



COMUNE DI CERVIA

Provincia di Ravenna

Settore Programmazione e Gestione del Territorio



Il Sindaco
Dott. Luca Coffari

L'Assessore all'Urbanistica
Arch. Natalino Giambi

Il Dirigente del Settore
Ing. Daniele Capitani

Il Servizio Urbanistica
Geom. Gianluca Magnani
Ing. Annalena Arfelli
Geom. Elena Taffagi
Arch. M. Laura Callegati
Nadia Nicolini



Quadro Conoscitivo



Oggetto	Scala	Elaborato
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Verifiche di liquefacibilità Fascia costiera

H2

DIRIGENTE DEL SETTORE PROGRAMMAZIONE E GESTIONE DEL TERRITORIO

Ing. Daniele Capitani

SERVIZIO URBANISTICA

Geom. Gianluca Magnani

Ing. Annalena Arfelli

Arch. M. Laura Callegati

Geom. Elena Taffagli

Ing. Caterina Girelli

Nadia Nicolini

GRUPPO DI LAVORO:

ATI composta da: Tecnicoop soc. coop.va; Arch. Carla Ferrari; Arch. Giuseppe Campos Venuti (QUADRO CONOSCITIVO ANNO 2013)

Arch. Carlo Lazzari (INDAGINE STORICA)

TEM - Territorio e Mercati - Arch. Sandra Vecchietti (SQUEA)

Ing. Simona Savini (SQUEA)

Dott. Geol. Fabbri Fabio (RISCHIO IDRAULICO)

Dott. Geol. Carlo Copioli (ZONAZIONE SISMICA ARENILE)

Dott. Geol. Samuel Sangiorgi (ZONAZIONE SISMICA)

Dott. Loris Venturini (CLASSIFICAZIONE ACUSTICA)

Ing. Chiara Semprini (VALSAT ARENILE)

Arch. Margherita Bastoni

APPORTI SPECIALISTICI SERVIZI COMUNALI

Edilizia Privata, Progettazione Infrastrutture e Mobilità Sostenibile, Viabilità e Manutenzione Infrastrutture, Progettazione e Manutenzione Fabbricati, Sviluppo Economico - Parco della Salina, Ambiente, SUAP, Protezione civile, Verde, Demografici, Demanio e Porto, Patrimonio, Turismo, Servizi alla persona, Servizi alla comunità, Progettazione culturale, Politiche educative, Tributi, Polizia municipale

ENTI E SOCIETA' DI SERVIZI

ANAS, Agenzia delle entrate - Ufficio territorio di Ravenna, ARPAE, ATERSIR, Autorità di Bacino del fiume Po, AUSL, CER, Consorzio di Bonifica della Romagna, ENEL, FF.SS., HERA Ravenna, Provincia di Ravenna, Regione Emilia Romagna, Romagna Acque, SNAM, TERNA, Soprintendenza archeologia, belle arti e paesaggio, Parco del Delta del Po

COMUNE DI CERVIA

PROVINCIA DI RAVENNA

STUDIO GEOLOGICO E DI MICROZONIZZAZIONE SISMICA DI III LIVELLO
DI APPROFONDIMENTO PER L'ADEGUAMENTO DEL PIANO
DELL'ARENILE DEL COMUNE DI CERVIA ALLA L.R. 9/2002 E ALLE
DISPOSIZIONI DELLA DELIBERA DELLA REGIONE
EMILIA-ROMAGNA N. 468/2003



RELAZIONE GEOLOGICA

ELABORATO 2 - VERIFICHE DI LIQUEFACIBILITA'

Dott. Geol. Carlo Copioli

Collaboratore: Dott. Geol. Fabio Vannoni



GEOPROGET

Studio di Geologia
via Ceccarini, 171 - Palazzo La Viola
Riccione - 47838 - (RN) Tel/Fax 0541/606464
E-MAIL vannoni.fabio1960@libero.it
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Rif.2198 - Maggio 2016

ALLEGATO N.1

**"VERIFICHE DI CALCOLO DEL POTENZIALE DI LIQUEFACIBILITÀ CON
MAGNITUDO MW = 5,50 "**

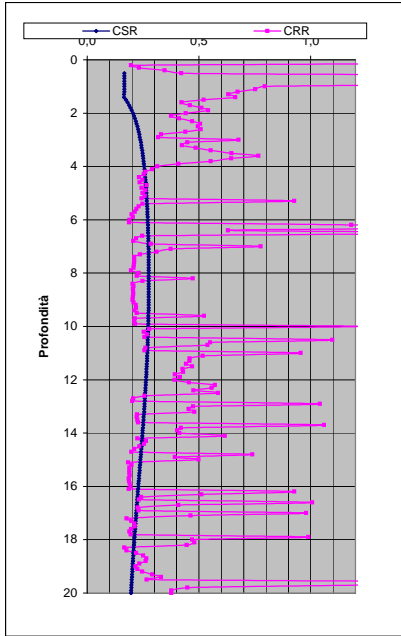
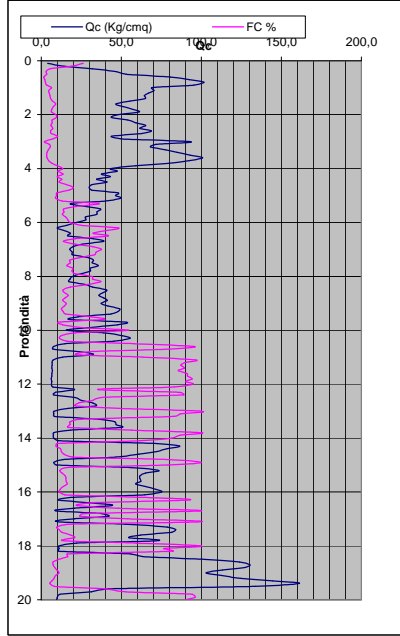


GEOPROGET

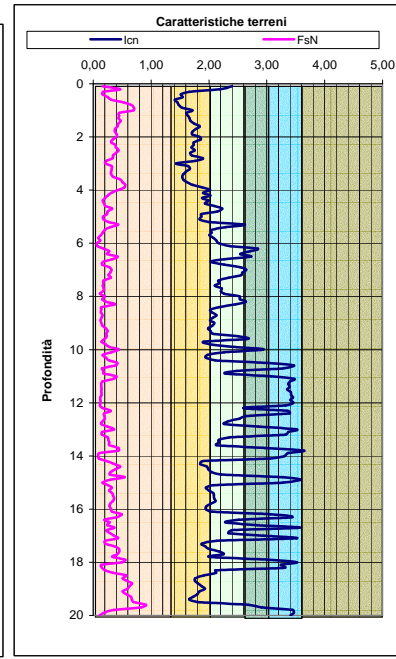
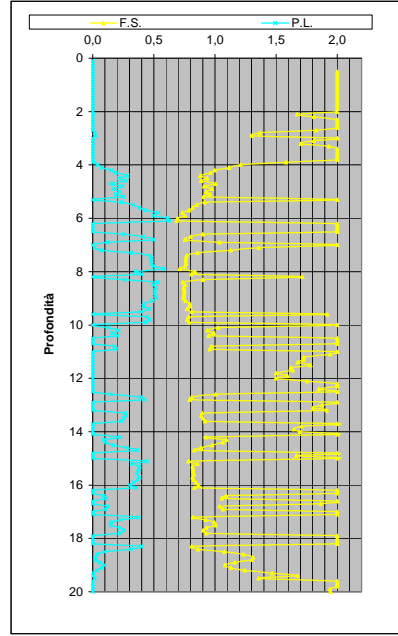
Studio di Geologia

via Ceccarini, 171 - Palazzo La Viola
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DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 1



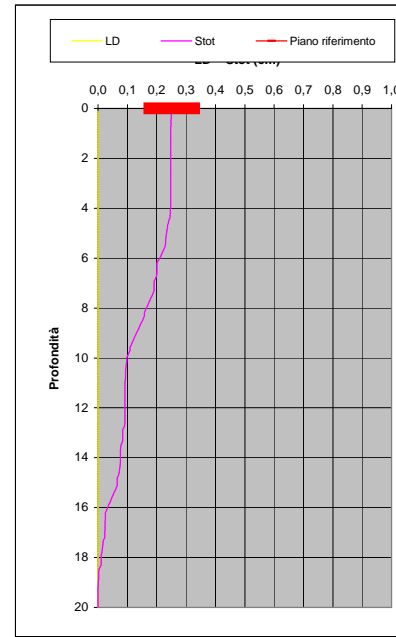
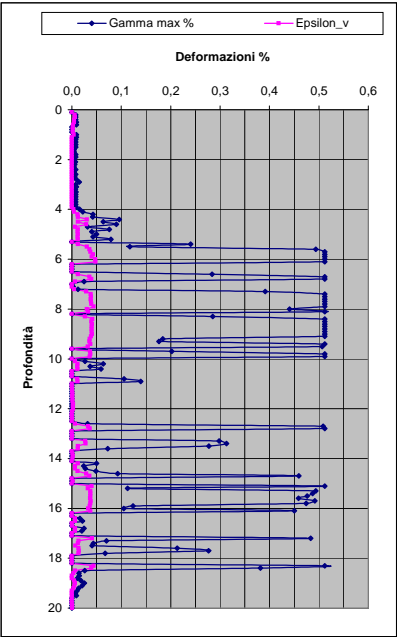
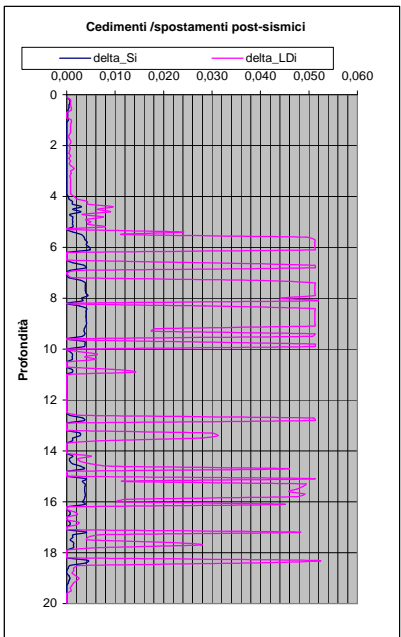
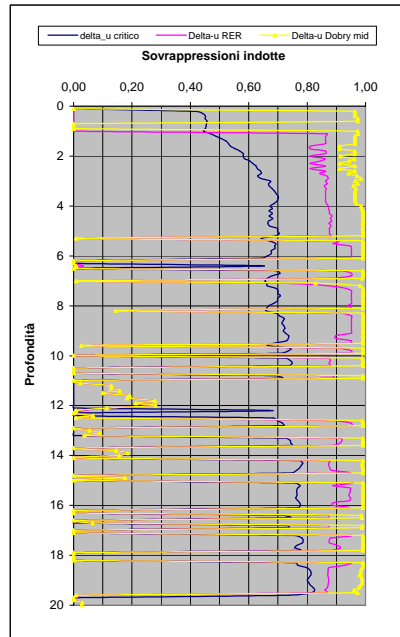
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento i-esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



IPL = 6,35 PL = 15,33 LDI = 2,679 Stot = 0,251 (mt) LD = 0,00 (mt) SLiq = 8,00 (mt) LSN = 27,66 PG = 0,45

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

CPT-based liquefaction triggering analysis for a single sounding

Enviromenti: C Hill-H Plain-P Coast-C
Behaviours: E Sand like-S

Computer constants: no. n=18.0
MSF NCEER: 0.0337
Patm=101.32 (cov=0.35-35%)
KOR=1.350
IP COR=1.2

Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTE 2"



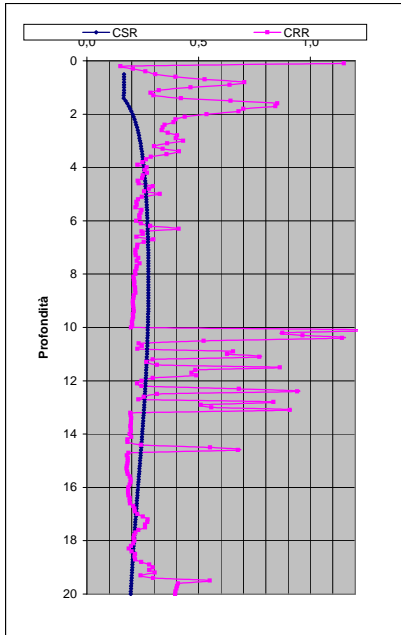
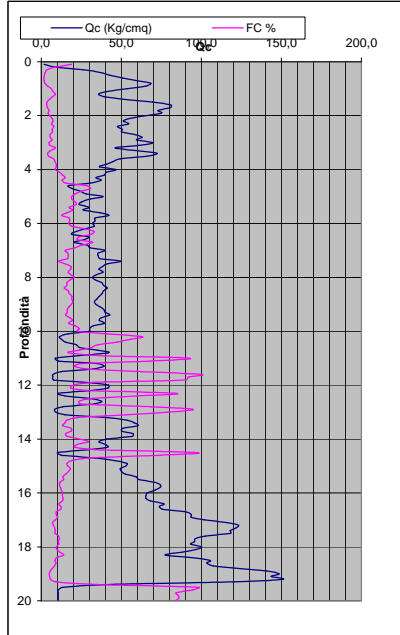
Table with 2 columns: LsN and LsN Expression. It defines damage levels from Severe Damage to Little to No.

Main data table header with columns for Depth (m), Soil Classification, Soil Parameters (qc, fs, etc.), and various probability and liquefaction indices (PL, LDI, etc.).

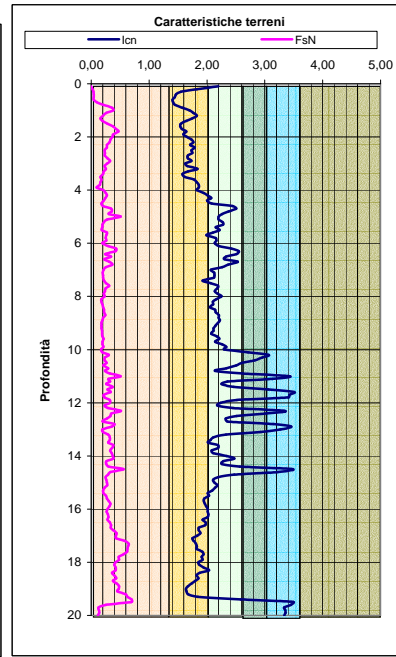
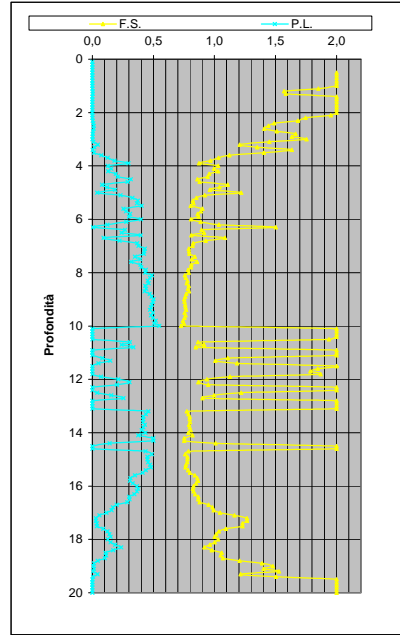
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 | LDI = 3,884 | Stot = 0,343 (mt) | IPL = 7,92 | PL = 20,34 | LD = 0,00 (mt) | PG = 0,71 | SLiq = 10,1 (mt) | LSN = 36,2

Main data table body containing 100 rows of soil sounding data, including depth, soil type, and calculated liquefaction parameters.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT2



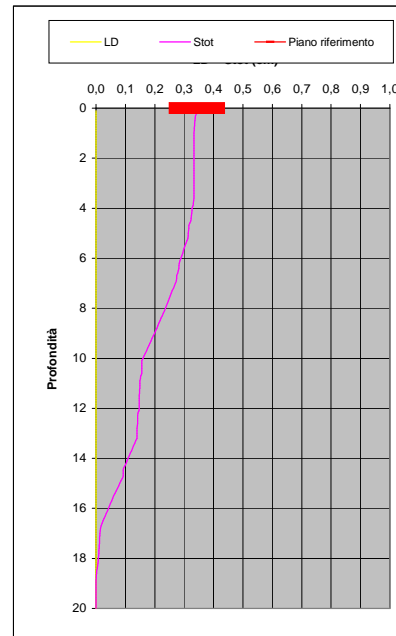
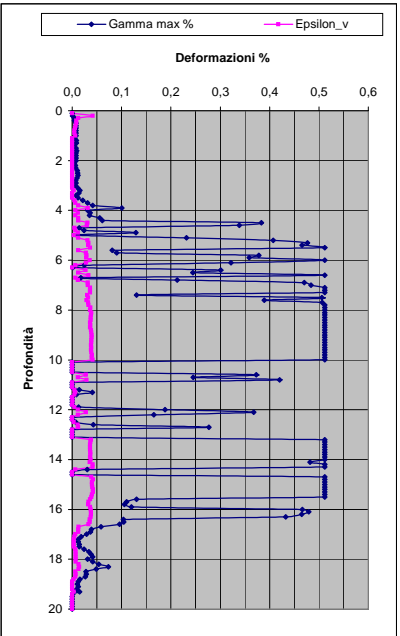
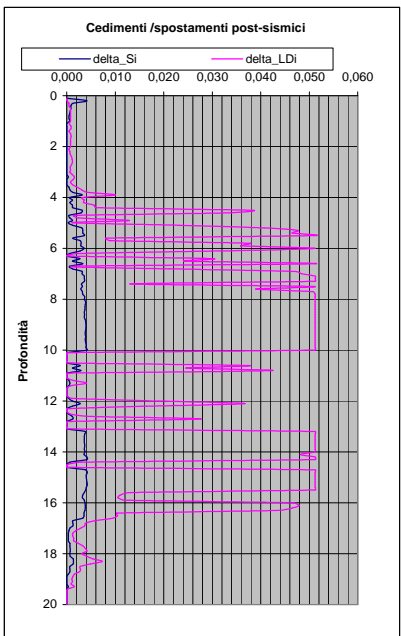
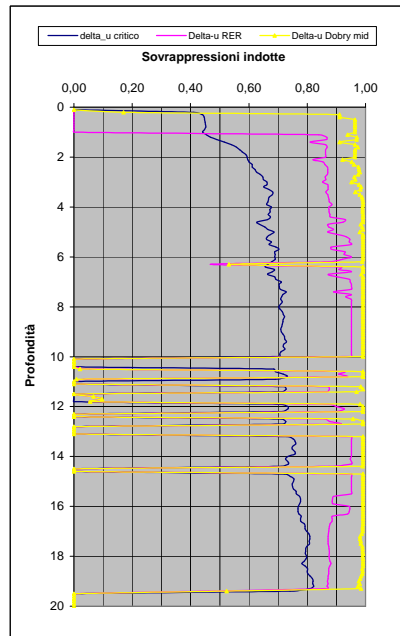
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- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



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$P_G \leq 0.1$	extremely low to none

IPL = 7,92 PL = 20,34 LDI = 3,884 Stot = 0,343 (mt) LD = 0,00 (mt) SLiq = 10,10 (mt) LSN = 36,17 PG = 0,71

CPT-based liquefaction triggering analysis for a single sounding

Enviroments: Hill-H Plain-P Coast-C Behaviours: Sand like-S

Computer constants: no. n=25, alpha (N) = 1, Patm = 101.32, MSF NCEER = 0.357, MSF NCEER = 0.357

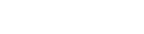
Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTE 3"



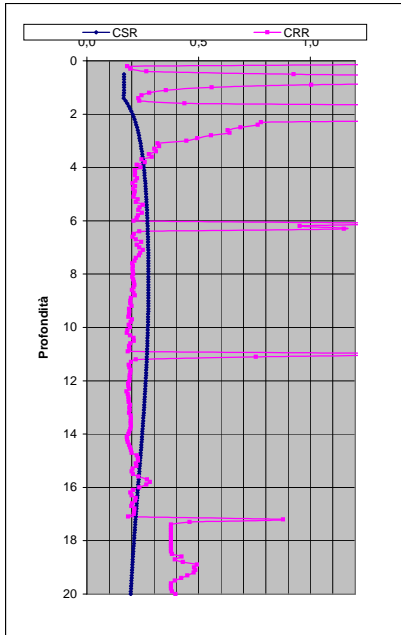
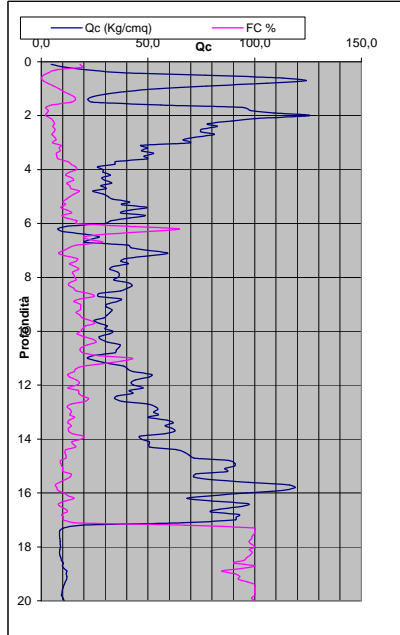
DISPLACEMENT PARAMETERS: Delta H, ALDI, Vertical recons. Strain, etc.

Potential flow failure if (N) <= 10 and (q) <= 100. No flow liquefaction if (q) <= 65.

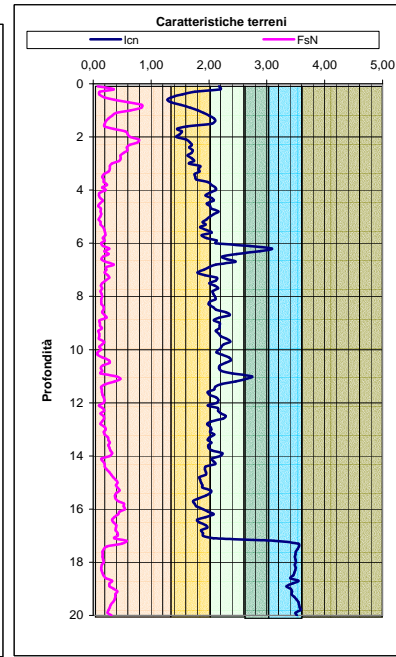
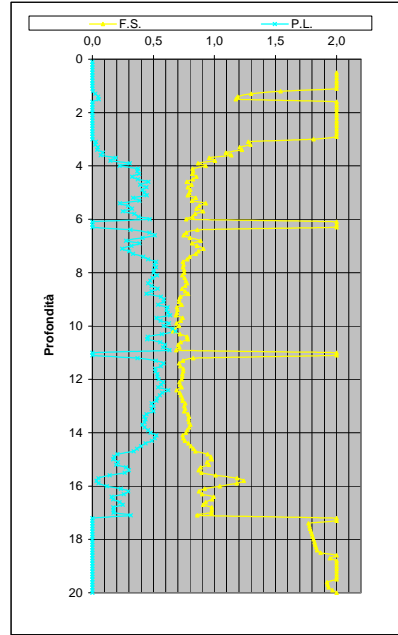
Table with columns for Depth (m), qc(N/m²), fs(N/m²), etc. Includes a summary row at the bottom with values like LDI = 4,678, Stot = 0,440, IPL = 12,49, etc.

Main data table with columns for Depth (m), qc(N/m²), fs(N/m²), etc. Contains 100 rows of data for different soil layers.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTÉ 3



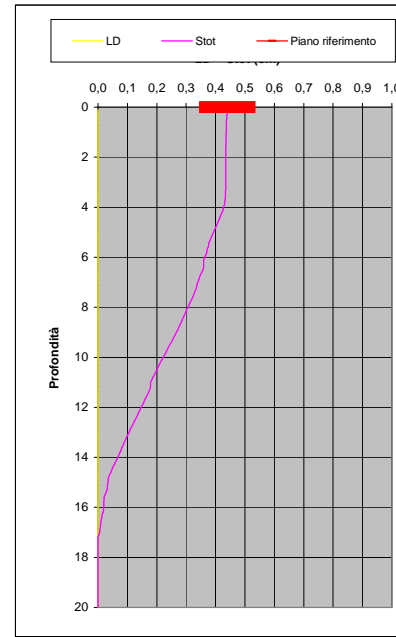
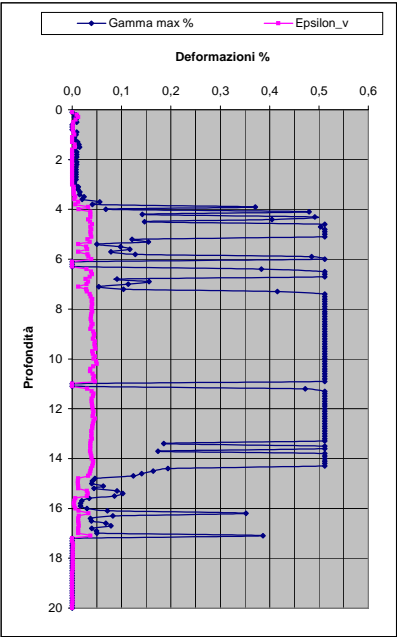
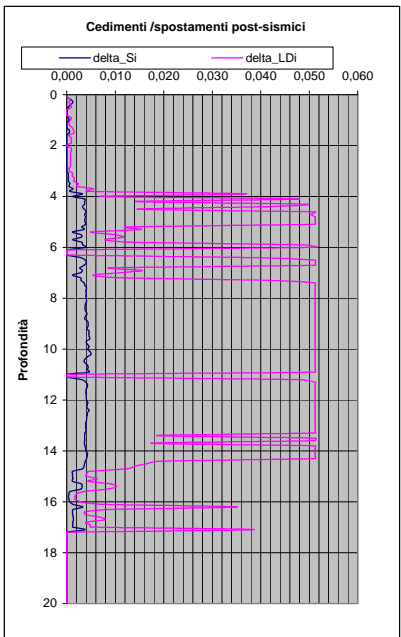
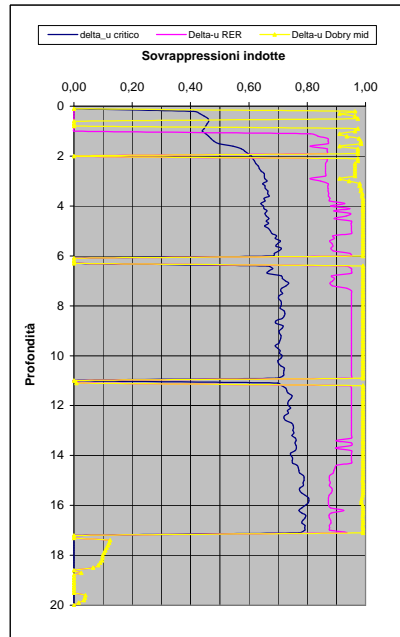
Soil Classification	Zone No.*	Range of CPT Index I_c Values
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- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



IPL= 12,49

PL= 40,86

LDI = 4,678 Stot = 0,440 (mt)

LD = 0,00 (mt)

SLiq = 12,40 (mt)

LSN = 51,02 PG= 0,98

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

CPT-based liquefaction triggering analysis for a single sounding

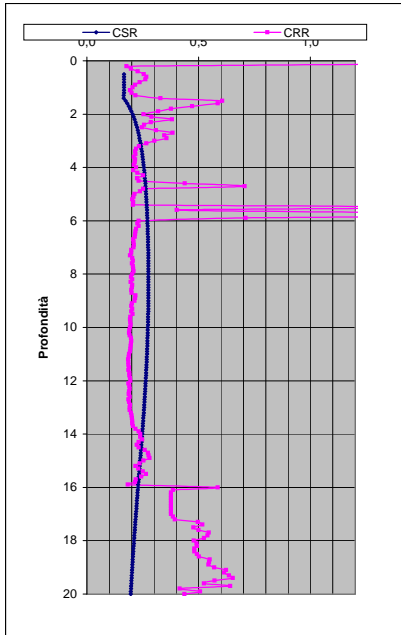
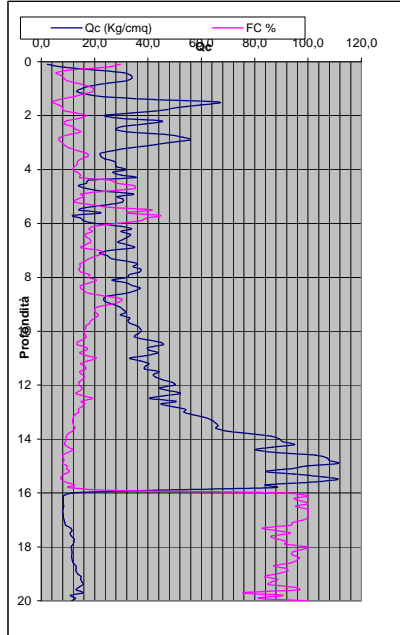
Enviromenti Behaviours, Computer constants, Probabilità e potenziale di liquefazione, Probabilità e suscettibilità di liquefazione, PL Overall Probability, Robertsson & Wride, agg. 2009, PROVA "CPTE 4", L&N, L&N Expression

Table with columns: Depth (m), q_{tip} (kPa), F_{an} (kPa), q_{vc} (kPa), q_{vc} (kPa), Q_i, Q_{tn}, F, I_c, I_{cN2}, N₁₍₆₀₎, n, K_c, L_{layer}, Flag, FC, Kh, Interpret. di q_{tip}, q_{tip}, q_{tip}, q_{tip}, CSR, K_r, ξ, K_a, CRR, Factor of Safety FS, MSF, Limiting shear strain γ_{lim}, ΔH, ALDI, Vertical recons. Strain, ASI, P_{max}, F, I_h, I_h, Au/D', Au/D', Ru, Au/D', Dr, ϕ, Ruc, Su/D'vc, OCR, q_{tip}, S_r, Su/D'vc, Su/D'vc, LSN

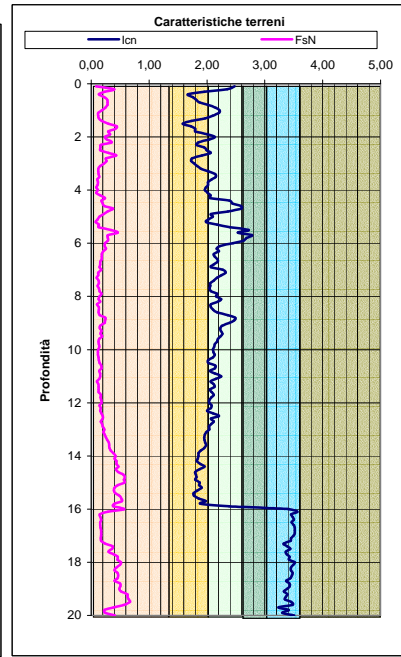
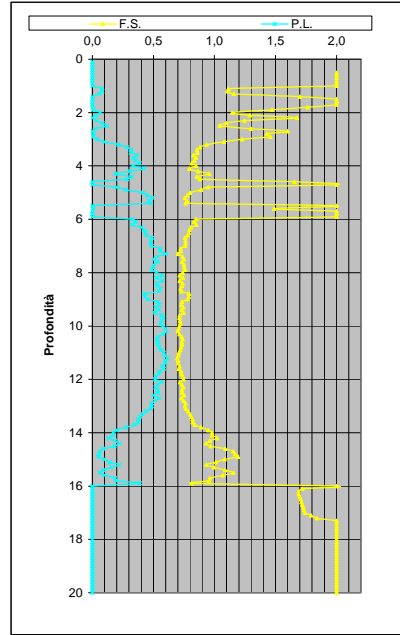
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 LDI = 4,630 Stot = 0,423 (mt) IPL = 12,70 PL = 42,00 LD = 0,00 (mt) PG = 0,99 SLiq = 11,1 (mt) LSN = 54,8

Main data table with 30 columns and 100 rows of numerical data for each depth level, including soil classification, stress ratios, and various geotechnical parameters.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTE 4



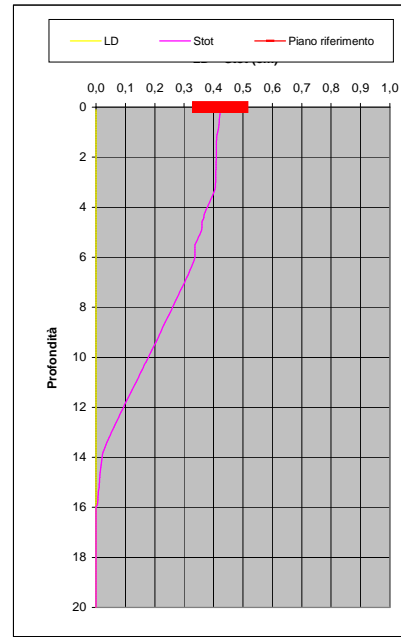
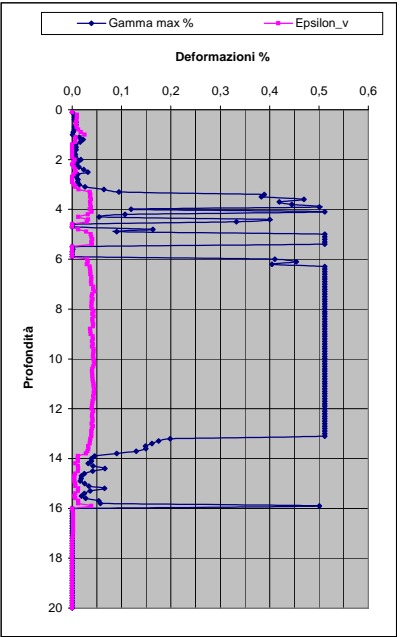
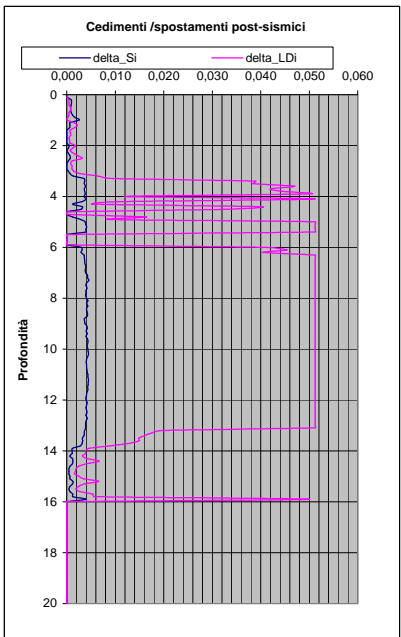
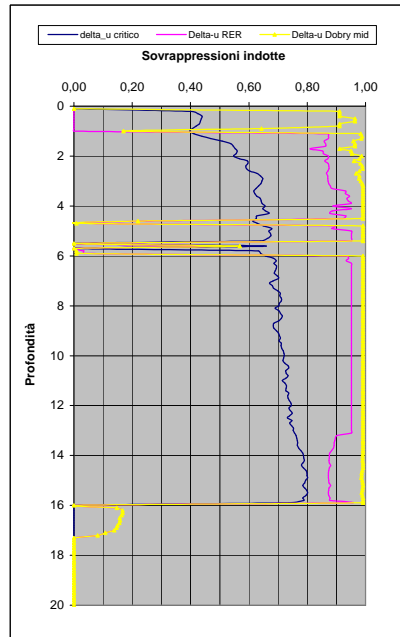
Soil Classification	Zone No.*	Range of CPT Index I_v Values
Organic Clay Soils	2	$I_v > 3.60$
Clays	3	$2.95 < I_v < 3.60$
Silt Mixtures	4	$2.60 < I_v < 2.95$
Sand Mixtures	5	$2.05 < I_v < 2.60$
Sands	6	$1.31 < I_v < 2.05$
Gravelly Sands	7	$I_v < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- lcn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento -esimo dello strato (mt)
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- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
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- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
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* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

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$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL= 12,70

PL= 42,00

LDI = 4,630 Stot = 0,423 (mt)

LD = 0,00 (mt)

SLiq = 11,10 (mt)

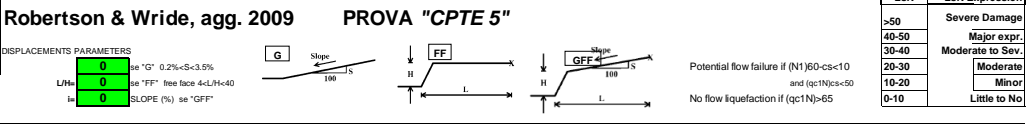
LSN = 54,77 PG= 0,99

CPT-based liquefaction triggering analysis for a single sounding

Environmental parameters: Soil Classification, Zone No., Range of CPT Index Values, Peak ground accel (g), Earthquake magnitude, Water table depth, Average above water table, Average below water table, Equipment, Behaviours, Sand-like, Hill-H Plain-P Coast-C, Computer constants, Probabilità e potenziale di liquefazione, Probabilità e suscettibilità di liquefazione, PL Overall Probability, Risk level, IPL, PL, Displacements parameters, Diagrams, and various tables for soil properties and liquefaction potential.

Main data table with columns: Depth (m), q_{tip} (kPa), F_{tip} (kPa), q_{tip} (kPa), q_{tip} (kPa), Q₁, Q₂, F, I_c, I_{c2}, N₁₍₆₀₎, n, K_c, Layer, Flag, FC, Kh, Interpretation, CSR, K_σ, ξ, K_σ, CRR, Factor of Safety FS, MSF SAND & CLAY, Limiting shear strain, ΔH, ALDI, Vertical recons. Strain, ASI, P_{max} PL, JUNG, F, I_h, I_h, Au', Au', Ru, Au', Dr, Ruc, Su/σ'vc, OCR, q_{c1N}, S_r, Su/σ'vc, Su/σ'vc, LSN, LSN Expression, Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No.

Main data table (continued) showing depth from 0.1 to 10.1 meters and corresponding soil parameters, CSR values, and LSN values. The table is color-coded by soil state (e.g., yellow for saturated, green for unsaturated).



Robertson & Wride, agg. 2009

PL Overall Probability

Risk level, IPL, PL

Very High, High, Low

Severe, Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

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Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

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Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

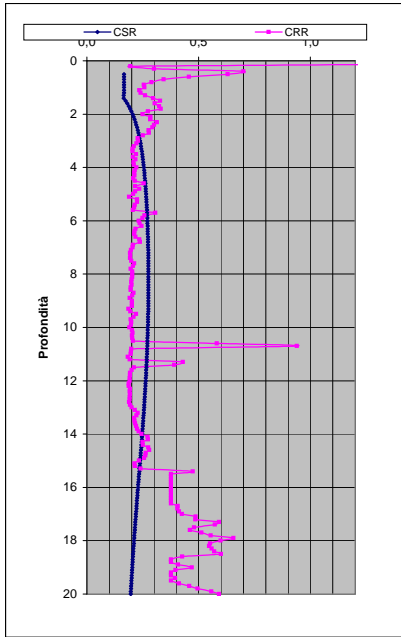
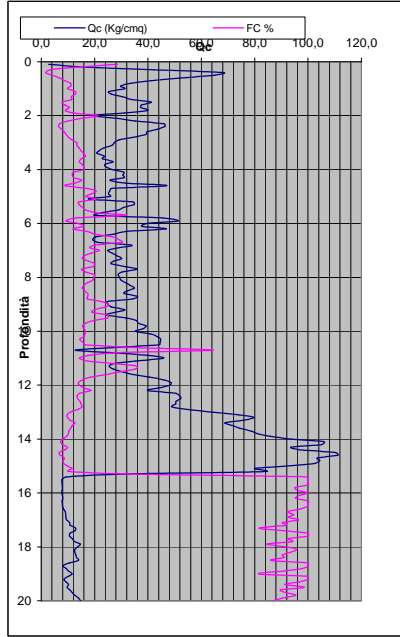
Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

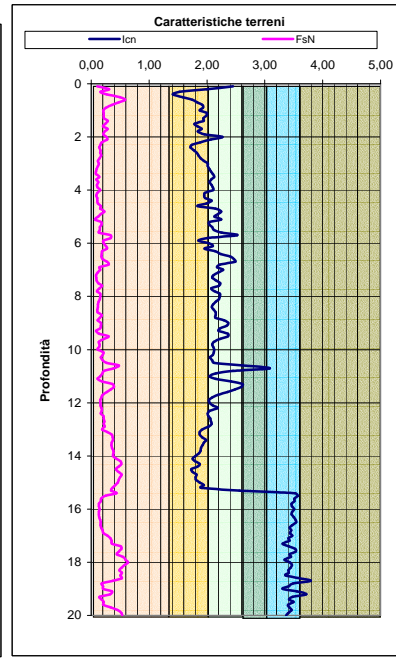
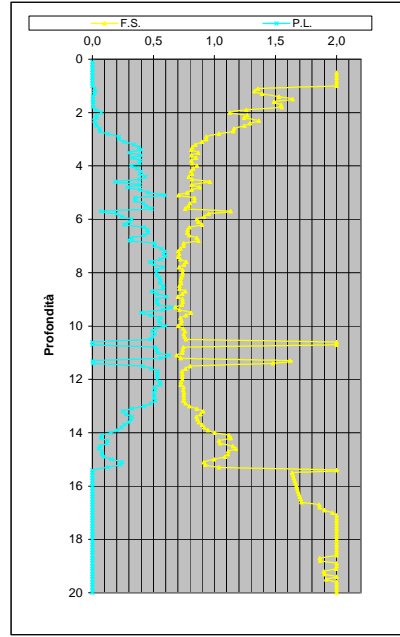
Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTE 5



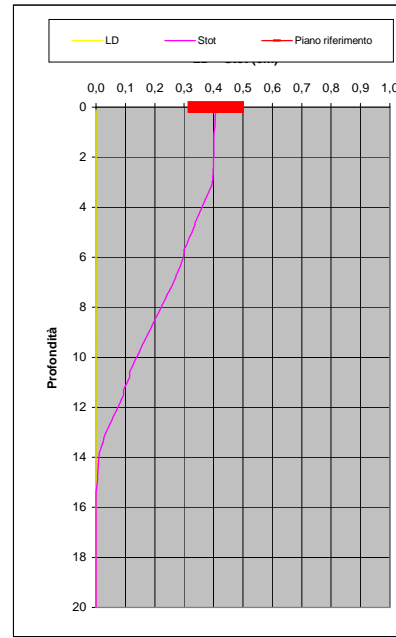
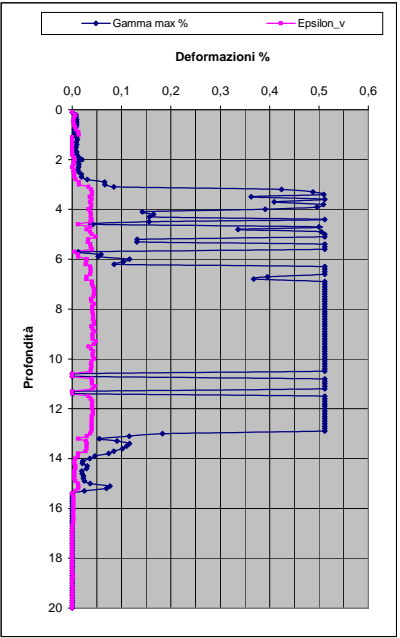
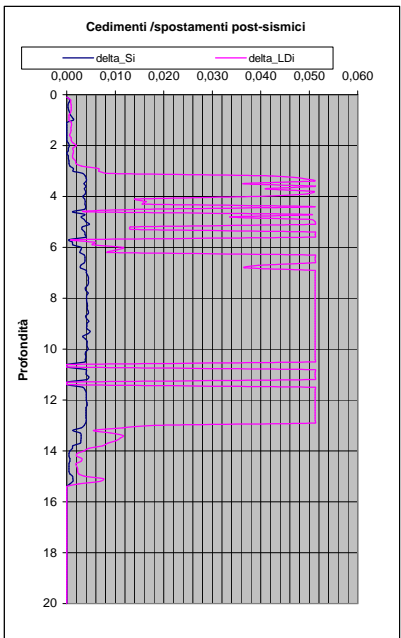
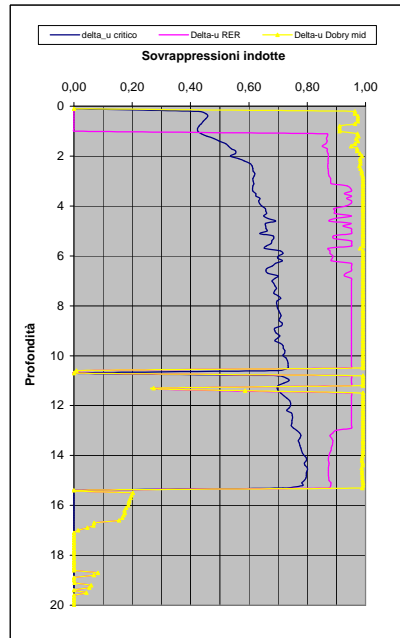
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
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- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
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- γ max** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δ si** = cedimento -esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
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- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
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- Stot** = Cedimento post-sismico totale (mt)
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- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



IPL= 12,98

PL= 43,47

LDI = 4,381 Stot = 0,407 (mt)

LD = 0,00 (mt)

SLiq = 10,90 (mt)

LSN = 57,24 PG= 0,99

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
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* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
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$P_G \leq 0.1$	extremely low to none

CPT-based liquefaction triggering analysis for a single sounding

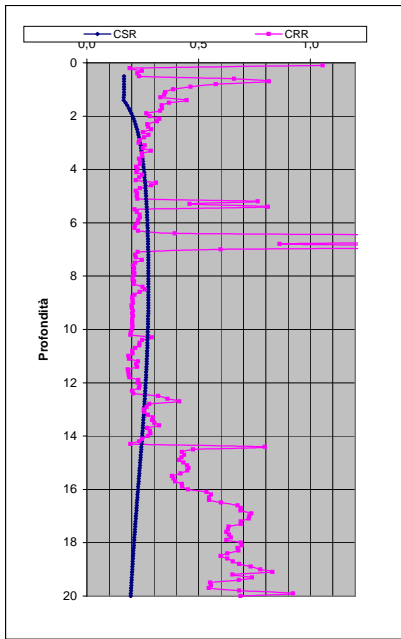
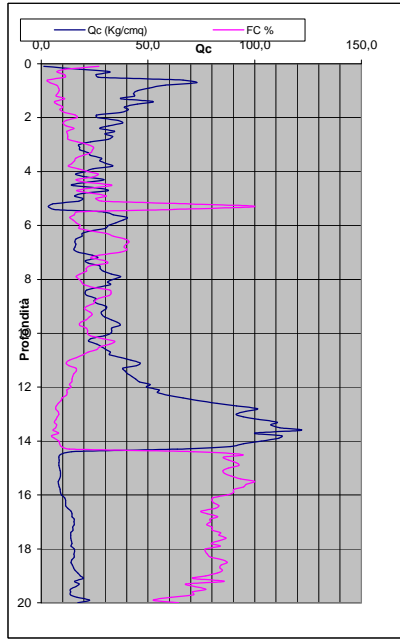
Environments: Hill-H Plain-P Coast-C. Behaviours: Sand-like-S. Computer constants: (B' 2007 - 'Cefin' 2004 - 'NCEER' - 'Blake'). Probabilità e potenziale di liquefazione. Probabilità e suscettibilità di liquefazione. PL Overall Probability. Risk lev. IPL. PL. Displacements Parameters. Diagrams showing stress paths and failure envelopes.

Table with columns: Depth (m), q_v (kPa), q_u (kPa), F, I_c, I_{nc2}, N₁₍₆₀₎, n, K_c, Layer, Flag, FC, Kh, Interpretation, q_{c1N}, q_u, CSR, K_r, ξ, K_σ, CRR, Factor of Safety FS, MSF, Limiting shear strain γ_{lim}%, ΔH, ALDI, Vertical recons. Strain, ASI, P_{max} PL, J_u, F, I_u, A_u, R_u, A_u, D_r, S_u, O_{CR}, q_{c1N}, S_r, S_r, L_{SN}.

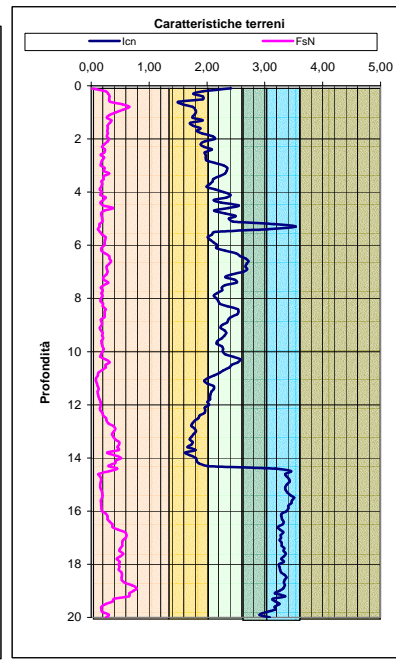
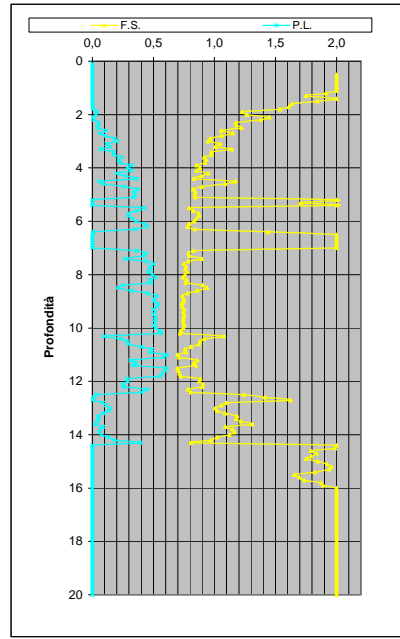
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0. LDI = 3,142. Stot = 0,281 (mt). IPL = 8,48. PL = 22,39. LD = 0,00 (mt). PG = 0,79. SLiq = 8,2 (mt). LSN = 38,1.

Main data table with 30 columns and 100 rows of numerical data for each depth level, including soil classification, stress ratios, and various engineering parameters.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTE 6



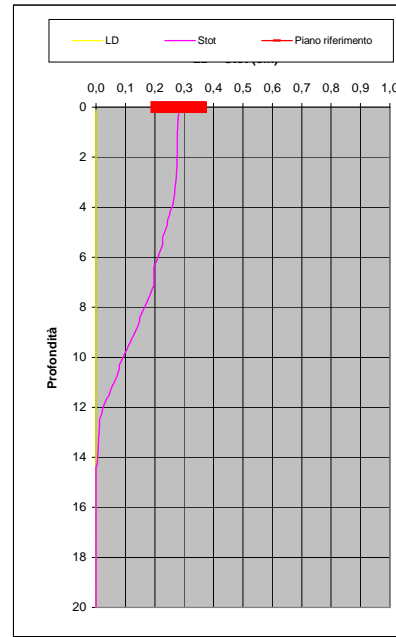
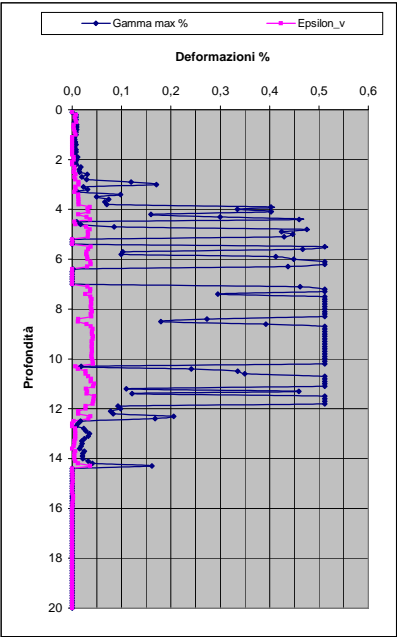
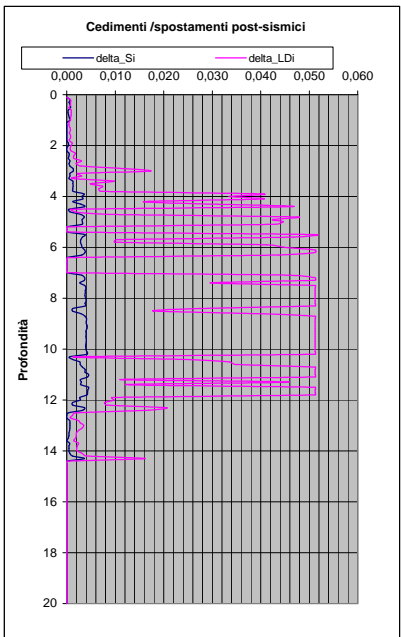
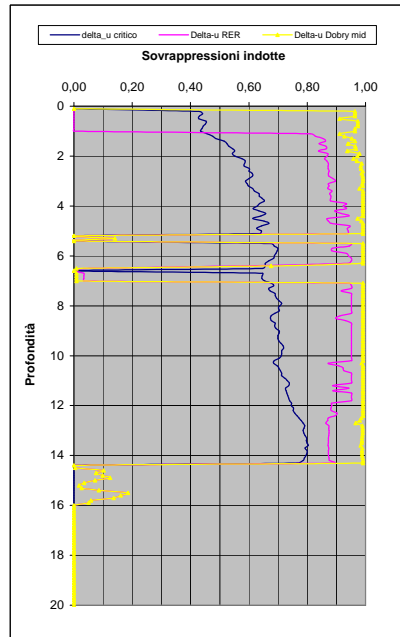
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Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento -esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- ϕ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL = 8,48 PL = 22,39 LDI = 3,142 Stot = 0,281 (mt) LD = 0,00 (mt) SLiq = 8,20 (mt) LSN = 38,13 PG = 0,79

CPT-based liquefaction triggering analysis for a single sounding

Input parameters table including Peak ground accel (g), Earthquake magnitude (M), Water table depth (m), Average above water table (N60)30, Average below water table (N60)30, and Equipment (CPT-CP7M).

Environments

Behaviours table with columns for Soil Classification, Zone No., Range of CPT Index / Values, and Soil Name.

Computer constants

Computer constants table with columns for Soil Name, n, Kc, L, Layer, and various constants.

Probabilità e potenziale di liquefazione

Probabilità e potenziale di liquefazione table with columns for Probabilità, Pot di Liq, and IPL.

Probabilità e suscettibilità di liquefazione

Probabilità e suscettibilità di liquefazione table with columns for Probabilità, Suscettibilità, and Quasi certa.

PL Overall Probability

PL Overall Probability table with columns for Risk lev., IPL, and PL.

Displacement Parameters

Displacement Parameters table with columns for PL, FS, and various parameters.

Robertson & Wride, agg. 2009

Robertson & Wride, agg. 2009 table with columns for PL, FS, and various parameters.

PROVA "CPTE 7"



Table Headers

Table headers for the main data table, including Depth, q, qc, fs, etc.

PROFONDITA' DI CALCOLO (mt da p.c.):

PROFONDITA' DI CALCOLO (mt da p.c.): 0,0

LDI = 3,725

LDI = 3,725

Stot = 0,342 (mt)

Stot = 0,342 (mt)

IPL = 14,81

IPL = 14,81

PL = 53,41

PL = 53,41

LD = 0,00 (mt)

LD = 0,00 (mt)

PG = 1,00

PG = 1,00

SLiq = 10,1 (mt)

SLiq = 10,1 (mt)

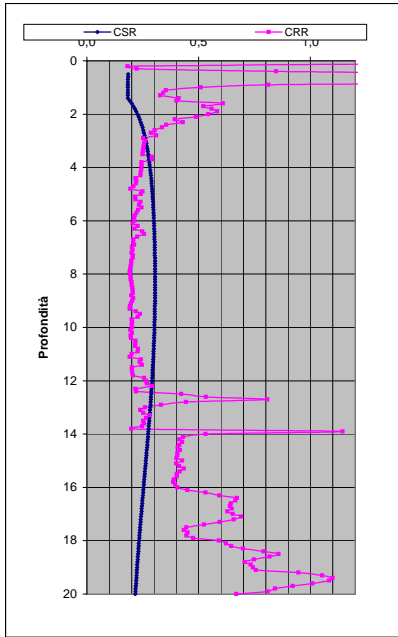
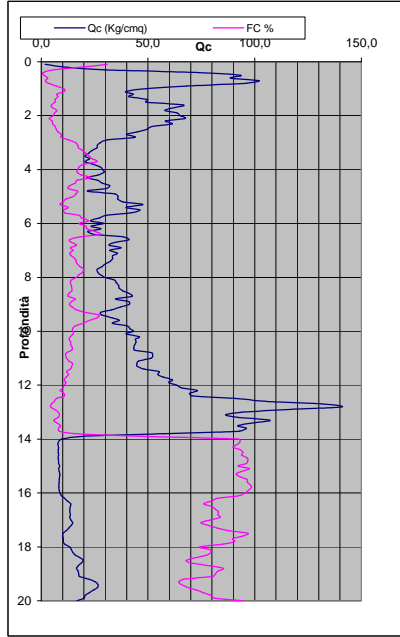
LSN = 48,0

LSN = 48,0

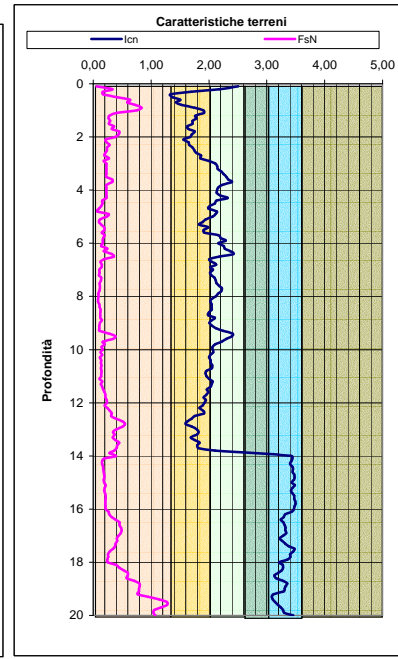
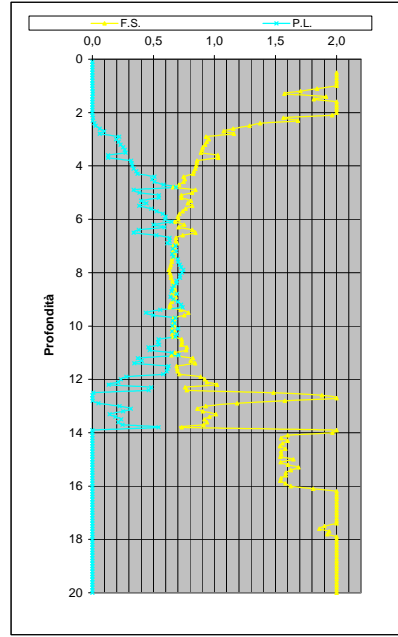
Table Data

Table data rows starting from Depth 0.1 to 10.1.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTE 7



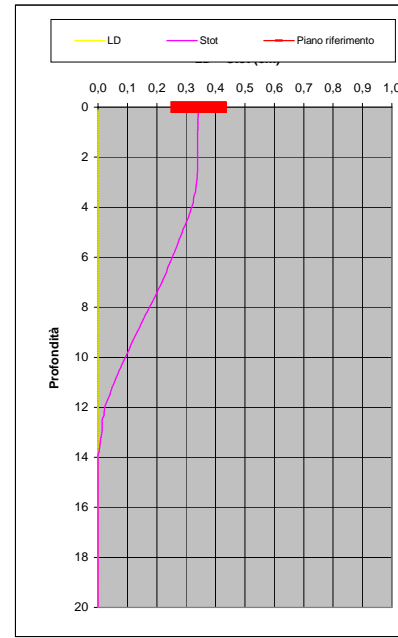
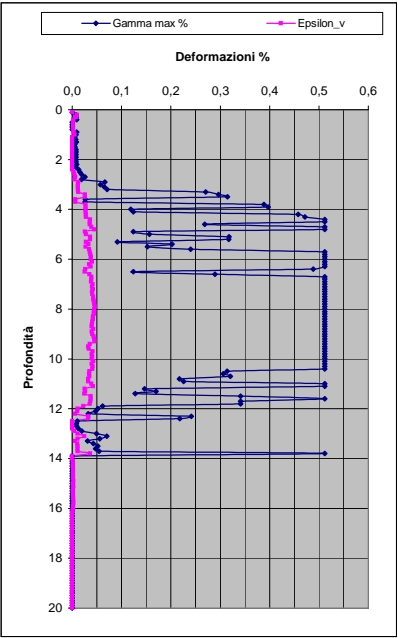
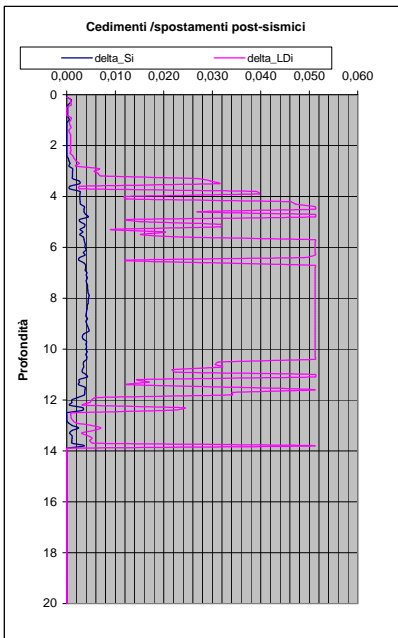
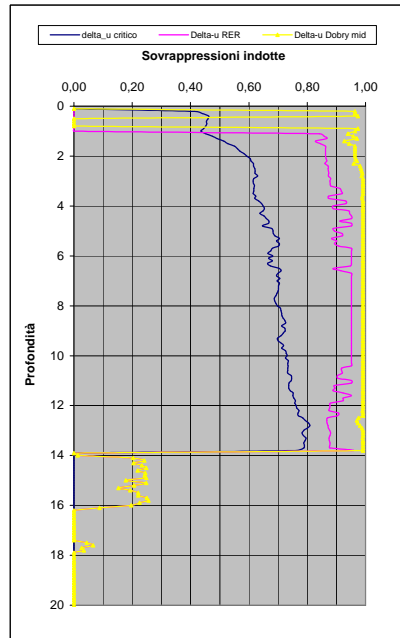
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3,60$
Clays	3	$2,95 < I_c < 3,60$
Silt Mixtures	4	$2,60 < I_c < 2,95$
Sand Mixtures	5	$2,05 < I_c < 2,60$
Sands	6	$1,31 < I_c < 2,05$
Gravelly Sands	7	$I_c < 1,31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

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- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0,074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento i-esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
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- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- ϕ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



IPL= 14,81 PL= 53,41 LDI = 3,725 Stot = 0,342 (mt) LD = 0,00 (mt) SLiq = 10,10 (mt) LSN = 47,97 PG= 1,00

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0,9 < P_G$	extremely high to absolutely certain
$0,7 < P_G \leq 0,9$	high
$0,3 < P_G \leq 0,7$	medium
$0,1 < P_G \leq 0,3$	low
$P_G \leq 0,1$	extremely low to none

CPT-based liquefaction triggering analysis for a single sounding

Input parameter table with columns for Soil Classification, Zone No., Range of CPT Index / Values, and various soil parameters like Peak ground accel, Earthquake magnitude, Water table depth, etc.

Environments Behaviours

Table defining soil environments and behaviours, including Soil Classification, Zone No., Range of CPT Index / Values, and Soil Name.

Computer constants

Table of computer constants including parameters like alpha (N), N, Patm, Q, MSF, NCEER, etc.

Probabilità e potenziale di liquefazione

Table showing probability and potential of liquefaction, including columns for Probabilità, Pot di Liq, IPL, etc.

Probabilità e suscettibilità di liquefazione

Table showing probability and susceptibility of liquefaction, including columns for Probabilità, Suscettibilità, Quasi certa, etc.

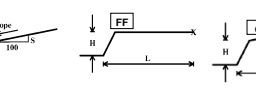
PL Overall Probability

Table for PL Overall Probability with columns for Risk lev., IPL, PL, etc.

Robertson & Wride, agg. 2009

Table for Robertson & Wride aggregation parameters, including columns for Displacements Parameters, PL, etc.

PROVA "CPTE 8"



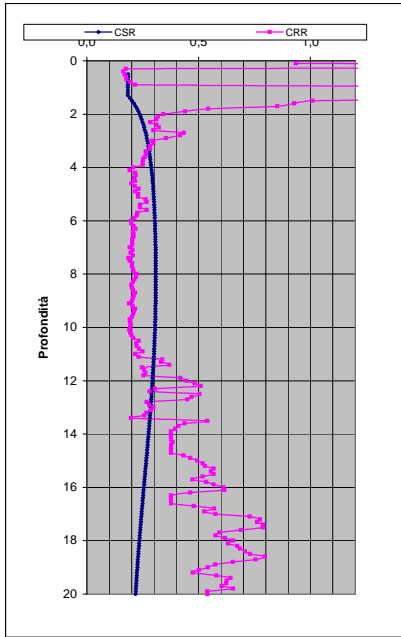
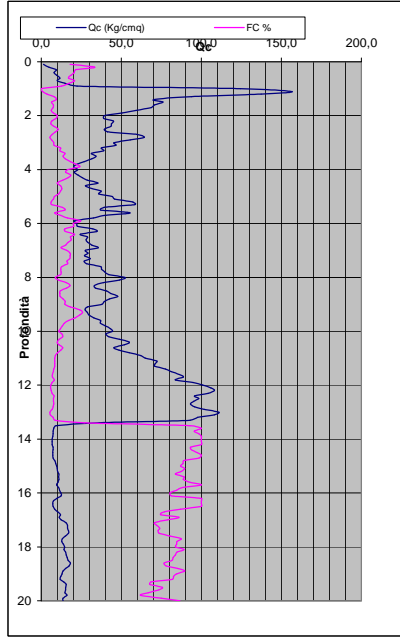
Main data table header with columns for Depth (m), Soil Name, Soil Classification, Zone No., Range of CPT Index / Values, and various soil parameters like qc, qn, F, Ic, etc.

Main data table body containing 101 rows of soil sounding data, including depth, soil name, and various geotechnical parameters.

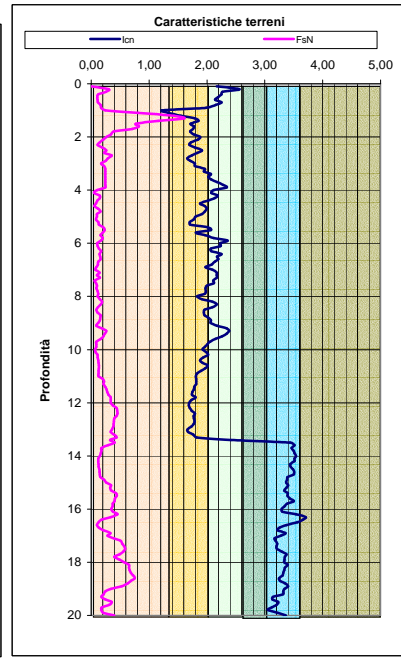
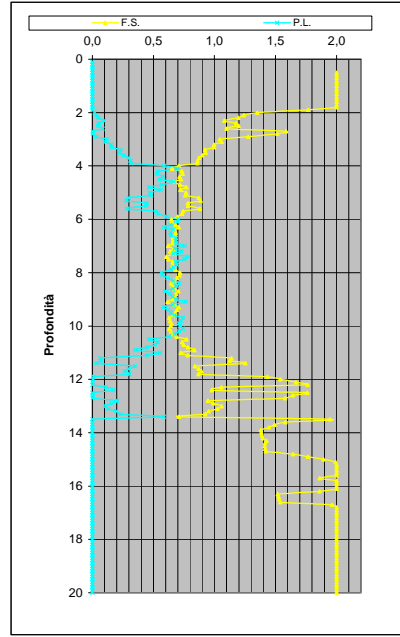
Table for LsN and LsN Expression, showing ranges for Severe Damage, Moderate to Severe, Moderate, Mild, and Little to No damage.

PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 LDI = 3,337 Stot = 0,337 (mt) IPL = 14,40 PL = 51,17 LD = 0,00 (mt) PG = 1,00 SLiq = 9,0 (mt) LSN = 46,6

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 8



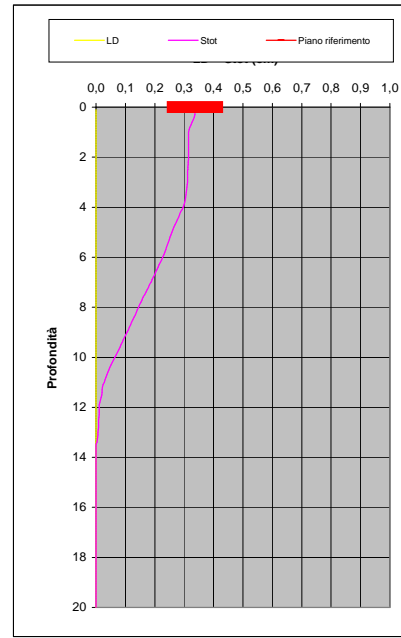
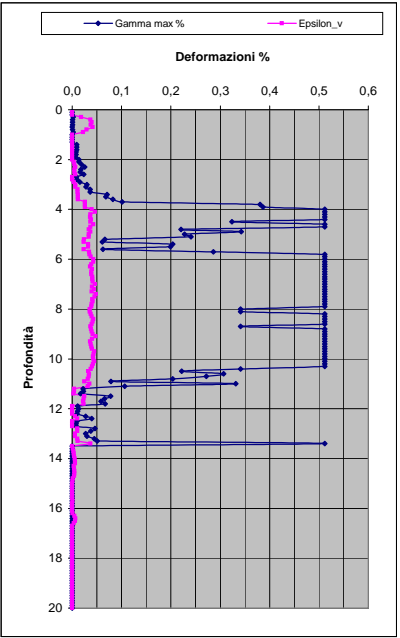
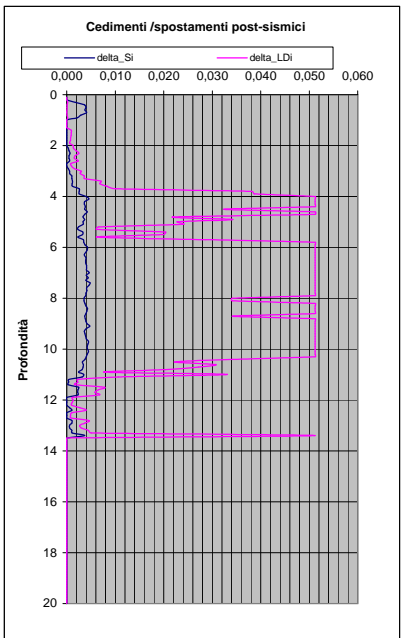
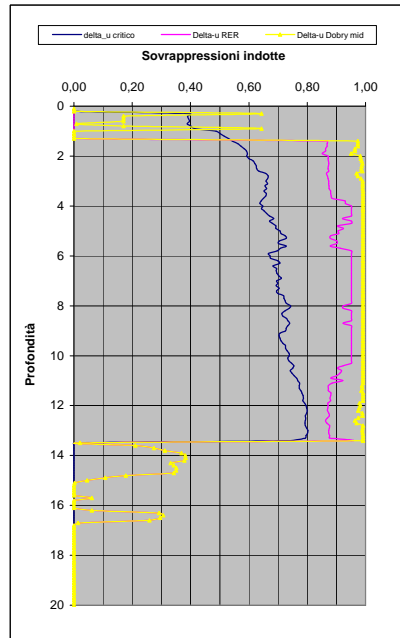
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

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- FC** = Fine content - passante 0.074 mm (%)
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- K α** = fatt. correttivo per sforzi di taglio (ad)
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- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
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- Δs_i** = cedimento i-esimo dello strato (mt)
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- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
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- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
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LSN Range	Expected ground surface damage
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* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

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$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL= 14,40

PL= 51,17

LDI = 3,337 Stot = 0,337 (mt)

LD = 0,00 (mt)

SLiq = 9,00 (mt)

LSN = 46,57 PG= 1,00

CPT-based liquefaction triggering analysis for a single sounding

Input parameter: Peak ground accel (g) = 0.236, Earthquake magnitude, M = 5.6, Water table depth (m) = 18.10, Average above water table (N60) = 19.7, Average below water table (N60) = 20.2

Environment: Hill-H Plain-P Coast-C, Behaviours: Sand like-S

Computer constants: Soil Classification: Sand-Clay-SC, Building (Y/N): Sedimentary environment, CPTs: CPTu=1

Probabilità e potenziale di liquefazione: Probabilità: 0.943, Pot di Liq: IPL=15

Probabilità e suscettibilità di liquefazione: Probabilità: 0.943, Suscettibilità: Quasi certa

PL Overall Probability: Risk lev. Very High, IPL: 15, PL: PL-54

Robertson & Wride, agg. 2009

PROVA "CPTE 9"

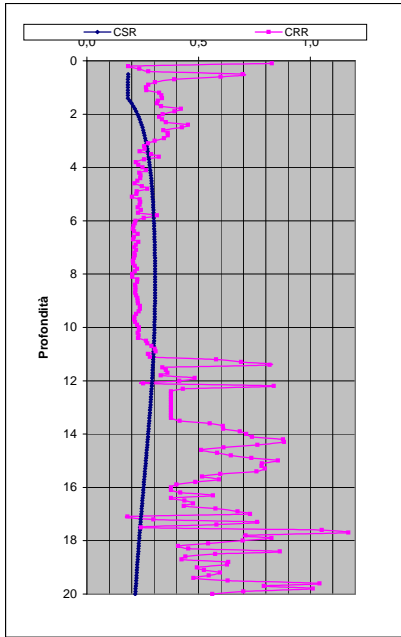
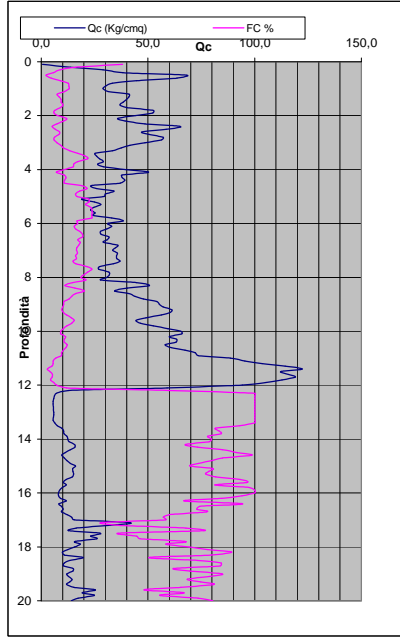


Potential flow failure if (N1)60<=10 and (q1)N60<=5, No flow liquefaction if (q1)N60<=5

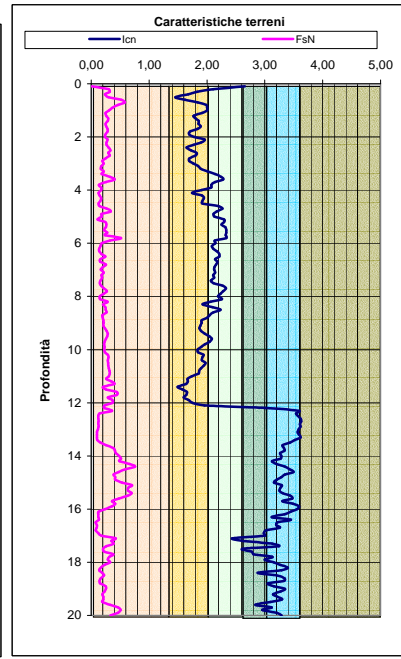
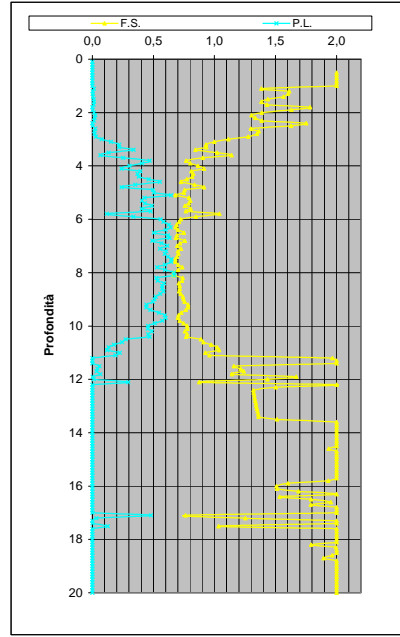
Table with columns for Depth (m), q1 (kPa), q2 (kPa), F, Ic, Ic2, N1(60), n, Kc, Layer, etc. Summary values: LDI = 2,808, Stot = 0,258, IPL = 11,20, PL = 34,28, LD = 0,00, PG = 0,96, SLiq = 7,8, LSN = 38,0

Main data table with 30 columns and 100 rows of soil sounding data, including depth, blow counts, and various soil parameters.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 9



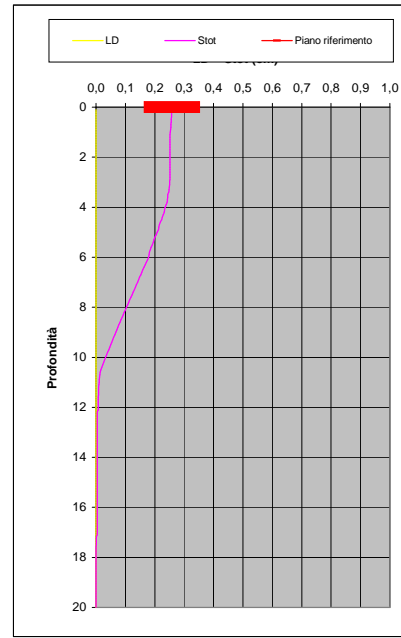
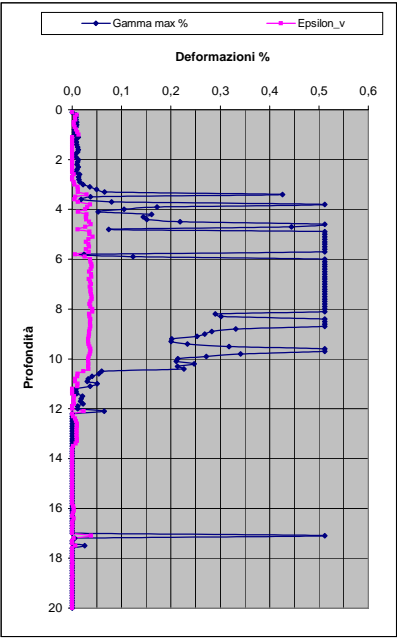
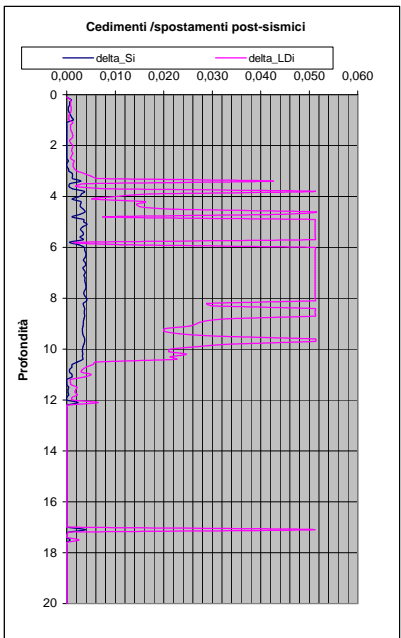
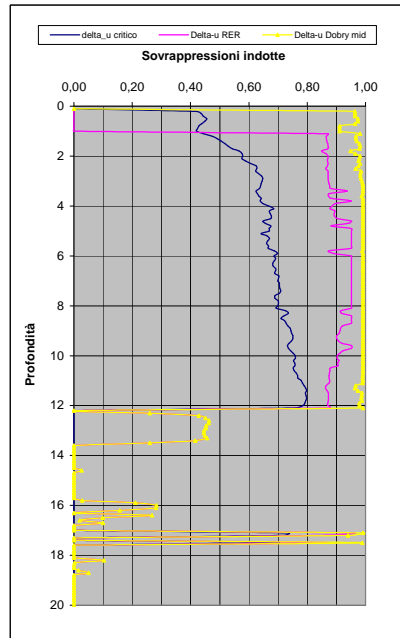
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- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento i-esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



IPL = 11,20

PL = 34,28

LDI = 2,808 Stot = 0,258 (mt)

LD = 0,00 (mt)

SLiq = 7,80 (mt)

LSN = 38,00 PG = 0,96

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction as surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

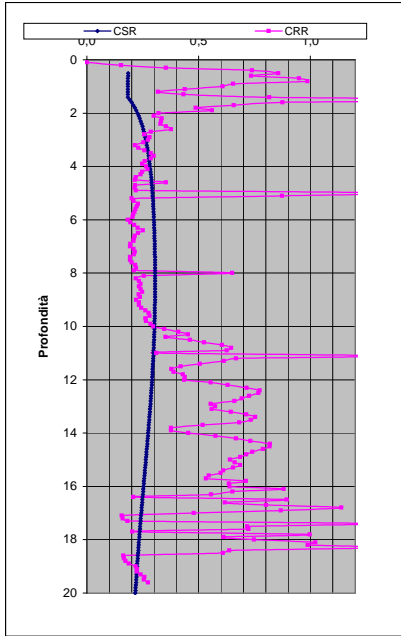
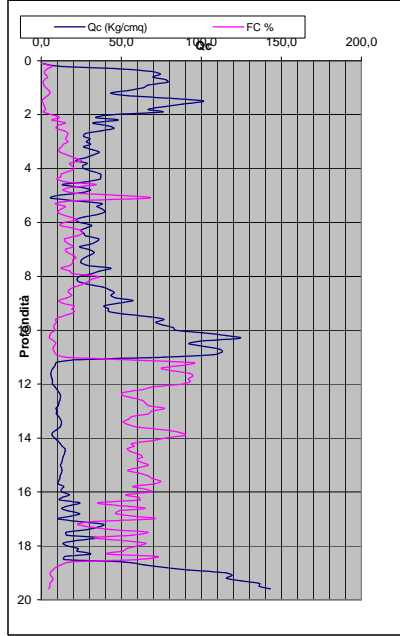
CPT-based liquefaction triggering analysis for a single sounding

Environmental parameters, soil classification, and various probability and potentiality charts for liquefaction analysis.

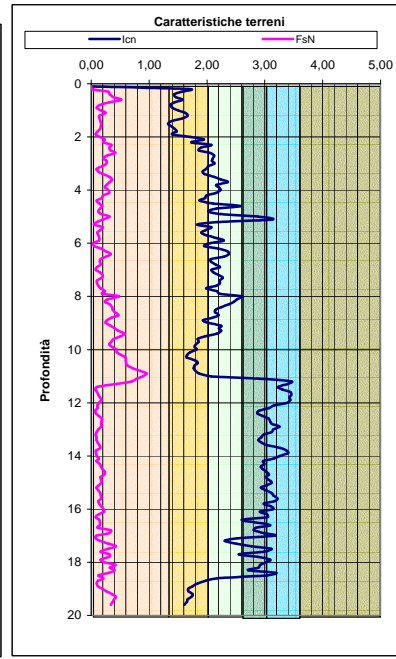
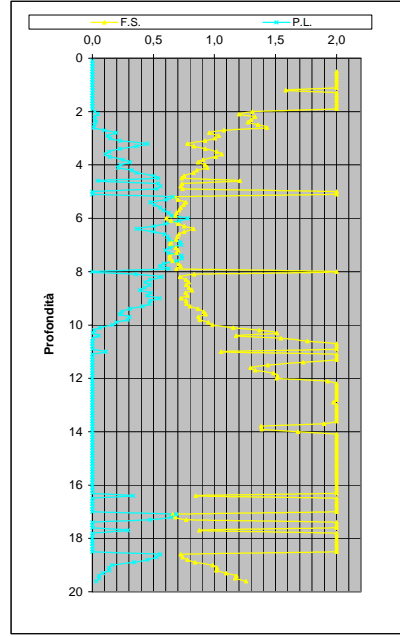
Main data table with columns for Depth (m), Soil Classification, and various parameters like q, qc, N, etc. Includes a color-coded 'Liquefaction' column and a 'Liquefaction' column at the bottom.

Summary table with columns for LSN, LSN Expression, and other key metrics.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT 10



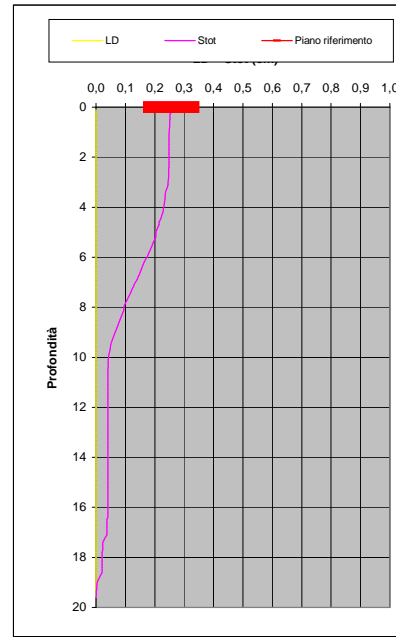
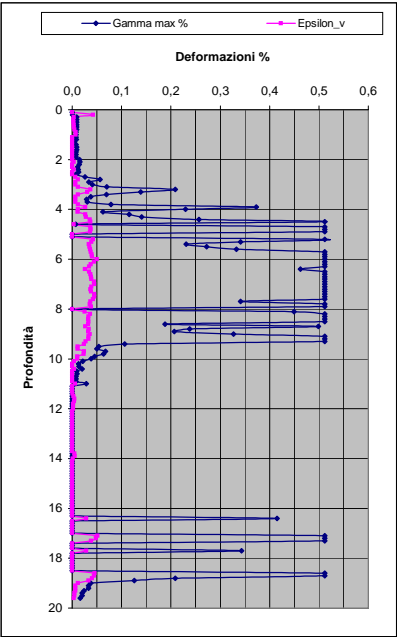
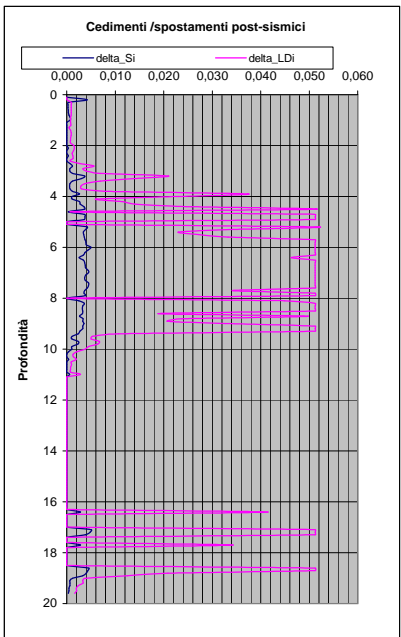
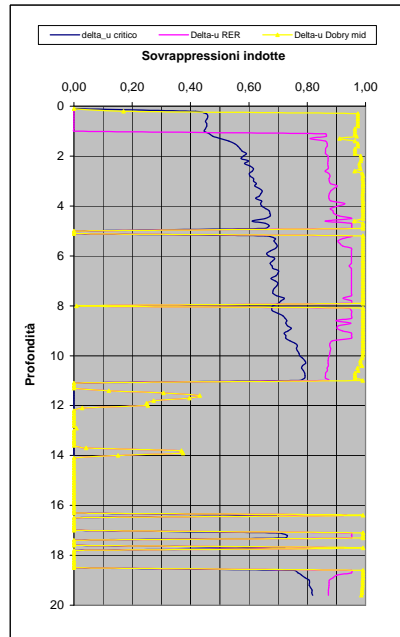
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
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- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

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- FC** = Fine content - passante 0.074 mm (%)
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- F** = rapporto di frizione
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- Icn** = Soil behaviour index normalized (ad)
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- K α** = fatt. correttivo per sforzi di taglio (ad)
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- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
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* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL= 10,04

PL= 28,82

LDI = 2,742 Stot = 0,256 (mt)

LD = 0,00 (mt)

SLiq = 7,40 (mt)

LSN = 36,77 PG= #NUM!

CPT-based liquefaction triggering analysis for a single sounding

Input parameter table with columns for parameter name, value, and unit. Includes Peak ground accel (g), Earthquake magnitude (M), Water table depth (m), etc.

Soil Classification table with columns for Zone No., Range of CPT Index / Values, and Soil Name. Lists zones 1 through 7 and their corresponding soil types.

Computer constants table with columns for parameter name, value, and unit. Includes alpha (N), N, Patm, Q, etc.

Probabilità e potenziale di liquefazione table with columns for Probabilità, Pot di Liq, IPL, etc. Includes values for different soil types and conditions.

Probabilità e suscettibilità di liquefazione table with columns for Probabilità, Suscettibilità, Quasi certa, etc. Includes values for different soil types and conditions.

PL Overall Probability table with columns for Risk lev., IPL, PL, etc. Includes values for different soil types and conditions.

DISPLACEMENT PARAMETERS table with columns for parameters like L, H, etc. Includes values for different soil types and conditions.

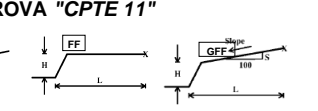


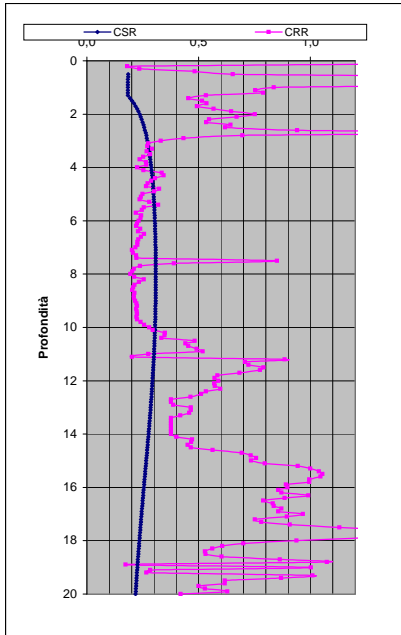
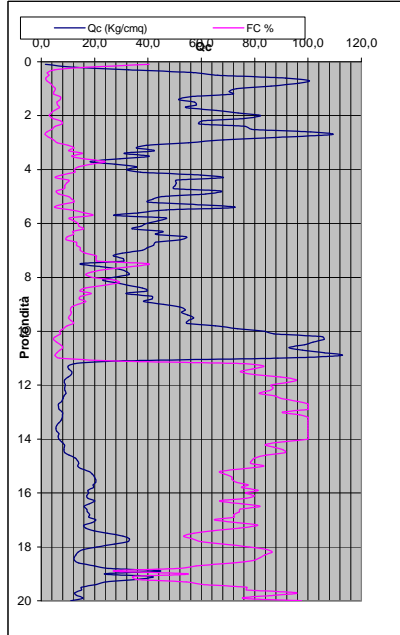
Table with columns for LSN, LSN Expression, and Severe Damage. Includes values for different soil types and conditions.

Main data table with columns for Depth (m), Soil type, and various parameters like q, qc, etc. Includes values for different soil types and conditions.

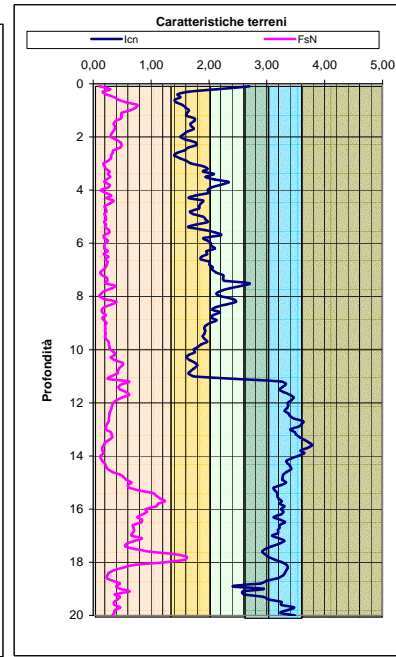
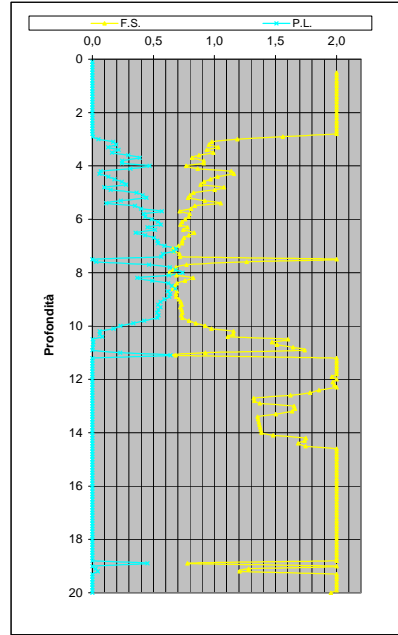
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 LDI = 1,967 Stot = 0,203 (mt) IPL = 8,78 PL = 23,55 LD = 0,00 (mt) PG = 0,82 SLiq = 6,5 (mt) LSN = 29,8

Main data table with columns for Depth (m), Soil type, and various parameters like q, qc, etc. Includes values for different soil types and conditions.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 11



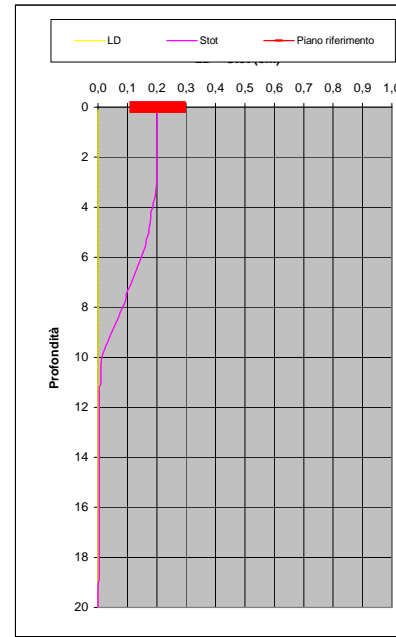
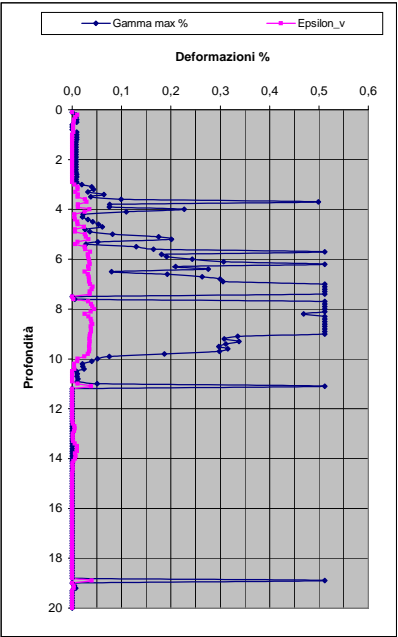
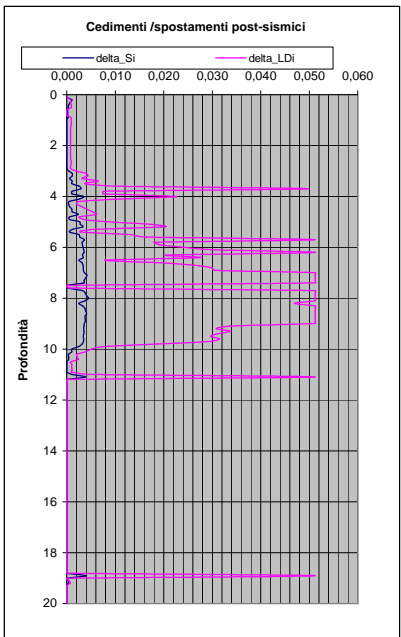
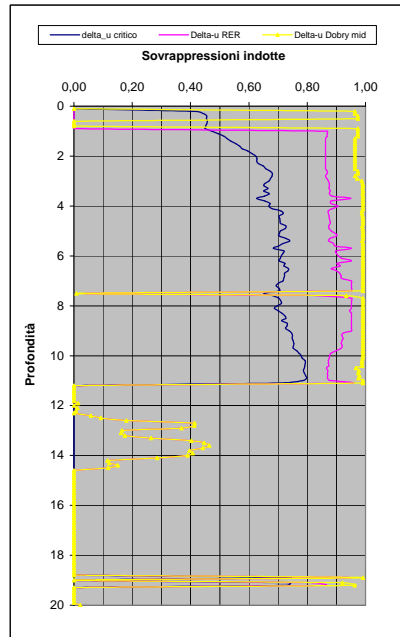
Soil Classification	Zone No.*	Range of CPT Index I_c Values
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After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

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LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
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- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
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* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
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$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL = 8,78

PL = 23,55

LDI = 1,967 Stot = 0,203 (mt)

LD = 0,00 (mt)

SLiq = 6,50 (mt)

LSN = 29,78 PG = 0,82

CPT-based liquefaction triggering analysis for a single sounding

Enviromenti: C Hill-H Plain-P Coast-C Behaviours: E Sand-like-S

Computer constants: no. n=350 Patm=101.32 (cov=0.35-35%)

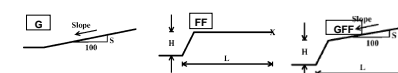
Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTE 12"



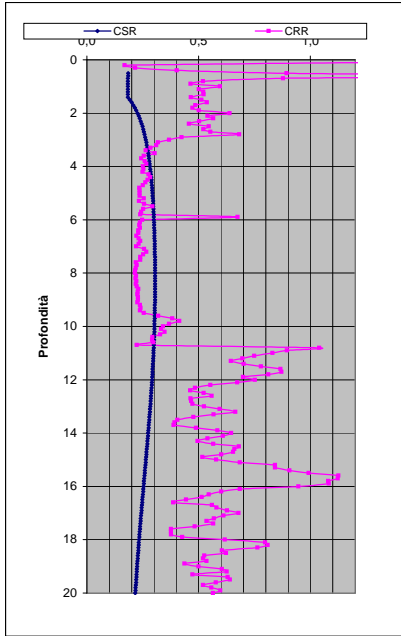
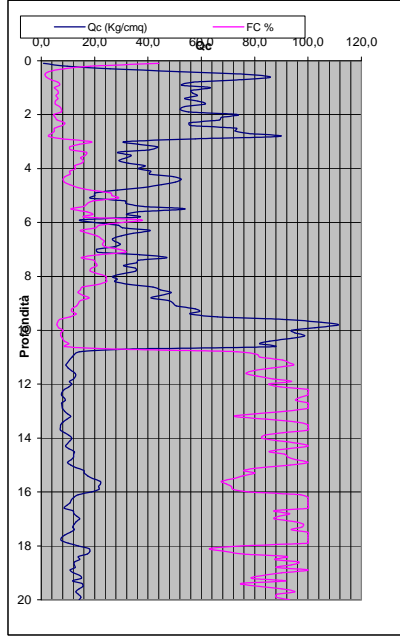
Potential flow failure if (N) < 60-cv<10 and (q) < 100-cv<50

No flow liquefaction if (q) < 10-cv<65

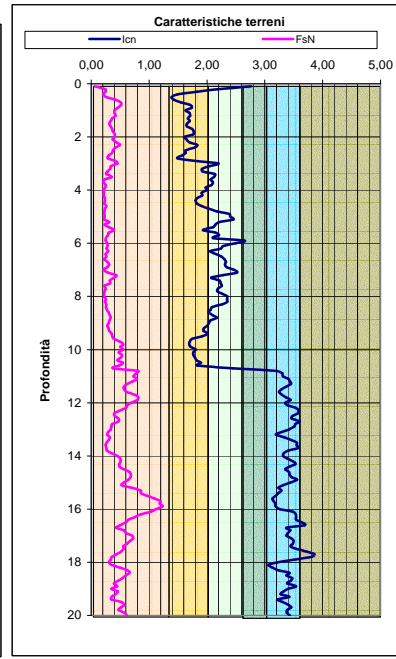
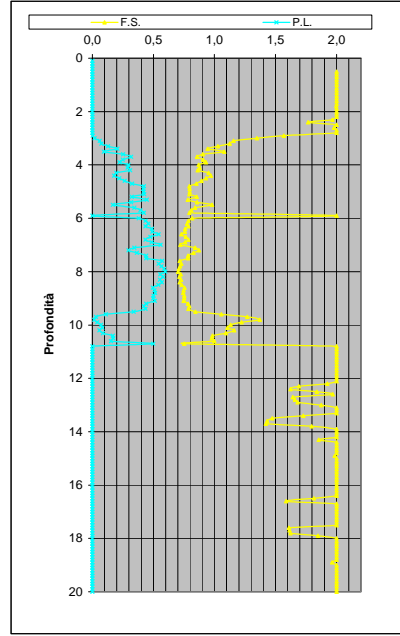
Table with 2 columns: LsN and LsN Expression. It shows ranges for Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, and Little to No.

Main data table with columns for Depth (m), q (kPa), q1 (kPa), q2 (kPa), F, Ic, In2, N1(60), n, Kc, Layer, Flag, FC, Kh, Interpret, qCN, qc1N, On-cs, R, CSR, Ks, ξ, Kα, CRR, Factor of Safety FS, MSF SAND & CLAY, Limiting shear strain γlim%, ΔH, ALDI, Vertical recons. Strain, ASI, Pmax PL, JUNG, F, IPI, Au', Au'', Ru, Dr, Ruc, Su/σ'vc, OCR, qc1N, Su/σ'vc, Su/σ'vc, Su/σ'vc, LSN, LSN Expression. The table contains 101 rows of data, with some cells highlighted in red and others in green.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 12



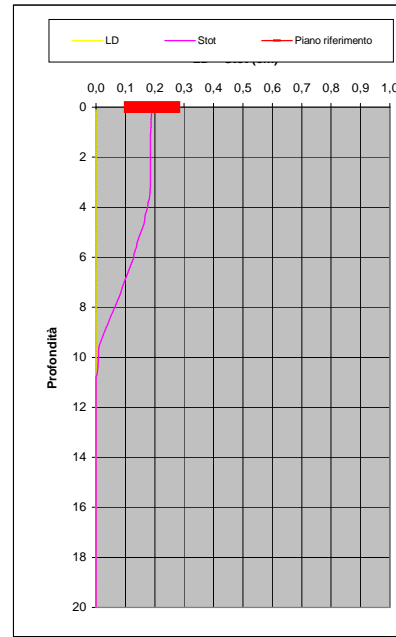
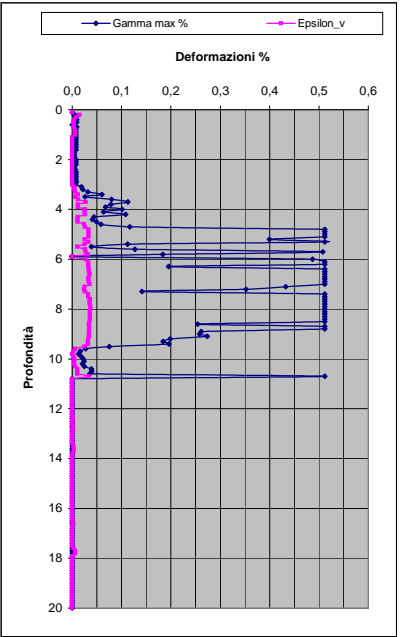
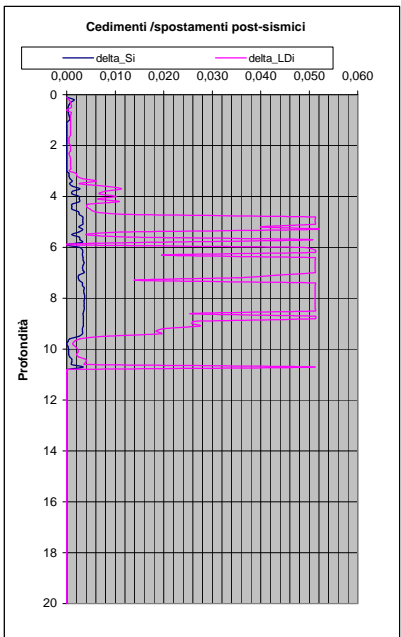
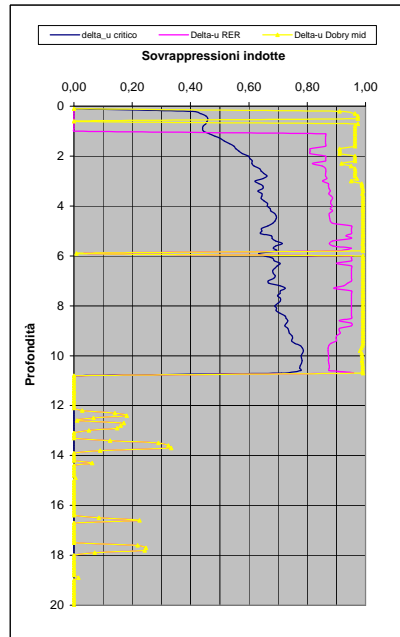
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- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- Ymax** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δ si** = cedimento i-esimo dello strato (mt)
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- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL = 7,79 PL = 19,89 LDI = 2,109 Stot = 0,190 (mt) LD = 0,00 (mt) SLiq = 6,40 (mt) LSN = 28,83 PG = 0,69

CPT-based liquefaction triggering analysis for a single sounding

Environments: Hill-H Plain-P Coast-C Behaviours: Sand like-S

Computer constants: no. of Blows (N) = 10.32 (MSF NCEER)

Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTU 1" - Colonia Montecatini

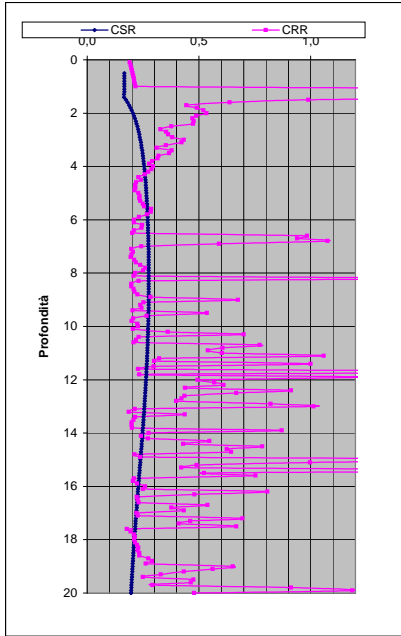
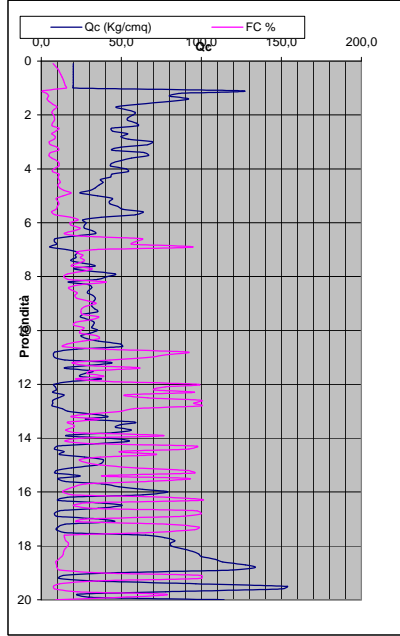
Table with 2 columns: LsN, LsN Expression. Values range from >50 to <50.

Main data table with columns: Depth (m), q (kPa), qc (kPa), fs (kPa), etc. Includes various soil parameters and calculated values.

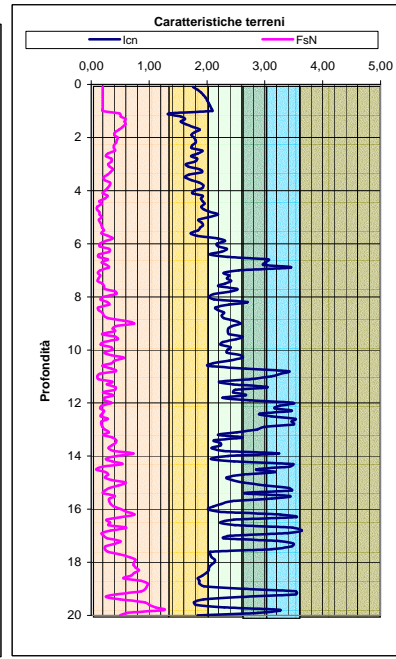
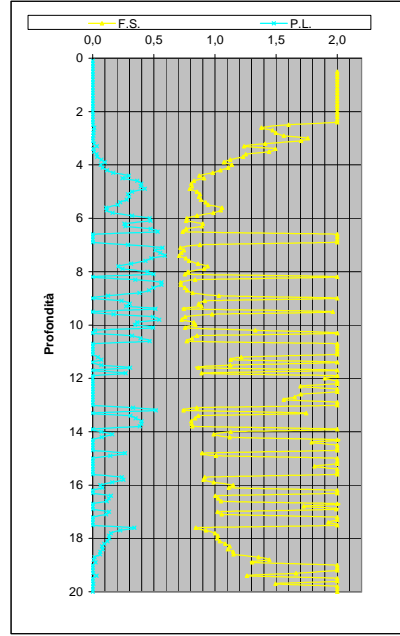
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 LDI = 2,495 Stot = 0,237 (mt) IPL = 6,30 PL = 15,20 LD = 0,00 (mt) PG = 0,44 SLiq = 6,8 (mt) LSN = 28,3

Main data table with columns: Depth (m), q (kPa), qc (kPa), fs (kPa), etc. This table contains the majority of the data rows, including values for various soil parameters and calculated values.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTU 1 - Colonia Montecatini



Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

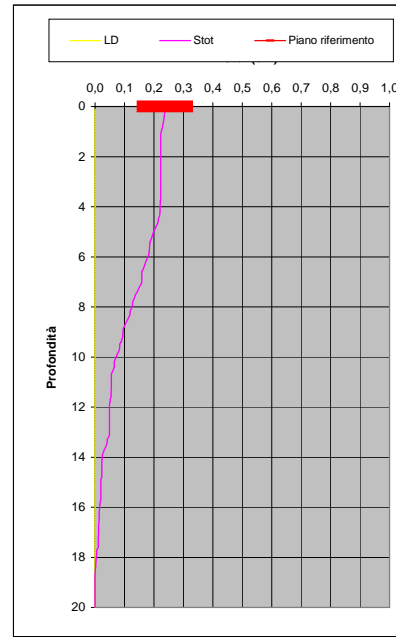
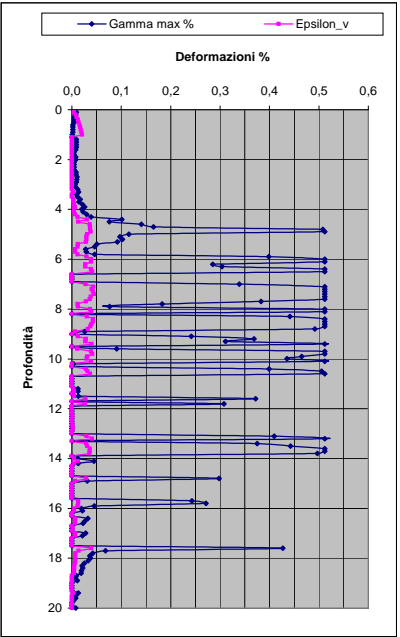
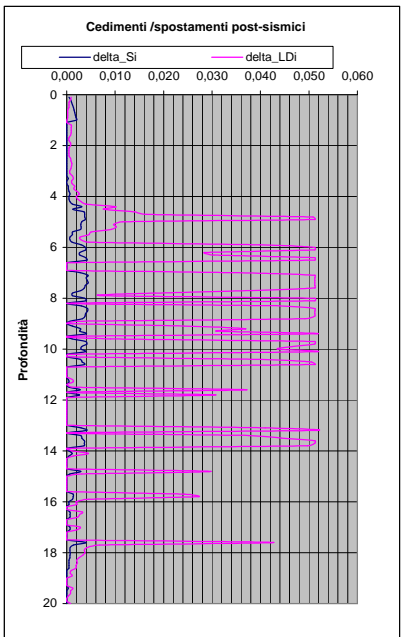
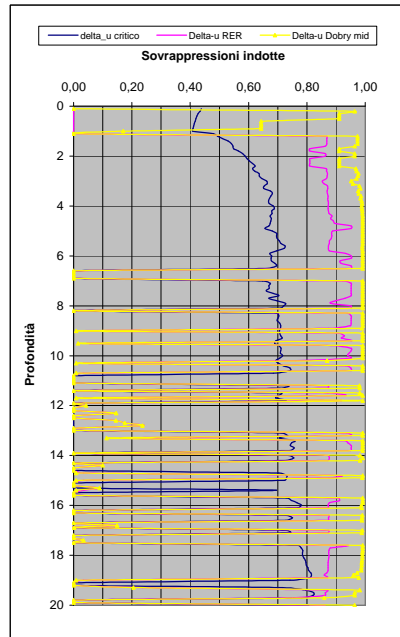
After Robertson and Wride (1998).

*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento i-esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- ϕ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



IPL = 6,30 PL = 15,20 LDI = 2,495 Stot = 0,237 (mt) LD = 0,00 (mt) SLiq = 6,80 (mt) LSN = 28,33 PG = 0,44

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction as surfaco, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

CPT-based liquefaction triggering analysis for a single sounding

Input parameters table including Peak ground accel (g), Earthquake magnitude (M), Water table depth (m), Average of above water table (N(N)3), Average of below water table (N(N)3), and Equipment.

Soil Classification table with columns for Zone No., Range of CPT Index / Values, and Soil Name.

Behaviours table with columns for Soil Name, Sand-like, and various soil parameters.

Computer constants table with columns for Soil Name, Patm, and various constants.

Probabilità e potenziale di liquefazione table with columns for Probabilità, Pot di Liq, and IPL.

Probabilità e suscettibilità di liquefazione table with columns for Probabilità, Suscettibilità, and Quasi certa.

PL Overall Probability table with columns for Risk lev., IPL, and PL.

DISPLACEMENT PARAMETERS table with columns for Displacement, Vertical recors. Strain, and ASI.

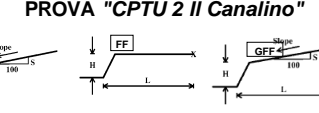


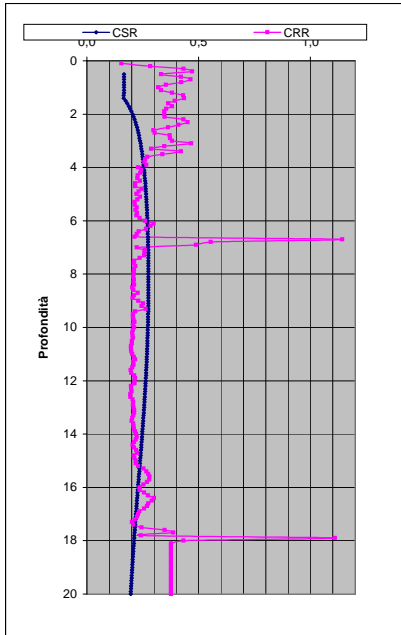
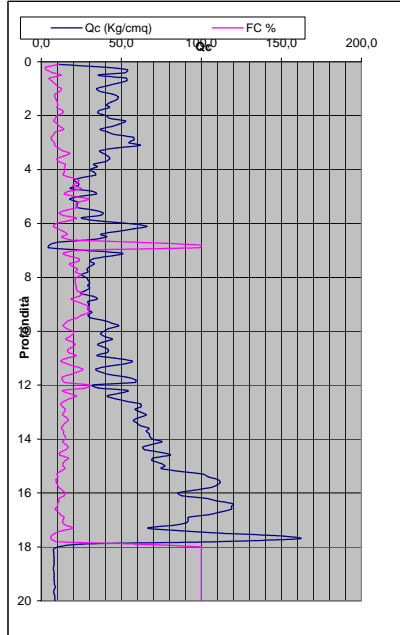
Table showing potential flow failure and no flow liquefaction criteria.

Main data table header with columns for Depth (m), Soil Name, and various geotechnical parameters like q, qc, fs, etc.

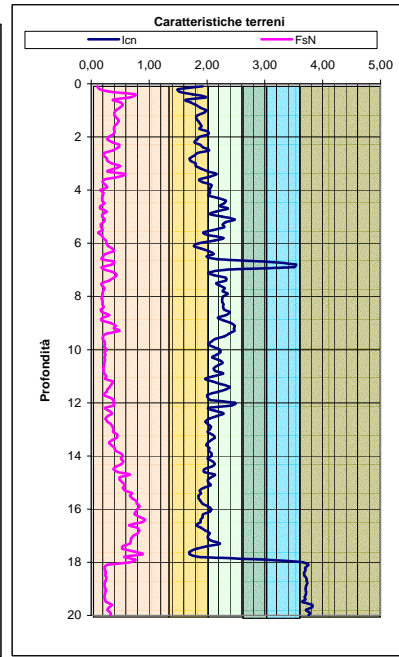
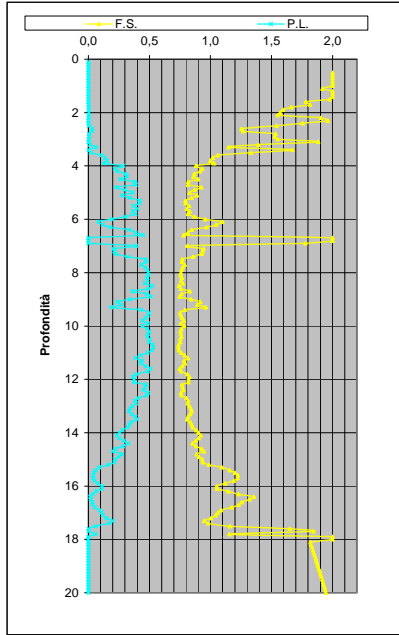
Main data table body containing numerical values for all parameters across multiple rows.

PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 | LDI = 3,839 | Stot = 0,356 (mt) | IPL = 9,73 | PL = 27,46 | LD = 0,00 (mt) | PG = 0,90 | SLiq = 11,0 (mt) | LSN = 41,1

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTU 2 - Il Canalino



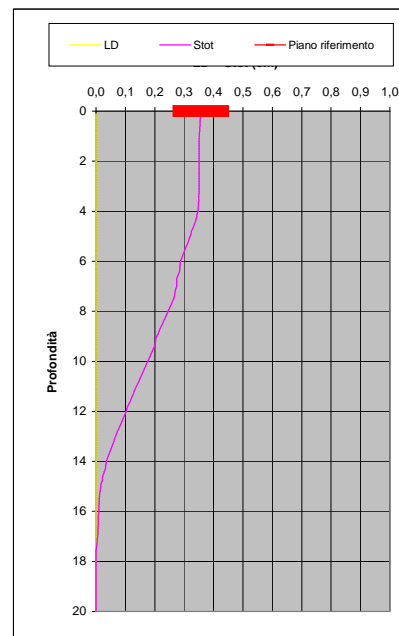
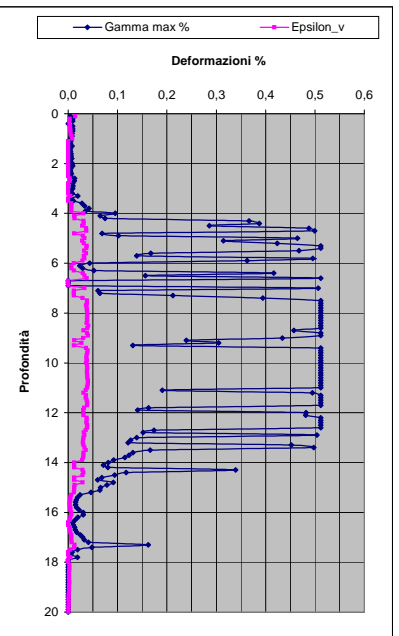
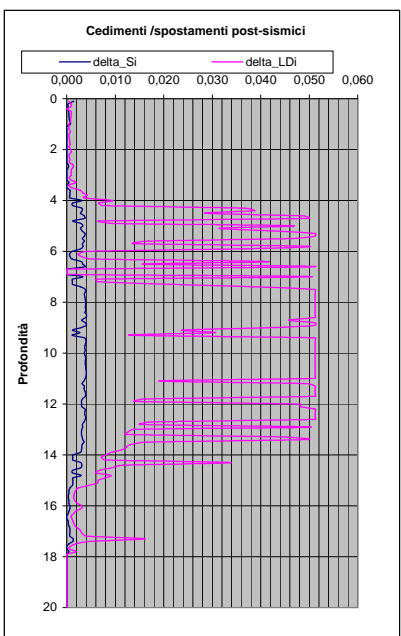
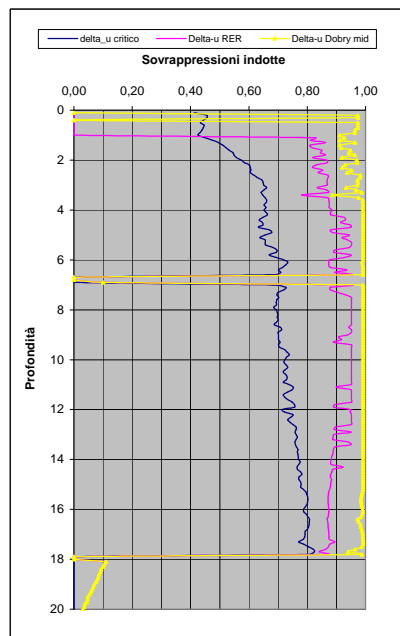
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc = Res. alla penetraz. (Kg/cmq)
- FC = Fine content - passante 0.074 mm (%)
- FsN = Attrito laterale (Kg/cmq)
- F = rapporto di frizione
- Qtn = parametro di resist. alla punta normal.
- Icn = Soil behaviour index normalized (ad)
- qc1N-cs = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH = fatt. correttivo per spessore strato (ad)
- Rd = stress reduction coefficient (ad)
- CN = fattore di normalizzazione per carico litostatico (ad)
- K σ = fatt. correttivo per sovraccarico-profondità (ad)
- K α = fatt. correttivo per sforzi di taglio (ad)
- MSF = magnitudo scaling factor (ad)
- F.S. = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR = Cyclic Stress ratio (ad)
- CRR = Cyclic Resistance Ratio (ad)
- P.L. = Probabilità di liquefazione (ad)
- IPL = Indice del potenziale di liquefazione (ad)
- γ_{max} = deformazione di taglio massima indotta dal sisma (%)
- ev = vertical reconsolidation strain
- Δs_i = cedimento -esimo dello strato (mt)
- Su = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot = Cedimento post-sismico totale (mt)
- LDI = Lateral Displacement Index (mt)
- Dr = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St = coefficiente di sensitività delle argille (ad)
- LSN = Liquefaction Severity Number (ad)



IPL = 9,73 PL = 27,46 LDI = 3,839 Stot = 0,356 (mt) LD = 0,00 (mt) SLiq = 11,00 (mt) LSN = 41,13 PG = 0,90

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
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40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

ALLEGATO N.2

**"VERIFICHE DI CALCOLO DEL POTENZIALE DI LIQUEFACIBILITÀ CON
MAGNITUDO MW = 6,14 "**



GEOPROGET

Studio di Geologia

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Riccione - 47838 - (RN) Tel/Fax 0541/606464
E-MAIL vannoni.fabio1960@libero.it
copicicarlo@libero.it

CPT-based liquefaction triggering analysis for a single sounding

Input parameters table including Peak ground accel (g), Earthquake magnitude (M), Water table depth (m), Average above water table (N160), Average below water table (N120), and Equipment.

Soil Classification table with columns for Zone No., Range of CPT Index Values, and Soil Name.

Behaviours table with columns for Soil Name, Sand-like, and various parameters like alpha (N1) and N160.

Computer constants table with columns for alpha (N1), N, Patm, and various constants like Q, T, B, Prof, L, Nk, and K.

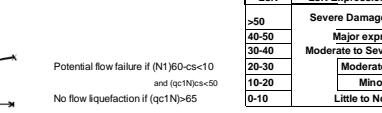
Probabilità e potenziale di liquefazione table with columns for Probabilità, Pot di Liq, and IPL.

Probabilità e suscettibilità di liquefazione table with columns for Probabilità, Suscettibilità, and Quasi certa.

PL Overall Probability table with columns for Risk lev., IPL, and PL.

Robertson & Wride, agg. 2009

PROVA "CPTE 1"



Header table for the sounding data with columns for Depth (m), q (kPa), F (kPa), Ic, N160, n, Kc, L, Layer, and various parameters like FC, Kh, CSR, Ks, Kc, CRR, Factor of Safety, MSF, Limiting shear strain, etc.

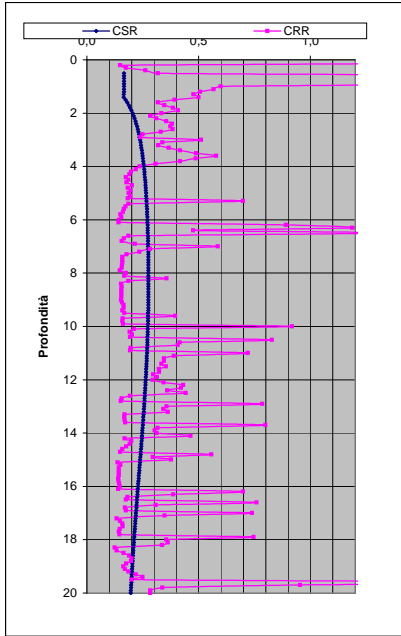
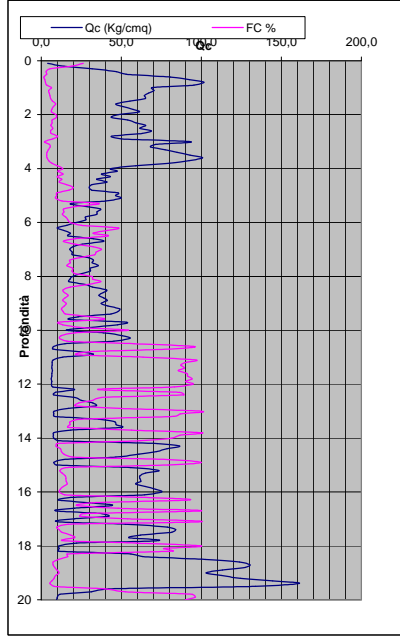
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0

LDI = 4,101 Stot = 0,343 (mt) IPL = 15,35

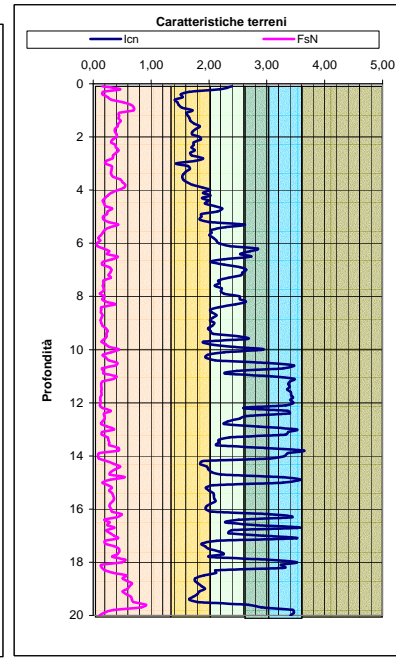
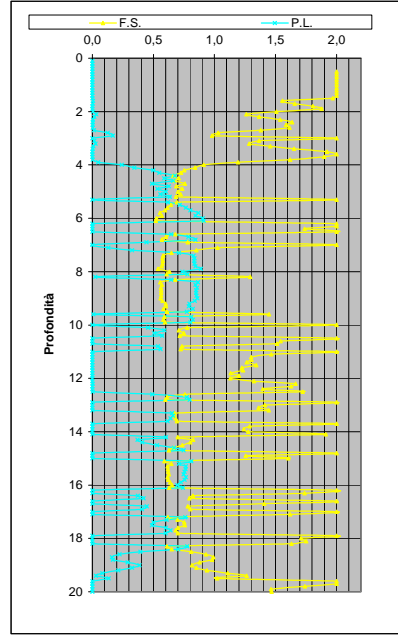
PL = 56,30 LD = 0,00 (mt) PG = 1,00 SLiq = 10,3 (mt) LSN = 38,4

Main sounding data table with 30 columns and 100 rows of data, including depth, cone resistance, friction, soil classification, and various calculated parameters.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 1



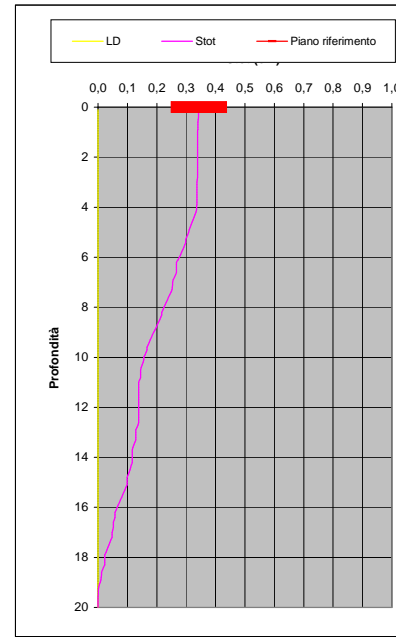
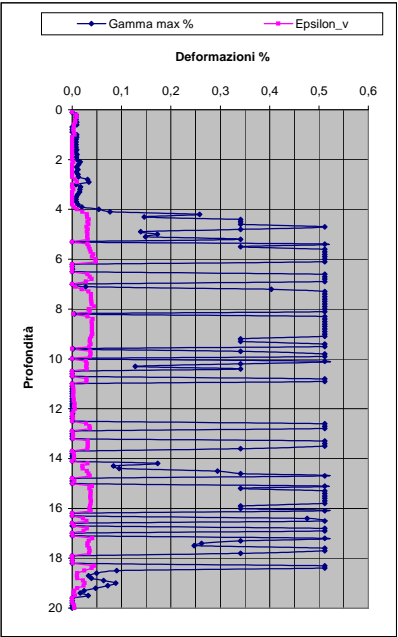
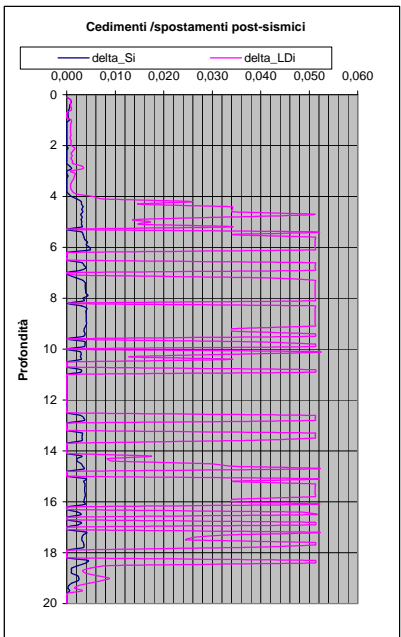
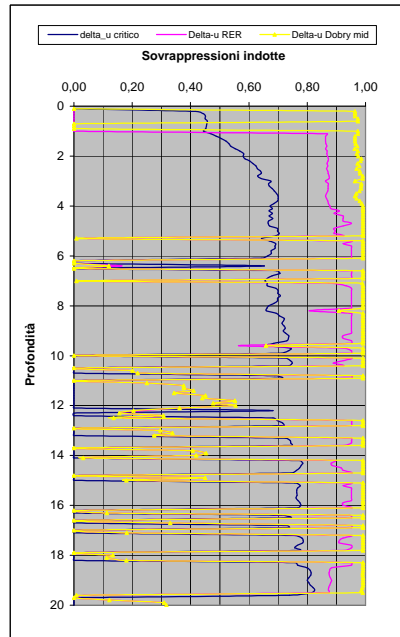
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento i-esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
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- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL= 15,35

PL= 56,30

LDI = 4,101 Stot = 0,343 (mt)

LD = 0,00 (mt)

SLiq = 10,30 (mt)

LSN = 38,42 PG= 1,00

CPT-based liquefaction triggering analysis for a single sounding

Enviromento: C Hill-H Plain-P Coast-C
Behaviours: e Sand like-s

Computer constants:
ms (Blaise) ("B" 2007 - "Cefin" 2004 - "NCEER" - "Blaise")

Input parameter:
Peak ground accel (g) = 0.213
Earthquake magnitude, M = 6.14
Water table depth (m) = 1.13
Average above water table (N60)3 = 18
Average below water table (N60)3 = 20

Soil Classification: Zon. No. 3 Range of CPT Index / Values
Sand-Clay-SC
Building (VM)
Sedimentary environment

Probabilità e potenziale di liquefazione
Probabilità e suscettibilità di liquefazione
PL Overall Probability

PL Overall Probability
Risk lev. IPL
Very High IPL
Low IPL

Robertson & Wride, agg. 2009

PROVA "CPTE 2"

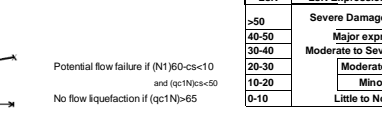
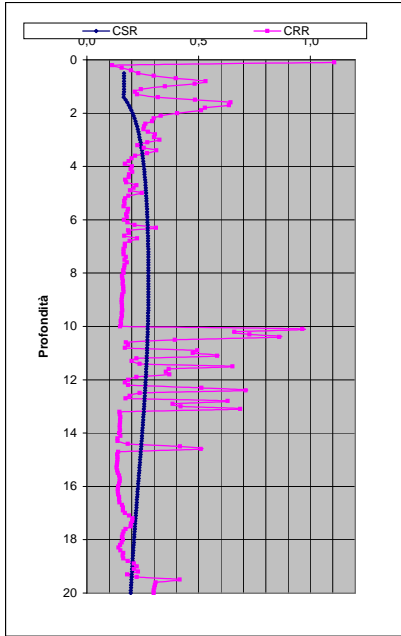
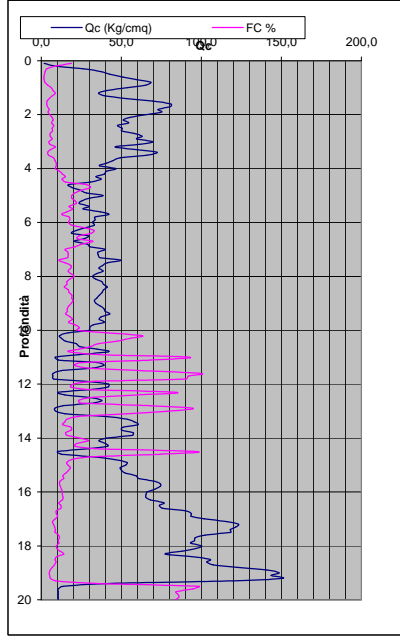


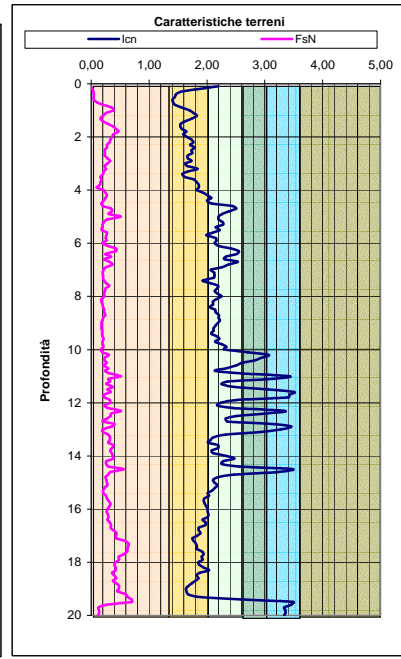
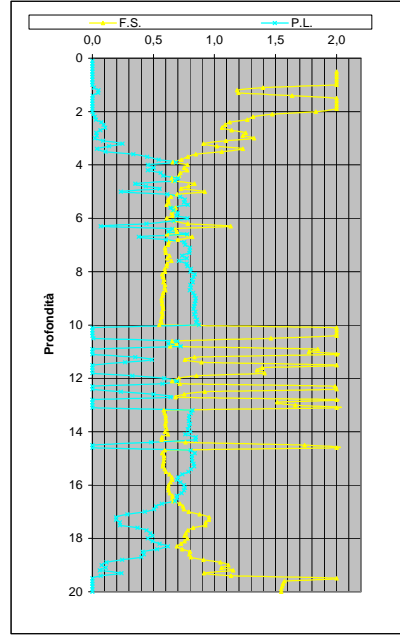
Table with 30 columns: Depth (m), qc(N/m^2), fs(N/m^2), etc. Summary values: LDI = 5,441; Stot = 0,457; IPL = 19,61; PL = 76,54; LD = 0,00; PG = 1,00; SLiq = 13,4; LSN = 51,2

Main data table with 30 columns for depth and various soil parameters. Values are color-coded: green for high values, yellow for medium, red for low. Includes a 'PROFONDITA' DI CALCOLO' row at 0,0 m.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT2



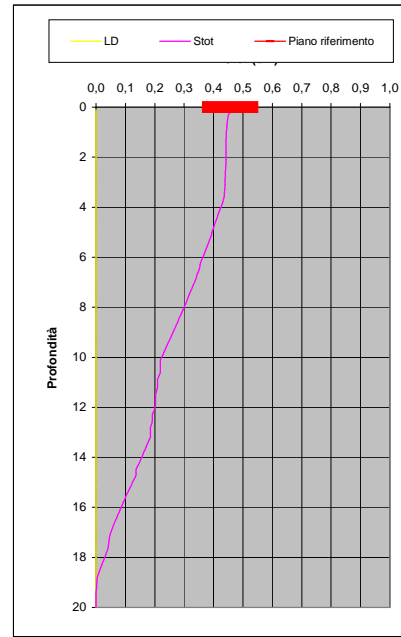
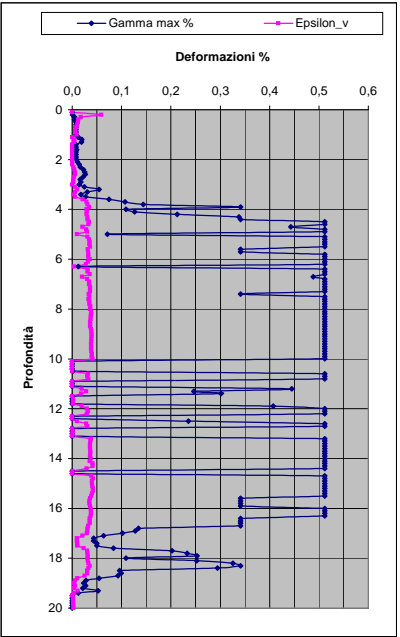
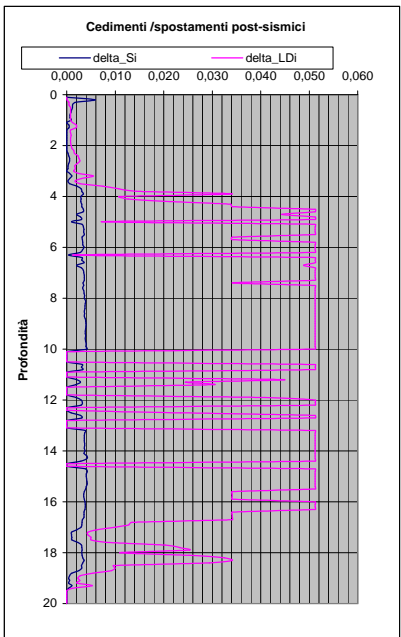
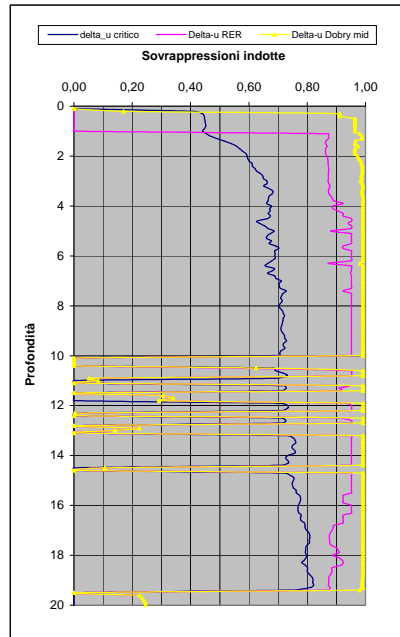
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
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LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
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- ξ = parametro di stato
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- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
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$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL= 19,61 PL= 76,54 LDI = 5,441 Stot = 0,457 (mt) LD = 0,00 (mt) SLiq = 13,40 (mt) LSN = 51,16 PG= 1,00

CPT-based liquefaction triggering analysis for a single sounding

Enviroments: C Hill-H Plain-P Coast-C Behaviours: Sand like-S

Computer constants: no. n: 10, 32; MSF NEER: 1; Patm: 101,32; cov=30-35%; K0: 1; IP COR: 1.2

Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTE 3"



DISPLACEMENT PARAMETERS: Lateral displacement, Vertical displacement, etc.

Potential flow failure if (N1)q0-c<10 and (q1)N1-q0>50

No flow liquefaction if (q1)N1<65

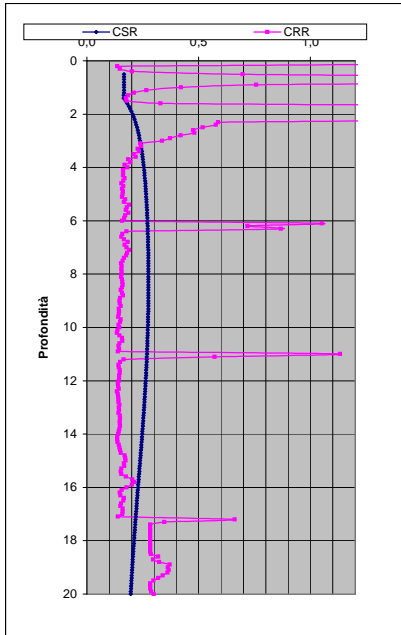
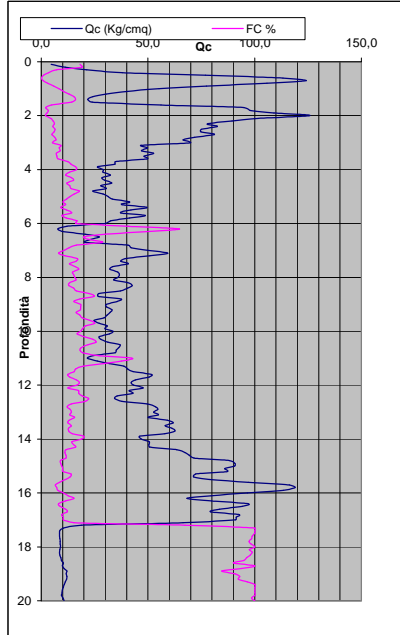
Table with columns for Soil Classification, Zone No., Range of CPT Index / Values, and various parameters like q1, qn, F, Ic, etc.

Table with columns for Depth (m), q1, qn, F, Ic, N1(60), n, Kc, Layer, etc.

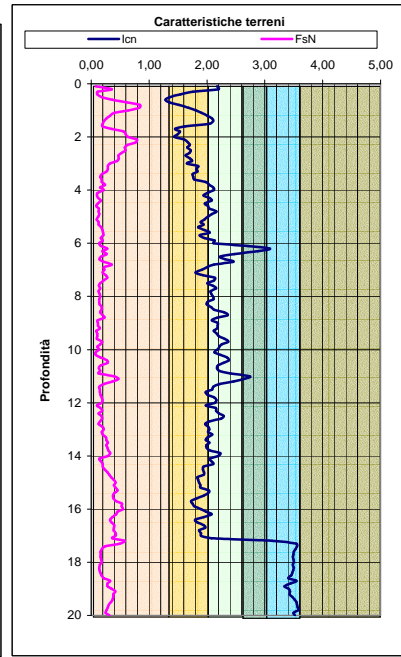
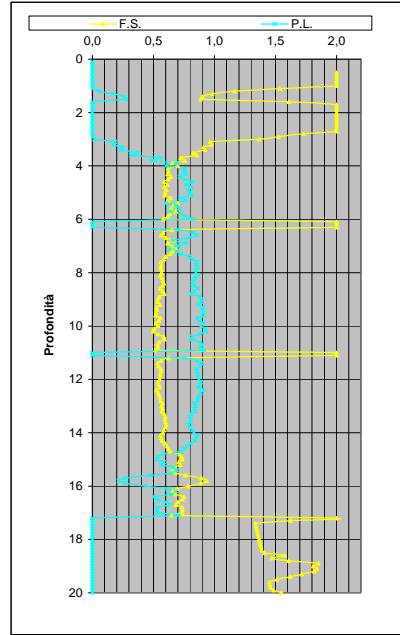
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0; LDI = 5,638; Stot = 0,508 (mt); IPL = 25,15; PL = 91,62; LD = 0,00 (mt); PG = 1,00; SLiq = 13,9 (mt); LSN = 63,1

Main data table with columns for Depth (m), q1, qn, F, Ic, N1(60), n, Kc, Layer, and various soil parameters and calculated values.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT 3



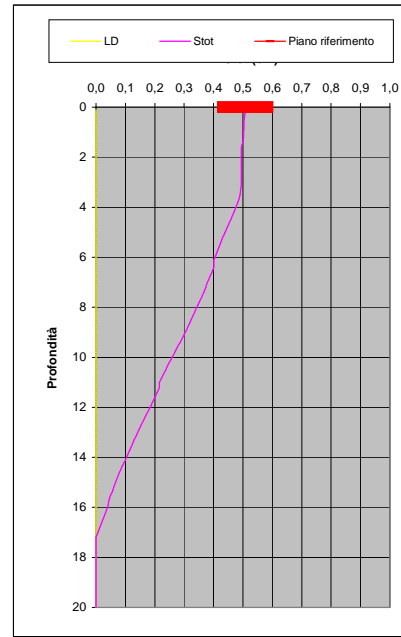
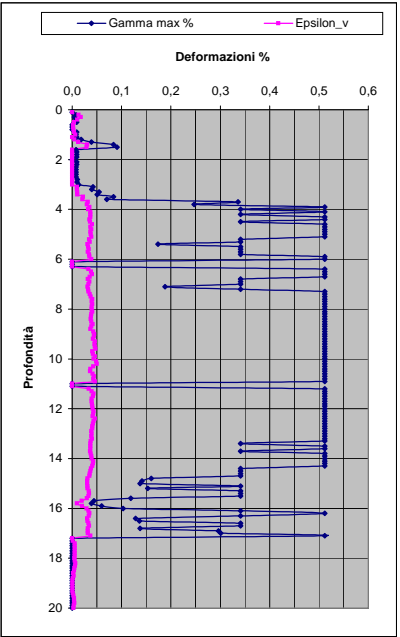
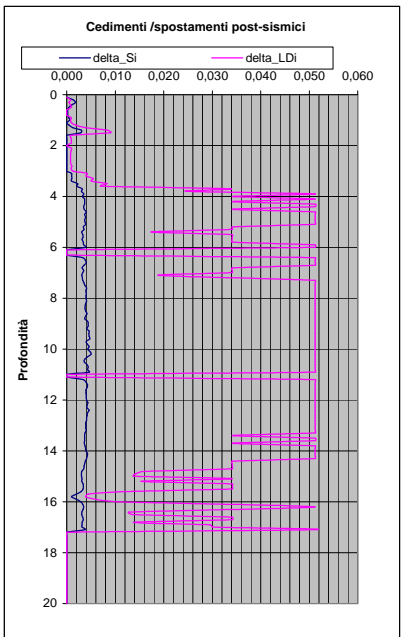
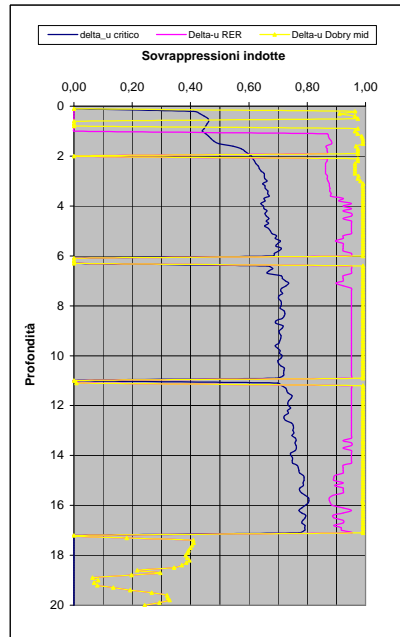
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LEGENDA

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- ev** = vertical reconsolidation strain
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LSN Range	Expected ground surface damage
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$P_G \leq 0.1$	extremely low to none

IPL = 25,15 PL = 91,62 LDI = 5,638 Stot = 0,508 (mt) LD = 0,00 (mt) SLiq = 13,90 (mt) LSN = 63,12 PG = 1,00

CPT-based liquefaction triggering analysis for a single sounding

Enviromenti: C Hill-H Plain-P Coast-C Behaviours: Sand like-S

Computer constants: no. n: 25 (MSF NCEER) Patm = 101.32 (cov=0.35-35%)

Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTE 4"



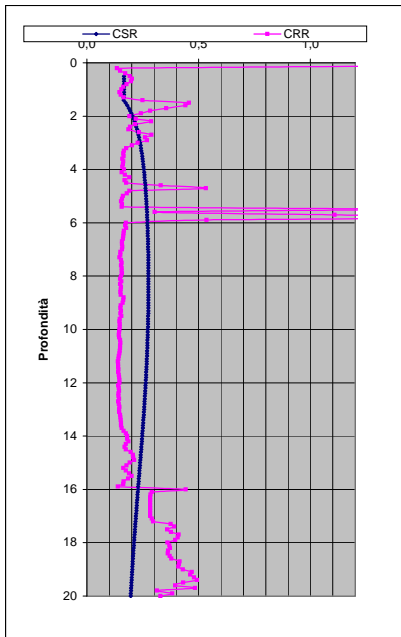
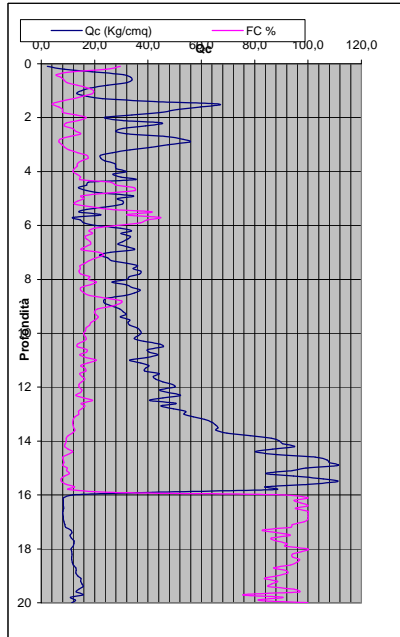
Potential flow failure if (N) < 60-cv<10 and (q) < 10-cv<50 No flow liquefaction if (q) < 10-cv<65

Summary table with columns for input parameters (Peak ground accel, Water table depth, etc.), soil classification, and various probability and liquefaction indices.

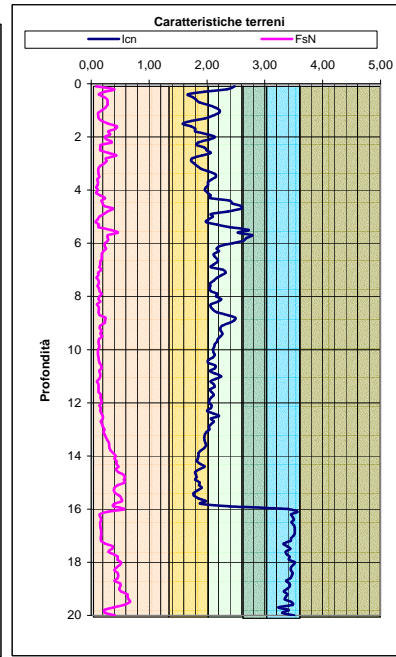
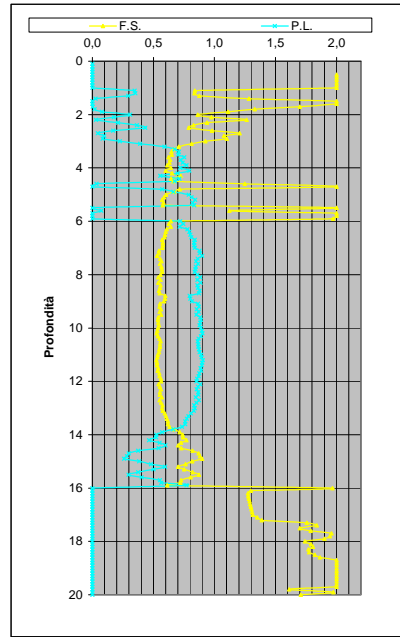
Table with columns for Depth (m), q (kPa), qc (kPa), F, Ic, N60, n, Kc, Layer, and various liquefaction indices like PL, ALDI, etc.

Main data table containing 101 rows of sounding data, including depth, blow counts, and calculated liquefaction parameters.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTE 4



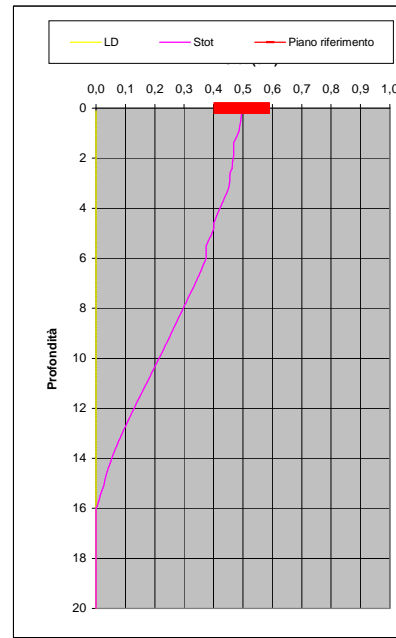
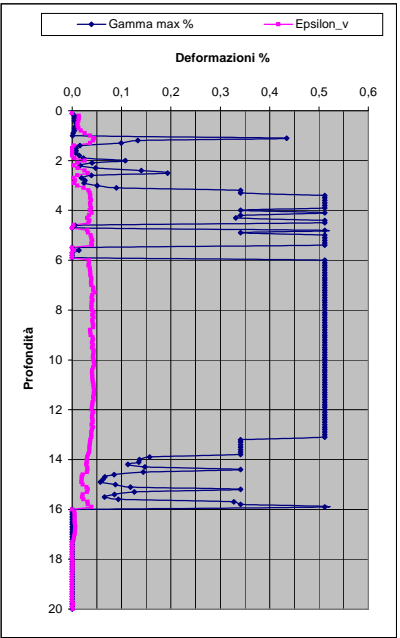
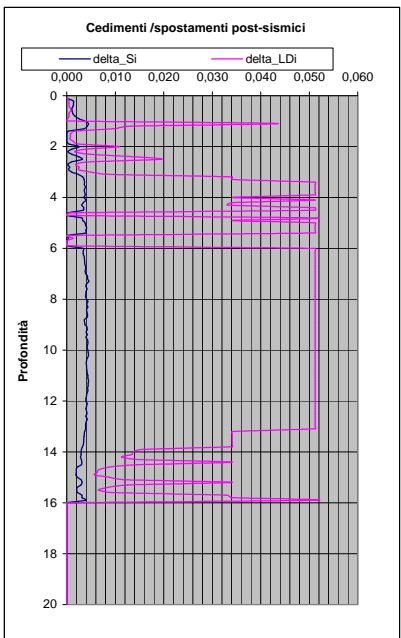
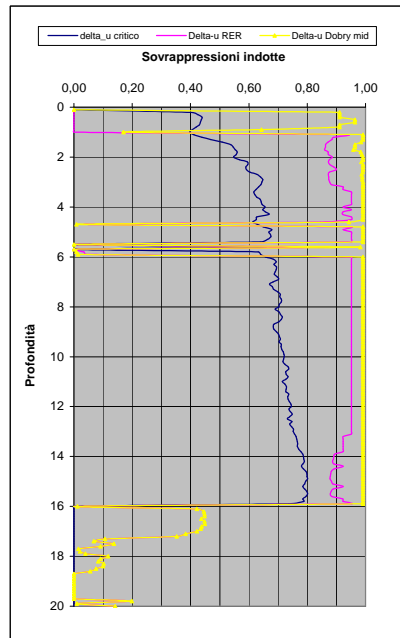
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Probability	Description of the risk of liquefaction-induced ground failure
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$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL = 25,74

PL = 92,55

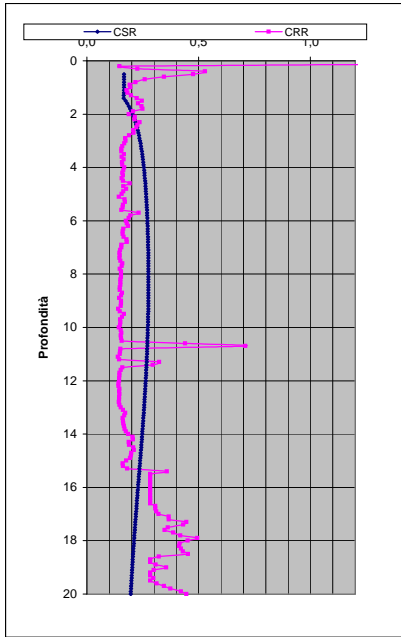
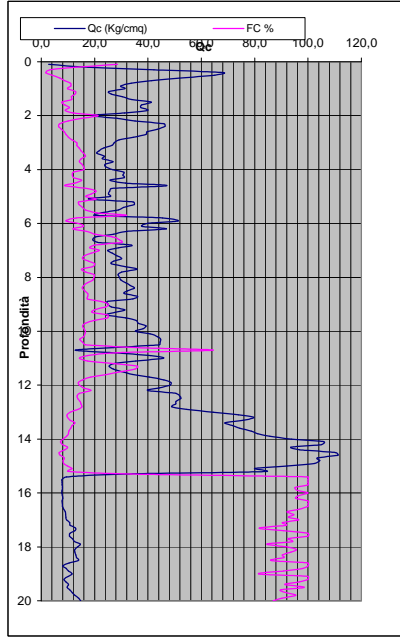
LDI = 5,410 Stot = 0,496 (mt)

LD = 0,00 (mt)

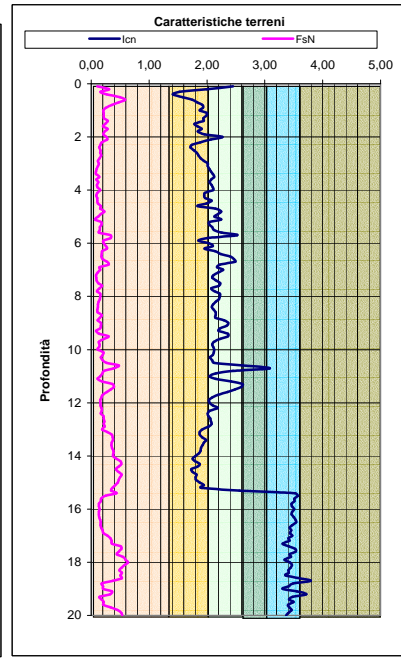
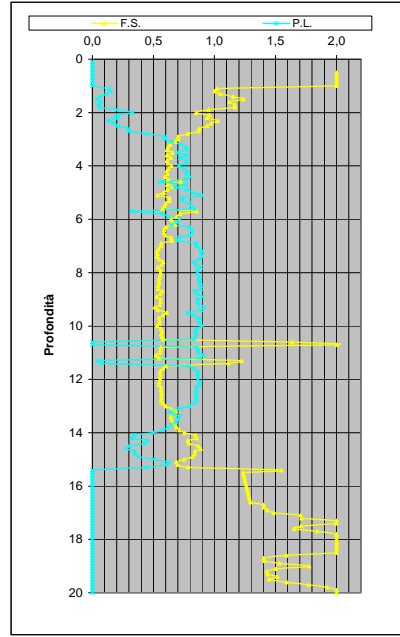
SLiq = 13,20 (mt)

LSN = 73,54 PG = 1,00

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT5



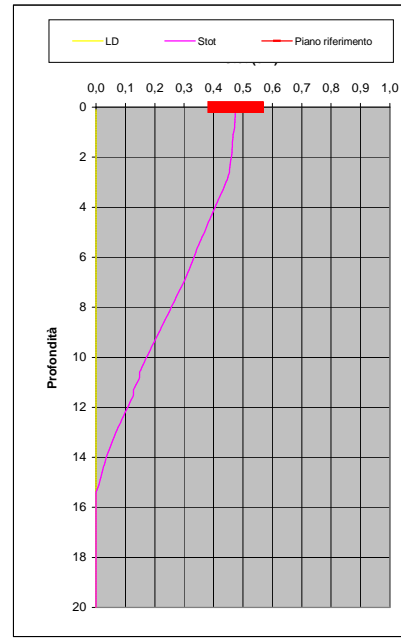
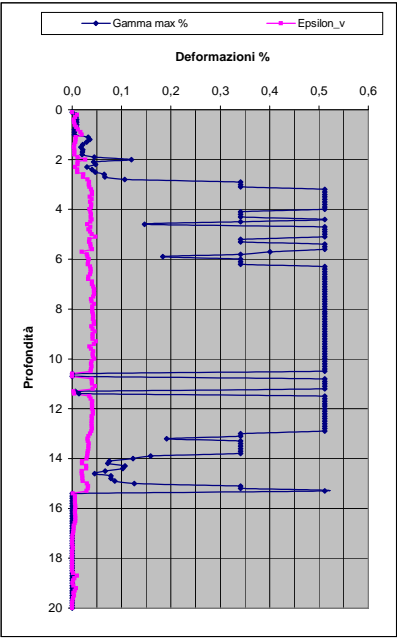
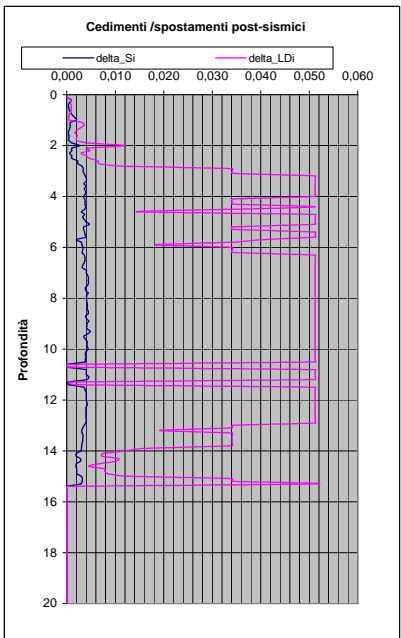
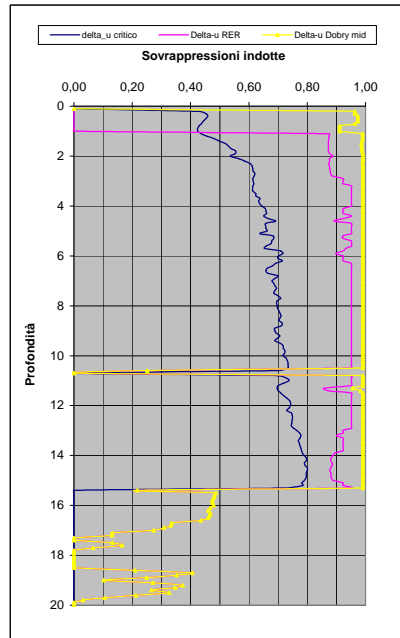
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento -esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL = 26,59

PL = 93,73

LDI = 5,276 Stot = 0,475 (mt)

LD = 0,00 (mt)

SLiq = 13,00 (mt)

LSN = 71,26 PG = 1,00

CPT-based liquefaction triggering analysis for a single sounding

Enviroments: C Hill-H Plain-P Coast-C Behaviours: Sand like-S

Computer constants: no. n=10, N=101.32, Patm=101.32, cov=0.35-35%, kDR=350, MSF=NECEER, alpha(N)=1, beta=1.2, gamma=1.2, delta=1.2, epsilon=1.2, zeta=1.2, eta=1.2, theta=1.2, iota=1.2, kappa=1.2, lambda=1.2, mu=1.2, nu=1.2, xi=1.2, omicron=1.2, pi=1.2, rho=1.2, sigma=1.2, tau=1.2, upsilon=1.2, phi=1.2, chi=1.2, psi=1.2, omega=1.2, A=1.2, B=1.2, C=1.2, D=1.2, E=1.2, F=1.2, G=1.2, H=1.2, I=1.2, J=1.2, K=1.2, L=1.2, M=1.2, N=1.2, O=1.2, P=1.2, Q=1.2, R=1.2, S=1.2, T=1.2, U=1.2, V=1.2, W=1.2, X=1.2, Y=1.2, Z=1.2

Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTE 6"



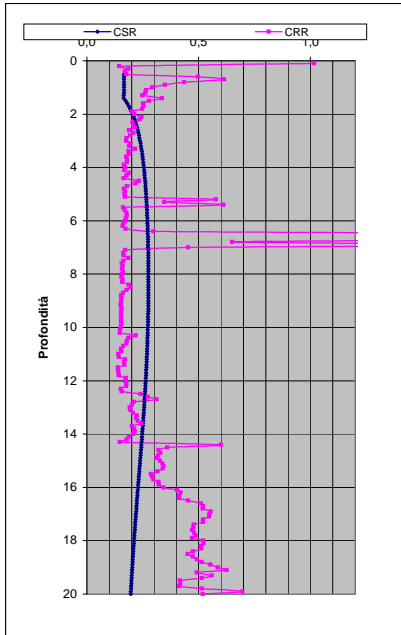
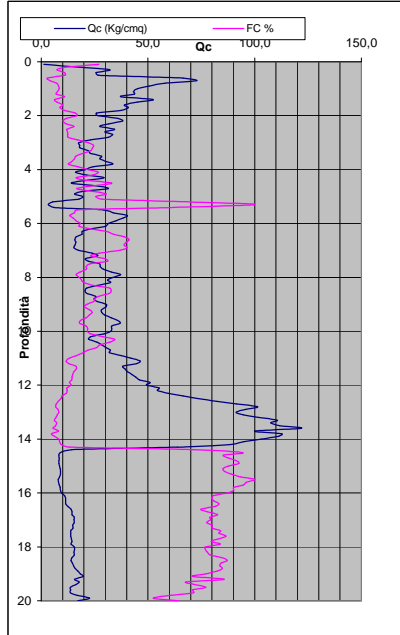
Severe Damage, Moderate to Severe, Minor, Little to No

Table with columns for input parameters (Peak ground accel, Earthquake magnitude, Water table depth, etc.), soil classification, and various geotechnical parameters (Q1, Qtn, F, Ic, etc.).

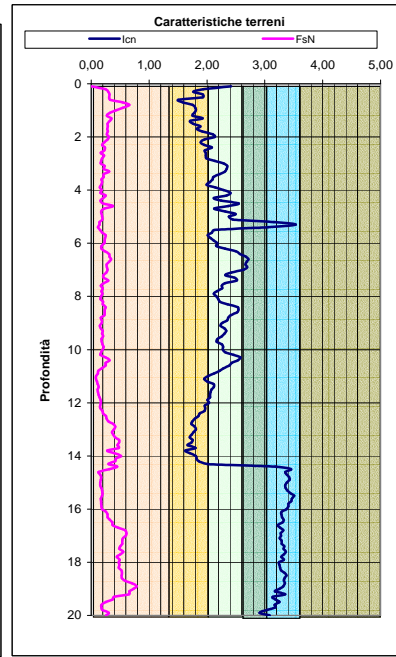
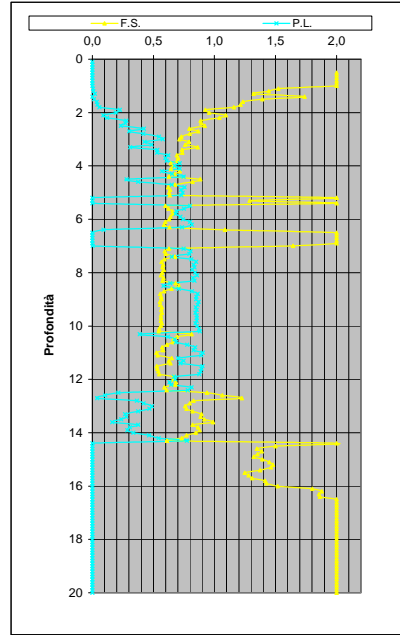
Main data table with columns for Depth (m), q (kPa), qc (kPa), F, Ic, N60, n, Kc, Layer, etc., containing numerical data for each sounding depth.

PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 LDI = 4,366 Stot = 0,368 (mt) IPL = 20,64 PL = 80,33 LD = 0,00 (mt) PG = 1,00 SLiq = 11,1 (mt) LSN = 55,8

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT6



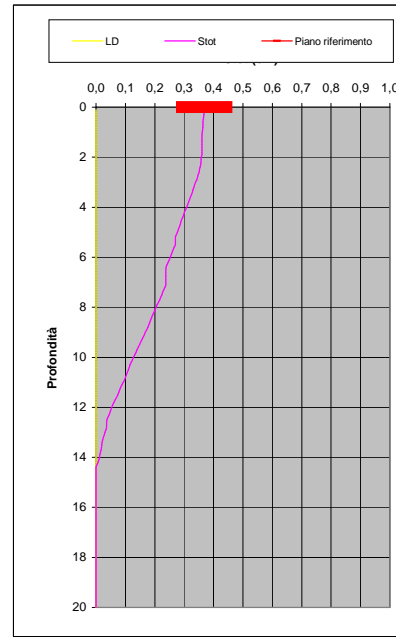
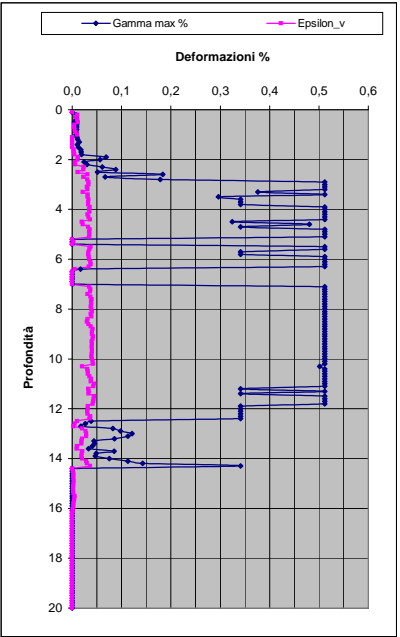
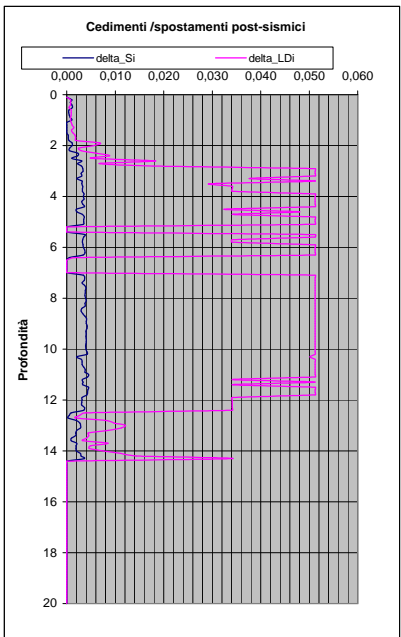
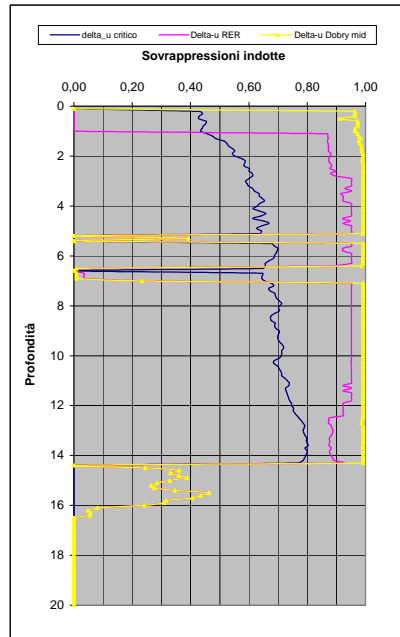
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- ymax** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i = cedimento -esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



IPL= 20,64 PL= 80,33 LDI = 4,366 Stot = 0,368 (mt) LD = 0,00 (mt) SLiq = 11,10 (mt) LSN = 55,80 PG= 1,00

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction as surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

CPT-based liquefaction triggering analysis for a single sounding

Environmental parameters, soil classification, and various probability and potentiality charts for liquefaction analysis.

Table with columns for Depth (m), Soil Classification, and various parameters like q_v, q_u, F, I_c, etc.

Main data table with columns for Depth (m), Soil Classification, and various parameters like q_v, q_u, F, I_c, etc. Includes a large section of numerical data.

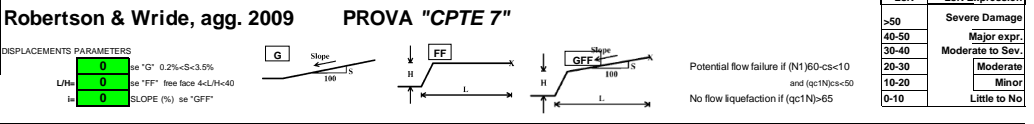
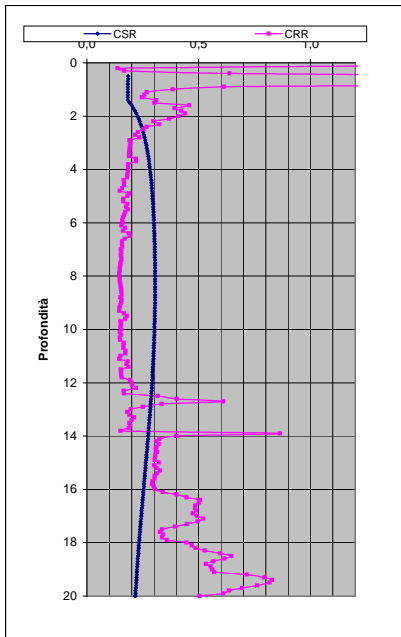
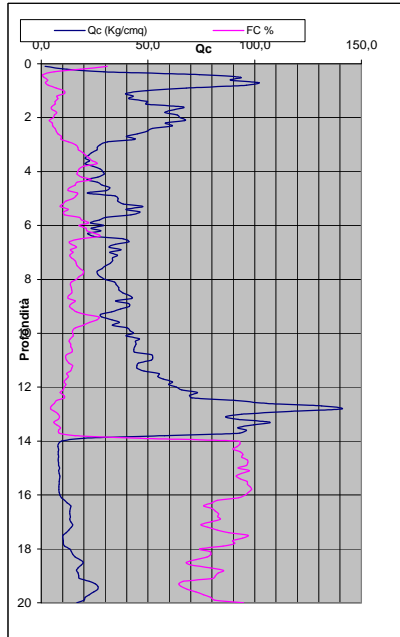


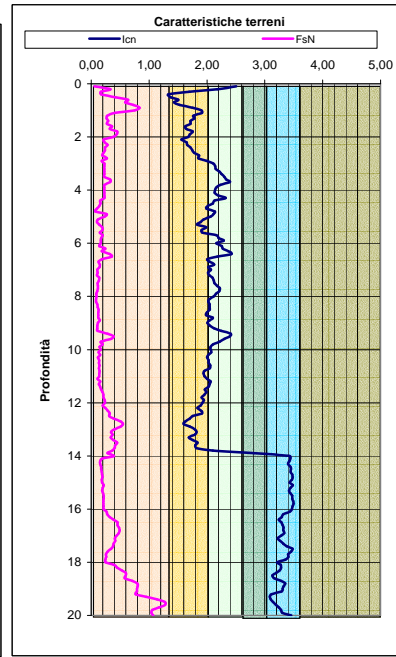
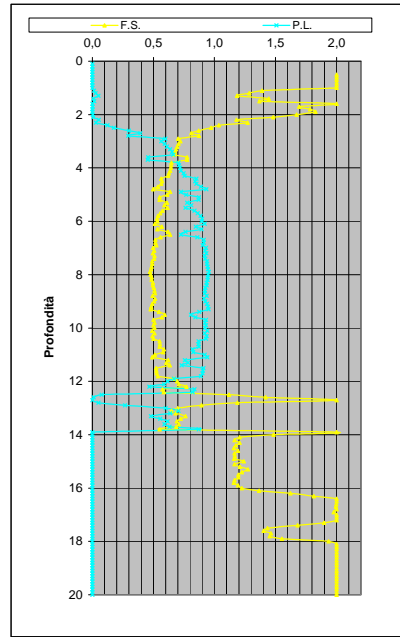
Table with columns for L₅₀, L₇₅, L₁₀₀, L₁₅₀, and L₂₀₀ values.

Table with columns for L₅₀, L₇₅, L₁₀₀, L₁₅₀, and L₂₀₀ values, corresponding to the main data table.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTE 7



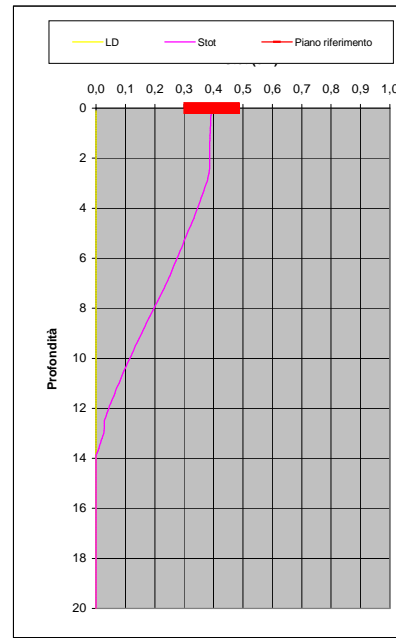
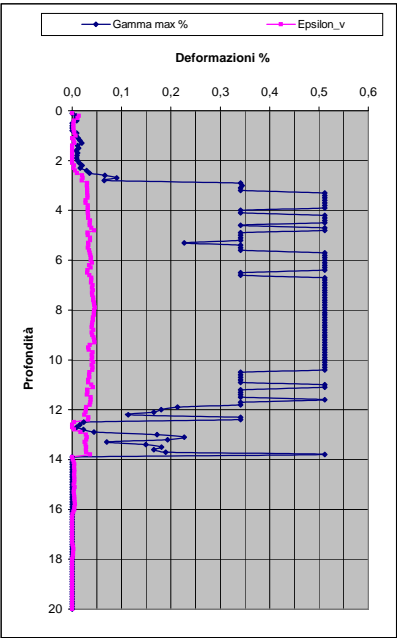
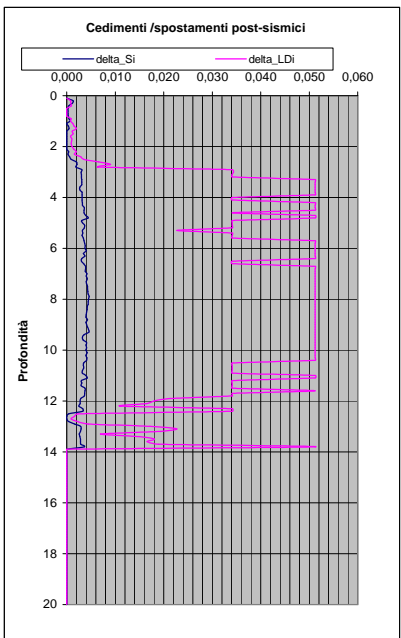
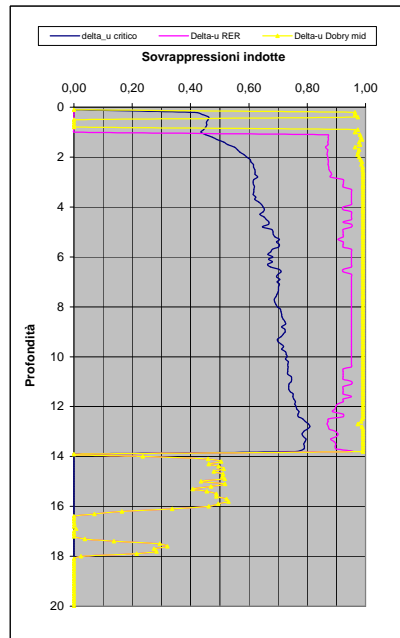
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
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- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
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- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
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- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento i-esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



IPL = 26,85

PL = 94,06

LDI = 4,501 Stot = 0,393 (mt)

LD = 0,00 (mt)

SLiq = 11,00 (mt)

LSN = 58,35 PG = 1,00

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
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* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

CPT-based liquefaction triggering analysis for a single sounding

Environment: Hill-H Plain-P Coast-C
Behaviours: Sand like-S

Computer constants: α (N) = 1.0, N = 101.32, Patm = 101.32, cov=0.35-35%, MSF NCEER = 1.0, MSF NCEER = 1.0, MSF NCEER = 1.0

Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTE 8"



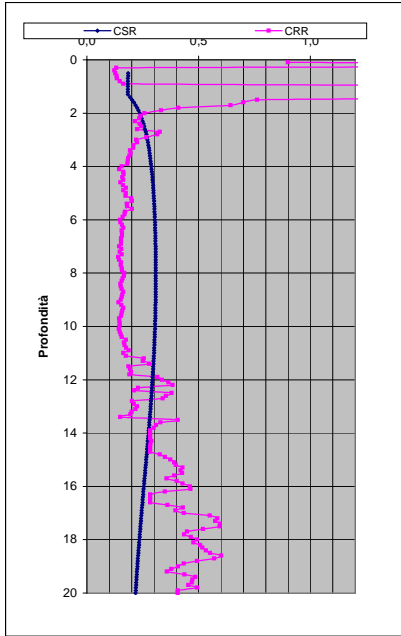
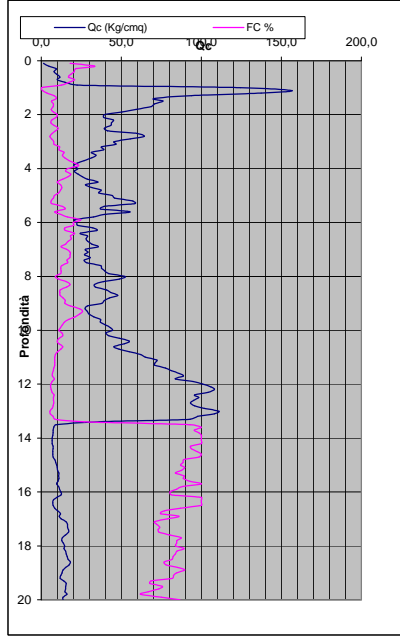
Table with 2 columns: LsN, LsN Expression. Values range from >50 to 0-10.

Main data table with columns: Depth (m), q (kPa), qc (kPa), fs (kPa), etc. Includes various parameters and calculated values.

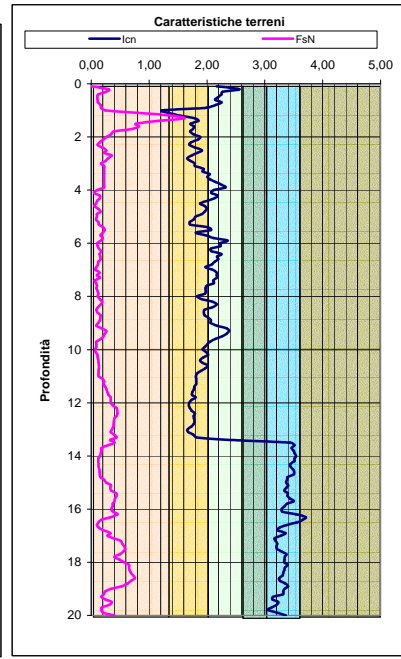
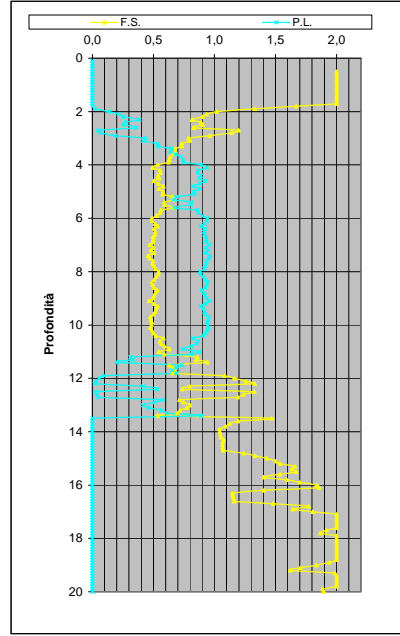
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 | LDI = 3,855 | Stot = 0,392 (mt) | IPL = 25,90 | PL = 92,79 | LD = 0,00 (mt) | PG = 1,00 | SLiq = 10,5 (mt) | LSN = 56,6

Main data table containing 100 rows of soil sounding data, including depth, cone resistance, sleeve friction, and various calculated parameters.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 8



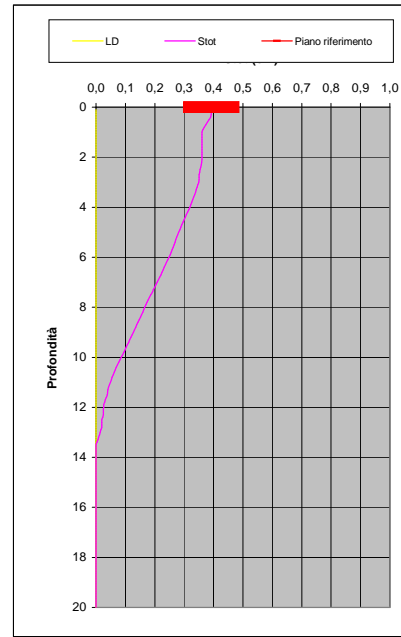
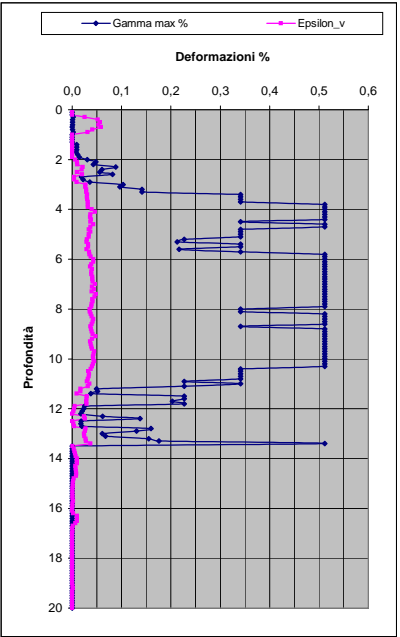
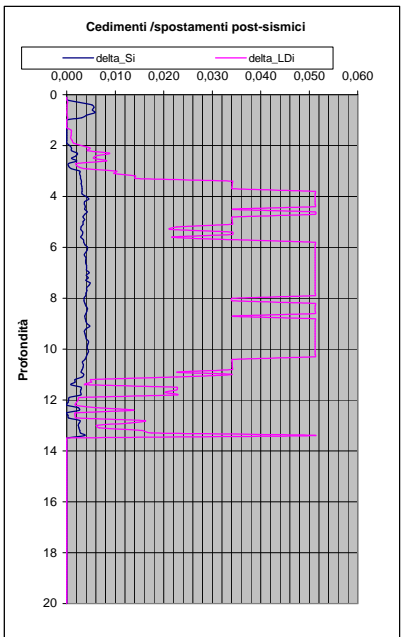
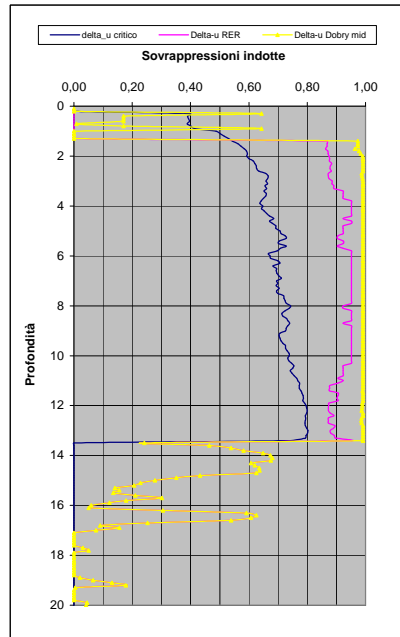
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento i-esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL= 25,90 PL= 92,79 LDI = 3,855 Stot = 0,392 (mt) LD = 0,00 (mt) SLiq = 10,50 (mt) LSN = 56,55 PG= 1,00

CPT-based liquefaction triggering analysis for a single sounding

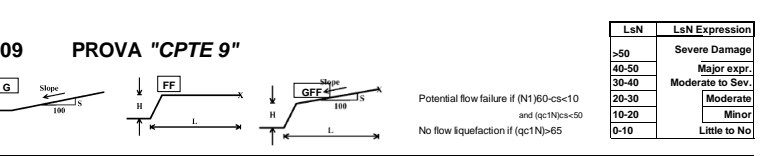
Input parameter table including Soil Classification, Peak ground accel (g), Earthquake magnitude (M), Water table depth (m), Average above water table (N60)30, Average below water table (N60)30, and Equipment.

Environmental and Behavioural parameters table including Soil Classification, Behaviours, Sand-like-SC, Building (V)M, Sedimentary environment, and CPT-CPTE=1.

Computer constants table including alpha (N) = 1, Patm = 101.32, MSF = 0.9357, and various stress and strain parameters.

Probability and potential of liquefaction table with columns for Probabilità, Pot di Liq, and IPL.

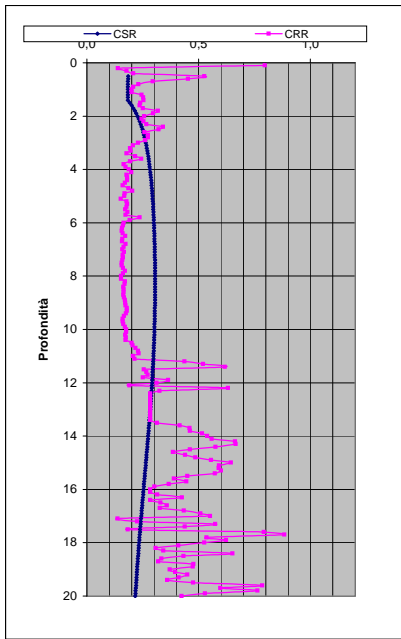
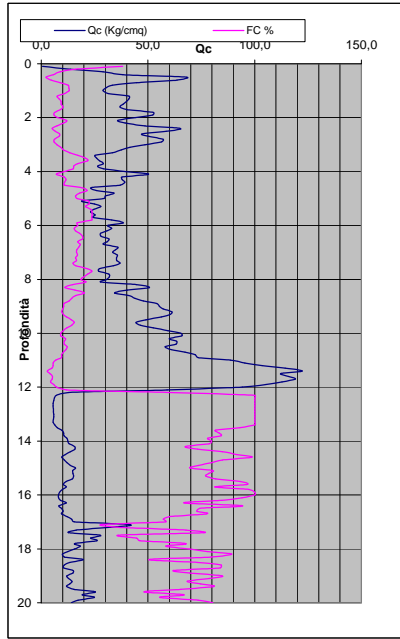
Probability and susceptibility of liquefaction table with columns for Probabilità, Suscettibilità, and FS=1.2.



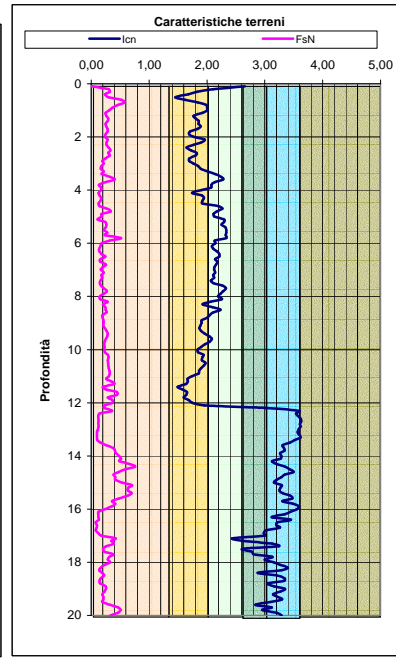
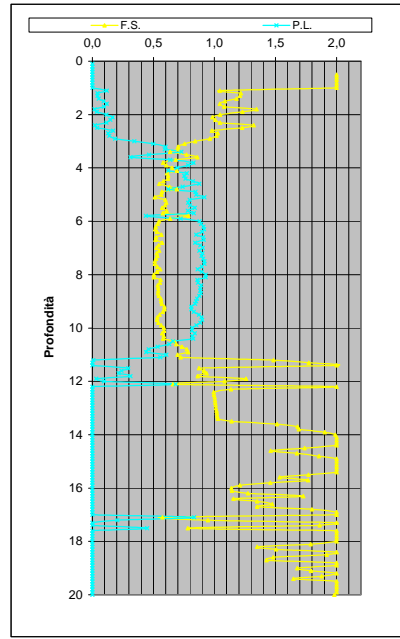
Main header table for the liquefaction analysis, including columns for Depth (m), q (kPa), qc (kPa), F, Ic, IcN2, N1(60), n, Kc, Layer, and various probability and safety factors.

Main data table containing 101 rows of liquefaction analysis results, including depth, soil parameters, and calculated safety factors.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 9



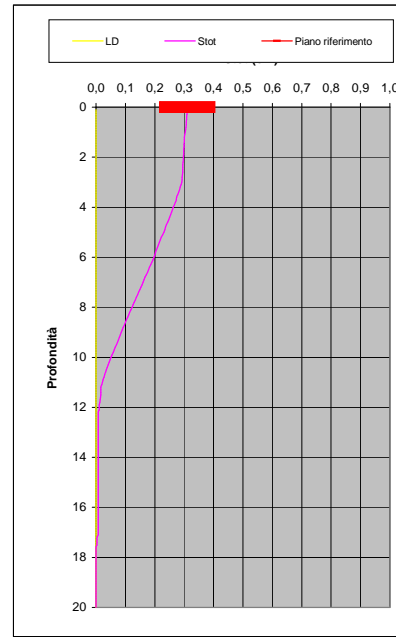
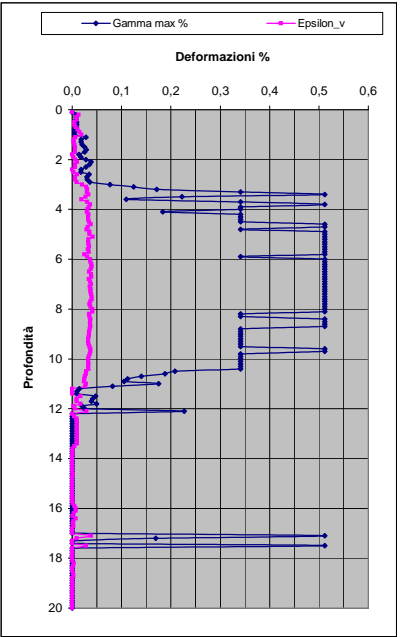
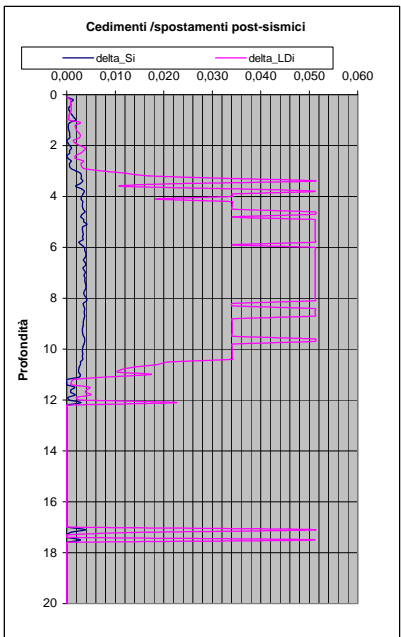
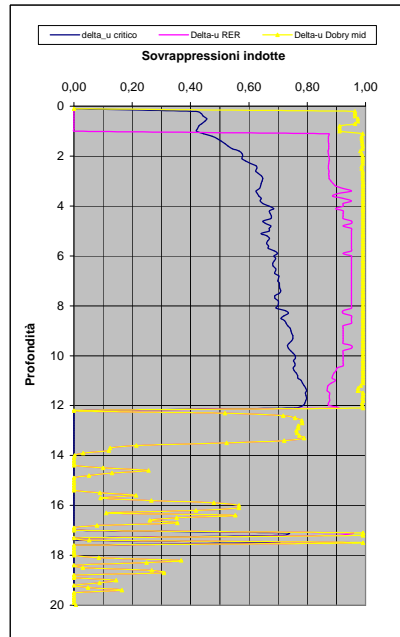
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

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- Argille - argilla/argilla limosa
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- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

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- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
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- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
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- Δs_i** = cedimento -esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
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- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
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- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
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- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
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>50	Severe damage, extensive evidence of liquefaction as surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
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$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL = 21,73 PL = 83,82

LDI = 3,484 Stot = 0,311 (mt)

LD = 0,00 (mt)

SLiq = 9,30 (mt)

LSN = 50,30 PG = 1,00

CPT-based liquefaction triggering analysis for a single sounding

Enviromenti: C Hill-H Plain-P Coast-C Behaviours: Sand like-s

Computer constants: no. n: 25.0 (B' 2007 - "Cefin" 2004 - "NCEER" - "Blake")

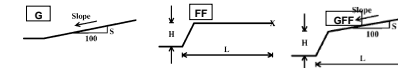
Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTe 10"



Potential flow failure if (N1)60<=C10 and (q1N)65 No flow liquefaction if (q1N)65

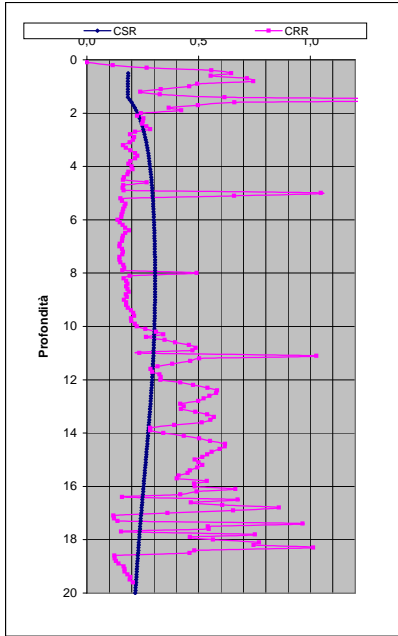
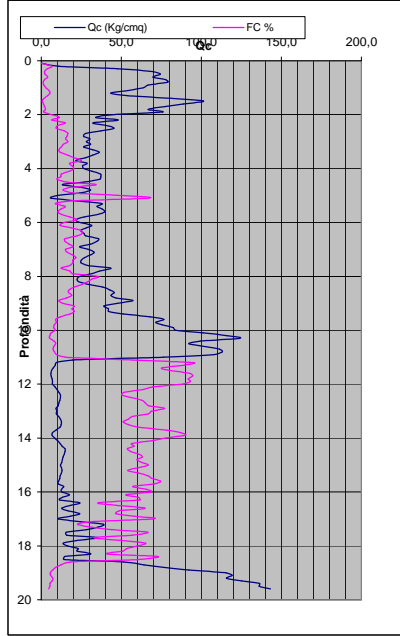
Table with 2 columns: LsN, LsN Expression. Values range from >=50 to <=10.

Main data table with columns for Depth (m), Soil Classification, Parameters (qc, q1N, etc.), and various probability and liquefaction indices.

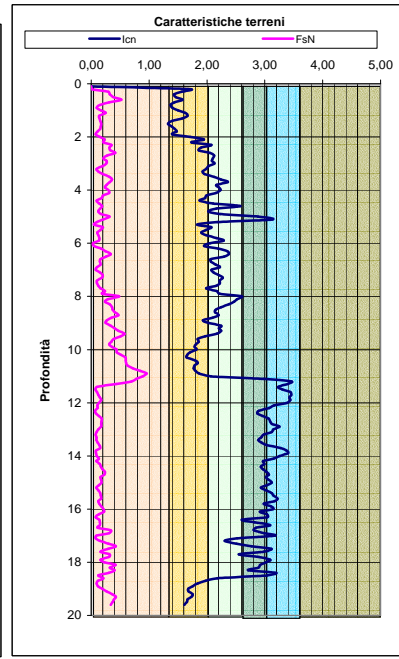
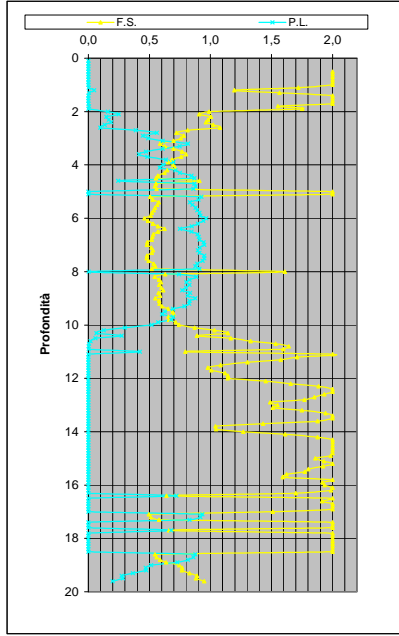
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 LDI = 3,474 Stot = 0,319 (mt) IPL = 19,85 PL = 77,48 LD = 0,00 (mt) PG = #NUM! SLiq = 9,4 (mt) LSN = 49,2

Main data table containing 100 rows of soil sounding data, including depth, soil type, and various geotechnical parameters.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 10



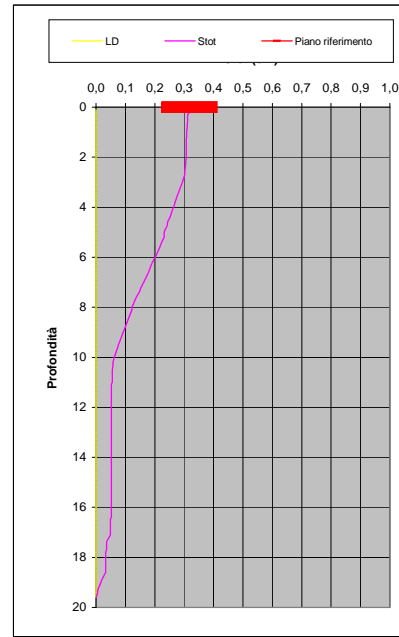
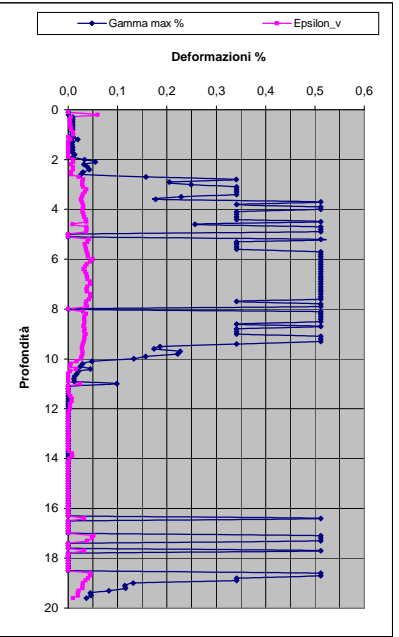
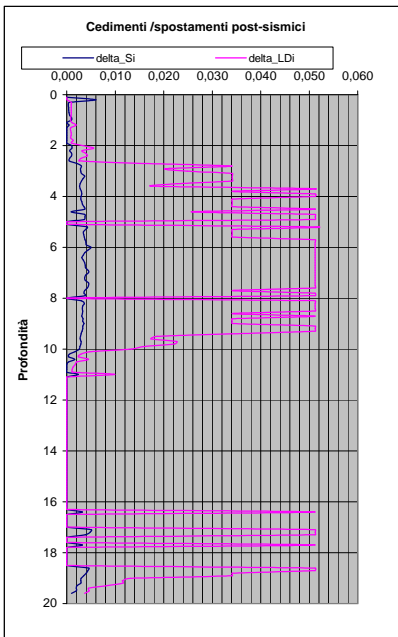
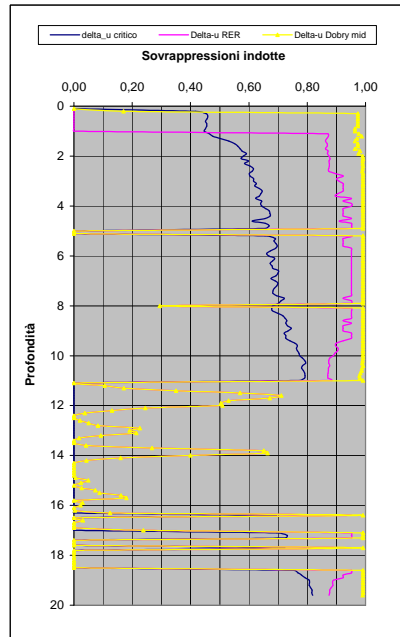
Soil Classification	Zone No.*	Range of CPT Index I_c Values
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- Miscela di sabbie - sabbia limosa/limo sabbioso
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LEGENDA

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- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
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- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
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$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL= 19,85 PL= 77,48 LDI = 3,474 Stot = 0,319 (mt) LD = 0,00 (mt) SLiq = 9,40 (mt) LSN = 49,18 PG= #NUM!

CPT-based liquefaction triggering analysis for a single sounding

Enviromenti

C

Behaviours

Sand like-S

Computer constants:

no. n=10, B=200, C=10, D=10, E=10, F=10, G=10, H=10, I=10, J=10, K=10, L=10, M=10, N=10, O=10, P=10, Q=10, R=10, S=10, T=10, U=10, V=10, W=10, X=10, Y=10, Z=10

Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Risk lev. IPL IPL IPL

Robertson & Wride, agg. 2009

PROVA "CPTE 11"

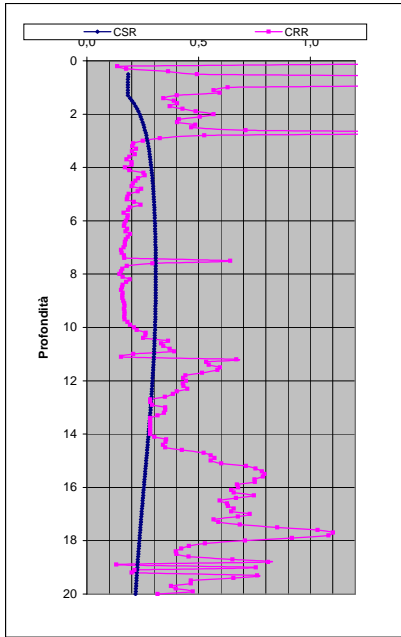
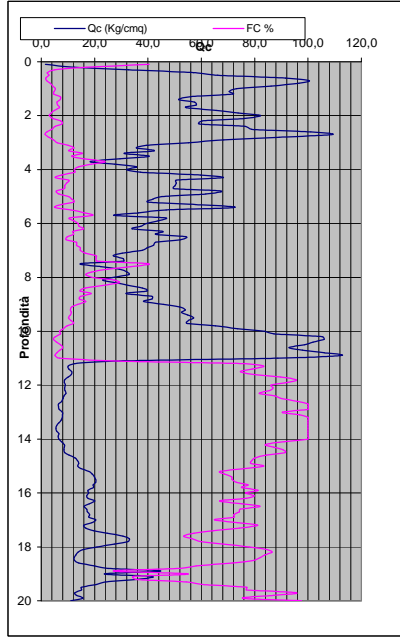


Table with columns for input parameters (Peak ground accel, Earthquake magnitude, Water table depth, etc.), soil classification, and various probability and liquefaction indices.

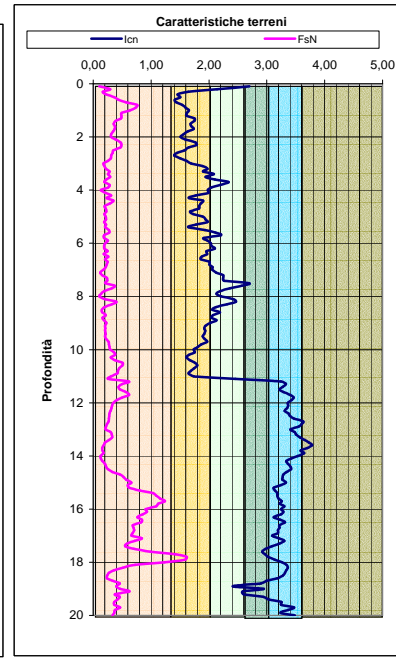
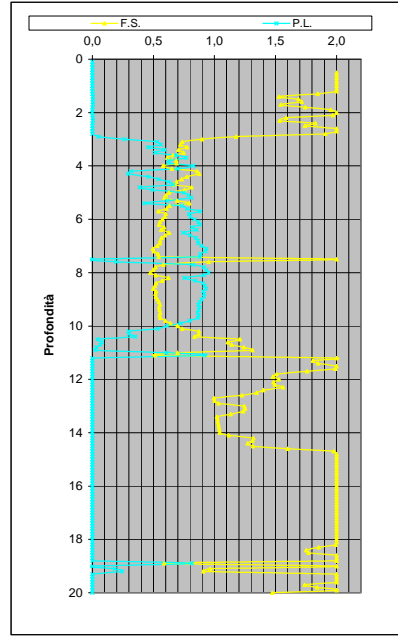
Table with columns for depth (m), q (kPa), qc (kPa), fs (kPa), and various soil strength and liquefaction parameters.

Main data table with columns for depth (m), q (kPa), qc (kPa), fs (kPa), and various soil strength and liquefaction parameters for each sounding.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 11



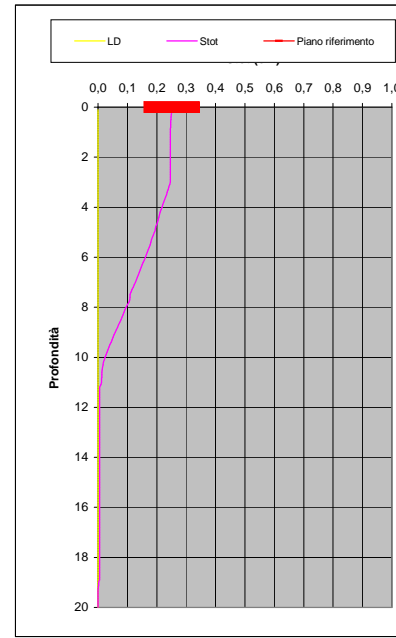
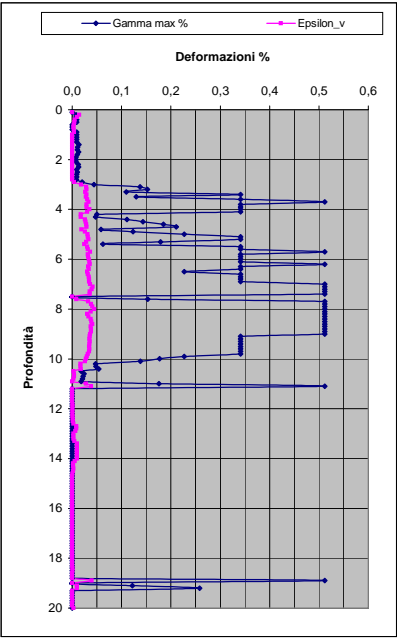
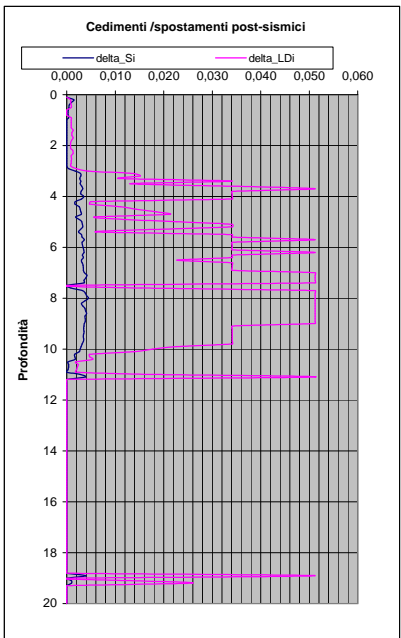
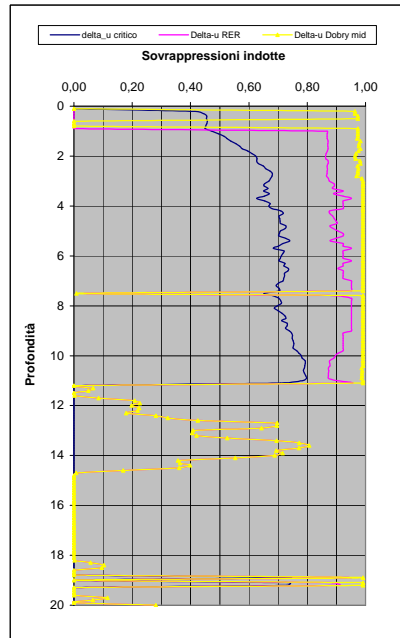
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
- Argille - argilla/argilla limosa
- Miscela di limi - limo argilloso/argilla limosa
- Miscela di sabbie - sabbia limosa/limo sabbioso
- Sabbie - sabbie pulite/sabbie limose
- sabbie ghiaiose / sabbie dense

LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
- FsN** = Attrito laterale (Kg/cmq)
- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento i-esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
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40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL = 18,22

PL = 70,70

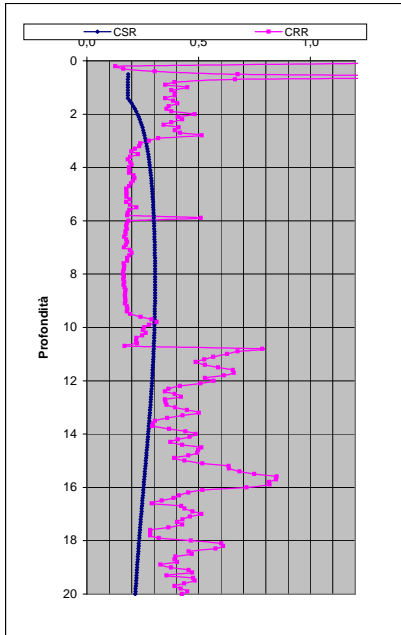
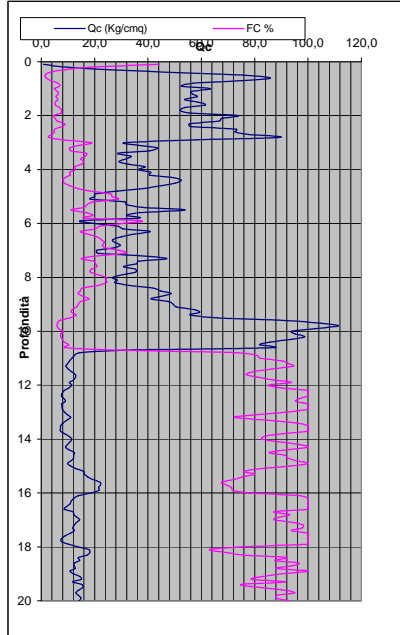
LDI = 2,579 Stot = 0,251 (mt)

LD = 0,00 (mt)

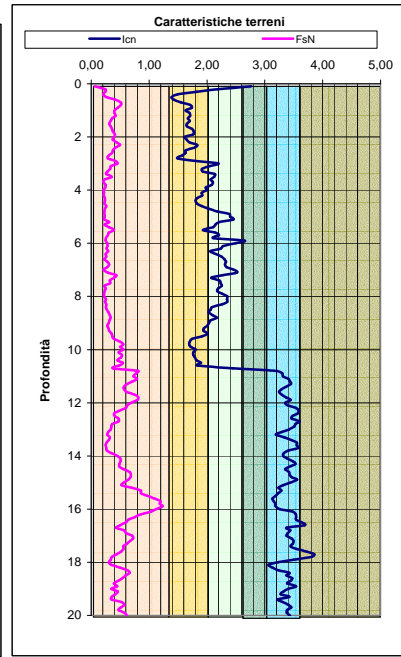
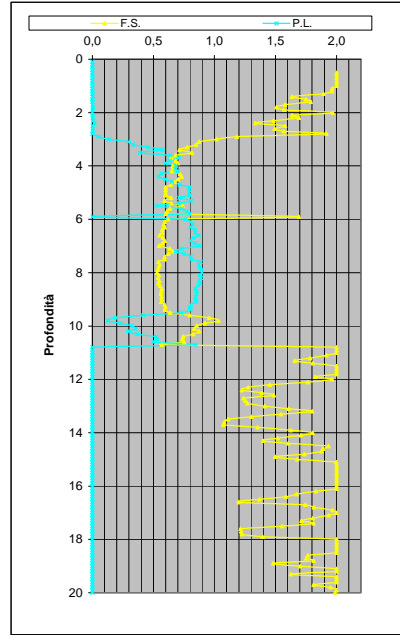
SLiq = 7,90 (mt)

LSN = 39,38 PG = 1,00

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPT E 12



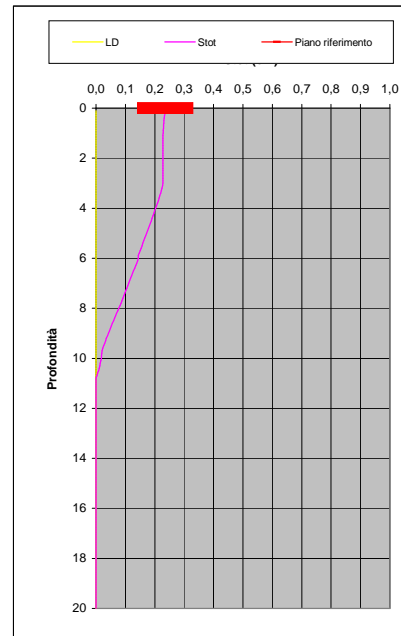
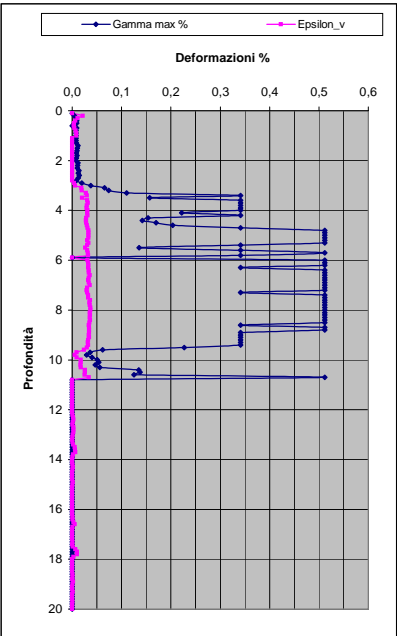
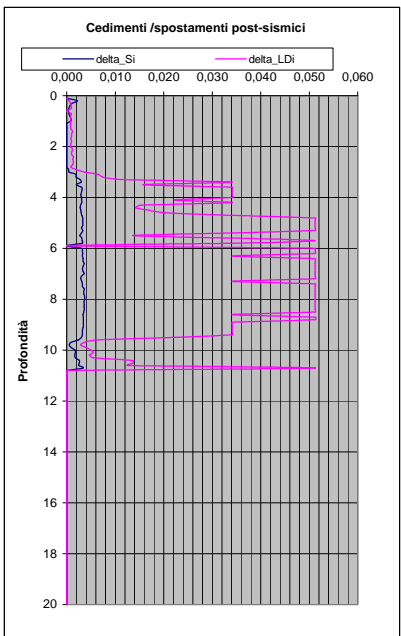
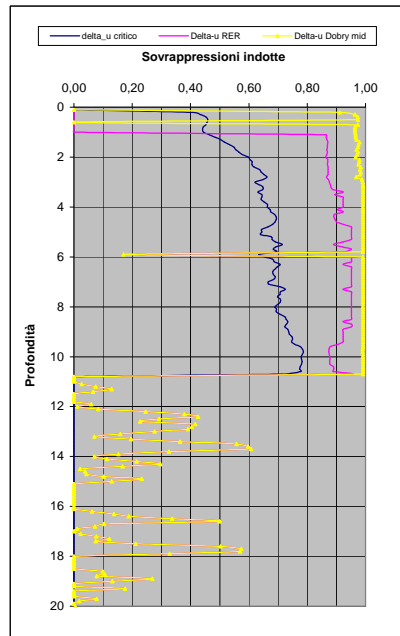
Soil Classification	Zone No.*	Range of CPT Index I_c Values
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Sand Mixtures	5	$2.05 < I_c < 2.60$
Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

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- Qtn** = parametro di resist. alla punta normal.
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- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
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- CRR** = Cyclic Resistance Ratio (ad)
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- IPL** = Indice del potenziale di liquefazione (ad)
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- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
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* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL= 17,31 PL= 66,39 LDI = 2,697 Stot = 0,235 (mt) LD = 0,00 (mt) SLiq = 7,50 (mt) LSN = 37,32 PG= 1,00

CPT-based liquefaction triggering analysis for a single sounding

Environments: C Hill-H Plain-P Coast-C Behaviours: E Sand like-S

Computer constants: no. 10,32 (B' 2007 - 'Cefin' 2004 - 'NCEER' - 'Blake') alpha (N) 1 MSF NCEER

Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTU 1" - Colonia Montecatini

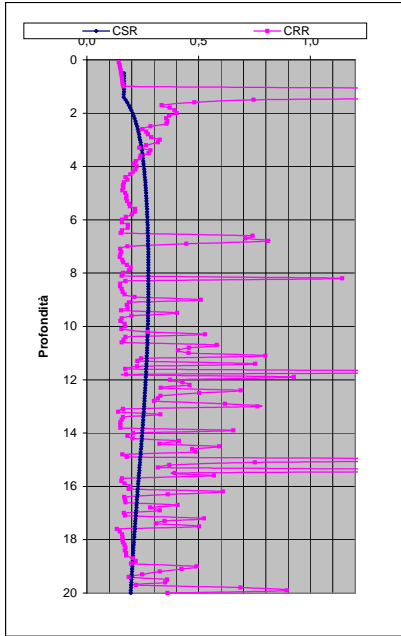
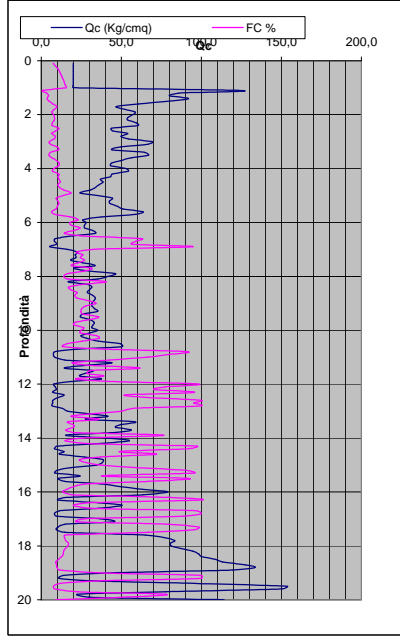
Table with 2 columns: LsN, LsN Expression. Values range from >50 to 0-10.

Main data table with columns: Depth (m), q1, qn, F, Ic, N1(60), n, Kc, Layer, etc. Includes various soil parameters and calculated values.

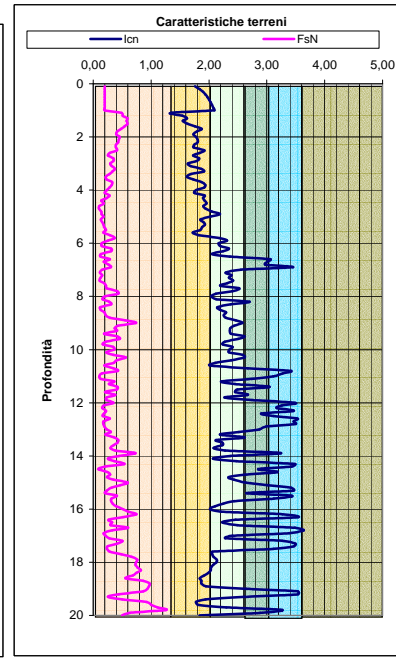
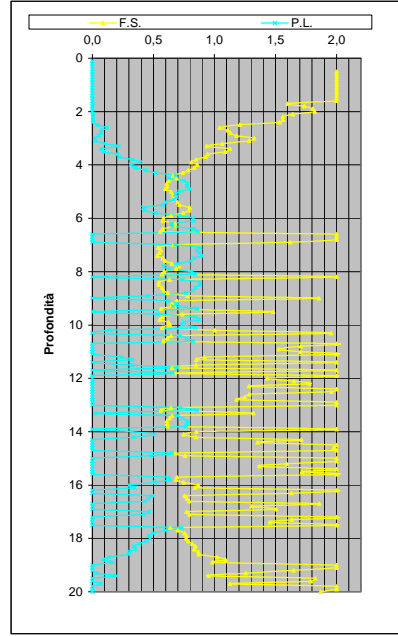
PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 LDI = 3,961 Stot = 0,346 (mt) IPL = 15,88 PL = 59,15 LD = 0,00 (mt) PG = 1,00 SLiq = 10,3 (mt) LSN = 40,8

Main data table with columns: Depth (m), q1, qn, F, Ic, N1(60), n, Kc, Layer, etc. This is the largest table containing the primary data for the sounding.

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTU 1 - Colonia Montecatini



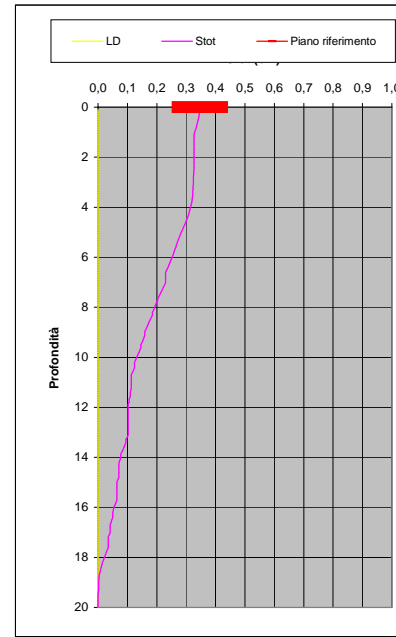
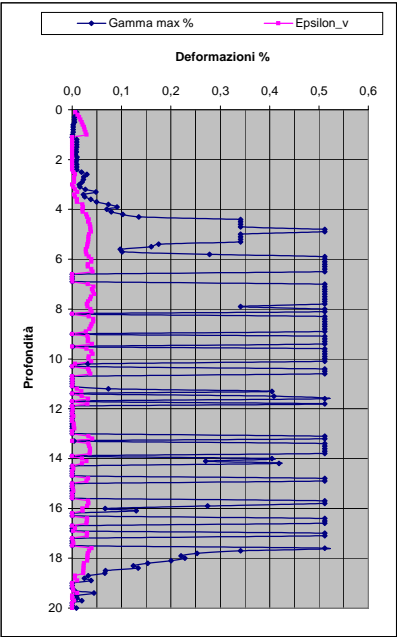
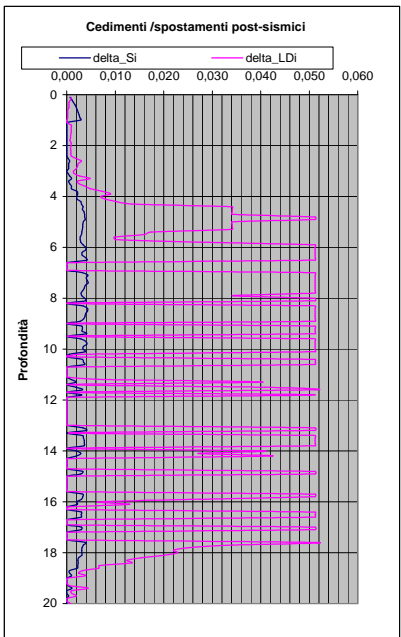
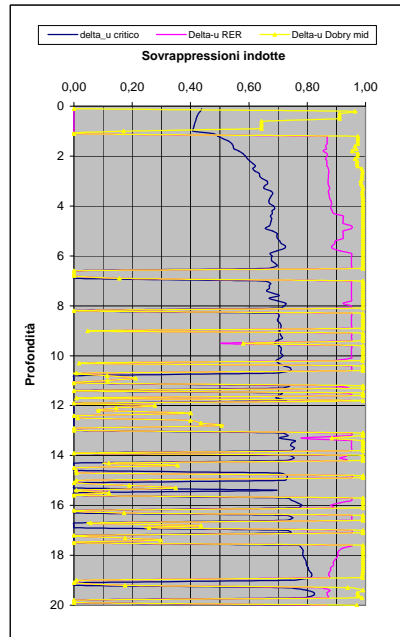
Soil Classification	Zone No.*	Range of CPT Index I_c Values
Organic Clay Soils	2	$I_c > 3.60$
Clays	3	$2.95 < I_c < 3.60$
Silt Mixtures	4	$2.60 < I_c < 2.95$
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Sands	6	$1.31 < I_c < 2.05$
Gravelly Sands	7	$I_c < 1.31$

After Robertson and Wride (1998).
*Note: Zone number per Robertson SBT (1990).

- Argille - terreni organici
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LEGENDA

- Qc** = Res. alla penetraz. (Kg/cmq)
- FC** = Fine content - passante 0.074 mm (%)
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- F** = rapporto di frizione
- Qtn** = parametro di resist. alla punta normal.
- Icn** = Soil behaviour index normalized (ad)
- qc1N-cs** = Resist. alla pentrez. corretta all'FC e normalizzata
- ξ = parametro di stato
- KH** = fatt. correttivo per spessore strato (ad)
- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
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- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



IPL= 15,88 PL= 59,15 LDI = 3,961 Stot = 0,346 (mt) LD = 0,00 (mt) SLiq = 10,30 (mt) LSN = 40,75 PG= 1,00

LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
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* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

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$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

CPT-based liquefaction triggering analysis for a single sounding

Enviromenti: C Hill-H Plain-P Coast-C
Behaviours: E Sand like-S

Computer constants: no. 1 "Blake" ("B" 2007 - "Cefin" 2004 - "NCEER" - "Blake")
ms. manuale cone c. 35.7 mm s 0.0357 NCEER
Building (Y/N) "B" "NCEER" "ANDRUS" "SID" "C"
Sedimentary environment
Cone-stress D-deltaflag - I-interbedded
CPTE - CPTU-1
Equipment (CPT-CPT):

Probabilità e potenziale di liquefazione

Probabilità e suscettibilità di liquefazione

PL Overall Probability

Robertson & Wride, agg. 2009

PROVA "CPTU 2 II Canalino"

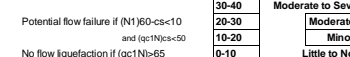


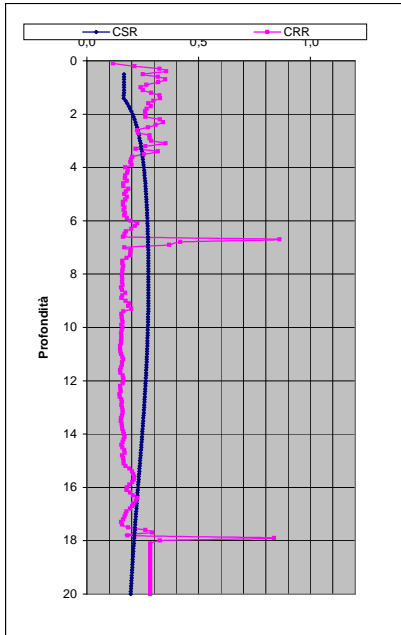
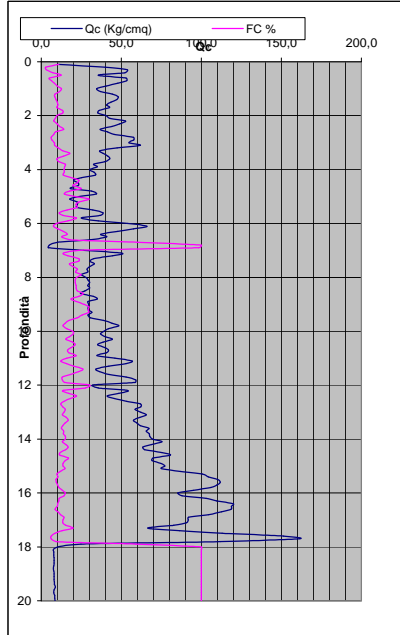
Table with columns: Input parameter, Soil Classification, Soil Parameters, Probabilities, and Displacement Parameters. Includes values for peak ground acceleration, soil strength, and various probability indices.

Main data table with columns: Depth (m), q (kPa), qc (kPa), fs (kPa), etc. This table contains the primary test results and calculated liquefaction parameters for each depth interval.

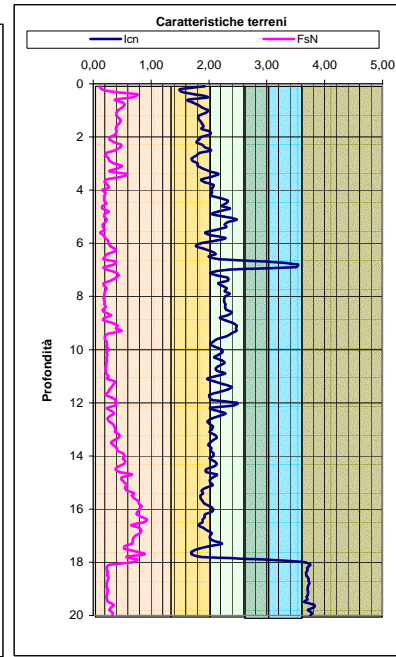
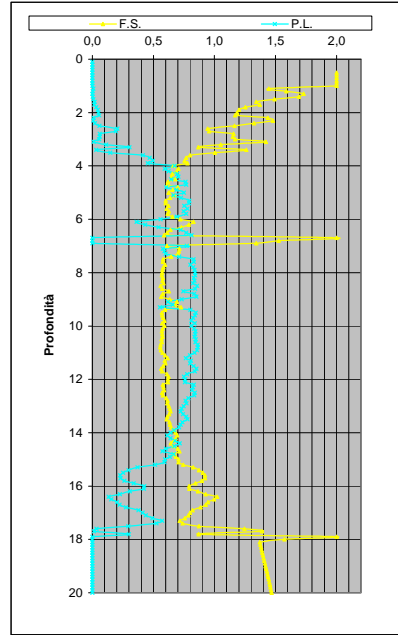
Table with columns: LsN, LsN Expression, Severe Damage, Major expr., Moderate to Sev., Moderate, Mild, Little to No.

PROFONDITA' DI CALCOLO (mt da p.c.): 0,0 LDI = 5,301 Stot = 0,463 (mt) IPL = 22,67 PL = 86,41 LD = 0,00 (mt) PG = 1,00 SLiq = 14,0 (mt) LSN = 54,9

DIAGRAMMI DI RIFERIMENTO VERIFICA LIQUEFAZIONE - METODO R. & W. , 2009



PROVA CPTU 2 - Il Canalino



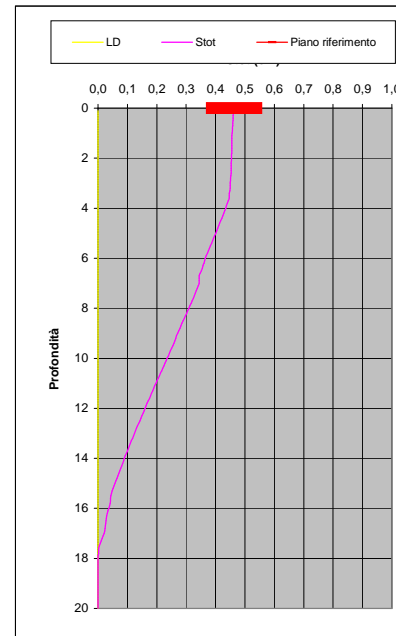
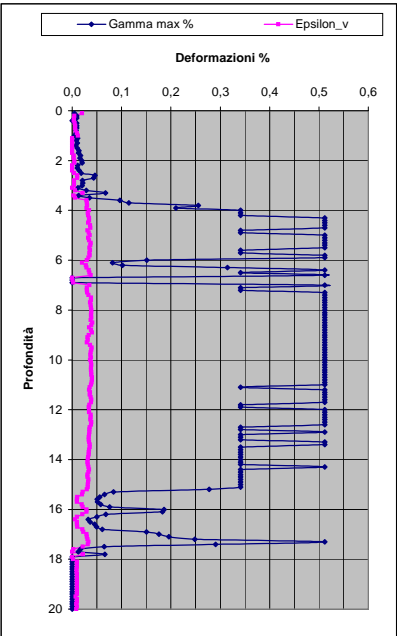
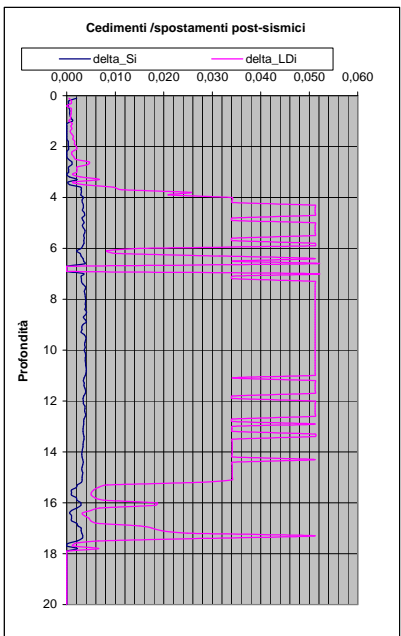
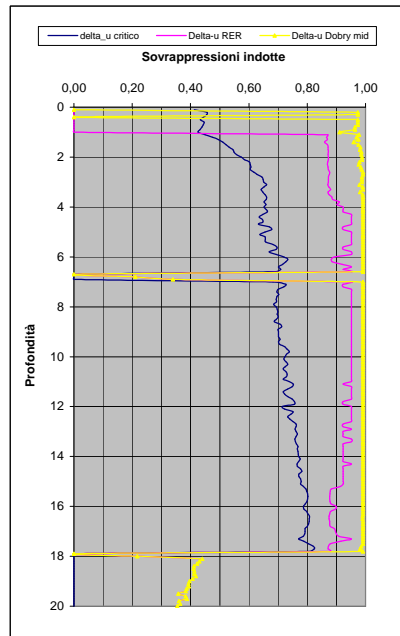
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After Robertson and Wride (1998).
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- Rd** = stress reduction coefficient (ad)
- CN** = fattore di normalizzazione per carico litostatico (ad)
- K σ** = fatt. correttivo per sovraccarico-profondità (ad)
- K α** = fatt. correttivo per sforzi di taglio (ad)
- MSF** = magnitudo scaling factor (ad)
- F.S.** = Fattore di sicurezza (CRR/CSR con correzioni) (ad)
- CSR** = Cyclic Stress ratio (ad)
- CRR** = Cyclic Resistance Ratio (ad)
- P.L.** = Probabilità di liquefazione (ad)
- IPL** = Indice del potenziale di liquefazione (ad)
- γ_{max}** = deformazione di taglio massima indotta dal sisma (%)
- ev** = vertical reconsolidation strain
- Δs_i** = cedimento -esimo dello strato (mt)
- Su** = S_u / σ'_{vc} resistenza totale non drenata - strati coesivi (ad)
- Sur** = S_{ur} / σ'_{vc} resistenza totale residua non drenata - strati coesivi (ad)
- qc1N-sr** = Resist. alla pentrez. corretta all'FC e normalizzata
- Sr** = S_r / σ'_{vc} resistenza residua - strati incoerenti (ad)
- Ruc** = $\Delta u / \sigma'_{vc}$ critico - stima sogliadi innesco fenomeni di instabilità/liquefazione
- Δu RER = $\Delta u / \sigma'_{vc}$ sovrappressioni circ. 112/2007 - tabella 2 R.E.R.
- Δu Dobry M. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "mean" x sabbie-Robertson '09 x argille
- Δu Dobry L. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "lower bound" x sabbie-Robertson '09 x argille
- Δu Dobry U. = $\Delta u / \sigma'_{vc}$ Dobry et al. 1984 "Upper bound" x sabbie-Robertson '09 x argille
- Stot** = Cedimento post-sismico totale (mt)
- LDI** = Lateral Displacement Index (mt)
- Dr** = Densità relativa (ad)
- θ = angolo di attrito interno (deg)
- OCR** = rapporto di sovraconsolidazione (sabbie e argille) (ad)
- St** = coefficiente di sensitività delle argille (ad)
- LSN** = Liquefaction Severity Number (ad)



LSN Range	Expected ground surface damage
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with some sand boils and structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlements of structures
>50	Severe damage, extensive evidence of liquefaction as surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from I&T report: Liquefaction Vulnerability Study

Probability	Description of the risk of liquefaction-induced ground failure
$0.9 < P_G$	extremely high to absolutely certain
$0.7 < P_G \leq 0.9$	high
$0.3 < P_G \leq 0.7$	medium
$0.1 < P_G \leq 0.3$	low
$P_G \leq 0.1$	extremely low to none

IPL= 22,67

PL= 86,41

LDI = 5,301 Stot = 0,463 (mt)

LD = 0,00 (mt)

SLiq = 14,00 (mt)

LSN = 54,87 PG= 1,00