AMBIENT VIBRATIONS OF UNREINFORCED MASONRY BUILDINGS IN DHAKA CITY

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By

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CERTIFICATE OF APPROVAL

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DECLARATION

It is hereby declared that, except for the contents where specific references have been made to the work of others, the studies contained in this thesis are the result of investigation carried out by the author under the supervision of Dr. RaquibAhsan, Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET).

Neither the thesis nor part of it is has been submitted to any other university or other educational establishments for a degree, diploma or other qualifications (except for publication).

(Muhammad Romeo Nowreen Khan)

DEDICATED TO

MY TEACHERS, PARENTS AND FAMILY

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ABSTRACTS

The ambient vibration investigations are performed for use in structural health monitoring and in structural control studies within the technical assessment of different kinds of structures. The ambient vibration tests define the linear behavior of structures, since the amplitudes of vibration are small. The actual responsive behaviour of structures under an earthquake is similar to the ambient vibration behaviour. It was shown that the dynamic behaviour of the masonry building, even if not regular and with deformable floors, can be effectively represented. Considering the above fact the main objectives of this research was to identify the pre-dominant or natural periods of the targeted unreinforced masonry (URM) buildings by performing ambient vibration tests, to compare the obtained structural pre-dominant period with the structural period calculated by the formula given in Bangladesh National Building Codes (BNBC) and to develop a relationship of structural period with different structural parameters of the URM buildings.

This paper presents evaluation of ambient vibrations and the identification of the pre-dominant frequencies of seventeen low-rise URM buildings by ambient vibration tests. The buildings are of different stories from single storey up to five stories with regular and irregular shape in plans and elevations located in Dhaka, the capital city of Bangladesh. These masonry buildings were built in between 1960 to 1990 without any seismic guidelines.

Attempt was made to correlate structural periods with heights and structural periods with total length of walls of structures by curve fittings and regression models. The multivariate linear regression analysis was selected for model development. Total three approaches were followed where structural period was the dependent variable. Approach 1was taken to find out an empirical model with the consideration that the dependent variable i.e. structural period is a cubic function of both the independent variables i.e. height of structures and total length of walls. Again Approach 2 was taken for the same with the consideration that the structural period is a quadratic function of both height of structures and total length of walls. Lastly Approach 3 considered that the structural period is a quadratic function of height of structures and a linear function of total length of walls, separately. Total four methods, namely the enter method, stepwise method, backward method and forward method, for each approach were used one after another as to check which one work better and provide realistic solution. Finally both forward selection and stepwise methods of Approach 1 and Approach 2 provided similar and the best possible statistical result combining height and total length of walls of structures. However analyzing all the findings of the regressions the parabolic curve fitting equation was selected for calculating structural periods of URM buildings.

The endeavours of identifying the correlations through regressions were successful. The study suggested an insertion of the finding in the form of a formula in the BNBC in future.

Keywords: URM, Ambient Vibration Test, Modal Analysis, Frequency Spectra, Pre-dominant Frequency, Structural Period.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variables
AVT	-	Ambient Vibration Test
BNBC	-	Bangladesh National Building Code
CES	-	Civil Engineering Structures
DB	-	Displacement Based
DBD	-	Displacement Based Design
DC	-	Direct Current
df	-	Degree of Freedom
DV	-	Dependent Variable
DW	-	Durbin Watson
EW	-	East-West
exp	-	Exponential
FE	-	Finite Element
FFT	-	Fast Fourier Transformation
IV	-	Independent Variable
KPI	-	Key Point Installation
MLR	-	Multiple Linear Regression
MS	-	Microsoft
NS	-	North-South
PP	-	Peak Picking
PSD	-	Power Spectral Density
RC	-	Reinforced Concrete
RCC	-	Reinforced Cement Concrete
SE	-	Standard Error
SHM	-	Structural Health Monitoring
SPSS	-	Statistical Package for the Social Sciences
URM	-	Unreinforced Masonry Building
USB	-	Universal Serial Bus

NOTATION

a, a_1, a_2, a_3	Parameters
b, b_1,b_2, b_3	Parameters
B	Unstandardized Coefficients
β_o	Slope of the Linear Model
β_1	Intercept on y-axis, and are the Regression Parameters
$\beta_{1,\dots\dots}\ \beta_k$	Regression Coefficients
E	Equation
ε_i	RandomError Termor the“StochasticDisturbance”
F	F-statistic for Overall Fit
f	Function
f	Frequency
Hz	Hertz
N	Number of Data
R	Multiple Correlation Coefficient
r	Pearson Correlation
R-sq (R^2)	Coefficient of Determination
Sig.	Significance
Sigf	Significance
T	Structural or Fundamental Periods
t	t-tests of Individual Parameters
X_i	Value of the Predictor Variable in the i^{th} Observation
X*ij*	Values ofi^{th} Observation of the j^{th}Independent Variable
Y	Primary Variable
Y_i	Value of the Response Variable in the i^{th} Observation
Y_t	Value of the Response Variable for the Predictor, t

CHAPTER ONE

INTRODUCTION

1.1 GENERAL

For any human community civil infrastructure such as buildings, bridges, pipelines (for water, gas and oil), electricity lines, dams etc. are an essential element. It plays an important part in providing safety and security to the billions of lives of the community. Buildings are one of the basic essentials of the modern human-built environment that are exposed to a combination of irregular dynamic and static forces continuously. Structural integrity and overall performance of the structure are affected by these forces. It is a usual phenomenon that all sorts of structures are undergoing structural deterioration due to ageing, deprivation of proper maintenance and repair, inappropriate design for the current loading demands and poor construction quality. The last reason is a major problem especially in the third world countries like Bangladesh.

Determination of the actual performance of a building due to variations arising during construction, the lack of structural drawings for older buildings and the unknown quality and type of materials used is a challenging task. Presently there is no quick and reliable diagnostic tool available to determine the in-place integrity of infrastructure and no effective and proven way to validate the assumed design parameters once construction is complete (Ren and De Roeck, 2002). The customary practice to determine the state of a structure basically involves visual inspections by highly qualified engineers. Structural damage frequently proliferates from within the structure itself, meaning that indicators of loss of integrity may be hidden from the human eye and consequently go unobserved. Traditional visual inspections are often laborious, costly, time consuming, and often result in a personal opinion. The installation of a system of sensors to monitor and record the in-place performance in combination with visual inspections of a structure has the potential to provide a better, rapid and reliable result about the state of the existing infrastructure.

Among the all types of structures brick masonry is one of the very important masonries. Vertical and horizontal elements, respectively by walls and floors delineate the structures of brick masonry building. For masonry, especially unreinforced masonry (URM), floors should be rigid in their plane to have the capacity to distribute the seismic or other lateral load among the vertical wall elements in proportion to their stiffness. Such floors are referred to as horizontal diaphragms. However diaphragms alone will be inadequate unless good connection between them and the supporting walls exists (Tomazevic et al. 1993). In the event of an earthquake, apart from the existing gravity loads, horizontal loads are imposed on buildings. For URM buildings the walls, as load carrying members, provide the capacity to resist the demand created by these gravity and earthquake loads.

History describes numerous earthquakes, since the beginning of civilization have caused tremendous loss of lives and destruction to infrastructure and property. Earthquakes generates sudden impulse-type load into buildings, setting them in vibratory motion. Earthquakes can be of different intensities and buildings respond to them differently based on their configuration, construction and materials. (Borg, 1983; Casciati et al., 2006).

URM buildings have become known as vulnerable due to their poor performance under seismic actions. Tensile and shearing stresses created in the walls due to strong earthquakes are the primary cause of damage suffered by URM buildings. For such buildings with inadequate capacity, exposed to severe and prolonged earthquake ground motions the cracks become wider and the masonry units become loose causing partial failure and gaps in walls occur due to falling of loose masonry units. Eventually walls get separated at corners and fall outwards leading to either partial or full collapse (Tomazevic 1999).

Experiences achieved from the evidences of earthquake damaged URM buildings show that well tied buildings with well-defined, continuous load path to the foundations performed much better in earthquakes. In many of those cases, even structural layout with symmetry and uniformity both in plan and elevation assisted greatly in better performances.

However for the poor performance in earthquakes, an understanding of the dynamic behaviour of URM buildings when subjected to earthquake excitation is of major concern in many seismically threatened countries such as Bangladesh. Masonry walls with adequate gravity load-bearing capacity have very low lateral load resistance capacity. For this reason, these buildings are considered to be highly vulnerable to seismic hazard.

Currently, structural health monitoring (SHM)has become very popular in the civil engineering research community with the aim to develop methods able to detect structural damage at the earliest possible stage and to assess the remaining useful life of structures (damage prognosis). Non-destructive vibration-based damage identification makes use of changes in dynamic characteristics (e.g., modal parameters) to identify structural damage. Vibration-based SHM is based on vibration testing of structures which requires high capacity actuators. Presently ambient and forced vibration tests are usual applied techniques for reinforced concrete or steel buildings to understand and ascertain their dynamic behaviour, less is known about masonry buildings. Certainly the dynamic behaviour of masonry buildings differs from that of concrete or steel buildings.

Dynamic characterization of civil engineering structures (CESs) has become increasingly significant for predicting dynamic response, finite element modal updating, SHM etc. It is important to define the dynamic parameters such as natural frequencies, damping factors and mode shapes, which are typically obtained using modal identification techniques by conducting ambient or forced vibration tests (Karim *et al.*, 2008). Dynamic characteristics have a key role on the seismic behavior and vulnerability of structures. Particularly, fundamental periods of vibration are needed, both in design of new buildings and in assessment of existing ones, so that their seismic response can be assessed. The knowledge of dominant frequency and damping ratio of structures is of uppermost importance, especially in earthquake engineering, to evaluate the seismic demand.

Ambient vibration can be from sources such as wind, waves, traffic i.e. pedestrian or vehicles, and/or micro-seismic tremors with the vibration not controlled but instead considered as a stationary random process. Thus, the response data from the structure alone is used to estimate the dynamic parameters (Shabbir, 2008). In contrast, forced vibration testing provides a known input force over the frequency bands of interest, which can be achieved by the excitation input motions. Thus, the dynamic characteristics of structures can be explicitly recognized.

Ambient vibration test has two major advantages compared to forced vibration test for obtaining dynamic characteristics of large CESs. Firstly it is not expensive and heavy excitation devices are not required, and, therefore ease and economic to implementation. The other advantage is that all (or part) of measurement coordinates can be used as references. It is also considered to be more practical.

For heritage structures where simulated loading might induce significant damage to the tested structures and thus forced vibration testing is not preferred. Thus, monitoring of structural responses from ambient vibration is preferred, since dynamic properties can be identified by analyzing ambient responses of the buildings. The structural vibratory responses depend on both spectral content of the excitations and dynamic characteristics of the structure. Structural responses signify directly the structural dynamic characteristics which are useful to understand behavior of the structure and further assess structural integrity. For example, natural frequencies and mode shapes can be used for examining overall structural stiffness.

1.2 BACKGROUND OF THE PRESENT RESEARCH

Bangladesh is situated in moderate earthquake prone region. Considering the early history of major earthquakes in and near Bangladesh, it is already overdue with a major one for a decade. Major metropolitan cities including the capital city Dhaka of Bangladesh are under serious threat because of faulty design, poor construction of structures and the absence of enforcement of rules and regulations. Weak buildings designed without seismic consideration could be susceptible to damage under moderate ground shaking from distant earthquakes. So the structural engineers now-a-days are more concerned about the different earthquake analysis procedures.

Figure 1.1: Dhaka City (Google Map)

Dhaka city started experiencing development in the infrastructural sectors especially since the immergence of India and Pakistan from the Indian Sub-continent in 1947.Over the past 30 years or so Dhaka city has experienced a rapid growth of urban population and it will continue in the future due to necessary demands by the nation. It is observed that till 1970 there were abundance of buildings particularly government buildings built as URM structures.

Bangladesh, in particular, Dhaka City has numerous URM buildings. Most of which are built before 1970s and without seismic consideration. These could be susceptible to damage under moderate ground shaking from distant earthquakes. It is mentionable that Bangladesh published its first ever building code as Bangladesh National Building Code (BNBC) in 1993. Before this all the civil engineering constructions either followed Adhoc regulations of government or did not followed at all. Still, URM buildings are being constructed in Bangladesh following the code prescribed in BNBC 1993 Part 6 Chapter 4.

Now after several decades of construction, it is important to investigate the structural health conditions of these URM buildings for the necessity of the safety of many lives and structures. Now-a-days, SHM technique by vibration tests are commonly used to identify structural damage at the earliest possible stage and to assess the remaining useful life of structures (damage prognosis).Vibration-based tests are usual applied techniques for buildings to understand and ascertain their dynamic behaviour. Pre-dominant or natural period of structures is one of the vital dynamic properties of structures. The knowledge of fundamental frequency and damping ratio of structures is of principal importance to estimate the seismic demand.

There are several empirical formulae for calculating pre-dominant or natural period of structures in the codes of various countries. But these formulae are based largely on observations of the dynamic response of multi-storied steel and reinforced concrete structures and masonry structures are included in the "others" structures category (for Bangladesh BNBC 1993).

For the seismic design of structures, the fundamental period is very important. Because the design base shear of any structures depends largely on the fundamental period. If the value of the fundamental period is wrong, it may lead to an erroneous determination of design base shear. Again the response spectra will also be inaccurate. All these may ultimately result an unsafe structure. Considering the above fact there is a necessity to have a relation specified for calculating pre-dominant or natural period of URM structures.

1.3 OBJECTIVES

This paper describes the low-rise URM buildings tested within Dhaka city, the tests and results, and the methodologies and the equipment used. Based on the above mentioned background, the objectives of this research were as followings:

a. To identify the pre-dominant or natural periods of the targeted URM buildings by performing ambient vibration tests (AVTs).

b. To compare the obtained structural pre-dominant period with the structural period calculated by the formula given in BNBC.

c. To develop a relation of structural period of the URM buildings with different structural parameters such as total height of building, height of stories, total length of wall of structures in two principal directions, thickness of load bearing wall etc. of such buildings in Dhaka City using the experimental dynamic data acquired.

It is expected that the outcome of this research work will facilitate identification of the pre-dominant vibration period of URM buildings. The research results will assist in recommending an empirical formula for the structural period of URM building for Bangladesh that may provide some base line to predict the dynamic behaviour of the URM structure under earthquake excitation. It may allow determining the total design base shear of URM building in a given direction more accurately. These would provide an opportunity to determine the structural health and extent of necessary retrofitting of URM buildings for minimizing seismic damages.

1.4 SCOPES

The AVTs for this research are carried out in several location of Dhaka city only with a specific equipment. However this test can be carried out with other available equipment manufactured in different countries of the world. The targeted URM buildings ranged in the height from 2.59m to 15.24m and in stories from one to five stories.

AVTs were carried out to determine the dynamic properties of URM buildings' structural systems. Collection of ambient vibration data was based on in-situ records, with highly sensitive dynamic sensors located at the top, mid and ground levels of an existing structure to capture with great accuracy the key trends of the manner the structure is vibrating. After instrumenting a single building, 24 hours data were collected as it was recorded in the data logger through tri-axial sensors provided with the seismic noise recorder. The MATLAB program was used to calculate Fast Fourier Transforms (FFT) of the obtained horizontal acceleration data. Then data were analyzed using resulted frequency spectrum. Peak picking (PP) method was used to identify the pre-dominant frequencies.

From the identified pre-dominant frequencies natural periods of the URM buildings were obtained. It is mentionable that there are several empirical formulae for calculating natural period of structures in the codes of various countries (for Bangladesh BNBC 1993). The masonry structures are included in the "others" structures category. All the natural periods obtained experimentally were compared with the structural period calculated by the formula given in BNBC. The differences were analyzed and discussed.

Later regression analyses were carried out by Microsoft (MS) Excel and Statistical Package for the Social Sciences (SPSS) 11.5 models to find some relations of structural periods of the URM buildings with different structural parameters such as total height of building, height of stories, total length of wall of structures in two principal directions, thickness of load bearing wall etc. of such buildings in Dhaka City using the experimental dynamic data acquired. The research results will assist in recommending an empirical formula for the structural period of URM building for Bangladesh.

In the entire study the variety of quality of materials, quality of workmanships or the age of structures were not considered. Research carried out purely on available AVT data, sorted out on the basis of few engineering judgment.

1.5 OUTLINE OF METHODOLOGY/EXPERIMENTAL DESIGN

The total experiment will be conducted on one RCC building and seventeen masonry buildings in Dhaka City. One RCC building is taken as a sample of the pilot project to verify the accuracy of the instrument by comparing the structural period obtained from the formula given in BNBC 1993 and the same obtained from the experiment. In order to conduct the entire research, the following methodology is proposed:

a. URM buildings are selected on random basis only keeping in mind that a number of buildings of different heights and stories remain within the total samples so that the objective of the research is achieved.

b. AVTs will be carried out to determine the dynamic properties of URM buildings' structural systems. Unlike forced vibration testing, the forces applied to the structure in ambient vibration testing are not controlled. The structure is assumed to be excited by wind, traffic and human activity.

c. The time history records of two principal axes of the building with the aim of determining the dynamic properties in two cardinal directions will be obtained.

d. Obtained data will be used to get the fundamental structural vibration frequencies from the frequency spectra using MATLAB. From this fundamental frequency fundamental period can be acquired.

e. Taking the fundamental or pre-dominant periods in cognizance, regression analysis will be carried out basing on the different parameters of the targeted URM buildings.

f. Obtained structural period from the study will be validated by comparing the same calculated from the formula given in BNBC 1993 and Draft BNBC 2010 (formula are given in details in Appendix A and B respectively).

g. The fundamental or pre-dominant periods of several URM buildings will be analyzed with their structural properties to obtain an empirical formula.

1.6 OVERVIEW OF ORGANIZATION OF THIS THESIS PAPER

The main effort of this research was to find out a relation of structural period of the URM buildings of Dhaka city with their different structural parameters. The research work conducted for achieving the stated objective is presented through several chapters of this thesis. There are five more chapters in this thesis excluding the current chapter. Brief discussions of those chapters are stated in the next page:

Chapter 2 (Literature Review): This chapter is dedicated to the review of past researches in the world. Details of vibration-based tests on URM buildings are discussed in this chapter. Effect of different structural and dynamic properties especially related with the structural period are described in this chapter.

Chapter 3 (Methodology): Experimental design and analytical methods are discussed here. Field test programs are described. The collected field data of selected URM buildings and important input parameters for MATLAB program followed by their resulted frequency spectra are highlighted. Theoretical aspects of the research and the regression analysis are presented and discussed in this chapter.

Chapter 4 (Ambient Vibration Measurements): Field data such as history and different structural parameters including the digital photographs of the selected URM buildings are provided. Information on the sub-soil characteristics of the selected URM buildings are presented in this chapter. Besides AVT methods are discussed here. Using dynamic properties as input to MATLAB software pre-dominant frequency is obtained for each URM building. Frequencies are converted into structural periods and their analysis are presented and discussed in this chapter.

Chapter 5 (Statistical Analysis): The structural period, height and total length of walls of structures are taken to determine a relation among these three variables as the basic variables input to SPSS. The initial objective of research data analysis process and steps through empirical model development was to select a model from each method and finally select one. The analyses performed by SPSS are discussed in separate two sections basing on the experimental structural period data of NS (principal) direction and EW (non-principal) direction.

Chapter 6 (Results and Discussions): Results of relations found out of different structural parameters with structural periods obtained through analysis are presented along with related discussions.

Chapter 7 (Conclusions and Recommendations): Findings of the research program and related discussions are presented in this chapter. This chapter also includes scopes for future researches with specific recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 GENERAL

The objective of this chapter is to analyze the past researches related to ambient vibrations of URM structures. In addition for drawing relevant aspects some AVTs on reinforced concrete (RC) structures are explored. Again considerable detail theoretical aspects are also discussed whenever felt appropriate keeping in view the main objectives of the research.

2.2 PAST RESEARCHES

There exists numerous research works on AVTs on different types of structures of RC, steel, masonry, timber etc. Expectedly lesser numbers of research works are available on URM structures in this aspect.

Structures are enduringly subjected to ambient vibrations due to ground ambient vibrations in a wide frequency range; atmosphere, i.e. wind, wave etc.; at low frequencies; internal sources (pedestrians, machines like lifts, air-conditioners) and traffics etc. with great amplitudes at well-defined frequencies.

Ambient vibration measurements by different sensing equipment give the actual dynamic behaviour of structures under small vibrations. This behaviour depends on structural properties such as geometry, material properties etc. However the dynamic behaviour is also affected by environmental parameters such as temperature, soil-structure interaction, by the participation of non-structural elements, etc. Clinton et al. (2006) revealed that the environmental parameters changed ±4% vibration frequency of the Millikan Library in California, USA.

Carder presented the beginning of the ambient and forced vibration tests of structures in 1936 by the U.S. Coast and Geodetic Survey (USCGS) for determining the fundamental periods of vibration for some high-rise buildings, and in 1937 for determining the fundamental periods of vibration of some bridges. After about 28 years, Crawford and Ward (1964) and Ward and Crawford (1966) revitalized the significance of this method showing that it can be used to identify the lowest frequencies and modal shapes of complete structures.

Grithiths and Klopp (1991) instrumented fourteen URM buildings to assess applicability of the simplified design formulae in Australian earthquake codes, AS 2121, and another in the draft of AS 1170.4 to low-rise-URM buildings. However, these formulae were based mostly on observations of the dynamic response of multi-storied steel and RC structures. For estimating structural period from AS 2121 which accounts for the plan dimension of the building, noticeably, became the best of the three code formulae considered in the study.

One of the major developments in seismic design over the past couple of decades has been increased emphasis on limit states design, now generally termed Performance Based

Engineering. The capacity spectrum approach, the N2 method and direct displacement-based design, these three techniques have now matured to the stage where seismic assessment of existing structures, or design of new structures can be carried out to ensure that particular deformation-based criteria are met. Priestley (2000) outlined and compared the three methods, and discussed them in the context of traditional force-based seismic design and earlier designs approaches which contained some elements of performance based design.

Ivanovic et al. (2000) conducted reviewed study by two detail ambient vibration surveys on a seven storied RC hotel building in Van Nuys, California, USA in the spring of 1994 after being damaged by the January 17th, 1994 Northridge earthquake. by simple analyses of the ambient noise data, the attempt to identify the highly localized damage was not successful. Study suggested very high spatial resolution of recording for the said purpose. It also revealed that loss of axial capacity of the damaged columns could be seen in the vertical response, but similar moderate or weak damage typically would not be noticed in AVTs.AVT and modal identification of a newly completed 15-storey office building in Tokyo was conducted by Zhang et al. (2002). Accurate damping estimation was conducted based on damping convergence with increasing frequency resolution of the Power Spectral Density (PSD) measurement. The identified modal frequencies and mode shapes were used for Finite Element (FE) model correlation and tuning. Modal parameters up to 9 modes has been achieved with respect to the final tuned FE model.

Balkaya and Kalkan (2003) analyzed a total of 80 different shear wall dominated RC buildings configurations by using three-dimensional FE modeling and proposed a set of new empirical equations for estimating fundamental periods. The results of the analyses demonstrate that given formulas including new parameters provide accurate predictions for the broad range of different architectural configurations, roof heights and shear-wall distributions, and may be used as an efficient tool for the implicit design of those structures.

A series of AVTs were conducted by Turek et al. (2003) on three low-rise unreinforced brick masonry buildings located in the Chinatown district of Vancouver, British Columbia, Canada. The tests were intended to accumulate primary information on the dynamic properties of the buildings. Measurements were taken on selected locations of each structure to identify their overall mode shapes, modal frequencies and modal damping. Besides, microtremor measurements were conducted near the buildings to determine the period of the site and evaluate the potential effects of soil-structure interaction, which could have a substantial effect on the seismic performance of the buildings during a severe earthquake. It was found that the site frequency for the Chinatown district was close to the range of the higher modes of vibration for the buildings measured, as shown in the AVT results. This raises the possibility of soil-structure interaction and should be addressed for retrofit design considerations. The dynamic response of the buildings during a severe earthquake could be significantly affected by soil-structure interaction effects.

The previously developed displacement based design (DBD) procedure for the seismic assessment of URM walls Griffith et al. (2004) to account for the response behaviour of the

URM building. The displacement based (DB) analyses indicated that only one wall developed sufficient out-of-plane displacement to cause wall instability and failure.

Searer and Freeman (2004) presented analysis of near-fault and non-near-fault earthquake records to show the applicability of the use of these minimum base shears for determination of drift and suggested modifications to current building codes.

Gentile and Saisi (2006) conducted AVTs on to assess the structural conditions of a masonry bell-tower, dating back to the XVII century and about 74 m high. It was characterized by the presence of major cracks on its western and eastern load-bearing walls. They found a good match between theoretical and experimental modal parameters for relatively low stiffness ratios in the most damaged regions of the tower. Moreover, the model identification, carried out by using two different methods, provided consistent structural parameters which are also in close agreement with the available characterization of the materials.

Magalhães et al. (2007) studied the accuracy provided by the identification of modal damping ratios by developing numerical simulations to generate artificial experimental data concerning both based on ambient and free vibration tests. This simulated data allowed the illustration of the influence of factors like non-proportional damping or the proximity of natural frequencies on the quality of the estimates.

The analytical solution of the equations of motion makes it possible to simulate the motion due to a weak to moderate earthquake and then the inter-storey drift knowing only the modal parameters (modal model). Michel et al. (2007) used the process to a 9-storey RC dwelling in Grenoble (France). They successfully compared the building motion for an artificial ground motion deduced from the model estimated using ambient vibrations and recorded in the building.

Wilson et al. (2008) conducted a series of modal tests on the third floor of timber diaphragm Nathan building typical of New Zealand historic URM construction located in Auckland’s Britomart Precinct. They found that the fundamental horizontal natural frequency reasonably matches the finite element model frequency.

Bourahla et al. (2008) presented a study on the renovation and required seismic upgrading of a 100 year old masonry infill (thick stone and brick masonry walls along its perimeter) steel frame (riveted steel trusses and columns) building located in the centre of Algiers. The structure was numerically simulated using 3D finite elements models (FEMs). The data, obtained from an extensive program of non-destructive and destructive tests on the constituent materials, were introduced into the numerical models and a series of AVTs together with modal analyses were performed to validate the mathematical models. A linear elastic analysis was carried out on the calibrated numerical model of the structure using the most recent elastic spectrum of the Algerian seismic code. Results of load combinations helped identify critical regions and seismic deficiencies. They proposed upgrade strategies and a solution for strengthening the structure on the basis of their findings.

Gilles and McClure (2008) conducted a research to expand global period database and create database specific to Montreal in Canada. Hancilar et al (2008) assessed the earthquake vulnerability of a four-storey unreinforced clay brick masonry historical building built in 1869 in Istanbul by the Schmidt hammer and ambient vibration tests. They proposed reinforced cement jacketing of the main load-carrying walls and application of fiber reinforced polymer (FRP) bands to the secondary walls as a solution for seismic rehabilitation/strengthening of the building.

Karim et al. (2008) presented the results of non-destructive forced vibration tests on a small scale URM house with a flexible timber diaphragm. Frequency modes matched between the FE model and experimental data, specifically for NS excitation. But, the frequency mode in the EW direction estimated by the FE model was found significantly greater than the experimental value.

The period of vibration is a fundamental parameter in the force-based design of structures as this parameter defines the spectral acceleration and thus the base shear force to which the building should be designed. Pinho and Crowley (2009)look critically at the way in which seismic design codes around the world have allowed the designer to estimate the period of vibration of RC buildings for use in both linear static and dynamic analysis.

Michel et al. (2009) tested two URM buildings with RC slabs, typical of Swiss construction between 1940 and 1960 located in Visp (Valais) using full-scale ambient vibrations. The comparison with a simplified DB approach and a numerical model showed important discrepancies: the first method underestimated the elastic periods leading to too small displacement capacity. The numerical model gives consistent period values but shows that the severe damage grade may be over-estimated in the proposed method. So, they proposed a coupling of the method and a mechanical method is necessary to obtain all the fragility curves.

Karim et al. (2009) presented the results of non-destructive forced vibration tests on a small-scale URM house. It was found that the basic dynamic properties (natural frequency and mode shapes) and the force path of the as-built structure were considerably affected after applying the plywood retrofit.

Michel et al. (2010) identified the vulnerability of different buildings classes studying 21 typical buildings in the city of Visp (Valais) Switzerland, including ambient vibration tests, and analytical models computation. Fragility curves for URM structures with rigid slabs are proposed according to a newly developed method.

Moaveni et al. (2010) studied a full-scale seven-story RC building section was tested on the UCSD-NEES shake table during the period October 2005–January 2006. Modal parameters (natural frequencies, damping ratios and mode shapes) of the building were identified at different damage levels based on the response of the building to ambient as well as low-amplitude white noise base excitations, measured using DC coupled accelerometers.

Hachen et al. (2010) carried out an analysis of current code requirements and common practices in several countries, including the United States, China, the European Union, New Zealand and Taiwan. They compared the current code requirements and practices in these regions, and investigate similarities and differences, and opportunities for harmonization.

Haritos (2010) sited several examples of application of vibration-based dynamic testing drawn from his experience to illustrate the utility of the approaches adopted concentrating on (but not restricted to) bridge engineering applications.

Michel et al. (2010) found a value of 2/3 of the ambient vibration frequency to be relevant for the earthquake engineering assessment a URM building. However, the effect of soil–structure interaction also affected these parameters. Hence, an analytical methodology is proposed to derive first the fixed-base frequency before using these results.

Stempniewski (2011) presented outcomes of an experimental test campaign for the validation of the performance of a seismic reinforcing strategy of a two-storey stone masonry buildings based on the full covering of the building by means of an innovative multifunctional technical textile. This “Composite Seismic Wallpaper” solution is made of glass and polymeric fibres in a multi-axial textile structure featuring embedded fibre optics sensors which is connected to the substrate using a special cementitius matrix.

Hancilar et al. (2011) described the earthquake performance assessment of two historical URM buildings located in Istanbul, Turkey exposed to an Mw=7+ earthquake expected to hit the city and proposes solutions for their structural rehabilitation and/or strengthening. Dynamic properties (fundamental vibration periods) of the buildings were measured by ambient vibration tests.

During the years from 2001 to 2011, the Romanian National Center for Earthquake Engineering and Vibration (RNCEEV) performed many AVTs results of some of these investigations and to show how these could be used in the technical assessments of existing structures.

Deutsch (2011) assessed of the damage to a 9-storey precast concrete hotel and a 5-story precast concrete parking garage resulting from magnitude 6.3 earthquake in Christchurch, New Zealand on February 22, 2011. Crack maps for damage assessment and tabulated values of fundamental periods and damping obtained using the acceleration data from earthquake events and ambient vibrations for both structures.

Taleb et al. (2012) identified and evaluated of the seismic properties of an old three storied URM building with irregular shape located in Algiers (Algeria) by ambient and forced vibration tests. The building was rehabilitated by hysteretic dampers system. Ambient vibrations were measured before and after rehabilitation.

Anastasia and Athanasios (2013) carried out a survey on post-earthquake scenario in an extended region of Attica in Greek wherein the performance levels are defined according to the physical description of the seismic damage and, as well, in terms of structural and economical damage index. In their research the fundamental periods of vibration for RC buildings only are calculated for several reinforced concrete building types according to existing simple relationships. They also drew on the parameters (height, structural type, etc.) that influence the seismic response and the development of damage based on the wide database.

Sevim et al. (2013) presented the structural identification of concrete arch dams using ambient vibration tests which is one of the modal testing methods. There was a good agreement between the results for all measurements. Though, the theoretical fundamental frequency of Berke Arch Dam is a little different from the experimental.

Boutin et al. (2013) presented the dynamic characteristics for school buildings in Quebec based on ambient vibration measurements. It was part of an initiative to establish a reliable database on the seismic vulnerability and dynamic characteristics of existing URM buildings. It contributed to the development of empirical formulas for the prediction of fundamental vibration periods to be used by engineers involved in URM seismic rehabilitation projects.

Beskhyroun et al. (2013) investigated the dynamic behavior (modal parameters utilizing a range of methods in both the frequency and time domain) of a full scale 13-story RC office building in the University of Auckland under forced vibration, ambient vibration and distal earthquake excitation. They found consistent results for modal parameters obtained from various methods.

Min et al. (2013) investigated dynamic characteristics of a historic wooden structure by ambient vibration testing, presenting a novel estimation methodology of story stiffness for the purpose of vibration-based structural health monitoring. Using the identified natural frequencies, the eigenvalue problem is efficiently solved and uniquely yields story stiffness.

The Egyptian code provisions for building seismic design adopt the traditional approach of equivalent static load method as the main method for evaluating seismic actions and recommend the response spectrum method for non-symmetrical buildings. Raheem (2013) evaluated the Egyptian code provisions for the seismic design of moment-resistant frame multi-storey building through using non-linear time history analysis. The analysis procedures are evaluated for their ability to predict deformation demands in terms of inter-storey drifts, potential failure mechanisms and storey shear force demands. The results of the analysis of the different approaches are used to evaluate the advantages, limitations, and ease of application of each approach for seismic analysis.

Omenzetter et al. (2013) studied four different bridges (a two-span cable-stayed pedestrian bridge, a two-span concrete motorway bridge, an 11-span post-tensioned concrete motorway off-ramp, and a major 12-span post-tensioned concrete motorway viaduct) using ambient excitation (e.g. vehicular traffic) and/or forcing provided by shakers. Computer models of the bridges were calibrated against experimental data using several model updating approaches. They proposed a novel optimization method for updating of structural models.

Oyarzo-Vera et al. (2014) determined the spatial distribution of damage, i.e. modal frequency variation and modal assurance criteria of a dynamically loaded URM house model using eccentric-mass shakers, with structural damage initiated by increasing the amplitude of the shaker load applied. They concluded based on the information collected for the individual walls, a rough identification of the spatial distribution of damage damaged) can be achieved with acceptable levels of reliability.

Simkin et al. (2014) collected data from six buildings in the Wellington CBD instrumented during the July 21, 2013, MW 6.5 Cook Strait earthquakes and determined modal characteristics with a high level of accuracy and confidence. The earthquake response measurements were effective in determining the fundamental frequencies and mode shapes of each building, which is traditionally regarded as the most important mode in the seismic design of engineered structures.

Walsh et al. (2014) investigated a new damage detection method based on the change in the first vertical mode extracted from the transverse direction of a prestress RC bridge. The mode was determined through application of modal curve fitting to frequency response functions (FRFs) using vertical response data obtained in the direction perpendicular to the bridge's longitudinal axis. Both local and global damage in the bridge was revealed having a localized effect on the bridge response. Moreover, damage is revealed in such a way that it enables differentiation of the damage types. To establish the effectiveness of the method, modal parameters were extracted from acceleration data obtained from a FEM of a full bridge. Analysis of the modal parameters showed that the proposed approach could not only detect both type of damages, but could also differentiate between damage types using only one mode shape.

Majumder et al. (2014) presented a simple but robust damage detection methodology to determine the locations and amount of damages from changes in modal parameters (such as natural frequencies and mode shapes) in steel cantilever beam structures using continuous ant colony optimization algorithm.

Kechidi et al. (2014) presented an overview of the experimental and analytical studies performed on the structure made up by two principal RC cores of Bab Ezzouar, Algiers of Algeria, is presented. Series of ambient vibrations were conducted to determine the dynamic characteristics of the building, namely the lateral and torsional fundamental frequencies as well as the corresponding damping ratios. A good agreement was reached after tuning the model by integrating certain non-structural elements.

2.3 Conclusion

From the above indicated literature review it can be ascertained that most of the researcher performed basically two techniques to study the dynamic characteristics of different types of structures basing on their construction materials i.e. RCC, URM buildings with RC slabs or timber diaphragm, steel, wood etc. Structures range from model of section of wall and building, existing low to high rise buildings, bridges, dam, tower, chimney etc. For the vibration-based test diverse kinds of instruments were used.

Many of them worked for determining the fundamental periods of structures. Some studied to assess the structural conditions and later suggested the retrofitting or renovation required for the seismic upgrading of the structure. Some toiled on different damage levels based on the response of the building to ambient vibrations. Again some took endeavors to assess the dynamic characteristics and damage pattern during the occurrence of real earthquake. Few tried to detect the locations and amount of damages of structures from changes in modal parameters. Few tried to find out structural model updating approaches with optimization method. Many used basically FEM for analyzing structures and models.

Very few worked to assess applicability of the simplified design formulae like the assessment of Australian earthquake codes. Few others analyzed the codes for determining fundamental period of RC structures. A study was found to develop empirical formulas for the prediction of fundamental vibration periods to be used by engineers involved in URM seismic rehabilitation projects in Canada. However none else found to study on the existing codes for determining fundamental period of URM structures.

All the researches related to the study of the dynamic characteristics of structures were conducted outside the Bangladesh with different aim, in different environment and by different construction materials, codes, standards and practices. Considering the above fact it was felt necessary a study should be carried out on the considerations of Bangladesh, Dhaka city in particular as it is the capital and the most populous city with many URM constructions.

This study used the ambient vibrations data to identify the pre-dominant frequencies of several URM buildings in a number of locations of Dhaka City with a view to determining the natural structural periods of those buildings. Later took an endeavor to innovate an equation for finding out structural periods of low-rise URM buildings from the structural parameters of those low-rise URM buildings.

CHAPTER THREE

METHODOLOGY

3.1 GENERAL

The purpose of this chapter is to highlight the experimental sequences that were followed to conduct the research. As such this chapter describes the method or the steps followed in a logical order so that the whole research work can be consolidated appropriately. An endeavor has been taken to arrange the study work in an orderly manner which will assist in the attainment of the aim and objectives of the research.

Field test programs and computer-based analysis using softwares are illustrated in this chapter. Test locations for the research including field and laboratory test procedures are described here. Structural dimension such as height, width, length of building, thickness of wall, thickness and type of slab, type and materials of masonry were collected directly from the field. Besides ambient vibrations of all targeted URM buildings were taken in-situ. Acceleration data of each URM buildings were used to identify the pre-dominant frequency and natural periods of the URM buildings.

3.2 OUTLINE OF THE METHODOLOGY

In short the methodology mentioned above is presented below by a flow chart for better comprehension. It is worth mentionable that the entire methodology was applied on an 11-storied RCC framed structure with masonry wall infill as a pilot case study to verify the precision of the instrument by comparing the structural period obtained from the formula given in BNBC 1993 and the same obtained from the experiment.

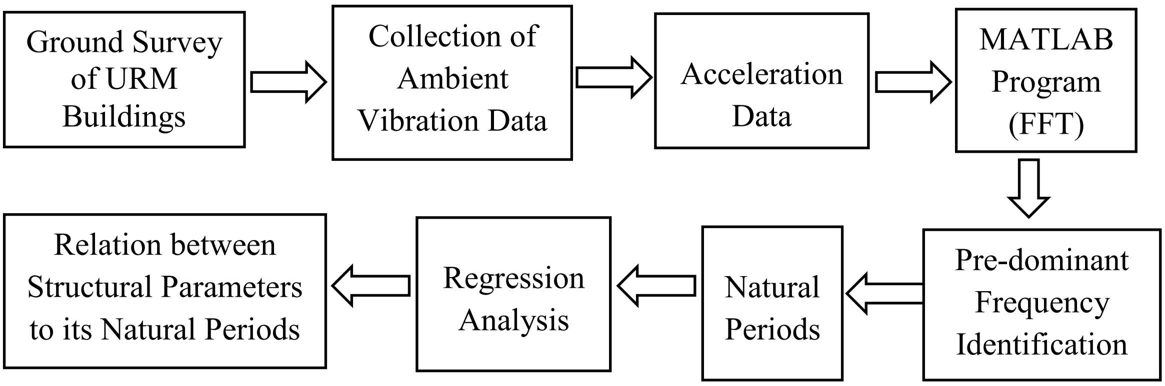


Figure 3.1: Flow Chart of Research Methodology

3.3 SELECTION OF STUDY AREA

Keeping in view the objective of the research Dhaka, the Capital City of Bangladesh was selected to be the study area. The main reason behind it is the existence of different types of URM structures in this city. Field data were collected from four separate sites of the city as mentioned in Table 3.1.These sites are shown by a city map in Fig. 3.2 and their location details are given in Table 3.1. These locations were selected based on the importance of the areas. Three selected sites out of all are located in the northern part of the Dhaka city towards which the capital city is expanding rapidly. The other site is at the south near the old city centre and the Buriganga River. The sites are designated as location 1 to 4 for the easy assimilations in subsequent paragraphs.

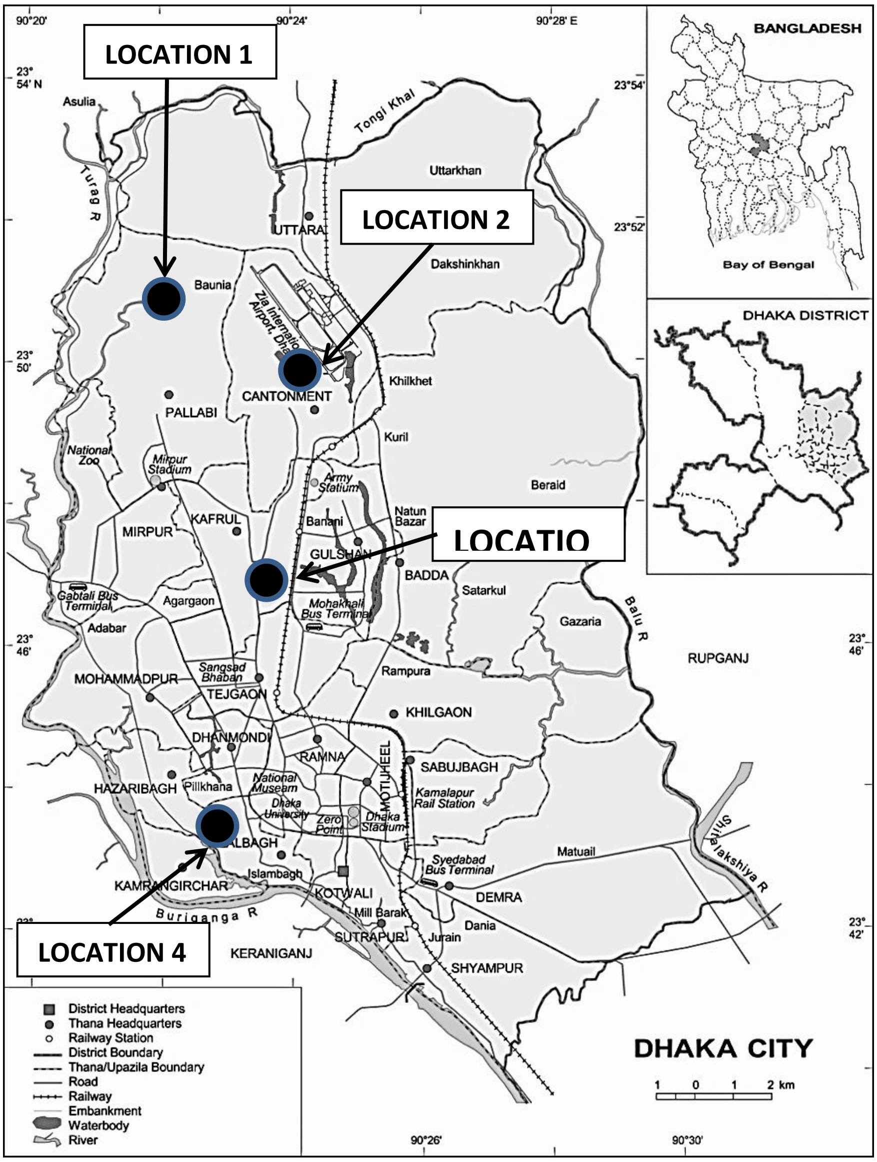


Figure 3.2: Map showing the selected areas of Dhaka city for the research

Table 3.1: Selected Locations of Dhaka City for the Research

LOCATION CODE	LOCATION NAME	LATITUDE	LONGITUDE
Location - 1	KURMITOLA (Balurghat)	$23^0$83′02.1″	$90^0$40′66.2″
Location - 2	TEJGAON	$23^0$78′19.7″	$90^0$40′26.8″
Location - 3	MIRPUR CANTONMENT	$23^0$83′82.7″	$90^0$35′97.6″
Location - 4	PALASHI (BUET Teachers' Residential Area)	$23^0$72′17.1″	$90^0$38′97.3″

Location - 1 is about 5 km away from both the location - 2 and location - 3. Again location - 4 is about 7.5 km away from location - 3.

3.4 TEST PROCEDURES

The total study is conducted on one RCC building and seventeen masonry buildings in Dhaka City.

3.4.1 Ground Survey of the URM Buildings

First, a precise field survey of the building configuration was carried out for each low-rise URM building. The survey was mainly focused on identifying structural parameters such as type, size and shape, height, type of foundation, slab type, clear distances from surrounding structures etc. and basic information of the building like year of construction, number of stories, any change or renovation done so far, any addition to or vertical extension of the structure etc. The detail analysis covered the determination of plinth area (length x width), but for irregular plans approximate plinth area basing on the average width and/or length estimated.

3.4.2 Collection of Ambient Vibration Data

The Earth’s surface is in a state of almost incessant agitation. This motion provides the low amplitude, irregular wave pattern, known as “seismic noise. The source of the seismic noise can be categorized into two major types: those that result from human’s activities (cultural noise) and those that occur naturally (microseism) [Vlad and Vlad (2011)]. The term “cultural noise” is used to describe any seismic noise associated with man or man-made machinery: operations of elevators, air-conditioners, power plants, factories, trains and vehicle on highway, and pedestrian etc. Natural sources are wind, waves etc. Ambient vibration can be from sources mentioned above and/or micro-seismic tremors which cannot be controlled but instead considered as a stationary random process. Accordingly, the response data from the structure alone can be used to assess the dynamic parameters. However cultural noises can be avoided in some particular cases.

AVTs were carried out to determine the dynamic properties of URM buildings' structural systems. Unlike forced vibration testing, the forces applied to the structure in ambient vibration testing are not controlled. Collection of ambient vibration data was based on in-situ records, with highly sensitive dynamic sensors located at the top, mid and ground levels of an existing structure to capture with great accuracy the key trends of the manner the structure is vibrating.

After instrumenting a single building, 24 hours data were collected as it was recorded in the data logger through tri-axial sensors provided with the seismic noise recorder. All data were transferred into a laptop directly using USB ports. The time history records of two principal axes of the building with the aim of determining the dynamic properties in two cardinal directions were obtained.

3.4.3 Acceleration Data of Ambient Vibrations

Eqwave 3.4 software was used to open all recorded data and to save all in MS text files. Only acceleration data were separately copied into MS Excel files for further use in MATLAB programs.

3.4.4 MATLAB Program

The time history plot of ambient vibrations does not resemble a periodic pattern. Thus the MATLAB was used to calculate Fast Fourier Transforms (FFT) of the obtained horizontal acceleration data. Then data were analyzed using resulted frequency spectrum. In the frequency spectrum the plot of Fourier amplitude (energy) versus structural vibration frequencies are clearly presented.

Past research and experience has shown that URM does not perform well beyond its elastic limit and so it is normally designed to remain elastic. It is anticipated that the results of the small amplitude vibration tests will be applicable for most of the elastic range of behaviour of URM structures (Griffiths and Klopp, 1991).

3.4.5 Pre-Dominant Frequency Identification

The easiest way to acquire modal information from ambient vibration recordings is to assess their spectra. The research reckons the frequency spectrum, and then, the Fourier Transforms of these. The peaks in the spectra can be either due to ambient loading, internal sources or structural modes. Very sharp peaks are neglected since they represented high noises.

The conventional approach to estimate the modal parameters of a structure is often called PP method after its basic step i.e. the identification of the resonant frequencies as the peaks. The PP technique leads to reliable results provided that the basic assumptions of low damping and well-separated modes are satisfied. The drawbacks of the method are related to the difficulties in identifying closely spaced modes and damping ratios (Binda et al., 1995).

3.4.6 Natural Periods

From the fundamental frequency (f) fundamental period (T) can be simply acquired as from following formula:

$$T = 1/f \qquad (5)$$

3.4.7 Regression Analysis

Taking the fundamental or pre-dominant periods in cognizance, initially MS Excel based regression analysis are carried out basing on the different parameters of the targeted URM buildings. Later statistical analysis through different regression analyses with various methods by SPSS 11.5 software are performed to get the best suited relationship between structural parameters to its natural periods. Regression analyses with various methods by SPSS 11.5 are elaborated in the following two paragraphs.

3.4.8 Statistical Analysis and Model Development by SPSS 11.5

3.4.8.1 General

This part of the analyses involved the use of relevant statistical procedures such as correlation coefficients, regression analysis using SPSS 11.5. It also involves testing the significances of the statistical values to support the experimental results on the basis of the data obtained by field survey. The relative importance of the major structural features that affect the structural periods of URM buildings in Dhaka city, their interdependency and test of significance were also tested.

This section amasses all the theoretical aspects of multivariate linear regressions (MLR) analysis by SPSS 11.5 in a nutshell. It includes all the necessary assumptions and statistical tests to support the justification of the models from the statistical point of view. Besides practical significance are considered as to justify the end result on the basis of reality. It also shows the steps and process of data analysis using SPSS 11.5 to construct a final empirical model.

The development of the model was based on the analysis of experimental results and MS Excel based regression analysis. Experimental results were achieved on the basis of the data obtained by field survey that was carried out on ten URM buildings. The analyses show different types of relations separately between the structural periods and the height of structures and between the structural periods and the total length of walls of structures. All the three numerical variables of respective building were put into SPSS 11.5 and regression analysis was done base upon which the model was automatically generated by the software.

3.4.8.2Regression Analysis

Regression analysis is the statistical method which is the main tool of the SPSS 11.5 for reaching to a decision. It is concerned with the study of the dependence of a variable (DV) Y, on a set of independent variables (IV) $X_1, X_2 \ldots, X_k$ with the view to:

(a) Formulating a mathematical model to represent the statistical relation;

(b) Estimating the model parameters and;

(c) Using the model to make inferences about the DV that is, to predict the DV or the primary variable, describe the behaviour of the primary variable, (Y), based on the IV the influencing variable, (X_i).

(d) The primary variable, (Y), measures the effect or response resulting from a certain combination of factors under specified conditions. It establishes the relationship between variables and the effect of a change in one variable on the other.

3.4.8.3 Simple Regression Model

This model has only one predictor variable and is the simplest regression relationin which the regression function is a linear function of the predictor variable. Linear regression requires a linear model. The simple linear regression model is given by the equation;

$$Y_i = \beta_o + \beta_1 X_i + \varepsilon_i \qquad (6)$$

Where, Y_i- is the value of the response variable in the i^{th} observation.

X_i - is the known value of the predictor variable in the i^{th} observation.

ε_i- is the random error term or the “stochastic disturbance” which caters for the errors due to chance and neglected factors which are assumed not important.

β_1 - gives the intercept on y-axis, and are the regression parameters.

β_o - measures the slope of the linear model.

3.4.8.4 MLR: An Overview

MLR are a regression that involves more than one independent variable. It is a straight forward extension of simple linear regression and is one of the most widely used techniques. The purpose of multiple regressions is to predict a single variable from one or more IVs. Multiple regressions with many predictor variables are an extension of linear regression with two predictor variables. A linear transformation of the X variables is done so that the sum of squared deviations of the observed and predicted Y is a minimum. The computations become more or more complex based on the number of IVs, however, because the interrelationships among all the variables must be taken into account in the weights assigned to the variables.

The interpretation of the results of a multiple regression analysis is also the prediction of Y is accomplished by the following equation:

$$Y_i = \beta_1 + \beta_2 X_{2k} + \beta_3 X_{3k} + \cdots\cdots\cdots + \beta_k X_{ij} + \varepsilon_i \qquad (7)$$

Where,

Y_i - is the value of the response variable in the ith observation.

X_{ij}- are the values of i^{th} observation of the j^{th} independent variable;

β_1 ..β_k - are the population regression coefficients which indicate the effect of a given X on Y

β_0 - is the intercept which indicates the expected value of Y when all of the X are Zero;

$\mathcal{E}i$ -is the i^{th} observation of the disturbance or stochastic (error) term i =1,2...n, j =1, 2,…, k.

Multiple regressions also allow one to determine the overall fit (variance explained) of the model and the relative contribution of each of the predictors to the total variance explained.

3.4.8.5 Important Definitions and Clarifications:

3.4.8.5.1 Descriptive Statistics

Descriptive statistics allow a researcher to describe or summarize their data. For example, descriptive statistics for a study using subjects might include the sample size, mean, median, mode, standard error, Skewness, Kurtosis etc.

3.4.8.5.2 Inferential Statistics

Inferential statistics are usually the most important part of a dissertation's statistical analysis. These statistics are used to allow a researcher to make statistical inferences that draw conclusions about the study objectives based upon the sample data. There are two main types of Inferential Statistics, estimation and hypothesis testing.

3.4.8.5.3 Estimation Statistics

Estimation statistics are used to make estimates about population values based on sample data. There are two types of estimation statistics, confidence intervals and parameter estimation.

3.4.8.5.4 Confidence Intervals

These statistics establish a range that has a known probability of capturing the true population value. There are many different confidence interval formulas, for example for estimating the population mean, or the percentage of a characteristic in the population.

3.4.8.5.5 Parameter Estimation

Parameter estimation statistics allow one to make inferences about how well a particular model might describe the relationship between variables. Examples of parameter estimation statistics include a linear regression model, a logistic regression model, and the Cox regression model.

3.4.8.5.6 Hypothesis Testing Statistics

Hypothesis testing statistics allow one to use Statistical Data Analysis to make statistical inferences about whether or not the data we gathered support a particular hypothesis. There are many hypothesis testing procedures. Some of these are the T-Test, F-Test etc. "T" and "F" test can be tested by level of significance also.

3.4.8.6 Assumptions of MLR Analysis and Relevant Tests

When one choose to analyze any set of data using multiple regression, part of the process involves checking to make sure that the data to analyze can actually be analyzed using multiple regression. It is needed to do this because it is only appropriate to use multiple regressions if the data "passes" few assumptions that are required for multiple regressions to give a suitable result.

Before introducing to these assumptions, no one to be surprised if, when analyzing the data using SPSS Statistics, one or more of these assumptions is violated (i.e., not met). This is not uncommon when working with real-world data rather than textbook examples, which often only show as how to carry out multiple regressions when everything is ideal. Even when the data fails certain assumptions, there is often a solution to overcome this. The assumptions are followings:

a. Assumption No. 1: Linear regression model. The regression model is linear in parameter (coefficient) not necessarily linear in variables. Basing on this assumption the model is set linear from the beginning.

b. Assumption No. 2: DV should be measured on a continuous scale (i.e., it is either an interval or ratio variable).

c. Assumption No. 3: There have to be two or more IVs, which can be either continuous (i.e., an interval or ratio variable) or categorical (i.e., an ordinal or nominal variable). The independent variables may be dichotomous, trichotomous or even more.

d. Assumption No. 4: The data must not show multi-collinearity, which occurs when we have two or more IVs that are highly correlated with each other. This leads to high R^2 value but standard error also become high, thereby creating insignificant "t" ratio with high level of significance which is not desirable. This assumption can be checked by Tolerance or

VIF values. The guidelines are the VIF and Tolerance value should be maximum 10 and minimum 0.2 respectively. If these conditions are not met, it can be solved by three ways; these are increasing the sample size, transformation of variables or removing a variable.

e. Assumption No. 5: The data needs to show homoscedasticity, which is where the variances along the line of best fit remain similar as one move along the line. To check this assumption, one need to plot the standardized residuals against the un-standardized predicted values during the analysis of data. In this plot the points should not have any systematic pattern; rather it should be random over the graph.

f. Assumption No. 6: There should be no significant outliers, high leverage points or highly influential points. Outliers, leverage and influential points are different terms used to represent observations in the data set that are in some way unusual to perform a multiple regression analysis. These different classifications of unusual points reflect the different impact having on the regression line. All these points can have a very negative effect on the regression equation that is used to predict the value of the DV based on the IVs. This can change the output that SPSS Statistics produces and reduce the predictive accuracy of results as well as the statistical significance. Fortunately, when using SPSS Statistics to run multiple regressions on the data, one can detect possible outliers by "Box and Whiskers Plot" and other techniques and check for influential points in SPSS Statistics using a measure of influence known as Cook's Distance, before presenting some practical approaches in SPSS Statistics to deal with any influential points. Box plot will be discussed in this chapter under separate sub heading.

g. Assumption No. 7: Finally, check is needed that the residuals (errors) are not serially correlated or have autocorrelation, approximately normally distributed. This can be easily checked using the Durbin-Watson statistic, which is a simple test to run using SPSS Statistics. Two more common methods to check this assumption include using: (a) a histogram (with a superimposed normal curve) and a Normal P-P Plot; or (b) a Normal Q-Q Plot of the residuals. This study will limit to Durbin Watson (DW) Test. If the value of DW is close to 0 (zero), it indicates strong positive serial correlation and if same is close to 4 (four), it indicates strong negative serial correlation. As a guideline statisticians use the value to be within the range of 1.5 to 2.5, which means no autocorrelation exist.

3.4.8.7 Note to SPSS

SPSS-17 formulates the linear model by selecting linear regression model and first three assumptions are met automatically. In output file if level of significance becomes less than 0.05 for "F" and "t" statistics then the 5th and 6th assumptions are met automatically. Assumptions 6 is need to be checked by Box and Whisker Plots for each variables formulate the models and finally 7th assumptions can be checked from output of residual plot.

There are more three assumptions which are also met in the process of data collecting, sorting and analysis. These are:

a. Assumption No. 8: Number of observations must be greater than number of parameter.

b. Assumption No. 9: The value of independent should be stochastic.

c. Assumption No. 10: The regression model is correctly specified.

3.4.8.8 Decision Rules for Development of Model

Before development of model, few checks like Descriptive Statistics, Correlation Matrix, Curve Estimation (Curve Fit), histogram (for normal distribution) and Boxplot (for outliers) are carried out.

3.4.8.9 Descriptive Statistics:

Descriptive Statistics gives a clear idea about the quality of data and also its reliability. For this study ten data from each variable are obtained. So N=10 mean during analysis all 10 numbers of data are considered and valid. From Range, Minimum and Maximum value we get the reliability whether the data seem to be of normal value. Standard Error, Standard Deviation and Variance give us the idea about dispersion of data. Skewness measures the asymmetry and gives an idea about mean, mode and median's direction. On the other hand, Kurtosis measures the peak of the curve. Skewness and Kurtosis measure the shape of the curve. Interpretation of skewness and kurtosis are as under:

Skewness quantifies how symmetrical the distribution is.

A symmetrical distribution has a skewness of 0 (zero).

Positive value indicates a positive skewness i.e., an asymmetrical distribution with a long tail to the right.

Negative value indicates a negative skewness i.e., an asymmetrical distribution with a long tail to the left.

The skewness is unit less.

Any threshold or rule of thumb is arbitrary, but here is one: If the skewness is greater than 1.0 (or less than -1.0), the skewness is substantial and the distribution is far from symmetrical.

Kurtosis quantifies whether the shape of the data distribution matches the Gaussian distribution.

A Gaussian distribution has a kurtosis of 0.

A flatter distribution has a negative kurtosis

A distribution more peaked than a Gaussian distribution has a positive kurtosis.

Kurtosis has no units.

The value that Prism reports is sometimes called the excess kurtosis since the expected kurtosis for a Gaussian distribution is 0.0.

An alternative definition of kurtosis is computed by adding 3 to the value reported by Prism. With this definition, a Gaussian distribution is expected to have a kurtosis of 3.0.

Anybody interested in data may take an overview whether the data set can be used in other model.

3.4.8.10 Correlation Matrix:

This matrix is displays Pearson's Correlation Coefficient between two variables. In the study there are only three variables including dependent one. It shows percentage (5% to 10% level) of significance by two tailed test. "**" sign denotes that the correlation is significant at the 0.01 level (2-tailed) of significance and "*" sign denotes the correlation is significant at the 0.05 level (2-tailed) of significance. From this matrix it can also be manually chosen which variable will generate better model with high coefficient of determination (R^2) value i.e., Goodness of Fit. It also guides in advance the possibilities of multi-collinearity.

3.4.8.11 Curve Estimation:

SPSS can generate 11 types of curves from bivariate regression. These are as follows:

(1) Linear $E(Y_t)=\beta_0+\beta_1 t$
(2) Logarithmic $E(Y_t)= \beta_0+ \beta_1 ln(t)$
(3) Inverse $E(Y_t)= \beta_0+ \beta_1/t$
(4) Quadratic $E(Y_t)= \beta_0+ \beta_1 t+\beta_2 t_2$
(5) Cubic $E(Y_t)= \beta_0+ \beta_1 t+\beta_2 t_2+\beta_3 t_3$
(6) Compound $E(Y_t)= \beta_0\beta t_1$
(7) Power $E(Y_t)= \beta_0 t\ \beta_1$
(8) S $E(Y_t)=exp\ (\beta_0+\beta_1/t)$
(9) Growth $E(Y_t)=exp\ (\beta_0+ \beta_1 t)$
(10) Exponential $E(Y_t)= \beta_0 e\ \beta_1 t$
(11) Logistic $E(Y_t)=(1u+ \beta_0\beta t_1)-1$

All the IVs were tested as function of DV. The various R^2, "F" statistics for each curve and corresponding level of significance with probable coefficient are used to predict the best curve for each IV with DV. In the process if need be transformation decision will be easier in case of less value of R^2.

3.4.8.12 Histogram and Box Plot:

Histograms measure whether the distributions normal or not and Boxplots find the outliers. In descriptive statistics, a box plot is a convenient way of graphically depicting groups of numerical data through their quartiles. Box plots may also have lines extending vertically from the boxes (whiskers) indicating variability outside the upper and lower quartiles, hence the terms box-and-whisker plot and box-and-whisker diagram. Outliers may be plotted as individual points. Box plots are non-parametric: they display variation in samples of a statistical population without making any assumptions of the underlying statistical distribution.

The spacing between the different parts of the box indicates the degree of dispersion (spread) and skewness in the data, and show outliers. In addition to the points, it allow one to visually estimate various L-estimators, notably the inter-quartile range, mid hinge, range, mid-range, and tri mean. Box plots can be drawn either horizontally or vertically. Any data not included between the whiskers is plotted as an outlier with a dot, small circle, or star, but occasionally this is not done. Box plot shows the first (bottom of box) and third (top of box) quartiles, the median (the horizontal line in the box), the range (excluding outliers and extreme scores), the "whiskers" or lines that extend from the box show the range, outliers (a circle represents each outlier the number next to the outlier is the observation number).

An outlier is defined as a score that is between 1.5 and 3 box lengths away from the upper or lower edge of the box (remember the box represents the middle 50 percent of the scores). An extreme score is defined as a score that is greater than 3 box lengths away from the upper or lower edge of the box. Individual points above or below 3 box heights are considered extreme outliers, and are marked with asterisks points for individuals that fall above or below 1.5 to 3.0 box heights from the top or bottom of the filled box are considered outliers.

3.4.8.13 Data Sorting and Finalizing

Out of total 17 data of each variable extreme outliers were removed after the analysis of MS Excel plotting. The separate box plot shows these data to be valid. This data is the basis for the analysis.

3.4.8.14 Decision Rule for Model Development

The model was interpreted based on the following statistical parameters to investigate the relationship between the IVs and the DV (structural period). Statistical tests were conducted to confirm the reliability of output. Then the practical significance was observed for accepting the model. Till such time numbers of iteration was conducted. The decision was taken at every level by statistical inference and also practical significance. These are described below in short:

Firstly: From the "Model Summary" the model will be accepted if

Large Coefficient of determination-square, R^2 (Goodness of Fit).
Large Adjusted R^2 with minimum decrease in value with R^2.
Minimum Standard Error (SE).

Secondly: From the "ANOVA" table will be accepted if

Overall model is significant at 5% level of significance which is tested by "F" statistics from SPSS output.

Thirdly: From the "Coefficient" table will be accepted if

All the variables in the model must be individually statistical significant at 5% of level by "T" statistics and significance value from SPSS output.

Finally: practical significance of each coefficient from "Coefficient Table" will be checked. The decision rule is that, if the algebraic sign is same in the coefficient as it is in practice: the individual variable will be considered, if otherwise the variable will be dropped till the condition is met. These four steps will continue till formulation of final model. If in the process value of R^2 reduce substantially or SE increase much transformation or non-linear model will be considered.

3.4.8.15 Data Processing and Analysis

The final empirical model will strictly depend on input data. In SPSS 11.5 there are four methods of linear regression analysis.

3.4.8.16 Methods of Linear Regression for the Model

Enter Method: This method does not eliminate any variable rather show probable coefficients (parameter), B, against all IV in selected with individual "T" statistics and level of significance. This method gives an idea about all the IV and its contribution to the model. If sig value for each IV is not less than or equal to 0.050 (5%) then the model will be rejected.

Stepwise Regression: This method carry out regression by taking IV one after another considering "F" statistics sig at 5% to 10% of sig. This method enters a variable if probability of "F" statistics is less than or equal to 0.5 and remove if the same crosses 0.10. The method works with all variables and stops after checking all and gives the best model with the variables whose "T" stat is at minimum 10% level of sig. It gives summary of the all models it considered to be sig.

Backward Elimination: This method carries out regression by taking all the IV in the first go and removes one after another if "F" statistics is not sig and P value crosses 0.10. This process continues till it gets a model with all the variables to be statistically significance at minimum 10% level. This method also gives summary of the all models it considered be it statically significant or not.

Forward Selection: This method is somewhat like stepwise regression except it does not enter new variables if "F" statistics sig is more than 5%.

3.4.8.17 Mode of Analysis for Final Model

Initially, regression by all four methods will be performed. If a single method shows better result in the process, that method will be continued till the formulation of final model. If more than one models from various methods show potentiality of being selected, the model with maximum R2 and minimum SE provided the P value is less than or equal to 0.050 will be nominated as the final one. All the methods produce similar table and figure like "Model Summary", "ANOVA", "Coefficient", "Excluded Variable", "Residual Statistics" etc. These are the tools to selection of the final options which entirely depends on the researcher. As the study has only three variables with ten data each, during iteration till formulation of final model, all the details except "Model Summary", "ANOVA" and "Coefficient" will be avoided.

3.4.8.18 Test of Significance

In this chapter each model will be explained basically for the test of significance under three heading. These are "The Model Summary", "ANOVA" and "Coefficient". If model is significant in all three tests, they will be tested for the practical significance. If one of the models qualifies in all the tests, that model will be accepted for the study.

For the study as it considered all practically verified numerical data all the above are assumptions are not tested separately. However in the process of modeling many are tested appropriately.

3.4.9 Relation between Structural Parameters to its Natural Periods

Identified structural periods T (sec) from the study are validated by comparing the same approximated from the equation (1) as mentioned earlier taken from the BNBC 1993. Again those identified structural periods T (sec) from the study are validated by comparing the same approximated from the equation (2) as mentioned earlier taken from the Draft BNBC 2015.

The fundamental or natural periods of all low-rise URM buildings under study are analyzed thoroughly. Results of all the regression analyses are compared logically to obtain a relationship between fundamental or natural periods and couple of structural properties through an empirical formula.

CHAPTER FOUR

AMBIENT VIBRATION MEASUREMENTS

4.1 GENERAL

Bangladesh is located close to the junction of two subduction zones created by two active tectonic plates: the Indian plate and the Eurasian plate. Moreover, the country is surrounded by the Himalayan Arc, the Shillong Plateau and the Dauki fault system in the north, the Burmese Arc and Arakan Yoma anticlinorium in the east, and the Naga Disang Haflong thrust zone in the northeast (Ali and Choudhury, 2001). Based on the severity of the probable intensity of seismic ground motion and damages, Bangladesh has been divided into three seismic zones and Dhaka falls within the Zone 2 corresponds to resonance frequencies in a band of 3 to 5 Hz having a ground motion amplification of 1.8 (BNBC 1993). But in the Draft BNBC 2010, the country has been divided into four seismic zones with different levels of ground motion and Dhaka city falls in the moderate seismic intensity zone with Z=0.2g. The proposed seismic zoning in the Draft BNBC 2015 is given as Figure 4.1.

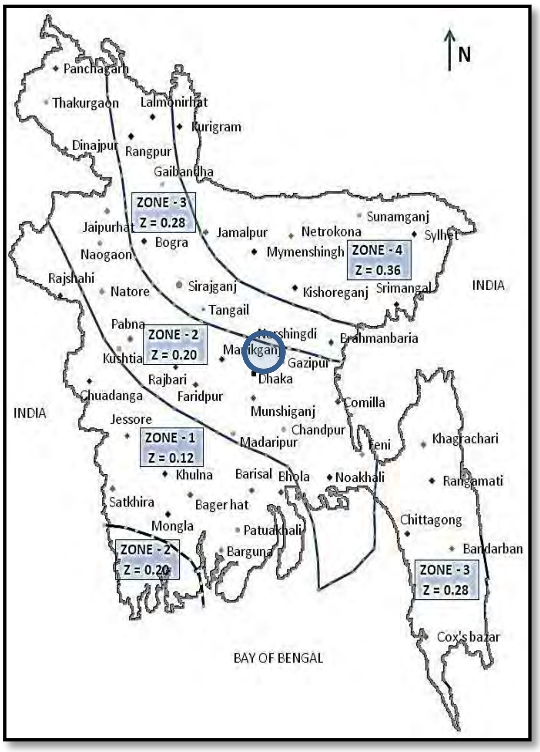


Figure 4.1: Proposed Seismic Zoning Map of Bangladesh

Earthquakes generates sudden impulse-type load into buildings, setting them in vibratory motion. Dynamic characteristics have a key role on the seismic behavior and vulnerability of structures. Particularly, base shear is needed, both in design of new buildings and in assessment of existing ones. Again the fundamental period is very important as the design base shear of any structure depends largely on base shear.

Presently ambient and forced vibration tests are usual applied techniques for buildings to understand and ascertain their dynamic behaviour. Ambient vibration test has two major overriding advantages over the forced vibration technique. Among the field tests, ambient vibration experiments are most common as they are economical, non-destructive, and fast and easy to implement. As ambient vibration testing is output driven, it is highly cost effective and is regarded as being harmless to the integrity of the structure (Endrun et al., 2010; Celebi, 2009). In ambient vibration measurements, the input force is unknown, thus output-only modal parameter identification techniques must be applied for modal analysis.

With the above mentioned background knowledge, the aim this chapter is to describe all the targeted URM buildings in details and narrate in details the ambient vibration tests conducted for those URM buildings under study.

4.2 OVERALL DESCRIPTIONS OF THE LOCATION AND URM BUILDINGS

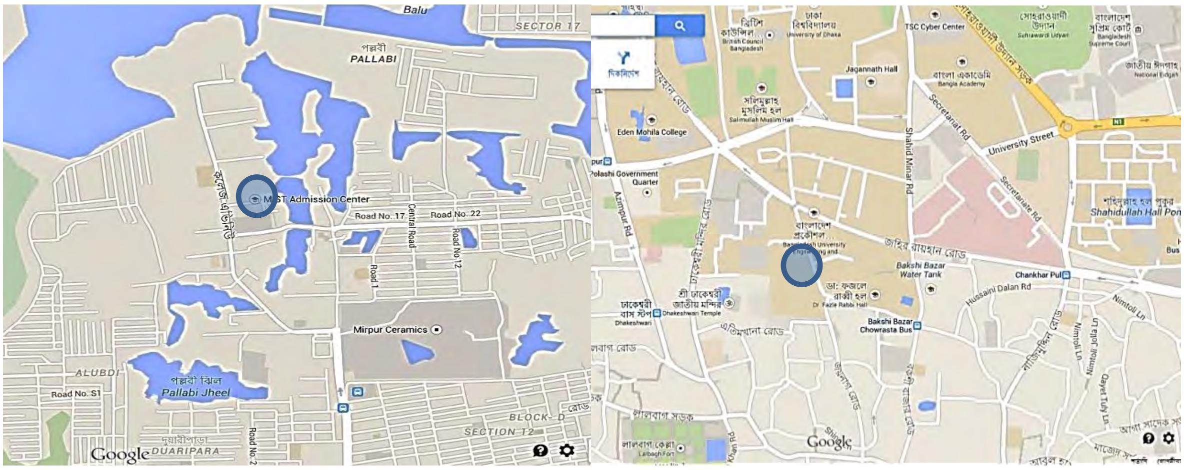
All the URM buildings are located in Dhaka, the capital city of Bangladesh. Dhaka being located on the northern bank of Buriganga River is a highly and densely populated metropolitan city. It is frequently facing earthquakes of low to medium intensity and on the basis of the historical recurrence, expecting some serious seismic threats in the near future. All the locations of the URM buildings in Dhaka are given at Figure 4.2 (a), Figure 4.2 (b), Figure 4.2 (c) and Figure 4.2 (d).In the location 1 (Figure 4.2a), the soil is light brown to brown or reddish brown or light red to red clay/silt with grey mottling trace of fine sand low to high plastic. In the location 2 (Figure 4.2b), the soil is light brown to brown or reddish brown or light red to red clay with grey mottling trace to considerable fine sand low to high plastic. But for the location 3 (Figure 4.2c), soil of southern part which is much nearer to the Buriganga River is brown or reddish brown or red clay with grey mottling trace to considerable fine sand high plastic (Serajuddin et al., 2001). The soil in the areas of location 4 (Figure 4.2d) is generally stiff silty clay.

All the structures in the first location (Figure 4.2a) were designed and built in 1960, in the second location in 1972 (Figure 3b), in the third location in 1977 (Figure 3c) and in the fourth location in 1990. The designs and drawings related to structures built before 1980 could not be found. All data related to those buildings are taken from the visual observations. The structures are composed of load bearing walls of clay-bricks in both the longitudinal and transverse direction with slabs made of Reinforced Concrete (RC). The roofs are constructed as the floors, providing continuity of the construction, and later on the possibility for additional stories to be added. The load bearing walls are solid brick masonry walls of different thicknesses of 25cm, 39.2cm, 40cm and 43cm. Bricks are of standard dimensions 24cm x 11.43 cm x 6.99 cm, connected by Portland cement mortar. All the foundations are assumed to be wall foundation of stepped footings. This is based on the design found for the renovation works of all 3-storied buildings. The width of the bottom step is 1m, then in upward direction 0.875m, 0.75m, 0.625m, 0.50m, 0.375m and ultimately 0.25m at the Ground Level (GL).

Constructions of these structures were regulated by practice of construction at the time when these were constructed. It is mentionable that as at that time there was no authorized national code in Bangladesh. Visual inspection revealed that there were no major cracks on any of the structure.

Location 1

(b) Location 2



(c) Location 3

(d) Location 4

Figure 4.2: Different Locations of Targeted URMs in Dhaka City

4.3 URM BUILDINGS INVENTORY

URM buildings are selected on random basis only keeping in mind that a number of buildings of different heights, stories and plan views remain within the total samples so that the objective of the research is achieved. The structural description and geometry of the URM buildings are stated in the following sub-sections.

4.3.1 Single-Storied URM Buildings

4.3.1.1 Structural Description and Geometry of Building No. 6A

This I-shaped structure was built in 1977. It was basically used as single-lined vehicle garages. Later in 1998 it was renovated to use as workshops. For the said purposes non-loadbearing wall of 2' feet height and 15 cm thickness was added to support the glass frame at the eastern part of each parking bay. The front and rear views of the building are given at Figure 4.3. The plan view illustrated in Figure 4.6 shows the layout of the structure with load bearing walls in both the cardinal directions. The height of this structure is 3.81m and thickness of the load bearing walls are 25cm. In the plan, the structure is of dimensions 43.34m by 6.98m.

(a) (b)

Figure 4.3: (a) Front and (b) Rear View of Building No. 6A

4.3.1.2 Structural Description and Geometry of Building No. 6B

This I-shaped structure was built in 1977. It was basically used as single-lined vehicle garages like building no. 6A. Later in 1998 the western half of it was renovated to use as workshops. For the said purposes wall of 2' feet height and 15 cm thickness was added to support the glass frame at the western half part of each parking bay. Again the westernmost bay was converted in to number of lavatories. It is connected to the building no. 6C by a common wall of 5' height and 15 cm thickness from its mid-length, just to separate the present workshop area and the garages. The height of this structure is 3.81m and thickness of the load bearing walls are 25cm. The view of the building in Figure 4.4 and a plan view illustrated in Figure 4.6. In the plan, the structure is of dimensions 29.42m by 6.68m. It is mentionable that the parking bays do not have constructed floors.

Figure 4.4: Front View of Building No. 6B

4.3.1.3 Structural Description and Geometry of Building No. 6C

This I-shaped structure was built in 1977. It was basically used as back to back double-lined vehicle garages. Later in 1998 the western part of it was renovated to use as workshops. For the said purposes wall of 2' feet height and 15 cm thickness was added to support the glass frame at the western half part of each parking bay. The eastern presently comprises of vehicle garages, office and a Fuel Store. A single-storied structure being used as garages is located at eastern side of building no. 6C and parallel to its longer dimension. Another structure is located at the north of building no. 6C. The neighboring structures at its north (an office) and at its east (vehicle garages) are connected with building no. 6C at the roof level by means of sheds (Figure No. 4.6). These sheds are made of steel trusses having plastic sheets over them. It is connected to the building no. 6B by a common wall of 5' height and 15 cm thickness from its mid-width, just to separate the present workshop area and the garages. The height of the northern part of this structure is 3.81m and the southern part is 4.57m and thickness of the load bearing walls are 25cm. The view of the building in Figure 4.5 and a plan view illustrated in Figure 4.7. In the plan, the structure is of dimensions 31.2m by 13m. It is mentionable that the parking bays do not have constructed floors.


(a) (b)

Figure 4.5: Views from (a) right side and (b) left side of the Building No. 6C

(b)

Figure 4.6: Photo (a) from the Top and (b) Beneath the Shed Connecting Building No. 6C and its Neighbouring Buildings at their Roof Level

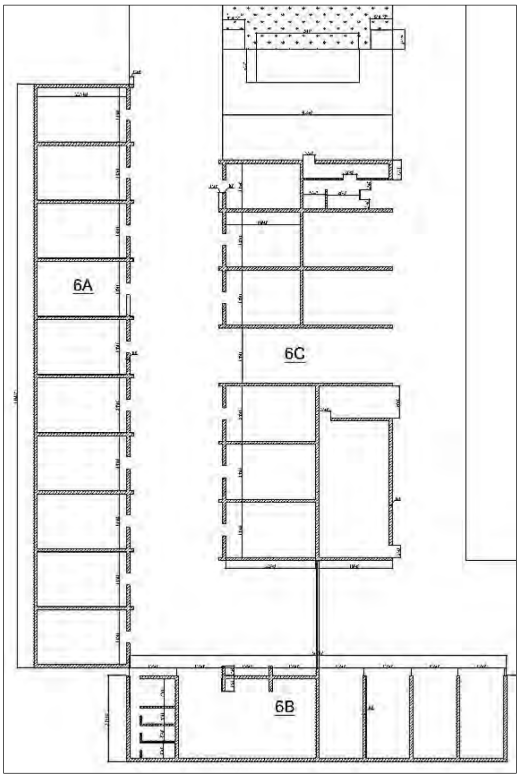


Figure 4.7: Plans of the Building No. 6A, 6B and 6C

4.3.1.4 Structural Description and Geometry of Building No. 8

This structure was built in 1977. The structure is a combination of two octagonal shaped rooms of different dimension and other irregular shaped rooms. The recent view of the building is given at Figure 8. The bigger octagon is of 3.05m high and other parts are of 6.10m high. So the building has a vertical geometric irregularity. The building is used as cafeteria including a kitchen. It is connected to building no. 7 side to side with a porch like slab at a height of 3.05m. The view of the building is given in Figure 4.8. The plan view illustrated in Figure 4.9 shows the layout of the structure with load bearing walls of 40cm thickness in both the cardinal directions. In the plan, the structure has a floor area of about 217.65m^2.

(a) (b)

(c)

Figure 4.8: (a) Front, (b) Rear and (c) Side Views of Building No. 8

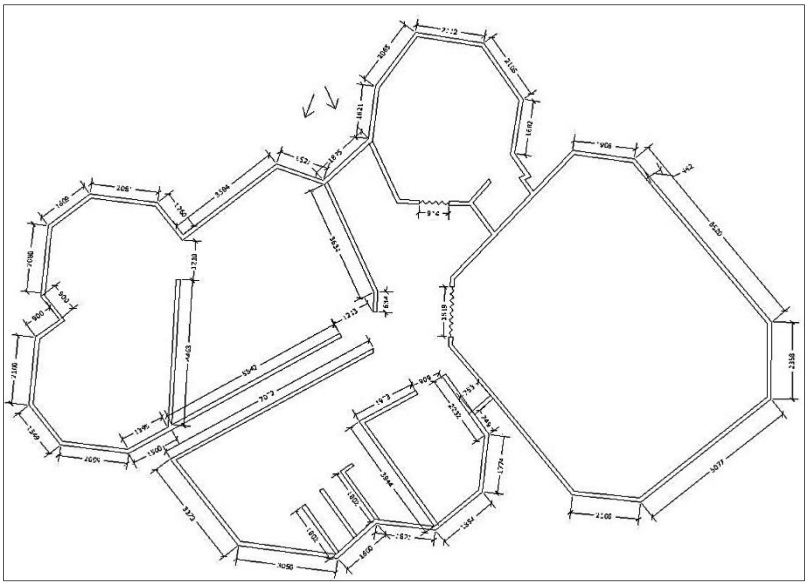


Figure 4.9: Plan of the Building No. 8

4.3.1.5 Structural Description and Geometry of Building No. 13

This structure was built in 1977. This building is being used as store. In 1998, in the western side of it a new room was added to its structure. The height of this structure is 2.59m and thickness of the load bearing walls are 25cm. In the plan, the structure is of dimensions 17.07m by 11.17m approximately with a floor area of about 139.72m^2. The view of the building is in Figure 4.10 and a plan view is shown in Figure 4.11.

(a) (b)

Figure 4.10: (a) Front and (b) Side View ofBuilding No. 13

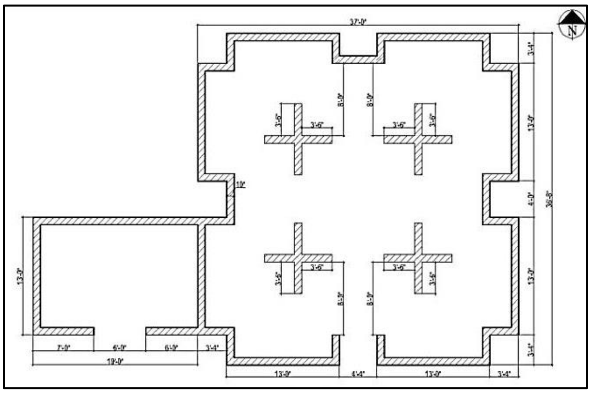


Figure 4.11: Plan of Building No. 13

4.3.1.6 Structural Description and Geometry of SLA Building

This structure was built between 1972 and 1973. Presently it is being used as an office cum residential building. The height of this structure is 3.28m in the rear side and 2.90m in the front side. The thickness of the load bearing walls is 39.4cm. In the plan, the structure is a rectangular of dimensions 24.41m by 22.79m. Different views of the building are given at Figure 4.11. The plan view illustrated in Figure 4.12 shows the layout of the structure with load bearing walls in both the cardinal directions.

(a)

(b)

(c)

Figure 4.12: (a) Front View, (b) Side View and (c) Rear View of SLA Building

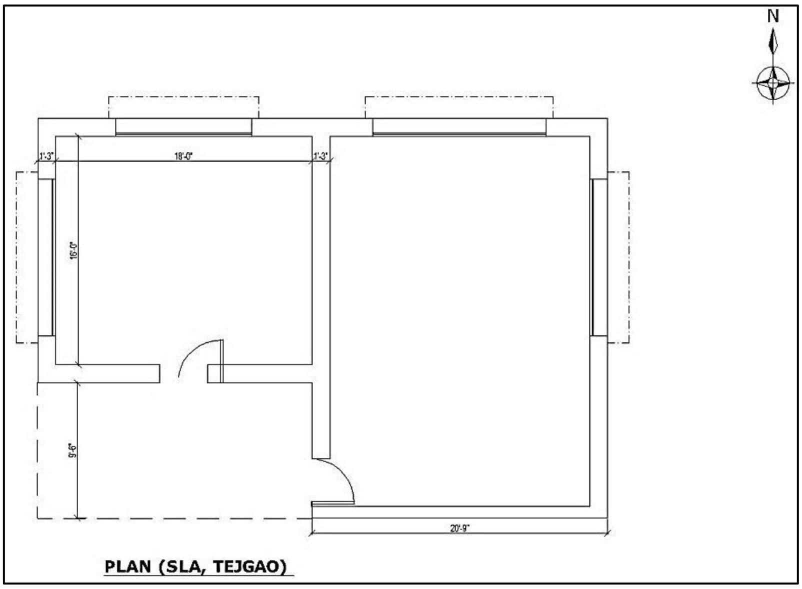


Figure 4.13: Plan of SLA Building

4.3.2 Two-Storied URM Buildings

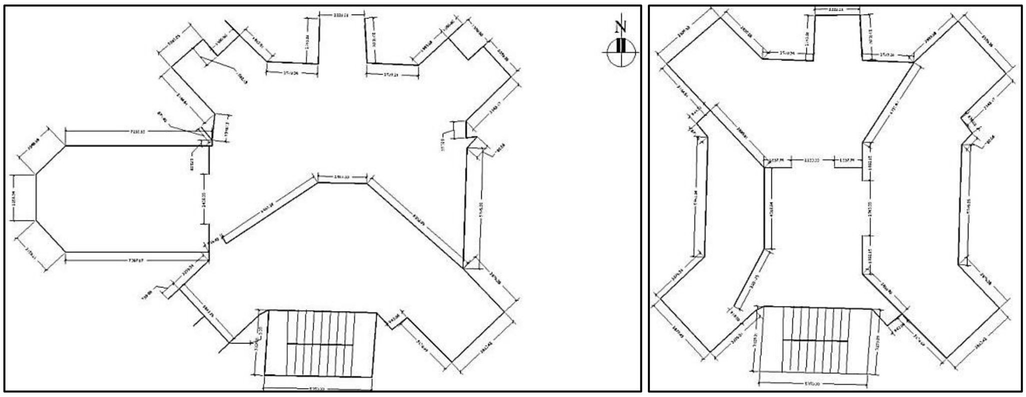
4.3.2.1 Structural Description and Geometry of Building No. 10

This structure was built as an X-shaped building in 1977. But in 2005 a rectangular room was added to its western side. The ground floor of this structure is being used as cafeteria and canteen and the upper floor is used as tailor's shop and a day care centre. The front and rear view of the building are given at Figure 4.13. The plan views in Figure 4.14 shows the layout of the structure with load bearing walls in both the cardinal directions. The height of this structure is 6.1m and thickness of the load bearing walls are 25cm. In the plan, the structure is of dimensions 19.47m by 12.27m approximately.

(a)

(b)

Figure 4.14 : (a) Front and (b) Side View of Building No.10



(a) (b)

Figure 4.15: Plan View of (a) Ground Floor and (b) First Floor of Building No.10

4.3.2.2 Structural Description and Geometry of Building No. 15A

This structure was built in 1977. The structure is being used as laboratories and offices. The height of this structure is 7.32m and thickness of the load bearing walls are 25cm. The stair case to go to the first floor is built within the building. In the plan, the structure is of dimensions 21.49 by 10.67m. The front and side views of the building are given at Figure 4.15. The rectangular plan view illustrated in Figure 4.16 shows the layout of the structure with load bearing walls in both the cardinal directions.

(a) (b)

Figure 4.16: (a) Front View and (b) Side View of Building No.15A

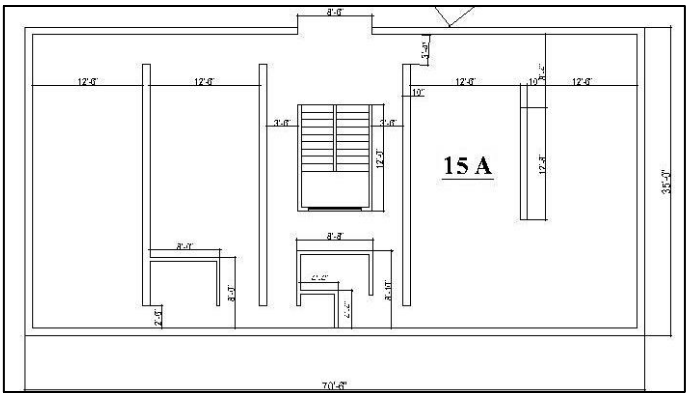


Figure 4.17: Plan of Building No.15A

4.3.2.3 Structural Description and Geometry of Building No. 15B

This circular structure was built in 1977. This circular structure is being used as laboratory, library and office. The height of this structure is 7.32m and thickness of the load bearing walls are 25cm. The front and side views of the building are given at Figure 4.17. In the plan, the structure has an area of about 261.42m^2. The plan view illustrated in Figure 4.18 shows the layout of the structure with load bearing walls in both the cardinal directions.

(a) (b)

Figure 4.18: (a) Front View and (b) Side View of Building No.15B

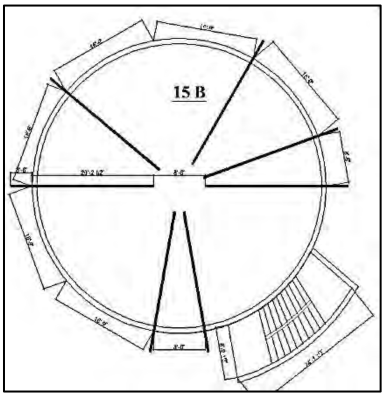


Figure 4.19: Plan View of Building No.15B

4.3.2.4 Structural Description and Geometry of Building No. 18A

This T-shaped structure with masonry columns was built in 1960. At the front side a wide verandah of 9.5 feet width exists on each floor. This structure is being used as accommodations and stores. The height of this structure is 7.32m and thickness of the load bearing walls are 43.2cm. The front, rear and side views of the building are given at Figure 4.19. In the plan, the structure has an area of about 205.45m^2. The plan view illustrated in Figure 4.21 shows the layout of the structure with load bearing walls in both the cardinal directions.

(a)

(b) (c)

Figure 4.20: (a) Front View, (b) Side View and (c) Rear View of Building No.18A

4.3.2.5 Structural Description and Geometry of Building No. 18B

This I-shaped structure with masonry columns was built in 1960 alongside building no. 18A. At the front side a wide verandah of 9.5 feet width exists on each floor. This structure is being used as accommodations, gymnasium and stores. The height of this structure is 7.32m and thickness of the load bearing walls are 43.2cm. The front, rear and side views of the building are given at Figure 4.20. In the plan, the structure has an area of about 247.72m^2. The plan view illustrated in Figure 4.21 shows the layout of the structure with load bearing walls in both the cardinal directions.

(a) (b)

Figure 4.21: (a) Front View and (b) Rear View of Building No.18B

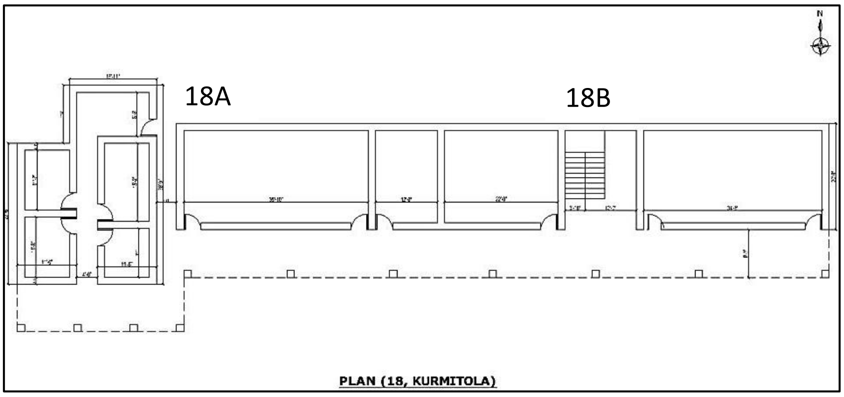


Figure 4.22: Plan View of Building No.18A and 18B

4.3.3 Three-storied URM Buildings

4.3.3.1 Structural Description and Geometry of Building No. 2

This structure was built in 1977.This structure is being used as hospital. The height of this structure is 9.15m and thickness of the load bearing walls are 25cm. The front and side views of the building are given at Figure 4.22. In the plan, the structure has an area of about 338.20m^2. The plan view illustrated in Figure 4.23 shows the layout of the structure with load bearing walls in both the cardinal directions.

(a)

(b)

Figure 4.23: (a) Front View and (b) Side View of Building No.2

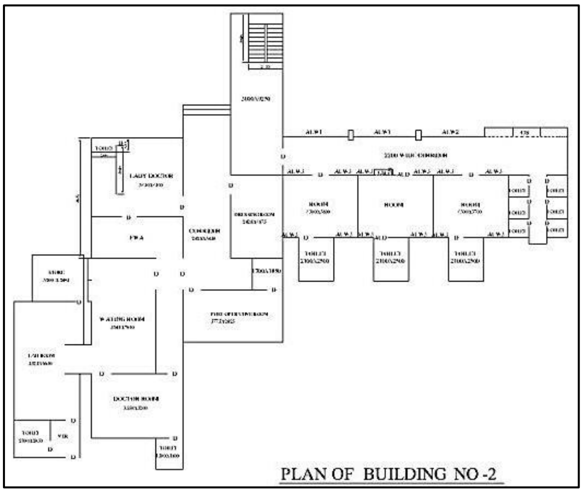


Figure 4.24: Plan of Building No. 2

4.3.4 Four-storied URM Buildings

4.3.4.1 Structural Description and Geometry of Building No. 7

This structure was built in 1977 as a three-storied building. This is a typical masonry residential building. During its life time there have been no changes regarding its layout and usage. However a vertical extension of a floor was performed in 1998. In the southern side of the building, an additional wall, having a circular hole of 25 feet diameter, exists starting from the roof down to the ground. It acts like an apron to the building. It is connected to building no. 8 side to side with a porch like slab. The height of this structure is 12.19m and thickness of the load bearing walls are 25cm. The front and rear views of the building are given at Figure 4.24. In the plan, the structure has an area of about 168.12m^2. The plan view illustrated in Figure 4.25 shows the layout of the structure with load bearing walls in both the cardinal directions.

(a) (b)

Figure 4.25: (a) Front Side (b) Rear Side of Building No.7

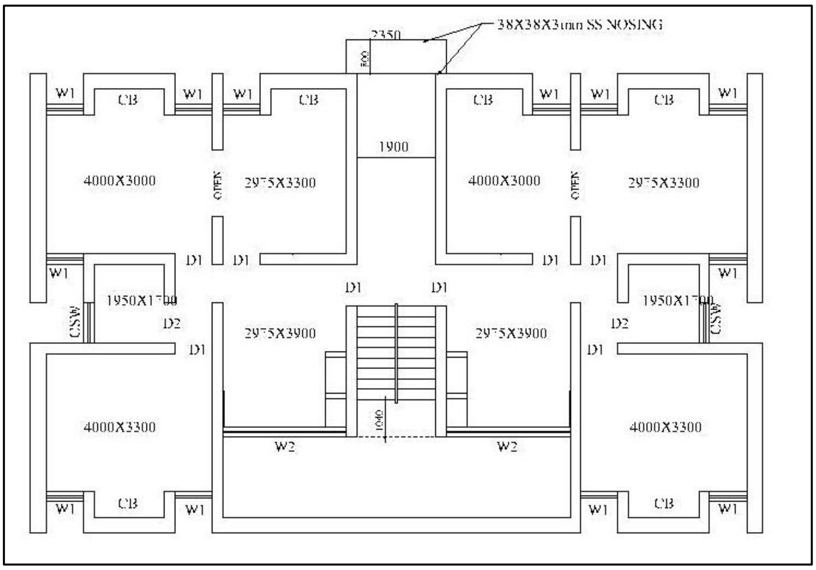


Figure 4.26: Plan of Building No. 7

4.3.4.2 Structural Description and Geometry of Building No. 9A

This structure was built in 1977 as a three-storied building. However a vertical extension of a floor was performed in 1998. This building is located alongside other three buildings and all four buildings are connected by construction joints. This is an office cum university academic building. The height of this structure is 14.63m and thickness of the load bearing walls are 25cm. The front and rear views of the building are given at Figure 4.26. In the plan, the structure has a floor area in each floor of about 216.62m^2. The plan view illustrated in Figure 4.28 shows the layout of the structure with load bearing walls in both the cardinal directions.

(a) (b)

Figure 4.27: (a) Front View and (b) Side View of Building No.9A

4.3.4.3 Structural Description and Geometry of Building No. 9D

This structure was built in 1977 as a three-storied building. However a vertical extension of a floor was performed in 1998. This is an office cum university academic building having two laboratories inside it. The height of this structure is 14.63m and thickness of the load bearing walls are 25cm. The front view of the building is given at Figure 4.26. In the plan, the structure has a floor area in each floor of about 206.95m^2. The plan view illustrated in Figure 4.28 shows the layout of the structure with load bearing walls in both the cardinal directions.

Figure 4.28: Front View of Building No.9D

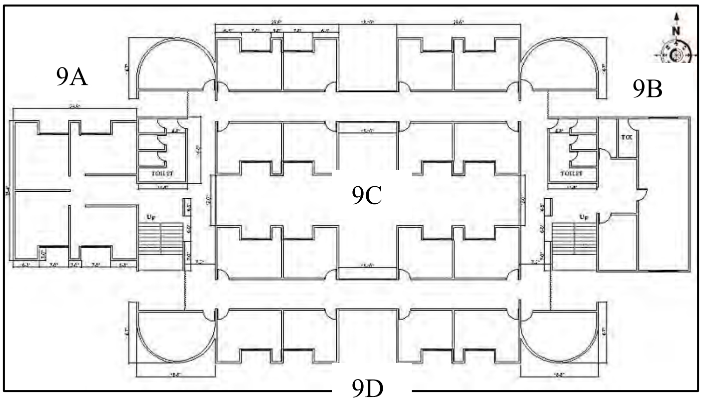


Figure 4.29: Plan of Building No. 9A and 9B

All the four buildings are connected at their roofs by means of a shed. These shed is made of steel trusses having plastic sheets over them. The photo of the shed taken from below is given at Figure 4.29.

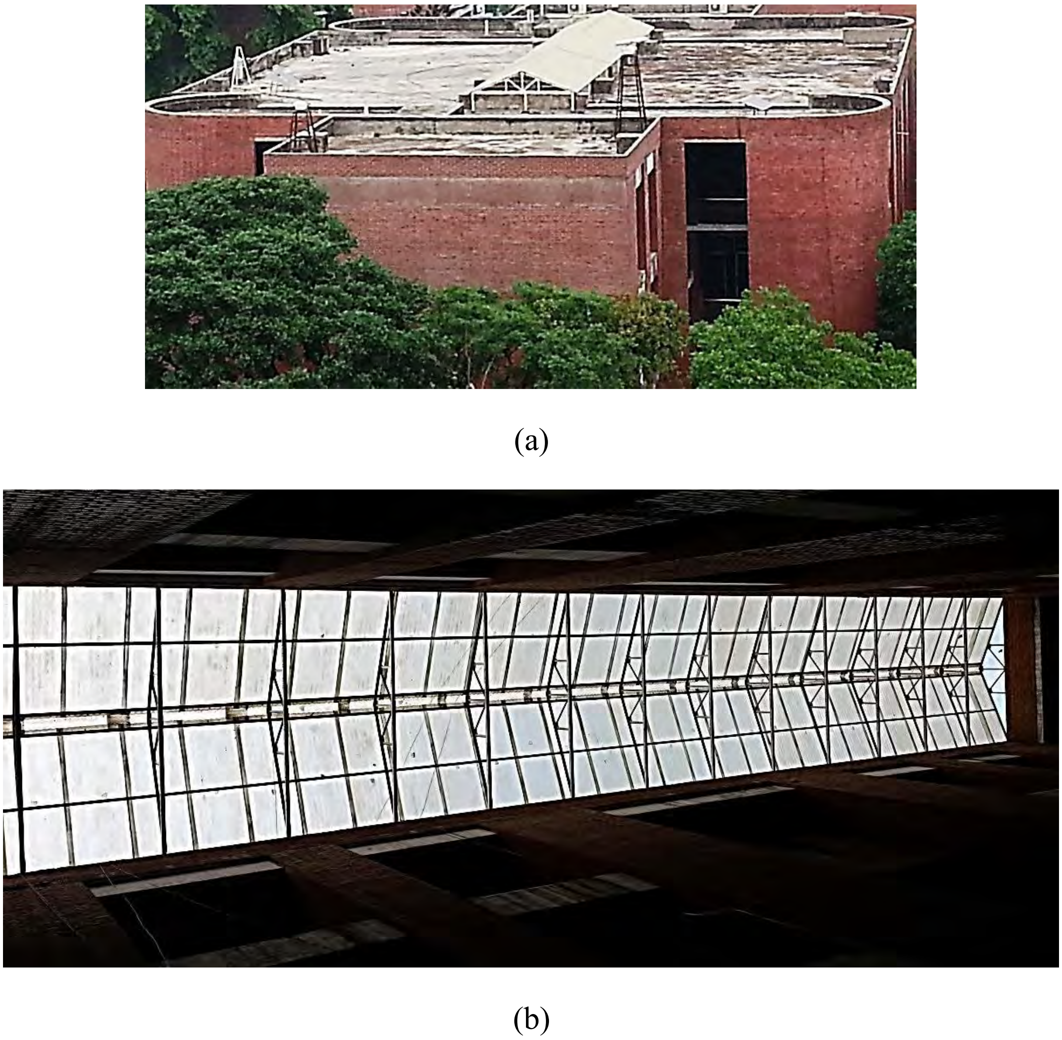
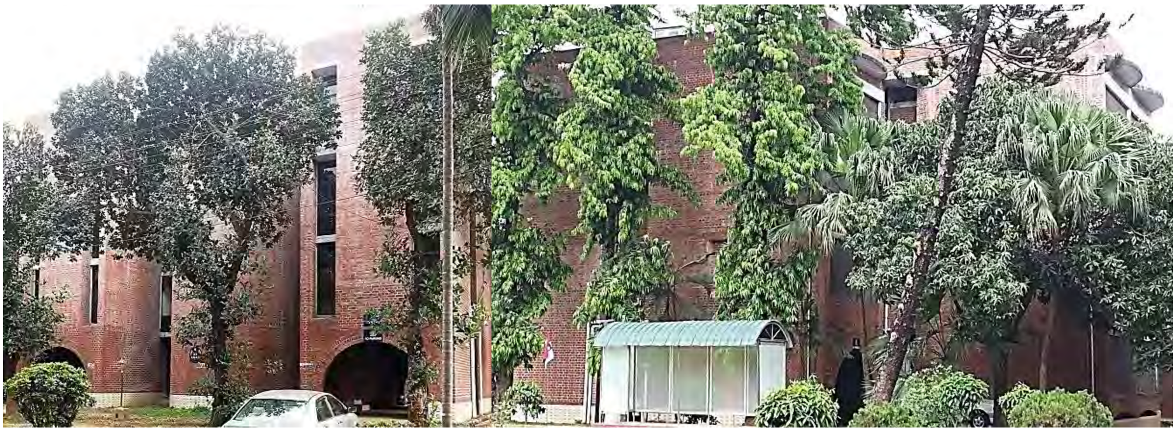


Figure 4.30: Photo (a) from the Top and (b) Beneath the Shed Connecting Building No. 9A, 9B, 9C and 9D at their Roof Level

4.3.4.4 Structural Description and Geometry of Building No. 11

This structure was built in 1977. This is a residential building having a circular stair case. There are two porches on both the sides at the ground floor of the building. During its life time there have been no changes regarding its layout and usage. The height of this structure is 12.19m and thickness of the load bearing walls are 25cm. In the plan, the structure has an area of about 280.10m^2. The front and side views are given in Figure 4.30. The plan view illustrated in Figure 4.31 shows the layout of the structure with load bearing walls in both the cardinal directions.



(a) (b)

Figure 4.31: (a) Front View and (b) Side View of Building No.11

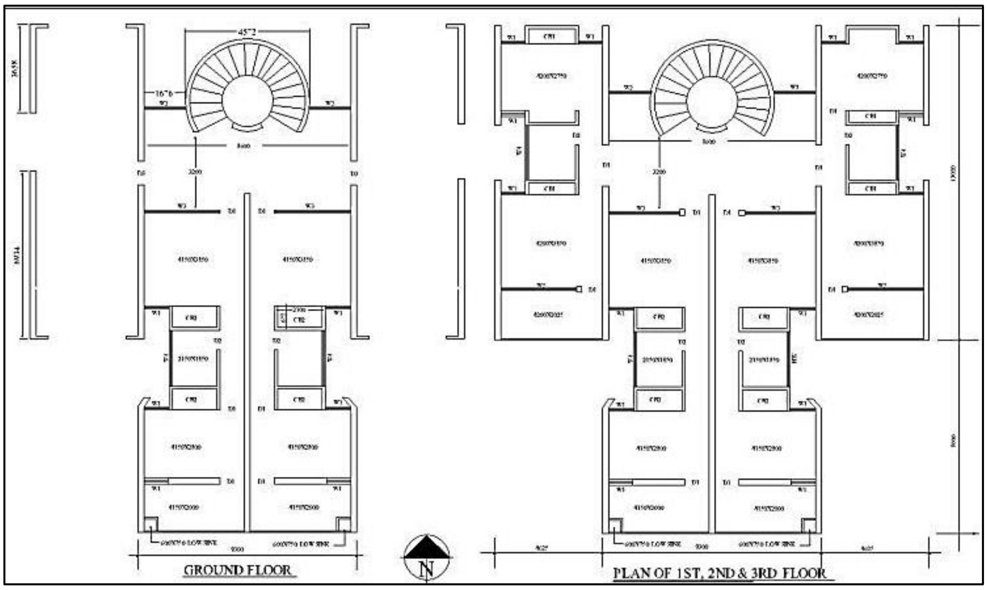
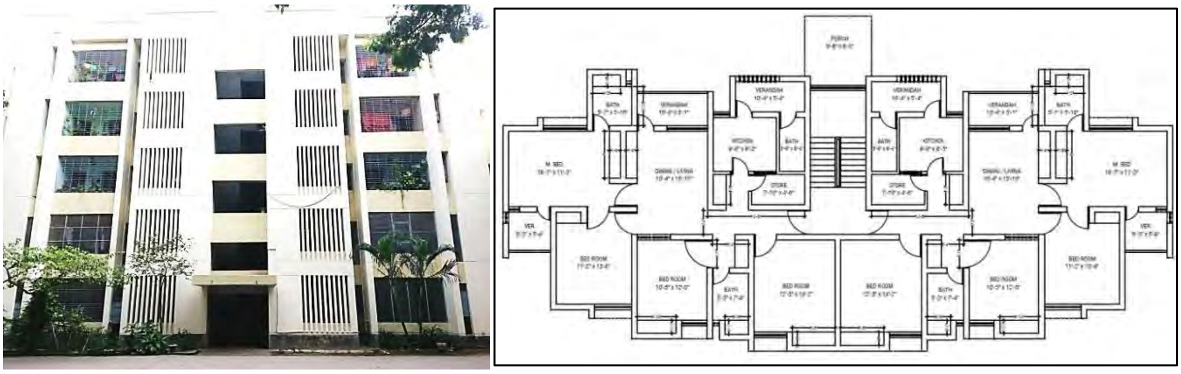


Figure 4.32: Plan of Building No.11

4.3.5 Five-storied URM Buildings

4.3.5.1 Structural Description and Geometry of Building No. 46

This structure was built in 1990. This is a typical masonry residential building. During its life time there have been no changes regarding its layout and usage. The height of this structure is 15.24m and thickness of the load bearing walls are 25cm. In the plan, the structure has an area of about 319.75m^2. The front view and plan view showing the layout of the structure with load bearing walls in both the cardinal directions are illustrated in Figure 4.32.



(a) (b)

Figure 4.33: (a) Front View and (b) Plan of Building No.46

The details of the parameters of the URM buildings under study are summarized and appended at Appendix C.

4.4 AMBIENT VIBRATION TESTS

Ambient vibration is the excitation from the environmental elements. It can be produced from cultural noises, natural sources and/or micro-seismic tremors. Unlike forced vibration testing, the forces applied to the structure in ambient vibration testing, a non-destructive technique, are not controlled. The structure is assumed to be excited by wind, traffic and human activity. The measurements, typically accelerations, are taken for a long duration to ensure that all the modes of interest are sufficiently excited.

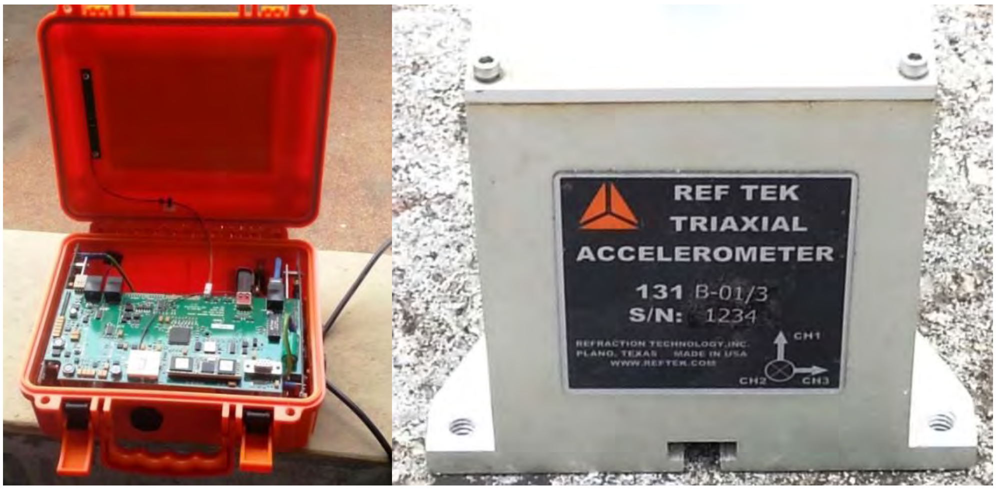
An ambient vibration test describes the linear behaviour of structures, since the amplitudes of the vibration are small (Ivanovic et al., 2000). The purpose of performing ambient vibration test in general is to find out the dynamic characteristics and damping estimates of a structure. The most frequent use of it now-a-days is to identify natural frequencies and corresponding mode shapes of structures. Consequently it is being extensively used for SHM of CESs. The identification of dynamic characteristics is a necessary and important task in the course of seismic design of civil engineering structures (Farrar and H., 1997). These tests allow to determine the dynamic behaviour of structures under low vibrations.

4.5 EQUIPMENT

The dynamic behaviours of targeted URM buildings have been monitored by Kelunji EchoPro Seismic Recorder which is a product of Environmental Systems & Services (ES&S) of Australia. Simultaneous recordings in maximum four points of all the structures are possible by four tri-axial sensors connected with the MEMS (Micro-ElectroMechanical Systems) type accelerometer and cables for the vibration measurements. However the equipment procured by BUET had three tri-axial sensors supplied with it and available for the research. The photo of the equipment set is given at Figure 4.34.

Figure 4.34: Photo of the Kelunji EchoPro Seismic Recorder Set

Each sensor is connected to 3-channel input providing data recorded separately for three orthogonal directions. It records three types of data for each sensor, i.e. acceleration, velocity and displacement. There are four processes in which data can be recorded. These processes are continuous recording process, Short Time Average (STA)/Long Time Average (LTA) trigger process, level trigger process and histogram recording process. All channels of EchoPro are sampled at a common sample rate. This is the speed at which the Analogue to Digital Converters (ADCs) runs to gather data from the sensors. There are two types of data sampling available - unfiltered and filtered. The internal view of the Data Recorder and a closer view of a sensor are given in Figure 4.35.



(a) (b)

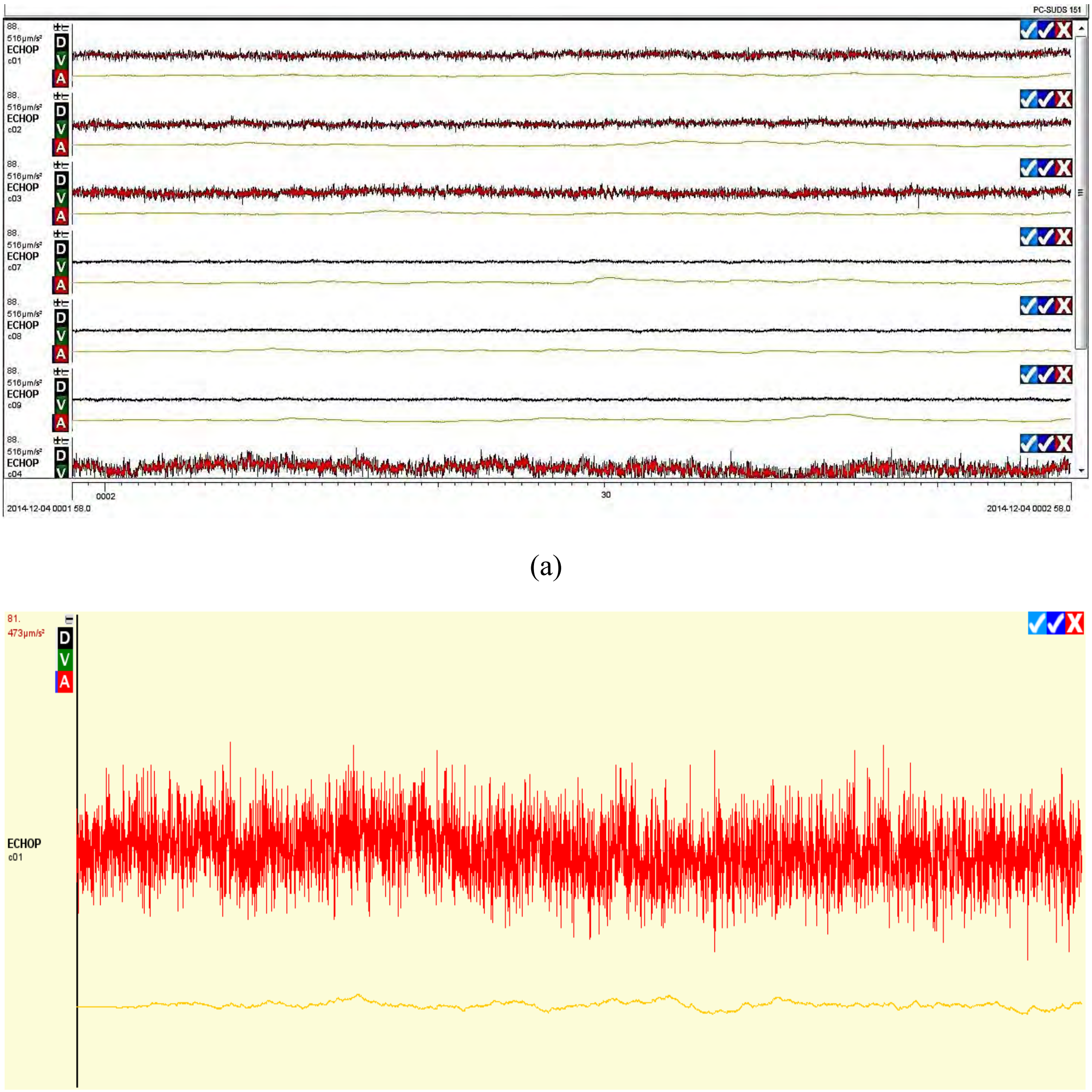
Figure 4.35: (a) The Internal view of the Data Recorder and (b) a Closer View of a Sensor

4.6 SENSOR PLACEMENTS

A single building was instrumented with three sensors. Each of which was placed at top floor (on the roof), at mid height and at the ground floor. Again while positioning the sensors these were placed on a same vertical plane as far as possible and at the centre of the floors wherever possible.

4.7 DATA ACQUISITION

Kelunji EchoPro Seismic Recorder is used to transfer analog signal to digital data, and to data recording in data-logger of the instrument. Vertical part of ambient forces is usually less significant in structural engineering so this study will emphasis on the lateral forces. The time history records in the form of Digitized acceleration signals of the two principal horizontal axes of the buildings were considered. The data were obtained from the data-logger of the instrument through a life book laptop computer. The aim was to identify the dynamic properties of two cardinal directions. The recording process used was a continuous recording process. Sampling rate is selected as 100 samples per second (sps). Duration of each record is 60 sec. Time series of each minute recording has 6,000 points. A time history of all the channels and a particular channel of a minute are shown in Figure 4.36. Ambient response measurements and data acquisition were conducted in different days of the duration from July 2014 for the pilot project on a 11-storied RCC building and from December 2014 to March 2015 on URM buildings. For the URMs under study, it took about 3 hours to finish the setup of the instruments. Data of a complete day (24 hours) acquired for each of the building.



(a)

(b)

Figure 4.36: A Time History of (a) All the Channels and (b) A Particular Channel of a Minute Obtained from the Data Recorder

4.8 DATA PROCESSING

The time history records obtained from Seismic Recorder are converted into common text files by a software named Eqwave 3.4 supplied with the equipment. Then text files are converted into MS Excel files for using it as an easy source of data for programing. From the data acquired, data of seven minutes each from the morning, noon/afternoon and night are gathered together separately for the top floor and ground floor. This overlapping was done to increase the number of average. Obtained data of total twenty one minutes i.e. 21x6000 = 126,000 data points separately for the top floor and ground floor are then inserted into a program aimed to convert the time history data into a legible plot through FFT created by MATLAB. In the process the program ran on the basis of 212 = 4096 data points for each 1-minute time series. So there were 21x4096 = 86016 data points each for the top floor and ground floor accelerations. They were followed by data representing top floor accelerations/ground floor accelerations as means to transfer function. The transfer function was applied to eliminate the noises at the ground floor and get different modes of the ambient vibrations in the plot.

A FFT is performed on all the time signals which convert the signals to the frequency domain. Thus frequency spectra were composed based on digital FFT. Then the pre-dominant structural vibration frequencies from frequency spectra are obtained where the magnitudes of the amplitudes are plotted against frequency. From this fundamental frequency fundamental periods in the longitudinal and transverse direction of the instrument for each URM are acquired.

As vertical forces are usually less important in structural engineering especially SHM, this research focuses on the lateral forces for identifying the modal shapes.

4.9 AMBIENT MODAL IDENTIFICATION

Ambient vibrations have a random nature and cover a relatively wide band of frequencies (Vlad and Vlad, 2011). From there the peaks are identified as resonance frequencies at a particular point. Modes shapes of the structure can then be estimated from those plots using the classical PP method. PP from frequency spectra is one of the most advantageous systems for the basic ambient modal identifications. PP is probably the simplest, yet very useful, quick and practical, system identification method (Omenzetter et al., 2013). It is simple and easy, but there remains the difficulty of dealing with close-spaced mode. Pre-dominant frequency of the top floor of an URM building is given at Figure 4.37.

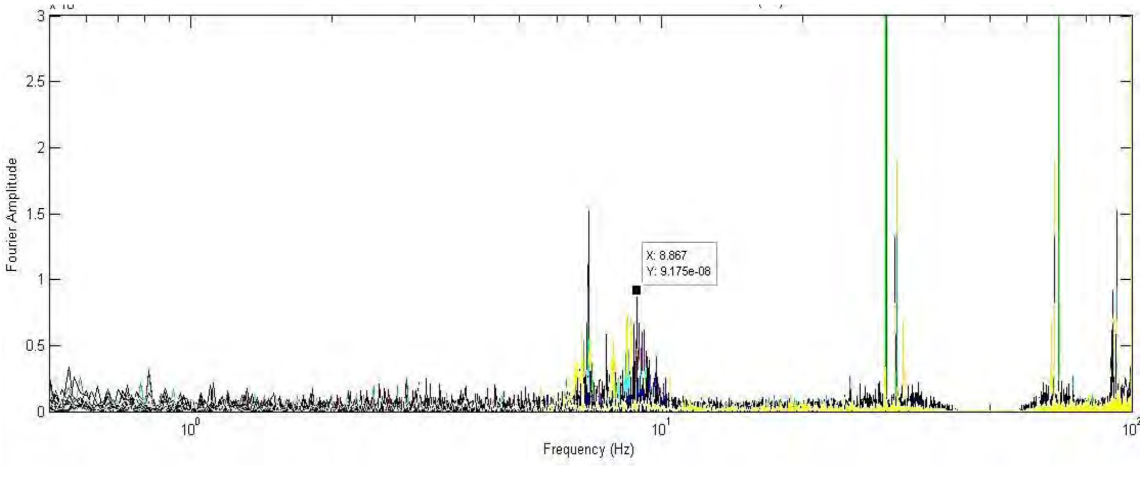


Figure 4.37: Pre-dominant Frequency of the Top Floor of an URM Building

Pre-dominant frequency of an URM building at its top floor after performing transfer function is given at Figure 4.38.

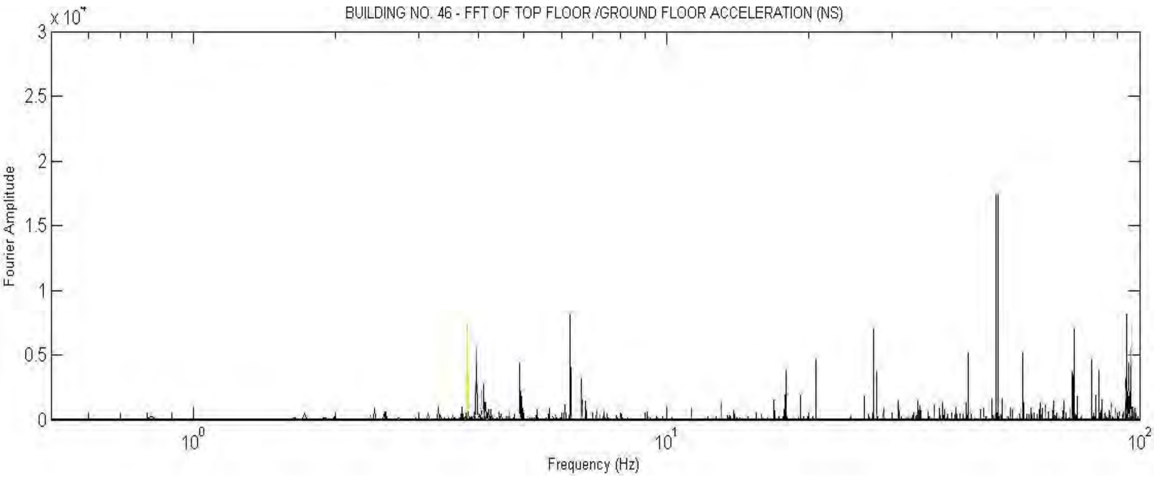


Figure 4.38: Pre-dominant Frequency of the Top Floor of a URM Building after performing Transfer Function

4.10 VALIDATION TEST ON A RCC BUILDING

An 11-storied RCC building at BUET Teachers' Residential Area was selected to be the object of the pilot test. This framed structure has two lift cores side by side and based on pile foundations. The building was instrumented keeping one sensor at top floor i.e. on the roof, one at the sixth floor and another at the ground floor. The front and side views of the building are given at Figure no. 4.39 and the plan of the building is given at Figure no. 4.40.

(b)

Figure 4.39: (a) The Front and (b) Side Views of RCC Building

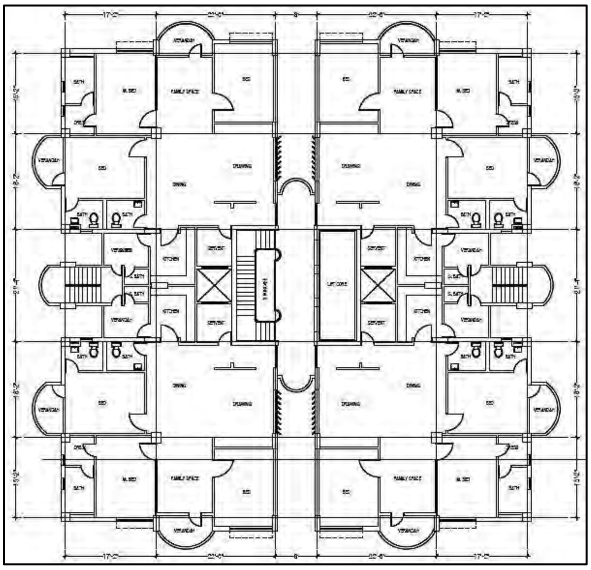
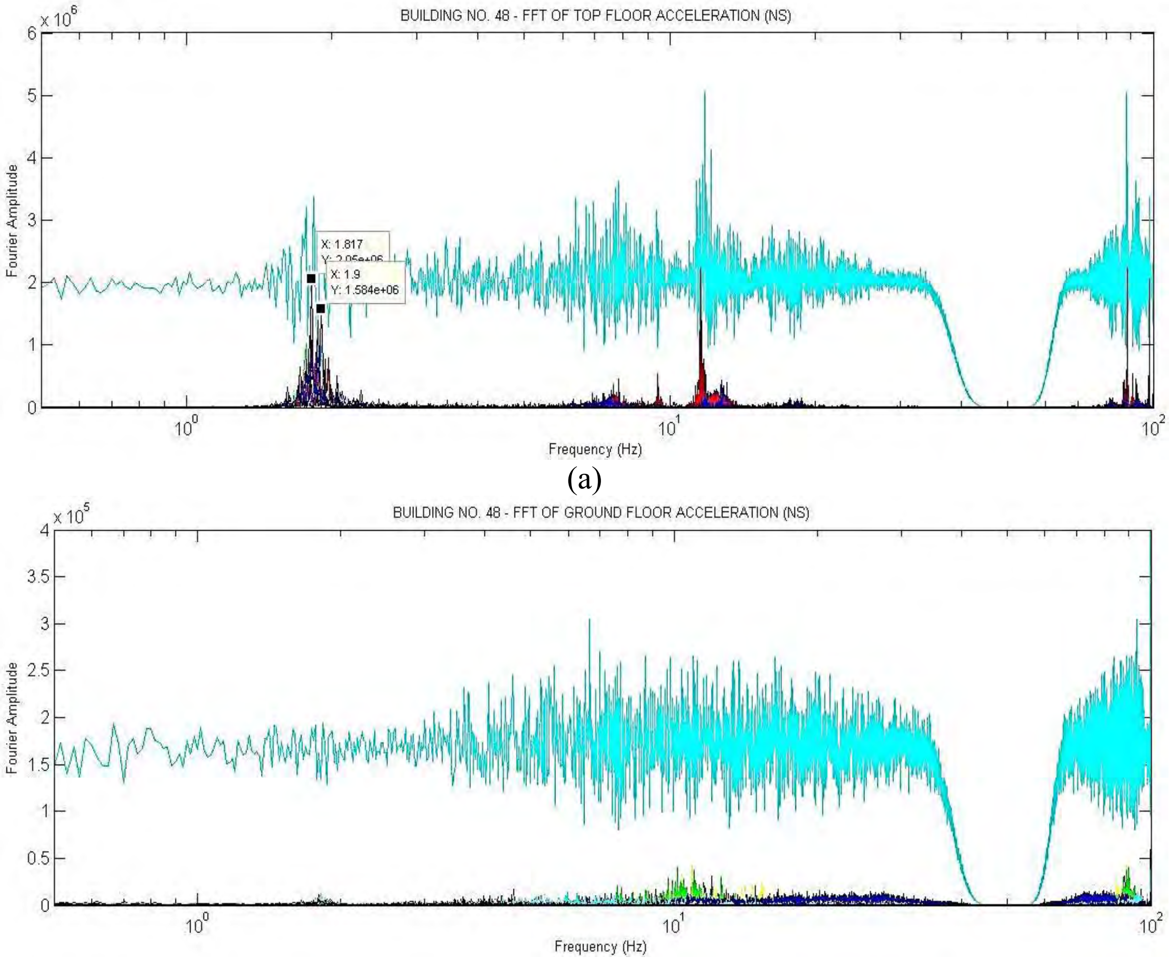


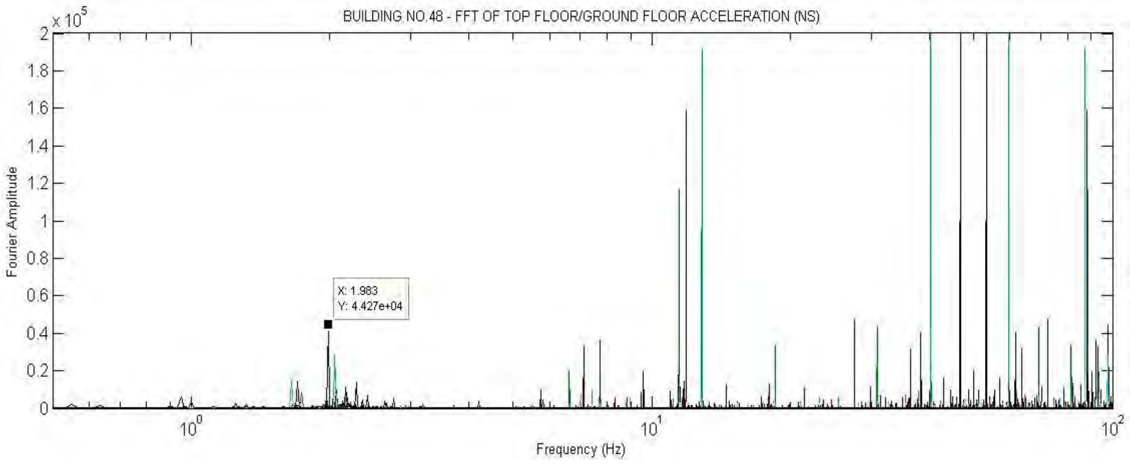
Figure 4.40: The Plan View of RCC Building

The building is 33.73m in NS direction and 29.93m in EW direction in plan and its height is 33.53m. The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration (after performing transfer function) for NS direction are given in Figure no. 4.41.



(a)

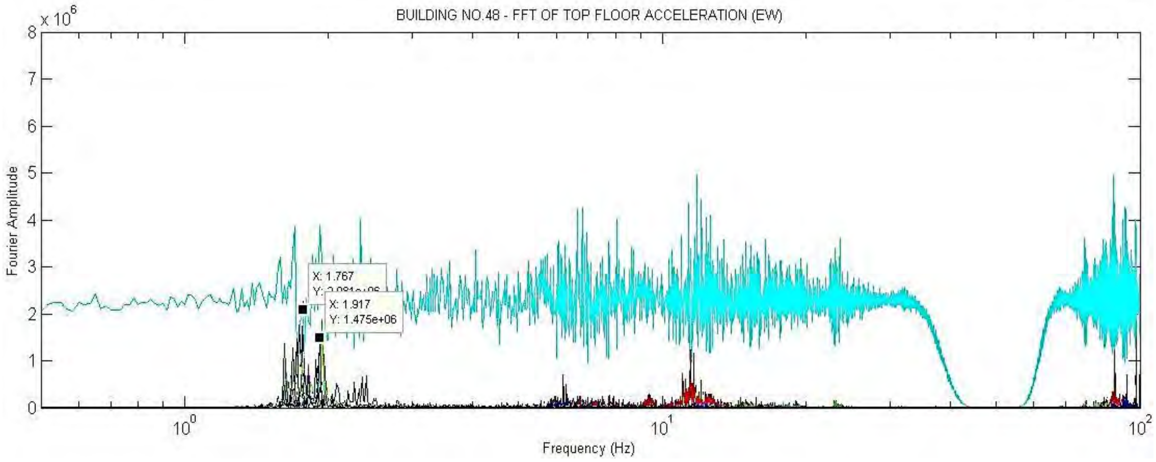
(b)



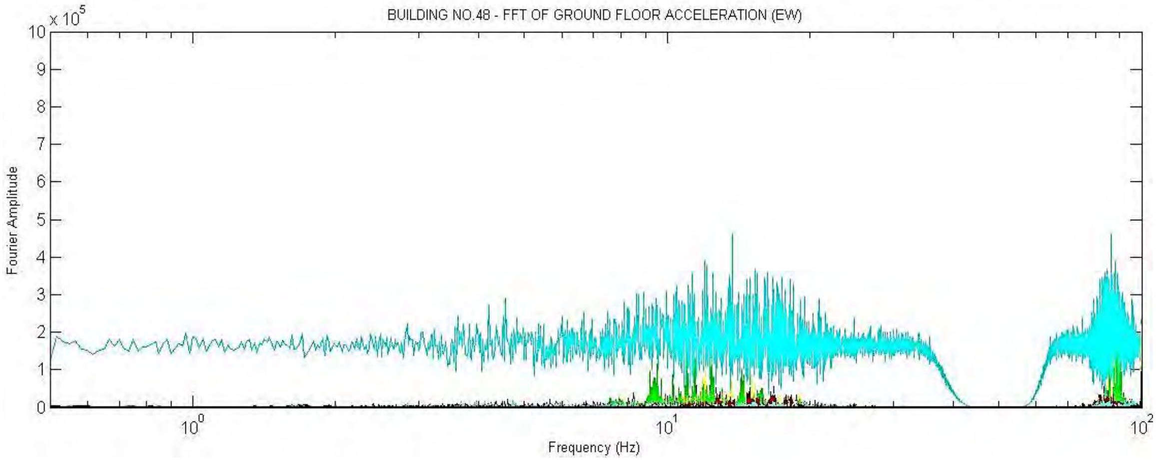
(c)

Figure 4.41: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction 11-storied RCC building

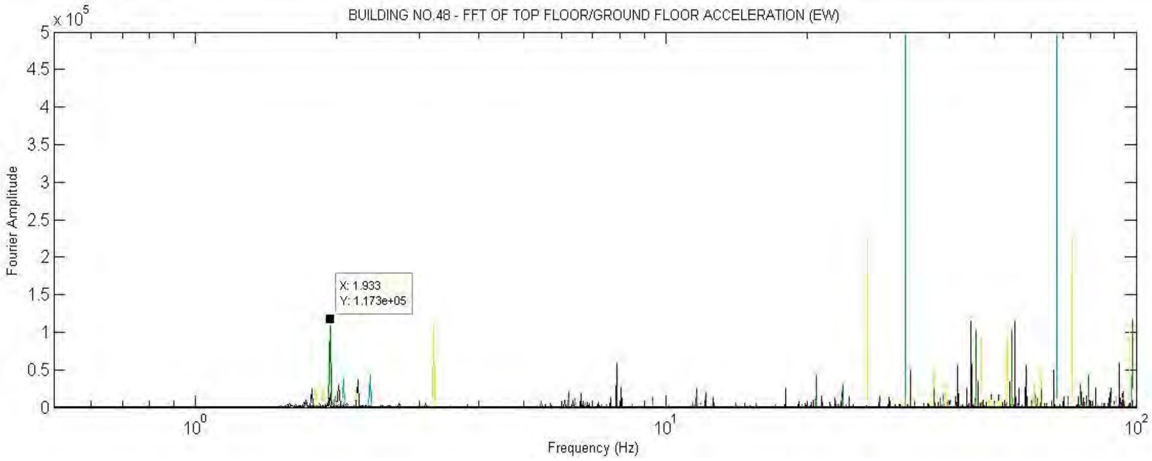
The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration (after performing transfer function) for EW direction are given in Figure no. 4.42.



(a)



(b)



(c)

Figure 4.42: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction 11-storied RCC building

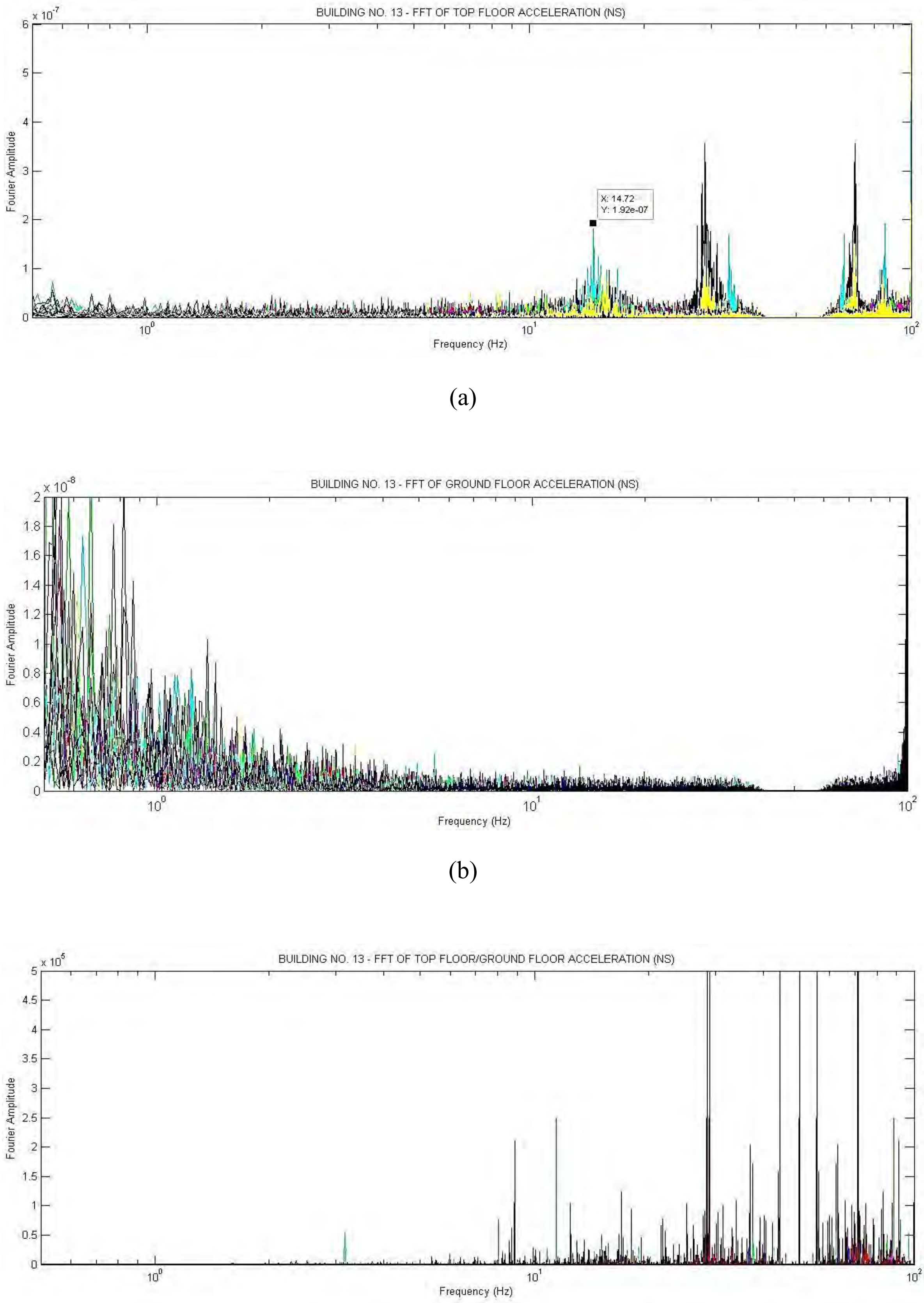
The pre-dominant frequencies obtained from top floor accelerations are 1.817Hz and 1.767Hz and modified top floor accelerations are 1.983Hz and 1.933Hz in NS and EW directions respectively.

4.11 AMBIENT VIBRATIONS TEST RESULTS OF URM BUILDINGS

All modes from top floor, ground floor and from modified top floor accelerations were observed categorically. However, the modes from modified top floor accelerations were not distinct and which might lead to erroneous determination of pre-dominant frequencies. Thus for all the URM buildings under study, pre-dominant frequencies were obtained from the top floor accelerations in both the horizontal cardinal directions.

4.11.1 Ambient Vibrations of Single-Storied URM Buildings

The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration (after performing transfer function) for NS direction of Building no. 13 are given in Figure no. 4.43.



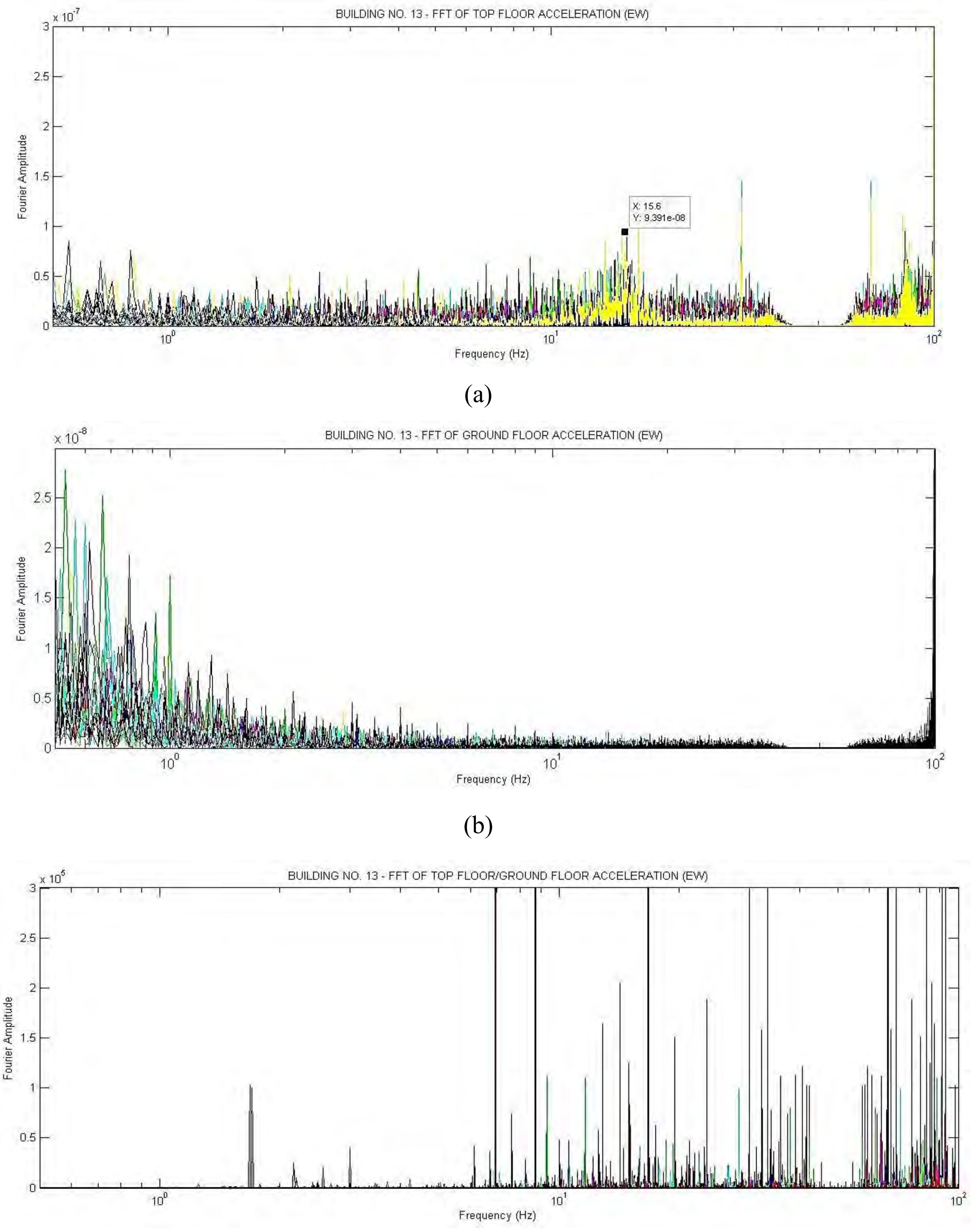
(a)

(b)

(c)

Figure 4.43: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction of Building no. 13

The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration after performing transfer function for EW direction of Building no. 13 are given in Figure no. 4.44.



(a)

(b)

(c)

Figure 4.44: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction of Building no. 13

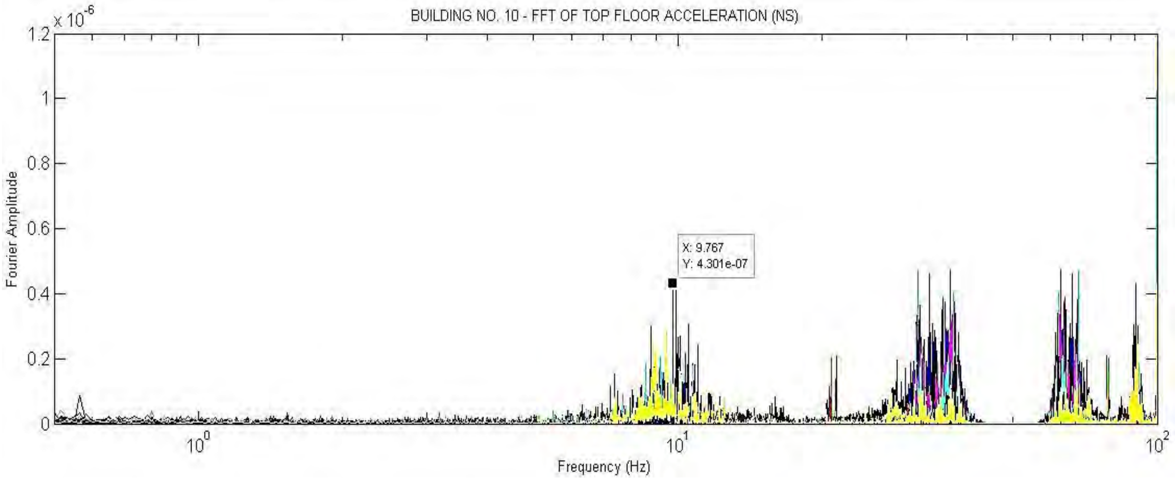
It is noticeable that the pre-dominant frequencies of the single-storied buildings range from 8.767Hz to 17.78 Hz and to get a rough average it is 12.25Hz irrespective of their heights. The pre-dominant frequencies of all the Single-Storied URM Buildings in NS and EW directions are given at Table 4.1.

Table 4.1: Pre-Dominant Frequencies of the Single-Storied URM Buildings

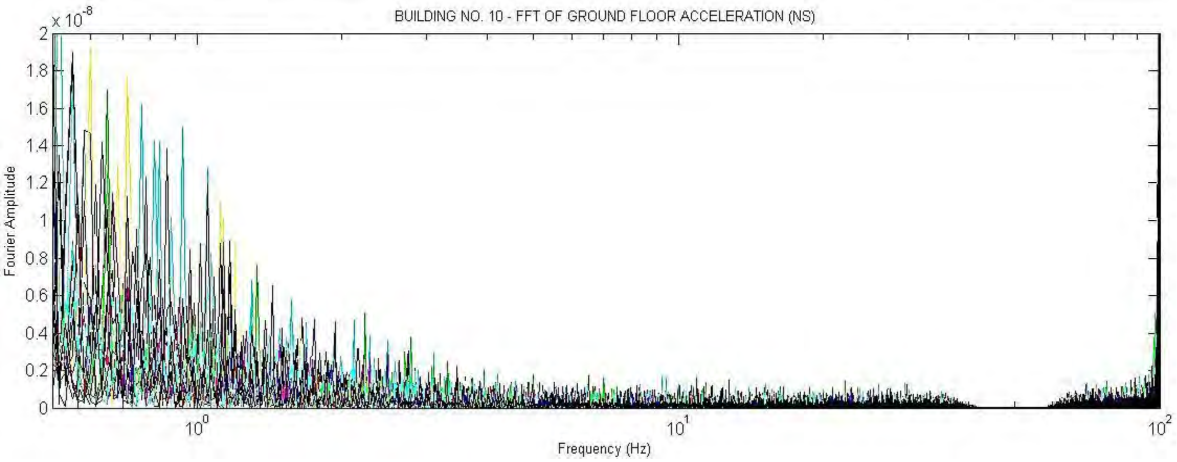
Building No.	Maximum Height at Top Floor from P.L.		Dominant Frequency at Top Floor (Hz)	
	Meter (m)	Feet (Ft)	NS	EW
13	2.59	8.5	14.72	15.60
SLA	3.28	10.75	9.75	10.80
6A	3.81	12.5	15.10	8.767
6B			17.78	11.25
6C	4.57	15	9.95	10.28
8	6.10	20	11.45	11.52

4.11.2 Ambient Vibrations of Two-Storied URM Buildings

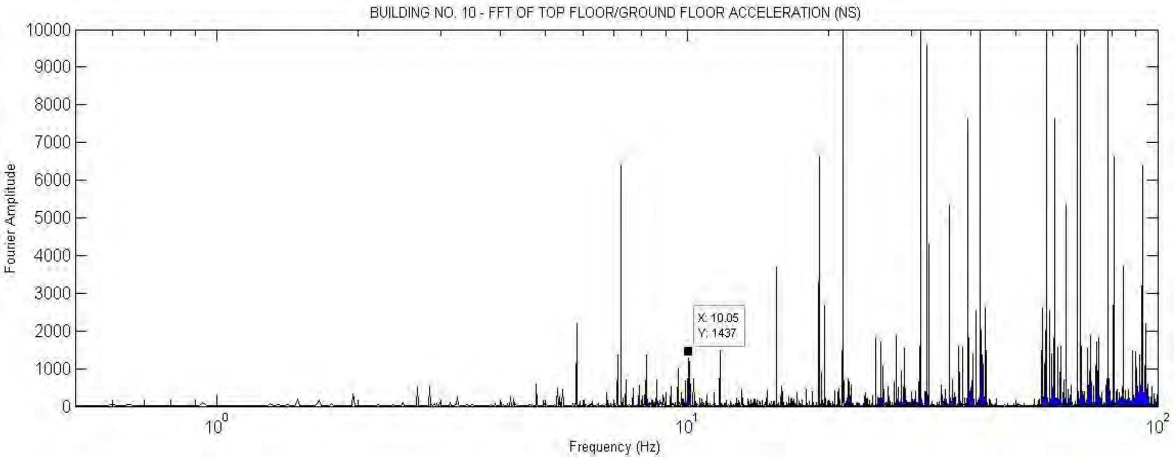
The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration (after performing transfer function) for NS direction of Building no. 10 are given in Figure no. 4.45.



(a)



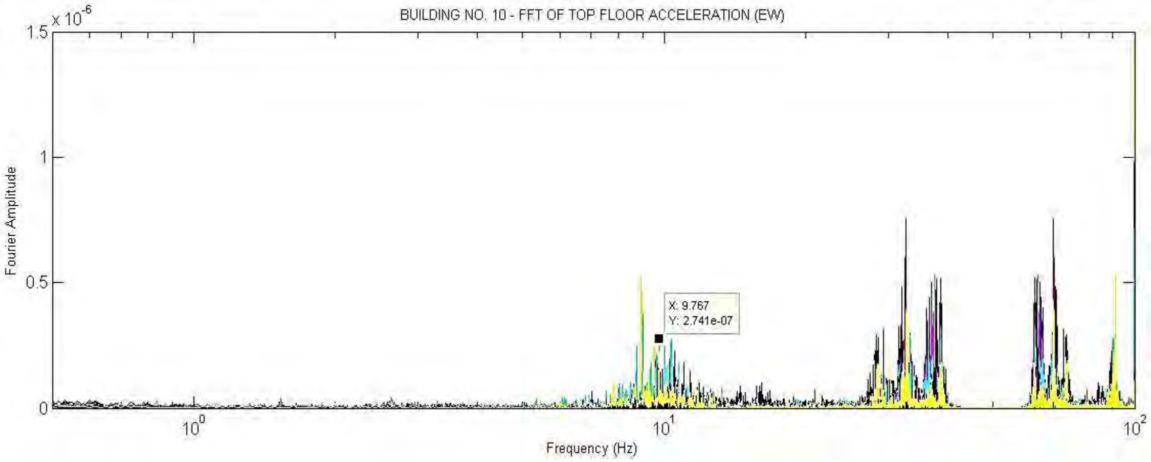
(b)



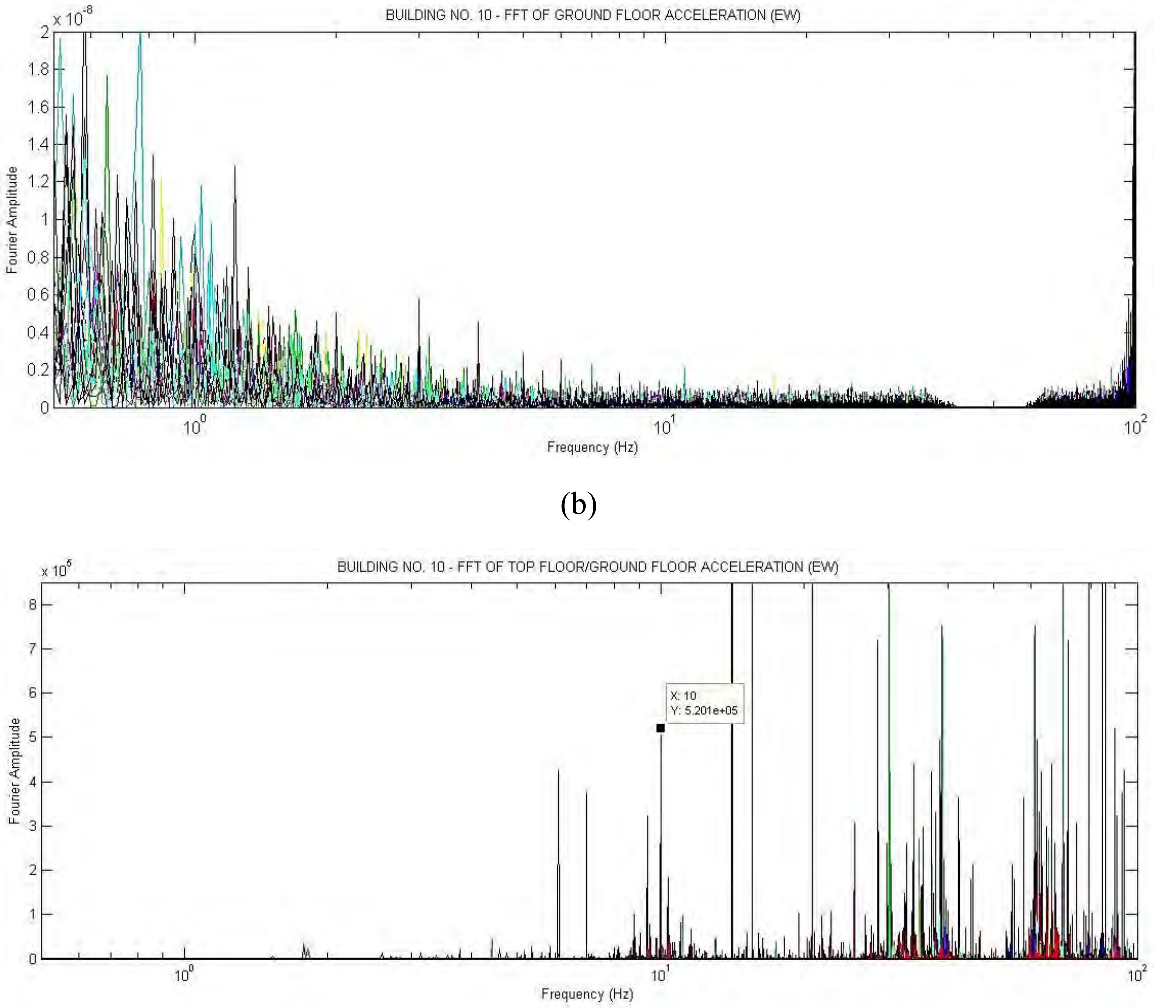
(c)

Figure 4.45: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction of Building no. 10

The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration after performing transfer function for EW direction of Building no. 10 are given in Figure no. 4.46.



(a)



(b)

(c)

Figure 4.46: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction of Building no. 10

The pre-dominant frequencies of all the two-Storied URM Buildings in NS and EW directions are given at Table 4.2.

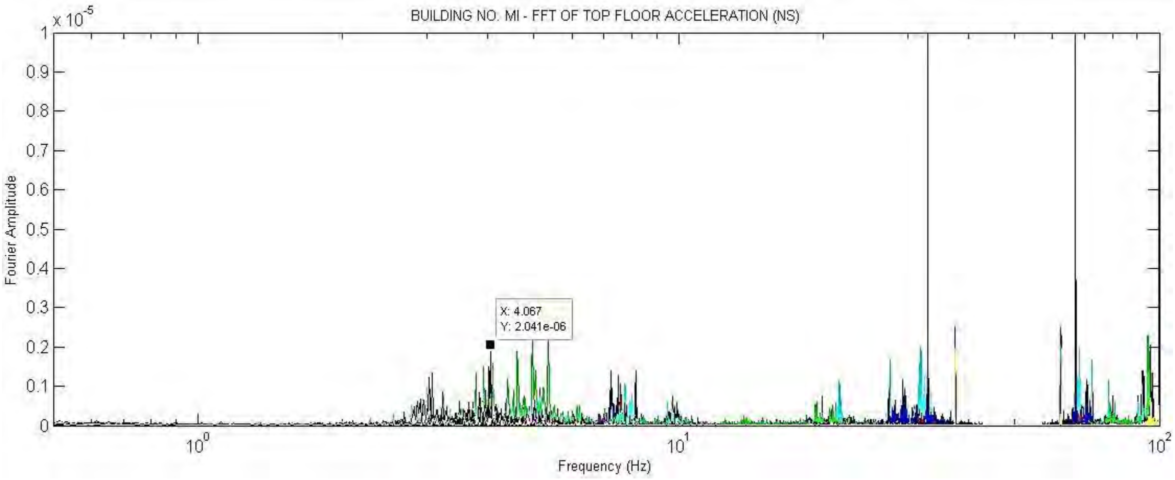
Table 4.2: Pre-Dominant Frequencies of the Two-Storied URM Buildings

Building No.	Maximum Height at Top Floor from P.L.		Dominant Frequency at Top Floor (Hz)	
	Metre (m)	Feet (Ft)	NS	EW
10	6.10	20	9.77	9.77
15A	7.32	24	10.67	6.30
15B			8.87	7.27
18A			3.97	3.85
18B			2.87	3.75

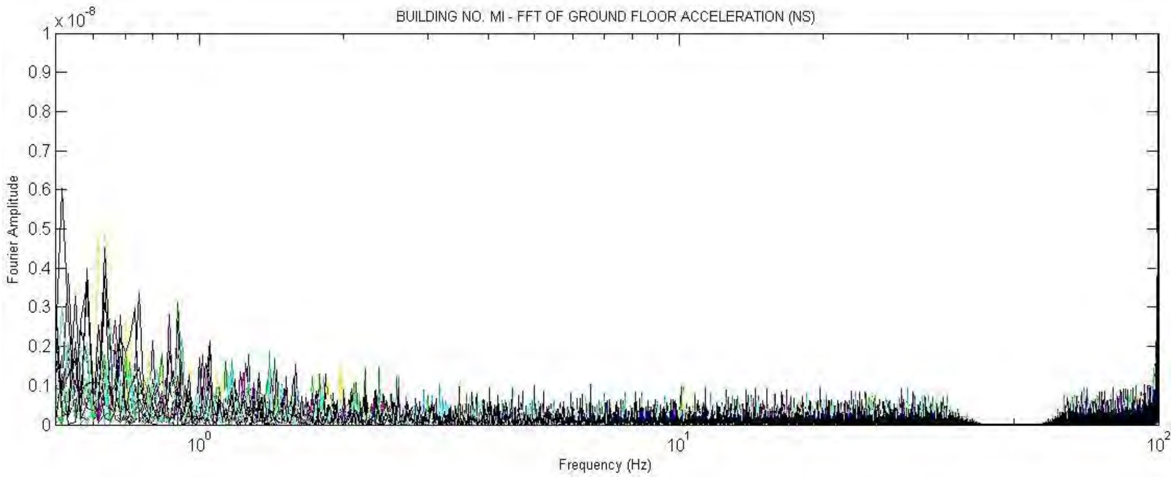
The pre-dominant frequencies of Building no. 18A and 18B were drastically abnormal comparing with pre-dominant frequencies of other two-storied buildings. . It may be due to faulty settings of the instruments or any other unknown reasons. Therefore their data were ignored for the research. It is noticeable that the pre-dominant frequencies of the other three two-storied buildings range from 6.30Hz to 10.67 Hz and to get a rough average it is 8.77Hz irrespective of their heights.

4.11.3 Ambient Vibrations of Three-Storied URM Buildings

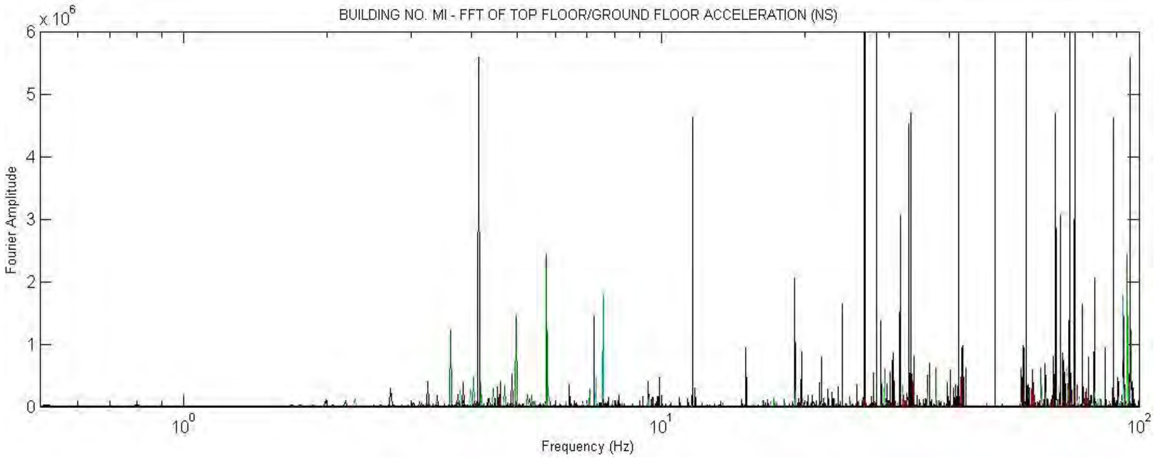
The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration (after performing transfer function) for NS direction of Building no. 2 are given in Figure no. 4.47.



(a)



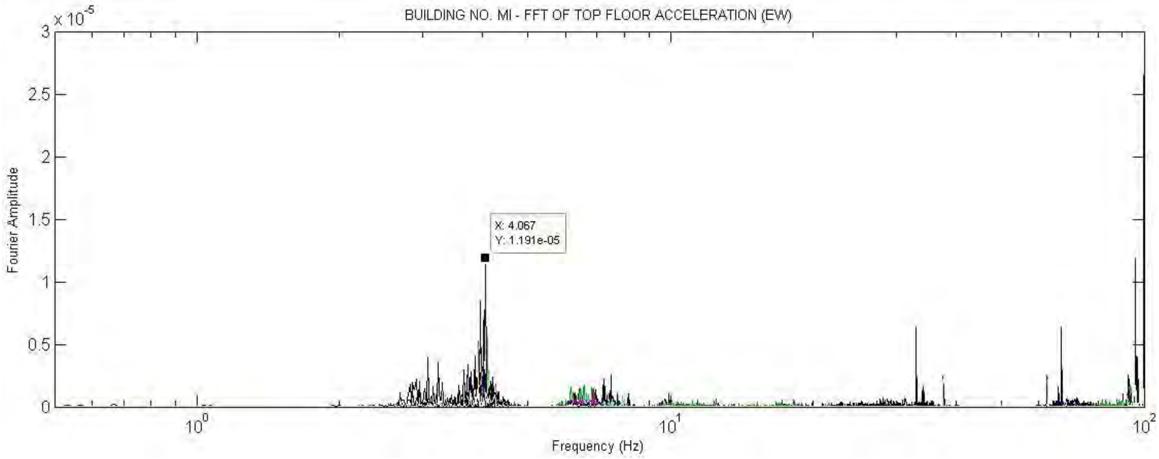
(b)



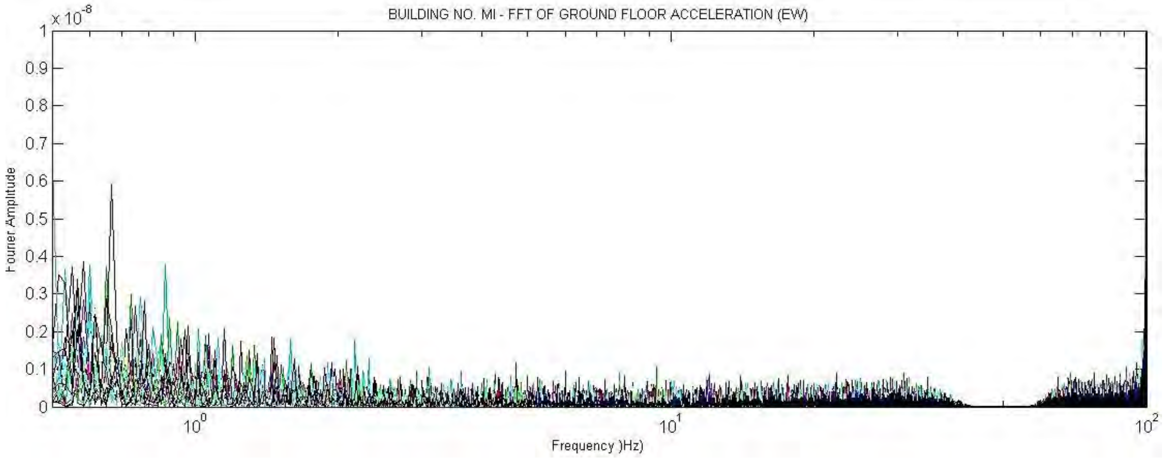
(c)

Figure 4.47: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction of Building no. 2

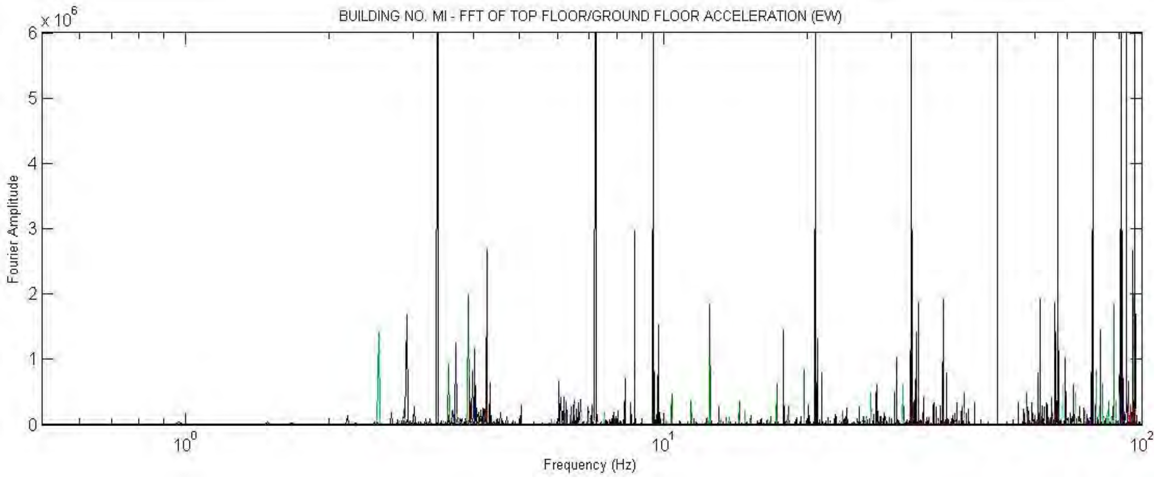
The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration after performing transfer function for EW direction of Building no. 2 are given in Figure no. 4.48.



(a)



(b)



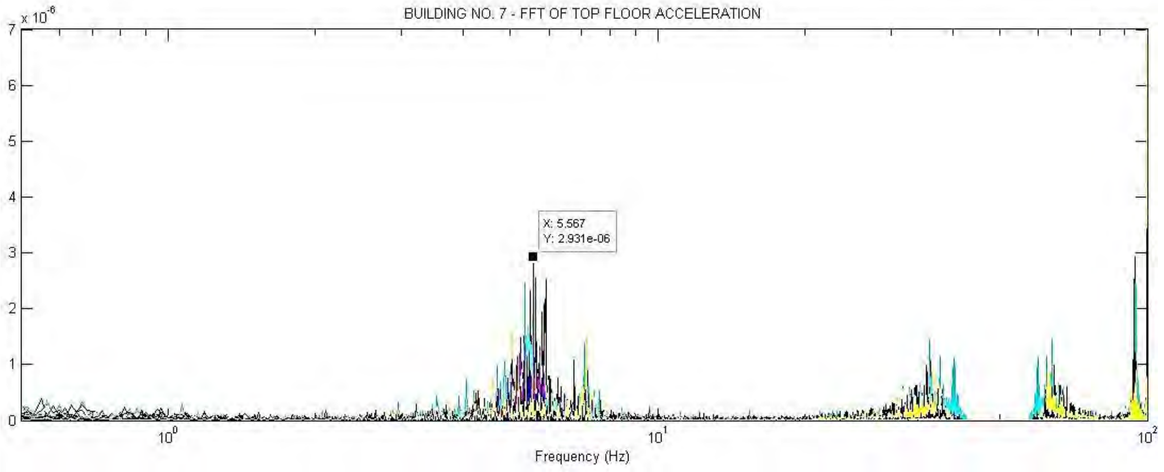
(c)

Figure 4.48: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction of Building no. 2

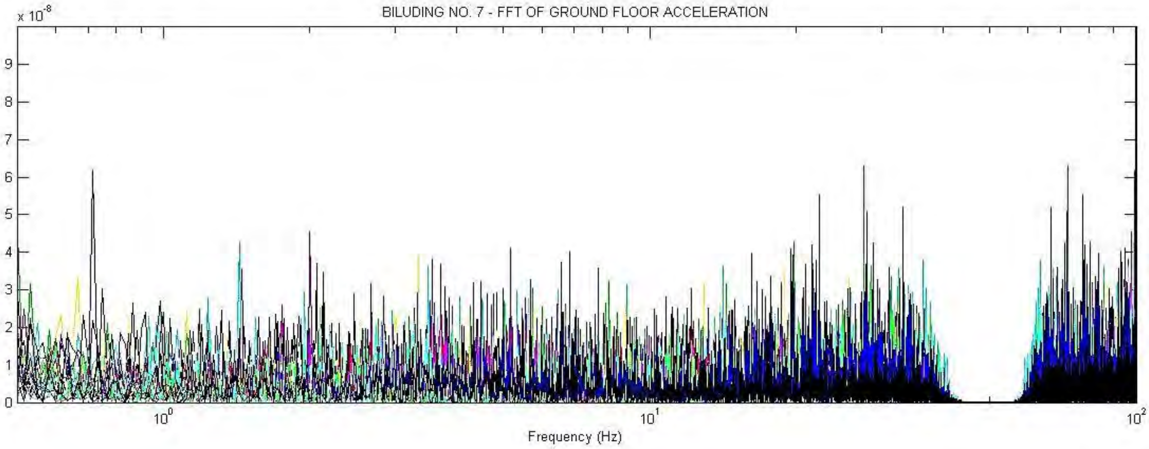
It is noticeable that the pre-dominant frequencies of the three-storied are coincidently 4.087Hz in both the NS and EW directions.

4.11.4 Ambient Vibrations of Four-Storied URM Buildings

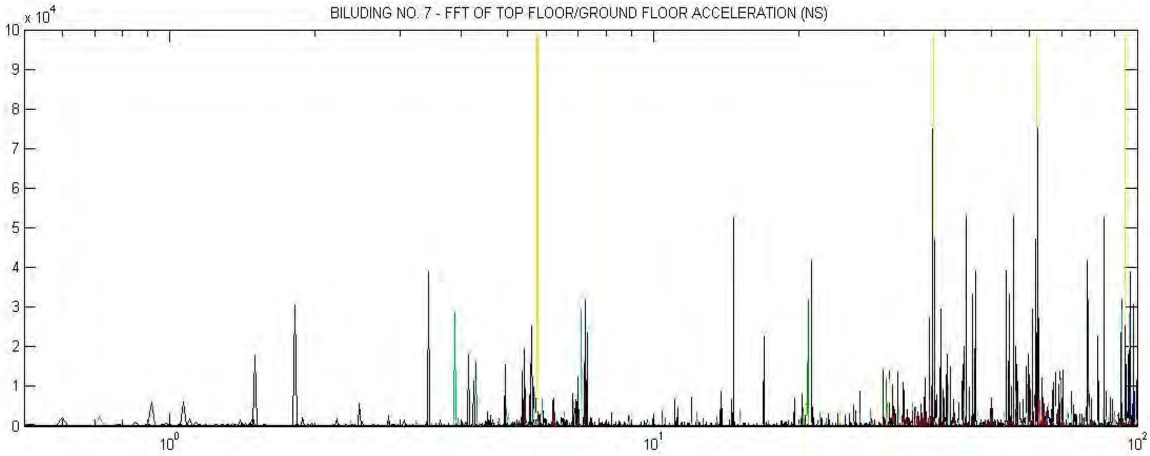
The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration (after performing transfer function) for NS direction of Building no. 7 are given in Figure no. 4.49.



(a)



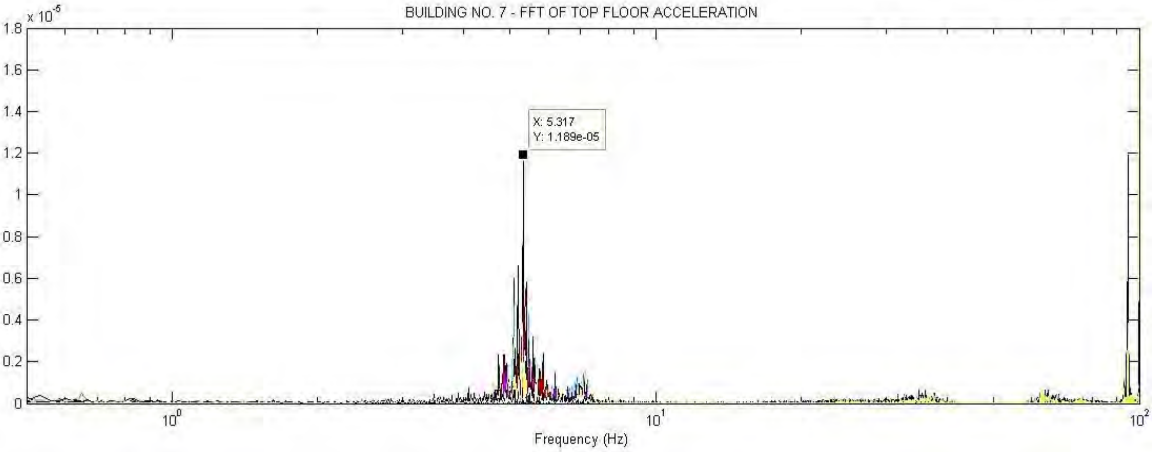
(b)



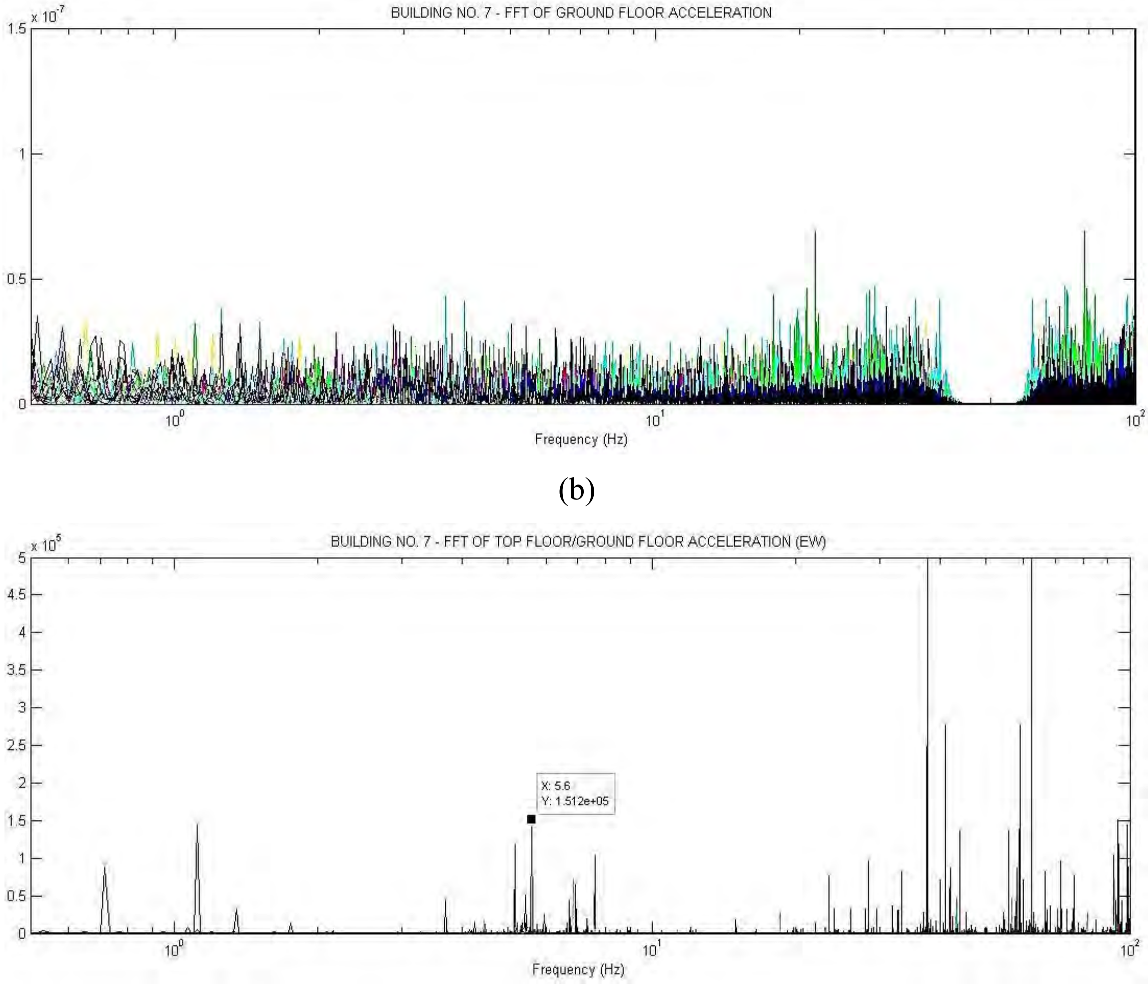
(c)

Figure 4.49: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction of Building no. 7

The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration after performing transfer function for EW direction of Building no. 13 are given in Figure no. 4.50.



(a)



(b)

(c)

Figure 4.50: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction of Building no. 7

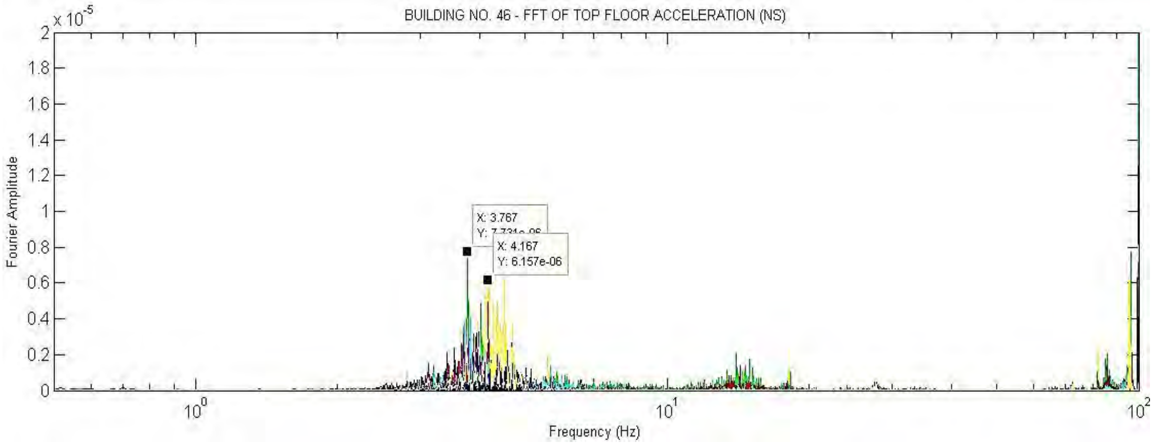
It is noticeable that the pre-dominant frequencies of the four-storied buildings range from 3.70z to 6.62 Hz and to get a rough average it is 4.91Hz irrespective of their heights. The pre-dominant frequencies of all the four-Storied URM buildings in NS and EW directions are given at Table 4.3.

Table 4.3: Pre-Dominant Frequencies of the Four-Storied URM Buildings

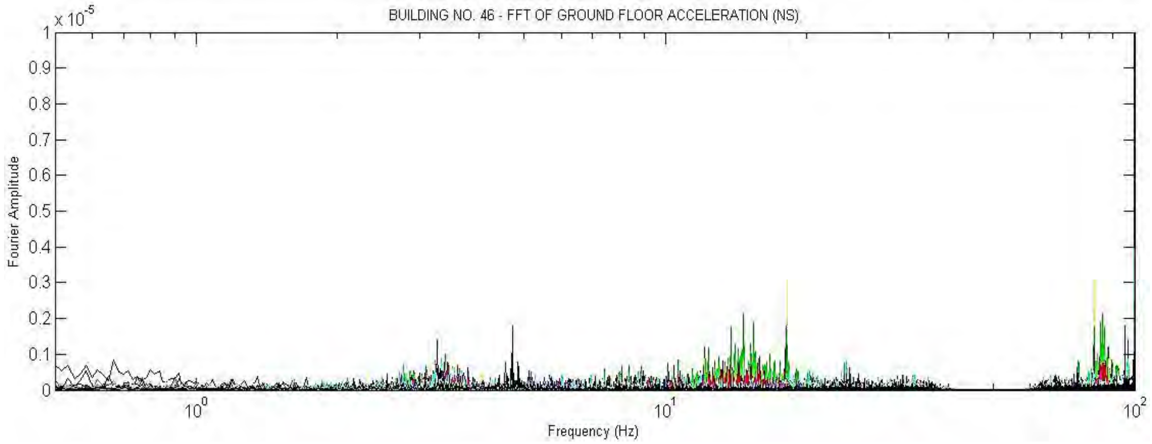
Building No.	Maximum Height at Top Floor from P.L.		Dominant Frequency at Top Floor (Hz)	
	Metre (m)	Feet (Ft)	NS	EW
7	12.192	40	5.57	5.32
11			6.62	3.70
9A	14.64	48	5.283	3.833
9B			5.133	3.75

4.11.5 Ambient Vibrations of Five-Storied URM Buildings

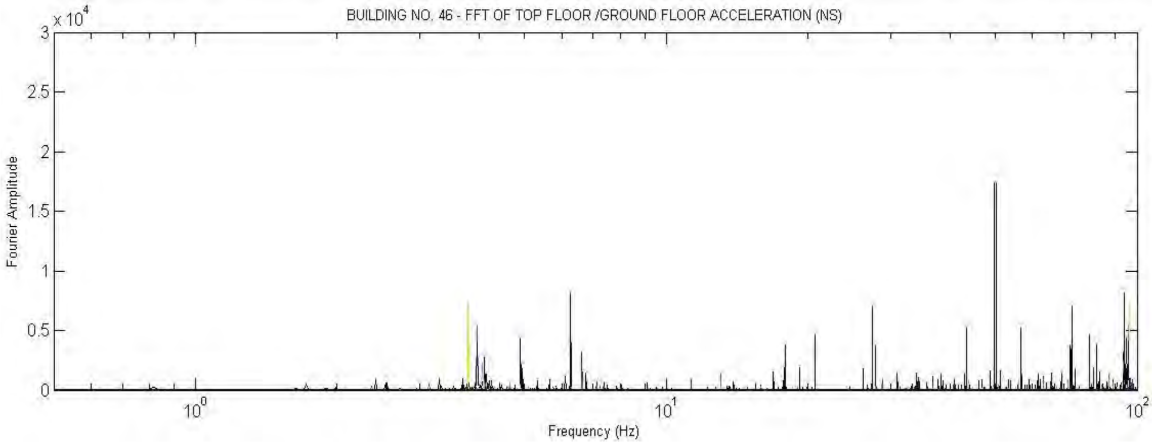
The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration (after performing transfer function) for NS direction of Building no. 46 are given in Figure no. 4.51.



(a)



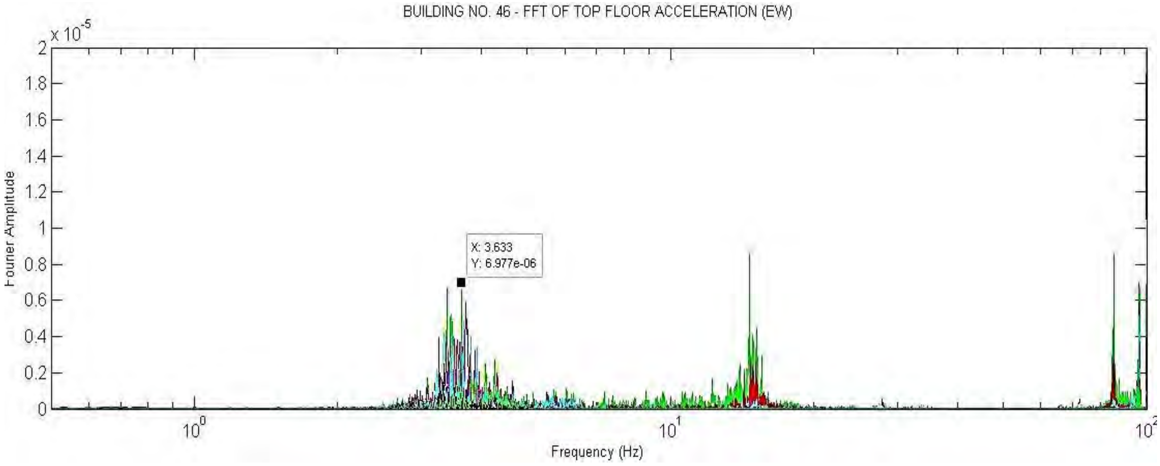
(b)



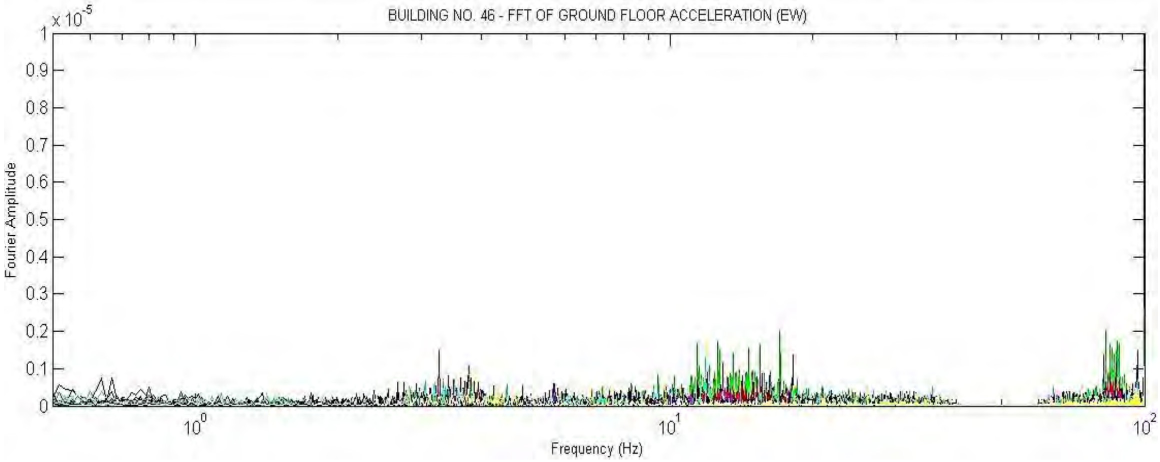
(c)

Figure 4.51: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction of Building no. 46

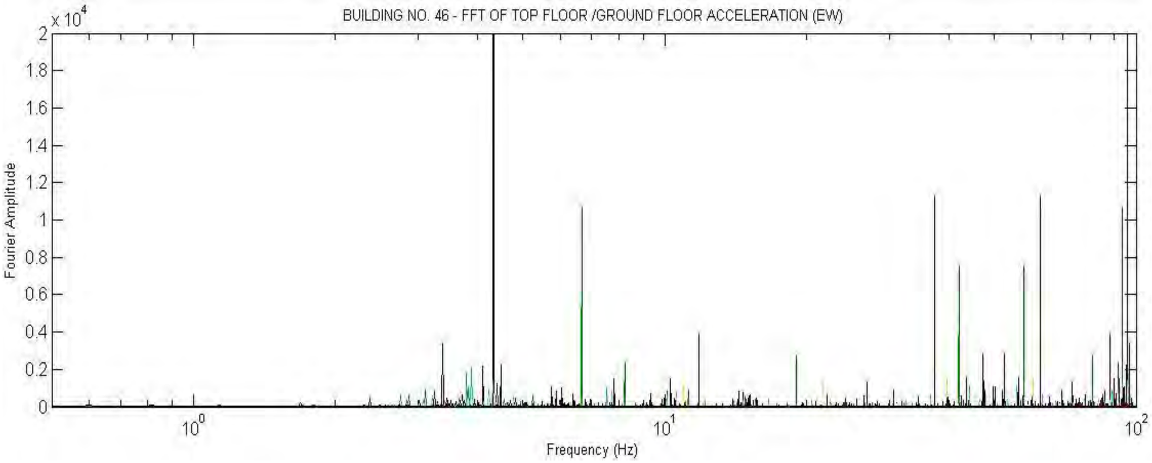
The frequency spectra of top floor and ground floor accelerations and frequency spectra of modified top floor acceleration after performing transfer function for EW direction of Building no. 46 are given in Figure no. 4.52.



(a)



(b)



(c)

Figure 4.52: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction of Building no. 46

It is noticeable that the pre-dominant frequencies of the five-storied building are 3.70Hz and in 3.63Hz the NS and EW directions respectively.

It is worth mentionable that the modal shapes and the pre-dominant frequencies become more and more distinct with the increase of structure's height.

The FFT outputs in figures for the all URM buildings are given at Appendix D. A summary of the pre-dominant frequencies of the all URM buildings are given at Appendix E which will be subsequently discussed. Basing on the pre-dominant frequencies obtained from frequency spectra, the structural periods and regression results are discussed in the next chapter.

4.12 LIMITATIONS OF THE RESEARCH

a. Main limitation of this study is number of primary AVT data for the analysis process. AVT data of seventeen URM buildings from only four locations in the Dhaka city are planned to be collected and be analyzed. The height of buildings ranges from 2.59m to 15.24m and in stories ranges from one to five stories.

b. The selected URM buildings are of varying ages, as the construction years varied from 1972 to 1990. Thus they have varying quality of workmanships and the construction. No measuring tool was available to measure quality of workmanship and construction.

c. From the ground survey variations are found only in the height and the total length of walls of structures. However being practically significant, other structural parameters i.e. thickness of walls, thickness of slabs, and types of foundations cannot be considered in the analyses, because considerable number of variations is not found in these structural parameters. Again the dissimilarities in construction materials cannot be ascertained due to ages and occupancies of the buildings.

CHAPTER FIVE

STATISTICAL ANALYSIS

5.1 GENERAL

Among all the relations the relation between the structural period, height and total length of walls of structures are very significant. Again variations in thickness of RC slab or the load bearing walls could not be found. As such structural period, height and total length of walls of structures are taken to determine a relation among these three variables as the basic variables input to SPSS. The analyses performed by SPSS are discussed in separate two sections basing on the experimental structural period data of NS (principal) direction and EW (non-principal) direction considering the walls of URM buildings.

5.2 ANALYSIS TAKING EXPERIMENTAL STRUCTURAL PERIOD DATA OF NS DIRECTION

5.2.1 Pearson Correlation (r) between All Variables

The bivariate Pearson correlation indicates the following:

- Whether a statistically significant linear relationship exists between the continuous variables.
- The strength of a linear relationship (i.e., how close the relationship is to being a perfectly straight line).
- The direction of a linear relationship (increasing or decreasing).

A bivariate correlation analysis is performed to get the Pearson Correlation between all the selected variables i.e. structural period, height and total length of walls of structures. The bivariate Pearson correlation obtained is shown in the Table 5.1.

Table 5.1: Bivariate Pearson Correlation between Structural Period, Height and Total Length of Walls of Structures (Experimental Structural Period Data of NS Direction)

		structural period	height	total length of walls
structural period	Pearson Correlation	1	.936(**)	.944(**)
	Sig. (2-tailed)	.	.000	.000
	N	10	10	10
height	Pearson Correlation	.936(**)	1	.892(**)
	Sig. (2-tailed)	.000	.	.001
	N	10	10	10
total length of walls	Pearson Correlation	.944(**)	.892(**)	1
	Sig. (2-tailed)	.000	.001	.
	N	10	10	10

** Correlation is significant at the 0.01 level (2-tailed)

The r value between structural period and height is 0.936 and between structural period and total length of walls is 0.944. Again between height and total length of walls is 0.892. As the r values mentioned above are close to 1, it means that there are strong relationships between the variables.

Besides the variables are positively correlated i.e. each pair of variables is proportional. In general terms, this means that as one variable increases in value, the second variable also increase in value. Similarly, as one variable decreases in value, the second variable also decreases in value.

Again maximum sig. (2-tailed) value is 0.001 i.e. 0.1% (much less than 0.01 i.e. 1%) that is there are statistically significant correlations between each pair of variables. That means, increases or decreases in one variable do significantly relate to increases or decreases in the second variable. Thus potentiality of forming a relation between the three variables is very high.

5.2.2 Determining Outliers from the Data of the Variables

A boxplot analysis is conducted to determine any outliers from the data of the three variables. It is found no data out of 30 data (10 each from each of the three variables) is an outlier. The box plot is given at Appendix F.

5.2.3 Curve Estimation of Each Pair of Variables

Curve estimation separately for structural period versus height of structures and structural period versus total length of walls of structures are performed. The purpose is to find out a functional form for the data used. This module can compare linear, logarithmic, inverse, quadratic, cubic, power, compound, S-curve, logistic, growth, and exponential models based on their relative goodness of fit where a single dependent variable is predicted by a single independent variable.Data of important aspects of the curve estimation for structural period versus height of structures are given in Table 5.3. Beneath that the curve estimation plots are given in Figure No. 5.1.

Table 5.2: Important Aspects of the Curve Estimation for Structural Period versus Height of the Structures (Experimental Structural Period Data of NS Direction)

Serial	Method (Mth)	R sq	Sigf
1.	**LIN**	**.876**	**.000**
2.	LOG	.738	.001
3.	INV	.532	.017
4.	**QUA**	**.920**	**.000**
5.	**CUB**	**.921**	**.001**
6.	COM	.867	.000
7.	POW	.781	.001
8.	S	.605	.008
9.	GRO	.867	.000
10.	EXP	.867	.000
11.	LGS	.867	.000

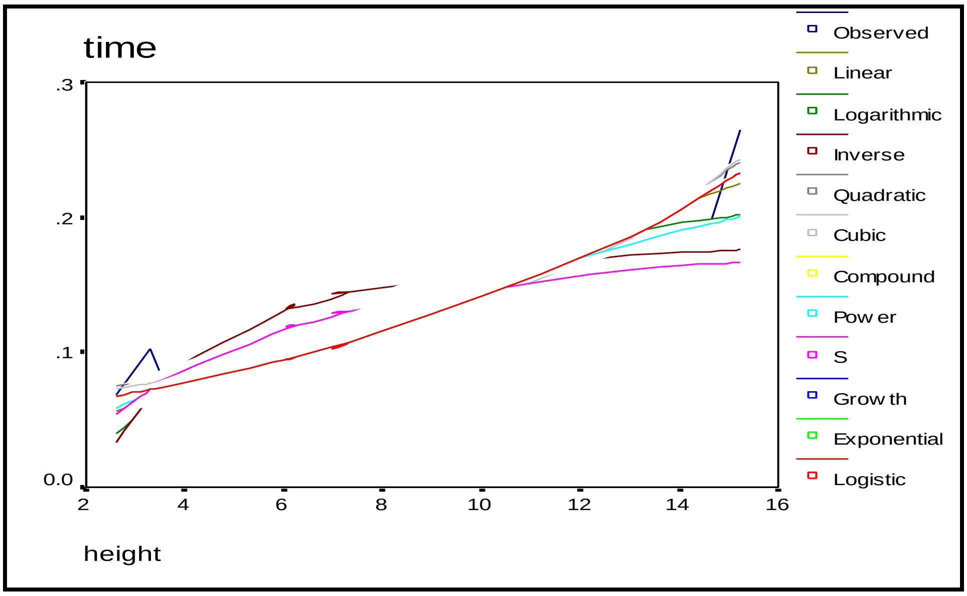


Figure 5.1: Curve Estimation Plots for Structural Period (NS Direction) versus Height of Structures

Considering the R-sq and sigf value it is observed that the cubic, quadratic and linear functional forms are the best three among all functional forms presented in Table 5.2 and displayed in Figure 5.1.

Data of important aspects of the curve estimation for structural period versus total length of walls of structures are given in Table 5.3. Beneath that the curve estimation plots are given in Figure No. 5.2.

Table 5.3: Important Aspects of the Curve Estimation for Structural Period versus Total Length of Walls of the Structures (Experimental Structural Period Data of NS Direction)

Serial	Method (Mth)	R sq	Sigf
1.	**LIN**	**.891**	**.000**
2.	LOG	.673	.004
3.	INV	.297	.103
4.	**QUA**	**.894**	**.000**
5.	**CUB**	**.956**	**.000**
6.	COM	.787	.001
7.	POW	.667	.004
8.	S	.307	.097
9.	GRO	.787	.001
10.	EXP	.787	.001
11.	LGS	.787	.001

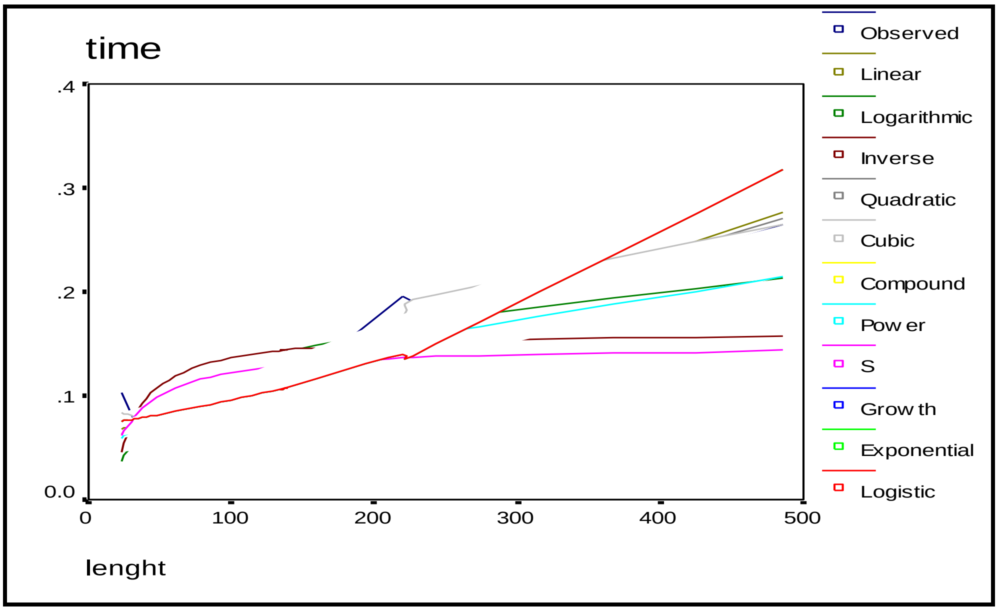


Figure 5.2: Curve Estimation Plots for Structural Period (NS Direction) versus Total Length of Walls of Structures

Considering the R-square and sigf value it is observed that the cubic, quadratic and linear functional forms are the best three among all functional forms presented in Table 5.3 and displayed in Figure 5.2. The details of the curve estimation i.e. curve fit is given at Appendix G.

5.2.4 Approaches of Analysis to Reach a Final Model

On the basis of the R-sq (R^2) values obtained with the MS Excel plot and curve estimation or curve fit analysis by SPSS 11.5 following approaches are taken:

a. Approach 1: Empirical Model with the consideration that DV i.e. structural period is a cubic function of both the IVs i.e. height of structures and total length of walls, separately.

b. Approach 2: Empirical Model with the consideration that DV i.e. structural period is a quadratic function of both the IVs i.e. height of structures and total length of walls, separately.

c. Approach 3: Empirical Model with the consideration that DV i.e. structural period is a quadratic function of height of structures and is having a linear function of total length of walls, separately.

These three approach types will be analyzed in three different sections separately.

5.2.5 Approach 1

The cubic functions of structural period (T) in seconds with the height (H) in meter of the structures will be followings:

$T = a + a_1H+a_2H^2+a_3H^3$ (8)

The cubic functions of structural period (T) in seconds with the total length of walls (L) in meter of the structures will be followings:

$T = b + b_1L+b_2L^2+b_3L^3$ (9)

The objective of this analysis is to correlate and combine equation (8) and (9) together to obtain a single equation where T = f (H, L). So the IVs are H, H^2, H^3, L, L^2 and L^3. The variables will be analyzed by four methods first. Then suitable method or methods will be chosen up to the end to get better and reasonable result. If the overall and individual significance of the model and variables remain below 5% level then the variables will be observed for practical significance. The practical significance is judged by coefficient sign (+/-). The sign of coefficient must be same as it is in reality. If any IV is such that increase of it increases the DV then the coefficient sign must be positive.

All the output tables of the four methods are illustrated at Appendix H. The important tables from the methods are discussed in details in the following paragraphs.

5.2.5.1 Model by Enter Method

The Enter Regression has produced a single model automatically as the Table 5.5 shows that. The model excluded the H^2 variable finding its significance 0.648 i.e. 64.8%. The important tables from the enter method are as follows:

Table 5.4: Correlations between the Variables (Enter Method, Approach 1, NS)

		T	H	H^2	H^3	L	L^2	L^3
Pearson Correlation	T	1.000	.936	.958	.957	.947	.888	.821
	H	.936	1.000	.984	.957	.897	**.759**	**.662**
	H^2	.958	.984	1.000	.993	.910	.804	**.718**
	H^3	.957	.957	.993	1.000	.906	.827	**.752**
	L	.947	.897	.910	.906	1.000	.960	.909
	L^2	.888	**.759**	.804	.827	.960	1.000	.989
	L^3	.821	**.662**	**.718**	**.752**	.909	.989	1.000

From the table above it is observed that the Pearson Correlation between H and L^2, H and L^3, H^2 and L^3, H^3 and L^3 are not convincing. It means that the variables as mentioned are not strongly associated with each other which may generate erroneous result.

Table 5.5: Model Summary (Enter Method, Approach 1, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.990	.981	.957	.01369	2.830

Referring to Table 5.5, the value of R^2 and Adjusted R^2 are 0.981 and 0.957. There is no considerable change between R^2 and Adjusted R^2. This means that considering even the adjusted R^2 the model can explain 95.7% of the variability with the 7 variables. The Standard Error (SE) 0.01369 i.e. about 1.4% which is very small in regards to the DV in question. However the Durbin-Watson value 2.83 is more than the maximum value of 2.5, which indicates strong negative serial correlation and some autocorrelation exist between the variables considered. It may lead to impractical test results.

Table 5.6: ANOVA (Enter Method, Approach 1, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.038	5	.008	40.878	.002(a)
	Residual	.001	4	.000		
	Total	.039	9			

a. Predictors: (Constant), L^3, H, H^3, L, L^2

Referring to Table 5.6, the F ratio for degree of freedom (df) 5 and 4 is 40.878 which is more or less acceptable with 0.002 level of significance (Confidence Interval 99.8%). That means the overall model is significant. If p (sig.) value is less than or equal to 0.05 than F ratio will always be significant.

Table 5.7: Coefficients (Enter Method, Approach 1, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.064	.021		2.969	.041
	H	.018	.009	1.286	2.014	**.114**
	H^3	-2.163E-05	.000	-.443	-.948	**.397**
	L	-.002	.001	-3.237	-2.154	**.098**
	L^2	7.278E-06	.000	7.941	2.353	**.078**
	L^3	-8.580E-09	.000	-4.607	-2.176	**.095**

Referring to Table 5.7, the only constant is significant at 5% level. Other variables are not significant as shown in the last column (Sig.). Necessity of checking other values is of no use. So the model cannot be accepted with all these variables.

Concluding Remarks of the Model by Enter Method

Model cannot be accepted as individual level of significance of each variable crossed 5%.

5.2.5.2 Model by Stepwise Regression Method

IVs are included in the model successively one after another. Table 5.8 shows that the Stepwise Regression has produced two models automatically. The important tables from the Stepwise Regression method are as follows:

Table 5.8: Variables Entered/Removed (Stepwise Method, Approach 1, NS)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	L^2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

The Table 5.8 shows that this method only considered the H^2 and L^2 variables others are removed from the process.

Table 5.9: Model Summary (Stepwise Method, Approach 1, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.958(a)	.918	.908	.01999	
2	.978(b)	.957	.945	.01550	2.981

Referring to Table 5.9, the value of R^2 and Adjusted R^2 of the last model i.e. model serial 2, are 0.957 and 0.945. There is no considerable change between R^2 and Adjusted R^2. It means that considering even the adjusted R^2 the model can explain 94.5% of the variability with the 3 variables. The Standard Error (SE) 0.0155 i.e. about 1.6% which is very small in regards to the DV in question. However the Durbin-Watson value 2.981 is more than the maximum value of 2.5, which indicates strong negative serial correlation and some autocorrelation exist between the variables considered. It may lead to impractical test results due to generation of multi-collinearity problem.

It is mentionable referring to the 'Notes to SPSS' that the model generated by SPSS automatically meet few assumptions during the analysis process as in this case.

Table 5.10: ANOVA (Stepwise Method, Approach 1, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			
2	Regression	.037	2	.019	77.853	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

a. Predictors: (Constant), H^2
b. Predictors: (Constant), H^2, L^2

Referring to Table 5.10 in the last model i.e. model serial 2, the F ratio for degree of freedom (df) 2 and 7 is 77.853 which is acceptable with 0.000 level of significance (Confidence Interval 99.99%). That means the overall model is significant. If p (sig.) value is less than or equal to 0.05 than F ratio will always be significant.

Table 5.11: Coefficients (Stepwise Method, Approach 1, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.066	.009		7.426	.000
	H^2	.001	.000	.958	9.474	.000
2	(Constant)	.071	.007		9.904	**.000**
	H^2	.001	.000	.692	5.243	**.001**
	L^2	3.039E-07	.000	.332	2.513	**.040**

Referring to Table 5.11, in the last model i.e. model serial 2, all the variables are significant (p value less than 0.05) as less than 5% level shown in the last column (Sig.). So the model can be accepted with all these variables. Now practical significance is checked in the next paragraph.

Practical Significance

Referring to Table 5.11, in 2nd model each of the variables is individually significant below 5% level. Again all the coefficients are positive i.e., if H^2 increases the L^2 will also increase and vice versa. So, model can be accepted.

Concluding Remarks of the Models with Stepwise Regression

Model 2 may be accepted with $R^{2\,=}$ 0.957 and SE = 0.0155.

5.2.5.3 Model with Backward Elimination Method

Table 5.13 shows that the Backward Elimination Method of Regression has produced two models automatically. At the first model all the IVs excluding H^2 are included in the model. In the each successive step single variable is removed one after another depending on p value greater than or equal to 0.100. It removes the variable first whose P value is maximum. From Table 5.7 (Coefficient of Enter Method) it is seen that H^3 has maximum P value (0.397), so it is removed in the second model. Again the H^2 is excluded from this analysis. The important tables from the Backward Elimination method are as follows:

Table 5.12: Variables Entered/Removed (Backward Method, Approach 1, NS)

Model	Variables Entered	Variables Removed	Method
1	L^3, H, H^3, L, L^2(a)	.	Enter
2	.	H^3	Backward (criterion: Probability of F-to-remove >= .100).

Table 5.13: Model Summary (Backward Method, Approach 1, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.990(a)	.981	.957	.01369	
2	.988(b)	.976	.958	.01355	2.892

Referring to Table 5.13 the values of R^2 of model 1 and 2 are 0.981 and 0.976 respectively. Corresponding Adjusted R^2 of model 1 is 0.957 and for other model it is almost same (0.958). There is no considerable change between R^2 and Adjusted R^2. This means that the models can explain more than 97.6% of the variability. Corresponding Standard Errors (SE) are 0.01369 and 0.01355 which are very small in regards to the DV in question. It is confirmed that all the models are good having fractional variation in goodness of fit and SE. However model two is better of the two.

Durbin-Watson value 2.892 is more than the maximum value of 2.5, which indicates strong negative serial correlation and some autocorrelation exist between the variables considered. It may lead to impractical test results due to generation of multi-collinearity problem.

Table 5.14: ANOVA (Backward Method, Approach 1, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.038	5	.008	40.878	.002(a)
	Residual	.001	4	.000		
	Total	.039	9			
2	Regression	.038	4	.010	51.934	.000(b)
	Residual	.001	5	.000		
	Total	.039	9			

Referring to Table 5.14, the F ratio of model serial 2 is more acceptable with 0.000 level of significance (Confidence Interval 99.99%) than the first one.

Table 5.15: Coefficients (Backward Method, Approach 1, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.064	.021		2.969	.041
	H	.018	.009	1.286	2.014	**.114**
	H^3	-2.163E-05	.000	-.443	-.948	**.397**
	L	-.002	.001	-3.237	-2.154	**.098**
	L^2	7.278E-06	.000	7.941	2.353	**.078**
	L^3	-8.580E-09	.000	-4.607	-2.176	**.095**
2	(Constant)	.074	.019		3.951	.011
	H	.011	.004	.745	2.637	.046
	L	-.001	.000	-2.107	-2.327	**.067**
	L^2	5.233E-06	.000	5.709	2.385	**.063**
	L^3	-6.336E-09	.000	-3.402	-2.030	**.098**

Referring to Table 5.15, only the constant in first model and constant and H in the second model are individually statistically significant (below 5% level). None of the models can be accepted with all these variables.

Practical Significance

Referring to Table 5.15, the first model has all variables' individually insignificant above 5% level. In the second model the coefficients of L and L^3 is negative i.e., if these value is decreased the value of H and L will increase and vice versa. In real world it is never true. So we cannot accept the model from the point of view of its practical significance.

Concluding Remarks of the Models with Backward Elimination

None of the models are acceptable because they do not qualify both statistically and in practical significant.

5.2.5.4 Model with Forward Selection Method

The important tables from the Forward Selection method are as follows:

Table 5.16: Variables Entered/Removed (Forward Method, Approach 1, NS)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Forward (Criterion: Probability-of-F-to-enter <= .05)
2	L^2	.	Forward (Criterion: Probability-of-F-to-enter <= .05)

Table 5.17: Model Summary (Forward Method, Approach 1, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.958(a)	.918	.908	.01999	
2	.978(b)	.957	.945	.01550	2.981

Table 5.18: ANOVA (Forward Method, Approach 1, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			
2	Regression	.037	2	.019	77.853	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

Table 5.19: Coefficients (Forward Method, Approach 1, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.066	.009		7.426	.000
	H^2	.001	.000	.958	9.474	.000
2	(Constant)	.071	.007		9.904	.000
	H^2	.001	.000	.692	5.243	.001
	L^2	3.039E-07	.000	.332	2.513	.040

The information of Table 5.17, 5.18, 5.19 and 5.20 are same as stated in Stepwise Regression (Table 5.9, 5.10, 5.11 and 5.12). So these need not be discuss further.

Concluding Remarks for Approach 1

Comparing the outputs of all four methods neither any result from Enter Method (Statistically Insignificant) nor from Backward Elimination Method can be accepted (Practically Insignificant). Only Model 2 derived from both Stepwise Regression and Forward Selection method) can be accepted.

The model is as under (R^2= 0.957, Adjusted R^2=0.945 and SE= .0155)

Structural Period, T (sec) = $0.071 + 0.001 \times H^2 + 3.039E\text{-}07 \times L^2$

5.2.6 Approach 2

The quadratic functions of structural period (T) in seconds with the height (H) in meter of the structures will be followings:

$$T = a + a_1H + a_2H^2 \qquad (10)$$

The cubic functions of structural period (T) in seconds with the total length of walls (L) in meter of the structures will be followings:

$$T = b + b_1L + b_2L^2 \qquad (11)$$

The objective of this analysis is to correlate and combine equation (10) and (11) together to obtain a single equation where T = f (H, L). So the IVs are H, H^2, L and L^2. The variables will be analyzed similarly as the Approach 1.

All the output tables of the four methods are illustrated at Appendix I. The important tables from the methods are discussed in details in the following paragraphs.

5.6.2.1 Model by Enter Method

The Enter Regression has produced a single model automatically as the Table 5.21shows that. The model included all the variables. The important tables from the enter method are as follows:

Table 5.20: Correlations between the Variables (Enter Method, Approach 2, NS)

		T	H	H^2	L	L^2
Pearson Correlation	T	1.000	.936	.958	.947	.888
	H	.936	1.000	.984	.897	**.759**
	H^2	.958	.984	1.000	.910	.804
	L	.947	.897	.910	1.000	.960
	L^2	.888	**.759**	.804	.960	1.000

From the table above it is observed that the Pearson Correlation between H and L^2 is not much convincing. It means that the variables as mentioned are not strongly associated with each other which may generate erroneous result.

Table 5.21: Model Summary (Enter Method, Approach 2, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.979(a)	.959	.926	.01787	2.660

Referring to Table 5.21, the value of R^2 and Adjusted R^2 are 0.959 and 0.926. There is no considerable change between R^2 and Adjusted R^2. This means that considering even the adjusted R^2 the model can explain 92.6% of the variability with the 5 variables. The Standard Error (SE) 0.01787 i.e. about 1.8% which is very small in regards to the DV in question. However the Durbin-Watson value 2.66 is little more than the maximum value of 2.5, which indicates strong negative serial correlation and some autocorrelation exist between the variables considered. It may lead to impractical test results.

Table 5.22: ANOVA (Enter Method, Approach 2, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.037	4	.009	29.334	.001(a)
	Residual	.002	5	.000		
	Total	.039	9			

a. Predictors: (Constant), H, H^2, L, L^2

Referring to Table 5.22, the F ratio for degree of freedom (df) 4 and 5 is 29.334 which is more or less acceptable with 0.001 level of significance (Confidence Interval 99.9%). That means the overall model is significant. If p (sig.) value is less than or equal to 0.05 than F ratio will always be significant.

Table 5.23: Coefficients (Enter Method, Approach 2, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.057	.033		1.733	**.144**
	H	.007	.014	.486	.510	**.632**
	H^2	.000	.001	.360	.496	**.641**
	L	.000	.000	-.465	-.454	**.669**
	L^2	6.195E-07	.000	.676	.900	**.409**

Referring to Table 5.23, none of the variables is significant at 5% level. However the model is kept under consideration as the R^2 values both from the MS Excel and SPSS show a closer resemblance.

5.2.6.2. Model by Stepwise Regression Method

IVs are included in the model successively one after another. Table 5.24 shows that the Stepwise Regression has produced two models automatically. The important tables from the Stepwise Regression method are as follows:

Table 5.24: Variables Entered/Removed (Stepwise Method, Approach 2, NS)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	L^2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

Table 5.25: Model Summary (Stepwise Method, Approach 2, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.958(a)	.918	.908	.01999	
2	.978(b)	.957	.945	.01550	2.981

Table 5.26: ANOVA (Stepwise Method, Approach 2, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			
2	Regression	.037	2	.019	77.853	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

a. Predictors: (Constant), H^2. b. Predictors: (Constant), H^2, L^2

Table 5.27: Coefficients (Stepwise Method, Approach 2, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.066	.009		7.426	.000
	H^2	.001	.000	.958	9.474	.000
2	(Constant)	.071	.007		9.904	**.000**
	H^2	.001	.000	.692	5.243	**.001**
	L^2	3.039E-07	.000	.332	2.513	**.040**

The information of Table 5.24, 5.25, 5.26 and 5.27 are same as stated in Stepwise Regression (Table 5.8, 5.9, 5.10 and 5.11) of Approach 1. So these need not be discuss further.

5.2.6.3 Model with Backward Elimination Method

Table 5.28 shows that the Backward Elimination Method of Regression has produced three models automatically. At the first model all the IVs are included in the model. In the each successive step single variable is removed one after another depending on p value greater than or equal to 0.10. It removes the variable first whose P value is maximum. From Table 5.23 (Coefficient of Enter Method) it is seen that L has maximum P value (0.669), so it is removed in the second model. Then H with p value 0.632 is removed in the third model. The important tables from the Backward Elimination method are as follows:

Table 5.28: Variables Entered/Removed (Backward Method, Approach 2, NS)

Model	Variables Entered	Variables Removed	Method
1	L^2, H, H^2, L(a)	.	Enter
2	.	L	Backward (criterion: Probability of F-to-remove >= .100).
3	.	H	Backward (criterion: Probability of F-to-remove >= .100).

Table 5.29: Model Summary (Backward Method, Approach 2, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.979(a)	.959	.926	.01787	2.981
2	.978(b)	.957	.936	.01665	
3	.978(c)	.957	.945	.01550	

Referring to Table 5.29 the values of R^2 of model 1, 2 and 3 are 0.959, 0.957 and 0.957

respectively. Corresponding Adjusted R^2 of model 1 is 0.926, model 2 is 0.936 and for model 3 is 0.9458. There is no considerable change between R^2 and Adjusted R^2. This means that the models can explain more than 95.7% of the variability. Corresponding Standard Errors (SE) are 0.01787, 0.01665 and 0.0155 which are very small in regards to the DV in question. It is confirmed that all the models are good having fractional variation in goodness of fit and SE. However model three is best of the three.

Table 5.30: ANOVA (Backward Method, Approach 2, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.037	4	.009	29.334	.001(a)
	Residual	.002	5	.000		
	Total	.039	9			
2	Regression	.037	3	.012	45.000	.000(b)
	Residual	.002	6	.000		
	Total	.039	9			
3	Regression	.037	2	.019	77.853	.000(c)
	Residual	.002	7	.000		
	Total	.039	9			

Table 5.31: Coefficients (Backward Method, Approach 2, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.057	.033		1.733	.144
	H	.007	.014	.486	.510	.632
	H^2	.000	.001	.360	.496	.641
	L	.000	.000	-.465	-.454	.669
	L^2	6.195E-07	.000	.676	.900	.409
2	(Constant)	.065	.026		2.529	.045
	H	.002	.007	.127	.257	.806
	H^2	.000	.000	.557	1.032	.342
	L^2	3.144E-07	.000	.343	2.308	.060
3	(Constant)	.071	.007		9.904	**.000**
	H^2	.001	.000	.692	5.243	**.001**
	L^2	3.039E-07	.000	.332	2.513	**.040**

The information of third and the suitable model in Table 5.30 and 5.31 are same as stated in Stepwise Regression (Table 5.26 and 5.27). So these need not be discuss further.

5.2.6.4 Model with Forward Selection Method

The important tables from the Forward Selection method are as follows:

Table 5.32: Variables Entered/Removed (Forward Method, Approach 2, NS)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Forward (Criterion: Probability-of-F-to-enter <= .050)
2	L^2	.	Forward (Criterion: Probability-of-F-to-enter <= .050)

Table 5.33: Model Summary (Forward Method, Approach 2, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.958(a)	.918	.908	.01999	
2	.978(b)	.957	.945	.01550	2.981

Table 5.34: ANOVA (Forward Method, Approach 2, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			
2	Regression	.037	2	.019	77.853	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

Table 5.35: Coefficients (Forward Method, Approach 2, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.066	.009		7.426	.000
	H^2	.001	.000	.958	9.474	.000
2	(Constant)	.071	.007		9.904	**.000**
	H^2	.001	.000	.692	5.243	**.001**
	L^2	3.039E-07	.000	.332	2.513	**.040**

The information of Table 5.32, 5.33, 5.34 and 5.35 are same as stated in Stepwise Regression (Table 5.8, 5.9, 5.10 and 5.11) of Approach 1. So these need not be discuss further.

5.2.6.5 Concluding Remarks for Approach 2

Comparing the outputs of all four methods, it is seen all methods except Enter Method (Statistically Insignificant) can be accepted (Statistically and Practically significant).

The model is as under (R^2= 0.957, Adjusted R^2=0.945 and SE= .0155)

Structural Period, T (sec) = 0.071+ 0.001 ×H^2 + 3.039E-07× L^2

5.2.7 Approach 3

The quadratic functions of structural period (T) in seconds with the height (H) in meter of the structures is given in equation (10)

The linear functions of structural period (T) in seconds with the total length of walls (L) in meter of the structures will be followings:

$$T = b + b_1L \qquad (12)$$

Consideration of combining of quadratic function and linear function is based on the R^2 of Table 5.3. In that the R^2 values of quadratic and linear function are very close i.e. 0.894 and 0.891 respectively.

The objective of this analysis is to correlate and combine equation (10) and (12) together to obtain a single equation where T = f (H, L). So the IVs are H, H^2 and L. The variables will be analyzed similarly as the Approach 1.

All the output tables of the four methods are illustrated at Appendix J. The important tables from the methods are discussed in details in the following paragraphs.

5.2.7.1 Model by Enter Method

The Enter Regression has produced a single model automatically as the Table 5.36 shows that. The model included all the variables. The important tables from the enter method are as follows:

Table 5.36: Correlations between the Variables (Enter Method, Approach 3, NS)

		T	H	H^2	L
Pearson Correlation	T	1.000	.936	.958	.947
	H	.936	1.000	.984	**.897**
	H^2	.958	.984	1.000	.910
	L	.947	.897	.910	1.000

From the table above it is observed that the Pearson Correlations between all the variables are very convincing. It means that the variables as mentioned are strongly associated with each other which may generate a good result.

Table 5.37: Model Summary (Enter Method, Approach 3, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.976	.953	.929	.01759	3.118

Referring to Table 5.37, the value of R^2 and Adjusted R^2 are 0.976 and 0.953. There is no considerable change between R^2 and Adjusted R^2. This means that considering even the adjusted R^2 the model can explain 95.3% of the variability with the 4 variables. The Standard Error (SE) 0.01759 i.e. about 1.8% which is very small in regards to the DV in question. However the Durbin-Watson value 3.118 is much more than the maximum value of 2.5, which indicates strong negative serial correlation and some autocorrelation exist between the variables considered. It may lead to impractical test results.

Table 5.38: ANOVA (Enter Method, Approach 3, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.037	3	.012	40.111	.000(a)
	Residual	.002	6	.000		
	Total	.039	9			

a. Predictors: (Constant), H, H^2, L

Referring to Table 5.38, the F ratio for degree of freedom (df) 5 and 4 is 40.878 which is more or less acceptable with 0.000 level of significance (Confidence Interval 99.99%). That means the overall model is significant. If p (sig.) value is less than or equal to 0.05 than F ratio will always be significant.

Table 5.39: Coefficients (Enter Method, Approach 3, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.074	.027		2.770	.032
	H	-.003	.007	-.240	-.484	**.646**
	H^2	.001	.000	.798	1.506	**.183**
	L	.000	.000	.437	2.037	**.088**

Referring to Table 5.40, only the constant is significant below 5% level. Other variables are not significant as shown in the last column (Sig.). Necessity of checking other values is of no use. So the model cannot be accepted with all these variables.

Concluding Remarks of the Model by Enter Method

Model cannot be accepted because individual level of significance crossed 5%.

5.2.7.2 Model by Stepwise Regression Method

IVs are included in the model successively one after another. Table 5.40 shows that the Stepwise Regression has produced one model automatically. The important tables from the Stepwise Regression method are as follows:

Table 5.40: Variables Entered/Removed (Stepwise Method, Approach 3, NS)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

The Table 5.40 shows that this method only considered the H^2 which is denying the objective of the analysis are removed from the process. So this method will not be discussed further.

5.2.7.3 Model with Backward Elimination Method

Table 5.41 shows that the Backward Elimination Method of Regression has produced two models automatically. At the first model all the IVs are included in the model. In the each successive step single variable is removed one after another depending on p value greater than or equal to 0.100. It removes the variable first whose P value is maximum. From Table 5.40 (Coefficient of Enter Method) it is seen that H has maximum P value (0.646), so it is removed in the second model. The important tables from the Backward Elimination method are as follows:

Table 5.41: Variables Entered/Removed (Backward Method, Approach 3, NS)

Model	Variables Entered	Variables Removed	Method
1	L, H, H^2(a)	.	Enter
2	.	H	Backward (criterion: Probability of F-to-remove >= .100).

a. All requested variables entered.

Table 5.42: Model Summary (Backward Method, Approach 3, NS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.976(a)	.953	.929	.01759	
2	.975(b)	.951	.937	.01659	2.941

Referring to Table 5.42 the values of R^2 of model 1 and 2 are 0.953 and 0.951 respectively. Corresponding Adjusted R^2 of model 1 is 0.929 and for other model it is 0.937. There is no considerable change between R^2 and Adjusted R^2. This means that the models can explain more than 95.1% of the variability. Corresponding Standard Errors (SE) are 0.01759 and 0.01659 which are very small in regards to the DV in question. It is confirmed that all the models are good having fractional variation in goodness of fit and SE. However model two is better of the two.

Durbin-Watson value 2.941 is more than the maximum value of 2.5, which indicates strong negative serial correlation and some autocorrelation exist between the variables considered. It may lead to impractical test results due to generation of multi-collinearity problem.

Table 5.43: ANOVA (Backward Method, Approach 3, NS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.037	3	.012	40.111	.000(a)
	Residual	.002	6	.000		
	Total	.039	9			
2	Regression	.037	2	.019	67.429	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

Referring to Table 5.43, the F ratio of both model are acceptable with 0.000 level of significance (Confidence Interval 99.99%).

Table 5.44: Coefficients (Backward Method, Approach 3, NS)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.074	.027		2.770	.032
	H	-.003	.007	-.240	-.484	**.646**
	H^2	.001	.000	.798	1.506	**.183**
	L	.000	.000	.437	2.037	**.088**
2	(Constant)	.061	.008		7.876	.000
	H^2	.000	.000	.563	2.786	.027
	L	.000	.000	.434	2.147	**.069**

Referring to Table 5.44, only the constant in first model is individually statistically significant (below 5% level). In the second model L has significance more than 5% level. None of the models can be accepted with all these variables.

Concluding Remarks of the Models with Backward Elimination

None of the models are acceptable because they do not qualify statistically significant.

5.2.7.4 Model with Forward Selection Method

The important tables from the Forward Selection method are as follows:

Table 5.45: Variables Entered/Removed (Forward Method, Approach 3, NS)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Forward (Criterion: Probability-of-F-to-enter <= .05)

The Table 5.45 shows that this method only considered the H^2 which is denying the objective of the analysis are removed from the process. So this method will not be discussed further.

5.2.7.5 Concluding Remarks for Approach 3

Comparing the outputs of all four methods neither of the results i.e. models can be accepted (Statistically Insignificant).

5.2.8 Summary

Considering all the above three approaches it is found that only a single model is suitable to be used as the relation between structural periods, height and the total length of walls of the structures. Again Approach 1 and Approach 2 both support it being statistically and practically significant. The model is as under (R^2= 0.957, Adjusted R^2=0.945 and SE= .0155)

$$\textbf{Structural Period, T (Sec) = } 0.071 + 0.001 \times H^2 + 3.039\text{E-}07 \times L^2 \qquad \textbf{(13)}$$

5.3 ANALYSIS TAKING EXPERIMENTAL STRUCTURAL PERIOD DATA OF EW DIRECTION

5.3.1 Pearson Correlation (r) between All Variables

A bivariate correlation analysis is performed to get the Pearson Correlation between all the selected variables i.e. structural period, height and total length of walls of structures. The bivariate Pearson correlation obtained is shown in the Table 5.46.

Table 5.46: The bivariate Pearson Correlation between Structural Period, Height and Total Length of Wall of Structures (Experimental Structural Period Data of EW Direction)

		structural period	height of building	total length of walls
structural period	Pearson Correlation	1	.969(**)	.871(**)
	Sig. (2-tailed)	.	.000	.001
	N	10	10	10
height of building	Pearson Correlation	.969(**)	1	.892(**)
	Sig. (2-tailed)	.000	.	.001
	N	10	10	10
total length of walls	Pearson Correlation	.871(**)	.892(**)	1
	Sig. (2-tailed)	.001	.001	.
	N	10	10	10

The r value between structural period and height is 0.969 and between structural period and total length of walls is 0.871. Again between height and total length of walls is 0.892. There are strong relationships between the variables.

Besides the variables are positively correlated i.e. each pair of variables is proportional. In general terms, this means that as one variable increases in value, the second variable also increase in value. Again maximum sig. (2-tailed) value is 0.001 i.e. 0.1% (much less than 0.01 i.e. 1%) that is there are statistically significant correlations between each pair of variables. That means, increases or decreases in one variable do significantly relate to increases or decreases in the second variable. Thus potentiality of forming a relation between the three variables is very high.

In connection to the statistical analyses the histograms of structural periods, heights and the total length of walls of structures are given at Appendix K.

5.3.2 Determining Outliers from the Data of the Variables

By boxplot it is found no data out of 30 data (10 each from each of the three variables) is an outlier. The box plot is given at Appendix L.

5.3.3 Curve Estimation of Each Pair of Variables

Data of important aspects of the curve estimation for structural period versus height of structures are given in Table 5.47. Beneath that the curve estimation plots are given in Figure No. 5.3.

Table 5.47: Important Aspects of the Curve Estimation for Structural Period versus Height of the Structures

Serial	Method (Mth)	R sq	Sigf
1.	**LIN**	**.939**	**.000**
2.	LOG	.839	.000
3.	INV	.652	.005
4.	**QUA**	**.951**	**.000**
5.	**CUB**	**.955**	**.000**
6.	COM	.918	.000
7.	POW	.893	.000
8.	S	.765	.001
9.	GRO	.918	.000
10.	EXP	.918	.000
11.	LGS	.918	.000

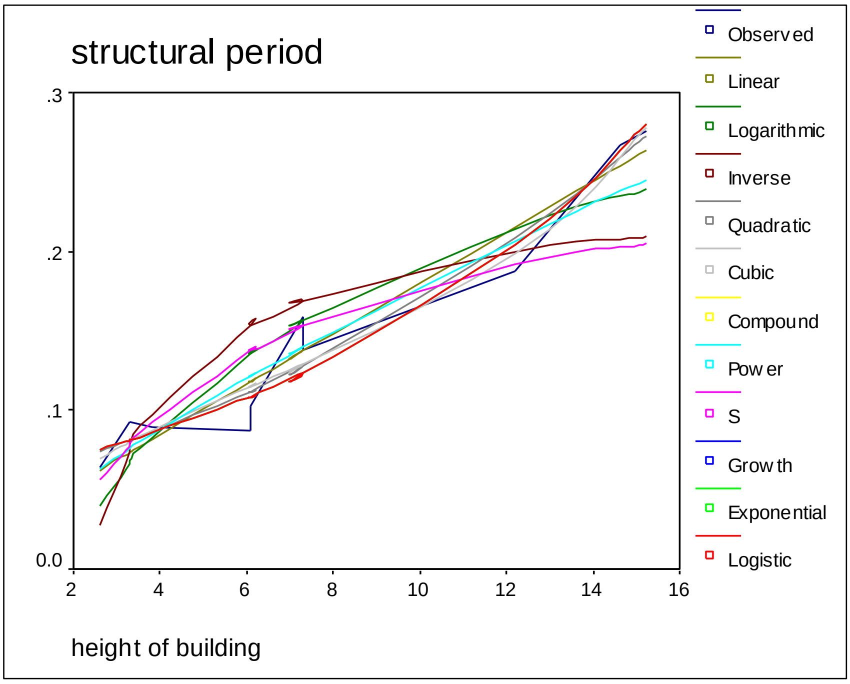


Figure 5.3: Curve Estimation Plots for Structural Period (EW) Versus Height of Structures

Considering the R-square and sigf value it is observed that the cubic, quadratic and linear functional forms are the best three among all functional forms presented in Table 5.47 and displayed in Figure 5.3.

Data of important aspects of the curve estimation for structural period versus total length of walls of structures are given in Table 5.48. Beneath that the curve estimation plots are given in Figure No. 5.4.

Table 5.48: Important Aspects of the Curve Estimation for Structural Period versus Total Length of Walls of the Structures (Experimental Structural Period Data of EW Direction)

Serial	Method (Mth)	R sq	Sigf
1.	**LIN**	**.759**	**.001**
2.	LOG	.711	.002
3.	INV	.416	.044
4.	**QUA**	**.811**	**.003**
5.	**CUB**	**.837**	**.009**
6.	COM	.749	.002
7.	POW	.478	.001
8.	S	.711	.027
9.	GRO	.711	.002
10.	EXP	.711	.002
11.	LGS	.711	.002

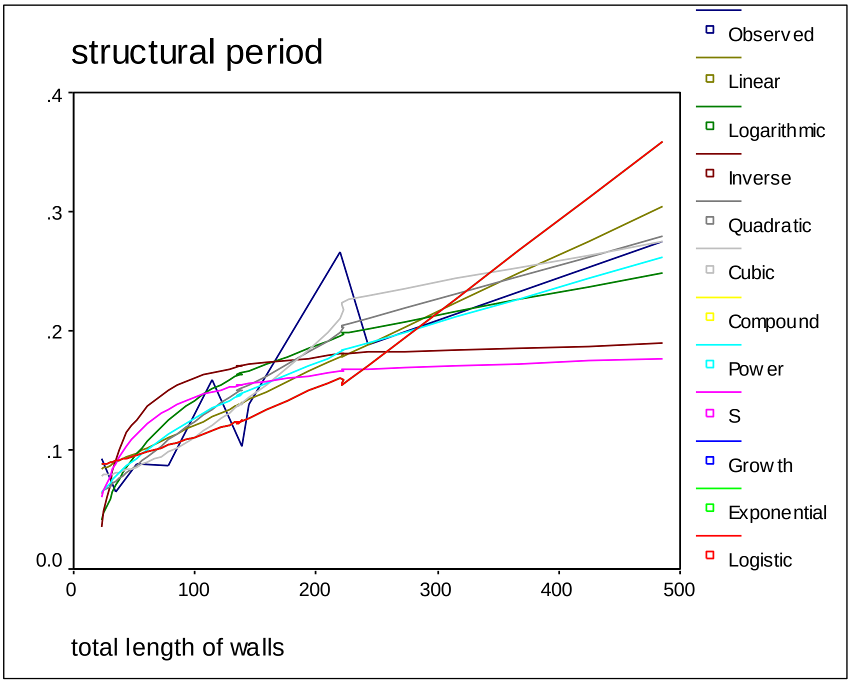


Figure 5.4: Curve Estimation Plots for Structural Period (EW) versus Total Length of Walls of Structures

Considering the R-square and sigf value it is observed that the cubic, quadratic and linear functional forms are the best three among all functional forms presented in Table 5.48 and displayed in Figure 5.4. The details of the curve estimation i.e. curve fit is given at Appendix M.

5.3.4 Approaches of Analysis to Reach a Final Model

Three types of approaches will be analyzed in three different sections separately as section 5.2.

5.3.5 Approach 1

The approach is similar to sub-section 5.2.5. All the output tables of the four methods are similar to NS Data analyses. The important tables from the methods needed for decision making are discussed in details in the following paragraphs.

5.3.5.1 Model by Enter Method

The Enter Regression of any method of any approach of Section 5.2 did not form any convincing model with variables significant individually. At this stage the co-efficient table is shown as follows:

Table 5.49: Coefficients (Enter Method, Approach 1, EW)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.043	.037		1.183	**.302**
	H	.004	.016	.239	.252	**.814**
	H^3	4.067E-05	.000	.725	1.044	**.355**
	L	.001	.001	1.355	.607	**.577**
	L^2	-3.568E-06	.000	-3.389	-.676	**.536**
	L^3	4.501E-09	.000	2.104	.669	**.540**

Referring to Table 5.49, none of the variables are significant as shown in the last column (Sig.). Necessity of checking other values is of no use. So the model cannot be accepted with all these variables.

5.3.5.2 Model by Stepwise Regression Method

IVs are included in the model successively one after another.

Table 5.50: Variables Entered/Removed (Stepwise Method, Approach 1, EW)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

Table 5.50 shows that the Stepwise Regression has produced only one model and only considered the H^2 variable others are removed from the process. It is not compatible with the objective of the regression so the model cannot be accepted with this variable.

5.3.5.3 Model with Backward Elimination Method

This method automatically analyzed five models shown in Table 5.51.

Table 5.51: Coefficients (Backward Method, Approach 1, EW)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.043	.037		1.183	.302
	H	.004	.016	.239	.252	.814
	H^3	4.067E-05	.000	.725	1.044	.355
	L	.001	.001	1.355	.607	.577
	L^2	-3.568E-06	.000	-3.389	-.676	.536
	L^3	4.501E-09	.000	2.104	.669	.540
2	(Constant)	.049	.026		1.852	.123
	H^3	4.945E-05	.000	.882	3.151	.025
	L	.001	.001	1.811	1.538	.185
	L^2	-4.325E-06	.000	-4.108	-1.105	.319
	L^3	5.223E-09	.000	2.441	.951	.385
3	(Constant)	.068	.017		4.011	.007
	H^3	4.133E-05	.000	.737	3.162	.020
	L	.000	.000	.784	1.681	.144
	L^2	-6.199E-07	.000	-.589	-1.677	.145
4	(Constant)	.090	.012		7.742	.000
	H^3	4.921E-05	.000	.878	3.596	.009
	L	4.952E-05	.000	.092	.377	.717
5	**(Constant)**	.093	.009		10.540	.000
	H^3	5.389E-05	.000	.961	9.850	.000

Referring to Table 6.51, the fifth and its best model have the constant and H^3 in the model are individually statistically significant (below 5% level). However it is not compatible with the objective of the regression analysis so the model cannot be accepted with this variable.

5.3.5.4 Model with Forward Selection Method

The important table from the Forward Selection method is as follows:

Table 5.52: Variables Entered/Removed (Forward Method, Approach 1, EW)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Forward (Criterion: Probability-of-F-to-enter <= .050)

Table 5.52 shows that the Stepwise Regression has produced only one model and only considered the H^2 variable others are removed from the process. It is not compatible with the objective of the regression so the model cannot be accepted with this variable.

5.3.5.5 Concluding Remarks for Approach 1

Comparing the outputs of all four methods neither of the models from any method is statistically significant, so none can be accepted.

5.3.6 Approach 2

Analyzing earlier models it is found model from enter methods is not statistically significant. Stepwise and forward methods show similar result. So in the subsequent sections stepwise and backward methods are highlighted. All the output tables of the four methods are similar to NS Data analyses.

5.3.6.1 Model by Stepwise Regression Method

IVs are included in the model successively one after another. Table 5.53 shows that the Stepwise Regression has produced one model. The table is as follows:

Table 5.53: Variables Entered/Removed (Stepwise Method, Approach 2, EW)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

Table 5.53 shows that the Stepwise Regression has produced only one model and only considered the H^2 variable others are removed from the process. It is not compatible with the objective of the regression so the model cannot be accepted with this variable.

5.3.6.2 Model with Backward Elimination Method

This method automatically analyzed five models shown in Table 5.54.

Table 5.54: Coefficients (Backward Method, Approach 2, EW)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.054	.041		1.318	.245
	H	.007	.017	.402	.388	.714
	H^2	.001	.001	.588	.743	.491
	L	-2.578E-05	.001	-.048	-.043	.967
	L^2	4.386E-08	.000	.042	.051	.961
2	(Constant)	.055	.031		1.748	.131
	H	.006	.009	.365	.693	.514
	H^2	.001	.001	.608	1.053	.333
	L^2	7.747E-09	.000	.007	.046	.965
3	(Constant)	.055	.028		1.942	.093
	H	.006	.008	.358	.769	.467
	H^2	.001	.000	.621	1.335	.224
4	**(Constant)**	.076	.008		9.251	.000
	H^2	.001	.000	.973	11.990	.000

Table 5.54 shows that the backward regression has produced its best model considering the H^2. It is not compatible with the objective of the regression so the model cannot be accepted.

5.3.7 Approach 3

All the output tables of the four methods are similar to NS Data analyses. The important tables from the methods are discussed in details in the following paragraphs.

5.3.7.1 Model by Stepwise Regression Method

Table 5.55 shows that the Stepwise Regression has produced one model.

Table 5.55 Variables Entered/Removed (Stepwise Method, Approach 3, EW)

Model	Variables Entered	Variables Removed	Method
1	H^2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

Table 5.55 shows that this method only considered the H^2 which denies the objective of the analysis. So this method will not be discussed further.

5.3.7.2 Model with Backward Elimination Method

This method automatically analyzed three models shown in Table 5.56.

Table 5.56: Coefficients (Backward Method, Approach 3, EW)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.055	.031		1.791	.123
	H	.006	.008	.357	.711	.504
	H^2	.001	.000	.615	1.147	.295
	L	4.118E-06	.000	.008	.035	.973
2	(Constant)	.055	.028		1.942	.093
	H	.006	.008	.358	.769	.467
	H^2	.001	.000	.621	1.335	.224
3	**(Constant)**	.076	.008		9.251	.000
	H^2	.001	.000	.973	11.990	.000

Table 5.56 shows that the backward regression has produced its best model considering the H^2. It is not compatible with the objective of the regression so the model cannot be accepted.

5.3.8 Summary

Considering all the above three approaches it is found that no model is suitable to be used as the relation between structural periods, height and the total length of walls of the structures.

CHAPTER SIX

RESULT AND DISCUSSION

6.1 GENERAL

To understand seismic response of structures properly it is essential to know the concepts in dynamics of structures. Because dynamic properties of structures have a key role on the seismic behavior and vulnerability of building structures. Particularly, fundamental periods of vibration are needed, both in design of new buildings and in assessment of existing ones, so that their seismic response can be evaluated. Basing on the ground motion, the knowledge of fundamental frequency and damping ratio of structures is of uppermost importance in earthquake engineering, especially to estimate the seismic demand (Reaz, 2012).

Any external force applied to a structure, as envisaged, is generally distributed among the three components of the structure, i.e. its stiffness, damping and mass components. Hence structural parameters have great influence on the dynamic properties of structures. With this introduction the aim of this chapter is to pledge the results obtained from the research and discuss those in details from the perspective of the objectives of the study.

6.2 RESULT OF THE PILOT TEST ON THE RCC BUILDING

The pre-dominant frequencies obtained from top floor accelerations are 1.817Hz and 1.767Hz and modified top floor accelerations are 1.983Hz and 1.933Hz in NS and EW directions respectively. The same pre-dominant frequencies calculated from the formula given in BNBC 1993 are 2.208Hz and 2.0334Hz in NS and EW directions respectively.

The structural period (T) from the pre-dominant frequencies (f) are obtained as $T = 1/f$ and given in the Table 6.1.

Table 6.1: The Structural Period (T) from the Pre-Dominant Frequencies (f)

Basis	f (Hz)		T (Secs)	
	NS	EW	NS	EW
Experiment (Top Floor Accelerations)	1.817	1.767	0.55035	0.56593
Experiment (Modified Top Floor Accelerations)	1.983	1.933	0.50428	0.51733
BNBC 1993	2.208	2.0334	0.45397	0.4918

It is observed that considering the top floor accelerations the T (sec) are about 21% and 15% more than the T (sec) from BNBC 1993. However considering the modified top floor accelerations T (sec) are about 11% and 5% more than the T (sec) from BNBC 1993. Though the modes of the modified top floor accelerations are not much defined to recon the pre-dominant frequencies. So there may be a need to redefine the process of estimating the structural period (T) given at BNBC 1993.

6.3 RELATION BETWEEN STRUCTURAL PERIODS AND STRUCTURAL PARAMETERS OF URM BUILDINGS

Structural parameters i.e. geometry, height of structure, height of storey, thickness of load bearing wall, length of wall in two cardinal directions, RC slab thickness, construction materials etc. have great effect on the dynamic properties i.e. structural period of structures.

After obtaining all the pre-dominant frequencies of all the URM buildings, it is found that the three-storied building gives in consistent frequency considering others. So the building was dropped out of the research. Firstly the study considered the relationship between the length of wall and the frequency of structures irrespective of their other characteristics. As usual it is found that the frequency increases with the length of wall within a structure only irrespective of their cardinal directions. Thus a decrease in structural period with the increase of length of wall within the same structure only is resulted.

6.4 ANALYSIS BY MS EXCEL

6.4.1 Relationship between Structural Periods and Heights of URM Buildings

An Excel based analysis was carried out by plotting structural periods versus heights of all URM buildings. There is a parabolic relationship found between structural periods and heights of all fourteen URM buildings, irrespective of principal directions and all in NS direction of the structures as seen in the Figure No. 6.1. However the best fit curvature line shows the lower part of a parabola.

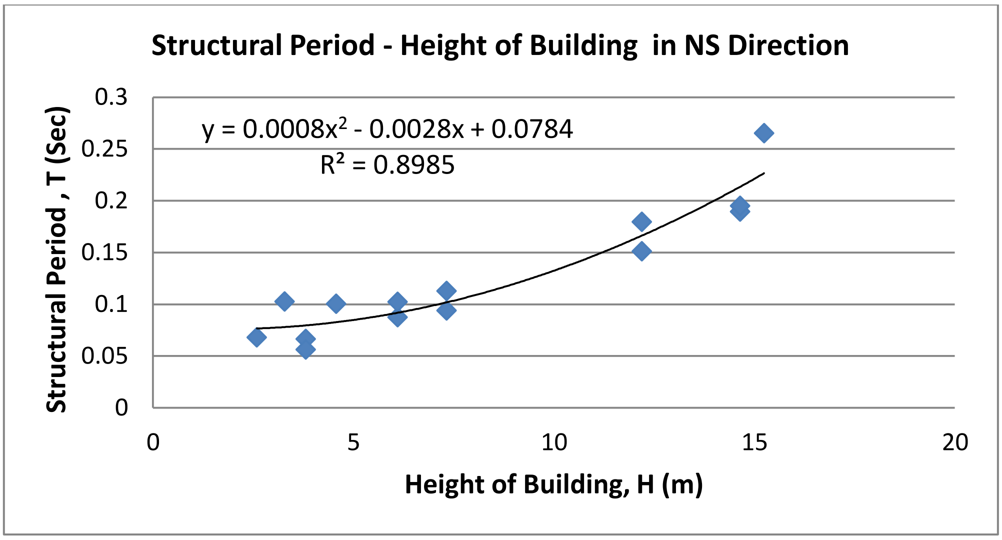


Figure 6.1: Relationship between Structural Periods and Heights Irrespective of Principal Directions of Structures in NS direction

Coefficient of determination, R-square value represents the strength of association between the independent and the dependent variable. The Figure No. 6.1 reveals that in an overall perspective, the independent variable is strongly associated with the dependent variable.

While considering building orientation in EW direction and walls in NS direction, the NS direction is considered as the principal direction of a building. The number of such buildings within those fourteen URM buildings stands to be ten. There also a parabolic relationship exists between structural periods and heights of all these ten URM buildings which are seen in the Figure No. 6.2. However this parabola has a larger radius and stronger relationship than that of Figure No. 6.1.

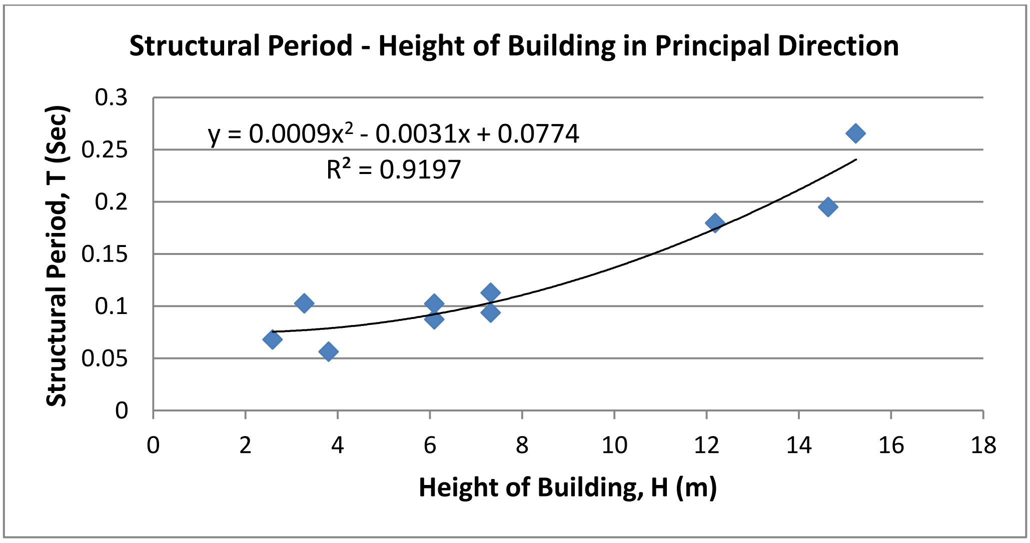


Figure 6.2: Relationship between Structural Periods and Heights in the Principal (NS) Directions of Structures

In this case the Figure No. 6.2 reveals that in an overall perspective, the association of the independent variable with the dependent variable is much stronger.

Again in the EW direction, there is a parabolic relationship found between structural periods and heights of all fourteen URM buildings, irrespective of principal directions of the structures as seen in the Figure No. 6.3. However the best fit curvature line also shows the lower part of a parabola.

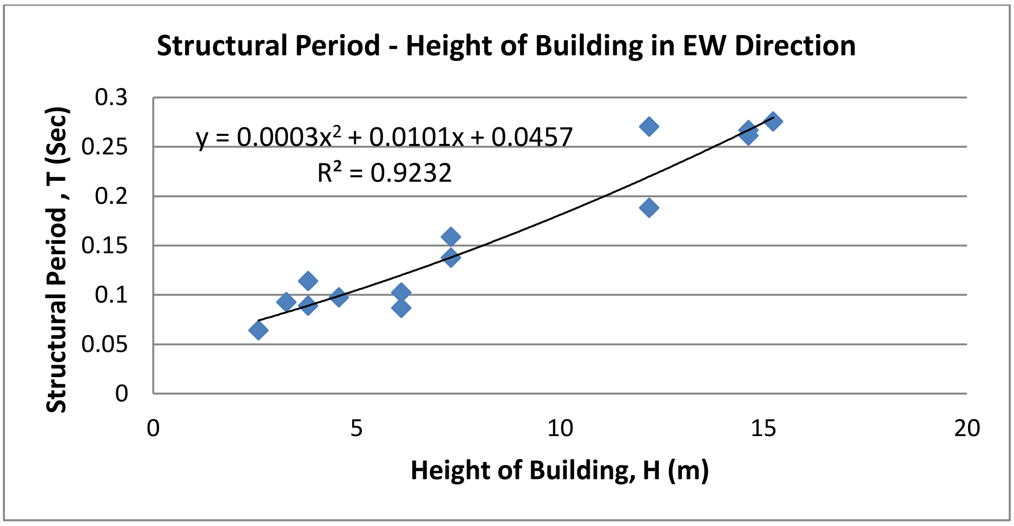


Figure 6.3: Relationship between Structural Periods and Heights Irrespective of Principal Directions of Structures in EW direction

The ten URM buildings considered in Figure No. 6.2 have their principal axis oriented in NS direction. When the relationship between their structural periods and heights are considered in EW directions, a different parabolic relation with strong association between the independent variable and the dependent variable is obtained. This relationship is shown in the Figure No. 6.4. Again this parabola has a stronger relationship than that of Figure No. 6.3.

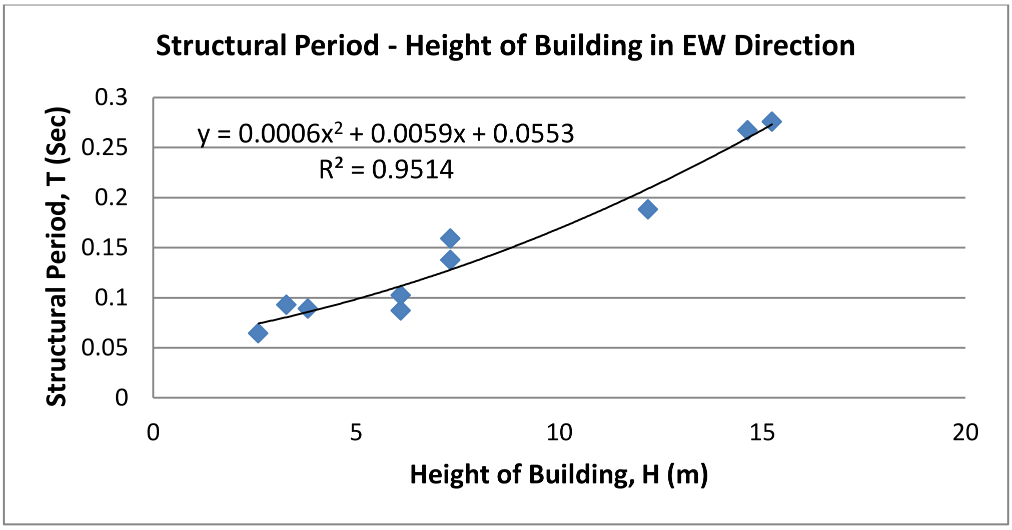


Figure 6.4: Relationship between Structural Periods and Heights in the EW (Opposite to Principal) Directions of Structures

Among all the URM buildings under study only five has rectangular shaped plan. It is found that URM buildings having rectangular shaped plan have the parabolic relationship between their structural periods and heights in both the principal and its other (non-principal) directions. However the R-squared value represents stronger association between the independent variable and the dependent variable in EW (non-principal) direction. The Figure No. 6.5 and Figure No.6.6 show the relationships.

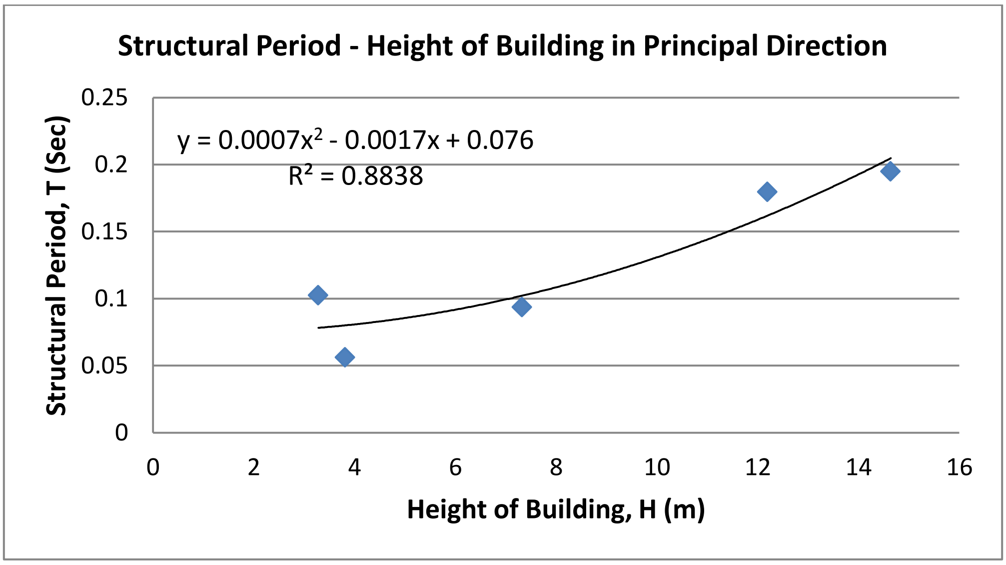


Figure 6.5: Relationship between Structural Periods and Heights in the Principal (NS) Directions of Structures of Rectangular Shaped Plan

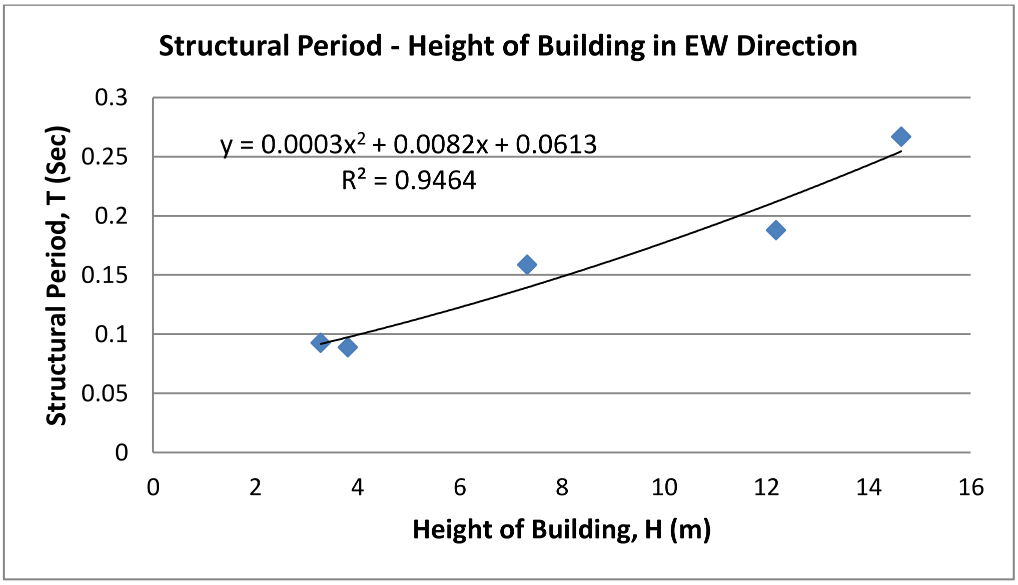


Figure 6.6: Relationship between Structural Periods and Heights in the EW Directions of Structures of Rectangular Shaped Plan

6.4.2 Relationship between Structural Periods and Total Lengths of Wall of URM Buildings

The Excel based analysis shows that there is a parabolic relationship found between structural periods and walls of all fourteen URM buildings, irrespective of principal directions of the structures as seen in the Figure No. 6.6. However the best fit curvature line shows the upper part of a parabola.

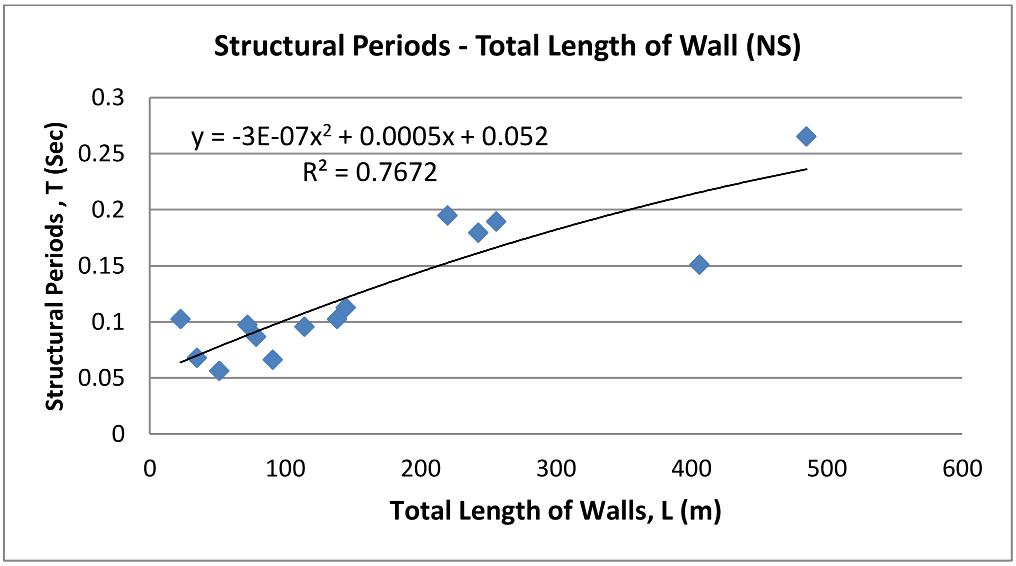


Figure 6.7: Parabolic Relationship between Structural Periods and Walls Irrespective of Principal Directions of Structures

The Figure No. 6.7 reveals that in an overall perspective, the independent variable is strongly associated with the dependent variable, but impractical. However the linear plot of the Figure No. 6.7 shown in Figure No. 6.8 represents almost a similar strength of relationship.

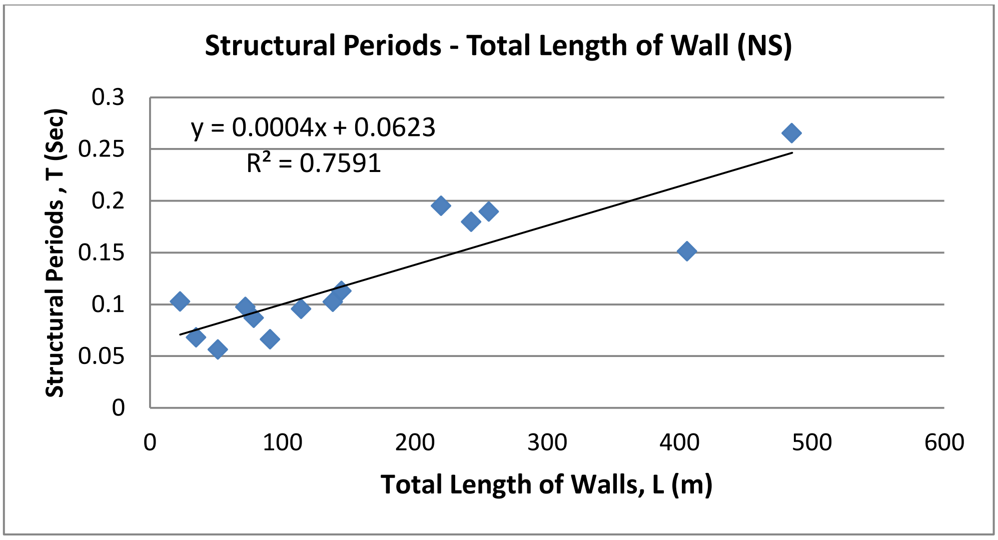


Figure 6.8: Linear Relationship between Structural Periods and Walls Irrespective of Principal Directions of Structures

Considering direction of walls in the NS direction of a building, there is also a similar but stronger parabolic relationship exists between structural periods and walls of ten URM buildings which are seen in the Figure No. 6.9. However the best fit curvature line represents upper part of a parabola like Figure No. 6.7.

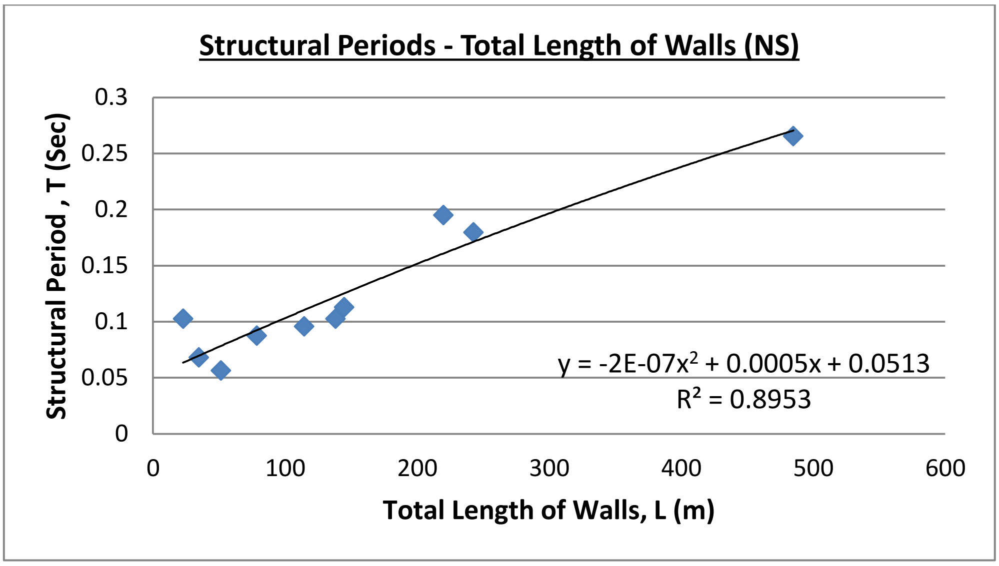


Figure 6.9: Parabolic Relationship between Structural Periods and Walls in the Principal Directions of Structures

The linear plot of the Figure No. 6.9 shown in Figure No.6.10 represents almost a similar strength of relationship, but impractical.

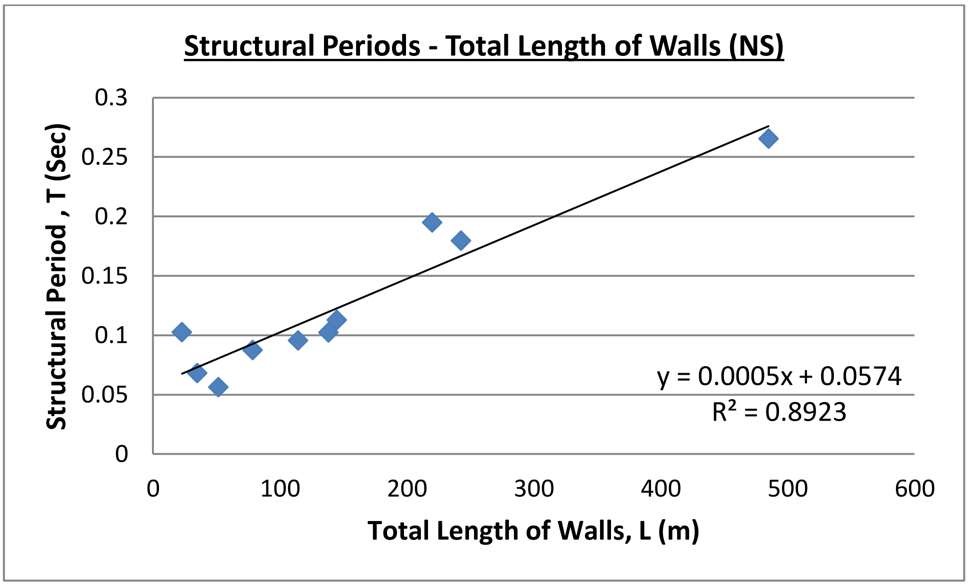


Figure 6.10: Linear Relationship between Structural Periods and Walls in the Principal Directions of Structures

Again in the EW direction, there is a parabolic relationship found between structural periods and lengths of all fourteen URM buildings, irrespective of principal directions of the structures as seen in the Figure No. 6.11. However the best fit curvature line also shows the upper part of a parabola.

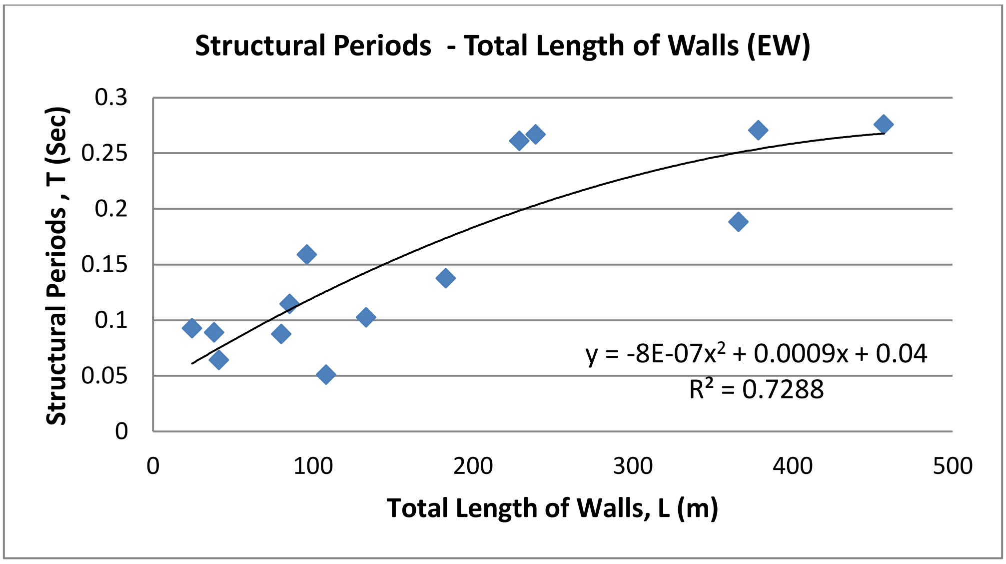


Figure 6.11: Parabolic Relationship between Structural Periods and Heights Irrespective of Principal Directions of Structures in EW direction

The linear plot of the Figure No. 6.11 shown in Figure No. 6.12 represents a little lesser strength of relationship.

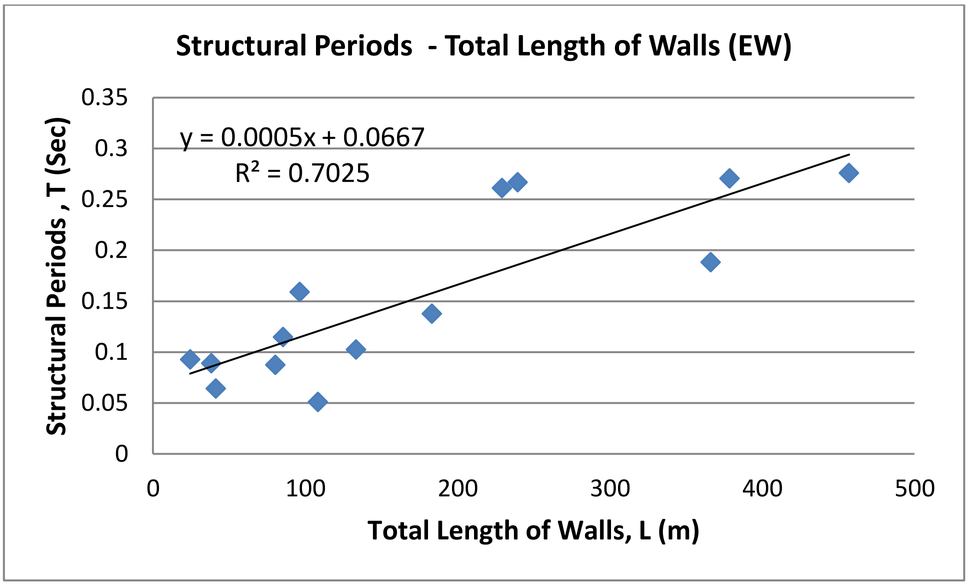


Figure 6.12: Linear Relationship between Structural Periods and Walls Irrespective of Principal Directions of Structures

Now the parabolic relationship between structural periods and walls is given in the Figure No. 6.13 for the buildings oriented in NS direction with their longer axis. In the case of opposite to the principal direction, it reveals that in an overall perspective, the association of the independent variable with the dependent variable is much stronger.

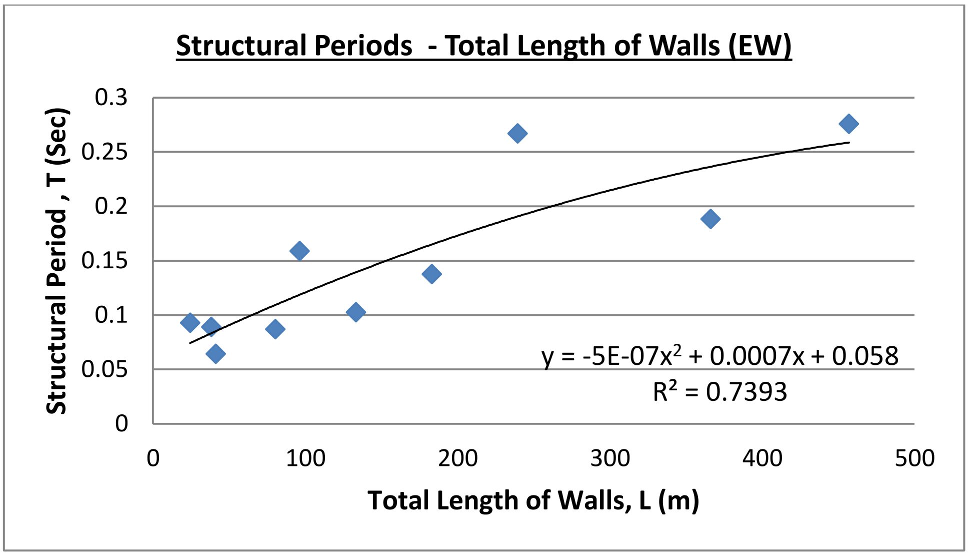


Figure 6.13: Parabolic Relationship between Structural Periods and Walls in the EW (Opposite to Principal) Directions of Structures

The linear plot of the Figure No. 6.13 shown in Figure No. 6.14 represents a little lesser strength of relationship.

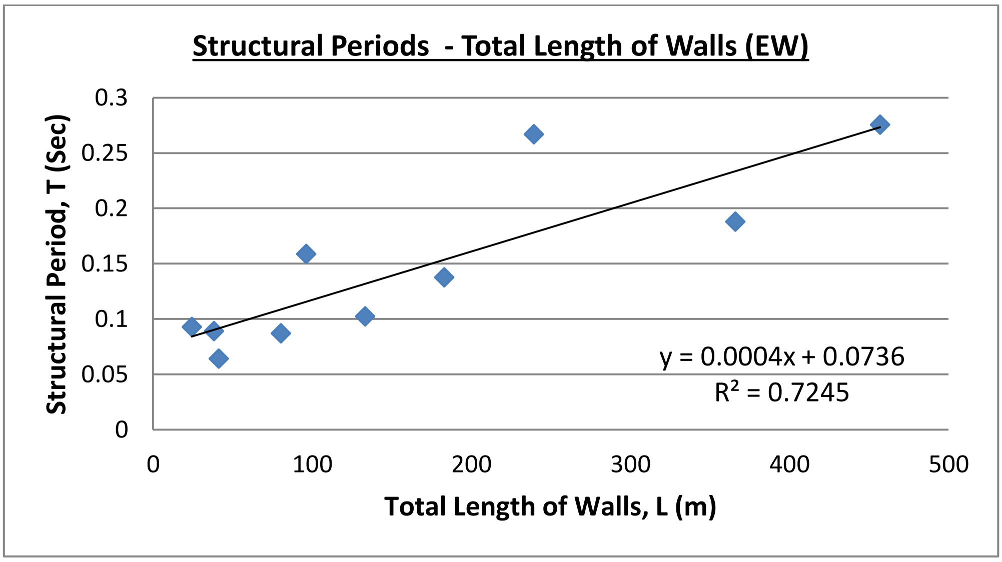


Figure 6.14: Linear Relationship between Structural Periods and Walls in the EW (Opposite to Principal) Directions of Structures

According to Figure No. 6.9, 6.11 and 6.13, for structures of great lengths of total walls may have lesser and lesser structural period which may not be the case for the real structures. It is obvious that the structural period increases with the increase of total length of walls. So this parabolic relation of structural period with total length of walls of structures can be ignored. Since the linear relationship has the practical significance it can be accepted.

6.4.3 Relationship between Structural Periods and Aspect Ratio of URM Buildings

These relationships are analyzed for the URM buildings oriented in NS direction with their longer dimensions. The relation between structural periods of both the cardinal direction and the aspect ratios are plotted in the Figure No. 6.15 and Figure No. 6.16.

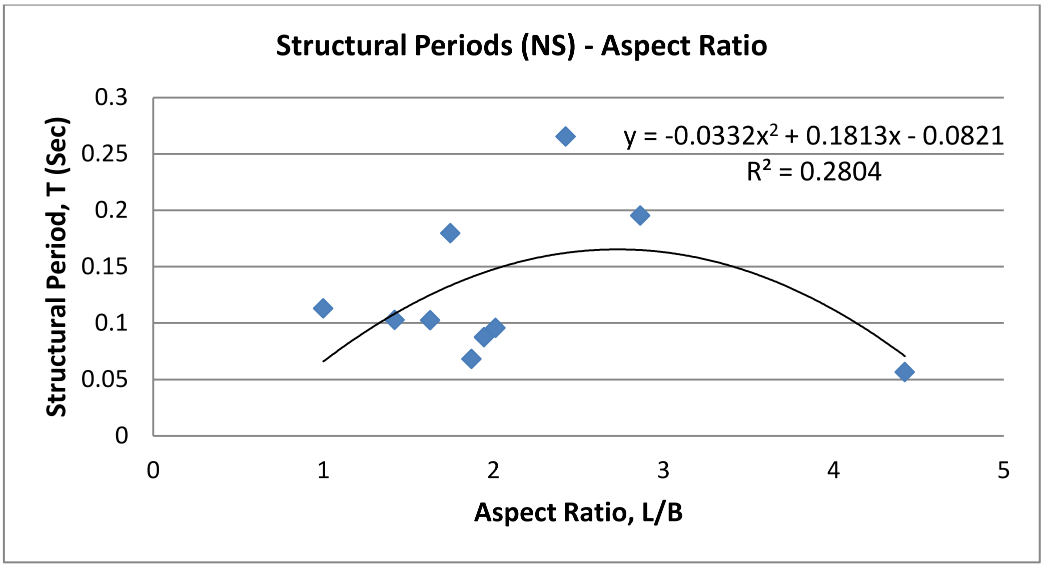


Figure 6.15: Relationship between Structural Periods of NS Directions and Aspect Ratios of the Structures

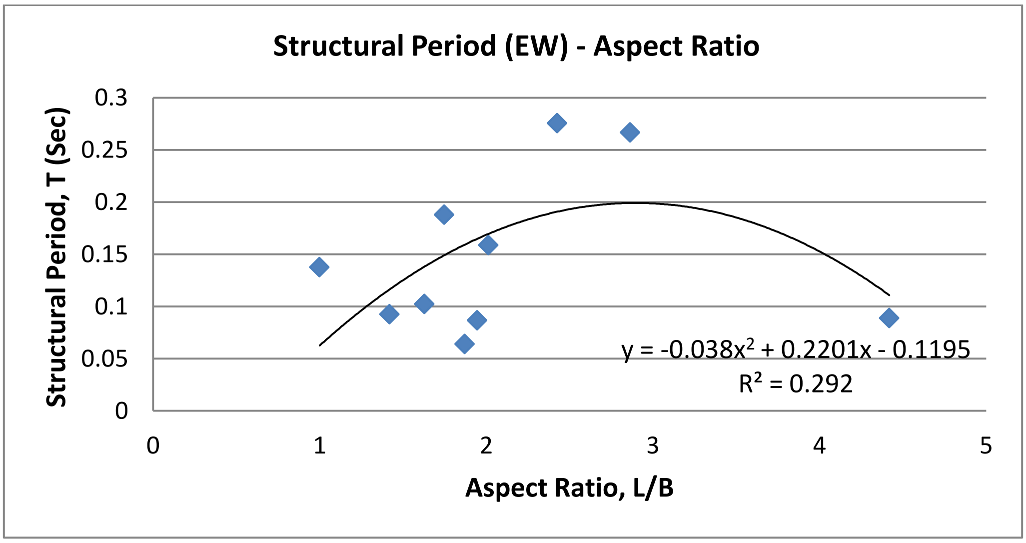


Figure 6.16: Relationship between Structural Periods of EW Directions and Aspect Ratios of the Structures

Both the relationship in the Figure No. 6.15 and Figure No. 6.16 show that a parabolic relation exists between structural periods of both the cardinal direction and the aspect ratios of the structures. However considering the R-square value represents the strength of association between the dependent and independent variables are very weak.

Again in another way, the relationships between structural periods and ratio of the heights and the least dimensions in the plans are also analyzed for the URM buildings oriented in NS direction with their longer dimensions. These relations in both the cardinal direction are plotted in the Figure No. 6.17 and Figure No. 6.18.

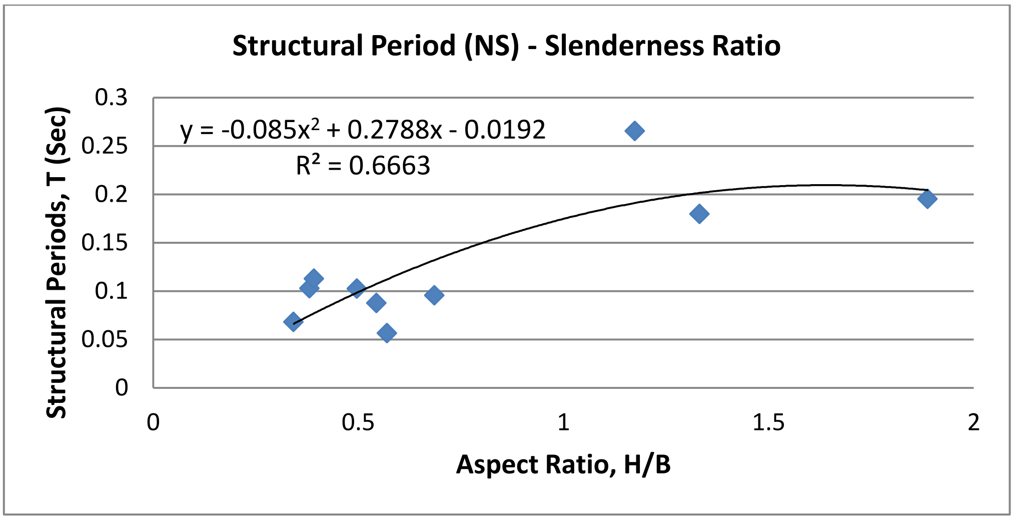


Figure 6.17: Relationship between Structural Periods of NS Directions and Aspect Ratios of the Structures

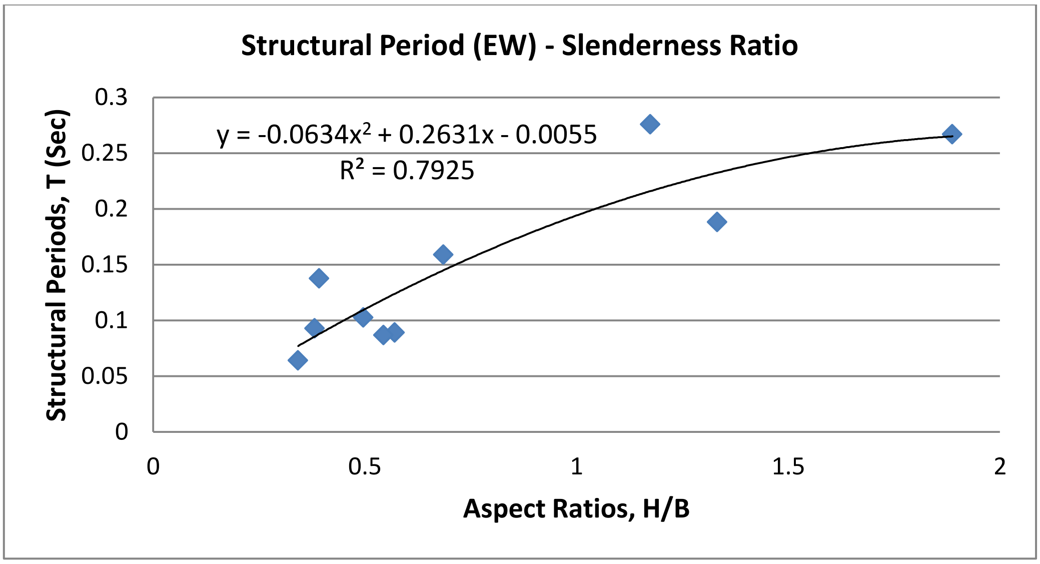


Figure 6.18: Relationship between Structural Periods of EW Directions and Aspect Ratios of the Structures

Both the relationship in the Figure No. 6.17 and Figure No. 6.18 show that a parabolic relation exists between structural periods of both the cardinal direction and the ratio of the heights and the least dimensions in the plans of the structures. The R-square values of both the relationship in the Figure No. 6.17 and Figure No. 6.18 do not represent convincing strength of association between the dependent and independent variables.

6.5 ANALYSIS OF THE RESULTS

6.5.1 Results Obtained from the Formula of BNBC

The structural periods T (Sec) of ten URM buildings obtained from BNBC 1993 from following:

$$T = C_t (h_n)^{3/4} \qquad (14)$$

where, C_t = 0.049 for all other structural systems

h_n = Height in metres above the base to level n.

Again the same obtained from Draft BNBC 2015 from following:

$$T = C_t (h_n)^{m} \qquad (15)$$

where,

h_n = Height of building in metres from foundation or from top of rigid basement. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected.

C_t and m are 0.488 and 0.75 respectively.

The obtained results are given in Table 6.2.

Table 6.2: Structural Periods T (Sec) Obtained from the Formula of BNBC

Building No	T (Sec) From BNBC 1993	T (Sec) From Draft BNBC 2015
13	0.10003936	0.09963
SLA	0.11942671	0.11894
6B	0.13362564	0.13308
8	0.19019253	0.18942
10	0.19019253	0.18942
15A	0.21806170	0.21717
15B	0.21806170	0.21717
7	0.31970711	0.31840
9B	0.36673460	0.36524
46	0.37795040	0.37641

6.5.2 Results Obtained Experimentally

Experimental structural periods obtained from ten URM buildings which are oriented in NS direction are given in Table 6.3.

Table 6.3: Experimental Results

Building No.	Height (m)	T (Sec)
13	2.59	0.0679348
SLA	3.28	0.1025641
6B	3.81	0.0562430
8	6.10	0.0873362
10	6.10	0.1023541
15A	7.32	0.0937207
15B	7.32	0.1127396
7	12.192	0.1795332
9B	14.64	0.1949318
46	15.24	0.2652520

The study will compare other structural periods obtained from different formula and procedures on the basis of these experimental values of structural periods.

6.5.3 Results Obtained from MS Excel Plots

Ten URM buildings are oriented in NS direction and their structural periods T (Sec) with their heights are related as follows:

$$T = 0.0009H^2 - 0.0031H + 0.0774 \tag{14}$$

Again the same URM buildings are related with their structural periods T (Sec) and total length of walls as follows:

$$T = 0.0005L + 0.0574 \tag{15}$$

Structural periods T (Sec) found from those formula are given in Table 6.4.

Table 6.4: Structural Periods T (Sec) Obtained from MS Excel Plots

Building No.	$T = 0.0009H^2 - 0.0031H + 0.0774$	$T = 0.0005L + 0.0574$
13	0.075408	0.074825
SLA	0.076915	0.068795
6B	0.078653	0.083145
8	0.091979	0.09667
10	0.091979	0.09113
15A	0.102932	0.1146
15B	0.102932	0.12979
7	0.173385	0.17878
9B	0.224913	0.167375
46	0.239188	0.299925

6.5.4 Results Obtained from SPSS 11.5

Taking the experimental data of NS direction the study performed analyses of 12 models (four models each i.e. enter, stepwise, backward elimination and forward selection procedure of regression) of all the three approaches. It was found that only a single model is suitable to be used as the relation between structural periods, height and the total length of walls of the structures. Again Approach 1 and Approach 2 both support it being statistically and practically significant. The model is as under (R^2= 0.957, Adjusted R^2=0.945 and SE= .0155). The relation between structural periods in the principal direction, height and the total length of walls of the structures is found as per the equation (13) and the structural periods T (Sec) found from that are given in Table 6.5.

It is mentionable that same procedure was followed by taking the experimental data of EW direction. However no model could be accepted as all the 12 models failed to provide any relation combining the height and the total length of walls with structural periods of the structures.

Table 6.5: Structural Periods T (Sec) in the Principal Direction Obtained from SPSS

Building No	**$T = 0.071+ 0.001 H^2 + 3.039E-07* L^2$**
13	0.07772
SLA	0.08179
6B	0.08558
8	0.10863
10	0.10863
15A	0.12545
15B	0.12545
7	0.22636
9B	0.29929
46	0.31965

Equation (13) has added three terms, first the constant 0.071, then 0.001 H^2 and the third and the last 3.039E-07* L^2. The co-efficient of the third term is 3.039E-07 i.e. 0.0000003039 which is very insignificant, when it is multiplied with L^2. It may carry some contribution for the structural periods of buildings having great length total of walls in m.

6.5.5 Comparison between the Results Obtained

A comparative statement of all values of structural periods obtained from different formula and procedures in the Table 6.6.

Table 6.6: Comparative Statement of the Structural Periods

Building No.	**H (m)**	BNBC 1993	Draft BNBC 2015	Experiment	MS Excel Plot for Best Fit Curve		SPSS Regression
					T vs H	T vs L	
13	2.59	0.1000394	0.09963	**0.067935**	0.075408	0.074825	0.07772
SLA	3.28	0.1194267	0.11894	**0.102564**	0.076915	0.068795	0.08179
6B	3.81	0.1336256	0.13308	**0.056243**	0.078653	0.083145	0.08558
8	6.10	0.1901925	0.18942	**0.087336**	0.091979	0.09667	0.10863
10	6.10	0.1901925	0.18942	**0.102354**	0.091979	0.09113	0.10863
15A	7.32	0.2180617	0.21717	**0.093721**	0.102932	0.11460	0.12545
15B	7.32	0.2180617	0.21717	**0.112740**	0.102932	0.12979	0.12545
7	12.192	0.3197071	0.31840	**0.179533**	0.173385	0.17878	0.22636
9B	14.64	0.3667346	0.36524	**0.194932**	0.224913	0.167375	0.29929
46	15.24	0.3779504	0.37641	**0.265252**	0.239188	0.299925	0.31965

The general observations, excluding the structural periods of building no. SLA, From the Table 6.6 are stated as follow:

The structural periods obtained using the formula of both the BNBC are much higher than the experimental values and values calculated from MS Excel parabolic equation of the same. It signifies that BNBC states larger structural periods which leads to determination of lesser design base shear thus designing an unsafe URM structures.

Again the structural periods obtained using the SPSS 11.5 are a little higher than the experimental values and values calculated from MS Excel parabolic equation of the same.

However the structural periods obtained using the MS Excel plotting are very close to the same of the experimental values. Average variation between the values of MS Excel plot and experimental values is 13.3%.

6.6 FINAL DEDUCTION

This coefficient of determination, R^2 is the proportion of variance in the dependent variable which can be explained by the independent variables. This is an overall measure of the strength of association between independent variable and the dependent variable. The larger the value the better the regression line describes the data. It is worth mentionable and noticeable that the MS Excel Polynomial Fit i.e. parabolic fit for the relation between structural periods, T (Sec) with the heights, H (m) of structures has the R^2 value 0.9197. However the MS Excel Linear Fit for the relation between structural periods T (Sec) with the total length of walls, L (m) of structures has the R^2 value 0.8923.

Therefore, bearing in mind all the facts and findings of the research, the equation (14) may be utilized to obtain the structural periods T (Sec) while taking height, H (m) of structures in cognizance. So the study suggests a change in the present code (BNBC 1993) and inclusion in the BNBC in future about calculation of structural periods of URM structures ranging from single-storied to five-storied (height ranges from 2.59m to 15.24m) by the above mentioned equation (14) in the following form:

$$T = 0.001H^2 - 0.003H + 0.08 \qquad (15)$$

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 GENERAL

Any structure must be able to resist the dynamic effect contributed by an earthquake. Earthquake loads are inertia forces resulting from ground movements and they impose certain demands on the structures related to strength, ductility and energy dissipation (Rai, 2000). The actual responsive behaviour of structures under an earthquake is similar to the ambient vibration behaviour. That is why ambient vibration behaviour is being used for SHM. Purposes of this chapter are to present the summary and salient conclusions derived from this study. The research has included both software analysis and physical testing of the URM buildings. Software analysis using accurate nonlinear time history analysis of AVT enabled to analyze the URM buildings with its ambient vibrations and geometry.

7.2 RELATIONS BETWEEN STRUCTURAL PERIODS, HEIGHTS AND TOTAL LENGTH OF WALLS OF STRUCTURES

The first step of this study conducted AVT on 17 URM buildings of several locations in the Dhaka city. Then with those data from AVTs the pre-dominant or natural frequencies of the targeted URM buildings were identified. This step involved a program in MATLAB. Based on that data, structural pre-dominant periods were calculated for those URM buildings. Besides 10 URM buildings were identified which were oriented in the NS direction with their longer sides in plans. Relations between structural periods and different parameters of structures were analyzed individually by MS Excel separately for all and the buildings oriented in the NS direction. Basing on the strength of association, the data of structural periods, heights and total length of walls of structures were analyzed using multivariate regression analysis to determine a suitable model accurately for the buildings oriented in the NS direction. Computer aided software name SPSS made the process easy and reduced time and also allowed many iterations to get a reliable result. The multivariate regression analysis was selected for model development.

Total three approaches each for both the input data (experimental structural periods for NS and EW directions) were followed where structural period was the DV for all three. The objective of this analysis is to correlate and combine structural periods, heights and total length of walls of structures. Approach 1 consideration the DV i.e. structural period is a cubic function of both the IVs i.e. height of structures and total length of walls separately. Approach 2 consideration the DV i.e. structural period is a quadratic function of both the IVs i.e. height of structures and total length of walls separately. Later Approach 3 considered DV i.e. structural period is a quadratic function of height of structures and is having a linear function of total length of walls, separately.

Total four methods for each approach were used one after another as to check which one work better and provide realistic solution. Finally both the forward selection and stepwise methods of Approach 1 and Approach 2 (having data of experimental structural periods for NS direction) provided similar and the best possible result.

All the models had a constant, square of both height and total length of walls of structures with significance at 0% level, at 0.1% level and at 4% level individually respectively. Significances of variables met the acceptable level of significance. The model can explain 95.7% of the variability with the 3 variables. The Standard Error (SE) 0.0155 i.e. about 1.6% which is very small in regards to the DV in question. However the Durbin-Watson value 2.981 is more than the maximum value of 2.5, which indicates strong negative serial correlation and some autocorrelation exist between the variables considered. It may lead to impractical test results due to generation of multi-collinearity problem.

All the important assumptions of multiple linear regressions was tested before and in the process of mode and met almost full. Sensitivity analysis of variables for the model was performed and passed (Appendix N). It is mentionable that no significant changes in the relations were found in the results obtained from SPSS analysis.

These obtained structural pre-dominant periods were compared with the structural period calculated by the formula given in BNBC. However a comparison between the experimental results, best fit curvature for the relation between structural periods and heights of structures and best fit line for the relation between structural periods and total length of walls of structures, BNBC and SPSS results were performed.

The structural periods obtained using the formula of both the BNBC are much higher than the experimental values and values calculated from MS Excel parabolic equation of the same. Again the structural periods obtained using the SPSS 11.5 are a little higher than the experimental values. However the structural periods obtained using the MS Excel plotting are very close to the same of the experimental values.

7.3 FINDINGS FROM THE STUDY

Attempt was made to correlate structural periods with heights and structural periods with total length of walls of structures by MS Excel plots. Again between all the three parameters i.e. structural periods, heights and total length of walls of structures correlation was modeled by various methods of SPSS. Finally a model was selected combining structural periods, heights and total length of walls of structures. However that statistically significant model has very little practical significance.

Bearing in mind all the facts, following findings from the research can be summarized:

a. The modal shapes and the pre-dominant frequencies become more and more distinct with the increase of structure's height.

b. There is a strong relationship among structural periods, heights and total length of walls in two cardinal directions of URM structures.

c. There is a strong parabolic relationship between the structural periods and the heights and linear relationship between the structural periods and the total length of walls in two cardinal directions of URM structures. However the relationship between the structural periods and the heights of URM structures is much stronger.

d. The structural periods obtained using the formula of both the BNBC are much higher than the experimental values and values calculated from MS Excel parabolic equation and SPSS model of the same. It signifies that BNBC states larger structural periods which leads to determination of lesser design base shear thus designing an unsafe URM structures.

e. Again the structural periods obtained using the SPSS model are a little higher than the experimental values and values calculated from MS Excel parabolic equation of the same.

f. The structural periods obtained using the MS Excel parabolic equation are very close to the same of the experimental values.

Basing on all the facts and findings, the study proposes the equation (15) may be utilized to obtain the structural periods T (Sec) while taking height, H (m) of structures in cognizance. So the study suggests a change in the present code (BNBC 1993) and inclusion in the BNBC in future about calculation of structural periods of URM structures ranging from single-storied to five-storied (height ranges from 2.59m to 15.24m):

$$T = 0.001H^2 - 0.003H + 0.08 \qquad (15)$$

7.4 RECOMMENDATION FOR FUTURE RESEARCH

This section will discuss some recommendations for future study. The followings are the recommendations for future study.

a. If the number of sample URM buildings and locations are increased within Dhaka city or in a bigger frame country wide it is likely to provide a validation of this study and a period database can be developed for URM buildings in Dhaka city or for that matter for URM buildings in Bangladesh.

b. Additional researches could be conducted to examine deeper into this field through overcoming the limitations presented above.

c. More design variables (structural parameters i.e. thickness of walls, thickness of slabs, types of foundations, aspect ratio, slenderness ratio, age of structures, variations in construction materials etc.) may be included in future.

d. Other non-linear models and softwares can be used to do further research.

e. Similar research can be conducted on structures other than URM buildings i.e. arch bridge, chimneys, towers etc.

f. It is also expected that the modeling technique will unfold a new avenue for the researchers of Bangladesh for making further study of similar nature.

g. Further research based on AVT can be conducted using models prepared in laboratory. A work on the laboratory shake table testing model can be an important one.

h. Very important masonry structures i.e. URM KPIs of Bangladesh may be instrumented permanently for their SHM through continuous recordings of ambient vibrations.

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DETERMINATION OF STRUCTURAL PERIOD (BNBC 1993)

2.5.6.2 Structure Period: The value of the fundamental period, T of the structure shall be determined from one of the following methods:

a) **Method A:** For all buildings the value of T may be approximated by the following formula:

$$T = C_t \, (h_n)^{3/4} \qquad (2.5.3)$$

where, C_t = 0.083 for steel moment resisting frames

= 0.073 for reinforced concrete moment resisting frames, and eccentric braced steel frames

= 0.049 for all other structural systems

h_n = Height in metres above the base to level n.

Alternatively, the value of C_t for buildings with concrete or masonry shear walls may be taken as $0.031/\sqrt{A_c}$. The value of A_c shall be obtained from the relation:

$$A_c = \sum A_e \left[0.2 + (D_e / h_n)^2\right] \qquad (2.5.4)$$

where, A_c = The combined effective area, in square metres, of the shear walls in the first storey of the structure.

A_e = The effective horizontal cross-sectional area, in square metres of a shear wall in the first storey of the structure.

D_e = The length, in metre of a shear wall element in the first storeyin the direction parallel to the applied forces.

The value of D_e / h_n for use in Eq (2.5.4) shall not exceed 0.9.

DETERMINATION OF BUILDING PERIOD (DRAFT BNBC 2015)

2.5.9.2 BUILDING PERIOD

The fundamental period T of the building in the horizontal direction under consideration shall be determined using the following guidelines:

a) Structural dynamics procedures (such as Rayleigh method), using structural properties and deformation characteristics of resisting elements, may be used to determine the fundamental period T of the building in the direction under consideration. This period shall not exceed the approximate fundamental period determined by Equation (6.2.5.8) by more than 40%.

b) The building period T (in secs) may be approximated by the following formula:

$$T = C_t (h_n)^m \qquad (6.2.5.8)$$

where,

h_n = Height of building in metres from foundation or from top of rigid basement. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected.

C_t and m are obtained from Table 6.2.5.8.

Table 6.2.5.8: Values for coefficients to estimate approximate period

Structure type	C_t	m
Concrete moment-resisting frames	0.0466	0.90
Steel moment-resisting frames	0.0724	0.80
Eccentrically braced steel frame	0.0731	0.75
All other structural systems	0.0488	0.75

NOTE:

Consider moment resisting frames as frames which resist 100% of seismic force and are not enclosed or adjoined by components that are more rigid and will prevent the frames from deflecting under seismic forces.

c) For masonry or concrete shear wall structures, the approximate fundamental period, T in secs may be determined as follows:

$$T = \frac{0.0062}{\sqrt{C_w}} h_n \qquad (6.2.5.9)$$

where,

$$C_w = \frac{100}{A_B}\sum_{i=1}^{x}\left(\frac{h_n}{h_i}\right)^2 \frac{A_i}{\left[1+0.83\left(\frac{h_i}{D_i}\right)^2\right]} \qquad (6.2.5.10)$$

where,

A_B = area of base of structure

A_i = web area of shear wall “i”

D_i = length of shear wall “i”

h_i = height of shear wall “i”

x = number of shear walls in the building effective in resisting lateral forces in the direction under consideration.

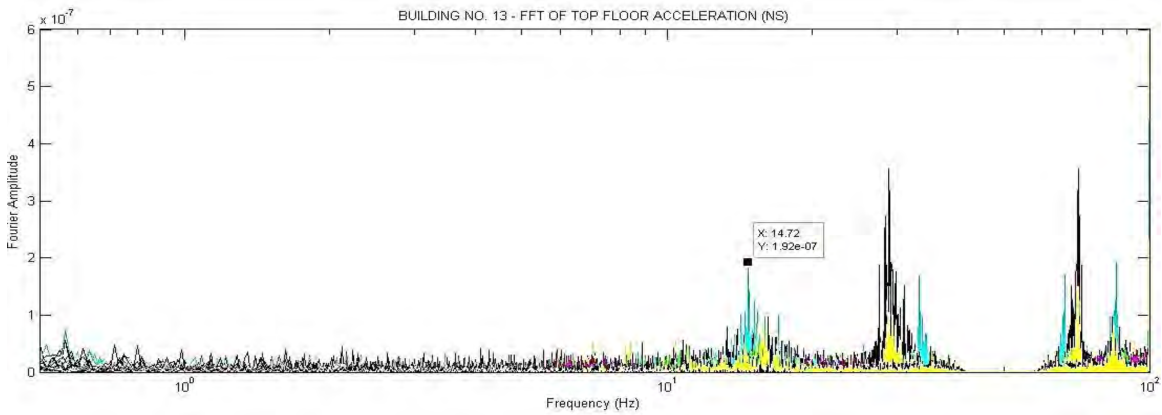
DIFFERENT PARAMETERS OF URM BUILDINGS UNDER STUDY

Ser	Storey	Building Identification No.	Maximum Height at Top Floor from P.L.		Wall Thickness (cm)	Length of Wall (m) per Floor	
			m	Ft		NS	EW
1.	Single	13	2.59	8.5	25	34.85	41.35
2.		SLA	3.28	10.75	39.4	22.79	24.41
3.		6A	3.81	12.5	25	90.93	85.50
4.		6B				51.49	38.36
5.		6C	4.57	15		72.14	101.05
6.		8	6.10	20	40	78.54	80.36
7.	2-storied	10 (Grd)	6.10	20	25	67.46	73.33
		10 (1st)				70.92	59.99
8.		15A (Grd)	7.32	24	25	57.20	46.94
		15A (1st)				57.20	49.38
9.		15B (All)				72.39	91.54
10.		18A (T Type)			43.2	52.28	49.69
11.		18B (All)				25.30	45.72
12.	3-storied	2 (Grd)	9.144	30	25	136.93	122.65
		2 (Others)				55.47	67.38
13.	4-storied	7 (All)	12.192	40'	25	60.69	91.55
14.		11 (Grd)				96.53	63.14
		11 (Others)				103.15	105.14
15.		9A (1st)	14.64	48'		71.62	67.07
16.	4-storied	9B (Grd)	14.64	48'		62.08	48.06
		9B (1st)				62.33	80.40
		9B (2nd)				51.44	44.40
		9B (3rd)				44.10	66.60
17.	5-storied	46 (All)	15.24	50'	25	97.01	91.42

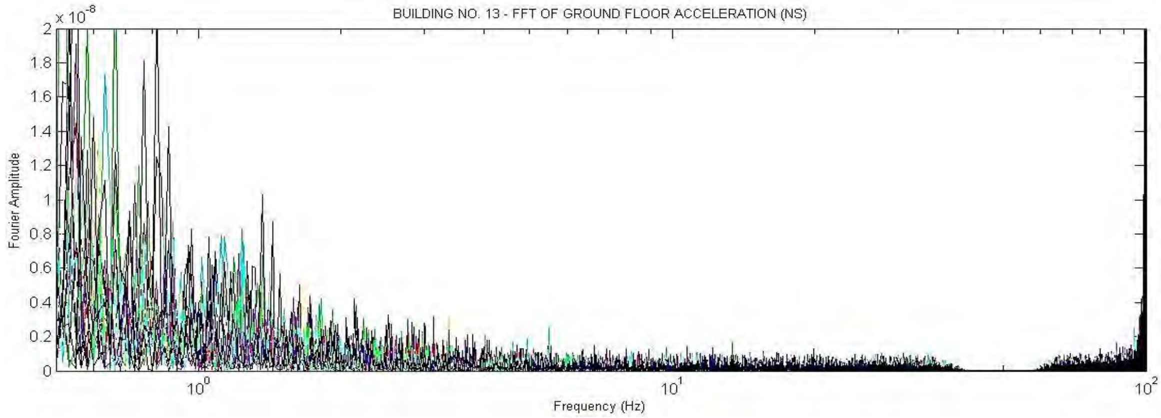
FFT OUTPUTS OF FLOOR ACCELERATIONS OF URM BUILDINGS UNDER STUDY

1. FFT Outputs of Single-Storied URM Buildings.

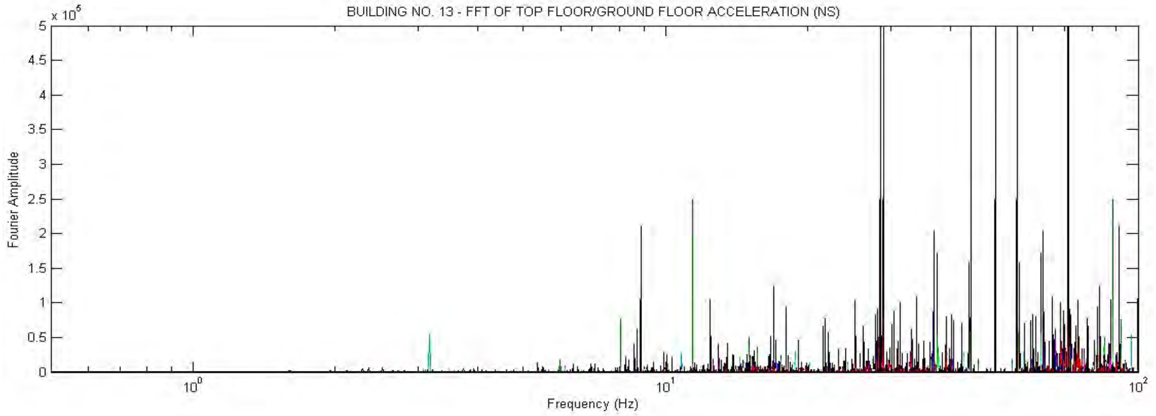
Building No. 13.



(a)

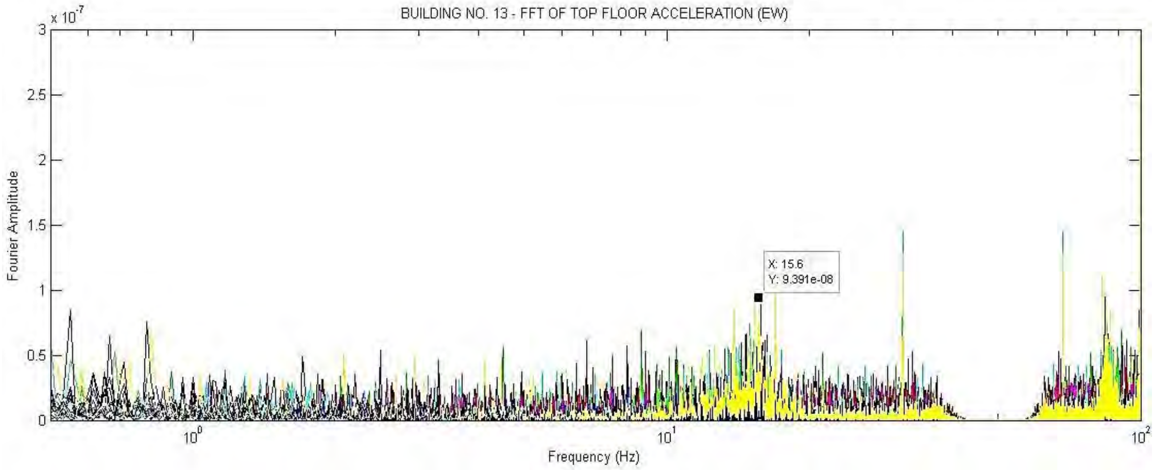


(b)

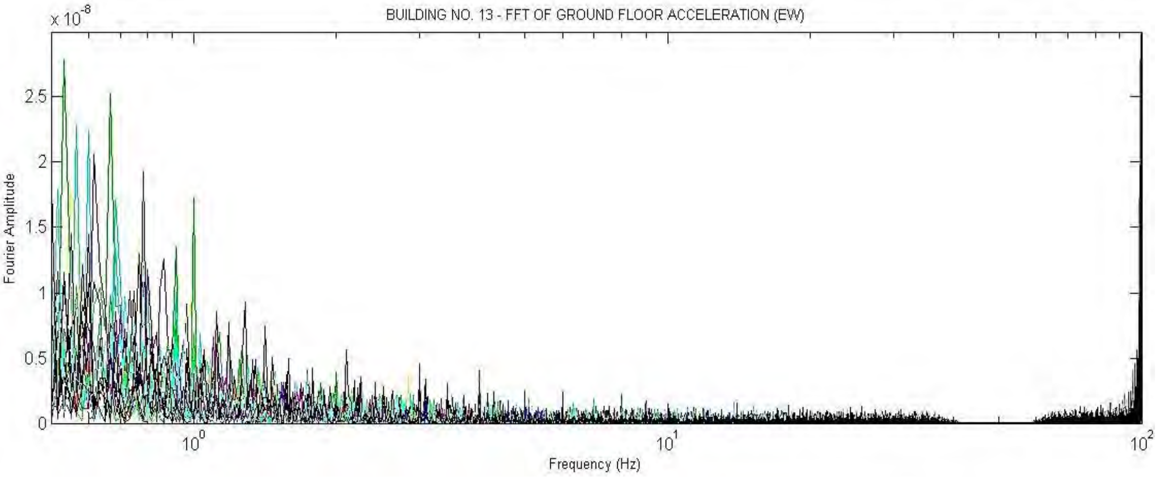


(c)

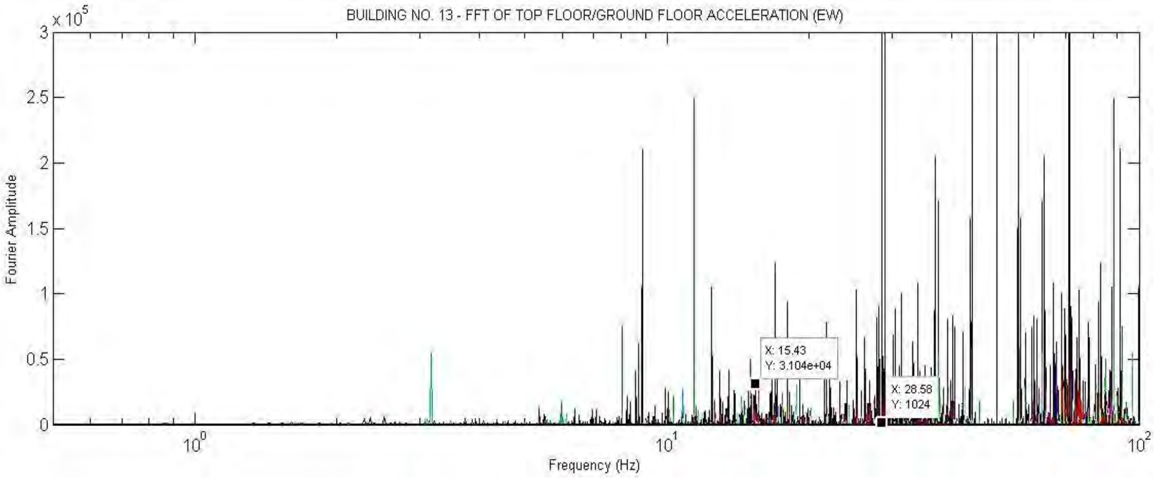
Figure D.1: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



(a)



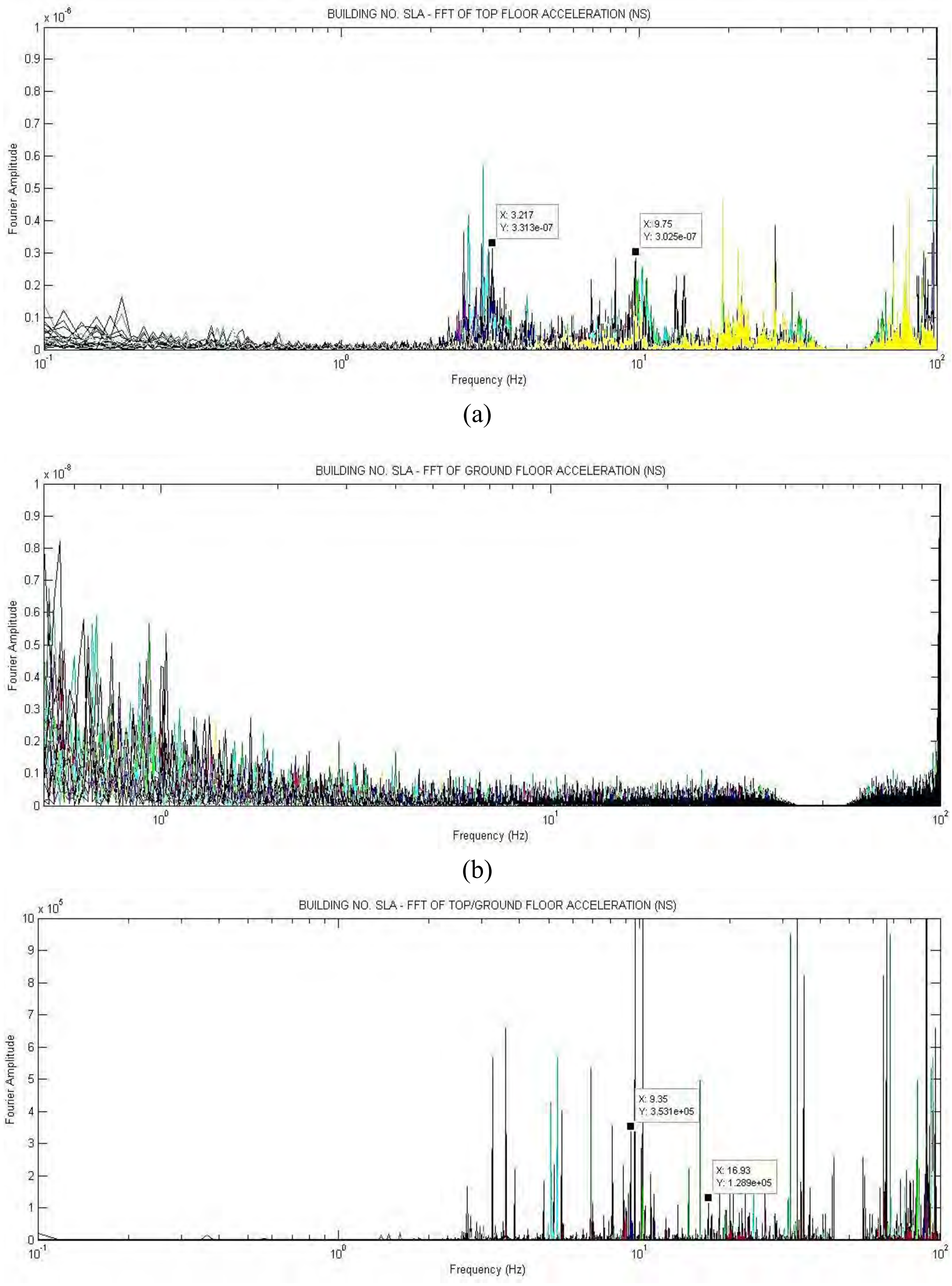
(b)



(c)

Figure D.2: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

Building No. SLA.

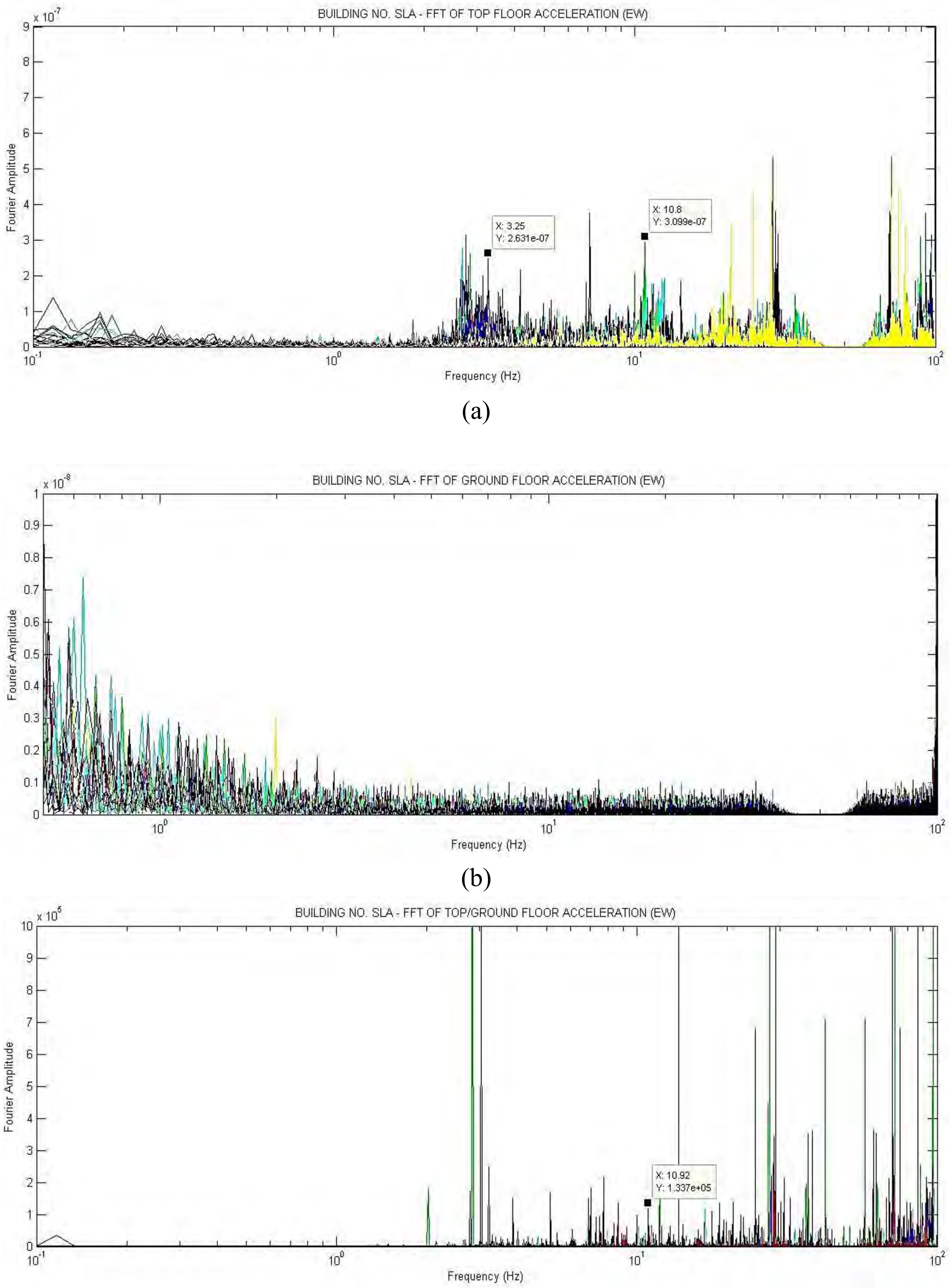


(a)

(b)

(c)

Figure D.3: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



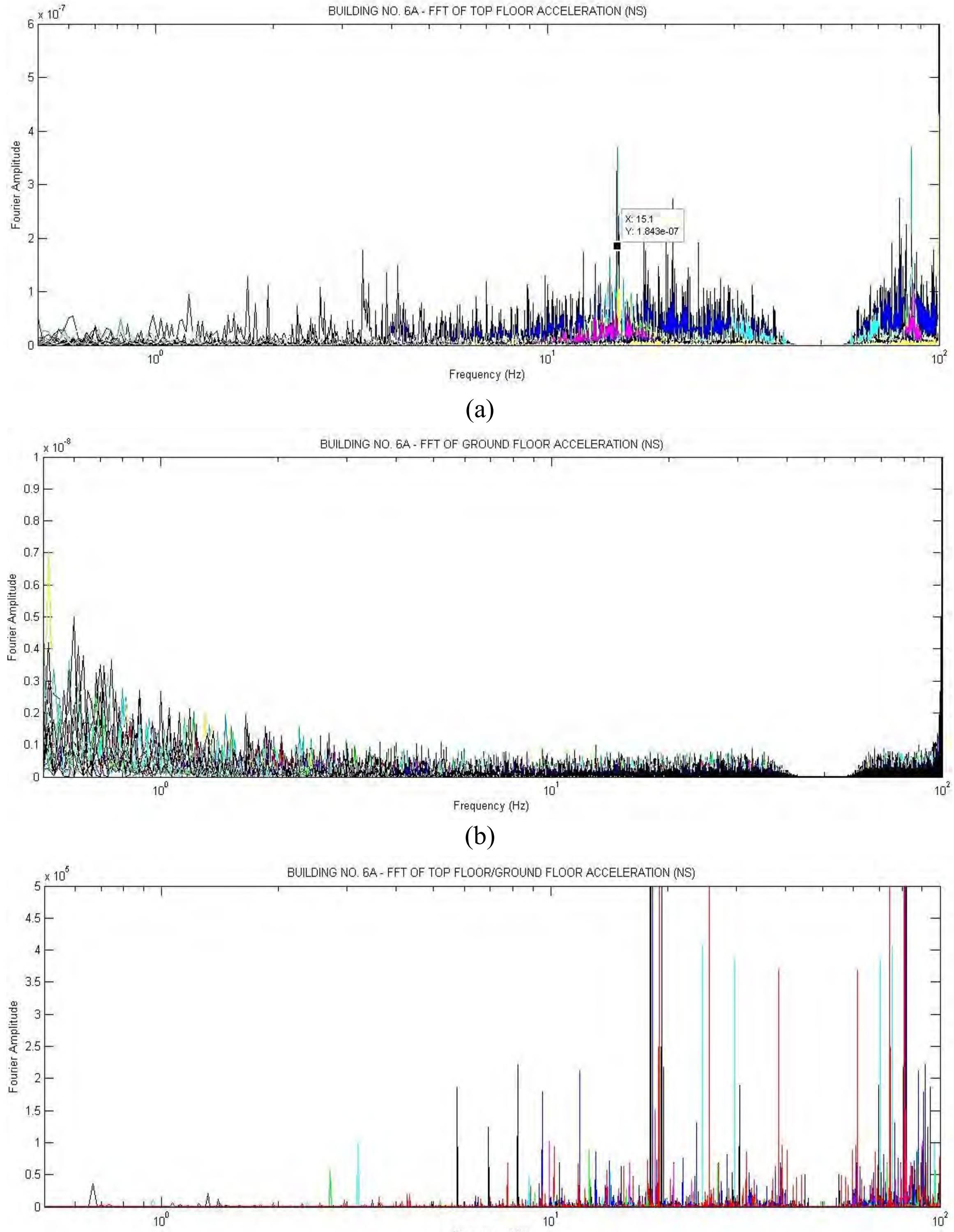
(a)

(b)

(c)

Figure D.4: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

Building No. 6A.

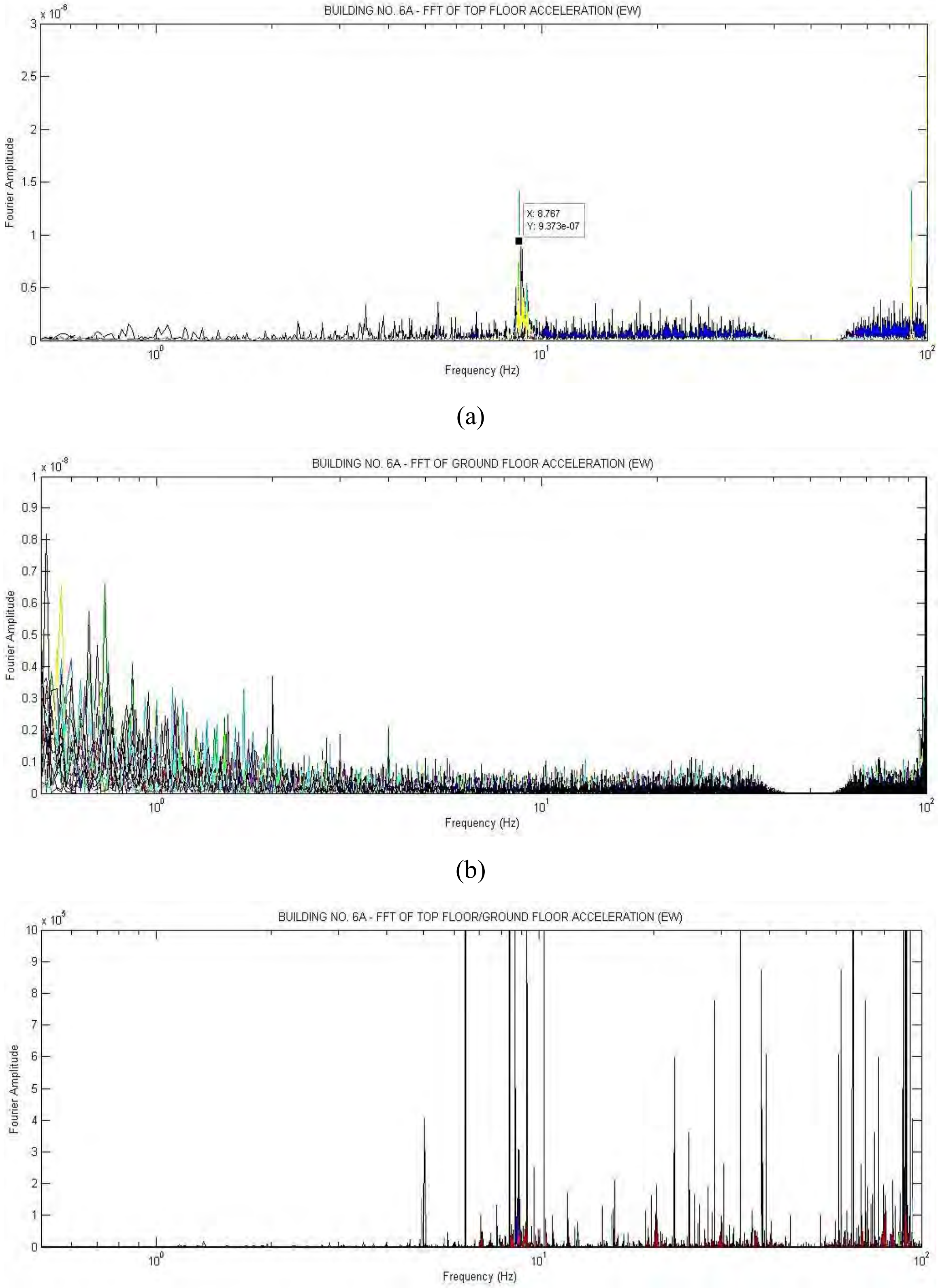


(a)

(b)

(c)

Figure D.5: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



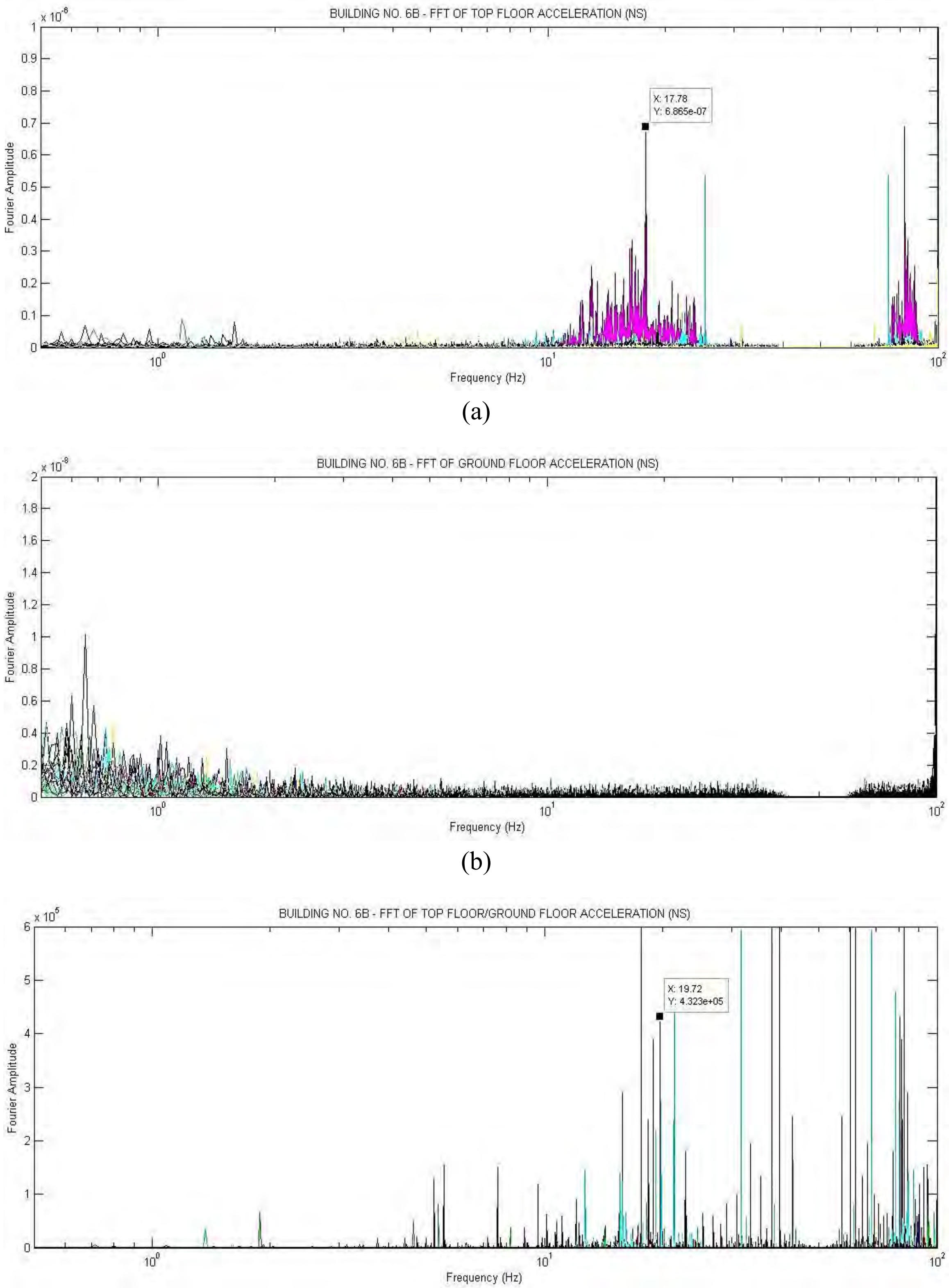
(a)

(b)

(c)

Figure D.6: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

Building No. 6B.

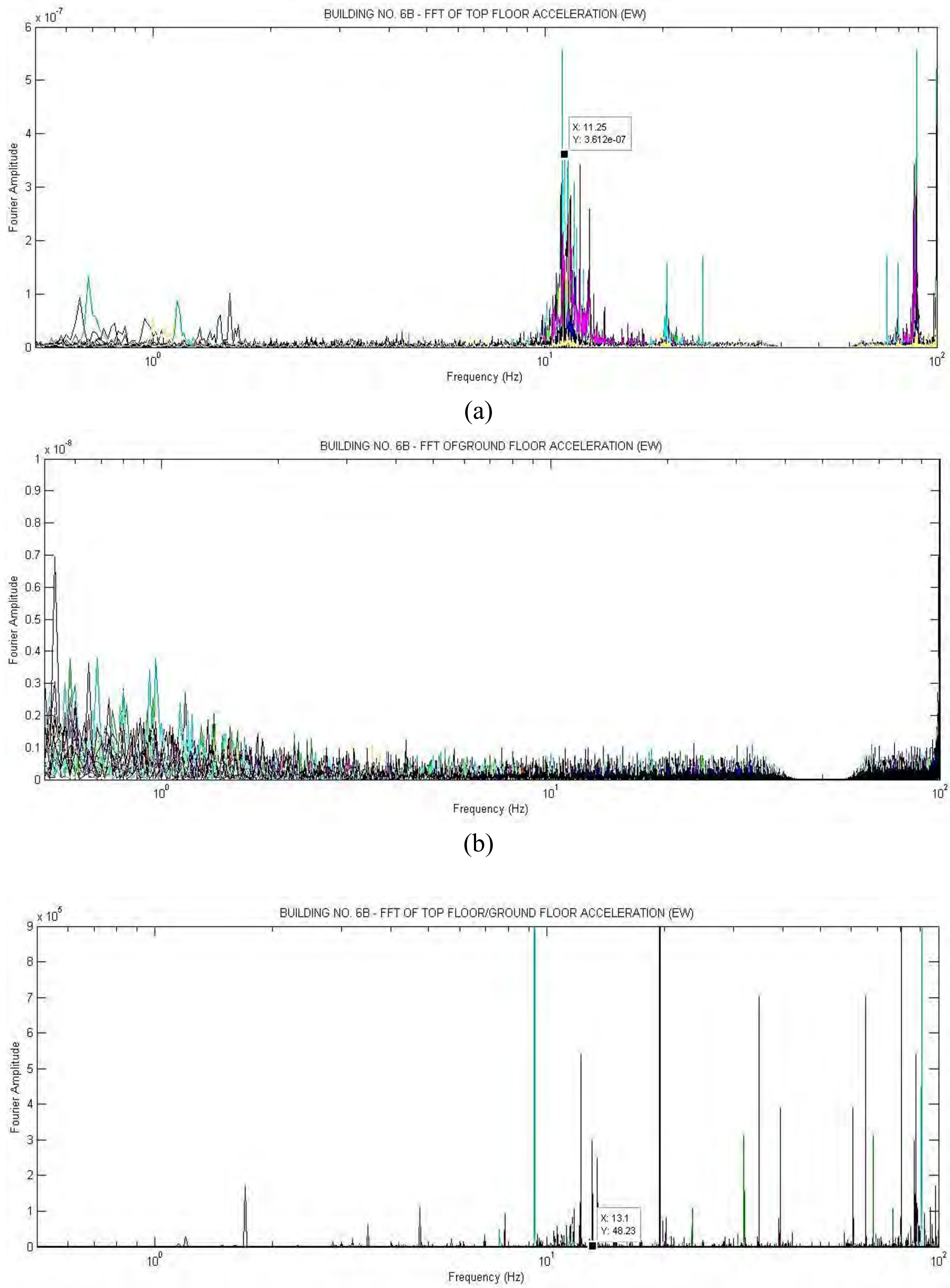


(a)

(b)

(c)

Figure D.7: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



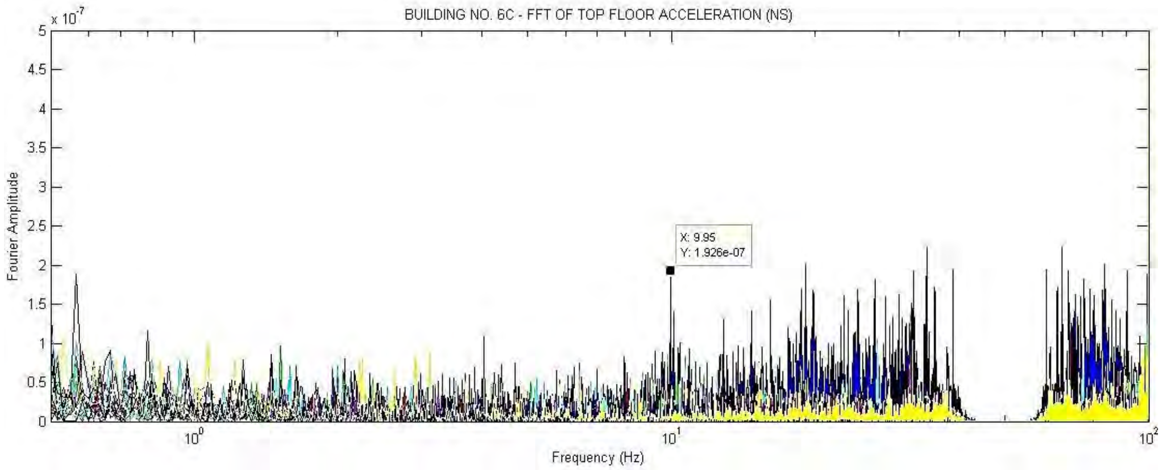
(a)

(b)

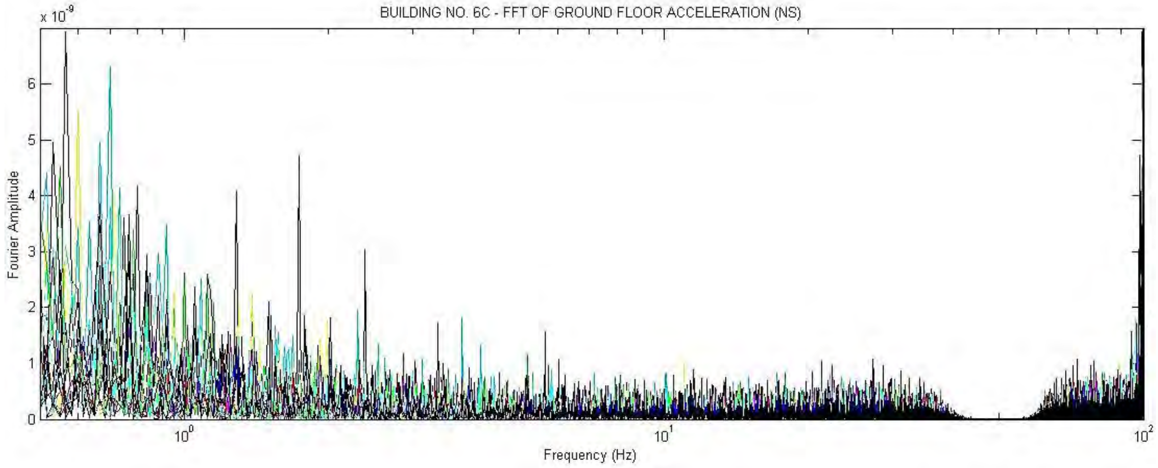
(c)

Figure D.8: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

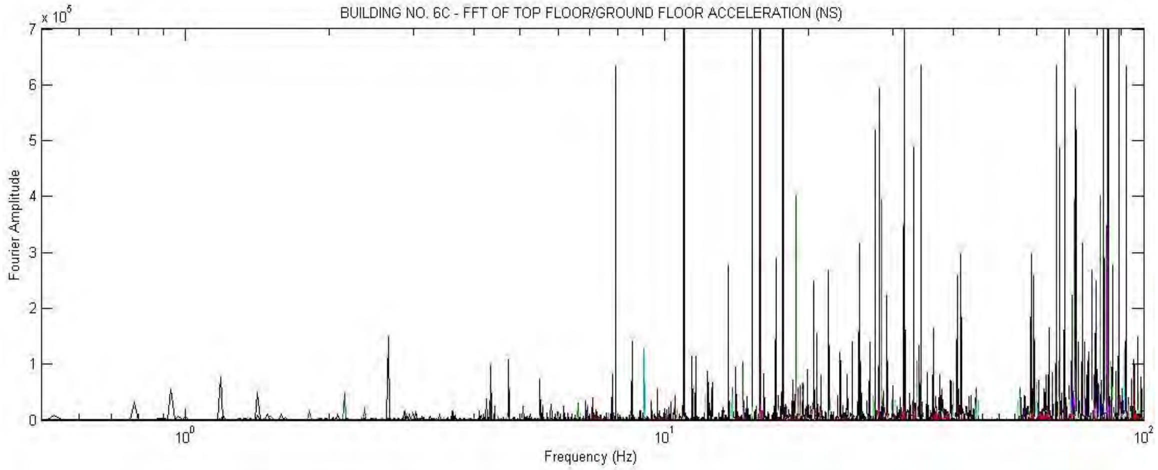
e. **Building No. 6C**.



(a)

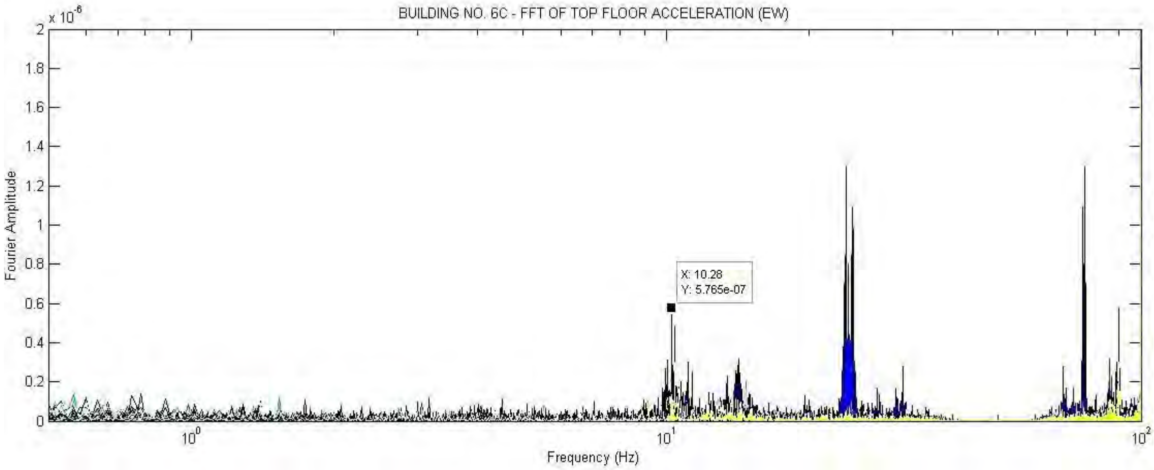


(b)

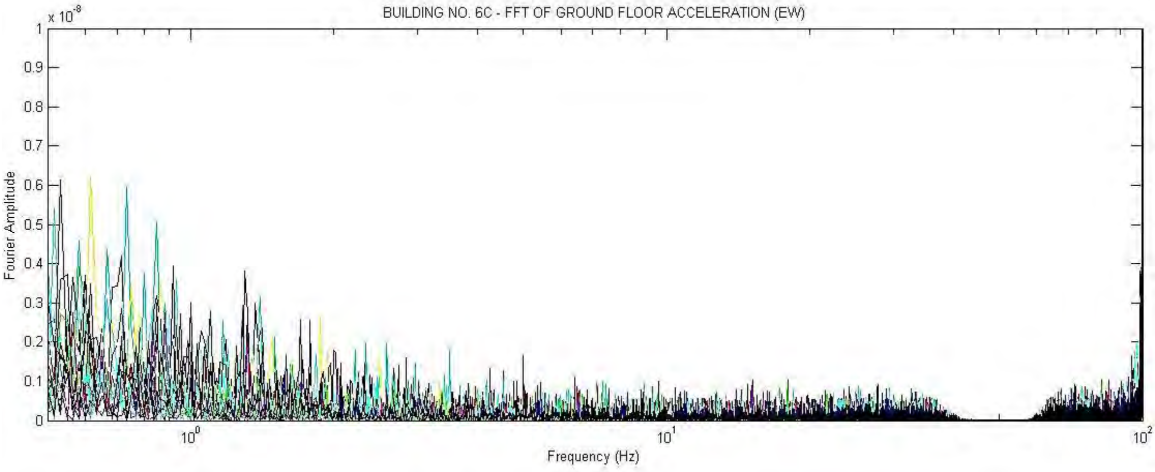


(c)

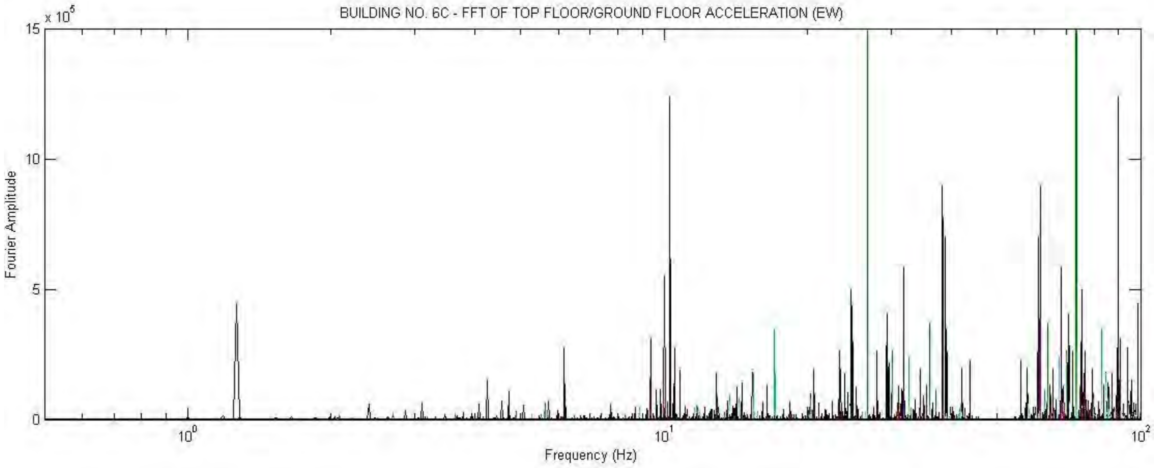
Figure D.9: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



(a)



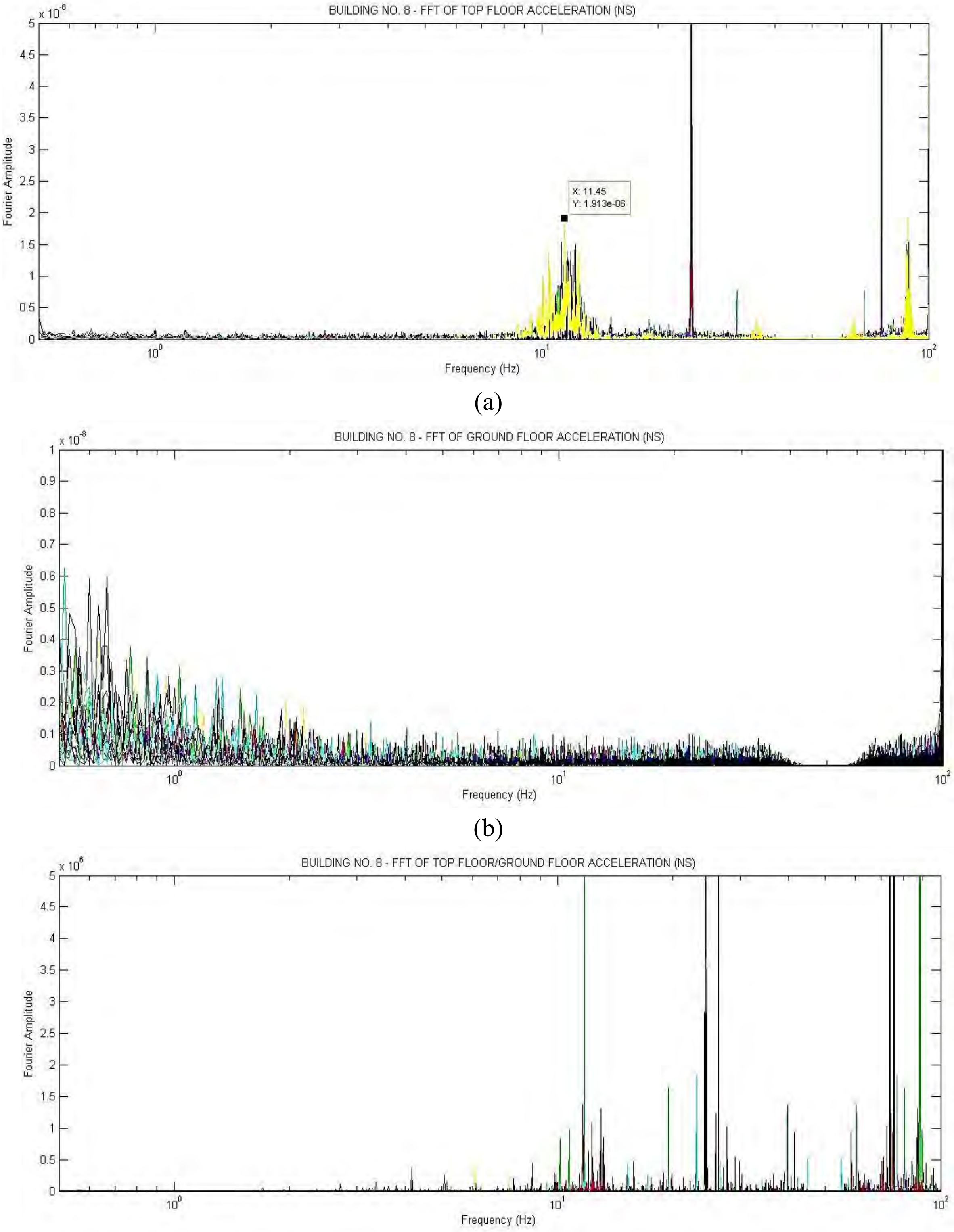
(b)



(c)

Figure D.10: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

f. **Building No. 8**.

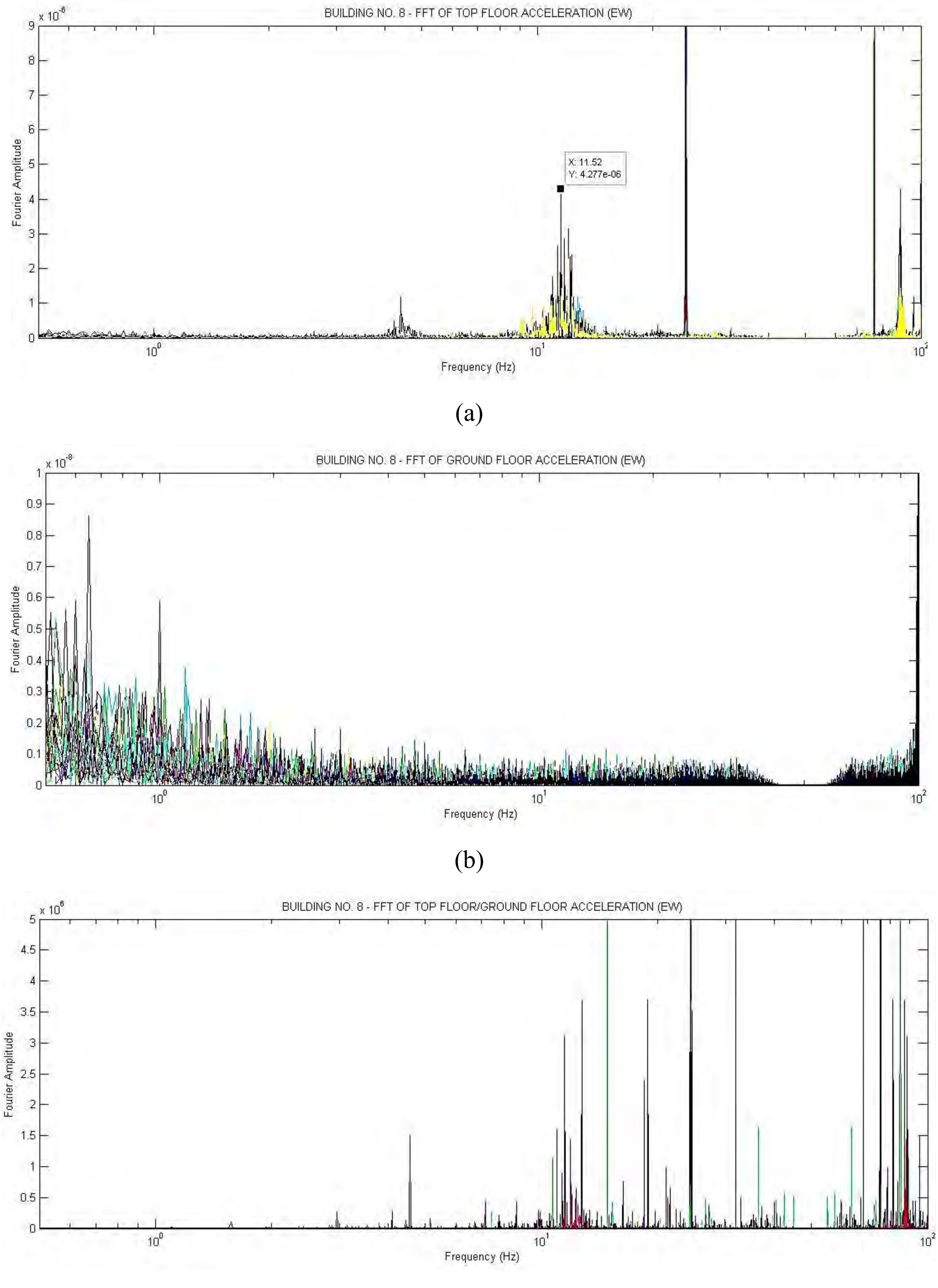


(a)

(b)

(c)

Figure D.11: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



(a)

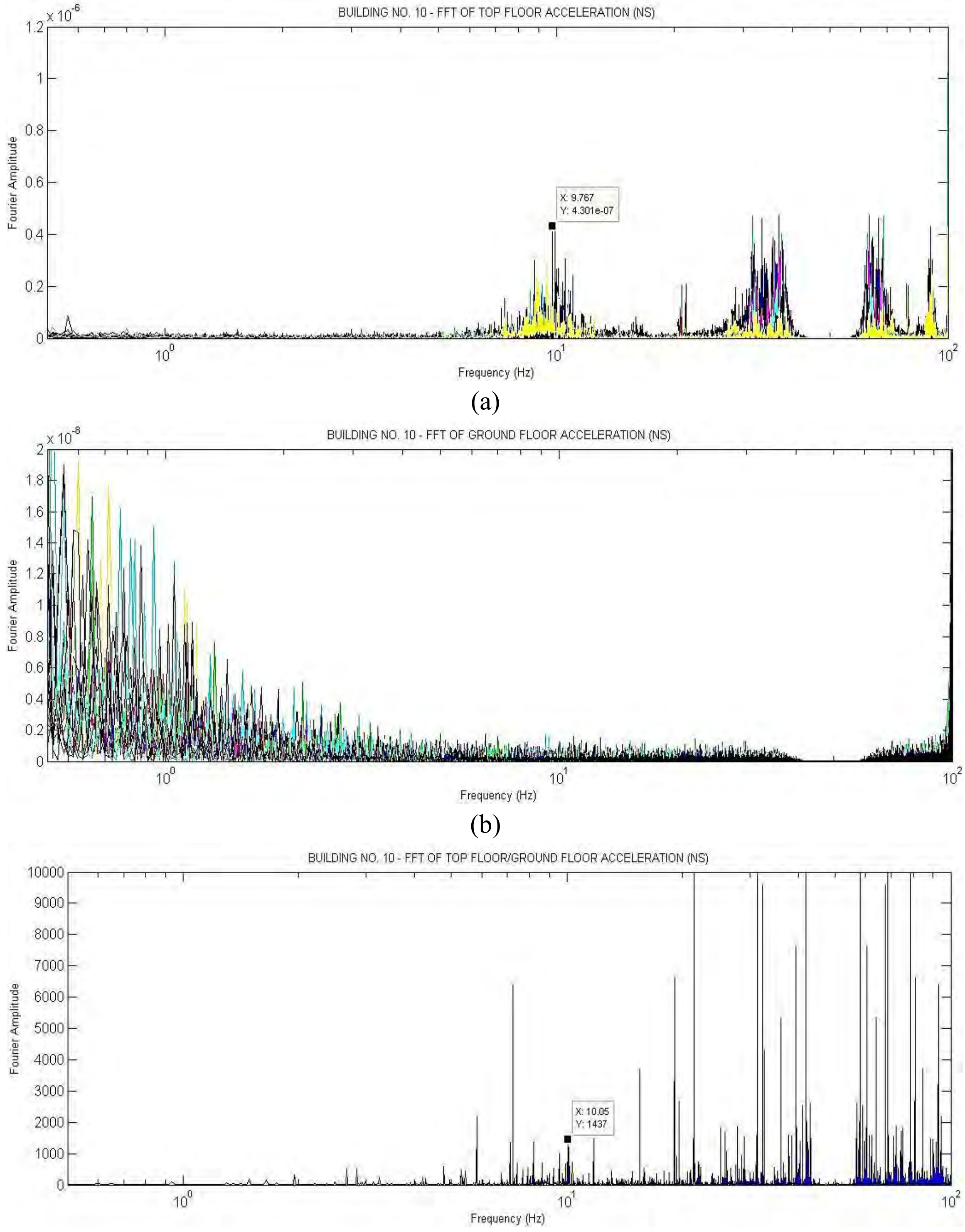
(b)

(c)

Figure D.12: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

2. **FFT Outputs of Two-Storied URM Buildings**.

Building No. 10.



(a)

(b)

(c)

Figure D.13: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction

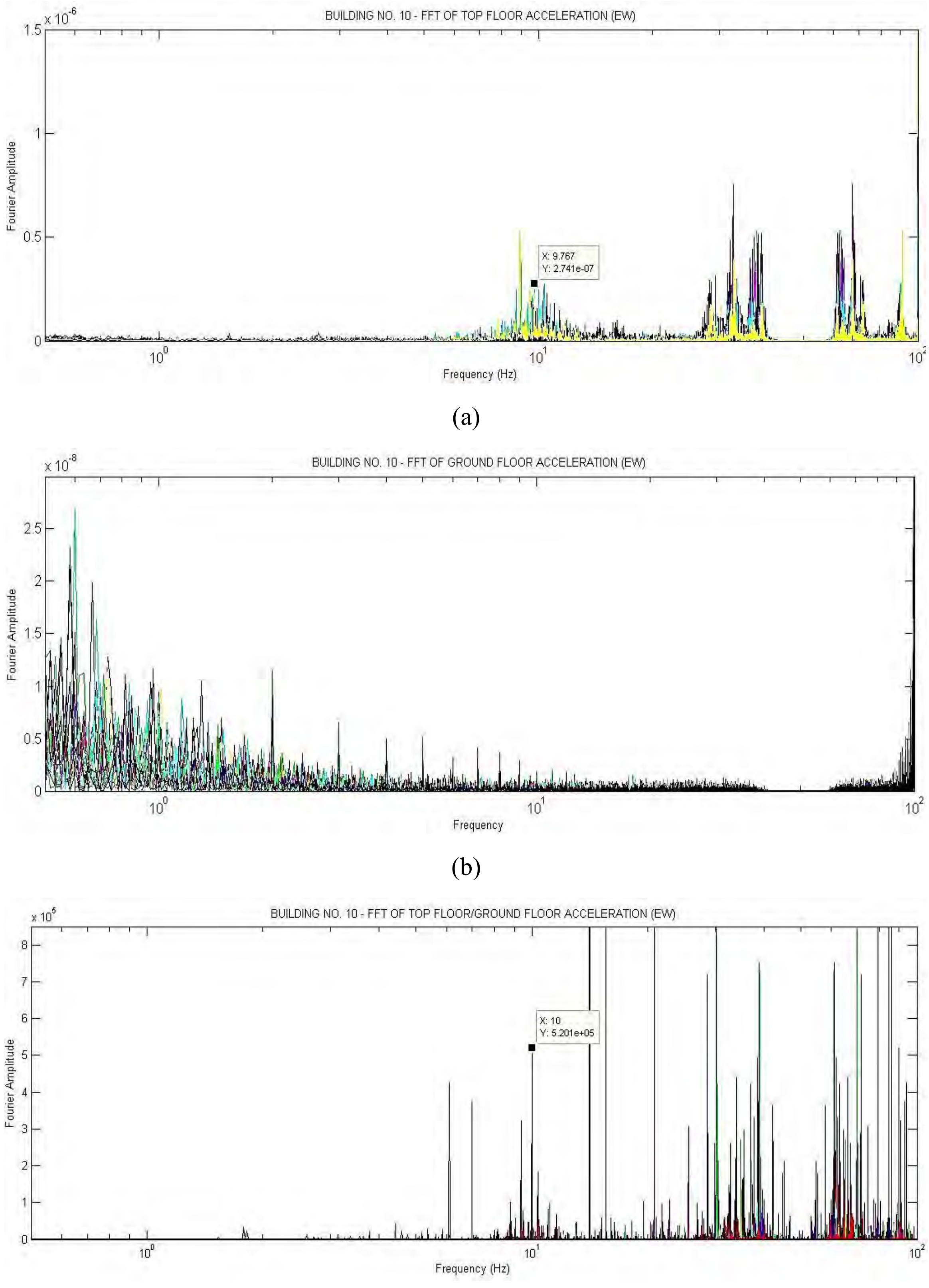
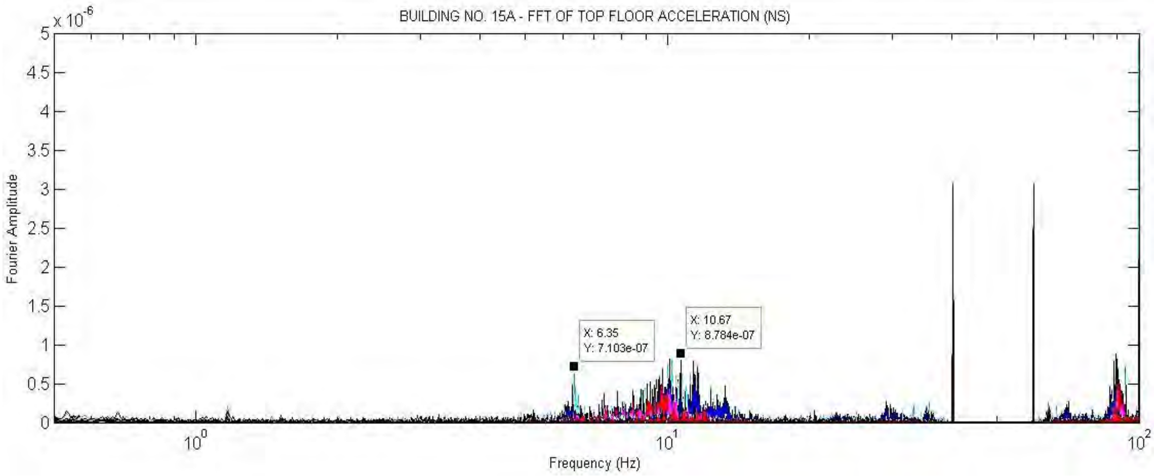
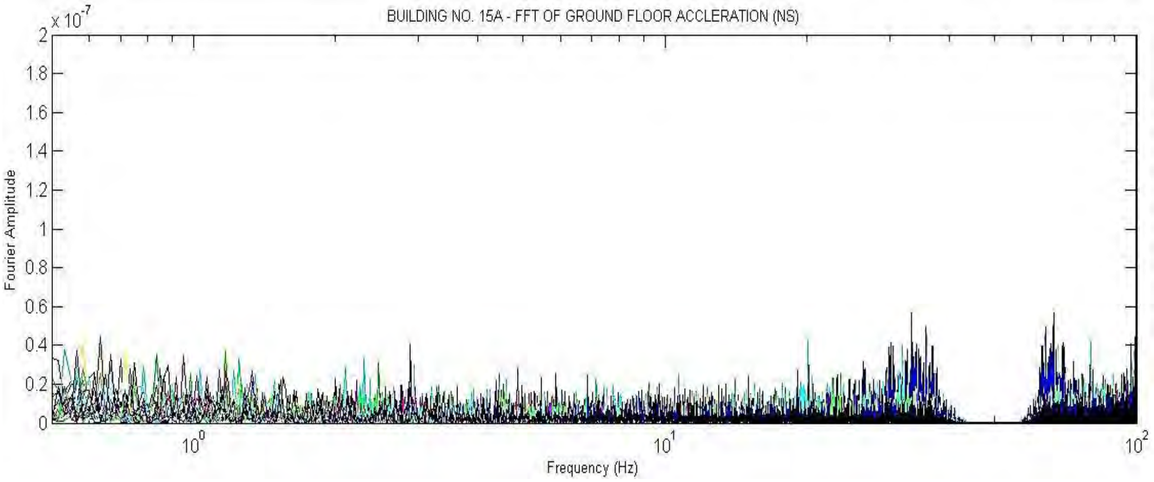


Figure D.14: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

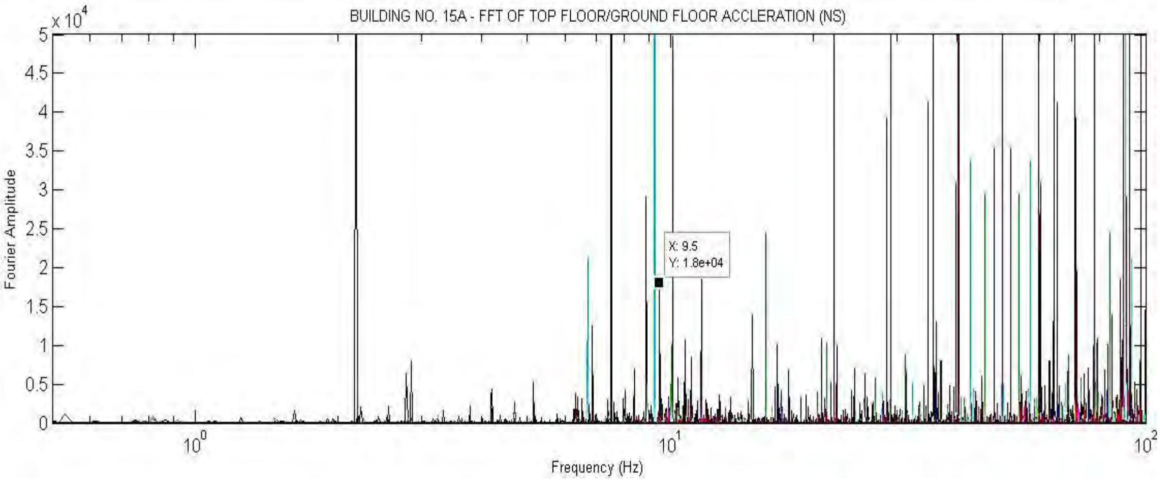
b. Building No. 15A.



(a)

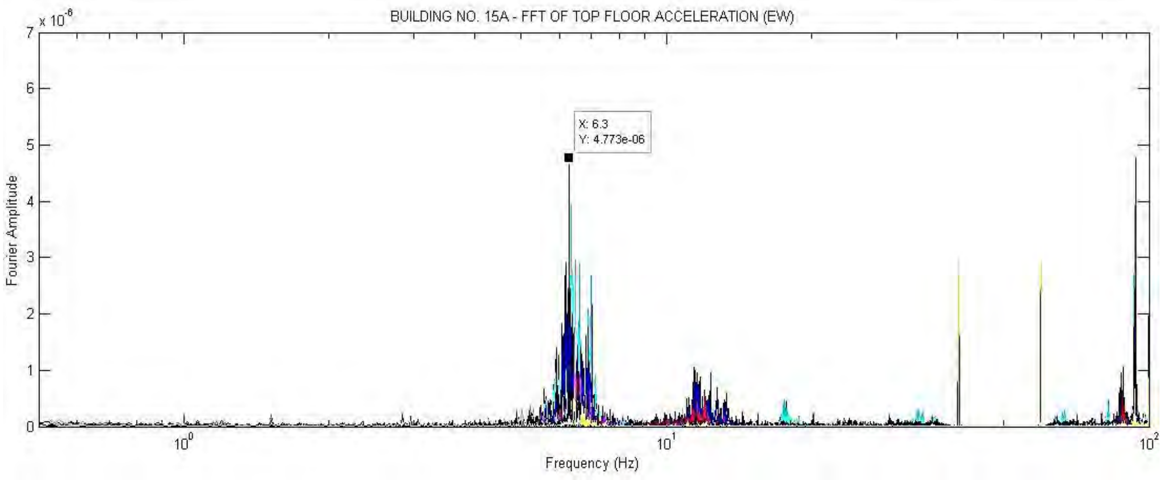


(b)

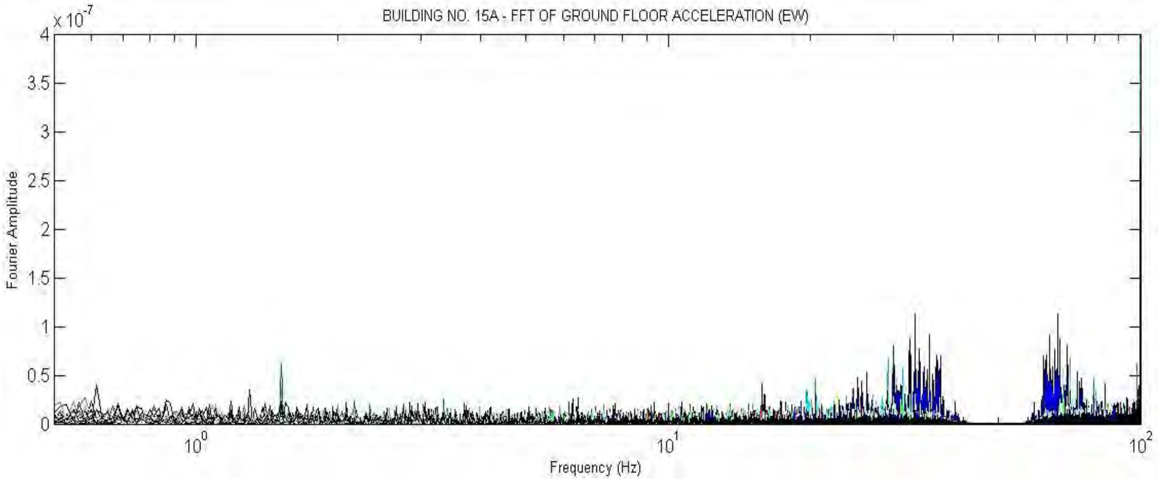


(c)

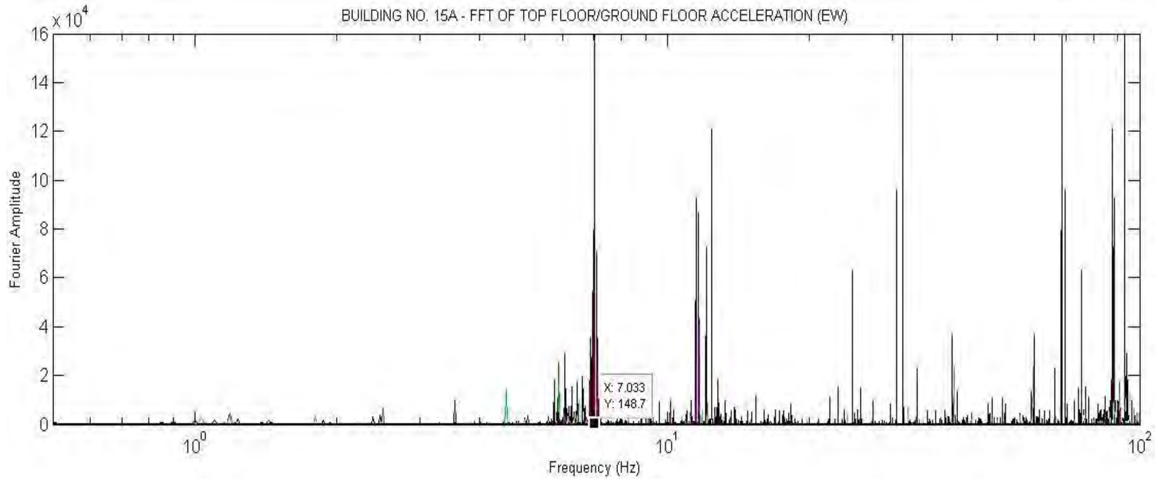
Figure D.15: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



(a)



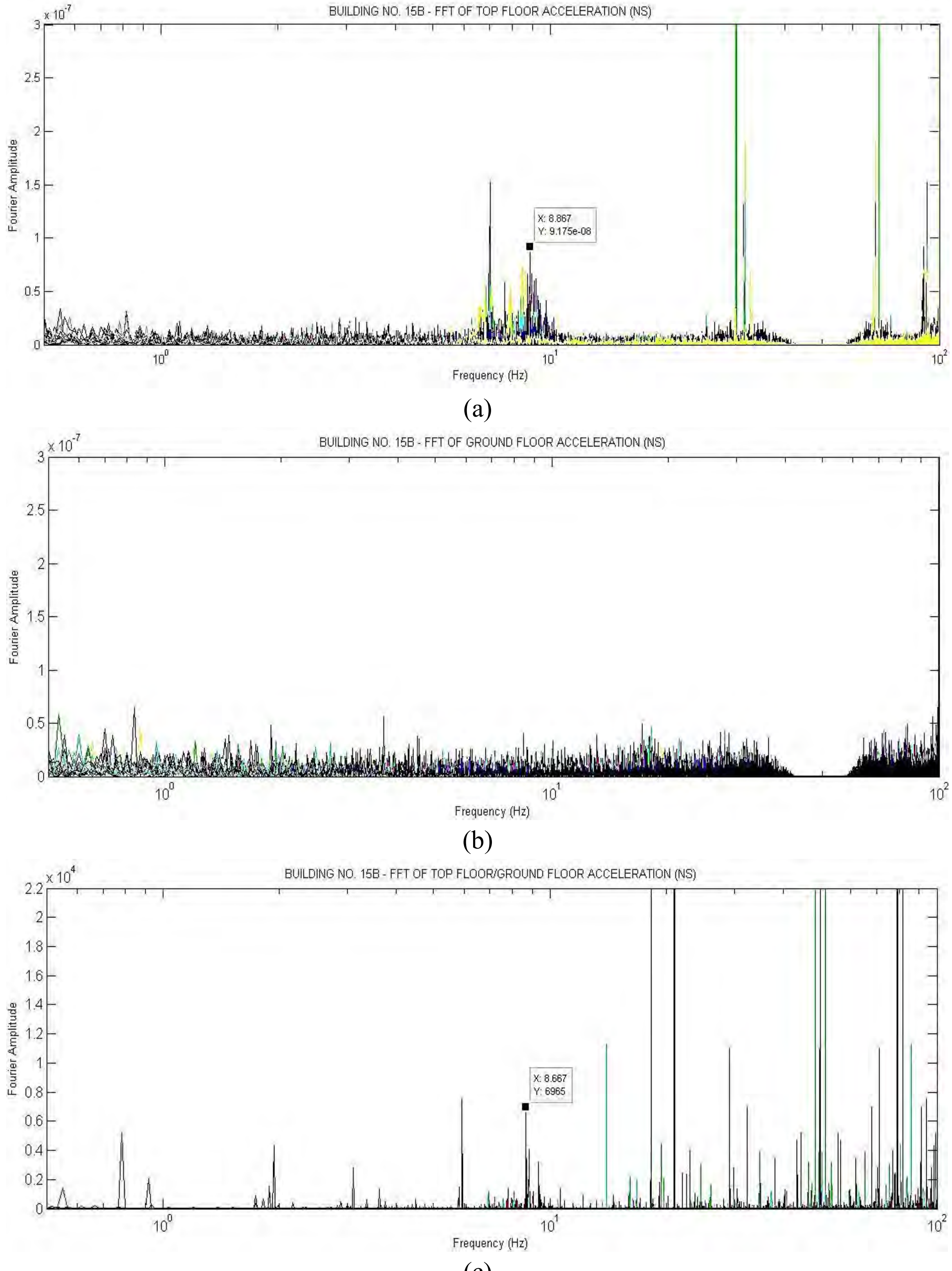
(b)



(c)

Figure D.16: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

c. **Building No. 15B**.

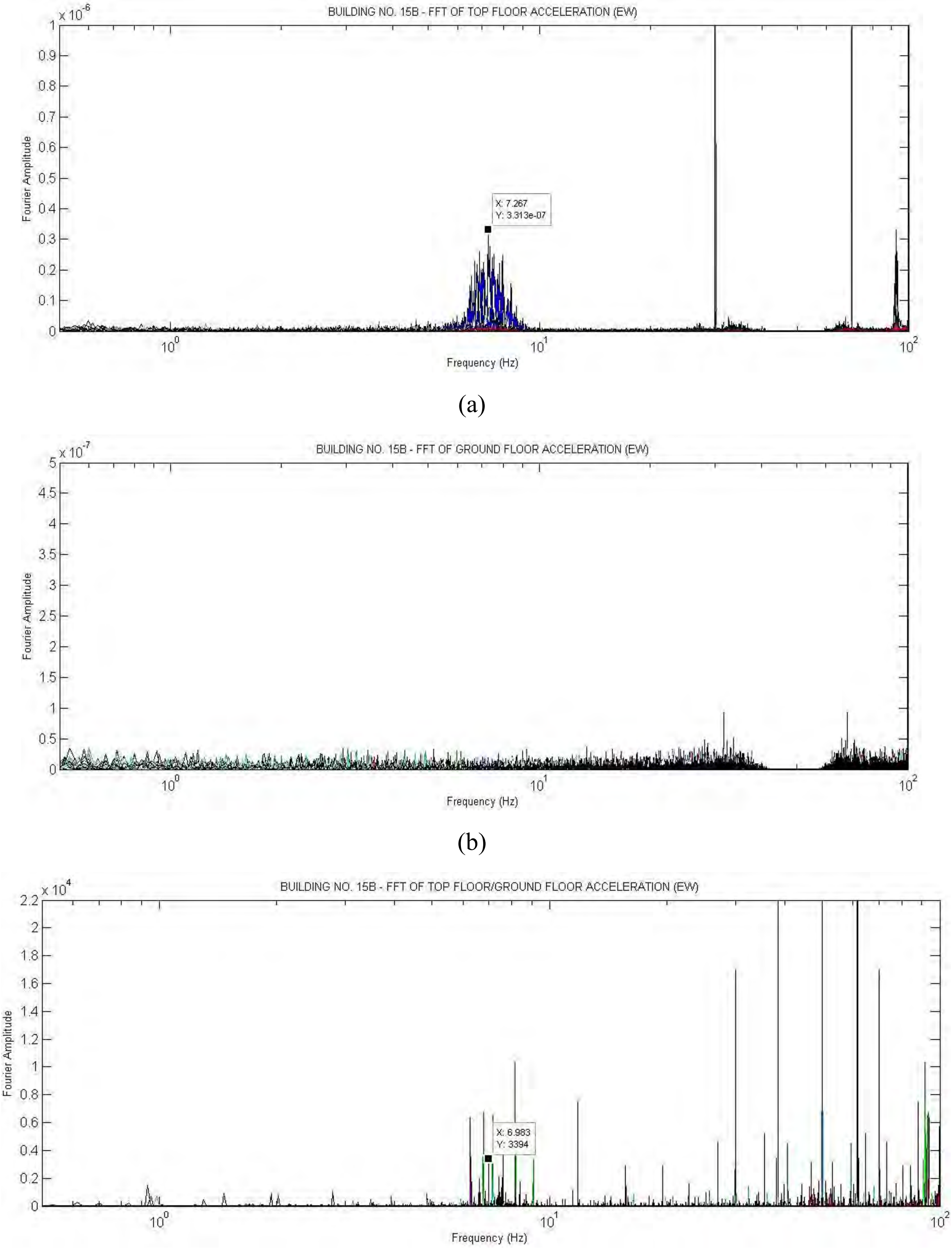


(a)

(b)

(c)

Figure D.17: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



(a)

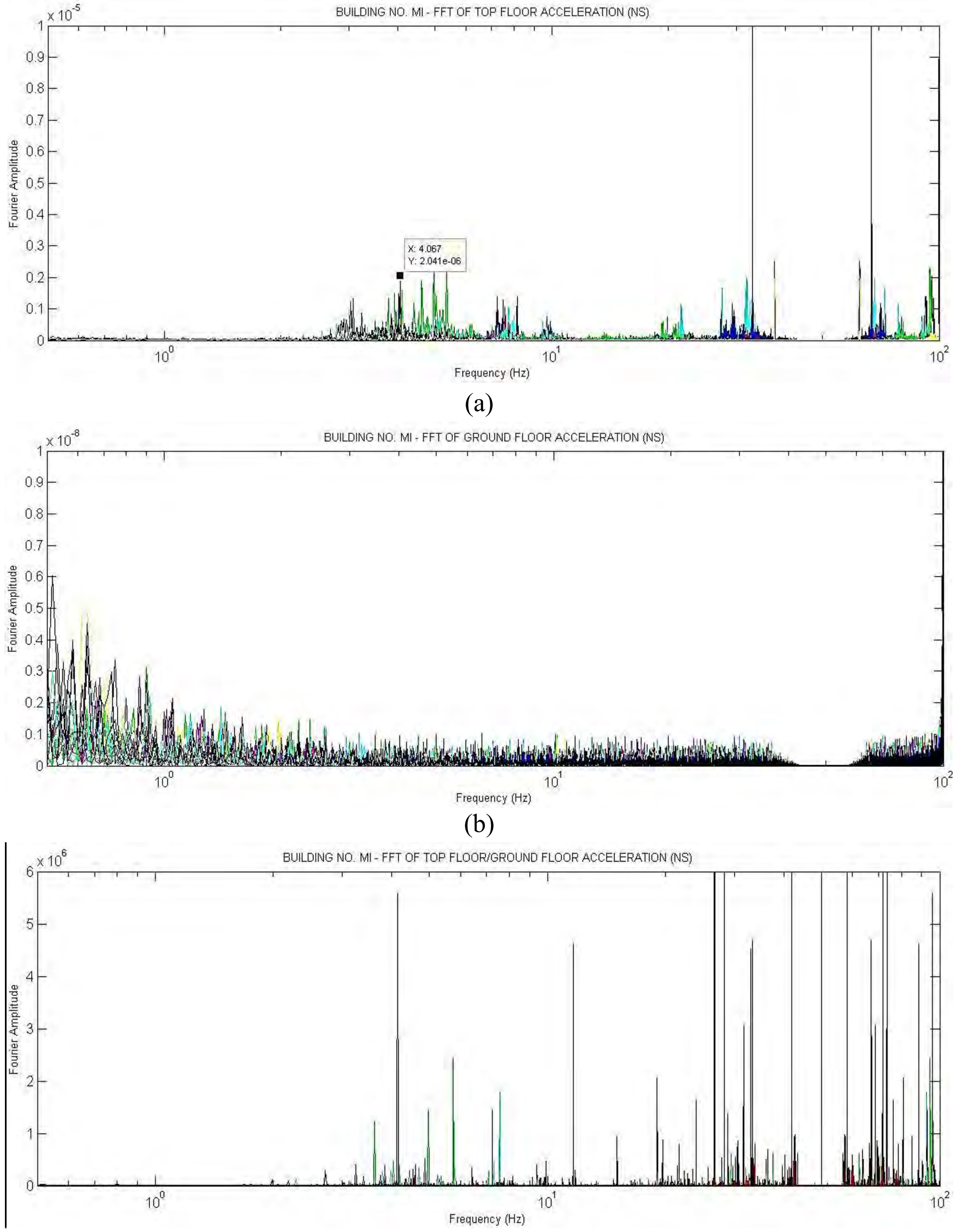
(b)

(c)

Figure D.18: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

3. FFT Outputs of Three-Storied URM Buildings.

a. Building No. 2.

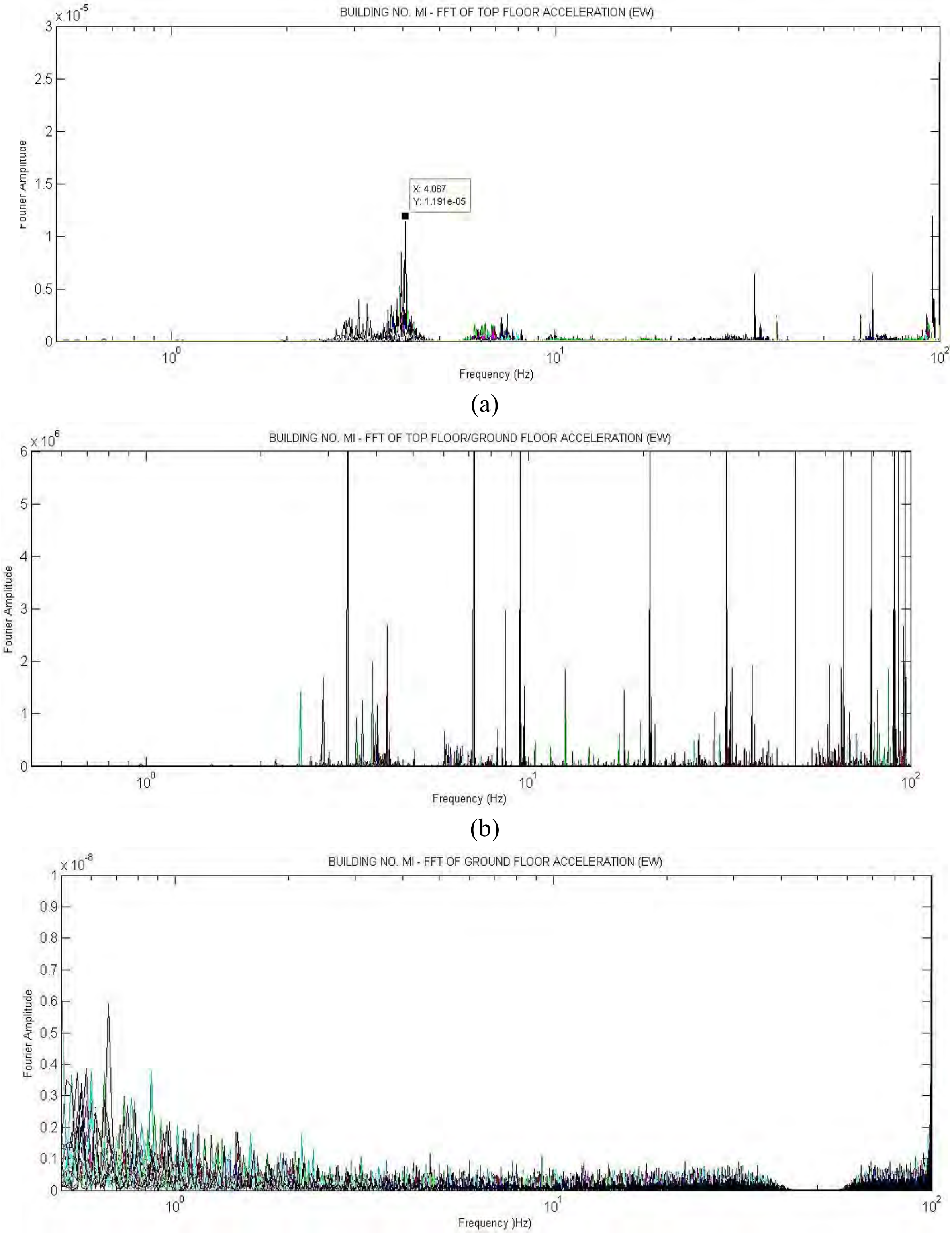


(a)

(b)

(c)

Figure D.19: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



(a)

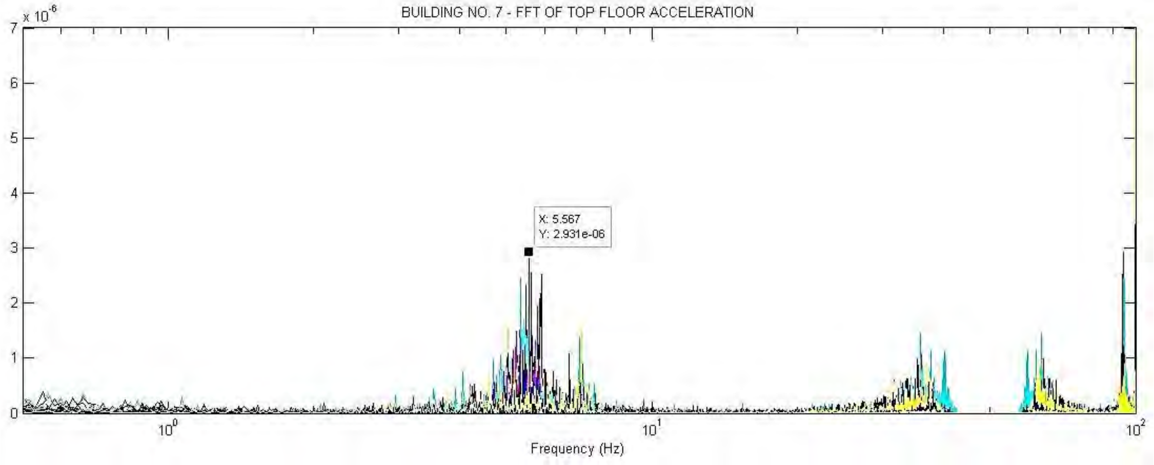
(b)

(c)

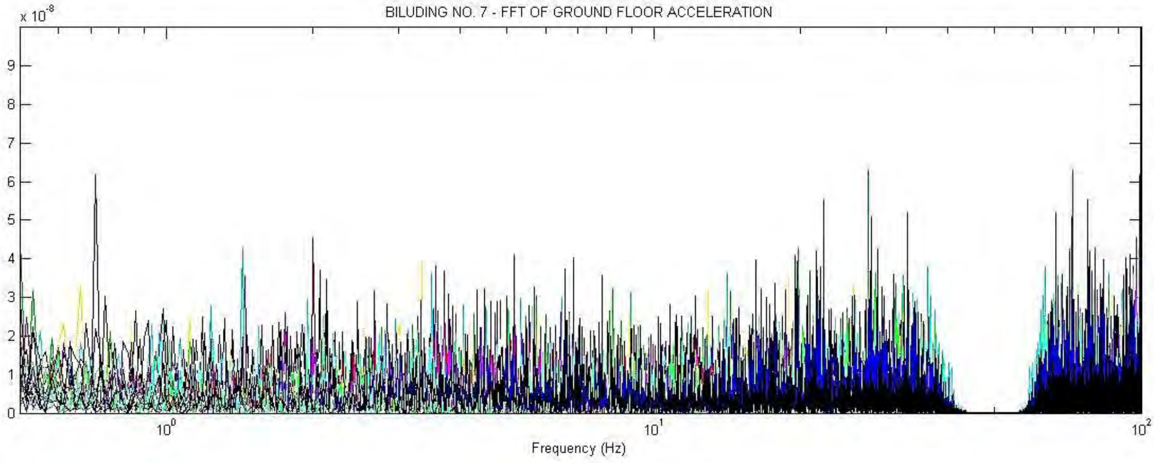
Figure D.20: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

4. **FFT Outputs of Four-Storied URM Buildings.**

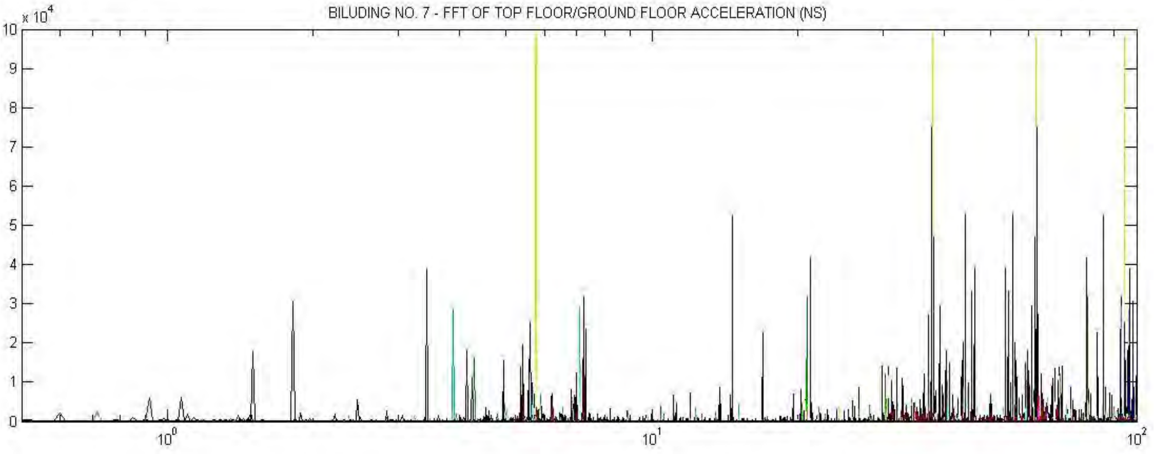
a. **Building No. 7.**



(a)

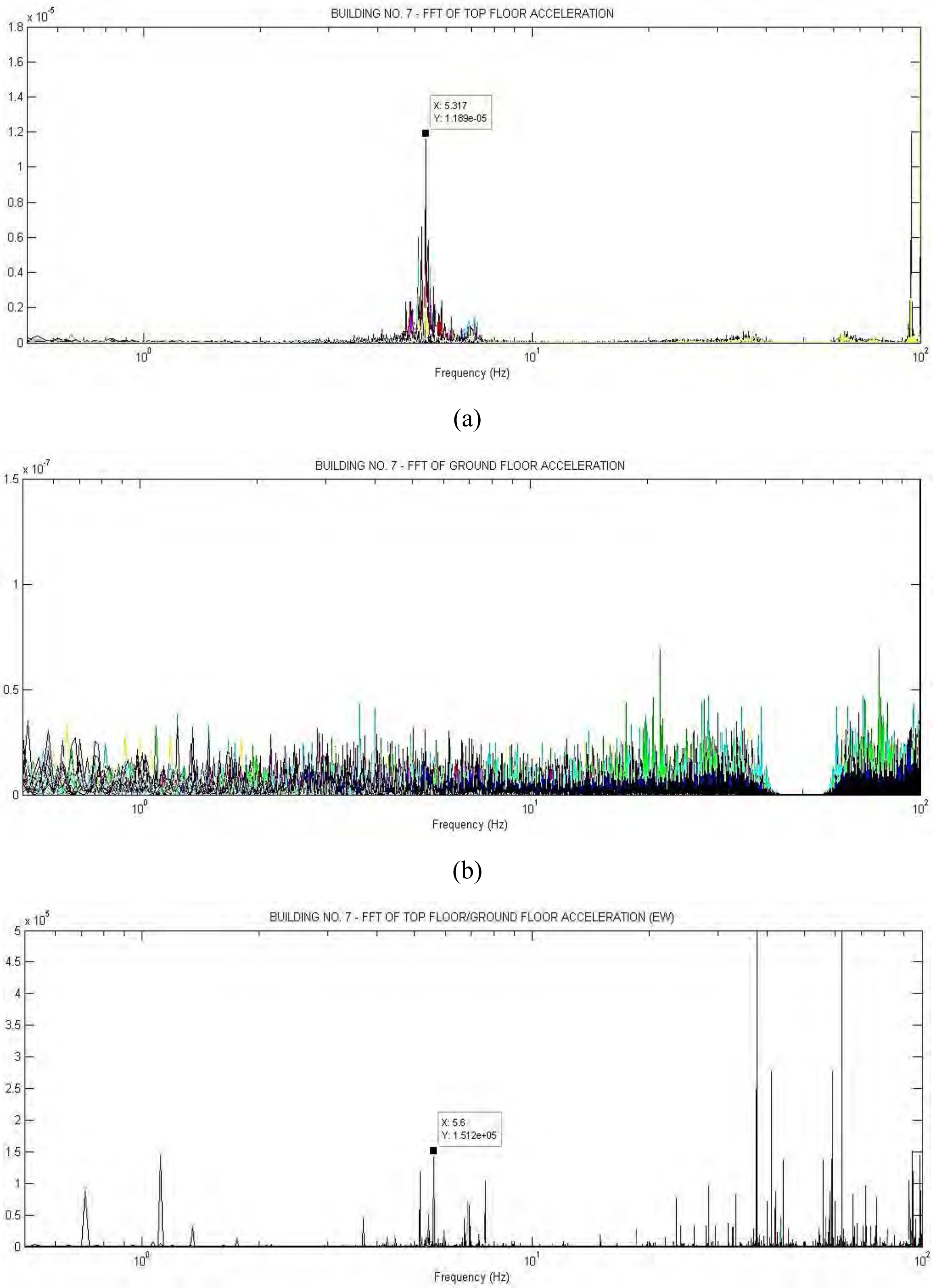


(b)



(c)

Figure D.21: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



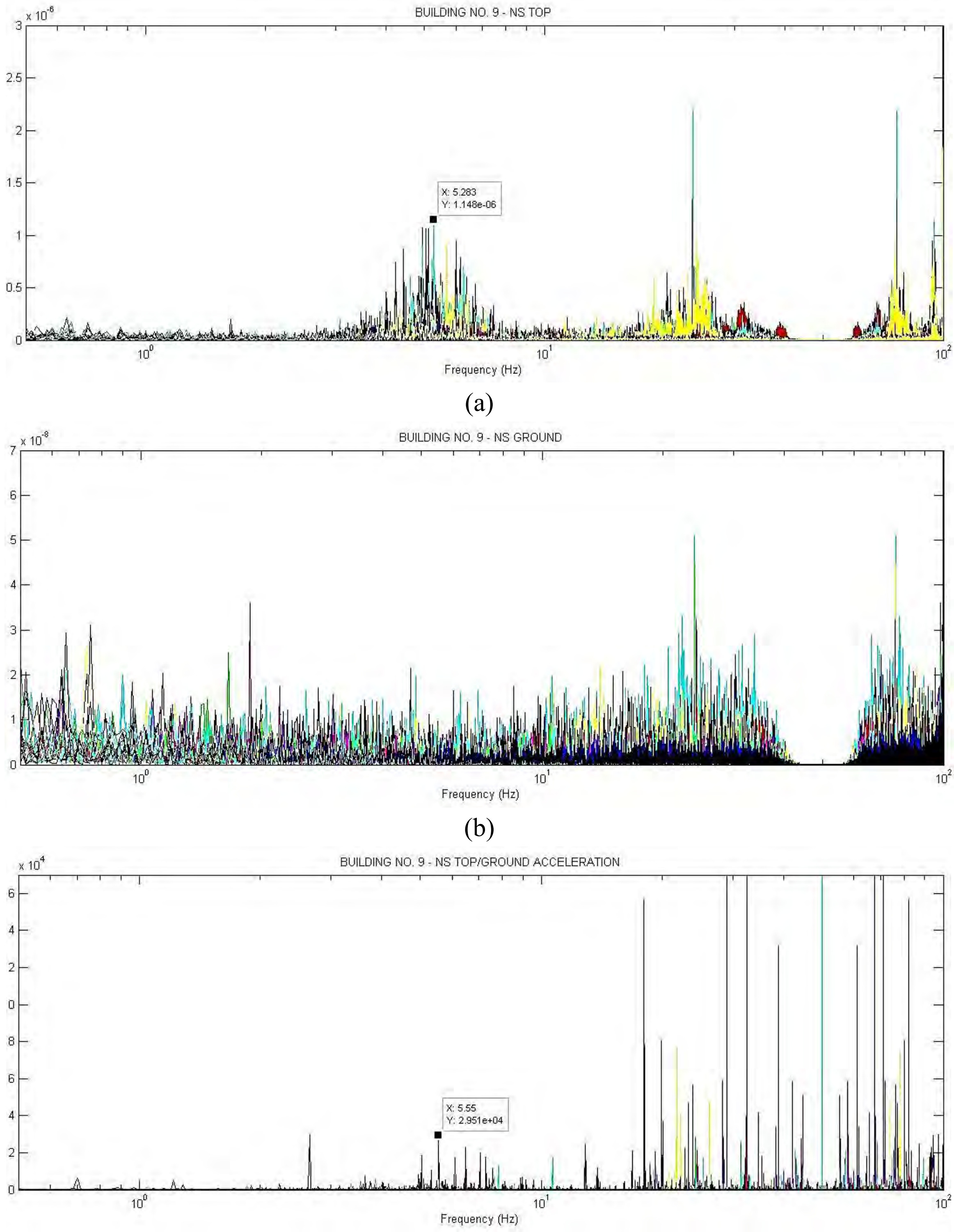
(a)

(b)

(c)

Figure D.22: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

b. Building No. 9A.

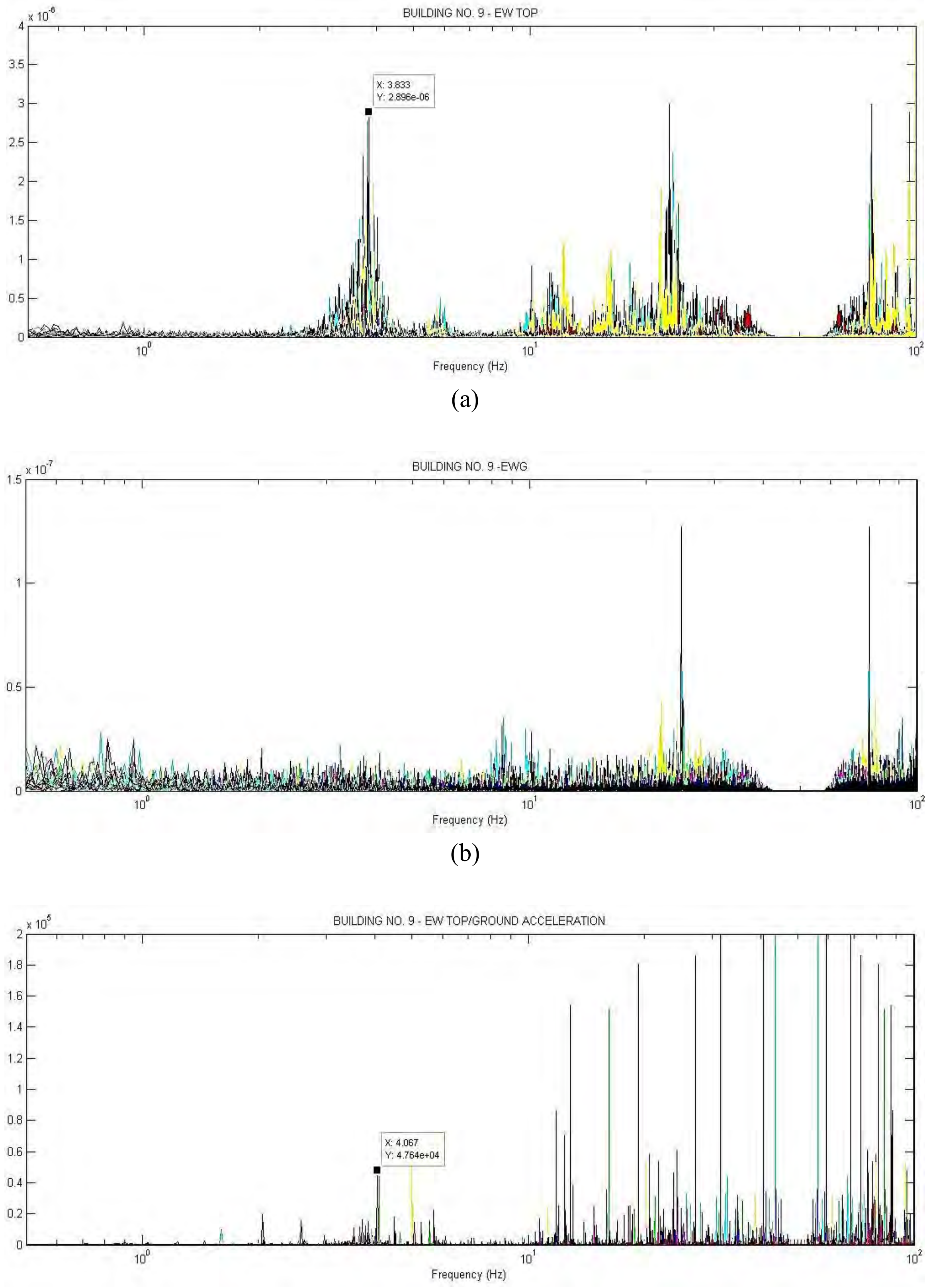


(a)

(b)

(c)

Figure D.23: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



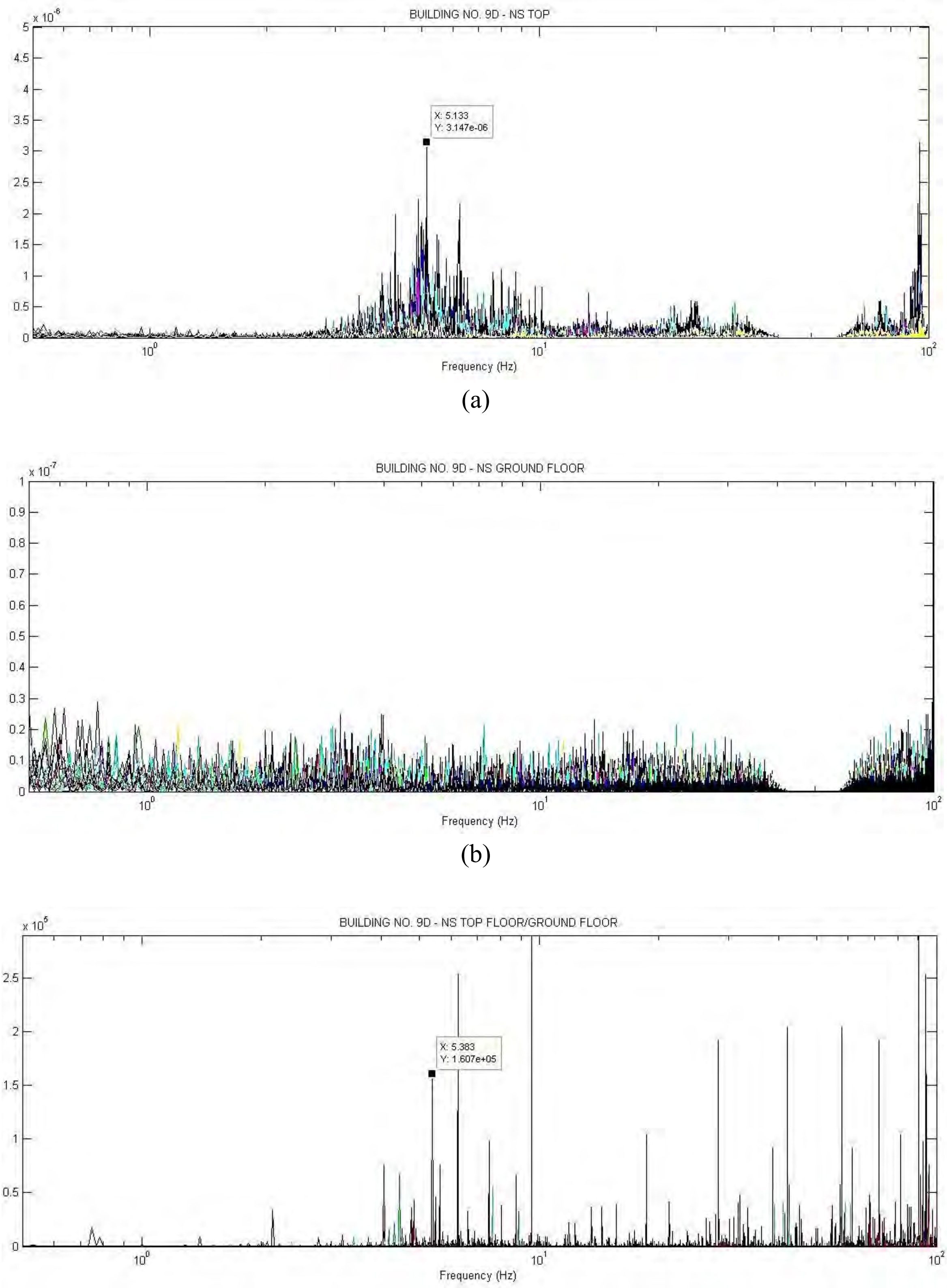
(a)

(b)

(c)

Figure D.24: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

c. Building No. 9D.

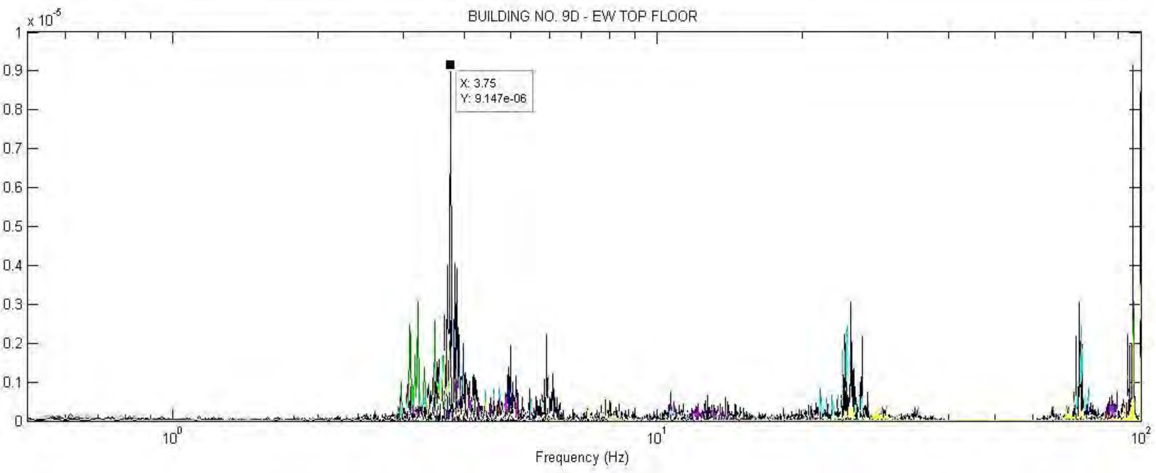


(a)

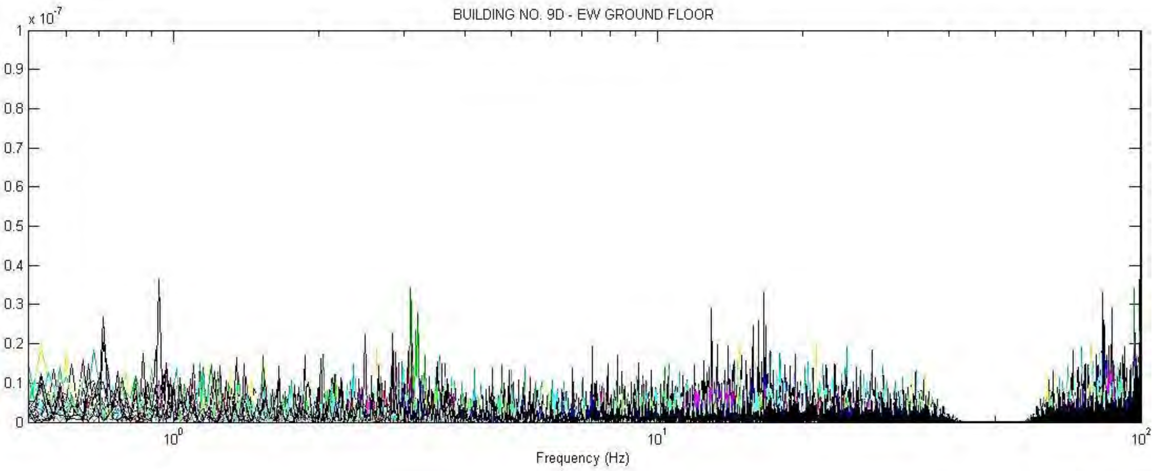
(b)

(c)

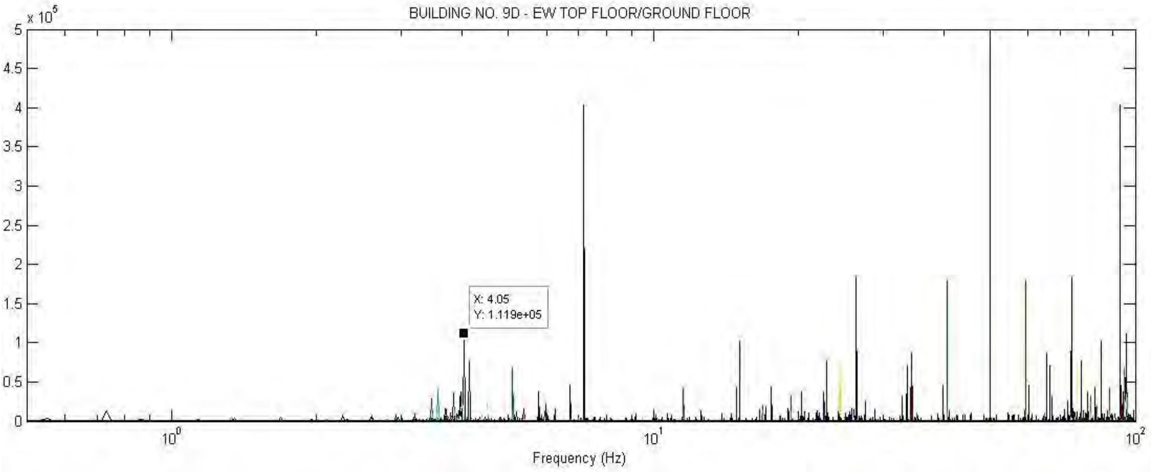
Figure D.25: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



(a)



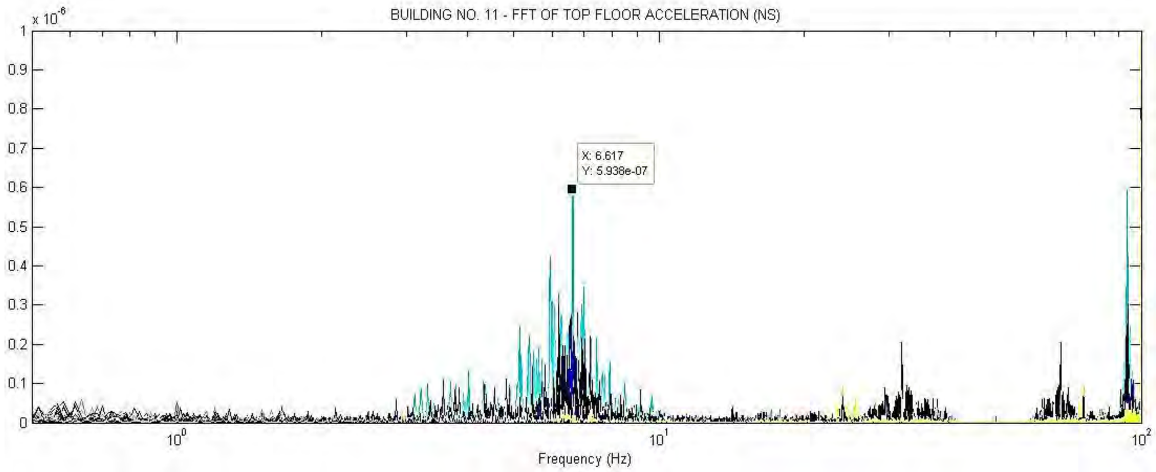
(b)



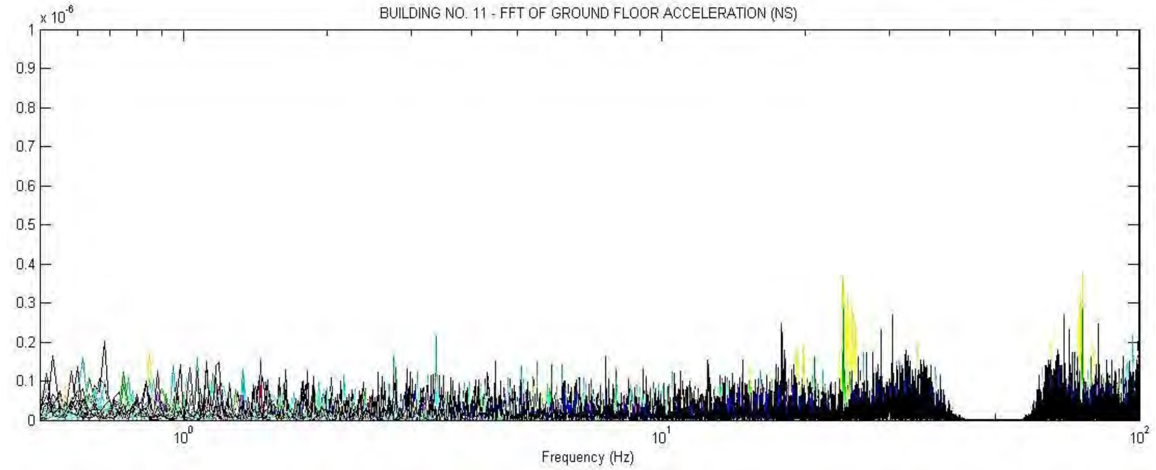
(c)

Figure D.26: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

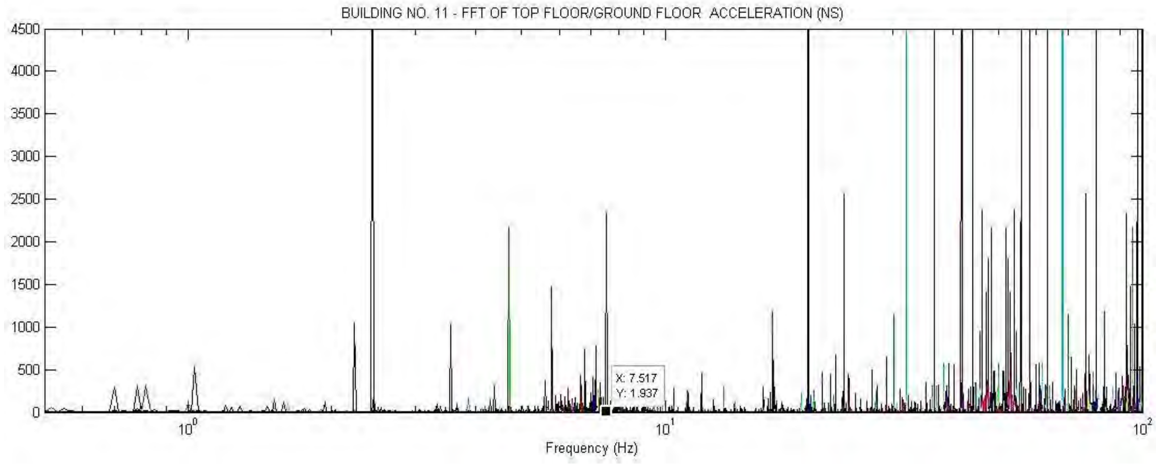
d. **Building No. 11**.



(a)

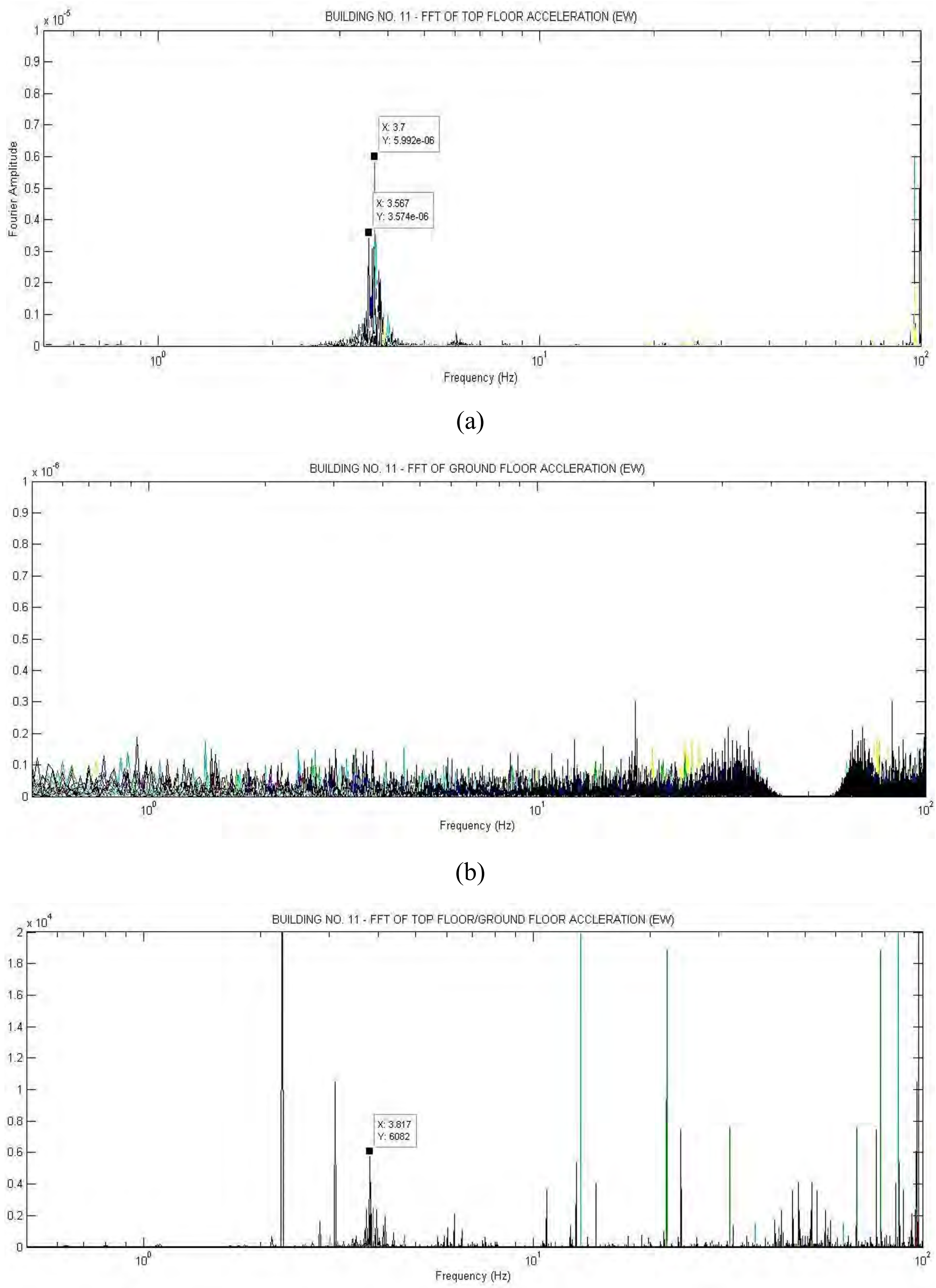


(b)



(c)

Figure D.27: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



(a)

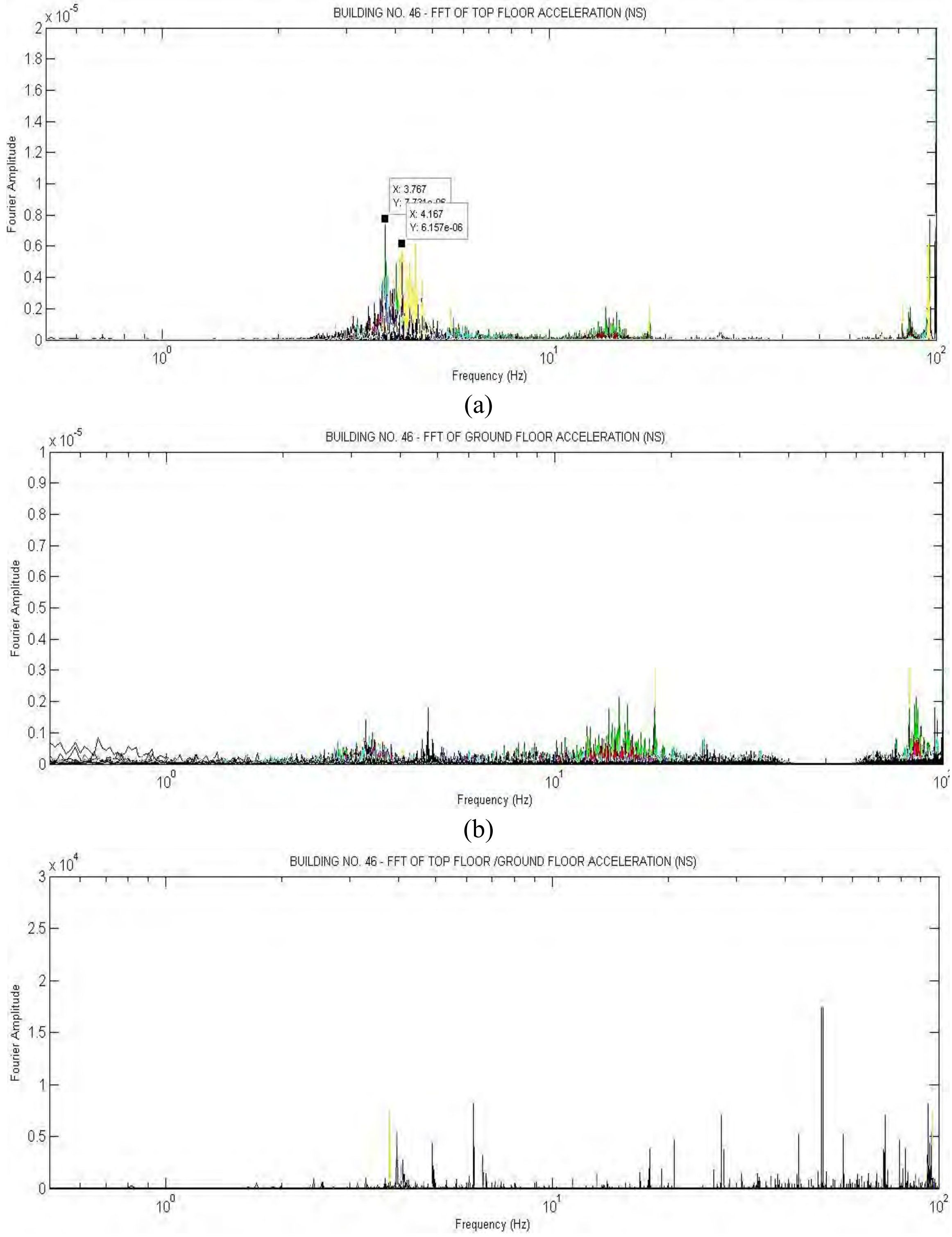
(b)

(c)

Figure D.28: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

4. **FFT Outputs of Five-Storied URM Buildings**.

a. **Building No. 46**.

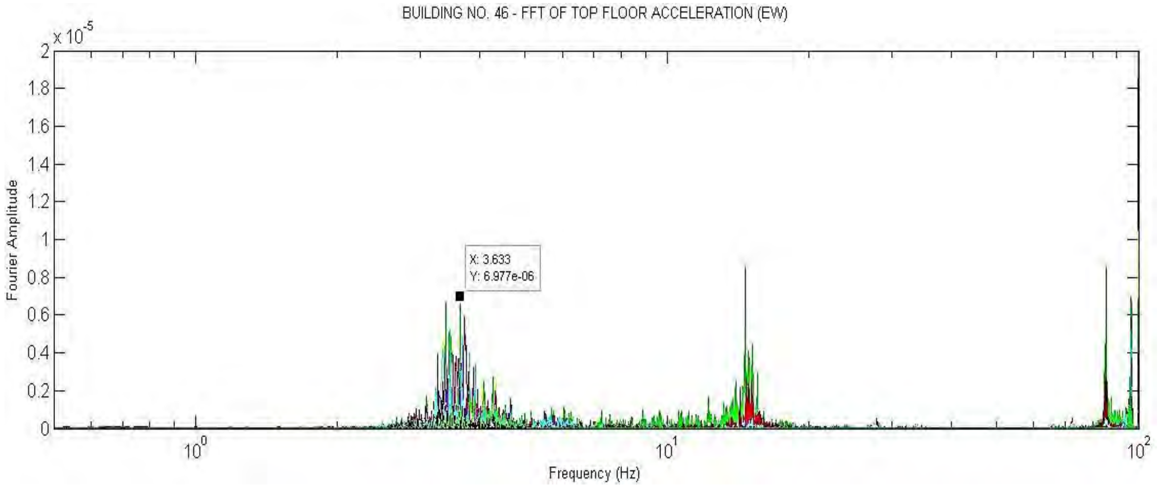


(a)

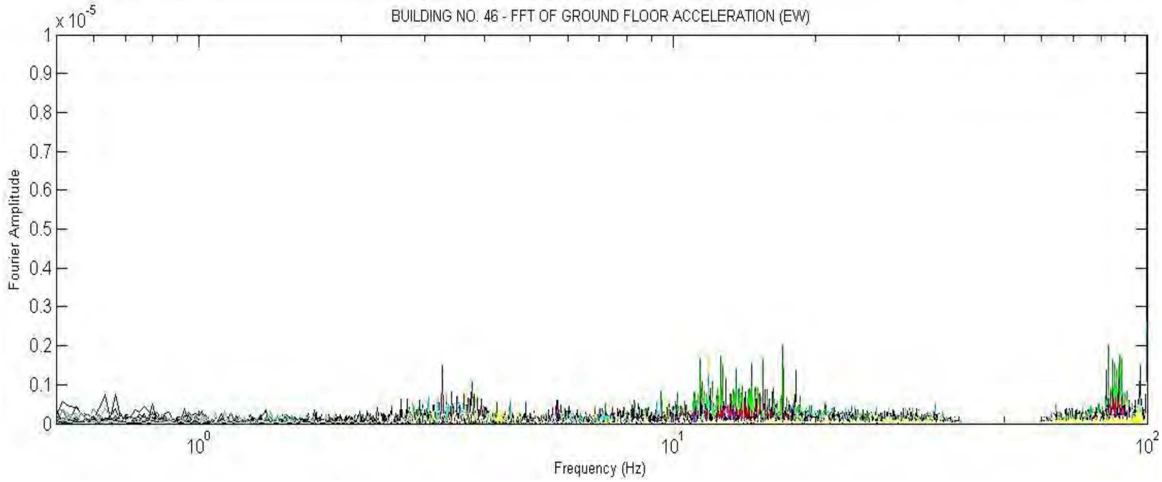
(b)

(c)

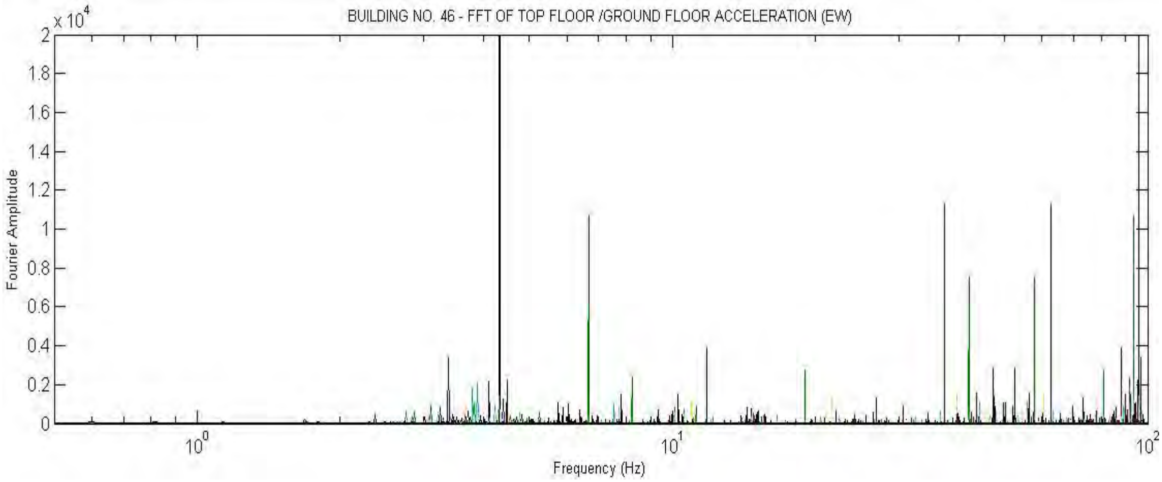
Figure D.29: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in NS Direction



(a)



(b)



(c)

Figure D.30: FFT Output of (a) Top, (b) Ground and (c) Modified Top Floor Accelerations in EW Direction

Appendix E

SUMMARY OF THE PRE-DOMINANT FREQUENCIES OF THE URM BUILDINGS UNDER STUDY

Ser	Storey	Building No.	Maximum Height at Top Floor from P.L.		Wall Thickness (cm)	Length of Wall (m) per Floor		Dominant Frequency at Top Floor (Hz)	
			m	Ft		NS	EW	NS	EW
1.	Single	13	2.59	8.5	25	34.85	41.35	14.72	15.60
2.		SLA	3.28	10.75	39.4	22.79	24.41	9.75	10.80
3.		6A	3.81	12.5	25	90.93	85.50	15.10	8.767
4.		6B				51.49	38.36	17.78	11.25
5.		6C	4.57	15		72.14	101.05	9.95	10.28
6.		8	6.10	20	40	78.54	80.36	11.45	11.52
7.	2-storied	10 (Grd)	6.10	20	25	67.46	73.33	9.77	9.77
		10 (1st)				70.92	59.99		
8.		15A (Grd)	7.32	24	25	57.20	46.94	10.67	6.30
		15A (1st)				57.20	49.38		
9.		15B (All)				72.39	91.54	8.87	7.27
10.	3-storied	2 (Grd)	9.144	30	25	136.93	122.65	4.09	4.09
		2 (Others)				55.47	67.38		
11.	4-storied	7 (All)	12.192	40	25	60.69	91.55	5.57	5.32
12.		11 (Grd)				96.53	63.14	6.62	3.70
		11 (Others)				103.15	105.14		
13.	4-storied	9A (1st)	14.64	48	25	71.62	67.07	5.283	3.833
		9A (Others)				61.46	54.01		
14.		9D (Grd)				62.08	48.06	5.133	3.75
		9D (1st)				62.33	80.40		
		9D (2nd)				51.44	44.40		
		9D (3rd)				44.10	66.60		
15.	5-storied	46 (All)	15.24	50		97.01	91.42	3.77	3.63

BOX PLOT OF THE VARIABLES (NS DATA)

Table F-1: Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
structural period	10	90.9%	1	9.1%	11	100.0%
height of building	10	90.9%	1	9.1%	11	100.0%
total length of walls	10	90.9%	1	9.1%	11	100.0%

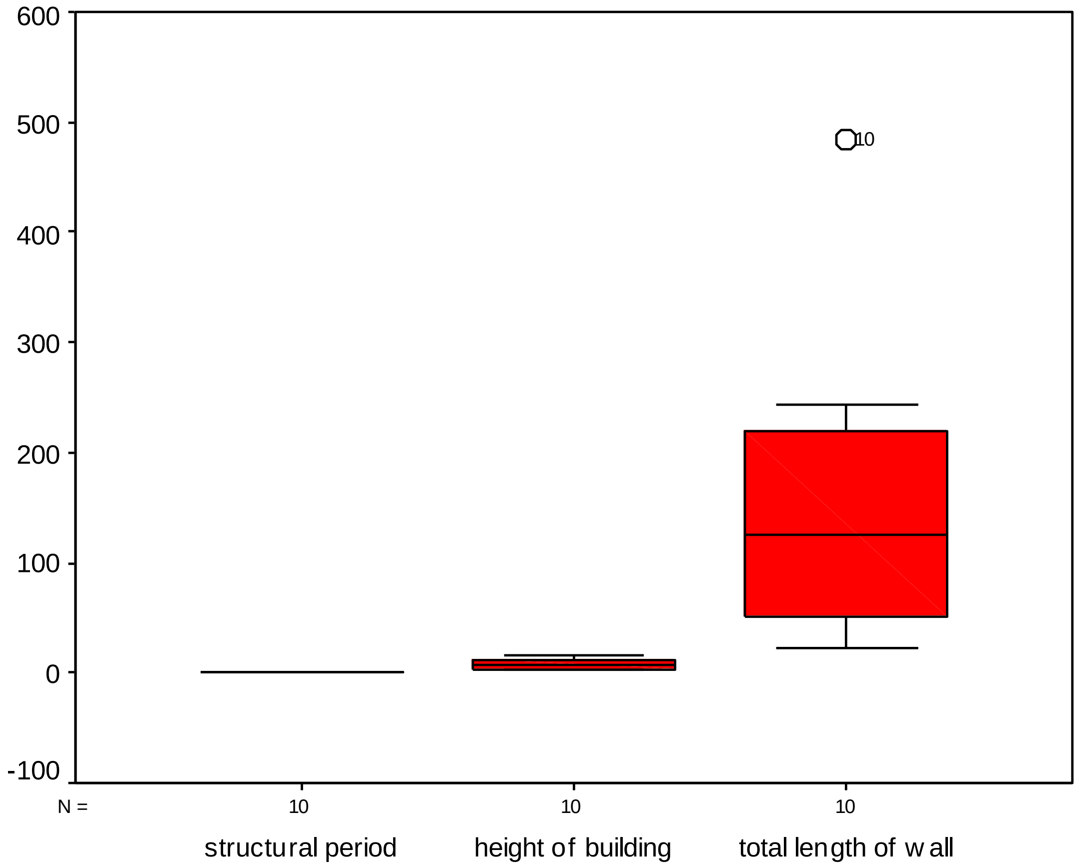


Figure F-1: Box Plot of the Variables

CURVE FIT ANALYSIS (NS DATA)

Table G-1: Curve Fit Analysis for Height

Independent: HEIGHT										
Dependent	Mth	R sq	d.f.	F	Sigf	Upper bound	b0	b1	b2	b3
TIME	**LIN**	**.876**	8	56.35	.000		.0211	.0134		
TIME	LOG	.738	8	22.50	.001		-.0483	.0919		
TIME	INV	.532	8	9.09	.017		.2053	-.4465		
TIME	**QUA**	**.920**	7	40.06	.000		.0774	-.0031	.0009	
TIME	**CUB**	**.921**	6	23.21	.001		.0599	.0056	-.0003	4.7E-5
TIME	COM	.867	8	52.13	.000		.0525	1.1027		
TIME	POW	.781	8	28.50	.001		.0303	.6944		
TIME	S	.605	8	12.25	.008		-1.5602	-3.4962		
TIME	GRO	.867	8	52.13	.000		-2.9473	.0977		
TIME	EXP	.867	8	52.13	.000		.0525	.0977		
TIME	LGS	.867	8	52.13	.000	.	19.0545	.9069		

Table G-2: Curve Fit Analysis for Total Length of Walls

Independent: TOTAL LENGTH OF WALLS										
Dependent	Mth	Rsq	d.f.	F	Sigf	Upper bound	b0	b1	b2	b3
TIME	**LIN**	**.891**	8	65.48	.000		.0572	.0005		
TIME	LOG	.673	8	16.43	.004		-.1428	.0576		
TIME	INV	.297	8	3.39	.103		.1636	-2.7005		
TIME	**QUA**	**.894**	7	29.53	.000		.0511	.0005	-2.E-07	
TIME	**CUB**	**.956**	6	43.97	.000		.0966	-.0007	7.3E-06	-1.E-8
TIME	COM	.787	8	29.53	.001		.0702	1.0031		
TIME	POW	.667	8	16.00	.004		.0158	.4211		
TIME	S	.307	8	3.54	.097		-1.9006	-20.136		
TIME	GRO	.787	8	29.53	.001		-2.6559	.0031		
TIME	EXP	.787	8	29.53	.001		.0702	.0031		
TIME	LGS	.787	8	29.53	.001	.	14.2379	.9969		

REGRESSIONS BY SPSS- APPROACH 1 (NS DATA)

Regression (Enter Method)

Table H-1: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H^2	80.8799	85.27288	10
H^3	983.6046	1349.87258	10
L	146.2070	140.62249	10
L^2	39173.7041	71879.12599	10
L^3	14458070.2393	35375105.36116	10

Table H-2: Correlations

		T	H	H2	H3	L	L2	L3
Pearson Correlation	T	1.000	.936	.958	.957	.947	.888	.821
	H	.936	1.000	.984	.957	.897	.759	.662
	H^2	.958	.984	1.000	.993	.910	.804	.718
	H^3	.957	.957	.993	1.000	.906	.827	.752
	L	.947	.897	.910	.906	1.000	.960	.909
	L^2	.888	.759	.804	.827	.960	1.000	.989
	L^3	.821	.662	.718	.752	.909	.989	1.000
Sig. (1-tailed)	T	.	.000	.000	.000	.000	.000	.002
	H	.000	.	.000	.000	.000	.005	.018
	H^2	.000	.000	.	.000	.000	.003	.010
	H3	.000	.000	.000	.	.000	.002	.006
	L	.000	.000	.000	.000	.	.000	.000
	L^2	.000	.005	.003	.002	.000	.	.000
	L^3	.002	.018	.010	.006	.000	.000	.
N	T	10	10	10	10	10	10	10
	H	10	10	10	10	10	10	10
	H^2	10	10	10	10	10	10	10
	H^3	10	10	10	10	10	10	10
	L	10	10	10	10	10	10	10
	L^2	10	10	10	10	10	10	10
	L^3	10	10	10	10	10	10	10

Table H-3: Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	L^3, H, H^3, L, L^2(a)	.	Enter

a Tolerance = .000 limits reached.
b Dependent Variable: T

Table H-4: Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.990(a)	.981	.957	.01369	.981	40.878	5	4	.002	2.830

a Predictors: (Constant), L3, H, H3, L, L2
b Dependent Variable: T

Table H-5: ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.038	5	.008	40.878	.002(a)
	Residual	.001	4	.000		
	Total	.039	9			

a Predictors: (Constant), L3, H, H3, L, L2
b Dependent Variable: T

Table H-6: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.064	.021		2.969	.041	.004	.123		
	H	.018	.009	1.286	2.014	.114	-.007	.044	.012	84.939
	H3	-2.163E-05	.000	-.443	-.948	.397	.000	.000	.022	45.565
	L	-.002	.001	-3.237	-2.154	.098	-.003	.000	.002	470.772
	L2	7.278E-06	.000	7.941	2.353	.078	.000	.000	.000	2374.196
	L3	-8.580E-09	.000	-4.607	-2.176	.095	.000	.000	.001	934.002

a Dependent Variable: T

Table H-7: Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	H2	-5.791(a)	-.506	.648	-.281	4.504E-05	22200.993	4.504E-05

a Predictors in the Model: (Constant), L3, H, H3, L, L2
b Dependent Variable: T

Table H-8: Collinearity Diagnostics(a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions					
				(Constant)	H	H3	L	L2	L3
1	1	4.942	1.000	.00	.00	.00	.00	.00	.00
	2	.835	2.433	.02	.00	.00	.00	.00	.00
	3	.198	4.994	.05	.00	.03	.00	.00	.00
	4	.022	14.850	.26	.01	.17	.02	.00	.00
	5	.002	45.994	.65	.59	.26	.09	.01	.06
	6	.000	161.515	.02	.39	.54	.89	.99	.94

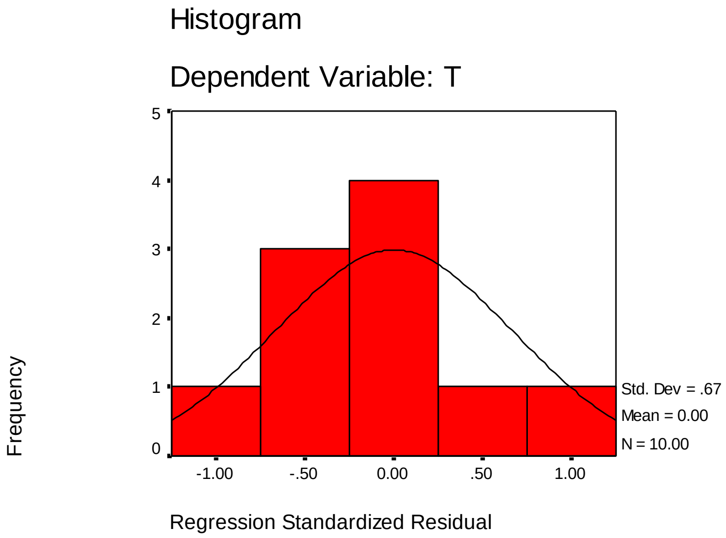
a Dependent Variable: T

Table H-9: Residuals Statistics (a)

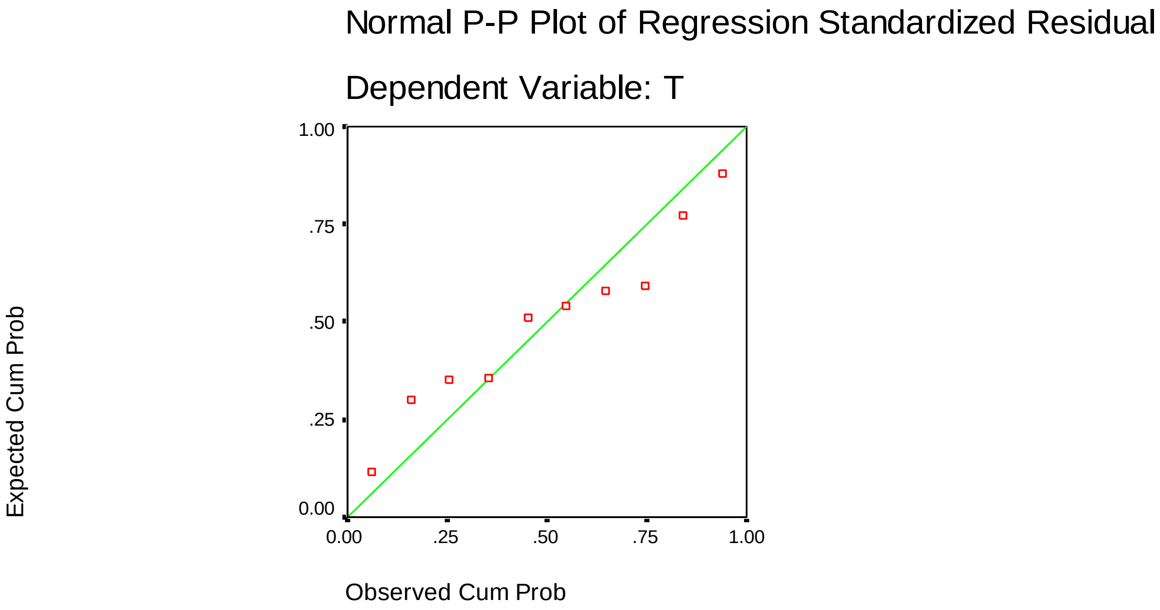
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0666	.2649	.1263	.06525	10
Std. Predicted Value	-.914	2.125	.000	1.000	10
Standard Error of Predicted Value	.00716	.01369	.01033	.00252	10
Adjusted Predicted Value	-1.4184	.2591	-.0570	.48270	10
Residual	-.0164	.0160	.0000	.00913	10
Std. Residual	-1.195	1.168	.000	.667	10
Stud. Residual	-1.739	1.743	.274	1.285	10
Deleted Residual	-.0796	1.6836	.1832	.53180	10
Stud. Deleted Residual	-3.050	3.075	.455	1.994	10
Mahal. Distance	1.562	8.098	4.500	2.535	10
Cook's Distance	.006	2519.584	255.875	795.452	10
Centered Leverage Value	.174	.900	.500	.282	10

a Dependent Variable: T

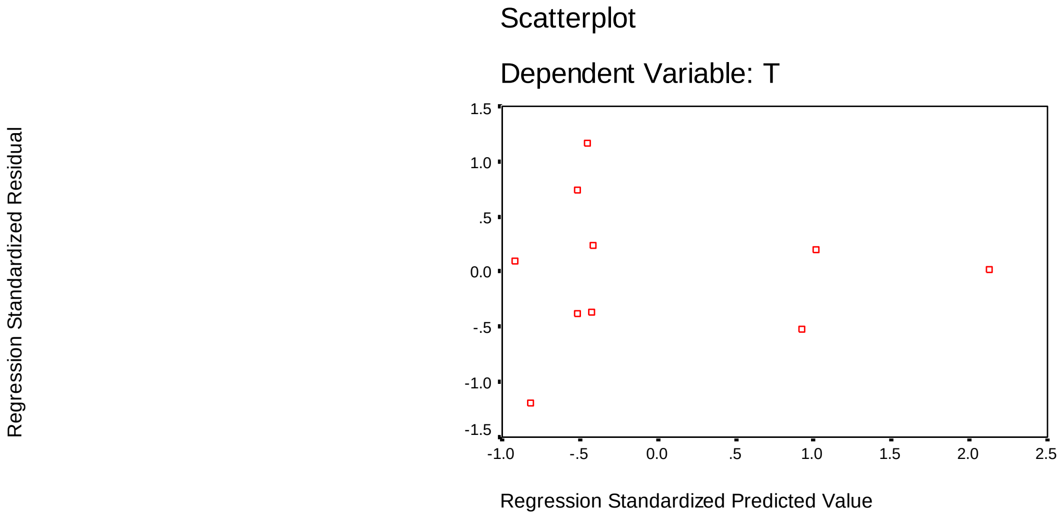
Charts


Histogram

Dependent Variable: T


Normal P-P Plot of Regression Standardized Residual

Dependent Variable: T


Scatterplot

Dependent Variable: T

Regression (Stepwise Method)

Table H-10: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
H3	983.6046	1349.87258	10
L	146.2070	140.62249	10
L2	39173.7041	71879.12599	10
L3	14458070.2393	35375105.36116	10

Table H-11: Correlations

		T	H	H2	H3	L	L2	L3
Pearson Correlation	T	1.000	.936	.958	.957	.947	.888	.821
	H	.936	1.000	.984	.957	.897	.759	.662
	H2	.958	.984	1.000	.993	.910	.804	.718
	H3	.957	.957	.993	1.000	.906	.827	.752
	L	.947	.897	.910	.906	1.000	.960	.909
	L2	.888	.759	.804	.827	.960	1.000	.989
	L3	.821	.662	.718	.752	.909	.989	1.000
Sig. (1-tailed)	T	.	.000	.000	.000	.000	.000	.002
	H	.000	.	.000	.000	.000	.005	.018
	H2	.000	.000	.	.000	.000	.003	.010
	H3	.000	.000	.000	.	.000	.002	.006
	L	.000	.000	.000	.000	.	.000	.000
	L2	.000	.005	.003	.002	.000	.	.000
	L3	.002	.018	.010	.006	.000	.000	.
N	T	10	10	10	10	10	10	10
	H	10	10	10	10	10	10	10
	H2	10	10	10	10	10	10	10
	H3	10	10	10	10	10	10	10
	L	10	10	10	10	10	10	10
	L2	10	10	10	10	10	10	10
	L3	10	10	10	10	10	10	10

Table H-12: Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	H2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	L2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: T

Table H-13: Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.958(a)	.918	.908	.01999	.918	89.749	1	8	.000	
2	.978(b)	.957	.945	.01550	.039	6.316	1	7	.040	2.981

a Predictors: (Constant), H2
b Predictors: (Constant), H2, L2
c Dependent Variable: T

Table H-14: ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			
2	Regression	.037	2	.019	77.853	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

a Predictors: (Constant), H2
b Predictors: (Constant), H2, L2
c Dependent Variable: T

Table H-15: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.066	.009		7.426	.000	.046	.087		
	H2	.001	.000	.958	9.474	.000	.001	.001	1.000	1.000
2	(Constant)	.071	.007		9.904	.000	.054	.088		
	H2	.001	.000	.692	5.243	.001	.000	.001	.353	2.831
	L2	3.039E-07	.000	.332	2.513	.040	.000	.000	.353	2.831

a Dependent Variable: T

Table H-16: Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	H	-.216(a)	-.362	.728	-.135	.032	31.194	.032
	H3	.390(a)	.432	.679	.161	.014	71.435	.014
	L	.434(a)	2.147	.069	.630	.172	5.800	.172
	L2	.332(a)	2.513	.040	.689	.353	2.831	.353
	L3	.275(a)	2.382	.049	.669	.484	2.064	.484
2	H	.127(b)	.257	.806	.104	.029	34.313	.024
	H3	-.333(b)	-.433	.680	-.174	.012	85.191	.012
	L	-.030(b)	-.057	.956	-.023	.025	39.811	.025
	L3	-.628(b)	-.541	.608	-.216	.005	196.926	.004

a Predictors in the Model: (Constant), H2
b Predictors in the Model: (Constant), H2, L2
c Dependent Variable: T

Table H-17: Collinearity Diagnostics(a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	H2	L2
1	1	1.707	1.000	.15	.15	
	2	.293	2.414	.85	.85	
2	1	2.377	1.000	.05	.03	.04
	2	.515	2.149	.57	.01	.18
	3	.109	4.679	.37	.97	.78

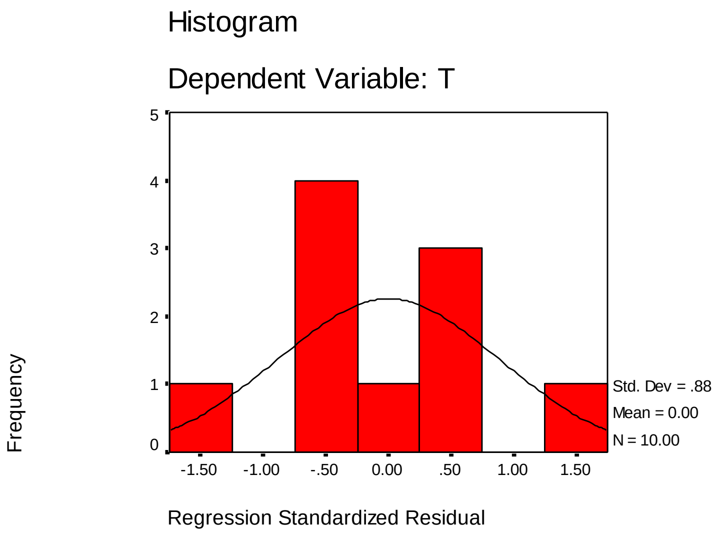
a Dependent Variable: T

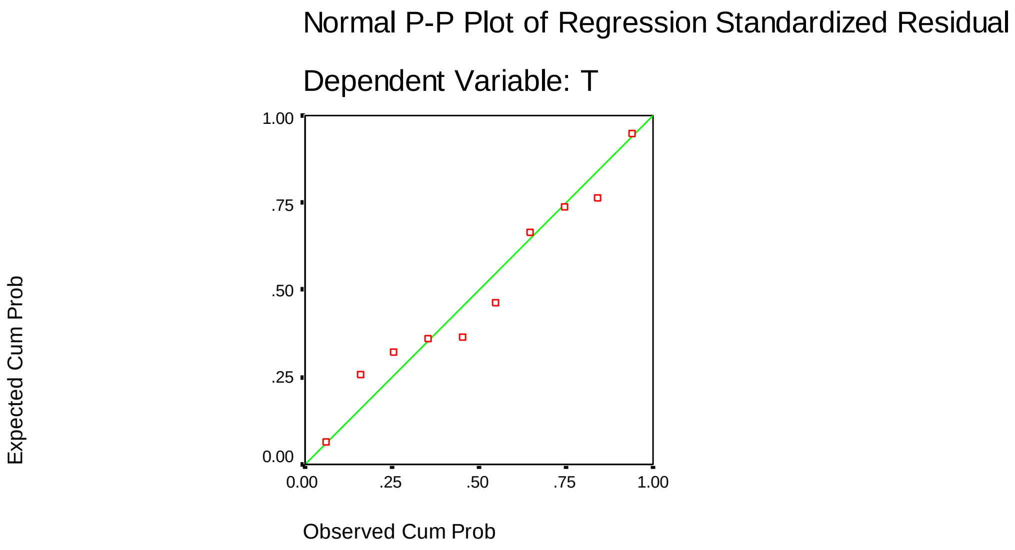
Table H-18: Residuals Statistics(a)

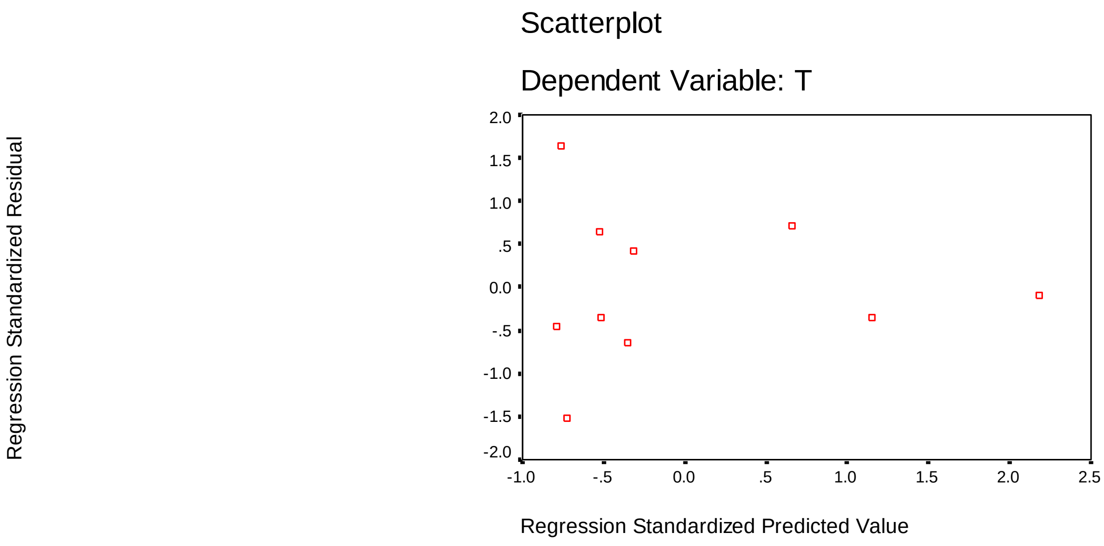
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0751	.2667	.1263	.06445	10
Std. Predicted Value	-.794	2.180	.000	1.000	10
Standard Error of Predicted Value	.00517	.01536	.00775	.00364	10
Adjusted Predicted Value	.0714	.3486	.1361	.08757	10
Residual	-.0235	.0255	.0000	.01367	10
Std. Residual	-1.514	1.647	.000	.882	10
Stud. Residual	-1.663	1.819	-.094	1.014	10
Deleted Residual	-.0834	.0311	-.0098	.03157	10
Stud. Deleted Residual	-1.980	2.318	-.070	1.167	10
Mahal. Distance	.103	7.940	1.800	2.795	10
Cook's Distance	.007	9.483	1.068	2.963	10
Centered Leverage Value	.011	.882	.200	.311	10

a Dependent Variable: T

Charts


Histogram
Dependent Variable: T
Frequency
5
4
3
2
1
0
-1.50
-1.00
-.50
0.00
.50
1.00
1.50
Std. Dev = .88
Mean = 0.00
N = 10.00
Regression Standardized Residual


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: T
Expected Cum Prob
1.00
.75
.50
.25
0.00
0.00
.25
.50
.75
1.00
Observed Cum Prob


Scatterplot
Dependent Variable: T
Regression Standardized Residual
2.0
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
-2.0
-1.0
-.5
0.0
.5
1.0
1.5
2.0
2.5
Regression Standardized Predicted Value

Regression (Backward Method)

Table H-19: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
H3	983.6046	1349.87258	10
L	146.2070	140.62249	10
L2	39173.7041	71879.12599	10
L3	14458070.2393	35375105.36116	10

Table H-20: Correlations

		T	H	H2	H3	L	L2	L3
Pearson Correlation	T	1.000	.936	.958	.957	.947	.888	.821
	H	.936	1.000	.984	.957	.897	.759	.662
	H2	.958	.984	1.000	.993	.910	.804	.718
	H3	.957	.957	.993	1.000	.906	.827	.752
	L	.947	.897	.910	.906	1.000	.960	.909
	L2	.888	.759	.804	.827	.960	1.000	.989
	L3	.821	.662	.718	.752	.909	.989	1.000
Sig. (1-tailed)	T	.	.000	.000	.000	.000	.000	.002
	H	.000	.	.000	.000	.000	.005	.018
	H2	.000	.000	.	.000	.000	.003	.010
	H3	.000	.000	.000	.	.000	.002	.006
	L	.000	.000	.000	.000	.	.000	.000
	L2	.000	.005	.003	.002	.000	.	.000
	L3	.002	.018	.010	.006	.000	.000	.
N	T	10	10	10	10	10	10	10
	H	10	10	10	10	10	10	10
	H2	10	10	10	10	10	10	10
	H3	10	10	10	10	10	10	10
	L	10	10	10	10	10	10	10
	L2	10	10	10	10	10	10	10
	L3	10	10	10	10	10	10	10

Table H-21: Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	L3, H, H3, L, L2(a)	.	Enter
2	.	H3	Backward (criterion: Probability of F-to-remove >= .100).

a Tolerance = .000 limits reached.
b Dependent Variable: T

Table H-22: Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.990(a)	.981	.957	.01369	.981	40.878	5	4	.002	
2	.988(b)	.976	.958	.01355	-.004	.898	1	4	.397	2.892

a Predictors: (Constant), L3, H, H3, L, L2
b Predictors: (Constant), L3, H, L, L2
c Dependent Variable: T

Table H-23: ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.038	5	.008	40.878	.002(a)
	Residual	.001	4	.000		
	Total	.039	9			
2	Regression	.038	4	.010	51.934	.000(b)
	Residual	.001	5	.000		
	Total	.039	9			

a Predictors: (Constant), L3, H, H3, L, L2
b Predictors: (Constant), L3, H, L, L2
c Dependent Variable: T

Table H-24: Coefficients (a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.064	.021		2.969	.041	.004	.123		
	H	.018	.009	1.286	2.014	.114	-.007	.044	.012	84.939
	H3	-2.163E-05	.000	-.443	-.948	.397	.000	.000	.022	45.565
	L	-.002	.001	-3.237	-2.154	.098	-.003	.000	.002	470.772
	L2	7.278E-06	.000	7.941	2.353	.078	.000	.000	.000	2374.196
	L3	-8.580E-09	.000	-4.607	-2.176	.095	.000	.000	.001	934.002
2	(Constant)	.074	.019		3.951	.011	.026	.121		
	H	.011	.004	.745	2.637	.046	.000	.021	.059	16.972
	L	-.001	.000	-2.107	-2.327	.067	-.002	.000	.006	174.450
	L2	5.233E-06	.000	5.709	2.385	.063	.000	.000	.001	1218.754
	L3	-6.336E-09	.000	-3.402	-2.030	.098	.000	.000	.002	597.225

a Dependent Variable: T

Table H-25: Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	H2	-5.791(a)	-.506	.648	-.281	4.504E-05	22200.993	4.504E-05
2	H2	-.749(b)	-.996	.376	-.446	.008	120.168	.000
	H3	-.443(b)	-.948	.397	-.428	.022	45.565	.000

a Predictors in the Model: (Constant), L3, H, H3, L, L2
b Predictors in the Model: (Constant), L3, H, L, L2
c Dependent Variable: T

Table H-26: Collinearity Diagnostics (a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions					
				(Constant)	H	H3	L	L2	L3
1	1	4.942	1.000	.00	.00	.00	.00	.00	.00
	2	.835	2.433	.02	.00	.00	.00	.00	.00
	3	.198	4.994	.05	.00	.03	.00	.00	.00
	4	.022	14.850	.26	.01	.17	.02	.00	.00
	5	.002	45.994	.65	.59	.26	.09	.01	.06
	6	.000	161.515	.02	.39	.54	.89	.99	.94
2	1	4.072	1.000	.00	.00		.00	.00	.00
	2	.832	2.212	.03	.00		.00	.00	.00
	3	.090	6.714	.23	.05		.00	.00	.00
	4	.005	28.618	.05	.92		.29	.00	.03
	5	.000	102.701	.69	.02		.71	1.00	.96

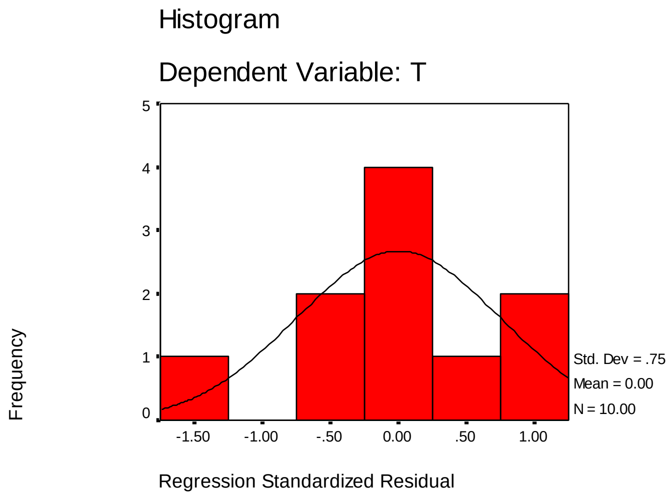
a Dependent Variable: T

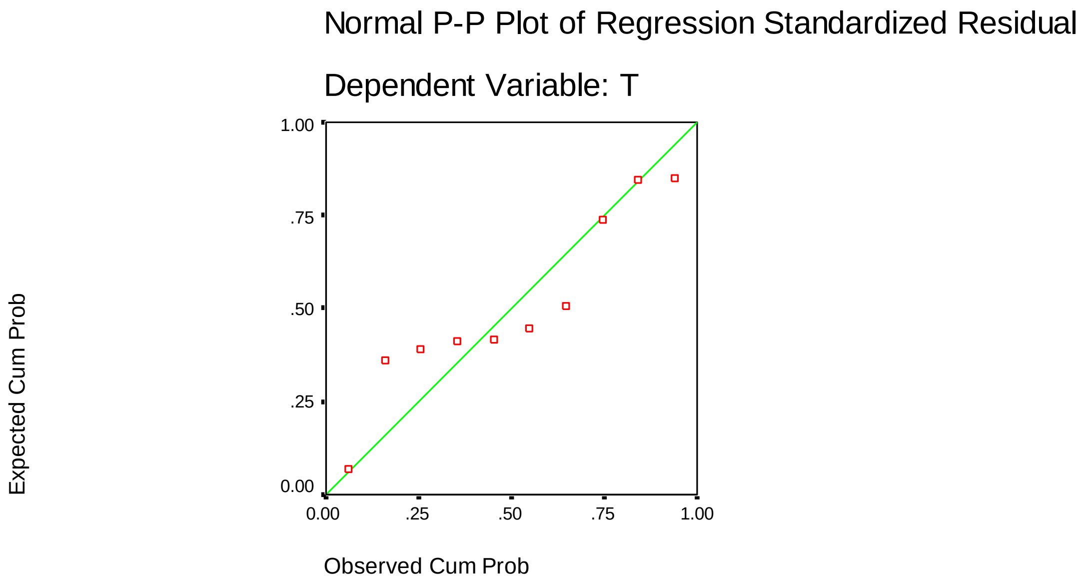
Table H-27: Residuals Statistics (a)

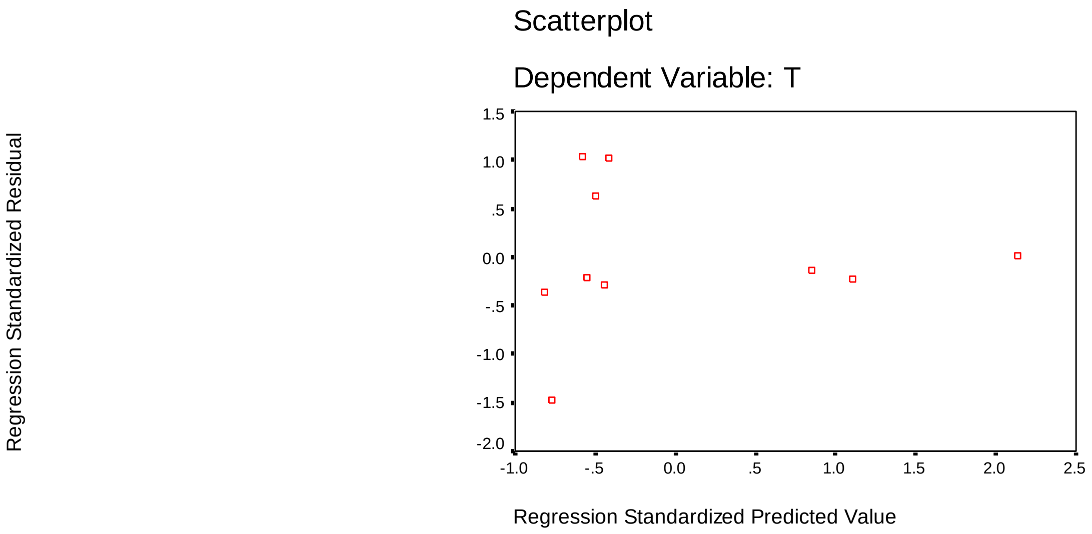
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0728	.2650	.1263	.06511	10
Std. Predicted Value	-.821	2.131	.000	1.000	10
Standard Error of Predicted Value	.00596	.01355	.00927	.00254	10
Adjusted Predicted Value	-.6704	.2094	.0320	.25143	10
Residual	-.0200	.0140	.0000	.01010	10
Std. Residual	-1.479	1.030	.000	.745	10
Stud. Residual	-1.647	1.513	.135	1.020	10
Deleted Residual	-.0248	.9357	.0943	.29617	10
Stud. Deleted Residual	-2.177	1.837	.156	1.208	10
Mahal. Distance	.841	8.098	3.600	2.422	10
Cook's Distance	.004	953.276	95.471	301.402	10
Centered Leverage Value	.093	.900	.400	.269	10

a Dependent Variable: T

Charts


Histogram
Dependent Variable: T
Frequency
5
4
3
2
1
0
-1.50
-1.00
-.50
0.00
.50
1.00
Std. Dev = .75
Mean = 0.00
N = 10.00
Regression Standardized Residual


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: T
Expected Cum Prob
1.00
.75
.50
.25
0.00
0.00
.25
.50
.75
1.00
Observed Cum Prob


Scatterplot
Dependent Variable: T
Regression Standardized Residual
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
-2.0
-1.0
-.5
0.0
.5
1.0
1.5
2.0
2.5
Regression Standardized Predicted Value

Regression (Forward Method)

Table H-28: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
H3	983.6046	1349.87258	10
L	146.2070	140.62249	10
L2	39173.7041	71879.12599	10
L3	14458070.2393	35375105.36116	10

Table H-29: Correlations

		T	H	H2	H3	L	L2	L3
Pearson Correlation	T	1.000	.936	.958	.957	.947	.888	.821
	H	.936	1.000	.984	.957	.897	.759	.662
	H2	.958	.984	1.000	.993	.910	.804	.718
	H3	.957	.957	.993	1.000	.906	.827	.752
	L	.947	.897	.910	.906	1.000	.960	.909
	L2	.888	.759	.804	.827	.960	1.000	.989
	L3	.821	.662	.718	.752	.909	.989	1.000
Sig. (1-tailed)	T	.	.000	.000	.000	.000	.000	.002
	H	.000	.	.000	.000	.000	.005	.018
	H2	.000	.000	.	.000	.000	.003	.010
	H3	.000	.000	.000	.	.000	.002	.006
	L	.000	.000	.000	.000	.	.000	.000
	L2	.000	.005	.003	.002	.000	.	.000
	L3	.002	.018	.010	.006	.000	.000	.
N	T	10	10	10	10	10	10	10
	H	10	10	10	10	10	10	10
	H2	10	10	10	10	10	10	10
	H3	10	10	10	10	10	10	10
	L	10	10	10	10	10	10	10
	L2	10	10	10	10	10	10	10
	L3	10	10	10	10	10	10	10

Table H-30: Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	H2	.	Forward (Criterion: Probability-of-F-to-enter <= .050)
2	L2	.	Forward (Criterion: Probability-of-F-to-enter <= .050)

a Dependent Variable: T

Table H-31: Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.958(a)	.918	.908	.01999	.918	89.749	1	8	.000	
2	.978(b)	.957	.945	.01550	.039	6.316	1	7	.040	2.981

a Predictors: (Constant), H2
b Predictors: (Constant), H2, L2
c Dependent Variable: T

Table H-32: ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			
2	Regression	.037	2	.019	77.853	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

a Predictors: (Constant), H2
b Predictors: (Constant), H2, L2
c Dependent Variable: T

Table H-33: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.066	.009		7.426	.000	.046	.087		
	H2	.001	.000	.958	9.474	.000	.001	.001	1.000	1.000
2	(Constant)	.071	.007		9.904	.000	.054	.088		
	H2	.001	.000	.692	5.243	.001	.000	.001	.353	2.831
	L2	3.039E-07	.000	.332	2.513	.040	.000	.000	.353	2.831

a Dependent Variable: T

Table H-34: Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	H	-.216(a)	-.362	.728	-.135	.032	31.194	.032
	H3	.390(a)	.432	.679	.161	.014	71.435	.014
	L	.434(a)	2.147	.069	.630	.172	5.800	.172
	L2	.332(a)	2.513	.040	.689	.353	2.831	.353
	L3	.275(a)	2.382	.049	.669	.484	2.064	.484
2	H	.127(b)	.257	.806	.104	.029	34.313	.024
	H3	-.333(b)	-.433	.680	-.174	.012	85.191	.012
	L	-.030(b)	-.057	.956	-.023	.025	39.811	.025
	L3	-.628(b)	-.541	.608	-.216	.005	196.926	.004

a Predictors in the Model: (Constant), H2

b Predictors in the Model: (Constant), H2, L2

c Dependent Variable: T

Table H-35: Collinearity Diagnostics (a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	H2	L2
1	1	1.707	1.000	.15	.15	
	2	.293	2.414	.85	.85	
2	1	2.377	1.000	.05	.03	.04
	2	.515	2.149	.57	.01	.18
	3	.109	4.679	.37	.97	.78

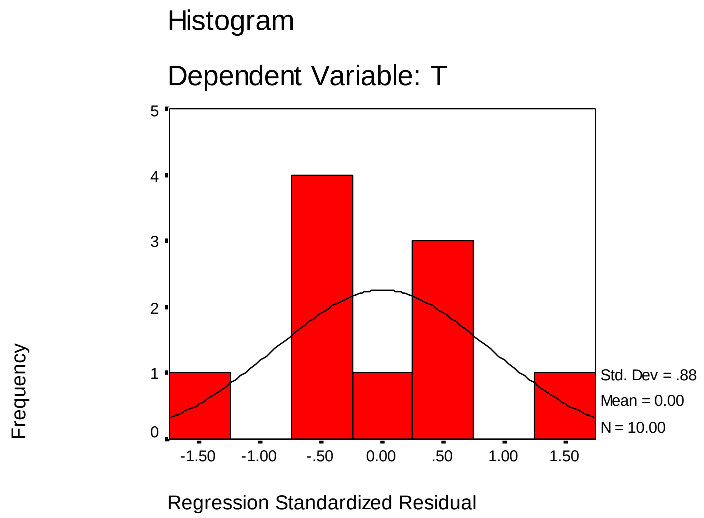
a Dependent Variable: T

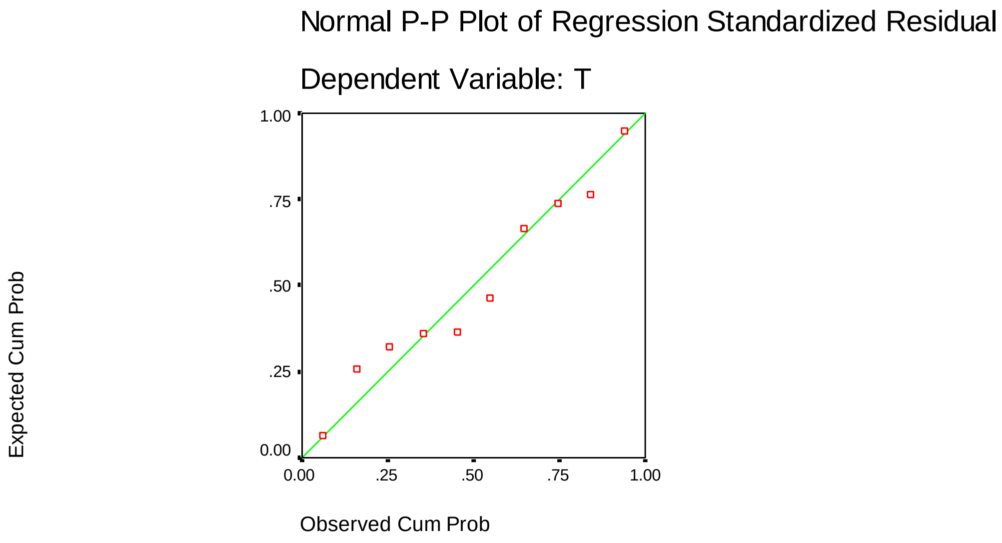
Table H-36: Residuals Statistics(a)

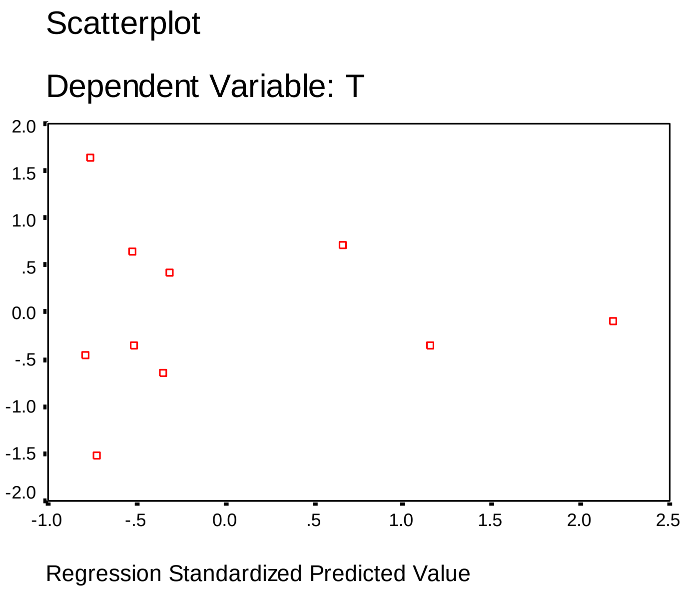
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0751	.2667	.1263	.06445	10
Std. Predicted Value	-.794	2.180	.000	1.000	10
Standard Error of Predicted Value	.00517	.01536	.00775	.00364	10
Adjusted Predicted Value	.0714	.3486	.1361	.08757	10
Residual	-.0235	.0255	.0000	.01367	10
Std. Residual	-1.514	1.647	.000	.882	10
Stud. Residual	-1.663	1.819	-.094	1.014	10
Deleted Residual	-.0834	.0311	-.0098	.03157	10
Stud. Deleted Residual	-1.980	2.318	-.070	1.167	10
Mahal. Distance	.103	7.940	1.800	2.795	10
Cook's Distance	.007	9.483	1.068	2.963	10
Centered Leverage Value	.011	.882	.200	.311	10

a Dependent Variable: T

Charts


Histogram
Dependent Variable: T
Frequency
5
4
3
2
1
0
-1.50
-1.00
-.50
0.00
.50
1.00
1.50
Std. Dev = .88
Mean = 0.00
N = 10.00
Regression Standardized Residual


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: T
Expected Cum Prob
1.00
.75
.50
.25
0.00
0.00
.25
.50
.75
1.00
Observed Cum Prob


Scatterplot
Dependent Variable: T
2.0
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
-2.0
-1.0
-.5
0.0
.5
1.0
1.5
2.0
2.5
Regression Standardized Predicted Value

REGRESSIONS BY SPSS- APPROACH 2 (NS DATA)

Regression (Enter Method)

Table I-1: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
L	146.2070	140.62249	10
L2	39173.7041	71879.12599	10

Table I-2: Correlations

		T	H	H2	L	L2
Pearson Correlation	T	1.000	.936	.958	.947	.888
	H	.936	1.000	.984	.897	.759
	H2	.958	.984	1.000	.910	.804
	L	.947	.897	.910	1.000	.960
	L2	.888	.759	.804	.960	1.000
Sig. (1-tailed)	T	.	.000	.000	.000	.000
	H	.000	.	.000	.000	.005
	H2	.000	.000	.	.000	.003
	L	.000	.000	.000	.	.000
	L2	.000	.005	.003	.000	.
N	T	10	10	10	10	10
	H	10	10	10	10	10
	H2	10	10	10	10	10
	L	10	10	10	10	10
	L2	10	10	10	10	10

Table I-3: Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	L2, H, H2, L(a)	.	Enter

a All requested variables entered.
b Dependent Variable: T

Table I-4: Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.979(a)	.959	.926	.01787	.959	29.334	4	5	.001	2.660

a Predictors: (Constant), L2, H, H2, L
b Dependent Variable: T

Table I-5: ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.037	4	.009	29.334	.001(a)
	Residual	.002	5	.000		
	Total	.039	9			

a Predictors: (Constant), L2, H, H2, L
b Dependent Variable: T

Table I-6: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.057	.033		1.733	.144	-.027	.141		
	H	.007	.014	.486	.510	.632	-.028	.042	.009	110.808
	H2	.000	.001	.360	.496	.641	-.001	.002	.016	64.371
	L	.000	.000	-.465	-.454	.669	-.001	.001	.008	128.561
	L2	6.195E-07	.000	.676	.900	.409	.000	.000	.014	68.995

a Dependent Variable: T

Table I-7: Collinearity Diagnostics(a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions				
				(Constant)	H	H2	L	L2
1	1	4.301	1.000	.00	.00	.00	.00	.00
	2	.560	2.770	.03	.00	.00	.00	.01
	3	.128	5.801	.05	.00	.02	.00	.02
	4	.009	21.479	.24	.02	.21	.18	.12
	5	.001	61.833	.68	.97	.77	.82	.85

a Dependent Variable: T

Table I-8: Residuals Statistics(a)

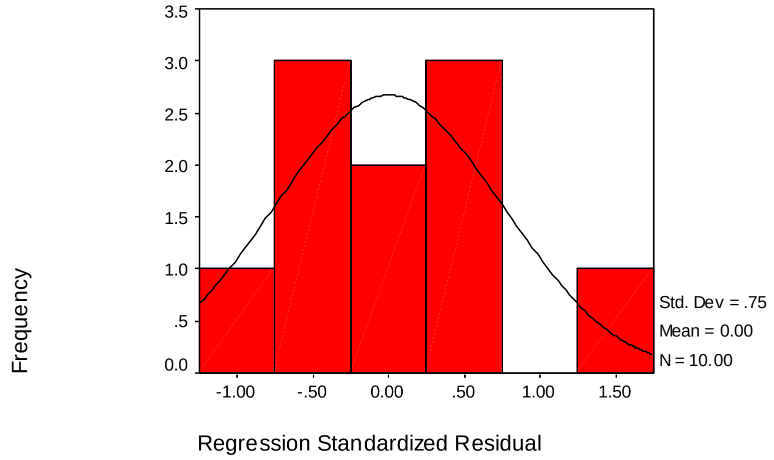
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0698	.2673	.1263	.06452	10
Std. Predicted Value	-.875	2.185	.000	1.000	10
Standard Error of Predicted Value	.00860	.01781	.01227	.00320	10
Adjusted Predicted Value	.0630	.5765	.1601	.15599	10
Residual	-.0215	.0247	.0000	.01332	10
Std. Residual	-1.201	1.379	.000	.745	10
Stud. Residual	-1.401	1.747	-.147	1.057	10
Deleted Residual	-.3113	.0395	-.0339	.10113	10
Stud. Deleted Residual	-1.607	2.502	-.107	1.260	10
Mahal. Distance	1.183	8.042	3.600	2.388	10
Cook's Distance	.009	60.285	6.277	18.983	10
Centered Leverage Value	.131	.894	.400	.265	10

a Dependent Variable: T

Charts

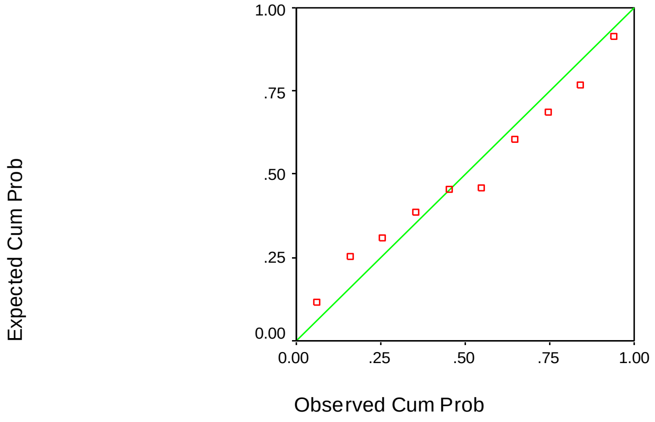
Histogram

Dependent Variable: T



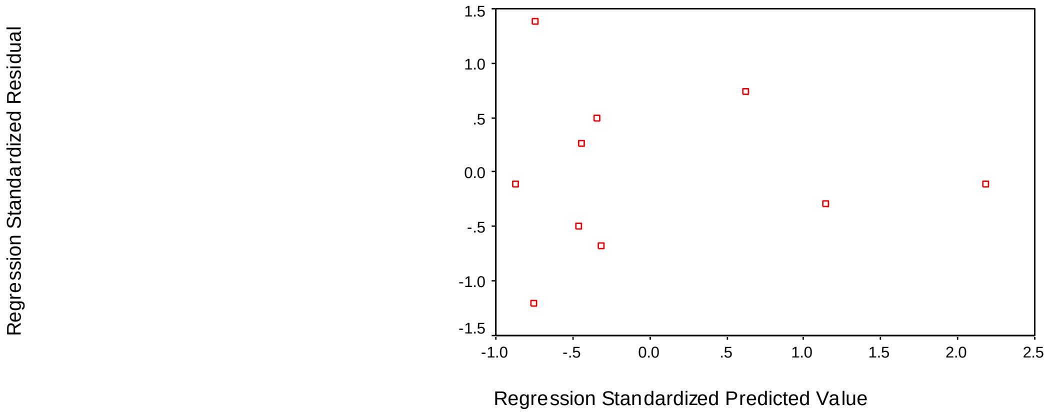
Normal P-P Plot of Regression Standardized Residual

Dependent Variable: T



Scatterplot

Dependent Variable: T



Regression (Stepwise Method)

Table I-9: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
L	146.2070	140.62249	10
L2	39173.7041	71879.12599	10

Table I-10: Correlations

		T	H	H2	L	L2
Pearson Correlation	T	1.000	.936	.958	.947	.888
	H	.936	1.000	.984	.897	.759
	H2	.958	.984	1.000	.910	.804
	L	.947	.897	.910	1.000	.960
	L2	.888	.759	.804	.960	1.000
Sig. (1-tailed)	T	.	.000	.000	.000	.000
	H	.000	.	.000	.000	.005
	H2	.000	.000	.	.000	.003
	L	.000	.000	.000	.	.000
	L2	.000	.005	.003	.000	.
N	T	10	10	10	10	10
	H	10	10	10	10	10
	H2	10	10	10	10	10
	L	10	10	10	10	10
	L2	10	10	10	10	10

Table I-11: Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	H2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	L2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: T

Table I-12: Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.958(a)	.918	.908	.01999	.918	89.749	1	8	.000	
2	.978(b)	.957	.945	.01550	.039	6.316	1	7	.040	2.981

a Predictors: (Constant), H2
b Predictors: (Constant), H2, L2
c Dependent Variable: T

Table I-13: ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			
2	Regression	.037	2	.019	77.853	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

a Predictors: (Constant), H2
b Predictors: (Constant), H2, L2
c Dependent Variable: T

Table I-14: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.066	.009		7.426	.000	.046	.087		
	H2	.001	.000	.958	9.474	.000	.001	.001	1.000	1.000
2	(Constant)	.071	.007		9.904	.000	.054	.088		
	H2	.001	.000	.692	5.243	.001	.000	.001	.353	2.831
	L2	3.039E-07	.000	.332	2.513	.040	.000	.000	.353	2.831

a Dependent Variable: T

Table I-15: Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	H	-.216(a)	-.362	.728	-.135	.032	31.194	.032
	L	.434(a)	2.147	.069	.630	.172	5.800	.172
	L2	.332(a)	2.513	.040	.689	.353	2.831	.353
2	H	.127(b)	.257	.806	.104	.029	34.313	.024
	L	-.030(b)	-.057	.956	-.023	.025	39.811	.025

a Predictors in the Model: (Constant), H2

b Predictors in the Model: (Constant), H2, L2

c Dependent Variable: T

Table I-16: Collinearity Diagnostics(a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	H2	L2
1	1	1.707	1.000	.15	.15	
	2	.293	2.414	.85	.85	
2	1	2.377	1.000	.05	.03	.04
	2	.515	2.149	.57	.01	.18
	3	.109	4.679	.37	.97	.78

a Dependent Variable: T

Table I-17: Residuals Statistics(a)

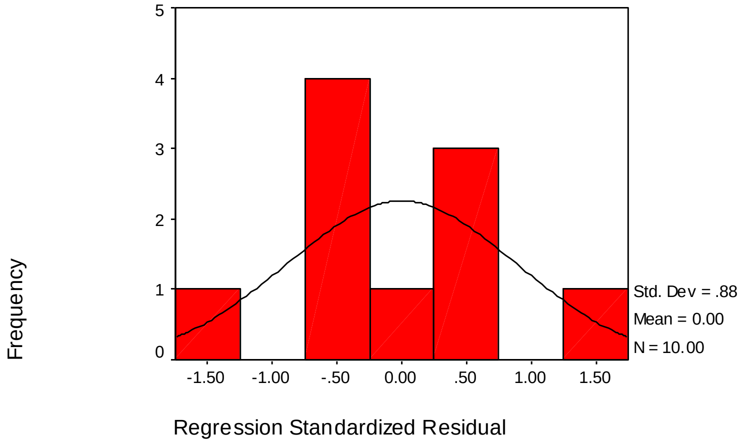
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0751	.2667	.1263	.06445	10
Std. Predicted Value	-.794	2.180	.000	1.000	10
Standard Error of Predicted Value	.00517	.01536	.00775	.00364	10
Adjusted Predicted Value	.0714	.3486	.1361	.08757	10
Residual	-.0235	.0255	.0000	.01367	10
Std. Residual	-1.514	1.647	.000	.882	10
Stud. Residual	-1.663	1.819	-.094	1.014	10
Deleted Residual	-.0834	.0311	-.0098	.03157	10
Stud. Deleted Residual	-1.980	2.318	-.070	1.167	10
Mahal. Distance	.103	7.940	1.800	2.795	10
Cook's Distance	.007	9.483	1.068	2.963	10
Centered Leverage Value	.011	.882	.200	.311	10

a Dependent Variable: T

Charts

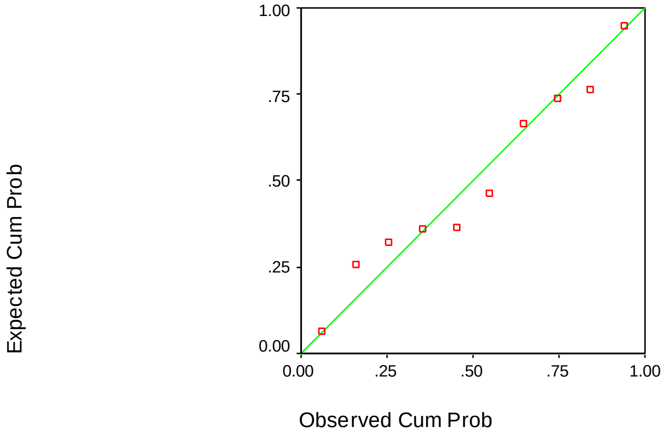
Histogram

Dependent Variable: T



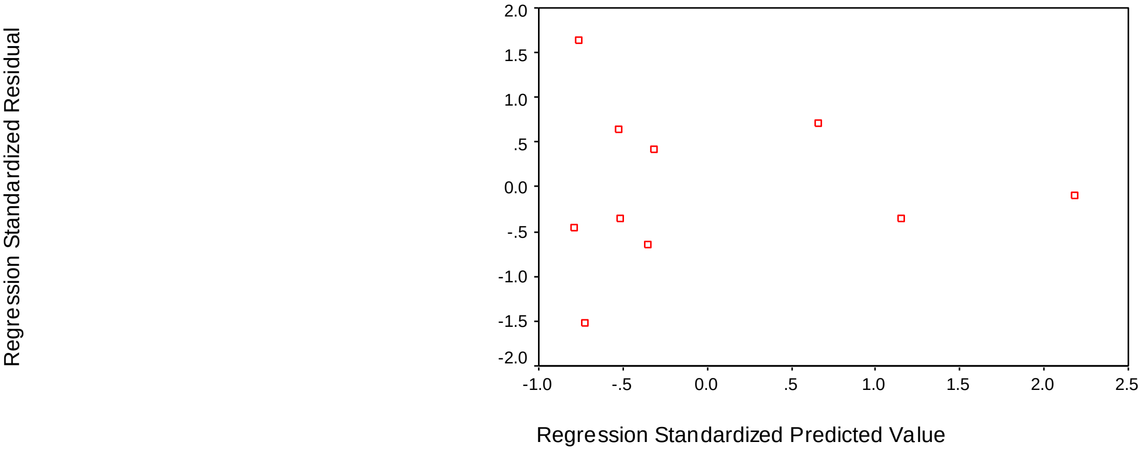
Normal P-P Plot of Regression Standardized Residual

Dependent Variable: T



Scatterplot

Dependent Variable: T



Regression (Backward Method)

Table I-18: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
L	146.2070	140.62249	10
L2	39173.7041	71879.12599	10

Table I-19: Correlations

		T	H	H2	L	L2
Pearson Correlation	T	1.000	.936	.958	.947	.888
	H	.936	1.000	.984	.897	.759
	H2	.958	.984	1.000	.910	.804
	L	.947	.897	.910	1.000	.960
	L2	.888	.759	.804	.960	1.000
Sig. (1-tailed)	T	.	.000	.000	.000	.000
	H	.000	.	.000	.000	.005
	H2	.000	.000	.	.000	.003
	L	.000	.000	.000	.	.000
	L2	.000	.005	.003	.000	.
N	T	10	10	10	10	10
	H	10	10	10	10	10
	H2	10	10	10	10	10
	L	10	10	10	10	10
	L2	10	10	10	10	10

Table I-20: Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	L2, H, H2, L(a)	.	Enter
2	.	L	Backward (criterion: Probability of F-to-remove >= .100).
3	.	H	Backward (criterion: Probability of F-to-remove >= .100).

a All requested variables entered.

b Dependent Variable: T

Table I-21: Model Summary (d)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.979(a)	.959	.926	.01787	.959	29.334	4	5	.001	
2	.978(b)	.957	.936	.01665	-.002	.206	1	5	.669	
3	.978(c)	.957	.945	.01550	.000	.066	1	6	.806	2.981

a Predictors: (Constant), L2, H, H2, L
b Predictors: (Constant), L2, H, H2
c Predictors: (Constant), L2, H2
d Dependent Variable: T

Table I-22: ANOVA(d)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.037	4	.009	29.334	.001(a)
	Residual	.002	5	.000		
	Total	.039	9			
2	Regression	.037	3	.012	45.000	.000(b)
	Residual	.002	6	.000		
	Total	.039	9			
3	Regression	.037	2	.019	77.853	.000(c)
	Residual	.002	7	.000		
	Total	.039	9			

a Predictors: (Constant), L2, H, H2, L
b Predictors: (Constant), L2, H, H2
c Predictors: (Constant), L2, H2
d Dependent Variable: T

Table I-23: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.057	.033		1.733	.144	-.027	.141		
	H	.007	.014	.486	.510	.632	-.028	.042	.009	110.808
	H2	.000	.001	.360	.496	.641	-.001	.002	.016	64.371
	L	.000	.000	-.465	-.454	.669	-.001	.001	.008	128.561
	L2	6.195E-07	.000	.676	.900	.409	.000	.000	.014	68.995
2	(Constant)	.065	.026		2.529	.045	.002	.128		
	H	.002	.007	.127	.257	.806	-.015	.019	.029	34.313
	H2	.000	.000	.557	1.032	.342	-.001	.001	.024	41.160
	L2	3.144E-07	.000	.343	2.308	.060	.000	.000	.321	3.114
3	(Constant)	.071	.007		9.904	.000	.054	.088		
	H2	.001	.000	.692	5.243	.001	.000	.001	.353	2.831
	L2	3.039E-07	.000	.332	2.513	.040	.000	.000	.353	2.831

a Dependent Variable: T

Table I-24: Collinearity Diagnostics (a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions				
				(Constant)	H	H2	L	L2
1	1	4.301	1.000	.00	.00	.00	.00	.00
	2	.560	2.770	.03	.00	.00	.00	.01
	3	.128	5.801	.05	.00	.02	.00	.02
	4	.009	21.479	.24	.02	.21	.18	.12
	5	.001	61.833	.68	.97	.77	.82	.85
2	1	3.334	1.000	.00	.00	.00		.02
	2	.536	2.494	.04	.00	.00		.20
	3	.126	5.154	.07	.01	.03		.65
	4	.004	28.597	.89	.99	.96		.13
3	1	2.377	1.000	.05		.03		.04
	2	.515	2.149	.57		.01		.18
	3	.109	4.679	.37		.97		.78

a Dependent Variable: T

Table I-25: Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
2	L	-.465(a)	-.454	.669	-.199	.008	128.561	.008
3	L	-.030(b)	-.057	.956	-.023	.025	39.811	.025
	H	.127(b)	.257	.806	.104	.029	34.313	.024

a Predictors in the Model: (Constant), L2, H, H2

b Predictors in the Model: (Constant), L2, H2

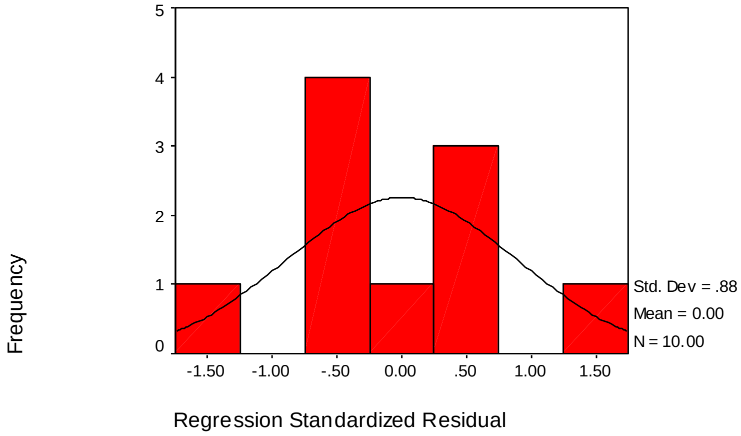
c Dependent Variable: T

Table I-26: Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0751	.2667	.1263	.06445	10
Std. Predicted Value	-.794	2.180	.000	1.000	10
Standard Error of Predicted Value	.00517	.01536	.00775	.00364	10
Adjusted Predicted Value	.0714	.3486	.1361	.08757	10
Residual	-.0235	.0255	.0000	.01367	10
Std. Residual	-1.514	1.647	.000	.882	10
Stud. Residual	-1.663	1.819	-.094	1.014	10
Deleted Residual	-.0834	.0311	-.0098	.03157	10
Stud. Deleted Residual	-1.980	2.318	-.070	1.167	10
Mahal. Distance	.103	7.940	1.800	2.795	10
Cook's Distance	.007	9.483	1.068	2.963	10
Centered Leverage Value	.011	.882	.200	.311	10

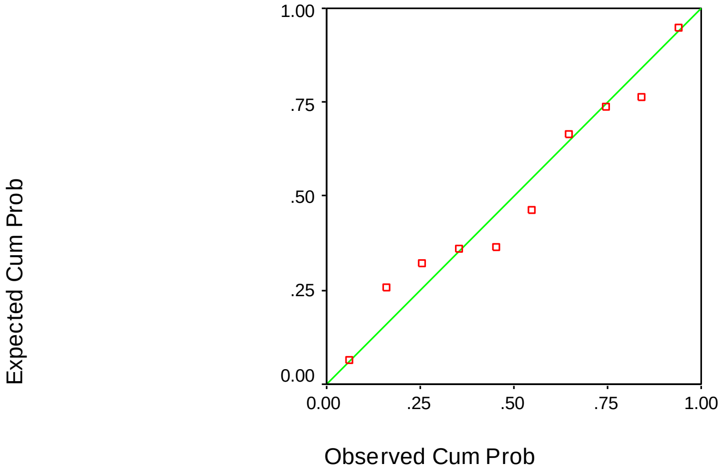
a Dependent Variable: T

Charts



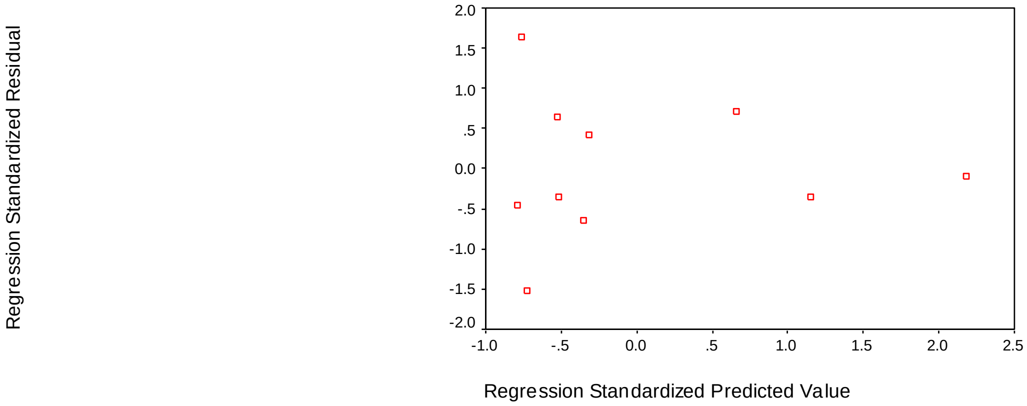
Histogram

Dependent Variable: T



Normal P-P Plot of Regression Standardized Residual

Dependent Variable: T



Scatterplot

Dependent Variable: T

Regression (Forward Method)

Table I-27: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
L	146.2070	140.62249	10
L2	39173.7041	71879.12599	10

Table I-28: Correlations

		T	H	H2	L	L2
Pearson Correlation	T	1.000	.936	.958	.947	.888
	H	.936	1.000	.984	.897	.759
	H2	.958	.984	1.000	.910	.804
	L	.947	.897	.910	1.000	.960
	L2	.888	.759	.804	.960	1.000
Sig. (1-tailed)	T	.	.000	.000	.000	.000
	H	.000	.	.000	.000	.005
	H2	.000	.000	.	.000	.003
	L	.000	.000	.000	.	.000
	L2	.000	.005	.003	.000	.
N	T	10	10	10	10	10
	H	10	10	10	10	10
	H2	10	10	10	10	10
	L	10	10	10	10	10
	L2	10	10	10	10	10

Table I-29: Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	H2	.	Forward (Criterion: Probability-of-F-to-enter <= .050)
2	L2	.	Forward (Criterion: Probability-of-F-to-enter <= .050)

a Dependent Variable: T

Table I-30: Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.958(a)	.918	.908	.01999	.918	89.749	1	8	.000	
2	.978(b)	.957	.945	.01550	.039	6.316	1	7	.040	2.981

a Predictors: (Constant), H2
b Predictors: (Constant), H2, L2
c Dependent Variable: T

Table I-31: ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			
2	Regression	.037	2	.019	77.853	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

a Predictors: (Constant), H2
b Predictors: (Constant), H2, L2
c Dependent Variable: T

Table I-32: Coefficients (a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.066	.009		7.426	.000	.046	.087		
	H2	.001	.000	.958	9.474	.000	.001	.001	1.000	1.000
2	(Constant)	.071	.007		9.904	.000	.054	.088		
	H2	.001	.000	.692	5.243	.001	.000	.001	.353	2.831
	L2	3.039E-07	.000	.332	2.513	.040	.000	.000	.353	2.831

a Dependent Variable: T

Table I-33: Excluded Variables(c)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	H	-.216(a)	-.362	.728	-.135	.032	31.194	.032
	L	.434(a)	2.147	.069	.630	.172	5.800	.172
	L2	.332(a)	2.513	.040	.689	.353	2.831	.353
2	H	.127(b)	.257	.806	.104	.029	34.313	.024
	L	-.030(b)	-.057	.956	-.023	.025	39.811	.025

a Predictors in the Model: (Constant), H2
b Predictors in the Model: (Constant), H2, L2
c Dependent Variable: T

Table I-35: Collinearity Diagnostics (a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	H2	L2
1	1	1.707	1.000	.15	.15	
	2	.293	2.414	.85	.85	
2	1	2.377	1.000	.05	.03	.04
	2	.515	2.149	.57	.01	.18
	3	.109	4.679	.37	.97	.78

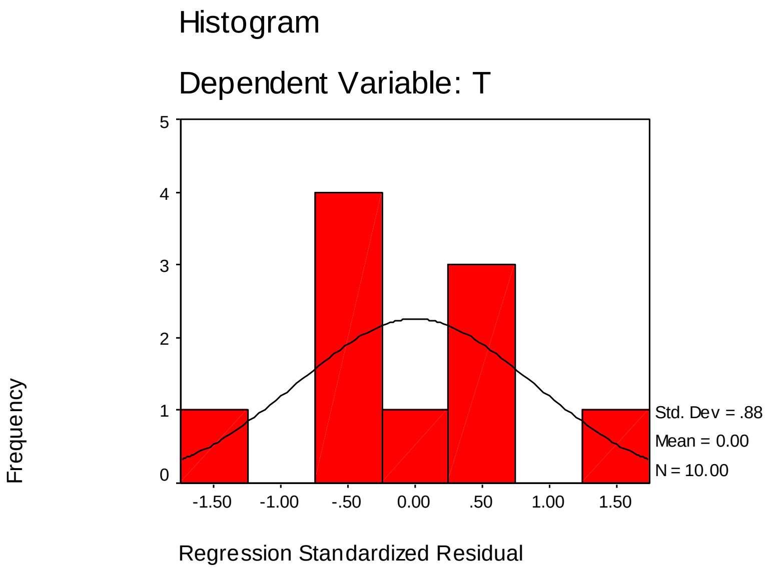
a Dependent Variable: T

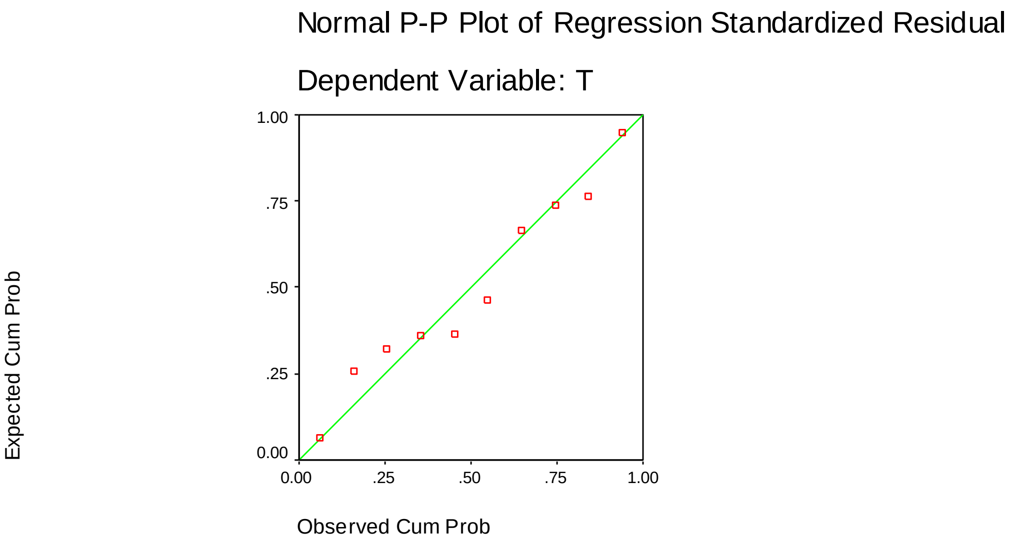
Table I-36: Residuals Statistics (a)

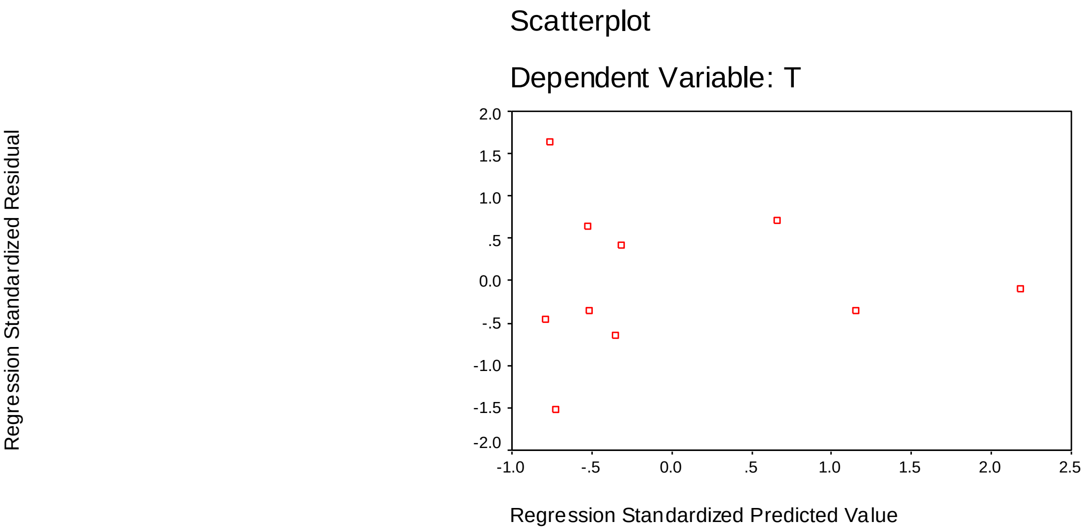
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0751	.2667	.1263	.06445	10
Std. Predicted Value	-.794	2.180	.000	1.000	10
Standard Error of Predicted Value	.00517	.01536	.00775	.00364	10
Adjusted Predicted Value	.0714	.3486	.1361	.08757	10
Residual	-.0235	.0255	.0000	.01367	10
Std. Residual	-1.514	1.647	.000	.882	10
Stud. Residual	-1.663	1.819	-.094	1.014	10
Deleted Residual	-.0834	.0311	-.0098	.03157	10
Stud. Deleted Residual	-1.980	2.318	-.070	1.167	10
Mahal. Distance	.103	7.940	1.800	2.795	10
Cook's Distance	.007	9.483	1.068	2.963	10
Centered Leverage Value	.011	.882	.200	.311	10

a Dependent Variable: T

Charts


Histogram
Dependent Variable: T
Frequency
5
4
3
2
1
0
-1.50
-1.00
-.50
0.00
.50
1.00
1.50
Std. Dev = .88
Mean = 0.00
N = 10.00
Regression Standardized Residual


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: T
Expected Cum Prob
1.00
.75
.50
.25
0.00
0.00
.25
.50
.75
1.00
Observed Cum Prob


Scatterplot
Dependent Variable: T
Regression Standardized Residual
2.0
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
-2.0
-1.0
-.5
0.0
.5
1.0
1.5
2.0
2.5
Regression Standardized Predicted Value

Appendix J

REGRESSIONS BY SPSS- APPROACH 3 (NS DATA)

Regression (Enter Method)

Table J-1: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
L	146.2070	140.62249	10

Table J-2: Correlations

		T	H	H2	L
Pearson Correlation	T	1.000	.936	.958	.947
	H	.936	1.000	.984	.897
	H2	.958	.984	1.000	.910
	L	.947	.897	.910	1.000
Sig. (1-tailed)	T	.	.000	.000	.000
	H	.000	.	.000	.000
	H2	.000	.000	.	.000
	L	.000	.000	.000	.
N	T	10	10	10	10
	H	10	10	10	10
	H2	10	10	10	10
	L	10	10	10	10

Table J-3: Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	L, H, H2(a)	.	Enter

a All requested variables entered.
b Dependent Variable: T

Table J-4: Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.976(a)	.953	.929	.01759	.953	40.111	3	6	.000	3.118

a Predictors: (Constant), L, H, H2
b Dependent Variable: T

Table J-5: ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.037	3	.012	40.111	.000(a)
	Residual	.002	6	.000		
	Total	.039	9			

a Predictors: (Constant), L, H, H2
b Dependent Variable: T

Table J-6: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.074	.027		2.770	.032	.009	.138		
	H	-.003	.007	-.240	-.484	.646	-.021	.014	.032	31.211
	H2	.001	.000	.798	1.506	.183	.000	.002	.028	35.443
	L	.000	.000	.437	2.037	.088	.000	.000	.172	5.803

a Dependent Variable: T

Table J-7: Collinearity Diagnostics(a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	H	H2	L
1	1	3.594	1.000	.00	.00	.00	.01
	2	.351	3.199	.09	.00	.01	.03
	3	.051	8.420	.01	.02	.07	.96
	4	.005	27.838	.91	.98	.92	.01

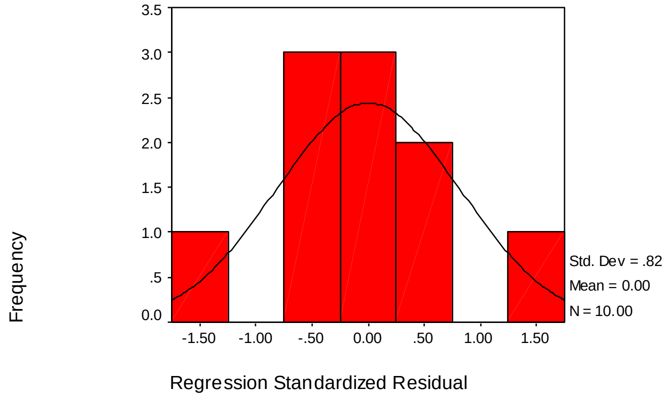
a Dependent Variable: T

Table J-8: Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0735	.2635	.1263	.06430	10
Std. Predicted Value	-.820	2.134	.000	1.000	10
Standard Error of Predicted Value	.00748	.01703	.01060	.00356	10
Adjusted Predicted Value	.0610	.2514	.1286	.06732	10
Residual	-.0237	.0290	.0000	.01436	10
Std. Residual	-1.346	1.650	.000	.816	10
Stud. Residual	-1.517	1.976	-.036	1.011	10
Deleted Residual	-.0564	.0416	-.0024	.02867	10
Stud. Deleted Residual	-1.763	3.052	.047	1.300	10
Mahal. Distance	.730	7.545	2.700	2.584	10
Cook's Distance	.001	2.331	.372	.719	10
Centered Leverage Value	.081	.838	.300	.287	10

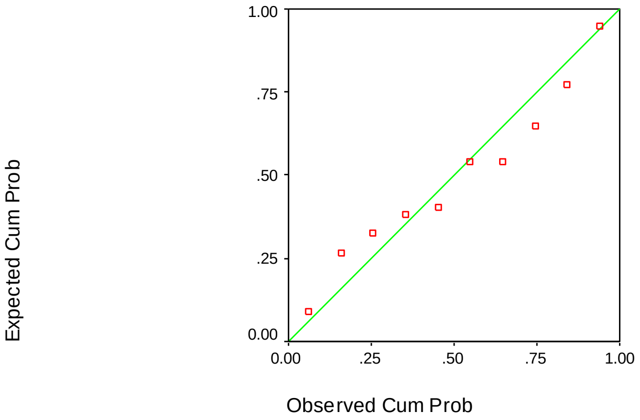
a Dependent Variable: T

Charts



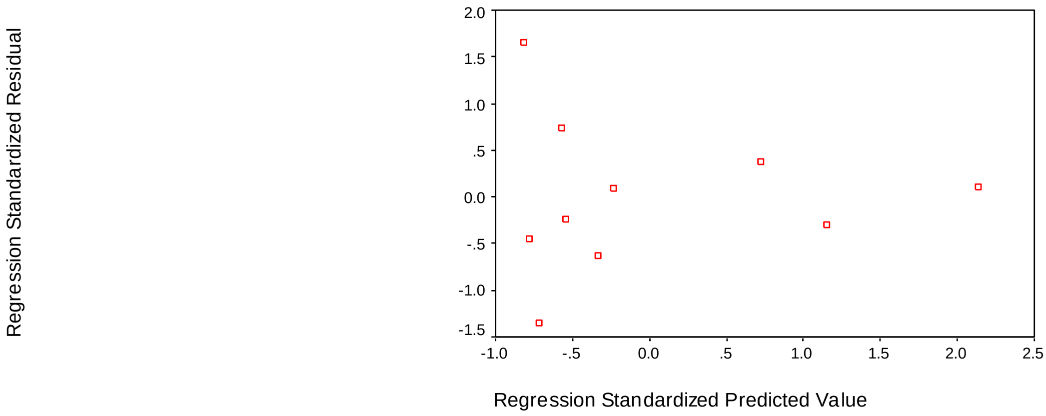
Histogram

Dependent Variable: T



Normal P-P Plot of Regression Standardized Residual

Dependent Variable: T



Scatterplot

Dependent Variable: T

Regression (Stepwise Method)

Table J-9: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
L	146.2070	140.62249	10

Table J-10: Correlations

		T	H	H2	L
Pearson Correlation	T	1.000	.936	.958	.947
	H	.936	1.000	.984	.897
	H2	.958	.984	1.000	.910
	L	.947	.897	.910	1.000
Sig. (1-tailed)	T	.	.000	.000	.000
	H	.000	.	.000	.000
	H2	.000	.000	.	.000
	L	.000	.000	.000	.
N	T	10	10	10	10
	H	10	10	10	10
	H2	10	10	10	10
	L	10	10	10	10

Table J-11: Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	H2	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: T

Table J-12: Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.958(a)	.918	.908	.01999	.918	89.749	1	8	.000	2.817

a Predictors: (Constant), H2
b Dependent Variable: T

Table J-13: ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			

a Predictors: (Constant), H2
b Dependent Variable: T

Table J-14: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.066	.009		7.426	.000	.046	.087		
	H2	.001	.000	.958	9.474	.000	.001	.001	1.000	1.000

a Dependent Variable: T

Table J-15: Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	H	-.216(a)	-.362	.728	-.135	.032	31.194	.032
	L	.434(a)	2.147	.069	.630	.172	5.800	.172

a Predictors in the Model: (Constant), H2
b Dependent Variable: T

Table J-16: Collinearity Diagnostics(a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions	
				(Constant)	H2
1	1	1.707	1.000	.15	.15
	2	.293	2.414	.85	.85

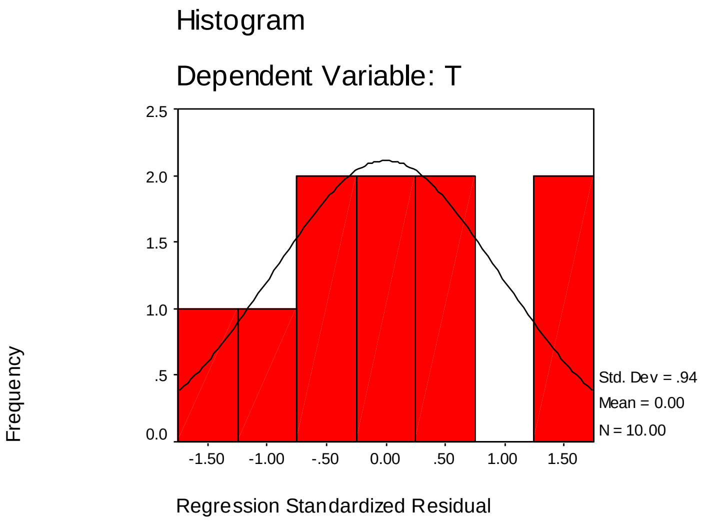
a Dependent Variable: T

Table J-17: Residuals Statistics(a)

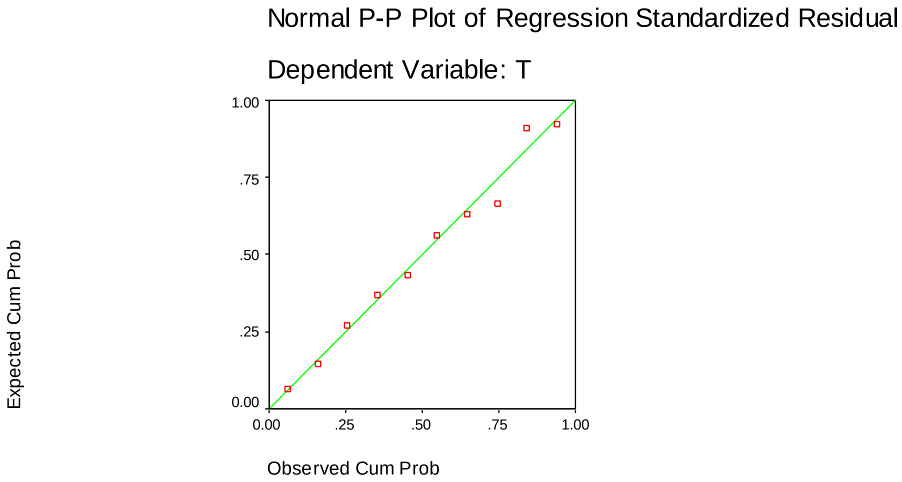
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0713	.2383	.1263	.06313	10
Std. Predicted Value	-.870	1.775	.000	1.000	10
Standard Error of Predicted Value	.00667	.01341	.00867	.00231	10
Adjusted Predicted Value	.0684	.2429	.1257	.06269	10
Residual	-.0301	.0282	.0000	.01885	10
Std. Residual	-1.507	1.411	.000	.943	10
Stud. Residual	-1.902	1.816	.010	1.135	10
Deleted Residual	-.0480	.0490	.0005	.02774	10
Stud. Deleted Residual	-2.403	2.216	.016	1.331	10
Mahal. Distance	.102	3.151	.900	1.043	10
Cook's Distance	.003	1.350	.288	.498	10
Centered Leverage Value	.011	.350	.100	.116	10

a Dependent Variable: T

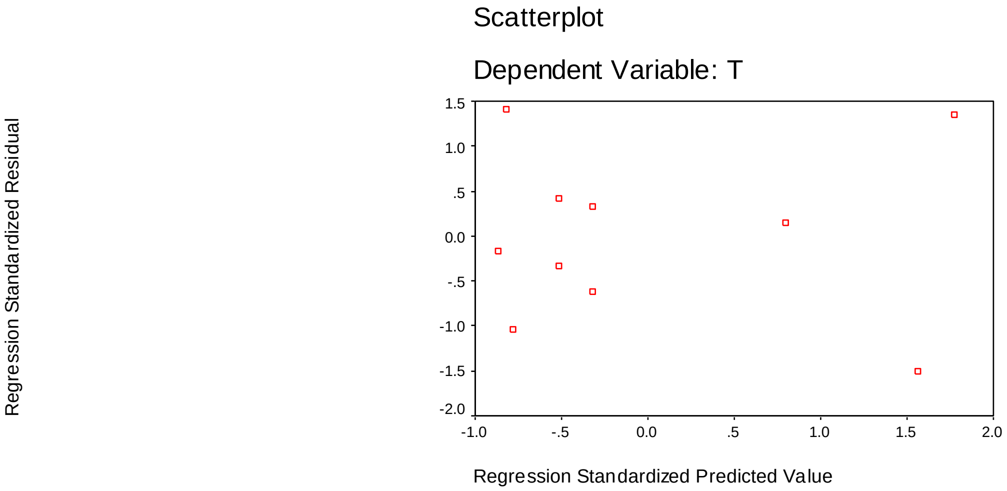
Charts


Histogram

Dependent Variable: T


Normal P-P Plot of Regression Standardized Residual

Dependent Variable: T


Scatterplot

Dependent Variable: T

Regression (Backward Method)

Table J-18: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
L	146.2070	140.62249	10

Table J-19: Correlations

		T	H	H2	L
Pearson Correlation	T	1.000	.936	.958	.947
	H	.936	1.000	.984	.897
	H2	.958	.984	1.000	.910
	L	.947	.897	.910	1.000
Sig. (1-tailed)	T	.	.000	.000	.000
	H	.000	.	.000	.000
	H2	.000	.000	.	.000
	L	.000	.000	.000	.
N	T	10	10	10	10
	H	10	10	10	10
	H2	10	10	10	10
	L	10	10	10	10

Table J-20: Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	L, H, H2(a)	.	Enter
2	.	H	Backward (criterion: Probability of F-to-remove >= .100).

a All requested variables entered.
b Dependent Variable: T

Table J-21: Model Summary(c)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.976(a)	.953	.929	.01759	.953	40.111	3	6	.000	
2	.975(b)	.951	.937	.01659	-.002	.234	1	6	.646	2.941

a Predictors: (Constant), L, H, H2
b Predictors: (Constant), L, H2
c Dependent Variable: T

Table J-22: ANOVA(c)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.037	3	.012	40.111	.000(a)
	Residual	.002	6	.000		
	Total	.039	9			
2	Regression	.037	2	.019	67.429	.000(b)
	Residual	.002	7	.000		
	Total	.039	9			

a Predictors: (Constant), L, H, H2
b Predictors: (Constant), L, H2
c Dependent Variable: T

Table J-23: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.074	.027		2.770	.032	.009	.138		
	H	-.003	.007	-.240	-.484	.646	-.021	.014	.032	31.211
	H2	.001	.000	.798	1.506	.183	.000	.002	.028	35.443
	L	.000	.000	.437	2.037	.088	.000	.000	.172	5.803
2	(Constant)	.061	.008		7.876	.000	.043	.080		
	H2	.000	.000	.563	2.786	.027	.000	.001	.172	5.800
	L	.000	.000	.434	2.147	.069	.000	.000	.172	5.800

a Dependent Variable: T

Table J-24: Collinearity Diagnostics(a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	H	H2	L
1	1	3.594	1.000	.00	.00	.00	.01
	2	.351	3.199	.09	.00	.01	.03
	3	.051	8.420	.01	.02	.07	.96
	4	.005	27.838	.91	.98	.92	.01
2	1	2.607	1.000	.05		.01	.01
	2	.351	2.727	.92		.04	.03
	3	.043	7.798	.03		.94	.96

a Dependent Variable: T

Table J-25: Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
2	H	-.240(a)	-.484	.646	-.194	.032	31.211	.028

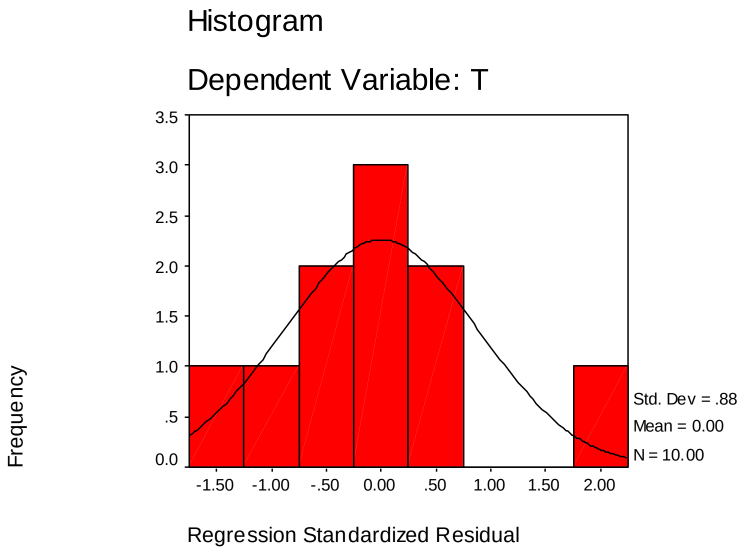
a Predictors in the Model: (Constant), L, H2
b Dependent Variable: T

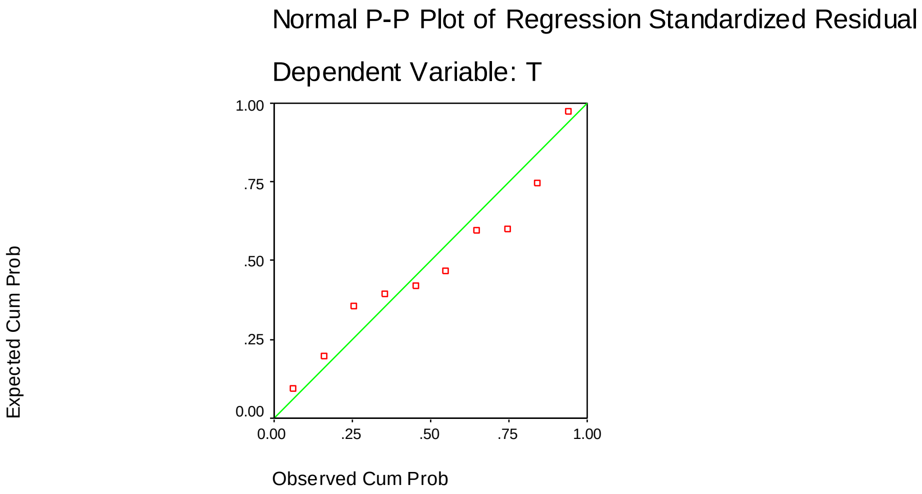
Table J-26: Residuals Statistics(a)

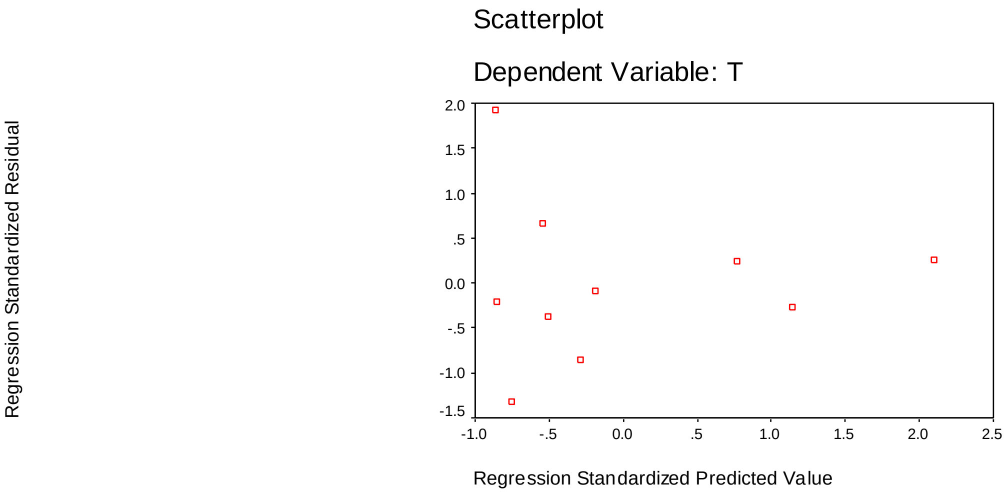
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0706	.2611	.1263	.06424	10
Std. Predicted Value	-.866	2.098	.000	1.000	10
Standard Error of Predicted Value	.00561	.01568	.00833	.00382	10
Adjusted Predicted Value	.0633	.2362	.1273	.06499	10
Residual	-.0219	.0319	.0000	.01464	10
Std. Residual	-1.318	1.924	.000	.882	10
Stud. Residual	-1.445	2.132	-.008	1.021	10
Deleted Residual	-.0413	.0392	-.0010	.02426	10
Stud. Deleted Residual	-1.597	3.334	.097	1.339	10
Mahal. Distance	.127	7.139	1.800	2.738	10
Cook's Distance	.001	1.842	.330	.600	10
Centered Leverage Value	.014	.793	.200	.304	10

a Dependent Variable: T

Charts


Histogram
Dependent Variable: T
Frequency
3.5
3.0
2.5
2.0
1.5
1.0
.5
0.0
-1.50
-1.00
-.50
0.00
.50
1.00
1.50
2.00
Std. Dev = .88
Mean = 0.00
N = 10.00
Regression Standardized Residual


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: T
Expected Cum Prob
1.00
.75
.50
.25
0.00
0.00
.25
.50
.75
1.00
Observed Cum Prob


Scatterplot
Dependent Variable: T
Regression Standardized Residual
2.0
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
-1.0
-.5
0.0
.5
1.0
1.5
2.0
2.5
Regression Standardized Predicted Value

Regression (Forward Method)

Table J-27: Descriptive Statistics

	Mean	Std. Deviation	N
T	.1263	.06588	10
H	7.8592	4.60832	10
H2	80.8799	85.27288	10
L	146.2070	140.62249	10

Table J-28: Correlations

		T	H	H2	L
Pearson Correlation	T	1.000	.936	.958	.947
	H	.936	1.000	.984	.897
	H2	.958	.984	1.000	.910
	L	.947	.897	.910	1.000
Sig. (1-tailed)	T	.	.000	.000	.000
	H	.000	.	.000	.000
	H2	.000	.000	.	.000
	L	.000	.000	.000	.
N	T	10	10	10	10
	H	10	10	10	10
	H2	10	10	10	10
	L	10	10	10	10

Table J-29: Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	H2	.	Forward (Criterion: Probability-of-F-to-enter <= .050)

a Dependent Variable: T

Table J-30: Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.958(a)	.918	.908	.01999	.918	89.749	1	8	.000	2.817

a Predictors: (Constant), H2
b Dependent Variable: T

Table J-31: ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.036	1	.036	89.749	.000(a)
	Residual	.003	8	.000		
	Total	.039	9			

a Predictors: (Constant), H2
b Dependent Variable: T

Table J-32: Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.066	.009		7.426	.000	.046	.087		
	H2	.001	.000	.958	9.474	.000	.001	.001	1.000	1.000

a Dependent Variable: T

Table J-33: Excluded Variables(b)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	H	-.216(a)	-.362	.728	-.135	.032	31.194	.032
	L	.434(a)	2.147	.069	.630	.172	5.800	.172

a Predictors in the Model: (Constant), H2
b Dependent Variable: T

Table J-34: Collinearity Diagnostics(a)

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions	
				(Constant)	H2
1	1	1.707	1.000	.15	.15
	2	.293	2.414	.85	.85

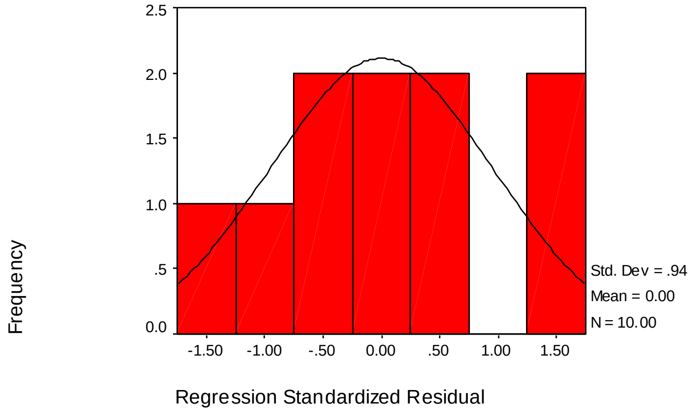
a Dependent Variable: T

Table J-35: Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.0713	.2383	.1263	.06313	10
Std. Predicted Value	-.870	1.775	.000	1.000	10
Standard Error of Predicted Value	.00667	.01341	.00867	.00231	10
Adjusted Predicted Value	.0684	.2429	.1257	.06269	10
Residual	-.0301	.0282	.0000	.01885	10
Std. Residual	-1.507	1.411	.000	.943	10
Stud. Residual	-1.902	1.816	.010	1.135	10
Deleted Residual	-.0480	.0490	.0005	.02774	10
Stud. Deleted Residual	-2.403	2.216	.016	1.331	10
Mahal. Distance	.102	3.151	.900	1.043	10
Cook's Distance	.003	1.350	.288	.498	10
Centered Leverage Value	.011	.350	.100	.116	10

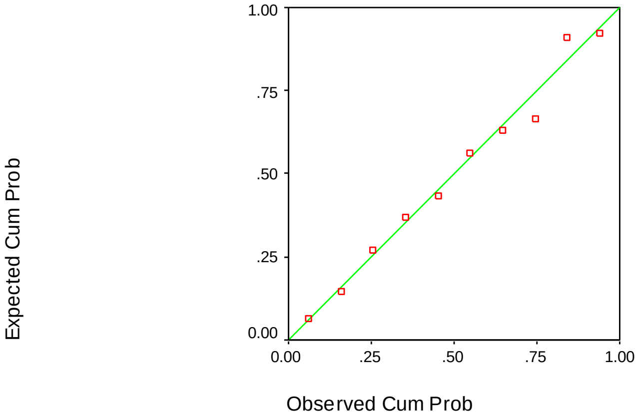
a Dependent Variable: T

Charts



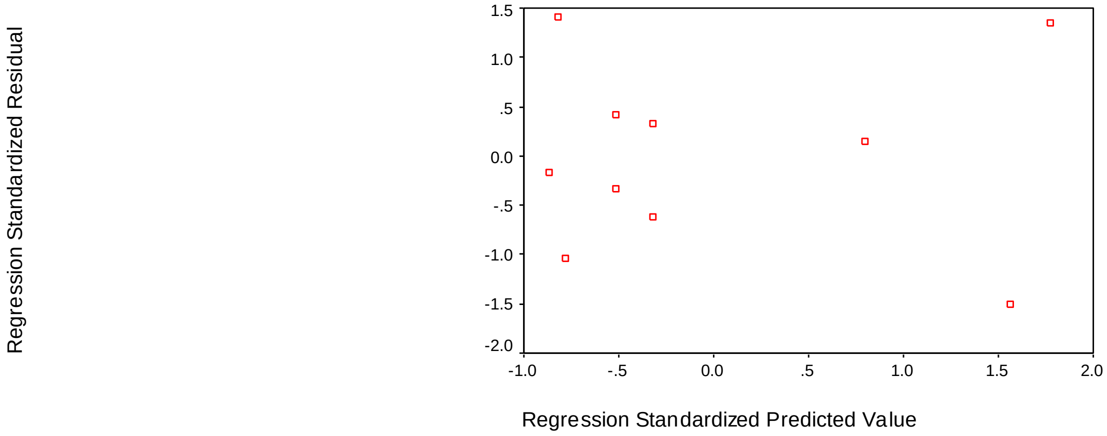
Histogram

Dependent Variable: T



Normal P-P Plot of Regression Standardized Residual

Dependent Variable: T



Scatterplot

Dependent Variable: T

HISTOGRAMS OF STRUCTURAL PERIODS, HEIGHTS AND TOTAL LENGTH OF WALLS OF STRUCTURES

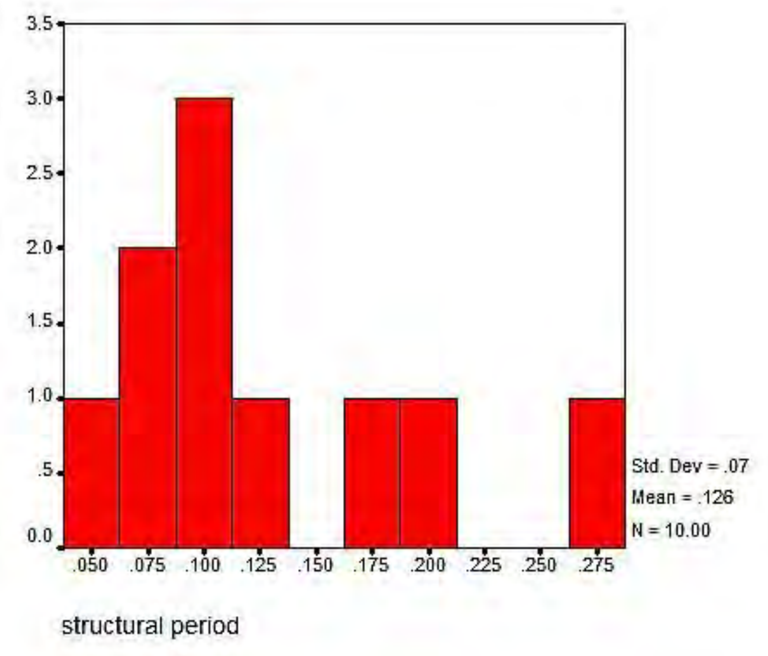


Figure K-1: Histograms of Structural Periods of Structures

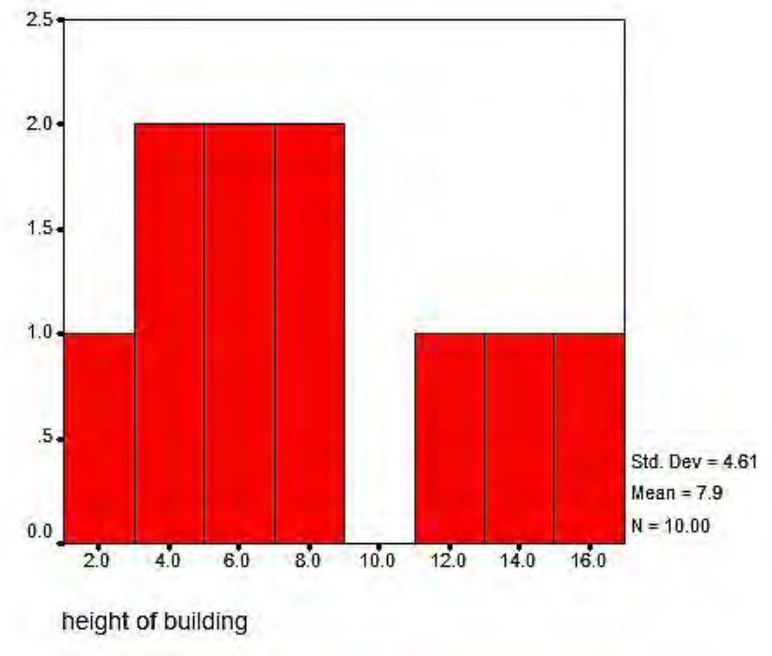


Figure K-2: Histograms of Heights of Structures

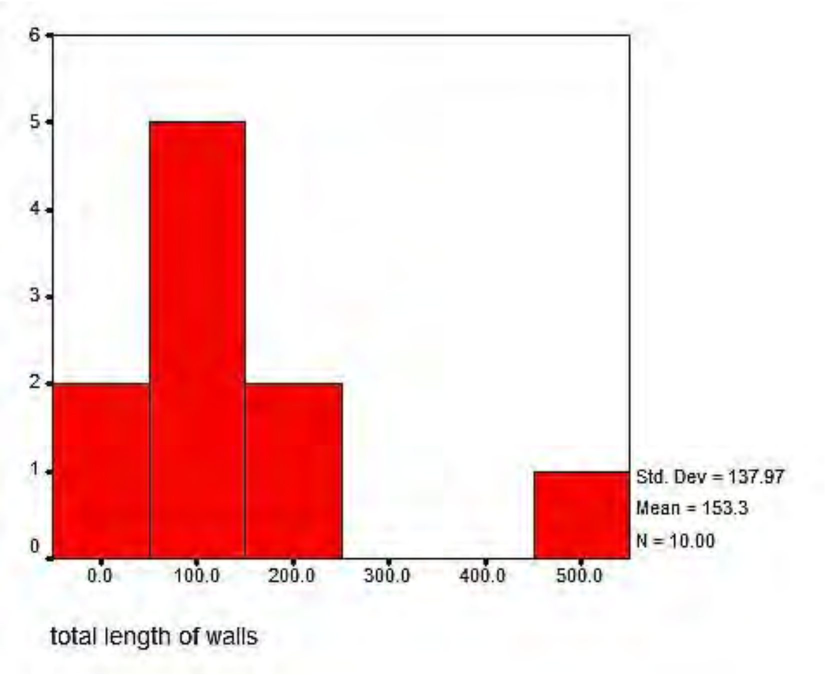


Figure K-3: Histograms of Total Length of Walls of Structures

BOX PLOT OF THE VARIABLES (EW DATA)

Table L-1: Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
structural period	10	90.9%	1	9.1%	11	100.0%
height of building	10	90.9%	1	9.1%	11	100.0%
total length of walls	10	90.9%	1	9.1%	11	100.0%

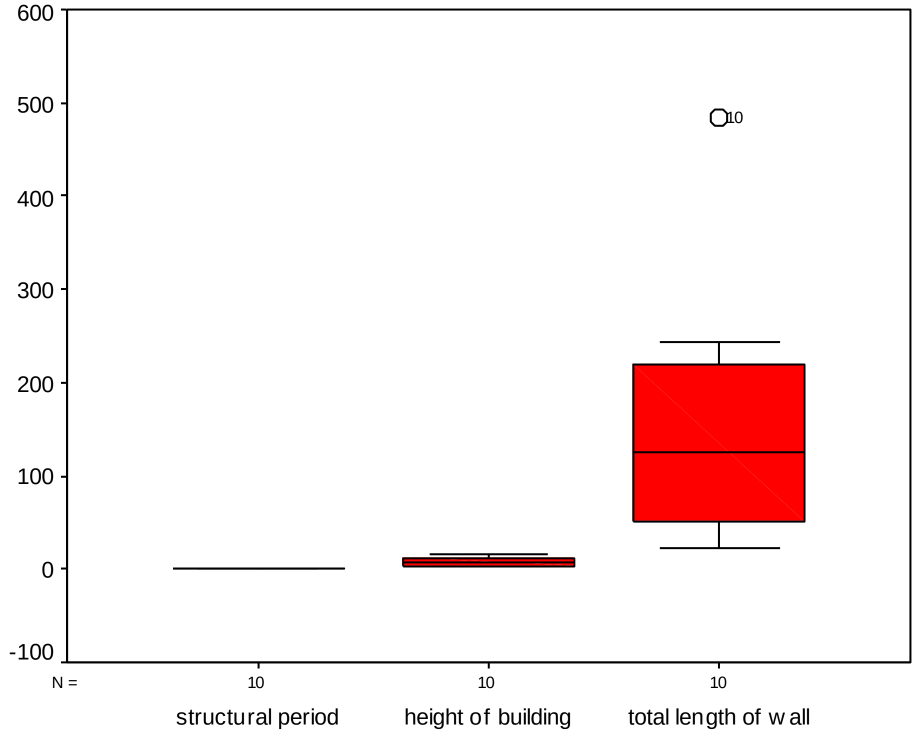


Figure L-1: Box Plot of the Variables

CURVE FIT ANALYSIS (EW DATA)

Table M-1: Curve Fit Analysis for Height

Independent: HEIGHT										
						Upper				
Dependent	Mth	Rsq	d.f.	F	Sigf	bound	b0	b1	b2	b3
TIME	LIN	**.939**	8	123.17	.000		.0210	.0159		
TIME	LOG	.839	8	41.78	.000		-.0677	.1126		
TIME	INV	.652	8	14.99	.005		.2467	-.5679		
TIME	QUA	**.951**	7	68.49	.000		.0553	.0059	.0006	
TIME	CUB	**.955**	6	42.45	.000		.0172	.0248	-.0021	.0001
TIME	COM	.918	8	89.97	.000		.0577	1.1093		
TIME	POW	.893	8	66.97	.000		.0305	.7658		
TIME	S	.765	8	26.00	.001		-1.3201	-4.0531		
TIME	GRO	.918	8	89.97	.000		-2.8529	.1037		
TIME	EXP	.918	8	89.97	.000		.0577	.1037		
TIME	LGS	.918	8	89.97	.000	.	17.3380	.9015		

Table M-2: Curve Fit Analysis for Total Length of Walls

Independent: LENGTH										
						Upper				
Dependent	Mth	Rsq	d.f.	F	Sigf	bound	b0	b1	b2	b3
TIME	LIN	**.759**	8	25.24	.001		.0728	.0005		
TIME	LOG	.711	8	19.67	.002		-.1716	.0680		
TIME	INV	.416	8	5.70	.044		.1969	-3.6705		
TIME	QUA	**.811**	7	15.02	.003		.0437	.0009	-8.E-07	
TIME	CUB	**.837**	6	10.24	.009		.0772	-5.E-05	4.7E-06	-8.E-09
TIME	COM	.711	8	19.69	.002		.0817	1.0031		
TIME	POW	.749	8	23.92	.001		.0152	.4603		
TIME	S	.478	8	7.34	.027		-1.6790	-25.933		
TIME	GRO	.711	8	19.69	.002		-2.5050	.0030		
TIME	EXP	.711	8	19.69	.002		.0817	.0030		
TIME	LGS	.711	8	19.69	.002	.	12.2440	.9970		

SENSITIVITY ANALYSIS

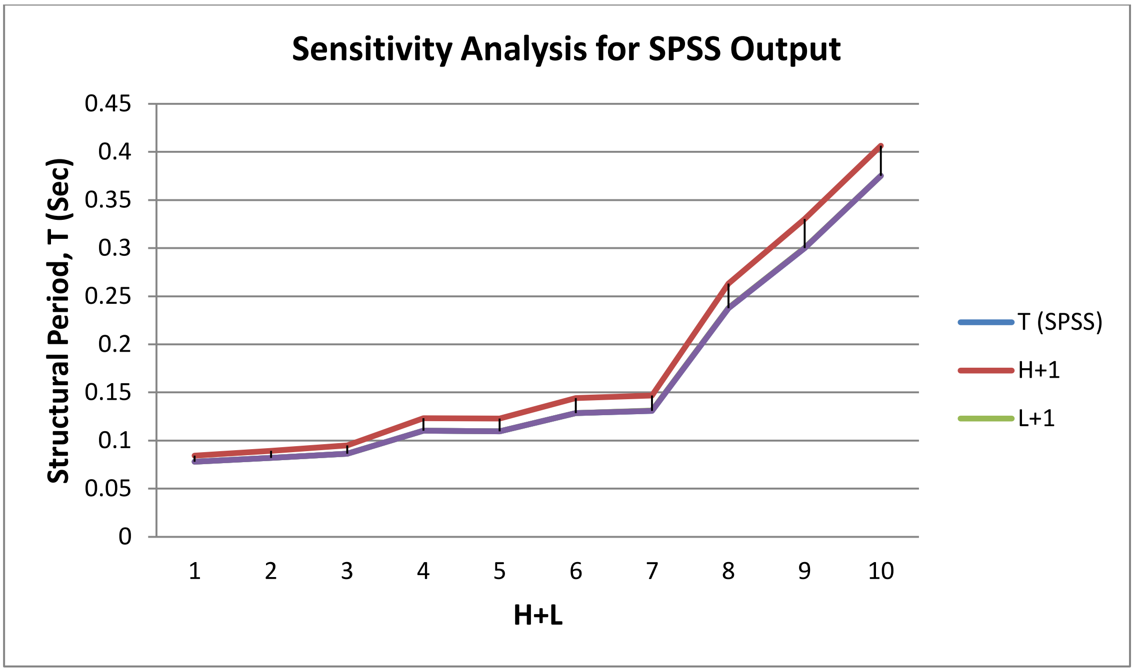


Figure N-1: Sensitivity Analysis of the Result Obtained from SPSS Analysis