

Kocaeli Event

This major strike-slip event occurred on the Northern Anatolian Fault in northwest Turkey. Widespread liquefaction, building damage and settlement, lateral spreading, and other seismic ground failures were observed after this earthquake. A large reconnaissance effort evaluated these after effects. The PEER website contains a wealth of site information including SPT and CPT logs, and site maps. PGA estimates were based on site response analyses and strong motion recordings.

There are two groups of sites. The first group is from Phase 4 of the PEER research on lateral spreads. The sites included are considered “level” ground sites. The second group of sites are from the town of Adapazari.

References

Cetin, K.O. (2002) Personal Communication.

PEER (2000). “Documenting Incidents of Ground Failure Resulting from the Aug. 17, \ 1999, Kocaeli, Turkey Earthquake.” <http://peer.Berkeley.edu>.

Sancio, R.B., Bray, J.D., Stewart, J.P., Youd, T.L., Dugrgunoglu, H.T., Onalp, A., Christensen, C., Baturay, M.B., Karadayilar, T., Seed, R.B. (2001). “Correlation Between Ground Failure and Subsurface Soil Conditions in Downtown Adapazari, Turkey.

Sancio, R.B. (2002) Personal Communication.

Youd, T.L., Bardet, J.P., and Bray, J.D., ed. (2000). “Kocaeli, Turkey, Earthquake of August 17, 1999 Reconnaissance Report.” Earthquake Spectra, Vol. 16, Supplement A.

Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Hotel Spanca SH-4 GW
References: PEER (2000), Cetin (2002)
Nature of Failure: Lateral Spreading

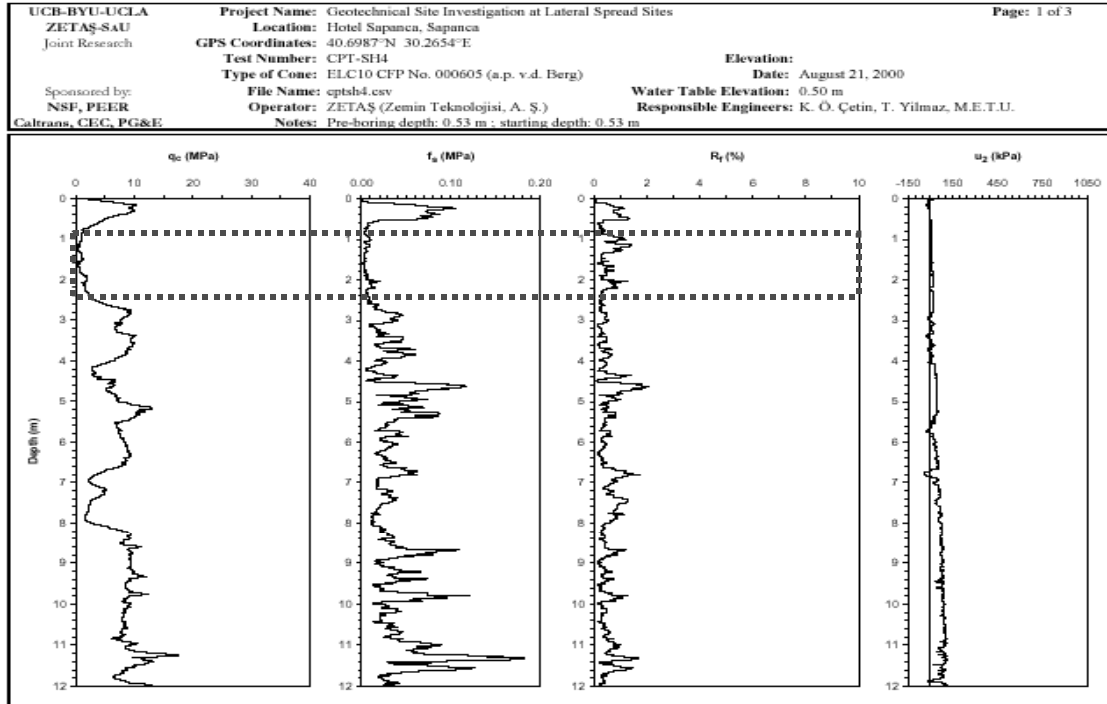
Comments: Level ground site.

Lateral spreading site horizontal displacement of 30 cm and vertical displacement of 20 cm at the hole location.

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	GW
Data Class	B	$D_{50(mm)}$	6.40
Critical Layer (m)	0.8 to 2.4	%Fines	5
Median Depth (m)	1.60	%PI	NP
st.dev.	0.27		
Depth to GWT (m)	0.50	q_c (MPa)	0.95
st.dev.	0.30	st.dev.	0.41
σ_v (kPa)	28.10	f_s (kPa)	4.27
st.dev.	5.07	st.dev.	1.99
σ_v' (kPa)	17.31	norm. exp.	0.70
st.dev.	2.66	C_q, C_f	2.00
a_{max} (g)	0.37	C_{thin}	1.00
st.dev.	0.09	f_{s1} (kPa)	8.54
r_d	0.96	st.dev.	3.99
st.dev.	0.03	q_{c1} (MPa)	1.91
M_w	7.40	st.dev.	0.83
st.dev.	0.11	$R_{f1}(\%)$	0.45
CSR_{eq}	0.38	stdev	0.29
st.dev.	0.13		
C.O.V. _{CSR}	0.34		

1999 Kocaeli, Turkey
Hotel Spanca SH-4 GW



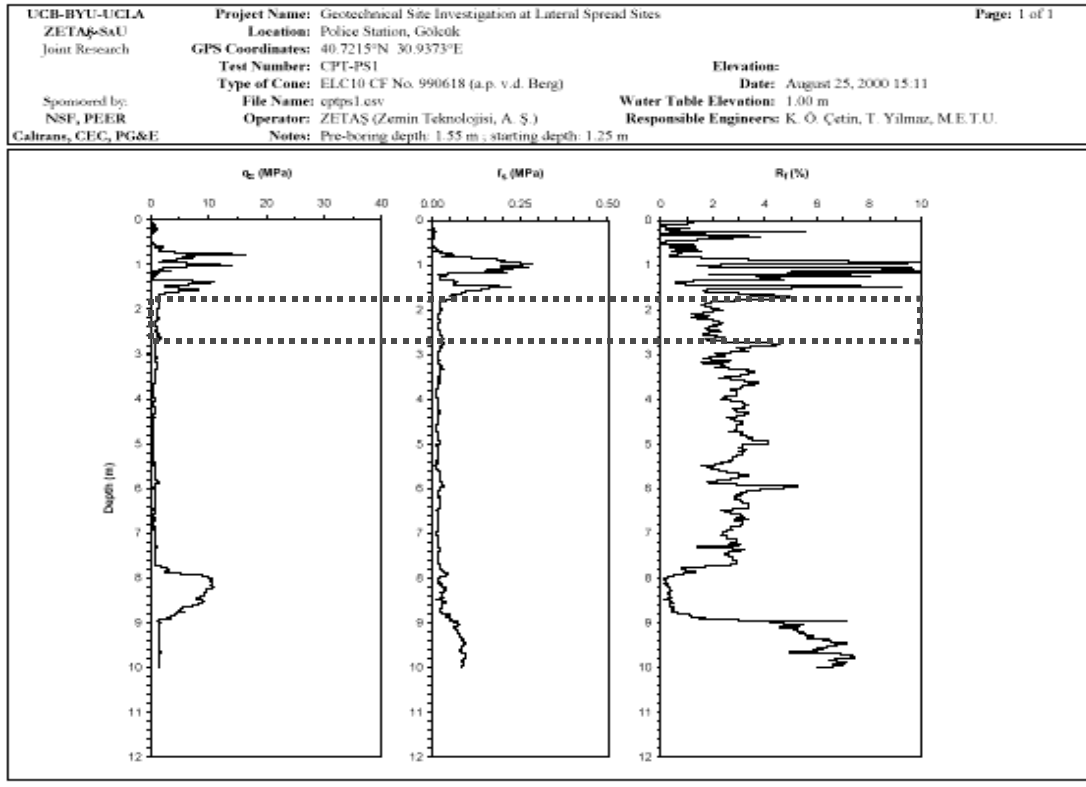
Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Police Station Site, PS-1
References: PEER (2000), Cetin (2002)
Nature of Failure: Lateral Spreading

Comments:

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	SM
Data Class	B	$D_{50(mm)}$	1.60
Critical Layer (m)	1.8 to 2.8	%Fines	12
Median Depth (m)	2.30	%PI	NP
st.dev.	0.17		
Depth to GWT (m)	1.00	q_c (MPa)	1.15
st.dev.	0.30	st.dev.	0.23
σ_v (kPa)	39.55	f_s (kPa)	21.62
st.dev.	3.38	st.dev.	4.51
σ_v' (kPa)	26.80	norm. exp.	0.54
st.dev.	2.48	C_q, C_f	2.00
a_{max} (g)	0.40	C_{thin}	1.00
st.dev.	0.10	f_{s1} (kPa)	43.23
r_d	0.94	st.dev.	9.03
st.dev.	0.05	q_{c1} (MPa)	2.29
M_w	7.40	st.dev.	0.47
st.dev.	0.11	$R_{f1}(\%)$	1.89
CSR_{eq}	0.36	stdev	0.55
st.dev.	0.10		
C.O.V. _{CSR}	0.28		

1999 Kocaeli, Turkey
Police Station Site, PS-1



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Soccer Field SF-5
References: PEER (2000), Cetin (2002)
Nature of Failure: Lateral Spreading

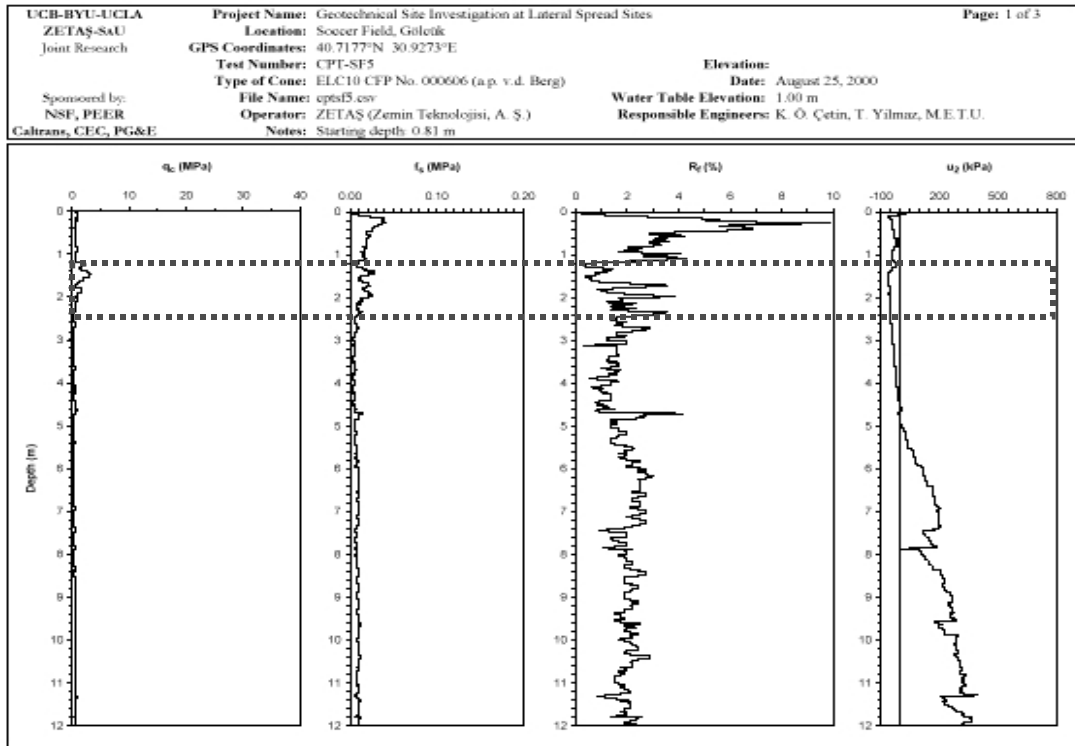
Comments: Level ground site.

Lateral spreading on the order of 30-40 cm measured at CPT location

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	SM
Data Class	C	$D_{50(mm)}$	1.30
Critical Layer (m)	1.2 to 2.4	%Fines	16
Median Depth (m)	1.80	%PI	NP
st.dev.	0.20		
Depth to GWT (m)	1.00	q_c (MPa)	1.30
st.dev.	0.30	st.dev.	0.81
σ_v (kPa)	30.30	f_s (kPa)	15.21
st.dev.	3.90	st.dev.	6.01
σ_v' (kPa)	22.45	norm. exp.	0.55
st.dev.	2.48	C_q	2.00
a_{max} (g)	0.37	C_f	2.27
st.dev.	0.13	f_{s1} (kPa)	34.58
r_d	0.96	st.dev.	13.66
st.dev.	0.04	q_{c1} (MPa)	2.61
M_w	7.40	st.dev.	1.62
st.dev.	0.11	$R_{f1}(\%)$	1.17
CSR_{eq}	0.31	stdev	0.97
st.dev.	0.12		
C.O.V. _{CSR}	0.39		

1999 Kocaeli, Turkey
 Soccer Field SF-5



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Yalova Harbor Site, CPTU-YH-3
References: PEER (2000), Cetin (2002)
Nature of Failure: Lateral Spreading

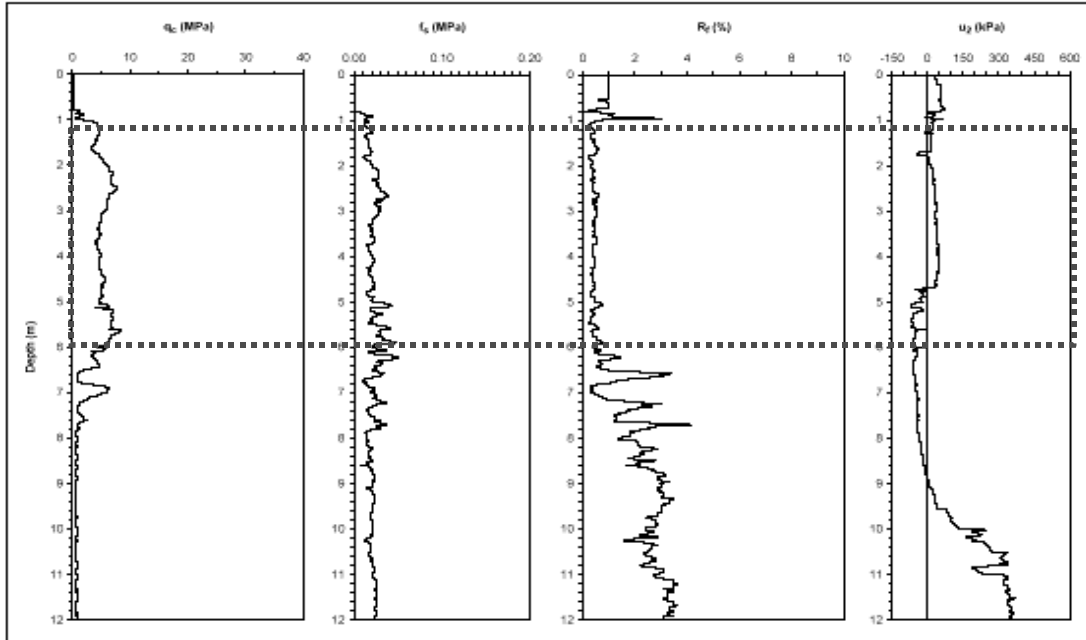
Comments:

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	SP-SM
Data Class	C	$D_{50(mm)}$	0.29
Critical Layer (m)	1.2 to 6.0	%Fines	9
Median Depth (m)	3.60	%PI	NP
st.dev.	0.80		
Depth to GWT (m)	1.00	q_c (MPa)	5.47
st.dev.	0.30	st.dev.	1.09
σ_v (kPa)	63.60	f_s (kPa)	23.17
st.dev.	14.93	st.dev.	6.57
σ_v' (kPa)	38.09	norm. exp.	0.57
st.dev.	5.30	C_q, C_f	1.73
a_{max} (g)	0.37	C_{thin}	1.00
st.dev.	0.13	f_{s1} (kPa)	40.16
r_d	0.90	st.dev.	11.38
st.dev.	0.07	q_{c1} (MPa)	9.49
M_w	7.40	st.dev.	1.89
st.dev.	0.11	$R_{f1}(\%)$	0.42
CSR_{eq}	0.36	stdev	0.15
st.dev.	0.16		
C.O.V. _{CSR}	0.45		

1999 Kocaeli, Turkey
 Yalova Harbor Site, CPTU-YH-3

UCB-BYU-UCLA ZETAS-SaU Joint Research	Project Name: Geotechnical Site Investigation at Lateral Spread Sites Location: Yalova Harbor, Yalova GPS Coordinates: 40.6597°N 29.2689°E Test Number: CPT-YH3 Type of Cone: ELC10 CFP No. 000605 (a.p. v.d. Berg)	Page: 1 of 2 Elevation: Date: September 6, 2000 17:07 Water Table Elevation: 0.75 m Responsible Engineers: K. Ö. Çetin, T. Yılmaz, M.E.T.U.
Sponsored by: NSF, PEER Caltrans, CEC, PG&E	File Name: cpyh3.csv Operator: ZETAS (Zemin Teknolojisi, A. Ş.) Notes:	



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site B
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Building Settlement and Tilting

Comments: Poor bldg performance over entire site. Bldg tilting, settlement, and rotation.

Kuyudibi Ave btw. Gull and Yaprak St., Karaosman District

Adapazari strong motion station distance of 4km gave 0.4 g.

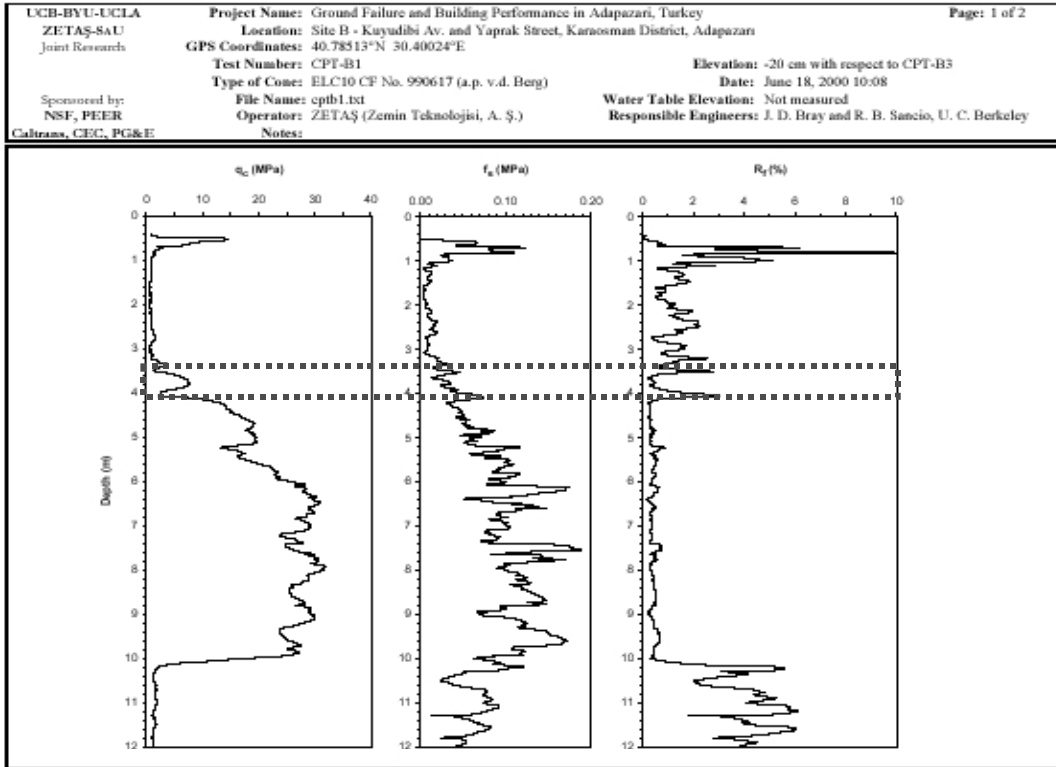
Site response analysis gives 0.3-0.4g

CPT-B1 & B4

Summary of Data:

Stress		Strength	
Liquefied	Y		
Data Class	B	Soil Class	SM to ML
Critical Layer (m)	3.3 to 4.3	$D_{50(mm)}$	0.12
Median Depth (m)	3.80	%Fines	35
st.dev.	0.17	%PI	na
Depth to GWT (m)	3.30		
st.dev.	0.30		
σ_v (kPa)	60.40	q_c (MPa)	3.94
st.dev.	3.86	st.dev.	1.78
σ_v' (kPa)	55.50	f_s (kPa)	30.34
st.dev.	3.10	st.dev.	9.38
a_{max} (g)	0.40	norm. exp.	0.65
st.dev.	0.10	C_q, C_f	1.47
r_d	0.89	C_{thin}	1.00
st.dev.	0.07	f_{s1} (kPa)	44.49
M_w	7.40	st.dev.	13.75
st.dev.	0.11	q_{c1} (MPa)	5.77
CSR_{eq}	0.25	st.dev.	2.62
st.dev.	0.07	$R_{f1}(\%)$	0.77
C.O.V. _{CSR}	0.28	stdev	0.42

1999 Kocaeli, Turkey
Adapazari Site B



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site C2
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Foundation settlement and sand boils.

Comments: Ejecta consisted of low plasticity silt and silty fine sand. Significant variation of stratigraphy both horizontally and vertically throughout the site; fluvial deposition.

Bldg C2, Boluk St. in Istiklal district

Adapazari strong motion station distance of 4km gave 0.4 g.

Site response analysis gives 0.3-0.4g

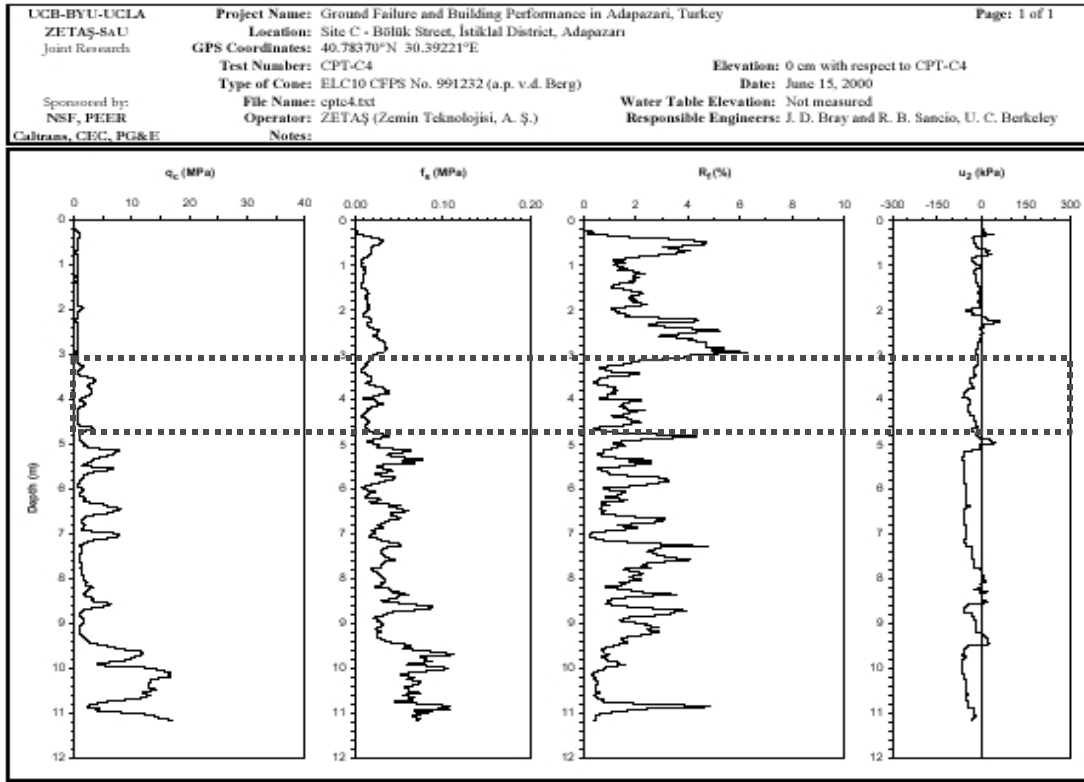
CPT-C4 and SPT-C4 & C3

The critical layer is over the depth range of 3.3 to 4.8 m.

Summary of Data:

Stress		Strength	
Liquefied	Y		
Data Class	B	Soil Class	SM to ML
Critical Layer (m)	3.3 to 4.8	$D_{50(mm)}$	0.12
Median Depth (m)	4.05	%Fines	35
st.dev.	0.25	%PI	na
Depth to GWT (m)	0.44		
st.dev.	0.30		
σ_v (kPa)	73.61	q_c (MPa)	1.74
st.dev.	5.26	st.dev.	1.01
σ_v' (kPa)	38.19	f_s (kPa)	17.96
st.dev.	3.41	st.dev.	8.18
a_{max} (g)	0.40	norm. exp.	0.64
st.dev.	0.10	C_q, C_f	1.85
r_d	0.88	C_{thin}	1.00
st.dev.	0.08	f_{s1} (kPa)	33.25
M_w	7.40	st.dev.	15.15
st.dev.	0.11	q_{c1} (MPa)	3.22
CSR_{eq}	0.44	st.dev.	1.87
st.dev.	0.13	$R_{f1}(\%)$	1.03
C.O.V. _{CSR}	0.29	stdev	0.76

1999 Kocaeli, Turkey
Adapazari Site C2



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site D
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Bldg settlement and rotation.

Comments: Meydan Street, Çukurahmediye District

 Adapazari strong motion station distance of 4km gave 0.4 g.

 Site response analysis gives 0.3-0.4g

 CPT-C1 and SPT-C1

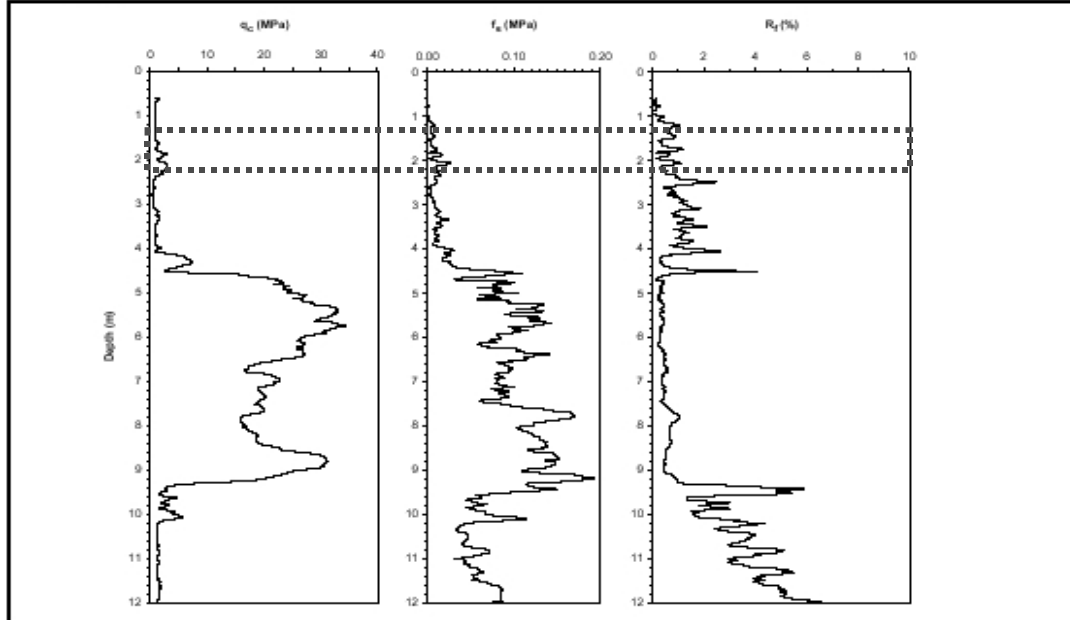
 Thin Layer corrected

Summary of Data:

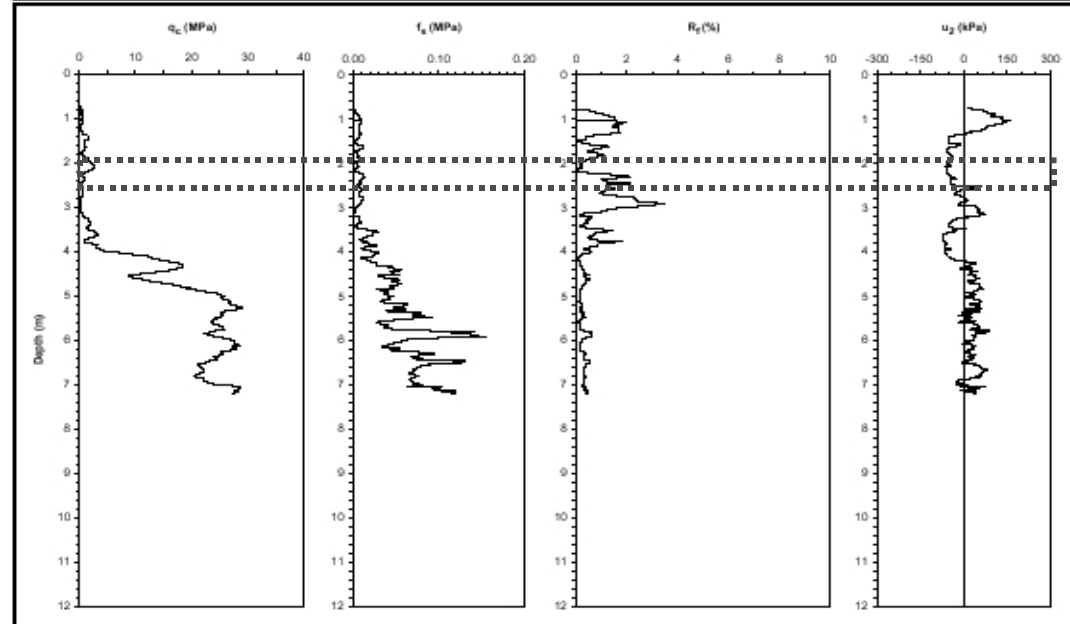
Stress		Strength	
Liquefied	Y		
Data Class	B	Soil Class	ML
Critical Layer (m)	1.8 to 2.5	$D_{50(mm)}$	0.06
Median Depth (m)	2.15	%Fines	65
st.dev.	0.12	%PI	na
Depth to GWT (m)	1.50		
st.dev.	0.30		
σ_v (kPa)	35.28	q_c (MPa)	1.27
st.dev.	2.56	st.dev.	0.72
σ_v' (kPa)	28.90	f_s (kPa)	7.29
st.dev.	2.39	st.dev.	4.07
a_{max} (g)	0.40	norm. exp.	0.75
st.dev.	0.10	C_q, C_f	2.00
r_d	0.95	C_{thin}	1.10
st.dev.	0.04	f_{s1} (kPa)	14.58
M_w	7.40	st.dev.	8.14
st.dev.	0.11	q_{c1} (MPa)	2.79
CSR_{eq}	0.30	st.dev.	1.43
st.dev.	0.08	$R_{f1}(\%)$	0.58
C.O.V. _{CSR}	0.28	stdev	0.40

1999 Kocaeli, Turkey
Adapazari Site D

UCB-BYU-UCLA ZETAŞ-SAU Joint Research	Project Name: Ground Failure and Building Performance in Adapazari, Turkey Location: Site D - Meydan Street, Çukurahmediye District, Adapazari GPS Coordinates: 40.76929°N 30.40828°E Test Number: CPT-D1 Type of Cone: ELC10 CP No. 990617 (a.p. v.d. Berg) File Name: cptd1.txt Operator: ZETAŞ (Zemin Teknolojisi, A. Ş.) Notes:	Page: 1 of 3 Elevation: 0 cm with respect to CPT-D1 Date: June 16, 2000 16:54 Water Table Elevation: Not measured Responsible Engineers: J. D. Bray and R. B. Sancio, U. C. Berkeley
Sponsored by: NSF, PEER Caltrans, CEC, PG&E		



UCB-BYU-UCLA ZETAŞ-SAU Joint Research	Project Name: Ground Failure and Building Performance in Adapazari, Turkey Location: Site D - Meydan Street, Çukurahmediye District, Adapazari GPS Coordinates: 40.76929°N 30.40828°E Test Number: CPT-D2 Type of Cone: ELC10 CFPS No. 991232 (a.p. v.d. Berg) File Name: cptd2.txt Operator: ZETAŞ (Zemin Teknolojisi, A. Ş.) Notes:	Page: 1 of 1 Elevation: -10 cm with respect to CPT-D1 Date: June 17, 2000 Water Table Elevation: Not measured Responsible Engineers: J. D. Bray and R. B. Sancio, U. C. Berkeley
Sponsored by: NSF, PEER Caltrans, CEC, PG&E		



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site E
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Bldg settlement, floor heave, sand boils.

Comments: Kavaklar Street, Tigcilar District

Adapazari strong motion station distance of 4km
gave 0.4 g.

Site response analysis gives 0.3-0.4g

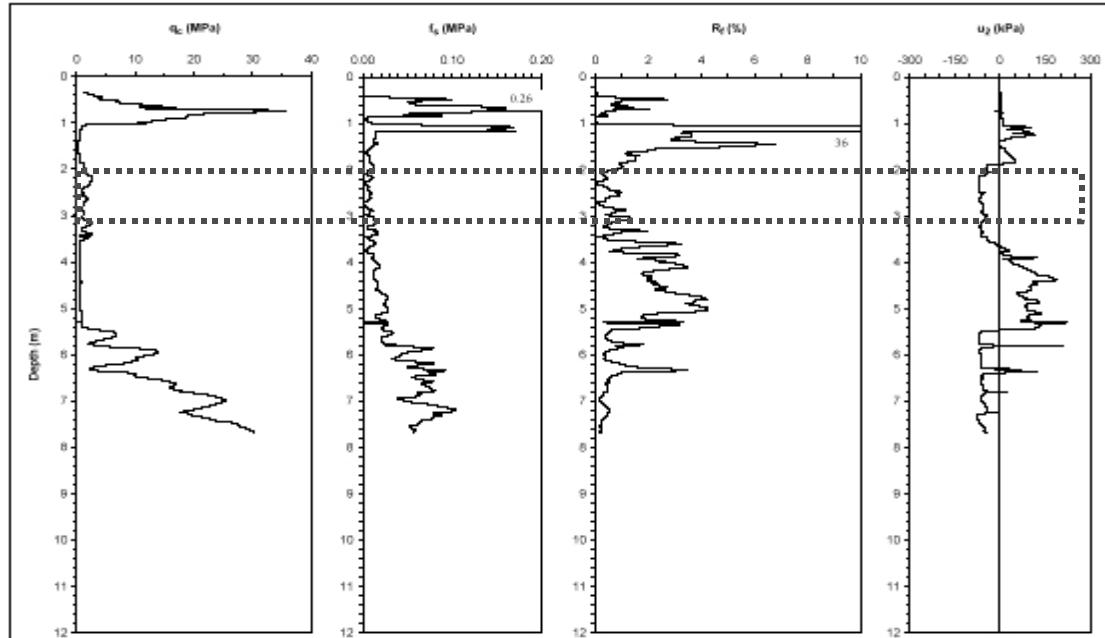
Settlement of bldgs on both mat and spread foundations.

Summary of Data:

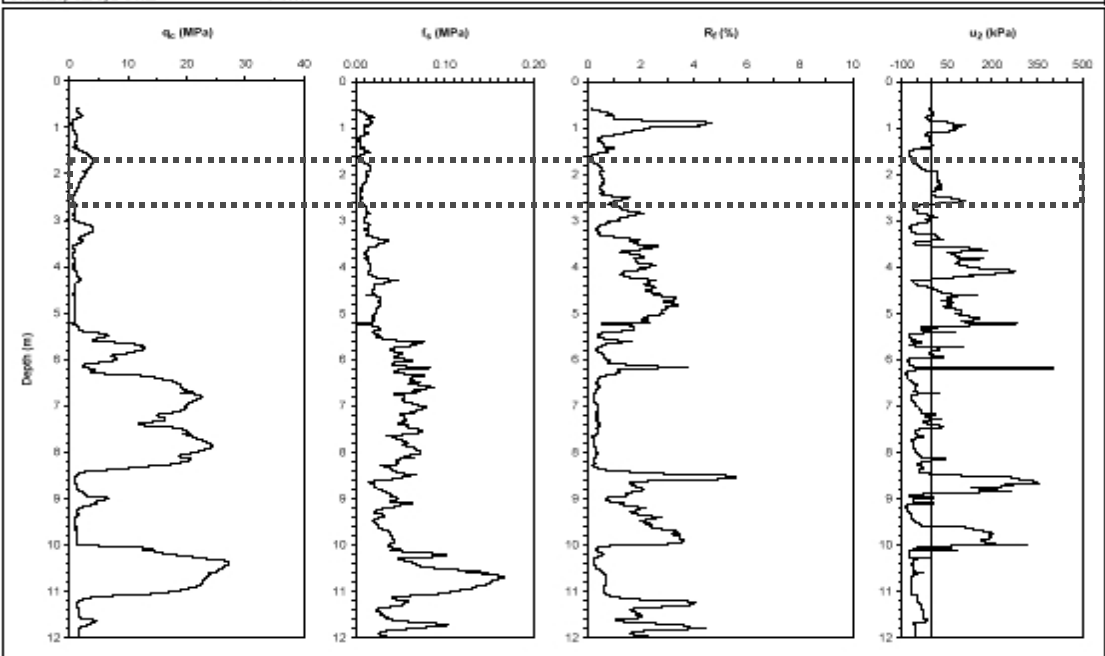
Stress		Strength	
Liquefied	Y		
Data Class	B	Soil Class	SP
Critical Layer (m)	1.5 to 3.0	$D_{50(mm)}$	0.51
Median Depth (m)	2.25	%Fines	2
st.dev.	0.25	%PI	na
Depth to GWT (m)	0.50		
st.dev.	0.30		
σ_v (kPa)	40.13	q_c (MPa)	2.03
st.dev.	4.85	st.dev.	0.94
σ_v' (kPa)	22.96	f_s (kPa)	8.24
st.dev.	2.75	st.dev.	3.98
a_{max} (g)	0.40	norm. exp.	0.73
st.dev.	0.10	C_q, C_f	2.00
r_d	0.94	C_{thin}	1.00
st.dev.	0.05	f_{s1} (kPa)	16.48
M_w	7.40	st.dev.	7.97
st.dev.	0.11	q_{c1} (MPa)	4.06
CSR_{eq}	0.43	st.dev.	1.89
st.dev.	0.13	$R_{f1}(\%)$	0.41
C.O.V. _{CSR}	0.30	stdev	0.27

1999 Kocaeli, Turkey
Adapazari Site E

UCB-BYU-UCLA ZETAŞ-SAU Joint Research	Project Name: Ground Failure and Building Performance in Adapazari, Turkey Location: Site E - Kavaklar Avenue, Tigeilar District, Adapazari GPS Coordinates: 40.77778° N 30.40518° E Test Number: CPT-E3 Type of Cone: ELC10 CFPS No. 991232 (a.p. v.d. Berg) File Name: cpte3.txt Operator: ZETAŞ (Zemin Teknolojisi, A. Ş.) Notes:	Page: 1 of 1 Elevation: -5 cm with respect to CPT-E1 Date: June 20, 2000 Water Table Elevation: Not measured Responsible Engineers: J. D. Bray and R. B. Sancio, U. C. Berkeley
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UCB-BYU-UCLA ZETAŞ-SAU Joint Research	Project Name: Ground Failure and Building Performance in Adapazari, Turkey Location: Site E - Kavaklar Avenue, Tigeilar District, Adapazari GPS Coordinates: 40.77778° N 30.40518° E Test Number: CPT-E1 Type of Cone: ELC10 CFPS No. 991232 (a.p. v.d. Berg) File Name: cpte1.txt Operator: ZETAŞ (Zemin Teknolojisi, A. Ş.) Notes:	Page: 1 of 3 Elevation: 0 cm with respect to CPT-E1 Date: June 20, 2000 Water Table Elevation: 28 cm Responsible Engineers: J. D. Bray and R. B. Sancio, U. C. Berkeley
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Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site F
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Building Settlement

Comments:

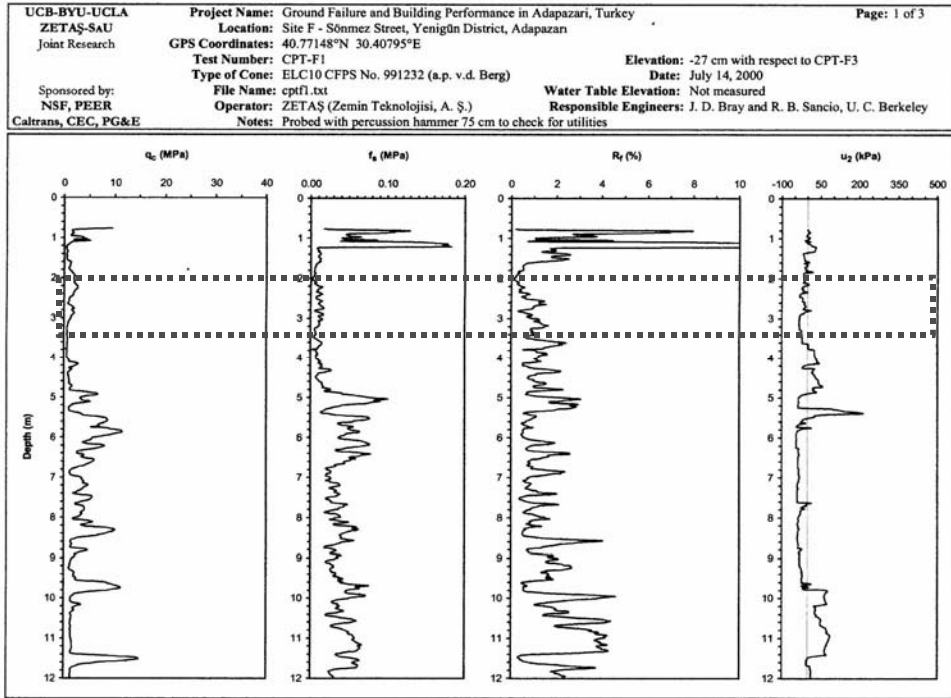
Adapazari strong motion station epicentral distance of 4km gave 0.4 g.

Site response analysis gives 0.3-0.4g

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	SM
Data Class	B	$D_{50(mm)}$	0.09
Critical Layer (m)	1.8 to 3.0	%Fines	42
Median Depth (m)	2.40	%PI	NP
st.dev.	0.20		
Depth to GWT (m)	0.50	q_c (MPa)	3.36
st.dev.	0.30	st.dev.	1.17
σ_v (kPa)	42.90	f_s (kPa)	10.00
st.dev.	4.01	st.dev.	7.35
σ_v' (kPa)	24.26	norm. exp.	0.73
st.dev.	2.66	C_q, C_f	2.00
a_{max} (g)	0.40	C_{thin}	1.00
st.dev.	0.10	f_{s1} (kPa)	20.00
r_d	0.94	st.dev.	14.71
st.dev.	0.05	q_{c1} (MPa)	6.72
M_w	7.40	st.dev.	2.34
st.dev.	0.11	$R_{f1}(\%)$	0.30
CSR_{eq}	0.43	stdev	0.24
st.dev.	0.13		
C.O.V. _{-CSR}	0.29		

1999 Kocaeli, Turkey
 Adapazari Site F



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site G
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Bldg settlement, foundation failure, and sand boils.

Comments: Hasircilar Street, Yenigün District

Adapazari strong motion station distance of 4km gave 0.4 g.

Site response analysis gives 0.3-0.4g

CPT-G1 and SPT-G2 representative for all bldgs.

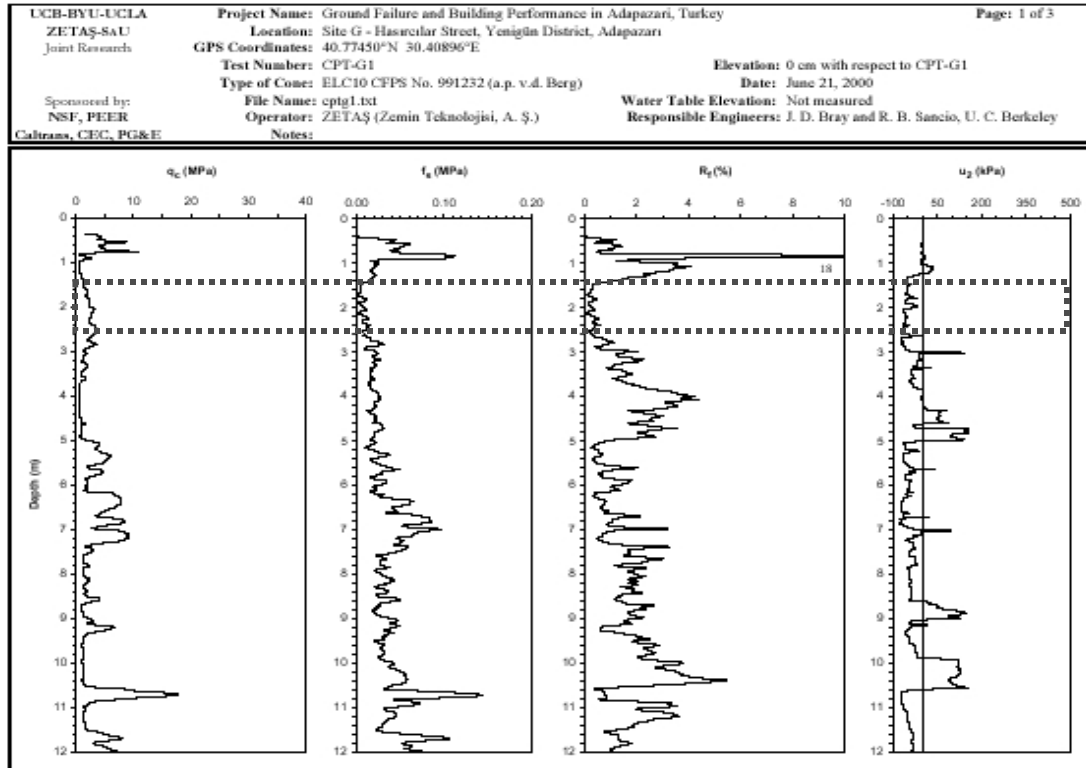
1 to 5 story bldgs all suffered damage and settlement

Ejecta of silty fine sand (SM)

Summary of Data:

Stress		Strength	
Liquefied	Y		
Data Class	B	Soil Class	ML
Critical Layer (m)	1.5 to 2.7	$D_{50(mm)}$	0.04
Median Depth (m)	2.10	%Fines	65
st.dev.	0.20	%PI	na
Depth to GWT (m)	0.45		
st.dev.	0.30		
σ_v (kPa)	37.50	q_c (MPa)	2.52
st.dev.	3.96	st.dev.	0.64
σ_v' (kPa)	21.31	f_s (kPa)	7.95
st.dev.	2.58	st.dev.	3.82
a_{max} (g)	0.40	norm. exp.	0.84
st.dev.	0.10	C_q, C_f	2.00
r_d	0.95	C_{thin}	1.00
st.dev.	0.04	f_{s1} (kPa)	15.90
M_w	7.40	st.dev.	7.65
st.dev.	0.11	q_{c1} (MPa)	5.03
CSR_{eq}	0.43	st.dev.	1.28
st.dev.	0.13	$R_{f1}(\%)$	0.32
C.O.V. _{CSR}	0.30	stdev	0.17

1999 Kocaeli, Turkey
Adapazari Site G



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site H
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Widespread and significant liquefaction

Comments: Kinali St., Yagcilar District

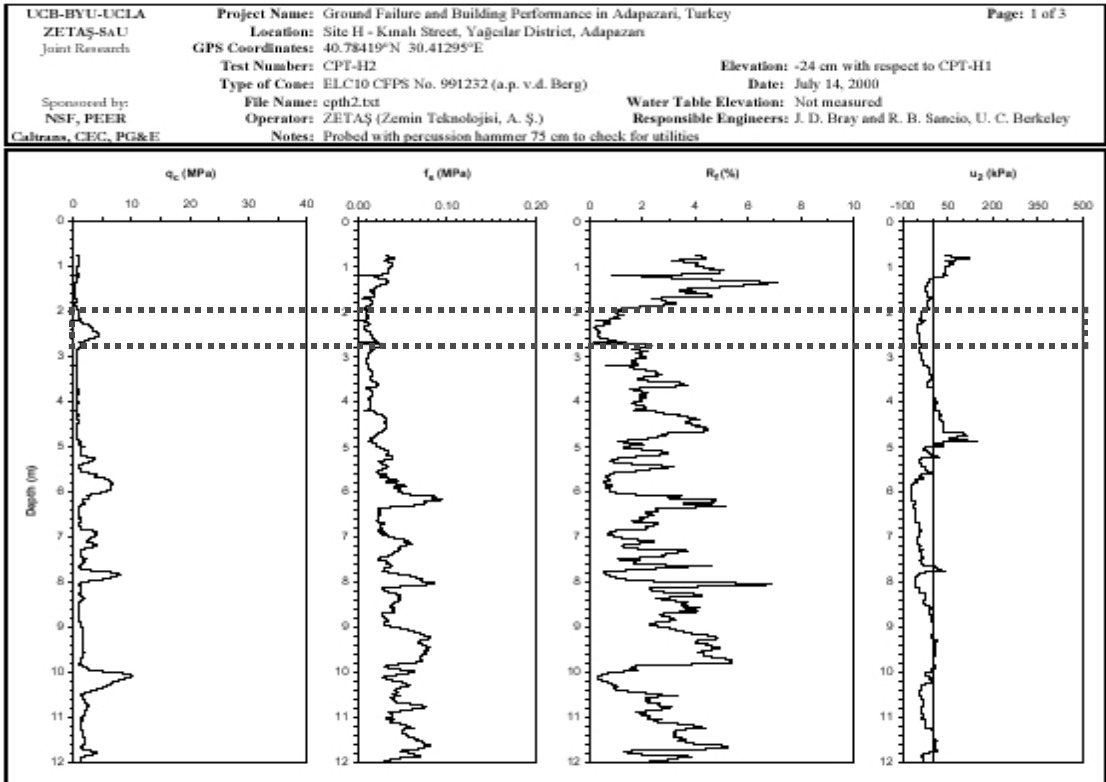
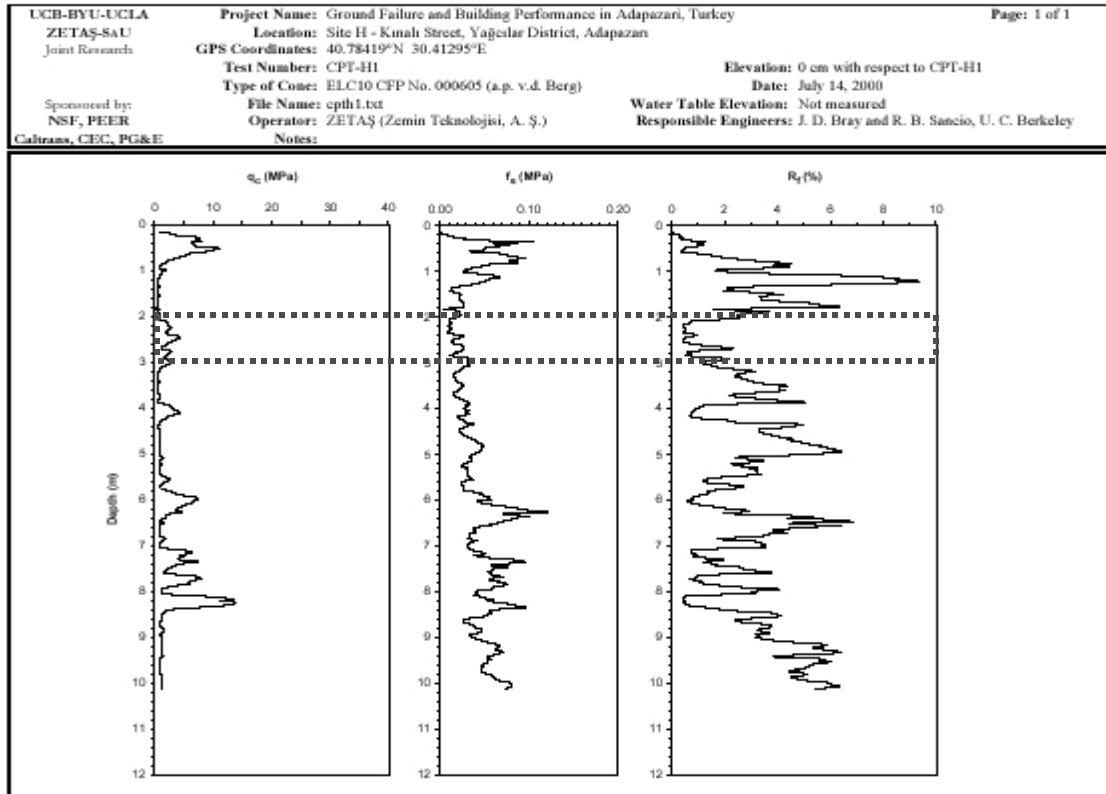
Adapazari strong motion station distance of 4km gave 0.4 g.

Site response analysis gives 0.3-0.4g

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	SM
Data Class	B	$D_{50(mm)}$	0.19
Critical Layer (m)	2 to 3	%Fines	15
Median Depth (m)	2.50	%PI	na
st.dev.	0.17		
Depth to GWT (m)	1.72		
st.dev.	0.30		
σ_v (kPa)	41.09	q_c (MPa)	2.63
st.dev.	3.43	st.dev.	0.97
σ_v' (kPa)	33.44	f_s (kPa)	15.34
st.dev.	2.56	st.dev.	5.99
a_{max} (g)	0.40	norm. exp.	0.68
st.dev.	0.10	C_q, C_f	2.00
r_d	0.94	C_{thin}	1.00
st.dev.	0.05	f_{s1} (kPa)	30.69
M_w	7.40	st.dev.	11.99
st.dev.	0.11	q_{c1} (MPa)	5.27
CSR_{eq}	0.30	st.dev.	1.93
st.dev.	0.08	$R_{f1}(\%)$	0.58
C.O.V. _{CSR}	0.28	stdev	0.31

1999 Kocaeli, Turkey
Adapazari Site H



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site I
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Structural damage and bldg settlement.

Comments: Çark Avenue, near the intersection with Sedat Kirtetepe Avenue
Semerciler District

Adapazari strong motion station distance of 4km
gave 0.4 g.

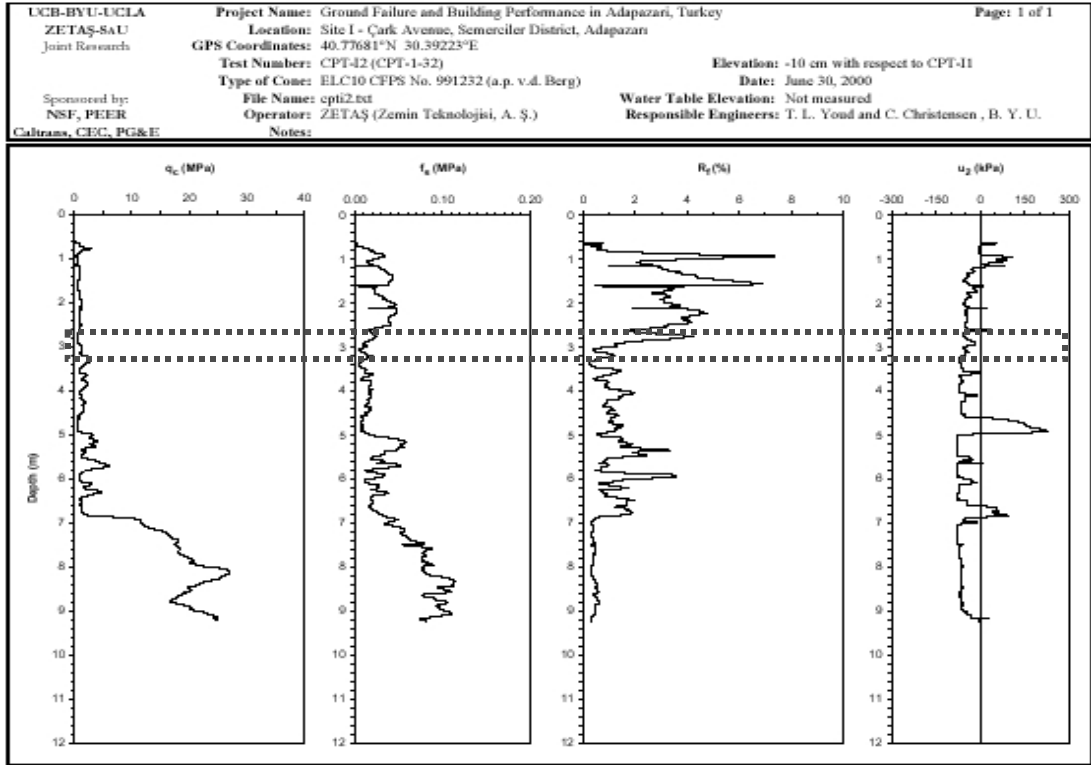
Site response analysis gives 0.3-0.4g

No surface evidence of liquefaction (e.g. sidewalk bulges,
sand boils, etc.)

Summary of Data:

Stress		Strength	
Liquefied	Y		
Data Class	B	Soil Class	ML
Critical Layer (m)	3.0 to 3.5	$D_{50(mm)}$	0.02
Median Depth (m)	3.25	%Fines	65
st.dev.	0.08	%PI	na
Depth to GWT (m)	0.71		
st.dev.	0.30		
σ_v (kPa)	58.00	q_c (MPa)	1.74
st.dev.	2.46	st.dev.	0.47
σ_v' (kPa)	33.08	f_s (kPa)	9.75
st.dev.	2.69	st.dev.	4.85
a_{max} (g)	0.40	norm. exp.	0.72
st.dev.	0.10	C_q, C_f	2.00
r_d	0.91	C_{thin}	1.00
st.dev.	0.06	f_{s1} (kPa)	19.50
M_w	7.40	st.dev.	9.69
st.dev.	0.11	q_{c1} (MPa)	3.47
CSR_{eq}	0.42	st.dev.	0.94
st.dev.	0.11	$R_{f1}(\%)$	0.56
C.O.V. _{CSR}	0.27	stdev	0.32

1999 Kocaeli, Turkey
Adapazari Site I



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site J
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Bldg settlement, sidewalk heave, and sand boils

Comments: Çirak Street, Yenigün District

Adapazari strong motion station distance of 4km
gave 0.4 g.

Site response analysis gives 0.3-0.4g

Boil ejecta silty sand (SM)

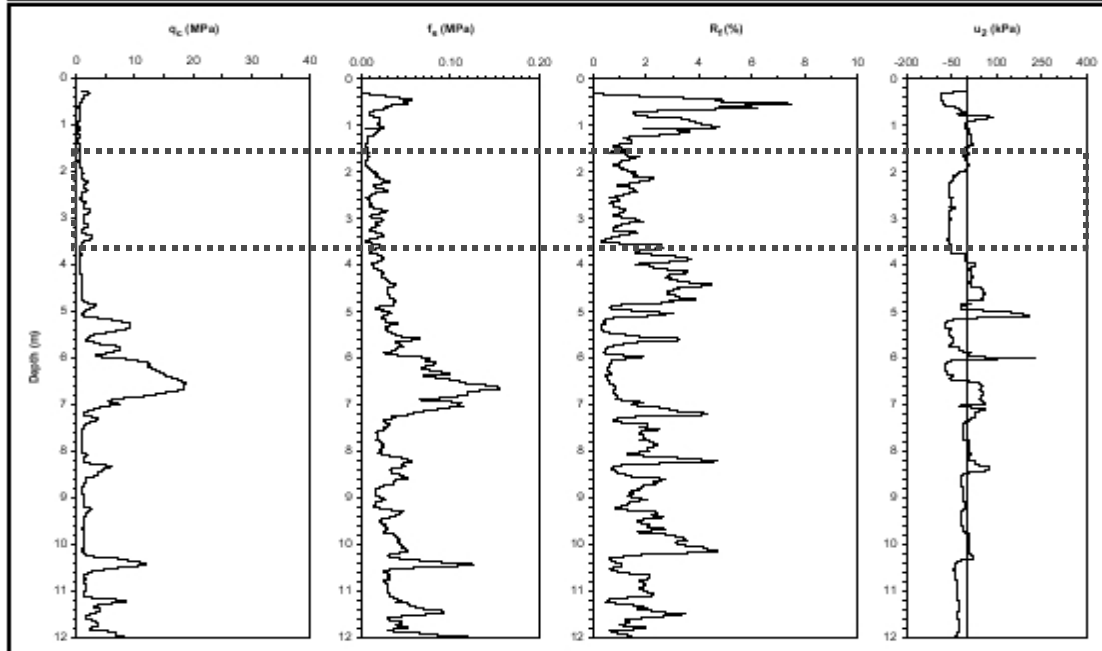
Uniform bldg settlement across site consistent with relatively
constant soil profile.

Summary of Data:

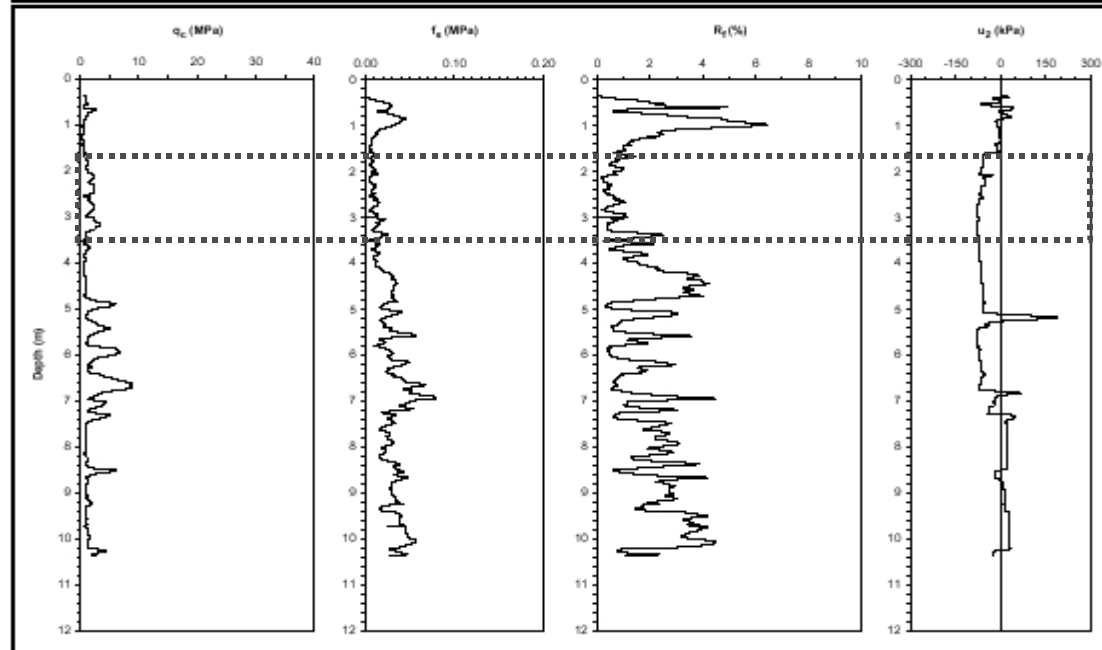
Stress		Strength	
Liquefied	Y	Soil Class	ML
Data Class	B	$D_{50(mm)}$	0.02
Critical Layer (m)	1.5 to 3.5	%Fines	82
Median Depth (m)	2.50	%PI	3
st.dev.	0.33		
Depth to GWT (m)	0.60	q_c (MPa)	1.52
st.dev.	0.30	st.dev.	0.64
σ_v (kPa)	44.45	f_s (kPa)	12.83
st.dev.	6.36	st.dev.	6.39
σ_v' (kPa)	25.81	norm. exp.	0.65
st.dev.	3.07	C_q, C_f	2.00
a_{max} (g)	0.40	C_{thin}	1.00
st.dev.	0.10	f_{s1} (kPa)	25.65
r_d	0.94	st.dev.	12.77
st.dev.	0.05	q_{c1} (MPa)	3.04
M_w	7.40	st.dev.	1.28
st.dev.	0.11	$R_{f1}(\%)$	0.85
CSR_{eq}	0.42	stdev	0.55
st.dev.	0.13		
C.O.V. _{CSR}	0.31		

1999 Kocaeli, Turkey
Adapazari Site I

UCB-BYU-UCLA ZETAŞ-SAU Joint Research	Project Name: Ground Failure and Building Performance in Adapazari, Turkey Location: Site J - Çarık Street, Yenigün District, Adapazari GPS Coordinates: 40.77518°N 30.41077°E Test Number: CPT-J2 Type of Cone: ELC10 CFPS No. 991252 (a.p. v.d. Berg) File Name: cptj2.txt Operator: ZETAŞ (Zemin Teknolojisi, A. Ş.)	Page: 1 of 3 Elevation: 0 cm with respect to CPT-J2 Date: June 19, 2000 Water Table Elevation: Not measured Responsible Engineers: J. D. Bray and R. B. Sancio, U. C. Berkeley
Sponsored by: NSF, PEER Caltrans, CEC, PG&E	Notes:	



UCB-BYU-UCLA ZETAŞ-SAU Joint Research	Project Name: Ground Failure and Building Performance in Adapazari, Turkey Location: Site J - Çarık Street, Yenigün District, Adapazari GPS Coordinates: 40.77518°N 30.41077°E Test Number: CPT-J4 Type of Cone: ELC10 CFPS No. 991252 (a.p. v.d. Berg) File Name: cptj4.txt Operator: ZETAŞ (Zemin Teknolojisi, A. Ş.)	Page: 1 of 1 Elevation: +2 cm with respect to CPT-J2 Date: June 19, 2000 Water Table Elevation: Not measured Responsible Engineers: J. D. Bray and R. B. Sancio, U. C. Berkeley
Sponsored by: NSF, PEER Caltrans, CEC, PG&E	Notes:	



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site K
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Bldg settlement and liquefaction

Comments: Kavaklar Ave

Adapazari strong motion station distance of 4km gave 0.4 g.

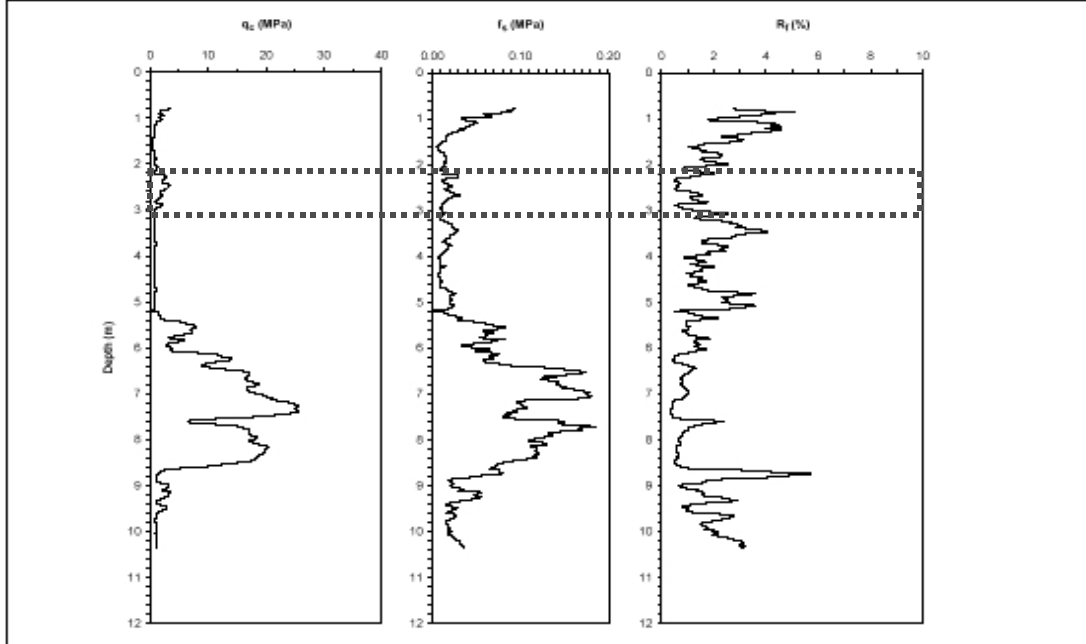
Site response analysis gives 0.3-0.4g

Summary of Data:

Stress		Strength	
Liquefied	Y		
Data Class	B	Soil Class	ML
Critical Layer (m)	2 to 3	$D_{50(mm)}$	0.03
Median Depth (m)	2.50	%Fines	86
st.dev.	0.17	%PI	9
Depth to GWT (m)	0.80		
st.dev.	0.30		
σ_v (kPa)	43.85	q_c (MPa)	1.87
st.dev.	3.43	st.dev.	0.73
σ_v' (kPa)	27.17	f_s (kPa)	16.95
st.dev.	2.55	st.dev.	6.35
a_{max} (g)	0.40	norm. exp.	0.62
st.dev.	0.10	C_q, C_f	2.00
r_d	0.94	C_{thin}	1.00
st.dev.	0.05	f_{s1} (kPa)	33.90
M_w	7.40	st.dev.	12.69
st.dev.	0.11	q_{c1} (MPa)	3.74
CSR_{eq}	0.39	st.dev.	1.46
st.dev.	0.11	$R_{f1}(\%)$	0.91
C.O.V. _{CSR}	0.28	stdev	0.49

1999 Kocaeli, Turkey
Adapazari Site K

UCB-BYU-UCLA ZETAŞ-SaU Joint Research	Project Name: Ground Failure and Building Performance in Adapazari, Turkey Location: Site K - Kavaklar Avenue, Tığlar District, Adapazarı GPS Coordinates: 40.7775°N 30.4034°E Test Number: CPT-K1 Type of Cone: ELC10 CF No. 990618 (a.p. v.d. Berg) File Name: cptk1.txt Operator: ZETAŞ (Zemin Teknolojisi, A. Ş.) Notes: Probed with percussion hammer 75 cm to check for utilities	Page: 1 of 1 Elevation: 0 cm with respect to CPT-K1 Date: July 18, 2000 18:09 Water Table Elevation: Not measured Responsible Engineers: J. D. Bray and R. B. Sancio, U. C. Berkeley
Sponsored by: NSF, PEER Caltrans, CEC, PG&E		



Earthquake: 1999 Kocaeli, Turkey
Magnitude: $M_w=7.4$
Location: Adapazari Site L
References: PEER (2000), Sancio (2001), Sancio (2002)
Nature of Failure: Bldg settlement and liquefaction

Comments:

Adapazari strong motion station distance of 4km gave 0.4 g.

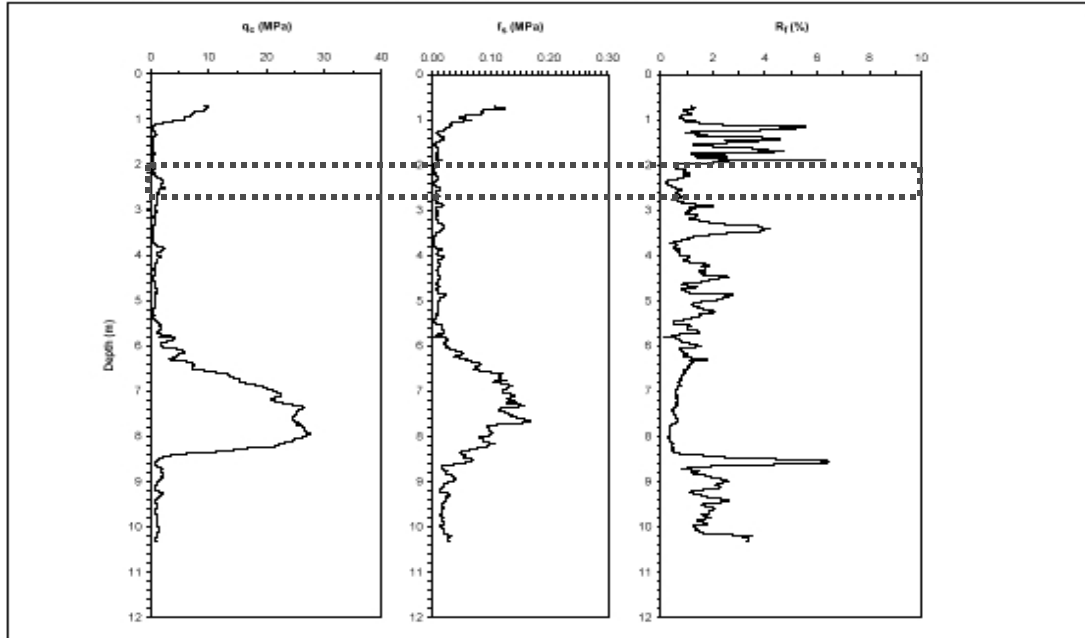
Site response analysis gives 0.3-0.4g

Summary of Data:

Stress		Strength	
Liquefied	Y		
Data Class	B	Soil Class	ML
Critical Layer (m)	2.0 to 2.8	$D_{50(mm)}$	0.05
Median Depth (m)	2.38	%Fines	74
st.dev.	0.13	%PI	na
Depth to GWT (m)	1.72		
st.dev.	0.30		
σ_v (kPa)	38.78	q_c (MPa)	1.30
st.dev.	2.75	st.dev.	0.62
σ_v' (kPa)	32.35	f_s (kPa)	7.41
st.dev.	2.46	st.dev.	3.03
a_{max} (g)	0.40	norm. exp.	0.75
st.dev.	0.10	C_q, C_f	2.00
r_d	0.94	C_{thin}	1.00
st.dev.	0.05	f_{s1} (kPa)	14.82
M_w	7.40	st.dev.	6.07
st.dev.	0.11	q_{c1} (MPa)	2.61
CSR_{eq}	0.29	st.dev.	1.24
st.dev.	0.08	$R_{f1}(\%)$	0.57
C.O.V. _{CSR}	0.27	stdev	0.36

1999 Kocaeli, Turkey
 Adapazari Site L

UCB-BYU-UCLA ZETAŞ-SaU Joint Research	Project Name: Ground Failure and Building Performance in Adapazari, Turkey	Page: 1 of 1
	Location: Site L - Ankara Avenue, Orta District, Adapazari	Elevation: 0 cm with respect to CPT-L1
Sponsored by: NSF, PEER Caltrans, CEC, PG&E	GPS Coordinates: 40.77855°N 30.40272°E	Date: July 18, 2000 08:30
	Test Number: CPT-L1	Water Table Elevation: Not measured
	Type of Cone: ELC10 CF No.990618 (a.p. v.d. Berg)	Operator: ZETAŞ (Zemin Teknolojisi, A. Ş.)
	File Name: cpt1.txt	Responsible Engineers: J. D. Bray and R. B. Sancio, U. C. Berkeley
Notes: Probed with percussion hammer 70 cm to check for utilities		



Chi-Chi Event

This large $M_w=7.6$, thrust event, occurred near the town of Chi-Chi in central Taiwan, on September 21, 1999. Primary rupture occurred on the Chelungpu fault with vertical offsets on the order of 4-8 m. Large amounts of seismic induced liquefaction and other forms of ground damage were observed.

There are two groups of case histories, the first group was collected and reported by Jon Stewart via PEER (2000). The second group was collected by Taiwan NCREE and posted via PEER (2000). A number of the NCREE sites did not have water table measurements in the direct vicinity of the CPT logs. Because water table is a sensitive parameter in liquefaction analysis, the sites lacking water tables measurements were omitted from this database.

The PEER website contains site information including SPT and CPT logs, and site maps. PGA estimates were based predominantly on strong motion recordings, as Taiwan has an extensive strong motion network.

References

- PEER (2000). "Documentation of Soil Conditions at Liquefaction Sites from 1999 Chi-Chi, Taiwan Earthquake." <http://www.cce.ucla.edu/faculty/Taiwanwebpage/Main.htm>
- Stewart, J.P. (2002) Personal Communication.
- Stewart, J.P. coordinator (2001). "Chapter 4: Soil Liquefaction. Chi-Chi, Taiwan Earthquake of September 21, 1999 Reconnaissance Report." Earthquake Spectra, Vol. 17, Supplement A, p. 37-60.
- Stewart, J.P., Chu, D.B., Lee, S., Tsai, J.S., Lin, P.S., Chu, B.L., Moss, R.E.S., Seed, R.B., and Hsu, S. (2003). Liquefaction and non-liquefaction from 1999 Chi-Chi, Taiwan, Earthquake." Proc. 6th U.S. Conference and Workshop on Lifeline Earthquake Engineering.

Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Nantou Site C, NCC-1, 2, & 3 and NCS-1
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Lateral spreading and sand boils

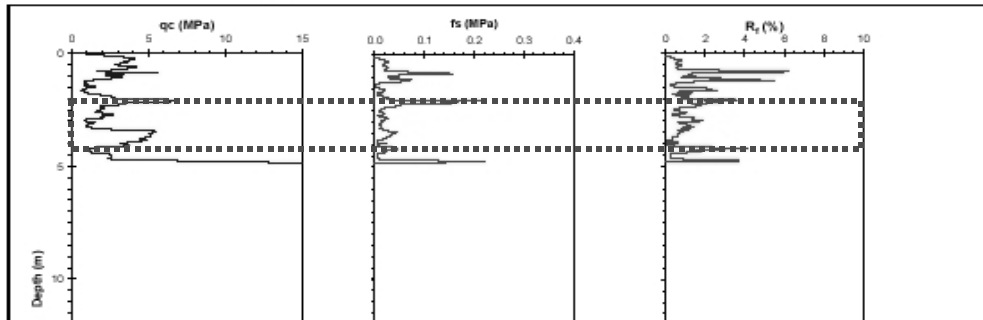
Comments: PGA=0.5 recorded nearby
 sand w/ gravel to silty sand

Summary of Data:

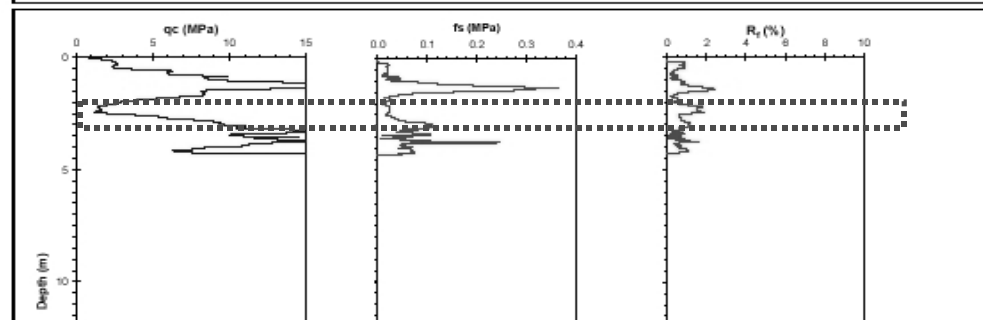
Stress		Strength	
Liquefied	Y		
Data Class	B	Soil Class	SP-SM
Critical Layer (m)	2.0 to 4.5	$D_{50(mm)}$	0.08
Median Depth (m)	3.25	%Fines	38
st.dev.	0.42	%PI	na
Depth to GWT (m)	1.00		
st.dev.	0.30		
σ_v (kPa)	58.75	q_c (MPa)	2.54
st.dev.	8.12	st.dev.	1.18
σ_v' (kPa)	36.68	f_s (kPa)	23.39
st.dev.	3.65	st.dev.	11.41
a_{max} (g)	0.38	norm. exp.	0.56
st.dev.	0.08	C_q, C_f	1.75
r_d	0.92	C_{thin}	1.00
st.dev.	0.06	f_{s1} (kPa)	41.01
M_w	7.60	st.dev.	20.02
st.dev.	0.10	q_{c1} (MPa)	4.46
CSR_{eq}	0.36	st.dev.	2.07
st.dev.	0.10	$R_{f1}(\%)$	1.11
C.O.V. _{CSR}	0.27	stdev	0.62

1999 Chi-Chi, Taiwan
 Nantou Site C, NCC-1, 2, & 3 and NCS-1

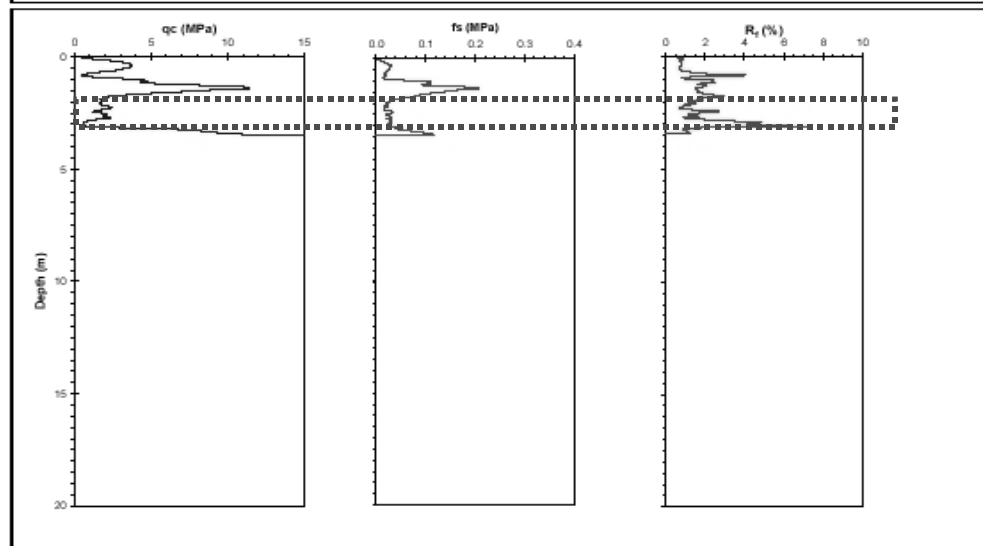
UCLA	Project Name: PEER Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Miao-Lo River, Nantou, Taiwan	
	GPS Coordinates: N23.91594°, E120.69296°	
	Test Number: NCC-1	Survey Coordinates (m):
Sponsored by:	Type of Cone: ELC10 CF No. 627	Elevation (m):
PEER, Caltrans, CEC	File Name: NCC1.XLS	Date: 3-Oct-01
& PG&E	Operator: Yang, RESI	Water Table Elevation (m):
	Notes:	Responsible Engineers: D. Chu, UCLA



UCLA	Project Name: PEER Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Miao-Lo River, Nantou, Taiwan	
	GPS Coordinates: N23.91576°, E120.69312°	
	Test Number: NCC-2	Survey Coordinates (m):
Sponsored by:	Type of Cone: ELC10 CF No. 627	Elevation (m):
PEER, Caltrans, CEC	File Name: NAC1.XLS	Date: 3-Oct-01
& PG&E	Operator: Yang, RESI	Water Table Elevation (m):
	Notes:	Responsible Engineers: D. Chu, UCLA



UCLA	Project Name: PEER Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Miao-Lo River, Nantou, Taiwan	
	GPS Coordinates: N23.91551°, E120.69328°	
	Test Number: NCC-3	Survey Coordinates (m):
Sponsored by:	Type of Cone: ELC10 CF No. 627	Elevation (m):
PEER, Caltrans, CEC	File Name: NAC1.XLS	Date: 3-Oct-01
& PG&E	Operator: Yang, RESI	Water Table Elevation (m):
	Notes:	Responsible Engineers: D. Chu, UCLA



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: WuFeng Site A West Side, WAC-6 & WAS-2
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Corner punching of large buildings

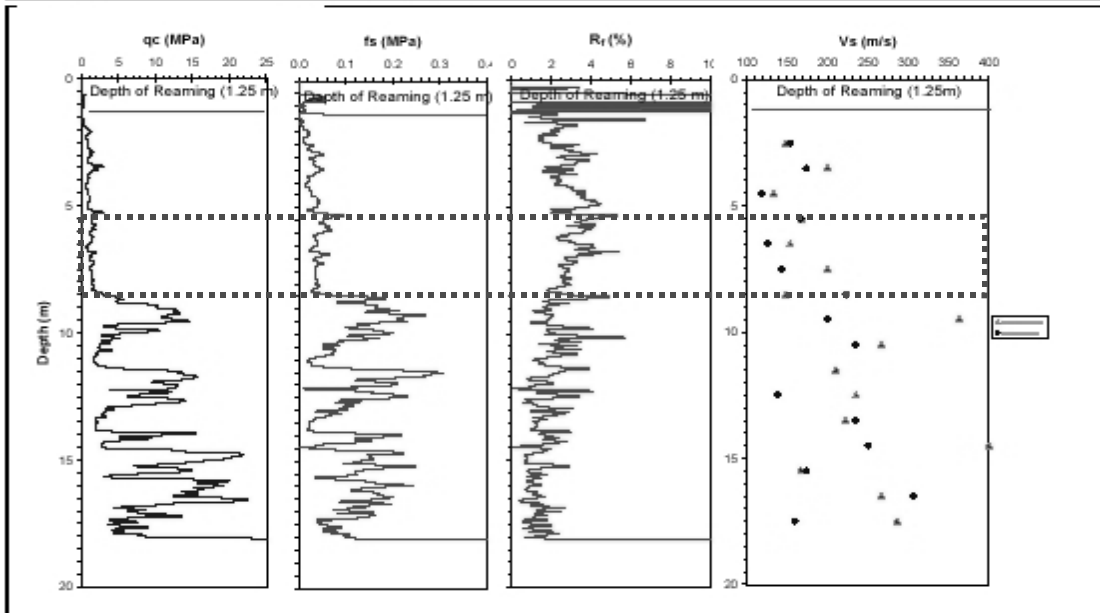
Comments: Large amount of bearing failure of structures.

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	ML
Data Class	B	$D_{50(mm)}$	0.04
Critical Layer (m)	5.5 to 8.5	%Fines	88
Median Depth (m)	7.00	%PI	5
st.dev.	0.50		
Depth to GWT (m)	0.80	q_c (MPa)	0.75
st.dev.	0.30	st.dev.	0.29
σ_v (kPa)	130.60	f_s (kPa)	15.42
st.dev.	10.35	st.dev.	7.08
σ_v' (kPa)	69.78	norm. exp.	0.75
st.dev.	5.46	C_q, C_f	1.31
a_{max} (g)	0.60	C_{thin}	1.00
st.dev.	0.12	f_{s1} (kPa)	20.20
r_d	0.71	st.dev.	9.27
st.dev.	0.12	q_{c1} (MPa)	0.99
M_w	7.60	st.dev.	0.38
st.dev.	0.10	$R_{f1}(\%)$	2.14
CSR_{eq}	0.52	stdev	0.66
st.dev.	0.15		
C.O.V. _{CSR}	0.29		

1999 Chi-Chi, Taiwan
 WuFeng Site A West Side, WAC-6 & WAS-2

UCLA	Project Name: PEER Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Lan-Shen Day Care Center Site, Wufeng, Taiwan	
	GPS Coordinates: N 24°3'24", E 120°41'48"	Survey Coordinates (m): N 2861335, E 219136
	Test Number: WAC-6	Elevation: 55.596
	Type of Cone: ELC10 CF No. 627	Date: 26-Sep-01
Sponsored by: PEER, Caltrans, CEC & PG&E	File Name: WAC6.XLS Operator: Yang, RESI	Water Table Elevation: 54.3 Responsible Engineers: D. Chu, UCLA
	Notes: Ream down to 1.25 m	



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: WuFeng Site B: WBC-1, 2, & 4 and WBS-1
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Lateral spreading and sand boils

Comments: In the parking lot next to the driving range.

Strong motion station in the direct vicinity on similar soil stratigraphy, $PGA=0.6$.

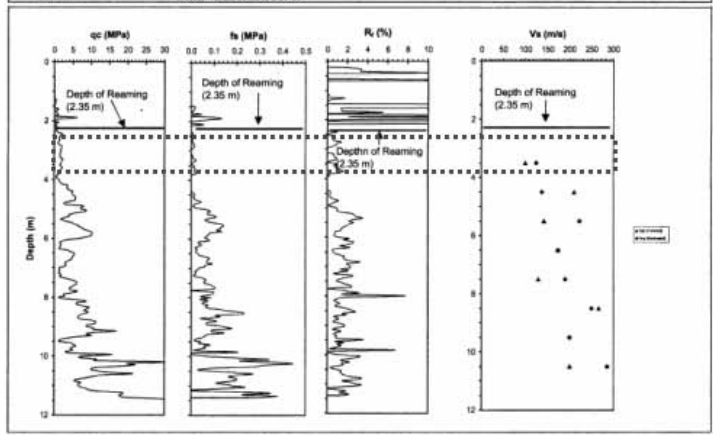
Borings are back from a 2 m free face along channel.

Reaming with a dummy cone was used to get through pavement and fill.

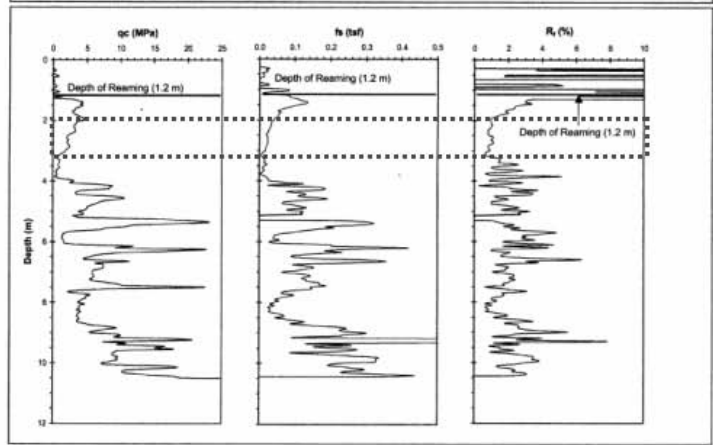
Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	SM
Data Class	B	$D_{50(mm)}$	0.10
Critical Layer (m)	2.5 to 5.0	%Fines	35
Median Depth (m)	4.25	%PI	na
st.dev.	0.42		
Depth to GWT (m)	1.12		
st.dev.	0.30	q_c (MPa)	2.12
σ_v (kPa)	77.39	st.dev.	0.78
st.dev.	8.25	f_s (kPa)	20.32
σ_v' (kPa)	46.68	st.dev.	10.56
st.dev.	3.92	norm. exp.	0.55
a_{max} (g)	0.60	C_q, C_f	1.52
st.dev.	0.12	C_{thin}	1.00
r_d	0.85	f_{s1} (kPa)	30.90
st.dev.	0.08	st.dev.	16.05
M_w	7.60	q_{c1} (MPa)	3.22
st.dev.	0.10	st.dev.	1.19
CSR_{eq}	0.55	$R_{f1}(\%)$	0.96
st.dev.	0.14	stdev	0.61
C.O.V. _{CSR}	0.26		

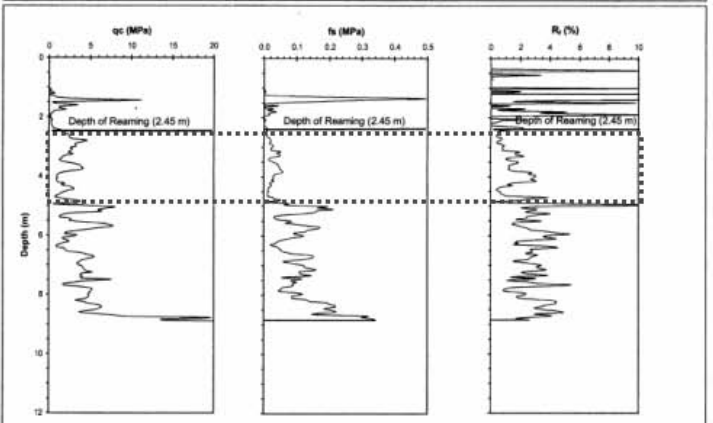
UCLA Project Name: PEER Taiwan Chi-Chi Earthquake Liquefaction Research Project Page: 1 of 1
 Location: Provincial Council Parking, Wufeng, Taiwan
 GPS Coordinates: N 24°3'13", E 120°41'57" Survey Coordinates (m): N 2060971, E 219395
 Test Number: WBC-2 Elevation: 58.721
 Type of Case: ELC10 CF No. 627 Date: 25-Sep-01
 File Name: WBC2.XLS Water Table Elevation: 57.5
 Operator: Yang, RESI Responsible Engineers: D. Chu, UCLA
 Notes: Risen down to 2.35 m



UCLA Project Name: PEER Taiwan Chi-Chi Earthquake Liquefaction Research Project Page: 1 of 1
 Location: Provincial Council Parking, Wufeng, Taiwan
 GPS Coordinates: N 24°3'12", E 120°41'56" Survey Coordinates (m): N 2060982, E 219370
 Test Number: WBC-4 Elevation: 58.288
 Type of Case: ELC10 CF No. 627 Date: 25-Sep-01
 File Name: WBC4.XLS Water Table Elevation: 57.0
 Operator: Yang, RESI Responsible Engineers: D. Chu, UCLA
 Notes: Risen down to 1.2 m



UCLA Project Name: PEER Taiwan Chi-Chi Earthquake Liquefaction Research Project Page: 1 of 1
 Location: Provincial Council Parking, Wufeng, Taiwan
 GPS Coordinates: N 24°3'13", E 120°41'56" Survey Coordinates (m): N 2060987, E 219371
 Test Number: WBC-1 Elevation: 58.122
 Type of Case: ELC10 CF No. 627 Date: 25-Sep-01
 File Name: WBC1.XLS Water Table Elevation (m): 57.0
 Operator: Yang, RESI Responsible Engineers: D. Chu, UCLA
 Notes: Risen down to 2.45 m



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: WuFeng Site C: WCC-6-11 & WCS-2
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Lateral spreading and sand boils

Comments: Located in rice paddy.

Borings are set back from low angle free face of channel.

Strong motion station in the direct vicinity founded on similar soil stratigraphy, $PGA=0.6$.

Used wcc6 & 9 for cone readings

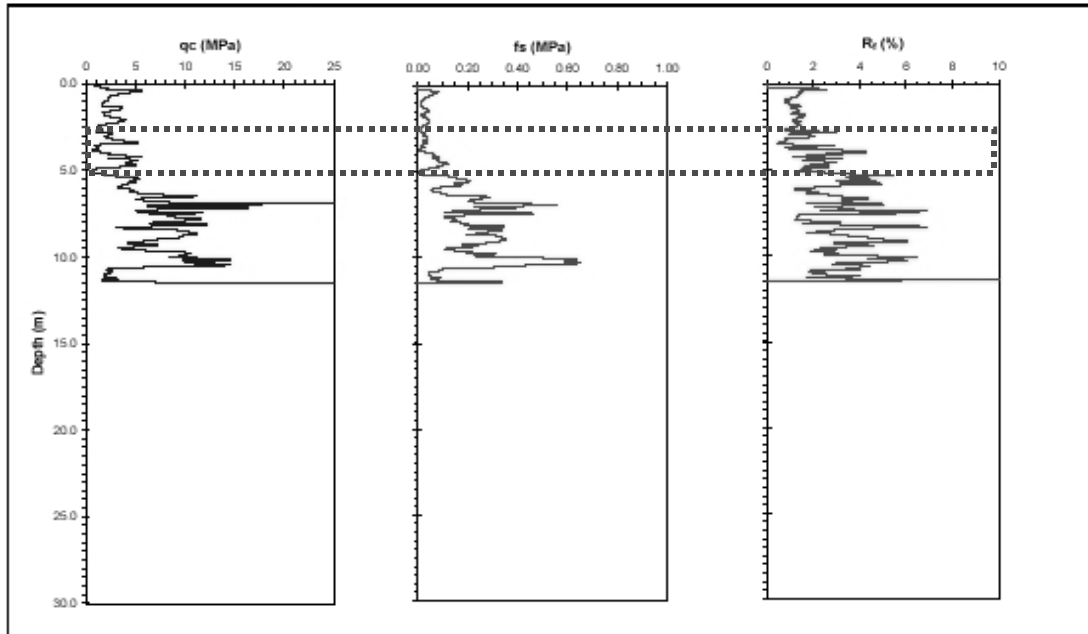
Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	SM
Data Class	B	$D_{50(mm)}$	0.17
Critical Layer (m)	2.5 to 5.5	%Fines	14
Median Depth (m)	4.00	%PI	na
st.dev.	0.50		
Depth to GWT (m)	1.20		
st.dev.	0.30		
σ_v (kPa)	72.40	q_c (MPa)	1.88
st.dev.	9.74	st.dev.	0.44
σ_v' (kPa)	44.93	f_s (kPa)	34.61
st.dev.	4.19	st.dev.	23.55
a_{max} (g)	0.60	norm. exp.	0.65
st.dev.	0.12	C_q, C_f	1.68
r_d	0.86	C_{thin}	1.00
st.dev.	0.08	f_{s1} (kPa)	58.22
M_w	7.60	st.dev.	39.61
st.dev.	0.10	q_{c1} (MPa)	3.16
CSR_{eq}	0.54	st.dev.	0.73
st.dev.	0.15	$R_{f1}(\%)$	1.84
C.O.V. _{CSR}	0.27	stdev	1.33

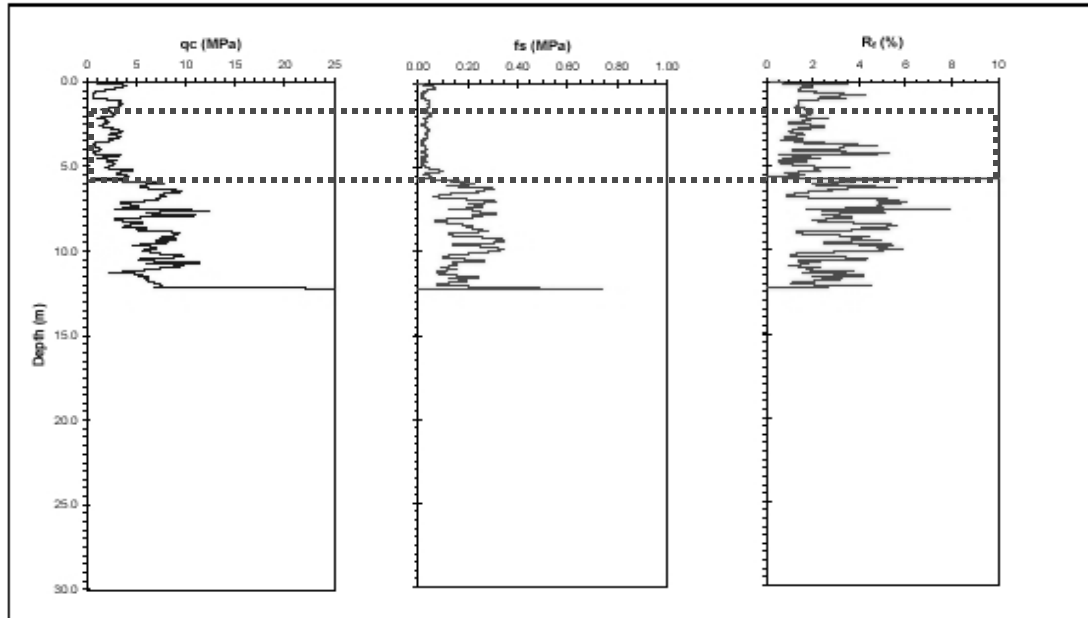
1999 Chi-Chi, Taiwan

WCC6

UCLA	Project Name: PEER Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Yue-The Rd. Rice Paddy	
	GPS Coordinates: N 24°3'12", E120°41'46"	Survey Coordinates (m): N 2660953, E 219091
	Test Number: WCC-6	Elevation (m): 56.11
Sponsored by: PEER, Caltrans, CEC & PG&E	Type of Cone: ELC10 CF No. 627	Date: 17-Jul-02
	File Name: WCC6.XLS	Water Table Elevation (m): 55.00
	Operator: Yang, RESI	Responsible Engineers: D. Chu, UCLA
	Notes:	



UCLA	Project Name: PEER Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Yue-The Rd. Rice Paddy	
	GPS Coordinates: N 24°3'12", E120°41'46"	Survey Coordinates (m): N 2660968, E 219079
	Test Number: WCC-9	Elevation (m): 56.12
Sponsored by: PEER, Caltrans, CEC & PG&E	Type of Cone: ELC10 CF No. 627	Date: 18-Jul-02
	File Name: WCC9.XLS	Water Table Elevation (m): 55.00
	Operator: Yang, RESI	Responsible Engineers: D. Chu, UCLA
	Notes:	



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Nantou Site C-3 & C-16 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

Comments:

liquefaction and sand boils

The critical layer is over the depth range of 12 to 16 m.

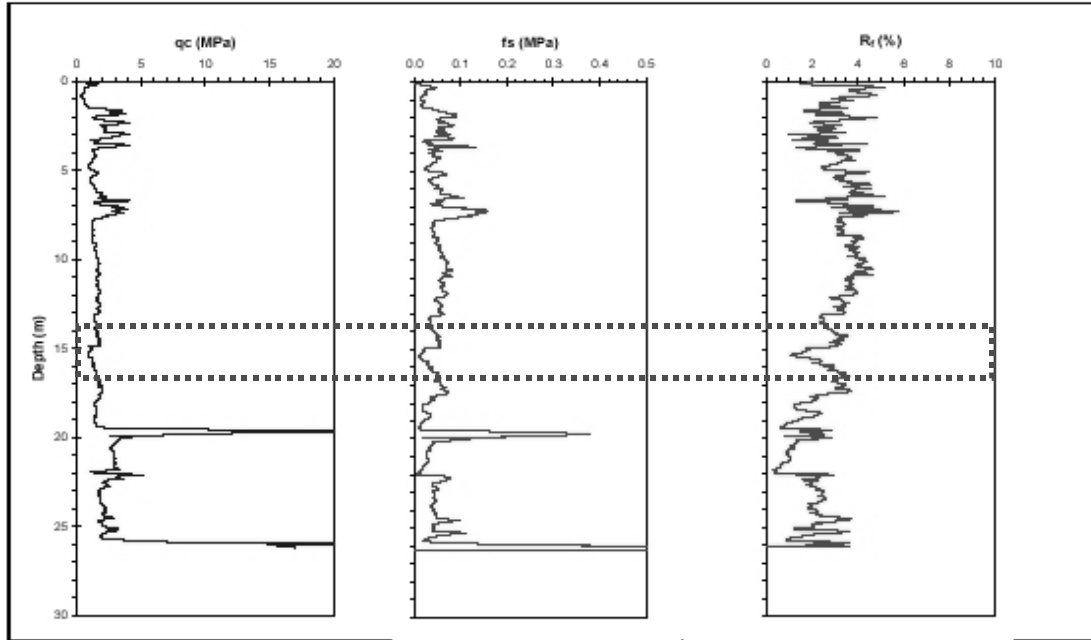
Summary of Data:

Stress		Strength	
Liquefied	Y		
Data Class	C	Soil Class	
Critical Layer (m)	12 to 16	$D_{50(mm)}$	
Median Depth (m)	14.00	%Fines	
st.dev.	0.67	%PI	
Depth to GWT (m)	1.00		
st.dev.	0.30		
σ_v (kPa)	263.00	q_c (MPa)	1.51
st.dev.	15.19	st.dev.	0.28
σ_v' (kPa)	135.47	f_s (kPa)	29.63
st.dev.	9.53	st.dev.	16.16
a_{max} (g)	0.38	norm. exp.	0.74
st.dev.	0.08	C_q, C_f	0.80
r_d	0.55	C_{thin}	1.00
st.dev.	0.20	f_{s1} (kPa)	23.67
M_w	7.60	st.dev.	12.91
st.dev.	0.10	q_{c1} (MPa)	1.21
CSR_{eq}	0.26	st.dev.	0.23
st.dev.	0.11	$R_{f1}(\%)$	1.96
C.O.V. _{CSR}	0.42	stdev	1.13

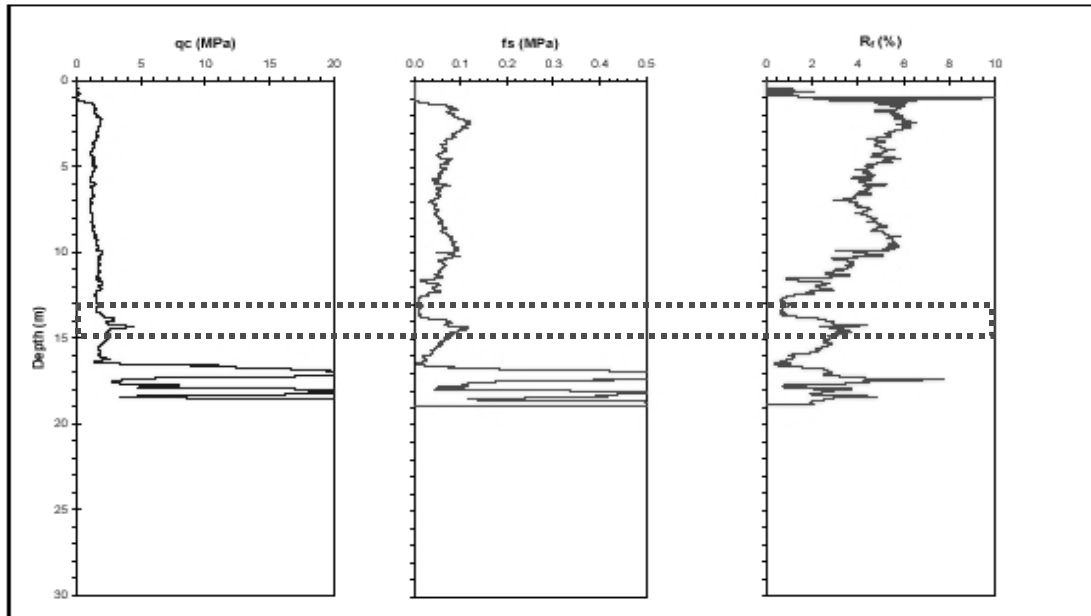
1999 Chi-Chi, Taiwan

N

UCLA	Project Name: NCREE Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Nantou, Taiwan	
	GPS Coordinates:	Survey Coordinates (m): N 2648135.689 E217855.788
	Test Number: C-3	Elevation (m): 87.633
Sponsored by:	Type of Cone: 688TC	Date: 17-Dec-99
PEER, Caltrans, CEC & PG&E	File Name: NCREE-N-CPT3.xls	Water Table Elevation (m): 16.45
	Operator: Yu & Chen	Responsible Engineers: Moh and Associates
	Notes:	



UCLA	Project Name: NCREE Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Nantou, Taiwan	
	GPS Coordinates:	Survey Coordinates (m): N2648270.273 E217752.735
	Test Number: C-16	Elevation (m): 87.696
Sponsored by:	Type of Cone: 688TC	Date: 21-Jan-00
PEER, Caltrans, CEC & PG&E	File Name: NCREE-N-CPT16.xls	Water Table Elevation (m): 18.90
	Operator: Yu & Chen	Responsible Engineers: Moh and Associates
	Notes:	



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Nantou Site C-7 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

Comments:

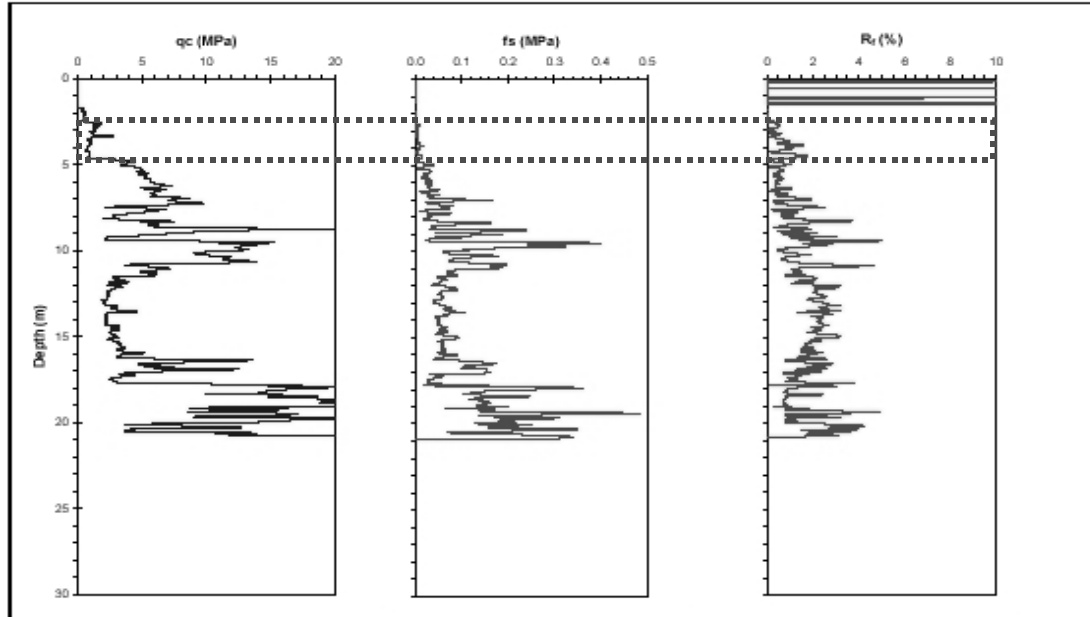
grnd failure and sand boils in banana field and along dike and road embankment pulled away from bridge abutment

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	2.5 to 4.5	%Fines	
Median Depth (m)	3.50	%PI	
st.dev.	0.33		
Depth to GWT (m)	1.00		
st.dev.	0.30	q_c (MPa)	1.16
σ_v (kPa)	63.50	st.dev.	0.43
st.dev.	6.63	f_s (kPa)	6.60
σ_v' (kPa)	38.98	st.dev.	4.37
st.dev.	3.38	norm. exp.	0.76
a_{max} (g)	0.38	C_q, C_f	2.00
st.dev.	0.08	C_{thin}	1.00
r_d	0.91	f_{s1} (kPa)	13.21
st.dev.	0.07	st.dev.	8.74
M_w	7.60	q_{c1} (MPa)	2.31
st.dev.	0.10	st.dev.	0.87
CSR_{eq}	0.37	$R_{f1}(\%)$	0.57
st.dev.	0.09	stdev	0.43
C.O.V. _{CSR}	0.25		

1999 Chi-Chi, Taiwan
Nantou Site C-7 NCREE

UCLA	Project Name: NCREE Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Nantou, Taiwan	
	GPS Coordinates:	Survey Coordinates (m): N2646223.803 E218321.788
	Test Number: C-7	Elevation (m): 88.79
Sponsored by: PEER, Caltrans, CEC & PG&E	Type of Cone: 688TC File Name: NCREE-N-CPT7.xls Operator: Yu & Chen	Date: 19-Feb-99 Water Table Elevation (m): 20.90 Responsible Engineers: Moh and Associates
	Notes:	



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Nantou Site C-8 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

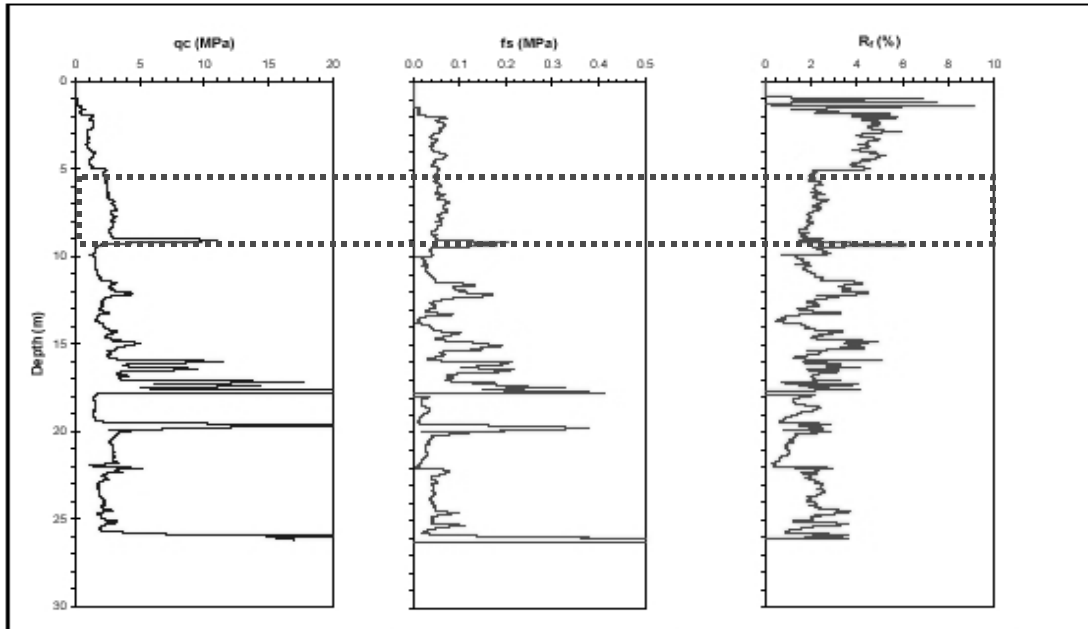
Comments:

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	5 to 9	%Fines	
Median Depth (m)	7.00	%PI	
st.dev.	0.67		
Depth to GWT (m)	1.00		
st.dev.	0.30		
σ_v (kPa)	130.00	q_c (MPa)	2.75
st.dev.	13.28	st.dev.	0.29
σ_v' (kPa)	71.14	f_s (kPa)	57.10
st.dev.	6.03	st.dev.	9.33
a_{max} (g)	0.38	norm. exp.	0.55
st.dev.	0.08	C_q, C_f	1.21
r_d	0.77	C_{thin}	1.00
st.dev.	0.12	f_{s1} (kPa)	68.86
M_w	7.60	st.dev.	11.25
st.dev.	0.10	q_{c1} (MPa)	3.31
CSR_{eq}	0.35	st.dev.	0.34
st.dev.	0.10	$R_{f1}(\%)$	2.08
C.O.V. _{CSR}	0.29	stdev	0.40

1999 Chi-Chi, Taiwan
Nantou Site C-8 NCREE

UCLA	Project Name: NCREE Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Nantou, Taiwan	
	GPS Coordinates:	Survey Coordinates (m): N2645559.573 E217867.935
	Test Number: C-8	Elevation (m): 89.069
Sponsored by:	Type of Cone: 688TC	Date: 18-Dec-99
PEER, Caltrans, CEC & PG&E	File Name: NCREE-N-CPT8.xls	Water Table Elevation (m): 17.80
	Operator: Yu & Chen	Responsible Engineers: Moh and Associates
	Notes:	



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: WuFeng Site C-10 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction, lateral Spreading, and foundation failure.

Comments:

across the river from site C

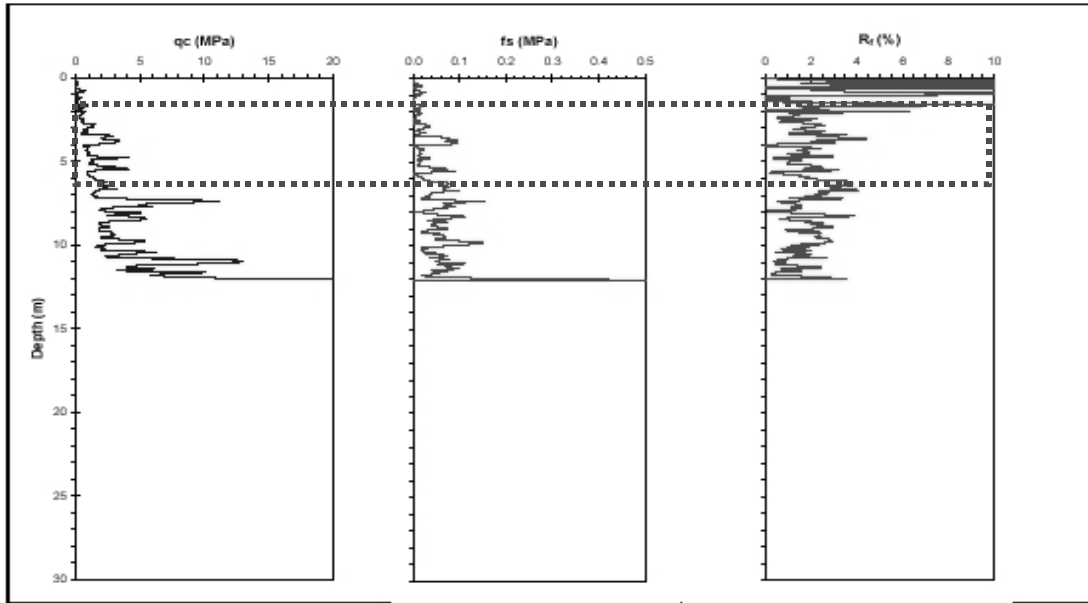
additional data from RESI

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	2.5 to 7.0	%Fines	
Median Depth (m)	4.75	%PI	
st.dev.	0.75		
Depth to GWT (m)	1.00		
st.dev.	0.30	q_c (MPa)	1.70
σ_v (kPa)	87.25	st.dev.	0.91
st.dev.	14.49	f_s (kPa)	36.96
σ_v' (kPa)	50.46	st.dev.	30.92
st.dev.	5.65	norm. exp.	0.58
a_{max} (g)	0.60	C_q, C_f	1.49
st.dev.	0.12	C_{thin}	1.00
r_d	0.82	f_{s1} (kPa)	54.95
st.dev.	0.09	st.dev.	45.98
M_w	7.60	q_{c1} (MPa)	2.52
st.dev.	0.10	st.dev.	1.36
CSR_{eq}	0.55	$R_{f1}(\%)$	2.18
st.dev.	0.17	stdev	2.16
C.O.V. _{CSR}	0.30		

1999 Chi-Chi, Taiwan
WuFeng Site C-10 NCREE

UCLA	Project Name: NCREE Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Wufeng, Taiwan	
	GPS Coordinates:	Survey Coordinates (m): N2661221.47 E218349.006
	Test Number: U-C-10	Elevation (m): 56.881
Sponsored by:	Type of Cone: 688TC	Date: 21-Dec-99
PEER, Caltrans, CEC & PG&E	File Name: NCREE-W-CPT10.xls	Water Table Elevation (m): 12.15
	Operator: Yu & Chen	Responsible Engineers: Moh and Associates
	Notes:	



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Yuanlin C-2 & BH-3 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

Comments:

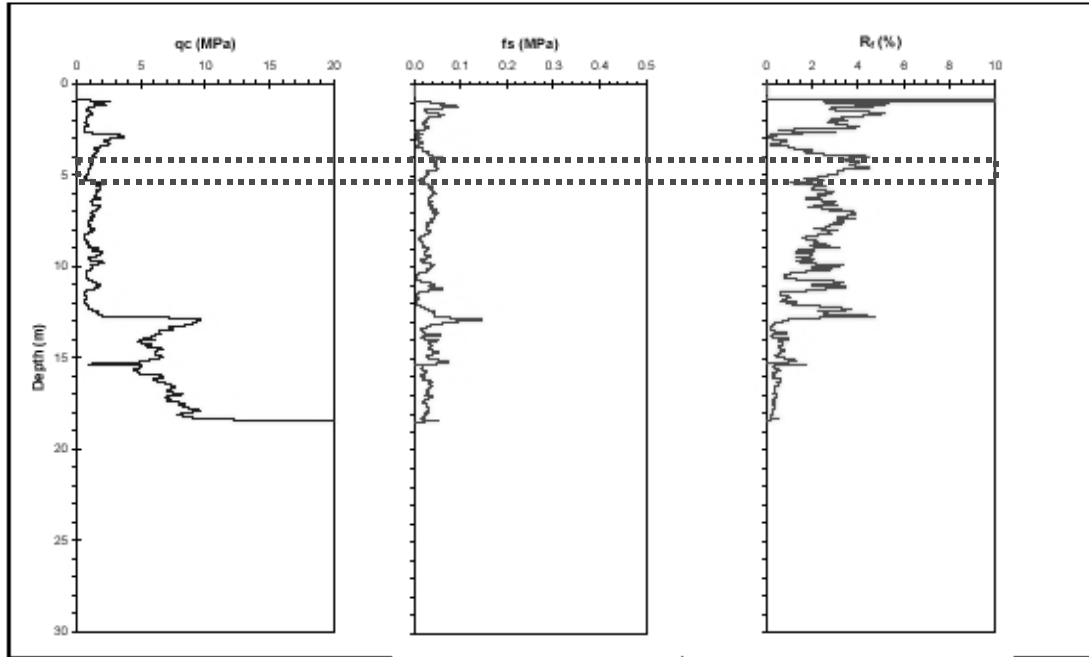
Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	2.5 to 4.0	%Fines	
Median Depth (m)	3.25	%PI	
st.dev.	0.25		
Depth to GWT (m)	0.56		
st.dev.	0.30		
σ_v (kPa)	60.07	q_c (MPa)	2.48
st.dev.	5.14	st.dev.	0.77
σ_v' (kPa)	33.68	f_s (kPa)	12.22
st.dev.	3.11	st.dev.	5.70
a_{max} (g)	0.25	norm. exp.	0.75
st.dev.	0.05	C_q, C_f	2.00
r_d	0.93	C_{thin}	1.00
st.dev.	0.06	f_{s1} (kPa)	24.44
M_w	7.60	st.dev.	11.41
st.dev.	0.10	q_{c1} (MPa)	4.95
CSR_{eq}	0.27	st.dev.	1.55
st.dev.	0.07	$R_{f1}(\%)$	0.49
C.O.V. _{CSR}	0.24	stdev	0.28

1999 Chi-Chi, Taiwan

Y1

UCLA	Project Name: NCREE Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Yuanlin, Taiwan	
	GPS Coordinates:	Survey Coordinates (m): N 2653689 E 205641
	Test Number: C-2	Elevation (m): 19.498
Sponsored by:	Type of Cone: 68RTC	Date: 19-Nov-99
PEER, Caltrans, CEC	File Name: NCREE-Y-CPT2.xls	Water Table Elevation (m): 18.94
& PG&E	Operator: Yu & Chen	Responsible Engineers: Moh and Associates
	Notes:	



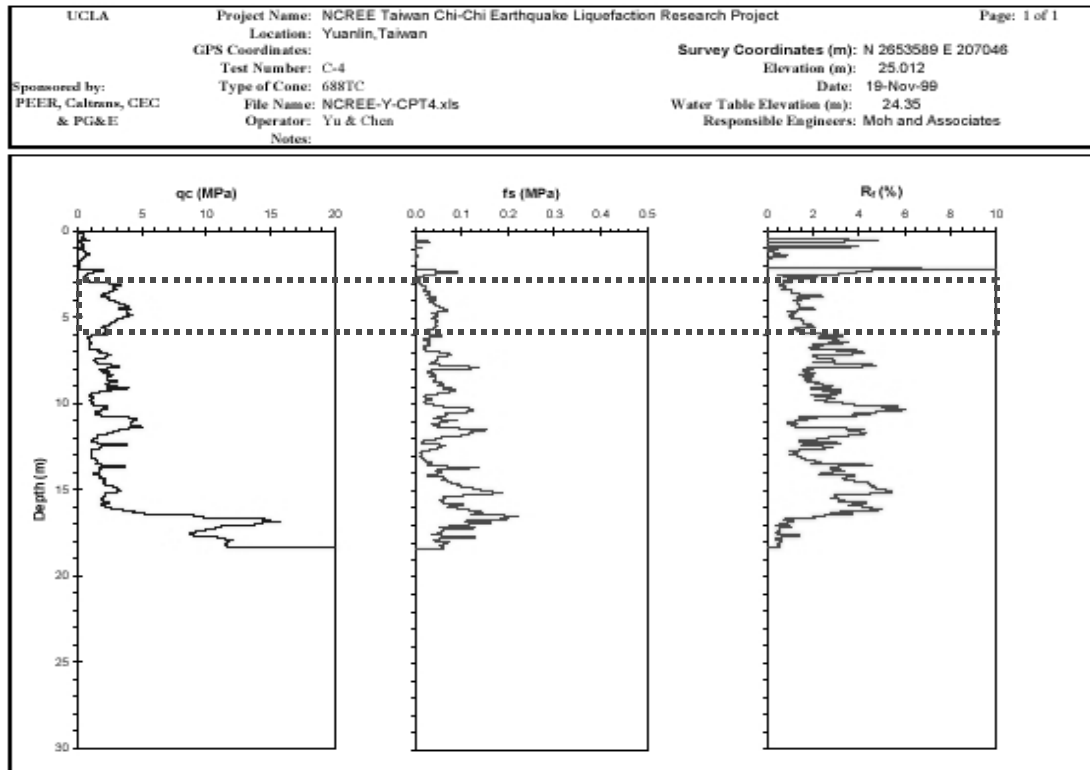
Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Yuanlin C-4 & BH-5 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

Comments:

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	3 to 6	%Fines	
Median Depth (m)	4.50	%PI	
st.dev.	0.50		
Depth to GWT (m)	0.66		
st.dev.	0.30	q_c (MPa)	2.99
σ_v (kPa)	83.52	st.dev.	0.71
st.dev.	9.86	f_s (kPa)	38.80
σ_v' (kPa)	45.85	st.dev.	38.92
st.dev.	4.47	norm. exp.	0.55
a_{max} (g)	0.25	C_q, C_f	1.54
st.dev.	0.05	C_{thin}	1.00
r_d	0.89	f_{s1} (kPa)	59.57
st.dev.	0.08	st.dev.	59.76
M_w	7.60	q_{c1} (MPa)	4.60
st.dev.	0.10	st.dev.	1.09
CSR_{eq}	0.26	$R_{f1}(\%)$	1.30
st.dev.	0.07	stdev	1.34
C.O.V. _{-CSR}	0.27		

1999 Chi-Chi, Taiwan
Yuanlin C-4 & BH-5 NCREE



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Yuanlin C-19 & BH-25 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

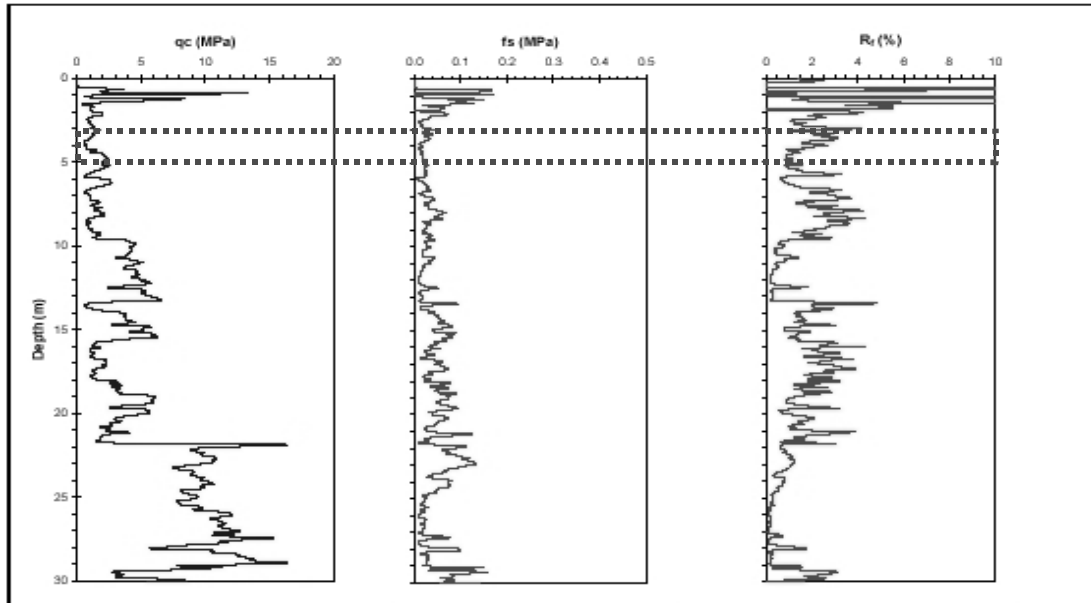
Comments:

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	4.0 to 5.8	%Fines	
Median Depth (m)	6.50	%PI	
st.dev.	0.30		
Depth to GWT (m)	0.57		
st.dev.	0.30	q_c (MPa)	2.06
σ_v (kPa)	121.79	st.dev.	0.40
st.dev.	6.92	f_s (kPa)	22.23
σ_v' (kPa)	63.62	st.dev.	4.25
st.dev.	4.71	norm. exp.	0.67
a_{max} (g)	0.25	C_q, C_f	1.35
st.dev.	0.05	C_{thin}	1.00
r_d	0.82	f_{s1} (kPa)	30.10
st.dev.	0.11	st.dev.	5.76
M_w	7.60	q_{c1} (MPa)	2.78
st.dev.	0.10	st.dev.	0.54
CSR_{eq}	0.25	$R_{f1}(\%)$	1.08
st.dev.	0.07	stdev	0.29
C.O.V. _{CSR}	0.26		

1999 Chi-Chi, Taiwan
Yuanlin C-19 & BH-25 NCREE

UCLA	Project Name: NCREE Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Yuanlin, Taiwan	
	GPS Coordinates:	Survey Coordinates (m): N 2649876 E 205529
	Test Number: C-19	Elevation (m): 25.345
Sponsored by:	Type of Cone: 688TC	Date: 06-Nov-99
PEER, Caltrans, CEC	File Name: NCREE-Y-CPT19.xls	Water Table Elevation (m): 24.78
& PG&E	Operator: Yu & Chen	Responsible Engineers: Moh and Associates
	Notes:	



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Yuanlin C-22 & BH-30 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

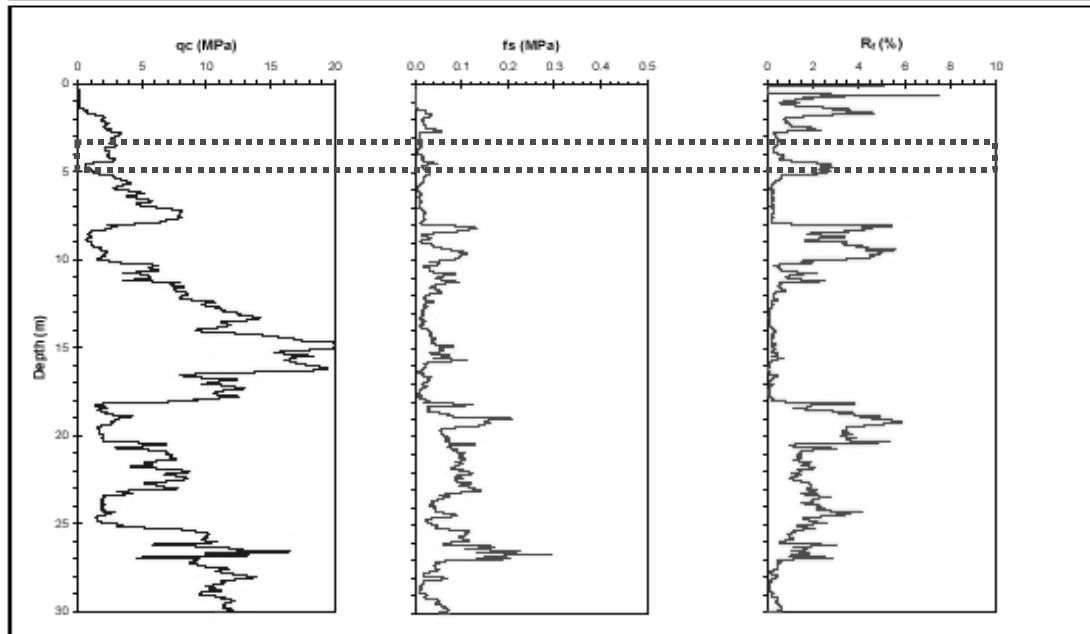
Comments:

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	2.8 to 4.2	%Fines	
Median Depth (m)	3.50	%PI	
st.dev.	0.23		
Depth to GWT (m)	1.13		
st.dev.	0.30	q_c (MPa)	2.72
σ_v (kPa)	63.11	st.dev.	0.37
st.dev.	4.83	f_s (kPa)	12.59
σ_v' (kPa)	39.86	st.dev.	4.34
st.dev.	3.01	norm. exp.	0.70
a_{max} (g)	0.25	C_q, C_f	1.90
st.dev.	0.05	C_{thin}	1.00
r_d	0.92	f_{s1} (kPa)	23.97
st.dev.	0.07	st.dev.	8.27
M_w	7.60	q_{c1} (MPa)	5.17
st.dev.	0.10	st.dev.	0.70
CSR_{eq}	0.24	$R_{f1}(\%)$	0.46
st.dev.	0.06	stdev	0.17
C.O.V. _{CSR}	0.24		

1999 Chi-Chi, Taiwan
Yuanlin C-22 & BH-30 NCRFF

UCLA	Project Name: NCRFF Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Yuanlin, Taiwan	
	GPS Coordinates:	Survey Coordinates (m): N 2649901 E 208076
	Test Number: C-22	Elevation (m): 29.382
	Type of Cone: 688TC	Date: 07-Nov-99
Sponsored by: PEER, Caltrans, CEC & PG&E	File Name: NCRFF-Y-CPT22.xls	Water Table Elevation (m): 28.25
	Operator: Yu & Chen	Responsible Engineers: Moh and Associates
	Notes:	



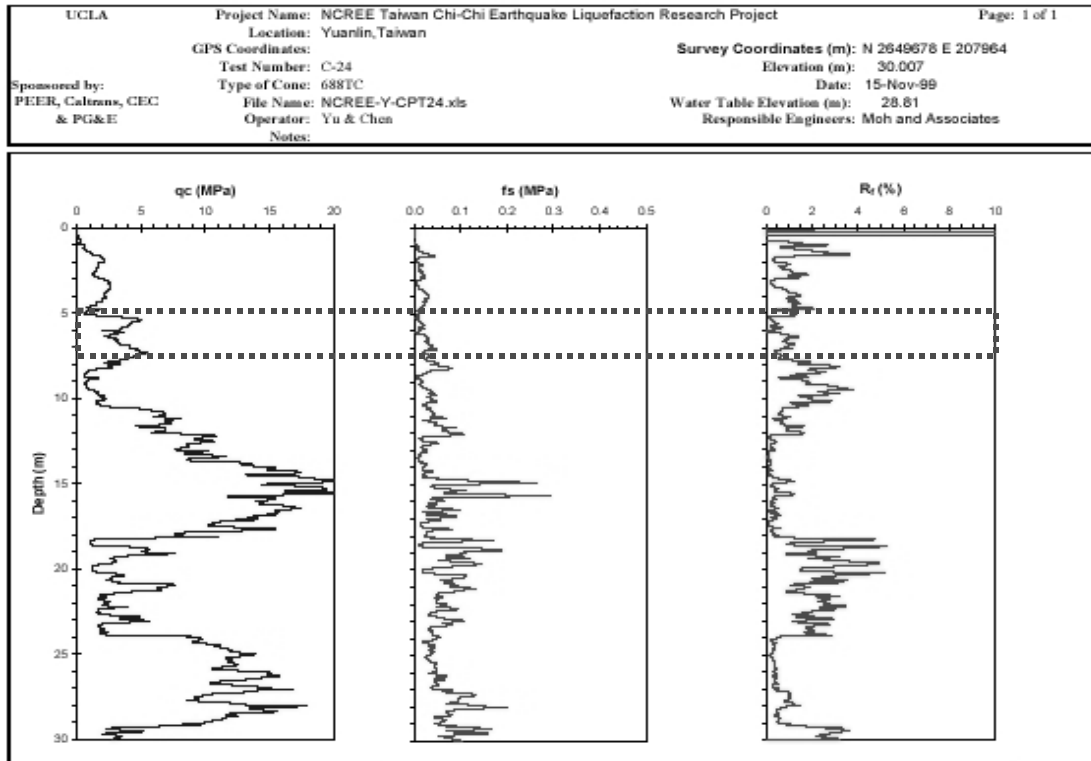
Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Yuanlin C-24 & BH-29 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

Comments:

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	5.2 to 7.8	%Fines	
Median Depth (m)	6.20	%PI	
st.dev.	0.33		
Depth to GWT (m)	1.20		
st.dev.	0.30	q_c (MPa)	3.87
σ_v (kPa)	114.20	st.dev.	0.90
st.dev.	7.19	f_s (kPa)	23.27
σ_v' (kPa)	65.15	st.dev.	8.39
st.dev.	4.39	norm. exp.	0.75
a_{max} (g)	0.25	C_q, C_f	1.38
st.dev.	0.05	C_{thin}	1.00
r_d	0.83	f_{s1} (kPa)	32.09
st.dev.	0.11	st.dev.	11.57
M_w	7.60	q_{c1} (MPa)	5.33
st.dev.	0.10	st.dev.	1.24
CSR_{eq}	0.24	$R_{f1}(\%)$	0.60
st.dev.	0.06	stdev	0.26
C.O.V. _{CSR}	0.26		

1999 Chi-Chi, Taiwan
Yuanlin C-24 & BH-29 NCREE



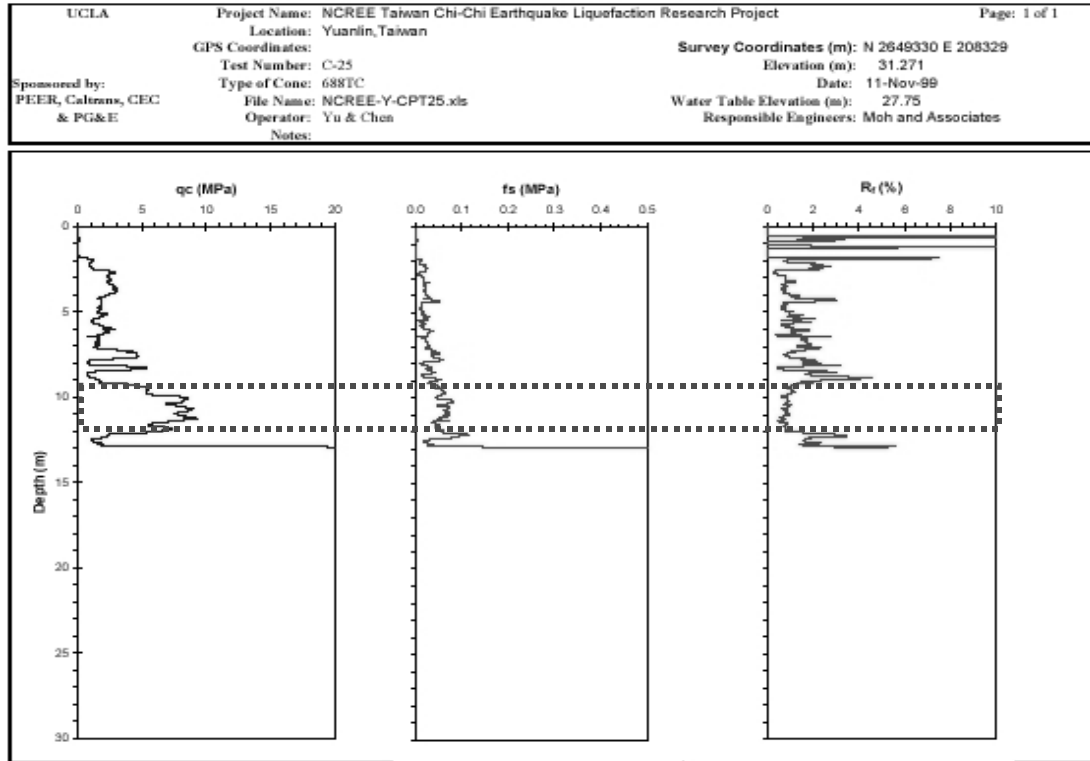
Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Yuanlin C-25 & BH-47 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

Comments:

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	9.5 to 12	%Fines	
Median Depth (m)	10.75	%PI	
st.dev.	0.42		
Depth to GWT (m)	3.52		
st.dev.	0.30	q_c (MPa)	7.74
σ_v (kPa)	193.69	st.dev.	1.09
st.dev.	9.49	f_s (kPa)	61.67
σ_v' (kPa)	122.76	st.dev.	12.21
st.dev.	6.11	norm. exp.	0.61
a_{max} (g)	0.25	C_q, C_f	0.88
st.dev.	0.05	C_{thin}	1.00
r_d	0.67	f_{s1} (kPa)	54.42
st.dev.	0.18	st.dev.	10.77
M_w	7.60	q_{c1} (MPa)	6.83
st.dev.	0.10	st.dev.	0.97
CSR_{eq}	0.17	$R_{f1}(\%)$	0.80
st.dev.	0.06	stdev	0.19
C.O.V. _{CSR}	0.34		

1999 Chi-Chi, Taiwan
Yuanlin C-25 & BH-47 NCREE



Earthquake: 1999 Chi-Chi, Taiwan
Magnitude: $M_w=7.6$
Location: Yuanlin C-32 & BH-21 NCREE
References: PEER (2000), Stewart (2002, 2003)
Nature of Failure: Liquefaction

Comments:

Summary of Data:

Stress		Strength	
Liquefied	Y	Soil Class	
Data Class	B	$D_{50(mm)}$	
Critical Layer (m)	4.5 to 7.5	%Fines	
Median Depth (m)	6.00	%PI	
st.dev.	0.50		
Depth to GWT (m)	0.74		
st.dev.	0.30	q_c (MPa)	3.39
σ_v (kPa)	111.78	st.dev.	1.05
st.dev.	10.13	f_s (kPa)	21.03
σ_v' (kPa)	60.18	st.dev.	6.66
st.dev.	5.03	norm. exp.	0.70
a_{max} (g)	0.25	C_q, C_f	1.43
st.dev.	0.05	C_{thin}	1.00
r_d	0.84	f_{s1} (kPa)	30.01
st.dev.	0.11	st.dev.	9.50
M_w	7.60	q_{c1} (MPa)	4.83
st.dev.	0.10	st.dev.	1.49
CSR_{eq}	0.25	$R_{f1}(\%)$	0.62
st.dev.	0.07	stdev	0.27
C.O.V. _{CSR}	0.27		

1999 Chi-Chi, Taiwan
Yuanlin C-32 & BH-21 NCREE

UCLA	Project Name: NCREE Taiwan Chi-Chi Earthquake Liquefaction Research Project	Page: 1 of 1
	Location: Yuanlin, Taiwan	
	GPS Coordinates:	Survey Coordinates (m): N 2650623 E 208000
	Test Number: C-32	Elevation (m): 28.293
Sponsored by:	Type of Cone: 688TC	Date: 07-Nov-99
PEER, Caltrans, CEC & PG&E	File Name: NCREE-Y-CPT32.xls	Water Table Elevation (m): 27.55
	Operator: Yu & Chen	Responsible Engineers: Moh and Associates
	Notes:	

