Proceedings of IOE Graduate Conference, 2016
pp. 139–146

Dynamic Characteristics Study of RCC Building using Micro Tremor measurement in Thapathali, Kathmandu Nepal

Thaman Bahadur Khadka [1]*, Rishi Ram Parajuli [2], Hari Ram Parajuli [3]

[1] *Department of Civil Engineering, Thapathali Campus, Institute of Engineering, Tribhuvan University, Nepal*
[2] *Department of Urban Management, Kyoto University*
[3] *Department of Civil Engineering, Thapathali Campus ,Institute of Engineering, Tribhuvan University, Nepal*
***Corresponding Email**: thamankhadka7@gmail.com

Abstract

At April 25 2015, Nepal face big Earthquake of magnitude Mw 7.8 having epicenter at Gorkha District at approximate 77 km Northwest of Kathmandu. This results in huge loss of life and properties, more than 10,000 people losses their life. Earthquake itself does not harm us but man-made structure, create problem during the Earthquake. Low grade construction material and haphazard construction of the structures are the main element, which are responsible for damage of structure. As a mitigation measures, appropriate technique and methodology should be implemented during the construction process. Micro tremor measurement of E- building of Thapathali campus were analyzed to determine the natural frequency of the model building. Natural frequency of the building is determined from the Fourier spectra and its estimated value is 2.48 Hz and 2.37 Hz in longitudinal and transverse direction respectively. Similarly rocking frequency and translational frequency of the building is also determined from the spectral ratio of the various location.

Keywords

Micro tremor measurement – RCC Building – Natural frequency – fourier spectra

Introduction

Nepal rests on a major fault-line between two tectonic plates. One bears India, pushes north and east at a rate of about 2cm (0.8 inches) per year against the other, which carries Europe and Asia. This process created the Himalaya mountain range and causes earthquakes when strain built up along the fault gives way periodically, thrusting the overlying landmass up and outward.

Himalayan Frontal Thrust (HFT), the Main Boundary Thrust (MBT) and Main Central Thrust (MCT) are the main faults in the region and they are part of the Great Himalayan range. Presently the main tectonic displacement zone is the Himalayan Frontal Thrust Fault (HFTF) System, which comprises Himalayan Frontal Fault at the edge of the Indo-Gangetic plains, and several active anticlines and synclines to the north. The Himalayan front in the western Nepal is characterized by several discontinuous segments of the HFT and its subsidiary faults [1].

The Gorkh Earthquake (Mw7.8) had occurred at 11:56 NST on 25 April 2015 with an epicenter 77 km (48 miles) northwest of Kathmandu, the capital city of Nepal, that is home to nearly 1.5 million inhabitants, and at a focal depth of approximately 10-15 km This earthquake was the one of the most powerful earthquakes to strike Nepal since the 1934 Nepal-Bihar earthquake (Mw8.1). Based on the information by the United Nations, eight million people have been affected by the Gorkha earthquake in Nepal, more than a quarter of the Nepal's population. Gorkha earthquake was of low frequency dominant in Kathmandu valley that saved much of structures having high natural frequency. If the ground motion was of high frequency dominant, damages would be much worse than that happened [2].

The main cause of loss of life and property is weak and haphazard construction of Masonry Building, RCC Building, Bridges, Dams, and Towers etc. Raising the need of reduction in earthquake disaster, investigation regarding the capacity of the building and the ground property must be identified before the construction procedure. As the part of the project micro tremor measurement was made in the E- Building of IOE-Thapathali Campus Kathmandu. The property of micro tremor was used to analyze Natural frequency, Rocking frequency and Translation frequency of the respective Building.

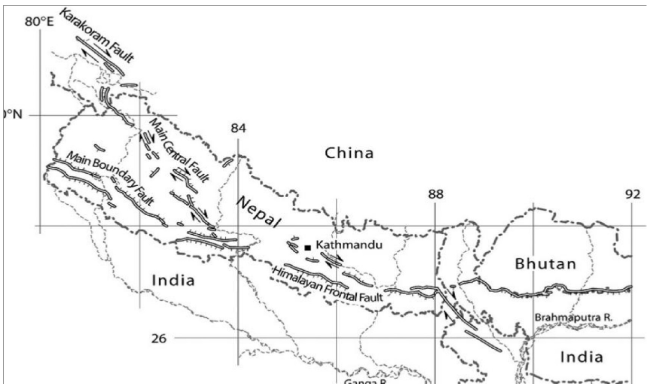

Figure 1: Distribution of the active faults in and around Nepal Himalaya (from Nakata and Kumahara 2002

Micro-tremor is a low amplitude (in the order of micrometres) ambient vibration of the ground caused by man-made or atmospheric disturbances. The term Ambient Vibrations is now preferred to talk about this phenomenon. Observation of micro tremors can give useful information on dynamic properties of the site such as predominant period and amplitude. Microtremor observations are easy to perform, inexpensive and can be applied to places with low seismicity as well, hence, micro tremor measurements can be used conveniently for seismic micro zonation. Stable estimation of the predominant frequency and the amplification factor can be made even in presence of a certain degree of the artificial tremor and there is no need any more for time restriction on the micro tremor measurement [3].

1. Background

After the pioneering work by Kannai and Tanaka, many researchers have investigated the applicability and reliability of the micro tremor method. The major drawback of the method proposed by Kannai and Tanaka was that they considered the Fourier spectra of observed horizontal motions to reflect the transfer function of the surface. It has now been established that the horizontal micro tremor spectra often show the characteristics of the source rather than the transfer function of a site.

Yukta Nakamura in 1989, modified micro tremor analysis by proposing a new technique, generally referred to as the H/V method. In this technique, it was shown that the source effect can be minimized by normalizing the horizontal spectral amplitude with the vertical spectral amplitude. Assuming that the shear wave dominates the micro tremor, Nakamura indicated that the horizontal-to-vertical (H/V) spectral ratio of micro tremors at a site roughly equals the S-wave transfer function between the ground surface and bedrock at a site. This means that the H/V peak period and peak value itself correspond to the natural site period and amplification factor respectively (NAKAMURA, 1989).

Due to the close relation between the nature of micro tremors and the fundamental dynamic behavior of the surface soil layer, these small vibrations are well-known and useful in the field of earthquake engineering. The technique of micro tremors measurement and analysis has been successful for micro zoning in many places around the world. This technique has the advantage of being a fast and easy way to estimate the effect of ground motion characteristics due to an earthquake. The characteristics of micro tremors are dependent on the type of deposits. At the same time, the amplitude is not stable. Site effect plays an important role in micro tremors measurements [4].

2. Methodology

The Building under study was approximately 15 years old and four story with its basement located in Thapathali, Kathmandu the capital city of Nepal. RCC framed with infill brick masonry building having L shape and approximate height above the plinth level was 40 feet. The building was highly suffered from the Gorkha Earthquake-2015 and some part of the building got damaged which are under maintenance. The plan of building is shown as below.

Dynamic characteristic study of the E-Building of Thapathali campus using Micro-tremor data Micro-tremor data was taken with the application of the

Seismometer at different part of the building and these data were analyzed for the determination of the Natural Frequency, Rocking Frequency and Translation Frequency of the Building .

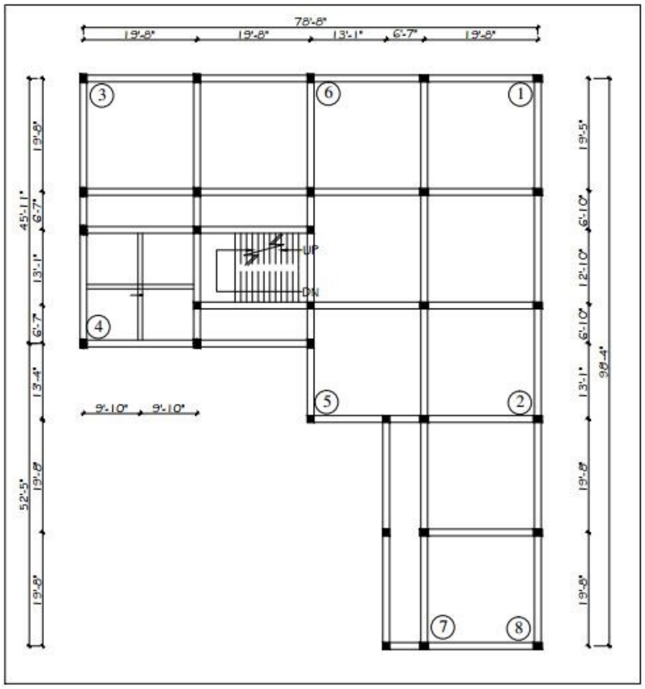

Figure 2: plan of the building showing the location of micro tremor measurement (1 to 8

Determination of Natural Frequency of the Building

Micro tremor measurement in the E-Building at various location is shown in the plan above. The Micro-tremor data was obtained in three orthogonal directions along with time. Assuming that all the records were stationary , then overall data are cut into six segments having no of data in each segment is in the form of 2 power n which is essential for the Fast Fourier Transformation (FFT). The recorded data were used to determine the Natural Frequency of the Building. The ambient vibration of the building get amplified at its natural Frequency of the structure which can be identified from the Fourier spectrum and this process is said to be Structural Identification Technique [5].

Fourier Spectra of all the records together with longitudinal and transverse direction at different part of the building were calculated and plotted in the graph. Frequency corresponding to the highest amplitude are said to be the Natural Frequency of the building at different modes [5].

Determination of the Rocking frequency

The ratio of the Fourier Spectrum between the other floor (Ground floor, 1st, 2nd, 3rd and 4th) with the Basement was plotted in the frequency domain for both longitudinal and transverse direction .The frequency corresponding to the respective highest Fourier ratio is termed as the natural rocking frequency of the building at various modes.

Determination of the Translation frequency

The ratio of the Fourier Spectrum between the same floor micro tremor data was plotted in the frequency domain for both longitudinal and transverse direction .The frequency corresponding to the respective highest Fourier ratio is termed as the Translation frequency of the building at various modes.

3. Results

Three orthogonal component of the micro tremor measurement is plotted as shown in the figure below.

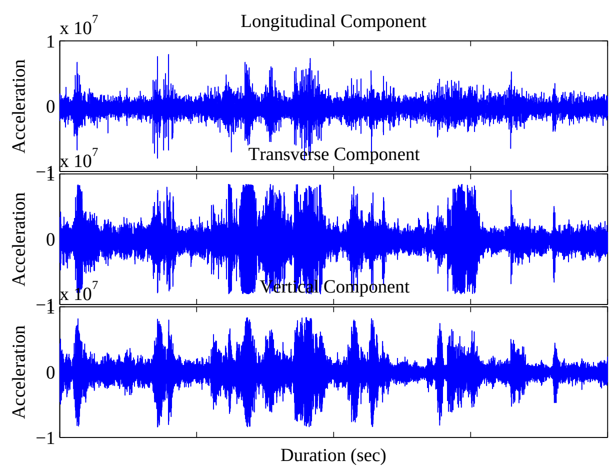

Figure 3: Sample micro tremor Record

Natural Period of the Building.

The microtremor data at various location of the building was used to construct the fourior spectra and the frequency at the highest amplitude is taken as the natural Frequency of the building. The avg frequency of the building is seems to be 2.48 Hz in longitudinal direction and 2.37 Hz in transverse direction.

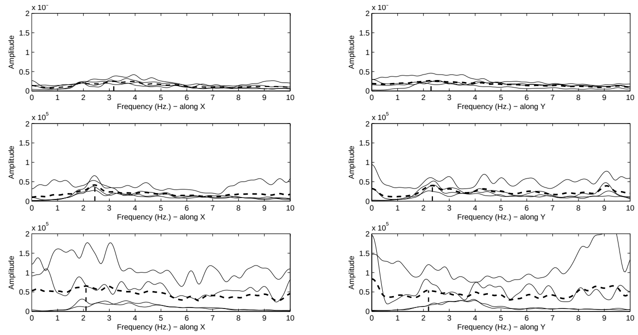

Figure 4: Fourier spectra of Basement 7, 8, and 1

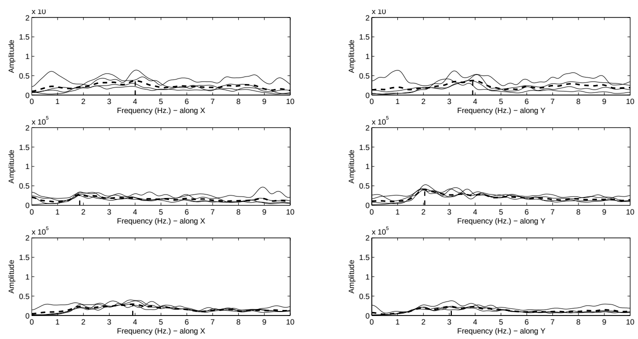

Figure 5: Fourier Spectra, Basement 2 and GF 1 and 2

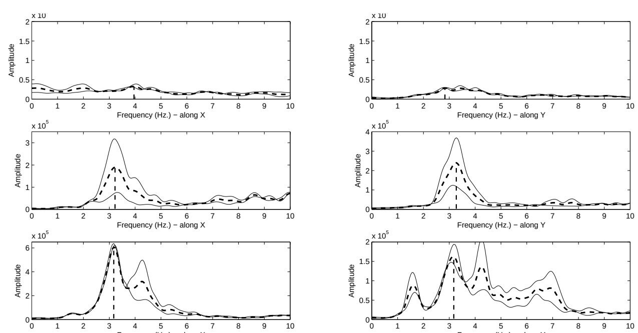

Figure 6: Fourier Spectra, Basement 3, 4 and 5

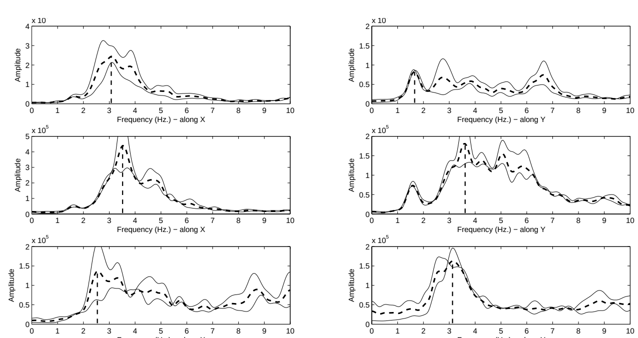

Figure 7: Fourier spectra Basement 6 and GF 1 and 2

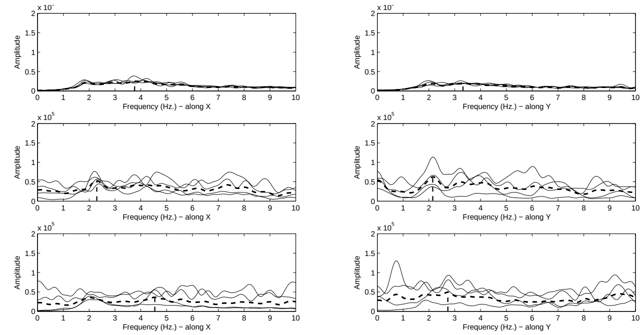

Figure 8: Fourier Spectra, GF, 3, 4, and, 5

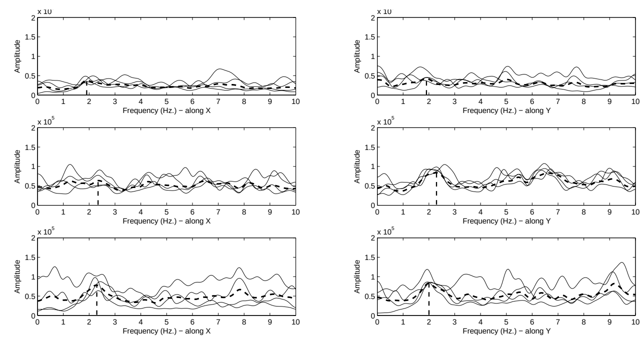

Figure 9: Fourier Spectra GF 1and 1st Floor 7and 8

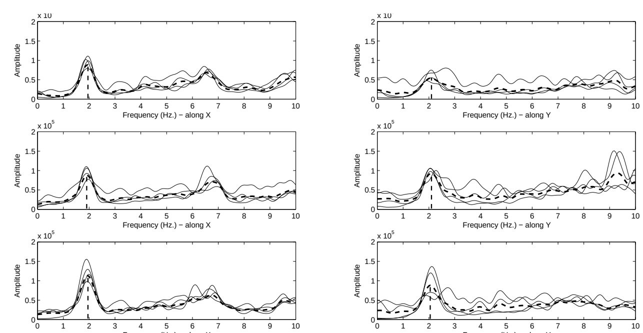

Figure 10: Fourier Spectra 1st Floor 1,2 and 3

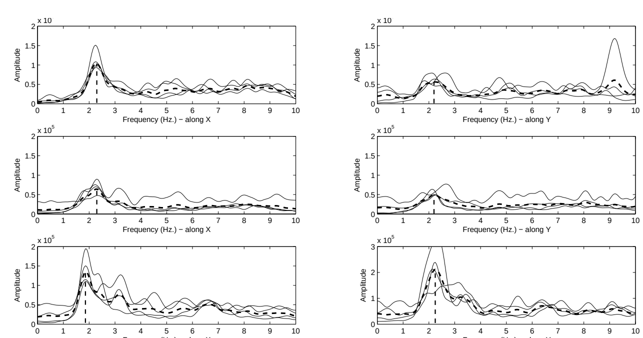

Figure 11: Fourier spectra 1st floor 4,5 and 6

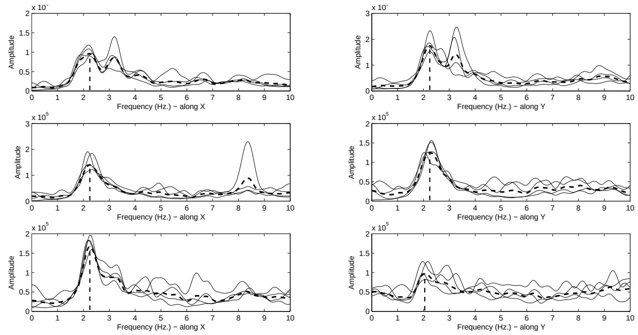

Figure 12: Fourier Spectra 2nd floor 7,8 and 1

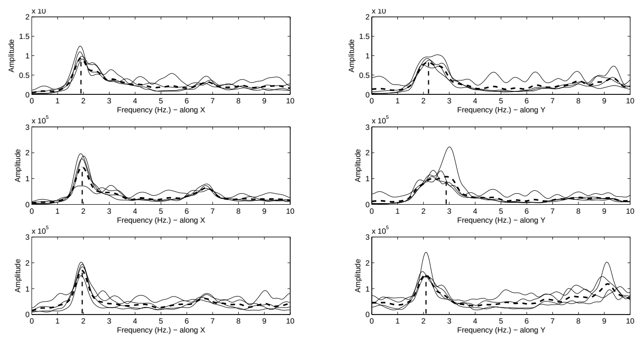

Figure 13: Fourier Spectra 2nd floor 2,3 and 4

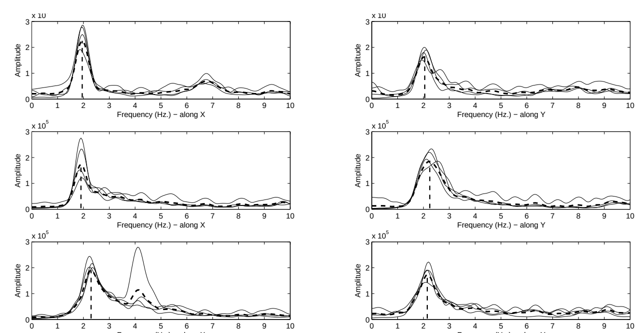

Figure 14: Fourier Spectra 2nd floor 5 and 6, 3rd floor 7

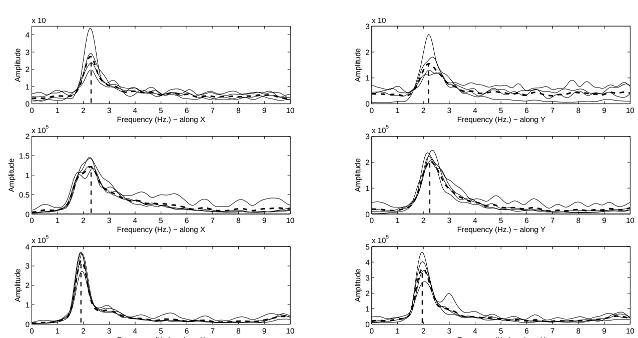

Figure 15: Fourier spectra, 3rd floor 8, 1 and 2

Table 1: Natural Frequency determination

Fig No	Floor	Location	X (Hz)	Y(Hz)
4	Basement	7	3.17	2.30
4	Basement	8	2.44	2.34
4	Basement	1	2.10	2.20
5	Basement	2	4.00	3.91
5	G Floor	1	3.96	2.83
5	G Floor	2	3.22	2.27
6	Basement	3	3.17	3.17
6	Basement	4	3.08	1.66
6	Basement	5	3.52	3.61
7	Basement	6	2.54	3.13
7	G Floor	7	1.86	2.05
7	G Floor	8	3.91	3.08
8	G Floor	3	3.76	3.32
8	G Floor	4	2.30	2.15
8	G Floor	5	4.54	2.73
9	G Floor	6	1.90	1.90
9	1st floor	7	2.34	2.30
9	1st floor	8	2.30	2.00
10	1st floor	1	1.95	2.10
10	1st floor	2	1.90	2.10
10	1st floor	3	1.95	2.05
11	1st floor	4	2.30	2.20
11	1st floor	5	2.30	2.20
11	1st floor	6	1.86	2.25
12	2nd Floor	7	2.25	2.25
12	2nd Floor	8	2.25	2.25
12	2nd Floor	1	2.25	2.05
13	2nd Floor	2	1.90	2.20
13	2nd Floor	3	1.95	2.88
13	2nd Floor	4	1.95	2.10
14	2nd Floor	5	1.95	2.05
14	2nd Floor	6	1.90	2.25
14	3rd Floor	7	2.30	2.15
15	3rd Floor	8	2.30	2.20
15	3rd Floor	1	2.30	2.25
15	3rd Floor	2	1.90	1.95
16	3rd Floor	3	1.90	2.10
16	3rd Floor	4	1.90	2.20
16	3rd Floor	5	1.90	1.95
17	3rd Floor	6	1.86	2.30
Avg	-	-	2.48	2.37

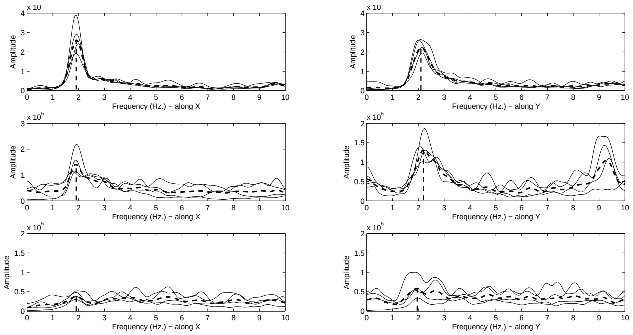

Figure 16: Fourier Spectra, 3rd floor 3, 4 and 5

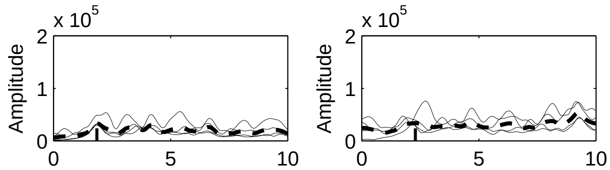

Figure 17: Fourier Spectra 3rd Floor 6

Rocking Frequency of the Building

Rocking frequency of the building was obtained by taking the Fourier Spectral ratio between Ground Floor,1st Floor,2nd floors and 3rd floor with Basement as shown in the figure below. From the observation first mode rocking frequency is 1.898 Hz in Longitudinal and 1.935 in Transverse Direction respectively.

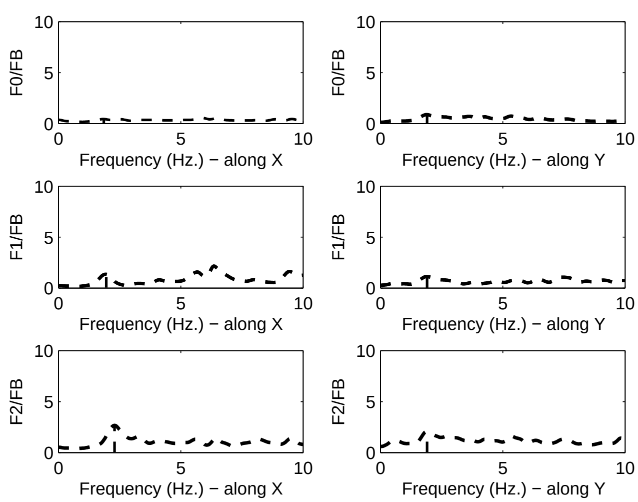

Figure 18: Spectral ratio between ground floor, 1st and 2nd Floor with Basement at 1st location

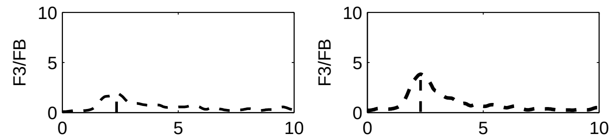

Figure 19: Spectral ratio between 3rd Floor with Basement at 1st location

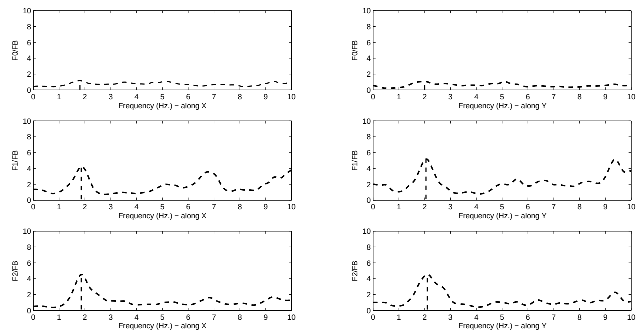

Figure 20: Spectral ratio between ground floor, 1st and 2nd Floor with Basement at 2nd location

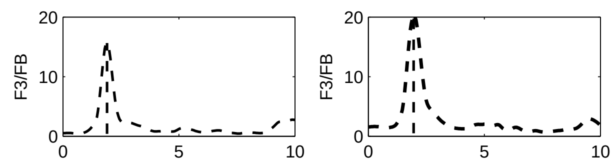

Figure 21: Spectral ratio between 3rd Floor with Basement at 2nd location

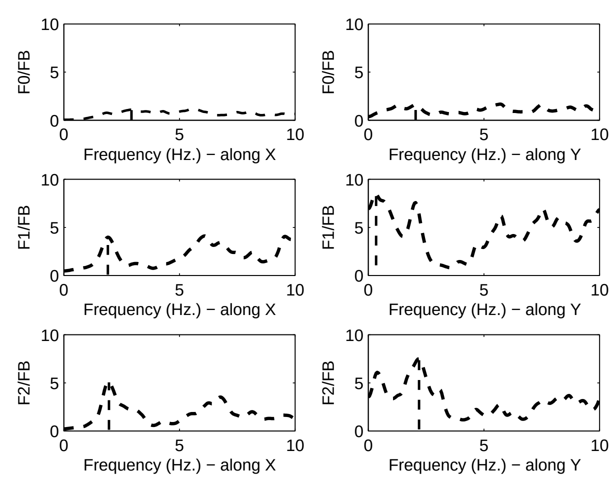

Figure 22: Spectral ratio between ground floor, 1st and 2nd Floor with Basement at 3rd location

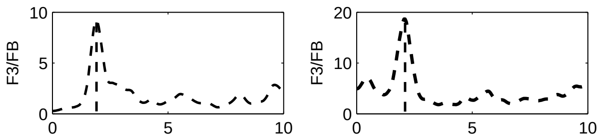

Figure 23: Spectral ratio between 3rd Floor with Basement at 3rd location

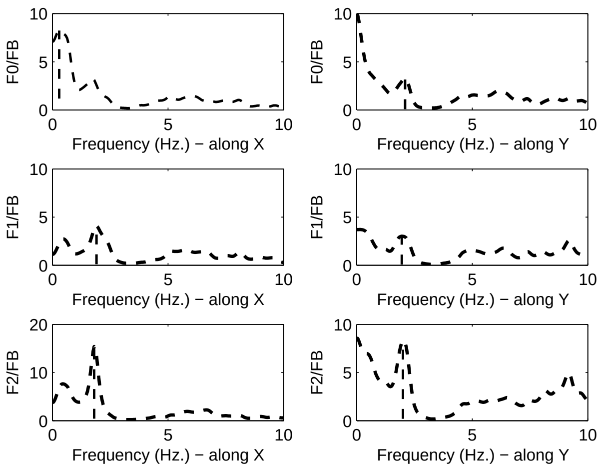

Figure 24: Spectral ratio between ground floor, 1st and 2nd Floor with Basement at 4th location

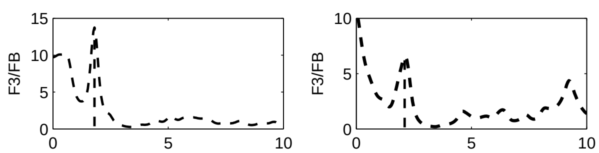

Figure 25: Spectral ratio between 3rd Floor with Basement at 4th location

Table 2: Roking Frequency determination

Fig No	Floor	location	x	y
18	F0/FB	1	1.855	1.904
18	F1/FB	1	1.953	1.904
18	F2/FB	1	2.295	1.904
19	F3/FB	1	2.344	2.295
20	F0/FB	2	1.807	2.002
20	F1/FB	2	1.855	2.051
20	F2/FB	2	1.855	2.100
21	F3/FB	2	1.904	1.953
22	F0/FB	3	2.930	2.051
22	F1/FB	3	1.904	0.342
22	F2/FB	3	1.953	2.197
23	F3/FB	3	1.904	2.100
24	F0/FB	4	0.293	2.100
24	F1/FB	4	1.904	1.953
24	F2/FB	4	1.807	2.002
25	F3/FB	4	1.807	2.100
Average	-	-	1.898	1.935

Translation Frequency of the Building

Translation Frequency of Building was obtained from the Spectral ratio between various locations of same floors as shown in the figure given below. From the observation the translation frequency of the building is 2.555 Hz and 2.930 Hz in Longitudinal and Transverse direction respectively.

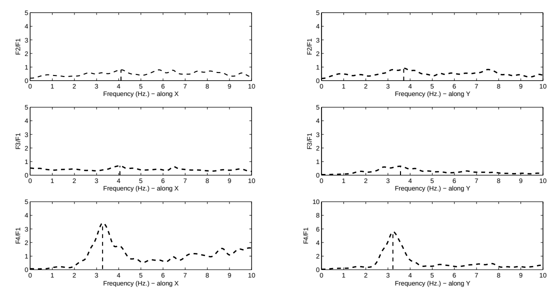

Figure 26: Spectral ratio between different positions of Basement

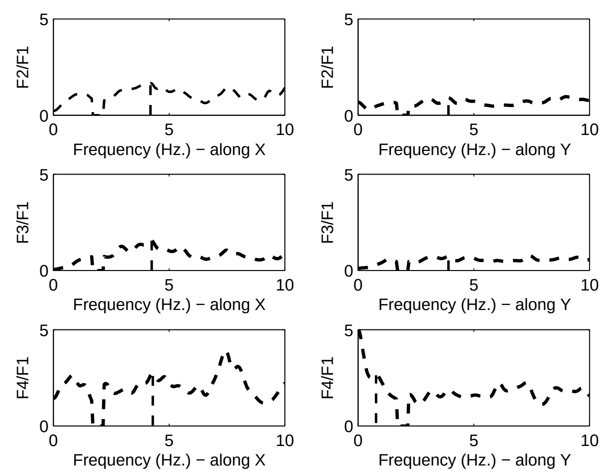

Figure 27: Spectral ratio between different positions of GF

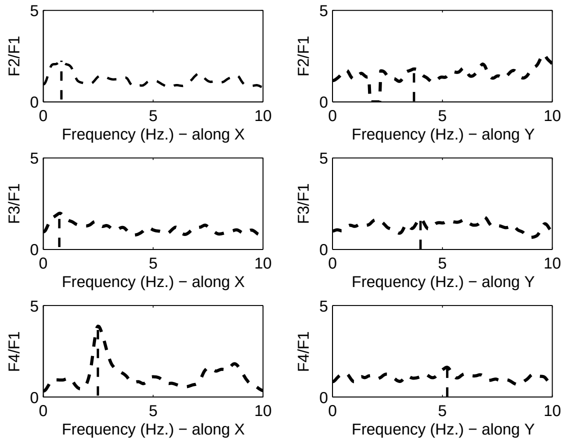

Figure 28: Spectral ratio between different positions of 1st Floor

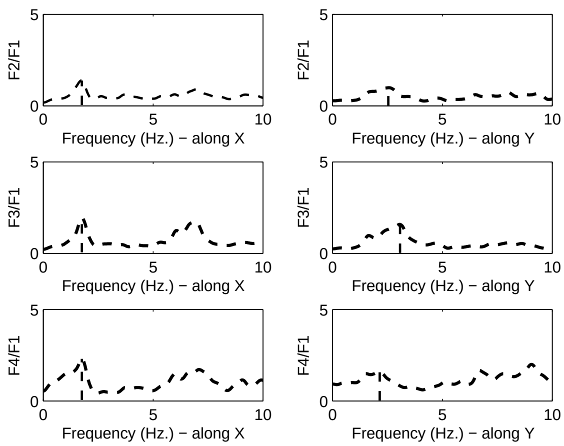

Figure 29: Spectral ratio between different positions of 2nd Floor

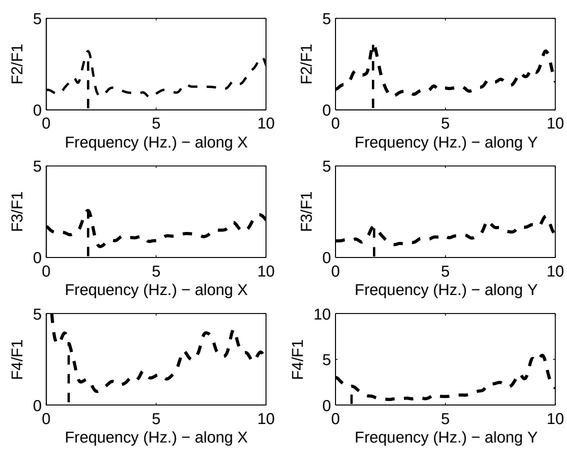

Figure 30: Spectral ratio between different positions of 3rd Floor

Table 3: Translation Frequency determination

Fig No	Floor	location	x	y
26	BM	2nd/ 1st	4.102	3.711
26	BM	3nd/ 1st	4.053	3.564
26	BM	4nd/ 1st	3.272	3.223
27	GF	2nd/ 1st	4.199	3.906
27	GF	3nd/ 1st	4.248	3.906
27	GF	4nd/ 1st	4.297	0.781
28	1st	2nd/ 1st	0.830	3.711
28	1st	3nd/ 1st	0.732	4.004
28	1st	4nd/ 1st	2.49	4.981
29	2nd	2nd/ 1st	1.758	2.539
29	2nd	3nd/ 1st	1.758	3.076
29	2nd	4nd/ 1st	1.758	2.148
30	3rd	2nd/ 1st	1.904	1.907
30	3rd	3nd/ 1st	1.904	1.758
30	3rd	4nd/ 1st	1.025	0.732
Average	-	-	2.555	2.930

4. Conclusion

Dynamics Characteristics of E-Building Thapathali Campus was analyzed by using Micro tremor reading. Natural Frequency of the E-Building was obtained from the Fourier Spectrum and its value is 2.48 Hz in longitudinal and 2.37 Hz in Transverse direction. Rocking frequency was obtained from spectral ratio between different floors and its value is 1.898 Hz and 1.935 Hz in X and Y direction respectively. Similarly Translation frequency was obtained from the spectral ratio between various location of the same floor and its value was determined as 2.555 Hz and 2.930 Hz in X and Y direction respectively.

References

[1] Omer AYDAN and R.U. The quick report on the 2015 gorkha (nepal) earthquake and its geo-engineering aspects. 2015.

[2] R.R Parajuli and J. Kiyono. Ground motion characteristics of the 2015 gorkha earthquake, survey of damage to stone masonry structures and structural field tests. frontiers in built environment. 2015.

[3] Yataka Nakamura. A method of dynamics characteristics estimation of the sub surface using the microtremor on the ground surface. *Railway Technical research Institute*, 30 No 1, 1989.

[4] M. M. DYKMEN. Application of microtremors to seismic microzoning procedure. 2003.

[5] Hari Ram Parajuli, Junji Kiyono, Masatoshi Tatsumi, Yoshiyuki Suzuki, Hisashi Umemura, Hitoshi Taniguchi, Kenzo Toki, Aiko Furukawa, and Prem Nath Maskey. Dynamic characteristic investigation of a historical masonry building and surrounding ground in kathmandu. Vol.6 No.1, 2011.