Dynamic Response of Levees

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The Delta

Photo courtesy of Roy Tennant.

http://sanjoaquinbasin.com/images/joaquin_dec.png

http://pubs.usgs.gov/fs/2010/3032/images/map01.png
Land Subsidence

DRMS (2008)
Testing of Sherman Island Peat
How Soft is the Peat?
Cyclic Simple Shear Laboratory Testing Device

Vertical Stress

Force

Disp

Strain = Disp/Height
Stress = Force/Area

Height

Soil Sample

Shafiee et al. (2015)
Peat Settlement Potential

(a) 

\[ r_u \]

- \( \gamma_{cyc} = 1\% \)
- \( \gamma_{cyc} = 3\% \)
- \( \gamma_{cyc} = 10\% \)

(b) 

\[ \varepsilon_v (\%) \]

- \( \gamma_{cyc} (\%) \)
- \( \varepsilon_v (\%) \)
- \( t \) (min)

(c) 

\[ \varepsilon_v (\%) \]

- \( \gamma_{cyc} (\%) \)

Shafiee et al. (2015)
iConsol.js Computer Code

- iConsol.js is an nonlinear consolidation code publicly accessible online at www.uclageo.com/Consolidation/ and described by Brandenberg (2017).
- “Uniform” layer of soil has constant compressibility and permeability constitutive relationship.
Test Location

Vibration Level
1 Acceptable for modern buildings
2 Acceptable for historic buildings
3 Acceptable for fragile structures
4 Car driving over levee crest
5 Barely perceptible
6 Ambient vibrations during quiet time

Reinert et al. (2014)
MK-15 Mobile Field Shaker

Reinert et al. (2014)
Sample Data

Reinert et al. (2014)
Sample Data

\[ r_{ur} = \frac{\Delta u}{\sigma_{vo}} \]

Reinert et al. (2014)
Levee Centrifuge Models

Clay Levee Model (Non-Liquefiable)

Sand Levee Model (Liquefiable)

Cappa et al. (2017)
Shaking Sandy Levee
Fragility Functions

Table 1. Damage levels assigned to levee segments

<table>
<thead>
<tr>
<th>Damage Level</th>
<th>Crack depth (cm)</th>
<th>Crack width (cm)</th>
<th>Subsidence (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>No damage reported</td>
</tr>
<tr>
<td>1</td>
<td>0~100</td>
<td>0~10</td>
<td>0~10</td>
<td>Slight damage, small cracks</td>
</tr>
<tr>
<td>2</td>
<td>100~200</td>
<td>10~50</td>
<td>10~30</td>
<td>Moderate damage, cracks or small lateral spreading</td>
</tr>
<tr>
<td>3</td>
<td>200~300</td>
<td>50~100</td>
<td>30~100</td>
<td>Severe damage, lateral spreading</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 300</td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>Levee collapse</td>
</tr>
</tbody>
</table>

Kwak et al. (2016a)
Fragility Functions

Kwak et al. (2016a)
System Analysis

For segment $i$: $\exp(\mu_{inc}) = 108$ cm/s, $\sigma_{inc} = 0.89$

For segment $j$: $\exp(\mu_{inc}) = 84$ cm/s, $\sigma_{inc} = 0.80$

Kwak et al. (2016b), Zimmaro et al. (2018)
System Analysis

\[ P(F_R | E) = 1 - \left( 1 - P(F_{Seg} | E) \right) \exp \left( - \frac{L}{2\pi} \sqrt{\frac{d^2 \rho_Z(0)}{dx^2}} \times \exp \left( - \frac{\beta_{Seg}^2}{2} \right) \right) \]

Kwak et al. (2016b)
Conclusions

• The Sacramento / San Joaquin Delta is an important piece of infrastructure, serving as the hub of California’s water distribution system.

• Earthquakes pose a particularly onerous hazard to the Delta due to the potential for multiple simultaneous levee breaches and intrusion of saline water.

• Laboratory, field, and centrifuge testing has helped us characterize the seismic response of levees.

• Fragility curves have been developed from field observations of levee damage in Japan.

• A new system reliability analysis procedure was developed to compute the probability of system failure given levee capacity and demand as spatially correlated random fields.
References


