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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
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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

Why Earthquakes in the Nepal?

Active Thrust Faults

Nepal: Geology and Geomorphology

Earthquakes in Nepal and its Periphery
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

Major Earthquakes in Nepal Himalayan Region and Zone of Seismic Gap (Jamo et al., 2003)

Zone of seismic gap

INDIA

TIBET

7

Recorded Earthquake History of Nepal

When ??

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

Damage in the 1934 Earthquake

Ghantaghar and Kathmandu Durbar Square

Fall of Dhanaula at present

Dhanaula in 1934 earthquake

Zone of seismic gap

Distribution of earthquake macroseismic intensity (Jamo et al., 2003)

Data | Magnitude | Intensity | Latitude | Longitude | Epicenter dist. (km) | Assumed PGA (m/s²)
--- | --- | --- | --- | --- | --- | ---
1557/1/7 | 7.3 (assumed) | X | NA | NA | Near KTM | NA
1448 | NA | X | NA | NA | Near KTM | NA
1881 | 7 (assumed) | IX | NA | NA | Near KTM | NA
1810 | NA | IX | NA | NA | NA | NA
1813 | 7 | X | 27 | 84 | 38 | 117
1833/3/26 | 7 | X | 27 | 84 | 150 (Kathmand) | 37
1833/5/24 | 5 | IX | 27 | 88 | 380 (Kathmand) | 37
1934/3/15 | 8.4 | IX | 27 | 87 | 177 (South of Kathmand) | 188
1936/5/27 | 7 | NA | 28 | 80 | 100 | 18
1954/9/4 | 6.5 | NA | 28 | 83 | 165 | 14
1988/4/18 | 6.5 | IX | 28 | 82 | 167 (Chitwan) | 26

Note: X here represents data not available

When ??
Before the earthquake

After the earthquake

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 injuries: 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

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

Population growth in Kathmandu Valley

Rapid population increase

At Present

- Old buildings/houses
- Slender buildings/houses (Improper design?)

Legend

- Heavy Damaged
- Moderately Damaged
- Lightly Damaged
- Undamaged

Population Growth

- Kathmandu
- Lalitpur
- Bhaktapur

Confluence point of Bagmati and Manohara rivers
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

Formation of Kathmandu Valley
Shock Wave Transfer in Ground

- Hard strata: No reflection
- Soft strata: Complete reflection

Water Bowl Model

- Incident wave
- Refraction
- Reflection
- No refraction

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

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.

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

**Geo-info Database**
Borehole Data:
Boreholes for various purposes

**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

- Damage Prediction

**Microtremor sources**
- Kathmandu: Vehicle movement, Winds, Industrial machines, etc.
- Lalitpur: Vehicles, Strong winds, Shock waves, etc.
- Bhaktapur: Industrial machines, etc.

**Microtremor Survey Area**
Kathmandu, Lalitpur, Bhaktapur

**MT Survey in Kathmandu Valley**

**Legend**
- Kathmandu
- Lalitpur
- Bhaktapur
- Legend
Three velocity components (EW, NS, and UP) are measured (Time domain).

Fourier Amplitude Versus Frequency (Frequency domain).

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

Analysis

F = 0.95 Hz
F = 8.9 Hz

F = 0.73 Hz

F = 3.0 Hz

( F: Predominant frequency of the sites)
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.

### Predominant period range

<table>
<thead>
<tr>
<th>Zone</th>
<th>Period Range</th>
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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>
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Period range A

- **Description of zone:**
  - Predominant period range: 0.11 s to 0.60 s
  - The period range A is located in the central part of the valley, which covers about 30% of the urban area of the valley.

Period range B

- **Description of zone:**
  - Predominant period range: 0.60 s to 0.80 s
  - The period range B is characterized by a higher period range in the eastern and western part of the valley.

Period range C

- **Description of zone:**
  - Predominant period range: 0.80 s to 1.01 s
  - The period range C is distinguished by a longer low period line extended from north-west to south-east in the valley.

Period range D

- **Description of zone:**
  - Predominant period range: 1.01 s to 1.30 s
  - This zone is characterized by a higher period range in the eastern and western part of the valley.

Period range E

- **Description of zone:**
  - Predominant period range: 1.30 s to 2.05 s
  - The period range E is distinguished by a higher period range in the eastern and western part of the valley.
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P 82

0.1
1
10
0.1 1 10

Frequency

H/V spectral ratio

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 20% measurement points exhibit double peaks and mostly in the central and northern part of the valley.

Kathmandu Lalitpur Bhaktapur

27 points in Kathmandu City
2 points in Bhaktapur City
6 points in Lalitpur City

Distribution of multiple resonant frequencies

First resonant frequency f_0
Second resonant frequency f_1

Microtremor observation points

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.

Legend

Multiple ampliﬁed microtremor observation points
Airport
Multiple ampliﬁed microtremor observation points
Rivers and water bodies
Major road
Study area

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

100
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 the 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