Simulation of bedrock motion to obtain PGA values

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Objective

- To develop the seismic hazard map for Sri Lanka using numerical simulation.
Seismicity of Earth

Preliminary Determination of Epicenters
358,214 Events, 1963 - 1998
Indo-Australian Plate
Intraplate Earthquake: Bhuj Earthquake (2001, Mw=7.6)
Earthquake in Vicinity of Sri Lanka (1000 - 2012 A.D.)
Sources of Data Collection

- Chandra [1977],
- Rao and Rao [1984],
- Guha and Basu [1993],
- Iyengar et al. [1999] and
- Vithanage et al
- Jaiswal and Sinha [2007]
- National Earthquake Information Centre (NEIC)
- International Seismological Centre (ISC),
- Incorporated Research Institutions for Seismology (IRIS),
- India Metrological Department (IMD)
- USGS Database
- PEER Database
FLAC is a two-dimensional finite difference program for engineering mechanics computation. FLAC's analysis capability to a wide range of dynamic problems in disciplines such as earthquake engineering, seismology and mine rock bursts.
Finite Difference Method - Overview

- Replace derivatives of governing equations with algebraic difference quotients
- Results in a system of algebraic equations solvable for dependent variables at discrete grid points
- Analytical solutions provide closed-form expressions – variation of dependent variables in the domain
- Numerical solutions (finite difference) - values at discrete points in the domain
Grid Discretization

- For accurate representation of wave transmission through a model, element size $\Delta l$, must be smaller than approximately one-tenth to one-eight of the wave length of the input wave.

$$\Delta l \leq \frac{\lambda}{10}$$

- $\lambda$ is the wave length associated with the highest frequency component that contains appreciable energy.
Considering the dynamic equilibrium

\[
\left( \sigma_{x0} + \frac{d\sigma_x}{dx} \right) A - \sigma_{x0} = \rho A dx \frac{d^2u}{dt^2}
\]

\[
\frac{\partial^2 u}{\partial t^2} = v_P^2 \frac{\partial^2 u}{\partial x^2}
\]
Wave Equation

- Considering second order wave equation.

\[ \frac{\partial^2 u}{\partial t^2} = \nu^2 \frac{\partial^2 u}{\partial x^2} \]

- Discretization is implemented by replacing the second order derivatives in the wave equation by their standard finite difference approximations:

\[ \frac{\partial^2 u}{\partial t^2}(t_j, x_m) \approx \frac{u(t_{j+1}, x_m) - 2u(t_j, x_m) + u(t_{j-1}, x_m)}{(\Delta t)^2} + O((\Delta t)^2) \]

\[ \frac{\partial^2 u}{\partial x^2}(t_j, x_m) \approx \frac{u(t_j, x_{m+1}) - 2u(t_j, x_m) + u(t_j, x_{m-1})}{(\Delta x)^2} + O((\Delta x)^2) \]
Selected Cross Sections
Cross section obtained from Google earth
Details of the Model

- Google Earth® maps were used to acquire the cross section
- Element size $100 \text{ m} \times 100 \text{ m}$
- Total size $15 \text{ km}$ in height, $214 \text{ km}$ in width
- Shear wave velocity $= 5000 \text{ m/s}$
- Density $= 2000 \text{ kg/m}^3$
- Bulk Modulus $= 0.3 \text{ Gpa}$
- Shear Modulus $= 0.3 \text{ GPa}$
Finite Difference Model

- Cities: Colombo, Kandy, Hunnas and Pasikuda
Finite Difference Model

Developed FLAC 2D model
Simulated Earthquake
Seismic Input

- Select 7 accelerograms from Intraplate earthquakes of magnitude around 7.4 recorded around 90 km.
Resultant Response Spectra

- Colombo Fort
- Colombo 13
- Kotahena
- Colombo 14
- Sedawatta
- Peliyagoda
- Himbutuwelgoda
- Dalugama
- Kiribatgoda
- Mahara
- Weliweriya
- Radawana
- Mawanella
- Kandy
- Baticoloa

Spectral Acceleration (g) vs. Period (s)
Proposed Zonation Map

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
<th>PGA Value (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>from the western coastal Belt</td>
<td>0.12</td>
</tr>
<tr>
<td>Zone 2</td>
<td>30 km – 60 km from the western coastal Belt</td>
<td>0.07</td>
</tr>
<tr>
<td>Zone 3</td>
<td>Rest of the country starting 60 km from the western coastal Belt</td>
<td>0.05</td>
</tr>
</tbody>
</table>
References

- Seth Stein & Michel Wysession, An Introduction to Seismology, Earthquakes and Earth Structures
- Seth Stein, Approaches to continental Intraplate earthquake issues
- Kaye M. Shedlock, Intraplate earthquakes
- Steven L. Kramer, Geotechnical Earthquake Engineering
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Thank You !!!