A COMPARATIVE STUDY ON SEISMIC ANALYSIS OF A (G+9) 10 STORIED RESIDENTIAL BUILDING FOR DIFFERENT ZONES IN BANGLADESH USING ETABS ACCORDING TO BNBC 2020

By

MD. SHAHIDUR RAHMAN

MD. SALMAN ISLAM

MD. NAWSHAD ISLAM

MD. KAOSAR ALI

MD. RIFAT AL HASAN

A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering



Department of Civil Engineering

Sonargaon University

147/I, Green Road, Dhaka-1215, Bangladesh

Section: 24A+24E

Semester: Spring-2025

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By

MD. SHAHIDUR RAHMAN	ID: BCE2103024214
MD. SALMAN ISLAM	ID: BCE2103024195
MD. NAWSHAD ISLAM	ID: BCE2003021022
MD. KAOSAR ALI	ID: BCE2103024190
MD. RIFAT AL HASAN	ID: BCE2103024156

Supervisor

HIMLITA MONDAL
LECTURER
DEPARTMENT OF CIVIL ENGINEERING
SONARGAON UNIVERSITY (SU)

A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering

Department of Civil Engineering

Sonargaon University

147/I, Green Road, Dhaka-1215, Bangladesh

Section: 24A+24E

Semester: Spring-2025

BOARD OF EXAMINERS

The thesis titled "**A COMPARATIVE STUDY ON SEISMIC ANALYSIS OF A (G+9) 10 STORIED RESIDENTIAL BUILDING FOR DIFFERENT ZONES IN BANGLADESH USING ETABS ACCORDING TO BNBC 2020"** submitted by Student Name: Md. Shahidur Rahman Student ID: BCE2103024214, Student Name: Md. Salman Islam, Student ID: BCE2103024195, Student Name: Md. Nawshad Islam, Student ID: BCE2003021022, Student Name: Md. Kaosar Ali, Student ID: BCE2103024190, Student Name: Rifat Al Hasan, Student ID: 2103024156 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering on January 20, 2023.

……

1. Hemlita Mondal — Chairman
   Lecturer
   Department of Civil Engineering
   Sonargaon University

……

2. Internal / External Member — Member

……

3. Internal / External Member — Member

DECLARATION

It is hereby declared that all studies presented in this thesis, with the exception of those in which particular references have been made to the work of others, are the outcomes of research done by the authors under the supervision of Hemlita Mondal, Lecturer, Department of Civil Engineering, Sonargaon University. This thesis/project or any part of it has not been submitted elsewhere for the award of any degree, diploma or other certification (except for publications).

STUDENT NAME	STUDENT ID.	SIGNATURE
MD. SHAHIDUR RAHMAN	ID: BCE2103024214	
MD. SALMAN ISLAM	ID: BCE2103024195	
MD. NAWSHAD ISLAM	ID: BCE2003021022	
MD. KAOSAR ALI	ID: BCE2103024190	
MD. RIFAT AL HASAN	ID: BCE2103024156	

Dedicated

to

"Almighty Allah,

Our Parents,

Our Family

and

Our Honorable Teachers"

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ABSTRACT

The earthquake, which has the greatest impact on both human life and built infrastructure, is the most devastating and unpredictably occurring natural occurrence. A structure can suffer severe damage as a result of seismic forces brought on by earthquakes, which frequently result in structural collapse. Since the day it became a reality, earthquakes have today become a threat to human advancement. According to previous earthquakes, a significant number of structures have unquestionably suffered damage as a result of earthquakes. Due to the spread of earthquake-prone regions, earthquake analysis is now one of the most important factors in the planning of any structure. Bangladesh is especially vulnerable to earthquake activity. Because of this, it is now crucial to choose seismic reactions over constructions in various zones. This study examines the design and analysis of a (G+9) 10 storied residential structure that is situated in Bangladesh's Zone II, Zone III, and Zone IV seismic zones. In this study, BNBC 2020 and ETABS 2016 are used to analyze the seismic response and stability of residential buildings against extreme earthquakes or seismic conditions. This research defined the base shear, torsional irregularity, story drift, and story displacement of various seismic zones in Bangladesh and presents the comparative analysis. The highest story drift, story displacement and base shear were found in Zone IV (Sylhet), then Zone II (Dhaka), then Zone III (Chattogram). Torsion irregularity was same and normal for all zones. The design was ok for all seismic zones in Bangladesh. According to research, whenever the seismic coefficients increase, the seismic effects also increase. Eventually alternative things are happened due to other coefficients such as Zone II (Dhaka). Finally, we can state that the research work helps to solidify our understanding of the analysis and design of structures under seismic influences.

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LIST OF NOTATIONS

Notation	Meaning
C_d	Deflection amplification factor.
C_f	Force coefficient to be used in determination of wind loads for other structures.
C_N	Net pressure coefficient to be used in determination of wind loads for open buildings.
C_p	External pressure coefficient to be used in determination of wind loads for buildings.
C_s	Normalized acceleration response spectrum.
C_t	Numerical coefficient to determine building period.
D	Dead loads, or related internal moments and forces.
E	Total load effects of earthquake that include both horizontal and vertical, or related internal moments and forces.
F	Design wind force for other structures, in N.
F	Loads due to weight and pressures of fluids with well-defined densities and controllable maximum heights or related internal moments and forces.
H	Loads due to weight and pressure of soil, water in soil, or other materials, or related internal moments and forces.
L	Live loads.
L_r	Roof live loads, or related internal moments and forces.
R	Rain load, or related internal moments and forces.
T	Self-straining forces and cumulative effect of temperature, creep, shrinkage, differential settlement, and shrinkage-compensating concrete, or combinations thereof, or related internal moments and forces.
W	Total seismic weight of building.
W	Wind load, or related internal moments and forces.
X+E	X Direction + Eccentricity (Ecc. Ratio = 0.05).
X-E	X Direction - Eccentricity (Ecc. Ratio = 0.05).
Y+E	Y Direction + Eccentricity (Ecc. Ratio = 0.05).
Y-E	Y Direction - Eccentricity (Ecc. Ratio = 0.05).

CHAPTER 1
Introduction

1.1 Background and Motivations

A natural disaster known as an earthquake can also result from the migration of magma or an unexpected ground subsidence. However, there are times when earthquakes are brought on by human action, such as overloading the earth's crust or causing nuclear explosions underneath.

Earthquake is a natural disaster that causes significant loss of life and property, leaves many people homeless, orphans and widows, and has a severe negative impact on a nation's economy. To recoup and make up for the loss an earthquake inflicted, it takes many years. Even at great distances from the epicenter, earthquake tremors can be felt. One of the most severe natural disasters is an earthquake, which causes the earth's surface to tremble as seismic energy is released from the crust along a fault. The building is negatively affected by an earthquake. When seismic waves are exposed to a building, the building's foundation begins to tremble and eventually collapses. Seismic waves are generated from the crust and propagate toward the earth's surface. The purpose of seismic analysis is to comprehend how a building will react to an earthquake. Multi-storied building construction is becoming unavoidable for both commercial and residential uses. The tall raised buildings are not adequately constructed to resist lateral stresses and it can result in the total collapse of the structures [1].

Earthquakes are a major cause of property damage and fatalities because they can force buildings to collapse. Large earthquakes can sometimes trigger disease outbreaks due to loss of housing, contaminated water, and other issues affecting public health. Surface displacement, electrical and gas pipeline breaks, and fire all contribute to the occurrence of fire. There are frequently side effects from earthquakes or connections to other natural disasters.

Bangladesh is a South Asian nation well renowned for its frequent natural disasters. It is situated between 20.35°N and 26.75°N Latitude and 88.03°E and 92.75°E Longitude. Bangladesh is ranked 5th in terms of risk and 10th in terms of exposure to nature catastrophes in the 2015 Asia Pacific Disaster Report. Natural disasters like

Cyclones, floods, droughts, earthquakes, river bank erosion, etc. occur every year throughout the nation. But studies have shown that Bangladesh is the country most at risk from earthquakes. Bangladesh is one of the most tectonically active regions in the world since it is surrounded mostly by India and to a lesser extent by Myanmar and is situated where three tectonic plates-Eurasia, India, and Burma meet. Bangladesh has been the victim of numerous destructive as well as minor earthquakes during the past 200 years. Bangladesh has had around 250 earthquakes since gaining its independence in 1971, some of which had a magnitude greater than 6.0. But one cannot overlook the risks. Studies have also demonstrated the potential for fatalities. There is no way to predict or prevent earthquakes from occurring in earthquake-prone areas, but we can reduce the number of lives lost and the damage to property by conducting in-depth research, issuing warnings, and putting settlement management techniques into practice for both pre-disaster and post-disaster management[2].

Depending on the earthquake's magnitude, it arrives quickly for a few seconds and results in little, moderate, or large loss of life and property. Although it cannot be entirely avoided, it can be managed. Therefore, earthquake mitigation and prevention are major global concerns right now.

The seismic analysis can be used to create a construction that is earthquake resistant. This study's main objective is to examine seismic response in various structural zones for static and dynamic assessment in typical minute opposed casing. For the seismic analysis, we took a (G+9) 10 storied residential structure into consideration. The procedure for determining the base plan loads that must be acquired for forced loads, dead loads, and other external loadings attaches the fundamental requirements relating to the fundamental security of structures. According to BNBC 2020, the entire structure was examined using ETABS software on a computer.

An analysis of a (G+9) 10 storied residential RC building subjected to seismic loads for Dhaka District (Zone II), presented in this thesis or dissertation. This thesis displays the story drift, story displacement, torsional irregularity, base shear, and other structural characteristics of this building.

1.2 Research Objectives and Overview

The principal objectives of this research work are given in below:

- To conduct seismic analysis on structures for different zone in Bangladesh.
- To examine the impact of different types of loads placed on a building.

1.3 Analysis Methods

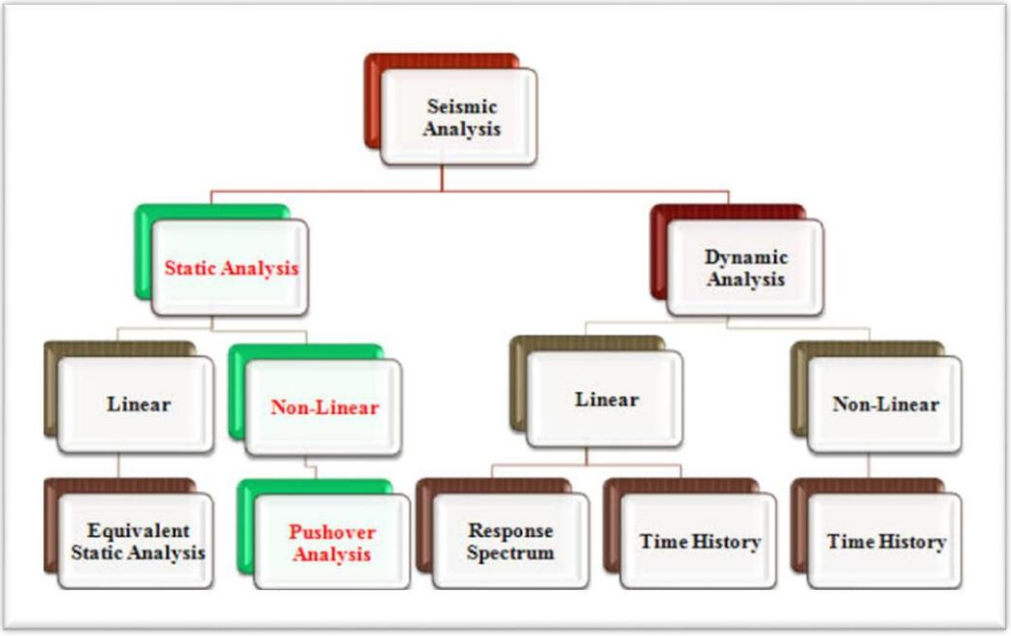


Figure 1.1: Different Types of Analysis Method

1.4 Methods Considered

1.4.1 Equivalent Static Analysis

It is one of the techniques used to determine seismic loads. Practicality is compromised since it does not account for all the elements that influence how

Important the foundation condition is. Only for small structures is the corresponding static analysis used in the design process. For each orientation, just one mode is taken into account in this procedure. The corresponding static method is sufficient for constructing low rise structures to withstand earthquakes [4]. It presupposes that construction operates in its core manner.

1.4.2 Response Spectrum Analysis

This method enables consideration of a building's multiple forms of response. These modes can be found for a structure via computer analysis. Analyzing the response spectrum is a method for calculating the structural reaction to brief, unpredictable dynamic events. Such phenomena include earthquakes and shocks. The inability to

know the load's precise temporal history makes it challenging to conduct a time-dependent analysis.

1.4.3 Time History Method

An in-depth investigation of a structure's dynamic reaction to a given loading that may change over time is called a time history study. Time history analysis is used to estimate the seismic response of a structure under dynamic loading of a representative earthquake.

1.5 Organization of the Thesis

The thesis is organized into five unique chapters that each address one of the following issues:

Chapter 1: Introduction and Objective. The context and driving forces behind the research are presented in this chapter. This chapter also includes a description of the general goals and anticipated results.

Chapter 2: Literature Review. In this chapter, the pertinent literature is reviewed. The previous analysis history of earthquakes or seismic waves is covered in this section, along with recent research on seismic zones, BNBC, ETABS and etc.

Chapter 3: Methodology. The methodology used to conduct the research is described in this chapter. This chapter goes through each phase of the analytical process in great depth. In this chapter, the zonal parameters, load principles, and different types of loads operating on the structure are also covered.

Chapter 4: Results and Discussion. The load calculations for the proposed buildings as well as their material characteristics are covered in this chapter. In this chapter, various floor plan views, 3D views, zonal soil details, and building analysis images are also displayed. This chapter also discusses the data and findings from base shear analysis, torsional irregularity, overall and zone-to-zone story drift, and story displacement.

Chapter 5: Conclusions and Future Work. The conclusions, limitations, thoughts, and recommendations made by this study are outlined in this chapter, along with some suggestions for additional research that should be done in the future.

CHAPTER 2
Literature Review

2.1 Introduction

Bangladesh is particularly susceptible to seismic activity, however its type and intensity are still unknown. Complete seismic monitoring infrastructure is not present in Bangladesh. A seismic observatory was built at Chittagong by the Bangladesh Meteorological Department in 1954 and it is still the sole observatory in the nation [5].

Bangladesh has experienced earthquakes over the past 250 years, according to available data. The seismic data indicates that Bangladesh has seen more than 100 moderate to major earthquakes since 1900, of which more than 65 occurred since 1960 and this reveals that there has been an increase in earthquake frequency during the past 30 years [6]. This spike in earthquake activity may be the result of recent tectonic activity or the spread of fissures from nearby seismic zones. There were no known earthquakes in this region prior to the arrival of the Europeans and it is clear from previous earthquake data that this region's borders are the most likely places for earthquakes to occur and also the large and significant earthquakes that struck Bangladesh caused serious damage, and the majority of their epicenters were situated near the border between Bangladesh and India, where the majority of Bangladesh's rivers arrived from India [7]. Bangladesh is located where the Indian, Eurasian, and Burmese tectonic plates collide, and as a result, there have historically been numerous, severe earthquakes there. At the moment, the Eurasian plate is migrating north at a rate of 2 centimeters per year, whereas the Indian plate is moving in the north-east at a rate of roughly 6 cm per year. Bangladesh and its surroundings are home to five significant fault zones. We have listed the fault zones and the maximum earthquake magnitudes that could potentially occur in Table 2.01. There is a subduction zone with a length of around 250 kilometers that can cause earthquakes with a magnitude of 8.2 to 9.0, according to a recent research Scientists have determined that eastern Bangladesh and some of eastern India are moving diagonally into western Myanmar at a rate of 46 millimeter per year, or about 1.8 inches, after installing two dozen ground-positioning (GPS) instruments linked to satellites that are capable of tracking minute ground motions. The measurements reveal that a large portion of the ensuing strain has been absorbed by many known, slowly moving Surface faults in India and Myanmar after being combined with the already-existing

GPS data from India and Myanmar. However, the remaining movement, which is around 17 millimeters or two-thirds of an inch per year, is reducing the distance between Myanmar and Bangladesh, which is implied to be the result of an ongoing subduction process. Pressure is being built by this reduction in distance, which is occurring several kilometers below the surface, and this process has been ongoing for a while. Even while there is controversy about whether or not there is such a subduction zone, if additional data supports its presence, it will pose the greatest threat to Bangladesh, according to LDEO in 2016[8].

Table 2.1: The Maximum Magnitude of the Earthquakes That Can Be Produced from the Fault Zones

Serial Number	Fault Zones	Maximum Magnitude
01	Bogra Fault Zone	7
02	Tripura Fault Zone	7
03	Shilong Plateau	7
04	Dauki Fault Zone	7.3
05	Assam Fault Zone	8.5

Table 2.2: List of the Biggest Earthquakes That Have Occurred in the Past

Date	Historical Name	Magnitude
January 10, 1869	Cachar Earthquake	7.39
July 14, 1885	Bengal Earthquake	7
January 10, 1889	Meghalaya Earthquake	7.5
June 12, 1897	Great Indian Earthquake	8
July 18, 1918	The Srimangal Earthquake	7.6

September 9, 1923	Meghalaya Earthquake	7.1
July 3, 1930	The Dubri Earthquake	7.1
August 15, 1950	The Assam Earthquake	8.7
August 11, 2009	The Bay of Bengal Earthquake	7.5
August 24, 2016	The Myanmar Earthquake	6.8

The "size" or amplitude of the seismic waves produced by the source of an earthquake and detected by seismographs is referred to as the "earthquake magnitude". The maximum seismic wave amplitude (measured in thousandths of a millimeter) as recorded on a typical seismograph served as the basis for the magnitude scale of earthquakes developed by American seismologist Charles F. Richter in 1935. The Table 2.03 displays the Richter scale in its most recent incarnation.

Table 2.3: Richter Scale of Earthquake Magnitude

Magnitude Level	Category	Effects	Earthquakes Annually
Less than 1.0 to 2.9	Micro	While recorded on local instruments, people often do not feel it.	More than 100,000
3.0-3.9	Minor	Felt by many; no harm.	12,000-100,000
4.0-4.9	Light	Sensed by everybody; small object breakage.	2,000-12,000
5.0-5.9	Moderate	Some harm to fragile structures.	200-2,000
6.0-6.9	Strong	Moderate harmed in	20-200

		Inhabited regions.	
7.0-7.9	Major	Loss of lives and significant damage to vast areas.	3-20
8.0 and Higher	Great	Over a vast area, there has been terrible destruction and death.	Fewer than 3

So, seismic analysis is so important to design and construct a safe and secure building in the unfavorable circumstances like as tectonically strong zones. Without these the damages and destruction can be reduced by seismic analysis.

For those reasons, this thesis "A COMPARATIVE STUDY ON SEISMIC ANALYSIS OF A (G+9) 10 STORIED RESIDENTIAL BUILDING FOR DIFFERENT ZONES IN BANGLADESH USING ETABS ACCORDING TO BNBC 2020" is so important.

2.2 Mainstream Seismology Timeline in Brief

According to Ari Ben-Menahem (1995), since man first responded literarily to the occurrences of earthquakes and volcanoes some 4000 years ago, the history of seismology has been documented. Man, first started looking for earthquake-causing natural phenomena 26 centuries ago. Following the Lisbon earthquake in 1755, the groundbreaking works of John Bevis (1757) and John Michell marked the beginning of modern seismology (1761). With Robert Mallet's sobering speeches, it achieved its zenith (1862). About a century ago, in 1889, Ernst Von Rebeur-Paschwitz in Potsdam discovered the first teleseismic record, and John Milne and his collaborators in Japan created the first prototype of the modern seismograph. These two events marked the beginning of the science of seismology. The early explorers Lamb, Love, Oldham, Wieehert, Omori, Golitzin, Volterra, Mohoroviie, Reid, Zppritz, Herglotz, and Shida made significant progress in the years that followed. The subsequent generation of seismologists, including experimentalists and theoreticians Gutenberg, Richter, Jeffreys, Bullen, Lehmann, Nakano, Wadati, Sezawa, Stoneley, Pekeris, and Benioff,

made considerable advancements. Seismology was finally able to make use of the extensive information contained in seismic signals on both a global and local scale with the development of long-period seismographs and computers (1934-1962)[10].

At present there are so many software and modern technologies are invented to analyze and determine the seismic such as ETABS.

2.3 Relevant Works History

The BNBC 1993 modifications were initially advised by the Al-Husaini, T. M. et al. (2012). They carried out a thorough analysis of the Peak Ground Acceleration (PGA), Spectral Acceleration, a ground categorization system, and an on-site response spectrum [11].

Sarothi S. Z. et al. (2019) investigate and quantify changes in the analysis of wind and seismic loads from a structural and economic perspective by highlighting the key distinctions between BNBC 1993 and 2017. In BNBC 2017 compared to BNBC 1993, seismic base shear is higher due to changes in the zone coefficient (Z), response modification factor (R), and the addition of CS (normalized acceleration response spectrum) [12].

Rathod and Chandrashekhar (2017) present seismic analysis can be used to design and build a structure that can survive the strong lateral displacement of the earth's crust during an earthquake. ETABS can be used to evaluate any kind of construction, no matter how simple or sophisticated, whether it is under static or dynamic situations. ETABS is one of the greatest structural software for building systems since it is a coordinated and effective tool for analysis and designs, ranging from straightforward 2D frames to contemporary high-rises [13].

The structural behavior of multi-story buildings is particularly highlighted in a case study in a paper by Abhay Guleria (2014). The ETABS program is used to model a 15-story R.C.C.-framed skyscraper for study. Maximum shear forces, bending moments, and maximum storey displacement are calculated after the structure has been studied, and they are then compared for all the analyzed scenarios [14].

Ali Kadhim Sallal (2018) present using ETABS software, a building's design and analysis were done while taking earthquake and wind pressure into consideration.

ETABS software is used to simulate the eight-story, (18 x 18 m), construction in this scenario. The structure's total height is calculated by using ten stories at a height of 3 meters (31m)[15].

Kakpure and Mundhda (2016) present using ETABS, an examination of the earlier research on earthquake analysis for multi-story buildings. Building static and dynamic analysis is the main topic. The contrast of static and dynamic analysis of multistory buildings is reviewed in this essay. The study concentrated on design characteristics such displacement, bending moment, base shear, story drift, torsion, and axial force[16].

Balaji and Selvarasan (2016) investigated a G+13 storied residential building. Using ETABS, the building's earthquake loads were examined. Static and dynamic analyses were carried out assuming linear material characteristics. Calculations of several responses, including displacement and base shear, revealed that displacement grew with building height [17].

2.4 BNBC (Bangladesh National Building Code)

To control building construction and maintain and keep them to specific standards, the Bangladesh National Building Code (BNBC) was first issued in 1993. Prior to the code, the Building Construction Act, passed back in 1952 during Pakistan's existence, was the only regulation governing construction. The Bangladesh National Building Code (BNBC) was required as a result of the nation's quick expansion and development, which began in the early 1990s and resulted in a significant real estate boom. In 1993, the first edition was released [18].

Two principal objectives of the BNBC are given below:

- To control all building-related operations, such as planning, designing, and building, in order to maintain a safe and healthy environment.
- To offer guidelines for consistent planning, design, construction, and servicing facilities such electrical, mechanical, sanitary, and other services.

BNBC editions are given below:

- First edition: BNBC 1993
- Latest edition: BNBC 2020

Without these there are some editions of BNBC.

2.5 ETABS

Engineering software called ETABS is used to analyze and design multi-story buildings. The grid-like geometry specific to this form of construction is taken into account via modeling tools and templates, code-based load prescriptions, analysis techniques, and solution approaches. ETABS can be used to analyze simple or complex systems under static or dynamic conditions.

There are so many versions of ETABS such as ETABS 9, ETABS 16, ETABS 18, ETABS 19, ETABS 20 and other so many versions.

2.6 Summary

This chapter presents literature review and motivations. Without these Seismology History has been presented here. Relevant work history, BNBC and ETABS has been also discussed in this chapter.

CHAPTER 3
Methodology

3.1 Introduction

Calculating a building's earthquake response falls under the category of seismic analysis, which is a branch of structural analysis. The research study's methodology will be covered in this chapter. This Chapter will go over the specific steps that were taken to complete the task in details. The thesis dissertation's research of the seismic provisions of the BNBC 2020 provided the impetus to accomplish the aforementioned goals. This chapter includes descriptions of the materials, procedure, theory, technique, equipment, calibration, calculation stages, descriptions of the analytical methods, and references to any specific software that may have been utilized. Earthquake load, Wind load and so many loads which are acting on the building has been described in details.

3.2 Methodology Overview

This project's completion schedule is broken down into five phases. All the phases are displayed by a flow chart.

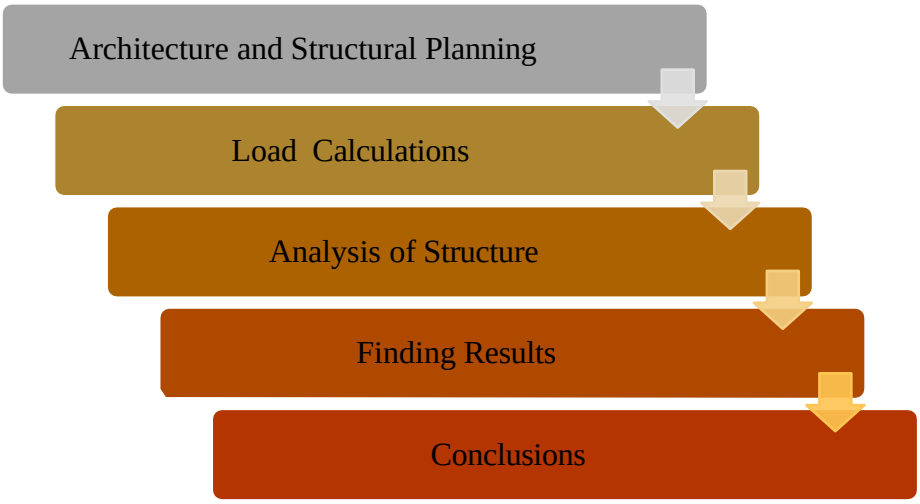


Figure 3.1: Five Phases to Accomplish the Project

3.1.1

3.3 Building Design Code

The building design code is Bangladesh National Building Code (BNBC). The BNBC edition is BNBC 2020.

3.4 Used Software

The used software for this project is given below:

- AutoCAD 2007 (For Architectural Planning)
- ETABS 2016 (For Structural Analysis)

3.5 ETABS Design Code

As per BNBC 2020 the code for structure to analyze in ETABS is given below:

- Concrete Design Code: ACI 318-08
- Steel Design Code: AISC 360-05
- Seismic Load: UBC-94
- Wind Load: UBC-94
- RCC: ACI 318-08

3.6 Occupancy Category

There are four Occupancy Categories name as Occupancy Category I, Occupancy Category II, Occupancy Category III and Occupancy Category IV.

Occupancy Category II: everything except the ones specified in Occupancy Categories I, III, and IV, including buildings and other structures

3.7 Types of Load Acting on a Structure

Protection and economy are two important factors to consider when developing something. Economic system is impacted by judging hundreds and taking them more severely, while the protection is jeopardized by seeing the economy and taking masses less severely.

In order to accurately estimate the numerous loads acting, calculations must be made. Different design loads for buildings and other structures are specified in BNBC 2020 and ASCE (American Society of Civil Engineers) 7: Minimum Design Loads for Buildings and Other Structures.

Loads are given below.

- Dead Loads

- Live Loads or Imposed Loads
- Earthquake Loads
- Wind Loads
- Snow Loads
- Special Loads

3.8 Dead Load

A steady load placed on a structure (such as a bridge, building, or machine) as a result of the member's weight, the structure it supports, and any fixed fixtures or accessories.

Table 3.1: Unit Weight of Basic Materials in Model Building

Material	Unit Weight (KN/m^3)
Aluminium	27.0
Asphalt	21.2
Brick	18.9
Cement	14.7
Iron (Cast)	70.7
Iron (Wrought)	75.4
Limestone	24.5
Marble	26.4
Sand (Dry)	15.7
Concrete-Stone Aggregate (Unreinforced)	22.8*
Concrete-Brick Aggregate (Unreinforced)	20.4*
Sand Stone	22.6

Slate	28.3
Steel	77.0
Stainless Steel	78.75
Timber	5.9-11.0
(*) for reinforced concrete, add 0.63 KN/m^3 for each 1% by volume of main reinforcement.	

3.9 Live Load or Imposed Load

In contrast to construction loads, environmental loads (such as wind loads, snow loads, rain loads, earthquake loads, and flood loads), and dead loads, live loads are those produced by the usage and occupancy of a building or structure. Live loads, also known as imposed loads, are moving or movable loads that do not accelerate or experience any impact. A building's occupant brings all of these loads with them. Usually, these are pieces of furniture and portable walls.

Table 3.2: Live Load Distribution According to BNBC 2020

Occupancy	Use of Floor	KN/m^2	lb/ft^2
Two Unit	All other areas except stairs and balconies	2.0	42
Two Unit	Internal stairs and exit ways	4.8	100
As Above	Balconies (Exterior)	4.8	100

3.10 Earthquake Load

3.10.1 Structural Importance Factor

Structural Importance Factor is shown in Table 3.03.

Table 3.3: Importance Factors for Buildings and Structures for Earthquake Design

Occupancy Category	Importance Factor
I and II	1.00
III	1.25
IV	1.50

3.10.2 Seismic Zone Coefficient

All the details about Seismic Zone Coefficient are provided.

Table 3.4: Description of Seismic Zone

Seismic Zone	Location	Seismic Intensity	Seismic Zone Coefficient, Z
I	Southwestern part including Barisal, Khulna, Jessore, Rajshahi	Low	0.12
II	Lower Central and Northwestern part including Noakhali, Dhaka, Pabna, Dinajpur, as well as Southwestern corner including Sundarbans	Moderate	0.20
III	Upper Central and Northwestern part including Brahmanbaria, Sirajganj, Rangpur	Severe	0.28
IV	Northeastern part including Sylhet, Mymensingh, Kurigram	Very Severe	0.36

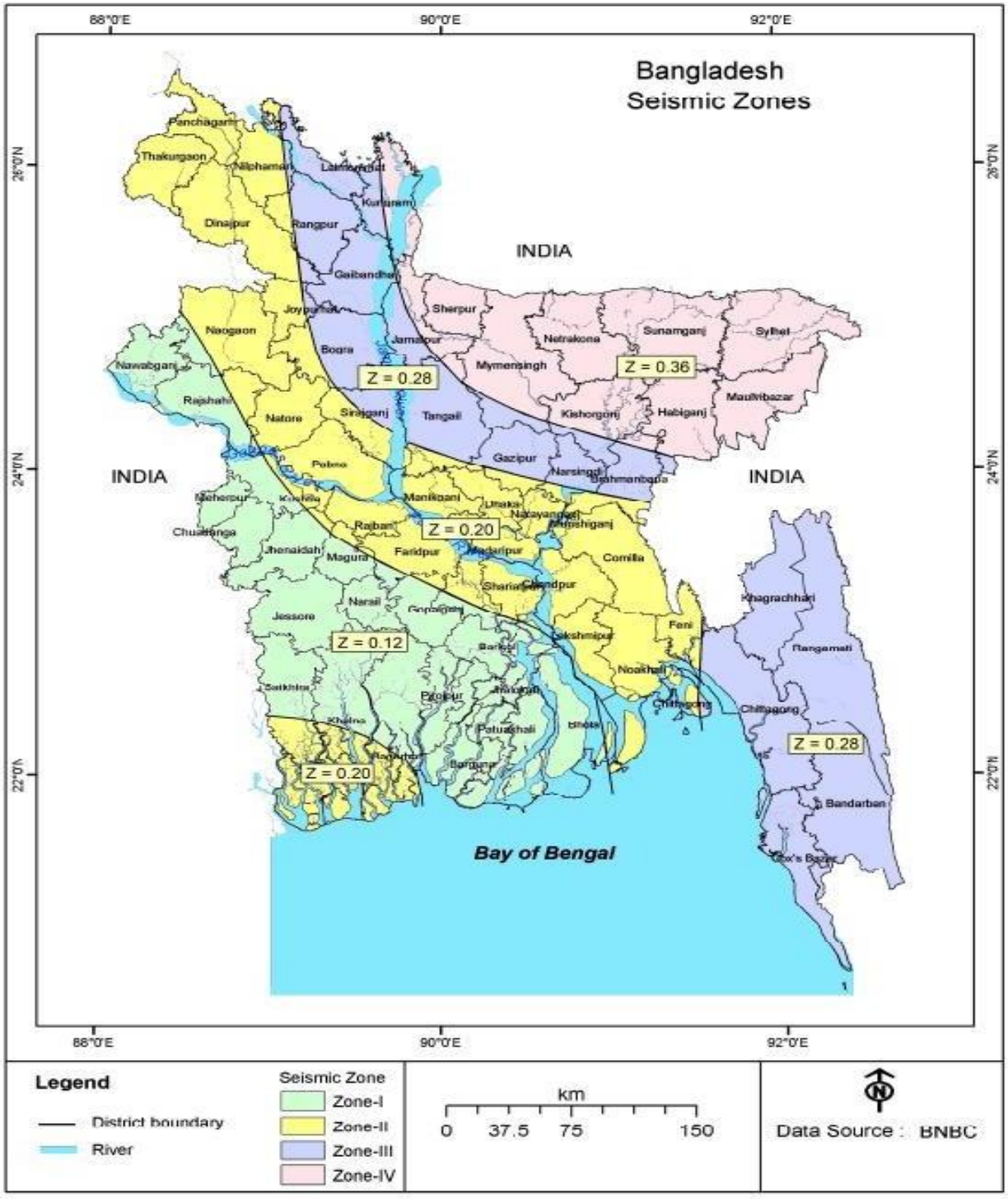


Figure 3.2: Seismic Zoning Map of Bangladesh

Table 3.5: Seismic Zone Coefficient Z for Some Important Town of Bangladesh

Town	Z	Town	Z
Bagerhat	0.12	Madaripur	0.20
Bandarban	0.28	Magura	0.12
Barguna	0.12	Manikganj	0.20
Barisal	0.12	Maulvibazar	0.36
Bhola	0.12	Meherpur	0.12
Bogra	0.28	Mongla	0.12
Brahmanbaria	0.28	Munshiganj	0.20
Chandpur	0.20	Mymensingh	0.36
Chapainababganj	0.12	Narail	0.12
Chitagong	0.28	Narayanganj	0.20
Chuadanga	0.12	Narsingdi	0.28
Comilla	0.20	Natore	0.20
Cox's Bazar	0.28	Naogaon	0.20
Dhaka	0.20	Netrakona	0.36
Dinajpur	0.20	Nilphamari	0.12
Faridpur	0.20	Noakhali	0.20
Feni	0.20	Pabna	0.20
Gaibandha	0.28	Panchagarh	0.20
Gazipur	0.20	Patuakhali	0.12

Gopalganj	0.12	Pirojpur	0.12
Habiganj	0.36	Rajbari	0.20
Jaipurhat	0.20	Rajshahi	0.12
Jamalpur	0.36	Rangamati	0.28
Jessore	0.12	Rangpur	0.28
Jhalokati	0.12	Satkhira	0.12
Jhenaidah	0.12	Shariatpur	0.20
Khagrachari	0.28	Sherpur	0.36
Khulna	0.12	Sirajganj	0.28
Kishoreganj	0.36	Srimangal	0.36
Kurigram	0.36	Sunamganj	0.36
Kushtia	0.20	Sylhet	0.36
Lakshmipur	0.20	Tangail	0.28
Lalmanirhat	0.28	Thakurgaon	0.20

Table 3.6: Site Dependent Soil Factor and Other Parameters Defining Elastic Response Spectrum

Soil Type	S	T_B(s)	T_C(s)	T_D(s)
SA	1.0	0.15	0.40	2.0
SB	1.2	0.15	0.50	2.0
SC	1.15	0.20	0.60	2.0
SD	1.35	0.20	0.80	2.0

SE	1.4	0.15	0.50	2.0

3.10.3 Building Period

The building period T (in sec) may be approximate by the following formula.

$T = C_t(h_n)^m$

Where,

h_n = Height of the building in meters from foundation or from top of rigid basement. C_t

= Numerical coefficient to determine building period.

m = Coefficient which is related to C_t.

3.10.4 Fundamental Frequency

The fundamental frequency F (in Hz) formula is presented below.

$f = 1/T$

Where,

T = Building period in second.

3.10.5 Building or Other Structure Rigid

A building or other structure whose fundamental frequency is greater than or equal to 1 Hz is rigid.

3.11 Site Classification

Site will be classified as type SA, SB, SC, SD, S_1 and S_2.

3.12 Seismic Design Category

Buildings shall be assigned a seismic design category among B, C or D based on seismic zone, local site conditions and importance class of building.

3.13 Design Base Shear

The seismic design base shear force in a given direction shall be determined by this equation.

$V = S_a W$

Where,

S_a = Lateral seismic force coefficient. W

= Total seismic weight of building.

3.14 Story Drift, Drift Ratio and Displacement

3.14.1 Deflection and Story Drift

The deflections δ_x of level *x* at the center of the mass shell be determined in accordance with the following equation.

$$\delta_x = \frac{C_d \delta_{xe}}{I}$$

Where,

C_d = Deflection amplification factor.

I = Importance factor.

δ_{xe} = Deflection determined by an elastic analysis.

Story drift is the lateral displacement of one level to another level below. The design story drift at *x* shall be computed as the difference of the deflections at the centers of mass at the top and bottom of the story under construction.

$\Delta_X = \delta_X - \delta_{X-1}$

Allowable story drift limit (Δ_a) for occupancy category II (all other structures) is $0.020h_{sx}$.

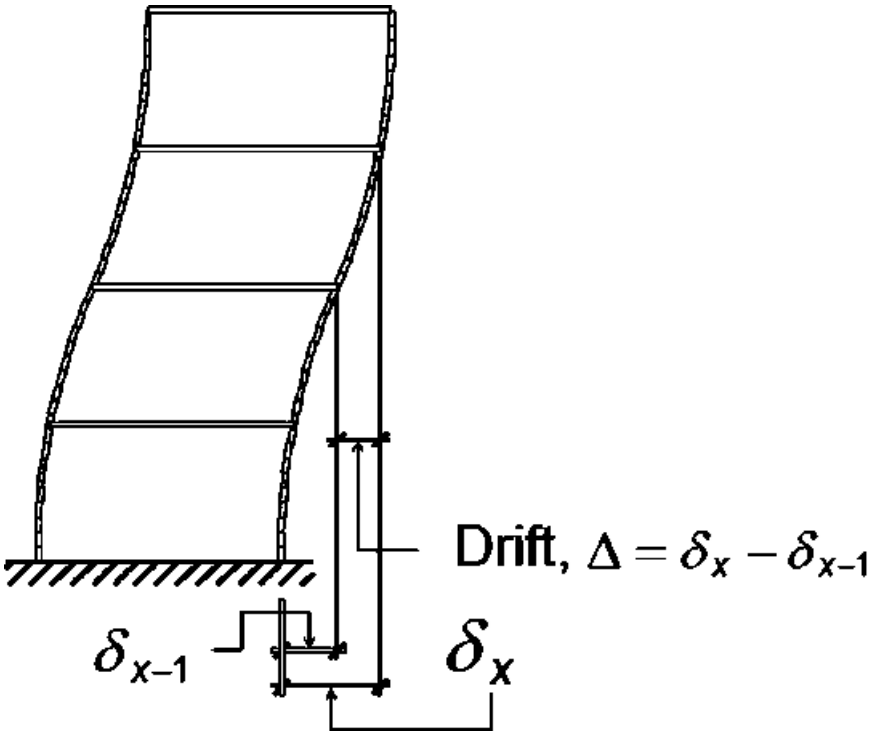


Figure 3.3: Deflection and Drift

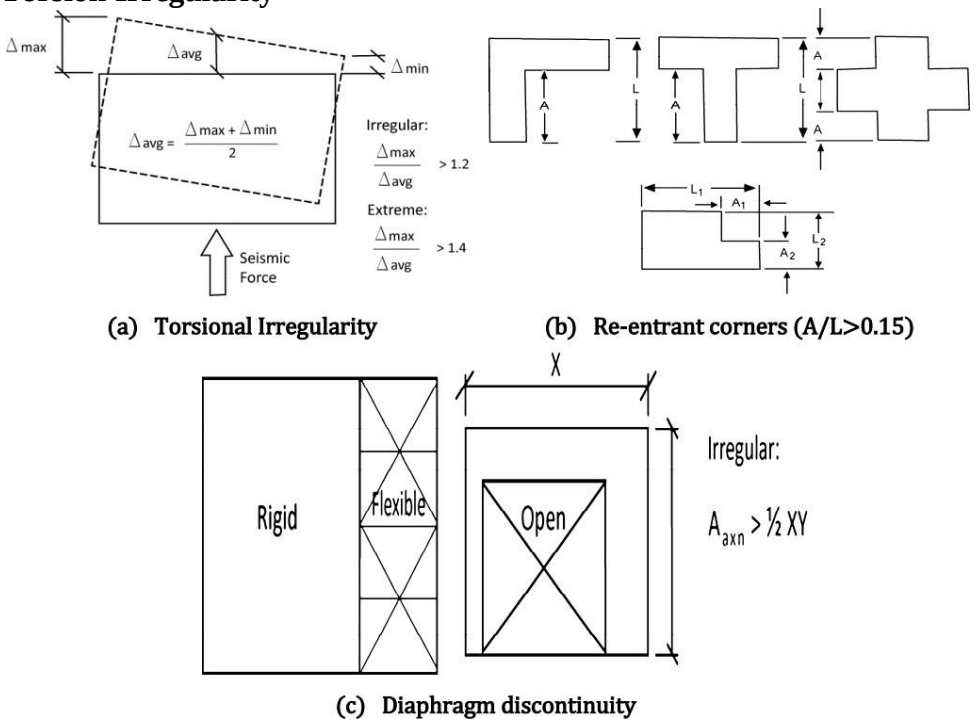
3.14.2 Story Displacement

Story displacement of floor or point from its original position.

3.14.3 Story Drift Ratio

Story drift ratio is the story drift divided by the story height.

3.15 Torsion Irregularity



(a) Torsional Irregularity

(b) Re-entrant corners (A/L>0.15)

(c) Diaphragm discontinuity

Figure 3.4: Irregularities of Building

3.16 Wind Load

Table 3.7: Importance Factor, I (Wind Loads)

Occupancy Category or Importance Class	Non-Cyclone Prone Regions and Cyclone Prone Regions with V = 38-44 m/s	Cyclone Prone Regions with V > 44 m/s
I	0.87	0.77
II	1.00	1.00
III	1.15	1.15
IV	1.15	1.15

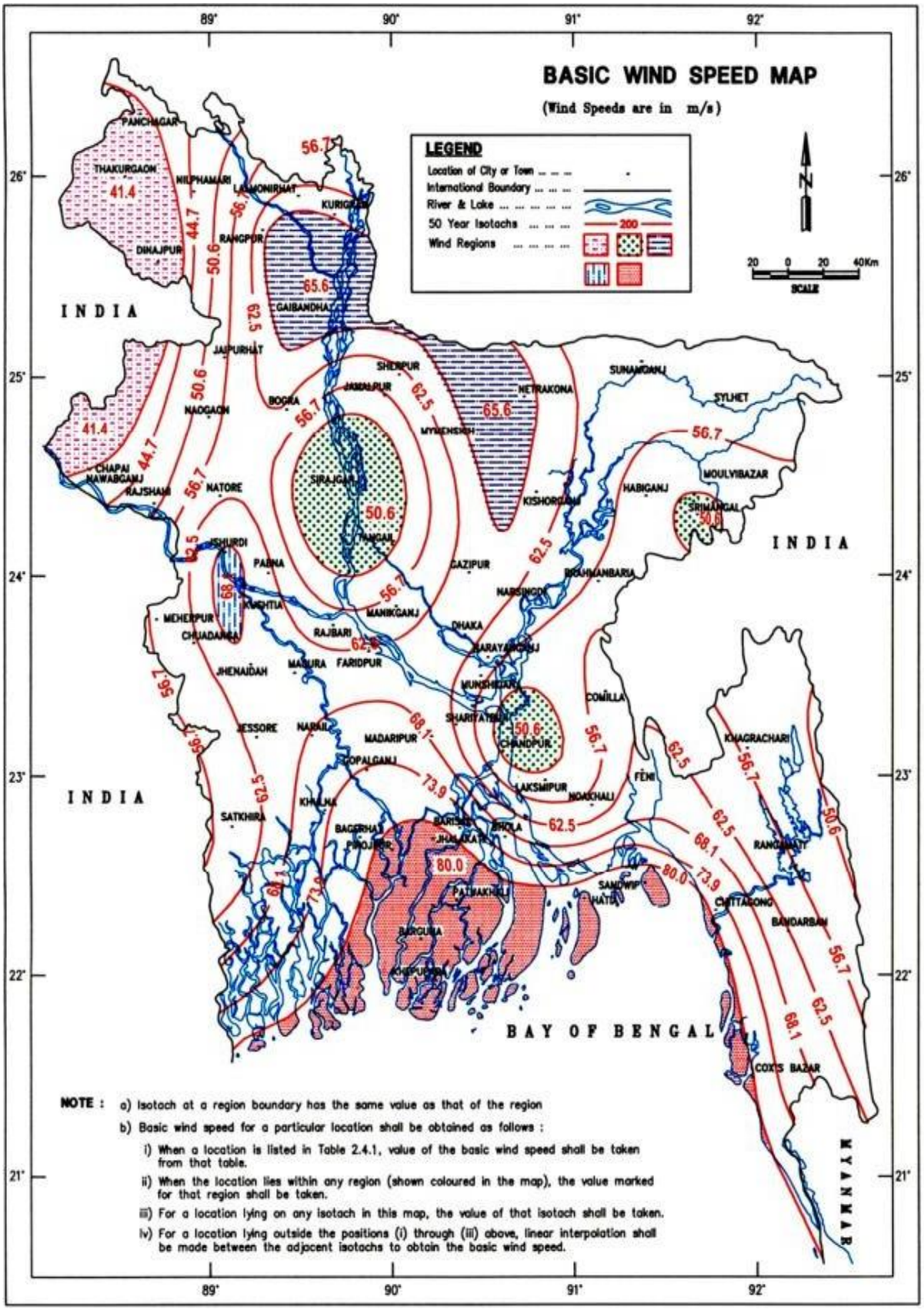


Figure 3.5: Basic Wind Speed (m/s) Map of Bangladesh

Table 3.8: Basic Wind Speed, V for Selected Locations in Bangladesh

Location	Basic Wind Speed (m/s)	Location	Basic Wind Speed (m/s)
Angarpota	47.8	Lalmonirhat	63.7
Bagerhat	77.5	Madaripur	68.1
Bandarban	62.5	Magura	65.0
Barguna	80.0	Manikganj	58.2
Barisal	78.7	Meherpur	58.2
Bhola	69.5	Maheshkhali	80.0
Bogra	61.9	Moulvibazar	53.0
Brahmanbaria	56.7	Munshiganj	57.1
Chandpur	50.6	Mymensingh	67.4
Chapainababganj	41.4	Naogaon	55.2
Chittagong	80.0	Narail	68.6
Chuadanga	61.9	Narayanganj	61.1
Comilla	61.4	Narsinghdi	59.7
Cox’s Bazar	80.0	Natore	61.9
Dahagram	47.8	Netrokona	65.6
Dhaka	65.7	Nilphamari	44.7
Dinajpur	41.4	Noakhali	57.1
Faridpur	63.9	Pabna	63.1
Feni	64.1	Panchagarh	41.4

Gaibandha	65.6	Patuakhali	80.0
Gazipur	66.5	Pirojpur	80.0

Gopalganj	74.5	Rajbari	59.1
Habiganj	54.2	Rajshahi	49.2
Hatiya	80.0	Rangamati	56.7
Ishurdi	69.5	Rangpur	65.3
Joypurhat	56.7	Satkhira	57.6
Jamalpur	56.7	Shariatpur	61.9
Jessore	64.1	Sherpur	62.5
Jhalakati	80.0	Sirajganj	50.6
Jhenaidah	65.0	Srimangal	50.6
Khagrachhari	56.7	St. Martin’s Island	80.0
Khulna	73.3	Sunamganj	61.1
Kutubdia	80.0	Sylhet	61.1
Kishoreganj	64.7	Sandwip	80.0
Kurigram	65.6	Tangail	50.6
Kushtia	66.9	Teknaf	80.0
Lakshmipur	51.2	Thakurgaon	41.4

3.17 Necessary Value and Theory

All other necessary values and theories are provided by BNBC 2020[19].

3.18 Combinations of Load Effects for Strength Design Method

Basic Combinations:

1. (DL + LL)
2. 1.4(DL) + 1.7(LL)
3. 1.4DL
4. 1.05DL+ 1.275LL+1.4025EQX
5. 1.05DL+ 1.275LL+1.4025EQX-1
6. 1.05DL+ 1.275LL+1.4025EQY
7. 1.05DL+ 1.275LL+1.4025EQY-1
8. 1.05DL+1.4025EQX
9. 1.05DL+1.4025EQX-1
10. 1.05DL+1.4025EQY
11. 1.05DL+1.4025EQY-1
12. 0.9DL+1.43EQX
13. 0.9DL+1.43EQX-1
14. 0.9DL+1.43EQY
15. 0.9DL+1.43EQY-1
16. 1.05DL+1.275LL+1.275WLX
17. 1.05DL+1.275LL+1.275WLX-1
18. 1.05DL+1.275LL+1.275WLY
19. 1.05DL+1.275LL+1.275WLY-1
20. 1.05DL+1.275WLX
21. 1.05DL+1.275WLX-1
22. 1.05DL+1.275WLY
23. 1.05DL+1.275WLY-1
24. 0.9DL+1.3WLX
25. 0.9DL+1.3WLX-1
26. 0.9DL+1.3WLY
27. 0.9DL+1.3WLY-1

Earthquake Load Combinations:

1. For use in load combination 5, E shall be taken equal to E_m as determined in accordance with the following equation.

$E_m = E_{mh} + E_v$

2. For use in load combination 7, E shall be taken equal to E_m as determined in accordance with the following equation.

$E_m = E_{mh} + E_v$

Where,

E_m = Total seismic load effect including over strength factor.

E_{mh} = Effect of horizontal seismic forces including structural over strength. E_v

= Effect of vertical seismic forces.

3.19 Summary

This chapter presents a methodology to fulfil the project. There are many important theory, formula, table, figure and other necessary topics, which is related to this projects are shown in this chapter. For example story drift, story displacement, torsion irregularity, earthquake load, dead load, live load, wind load and etc.

CHAPTER 4
Results and Discussion

4.1 Introduction

The findings from the entire investigation are compiled and explained in this chapter. In this chapter the seismic analysis of a (G+9) 10 storied residential building for different seismic zones in Bangladesh is done by ETABS as per BNBC 2020. Then necessary results are collected. After that all that results is compared with each another. This chapter presents all zonal parameters and data for analysis. Discussions on the project and results are also displayed here.

4.2 Zonal Parameters and Various Details

Zonal parameters and its various details for the design of (G+9) 10 storied residential building is given in the Table 4.01.

Table 4.1: Zonal Parameters and Various Details

Parameters and Topic	Zone IV (Sylhet)	Zone II (Dhaka)	Zone III (Chattogram)
Seismic Zone Coefficient, Z	0.36	0.20	0.28
Basic Wind Speed	137 mph	147.17 mph	137 mph
Building Length	62 feet	62 feet	62 feet
Building Breadth	50 feet	50 feet	50 feet
Occupancy Category	II	II	II
Importance Factor (Earthquake), I	1.00	1.00	1.00
Time Period, T	1.25 sec	1.25 sec	1.25 sec
Frequency, f	0.8 Hz	0.8 Hz	0.8 Hz

Diaphragm	Semi Rigid	Semi Rigid	Semi Rigid	Semi Rigid
Soil Class	SD	SD	SC	SC
Seismic Design Category	C	D	D	D
Importance Coefficient, R	7	7	7	7
Deflection Amplification Factor, C_d	5.5	5.5	5.5	5.5
Horizontal Seismic Over Strength Factor, Ω_o	2.5	2.5	2.5	2.5
S_s	0.3	0.5	0.7	0.9
S_1	0.12	0.2	0.28	0.36
F_a	1.35	1.35	1.15	1.15
F_v	2.7	2.7	1.725	1.725
Site Class (ETABS)	F	F	F	F
Long Period Transition Period	2 sec	2 sec	2 sec	2 sec
S	1.35	1.35	1.15	1.15
T_B	0.20	0.20	0.20	0.20
T_C	0.80	0.80	0.60	0.60
T_D	2.0	2.0	2.0	2.0
C_S	2.16	2.16	1.38	1.38
S_a	0.0246	0.0411	0.0368	0.0473
$S_{a(min)}$	0.0119	0.0198	0.0237	0.0305

Importance Factor (Wind), I	1.00	1.00	1.00	1.00
Exposure Type	B	A	B	B
Exposure Type (ETABS)	C	B	C	C
Topographical Factor, K_{zt}	1.00	1.00	1.00	1.00
Gust Factor (Normal)	0.933	0.876	0.891	0.895
Gust Factor (Parallel)	0.952	0.897	0.906	0.911
Windward Coefficient	0.8	0.8	0.8	0.8
Leeward Coefficient (X)	0.316	0.316	0.316	0.316
Leeward Coefficient (Y)	0.50	0.50	0.50	0.50
Side Wall Coefficient	0.70	0.70	0.70	0.70
Damping Ratio	0.050	0.050	0.050	0.050
e_x	0.15	0.15	0.15	0.15
O_y	0.15	0.15	0.15	0.15
K_d	0.85	0.85	0.85	0.85
C_t	0.0350	0.0350	0.0350	0.0350
f_y (Steel)	60000 psi	60000 psi	60000 psi	60000 psi
Concrete f´c (Column)	3500 psi	3500 psi	3500 psi	3500 psi
Concrete f´c (Beam)	3500 psi	3500 psi	3500 psi	3500 psi
Concrete f´c (Slab)	3500 psi	3500 psi	3500 psi	3500 psi
Slab Thickness	6 inch	6 inch	6 inch	6 inch

Stair Rise	6 inch	6 inch	6 inch	6 inch
Stair Slab Thickness	8.1 inch	8.1 inch	8.1 inch	8.1 inch

4.3 Details of Loads and Material Properties

Table 4.2: Summary of the Design Considerations and Specification of the Study

Items	Description
Design Code	➢ Bangladesh National Building Code (BNBC) 2020.
Building Components	➢ Column type = Tied ➢ Foundation type = Deep foundation (Pilling) ➢ Thickness of all partition walls = 6 inch ➢ Wall thickness = 6 inch
Material Properties	➢ Normal density concrete, unit weight = 150 psf ➢ Unit weight of Brick = 120 psf

4.4 Acting Loads on the Building

4.4.1 Dead Load

- Floor Finish Load = 20 lb/ft^2
- Floor Finish Load (Roof) = 20 lb/ft^2
- Floor Finish Load (Veranda) = 20 lb/ft^2
- Partition Wall Load = 0.35kip/ft
- Wall Load = 0.35kip/ft
- Wall Load Roof (Parapet) = 0.35kip/ft
- Partition Wall Load (Veranda) = 0.35kip/ft
- Floor Finish Load (Landing Slab) = 20 lb/ft^2
- Floor Finish Load (Waist Slab) = 20 lb/ft^2

4.4.2 Live Load

- Live Load = 42 Psf
- Live Load (Roof) = 42 Psf
- Live Load (Veranda) = 42 Psf
- Live Load (Lift Machine Room Bottom Slab) = 103 Psf
- Live Load (Lift Machine Room Top Slab) = 103 Psf
- Live Load (Water Tank Bottom Slab) = 63 Psf
- Live Load (Water Tank Top Slab) = 63 Psf
- Live Load (Water Tank Side Wall) = 63 Psf

4.4.3 Unit Conversion

1.0 ft = 0.3048 m; 1.0 ft^2 = 0.0929 m^2; 1.0 psf = 0.0479 KN/m^2;

4.5 Floor Plan Details

- Height of the building = 127 ft = 38.7096 m
- Length of the building = 62 feet = 18.90 m
- Breadth of the building = 50 feet = 15.24 m

Table 4.3: Dimension of Building Columns and Beams

Column Name	Column Size	Beam Name	Beam Size
C1	12 inch X 25 inch	Grade Beam	12 inch X 20 inch
C2	12 inch X 30 inch	Floor Beam	10 inch X 20 inch
C3	12 inch X 30 inch	Stair Beam	10 inch X 20 inch
C4	12 inch X 36 inch		
C5	15 inch X 30 inch		
C6	12 inch X 36 inch		
C7	12 inch X 40 inch		
C8	12 inch X 40 inch		

4.6 Plan View of Different Floors

4.6.1 Ground Floor

Ground floor is 2 feet above from Street level. The total ground floor area is 3100 ft^2 or 288 m^2.

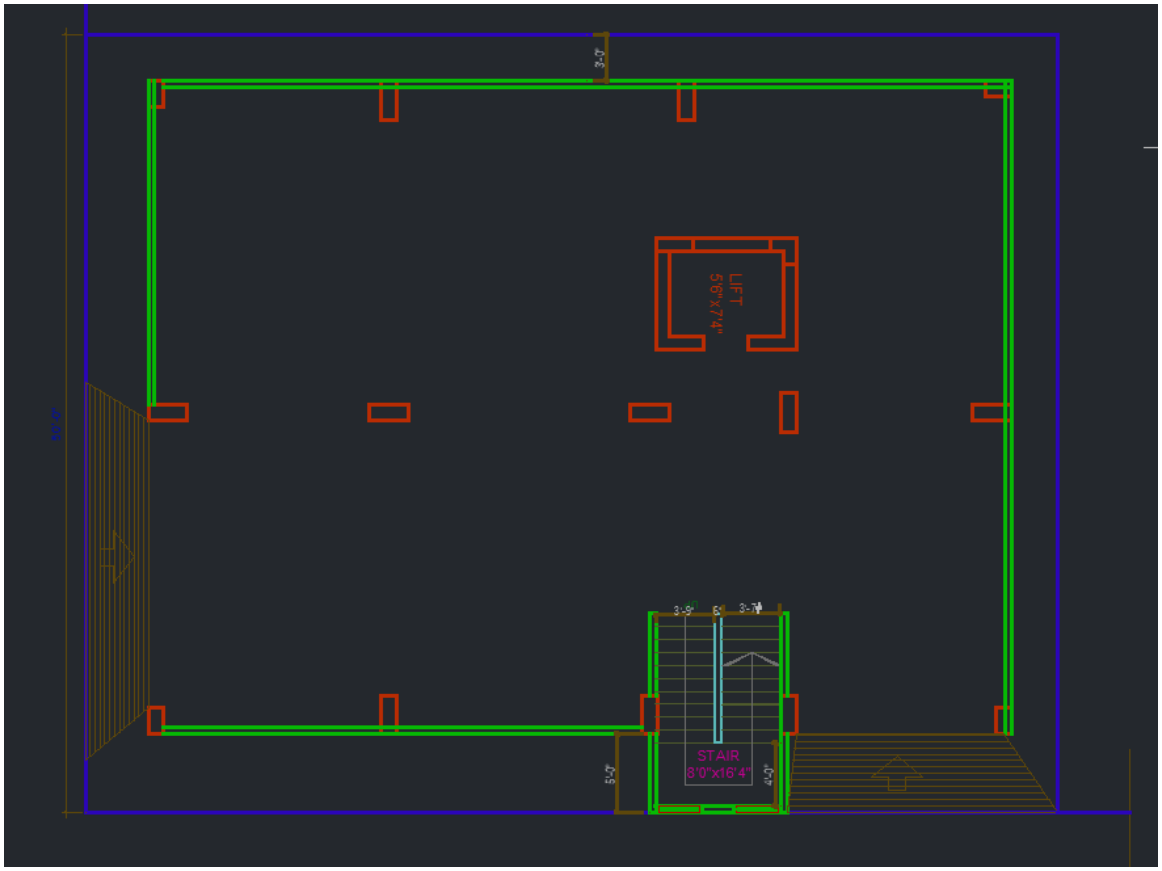


Figure 4.1: Ground Floor Plan

4.6.2 Floor Plan

The total floor area is 3100 ft^2 or 288 m^2.

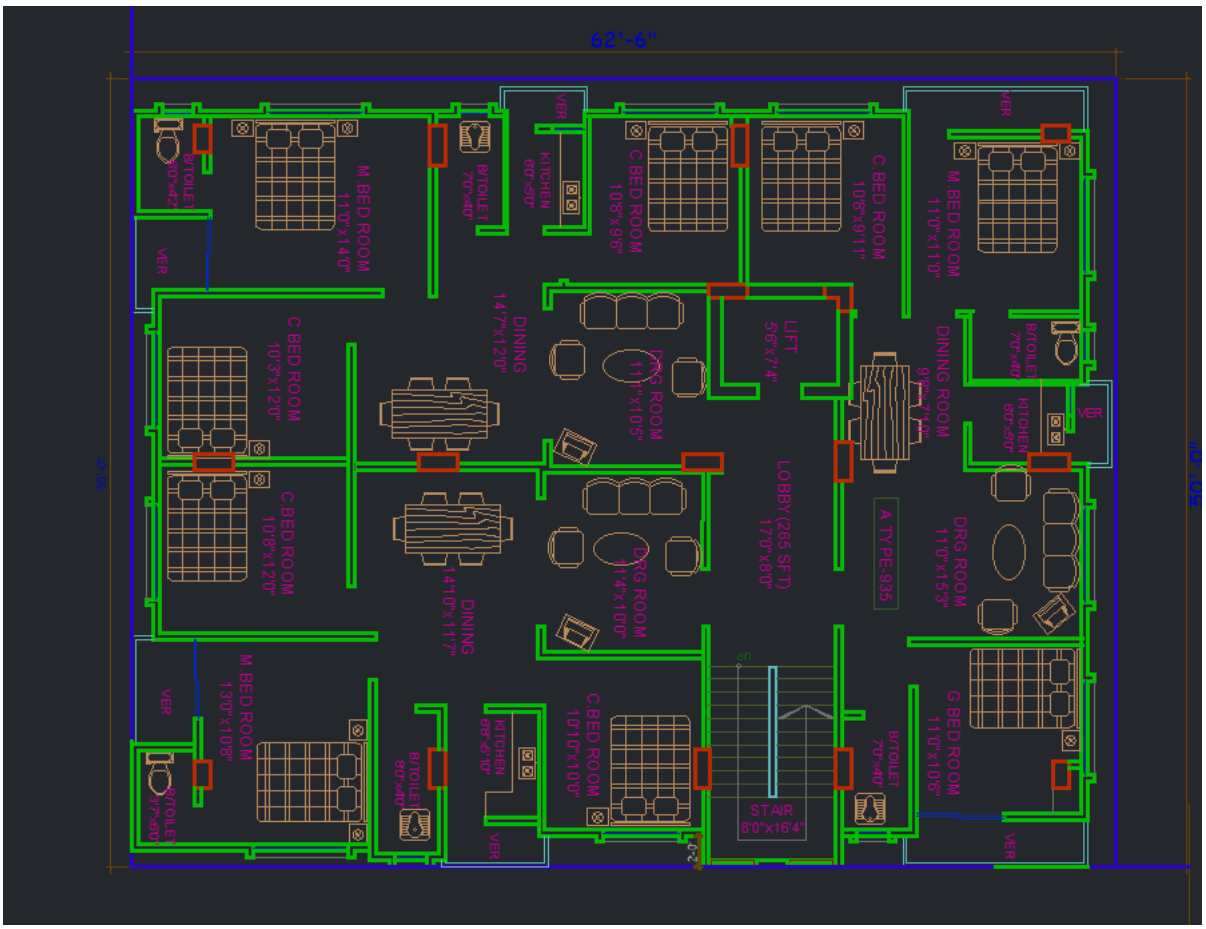


Figure 4.2: Typical Floor Plan

4.6.3 Roof Plan

The total roof area is 3100 ft^2 or 288 m^2.

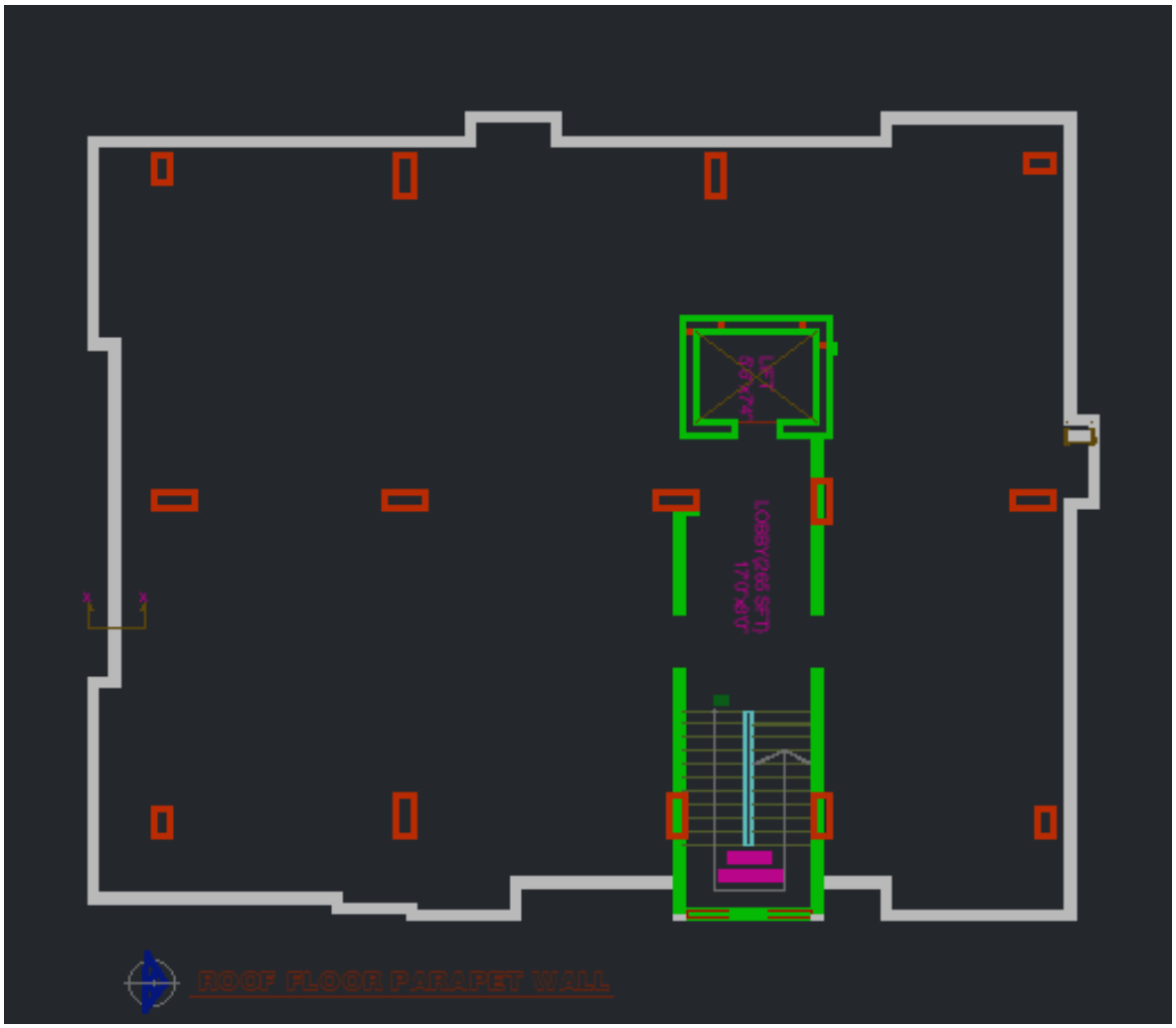


Figure 4.3: Roof Floor Plan

4.6.4 Building Analysis Figures by ETABS

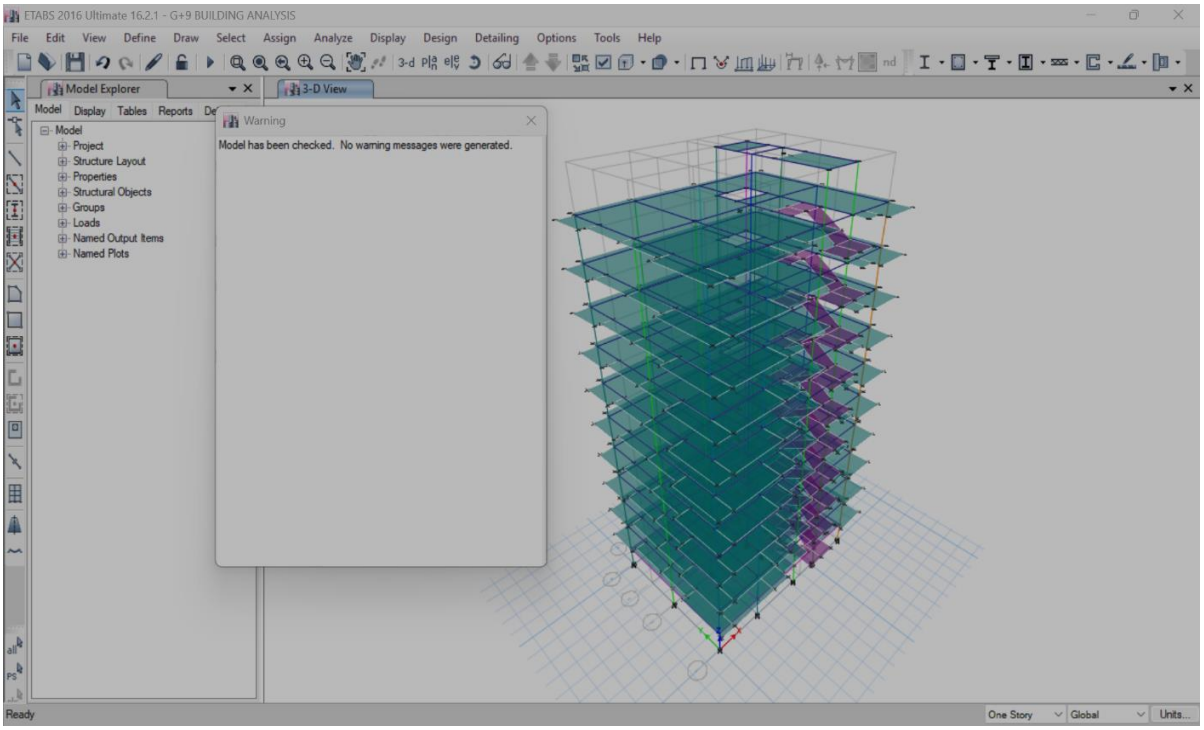


Figure 4.4: No Warning Message (Model Check)

4.6.5 Building Analysis Figures by ETABS

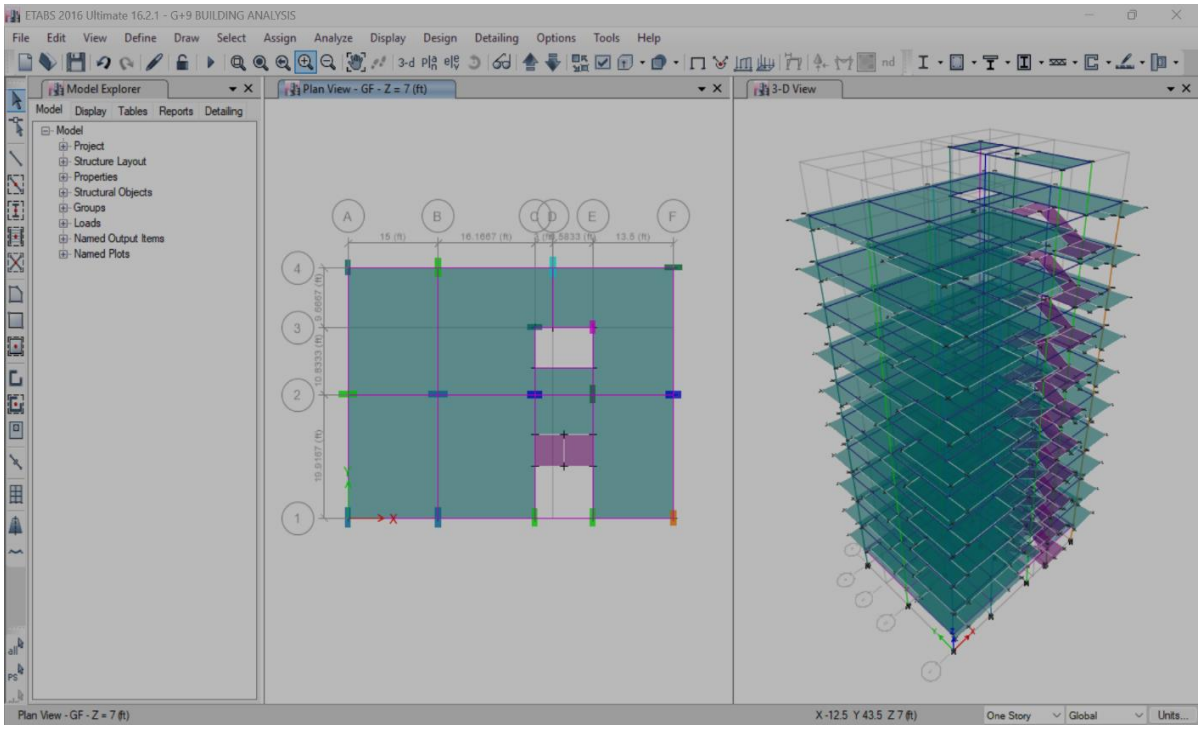


Figure 4.5: Ground Floor Plan View

4.6.6 Building Analysis Figures by ETABS

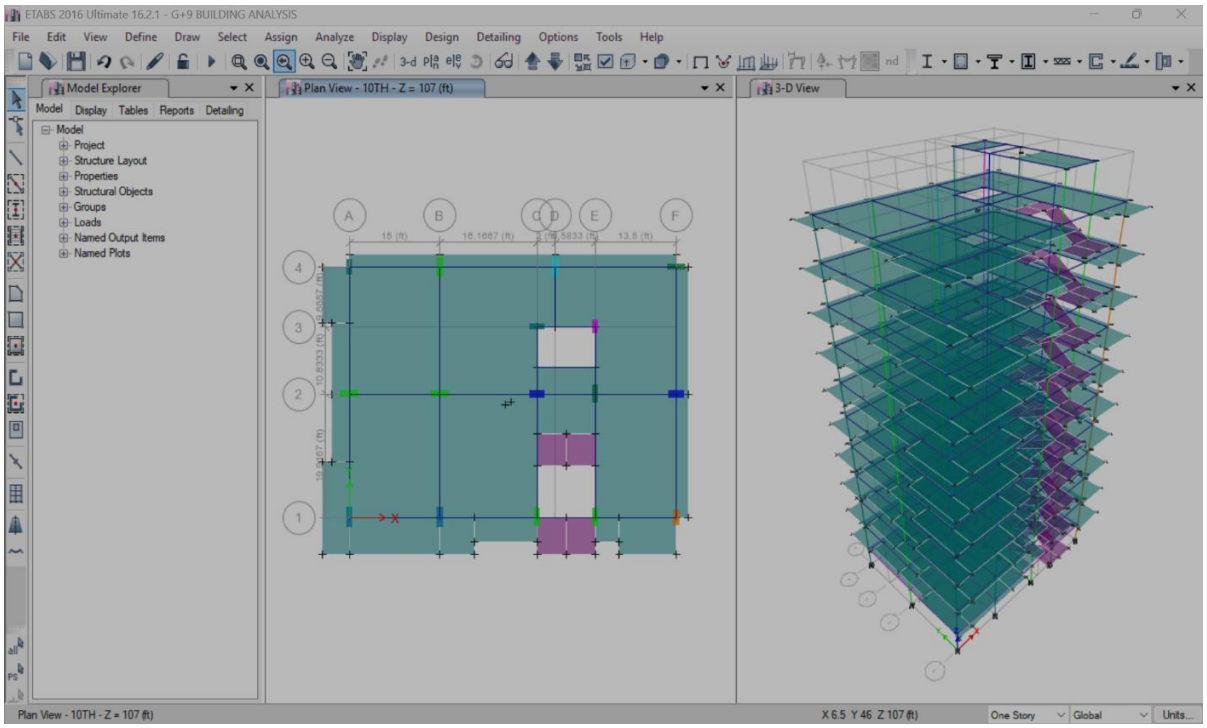


Figure 4.6: Typical Floor Plan View

4.6.7 Building Analysis Figures by ETABS

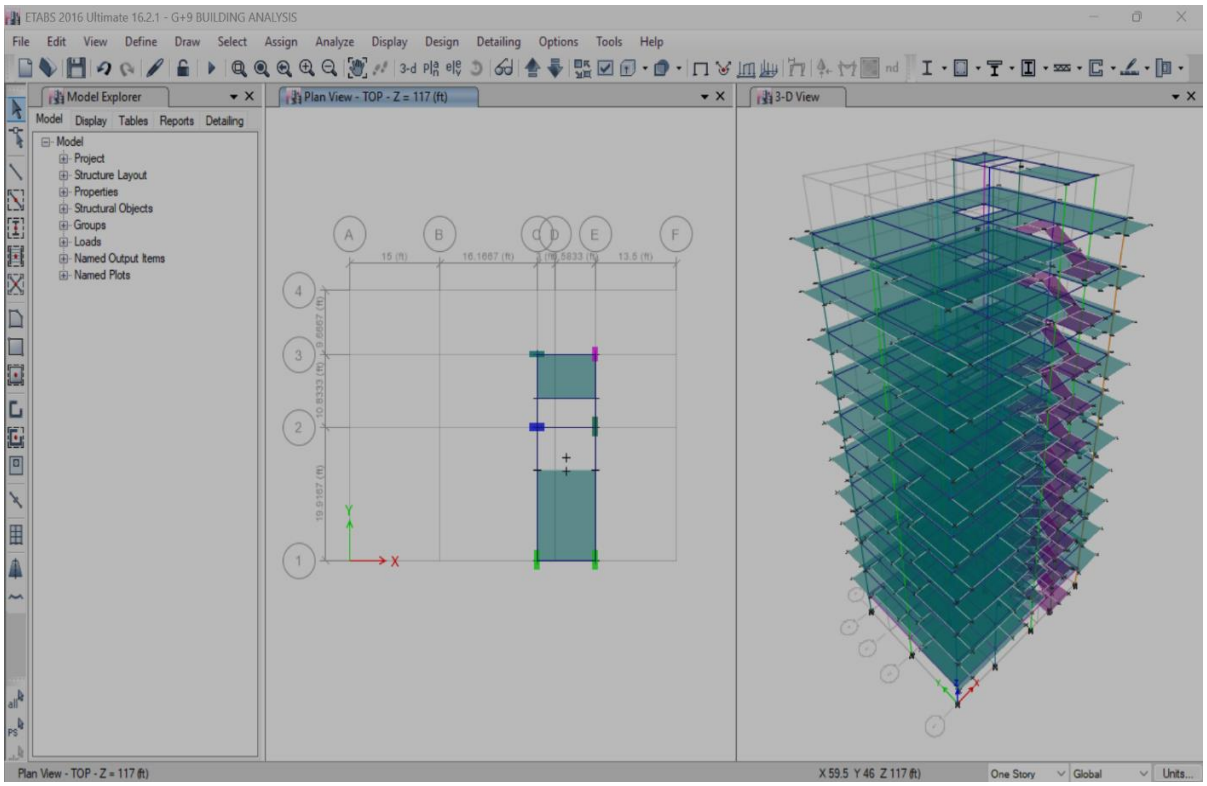


Figure 4.7: Top Floor Plan View

4.6.8 Building Analysis Figures by ETABS

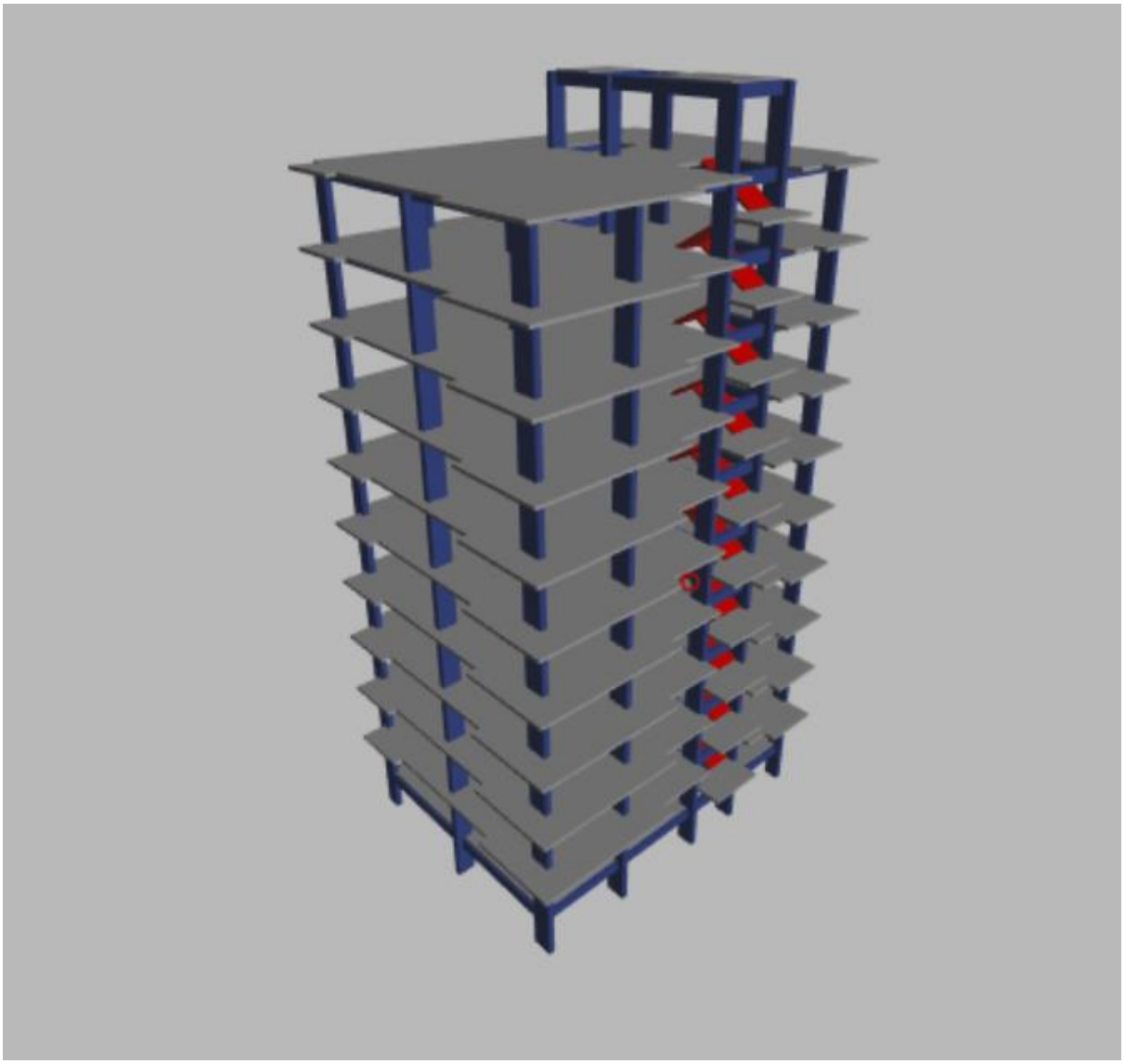


Figure 4.8: 3D View without Wall

4.7 Drift and Building Separation for Displacement (BNBC-2020)

Drift the Limitation: Story drift is the displacement of one level relative to the level above:

a) Story drift, A shall be limited as follows:

$\Delta \leq 0.005h$ for $T < 0.7$ sec

$\Delta \leq 0.004h$ for $T > 0.7$ sec

$\Delta \leq 0.0025h$ for unreinforced masonry structures

Where h= height of the building or Structure. The period T used in calculation shall be the same as that used for determining the base shear.

Table 4.4: Maximum Story Displacement and Drifts for Sylhet Zone IV (Seismic Load)

Load Type	Displacement (Δm (in)	Drifts (Δi (in)	Allowable Displacement (Δm (in)	Allowable Drifts (Δi (in)	Check
EQX	4.176, (TOP)	0.004117	28.08	0.48	Safe
EQY	4.90, (10^{TH})	0.00064	28.08	0.48	Safe

4.7.1 Story Response - Maximum Story Displacement

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EQX	Top Story	TOP
Output Type	Not Applicable	Bottom Story	Base

Plot



Figure 4.9: Maximum Displacement EQX

Table 4.5: Tabulated Plot Coordinates Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft		in	in
TOP	117	Top	4.176759	0.074786
10TH	107	Top	4.073568	0.4169
9TH	97	Top	3.857766	0.420763
8TH	87	Top	3.585897	0.418111
7TH	77	Top	3.254172	0.401807
6TH	67	Top	2.867579	0.369629
5TH	57	Top	2.43431	0.321718
4TH	47	Top	1.964716	0.259139
3RD	37	Top	1.471665	0.184067
2ND	27	Top	0.972947	0.101999
1ST	17	Top	0.497969	0.045564
GF	7	Top	0.133815	0.01075
Base	0	Top	0	0

4.7.2 Story Response - Maximum Story Displacement

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story displ	Story Range	All Stories
Load Case	EQY	Top Story	TOP
Output Type	Not Applicable	Bottom Story	Base

Plot

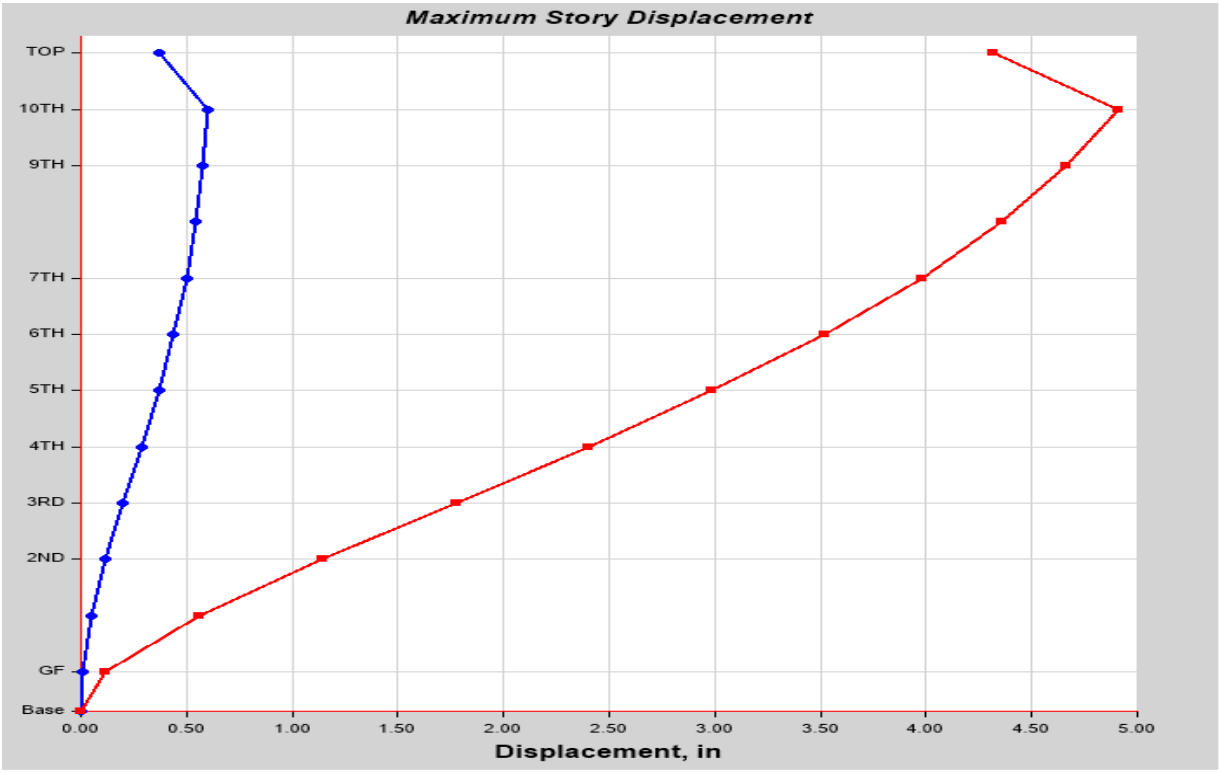


Figure 4.10: Maximum Displacement EQY

Table 4.6: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft		in	in
TOP	117	Top	0.373705	4.31794
10TH	107	Top	0.602598	4.906982
9TH	97	Top	0.578146	4.664851
8TH	87	Top	0.544326	4.360168
7TH	77	Top	0.497785	3.976964
6TH	67	Top	0.438077	3.515702
5TH	57	Top	0.366413	2.98486
4TH	47	Top	0.285471	2.398055
3RD	37	Top	0.199726	1.774564
2ND	27	Top	0.116498	1.143849
1ST	17	Top	0.047235	0.55777
GF	7	Top	0.007149	0.118852
Base	0	Top	0	0

4.7.3 Story Response - Maximum Story Drifts

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name StoryResp1

Display Type Max story drifts

Load Case EQX

Output Type Not Applicable

Story Range All Stories

Top Story TOP

Bottom Story Base

Plot

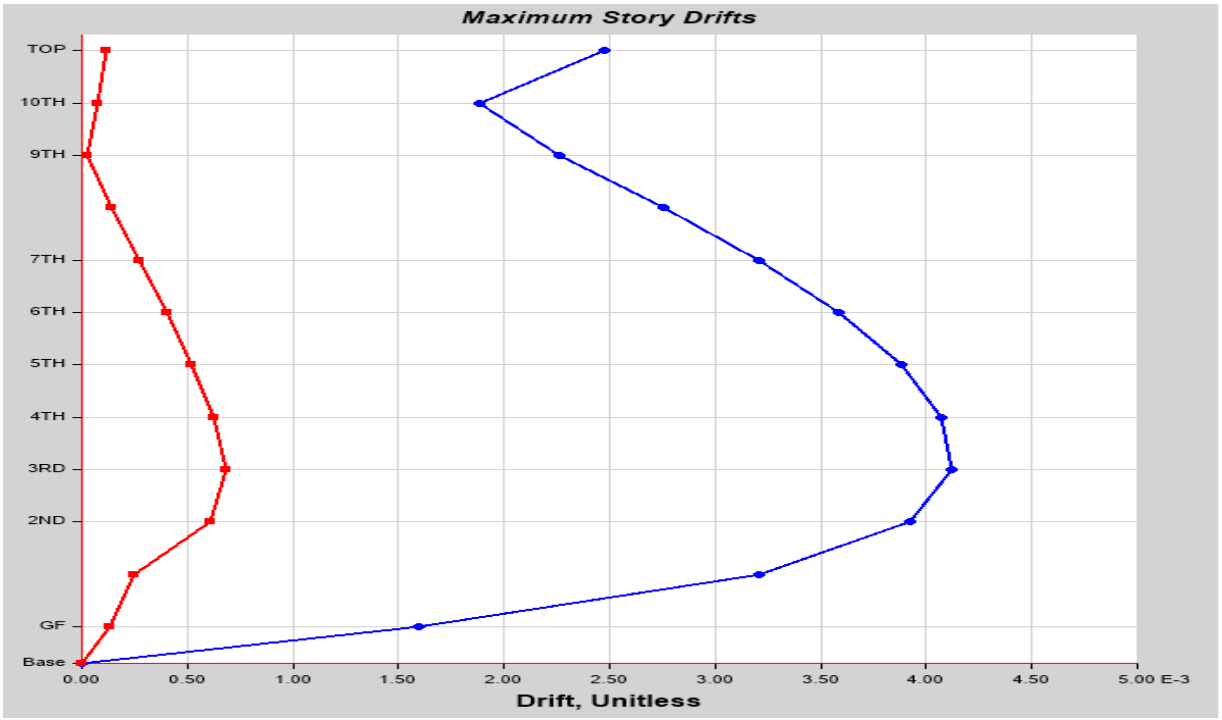


Figure 4.11: Maximum Drifts EQX

Table 4.7: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft			
TOP	117	Top	0.002475	0.000115
10TH	107	Top	0.001884	0.000075
9TH	97	Top	0.002265	0.000022
8TH	87	Top	0.002756	0.000136
7TH	77	Top	0.003206	0.000268
6TH	67	Top	0.003587	0.000399
5TH	57	Top	0.003883	0.000521
4TH	47	Top	0.004072	0.000626
3RD	37	Top	0.004117	0.000684
2ND	27	Top	0.003926	0.000606
1ST	17	Top	0.003211	0.000246
GF	7	Top	0.001593	0.000128
Base	0	Top	0	0

4.7.4 Story Response - Maximum Story Drifts

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp1		
Display Type	Max story drifts	Story Range	All Stories
Load Case	EQY	Top Story	TOP
Output Type	Not Applicable	Bottom Story	Base

Plot

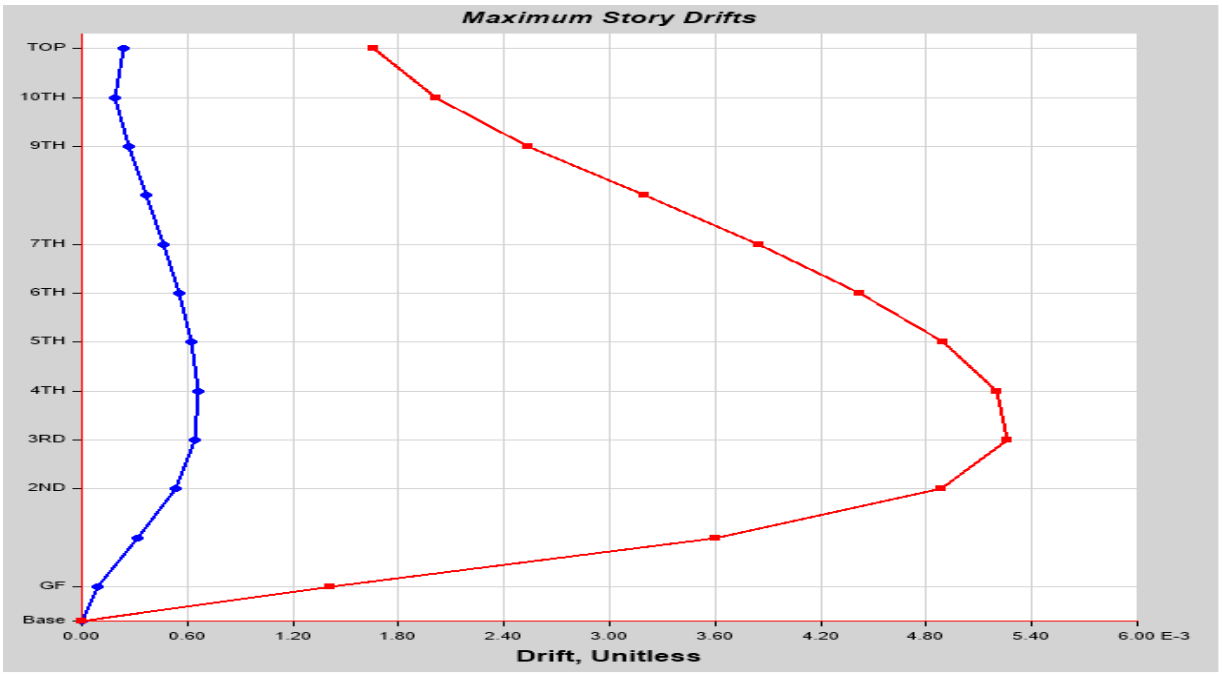


Figure 4.12: Maximum Drifts EQY

Table 4.8: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft			
TOP	117	Top	0.00024	0.001656
10TH	107	Top	0.00019	0.002018
9TH	97	Top	0.000263	0.002539
8TH	87	Top	0.000361	0.003193
7TH	77	Top	0.000462	0.003844
6TH	67	Top	0.000554	0.004424
5TH	57	Top	0.000625	0.00489
4TH	47	Top	0.000661	0.005196
3RD	37	Top	0.00064	0.005256
2ND	27	Top	0.000531	0.004884
1ST	17	Top	0.000311	0.003601
GF	7	Top	0.000085	0.001415
Base	0	Top	0	0

Table 4.9: Maximum Story Displacement and Drifts for Dhaka Zone II (Seismic Load)

Load Type	Displacement (Δm (in)	Drifts (Δi (in)	Allowable Displacement (Δm (in)	Allowable Drifts (Δi (in)	Check
EQX	1.856337, (TOP)	0.00183 (3^{RD})	28.08	0.48	Safe
EQY	2.180881, (10^{TH})	0.002336 (3^{RD})	28.08	0.48	Safe

4.7.5 Story Response - Maximum Story Displacement

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp4		
Display Type	Max story displacement	Story Range	User Specified
Load Case	EQX	Top Story	TOP
Output Type	Not Applicable	Bottom Story	Base

Plot

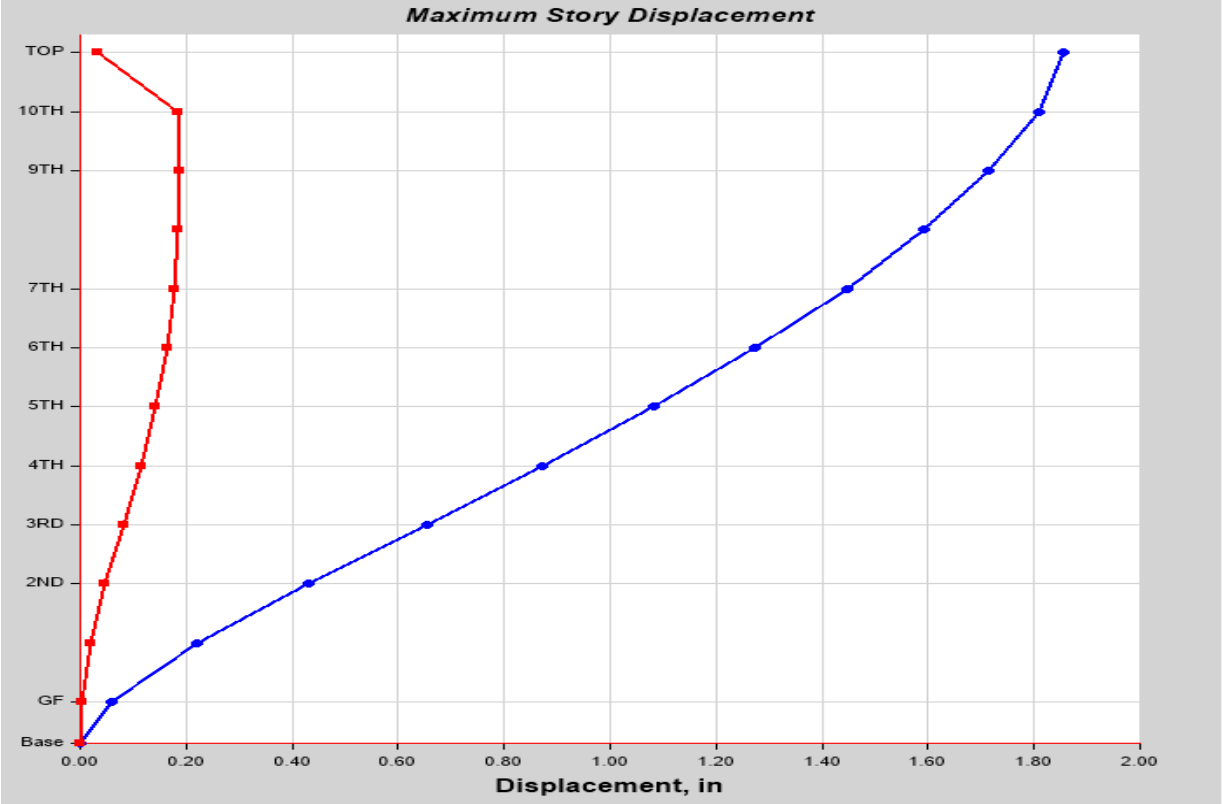


Figure 4.13: Maximum story displacement (EQX)

Table 4.10: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft		in	in
TOP	117	Top	1.856337	0.033238
10TH	107	Top	1.810475	0.185289
9TH	97	Top	1.714563	0.187006
8TH	87	Top	1.593732	0.185827
7TH	77	Top	1.446299	0.178581
6TH	67	Top	1.27448	0.16428
5TH	57	Top	1.081915	0.142986
4TH	47	Top	0.873207	0.115173
3RD	37	Top	0.654073	0.081807
2ND	27	Top	0.432421	0.045333
1ST	17	Top	0.22132	0.02025
GF	7	Top	0.059473	0.004778
Base	0	Top	0	0

4.7.6 Story Response - Maximum Story Displacement

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp4		
Display Type	Max story displ	Story Range	User Specified
Load Case	EQY	Top Story	TOP
Output Type	Not Applicable	Bottom Story	Base

Plot

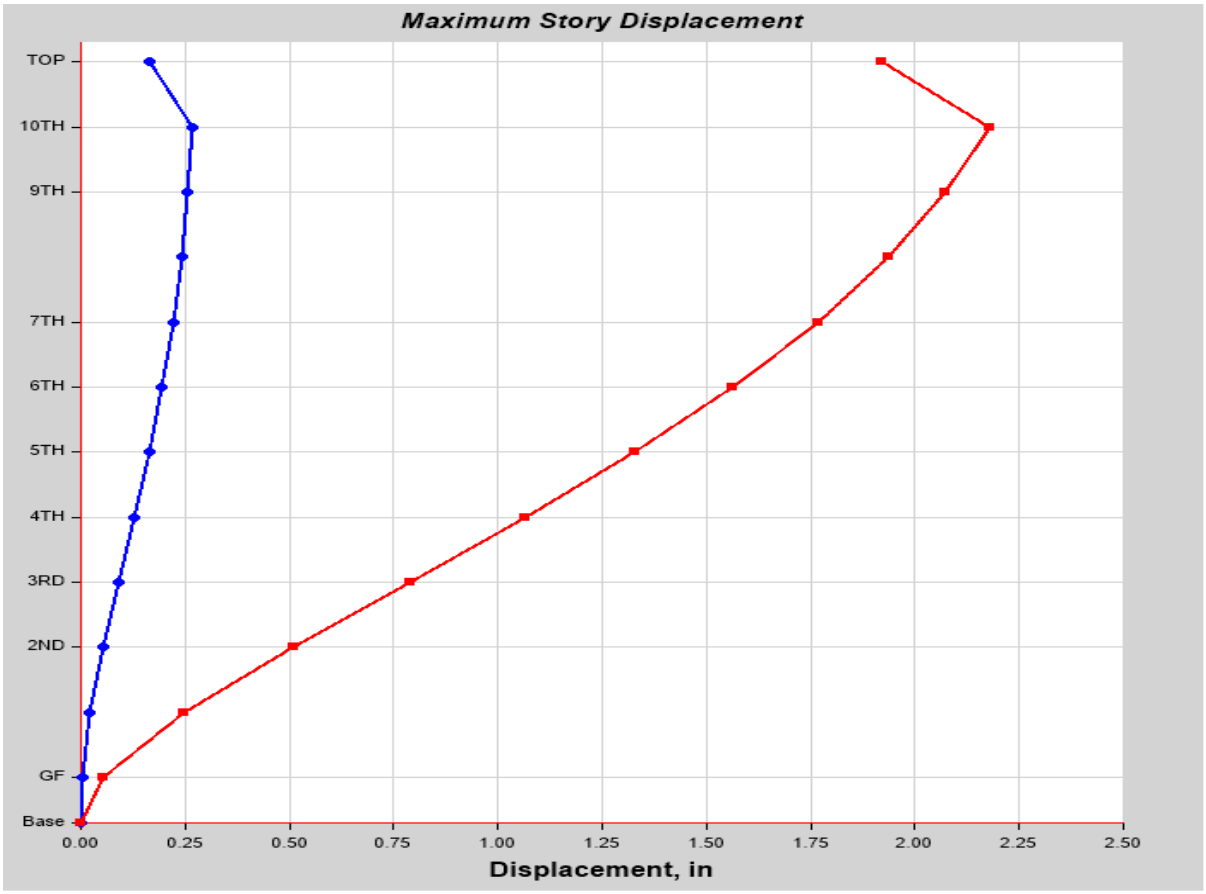


Figure 4.14: Maximum story displacement (EQY)

Table 4.11: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft		in	in
TOP	117	Top	0.166091	1.919085
10TH	107	Top	0.267821	2.180881
9TH	97	Top	0.256954	2.073267
8TH	87	Top	0.241922	1.937852
7TH	77	Top	0.221238	1.76754
6TH	67	Top	0.194701	1.562534
5TH	57	Top	0.16285	1.326605
4TH	47	Top	0.126876	1.065802
3RD	37	Top	0.088767	0.788695
2ND	27	Top	0.051777	0.508377
1ST	17	Top	0.020993	0.247898
GF	7	Top	0.003177	0.052823
Base	0	Top	0	0

4.7.7 Story Response - Maximum Story Drifts

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp4		
Display Type	Max story drifts	Story Range	User Specified
Load Case	EQX	Top Story	TOP
Output Type	Not Applicable	Bottom Story	Base

Plot

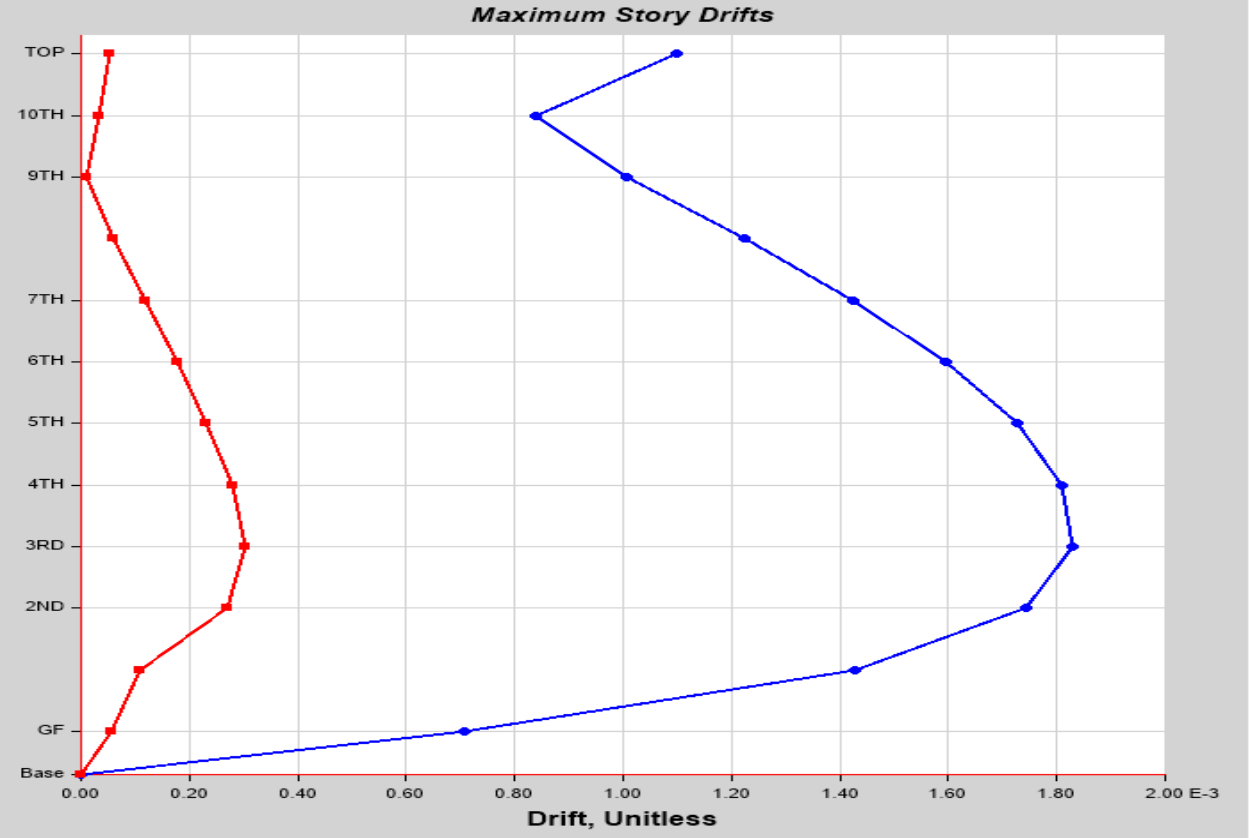


Figure 4.15: Maximum story Drifts (EQX)

Table 4.12: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft			
TOP	117	Top	0.0011	0.000051
10TH	107	Top	0.000837	0.000033
9TH	97	Top	0.001007	0.00001
8TH	87	Top	0.001225	0.00006
7TH	77	Top	0.001425	0.000119
6TH	67	Top	0.001594	0.000177
5TH	57	Top	0.001726	0.000232
4TH	47	Top	0.00181	0.000278
3RD	37	Top	0.00183	0.000304

Story	Elevation	Location	X-Dir	Y-Dir
	ft			
2ND	27	Top	0.001745	0.000269
1ST	17	Top	0.001427	0.000109
GF	7	Top	0.000708	0.000057
Base	0	Top	0	0

4.7.8 Story Response - Maximum Story Drifts

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp4		
Display Type	Max story drifts	Story Range	User Specified
Load Case	EQY	Top Story	TOP
Output Type	Not Applicable	Bottom Story	Base

Plot

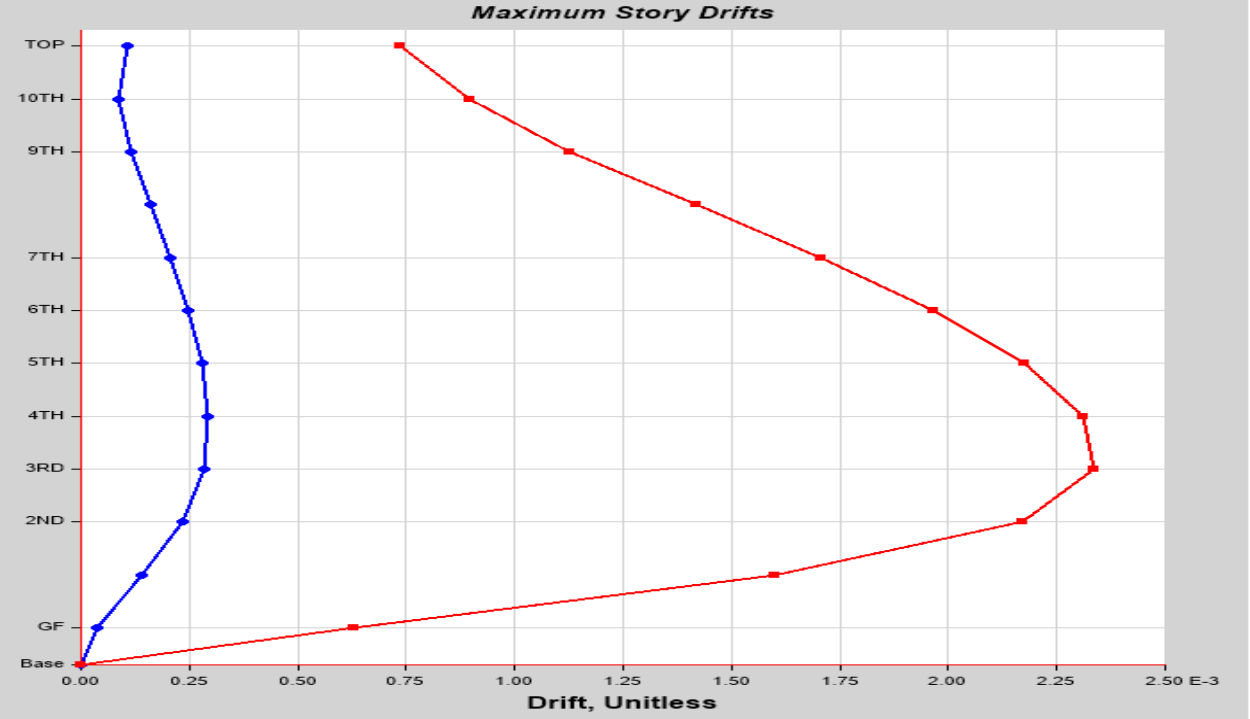


Figure 4.16: Maximum story drifts (EQY)

Table 4.13: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft			
TOP	117	Top	0.000107	0.000736
10TH	107	Top	0.000084	0.000897
9TH	97	Top	0.000117	0.001128
8TH	87	Top	0.000161	0.001419

Story	Elevation	Location	X-Dir	Y-Dir
	ft			
7TH	77	Top	0.000206	0.001708
6TH	67	Top	0.000246	0.001966
5TH	57	Top	0.000278	0.002173
4TH	47	Top	0.000294	0.002309
3RD	37	Top	0.000285	0.002336
2ND	27	Top	0.000236	0.002171
1ST	17	Top	0.000138	0.001601
GF	7	Top	0.000038	0.000629
Base	0	Top	0	0

Table 4.14: Maximum Story Displacement and Drifts for Chattogram Zone III (Seismic Load)

Load Type	Displacement (Δm (in)	Drifts (Δi (in)	Allowable Displacement (Δm (in)	Allowable Drifts (Δi (in)	Check
EQX	3.2485, (TOP)	0.003202 (3^{RD})	28.08	0.48	Safe
EQY	3.35, (10^{TH})	0.000413 (3^{RD})	28.08	0.48	Safe

4.7.9 Story Response - Maximum Story Displacement

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name	StoryResp3		
Display Type	Max story displ	Story Range	All Stories
Load Case	EQX	Top Story	TOP
Output Type	Not Applicable	Bottom Story	Base

Plot

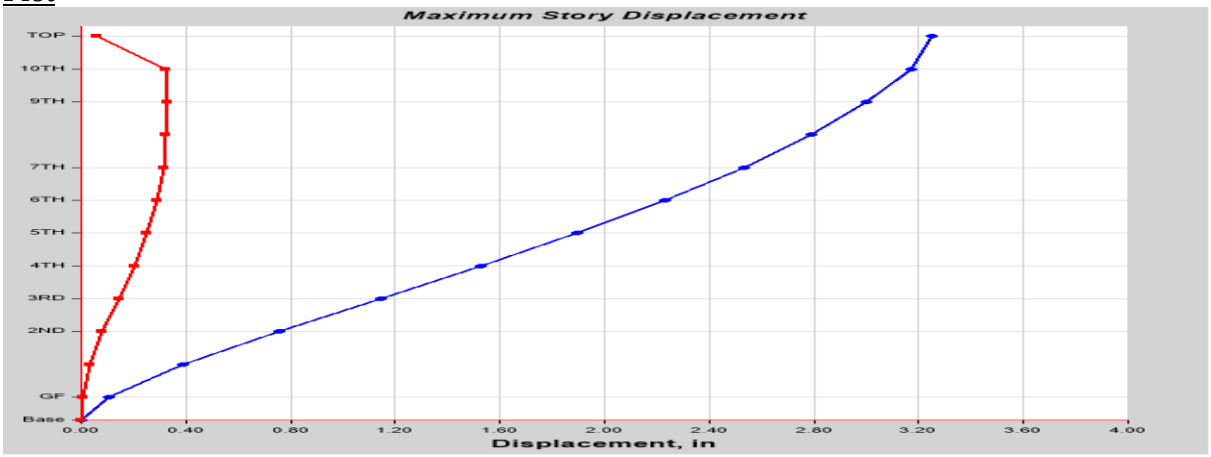


Figure 4.17: Maximum Displacement EQX

Table 4.15: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft		in	in
TOP	117	Top	3.24859	0.058167
10TH	107	Top	3.168331	0.324256
9TH	97	Top	3.000485	0.32726
8TH	87	Top	2.789031	0.325198
7TH	77	Top	2.531023	0.312516
6TH	67	Top	2.23034	0.28749
5TH	57	Top	1.893352	0.250225
4TH	47	Top	1.528113	0.201553
3RD	37	Top	1.144628	0.143163
2ND	27	Top	0.756737	0.079333
1ST	17	Top	0.38731	0.035438
GF	7	Top	0.104078	0.008361
Base	0	Top	0	0

4.7.10 Story Response - Maximum Story Displacement

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name StoryResp3

Display Type Max story displ

Load Case EQY

Output Type Not Applicable

Story Range All Stories

Top Story TOP

Bottom Story Base

Plot

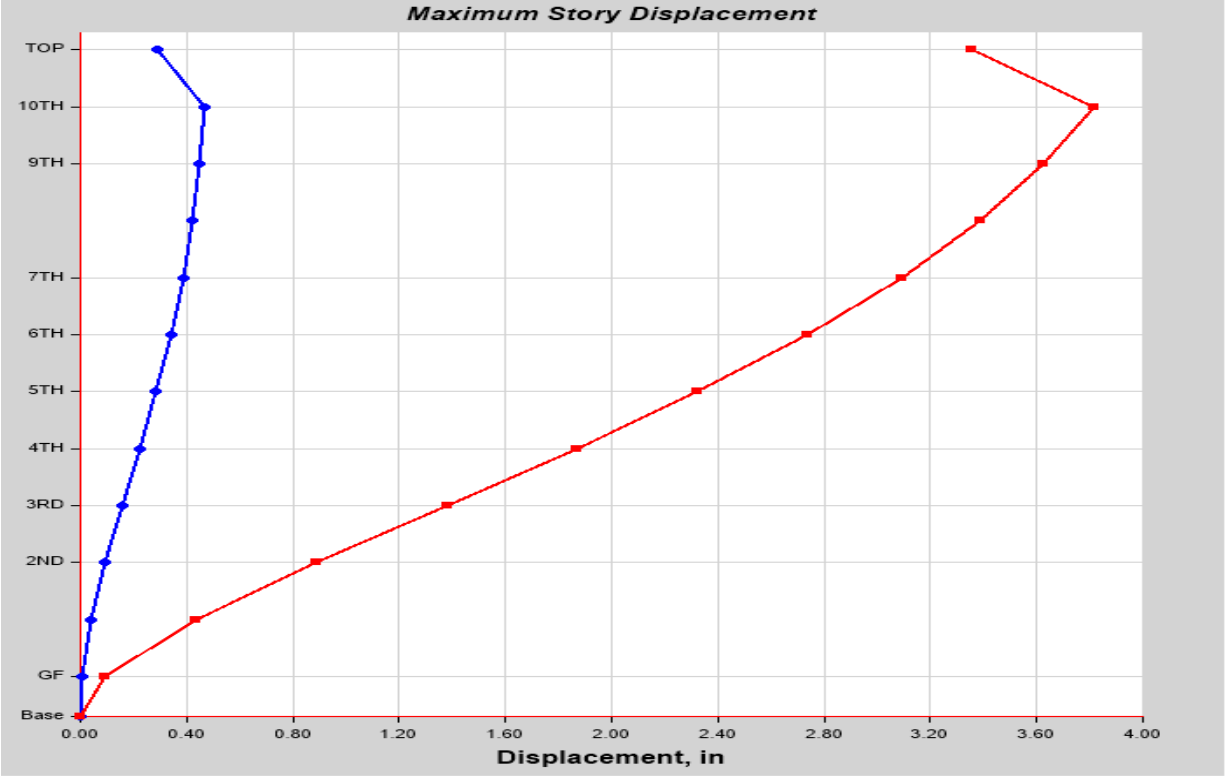


Figure 4.18: Maximum Displacement EQY

Table 4.16: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft		in	in
TOP	117	Top	0.290659	3.358398
10TH	107	Top	0.468687	3.816542
9TH	97	Top	0.449669	3.628217
8TH	87	Top	0.423364	3.391242
7TH	77	Top	0.387166	3.093195
6TH	67	Top	0.340726	2.734435
5TH	57	Top	0.284988	2.321558
4TH	47	Top	0.222033	1.865154
3RD	37	Top	0.155342	1.380217
2ND	27	Top	0.09061	0.88966
1ST	17	Top	0.036738	0.433821
GF	7	Top	0.00556	0.092441
Base	0	Top	0	0

4.7.11 Story Response - Maximum Story Drifts

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name StoryResp3

Display Type Max story drifts

Load Case EQX

Output Type Not Applicable

Story Range All Stories

Top Story TOP

Bottom Story Base

Plot

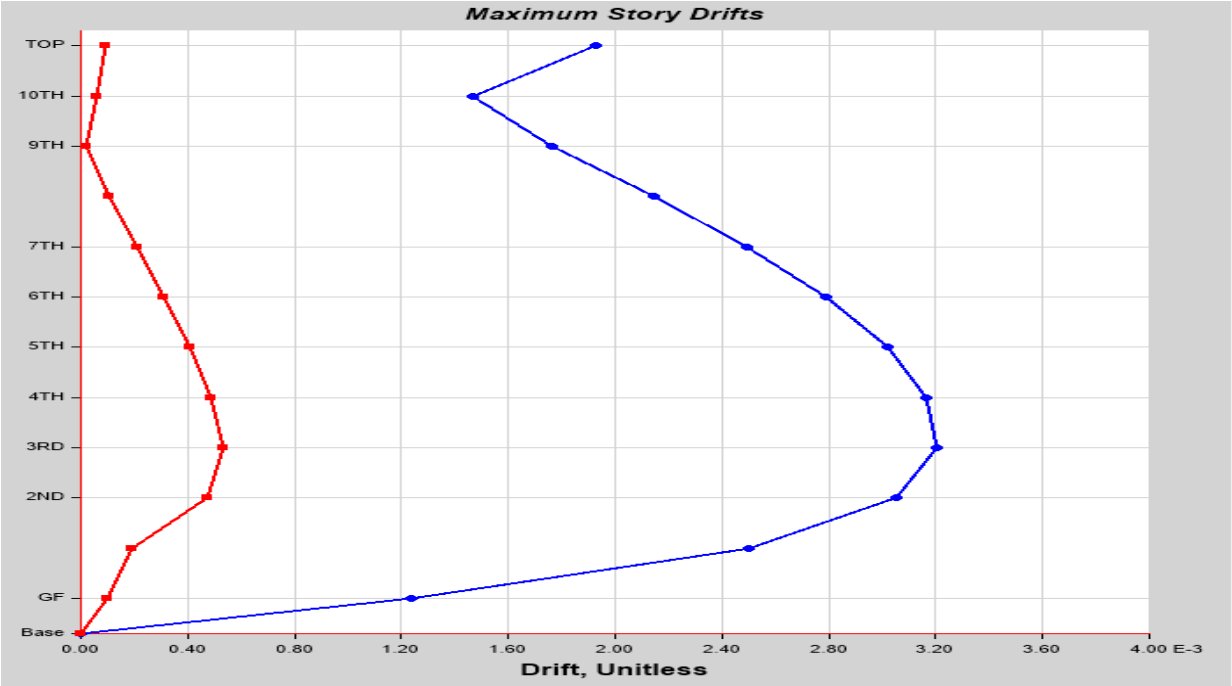


Figure 4.19: Maximum Drifts EQX

Table 4.17: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft			
TOP	117	Top	0.001925	0.00009
10TH	107	Top	0.001465	0.000059
9TH	97	Top	0.001761	0.000017
8TH	87	Top	0.002144	0.000106
7TH	77	Top	0.002493	0.000209
6TH	67	Top	0.00279	0.000311
5TH	57	Top	0.00302	0.000406
4TH	47	Top	0.003167	0.000487
3RD	37	Top	0.003202	0.000532
2ND	27	Top	0.003054	0.000472
1ST	17	Top	0.002498	0.000191
GF	7	Top	0.001239	0.0001
Base	0	Top	0	0

Story Response - Maximum Story Drifts

This is story response output for a specified range of stories and a selected load case or load combination.

Input Data

Name StoryResp3
Display Type Max story drifts
Load Case EQY
Output Type Not Applicable
Story Range All Stories
Top Story TOP
Bottom Story Base

Plot

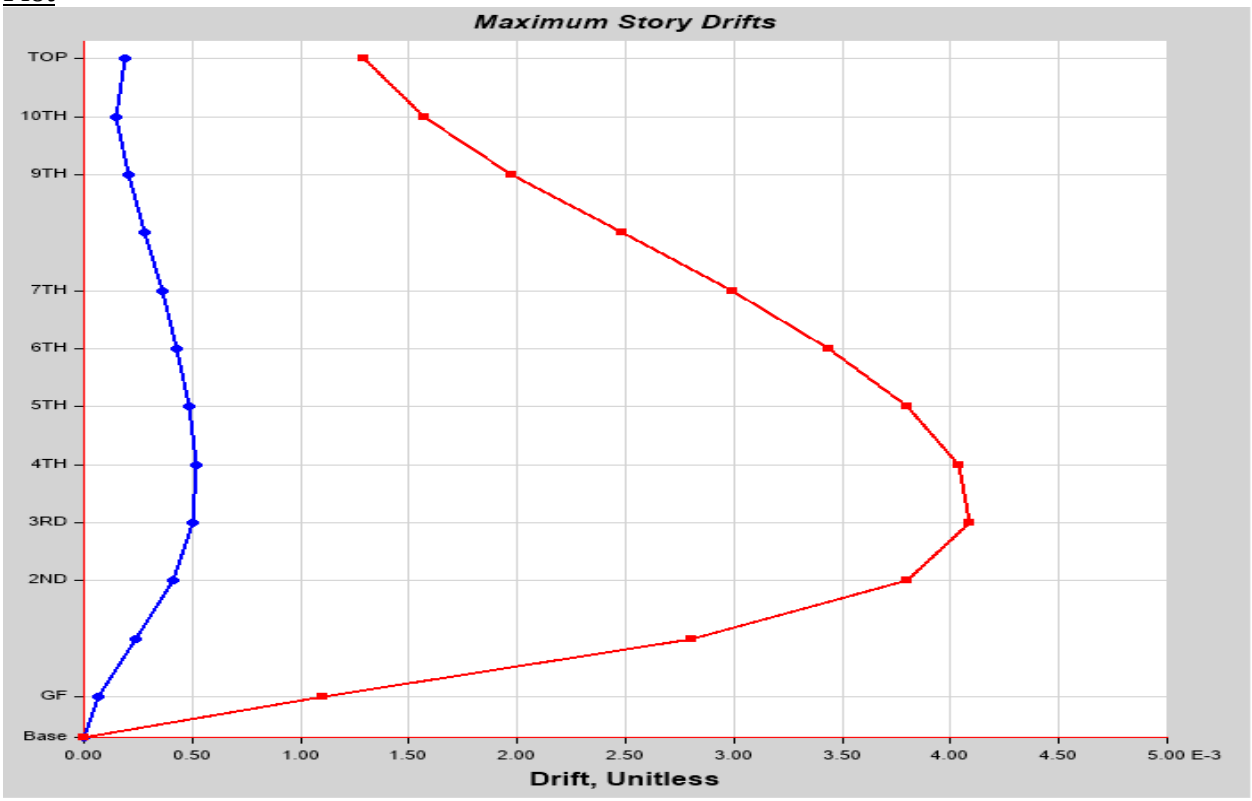


Figure 4.20: Maximum Drifts EQY

Table 4.18: Tabulated Plot Coordinates

Story Response Values

Story	Elevation	Location	X-Dir	Y-Dir
	ft			
TOP	117	Top	0.000187	0.001288
10TH	107	Top	0.000148	0.001569
9TH	97	Top	0.000205	0.001975
8TH	87	Top	0.000281	0.002484
7TH	77	Top	0.00036	0.00299
6TH	67	Top	0.000431	0.003441
5TH	57	Top	0.000486	0.003803
4TH	47	Top	0.000514	0.004041
3RD	37	Top	0.000498	0.004088
2ND	27	Top	0.000413	0.003799
1ST	17	Top	0.000242	0.002801
GF	7	Top	0.000066	0.0011
Base	0	Top	0	0

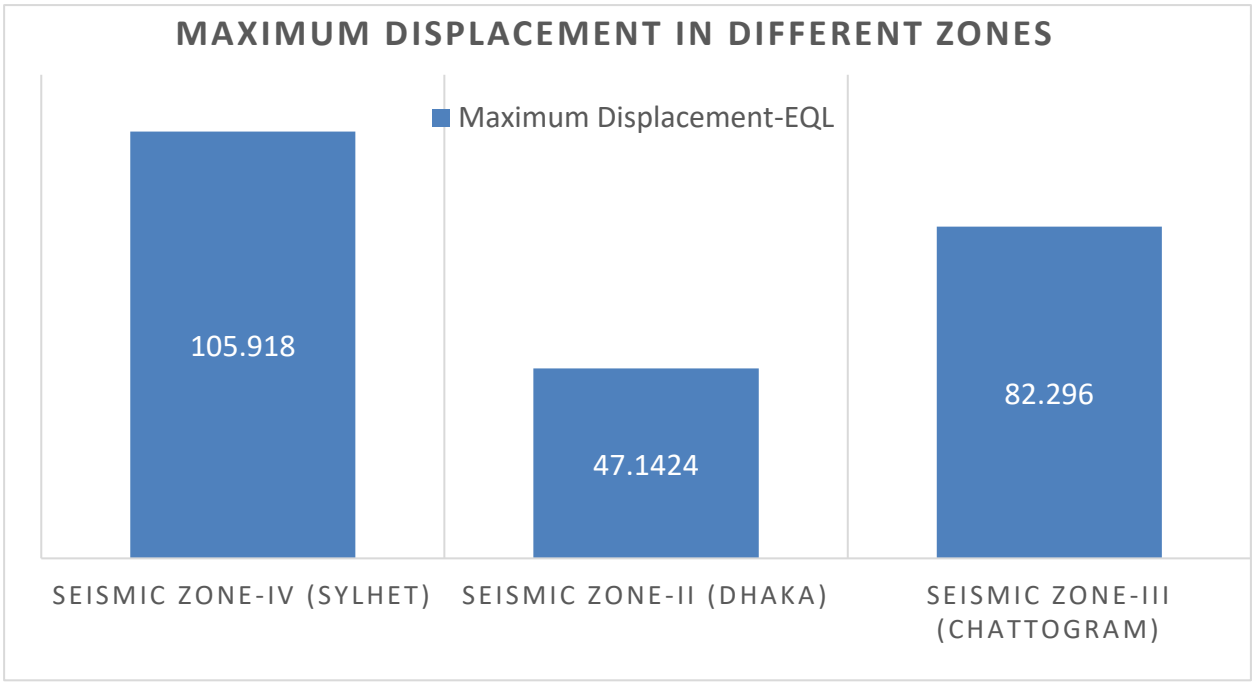


Figure 4.21: Maximum Displacement in Different Zones

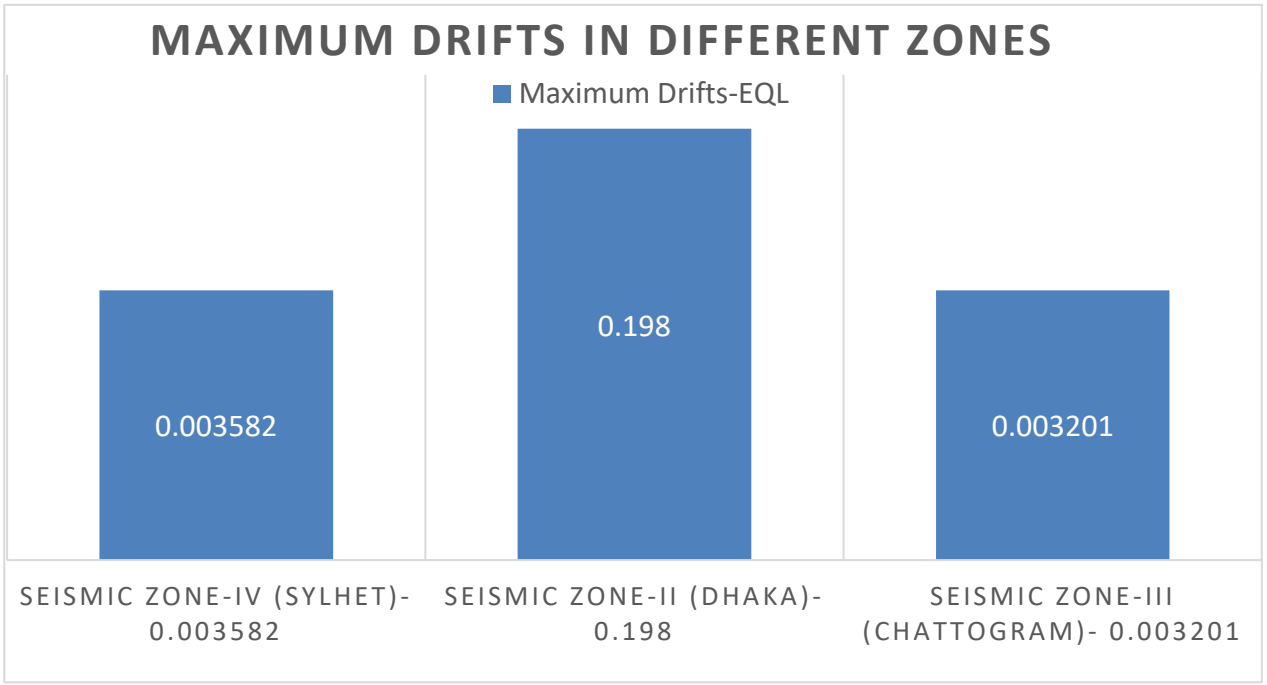


Figure 4.22: Maximum Drifts in Different Zones

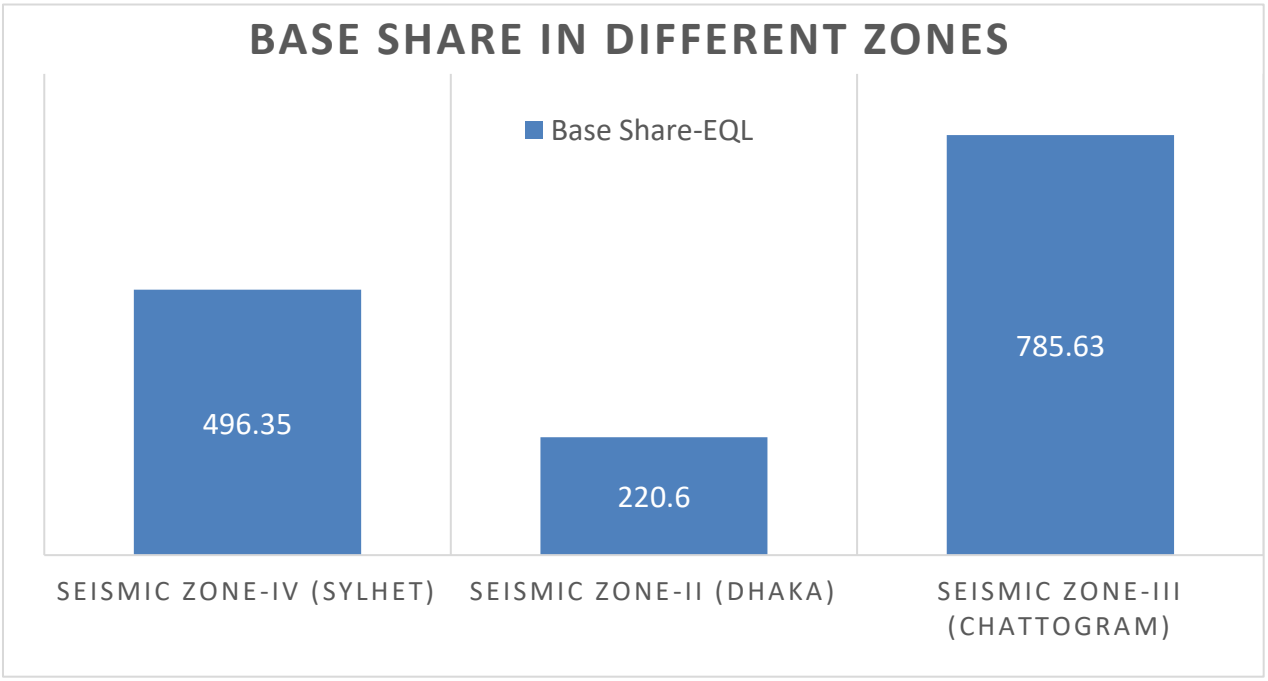


Figure 4.23: Maximum Base Share in Different Zones

Comparison Displacement and Drifts Value with BNBC 2020 and Different Zone

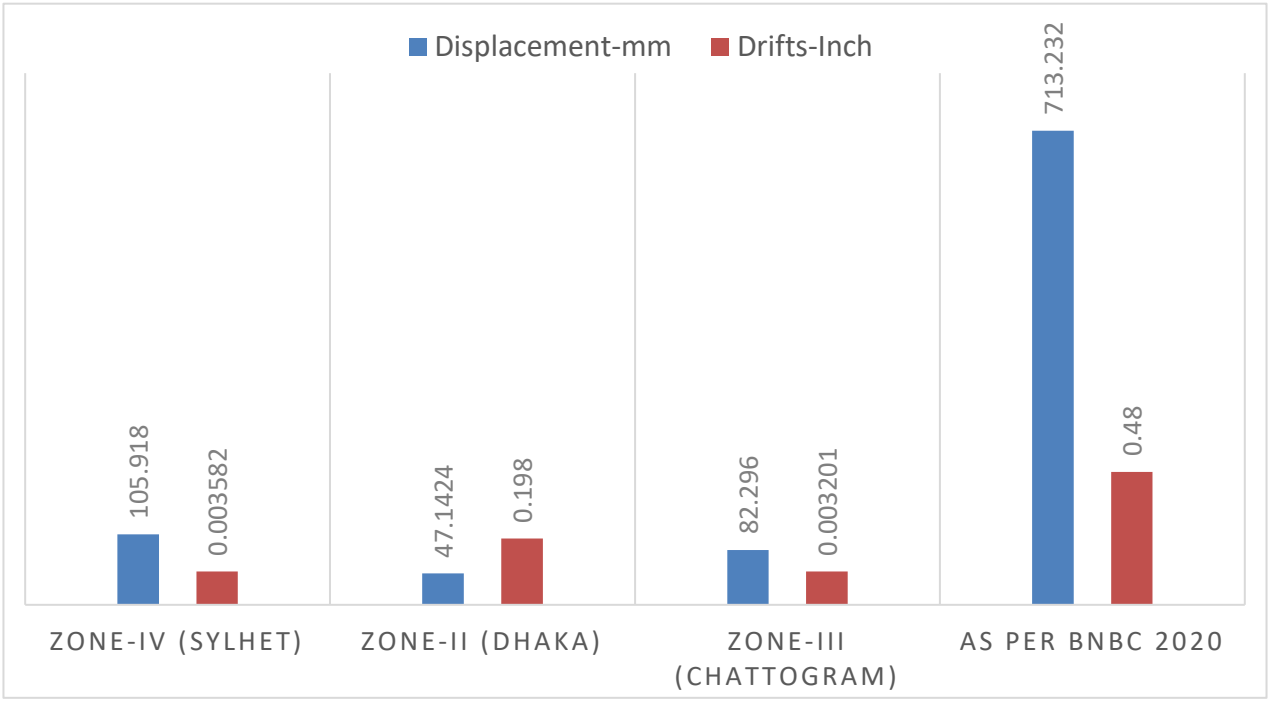


Figure 4.24: Comparison with Different Zones and BNBC

CHAPTER 5
Conclusions and Future Works

5.1 Conclusions

In this chapter, the outcomes of the study has been conclude obtained from ETABS software as per BNBC 2020.

1. The building is safe for all zones as per story drift and displacement check and torsion irregularity check.
2. Highest story displacement is occurred in Zone IV (Sylhet), then Zone II (Dhaka), and then Zone III (Chattogram).
3. The Zone II (Dhaka) is the safest location for structure according to story displacement.
4. Highest story drift is occurred in Zone II (Dhaka), then Zone IV (Sylhet), and then Zone III (Chattogram).
5. The Zone III (Chattogram) is the safest location for structure according to story drift.
6. The Maximum highest story drift is occurred on the Story3.
7. Maximum highest story displacement and story drift is occurred in X+Y direction of this building for Top and 3rd floor level zones.
8. The maximum base shear is present in Zone III (Chattogram), then Zone IV (Sylhet), and then Zone II (Dhaka).
9. Above all the more safe location for construction building and other structures is Zone II, then Zone III, then Zone IV,

5.2 Limitations and Recommendations for Future Works

5.2.1 Limitations

There are some limitations of this project:

- An idea for a medium-rise structural design was used for this study.
- The structure is designed in rectangular shape.
- Regular plan patterns are the only ones covered by this study.
- ETABS 2018 and AutoCAD 2007 were used for the analysis, design, and specifics.
- According to the BNBC 2020 code, the architectural plan was developed.

- The scope of the work is restricted to torsional irregularity, base shear, story displacement, and story drifts.
- The Equivalent Static Analysis Method and Response Spectrum Analysis Method are used in this project.

When designing the structure, the following factors weren't taken into account:

- The design, estimation, and cost analysis of the foundation for the building were not finished.
- This research does not take other factors into account, such as brickwork, plumbing, or electricity.
- This analysis does not include the Pounder effect.
- Pile design is not present in here.
- Stiffness irregularity check is not account.

5.2.2 Recommendations for Future Works

The recommendations for future works are following:

- Further analysis can be carried out by different BNBC codes and other codes such as IS code, BNBC 2017, Euro code, AS or NZS code, BNBC upcoming code and etc.
- Further research can be done on the design and analysis of various multi storied building types (such as composite and steel).
- Although the analysis in this work focuses on earthquake load, wind load analysis is also possible. Additionally, the lateral load, which combines the effects of wind and earthquakes, can be examined.
- The analysis can also be done using additional various methods.
- It is possible to proceed with the design and study of multistory buildings of several types, including those used for agriculture, business, education, government, industry, the military, parking and storage facilities, transportation, infrastructure and power plants.
- Research can be carried out on taller constructions in various Bangladeshi earthquake zones.
- Steel frame buildings, typical moment resistant frames and masonry structures can all be the subject of a comparable analysis.

- The dynamic analysis method can be used to conduct a more accurate examination of a high-rise structure under an earthquake load.
- Sway and deflection control should be taken into consideration during analysis and design.
- The only goal of this investigation was to establish regular organization. Future studies might concentrate on other irregular structures.

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APPENDIX

APPENDIX A

LIST OF ABBREVIATIONS

Abbreviation	Full Text
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
AS	Australian Standards
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council
BNBC	Bangladesh National Building Code
EDC	Earthquake Design Category
GPS	Global Positioning System
IBC	International Building Code
IS	Indian Standards
LDEO	Lamont-Doherty Earth Observatory
MR	Machine Room
NEHRP	National Earthquake Hazards Reduction Program
NZS	New Zealand Standards
RCC	Reinforced Cement Concrete
WT	Water Tank

APPENDIX B

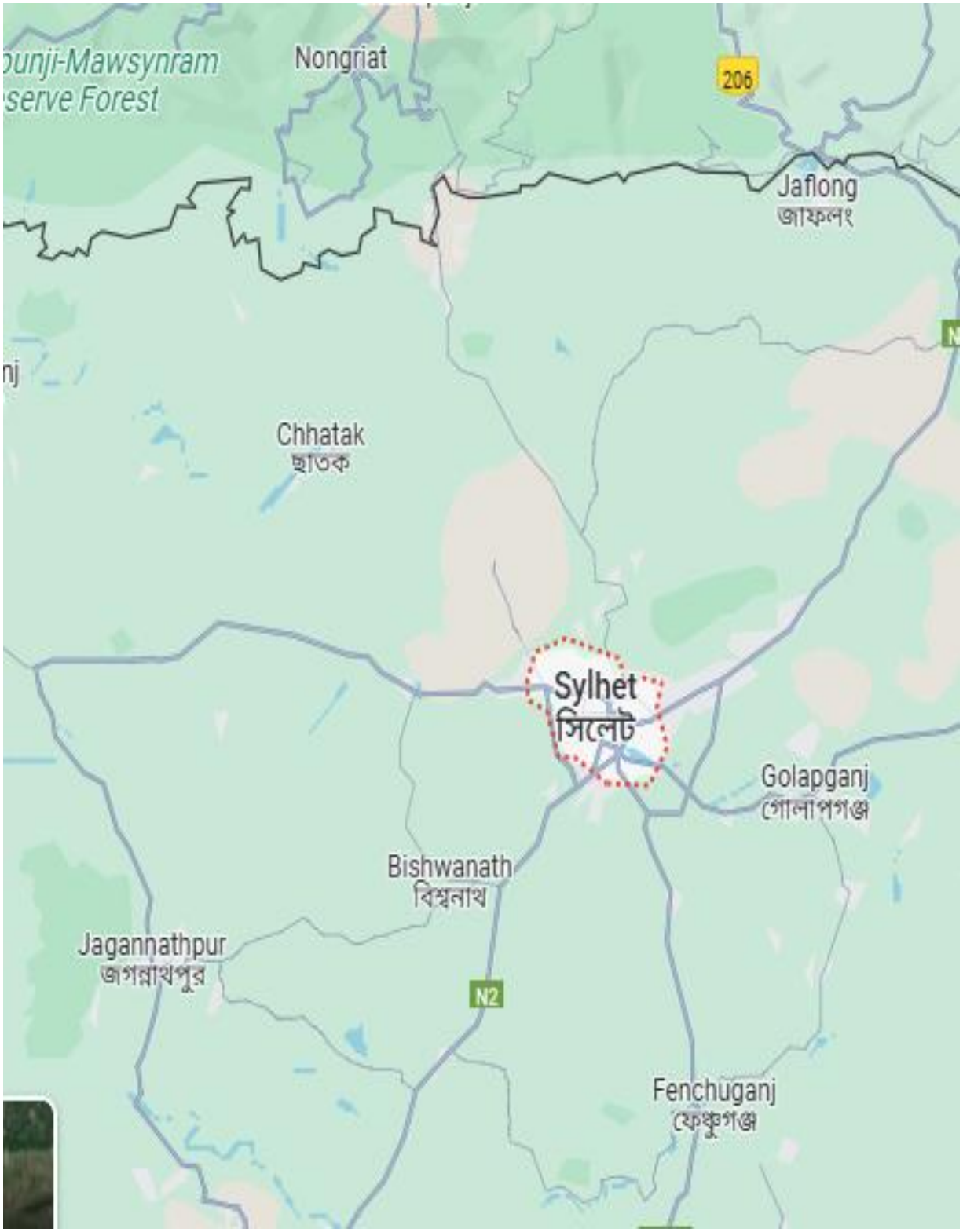


Figure 5.1: Sylhet Area for Zone I (Dotted Red Line Indicates the Boundary)

APPENDIX C

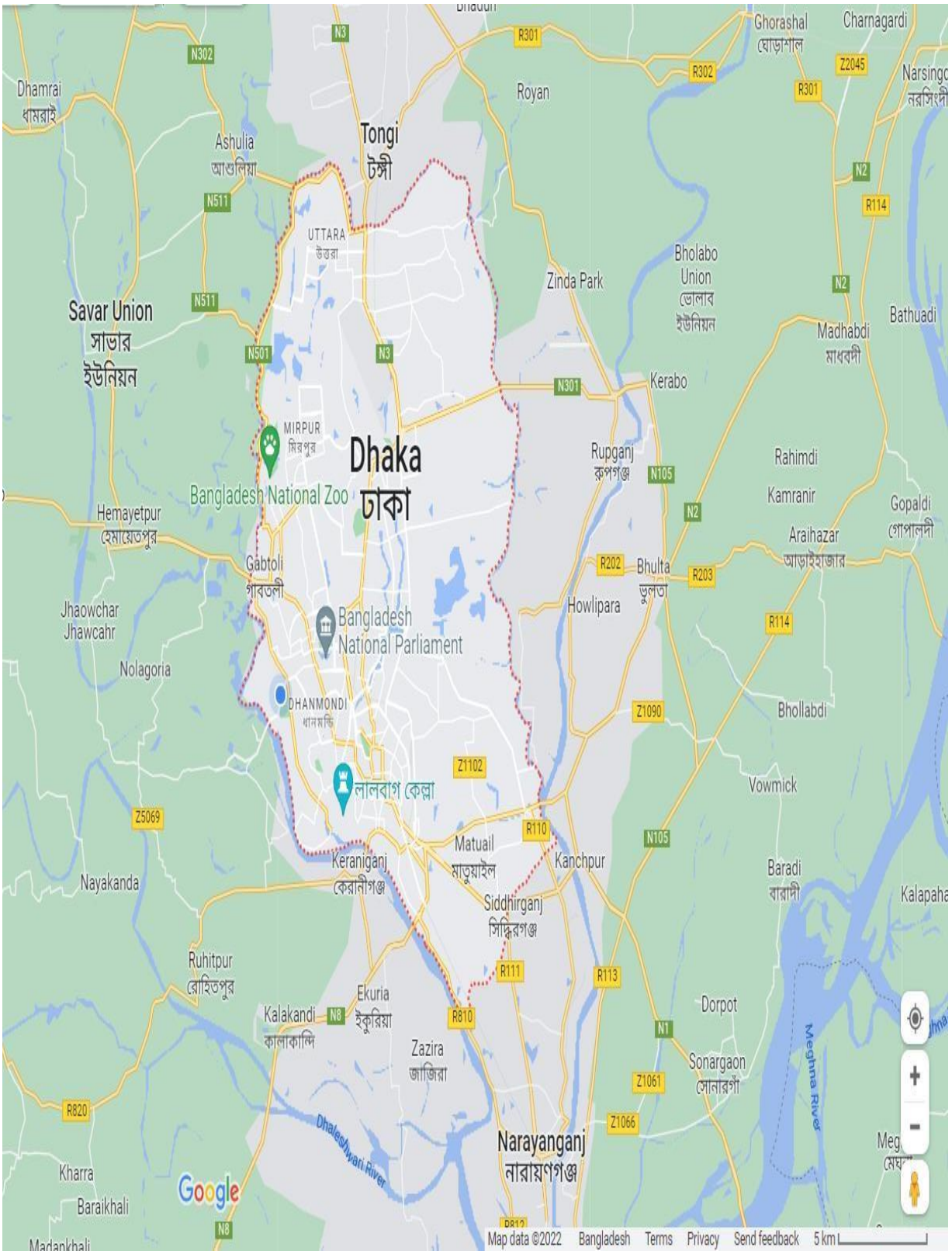


Figure 5.2: Dhaka Area for Zone II (Dotted Red Line Indicates the Boundary)

APPENDIX D



Figure 5.3: Chattogram Area for Zone III (Dotted Red Line Indicates the Boundary)