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Determination of natural frequency of the building using the microtremer measurement and comparison its result with SAP analysis

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ABSTRACT

Micro tremor measurement of Building of Thapathali in Kathmandu valley was analyzed to determine the natural frequency of the building. Natural Frequency of the building was determined from the Fourier spectra and its value is 2.48 Hz and 2.40 Hz in the longitudinal and transverse direction respectively. Regarding the damage in building due to Gorkha EQ-2015 three types of modal were prepared for sap Analysis. Among them, 1st modal of the building was prepared without any damage that resembles the normal building before EQ and its obtained frequency is 2.372 Hz. Similarly, 2nd modal of the building was prepared with considering the damaged part of the column due to EQ. We have reduced the stiffness of the cracked section by 70% of its original value and modal is prepared and its obtained frequency is 2.358 Hz. Finally, the third modal was prepared according to retrofitting condition and its obtained frequency is 2.521 Hz. Similarly, the codal procedure was also performed to determine the frequency of the building and its value was found to be 2.207 Hz.

Keywords— *Microtremor Measurement, RCC Building, Fourior Spectra, Natural Frequency,*

1. INTRODUCTION

The risk of earthquake occurances is high in the context of Nepal. The earthquake in Nepal has caused serious loss of human life and property. The main cause of the loss of life and property is the weak and haphazard construction of masonry Building, RCC Building, bridges, dams, towers etc. It is necessary to determine the dynamic characteristics of the building as well as ground during the design phase of the building. The resonance effect shall have developed if the natural period of building and its ground are matched, which results in a high response in the building during earthquake and damage of structure. Therefore, the fundamental period of the building and natural period of the building should not be matched.

The micro tremor measurement has been a useful tool in order to determine the ground motion characteristics, amplification of soil deposits (H/V-ratio), micro zonation and dynamic behavior of existing structures (cross-spectrum technique and coherence). Micro tremor is a low amplitude (in the order of micrometers) ambient vibration of the ground caused by manmade or atmospheric disturbances. Micro tremor observations are easy to perform, inexpensive and can be applied to places with low seismicity as well. More detailed information on the shear wave velocity profile of the site can be obtained from micro tremor array observation.

When the frequency of a building is equal or close to the frequency of the ground, resonance will take place, leading to an enhanced vibration of the structure and higher possibilities of collapse. The resonant frequency of a site is particularly important because it indicates the frequency of the spectrum under which the near-surface soft sediment amplifies the earthquake ground motion. This particular phenomenon is known as the site effect, which is generally studied through a borehole with PS logging, strong ground motion analysis, micro tremor data analysis, etc. Boreholes with PS logging method and strong ground motion analysis are not feasible, mainly because of the cost involved and unavailability of the strong ground motion data recording system in the required site. In this situation, the micro tremor analysis may be a good option for the study.

The Horizontal-to-Vertical spectral (H/V) ratio method has been widely applied in the last two decades for the study of site effects in different geographical and geological regions of the world. According to Nakamura (1989), the Horizontal-to-Vertical spectral (H/V) ratio is the Quasi Transfer Spectra (Transfer Function) of the soil strata over bedrock, which is obtained by taking the spectral ratio of the horizontal to the vertical component of ground motion at a single station. Kanai published an empirical relationship between the magnitude of recorded earthquakes and the associated predominant ground period and concluded that, provided the magnitude of an earthquake exceeded a certain value, the predominant period of earthquake motion had a constant value at each place and this approximated to the predominant period as observed in micro tremors. Most of the past studies have shown that the distribution of earthquake damage in a particular area is correlated with its fundamental frequency. However, some studies also indicate that depending upon the soil conditions of underlain strata, a second amplified frequency is locally revealed, which can play an important role in creating a resonance with the structures built over the ground during an earthquake (Paudyal Y.R., 2012). The geological structure and sediment depositional environment in the Kathmandu Valley consists of many strata of sand, silt, and clay sediments, which bring forward a possibility that two or more amplified frequencies occur during an earthquake (Paudyal Y.R., 2012). As the Kathmandu valley accommodates a number of low-rise to medium-rise buildings, historically important places, and monuments, there are possibilities during an earthquake that the multiple amplified frequency may cause a resonance with structures in a broad frequency range.

The capacity of the building and the ground property has to be investigated before the construction process to minimize the loss of life and property due to the earthquake disaster. This study has been undertaken to investigate the response of the surface layer during earthquake using the Horizontal-to-Vertical spectral (H/V) ratio method along with the natural frequency of the building to determine the probable resonance condition of the structure.

2. RESEARCH METHODOLOGY

After formulating the problem and defining the scope of the research work the next steps is to select the appropriate site in which the whole study work is conducted. In this study, RCC Building is selected as the Model Building to determine the natural frequency of the building. The Building under study was approximately 15 years old, four stored having its one basement is located within the boundary of IOE- Thapathali Engineering Campus, Kathmandu. The building is RCC framed type with infill brick masonry building having L shape and approximate height above the plinth level is 40 feet.

2.1 Data collection

After the selection of an appropriate site, the data required for the analysis procedure has taken. Before data collection, we had finalized appropriate location in the building from where the data is collected. In our study location from where the data is collected, plays an important role in the output of the study. So precise data had collected in a specific location of the modal Building Sincerely. Dynamic characteristic study of the E-Building of Thapathali campus and its surrounding ground is performed using Micro-tremor data Micro-tremor data is taken with the application of the Seismometer at a different part of the building along with the periphery and these data are analyzed for the determination of the Predominant ground frequency. The micro tremor observations were made at a total of 40 stations in the building that is 8 station at the corner of each floor.

The main source of micro tremors could be a vehicular movement that takes place almost 24 h in the city and the industrial facilities in and around the valley. Other possible sources of micro tremors could also be human activities (construction activities, etc.), and the effects of winds on trees and buildings. Three orthogonal components of micro tremor were recorded for 2-3 min and sample records are shown in Fig below. At each station point, the micro tremor data were recorded at a sampling frequency of 100 Hz. External disturbance causing noise in recorded signals was avoided by using a low-pass filter with a 35 Hz cutoff frequency. Even within records, large amplitude variations often occur, however. Given that records are stationary, the whole record where amplitudes are uniform is cut into six segments having a number of data in each segment equivalent to 2N essential for fast Fourier transformation (FFT). The Fourier spectrum of individual segments was plotted. FFT of the six segments plotted in the same figures. Dark lines are averages of the six-segment FFT after passing Parzen window with smoothening window 0.5 Hz.
The average spectral ratio of the horizontal component of vibration to vertical (i.e., H/V) in each window was derived from (Delgado et al., 2000).

$$H/V = \sqrt{\frac{(FNS)^2 + (FEW)^2}{2(FUD)^2}}$$

Here, FNS, FEW and FUD are the Fourier amplitude spectra in the North-South (NS), East-West (EW) and Up-Down (UD) directions, respectively.

After processing the data obtained from the Modal Building, they will be analyzed to determine the various Characteristics of the Modal building. During the analysis process programming language, FORTRAN is used to process the data. Along with this MAT LAB is also used to shows the results of the study.

2.2 Determination of the natural frequency of the building

Fourier Spectra of all the records together with longitudinal and transverse direction at a different part of the building was calculated and plotted in the graph. The frequency corresponding to the highest amplitude is said to be the Natural Frequency of the building at different modes (Parajuli, 2011).

3. ANALYSIS, RESULT AND DISCUSSION

Dynamic characteristic study of the E-Building of Thapathali campus and its surrounding ground is performed using Micro-tremor data Micro-tremor data is taken with the application of the Seismometer and data are analyzed for the determination of the Predominant ground frequency. Along with this Natural Frequency, Rocking Frequency and Translation Frequency of the Building is also identified.

3.1 Natural period of the building

The micro tremor data at the various location of the building is used to construct the Fourier spectra and the frequency at the highest amplitude is taken as the natural Frequency of the building. The average frequency of the building is seems to be 2.48 Hz in the longitudinal direction and 2.37 Hz in the transverse direction. (Thaman, 2016)

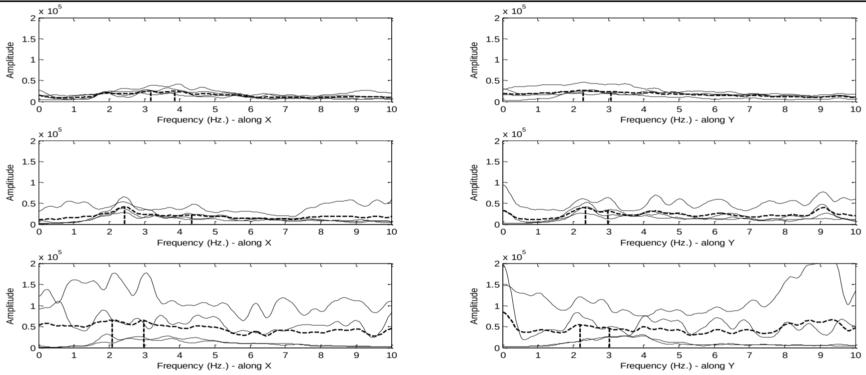

Fig. 1: Fourier spectra of basement, 7, 8, and 1

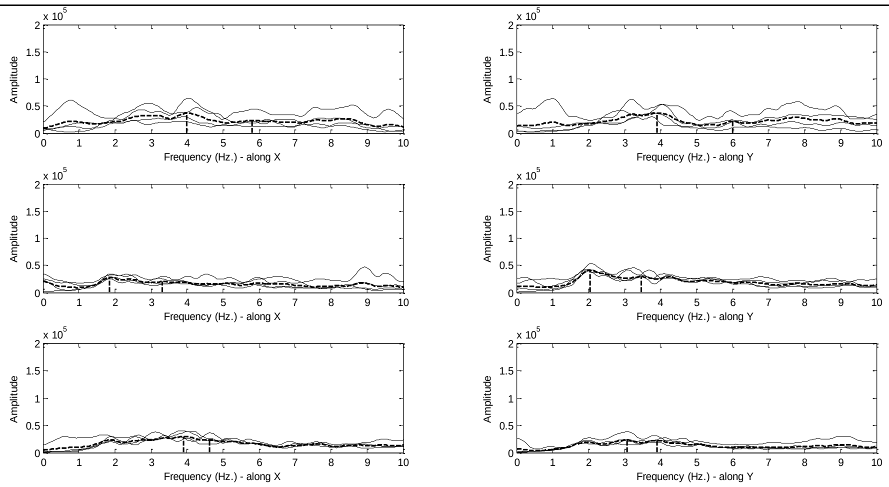

Fig. 2: Fourier spectra, basement 2 and GF 1 and 2

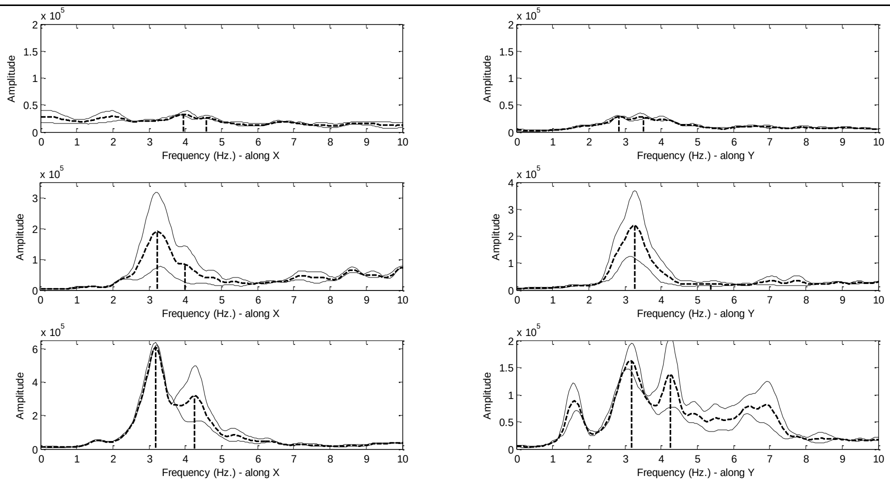

Fig. 3: Fourier spectra, basement 3, 4 and 5

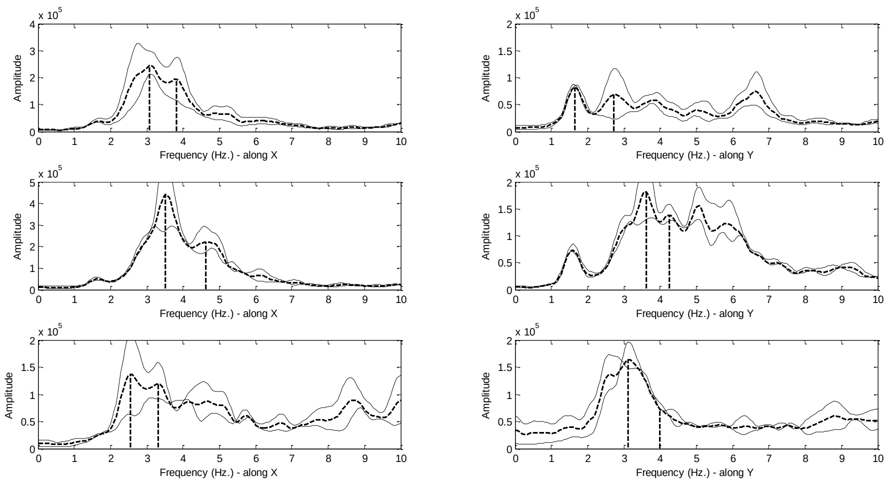

Fig. 4: Fourier spectra basement 6 and GF 7 and 8

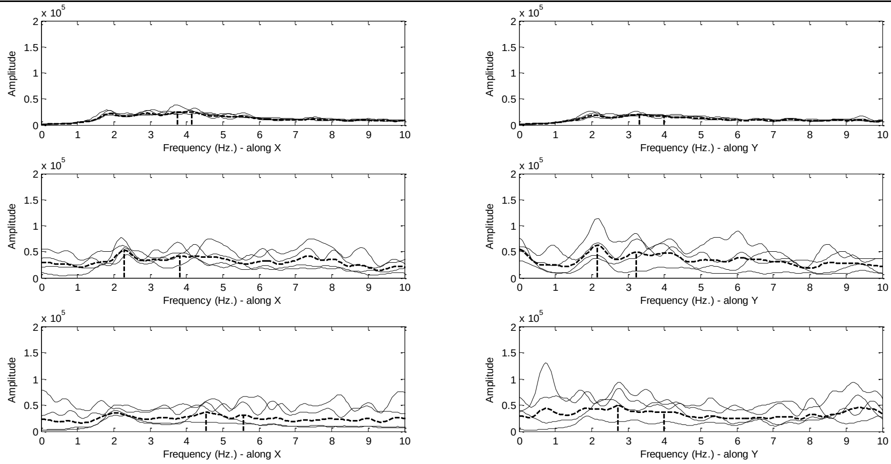

Fig. 5: Fourier Spectra, GF, 3, 4, and, 5

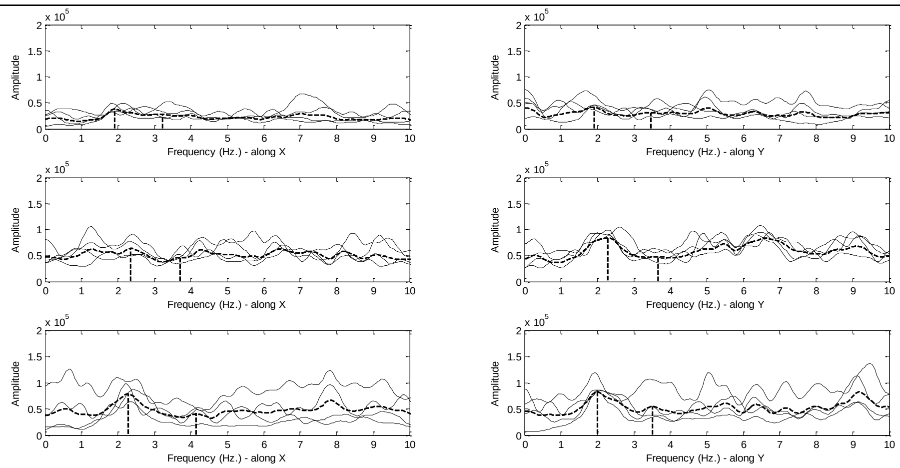

Fig. 6: Fourier Spectra GF 6 and 1st Floor 7and 8

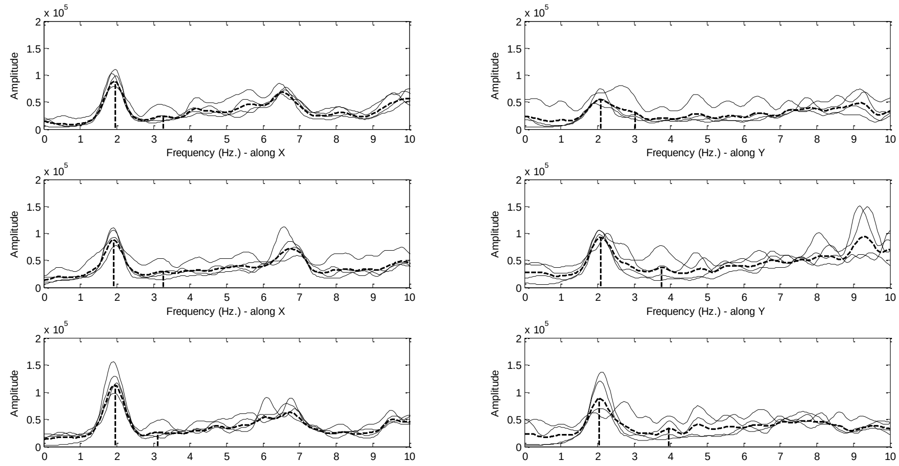

Fig. 7: Fourier Spectra 1st Floor 1, 2 and 3

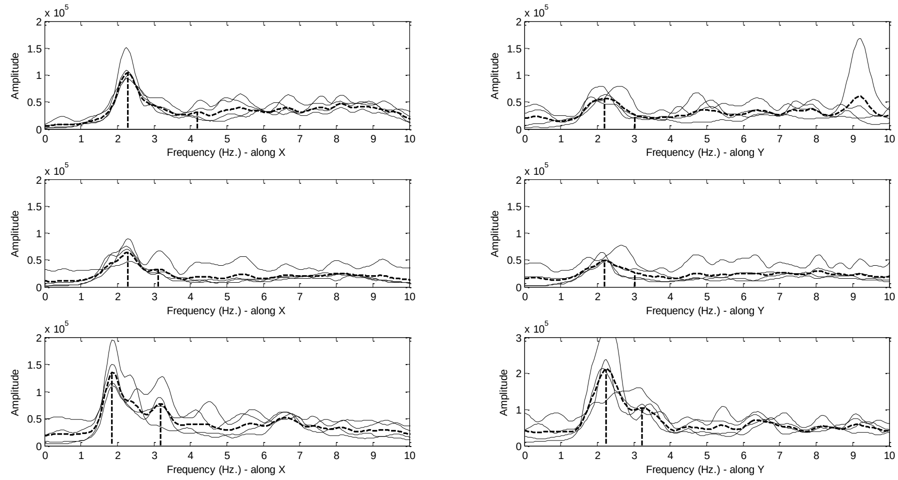

Fig. 8: Fourier spectra 1st floor 4, 5 and 6

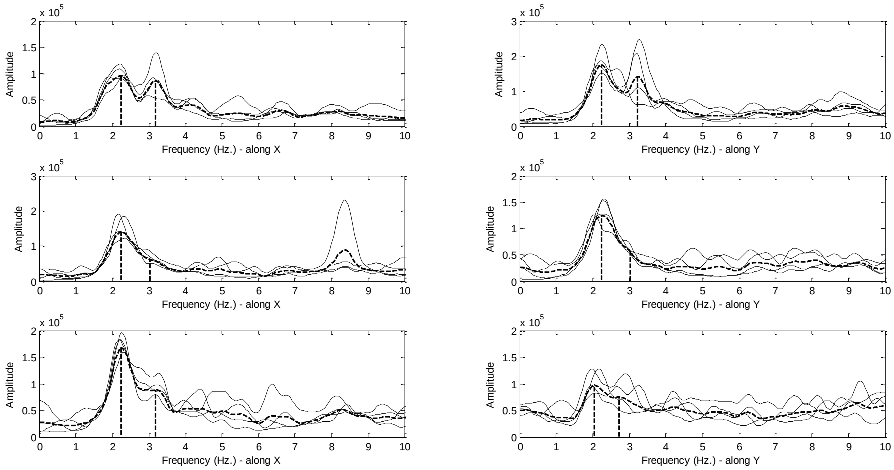

Fig. 9: Fourier Spectra 2nd floor 7, 8 and 1

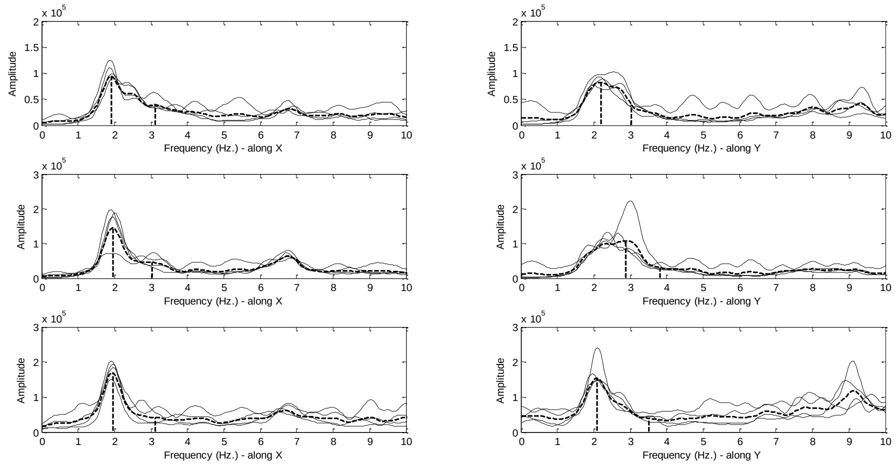

Fig. 10: Fourier Spectra 2nd floor 2, 3 and 4

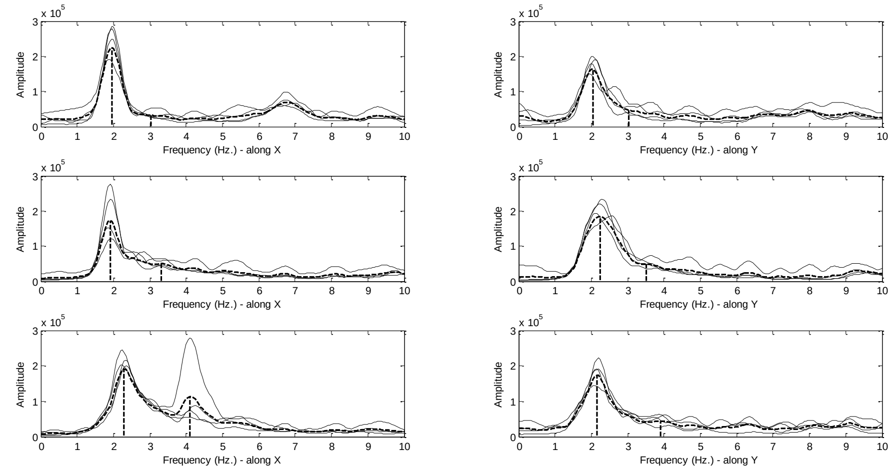

Fig. 11: Fourier Spectra 2nd floor 5 and 6, 3rd floor 7

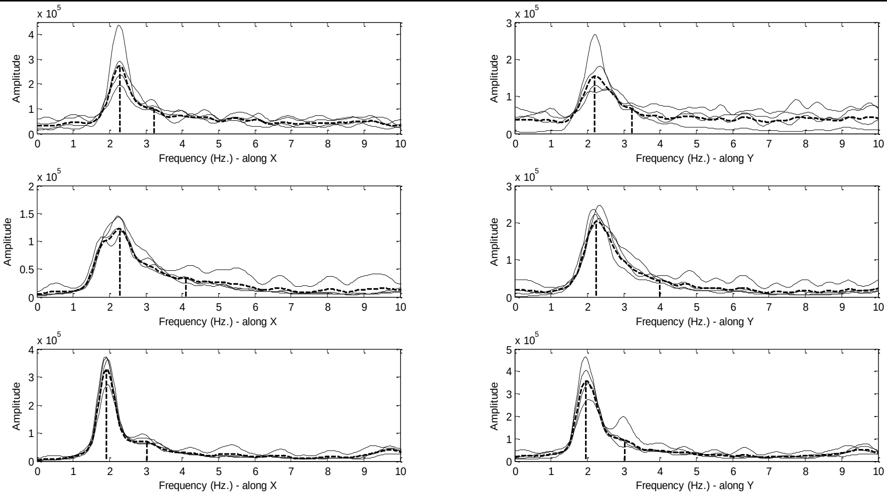

Fig. 12: Fourier spectra, 3rd floor 8, 1 and 2

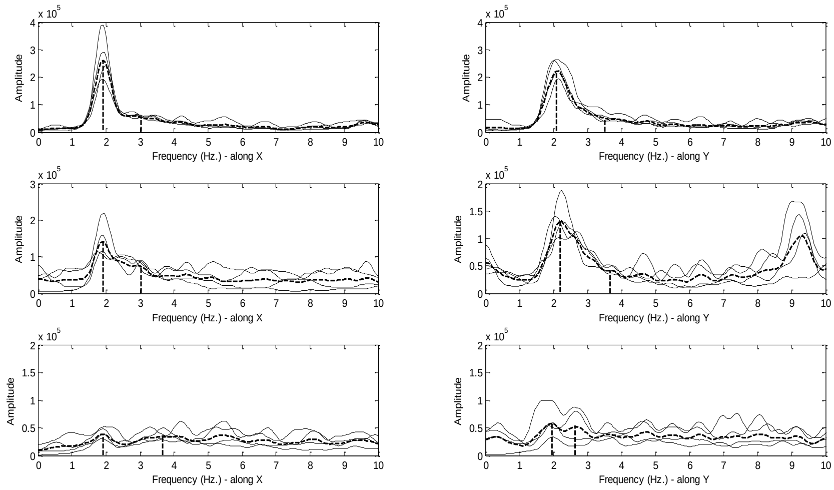

Fig. 13: Fourier Spectra, 3rd floor 3, 4 and 5

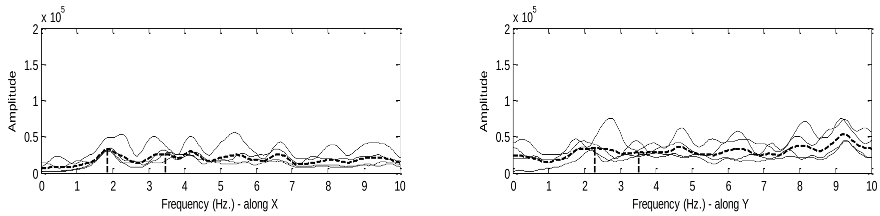

Fig. 14: Fourier Spectra 3rd Floor 6

Table 1: Natural Frequency of building

Figure Number	Floor	Position in plan	1st mode	
			X	Y
4-2	Basement	7	3.174	2.295
4-2	Basement	8	2.441	2.344
4-2	Basement	1	2.100	2.197
4-3	Basement	2	4.004	3.906
4-3	G Floor	1	1.855	2.051
4-3	G Floor	2	3.906	3.076
4-4	Basement	3	3.955	2.832
4-4	Basement	4	3.223	3.272
4-4	Basement	5	3.174	3.174
4-5	Basement	6	3.076	1.660
4-5	G Floor	7	3.516	3.613
4-5	G Floor	8	2.539	3.125
4-6	G Floor	3	3.760	3.320
4-6	G Floor	4	2.295	2.148
4-6	G Floor	5	4.541	2.734
4-7	G Floor	6	1.904	1.904
4-7	1st floor	7	2.344	2.295
4-7	1st floor	8	2.295	2.002
4-8	1st floor	1	1.953	2.100
4-8	1st floor	2	1.904	2.100
4-8	1st floor	3	1.953	2.051
4-9	1st floor	4	2.295	2.197
4-9	1st floor	5	2.295	2.197
4-9	1st floor	6	1.855	2.246
4-10	2nd Floor	7	2.246	2.246
4-10	2nd Floor	8	2.246	2.246
4-10	2nd Floor	1	2.246	2.051
4-11	2nd Floor	2	1.904	2.197
4-11	2nd Floor	3	1.953	2.881
4-11	2nd Floor	4	1.953	2.100
4-12	2nd Floor	5	1.953	2.051
4-12	2nd Floor	6	1.904	2.246
4-12	3rd Floor	7	2.295	2.148
4-13	3rd Floor	8	2.295	2.197
4-13	3rd Floor	1	2.295	2.246

4-13	3rd Floor	2	1.904	1.953
4-14	3rd Floor	3	1.904	2.100
4-14	3rd Floor	4	1.904	2.197
4-14	3rd Floor	5	1.904	1.953
4-15	3rd Floor	6	1.855	2.295
	Average		2.478	2.399

4. SAP ANALYSIS OF MODAL BUILDING

After the determination of various dynamic properties of the modal building using micro tremor measurement, we will have to check, whether obtained result is appropriate or not. For the validation of the results obtained from the micro tremor measurement, sap analysis was performed. If the results obtained from all these methods are approximately the same, then the results of the project work can say to be validated.

Reinforced concrete (RC) frame buildings with masonry infill walls have been widely constructed for commercial, industrial and multi-family residential uses in seismic-prone regions worldwide. Masonry infill typically consists of brick masonry or concrete block walls, constructed between columns and beams of an RC frame. These panels are generally not considered in the design process and treated as non-structural components. Though the brick masonry infill is considered to be a non-structural element, it has its own strength and stiffness. Hence if the effect of brick masonry is considered in analysis and design, a considerable increase in strength and stiffness of overall structure may be observed. It can be understood that if the effect of infill is taken into account in the analysis and design of the frame, the resulting structure may be significantly different. Significant experimental and analytical research is reported in the various literature, which attempts to explain the behavior of in filled frames.

4.1 Preliminary Data

To analyses the Time period of the Modal building we considered 4 stored RC framed building with its one basement. The general parameters required for the modelling of the buildings are as follows:

Table 2: General Parameter for Modelling of Building

Type of Frame	: Special RC moment resisting frame fixed at the base
Seismic zone	: V
Number of stores	: G+4
Floor height	: 3.5m
Number of stores	: G+4
Plinth height	:1.5 m
Depth of Slab	: 150 mm
Live load on the floor level	: 2 KN/m2
Live load on roof level (not accessible)	: 1 KN/m2
Staircase load	: 3 KN/m3
Floor finish	: 1.0 KN/m2
Materials	: M 15 concrete, Fe 415 steel, and Brick infill
The thickness of the infill wall	: 230 mm
Density of concrete	: 25 KN/m3
Density of infill	: 20 KN/m3
Type of soil	: Medium
Response spectra	: As per IS 1893(Part-1):2002
Damping of structure	: 5 %

4.2 Member and material properties

Dimensions of the beams and columns are determined from the field measurement. For the determination of the grade of concrete in a various member of the building, rebound hammer test was performed. The test procedure was started after the calibration of the hammer. Then after rebound hammer was held at right angles to the surface of the concrete structure for taking the readings. Thus test can be conducted horizontally on a vertical surface and vertically upwards or downwards on a horizontal surface. By using the chart, we have determined the grade of the concrete corresponding to Rebound number and obtained a grade of concrete is M15.

4.3 Diagonal Strut Modelling of Masonry Infill

In this study, the strength and stiffness of the brick masonry infill are considered and the brick masonry infill is modelled using single diagonal strut. The diagonal strut has been modelled using software package SAP 2000. The analysis is performed using "Linear static analysis" for understanding the improvement in stiffness parameters.

4.4 Modelling of RC Framed Building with a Masonry Diagonal Strut

RC framed building is modelled in SAP2000 software package based on the preliminary data mentioned in earlier sections. The building is modelled as 3D-framed building with member and material properties as bare frame model without infill's walls but considered the load and strength of the brick masonry on the beams. The modelled building which is G+4 storey building with the same floor height of 3.5m and plinth height of 1.5m and the model of the building plan is shown in the figures below.

The time period and frequency of the building is shown in the table below.

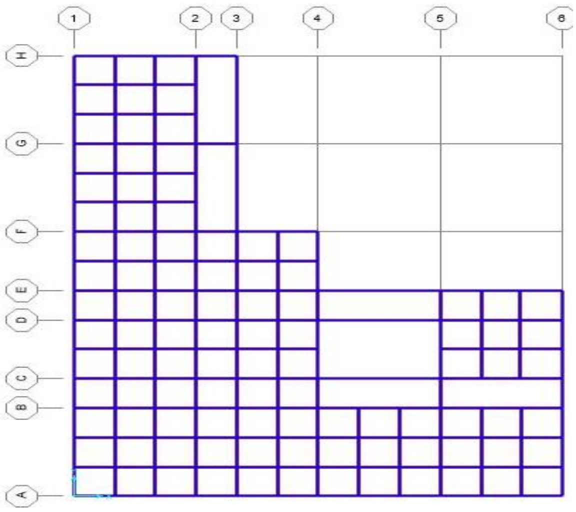

Fig. 15: Plan of Sap Model

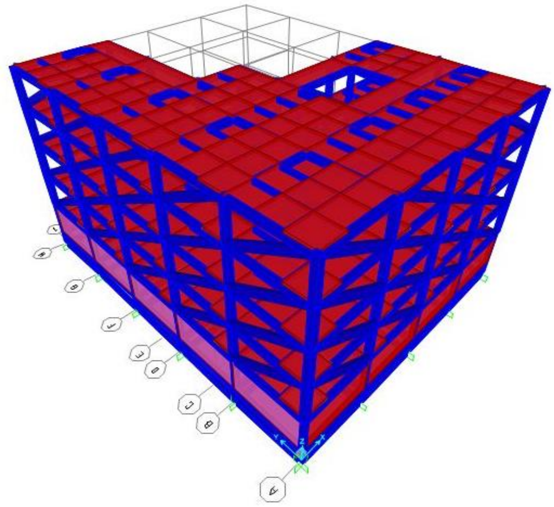

Fig. 16: 3D Modal in Sap

Table 3: Time period and frequency before earthquake

Output Case	Step Type Text	Mode	Period (Sec)	Frequency (Cycle/Sec)	Circ Frequency (rad/Sec)	Eigen Value (rad2/sec)
MODAL	Mode	1	0.422	2.372	14.905	222.170
MODAL	Mode	2	0.400	2.498	15.696	246.365
MODAL	Mode	3	0.318	3.144	19.756	390.316
MODAL	Mode	4	0.154	6.501	40.847	1668.514
MODAL	Mode	5	0.146	6.838	42.967	1846.193
MODAL	Mode	6	0.130	7.708	48.432	2345.644
MODAL	Mode	7	0.122	8.184	51.423	2644.321
MODAL	Mode	8	0.119	8.402	52.788	2786.605
MODAL	Mode	9	0.114	8.789	55.220	3049.295
MODAL	Mode	10	0.110	9.084	57.076	3257.621
MODAL	Mode	11	0.108	9.219	57.926	3355.416
MODAL	Mode	12	0.104	9.598	60.309	3637.133

5. CODAL PROCEDURE TO ANALYZE OF BUILDING

According to NBC 105 for the purposes of initial member sizing, the following approximate formulae for the Time period may be used as follow.

For Concrete framed structures with no rigid elements limiting the deflection

Time Period

$$T = 0.06H^{3/4}$$

Where, H is the height of the building

For Modal Building,

The height of the building H= 48’6” = 14.7828 m

Time period of the building T= $0.06 * 14.7826^{\frac{3}{4}}$ = 0.4523 sec

The natural frequency of the building =1/0.4523=2.21 Hz.

6. COMPARISON OF THE ANALYSIS RESULT

After the determination of various dynamic properties of the modal building using micro tremor measurement, Sap analysis as well as codal procedure, we have displayed the results in term of Time period and Frequency at the various condition. Comparison of Time period and Frequency at various condition is shown in the table below.

Table 4: Comparison between various time periods of the building

S. No	Tools	Time period (Sec)	Frequency (Hz)
1	Micro tremor analysis	0.403	2.480
2	Sap Analysis	0.422	2.372
3	Codal Procedure	0.453	2.207

7. CONCLUSION

Dynamics Characteristics of building as well as Ground has been investigated by using the method of Micro tremor analysis. Similarly, Natural Frequency of the E-Building in IOE-Thapathali Campus is found to 2.48 Hz and 2.40 Hz longitudinal and transverse direction respectively. The frequency of the Building from micro tremor and Sap analysis is nearly equal. Frequency variation between the results from Micro tremor analysis, Sap analysis, and the Codal procedure is due to instrumental error, Precision error, and operational error.

8. REFERENCES

[1] DÝKMEN, M. M. (2003). Application of microtremors to seismic microzoning procedure.
[2] Gautam, D. C. (2015). Assessment of Urban Seismic Hazard due to 2015 Gorkha Seismic Sequence.
[3] JICA. (2002). The Study on earthquake disaster mitigation in the Kathmandu Valley. Kathmandu: Japan International Cooperation Agency (JICA) and Ministry of Home Affairs His Majesty's Government of Nepal.
[4] Kramer, S. L. (1996). Geotechnical Earthquake Engineering, Prentice Hall.
[5] Midorikawa, V. H. (2002). Applicability of the H/V Spectral ratio of the microtremors in assesing the Site effects on the Seismic motion.
[6] Moribayashi, S. a. (1980). Basement topography of the Kathmandu Valley Nepal- An application of the gravitational method to the survey of a tectonic basin in the Himalaya. Journal of Japan Society of Engineering Geology.
[7] NAKAMURA, Y. (1989). A method of Dynamics characteristics Estimation of the sub surface using the microtremor on the Ground Surface.
[8] Nakamura, Y. (2000). Clear Identification OF Fundamental idea of Nakamura's Techniques and its appllication.
[9] Ömer AYDAN, R. U. (2015). The quick report on THE 2015 GORKHA (NEPAL) EARTHQUAKE and its Geo-Engineering aspects.
[10] Parajuli, H. (2011). Dynamic Characteristic Investigation of a Historical Masonry Building and Surrounding Ground in Kathmandu.
[11] Pashalis APOSTOLIDIS, D. R. (2004). The use of the microtremor for the defination of the soil property and the bed rock depth in Urban Areas.
[12] Paudyal Y.R., Y. R. (2012). A study of local amplifi cation effect of soil layers on ground motion in the Kathmandu Valley using microtremor analysis. EARTHQUAKE ENGINEERING AND ENGINEERING VIBRATION.
[13] Paudyal, Y. R. (2012). Microtremor Based Earthquake Disaster Risk Evaluation of the. Japan.
[14] Taylor*, I. M. (1973). APPLICATION OF MICROTREMOR MEASUREMENTS TO EARTHQUAKE ENGINEERING. Bulletin of the N.Z. Society for Earthquake Engineering, Vol.6, No.4 December 1973.
[15] Thaman, R. a. (2016). Dynamic Characteristics Study of RCC Building using Micro Tremor measurement in Thapathali, Kathmandu Nepal. Proceedings of IOE Graduate Conference, 2016, 9.
[16] Tsutomu SATO, Y. N. (August 1-6, 2004). EVALUATION OF THE AMPLIFICATION CHARACTERISTICS OF SUBSURFACE USING MICROTREMOR AND STRONG MOTION - THE STUDIES AT MEXICO CITY -. 13th World Conference on Earthquake Engineering, (p. Paper No. 862). Vancouver, B.C., Canada.

