Mississippi Embayment and Site Factors in Mid-America (P08-1563)

Monday, January 14, 2008, 7:30pm- 9:30pm, Shoreham, Palladian

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University of Illinois at Urbana-Champaign

SESSION #: 398; Seismic Site Response at Non-NEHRP Bridge Sites
SPONSORED BY: Seismic Design and Performance of Bridges; Geoseismic Issues of Bridges
PRESIDING OFFICERS: Scott M. Olson, University of Illinois, Urbana-Champaign;
Donald Gordon Anderson, CH2M Hill
Outline

• Background
• Response of deep soil deposits
• PSHA-NL: Integrated probabilistic seismic hazard analysis with non-linear site effects
  • Randomized soil profiles
  • Logic Tree
  • Strong shaking closer to faults
  • Point sources and finite fault models
• NEHRP style depth dependent site coefficients
• Comparisons with other studies
• Concluding remarks
Background: Mid-America Regional Issues

Current (2002) USGS/NEHRP ($F_a$, $F_v$) seismic hazard characterization does not specifically account for Mississippi Embayment effects.

Note vertical scale exaggeration
PSHA-NL: Integrated Probabilistic Seismic Hazard Analysis with Non-linear Site Effects

PSHA-NL combines source/path effects + site effects while preserving probabilistic features: applied to Central US

Output
1. Seismic hazard maps that incorporate embayment deposits effects
2. Depth dependent NEHRP style site coefficients
PSHA-NL: PSHA with Nonlinear Site Effects

**Step 1** Select Site coordinates, site profiles, and dynamic properties.

**Step 2** Perform PSHA at hard rock (Site Class A).
- Choose number of simulations ($N$)
- Output: a) Suite of hard rock motions, b) UHRS

*Point Source model & finite fault model*

**Step 3** Propagate the hard rock motions through B/C Boundary
- Output: UHRS

**Step 4** Propagate the hard rock motions through site profiles using DEEPSOIL
- Output: a) suite of site specific motions, b) UHRS

**Step 5** Develop depth dependent site coefficients and hazard maps

Is UHRS close to USGS B/C hazard maps?
- Yes
- No
Step 1: site selection in Mississippi Embayment
Step 1: Site selection

<table>
<thead>
<tr>
<th>Site No</th>
<th>$S_s$ (g)</th>
<th>$S_i$ (g)</th>
<th>PGA (g)</th>
<th>$F_a$</th>
<th>$F_v$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.656</td>
<td>0.20</td>
<td>0.307</td>
<td>1.28</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>0.22</td>
<td>0.34</td>
<td>1.2</td>
<td>1.96</td>
</tr>
<tr>
<td>3</td>
<td>1.00</td>
<td>0.30</td>
<td>0.568</td>
<td>1.1</td>
<td>1.8</td>
</tr>
<tr>
<td>4</td>
<td>1.25</td>
<td>0.34</td>
<td>0.66</td>
<td>1.0</td>
<td>1.72</td>
</tr>
<tr>
<td>5</td>
<td>1.50</td>
<td>0.40</td>
<td>0.796</td>
<td>1.0</td>
<td>1.6</td>
</tr>
<tr>
<td>6</td>
<td>1.84</td>
<td>0.50</td>
<td>1.01</td>
<td>1.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

- Eight sites selected to cover range of spectral accelerations
- Thickness of embayment deposits hypothetically varied
- Avoid the computationally intensive task of calculations at a grid pattern
### Step 2: PSHA at Hard Rock (Site Class A)

#### Smoothed sources/gridded seismicity

<table>
<thead>
<tr>
<th>Attenuation relationships adopted in 2002 USGS map</th>
<th>Proposed method: Generate ground motion time history</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toro et al (w=0.286)</td>
<td>Single-corner model (w=0.286)</td>
</tr>
<tr>
<td>Frankel et al. (w=0.286)</td>
<td>Single-corner model (w=0.286)</td>
</tr>
<tr>
<td>Atkinson and Boore (w=0.286)</td>
<td>Double-corner model (w=0.286)</td>
</tr>
<tr>
<td>Campbell (w=0.142)</td>
<td>Single-corner model (w=0.143)</td>
</tr>
</tbody>
</table>

#### Fault sources/characteristic earthquakes

<table>
<thead>
<tr>
<th>Attenuation relation adopted in 2002 USGS map</th>
<th>Proposed method: Generate ground motion time history</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toro et al (w=0.25)</td>
<td>Finite-fault model (w=0.25)</td>
</tr>
<tr>
<td>Frankel et al. (w=0.25)</td>
<td>Finite-fault model (w=0.25)</td>
</tr>
<tr>
<td>Atkinson and Boore (w=0.25)</td>
<td>Finite-fault model (w=0.25)</td>
</tr>
<tr>
<td>Campbell (w=0.125)</td>
<td>Finite-fault model (w=0.125)</td>
</tr>
<tr>
<td>Somerville et al. (w=0.125)</td>
<td>Finite-fault model (w=0.125)</td>
</tr>
</tbody>
</table>
Step 3: Finite fault model

Comparison of Finite-fault model and Frankel et al. (1996) attenuation relationship for characteristic earthquake (M = 7.7) for NEHRP B/C boundary.
Step 3: Comparison of Uniform Hazard Response Spectra with USGS (B/C boundary)

Number of motions generated 9,000 – 10,000

Comparison of 2% probability of exceedance in 50 years simulated UHRS for Site Class B (B/C boundary).

FF: finite fault to represent characteristic earthquakes.

PS: point source to represent characteristic earthquakes.
Step 4: Modeling of site response of thick soil deposit-DEEPSOIL

-Nonlinear analysis (time domain):
  > Pressure dependent soil model
  > Rayleigh Viscous Damping formulation

-Equivalent linear (Frequency domain):
  > Three types of complex shear modulus

-Graphical User Interface, User Base ~ 700 users

http://www.uiuc.edu/~DEEPSOIL
Step 4: Mississippi Embayment properties

- Dynamic properties from laboratory tests

![Graph showing VS vs. depth](image)

- Lowlands Profile
- Uplands Profile

- Hard rock $V_s = 3000 \text{ m/sec}$

![Graph showing Soil Damping - G/G_max (%) vs. Shear strain $\gamma$ (%)](image)

- EPRI
- ME

<table>
<thead>
<tr>
<th>Layer</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10m</td>
</tr>
<tr>
<td>2</td>
<td>20m</td>
</tr>
<tr>
<td>3</td>
<td>50m</td>
</tr>
<tr>
<td>4</td>
<td>100m</td>
</tr>
<tr>
<td>5</td>
<td>200m</td>
</tr>
<tr>
<td>6</td>
<td>300m</td>
</tr>
<tr>
<td>7</td>
<td>400m</td>
</tr>
<tr>
<td>8</td>
<td>500m</td>
</tr>
<tr>
<td>9</td>
<td>1000m</td>
</tr>
</tbody>
</table>
Step 4: Significance of overburden pressure dependency

**1000 m Soil Column**

- **Soil Column: 1000 m**
  - **Amplification of Long Period Waves**
  - **Propagation of High Frequency Waves**

**100 m Soil Column**

- **Soil Column: 100 m**
  - **Input Motion (after deconvolution):**
    - Yerba Buena
    - Loma Prieta Earthquake
Step 4: Site effects & response

- 9000 generated rock motions are propagated through randomized soil profiles
  - 30 profiles

<table>
<thead>
<tr>
<th>Shear Wave Velocity Profiles</th>
<th>Dynamic Soil Properties</th>
<th>Weight (No. of Simulation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uplands</td>
<td>ME properties</td>
<td>0.75w (22)</td>
</tr>
<tr>
<td></td>
<td>EPRI properties</td>
<td>0.25w (8)</td>
</tr>
<tr>
<td>Lowlands</td>
<td>ME properties</td>
<td>0.75w (22)</td>
</tr>
<tr>
<td></td>
<td>EPRI properties</td>
<td>0.25w (8)</td>
</tr>
</tbody>
</table>
Step 4: site response

Comparison of PSHA-NL [FF] 2% in 50 years UHRS of 30 m depth soil column and NEHRP design spectra for site class D
2% in 50 year UHRS and the proposed NEHRP type design spectrum of the different depths of soil columns resulting from propagating generated motions at site 6
Step 5: Simplified NEHRP style depth dependent Site Factors

(a) Uplands

(b) Lowlands

Proposed NEHRP:
- 1: $S_s = 0.25g$
- 2: $S_s = 0.50g$
- 3: $S_s = 0.75g$
- 4: $S_s = 1.00g$
- 5: $S_s >= 1.25g$
Step 5: Simplified NEHRP style depth dependent Site Factors

(a) Uplands

(b) Lowlands

Proposed

NEHRP

1: $S_l = 0.10g$
2: $S_l = 0.20g$
3: $S_l = 0.30g$
4: $S_l = 0.40g$
5: $S_l \geq 0.50g$
Step 5

Propose spectral ratios
Step 5: 2% in 50 year PGA hazard maps of the UME

- (a) USGS B/C boundary

- (b) With NEHRP site class D

- (c) PSHA-NL(FF) using proposed site coefficients

- (d) PSHA-NL(FF) using spectral ratio
Step 5: 2\% in 50 year 0.2 sec $S_a$ hazard maps of the UME
Step 5: 2% in 50 year 1.0 sec $S_a$ hazard maps of the UME

(a) USGS B/C boundary
(b) With NEHRP site class D
(c) PSHA-NL(FF) using proposed site coefficient
(d) PSHA-NL(FF) using spectral ratio
Comparisons with other studies

Comparison of PGA hazard map (probability of exceedance 2% in 50 year) in UME obtained by
(a) Cramer (2006),
(b) (b, c) PSHA-NL [FF]
Comparisons with other studies

Comparison of 1.0 sec Sa hazard map (probability of exceedance 2% in 50 year) in UME obtained by
(a) Cramer (2006),
(b) (b, c) PSHA-NL [FF]
Concluding Remarks

• NEHRP site factors do not account for effect of deep deposits.
• A possible remedy is the inclusion of depth dependent site factors.
• Spectral ratios, more accurate, provide better results.
• For important bridges/structures site specific analyses are needed, DEEPSOIL ….