Acknowledgements

- Pacific Earthquake Engineering Research Center (PEER)
- Staff and a group of graduate students at UCSD
- Ram Jack
Presentation Outline

- Background and Motivation
- Experimental Program
- Test Series #1
- Future Testing Program

Field Reconnaissance and Observations (March 11, 2011 Tohoku Earthquake Mw 9.0)

- Widespread Liquefaction
  - 27,000 buildings damaged
  - Similar to Christchurch, NZ

- Building foundation performance varied
  - Deep foundations => good performance
  - Shallow foundations => extensive damage
  - 0 cm < 30 cm < 70 cm
  - Factor of 2.3

![Building (Pile Supported) - No Settlement](image)
![Free field - 30cm Settlement](image)
![Building (Mat Foundation) - 70cm Settlement](image)
Research Approaches

- Field case histories
- Centrifuge tests
  - 1-g shaking table tests
- Field tests

Shake Table Experiments

- Model size vs. cost

<table>
<thead>
<tr>
<th>Scale of Model</th>
<th>Cost per Test ($)</th>
<th>Number of Tests (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>Moderate</td>
<td>$$</td>
<td>$$</td>
</tr>
<tr>
<td>Large</td>
<td>$$$</td>
<td>$$$</td>
</tr>
</tbody>
</table>

- H: 5 m
- H: 4.7 m
- H: 2.9 m
- H: 0.8 m
Testing Program of Study

- Two series of tests
  1. Without any mitigation (benchmark test) – Completed June 2018
  2. With helical piles as a countermeasure
- Multiple shakings including white noises during each test

<table>
<thead>
<tr>
<th>Test #</th>
<th>PGA (g)</th>
<th>GWT (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>0.15 g</td>
<td>0.6</td>
</tr>
<tr>
<td>1-2</td>
<td>0.3 g</td>
<td>0.6</td>
</tr>
<tr>
<td>1-3</td>
<td>0.3 g</td>
<td>0</td>
</tr>
</tbody>
</table>

Target Input Motion

Benchmark Test Layout

Test Series#1:
- Isolated footing,
- GWT @ 0.6m
- Uniform liquefiable layer w/o mitigations
- 41.6kPa contact pressure was meant to reproduce a low-story building foundation
- Extensive instrumentation
Laminar Box at UCSD’s Powell Lab

- Height = 2.9m (9.5 ft), Width = 1.8m (5.9 ft), Length = 3.9m (12.8 ft)

Model Preparation

Dense Layer

Footing
Characterization of Soil Layers

- Material: Ottawa F-65 Sand
- Three layers: (1) shallow crust, (2) thick loose, (3) dense
- Model preparation
- Three methods used for relative density calculations:
  1- Sand cone test
  2- Based on volume and weight of each layer
  3- Dynamic Cone Penetrometer (DCP) test

<table>
<thead>
<tr>
<th>Layer</th>
<th>Dr % (Sand cone)</th>
<th>Dr % (Weight)</th>
<th>Dr % (DCP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense</td>
<td>90</td>
<td>87</td>
<td>83</td>
</tr>
<tr>
<td>Loose</td>
<td>-</td>
<td>41</td>
<td>-</td>
</tr>
<tr>
<td>Crust</td>
<td>52</td>
<td>53</td>
<td>-</td>
</tr>
</tbody>
</table>
**Instrumentation Plan**

**Types and number of instrumentation**

<table>
<thead>
<tr>
<th>Type</th>
<th>Accelerometer</th>
<th>High Resolution Acc.</th>
<th>PWP</th>
<th>String Pot.</th>
<th>Linear Pot.</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>#</td>
<td>35</td>
<td>28</td>
<td>47</td>
<td>18</td>
<td>6</td>
<td>134</td>
</tr>
</tbody>
</table>

**Diagram**

- Acc (Accelerometer)
- SP (String Pot.)
- PWP (Pressure Pot.)
- LP (Linear Pot.)
Test #1-1: PGA= 0.15g, GWT= 0.6m

Observations and Conclusions

- Test series#1 (benchmark) results are being processed
- Extensive liquefaction and sand ejecta were achieved
- So far, very good agreement with published literature and prior 1-g scaled shake table tests at UNR
- Benchmark test is being evaluated for a potential blind prediction contest through PEER => information to follow
Mitigation Measures

- Cost effective
- Applicable to new construction and existing buildings
- Helical piles
- 1-g shaking table testing on dry sands and liquefied soils

Thank you and questions