Ground Motions and Ground Failure

Jonathan P. Stewart, UCLA

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Impacts

- Ground motions well recorded
- Important features of ground motions
  - Near fault effects
  - Local damage from site amplification
- Broad range of ground failure
  - Liquefaction-related features
  - Ground failure in non-traditional soils
  - Landslides
Impacts: Ground motions

Instrumental intensity Shakemap.

Source: http://earthquake.usgs.gov/earthquakes/shakemap/sc/shake/Northridge/
Impacts: Ground motions

Source: http://pasadena.wr.usgs.gov/office/wald/CUREe.html
Impacts: Ground motions

Clustering of red-tagged buildings

Source: Davis et al., 2000: Science.
Impacts: Liquefaction

Tapo Canyon flow failure

Source: Yoshi Moriwaki
Impacts: Liquefaction

Redondo Beach Wharf failure

Source: Stewart et al., 1994: EERC 94-08.
Impacts: Liquefaction

Pipe breaks – many in liquefaction zones

Source: Jeon and O’Rourke, 2005; Stewart et al., 1996 BSSA.
Impacts: Ground failure in fine-grained soils

Balboa Blvd., Grenada Hills

Malden St., Northridge

Source: Kerry Sieh

Source: John Tinsley
Impacts: Ground failure in compacted fills

Ground deformations in unsaturated, compacted fills soils

Source: Alan Kropp & David McMahon
Impacts: Landslides

Widespread seismic landslides.

Incidents of ‘valley fever’

Source: Jibson, 2002: *Surveys in Geophysics*
Outcomes: Ground motion

- **NGA program:**
  - Improved processing and dissemination of ground motions.
  - Ground motion prediction models, including near-source and site effects

- **Building code ground motions:**
  - Mapping
  - Site amplification
Outcomes: Ground motion prediction

Global Active Crustal Regions (ACRs)

Pre-Northridge recordings
Outcomes: Ground motion prediction

Global Active Crustal Regions (ACRs)

Pre-Northridge recordings

Northridge recordings
Outcomes: Ground motion prediction

**Pre-Northridge recordings**

**Northridge recordings**

**Current DB (NGA-West 2)**
Outcomes: Building code ground motions

**Before Northridge:**
1. Zone map

Source: Blue Book, 1996
Outcomes: Building code ground motions

**Before Northridge:**
1. Zone map
2. Linear PGA site factor

### Table 104-2. Site Coefficients

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>S Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_1$</td>
<td>A soil profile with either: 1. A rock-like material characterized by a shear-wave velocity greater than 2,500 feet per second, or by other suitable means of classification or: 2. Medium stiff to stiff or medium dense to dense soil conditions where soil depth is less than 200 feet</td>
<td>1.0</td>
</tr>
<tr>
<td>$S_2$</td>
<td>A soil profile with predominantly medium dense to dense or medium stiff to stiff soil conditions, where soil depth exceeds 200 feet</td>
<td>1.2</td>
</tr>
<tr>
<td>$S_3$</td>
<td>A soil profile containing more than 20 feet of soft to medium stiff clay but not more than 40 feet of soft clay</td>
<td>1.5</td>
</tr>
<tr>
<td>$S_4$</td>
<td>A soil profile characterized by a shear wave velocity of less than 500 feet per second, and containing more than 40 feet of soft clay</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Source: Blue Book, 1996
Outcomes: Building code ground motions

Before Northridge:
1. Zone map
2. Linear PGA site factor
3. Site-dependent spectral shapes

Source: Blue Book, 1996
Outcomes: Building code ground motions

Since Northridge:
1. USGS online hazard maps

Source: http://earthquake.usgs.gov/hazards/
Outcomes: Building code ground motions

Since Northridge:
1. USGS online hazard maps
2. Nonlinear site factors for short- and mid-periods ($F_a$ and $F_v$)
3. Procedures for site-specific analysis

Outcomes: Ground failure

Implementation of 1990 Seismic Hazards Zoning Act

Legend
- Earthquake-Induced Landslides
- Liquefaction

Source: C. Real, 2014
Outcomes: Ground failure

Many high-risk areas remain unmapped.

Source: C. Real, 2014

Seismic Hazard Mapping Act
Progress as of 2013

Source: C. Real (pers. communication, 2003)
Next Steps and Recommendations

- Sustained funding for ground motion research
  - Maintenance of arrays
  - Updating of databases
  - Periodic development of improved GMPEs

- Develop community ground failure database & models

- Increase funding for CGS seismic hazards mapping (liquefaction, landslides, faults)
Friday Breakout

Ground motion, site response, and ground failure

- Ground motion simulations. Paul Somerville, URS.
- GMPE advancements. Yousef Bozorgnia, PEER.
- Ground motion selection/scaling. Christine Goulet, PEER.
- Nonlinear site response. Youssef Hashash, UIUC.
- Liquefaction and ground failure. Tom Holzer, USGS.
- Slope stability and compacted fill. Tom Blake, Fugro.
- Panel discussion.
Next Steps

- Periodic updating of GMPEs
  - Incorporate new data
  - Apply lessons learned from validated simulations
  - Especially critical for Pacific NW and CEUS

- Next-generation ground failure models
  - Fine-grained materials
  - Effects of ground failure on structures

- More complete seismic hazards mapping
  - Liquefaction and landslides
  - Surface fault rupture