# Microtremor observations in Kathmandu Valley, Nepal: Analysis of the correlation between local geology and damage by 1934 earthquake

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## 1. INTRODUCTION

Nepal, lying in the subduction zone of Indian and Eurasian plate, has experienced many destructive earthquakes over a long period of time. In each and every earthquake, Kathmandu Valley (KV), the capital of Nepal, has been suffered heavy devastation. In 1934 an earthquake of M8.4 with its epicenter located about 240 km east of KV was occurred and produced strong shaking in KV. About 19% of the total buildings in KV were destroyed and 38% were damaged partially by the earthquake. The devastation in KV caused by past earthquakes, the 1934 earthquake in particular shows that fluvio-lacustrine sediments play an important role for intensifying the ground motion. Due to unique characteristics of soil and variation in thickness of sediments within a short distances, the seismic waves were amplified which resulted in destruction of houses in KV. Similarly, varieties of damage distribution were observed from place to place based on the sediment thickness and their properties. Bhaktapur and neighboring villages in the eastern part of the valley were heavily damaged. The ratio of completely destroyed buildings to the damaged buildings is found more than one in Bhaktapur city while it is much lower than one in other two cities i.e. in Kathmandu and Lalitpur. Although Bhaktapur city was the smallest city with less population in comparison to Kathmandu and Lalitpur, a total of 1172 people were killed in Bhaktpaur city alone while only 479 and 547 people were killed in Kathmandu and Lalitpur respectively. The location map of KV and variation in damage distribution by 1934 earthquake is shown in Fig. 1.

In this study, microtremor measurements is done in different location of KV and the horizontal to vertical spectral ratio technique has been adopted for the analysis of microtremor measurements. A correlation between damage distributions by 1934 earthquake with the soil structure resonance is analyzed based on the result of microtremor observations. This paper is one of the first attempts to investigate the influence of site effects in devastation of KV by 1934 earthquake.

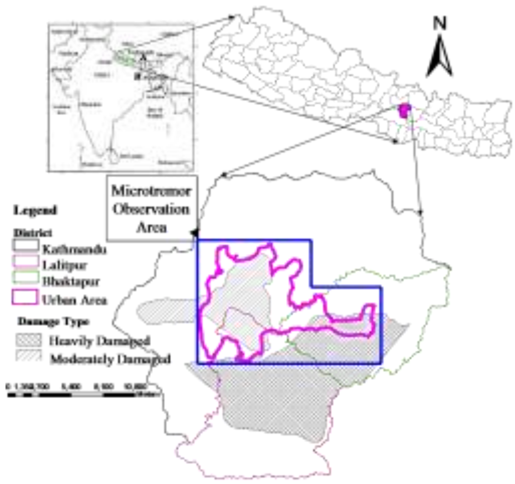


Fig. 1: Location map of KV and damage distribution by 1934 earthquake

## 2. MATERIALS AND METHOD

The microtremor observation was carried in urban area of the KV. For preparation of ground time period variation map of the KV, the study area was divided into 1 km squares and each corner of the square was identified as the microtremor observation point as shown in Fig. 2. The microtremor observations were performed using portable microtremor equipment; New PIC device manufactured by System and Data Research (SDR) Co. Ltd., Japan. Sampling frequency for all measurements was set at 100 Hz. The velocity sensor used can measure three components of vibration: two horizontal in east-west and north-south directions and one in vertical direction. A global positioning system (GPS) device was used for recording the coordinates of the observation points.

The microtremor device was setup in each observation point and the measurements were taken at each point in the grid as shown in Fig. 2. At each point, data were recorded for 300 seconds (i.e. 30,000 samples at a sampling rate of 100 Hz). The recorded data were extracted from data acquisition system, and velocity time histories of three components of all recorded data were drawn. Each component of signal was corrected by the base line and divided into 15 windows in which each window has 2048 samples (20.48 s). For each point, 8-12 windows were picked up for analysis, omitting the windows that are influenced by near by noise sources. Fourier Analysis of the each window was carried out using Fast Fourier Transform (FFT) computer program and the resulting spectra were smoothed using Parzen window of bandwidth 0.5 Hz. The average spectral ratio of horizontal to vertical components was obtained from Eq. (1) (Delgado et. al., 2000).

$$H/V = \sqrt{[(F_{NS}^{2} + F_{EW}^{2}) / (2F_{UD}^{2})]} \quad \text{---------------------} \quad (1)$$

Where, $F_{NS}$, $F_{EW}$ and $F_{UD}$ are the Fourier amplitude spectra in the north-south (NS), east-west (EW) and up-down (UD) direction, respectively.

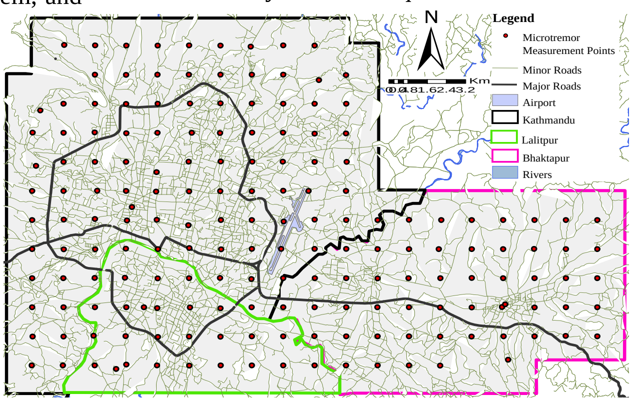


Fig. 2: Microtremor observation points

This procedure was repeated with the remaining windows. After obtaining the H/V spectra for all the windows, the average of the spectra was obtained as the H/V ratio for a particular point. The frequency corresponding to the first peak of the H/V spectrum plot shows the resonance frequency of the site. So, by measuring the three components of microtremor at a point, site specific resonance frequency and corresponding predominant period were obtained.

Keywords: Microtremor, seismic damage, Nepal
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In order to represent the spatial distribution of the predominant time period over the KV, interpolation of the obtained time periods were done by using the geostatistical technique: Inverse Distance Weighted (IDW) method and predominant time period variation map was prepared for KV using GIS.

Moreover, the survey of the houses of the KV is done and building time period (T) of KV is found out using the relation given by Uniform Building Code 1997 as shown in Eq. (2). Finally discussion regarding the soil structure resonance is done by comparing the time period of the ground with the time period of the buildings.

$T = 0.1N$ ………….. (2)

Where, N – Number of story of a building.

3. RESULTS AND DISCUSSION

Based on the result of microtremor observations in three major cities of KV, it is observed that predominant time periods of ground varies from 0.11 to 2.05 sec as shown in Fig 3. Large variation of predominant time periods are found within the short distances and higher time periods are found around the center core area of Kathmandu city. It is also observed that the time period decreases towards east-west and north-south directions from the center of the Kathmandu city.

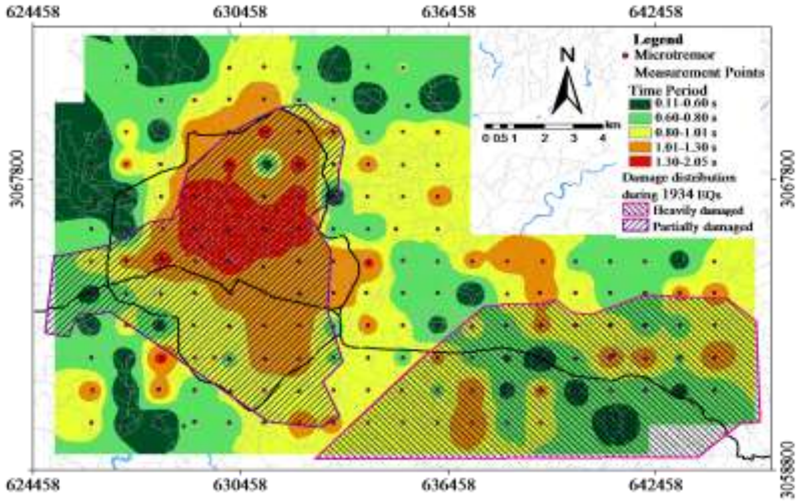


Fig 3: Predominant time period variation map of Kathmandu Valley

As it is illustrated in Fig. 3, predominant time period varies from 1.0 to 2.0 sec around the center core area of the Kathmandu city. Similarly, time period for the Lalitpur city varies from 0.8 to 1.3 sec and for the Bhaktapur city varies from 0.5 to 1.0 sec. This indicates that the possibility of devastation of higher period structure is high in the core city area of Kathmandu where as short to medium period structures is high in other two cities.

Table 1: Time period of buildings

| SN | Building Type | Story | Time period (T) (sec) | New Time period ($T_n$) due to stiffness degradation |
|---|---|---|---|---|
| 1 | Masonry | 3 | 0.3 | 0.48 |
| 2 | Masonry | 4 | 0.4 | 0.64 |
| 3 | Masonry | 5 | 0.5 | 0.80 |
| 4 | Masonry | 6 | 0.6 | 0.96 |


Fig. 4: Building story in study area

According to the survey of buildings in KV, it has been found that core city area encompasses buildings that are mainly of 3 to 5 stories in height as shown in Fig. 4. Most of them are brick masonry in mud and cement-sand mortar with thick wall. Most of the buildings are old and some of them have already experienced earthquakes. According to UBC 1997, the time period of such buildings is calculated around 0.3 to 0.5 sec as shown in Table 1 which is smaller than the predominant time period soil in the populated area of KV. According to Clinton et al. 2006, the time period of buildings increases up to 60% and more, depending upon the condition of buildings. The main reason for increase of time period of building in its life span is due to the decrease of stiffness because of increase in weight (due to increase of moisture), or cracks in buildings (due to poor maintenance). The elongation of time period can also be observed during strong shaking due to earthquakes (Clinton et al. 2006). In this study, increase in time period due to degradation of stiffness in KV buildings is taken as 60%. Then the new time period of such buildings is calculated around 0.48 to 0.96 sec which is equal and very close with the time period of ground in the eastern part of valley especially around Bhaktapur city. This causes the resonance between ground and buildings and buildings vibrate with higher amplitude and finally damage of buildings is occurred. Therefore, the resonance effect is the main cause for higher damage in Bhaktapur area than other part of the KV during 1934 earthquake.

4. CONCLUSIONS

Based on the result of microtremor observations, comparison between predominant time period of ground and buildings in KV is performed. The predominant time periods of soil in and around Bhaktapur city is found equal or very close to the predominant time periods of the buildings. This causes the resonance and resulted in higher damaged of buildings during 1934 earthquake. The observation shows that microtremor can be used as an appropriate tool for the estimation of site effects during earthquake. If any great earthquake strikes in KV, higher damage of higher period structures can be expected in center area of Kathmandu and higher damage of lower to moderate period structures can be expected in Bhaktapur and Lalitpur city. Therefore special attention should be given towards the seismically resistant design of such structures based on their location.

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