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

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

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Section: 16E

Semester: Fall-2022

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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. Omor Faruk, Student ID: BCE1901016166, Student Name: Ahidur Rahman, Student ID: BCE1901016205, Student Name: Md. Asraful Islam Shakil, Student ID: BCE1901016203, Student Name: Md. Sohel Rahman Biswas, Student ID: BCE1901016247, 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.

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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 Md. Lutfor Rahman, Associate Professor, 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).

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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 I, Zone II, Zone III, and Zone IV seismic zones. In this study, BNBC 2020 and ETABS 2018 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 (Habiganj), then Zone II (Dhaka), then Zone III (Tangail), then Zone I (Pirojpur). 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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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 Pirojpur District (Zone I), Dhaka District (Zone II), Tangail District (Zone III), and Habigonj District (Zone IV) is 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 principle objectives of this research work are given in below:

- To conduct seismic analysis on structures for different zones in Bangladesh.
- To examine the impact of different loads placed on a building.
- To ensure that buildings are protected against seismic waves in different zones.
- To evaluate the effects of a building on an earthquake or a seismic and wind load.
- To compare story displacements, story drifts, torsional irregularities and base shears which are subjected to seismic loading from one zone to another zone according to BNBC 2020.
- To compare various analysis results of the building in zones I, II, III, and IV which are gained using ETABS software.

1.3 Analysis Methods

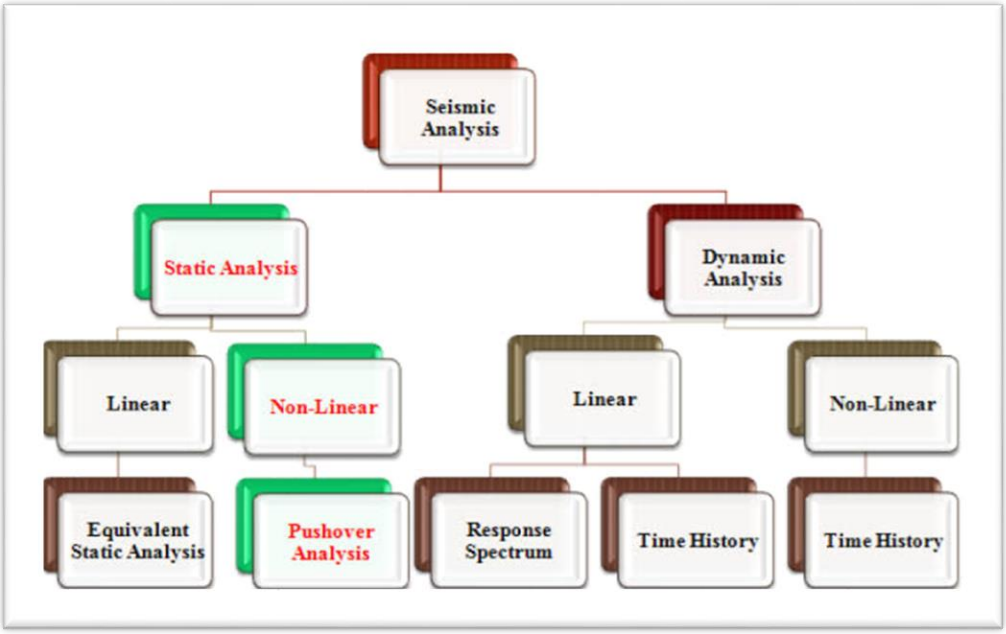

Figure 1.01: Different Types of Analysis Method[3]

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 2.01: 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 2.02: 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 2.03: Richter Scale of Earthquake Magnitude[9]

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 that 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.

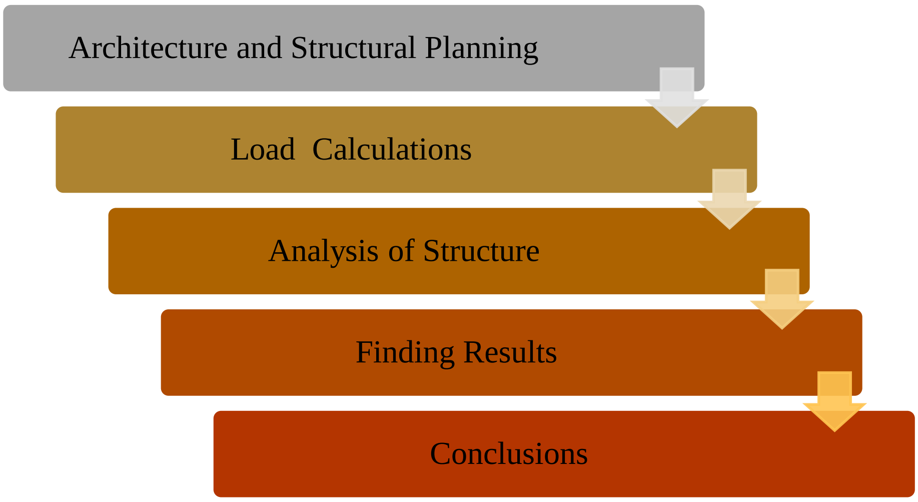

Figure 3.01: Five Phases to Accomplish the Project

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 2021 (For Architectural Planning)
- ETABS 2018 (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: ASCE 7-05
- Wind Load: ASCE 7-05
- 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 3.01: 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 3.02: 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 3.03: 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 3.04: 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

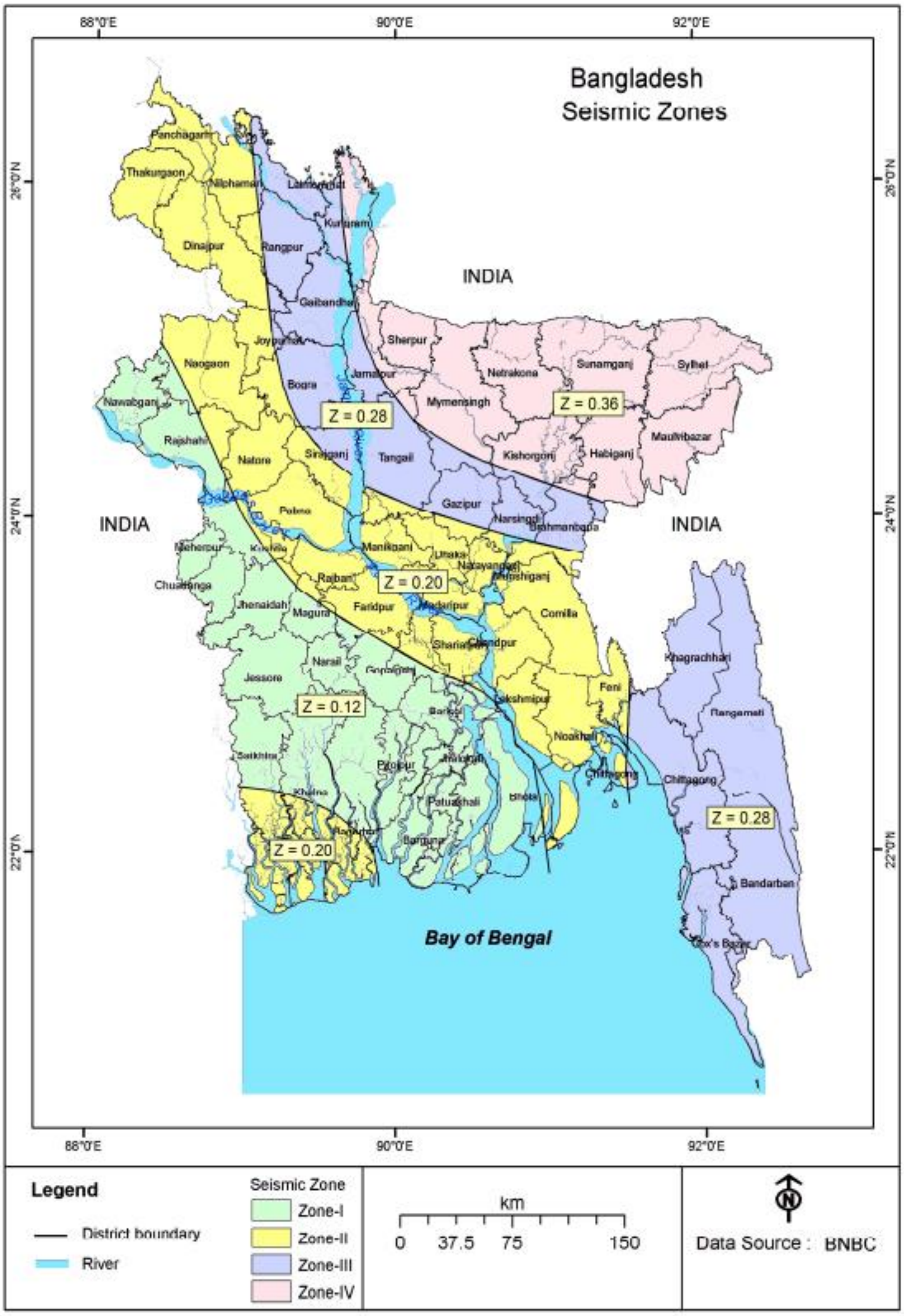

Figure 3.02: Seismic Zoning Map of Bangladesh

Table 3.05: 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

Site dependent Soil factor and other parameters defining Elastic Response Spectrum is given in the Table 3.06.

Table 3.06: 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 $0.020h_{sx}$.

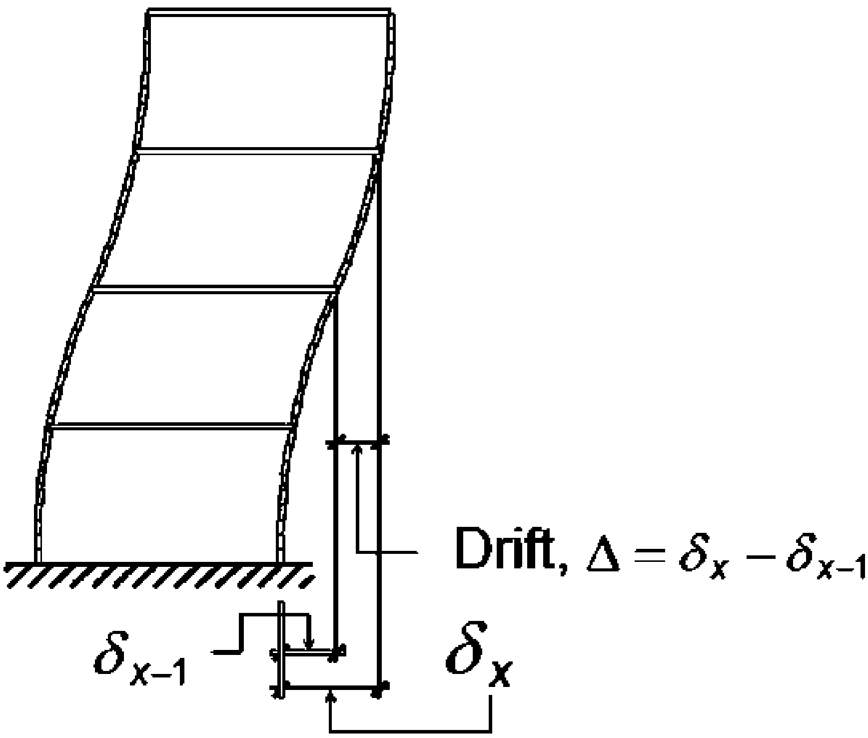

Figure 3.03: Deflection and Drift

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

To be considered for rigid floor diaphragms as shown in Figure 3.04.

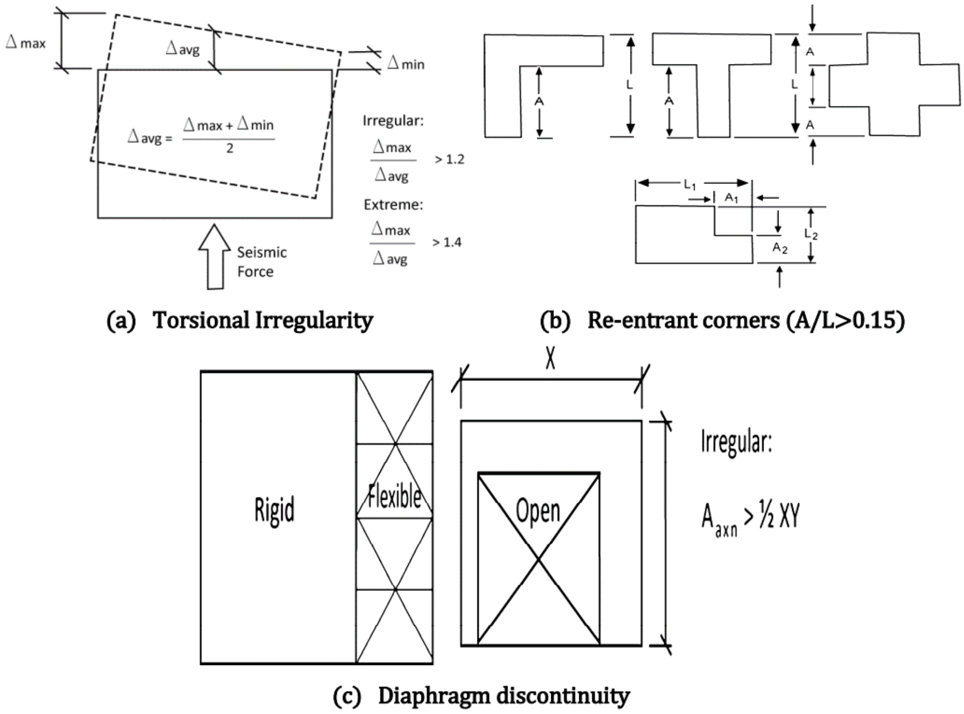

Figure 3.04: Irregularities of Building

3.16 Wind Load

Table 3.07: 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

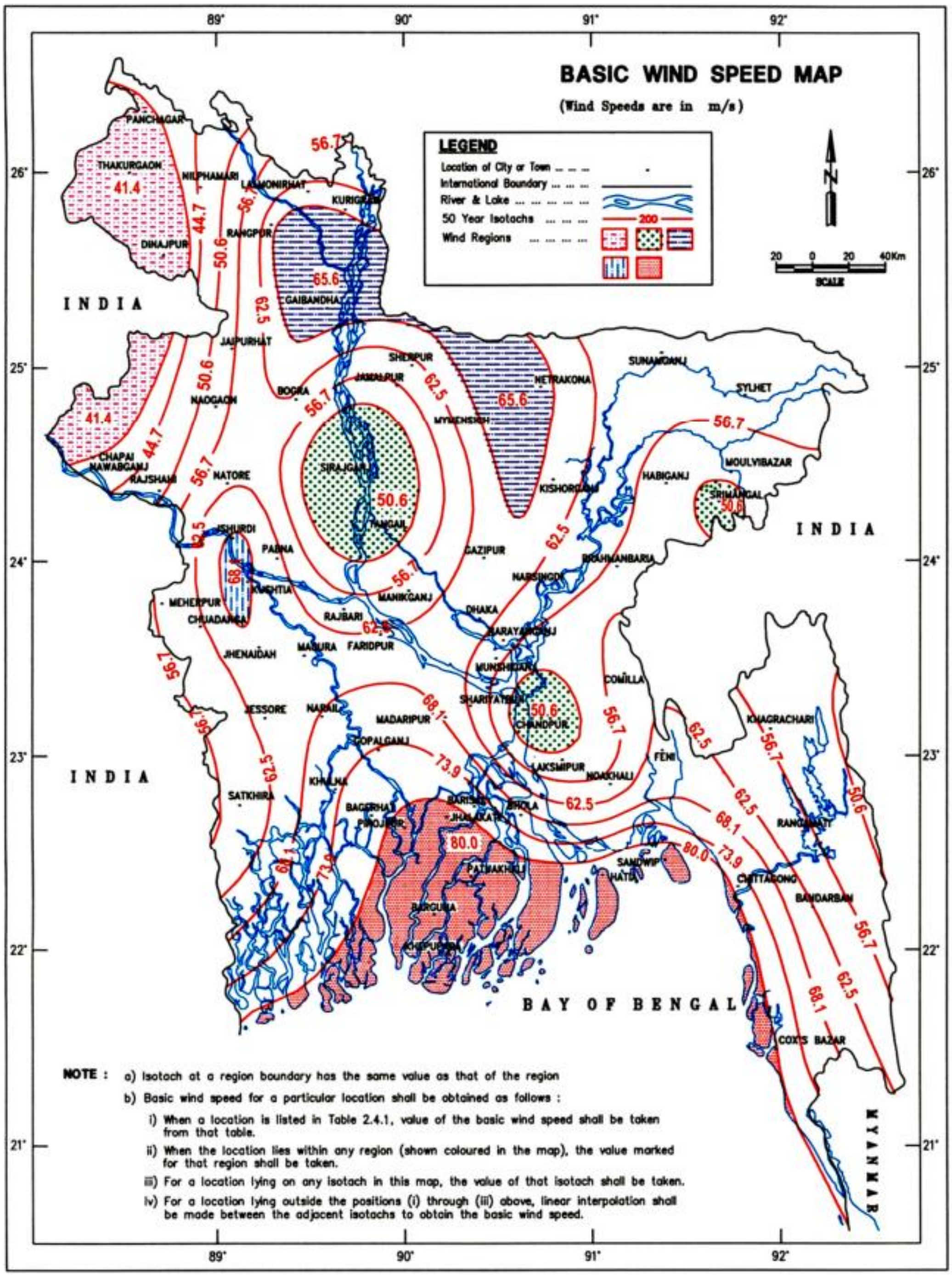

Figure 3.05: Basic Wind Speed (m/s) Map of Bangladesh

Table 3.08: 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. 1.4(D + F)

2. 1.2(D + F + T) + 1.6(L + H) + 0.5(L_r or R)
3. 1.2D + 1.6(L_r or R) + (L or 0.8W)
4. 1.2D + 1.6W + L + 0.5(L_r or R)
5. 1.2D + 1.0E + 1.0L
6. 0.9D + 1.6W + 1.6H
7. 0.9D + 1.0E +1.6H

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 4.01: Zonal Parameters and Various Details

Parameters and Topic	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
Seismic Zone Coefficient, Z	0.12	0.20	0.28	0.36
Basic Wind Speed	179.20 mph	147.17 mph	113.34 mph	121.41 mph
Building Length	72 feet	72 feet	72 feet	72 feet
Building Breadth	37.5 feet	37.5 feet	37.5 feet	37.5 feet
Occupancy Category	II	II	II	II
Importance Factor (Earthquake), I	1.00	1.00	1.00	1.00
Time Period, T	1.25 sec	1.25 sec	1.25 sec	1.25 sec
Frequency, f	0.8 Hz	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 Overstrength 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)	3000 psi	3000 psi	3000 psi	3000 psi
Concrete f´c (Beam)	3000 psi	3000 psi	3000 psi	3000 psi
Concrete f´c (Slab)	3000 psi	3000 psi	3000 psi	3000 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 4.02: 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 = 1 KN/m^2
- Floor Finish Load (Roof) = 1.5 KN/m^2
- Floor Finish Load (Veranda) = 1 KN/m^2
- Partition Wall Load = 2.5 KN/m^2
- Wall Load = 5 KN/m
- Wall Load Roof (Parapet) = 3 KN/m
- Partition Wall Load (Veranda) = 1.25 KN/m^2
- Floor Finish Load (Landing Slab) = 1 KN/m^2
- Floor Finish Load (Waist Slab) = 1 KN/m^2

4.4.2 Live Load

- Live Load = 2 KN/m^2
- Live Load (Roof) = 2.90 KN/m^2
- Live Load (Veranda) = 4.80 KN/m^2
- Live Load (Lift Machine Room Bottom Slab) = 10 KN/m^2
- Live Load (Lift Machine Room Top Slab) = 2 KN/m^2
- Live Load (Water Tank Bottom Slab) = 17.5 KN/m^2
- Live Load (Water Tank Top Slab) = 2 KN/m^2
- Live Load (Water Tank Side Wall) = 10KN/m^2

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 = 72 feet =21.9456 m
- Breadth of the building = 37 feet 6 inch = 11.43 m

Table 4.03: Dimension of Building Columns and Beams

Column Name	Column Size	Beam Name	Beam Size
C1	20 inch X 40 inch	Grade Beam	15 inch X 26 inch
C2	20 inch X 38 inch	Floor Beam	15 inch X 26 inch
C3	20 inch X 42 inch	Stair Beam	15 inch X 26 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 2343.75 ft^2 or 217.93 m^2.

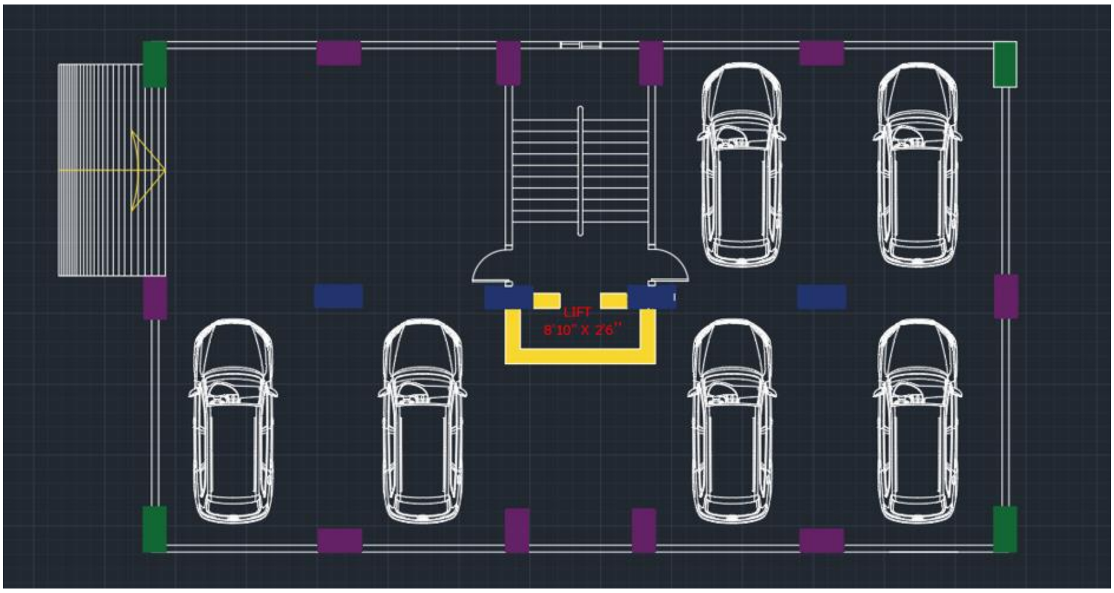

Figure 4.01: Ground Floor Plan

4.6.2 Floor Plan

The total floor area is 2700 ft^2 or 250.84 m^2.

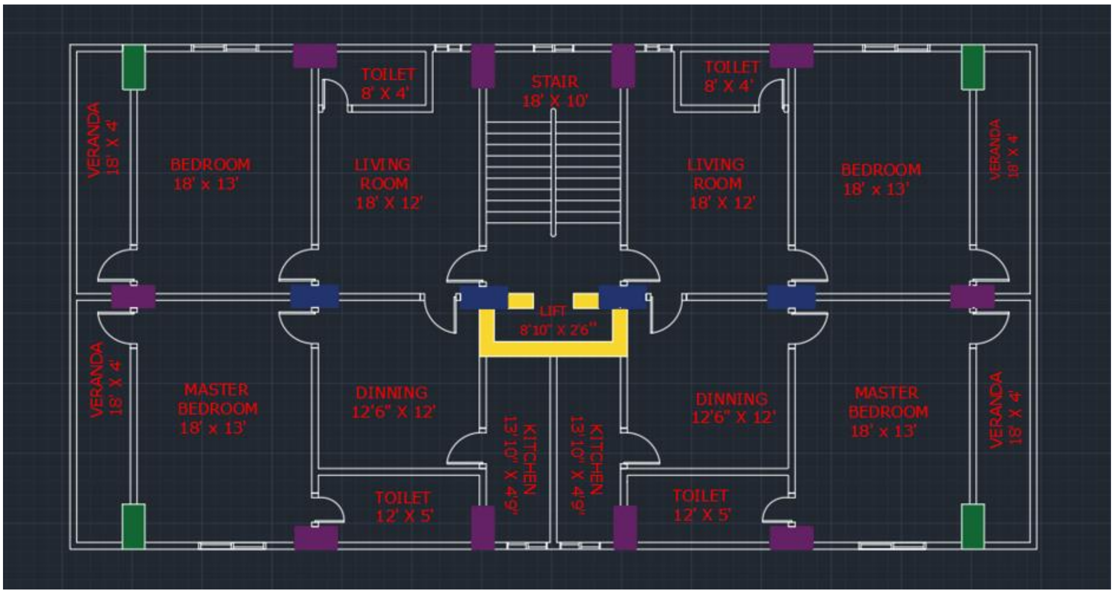

Figure 4.02: Floor Plan

4.6.3 Roof Plan

The total roof area is 2700 ft^2 or 250.84 m^2.

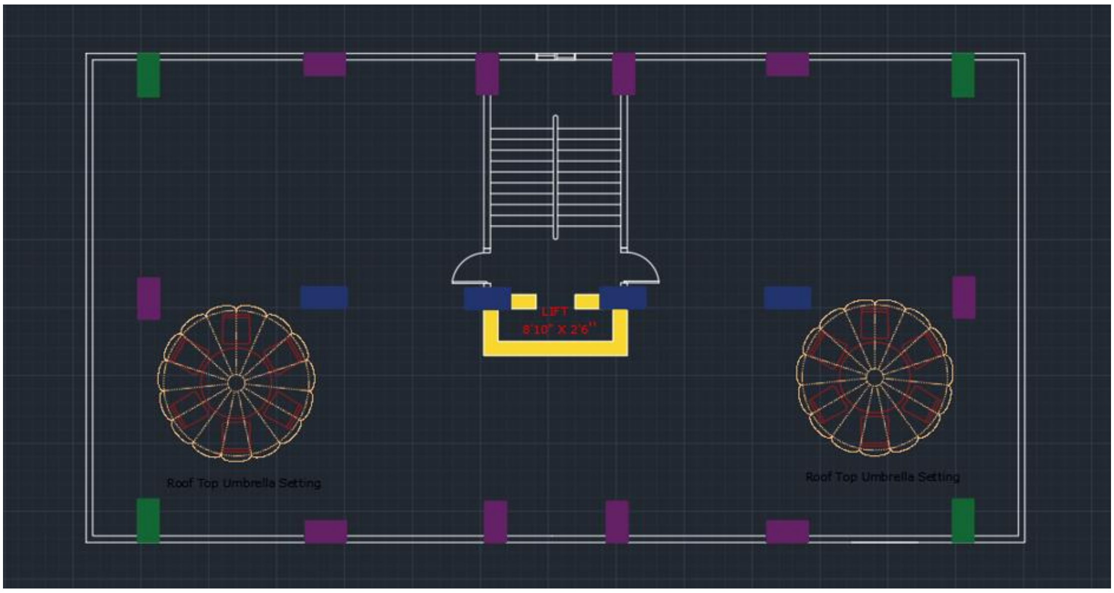

Figure 4.03: Roof Plan

4.7 Building Analysis Figures by ETABS

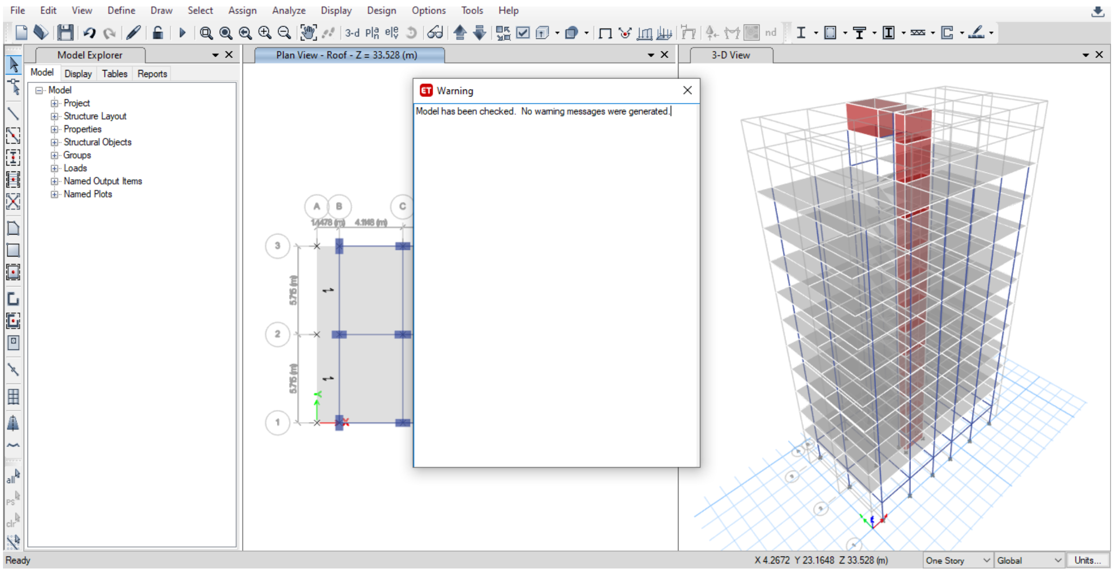

Figure 4.04: No Warning Message (Model Check)

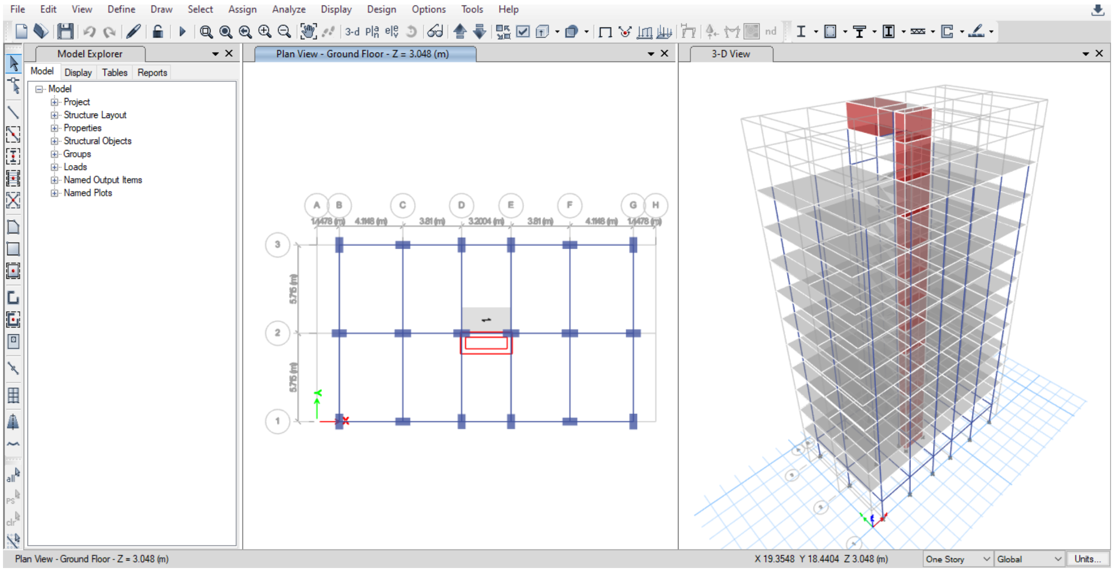

Figure 4.05: Ground Floor Plan View

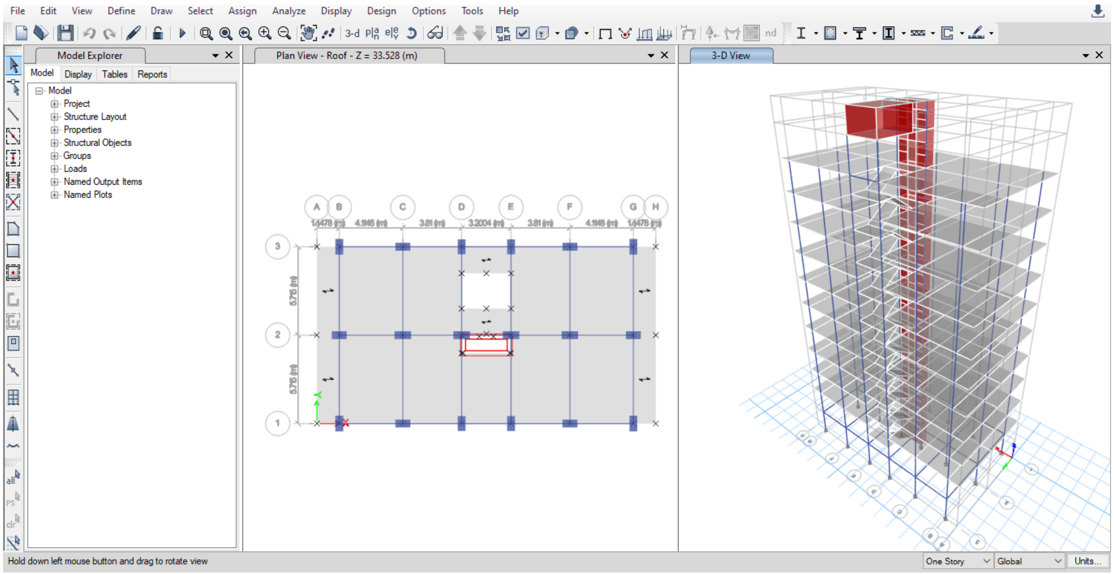

Figure 4.06: Roof Plan View

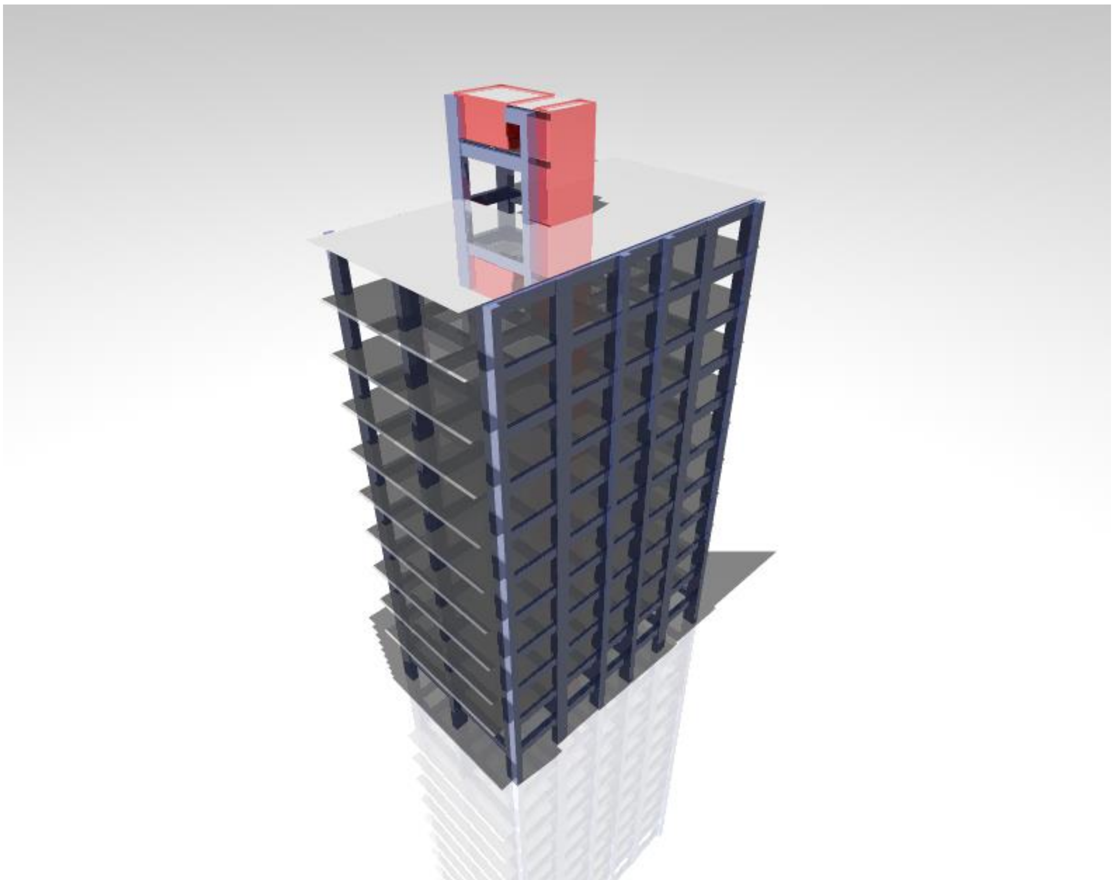

Figure 4.07: 3D View without Wall

4.8 Findings of Story Drift and Displacement

4.8.1 Zone I (Pirojpur)

Table 4.04: Story Drift and Displacement in X+E Direction of Zone I (Pirojpur)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	23.054	126.797	2.6675	42.672	Safe
WT and MR	3.048	22.569	124.1295	6.094	60.96	Safe
Roof	3.048	21.461	118.0355	7.2435	60.96	Safe
Story9	3.048	20.144	110.792	9.02	60.96	Safe

Story8	3.048	18.504	101.772	10.4225	60.96	Safe
Story7	3.048	16.609	91.3495	11.6655	60.96	Safe
Story6	3.048	14.488	79.684	12.6775	60.96	Safe
Story5	3.048	12.183	67.0065	13.3595	60.96	Safe
Story4	3.048	9.754	53.647	13.596	60.96	Safe
Story3	3.048	7.282	40.051	13.222	60.96	Safe
Story2	3.048	4.878	26.829	12.0175	60.96	Safe
Story1	3.048	2.693	14.8115	10.1365	60.96	Safe
Ground Floor	3.048	0.85	4.675	4.675	60.96	Safe
Base	0	0	0	0	0	Safe

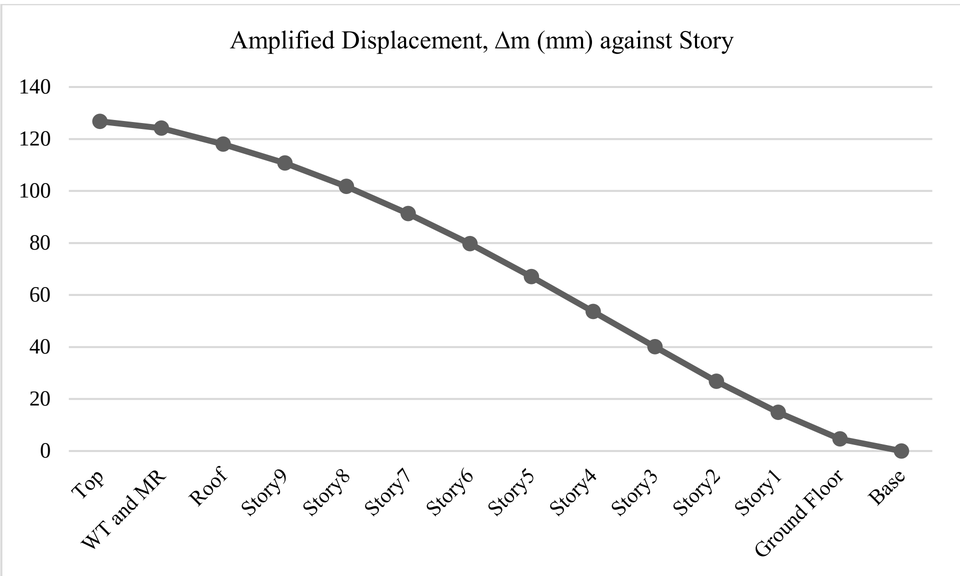

Figure 4.08: Amplified Displacement in X+E Direction of Zone I (Pirojpur)

Highest Amplified Displacement in X+E direction of Zone I (Pirojpur) = 126.797 mm.

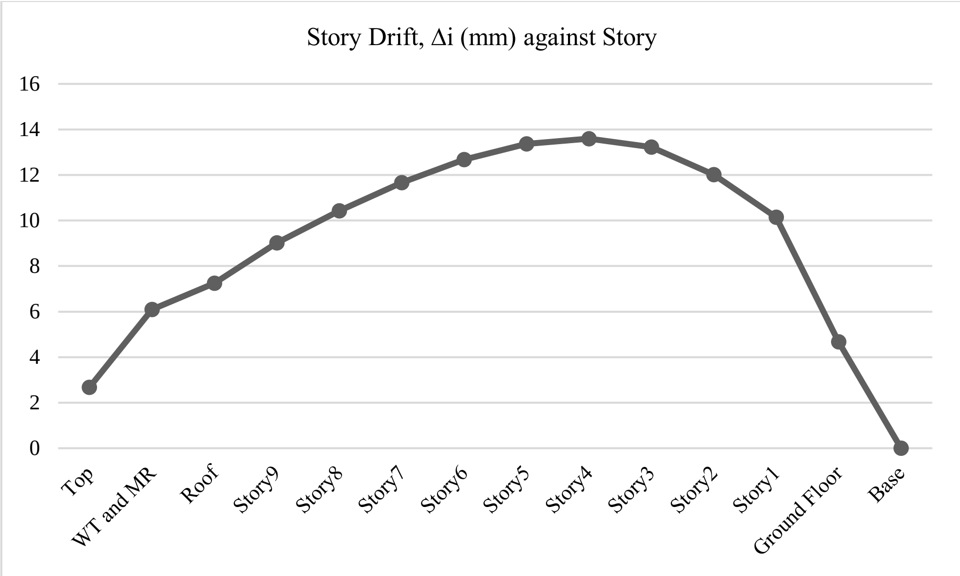

Figure 4.09: Story Drift in X+E Direction of Zone I (Pirojpur)

Highest Story Drift in X+E direction of Zone I (Pirojpur) = 13.596 mm.

Table 4.05: Story Drift and Displacement in X-E Direction of Zone I (Pirojpur)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	23.315	128.2325	6.1765	42.672	Safe
WT and MR	3.048	22.192	122.056	3.9545	60.96	Safe
Roof	3.048	21.473	118.1015	8.2555	60.96	Safe
Story9	3.048	19.972	109.846	9.7955	60.96	Safe
Story8	3.048	18.191	100.0505	10.978	60.96	Safe
Story7	3.048	16.195	89.0725	12.0945	60.96	Safe
Story6	3.048	13.996	76.978	13.002	60.96	Safe
Story5	3.048	11.632	63.976	13.541	60.96	Safe

Story4	3.048	9.17	50.435	13.563	60.96	Safe
Story3	3.048	6.704	36.872	12.881	60.96	Safe
Story2	3.048	4.362	23.991	11.286	60.96	Safe
Story1	3.048	2.31	12.705	8.3545	60.96	Safe
Ground Floor	3.048	0.791	4.3505	4.3505	60.96	Safe
Base	0	0	0	0	0	Safe

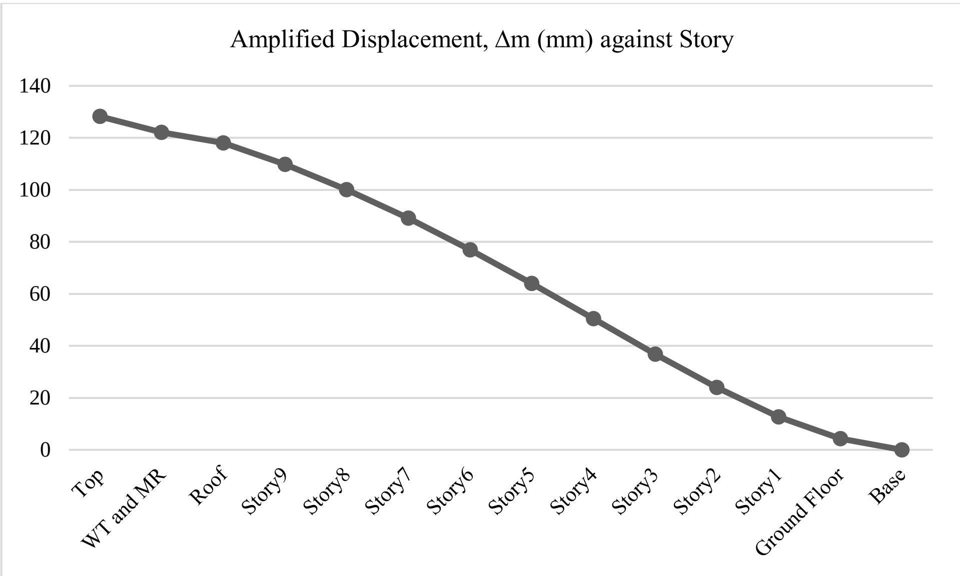

Figure 4.10: Amplified Displacement in X-E Direction of Zone I (Pirojpur)

Highest Amplified Displacement in X-E direction of Zone I (Pirojpur) = 128.2325 mm.

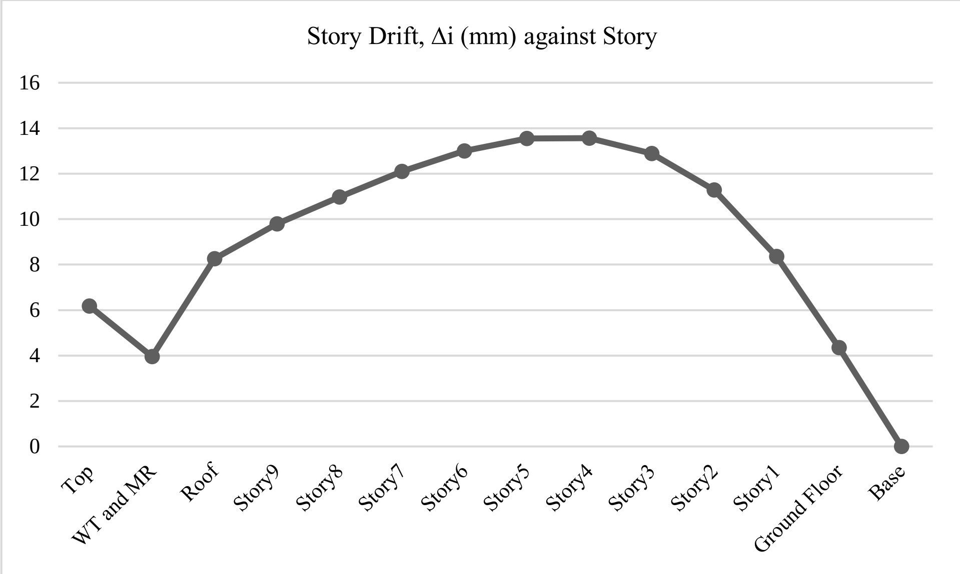

Figure 4.11: Story Drift in X-E Direction of Zone I (Pirojpur)

Highest Story Drift in X-E direction of Zone I (Pirojpur) = 13.563 mm.

Table 4.06: Story Drift and Displacement in Y+E Direction of Zone I (Pirojpur)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	48.294	265.617	10.2245	42.672	Safe
WT and MR	3.048	46.435	255.3925	3.1845	60.96	Safe
Roof	3.048	47.014	258.577	14.2395	60.96	Safe
Story9	3.048	44.425	244.3375	17.8585	60.96	Safe
Story8	3.048	41.178	226.479	21.5545	60.96	Safe
Story7	3.048	37.259	204.9245	25.0525	60.96	Safe
Story6	3.048	32.704	179.872	28.0225	60.96	Safe
Story5	3.048	27.609	151.8495	30.173	60.96	Safe

Story4	3.048	22.123	121.6765	31.196	60.96	Safe
Story3	3.048	16.451	90.4805	30.6625	60.96	Safe
Story2	3.048	10.876	59.818	27.907	60.96	Safe
Story1	3.048	5.802	31.911	22.704	60.96	Safe
Ground Floor	3.048	1.674	9.207	9.207	60.96	Safe
Base	0	0	0	0	0	Safe

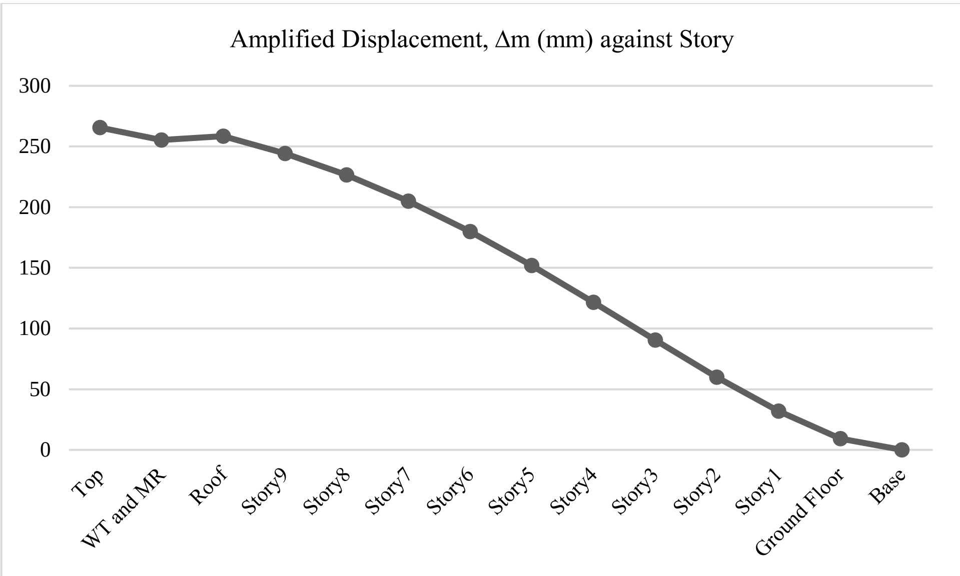

Figure 4.12: Amplified Displacement in Y+E Direction of Zone I (Pirojpur)

Highest Amplified Displacement in Y+E direction of Zone I (Pirojpur) = 265.617 mm.

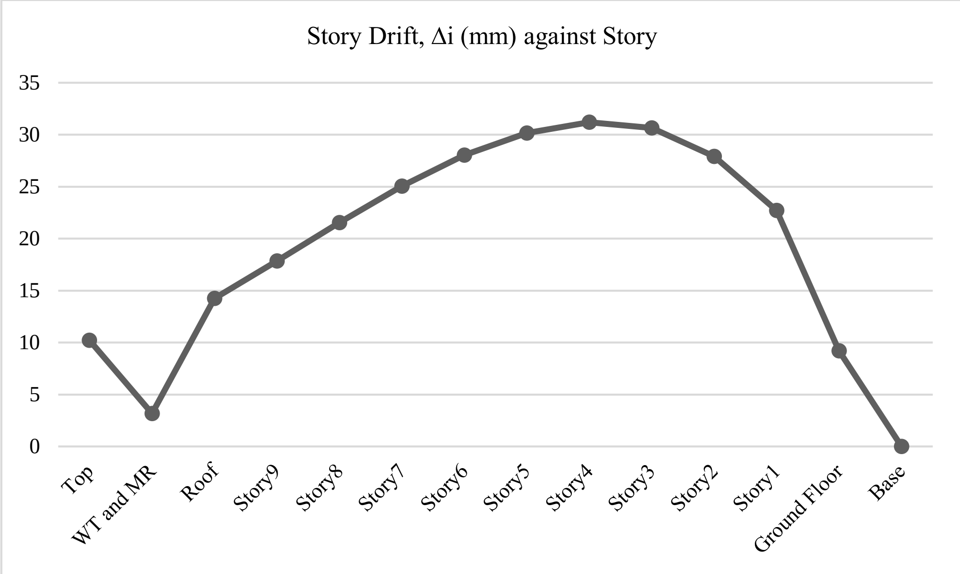

Figure 4.13: Story Drift in Y+E Direction of Zone I (Pirojpur)

Highest Story Drift in Y+E direction of Zone I (Pirojpur) = 31.196 mm.

Table 4.07: Story Drift and Displacement in Y-E Direction of Zone I (Pirojpur)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	48.303	265.6665	10.2355	42.672	Safe
WT and MR	3.048	46.442	255.431	3.135	60.96	Safe
Roof	3.048	47.012	258.566	14.1185	60.96	Safe
Story9	3.048	44.445	244.4475	17.7595	60.96	Safe
Story8	3.048	41.216	226.688	21.4665	60.96	Safe
Story7	3.048	37.313	205.2215	24.9755	60.96	Safe
Story6	3.048	32.772	180.246	27.9675	60.96	Safe
Story5	3.048	27.687	152.2785	30.1455	60.96	Safe

Story4	3.048	22.206	122.133	31.207	60.96	Safe
Story3	3.048	16.532	90.926	30.734	60.96	Safe
Story2	3.048	10.944	60.192	28.061	60.96	Safe
Story1	3.048	5.842	32.131	23.265	60.96	Safe
Ground Floor	3.048	1.612	8.866	8.866	60.96	Safe
Base	0	0	0	0	0	Safe

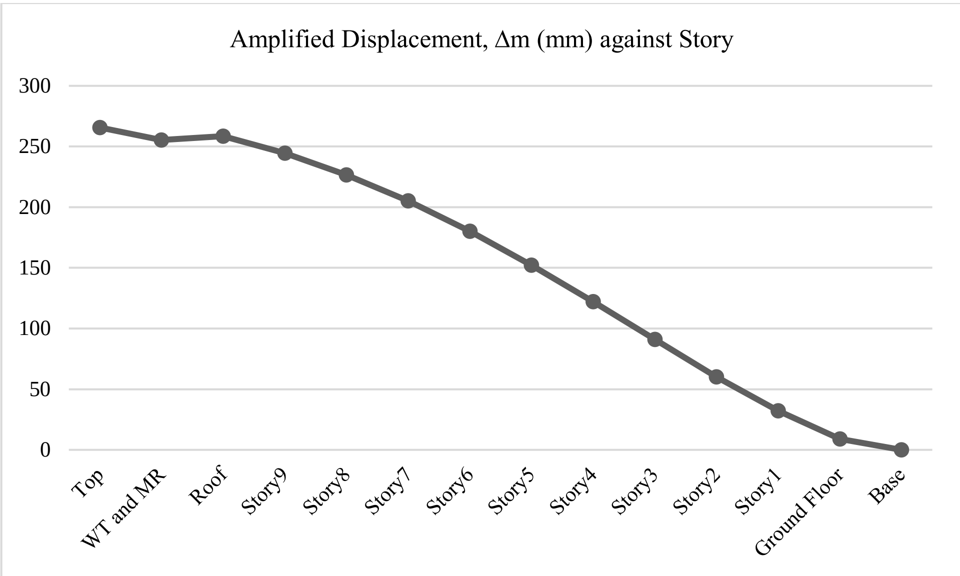

Figure 4.14: Amplified Displacement in Y-E Direction of Zone I (Pirojpur)

Highest Amplified Displacement in Y-E direction of Zone I (Pirojpur) = 265.6665 mm.

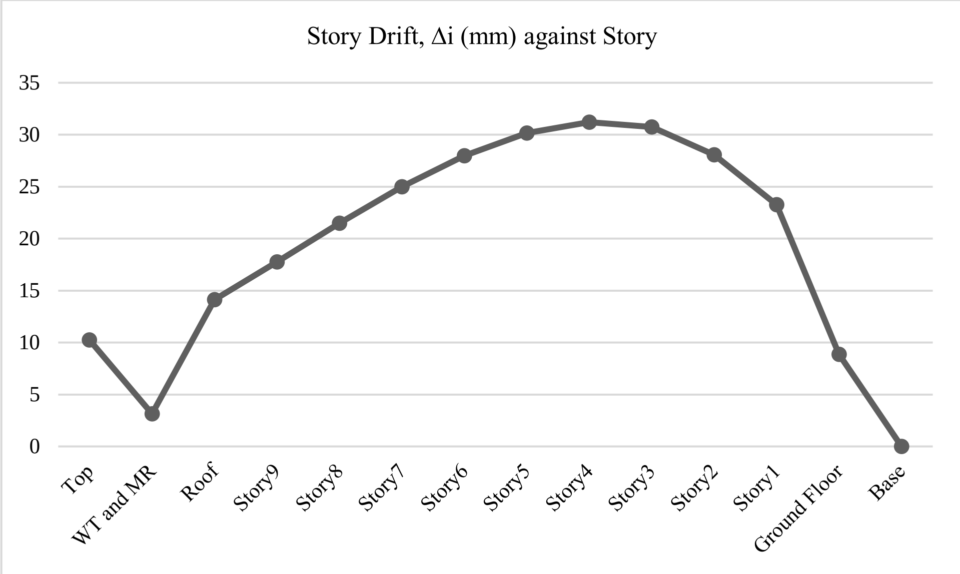

Figure 4.15: Story Drift in Y-E Direction of Zone I (Pirojpur)

Highest Story Drift in Y-E direction of Zone I (Pirojpur) = 31.207 mm.

4.8.2 Zone II (Dhaka)

Table 4.08: Story Drift and Displacement in X+E Direction of Zone II (Dhaka)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	38.424	211.332	4.455	42.672	Safe
WT and MR	3.048	37.614	206.877	10.153	60.96	Safe
Roof	3.048	35.768	196.724	12.0725	60.96	Safe
Story9	3.048	33.573	184.6515	15.037	60.96	Safe
Story8	3.048	30.839	169.6145	17.369	60.96	Safe
Story7	3.048	27.681	152.2455	19.437	60.96	Safe
Story6	3.048	24.147	132.8085	21.131	60.96	Safe

Story5	3.048	20.305	111.6775	22.2695	60.96	Safe
Story4	3.048	16.256	89.408	22.6545	60.96	Safe
Story3	3.048	12.137	66.7535	22.0385	60.96	Safe
Story2	3.048	8.13	44.715	20.031	60.96	Safe
Story1	3.048	4.488	24.684	16.8905	60.96	Safe
Ground Floor	3.048	1.417	7.7935	7.7935	60.96	Safe
Base	0	0	0	0	0	Safe

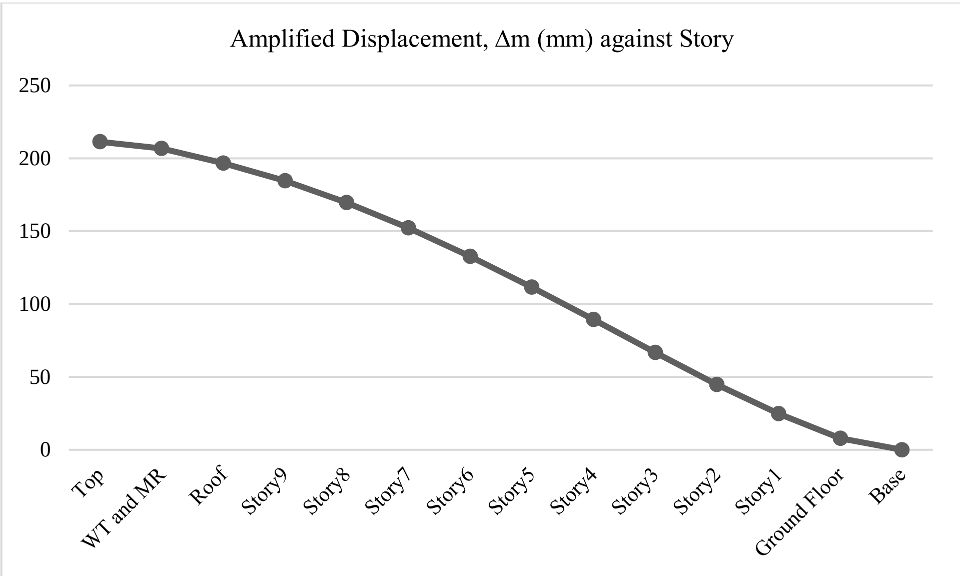

Figure 4.16: Amplified Displacement in X+E Direction of Zone II (Dhaka)

Highest Amplified Displacement in X+E direction of Zone II (Dhaka) = 211.332 mm.

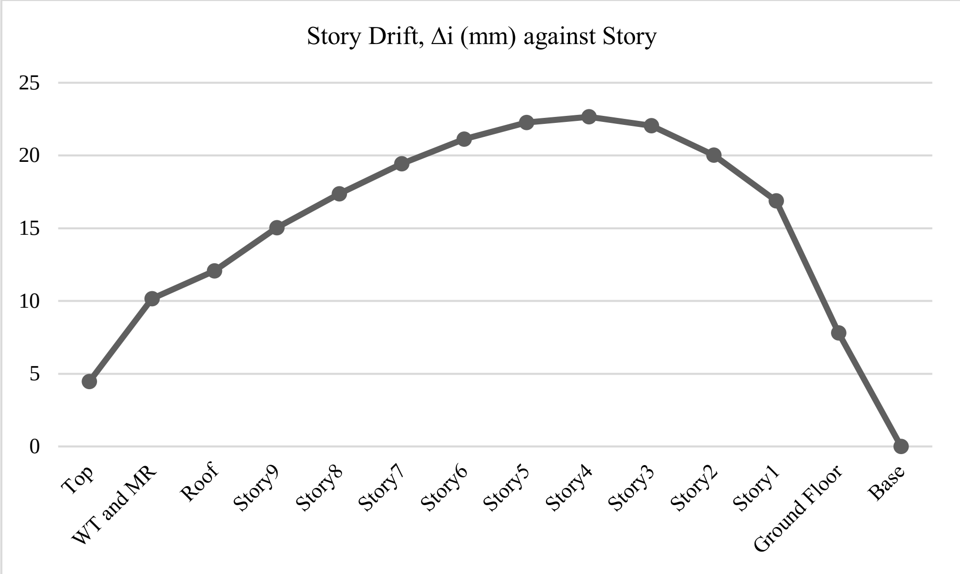

Figure 4.17: Story Drift in X+E Direction of Zone II (Dhaka)

Highest Story Drift in X+E direction of Zone II (Dhaka) = 22.6545 mm.

Table 4.09: Story Drift and Displacement in X-E Direction of Zone II (Dhaka)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	38.859	213.7245	10.3015	42.672	Safe
WT and MR	3.048	36.986	203.423	6.5835	60.96	Safe
Roof	3.048	35.789	196.8395	13.7665	60.96	Safe
Story9	3.048	33.286	183.073	16.3185	60.96	Safe
Story8	3.048	30.319	166.7545	18.304	60.96	Safe
Story7	3.048	26.991	148.4505	20.152	60.96	Safe
Story6	3.048	23.327	128.2985	21.67	60.96	Safe
Story5	3.048	19.387	106.6285	22.5665	60.96	Safe

Story4	3.048	15.284	84.062	22.605	60.96	Safe
Story3	3.048	11.174	61.457	21.4665	60.96	Safe
Story2	3.048	7.271	39.9905	18.821	60.96	Safe
Story1	3.048	3.849	21.1695	13.9205	60.96	Safe
Ground Floor	3.048	1.318	7.249	7.249	60.96	Safe
Base	0	0	0	0	0	Safe

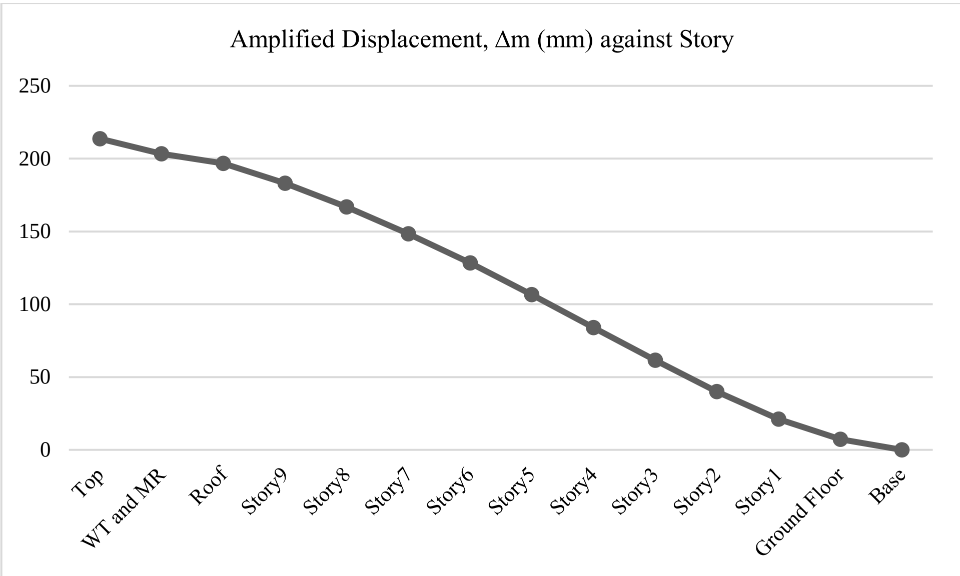

Figure 4.18: Amplified Displacement in X-E Direction of Zone II (Dhaka)

Highest Amplified Displacement in X-E direction of Zone II (Dhaka) = 213.7245 mm.

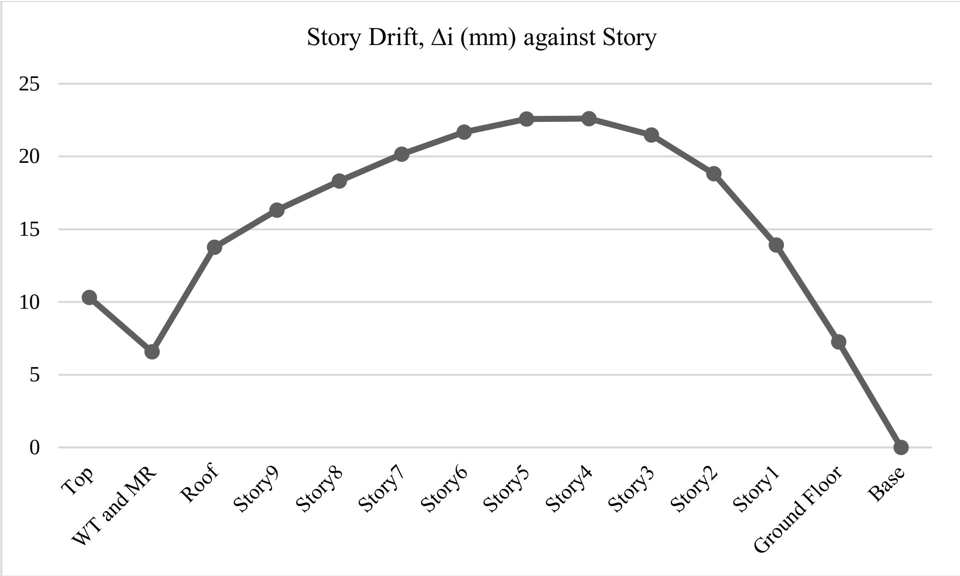

Figure 4.19: Story Drift in X-E Direction of Zone II (Dhaka)

Highest Story Drift in X-E direction of Zone II (Dhaka) = 22.605 mm.

Table 4.10: Story Drift and Displacement in Y+E Direction of Zone II (Dhaka)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	80.49	442.695	17.0445	42.672	Safe
WT and MR	3.048	77.391	425.6505	5.3075	60.96	Safe
Roof	3.048	78.356	430.958	23.7325	60.96	Safe
Story9	3.048	74.041	407.2255	29.766	60.96	Safe
Story8	3.048	68.629	377.4595	35.9205	60.96	Safe
Story7	3.048	62.098	341.539	41.7505	60.96	Safe
Story6	3.048	54.507	299.7885	46.7005	60.96	Safe
Story5	3.048	46.016	253.088	50.2975	60.96	Safe

Story4	3.048	36.871	202.7905	51.9915	60.96	Safe
Story3	3.048	27.418	150.799	51.1005	60.96	Safe
Story2	3.048	18.127	99.6985	46.5135	60.96	Safe
Story1	3.048	9.67	53.185	37.84	60.96	Safe
Ground Floor	3.048	2.79	15.345	15.345	60.96	Safe
Base	0	0	0	0	0	Safe

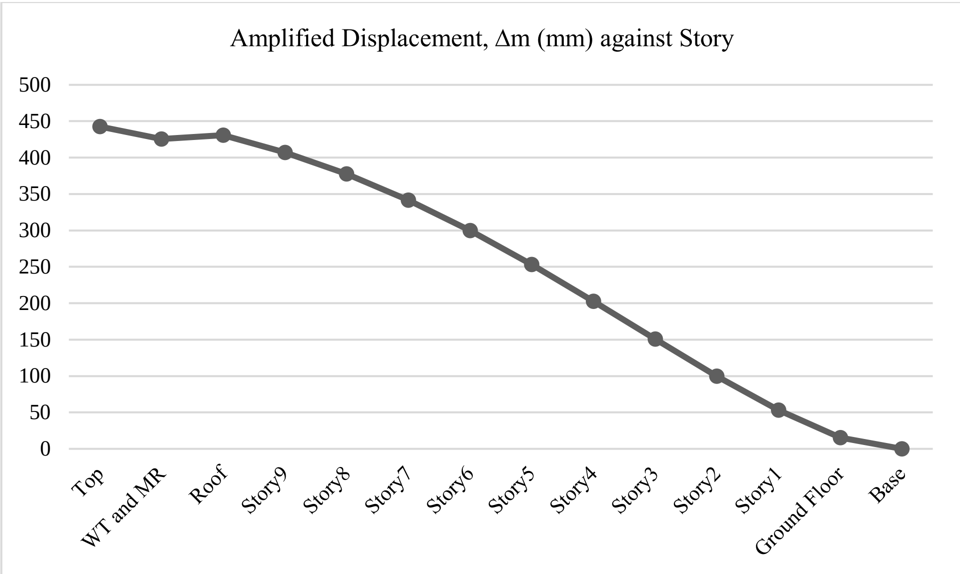

Figure 4.20: Amplified Displacement in Y+E Direction of Zone II (Dhaka)

Highest Amplified Displacement in Y+E direction of Zone II (Dhaka) = 442.695 mm.

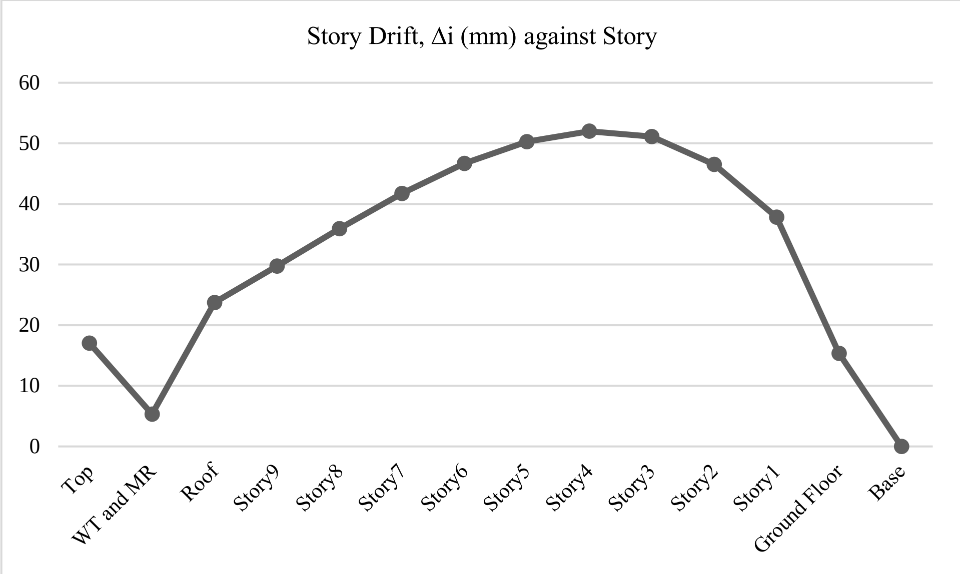

Figure 4.21: Story Drift in Y+E Direction of Zone II (Dhaka)

Highest Story Drift in Y+E direction of Zone II (Dhaka) = 51.9915 mm.

Table 4.11: Story Drift and Displacement in Y-E Direction of Zone II (Dhaka)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	80.505	442.7775	17.0555	42.672	Safe
WT and MR	3.048	77.404	425.722	5.225	60.96	Safe
Roof	3.048	78.354	430.947	23.5345	60.96	Safe
Story9	3.048	74.075	407.4125	29.601	60.96	Safe
Story8	3.048	68.693	377.8115	35.7775	60.96	Safe
Story7	3.048	62.188	342.034	41.624	60.96	Safe
Story6	3.048	54.62	300.41	46.607	60.96	Safe
Story5	3.048	46.146	253.803	50.248	60.96	Safe

Story4	3.048	37.01	203.555	52.0135	60.96	Safe
Story3	3.048	27.553	151.5415	51.227	60.96	Safe
Story2	3.048	18.239	100.3145	46.761	60.96	Safe
Story1	3.048	9.737	53.5535	38.7805	60.96	Safe
Ground Floor	3.048	2.686	14.773	14.773	60.96	Safe
Base	0	0	0	0	0	Safe

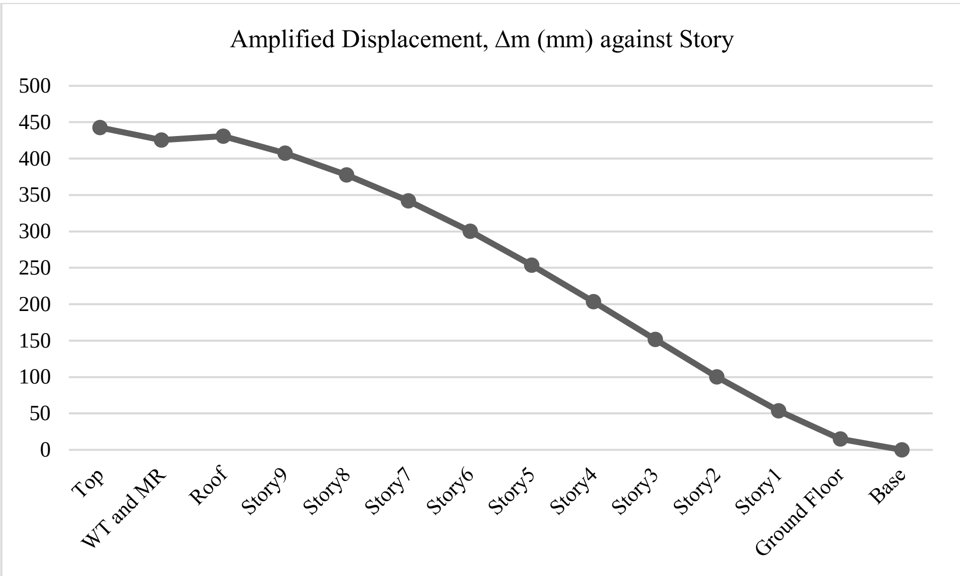

Figure 4.22: Amplified Displacement in Y-E Direction of Zone II (Dhaka)

Highest Amplified Displacement in Y-E direction of Zone II (Dhaka) = 442.7775 mm.

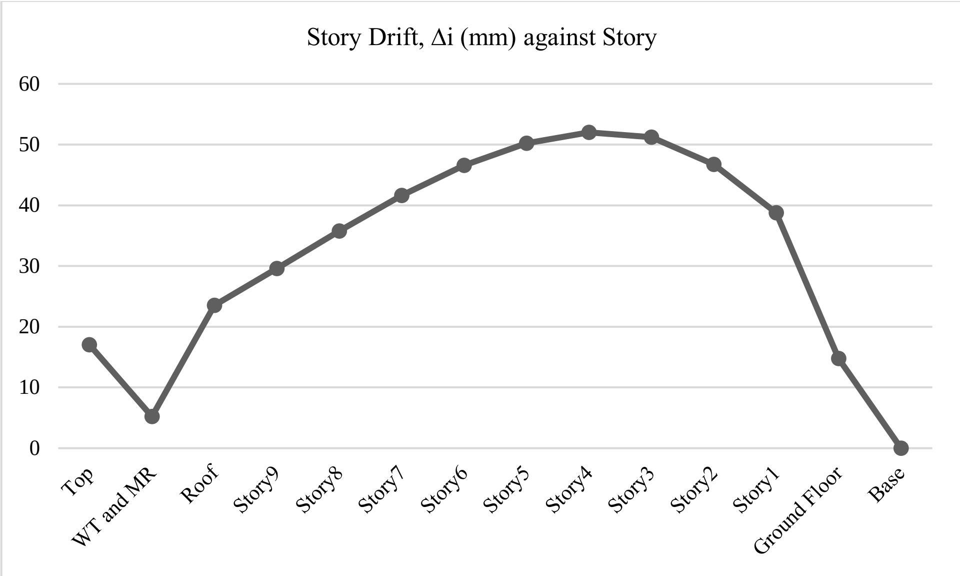

Figure 4.23: Story Drift in Y-E Direction of Zone II (Dhaka)

Highest Story Drift in Y-E direction of Zone II (Dhaka) = 52.0135 mm.

4.8.3 Zone III (Tangail)

Table 4.12: Story Drift and Displacement in X+E Direction of Zone III (Tangail)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	34.368	189.024	3.982	42.672	Safe
WT and MR	3.048	33.644	185.042	9.086	60.96	Safe
Roof	3.048	31.992	175.956	10.7965	60.96	Safe
Story9	3.048	30.029	165.1595	13.4475	60.96	Safe
Story8	3.048	27.584	151.712	15.5375	60.96	Safe
Story7	3.048	24.759	136.1745	17.3855	60.96	Safe
Story6	3.048	21.598	118.789	18.9035	60.96	Safe

Story5	3.048	18.161	99.8855	19.9155	60.96	Safe
Story4	3.048	14.54	79.97	20.262	60.96	Safe
Story3	3.048	10.856	59.708	19.712	60.96	Safe
Story2	3.048	7.272	39.996	17.919	60.96	Safe
Story1	3.048	4.014	22.077	15.103	60.96	Safe
Ground Floor	3.048	1.268	6.974	6.974	60.96	Safe
Base	0	0	0	0	0	Safe

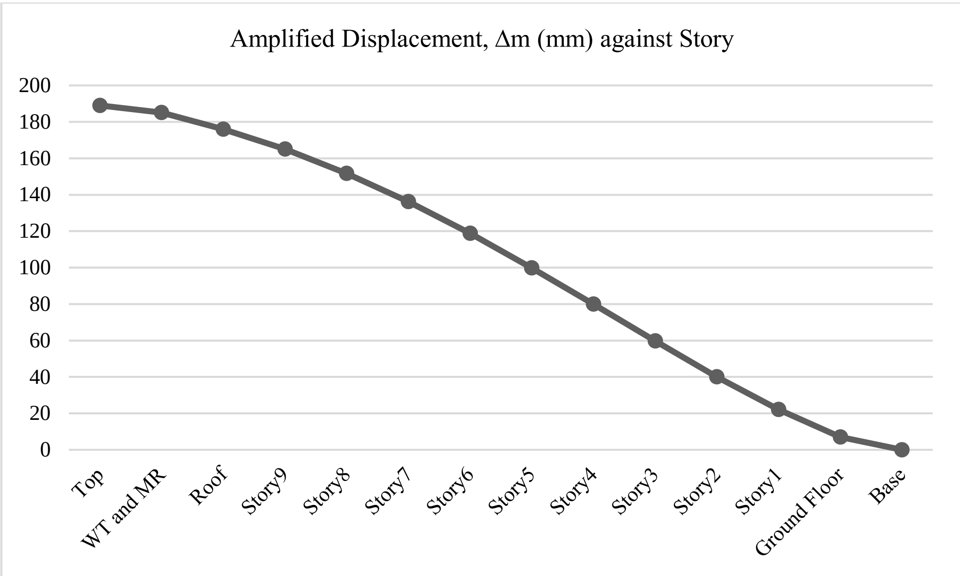

Figure 4.24: Amplified Displacement in X+E Direction of Zone III (Tangail)

Highest Amplified Displacement in X+E direction of ZoneIII (Tangail) = 189.024 mm.

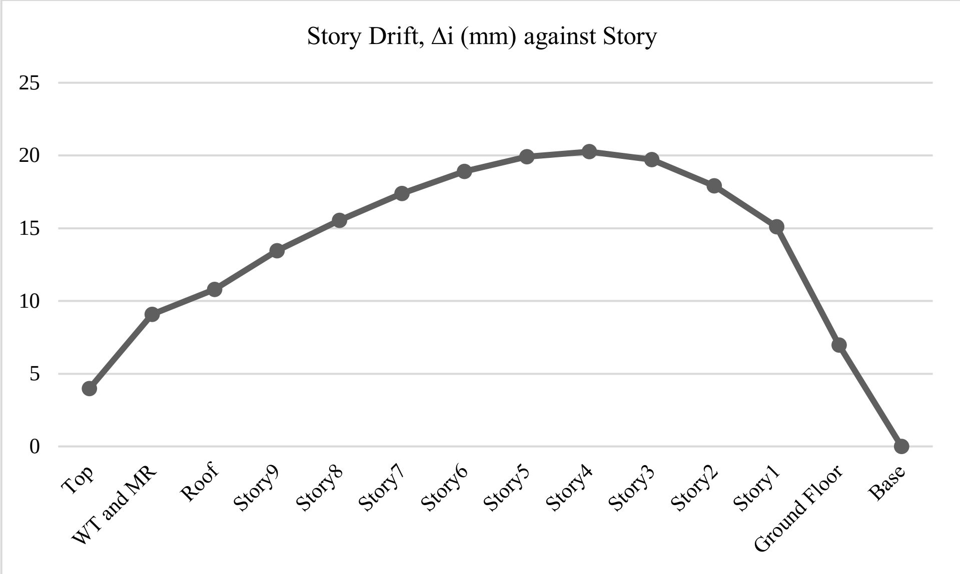

Figure 4.25: Story Drift in X+E Direction of Zone III (Tangail)

Highest Story Drift in X+E direction of Zone III (Tangail) = 20.262 mm.

Table 4.13: Story Drift and Displacement in X-E Direction of Zone III (Tangail)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	34.757	191.1635	9.2125	42.672	Safe
WT and MR	3.048	33.082	181.951	5.8905	60.96	Safe
Roof	3.048	32.011	176.0605	12.309	60.96	Safe
Story9	3.048	29.773	163.7515	14.6025	60.96	Safe
Story8	3.048	27.118	149.149	16.368	60.96	Safe
Story7	3.048	24.142	132.781	18.029	60.96	Safe
Story6	3.048	20.864	114.752	19.3765	60.96	Safe
Story5	3.048	17.341	95.3755	20.1905	60.96	Safe

Story4	3.048	13.67	75.185	20.218	60.96	Safe
Story3	3.048	9.994	54.967	19.2005	60.96	Safe
Story2	3.048	6.503	35.7665	16.83	60.96	Safe
Story1	3.048	3.443	18.9365	12.452	60.96	Safe
Ground Floor	3.048	1.179	6.4845	6.4845	60.96	Safe
Base	0	0	0	0	0	Safe

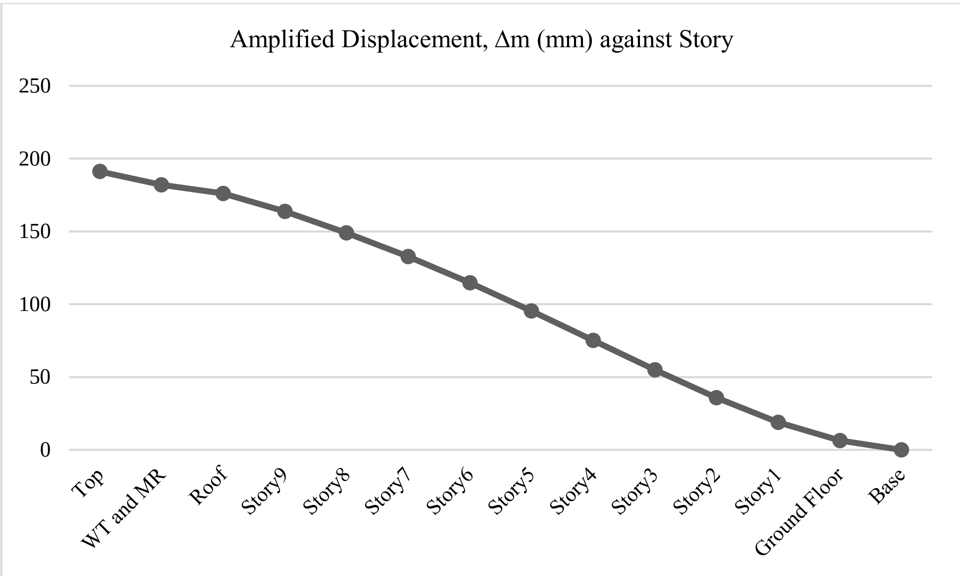

Figure 4.26: Amplified Displacement in X-E Direction of Zone III (Tangail)

Highest Amplified Displacement in X-E direction of Zone III (Tangail) = 191.1635 mm.

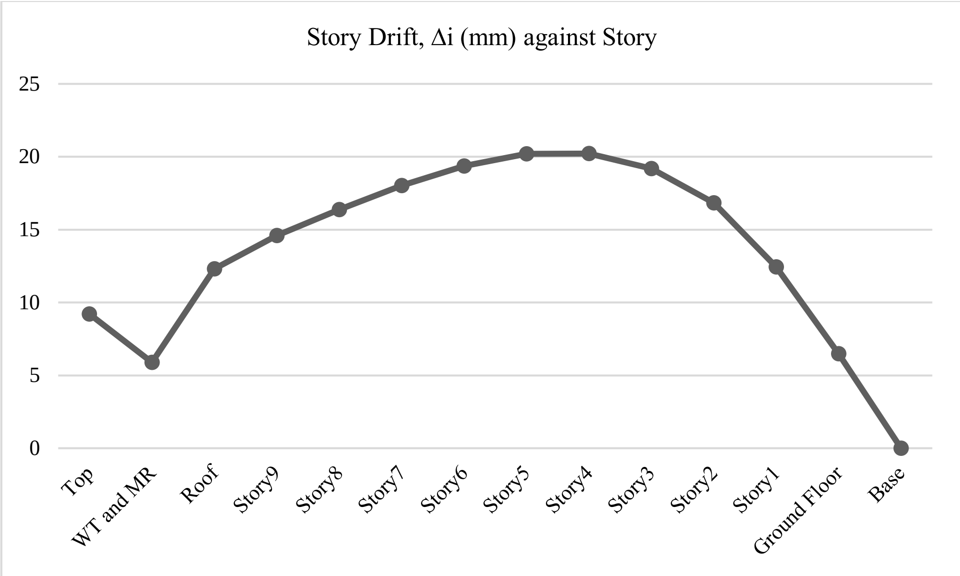

Figure 4.27: Story Drift in X-E Direction of Zone III (Tangail)

Highest Story Drift in X-E direction of Zone III (Tangail) = 20.218 mm.

Table 4.14: Story Drift and Displacement in Y+E Direction of Zone III (Tangail)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	71.994	395.967	15.246	42.672	Safe
WT and MR	3.048	69.222	380.721	4.7465	60.96	Safe
Roof	3.048	70.085	385.4675	21.2245	60.96	Safe
Story9	3.048	66.226	364.243	26.6255	60.96	Safe
Story8	3.048	61.385	337.6175	32.131	60.96	Safe
Story7	3.048	55.543	305.4865	37.3395	60.96	Safe
Story6	3.048	48.754	268.147	41.778	60.96	Safe
Story5	3.048	41.158	226.369	44.9845	60.96	Safe

Story4	3.048	32.979	181.3845	46.5025	60.96	Safe
Story3	3.048	24.524	134.882	45.705	60.96	Safe
Story2	3.048	16.214	89.177	41.6075	60.96	Safe
Story1	3.048	8.649	47.5695	33.8415	60.96	Safe
Ground Floor	3.048	2.496	13.728	13.728	60.96	Safe
Base	0	0	0	0	0	Safe

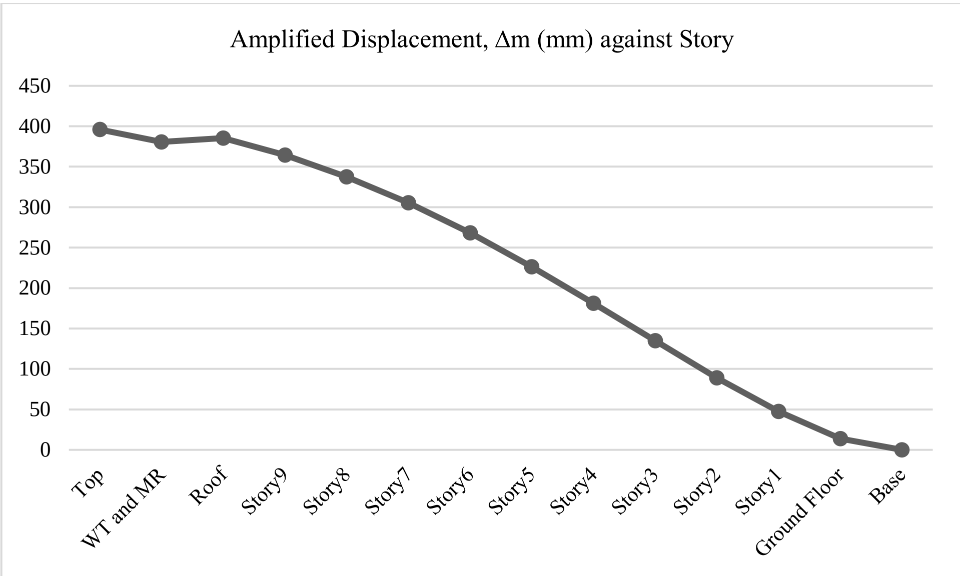

Figure 4.28: Amplified Displacement in Y+E Direction of Zone III (Tangail)

Highest Amplified Displacement in Y+E direction of Zone III (Tangail) = 395.967 mm.

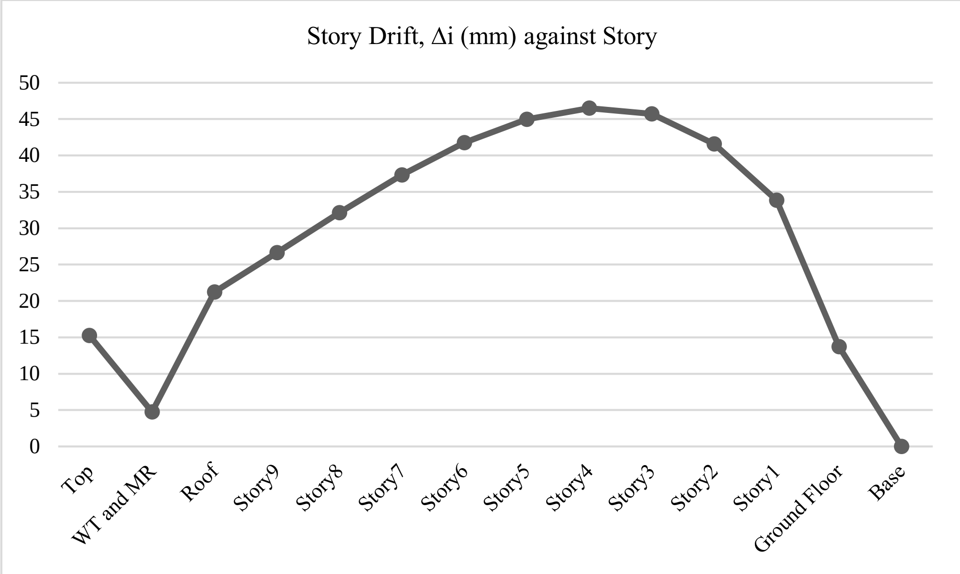

Figure 4.29: Story Drift in Y+E Direction of Zone III (Tangail)

Highest Story Drift in Y+E direction of Zone III (Tangail) = 46.5025 mm.

Table 4.15: Story Drift and Displacement in Y-E Direction of Zone III (Tangail)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	72.007	396.0385	15.257	42.672	Safe
WT and MR	3.048	69.233	380.7815	4.675	60.96	Safe
Roof	3.048	70.083	385.4565	21.0485	60.96	Safe
Story9	3.048	66.256	364.408	26.477	60.96	Safe
Story8	3.048	61.442	337.931	32.0045	60.96	Safe
Story7	3.048	55.623	305.9265	37.224	60.96	Safe
Story6	3.048	48.855	268.7025	41.69	60.96	Safe
Story5	3.048	41.275	227.0125	44.9405	60.96	Safe

Story4	3.048	33.104	182.072	46.5245	60.96	Safe
Story3	3.048	24.645	135.5475	45.8205	60.96	Safe
Story2	3.048	16.314	89.727	41.8275	60.96	Safe
Story1	3.048	8.709	47.8995	34.683	60.96	Safe
Ground Floor	3.048	2.403	13.2165	13.2165	60.96	Safe
Base	0	0	0	0	0	Safe

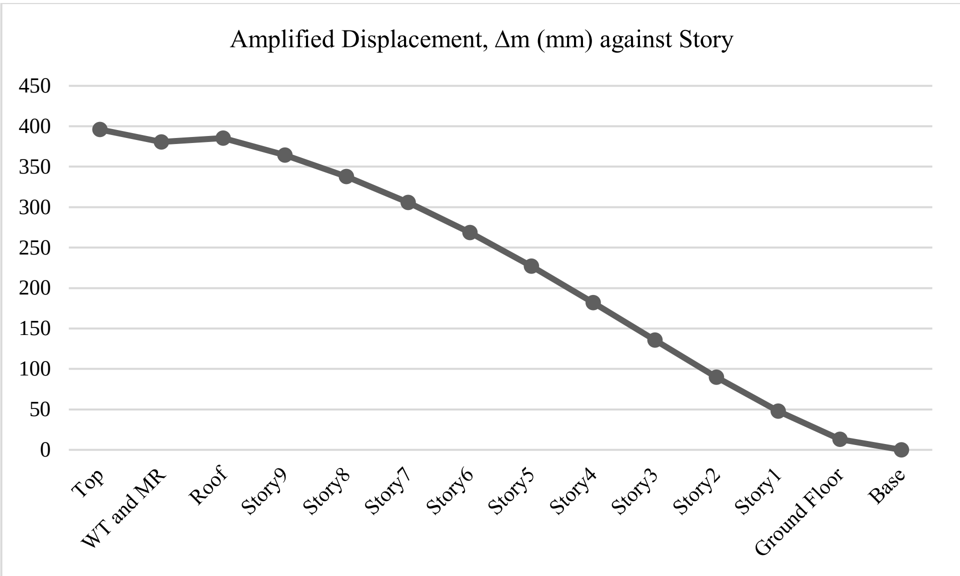

Figure 4.30: Amplified Displacement in Y-E Direction of Zone III (Tangail)

Highest Amplified Displacement in Y-E direction of Zone III (Tangail) = 396.0385 mm.

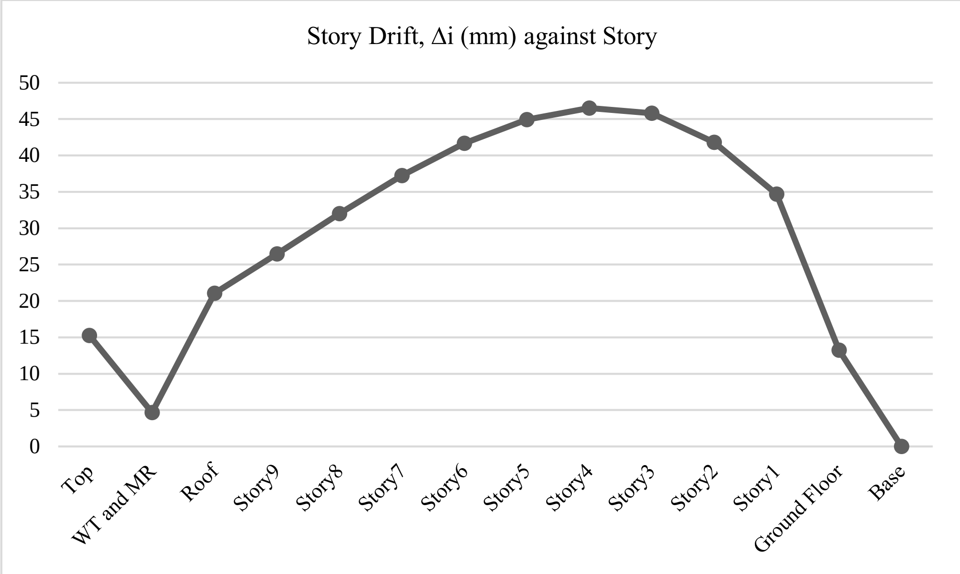

Figure 4.31: Story Drift in Y-E Direction of Zone III (Tangail)

Highest Story Drift in Y-E direction of Zone III (Tangail) = 46.5245 mm.

4.8.4 Zone IV (Habiganj)

Table 4.16: Story Drift and Displacement in X+E Direction of Zone IV (Habiganj)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	44.187	243.0285	5.1205	42.672	Safe
WT and MR	3.048	43.256	237.908	11.6765	60.96	Safe
Roof	3.048	41.133	226.2315	13.882	60.96	Safe
Story9	3.048	38.609	212.3495	17.292	60.96	Safe
Story8	3.048	35.465	195.0575	19.976	60.96	Safe
Story7	3.048	31.833	175.0815	22.352	60.96	Safe

Story6	3.048	27.769	152.7295	24.3045	60.96	Safe
Story5	3.048	23.35	128.425	25.6025	60.96	Safe
Story4	3.048	18.695	102.8225	26.0535	60.96	Safe
Story3	3.048	13.958	76.769	25.3495	60.96	Safe
Story2	3.048	9.349	51.4195	23.034	60.96	Safe
Story1	3.048	5.161	28.3855	19.4205	60.96	Safe
Ground Floor	3.048	1.63	8.965	8.965	60.96	Safe
Base	0	0	0	0	0	Safe

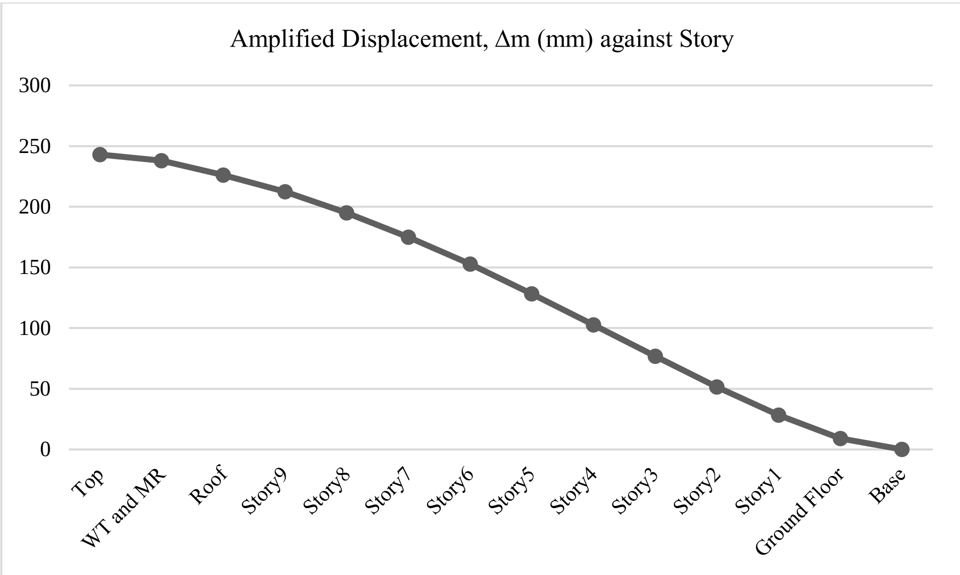

Figure 4.32: Amplified Displacement in X+E Direction of Zone IV (Habiganj)

Highest Amplified Displacement in X+E direction of Zone IV (Habiganj) = 243.0285 mm.

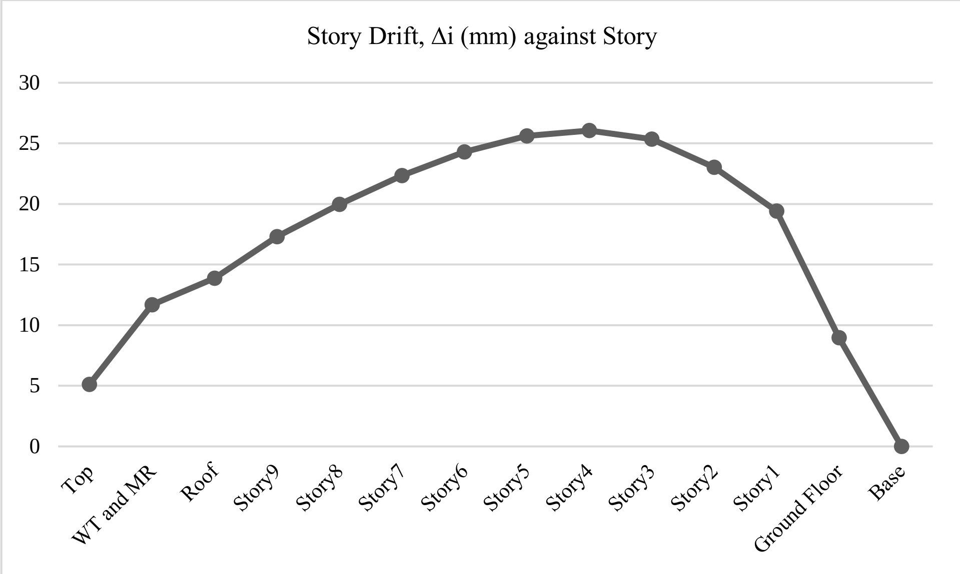

Figure 4.33: Story Drift in X+E Direction of Zone IV (Habiganj)

Highest Story Drift in X+E direction of Zone IV (Habiganj) = 26.0535 mm.

Table 4.17: Story Drift and Displacement in X-E Direction of Zone IV (Habiganj)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	44.688	245.784	11.847	42.672	Safe
WT and MR	3.048	42.534	233.937	7.5735	60.96	Safe
Roof	3.048	41.157	226.3635	15.829	60.96	Safe
Story9	3.048	38.279	210.5345	18.7715	60.96	Safe
Story8	3.048	34.866	191.763	21.043	60.96	Safe
Story7	3.048	31.04	170.72	23.177	60.96	Safe
Story6	3.048	26.826	147.543	24.9205	60.96	Safe

Story5	3.048	22.295	122.6225	25.9545	60.96	Safe
Story4	3.048	17.576	96.668	25.993	60.96	Safe
Story3	3.048	12.85	70.675	24.6895	60.96	Safe
Story2	3.048	8.361	45.9855	21.637	60.96	Safe
Story1	3.048	4.427	24.3485	16.016	60.96	Safe
Ground Floor	3.048	1.515	8.3325	8.3325	60.96	Safe
Base	0	0	0	0	0	Safe

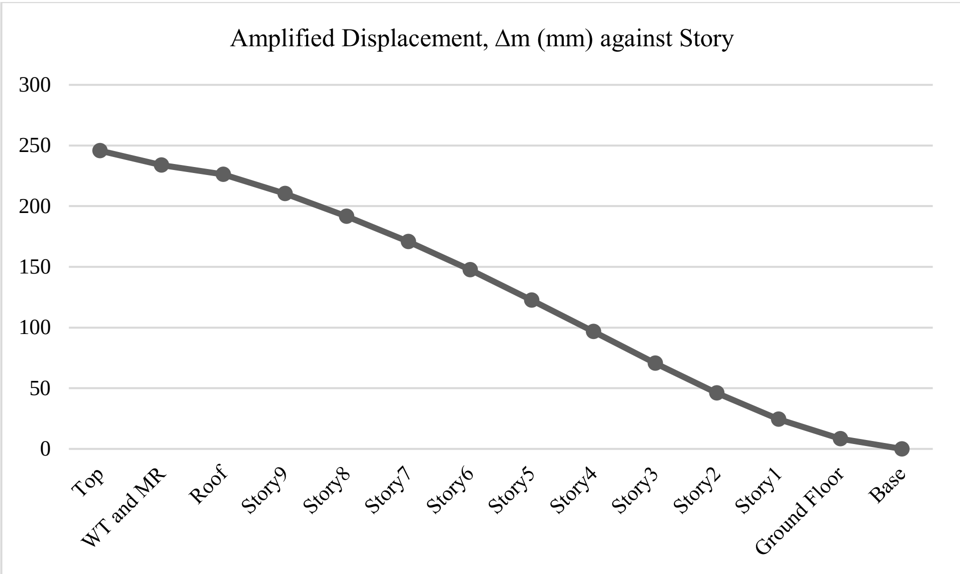

Figure 4.34: Amplified Displacement in X-E Direction of Zone IV (Habiganj)

Highest Amplified Displacement in X-E direction of Zone IV (Habiganj) = 245.784 mm.

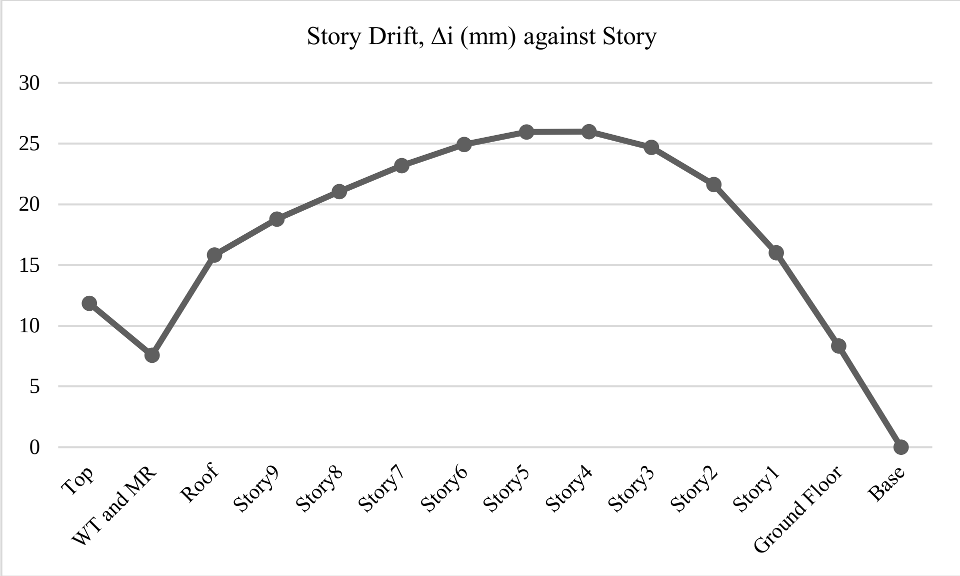

Figure 4.35: Story Drift in X-E Direction of Zone IV (Habiganj)

Highest Story Drift in X-E direction of Zone IV (Habiganj) = 25.993 mm.

Table 4.18: Story Drift and Displacement in Y+E Direction of Zone IV (Habiganj)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	92.563	509.0965	19.5965	42.672	Safe
WT and MR	3.048	89	489.5	6.105	60.96	Safe
Roof	3.048	90.11	495.605	27.2965	60.96	Safe
Story9	3.048	85.147	468.3085	34.2265	60.96	Safe
Story8	3.048	78.924	434.082	41.316	60.96	Safe
Story7	3.048	71.412	392.766	48.0095	60.96	Safe
Story6	3.048	62.683	344.7565	53.7075	60.96	Safe

Story5	3.048	52.918	291.049	57.805	60.96	Safe
Story4	3.048	42.408	233.244	59.8235	60.96	Safe
Story3	3.048	31.531	173.4205	58.7675	60.96	Safe
Story2	3.048	20.846	114.653	53.4875	60.96	Safe
Story1	3.048	11.121	61.1655	43.516	60.96	Safe
Ground Floor	3.048	3.209	17.6495	17.6495	60.96	Safe
Base	0	0	0	0	0	Safe

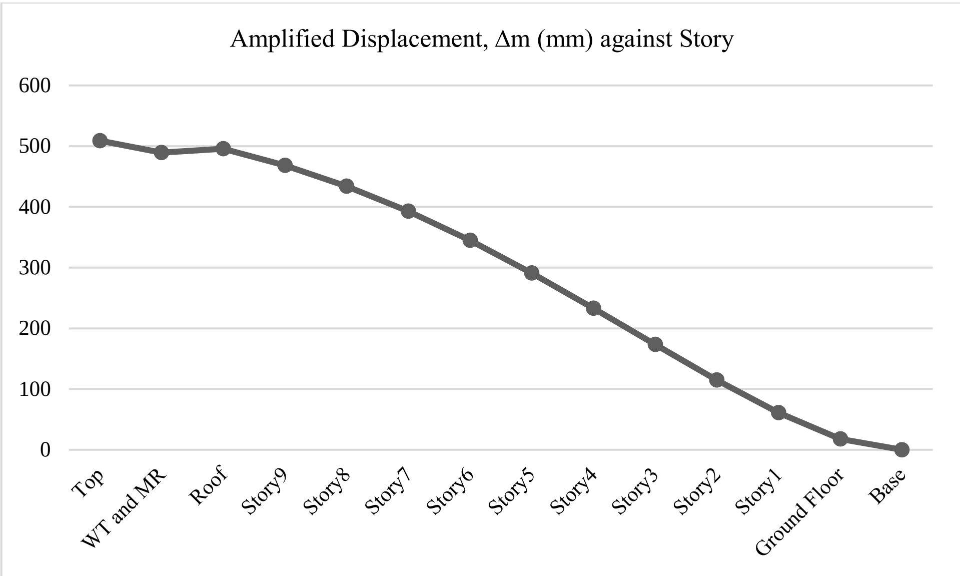

Figure 4.36: Amplified Displacement in Y+E Direction of Zone IV (Habiganj)

Highest Amplified Displacement in Y+E direction of Zone IV (Habiganj) = 509.0965 mm.

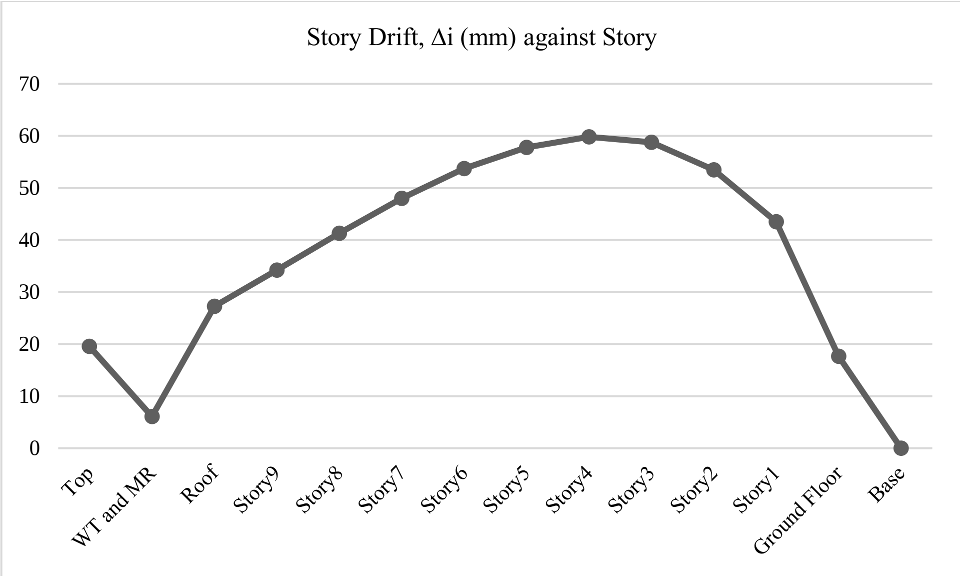

Figure 4.37: Story Drift in Y+E Direction of Zone IV (Habiganj)

Highest Story Drift in Y+E direction of Zone IV (Habiganj) = 59.8235 mm.

Table 4.19: Story Drift and Displacement in Y-E Direction of Zone IV (Habiganj)

Story Name	Height (m)	Elastic Displacement, δ (mm)	Amplified Displacement, Δm (mm)	Story Drift, Δi (mm)	Allowable Story Drift, Δa (mm)	Check
Top	2.1336	92.581	509.1955	19.6185	42.672	Safe
WT and MR	3.048	89.014	489.577	6.0115	60.96	Safe
Roof	3.048	90.107	495.5885	27.0655	60.96	Safe
Story9	3.048	85.186	468.523	34.0395	60.96	Safe
Story8	3.048	78.997	434.4835	41.1455	60.96	Safe
Story7	3.048	71.516	393.338	47.8665	60.96	Safe
Story6	3.048	62.813	345.4715	53.603	60.96	Safe

Story5	3.048	53.067	291.8685	57.7775	60.96	Safe
Story4	3.048	42.562	234.091	59.818	60.96	Safe
Story3	3.048	31.686	174.273	58.9105	60.96	Safe
Story2	3.048	20.975	115.3625	53.779	60.96	Safe
Story1	3.048	11.197	61.5835	44.594	60.96	Safe
Ground Floor	3.048	3.089	16.9895	16.9895	60.96	Safe
Base	0	0	0	0	0	Safe

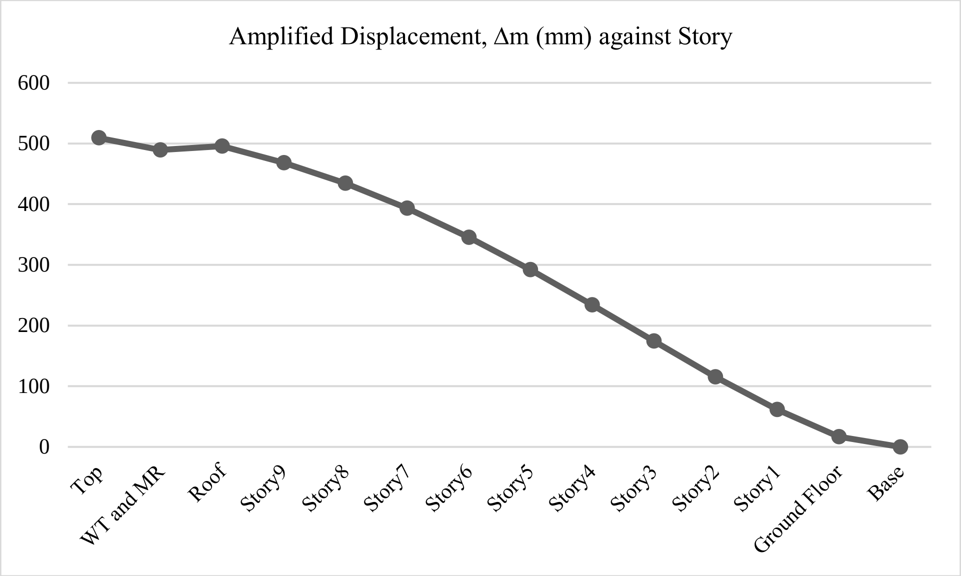

Figure 4.38: Amplified Displacement in Y-E Direction of Zone IV (Habiganj)

Highest Amplified Displacement in Y-E direction of Zone IV (Habiganj) = 509.1955 mm.

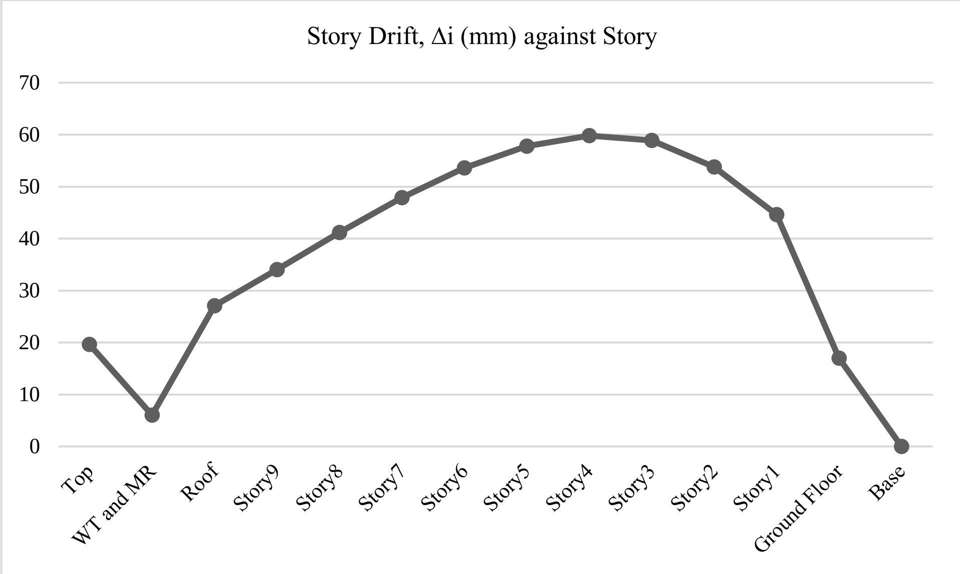

Figure 4.39: Story Drift in Y-E Direction of Zone IV (Habiganj)

Highest Story Drift in Y-E direction of Zone IV (Habiganj) = 59.818 mm.

4.9 Comparison of Highest Story Drift and Amplified Displacement

Table 4.20: Highest Story Amplified Displacement, ∆m (mm) in X+E Direction of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
X+E	126.797	211.332	189.024	243.0285

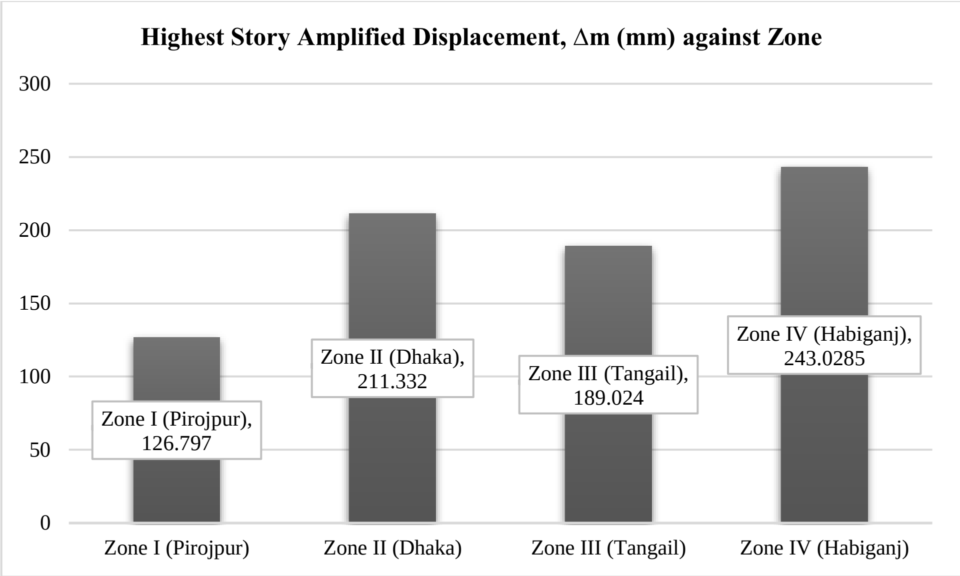

Figure 4.40: Highest Story Amplified Displacement, Δm (mm) in X+E Direction of All Zones

Highest Story Amplified Displacement, Δm in X+E direction among all zones is 243.0285 mm for Zone IV (Habiganj).

Table 4.21: Highest Story Amplified Displacement, Δm (mm) in X-E Direction of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
X-E	128.2325	213.7245	191.1635	245.784

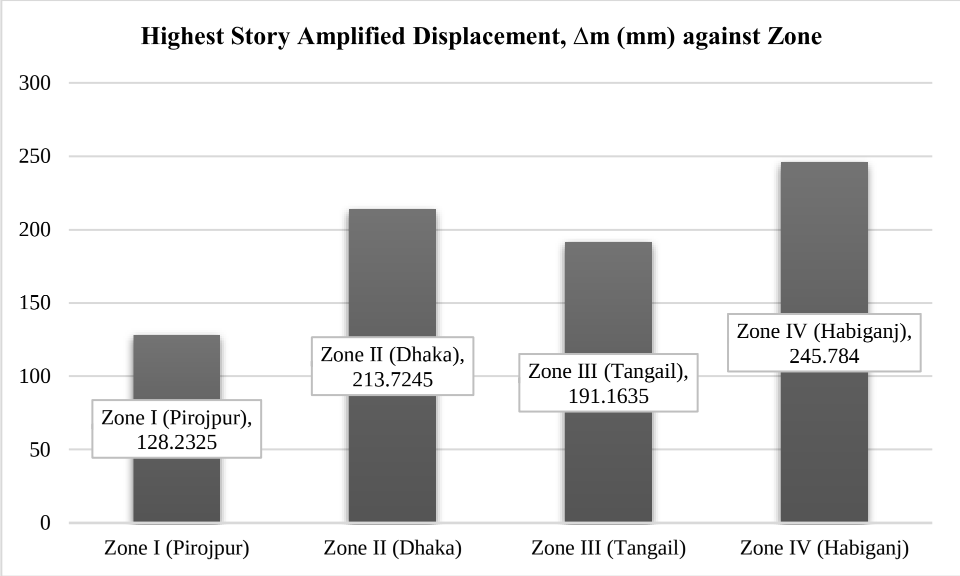

Figure 4.41: Highest Story Amplified Displacement, ∆m (mm) in X-E Direction of All Zones

Highest Story Amplified Displacement, ∆m in X-E direction among all zones is 245.784 mm for Zone IV (Habiganj).

Table 4.22: Highest Story Amplified Displacement, ∆m (mm) in Y+E Direction of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
Y+E	265.617	442.695	395.967	509.0965

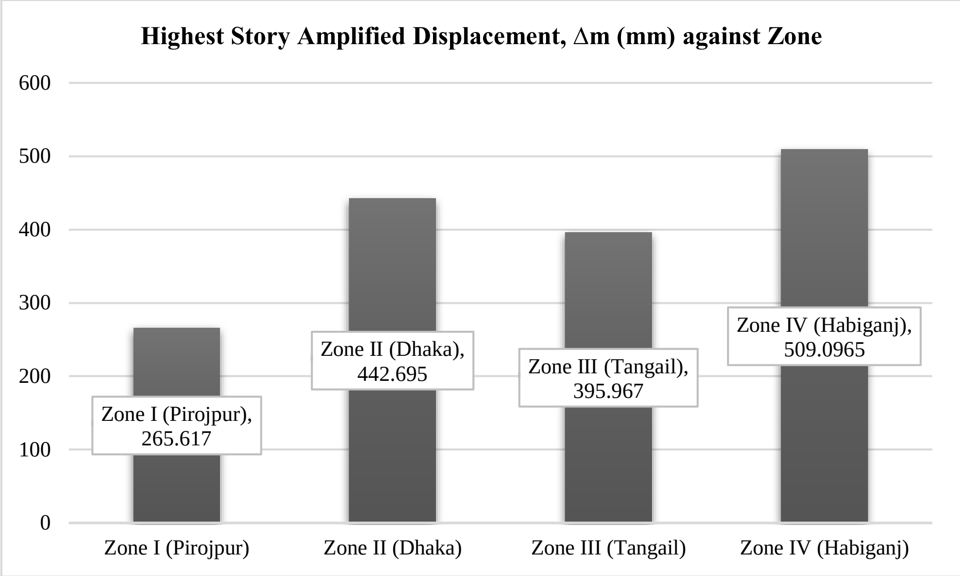

Figure 4.42: Highest Story Amplified Displacement, Δm (mm) in Y+E Direction of All Zones

Highest Story Amplified Displacement, Δm in Y+E direction among all zones is 509.0965 mm for Zone IV (Habiganj).

Table 4.23: Highest Story Amplified Displacement, Δm (mm) in Y-E Direction of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
Y-E	265.6665	442.7775	396.0385	509.1955

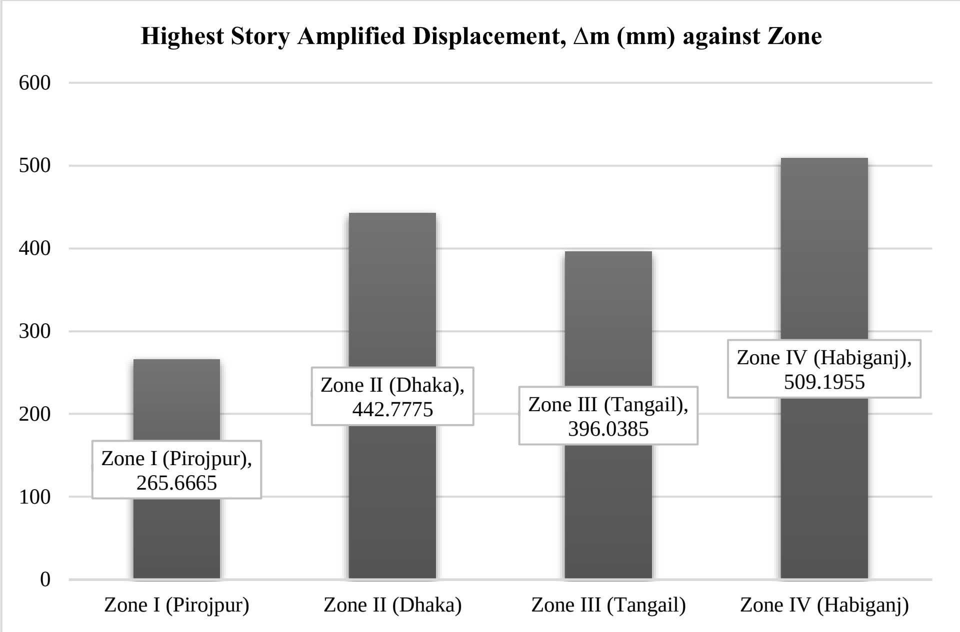

Figure 4.43: Highest Story Amplified Displacement, Δm (mm) in Y-E Direction of All Zones

Highest Story Amplified Displacement, Δm in Y-E direction among all zones is 509.1955 mm for Zone IV (Habiganj).

Table 4.24: Highest Story Amplified Displacement, Δm (mm) in All Directions of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
X+E	126.797	211.332	189.024	243.0285
X-E	128.2325	213.7245	191.1635	245.784
Y+E	265.617	442.695	395.967	509.0965
Y-E	265.6665	442.7775	396.0385	509.1955

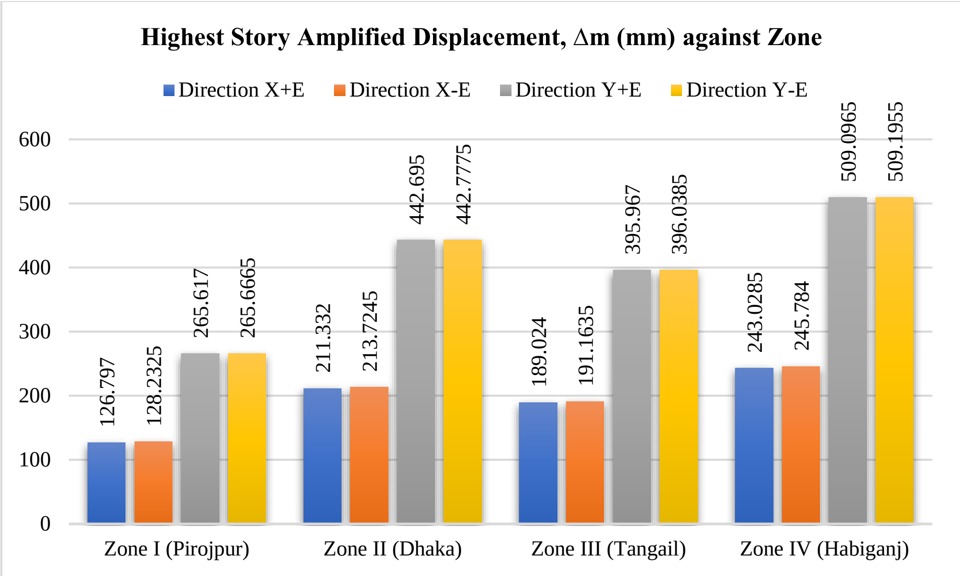

Figure 4.44: Highest Story Amplified Displacement, Δm (mm) in All Directions of All Zones

Highest Story Amplified Displacement, Δm in all directions of Zone I (Pirojpur) is 265.6665 mm for Y-E direction.

Highest Story Amplified Displacement, Δm in all directions of Zone II (Dhaka) is 442.7775 mm for Y-E direction.

Highest Story Amplified Displacement, Δm in all directions of Zone III (Tangail) is 396.0385 mm for Y-E direction.

Highest Story Amplified Displacement, Δm in all directions of Zone IV (Habiganj) is 509.1955 mm for Y-E direction.

Highest Story Amplified Displacement, Δm in all directions among all zones is 509.1955 mm for Y-E direction of Zone IV (Habiganj).

Table 4.25: Highest Story Drift, Δi (mm) in X+E Direction of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
X+E	13.596	22.6545	20.262	26.0535

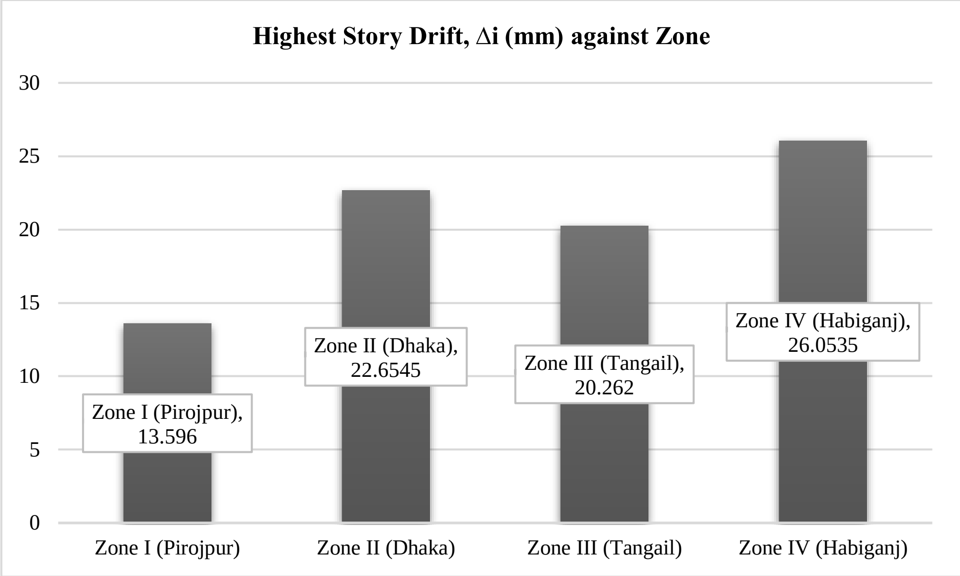

Figure 4.45: Highest Story Drift, ∆i (mm) in X+E Direction of All Zones

Highest Story Drift, ∆i in X+E direction among all zones is 26.0535 mm for Zone IV (Habiganj).

Table 4.26: Highest Story Drift, ∆i (mm) in X-E Direction of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
X-E	13.563	22.605	20.218	25.993

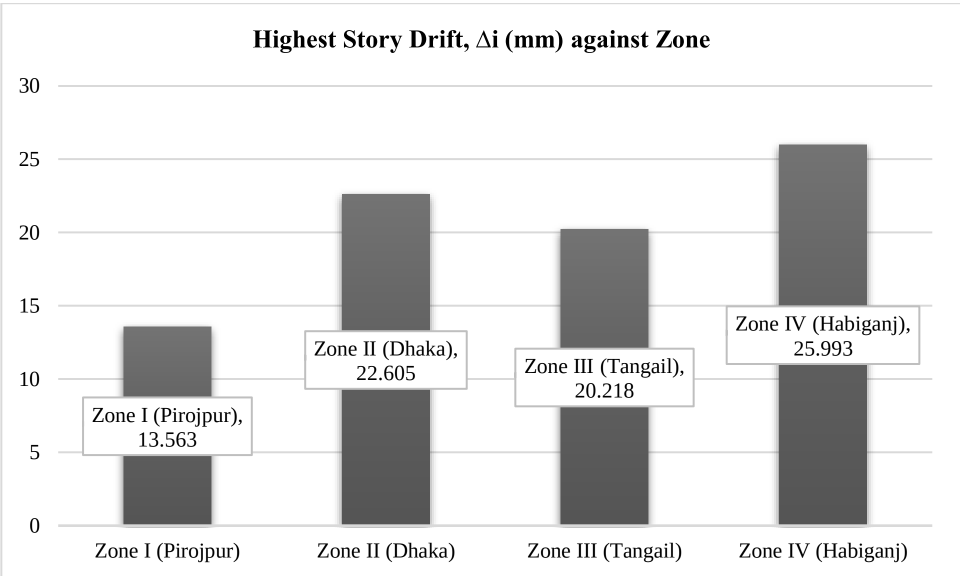

Figure 4.46: Highest Story Drift, ∆i (mm) in X-E Direction of All Zones

Highest Story Drift, ∆i in X-E direction among all zones is 25.993 mm for Zone IV (Habiganj).

Table 4.27: Highest Story Drift, ∆i (mm) in Y+E Direction of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
Y+E	31.196	51.9915	46.5025	59.8235

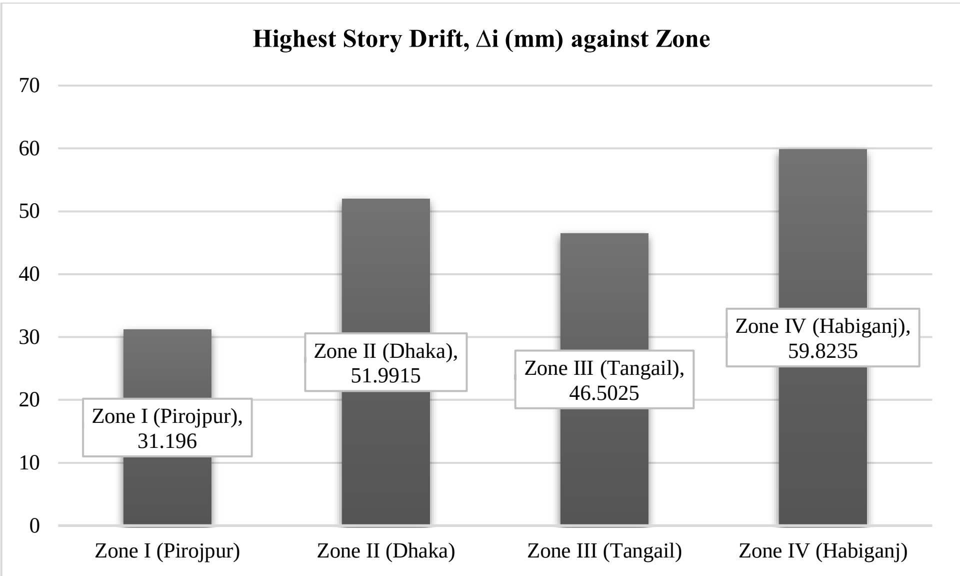

Figure 4.47: Highest Story Drift, ∆i (mm) in Y+E Direction of All Zones

Highest Story Drift, ∆i Y+E direction among all zones is 59.8235 mm for Zone IV (Habiganj).

Table 4.28: Highest Story Drift, ∆i (mm) in Y-E Direction of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
Y-E	31.207	52.0135	46.5245	59.818

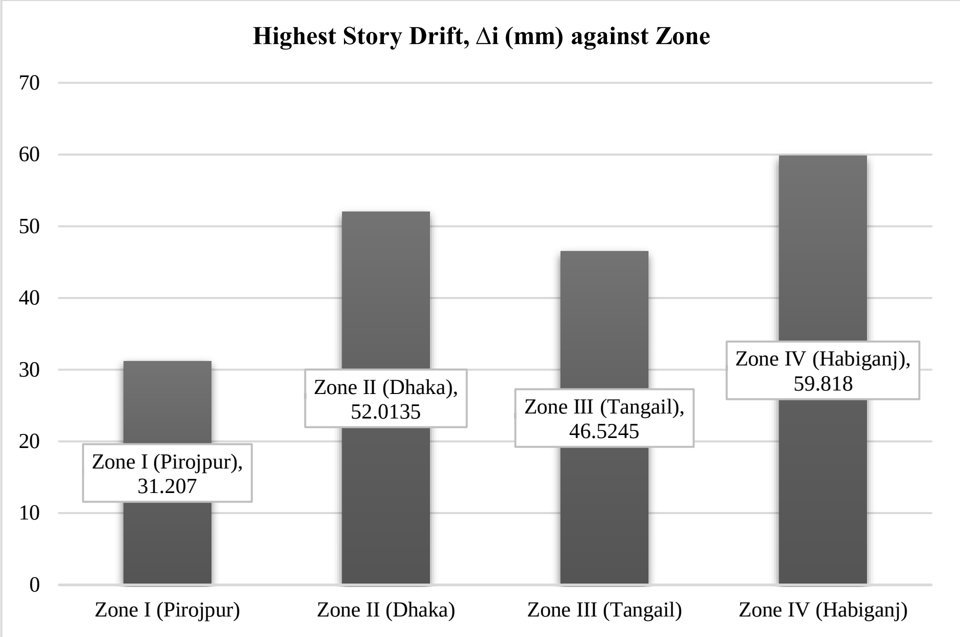

Figure 4.48: Highest Story Drift, ∆i (mm) in Y-E Direction of All Zones

Highest Story Drift, ∆i Y-E direction among all zones is 59.818 mm for Zone IV (Habiganj).

Table 4.29: Highest Story Drift, ∆i (mm) in All Directions of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
X+E	13.596	22.6545	20.262	26.0535
X-E	13.563	22.605	20.218	25.993
Y+E	31.196	51.9915	46.5025	59.8235
Y-E	31.207	52.0135	46.5245	59.818

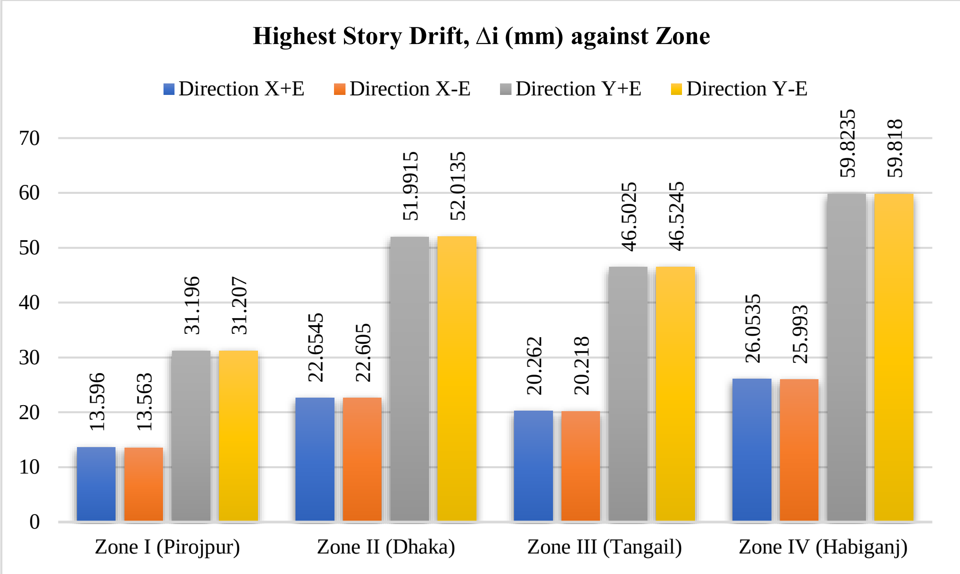

Figure 4.49: Highest Story Drift, Δi (mm) in All Directions of All Zones

Highest Story Drift, Δi in all directions of Zone I (Pirojpur) is 31.207 mm for Y-E direction.

Highest Story Drift, Δi in all directions of Zone II (Dhaka) is 52.0135 mm for Y-E direction.

Highest Story Drift, Δi in all directions of Zone III (Tangail) is 46.5245 mm for Y-E direction.

Highest Story Drift, Δi in all directions of Zone IV (Habiganj) is 59.8235 mm for Y+E direction.

Highest Story Drift, Δi in all directions among all zones is 59.8235 mm for Y+E direction of Zone IV (Habiganj).

4.10 Findings of Torsion Irregularity

4.10.1 Zone I (Pirojpur)

Table 4.30: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in X+E Direction of Zone I (Pirojpur)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check

Top	1.053	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.032	Regular	Regular
WT and MR	1.012	Regular	Regular
Roof	1.050	Regular	Regular
Story9	1.004	Regular	Regular
Story8	1.025	Regular	Regular
Story7	1.038	Regular	Regular
Story6	1.048	Regular	Regular
Story5	1.057	Regular	Regular
Story4	1.069	Regular	Regular
Story3	1.086	Regular	Regular
Story2	1.112	Regular	Regular
Story1	1.152	Regular	Regular
Ground Floor	1.001	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in X+E direction of Zone I (Pirojpur) = 1.152.

Table 4.31: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in X-E Direction of Zone I (Pirojpur)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.061	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.002	Regular	Regular
WT and MR	1.016	Regular	Regular
Roof	1.094	Regular	Regular
Story9	1.077	Regular	Regular
Story8	1.070	Regular	Regular
Story7	1.069	Regular	Regular
Story6	1.068	Regular	Regular
Story5	1.066	Regular	Regular
Story4	1.063	Regular	Regular
Story3	1.058	Regular	Regular
Story2	1.047	Regular	Regular
Story1	1.036	Regular	Regular
Ground Floor	1.001	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in X-E direction of Zone I (Pirojpur) = 1.094.

Table 4.32: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in Y+E Direction of Zone I (Pirojpur)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.044	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.011	Regular	Regular
WT and MR	1.004	Regular	Regular
Roof	1.069	Regular	Regular
Story9	1.079	Regular	Regular
Story8	1.089	Regular	Regular
Story7	1.095	Regular	Regular
Story6	1.099	Regular	Regular
Story5	1.102	Regular	Regular
Story4	1.106	Regular	Regular
Story3	1.111	Regular	Regular
Story2	1.120	Regular	Regular
Story1	1.118	Regular	Regular
Ground Floor	1.046	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in Y+E direction of Zone I (Pirojpur) = 1.120.

Table 4.33: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in Y-E Direction of Zone I (Pirojpur)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.047	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.015	Regular	Regular
WT and MR	1.004	Regular	Regular
Roof	1.057	Regular	Regular
Story9	1.072	Regular	Regular
Story8	1.083	Regular	Regular
Story7	1.091	Regular	Regular
Story6	1.096	Regular	Regular
Story5	1.101	Regular	Regular
Story4	1.106	Regular	Regular
Story3	1.114	Regular	Regular
Story2	1.127	Regular	Regular
Story1	1.126	Regular	Regular
Ground Floor	1.008	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in Y-E direction of Zone I (Pirojpur) = 1.127.

4.10.2 Zone II (Dhaka)

Table 4.34: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in X+E Direction of Zone II (Dhaka)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.053	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.032	Regular	Regular
WT and MR	1.012	Regular	Regular
Roof	1.050	Regular	Regular
Story9	1.004	Regular	Regular
Story8	1.025	Regular	Regular
Story7	1.038	Regular	Regular
Story6	1.048	Regular	Regular
Story5	1.057	Regular	Regular
Story4	1.069	Regular	Regular
Story3	1.086	Regular	Regular
Story2	1.112	Regular	Regular
Story1	1.152	Regular	Regular

Ground Floor	1.001	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in X+E direction of Zone II (Dhaka) = 1.152.

Table 4.35: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in X-E Direction of Zone II (Dhaka)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.061	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.002	Regular	Regular
WT and MR	1.016	Regular	Regular
Roof	1.094	Regular	Regular
Story9	1.077	Regular	Regular
Story8	1.070	Regular	Regular
Story7	1.069	Regular	Regular
Story6	1.068	Regular	Regular
Story5	1.066	Regular	Regular
Story4	1.063	Regular	Regular
Story3	1.058	Regular	Regular
Story2	1.047	Regular	Regular

Story1	1.036	Regular	Regular
Ground Floor	1.001	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in X-E direction of Zone II (Dhaka) = 1.094.

Table 4.36: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in Y+E Direction of Zone II (Dhaka)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.044	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.011	Regular	Regular
WT and MR	1.004	Regular	Regular
Roof	1.069	Regular	Regular
Story9	1.079	Regular	Regular
Story8	1.089	Regular	Regular
Story7	1.095	Regular	Regular
Story6	1.099	Regular	Regular
Story5	1.102	Regular	Regular
Story4	1.106	Regular	Regular
Story3	1.111	Regular	Regular

Story2	1.120	Regular	Regular
Story1	1.118	Regular	Regular
Ground Floor	1.046	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in Y+E direction of Zone II (Dhaka) = 1.120.

Table 4.37: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in Y-E Direction of Zone II (Dhaka)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.047	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.015	Regular	Regular
WT and MR	1.004	Regular	Regular
Roof	1.057	Regular	Regular
Story9	1.072	Regular	Regular
Story8	1.083	Regular	Regular
Story7	1.091	Regular	Regular
Story6	1.096	Regular	Regular
Story5	1.101	Regular	Regular
Story4	1.106	Regular	Regular

Story3	1.114	Regular	Regular
Story2	1.127	Regular	Regular
Story1	1.126	Regular	Regular
Ground Floor	1.008	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in Y-E direction of Zone II (Dhaka) = 1.127.

4.10.3 Zone III (Tangail)

Table 4.38: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in X+E Direction of Zone III (Tangail)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.053	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.032	Regular	Regular
WT and MR	1.012	Regular	Regular
Roof	1.050	Regular	Regular
Story9	1.004	Regular	Regular
Story8	1.025	Regular	Regular
Story7	1.038	Regular	Regular
Story6	1.048	Regular	Regular

Story5	1.057	Regular	Regular
Story4	1.069	Regular	Regular
Story3	1.086	Regular	Regular
Story2	1.112	Regular	Regular
Story1	1.152	Regular	Regular
Ground Floor	1.001	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in X+E direction of Zone III (Tangail) = 1.152.

Table 4.39: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in X-E Direction of Zone III (Tangail)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.061	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.002	Regular	Regular
WT and MR	1.016	Regular	Regular
Roof	1.094	Regular	Regular
Story9	1.077	Regular	Regular
Story8	1.070	Regular	Regular
Story7	1.069	Regular	Regular

Story6	1.068	Regular	Regular
Story5	1.066	Regular	Regular
Story4	1.063	Regular	Regular
Story3	1.058	Regular	Regular
Story2	1.047	Regular	Regular
Story1	1.036	Regular	Regular
Ground Floor	1.001	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in X-E direction of Zone III (Tangail) = 1.094.

Table 4.40: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in Y+E Direction of Zone III (Tangail)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.044	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.011	Regular	Regular
WT and MR	1.004	Regular	Regular
Roof	1.069	Regular	Regular
Story9	1.079	Regular	Regular
Story8	1.089	Regular	Regular

Story7	1.095	Regular	Regular
Story6	1.099	Regular	Regular
Story5	1.102	Regular	Regular
Story4	1.106	Regular	Regular
Story3	1.111	Regular	Regular
Story2	1.120	Regular	Regular
Story1	1.118	Regular	Regular
Ground Floor	1.046	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in Y+E direction of Zone III (Tangail) = 1.120.

Table 4.41: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in Y-E Direction of Zone III (Tangail)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.047	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.015	Regular	Regular
WT and MR	1.004	Regular	Regular
Roof	1.057	Regular	Regular
Story9	1.072	Regular	Regular

Story8	1.083	Regular	Regular
Story7	1.091	Regular	Regular
Story6	1.096	Regular	Regular
Story5	1.101	Regular	Regular
Story4	1.106	Regular	Regular
Story3	1.114	Regular	Regular
Story2	1.127	Regular	Regular
Story1	1.126	Regular	Regular
Ground Floor	1.008	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in Y-E direction of Zone III (Tangail) = 1.127.

4.10.4 Zone IV (Habiganj)

Table 4.42: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in X+E Direction of Zone IV (Habiganj)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.053	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.032	Regular	Regular
WT and MR	1.012	Regular	Regular

Roof	1.050	Regular	Regular
Story9	1.004	Regular	Regular
Story8	1.025	Regular	Regular
Story7	1.038	Regular	Regular
Story6	1.048	Regular	Regular
Story5	1.057	Regular	Regular
Story4	1.069	Regular	Regular
Story3	1.086	Regular	Regular
Story2	1.112	Regular	Regular
Story1	1.152	Regular	Regular
Ground Floor	1.001	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in X+E direction of Zone IV (Habiganj) = 1.152.

Table 4.43: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in X-E Direction of Zone IV (Habiganj)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.061	Regular	Regular
Top	1	Regular	Regular
WT and MR	1.002	Regular	Regular

WT and MR	1.016	Regular	Regular
Roof	1.094	Regular	Regular
Story9	1.077	Regular	Regular
Story8	1.070	Regular	Regular
Story7	1.069	Regular	Regular
Story6	1.068	Regular	Regular
Story5	1.066	Regular	Regular
Story4	1.063	Regular	Regular
Story3	1.058	Regular	Regular
Story2	1.047	Regular	Regular
Story1	1.036	Regular	Regular
Ground Floor	1.001	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in X-E direction of Zone IV (Habiganj) = 1.094.

Table 4.44: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in Y+E Direction of Zone IV (Habiganj)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.044	Regular	Regular
Top	1	Regular	Regular

WT and MR	1.011	Regular	Regular
WT and MR	1.004	Regular	Regular
Roof	1.069	Regular	Regular
Story9	1.079	Regular	Regular
Story8	1.089	Regular	Regular
Story7	1.095	Regular	Regular
Story6	1.099	Regular	Regular
Story5	1.102	Regular	Regular
Story4	1.106	Regular	Regular
Story3	1.111	Regular	Regular
Story2	1.120	Regular	Regular
Story1	1.118	Regular	Regular
Ground Floor	1.046	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in Y+E direction of Zone IV (Habiganj) = 1.120.

Table 4.45: Torsion Irregularity (Diaphragm Maximum Over Average Drifts) in Y-E Direction of Zone IV (Habiganj)

Story Name	Max Over Avg Drifts Ratio	Torsion Irregularity Check	Extreme Torsion Irregularity Check
Top	1.047	Regular	Regular

Top	1	Regular	Regular
WT and MR	1.015	Regular	Regular
WT and MR	1.004	Regular	Regular
Roof	1.057	Regular	Regular
Story9	1.072	Regular	Regular
Story8	1.083	Regular	Regular
Story7	1.091	Regular	Regular
Story6	1.096	Regular	Regular
Story5	1.101	Regular	Regular
Story4	1.106	Regular	Regular
Story3	1.114	Regular	Regular
Story2	1.127	Regular	Regular
Story1	1.126	Regular	Regular
Ground Floor	1.008	Regular	Regular
Base	0.000	Regular	Regular

Highest Diaphragm Max Over Avg Drifts Ratio in Y-E direction of Zone IV (Habiganj) = 1.127.

4.11 Comparison of Highest Diaphragm Max Over Avg Drifts Ratio

Table 4.46: Highest Diaphragm Max Over Avg Drifts Ratio in All Directions of All Zones

Direction	Zone I (Pirojpur)	Zone II (Dhaka)	Zone III (Tangail)	Zone IV (Habiganj)
X+E	1.152	1.152	1.152	1.152
X-E	1.094	1.094	1.094	1.094
Y+E	1.120	1.120	1.120	1.120
Y-E	1.127	1.127	1.127	1.127

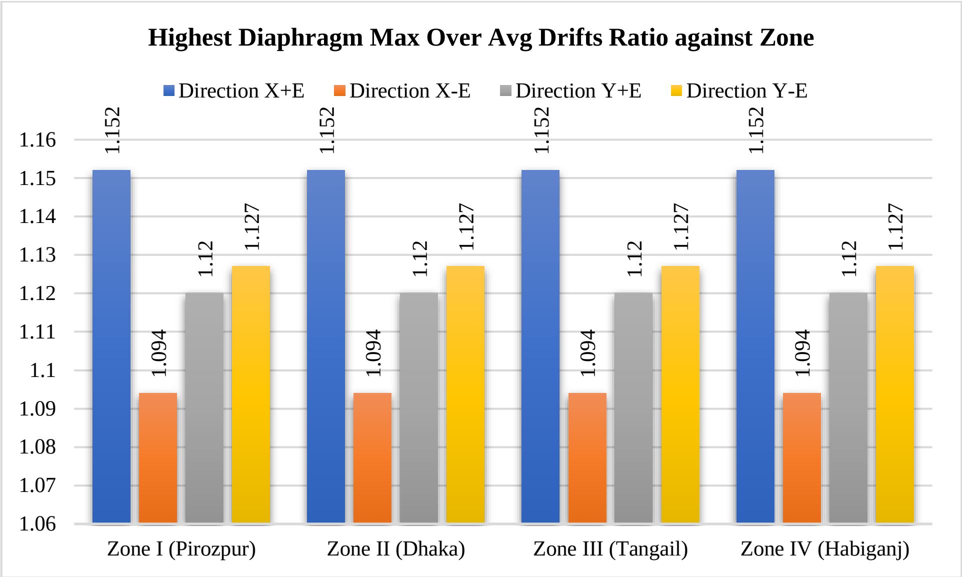

Figure 4.50: Highest Diaphragm Max Over Avg Drifts Ratio in All Directions of All Zones

Highest Diaphragm Max Over Avg Drifts Ratio in same directions of all zones are equal.

Highest Diaphragm Max Over Avg Drifts Ratio in all directions of all zones is 1.152.

4.12 Findings Base Shear

Table 4.47: Base Shear of All Zones

Zone	Base Shear, V (KN)

Zone I (Pirojpur)	1065.045
Zone II (Dhaka)	1779.404
Zone III (Tangail)	1593.238
Zone IV (Habiganj)	2047.830

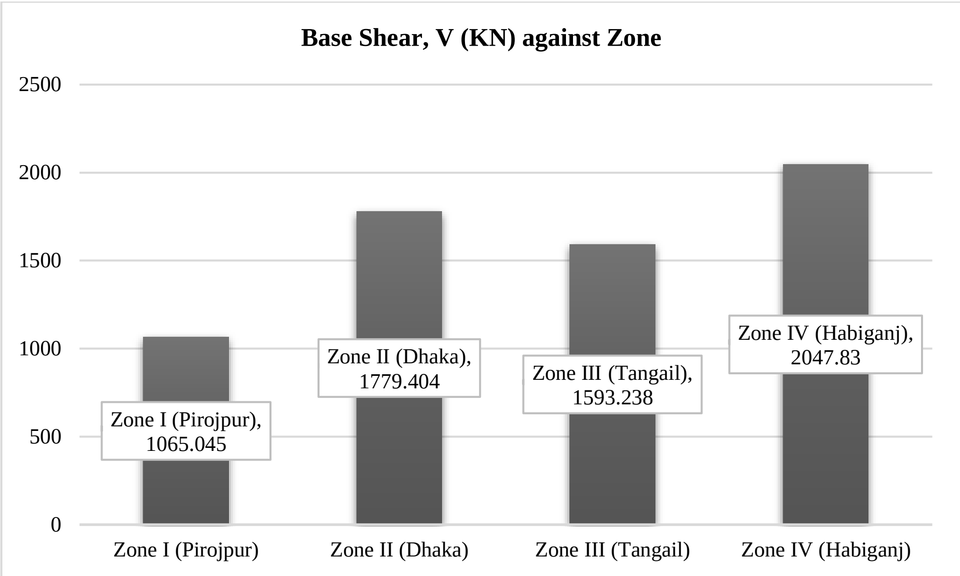

Figure 4.51: Base Shear of All Zones

Highest Base Shear is 2047.83 KN for Zone IV (Habiganj).

4.13 Summary

This chapter presents the result and discussion, which is the output of the project. There are many findings such as Story Drift, Story Displacement, Torsion Irregularity, Base Shear and etc. are shown in this chapter. Comparison of findings are also present here. Comparisons are as per zone to zone and direction to direction. This chapter helps to reach the conclusion.

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 (Habiganj), then Zone II (Dhaka), then Zone III (Tangail), then Zone I (Pirojpur).
3. The Zone I (Pirojpur) is the safest location for structure according to story displacement.
4. Highest story drift is occurred in Zone IV (Habiganj), then Zone II (Dhaka), then Zone III (Tangail), then Zone I (Pirojpur).
5. The Zone I (Pirojpur) is the safest location for structure according to story drift.
6. The Maximum highest story drift is occurred on the Story4.
7. Maximum highest story displacement and story drift is occurred in Y-E direction of this building for all zones.
8. Highest diaphragm maximum over average drifts ratio in same directions are equal for all zones.
9. Highest diaphragm maximum over average drifts ratio in X+E direction is occurred on the Story1 of all zones.
10. Highest diaphragm maximum over average drifts ratio in X-E direction is occurred on the Roof of all zones.
11. Highest diaphragm maximum over average drifts ratio in Y+E direction is occurred on the Story2 of all zones.
12. Highest diaphragm maximum over average drifts ratio in Y-E direction is occurred on the Story2 of all zones.
13. The highest diaphragm maximum over average drifts ratio is occurred on the Story2 of all zones.
14. The maximum base shear is present in Zone IV (Habiganj), then Zone II (Dhaka), then Zone III (Tangail), then Zone I (Pirojpur).

15. Above all the more safe location for construction building and other structures is Zone I, then Zone III, then Zone II, 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 2021 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 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

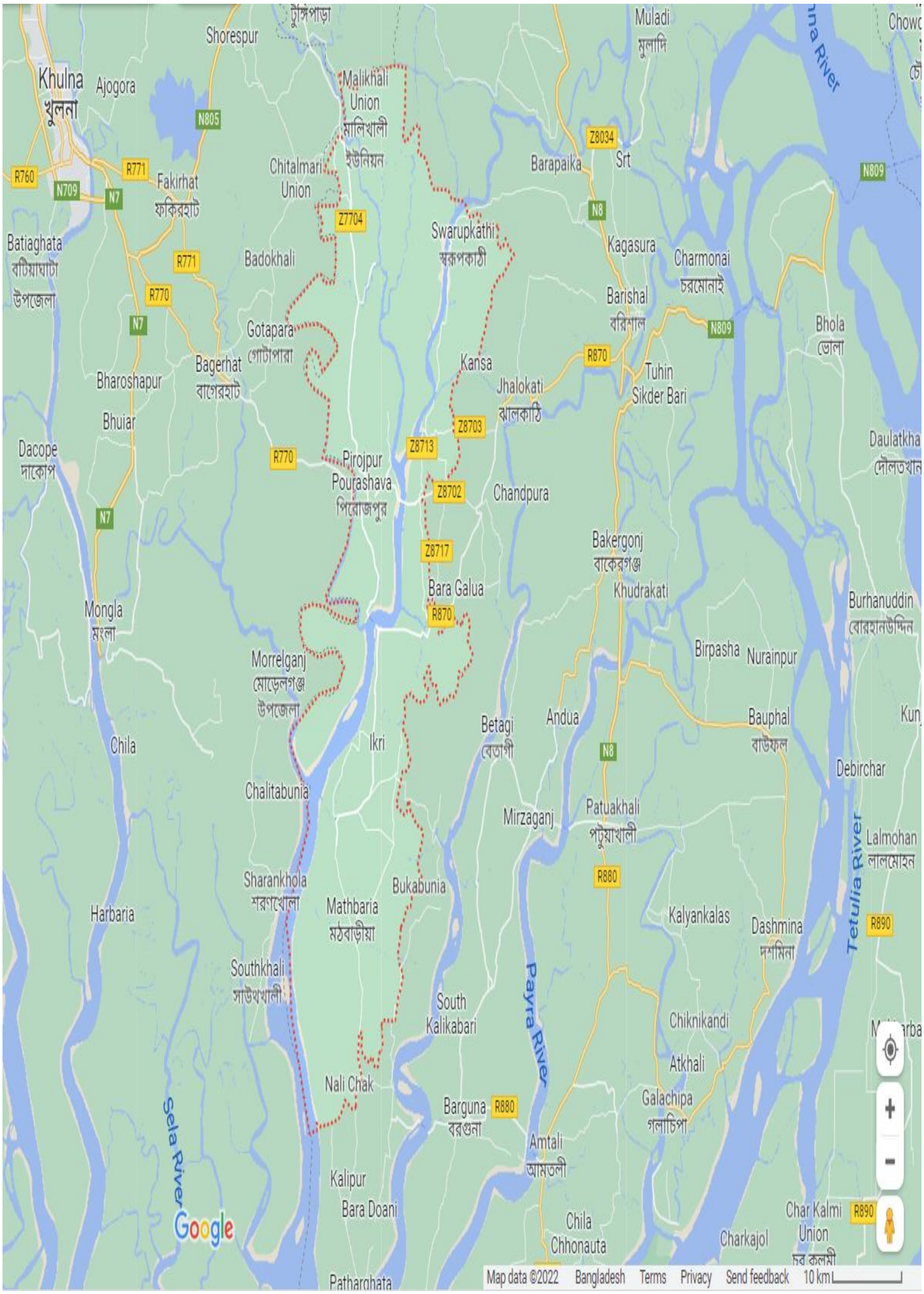

Figure: Pirojpur Area for Zone I (Dotted Red Line Indicates the Boundary)

APPENDIX C

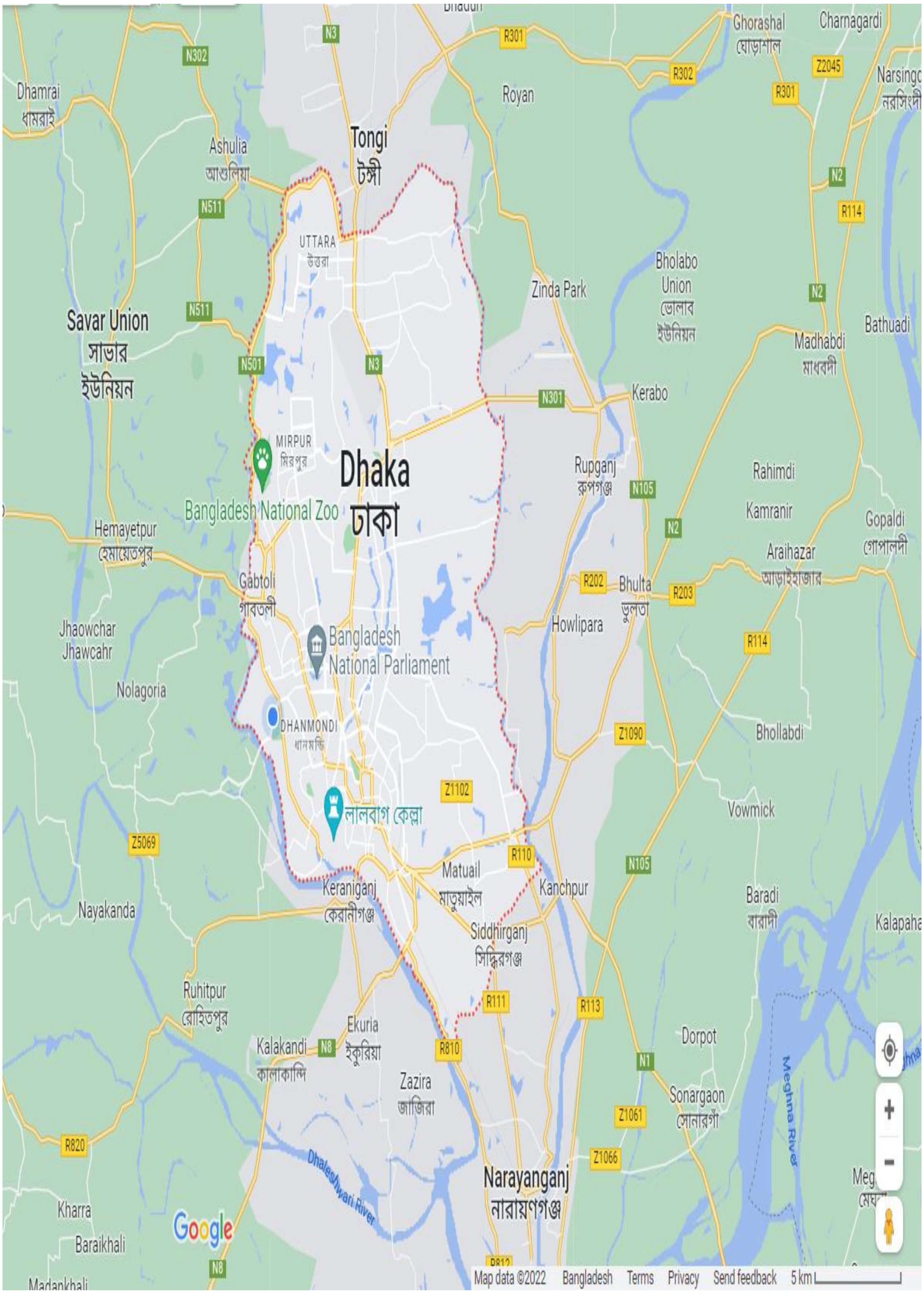

Figure: Dhaka Area for Zone II (Dotted Red Line Indicates the Boundary)

APPENDIX D

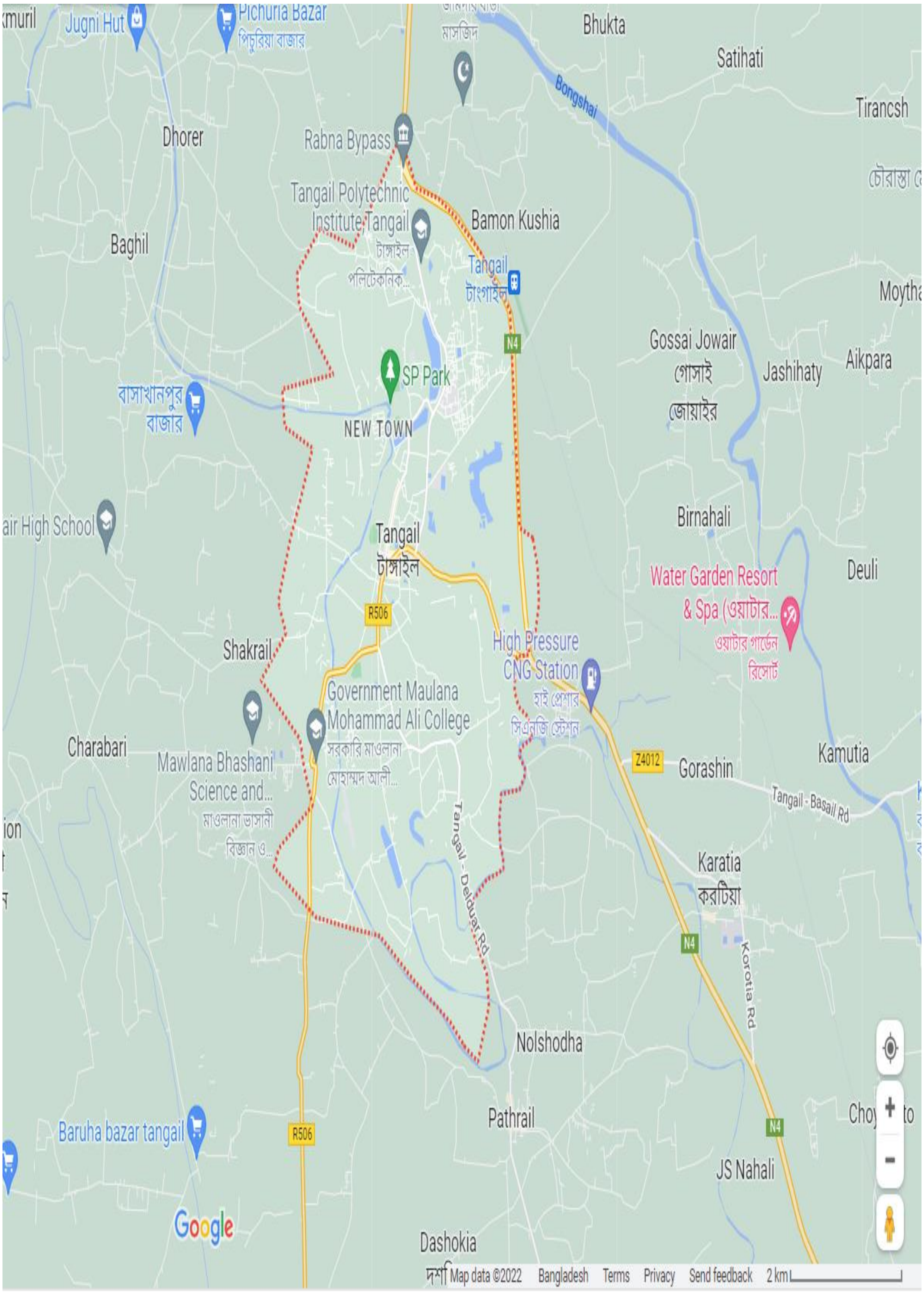

Figure: Tangail Area for Zone III (Dotted Red Line Indicates the Boundary)

APPENDIX E

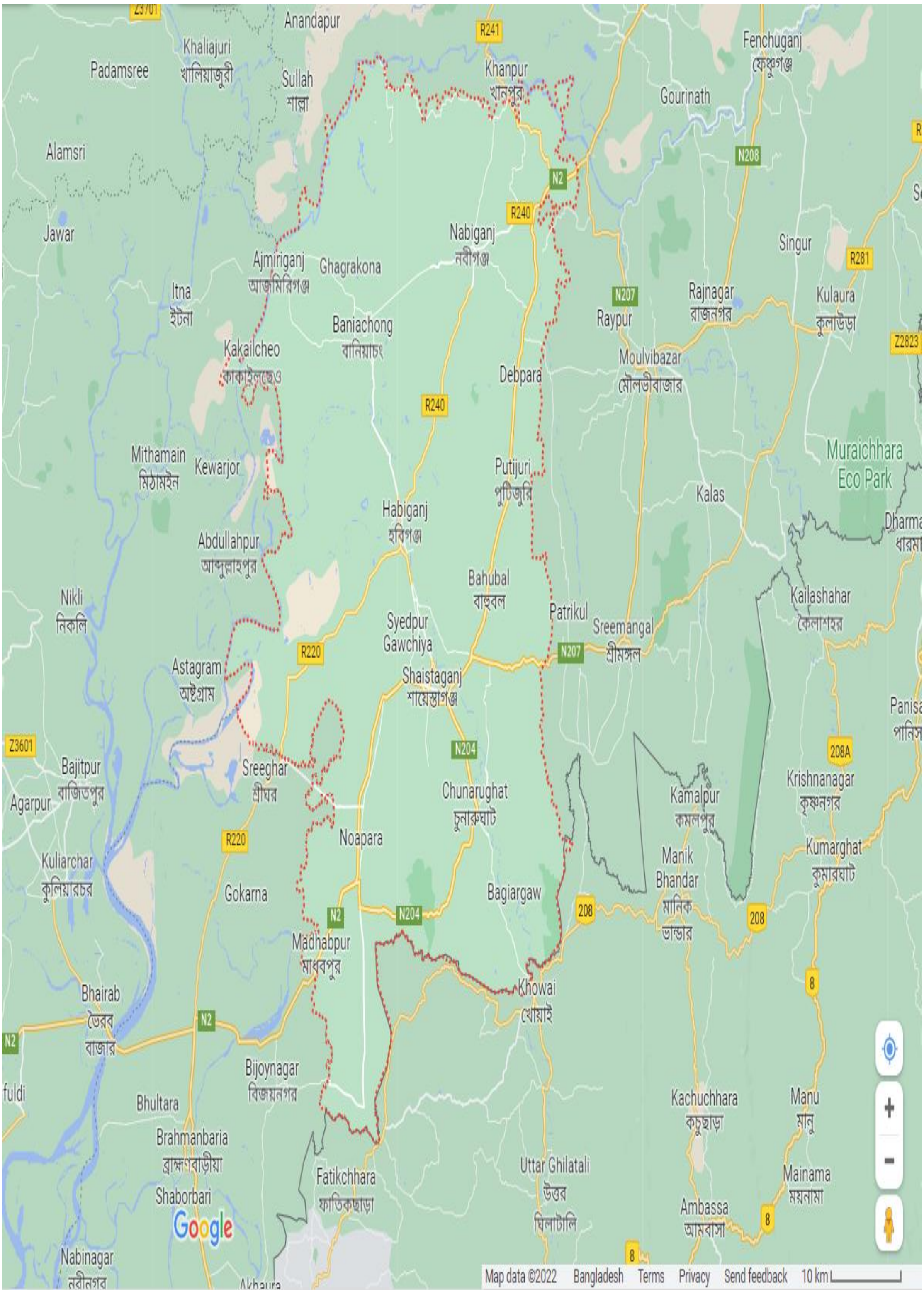

Figure: Habiganj Area for Zone IV (Dotted Red Line Indicates the Boundary)