Estimation of post-earthquake recovery on a university campus

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Shifting towards resilience

• Resilience is the capacity of an entity to adapt and recover from acute shocks or chronic stresses (Rockefeller Foundation)

• Building codes target life-safety, which does not have any bearing on functionality post-earthquake

• Consideration of functionality requires consideration of the people or entities within a building or campus
Recovery on a university campus

• **Metrics of interest**
  o Displacement & outmigration of students
  o Disruption of research & lecture

• **Return periods of interest**
  o Recovery was a particular focus at 200 year and 475 year events
  o At higher return periods, life-safety concerns were paramount
Stanford University in Loma Prieta 1989

PGA on campus = 0.3g

- Most buildings evacuated until post-earthquake inspection
  - Several residential buildings affected, displacing 1,000 students the night of the earthquake
  - Some students slept outdoors in tents, afraid to enter buildings

- All 400 buildings surveyed within 2 days
  - 242 with minor damage
  - 25 with significant damage (stayed closed afterwards)
Stanford University in Loma Prieta 1989
PGA on campus = 0.3g

• Restoration of residential space
  o Most students allowed back in dorms within 1 week, except for 150-200 that were provided alternate accommodation
  o All repairs to damaged residential buildings completed within 11 months

• Restoration of academic space
  o All classes cancelled day after the quake
  o Most classes resumed within 2-3 days inside buildings deemed safe
  o Lost 21 classrooms (14% of academic space), half of which were replaced by modular units
Case study: University of British Columbia

328 existing buildings
2/3 constructed prior to modern seismic codes
Portfolio risk assessment methodology

Seismic Retrofit Guidelines (SRG3)
- Determine earthquake scenario
- Simulate structural response

FEMA P-58 Loss Assessment
- Determine component damage
- Determine component losses

REDi™ Downtime Assessment for Buildings
- Estimate delays to repairs
- Estimate utility disruption
- Schedule building repairs
Predicted recovery of campus buildings

Interpretation of restoration curves

NIST Community Resilience Planning Guide Table

<table>
<thead>
<tr>
<th>Functional category (Occupancy)</th>
<th>200-year return period earthquake event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phase 1: Short-term (days)</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Classrooms</td>
<td>X</td>
</tr>
<tr>
<td>Research labs</td>
<td></td>
</tr>
<tr>
<td>Academic offices</td>
<td>X</td>
</tr>
<tr>
<td>Study spaces</td>
<td>X</td>
</tr>
<tr>
<td>Residential</td>
<td>X</td>
</tr>
<tr>
<td>Admin offices</td>
<td>X</td>
</tr>
</tbody>
</table>

X = Anticipated performance for 90% restoration
Predicted recovery of campus buildings

Median restoration curves by occupancy

Restoration Curve for Downtime to Functional Recovery

Classrooms
Research labs
Academic office
Study space & libraries
Residential (re-occupancy)
Residential (functional)
Admin office & central services
Total

Percentage of Square Footage Restored

Median Downtime to Functional Recovery (months)

0 months 6 months 1 year 1.5 years 2 years 2.5 years

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

200 year

475 year
Predicted recovery of campus buildings

Uncertainty in restoration curves

200 year

475 year
Utility disruption on campus
Methodology using fault trees
## Utility disruption on campus

### Best estimate results

<table>
<thead>
<tr>
<th>Earthquake Intensity Level</th>
<th>Electric Power</th>
<th>Water</th>
<th>Natural Gas</th>
<th>Thermal Energy</th>
<th>Sanitary Sewer*</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 year</td>
<td>1 day</td>
<td>2 months</td>
<td>2 - 6 days</td>
<td>0 days</td>
<td>4 days</td>
</tr>
<tr>
<td>475 year</td>
<td>2 - 3 days</td>
<td>2 - 2.5 months</td>
<td>1 - 2 weeks</td>
<td>0 days</td>
<td>6 days</td>
</tr>
</tbody>
</table>

*Indicates the time to repair sewer pipe breaks. The sanitary system will be unusable as long as water is disrupted, which will almost always govern.*
Student population vulnerability

Number of students (living on campus) displaced over time

- **1 day**: 12,000
- **3 days**: 12,000
- **1 week**: 10,000
- **1 month**: 8,000
- **3 months**: 6,000
- **6 months**: 4,000
- **1 year**: 2,000

**Inspection of buildings**
- 200 year
- 475 year

**Students likely to outmigrate**
Next steps

• Refinement of structural response predictions

• Further research of human factors
  o Will dormitories be occupied prior to complete functional recovery?
  o At what point does a displaced student decide to transfer university?
  o At what extent of a given damage type will a building inspect red-tag?

• Incorporation of mitigation measures
  o Will classes resume in temporary trailers?
  o Can some classes move to undamaged buildings?
Questions?