Past Successes of NSF-Sponsored Geotechnical Earthquake Reconaissance Investigations

by

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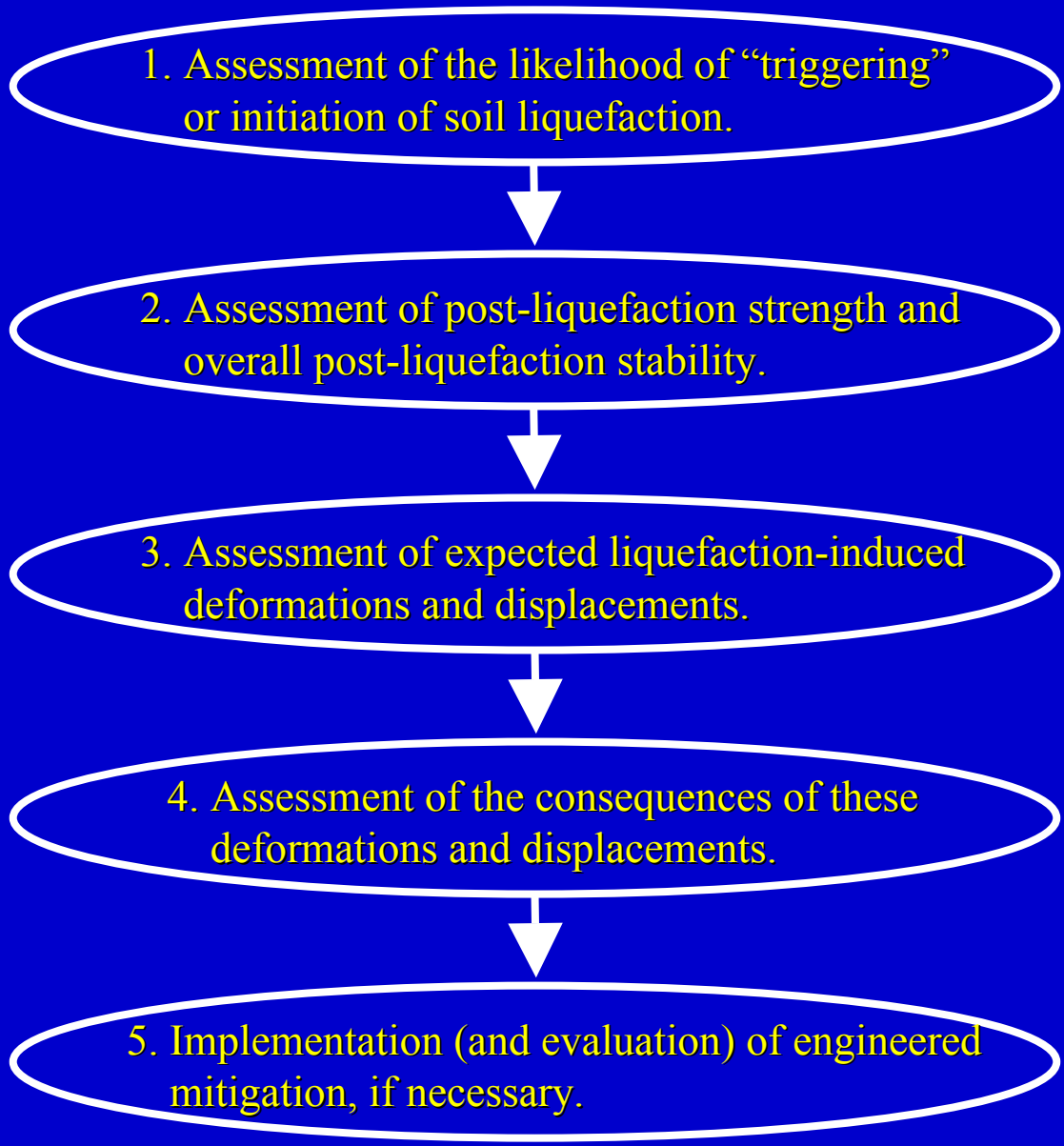
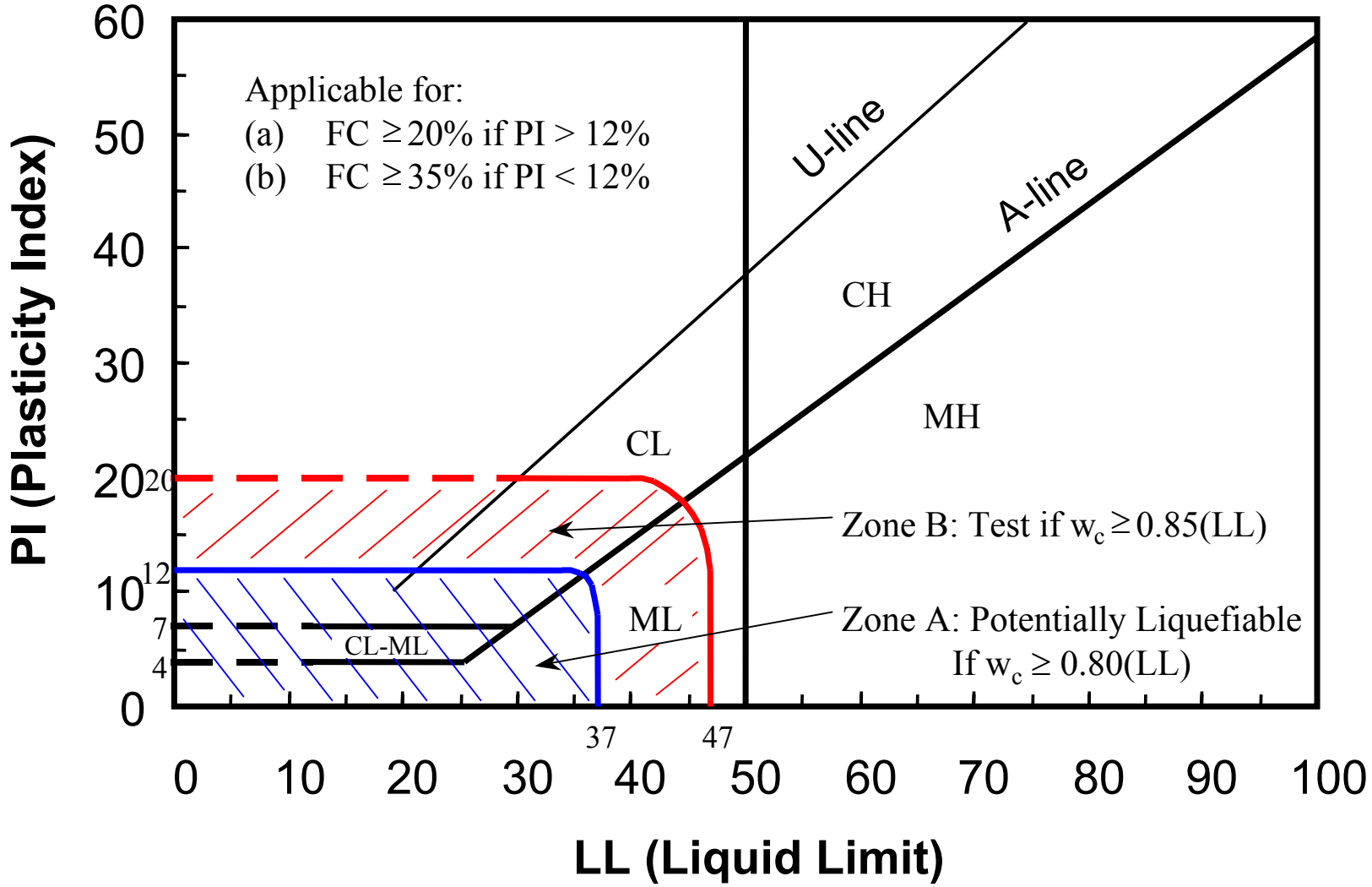
E. Rathje

Key Elements of Soil Liquefaction Engineering





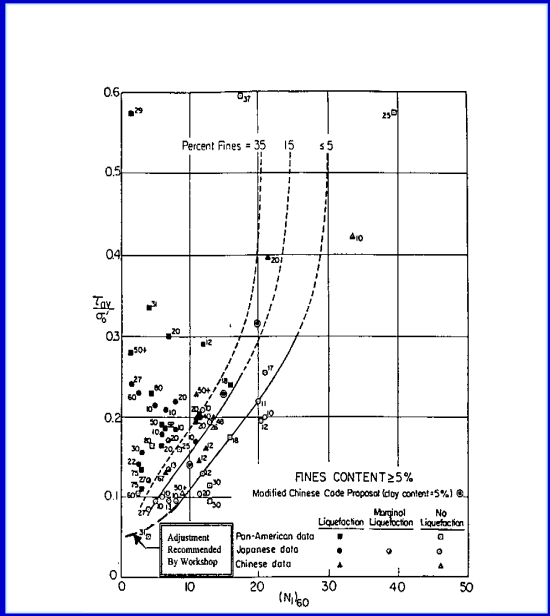
Criteria for Seismically Liquefiable Soils Based on Liquid Limit and Plasticity Index

SPT-Based Probabilistic Assessment of Soil Liquefaction Triggering Hazard

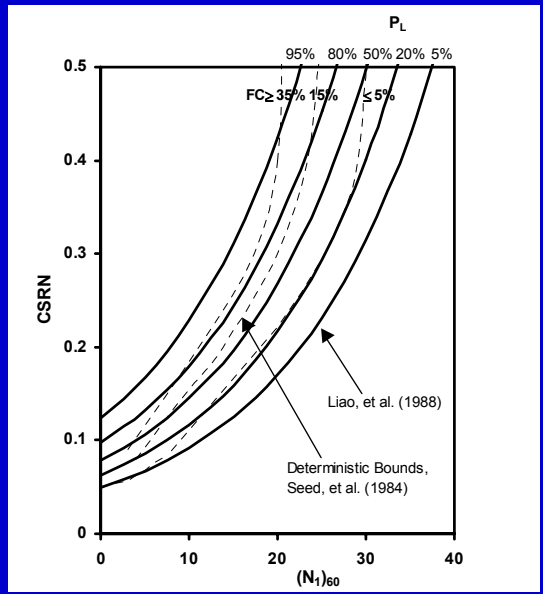
by

R. B. Seed, K. O. Cetin, A. Der Kiureghian, R. E. S. Moss,
K. Tokimatsu, R. E. Kayen, and L. F. Harder, Jr.

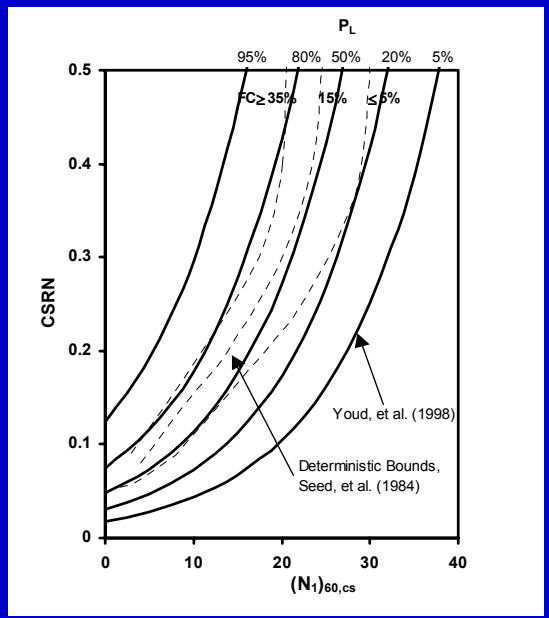
Seed et al. (1984,85)



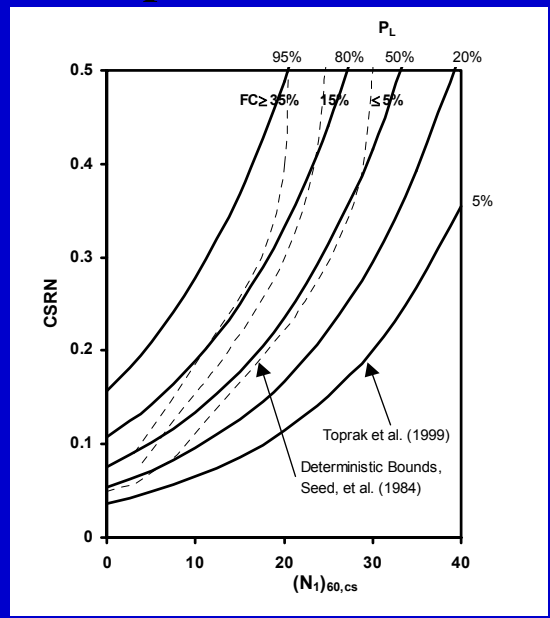
Liao et al., 1988



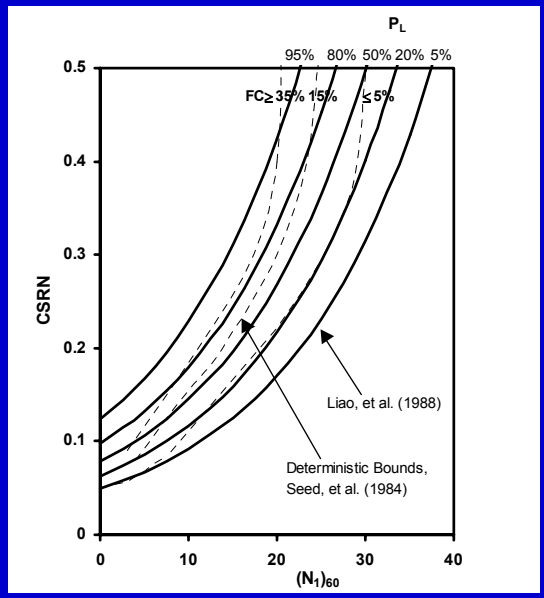
Youd et al., 1998



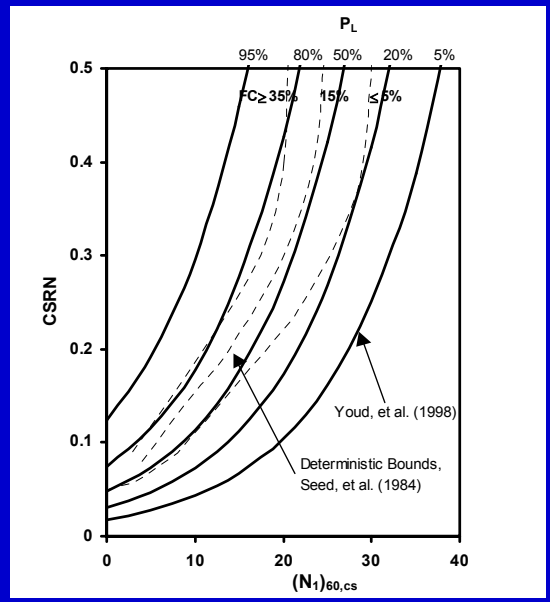
Toprak et al., 1999



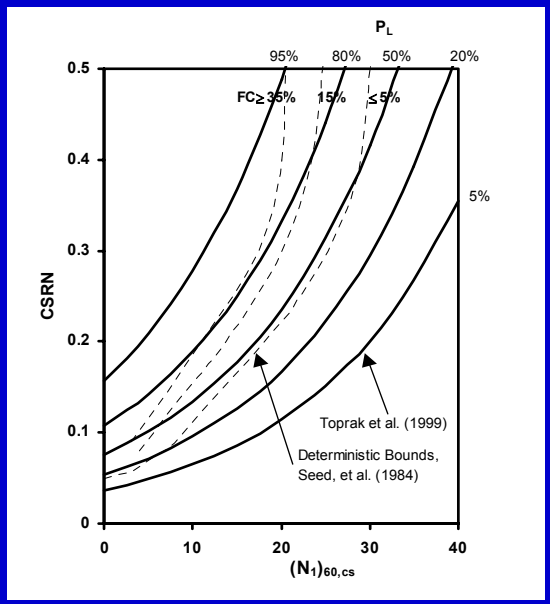
Liao et al., 1988



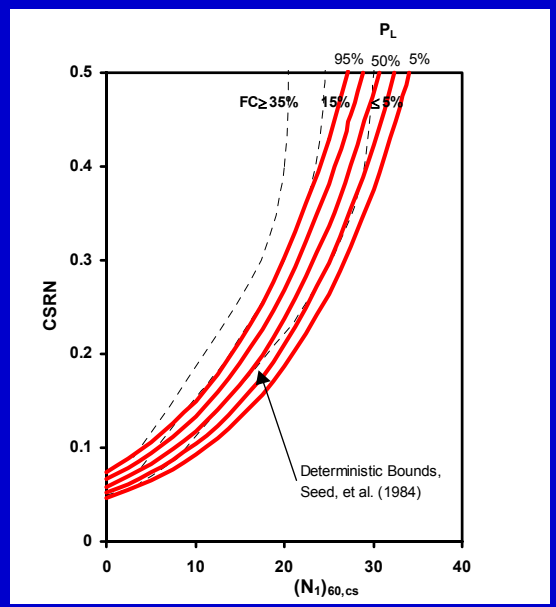
Youd et al., 1998



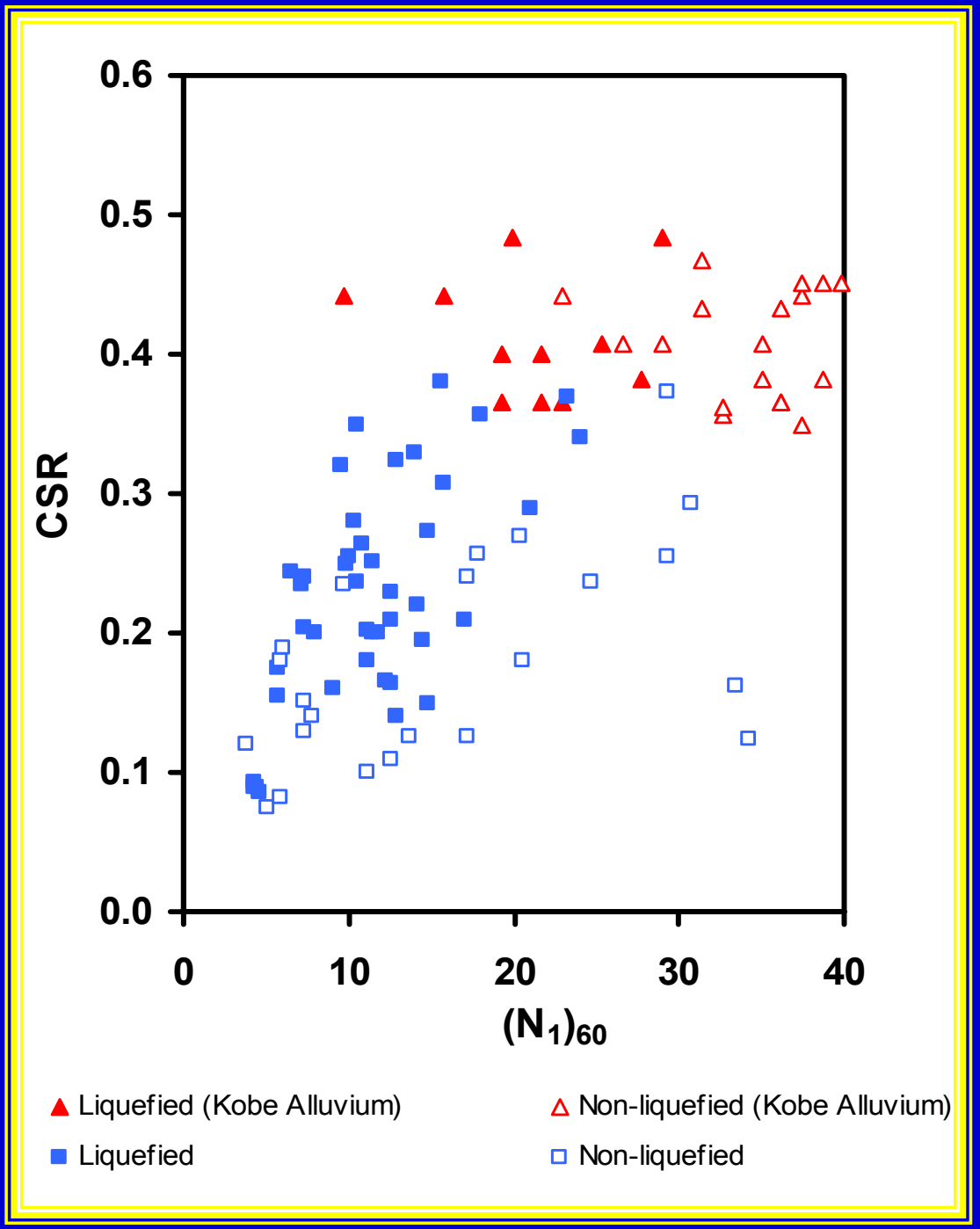
Toprak et al., 1999



Cetin et al., 2000

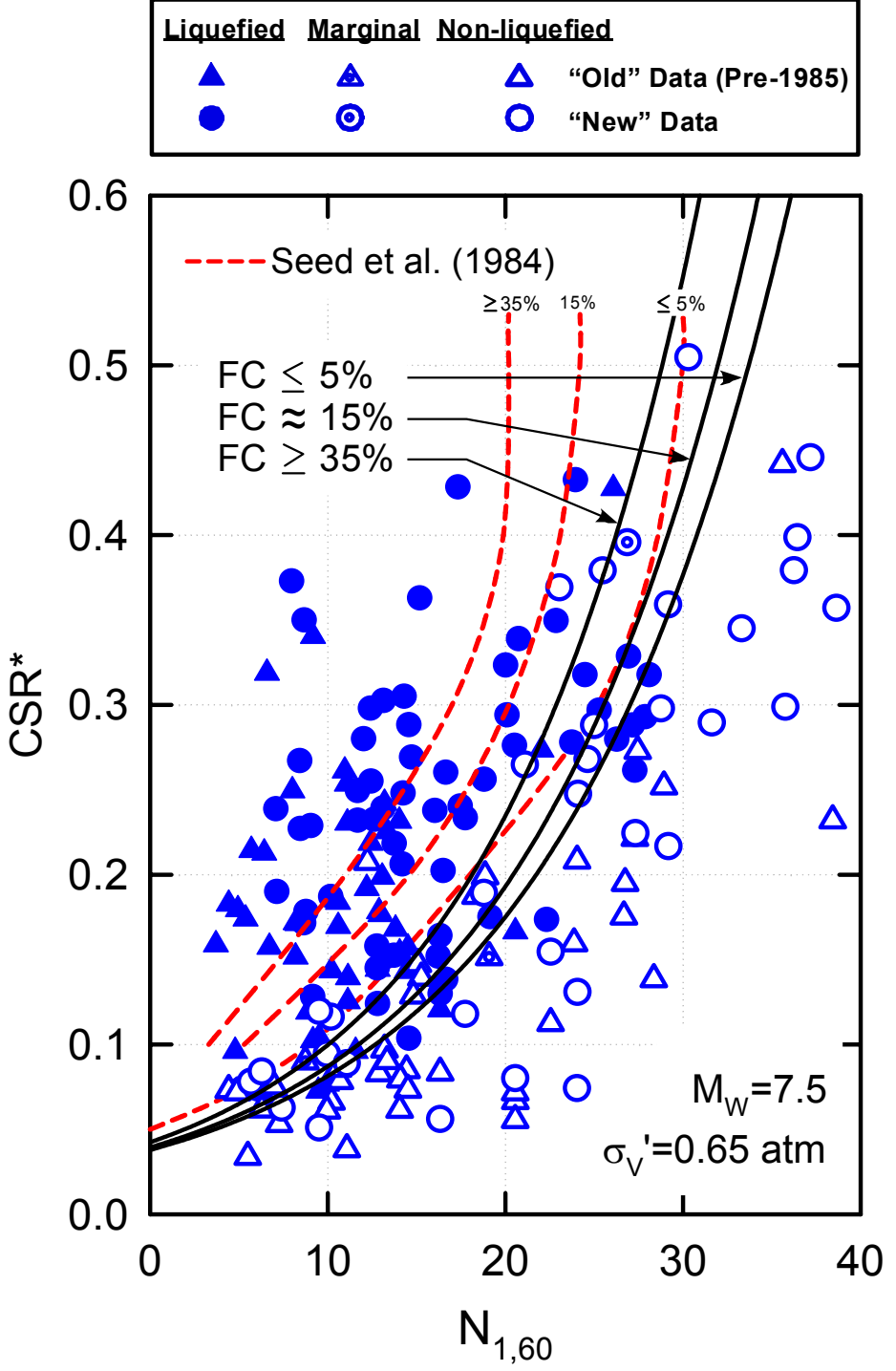


New Case History Data (M_w=6.2-7.8)



Boundary Curves for Probability of Liquefaction = 15%

(σ_v'= 0.65 atm)



Magnitude-Correlated Duration Weighting Factors (DWF_M)

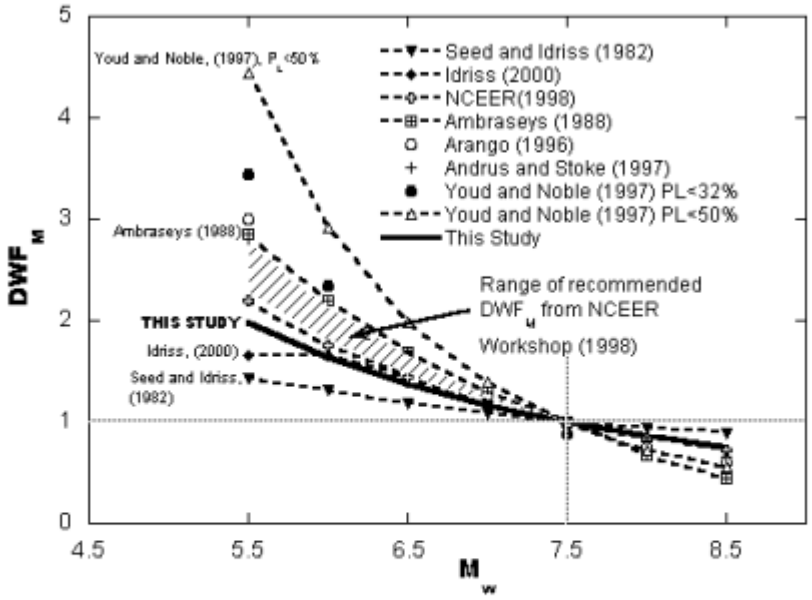


Figure 7(a) : Previous Recommendations for Magnitude-Correlated Duration Weighting Factor, With Recommendations from Current Studies.

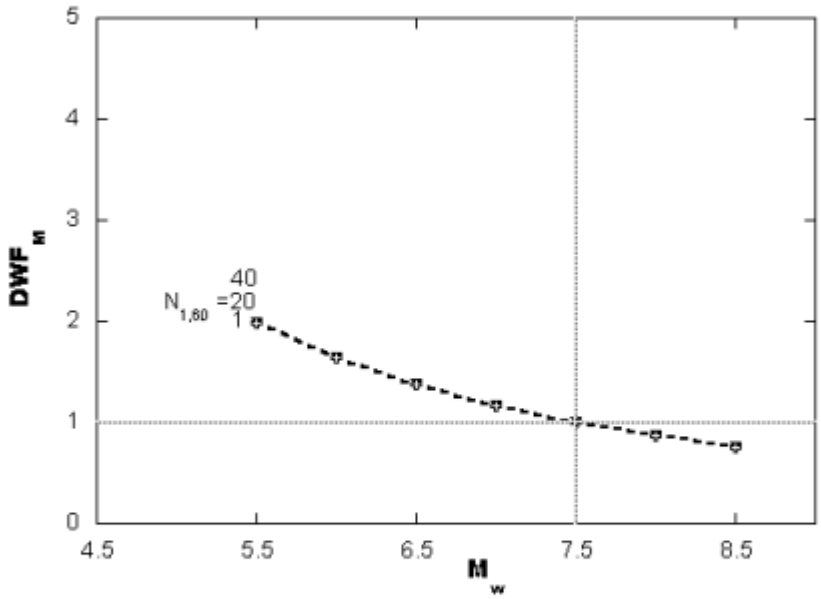


Figure 7(b) : Recommended Magnitude-Correlated Duration Weighting Factor as a Function of $N_{1,60}$.

CPT-Based Probabilistic Assessment of Seismic Soil Liquefaction Initiation

R.E.S. Moss, R.B. Seed, A. Der Kiureghian,
K.O.Cetin, R.E. Kayen, K. Tokimatsu,
J.S. Stewart, T.L. Youd and D. Chu

Pacific Earthquake Engineering Research Center (PEER)

UC Berkeley Caltech Stanford UC Irvine UCLA
UC Davis UCSD USC University of Washington

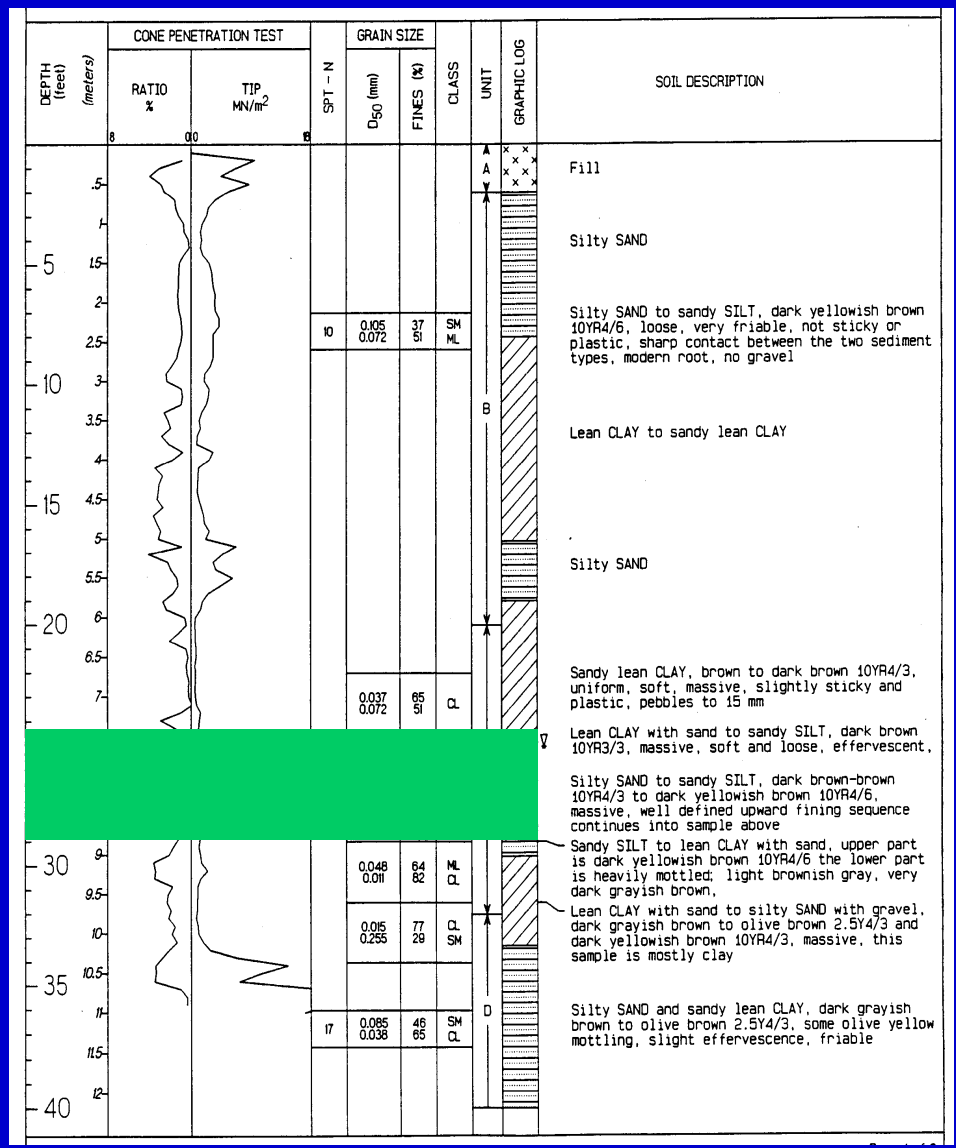
Collecting, Processing, & Analyzing Case Histories

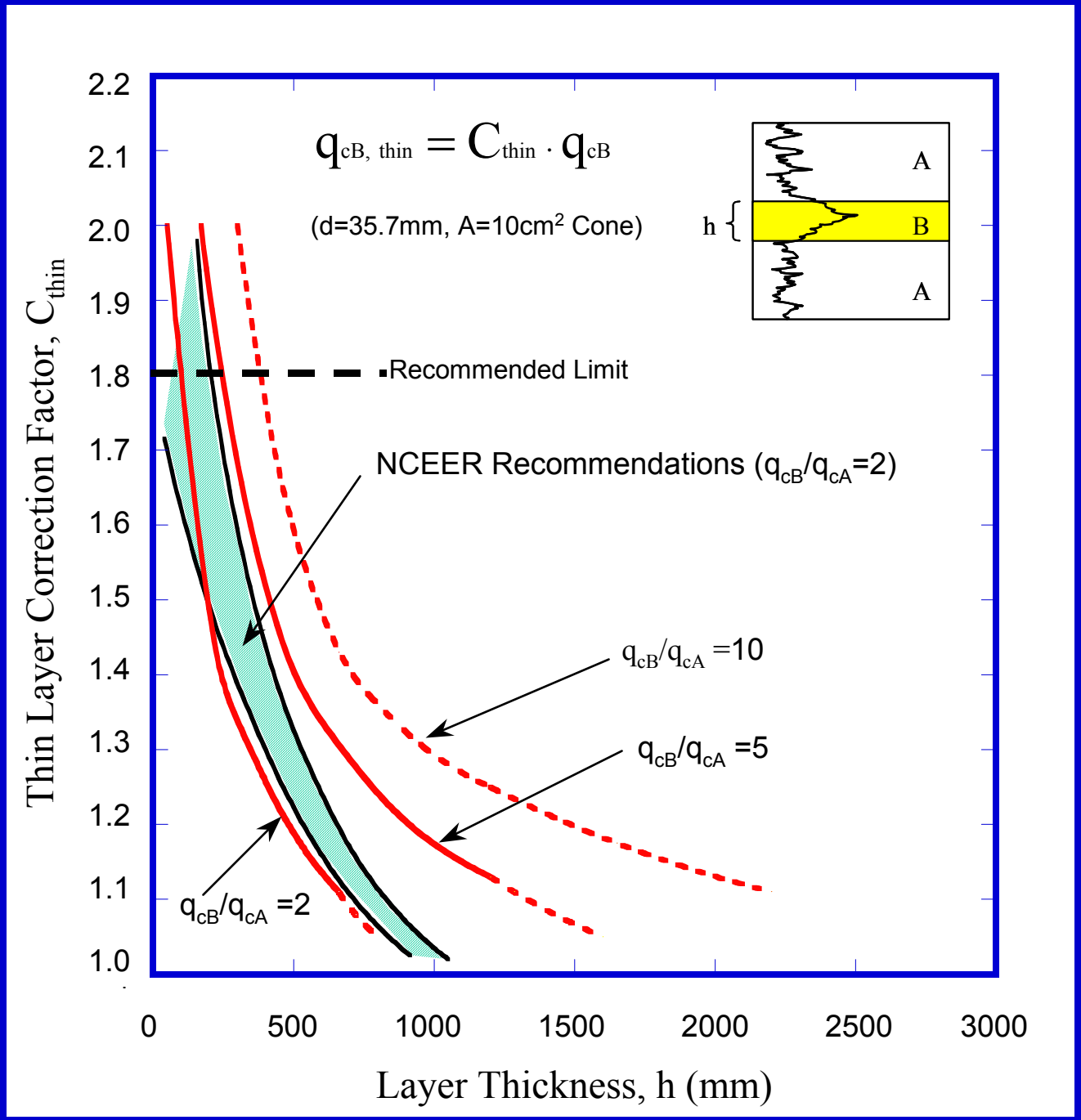
Thorough Processing

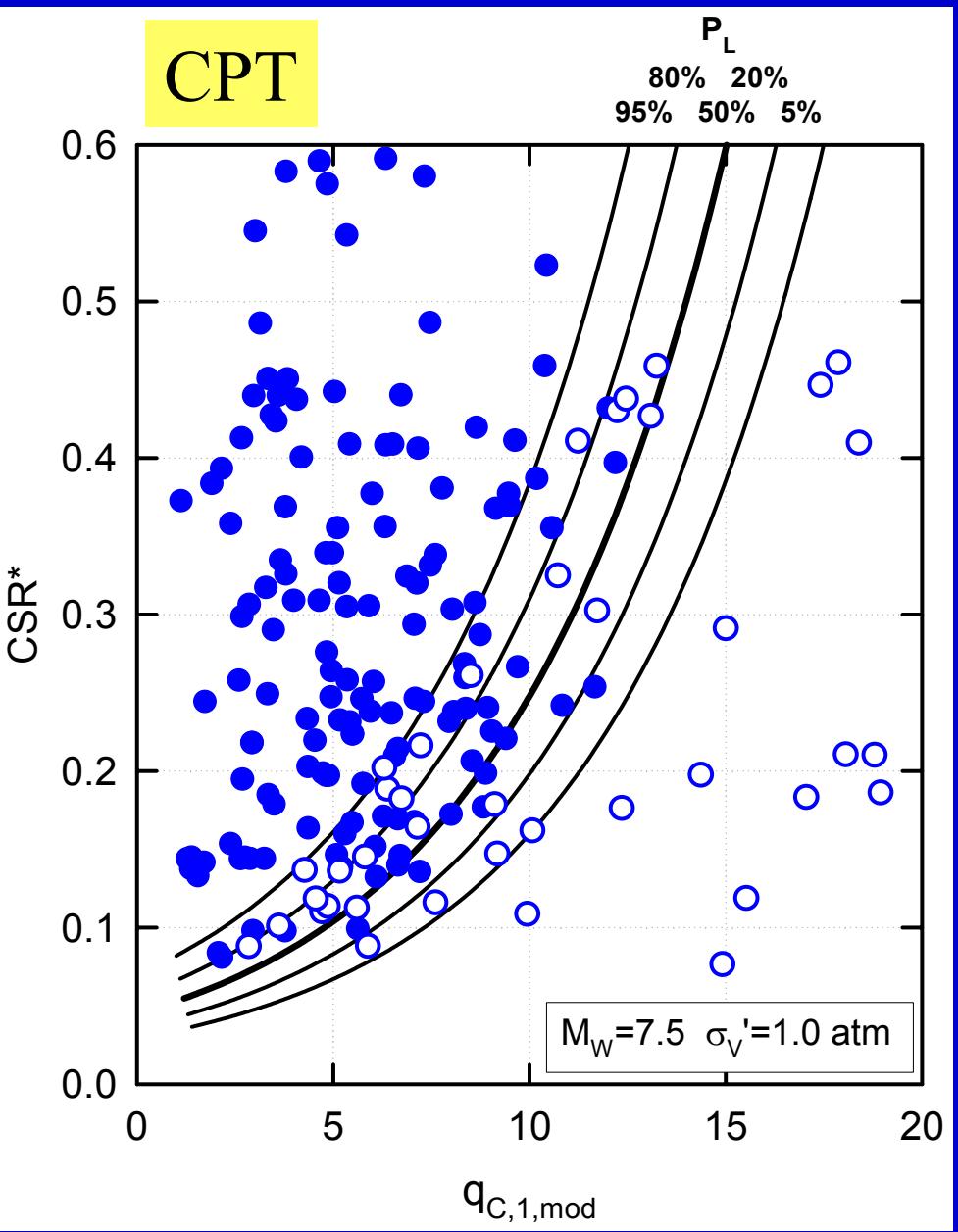
Expert Panel

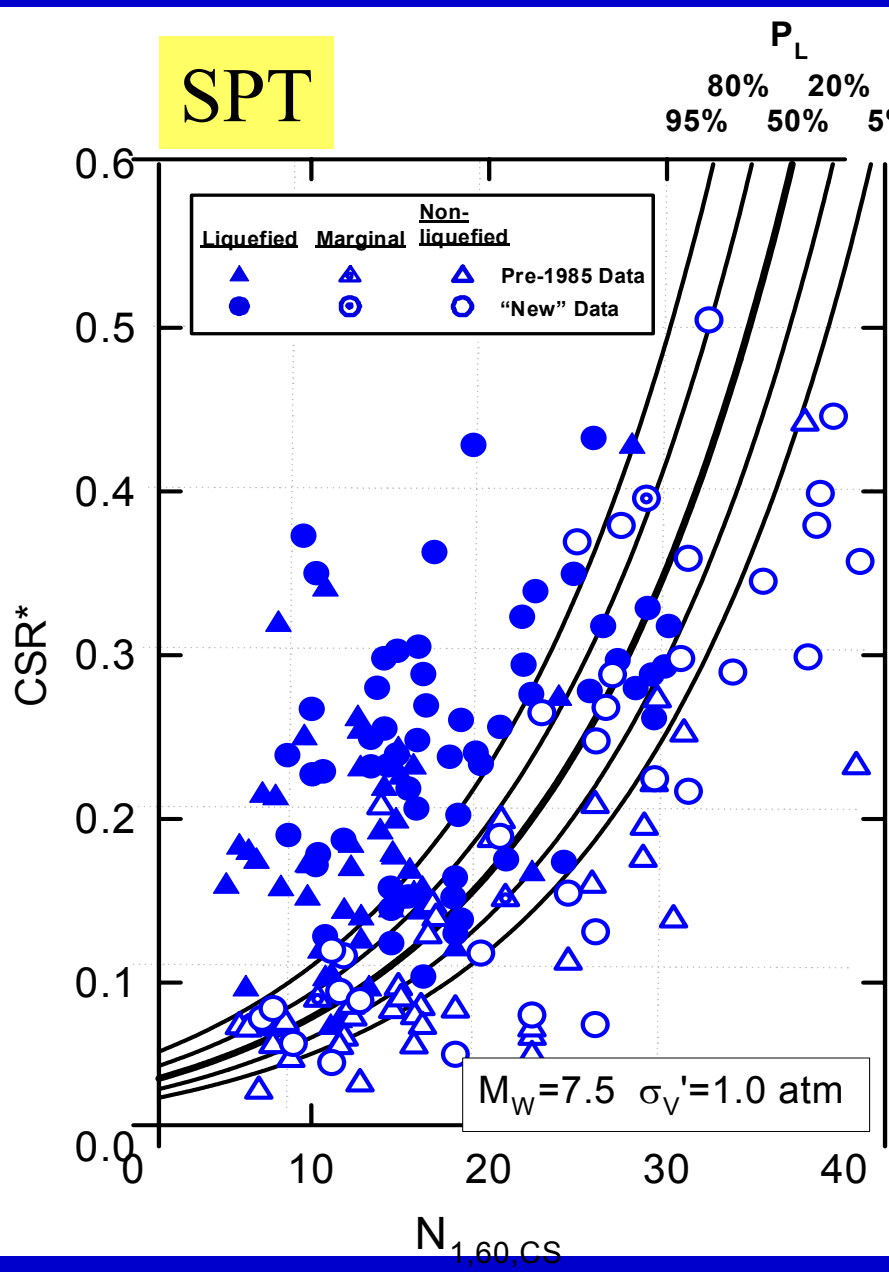
1999 Kocaeli, Turkey
1999 Chi-Chi, Taiwan
1995 Dinar, Turkey
1995 Kobe, Japan
1994 Northridge, CA
1989 Loma Prieta, CA
1987 Edgecumbre, New Zealand
1987 Superstition Hills, CA
1987 Elmore Ranch, CA
1983 Nihonkai-Chubu, Japan
1983 Borah Peak, ID
1981 Westmorland, CA
1980 Mexicali, Mexico
1979 Imperial Valley, CA
1977 Vrancea, Romania
1976 Tangshan, China
1975 Haicheng, China
1968 Inanguahua, New Zealand
1964 Niigata, Japan

>600 case histories




$q_{cB,\ thin} = C_{thin} \cdot q_{cB}$
(d=35.7mm, A=10cm² Cone)
h
A
B
A
Recommended Limit
NCEER Recommendations (q_{cB}/q_{cA}=2)
q_{cB}/q_{cA} =10
q_{cB}/q_{cA} =5
q_{cB}/q_{cA} =2
Thin Layer Correction Factor, C_{thin}
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
500
1000
1500
2000
2500
3000
Layer Thickness, h (mm)





Equivalent "Clean Sand"

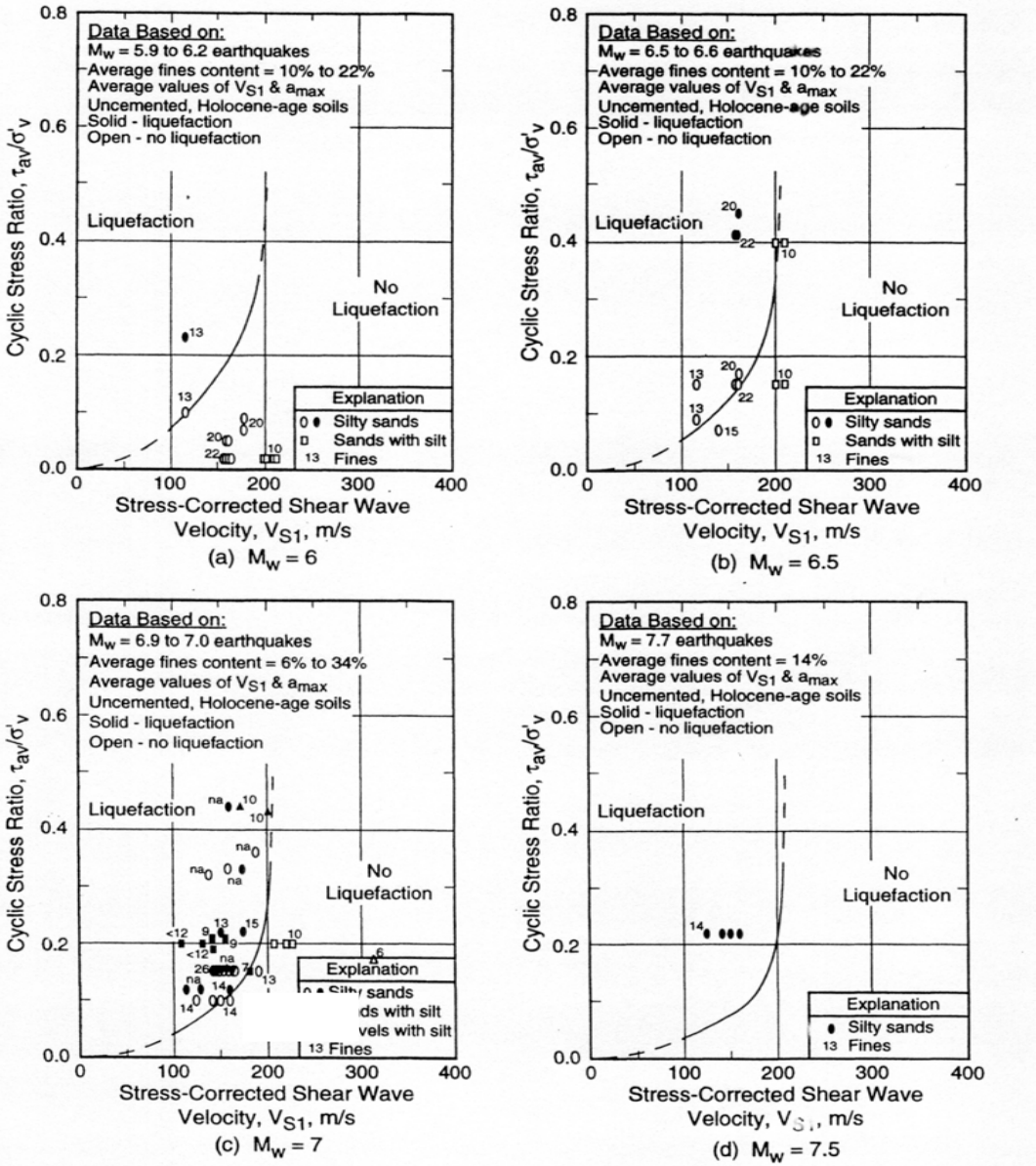
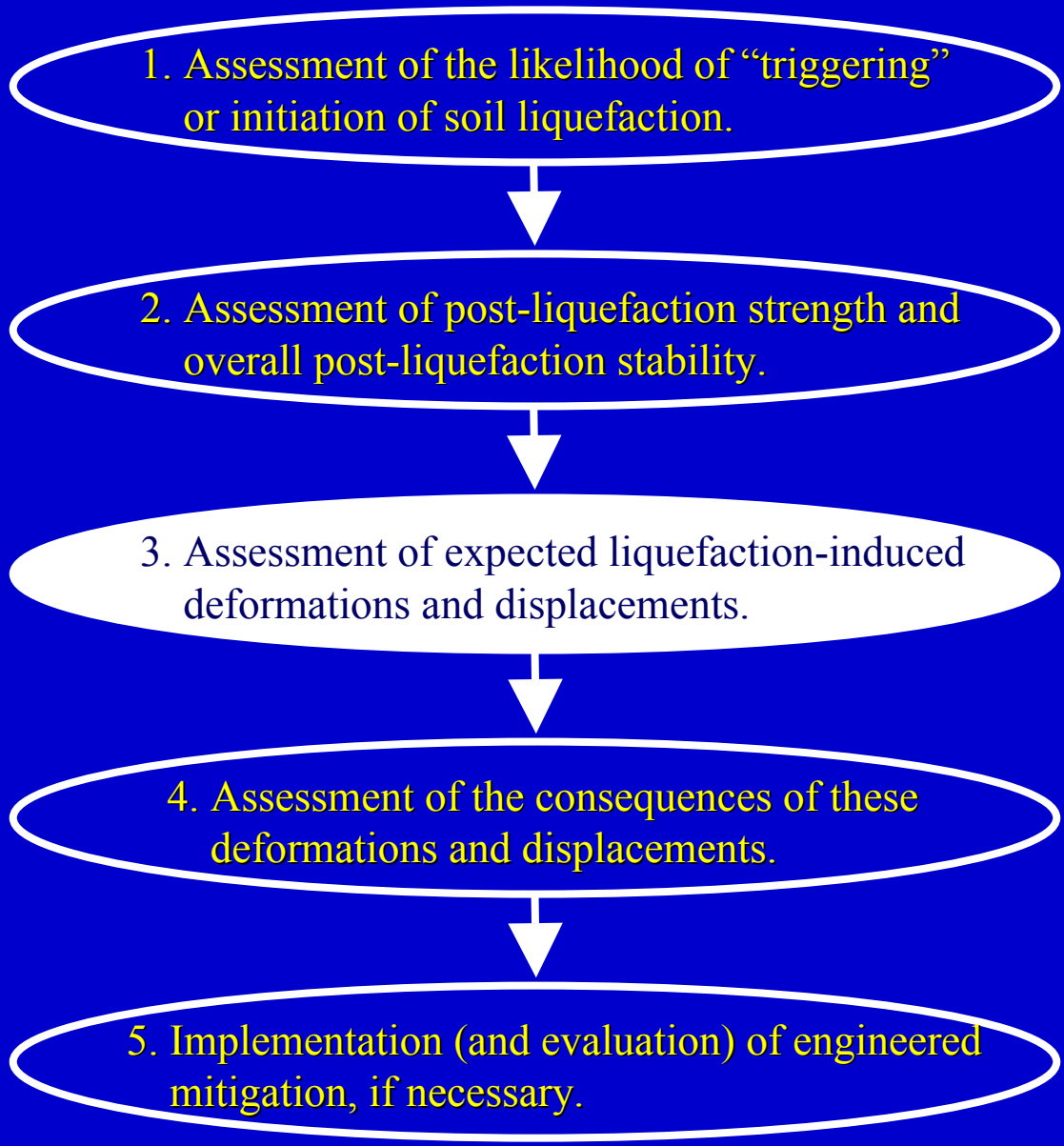


Fig. 9 - Comparison of Liquefaction Assessment Charts Based on V_{S1} and CSR from Analysis for this Report with Case Histories of Uncemented Soils with Fines Content of 6% to 34%.

V_S

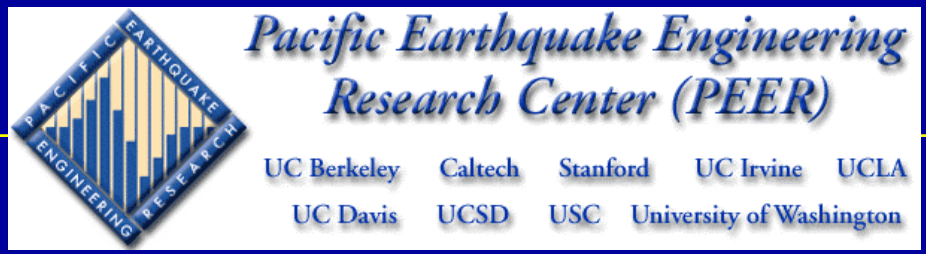
Andrus & Stokoe (1997)

Key Elements of Soil Liquefaction Engineering



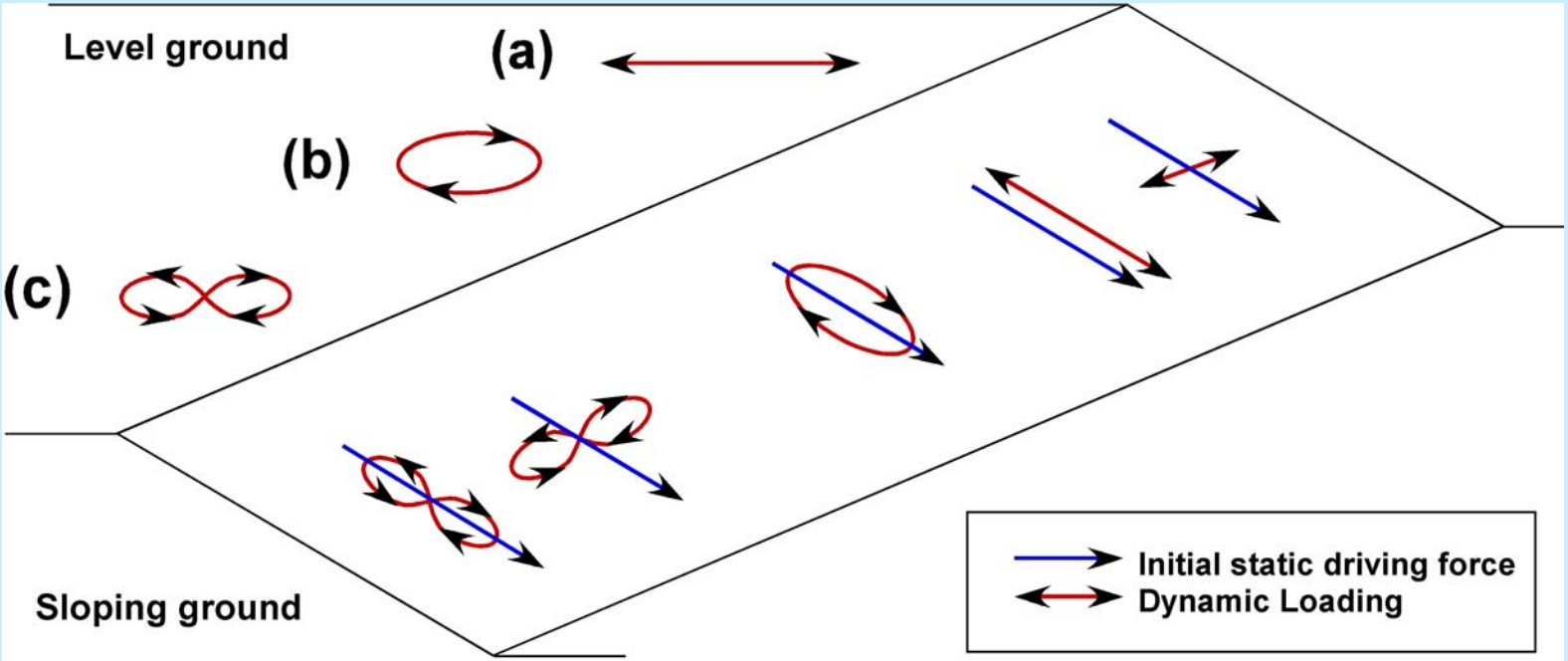
Liquefaction Induced Deformations Under Uni-Directional and Multi-Directional Loading

R. B. Seed, Annie Kammerer, Jiaer Wu,
J. M. Pestana, M. F. Riemer,
L. Salvati, J. Mayoral, P. Meymand

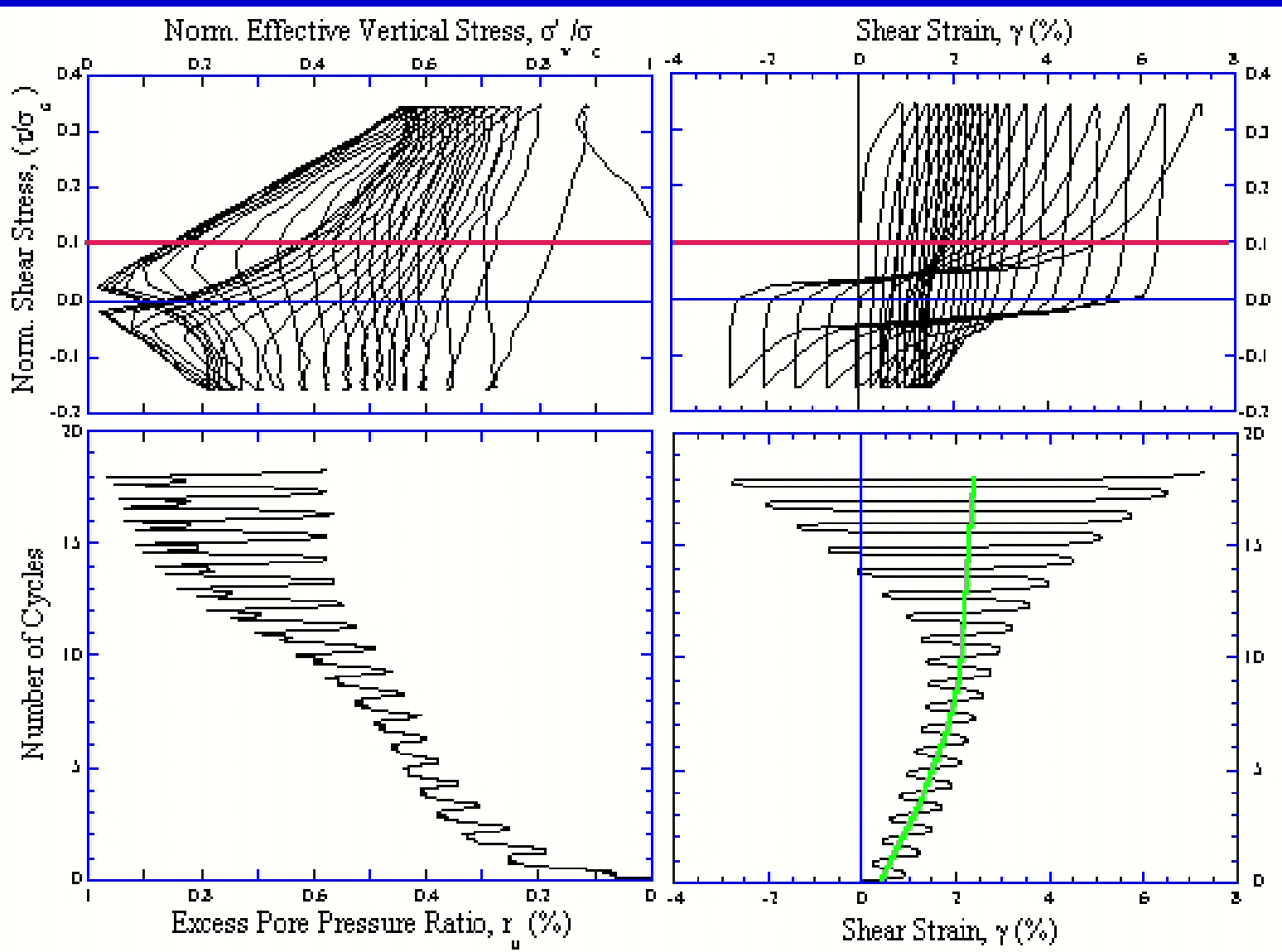



TOP
TOP

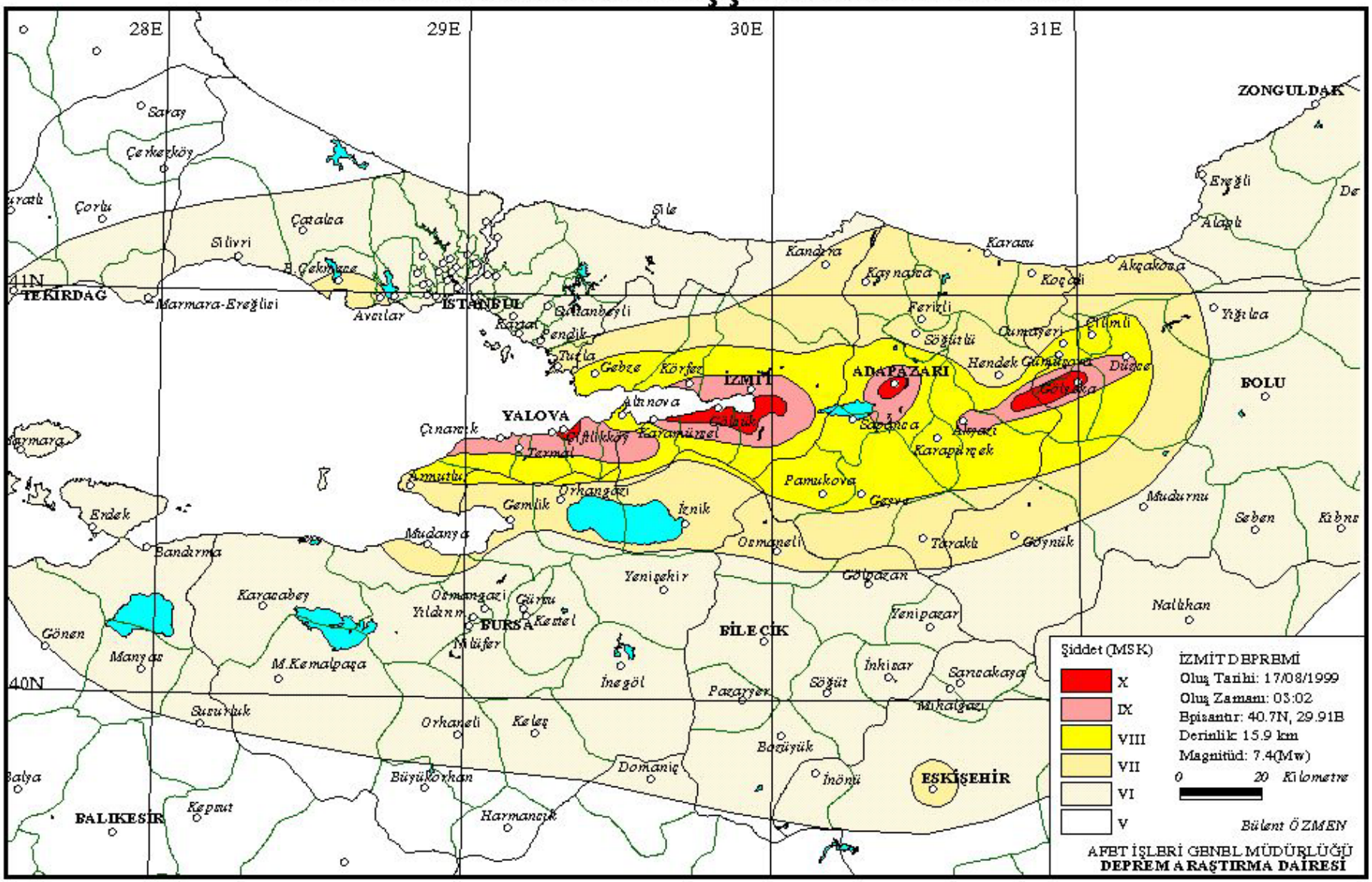
Summary of Testing



Schematic Illustration of 2-Directional Loading Conditions



D_r=65% σ_v=40 kPa CRR= 0.25 α= 0.10



Şekil 3 : İzmit depreminin eşşiddet haritası

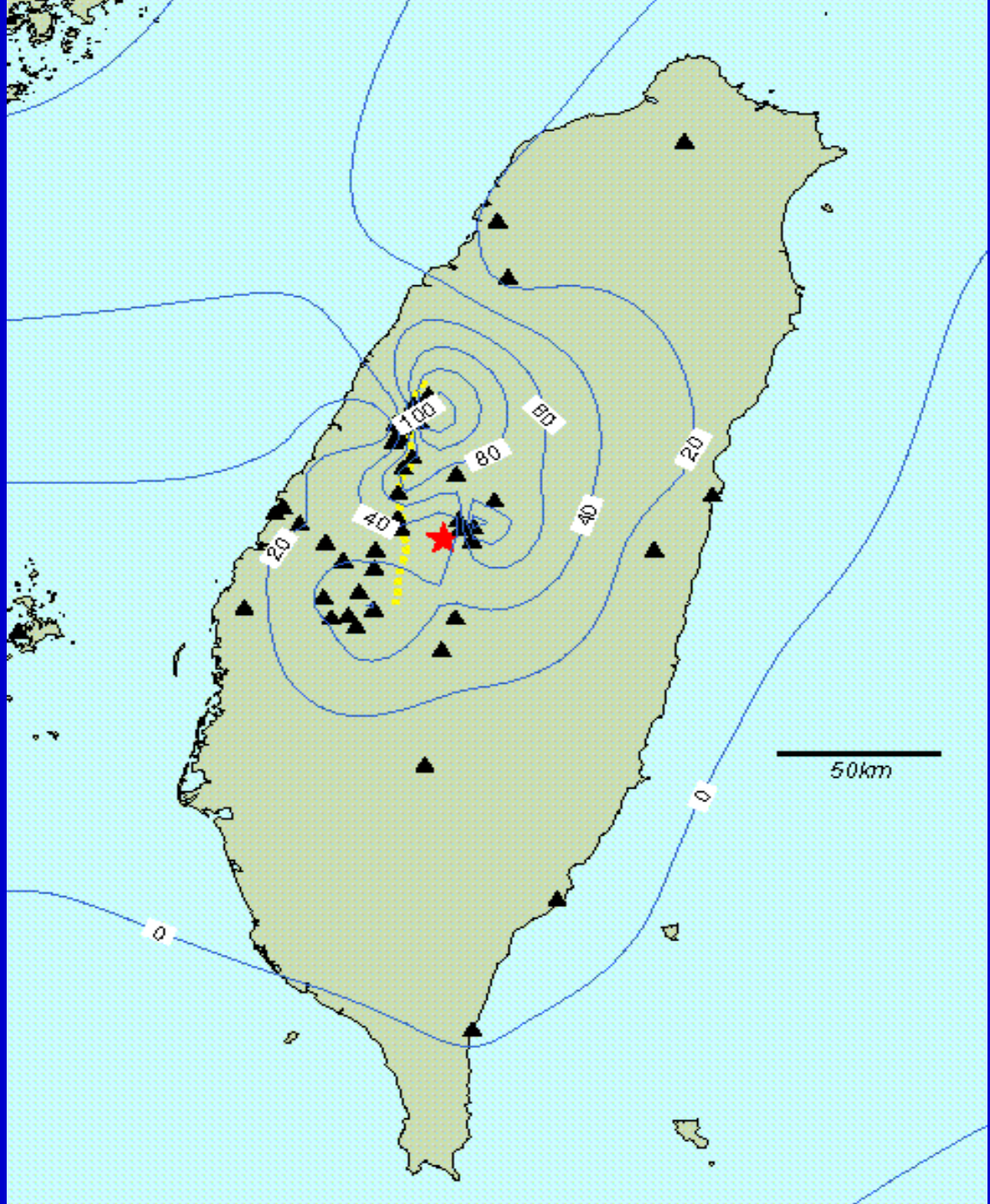
Isoseismal Map from the August 17, 1999 Kocaeli, Turkey Earthquake (M_w = 7.4) (http://www.deprem.gov.tr/main_e.htm)

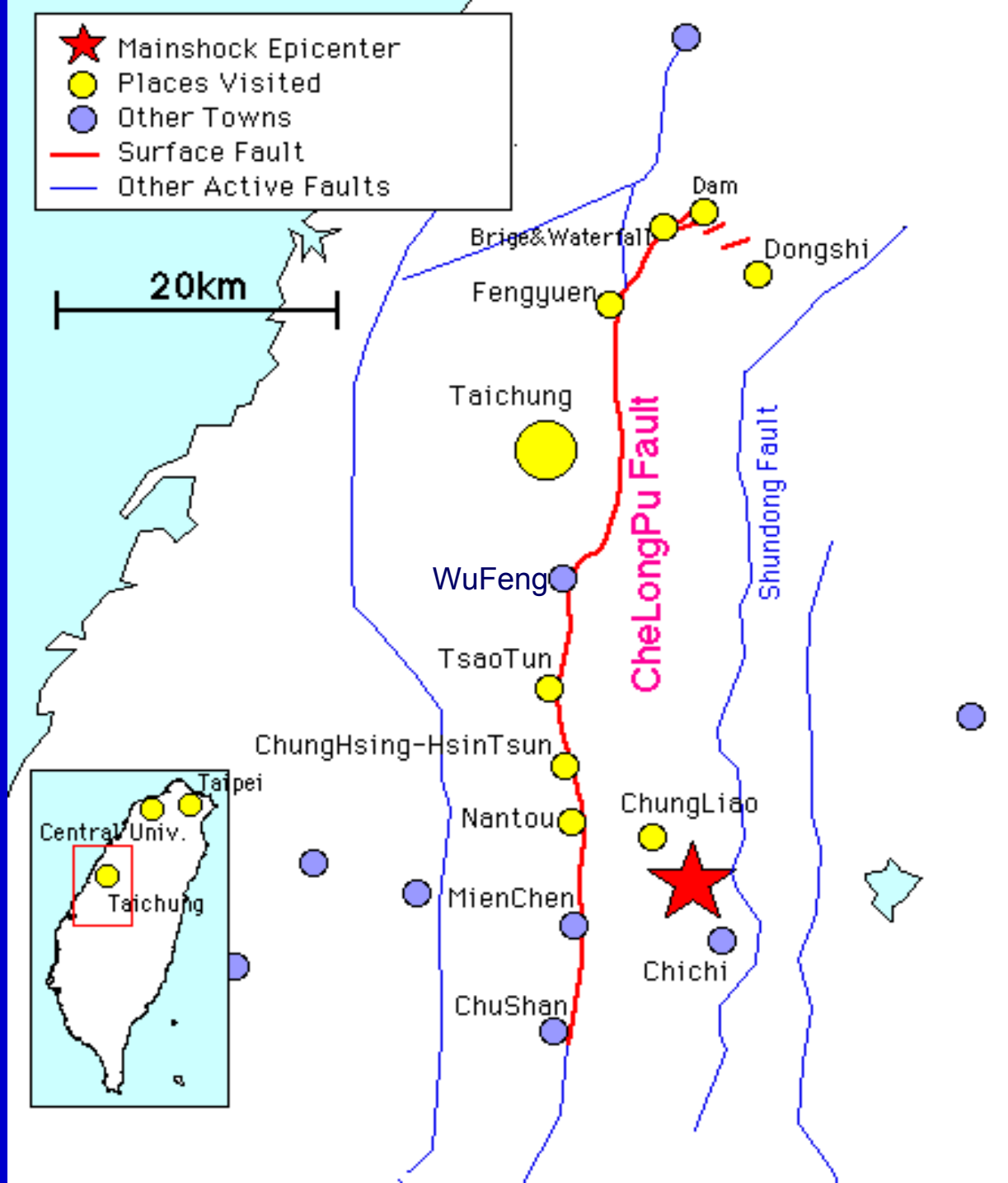
I. M. Idriss


EFES
Pilsen
BİRA
GÜRKAN RESTAURANT
EFES
Pilsen
BİRA

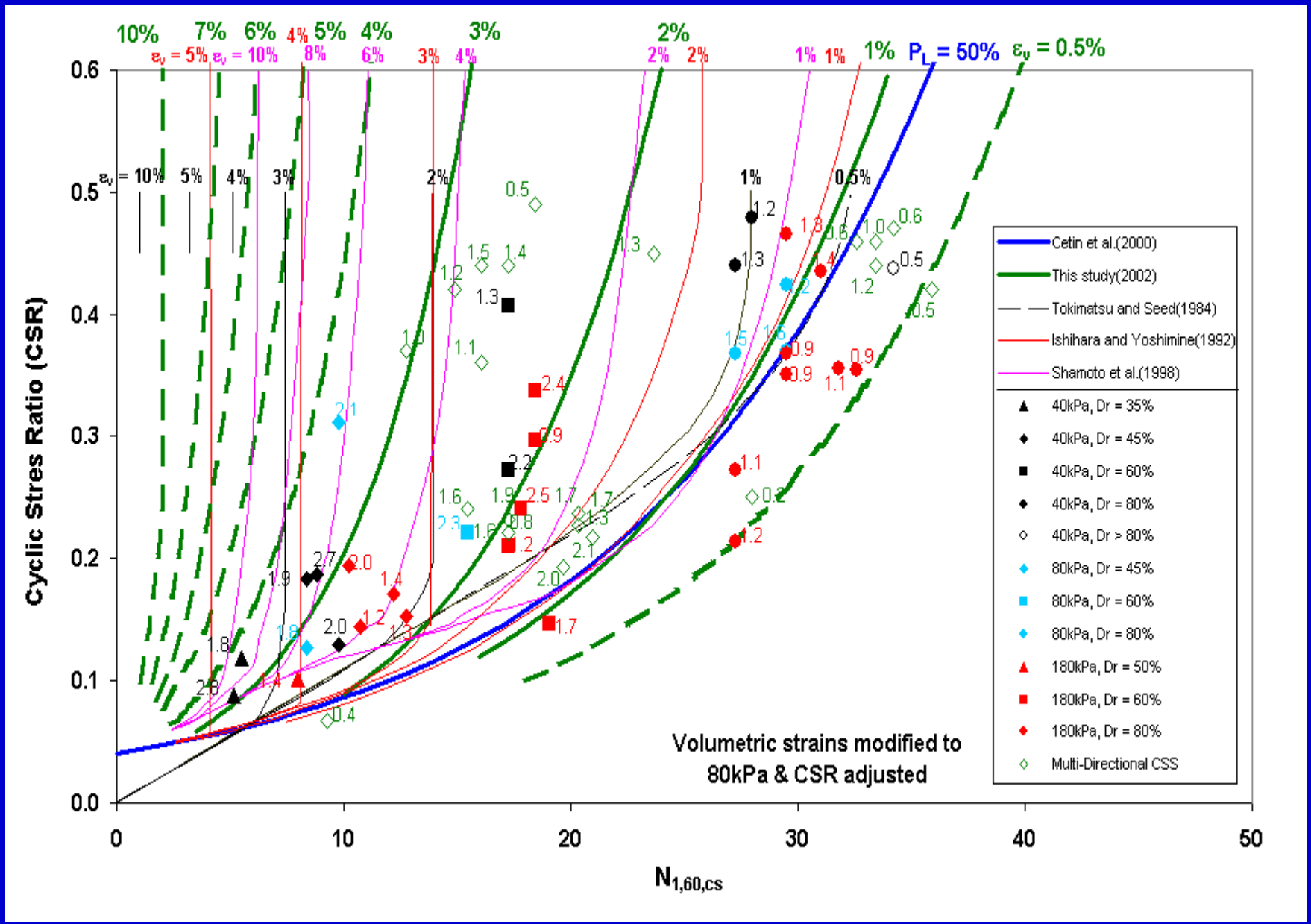
Adapazari

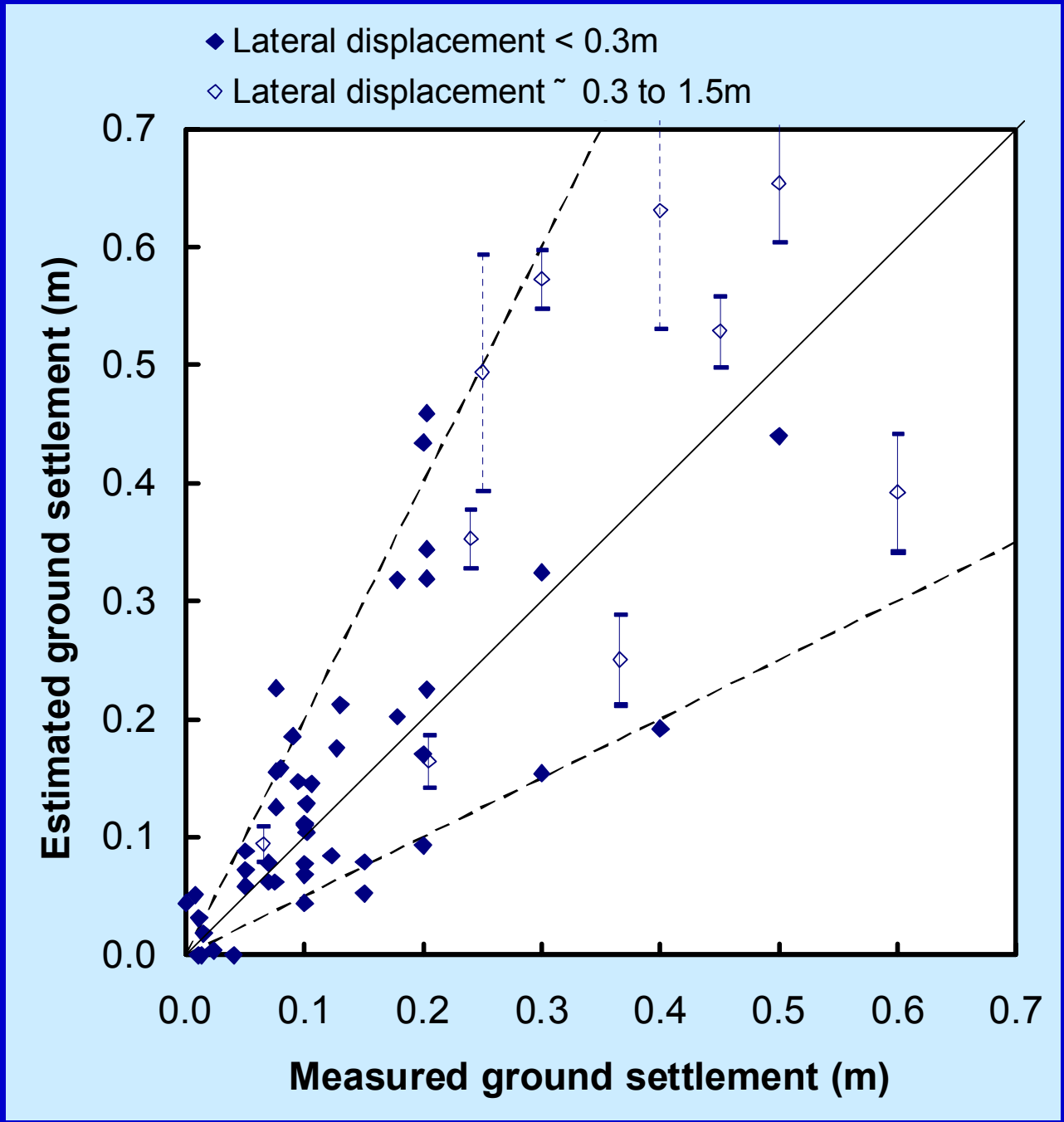
(O. Cetin, 1999)


100
80
60
40
20
40
20
0
0
50km

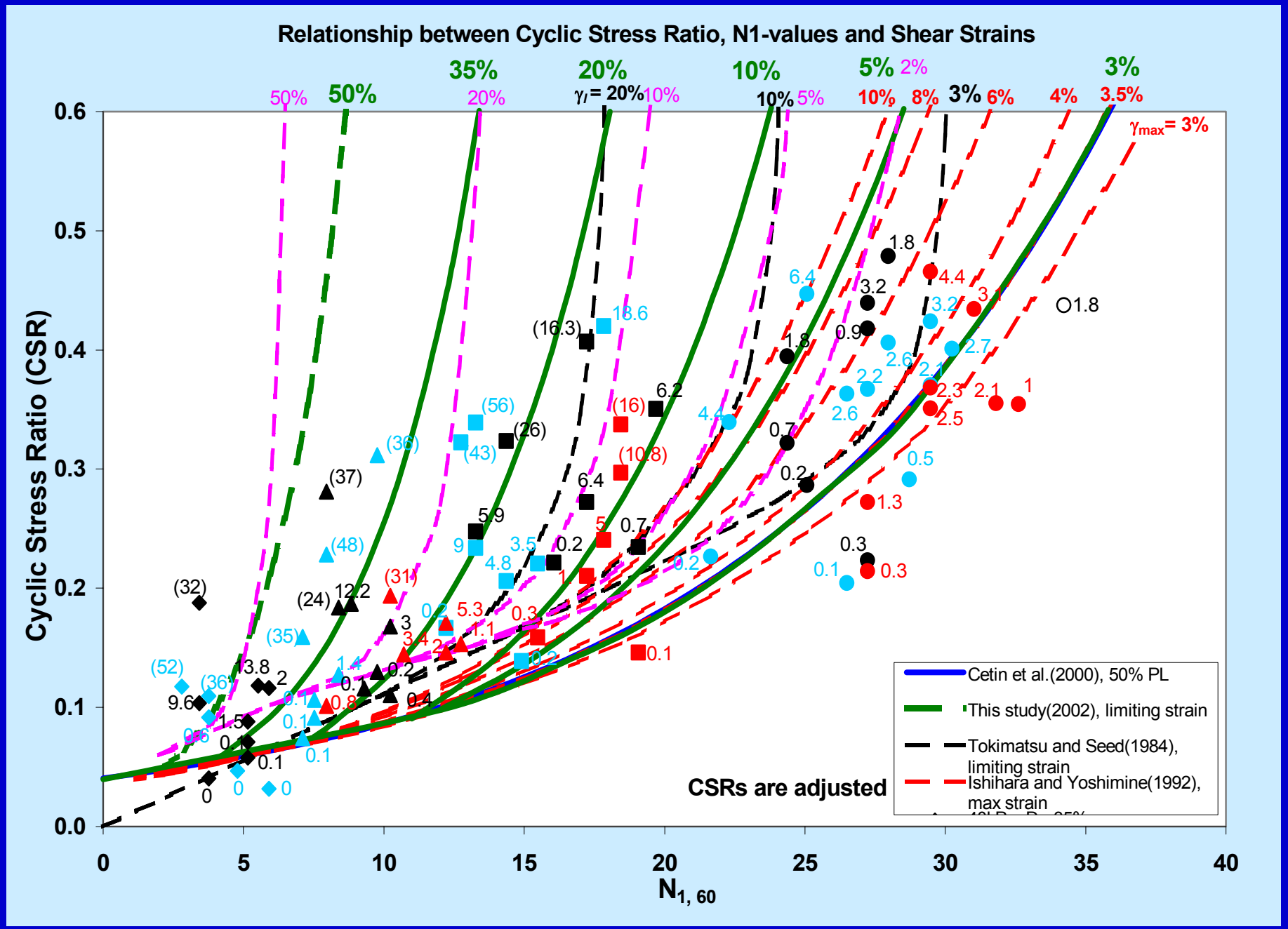

Mainshock Epicenter
Places Visited
Other Towns
Surface Fault
Other Active Faults
20km
Dam
Brige&Waterfall
Dongshi
Fengyuen
Taichung
CheLongPu Fault
Shundong Fault
WuFeng
TsaoTun
ChungHsing-HsinTsun
Nantou
ChungLiao
MienChen
Chichi
ChuShan
Taipei
Central Univ.
Taichung

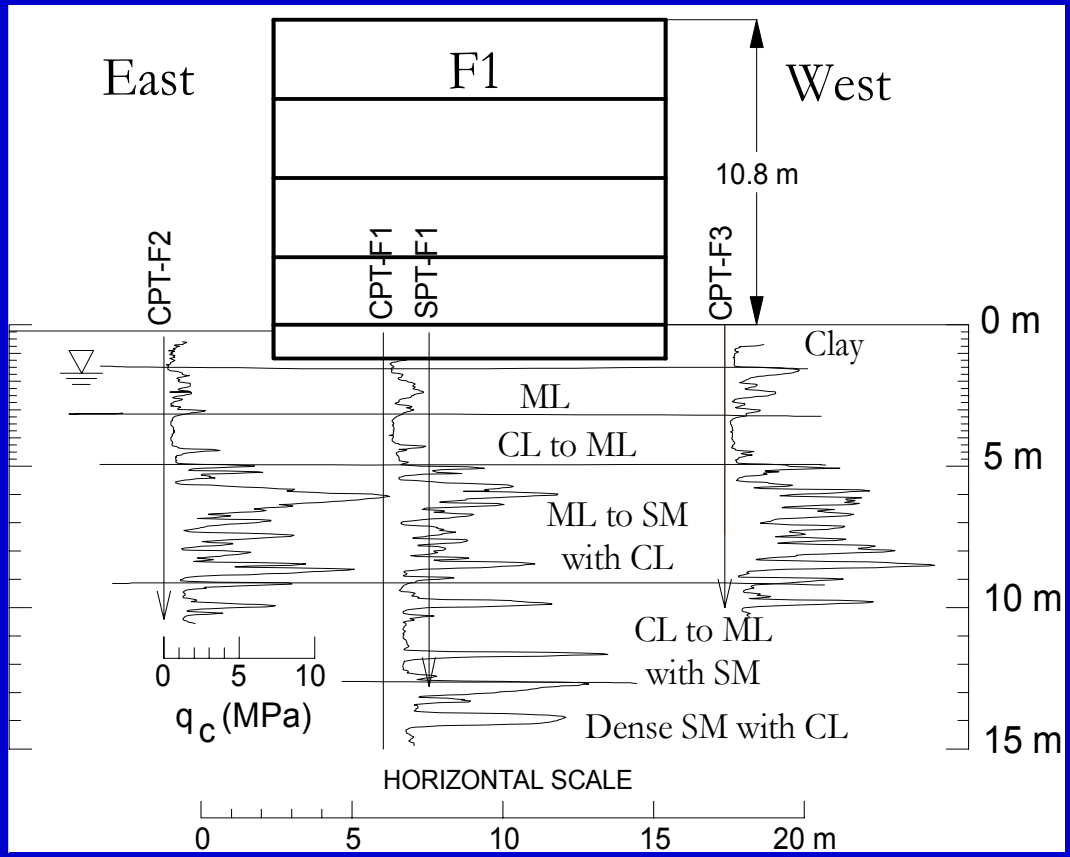
Post-Liquefaction Reconsolidation Ground Settlements


Cyclic Stres Ratio (CSR)
$N_{1,60,cs}$
Volumetric strains modified to
80kPa & CSR adjusted
P_L = 50%
ε_v = 0.5%
Cetin et al.(2000)
This study(2002)
Tokimatsu and Seed(1984)
Ishihara and Yoshimine(1992)
Shamoto et al.(1998)
40kPa, Dr = 35%
40kPa, Dr = 45%
40kPa, Dr = 60%
40kPa, Dr = 80%
40kPa, Dr > 80%
80kPa, Dr = 45%
80kPa, Dr = 60%
80kPa, Dr = 80%
180kPa, Dr = 50%
180kPa, Dr = 60%
180kPa, Dr = 80%
Multi-Directional CSS


Lateral displacement < 0.3m
Lateral displacement ~ 0.3 to 1.5m
Estimated ground settlement (m)
Measured ground settlement (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

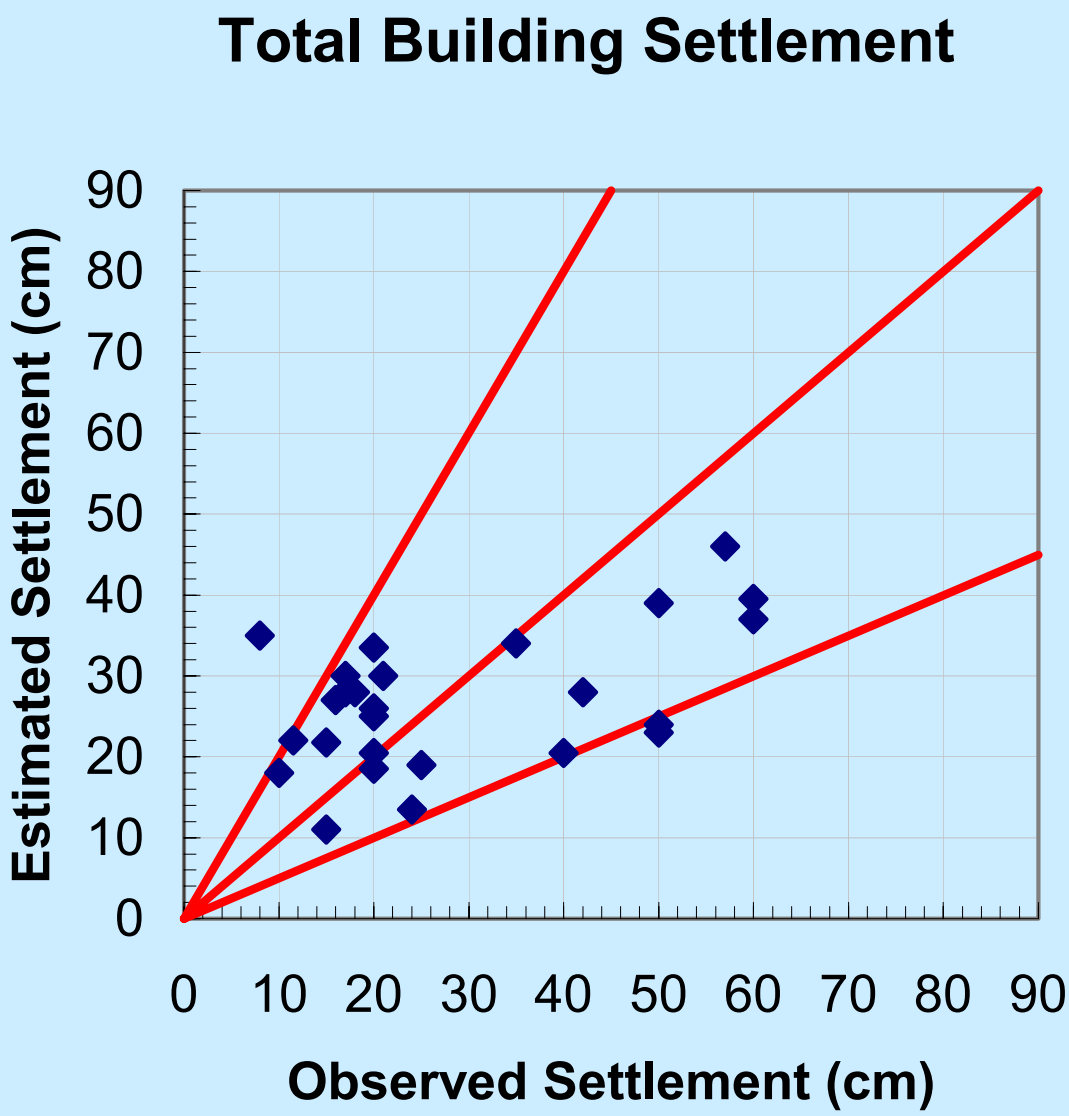
Liquefaction-Induced Building Settlements


Relationship between Cyclic Stress Ratio, N1-values and Shear Strains
Cyclic Stress Ratio (CSR)
N1, 60
γl = 20%
γmax = 3%
50%
35%
20%
10%
5%
3%
2%
CSRs are adjusted
Cetin et al.(2000), 50% PL
This study(2002), limiting strain
Tokimatsu and Seed(1984), limiting strain
Ishihara and Yoshimine(1992), max strain



$$\Delta Z_{total} = \Delta Z_{volumetric} + \Delta Z_{deviatoric}$$

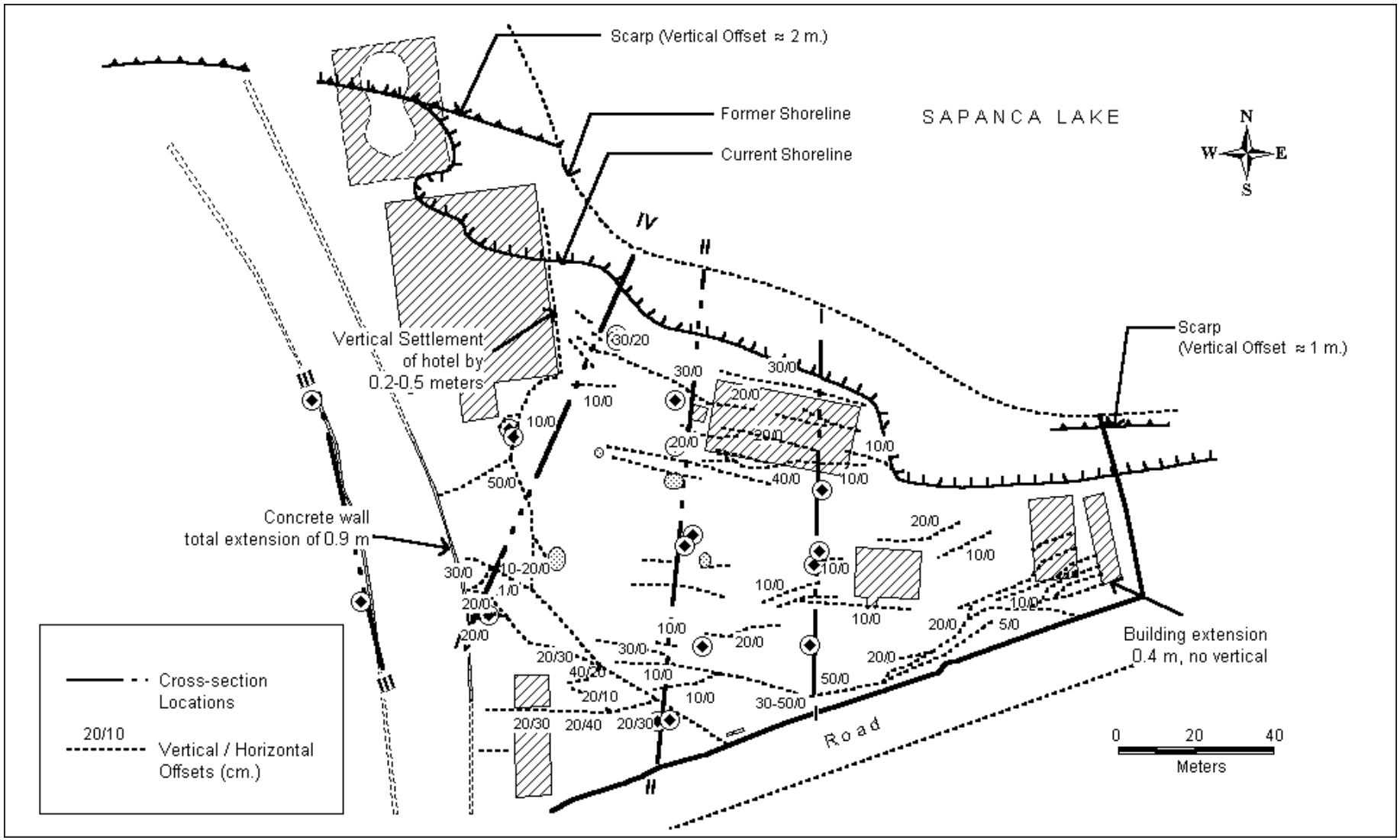
$$\Delta Z_{deviatoric} = f\,(CSR_{free\text{-}field}, CSR_{SSI}, SPI, \alpha, K_{\alpha,\varepsilon})$$


Total Building Settlement
Estimated Settlement (cm)
Observed Settlement (cm)
0
10
20
30
40
50
60
70
80
90

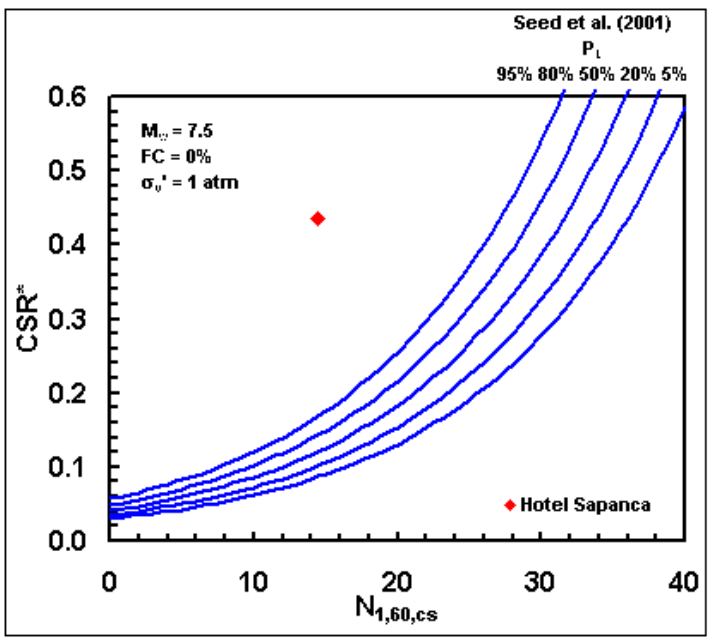
Hotel Sapanca, 1999 Kocaeli Earthquake

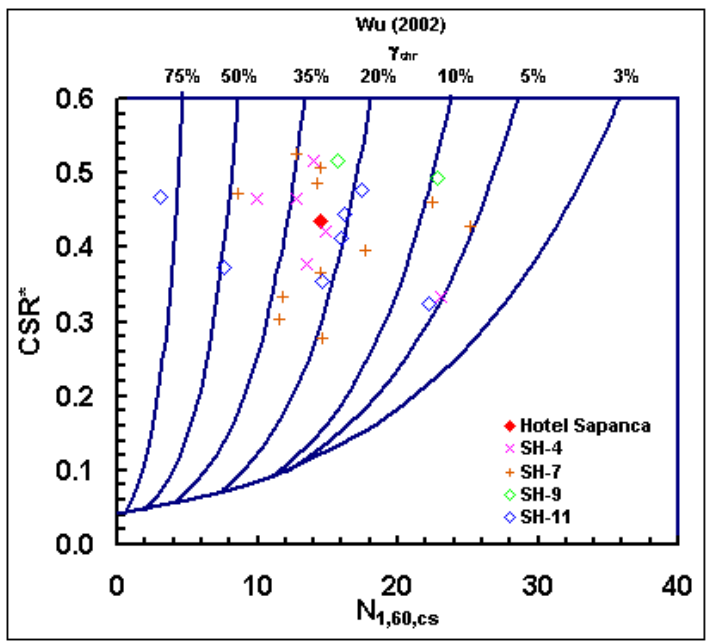
Photo courtesy of T.L. Youd

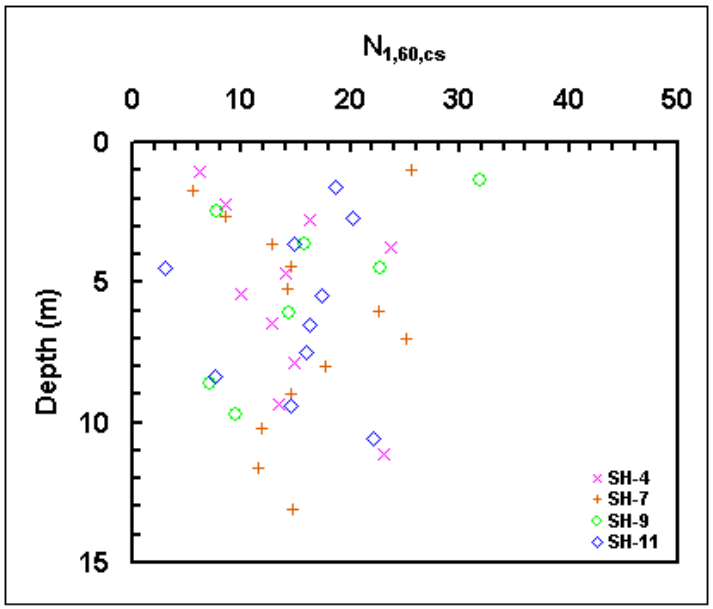
Hotel Sapanca, 1999 Kocaeli Earthquake

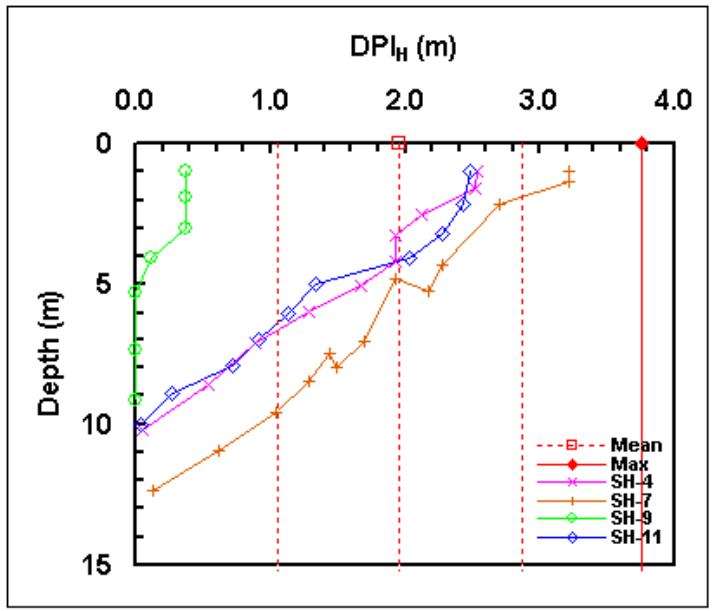


http://peer.berkeley.edu/turkey/adapazari/phase4/sapanca



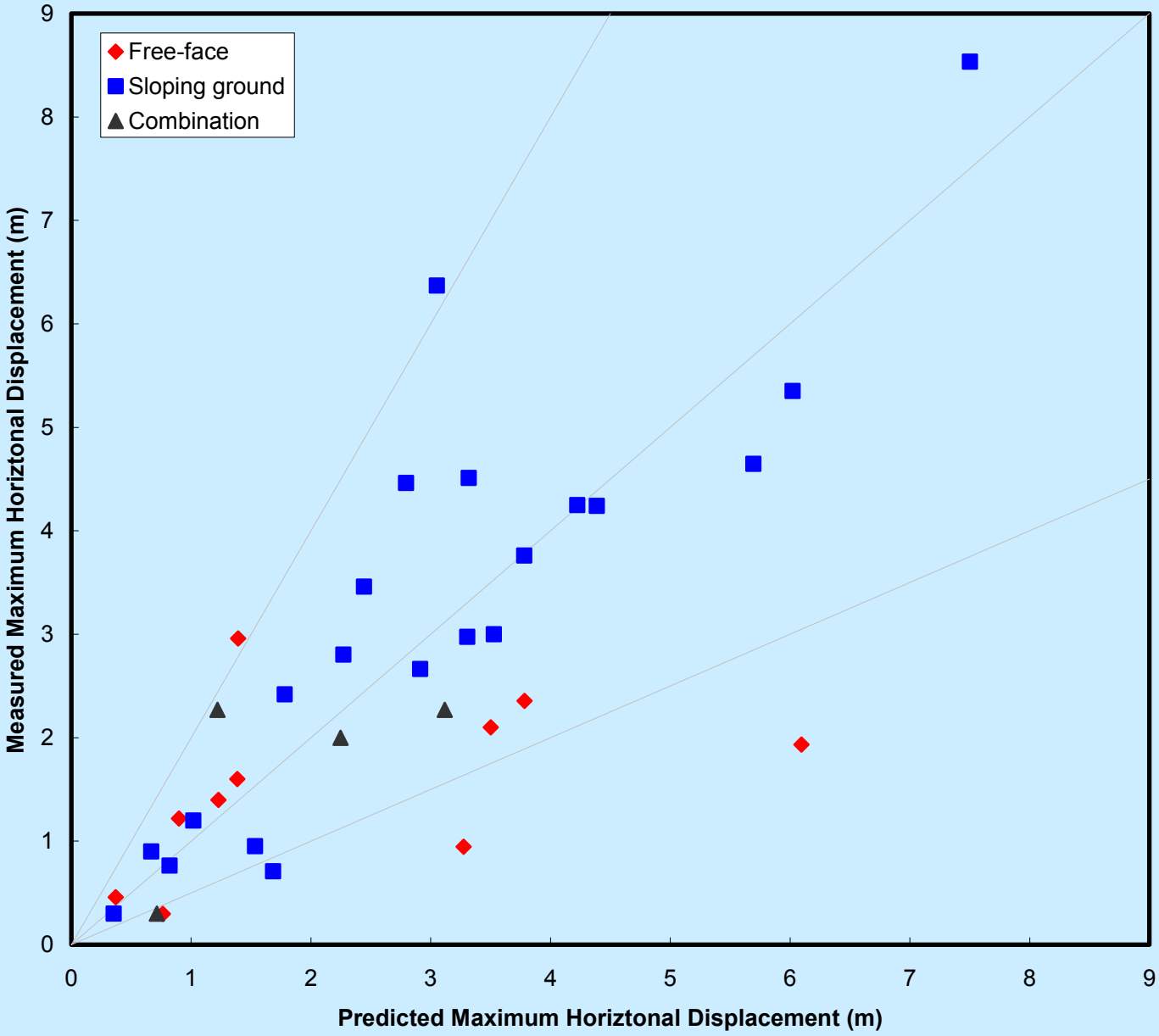




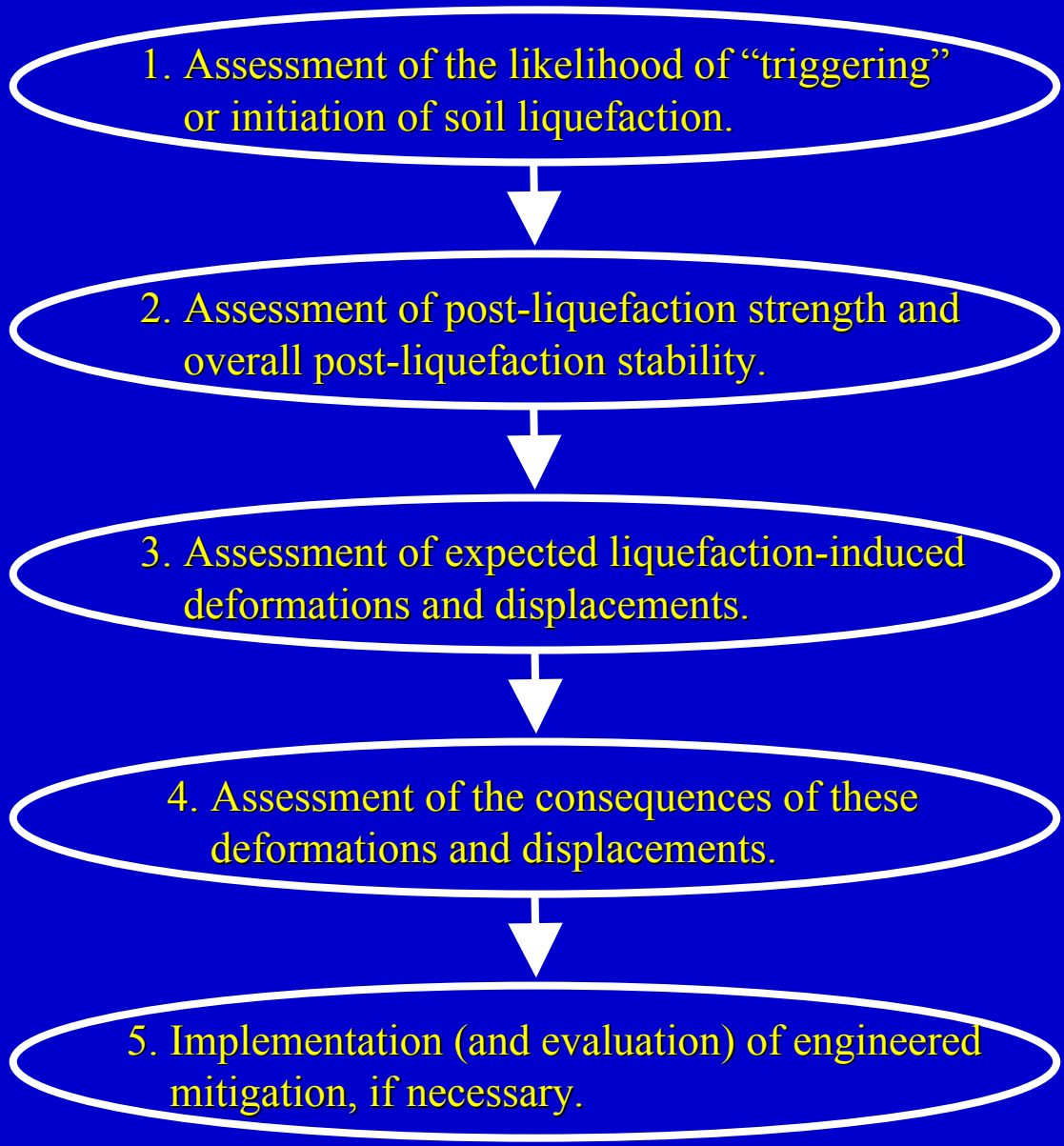


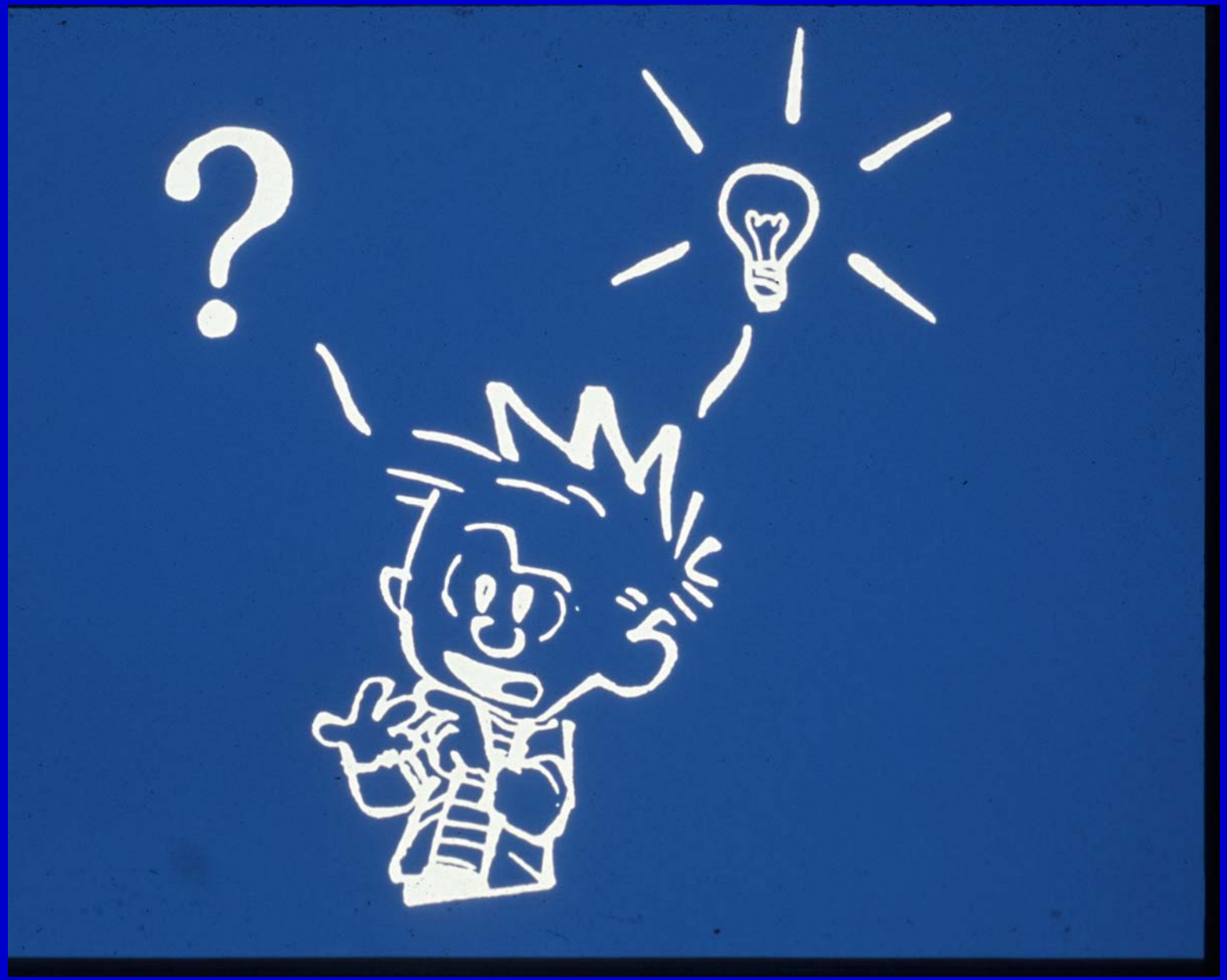
Plots of Liquefaction-Induced Lateral Spreading Assessment for Hotel Sapanca

REGRESSED FIELD CASE HISTORIES



Key Elements of Soil Liquefaction Engineering





Milestones in Geotechnical Earthquake Engineering

1964 Great Alaskan Earthquake
1964 Niigata Earthquake (Japan)

1971 San Fernando Earthquake

1986 Mexico City
1989 Loma Prieta Earthquake

1994 Northridge Earthquake
1995 Kobe Earthquake

1999 Kocaeli (Turkey) Earthquake
1999 Chi-Chi (Taiwan) Earthquake

2001 Bhuj (India) Earthquake

Key Attributes of "Important" Geotechnical Earthquake Investigations

1. Timely response.
   - Rapid (early) arrival of well-qualified "scouts"
   - Good communication
   - Adequate manpower and logistics for main study group(s)

2. Well-structured investigation teams.
   - "Experts" with good prior field experience
   - Less experienced team members (to learn….)
   - Very high levels of dedication, dilligence, sacrifice, and teamwork
   - Good social consciousness and cultural sensitivity

3. "Local" involvement on the team.

4. Open sharing.

5. Dilligent follow-on studies.

Degirmendere

K.O. Cetin, 1999