COMPARATIVE ANALYSIS OF G+5 MULTI STORIED SCHOOL BUILDING FOR DIFFERENT SEISMIC ZONES OF BANGLADESH

Submitted By

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A thesis submitted to the Department of Civil Engineering, Daffodil International University in Partial Fulfillment of the Requirements for the Degree of
Bachelor of Sciences in Civil Engineering

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DECLARATION

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ABSTRACT

The Bangladesh National Building Code (BNBC) outlines and governs the fundamental specifications for structural, architectural, and design standards within Bangladesh. Over the past thirty years, advancements in civil engineering techniques, knowledge, materials, and design criteria have been adapted to meet evolving requirements. According to BNBC 2020, the seismic zone of Bangladesh has been divided into four parts and in this analysis the building has been designed with the values of the four zones. By using Response Spectrum Analysis, this study aims to investigate how structures behave during seismic activity. Numerous factors, such as story drift, base shear, base reaction, story shear, displacement, and torsional irregularity, are examined for a building with a G+5 layout. The well-known finite element method software, ETABS 2016, is used to perform the thorough analysis and modeling of the structure. This thesis does dynamic analysis on SD type stiff soil under various conditions that match Bangladesh's seismic zones (Zone I, Zone II, Zone III, and Zone IV).

Key Words: Displacement, Base Shear, Story Drift, Seismic Zone, Torsional Irregularity.

List of ABBREVIATION

BNBC	Bangladesh National Building Code
RC	Reinforcement Cement
RCC	Reinforced Cement Concrete
SDOF	Single Degree of Freedom System
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
IS	Indian Standard Code

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CHAPTER 1

INTRODUCTION

Seismic tremors are a major characteristic catastrophe checked by the sudden shaking of the ground, which happens due to the proliferation of seismic waves through the Earth's hull. These waves are delivered when vitality amassed within the outside is unexpectedly discharged, more often than not as a result of the breaking and development of pushed shake arrangements. This quick vitality discharge causes the surface of the Soil to tremble, affecting both built situations and living creatures. The vibrations produced from this vitality discharge are influenced by different inside and outside components inside the Earth's surface, as often as possible driving to casualties and annihilation of framework.

Seismic tremors display a extend of power and extents, requiring an intensive examination of the seismic execution of fortified concrete (RC) structures beneath different conditions. Critical reaction measurements envelop story float, base shear, base response, story shear, relocation, and torsional abnormality. To ensure the security of structures amid seismic events, it is basic to perform energetic examinations to find out the greatest reaction to base excitation. Structures involvement not as it were gravitational powers but too horizontal loads produced by seismic action, which can lead to influencing. High-rise buildings are particularly powerless to these horizontal strengths in comparison to their low-rise partners.

The development of businesses, financial advance, and shifts in urban populace have brought about in a rise in high-rise structures, which show expanded helplessness to horizontal powers. Basic engineers are constantly tending to these horizontal loads by moving forward building solidness through the utilize of moment-resisting outlines, cross braces, stomachs, and shear dividers, all of which are vital for keeping up a building's auxiliary keenness. Instructive offices are planned with the imperative assets and innovation to encourage viable educating and learning. Also, specialized spaces such as research facilities, libraries, craftsmanship studios, and exercise rooms upgrade assorted instructive encounters.

1.1 Design Considerations

The design of a school building necessitates meticulous consideration of several critical factors to create an environment that is functional, safe, and supportive of educational pursuits. The key design considerations encompass:

1. Preliminary Planning

Architectural Layout: A building layout pertains to the foundational plan established on the ground surface. It is created similarly to a paper drawing, taking into account the architectural design along with various engineering specifications. The layout is developed following a conditional survey, which provides the dimensions, angles, and elevations of the structure to be erected. This layout is crucial prior to the commencement of excavation activities.

Load Estimation: The Dead Load (DL) is determined by the self-weight of the materials, while the Live Load (LL) is defined according to the occupancy type, as outlined in regulations such as BNBC-2020. Analyzing load considerations is essential in the structural design process. These considerations are influenced by the type of occupancy and the height of the building. Typically, there are three primary load categories for a structure: Dead Load (DL), Superimposed Dead Load (SDL), and Live Loads (LL), in addition to wind and seismic loads.

Site Conditions: Type of soil and its load-bearing capacity (for the design of foundations).

2. Structural Modeling in ETABS

Defining Material Properties: In ETABS, the material properties are consistently characterized as linear elastic. To access the Define Materials form, navigate to the Define menu and select the Material Properties command. This form allows you to add, modify, or remove material properties. To introduce a new material, click the Add New Material button.

Beams and Columns: Specify dimensions and reinforcement specifications.

Slabs: ETABS will determine the minimum reinforcement needs based on area, intensity, or the quantity of bars. The design process will take place at several locations. Design strips may be non-orthogonal and can vary in width.

Residential Buildings:	Light Loads: 100 mm to 150 mm (4 to 6 inches)
	Heavy Loads: Up to 200 mm (8 inches)
Commercial Buildings:	125 mm to 200 mm (5 to 8 inches)
Industrial Structures:	150 mm to 300 mm (6 to 12 inches)

Load Application: Implement dead, live, wind, seismic, and additional loads. Utilize load combinations in accordance with the design code (BNBC 2020 or ACI 318).

Load Combinations: Create combinations either automatically or manually in line with the design codes.

3. Analysis

Conduct Linear Static and Dynamic Analysis: Static analysis is a crucial step in the structural design process. Through static analysis, one can determine the structure's reaction to external forces. Additionally, static analysis is carried out when the structure experiences external displacements, including differential support settlements.

1. Identify the characteristics of the dynamic environment (loading conditions).
2. Develop an appropriate finite element model.
3. Choose and implement the suitable analysis methods to assess the structural behavior.
4. Analyze the outcomes.

Evaluate the structure for static loads. Perform a dynamic analysis, utilizing either Response Spectrum or Time History methods, to assess seismic loads.

To assess deflections, we typically determine them by computing the double integral of the Bending Moment Equation, represented as M(x), divided by the product of Young's Modulus (E) and the Moment of Inertia (I). The resulting unit of deflection, or displacement, is expressed in length, with millimeters being the standard measurement.

Base Reactions: Confirm the fundamental reactions for the design of the foundation.

Drift Check: Ensure that the narrative deviation stays within acceptable boundaries as stipulated by the applicable regulations.

4. Design

Concrete Design: Design beams, columns, slabs, and shear walls to resist flexural, shear, and axial loads.

Foundation Design: Design foundations, including isolated, combined, raft, or pile types, must be established based on the results of the soil report.

Lateral Load-Resisting System: Evaluate the effectiveness of shear walls, bracing systems, or structural frames.

5. Detailing

Reinforcement Detailing: Provide detailed reinforcement drawings for every structural component.

Serviceability Checks: Assess the criteria for crack width and deflection.

6. Report Preparation

Prepare a comprehensive structural analysis and design report including: Summary of load assessments and combinations, capacities of structural elements, evaluations of deflection, drift, and additional checks, along with the final details of reinforcement.

1.2 Seismic zoning

Bangladesh is divided into four seismic zones, each displaying different levels of ground motion. A map showing the boundaries of these zones can be found in Figure 1.1. Each zone is designated a seismic zone coefficient (Z), representing the maximum expected peak ground acceleration (PGA). The coefficients for the four zones are as follows: Z 0.12 for Zone I, Z 0.20 for Zone II, Z 0.28 for Zone III, and Z 0.36 for Zone IV. Zone IV, which includes the Sylhet region in the northeast, is recognized as the area most vulnerable to earthquakes, with a maximum PGA of 0.36g. Dhaka city lies within a zone of moderate seismic activity, indicated by a coefficient of Z 0.20, while Chittagong city is found in a zone of high intensity, with a coefficient of Z 0.28 (BNBC, 2020).

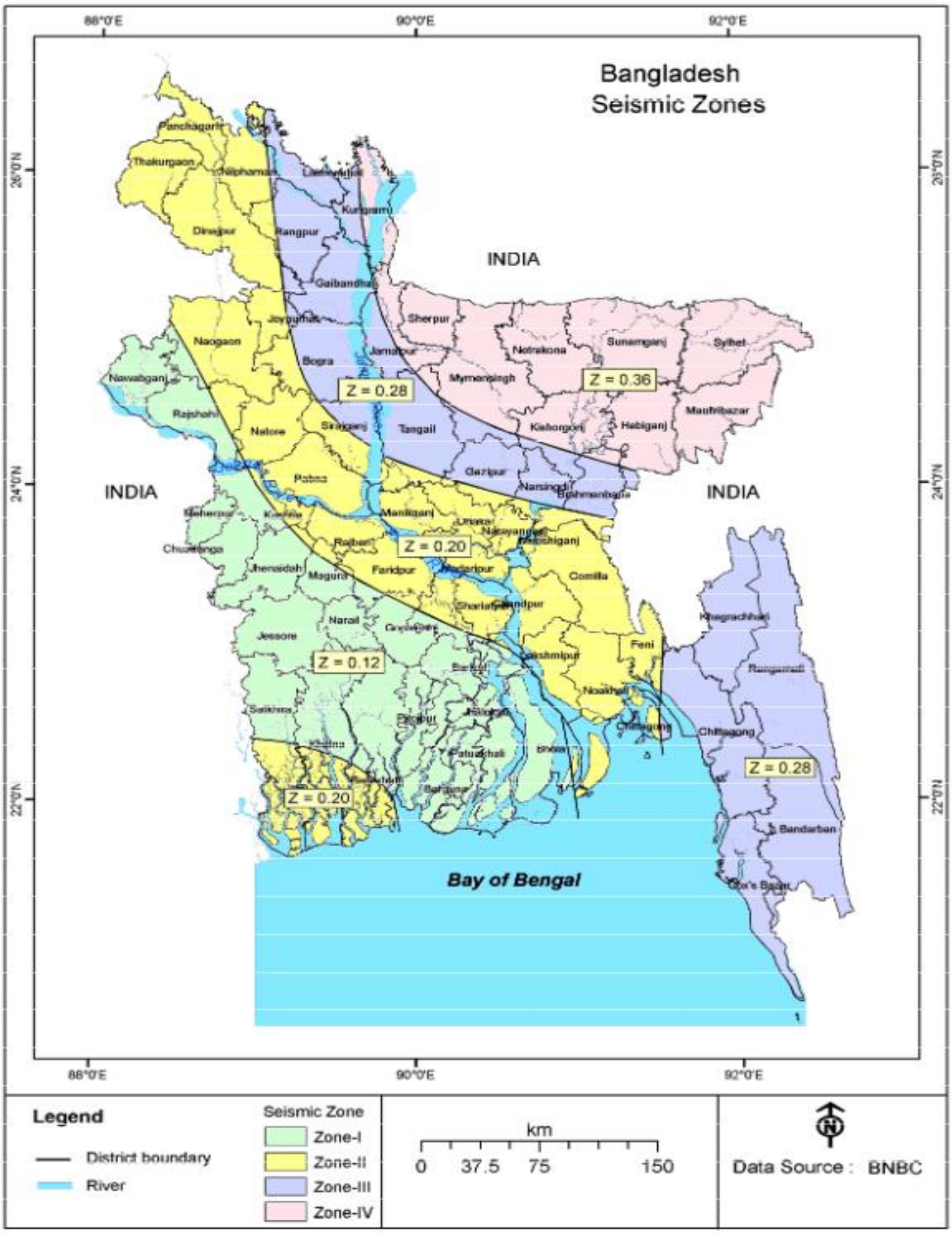

Figure 1.1: Seismic zoning map of Bangladesh (BNBC 2020)

1.3 Types of earthquake analysis methods

Earthquake analysis techniques are typically classified into the following categories:

1. Equivalent static analysis

2. Linear dynamic analysis

3. Non-linear dynamic analysis

4. Response spectrum analysis
5. Time history analysis
6. Push-over analysis
7. Non-linear static analysis

According to BNBC 2020, dynamic analysis is carried out for irregular and high-rise constructions. Either the Time History approach or the Response Spectrum method is used to carry out this dynamic analysis. The current study focuses on using response spectrum analysis and ETABS software to analyze a multi-story building. According to Lakshmaiah (2017), the Response Spectrum is a graph that shows the peak response of a single degree of freedom (SDOF) system, comprising maximum displacement, velocity, and acceleration, plotted against the natural frequency. Using smooth design spectra, which are the average of seismic motions, this method involves figuring out the uppermost acceptable limits for displacement values and forces across different vibration modes.

The Response Spectrum analysis's applicability, which is mostly limited to linear systems, is a major drawback. Furthermore, this study looks at the examination of multi-story structures' regular and irregular configurations in various seismic zones (Nair, 2017).

1.4 Requirement for dynamic analysis

Dynamic analysis is required for the buildings listed below to ascertain the design seismic force and to evaluate the distribution of this force across the different lateral load-resisting components and levels throughout the height of the structure:

(a) For regular buildings exceeding 40 meters in height located in Zones II, III, and IV, and those taller than 90 meters in Zone I (BNBC, 2020).

(b) For irregular buildings that are more than 12 meters high in Zones II, III, and IV, and those exceeding 40 meters in Zone I (BNBC, 2020).

1.5 Objectives of this thesis

The main objective of this thesis is:

1. To examine the structural characteristics concerning base shear, displacements, drifts, story deflection, story shear, and torsional irregularities for different seismic zones in Bangladesh through dynamic analysis.

CHAPTER 2

LITERATURE

Structural analysis and design are carried out on structures in all four regions to evaluate the seismic behavior of a typical G+10-story school building under revised seismic zones. In the current study, various seismic zone analyses of a multistory (G+5) residential building situated in every seismic region in Bangladesh are compared. This is done in order to use the new seismic zone and coefficient to compute the building's seismic impact (Riad et al., 2023) .

For this thesis, G+5-story commercial buildings have been taken into consideration. Guidelines from IS 456 (2000) have been adhered to, and the static technique has been used. ETABS has been used for the design and analysis of RCC frame members, including beams and columns (Shohag & Mozumder, 2022).

Seismic analysis can be used to design and build a structure that can survive the earth's crust's high lateral movement during an earthquake. With ETABS, any kind of structure, whether simple or complex, may be assessed under either static or dynamic settings. ETABS is one of the greatest structural software for building systems since it is a well-organized and effective tool for analysis and designs, ranging from basic 2D frames to contemporary high-rises (Hussain et al., 2021).

The primary focus of the case study is the structural behavior of multi-story buildings with various plan configurations, such as rectangular, C, L, and I shape. The ETABS program is used to model a 15-story R.C.C. framed building for study. Maximum shear forces, bending moments, and maximum story displacement are calculated after the structure has been studied, and the results are compared for each scenario that was examined (Sallal, 2018)

Although the structures are typically built on flat land, construction has begun on sloping terrain because level ground is scarce. Buildings on sloping terrain can be arranged in two different ways: step back and step back setback. The analysis in this study has taken into account a G+ 10-story RCC building with a ground slope that ranges from 100 to 300. The building's position on level ground has been compared. Using the structure analysis tool ETAB 2015, the building was modeled and analyzed to examine the impact of changing column heights in the bottom story at various locations during an earthquake (P Supraja et al., 2022).

Has out a comparative analysis of the optimal shear wall placements in different seismic zones for a multi-story RCC building. Story shear, displacement, and drift were among the characteristics found in each of the four zones (Zones II, III, IV, and V) of the four models that were made for the study. Shear walls have been found to function best when positioned toward the structure's borders, with zone V experiencing the most displacement and story drift (B.M.E et al., 2018).

Examined the nonlinear behavior of structures above the first storey that were overly strong and rigid. It is claimed that a building's response is highly sensitive to changes in stiffness along the structure's height and that the p-delta effects have a major impact on the response. It is suggested to utilize a safety factor to satisfy the local ductility requirements in a soft story, which are reliant on the structure's natural period (Yassin & Abdulhamid, 2019)

Ideal proportions feature the optimal stiffness co-relation between structural components and are less expensive than conventional state-of-the-art design techniques. The pursuit of ever-higher structures has not been without its challenges. The higher the building, the more important the structure's stiffness becomes. Despite peculiar loading effects and extraordinarily high loading values caused by lateral loads that predominate, tall structures have continued to rise in height. Strength, serviceability, stability, and human comfort are design considerations for tall structures. As a result, the effects of lateral loads, such seismic and wind forces, are growing more and more important, and almost all designers have to cope with the difficulty of providing adequate strength and stability against lateral pressures (Yadav & Reddy, 2017)

CHAPTER 3

METHODOLOGY

The general methodology for ETABS (Extended Three-dimensional Analysis of Building Systems) building analysis can be divided into multiple parts. To guarantee that the model is true, the analysis is accurate, and the outcomes are trustworthy for design and decision-making, each phase is essential. An outline of the standard process for using ETABS to analyze a building may be found below:

1. Defining the Problem

Project Requirements**:** The building's codes or regulations, architecture, and the type of analysis required (static, dynamic, linear, or non-linear) are recognized.

Building Information**:** Gather and assemble all necessary information, including design codes, material specifications, load requirements, structural drawings, and architectural designs.

2.Modeling the Structure in ETABS

Grid System and Floor Plan: The building's grid lines and layout, including floor layouts, elevation views, and other details, are established.

Structural Components: The structural components include foundational elements, walls, slabs, beams, and columns.

Beams and Columns: A detailed description of the different types of beams and columns is necessary, highlighting their shapes and the properties of the materials used in their construction.

Slabs and Walls: Specifications regarding slab thickness, wall dimensions, and additional relevant details must be provided.

Materials: The materials used for the structural elements are selected based on their properties, such as concrete or steel, in accordance with the project requirements.

3.Defining Loads and Load Combinations

Dead Loads (DL): Dead loads are assigned based on a structure's self-weight and permanent loads, such as the weight of equipment or finishes.

Live Loads (LL): Live loads for the building's different sections - offices, hallways, and roofs should be identified.

Wind Loads: Wind loads should be applied in accordance with local construction codes if necessary, or wind load analysis should be conducted based on the building's height, location, and other relevant factors.
Seismic Loads: Seismic forces are determined by the building's dynamic qualities, classification, and location (seismic zone). The calculation of seismic loads is performed automatically by ETABS with these values.
Other Loads: These loads, including snow, temperature changes, and unique loads (equipment or vehicle loads in parking structures), should be assigned as additional tasks.
Combinations of Loads: Use ETABS to create suitable load combinations in accordance with the applicable design codes (such as ASCE 7, Eurocode, or IS 456).

Load Combinations: Load combinations denote the organized approach to integrating different categories of loads that a structure might encounter concurrently throughout its duration. That’s are:

1. 1.4DL
2. 1.2DL+11.6LL
3. 1.2DL+LL
4. 1.2DL+0.8WX
5. 1.2DL-0.8WX
6. 1.2DL+0.8WY
7. 1.2DL-0.8WY
8. 1.2DL+LL+1.6WX
9. 1.2DL+LL-1.6WX
10. 1.2DL+LL+1.6WY
11. 1.2DL+LL-1.6WY
12. 1.2DL+LL+EX+0.3EY+ΛDL
13. 1.2DL+LL+EX-0.3EY+ΛDL
14. 1.2DL+LL-EX+0.3EY+ΛDL
15. 1.2DL+LL-EX-0.3EY+ΛDL
16. 1.2DL+LL+EY+0.3EX+ΛDL

17. 1.2DL+LL+EY-0.3EX+ΛDL
18. 1.2DL+LL-EY+0.3EX+ΛDL
19. 1.2DL+LL-EY-0.3EX+ΛDL
20. 0.9DL+EX+0.3EY-ΛDL
21. 0.9DL+EX-0.3EY-ΛDL
22. 0.9DL-EX+0.3EY-ΛDL
23. 0.9DL-EX-0.3EY-ΛDL
24. 0.9DL+EY+0.3EX-ΛDL
25. 0.9DL+EY-0.3EX-ΛDL
26. 0.9DL-EY+0.3EX-ΛDL
27. 0.9DL-EY-0.3EX-ΛDL
28. 0.9DL+1.6WX
29. 0.9DL-1.6WX
30. 0.9DL+1.6WY
31. 0.9DL-1.6WY

4.Defining Boundary Conditions and Constraints

Supports and Restraints: The base's and any intermediate support points' support conditions (such as fixed, pinned, or roller) should be established.

Connection Modeling: The relationships between various structural components should be modeled appropriately to depict the behavior.

5.Peforming the Analysis

Analysis Type: The analysis to be performed is selected.

Linear Static Analysis: This method is the simplest and fastest for buildings that behave elastically.

Dynamic Analysis: Buildings are subjected to dynamic loading, such as seismic analysis and wind loads, using methods like Response Spectrum Analysis or Time History Analysis.

Run the Analysis: The system of equations governing the behavior of the structure under applied loads is solved by ETABS to perform the analysis.

The full process of this thesis is shown in figure 3.1.

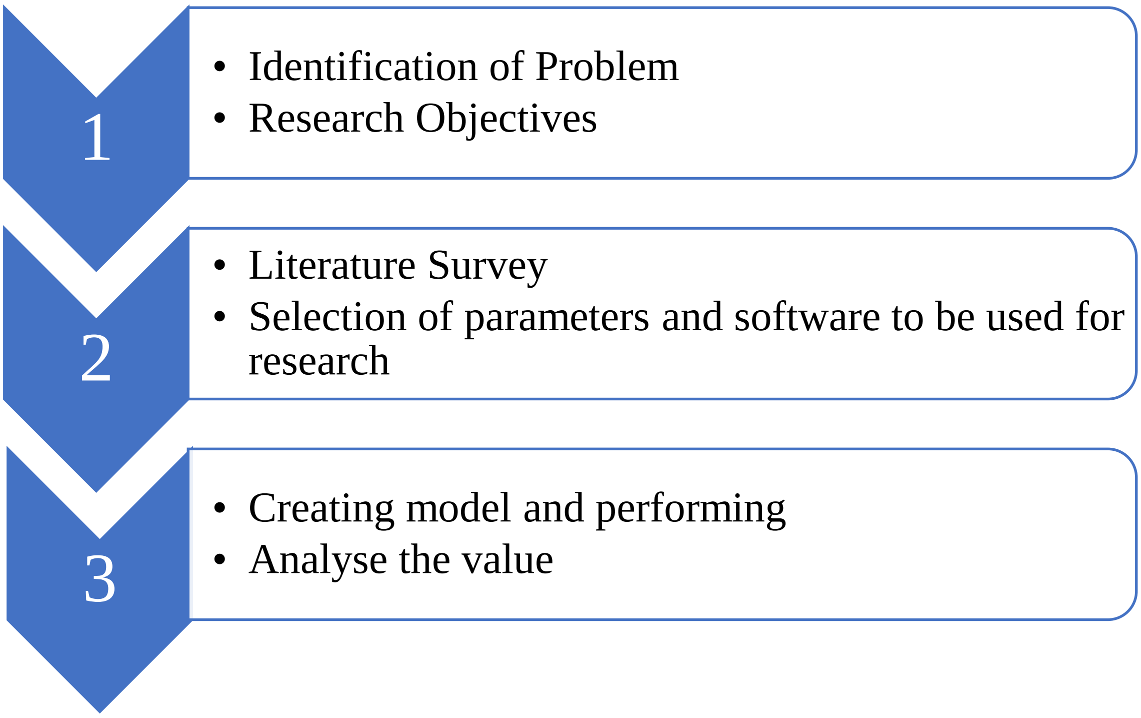

Figure 3.1: Working steps

3.1 Building model and analysis of structure

A G+5 Buildings made of reinforced concrete are modeled, examined, and researched. ETABS in Bangladesh's seismic zones (Zone I, Zone II, Zone III, and Zone IV) is used to assess the model and determine the best seismic zone for this building. Tables 3.1, 3.2, and 3.3 provide the building model parameters, material attributes, and loading information.

Table 3.1: Load details for the building

Load type	**Load**
Live load	40 lb/ft^2
Stair live load	100 lb/ft^2
Roof live load	100 lb/ft^2
Wall load on beams	486 lb/ft^2
Floor Finishing load	20 lb/ft^2

Table 3.2: Specifications of structure

Parameter	**Value**
Height of building	96 ft.
Type of structure	Multi story RC frame (G+5)
Floor to Floor height	12 ft.
Soil type	SD
Damping	5%
Support conditions	Fixed
Importance Factor, I	1.35
Response Reduction Factor, R	8
Size of beam	20″x20″
Thickness of slab	5″
Seismic zone	I, II, III and IV

Table 3.3: Column size

Name of column	**Ground to 5th floor**
C1	20″x22″
C2	22″x22″
C3	22″x24″

3.2 Structural models from ETABS are below:

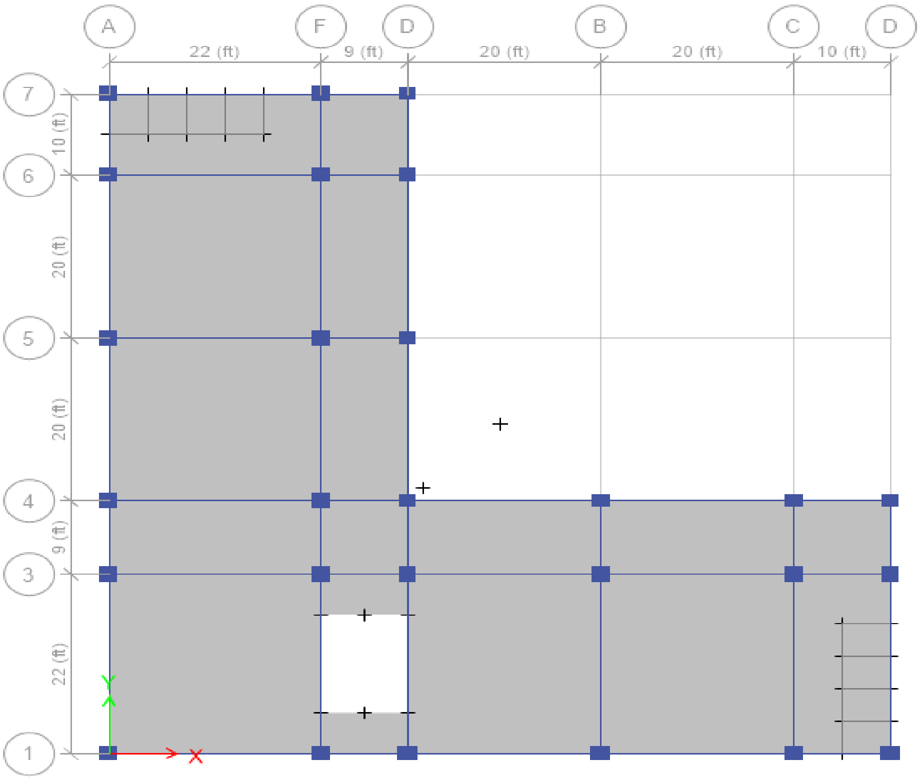

Figure 3.2: Plan of the building

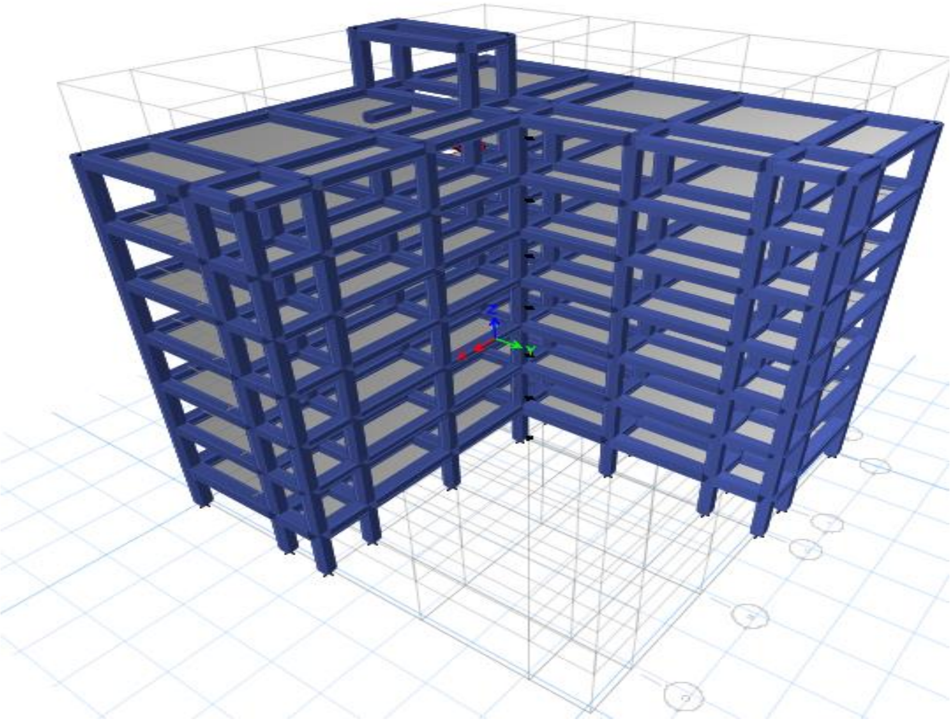

Figure 3.3: 3D (1) view of the building

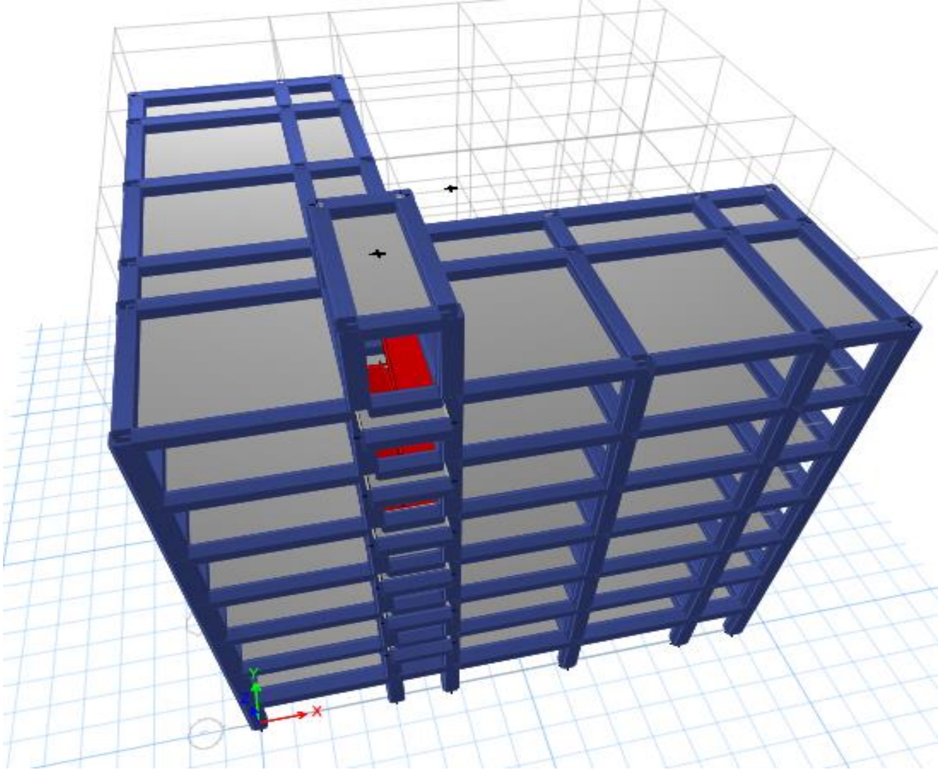

Figure 3.4: 3D (2) view of the building

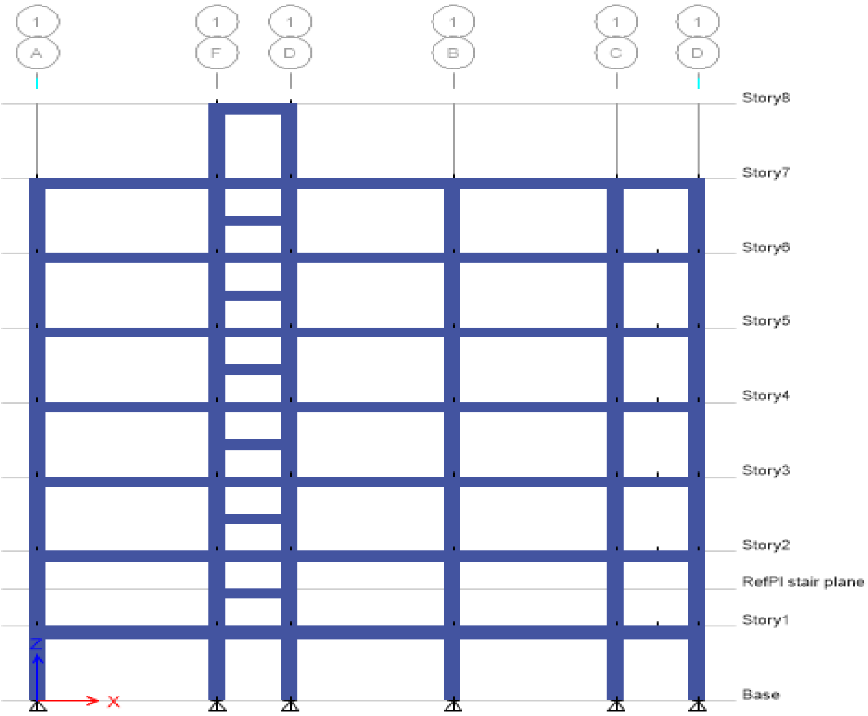

Figure 3.5: Elevation (1) view of the building

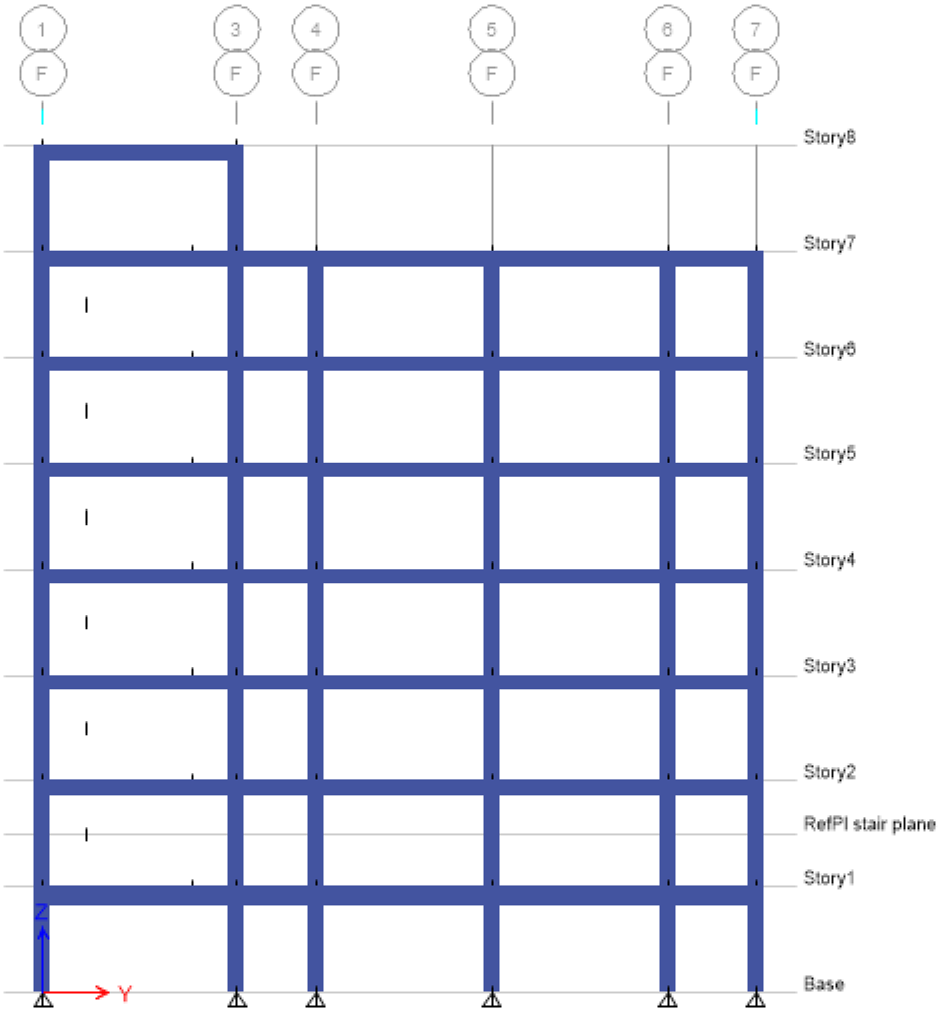

Figure 3.6: Elevation (F) view of the building

CHAPTER 4

RESULT AND DISCUSSION

4.1 Displacement

The displacement values are displayed in table 4.3-4.10 below. For seismic zones I, II, III, and IV, these tables show the maximum and average displacement caused by earthquake load along the X and Y directions.

4.2 Story drift

Story drift is the movement of one story in relation to another story, either above or below. The numbers for story drift are displayed in table 4.11-4.18. For seismic zones I, II, III, and IV, these tables show the maximum and average story drift caused by earthquake load along the X and Y directions.

4.3 Base shear

The base shear coefficients for zone I are K=1.123 and C=0.040. Zones II, III, and IV have base shear coefficients of C=0.067 and K=1.123, C=0.094 and K=1.123, and C=0.15 and K=1.123, respectively. The base shear for zones I, II, III, and IV is shown in Table 4.19.

4.4 Time period and frequency

Time and period frequency values for zone I, II, III and IV are showing in the following table 4.21.

4.5 Base reaction

The base shear determined from the reaction spectrum function (RSX, RSY) must be at least 85% of the computed static base shear (Ex1, Ex2, and Ey1, Ey2) in accordance with the ACI code. The base reaction values for seismic zones I, II, III, and IV along the X and Y directions are displayed in table 4.20 below. We can scale the response spectrum function to be greater than 85% if the base reaction is less than 85%.

4.6 Torsional Irregularity

The average narrative drift at two ends of the construction is 1.2 times smaller than the greatest story drift, including unintentional torsion, at one end transverse to an axis.

The average story drifts, $\partial\text{avg} = \frac{\partial\text{max}+\partial\text{min}}{2}$

Torsional irregularity coefficient, $\eta = \frac{\partial\text{max}}{\partial\text{avg}}$

If, $\eta > 1.2$, Torsional Irregularity exit.

If, η > 1.4, Extreme Torsional Irregularity exit.

If, η < 1.2, Torsional Regularity exit.

As η torsional values are same as zone I values that’s are 1.17 along X direction and 1.144 along Y direction. So, it should be said that Torsional Regularity exit.

4.7 Building time period

When exposed to ground shaking during an earthquake, a building's time period is its normal oscillation period. T=1.33 is the building time period.

4.8 Bending Moment

When an external force or moment is applied to a structural element, the reaction that results in the element becoming bent is referred to as the "bending moment." The beam is the most prevalent or basic structural component that experiences bending moments. The values of bending moments are displayed in table 4.22 below. The maximum bending moment for seismic zones I, II, III, IV, and all of the building's stories is shown in these tables.

4.9 Shear Force

An element of structural support that can withstand shear forces, such as strong winds and seismic activity, is called a shear wall. Shear force, as used in civil engineering, describes forces acting perpendicularly against a building's structural elements, such as beams, columns, and so forth, causing the structure to twist and bend. The following tables 4.23 display the shear force values for zones I, II, III, and IV.

4.10 Axial Force

In the building and construction sector, the word "axial forces" refers to the forces exerted along a structural element's longitudinal axis, like a beam or column. Table 4.24 displays the axial force values for zones I, II, III, and IV.

4.11 Torsion

When a torque is applied to a material, the resultant state of strain is called torsion. It will happen every time a twisting force is applied to a structural part. Table 4.25 displays the axial force values for zones I, II, III, and IV.

Buildings are checked for torsional irregularities by using the formulae D max/D avg.

If D max/D avg > 1.2, Torsional Irregularity exit.

If D max/D avg > 1.4, Extreme Torsional Irregularity exit.

If D max/D avg <1.2, Torsional regularity exit.

The D max/D avg ratio for a G+5 multi storied building for four seismic zones of Bangladesh (I, II, III, IV) along global X and Y directions has presented in the tables

of 4.1 and 4.2. Zone I value is 1.17 along X direction and 1.144 for Y direction. For the other zones (II, III, IV) torsional values are same as zone I values that's are 1.17 along X direction and 1.144 along Y direction.

Table 4.1: Torsional check along X direction

Torsional check along direction of X	
Zone	Along X
	Ex
I	1.17
II	1.17
III	1.17
IV	1.17

Table 4.2: Torsional check along Y direction

Torsional check along direction of Y	
Zone	Along Y
	Ey
I	1.144
II	1.144
III	1.144
IV	1.144

The tables in 4.3-4.10 show the maximum story displacements for a G+5 multi-story building along the X and Y directions in Bangladesh's four seismic zones (I, II, III, and IV). The maximum displacement in zone I is 1.744908 inches along the Y direction and 1.621551 inches along the X direction. The maximum displacement values in zone II are 2.922721 inches in the Y direction and 2.936862 inches in the X direction. The maximum displacement in zone III is 4.100535 inches in the Y direction and 4.120373 inches in the X direction. The maximum displacement in zone IV is 6.543406 inches in the Y direction and 6.575064 inches in the X direction. The greatest displacement determined by this research is 6.543406 inches along the Y direction and 6.575064 inches along the X direction. Analysis of figure 4.2 reveals that displacement increases from zone I to zone IV and reaches its maximum along the x direction at level 7. Additionally, the displacement increases from zone I to zone IV, with the largest displacement along the y direction occurring at level 7.

Table 4.3: Maximum and average story displacement due to earthquake load Ex in the direction of X in zone I.

Along X Direction			
Story	EX		
	Maximum (in)	Average (in)	Ratio
Story8	1.514311	1.45219	1.043
Story7	1.75335	1.525725	1.149
Story6	1.621551	1.409704	1.15
Story5	1.432193	1.245395	1.15
Story4	1.19137	1.038492	1.147
Story3	0.913602	0.801114	1.14
Story2	0.623075	0.55281	1.127
Story1	0.372665	0.337074	1.106

Table 4.4: Maximum and average story displacement due to earthquake load Ey in the direction of Y in zone I.

Along Y Direction			
Story	EY		
	Maximum (in)	Average (in)	Ratio
Story8	1.600042	1.578604	1.014
Story7	1.744908	1.564062	1.116
Story6	1.617268	1.452491	1.113
Story5	1.432817	1.289427	1.111
Story4	1.198178	1.080752	1.109
Story3	0.927274	0.838732	1.106
Story2	0.642531	0.583121	1.102
Story1	0.394826	0.360418	1.095

Ratio: On ETABS for displacement the ratio of maximum and average value is given on table (4.3 to 4.10). This table presents the maximum and average displacements measured in inches for various load cases and combinations in both the X and Y directions across all stories elevations. Additionally, the ratio of maximum to average displacement is included, indicating a slight variation between the maximum and average displacements for each scenario.

Table 4.5: Maximum and average story displacement due to earthquake load Ex in the direction of X in zone II.

Along X Direction			
Story	EX		
	Maximum (in)	Average (in)	Ratio
Story8	2.536472	2.432418	1.043
Story7	2.936862	2.55559	1.149
Story6	2.716098	2.361254	1.15
Story5	2.398922	2.086037	1.15
Story4	1.995545	1.739475	1.147
Story3	1.530283	1.341867	1.14
Story2	1.043651	0.925956	1.127
Story1	0.624215	0.5646	1.106

Table 4.6: Maximum and average story displacement due to earthquake load Ey in the direction of Y in zone II.

Along Y Direction			
Story	EY		
	Maximum (in)	Average (in)	Ratio
Story8	2.680071	2.644161	1.014
Story7	2.922721	2.619804	1.116
Story6	2.708924	2.432923	1.113
Story5	2.399968	2.15979	1.111
Story4	2.006948	1.81026	1.109
Story3	1.553184	1.404876	1.106
Story2	1.076239	0.976728	1.102
Story1	0.661334	0.6037	1.095

Table 4.7: Maximum and average story displacement due to earthquake load Ex in the direction of X in zone III.

Along X Direction			
Story	EX		
	Maximum (in)	Average (in)	Ratio
Story8	3.558632	3.412646	1.043
Story7	4.120373	3.585454	1.149
Story6	3.810645	3.312804	1.15
Story5	3.365652	2.926679	1.15
Story4	2.79972	2.440457	1.147
Story3	2.146965	1.882619	1.14
Story2	1.464227	1.299103	1.127
Story1	0.875764	0.792125	1.106

Table 4.8: Maximum and average story displacement due to earthquake load Ey in the direction of Y in zone III.

Along Y Direction			
Story	EY		
	Maximum (in)	Average (in)	Ratio
Story8	3.760099	3.709718	1.014
Story7	4.100535	3.675547	1.116
Story6	3.80058	3.413354	1.113
Story5	3.36712	3.030153	1.111
Story4	2.815718	2.539768	1.109
Story3	2.179094	1.97102	1.106
Story2	1.509947	1.370335	1.102
Story1	0.927842	0.846983	1.095

Table 4.9: Maximum and average story displacement due to earthquake load Ex in the direction of X in zone IV.

Along X Direction			
Story	EX		
	Maximum (in)	Average (in)	Ratio
Story8	5.678668	5.445711	1.043
Story7	6.575064	5.72147	1.149
Story6	6.080817	5.286389	1.15
Story5	5.370722	4.670232	1.15
Story4	4.467639	3.894346	1.147
Story3	3.426008	3.004179	1.14
Story2	2.336533	2.073036	1.127
Story1	1.397495	1.264029	1.106

Table 4.10: Maximum and average story displacement due to earthquake load Ey in the direction of Y in zone IV.

Along Y Direction			
Story	EY		
	Maximum (in)	Average (in)	Ratio
Story8	6.000159	5.919763	1.014
Story7	6.543406	5.865234	1.116
Story6	6.064755	5.446842	1.113
Story5	5.373063	4.835351	1.111
Story4	4.493167	4.052821	1.109
Story3	3.477278	3.145245	1.106
Story2	2.40949	2.186705	1.102
Story1	1.480599	1.351568	1.095

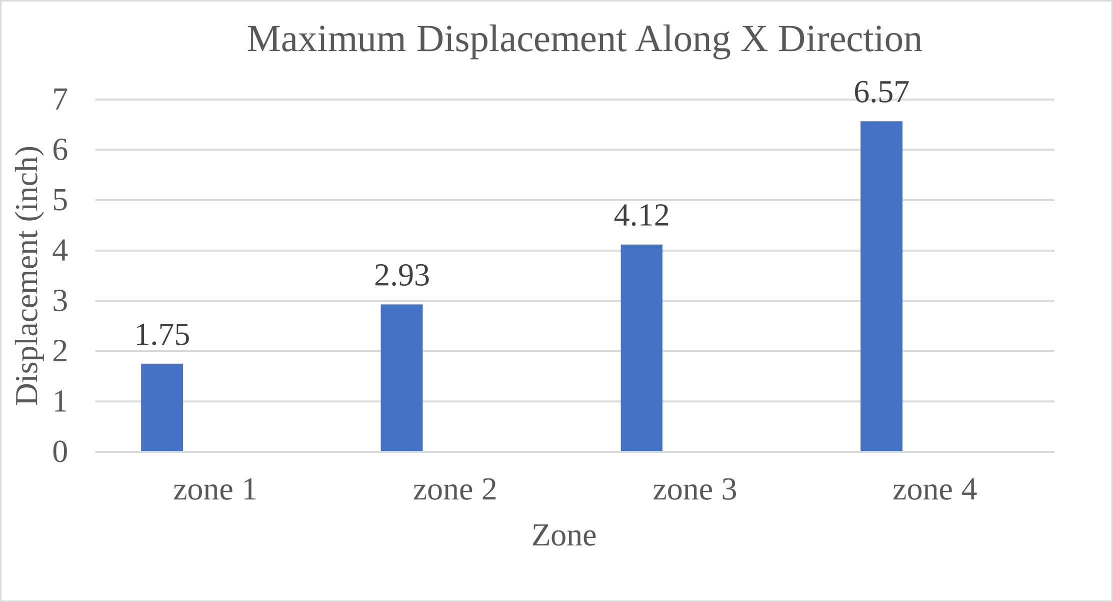

Figure 4.1: Maximum displacement (1) along X direction

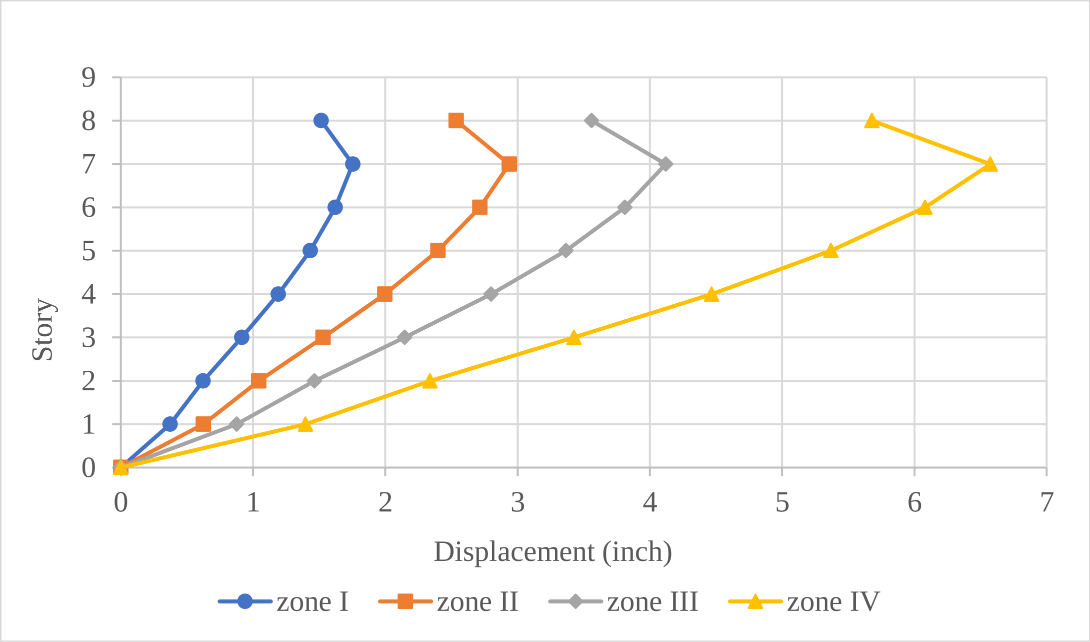

Figure 4.2: Maximum displacement (2) along X direction

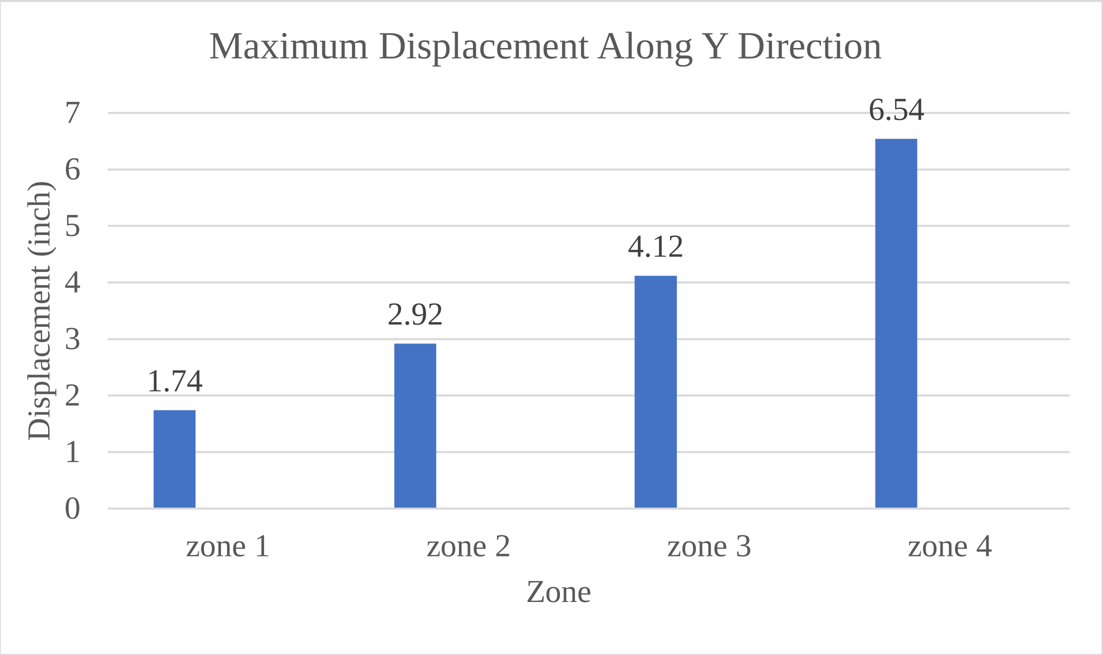

Figure 4.3: Maximum displacement (1) along Y direction

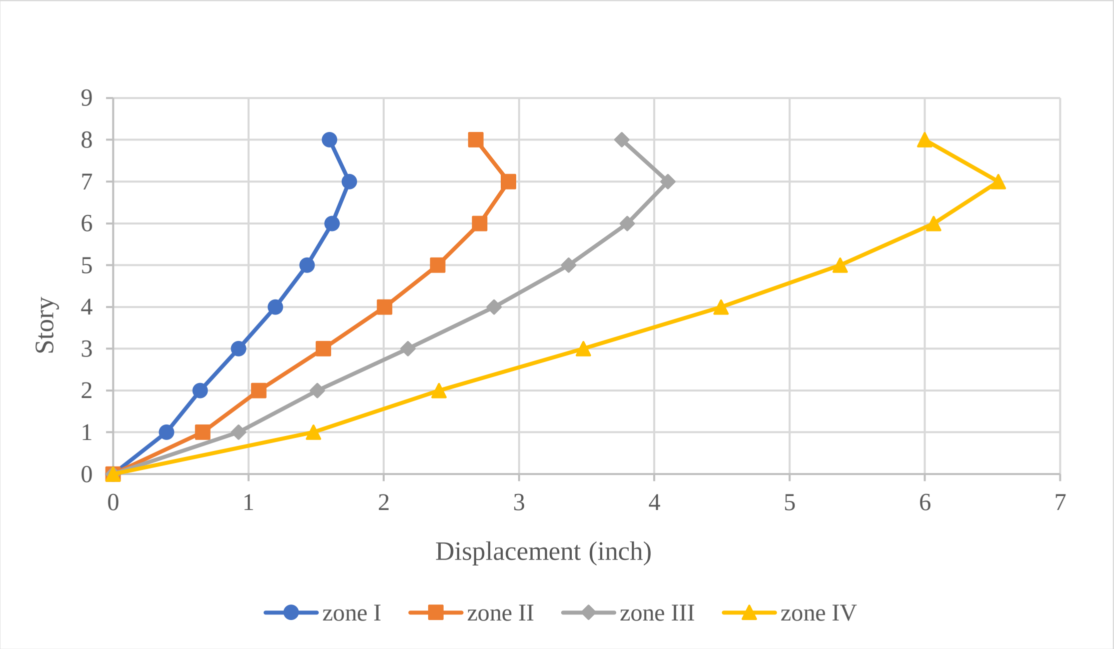

Figure 4.4: Maximum displacement (2) along Y direction

The prevalence of unconventional building construction has surged significantly, driven by aesthetic considerations and the restricted availability of land. The table indicates that structures exhibiting irregular configurations sustain damage during intense ground motion. Structural irregularities significantly contribute to the reduction of seismic performance in these buildings.

The following tables (4.11-4.18) show the building's maximum story drifts along Global X and Y directions. The maximum story drifts in seismic zone I are 0.372665 inches and 0394826 inches in the X and Y directions, respectively. The maximum story drifts in seismic zone II are 0.624215 and 0.661334 inches in the X and Y directions, respectively. The maximum story drifts in seismic zone III are 0.875764 inches and 0.927842 inches in the X and Y directions, respectively. The maximum story drifts in seismic zone IV are 1.397495 and 1.480599 inches in the X and Y directions, respectively. The maximum tale wanders 1.397495 inches in the X direction and 1.480599 inches in the Y direction, according to our analysis. Analysis of figure 4.6 reveals that tale drifts grow from zone I to zone IV, with the highest story drifts along the x direction occurring at floor 1. Additionally, tale drifts rise from zone I to zone IV, with the highest story drifts along the y direction occurring at level 7.

On ETABS for story drifts the ratio of maximum and average value is given on table (4.11 to 4.18). This table presents the maximum and average displacements measured in inches for various load cases and combinations in both the X and Y directions across all stories elevations.

Table 4.11: Maximum and average story drifts due to earthquake load Ex in the direction of X in zone I.

Along X Direction			
Story	EX		
	Maximum (in)	Average (in)	Ratio
Story8	0.092563	0.092265	1.003
Story7	0.131799	0.116021	1.136
Story6	0.189359	0.164309	1.152
Story5	0.240822	0.206903	1.164
Story4	0.277768	0.237378	1.17
Story3	0.290527	0.248305	1.17
Story2	0.25041	0.215735	1.161
Story1	0.372665	0.337074	1.106

Table 4.12 Maximum and average story drifts due to earthquake load Ey in the direction of Y in zone I.

Along Y Direction			
Story	EY		
	Maximum (in)	Average (in)	Ratio
Story8	0.078401	0.077056	1.017
Story7	0.12764	0.111571	1.144
Story6	0.184451	0.163064	1.131
Story5	0.234639	0.208674	1.124
Story4	0.270904	0.24202	1.119
Story3	0.284743	0.255611	1.114
Story2	0.247705	0.222703	1.112
Story1	0.394826	0.360418	1.095

Table 4.13: Maximum and average story drifts due to earthquake load Ex in the direction of X in zone II.

Along X Direction			
Story	EX		
	Maximum (in)	Average (in)	Ratio
Story8	0.155043	0.154545	1.003
Story7	0.220764	0.194336	1.136
Story6	0.317176	0.275217	1.152
Story5	0.403377	0.346562	1.164
Story4	0.465262	0.397608	1.17
Story3	0.486632	0.41591	1.17
Story2	0.419437	0.361357	1.161
Story1	0.624215	0.5646	1.106

Table 4.14: Maximum and average story drifts due to earthquake load Ey in the direction of Y in zone II.

Along Y Direction			
Story	EY		
	Maximum (in)	Average (in)	Ratio
Story8	0.131321	0.129069	1.017
Story7	0.213797	0.186882	1.144
Story6	0.308956	0.273133	1.131
Story5	0.39302	0.34953	1.124
Story4	0.453764	0.405384	1.119
Story3	0.476945	0.428148	1.114
Story2	0.414905	0.373028	1.112
Story1	0.661334	0.6037	1.095

Table 4.15: Maximum and average story drifts due to earthquake load Ex in the direction of X in zone III.

Along X Direction			
Story	EX		
	Maximum (in)	Average (in)	Ratio
Story8	0.217523	0.216824	1.003
Story7	0.309728	0.27265	1.136
Story6	0.444993	0.386125	1.152
Story5	0.565932	0.486222	1.164
Story4	0.652756	0.557838	1.17
Story3	0.682737	0.583516	1.17
Story2	0.588464	0.506978	1.161
Story1	0.875764	0.792125	1.106

Table 4.16: Maximum and average story drifts due to earthquake load Ey in the direction of Y in zone III.

Along Y Direction			
Story	EY		
	Maximum (in)	Average (in)	Ratio
Story8	0.184242	0.181081	1.017
Story7	0.299955	0.262192	1.144
Story6	0.43346	0.383201	1.131
Story5	0.551401	0.490385	1.124
Story4	0.636624	0.568748	1.119
Story3	0.669147	0.600686	1.114
Story2	0.582106	0.523352	1.112
Story1	0.927842	0.846983	1.095

Table 4.17: Maximum and average story drifts due to earthquake load Ex in the direction of X in zone IV.

Along X Direction			
Story	EX		
	Maximum (in)	Average (in)	Ratio
Story8	0.347112	0.345995	1.003
Story7	0.494247	0.435081	1.136
Story6	0.710095	0.616157	1.152
Story5	0.903083	0.775886	1.164
Story4	1.041632	0.890167	1.17
Story3	1.089475	0.931142	1.17
Story2	0.939038	0.809008	1.161
Story1	1.397495	1.264029	1.106

Table 4.18: Maximum and average story drifts due to earthquake load Ey in the direction of Y in zone IV.

Along Y Direction			
Story	EY		
	Maximum (in)	Average (in)	Ratio
Story8	0.294002	0.288959	1.017
Story7	0.478651	0.418392	1.144
Story6	0.691692	0.611491	1.131
Story5	0.879896	0.782529	1.124
Story4	1.015889	0.907576	1.119
Story3	1.067788	0.958541	1.114
Story2	0.928892	0.835137	1.112
Story1	1.480599	1.351568	1.095

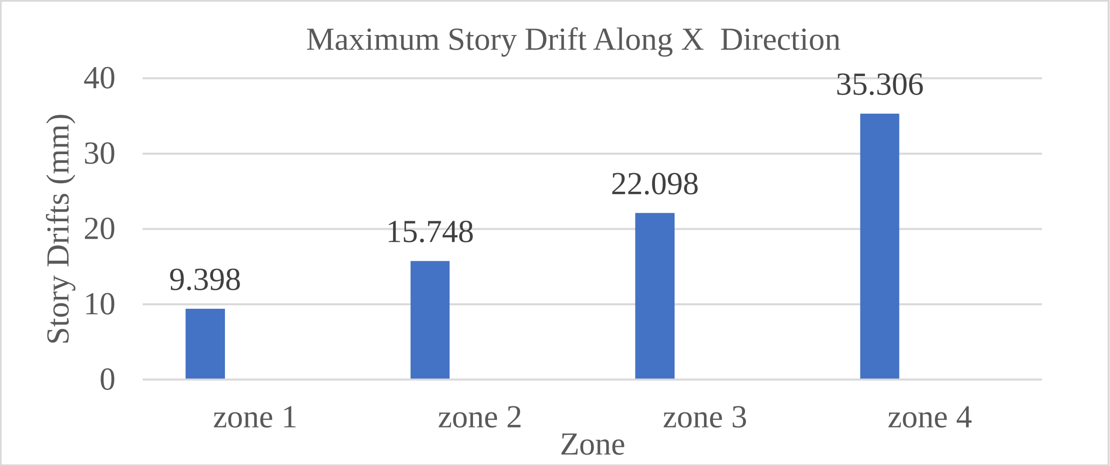

Figure 4.5: Maximum story drift (1) along X direction

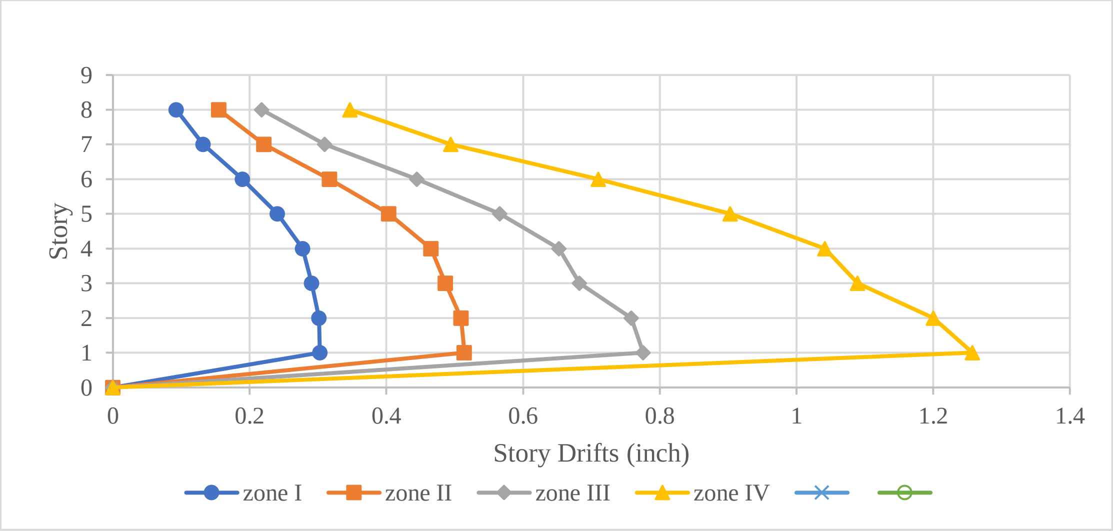

Figure 4.6: Maximum story drift (2) along X direction

The drift of the story within the structure is affected by seismic forces, especially in soft stories, where there is a noticeable reduction in drift from one level to the next. This suggests that when irregularities occur on the ground floor, the drift reaches its peak, subsequently decreasing as these irregularities move to upper levels.

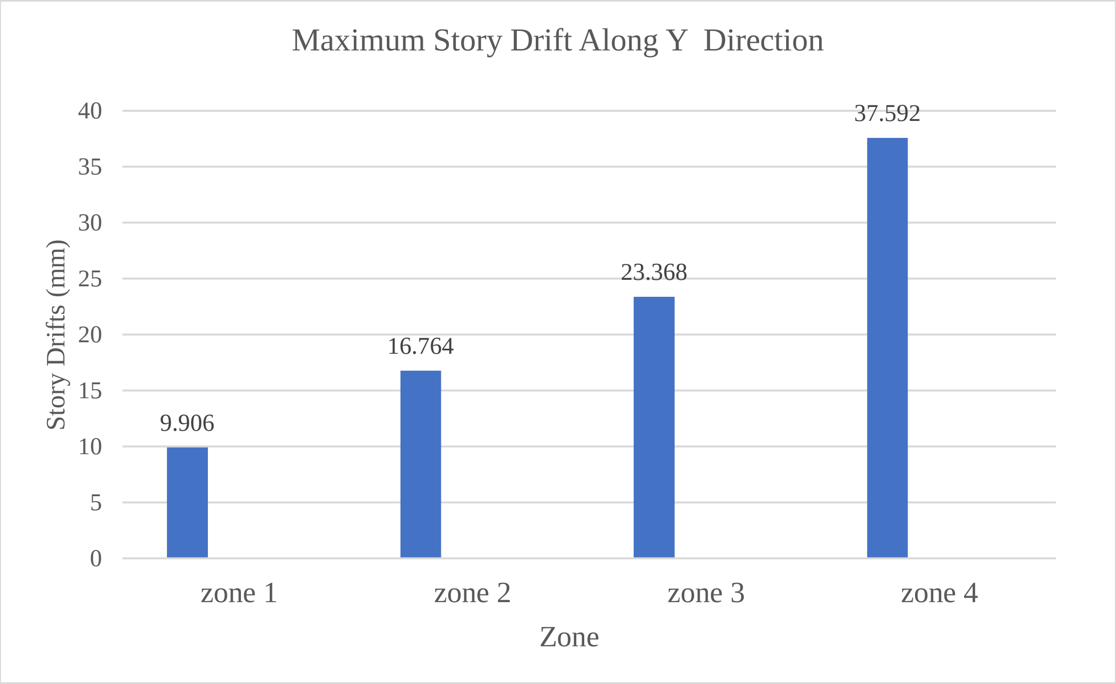

Figure 4.7: Maximum story drift (1) along Y direction

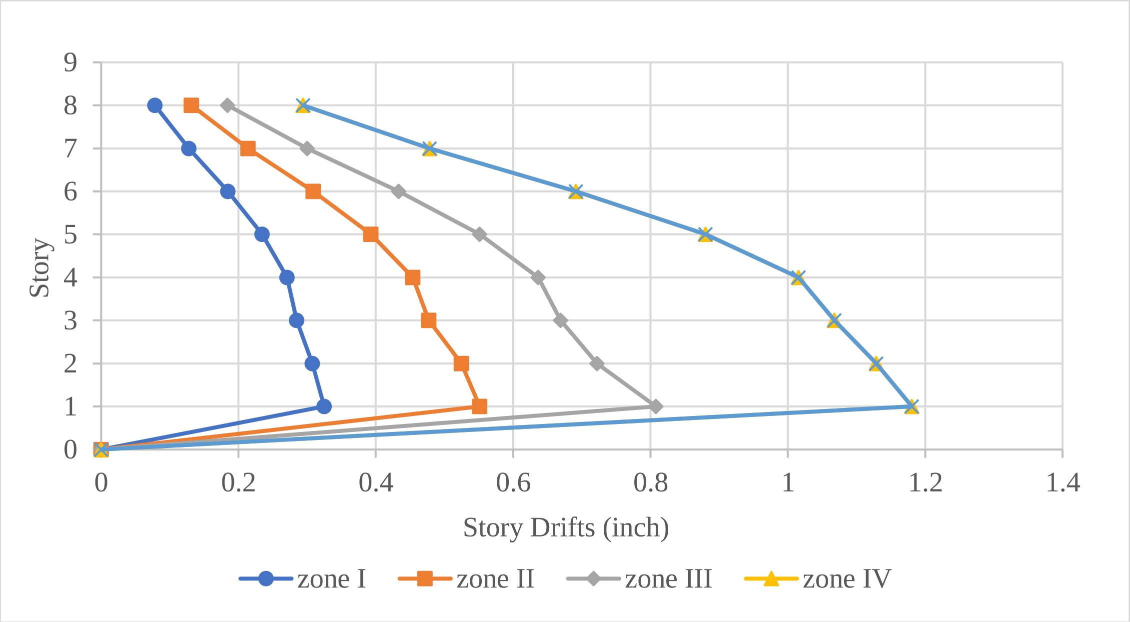

Figure 4.8: Maximum story drift (2) along Y direction

Table 4.19 shows the base shear for Bangladesh's seismic zones I, II, III, and IV. Zones I, II, III, and IV have maximum base shears of 248.707 kip, 416.584 kip, 584.461 kip, and 932.650 kip, respectively.

Table 4.19: Base shear in the direction of X and Y in zone I, II, III, IV

Base shear in the direction of X and Y in zone I, II, III, IV								
Direction	Zone I		Zone II		Zone III		Zone IV	
	Weight used kip	Base Shear kip	Weight used kip	Base Shear kip	Weight used kip	Base Shear kip	Weight used kip	Base Shear kip
X	6217.672	248.707	6217.672	416.584	6217.672	584.461	6217.672	932.651
X + Ecc. Y	6217.672	248.707	6217.672	416.584	6217.672	584.461	6217.672	932.651
X - Ecc. Y	6217.672	248.707	6217.672	416.584	6217.672	584.461	6217.672	932.651
Y	6217.672	248.707	6217.672	416.584	6217.672	584.461	6217.672	932.651
Y + Ecc. X	6217.672	248.707	6217.672	416.584	6217.672	584.461	6217.672	932.651
Y - Ecc. X	6217.672	248.707	6217.672	416.584	6217.672	584.461	6217.672	932.651

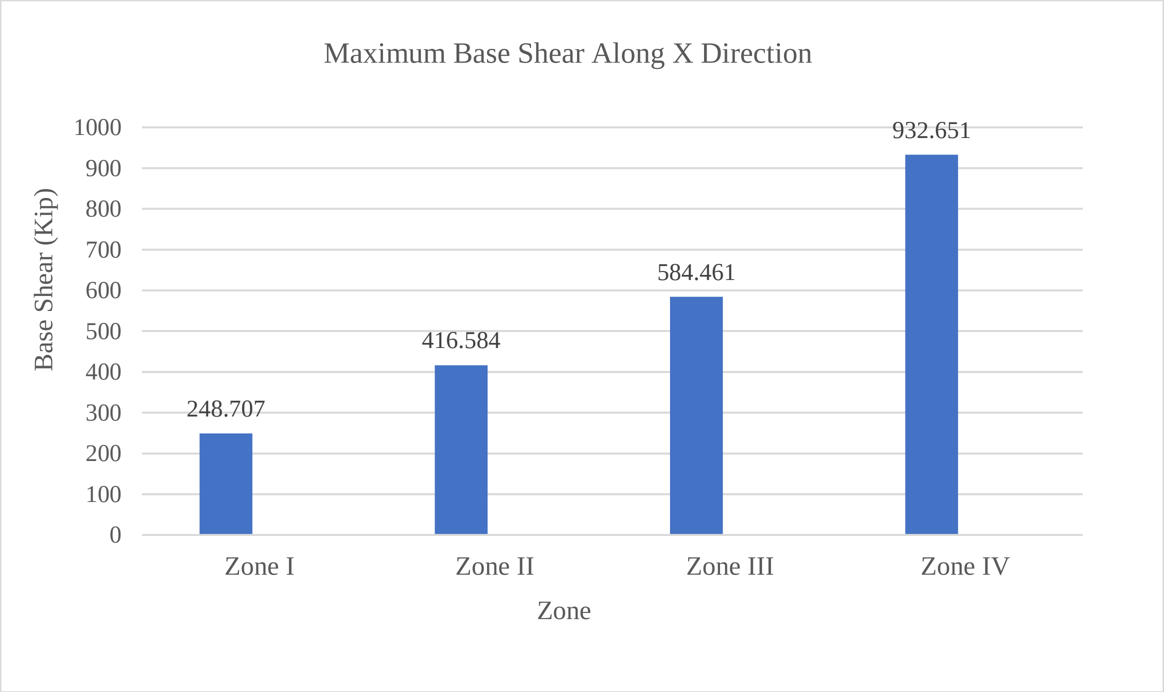

Figure 4.9: Maximum base shear along X direction

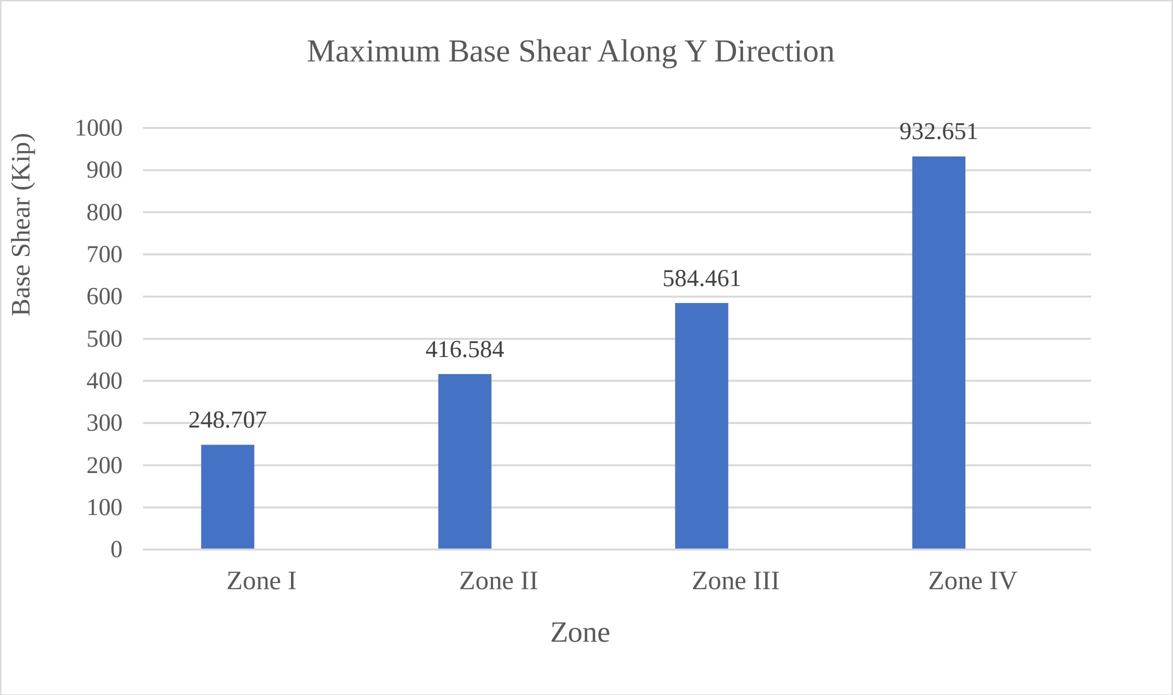

Figure 4.10: Maximum base shear along Y direction

The response spectrum function (RSX, RSY) is used to examine buildings for base reactions, which must be at least 85% of the calculated static base reaction (Ex1, Ex2, Ey1, Ey2). The base response values for seismic zones I, II, III, and IV are shown in Table 4.20. The maximum values of RXY are 376.81 kip, 437.73 kip, 729.85 kip, and 627.91 kip, while the maximum values of RSX for zones I, II, III, and IV are 296.34 kip, 457.26 kip, 636.34 kip, and 734.27 kip. Seismic zones I, II, III, and IV had maximum values of Ex of 248.71 kip, 416.58 kip, 584.46 kip, and 932.65 kip, respectively. Seismic zones I, II, III, and IV had maximum Ey values of 248.71 kip, 416.584 kip, 584.46 kip, and 932.65 kip, respectively.

Table 4.20: Base reaction due to earthquake load Ex and Ey in zone I, II, III, IV

Base reaction due to earthquake load Ex and Ey in zone I,II,III,IV								
Load	Zone I		Zone II		Zone III		Zone IV	
	Fx (kip)	Fy (kip)	Fx (kip)	Fy (kip)	Fx (kip)	Fy (kip)	Fx (kip)	Fy (kip)
EX1	-248.71	0	-416.58	0	-584.46	0	-932.65	0
EX2	-248.71	0	-416.58	0	-584.46	0	-932.65	0
RS-X Max	271.04	296.34	365.42	457.26	328.83	636.34	519.74	734.27
EY1	0	-248.71	0	-416.584	0	-584.46	0	-932.65
EY2	0	-248.71	0	-416.584	0	-584.46	0	-932.65
RS-Y Max	187.54	376.81	253.96	437.73	729.85	623.46	453.71	627.91

In order to achieve modal mass participation above 90%, response spectrum analysis is performed, and 14 mode shapes are selected for analysis. For every scenario, the building's basic time period and frequency are displayed in time period and frequency table 4.24.

Table 4. 21: Time period and frequency in zone I, II, III, IV

Time period and frequency in zone I, II, III and IV												
Zone I				Zone II			Zone III			Zone IV		
Case	Mode	Period sec	Frequency cyc/sec	Mode	Period sec	Frequency cyc/sec	Mode	Period sec	Frequency cyc/sec	Mode	Period sec	Frequency cyc/sec
Modal	1	1.553	0.644	1	1.553	0.644	1	1.553	0.644	1	1.553	0.644
Modal	2	1.523	0.656	2	1.523	0.656	2	1.523	0.656	2	1.523	0.656
Modal	3	1.417	0.706	3	1.417	0.706	3	1.417	0.706	3	1.417	0.706
Modal	4	0.511	1.958	4	0.511	1.958	4	0.511	1.958	4	0.511	1.958
Modal	5	0.498	2.007	5	0.498	2.007	5	0.498	2.007	5	0.498	2.007
Modal	6	0.466	2.148	6	0.466	2.148	6	0.466	2.148	6	0.466	2.148
Modal	7	0.285	3.509	7	0.285	3.509	7	0.285	3.509	7	0.285	3.509
Modal	8	0.273	3.667	8	0.273	3.667	8	0.273	3.667	8	0.273	3.667
Modal	9	0.216	4.623	9	0.216	4.623	9	0.216	4.623	9	0.216	4.623
Modal	10	0.181	5.516	10	0.181	5.516	10	0.181	5.516	10	0.181	5.516
Modal	11	0.173	5.784	11	0.173	5.784	11	0.173	5.784	11	0.173	5.784
Modal	12	0.134	7.447	12	0.134	7.447	12	0.134	7.447	12	0.134	7.447
Modal	13	0.112	8.937	13	0.112	8.937	13	0.112	8.937	13	0.112	8.937
Modal	14	0.093	10.793	14	0.093	10.793	14	0.093	10.793	14	0.093	10.793

The time period for modal "14" in zone I are 1.553, 1.523, 1.417, 0.511, 0.498, 0.466, 0.285, 0.273, 0.216, 0.181, 0.173, 0.134, 0.112 and 0.093 seconds. The time period values in zones II, III, and IV are identical to those in zone I.

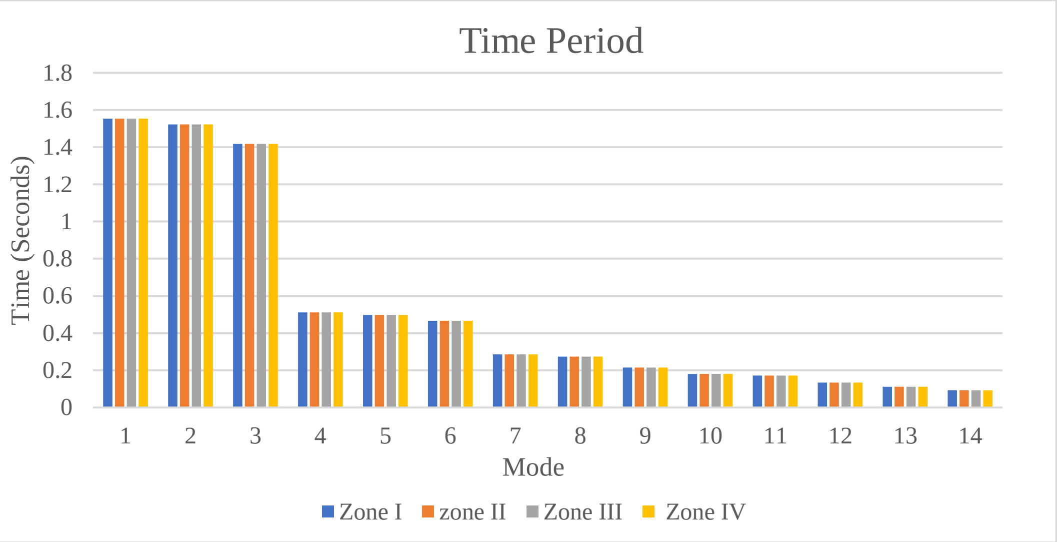

Figure 4.11: Building time period

The frequency for modal "14" in zone I are 0.664 cyc/sec, 0.656 cyc/sec, 0.706 cyc/sec, 1.985 cyc/sec, 2.007 cyc/sec, 2.148 cyc/sec, 3.506 cyc/sec, 3.667 cyc/sec, 4.623 cyc/sec, 5.516 cyc/sec, 5.784 cyc/sec, 7.447 cyc/sec, 8.937 cyc/sec and 10.793 cyc/sec are the corresponding frequency values. The frequency values in zones II, III, and IV are identical to those in zone I.

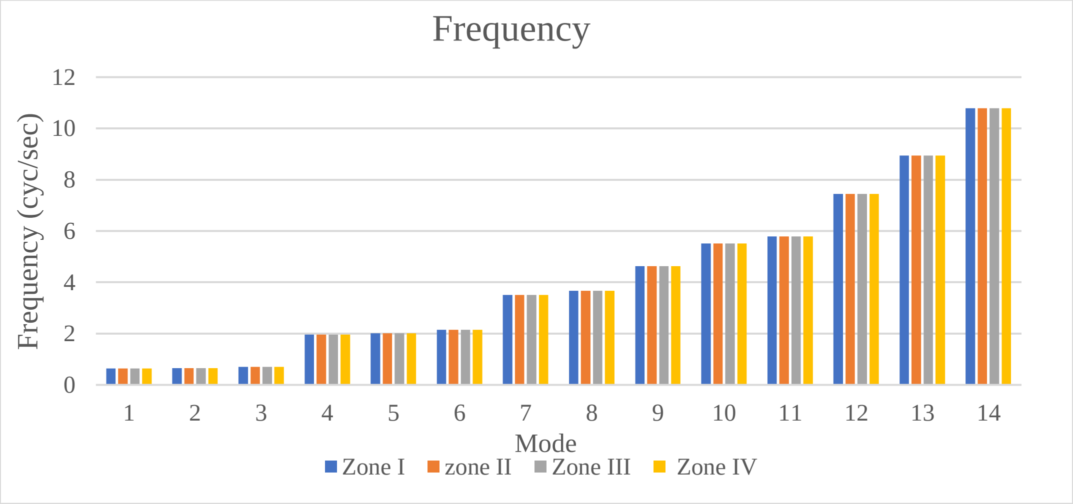

Figure 4.12: Building frequency

Table 4.23: Maximum Shear

Maximum Shear (kip) in Zone I, II, III, IV				
Story	zone I	zone II	zone III	zone IV
8	6.518	6.518	6.518	6.518
7	8.825	8.825	8.825	8.825
6	11.741	11.741	11.741	11.741
5	11.716	11.716	11.716	11.716
4	11.698	11.698	11.698	11.698
3	11.664	11.664	11.664	11.664
2	11.635	11.635	11.635	11.635
1	11.295	11.295	11.295	11.295

Table 4.22: Maximum Bending Moment

Maximum Bending Moment (kip-in) in Zone I, II, III, IV				
Story	zone I	zone II	zone III	zone IV
8	227.434	227.434	227.434	227.434
7	311.374	311.374	311.374	311.374
6	443.177	443.177	443.177	443.177
5	438.463	438.463	438.463	438.463
4	437.012	437.012	437.012	437.012
3	433.187	433.187	433.187	433.187
2	430.818	430.818	430.818	430.818
1	380.265	380.265	380.265	380.265

Table 4.24: Maximum Axial Force

Maximum Axial Force (kip) in Zone I, II, III, IV				
Story	zone I	zone II	zone III	zone IV
8	0	0	0	0
7	1.176	1.176	1.176	1.176
6	0.403	0.403	0.403	0.403
5	0.443	0.443	0.443	0.443
4	0.481	0.481	0.481	0.481
3	0.601	0.601	0.601	0.601
2	1.57	1.57	1.57	1.57
1	0	0	0	0

Table 4.25: Maximum Torsion

Maximum Torsion (kip-in) in Zone I, II, III, IV				
Story	zone I	zone II	zone III	zone IV
8	3.329	3.329	3.329	3.329
7	10.569	10.569	10.569	10.569
6	17.222	17.222	17.222	17.222
5	17.21	17.21	17.21	17.21
4	17.176	17.176	17.176	17.176
3	17.138	17.138	17.138	17.138
2	17.121	17.121	17.121	17.121
1	38.054	38.054	38.054	38.054

CHAPTER 5

CONCLUSION

The following conclusions are drawn from the analysis.

According to research, when compared to seismic zones I, II, and III, maximum displacement values are higher in seismic zone IV. The maximum displacement for zones I, II, III, and IV is shown in Figures 4.1 and 4.2. Additionally, when compared to seismic zones II, III, and IV, the minimum displacement values in seismic zone I are shown to be lower. It suggests that creating a structure with consistent stiffness can minimize displacement.

Additionally, research indicates that, in comparison to seismic zones II and III, tale drift values are higher in seismic zone IV. Story drifts are shown in Figures 4.5 and 4.6. Zone I has the least amount of tale drift and produces better results, whereas Zone IV has the most story drift. This suggests that creating a structure with consistent rigidity can also lessen tale drifts.

The appendix recommends a single-story limit for inter-story drift of 0.4 inches to limit damage to nonstructural components, or an overall building limit between h/400 and h/600 (where h = building height in feet). Ex and Ey direction ensure that all stories are safe after checking for tale drift. Therefore, zone I performs better than the other zones here as well. Thus, it may be said that buildings with consistent stiffness have produced better outcomes.

The minimum base shear value in Zone I is 248.707 kip, as can be seen from the maximum base shear figures 4.3 and 4.4. Zone IV's highest base shear value is 932.651 kip. Because zones I and II have more seismic demand than zones III and IV, the building's base shear values rise with the seismic zone. Out of all the zones, Zone IV regularly has the greatest base shear value.

The base reaction is not confirmed to be 85% across the entire zone because it is a static base reaction. improving outcomes in zones III and IV. The base response value must be scaled for zones II and III. We must scale the value in order to obtain an 85% base response.

For all zones I, II, III, and IV, torsional irregularity is seen as a result of load cases Ex and Ey in the global X and Y directions. The building is safe for zones I, II, III, and IV if the torsional value for each zone is less than 1.2.

According to BNBC 2020, the building's time period is determined by the building time period formula, Ta=1.33s, which is incompatible with any of the Modal 14 time periods displayed in the time period and frequency table and suggests that the building is immune to resonance effects.

In terms of maximum displacement, story drift, building time period, and base shear, it was found that the construction in zone I had produced better results. Thus, it may be said that buildings with consistent stiffness have produced better outcomes.

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