Evaluation of buildings and ground response in the Kathmandu Valley based on ground motion characteristics using microtremor

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1. INTRODUCTION

At 11:56 a.m. (Nepal Standard Time) of April 25, 2015, an M_w7.8 earthquake struck central Nepal with its epicenter at Barpak village of Gorkha district, about 77 km northwest of Kathmandu. It was the most devastating seismic event in the Kathmandu valley since the Great 1934 Earthquake (Mw 8.4) that caused massive destruction of ancient culture, craftsmanship and numerous monuments of cultural and historical importance along with the world cultural heritage sites. Kathmandu valley is an ancient lake with lacustrine and fluvio-lacustrine sediment deposition of about 550–650 m depth (Sakai et al., 2002). Damage to structures caused by earthquake motion is known to depend on the nature of the incoming seismic energy and the characteristics of structures and ground. Resonance during the earthquake motion is a prime factor that governs the degree of damage to exisiting structures. In this study, microtremor was used to acquire predominant frequency of existing buildings (44 sites) as well as natural frquency of grounds (51sites) at different sites to demonstrate the resonance characteristics with the earthquake data measured by Takai et al. (2016).

2. METHODOLOGY

Intensity of ground motion is a function of earthquake magnitude and distance from the seismic source, as well as local geological condition and topography of the area (Kramer, 1996). So, to understand the seismic response of the ground and structures, 44 building sites and 51 ground sites were selected for microtremor survey as shown in Fig. 1. The microtremor survey device consists of a seismometer with its natural period of one microsecond, a transducer, and a laptop computer to control the system and store the data. Measurements were repeated twice at each site to control the stability of the results for 300 seconds. The distance of the ground point from the building site ranged from 20m to 100m. From the measurement data, Fourier spectrum of two horizontal microtremor motions NS and EW directions and one vertical motion in UD direction were obtained.

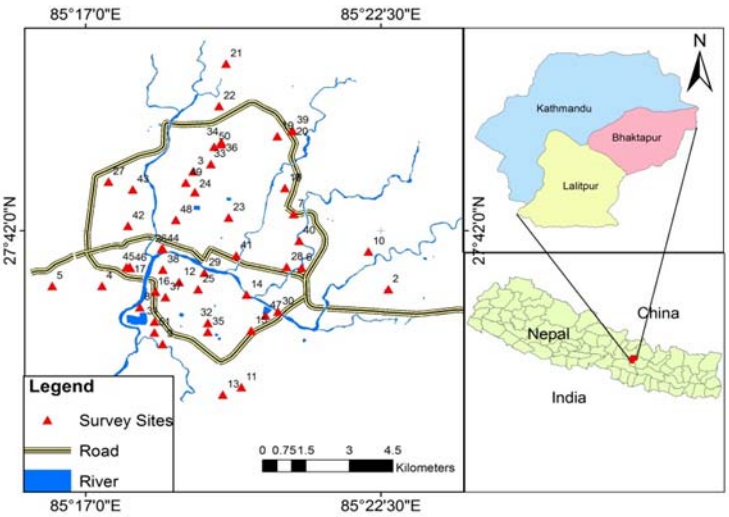


Fig 1 : Location map of microtremor survey sites in the Kathmandu valley

The horizontal-to-vertical spectral ratio (HVSR) method is used to find the amplification produced at the sites by evaluating the ratio between the horizontal and vertical spectral amplitudes of microtremors recorded at the site for short period (Eq. 1).

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

H/V spectral ratios for grounds, H/H spectral ratio for buildings were calculated by dividing a horizontal by vertical and horizontal by horizontal component of the obtained spectrum and were plotted as in Fig 2.

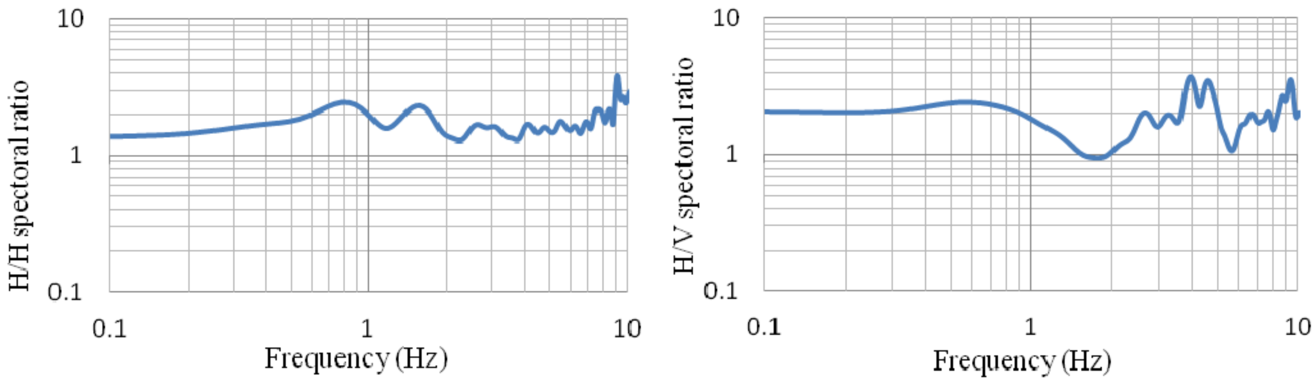


Figure 3: Comparison of H/H and H/V spectral ratio at Parkview horizon apartment (22).

Similarly, from the data measured by Takai et al. (2016) during the earthquake at five different sites, the velocity response spectra (damping ratio, h = 0.05) were drawn.

Finally, the following relationship (Eq. 2) was used to understand the relation between the displacements amplified with external force and static displacement.

$$\left|\frac{x}{x_s}\right| = \frac{1}{\sqrt{(1-(\omega/\omega_0)^2)+4h^2(\omega/\omega_0)^2}} \text{ --- (2)}$$

RESULTS AND DISCUSSION

Resonance is a phenomenon in which a structure behaves like a single mass body with its ground natural frequency during earthquakes and strong ground motions. Fig. 3 shows the horizontal velocity response spectra for the five sites in the Kathmandu Valley, which were derived from records observed at the near-surface fault (Takai et al. 2016). Two notable response spectra TKT (Takatori, Kobe, Japan) and TCU068 (Shigang District, Taichung, Taiwan) are also shown. From this figure, it is understood that during the 2015 Gorkha Earthquake KTP (Kirtipur Municipality Office, Kirtipur), KATNP (Kanti Path, Kathmandu), TVU (Central Department of Geology, Tribhuvan University, Kirtipur), KTP (Kirtipur Municipality Office,Kirtipur), PTN (Pulchowk Campus, Institute of Engineering, Tribhuvan University, Patan), and THM (University Grants Commission Office, Sanothimi, Bhaktapur), which were derived from the velocity pulses has spectral peaks from 3 to 5 seconds except for KTP. The TCU068 spectrum had a large peak at a period of 10s, which was several times larger than the KTP peak at 6s. Using these peaks, Fig. 4 was obtained for maximum displacement response magnification along with the building at those particular sites.

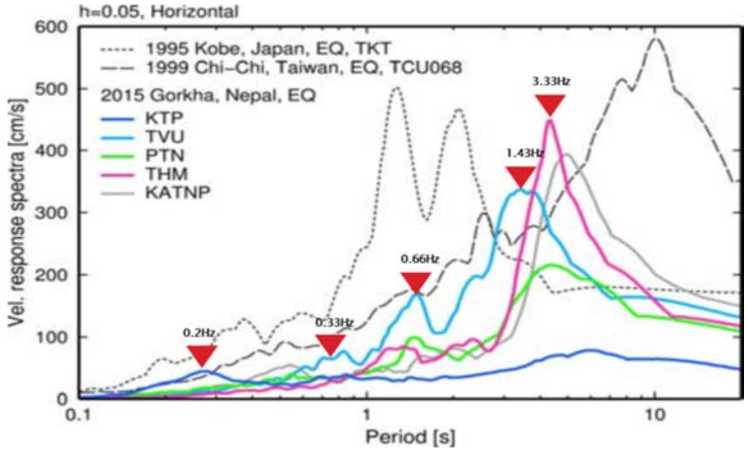
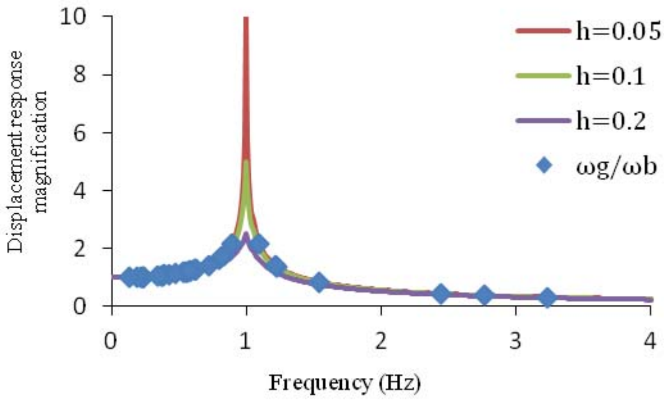


Figure 4: Ground response comparison 1995 Kobe, Japan, EQ, TKT, 1999 Chi-Chi ,Taiwan, EQ, TCU068 and 2015 Gorkha, Nepal EQ



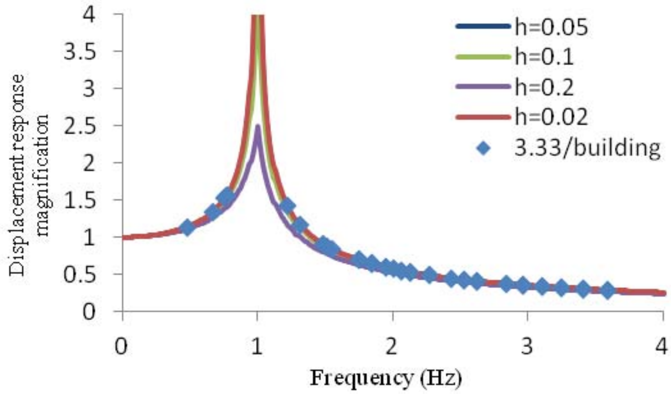


Figure 4: Displacement response magnification comparison from the earthquake data

According to the displacement response magnification, oscillation behavior of buildings considering the earthquake was found to be amplified.

3. CONCLUDING REMARKS

In Kathmandu valley predominant period of ground varying from 0.9-2 seconds almost equals to the exisitng high rise buildings which shows the possibility of resonance phenomenon during the earthquake with such magnitude. The multiple amplified frequencies in a particular area can show resonance effect both for short as well as tall buildings. Therefore, the behavior of the surface layer as well as the layer underneath should be taken into consideration during seismic risk studies in the valley for future disaster risk assessment studies.

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