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Ground Response Study in Kathmandu Valley of Nepal Using Microtremor Observations

Microtremor, Ground response, Nepal

○Y. R. Paudyal (Student), N. P. Bhandary (Regular), R. Yatabe (Fellow)
Graduate School of Science and Engineering, Ehime University

1. INTRODUCTION

Kathmandu Valley, the capital of Nepal, lies in active seismic region. It encompasses three cities, i.e. Kathmandu, Lalitpur, and Bhaktapur and is renowned for its historical and cultural richness. The location map of Kathmandu Valley (KV) is shown in Fig. 1. The valley soil consists of thick fluivo-lacustrine sediments of varying thickness up to 550 m which can change the properties of seismic waves. It has experienced several devastating earthquakes in the past. Devastation of KV in the historical earthquakes, particularly the M8.4 Bihar-Nepal Great earthquake of 1934, suggests that the spectral ground amplification due to fluivo-lacustrine sediments play the major role in intensifying the ground motion. It is therefore imperative to conduct a detailed site response analysis in KV. Site response analysis in different locations of the KV provides a basis for site-specific hazard analysis, which can assist in systematic earthquake mitigation programs. No in depth studies have been carried out for ground response of KV up until now.

The main objectives of the present study are to measure the microtremors in many locations specially covering densely populated areas of KV and to analyze and interpret them by the horizontal to vertical spectral ratio (HVSR) method in order to find out predominate period of the sites. Based on the obtained predominant time periods, a time period variation map is prepared. Moreover, the obtained results are compared with the results with the previous studies by other researchers, to validate the results from microtremor observations.

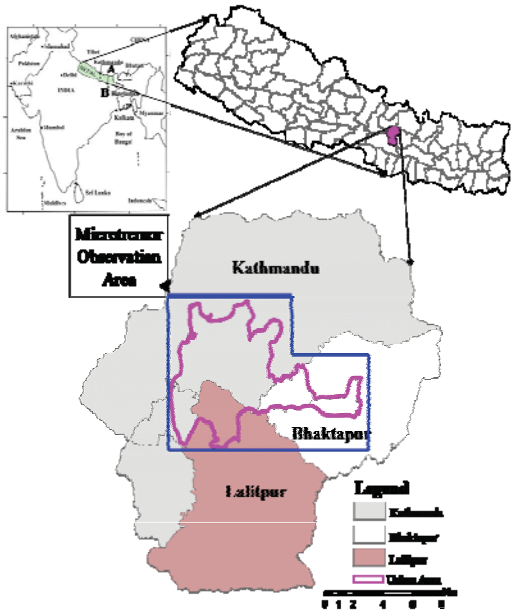

Fig. 1: Location map of KV

2. MATERIAL AND METHOD

For systematic ground response analysis of the KV, the core heavily urbanized area of KV 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. The sampling frequency for all measurements was set at 100 Hz. The high pass filter of 20 Hz was set in the data acquisition unit. 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.

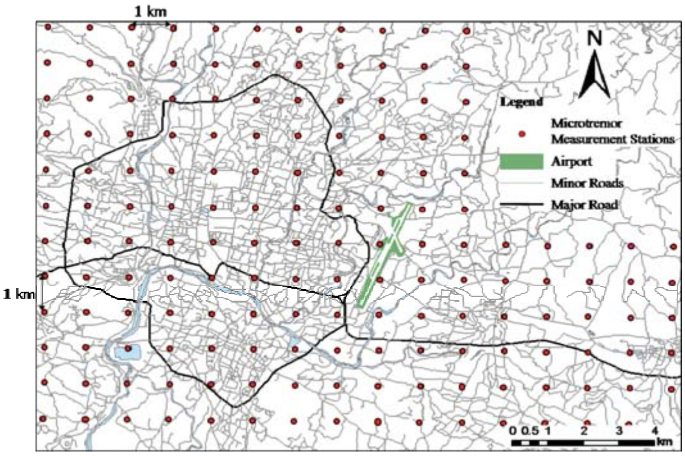

Fig. 2: Microtremor measurements stations

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. Microtremor observations were made at more than 176 points in KV. 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 the data acquisition system, and the 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)

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

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.

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 or transfer function 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 microtremors at a point, site specific resonance frequency and corresponding predominant period were obtained. 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.

3. RESULTS AND DISCUSSION

One typical example of microtremor measurement analysis and determination of predominant time period using HVSR technique is shown in Fig. 3. It includes predominant time period for east-west direction, north-south direction and average of both directions.

From the analysis of the data it has shown that the predominant time period varies from 0.11 sec to 2.05 sec in the KV. Based on the variation of the predominant time period, a contour map is plotted as shown in Fig. 4. Large variation of predominant time periods are found with in the short distances and higher time periods are obtained around the center core area of the KV. It is also observed that the time period decreases towards the east west and north south from the center of the KV and is found maximum where the density of population is high.

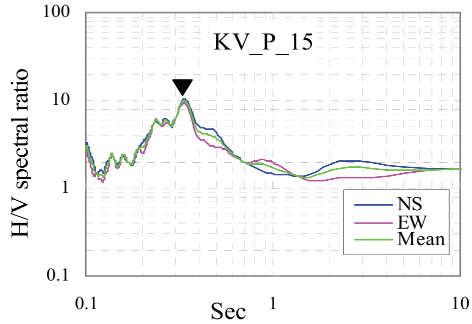

Fig. 3: A typical H/V spectral ratio verses time period graph

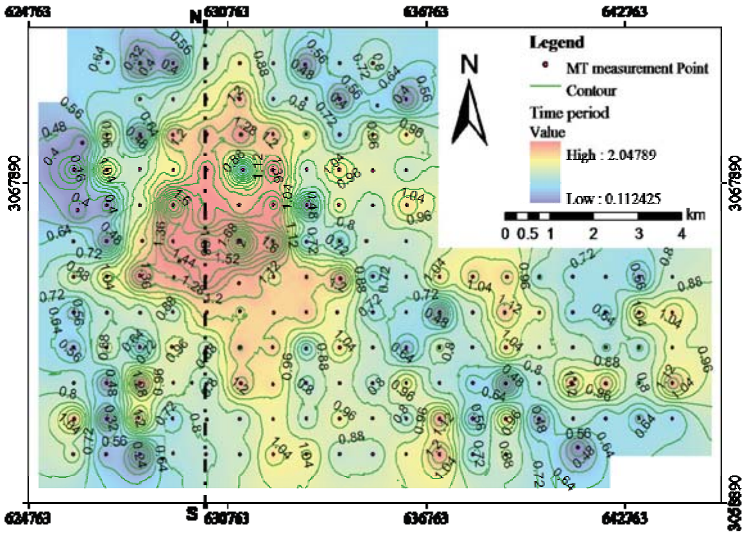

Fig. 4: Predominant time period contour for KV of Nepal

As it is illustrated in Fig. 4, predominate time period varies from 1.0 sec to 2.0 sec around the center of the Kathmandu Basin, where thickness of the sediment is high. When we compare this with the information about the sediment depth for KV (Katel et al., 1996) we find it in agreement with other studies (Delgado et. al., 2000) that the predominant time period becomes higher in areas where the sediment depth is greater and lower where it is shallower. One of the key factors controlling predominant time period of a site is soil thickness, i.e. sediment depth which varies rapidly in KV within a short distance.

While comparing the time period obtained by microtremor observations with sediment thickness of the Kathmandu basin proposed by Katel et al. (1996) as shown in Fig. 6, a profile along north to south as shown in Fig. 5 is drawn through the center of KV based on the predominant time period obtained by the HVSR technique, a good correlation were found between the sediment thickness and predominant time period of the ground.

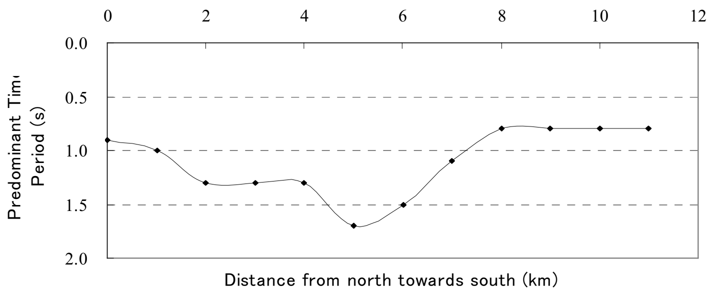

Fig. 5: Section from north to south along the center of KV based on predominant time period of ground

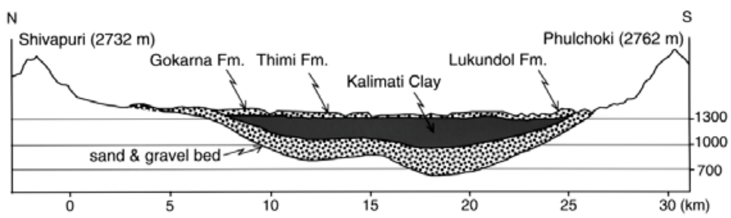

Fig. 6: Section from north to south along the center of KV based on variation of thickness of sediments (Katel et al. 1996)

4. CONCLUSIONS

Thus, using microtremor observation predominant time period variation map of Kathmandu Valley is prepared. The horizontal to vertical spectral ratio technique is used in this study because it provides a simple and economic means of determining the predominant time period of the ground: thus this turned out to be a useful tool for ground response analysis of the whole study area. The predominant time period varies rapidly within the short distances and found maximum around the center of the valley. Therefore, special attention should be given towards the seismically resistant design and construction of infrastructures in the Kathmandu Basin.

In the absence of enough and precise subsurface data of Kathmandu Valley, authors have developed a predominant time period variation contour map for Kathmandu Valley which is useful for planners and disaster managers to adopt a safer land use planning and application of building code in design and construction of buildings.

REFERENCES

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