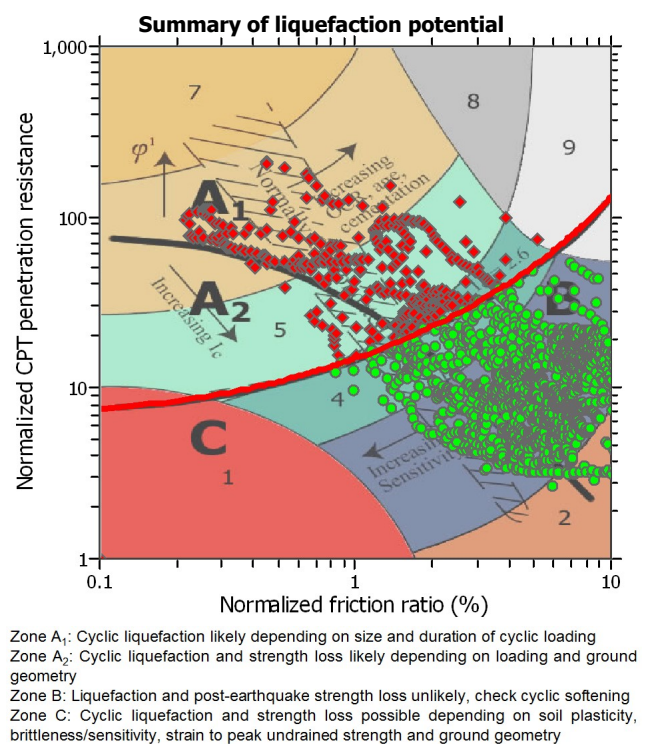
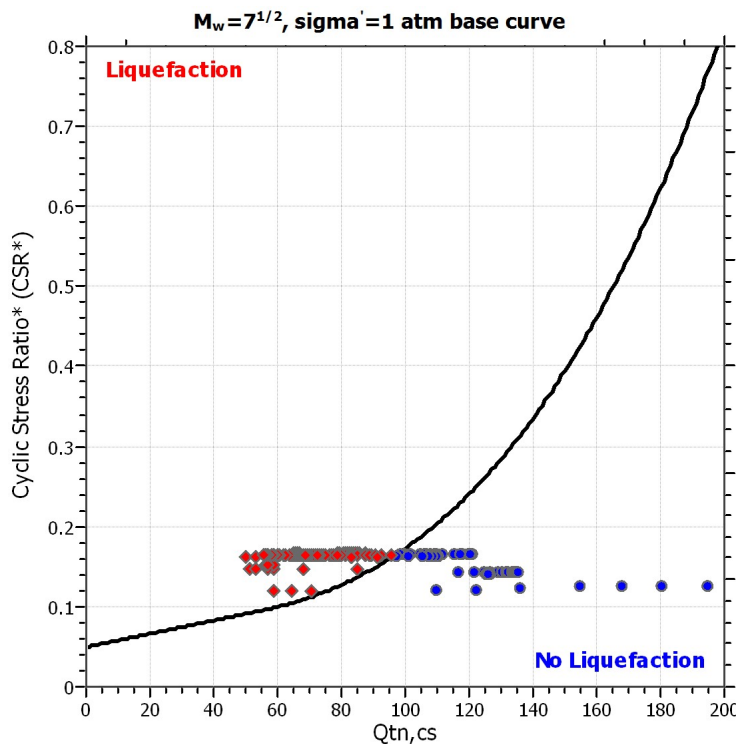
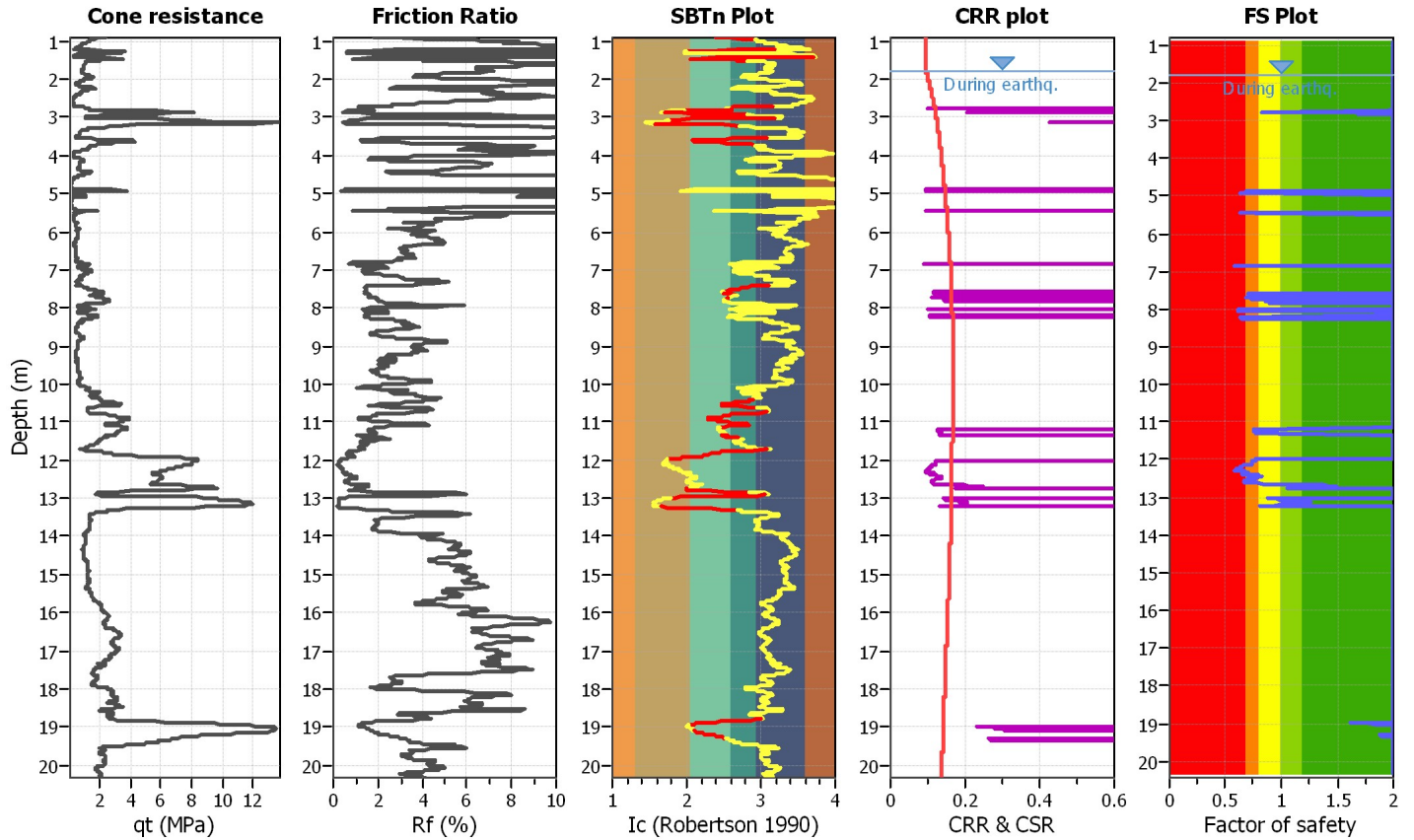
Project title : Studio del terreno di fondazione

Location : Duomo, Finale Emilia

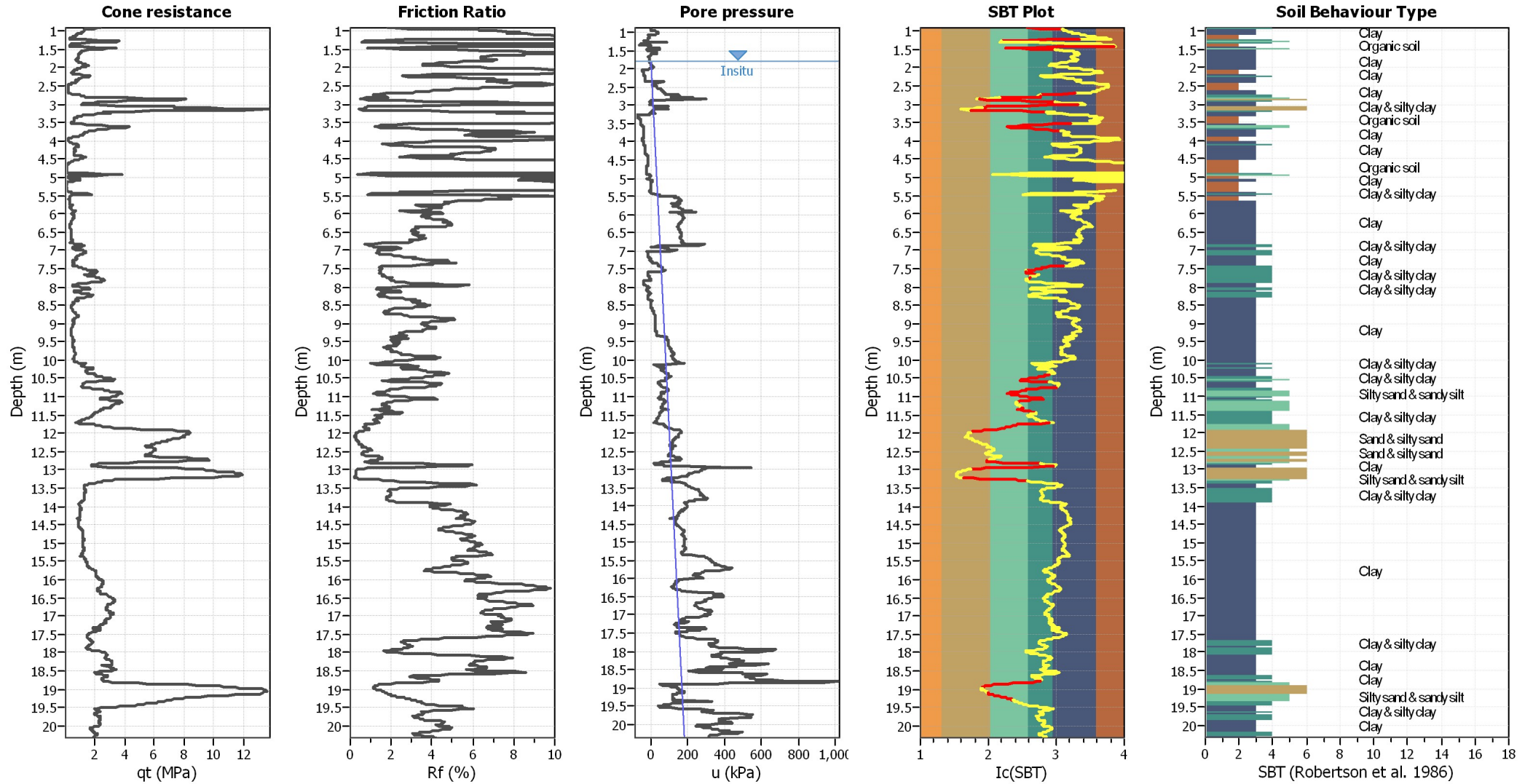
CPT file : CPTU 1 - RW - CAT C 0.25

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	1.80 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	1.80 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	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 based
Peak ground acceleration:	0.25	Unit weight calculation:	Based on SBT	K_g applied:	Yes		



CPT basic interpretation plots



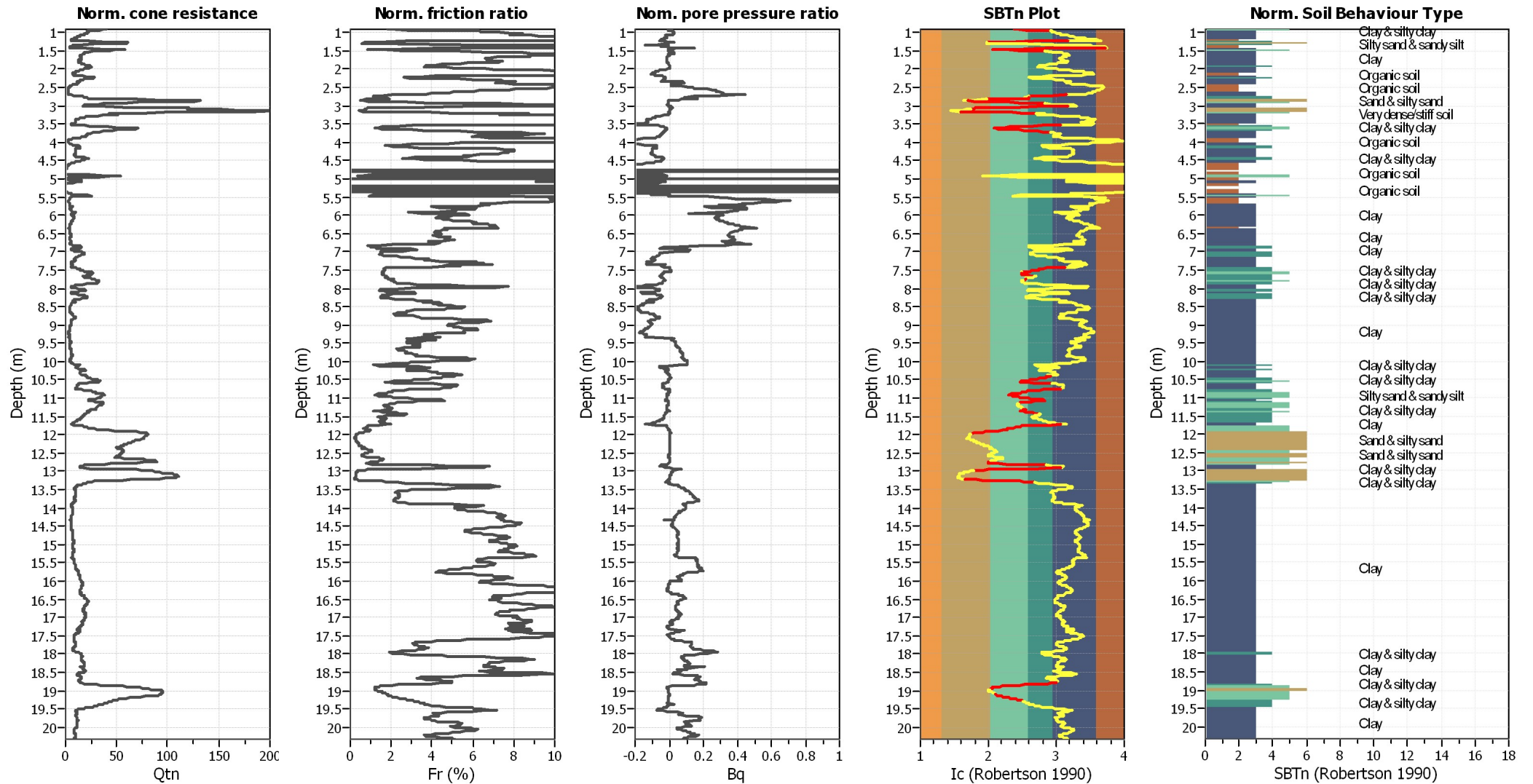
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_v applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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)



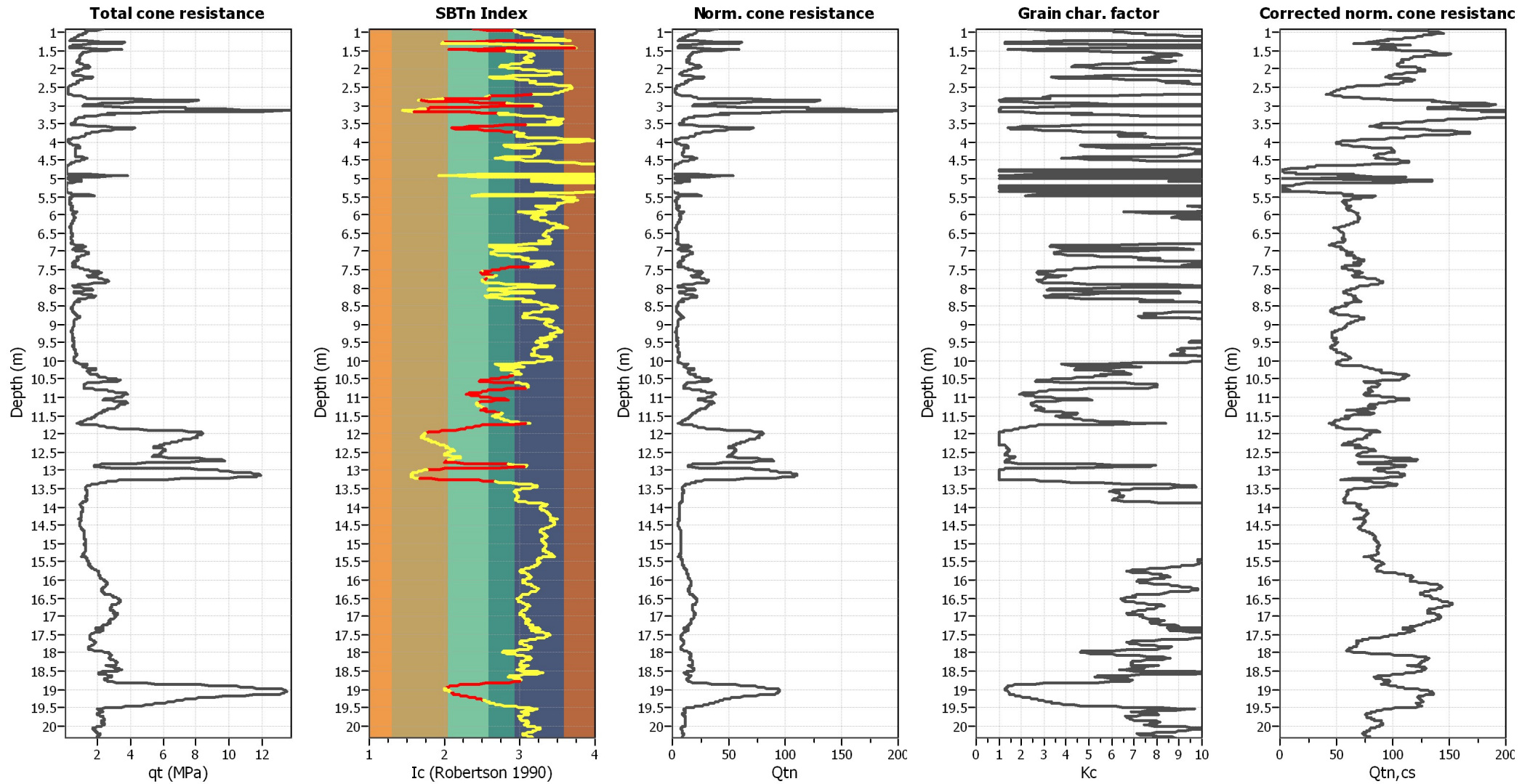
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_v applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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

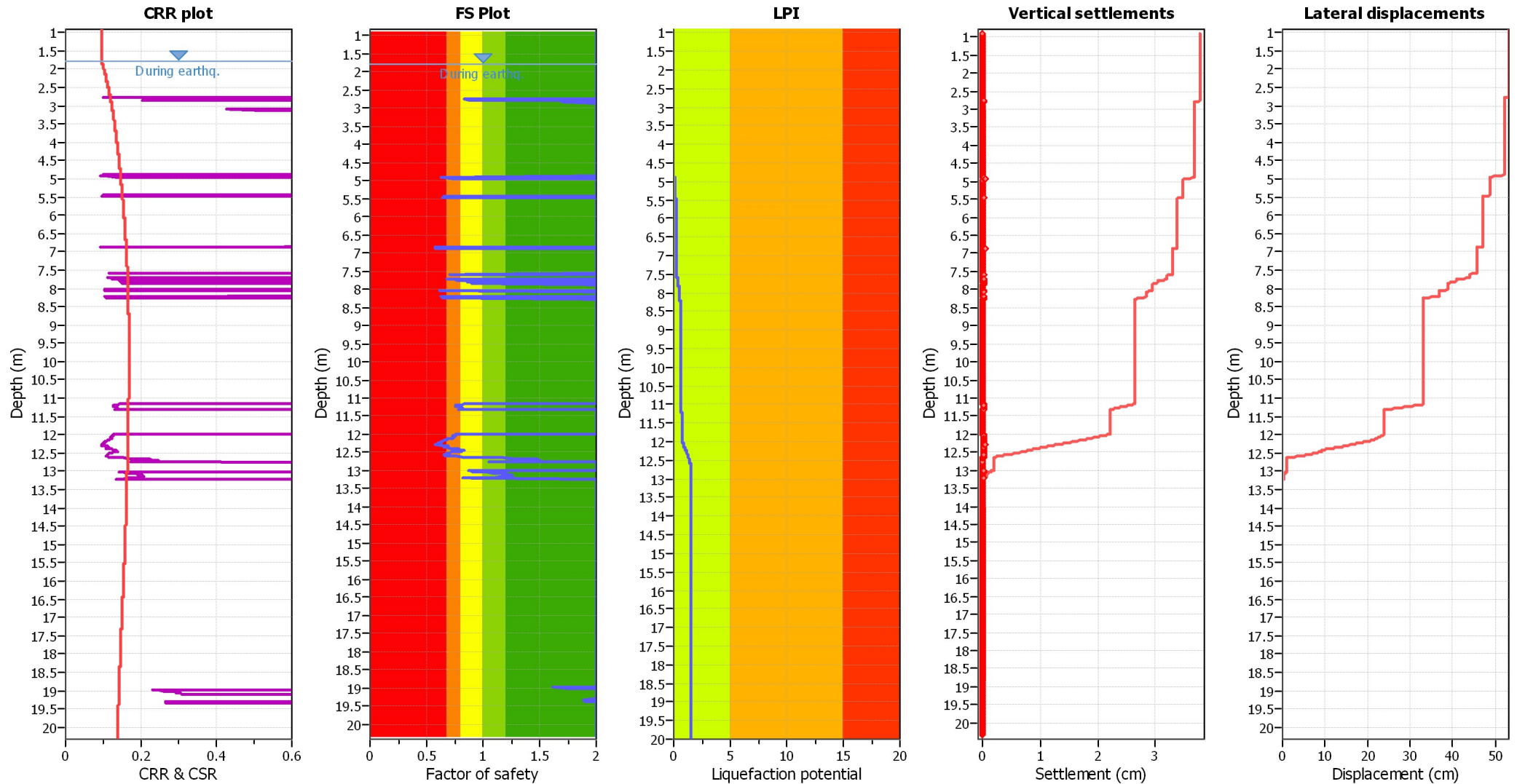
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _c applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_0 applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

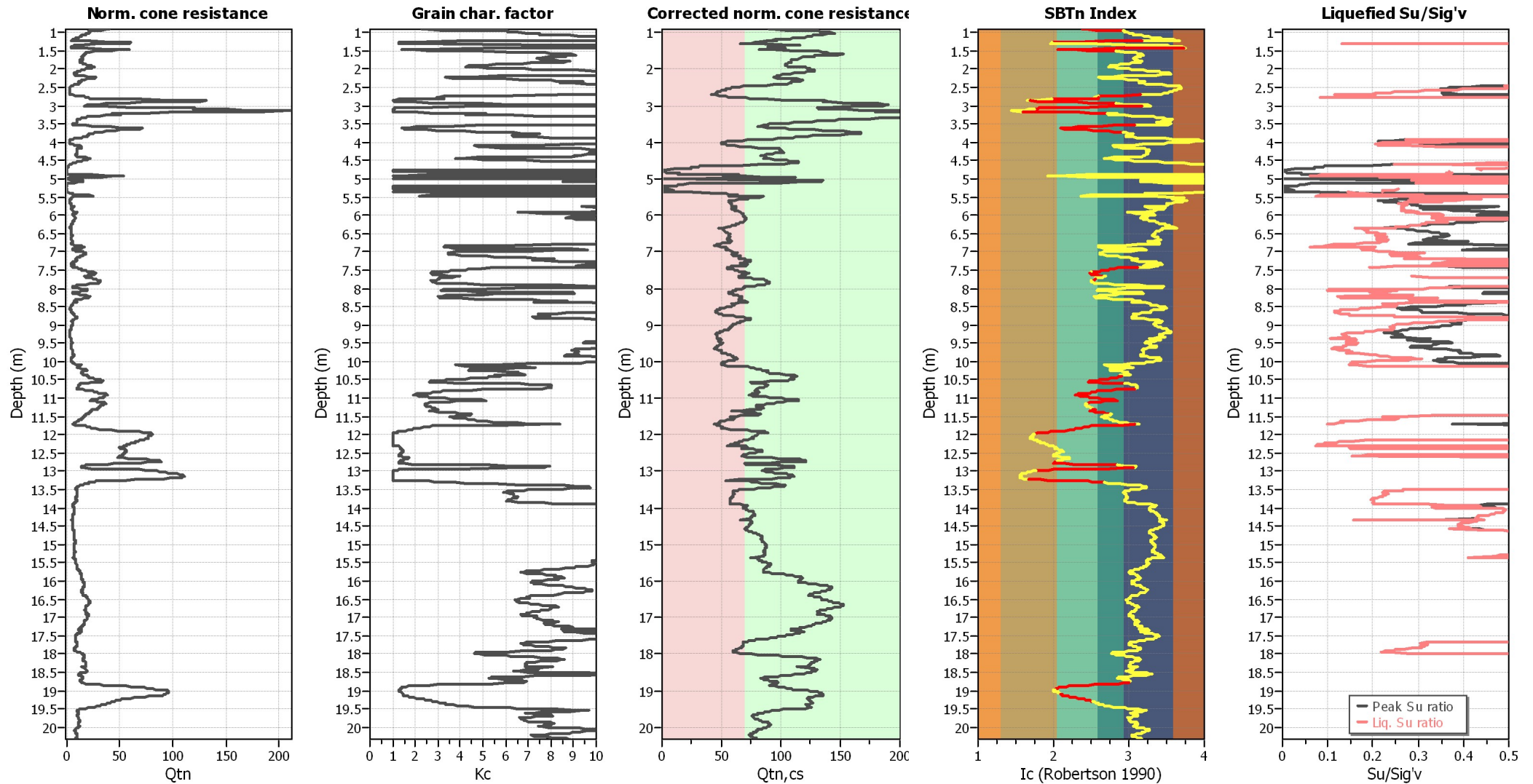
F.S. color scheme

- 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
- Low risk

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _c applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m



LIQUEFACTION ANALYSIS REPORT

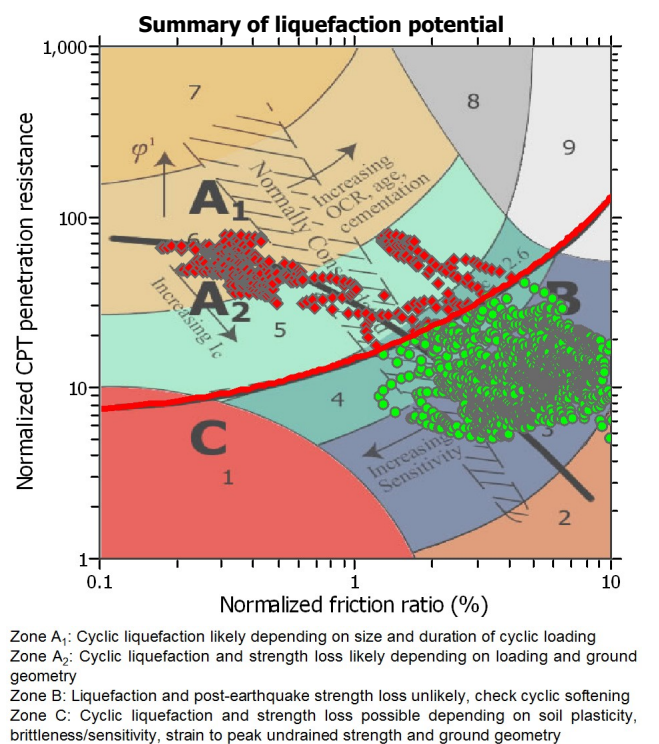
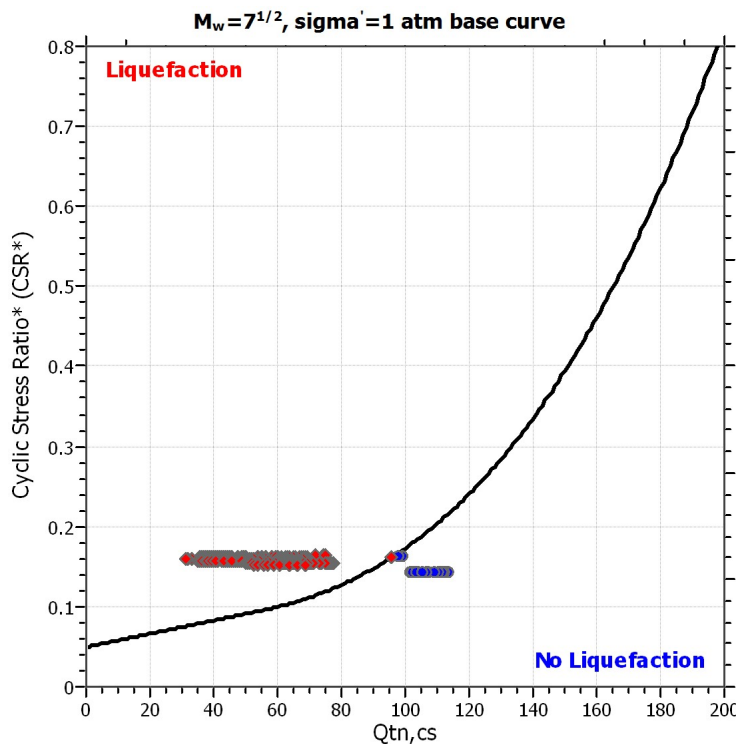
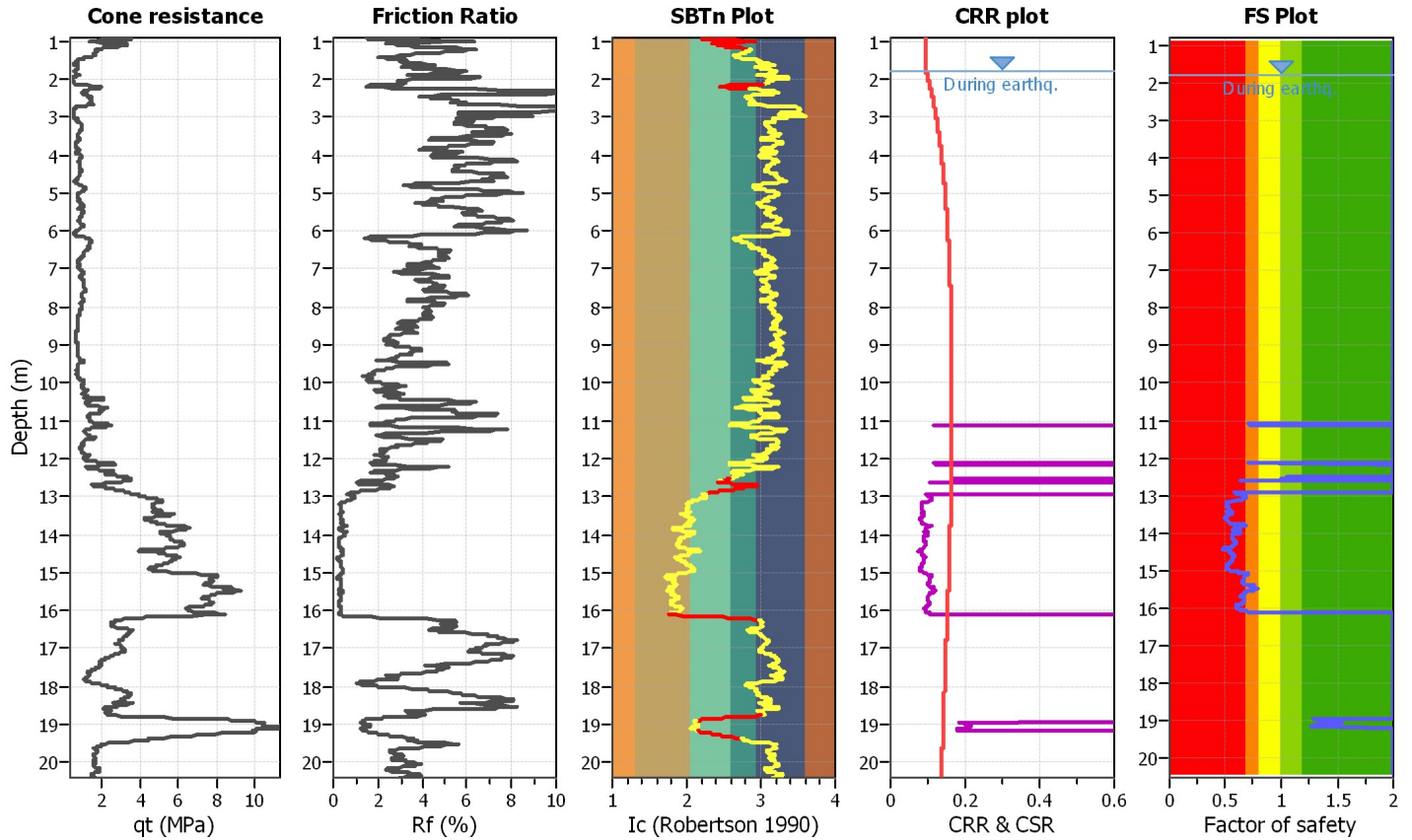
Project title : Studio del terreno di fondazione

Location : Duomo, Finale Emilia

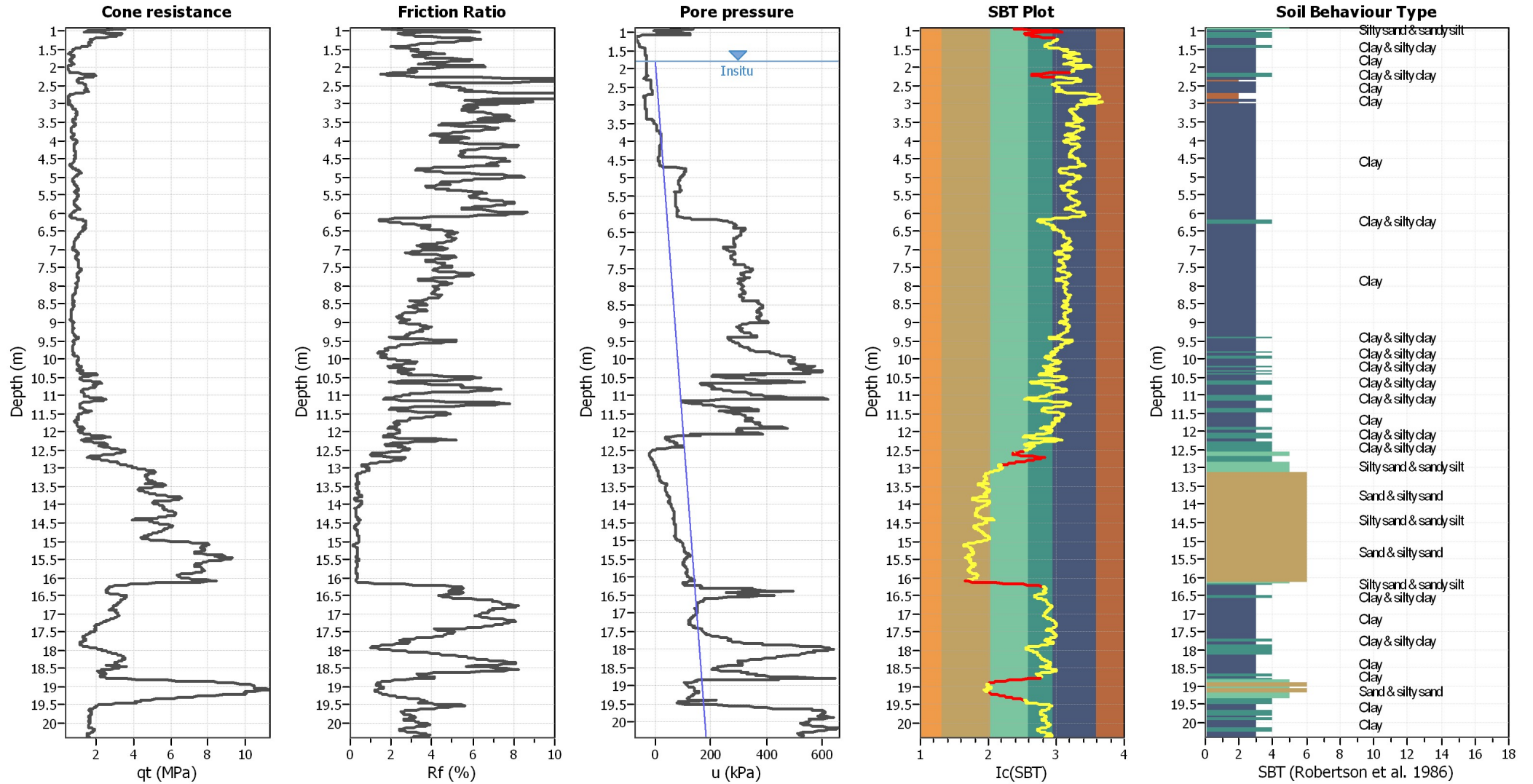
CPT file : CPTU 2 - RW - CAT C 0.25

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	1.80 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	1.80 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	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 based
Peak ground acceleration:	0.25	Unit weight calculation:	Based on SBT	K_g applied:	Yes		



CPT basic interpretation plots



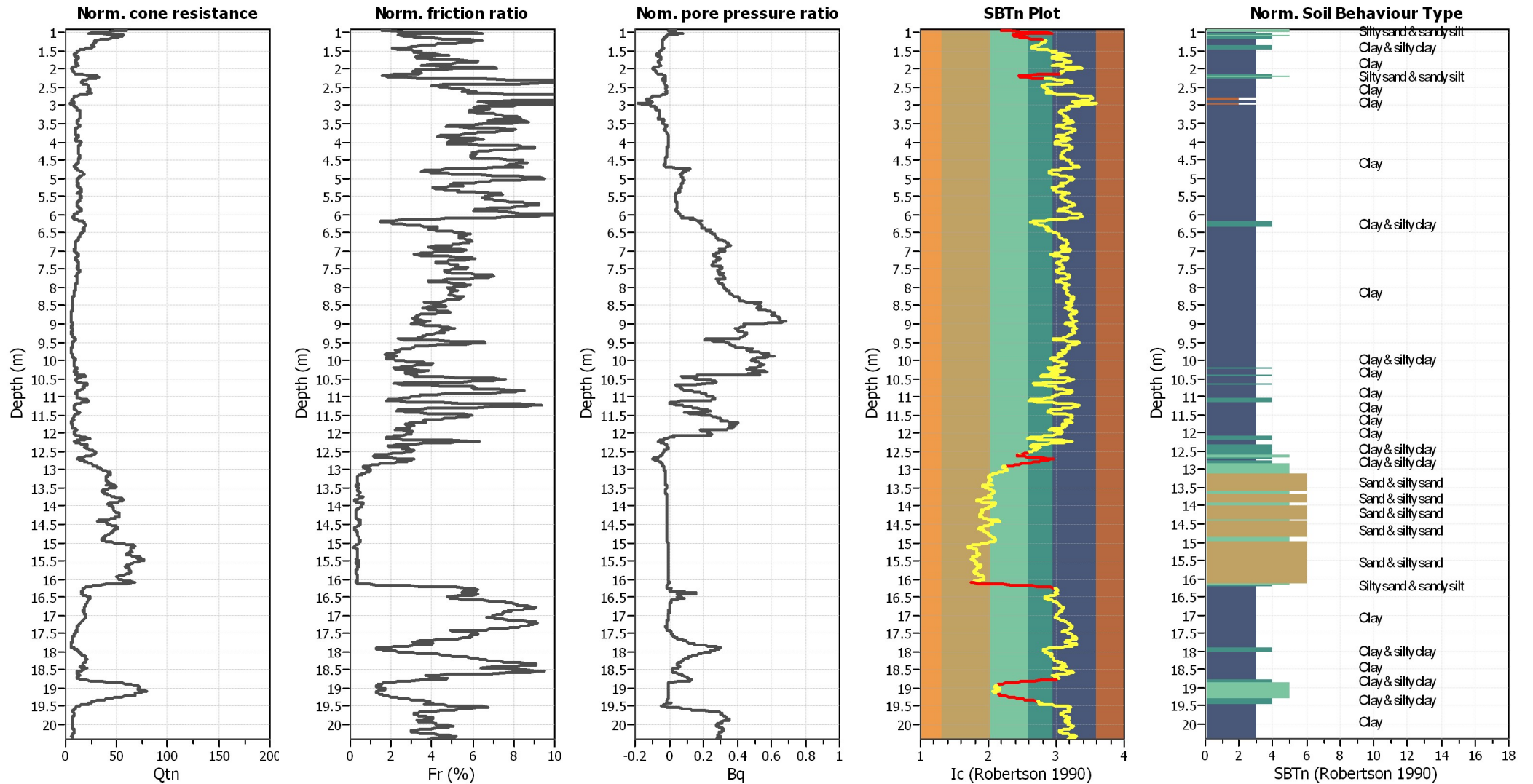
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_v applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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)



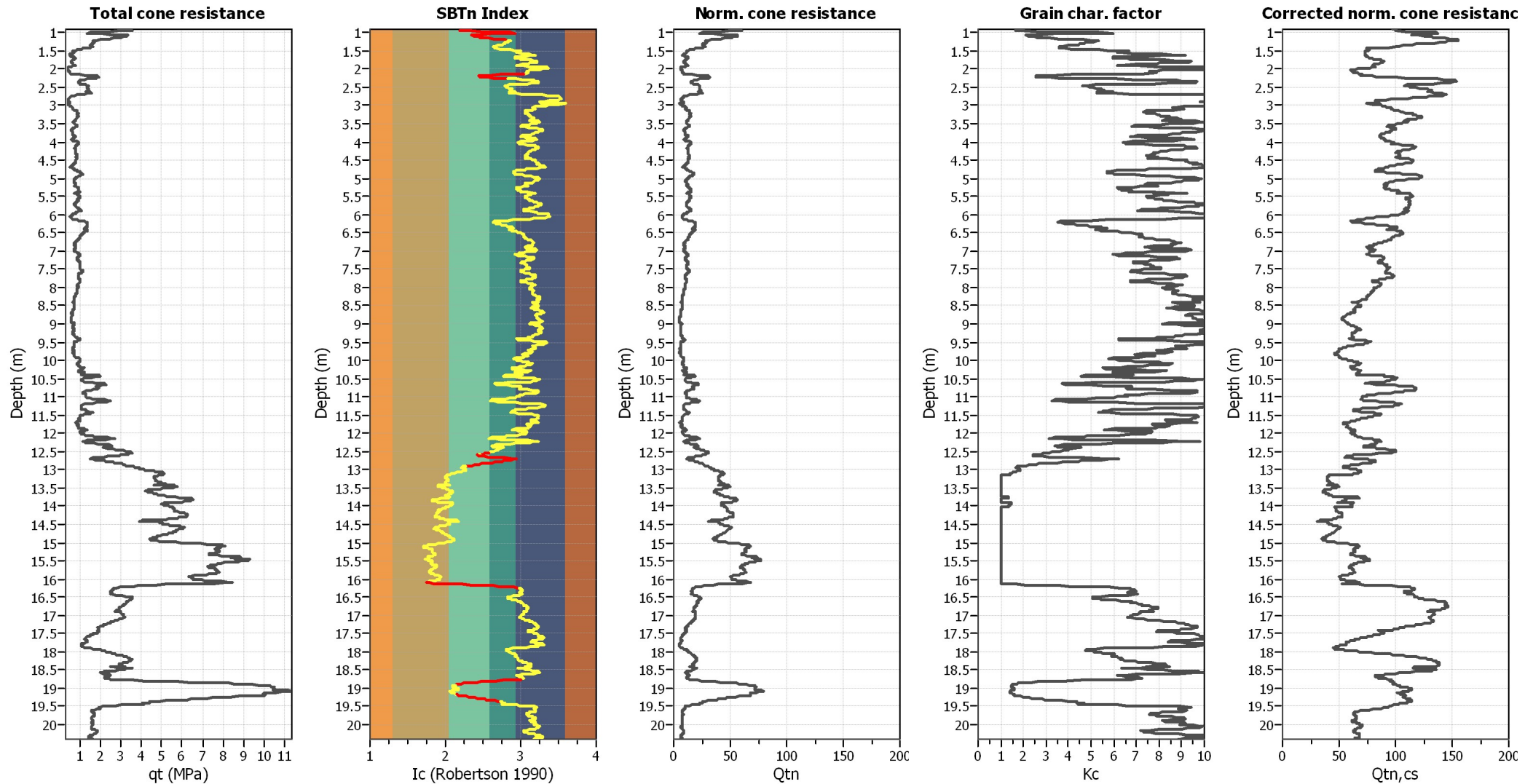
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_v applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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

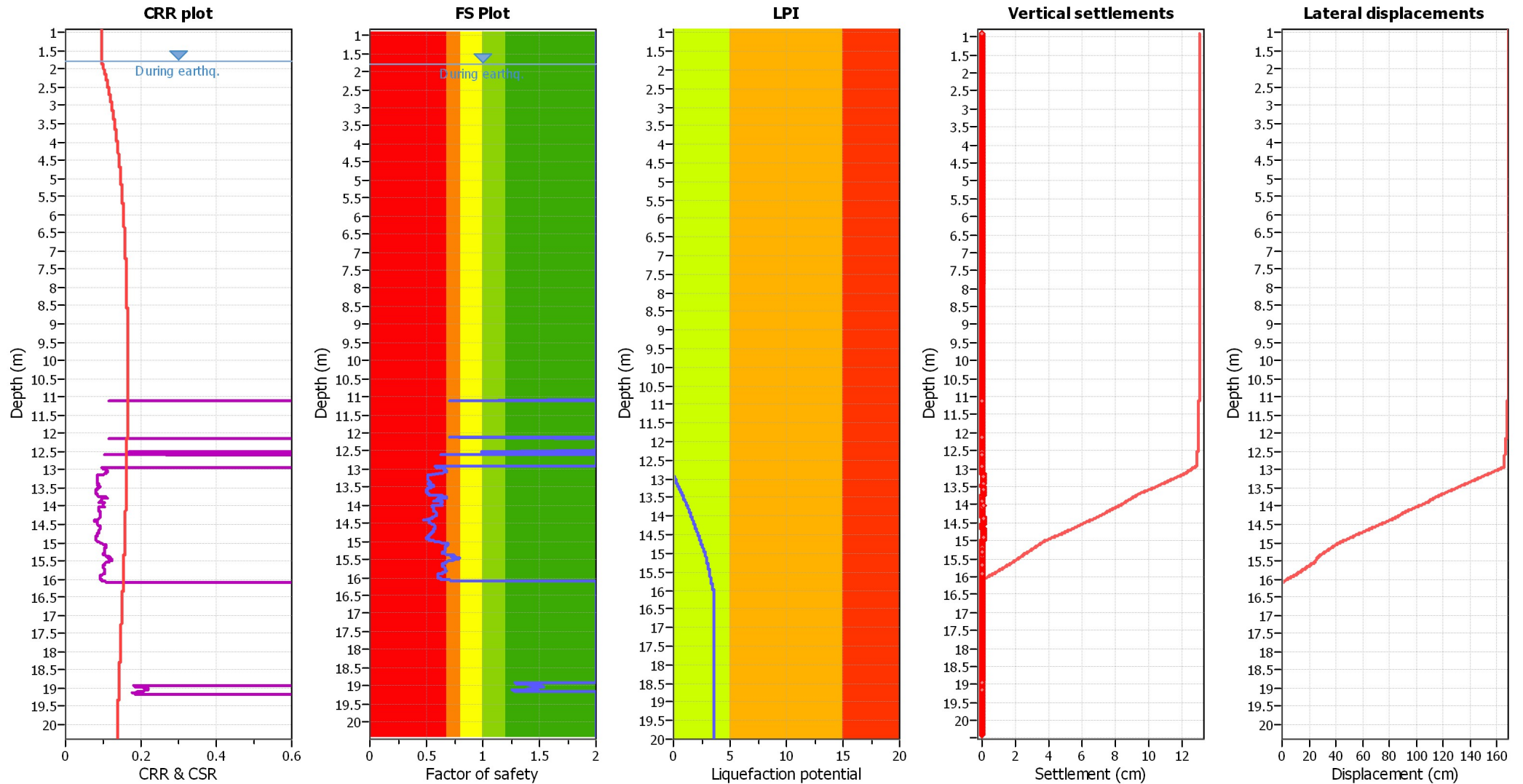
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _c applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_0 applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

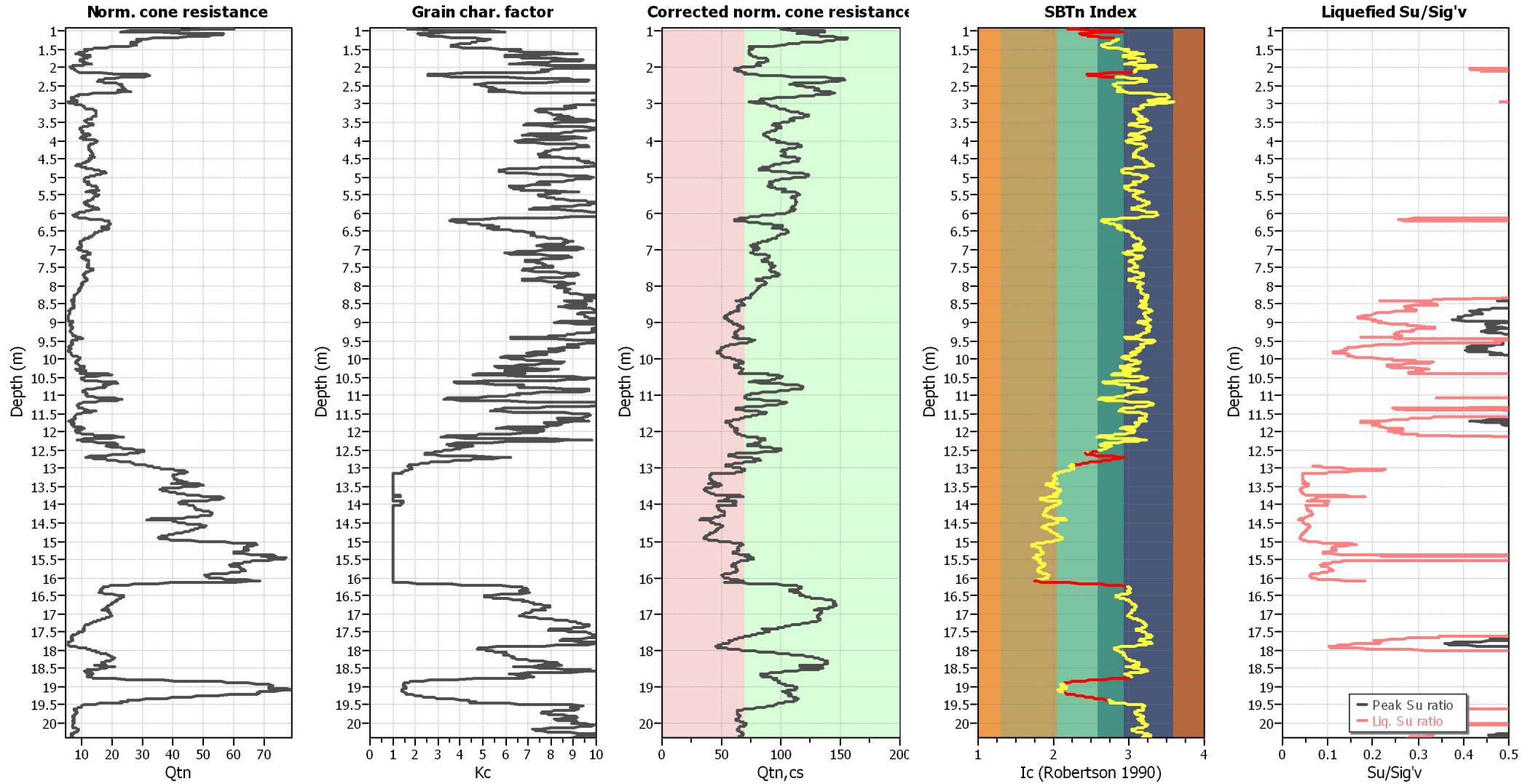
F.S. color scheme

- 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
- Low risk

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{α} applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m



LIQUEFACTION ANALYSIS REPORT

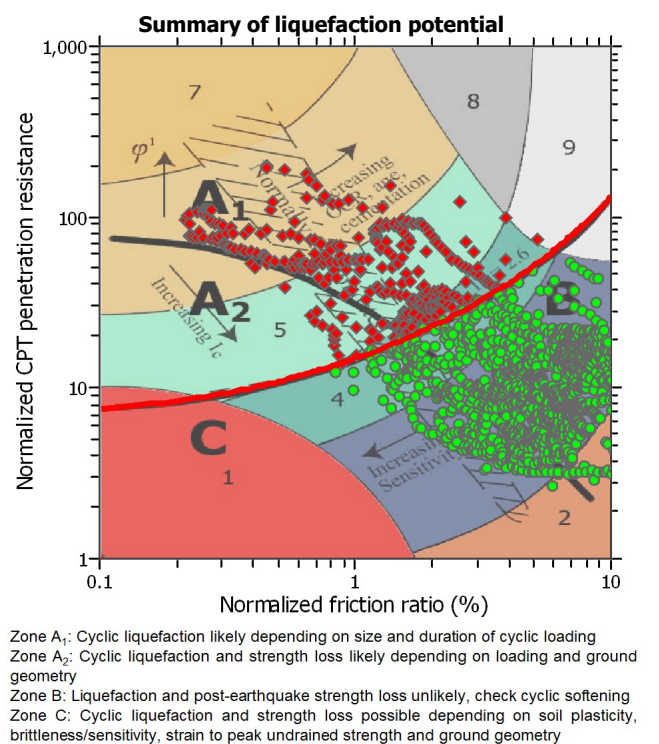
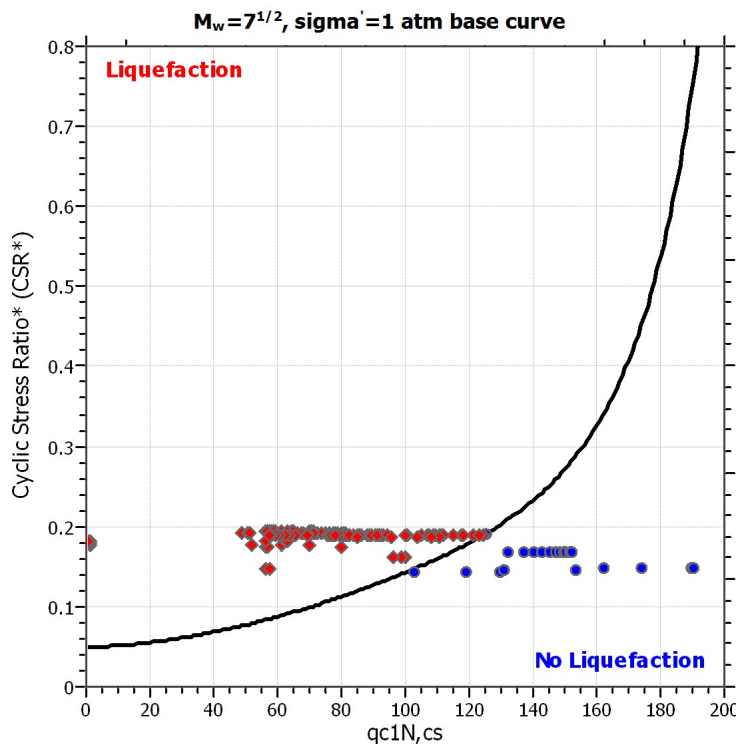
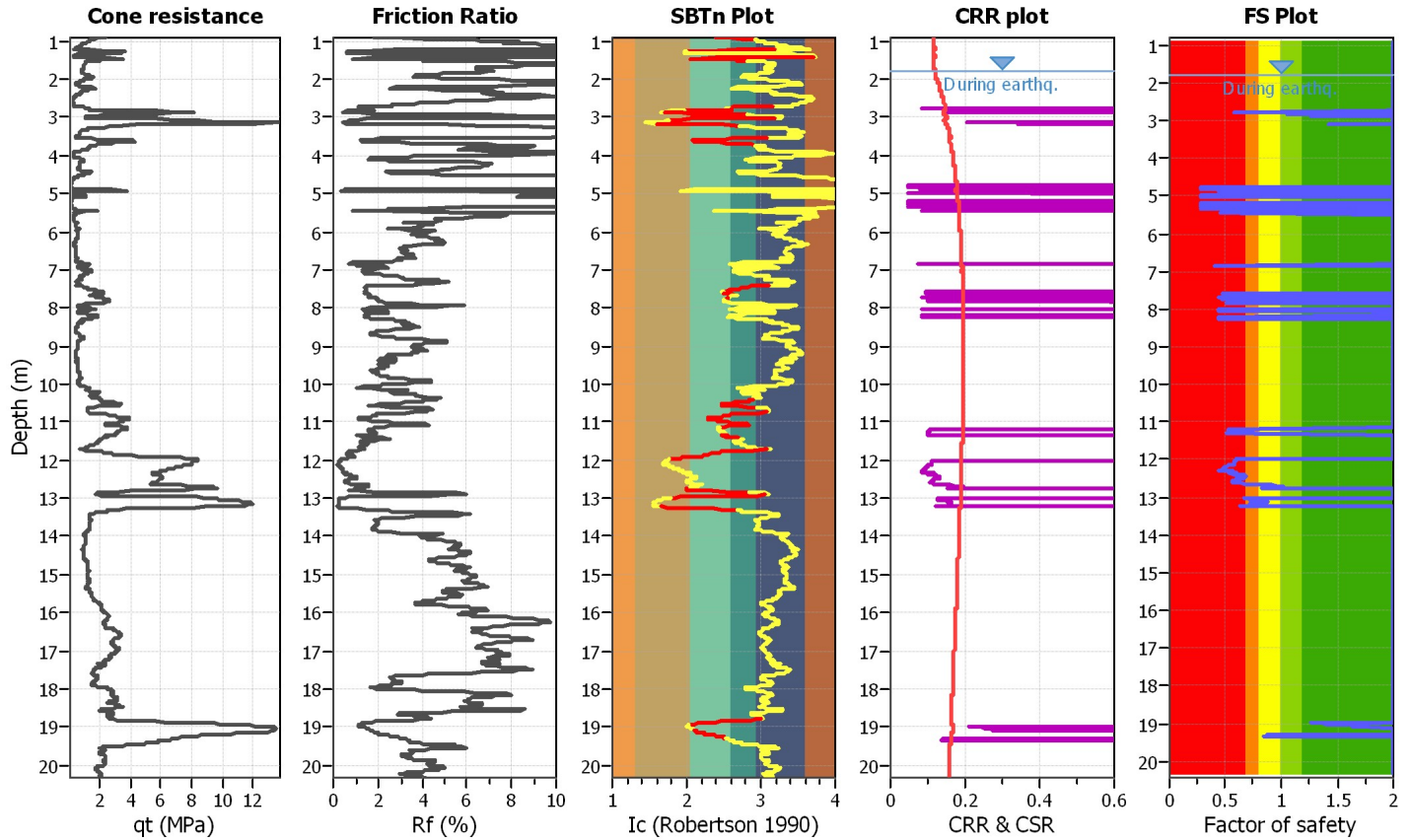
Project title : Studio del terreno di fondazione

Location : Duomo, Finale Emilia

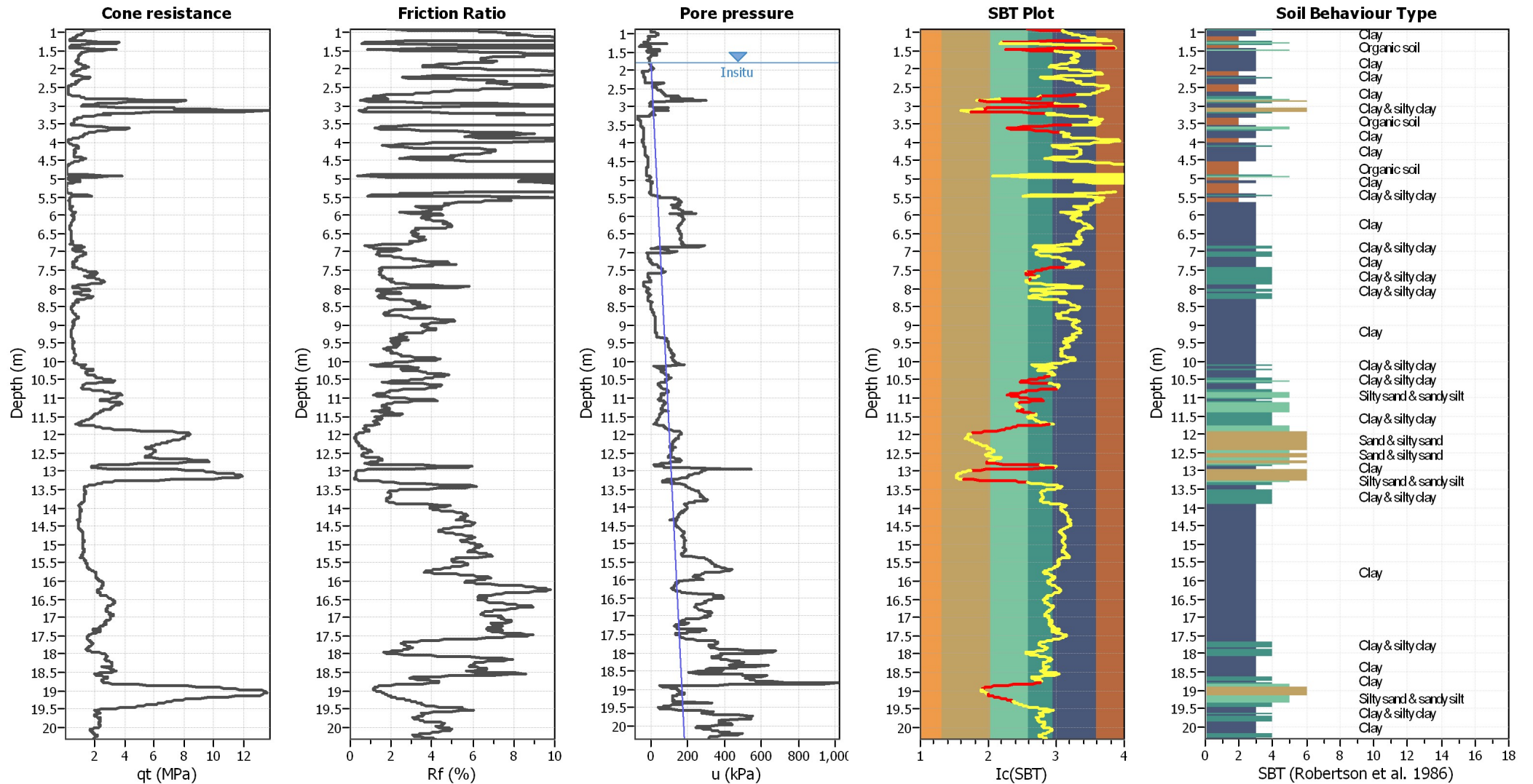
CPT file : CPTU 1 - IB - RSL 0.28

Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.80 m	Use fill:	No	Clay like behavior	
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	1.80 m	Fill height:	N/A	applied:	Sands only
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth applied:	Yes
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	Limit depth:	20.00 m
Peak ground acceleration:	0.28	Unit weight calculation:	Based on SBT	K_G applied:	Yes	MSF method:	Method based



CPT basic interpretation plots



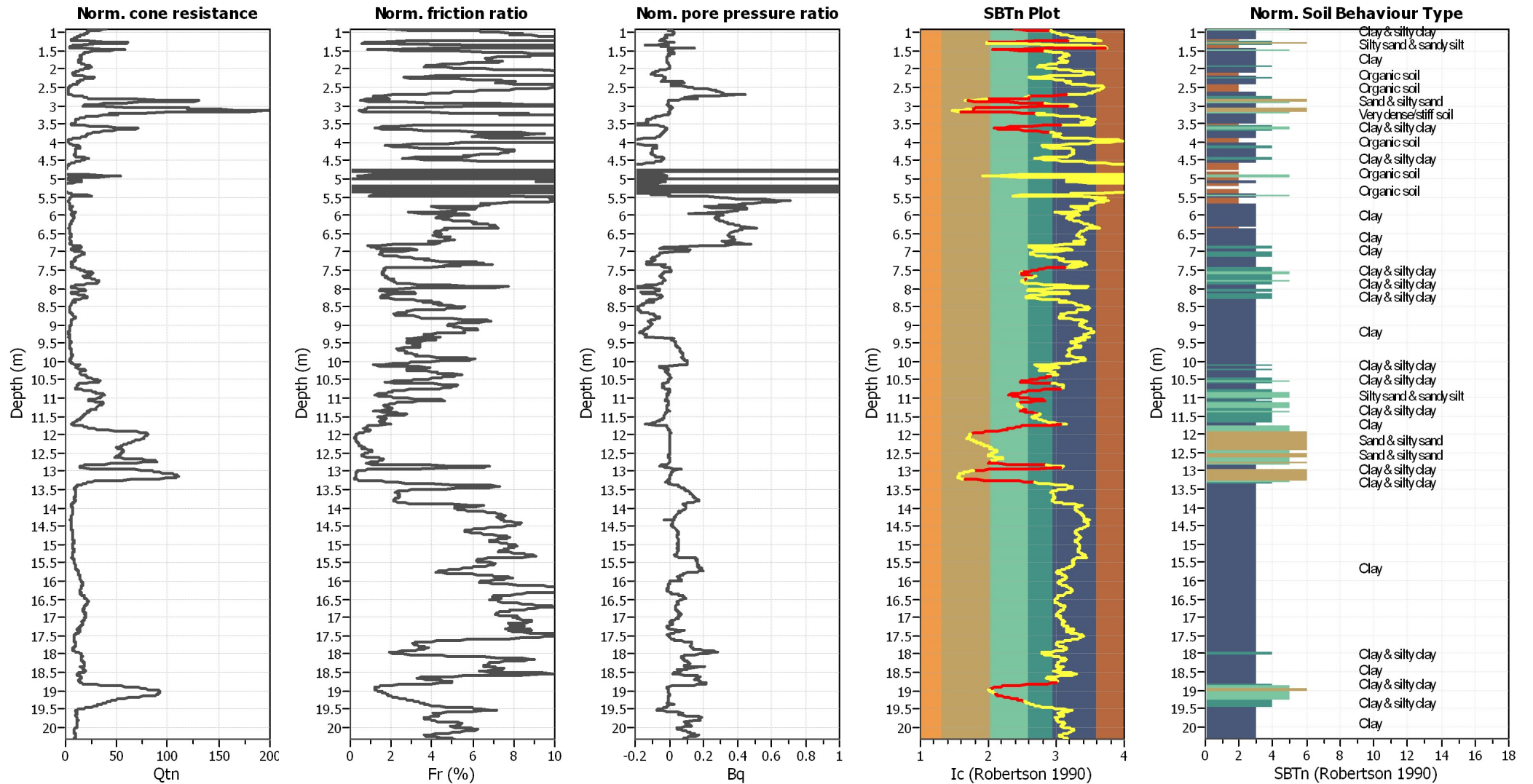
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _g applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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)



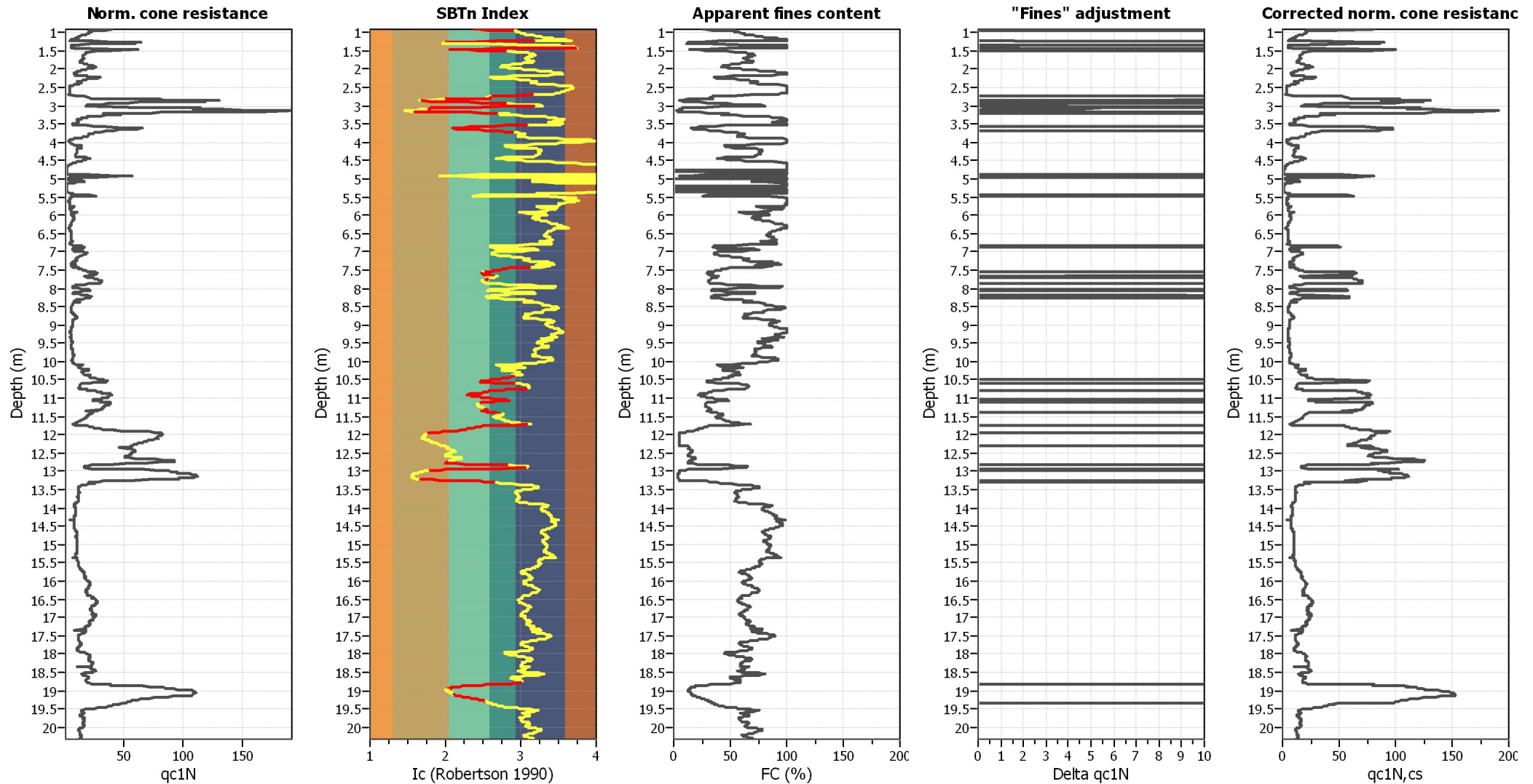
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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

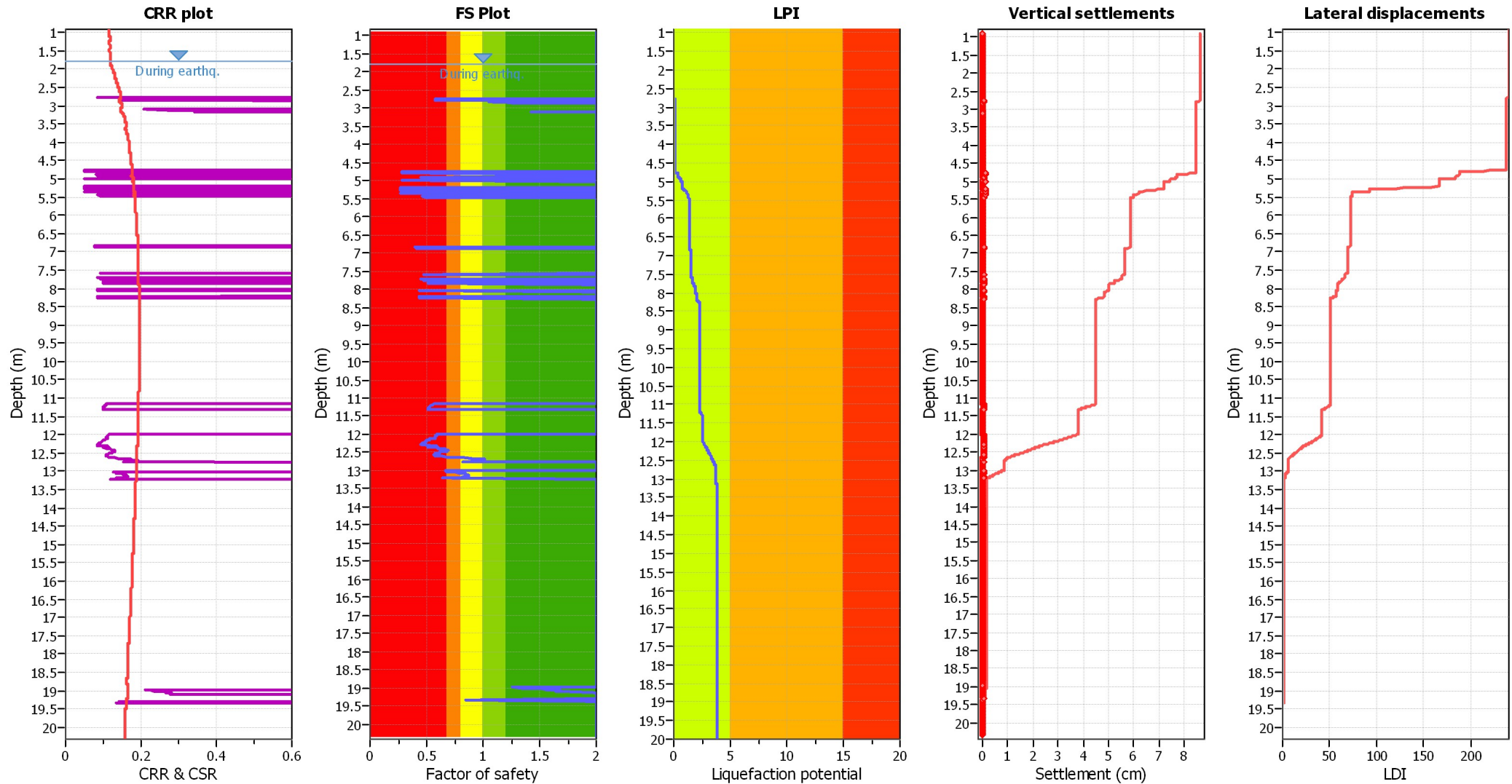
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_g applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

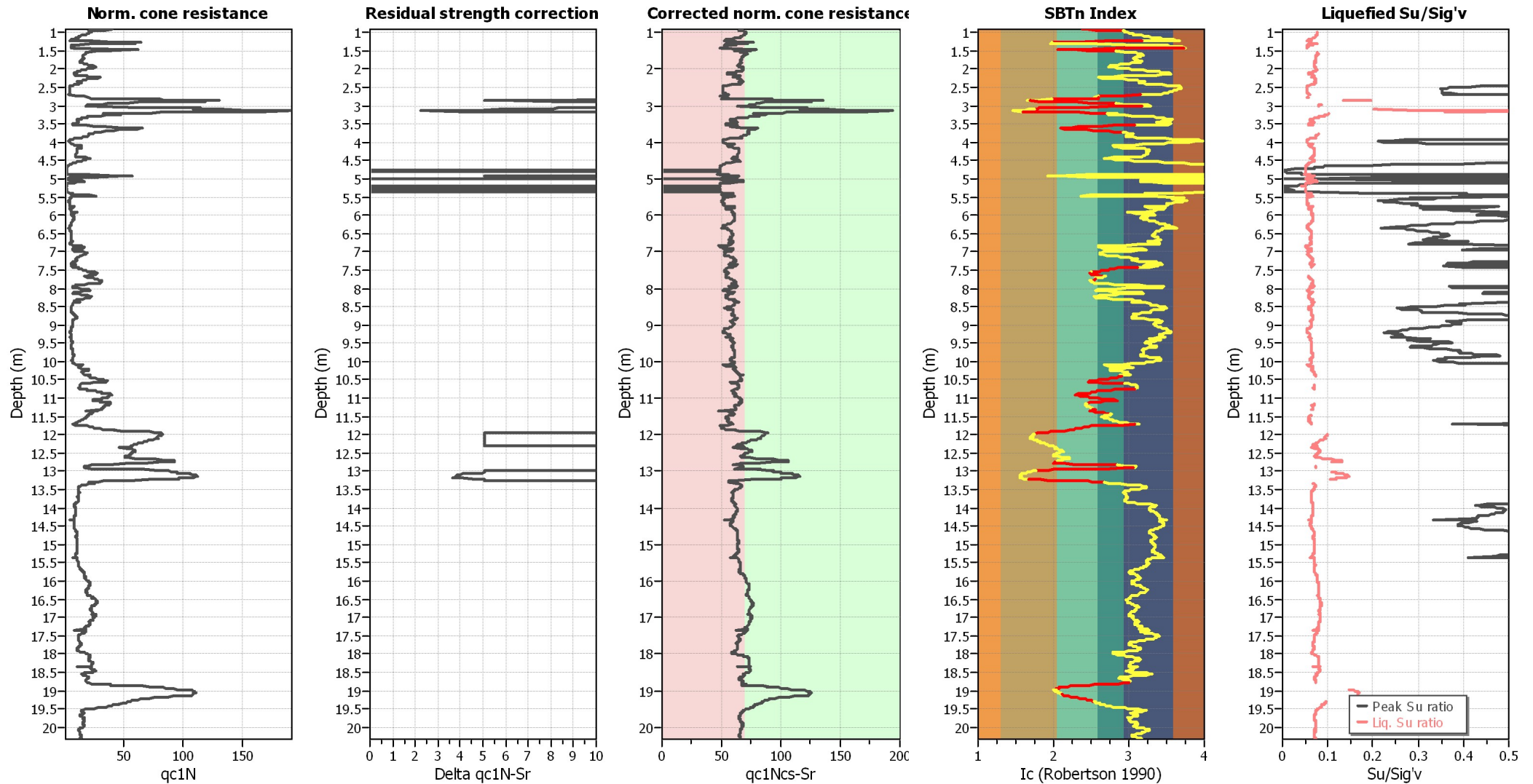
F.S. color scheme

- 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
- Low risk

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m



LIQUEFACTION ANALYSIS REPORT

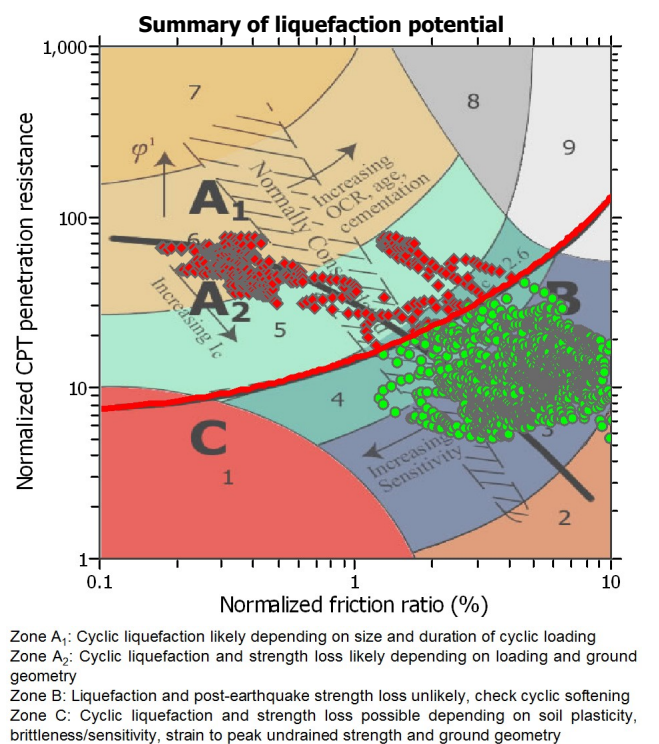
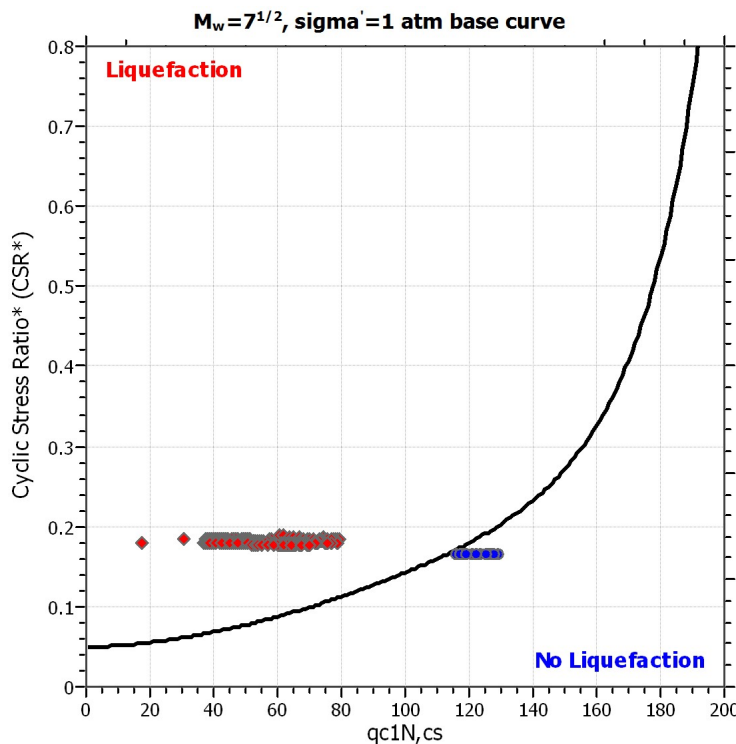
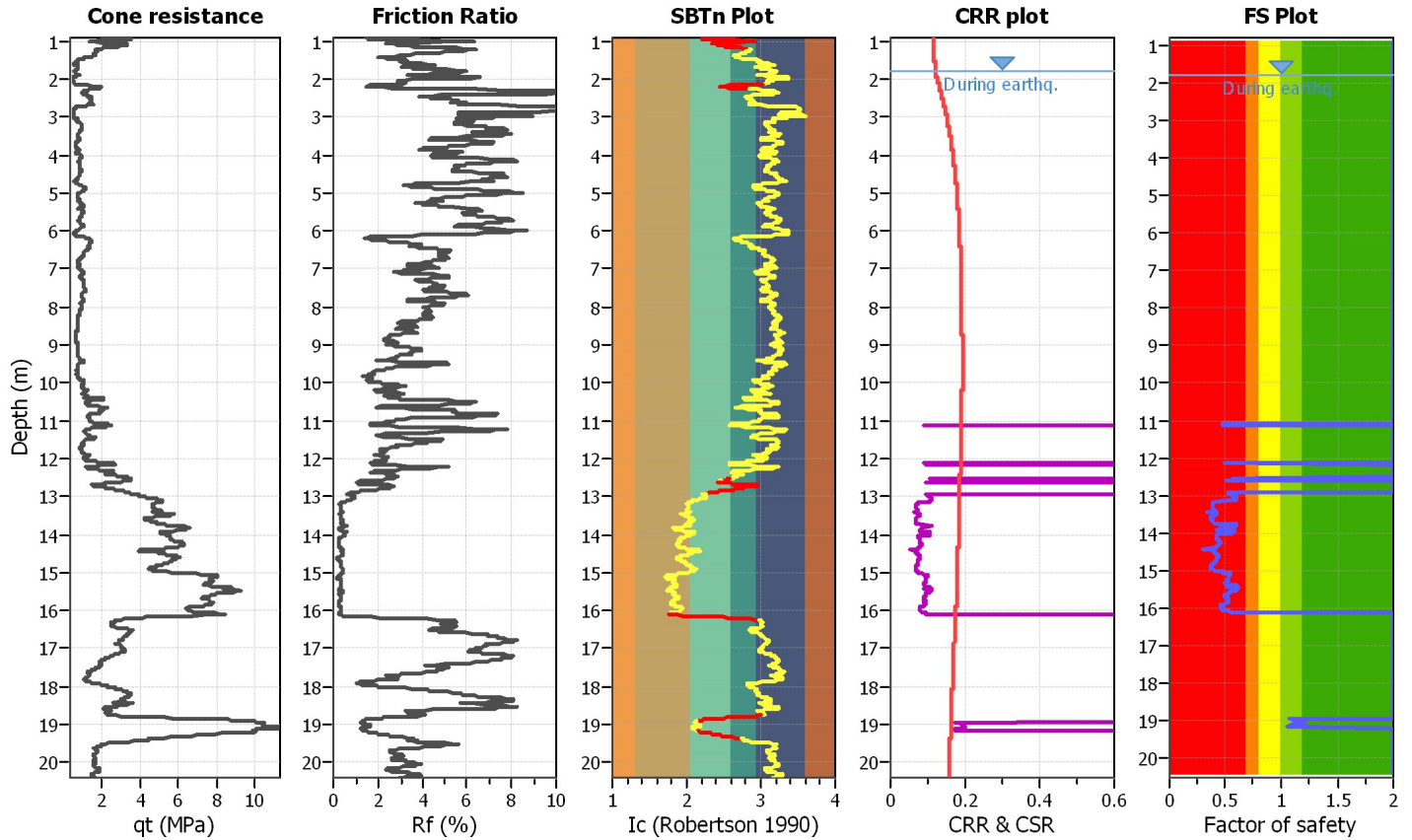
Project title : Studio del terreno di fondazione

Location : Duomo, Finale Emilia

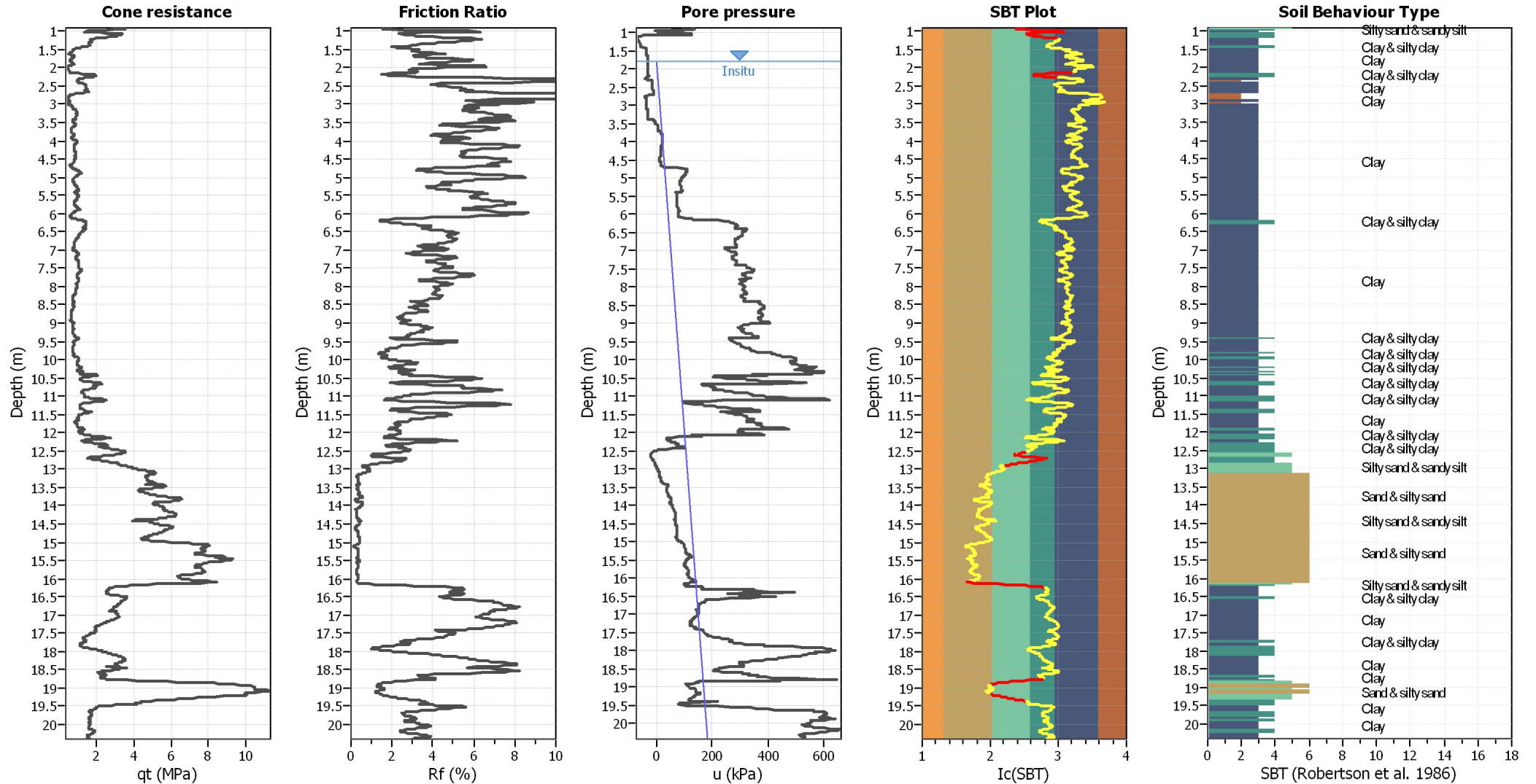
CPT file : CPTU 2 - IB - RSL 0.28

Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.80 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	1.80 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	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 based
Peak ground acceleration:	0.28	Unit weight calculation:	Based on SBT	K_G applied:	Yes		



CPT basic interpretation plots



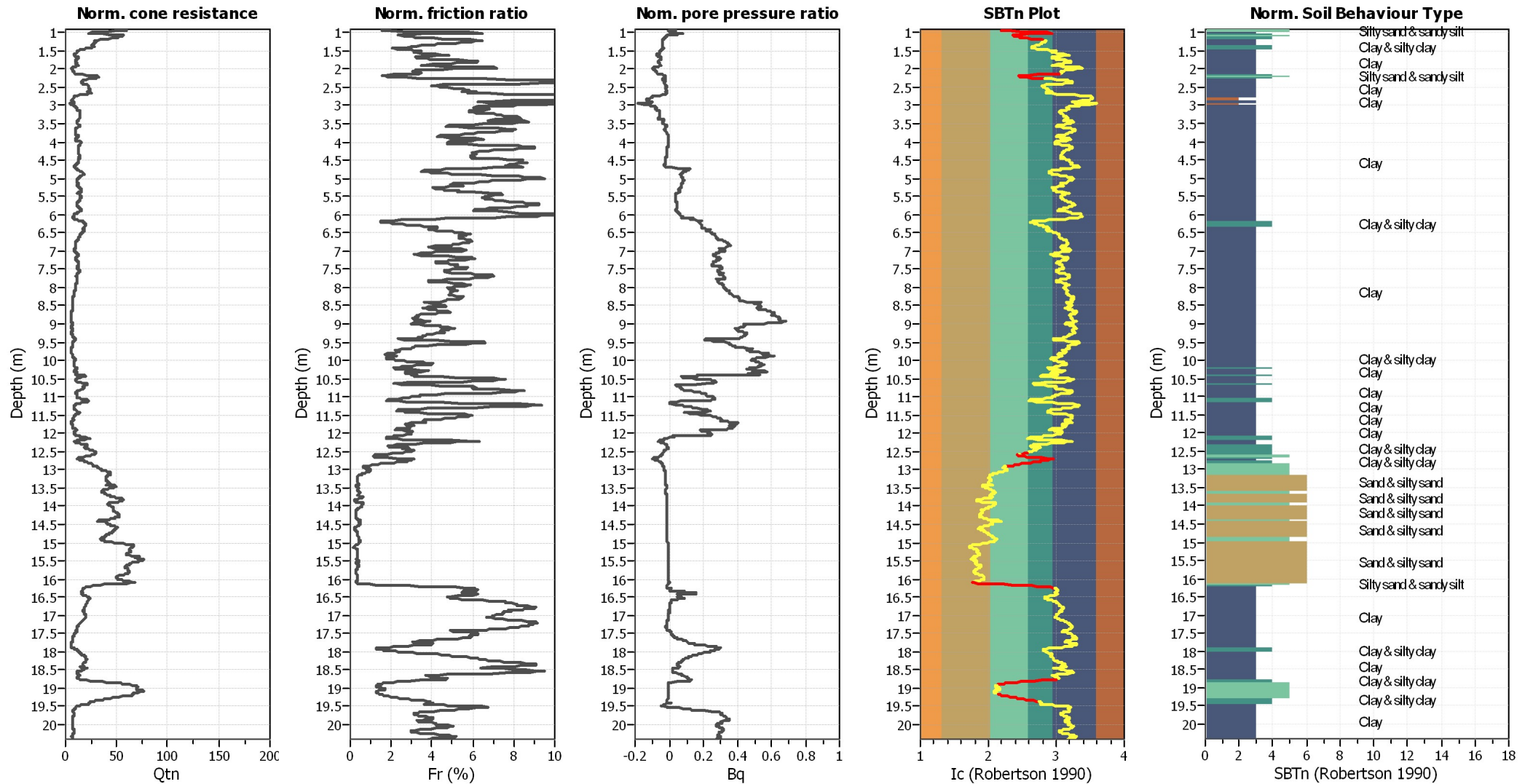
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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)



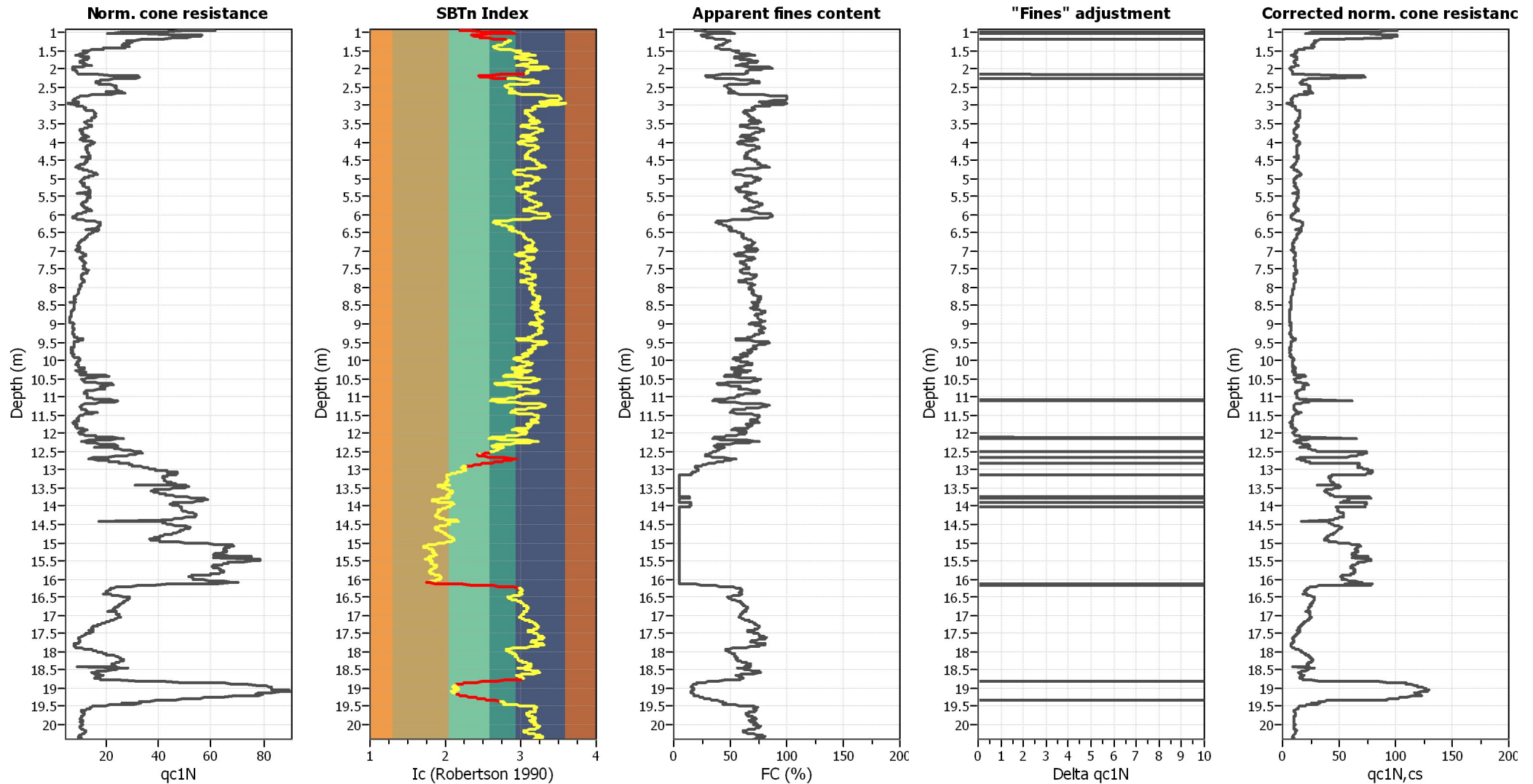
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_G applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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

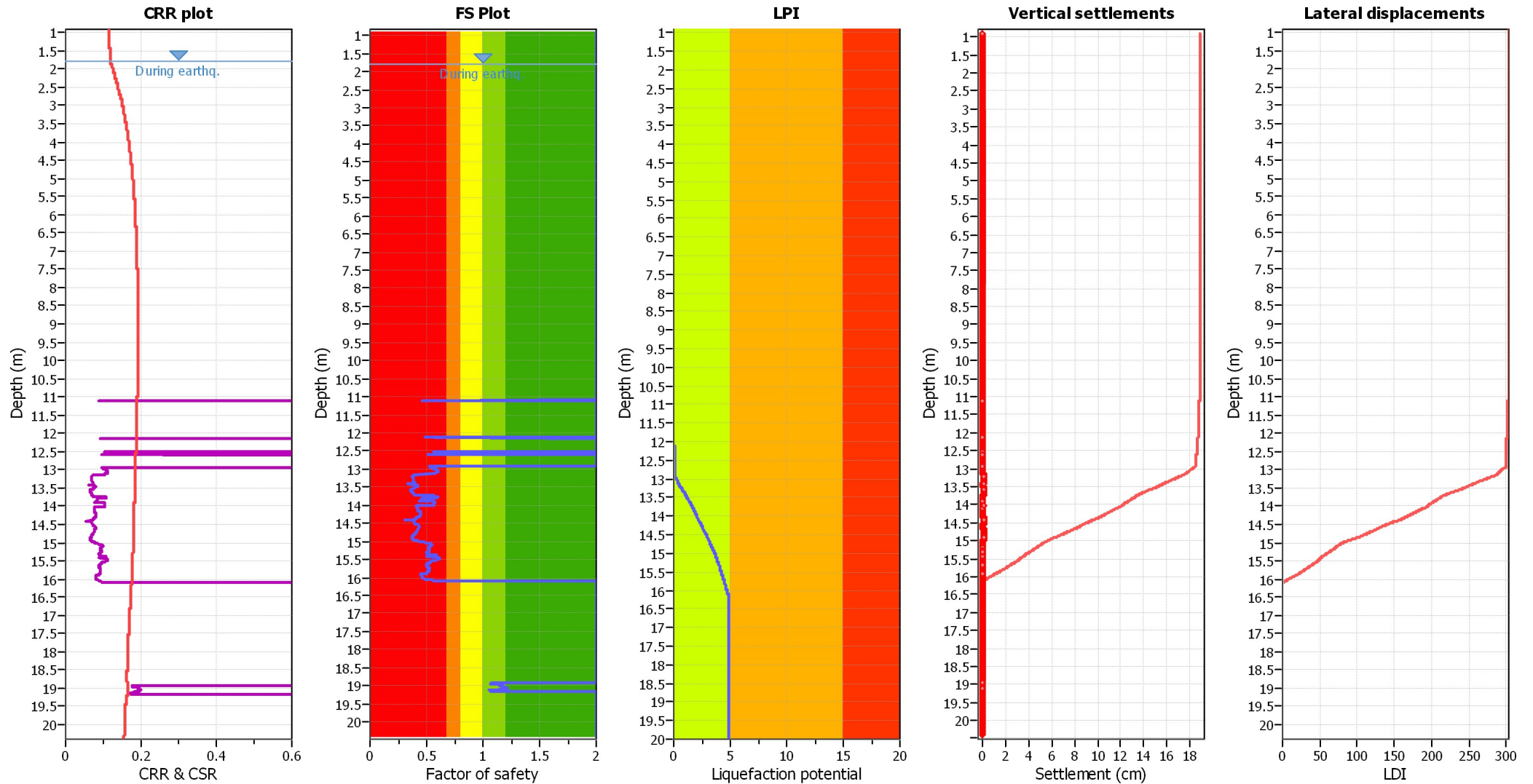
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _g applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

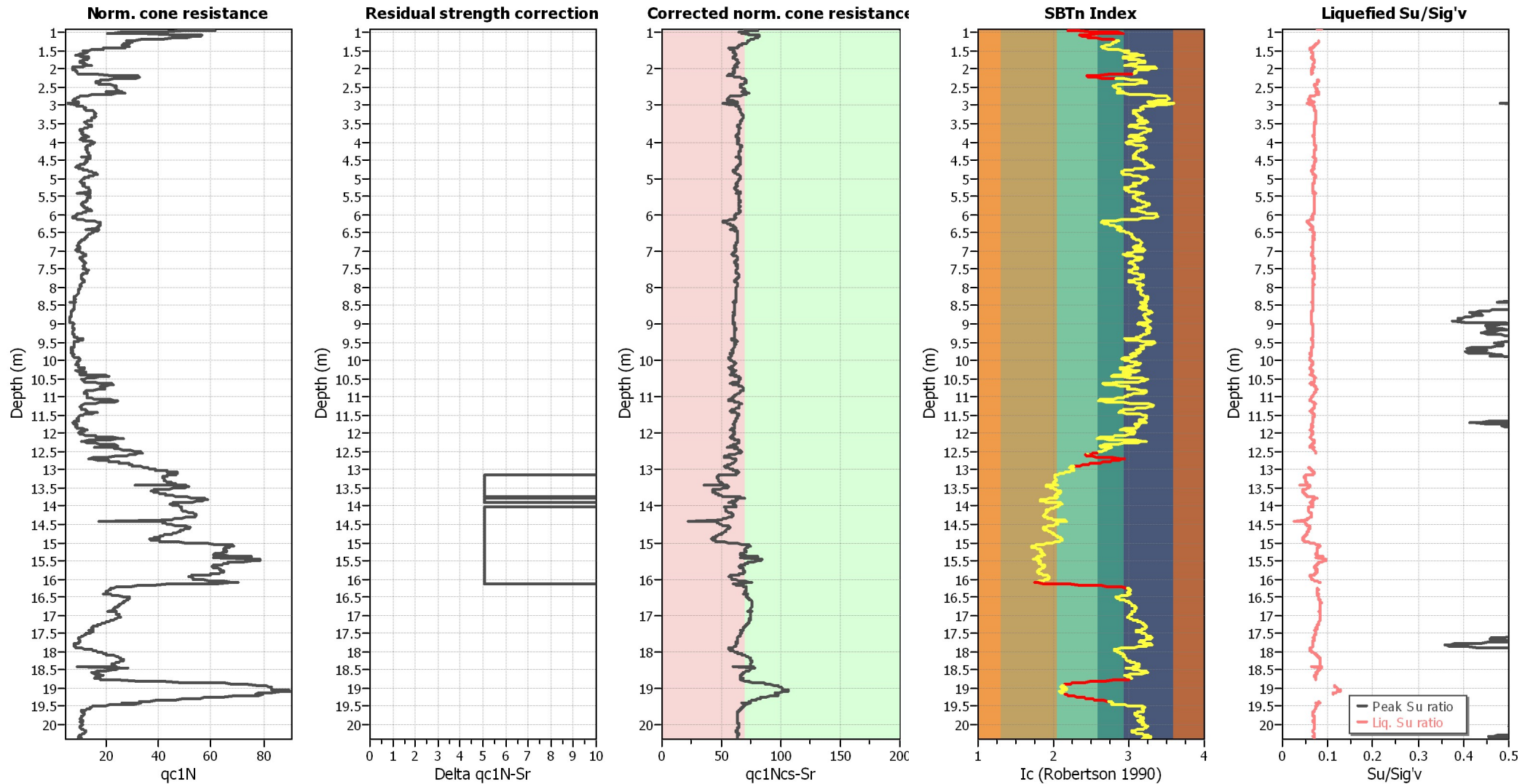
F.S. color scheme

- 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
- Low risk

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.28	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m



LIQUEFACTION ANALYSIS REPORT

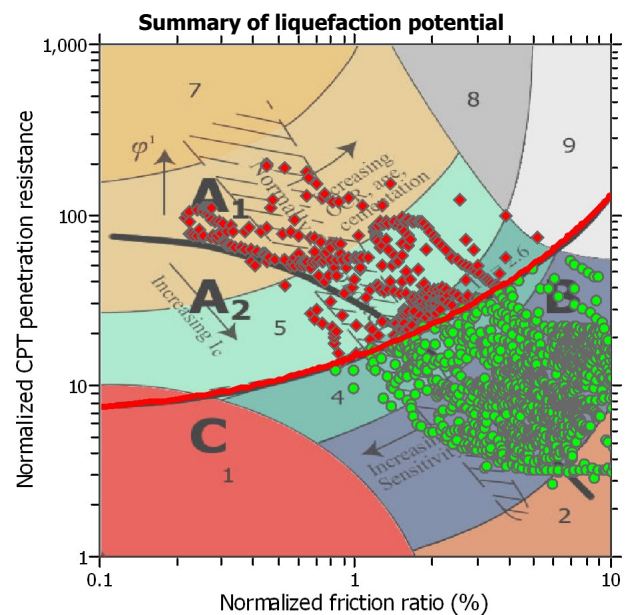
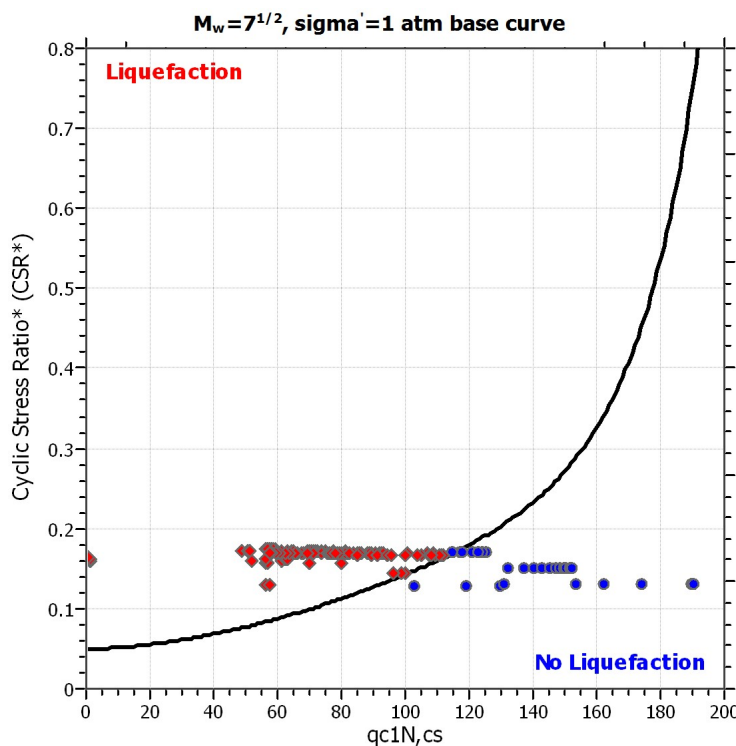
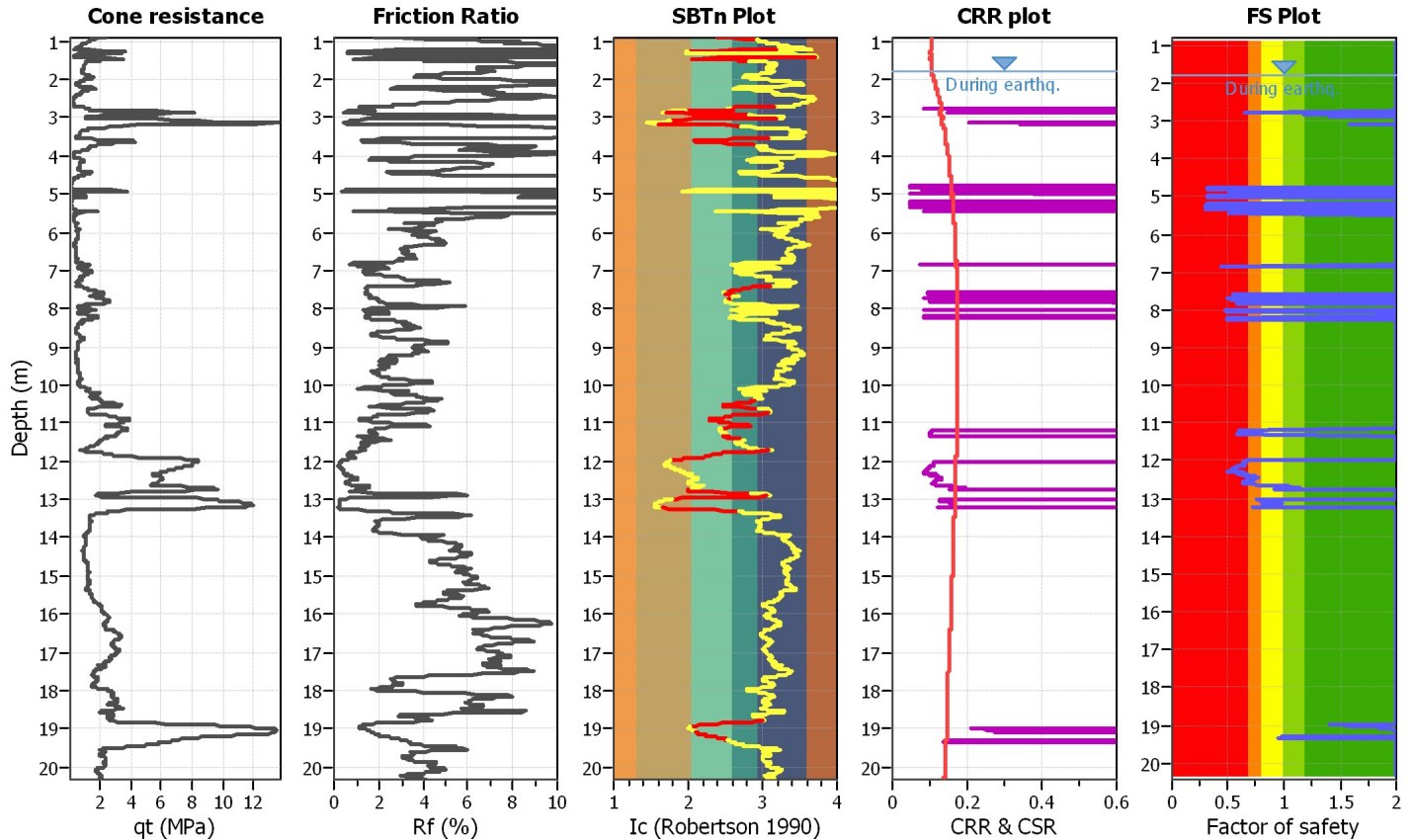
Project title : Studio del terreno di fondazione

Location : Duomo, Finale Emilia

CPT file : CPTU 1 - IB - CAT C 0.25

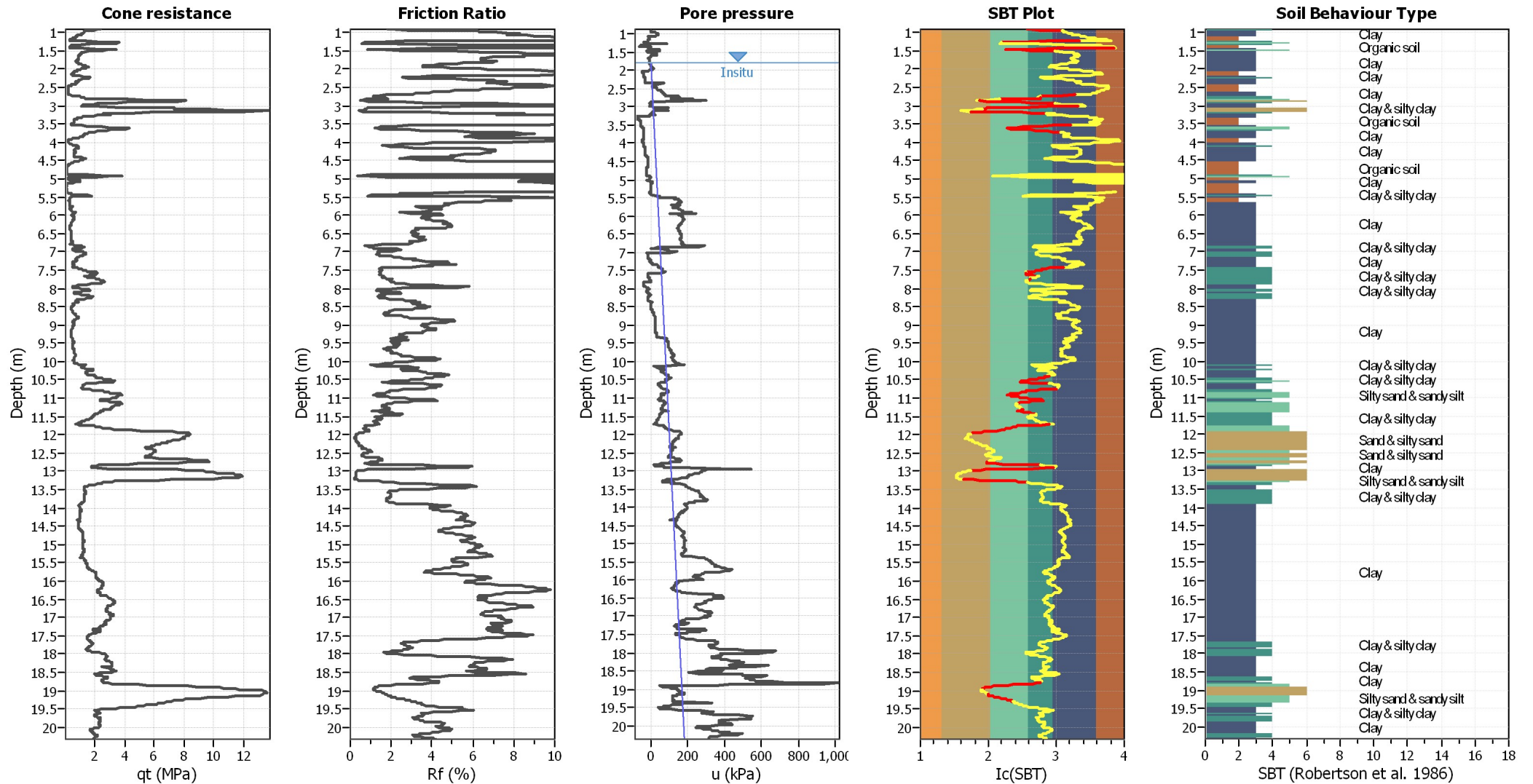
Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.80 m	Use fill:	No	Clay like behavior	
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	1.80 m	Fill height:	N/A	applied:	Sands only
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth applied:	Yes
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	Limit depth:	20.00 m
Peak ground acceleration:	0.25	Unit weight calculation:	Based on SBT	K_G applied:	Yes	MSF method:	Method based



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



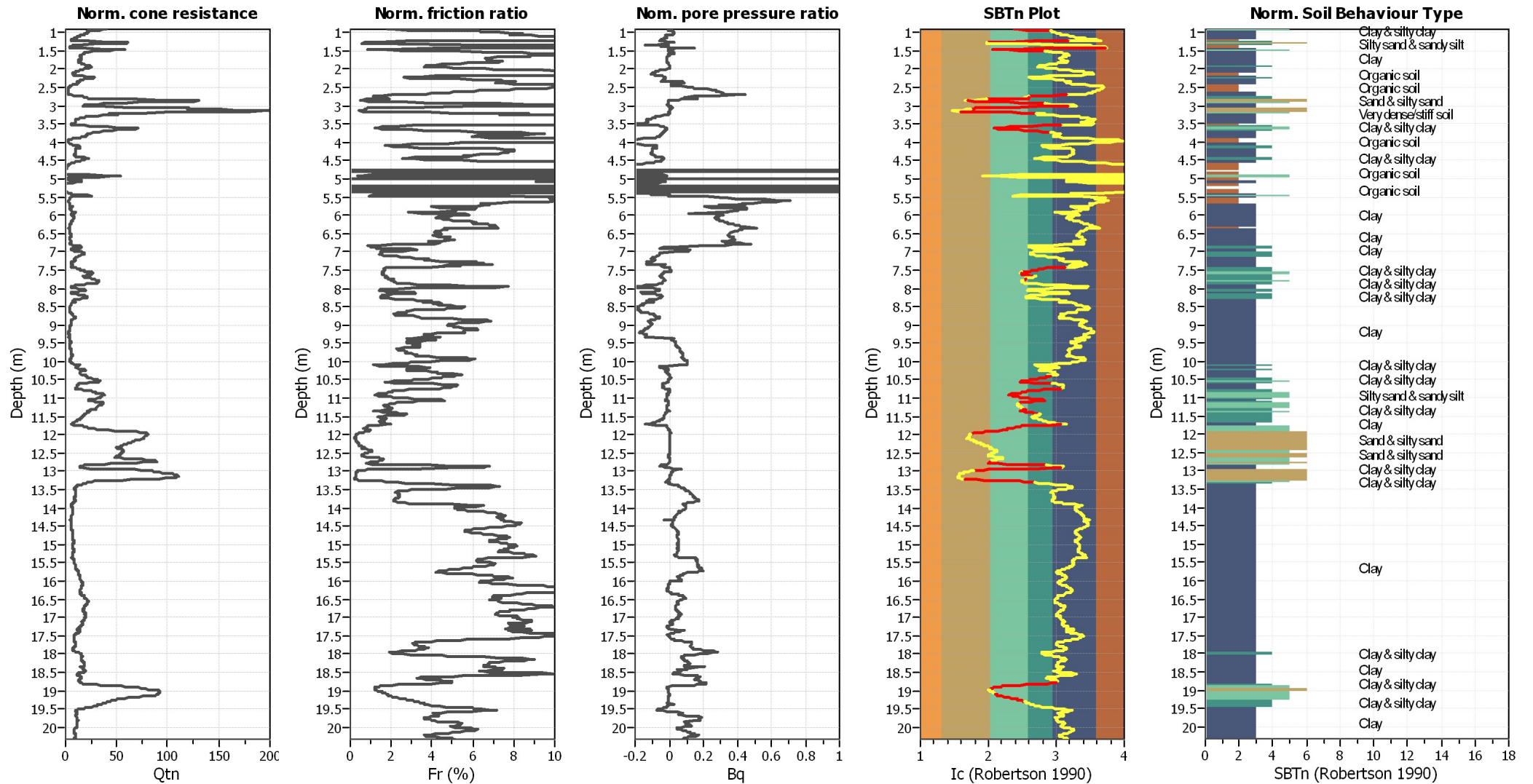
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _g applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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)



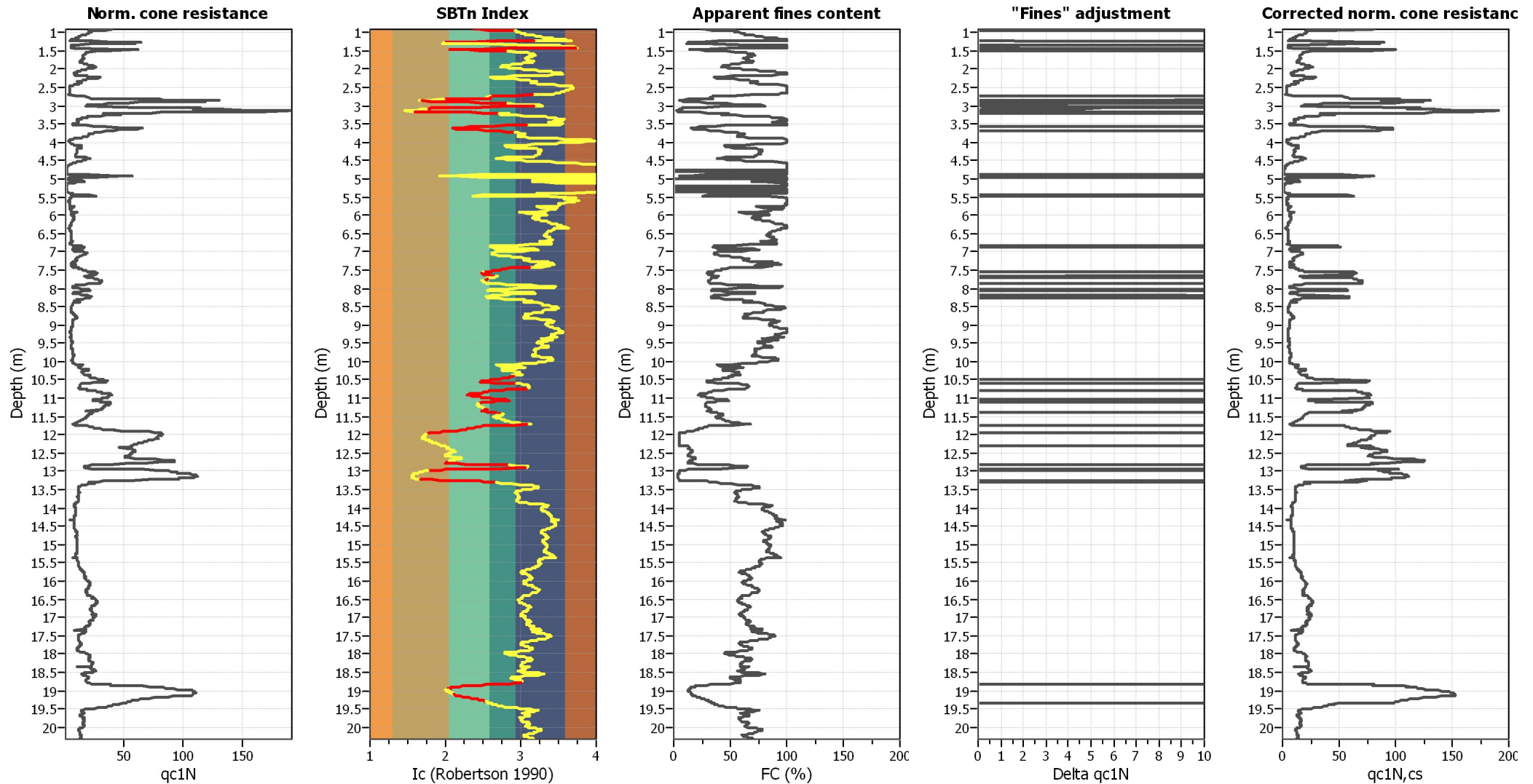
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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

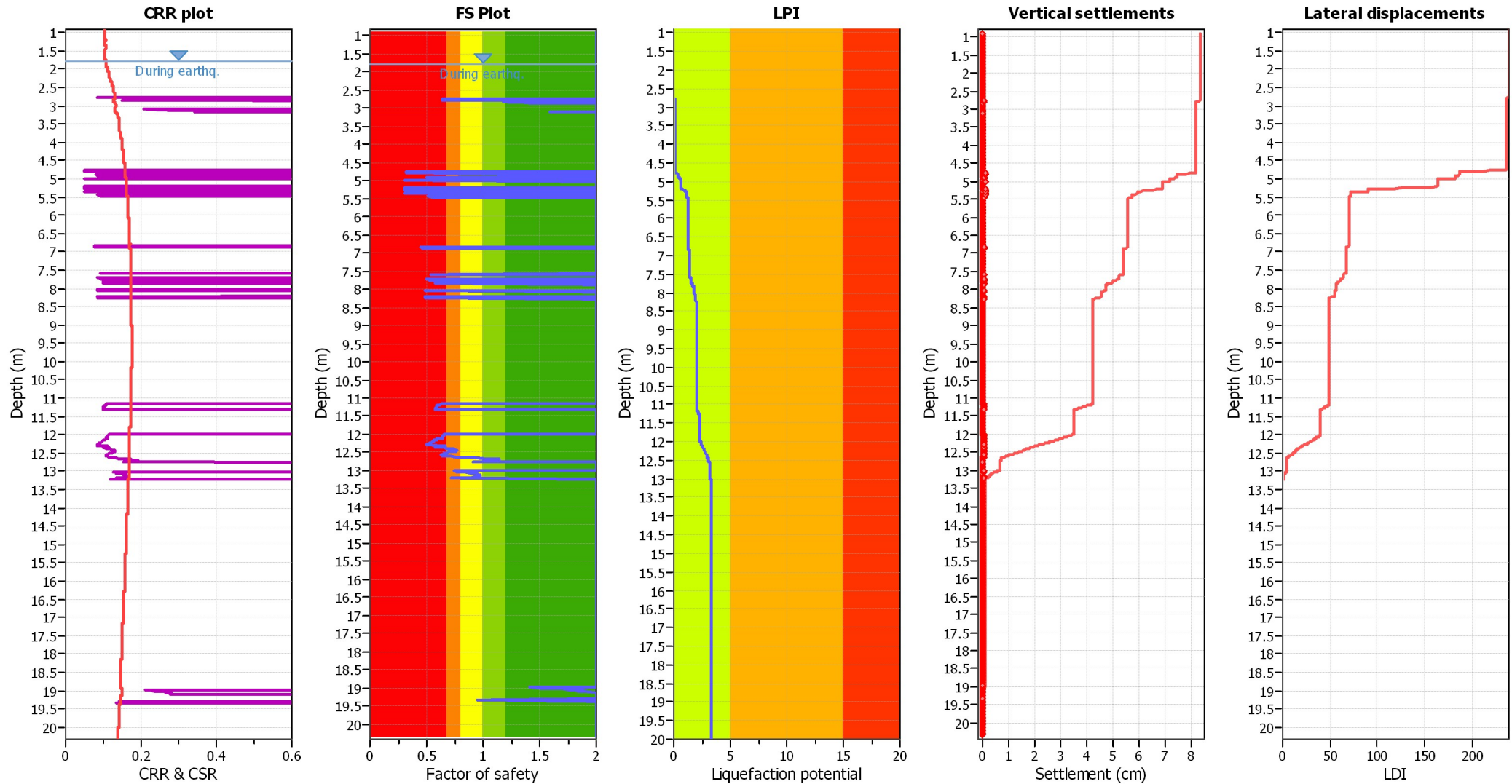
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_g applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

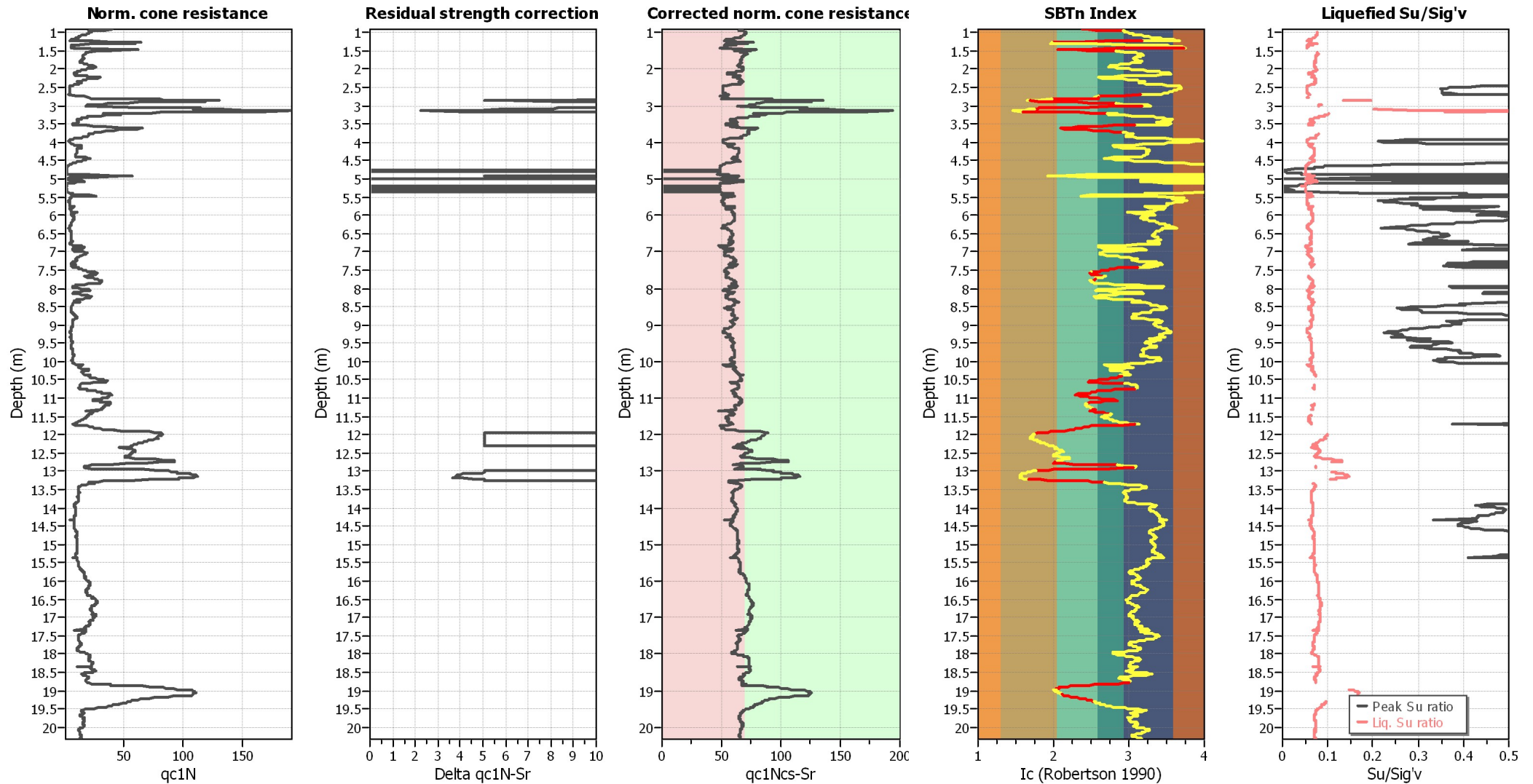
F.S. color scheme

- 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
- Low risk

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m



LIQUEFACTION ANALYSIS REPORT

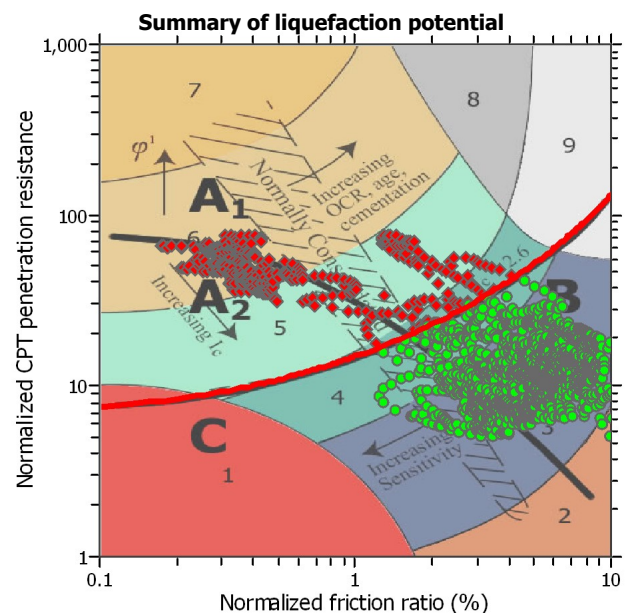
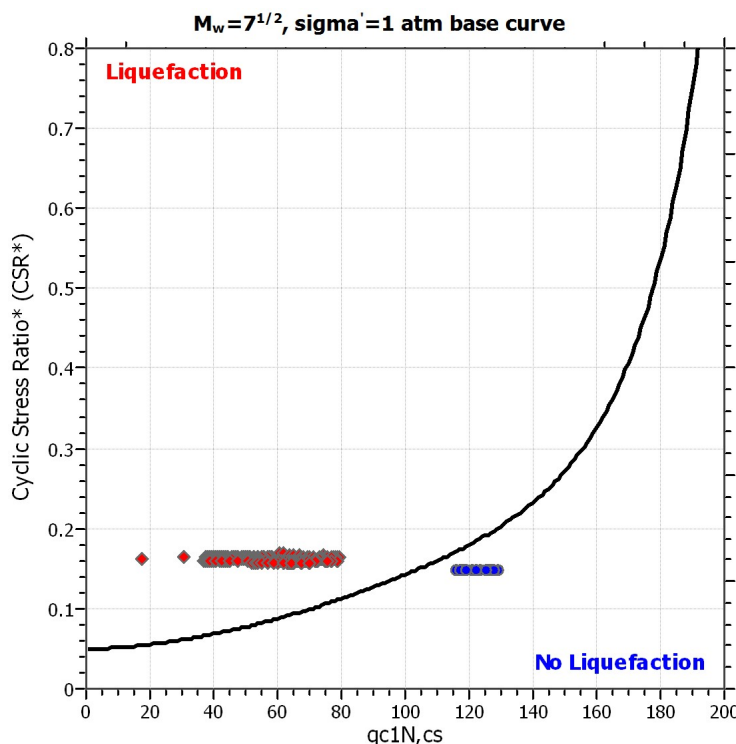
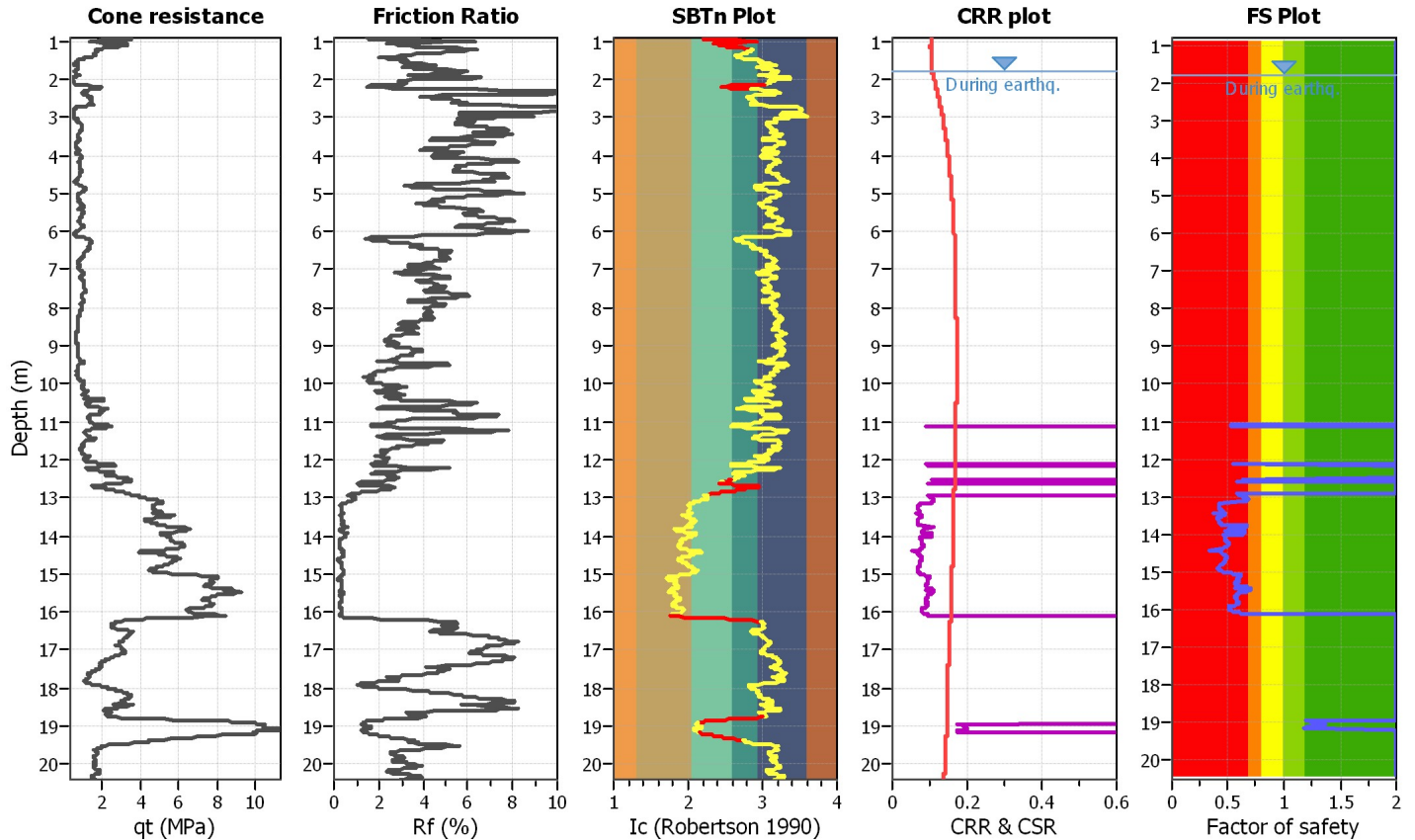
Project title : Studio del terreno di fondazione

Location : Duomo, Finale Emilia

CPT file : CPTU 2 - IB - CAT C 0.25

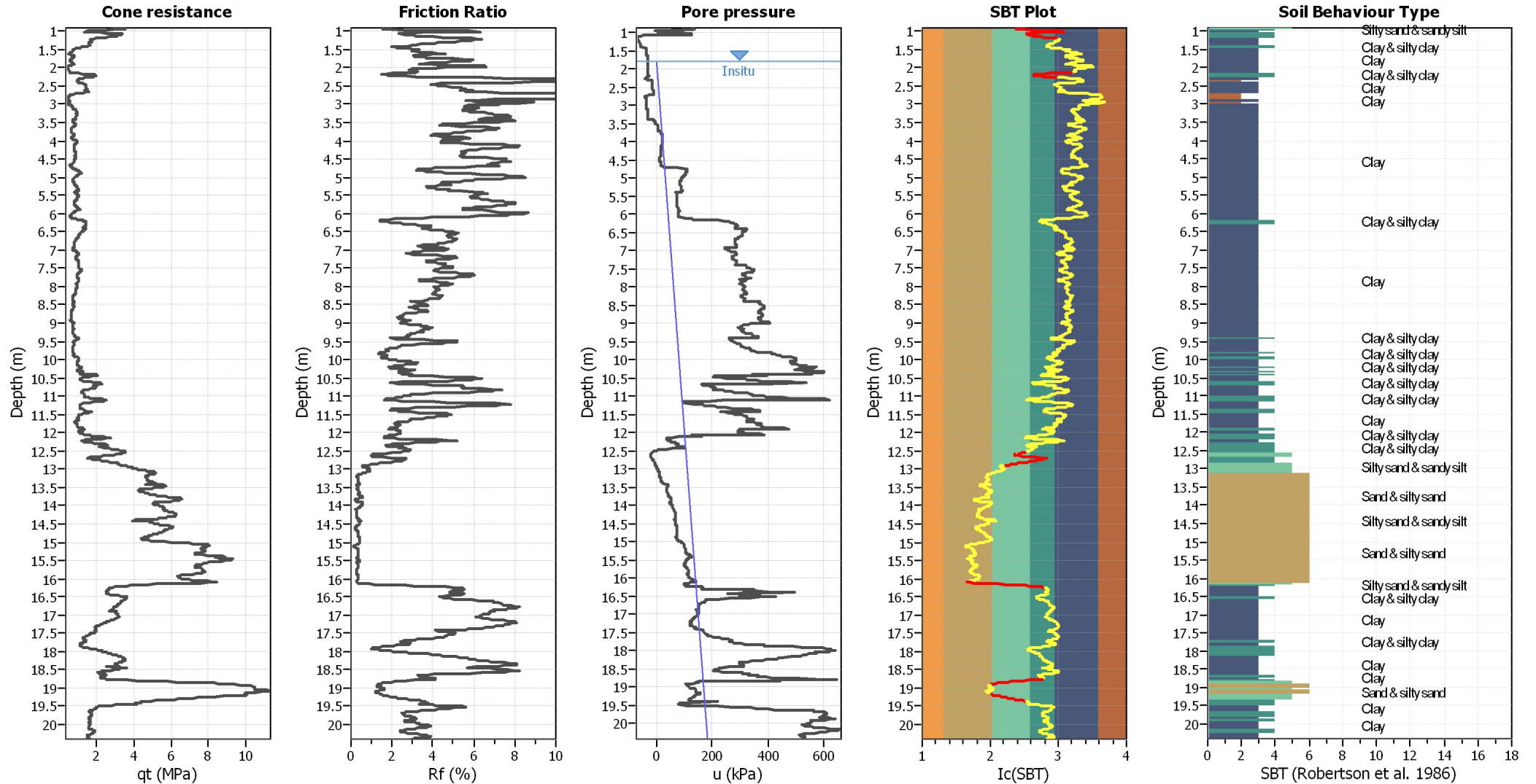
Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.80 m	Use fill:	No	Clay like behavior	
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	1.80 m	Fill height:	N/A	applied:	Sands only
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth applied:	Yes
Earthquake magnitude M_w :	6.14	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	Limit depth:	20.00 m
Peak ground acceleration:	0.25	Unit weight calculation:	Based on SBT	K_g applied:	Yes	MSF method:	Method based



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



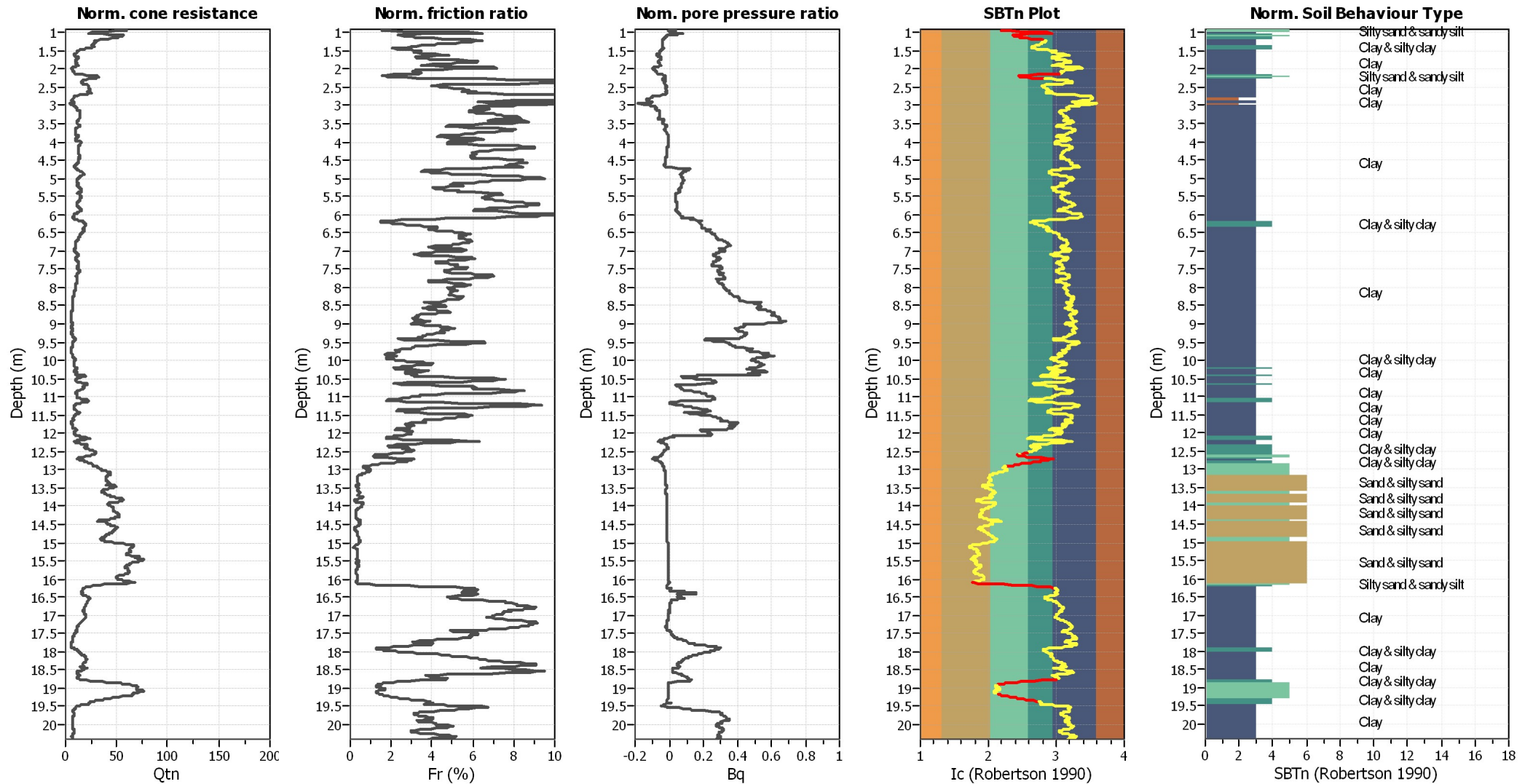
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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)



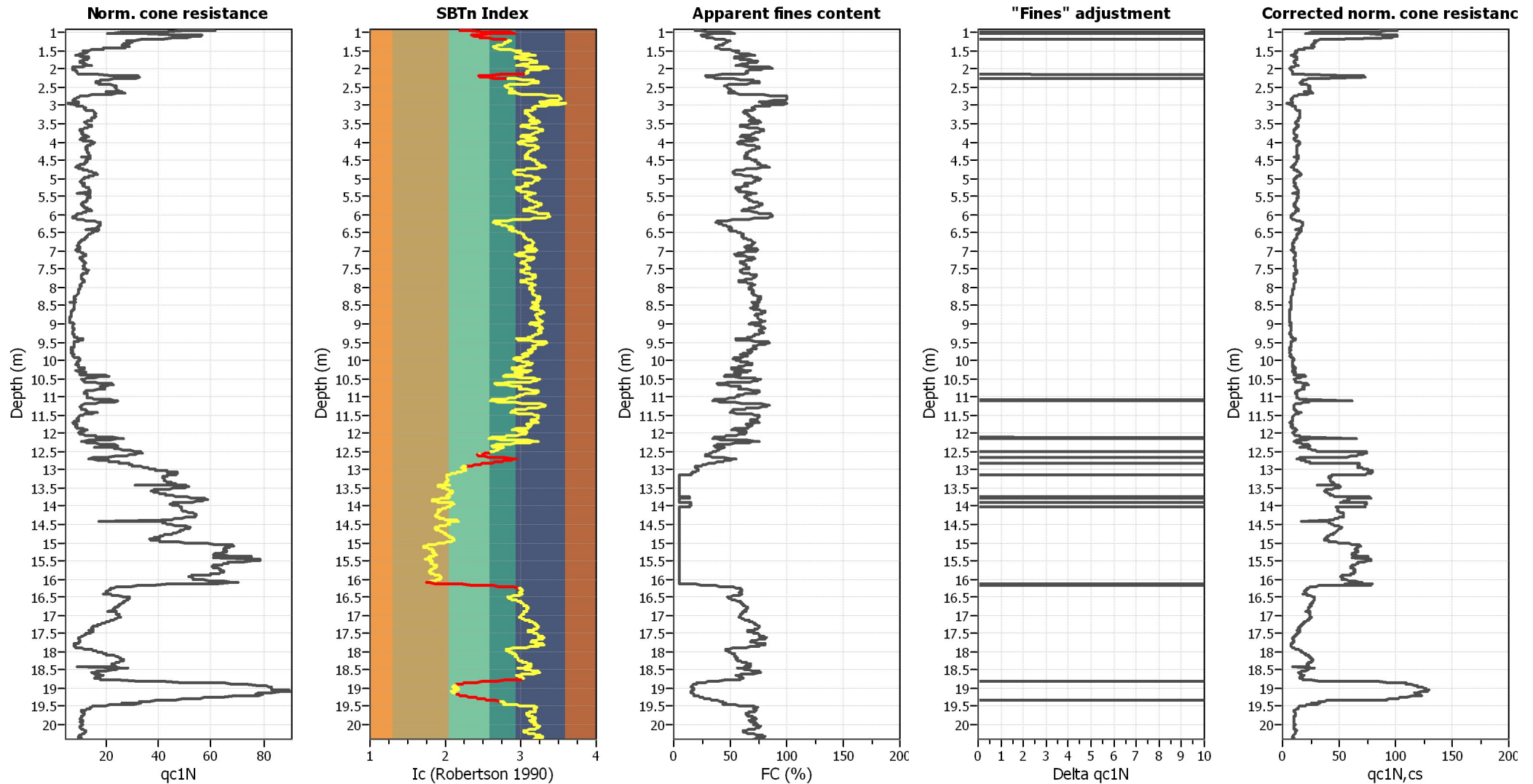
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	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

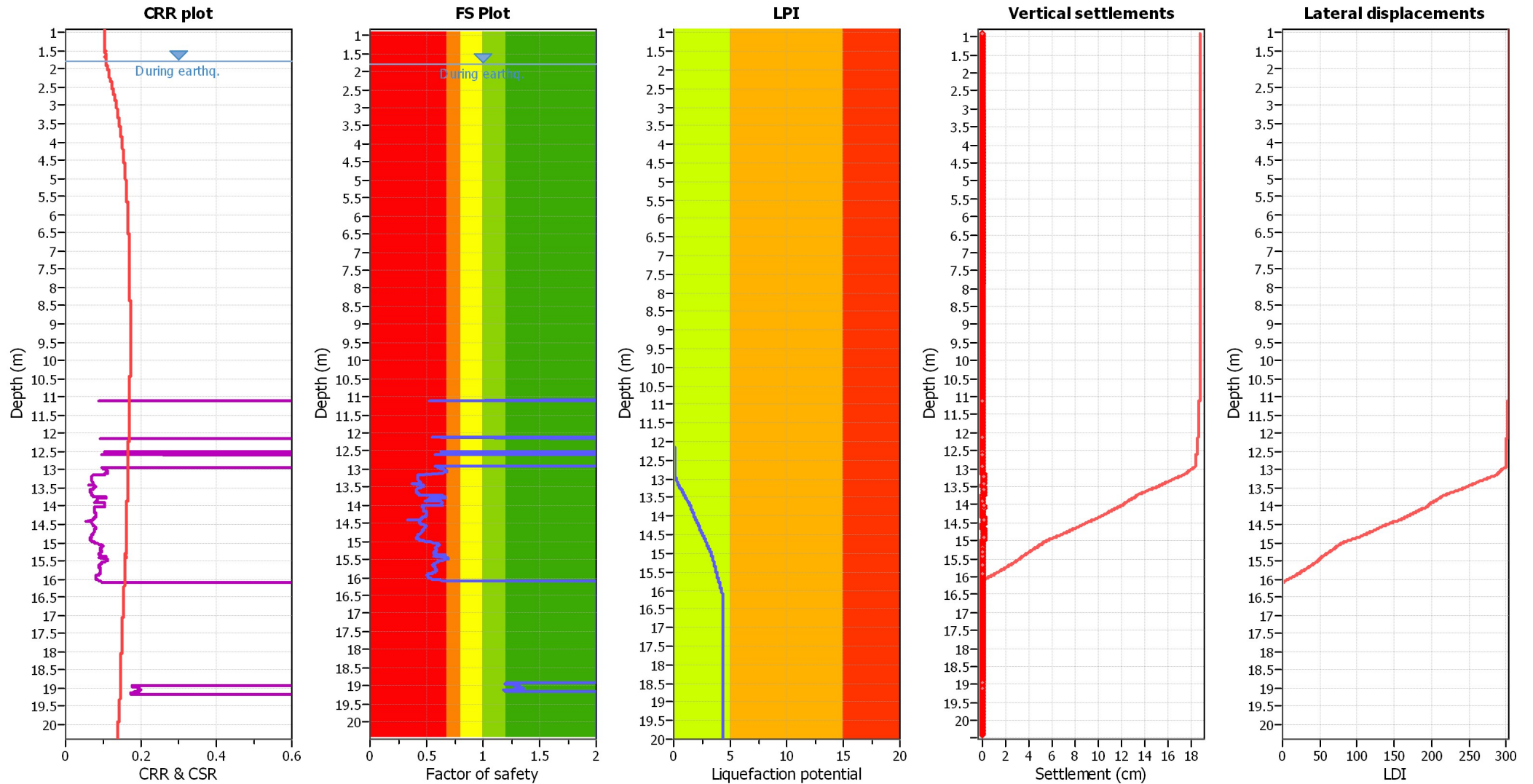
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_g applied:	Yes
Earthquake magnitude M_w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m

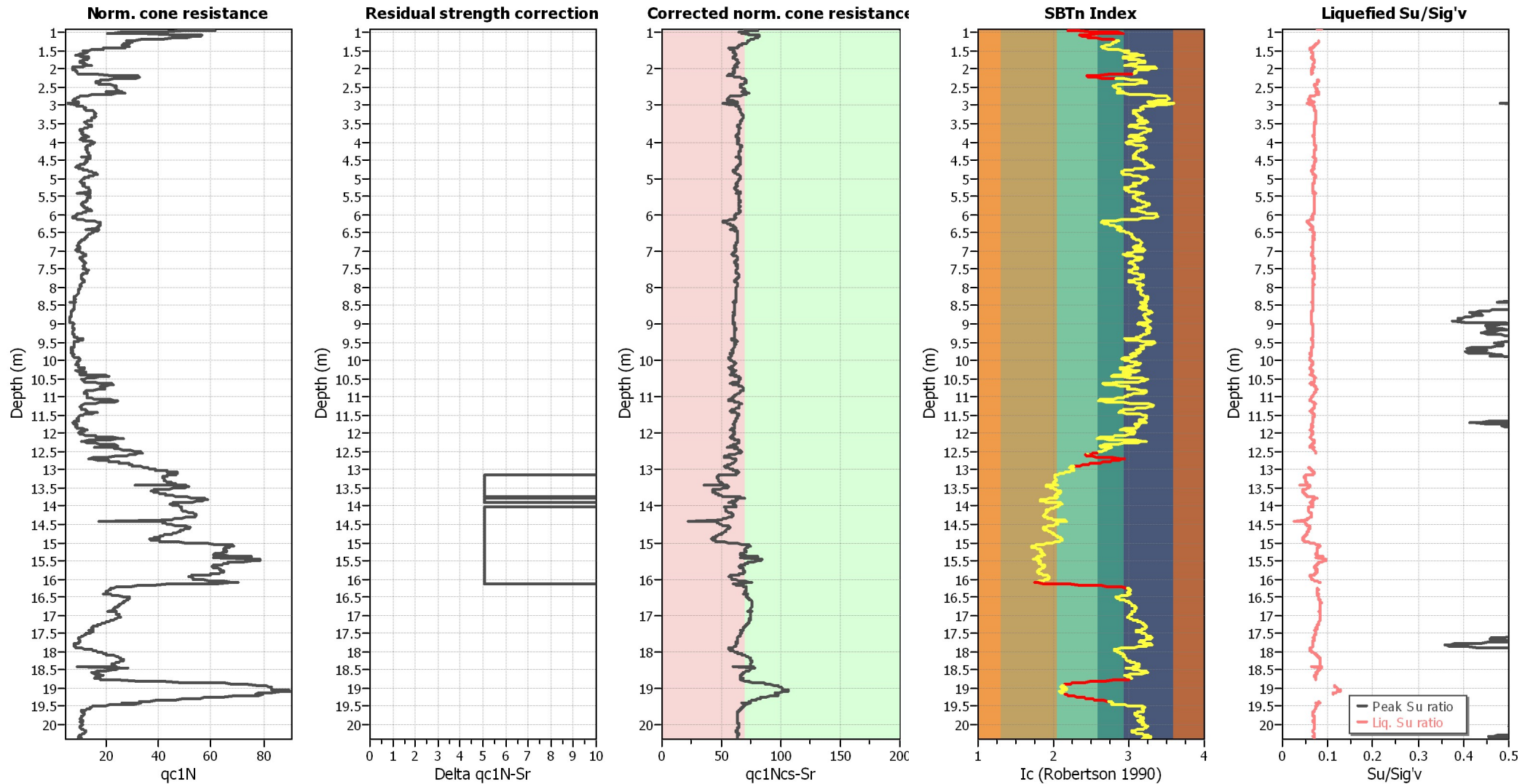
F.S. color scheme

- 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
- Low risk

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

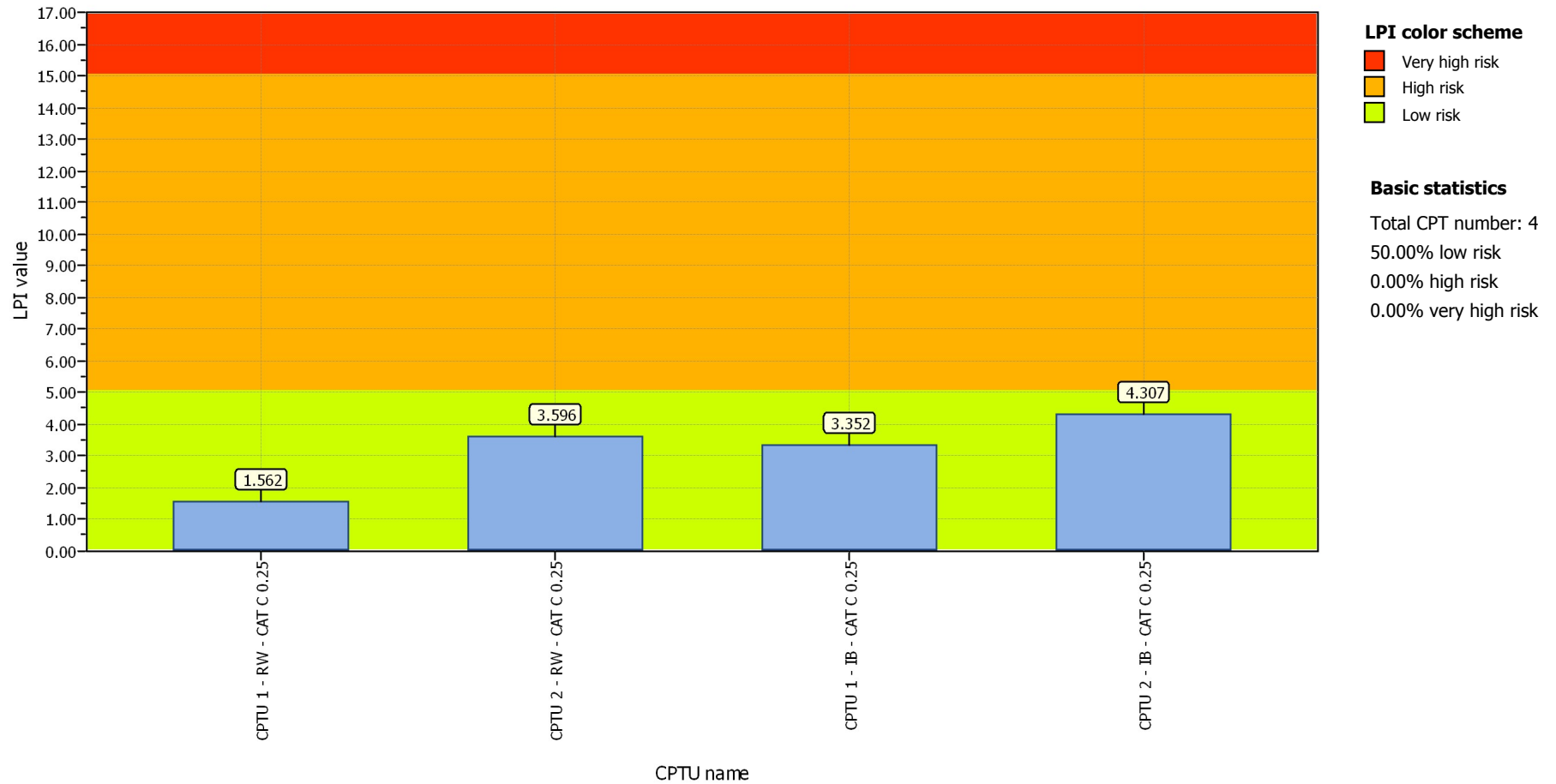
Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.80 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _G applied:	Yes
Earthquake magnitude M _w :	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.80 m	Fill height:	N/A	Limit depth:	20.00 m



Project title : Studio del terreno di fondazione

Location : Duomo, Finale Emilia

Overall Liquefaction Potential Index report





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Location : Duomo, Finale Emilia

Overall Liquefaction Potential Index report

