Geotechnical Lessons from Recent Earthquakes

Moderator: Russell Green, Virginia Tech

- 2010, $M_w$7.0 Haiti Earthquake
  Dr. Brady Cox, University of Arkansas

- 2010, $M_w$8.8 Maule, Chile Earthquake
  Dr. Scott Olson, University of Illinois at Urbana-Champaign

- 2010-2011, Canterbury New Zealand Earthquake Sequence
  Dr. Russell Green, Virginia Tech

- 2011, $M_w$9.0 Tohoku-Oki, Japan Earthquake
  Dr. Shideh Dashti, University of Colorado, Boulder

- Potential impact of lessons learned on practice
  Dr. Ellen Rathje, University of Texas at Austin
An Overview of the Geotechnical Aspects of the 2010-2011 Canterbury, New Zealand Earthquake Sequence

Russell A. Green

The Charles E. Via, Jr. Department of Civil and Environmental Engineering

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Outline

- Tectonics and seismicity of New Zealand
- 2010-2011 Canterbury Earthquake Sequence
- Geotechnical Related Damage
  - Soils of Christchurch
  - Impact of liquefaction and lateral spreading
    - Building structures
    - Buried pipelines
    - Bridges
  - Rockfalls and landslides
  - Port of Lyttelton
- The Future
- Summary and Conclusions
2010-2011 Canterbury Earthquake Sequence

4 Sept 2010
M_w 7.1, Darfield Earthquake

22 Feb 2011
M_w 6.2, Christchurch Earthquake

23 Dec 2011
M_w 6.0 Earthquake

13 June 2011
M_w 6.0 Earthquake

Seismicity to 13th March, 2012
Peak Ground Accelerations (PGA)

Shaking Intensity - 4 Sept 2010

Shaking Intensity - 22 Feb 2011

Shaking Intensity – 13 June 2011
Statistics

- **186 fatalities**: 0 – $M_w7.1$ Darfield eqk; 185 – $M_w6.2$ Christchurch eqk; 1 – $M_w6.0$ June eqk; 0 – $M_w6.0$ Dec eqk (~400,000 people live in the Christchurch region)

- ~$25$ - 30 billion NZ in damage (or 15 to 18% of New Zealand’s GDP)

- ~20,000 residential properties/ houses severely impacted (~7,000 beyond repair)

- ~1300-1400 buildings in CBD designated for demolition (>1/3 of buildings in CBD)

- 300 km of sewer pipes and 124 km of water pipes are being fixed

- 2900 “port-a-loos” issued to residents
Ground Cover: 1856

(Christchurch City Council 2003)
Soil Conditions: 7 to 10 ft Deep
Liquefaction: Grain-size Distributions

<table>
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<tr>
<th>Particle Size (mm)</th>
<th>Percent Finer by Weight</th>
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<tr>
<td>10</td>
<td>100</td>
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- **Gravel**: Most Liquefiable Soils
- **Sand**: Potentially Liquefiable Soils
- **Silt**: Liquefied soils in Christchurch region
- **Clay**: Colloids

(Tsuchida 1970) (Pender 2010)
Liquefaction: Darfield Earthquake
Liquefaction: Darfield Earthquake
Liquefaction: Darfield, Christchurch, and June EQs
CBD Liquefaction

(Misko Cubrinovski)
CBD Liquefaction

1.8 deg

15 cm

29 cm

(Misko Cubrinovski)
Severe Liquefaction in Eastern Suburbs

- Large settlement of residential houses (total and differential)

(Misko Cubrinovski)
Water and Wastewater Systems
Lateral Spreading

- Low gradients at both locations (~3°)

(Misko Cubrinovski: South Kaiapoi)
Lateral Spreading

~ 1.5 m wide cracks

(Misko Cubrinovski: South Kaiapoi)
Fitzgerald Ave. Bridge: North Approach
Redcliffs Quarry Wall Failure
Port of Lyttelton – CQ 1

(Glenn Rix)
Zones for Rebuilding: Christchurch

**Key**

- **Technical Category 1**
  Future land damage from liquefaction is unlikely.

- **Technical Category 2**
  Minor to moderate land damage from liquefaction is possible in future significant earthquakes.

- **Technical Category 3**
  Moderate to significant land damage from liquefaction is possible in future significant earthquakes.

- **N/A - Urban Nonresidential**

- **N/A - Rural & Unmapped**

- **Port Hills & Banks Peninsula**

- **Orange Zone**
  Further assessment required.

- **Red Zone**
  Land repair would be prolonged and uneconomic.
Summary and Conclusions

- The intensity of the shaking was severe
- Soils in Christchurch and Kaiapoi are highly susceptible to liquefaction
- Significant geotechnical related damage due to widespread and severe liquefaction and lateral spreading (most economic damage) and rockfalls/landslides in the Port Hills (6 fatalities)
  - Commercial and residential structural systems were distressed due to differential settlement and lateral spreading
  - Bridges distressed due to lateral spreading and slope failures at abutments
  - Buried pipelines experienced numerous breaks in liquefied ground; infiltration of liquefied sand
  - Levees (Stopbanks)...
- The Port of Lyttelton experienced some damage, but with only minimal impact on operations
- The Future: zonation based largely on observed liquefaction response
Thank You