Microtremor measurement-based prediction of ground shaking in Kathmandu Valley of Nepal

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Microtremor measurement-based prediction of ground shaking in Kathmandu Valley of Nepal

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Presentation Content
- Background information (Nepal and Kathmandu Valley)
- Microtremor Survey
- Analysis and Results
- Predominant period distribution map
- Double predominant period
- Concluding Remarks

Indian Plate

Kathmandu Valley
Pokhara

MCT: main central thrust
MBT: main boundary thrust
HFT: Himalayan front thrust

Active Thrust Faults

Nepal: Geology and Geomorphology

Earthquakes in Nepal and its Periphery
Major Earthquakes in Nepal Himalayan Region and Zone of Seismic Gap (Avouac et al., 2001)

When??

Talking of Extremity
- Transportation
  - Roads, Bridges, Airports
- Urban roads
- Glacier Lakes
  - Morain dam failure, debris flow, flooding
- Landslides
- Communication
- Hospitals
- Schools
- Government Buildings (Presidential Palace, Singh Durbar, Ministry and Ministerial Department Buildings, etc.)
  - and so on

Damage in the 1934 Earthquake

Ghantaghar and Kathmandu Durbar Square

Zone of seismic gap
Basic information (Kathmandu Valley)

- Three main cities: Kathmandu, Lalitpur, Bhaktapur
- Resident Population: About 5 million (estimated)
- Altitude: 1,300 (average)
- Estimated human death: 40,000 – 100,000
- Estimated Injury: 200,000
- Major Earthquake Recurrence Period: 80-100 years
- Minor Earthquake Recurrence Period: 10-20 years
- Less than 3 Richter Scale Earthquakes: Several times a year

Population Growth in Kathmandu Valley

- Population growth in Kathmandu Valley
- Source: Google Earth, www.google.com
- Rapid population increase
- 1964 Satellite image: Population: 309,000
- 2001 Satellite image: Population: 2.5 million
- 2010 Satellite image: Population: 1.1 million
- At Present: Old buildings/houses
- Slender buildings/houses (Improper design??)

Damage distribution in 1934 Earthquake in Kathmandu Valley

- Southern and eastern parts (Bhaktapur city area) were damaged very heavily than other areas of the valley

Legend
- Damaged Area
- Kathmandu
- Lalitpur
- Urban Area
- Damage Type
- Heavily Damaged
- Moderately Damaged

Rapid population increase

- Population: 1.1 million
- Urban Area
- Confluence point of Bagmati and Manohara rivers
- Airport
- Slender buildings/houses (Improper design??)
Vulnerable buildings with narrow streets

Historical Monuments (World Cultural Heritages)

- Seven World Cultural Heritage Sites in Kathmandu Valley
- Together with the environmental degradation and scenic deterioration following the urbanization, the earthquake disaster risk has increased greatly
- Disaster risk: Earthquake and Landslides

Pashupatinath Temple
Changunarayan

Bouddhanath Stupa
Swayambhunath Stupa

Formation of Kathmandu Valley

Fig. 3: Népal: geological cross-section in the Chaur app. (Sakai et al. 2002). A: Terai Group, B: Himalayan Group, C: Neokot Group, D: Khammar Group, E: Khammar Batholith, F: Kathmandu Basin-sediments, MHE: Main Fault, NHE: Main Boundary Thrust, NEHE: Main Central Thrust.
Building Structures

- Brick masonry: Recently: Cement mortar, Old structures: Brick powder mortar, lime mortar, mud mortar
- Reinforced concrete: RCC framed structure, Concrete block or brick masonry walls

**Major Problems**

- Earthquake resistability of hospitals
- Secondary disaster (Fire, aftershocks, etc.)
- Evacuation space (not properly identified)
- Lifeline damage: water pipeline (very old), power line, liquefaction-induced road damage, etc.

Earthquake Disaster Risk in Kathmandu Valley and Technical Studies

- UNDP Study (Year 1992)
- An Integrated Study of Earthquake Disaster Mitigation in Kathmandu Valley by JICA (Year 2001)
  - Expected Earthquakes (Three cases)
  - Liquefaction Analysis/Prediction
  - Slope Failure Prediction
  - Lifeline Damage Prediction (Power line, Water pipeline, Roads, Bridges, Telephone line, etc.)
  - Building structural Damage Estimation
  - Human Death Estimation
  - Identification of Evacuation Path and Evacuation Space

Geotechnical Study Plan at Ehime University

- Geo-info Database Preparation and Application
- Microtremor Survey and Earthquake Motion Analysis/Simulation
- Installation of Earthquake Accelerometers, Data Acquisition
- Groundwater Flow Simulation
- Ground Subsidence Prediction, etc.
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The Tenth International Symposium on Mitigation of Geo-disasters in Asia, MGDA, 2012.10.3-9, Japan

Geo-info Database

Borehole Data:
Boreholes for various purposes

Ground profile through A-B

Geological Strata of Kathmandu Valley Ground (Dubal et al. 2002)

Borehole Survey for Damage Prediction

Microtremor: vehicle movement, explosion, factory vibrations, etc.

Measurement
Data Analysis
Natural time period

H/V Spectrum
Natural time period estimation

Damage Prediction

Microtremor Survey Area

Kathmandu
Bhaktapur
Lalitpur

Legend
Kathmandu
Bhaktapur
Lalitpur
Urban Area

Microtremor Survey

MT Survey in Kathmandu Valley
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Location for MT Survey in KV

Device and Data

Microtremor data analysis

Analysis

Analysis Results

North-South Profiles

East-West Profiles
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The study area is divided into five different ranges of predominant periods, using natural break techniques, which regroups similar values together and represents the distribution properly.

<table>
<thead>
<tr>
<th>Predominant period range</th>
<th>Description of zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.11 s to 0.60 s</td>
</tr>
<tr>
<td>B</td>
<td>0.60 s to 0.80 s</td>
</tr>
<tr>
<td>C</td>
<td>0.80 s to 1.01 s</td>
</tr>
<tr>
<td>D</td>
<td>1.01 s to 1.30 s</td>
</tr>
<tr>
<td>E</td>
<td>1.30 s to 2.05 s</td>
</tr>
</tbody>
</table>

Seismic microzonation map of the study area

Profiles based on the predominant period of ground

Borehole data and microtremor analysis results
Multiple resonant frequency

- $f_0$: first resonant frequency of the site
- $f_1$: second resonant frequency of the site

Location of double peak H/V spectral ratio

- About 40% measurement points exhibit double peaks and mostly in the central and northern part of the valley.

Distribution of multiple resonant frequencies

- First resonant frequency $f_0$
- Second resonant frequency $f_1$

Amplitude of multiple resonant frequencies

- Amplitude of first resonant frequency $A_0$
- Amplitude of second resonant frequency $A_1$

Amplitude of the second resonant frequencies are found higher than the amplitude of the first resonant frequencies in some of the location.
### Estimation of top soil layer thickness in the Kathmandu Valley

<table>
<thead>
<tr>
<th>SN</th>
<th>Borehole Location</th>
<th>Borehole ID</th>
<th>Average shear wave velocity (m/sec)</th>
<th>Average shear wave velocity upto 30 m depth for Kathmandu Valley (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New Road BH1</td>
<td>188.87</td>
<td></td>
<td>246.87</td>
</tr>
<tr>
<td>2</td>
<td>Singha Durbar BH2</td>
<td>310.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Jawalakhel BH3</td>
<td>247.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Thimi BH4</td>
<td>254.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Bhaktapur BH5</td>
<td>252.93</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Average shear wave velocity based on JICA study for Kathmandu Valley (based on 5 PS logging sites) = 246.87 m/sec
- The second resonant frequency varies from 3.1 Hz to 7.5 Hz
- The depth of the top soil layer responsible for amplification of soil = 10 m - 20 m

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### Concluding Remarks

- Predominant period in the urban cores and peripheral settlements of the Kathmandu Valley varies from 0.1 s to 2.0 s, and that the period gradually decreases from a higher value in the central part of the valley to a low value in the outskirts.
- The trend of period variation is found to follow the distribution of sediment depth in the valley.
- In the central part, tall buildings and long-span bridges are susceptible to damage, while it is opposite in the outskirts.
- The investigation results show that two amplified frequencies appear at about 20% of the measurement sites, which are mainly distributed in the central and northern part of the basin.
- The first amplified frequencies vary from 0.5 Hz to 8.9 Hz, whereas the second amplified frequencies vary from 3.1 Hz to 7.5 Hz, in which most of them vary from 4 Hz to 6 Hz.
- Depending on the area, especially in the central and northern part, the top 10-20 m of the sediment layer plays an important role in making the second resonant effect in the Kathmandu Basin.