A COMPARISON OF WIND LOAD & EARTHQUAKE EFFECT ON A BULIDING ACCORDING TO BNBC 2006 & BNBC 2020

By

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

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

Section: 14A

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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”

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ABSTRACT

The Bangladesh National Building Code (BNBC) specifies and regulates the general specifications for structural, architecture and design parameters in Bangladesh. In the last three decades, Civil Engineering techniques, knowledge, and materials as well as design parameters have been modified as per requirement. Therefore, BNBC 2020 was written to reflect the transition. In this study, a systematic and parametric structural analysis of a Six-story residential building was analyzed (ETABS 18.0.2 software) by using BNBC 2006 and BNBC 2020 for two different locations (Dhaka and Sylhet) suited in two different zones to demonstrate how lateral load (Earthquake and Wind) affects structural analysis and design of high-rise infrastructure. The decision-making parameters for structural analysis and design are tremor and wind forces, story drift, wind and seismic shear and base shear for seismic forces according to BNBC 2020 vary significantly compared to BNBC 2006. In this study, the earthquake load varies from 34.04% to 44.30%, while wind force ranges from 17.90% to 27.24% in the x-direction and 47.66% to 27.66% for y-direction, and story drift for earthquake load ranges from 34.10% to 44.25% and for wind load ranges from 26.63% to 26.71%. The comparison of the aforesaid design parameters is depicted graphically, and relevant tables are presented in this research article. In comparison to BNBC 2006, the requirements of BNBC 2020 usually result in a less cost-effective design with a higher safety margin.

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CHAPTER 01

INTRODUCTION

1.1 Introduction

Building is the key to social progress of the country. Without construction of building, one nation can’t progress. For example, to make digital nation we need computer but to place this computer we need buildings. Many things which are related to development of buildings. Every human has desire to own comfortable hotness. It can be assumed or say or calendared that on an average generally one spends his two-third lifetimes in the house. So, the serenity envies sense of the responsible. Man needs house to protect them from various kind of danger, animal and Natural disaster. These are the few reasons which are responsible that the person does utmost effort and spend hard earned saving in owning houses. To archive safety for human live, every engineering portable meet the current seismic requirement during design and construction. In Bangladesh there are many buildings which do not meet the current seismic and wind load requirement and suffer extensive damage during the earthquake and wind load in Bangladesh during design and construction phases.

The reinforced concrete structure (RC), susceptible to seismic excitation, should be suitable for strength, ductility, and stiffness to meet earthquake-resistant design criteria. The arrangement of the fundamental building elements for rigidity and durability can regulate the reaction behavior of laterally loaded structures, and the damage recorded in earthquake structures was primarily due to their erroneous placement. Considering the increasing population, as well as lack of horizontal expansion, is not a reasonable solution. When houses and apartments are designed there are various structural issues occur such as lateral loads, side moving, stiffness and so on. In general, not only earthquake load affects, but also wind load are prominent for high-rise structures. Hence, different loads and corresponding effects on structures need to be considered for multiple floors. The lateral load impact is extremely important to take earthquake and wind loads into account.

Bangladesh is near the Himalayas, the highest mountain range in the world, and is well inside an active tectonic area and susceptible to significant earthquakes. Lists of some major earthquakes affecting in Bangladesh has been illustrated in Table 1. In an impoverished and heavily populated nation such as ours, the after-effects of an earthquake are harder than in other industrialized countries. Where high-rise structures have been built, several structural issues occur, such as the influence of lateral load, lateral moving, and rigidity on structure. In general, not only tremors are significant for high- rise buildings, but also wind loads. Therefore, understanding numerous loads and their influence on structures is crucial for a tall building. The influence of lateral loads, such as earthquake and wind loads, is critical to consider. In Bangladesh and other underdeveloped nations, the approach of earthquakes and wind analysis is used in a static analysis because of the lack of modern modeling and computing installations. With the increase in the number of high-rise structures, the code for design, detailing, and construction is increasingly significant.

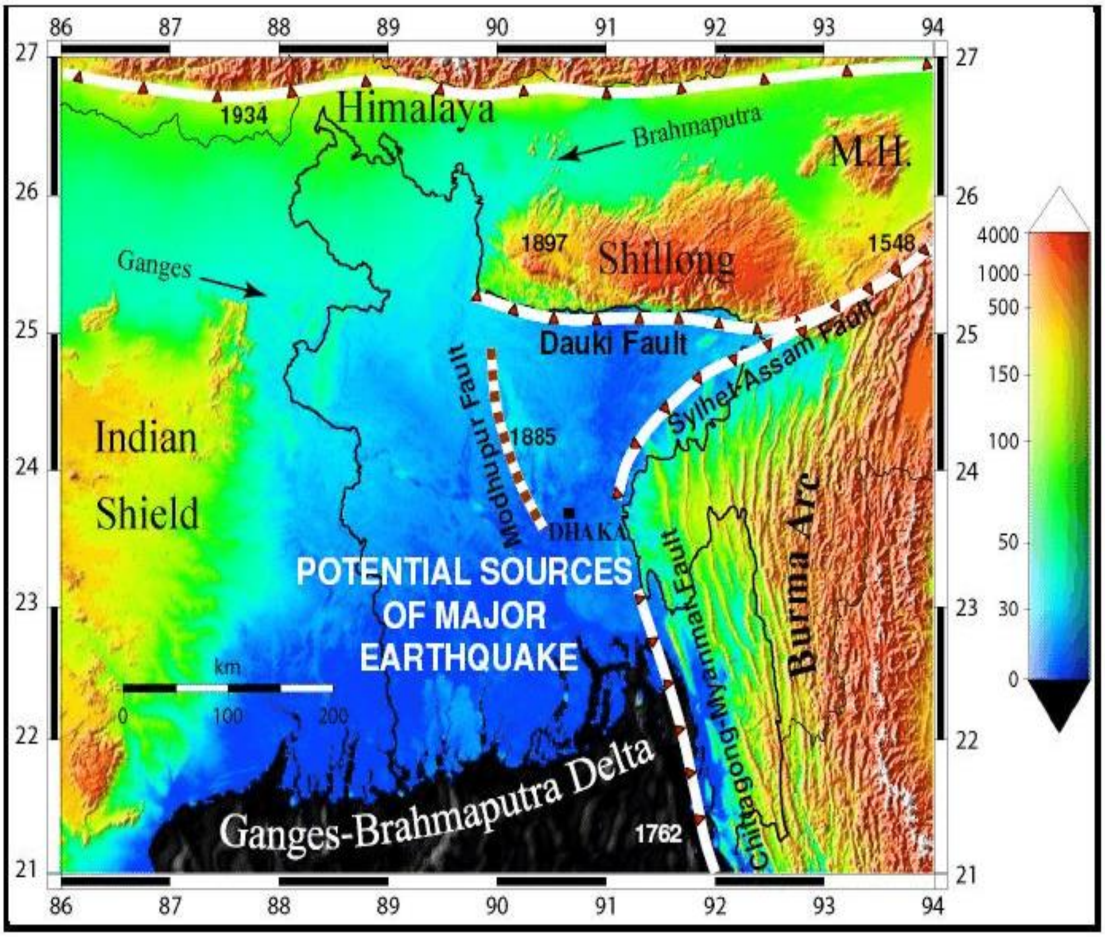

Figure 1.1: Active Fault lines in Bangladesh

Table 1.1: List of major earthquakes affecting Bangladesh

Date	Name of the earthquake	Magnitude (Richter)
10th Jan, 1869	Cachar Earthquake	7.5
14th Jul, 1885	Bengal Earthquake	7.0
10th Jan, 1889	Jaintia Hills Earthquake	7.5
12th Jun, 1897	Great Indian Earthquake	8.7
8th Jul, 1918	Srimongol Earthquake	7.6
3rd Jul, 1930	Dhubri Earthquake	7.1
5th Jan, 1934	Bihar-Nepal Earthquake	8.3

The Bangladesh National Building Code (BNBC) was developed in 1993 to offer recommendations for the development and implementation of modern projects that are prone to tremors, will cause a reduction of threat for all buildings. Relative research is interesting to search at the provisions of this code and to see whether adjustments to the latest upgrade code might be made to identify the changes in design and analysis of the various structures. With the development of tall buildings, the global regulations that control infrastructure design, detailing, and construction are updated regularly to reflect new practices. Wind is a dynamic occurrence that changes rapidly and depends on time and speed. It is due to wind movement from a high-pressure condition to a low pressure. Bangladesh National Building Code (BNBC) was initially published in 1993, and anticipated wind provision has been modified in BNBC 2017. The previously created Bangladesh Building Code (BNBC) was formally implemented in the year 2006 and was not amended for a long time.

In seismic analysis and design of buildings, attention for the combination of earthquakes and wind force has become extremely important since constructions in the unfavorable circumstances like as tectonically strong zones may inevitably be constructed. A comparative study was performed to observe the important modifications among the BNBC 1993 and the proposed BNBC 2012 in terms of lateral load alone. Significant improvements were made in BNBC 2017 to incorporate knowledge and advances in structural engineering during the last two decades. BNBC 1993 has been modified and published as BNBC 2020 considering the guidelines of other international building standards.

Figure 1.2: Earthquake damaged structures

The purpose of this study is to analysis and designs of six-storied reinforced concrete residential building for earthquake and wind performance which is situated in Dhaka and Sylhet. At First preliminary planning is done using RAJUK standard rule and regulation of building construction and then detailed evaluation is carried out to design the components under concern code which is Bangladesh National Building Code (BNBC). For applying earthquake loads and wind load, equivalent static lateral force method is used according to BNBC 2006 and BNBC 2020.

The reinforcement details of the building were not available as it is not designed. Design is prepared applying Dead, Live, Seismic and Wind loads in both span of the structure. This helps in estimating the reinforcement of each component of the building i.e. Slab, Column, Beam, Footing using hand calculation procedure later from governing moments, axial and shear effects. ETABS 18.0.1 (Extended 3D Analysis of Building Structure) is used for analyzing and designing the building.

This study tries to compare wind load and earthquake analysis laws given between BNBC 1993 and BNBC 2020. This Benchmarking investigation will offer designers who use BNBC 1993 as their platform for calculating design wind loads with a relationship indicating the percentage changes in design wind load in the new code compared to the old one. Again, this research study will create a pathway to compare with other building codes used all over the world in determining how many factors of safety against wind disaster are imposed considering the economic aspects and population of our country.

1.2 Research Objectives

The objectives of the study are:

1. To compare earthquake effect on a six storied building in different zone according to BNBC 2006 & BNBC 2020
2. To compare wind effect a on a six storied building in different zone according to BNBC 2006 & BNBC 2020

1.3 General Approach

- Getting an architectural design of a RCC Residential Six -storied building.
- Project on RCC Residential Building in Dhaka, Sylhet (Zone-2, 3)
- To establish the structural system for the ground and repeated floors of the building.
- Analysis of building, wind resisting system, and type of foundations will be determined taking into consideration the architectural drawings.

1.4 Statement of Project

Salient features:

1.Utility of building	: Residential purpose
2.No of stories	: Six storied
3.Shape of the building	: Rectangular
4.No of staircases	: 01
5.Type of construction	: R.C.C framed structure
6.Type of walls	: Bricks wall

Geometric Details:

1.Ground floor	: 10ft
2.Floor to floor height	: 10ft
3.Height of plinth	: 2.5ft

CHAPTER 02
LITERATURE REVIEW

2.1 Introduction

Many researchers already compared the previous existing code with earlier BNBC code like 1993 and 2006. There are some proposed BNBC codes like BNBC 2012, BNBC 2015, BNBC 2017. Researchers done some different comparison with these codes and their result is discussing below.

2.2 Previous Background of the Study

The BNBC 1993 amendments were first recommended by the (Al-Hussaini, et al., 2012). They performed a detailed investigation into Peak Ground Acceleration (PGA), Spectral Acceleration, a ground categorization system, and an on-site response spectrum. They showed that BNBC 1993 requires a considerable improvement in provisions of design and structural analysis. (Al-Hussaini, et al., 2012) The following are some references to literature on comparative research of existing codes in Bangladesh and throughout the world.

(Sarothi, et al., 2019) show primary differences between BNBC 1993 and 2017 to investigate and quantify the changes in the analysis of wind and seismic loads based on structural and economic perspective. They analyzed a multistoried commercial building (16.5 m x 24 m) situated in Chattogram for both low rise & high-rise building (8, 16 stories) using finite element analysis. Seismic Base shear is increased in BNBC 2017 with respect to BNBC 1993 because of variation in zone coefficient (Z), Response modification factor (R), and the introduction of Cs (normalized acceleration response spectrum). On the other hand, BNBC 1993 shows high wind load compared to that in BNBC 2017. Analysis results dictate, the newer code provisions generally result in a relatively less economic design with higher safety margin when compared to the design based on the old code.

(Sarothi, et al., 2019) were taken an attempt to undertake a systematic simulation analysis utilizing finite element method (FEM) based on the previous (BNBC 1993) and newly proposed (BNBC 2017) codes to establish a precise comprehension of improvements. They analyzed a multistoried commercial steel building of 16.5 m x 24.0 m with concentric braced framing system resting on soft to medium stiff clay (8 and 16 story) situated in Chattrogram. They observed that the rate of change in base shear reduces with story height owing to both earthquake and wind loads, and that base shear due to wind load is somewhat lower for BNBC 2017 than for BNBC 1993 because of reduced wind pressure coefficient.

(Sarothi, et al., 2019) examine the relative assessment of wind load effect in city, obstructed, and unobstructed plain territory type zones as per BNBC 1993 and BNBC 2015. They examined a multistory residential building (20.0 m × 20.0 m) of 100 m height for three exposure criteria (i.e. Exposure A, Exposure B, and Exposure C) to explore the effects in structural analysis using the both codes. The rate of change in wind thrust with respect to number of stories seems to be more consistent in BNBC 2015. As per BNBC 2015, exposure A significantly exceeds that of BNBC 1993 by 7-12%. But Exposure B & C is much reduced 2-10% in 2015 compared to BNBC 1993.

(Faysal, 2014) studied the comparative study of wind force analysis provided by BNBC 1993 and BNBC 2010. The wind provision recommended in BNBC 2010 is upgraded by the authority taking in consideration of the influence of surrounding structures and building height. Therefore, wind load in metropolitan regions (Exposure A) is discovered to be significantly greater (7-12%) compared to BNBC 1993. Meanwhile, wind load computed from this new code for obstructed and unobstructed plain territory region (Exposure B and C) is significantly lower than BNBC 1993.

(Imam, et al., 2014) investigate the comparative evaluation of wind and seismic analysis presented in the BNBC 1993 with the BNBC 2012 suggested. They analyzed a typical multistoried residential building with intermediate moment resisting frame system resting on medium dense soil situated in Dhaka to find the differences in structural analysis between BNBC 2012 and BNBC 1993. The analysis is conducted for variable number of stories (from 2 to 18) and it is found that maximum drift occurs almost at the mid height of the building in all cases. Base shear of the residential structure obtained by this new draft code varies significantly and the maximum lateral displacement and inter story drift with respect to number of stories is less in BNBC 2012 than in BNBC- 1993 for wind load only. They include that the design of RC building for lateral load in BNBC-2012 is relatively economic than BNBC-1993 as the amount of reinforcement required is less in BNBC-2012 although this is applicable for Dhaka city only.

(Bari & Das, 2013) illustrate the similarities among specific requirements in BNBC 1993, BNBC 2010, NBC 2005 and ASCE 7-05 regarding tectonic assessment of building codes. This study conveys a seismic safety message for our country at this current location. In this study, BNBC 1993 is shown to have the minimal base shear among the guidelines. Base shear values factorized for BNBC 2010 have improved considerably compared with BNBC 1993 in lower elevated structures (B ≤ 20 m) over the state across its antecedent. This enhancement of the earthquake safety factor established by the proposed BNBC 2010 code, which recommends greater base shear values, is noteworthy.

(Atique & Wadud, 2003) displays the study of various standards in the design codes (BNBC-93, UBC-91, UBC-97, NBC-83 and Bangladesh outline Code, 1979) for seismic and wind analysis from numerous countries of the world. They analyzed an office building (15.6 m x 15.6 m) located in the United States earthquake Zone 3 (UBC), in Indian Zone V (NBC-83) and Zone 3 (BNBC-93) in Bangladesh similar seismic activity. The analysis was carried out for ten, fifteen, twenty and twenty-five storied building and concluded that developed countries enhanced their seismic safety factor by proposing higher base shear value. In reference to contemporary codes in the current review, the seismic design standards in BNBC-93 are the least conservative in the construction and lead to a significant loss of life and property in a major quake.

2.3 Methods for analyzing a frame structure

There are some methods to analysis a frame. Method of analysis of statistically indeterminate portal frames:

1. Method of flexibility coefficients.
2. Slope displacements methods (iterative methods)
3. Moment distribution method
4. Cantilever method
5. Portal method
6. Matrix method

2.3.1 Methods of flexibility Co-efficient:

The flexibility coefficient is popularly used to implement the macroevolution of shape, safety, and economy for arch dam. The method of consistent deformations, or sometimes referred to as the force or flexibility method, is one of the several techniques available to analyze indeterminate structures.

The following is the procedure that describes the concept of this method for analyzing externally indeterminate structures with single or double degrees of indeterminacy. The method of analysis is Comprises reducing the hyper static structure to a determinate structure form by: Removing the redundant support (or) introducing adequate cuts (or) hinges.

Limitations:

It is not applicable for degree of redundancy>3

2.3.2 Slope displacement equations:

The slope deflection method is a structural analysis method for beams and frames introduced in 1914 by George A. Many. The slope deflection method was widely used for more than a decade until the moment distribution method was developed.

By forming slope deflection equations and applying joint and shear equilibrium conditions, the rotation angles (or the slope angles) are calculated. Substituting them back into the slope deflection equations, member end moments are readily determined.

Displacement is used for those cases which are given below:

1. General Case
2. Stiffness Coefficients
3. Stiffness Coefficients Derivation
4. Fixed-End Moments
5. Pin-Supported End Span
6. Typical Problems
7. Analysis of Beams
8. Analysis of Frames: No Sideway

9. Analysis of Frames: Sideway
10. A solution of simultaneous equations makes methods tedious for manual computations.
11. This method is not recommended for frames larger than two bays and two stories.

2.3.3 Moment Distribution method:

The moment distribution method is a structural analysis method for statically indeterminate beams and frames developed by Hardy Cross. It was published in 1930 in an ASCE journal. The method only accounts for flexural effects and ignores axial and shear effects. From the 1930s until computers began to be widely used in the design and analysis of structures, the moment distribution method was the most widely practiced method.

In the moment distribution method, every joint of the structure to be analyzed is fixed to develop the fixed-end moments. Then each fixed joint is sequentially released, and the fixed-end moments are distributed to adjacent members until equilibrium is achieved. The moment distribution method in mathematical tens can be demonstrated as the process of solving a set of simultaneous equations by means of iteration.

2.3.4 Cantilever method:

The Cantilever Method was devised to calculate and analyze shear forces and moments developed indifferent members, as beams and columns, of a frame or structure due to lateral loads. The lateral loads include wind load and earthquake load which must be taken into consideration while designing the buildings.

The assumptions which are assumed in this method are that the point of contra flexure is located at the mid-point of the vertical members as well as horizontal members and that the direct stresses in the columns are proportional to their distances from the centroid axis. The frame is analyzed in stepwise fashion, and the details can then be described by the diagram at the end. The method is quite versatile and can be used to analyze frame of any number of stores or floors.

The position of the centriole axis is determined by using the areas of the end columns and intermediate columns. The method is considered as one of the two approximate methods for indeterminate structural analysis of frames for lateral loads.

2.3.5 Portal method:

A portal frame is often used in a structure to transfer the laterally directed loads applied along the sides, to the supports at the base of the frame. Portal frames are often designed such that they can confidently withstand lateral loads. This results in many portal frames being statically indeterminate externally; because of the frames ability to support horizontal loading, this type of frame is commonly used in structures like buildings, factories, and bridges.

The approximate analysis of portal frames can be investigated through the portal method. Before the analysis, there are necessary assumptions to be made:

1. A point of inflection is located at the center of each member of the portal frame.
2. For each story of the frame, the interior columns bear twice as much shear as the exterior columns.
3. Lateral forces resisted by frame action.
4. Inflection points at mid-height of columns.
5. Inflection points at mid-span of beams.
6. Column shear is based on tributary area.
7. Overturn is resisted by exterior columns only.

2.3.6 Matrix method:

As one of the methods of structural analysis, the direct stiffness method, also known as the matrix stiffness method, is particularly suited for computer-automated analysis of complex structures including the statically indeterminate type. It is a matrix method that makes use of the members' stiffness relations for computing member forces and displacements in structures. The direct stiffness method is the most common implementation of the finite element method (FEM). In applying the method, the system must be modeled as a set of simpler, idealized elements interconnected at the nodes. The material stiffness properties of these elements are then, through matrix mathematics, compiled into a single matrix equation which governs the behavior of the entire idealized structure. The structure's unknown displacements and forces can then be determined by solving this equation. The direct stiffness method forms the basis for most residential and free source finite element software.

2.4 Software Used:

This project is mostly based on software, and it is essential to know the details about these software's.

List of software's used

1. ETABS 2018 (18.0.1)
2. Auto CAD 2007
3. Microsoft Word Document 2010

2.4.1 ETABS 18.0.1:

ETABS is powerful design software licensed by CSI. ETABS stands for Extended Three-Dimensional Analyses of Building Systems. Any object which is stable under a given loading can be considered as structure. The innovative and revolutionary new ETABS is the ultimate integrated software package for the structural analysis and design of buildings. Incorporating 40 years of continuous research and development, this latest ETABS offers unmatched 3D object-based modeling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide-range of materials, and insightful graphic displays, reports, and schematic drawings that allow users to quickly and easily decipher and understand analysis and design results.

Now a day's most of the high-rise buildings are designed by ETABS which makes a compulsion for a civil engineer to know about this software. This software can be used to carry RCC, steel, bridge, truss etc. according to various country codes.

2.4.2 AutoCAD 2007:

AutoCAD is a commercial software application for 2D and 3D computer-aided design (CAD) and drafting available since 1982 as a desktop application and since 2010 as a mobile web- and cloud based appmarketedasAutoCAD360.

Developed and marketed by Autodesk, Inc., AutoCAD was first released in December 1982, running on microcomputers with internal graphics controllers. Prior to the instruction of AutoCAD, most commercial CAD programs ran on mainframe computers or minicomputers, with each CAD operator (user) working at a separate graphics terminal.

AutoCAD is used across a wide range of industries, by architects, project managers, engineers, designers, and other professionals. We used AutoCAD for drawing the plan, elevation of the building. We also used AutoCAD to show the reinforcement details and design details of a staircase, retaining Wall, beam, slab, water tank, foundation etc. AutoCAD is a very easy software to learn and much user friendly for anyone to handle and can be learn quickly. Learning of certain commands is required to draw in AutoCAD.

CHAPTER 03
METHODOLOGY

3.1 Introduction

In this chapter methodology of the work has been discussed. Required data for analysis and model built-up with AutoCAD and ETABS are discussed detailly discussed here. Analysis has been done for Zone-2 (Dhaka) and Zone-3(Sylhet). Design data are picked from BNBC-2006 and BNBC-2020.

3.2 Different types of loads in structure

Structural members must be designed to support specific loads. Loads are those forces for which a given suture should be proportioned. In general, loads may be classified as

1. Dead Loads
2. Imposed loads or live load
3. Wind Loads
4. Earthquake loads

3.2.1 Dead Load:

Consist of the permanent construction material loads compressing the roof, floor, wall, and foundation systems, finishes and fixed equipment. Dead load is the total load of all the components of the building that generally do not change over time, such as the concrete columns, concrete floors bricks, roofing material etc. In ETABS, assignment of dead load is automatically done by giving the property of the member. In load case we have option called self-weight which automatically calculates weights using the properties of material i.e., density. In this study, dead loads on the slab consist of self-weight of slab, floor finish and partition wall. Total vertical load applied on the slab is 25 psf as floor finish and 30psf as Random wall in addition to self-weight of slab.

3.2.2 Live Load:

Live loads are produced by the use and occupancy of a building. Loads include those from human occupants, furnishings, no fixed equipment, storage, and construction and maintenance activities. As required to adequately define the loading condition, loads are presented in terms of uniform area loads, concentrated loads, and uniform line loads. In ETABS we assign live load in terms of U.D.L .we has to create a load case for live load and select all the slabs to carry such load. Since the structures of the present study are intended for residential use, the live load considered in the building is 40 psf floor & roof top and staircase 100 psf.

3.2.3 Wind Load: (Institute, 2006)

Buildings and their components are to be designed to withstand the code-specified wind loads. Calculating wind loads is important in design of the wind force-resisting system, including structural members, components, and cladding, against shear, sliding, overturning, and uplift actions. Design wind load is calculated from sustained wind pressure, zone a building surface at any height z above ground according to BNBC 2006

$$q_z=CcCICzVb2\text{……………….. (If Vb= km/h)}$$

$$q_z= 0.00256\ CICzVb2\text{………… (If Vb= mile/h)}$$

q_z=Sustained wind pressure at height z, kN/m2

CI= Structure importance Coefficient

Cc= Velocity to pressure conversion coefficient

Cz= Combined height and exposure coefficient (Calculate based on height)

Vb= Basic wind speed, km/h

From the above equation, design wind pressure, $p_z$is calculated as followed

$$P_z=C_GC_pq_z\text{…………………… (If } V_b\text{= km/h)}$$

$$P_z=CtC_GC_pq_z\text{………………… (If } V_b\text{= mile/h)}$$

Pz= Design wind pressure at height z, kN/m2

C_G = Gust coefficient (calculated based on building height)

C_P = Pressure coefficient

q_z=Sustained wind pressure at height z, KN/m^2

Ct= in plain train local topography coefficient =1

Total wind force is calculated by projected area method using the formula:

$Fz = \sum PzAz$

F_Z=Total wind force, KN

Pz=Design wind pressure (kN/m^2)

Az=Projected frontal Area, m^2

Wind Loads (BNBC-2020)

Sign Convention: Positive pressure acts toward the surface and negative pressure acts away from the surface.

Critical Load Condition: Values of external and internal pressures shall be combined algebraically to determine the most critical load.

Tributary Areas Greater than 65 m^2: Component and cladding elements with tributary areas greater than 65 m2shall be permitted to be designed using the provisions for MWFRSs.

Main wind-force resisting systems

Rigid Buildings of All Heights: Design wind pressures for the MWFRS of buildings of all heights shall be determined by the following equation:

$$p = qGCp - (GCpi) \quad \text{(kN/m2)}$$

Where,

$q = qz$for windward walls evaluated at height $z$above the ground

$q = qh$for leeward walls, side walls, and roofs, evaluated at height h

$qi = qh$for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative

Internal pressure evaluation in partially enclosed buildings.

$qi = qz$for positive internal pressure evaluation in partially enclosed buildings where height $z$is defined as the level of the highest opening in the building that could affect the positive internal pressure. For buildings sited in wind-borne debris regions,glazing that is not impact resistant or protected with an impact resistant covering, shall be treated as an opening in accordance with Sec

For positive internal pressure evaluation, qimay conservatively be evaluated at height h =

(qi= qh)

G = gust effect factor

Cp = external pressure coefficient

$GCpi$= internal pressure coefficient

Low-Rise Building: Alternatively, design wind pressures for the MWFRS of low-rise buildings shall be determined by the following equation:

$$p = qh[(GC_{pf})- (GCpi)] \text{ (kN/m}^2\text{)}$$

Where,

qh = velocity pressure evaluated at mean roof height h using exposure

GC_{pf}= external pressure coefficient

= internal pressure coefficient

Flexible Buildings: Design wind pressures for the MWFRS of flexible buildings shall be determined from the following equation:

$$p = qG_f Cp–(\ ) \text{ (kN/m}^2\text{)}$$

Parapets: The design wind pressure for the effect of parapets on MWFRSs of rigid, low-rise, or flexible buildings with flat, gable, or hip roofs shall be determined by the following equation:

$$p_p= q_p GC_{pn} \text{(kN/m2)}$$

Where,

p_p = Combined net pressure on the parapet due to the combination of the net pressures from the

front and back parapet surfaces. Plus (and minus) signs signify net pressure acting toward (and
away from) the front (exterior) side of the parapet

q_p= Velocity pressure evaluated at the top of the parapet

GC_{pn} = Combined net pressure coefficient

= +1.5 for windward parapet

= −1.0 for leeward parapet

3.2.4 Earthquake Load (BNBC-2006)

Earthquake loading as per BNBC-2006 has been calculated by the program and it has been applied to the mass center of the building. This 'Equivalent Static Analysis' of seismic vibration is based on the concept of replacing the inertia forces at various 'lumped masses' (i.e., story levels) by equivalent horizontal forces that are proportional the weight of the body (therefore its mass) and its displacement (therefore its acceleration). The summation of these concentrated forces is balanced by a 'base shear' at the base of the structure.

The following provisions are taken from the Uniform Building Code of USA (UBC, 1994), and is also valid for Bangladesh National Building Code (BNBC, 1993) for most part.

Design Base Shear

The total design base shear in a given direction is determined from the following relation:

$$V=\frac{ZIC}{R}W$$

Where,

Z = Seismic zone coefficient given in Table 3.1

I = Structure importance coefficient given in Table 3.2

R = Response modification coefficient for structural systems given in Table 3.3

W= Total seismic load defined in

C= Numerical coefficient given by the relation

$$C=\frac{1.25\,S}{T^{2/3}}$$

T=Fundamental period of vibration in sec.

S = Site coefficient for soil characteristics as provided in Table 3.4

The value of C need not exceed 2.75 and this value may be used for any structure without regard to soil type or structure period. Except for those requirements where Code prescribed forces are scaled up by 0.375R, the minimum value of the ratio C/R is 0.075.

Structure Period

The value of the fundamental period, T of the structure can be determined from one of the following methods:

Method A:

For all buildings the value of T may be approximated by the following formula:

$$\mathbf{C = C_t\ (h_n)^{3/4}}$$

Where,

Ct = 0.083 for steel moment resisting frames

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

= 0.073 for reinforced concrete moment

= 0.049 for all other structural systems

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

Alternatively, the value of Ct for buildings with concrete or masonry shear walls maybetaken as0.031/√Ac. The value of Ac shall be obtained from the relation:

$$Ac = \sum Ae[0.2+ (De/h_n)^2]$$

Where,

Ac = the combined effective area, in square meters, of the shear walls in the first story of the structure.

Ae = the effective horizontal cross—sectional area, in square meters of a shear walls in the first story of the structure.

De = the length, in meters of a shear wall element in the first story in the direction parallel to the applied forces.

The value of De/hn should not exceed 0.9

<u>Method B:</u> The fundamental period T may be calculated using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis.

This requirement may be satisfied by using the following formula:

The values of fi represent any lateral force distributed approximately in accordance with the principles

$$T = {}^{2\pi}\sqrt{\sum_{i=1}^{n} \omega} \, . \, \delta^2 / g \sum_{i=1}^{n} f \, . \, \delta$$

Table 3.1: Seismic Zone Coefficient, Z

Seismic Zone	Zone Coefficient
1	0.075
2	0.15
3	0.25

Table 3.2: Structural Importance Coefficient, I

Structure Importance Category	Structure Importance Coefficient	
	I	I’
I Essential Facilities	1.25	1.50
II Hazardous Facilities	1.25	1.50
III Special Occupancy Structures	1.00	1.00
IV Standard Occupancy Structures	1.00	1.00
V Low- risk structures	1.00	1.00

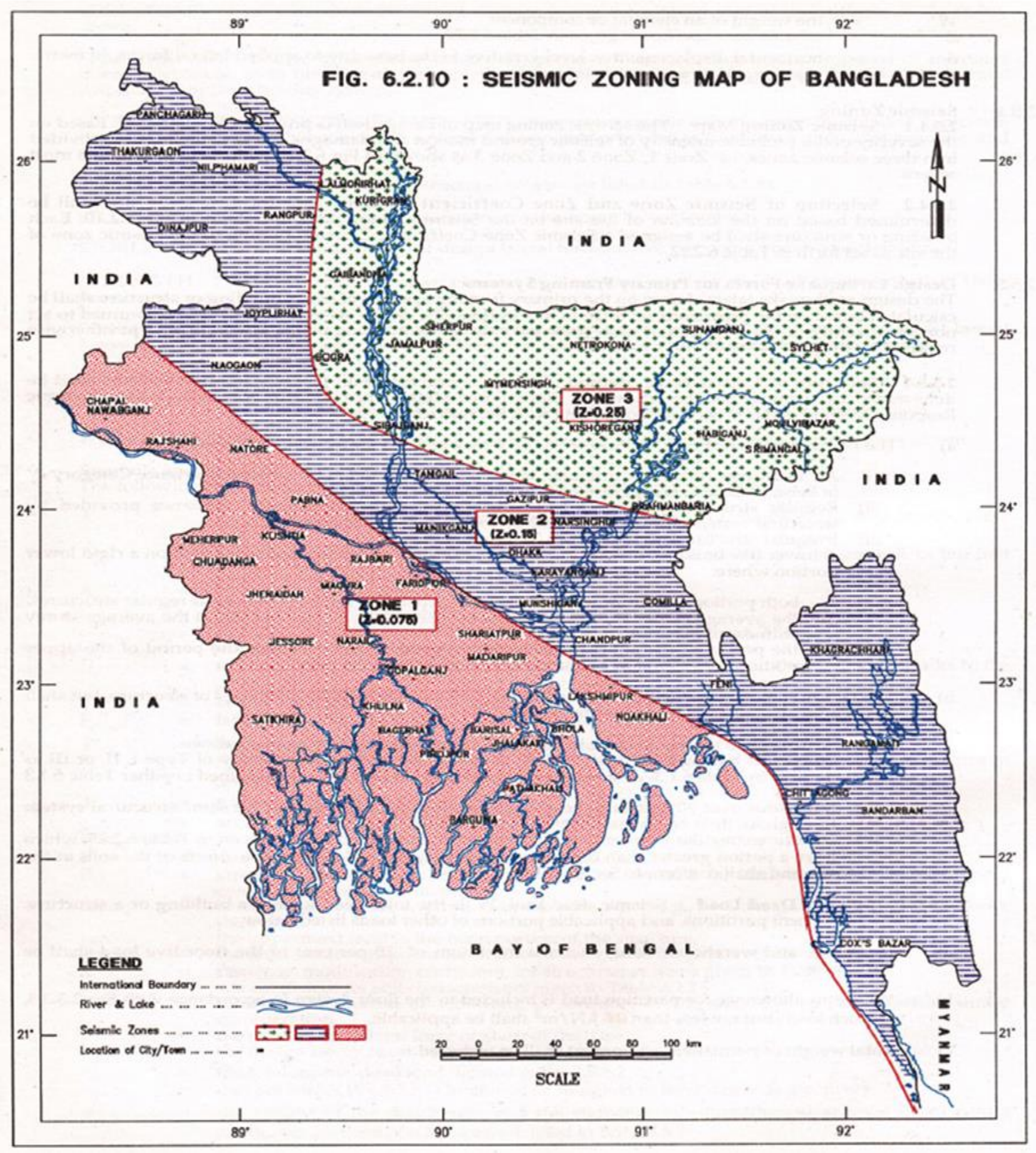

Figure: 3.1 (Seismic zone map-BNBC-2006)

Table 3.3: Response Modification Coefficient for Structural Systems, *R*

Basic Structural System[1]	Description of Lateral Force Resisting System	*R*[2]
a. Bearing Wall System	1. Light framed walls with shear panels	
	i) Plywood walls for structures, 3 stores or less	8
	ii) All other light framed walls	6
	2. Shear walls	
	i) Concrete	6
	ii) Masonry	6
	3. Light steel framed bearing walls with tension only bracing	4
	4. Braced frames where bracing carries gravity loads	6
	i) Steel	4
	ii) Concrete[3]	4
	iii) Heavy timber	
b. Building Frame System	1. Steel eccentric braced frame (EBF)	10
	2. Light framed walls with shear panels	
	i) Plywood walls for structures 3-storeys or less	9
	ii) All other light framed walls	7
	3. Shear walls	
	i) Concrete	8
	ii) Masonry	8
	4. Concentric braced frames (CBF)	
	i) Steel	8
	ii) Concrete[3]	8
	iii) Heavy timber	8
c. Moment Resisting Frame System	1. Special moment resisting frames (SMRF)	
	i) Steel	12
	ii) Concrete	12
	2. Intermediate moment resisting frames (IMRF), concrete[4]	8
	3. Ordinary moment resisting frames (OMRF)	6
	i) Steel	5
	ii) Concrete[5]	
d. Dual System	1. Shear walls	
	i) Concrete with steel or concrete SMRF	12
	ii) Concrete with steel OMRF	6
	iii) Concrete with concrete IMRF[4]	9
	iv) Masonry with steel or concrete SMRF	8
	v) Masonry with steel OMRF	6
	vi) Masonry with concrete IMRF[3]	7
	2. Steel EBF	
	i) With steel SMRF	12
	ii) With steel OMRF	6

	3. Concentric braced frame (CBF) i) Steel with steel SMRF ii) Steel with steel OMRF iii) Concrete with concrete SMRF[(3)] iv) Concrete with concrete IMRF[(3)]	 10 6 9 6
e. Special Structural Systems	See 1.3.2, 1.3.3, 1.3.5	
Notes: (1) Basic Structural Systems are defined in Sec 1.3.2, Chapter 1. (2) See Sec 2.5.6.6 for combination of structural systems, and Sec 1.3.5 for system limitations. (3) Prohibited in Seismic Zone 3. (4) Prohibited in Seismic Zone 3 except as permitted in Sec 2.5.9.3. (5)Prohibited in Seismic Zones 2 and 3. Sec 1.7.2.6.		

Table 3.4: Site Coefficient, S for Seismic Lateral Forces

Site Soil Characteristics		**Coefficients**
Type	Description	
S_1	A soil profile with either: 8. A rock-like material characterized by a shear-wave velocity greater than762 m/s or by other suitable means of classification, or 9. Stiff or dense soil condition where the soil depth is less than 61meters	1.0
S_2	A soil profile with dense or stiff soil conditions, where the soil depth exceeds61 meters	1.2
S_3	A soil profile 21 meters or more in depth and containing more than 6 metersof soft to medium stiff clay but not more than 12 meters of soft clay	1.5
S_4	A soil profile containing more than 12 metersof soft clay characterized by a shear wave velocity less than 152 m/s	2.0

Reduction of Live Loads: Reduction of live load is permitted for primary structural members supporting floor or roof, including beam, girder, buss, flat slab, flat plate, column, pier, footing and the like. Where applicable, the reduced live load on a primary structural member shall be obtained by multiplying the corresponding unreduced uniformly distributed live load with an appropriate live load reduction factor.

Load Groups: All possible live loads applied on floors and roof of a building due to various occupancies and uses, shall be divided into three load groups as described below for determining the appropriate live load reduction factors.

1. **Load Group 1 :** Uniformly distributed live loads arising from the occupancies and 2 uses of (i) assembly occupancies or areas with uniformly distributed live load of 5.0 kN/m or less, (ii) machinery and equipment for which specific live load allowances have been made, (iii) special roof live load and (iv) printing plants, vaults, strong rooms and armories, shall be classified under LoadGroup l. Reduction of live load shall not be allowed for members or portions thereof under this load group and a reduction factor, R —l .0 shall be applied for such cases.
2. **Load Group 2:** Uniformity distributed live loads resulting from occupancies or uses of (i) assembly areas with uniformly distributed live load greater than 5.0 kN/m, and (ii) storage, mercantile, industrial and retail stores, shall be classified under Load Group 2, Live load reduction factor, 1.0 < R< 0.7 shall be applied to this load group depending on the tributary area of the floors or roof supported by the member as specified.

Load Group 3: Uniformly distributed live loads arising due to all other occupancies and uses except those of Load Group I and Load Group 2, shall be grouped into Load Group 3. Live load reduction factor, 1.0 < R < 0.5 as specified, shall be applied to tributary areas under this load group.

Tributary Area: The tributary area of a structural member supporting floors or roof shall be determined as follows:

a) Tributary Area for Wall, Column, Pier, Footing and the like: Tributary areas of these members shall consist of portions of the areas of all floors, roof or combination thereof that contribute live loads to the member concerned.

b) Tributary Area for Beam, Girder, Flat plate and Flat slab: Tributary area for such a member shall consist of the portion of the roof or a floor at any single level that contributes loads to the member concerned.

Table 3.5: Live Load Reduction Factors for Various Occupancies and Uses (From BNBC)

Load Group	Occupancy or Use	Tributary [(1)] Area (floor, or roof, or combination) At (m^2)	Live Load [(2,3)] Reduction Factor, R
1	10. Assembly areas with uniformly distributed live load of 5.0 kN/m^2 or less. 11. Live loads from machinery and equipment for which specific load allowance has been made 12. Special roof live loads as specified in Sec 2.3.4.2 **13.** Printing plants, vaults, strong room and armories	All	1.0
2	14. Assembly areas with uniformly distributed live load greater than 5.0 kN/m^2. 15. Storage, mercantile, industrial, parking garage, retail stores	≤ 50 60 80 100 120 140 280 220 300 400 ≥ 800	1.00 0.97 0.92 0.88 0.86 0.84 0.81 0.79 0.76 0.74 0.70
3	a) Uniformly distributed live loads from all occupancies and uses except those listed in load groups 1 and 2 above.	< 25 25-30 40 50 60 80 100 120 140 180 ≥220	1.00 0.90 0.84 0.78 0.73 0.67 0.62 0.59 0.57 0.53 0.50

Note :(1) A_t = sum of all tributary areas with loads from any one load group (i.e. Load Group 1, 2 or 3

(2) Linear interpolation may be made to obtain values of R lying between the listed values.

(3) Live load reduction factor, R is based on the relations: $R=0.6+\sqrt{(8/A_t)}$ for Load Group 2

and $R=0.25+\sqrt{(14/A_t)}$ for Load Group 3

Table 3.6: Basic Wind Speeds for Selected Locations in Bangladesh

Location	Basic Wind Speed (km/h)	Location	Basic Wind Speed (km/h)
Angarpota	150	Lalmonirhat	204
Bagerhat	252	Madaripur	220
Bandarban	200	Magura	208
Barguna	260	Manikganj	185
Barisal	256	Meherpur	185
Bola	225	Maheshkhali	260
Bogra	198	Moulvibazar	168
Brahmanbaria	180	Munshiganj	184
Chandpur	160	Mymensingh	217
Chapai Nawabganj	130	Naogaon	175
Chittagong	260	Narail	222
Chuadanga	198	Narayanganj	195
Comilla	196	Narsinghdi	190
Cox’s Bazar	260	Natore	198
Dahagram	150	Netrokona	210
Dhaka	210	Nilphamari	140
Dinajpur	130	Noakhali	184
Faridpur	202	Pabna	202
Feni	205	Panchagarh	130
Gaibandha	210	Patuakhali	260
Gazipur	215	Pirojpur	260
Gopalganj	242	Rajbari	188
Habiganj	172	Rajshahi	155
Hatiya	260	Rangamati	180
Ishurdi	225	Rangpur	209
Joypurhat	180	Satkhira	183
Jamalpur	180	Shariatpur	198
Jessore	205	Sherpur	200
Jhalakati	260	Sirajganj	160

Jhenaidah	208	Srimangal	160
Khagrachhari	180	St. Martin's Island	260
Khulna	238	Sunamganj	195
Kutubdia	260	Sylhet	195
Kishoreganj	207	Sandwip	260
Kurigram	210	Tangail	160
Kushtia	215	Teknaf	260
Lakshmipur	162	Thakurgaon	130

Table 3.7: Basic load cases used for analysis

No.	Load Case	Direction
1	DL (Dead Load)	Downwards
2	LL (Live Load)	Downwards
3	EQX (Earthquake load in X direction)	X direction
4	EQY (Earthquake load in Y direction)	Y direction
5	WX (Wind load in X direction)	X direction
6	WY (Wind load in Y direction)	Y direction

Exposure Category: The terrain exposure in which a building or structure is to be sited shall be assessed as being one of the following categories:

1. **Exposure A:** Urban and sub-urban areas, industrial areas, wooded areas, hilly or other terrain covering at least 20 per cent of the area with obstructions of 6 meters or more in height and extending from the site at least 500 meters or 10 times the height of the structure, whichever is greater.

2. **Exposure B:** Open terrain with scattered obstructions having heights generally less than 10m extending 800 m or more from the site in any full quadrant. This category includes airfields, open park lands, sparsely built-up outskirts of towns, flat open country and grasslands.

3. **Exposure C:** Flat and unobstructed open terrain, coastal areas and riversides facing large bodies of water, over 1.5 km or more in width.

Exposure C extends inland from the shoreline 400 m or 10 times the height of structure, whichever is greater.

Load Combinations:

As per BNBC 2006, Chapter 2- Part 6 (Clause 11027.5), following load cases must be considered for analysis:

U=1.4 D.L

U=1.4 D.L+ 1.7 L.L

U = 1.05 D.L + 1.275 L.L± 1.4025 E.L

U = 1.05 D.L± 1.4025 EL

U = 0.9 D.L± 1.43 EL

U = 1.05 D.L + 1.275 L.L± 1.275 WL

U = 1.05 D.L± 1.275 W.L

U = 0.9 D.L± 1.3 W.L

Earthquake load and Wind Load must be considered for +X, -X, +Y and —Y directions. Thus, ±EL and ± WL above implies 24 cases, and in all, 26 cases as per Table 3.6 must be considered. All 26load combinations are analyzed using software.

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Equivalent Static Analysis

The evaluation of the seismic loads starts with the calculation of the design base shear which is derived from the design response spectrum presented in Sec 2.5.4.3. This Section presents different computations relevant to the equivalent static analysis procedure.

Design base shear

The seismic design base shear force in each direction shall be determined from the following relation:

$$V = S_a W$$

Where,

Sa= Lateral seismic force coefficient. It is the design spectral acceleration (in units of g) corresponding to the building period T

W = Total seismic weight of the building

Alternatively, for buildings with natural period less than or equal to 2.0 sec., the seismic design base shear can be calculated using ASCE 7-02 with seismic design parameters as given in Appendix C. However, the minimum value of $SSaa$should not be less than 0.044 SDSI.

Building period

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

1. Structural dynamics procedures (such as Rayleigh method or modal eigenvalue analysis), using structural properties and deformation characteristics of resisting elements, may be used to determine the fundamental period T of the building in the direction under consideration. This period shall not exceed the approximate fundamental period by more than 40 percent.
2. The building period T (in secs) may be approximated by the following formula:

$$\boldsymbol{T = (hn)}\mathbf{m}$$

Where,

hn= Height of building in meters from foundation or from top of rigid basement. This excludes the basement stores, where basement walls relate tothe ground floor deck or fitted between the building columns. But it includes the basement stores, when they are not so connected.

Design response spectrum

The earthquake ground motion for which the building has to be designed is represented by the design response spectrum. Both static and dynamic analysis methods are based on this response spectrum. This spectrum represents the spectral acceleration for which the building must be designed as a function of the building period, considering the ground motion intensity. The spectrum is based on elastic analysis but in order to account for energy dissipation due to inelastic deformation and benefits of structural redundancy, the spectral accelerations are reduced by the response modification factor R. For important structures, the spectral accelerations are increased by the importance factor I. The design basis earthquake (DBE) ground motion is selected at a ground shaking level that is 2/3 of the maximum considered earthquake (MCE) ground motion. The effect of local soil conditions on the response spectrum is incorporated in the normalized acceleration response spectrum Cs. The spectral acceleration for the design earthquake is given by the following equation:

$$\mathbf{S_a = \frac{2}{3}\frac{ZI}{R} C_s}$$

Where,

Sa = Design spectral acceleration (in units of ggwhich shall not be less than 0.67βZIS

β = coefficient used to calculate lower bound for Sa. Recommended value for $\beta$is 0.11

Z = Seismic zone coefficient

I = Structure importance factor

RR = Response reduction factor which depends on the type of structural system.

The ratio $\frac{I}{R}$cannot be greater than one.

Cs = Normalized acceleration response spectrum, which is a function of structure (building) period and soil type (site class).

$Cs = S\ (1 + \frac{T}{TB}\ (1+ 2\ 5\eta - 1))\ 0 \le T \le T_B$

$Cs = 2.5S\eta$ for $T_B \le T \le T_C$

$Cs = 2.5S\eta\ (\frac{Tc}{T})$ for $Tc \le T \le T_D$

$Cs = 2.5S\eta\ (\frac{TcTD}{T2})$ for $T_D \le T \le 4\ sec$

Cs depends on S and values of TB, TC and TD, which are all functions of the site class.

Constant Cs value between periods TB and TC represents constant spectral acceleration.

S = Soil factor which depends on site class

T = Structure (building) period

TB = Lower limit of the period of the constant spectral acceleration branch

T_C= Upper limit of the period of the constant spectral acceleration branch

T_D= Lower limit of the period of the constant spectral displacement branch

η = Damping correction factor as a function of damping with a reference value of η=1 for 5% viscous damping. It is given by the following expression:

$$\eta = \sqrt{10/(5+\xi)} \geq 0.55$$

Where, ξ is the viscous damping ratio of the structure, expressed as a percentage of critical damping. The value of η cannot be smaller than 0.55.

The anticipated (design basis earthquake) peak ground acceleration (PGA) for rock or very stiff soil (site class SA) is $\frac{2}{3}Z$. However, for design, the ground motion is modified through the use of response reduction factor R and importance factor I, resulting in $PGA_{rock} = \frac{2}{3}\frac{ZI}{R}$ the normalized acceleration responsespectrum Cs for 5% damping, which may be defined as the 5% damped spectral accelerationnormalized with respect to PGA_{rock}.

Table 3.8: Site Dependent Soil Factor and Other Parameters Defining Elastic Response Spectrum

Soil Type	S	TB(S)	TC (S)	TD (S)
SA	1.0	0.15	0.40	2.0
SB	1.2	0.15	0.50	2.0
SC	1.15	0.20	0.60	2.0
SD	1.35	0.20	0.80	2.0
SE	1.4	0.15	0.50	2.0

Table 3.9: Importance Factors for Buildings and Structures for Earthquake design

Occupancy Category	Importance factor I
I,II	1.00
III	1.25
IV	1.50

Table 3.10: Seismic Design Category of Buildings

Site Class	Occupancy Category I, II and III				Occupancy Category IV			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
SA	B	C	C	D	C	D	D	D
SB	B	C	D	D	C	D	D	D
SC	B	C	D	D	C	D	D	D
SD	C	D	D	D	D	D	D	D
SE,S1,S2	D	D	D	D	D	D	D	D

Table 3.11: Values for Coefficients to Estimate Approximate Period

Structure Type	C_t m
Concrete moment-resisting frames 0.0466 0.9 Steel moment-resisting frames 0.0724 0.8 Eccentrically braced steel frame 0.0731 0.75 All other structural systems 0.0488 0.75	Note: Consider moment resisting frames as frames which resist 100% of seismic force and are not enclosed or adjoined by components that are more rigid and will prevent the frames from deflecting under seismic forces.

Table 3.12: Response Reduction Factor, Deflection Amplification Factor and Height Limitations for Different Structural Systems

Seismic Force–Resisting System	Response Reduction Factor,	System Over strength Factor,	Deflection Amplification Factor,	Seismic Design Category	Seismic Design Category	Seismic Design Categ

	R	Ωo	**Cd**	B	C	ory D
				Height limit (m)		
A. BEARING WALL SYSTEMS (no frame)						
1. Special reinforced concrete shear walls	5	2.5	5	NL	NL	50
2. Ordinary reinforced concrete shear walls	4	2.5	4	NL	NL	NP
3. Ordinary reinforced masonry shear walls	2	2.5	1.75	NL	50	NP
4. Ordinary plain masonry shear walls	1.5	2.5	1.25	18	NP	NP
B. BUILDING FRAME SYSTEMS (with bracing or shear wall)						
1. Steel eccentrically braced frames, moment resisting connections at columns away from links	8	2	4	NL	NL	50
2. Steel eccentrically braced frames, moment-resisting, connections at columns away from links	7	2	4	NL	NL	50
3. Special steel concentrically braced frames	6	2	5	NL	NL	50
4. Ordinary steel concentrically braced Frames	3.25	2	3.25	NL	NL	11
5. Special reinforced concrete shear walls	6	2.5	5	NL	NL	50
6. Ordinary reinforced concrete shear walls	5	2.5	4.25	NL	NL	NP
7. Ordinary reinforced masonry shear walls	2	2.5	2	NL	50	NP
8. Ordinary plain masonry shear walls	1.5	2.5	1.25	18	NP	NP
C. MOMENT RESISTING FRAME SYSTEMS (no shear wall)						
1.Special steel moment frames	8	3	5.5	NL	NL	NL
2. Intermediate steel moment frames	4.5	3	4	NL	NL	35
3. Ordinary steel moment frames	3.5	3	3	NL	NL	NP
4. Special reinforced concrete moment frames	8	3	5.5	NL	NL	NL
5. Intermediate reinforced concrete moment	5	3	4.5	NL	NL	NP

frames 6. Ordinary reinforced concrete momentframes	3	3	2.5	NL	NP	NP
D. DUAL SYSTEMS: SPECIAL MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES (with bracing or shear wall)						
1.Steel eccentrically braced frames	8	2.5	4	NL	NL	NL
2.Special steel concentrically braced frames	7	2.5	5.5	NL	NL	NL
3.Special reinforced concrete shear walls	7	2.5	5.5	NL	NL	NL
4. Ordinary reinforced concrete shear walls	6	2.5	5	NL	NL	NP
E. DUAL SYSTEMS: INTERMEDIATE MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES (with bracing or shear wall)						
1. Special steel concentrically braced frames	6	2.5	5	NL	NL	11
2. Special reinforced concrete shear walls	6.5	2.5	5	NL	NL	50
3. Ordinary reinforced masonry shear walls	3	3	3	NL	50	NP
4. Ordinary reinforced concrete shear walls	5.5	2.5	4.5	NL	NL	NP
F. DUAL SHEAR WALL-FRAME SYSTEM: ORDINARY REINFORCED CONCRETE MOMENT FRAMES AND ORDINARY REINFORCED CONCRETE SHEAR WALLS	4.5	2.5	4	NL	NP	NP
G. STEEL SYSTEMS NOT SPECIFICALLY DETAILED FOR SEISMIC RESISTANCE	3	3	3	NL	NL	NP

Notes:

1. Seismic design category, NL = No height restriction, NP = Not permitted. Number represents maximum allowable height (m).
2. Dual Systems include buildings which consist of both moment resisting frame and shear walls (or braced frame) where both systems resist the total design forces in proportion to their lateral stiffness.
3. See Sec. 10.20 of Chapter 10 of this Part for additional values of R and $Cd$and height limits for some other types of steel structures not covered in this Table.
4. Where data specific to a structure type is not available in this Table, reference may be made to Table 12.2-1 of ASCE 7-05.

SEISMIC ZONE MAP ACCORDING TO BNBC-2020

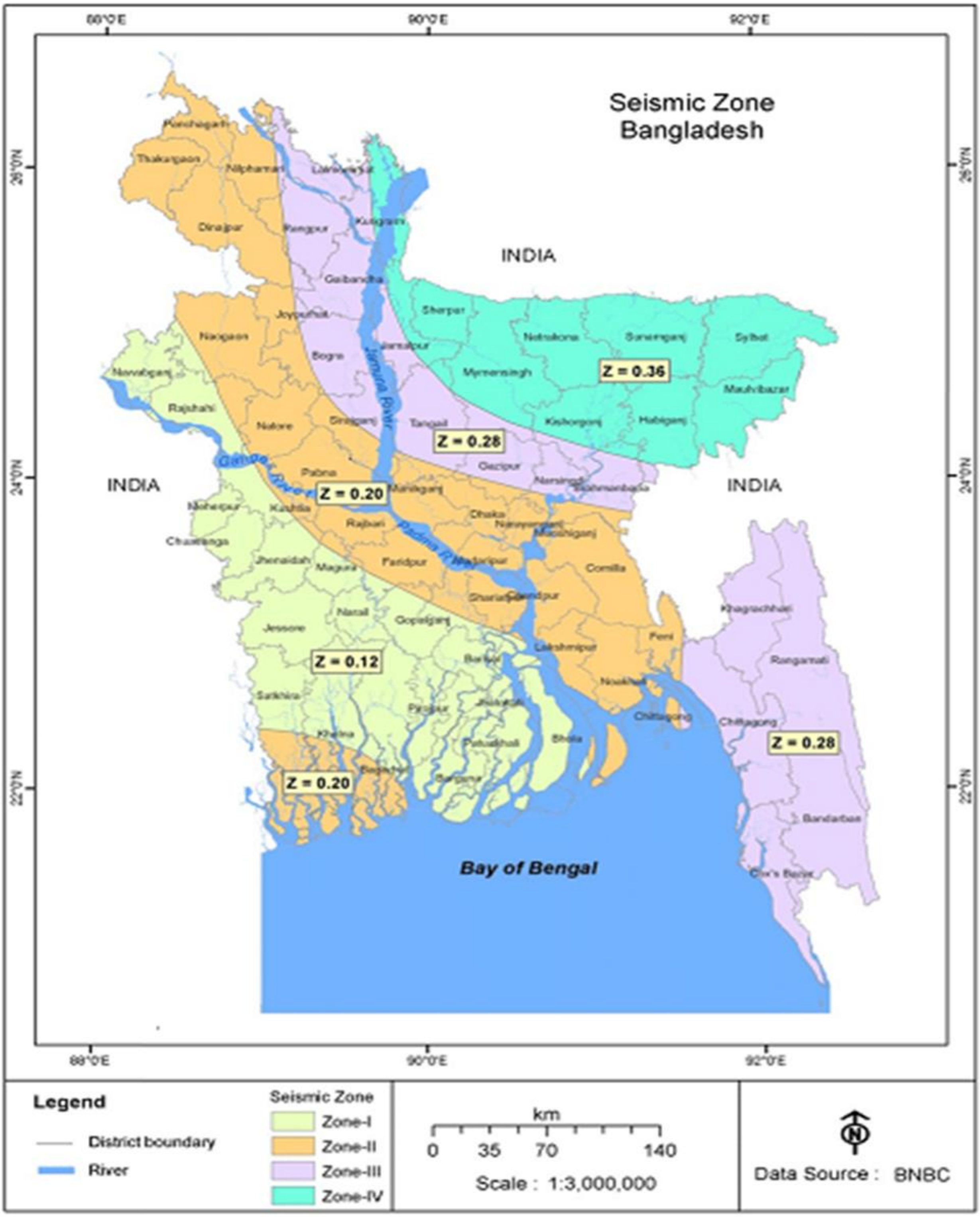


Figure: 3.2 (Seismic Zone map BNBC-2020)

Table 3.13: Basic Wind Speeds, V, for Selected Locations in Bangladesh

Location	Basic Wind Speed (m/s)	Location	Basic Wind Speed (m/s)
Angarpota	47.8	Lalmonirhat	63.7
Bagerhat	77.5	Madaripur	68.1
Bandarban	62.5	Magura	65.0
Barguna	80.0	Manikganj	58.2
Barisal	78.7	Meherpur	58.2
Bola	69.5	Maheshkhali	80.0
Bogra	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
Chuadanga	61.9	Narayanganj	61.1
Comilla	61.4	Narsinghdi	59.7
Cox’s Bazar	80.0	Natore	61.9
Dahagram	47.8	Netrokona	65.6
Dhaka	65.7	Nilphamari	44.7
Dinajpur	41.4	Noakhali	57.1
Faridpur	63.1	Pabna	63.1
Feni	64.1	Panchagarh	41.4
Gaibandha	65.6	Patuakhali	80.0
Gazipur	66.5	Pirojpur	80.0
Gopalganj	74.5	Rajbari	59.1
Habiganj	54.2	Rajshahi	49.2
Hatiya	80.0	Rangamati	56.7
Ishurdi	69.5	Rangpur	65.3
Joypurhat	56.7	Satkhira	57.6
Jamalpur	56.7	Shariatpur	61.9
Jessore	64.1	Sherpur	62.5
Jhalakati	80.0	Sirajganj	50.6
Jhenaidah	65.0	Srimangal	50.6
Khagrachhari	56.7	St. Martin’s Island	80..0
Khulna	73.3	Sunamganj	61.1
Kutubdia	80.0	Sylhet	61.1
Kishoreganj	64.7	Sandwip	80.0
Kurigram	65.6	Tangail	50.6
Kushtia	66.9	Teknaf	80.0
Lakshmipur	51.2	Thakurgaon	41.4

3.3 Design Data

Load Consideration: BNBC 2006 for Zone 2,3

1. Dead Load (BNBC 2006, Zone-2)

Floor Finish (FF)	: 25 psf
Random Wall (RW)	: 30 psf
Parapet wall (PPW)	: 150 psf (3ft)
Partition wall (PW)	: 450lb/ft (9.5ft)

2. Live Load (BNBC 2006)

Floor	: 25 psf
Stair	: 84 psf
Roof	: 42 psf
Over Head Water Tank	: 312 psf (6 ft)

3. Wind Pressure (BNBC 2006)

Basic Wind Speed, V	: 210 Km/h -130.49 mph (Dhaka)
Structural Importance Coefficient	: 1.0
Exposure Category	: B
Windward coefficient, Cq	:0.047
Leeward coefficient, Cq	: 0.405

4. Earthquake Base Shear (BNBC 2006)

Seismic Zone factor (Z)	: 0.15 (Zone II)
Response Modification Coefficient, R	: 8
Structural Importance Factor (I)	: 1.0
Site Coefficient (S)	: 1.5
Time Period, T	: 0.784 sec

1. Dead Load (BNBC 2006, Zone-3)

Floor Finish (FF)	: 25 psf
Random Wall (RW)	: 30 psf
Parapet wall (PPW)	: 150 psf (3ft)
Partition wall (PW)	: 450lb/ft (9.5ft)

2. Live Load (BNBC 2006)

Floor	: 25 psf
Stair	: 84 psf
Roof	: 42 psf
Over Head Water Tank	: 312 psf (6 ft)

3. Wind Pressure (BNBC 2006)

Basic Wind Speed, V	: 195 Km/h - 121.17 mph (Sylhet)
Structural Importance Coefficient	: 1.0
Exposure Category	: B
Windward coefficient, Cq	: 0.945
Leeward coefficient, Cq	: 0.405

4. Earthquake Base Shear (BNBC 2006)

Seismic Zone factor (Z)	: 0.25 (Zone III)
Response Modification Coefficient, R	: 8
Structural Importance Factor (I)	: 1.0
Site Coefficient (S)	: 1.5
Time Period, T	: 0.784 sec

Load Consideration: BNBC 2020 for Zone 2, 3

1. Dead Load: (for Zone -2)

Floor Finish (FF)	:25 psf
Random Wall (RW)	:30 psf
Parapet wall	:150 psf (3ft)
Partition wall (PW)	: 450 1b/ft(9.5ft)

2. Live Load:

Floor	: 2KN/m^2 or 41.76 psf (Table 6.2.3)
Stair	: 4.8KN/m^2 or 100 psf (Table 6.2.3)
Roof	: 1 KN/m^2 or 20.88 psf (Tab1e 6.2.4)
Over Head Water Tank	: 312 psf (6 ft)

3. Wind Pressure (BNBC 2020)

Basic Wind Speed, V	: 147 mph (Dhaka)
Structural Importance Coefficient	: 1.0
Exposure Category	: B
Gust factor	: 0.85
Directionally Factor, Kd	: 0.85

4.Earthquake Base Shear (BNBC 2020)

Seismic Zone factor (Z)	: 0.20 (Zone II)
Response Modification Coefficient, R	: 5
System Over strength. Ὠ (omega)	: 3
Deflection Amplification, Cd	: 4.5
Structural Importance Factor (I)	: 1.0
Spectral Response Acceleration, Ss	: 0.5
Spectral Response Acceleration, S1	: 0.2
Site Coefficient, Fa	: 1.15
Site Coefficient, Fv	:1.725
Time Period, T	: 0.78 sec

1. Dead Load: (for Zone -3)

Floor Finish (FF)	:25 psf
Random Wall (RW)	:30 psf
Parapet wall	:150 psf(3ft)
Partition wall (PW)	:450 1b/ft(9.5ft)

2. Live Load:

Floor	: 2KN/m^2 or 41.76 psf (Table 6.2.3)
Stair	: 4.8KN/m^2 or 100 psf (Table 6.2.3)
Roof	: 1 KN/m^2 or 20.88 psf (Tab1e 6.2.4)
Over Head Water Tank	: 312 psf (6 ft)

3. Wind Pressure (BNBC 2020)

Basic Wind Speed, V : 136.68 mph (Sylhet)

Structural Importance Coefficient : 1.0

Exposure Category : B

Gust factor : 0.85

Directionally Factor, Kd : 0.85

4. Earthquake Base Shear (BNBC 2020)

Seismic Zone factor (Z) :0.36 (Zone III)

Response Modification Coefficient, R: 5

System Over strength. ̓Ω (omega) : 3

Deflection Amplification, Cd : 4.5

Structural Importance Factor (I) : 1.0

Spectral Response Acceleration, Ss : 0.7

Spectral Response Acceleration, S1 : 0.28

Site Coefficient, Fa : 1.15

Site Coefficient, Fv :1.725

Time Period, T : 0.78 sec

Material Properties:

Unit weight of concrete : 150 lb/ft^3

Compressive Strength:

For slab, fc' : 4000 psi

For beam, fc' : 4000 psi

For Column: fc' : 4000 psi

Steel

Yield strength of Steel, f_y : 60 ksi

3.4 AutoCAD Model

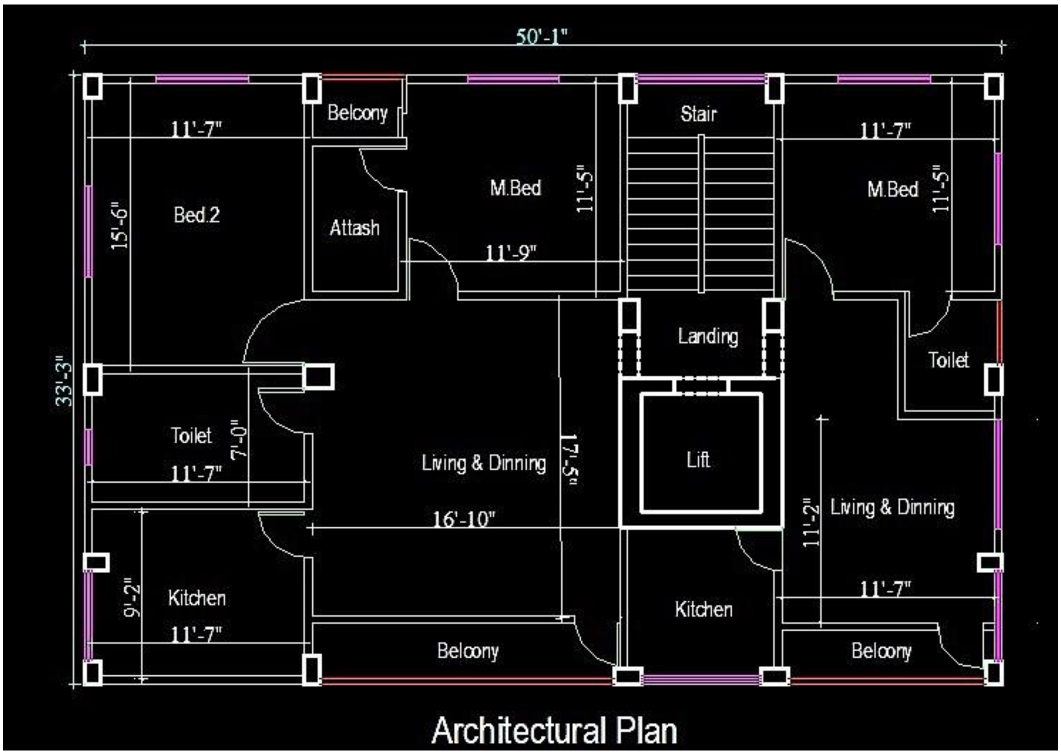


Figure 3.3: Architectural Plan of the model

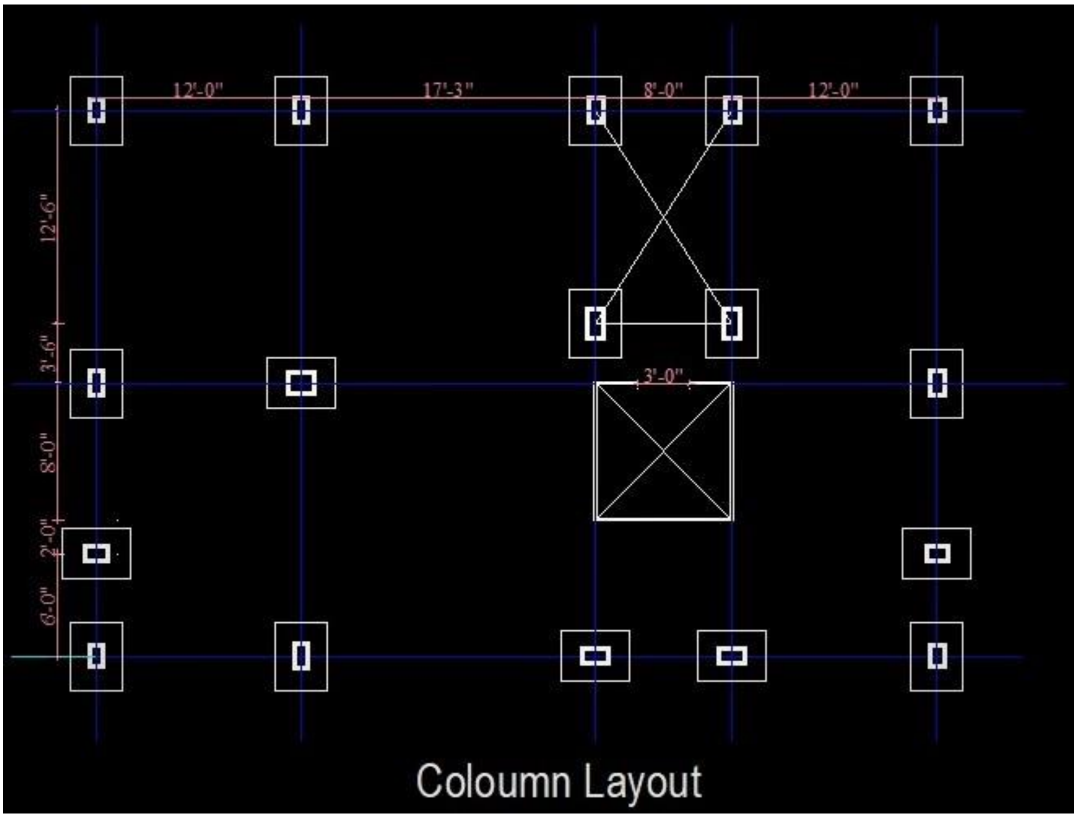


Figure 3.4: Footing layout of the model

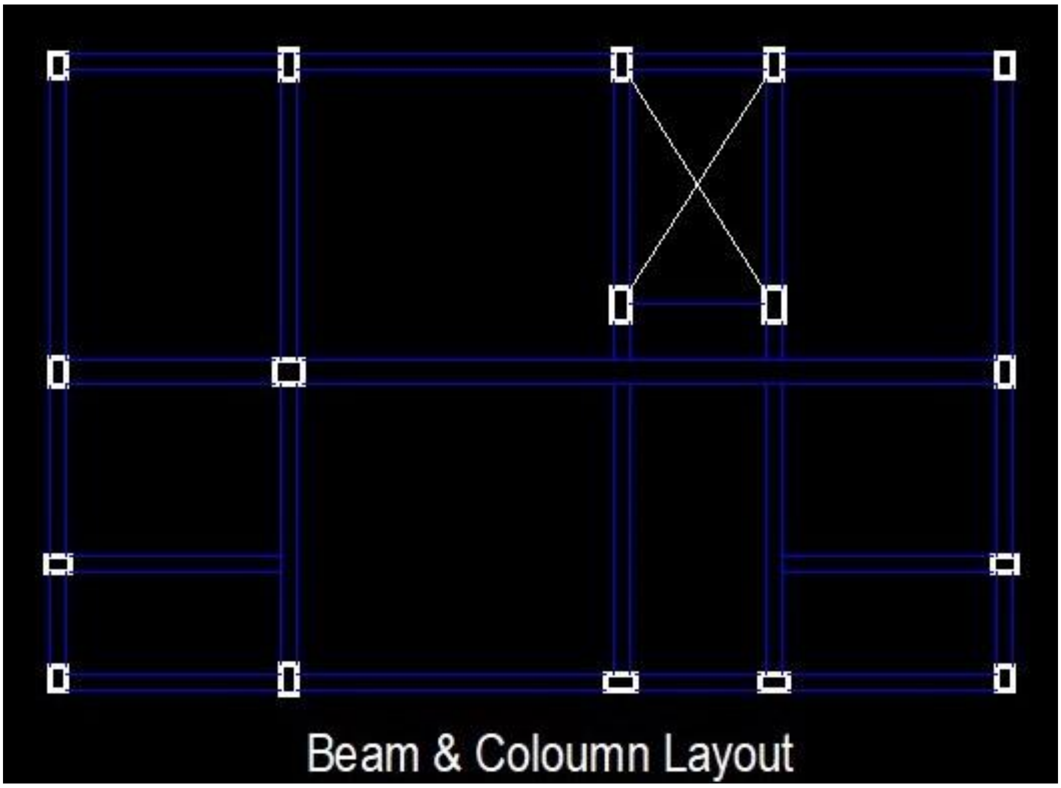


Figure 3.5: Beam & Column layout of the model

3.5 Modelling with ETABS

3.5.1 Model Initialization

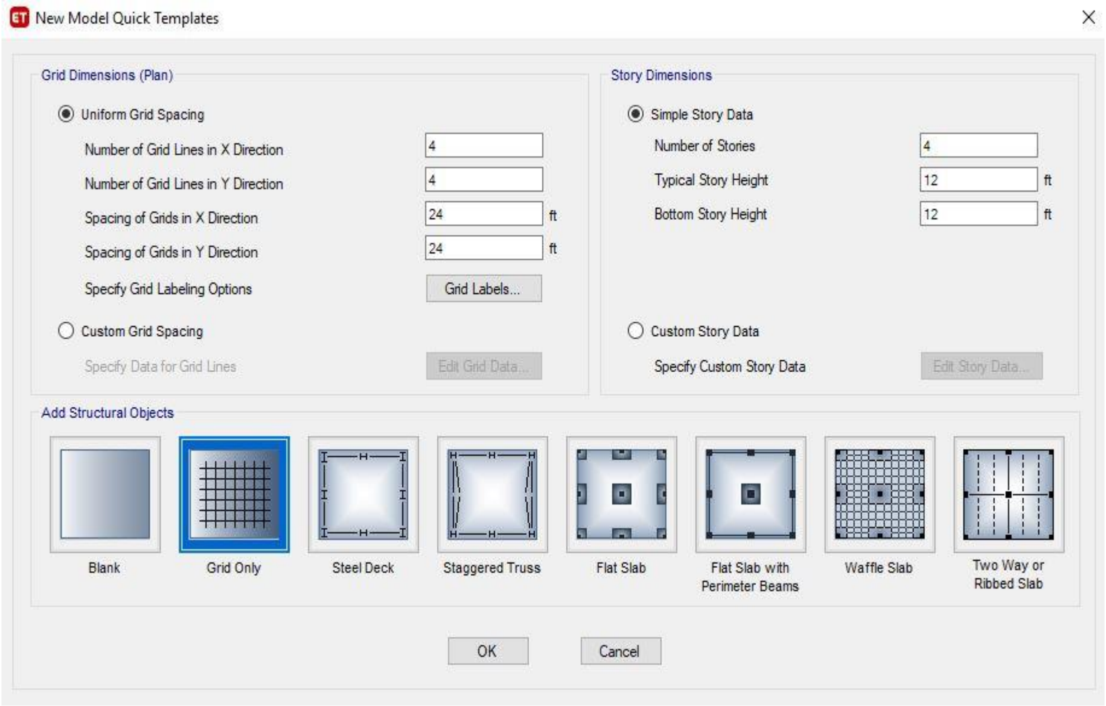


Figure 3.6: Grid Selection of the model

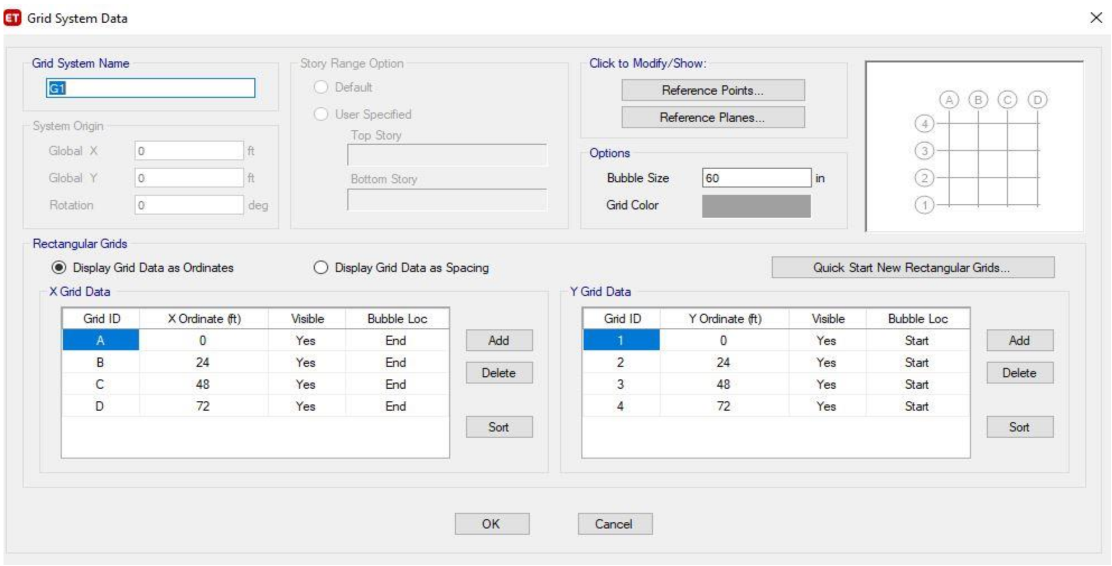


Figure 3.7: Grid Selection of the model

- File >New model
- If it is uniform grid then file up the "Uniform Grid Spacing" Box
- Input number of grid in X, Y direction
- Take number of Stories
- Change unit to kip-ft
- Input typical story height
- Input bottom story height
- If the grid is not uniform, then go to the "Custom Grid Spacing"
- Edit Grid
- Cheek Spacing
- Cheek glue to grid lines
- Input Spacing of grid in X, Y direction
- Ok

3.5.2 Define Materials Properties and Frame Section:

- Materials Properties

  i.Concrete

  ii.Modify if need
- Frame Section

  i.Select all existing property

  ii.Delete all

  iii.Add rectangle/circle

  iv.For beam

  v.SelectRainforcement

  vi.Then select beam

  vii.Define all frame section in this process

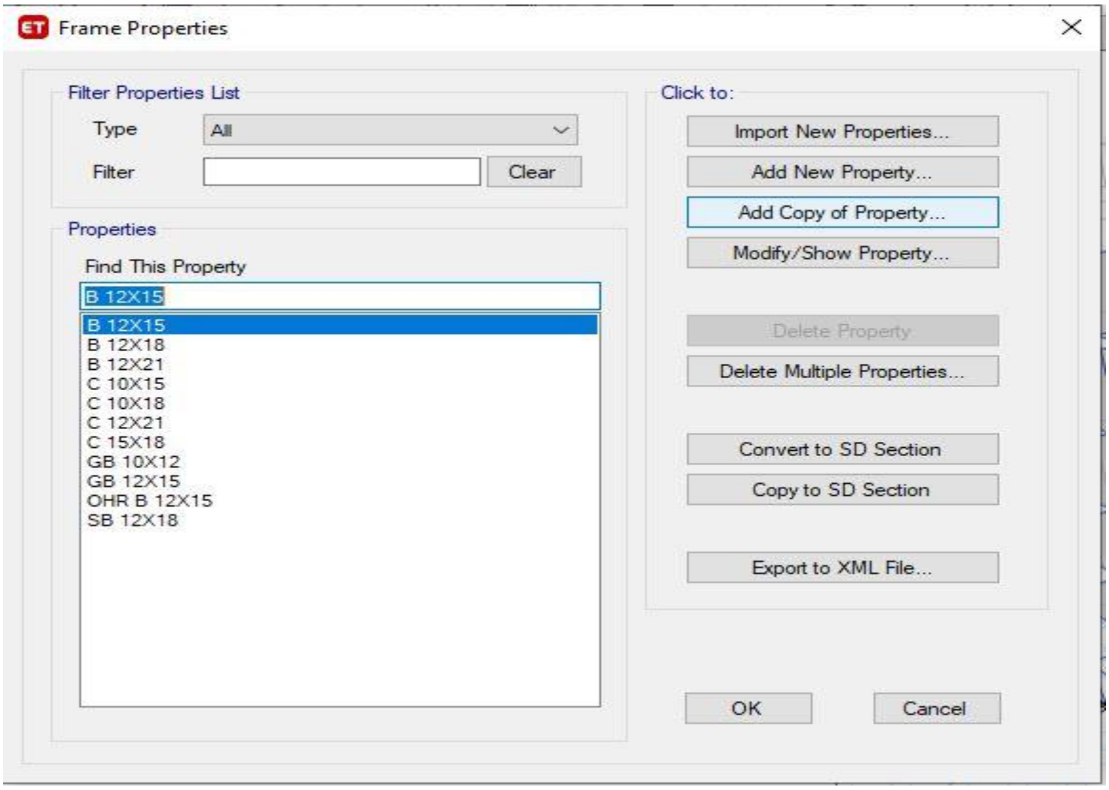


Figure 3.8: Material Property Initialization

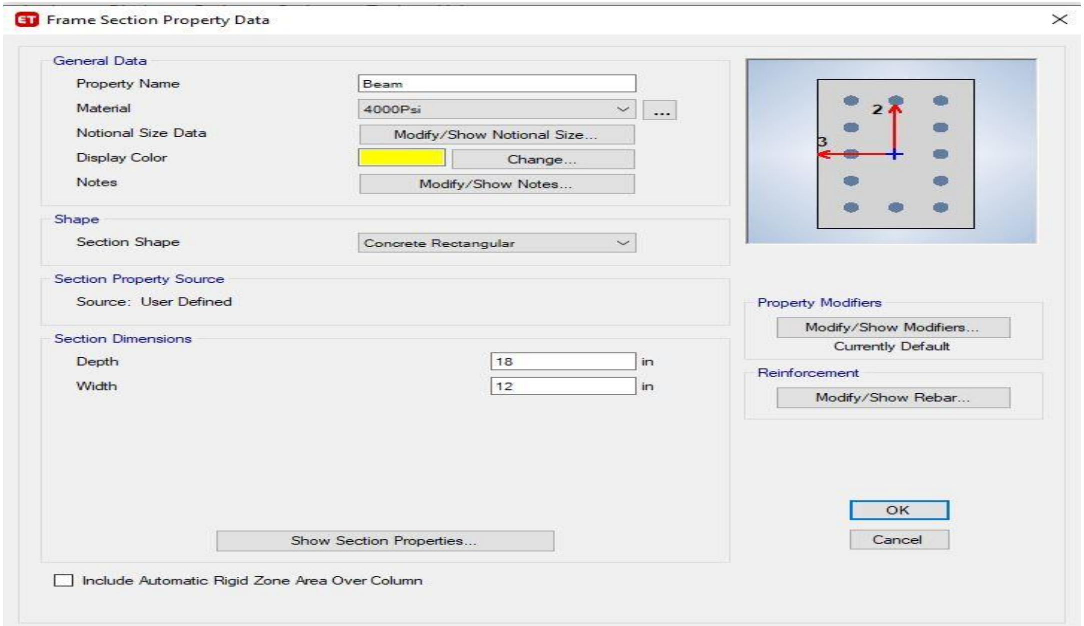


Figure 3.9: Material Property Initialization

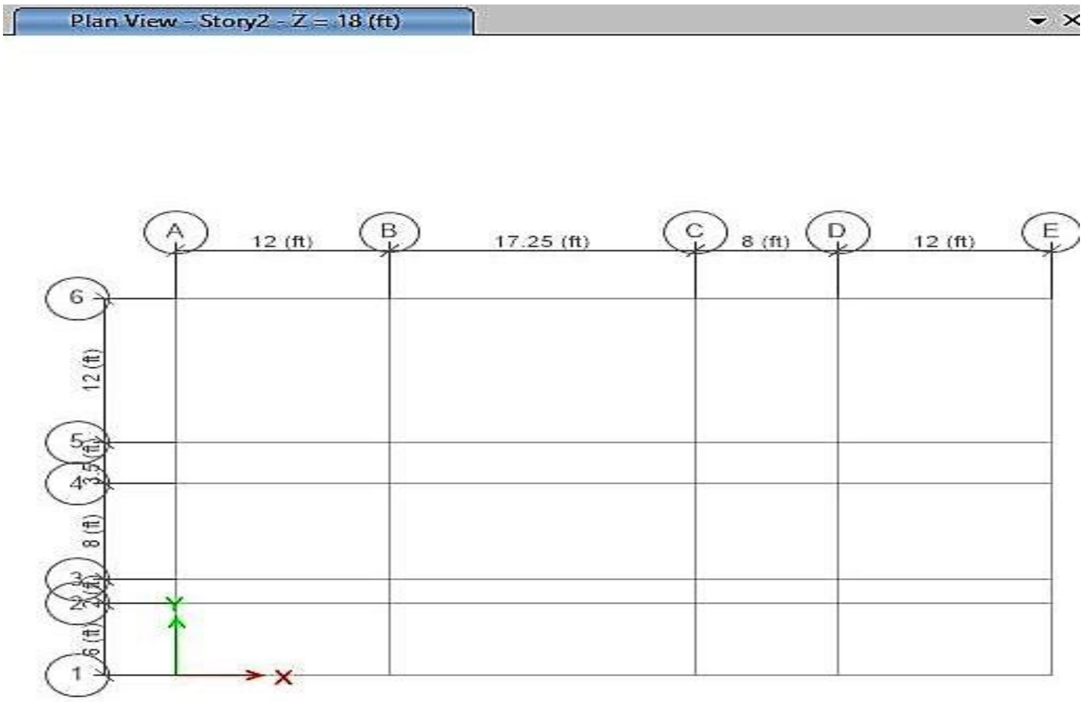


Figure 3.10: Proposed Grid of the model.

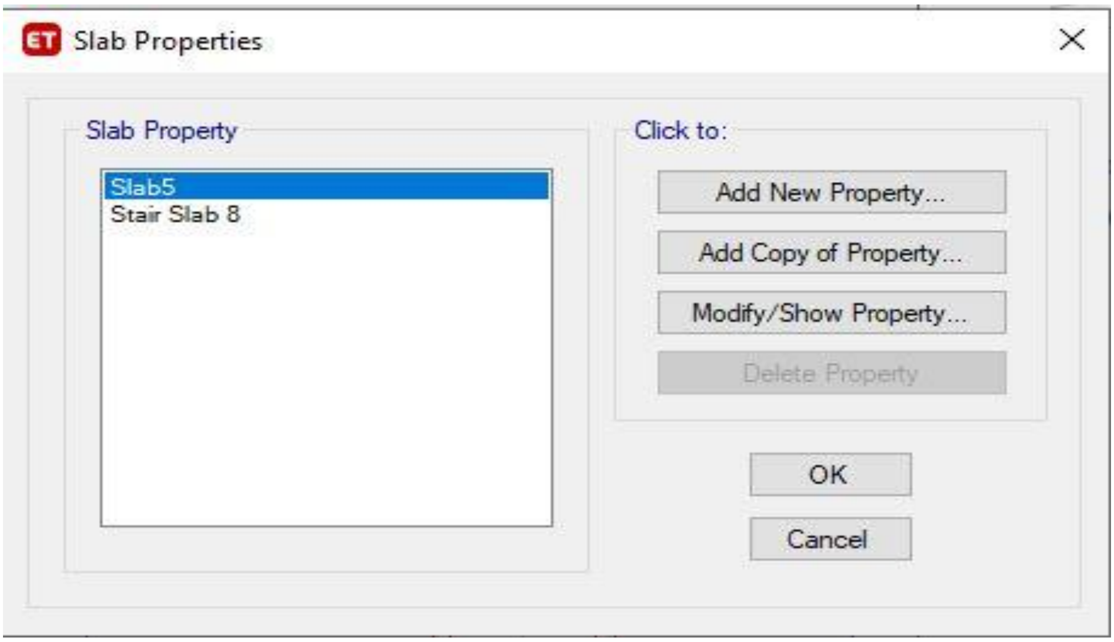


Figure 3.11: Slab Properties

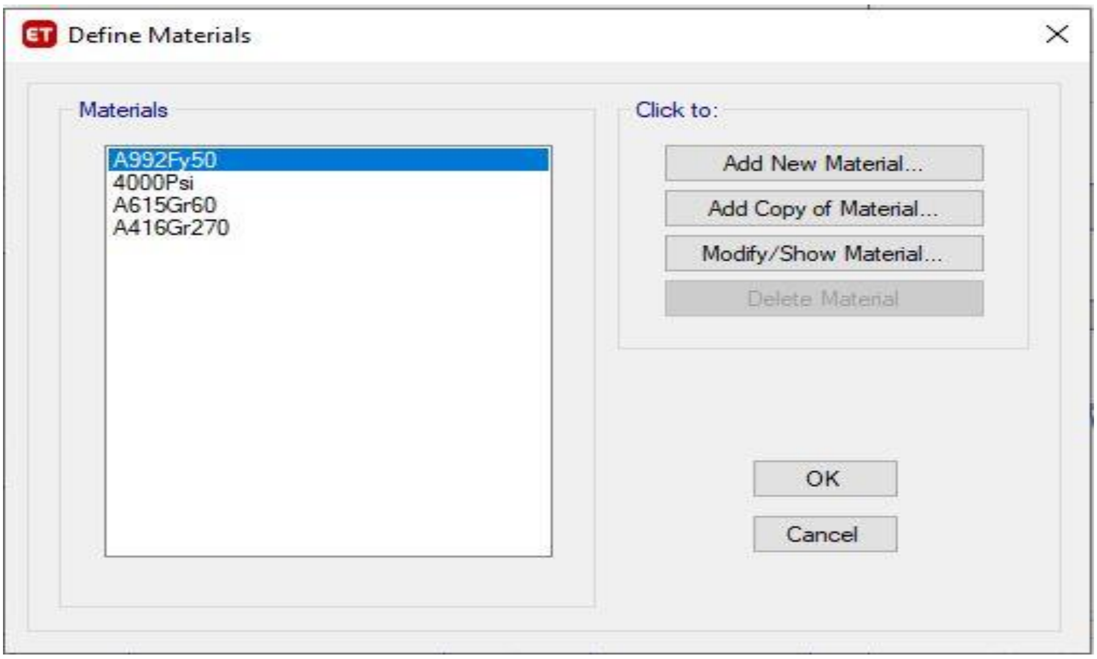


Figure 3.12: Define Materials

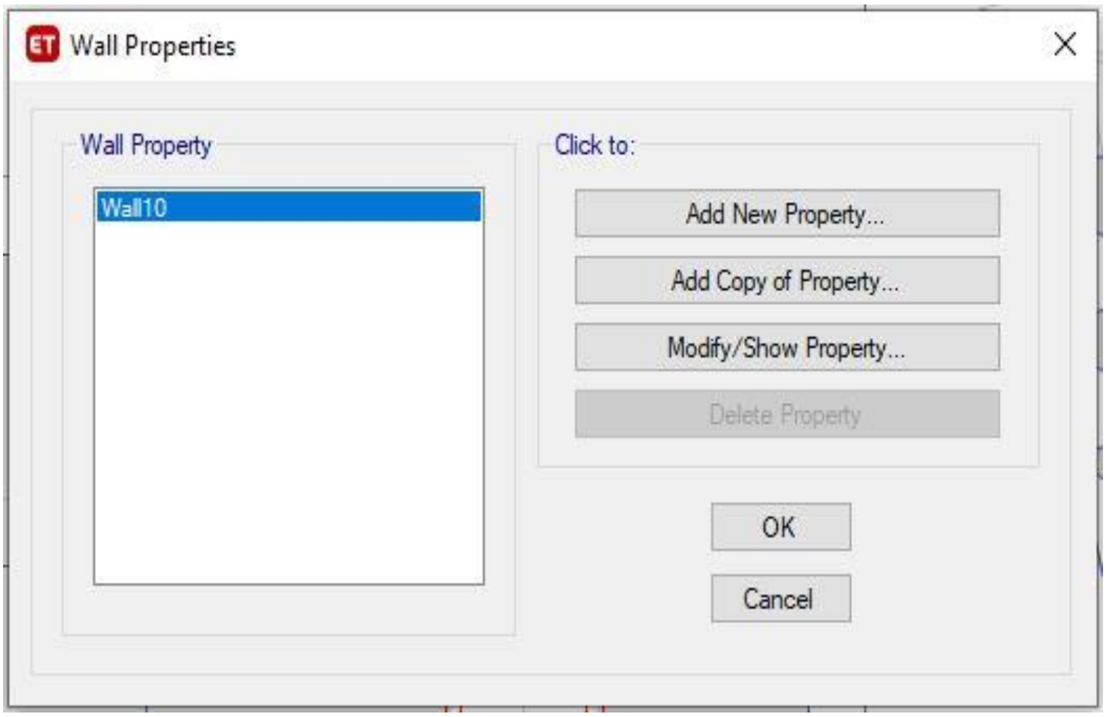


Figure 3.13: Define Wall Properties

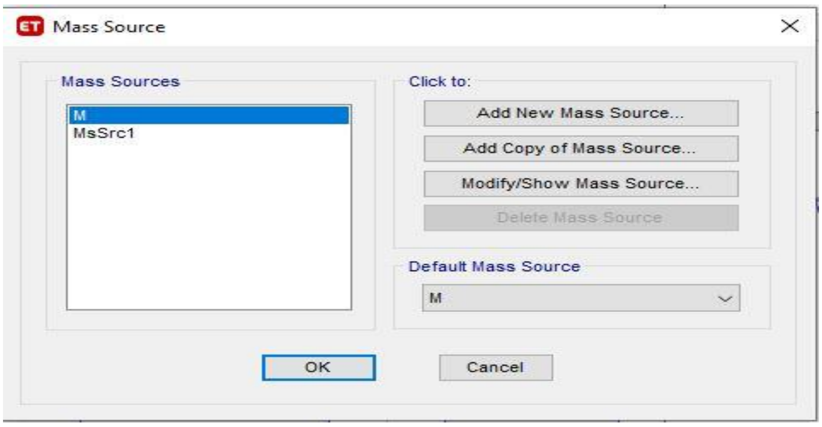


Figure 3.14: Mass Source

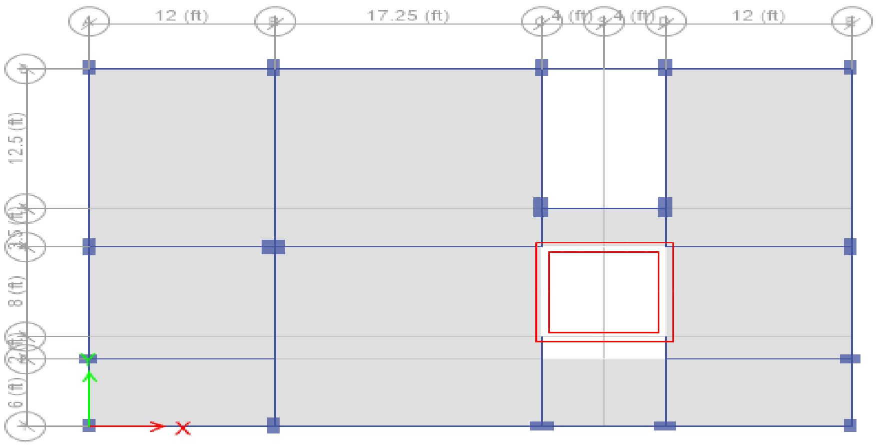


Figure 3.15: Plane for the 2D model

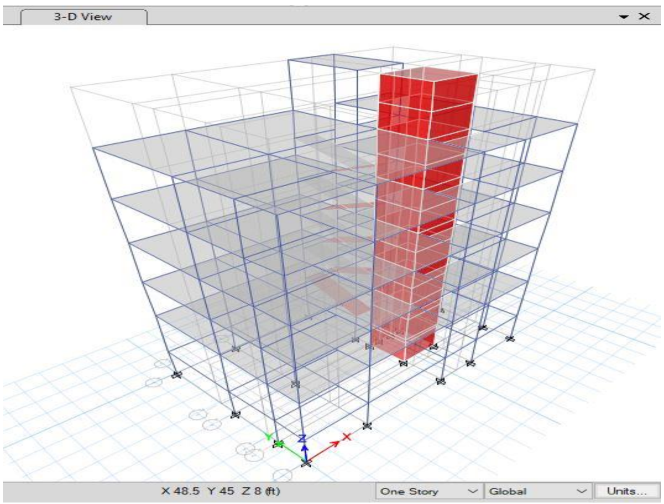


Figure 3.16: Plane for the 3D model

3.5.3 Structure Need to complete the following steps:

1. Open the Etabs window
2. Click new icon from main bar
3. Chose default from new model initialization window
4. Modify data from Building Plan Grid system and story data definition window.
5. Click set plan view icon from main toolbar and select plan view
6. Define load cases

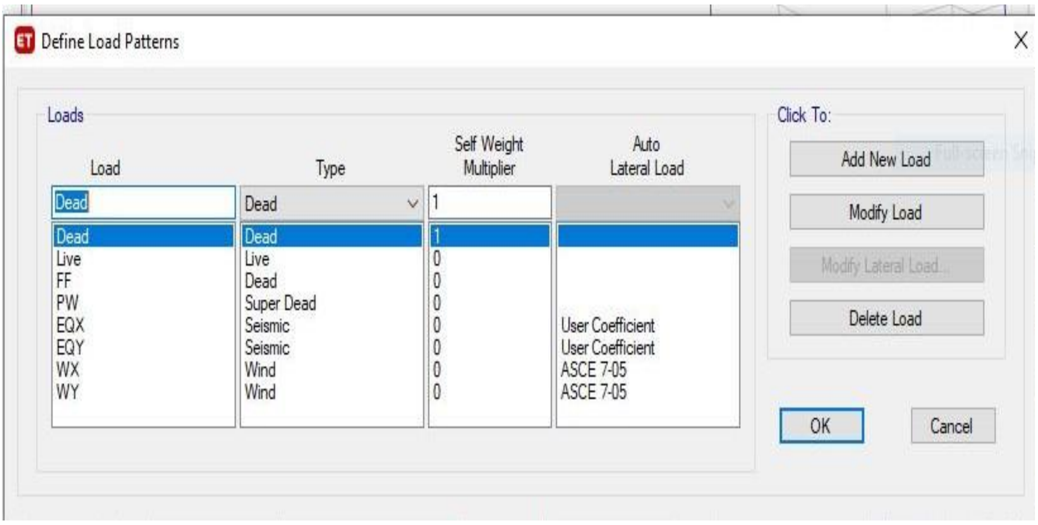


Figure 3.17 Load Pattern Assign for the model.

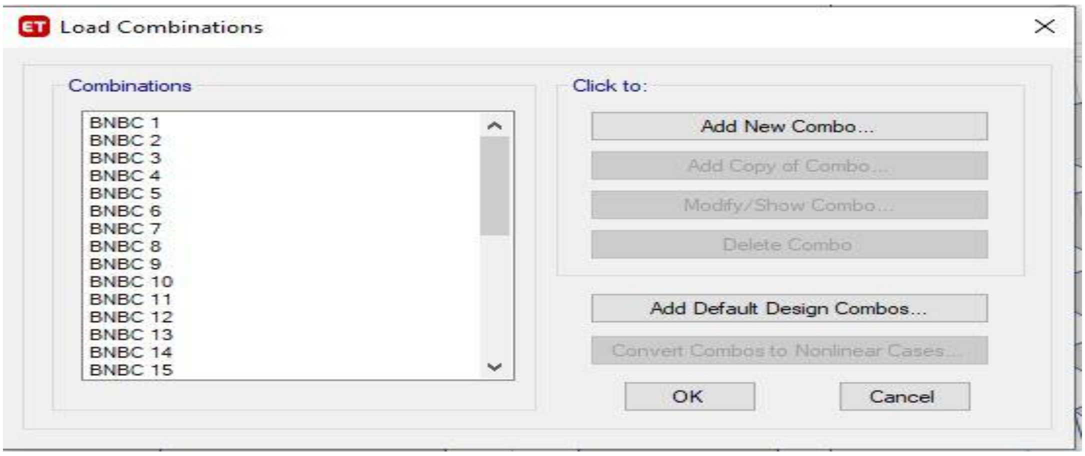


Figure 3.18: Load Combination Assign for the model.

1. Draw grade beams as shows in figure by clicking draw lines icon from draw toolbar and selecting GB1 & GB2 respectively
2. Place the column by create column region
3. Click edit –edit story data-insert story and change story height
4. Click define wall/slab section icon to define slab
5. Draw the beam by draw line from draw toolbar & selecting B1,B2,B3 respectively
6. Select the slab & click Assign – Shell area – Area object mesh option – auto mesh object into structural elements
7. Select one story from status bar
8. Select the column as the base where support to create and select Assign – Joint – Restrains/support and select the support condition
9. Click special seismic load effect – do not include special seismic design data – ok
10. Delete the unnecessary structural member from fourth & fifth floor.
11. Modify lateral loads by clicking Define static load case icon from define toolbar and put the reference value as follows
12. Select EQX & EQY and click modify lateral load and put the value as bellows

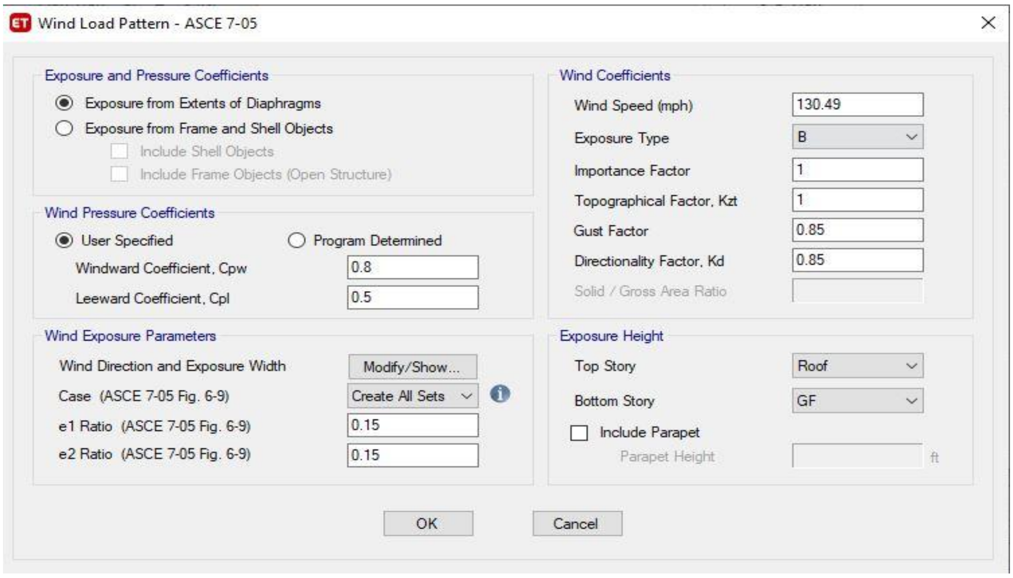


Figure 3.19: Define wind load pattern-ASCE7-05.

13. Finally click on Run Analysis icon from main toolbar

14. To cheek error in data input for lateral load click Display – show table and select the item and cheek the earthquake load in X,Y direction

15. To show deflected shape select the 3D view window & click show deformed shape icon from display window

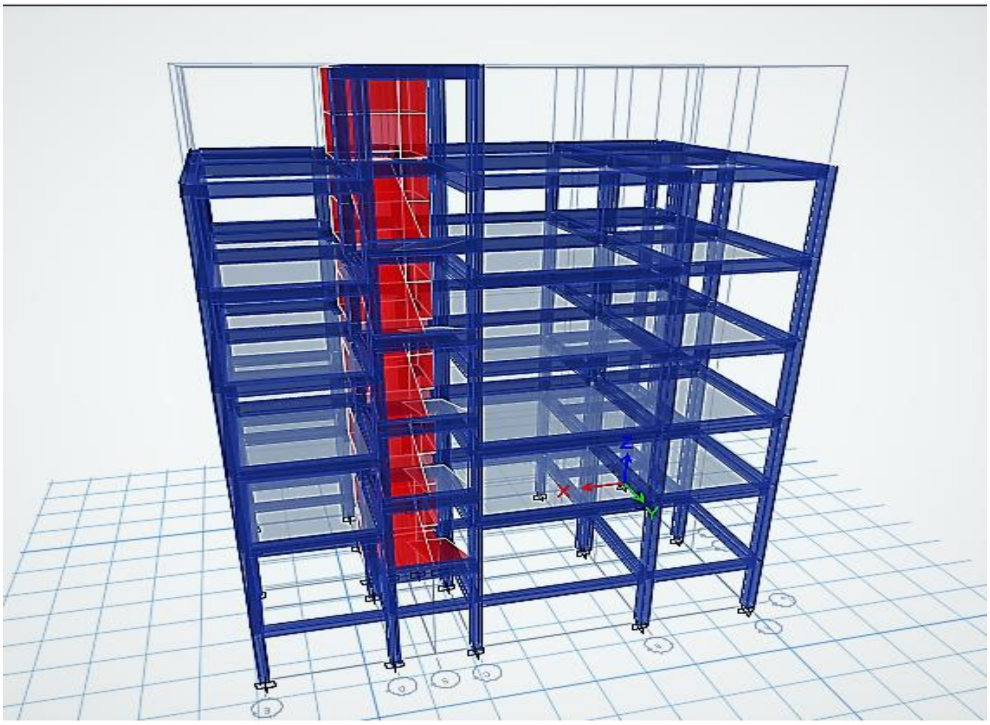


Figure 3.20: 3D Shape of the model

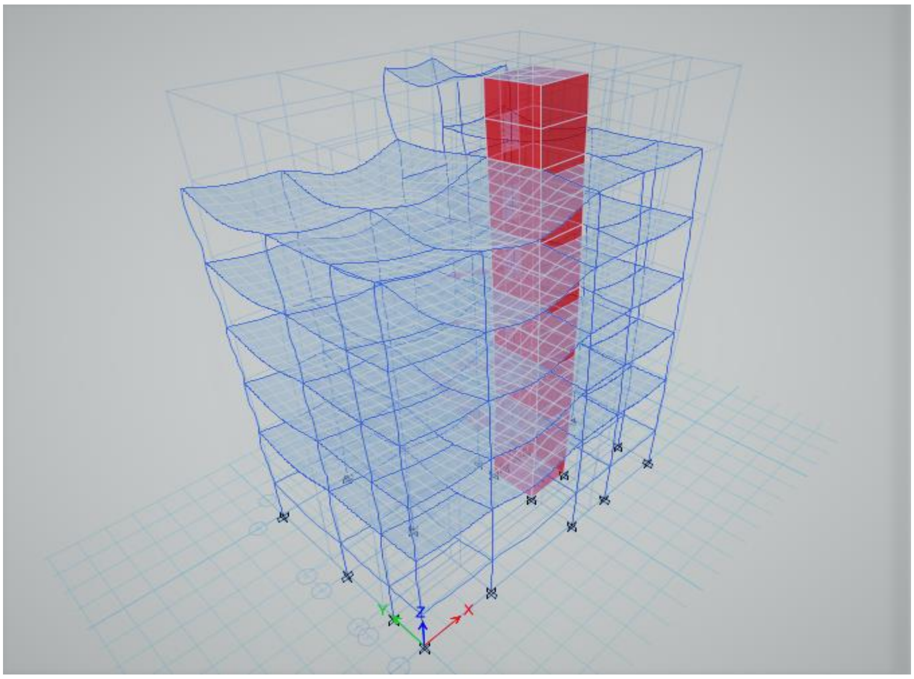


Figure 3.21: Deflected Shape of the model**.**

CHAPTER 04

RESULT AND DISCUSSION

4.1 Introduction

In this chapter result output of the model has been shown and discussed. From the result comparison it is seen that the BNBC 2006 and BNBC 2020 have huge difference in designing methods and formulas.

4.2 Drift and Building Separation (BNBC-2006)

Drift the Limitation: Story drift is the displacement of one level relative to the level above or below due to the design lateral forces. Except otherwise permitted in story drift shall include both translation and torsional deflections and confirm to the following requirements:

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

$\Delta \leq 0.04/R \leq 0.005h$ for $T < 0.7$ sec

$\Delta \leq 0.03/R \leq 0.004h$ for $T \geq 0.7$ sec

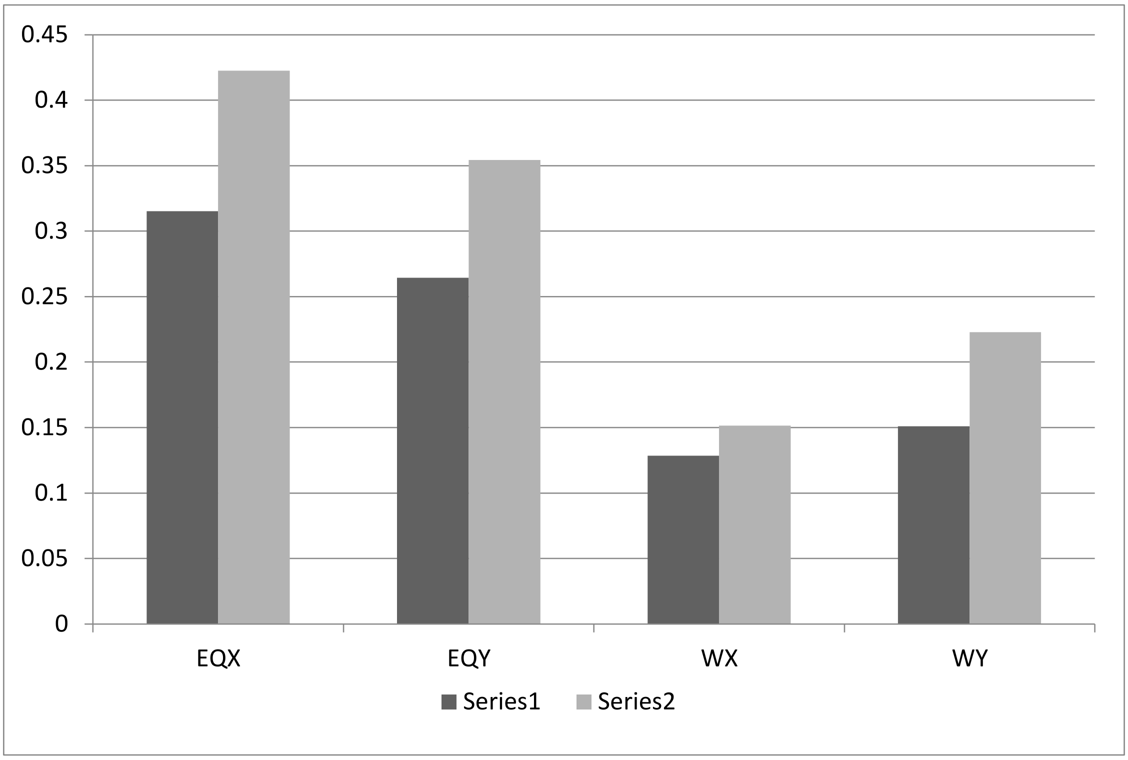
h = height of the building

Table 4.1: Maximum Story Displacement

Load Type	**BNBC 2006**		**BNBC 2020**	
	DHAKA	**SYLHET**	**DHAKA**	**SYLHET**
EQX	0.315266	0.529915	0.422590	0.764688
EQY	0.264419	0.444450	0.354435	0.641358
WX	0.128447	0.102939	0.151442	0.130978
WY	0.150893	0.151451	0.222813	0.192705

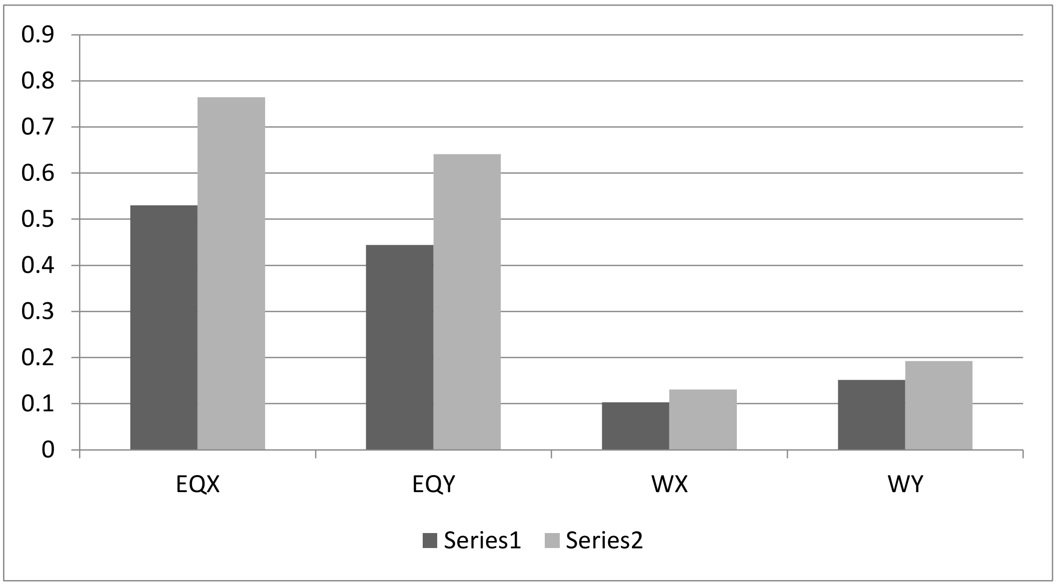
Table 4.2 Increase of Displacement Due to BNBC 2020

LOAD TYPE	DHAKA (%)	SYLHET (%)
EQX	34.04	44.30
EQY	34.04	44.30
WX	17.90	27.24
WY	47.66	27.66



Series1: DHAKA – (BNBC 2006)   Series2: DHAKA – (BNBC 2020)

Figure 4.1: Maximum Storey displacement for Earthquake and Wind-load (Dhaka)



Series1: SYLHET - (BNBC 2006)   Series2: SYLHET - (BNBC 2020)

Figure 4.2: Maximum Storey displacement for Earthquake and Wind-load (Sylhet)

4.3 Drift and Building Separation (According to BNBC-2020) Story drifts limitation:

Story drift is the horizontal displacement of one level of a building or structure relative to the level above or-below due to the design gravity (dead and live loads) or lateral forces (e.g., wind and earthquake loads). Calculated story drift shall include both translational and torsional deflections and conform to the following requirements:

1. Story drift, A for loads other than earthquake loads, shall be limited as follows:

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

$\Delta \leq 0.004\,h$ for $T \geq 0.7$ second

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

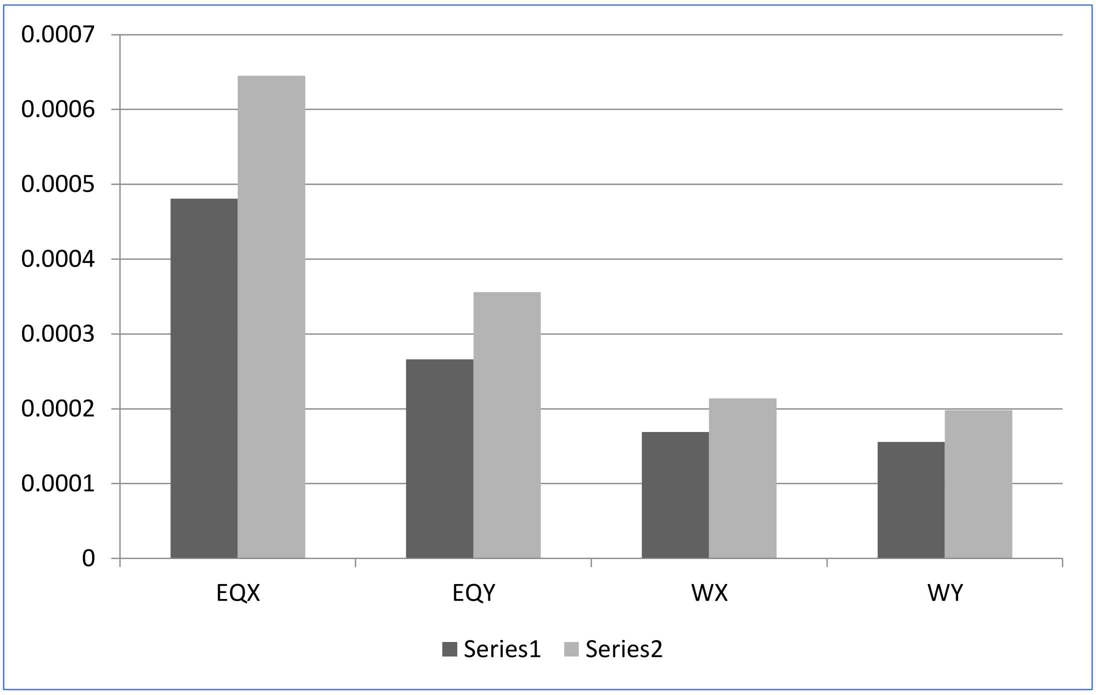
Where h= height of the building or structure. The period T used in this calculation shall be the same as that used for determining the base shear.

Table 4.3: Maximum Story Drift

Load Type	BNBC 2006		BNBC 2020	
	DHAKA	SYLHET	DHAKA	SYLHET
EQX	0.000481	0.000809	0.000645	0.001167
EQY	0.000266	0.000447	0.000356	0.000645
WX	0.000169	0.000146	0.000214	0.000185
WY	0.000156	0.000135	0.000198	0.000171

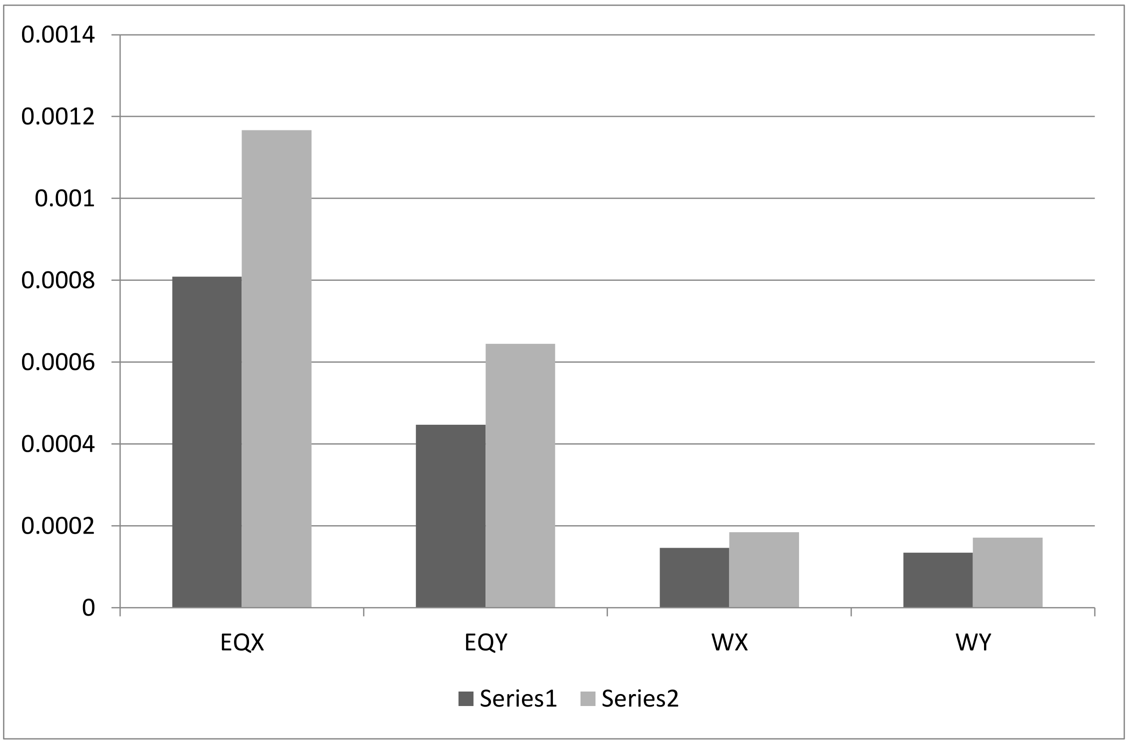
Table 4.4: Increase of Displacement Due to BNBC 2020

LOAD TYPE	DHAKA (%)	SYLHET (%)
EQX	34.10	44.25
EQY	33.83	44.30
WX	26.63	26.71
WY	26.92	26.67



Series1: DHAKA – (BNBC **2006**)   Series2: DHAKA – (BNBC 2020)

Figure 4.3**:** Maximum Storey drift for Earthquake and Wind-load (Dhaka)



Series1: SYLHET – (BNBC **2006**)   Series2: SYLHET – (BNBC 2020)

Figure 4.4**:** Maximum Storey drift for Earthquake and Wind-load (Sylhet)

4.4 Result Comparison and Discussion

Finally, we get this result for lateral load,

1. Earthquake effect on X-direction of BNBC 2020 is greater than BNBC 2006.
2. Earthquake effect on Y-direction of BNBC 2020 is greater than BNBC 2006.
3. Wind effect on X-direction of BNBC 2020 is greater than BNBC 2006.
4. Wind effect on X-direction of BNBC 2020 is greater than BNBC 2006.

BNBC-2020 Gives much lateral load for earthquake and wind compared to BNBC-2006 which means the structure must be designed with more care and with proper detailing. If anyone design a building using BNBC-2020 rather than BNBC-2006, they will be more solid and adequate.

The latest base shear values among both codes in this article is indicated by BNBC 2006. While Bangladesh lies on strong and susceptible earthquake zone, the question arises that the structures designed in accordance with the BNBC 2006 need to be retrofitted or refurbished. This conflict of BNBC may be dangerous when developed countries move towards more conservative design for the property owners following this code of practice to construct their project. BNBC 2020 will be a more cautious approach to Bangladesh's tectonic design sectors. Consequently, this improvement in the safety margin against the BNBC 2020 for earthquake with higher base shear values is significant. But the need for significantly greater reinforcement of low rise structures which might affect the design of the construction in Bangladesh for BNBC 2020. Throughout the study we found some parameters those are responsible for higher seismic base shear in BNBC like as increase in seismic zone coefficient (Z), Response Modification Coefficient (R) reduction, consider of upto 3 kN/n^2 with a minimum of 25% live load as a fixed seismic dead weight (W) for all cases, increased normalized response spectrum acceleration (C_c). The seismic design criterion is 0.67 times BNBC 2020's peak earthquake. For Seismic loading, BNBC 2006 uses force multiplier 1.4025. This indicates that due to ambiguity of load, the seismic load is boosted to 40 percent, despite the peak quake is considered and the multiplier is thus not necessary. Besides, the base shear, the story drift is found to be much higher for NBC 2020 than BNBC 2006. Despite modification of the code, BNBC 2020 still proposes lower base shear values than the other codes such as Indian and American code. In this respect further investigations must be performed. The vertical dispersion of earthquake force on the BNBC 2020 differs from that on the BNBC 2006. The BNBC 2020 specifies a straight dispersion and a parabolic dispersion for buildings with T less than 0.5 sec and T greater than 2.5 sec that range from 0 at the baseline to a peak at the apex. During mid-term period, a linear interpolation among a linear dispersion and a parabola dispersion or even a more restrictive parabola distribution could be used. For configuration with T is less than 0.7 sec, the BNBC 2006 uses a linear dispersion with zero value. The design base shear part ($0,07TV \leq 0.25V$) is focused for longer period buildings at the apex, the rest of the base shear being spread uniformly for short term buildings. A single experimental equation was employed prior BNBC 2006 in order to identify wind thrust that did not consider the influence of the adjacent item and the elevation of wind thrust on the structures. In the BNBC 2006 establishment of exposure classifications (A, B & C) and gust coefficient (G) was solved this limitation. In BNBC 2020 wind allowance, the impact of adjacent obstacles and structural heights has been significantly improved. As a result, according to BNBC 2020 wind load is found the be significantly lower for exposure category A compared to BNBC 2006. Two new terms topographic factor (K_{zt}) and directional factor (K_d) has been introduced in BNBC 2020. For wind load the maximum story drift with respect to story number is less in BNBC 2020 compared to BNBC 2006. The remarkable decrease in two important parameters, gust factor (G) and wind pressure coefficient is responsible for this reduction in wind force.

Integrating the findings obtained from multiple indicators, it can be concluded that when subjected to seismic loading, structural designs as per BNBC 2020 were more efficient than wind force. There is significant reduction in dead load, live load, wind and earthquake load in design load combination. That’s why the design is economical in BNBC 2020 compared to BNBC 2006 for both WSD and USD method although there is 14.3% increase in dead load and around 25% increase in wind load case has been suggested for USD method in BNBC 2020. Despite increase in earthquake load or reduction of wind force a reduction on the construction cost is anticipated due to change in load combinations.

CHAPTER 05

CONCLUSION AND RECOMMANDATION

5.1 Conclusion:

From the study it is observed that,

1. Effect of wind and earthquake is very important for building design
2. The lateral displacement due to earthquake of the structure analysis by BNBC-2020 code is more than the lateral displacement of the structure analysis by BNBC-2006 code
3. The lateral displacement due to wind of the structure analysis by BNBC-2020 code is more than the lateral displacement of the structure analysis by BNBC-2006 code.
4. The value of inter story drift is slightly greater than the value of the structure analysis by BNBC-2020 code compared to the structure analysis by BNBC-2006 code.
5. The building is analyzed linearly for seismic design.
6. All loads are taken according to BNBC code provided.
7. The building does not analyze non-linearly for seismic loads.

5.2 Recommendation:

1. The building is fully analyzed for seismic loads and wind loads by preliminary and detailed design procedure
2. BNBC 2020 is more updated than BNBC 2006. So, application of BNBC 2020 should be properly evaluated by respective authority.
3. In this study, only the ETABS software is used for the analysis. The software was a trial version; original software will be gives the more accurate results.
4. If the analysis results compare with the actual hand calculation data, then more reliable results will be found. It should be done in the future work.
5. The building is not designed for any expansion (horizontally or vertically) in future.

REFERENCES

Faysal, R. M., 2014. Comparison of Wind Load among BNBC and other Codes in different type of areas.

Akter, A. & Akter, S., 2018. Wind velocity for Dhaka Divition Wind velocity in Mymensing Division. pp. 1-12.

Al-Hussaini, T. M., Hossain, T. R. & Nayeem Al-Noman, M., 2012. Proposed changes to the geotechnical earthquake engineering provisions of the Bangladesh national building code. *Geotech. Eng.*, p. 1–7.

Atique , F. & Wadud, Z., 2003. a Comparison of Bnbc-93 With Other Building Codes With Respect To Earthquake and Wind Analysis. p. 0–5.

Bari, M. S. & Das, T., 2013. A Comparative Study on Seismic Analysis of Bangladesh National Building Code (BNBC) with Other Building Codes. *J. Inst. Eng. Ser. A ,* p. 131–137.

Brencich, A. & Gnecco, M., 2012. Failure Case Studies in Structural Engineering Courses and Professional Practice. *Arab. J. Sci. Eng.,* p. 2113–2126.

Gupta, S. D., Kanak, K. H., Islam, R. & Khan, F., 2020. Structural Analysis of a High-Rise Building under Strong Winds Using ETABS. p. 1–9.

Imam, F. S., Tahsin, S. & Hassan, A., 2014. Comparative Study On Lateral Load Analysis By BNBC - 1993 And Proposed BNBC- 2012. *Int. J. Sci. Technol.* , p. 57–61.

Institute, H. a. B. R., 2006. *Bangladesh National Building Code 2006.* s.l.:s.n.

Institute, H. a. B. R., 2020. *Bangladesh National Building Code (BNBC) 2020.* s.l.:s.n.

Islam, S., 2014. Analysis on the Structural Systems for Drift Control of Tall Buildings due to Wind Load: Critical Investigation on Building Heights. *J. Sci. Technol.,* p. 1–19.

Mahmoud, S., 2021. In-Plane Shear-Wall Configuration Effects on the Seismic Performance of Symmetrical Multistory Reinforced-Concrete Buildings. *Int. J. Civ. Eng.,* Volume 8.

Sarothi, S. Z. et al., 2019. COMPARATIVE ANALYSIS OF RC FRAME STRUCTURES FOLLOWING BNBC 1993 AND 2017 VERSIONS OF CODE FOR HIGH SEISMIC AND HIGH WIND ZONE Modeling and Analysis. pp. 84-88.

Tuken , A. & Siddiqui, N. A., 2013. Assessment of Shear Wall Quantity in Seismic-Resistant Design of Reinforced Concrete Buildings. *Arab. J. Sci. Eng.,* p. 2639–2648.

Varalakshmi, V., Kumar, G. S. & Sarma, . R. S., 2017. Analysis and Design of G + 5 Residential Building ABSTRACT . *Int. Res. J. Eng. Technol.,* p. 73–77.

Zakir, S., Akther, A. & Amanat, K., 2019. A Comparative Study of BNBC 1993 and 2017 Provisions for the Design of Multistoried Steel Buildings in High Wind and High Seismic Zone A Comparative Study of BNBC 1993 and 2017 Provisions FOR the Design of Multistoried Steel Buildings in High Wind. pp. 4-9.