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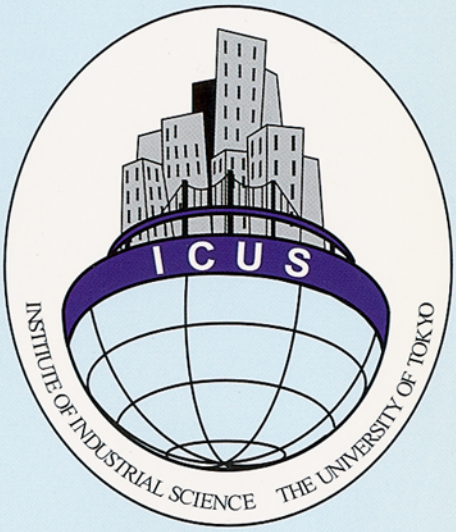

INTERNATIONAL CENTER FOR
URBAN SAFETY ENGINEERING

INSTITUTE OF INDUSTRIAL SCIENCE
THE UNIVERSITY OF TOKYO

EVALUATION OF THE SEISMIC VULNERABILITY OF BANGLADESHI BUILDINGS USING NON-DESTRUCTIVE TESTING

- MICROTREMOR MEASUREMENTS AND FERROSCAN -

Edited by

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Evaluation of the Seismic Vulnerability of Bangladeshi Buildings using Non-destructive Testing

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ABSTRACT

This study was undertaken by the Bangladesh Network Office for Urban Safety (BNUS), Bangladesh University of Engineering and Technology (BUET) and was supported by the International Centre for Urban Safety Engineering (ICUS), the University of Tokyo. The objective of the study was to assess the vulnerability of Bangladeshi building using non-destructive testing, namely microtremor measurements and Ferroscan. For this purpose, 17 reinforced concrete (RC) and 29 masonry buildings were surveyed mainly within BUET campus in June 2006.

This report presents the information of all surveyed buildings including findings of reinforcement detailing of 13 RC buildings and microtremor analysis of 17 RC and 29 masonry buildings. Using Ferroscan, reinforcement diameter and location within the RC buildings were detected. Microtremor measurements were used to determine the predominant period of RC and masonry buildings.

The natural period of some buildings was found to be close to that of soil, so their seismic response may be considerably amplified during an earthquake. All of the surveyed masonry buildings have torsional irregularity and re-entrant corner. Results obtained from Ferroscan survey showed that the reinforcement did not match the design detailing. Cover and spacing of lateral ties in columns and stirrups in beams widely vary from design.

Earthquake vulnerability of the surveyed buildings was assessed based on: 1) the possibility of resonance in case of an earthquake, i.e. whether the structure natural period was close to that of the soil; 2) the construction quality, based on whether reinforcement arrangement and concrete strength followed the design drawings; and 3) structural irregularities, based on visual inspection. For detected structurally vulnerable buildings, further structural analysis will be carried out in future. Empirical correlations between number of story and natural period of building for RC frame buildings and masonry buildings were also proposed.

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CHAPTER ONE

INTRODUCTION

1.1 General

In the Asian region, the fragility of a structure, which is based on the defect of design criteria, inadequate construction management and maintenance management, etc., is a big problem. Moreover, those structures were built during economic growth, which means that we should face a lot of problems at the same time in near future. Therefore, we have to solve these problems. In order to deal with these problems, the International Center for Urban Safety Engineering (ICUS) focuses on research activities with advanced technology tools such as numerical models, remote sensing, GIS, GPS, etc. for devising appropriate methodologies for management and maintenance of urban buildings, infrastructures, mitigation of urban disasters and environmental problems for sustainable development of Asian cities with adequate safety and security.

This study was undertaken by the Bangladesh Network office for Urban Safety (BNUS), Bangladesh University of Engineering and Technology and was supported by the International Centre for Urban Safety Engineering (ICUS), Institute of Industrial Science, the University of Tokyo. The report presents the information of all the buildings surveyed including findings of reinforcement detailing of 14 RCC buildings and microtremor analysis of 17 RCC and 29 masonry buildings.

1.2 Background of the Study

Prof. K. Meguro, Drs. M. Yoshimura and H. Kanada, members of ICUS, and Mr. K. Tsukimoto, graduate student of Meguro laboratory, visited Bangladesh University of Engineering & Technology (BUET) from June 14 to 19, 2006. On June 14, ICUS signed the contract for the establishment of the Bangladesh Network Office for Urban Safety (BNUS) with the Department of Civil Engineering, BUET. A short course on Evaluation of Concrete Structures was held on 14-15. Prof. Meguro, Prof. AMMT Anwar, Prof. M.A. Ansary, Dr. Yoshimura, and Dr. Kanada delivered presentations on the importance of earthquake disaster prevention, earthquake resistant bridge design, seismic vulnerability assessment using microtremor measurements and introduction of nondestructive inspection (NDT) methods for concrete structures, respectively. On the afternoon of the second day, a demonstration using actual equipments was performed for the participants.

From June 16 to 19, many structures (BUET facilities, fire stations and buildings under construction) were surveyed by Dr. Yoshimura, Dr. Kanada, Mr. Tsukimoto and BUET members under the supervision of Prof. M A Ansary and Dr. M A Noor. Dr. Yoshimura, Mr. Tsukimoto and Mr. S Z Rahman Russel measured the structure natural periods using microtremor measurement equipment and Dr. Kanada and Mr. Kamruzzaman investigated rebar arrangement using NDT equipment.

1.3 Project Description and Scope of the Works

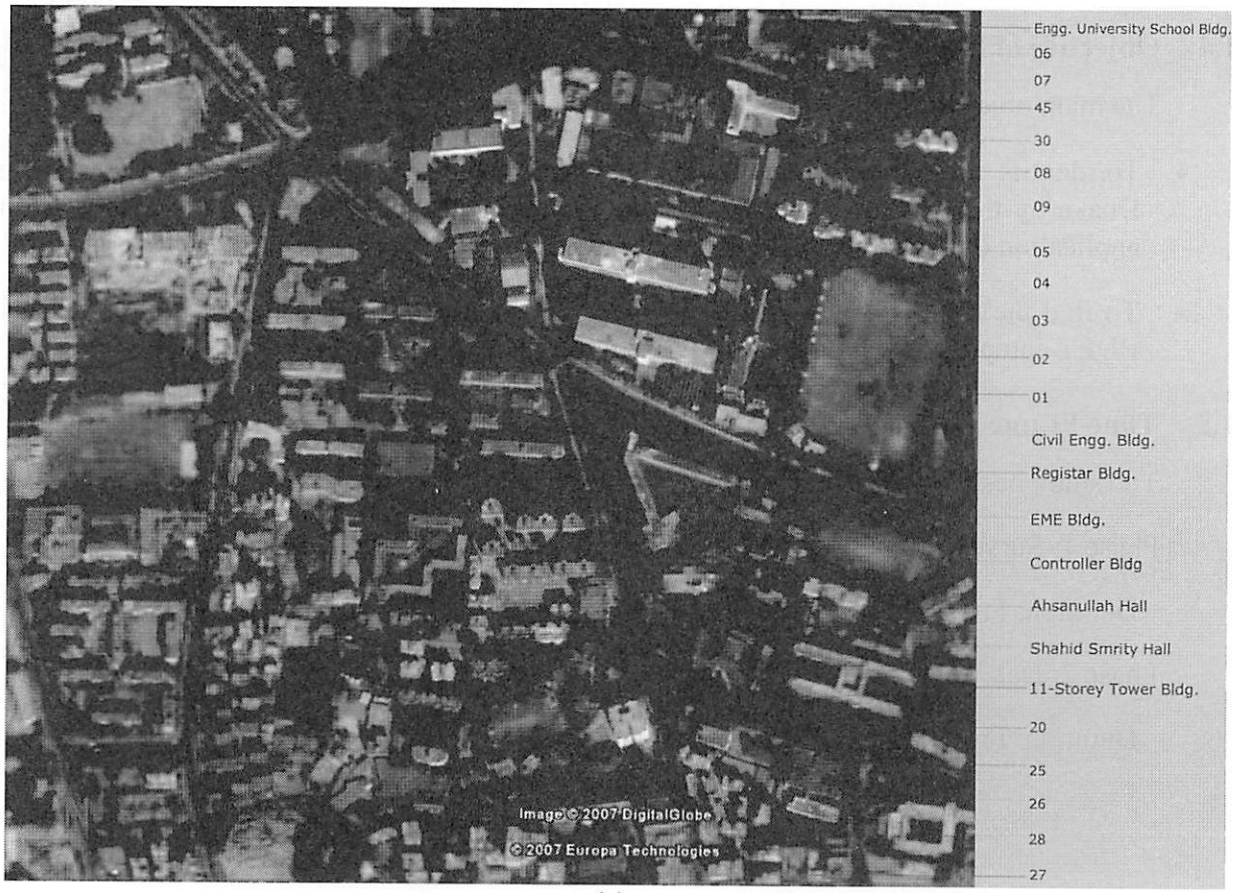
The aim of this project is to detect the earthquake vulnerability of BUET building by means of determining the location of the reinforcement and their spacing and microtremor observation. So there are mainly two parts of the study:

- Microtremor measurement
- Detection of reinforcement

The importance of dynamic properties of buildings becomes paramount when seismic design of the buildings is considered. This is because the response of structures mainly depends on the characteristics of both excitation forces and dynamic properties of buildings. In this regard, in order to design and analyze the earthquake resistant buildings, it is necessary to identify the dynamic properties of the buildings. For instance, the fundamental frequency is employed to determine the seismic coefficient and site-structure resonance factor in the base shear formula used in the static approach of many earthquake codes.

In general, the approaches to the identification the dynamic properties of buildings can be mainly categorized into three: (1) empirical, (2) numerical analysis, and (3) direct measurement approaches. The empirical approach provides simplified formulas for estimating the fundamental periods of buildings in terms of geometric dimensions of the buildings. The second approach, the numerical analysis, is normally used during the design process. A finite element model of the building, which consists of the mass and stiffness matrices of the system, is first formulated. Dynamic properties such as natural frequencies and vibration mode shapes are obtained by the eigen analysis. The third approach is the direct measurement approach, which first measures dynamic responses of existing buildings, and then identifies their dynamic properties from the measured responses.

On the other hand, detection of reinforcement includes determination of the number of rebars, spacing, cover depth, etc. Ferroscan is used to determine this reinforcement details. The determination of reinforcement in RCC building is very important for vulnerability assessment. This observation includes frame structure buildings, masonry buildings, fire stations, buildings under construction, etc. These buildings include academic buildings, residential buildings, schools, student's dormitory and fire stations. Most buildings are in BUET campus. Locations of 16 RCC and 30 masonry buildings of BUET campus is shown in Figure 1. Only three buildings are outside the campus.



(a)

(b)

Figure 1 BUET Campus from Google Earth

1.4 Objective of Study

The main objectives were:

- To identify the dynamic properties of low and medium-rise buildings in BUET campus, Dhaka by the ambient vibration method using the frequency domain technique with the application of controlled human excitation.
- To find the reinforcement details, spacing, cover, etc. in the frame structure buildings in BUET campus and also three building outside the campus.

1.5 Time Frame

The study has been completed in two phases:

Phase 1: Survey and non-destructive testing (NDT) of the buildings.

Duration: From June 15 to June 19, 2006; 5 days.

Phase 2: Data analysis

Duration: From June 20, 2006 to February 10, 2007

CHAPTER TWO
METHODOLOGY

2.1 General

Bangladesh has long been believed to be a country with medium seismic hazard. But the practical design and analysis of buildings have not paid attention to seismic aspects. However, in recent years, many reliable reports have revealed that Dhaka, the capital city of Bangladesh, has a potential risk from distant earthquakes due to the ability of underlying land fill to amplify the ground motion. For this reason, the seismic design and analysis of buildings cannot be neglected any more. Nevertheless, the dynamic properties of buildings, which are important to seismic design and analysis, have been limitedly studied in Dhaka, particularly for low and medium-rise buildings. Recently many high-rise building are constructed in Dhaka city. The identification of dynamic properties of buildings is therefore required and it will provide useful information for the development of design criteria of buildings in Dhaka.

2.2 Background

To identify the dynamic properties of buildings, the empirical approach is normally considered practical and widely used in a preliminary design process. This is because it is convenient to estimate these properties by simple empirical formulas, which are provided by building codes in seismic provisions. However, empirical formulas, which are recommended in many countries, are different because the required level of design force and the characteristics of building construction in alternative countries are different. As a result, the empirical formula based on the statistical data of measured dynamic properties in one country may not be able to apply to another country. Therefore, the numerical analysis approach, which normally uses a finite element model, may be employed to solve this problem. Design engineers have to incorporate all appropriate modeling assumptions to represent the real behaviors of buildings in order to identify accurate dynamic properties. In practice, many design engineers usually formulate the finite element model of the buildings with structural members such as beam, column, and shear wall members and they normally assume that the foundations of the buildings behave like a rigid foundation type (all degrees of freedom are constrained at ground level of first floor columns). This modeling may be good enough to design and analyze the buildings under static condition. However, above modeling, which considers only the structural members and the rigid foundations, is not appropriate to identify the dynamic properties of buildings because the dynamic properties mainly depend on the total stiffness of the buildings, which is also influenced by another assumption such as the stiffness of non-structural members, and the flexibility of the foundations. Following to incomplete modeling assumptions, the dynamic properties of buildings, which are calculated by numerical analysis, are not reliable. Then, these will lead design engineers to make mistakes when the dynamic properties of buildings are considered in design and analysis.

2.3 Direct Measurement Technique

In order to identify correct dynamic properties, the most accurate approach is the direct measurement approach because the properties are derived from actual dynamic response of existing buildings. In recent years, several direct measurement techniques for determining the dynamic properties of structures have been developed. These techniques can be categorized into three basic methods

(i) forced vibration method,

(ii) free vibration method, and

(iii) ambient vibration method.

In the forced vibration method, a structure is excited into a steady state response by mechanical shakers and its response is measured. Plotting the amplitudes of the responses against frequencies provides a frequency-response curve from which dynamic properties can be determined. In the free vibration method, a step or an impulse force is applied to the structure. A decay response curve can be utilized for system identification. The last method is the ambient vibration method. The ambient responses of a structure, which are generated by microtremor excitations such as wind forces, and traffic excitations, are measured. Dynamic properties of the structure are extracted from processing signals in the time domain technique or in the frequency domain technique. Both forced and free vibration approaches are expensive compared to the ambient vibration approach due to the need of mechanical shakers or impulse generators. Furthermore, in some situations building operation is disturbed by a controlled excitation from forced or free vibration test. In such a case, the ambient vibration measurement becomes an attractive option.

2.4 Ambient Vibration Technique

As mentioned above, the ambient vibration measurement requires processing signals for identifying dynamic properties of structures. The signal processing techniques can be categorized into time domain and frequency domain techniques. In the time domain technique, response-time history is employed directly in the identification of dynamic properties of structures. While in the frequency domain technique, response-time history has to be firstly converted into frequency domain by Fourier analysis. Dynamic properties are then extracted from the frequency spectrum, which is the plotting of Fourier magnitude response against frequencies. Although both techniques can be employed to identify the dynamic properties of buildings, the frequency domain technique gives a better physical interpretation than the time domain technique because it presents the response of buildings in the form of the frequency spectrum. This frequency spectrum can be used directly to identify natural frequencies from the frequencies corresponding to the peak values of Fourier magnitude and calculate vibration mode shapes from the spectral ratio method. In addition, an algorithm in the time domain technique is more complicated than frequency domain technique, which provides the algorithm in the form of Fast Fourier Transform (FFT). According to this algorithm, the computational work in the frequency domain technique can be significantly reduced. In this regard, the frequency domain technique is an attractive technique to identify dynamic properties from the ambient vibration measurement.

2.5 Microtremor Observation

Soil characteristics can be assessed by microtremor measurement. Hard soil gives high frequency and soft soil gives low frequency. A structure may experience a vibration period at which it oscillates in the earthquake vibration motion and will tend to response to that. Natural frequency of structure is obtained based on the spectral ratio of horizontal component of the building to that of ground. Wave propagation mechanism of microtremor and its relation with ground vibration characteristics were studied from the beginning of microtremor studies (Aki, 1957; Kanai and Tanaka, 1961). Meanwhile practical application of microtremor in the field of engineering has advanced tremendously. One of the powerful and simplest applications of microtremor observation is in seismic micro zoning.

Basically there are two types of microtremor observations to the number of observation points. These are point and array observations of microtremors (Ansary et al., 1996). From the array observation of microtremor of period greater than 1 sec, Rayleigh-wave and Love-wave

originating from natural sources, such as sea wave, variation of air and wind pressure can be recognized. On the other hand short-period microtremor of period less than 1 sec is thought to be generated by artificial noises such as traffic vehicles, industrial plants, household appliances, etc. Some researchers (Sato et al., 1991; Tokimatsu and Miyadera, 1992; Tokimatsu et al., 1994) have showed that microtremors are mainly composed of fundamental mode of Rayleigh-wave and some (Nakamura, 1989; Wakamatsu and Yasui, 1995) have showed that short-period microtremor bears resemblance to shear-wave characteristics. On the other hand, micro tremors can also be dominated by Love-wave (Tamura et al., 1993). Recently, Suzuki et al. (1995) have applied microtremor measurements to the estimation of earthquake ground motions based on a hypothesis that the amplitude ratio defined by Nakamura (1989) can be regarded identical with half of the amplification factor from bedrock to the ground surface. However, the real generation and nature of microtremors have not yet been established.

2.6 Procedure

In this observation, the team members fix the sensors first. They tried to fix one sensor at the roof top of the building, one at the free field near the building and other at any floor level of the building. In some building the team cannot place one sensor at the rooftop and then they place it at the top floor level of the building. Sometimes team members took observation of two building together to save the time. After taking the observation with the help of a program the time domain velocity data is converted to frequency domain data and the natural period of the buildings is found out. Microtremor measurement instrument with sensor and battery are shown in Figure 2(a). Figure 2 to Figure 5 show the microtremor equipment set up, microtremor observation, and type of buildings which were observed. Figure 10 to Figure 68 show time history and Fourier spectrum. The results shown in the graphs are only the result of one measurement, which had minimum disturbance of sound, vehicle, human being etc. Fourier Amplitude graphs represent the Fourier Spectrum of the measurement at the floor.

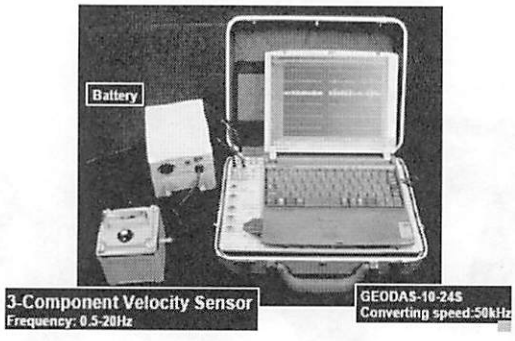


Figure 2(a) Microtremor measurement equipment with battery, 3-component velocity sensor, and GEODAS-10-24S

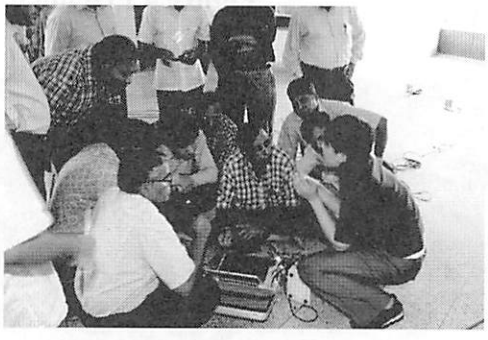


Figure 2(b) Microtremor observation

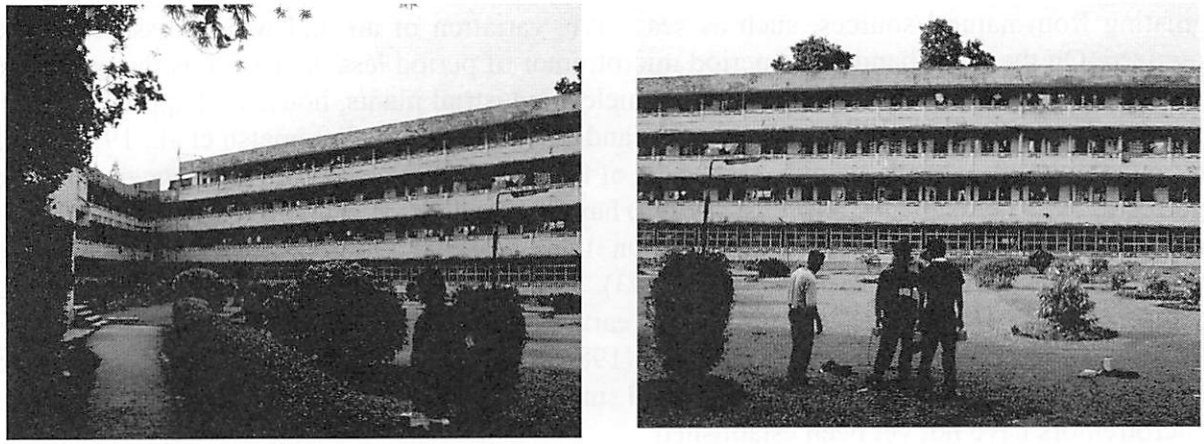


Figure 3 Inspection of building to decide the suitable placement of velocity sensor

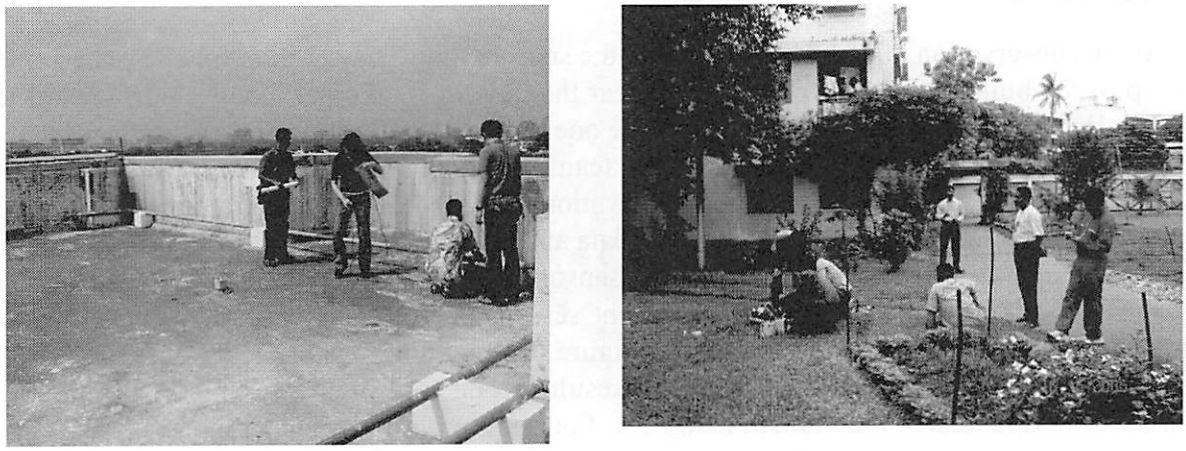


Figure 4 Placing of sensor on top of the building

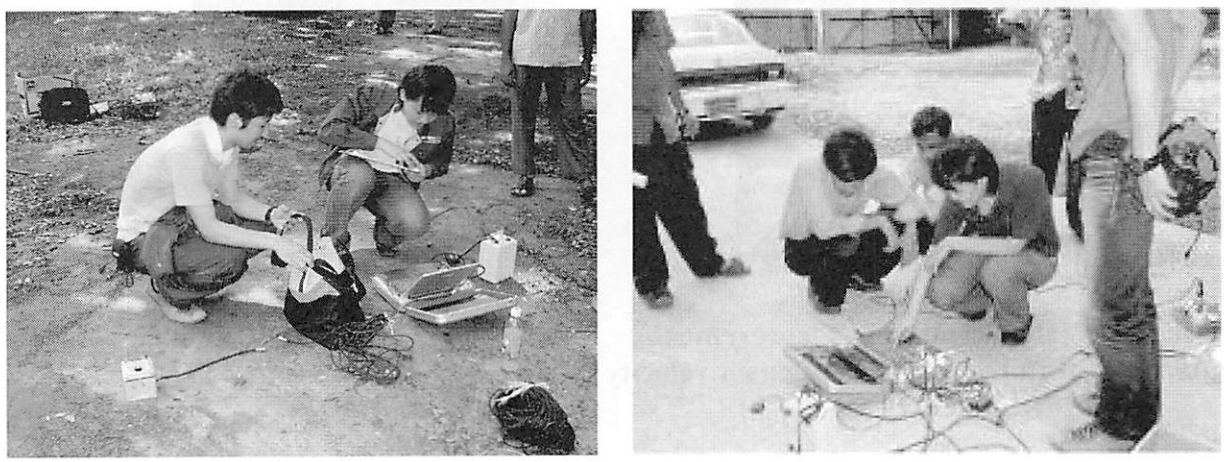


Figure 5 Microtremor observation

2.7 Reinforcement Detection

Reinforcement detection of reinforced concrete structures is essential for:

(i) seismic performance assessment of structures and

(ii) proper maintenance of structures.

Actual reinforcement detail is required to determine the capacity of the structure. There are many ways of finding the rebar arrangement. These are

(i) Electromagnetic method

(ii) X-ray measurement

(iii) High energy X-ray CT Scan

(iv) Radar inspection

Electromagnetic method is used in this study.

2.8 Principles of Electro-Magnetic Method

When electric current run through a coil of the apparatus, magnetic field is formed. Due to the magnetic field, electric current run is induced in the steel bar. Due to induced electric current in steel bar, magnetic field is formed around the bar. The field induces electric current in the secondary coil to be measured. When electric current runs through a coil of the electro-magnetic sensor, magnetic flux is measured. Electric current runs in steel bar due to magnetic flux produced by coil of sensor. Electromotive force of coil changes. Thickness of cover concrete or diameter of steel bar can be estimated from magnetic flux change. Induced magnetic field depends on the distance between sensor and reinforcement (Figure 6). When bars are too close, it becomes difficult to differentiate the numbers of bar.

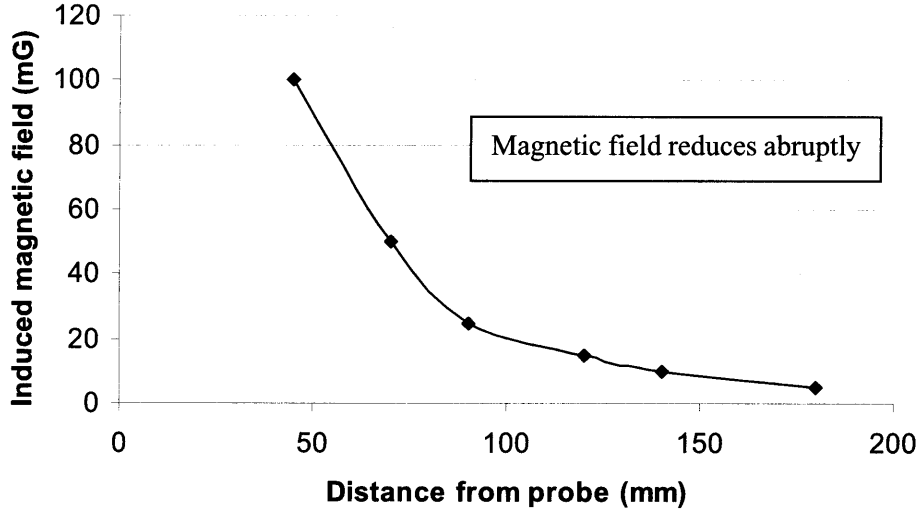


Figure 6 Induced magnetic field versus distance from probe plot

2.8.1 PS 200 Ferroscan

The Hilti PS 200 is a system used for high-end reinforcement detection. The key elements of the system are the Scanner, the Monitor and the software. Reinforcement detection with Ferroscan is shown in Figure 7.

Scanner (PS 200 S): Scans the reinforced concrete element.

Monitor (PS 200 M): It can show the bar and analyze on site.

Ferroscan Software: The Ferroscan software is used to view and analyze images and to produce professional report. They can be archived and printed with graphs of rebar layout as well as information about rebar depth and diameter at any point. The Ferroscan (PS 200) enables the detection of rebar in concrete, providing instant images of rebar layout, depth and diameter and determining rebar depth over large areas. PS 200 is used for avoiding rebar when drilling or coring to determine strength and fire and corrosion resistance of reinforcement concrete elements. Tunnels, bridges and other reinforced concrete structures often need to be checked for corrosion resistance because of salty water sprayed on concrete from passing traffic. The greater the concrete cover over the river, the better the resistance to corrosion of the reinforced concrete element. Before changing loads on reinforced concrete structures, engineers need to determine their actual strength, especially when plans are not available. In many cases, it is essential to avoid rebar when drilling or coring through reinforced concrete elements.

Technical performance:

PS 200 has outstanding technical performance

Rebar detection range	:	Mostly 120-150 mm depending on bar size. Maximum depth is 180 mm.
Depth measurement range	:	Mostly 100-140 mm depending on bar size.
Depth accuracy	:	± 2.5 mm for most bar at common depth. (varies with depth)

Data Analysis

The raw data collected from Ferroscan observation are analyzed with the help of Ferroscan software. The analyzed results are presented in a Table.

2.9 Inspection Method by X-ray Measurement

Bar arrangement can be captured by X-ray method. Using X-ray we can see inside the concrete in 2D. In this observation thickness is limited with in 20 cm. Bar depth can be estimated by comparing two photographs.

2.10 High Energy X-ray CT Scan

Three dimensional information can be obtained by CT scan. It is very expensive.

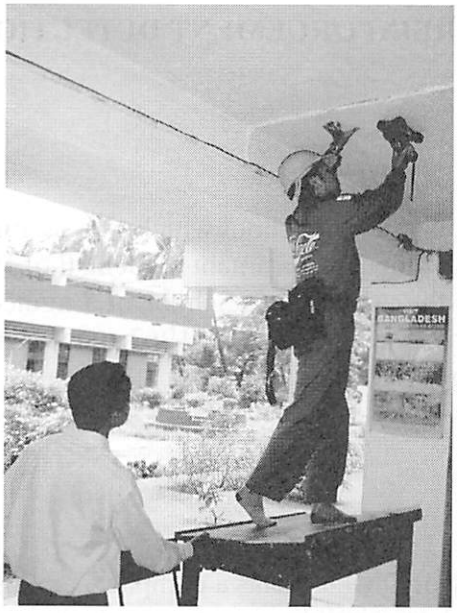


Figure 7(a) Slab reinforcement detection with Ferroscan in Titumir hall.

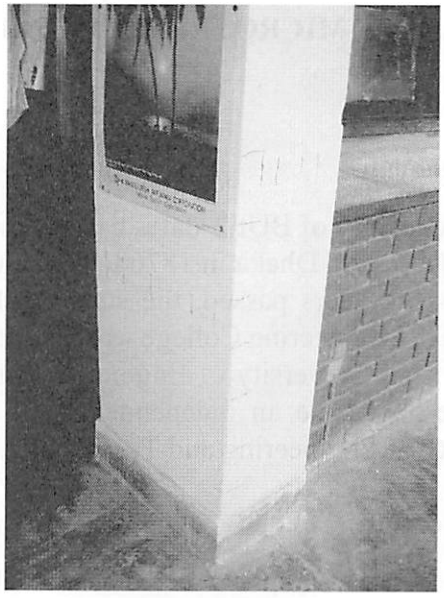


Figure 7(b) Marking of reinforcement in a column at ground floor of Titumir hall.

CHAPTER THREE

BUILDING MICROTREMOR ANALYSIS AND REINFORCEMENT DETECTION

3.1 General

The history of BUET dates back to the days of Dhaka Survey School which was established at Nalgola, in Old Dhaka in 1876 to train Surveyors for the then Government of Bengal of British India. As the years passed, the survey school became the Ahsanullah School of Engineering. Ahsanullah Engineering College was upgraded to the status of a University in 1962 and was named East Pakistan University of Engineering and Technology. After the war of Liberation in 1971, Bangladesh became an independent state and the university was renamed as the Bangladesh University of Engineering and Technology.

3.2 Location

The BUET campus is in the heart of the capital city of Dhaka. It has a compact campus with halls of residence within walking distances of the academic buildings. At present the campus occupies 31.1 hectares (76.85 acres) of land. The academic area is confined in and around the old campus occupying 12.24 hectares (30.24 acres) of land defined by Shahid Sharani, Bakshi Bazar road and the Asian Highway. The location map of BUET campus is shown in Figure 8.

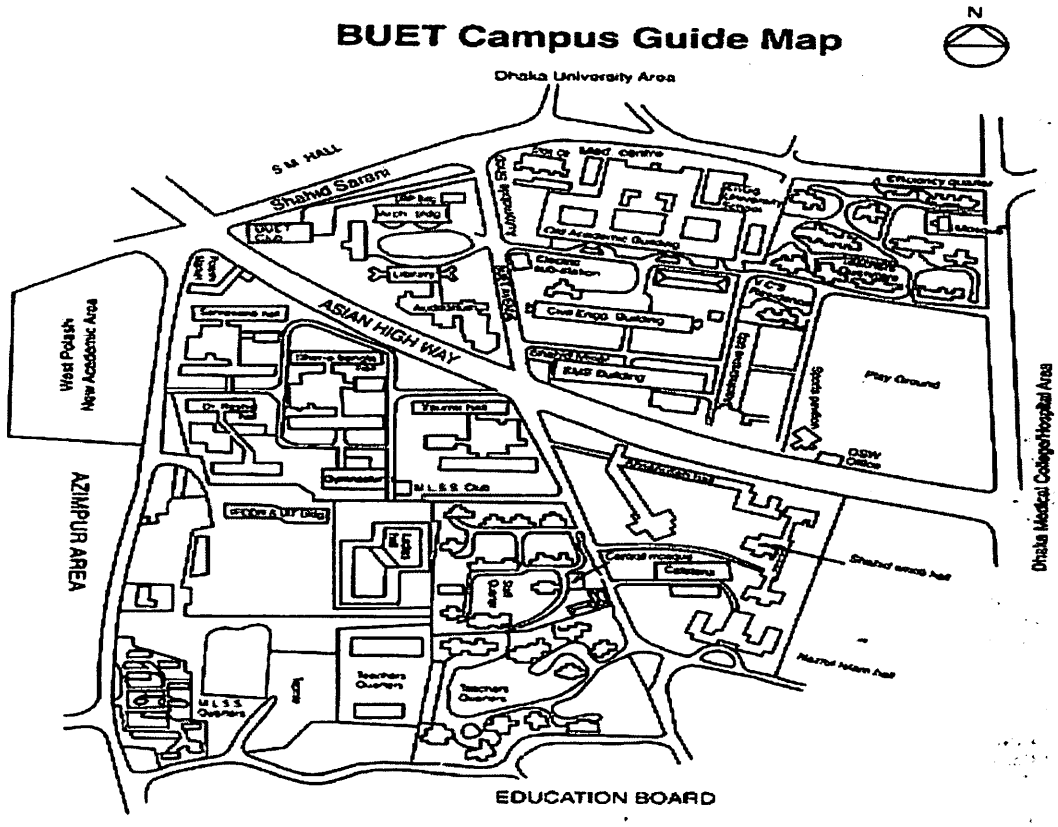


Figure 8 Location map of study area

3.3 Information of Buildings

There are totally 84 buildings owned by BUET. We studied 49 buildings which cover all academic buildings, residential buildings, student's dormitories of BUET campus and fire station outside the campus. Academic buildings include Civil Engineering Building, EME Building, Architecture Building, URP Building, ARC Building, Library Building, IFCDR Building, Controller Building, Register Building and New Academic building (under construction). Residential buildings include the Eleven Story Tower Building, teacher's quarter (building number 1, 2, 3, 4, 5, 6, 7, 8, 9, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 45, 46, 47) and staff quarter (building numbers 12, 13, 14, 18, 43, 62). Student's Dormitories include Dr. MA Rashid Hall, Sher-e Bangla Hall, Titumir Hall, Ahsanullah Hall and Shahid Smrity Hall. School Building includes Engineering University School Building. The buildings outside the BUET campus include Ban Bhaban and the Fire Service Station (head office building at Fulbaria and a branch office at Lalbag).

3.4 Assessment of Earthquake Vulnerability of Buildings

Earthquake vulnerability of the surveyed buildings are assessed from natural frequency obtained by analysis of microtremor data (resonance), reinforcement detection by Ferroscan, concrete compressive strength evaluation by Schmidt hammer test and visual inspection (structural irregularities).

Although the results of the microtremor observations at the free field are shown for each measured location, there is not a clear peak observed in most of the cases. Recently the shear wave velocity at BUET soil was measured with a portable seismograph. The obtained velocity (Vs) for the top layer was around 150m/s where the layer thickness (H), namely Red Dhaka clay, is around 10m. Using the formula, $T = 4H/Vs$, a fundamental period of 0.27s is obtained. Further analysis with 1D-SHAKE software suggested a period of approximately 0.30s. Based on these results, the natural period for the soil at BUET was assumed constant and equal to 0.3s in order to assess the possibility of structural resonance.

3.4.1 IFCDR Building

General Information:

Year of Construction: 1988
Type of Structure: Frame structure
No of story: 4
Use: Academic
Floor area: 930 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural Irregularities in Plan:

Torsional irregularity: no
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural Irregularities in Height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: 28.0 MPa (4068 psi)
Column: 28.3 MPa (4110 psi)
Shear wall: not applicable

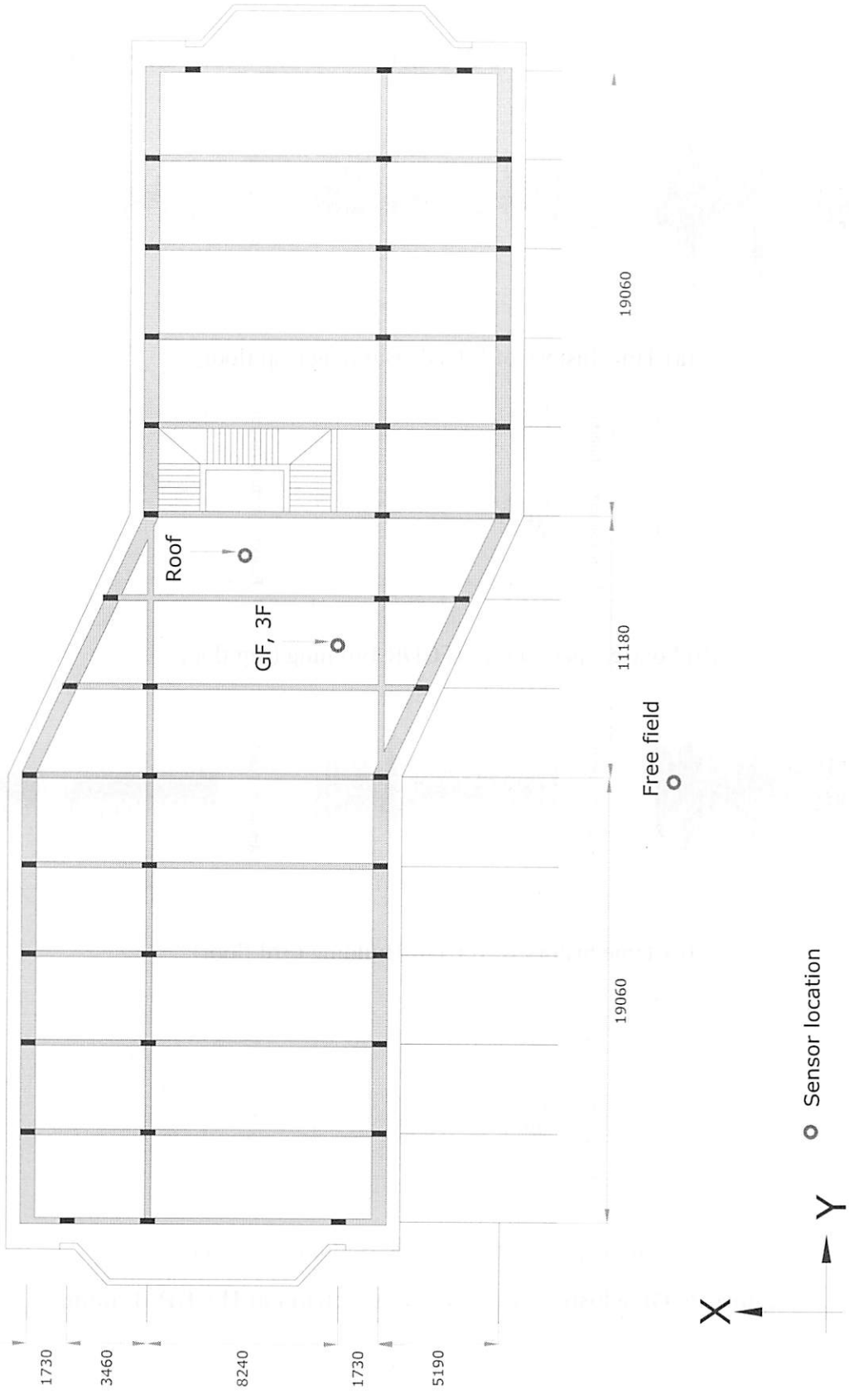
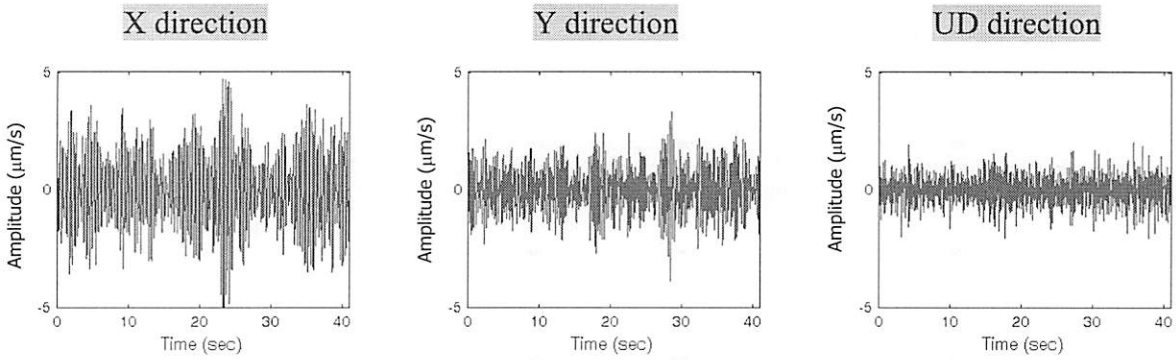
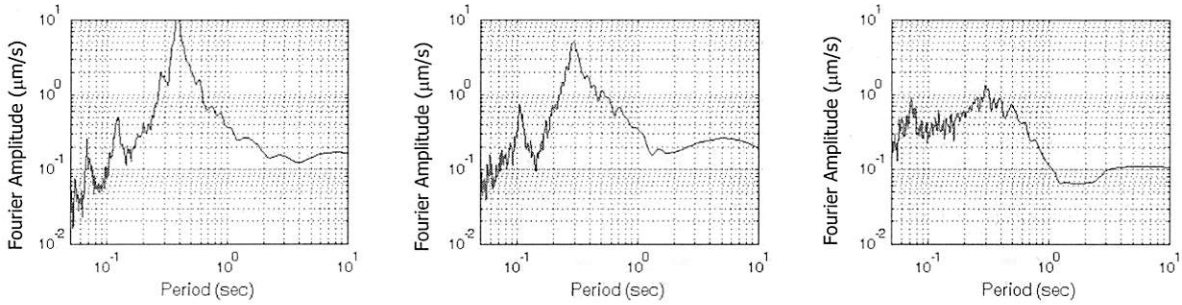


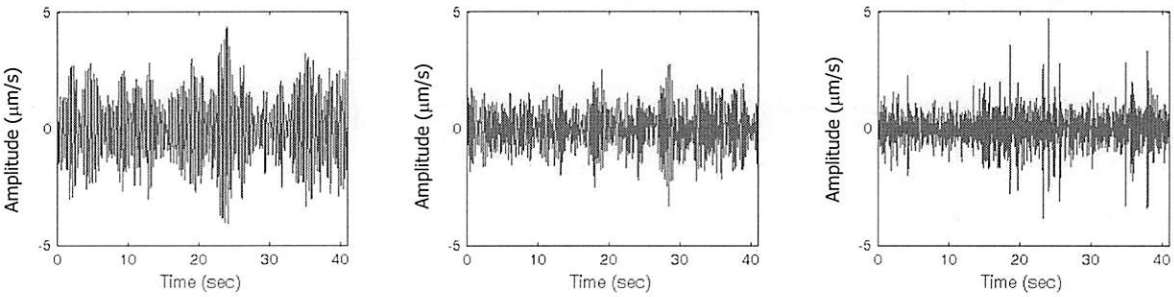
Figure 9 IFCDR Building Beam Column layout (linear dimensions are in millimeter)



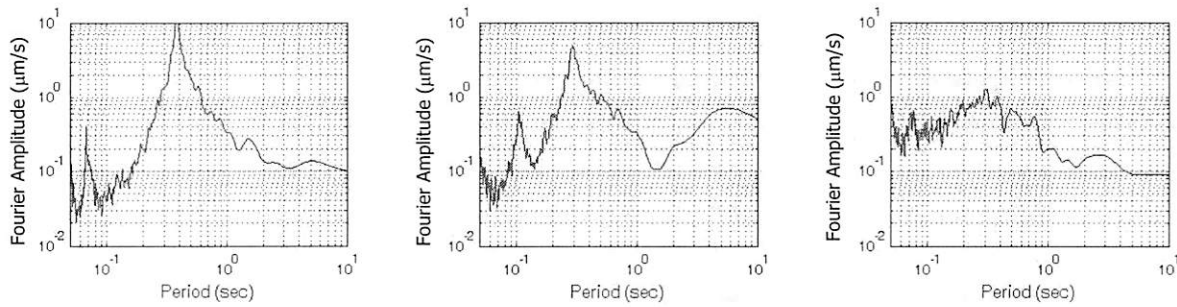
(a) Time history of IFCDR Building (top floor)



(b) Fourier spectrum of IFCDR Building (top floor)

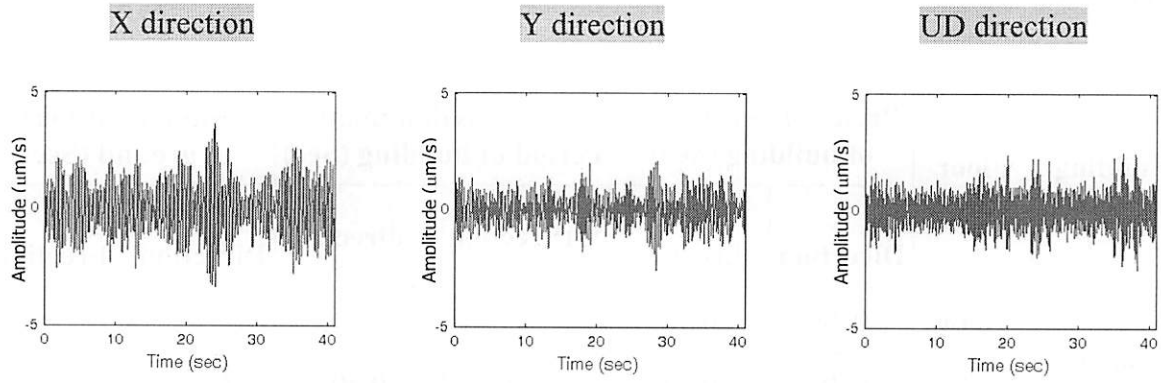


(c) Time history of IFCDR Building (3rd floor)

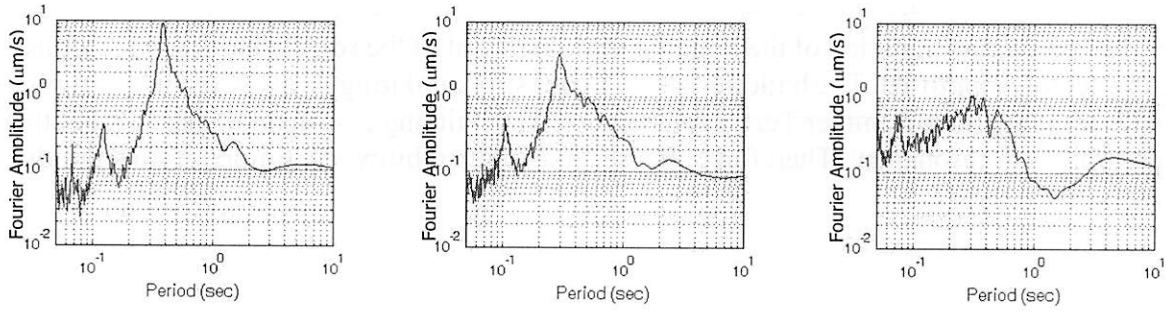


(d) Fourier spectrum of IFCDR Building (3rd floor)

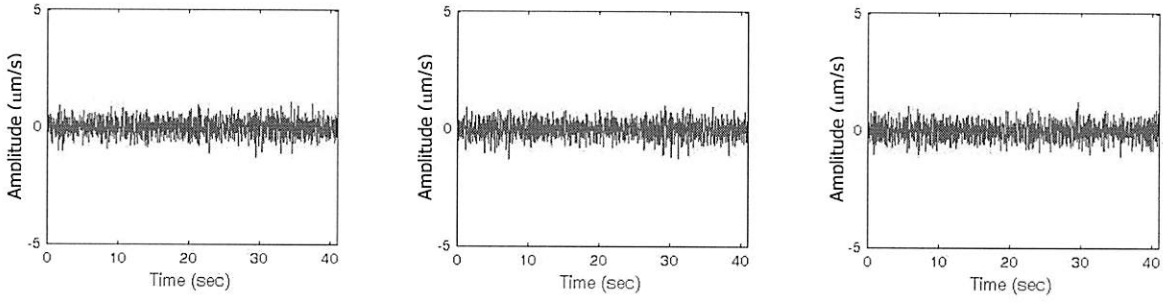
Figure 10 Time history and Fourier spectrum of IFCDR Building



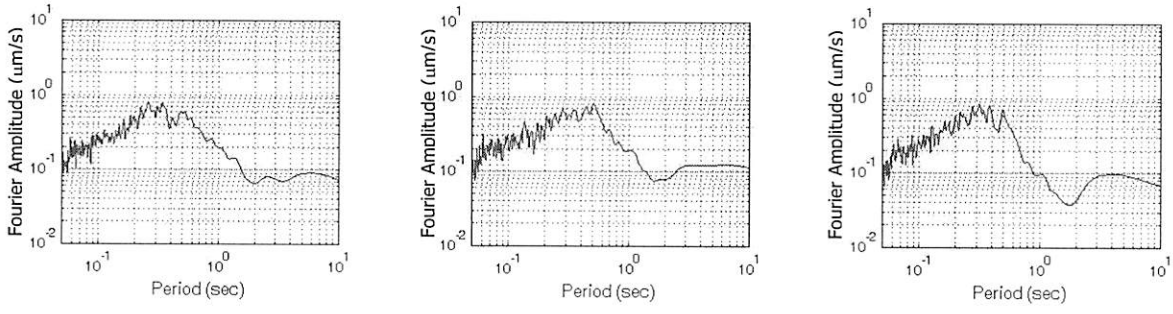
(e) Time history of IFCDR Building (2nd floor)



(f) Fourier spectrum of IFCDR Building (2nd floor)



(g) Time history of free field near IFCDR Building



(h) Fourier spectrum of free field near IFCDR Building

Figure 10 Time history and Fourier spectrum of IFCDR Building

Conclusion:

Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
IFCR Building	Roof	0.38	0.30	0.38	0.30	0.26	0.26
	3rd	0.38	0.30				
	2nd	0.38	0.29				

The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified. The building has no major structural irregularity. Concrete compressive strength from Schmidt Hammer Test is satisfactory. The building is structurally strong, but there is a possibility of resonance. Therefore, the seismic vulnerability condition of the building is moderate.

3.4.2 Eleven Story Tower Building

General Information:

Year of Construction: 2002
Type of Structure: Frame structure
No of story: 11
Use: Residential
Floor area: 673 sqm/floor
Foundation: Footing, pile
Lift: yes
Stair: yes
Shear wall: yes

Structural Irregularities in Plan:

Torsional irregularity: no
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural Irregularities in Height:

Storey stiffness irregularity: yes
Storey mass irregularity: yes
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: 20.0 MPa (2917 psi)
Column: 20.5 MPa (3005 psi)
Shear wall: not available

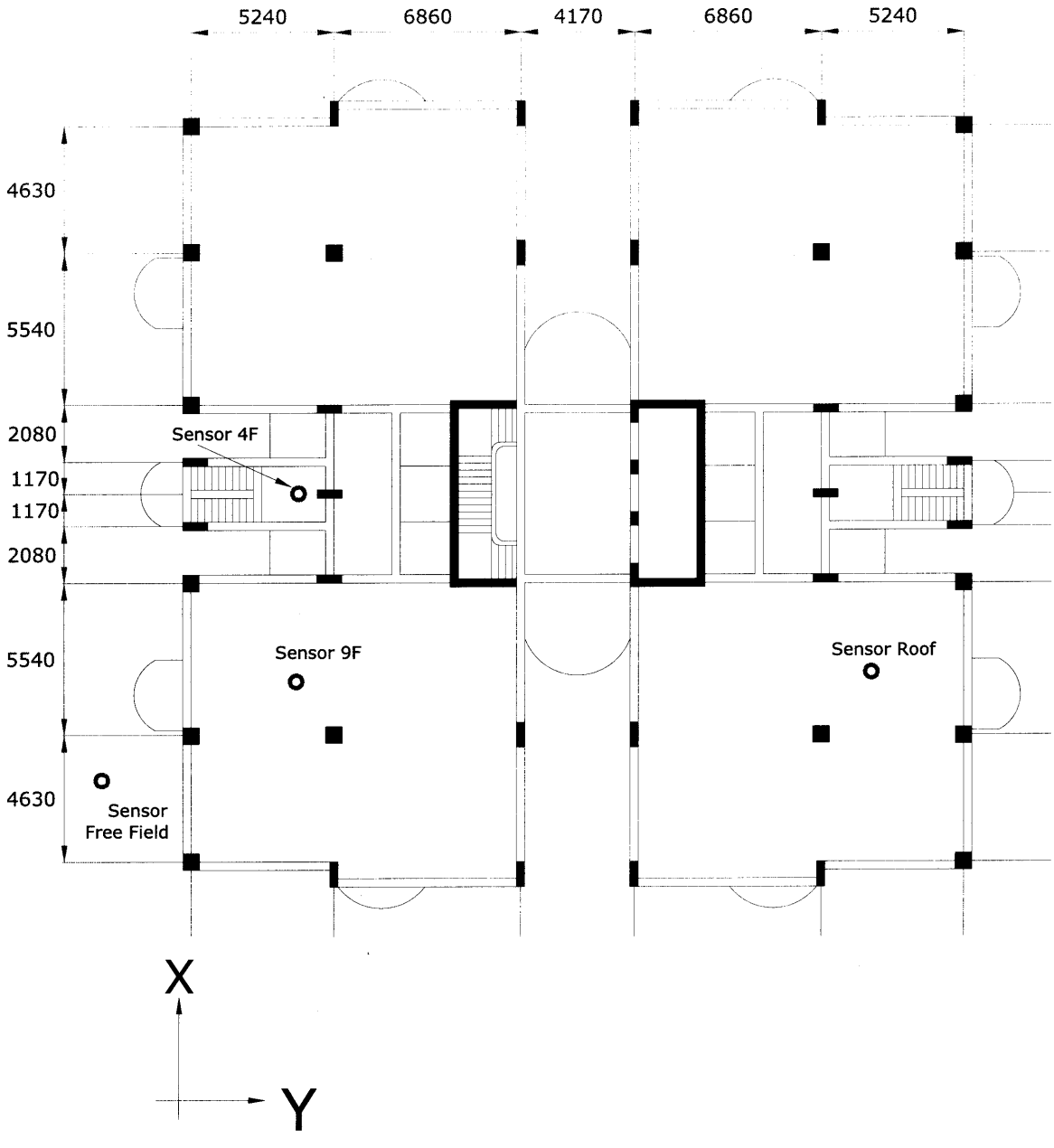
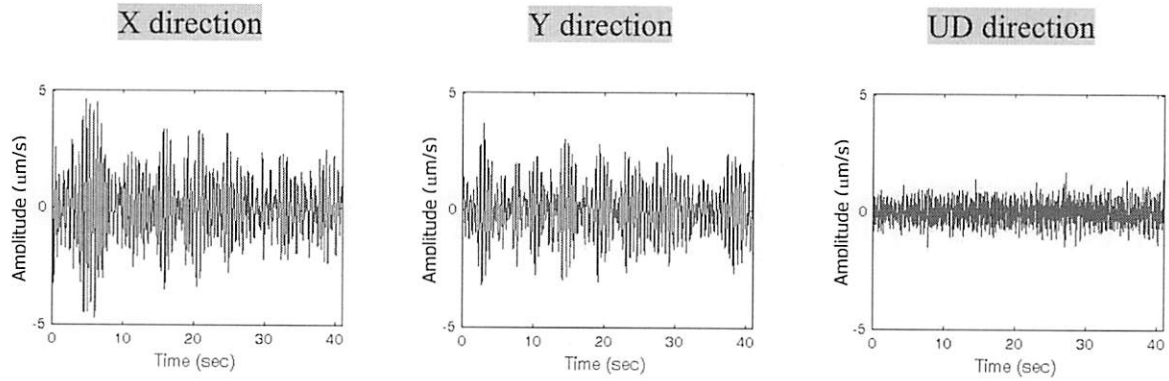
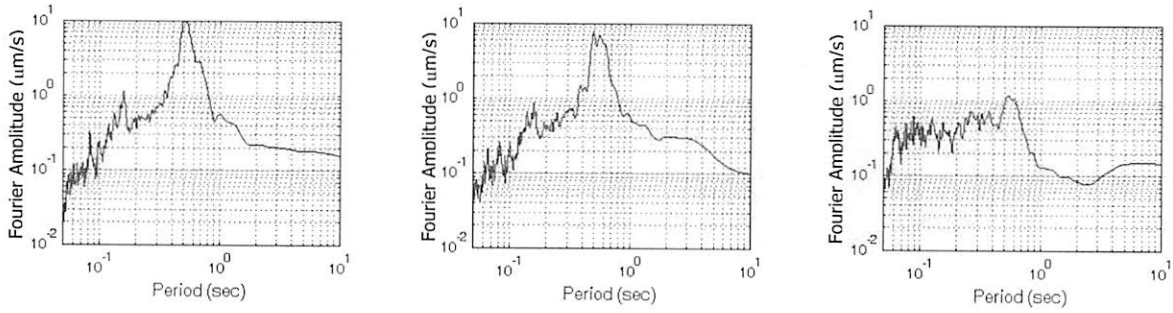


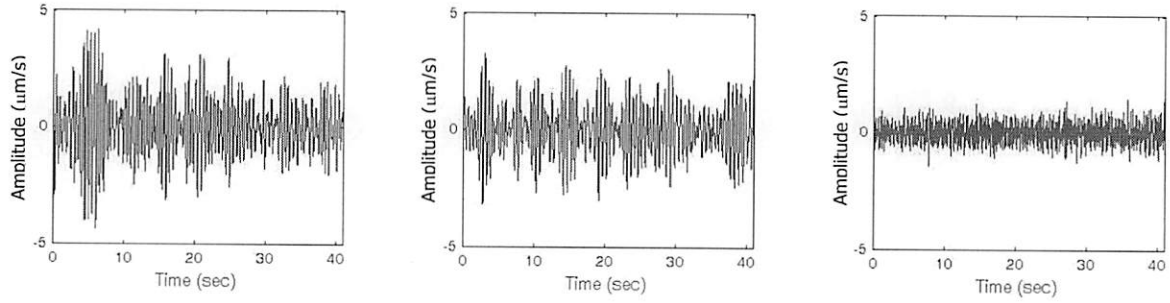
Figure 11 Eleven Story Tower Building Structural Element Layout (linear dimensions are in millimeter)



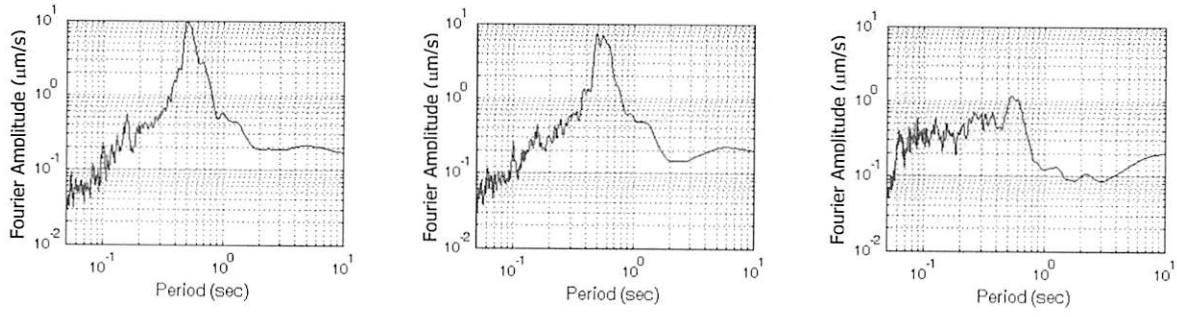
(a) Time history of 11 Storey Tower Building (top floor)



(b) Fourier spectrum of 11 Storey Tower Building (top floor)

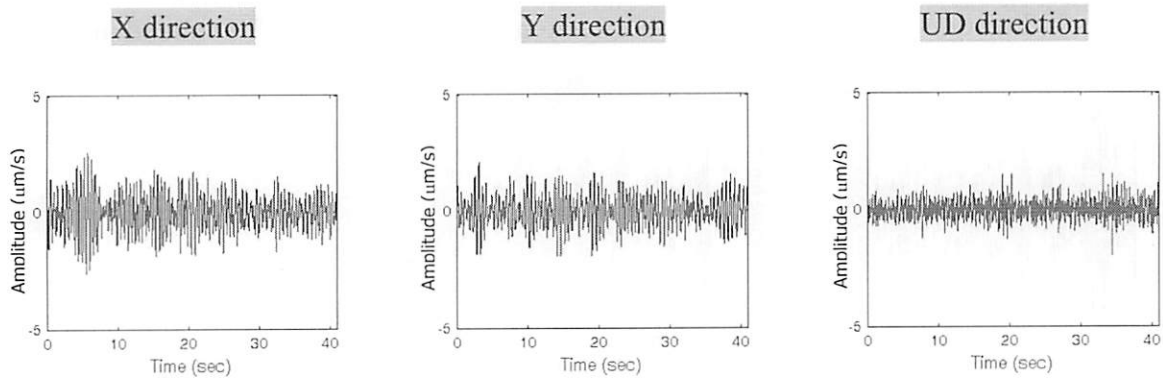


(c) Time history of 11 Storey Tower Building (9th floor)

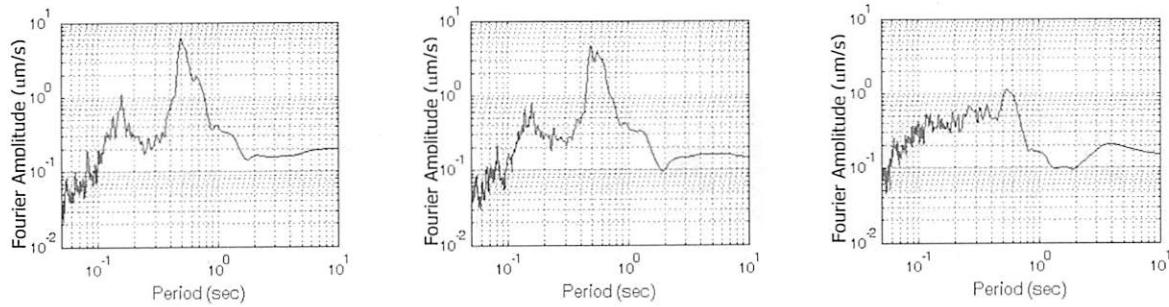


(d) Fourier spectrum of 11 Storey Tower Building (9th floor)

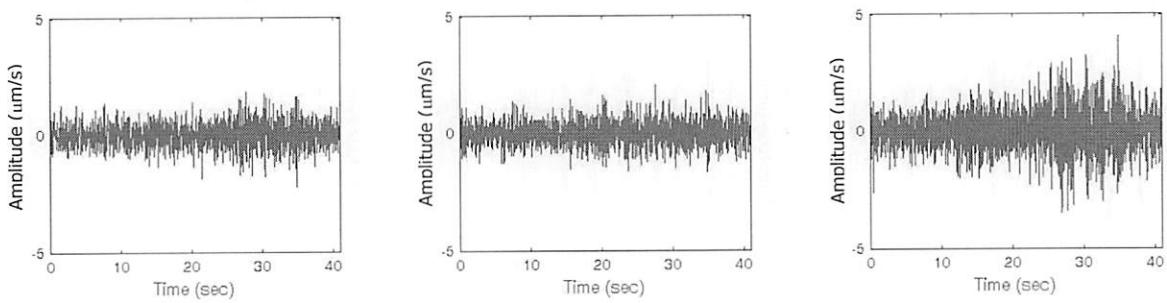
Figure 12 Time history and Fourier spectrum of 11 Storey Tower Building



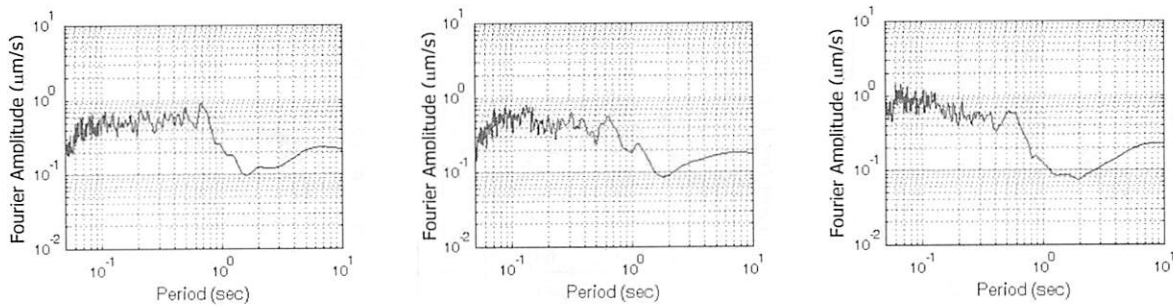
(e) Time history of 11 Storey Tower Building (4th floor)



(f) Fourier spectrum of 11 Storey Tower Building (4th floor)



(g) Time history of free field near 11 Storey Tower Building



(h) Fourier spectrum of free field near 11 Storey Tower Building

Figure 12 Time history and Fourier spectrum of 11 Storey Tower Building

Reinforcement Detection

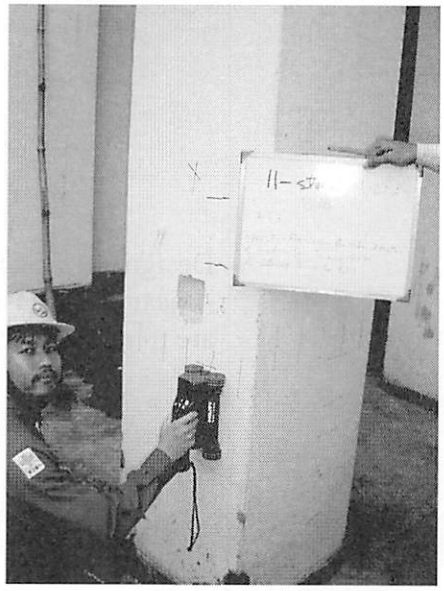


Figure 13(a) Column reinforcement detection with Ferroscan at 11 story Tower building.

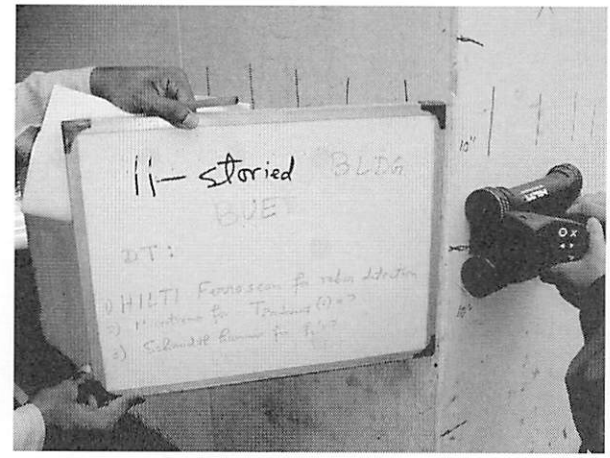
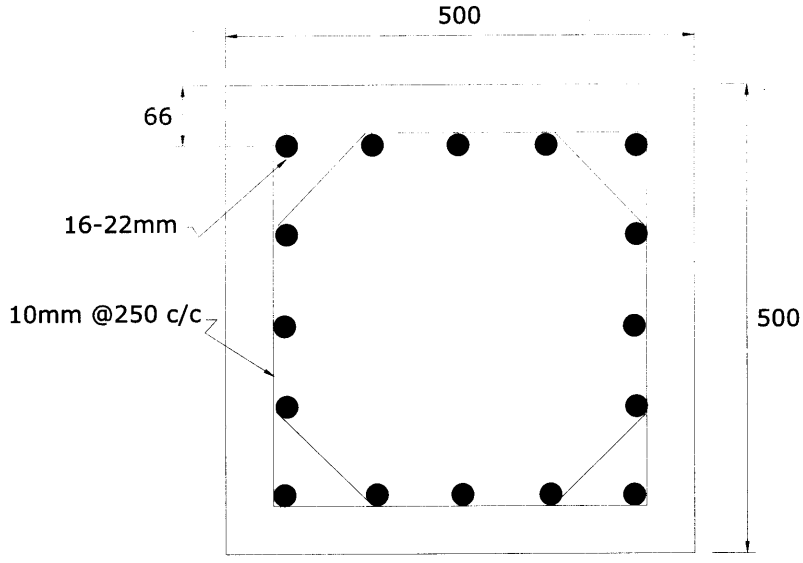


Figure 13(b) Column reinforcement detection at ground floor of 11 story Tower building.

Data Analysis

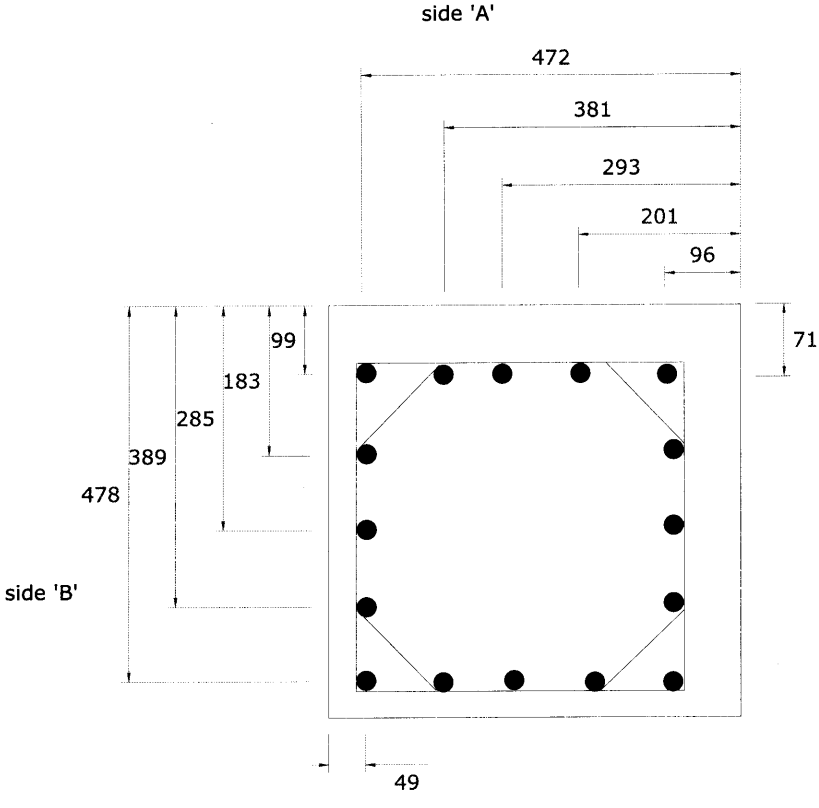
Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max[m]	Min[m]	Mean	Std-Dev	
Eleven Story Tower Building.	FQ000277	Column (Gr.)	Main Bar	5	22	74	61	71	1	M
	FQ000279	Column (Gr.)	Shear Reinforcement	5	10	57	48	52	3	M
	FQ000280	Column (Gr.)	Main Bar	5	22	52	46	49	2	M
	FQ000281	Column (Gr.)	Shear Reinforcement	5	10	34	22	26	5	M
	FQ000282	Shear Wall (Gr.)	Vertical	7	16	80	41	61	12	M
	FQ000283	Shear Wall (Gr.)	Horizontal	9	10	47	34	41	5	M
	FQ000284	Beam (Gr.)	Main Bar	3	19	56	48	53	5	M
	FQ000285	Beam (Gr.)	Main Bar	3	19	56	48	53	5	M
	FQ000286	Beam (Gr.)	Shear Reinforcement	4	10	79	67	78	4	M
	FQ000287	Beam (Gr.)	Main Bar	3	22	62	54	58	4	M
	FQ000288	Beam (Gr.)	Shear Reinforcement	5	10	59	52	55	4	M
	FQ000335	Shear Wall (4th)	Vertical	6	13	67	47	56	7	M
	FQ000336	Shear Wall (4th)	Horizontal	7	10	51	46	48	2	M
	FQ000337	Shear Wall (4th)	Vertical	8	16	77	63	69	5	M
	FQ000338	Shear Wall (4th)	Horizontal	7	16	89	61	71	11	M
	FQ000339	Column (4th)	Main Bar	5	19	72	56	64	6	M
	FQ000340	Column (4th)	Shear Reinforcement	5	10	43	39	40	2	M
	FQ000341	Shear Wall (4th)	Horizontal	5	13	105	51	57	6	M
	FQ000342	Shear Wall (4th)	Horizontal	6	10	119	81	91	8	M

Typical Column Section



28 days cylinder strength = 20.0 MPa (3000 psi)

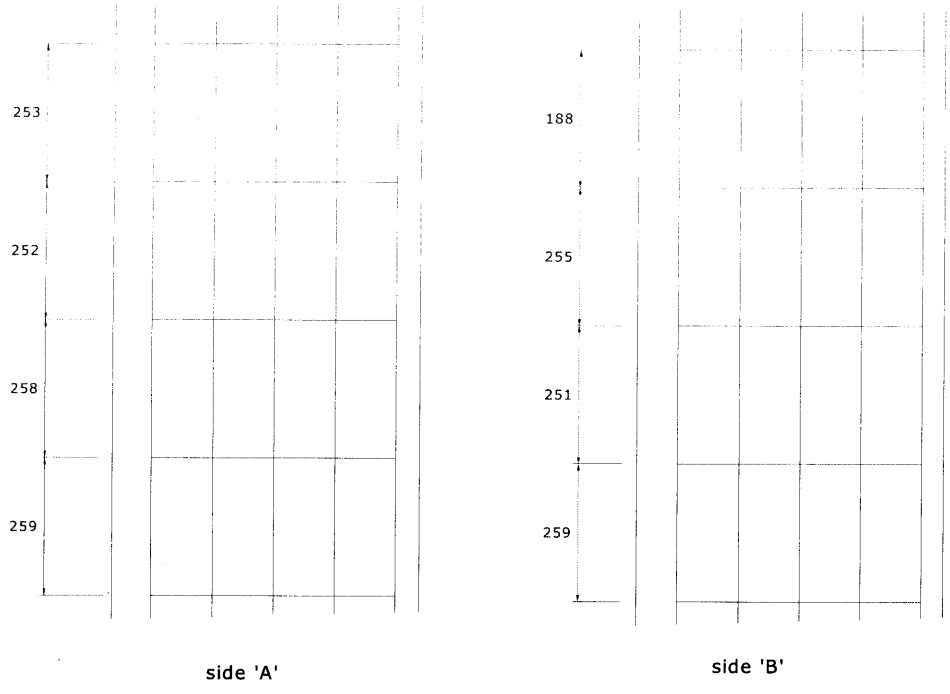
Design Section (linear dimensions are in millimeter)



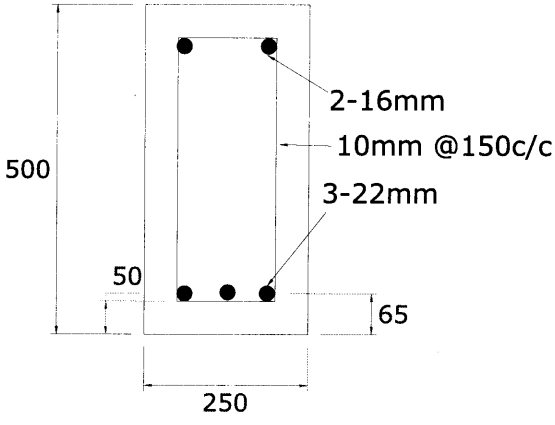
Concrete compressive strength from Schmidt Hammer Test = 20.5 MPa (3005 psi)

Observed Section (linear dimensions are in millimeter)

Observed lateral tie in the typical column (linear dimensions are in millimeter)



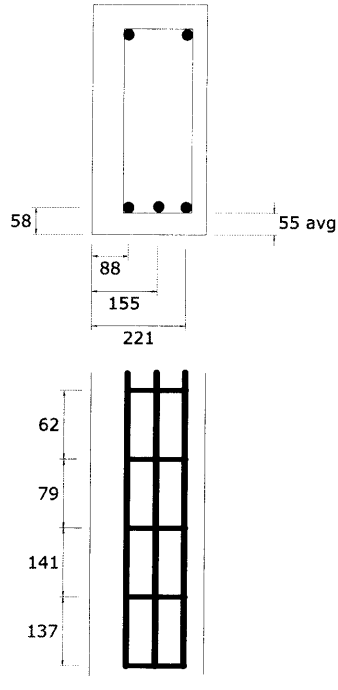
Typical Beam Section



28 days cylinder strength

= 20.0 MPa (3000 psi)

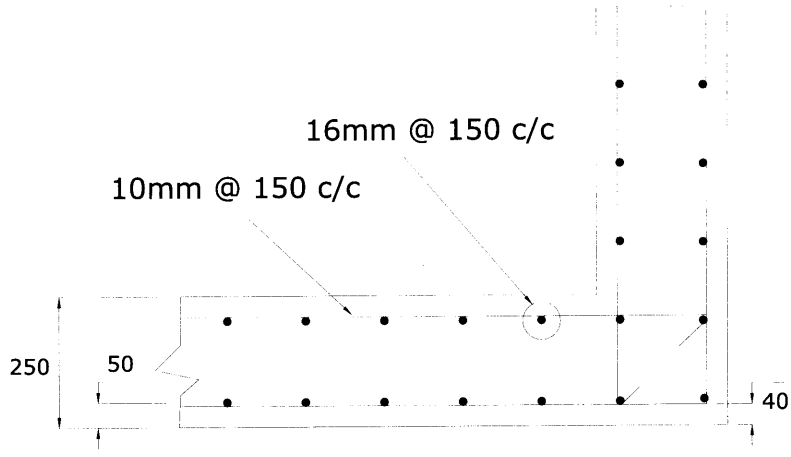
Design Section (linear dimensions are in millimeter)



Concrete compressive strength from Schmidt Hammer Test = 20.0 MPa (2917 psi)

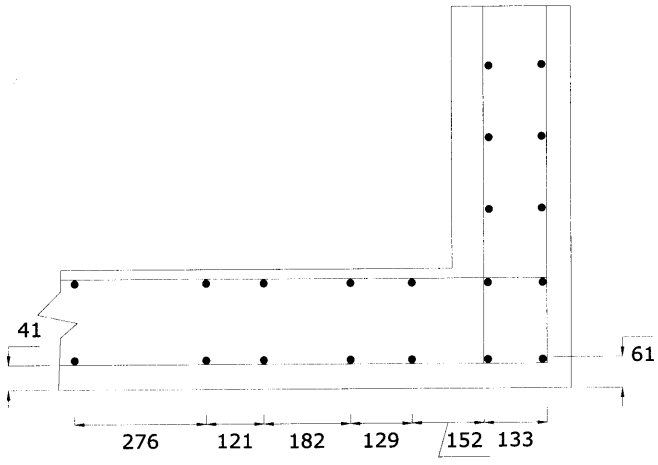
Observed Section (linear dimensions are in millimeter)

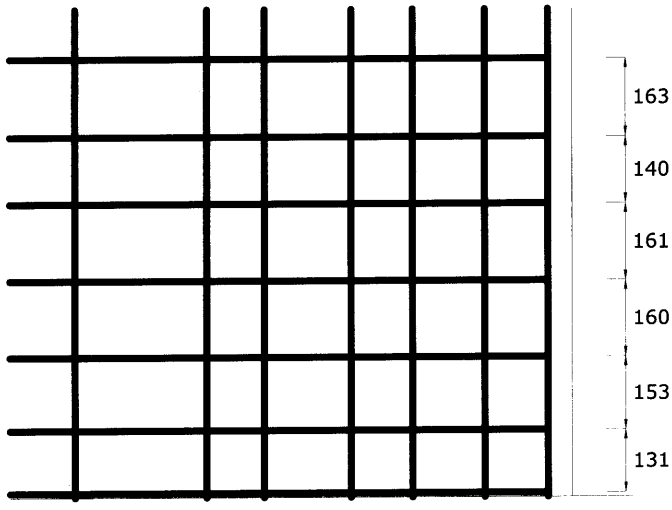
Typical Shear Wall (Lift Core) Section



28 days cylinder strength = 20.0 MPa (3000 psi)

Design Section (linear dimensions are in millimeter)





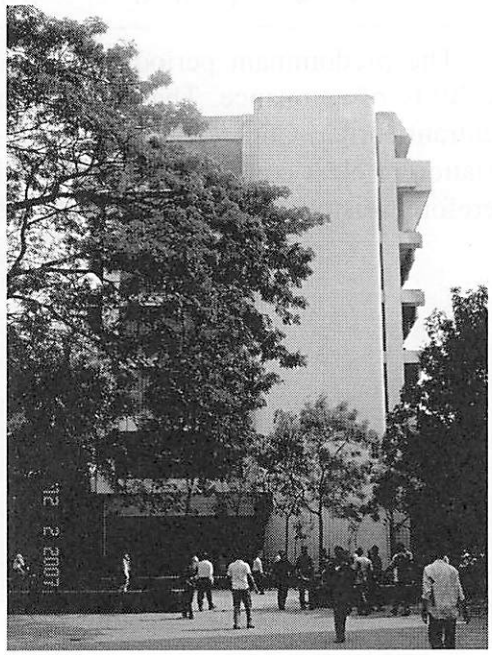
Observed Section (linear dimensions are in millimeter)

Conclusion:

Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
11-Story Tower Building	Roof	0.50	0.50	0.50	0.50	0.70	0.65
	9^{th}	0.50	0.50				
	4^{th}	0.50	0.50				

The predominant period of the building is not close to that of the soil, so there is no possibility of resonance. The building has major structural irregularities such as soft story and re-entrant corner. Concrete compressive strength from Schmidt Hammer Test is not satisfactory. Variation of clear cover from design is high. Spacing of lateral ties in column is not as per code. Therefore, seismic vulnerability condition of the building is high.

3.4.3 Civil Engineering Building



General Information:

Year of Construction: 1965
Type of Structure: Frame structure
No of story: 7
Use: Academic
Floor area: 1974 sqm/floor
Foundation: pile
Lift: yes
Stair: yes
Shear wall: yes

Structural irregularities in plan:

Torsional irregularity: no
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural irregularities in height:

Storey stiffness irregularity: yes
Storey mass irregularity: yes
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: 15.0 MPa (2183 psi)
Column: 20.0 MPa (3000 psi)
Shear wall: 10.5 MPa (1514 psi)

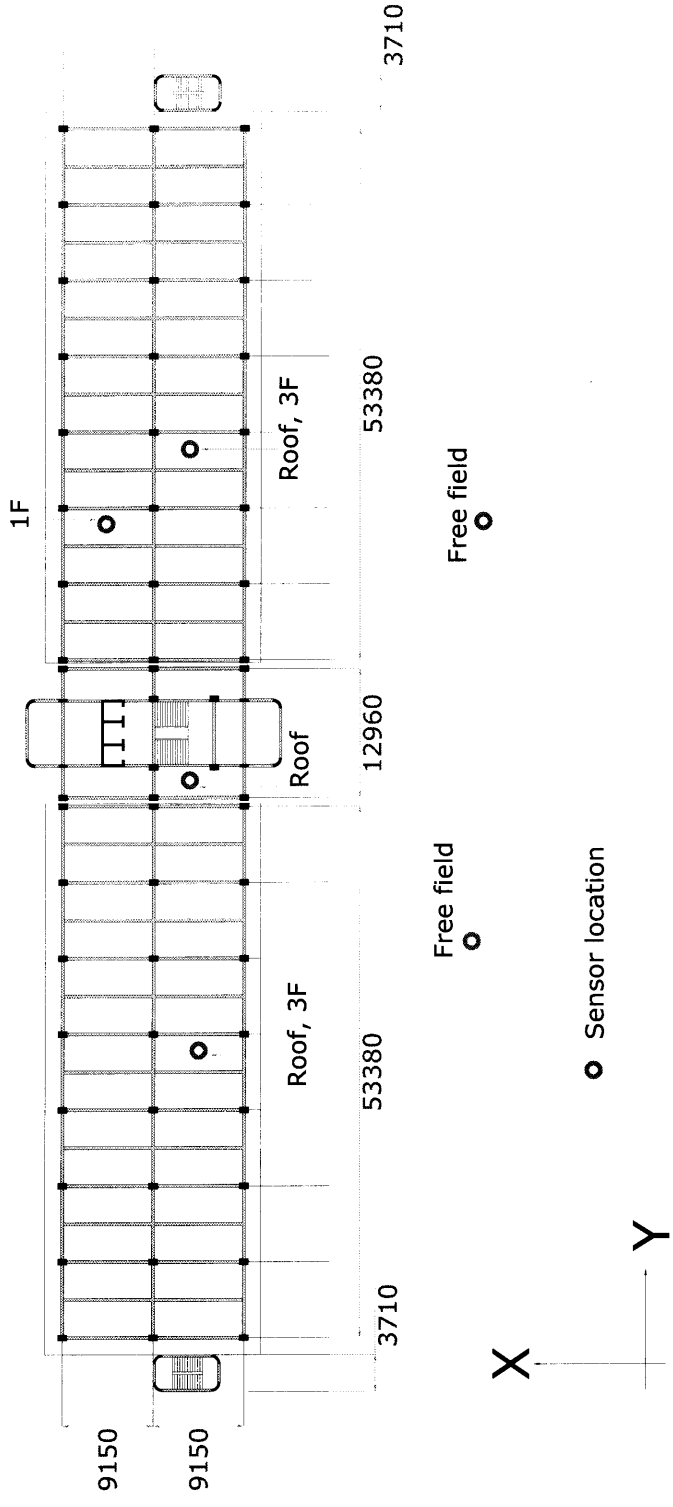
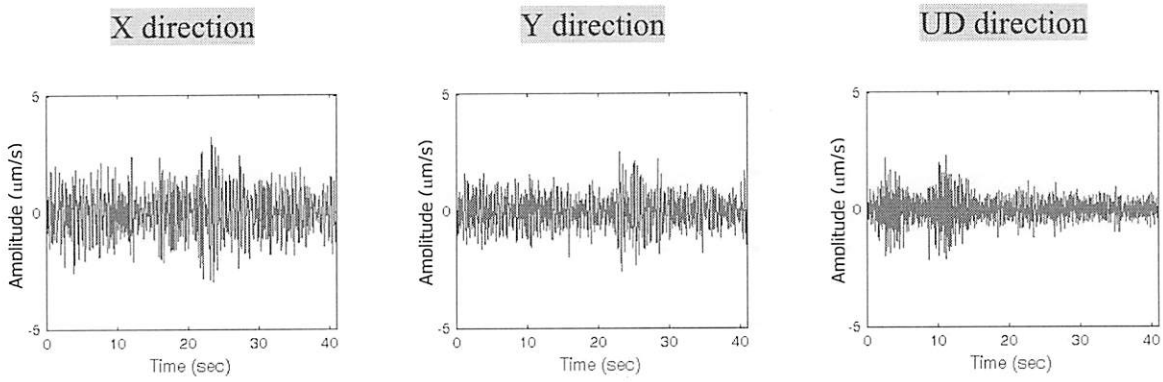
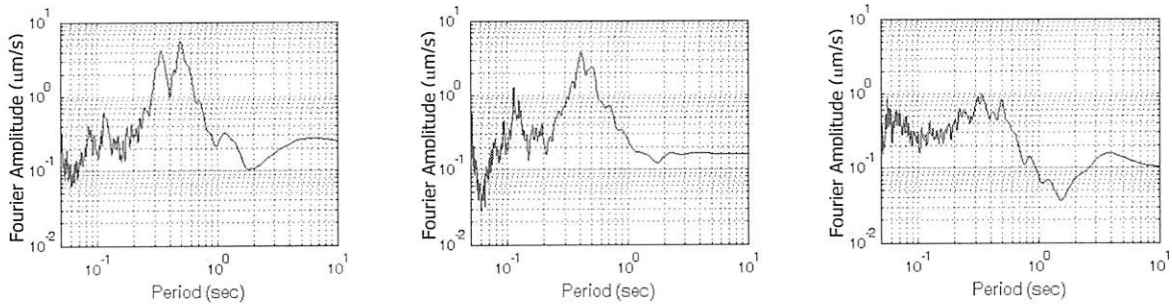


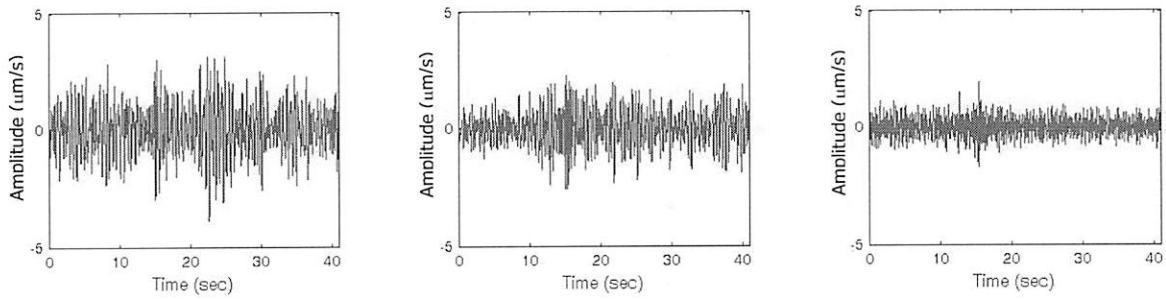
Figure 14 Civil Engineering Building Structural Element Layout (linear dimensions are in millimeter)



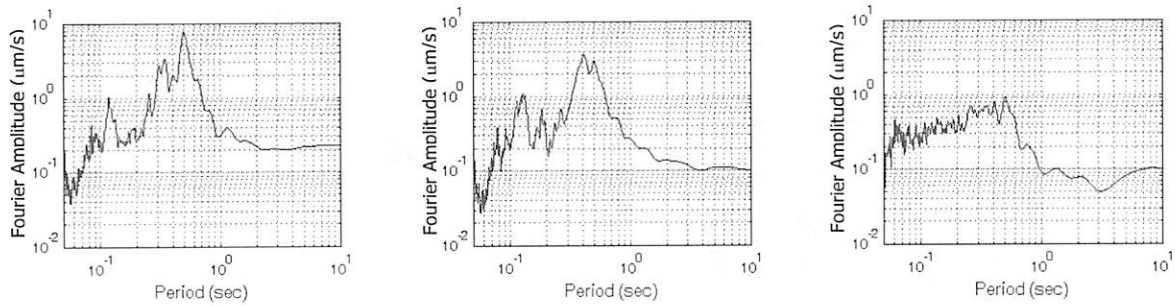
(a) Time history of Civil Engineering Building (top floor center t18)



(b) Fourier spectrum of Civil Engineering Building (top floor center t18)

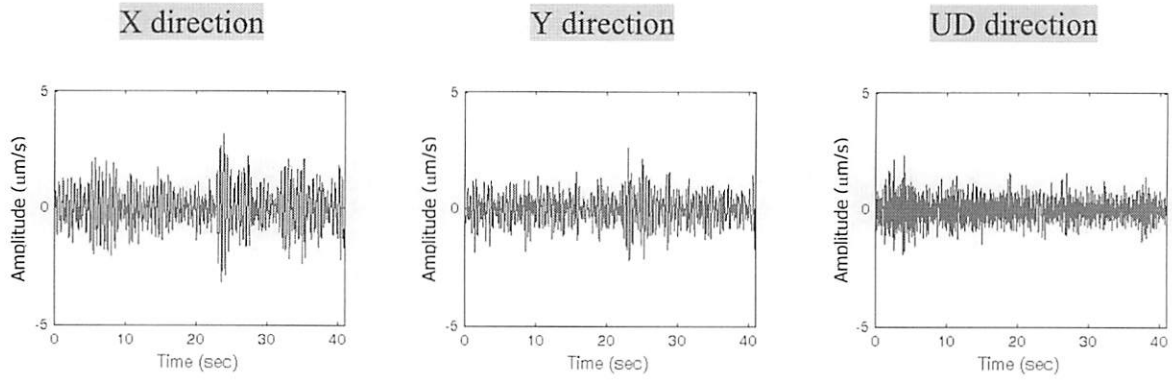


(c) Time history of Civil Engineering Building (top floor center t19)

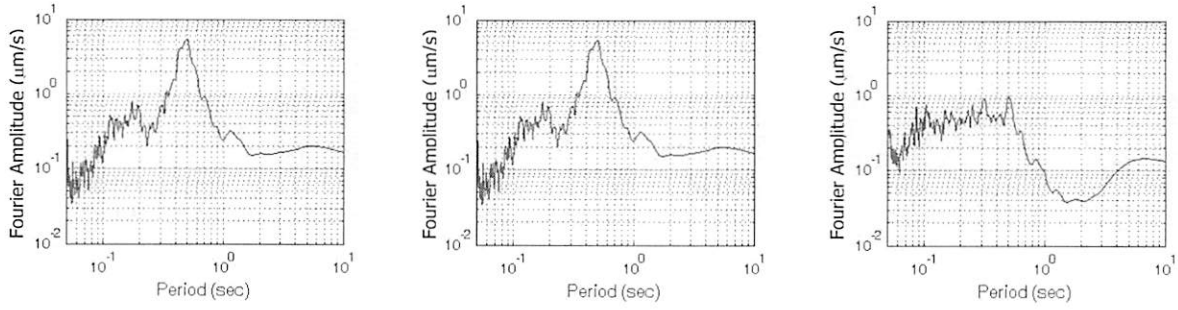


(d) Fourier spectrum of Civil Engineering Building (top floor center t19)

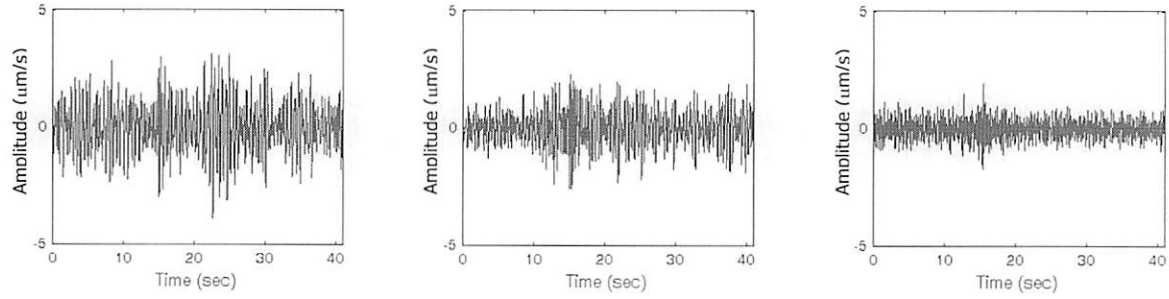
Figure 15 Time history and Fourier spectrum of Civil Engineering Building



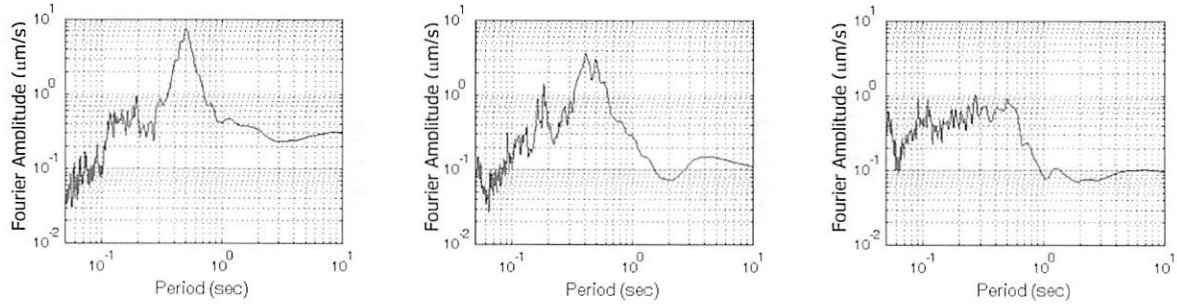
(a) Time history of Civil Engineering Building (top floor left)



(b) Fourier spectrum of Civil Engineering Building (top floor left)

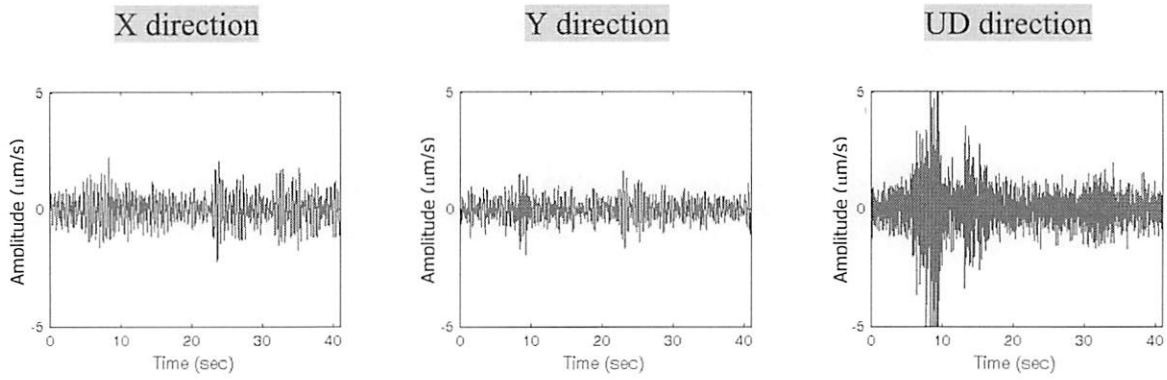


(c) Time history of Civil Engineering Building (top floor right)

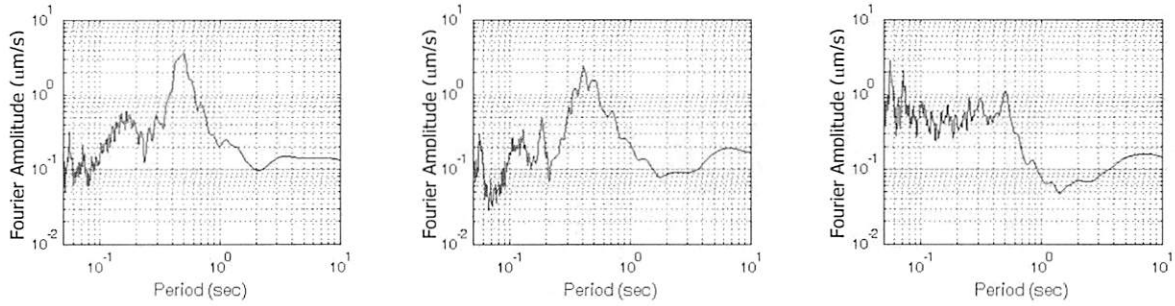


(d) Fourier spectrum of Civil Engineering Building (top floor right)

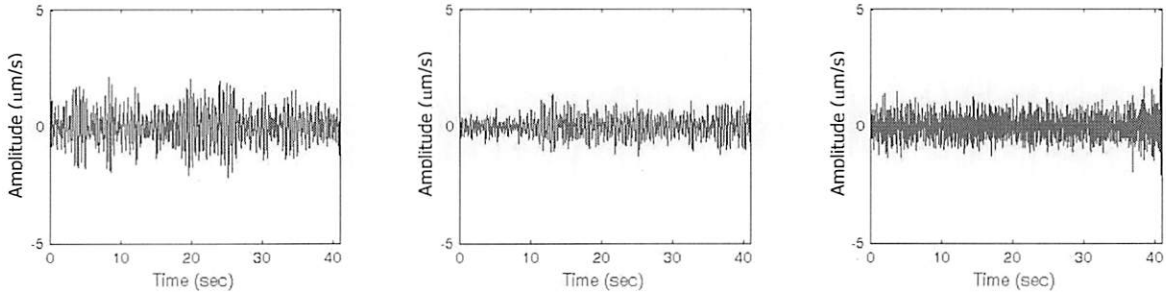
Figure 15 Time history and Fourier spectrum of Civil Engineering Building



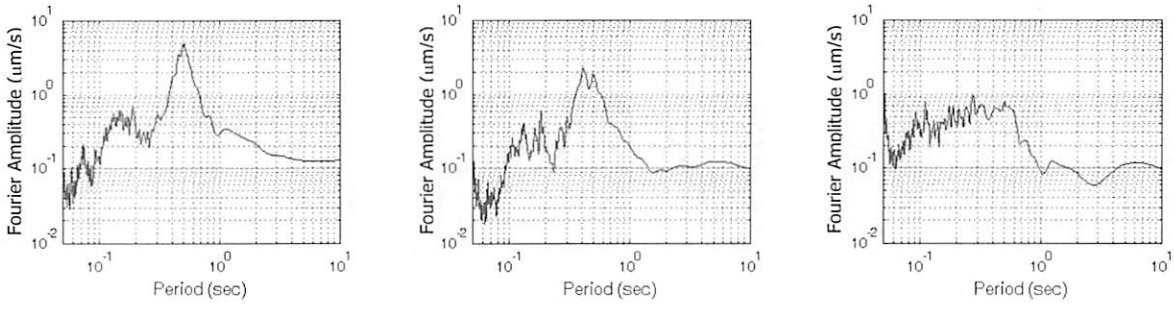
(a) Time history of Civil Engineering Building (3rd floor left)



(f) Fourier spectrum of Civil Engineering Building (3rd floor left)

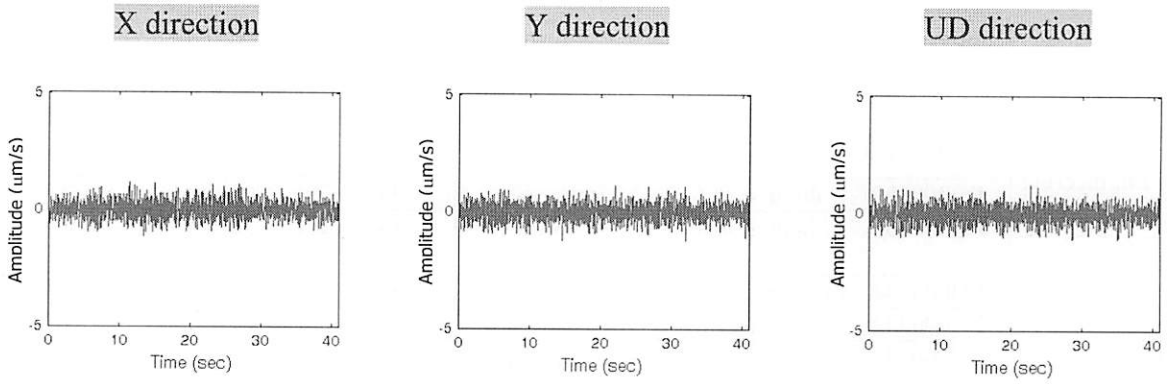


(g) Time history of Civil Engineering Building (3rd floor right)

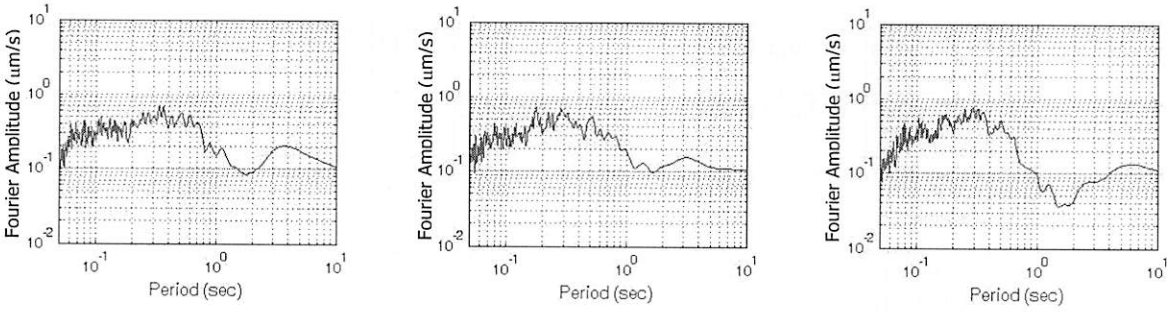


(h) Fourier spectrum of Civil Engineering Building (3rd floor right)

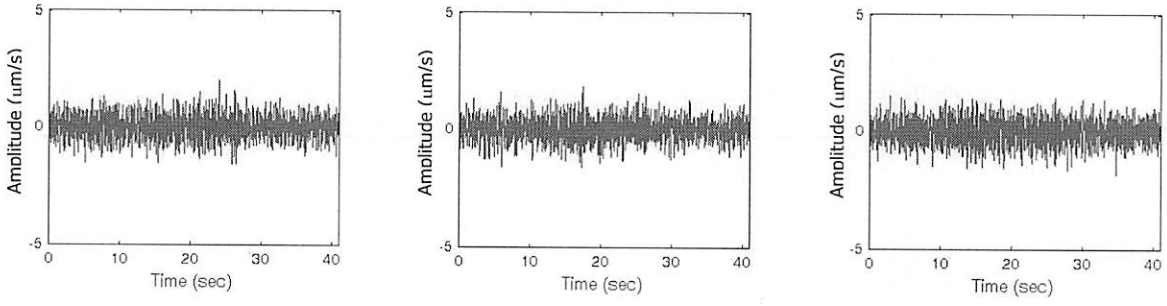
Figure 15 Time history and Fourier spectrum of Civil Engineering Building



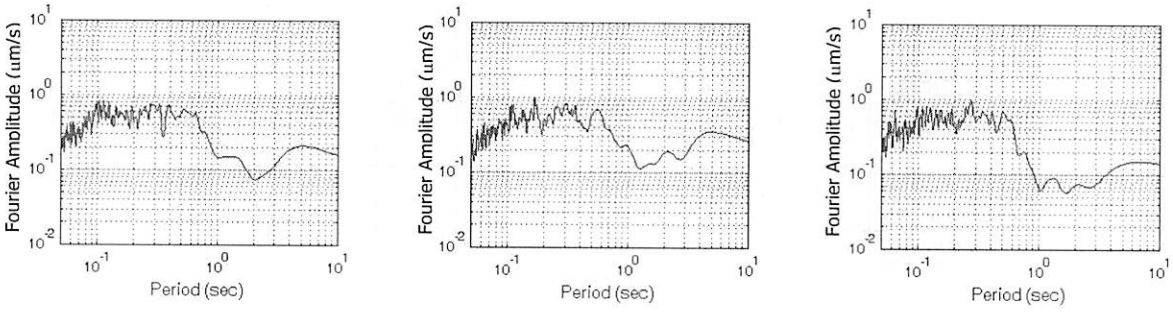
(a) Time history of free field near Civil Engineering Building (t18)



(f) Fourier spectrum of free field near Civil Engineering Building (t18)



(g) Time history of free field near Civil Engineering Building (t19)



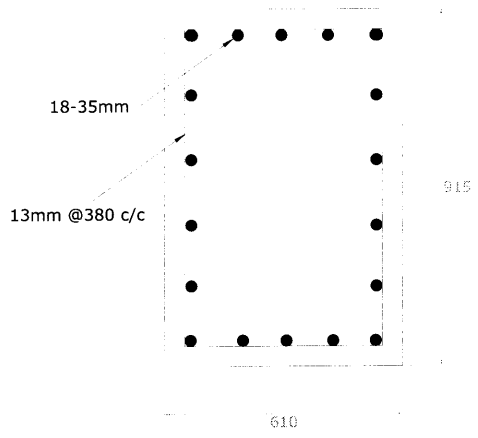
(h) Fourier spectrum of free field near Civil Engineering Building (t19)

Figure 15 Time history and Fourier spectrum of Civil Engineering Building

Data Analysis

Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max[m]	Min[m]	Mean	Std-Dev	
Civil Engineering Building.	FQ000228	Column (Gr.)	Main Bar(L)	10	35	76	67	85	5	M
	FQ000229	Column (Gr.)	Main Bar(S)	4	35	70	60	65	5	M
	FQ000230	Column (Gr.)	Shear Reinforcement	3	13	52	50	50	1	M
	FQ000231	Column (Gr.)	Main Bar(S)	5	35	63	44	52	7	M
	FQ000232	Column (Gr.)	Main Bar(S)	5	35	63	44	52	7	M
	FQ000233	Column (Gr.)	Main Bar(L)	6	35	76	57	67	8	M
	FQ000234	Column (Gr.)	Shear Reinforcement	5	13	46	27	38	8	M
	FQ000235	Column (Gr.)	Shear Reinforcement	6	13	70	63	65	2	M
	FQ000236	Column (Gr.)	Shear Reinforcement	5	13	67	16	30	21	M
	FQ000237	Column (Gr.)	Shear Reinforcement	2	13	34	32	33	1	M
	FQ000238	Beam (Gr.)	Main Bar	3	25	59	20	42	20	M
	FQ000239	Beam (Gr.)	Shear Reinforcement	5	13	92	65	83	11	M
	FQ000240	Beam (Gr.)	Main Bar	1	25	54	54	54	0	M
	FQ000241	Slab(Gr.)		7	13	45	31	39	5	M
	FQ000243	Slab(Gr.)		5	25	67	19	42	18	M
	FQ000244	Beam (Gr.)	Main Bar	3	32	75	15	49	31	M
	FQ000245	Beam (Gr.)	Shear Reinforcement	10	13	65	27	42	12	M
	FQ000247	Column (5th)	Main Bar(S)	3	25	57	51	54	3	M
	FQ000248	Column (5th)	Shear Reinforcement	4	10	72	38	48	16	M
	FQ000249	Beam(5th)	Main Bar	2	25	58	56	57	1	M
	FQ000250	Beam(5th)	Shear Reinforcement	4	10	59	54	56	2	M
	FQ000251	Beam(5th)	Main Bar	4	25	52	41	46	5	M
	FQ000252	Beam(5th)	Shear Reinforcement	4	10	33	23	28	4	M
	FQ000253	Lift Core (Gr.)	Vertical (Left Side)	15	25	86	37	49	14	M
	FQ000254	Lift Core (Gr.)	Vertical (Front Side)	7	25	62	23	40	16	M
	FQ000255	Lift Core (Gr.)	Horizontal	6	10	70	43	50	11	M
	FQ000256	Lift Core (5th)	Vertical (Left Side)	15	25	55	32	48	6	M
	FQ000257	Lift Core (5th)	Vertical (Front Side)	6	25	53	30	40	9	M
	FQ000258	Lift Core (5th)	Horizontal	7	10	102	56	64	11	M

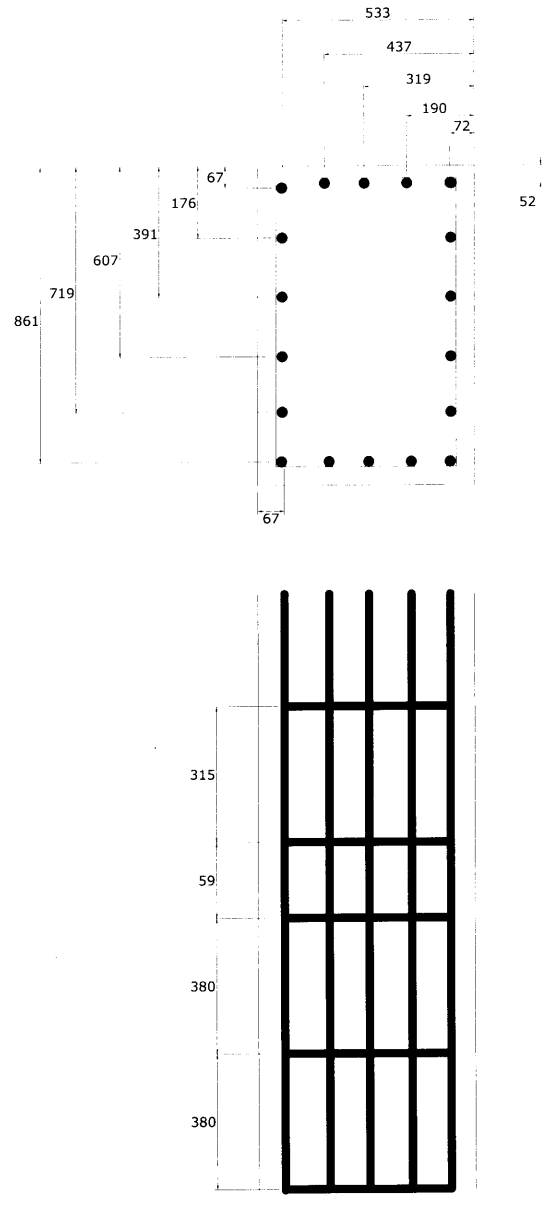
Typical Column Section



28 days cylinder strength

= 20.0 MPa (3000 psi)

Design Section (linear dimensions are in millimeter)

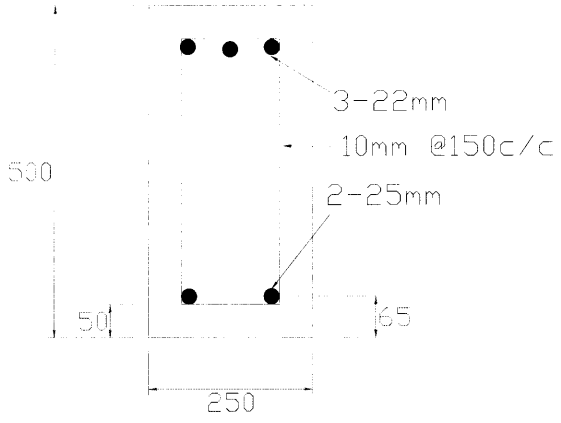


Concrete compressive strength from Schmidt Hammer Test

= 20.0 MPa (3000 psi)

Observed Section (linear dimensions are in millimeter)

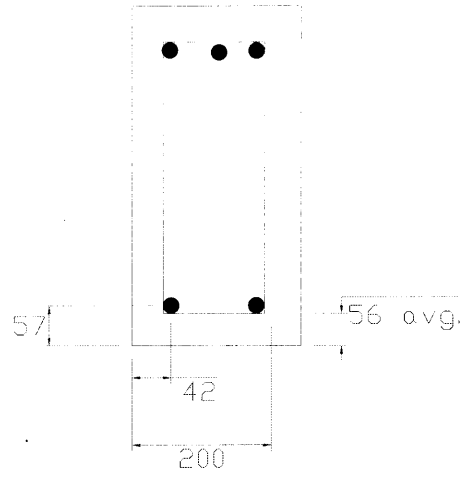
Typical Beam Section

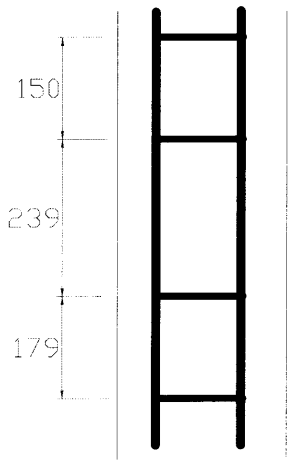


28 days cylinder strength

= 14.0 MPa (2000 psi)

Design Section (linear dimensions are in millimeter)

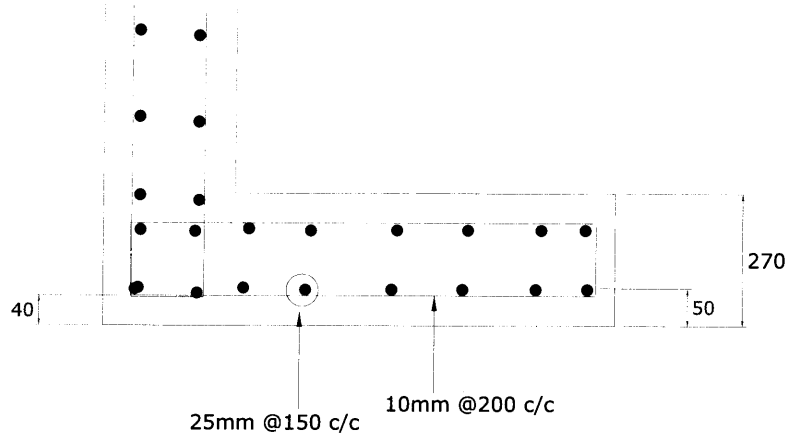




Concrete compressive strength from Schmidt Hammer Test = 15.0 MPa (2183 psi)

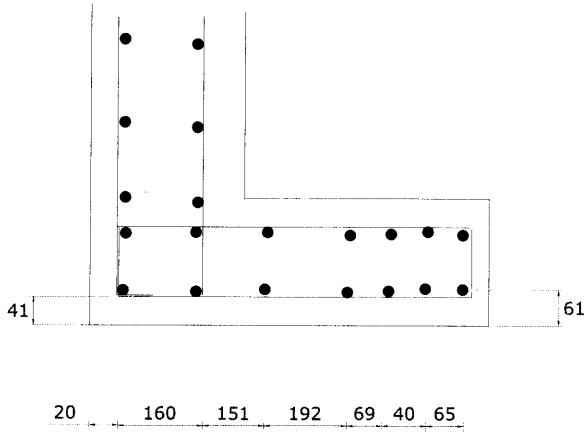
Observed Section (linear dimensions are in millimeter)

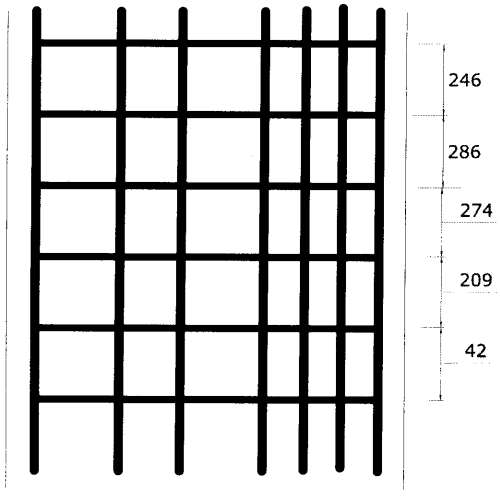
Typical Shear Wall (Lift Core) Section



28 days cylinder strength = 14.0 MPa (2000 psi)

Design Section (linear dimensions are in millimeter)





Concrete compressive strength from Schmidt Hammer Test = 10.5 MPa (1514 psi)

Observed Section (linear dimensions are in millimeter)

Conclusion:

Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Civil Engineering Building	Roof middle	0.50	0.40	0.50	0.40	0.30	0.30
	Roof middle	0.50	0.40				
	Roof left	0.50	0.40	0.50	0.40		
	3rd left	0.50	0.40				
	Roof right	0.50	0.40	0.50	0.40		
	3rd right	0.50	0.40				

The predominant period of the building is not close to that of the soil, so there is no possibility of resonance. The building has major structural irregularities such as mass discontinuity and stiffness irregularity. Concrete compressive strength from Schmidt Hammer Test is not satisfactory. Variation of clear cover from design is high. Seismic vulnerability condition of the building is moderate.

3.4.4 EME Building

General Information:

Year of Construction: 1965
Type of Structure: Frame structure
No of story: 6
Use: Academic
Floor area: 1973 sqm/floor
Foundation: pile
Lift: yes
Stair: yes
Shear wall: yes

Structural irregularities in plan:

Torsional irregularity: no
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural irregularities in height:

Storey stiffness irregularity: yes
Storey mass irregularity: yes
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: 16.5 MPa (2412 psi)
Column: 27.0 MPa (3894 psi)
Shear wall: 17.5 MPa (2566 psi)

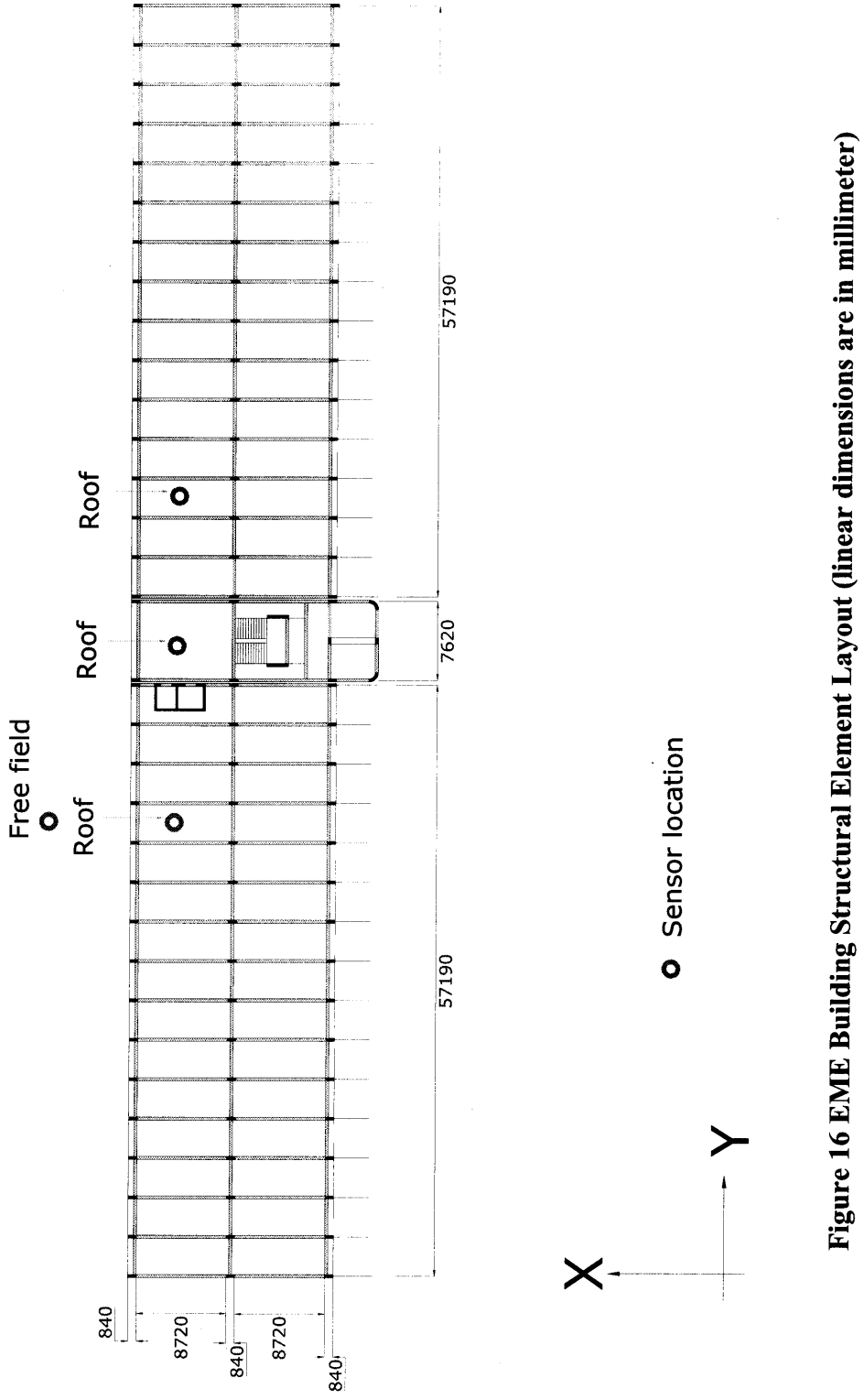
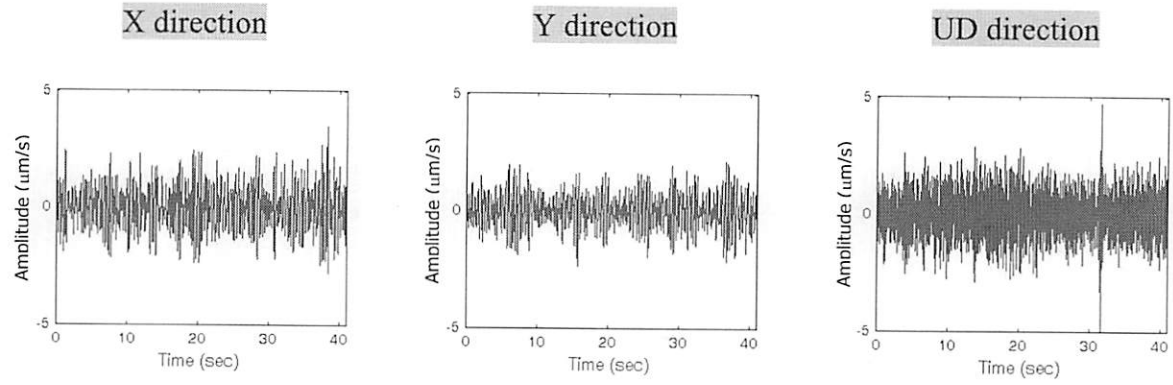
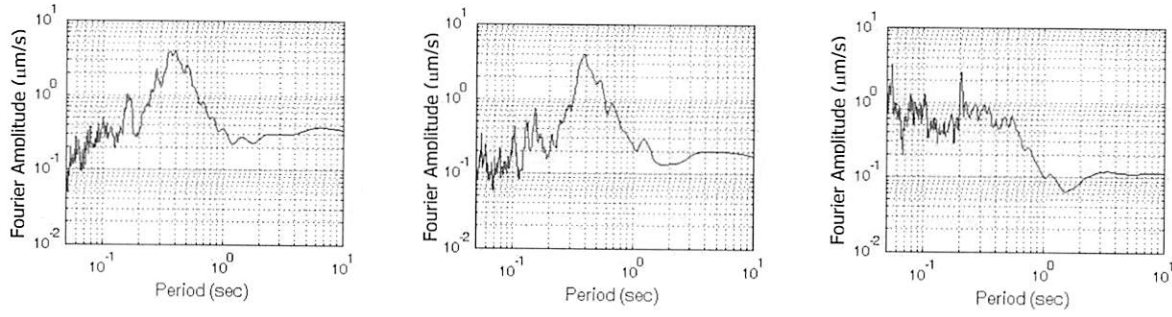


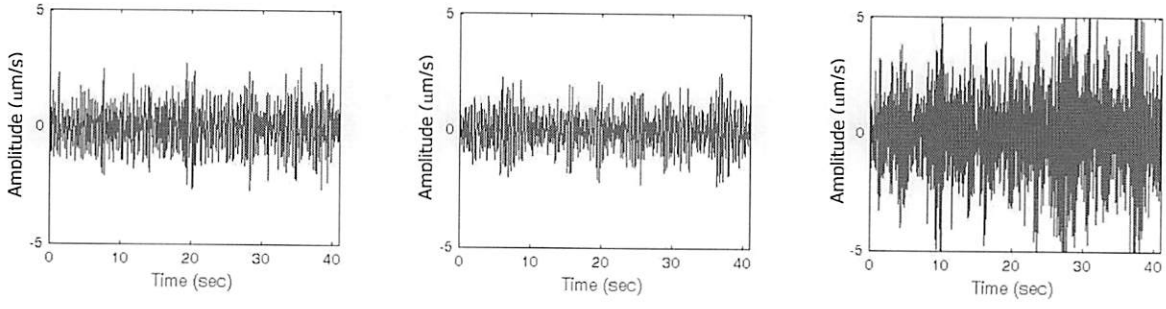
Figure 16 EME Building Structural Element Layout (linear dimensions are in millimeter)



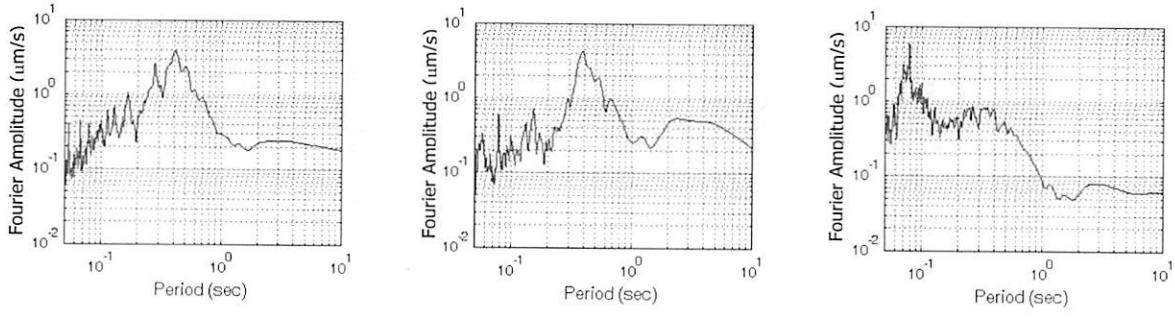
(a) Time history of EME Building (top floor right)



(b) Fourier spectrum of EME Building (top floor right)

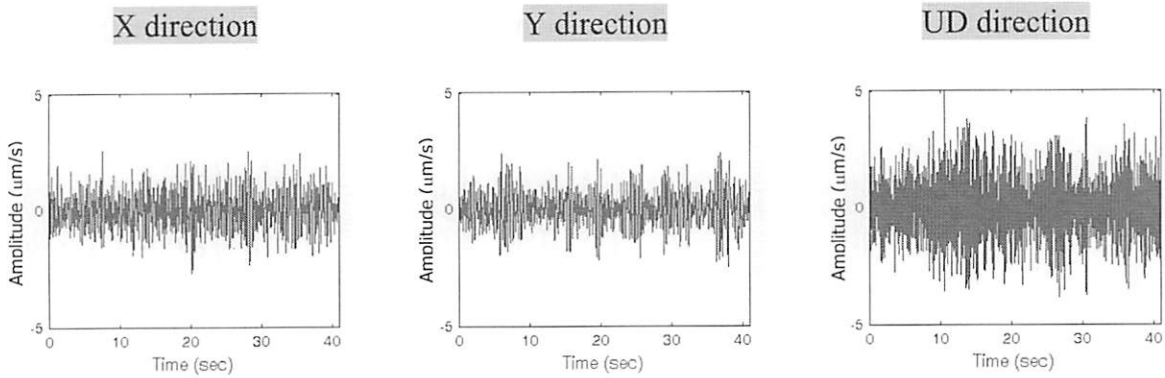


(c) Time history of EME Building (top floor left)

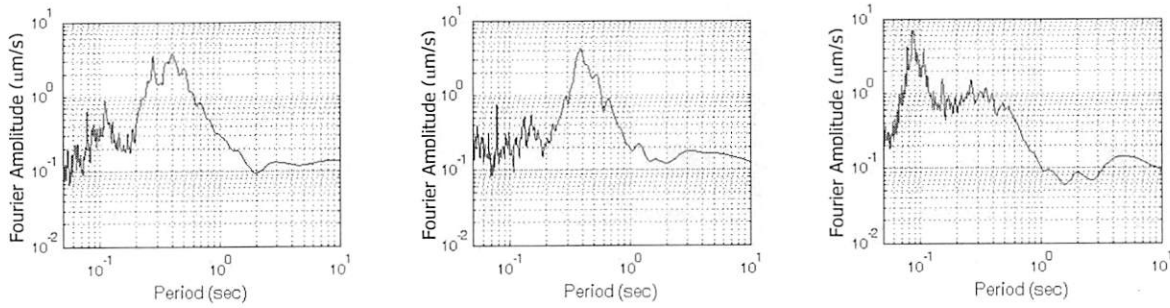


(d) Fourier spectrum of EME Building (top floor left)

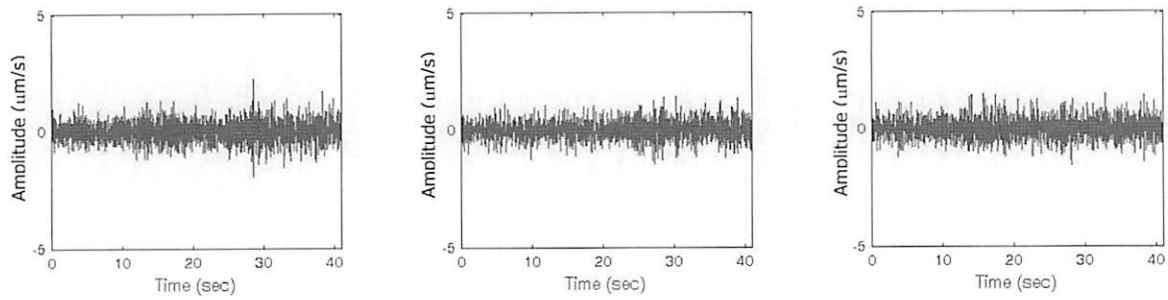
Figure 17 Time history and Fourier spectrum of EME Building



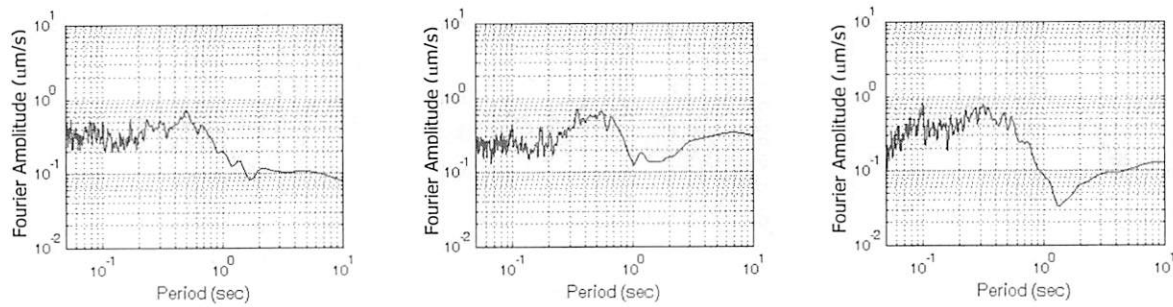
(a) Time history of EME Building (top floor center)



(f) Fourier spectrum of EME Building (top floor center)



(g) Time history of free field near EME Building



(h) Fourier spectrum of free field near EME Building

Figure 17 Time history and Fourier spectrum of EME Building

Reinforcement Detection

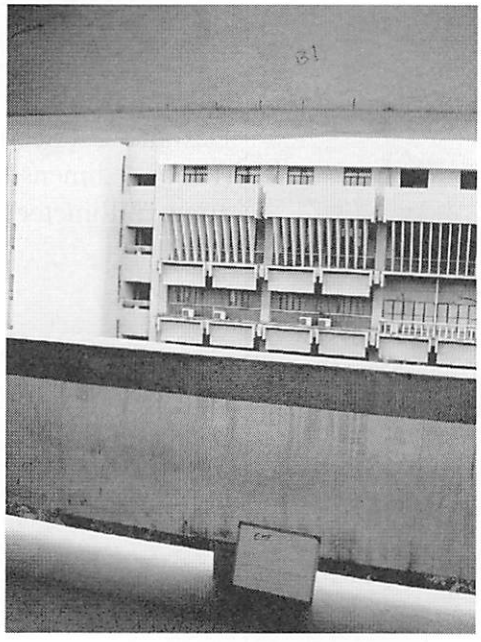


Figure 18(a) Detection of beam reinforcement at EME building

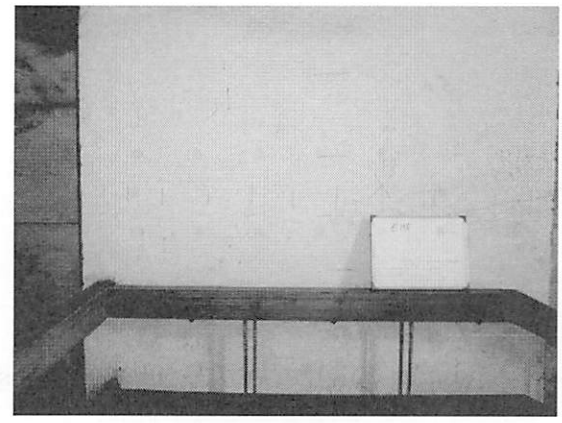
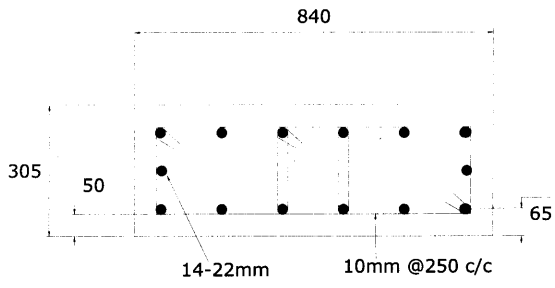


Figure 18(b) Detection of column reinforcement at the 6th floor of EME building.

Data Analysis

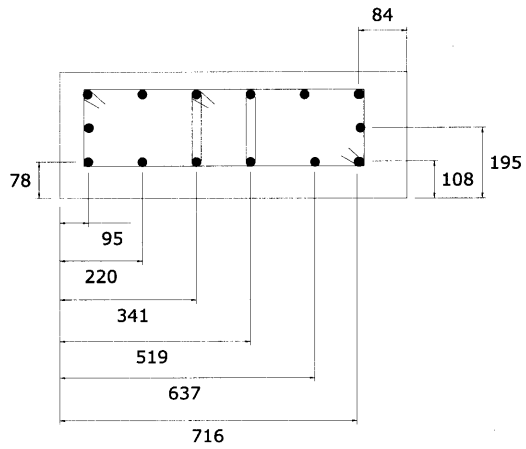
Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max[m]	Min[m]	Mean	Std-Dev	
EME Building.	FQ000259	Column (Gr.)	Main Bar (S)	3	25	84	71	77	7	M
	FQ000260	Column (Gr.)	Main Bar (L)	6	25	94	65	78	11	M
	FQ000261	Column (Gr.)	Shear Reinforcement	6	10	90	33	59	20	M
	FQ000262	Column (5^{th})	Main Bar (L)	4	25	87	77	83	5	M
	FQ000263	Column (5^{th})	Shear Reinforcement	5	10	66	45	58	8	M
	FQ000264	Shear Wall (5^{th})	Vertical	12	13	60	41	52	6	M
	FQ000265	Shear Wall (5^{th})	Horizontal	3	10	47	44	45	2	M
	FQ000266	Beam(5^{th})	Main Bar	4	19	48	19	36	13	M
	FQ000267	Beam(5^{th})	Shear Reinforcement	4	10	48	43	45	2	M
	FQ000268	Lift Core (Gr.)	Vertical	8	13	87	25	53	25	M
	FQ000269	Lift Core (Gr.)	Horizontal	4	10	119	74	77	3	M
	FQ000270	Shear Wall (Gr.)	Vertical	11	13	72	67	69	2	M
	FQ000271	Shear Wall (Gr.)	Horizontal	6	10	141	58	68	15	M
	FQ000272	Shear Wall (Gr.)	Vertical	2	13	78	77	77	1	M
	FQ000273	Column (Gr.)	Main Bar (L)	8	32	126	72	77	5	M
	FQ000274	Column (Gr.)	Main Bar (S)	3	32	97	87	92	5	M
	FQ000275	Column (Gr.)	Shear Reinforcement	5	10	76	56	67	8	M

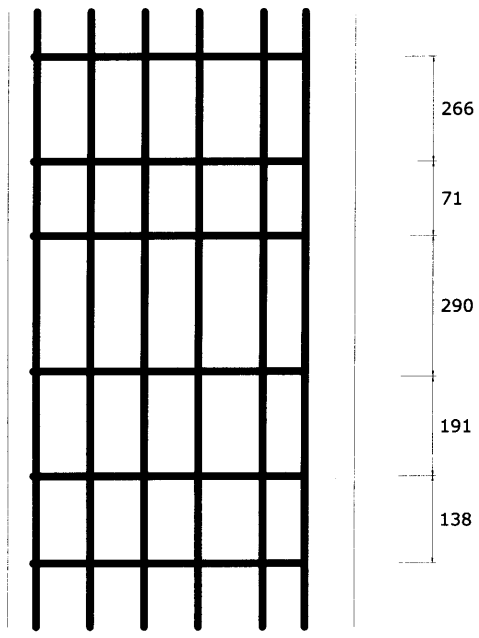
Typical Column Section



28 days cylinder strength = 20.0 MPa (3000 psi)

Design Section (linear dimensions are in millimeter)

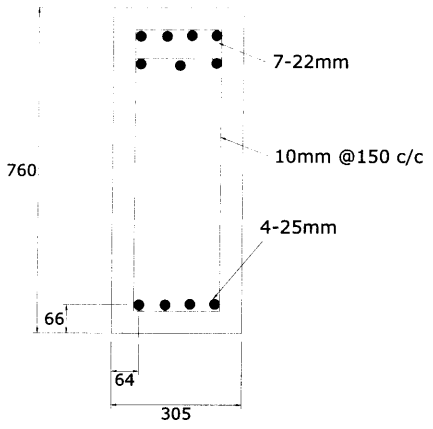




Concrete compressive strength from Schmidt Hammer Test = 27.0 MPa (3894 psi)

Observed Section (linear dimensions are in millimeter)

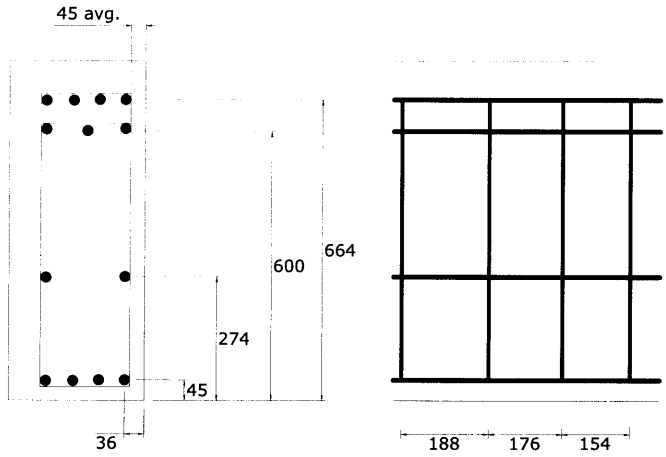
Typical Beam Section



28 days cylinder strength

= 14.0 MPa (2000 psi)

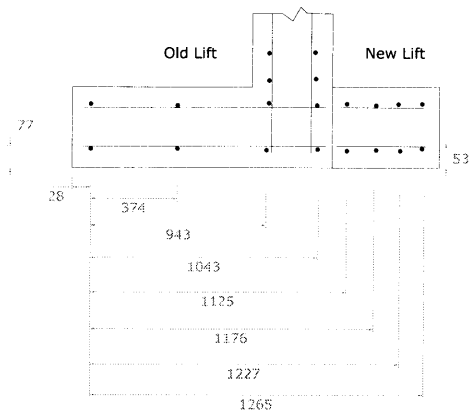
Design Section (linear dimensions are in millimeter)

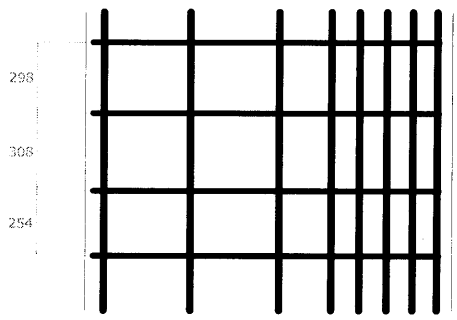


Concrete compressive strength from Schmidt Hammer Test = 16.5 MPa (2412 psi)

Observed Section (linear dimensions are in millimeter)

Typical Shear Wall (Lift Core) Section





Concrete compressive strength from Schmidt Hammer Test = 17.5 MPa (2566 psi)

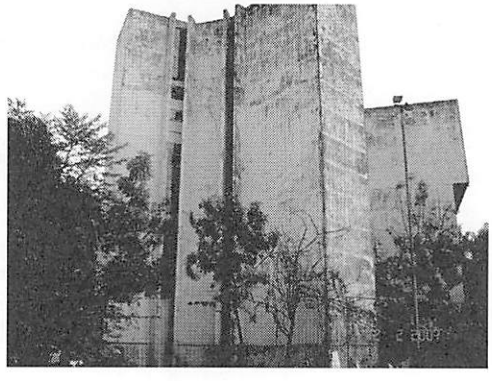
Observed Section (linear dimensions are in millimeter)

Conclusion:

Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
EME Building	Roof right	0.40	0.39	0.40	0.39	0.50	0.33
	Roof left	0.40	0.39	0.40	0.39		
	Roof middle	0.40	0.39	0.40	0.39		

The predominant period of the building is not close to that of the soil, so there is not possibility of resonance. Concrete compressive strength from Schmidt Hammer Test is satisfactory. The building has major structural irregularities such as mass discontinuity and stiffness irregularity. Variation of clear cover from design is high. Seismic vulnerability condition of the building is moderate.

3.4.5 Library Building



General Information:

Year of Construction: 1973
Type of Structure: Frame structure
No of story: 4
Use: Academic
Floor area: 741sqm/floor
Foundation: Footing, pile
Lift: yes
Stair: yes
Shear wall: yes

Structural irregularities in plan:

Torsional irregularity: no
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: yes

Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: Not available
Column: 11.5 MPa (1670 psi)
Shear wall:10.0 MPa (1419 psi)

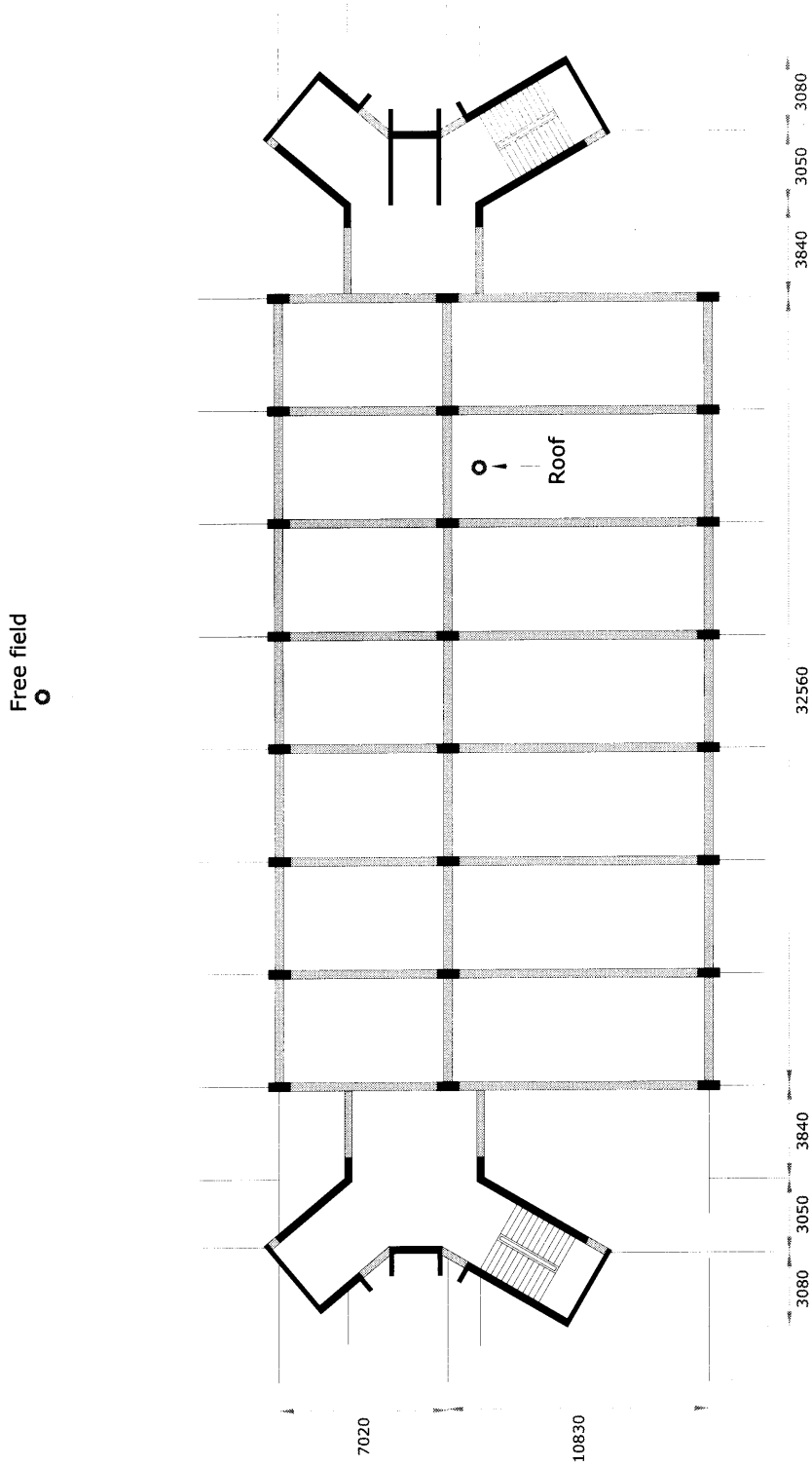
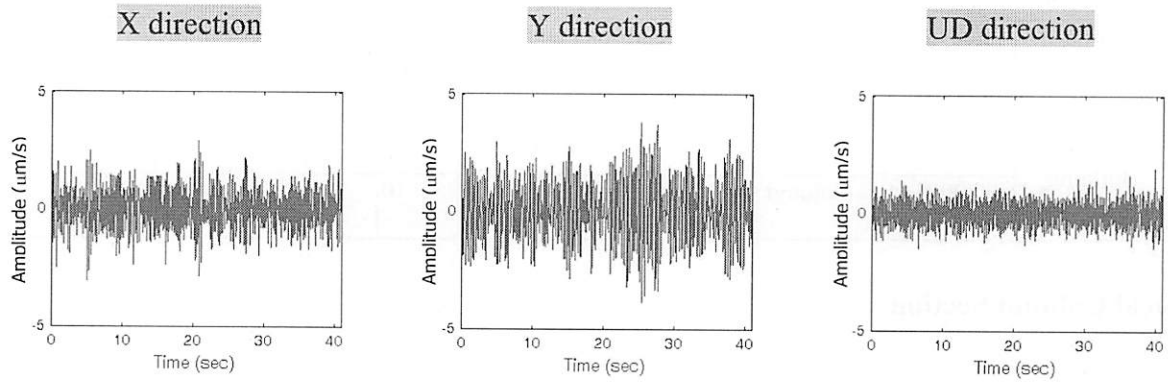
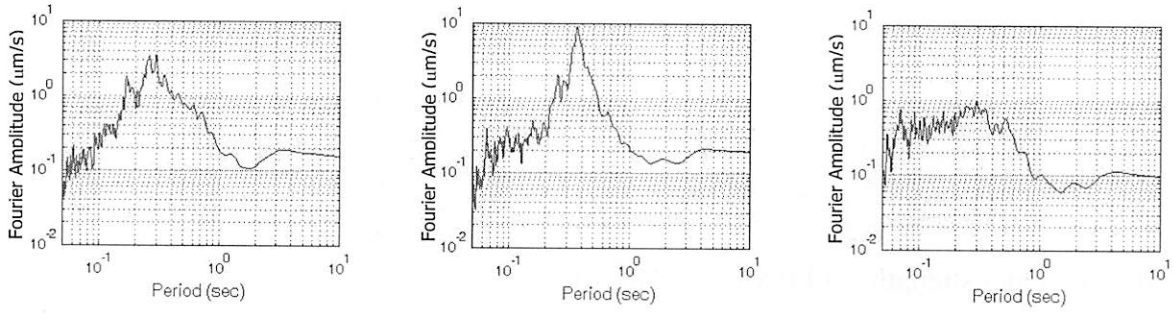


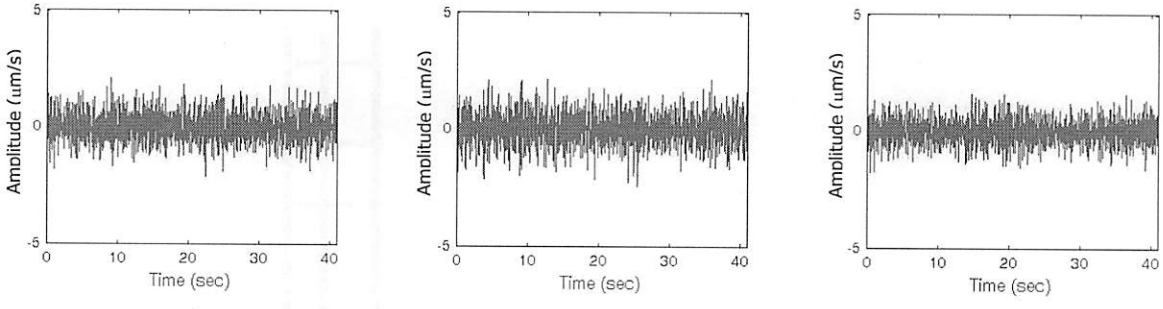
Figure 19 Library Building Structural Element Layout (linear dimensions are in millimeter)



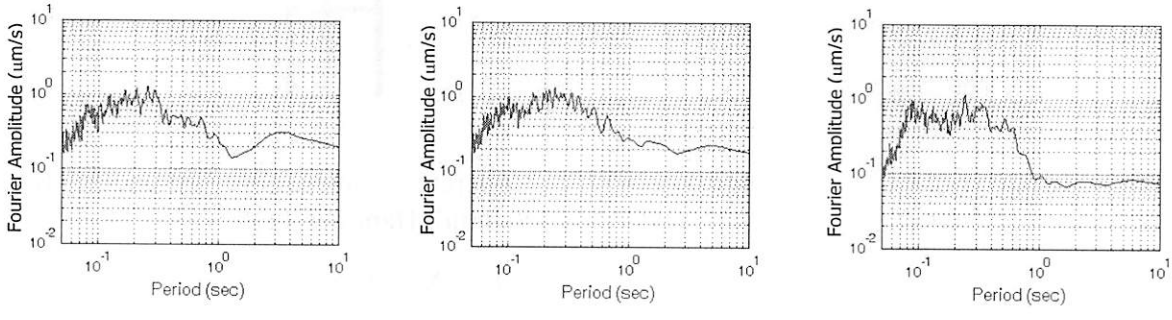
(a) Time history of Library Building (top floor)



(f) Fourier spectrum of Library Building (top floor)



(g) Time history of free field near Library Building and Architecture Building



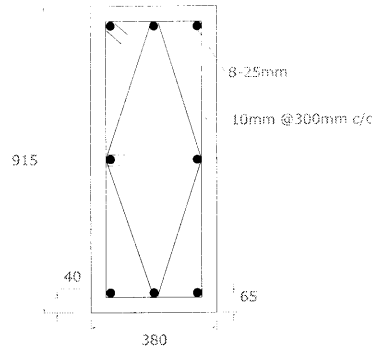
(h) Fourier spectrum of free field near Library Building and Architecture Building

Figure 20 Time history and Fourier spectrum of Library Building

Data Analysis

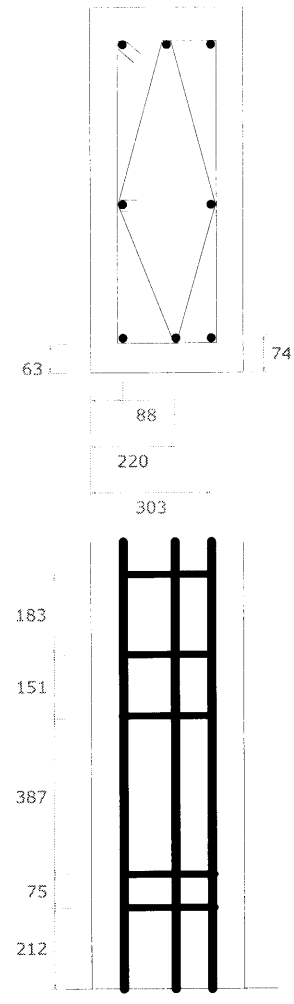
Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max[m]	Min[m]	Mean	Std-Dev	
Library Building.	FQ000343	Column (Gr.)	Main Bar	3	25	74	56	74	14	M
	FQ000344	Column (Gr.)	Shear Reinforcement	5	10	100	47	63	23	M

Typical Column Section



28 days cylinder strength = 14.0 MPa (2000 psi)

Design Section (linear dimensions are in millimeter)



Concrete compressive strength from Schmidt Hammer Test

= 11.5 MPa (1670 psi)

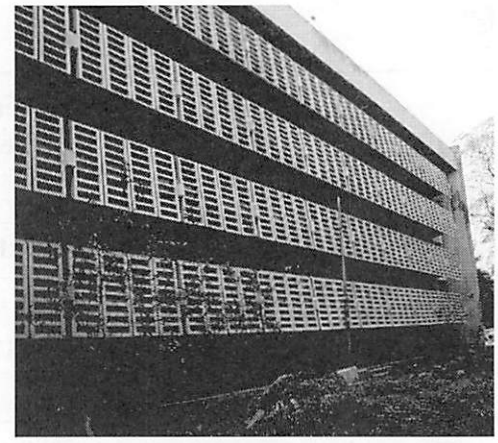
Observed Section (linear dimensions are in millimeter)

Conclusion:

Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Library Building	Roof	0.26	0.37	0.26	0.37	0.25	0.26

The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified. The building has no major structural irregularities. Concrete compressive strength from Schmidt Hammer Test is not satisfactory. Variation of clear cover from design is high. Seismic vulnerability condition of the building is moderate.

3.4.6 Architecture Building



General Information:

Year of Construction: 1968
Type of Structure: Frame structure
No of story: 5
Use: Academic
Floor area: 1200 sqm
Foundation: Footing, pile
Lift: yes
Stair: yes
Shear wall: yes

Structural irregularities in plan:

Torsional irregularity: no
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: yes
Nonparallel system: yes

Structural irregularities in height:

Storey stiffness irregularity: yes
Storey mass irregularity: yes
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: 32.5 MPa (4746 psi)
Column: 17.0 MPa (2507 psi)
Shear wall: 22.0 MPa (3216 psi)

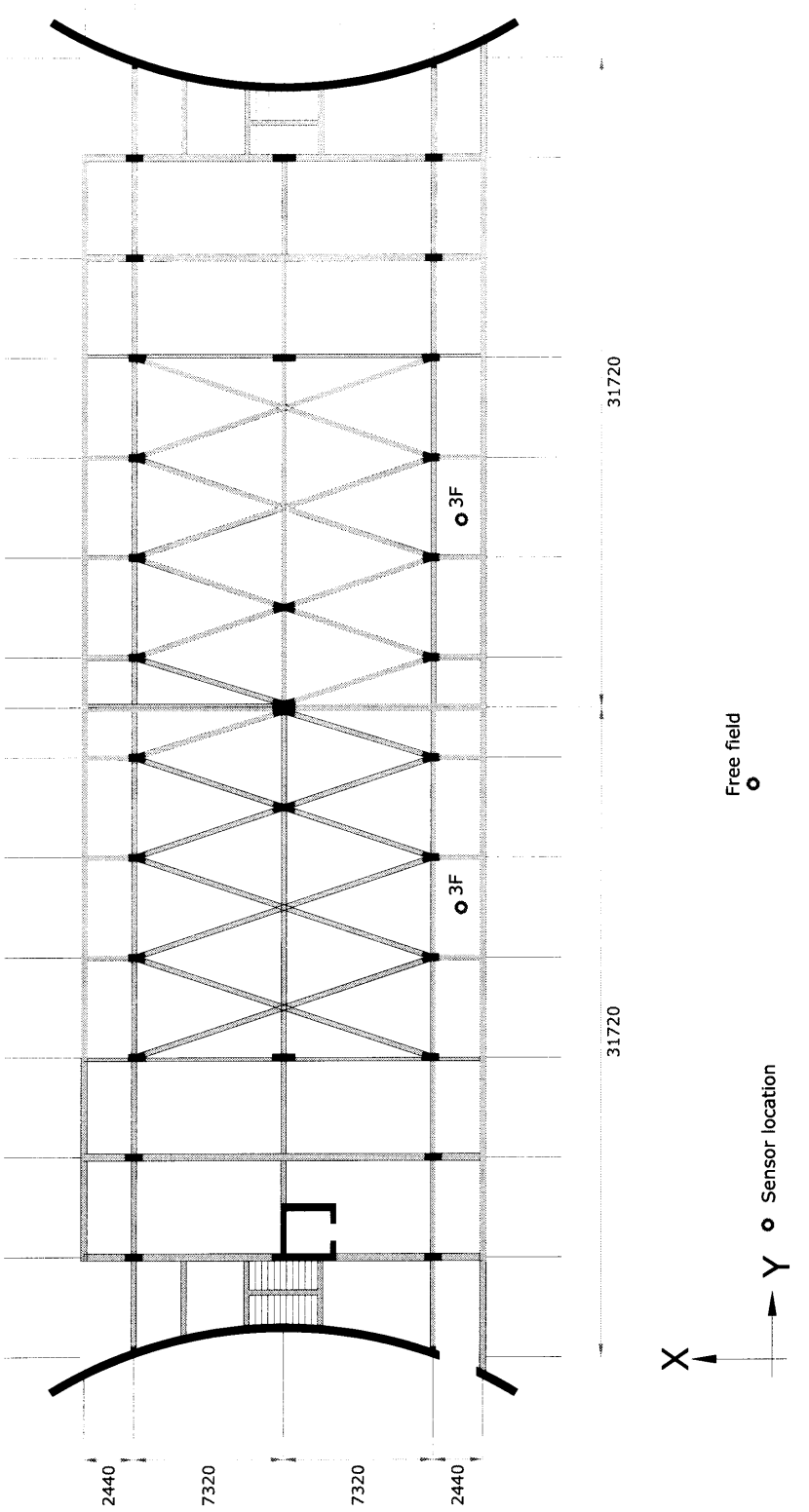
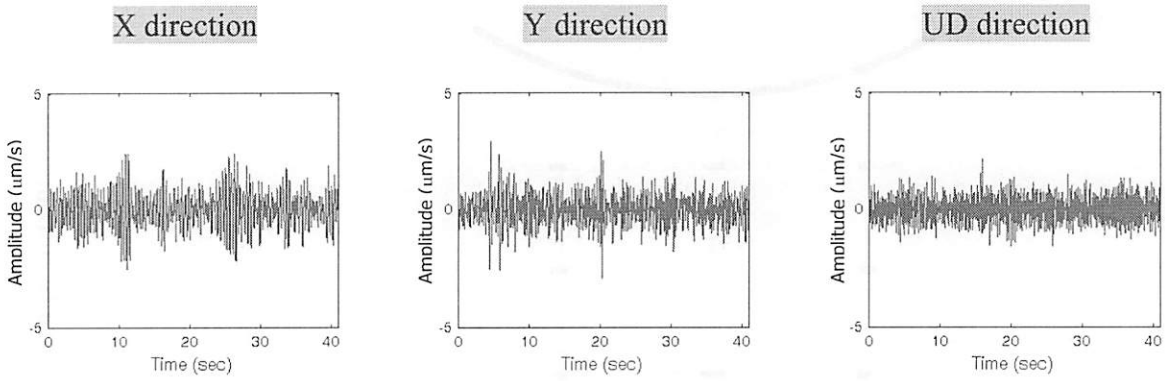
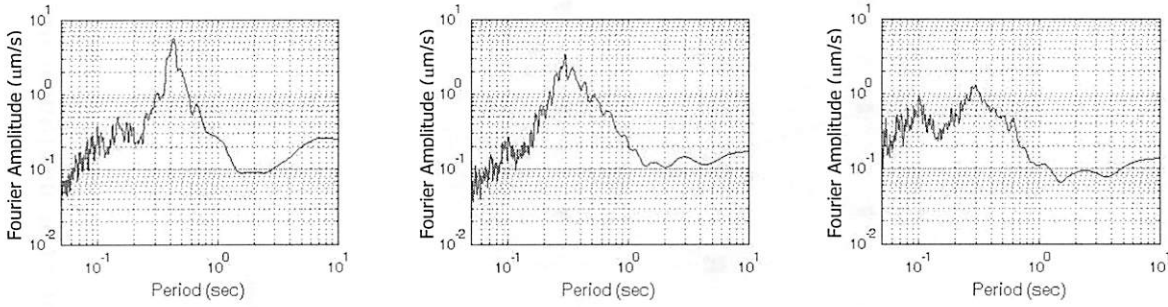


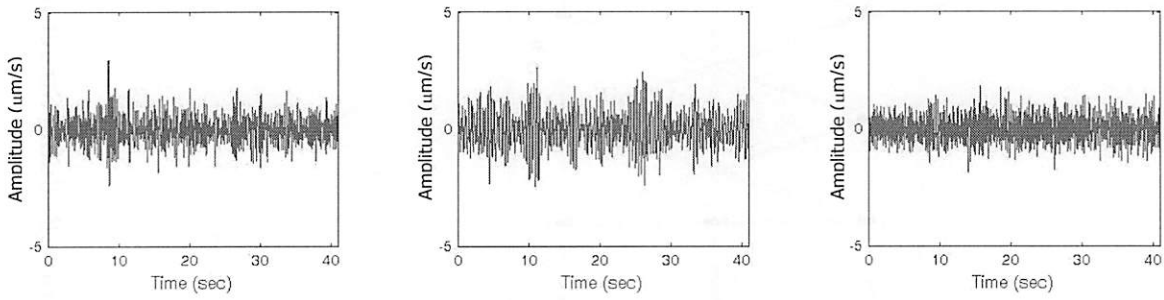
Figure 21 Architecture Building Structural Element layout (linear dimensions are in millimeter)



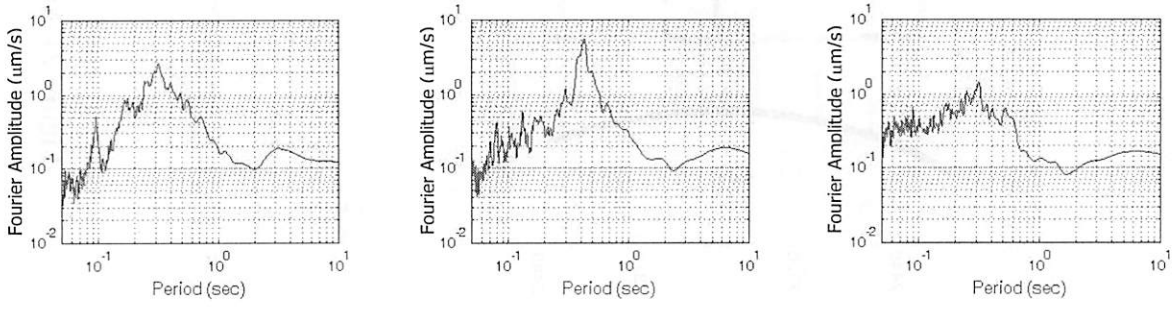
(a) Time history of Architecture Building (3rd floor right)



(b) Fourier spectrum of Architecture Building (3rd floor right)



(c) Time history of Architecture Building (3rd floor left)



(d) Fourier spectrum of Architecture Building (3rd floor left)

Figure 22 Time history and Fourier spectrum of Architecture Building

Reinforcement Detection

Figure 23(a) Beam reinforcement detection with Ferroscan at Architecture building

Figure 23(b) Marking of column reinforcement at the ground floor of Architecture building

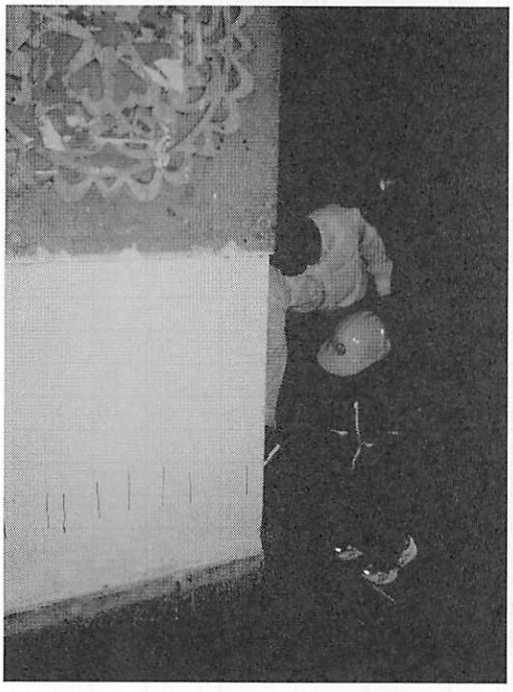


Figure 23(c) Column reinforcement detection with Ferroscan at Architecture building

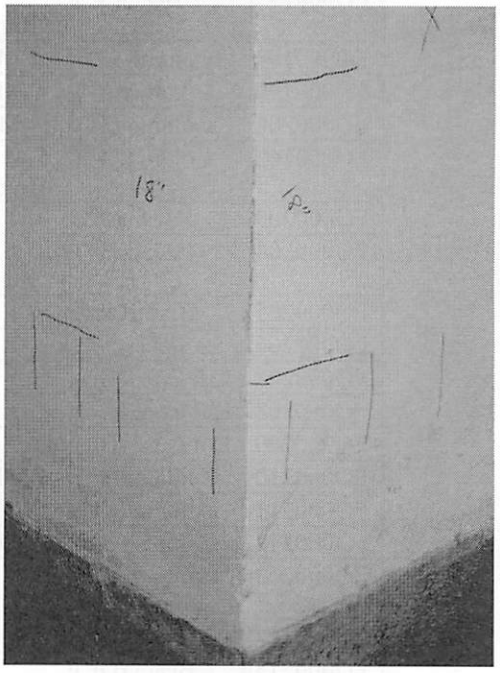
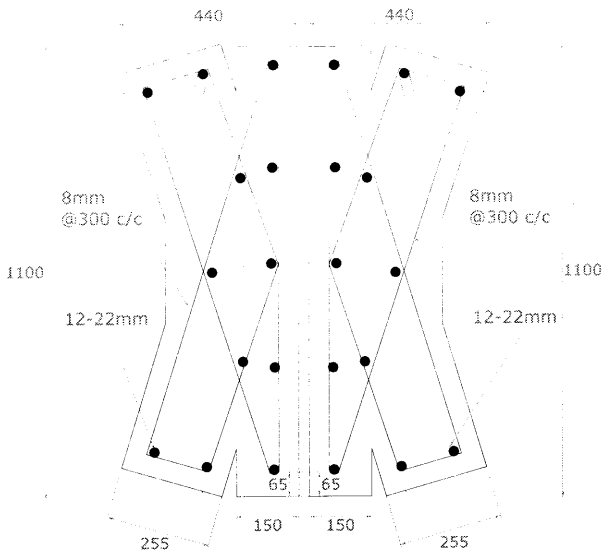


Figure 23(d) Marking of column reinforcement at ground floor of Architecture building

Data Analysis

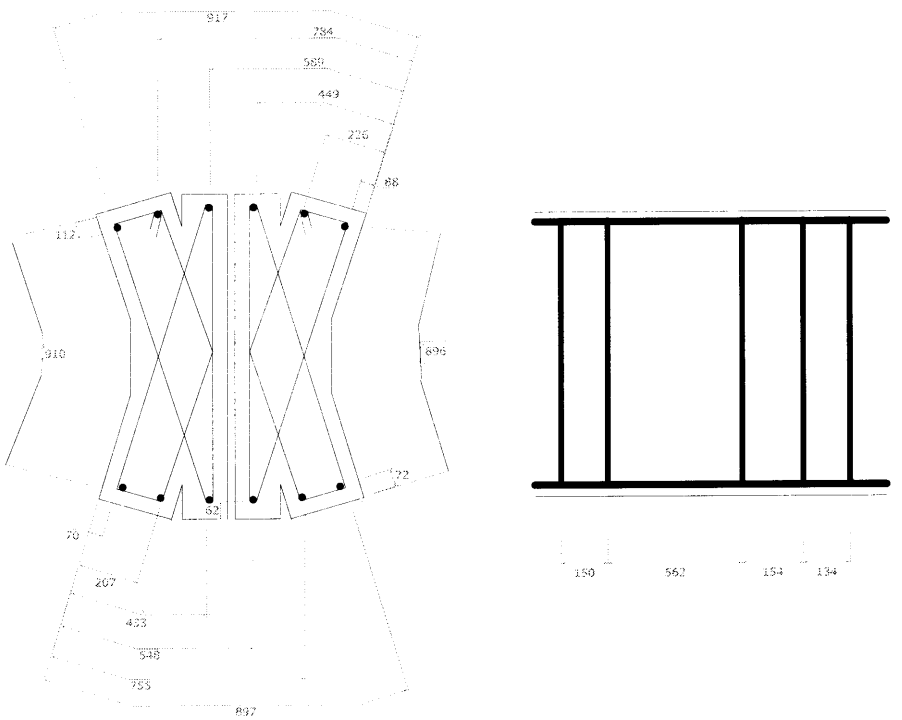
Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max[m]	Min[m]	Mean	Std-Dev	
Architecture Building	FQ000182	Column (3rd)	Main Bar(L)	4	35	95	78	87	7	M
	FQ000183	Column (3rd)	Main Bar(S)	2	35	66	53	59	9	M
	FQ000184	Column (3rd)	Main Bar(S)	2	35	66	53	59	9	M
	FQ000185	Column (3rd)	Shear Reinforcement	7	10	91	41	74	18	M
	FQ000186	Lift Core (3rd)	Horizontal	6	10	104	53	69	10	M
	FQ000187	Lift Core (3rd)	Vertical	5	13	75	35	54	15	M
	FQ000188	Beam(3rd)	Main Bar	2	22	54	33	43	15	M
	FQ000189	Beam(3rd)	Shear Reinforcement	1	10	26	26	26	0	M
	FQ000190	Beam(3rd)	Main Bar	3	25	56	55	55	1	M
	FQ000191	Beam(3rd)	Shear Reinforcement	5	10	62	57	59	2	M
	FQ000192	Column (3rd)	Main Bar	3	19	81	61	70	10	M
	FQ000193	Column (3rd)	Main Bar	3	19	87	71	78	8	M
	FQ000194	Column (3rd)	Main Bar	2	19	82	71	76	8	M
	FQ000195	Column (3rd)	Shear Reinforcement	6	10	105	38	55	18	M
	FQ000196	Beam(3rd)	Main Bar	4	19	57	41	47	8	M
	FQ000197	Beam(3rd)	Shear Reinforcement	4	10	63	56	59	3	M
	FQ000198	Column (3rd)	Main Bar (S)	2	32	97	67	82	21	M
	FQ000199	Column (3rd)	Main Bar (S)	2	32	97	67	82	21	M
	FQ000200	Column (3rd)	Main Bar (L)	4	32	100	87	92	6	M
	FQ000202	Column (3rd)	Shear Reinforcement	6	10	105	65	76	13	M
	FQ000203	Beam(3rd)	Main Bar	2	19	45	42	43	2	M
	FQ000204	Beam(3rd)	Shear Reinforcement	4	10	92	56	70	10	M
	FQ000205	Slab(Roof)		7	10	49	19	37	10	M
	FQ000206	Slab(Roof)		6	10	35	27	30	3	M
	FQ000207	Lift Core (Gr.)	Horizontal	4	10	132	35	46	10	M
	FQ000208	Lift Core (Gr.)	Horizontal	4	10	132	35	46	10	M
	FQ000209	Lift Core (Gr.)	Vertical	4	13	141	67	69	3	M
	FQ000210	Column (Gr.)	Main Bar (S)	2	32	66	65	65	1	M
	FQ000211	Column (Gr.)	Main Bar (L)	4	32	79	74	76	2	M
	FQ000212	Column (Gr.)	Main Bar (L)	4	32	79	74	76	2	M
	FQ000213	Column (Gr.)	Shear Reinforcement	6	10	95	64	67	15	M
	FQ000214	Beam (Gr.)	Main Bar	2	19	54	44	49	7	M
	FQ000215	Beam (Gr.)	Shear Reinforcement	4	10	75	66	69	5	M
	FQ000216	Column (Gr.)	Main Bar	6	32	73	57	62	7	M
	FQ000217	Column (Gr.)	Main Bar	2	32	81	69	75	8	M
	FQ000218	Column (Gr.)	Main Bar	6	32	81	61	72	7	M
	FQ000219	Column (Gr.)	Main Bar	2	32	82	79	80	2	M
	FQ000220	Column (Gr.)	Shear Reinforcement	5	10	95	45	69	24	M
	FQ000221	Column (Gr.)	Main Bar	3	19	54	47	49	4	M
	FQ000222	Column (Gr.)	Shear Reinforcement	5	10	84	32	46	22	M

Typical Column Section



28 days cylinder strength = 20.0 MPa (3000 psi)

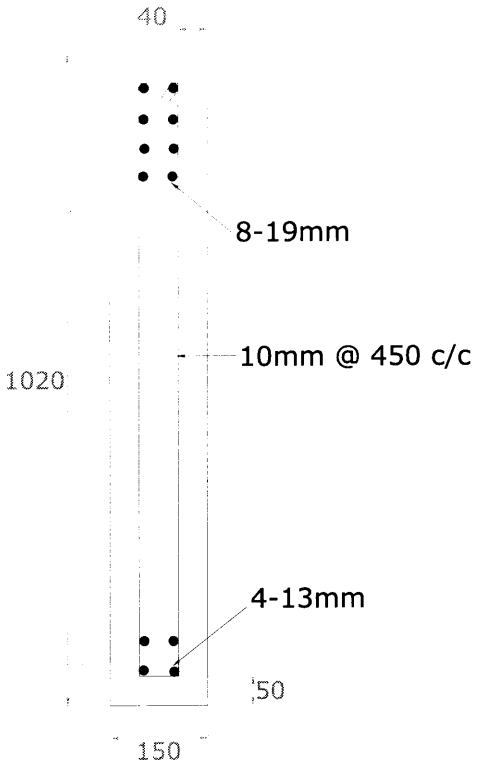
Design Section (linear dimensions are in millimeter)



Concrete compressive strength from Schmidt Hammer Test = 17.0 MPa (2507 psi)

Observed Section (linear dimensions are in millimeter)

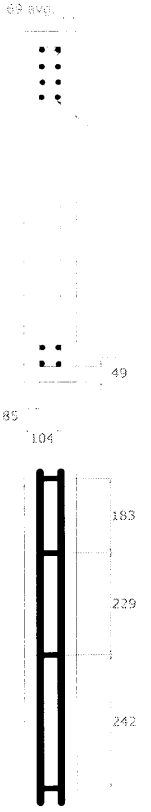
Typical Beam Section



28 days cylinder strength

= 20.0 MPa (3000 psi)

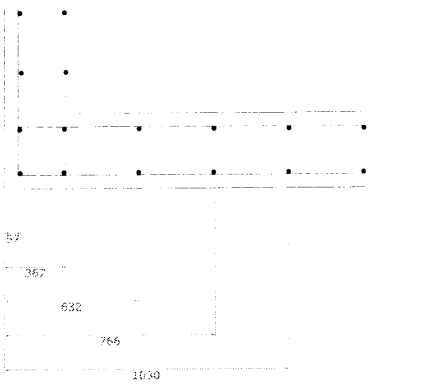
Design Section (linear dimensions are in millimeter)

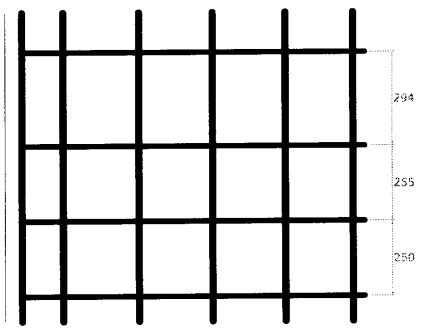


Concrete compressive strength from Schmidt Hammer Test = 32.5 MPa (4746 psi)

Observed Section (linear dimensions are in millimeter)

Typical Shear Wall (Lift Core) Section





Concrete compressive strength from Schmidt Hammer Test = 22.0 MPa (3216 psi)

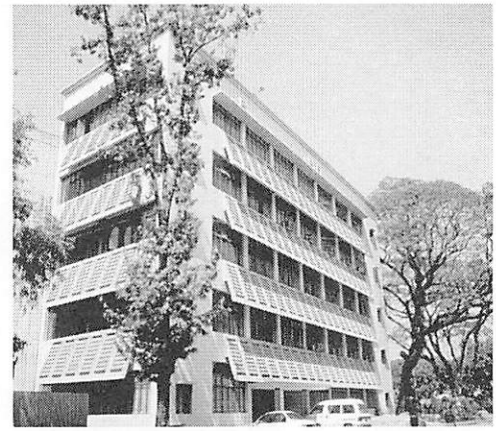
Observed Section (linear dimensions are in millimeter)

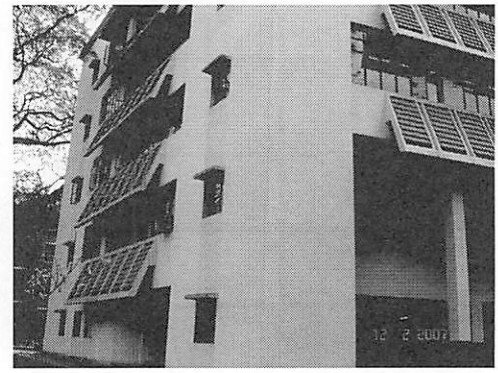
Conclusion:

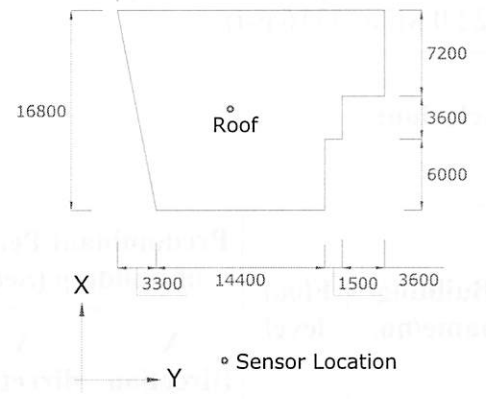
Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Architecture Building	3rd	0.42	0.30	0.37	0.36	0.25	0.26
	3rd	0.32	0.42				

The predominant period of the building is not close to that of the soil, so there is no possibility of resonance. The building has major structural irregularities such as, soft story and story mass irregularity. Concrete compressive strength from Schmidt Hammer Test is not satisfactory. Variation of clear cover from design is high. Seismic vulnerability condition of the building is high.

3.4.7 URP Building







General Information:

Year of Construction: 2001
Type of Structure: Frame structure
No of story: 5
Use: Academic
Floor area: 322 sqm/floor
Foundation: Footing, pile
Lift: yes
Stair: yes
Shear wall: no

Structural irregularities in plan:

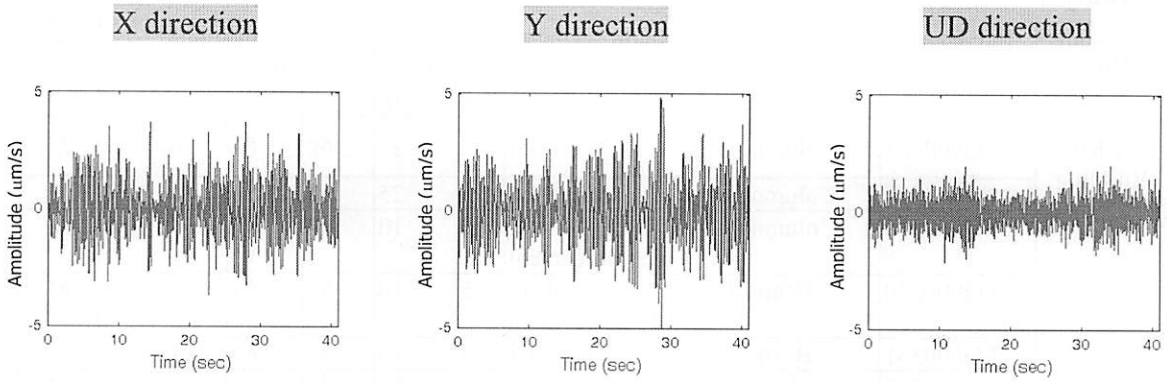
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: yes

Structural irregularities in height:

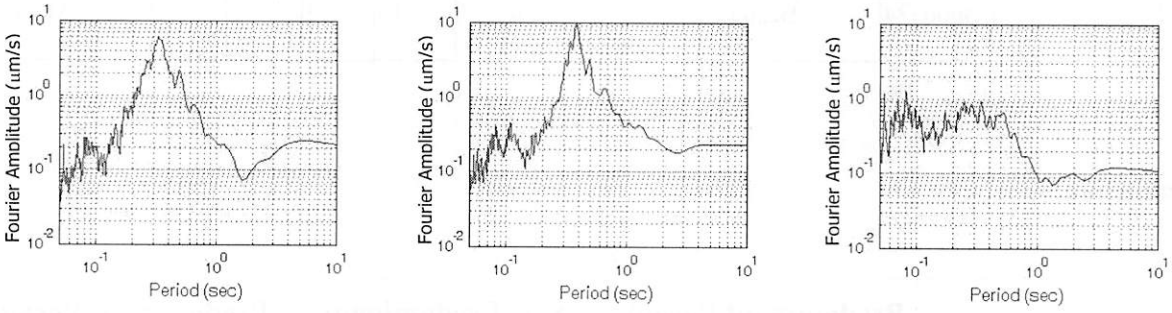
Storey stiffness irregularity: yes
Storey mass irregularity: yes
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

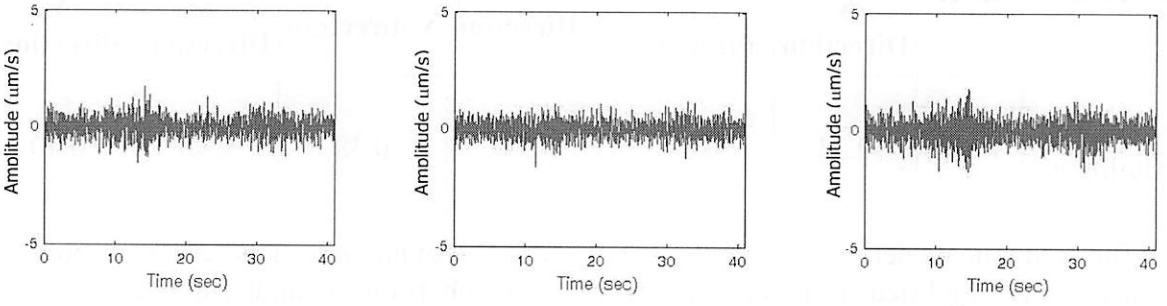
Beam: 20.0 MPa (2966 psi)
Column: 19.0 MPa 2745 psi)
Shear wall: not applicable



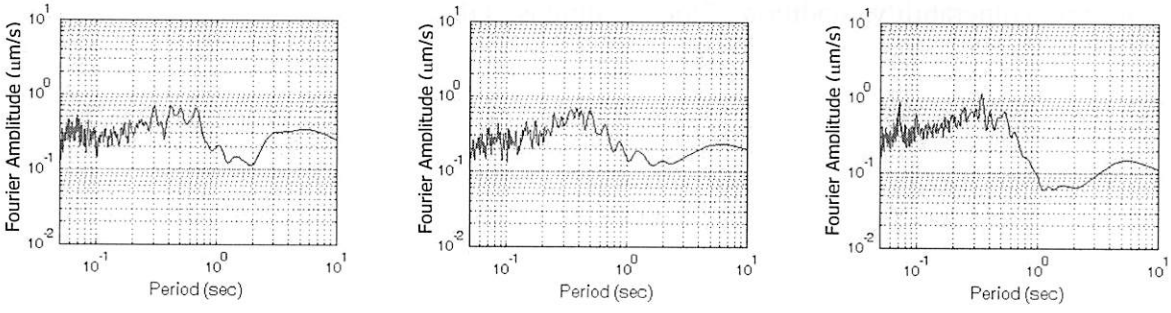
(a) Time history of URP Building (top floor)



(f) Fourier spectrum of URP Building (top floor)



(g) Time history of free field near ARC Building and URP Building



(h) Fourier spectrum of free field near ARC Building and URP Building

Figure 24 Time history and Fourier spectrum of URP Building

Data Analysis

Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max^{m}	Min^{m}	Mean	Std-Dev	
URP Building.	FQ000327	Column (Gr.)	Main Bar	5	25	69	66	67	1	M
	FQ000328	Column (Gr.)	Main Bar	5	25	68	59	64	4	M
	FQ000329	Column (Gr.)	Shear Reinforcement	4	10	48	45	46	1	M
	FQ000330	Beam (Gr.)	Shear Reinforcement	5	10	60	53	56	3	M
	FQ000331	Beam (Gr.)	Main Bar	4	19	80	69	75	6	M
	FQ000332	Column (4th)	Main Bar	4	19	85	66	76	8	M
	FQ000333	Column (4th)	Shear Reinforcement	5	10	71	65	68	2	M
	FQ000334	Beam(4th)	Shear Reinforcement	7	10	72	32	50	15	M

Conclusion:

Building name/no.	**Floor level**	**Predominant Period of building (Sec)**		**Avg. Predominant Period of building (Sec)**		**Predominant Period of ground (Sec)**	
		X Direction	**Y direction**	**X Direction**	**Y direction**	**X Direction**	**Y direction**
URP Building	Roof	0.33	0.38	0.33	0.38	0.40	0.40

The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified. Concrete compressive strength from Schmidt Hammer Test is not satisfactory. The building has major structural irregularities such as torsional irregularity, re-entrant corner, soft story and story mass irregularity. Variation of clear cover from design is high. Seismic vulnerability condition of the building is high.

3.4.8 ARC Building

General Information:

Year of Construction: 2003
Type of Structure: Frame structure
No of story: 4
Use: Academic
Floor area: 400 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: yes

Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: yes

Structural irregularities in height:

Storey stiffness irregularity: yes
Storey mass irregularity: yes
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: 21.5 MPa (3112 psi)
Column: 17.0 MPa (2460 psi)
Shear wall: not available

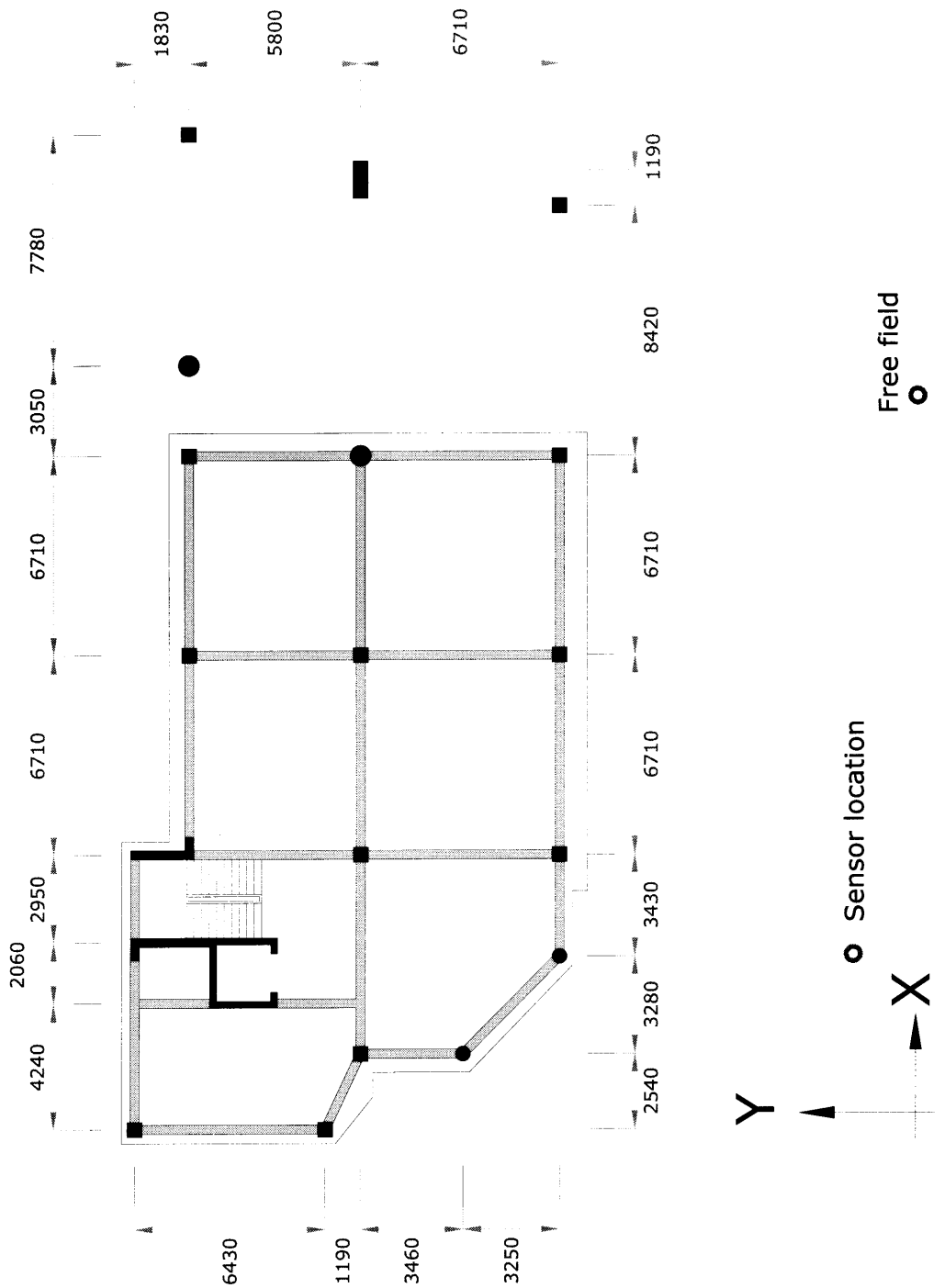


Figure 25 ARC Building (1st floor) Structural Element Layout (linear dimensions are in millimeter)

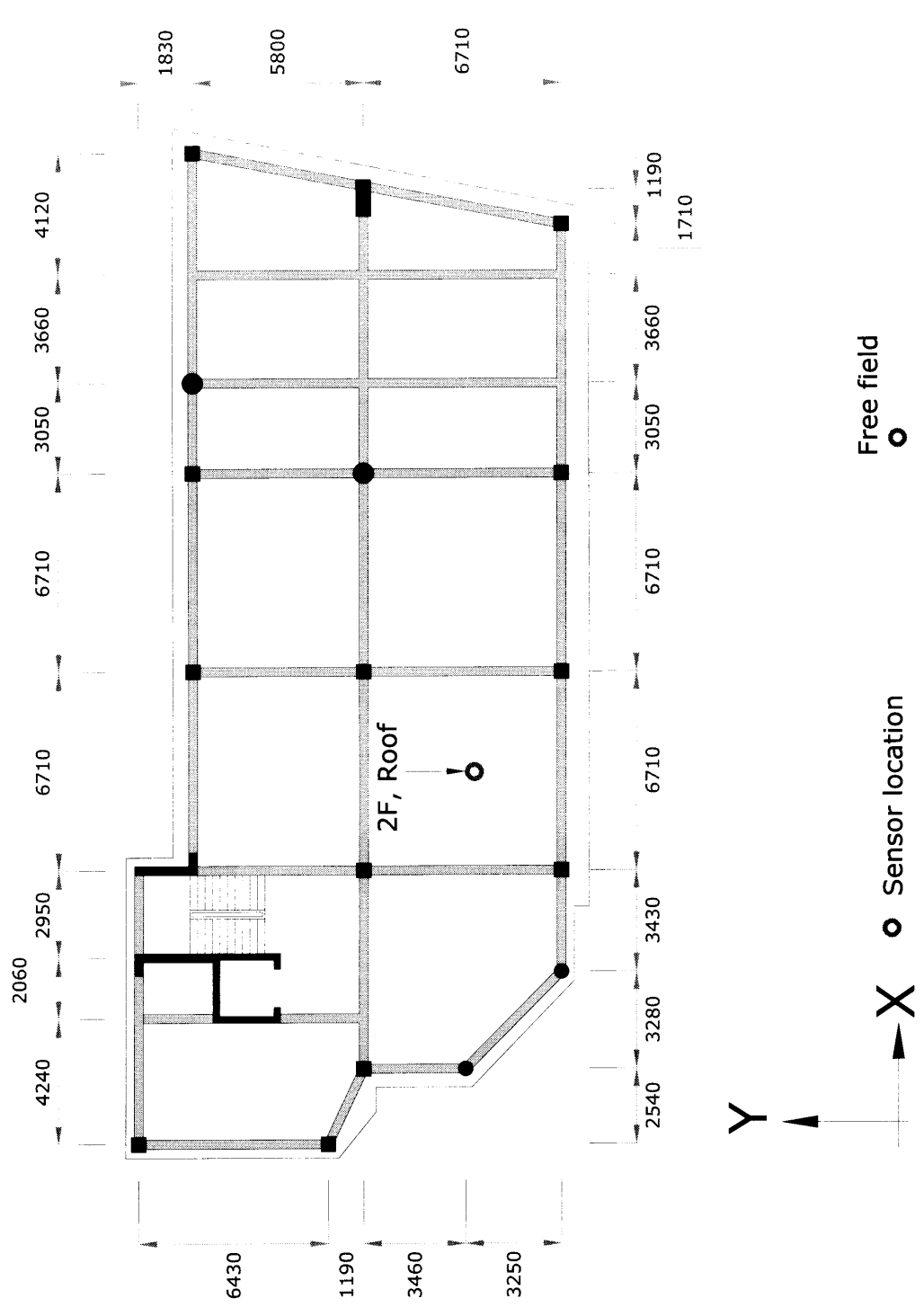
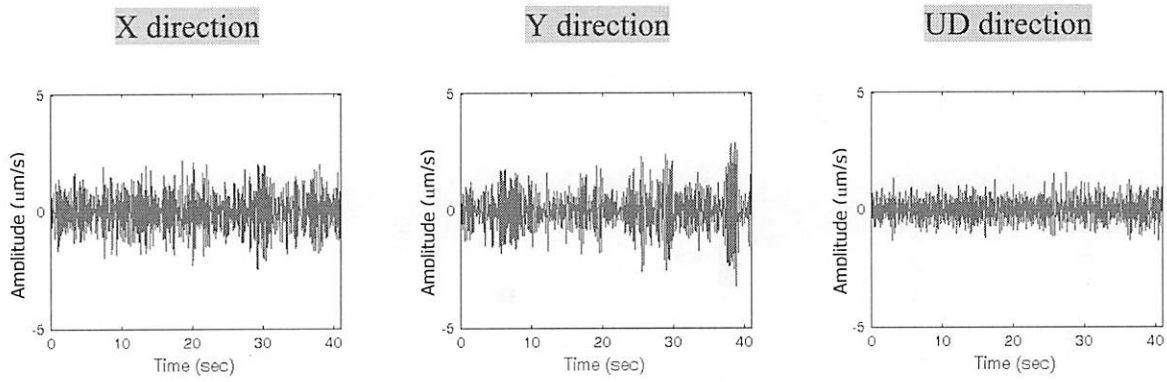
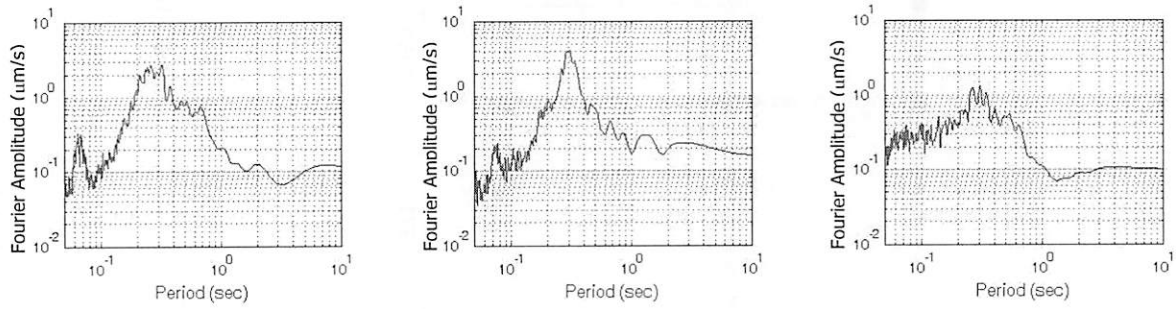


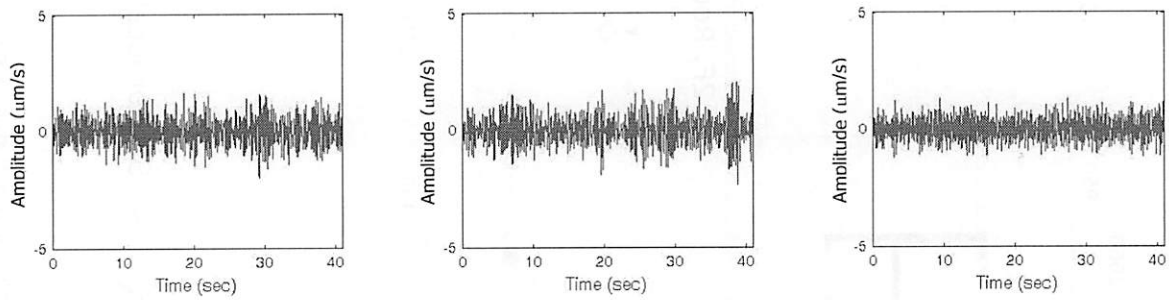
Figure 26 ARC Building (2nd and 3rd floor) Structural Element Layout (linear dimensions are in millimeter)



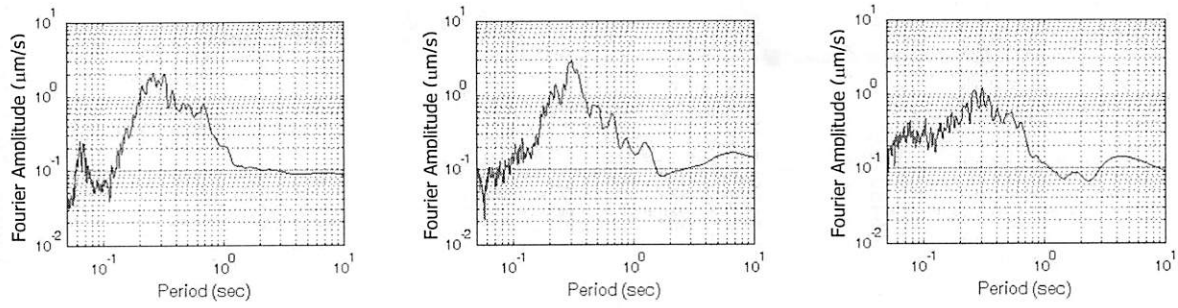
(a) Time history of ARC Building (top floor)



(b) Fourier spectrum of ARC Building (top floor)



(c) Time history of ARC Building (2nd floor)



(d) Fourier spectrum of ARC Building (2nd floor)

Figure 27 Time history and Fourier spectrum of ARC Building

Reinforcement Detection

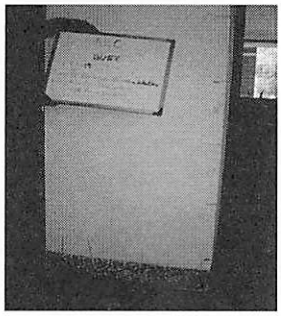
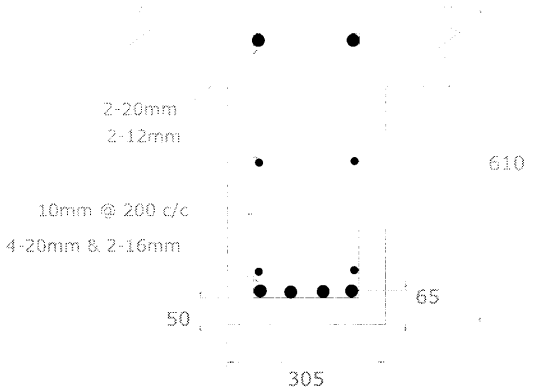
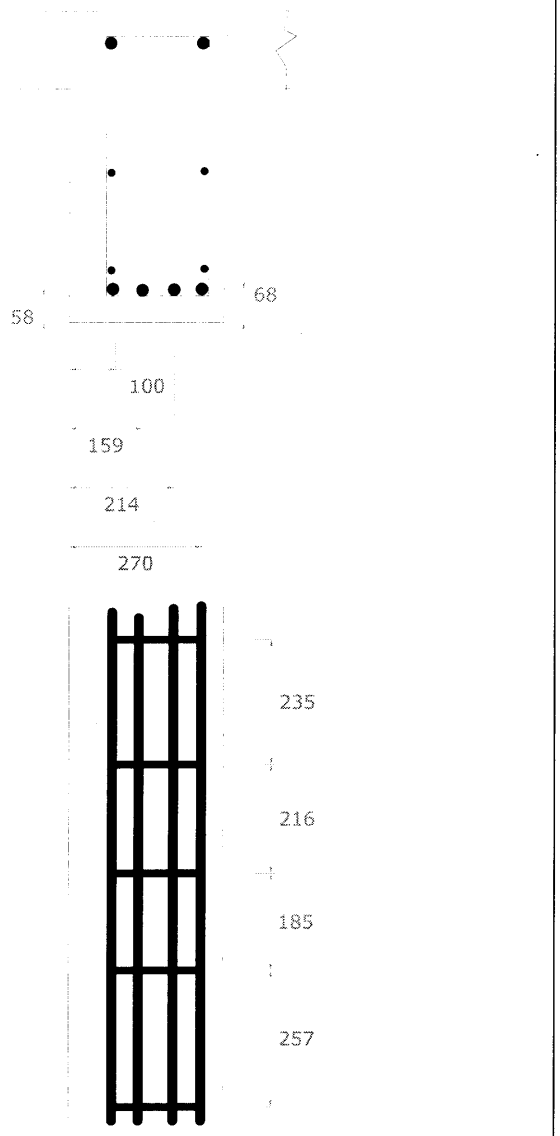


Figure 28 Detection of column reinforcement at ground floor of Accident Research Centre (ARC) building.

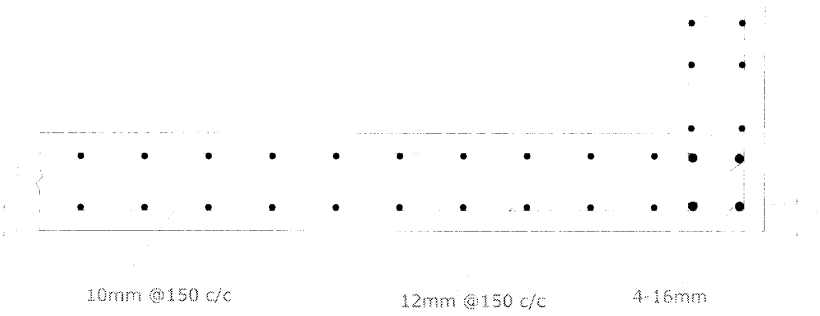
Data Analysis

Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max^{m}	Min^{m}	Mean	Std-Dev	
ARC Building.	FQ000113	Column (Gr.)	Main Bar	6	25	70	62	65	11	M
	FQ000114	Column (Gr.)	Main Bar	6	25	69	60	64	7	M
	FQ000115	Column (Gr.)	Shear Reinforcement	5	10	65	52	55	2	M
	FQ000116	Column (Gr.)	Main Bar	20	25	80	65	70		M
	FQ000118	Column (Gr.)	Shear Reinforcement	6	10	62	50	58	16	M
	FQ000119	Beam (Gr.)	Main Bar	4	20	70	66	68	13	M
	FQ000120	Beam (Gr.)	Shear Reinforcement	4	10	60	54	56	3	M
	FQ000121	Lift Core (Gr.)	Vertical	10	12	72	52	66	16	M
	FQ000122	Lift Core (Gr.)	Horizontal	6	10	63	48	55	10	M
	FQ000123	Column (Gr.)	Main Bar	8	25	75	66	70	9	M
	FQ000124	Column (Gr.)	Shear Reinforcement	7	10	62	50	58	11	M
	FQ000125	Beam (Gr.)	Main Bar	4	20	77	74	75	13	M
	FQ000126	Beam (Gr.)	Shear Reinforcement	5	10	62	57	60	2	M
	FQ000127	Column (4th)	Main Bar	3	25 , 22	70	62	65	7	M
	FQ000128	Column (4th)	Main Bar	3	25 , 22	72	60	64	6	M
	FQ000129	Column (4th)	Shear Reinforcement	5	10	62	48	58	2	M
	FQ000130	Beam(4th)	Main Bar	4	20	69	66	68	8	M
	FQ000131	Beam(4th)	Shear Reinforcement	5	10	61	54	58	3	M
	FQ000132	Slab(4th)	Main Bar	10	10	48	44	45	5	M
	FQ000134	Slab(4th)	Main Bar	5	10	50	45	47	7	M
	FQ000135	Slab(4th)	Main Bar	5	10	48	39	44	6	M
	FQ000136	Slab(4th)	Main Bar	6	10	49	40	47	3	M
	FQ000139	Beam(4th)	Main Bar	4	20	75	73	74	13	M
	FQ000140	Beam(4th)	Shear Reinforcement	6	10	63	57	60	3	M
	FQ000141	Lift Core (4th)	Vertical	8	12	72	63	68	5	M
	FQ000142	Lift Core (4th)	Horizontal	7	10	64	49	56	11	M

Typical Beam Section

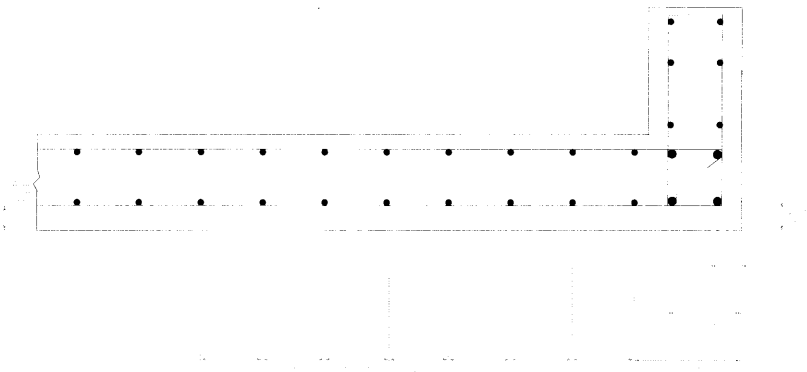
 28 days cylinder strength = 20.0 MPa (3000 psi)	 Concrete compressive strength from Schmidt Hammer Test = 21.5 MPa (3112 psi)
Design Section (linear dimensions are in millimeter)	Observed Section (linear dimensions are in millimeter)

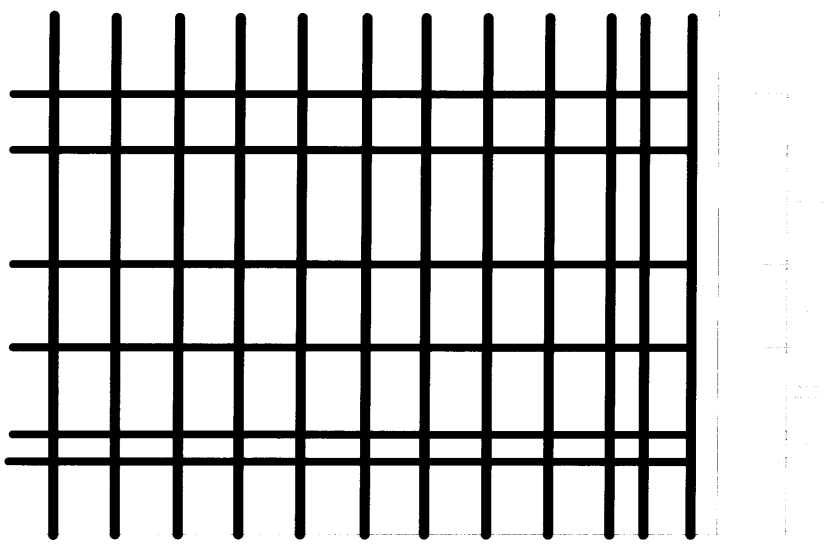
Typical Shear Wall (Lift Core) Section



28 days cylinder strength = 20.0 MPa (3000 psi)

Design Section (linear dimensions are in millimeter)





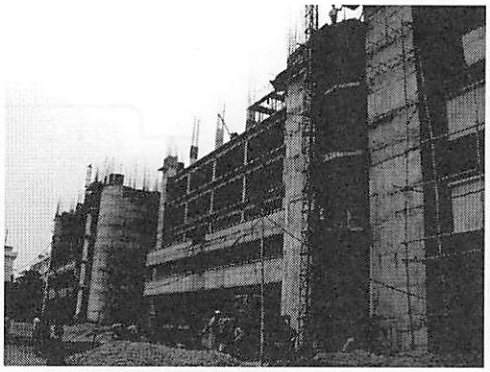
Observed Section (linear dimensions are in millimeter)

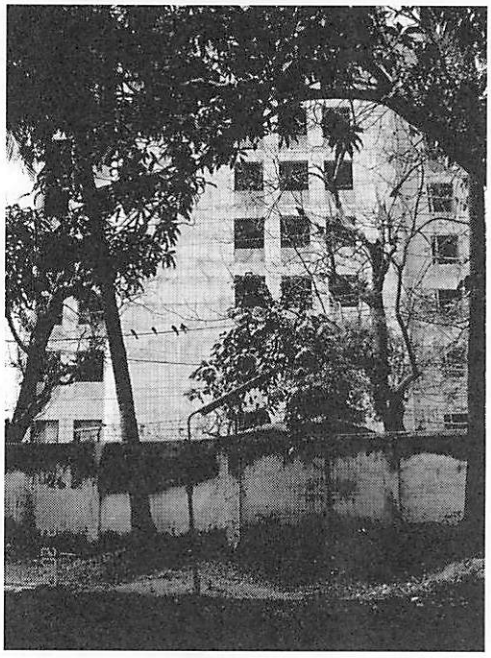
Conclusion:

Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
ARC Building	Roof	0.26	0.30	0.26	0.30	0.40	0.40
	2nd	0.26	0.30				

The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified. The building has almost all the major structural irregularities such as torsional irregularity, re-entrant corner, soft story and story mass irregularity. Concrete compressive strength from Schmidt Hammer Test is not satisfactory. Variation of clear cover from design is high. Seismic vulnerability condition of the building is high.

3.4.9 New Academic Building (under construction)





General Information:

Year of Construction: 2006 (under construction)
Type of Structure: Frame structure
No of story: 6
Use: Academic
Floor area: 3400 sqm/floor
Foundation: pile
Lift: yes
Stair: yes
Shear wall: yes

Structural irregularities in plan:

Torsional irregularity: no
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: not available
Column: 26.5 MPa (3820 psi)
Shear wall: 23.5 MPa (3406 psi)

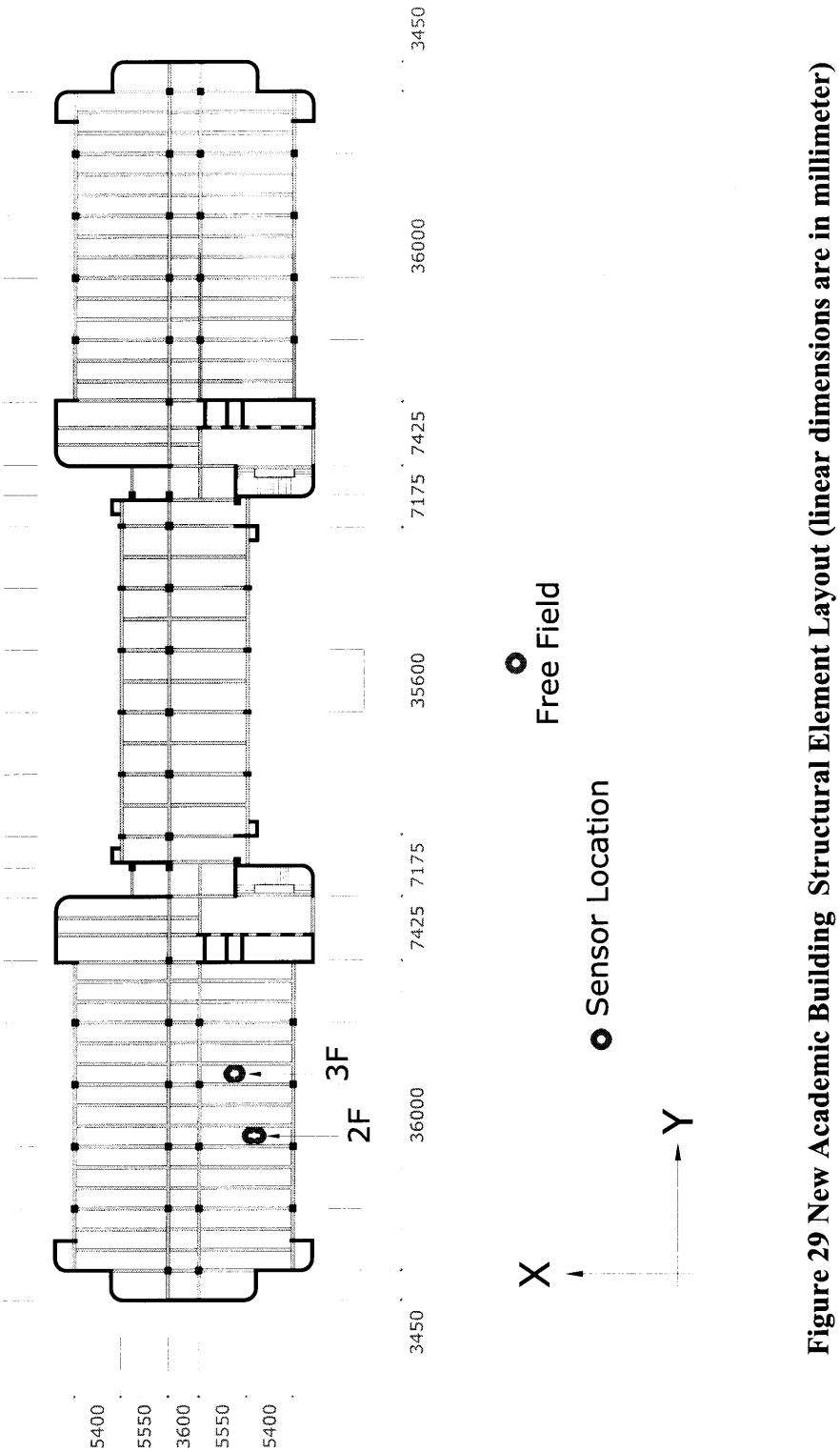
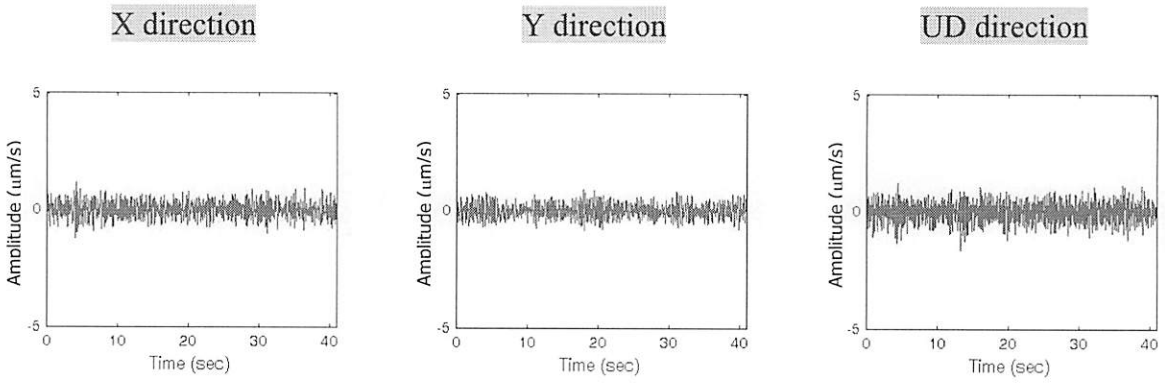
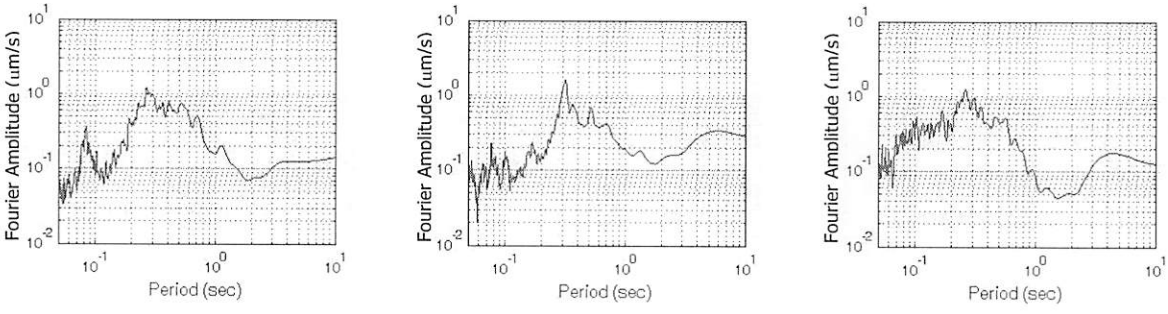


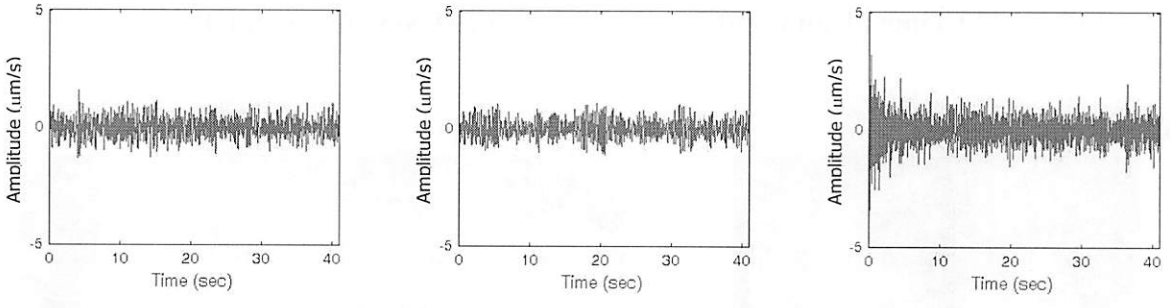
Figure 29 New Academic Building Structural Element Layout (linear dimensions are in millimeter)



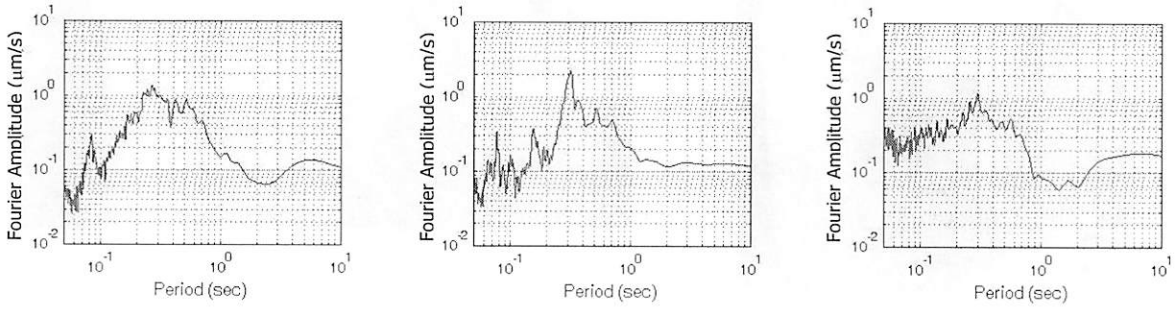
(a) Time history of New Academic Building (3rd floor)



(b) Fourier spectrum of New Academic Building (3rd floor)

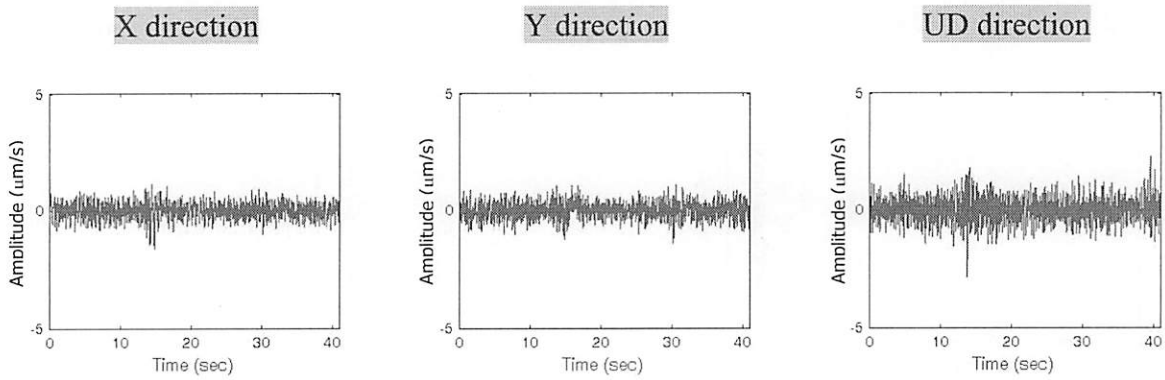


(c) Time history of New Academic Building (2nd floor)

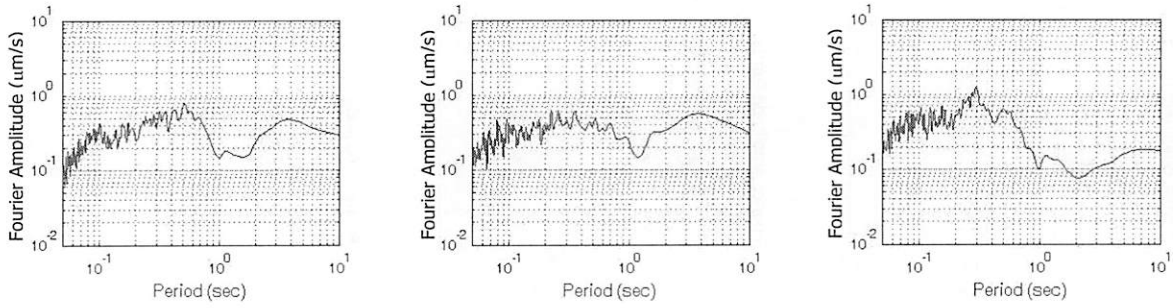


(d) Fourier spectrum of New Academic Building (2nd floor)

Figure 30 Time history and Fourier spectrum of New Academic Building



(g) Time history of free field near New Academic Building



(h) Fourier spectrum of free field near New Academic Building

Figure 30 Time history and Fourier spectrum of New Academic Building

Reinforcement Detection

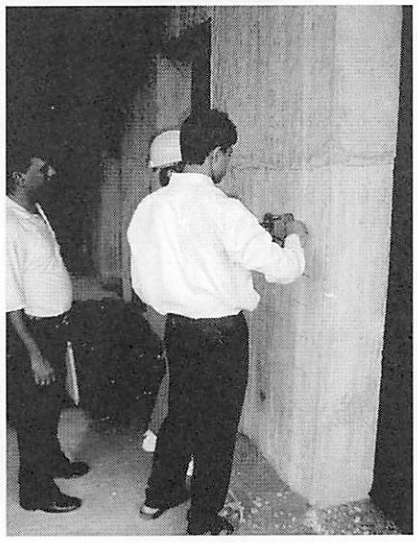


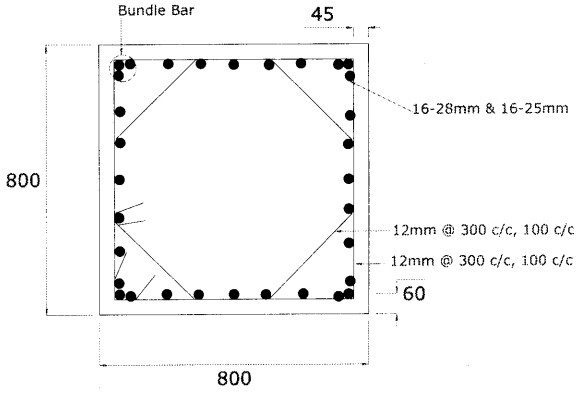
Figure 31(a) Column reinforcement detection with Ferroscan at New Academic Building (under construction)

Figure 31(b) Marking of column reinforcement at the ground floor of New Academic Building (under construction).

Data Analysis

Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max[m]	Min[m]	Mean	Std-Dev	
New Academic Building.	FQ000294	Shear Wall (1st)	Vertical	9	25	94	55	70	12	M
	FQ000295	Shear Wall (1st)	Horizontal	10	13	58	30	46	9	M
	FQ000296	Column (1st)	Main Bar(L)	5	29	91	71	79	8	M
	FQ000297	Column (1st)	Shear Reinforcement	6	10	49	30	40	7	M
	FQ000307	Column (1st)	Main Bar	7	25	70	52	59	7	M
	FQ000308	Column (1st)	Main Bar	8	25	82	50	64	11	M
	FQ000309	Column (1st)	Shear Reinforcement	7	10	45	31	35	5	M
	FQ000310	Beam (1st)	Shear Reinforcement	4	25	55	42	48	5	M
	FQ000311	Beam (1st)	Main Bar	8	10	68	43	53	8	M

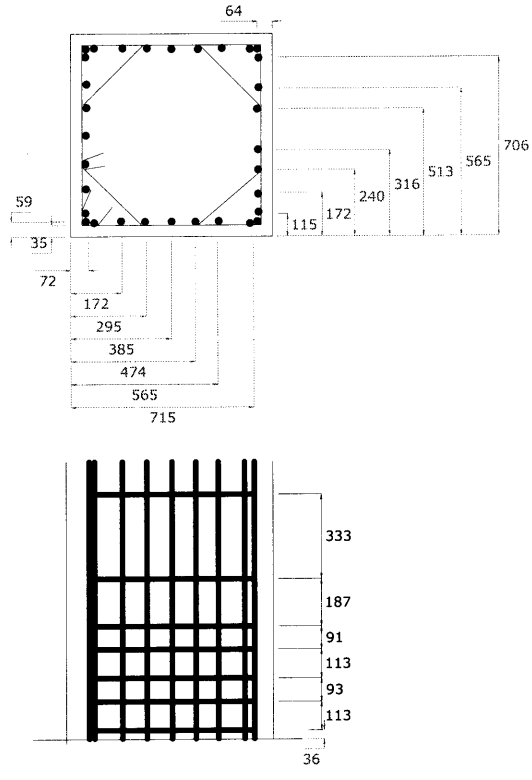
Typical Column Section



28 days cylinder strength

= 28.0 MPa (4000 psi)

Design Section (linear dimensions are in millimeter)

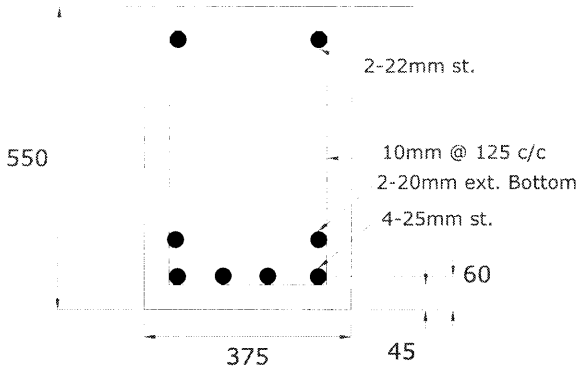


Concrete compressive strength from Schmidt Hammer Test

= 26.5 MPa (3820 psi)

Observed Section (linear dimensions are in millimeter)

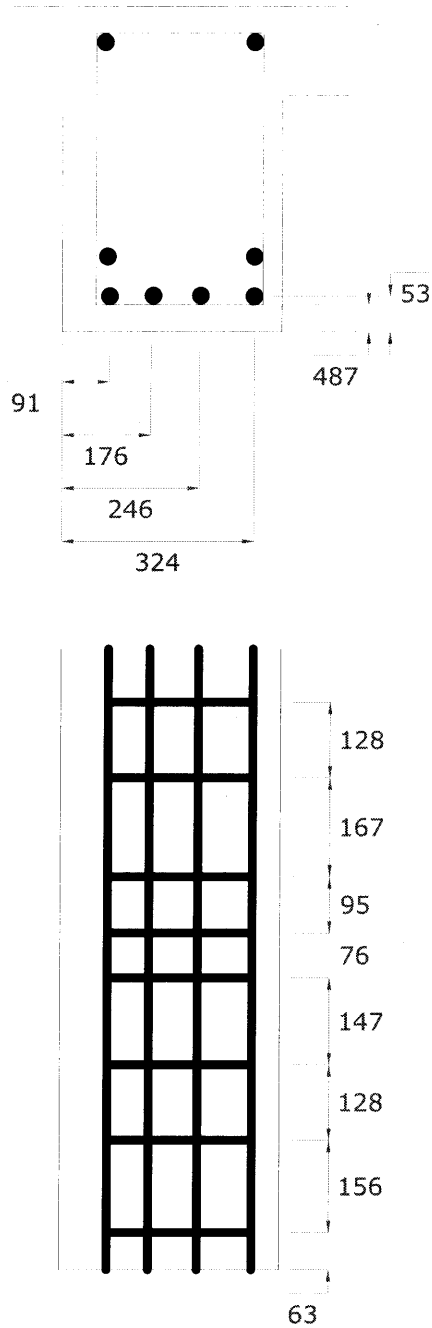
Typical Beam Section



28 days cylinder strength

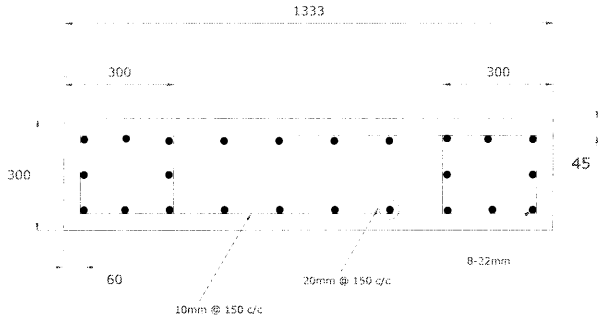
= 28.0 MPa (4000 psi)

Design Section (linear dimensions are in millimeter)



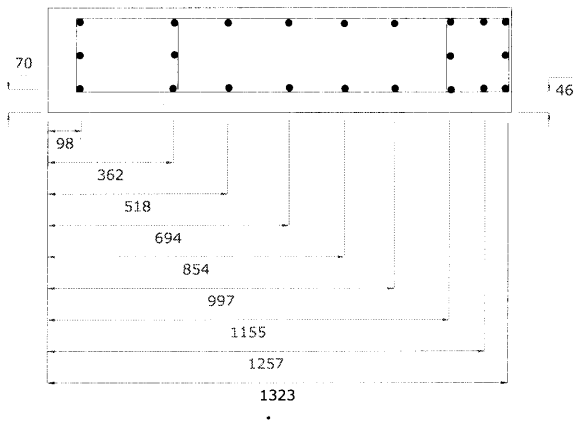
Observed Section (linear dimensions are in millimeter)

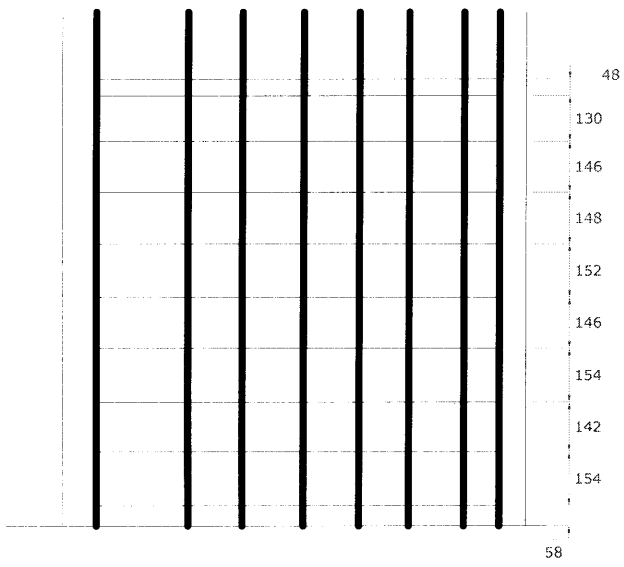
Typical Shear Wall (Lift Core) Section



28 days cylinder strength = 28.0 MPa (4000 psi)

Design Section (linear dimensions are in millimeter)





Concrete compressive strength from Schmidt Hammer Test = 23.5 MPa (3406 psi)

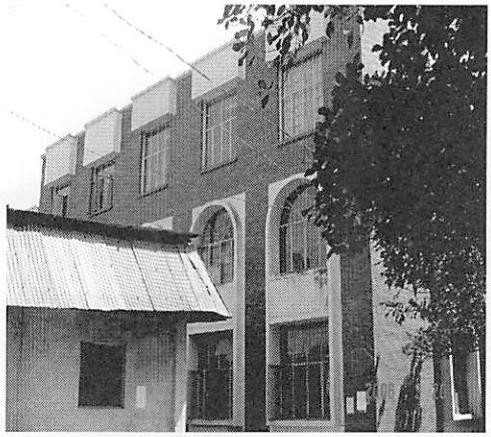
Observed Section (linear dimensions are in millimeter)

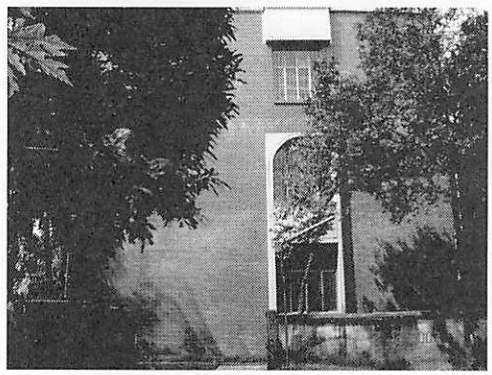
Conclusion:

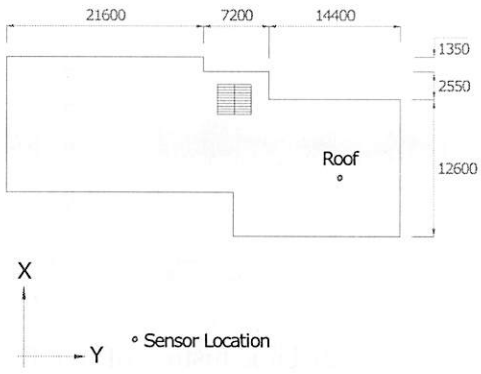
Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
New Academic bldg	3rd	0.27	0.30	0.27	0.30	0.50	0.26
	2nd	0.27	0.30				

The building is under construction. The building has no major structural irregularities. Concrete compressive strength from Schmidt Hammer Test is not satisfactory. Variation of clear cover from design is high. Quality control of construction work is not satisfactory.

3.4.10 Controller of Examination Building







General Information:

Year of Construction: 2000
Type of Structure: Frame structure
No of story: 3
Use: Academic
Floor area: 324 sqm
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

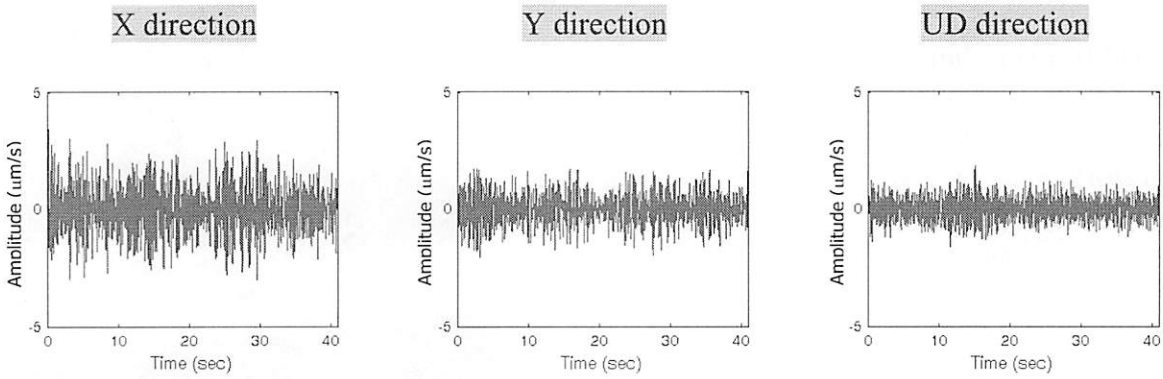
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural irregularities in height:

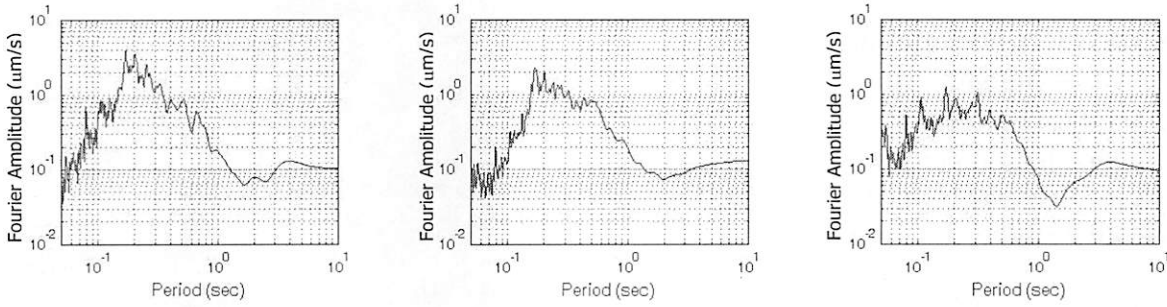
Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

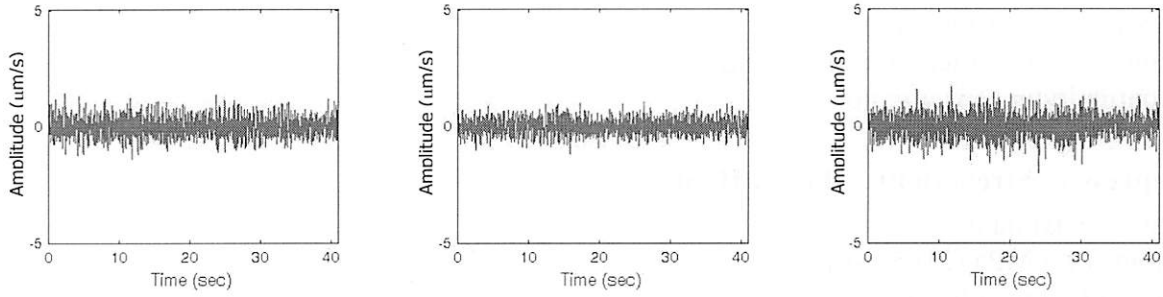
Beam: not available
Column: 14.5 MPa (2105 psi)
Shear wall: not applicable



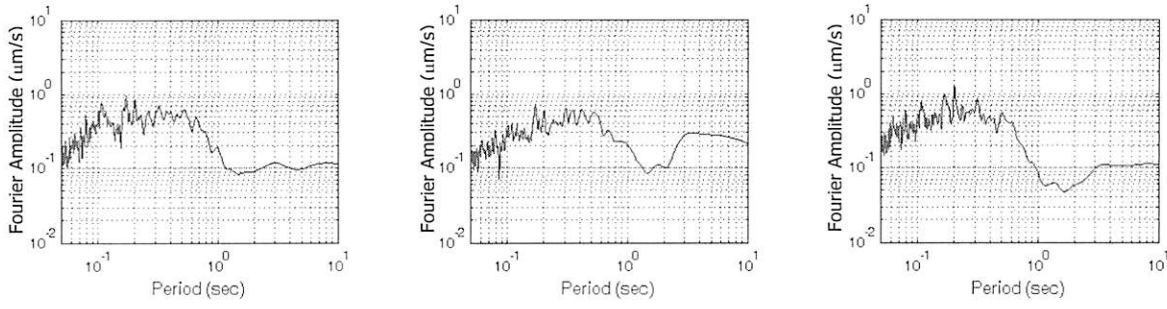
(a) Time history of Controller of Examination Building (top floor)



(f) Fourier spectrum of Controller of Examination Building (top floor)



(g) Time history of free field near Controller of Examination Building



(h) Fourier spectrum of free field near Controller of Examination Building

Figure 32 Time history and Fourier spectrum of Controller of Examination Building

Data Analysis

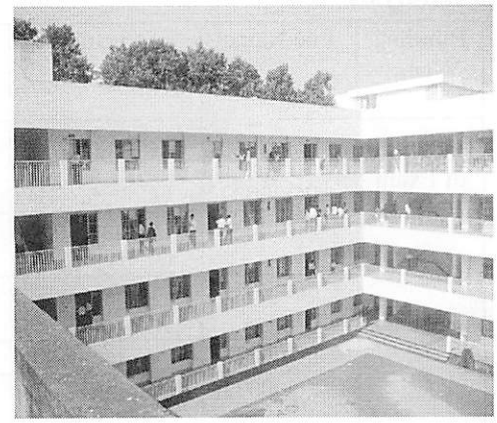
Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max^{m}	Min^{m}	Mean	Std-Dev	
Controller of Exam Building.	FQ000321	Column (Gr.)	Main Bar	4	19	46	31	38	6	M
	FQ000322	Column (Gr.)	Main Bar	3	19	79	69	72	6	M
	FQ000323	Column (Gr.)	Shear Reinforcement	4	10	26	16	21	4	M
	FQ000324	Beam(3rd)	Shear Reinforcement	8	10	57	43	52	5	M
	FQ000325	Column (2nd)	Main Bar	2	19	86	71	78	11	M
	FQ000326	Column (2nd)	Shear Reinforcement	3	10	70	61	66	5	M

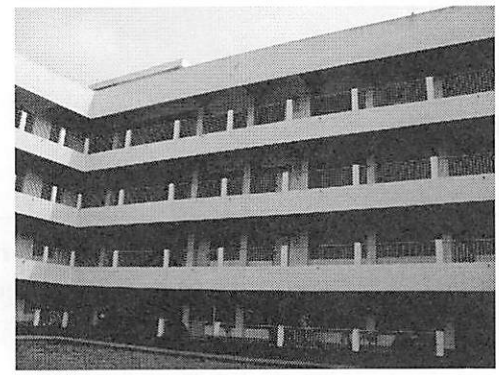
Conclusion:

Building name/no.	**Floor level**	**Predominant Period of building (Sec)**		**Avg. Predominant Period of building (Sec)**		**Predominant Period of ground (Sec)**	
		X Direction	**Y direction**	**X Direction**	**Y direction**	**X Direction**	**Y direction**
Controller of Exam Building	Roof	0.18	0.18	0.18	0.18	0.32	0.30

The predominant period of the building is not close to that of the soil, so there is no possibility of resonance. Concrete compressive strength from Schmidt Hammer Test is not satisfactory. The building has major structural irregularities such as torsional irregularity and re-entrant corner. Variation of clear cover from design is high. Seismic vulnerability condition of the building is moderate.

3.4.11 Engineering University School Building





General Information:

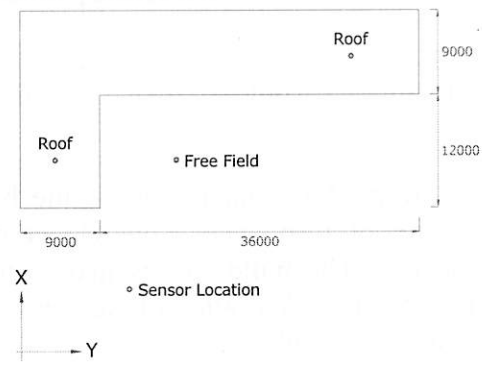
Year of Construction: 1984
Type of Structure: Frame structure
No of story: 4
Use: Academic
Floor area: 530 sqm/floor
Foundation: Footing, pile
Lift: yes
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

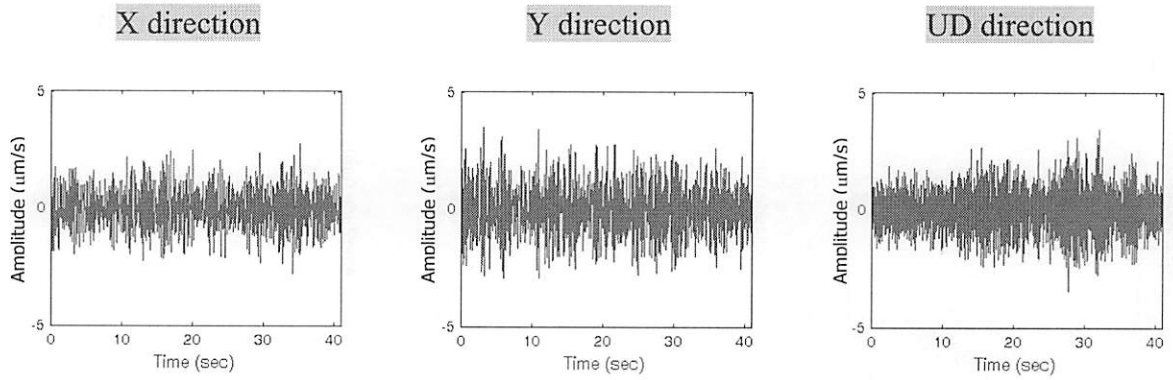
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

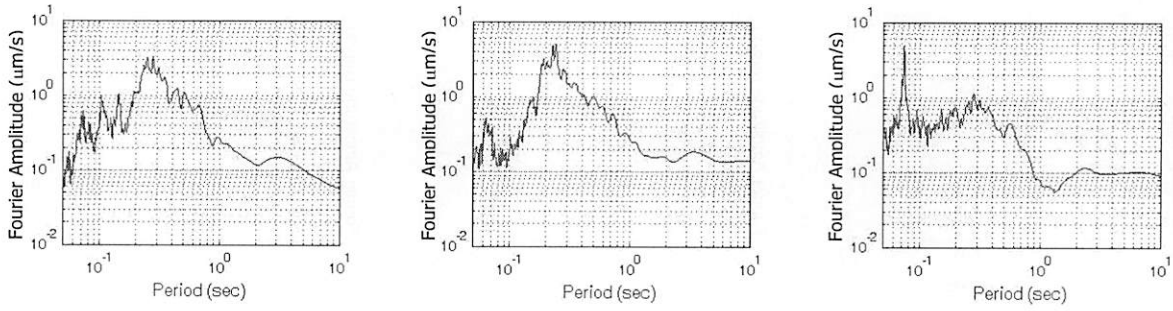


Compressive Strength by Schmidt Hammer:

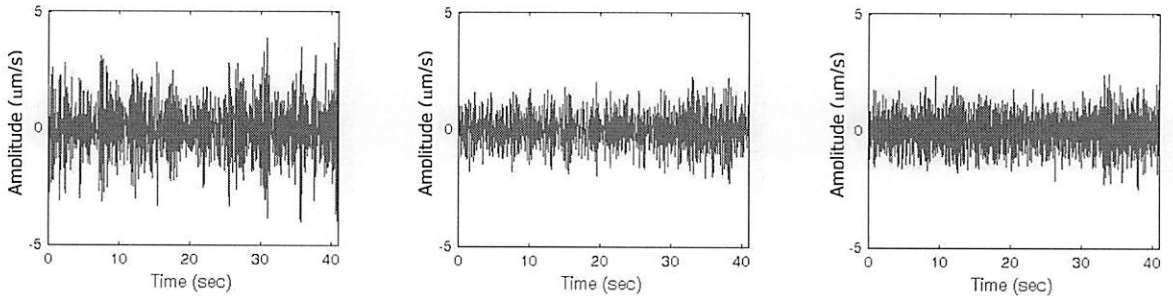
Beam: not available
Column: 21.5 MPa (3146 psi)
Shear wall: not applicable



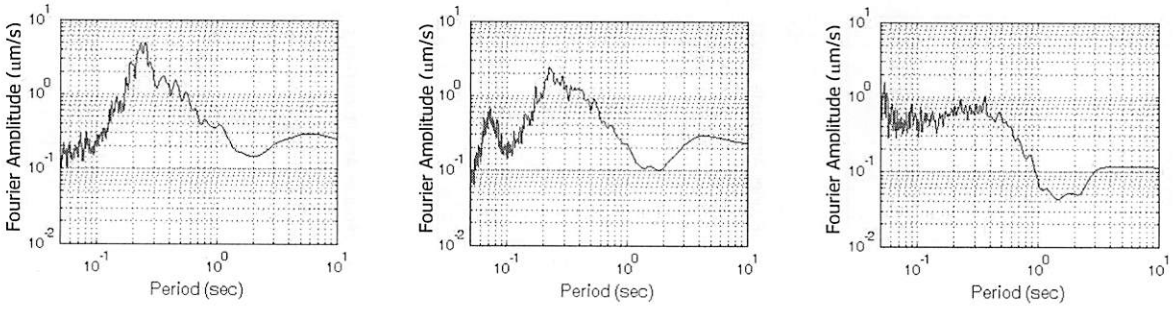
(a) Time history of Engineering University School Building (top floor, left)



(f) Fourier spectrum of Engineering University School Building (top floor, left)

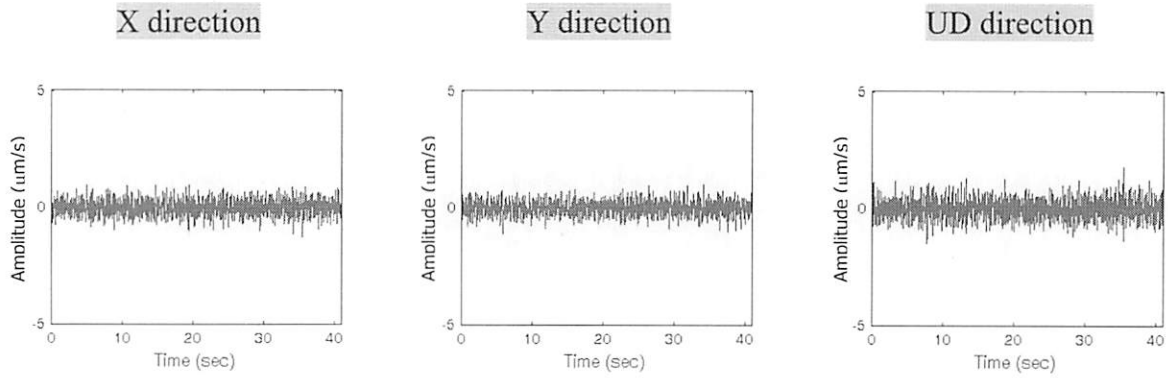


(g) Time history of Engineering University School Building (top floor, right)

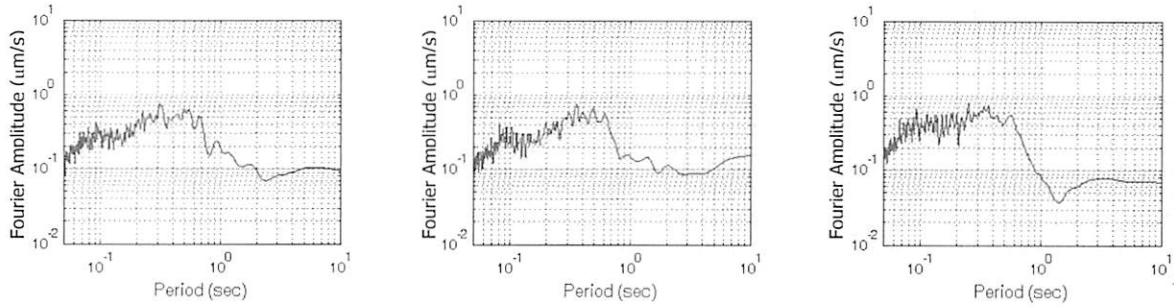


(h) Fourier spectrum of Engineering University School Building (top floor, right)

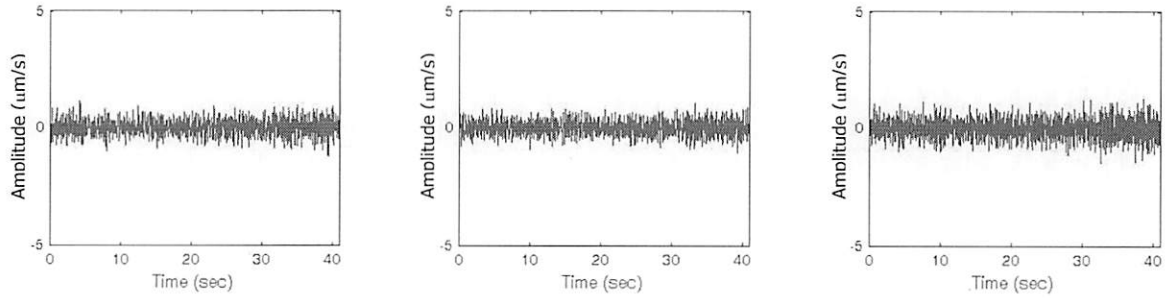
Figure 33 Time history and Fourier spectrum of Engineering University School Building



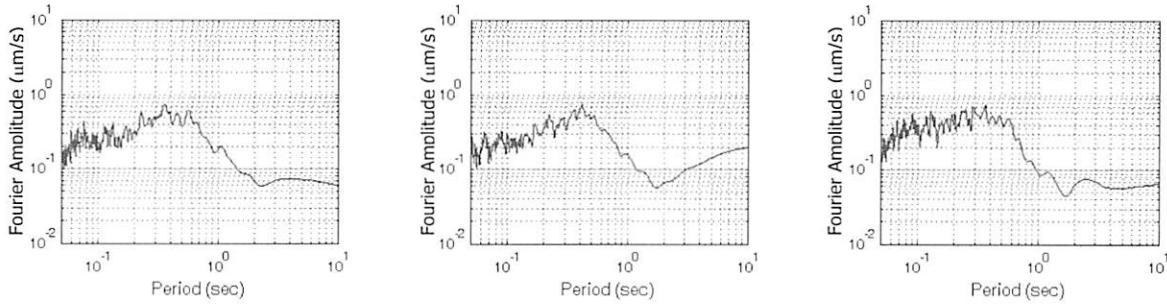
(a) Time history of free field near Engineering University School Building



(f) Fourier spectrum of free field near Engineering University School Building



(g) Time history of free field near Engineering University School Building



(h) Fourier spectrum of free field near Engineering University School Building

Figure 33 Time history and Fourier spectrum of Engineering University School Building

Reinforcement Detection

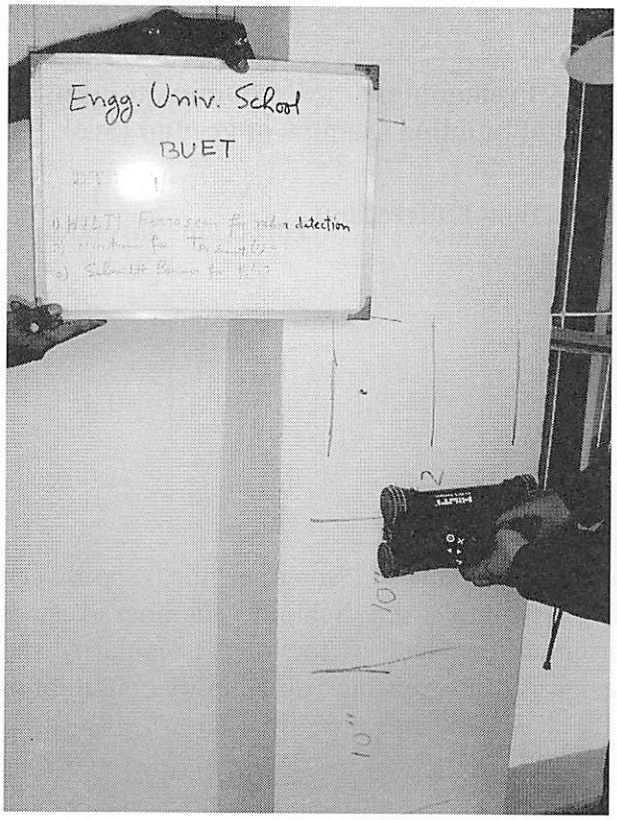


Figure 34(a) Column reinforcement detection with Ferroscan at Engineering University School Building

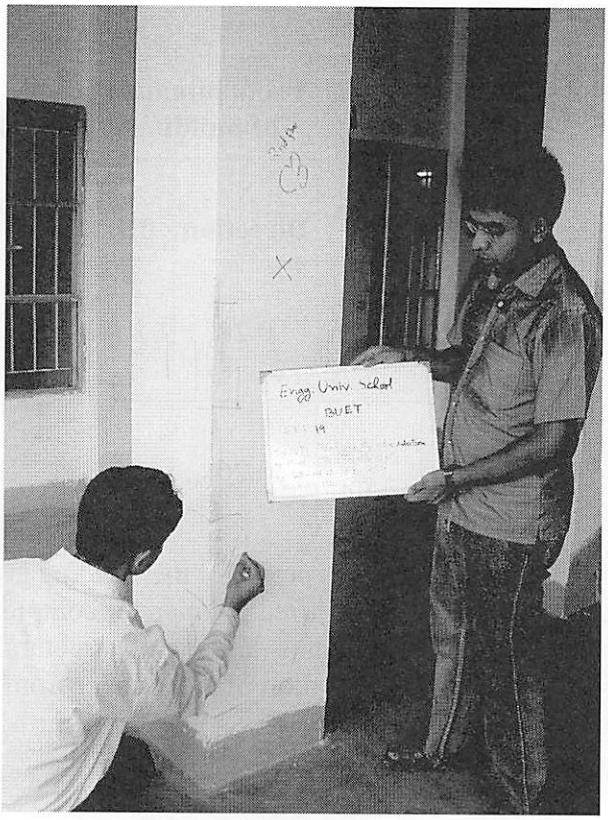


Figure 34(b) Marking in column at ground floor in Engineering University school building

Data Analysis

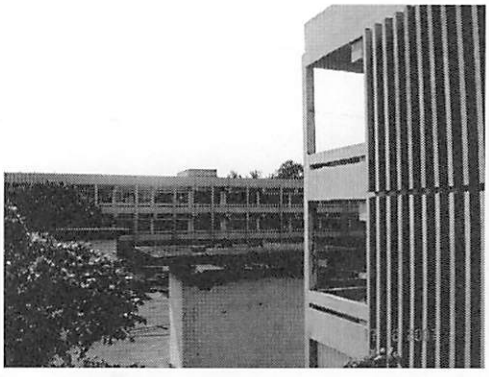
Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max^m	Min^m	Mean	Std-Dev	
Engineering University School Building.	FQ000298	Column (Gr.)	Main Bar	4	22	59	54	57	2	M
	FQ000299	Column (Gr.)	Shear Reinforcement	7	10	104	39	43	4	M
	FQ000300	Column (Gr.)	Main Bar	3	22	80	75	77	3	M
	FQ000301	Column (Gr.)	Shear Reinforcement	4	10	65	58	62	3	M
	FQ000302	Beam (Gr.)	Main Bar	3	19	59	40	49	10	M
	FQ000303	Beam (Gr.)	Shear Reinforcement	5	10	69	25	42	17	M
	FQ000304	Column (2^{nd})	Main Bar	3	19	76	69	71	4	M
	FQ000305	Column (2^{nd})	Main Bar	3	19	98	68	83	15	M
	FQ000306	Column (2^{nd})	Shear Reinforcement	5	10	62	57	59	3	M

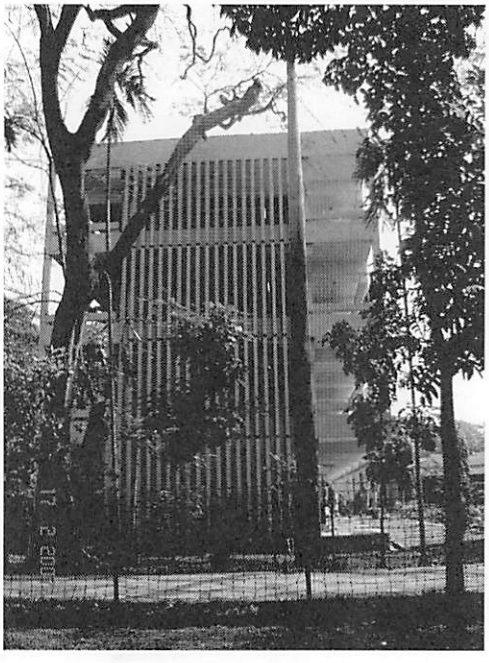
Conclusion:

Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Engineering University School Building	Roof left	0.28	0.24	0.27	0.23	0.30	0.35
	Roof right	0.26	0.22				

The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified. Concrete compressive strength from Schmidt Hammer Test is satisfactory. The building has major structural irregularities such as torsional irregularity and re-entrant corner. Variation of clear cover from design is high. Seismic vulnerability condition of the building is moderate.

3.4.12 Titumir Hall





General Information:

Year of Construction: 1965
Type of Structure: Frame structure
No of story: 4
Use: Dormitory
Floor area: 755 sqm/floor
Foundation: pile
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: no
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: yes
Nonparallel system: no

Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: 17.5 MPa (2538 psi)
Column: 25.0 MPa (3630 psi)
Shear wall: not applicable

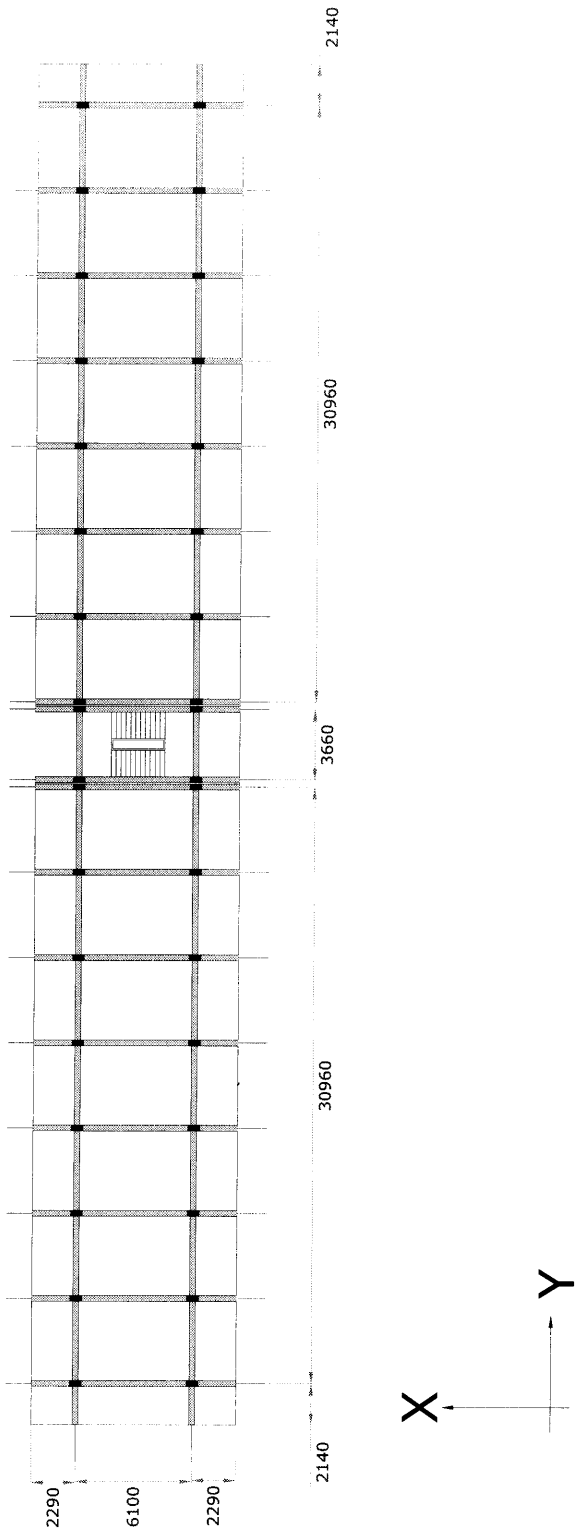


Figure 35 Titumir Hall Building Structural Element Layout (linear dimensions are in millimeter)

Reinforcement Detection

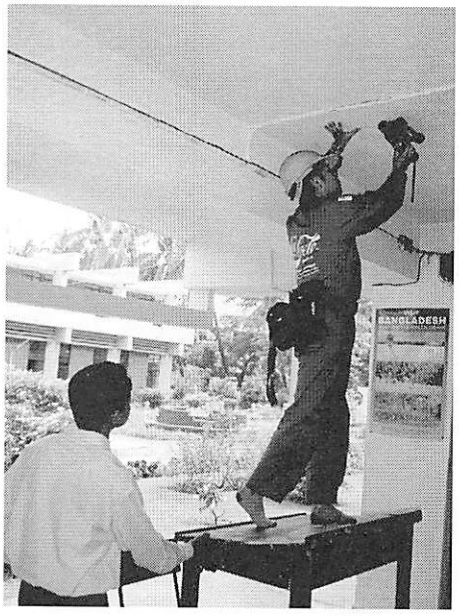


Figure 36(a) Slab reinforcement detection with Ferroscan at Titumir hall.

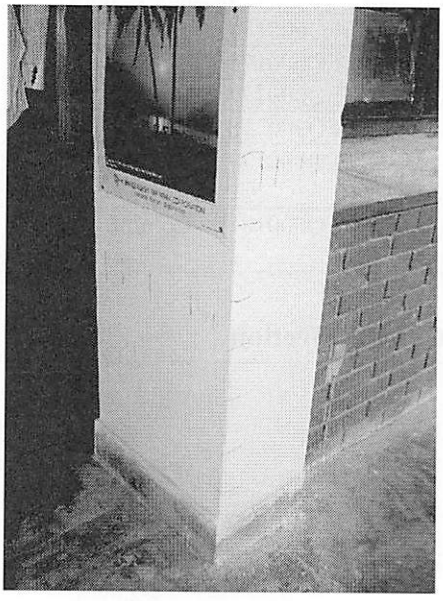


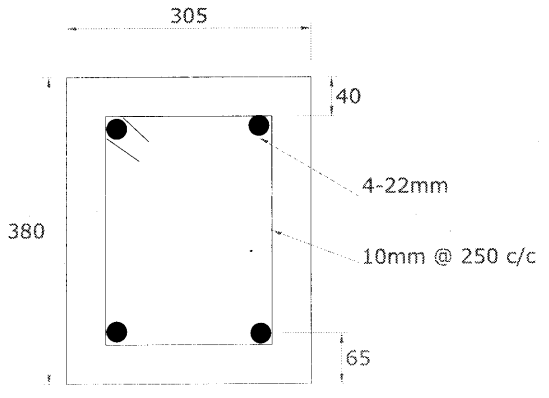
Figure 36(b) Marking of column reinforcement at the ground floor of Titumir hall.

Data Analysis

Building Name	File Name	Structural Element	Reinforcement Type	No. of Bar	Dia of Bar (mm)	Cover (mm)				Usage
						Max^m	Min^m	Mean	Std-Dev	
Titumir Hall Building.	FQ000148	Column (3rd)	Main Bar	2	19	70	70	70	0	M
	FQ000149	Column (3rd)	Shear Reinforcement	3	10	68	65	66	2	M
	FQ000150	Column (3rd)	Main Bar	2	19	60	53	56	5	M
	FQ000153	Column (3rd)	Main Bar	3	16	106	84	90	4	M
	FQ000154	Column (3rd)	Shear Reinforcement	4	10	54	41	48	9	M
	FQ000155	Column (3rd)	Main Bar	2	19	60	59	59	1	M
	FQ000156	Column (3rd)	Main Bar	2	19	65	59	62	4	M
	FQ000157	Column (3rd)	Shear Reinforcement	4	10	63	52	59	5	M
	FQ000159	Beam(3rd)	Main Bar	1	16	41	41	41	0	M
	FQ000161	Beam(3rd)	Shear Reinforcement	3	10	82	29	56	27	M
	FQ000162	Slab(Chilacota)	Main Bar	4	10	29	21	26	4	M
	FQ000163	Slab(Chilacota)	Main Bar	4	10	54	38	44	7	M
	FQ000164	Slab(Roof)	Main Bar	5	10	28	25	26	1	M
	FQ000165	Slab(Roof)	Main Bar	3	10	47	36	40	6	M
	FQ000166	Slab(3rd,upper)	Main Bar	3	10	47	36	40	6	M
	FQ000168	Slab(3rd,upper)	Main Bar	3	10	47	36	40	6	M
	FQ000169	Slab(3rd)	Main Bar	9	10	114	78	87	6	M
	FQ000170	Slab(3rd)	Main Bar	5	10	102	78	87	7	M
	FQ000171	Slab(Roof)	Main Bar	4	10	33	30	31	1	M
	FQ000172	Slab(Roof)	Main Bar	3	10	46	42	43	2	M
	FQ000173	Slab(3rd,upper)	Main Bar	4	10	101	92	95	4	M
Building	File Name	Structural	Reinforcement	No.	Dia of	Cover (mm)				Usage

Name		Element	Type	of Bar	Bar (mm)	Max[m]	Min[m]	Mean	Std-Dev	
Titumir Hall Building.	FQ000174	Slab(3rd,upper)	Main Bar	4	10	99	76	86	10	M
	FQ000175	Column (Gr.)	Main Bar	3	19	69	55	61	7	M
	FQ000176	Column (Gr.)	Main Bar	4	22	76	63	68	5	M
	FQ000177	Column (Gr.)	Main Bar	4	19	75	63	67	5	M
	FQ000178	Column (Gr.)	Main Bar	4	19	75	63	67	5	M
	FQ000179	Column (Gr.)	Shear Reinforcement	5	10	52	48	50	2	M
	FQ000181	Column (Gr.)	Shear Reinforcement	8	10	42	36	38	2	M

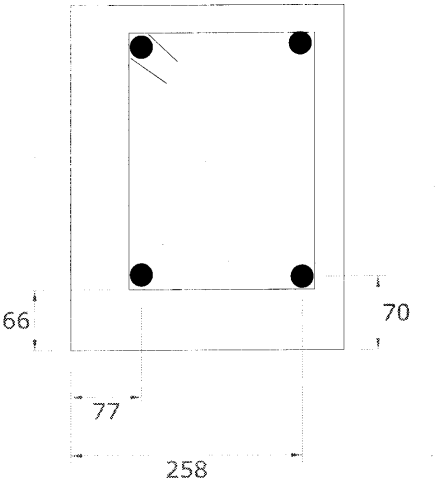
Typical Column Section

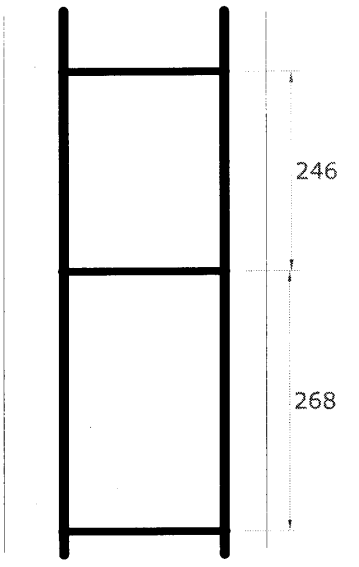


28 days cylinder strength

= 20.0 MPa (3000 psi)

Design Section (linear dimensions are in millimeter)



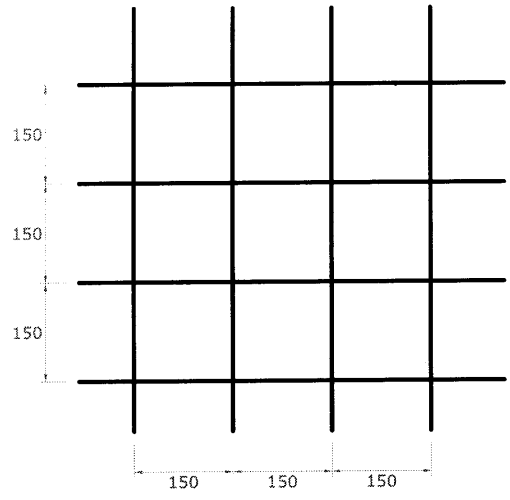


Concrete compressive strength from Schmidt Hammer Test

= 25.0 MPa (3630 psi)

Observed Section (linear dimensions are in millimeter)

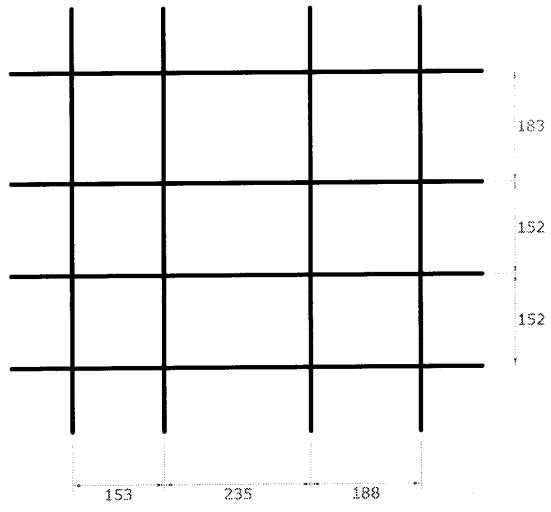
Typical Slab Reinforcement



28 days cylinder strength

= 20.0 MPa (3000 psi)

Design Section (linear dimensions are in millimeter)

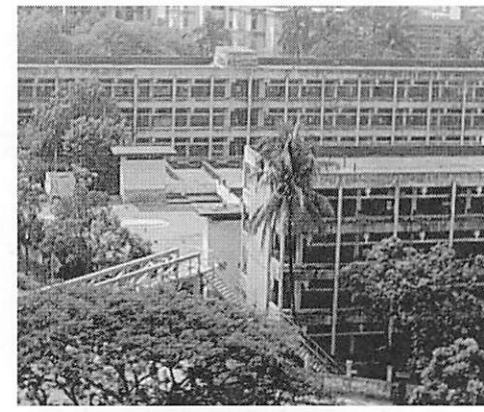


Observed Section (linear dimensions are in millimeter)

Conclusion:

The building has no major structural irregularities. Concrete compressive strength from Schmidt Hammer Test is satisfactory. Variation of clear cover from design is high.

3.4.13 Sher-e-Bangla Hall



General Information:

Year of Construction: 1965
Type of Structure: Frame structure
No of story: 4
Use: Dormitory
Floor area: 755 sqm/floor
Foundation: pile
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: no
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: yes
Nonparallel system: no

Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

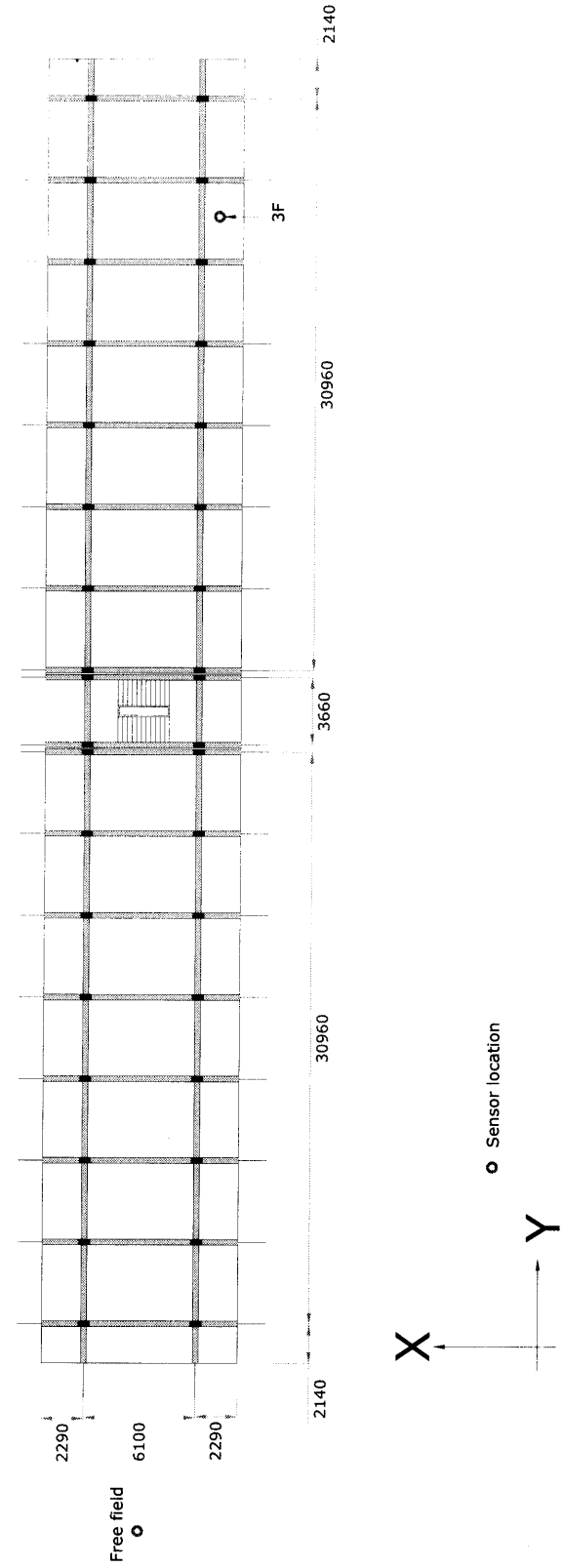
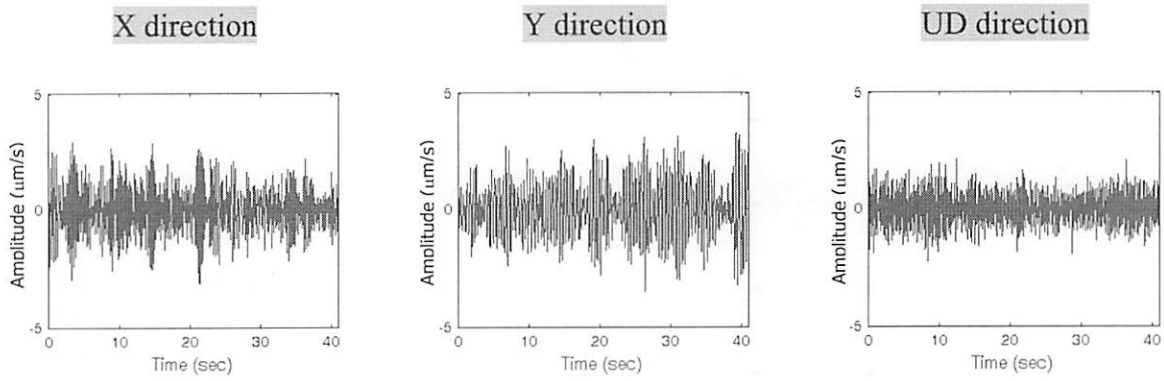
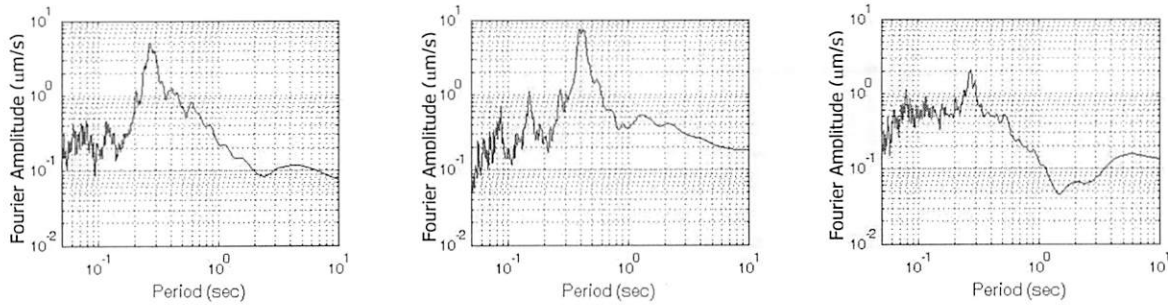


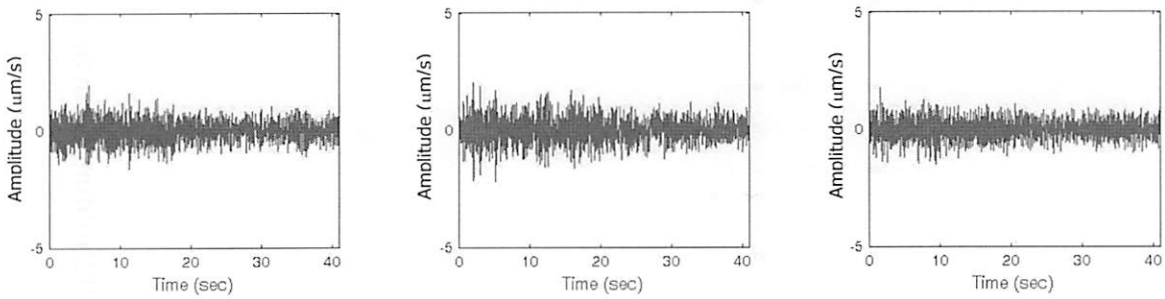
Figure 37 Sher-e-Bangla Hall Building Structural Element Layout (linear dimensions are in millimeter)



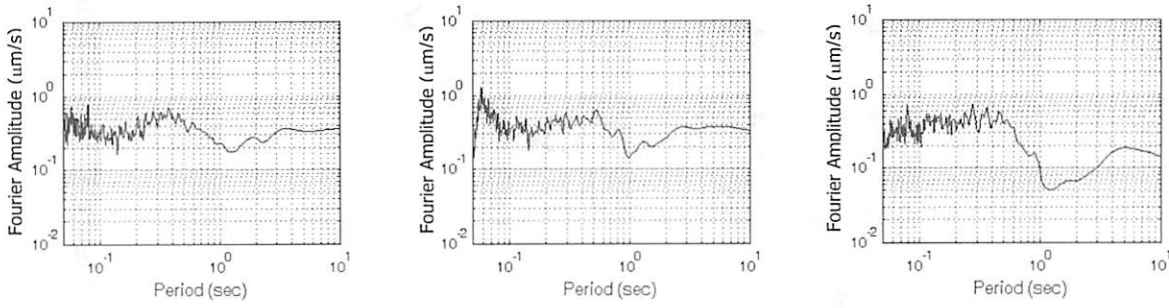
(a) Time history of Sher-e-Bangla Hall (4th floor)



(f) Fourier spectrum of Sher-e-Bangla Hall (4th floor)



(g) Time history of free field near Sher-e-Bangla Hall and Dr. MA Rashid Hall



(h) Fourier spectrum of free field near Sher-e-Bangla Hall and Dr. MA Rashid Hall

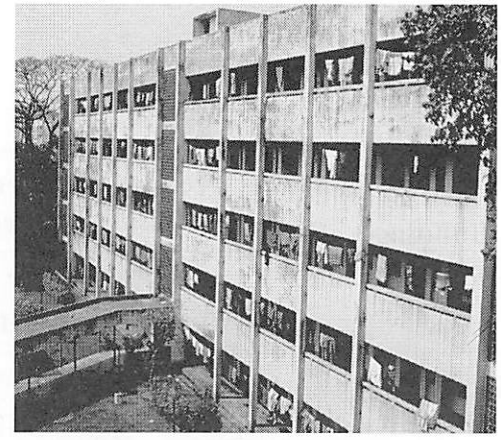
Figure 38 Time history and Fourier spectrum of Sher-e-Bangla Hall

Conclusion:

Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Sher-e-Bangla Hall Building	4th	0.27	0.40	0.27	0.40	0.38	0.52

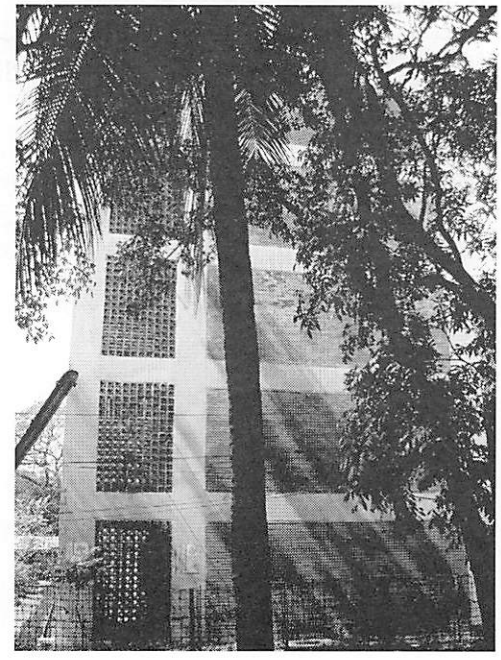
The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified.

3.4.14 Dr. MA Rashid Hall



General Information:

Year of Construction: 1980
Type of Structure: Frame structure
No of story: 5
Use: Dormitory
Floor area: 549 sqm
Foundation: pile
Lift: no
Stair: yes
Shear wall: no



Structural irregularities in plan:

Torsional irregularity: no
Re-entrant corner: no
Diaphragm discontinuity: no
Out of plan vertical element offset: yes
Nonparallel system: no

Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

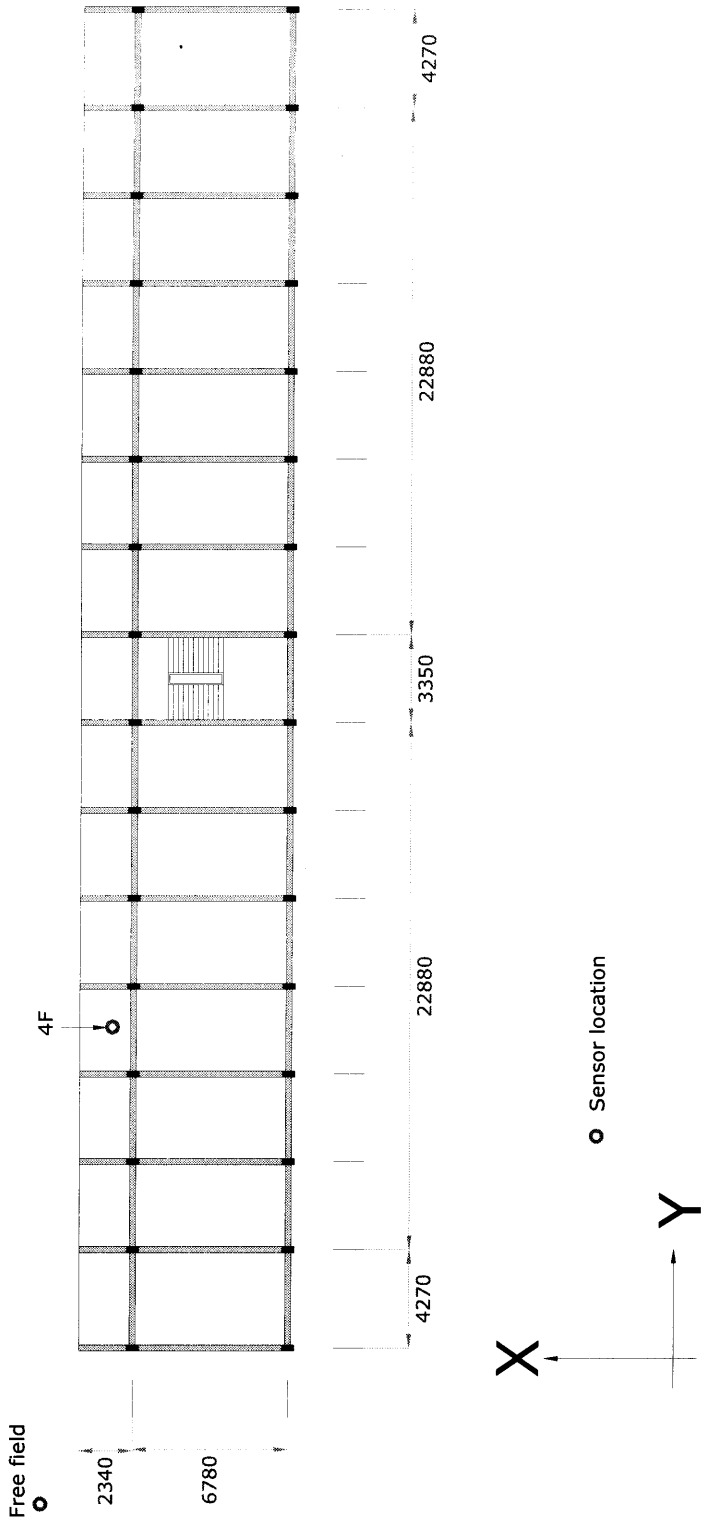
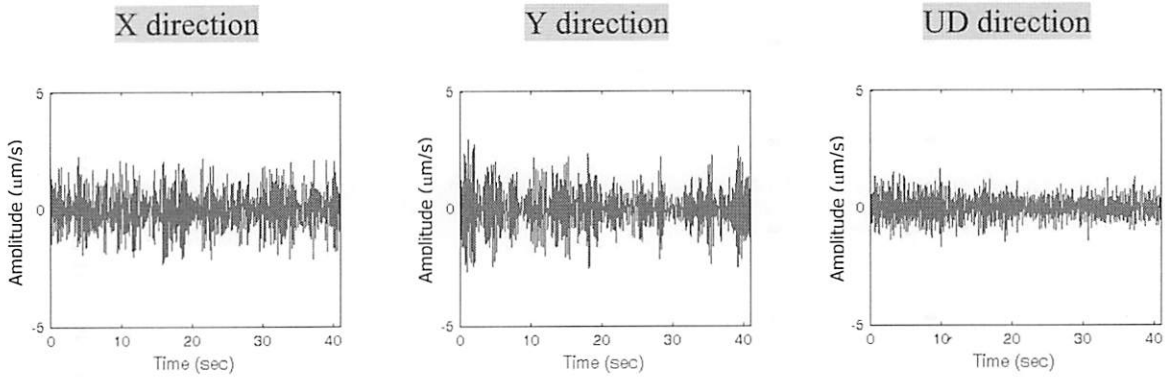
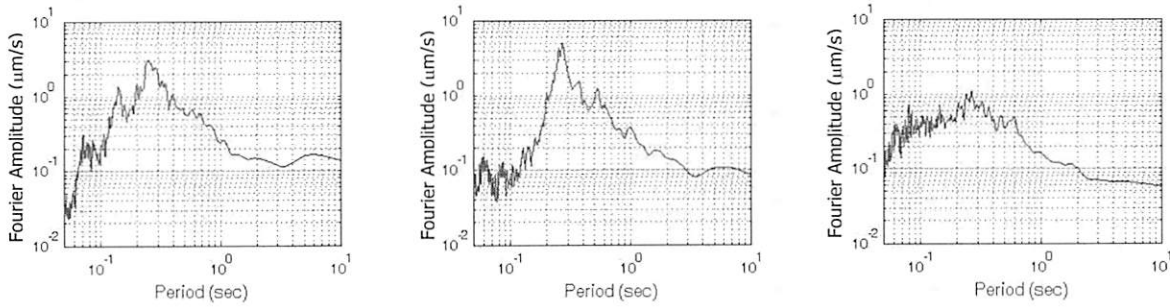


Figure 39 Dr. M A Rashid Hall Building Structural Element Layout (linear dimensions are in millimeter)



(a) Time history of Dr. MA Rashid Hall (4th floor)



(f) Fourier spectrum of Dr. MA Rashid Hall (4th floor)

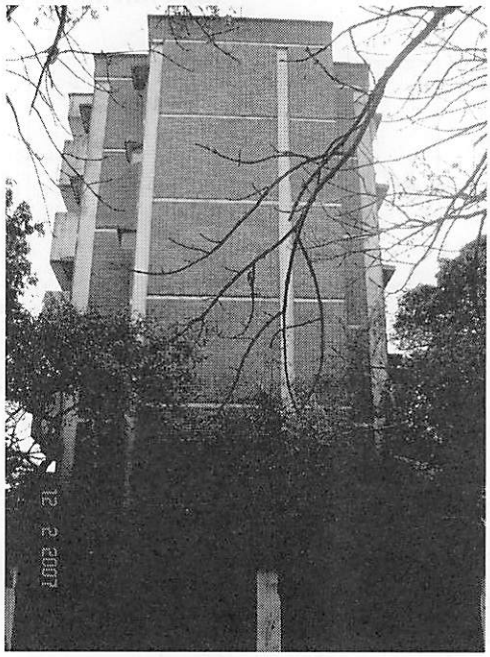
Figure 40 Time history and Fourier spectrum of Dr. MA Rashid Hall

Conclusion:

Building name/no.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Dr. M A Rashid Hall Building	4th	0.24	0.27	0.24	0.27	0.38	0.52

The predominant period of the building is close to that of the soil, so there is no possibility of resonance.

3.4.15 Building Number 47



General Information:

Year of Construction: 1997
Type of Structure: Frame structure
No of story: 6
Use: Residential
Floor area: 498 sqm
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

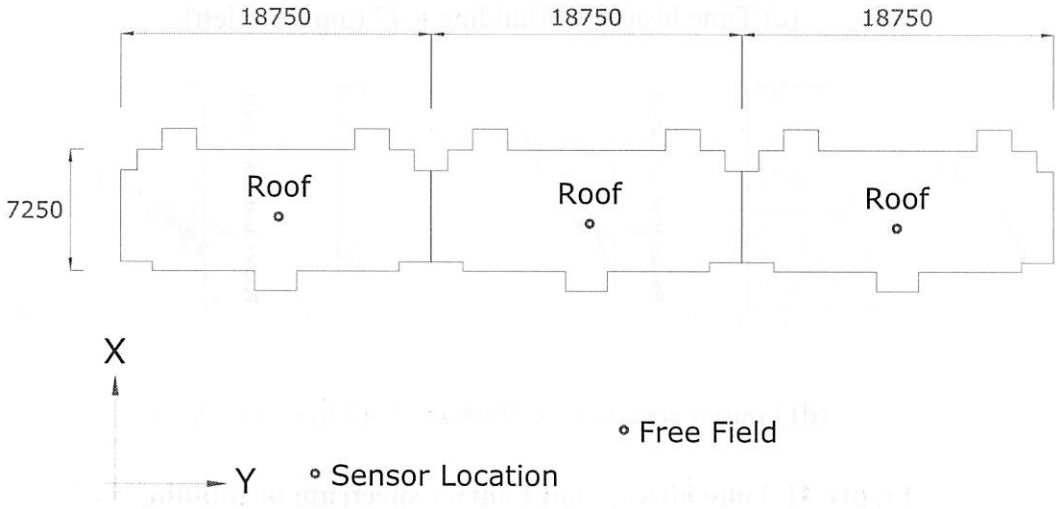
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

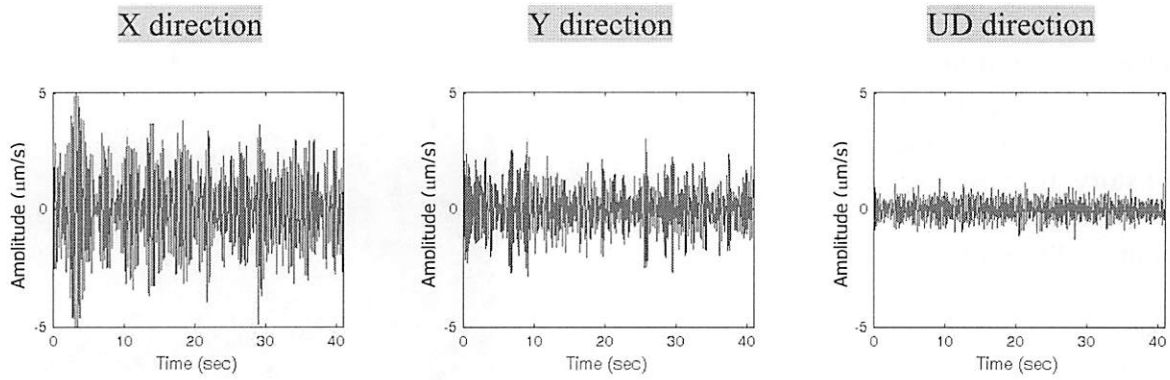
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

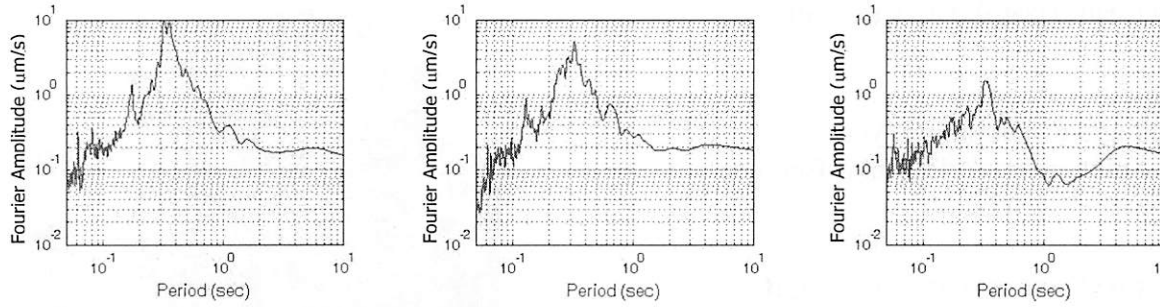
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: 17.5MPa (2531 psi)
Shear wall: not applicable

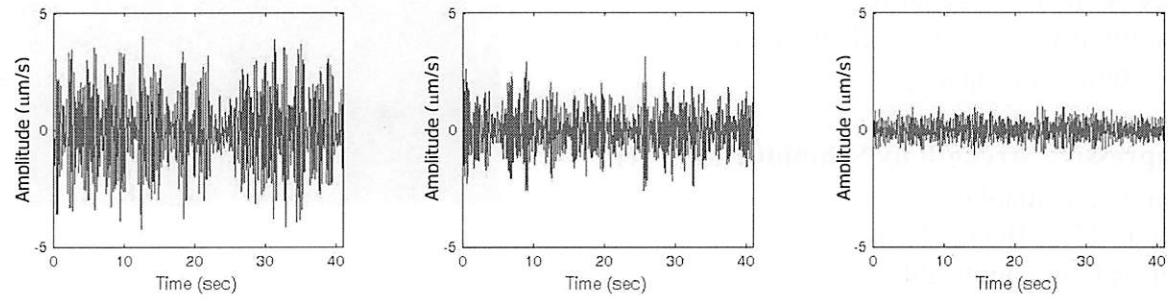




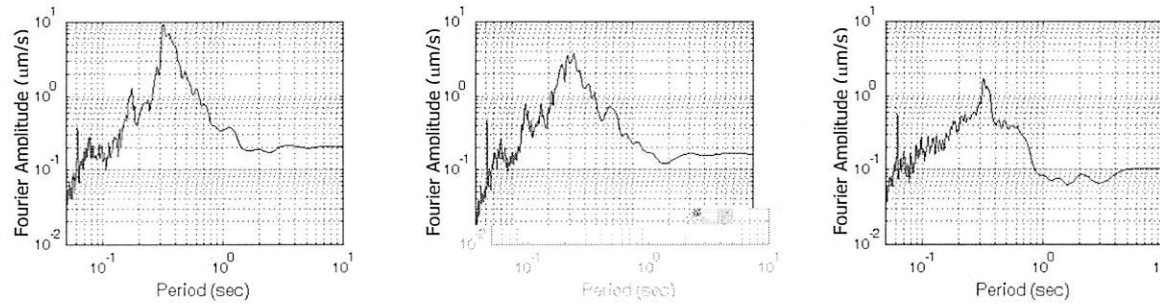
(a) Time history of Building # 47 (top floor right)



(b) Fourier spectrum of Building # 47 (top floor right)

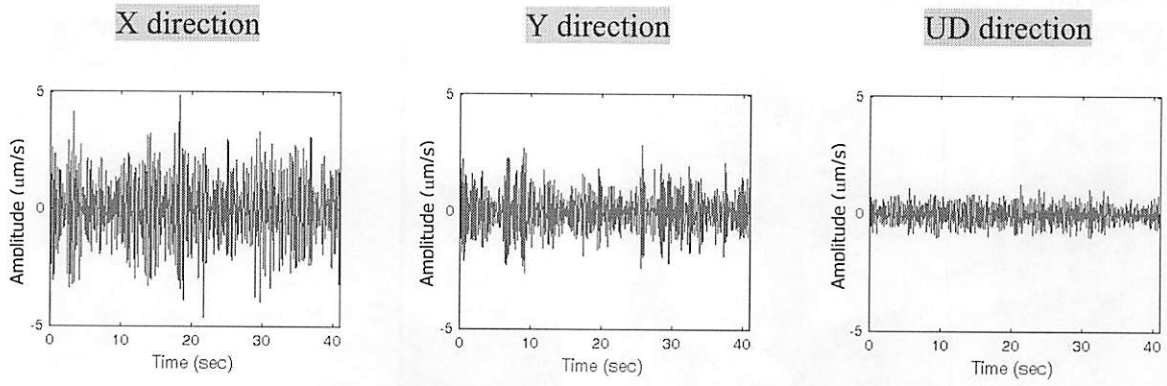


(c) Time history of Building # 47 (top floor left)

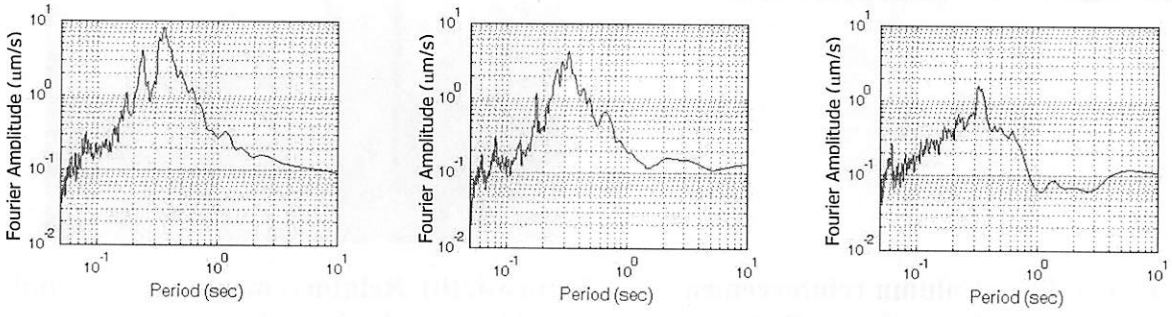


(d) Fourier spectrum of Building # 47 (top floor left)

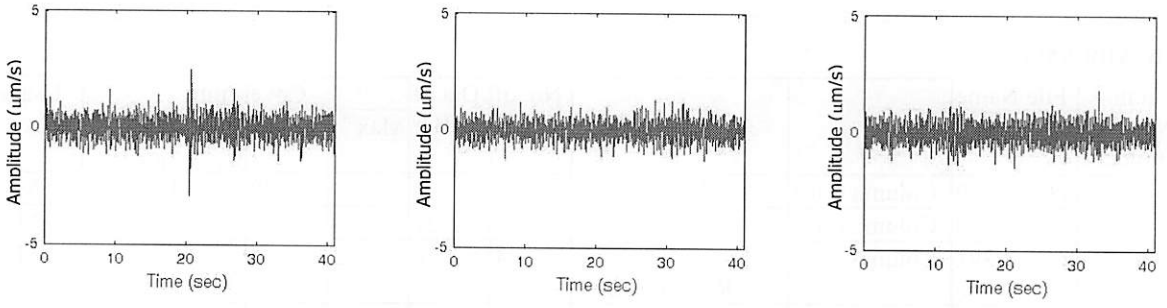
Figure 41 Time history and Fourier spectrum of Building # 47



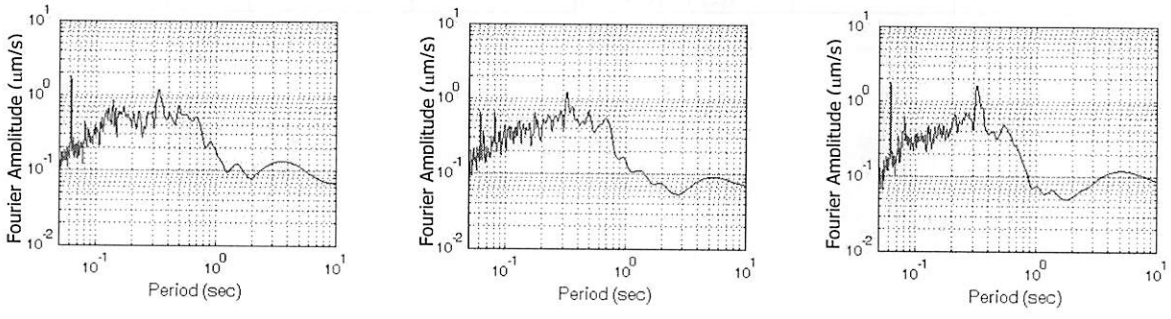
(a) Time history of Building # 47 (top floor middle)



(f) Fourier spectrum of Building # 47 (top floor middle)



(g) Time history of free field near Building # 47



(h) Fourier spectrum of free field near Building # 47

Figure 41 Time history and Fourier spectrum of Building # 47

Reinforcement Detection

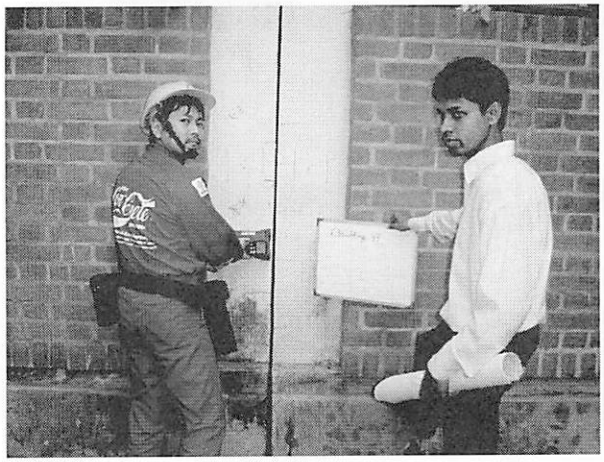


Figure 42(a) Column reinforcement detection with Ferroscan at Building 47

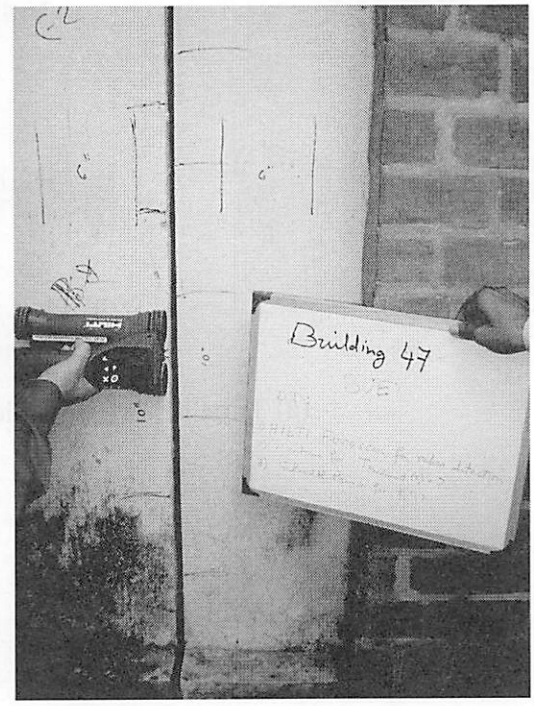


Figure 42(b) Reinforcement detection and marking in column at the ground floor of Building 47

Data Analysis

Building Name/ Number	File Name			No. of Bar	Dia of Bar	Cover, mm				Usage
						Max^m	Min^m	Mean	Std-Dev	
47	FQ000289	Column (Gr.)	Main Bar(S)	2	22	73	70	71	2	M
	FQ000290	Column (Gr.)	Main Bar(L)	3	22	78	63	72	8	M
	FQ000291	Column (Gr.)	Shear Reinforcement	4	10	63	53	58	5	M
	FQ000292	Beam (Gr.)	Main Bar	2	22	63	62	62	1	M
	FQ000293	Beam (Gr.)	Shear Reinforcement	5	10	48	35	42	5	M

Conclusion:

Building name/ number.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
47	Roof right	0.32	0.32	0.32	0.32	0.32	0.31
	Roof left	0.32	0.32				
	Roof middle	0.36	0.32				

The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified. Concrete compressive strength from Schmidt Hammer Test is not satisfactory. The building has no major structural irregularity. Variation of clear cover from design is in acceptable limit. Seismic vulnerability condition of the building is moderate.

3.4.16 Building Number 62

General Information:

Year of Construction: 2000
Type of Structure: Frame structure
No of story: 6
Use: Residential
Floor area: 223 sqm
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

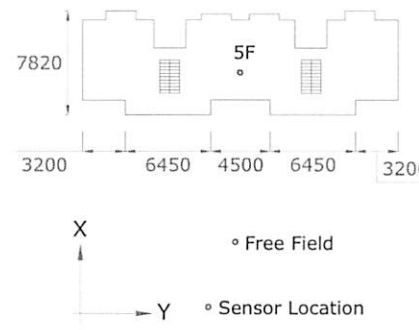
Torsional irregularity: no
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

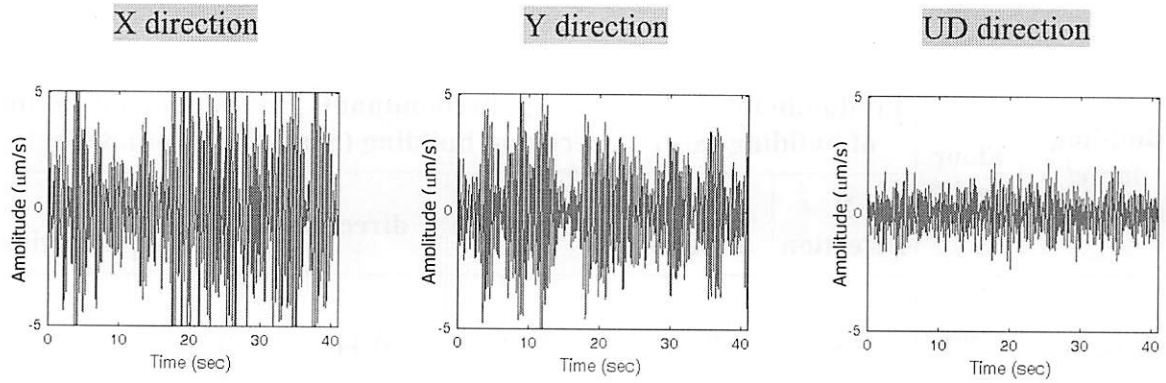
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

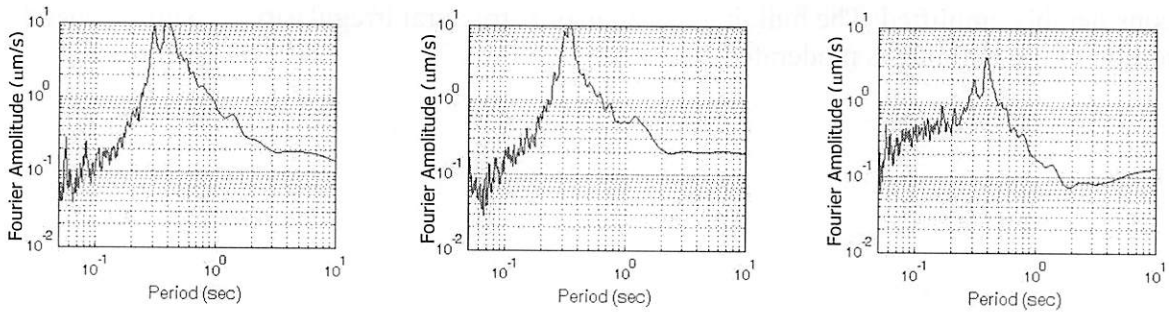
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

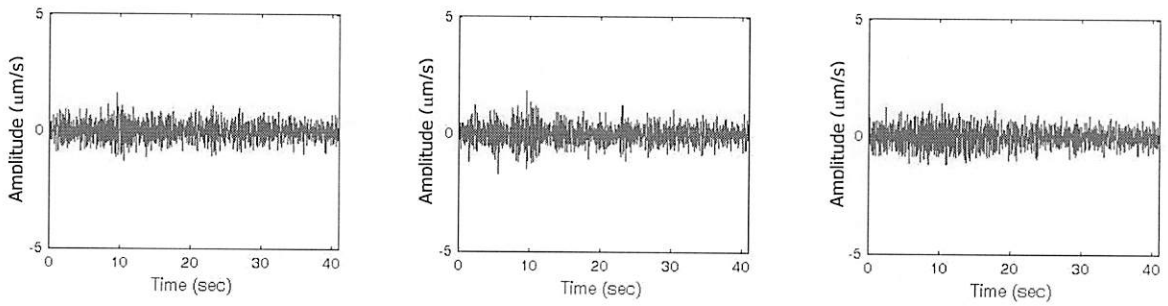




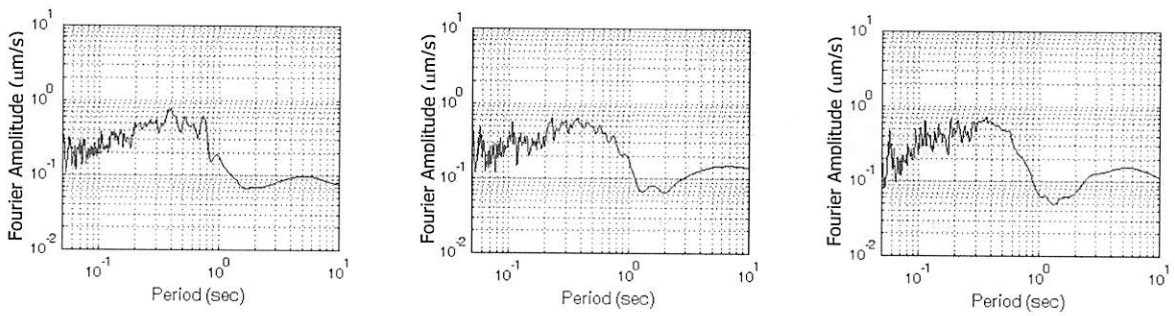
(a) Time history of Building # 62 (5th floor)



(f) Fourier spectrum of Building # 62 (5th floor)



(g) Time history of free field near Building # 62 and Building # 43



(h) Fourier spectrum of free field near Building # 62 and Building # 43

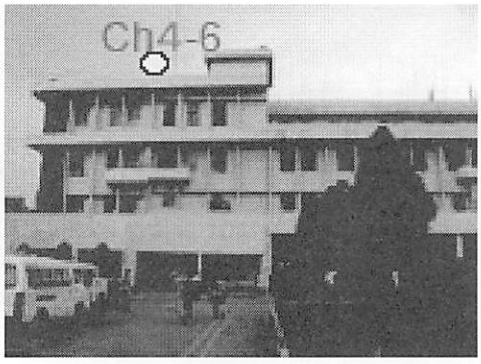
Figure 43 Time history and Fourier spectrum of Building # 62

Conclusion:

Building name/ number.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
62	5th	0.39	0.34	0.39	0.34	0.38	0.38

The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified. The building has no major structural irregularity. Seismic vulnerability condition of the building is moderate.

3.4.17 Fire Service Station (Head Office, Dhaka)



General Information:

Year of Construction: 1984
Type of Structure: Frame structure
No of story: 5 and 4
Use: Office
Floor area: -
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

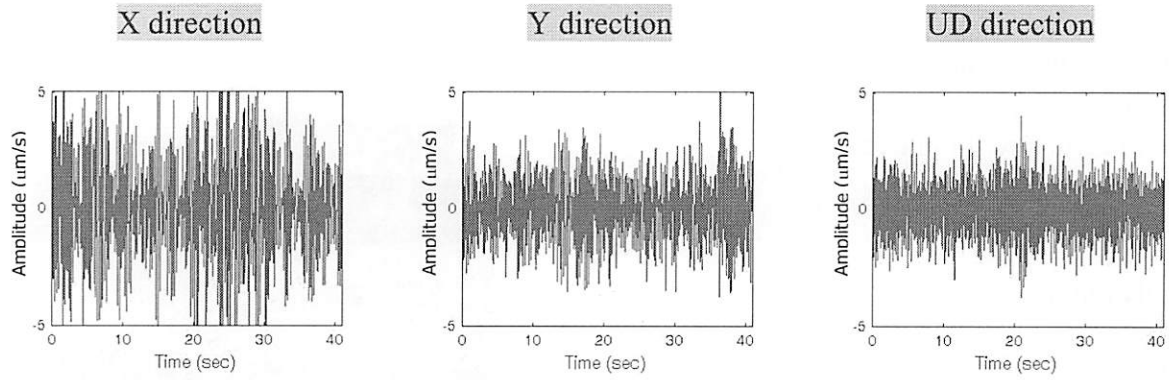
Torsional irregularity: yes
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural irregularities in height:

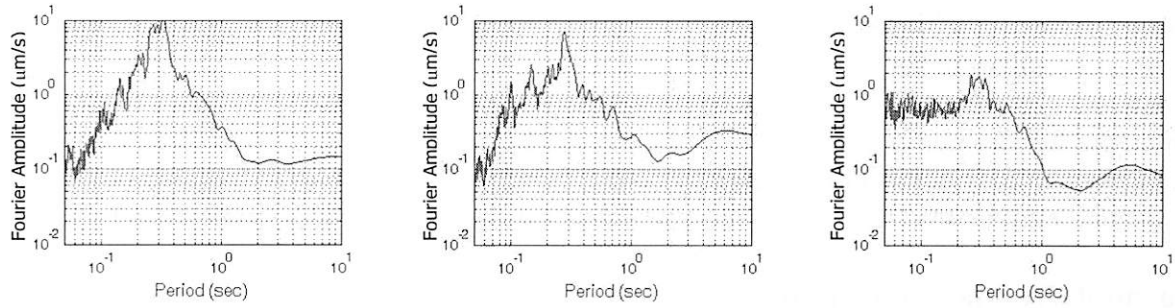
Storey stiffness irregularity: yes
Storey mass irregularity: yes
Storey geometry irregularity: yes
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

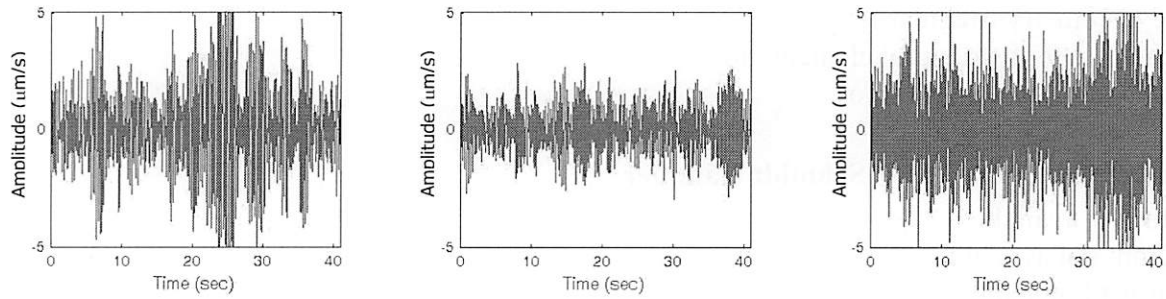
Beam: not available
Column: not available
Shear wall: not applicable



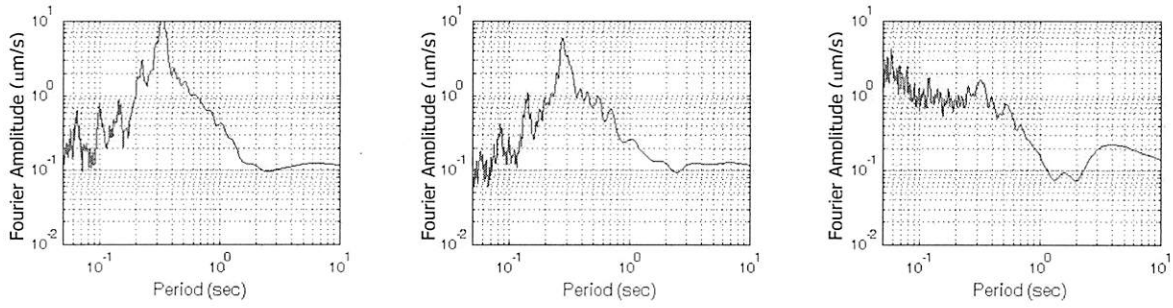
(a) Time history of Fire Service Station Head Office, Dhaka (top floor left)



(b) Fourier spectrum of Fire Service Station Head Office, Dhaka (top floor left)

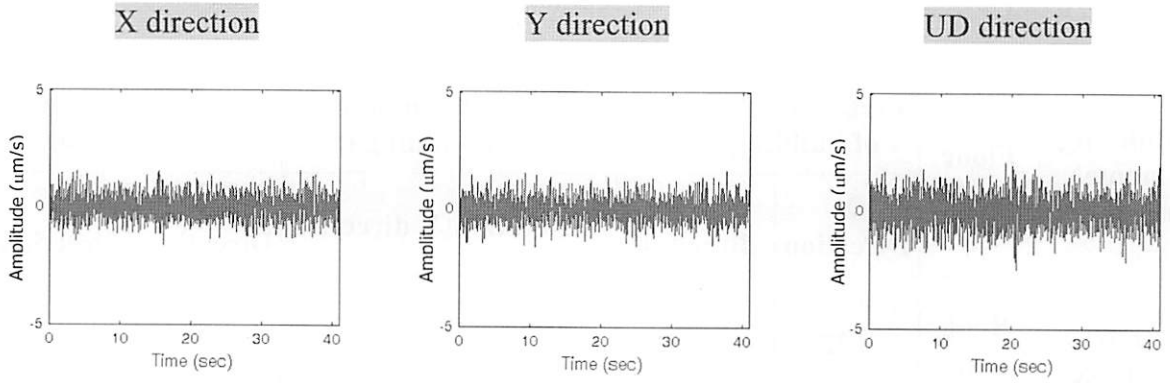


(c) Time history of Fire Service Station Head Office, Dhaka (3rd floor middle)

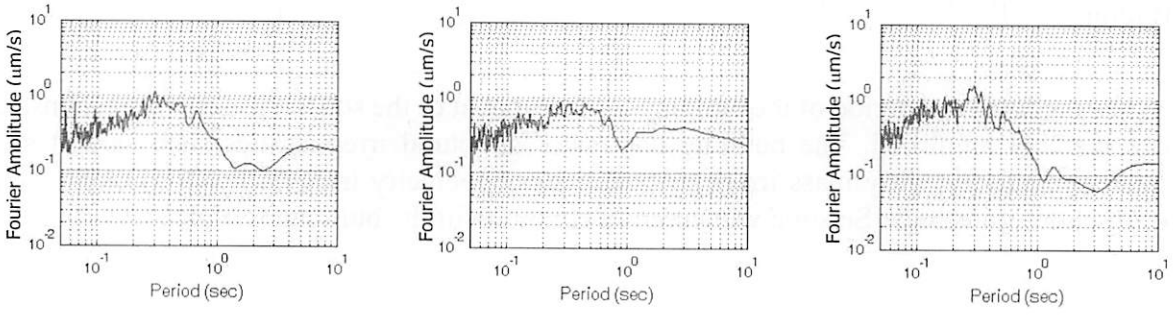


(d) Fourier spectrum of Fire Service Station Head Office, Dhaka (3rd floor middle)

Figure 44 Time history and Fourier spectrum of Fire Station Head Office, Dhaka



(g) Time history of free field near Fire Service Station Head Office, Dhaka



(h) Fourier spectrum of free field near Fire Service Station Head Office, Dhaka

Figure 44 Time history and Fourier spectrum of Fire Station Head Office, Dhaka

Reinforcement Detection - Data Analysis

Building Name/ Number	File Name			No. of Bar	Dia of Bar	Cover, mm				Usage
						Max^m	Min^m	Mean	Std-Dev	
Fire Service Station (Head office) Building.	FQ000312	Column (Gr.)	Main Bar	6	19	92	44	62	18	M
	FQ000313	Column (Gr.)	Shear Reinforcement	6	10	97	65	76	13	M
	FQ000314	Column (2nd)	Shear Reinforcement	6	10	51	37	46	6	M
	FQ000315	Column (2nd)	Main Bar	2	19	41	28	34	9	M
	FQ000316	Column (2nd)	Shear Reinforcement	6	10	74	31	45	20	M
	FQ000317	Beam (Gr.)	Main Bar	3	19	41	20	33	12	M
	FQ000318	Slab(Gr.)	Main Bar	5	10	56	37	47	7	M
	FQ000319	Slab(Gr.)	Main Bar	5	10	69	39	50	11	M
	FQ000320	Slab(Gr.)	Main Bar	6	10	51	16	36	15	M

Conclusion:

Building name/ number.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Fire Service Station Head office Building	Roof left	0.32	0.28	0.32	0.28	0.30	0.32
	Roof	0.32	0.28				

The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified. The building has major structural irregularities such as soft story, torsional irregularity, story mass irregularity and story geometry irregularity. Variation of clear cover from design is high. Seismic vulnerability condition of the building is high.

3.4.18 Ban Bhaban

General Information:

Year of Construction: 2006
Type of Structure: Frame structure
No of story: 4
Use: Office
Floor area: 465 sqm/floor
Foundation: pile
Lift: yes
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: no
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural irregularities in height:

Storey stiffness irregularity: yes
Storey mass irregularity: yes
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

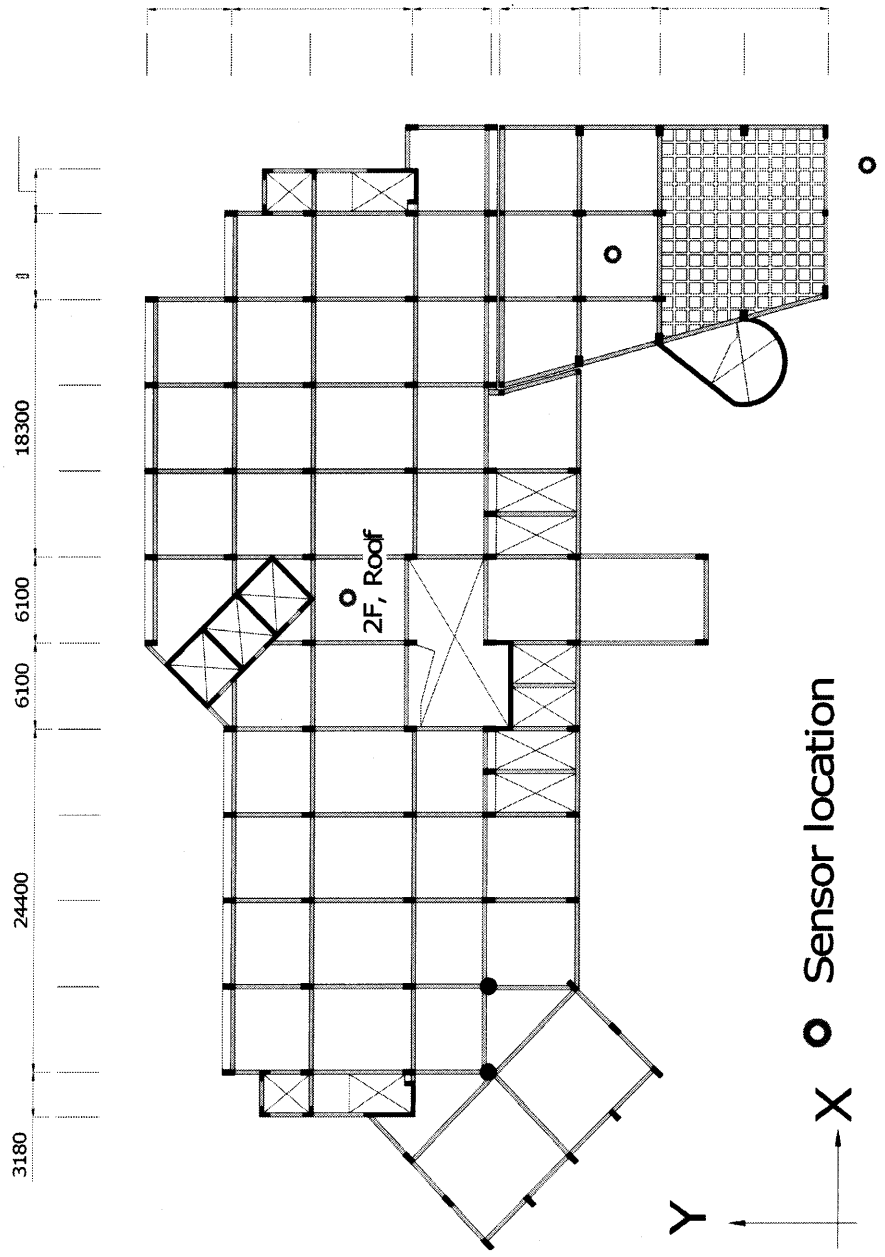
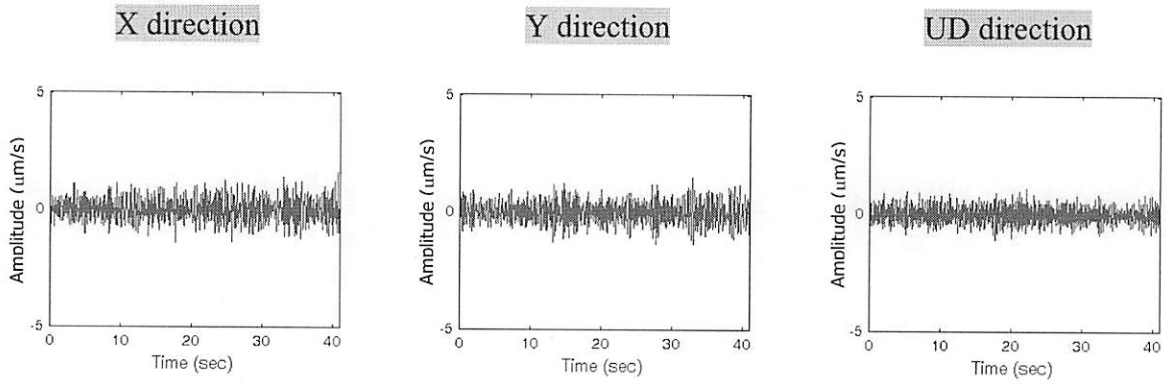
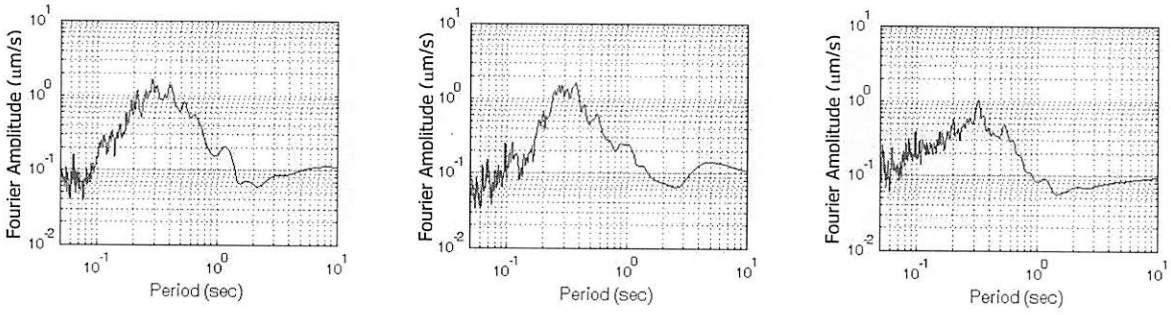


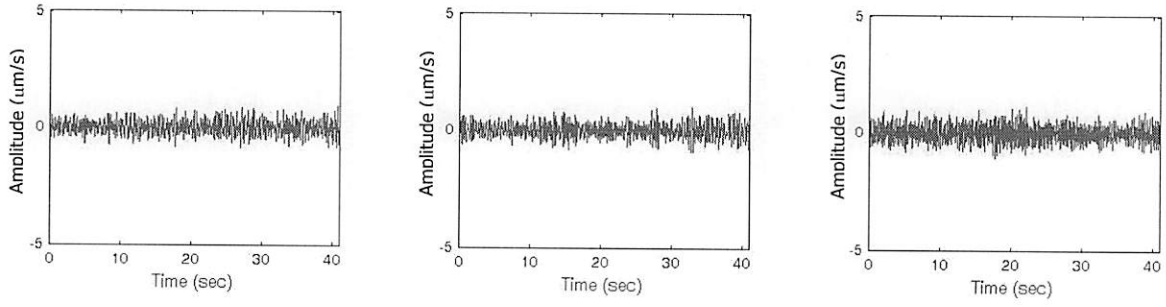
Figure 45 Ban Bhaban Building Structural Element Layout (linear dimensions are in millimeter)



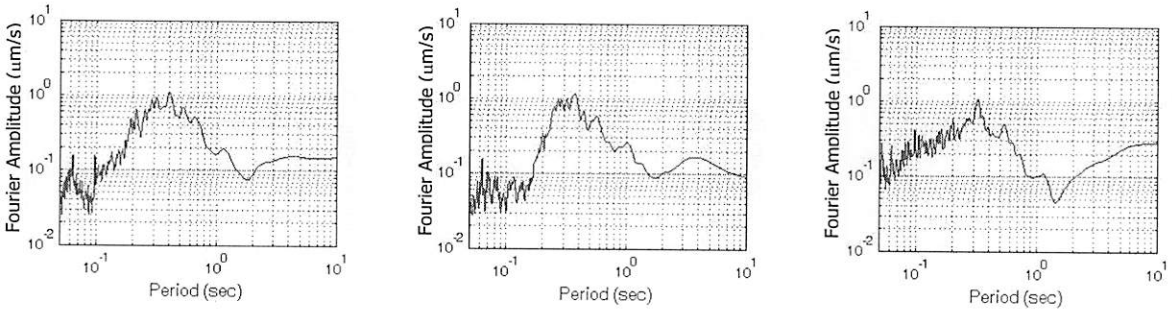
(a) Time history of Ban Bhaban main Building (top floor)



(b) Fourier spectrum of Ban Bhaban main Building (top floor)

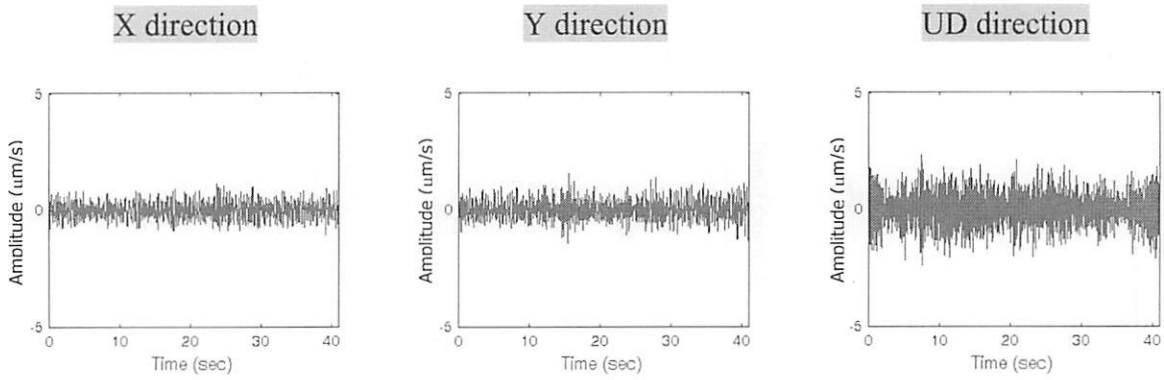


(c) Time history of Ban Bhaban main Building (2nd floor)

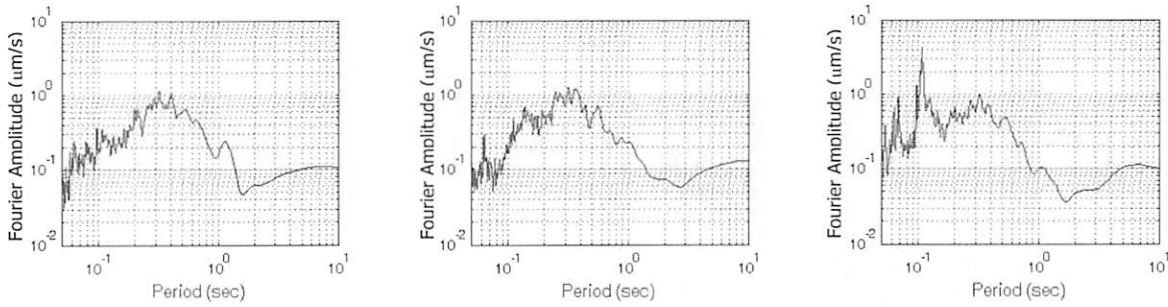


(d) Fourier spectrum of Ban Bhaban main Building (2nd floor)

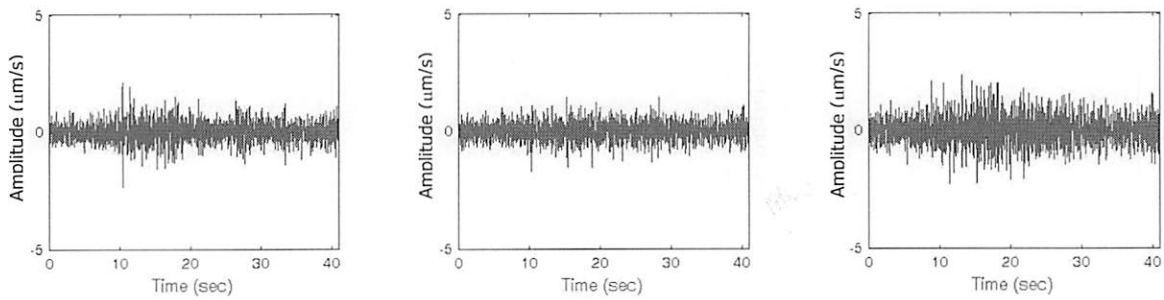
Figure 46 Time history and Fourier spectrum of Ban Bhaban



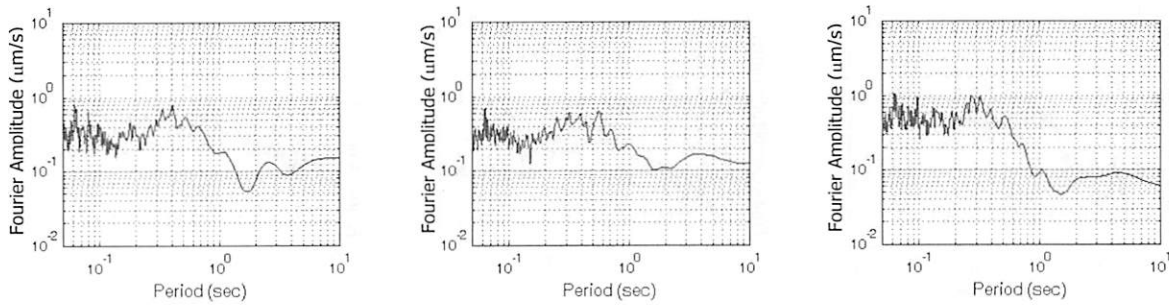
(a) Time history of Ban Bhaban extended left portion (3rd floor)



(f) Fourier spectrum of Ban Bhaban extended left portion (3rd floor)



(g) Time history of free field near Ban Bhaban



(h) Fourier spectrum of free field near Ban Bhaban

Figure 46 Time history and Fourier spectrum of Ban Bhaban

Reinforcement Detection

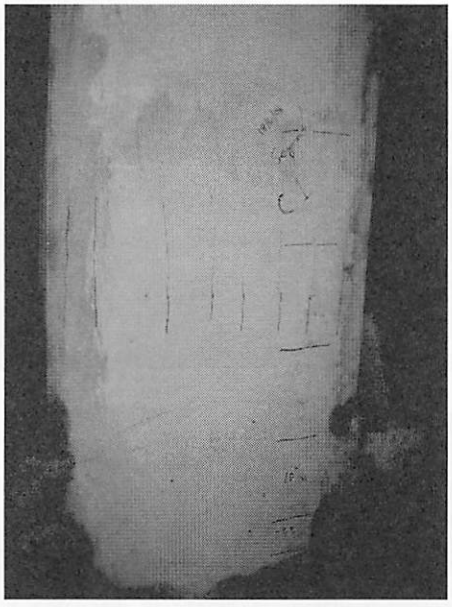


Figure 47(a) Marking of detected reinforcement of column at Ban Bhaban

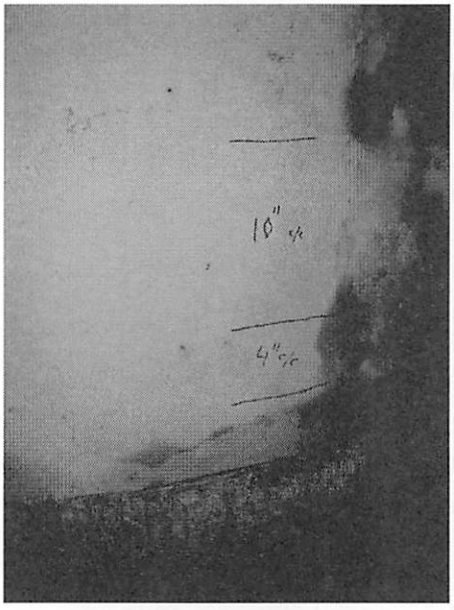


Figure 47(b) Marking of reinforcement in a column at ground floor of Ban Bhaban

Conclusion:

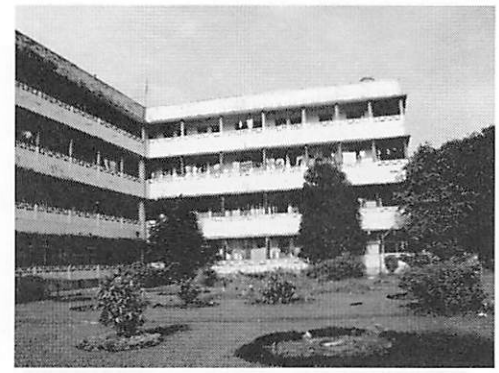
Building name/ number.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Ban Bhaban	Main Bldg Roof	0.40	0.38	0.40	0.38	0.30	0.30
	Main Bldg 2nd	0.40	0.38				
	Extended left portion Roof	0.30	0.30	0.30	0.30		

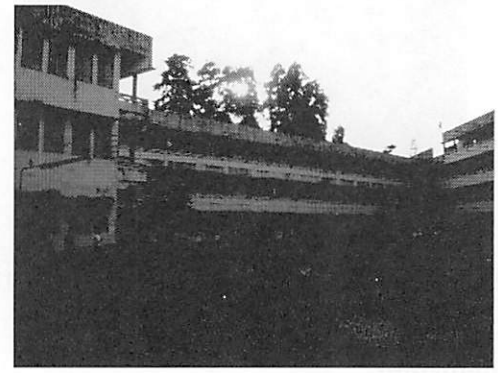
The predominant period of the building is close to that of the soil, so its seismic response can be considerably amplified. The building has major structural irregularities such as soft story, torsional irregularity and story mass irregularity. Seismic vulnerability condition of the building is moderate.

3.4.19 Ahsan-Ullah Hall

General Information:

Year of Construction: 1940
Type of Structure: Masonry
No of story: 4
Use: Dormitory
Floor area: -
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no





Structural irregularities in plan:

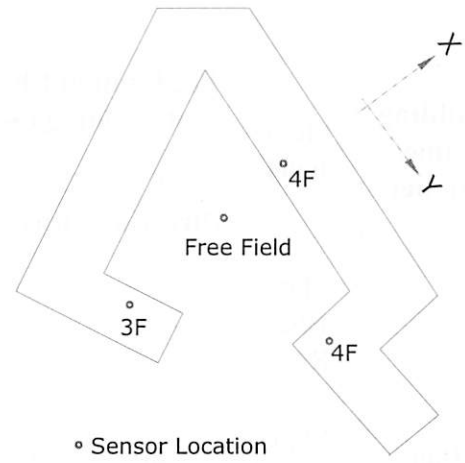
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: yes

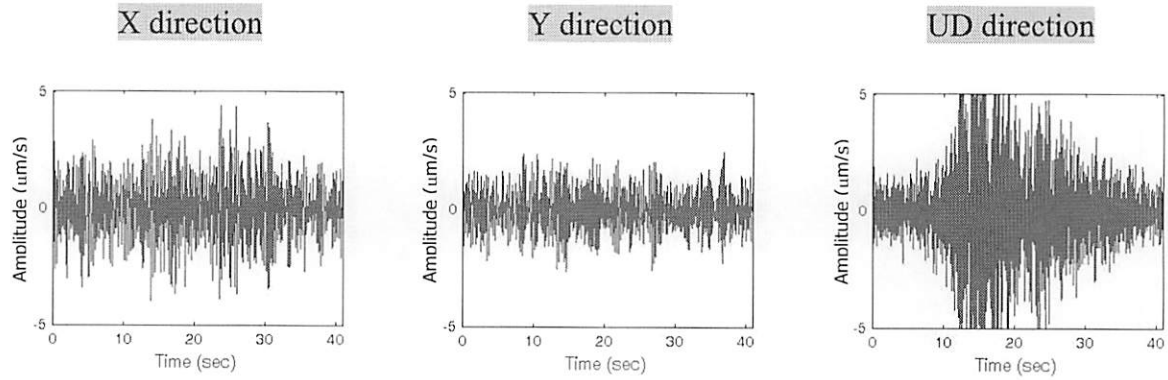
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: yes
Discontinuity of structural element: no
Discontinuity in capacity: no

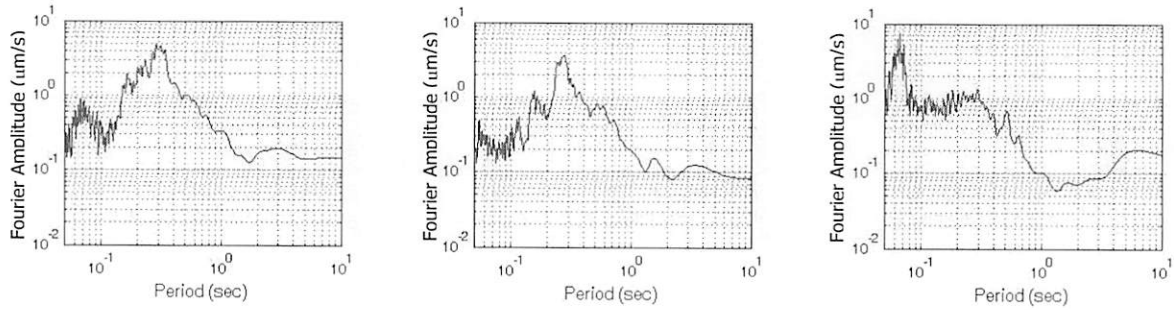
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

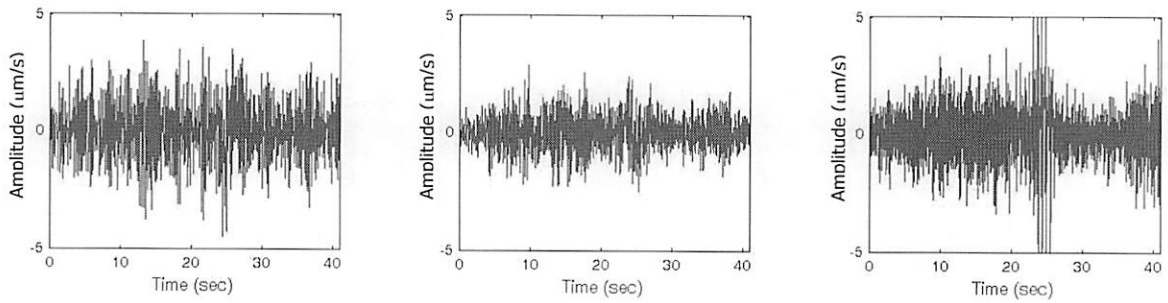




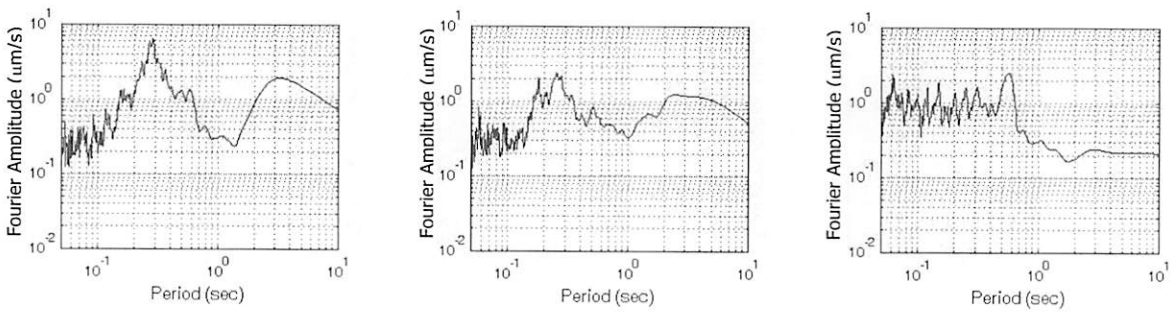
(a) Time history of Ahsan-Ullah Hall (4th floor middle)



(b) Fourier spectrum of Ahsan-Ullah Hall (4th floor middle)

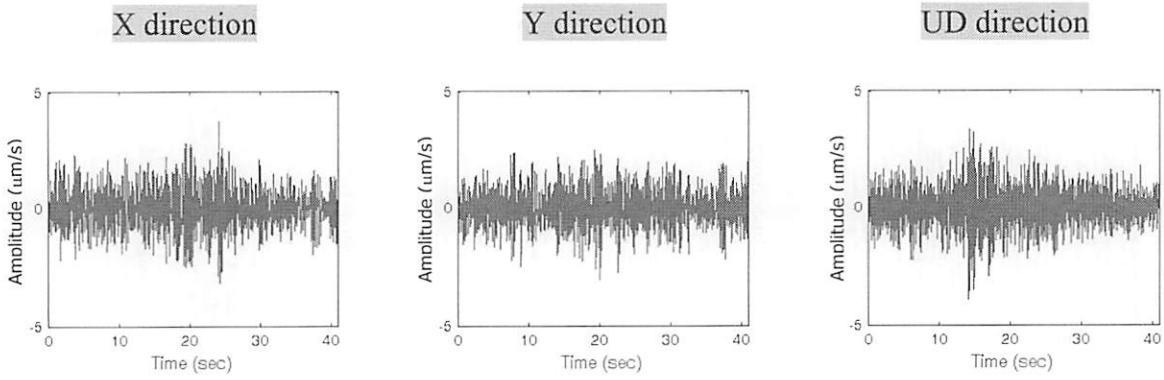


(c) Time history of Ahsan-Ullah Hall (4th floor right)

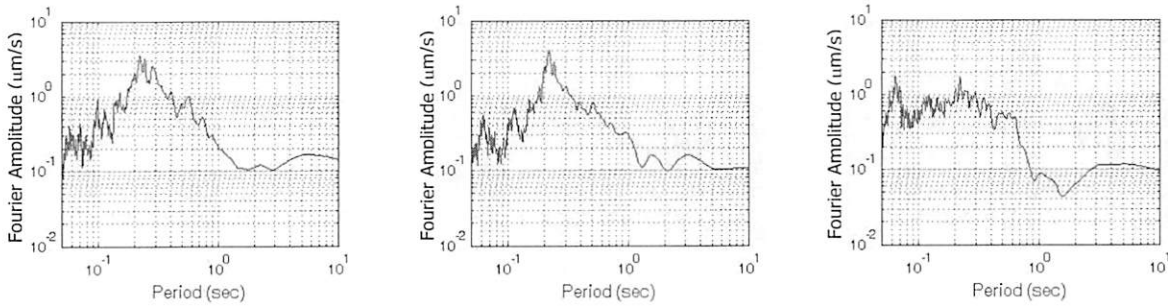


(d) Fourier spectrum of Ahsan-Ullah Hall (4th floor right)

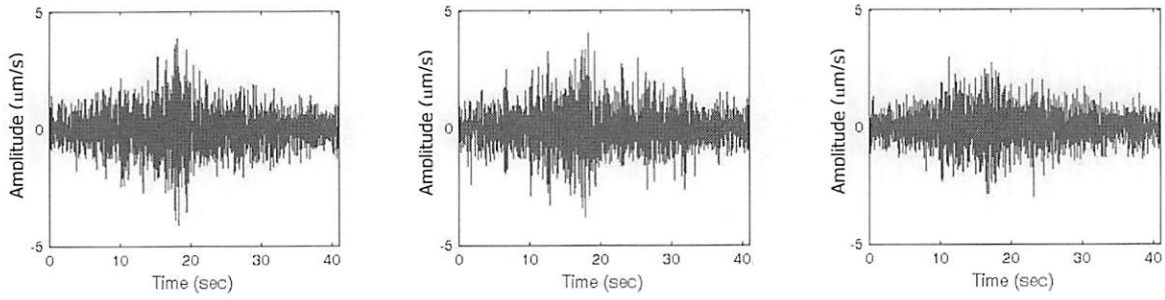
Figure 48 Time history and Fourier spectrum of Ahsan-Ullah Hall



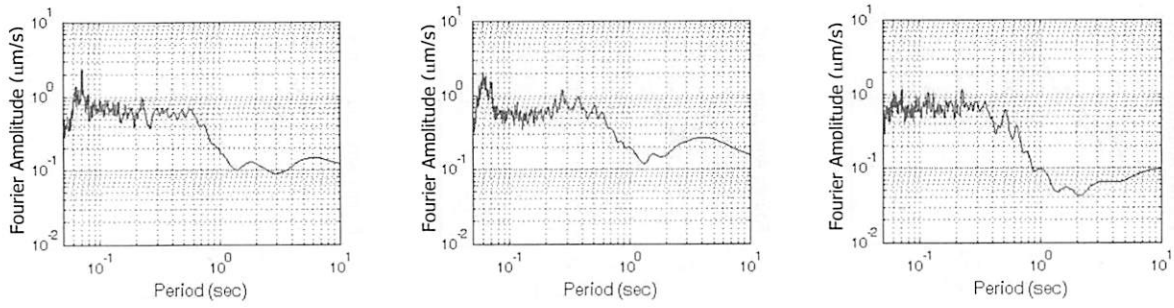
(a) Time history of Ahsan-Ullah Hall (3rd floor left)



(f) Fourier spectrum of Ahsan-Ullah Hall (3rd floor left)



(g) Time history of free field near Ahsan-Ullah Hall



(h) Fourier spectrum of free field near Ahsan-Ullah Hall

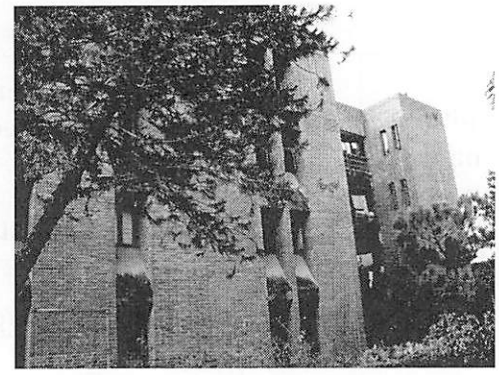
Figure 48 Time history and Fourier spectrum of Ahsan-Ullah Hall

Conclusion:

Building name/ number.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Ahsan-Ullah Hall	4th middle	0.30	0.28	0.27	0.25	0.07	0.06
	4th right	0.29	0.25				
	3rd left	0.22	0.22				

The predominant period of the building is close to that of the soil, so there is possibility of resonance. The building has major structural irregularities such as torsional irregularity, re-entrant corner, non-parallel system and story geometry irregularity. Seismic vulnerability condition of the building is high.

3.4.20 Shahid Smrity Hall



General Information:

Year of Construction: 1961
Type of Structure: Masonry
No of story: 5 and 4
Use: Dormitory
Floor area: -
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

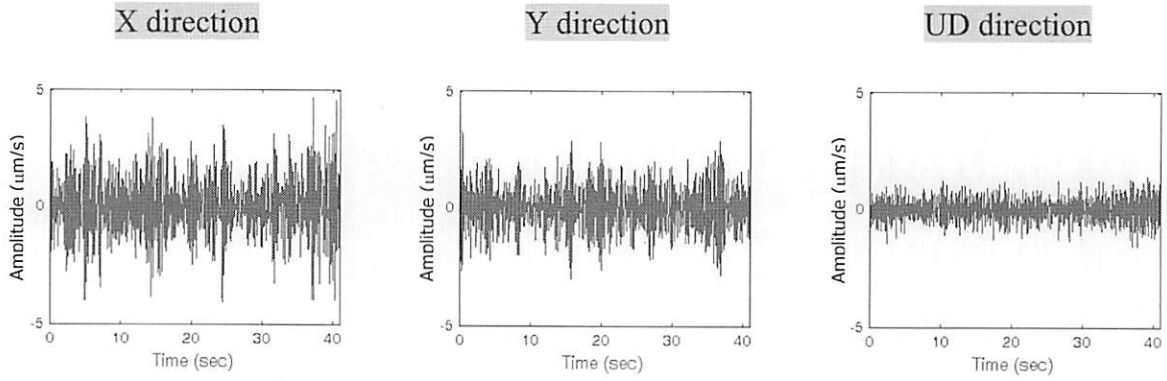
Torsional irregularity: no
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural irregularities in height:

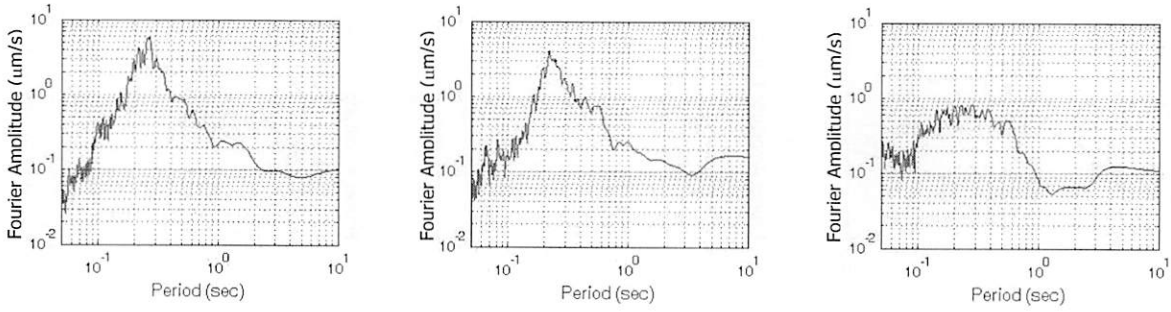
Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

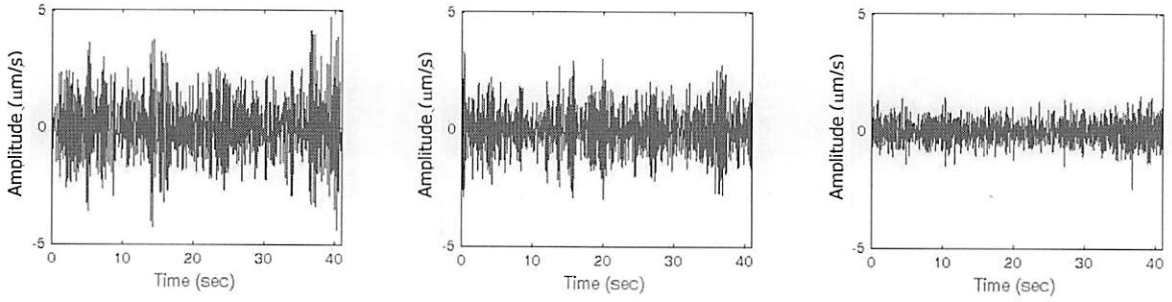
Beam: not available
Column: not available
Shear wall: not applicable



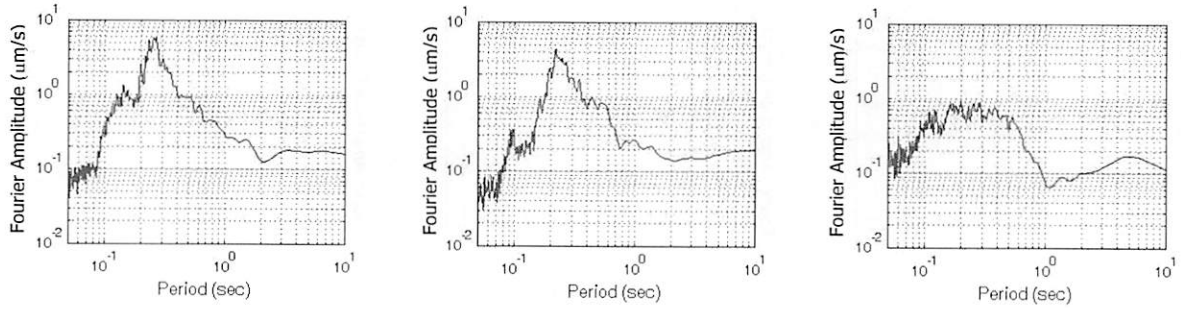
(a) Time history of Shahid Smrity Hall middle (top floor right)



(b) Fourier spectrum of Shahid Smrity Hall middle (top floor right)

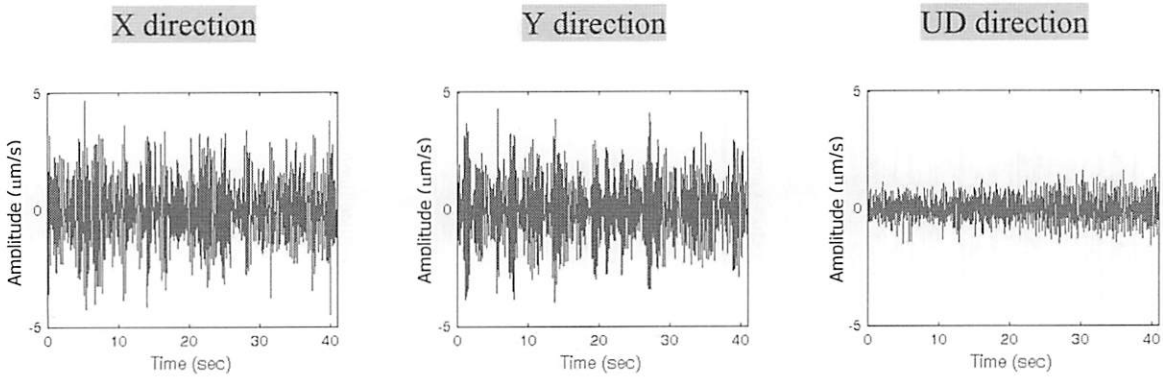


(c) Time history of Shahid Smrity Hall middle (top floor left)

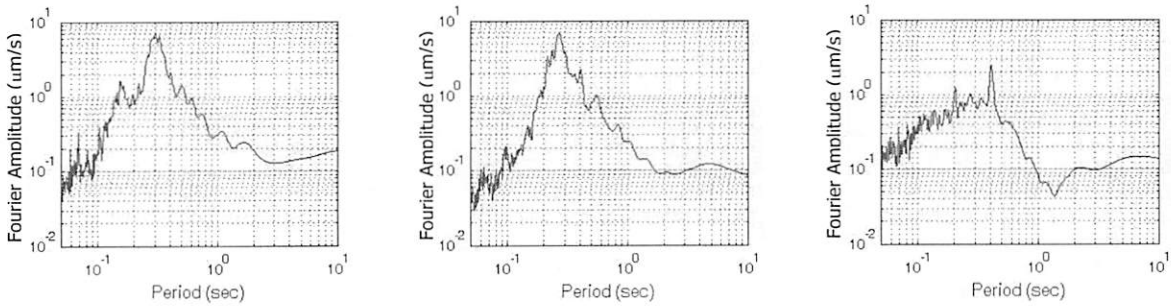


(d) Fourier spectrum of Shahid Smrity Hall middle (top floor left)

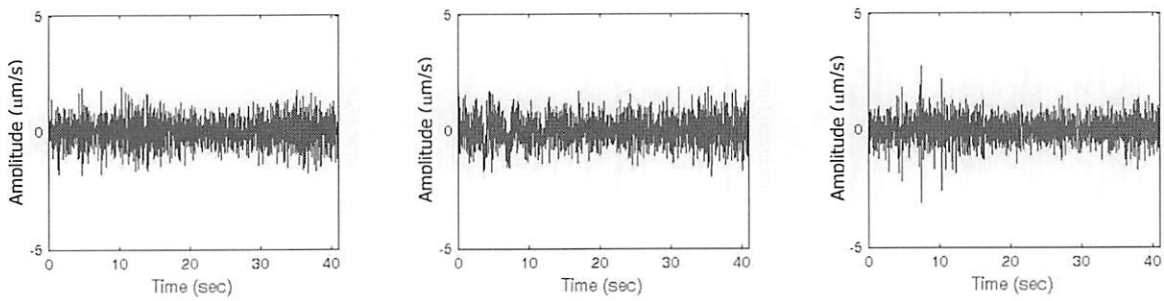
Figure 49 Time history and Fourier spectrum of Shahid Smrity Hall middle



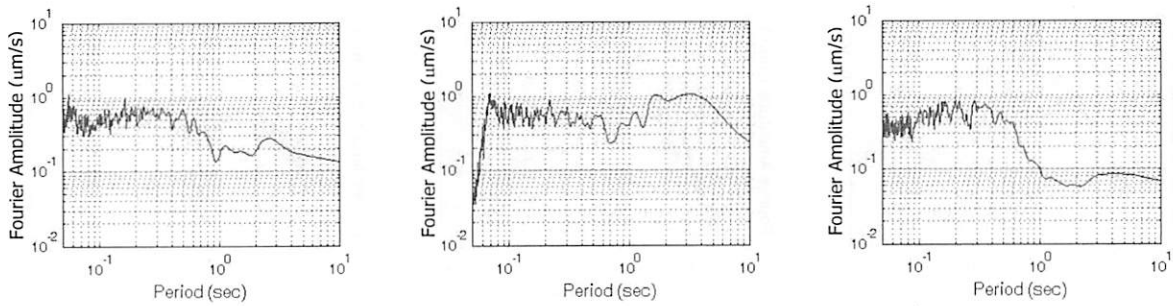
(a) Time history of Shahid Smrity Hall north (top floor center)



(f) Fourier spectrum of Shahid Smrity Hall north (top floor center)



(g) Time history of free field near Shahid Smrity Hall



(h) Fourier spectrum of free field near Shahid Smrity Hall north

Figure 50 Time history and Fourier spectrum of Shahid Smrity Hall north

Conclusion:

Building name/ number.	Floor level	Predominant Period of building (Sec)		Avg. Predominant Period of building (Sec)		Predominant Period of ground (Sec)	
		X Direction	Y direction	X Direction	Y direction	X Direction	Y direction
Shahid Smrity Hall middle bldg	Roof right	0.27	0.21	0.27	0.22	0.18	0.07
	Roof left	0.27	0.21				
Shahid Smrity Hall north bldg	Roof	0.30	0.28	0.30	0.28		

The predominant period of the building is close to that of the soil, so there is possibility of resonance. The building has no major structural irregularity. Seismic vulnerability condition of the building is moderate.

3.4.21 Register Building

General Information:

Year of Construction: 1910
Type of Structure: Masonry
No of story: 2
Use: Academic
Floor area: 2323 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

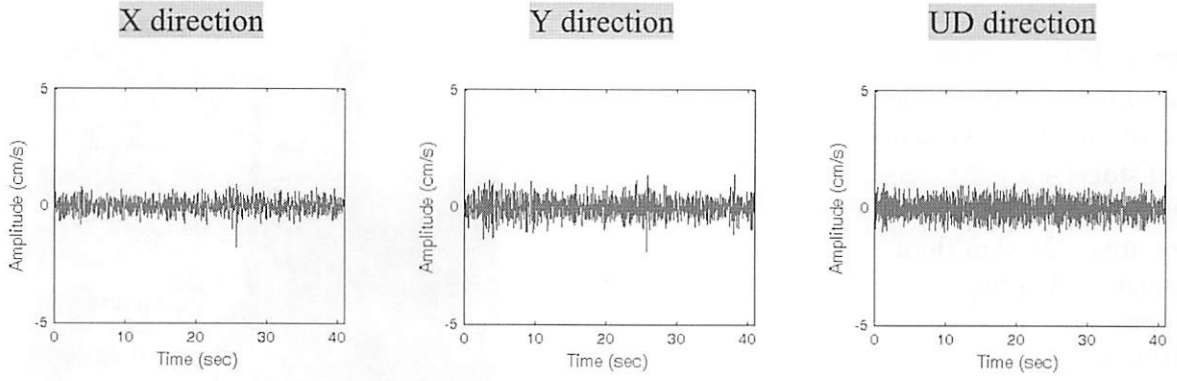
Torsional irregularity: no
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural irregularities in height:

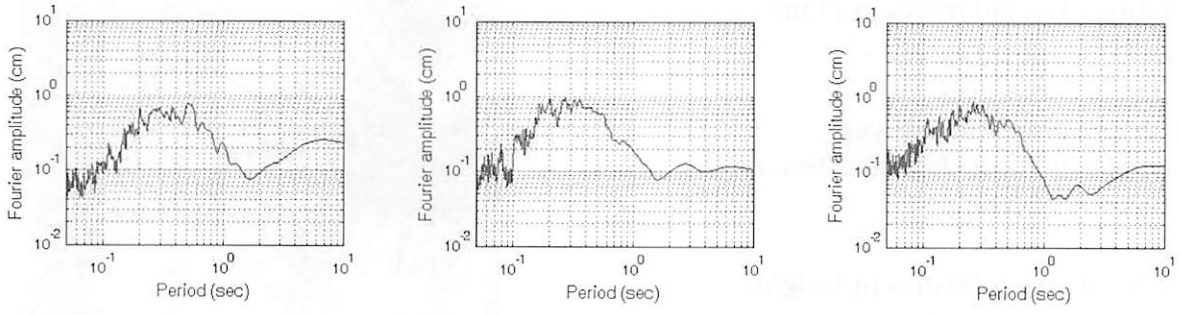
Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable



(a) Time history of Register Building (1st floor)



(f) Fourier spectrum of Register Building (1st floor)

Figure 51 Time history and Fourier spectrum of Register Building

3.4.22 Building Number 1

General Information:

Year of Construction: 1962
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 226 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural Irregularities in Plan:

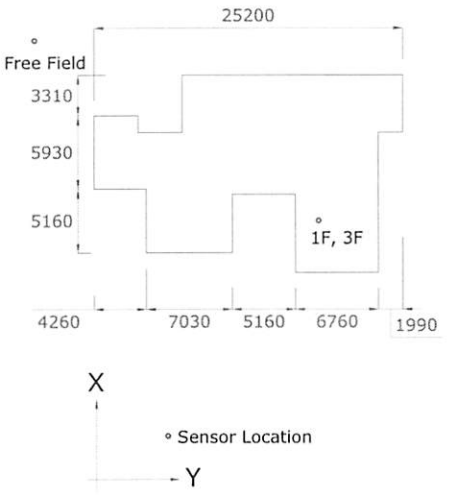
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

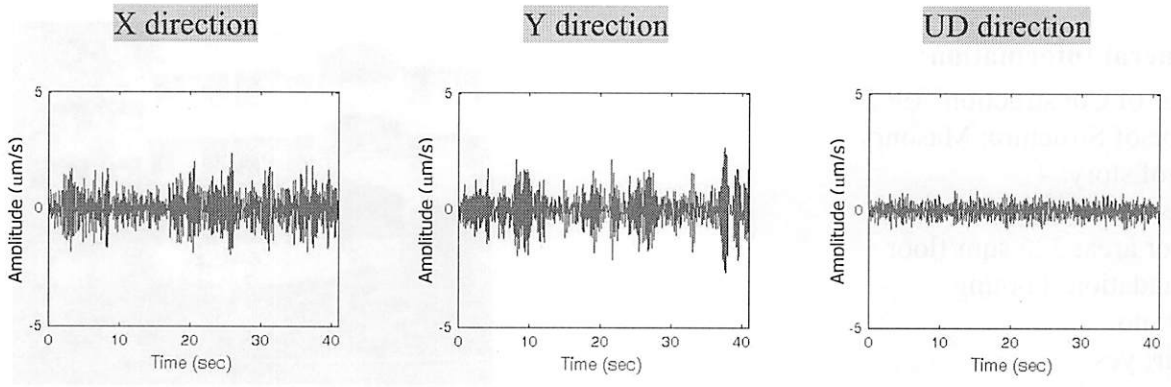
Structural Irregularities in Height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

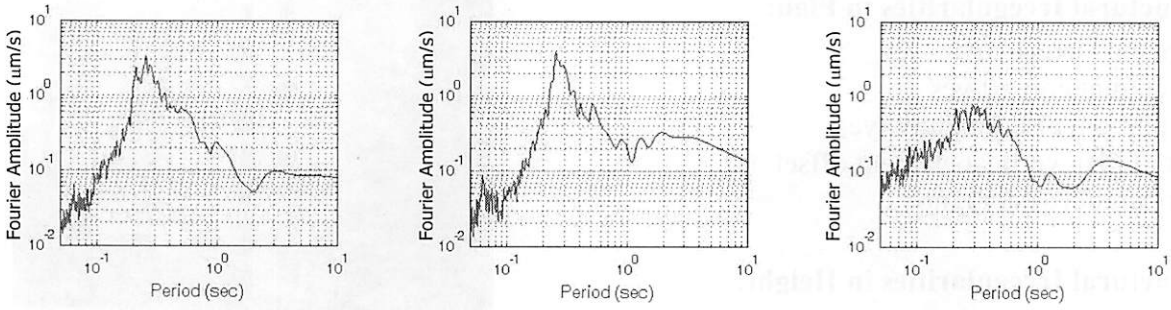
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

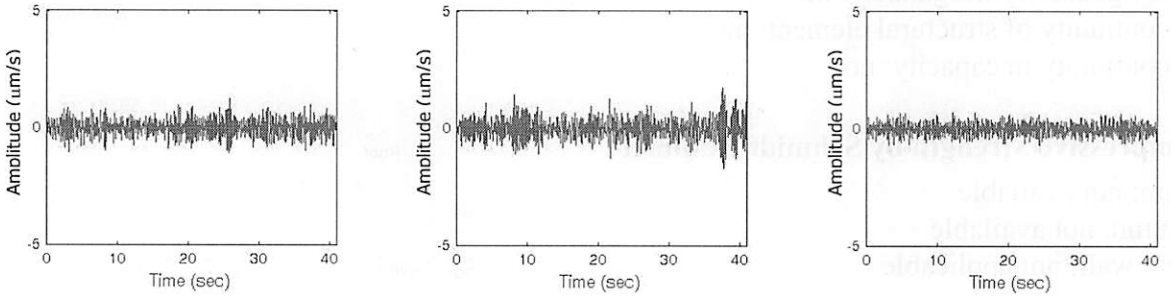




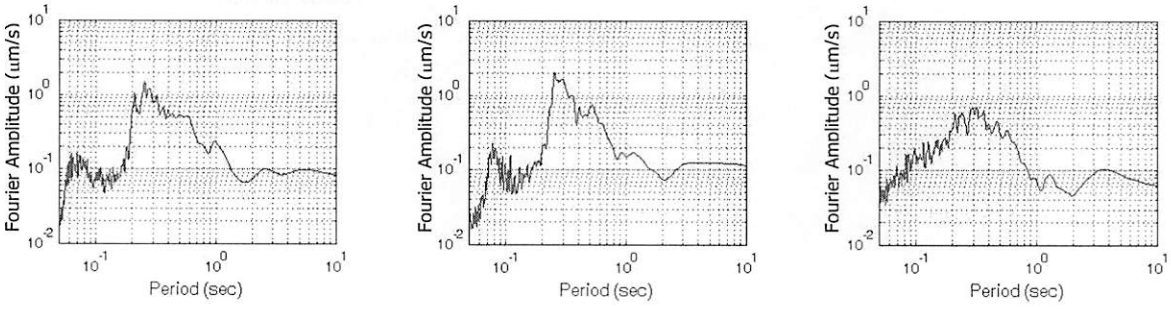
(a) Time history of Building # 1 (3rd floor)



(b) Fourier spectrum of Building # 1 (3rd floor)



(c) Time history of Building # 1 (1st floor)



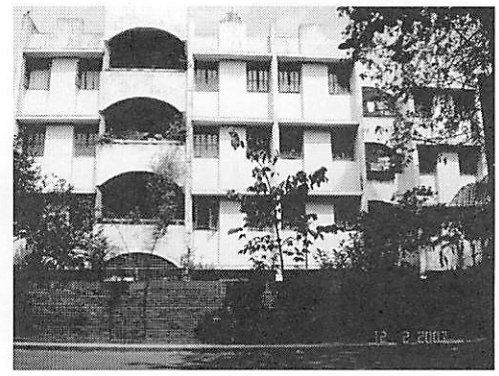
(d) Fourier spectrum of Building # 1 (1st floor)

Figure 52 Time history and Fourier spectrum of Building # 1

3.4.23 Building Number 2

General Information:

Year of Construction: 1962
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 226 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

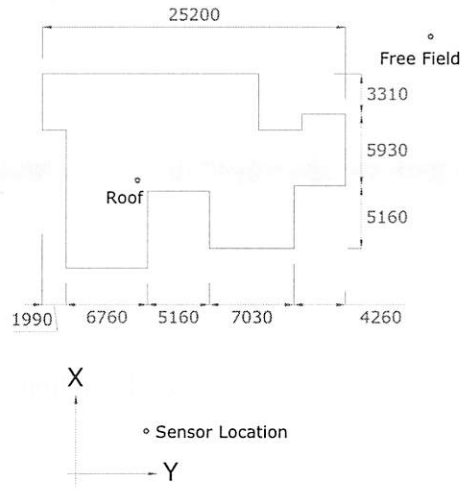


Structural Irregularities in Plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

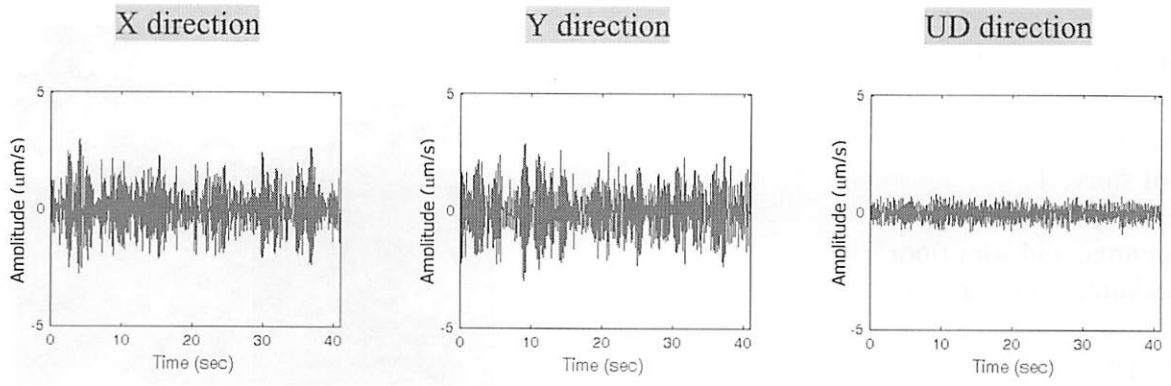
Structural Irregularities in Height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

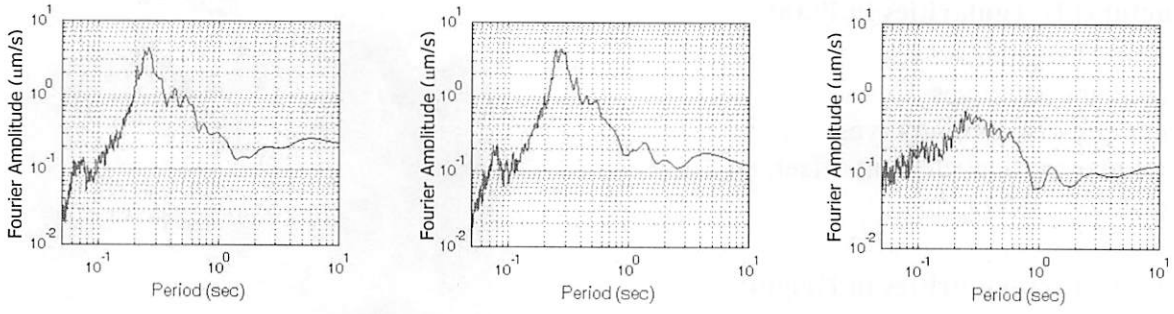


Compressive Strength by Schmidt Hammer:

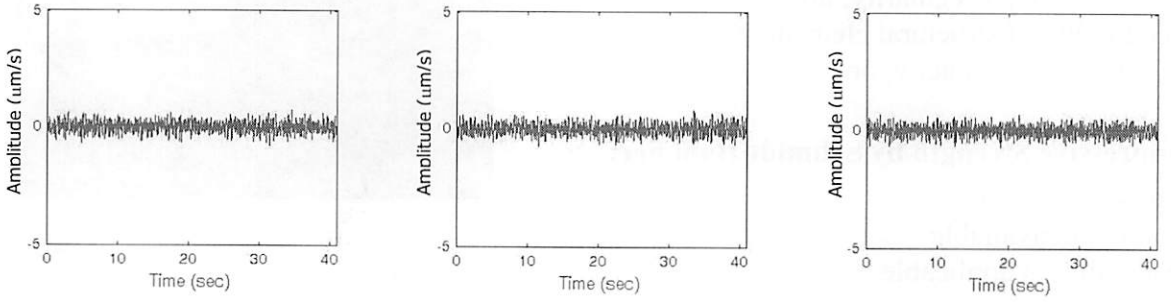
Beam: not available
Column: not available
Shear wall: not applicable



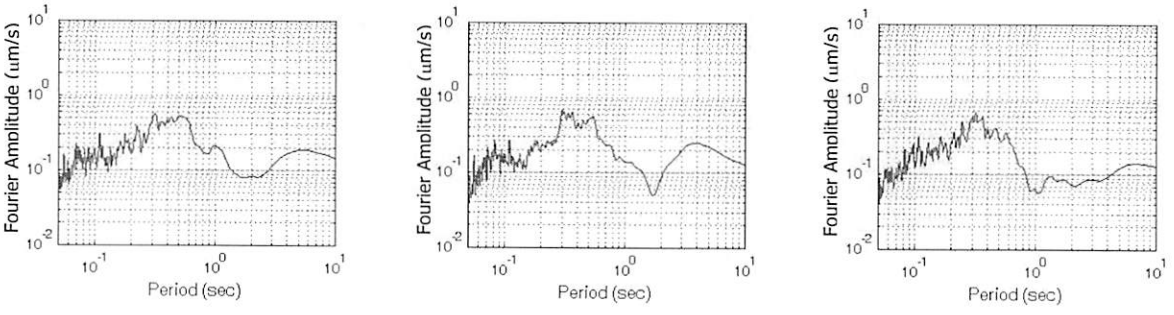
(a) Time history of Building # 2 (top floor)



(f) Fourier spectrum of Building # 2 (top floor)



(g) Time history of free field near Building # 1 and Building # 2



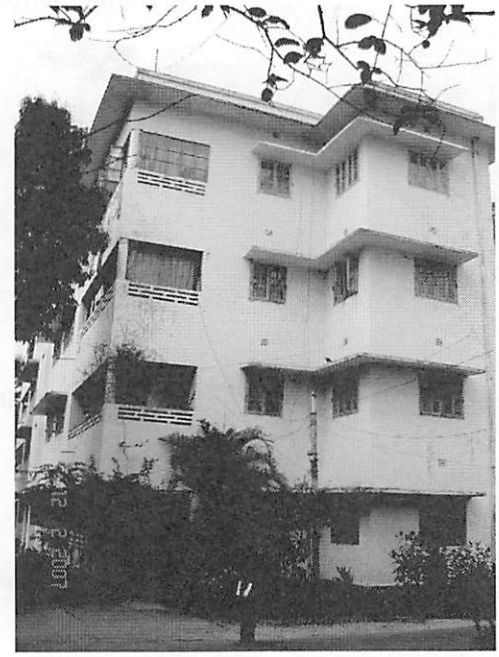
(h) Fourier spectrum of free field near Building # 1 and Building # 2

Figure 53 Time history and Fourier spectrum of Building # 2

3.4.24 Building Number 3

General Information:

Year of Construction: 1962
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 334 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no



Structural Irregularities in Plan:

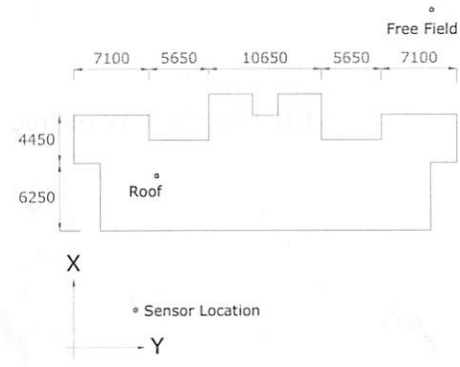
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

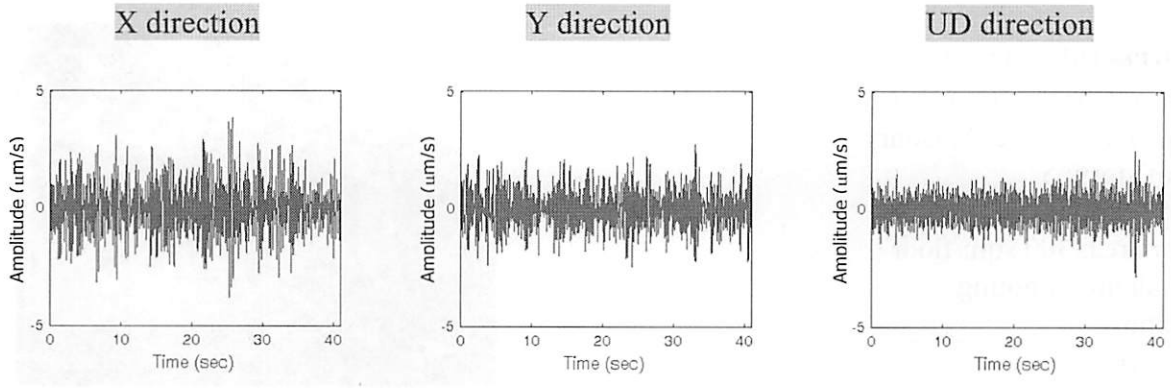
Structural Irregularities in Height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

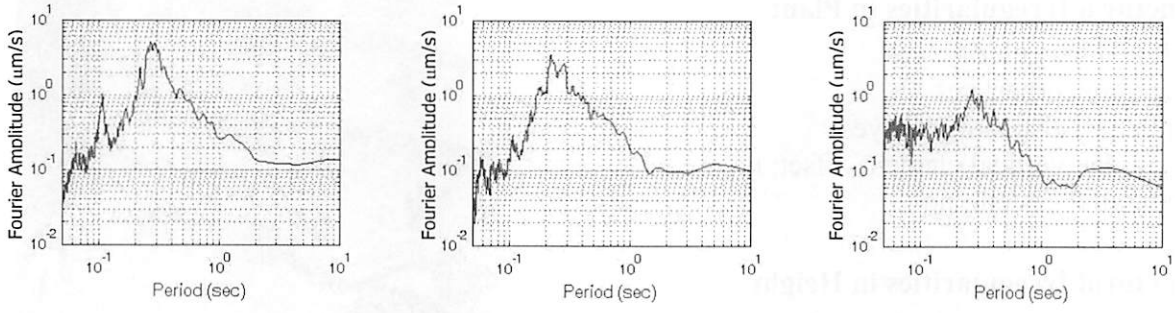
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

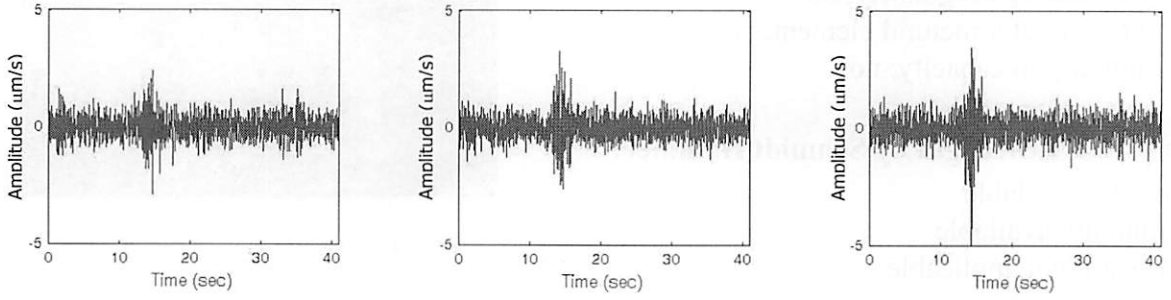




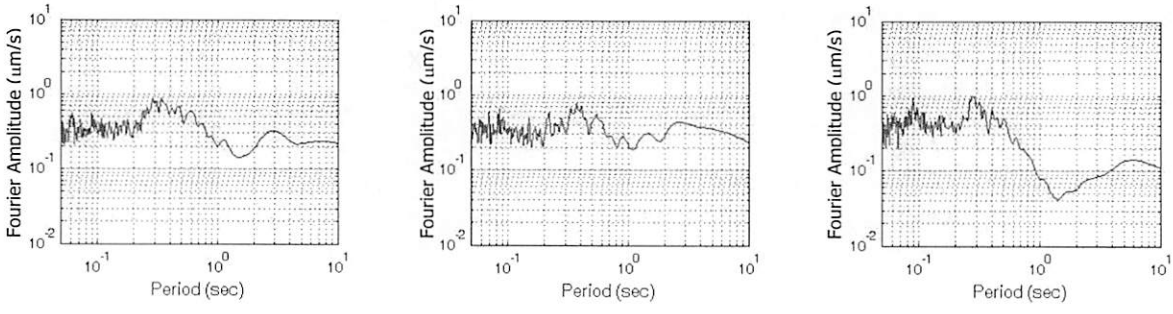
(a) Time history of Building # 3 (top floor)



(b) Fourier spectrum of Building # 3 (top floor)



(c) Time history of free field near Building # 3 and Building # 4



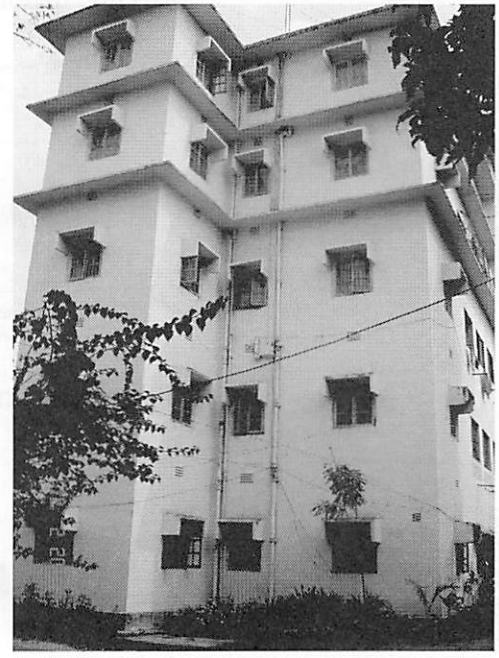
(d) Fourier spectrum of free field near Building # 3 and Building # 4

Figure 54 Time history and Fourier spectrum of Building # 3

3.4.25 Building Number 4

General Information:

Year of Construction: 1962
Type of Structure: Masonry
No of story: 5
Use: Residential
Floor area: 300 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

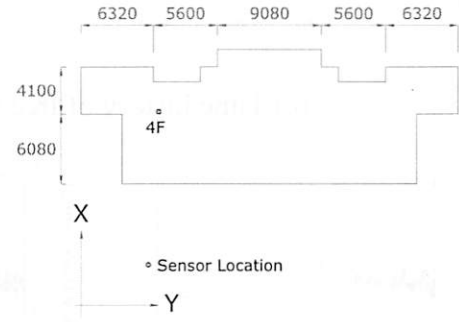


Structural Irregularities in Plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

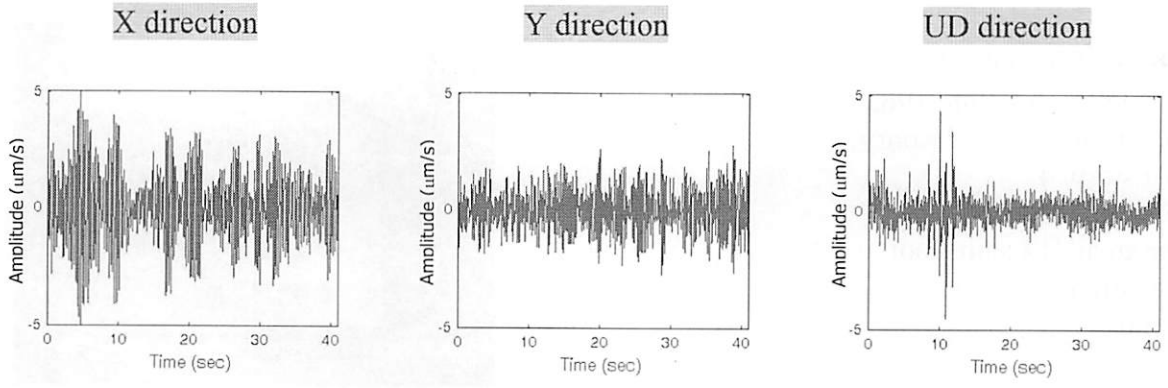
Structural Irregularities in Height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

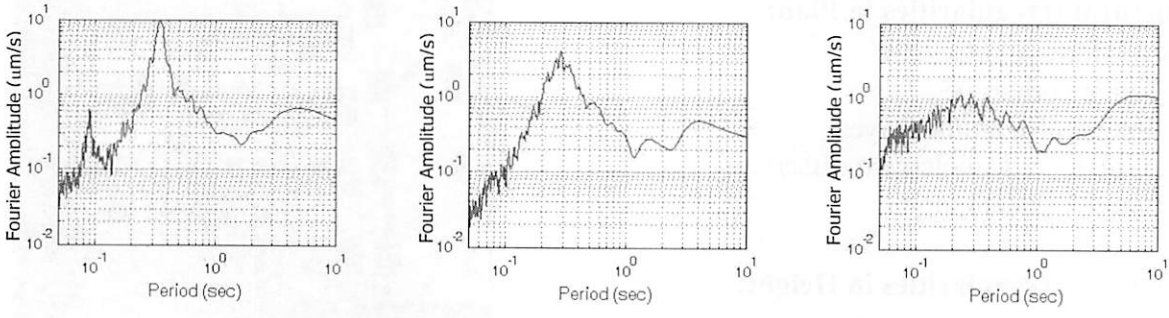


Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable



(a) Time history of Building # 4 (4th floor)



(b) Fourier spectrum of Building # 4 (4th floor)

Figure 55 Time history and Fourier spectrum of Building # 4

3.4.26 Building Number 5

General Information:

Year of Construction: 1962
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 414 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural Irregularities in Plan:

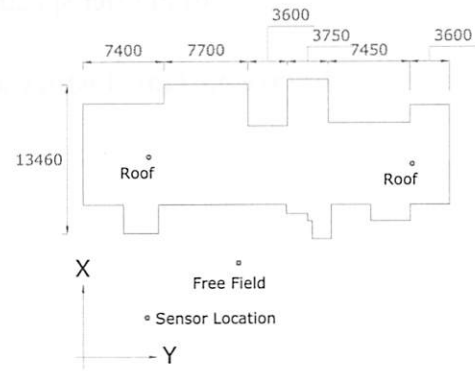
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

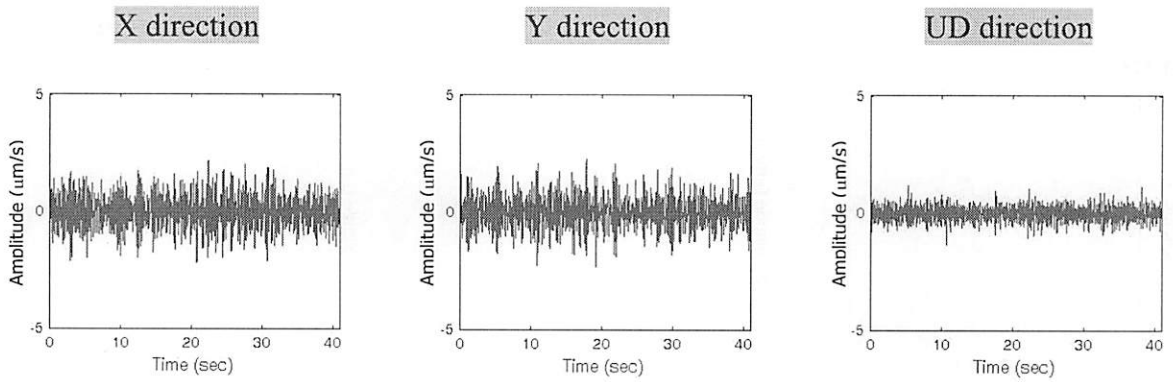
Structural Irregularities in Height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

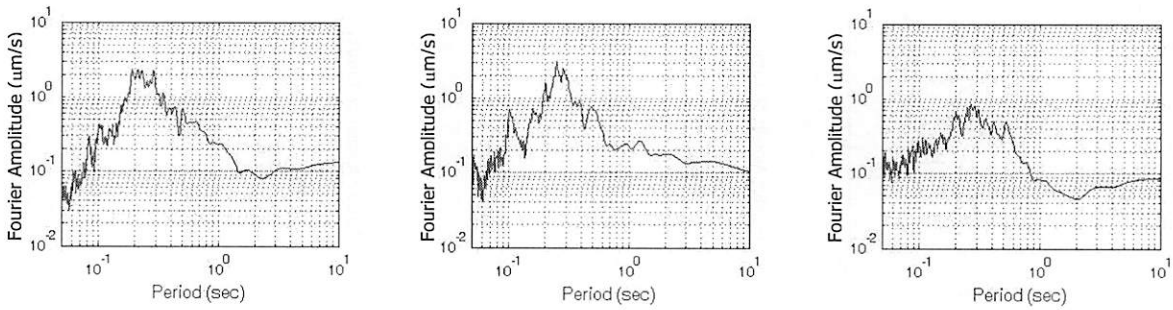
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

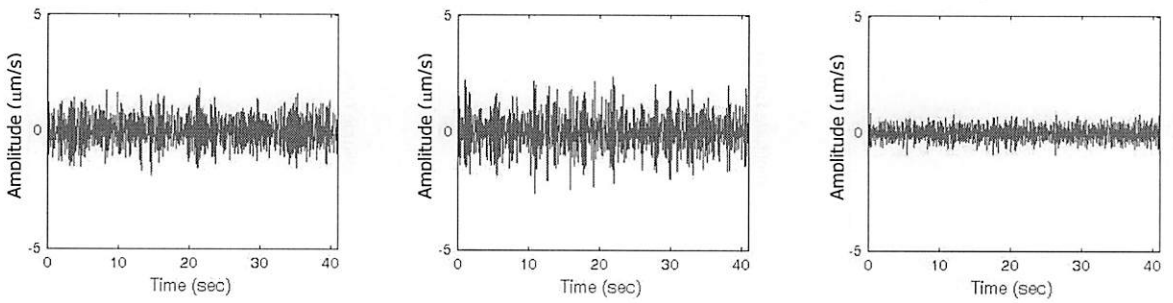




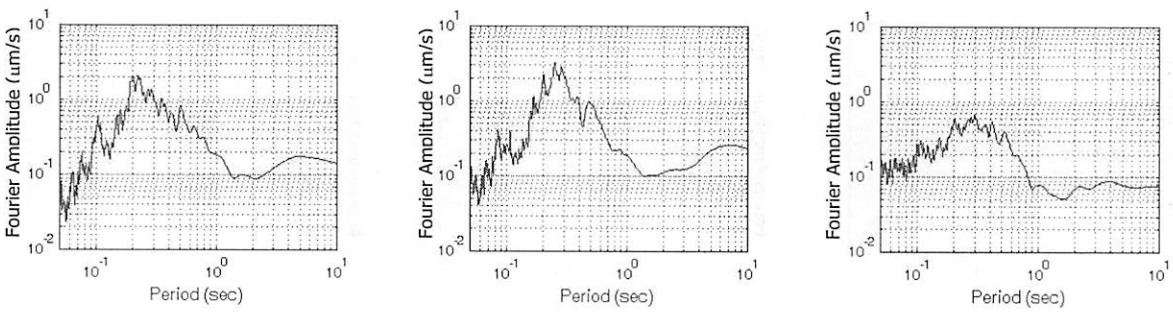
(a) Time history of Building # 5 (top floor left)



(b) Fourier spectrum of Building # 5 (top floor left)

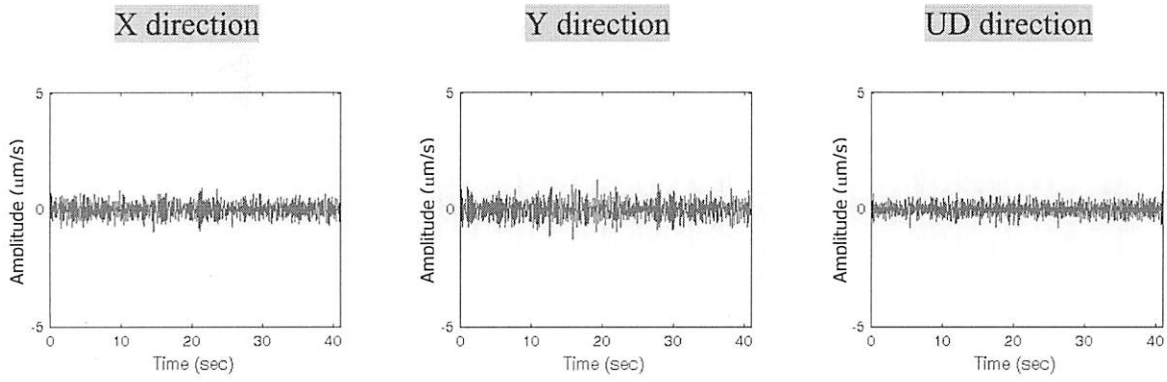


(c) Time history of Building # 5 (top floor right)

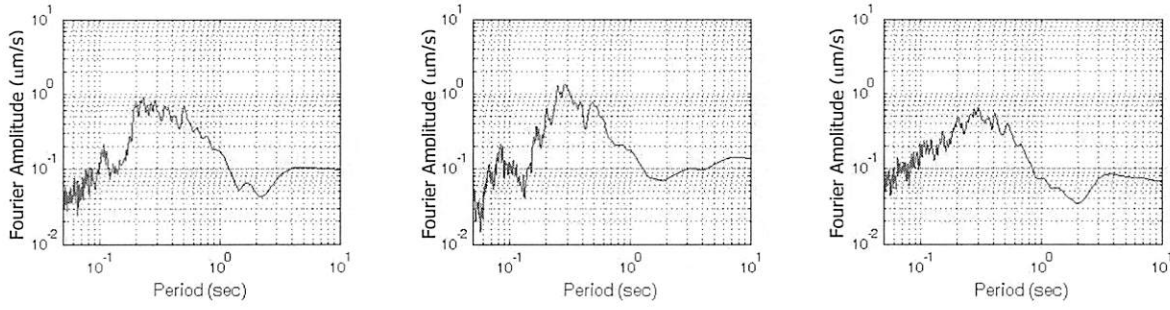


(d) Fourier spectrum of Building # 5 (top floor right)

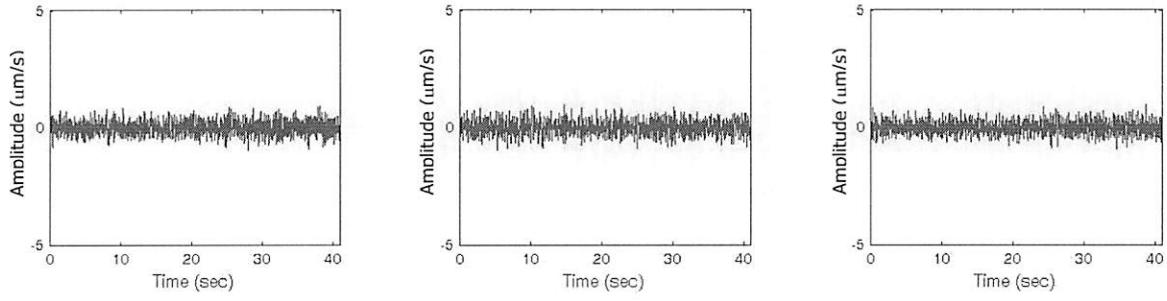
Figure 56 Time history and Fourier spectrum of Building # 5



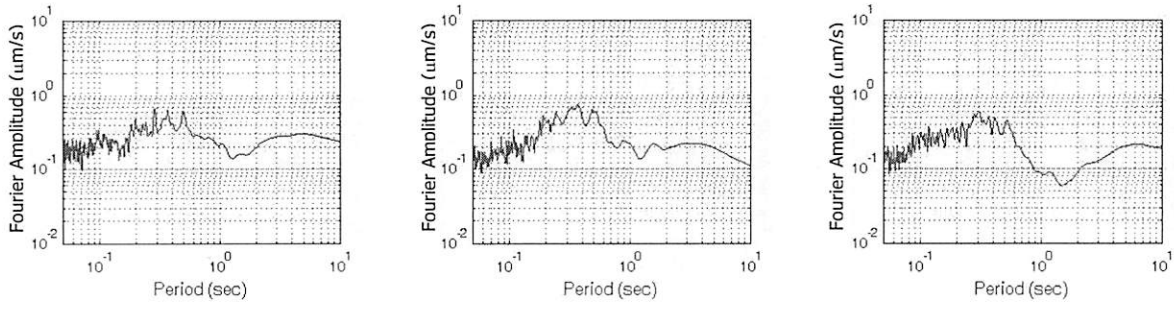
(a) Time history of Building # 5 (1st floor right)



(f) Fourier spectrum of Building # 5 (1st floor right)



(g) Time history of free field near Building # 5



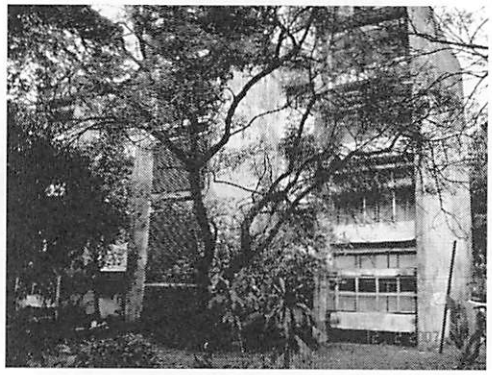
(h) Fourier spectrum of free field near Building # 5

Figure 56 Time history and Fourier spectrum of Building # 5

3.4.27 Building Number 6

General Information:

Year of Construction: 1962
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 213 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

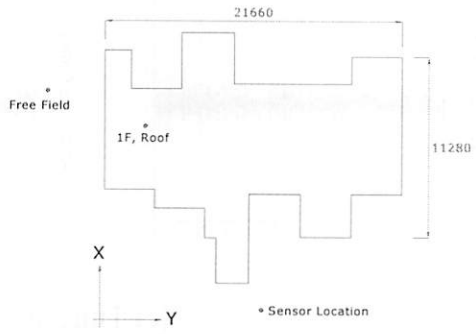


Structural Irregularities in Plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

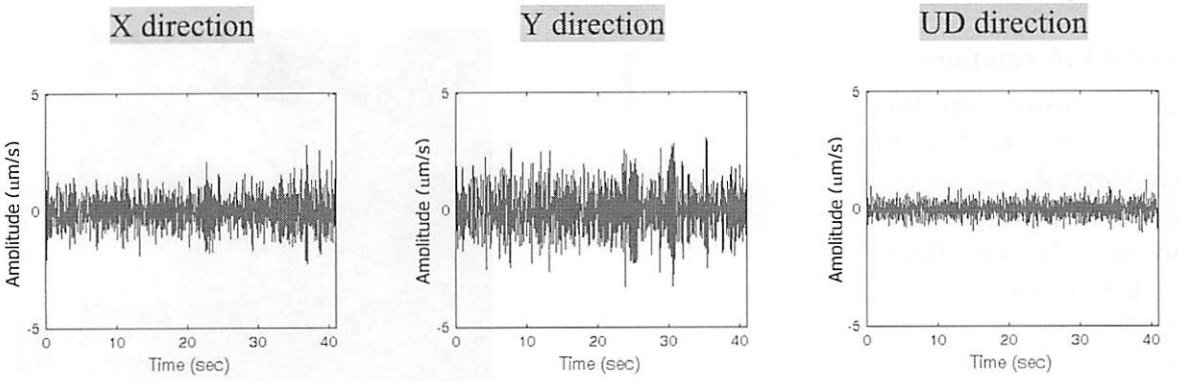
Structural Irregularities in Height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

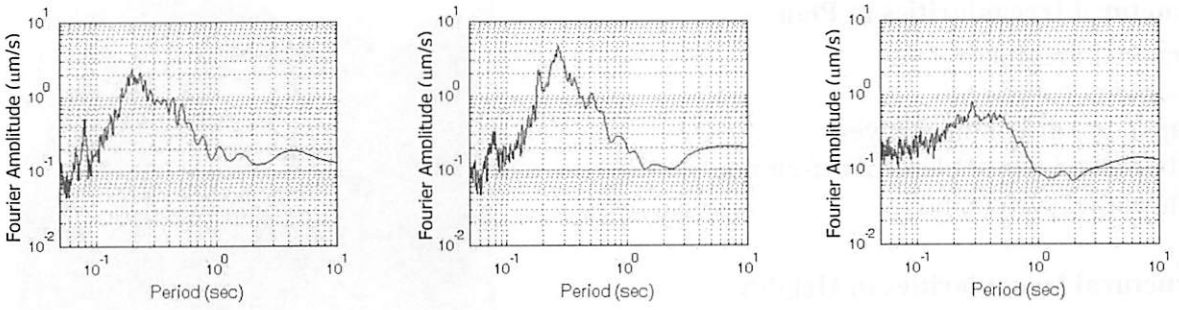


Compressive Strength by Schmidt Hammer:

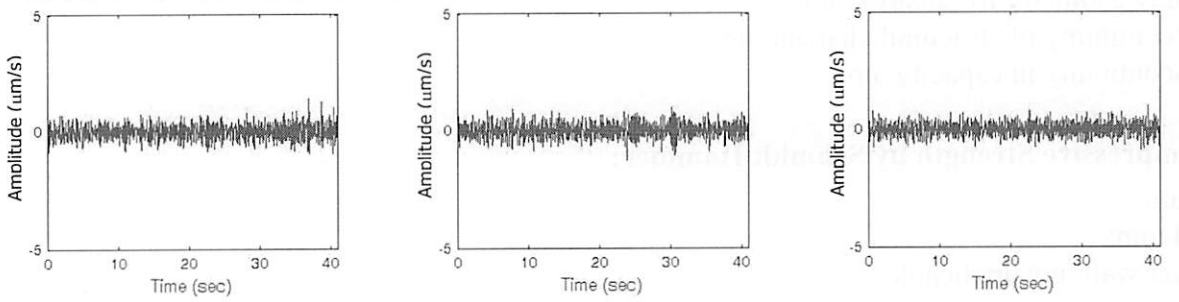
Beam:
Column:
Shear wall: not applicable



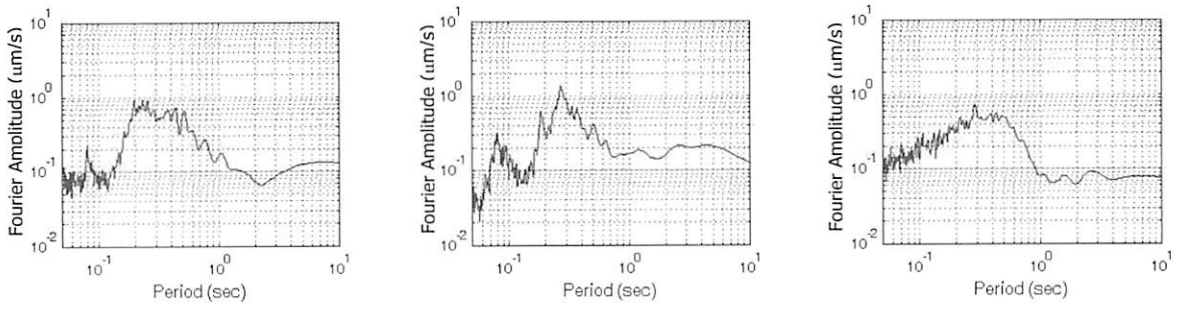
(a) Time history of Building # 6 (top floor)



(b) Fourier spectrum of Building # 6 (top floor)



(c) Time history of Building # 6 (1st floor)



(d) Fourier spectrum of Building # 6 (1st floor)

Figure 57 Time history and Fourier spectrum of Building # 6

3.4.28 Building Number 7

General Information:

Year of Construction: 1962
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 213 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural Irregularities in Plan:

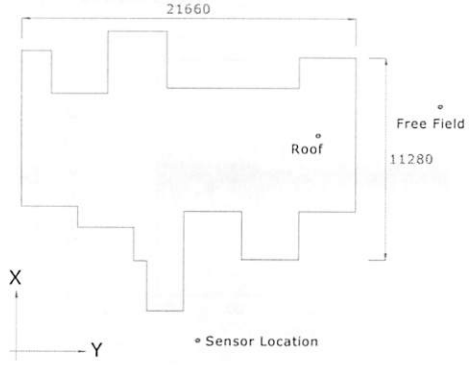
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

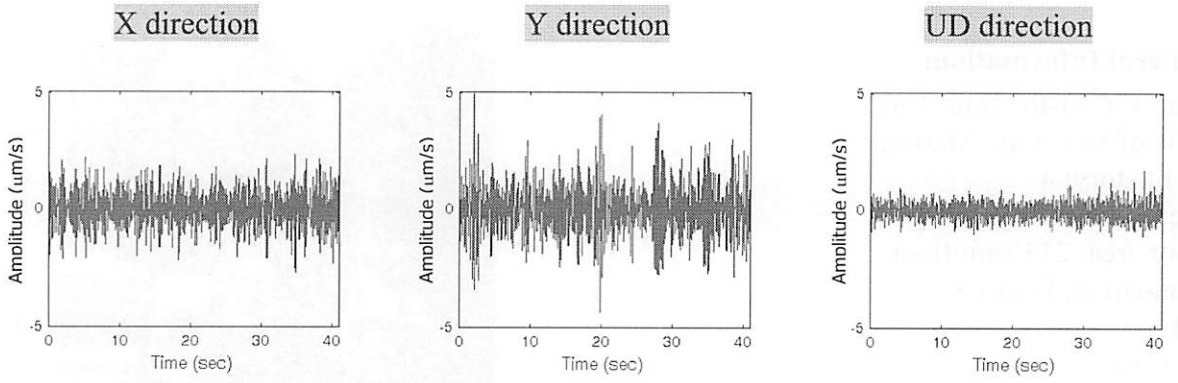
Structural Irregularities in Height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

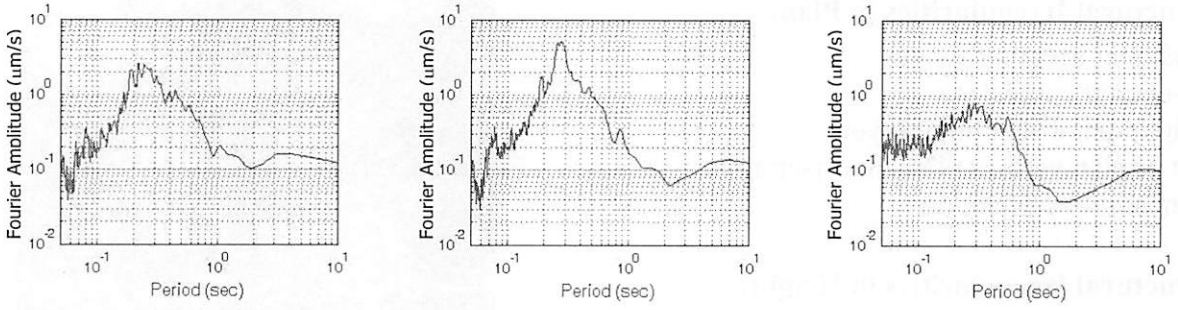
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

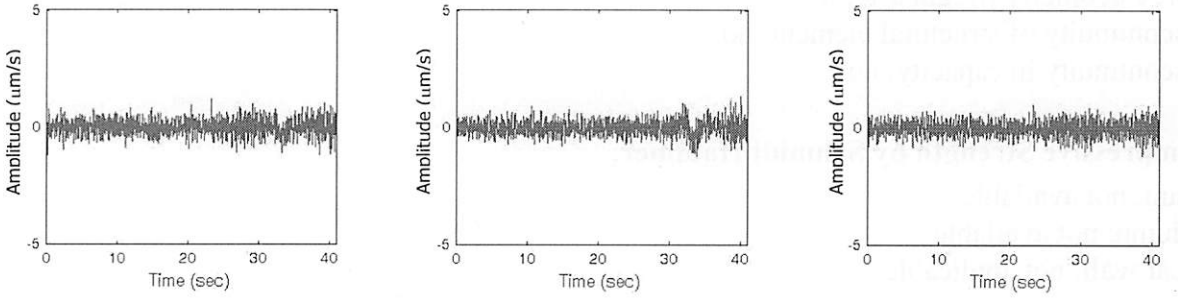




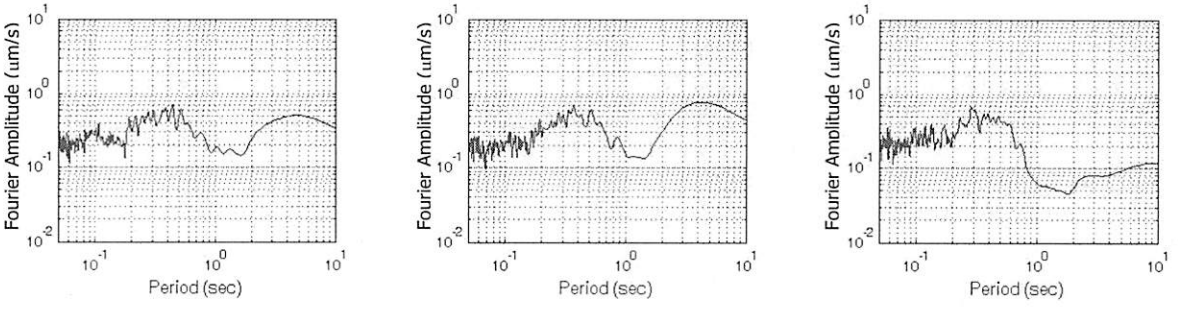
(a) Time history of Building # 7 (top floor)



(f) Fourier spectrum of Building # 7 (top floor)



(g) Time history of free field near Building # 6 and Building # 7



(h) Fourier spectrum of free field near Building # 6 and Building # 7

Figure 58 Time history and Fourier spectrum of Building # 7

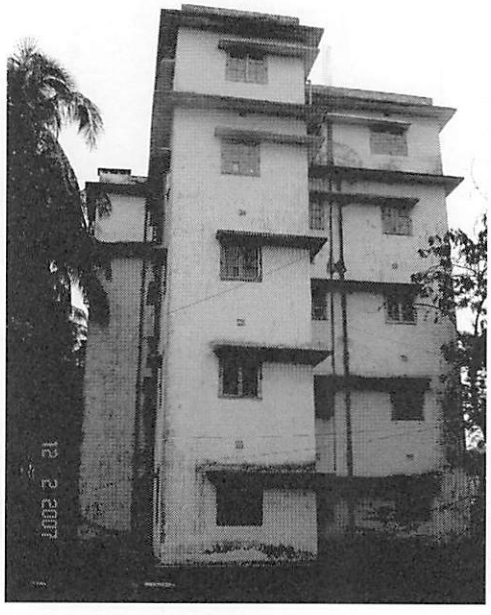
3.4.29 Building Number 8

General Information:

Year of Construction: 1962
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 394 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural Irregularities in Plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

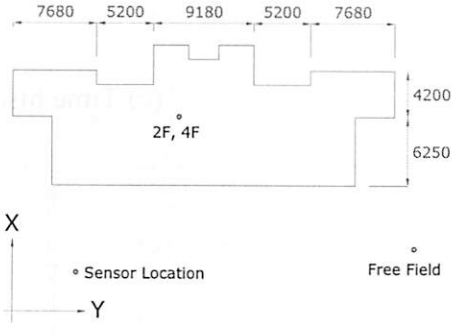


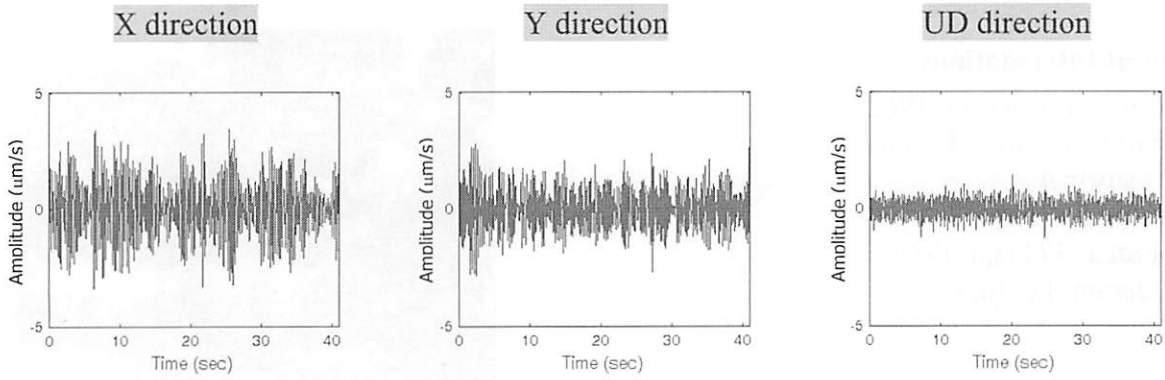
Structural Irregularities in Height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

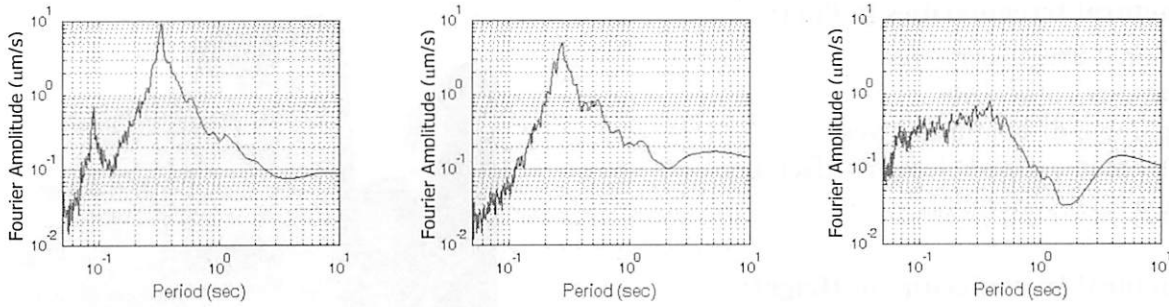
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

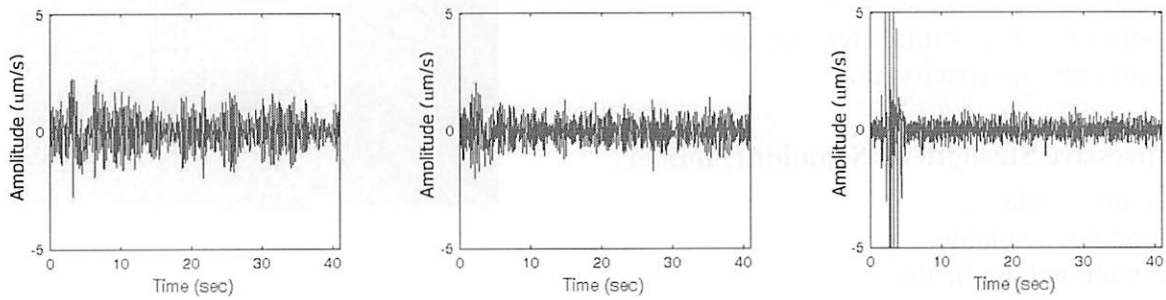




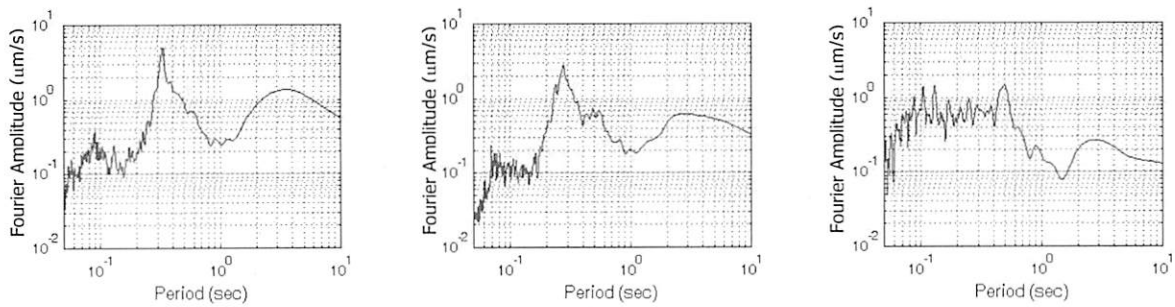
(a) Time history of Building # 8 (4th floor)



(b) Fourier spectrum of Building # 8 (4th floor)



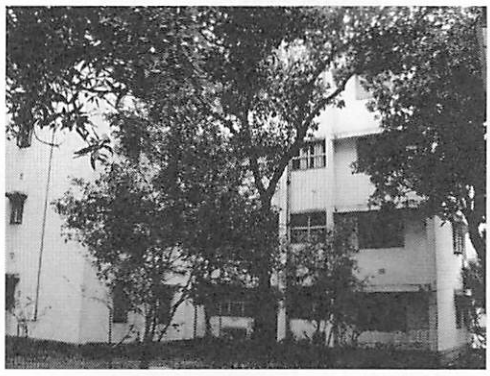
(c) Time history of Building # 8 (2nd floor)

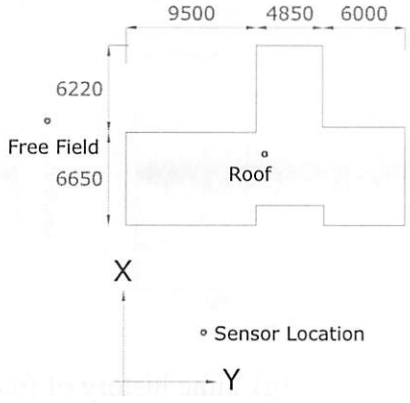


(d) Fourier spectrum of Building # 8 (2nd floor)

Figure 59 Time history and Fourier spectrum of Building # 8

3.4.30 Building Number 9





General Information:

Year of Construction: 1962
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 181 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

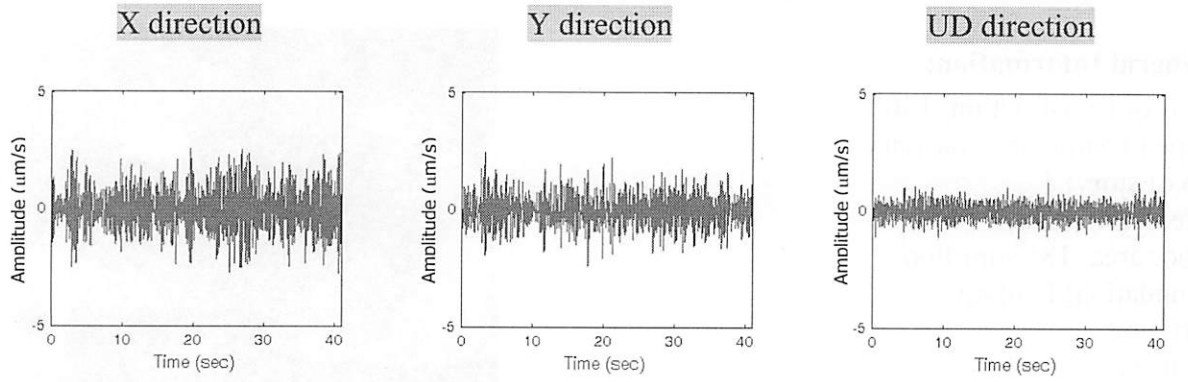
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

Structural irregularities in height:

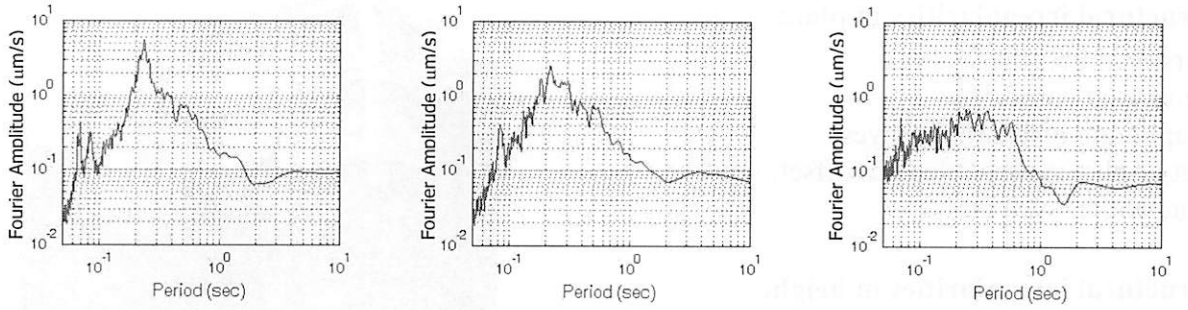
Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

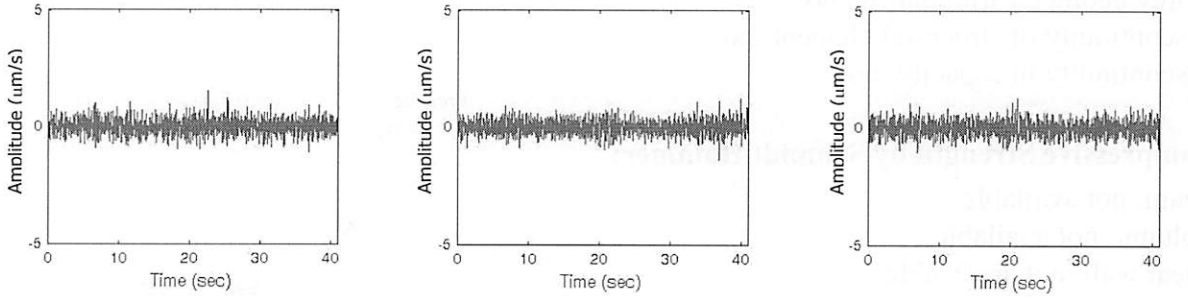
Beam: not available
Column: not available
Shear wall: not applicable



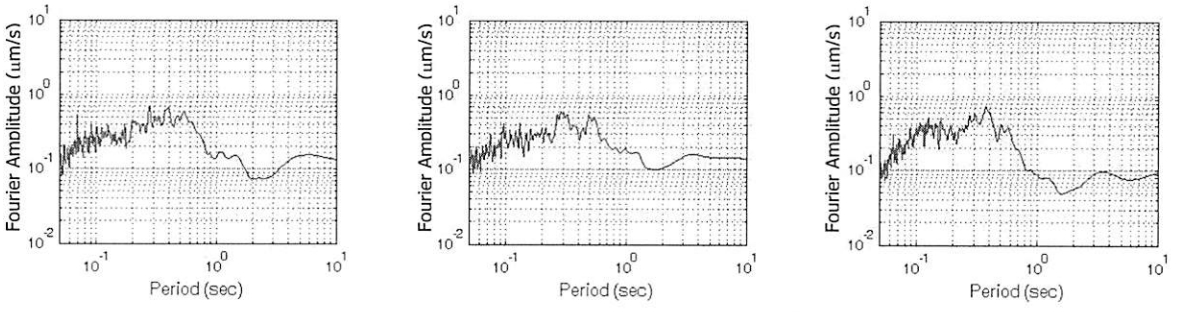
(a) Time history of Building # 9 (4th floor)



(f) Fourier spectrum of Building # 9 (4th floor)



(g) Time history of free field near Building # 8 and Building # 9



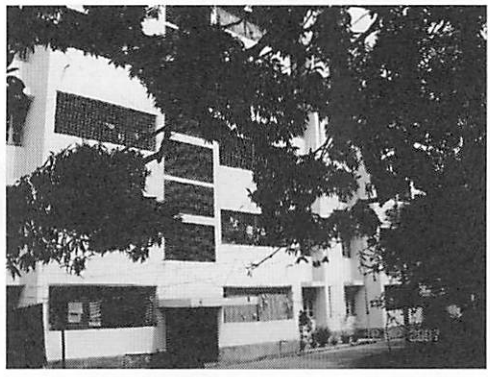
(h) Fourier spectrum of free field near Building # 8 and Building # 9

Figure 60 Time history and Fourier spectrum of Building # 9

3.4.31 Building Number 30

General Information:

Year of Construction: 1976
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 350 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

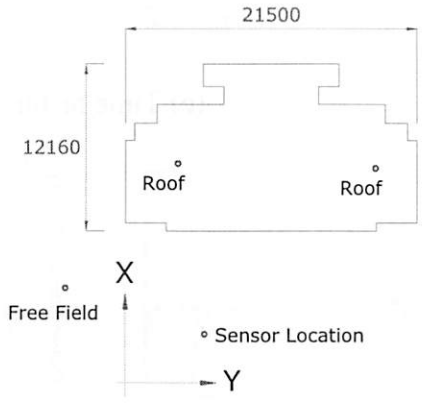


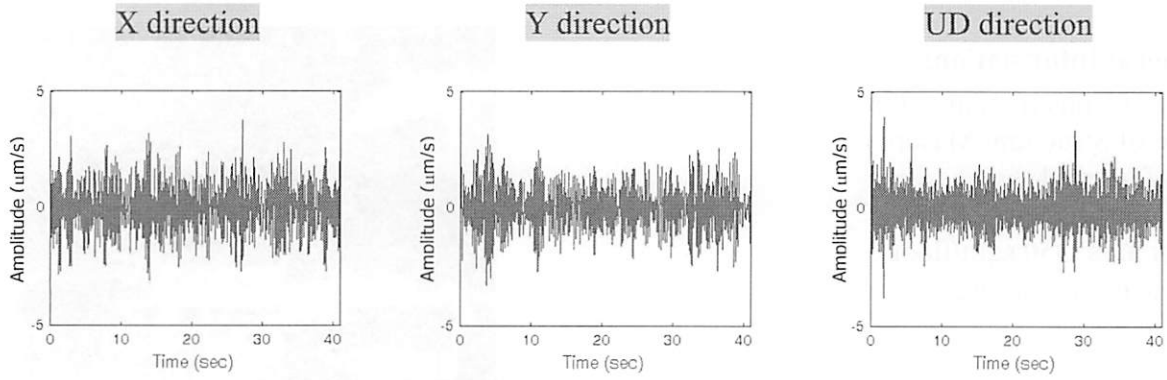
Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no
Structural irregularities in height:
Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

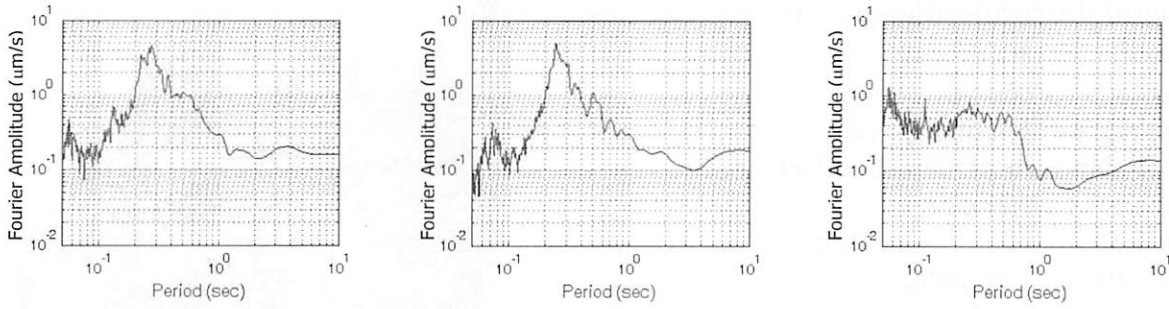
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

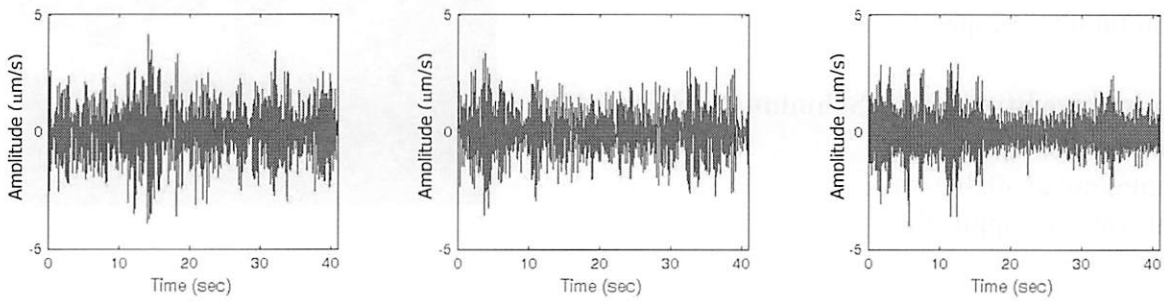




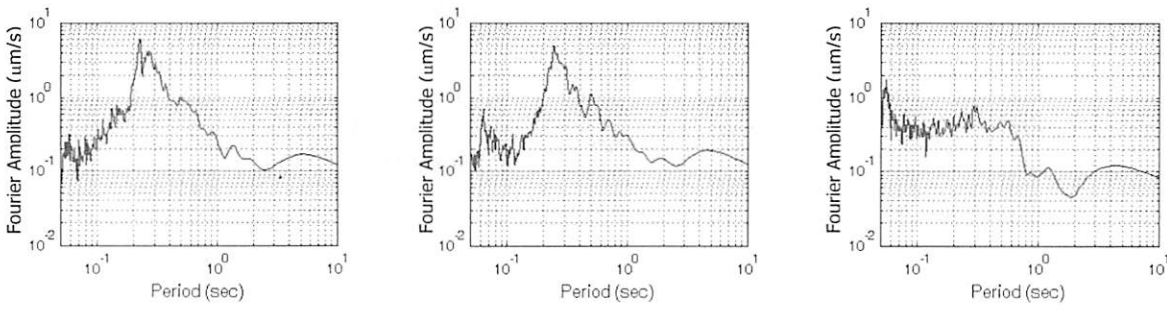
(a) Time history of Building # 30 (top floor left)



(b) Fourier spectrum of Building # 30 (top floor left)



(c) Time history of Building # 30 (top floor right)



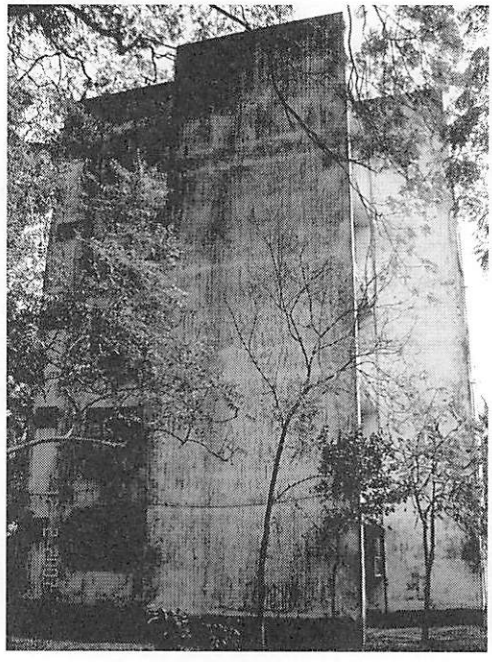
(d) Fourier spectrum of Building # 30 (top floor right)

Figure 61 Time history and Fourier spectrum of Building # 30

3.4.32 Building Number 45

General Information:

Year of Construction: 1988
Type of Structure: Masonry
No of story: 5
Use: Residential
Floor area: 186 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no



Structural irregularities in plan:

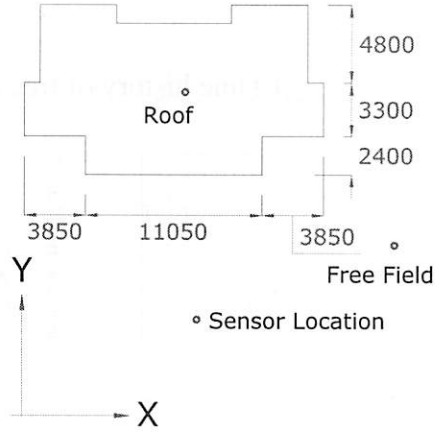
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

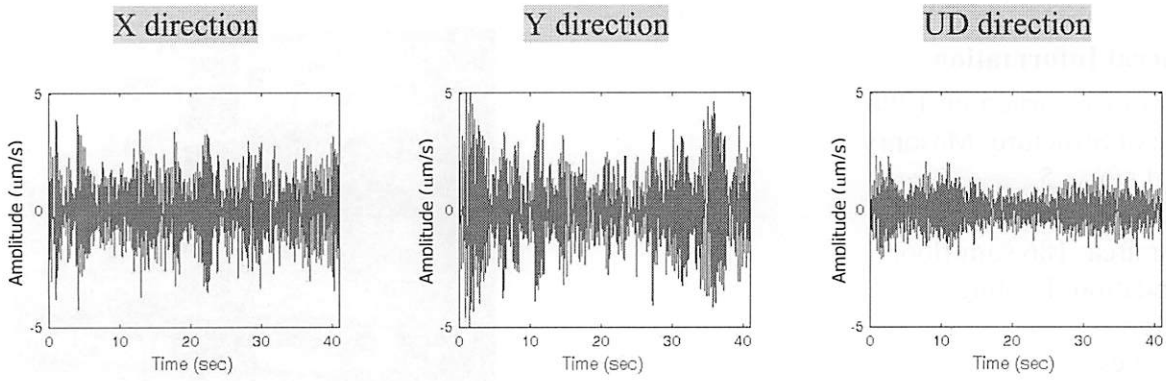
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

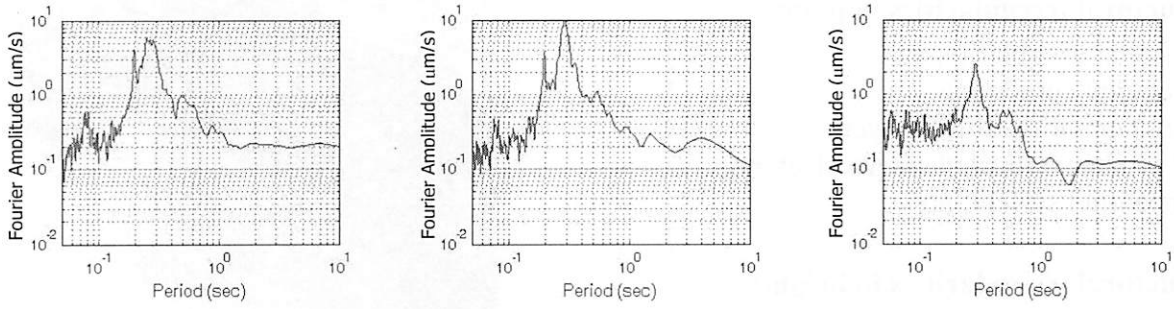
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

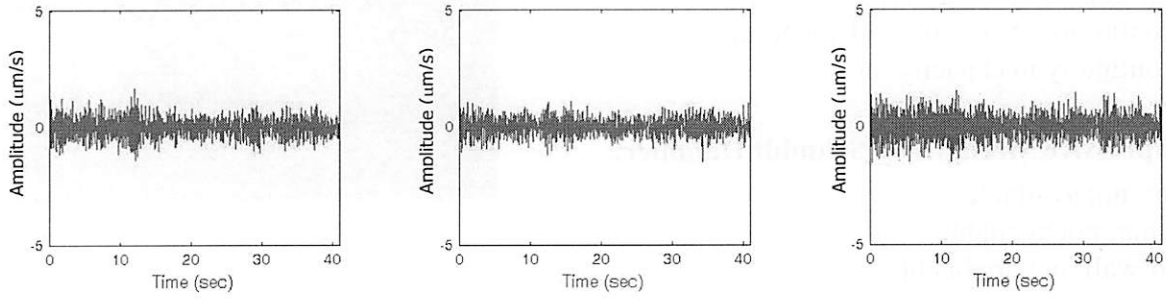




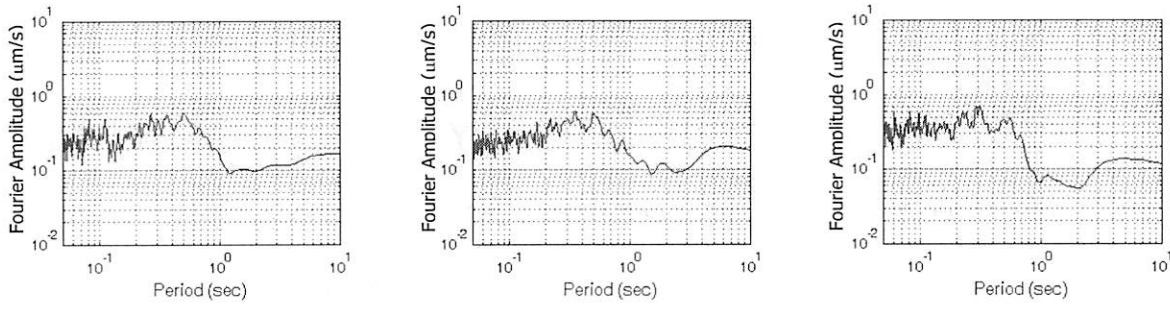
(a) Time history of Building # 45 (top floor)



(f) Fourier spectrum of Building # 45 (top floor)



(g) Time history of free field near Building # 30 and Building # 45



(h) Fourier spectrum of free field near Building # 30 and Building # 45

Figure 62 Time history and Fourier spectrum of Building # 45

3.4.33 Building Number 21

General Information:

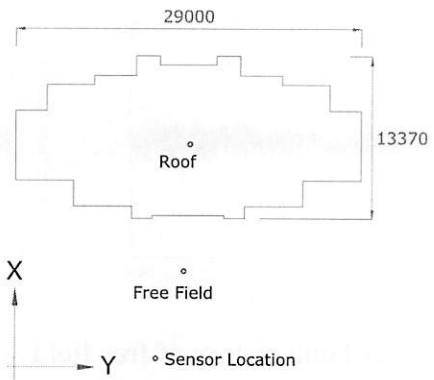
Year of Construction: 1972
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 478 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

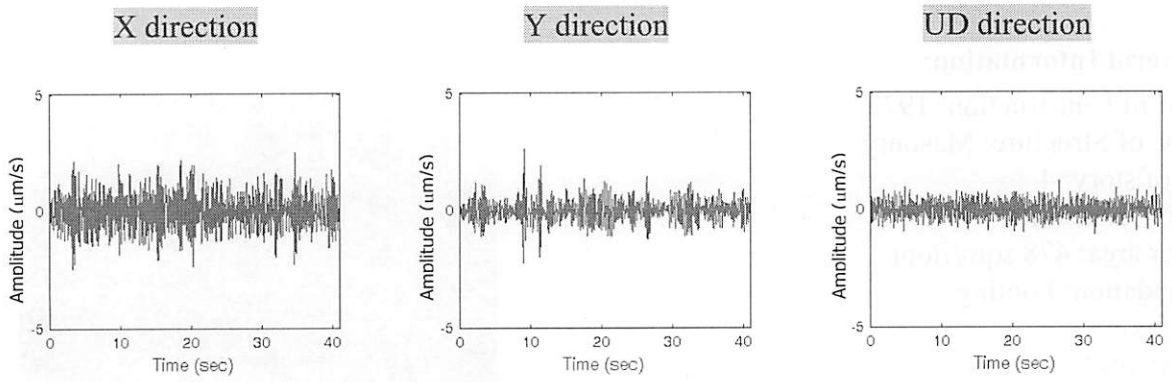
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

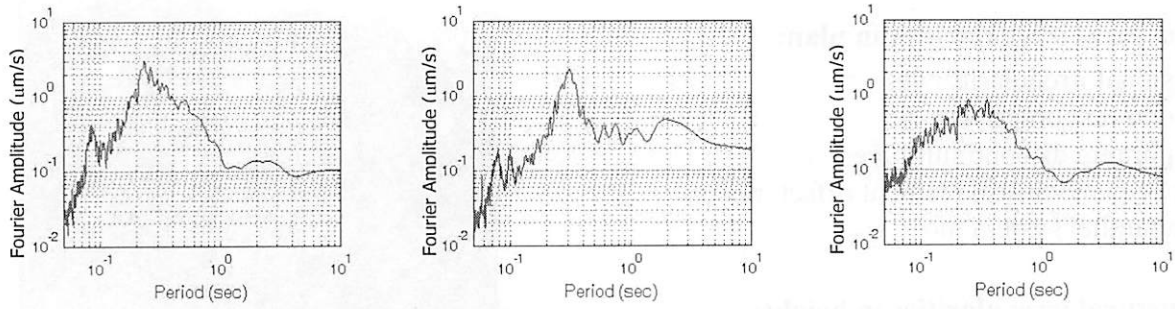


Compressive Strength by Schmidt Hammer:

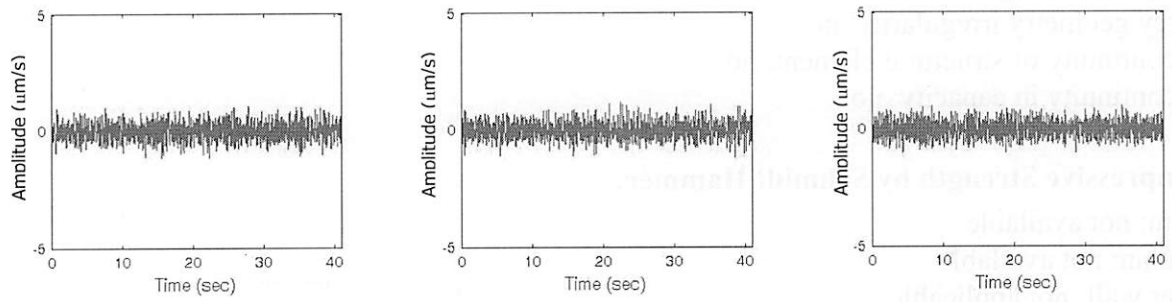
Beam: not available
Column: not available
Shear wall: not applicable



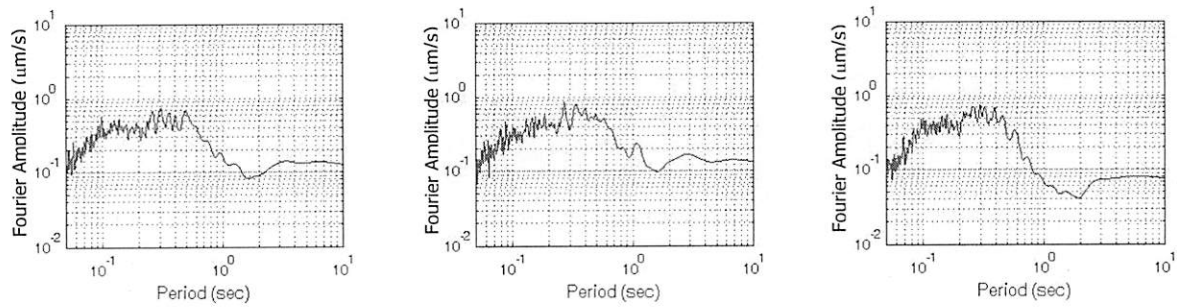
(a) Time history of Building # 21 (top floor)



(b) Fourier spectrum of Building # 21 (top floor)



(c) Time history of free field near Bldg. # 21 Bldg. # 22 Bldg. # 23 and Bldg. # 24



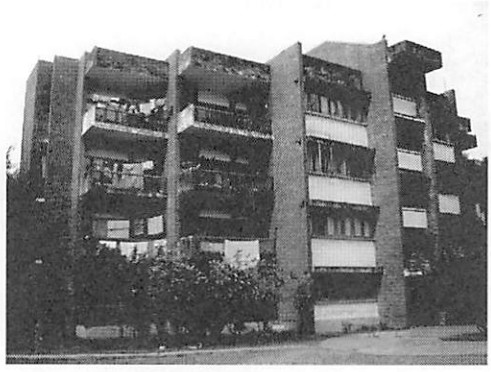
(d) Fourier spectrum of free field near Bldg. # 21 Bldg. # 22 Bldg. # 23 and Bldg. # 24

Figure 63 Time history and Fourier spectrum of Building # 21

3.4.34 Building Number 22

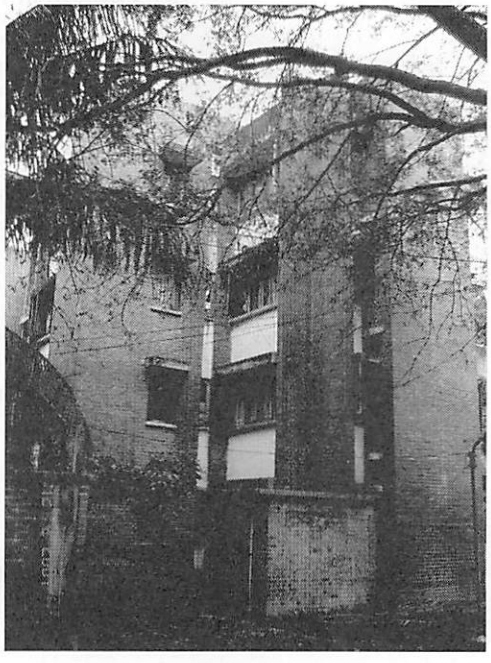
General Information:

Year of Construction: 1972
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 478 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no



Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

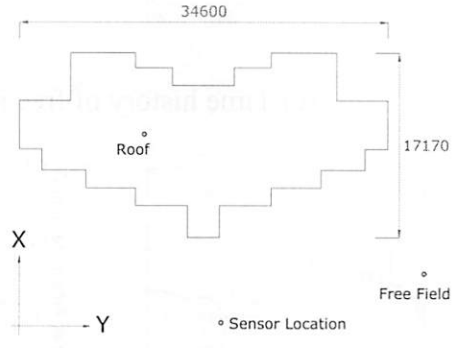


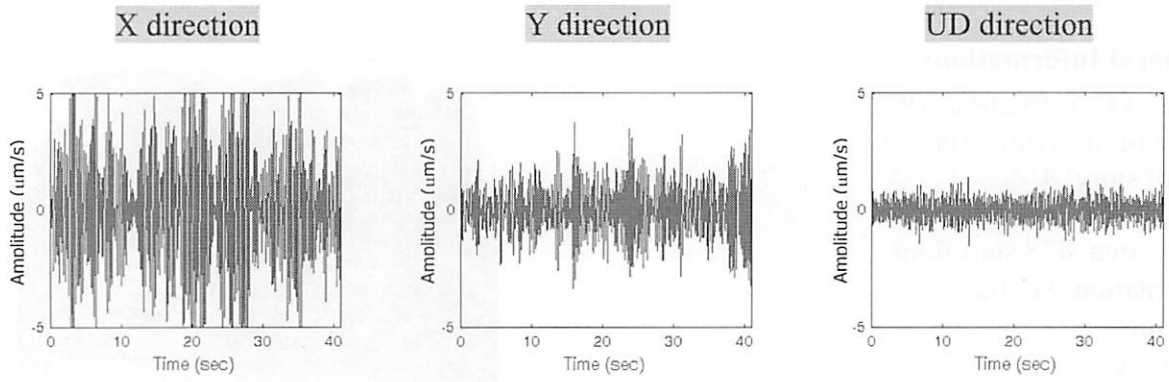
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

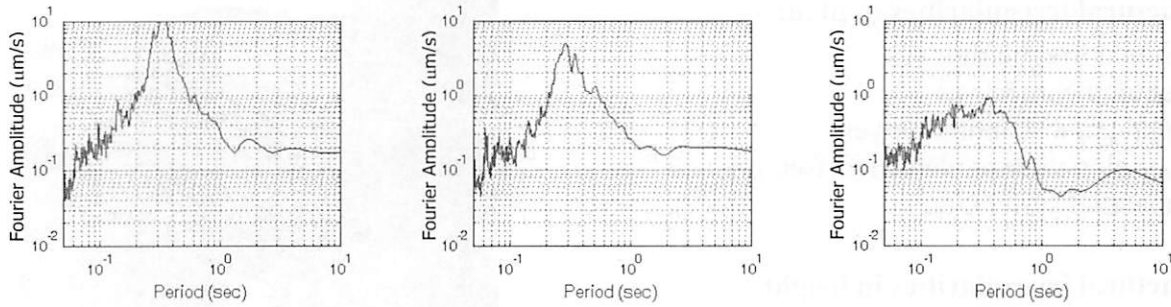
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

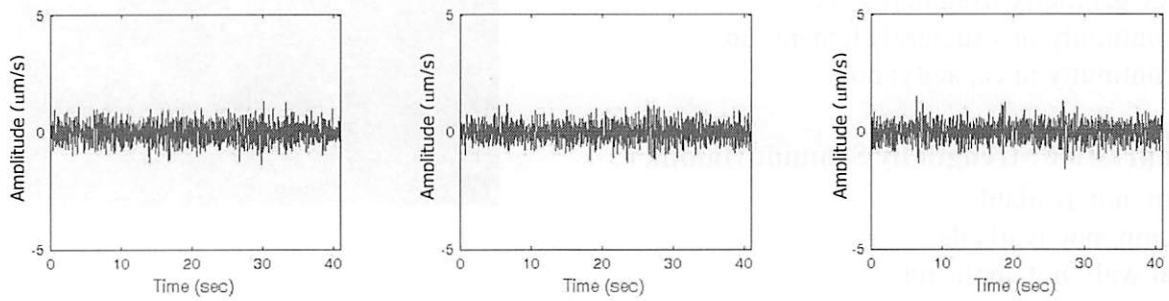




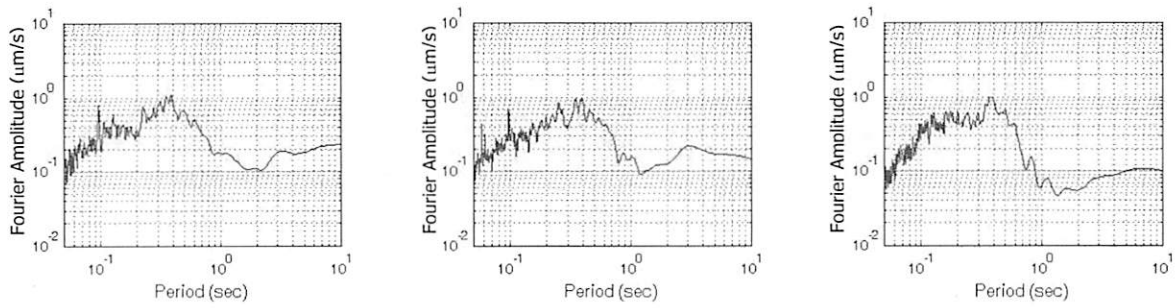
(a) Time history of Building # 22 (top floor)



(b) Fourier spectrum of Building # 22 (top floor)



(c) Time history of free field near Building # 22 and Building # 29



(d) Fourier spectrum of free field near Building # 22 and Building # 29

Figure 64 Time history and Fourier spectrum of Building # 22

3.4.35 Building Number 23

General Information:

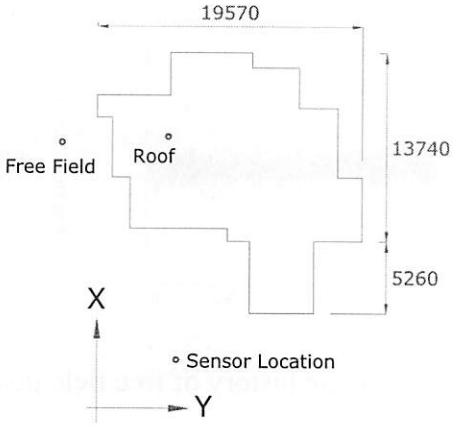
Year of Construction: 1972
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 202 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

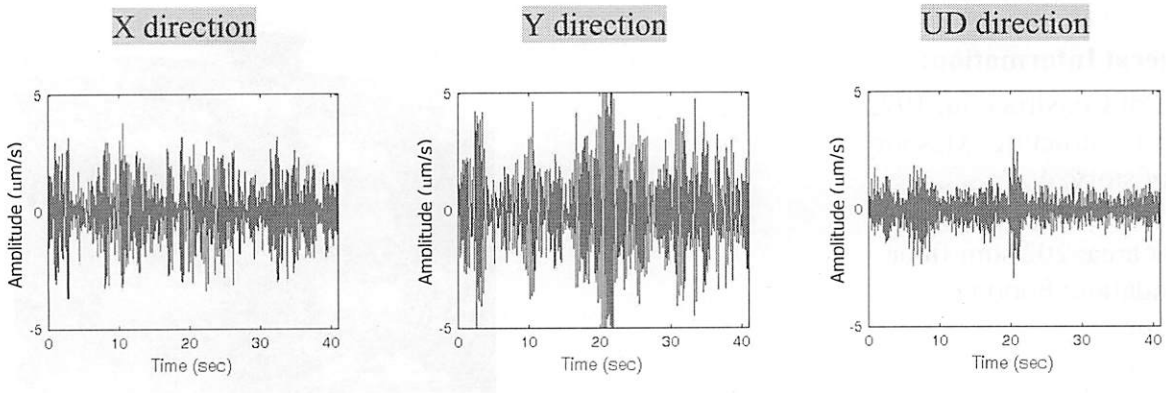
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

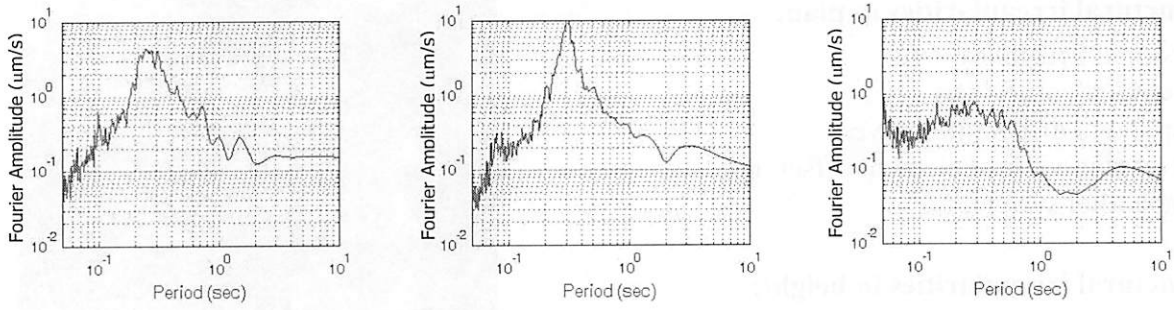


Compressive Strength by Schmidt Hammer:

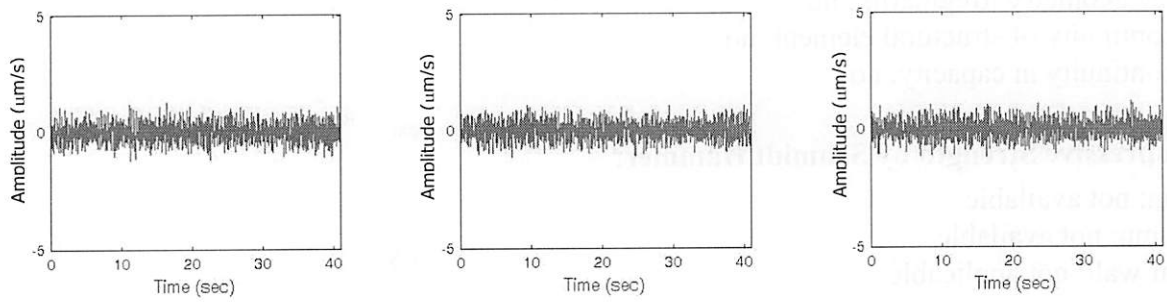
Beam: not available
Column: not available
Shear wall: not applicable



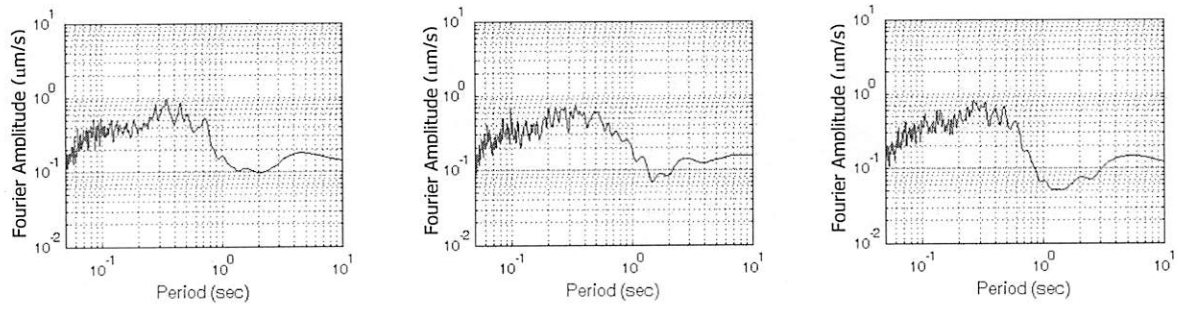
(a) Time history of Building # 23 (top floor)



(b) Fourier spectrum of Building # 23 (top floor)



(c) Time history of free field near Bldg. # 21 Bldg. # 22 Bldg. # 23 and Bldg. # 24



(d) Fourier spectrum of free field near Bldg. # 21 Bldg. # 22 Bldg. # 23 and Bldg. # 24

Figure 65 Time history and Fourier spectrum of Building # 23

3.4.36 Building Number 24

General Information:

Year of Construction: 1972
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 200 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

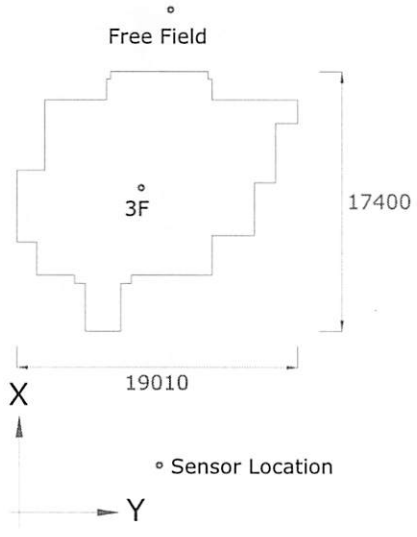
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

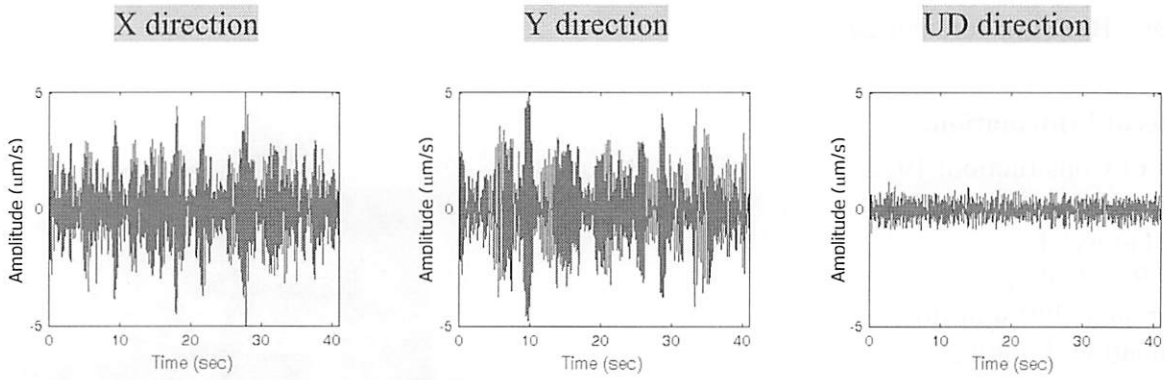
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

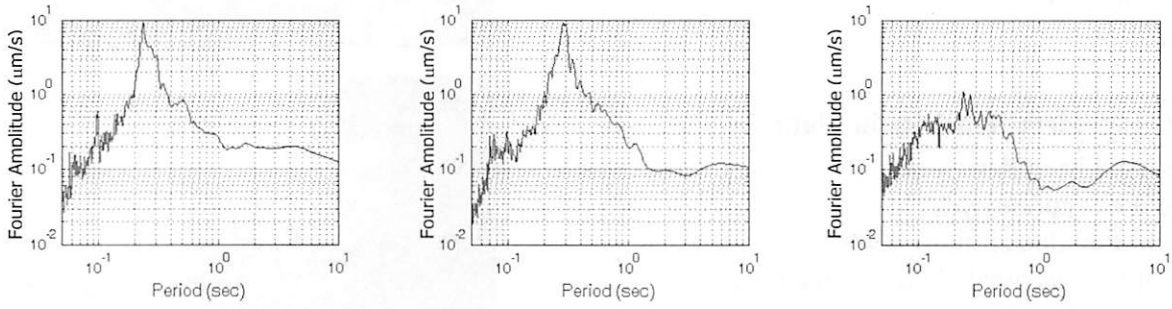
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable





(a) Time history of Building # 24 (3rd floor)



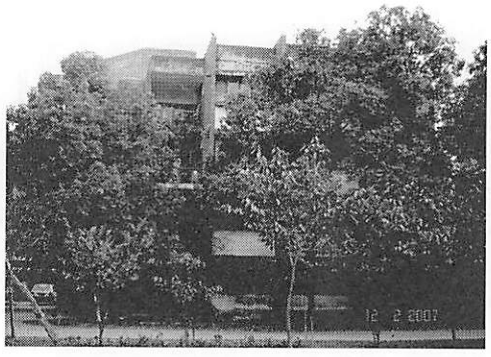
(b) Fourier spectrum of Building # 24 (3rd floor)

Figure 66 Time history and Fourier spectrum of Building # 24

3.4.37 Building Number 25

General Information:

Year of Construction: 1972
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 200 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no



Structural irregularities in plan:

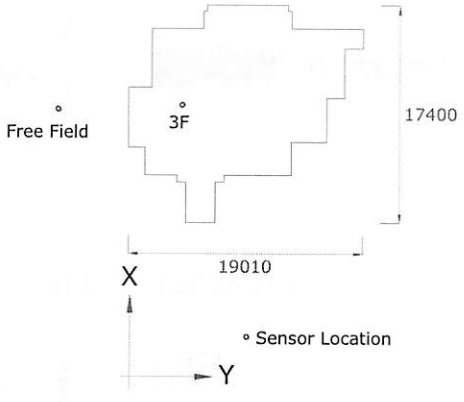
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

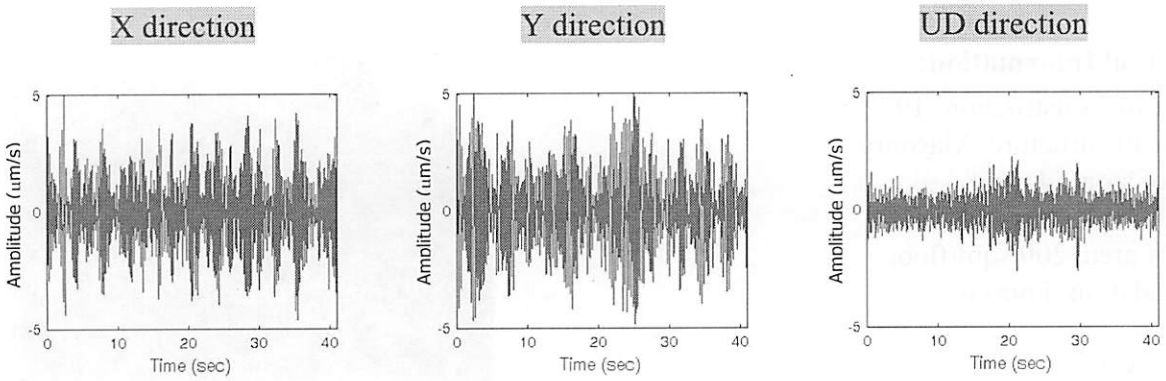
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

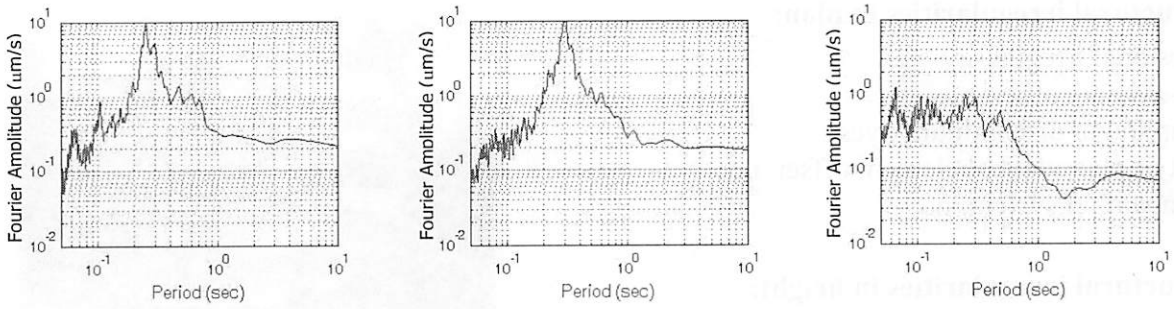
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

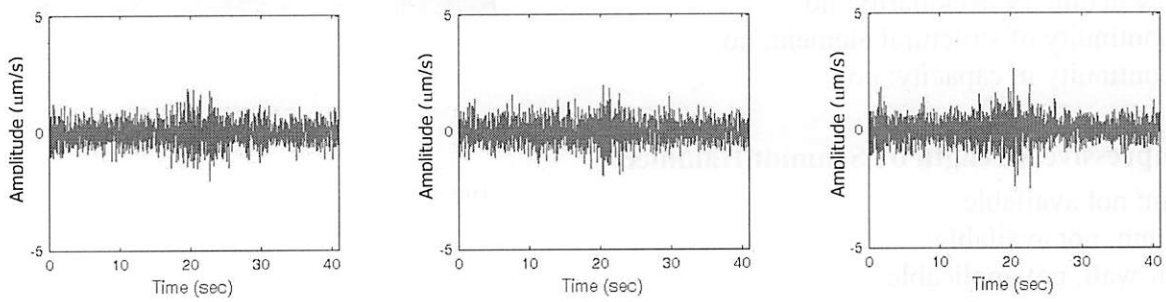




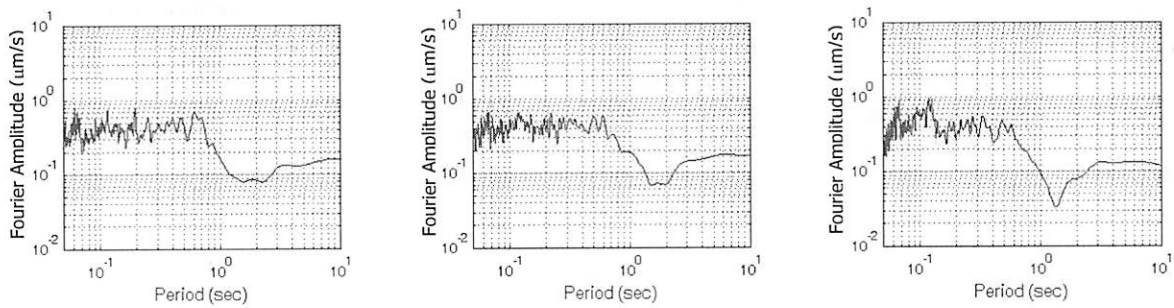
(a) Time history of Building # 25 (3rd floor)



(b) Fourier spectrum of Building # 25 (3rd floor)



(c) Time history of free field near Building # 20 and Building # 25



(d) Fourier spectrum of free field near Building # 20 and Building # 25

Figure 67 Time history and Fourier spectrum of Building # 25

3.4.38 Building Number 26

General Information:

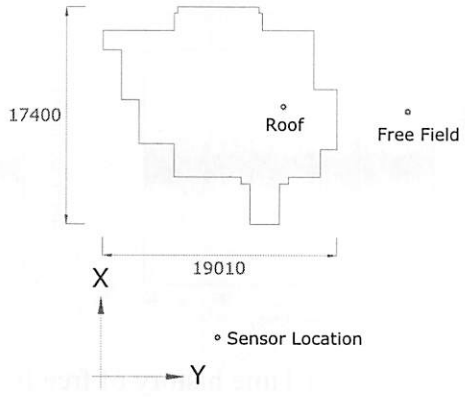
Year of Construction: 1972
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 200 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

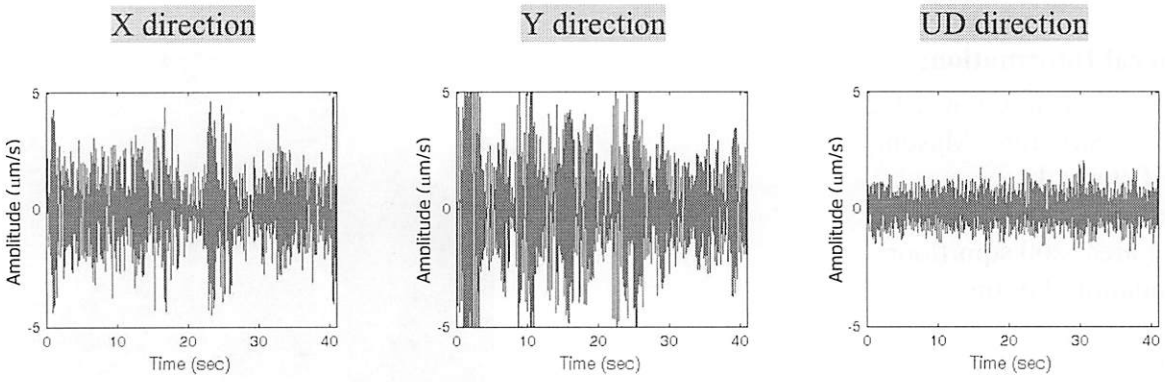
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

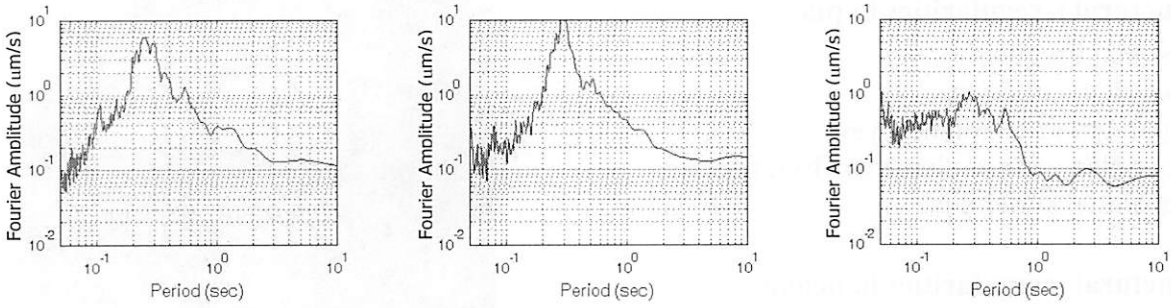


Compressive Strength by Schmidt Hammer:

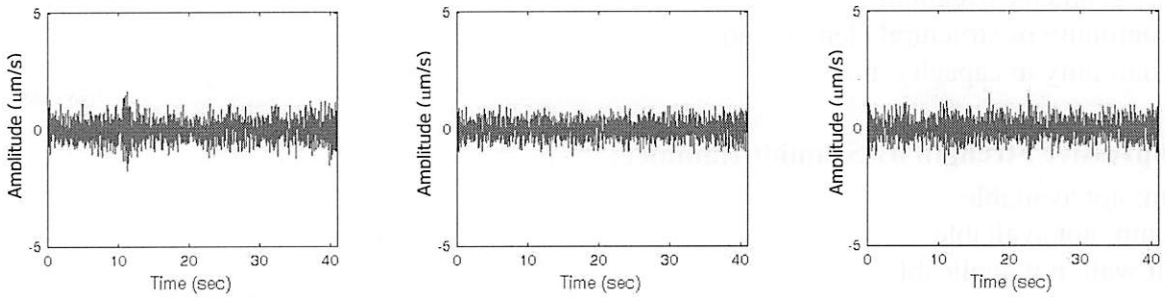
Beam: not available
Column: not available
Shear wall: not applicable



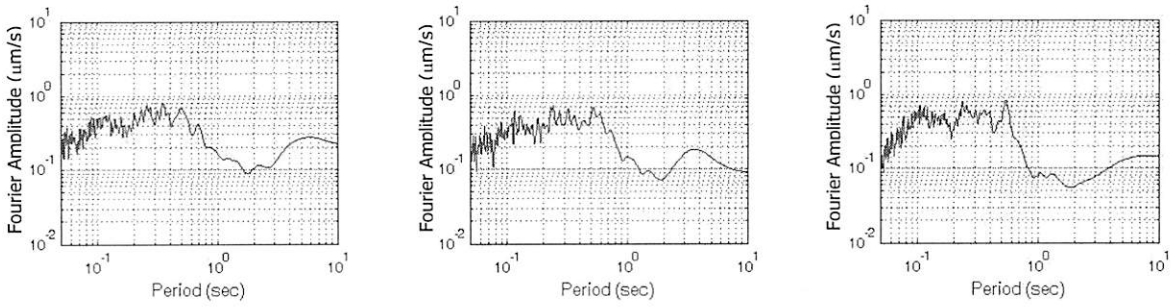
(a) Time history of Building # 26 (top floor)



(b) Fourier spectrum of Building # 26 (top floor)



(c) Time history of free field near Bldg. # 26 Bldg. # 27 and Bldg. # 28



(d) Fourier spectrum of free field near Bldg. # 26 Bldg. # 27 and Bldg. # 28

Figure 68 Time history and Fourier spectrum of Building # 26

3.4.39 Building Number 27

General Information:

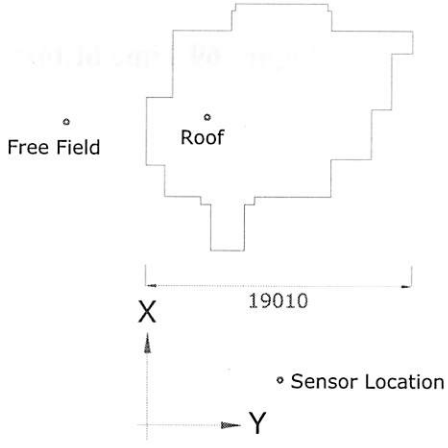
Year of Construction: 1972
Type of Structure: Masonry
No of story: 4
Use: Residential
Floor area: 200 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

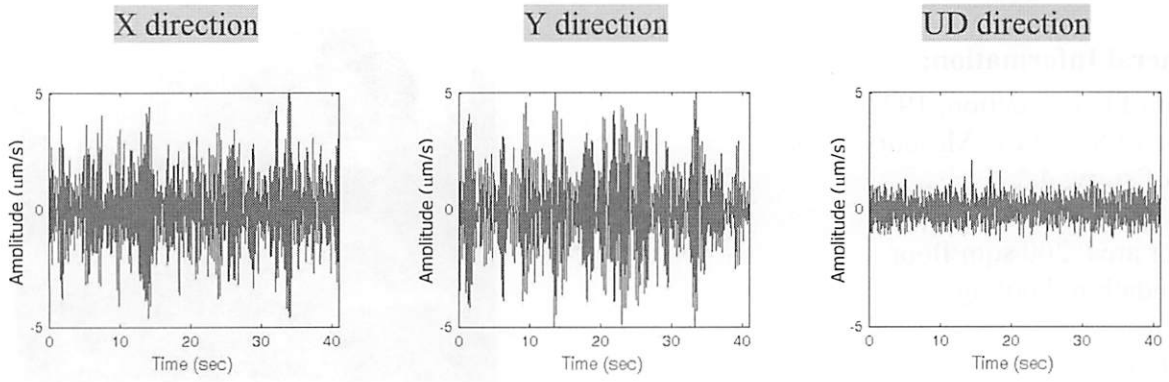
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

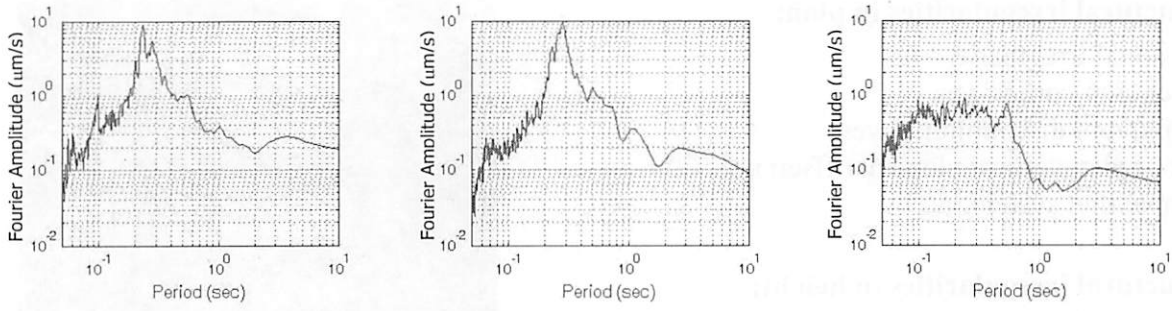


Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable



(a) Time history of Building # 27 (top floor)



(b) Fourier spectrum of Building # 27 (top floor)

Figure 69 Time history and Fourier spectrum of Building # 27

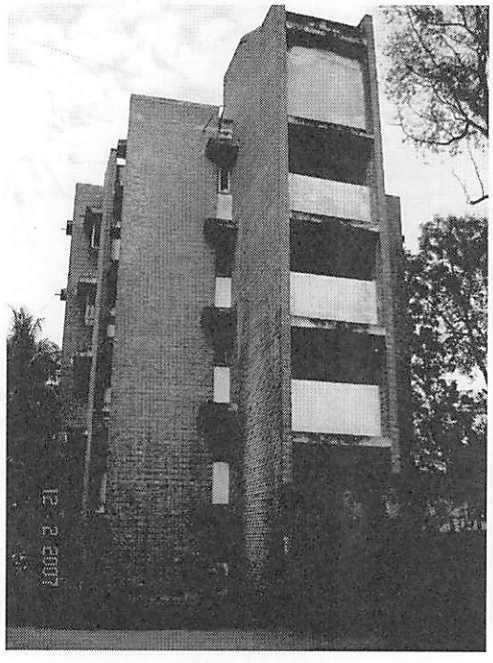
3.4.40 Building Number 28

General Information:

Year of Construction: 1978
Type of Structure: Masonry
Use: Residential
No of story: 5
Floor area: 354 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: yes

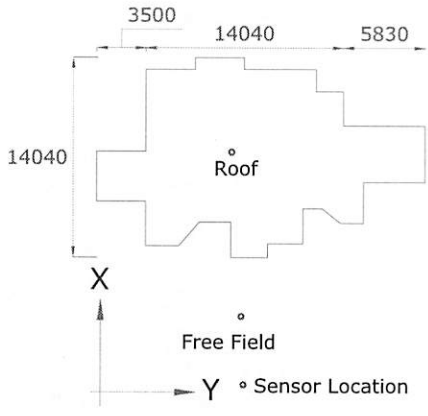


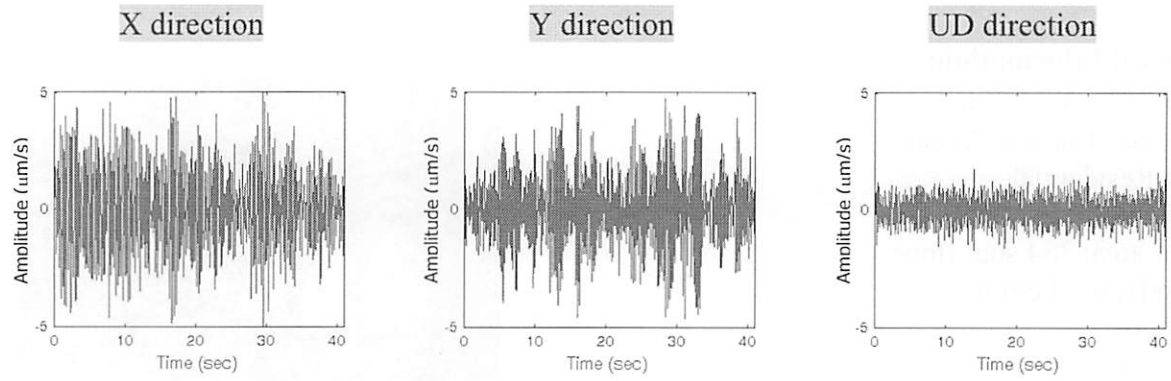
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

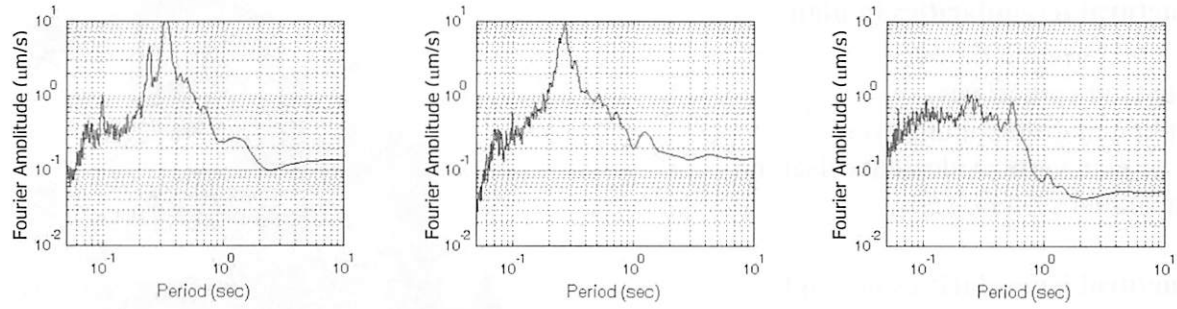
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable





(a) Time history of Building # 28 (top floor)



(b) Fourier spectrum of Building # 28 (top floor)

Figure 70 Time history and Fourier spectrum of Building # 28

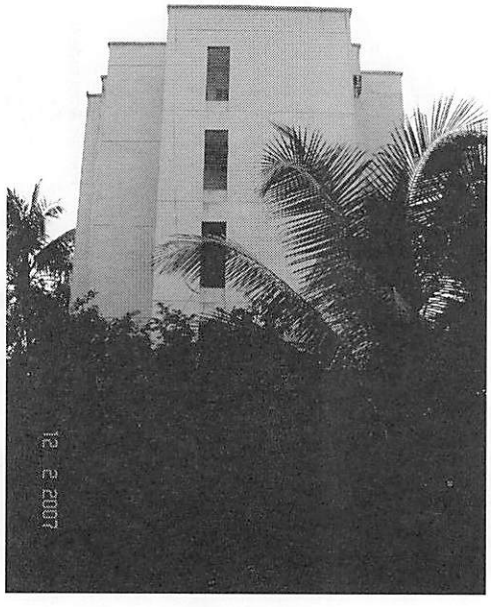
3.4.41 Building Number 46

General Information:

Year of Construction: 1993
Type of Structure: Masonry
No of story: 5
Use: Residential
Floor area: 326 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

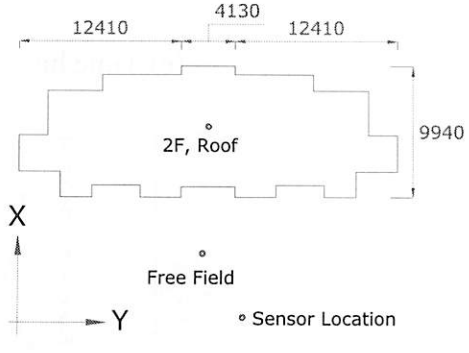


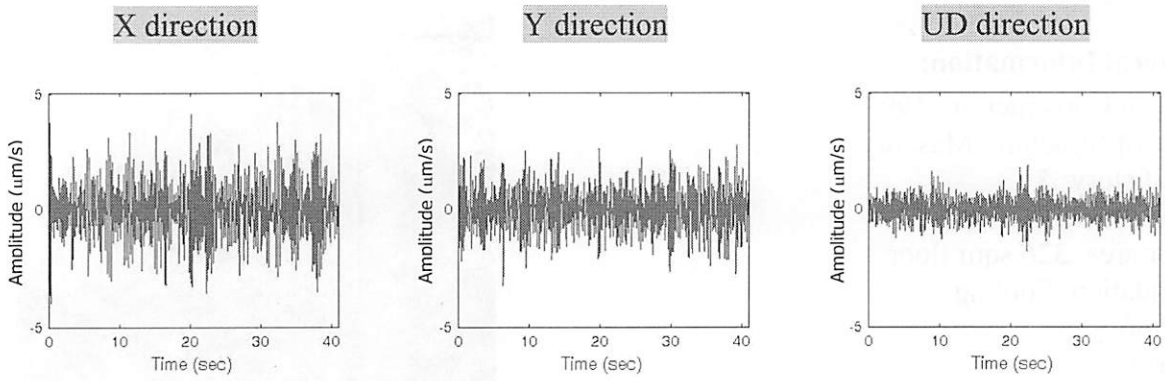
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

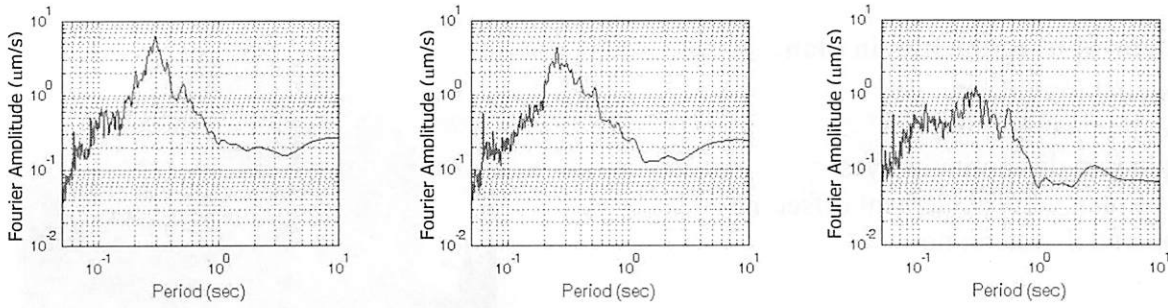
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

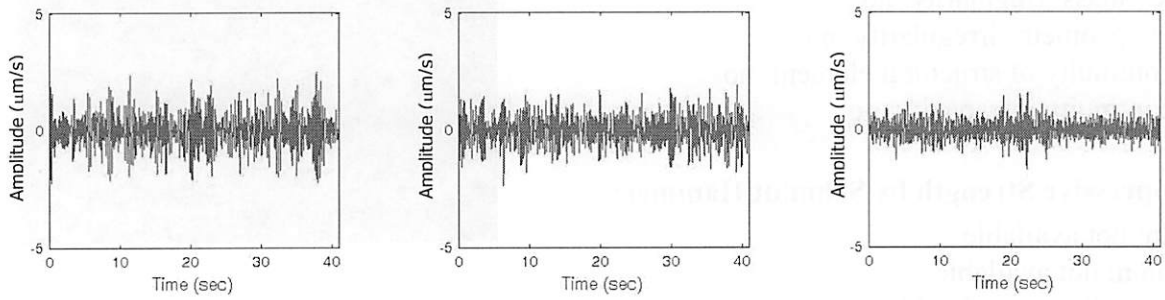




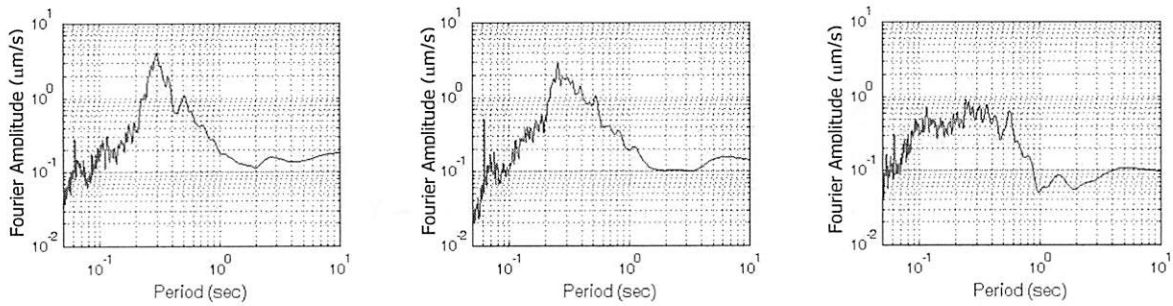
(a) Time history of Building # 46 (top floor)



(b) Fourier spectrum of Building # 46 (top floor)

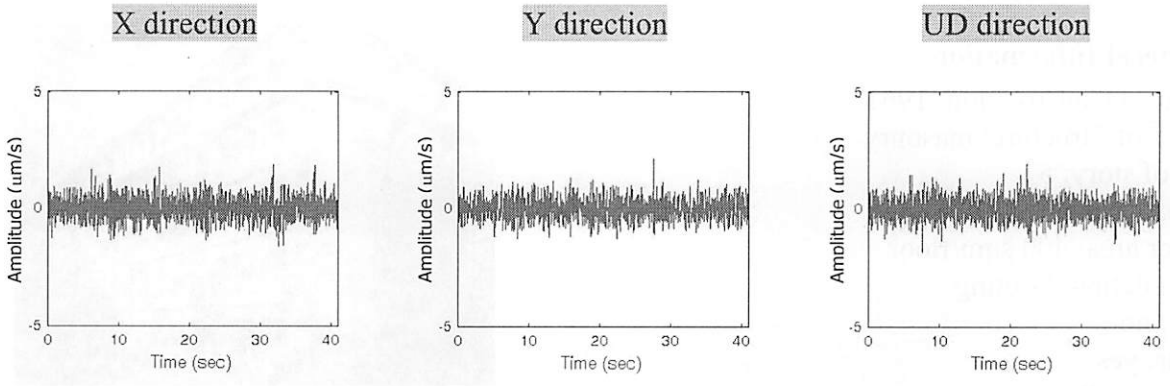


(c) Time history of Building # 46 (2nd floor)

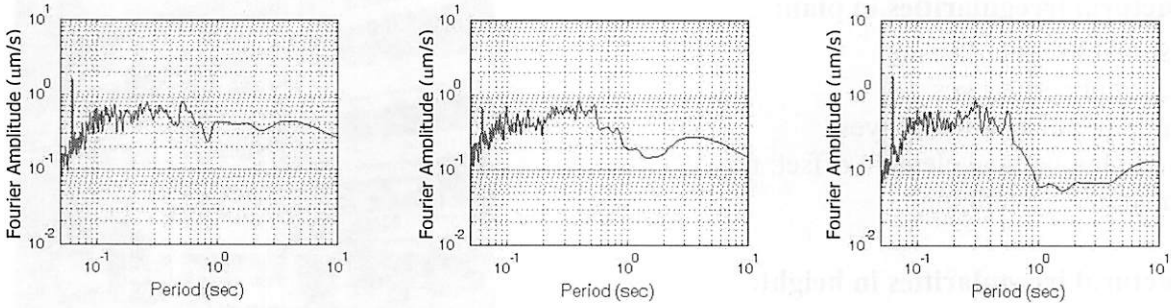


(d) Fourier spectrum of Building # 46 (2nd floor)

Figure 71 Time history and Fourier spectrum of Building # 46



(c) Time history of free field near Building # 46



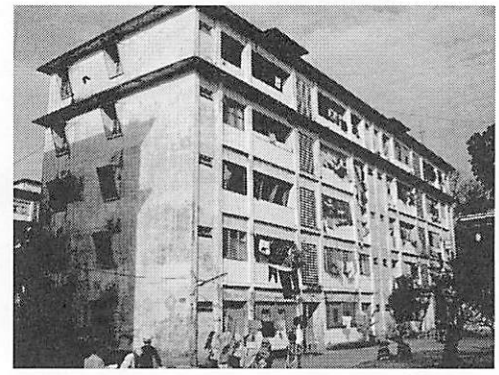
(d) Fourier spectrum of free field near Building # 46

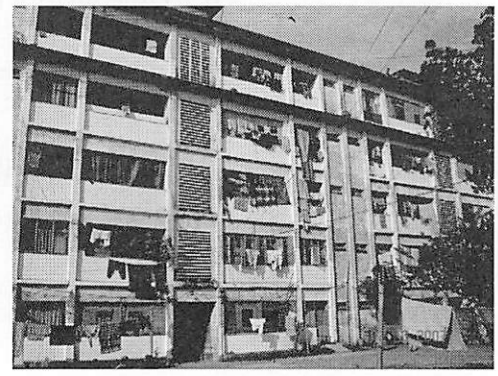
Figure 71 Time history and Fourier spectrum of Building # 46

3.4.42 Building Number 12

General Information:

Year of Construction: 1961
Type of Structure: masonry
No of story: 5
Use: Residential
Floor area: 400 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no





Structural irregularities in plan:

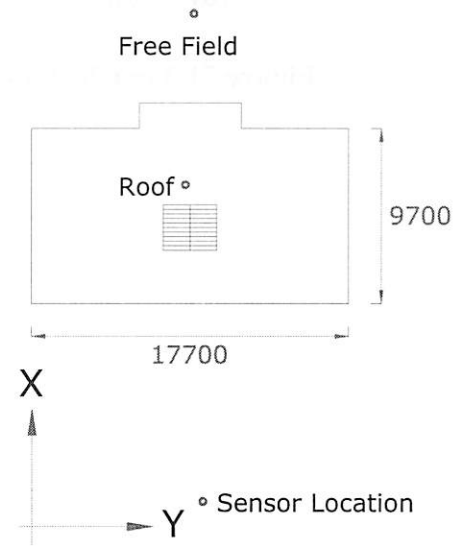
Torsional irregularity: no
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

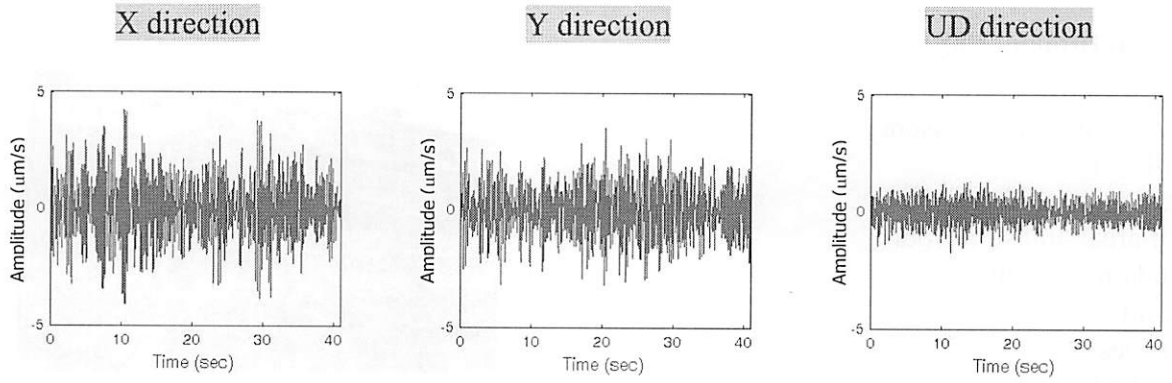
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

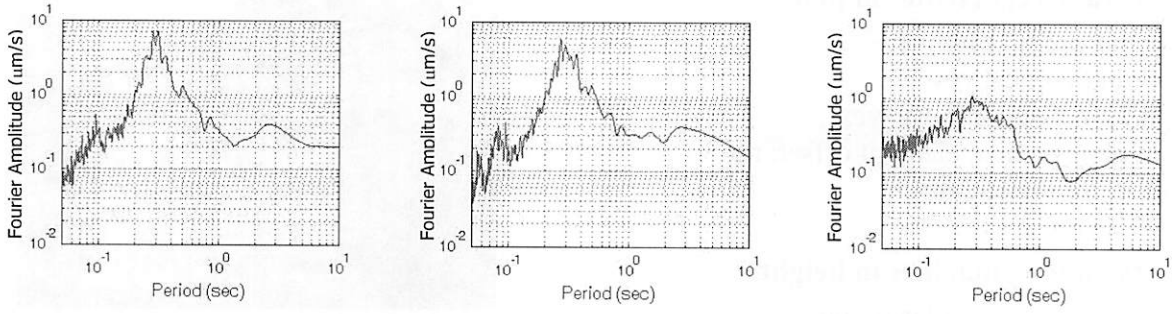
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

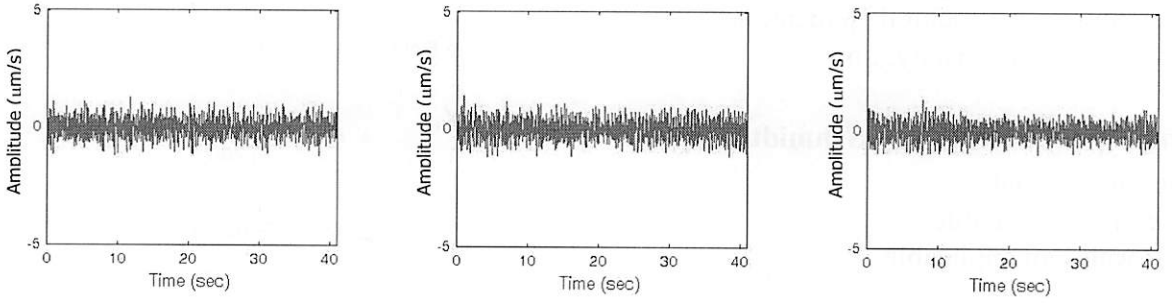




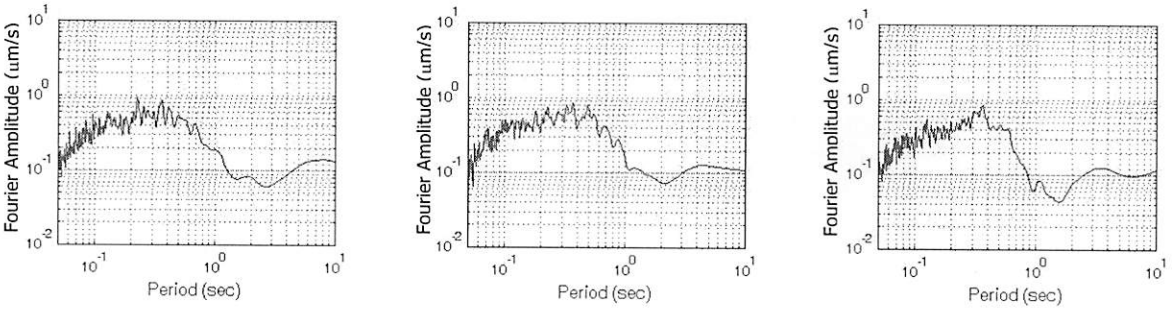
(a) Time history of Building # 12 (top floor)



(f) Fourier spectrum of Building # 12 (top floor)



(g) Time history of free field near Building # 12 and Building # 18



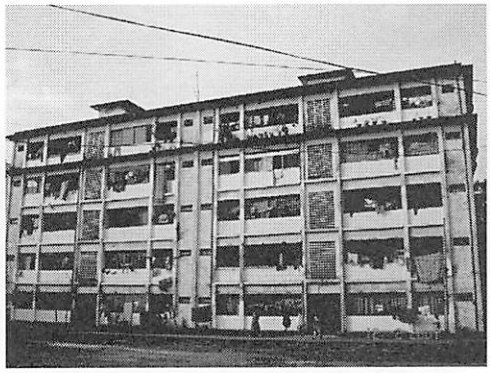
(h) Fourier spectrum of free field near Building # 12 and Building # 18

Figure 72 Time history and Fourier spectrum of Building # 12

3.4.43 Building Number 13

General Information:

Year of Construction: 1961
Type of Structure: Masonry
No of story: 5
Use: Residential
Floor area: 400 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

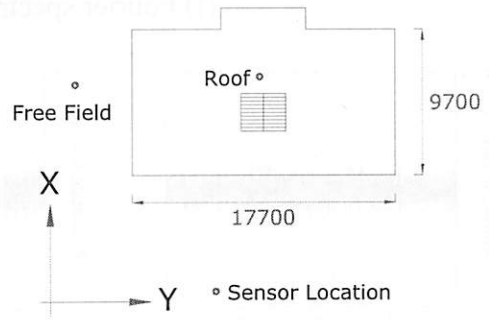


Structural irregularities in plan:

Torsional irregularity: no
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

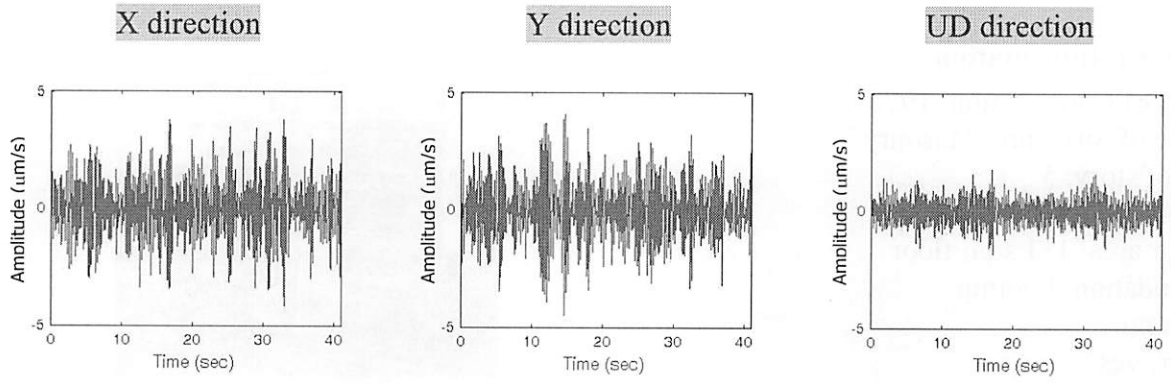
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

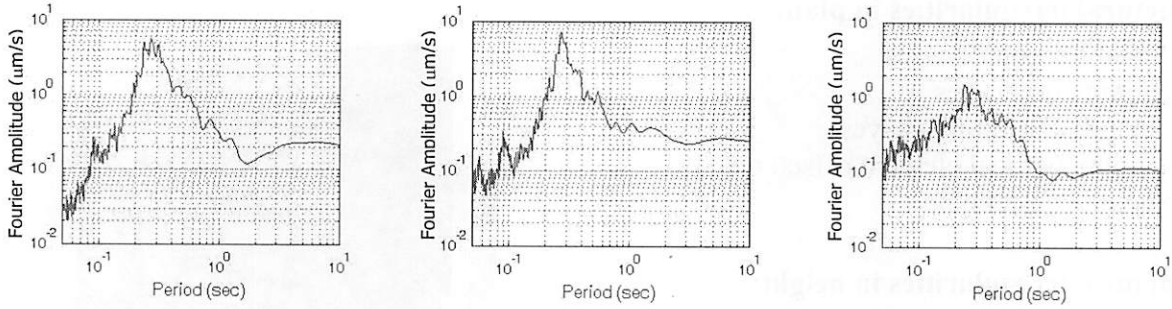


Compressive Strength by Schmidt Hammer:

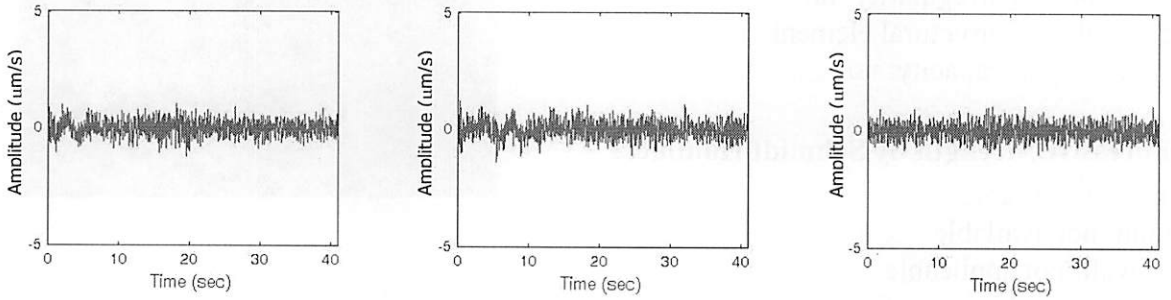
Beam: not available
Column: not available
Shear wall: not applicable



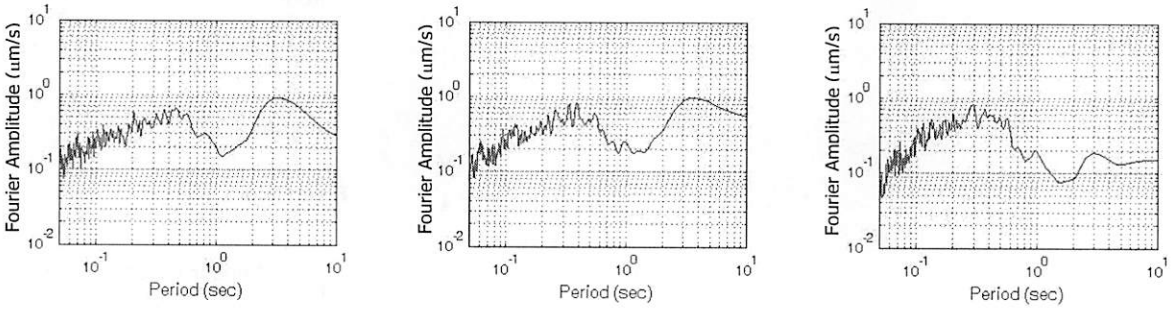
(a) Time history of Building # 13 (top floor)



(f) Fourier spectrum of Building # 13 (top floor)



(g) Time history of free field near Building # 13 and Building # 14



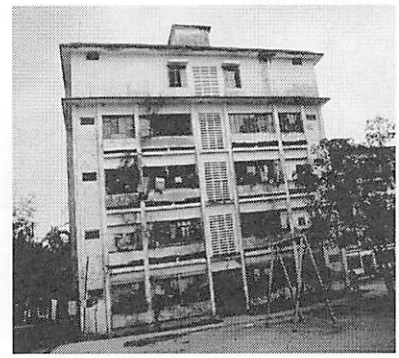
(h) Fourier spectrum of free field near Building # 13 and Building # 14

Figure 73 Time history and Fourier spectrum of Building # 13

3.4.44 Building Number 14

General Information:

Year of Construction: 1972
Type of Structure: Masonry
No of story: 5
Use: Residential
Floor area: 181 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no



Structural irregularities in plan:

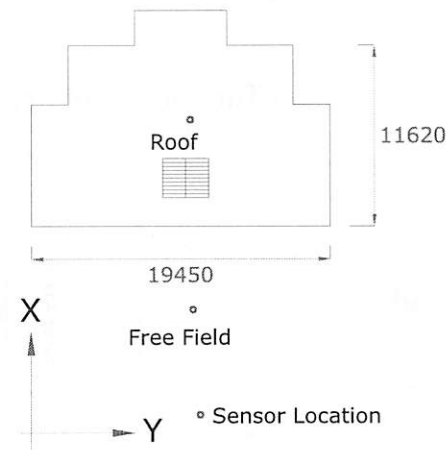
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

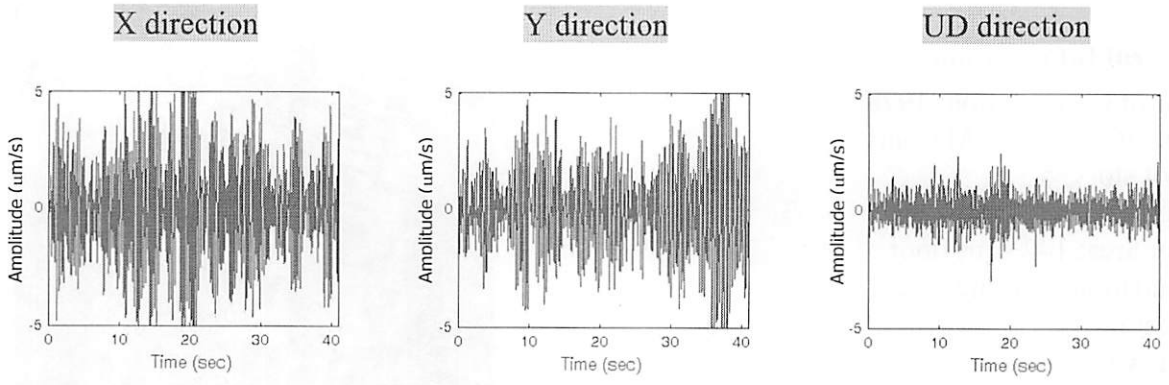
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

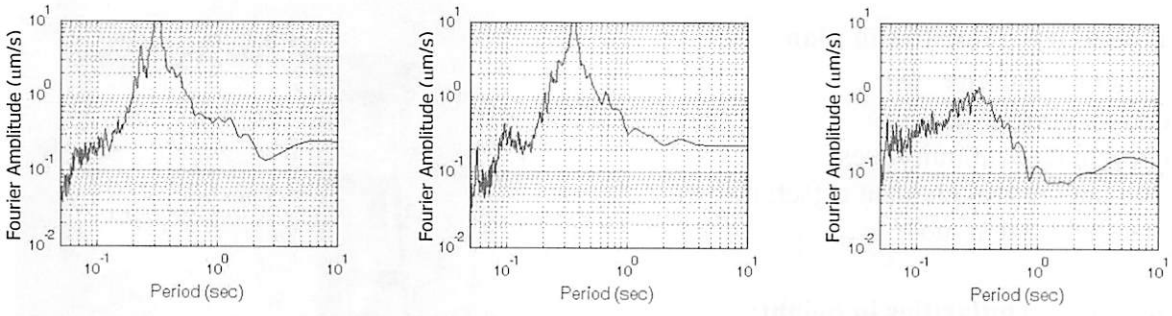
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable





(a) Time history of Building # 14 (top floor)



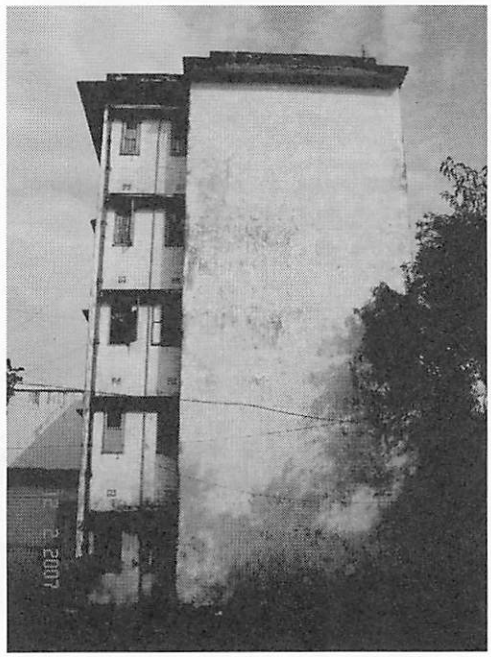
(f) Fourier spectrum of Building # 14 (top floor)

Figure 74 Time history and Fourier spectrum of Building # 14

3.4.45 Building Number 18

General Information:

Year of Construction: 1978
Type of Structure: Masonry
No of story: 5
Use: Residential
Floor area: 142 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no



Structural irregularities in plan:

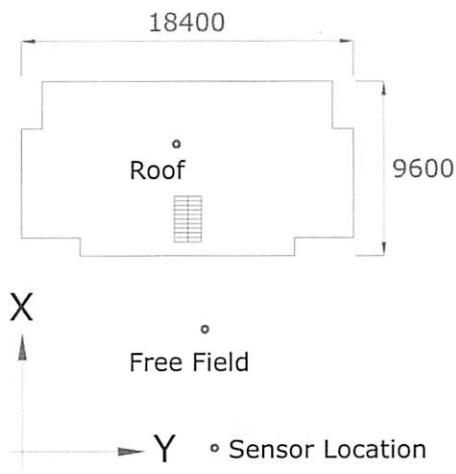
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

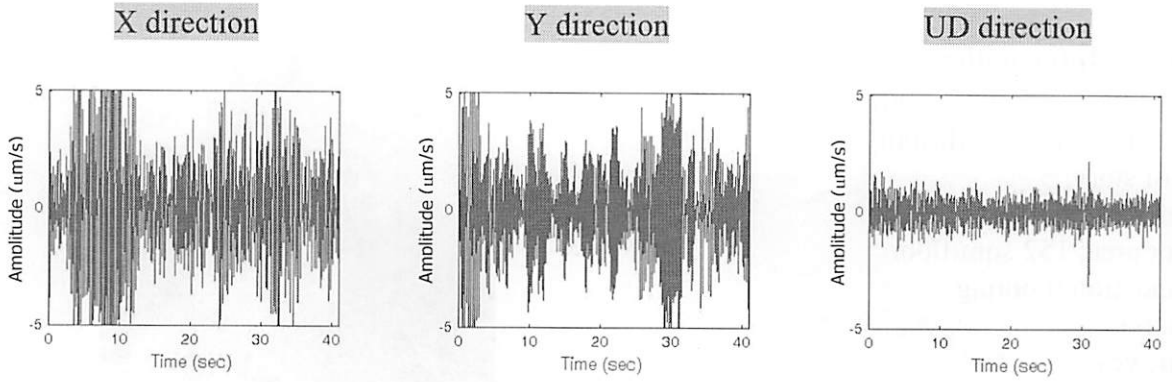
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

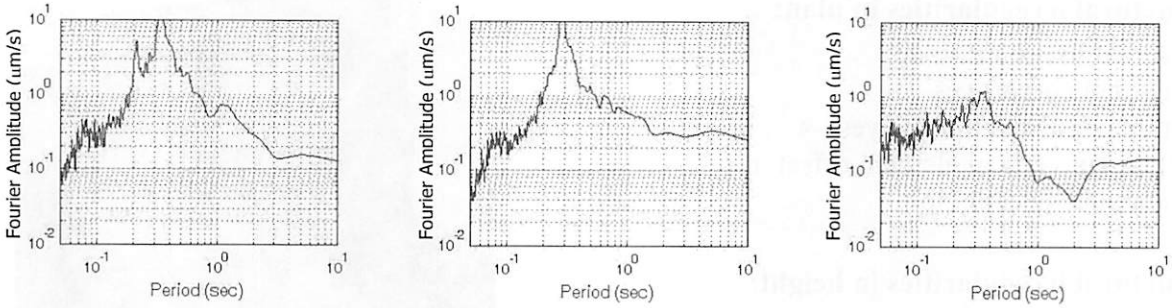
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable





(a) Time history of Building # 7 (top floor)



(f) Fourier spectrum of Building # 7 (top floor)

Figure 75 Time history and Fourier spectrum of Building # 18

3.4.46 Building Number 43

General Information:

Year of Construction: 1961
Type of Structure: Masonry
No of story: 5
Use: Residential
Floor area: 152 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

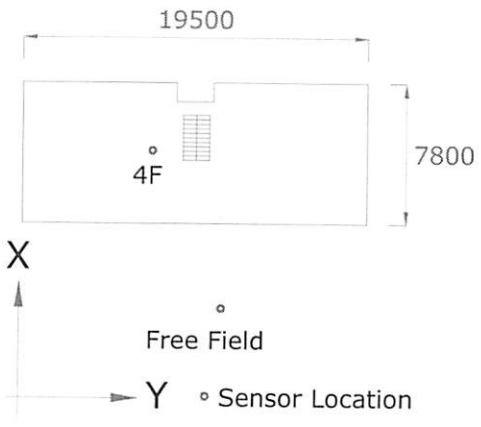
Torsional irregularity: no
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset: no
Nonparallel system: no

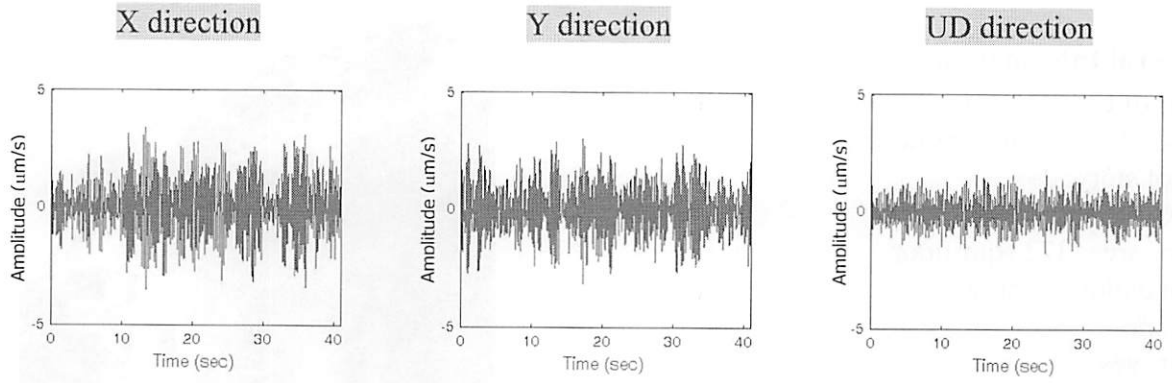
Structural irregularities in height:

Storey stiffness irregularity: no
Storey mass irregularity: no
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

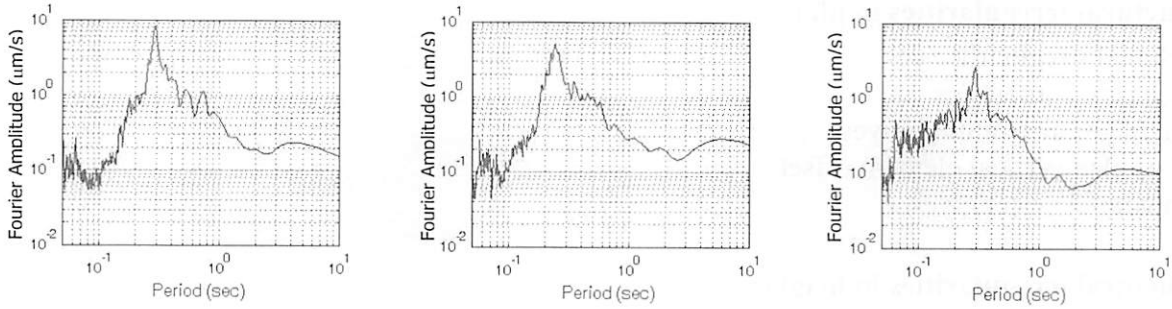
Compressive Strength by Schmidt Hammer:

Beam: not available
Column: not available
Shear wall: not applicable

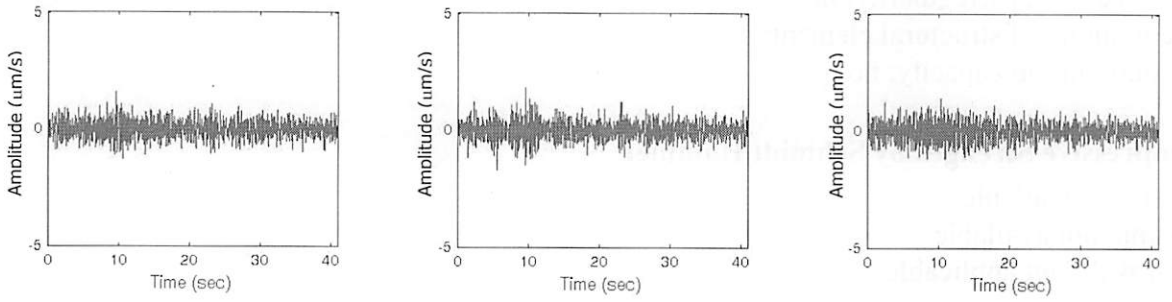




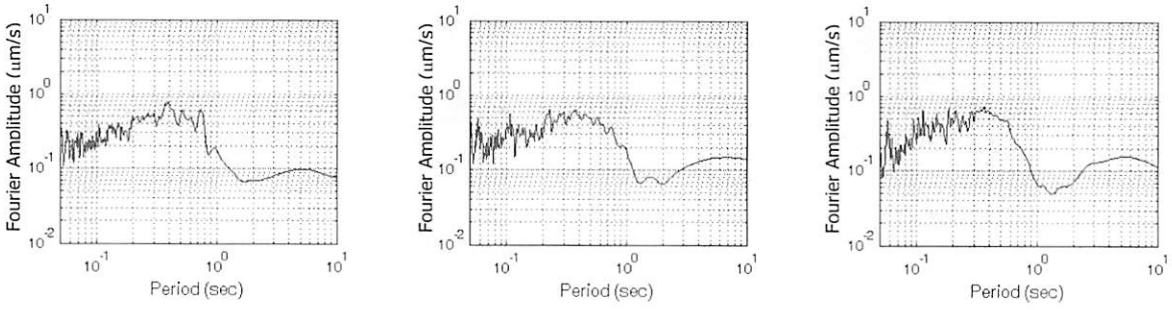
(a) Time history of Building # 43 (4th floor)



(f) Fourier spectrum of Building # 43 (4th floor)



(g) Time history of free field near Building # 43 and Building # 62



(h) Fourier spectrum of free field near Building # 43 and Building # 62

Figure 76 Time history and Fourier spectrum of Building # 43

3.4.47 Fire Station (Lalbag, Dhaka)

General Information:

Year of Construction: 2000
Type of Structure: Frame structure
No of story: 2
Use: Office
Floor area: 372 sqm/floor
Foundation: Footing
Lift: no
Stair: yes
Shear wall: no

Structural irregularities in plan:

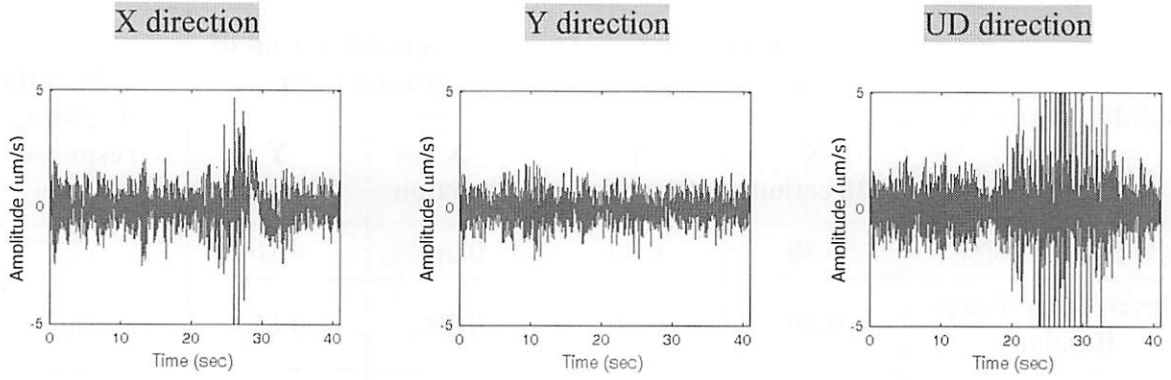
Torsional irregularity: yes
Re-entrant corner: yes
Diaphragm discontinuity: yes
Out of plan vertical element offset:
Nonparallel system: yes

Structural irregularities in height:

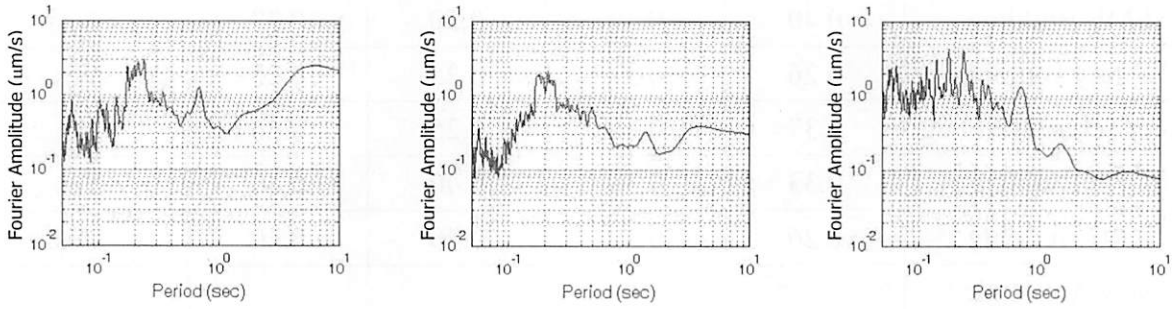
Storey stiffness irregularity: yes
Storey mass irregularity: yes
Storey geometry irregularity: no
Discontinuity of structural element: no
Discontinuity in capacity: no

Compressive Strength by Schmidt Hammer:

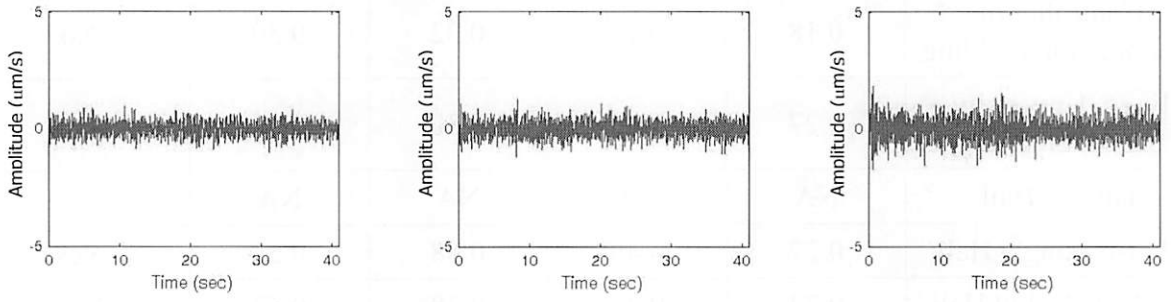
Beam: not available
Column: not available
Shear wall: not applicable



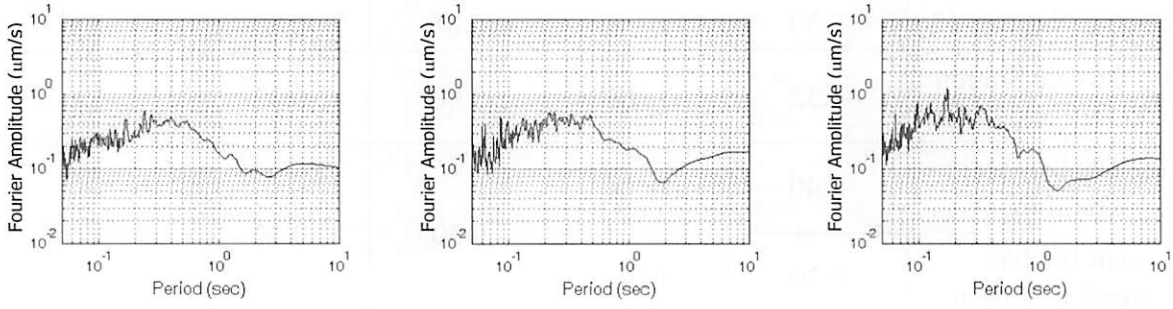
(a) Time history of Fire Station Lalbag, Dhaka (1st floor)



(f) Fourier spectrum of Fire Station Lalbag, Dhaka (1st floor)



(g) Time history of free field near Fire Station Lalbag, Dhaka



(h) Fourier spectrum of free field near Fire Station Lalbag, Dhaka

Figure 77 Time history and Fourier spectrum of Fire Station Lalbag, Dhaka

Predominant Period of RCC Frame Buildings

Building name/No.	Predominant period of building (sec)		Predominant period of ground (sec)		Amplification of seismic response
	X Direction	Y Direction	X Direction	Y Direction	
IFCDR Building	0.38	0.30	0.26	0.26	Yes
Eleven Story Tower Building	0.50	0.50	0.70	0.65	No
Civil Engineering Building	0.50	0.40	0.30	0.30	No
EME Building	0.40	0.39	0.50	0.33	No
Library Building	0.26	0.37	0.25	0.25	Yes
Architecture Building	0.37	0.36	0.25	0.26	No
URP Building	0.33	0.38	0.40	0.40	Yes
ARC Building	0.26	0.30	0.40	0.40	Yes
New Academic Building (under construction)	0.27	0.30	0.50	0.26	[1]
Controller of Examination building	0.18	0.18	0.32	0.30	No
Engg. University School Building	0.27	0.23	0.30	0.35	Yes
Titumir Hall	NA	NA	NA	NA	
Sher-e-Bangla Hall	0.27	0.40	0.38	0.52	Yes
Dr. MA Rashid Hall	0.24	0.27	0.38	0.52	Yes
Building Number 47	0.32	0.32	0.32	0.31	Yes
Building Number 62	0.39	0.34	0.38	0.38	Yes
Fire Service Station (Head Office, Dhaka)	0.32	0.28	0.30	0.32	Yes
Ban Bhaban Main Buliding	0.40	0.38	0.30	0.30	Yes
Ban Bhaban Extended Portion	0.30	0.30			
Fire Service Station, Lalbag	0.23	0.20	0.25	0.23	Yes

[1] Still under construction

Predominant Period of Masonry Buildings

Building name/No.	Predominant period of building (Sec)		Predominant period of ground (Sec)		Amplification of seismic response
	X Direction	Y Direction	X Direction	Y Direction	
Ahsan-Ullah Hall	0.27	0.25	0.07	0.06	Yes
Shahid Smrity Hall middle Building	0.27	0.21	0.18	0.07	Yes
Shahid Smrity Hall north Building	0.30	0.28			Yes
Register Building	0.20	0.20	0.32	0.30	No
1	0.25	0.25	0.30	0.30	Yes
2	0.25	0.26			Yes
3	0.28	0.22	0.35	0.37	Yes
4	0.33	0.29			Yes
5	0.22	0.26	0.37	0.37	Yes
6	0.23	0.27	0.45	0.37	Yes
7	0.25	0.27			Yes
8	0.32	0.28	0.28	0.30	Yes
9	0.24	0.22			No
30	0.26	0.24	0.50	0.50	No
45	0.27	0.29			Yes
21	0.23	0.30	0.30	0.33	Yes
22	0.33	0.29			Yes
23	0.25	0.30			Yes
24	0.24	0.29			Yes
25	0.25	0.30	0.60	0.60	Yes
26	0.25	0.30	0.35	0.32	Yes
27	0.23	0.29	0.35	0.32	Yes
28	0.33	0.28	0.35	0.32	Yes
46	0.30	0.26	0.50	0.50	Yes
12	0.30	0.28	0.36	0.38	Yes
13	0.28	0.28	0.48	0.40	Yes
14	0.31	0.35			Yes
18	0.33	0.29	0.36	0.38	Yes
43	0.29	0.25	0.38	0.38	Yes

3.5 Empirical Formulas for Fundamental Periods of Buildings

Most of the building codes define the magnitude of force, which should be sustained by buildings at specific stress level, related to the building period and provide the empirical formula to determine the lower bound fundamental period in order to establish the minimum load requirements. Bangladesh National Building Code (BNBC) defines that if the number of story is N then the fundamental period will be:

$$T = 0.1\ N$$

With this relation a graph is plotted in Figure 78. From analysis of microtremor observations, natural periods are also obtained. Microtremor observations give lower results for both masonry and frame structure type buildings than that in BNBC. For frame structures and masonry buildings different empirical relations are developed which are shown in Figure 78 and Figure 79 respectively.

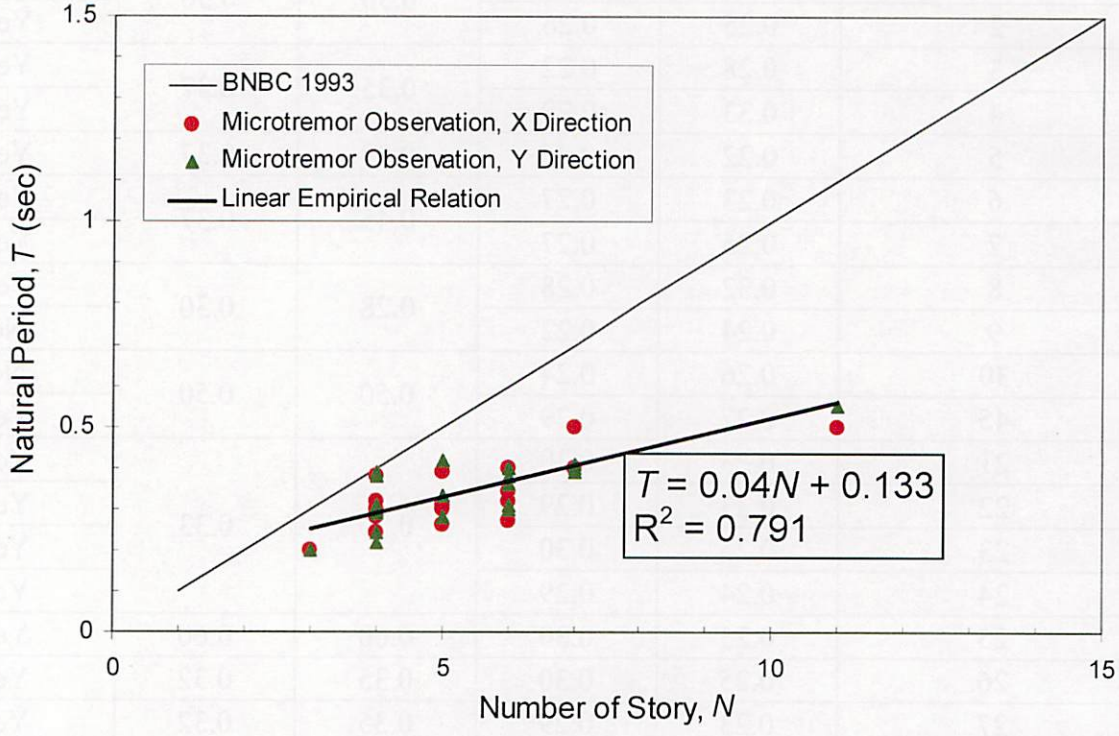


Figure 78 Empirical relation between number of story and natural period of surveyed RCC Buildings

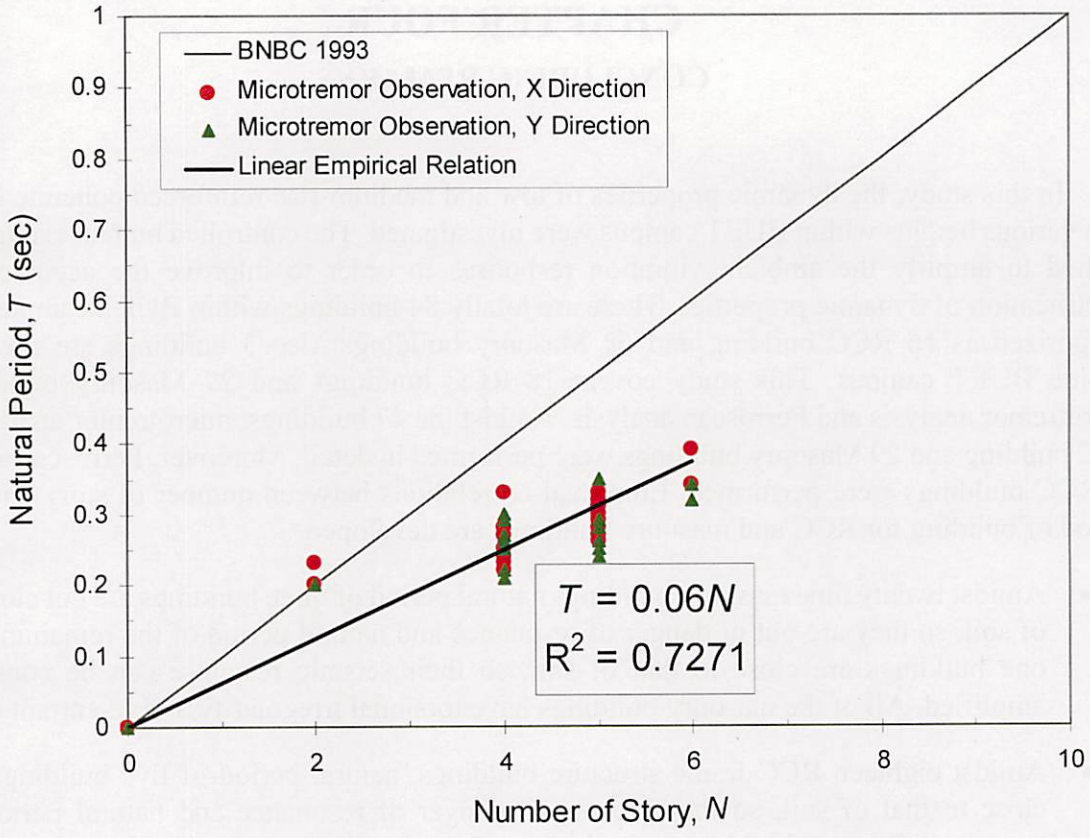


Figure 79 Empirical relation between number of story and natural period of surveyed masonry buildings

CHAPTER FOUR
CONCLUDING REMARKS

In this study, the dynamic properties of low and medium-rise reinforced concrete buildings with various heights within BUET campus were investigated. The controlled human excitation was applied to amplify the ambient vibration responses in order to improve the accuracy of the identification of dynamic properties. There are totally 84 buildings within BUET campus that are categorized as 16 RCC building and 68 Masonry building. Also 3 buildings are investigated outside BUET campus. This study covers 18 RCC buildings and 29 Masonry buildings for microtremor analysis and Ferroscan analysis. Amidst the 47 buildings, microtremor analysis of 17 RCC building and 29 Masonry buildings were performed in detail. Moreover, Ferroscan studies of 13 RCC buildings were performed. Empirical correlations between number of story and natural period of building for RCC and masonry buildings are developed.

- Amidst twenty nine masonry buildings natural period of three buildings are not close to that of soil, so they are out of danger of resonance and natural period of the remaining twenty one buildings are close to that of soil, so their seismic response can be considerably amplified. All of the masonry buildings have torsional irregularity and re-entrant corner.

- Amidst eighteen RCC frame structure buildings, natural period of five buildings are not close to that of soil, so they are out of danger of resonance and natural period of the remaining thirteen buildings are close to that of soil, so their seismic response can be considerably amplified. Among surveyed RCC frame buildings seven buildings have soft story.

- Results obtained from Ferroscan data analysis are not satisfactory. Variation of cover and spacing of lateral ties in columns and stirrups in beam from design are above acceptable limit. Concrete compressive strength from Schmidt hammer test is found satisfactory for four buildings and unsatisfactory for nine buildings.

- Empirical correlation between number of story and natural period of building for RCC frame buildings and masonry buildings are

  $T = 0.04N + 0.133$ [for RCC frame buildings]

  $T = 0.06N$ [for masonry buildings]

  Where, T = Natural period of building

  N = Number of story

Earthquake vulnerability of the surveyed buildings are assessed from natural frequency obtained by analysis of microtremor data (resonance), reinforcement detection by Ferroscan, concrete compressive strength by Schmidt hammer test and visual inspection (structural irregularities). Amidst forty seven buildings, earthquake vulnerability of seven buildings is low, that of thirty four buildings is moderate and that of six buildings is high. Six buildings for which earthquake vulnerability is high, require detail structural analysis to confirm this situation.

REFERENCES

Aki, K. (1957). Space and time spectra of stationary stochastic waves, with special reference to microtremors, Bull. of earthquake research institute, 35, 415-456.

Ansary, M.A., Yamazaki, F. and Katayama, T. (1996). Application of Microtremor Measurements to the estimation of site amplification characteristics, Bulletin of ERS, Vol 29, pp: 96-113.

Bangladesh National Building Code (1993). Housing and Building Research Institute, 1st ed., Dhaka.

Nakamura, Y. (1989). A method for dynamic characteristics estimation of subsurface using microtremor on the ground surface, QR of RTRI, 30, 25-33.

Saha, R. (2006). Earthquake Vulnerability Assessment of BUET Buildings, Undergraduate Thesis, Department of Civil Engg., BUET, Dhaka.

Sato, T., H. Kawase, M. Matsui, and S. Kataoka (1991). Array measurement of high frequency microtremors for underground structure estimation, proc. 4th int. conf. on seismic zonation, 11, 409-416.

Suzuki, T., Y. Adachi, and M. Tanaka(1995). Application of microtremor measurements to the estimation of earthquake ground motions in Kushiro city during the Kushiro-oki earthquake of 15 January 1993, Earthq. Eng. Struct. Dyn., 24, 595-613.

Tamura, T., O. Nagai, H. Kikubo, and H. Sumita (1993). Characteristics of wave group microtremors obtained by array measurement, J. Struct. Consr. Eng. AIJ 449, 83-91 (in Japanese).

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