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

Intraplate Earthquake: Bhuj Earthquake (2001, $M_w=7.6$)

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

- 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 Δl , must be smaller than approximately one-tenth to one-eighth of the wave length of the input wave.

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

- λ is the wave length associated with the highest frequency component that contains appreciable energy.

1D-Wave Equation

Considering the dynamic equilibrium

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

$$\frac{\partial^2 u}{\partial t^2} = v_P^2 \frac{\partial^2 u}{\partial x^2}$$

Wave Equation

- Considering second order wave equation.

$$\frac{\partial^2 u}{\partial t^2} = v^2 \frac{\partial^2 u}{\partial x^2}$$

- 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 m x 100 m
- Total size 15 km in height, 214 km in width
- Shear wave velocity = 5000 m/s
- Density = 2000 kg/m³
- Bulk Modulus = 0.3 Gpa
- Shear Modulus = 0.3 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 Resonse Spectra

Proposed Zonation Map

Zone	Description	PGA Value(g)
Zone 1	from the western coastal Belt	0.12
Zone 2	30 km – 60 km from the western coastal Belt	0.07
Zone 3	Rest of the country starting 60 km from the western coastal Belt	0.05

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 !!!