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Site Specific Ground Response Analysis of Singha Durbar using Microtremor

Bibek Gyawali [a], Youb Raj Paudyal [b]

[a] *Department of Civil Engineering, Thapathali Campus, IOE, TU, Nepal*
Corresponding Email: [a] bibekgyawali2046@gmail.com, [b] yrpaudyal@gmail.com

Abstract

Singha Durbar, one of the historical and administrative area of Kathmandu valley, is taken as study area as there was variation in the destruction pattern showing the need for the site-specific ground response analysis. Assessing local site effects is an important aspect of seismic hazards, which often causes amplification of ground motions and results in the increasing of the damage potential of earthquake. Microtremor studies have been widely popular in this regard. Nakamura's H/V method is a simple and inexpensive noise measurement technique for estimating dynamic characteristics of ground and structures using microtremor. In this research microtremor measurements have been used to implement Nakamura's H/V method. The microtremor study performed in this research is to understand dynamic characteristics of soil and structures, such as the predominant frequency. Earthquake damage strongly depends upon strength, period and duration of seismic motions. And these parameters are strongly influenced by seismic response characteristics of ground and structures. For the study, measurements were taken at 34 stations. The predominant frequency of the ground assessed varied from 0.39 Hz to 2.64 Hz.

Keywords

Microtremor, Nakamura Method, Predominant Frequency, Site Effect, Amplification Factor, Micro-zonation

1. Introduction

Kathmandu valley is located at with an average elevation of 1340 m from the main sea level, measure about 25 km east to west and 20 km north to south. Kathmandu valley is one of the most active tectonic zones of himalayan belt and has experienced many recurrence earthquake in the past.

Microseism and microtremors are terms used to determine the ambient vibrations of the ground caused by ambient or natural disturbances such as wind, traffic, sea waves etc. In practice, they are recorded by using high sensitivity seismometers. The use of microtremors in the detection of site response is based on the principal that microtremors spread in the ground are amplified at periods which are synchronous with the predominant period of site owing to the properties of selective resonance.

There are various methods available for ground response and microzonation studies. Most commonly used methods are bore hole with P-S logging, strong ground motion observation and microtremor measurement. However, bore hole method [1], is comparatively costly, time consuming and is not suitable for densely populated area. The method based on strong ground motion is also very common, but it is only possible where earthquakes are frequent and data can be recorded easily. In this situation, microtremor analysis may be a good option for ground response analysis in Singha Durbar area of Kathmandu Valley.

The microtremor analysis-based method was first introduced by Kanai(1957) [2]. In 1989, Nakamura [3], improved this method and now it has become widespread as low-cost and effective tool to estimate the fundamental resonant frequency of sediments by measuring microtremors at single station. According to Nakamura (1989) [3], the horizontal to vertical spectral (H/V) ratio is the Quasi Transfer Spectra of soil strata over bedrock, which is obtained by taking the spectral ratio [4] of the horizontal to vertical component of ground motion at single station. The specific objective of this research work is to assess the area of study to evaluate the predominant frequency and preparation of seismic micro-zonation map of Singha Durbar area. To achieve the above mentioned objectives, following tasks were performed.

1. First of all, study points was selected on interval of 100 m using GIS software as shown in Figure 1.
2. Grid of Singha Durbar area was prepared with 37 nodal points for measurements.
3. GPS device was used to locate these points at site.
4. Microtremor device was placed at each station and tremor data for X, Y and Z was recorded.
5. Data analysis was done using Fast Fourier Transform (FFT) method to obtain graph between spectrum ratio and frequency.

2. Objectives

The general objective of this research work is to evaluate the predominant frequency of Singha Durbar area. Following are specific objective of the study.

1. To obtain the predominant frequency of Singha Durbar area.
2. To prepare seismic microzonation map of study area using predominant frequency.

3. Methodology

Sensor Location

For microtremor data acquisition,the google earth information was used to prepare a location map of each observation point along with the predetermined geographic coordinates and elevation. The map to ground technique employed in this study enabled us to locate the grid points precisely.According to Borcherdt (1970), care must be taken to avoid the cultural noise and other disturbance like electrical generators. The observation point should be far from any influencial structures such tall buildings, electric poles, trees etc and were avoided during data recording as far as possible [5].

Data Acquisition

Microtremor observation was done in the pre-determined location as far as possible using a portable velocity sensor New PIC manufactured by system and Data Research (SDR) Co. Ltd. Japan as shown in Figure 2 and Figure 3. This device is capable of recording three components of vibration: two horizontally i.e., east-west direction and north-south direction and one vertical direction.During recording 34 number of points were observed with slight deviation in grid points for inaccessible location. Most of them were measured at midnight to avoid unusable noises around 10 PM to 2 AM. After placing sensor at point, the sensor was oriented and leveled in the specified direction with the help of leveling screws of sensor and compass. The flowchart for data measurement in the field is shown in Figure 4.

Figure 1: Microtremor observation points on study area (Singhadurbar) on Google earth


Figure 2: Instrument setup with Base plate, PIC sensor, Transducer, Inverter, Battery and laptop all connected with wire

The connectivity and sensitivity of sensor was checked

Figure 3: Photograph taken during microtremor observation in front of Prime Minster and Council of Minister's office inside Singha Durbar

before starting the recording of ground motion.The parameters of the velocity sensor is shown on Table 1.Two sets of data was recorded at each station and the noise was monitored and recorded in memo book in during the measurement time.

Data Analysis

Except for inaccessible grid points, the microtremor observation was possible at a total of 34 grid points in the demarcated area as shown in Figure 1. All the recorded data were then plotted in terms of velocity time histories and each component of the recorded signal was corrected by the baseline and divided into 15 windows of 2048 samples. After reviewing the plotted time history data and field memo book, the segment that was influenced by transient signal as shown in Figure 6 were removed.In general,10 to 14 windows with little or no noise record were considered for fourier analysis.

Fourier analysis [7] was carried out for each window seperately using Fast Fourier Transfer Computer Program to obtain the Fourier spectra [8] . The fourier spectrum of two horizontal microtremor motion and one vertical motion were obtained and H/V spectral ratio was obtained after dividing a horizontal by vertical component.The obtained H/V spectra were smoothed by Parzen window of bandwidth 0.5Hz as shown in Figure 5.

4. Result and Discussion

The results of the microtremor survey are expressed in terms of resonance frequency and corresponding dominant period of the ground at each survey point

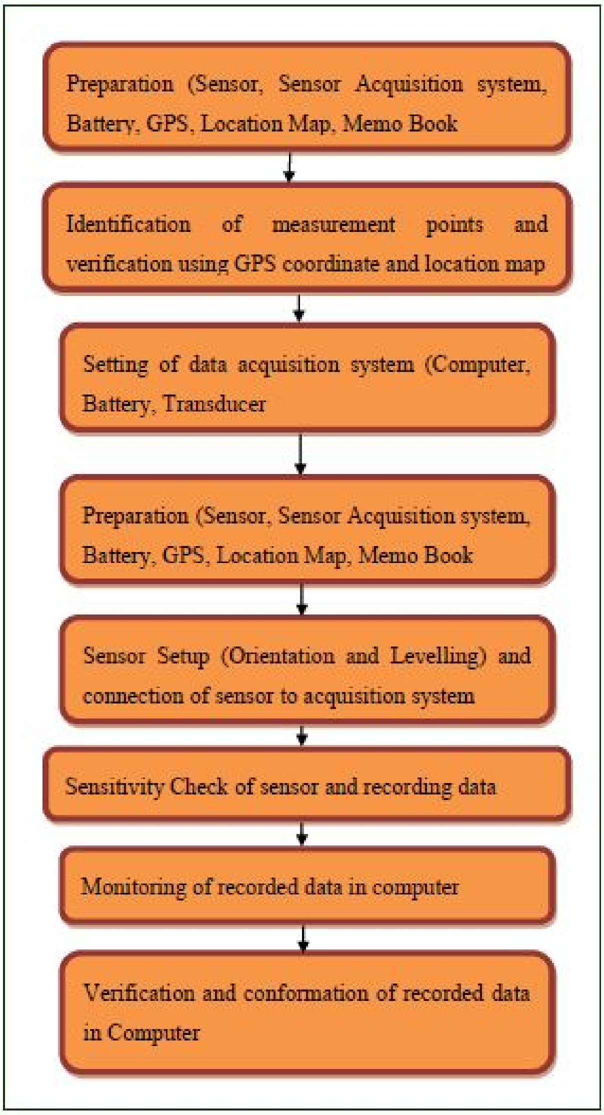

Figure 4: Flowchart of microtremor measurement in field

obtained form the H/V spectral ratio analysis as shown in Figure 7 a and b. Although there is noticeable scatter,the dominant period can be estimated uniquely from the maximum smoothed peak. The dominant periods of all the measurement points obtained in this way are listed in Table 2. The data in the table indicate that the dominant period in the surveyed area varies from 0.379 sec to 2.56 sec.

Based on the variation, the study area is divided into four different ranges grouped by dominant frequency (i.e., Period range A to Period range D) as shown in Table 3. Finally, an approximate seismic zonation map[6] based on dominant period of shaking was prepared [6] as shown in Fig 8 .The dominant period distribution map indicate that the most of the part of the Singha Durbar area falls under frequency range B

Table 1: Basic parameters of Velocity sensor [6]

Parameters, setting	Type of noise recording
Type of seismic Sensor	velocity sensor new PIC
Size of sensor	9cm x 9cm x 6cm
Sampling frequency	100Hz
Recording duration	5 min
Windowing (Length of FFT window	2048 values (20.48 sec)
Smoothing	Parzen window
Calculation of H/V ratio	H(EW)/V(UD), H(NS)/V(UD), (H(EW)+ H(NS))/V(UD)
Averaging of H/V ratio	mean value of several spectral ratio

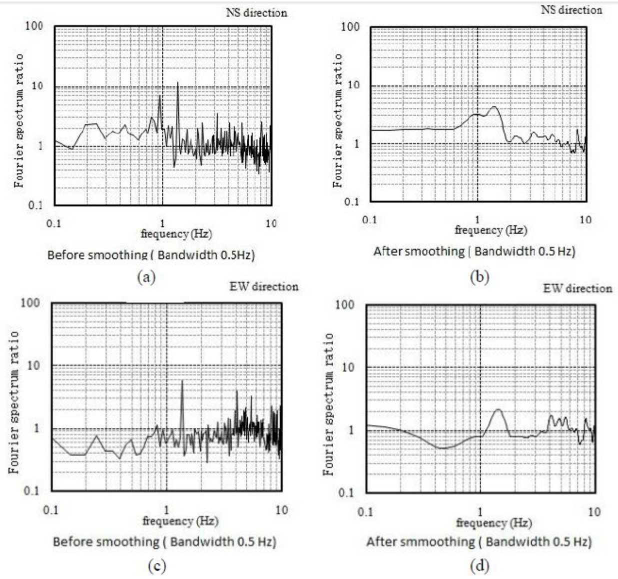

Figure 5: (a) and (c) are H/V spectral ratio of individual components NS and EW direction showing before smoothing and (b) and (d) are H/V ratio after smoothing by Parzon window of bandwidth of 0.5Hz

and frequency range C, which covers approximately 80 percent of the observed area.

To sum up, based on the approximate micro-zonation map and dominant period, it is understood that approximately 80 percent of the area is covered with dominant period with range of 0.47 sec - 1.042 sec. Building heights in the area vary from few storey up to 10 storey. In general, the fundamental period of the N-storey building can approximately 0.1N sec(Kramer, 1966). Based on this approximate relation, the dominant period of buildings of Singha Durbar area can be estimated to vary from 0.1 sec to 1.0 sec. If the dominant period of ground is equal or close to the period of structure over the ground, resonance will take place leading to enhance vibration ultimately causing higher degree of damage to the structure.

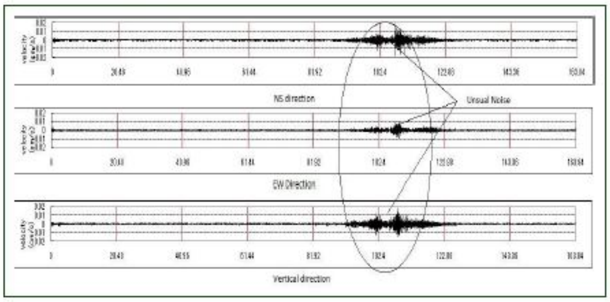

Figure 6: Typical pattern of velocity time series data of three components of ground data showing unusual noise during microtremor observation [8]

Therefore, it can be interpreted from the result that the study area is highly susceptible to seismic damage of short period structures.In order to mitigate the enhanced resonance damages from Earthquake, special consideration must be taken to build the structure having the fundamental frequency of vibration differ from approaching the observed fundamental frequency of the respective zone in the area.

Finally, microtremor based predominant frequency zonation map is prepared as shown in Fig 8 a final output of this investigation. This map will be useful for future more refine seismic microzonation map of the area and it can be taken as a basis for earthquake risk analysis to the structure. This map will serve as a reference for fundamental frequency based on based on ground motion analysis.

5. Conclusions

Singha Durbar is the very important area in terms of administrative area of Government of Nepal to launch post disaster program after disaster. Hence, at any cost, the buildings and area should be least vulnerable to natural disaster.

Table 2: Dominant period in the study area

SN	Microtremor observation point ID	Dominant Frequency	Dominant Period
1	11	0.830	1.205
2	12	1.123	0.890
3	13	1.221	0.891
4	14	1.465	0.683
5	15	1.172	0.853
6	18	2.197	0.455
7	19	1.123	0.890
8	20	0.586	1.707
9	21	1.562	0.640
10	22	1.172	0.853
11	23	0.391	2.560
12	26	1.074	0.931
13	27	1.270	0.788
14	28	1.172	0.853
15	29	1.269	0.788
16	30	1.953	0.512
17	31	2.051	0.488
18	34	0.976	1.024
19	35	1.660	0.602
20	36	1.221	0.819
21	37	0.781	1.280
22	38	1.807	0.554
23	39	1.074	0.931
24	43	2.051	0.488
25	44	2.588	0.386
26	45	0.781	1.280
27	46	1.267	0.788
28	47	1.312	0.759
29	49	1.905	0.523
30	51	1.611	0.621
31	52	1.172	0.853
32	53	1.172	0.853
33	54	1.312	0.759
34	55	2.673	0.379

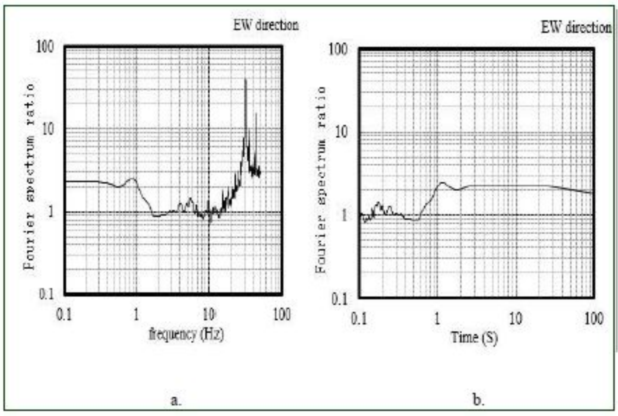

Figure 7: A typical horizontal to vertical spectral ratio graphs in the study area; a) frequency graph, b) period graph. The line represents the mean H/V ratio of EW direction and NS direction

Table 3: Classification of study area based on dominant periods of ground

Description of Zone	Dominant Period Range
A(Brown Color)	0.378 sec to 0.478 sec
B (Green Color)	0.479 sec to 0.657 sec
C(Blue Color)	0.658 sec to 1.042 sec
D(White Color)	1.043 sec to 2.56 sec

Microtremor data analysis at a total of 34 stations points at the spacing of 100 m x 100 m within the core area is performed to determine the predominant frequency.According to estimated predominant period shaking map of Singh Durbar area is prepared and is divided into four dominant period ranges. The following conclusions may be drawn form results obtained.

- Predominant frequency of the ground at Singha Durbar is determined from horizontal to vertical ratio of Fourier spectra which is varied from 0.379 sec to 2.56 sec.
- The obtained output such as estimated predominant frequency, microzonation map of Singha Durbar area as shown in Fig 8 is major finding of this study.
- The study area is divided into four dominant period range (i.e. period range A: 0.378 sec to 0.478 sec, period range B: 0.479 sec to 0.657 sec, period range C: 0.658 sec to 1.042 sec, period range D:1.043 sec to 2.56 sec. This reveals that most part about 80 percent of the study area falls under dominant period range of 0.658 sec

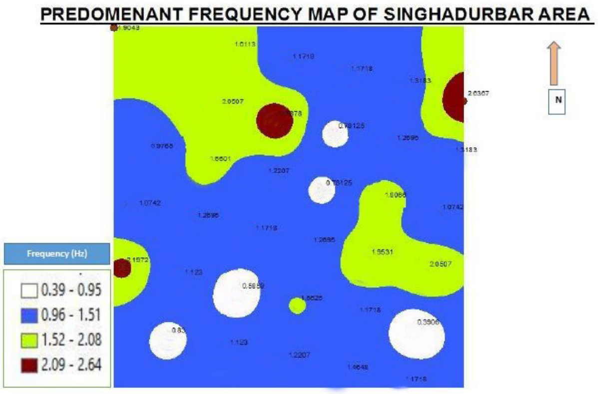

Figure 8: Estimated dominant frequency of shaking map(or Approximate seismic micro-zonation map) of Singha Durbar area based on variation of dominant frequency or period of ground

to 1.042 sec i.e. dominant period range C.

- The obtained result shows that there is high possibility of resonance effect in the buildings during the seismic activities.

Limitation and Recommendation

Due to earthquake hazard Singha Durbar may face a lots of problems.Similarly, the study has tried to solve the earthquake hazard disaster mitigation in the study area by determining the useful information about the dominant period, however there are still many unsolved problems in this study and need to be explored.Resonance effect will be developed if the natural period of building and its ground frequency matches, which results in high response in building during earthquake and damage the structure.

The predominant period is based on the ground shaking map prepared based on the microtremor observation in the grid of 100m x 10m spacing.The result showed variation of ground response within the short distance of study area. Hence, microtremor observation at 50m x 50m interval could give the better result and help to evaluate the characteristics of the study area.

The basement topography and sediment thickness layer of the study area could be determined if the number of boreholes with the reliable bedrock information were available. Due to insufficient geotechnical/geophysical data, verification of the microtremor result with the numerical analysis was not able to complete.Therefore, the present result should be verified through numerical investigation too.The study can further be extended to generate amplification map of the study area in order to better understand the damage from earthquake.

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