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<tr>
<td>Author(s)</td>
<td>Bhandary, Netra-Prakash</td>
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<td>Citation</td>
<td>Matsue Conference Proceedings (The Tenth International Symposium on Mitigation of Geo-disasters in Asia = 第10回地震・地盤災害軽減に関するアジア会議及び現地討論会) (2012): 50-52</td>
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<td>Kyoto University</td>
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Microtremor measurement-based prediction of ground shaking in Kathmandu Valley of Nepal

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Graduate School of Science and Engineering
Ehime University, JAPAN

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
Pokhara
MCT
MBT
HFT

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

Active Thrust Faults

Nepal: Geology and Geomorphology

Earthquakes in Nepal and its Periphery

DMG, Nepal, DASE France (1979-1999)
Microtremor measurement-based prediction of ground shaking in Kathmandu Valley of Nepal

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

Zone of seismic gap

INDIA

TIBET

Next Predicted Earthquake (within 10~20 years)

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

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

Recorded Earthquake History of Nepal

<table>
<thead>
<tr>
<th>Date</th>
<th>Magnitude</th>
<th>Intensity</th>
<th>Latitu-</th>
<th>Longitu-</th>
<th>Epicenter dzl. (Km)</th>
<th>Assumed PGA (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1554/7</td>
<td>7.3</td>
<td>X</td>
<td>NA</td>
<td>NA</td>
<td>Near KTM</td>
<td>NA</td>
</tr>
<tr>
<td>1548</td>
<td>7.3</td>
<td>X</td>
<td>NA</td>
<td>NA</td>
<td>Near KTM</td>
<td>NA</td>
</tr>
<tr>
<td>1881</td>
<td>7.0</td>
<td>IX</td>
<td>NA</td>
<td>NA</td>
<td>Near KTM</td>
<td>NA</td>
</tr>
<tr>
<td>1910</td>
<td>NA</td>
<td>IX</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>1833/01/26</td>
<td>7</td>
<td>X</td>
<td>27</td>
<td>84</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>1833/10/18</td>
<td>7</td>
<td>VIII</td>
<td>27</td>
<td>84</td>
<td>172(Kathmand)</td>
<td>93</td>
</tr>
<tr>
<td>1900/09/05</td>
<td>7</td>
<td>X</td>
<td>27.7</td>
<td>83.5</td>
<td>Kathmand</td>
<td>NA</td>
</tr>
<tr>
<td>1920/07/7</td>
<td>7</td>
<td></td>
<td>28.8</td>
<td>82.5</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>1934/11/15</td>
<td>8.3</td>
<td>IX-X</td>
<td>25.55</td>
<td>87</td>
<td>177 (South of Kathm)</td>
<td>188</td>
</tr>
<tr>
<td>1936/5/27</td>
<td>7</td>
<td>NA</td>
<td>28.30</td>
<td>83.5</td>
<td>109</td>
<td>18</td>
</tr>
<tr>
<td>1945/04/16</td>
<td>6.5</td>
<td>NA</td>
<td>28.30</td>
<td>83.4</td>
<td>165</td>
<td>14</td>
</tr>
<tr>
<td>1946/09/18</td>
<td>6.5</td>
<td></td>
<td>28.30</td>
<td>83.62</td>
<td>167 (Churep)</td>
<td>36</td>
</tr>
</tbody>
</table>

Note: -4 here represents data not available

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

Damage in the 1934 Earthquake

Dharahara at present

Fall of Dharahara in 1934 earthquake

Ghantaghar and Kathmandu Durbar Square

Collapse of Ghantaghar in 1934 earthquake

Destruction of Kathmandu Durbar Square during 1934 earthquake
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:
- Kathmandu
- Bhaktapur
- Lalitpur
- Urban Area
- Damage Type
- Heavily Damaged
- Moderately Damaged

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

- Source: Google Earth, www.google.com

Rapid population increase

- 2010 Satellite image: Population: 2.5 million
- 1964 Satellite image: Population: 308,000

At Present

- Old buildings/houses
- 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

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

The Tenth International Symposium on Mitigation of Geo-disasters in Asia, MGDA, 2012.10.3-9, Japan

Shock Wave Transfer in Ground

- Incident shock wave
- Soft strata: No refraction
- Hard strata: No reflection
- Water Bowl Model
- Complete reflection

Natural Time Period and Excitation

- Earthquake shock wave
- Time
- Structural vibration characteristics

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

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.

Status of Borehole Exploration in Kathmandu Valley (from 1980 to 2002)
Geo-info Database

Borehole Data:
- Boreholes for various purposes

Ground profile through A-B

Geological Strata of Kathmandu Valley Ground (Sakai et al. 2001)

Microtremor Survey for Damage Prediction

- Microtremor: vehicle movement, explosion, factory vibrations, etc.
- Highly sensitive accelerometer

Measurement
- Data Analysis
- Fourier Analysis
- H/V Spectrum
- Natural time period estimation
- Natural time period
- Damage Prediction

Microtremor sources

- Kathmandu: Vehicle movement, Winds, Industrial machines, etc.
- Lalitpur: Shock waves, etc.
- Bhaktapur: Railway, Strong winds, etc.

Microtremor Survey Area

Legend
- Kathmandu
- Lalitpur
- Bhaktapur

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

Three velocity components (EW, NS, and UP) are measured (Time domain)

Frequency correspondences to maximum value of H/V ratio gives the predominant frequency of the site

Analysis Results

North-South Profiles

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

<table>
<thead>
<tr>
<th>Predominant period range</th>
<th>Description of zone</th>
</tr>
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<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>

Period in the study area varies from 0.1-2.05 s. Period in central part varies from 0.6 to 2 s, which covers about 30% of the urban area of the valley.

The predominant period contours for the Kathmandu Valley show that higher period range in the eastern and western part of the valley is separated by the long low period line extended from north-west to south-east in the valley.

Profiles based on the predominant period of ground display borehole data and microtremor analysis results.
Microtremor measurement-based prediction of ground shaking in Kathmandu Valley of Nepal

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Multiple resonant frequency

\[ f_0 \]: First resonant frequency of the sites

\[ f_1 \]: Second resonant frequency of the sites

H/V spectral ratio

Frequency

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

Distribution of multiple resonant frequencies

- First resonant frequency \( f_0 \)
- Second resonant frequency \( f_1 \)

Location of double peak H/V spectral ratio

About 30% of measurement points exhibit double peaks and mostly in the central and northern part of the Valley.

Location of double resonance area and JICA (2002) PS logging sites in Kathmandu Valley

- Microtremor observation points
- Major roads
- Rivers and water bodies
- JICA (2002) PS logging point

Distribution of multiple resonant frequencies

- First resonant frequencies vary from 0.48 Hz to 1.52 Hz
- Second resonant frequencies vary from 3.1 Hz to 7.5 Hz, however mostly vary from 4 Hz to 6 Hz
- The ratio of second to first resonant frequency is found about 5

Legend

- Microtremor observation points
- Major roads
- Rivers and water bodies
- JICA (2002) PS logging point
- Airport

About 30% of measurement points exhibit double peaks and mostly in the central and northern part of the Valley.
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.

Thank you