ALLEGATO 3

VERIFICHE GEOTECNICHE

DATI GENERALI

Larghezza fondazione	1.5 m
Lunghezza fondazione	2.5 m
Profondità piano di posa	1.0 m
Profondità falda	1.5

STRATIGRAFIA TERRENO

Spessore strato [m]	Peso unità di volume [kN/m³]	Peso unità di volume saturo [kN/m³]	Angolo di attrito [°]	Coesione [kN/m²]	Coesione non drenata [kN/m²]	Modulo Elastico [kN/m²]	Modulo Edometrico [kN/m²]	Descrizione
3.8	17.5	20.5	22.0	4.0	40.0	5600.0	3000.0	A
6.2	18.0	21.0	23.0	4.5	45.0	6300.0	3500.0	B
1.0	18.5	21.5	29.0	0.0	0.0	9000.0	0.0	C
2.2	18.0	21.0	23.0	5.5	55.0	7700.0	4000.0	D
2.6	18.5	21.5	25.0	9.0	90.0	12600.0	9000.0	E
1.0	18.5	21.5	28.0	0.0	0.0	7000.0	0.0	F
3.2	18.5	21.5	25.0	8.0	80.0	11200.0	7000.0	G

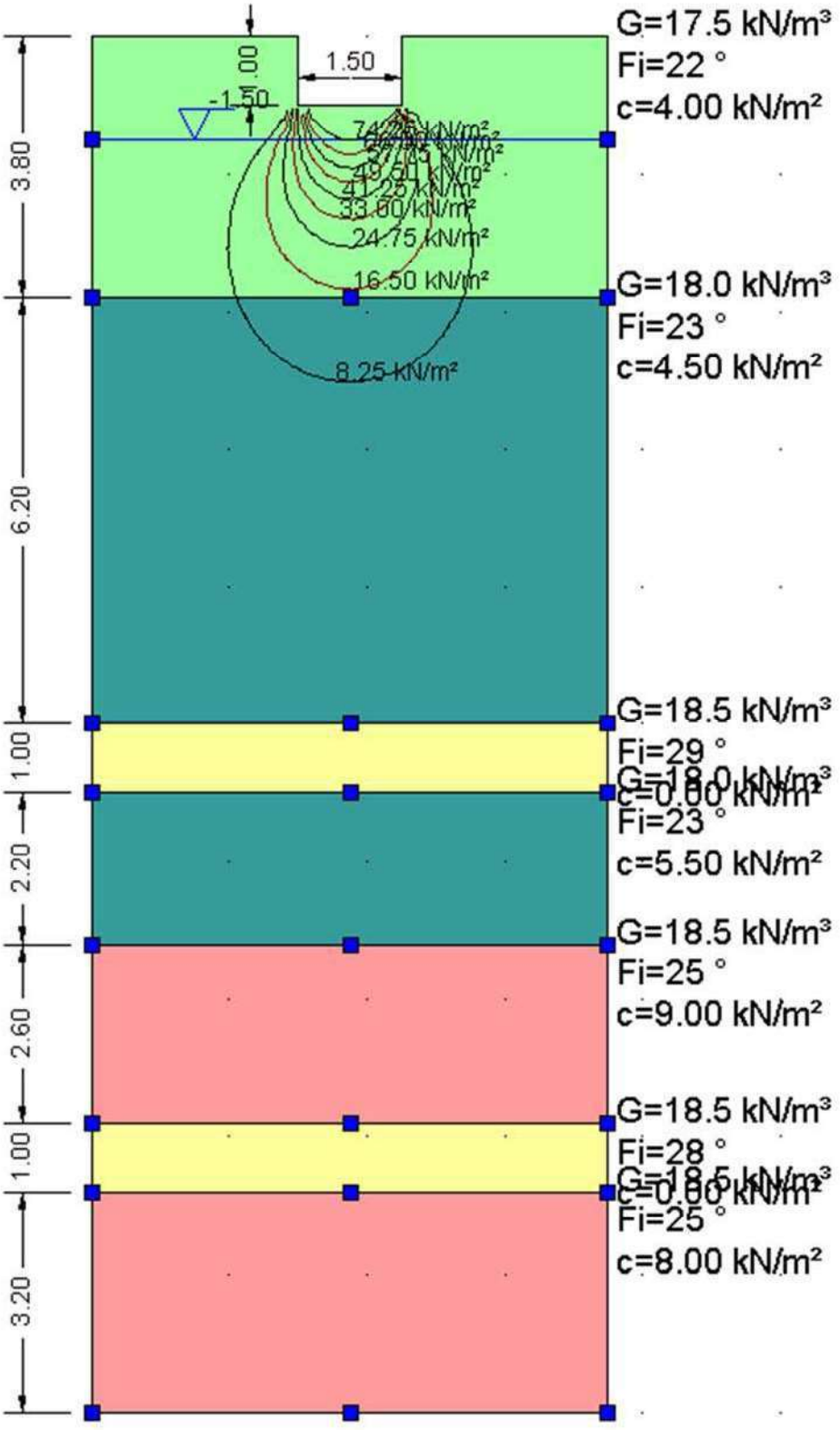
CEDIMENTI PER OGNI STRATO

***Cedimento edometrico calcolato con: Metodo consolidazione monodimensionale di Terzaghi**

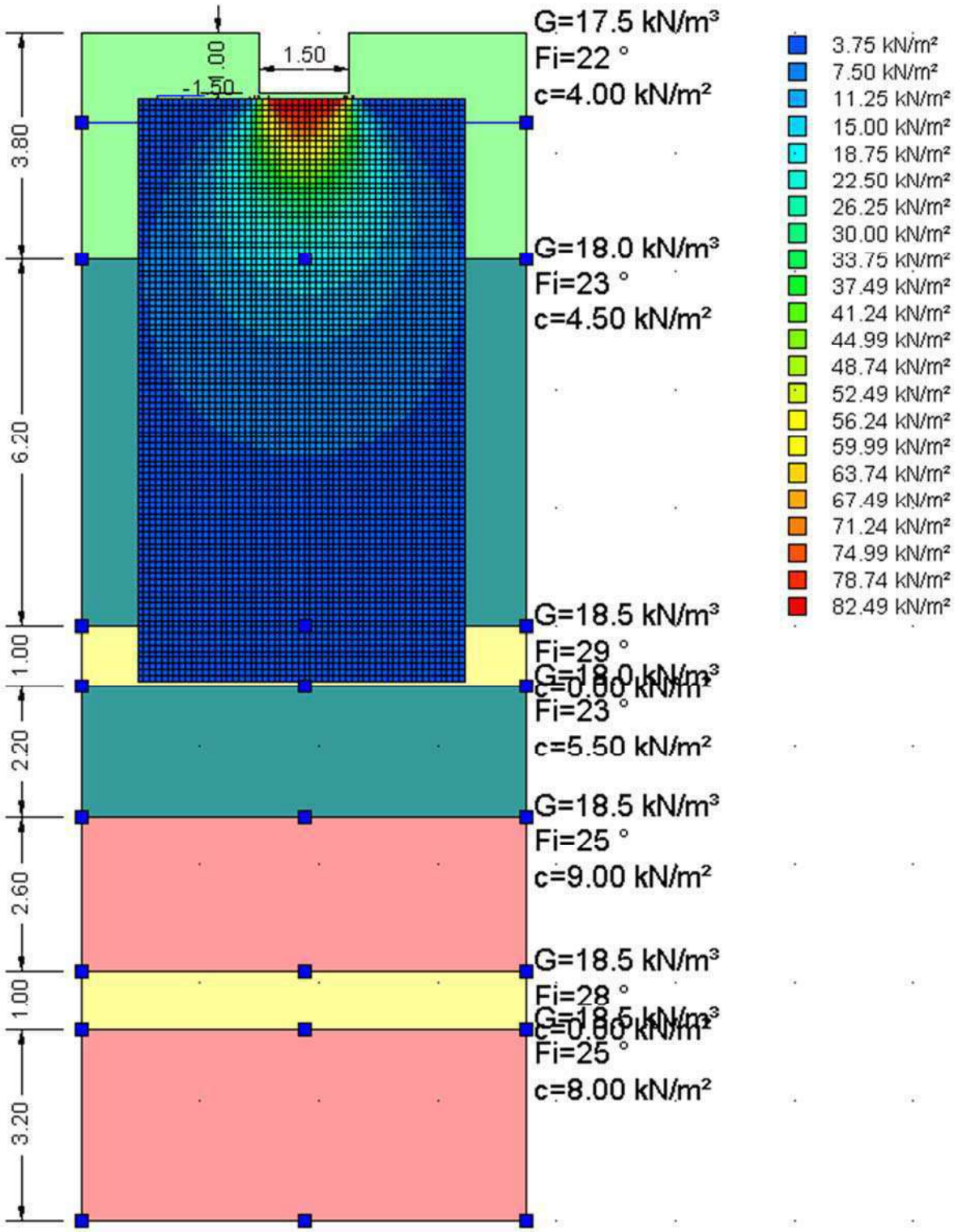
Pressione normale di progetto	100.0 kN/m²
Cedimento totale	**1.899 cm**

Z: Profondità media dello strato; Dp: Incremento di tensione; Wc: Cedimento consolidazione; Ws:Cedimento secondario; Wt: Cedimento totale.

Strato	Z (m)	Tensione (kN/m²)	Dp (kN/m²)	Metodo	Wc (cm)	Ws (cm)	Wt (cm)
1	2.4	35.874	12.777	Edometrico	1.1925	--	1.1925
2	6.9	85.542	3.392	Edometrico	0.6008	--	0.6008
3	10.5	0	0	Schmertmann	0	--	0
4	12.1	144.246	1.12	Edometrico	0.0616	--	0.0616
5	14.5	171.759	0.773	Edometrico	0.0223	--	0.0223
6	16.3	0	0	Schmertmann	0	--	0
7	18.4	217.362	0.474	Edometrico	0.0217	--	0.0217



Bulbo dei cedimenti



Mappa delle tensioni

ALLEGATO 4

INDAGINI SISMICHE

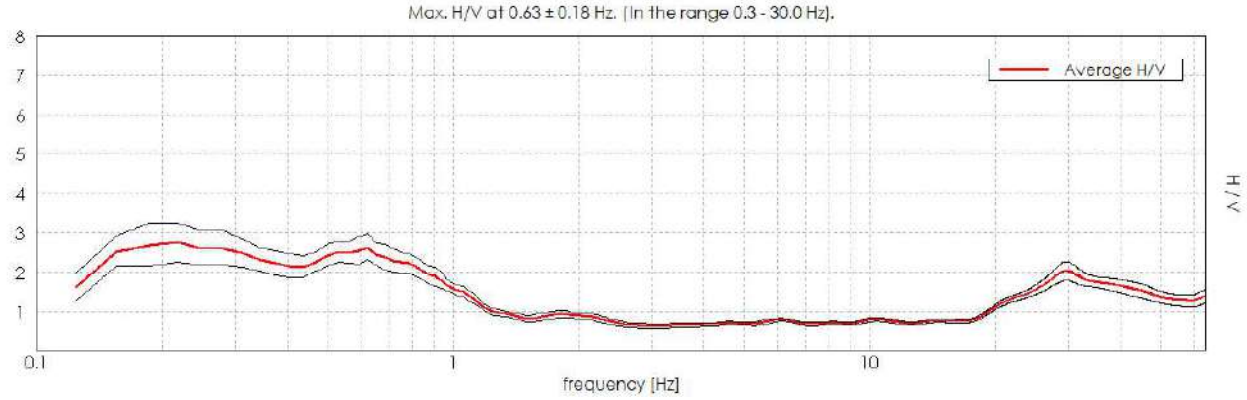
HVSR N.1

CARPI - SANTA CROCE

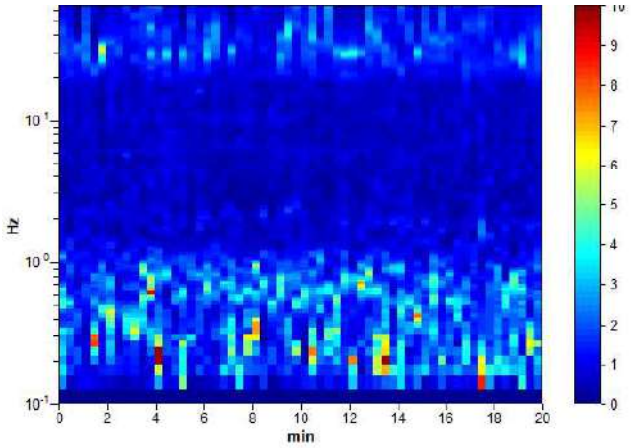
Instrument: TE3-0303/01-17
Data format: 32 byte
Full scale [mV]: 51
Start recording: 03/12/20 12:17:51 End recording: 03/12/20 12:37:51
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h20'00''. Analysis performed on the entire trace.
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

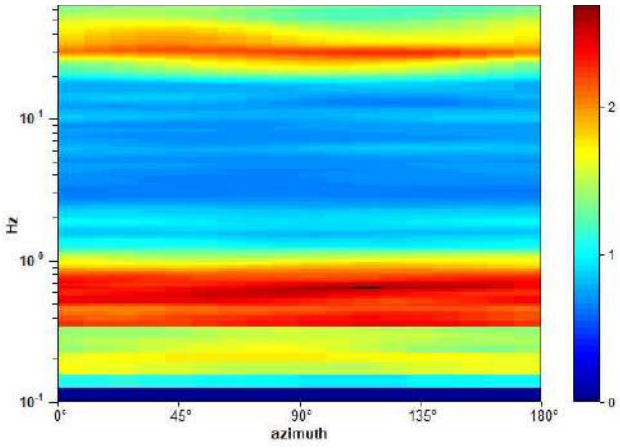
HORIZONTAL TO VERTICAL SPECTRAL RATIO



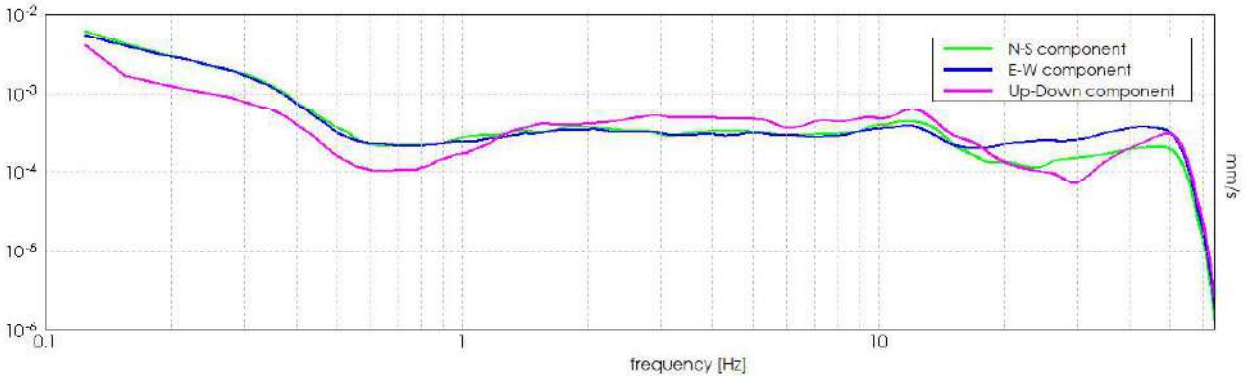
H/V TIME HISTORY



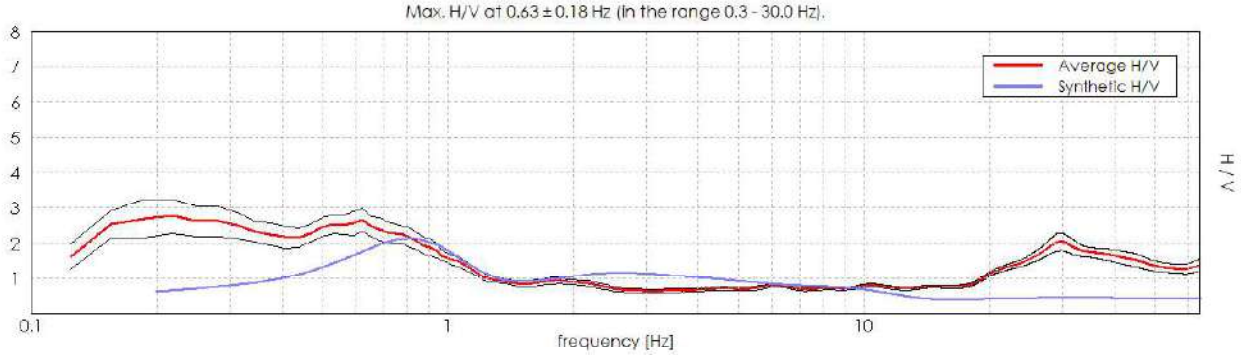
DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



EXPERIMENTAL vs. SYNTHETIC H/V



Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	Poisson ratio
4.00	4.00	140	0.48
14.00	10.00	210	0.47
34.00	20.00	280	0.46
64.00	30.00	340	0.44
114.00	50.00	380	0.43
inf.	inf.	550	0.42

[According to the SESAME, 2005 guidelines. **Please read carefully the *Grilla* manual before interpreting the following tables.**]

Max. H/V at 0.63 ± 0.18 Hz (in the range 0.3 - 30.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.63 > 0.50	OK	
$n_c(f_0) > 200$	750.0 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5$Hz **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5$Hz**	Exceeded 0 out of 31 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 $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	1.156 Hz	OK	
$A_0 > 2$	2.65 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.28003| < 0.05		NO
$\sigma_f < \varepsilon(f_0)$	0.17502 < 0.09375		NO
$\sigma_A(f_0) < \theta(f_0)$	0.3269 < 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
$\sigma_{logH/V}(f)$	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 $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

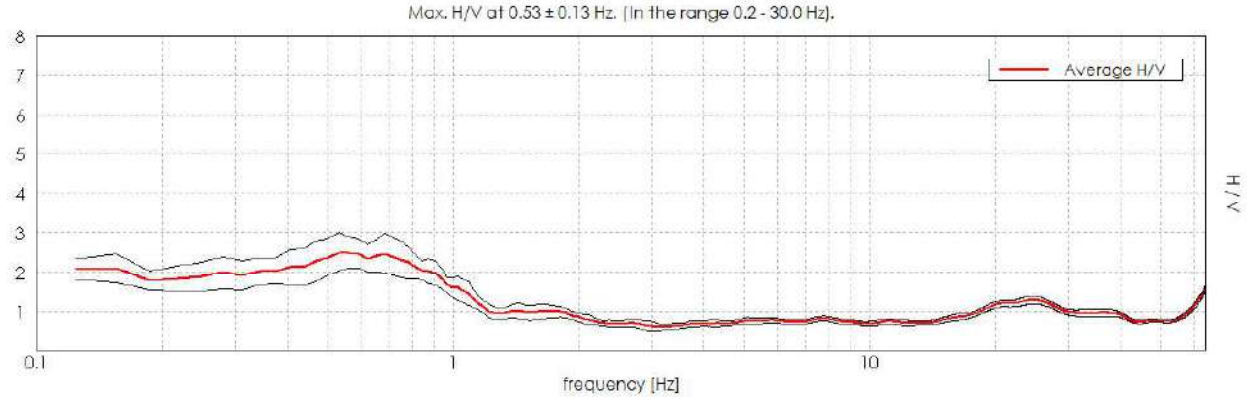
HVSR N.2

CARPI - SANTA CROCE

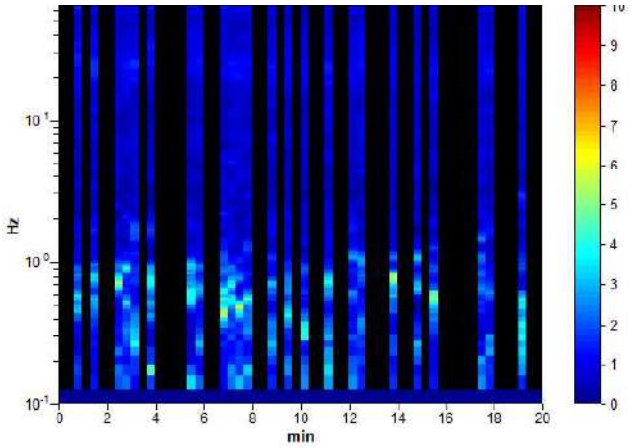
Instrument: TE3-0303/01-17
Data format: 32 byte
Full scale [mV]: 51
Start recording: 03/12/20 12:38:43 End recording: 03/12/20 12:58:43
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h20'00". Analyzed 40% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

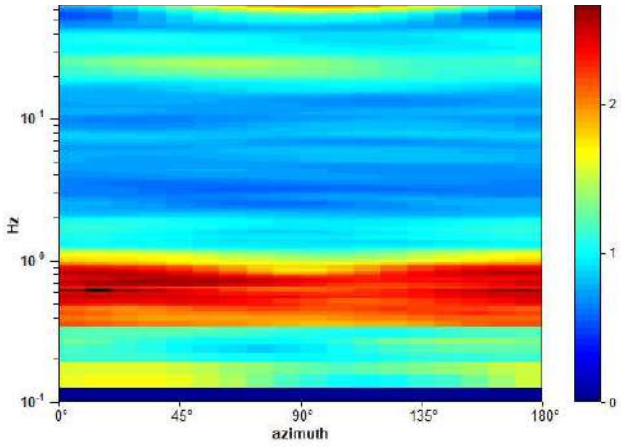
HORIZONTAL TO VERTICAL SPECTRAL RATIO



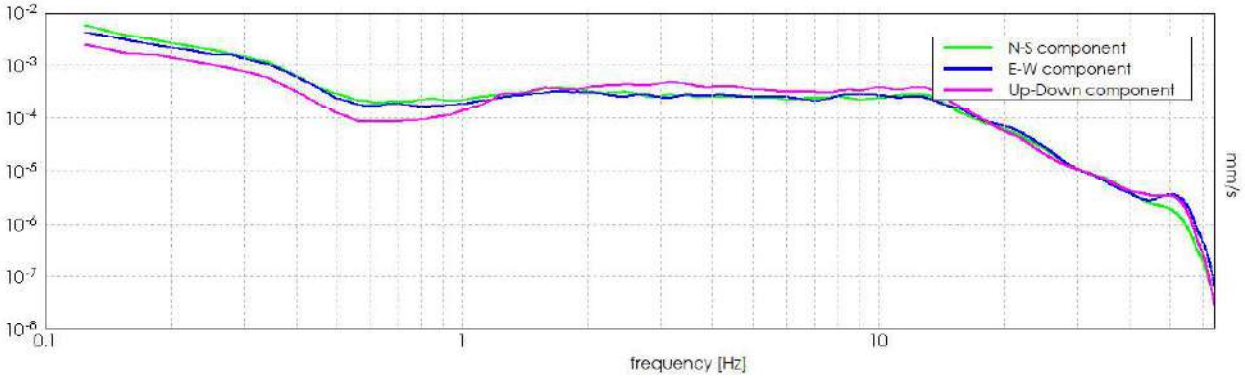
H/V TIME HISTORY



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 0.53 ± 0.13 Hz (in the range 0.2 - 30.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.53 > 0.50	OK	
$n_c(f_0) > 200$	255.0 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5$Hz **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5$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 $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	1.156 Hz	OK	
$A_0 > 2$	2.51 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.24134| < 0.05		NO
$\sigma_f < \varepsilon(f_0)$	0.12821 < 0.07969		NO
$\sigma_A(f_0) < \theta(f_0)$	0.4831 < 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
$\sigma_{logH/V}(f)$	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 $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

MASW

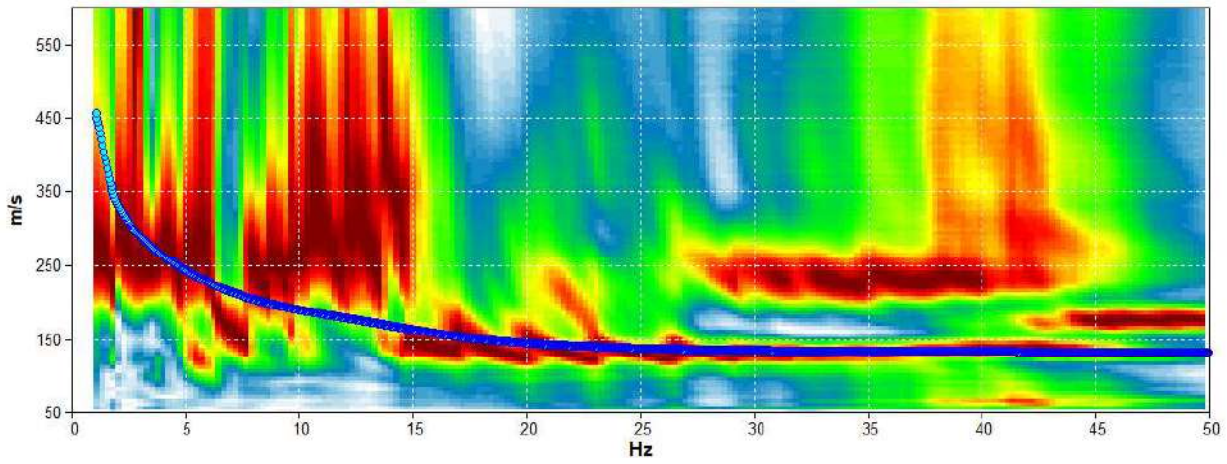
CARPI - SANTA CROCE

Start recording: 03/12/20 12:17:51 End recording: 03/12/20 12:37:51
Trace length: 0h20'00''. Analysis performed on the entire trace.
Sampling rate: 128 Hz

Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN

Array geometry (x): 0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0 32.0 34.0 m

MODELLED RAYLEIGH WAVE PHASE VELOCITY DISPERSION CURVE

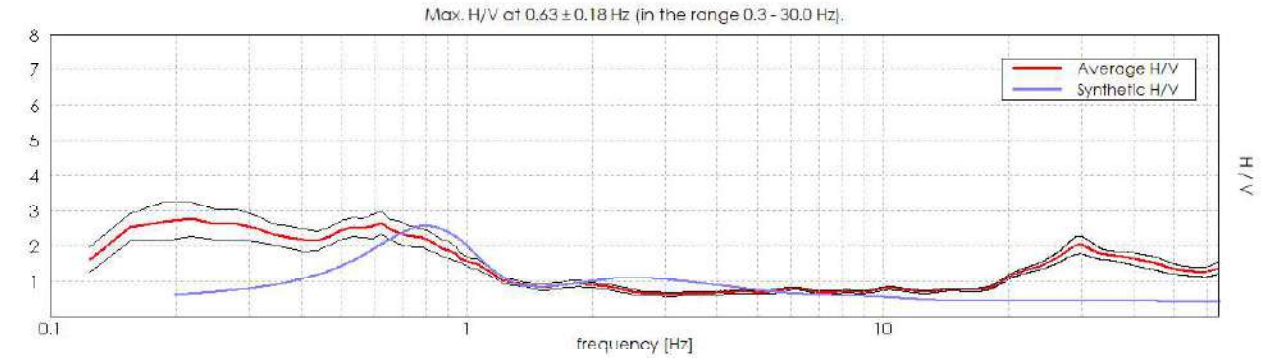


Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	Poisson ratio
4.00	4.00	140	0.48
14.00	10.00	210	0.47
34.00	20.00	280	0.46
64.00	30.00	340	0.44
114.00	50.00	380	0.43
inf.	inf.	550	0.42

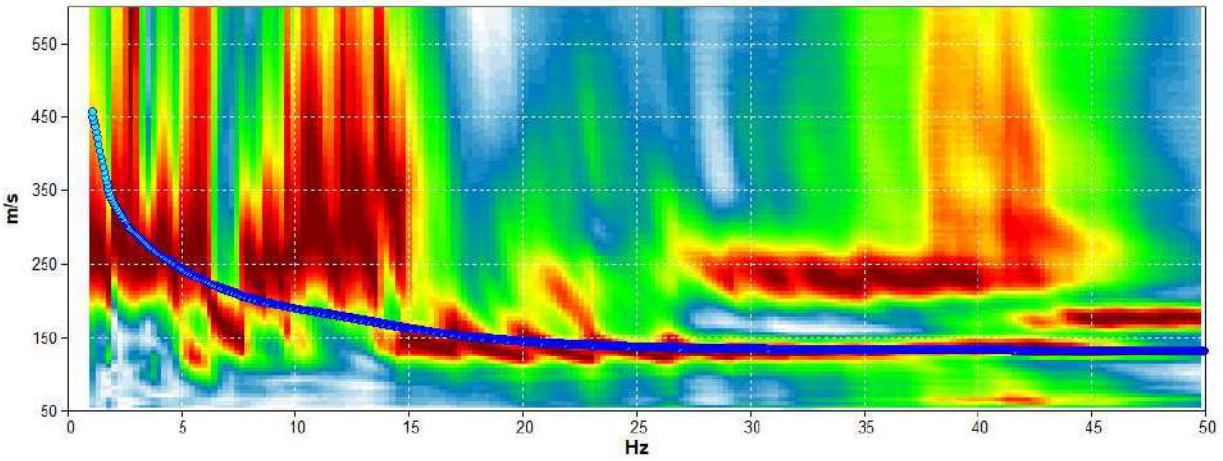
Vs (0.0-30.0) = 225 m/s

ELABORAZIONE CONGIUNTA HVSR1 E MASW

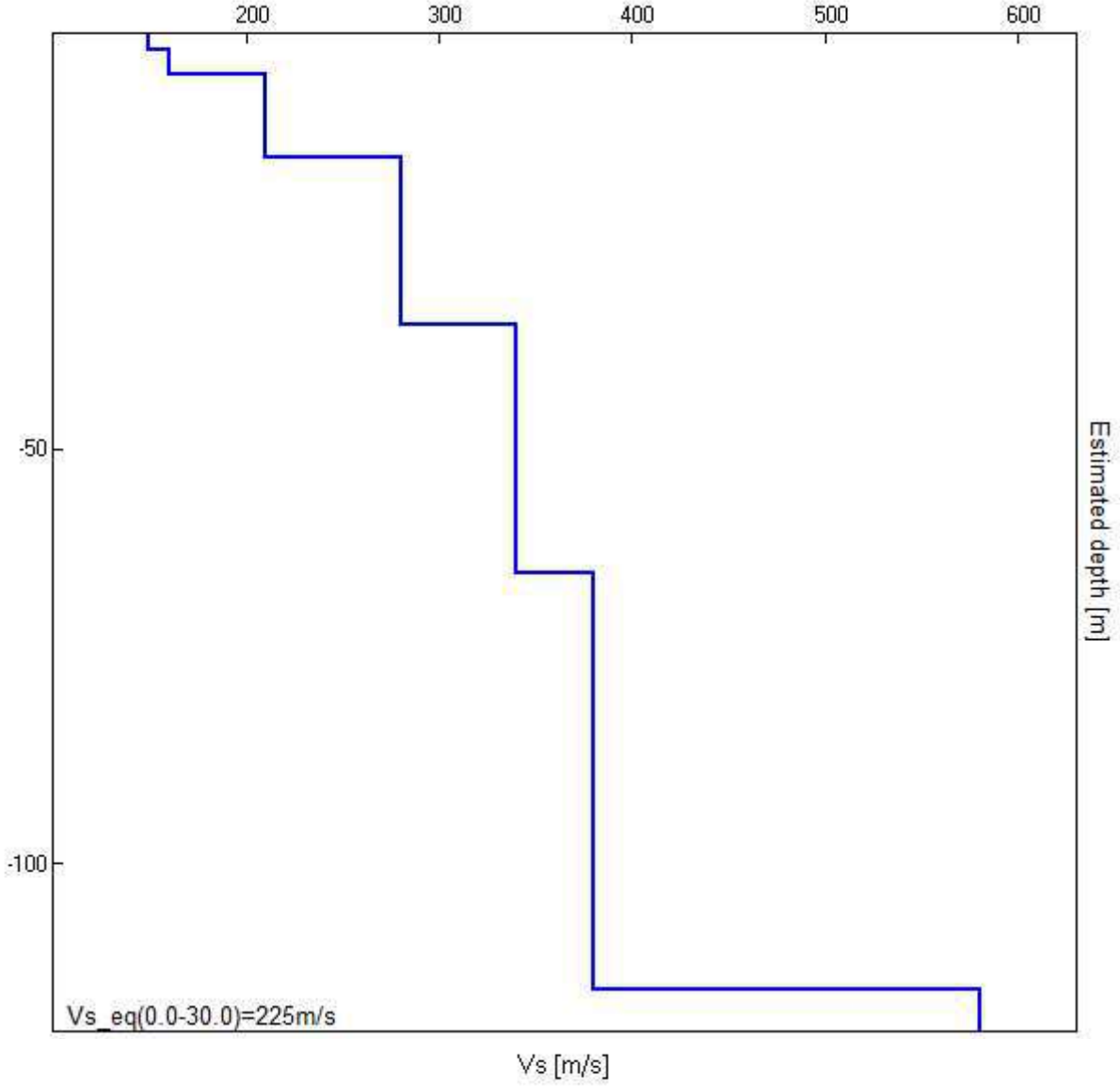
XPERIMENTAL vs. SYNTHETIC H/V



MODELLED RAYLEIGH WAVE PHASE VELOCITY DISPERSION CURVE



Depth at the bottom of the layer [m]	Thickness [m]	Vs [m/s]	Poisson ratio
4.00	4.00	140	0.48
14.00	10.00	210	0.47
34.00	20.00	280	0.46
64.00	30.00	340	0.44
114.00	50.00	380	0.43
inf.	inf.	550	0.42


200
300
400
500
600
-50
-100
Estimated depth [m]
Vs_eq(0.0-30.0)=225m/s
Vs [m/s]

ALLEGATO 5

VERIFICA ALLA LIQUEFAZIONE

CPTU

Geo Group S.r.l.
v. per Modena, 12- Castelnuovo Rangone (MO)
059 3967169
info@geogroupmodena.it

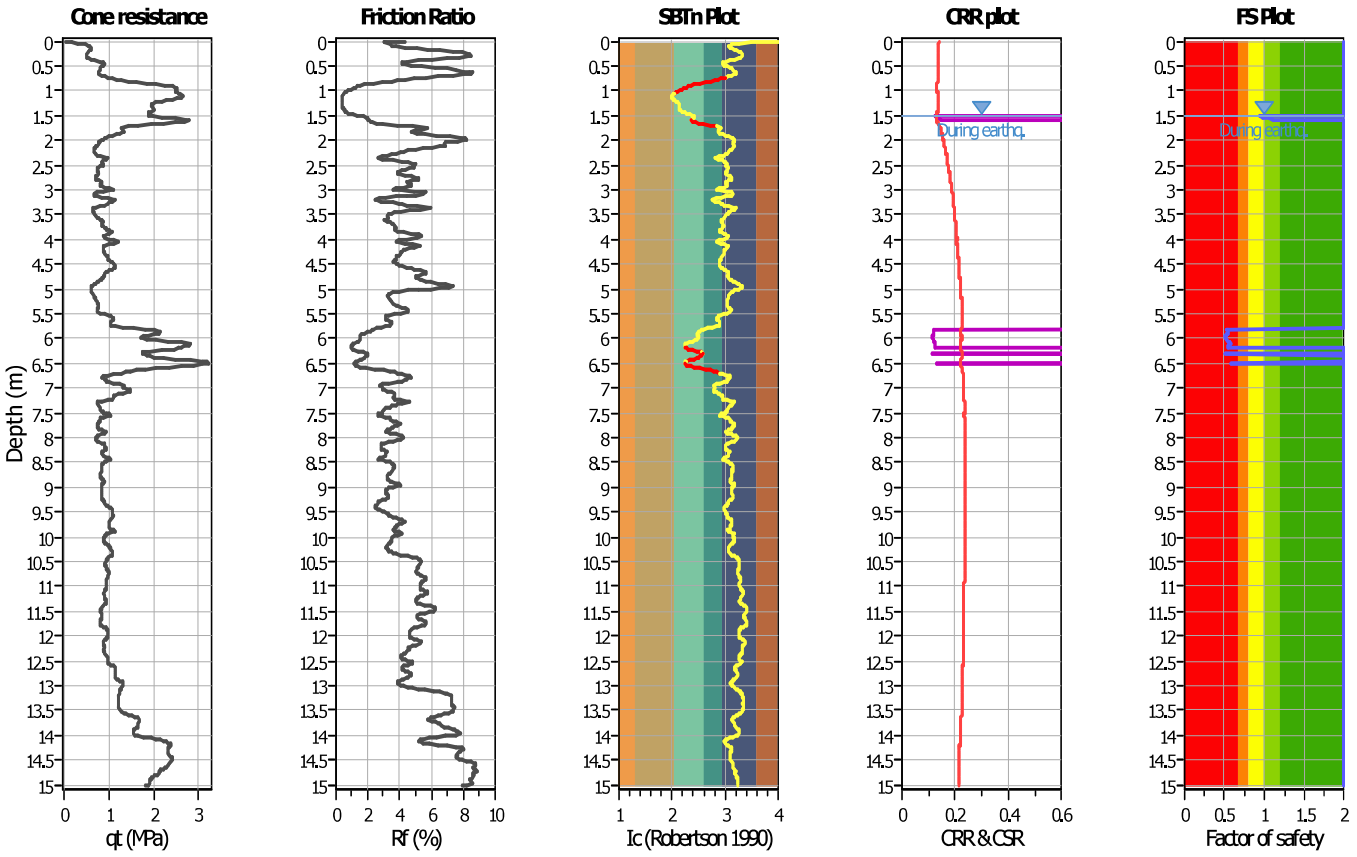
LIQUEFACTION ANALYSIS REPORT

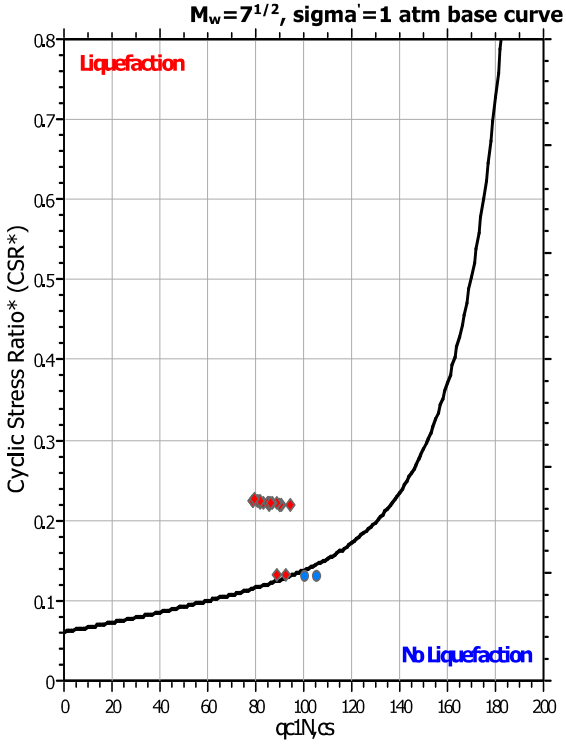
Project title : STUDIO TDEL TERRENO DI FONDAZIONE **Location : CARPI - SANTA CROCE**

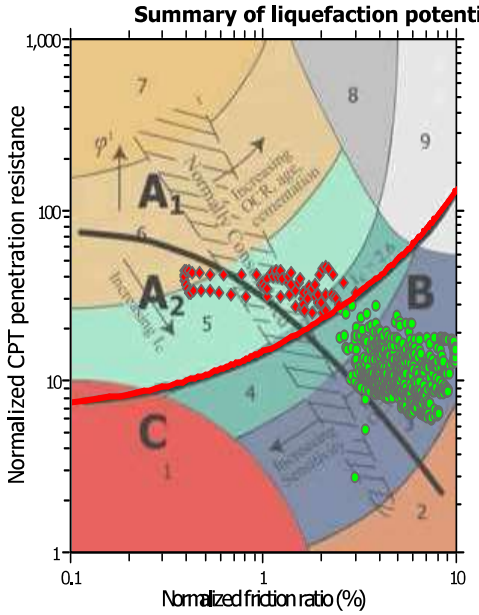
CPT file : CPTU1

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	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:	0.25	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

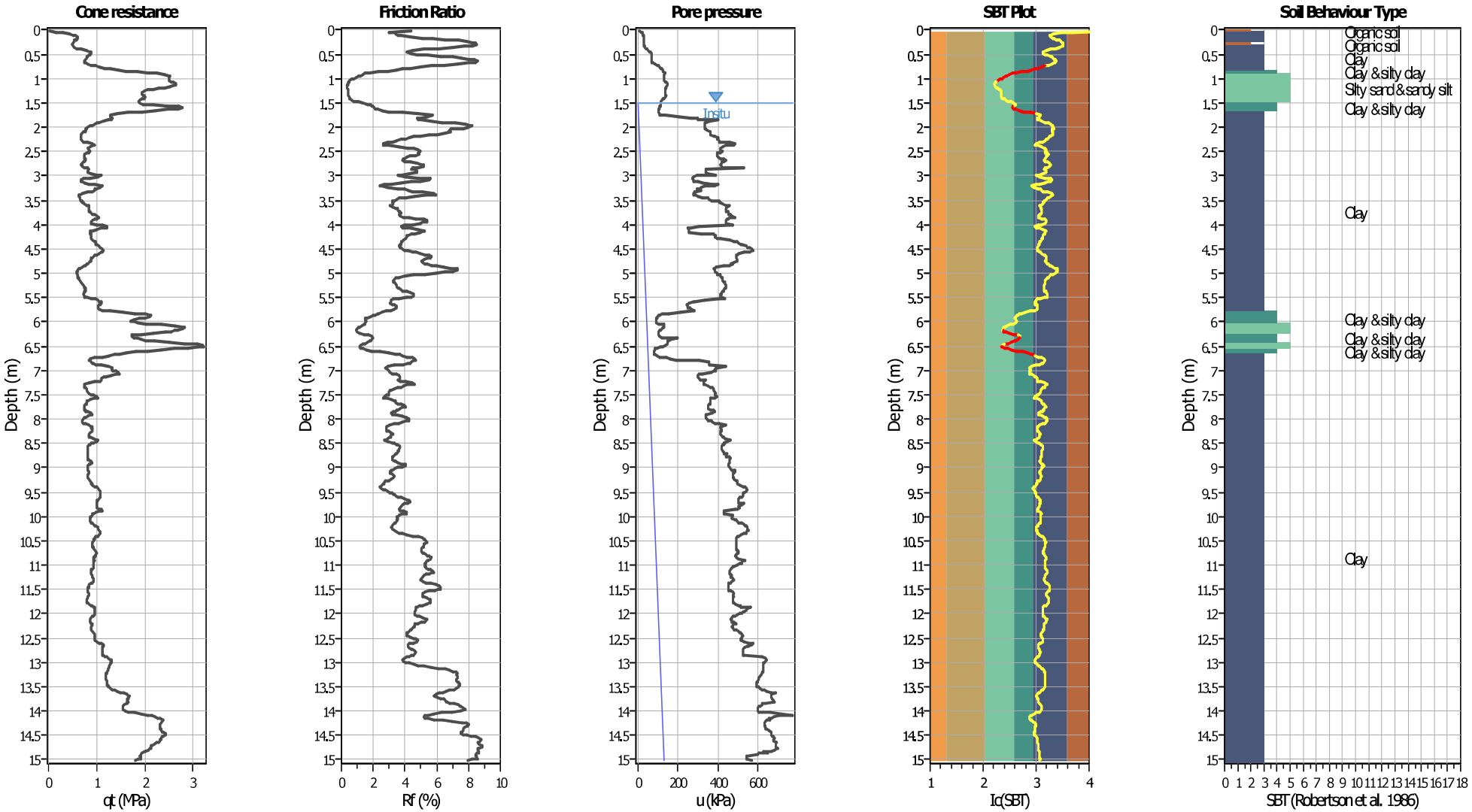






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



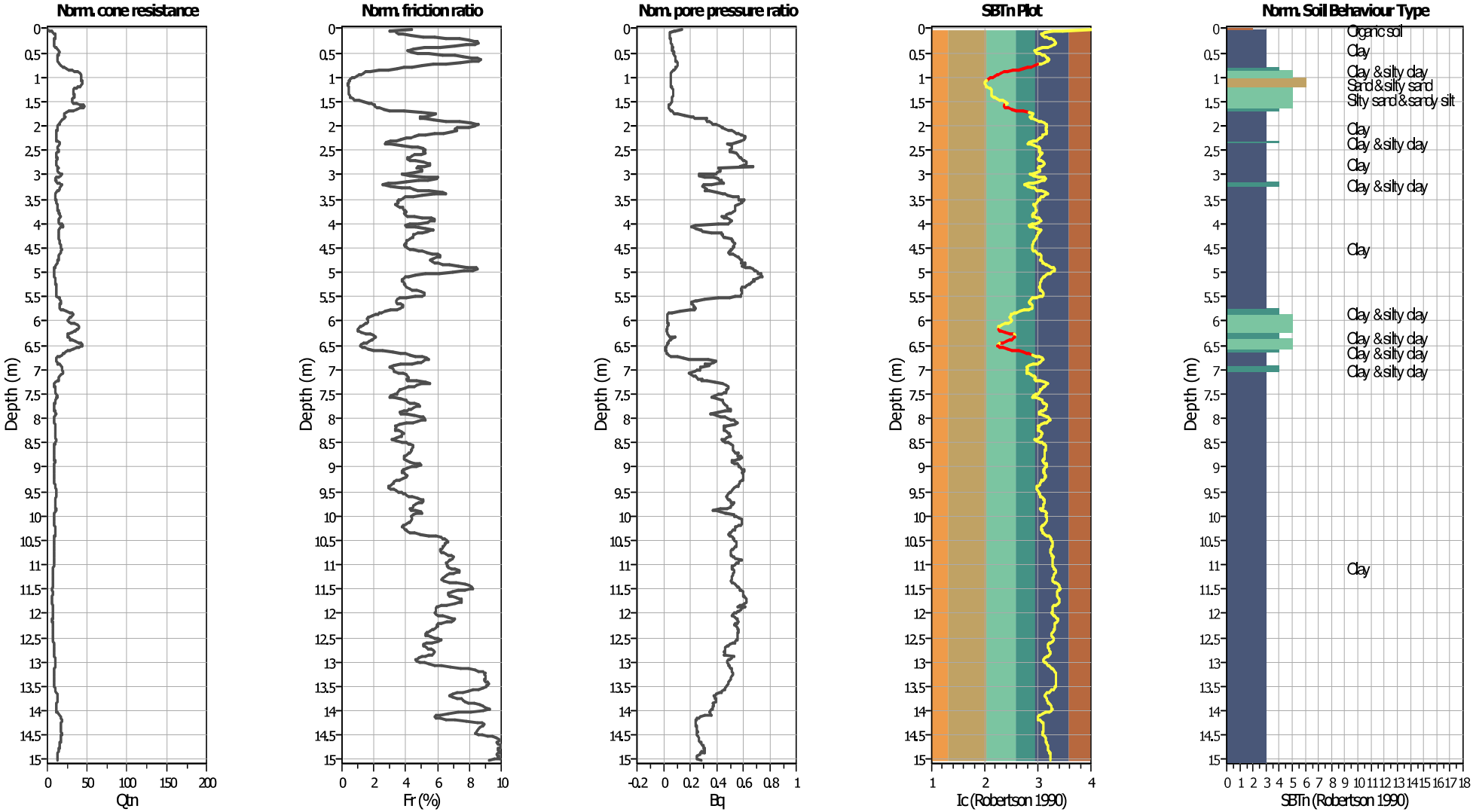
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	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:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

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)



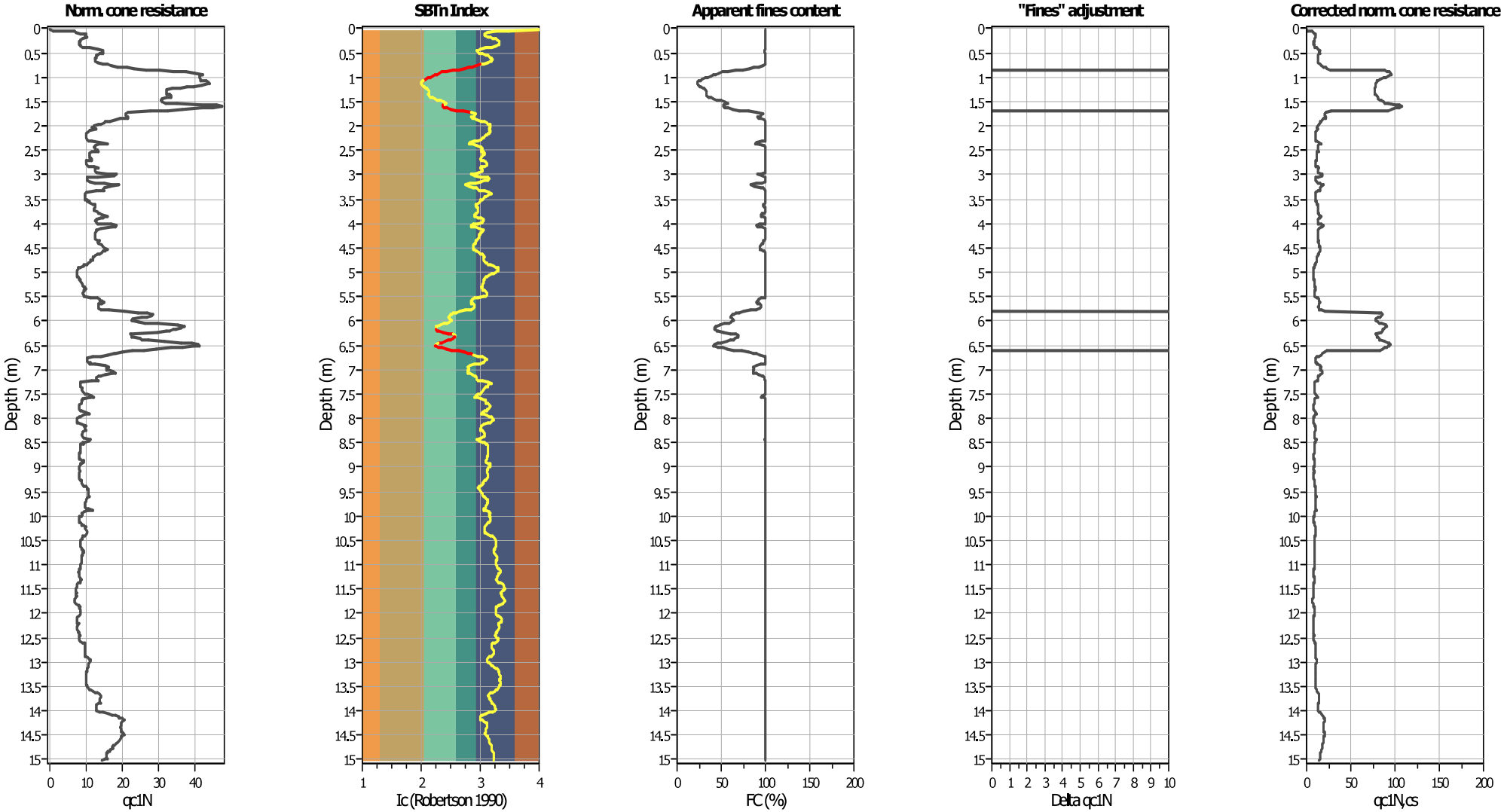
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	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:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

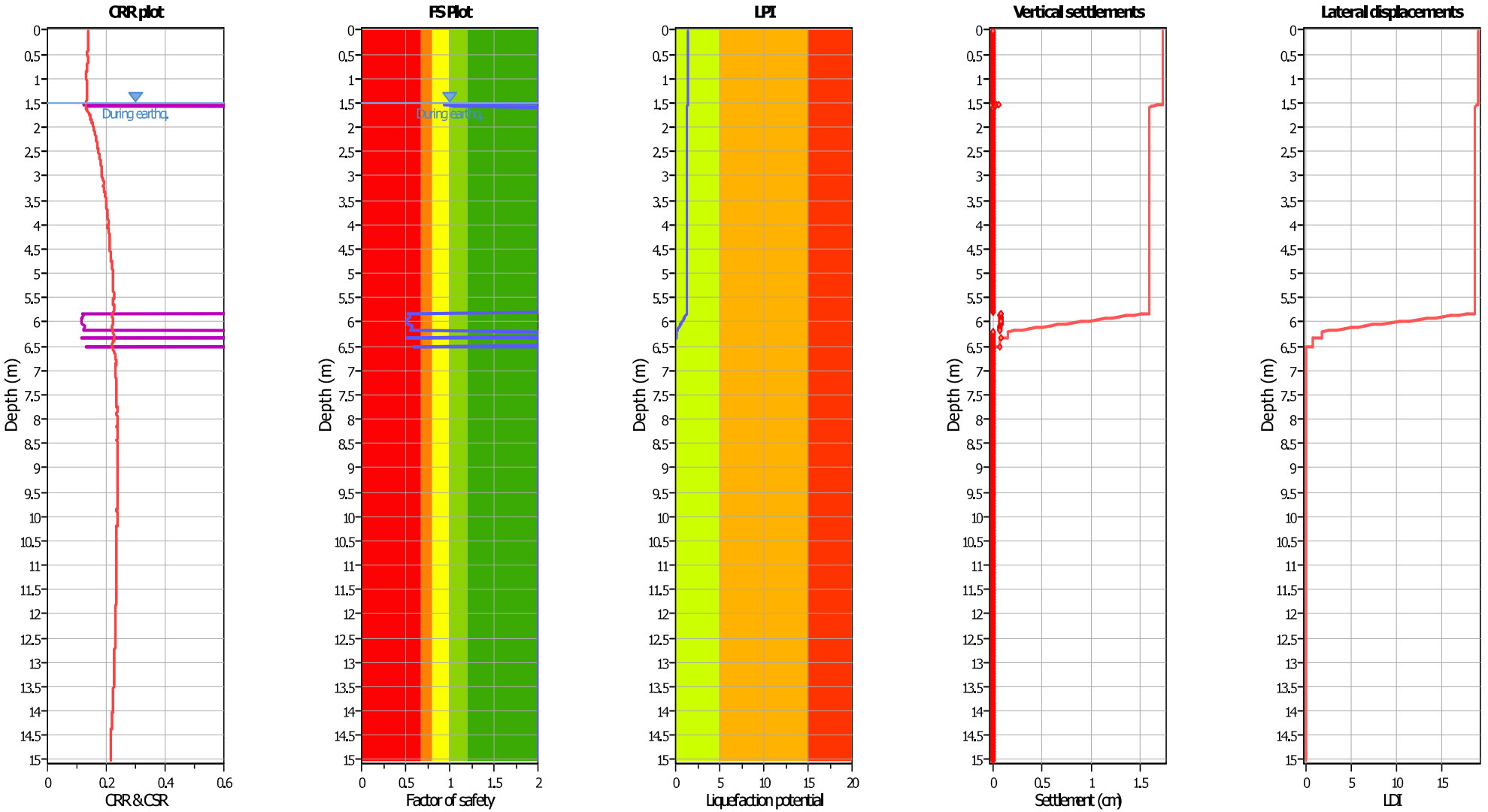
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	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:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	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:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

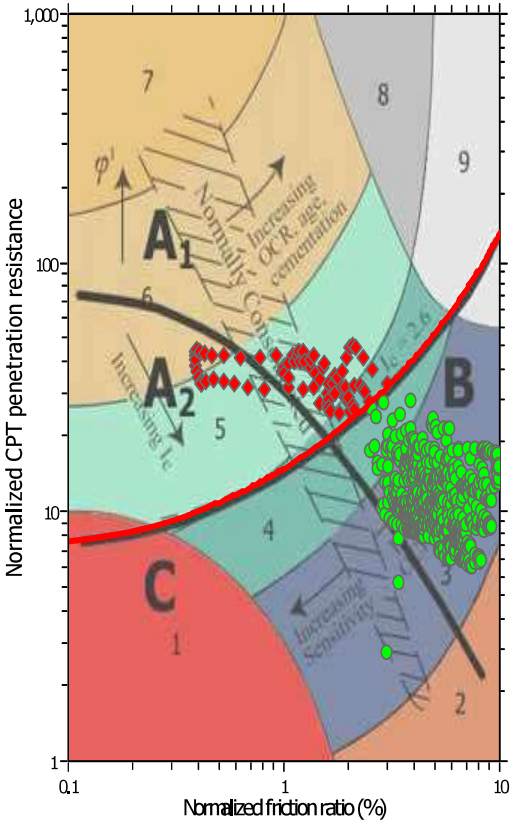
F.S. color scheme

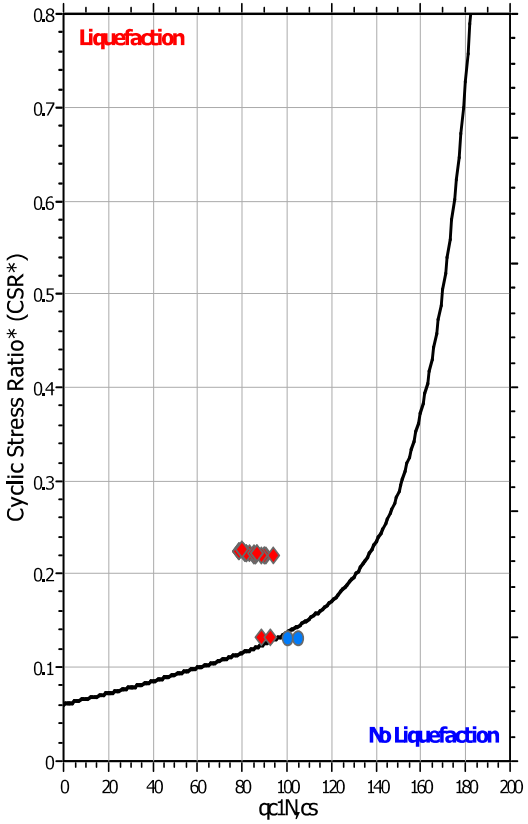
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

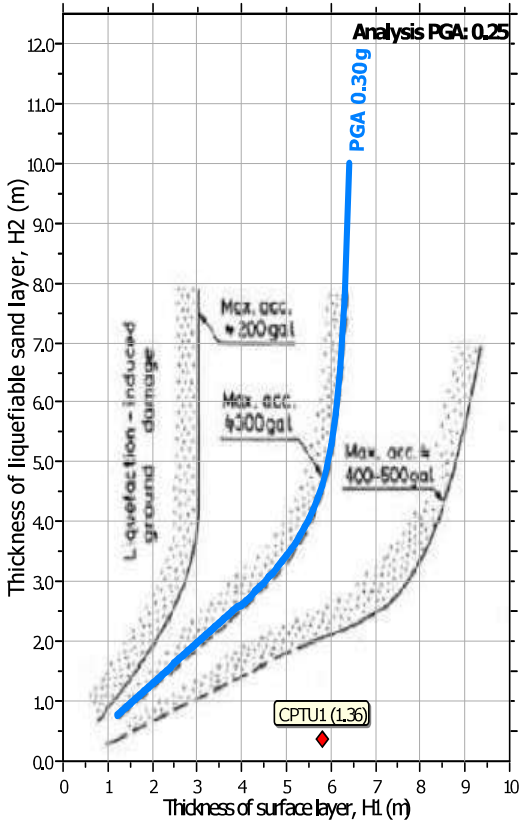
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots



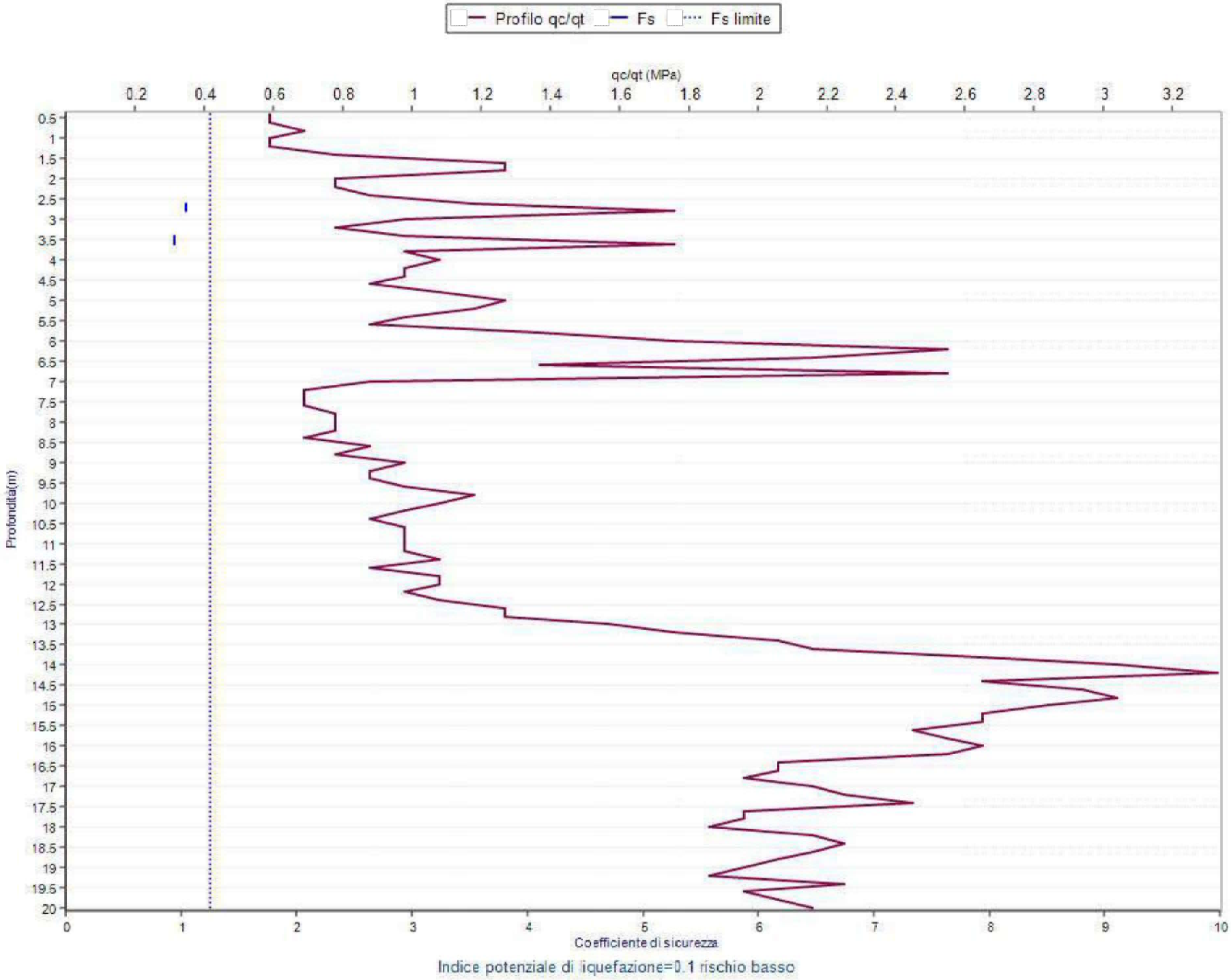




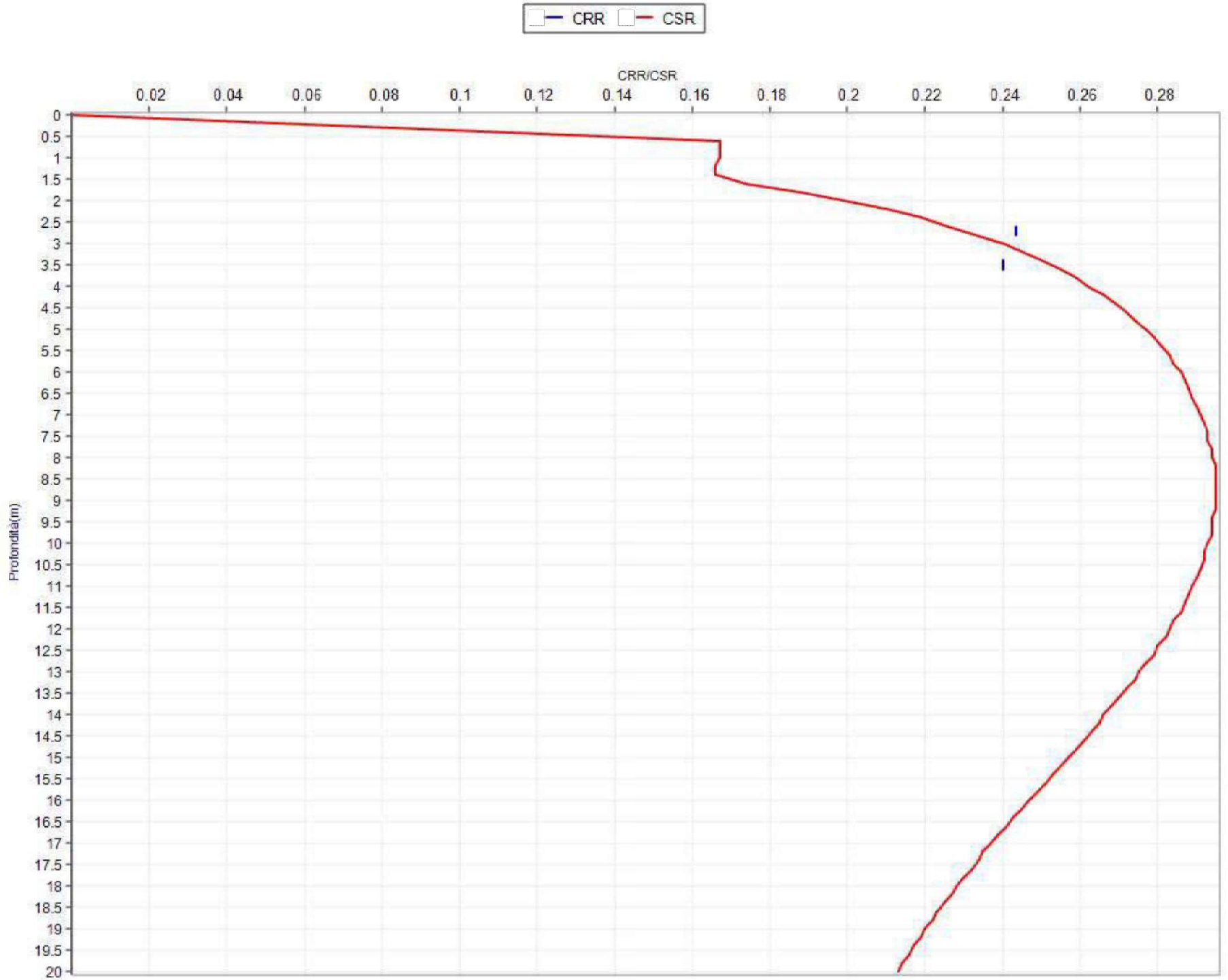
Input parameters and analysis data

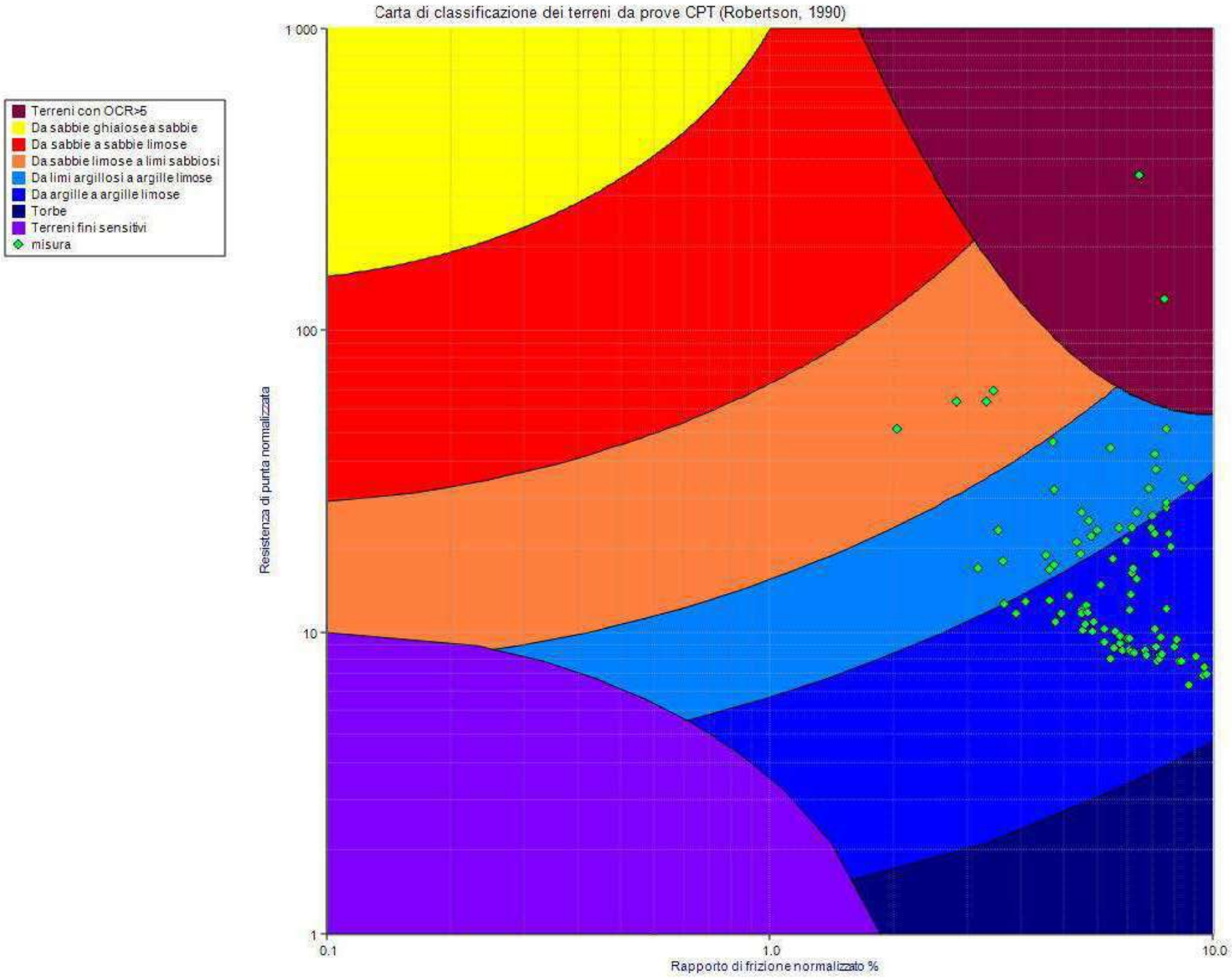
Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.14	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.25	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

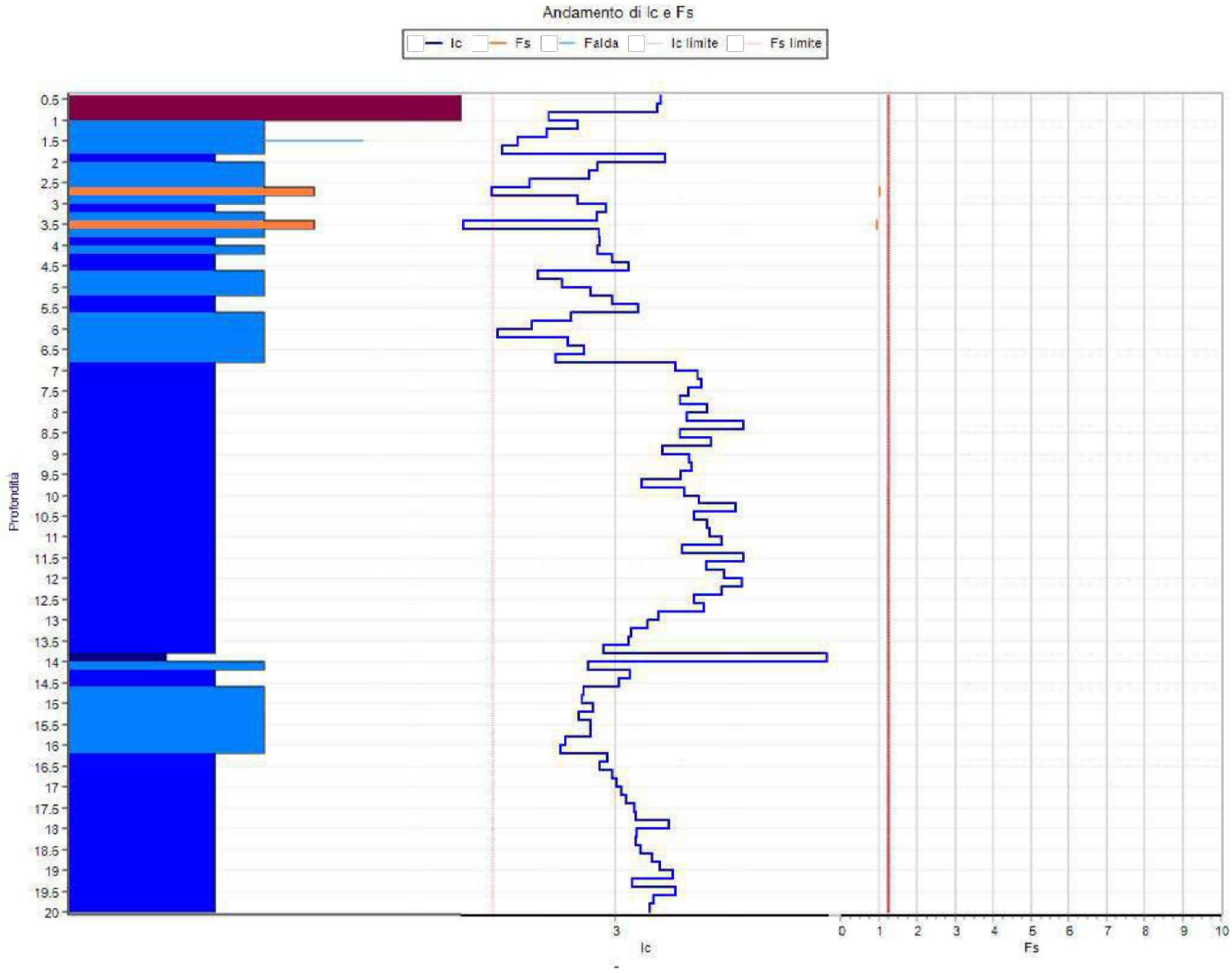
CPT1



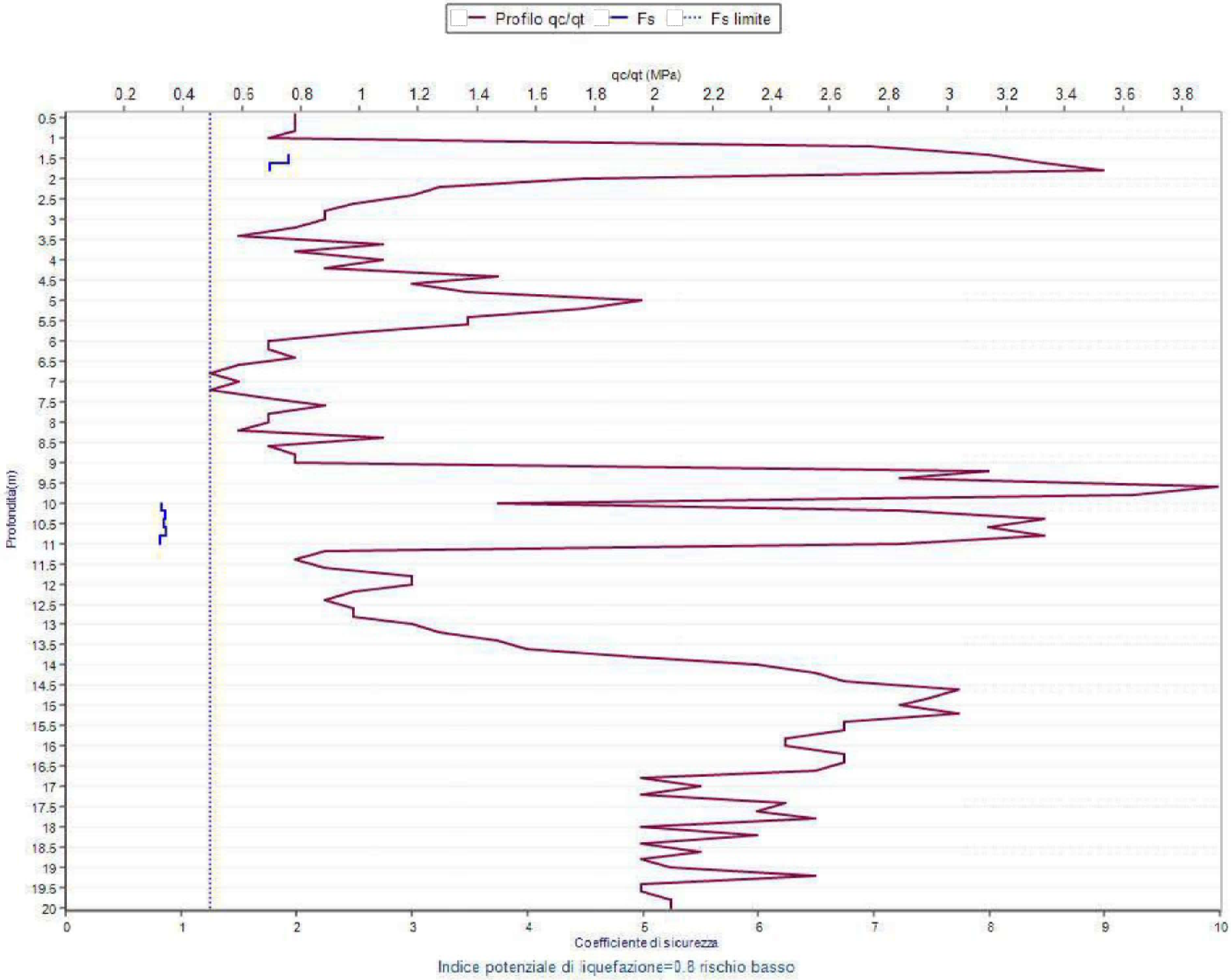
Indice potenziale di liquefazione=0.1 rischio basso


CRR
CSR
CRR/CSR
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
Profondità(m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
19
19.5
20

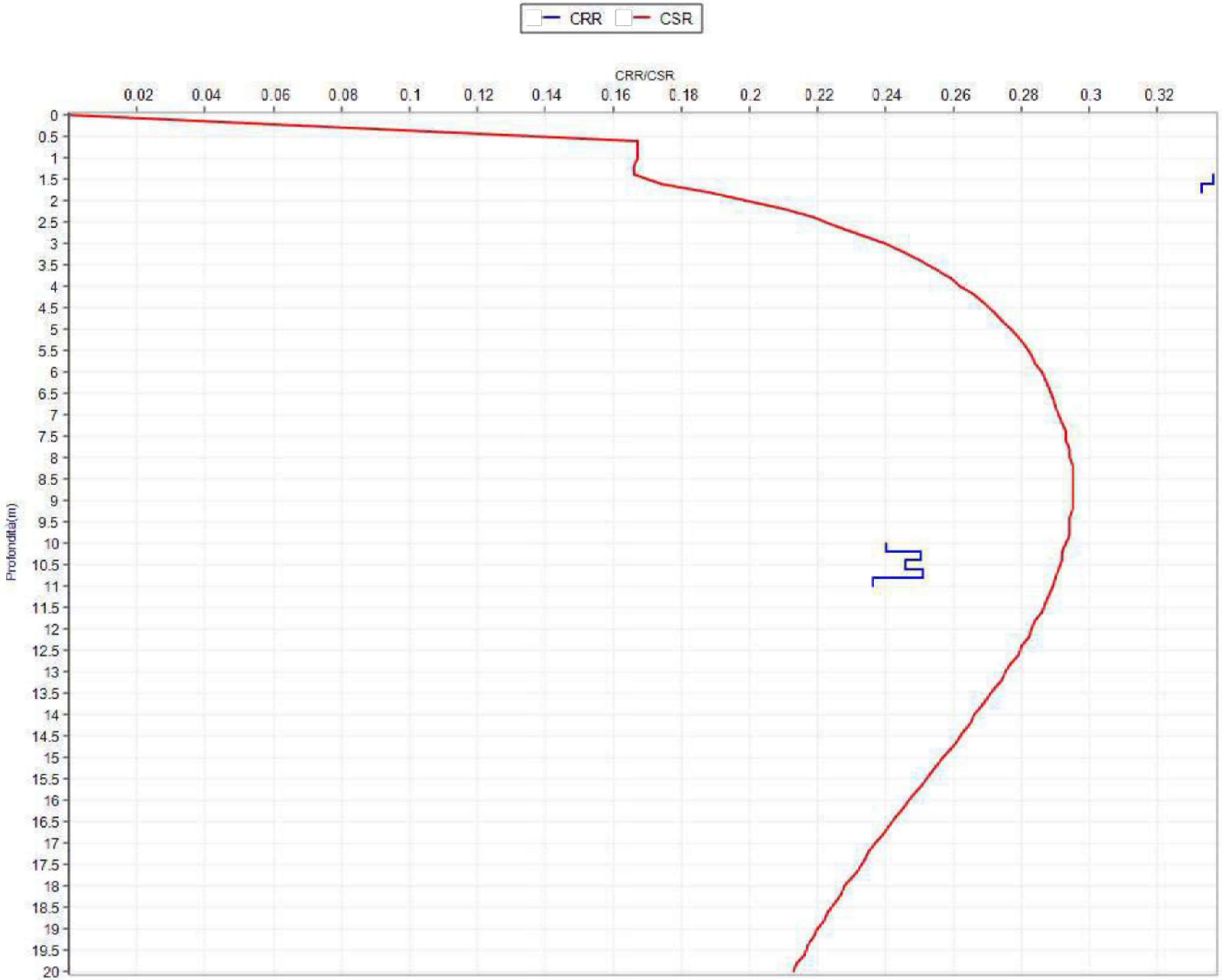

Carta di classificazione dei terreni da prove CPT (Robertson, 1990)
Terreni con OCR>5
Da sabbie ghiaiose a sabbie
Da sabbie a sabbie limose
Da sabbie limose a limi sabbiosi
Da limi argillosi a argille limose
Da argille a argille limose
Torbe
Terreni fini sensitivi
misura
1 000
100
10
1
Resistenza di punta normalizzata
0.1
1.0
10.0
Rapporto di frizione normalizzato %


Andamento di Ic e Fs
Ic
Fs
Falda
Ic limite
Fs limite
Profondità
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
19
19.5
20
3
Ic
0
1
2
3
4
5
6
7
8
9
10
Fs

CPT2



Indice potenziale di liquefazione=0.8 rischio basso


CRR
CSR
CRR/CSR
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
0.3
0.32
Profondità(m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
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8.5
9
9.5
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10.5
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11.5
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12.5
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13.5
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16.5
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17.5
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18.5
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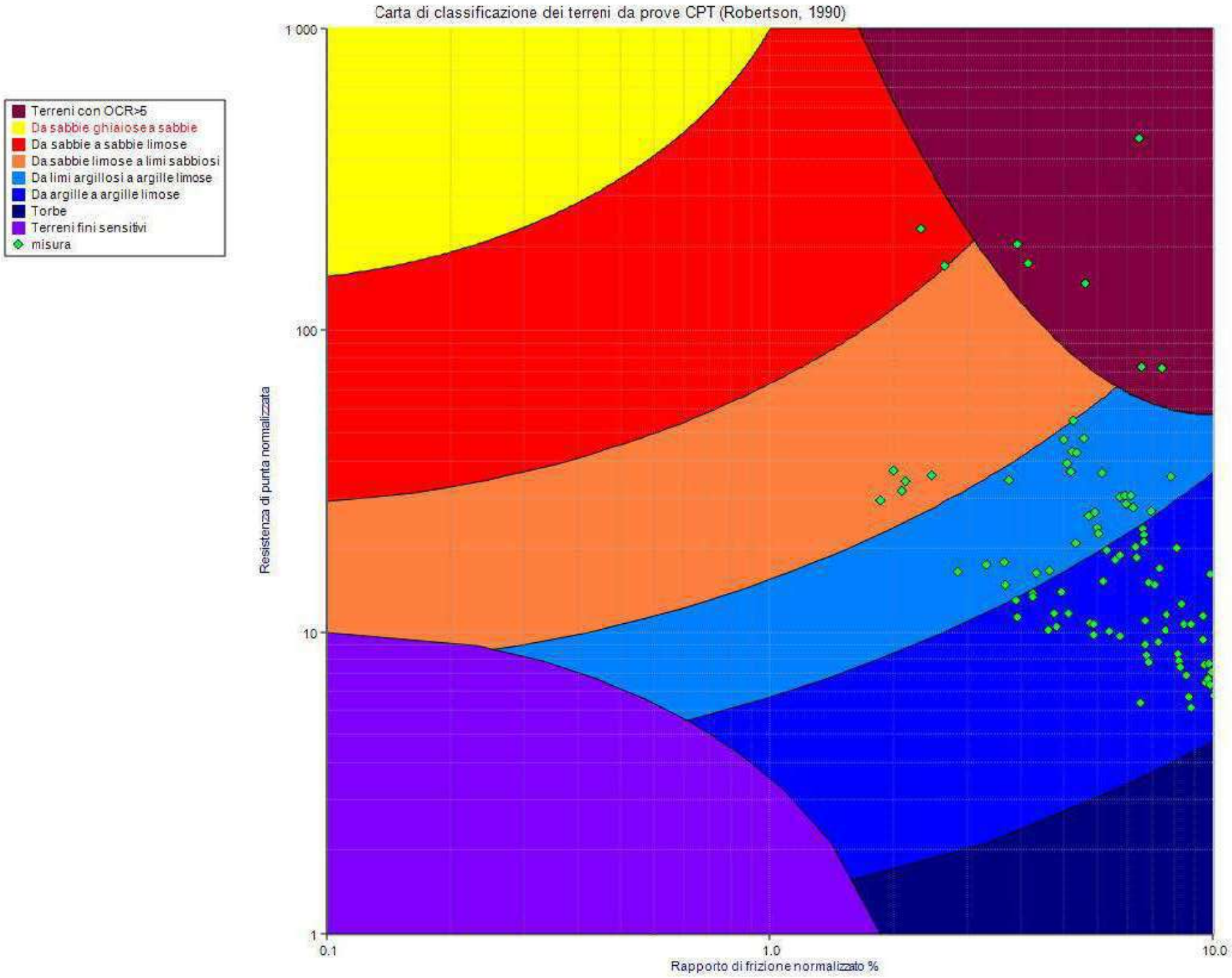
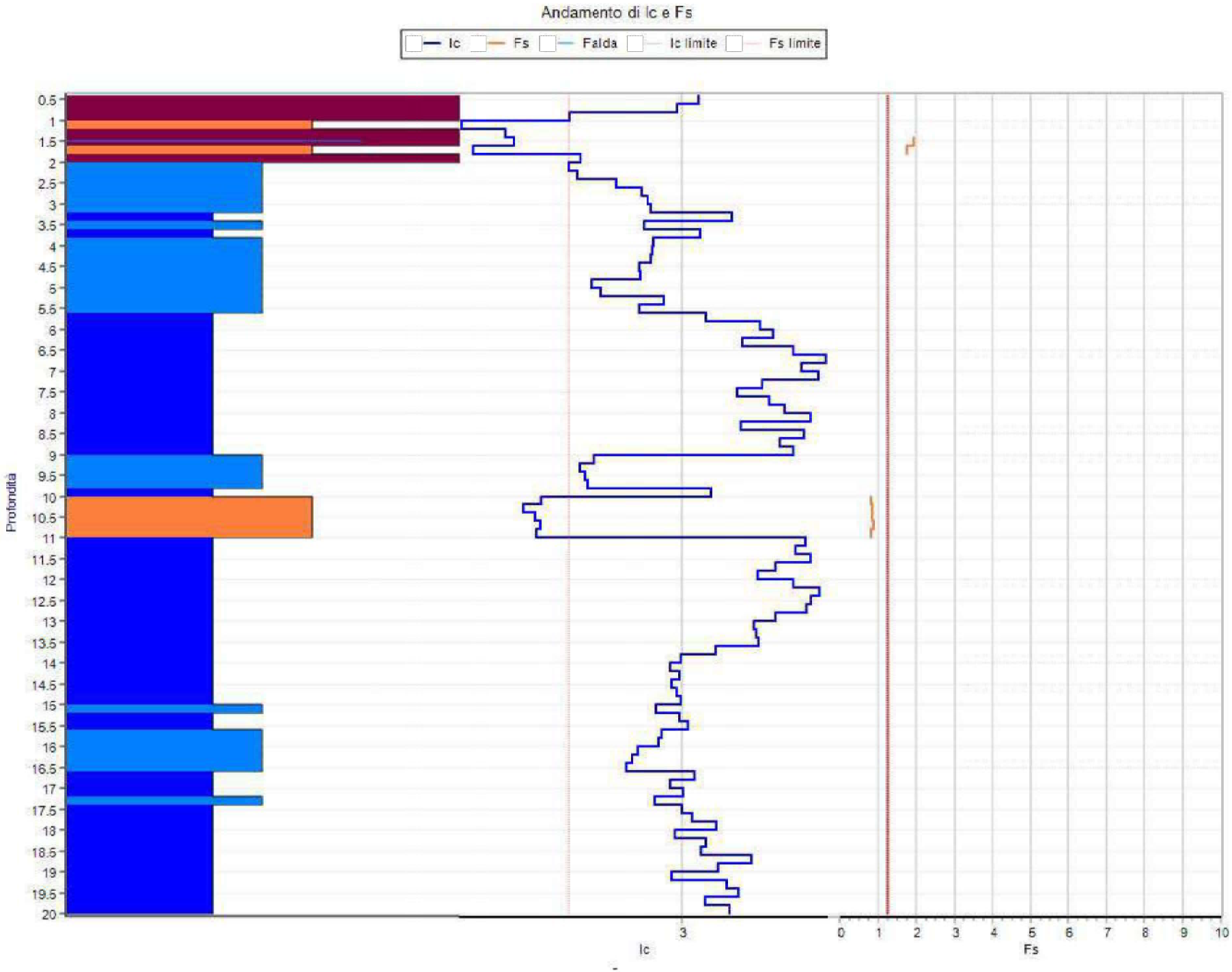
19.5
20


Carta di classificazione dei terreni da prove CPT (Robertson, 1990)
Terreni con OCR>5
Da sabbie ghiaiose a sabbie
Da sabbie a sabbie limose
Da sabbie limose a limi sabbiosi
Da limi argillosi a argille limose
Da argille a argille limose
Torbe
Terreni fini sensitivi
misura
1 000
100
10
1
Resistenza di punta normalizzata
0.1
1.0
10.0
Rapporto di frizione normalizzato %


Andamento di Ic e Fs
Ic
Fs
Falda
Ic limite
Fs limite
Profondità
0.5
1
1.5
2
2.5
3
3.5
4
4.5
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5.5
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6.5
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7.5
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8.5
9
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
19
19.5
20
3
Ic
0
1
2
3
4
5
6
7
8
9
10
Fs