Overview of the NGA Program

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PEER-Lifelines NGA Program

• Sponsors
  – Caltrans
  – PG&E
  – California Energy Commission

• Collaboration between PEER, USGS, and SCEC
Acronyms

• NGA: **Next Generation of Attenuation model**
  – Cliff Roblee coined this name
  – “Introduction to the PEER-LL Next Generation Attenuation (NGA) Program”, October, 2002

• GMPE: **Ground Motion Prediction Equation**
  – In lieu of attenuation relationship, attenuation relation, or attenuation model
An Overview of the NGA Project

Maurice Power, a) M.EERI, Brian Chiu, b) Norman Abrahamson, c) M.EERI, Yousef Bozorgnia, d) M.EERI, Thomas Shantz, b) and Clifford Roblee, b) M.EERI

The “Next Generation of Ground-Motion Parameters” project is a multidisciplinary research program of the Pacific Earthquake Engineering Research Program (PEER) in partnership with the U.S. Geological Survey Earthquake Center. The objective of the project is to develop strong-motion prediction relations through a comprehensive research program. Five sets of ground-motion prediction equations are being developed, with each set being supported by other project components, which include: (1) an updated and expanded PEER database of recorded strong-motion data and supporting information on the strong-motion sources, travel path, and recording station site conditions, (2) conducting supporting research projects to provide guidance on the selected functional forms of prediction relations, and (3) developing and testing prediction relations in 2D and 3D simulations.
Program Overview

• Duration and cost
  – Multi-year program: 2002 - 2007
  – Cost
    • In-kind service
    • Cost share
    • Unpaid help

• Participants
  – 5 teams, 9 model developers
  – About 40 researchers from USGS, SCEC, PG&E, Caltrans, consultants
  – Users
Program Overview

• Approach
  – Coordinated study by various institutions
    • Leverage resources and expertise of each participating institutions
  – Interaction between model developers
    • Check and peer review of each other’s model
  – External reviews by USGS/CGS
    • Ready for deployment
Products: PEER-NGA Web Site

Next Generation Attenuation (NGA) Models

Use of the NGA models for any purpose is the sole responsibility of the user. Incorporation of directivity effects in the models is under development and not yet implemented.

Questions and review comments on the NGA models are welcome and can be addressed directly to the authors (copy to Dr. Yousef Bozorgnia of PEER, Email: Yousef@Berkeley.edu).

- Boore-Atkinson NGA Report and Files - January 6, 2008
- Campbell-Bozorgnia NGA Report and Files - January 3, 2008
- Chiou-Youngs NGA Report and Files - May 4, 2009
- Idriss NGA Report and Files – December 12, 2007
- Abrahamson-Silva NGA Report and Files - October 19, 2007

NGA Flatfile Used for Development of NGA Models

Selected Publications Related to NGA Program
Products: PEER-NGA Web Site

- PEER reports
- Resources for implementing NGA models, provided by developers
  - Fortran codes
  - Excel spreadsheets
- NGA database
- Meeting notes, workshop presentations, documentations
- Selected publications related to NGA program
Products: Earthquake Spectra Special Issue (Feb, 2008)

- Overview
- Synthesis
- Five NGA models
- Directivity model
- NGA resources (selected)
  - Database
  - Site response
  - 3-D basin response
- Other papers
  - Correlation between periods
  - Maximum response
NGA Models

• NGA developers consider the NGA models to be improvements over their previous models
  – Previous models have much smaller data sets and not as much review of the data sets
  – Working together has provided checks and peer reviews along the way
Deployment

- Models were adopted by USGS for the 2007 update of national hazard map.

- Models were adopted by Caltrans for the update of deterministic seismic hazard map.

ARS – Online
(Next presentation)
Ongoing Work

• Strike-normal/strike-parallel components (2009)
  – Correction factor to NGA model predictions
  – Why stops at SN/SP components? -- Rotation to any direction!

• Vertical Component (?)
  – Currently, not a high priority for Caltrans!
Ongoing Work

• Epistemic uncertainty is not fully captured
  – Additional uncertainty (conservatism) has been recommended by the NGA developers
  – NGA project plans to issue a white paper on this issue

• Model extension
  – Small-to-moderate earthquake ($3 \leq M \leq 5.5$)
    • Chiou and others (2009), to be submitted to *Earthquake Spectra*
Comparisons of the NGA Ground-Motion Relations

Norman Abrahamson, a) M.EERI, Gail Atkinson, b) M.EERI, David Boore, c) Yousef Bozorgnia, d) M.EERI, Kenneth Campbell, e) M.EERI, Brian Chiou, f) I. M. Idriss, g) M.EERI, Walter Silva, h) M.EERI, and Robert Youngs, i) M.EERI

The data sets, model parameterizations, and models for shallow crustal earthquakes are compared. A key difference in the data sets is the presence of aftershocks. A comparison of the median ground motions for shallow crustal earthquakes shows that they are within a factor of 2 for M5 and M8 earthquakes, for buried rupture depths less than 10 km. For soil sites, the differences are within a factor of 2 for M5 and M8 earthquakes, with a depth effect increase the range in the median ground motions to a factor of 3 for M7 strike-slip earthquakes to a factor of 5 for M8 dip-slip earthquakes.
New Features of NGA Models

- Depth to the top of rupture (AS08 & CY08)

- Hanging wall effect
  - No hard boundary for region affected by hanging wall effect
  - Poorly constrained effect

\[ \text{PGA} \]  
\[ M 6, R_{JB}=10 \text{ km} \]
PGA
M 6.7, $V_{S30} = 760$ m/s

Note the difference in X-axis scale!
Soil Response

• Previous study: rock-soil category
  – A model for each category
  – Ambiguity in rock definition
    • Many ‘rock’ sites were misclassified earlier

• In NGA, $V_{S30}$ is used as the primary predictor of soil response

<table>
<thead>
<tr>
<th>Model</th>
<th>$V_{S30}$ of Generic Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrahamson &amp; Silva (1997)</td>
<td>~ 550 m/sec</td>
</tr>
<tr>
<td>Boore, Joyner, and Fumal (1997)</td>
<td>620 m/sec</td>
</tr>
<tr>
<td>Campbell and Bozorgnia (2003)</td>
<td>~ 620 m/sec</td>
</tr>
<tr>
<td>Sadigh and others (1997)</td>
<td>~ 520 m/sec</td>
</tr>
</tbody>
</table>
Soil Response

- Nonlinear soil response is explicitly modeled.
- Soil amplification factor is a function of:
  - $y_{ref}$
    - ground motion on rock, PGA or spectral acc.
  - $\ln(V_{S30})$

\[ y_{ref} \times \text{Soil Amplification Factor} = y \]
Nonlinear Soil Response Model

PSA [$T=0.2s$]

Soil Amplification Factor vs. $V_{S30}$ (m/sec)

- 0.01 g
- 0.2 g
- 0.6 g
- 1.2 g
Nonlinear Soil Response in the NGA Data

$0 < y_{ref} < 0.04 \text{ g}$

$0.15 < y_{ref} < 0.25 \text{ g}$

$0.55 < y_{ref} < 0.75 \text{ g}$

$1.1 < y_{ref} < 1.3 \text{ g}$
Depth to Bedrock

• Depth to bedrock ($Z_{1.0}$ & $Z_{2.5}$)
  – Bedrock
    • $Z_{1.0} = $ Depth to 1.0 km/s shear-wave velocity horizontal
    • $Z_{2.5} = $ Depth to 2.5 km/s shear-wave velocity horizontal

  – Amplification for large $Z_{1.0}$ site ( $>>$ 400m), or large $Z_{2.5}$ site ( $>>$ 3km)
    • Maximum amplification varies with period

  – Currently, no reliable resource for depth estimate, except southern California sites
Depth to Bedrock ($Z_{1.0}$)

PGA

1-Sec
Thank You