Journal of Geoscience and Environment Protection, 2019, 7, 300-308
http://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Estimation of Shear Wave Structure and Horizontal to Vertical Spectral Ratio at Different Sites in Kathmandu Valley

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How to cite this paper: Poudel, S., & Ghimire, S. (2019). Estimation of Shear Wave Structure and Horizontal to Vertical Spectral Ratio at Different Sites in Kathmandu Valley. *Journal of Geoscience and Environment Protection, 7,* 300-308.
https://doi.org/10.4236/gep.2019.75022

Received: April 8, 2019
Accepted: May 28, 2019
Published: May 31, 2019

Abstract

The present study was carried out to evaluate resonant frequency of the ground and to characterize subsurface ground based on shear wave velocity structure. For this, five sites were selected such as Pulchowk, Chhauni, Gaushala, Buddhanagar and Bhainsepati. About 20 data were recorded in each site and then shear wave velocity structure and graph of amplification ratio with their spatial distribution has been established with the help of software i.e. Seisimager/Seismodule Controller. The results of both analysis methods were then compared to the amplitude of the Gorkha Earthquake and borehole data. All these data and study indicates that the Kathmandu Valley sediments are dependent on the frequency of the seismic waves and the wave velocity is greater in the peripheral region than in the central part of the Valley. The result had also shown that the presence of silty-sand, clay and loose gravel soil with low bearing capacity and elastic modulus in most of the sites are responsible for devastation. It was also noted that apart from few limitations, a non-intrusive microtremor analysis can be adopted for earthquake site characterization in the Kathmandu Valley which can be readily applied and expanded upon in future seismic hazard and microzonation efforts for Kathmandu.

Keywords

Microtremor, Passive Source, Array, Borehole, Microzonation

1. Introduction

The Kathmandu Valley, falls in one of the most active tectonics zones of the Himalayan belt and has experienced many destructive earthquakes in the past

(Pandey et al. 1995). Geological exploration has revealed that the Valley is an ancient lake deposit which is made up of thick layers of clay, silt, sand and gravel in irregular layer of deposition, which measures several hundred meters at the deepest point. **Figure 1** represents the location map of the study area where borehole as well as microtremor survey has been carried out. Since the Kathmandu Valley is the parts of active collisional orogenic belt, combining rapid crustal shortening and thickening, that causes frequent strong earthquakes. Also, the level of seismic hazard in the Valley is high (Wesnousky et al. 1999) which makes Valley susceptible to substantial loss during an earthquake event. Kathmandu Valley endured an extensive damage during the 1934 Nepal-Bihar Earthquake (Rana 1935). It would be prudent to consider that Kathmandu Valley is vulnerable to considerable damages in future during similar events. So, the geophysical investigation of the subsurface material may be a good option for the study. Hence, geological evaluation using borehole data, microtremor method of data collection and analysis, frequency response of top soil layer through HVSR method in the Kathmandu Valley have been carried out. It has been noted that the level of hazard is not uniform within the Valley due to differential lateral variation on geology and geometry.

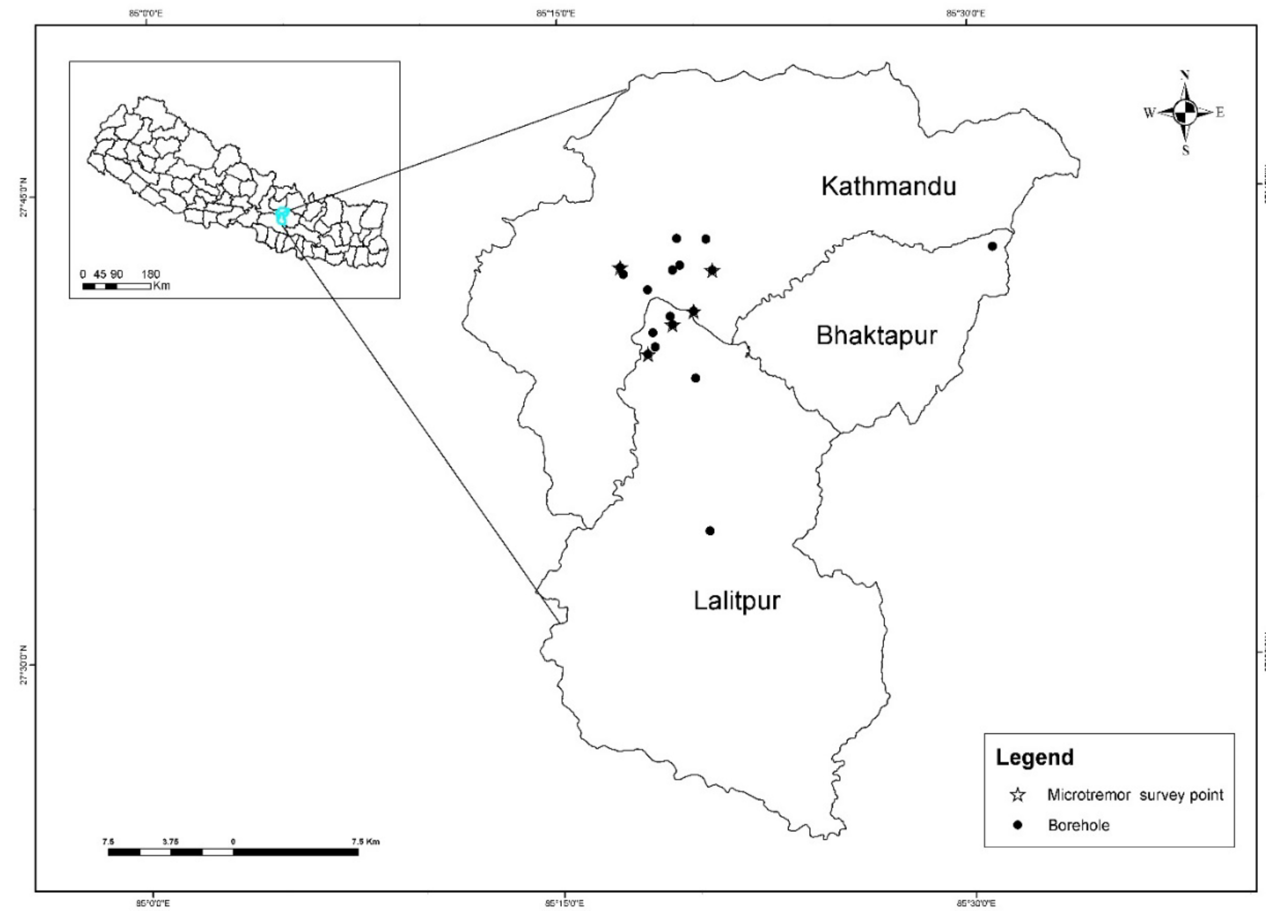

Figure1. Location map of the study area.

Objectives

The objectives of the study are to evaluate the resonant frequency of the ground, to characterize subsurface ground based on shear wave velocity structure and to compute the relationship between Shear wave velocity structure, Horizontal-to-Vertical Spectral Ratio (HVSR) and borehole data

2. Methodology

Microtremor Array Measurement (MAM) survey with Horizontal to Vertical Spectral Ratio (HVSR) was carried out in selected sites. Data were processed and inversion was done with sophisticated software Seisimager. Tabulated value of both compressional wave velocity (Vp) and shear wave velocity (Vs) were used to compute different geotechnical parameters. About 20 data for microtremor and 10 data for HVSR were created. Shear wave velocity profile (**Figure 2**) and HVSR model (**Figure 11**) has been established. The HVSR model at each borehole was compared with the M_w 7.8 Gorkha Earthquake recorded at four different seismic stations whereas the shear wave and compressional wave velocity was compared with borehole data (Secondary data).

Site classification system proposed by Ambraseys et al. (1996) based on the average shear wave velocity, Vs30 of the uppermost 30 m of the soil profile have been assumed for very soft soil, soft soil, stiff soil and rock respectively to make comparison between obtained and calculated results. The results, obtained in terms of seismic wave velocity models (Vs and Vp) and the amplification ratio (HVSR) were presented graphically as a function of their spatial distribution.

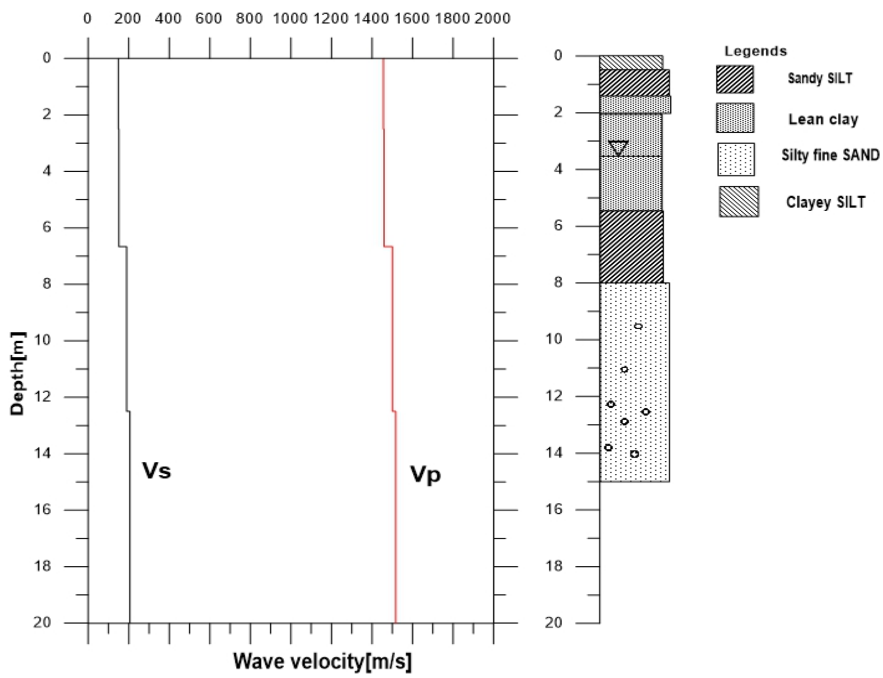

Figure 2. Borehole log with shear wave and compressional wave velocity at pulchowk.

3. Results and Discussions

3.1 Shear Wave and Compressional Wave Velocity Profiles with Borehole Log

The maximum average value of Vs30 obtained at Chhauniis 233.8 m/s (as shown in **Figure 3**) whereas minimum value obtained at Buddhanagar is 124.4 m/s (as shown in **Figure 4**). The average values of Vs 30 up to 20 m at other sites are 174.9 m/s obtained at Pulchowk (as shown in **Figure 2**), 174.0 m/s obtained at Gaushala (as shown in **Figure 5**) and 142.2 m/s obtained at Bhainsepati (as shown in **Figure 6**). This shows that the parametric values of the ground motion are greater in the peripheral region than in the central part of the Valley.

3.2. Determination of Average Horizontal to Vertical Spectral Ratio (HVSR)

The maximum and minimum values of frequency of the peak average value of HVSR obtained at Bhainsepati (as shown in **Figure 7**) is between 22 - 26 Hz and minimum values of frequency of the peak average value of HVSR obtained at Buddhanagar (as shown in **Figure 8**) is between 1 - 5 Hz respectively. The values of frequency of the peak average value of HVSR obtained at other sites are Chhauni (6 - 10 Hz) (as shown in **Figure 9**), Gaushala (6 - 10 Hz) (as shown in **Figure 10**) and Pulchowk (5 - 9 Hz) (as shown in **Figure 11**).

The result shows the presence of terrace forming sand (Chapagaun Formation) to monotonously clay from fluvio-deltaic of fluvio-lacustrine sediments in the central part of the Kathmandu Valley (Kalimati Formation). This older sediment of central part is covered with thick sequence of sandy and silty sediments without clay (Gokarna Formation) and Patan Formation. The result of present dissertation thus resembles nearly with the previous studies and outcomes.

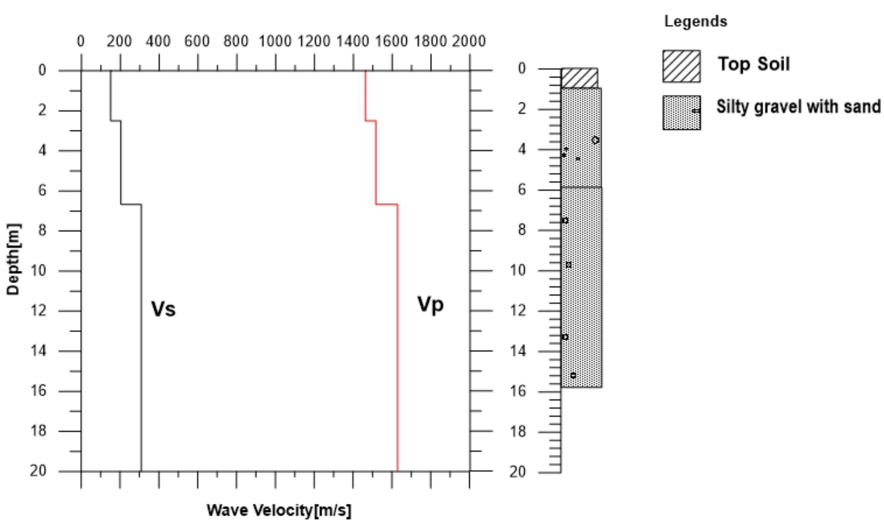

Figure 3. Borehole log with shear wave and compressional wave velocity at chhauni.

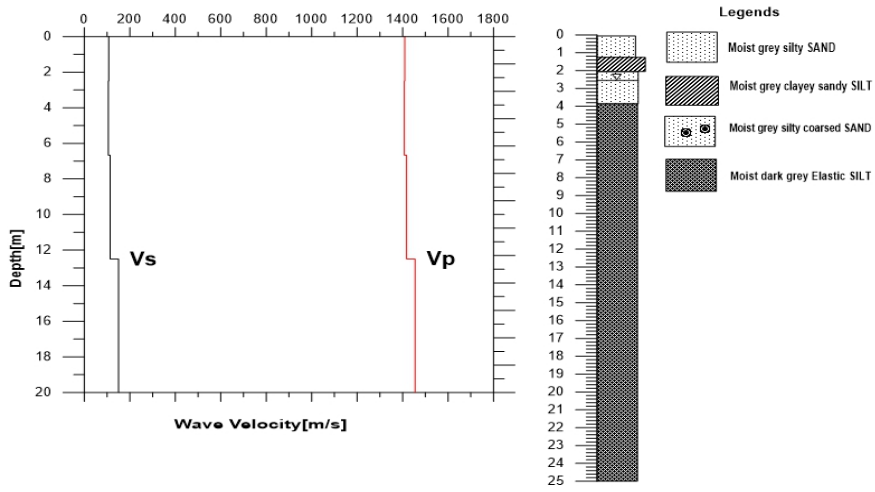

Figure 4. Borehole log with Shear Wave and Compressional Wave Velocity at Buddhanagar.

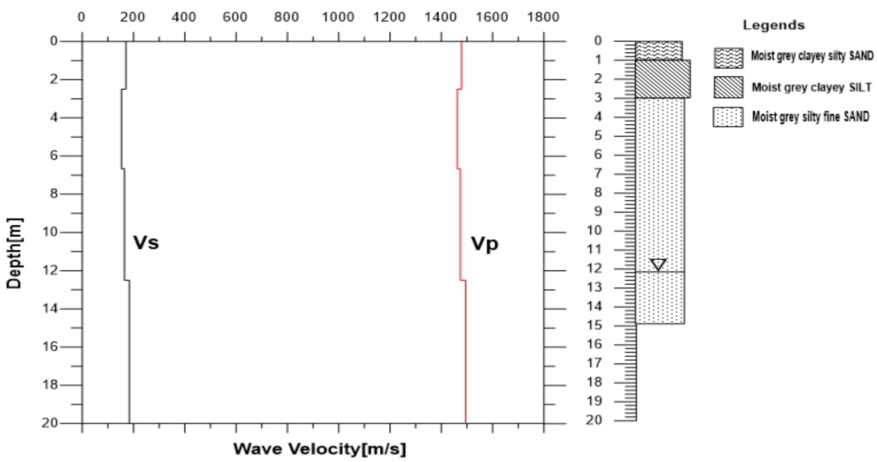

Figure 5. Borehole log with shear wave and compressional wave velocity at gaushala.

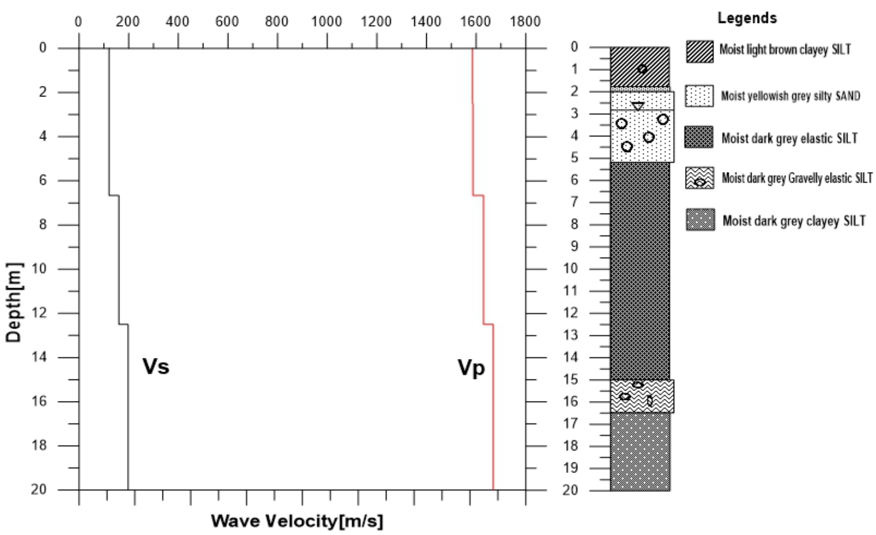

Figure 6. Borehole log with shear wave and compressional wave velocity at bhainsepati.

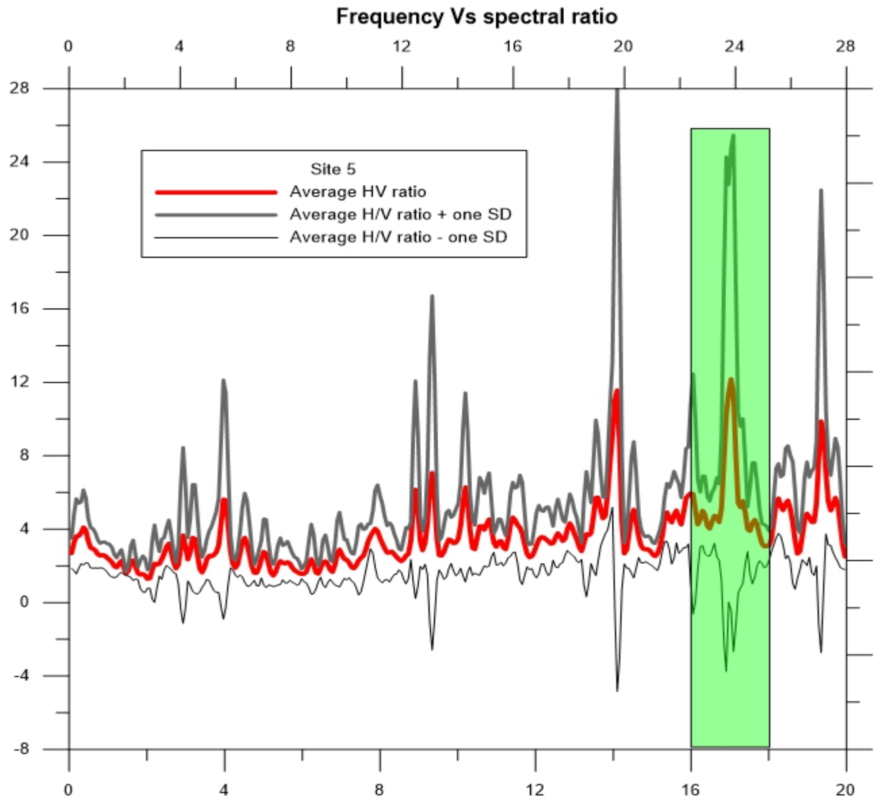

Figure 7. Average MHVSR (thick line) and one standard deviation (thin lines) curves at Bhainsepati site.

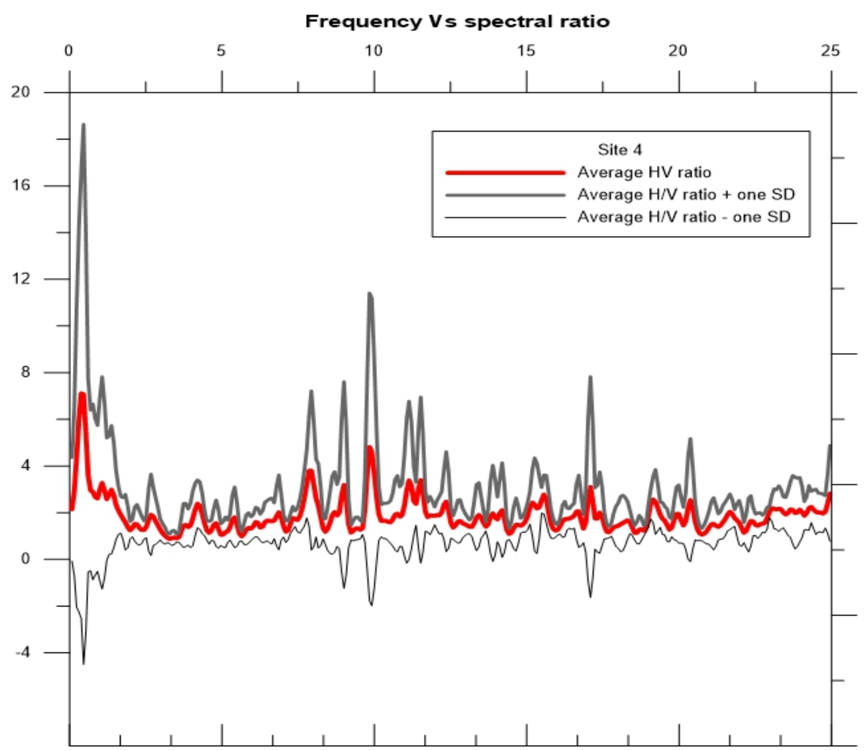

Figure 8. Average MHVSR (thick line) and one standard deviation (thin lines) curves at Buddhanagar site.

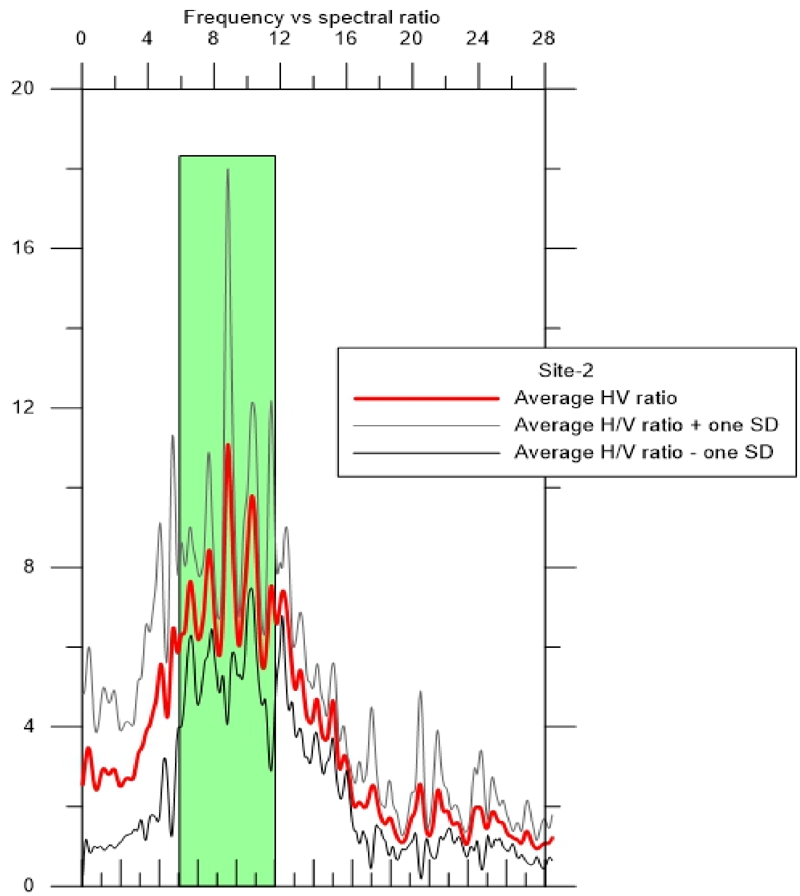

Figure 9. Average MHVSR (thick line) and one standard deviation (thin lines) curves at Chhauni site.

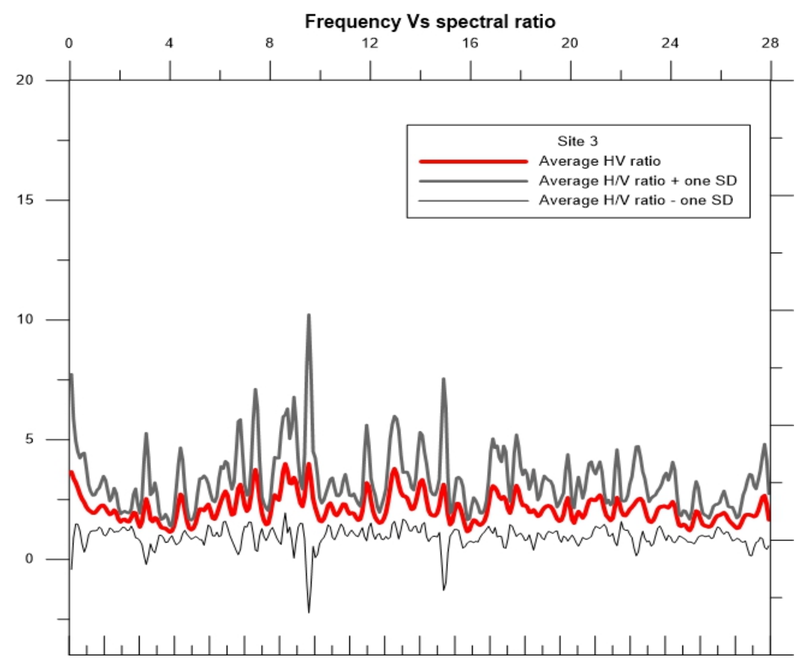

Figure 10. Average MHVSR (thick line) and one standard deviation (thin lines) curves at Gaushala site.

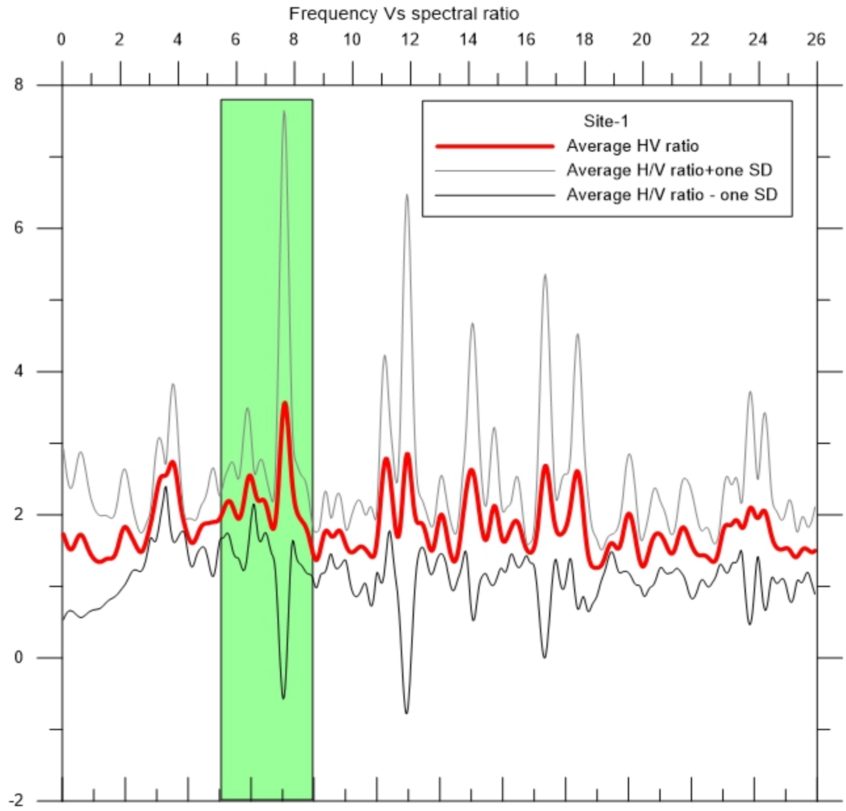

Figure 11. Average MHVSR (thick line) and one standard deviation (thin lines) curves at Pulchowk site.

S-wave velocity and P-wave velocity of the particular area are obtained and is correlated with borehole data. The N-value obtained from existing bore-hole data (SPT Test Number) can also be compared with the N-value obtained from seismic method (MAM). The HVSR for ten site has a relatively clear peak frequency and has been used to determine predominant period and amplification of a site and these results are also compared with the Gorkha Earthquake 2015. These HVSR results are generally consistent with previous microtremor HVSR results (Bhandary et al. 2014, Paudyal et al. 2013) and observed amplification response during the main shock (Galetzka et al. 2015, Takai et al. 2016).

These results can only be considered as general indications of what has occurred during the earth quake as analysis help us to explain the pattern of damage observed in the Kathmandu Valley.

4. Conclusion

Microtremor Array Measurement (MAM) survey with Horizontal to Vertical Spectral Ratio (HVSR) was carried out in selected sites. Data were processed and inversion was done with sophisticated software Seisimager. Also, the data were used for the evaluation of the resonant frequency of ground to study the topsoil response and ground characteristics of the selected sites in the Kathmandu Valleyhave indicated that the Kathmandu Valley sediments are dependent on the frequency of the seismic waves.

The minimum value of Vs30 recorded in Buddhanagar was 124.4 m/s and the maximum value of Vs30 recorded in Chhauni was 233.8 m/s. The average value of Vs30 recorded for most of the sites are near to 142.2 m/s, indicating that near surface deposits are relatively soft. The inversion velocity models have shown the presence of clayey sandy, silty-sandy to sands, gravelly sand and their mixtures.

The low velocity model for most of the sites is due to presence of soft soil in that area are responsible for the destruction in most of the sites. The results also have shown that the parametric values of the ground motion are greater in the peripheral region than in the central part of the Valley.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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