

Post-Cyclic Behavior of Sherman Island Peat

Ali Shafiee

*UCLA Civil & Environmental Engineering
Department*

8th Biennial Delta Science Conference
Sacramento, CA
Oct. 30, 2014

Outline

- Levees: critical components of Delta system
- Field sampling
- Laboratory test devices
- Test results
- Range of possible settlement: example
- Future work

Levees: critical components

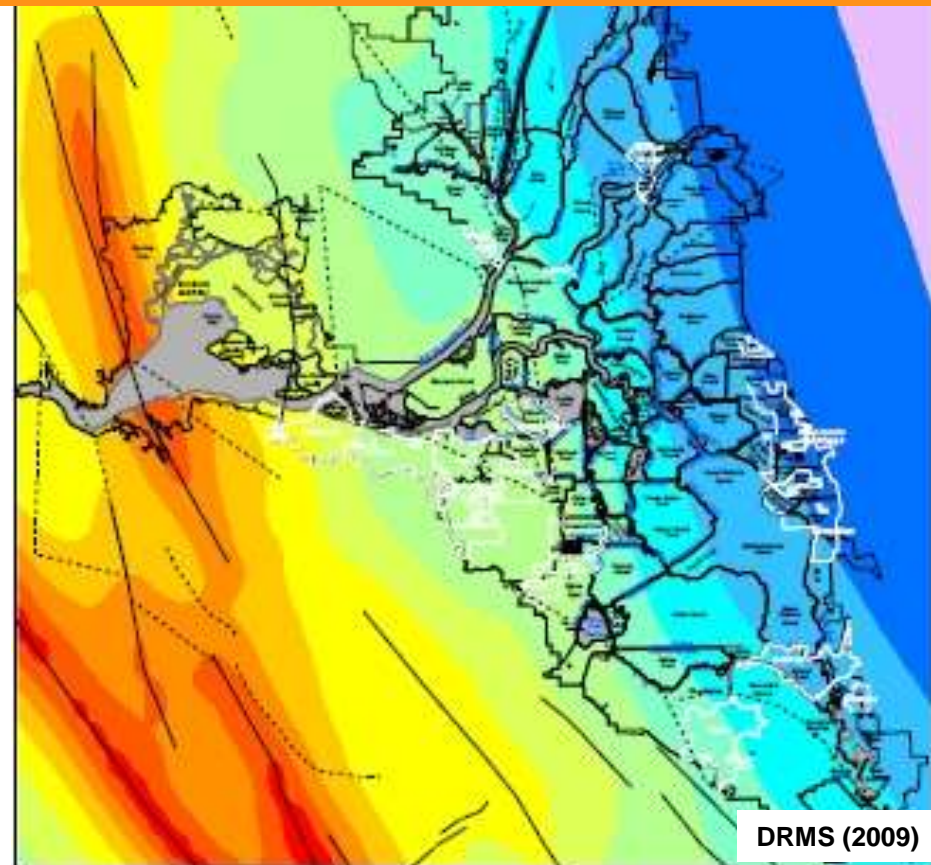
- **1115 miles of levees protect lowlands**
- **uncompacted to poorly compacted soils on peaty organic soils**
- **about 1.0-1.5 m of freeboard above the water level at high tide**



Levees: critical components

Seismic Hazard

- seismic hazard: potential for multiple simultaneous breaches inundating many islands
- Levees failure: up to 28 months of time fresh water deliveries from the Delta would not be possible

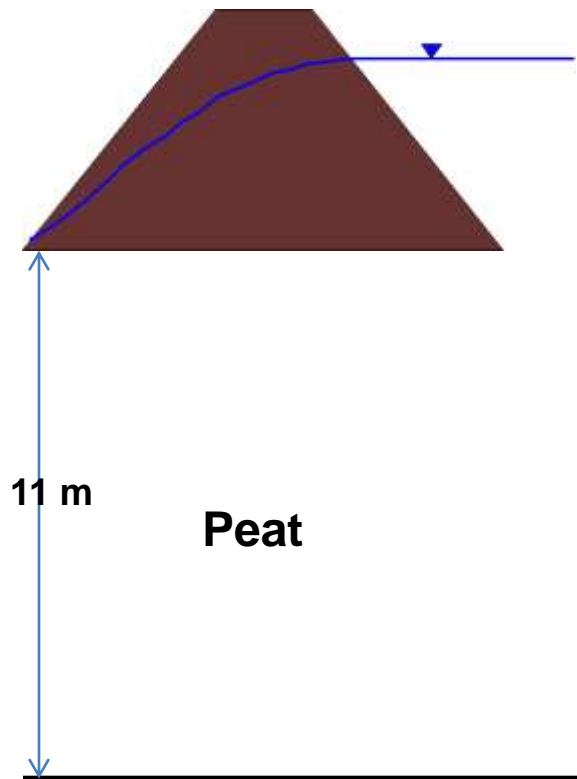


Legend

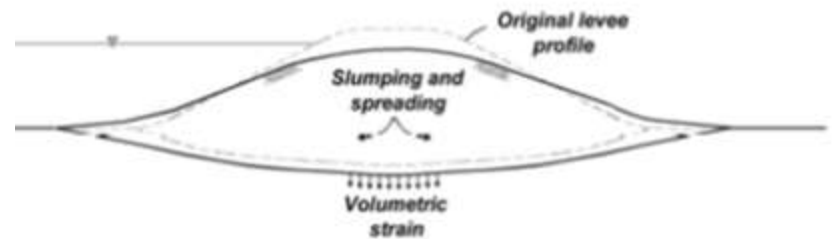
Mapped Faults		PGA, 600 Year Return Period	
—	Surficial faults used in the hazard analysis	0.00 - 0.10	0.36 - 0.40
---	Blind Faults	0.11 - 0.15	0.41 - 0.45
---	Blind faults used in the hazard analysis	0.16 - 0.20	0.46 - 0.50
---	Legal Delta and Suisun Marsh Boundary	0.21 - 0.25	0.51 - 0.55
---		0.26 - 0.30	0.56 - 0.60
---		0.31 - 0.35	0.61 - 0.65
---			0.66 - 0.70



Levees: critical components



Potential Failure Mechanism

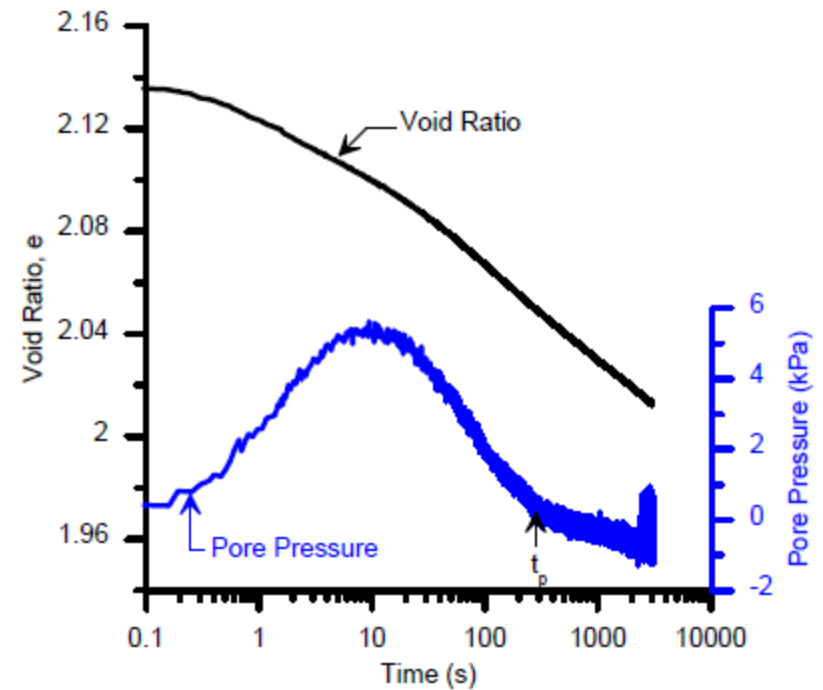
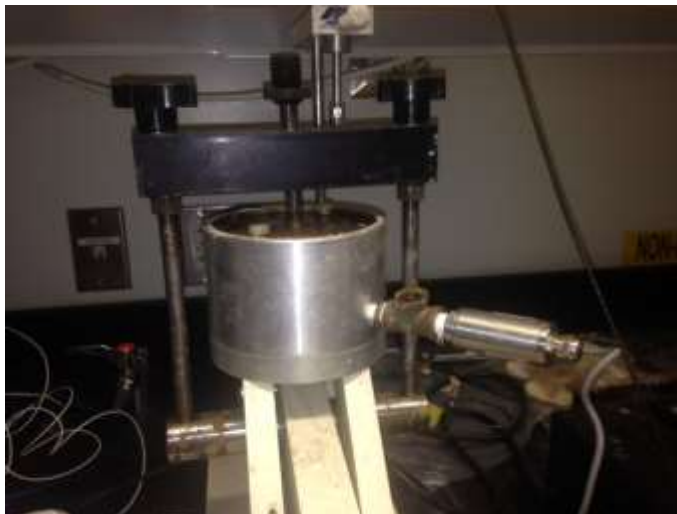
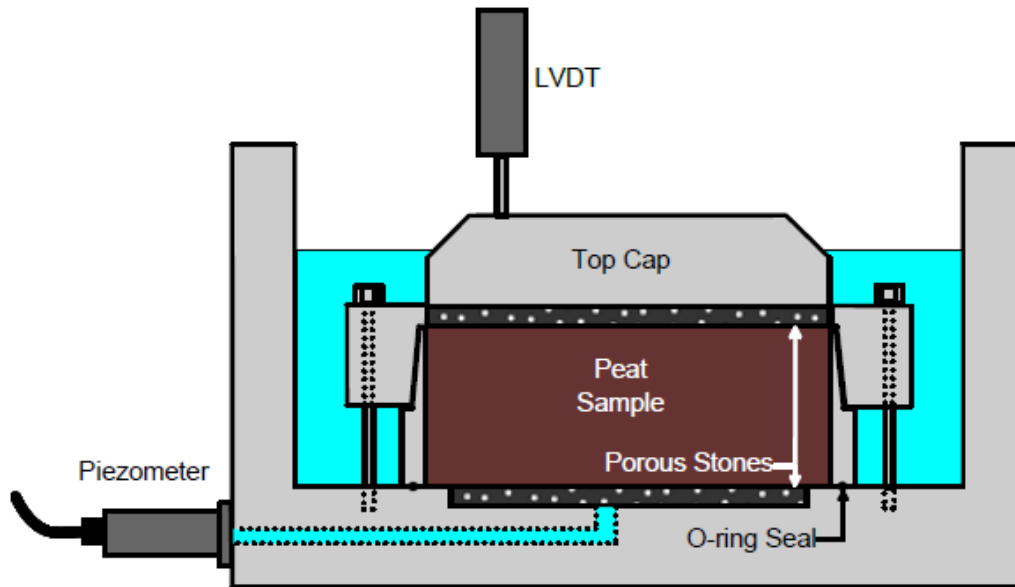


Peat



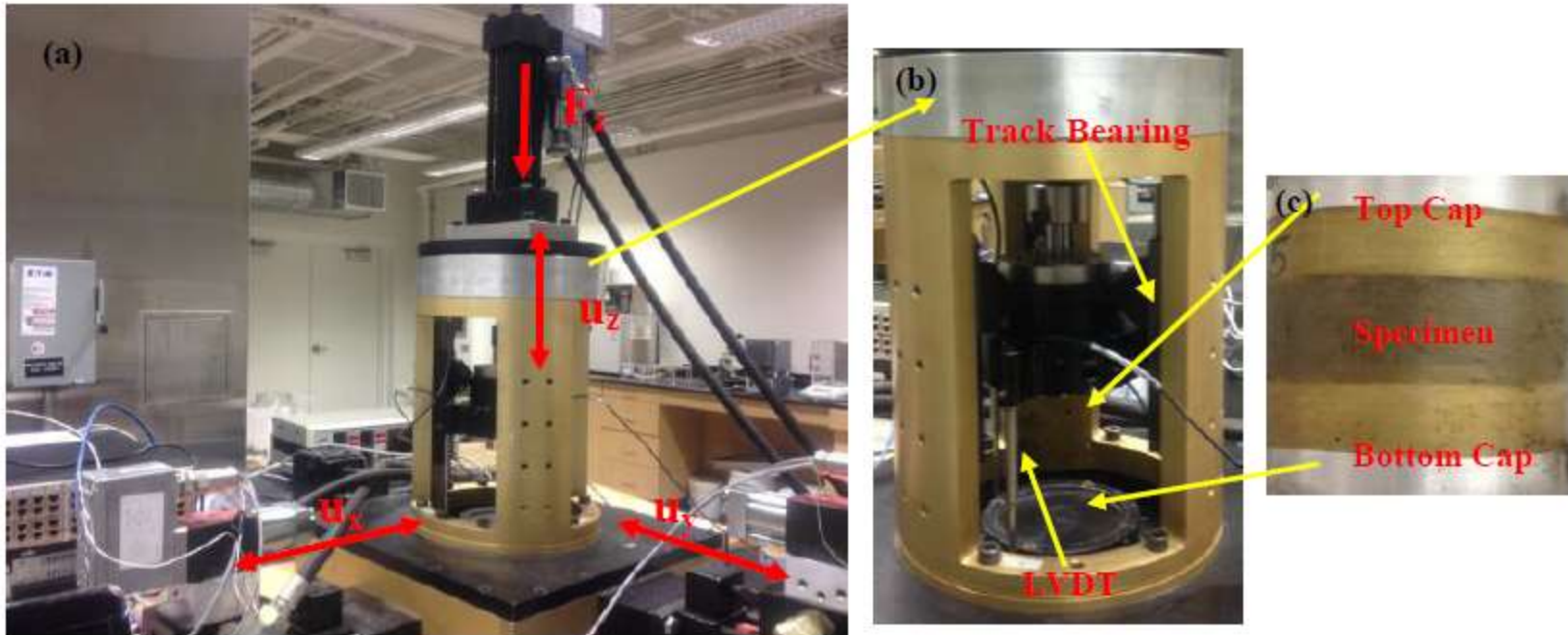
Laboratory Test Devices

Consolidation cell with pore pressure measurement



Laboratory Test Devices

Digitally-controlled simple shear device

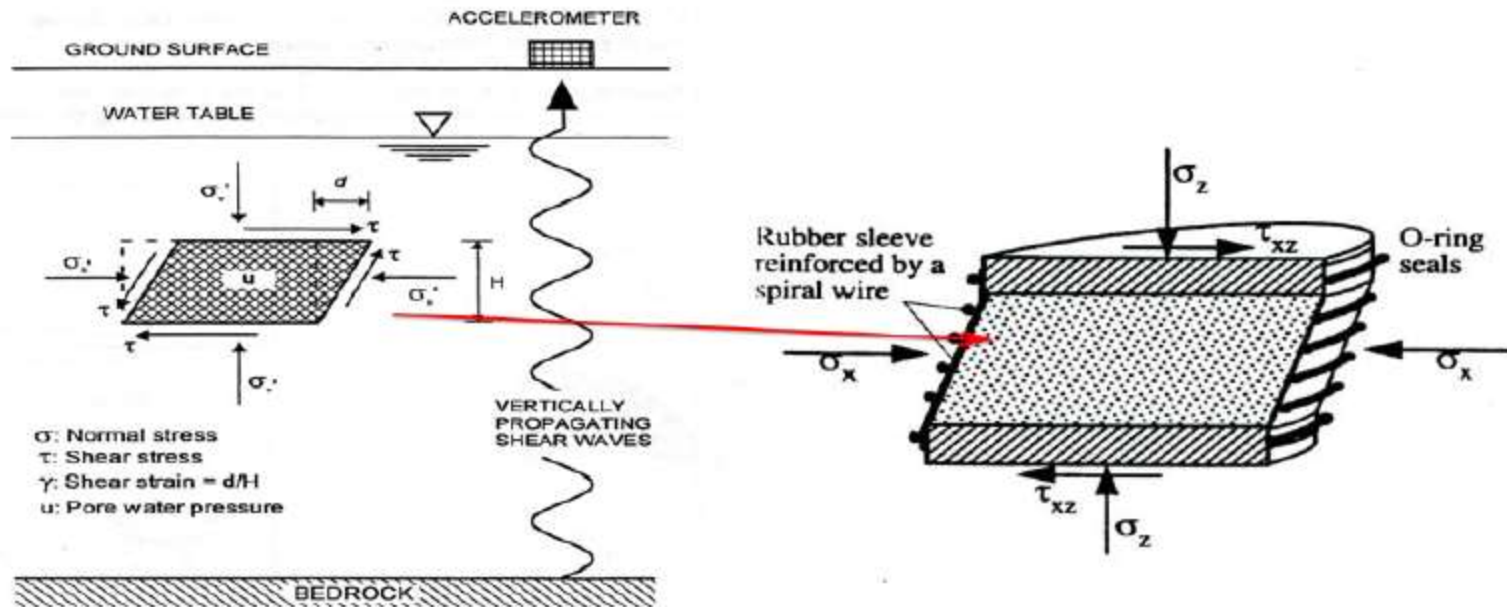


Attributes:

- Specimens: K_0 -conditions due to wire-reinforced membranes. Diameter up to 10.2 cm
- Vertical direction: capabilities for stress/strain controlled consolidation, and constant load (drained) or constant height (undrained) control during shear
- Horizontal direction: cyclic or broadband demands; two horizontal directions; strain-controlled or stress-controlled testing
- Uses servo hydraulic actuators

Laboratory Test Devices

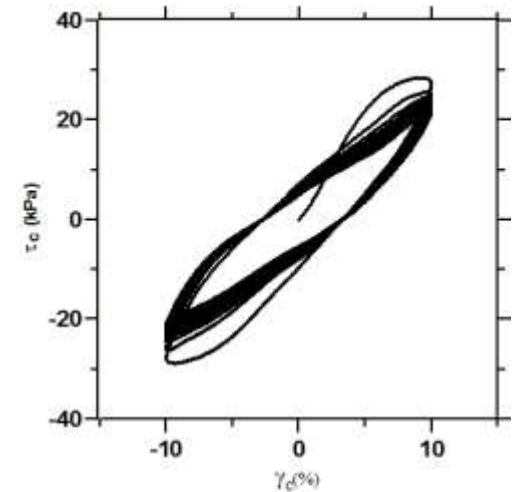
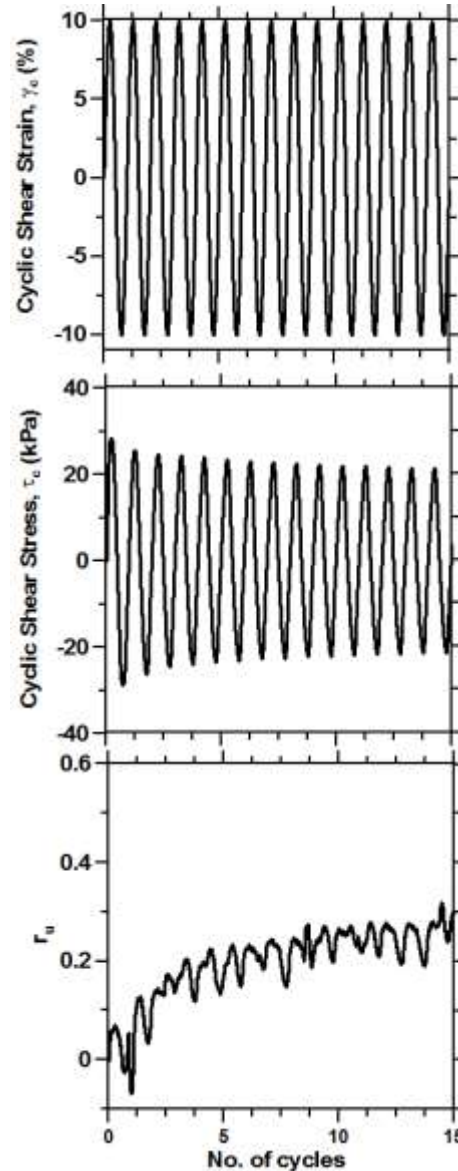
Simple shear testing simulates vertical shear wave propagation



Chu-Chang (2002)

Simple Shear Testing

Typical result of constant volume cyclic strain-controlled test



OCR=1.33

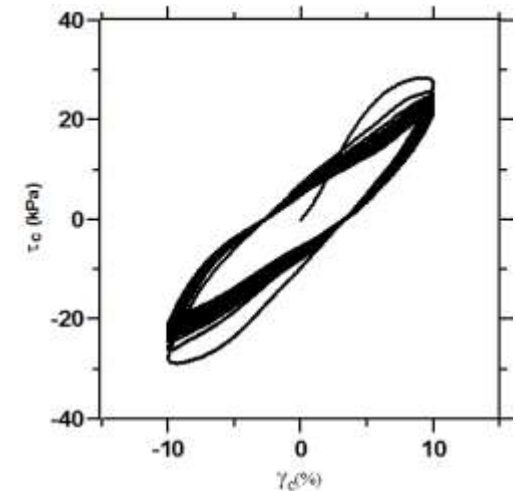
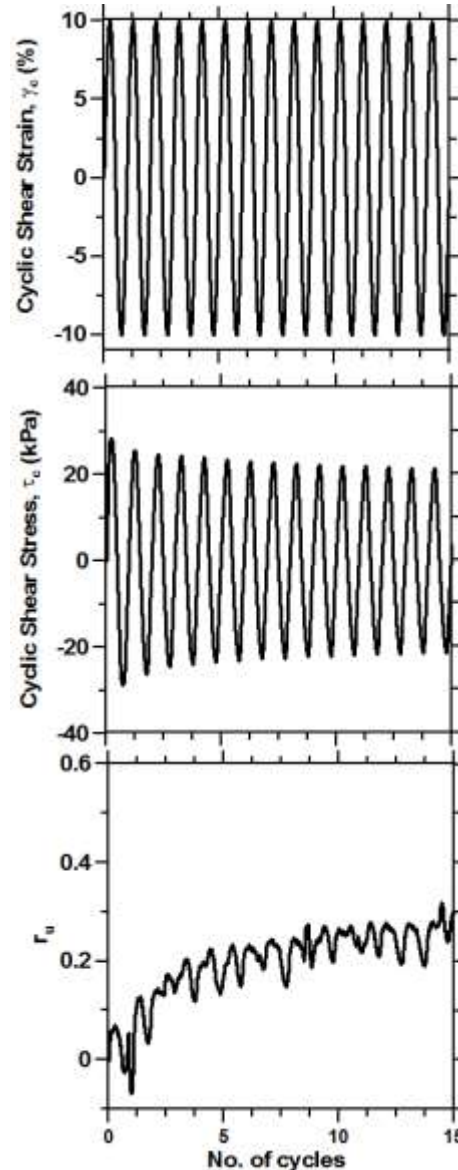
OC=67%

σ'_{v0} =65 kPa

Simple Shear Testing

Typical result of constant volume cyclic strain-controlled test

Pore pressure is generated



OCR=1.33

OC=67%

$\sigma'_{v0}=65$ kPa

$$r_u = \Delta u / \sigma'_{v0}$$

Influence of Cyclic Strain on Secondary Comp.

- Sequence of constant volume strain-controlled simple shear test at varying γ_{cyc} followed by post-cyclic volume change

Sherman Island Peat

$\sigma'_{v0}=12$ kPa

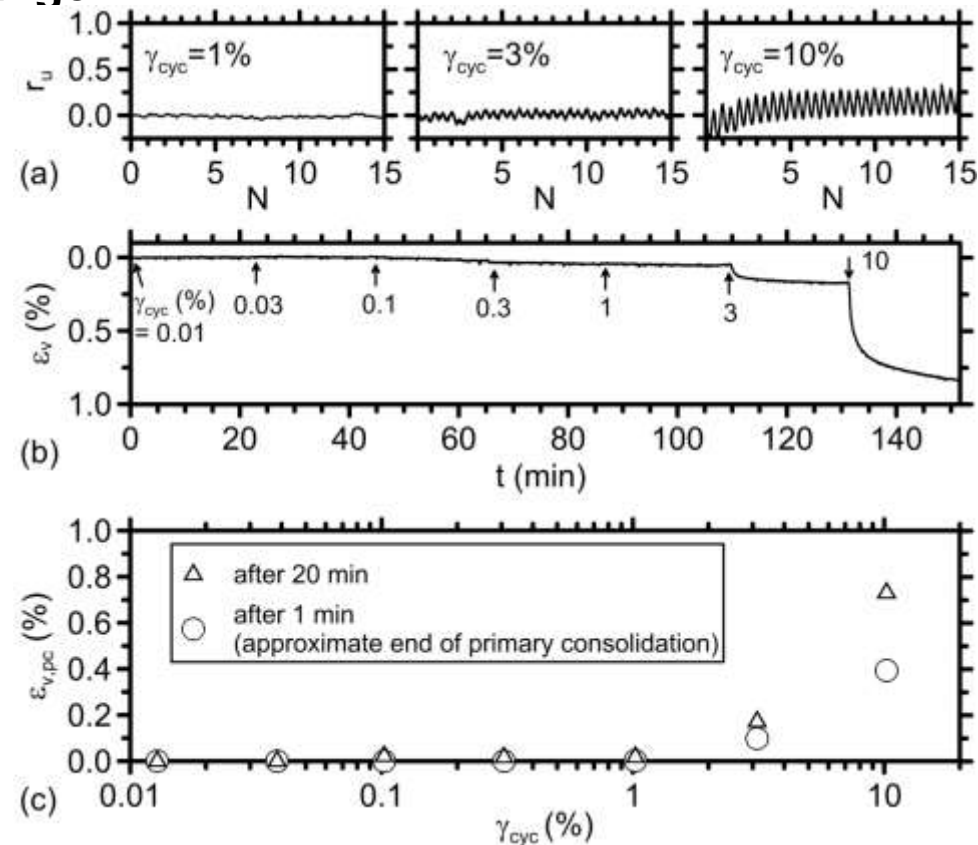
OCR=4.9

OC=55%

- r_u increases with γ_{cyc}

- Rate of secondary compression increases with γ_{cyc}

- Post-cyclic volumetric strain ($\varepsilon_{v,pc}$) increases with γ_{cyc}



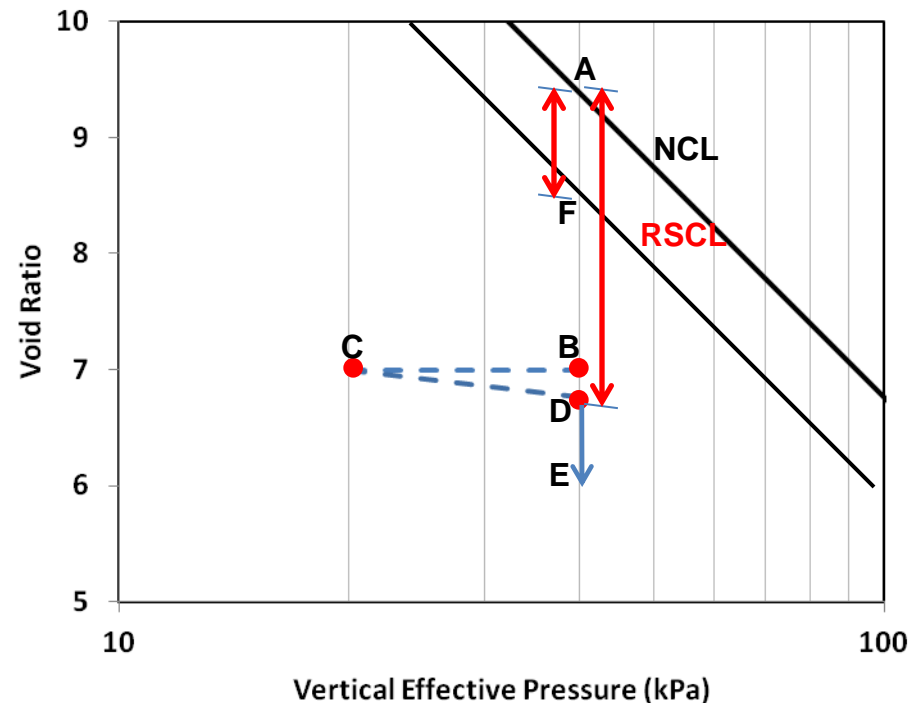
Reset Index

- Kutter and Sathialingam (1992) postulated that (de/dt) is a function of distance from the NCL
- Increase in strain rate means the distance from NCL has been decreased

$$\text{Reset Index} = \frac{AF}{AD}$$

Reset Index=0, No Reset at all

Reset Index=1, Fully Reset

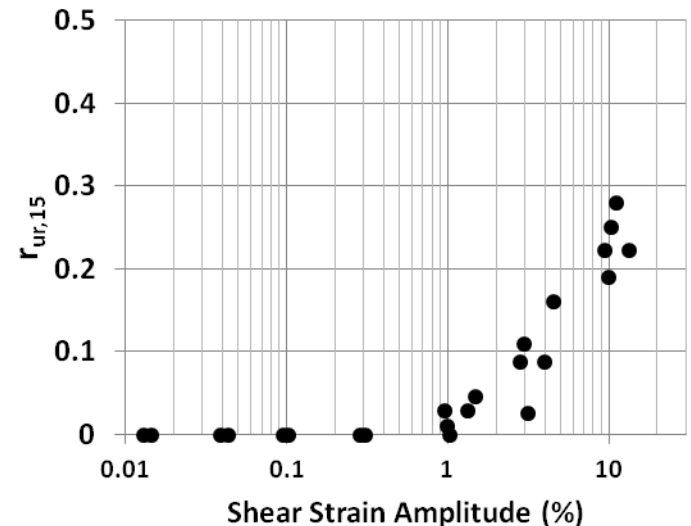
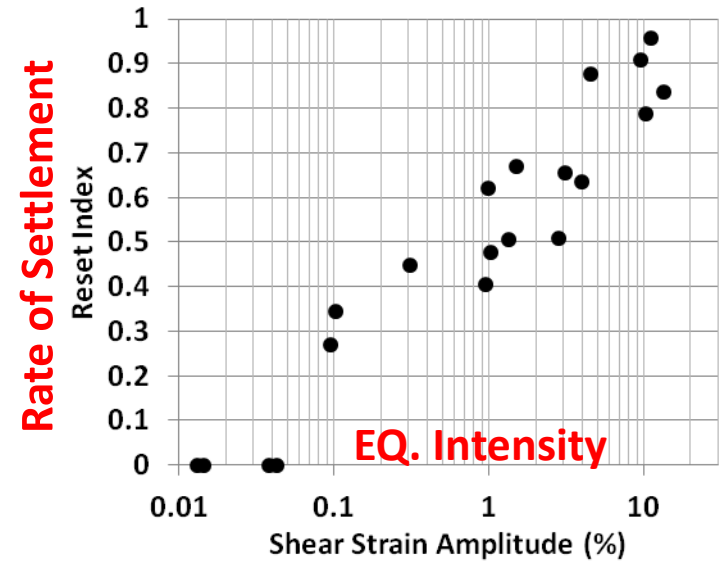


RSCL: Reference Secondary Compression Line

Reset Index

- Reset index is mostly correlated with γ_{cyc}
- Secondary compression and r_u both have a threshold shear strain below which no secondary compression and pore pressure happens
- Threshold shear strain for secondary compression is less than that of r_u

$$r_{ur} = \frac{\Delta u_r}{\sigma'_{vc}}$$



Range of Possible Settlement: An Example

Sherman Island Peat :

$$C_c = 6.6$$

$$C_r = 0.57$$

$$C_\alpha = 0.3$$

Layer Thickness = 11.0 m

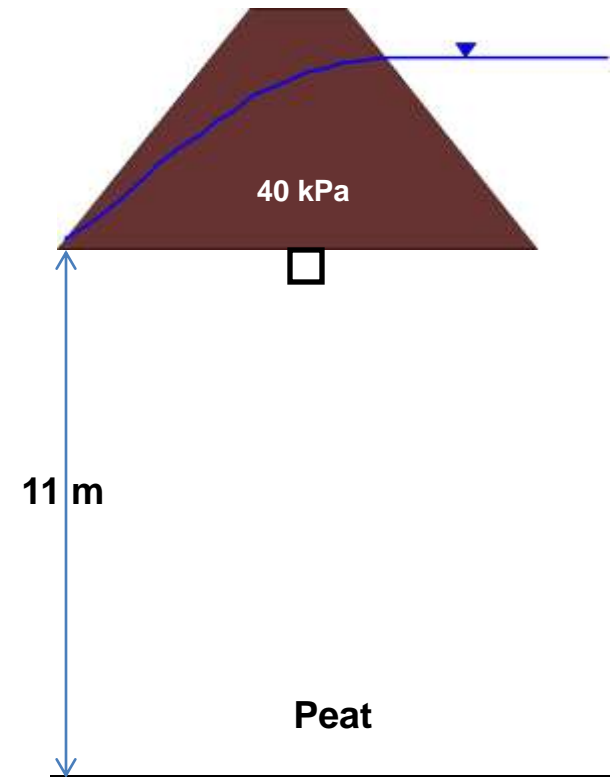
Levees were built 150 years ago

Objective:

Estimation of settlement following earthquake:

- 1) $r_u = 0$, no earthquake, no reset (**No. EQ**)
- 2) $r_u = 0.3$, no reset
- 3) $r_u = 0.3$, fully reset (R.I.=1.00) (**Strong EQ**)
- 4) $r_u = 0.2$, partially reset (R.I.=0.80)
- 5) $r_u = 0.1$, partially reset (R.I.=0.55) (**Small to Medium EQ**)
- 6) $r_u = 0.0$, partially reset (R.I.=0.30)

R.I.: Reset Index



Range of Possible Settlement: An Example

Non-linear consolidation computer program

(considers volumetric strains from secondary compression during consolidation)

Compressibility Properties

Virgin Compression Index, C_c 0.50
Recompression Index, C_r 0.05
Reference Pressure, $\sigma'_{v,ref}$ 50.0 kPa
Reference Void Ratio, $e_{\sigma v,ref}$ 1.4
Specific Gravity of Solids, G_s 2.7

Permeability Properties

Reference Permeability, k_{ref} 1.0e-8 m/s
Reference Void Ratio, $e_{k,ref}$ 0.8
Coefficient of Permeability Variation, C_k 0.5

Secondary Compression Properties

Secondary Compression Index, C_{α} 0.025
Reference time, $t_{ca,ref}$ 100.0 s
Reference void ratio, $e_{ca,ref}$ 1.4
Reference vertical effective stress, $\sigma'_{ca,ref}$ 50.0 kPa

Loading Conditions

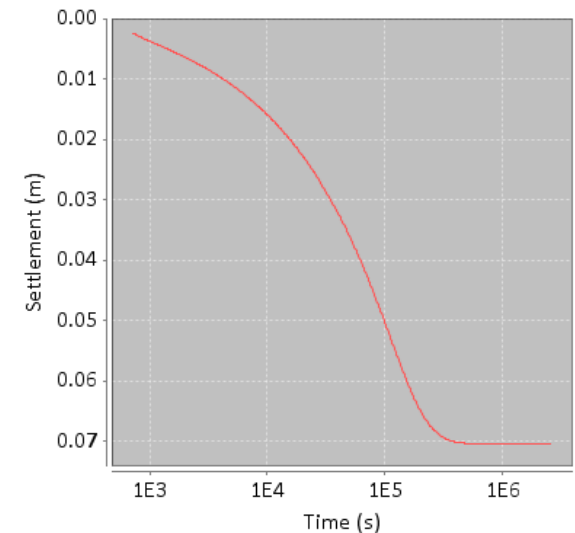
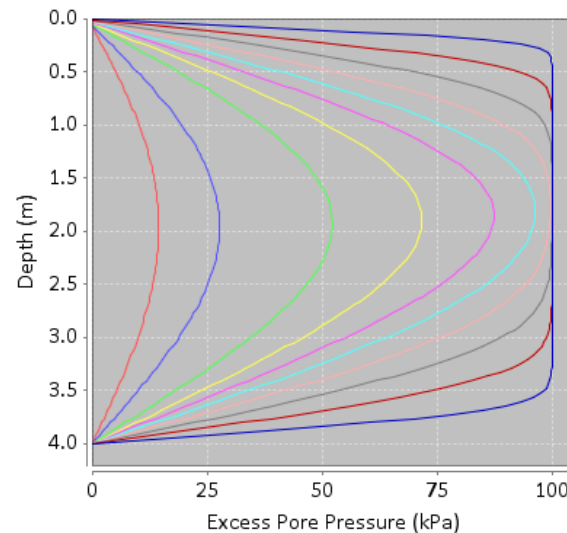
Height 4.0 m
Initial Overburden Pressure, q_o 10.0 kPa
Vertical Total Stress Change, $\Delta\sigma_v$ 100.0 kPa
Initial Excess Pore Pressure Ratio, r_u 0.0

Constant Void Ratio

1.0

Number of elements 100
Number of time steps 500
Max time, t_{max} 2.561e6 s

Adjust Isochrone Plot



Save Data Options

- ☒ Settlement Versus Time
- ☒ Pore Pressure Isochrones for Plotted Time Steps
- ☐ Pore Pressure Isochrones for All Time Steps
- ☒ Nodal Depths for Plotted Time Steps

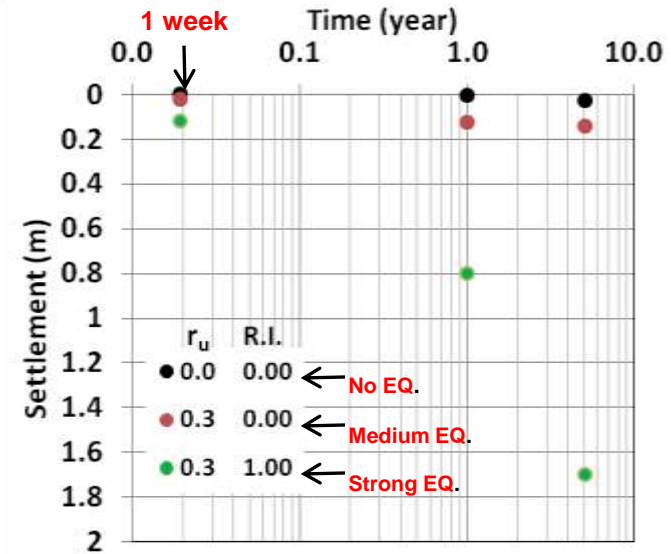
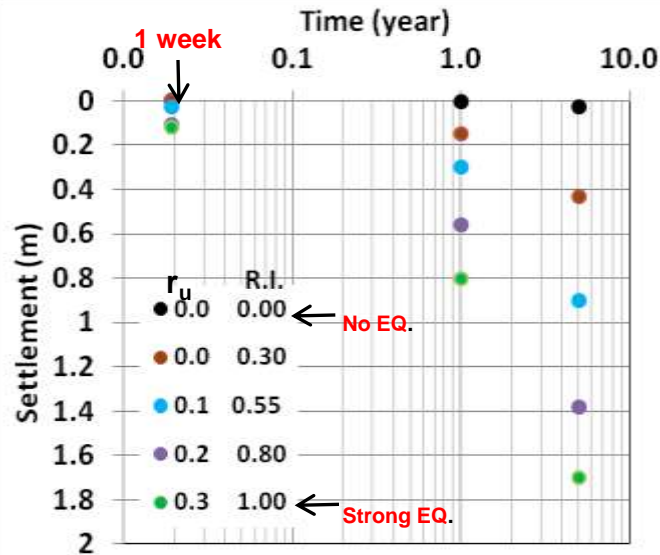
UCLA

UCLA Nonlinear Consolidation: An Implicit Finite Difference Consolidation Program Including Secondary Compression.

Acknowledgments

This program uses the following libraries:

Range of Possible Settlement: An Example



R.I.=Reset Index

Future Work

- **Developing a webpage for the project that includes all the raw and processed data**
- **Continuation of 1-D consolidation, monotonic tests, cyclic strain-controlled tests, cyclic stress-controlled at different organic contents and OCRs.**
- **Broadband dynamic consolidated-undrained tests**

Acknowledgement

**Support for this research has been provided by
DWR
and
USGS**

Thank You for Your Attention