Evaluation of soil liquefaction using the CPT - Worked Examples

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Definitions of Liquefaction

- Cyclic (seismic) Liquefaction
  - *Zero effective stress* *(during cyclic loading)*
- Flow (static) Liquefaction
  - *Strain softening response*

Liquefaction - Level Ground Sites

Sites defined as:

Level ground, gently sloping (< 5 degrees) or level with nearby steep slope or free-face

Sequence to evaluate (cyclic) liquefaction:

1. Evaluate susceptibility to cyclic liquefaction
2. Evaluate triggering of cyclic liquefaction
3. Evaluate post-earthquake deformations
   a. Reconsolidation settlement
   b. Lateral spreading

Worked Examples CLiq (slick)

http://www.geologismiki.gr/
John Th. Ioannides

Moss Landing State Beach

0cm 10-30cm → 30-60cm →

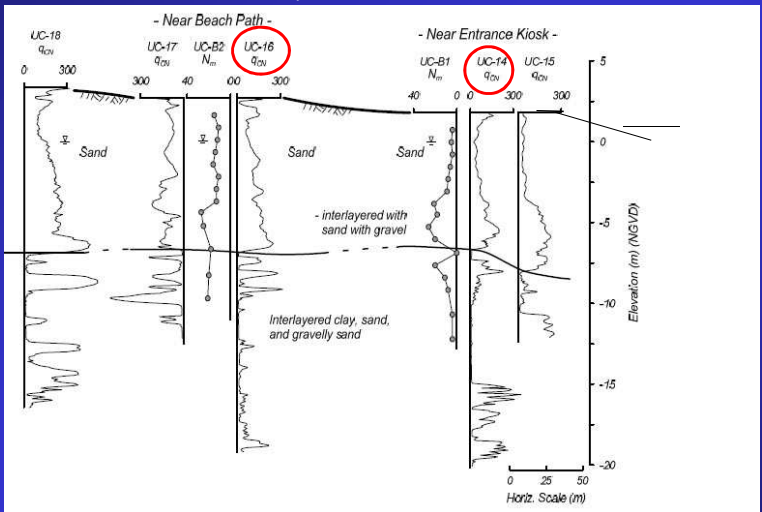
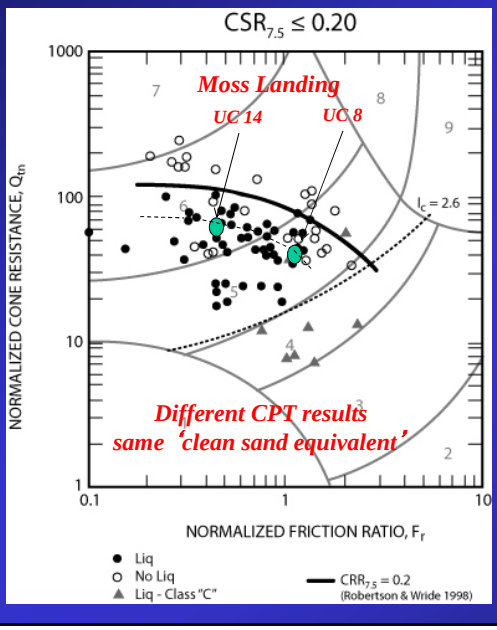


Figure 3.2: Profile at the Moss Landing State Beach (Boulanger et al. 1997)

Example - Moss Landing



Moss Landing Examples

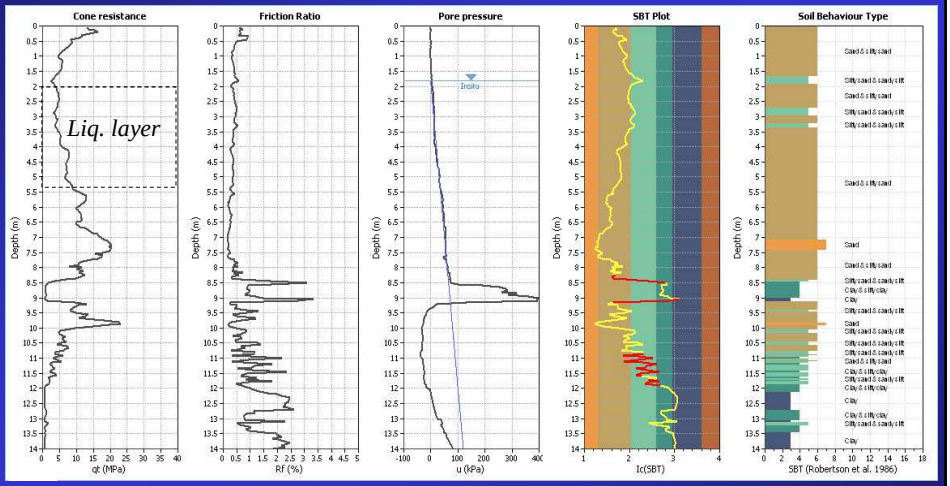
UC 14 State Beach site
Clean sand
(*FC* < 5% , I_c < 1.6)

UC 8 Marine Lab site
Silty sand
(*FC* ~20% , I_c ~ 2.2)

Both had post-earthquake settlements and lateral spreading

Database based on 'average' values within critical layer

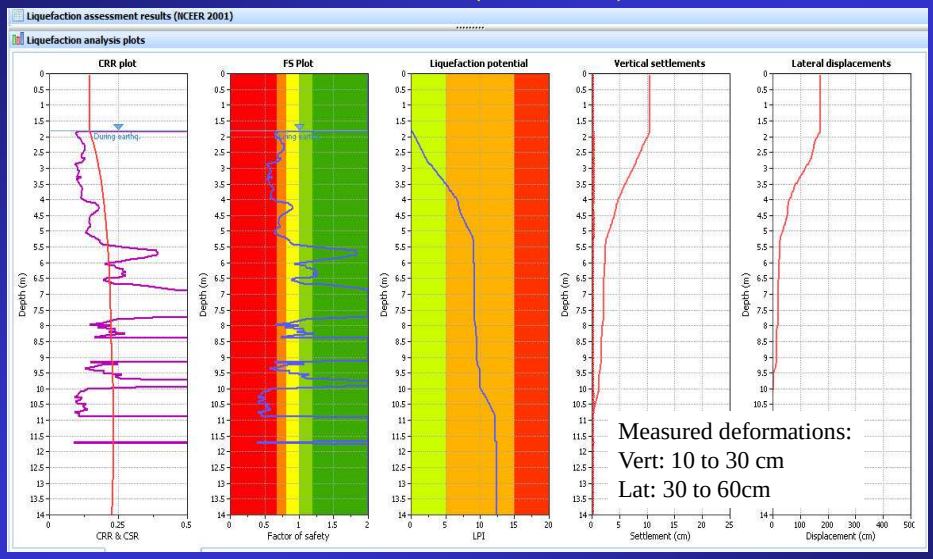
Moss Landing State Beach UC 14



Example in I&B 2008 Appendix B: L = 20m, H = 5m
$a_{(max)}$ = 0.28g, M = 6.9

Moss Landing UC 14

UC 14 NCEER (R&W) Method

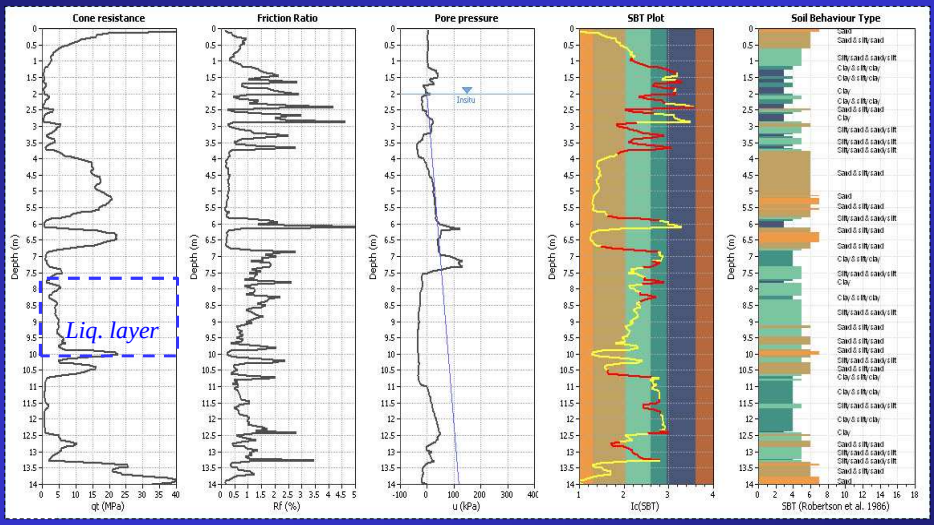


Example in I&B 2008 Appendix B: L = 20m, H = 5m

Moss Landing UC 14

Moss Landing - Lateral Spread

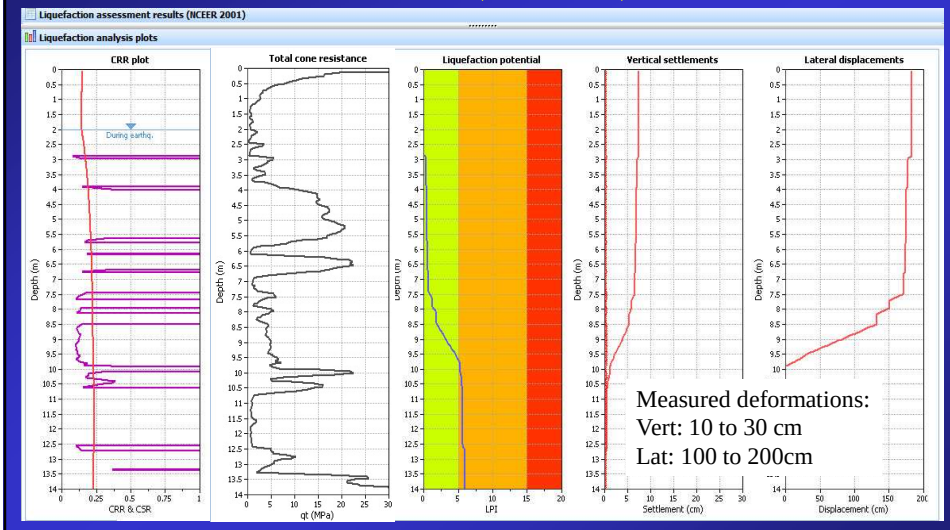
Moss Landing Marine Lab UC 8



L = 20m, H = 5m; $a_{(max)}$ = 0.28g, M = 6.9

Moss Landing UC 8

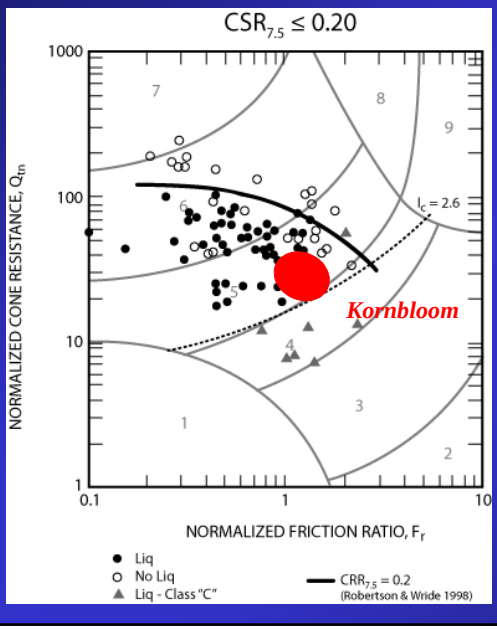
UC 8 NCEER (R&W) Method



L = 20m, H = 5m

Moss Landing UC 8

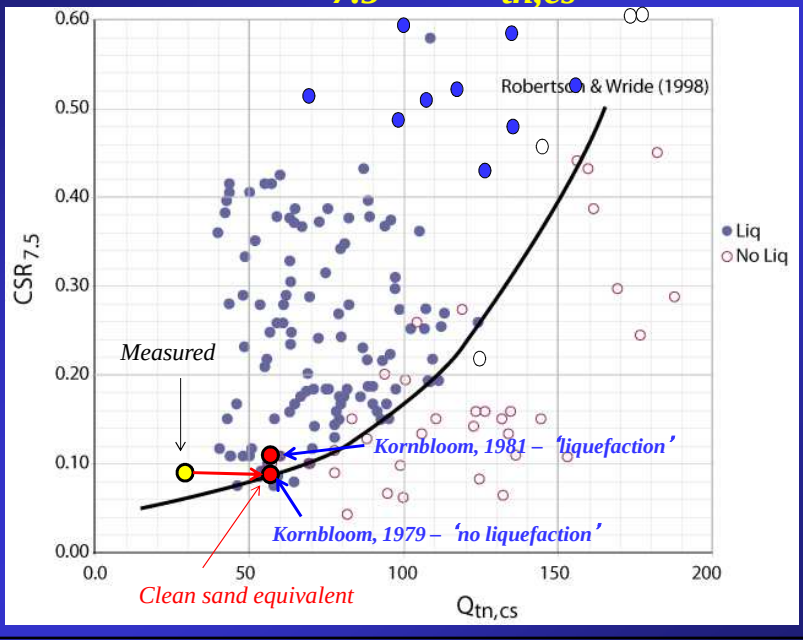
Kornbloom (Imperial Valley)



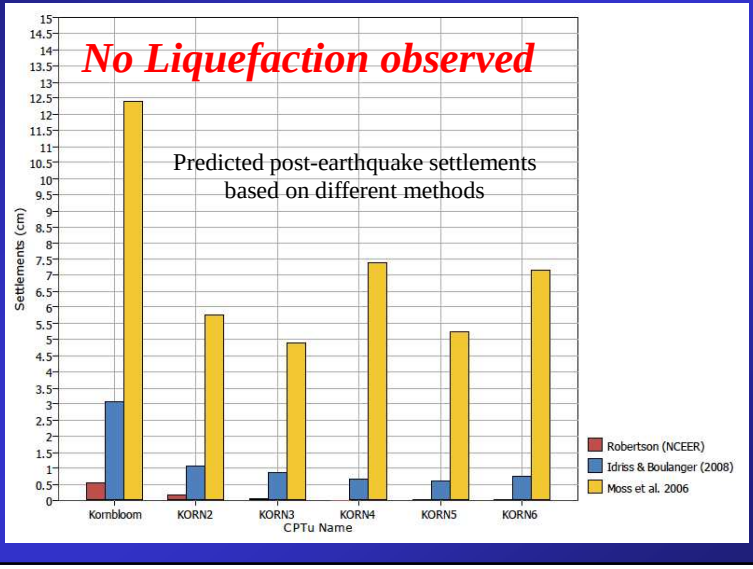
- **1981 Westmorland EQ**
  - M = 6.0, $a_{(max)}$ = 0.19g (CSR = 0.09-0.11)
  - Liquefaction observed (sand boils, surface movement)
  - Silty sand deposit (i.e. large 'correction' to clean sand equivalent)
- **1979 Imperial Valley EQ**
  - M = 6.6, $a_{(max)}$ = 0.13g (CSR = 0.08-0.09)
  - No liquefaction observed (no sand boils, etc.)

6 CPT's at site

$CRR_{7.5}$ vs $Q_{tn,cs}$



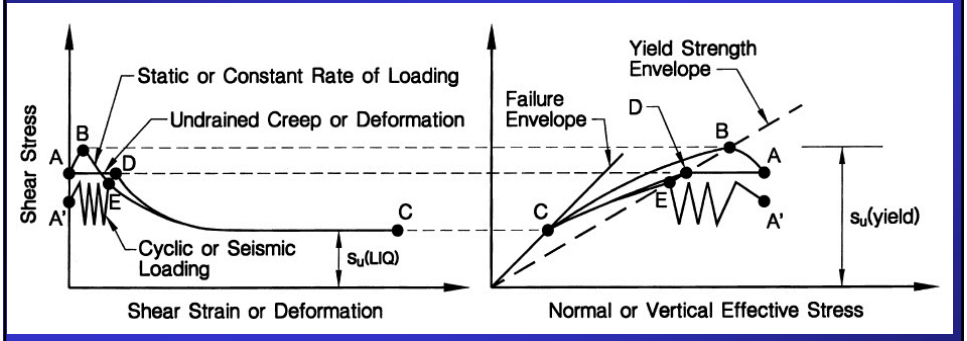
Kornbloom, Imperial Valley 1979
M= 6.6, $a_{(max)}$ = 0.13g: Silty Sand



Flow (static) Liquefaction

- Strain softening response in undrained shear
- Trigger mechanism required
- Static shear stress greater than minimum (*liquefied*) undrained shear strength
- Kinematic mechanism required
  - Uncontained flow
  - Contained deformation

Schematic undrained response of saturated, contractive sandy soil



After Olson & Stark, 2003

Flow (static) liquefaction steeply sloping ground

Sites defined as:

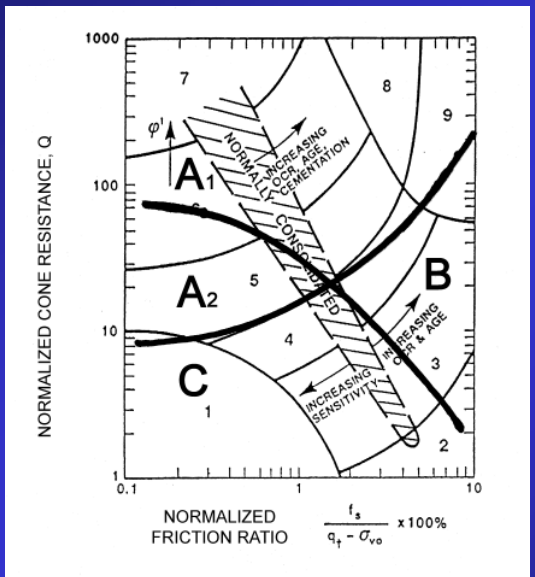
Steeply sloping (> 5 degrees) or earth embankments (e.g. dams)

Sequence to evaluate flow liquefaction:

1. Evaluate susceptibility for strength loss
2. Evaluate stability using post-earthquake shear strengths
3. Evaluate trigger for strength loss

If soils are susceptible, and instability possible, it is often prudent to assume trigger will occur

Regions of potential liquefaction



Cohesionless soils (A_1 & A_2) - Evaluate potential behavior using CPT-based case-history liquefaction correlations.

A_1 Cyclic liquefaction possible depending on level and duration of cyclic loading.

A_2 Cyclic liquefaction and post earthquake strength loss possible depending on loading and ground geometry.

Cohesive soils (B & C) – Evaluate potential behavior based on in-situ or laboratory test measurements or estimates of monotonic and cyclic undrained shear strengths.

B Cyclic softening possible depending on level and duration of cyclic loading.

C Cyclic softening and post earthquake strength loss possible depending on soil sensitivity, loading and ground geometry

Questions?

CLiq v.1.7

GeoLogismiki, in collaboration with Gregg Drilling Inc. and Prof. Peter Robertson, is pleased to announce the availability of our new Cone Penetration Test based soil liquefaction assessment software, ***CLiq***.