PANEL DISCUSSION ON PERFORMANCE-BASED APPROACH TO SEISMIC DESIGN

SMiRT-19 CONFERENCE
TORONTO, CANADA
August 16, 2007
SESSION: WM

Keshab K. Dwivedy
Dominion
Richmond, Virginia, USA

Panelists

- Mr. Divakar Bhargava
- Mr. Greg Hardy
- Dr. Andrew Murphy
- Dr. Aleksander Paskalov
- Mr. Emmanuel Viallet

Deterministic Approach (DSHA)

- Select a small number of Individual Earthquake Scenarios (M, R) pairs
- Compute the ground motion for each pair for 50% and 16% chance of being exceeded
- Select the largest ground motion from any of the pairs

Magnitude (M)

- At Fault:
  - Determine the maximum based on fault dimension
- At Source Zone:
  - Largest magnitude at the closest point in the Zone to the site

Distance (R)

- Use the shortest distance from the fault to the site
- For Zone containing the site select several M and R pairs

Why PSHA?

- It is difficult to select reasonable background earthquake, in DSHA which led to the development of PSHA
- The need to consider both the rate of earthquake and the chance of the ground motion leads to PSHA

Probabilistic Seismic Hazard Approach

- Consider all possible earthquake scenarios (possible M and R pairs).
- Specify the rate at which each earthquake scenario occurs.
- Consider a full range of possible ground motions for each earthquake scenario.
- Use ε: standard deviation of +/- 3 from the median.
- Specify the probability of each ground motion for each scenario.
- The ground motion model used in PSHA is referred to as an Attenuation Relationship.

Hazard Calculation

- Compute ground motion at the site for each scenario (M, R, ε)
- Rank scenarios (M, R, ε) in order of decreasing severity of shaking (Spectral Acceleration/ Spectral Velocity)
- Prepare a table of ground motions (S_a / S_v) and rates

Hazard Calculation (continued)

- To get hazard curve, sum up rates of scenarios with ground motion above a specified level.

- Select ground motion for design hazard level
- Back off from worst-case ground motion until either:
  - Ground motion does not lead to excessive cost, or
  - The hazard level is not too small to ignore

Hazard Calculation (continued)

- A reasonable ground motion should have acceptably small risk of undesired performance
- Seismic PRA:
  - Direct computation of probability of undesired performance
- PSHA:
  - Selection of a return period for design ground motions is a simplified risk calculation
- If we design for a return period then probability of undesired performance is smaller than hazard
  - It becomes necessarily conservative
  - This led to the performance based method

Aleatory Variability in a PSHA

- Range of possible magnitudes
- Range of possible locations that controls the distance
- Range of possible ε (Number of Standard deviation above or below the median)
- Aleatory uncertainties are generally handled with probability distributions.

Epistemic Uncertainty

- Epistemic uncertainty is due to lack of data
- Less data implies larger uncertainty
- Epistemic uncertainty is typically estimated using available alternate models
- Few available studies lead to small uncertainty
- Many available studies lead to larger uncertainty (more alternatives available)
- Epistemic uncertainties have traditionally handled with logic trees. (Discrete possible values with associated weights)

Summary

- **Point Source**
  - The rate which the ground motion from the i^th^ source exceed the test level z can be expressed as:

$$\nu_i(A > z) = N_i\,(M_{\min}) \int_{r=0}^{\infty} \int_{m=M_{\min}}^{M_{\max_i}} \int_{\varepsilon=\varepsilon_{\min}}^{\varepsilon_{\max}} f_{m_i}(m)\; f_{r_i}(r)\; f_{\varepsilon}(\varepsilon)\; P(A > z \mid m, r, \varepsilon)\; dr\; dm\; d\varepsilon$$

Summary (continued)

- **Planar Source**
  - The formulation of point source can be extended to planar source by using rupture area (RA) and rupture width (W)

$$\nu_i(A>z) = N_i(M_{\min}) \int_{W=0}^{\infty} \int_{RA=0}^{\infty} \int_{Ex=0}^{1} \int_{Ey=0}^{1} \int_{m=M_{\min}}^{M_{\max_i}} \int_{\varepsilon=\varepsilon_{\min}}^{\varepsilon_{\max}} f_{m_i}(m)\; f_{W_i}(m,W)\; f_{RA_i}(m,RA)\; f_{Ex_i}(x) \ldots$$

$$f_{Ey_i}(y)\; f_{\varepsilon}(\varepsilon)\; P(A>z \mid m(RA,W),\, r(x,y),\, \varepsilon)\; dW\, dRA\, dx\, dy\, dm\, d\varepsilon$$

  - N_i (M_{min}) is the rate of the earthquakes with magnitude greater than M_{min} from the i^{th} source.