A COMPARISON STUDY ON SEISMIC ANALYSIS OF MULTI-STORIED (G+5=6) RESIDENTIAL BUILDING FOR DIFFERENT ZONES IN BANGLADESH USING ETABS.

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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

Department of Civil Engineering

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Section: 14C

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DECLARATION

It is hereby declared that this thesis/project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedicated

To

“Our Parents,

And

Our Honorable Teachers”

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ABSTRACT

This study aims at the comparison of provisions of earthquake analysis given in BNBC 2020. The revised BNBC 2020 has divided the seismic zones of Bangladesh into four different categories such as Zone-I, Zone-II, Zone-III and Zone-IV respectively. They have different seismic zone coefficients. Finally, structural analysis and design of a typical G+5 storey residential building situated in all four seismic zones is conducted to investigate the seismic behavior of that building under revised seismic zones and seismic zone coefficients. It is found that seismic base shear, displacement is much higher in zone-IV compared to other zones. For seismic zone-IV, overall highest displacement 46.19 mm and lowest displacement 4.64 mm in zone-I. The deflection of various members, inter storey drift, lateral displacement of the whole structure and stress of all members, inter storey lateral displacement of the whole structure and stress of all members were checked comparison with limiting value of the design criteria. After the preliminary design, the various cross section of beams and column and beam which the volume of concrete and quantity of steel is saved to precise amount and maximize the usable floor area by satisfying the design criteria. Finally, the member of column & beam sizes increases same seismic zone variation concrete.

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CHAPTER 1
INTRODUCTION

1.1 General

- Earthquakes are a real threat to people's lives and property. The recent earthquake in Dhaka city is the best proof that it is time to take seismic load seriously.
- Therefore, it is a must now to predict the strength of the earthquake and prepare for it to avoid or minimize damage.
- It should be noted here that strengthening the building against seismic load increases its cost, so this work was done.

The increase in population by which land deficit occurs and to control that, high-Rise buildings are opted. These types of high-rise buildings are affected by the natural calamities. Calamities like earthquakes are the most dangerous by means of the damage and chaos caused to the structural components and they cannot be controlled. These natural calamities caused property damage and interruptions in development of the normal lifecycle. Since it’s a global concern, most of the analysis should be carried out and provided with the results to prep the structure in order to attain time period. A seismic wave is the cause of ground motions that are much larger on the soil surface than on the rock base. Structures located on such sites sustain more damage than sites located closer to the rock surface [1].The seismic effect on any structure is determined by the seismic zone coefficient, response reduction factor, soil characteristics, structure importance, and so on. It is necessary to be aware of the most recent earthquake codes in order to design an earthquake-resistant structure. In most small and moderate-sized buildings, the dynamic effects of earthquake loads are typically analyzed as an equivalent static load [2]. Recent earthquakes in Bangladesh's urban areas have highlighted the importance of pushing to strengthen these seismically deficient structures and making progress in developing various strengthening and rehabilitation techniques to improve the seismic performance of structures [3].

1.2 Background of the Study

It is indicated that a significant number of structures are completely or partially harmed as a result of earthquakes, and it is now critical to decide seismic reactions over such structures. Structural analysis is a branch of engineering that focuses on the assurance of structures with the goal of anticipating the reactions of genuine structures such as structures, spans, trusses, and so on before developing any structure, basic outlining necessitates basic investigation and seismic examination. In order to meet the needs of this growing population in a constrained space, the building's height has been reduced to medium to tall. As a result, seismic examination study and planning quake protection structures are required to ensure safety against seismic powers of multistory working. Displacement of structure begins from the purposes of a shortcoming during an earthquake. Geometry, mass brokenness, and structure solidity are the most common causes of shortcoming. That is why' in general, structures fail during earthquakes due to vertical abnormality

The initial goal of this research is to investigate seismic reaction in various zones of structure for static and dynamic examination in standard minute opposing casing. We considered a residential building with (G+5) stories for the seismic Investigation. The method for establishing the base plan loads that must be acquired for dead loads, forced burdens, and other outside loadings attaches the basic necessities relating to the basic security of structures. The total structure was analyzed on a computer using the ETABS software. In this paper, an analysis done for (G+5=6) RCC building under seismic loads for Khulna District (Zone I), Dhaka District (Zone II), Rangpur District (Zone Ill) and Sylhet District (Zone IV). Numerous load combinations are observed in accordance with BNBC 2020.

1.3 Objective

- To analyze a six storied Residential building.
- Considering Seismic load at four different Seismic zone of Bangladesh.
- To check maximum drift and displacement for four different zone.
- To compare Maximum Drift & Displacement among four Different Zone.

This work focuses to demonstrate the validity and efficiency of pushover analysis method as incorporated in ETAB 18 the work would also study the effectiveness of pushover analysis in comparison to more rigorous nonlinear time history analysis with particular emphasis on the load pattern employed in pushover analysis. Finally, performance of building frames designed as per BNBC 2020 will be evaluated against targeted performance levels for serviceability.

1.4 Organization of the thesis

Chapter 1: Introduction and Objective. This chapter provides the background of study and motivations of the research. The overall objectives and expected outcomes are also described in this chapter.

Chapter 2: Literature Review. This part discusses the previous analysis history about earthquake or seismic wave, recent research on seismic zone, seismic design requirements as per BNBC-2020, lift pit details specifications, wind load and wind load code provisions as per BNBC-2020, seismic load and seismic load code provisions as per BNBC-2020.

Chapter 3: Methodology. This chapter discusses the analytical process in details step by step. The Zonal Parameters, Load principles and types of load acting on the structure are also discussed in this chapter.

Chapter 4: Results and Discussion. This chapter describes the results of the proposed buildings load and material properties, building load calculation. Different floor plan view and building analysis image are also shown in this chapter. Overall and zone to zone story drift, story displacement, Torsional irregularity and Base shear analysis data and results are also discussed in this chapter.

Chapter 5: Conclusions and Future Work. This chapter summarizes the conclusions and major contributions of this study and provides recommendations for future studies.

CHAPTER 2

Literature Review

2.1 Introduction

Millions of people have died due to natural disasters, more than half have died in earthquakes and the rest due to weather and climate-related hazards. The poorest nations paid the highest price in terms of disaster deaths. Therefore, new advanced, ideal and inexpensive techniques should be used for the design and construction of structures. Due to the rapid urbanization of a large number of multi-story buildings, [4] many existing RCC buildings in seismic zones are not earthquake proof. To meet the demands of this growing population in the limited the land, the height of the building is turned from medium to high. Today, due to the dramatic increase in urban population, land scarcity, and high cost, multi-story buildings are widespread in urban areas around the world. The challenge, however, is that as the height of the structure increases, the lateral loads are affected. These lateral loads are mainly presented in the form of wind load and seismic load. Therefore, an effective design approach and advanced construction techniques are applied to protect buildings from wind load and seismic load. Much research and studies have been done to improve the performance of tall buildings against these loads. The most important and effective design approach among these methods is to change the geometry of the building floor plan and, furthermore, it is very simple and does not require many more techniques. In the past, a rectangular plan shape was mainly adopted, but today many more different plant shapes are used. Therefore, it is necessary to examine the behavior of buildings with different floor plans and compare them against various parameters to find the most suitable floor plan [5].

2.2 Earlier Research on Seismic Zone

Mir Abdul Kuddus, ParthaPritomDey:In this study, 3 separate ground plus 19 storied buildings of R.C.C., Steel and Steel-Concrete composite frame are designed by ETABS software and the design parameters are considered for relative comparison. The literature relating to R.C.C., Steel and Steel-Concrete composite structure for designing concept are reviewed.Evaluation of load patterns and lateral forces according to UBC

94 codes were assigned and then the static and dynamic analysis was performed by using response spectrum analysis in ETABS to design the building. Then the comparative dynamic behavior is reviewed and estimation of the cost of superstructures frame is also calculated to find out the comparative differences. The building is considered to be constructed in Mongla Port, second largest international sea port in Bangladesh. Moreover, the building is designed to use as a multi-storied car parking for imported car from different countries of the world. The port is located 48 km south of Khulna city. The Port is surrounded as well as well protected by the Sundarban mangrove forest. The port is situated at the confluence of the Pashur River and the Mongla River. It lies about 62 miles (100km) north of the Bay of Bengal. According to Bangladesh National Building Code (BNBC2010), the basic wind speed is taken for Mongla Port Area is 279 km/hr. In Bangladesh most of the building structures fall under the category of low-rise buildings. So, for these structures reinforced concrete members are used widely because the construction becomes quite convenient and economical in nature. But since the population in cities is growing exponentially and the land is limited, there is a need of vertical growth of buildings in these cities. So, for the fulfillment of this purpose a large number of medium to high rise buildings are coming up these days.

2.3 Seismic Design Requirements for RCC Beam Design for Residential Buildings

- ❑ Material Strength
  - ✓ Minimum specified compressive strength f'_c = 3,500psi
  - ✓ Maximum specified yield strength of reinforcement, F_y = 60,000psi
- ❑ Clear Span of Beam for Buildings
  - ✓ Clear span > four times the effective depth i.e., In >4d
- ❑ Sectional dimensions of the beam for Buildings
  - ✓ Width-to-depth ratio 0.3 i.e., b/h 20.3
  - ✓ Minimum width 10 inch
  - ✓ Minimum width of the beam S [width of the supporting column + 1.5h]
- ❑ Main reinforcement
  - ✓ ƿ min ≥ 200/ f_y
  - ✓ ƿ max ≤ 0.0250

Both the top and bottom of the member should have two continuous bars. The top or bottom steel at any section should not be less than 14 of the steel for the maximum (- ve) moment at the supports. The min bottom (+ ve) steel at each support must be equal to 12 of the (- ve) moment steel [6]

- ❑ Spacing of main reinforcement
  - ✓ Splices are not permitted to be used I within joints within 2 hours of the column face. Splices must be held together by hoops or spiral reinforcement with a maximum spacing or pitch of d/4 or 4 inches, whichever is less.
- ❑ Transverse reinforcement details

Total required steel area, Av = $\frac{\frac{Vn}{\phi}}{Fy*d} * S$

Hoops are used to provide confinement reinforcement.

Hoops are required over a 2h (h = depth of beam) distance from the faces of both supports.

The first hoop will be placed 2 inches from the face of the support

The smallest of the following values is the maximum hoop spacing: d/4

8 x diameter of smallest longitudinal bar

24 x the hoop bar's diameter (12 inches)

Stirrups with seismic hooks at both ends (detail A) shall be spaced not more than d/2 along the length of the member where hoops are not required (beyond the confinement zone and splicing).

2.4 Seismic Considerations for Column Design for Residential Buildings

❑ Material Strength

- Minimum compressive strength of all types of concrete, fc'= 4,000psi
- Maximum yield strength of reinforcement, f_r= 60,000psi
- Normal density concrete is preferable, w_c: 140-450 psf [7]

- Main reinforcement ratio

Columns are generally designed with reinforcement ratio between 1% to 8% of the gross section area. Oversized columns widely referred to as "Architectural Columns", are often needed for functional purposes resulting in reinforcement ratios below 1% [8]

  - ✓ ꝑ min = 0.01
  - ✓ ꝑ max = 0.06
  - ✓ Preferable ꝑ = 0
- Splicing of the Main reinforcement
  - ✓ Lap splice shall be used only within the center of the column.
  - ✓ Welded splices may be used at any section of column, provided that:

a) They are used only alternate longitudinal bars at a section.
b) The distance between splices along the longitudinal axis of reinforcement 24".
c) Splices are to be confined by hoops or spiral reinforcement with maximum spacing or pitch of d/4 or 4 inch whichever is smaller.

- **Splice length**

$$I_d \geq \left\{ 0.0004 d_b f_y * \frac{0.04 A_b * f_y}{\sqrt{f'_y}} \right\}$$

Where,

Ab= Bar area

Splice length = 1.3 Id (class B splice)

Id = development length of the bars.

- Transverse reinforcement

Such reinforcement is provided as closed hoops for tied column or circular hoops for spiral column.

- **Circular hoops:** steel ratio of circular/spiral hoops

$$\rho_s \geq \left\{0.12\frac{f'_c}{f_{yh}} * 0.45\ \left(\frac{A_g}{A_{ch}} - 1\right)\frac{f'_c}{f_y}\right\}$$

Where,

F_{yh} = yield strength of hoop reinforcement.

A_{ch} = core area of column section measured to the outside of hoop reinforcement.

- **Closed hoops**: Total cross-sectional area of closed hoops

$$A_s \geq \left\{0.09s_o h_c * 0.3s_o h_c \left(\frac{Ag}{Ac} - 1\right)\frac{f'_c}{f_y}\right\}$$

Here,

h_c =cross-sectional dimension of column core measured center-to-center of hoop reinforcement.

S_o = vertical spacing of hoop reinforcement.

- **Confinement length**: confinement reinforcement is to be provided over a length 10 from each joint face of the column.

$$A_s \geq \left\{\frac{1}{6}\ (clearspan\ of\ the\ column)\right\}\ depth\ of\ member\ 18''$$

The first hoop will be placed at 2 inches from the joint.

- Main reinforcement ratio
  - ✓ ρ min = 0.01
  - ✓ ρ max = 0.06
  - ✓ Preferable ρ = 0.04

- Splicing of the Main reinforcement
  - ✓ Lap splice shall be used only within the center of the column.
  - ✓ Welded splices may be used at any section of column, provided that.
  - ✓ They are used only alternate longitudinal bars at a section.

- ✓ The distance between splices along the longitudinal axis of reinforcement 24".
- ✓ Splices are to be confined by hoops or spiral reinforcement with maximum spacing or pitch of d/4 or 4 inch whichever is smaller.

- **Splice length**:

$$Id \geq \left\{ 0.0004 d_b f_y * \frac{0.04 Ab * Fy}{\sqrt{f'c}} \right\}$$

Here,

Ab = Bar area

Splice length = 1.3 Id (class B splice)

Where, Id = development length of the bars

❑ Transverse reinforcement

Closed hoops are used for tied columns, while circular hoops are used for spiral columns.

- **Circular hoops**: steel ratio of circular/spiral hoops

$$\rho_s \geq \left\{ 0.12 \frac{f'_c}{f_{yh}} * 0.45 \left(\frac{A_g}{A_{ch}} - 1 \right) \frac{f'_c}{f_{yh}} \right\}$$

Here,

f_{yh} = hoop reinforcement yield strength.

Ach = column section core area measured from the outside of the hoop reinforcement.

- **Closed hoops:** Closed hoop total cross-sectional area

$$A_s \geq \left\{ 0.09 s_o h_c * 0.3 s_o h_c \left(\frac{Ag}{Ac} - 1 \right) \frac{f'_c}{f_y} \right\}$$

In this case, hc is the cross-sectional dimension of the column core measured from center to center of the hoop reinforcement. So = hoop reinforcement vertical spacing.

- **Confinement length**: Concealment reinforcement should be applied along a length 10 from each joint face

$$A_s \geq \begin{cases} \frac{1}{6} \ (clearspan\ of\ the\ column) \\ depth\ of\ member \\ 18'' \end{cases}$$

The first hoop will be placed 2 inches away from the joint.

2.5 Lift Pits

- ✓ Lift pits with depths greater than 1.6 m must have a suitable descending arrangement to reach the lift pit.
- ✓ At the bottom of each lift well, a lift pit must be provided.

Table 2-1. Lift Pit Recommendations

Speed (m/s)	0.5	1	1.5	2	2.5	3	3.5	4
				Depth (m)				
i) With restrained rope compensation.	-	-	-	1.6	2.6	2.8	3.0	3.2
ii) With chain, free rope or travelling cable compensation.	1.5	1.5	1.6	2.4	2.5	-	-	-
iii) With reduced stroke buffer and either restrained rope chain travelling cable or free rope compensation.	-	-	1.5	1.6	2.4	2.6	2.6	2.8

2.6 Wind Loads

Wind Load refers to any pressures or forces apply by the wind on a building or structure. There are three types of wind forces that can be applied to a building Wind Loads: Uplift Wind Load, Shear Wind Load, and Lateral Wind Load.

Wind loads are dynamic loads that are applied at random. Wind velocity, air density, structure orientation, area of contact surface, and structure shape all influence the intensity of wind pressure on a structure's surface. Due to the complexities involved in defining both the dynamic wind load and the behavior of an indeterminate steel structure when subjected to wind loads, building codes and standards have adopted design criteria based on the application of an equivalent static wind pressure [9].

2.7 Basic Wind Speed

The basic wind speed, V used in the determination of design wind loads on buildings and other structures. The wind shall be assumed to come from any horizontal direction.

Where records or experience show that wind speeds are higher than those depicted in Figure 2.1, the fundamental wind speed shall be raised. Unusual wind conditions will be investigated in mountainous terrain, canyons, and peculiar places. If necessary, the authority of BNBC with jurisdiction will update the values in Figure 2.1 to accommodate for increased local wind speeds. This modification must be based on accurate weather data and other relevant data.

Table 2-2. Basic Wind Speeds, V, for selected Location in Bangladesh [10]

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
Barishal	77.7	Meherpur	58.2
Bhola	69.5	Maheshkhali	80.0
Bagra	61.9	Moulvibazar	53.0
Brahmanbaria	56.7	Munshiganj	57.1
Chandpur	50.6	Mymensingh	67.4
Chapai Nawabganj	41.4	Naogaon	55.2
Chittagong	80.0	Narail	68.6
Chandanga	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	63.1	Pabna	63.1
Feni	64.1	Panchagarh	41.4
Gaibandha	65.6	Patuakhali	80.0
Gazipur	66.5	Pirojpur	80.0
Gopanganj	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	73.7	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

2.8 Exposure Category according BNBC 2020

Exposure A: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced interference the size of single-family homes or larger

Exposure B: Open terrain with scattered interference at heights of less than 9.1 meters. Flat open country, grasslands, and all water surfaces in cyclone-prone areas fall into this category.

Exposure C: Flat, unobstructed areas and water surfaces outside cyclone inclined regions. This category includes smooth mud flats and salt flats [11].

2.9 Variables Affecting Wind Pressure Distributions

- **Building Shape:** Pressure on specific parts of a structure is very sensitive to changes in the building's shape. Inconsistent have little effect on suction on the windward side or suction on the leeward side. Shape details can have an unexpectedly large impact on wind pressure distribution. Parapet walls, large chimneys, silos, and spires can all have a significant impact, and testing a scale model in a wind tunnel is often the only way to assess such effects.
- **Openings:** The internal pressure that must be considered in the calculation of net forces of walls and roofs is determined by the size and location of openings such as windows and doors. Internal pressure tends to take on the values associated with the exterior of the wall where the opening dominates. If they are small and evenly distributed, a value of 2 is recommended, with the more critical of the two to be considered in each case.

- **Wind direction:** Orientation of the building toward the wind has a logistic effect on pressure distribution, particularly at maximum suction, which occurs over a small area near the leading edges of the roofs.

- **Increase of wind speed with height:** Because wind speed and thus velocity pressure increase with height above ground, a height factor is added to the base pressure in building design.

2.10 Seismic Zone Coefficients:

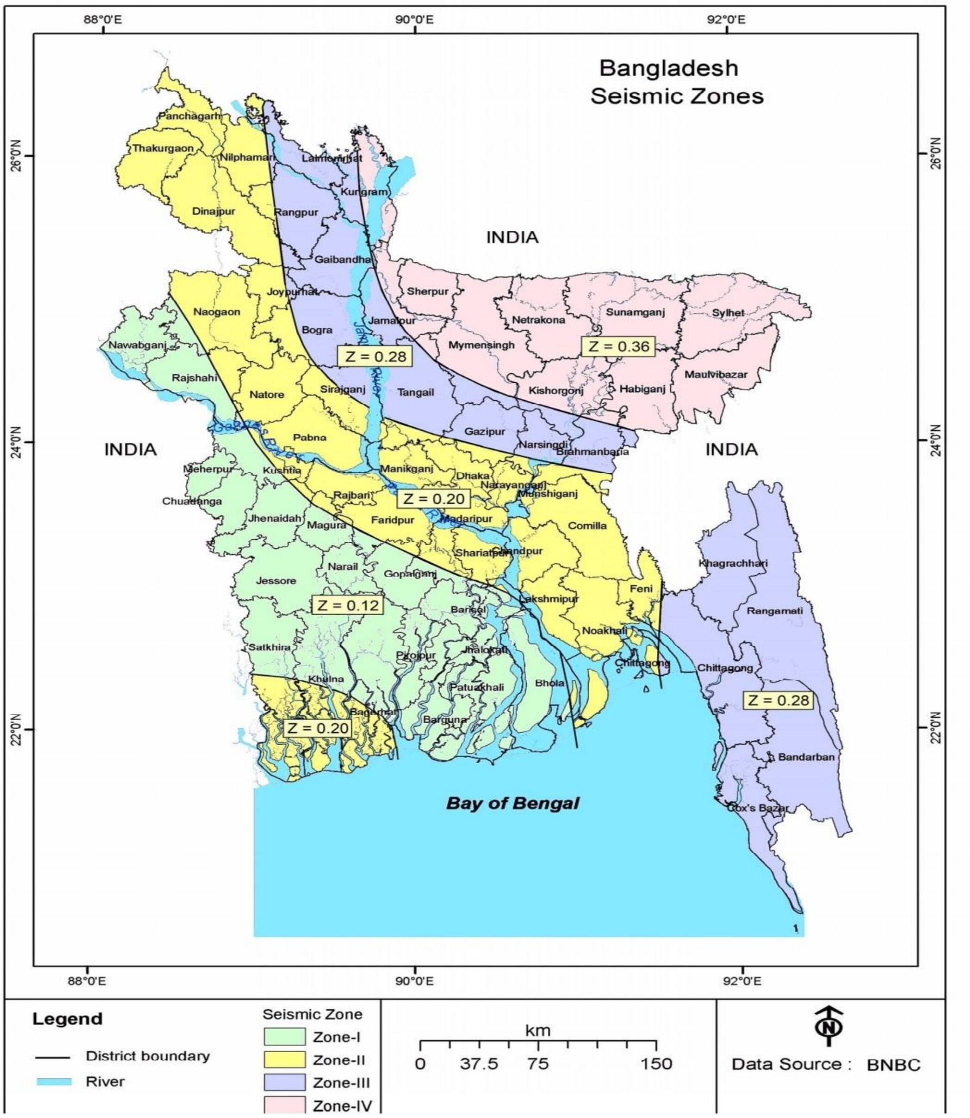


Figure 2-1. Seismic Zone Coefficients Bangladesh [12]

- **Observation** – Above is the seismic zone coefficients figure for Bangladesh. In the legend, its color is mentioned as follows:
  - Light green is Khulna District (zone I) Z = 0.12
  - Turmeric Yellow is Dhaka District (zone II) Z = 0.20
  - Light Purple is Rangpur District (zone III) Z = 0.28
  - Deep Green is Sylhet District (zone IV) Z = 0.36

Table 2-3. Seismic Zone Coefficients Z

Seismic Zone	Zone Coefficient
Zone I	0.12
Zone II	0.20
Zone III	0.28
Zone IV	0.36

Table 2-4. Structure Importance Coefficients I~I'

Structure Importance Category	Structure Importance Coefficient	
	I	I'
Essential facilities	1.25	1.50
Hazardous facilities	1.25	1.50
Special occupancy structures	1.00	1.00
Standard occupancy structures	1.00	1.00
Low-risk Structures	1.00	1.00

C must not be greater than 2.75, and this value can be used for any structure regardless of soil type or structure period. Except for requirements where the Code prescribed forces are scaled up by 0.375R, the minimum value of the C/R ratio is 0.12.

2.11 Earth Quake Magnitude

According to the depth of field, the tectonic earthquake is classified as follows: Shallow: the depth of field is "less than 60 km. Medium: depth of field between 60 and 70 1m. Depth: depth of field greater than 70 km. El The scale of seismic intensities was conveniently divided into 12 categories, until in 1935 CF Richter designed a scale with the number J5, with the magnitude of seismic strength 10 being the highest on this scale. The strength of the earthquake in relation to the Richter scale is expressed as:

- ✓ Instrumental: detected by seismograph, magnitude 13;
- ✓ weak: only perceived by sensitive people
- ✓ light: it is like the vibration of a passing truck, felt on the upper floors, size 3.5 to 4.2;
- ✓ Moderate: felt when walking, intensity 4.3;
- ✓ Strong: trees sway, hanging objects sway, fall loose, objects, magnitude 4.9 to 5.4;
- ✓ Very strong: cracked walls, plaster falls, thickness 5.5-6;
- ✓ Destructive: chimneys fall; Damaged building, magnitude 6.8;
- ✓ Ruinous: collapse of houses, cracks in the floor, broken pipes, magnitude 6.9;
- ✓ Catastrophic: The cracks in the floor move a lot. Destroyed, bent tracks, thickness 7 to 7.3;
- ✓ Very catastrophic: few buildings remain standing; Bridges destroyed, landslides and major floods, magnitude 7.4 to 8.1;
- ✓ Catastrophic: total destruction. Objects thrown into the air, the ground rises and falls in waves, magnitude 8.2 and higher.

There are three zones, mainly Zone I, which is the most active, Zone II, which is least active, and Zone III, which is the lowest possible earthquake magnitude. See figure **2.2. The probable seismic magnitudes are:**

Zone	Richter Scale
I	7.0
II	6.50-7.0
III	6.0-6.5

Buildings should be designed for earthquake resistance in Zone I, of course. However, for low-rise buildings, an additional provision of 33 percent reinforcement may be provided. Qualified Civil Engineers should create proper technical designs for high-rise buildings [13].

2.12 Earthquake Effected Areas Recorded in Bangladesh

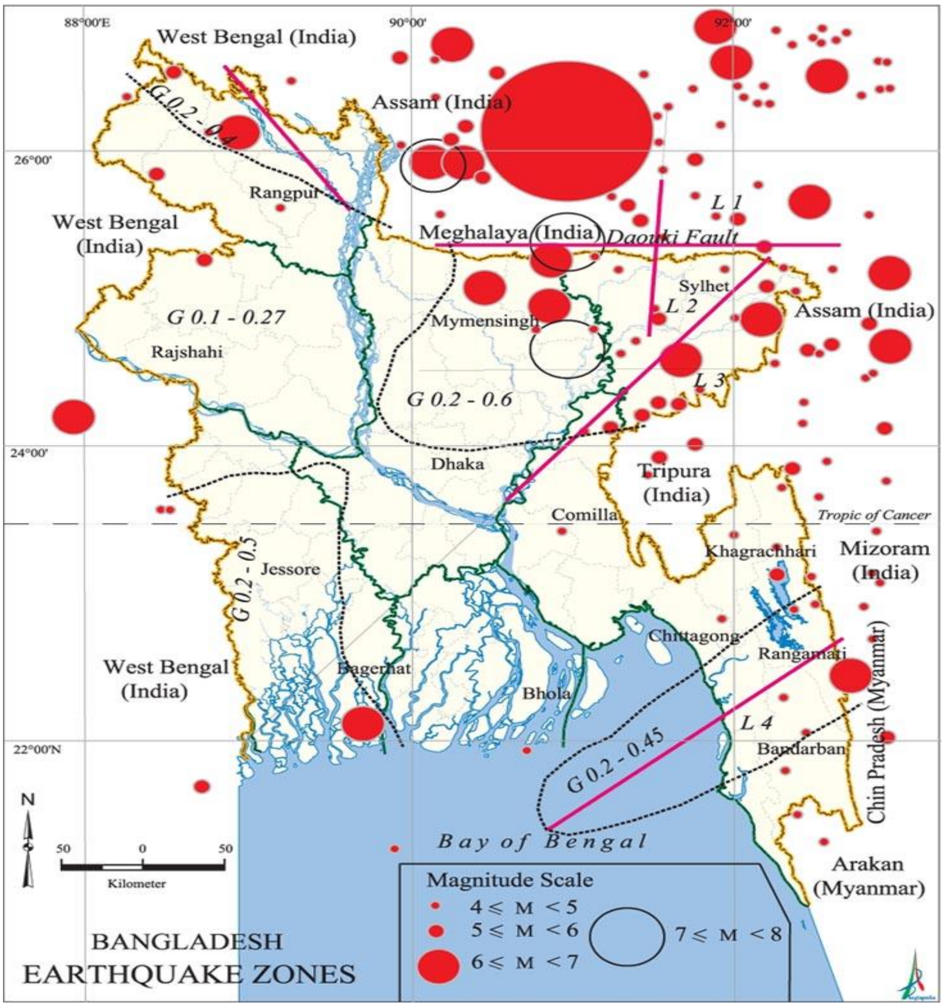


Figure 2-2. Bangladesh Earthquake Zones

CHAPTER 3
Methodology

3.1 Introduction

The Seismic analysis is a section of structural analysis that involves calculating a building's earthquake response. In earthquake-prone areas, it is a part of the structural design, earthquake engineering, or structural evaluation and retrofit process. Civil engineering is primarily concerned with structural design. The design of the basic components and parts of a building, such as slabs, beams, columns, and footings, is the most fundamental in structural engineering. The analysis of seismic provisions of the Bangladesh National Building Code-BNBC 2020 in the thesis approach prompted the thesis dissertation to achieve the above-mentioned aims. The steps in the structure analysis process are as follows:

- ✓ Architectural & Structural Planning.
- ✓ Load Calculations.
- ✓ Analysis of Structure.
- ✓ Finding results.
- ✓ Conclusions.

This chapter gives the outlines of the procedures that were followed to complete this study. Also loads (wind & earthquake) calculations are presented in details.

3.2 Notation

- ✓ A_g= gross sectional area
- ✓ A_v= shear reinforcement area
- ✓ d= distance between the extreme compression fiber and the tension reinforcement centroid
- ✓ $f_{c'}$= concrete's specified compressive strength
- ✓ f_y= reinforcement yield strength specified
- ✓ h= overall member thickness
- ✓ h_w= total wall height from base to top
- ✓ k= effective length factor
- ✓ l_e= vertical distance between the support.
- ✓ I_w= horizontal length of the wall.
- ✓ M_u= sectional factored moment
- ✓ N_u= factored axial load normal to cross section that occurs concurrently with Vu
- ✓ P_{nw}= nominal axial load strength of the wall.

- ✓ S_1= vertical reinforcement spacing in a wall.
- ✓ S_2= horizontal reinforcement spacing in a wall
- ✓ V_s= shear reinforcement's shear strength.
- ✓ V_n= nominal shear strength.
- ✓ V_u= shear force factor.
- ✓ V_e= nominal shear strength provided by concrete.
- ✓ P_h= the ratio of horizontal shear reinforcement area to vertical section gross concrete area.
- ✓ P_v= the ratio of vertical shear reinforcement area to horizontal section gross concrete area.

3.3 Bangladesh National Building Code (BNBC)

In this segment, provision for the one-of-a-kind seismic region in the BNBC (2020) has been explained. BNBC has been organized in the mild of internationally identified requirements of security and serviceability plausible by using software of cutting-edge science within the socioeconomic context of Bangladesh. Through adherence to the number necessities of the code, non-public and public builders and man or woman proprietors will be in a position to make certain a minimal and uniform well-known of constructions in the country.

3.4 Scope of the Code

a) The walls of the building must be designed to withstand eccentric loads as well as lateral or other loads that may be applied to them.

b) Axial load walls must be designed using several sections.

c) Unless detailed analysis proves otherwise, the horizontal length of the effective wall for each concentrated load should not exceed the center-to-center distance between the loads, nor should it exceed the load-bearing width plus four times the wall thickness.

3.5 Minimum Reinforcement and Spacing in Slab

- The minimum vertical reinforcement area to gross concrete area ratio shall be:

a) 0.0012 for deformed bars no larger than 16mm in diameter with a specified yield strength of at least 410 N/mm2, or

b) 0.0015 For the remaining bars.

- The minimum horizontal reinforcement area to gross concrete area ratio shall be:

a) 0.0020 for deformed bars no larger than 16mm in diameter with a specified yield strength of at least 410 N/mm2, or

b) 0.0025 for the remaining deformed bars

In addition to the minimum reinforcement, at least two 16mm bars must be installed around all opening windows and doors. Such bars were extended by at least 600 mm beyond the corners of the openings.

3.6 Design of Building

The building model under this study has (G+5=6) ten stories with a constant floor height of 10 feet four areas are used for analysis, and the equal length and width along the two horizontal directions are kept constant in each area for ease of use. Use different ZONE FACTOR values and explain their corresponding effects in the results. Other details are as follows:

Table 3-1. Zonal Parameter and Its Various Details

PARAMETERS	ZONE I Khulna	ZONE II Dhaka	ZONE III Rangpur	ZONE IV Sylhet
Seismic Zone factor, Z=	0.12	0.20	0.28	0.36
Basic wind speed	179mh	147m h	113m h	140m h
Response reduction factor	12	12	12	12
importance factor, I=	1	1	1	1
importance coefficient R=	7	7	7	7
Site co-efficient, S=	1.35	1.35	1.35	1.35
C_d classes of soil de end	5.5	5.5	5.5	5.5
n Nutrient availability Soil	2.5	2.5	2.5	2.5
Ss Spectral Acceleration	0.3	0.3	0.3	0.3
Seismic Desi n Cate o				
Soil condition o inion	Good	Good	Good	Good
Slab thickness	5 inches	5 inches	5 inches	5 inches
Floor finish	25 sf	25 sf	25 sf	25 sf
All Steel F_y	60000psi	60000psi	60000psi	60000psi
All Concrete Fc Column	4000 psi	4000 psi	4000 psi	4000 psi
All Concrete Fc Beam	3500 psi	3500 psi	3500si	3500si
All Concrete Fc Slab	3000 psi	3000 psi	3000 psi	3000 psi
Diaphragms	Rigid	Rigid	Rigid	Rigid
Poisson's ration of Concrete	0.15	0.15	0.15	0.15
Moment of inertia for Column	1	1	1	1
Torsional Constant Column	1	1	1	1
Moment of inertia for Beam	0.5	0.5	0.5	0.5
Torsional Constant Beam	0.5	0.5	0.5	0.5

3.7 Loads Acting on a Structure

A building of constructing two necessary elements regarded are protection and economy. If hundreds are adjudged and taken greater then economic system is affected, and if economic system is viewed and masses are taken lesser, then the protection is compromised.

Simply, if the hundreds are adjudged and spend greater financial system (cost) than plan, it would be higher for safety. But if financial system (expense) is regarded and stored in accordance to graph by means of offering much less load bearing materials, the protection will be compromised which is no longer safer for a structure.

So, the estimation of various loads acting is to calculate precisely. BNBC-2020 and American Standard Code ASCE 7: Minimum Design Loads for Buildings and Other Structures specifies various design loads for buildings and structures.

1. Dead loads.
2. Live Loads.
3. Wind loads.
4. Snow loads.
5. Earthquake loads.
6. Special loads.

3.8 Loads on Structures

The two most important detail to consider when building a structure are safety and cost. If the loads are adjudged and taken higher, the economy suffers; if the economy is considered and the loads are taken lower, the safety suffers. Loads acting on buildings and other structures are broadly Classified as vertical loads, horizontal loads, and longitudinal loads. Vertical loads are made up of dead load, live load, and impact load. Wind and earthquake loads are examples of horizontal loads. In the design of bridges, gantry girders, and other structures, longitudinal loads, such as tractive and braking forces, are taken into account.

Table 3-2. Load Principles [14]

Combination Case 1	0.8 DL + LOEQX	Combination Case 25	1.2DL+1.6RLL+1.0LL
Combination Case 2	0.8 DL + LOEQX-	Combination Case 26	1.2DL+1.6RLL-0.8LL+0.5RLL
Combination Case 3	0.8 DL + LOEQY	Combination Case 27	1.3DL+1.0LL-1.0EQX
Combination Case 4	0.8 DL + LOEQY-	Combination Case 28	1.3DL+1.0LL-1.0EQX-
Combination Case 5	0.8 DL - LOEQX	Combination Case 29	1.3DL+1.0LL-1.0EQY
Combination Case 6	0.8 DL - LOEQX-	Combination Case 30	1.3DL+1.0LL-1.0EQY-
Combination Case 7	0.8 DL - LOEQY	Combination Case 31	1.3DL+1.0LL+1.0EQX
Combination Case 8	0.8 DL - LOEQ-	Combination Case 32	1.3DL+1.0LL+1.0EQX-
Combination Case 10	0.9DL	Combination Case 33	1.3DL+1.0LL+1.0EQY-
Combination Case 11	0.9DL+1.3WLX	Combination Case 34	1.4DL
Combination Case12	0.9DL+1.3WLY	Combination Case 35	1.4DL+1.4LL-1.4EQX
Combination Case13	0.9DL-1.3WLX	Combination Case 36	1.4DL+1.4LL-1.4EQY
Combination Case 14	0.9DL-1.3WLY	Combination Case 37	1.4DL+1.7LL
Combination Case 15	0.9DL+1.43EQX	Combination Case 38	
Combination Case 16	0.9DL-1.43EQX	Combination Case 39	DL+LL
Combination Case 17	1.2DL+1.0LL	Combination Case 40	
Combination Case 18	1.2DL+1.0LL+1.0EQX	Combination Case 41	0.75(1.4DL+1.7EQX)
Combination Case 19	1.2DL+1.0LL+0.5RLL	Combination Case 42	0.75(1.4DL+1.7EQY)
Combination Case 20	1.2DL+1.6LL	Combination Case 43	0.75(1.4DL+1.7WLX)
Combination Case 21	1.2DL+1.6LL+0.5RLL	Combination Case 44	0.75(1.4DL+1.7WLX-)
Combination Case 22	1.2DL+1.6RLL	Combination Case 45	0.75(1.4DL+1.7WLY)
Combination Case 23	1.2DL-1.6RLL+0.8WLX	Combination Case 46	0.75(1.4DL+1.7WLY-)

3.9 Dead Loads (DL)

The dead load is the first vertical load to be considered. Dead loads are permanent or immobilized loads that are transferred to a structure over the course of its life. The self-weight of structural members, permanent partition walls, fixed permanent equipment, and the weight of various materials are the primary causes of dead load. It primarily consists of the weight of roofs, beams, walls, and columns, among other things, which are otherwise permanent parts of the structure. [15]

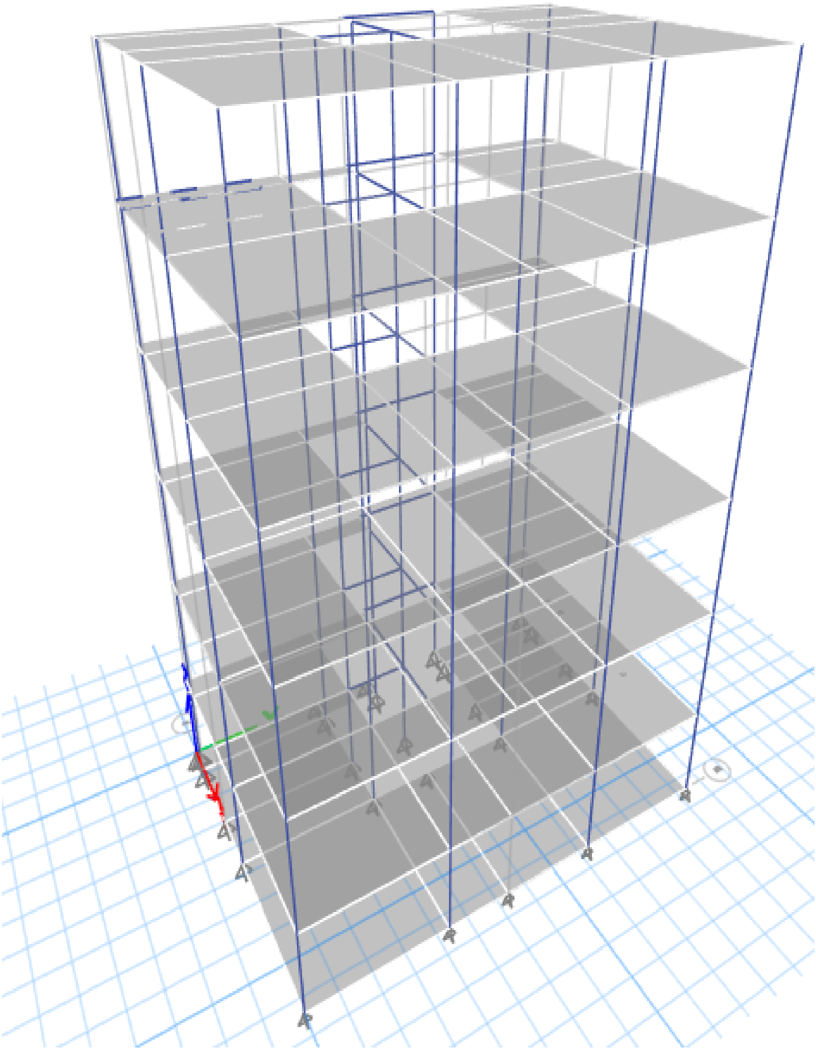


Figure 3-1. Dead Load

Table 3-3. Weight of Dead Load Materials in Model Building

SI No.	Material	Weight
1.	Brick Masonry	18.8 kN/m^3
2.	Stone Masonry	20.4-26.5 kN/m^3
3.	Plain Cement Concrete	24 kN/m^3
4.	Reinforced Cement Concrete	24 kN/m^3
5.	Timber	5-8 kN/m^3

3.10 Live Load (LL)

Imposed loads or live loads are the second vertical load that must be considered in the design of a structure. Live loads are portable or moving loads that do not experience any acceleration or impact these loads are assumed to be produced by the building's intended use or occupancy, and include the weights of movable partitions or furniture, among other things Some of the important values are presented in the table below, which are the minimum values, and where more than these values are required, they are to be assumed.

Table 3-4. Live Load Distribution according to BNBC 2020

Occupancy	Use of floor	KN/m	lb./ft
Two unit	All other areas except stairs and balconies	2.0	42
	Internal Stairs and Exit ways	4.8	100
As above	Balconies Exterior	4.8	100

The wind load is not critical for low-rise buildings of four to five stories because the moment of resistance provided by the continuity of the floor system to column connection and the walls provided between columns are sufficient to accommodate the effect of these forces. Furthermore, when wind is considered in the limit state method, the factor for design load is reduced to 1.2 (DL+LL+WL) as opposed to 1.5 (DL+LL)

calculate the design wind velocity, $Vz = k1 * k2 * k3 * Vb$ Where, kl is the risk coefficient, k2 is the terrain, height and structure size coefficient, and k3 is the topography factor. As a result, pz = 0.6V2z gives the design wind pressure. Where p_z is the pressure in N/m2 at height Z and V_z is the speed in m/sec. Wind pressure is assumed to be uniform up to a height of 30 m. Wind pressure rises above a height of 30 meters.

3.11 Wind Load

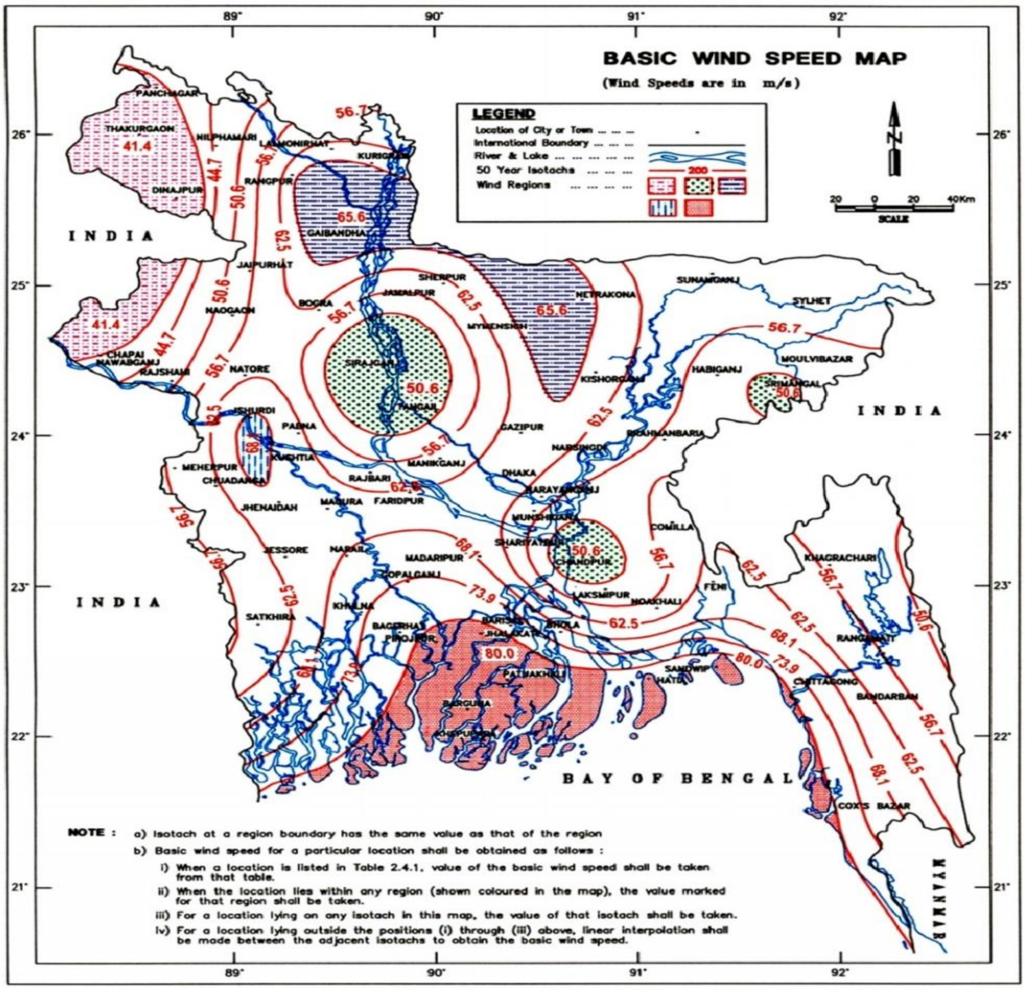


Figure 3-2. Basic wind speed map of Bangladesh [16]

CHAPTER 4

Results and Discussion

4.1 Introduction

The following is the structural organization of this Chapter:

- Article
  - ✓ Discusses the planned building's loads and material properties.
  - ✓ Building Load Calculation.

4.2 Details of Loads and Material Properties

The entire inquiry is based on a few criteria and specifications, as shown in Table.

Table 4-1. 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 = 5 inch. Thickness of Slab (All slabs) = 5 inch.
Material Properties	Yield strength of reinforcing bar, f_r = 60,000 psi Concrete compressive strength, fc' = 4,000 psi (Column) Concrete compressive strength, fc'= 3,500 psi (Beam) Concrete compressive strength, fc' = 3,000 psi (Slab) Normal density concrete, unit weight = 150 psf. Unit weight of brick = 120 psf. Unit weight of water = 62.5 psi

4.3 Load Calculation of the Building

- **Dead loads:**
  - ✓ Floor finish for floor & stair =30psf
  - ✓ Floor finish for stair room, car parking= 30psf
  - ✓ Parapet wall load calculation = 25psf

- **Live loads:**
  - ✓ For floor = 78.33psf (with partition wall)
  - ✓ For floor = 42psf (no partition wall)
  - ✓ For stair = 100.22psf (20.88 X 4.80)
  - ✓ For car parking slab = 50psf
  - ✓ For stair room = 15psf

- **Seismic and Wind Loads:**

- **Seismic Zone 1 (Khulna District)**
  - ✓ Coefficient Z= 0.12
  - ✓ Importance Coefficient (Essential facilities), I = 1
  - ✓ Exposure Condition = B
  - ✓ Wind Pressure in Khulna, V_b = 80.0 m/s or 178.96 mph or 288.0 kmph
  - ✓ Windward coefficient = 0.80
  - ✓ Leeward coefficient = 0.50

- **Seismic Zone 2 (Dhaka District)**
  - ✓ Coefficient Z = 0.20
  - ✓ Importance Coefficient (Essential facilities), I = 1
  - ✓ Exposure Condition = A
  - ✓ Wind Pressure in Dhaka City; V_b = 65.7 m/s or 146.97mph or 236.52 kmph
  - ✓ Windward coefficient = 0.80
  - ✓ Leeward coefficient = 0.50

- **Seismic Zone 3 (Rangpur District)**
  - ✓ Coefficient, Z = 0.28
  - ✓ Importance Coefficient (Essential facilities), I = 1
  - ✓ Exposure Condition = B
  - ✓ Wind Pressure in Rangpur; V_b = 50.6 m/s or 113.18mph or 182.16kmph
  - ✓ Windward coefficient = 0.80
  - ✓ Leeward coefficient = 0.50

- **Seismic Zone 4 (Sylhet District)**
  - ✓ Coefficient, Z = 0.36
  - ✓ Importance Coefficient (Essential facilities), 1= 1
  - ✓ Exposure Condition = B
  - ✓ Wind Pressure in Sylhet, V_b = 54.2 m/s or 121.24mph or 195.12 kmph
  - ✓ Windward coefficient = 0.80
  - ✓ Leeward coefficient = 0.50

Note-ETABS-2018 auto-calculated wind and earthquake loads using ASCE 7-05, which is the most often used BNBC-2020 code.

4.4 Floor Plan details

- Height of building: 58 ft.
- Length of building: 50 ft.
- Width of building: 36 ft.
- Total floors: 6 nos. (Typical Floors, 1st to 6th, Lift Machine Room, Stair Top and OHWR)

- **Ground Floor:**

2'above street level, with one stair and an eight-person lift connecting it to the other.

- ✓ The floor is 1552.5 ft^2
- ✓ The floor height is 12 ft

- [ ] **Ground Floor**

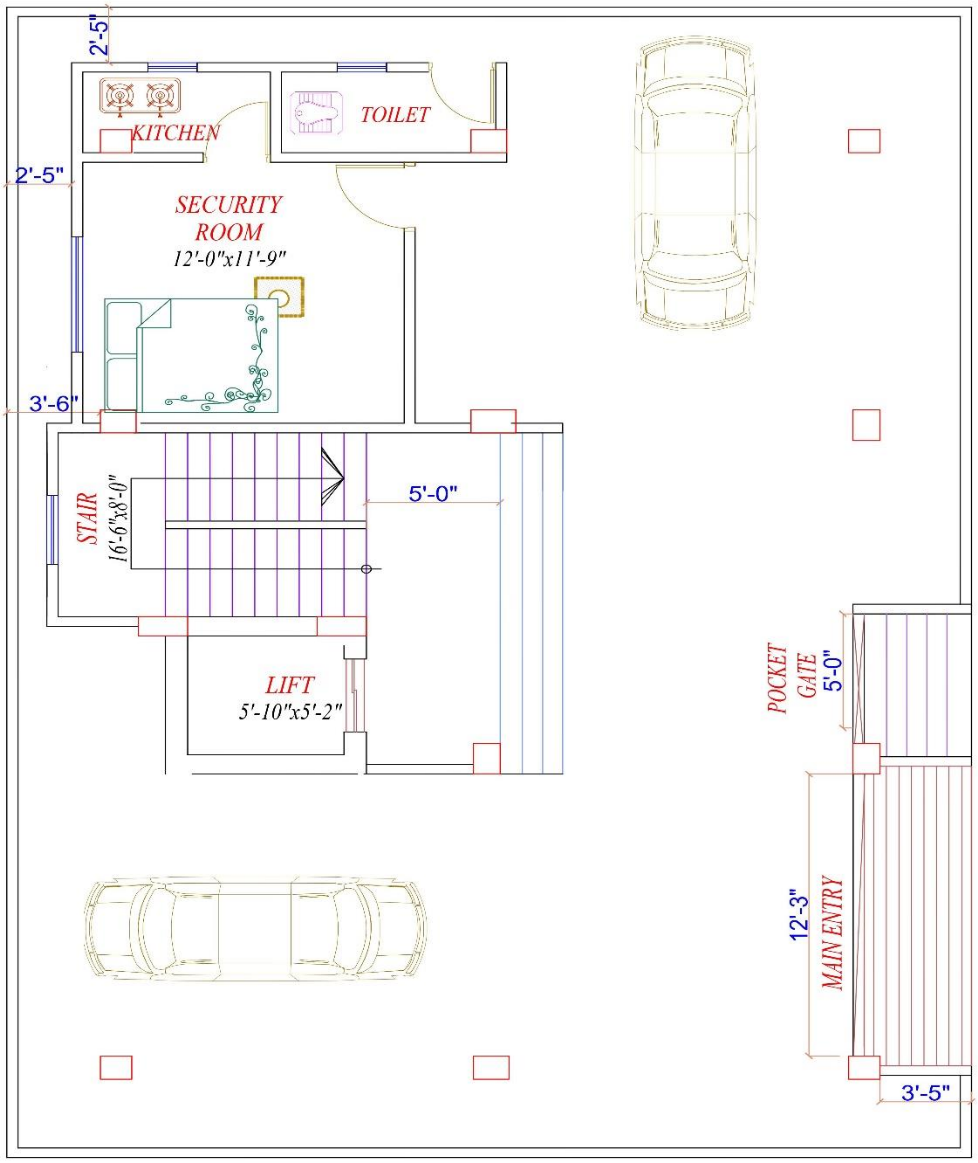


Figure 4-1. Ground floor plan

- **Typical Floor Plan (1st Floor 5th Floor)**
  - ✓ Connected to other floors via one stairwell and an eight-person lift.
  - ✓ Total floor area = 1800 ft^2
  - ✓ Total floor height = 10 ft

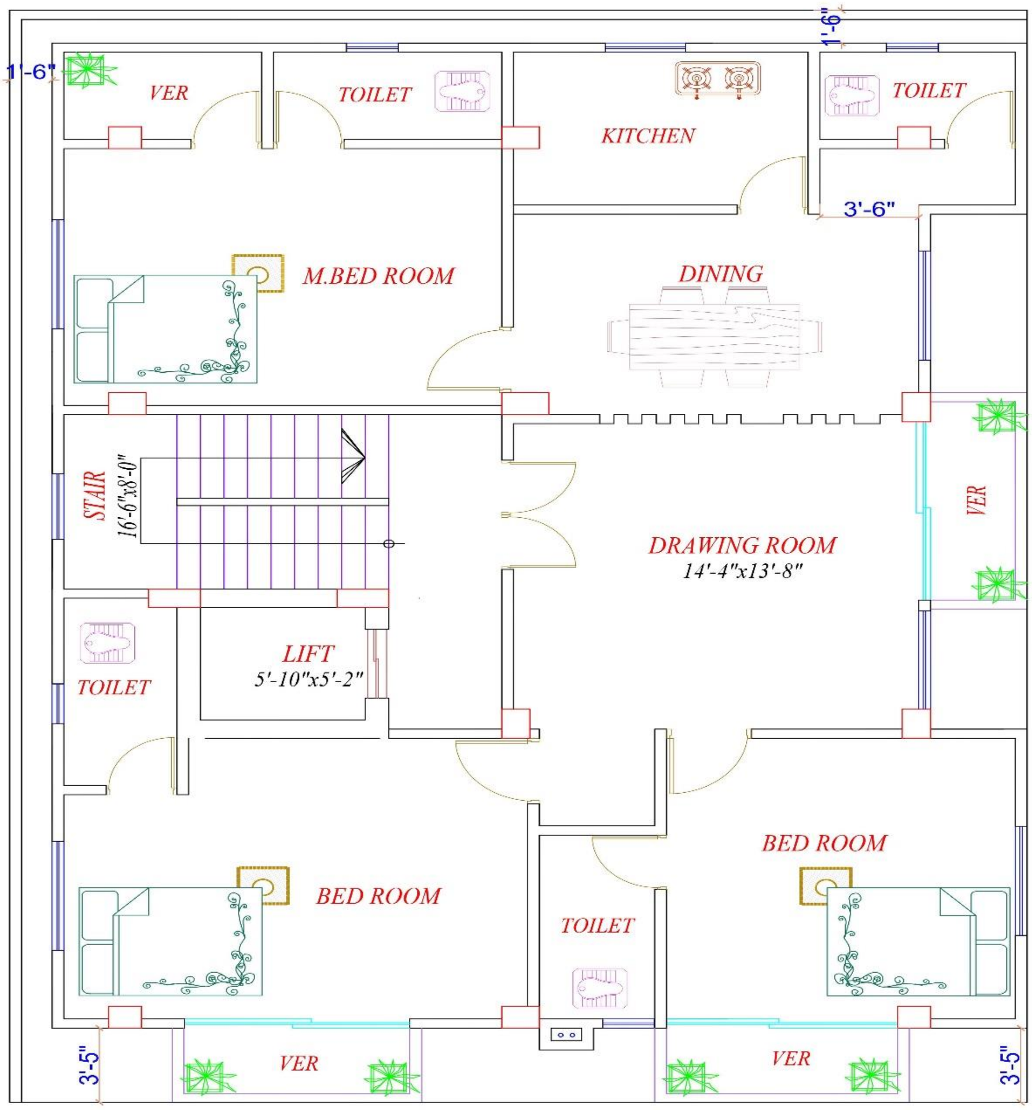


Figure 4-2. Typical Floor Plan (1st Floor 5th Floor)

Table 4-2. Legend of Building Columns and Beams

Column Name	Column Sizes	Beam Name	Beam Sizes
C1	12 x 24	Grade Beam GB	12 x 18
C2	12 x 16	Floor Beam FB	12 x 15
C3	10 x 20	Stair Beam FB	12 x 18

❖ **Column Layout**

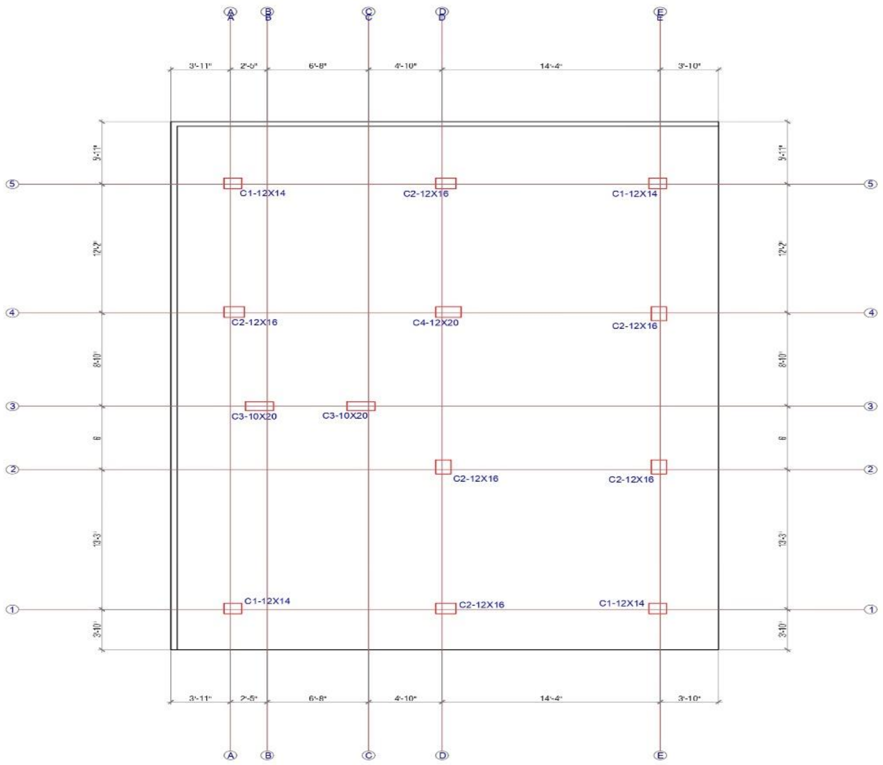


Figure 4-3. Column Layout

4.5 Soil Result Comparison

According to the soil feature, we find that the best soil for the average vertical structures is in the Zone Ill (Rangpur District) region as the SPT 21 value below is 20 m of fine sand. Moreover, it is 14 meters higher than sea level which is very important these days in order to last longer and be safer for residents during flood disaster. Wind pressure for Zone Ill (Rangpur District) 113.18 mph. District Sylhet (Zone IV) has roughly similar wind speeds of 121.24 mph and 15 meters above sea level, which is a good sign but the area factor (0.36) makes it the most vulnerable to average vertical structures in Bangladesh. District Dhaka (Zone II) has a better seismic area factor (0.20), wind speed of 146.95 mph and soil compatible is the first priority for most designers. This analysis recommends Zone Ill (Rangpur District) with area factor (0.28) as the second-best location for residential building construction (G +5 = 6 floors) and will also help in erasing the population pressure on the Dhaka district area.

4.6 Building Analysis Figures by (ETABS 2018)

Figure 4-4. Perspective Analysis Image (Front)

- **Observation**: While analyzing the G+5 building by ETABS 2018, it was observed that the building is still stable and bears all the loads mentioned above.

4.7 Building Analysis by (ETASB 2018)

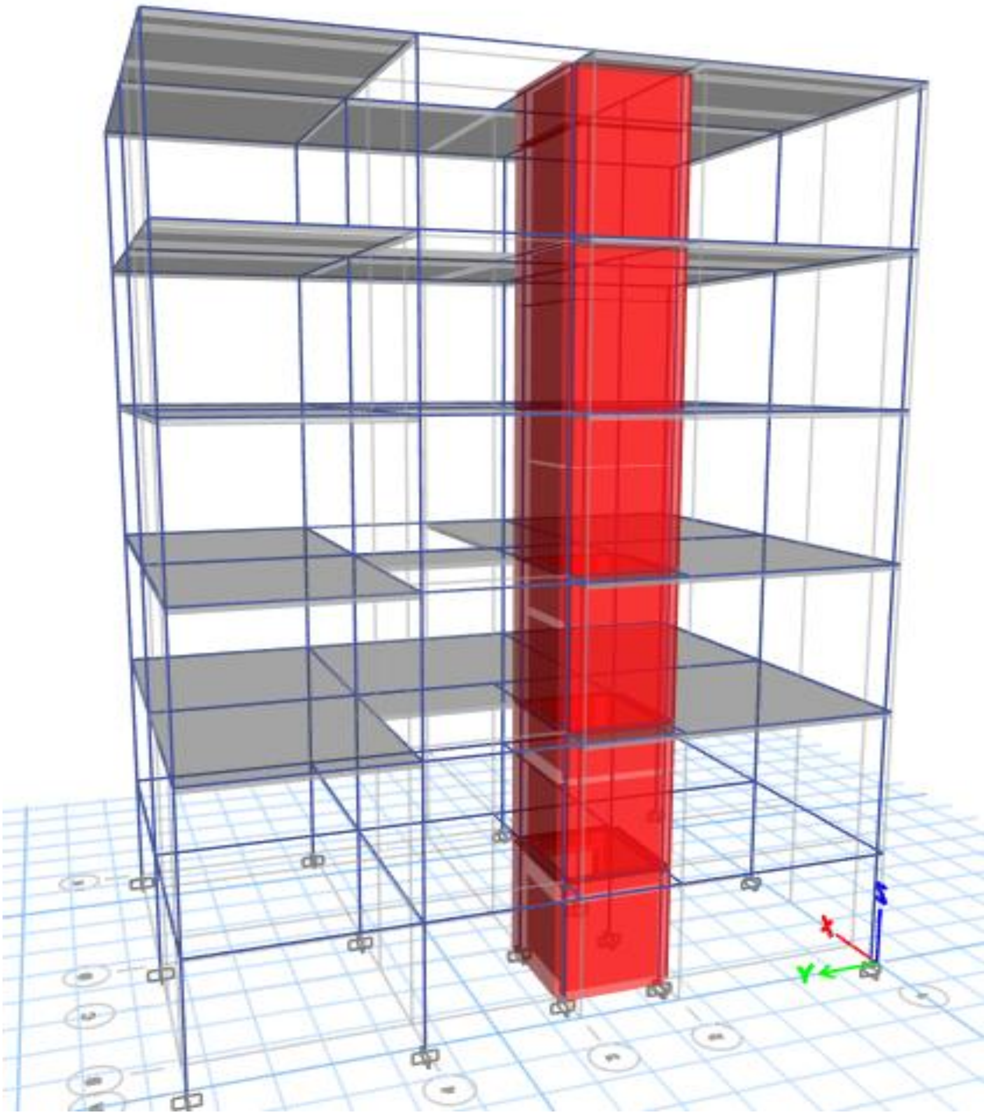


Figure 4-5. Back side analysis image

- **Observation**: while analyzing the G+5 building by ETABS 2018, it was observed that the building is still stable and bears all the load mentioned above.

4.8 Residential building without partition walls

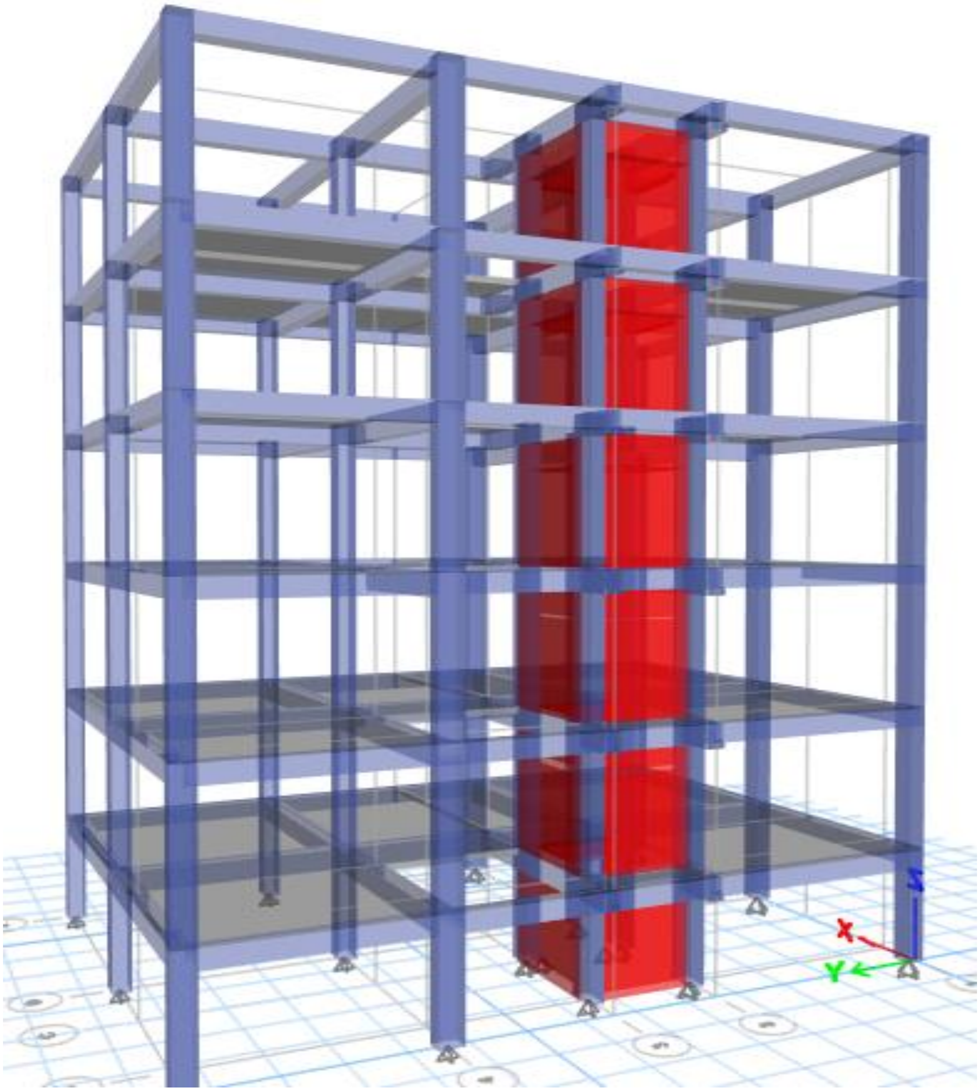


Figure 4-6. 3D view of a residential buildings slab, beam, column, lift

- ❖ **Observation**: The building in three dimensions, without the partition walls.

4.9 Earthquake load analyzing

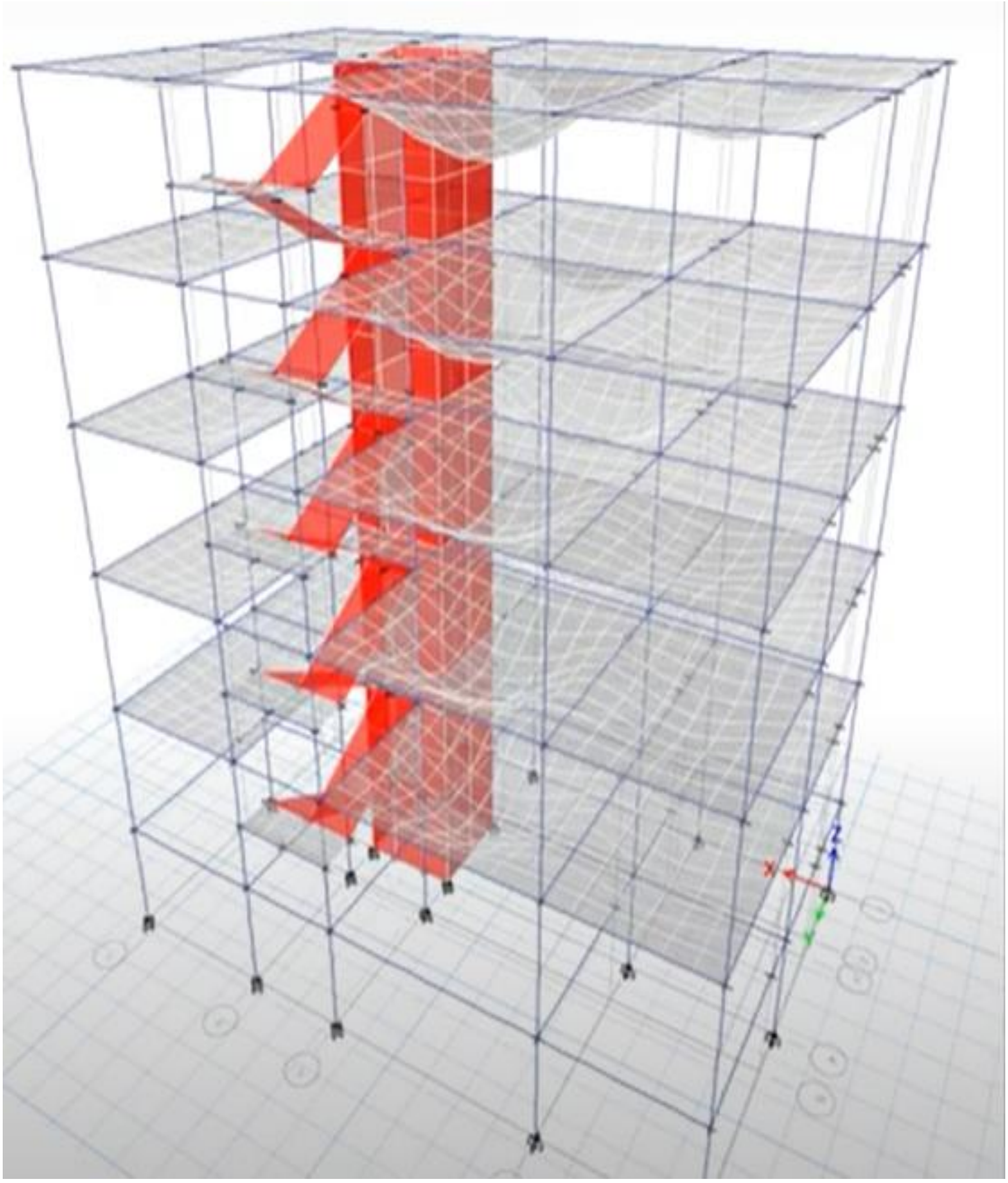


Figure 4-7. Earthquake load analyzing

- **Observation**: Earthquake load analyzing using ETABS 2018

4.10 Overall drift

The statistical details of drift are monitored to detect it. It describes the gauge's sluggish change in responsiveness. The displacement of one level in relation to the level above or below it is known as story drift. All drift limits are taken into account here based on seismic and wind forces, as well as the combination of loads indicated before. The seismic provisions of the construction account for the differences in different floors. Although there isn't much of a difference between the Load Combination and Direct Load cases.

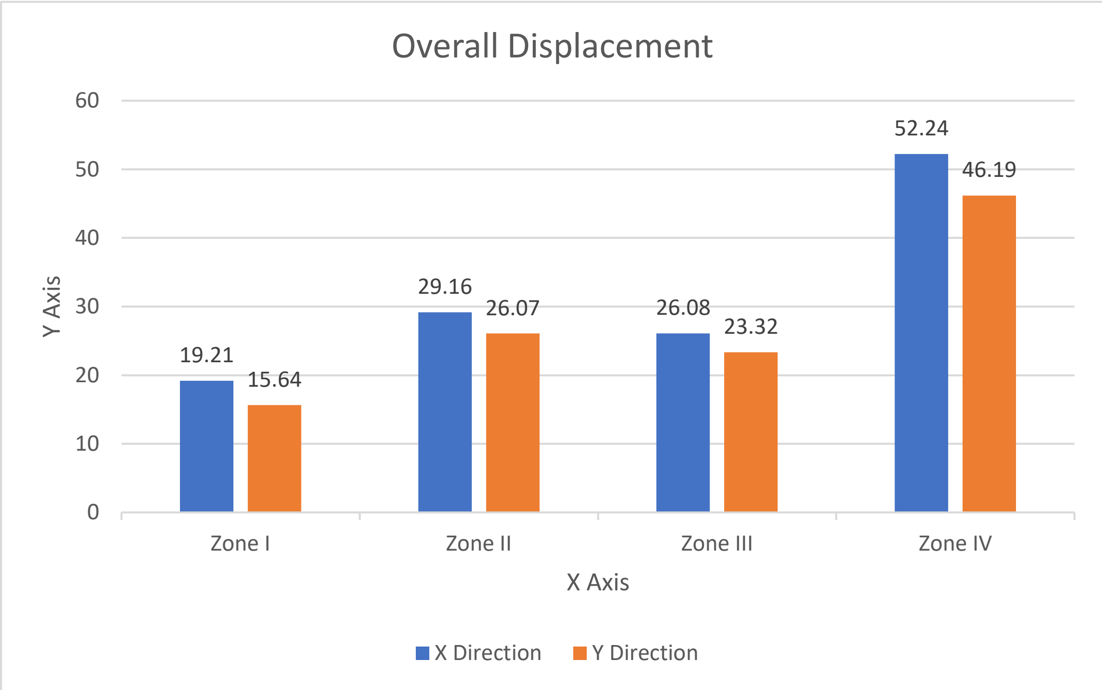
Table 4-3. Overall drift

Overall Highest Drift		**Overall Lowest Drift**	
WX direction	WY direction	WX direction	WY direction
Sylhet (Zone IV)	Sylhet (Zone IV)	Khulna (Zone I)	Khulna (Zone I)
3rdFloor(0.002795)	4^{tn}Floor(0.002462)	G.Floor(0.000352)	G.Floor(0.000262)

Table 4-4. Six Storied Building Displacement Overall Data in One Glance

Zone	**X Direction**	**Y Direction**
Khulna Zone I	19.21	15.64
Dhaka Zone Il	29.16	26.07
Rangpur Zone III	26.08	23.32
Sylhet Zone IV	52.24	46.19

❖ Graphically Overall Displacement



4.11 Overall displacement

The phrase "displacement" refers to a shift in an object's position. The phrase "displacement" refers to a vector. This means it has both a direction and a magnitude, and it is visually depicted as an arrow pointing from the starting point to the ending location. Moving up, forward, or to the right would be considered positive displacement. Moving down, backward, or to the left would be considered negative displacement. The object's final location is when it comes to an end. The direction is taken into account because it is a vector.

Table 4-5. Overall displacement

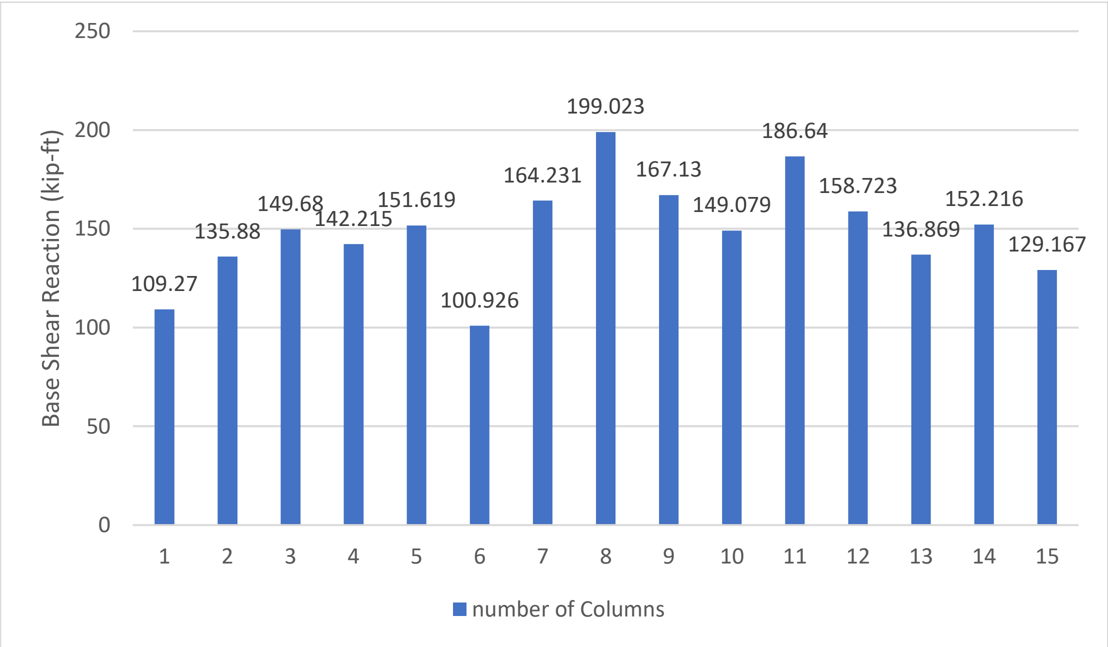
Overall highest	Displacement	Overall lowest	Displacement
WX Direction	WY Direction	WX Direction	WY Direction
Sylhet Zone IV	Sylhet Zone IV	Khulna Zone I	Khulna Zone I
52.24 mm	46.19 mm	4.21 mm	4.64 mm

4.12 Displacement Result:

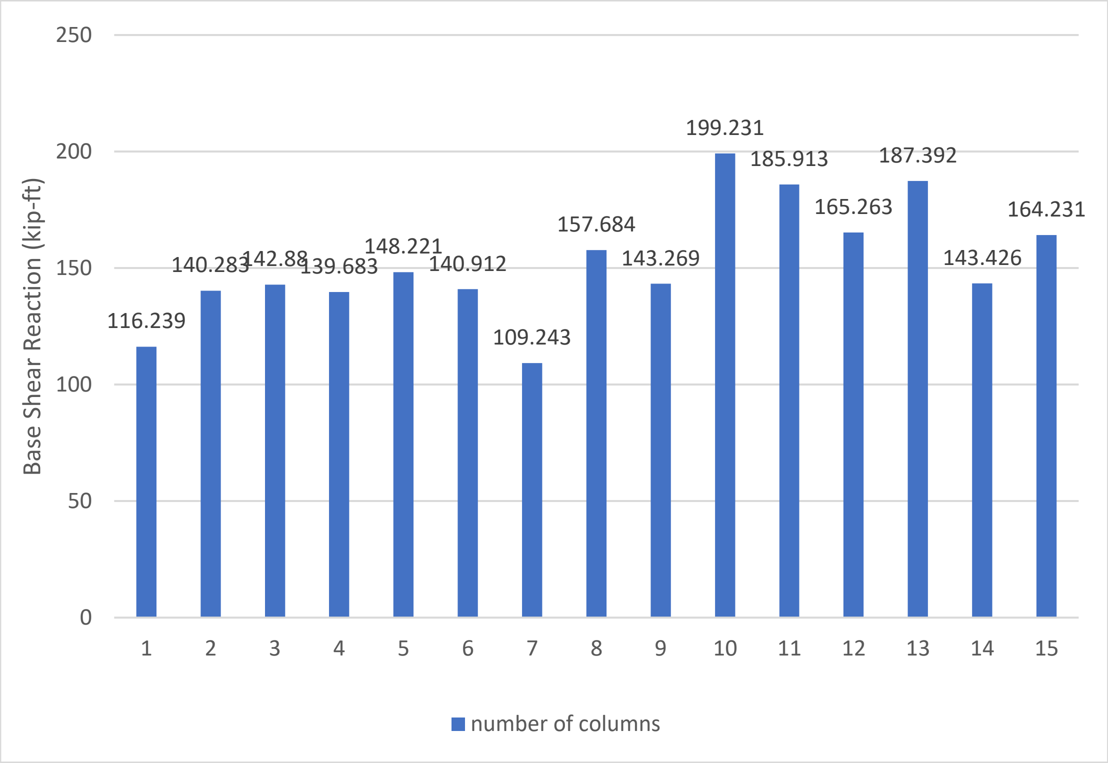
After analyzing different seismic zones for a residential G+5 structure, we discovered that the total building height is 29014.4 mm and the maximum displacement (H/500) is 52.24 mm) and that all buildings in each zone are safe and stable. According to our findings, the safest zone is Zone-I (Khulna district), followed by Zone-III (Rangpur district), and the least safe zones are Zone-II and Zone-IV (Dhaka and Sylhet districts).

- ❑ **Base Shear reaction**

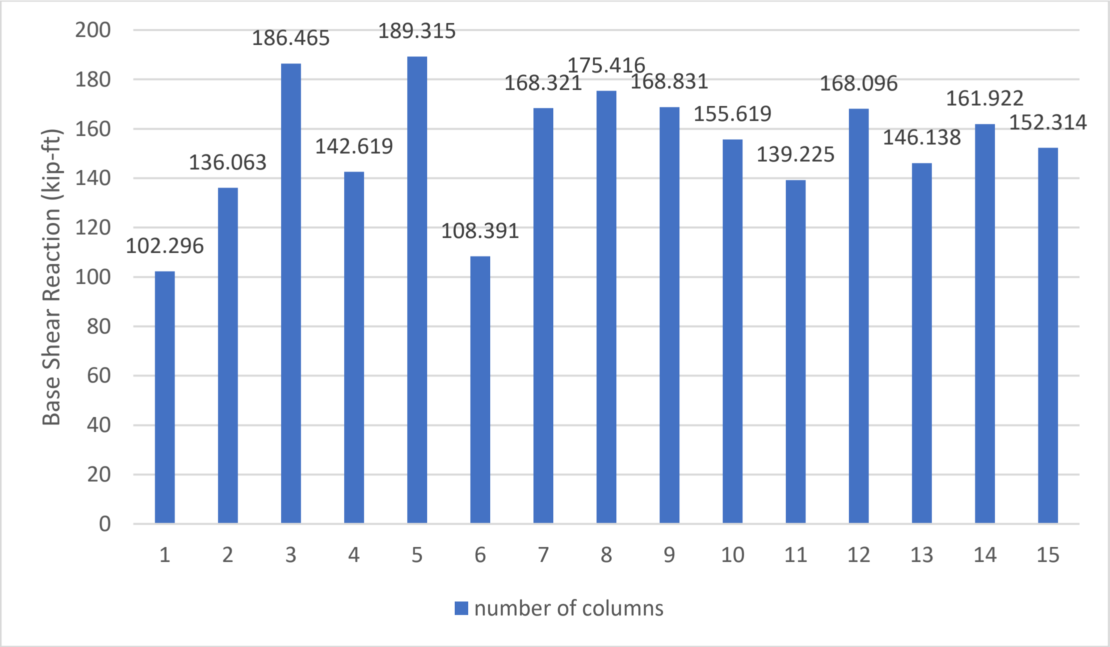
- ✓ **Khulna Zone I**



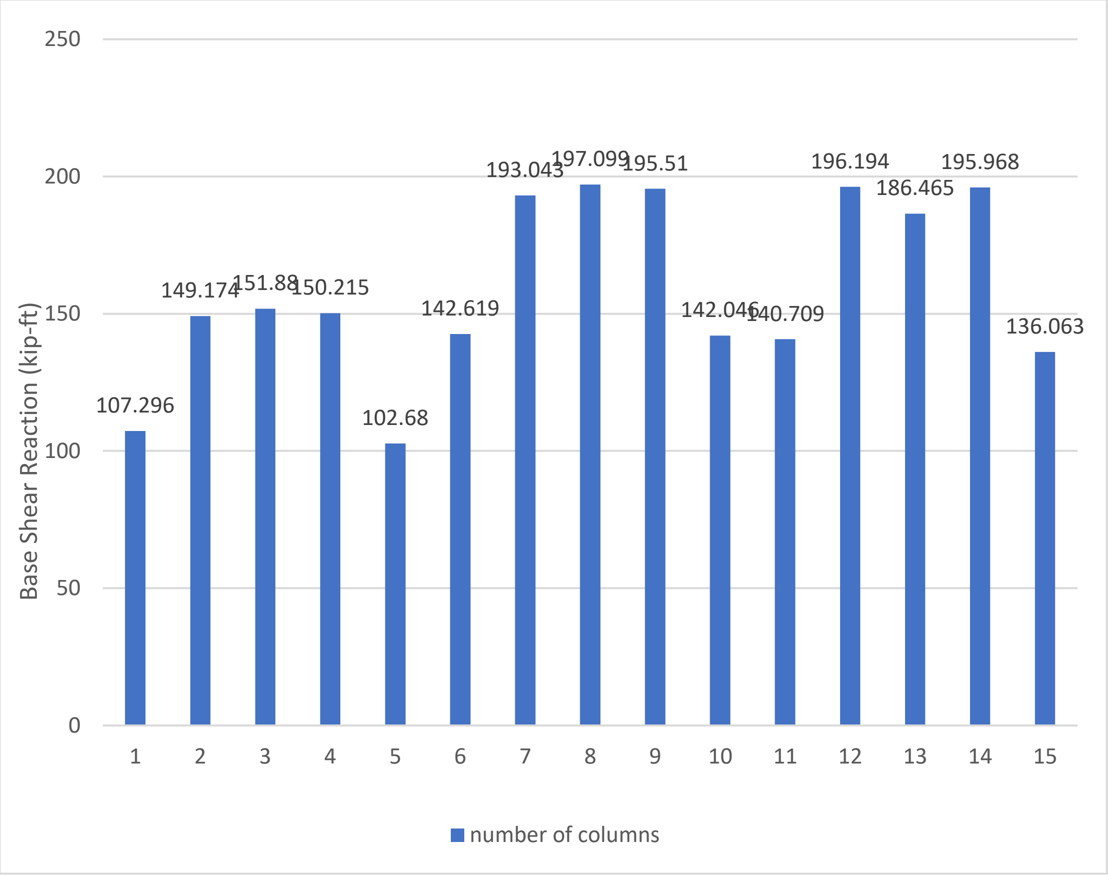
✓ **Dhaka Zone II**



✓ **Rangpur Zone III**



✓ **Sylhet Zone IV**



CHAPTER 5

Conclusions and Future Works

5.1 Conclusions

- ✓ In this study, a (G+5) storied residential building have been analyzed by ETABS Software 2018, BNBC 2020
- ✓ We have completed analysis & design a (G+5) storied residential building the detail of the member (Beam, Column) for seismic load at Zone-I (0.12), Zone-II (0.20), Zone-III (0.28) & Zone IV (0.36) and variation of different wind pressure and seismic effect by ETABS (Extended 3-Dimentional Analysis of Building System).
- ✓ The design criteria are efficiency of system, member depth and balance between sizes of beam and column, as well as spacing of columns.
- ✓ Displacement was checked within limits, then column and beams have been designed.
- ✓ The calculation of seismic weight by both manual and software analysis yields the same result
- ✓ There is a slight difference in the values of base shear in both manual and software analysis are performed.
- ✓ Manual analysis produces slightly larger base shear values than automated software analysis.
- ✓ From the Result it is found that among four Different Zone Maximum Displacement and reinforcement percentage at Zone-IV.
- ✓ The highest drift was found on the third floor of Sylhet district, and the lowest on the ground floor of Khulna district.
- ✓ The highest displacement was found in Sylhet and Dhaka district, and the lowest in Khulna district.
- ✓ In all zones, there is no P-Delta impact, showing that the design is ok.

5.2 Limitations

- ✓ This research was conducted using a medium-rise structural design concept.
- ✓ For analysis, design, and details, Etabs-2018 and AutoCAD-2020 were utilized.

- ✓ ETABS is used to design stairwells, elevator tracks, and other structures.
- ✓ The architectural plan was created in accordance with the BNBC 2020 code.
- ✓ The current study is limited to regular plan shapes.
- ✓ The work is limited to parameters such as story displacement, story drifts, base shear, and torsional irregularity.
- ✓ The Equivalent Static Force Method was used for analysis.
- ✓ The following parameters were not considered when designing the structure: Deflection effects
- ✓ Beam-column joint design,Plumbing, electricity, and brickwork, among other things, are not considered in this analysis
- ✓ The structure's foundation design, estimation, and cost analysis were not completed.
- ✓ The Pounder effect is not taken to this analysis.

5.3 Recommendation for Future Works

- ❑ The following recommendations can be made for future research work-
- ✓ The case study conducted in this research is for three districts of Bangladesh. However, the different Seismic zone coefficient and Wind varies for different parts of Bangladesh. Similar study can be performed for other parts of Bangladesh especially for different area and different seismic zones.
- ✓ Similar study can be performed for other types of buildings such as steel frames, ordinary moment resisting frames and masonry structures etc. located in different in places with different site conditions.
- ✓ To find the impact on design only the reinforcement requirement in point displacement, story drifts and longitudinal reinforcement are considered. This study can be extended of analysis Steel building.
- ✓ The current research was conducted on only one types of structural systems. Other structural systems listed in BNBC-2020, can be investigated further.
- ✓ Continuity of study on higher vertical structures in different seismic zones of Bangladesh.
- ✓ A more realistic analysis of a high-rise structure under earthquake load can be achieved using the dynamic analysis method.

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