Building-Code Applications of Seismic Hazard: Issues and Opportunities

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Outline

- Brief history of U.S. building-code applications of seismic hazard
- BSSC/FEMA-USGS Project ’17 issues
- Opportunities for improvement
Applications/Users of USGS Seismic Hazard

Other seismic hazard modelers
(e.g., for insurance risk modeling)

Earthquake engineers
(e.g., for building codes)

Emergency-response planners
(e.g., HAZUS users)

The public
(e.g., the media, website users)

Primary focus of this presentation
Since 1978 ATC 3-06 Tentative Provisions ...

TENTATIVE PROVISIONS FOR THE DEVELOPMENT OF SEISMIC REGULATIONS FOR BUILDINGS
A Cooperative Effort with the Design Professions, Building Code Interests and the Research Community

Prepared by
APPLIED TECHNOLOGY COUNCIL
Associated with the Structural Engineers Association of California

National Science Foundation
National Bureau of Standards

National Academies of Sciences, Engineering, and Medicine Meeting of the Committee on Seismology and Geodynamics

“Building-Code Applications of Seismic Hazard,” N. Luco (USGS)
Since 1978 ATC 3-06 Tentative Provisions …
Until 1997 *Uniform Building Code* ...
Since 1997 NEHRP Recommended Provisions ...
Since 2009 NEHRP Recommended Provisions …

RISK-TARGETED MAXIMUM CONSIDERED EARTHQUAKE ($\text{MCE}_R$)
GROUND MOTION SPECTRAL ACCELERATION CONTOUR MAPS
What are (these) Risk-Targeted Ground Motions?

<table>
<thead>
<tr>
<th>Uniform-Hazard Ground Motions</th>
<th>Risk-Targeted Ground Motions</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g., 2,500-year (a.k.a., 2%-in-50-year)</td>
<td>e.g., 1%-in-50-years</td>
</tr>
<tr>
<td>i.e., Ground motions that each have a 2% <strong>probability of being exceeded</strong> in 50 years (the assumed life expectancy of a building).</td>
<td>i.e., Ground motions that, when used for design, result in buildings with a 1% <strong>probability of collapse</strong> in 50 years.</td>
</tr>
</tbody>
</table>
For 2020 NEHRP Provisions – Project ‘17

- **Project ’97** – Established procedure for *directly* basing building-code maps on USGS hazard assessment.

- **Project ‘07** – Reassessed Project ‘97 procedure and introduced current “risk-targeted” maps.

- **Project ‘17** – Will propose new ground motion maps for, ultimately, the 2024 *International Building Code*. 
Project ’17 Issues

Project 17 Final Report

September 26, 2018

by

National Institute of Building Sciences
Building Seismic Safety Council
Project 17 Committee (chair: Ron Hamburger)

Sponsored by

Federal Emergency Management Agency
in coordination with the
U.S. Geological Survey

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• Acceptable Risk
• Deterministic Values
• Stabilizing Mapped Values
• Multi-Period Spectral Values

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Current probability of collapse in 50 years
In the future, targeting casualty/fatality risk (and repair costs and downtime) will help in setting the acceptable level, via …

- comparisons across hazards (e.g., seismic vs. wind);
- comparisons across structures (e.g., buildings vs. bridges, new vs. existing);
- communication with stakeholders

Collapse risk targeting is a step in this direction.
### Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

<table>
<thead>
<tr>
<th>Value of $S_{DS}$</th>
<th>I or II or III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{DS} &lt; 0.167$</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>$0.167 \leq S_{DS} &lt; 0.33$</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>$0.33 \leq S_{DS} &lt; 0.50$</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>$0.50 \leq S_{DS}$</td>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>

### Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

<table>
<thead>
<tr>
<th>Value of $S_{DI}$</th>
<th>I or II or III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{DI} &lt; 0.067$</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>$0.067 \leq S_{DI} &lt; 0.133$</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>$0.133 \leq S_{DI} &lt; 0.20$</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>$0.20 \leq S_{DI}$</td>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>
3. **ISSUES**

The Project 17 Planning Committee initially identified the following issues as important for consideration in the Project 17 effort:

1. Timing for Updated Map Publication
2. Design Value Conveyance
3. Precision and Uncertainty
4. Acceptable Collapse Risk
5. Collapse Risk Definition
6. Maximum Direction Ground Motion Components
7. Multi-Period Spectral Values
8. Duration as a Mapped Parameter
9. Damping Levels
10. Vertical Motion Parameters
11. Use and Definition of Deterministic Parameters
12. Basin Effects
13. **Use of 3-D Simulation to Develop Long Period Parameters**

In addition to the above issues, the Planning Committee also considered several other potential issues including:

1. Providing Mapped Parameters for additional levels of hazard including potential Service and/or Function Level earthquakes.
2. **Decoupling Seismic Design Categories from site class effects.**
3. **Inclusion of induced seismicity in seismic hazard calculation.**
Use of 3-D Simulation for Long-Period Parameters


By Erin A. Wirth, Susan W. Chang, and Arthur D. Frankel

Open-File Report 2018–1149

Integrate Urban-Scale Seismic Hazard Analyses with the U.S. National Seismic Hazard Model

Published Online 28 February 2018

Use of 3-D Simulation for Long-Period Parameters

Southern California Earthquake Center (SCEC) Committee for Utilization of Ground Motion Simulations (UGMS)

Site-Specific MCEₚ & Design Response Spectra per Sect. 21.2, 21.3, 21.4 of ASCE 7-16

Input Parameters

Report Title
My Report

Latitude and longitude in decimal degrees (or click on map to select site):

Latitude (e.g. 34.45)

Longitude (e.g. -118.35)

Site Geotechnical Classification:

- Site Class - Select -
  Site Class NOT automatically determined based on site location.

- OR -
  Vₛ₃₀ (m/s) Value

- OR -
  Unknown (Vs₃₀ estimated from Wills et al., 2015)

Compute Response Spectra

The UGMS MCEₚ tool was developed by the SCEC Committee for Utilization of Ground Motion Simulations (or "UGMS Committee") from research supported by the Southern California Earthquake Center (SCEC). SCEC is funded by NSF Cooperative Agreement EAR-1033462 & USGS Cooperative Agreement G12AC20038. For more information on the UGMS Committee, visit https://www.scec.org/research/ugms.

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16.2.2 Ground Motion Selection. A suite of not less than 11 ground motions shall be selected for each target spectrum. Ground motions shall consist of pairs of orthogonal horizontal ground motion components and, where vertical earthquake effects are considered, a vertical ground motion component. Ground motions shall be selected from events within the same general tectonic regime and having generally consistent magnitudes and fault distances as those controlling the target spectrum and shall have similar spectral shape to the target spectrum. For near-fault sites, as defined in Section 11.4.1, and other sites where MCE\textsubscript{R} shaking can exhibit directionality and impulsive characteristics, the proportion of ground motions with near-fault and rupture directivity effects shall represent the probability that MCE\textsubscript{R} shaking will exhibit these effects. Where the required number of recorded ground motions is not available, it shall be permitted to supplement the available records with simulated ground motions. Ground motion simulations shall be consistent with the magnitudes, source characteristics, fault distances, and site conditions controlling the target spectrum.

16.2.3 Ground Motion Modification. Ground motions shall either be amplitude-scaled in accordance with the requirements of Section 16.2.3.2 or spectrally matched in accordance with the
Use of 3-D Simulation for Long-Period Seismograms

Southern California Earthquake Center
Studying earthquakes and their effects in California and beyond

Working Group: Earthquake Engineering Implementation Interface

Research Objectives

The purpose of the Earthquake Engineering Implementation Interface is to create and maintain collaborations with research and practicing engineers, much as the Seismic Hazard and Risk Analysis focus group did during SC3. These activities may include ground motion simulation validation, rupture-to-rafters simulations of building response as well as the end-to-end analysis of large-scale, distributed risk (e.g., ShakeOut-type scenarios). Our goal of impacting engineering practice and large-scale risk assessments requires even broader partnerships with the engineering and risk-modeling communities, which motivates the activities described next.

Research Priorities

Technical Activity Group (TAG) on Ground Motion Simulation Validation (GMSV)
Inclusion of Induced Seismicity in Seismic Hazard

1. One-year forecasts vs. 50-year life expectancy of buildings.

2. Maps for design of new buildings, evaluation and retrofit of existing buildings, or both?

3. Very large MCE\textsubscript{R} ground motions due to large frequencies of earthquake occurrence.

4. Stability of design maps vs. uncertainty in forecasts.
Increases in Life-Safety Risks to Building
Occupants from Induced Earthquakes in the Central United States

Taojun Liu,*† Nicolas Luco,*‡ MEERI and Abbie B. Liel,*‡ MEERI

Earthquake occurrence rates in some parts of the central United States have been elevated for a number of years; this increase has been widely attributed to deep wastewater injection associated with oil and gas activities. This induced seismicity has caused damage to buildings and infrastructure and substantial public concern. In March 2016, the U.S. Geological Survey (USGS) published its first earthquake ground motion hazard model that accounts for the elevated seismicity, producing a one-year forecast encompassing both induced and natural earthquakes. To assess the potential impacts of the elevated seismicity on buildings and the public, this paper quantifies forecasted risks of a) building collapse and b) falling of nonstructural building components, by combining the 2016 USGS hazard model with fragility curves for generic modern code-compliant buildings. The assessment shows significant increases in both types of risk compared to that due to non-induced earthquakes alone; the magnitudes of the increases vary from a few times to more than a 100 times, depending on location, building period (which is correlated to building height), alternatives for the hazard model, and the type of risk of interest. For exploratory purposes only, we also estimate revised values of the risk-targeted ground motion that are currently used for designing buildings.

Induced Seismicity in Groningen
Assessment of Hazard, Building Damage and Risk

November 2017

By Jan van Elk and Dirk Doornhof

National Academies of Sciences, Engineering, and Medicine Meeting of the Committee on Seismology and Geodynamics

“Building-Code Applications of Seismic Hazard,” N. Luco (USGS)
Opportunities for Improvement

- Multidisciplinary discussion of incorporation of induced seismicity in building-code applications
- Utilization of physics-based ground motion simulations for building-code maps and seismograms
- Quantification of uncertainty of seismic hazard, e.g. for stabilizing mapped values in building codes
- Decisions on acceptable seismic risk, for new and existing buildings and other structures
Engineering Applications of Real-Time Seismic Hazard

“Building-Code Applications of Seismic Hazard,” N. Luco (USGS)
Why Risk-Targeted Ground Motions?

From ATC 3-06 (1978), Section 1.4.1:

“... it really is the probability of structural failure [i.e., the collapse risk] with resultant casualties that is of concern, and the geographical distribution of that probability is not necessarily the same as the distribution of the probability of exceeding some ground motion [i.e., the ground-motion hazard].”

“Thus [uniform ground-motion hazard] is not necessarily the ideal goal, but it is judged to be the most workable goal for the present time [i.e., 1978].”
From ATC 3-06 (1978), Section 1.4.1:

“Often the courts become the final judge of whether a proposed course of action for mitigating a hazard is acceptable. The body of law that has been developed in the area of flood plain regulation is a useful guide to judicial reactions to hazard mitigation. The lesson is to match severity of the regulation to the severity of the risk. The courts follow the principle of the reasonable person who strives to achieve this balance, and uses data to support findings of the appropriate balance.”
GM Simulations for Building Codes – Motivation

From PEER NGA-West2 Database

M ≥ 6.5, R ≤ 20km
Recordings

From PEER NGA-West2 Database

M ≥ 6.5, R ≤ 20km
Recordings

American Society of Civil Engineers (ASCE) Convention Technical Tour

“USGS National Seismic Hazard Modeling Project and Engineering & Risk Project,” N. Luco, K. Jaiswal, & S. Rezaeian

October 12, 2018