A COMPARISON OF WIND LOAD AND SEISMIC EFFECT ON LOW-RISE AND HIGH-RISE MULTI-STORY STRUCTURES ACCORDING TO BNBC 2020 BY 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.

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Section: 20A

Fall-2023

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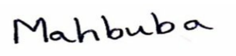
Mst. Mahbuba Mahnur	CE2002020070	
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Dedicated

to

“Our Respectful Teachers & 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 was written to reflect the transition. In this study, a systematic and parametric structural analysis of six-story (Low-rise) and Twelve-story (High-Rise) residential building was analyzed (ETABS 21. 0. 0 software) by using BNBC 2020. In this project lateral load (Earthquake and Wind) affects structural analysis and design of high-rise infrastructure for Kushtia which is situated in Kushtia district, Khulna, Bangladesh. 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. In this study, the maximum story displacement of low-rise to High-Rise multi-story structure is 197. 08%, 247. 95%, 453. 82% and 548. 35% for load EQX, EQY, WX and WY respectively. And the maximum story drift of low-rise to High-Rise multi-story structure is 53. 35%, 92. 98%, 181. 24%, and 268. 10% for load EQX, EQY, WX and WY respectively. The comparison of the aforesaid design parameters is depicted graphically, and relevant tables are presented in this research article. In comparison of wind load and seismic effect on low-rise and high-rise multi-story structures, 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 and background

The construction of buildings has been a fundamental aspect of human civilization, serving as the physical embodiment of our societal, cultural, and functional needs. It involves the process of planning, designing, and erecting structures that accommodate various purposes, such as residential, commercial, industrial, or institutional. Throughout history, the evolution of building construction has seen remarkable advancements in materials, techniques, and architectural styles. Ancient civilizations, like the Egyptians, Greeks, and Romans, developed sophisticated building methods using materials such as stone, mud-brick, and timber, showcasing remarkable engineering feats in structures like the pyramids, temples, and aqueducts. Modern building practices involve a synergy of architectural design, engineering principles, and technological innovation. Architects conceptualize the design, considering aesthetics, functionality, and sustainability. Engineers work on structural integrity, ensuring buildings can withstand environmental forces and meet safety standards. Construction workers then bring these designs to life, utilizing various materials like concrete, steel, glass, and wood to create sturdy and visually appealing structures. The building process typically involves several stages: site preparation, foundation laying, structural framework construction, installation of utilities and systems, interior finishing, and exterior detailing. Additionally, sustainability and energy efficiency have become crucial considerations in contemporary construction, leading to the adoption of green building practices and environmentally friendly materials. Building codes and regulations are implemented to ensure safety, accessibility, and adherence to standards during construction. These guidelines vary across regions and cover aspects such as structural stability, fire safety, electrical and plumbing standards, and accessibility for people with disabilities. The construction of buildings not only shapes skylines but also influences the way people live, work, and interact within their environments. From towering skyscrapers to humble dwellings, each structure reflects the aspirations,

technological prowess, and cultural identity of its time. Building construction involves a multifaceted process that encompasses various aspects and disciplines:
Architecture and Design: Architects play a pivotal role in conceptualizing and designing buildings. They consider functionality, aesthetics, spatial utilization, and environmental impact. Modern architecture often integrates innovative design principles, such as sustainable design, adaptive reuse of materials, and smart technology integration. Engineering and Structural Design: Structural engineers ensure the stability and safety of buildings. They calculate loads, stresses, and forces acting on structures, determining the materials and structural systems needed for durability and safety.

Advanced computer-aided design (CAD) and Building Information Modeling (BIM) technologies aid in designing complex structures. Construction Materials and Techniques: Various materials, including concrete, steel, wood, glass, and sustainable alternatives like bamboo or recycled materials, are used in construction. Techniques such as prefabrication, modular construction, and 3D printing are revolutionizing the way buildings are created, often reducing construction time and costs.

Construction Processes: Construction involves several stages, starting from site preparation (clearing, excavation, and leveling), followed by the laying of foundations (footings, piers, or slabs). The structural framework, including walls, floors, and roofs, is then constructed, followed by the installation of utilities (electrical, plumbing, HVAC systems) and interior finishing (painting, flooring, fixtures). Project Management: Construction projects require coordination among various stakeholders - architects, engineers, contractors, subcontractors, and suppliers. Project managers oversee timelines, budgets, and quality control to ensure the project progresses smoothly and meets deadlines. Regulations and Compliance: Building codes and regulations are crucial in ensuring safety and compliance with standards. These rules cover structural stability, fire safety, accessibility, environmental impact, and energy efficiency. Compliance with these regulations is necessary throughout the building process.

Sustainability and Green Building Practices: Sustainable construction practices aim to reduce the environmental impact of buildings. This includes using eco-friendly materials, implementing energy-efficient designs, utilizing renewable energy sources, and managing waste effectively. Building Maintenance and Renovation: After construction, buildings require regular maintenance to ensure longevity and safety.

Renovation or adaptive reuse projects repurpose existing structures, promoting sustainability and preserving cultural heritage. The construction industry continually evolves with technological advancements, embracing innovative materials, methods, and sustainability practices to create safer, more efficient, and environmentally conscious structures.

The Bangladesh National Building Code (BNBC) is a comprehensive set of guidelines and regulations that govern the design, construction, occupancy, and maintenance of buildings and structures within Bangladesh. It serves as a standard for architects, engineers, builders, and other stakeholders involved in the construction sector to ensure safety, structural integrity, and adherence to specific standards. They must follow these codes to gain permission for planning and construction from the authorities. The main purpose of a building code is to secure the health, safety, and overall well-being of its occupants by ensuring proper standards in the construction and design of buildings. Generally various types of building structure builds in our country. The purpose of the study is to design & analysis of six-storied & twelve storied reinforced concrete residential building for earthquake and wind performance for Kushtia city which is situated in Kushtia, Khulna, Bangladesh. At First preliminary planning is done and approved from Kushtia Municipality 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 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 21.0.0 (Extended 3D Analysis of Building Structure) is used for analyzing and designing the building. This study tries to compare wind load and earthquake analysis for low-rise and high-rise multi-story structures by BNBC 2020.

Table 1. 1: List of major earthquakes affecting Bangladesh

Date	Name of Earthquake	Magnitude	Epicenter
26 November 2021	Chittagong	6. 2	Chittagong
12 May, 2015	Dolakha, Nepal	7. 3	Dolakha & Sindhupalchawk
25 April, 2015	Gorkha, Nepal	8. 1	Barpac, Gorkha
12 September 2007	Tsunami due earthquake (Cox`s bazar)	8. 5	Benkula, sumatra
26 December, 2004	Cox’s Bazar earthquake	7. 0	Bonda
21 November, 1997	Bandarban earthquake	7. 1	Mizoram, Mayanmar border
21 March, 1994	Monipur-Mayanmar earthquake	7. 4	Monipur

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 compared to the old one. Again, this research study will create a pathway to compare with wind load and earthquake analysis for low-rise and high-rise multi-story structures by latest code BNBC 2020. 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:

- ❖ To compare of wind load effect on low-rise and high-rise multi-story structures according to BNBC 2020 by using ETABS.
- ❖ To compare of seismic effect on low-rise and high-rise multi-story structures according to BNBC 2020 by using ETABS.

1. 3 General Approach

- ❖ Getting architectural design of two RCC Residential Six –storied and Twelve-storied building.
- ❖ Project on RCC Residential Building in Kushtia.
- ❖ To establish the structural system for the ground and repeated floors of the building.
- ❖ To understand the structural response of forces acting on the structure as the height of the building increases.
- ❖ Analysis of building, wind resisting system, and type of foundations.
- ❖ It will be determined taking into consideration the architectural drawings.

1. 4 Statement of project Salient features

Table 1. 2: Statement of project Salient features

Utility building	Residential purpose	
No of Stories	Six Storied	Twelve Storied
Shape of Building	Rectangle	Rectangle
No of staircase and lift	01	01
Types of construction	RCC framed structure	RCC framed structure
Types of walls	Masonry wall	Masonry wall

Geometric details:

Table 1. 3: Statement of project Geometric Details

Foundation to Ground floor	6 ft
Hight of plinth	2. 5ft
Floor to floor height	10 ft

1.5 Outline of The Thesis

The contents of this work are organized into five chapters.

[1] The current chapter is Chapter 1, which introduces the reader with the project work.

[2] In chapter 2, we discuss about literature review and relevant method.

[3] In chapter 3, presents the Architectural Drawing, plan view of different floors, Elevation & Section of project building. Structural Design, Drawing & the methodology for modeling the building by using a structural Analysis and design software (ETABS) are presented.

[4] In chapter 4, we discuss about result.

[5] In chapter 5, we discuss about future development, any extension, our assumption etc.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction:

Many research has done on Earthquake and Wind load by many researchers. They advance in earthquake & wind engineering research have taken place over the last two decades. Researchers have done some different comparison with these earthquake & wind load and their result is discussed below.

2.2 Previous Background of the Study:

The Bangladesh National Building Code (BNBC) has not been updated since its inception in 1993. Earthquake design provisions are important, since Bangladesh is located in a seismically active region not far from the boundary of the Indian Plate and Eurasian Plate. Many advances in earthquake engineering research have taken place over the last two decades.

(Parasiya & Nimodiya, 2013) A review on comparative analysis of brace frame with conventional lateral resisting frame in RCC structure using software. In this paper, a few of the past research work has been discussed for modeling and analysis of brace frame RC structure and conventional lateral load resisting frame structures, co-relation of efficiency and various parameters are compared. It is found from the analysis in software, The type of bracing, location of bracing, bracing stiffness and bracing material, etc. have significant effects to the lateral capacity of the structure. In this paper comparative study of RC brace frame structure with conventional lateral load resisting frame has been carried out with different type of bracing, various parameters of bracing and property of bracing by different researchers discussed.

(Awida, 2010) showed the structural behavior of low/medium/high-rise concrete office buildings in Kuwait. The main concern of this paper is to provide an extensive study for the structural behavior of low/medium/High-Rise office buildings aiming to deepen structure and architect designers understanding for such type of buildings. The study is performed on reinforced concrete and emphasized only on Kuwait City conditions for wind. Regular layout plan building with different heights ranging from five to fifty typical office stories are investigated in this study. Three- dimensional finite element techniques through ETABS software are used in conducting analysis for structures presented here-in. A serviceability study is performed to ensure that buildings have sufficient stability to limit lateral drift and peak acceleration within the acceptable range of occupancy comfort. The building slenderness ratio and the building core size and location are the studied parameters since they are the key drivers for the efficient structural design.

(Sandeep & Varaprashad, 2020) Comparative study of static and dynamic seismic analysis of multi storied building R.C.C building by using ETABS software. In this study describes the effect of earthquake load which is one of the most important dynamic loads along with its consideration during the analysis of the structure. The principal objective of this project is the comparative study on design and analysis of multi-storied building (G+8) by ETABS software's. In this project we analyze the G+8 building for finding the shear forces, bending moments, deflections & reinforcement details for the static and dynamic seismic analysis of multi storied building.

(Varghese, 2013) presents the comparative study of special moment reinforced building over ordinary moment reinforced building with seismic and wind effect. The forces on OMRF structure are comparatively much higher than that of SMRF structure. It is safe to design a ductile detailing structure than the non –ductile detailing structure. The quantity of steel is found to be more in case of SMRF than that of OMRF.

(Reddy, S.A & Tupat, 2014) journalised "The effect of zone factors on wind and earthquake loads of High-Rise structures". The purpose of this research is to present a comparative study of wind and earthquake loads to decide the design loads of a multi-storied building. The significance of research is to estimate the design loads of a structure when subjected to wind and earthquake loads in every earthquake zone. The research design made use of equivalent lateral load method for the calculation of the forces on the structures. Research considered the wind load as stochastic and time dependent. It estimated wind load based on the design wind speed of that zone with a variation of 20%. He made the analysis on the low, medium and High-Rise buildings. The wind forces are constant up to the third floor and has increased beyond third floor at a constant rate. The wind pressure increased as the height of the building increased.

As zone factor increases the earthquake forces also increased gradually. He concluded that wind loads are more critical than the earthquake loads.

(Bhattacharjee & Amit, 2020) studied about “Comparative study of seismic force & wind force in low- rise and high-rise building”. In this research comparative study of the Seismic effect and wind effect are studied on a high-rise and low-rise building as per the Indian Standard Code. In this study the design loading for a high-rise and low-rise building is subjected to different Earthquake Zones (II, III, IV, and V) and different Wind Zones (II, III, IV, V, VI). The analysis is done by the ETABS (2015) software. These results can be used for any building situated in these earthquake and wind zone. After the study it is found that the low-rise buildings are more affected when they are subjected to Seismic forces whereas high-rise structures are equally affected by Wind forces when compared to Seismic forces.

(Chauhan, Pomal & Bhutaet, 2013) studied in a comparative study of wind forces on high- rise buildings as per IS 875-iii (1987) and proposed draft code (2011). The paper presented a study on the comparative study of wind forces on High-Rise buildings. For analysis he used E- TABS software with four terrain categories and six different wind speeds. He performed the analysis on 60m and 120m building. In static analysis, both buildings give almost same values of shear forces & bending moments. IS present code gives increased values of base shear compared to IS Draft code. IS Draft code gives more accurate and more direct than present code for estimating response parameters such as acceleration and forces.

(Holmes,Tamura & Krishna,2008) studied about “Wind loads on low, medium and high-rise buildings by Asia-Pacific codes”. The paper describes a comparison of wind load calculations on three buildings with different wind loading codes and standards from the Asia-Pacific Region. He performed an analysis on the low(6m), medium(48m), and High-Rise(183m) structures. The low building, almost all the parameters have been normalized in this example, the only variable is the coefficient of pressure, and the variation does appear to be rather large. The tall building has a significant amount of resonant dynamic response to wind which complicates the evaluation of base shear, bending moments and acceleration at the top of the building. The coefficients of variation for both along- wind and cross- wind responses were relatively small in the range of 14% to 18%.

(Mironova, 2020) researched on "Wind impact on low-rise buildings when placing high-rises into the existing development". The paper presented a study on the Wind impact on low-rise buildings when placing high-rises into the existing development. The purpose of the study is to model wind flows to determine maximum aerodynamic wind effects on multistore buildings and their surroundings. In this study numerical experiments on modelling the distribution of wind flows in a virtual wind tunnel for an existing low-rise building have been carried out. Based on their results, an increasing coefficient in the expression for determining the wind load depending on the height of a multi-store building and the distance to it is proposed. The results obtained can be used in determining wind loads during the reconstruction of low-rise buildings and their verification calculations when placing multistore and high-rise buildings in existing buildings.

(Ndihokubwayor, 2014) researched on "Lateral and base shear forces acting on 20 stories building in Bujumbura city during the seismic activity". The paper presented a study on the extensive study lateral and base shear forces acting on 20 stories building in Bujumbura city during the seismic Activity using the E-TABS software for analysis. He observed that the seismic shear forces and lateral forces can reach 2000 KN and 230 KN respectively.

(Pavan, Kire & Wani, 2021) researched on a comparative study on effect of wind load for low-rise and high-rise building using ETABS. In this study, A symmetric building plan is considered for the study. For a low-rise building (G+4) is considered and for high-rise multi-story structure (G+12) is considered. The analysis is carried out using the software E-tabs. The multi-storied building excited to different wind forces are studied. The displacements, story shears increase as the wind speed increases. The High-Rise stories are more effected by the wind forces and the wind influence increases if the height of the structure increases further. It is observed that, the lateral forces excited on the structure have shown increasing severity with increase in the wind speed. From this, it can also be concluded that the High-Rise buildings are more effected by the wind forces when compared to low-rise buildings.

(Sikka & Naresh, 2023) researched on “Comparison of Influence of Wind and Earthquake Forces on Low-Rise and High-Rise multi-story Structures”. This paper presents a comparative study of these verity effect of earthquake and wind forces on a multi-story building. It is very essential to consider the effects of lateral loads in the design of reinforced concrete structures. It determines the critical design loading for a multi-story Buildings subjected to different basic wind speeds (39,44,47,50,55m/s) and earthquake zones (II, III, IV, V).

2.3 There are some methods to analysis a frame

Method of analysis of statistically indeterminate portal frames:

- Method of flexibility coefficients.
- Slope displacements methods (iterative methods)
- Moment distribution method
- Cantilever method
- Portal method
- Matrix method

2.3.1 Method of flexibility coefficients

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:

- General Case
- Stiffness Coefficients
- Stiffness Coefficients Derivation
- Fixed-End Moments
- Pin-Supported End Span
- Typical Problems
- Analysis of Beams
- Analysis of Frames: No Sideway
- Analysis of Frames: Sideway

Limitations:

- A solution of simultaneous equations makes methods tedious for manual computations.
- 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 so as 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 terms 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 centroidal axis. The frame is analyzed in step-wise 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 are able to 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:

- A point of inflection is located at the center of each member of the portal frame.
- For each story of the frame, the interior columns bear twice as much shear as the exterior columns.

- Lateral forces resisted by frame action.
- Inflection points at mid-height of columns.
- Inflection points at mid-span of beams.
- Column shear is based on tributary area.
- 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 SOFTWARES USED

This project is mostly based on software and it is essential to know the details about this software. List of used software:

- ETABS 2021
- Auto CAD 2021
- Microsoft Word
- Microsoft Excel

ETABS 2021

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.

AutoCAD 2021

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 introduction 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 stair case, 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

Methodology of the work has been discussed in this chapter. Required data for analysis and model built-up with AutoCAD and ETABS (2021) are discussed details here. Analysis has been done for Zone-2 (Kushtia). Design data are picked from BNBC-2020.

3. 2 Types of different 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

- Dead Loads
- Imposed loads or live load
- Wind Loads
- Earthquake loads

3. 2. 1 Dead Load

The term "dead load" refers to the static or constant weight of a structure, including its permanent fixtures, elements, and materials. It encompasses the weight of the building itself along with fixed components like walls, floors, beams, columns, roofing, and any other permanent elements that do not change or move. Dead loads are critical considerations in structural engineering and construction, as they directly influence the design and integrity of a building. Calculating dead loads involves estimating the weight of all permanent elements within a structure. This estimation considers the density and volume of materials used in construction. For instance:

Concrete: Its weight can vary based on the type and density, typically ranging from 140 to 150 pounds per cubic foot. Steel: Its weight depends on the type and dimensions of the steel used, commonly around 490 pounds per cubic foot.

Wood: Weight varies by species and moisture content, but a rough estimate is about 40 pounds per cubic foot for framing lumber. Flooring, walls, roofing materials, and other fixtures also contribute to the dead load. Engineers use these values and estimates of the structure's dimensions to calculate the cumulative dead load. This calculation is essential in designing the structural elements to bear and support these static weights without compromising the building's safety and stability. During the design phase, engineers ensure that the building can support not only its dead load but also live loads (temporary or moving loads) and other environmental factors like wind, earthquakes, and snow loads. Accurate calculations of dead loads are crucial in designing safe and durable structures, ensuring that the building can withstand the weight of its components without experiencing excessive stress or deformation.

3. 2. 2 Live Load

In structural engineering and construction, a "live load" refers to the transient or temporary forces that a structure experiences due to movable or variable loads. Unlike dead loads that are constant and permanent, live loads are dynamic and can change in magnitude, location, or duration over time. Live loads are typically associated with human occupancy, furniture, equipment, vehicles, or other movable elements that may be present within or on a building. Examples of live loads include:

People: The weight of occupants in buildings, such as residential, commercial, or public spaces.

Furniture and Equipment: The weight of movable items, such as chairs, tables, appliances, machinery, etc.

Vehicles: Loads imposed by cars, trucks, or other vehicles on bridges, parking structures, or elevated platforms.

Storage: Weight from stored materials or goods in warehouses or storage facilities.

Snow: In areas prone to snowfall, the temporary weight of accumulated snow on roofs, decks, or other surfaces.

Engineers calculate and design structures to accommodate both dead loads (permanent) and live loads (variable) to ensure safety and structural integrity. Live loads are determined based on building codes, standards, and guidelines specific to the type of structure, its intended use, occupancy, and local regulations. Designing for live loads involves estimating the maximum expected weight or force that the structure may experience during its use. Engineers factor in safety margins and load combinations to ensure that the building can safely support these temporary loads without experiencing excessive stress, deformation, or failure.

Proper consideration of live loads is essential in the design and construction of buildings and structures to ensure they can withstand the varying forces they may encounter during their lifespan while maintaining safety for occupants and preventing structural damage.

3. 2. 3 Wind Load

Wind load refers to the force exerted by the wind on structures, buildings, and other exposed surfaces. It's a significant factor in structural engineering and building design, especially in areas prone to strong winds or where specific wind conditions are prevalent. Several factors influence wind load on structures:

Wind Speed: The velocity of the wind is a crucial factor. Engineers refer to historical data and regional codes to determine the design wind speed for a particular location. Wind speeds can vary significantly based on geographical location, terrain, and local weather patterns.

Building Height and Shape: Taller structures are more exposed to wind forces and experience higher wind loads compared to lower buildings. The shape and aerodynamics of the structure also play a role; certain designs may cause wind to exert higher pressures or induce turbulence.

Terrain and Surroundings: The surrounding terrain affects wind flow patterns. Buildings located in open, flat areas may experience different wind loads compared to those situated in urban areas with many other structures nearby. Hills, valleys, trees, and other obstructions can also influence wind behavior.

Building Characteristics: Factors like the building's surface area, orientation, openings (like doors and windows), and roof shape impact how wind affects the structure. Features such as canopies, overhangs, and parapets can alter wind pressures on a building.

Engineers calculate wind loads using specialized codes and standards (such as ASCE 7.05 in the United States) that provide guidelines for determining the design wind pressure based on the factors mentioned above. These codes help engineers estimate the magnitude and direction of wind forces acting on various parts of the structure. Structural elements like walls, roofs, windows, and foundations are designed to withstand these calculated wind pressures. Properly accounting for wind loads in the design phase ensures that buildings and structures can resist these forces and remain structurally sound and safe during high wind events or adverse weather conditions.

Method 1: simplified procedure specified for building and structure meeting the requirements specified therein;
Method 2: Analytical procedure specified for building and structure meeting the requirements specified therein;
Method 3: Wind tunnel procedure.

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 2020.

Sustained wind pressure at height z, kN/m^2 :

$q_z = C_c C_i C_z V^2 b$.................... (If, V b= Km/h) ………………………… (i)

Cc= Velocity to pressure conversion coefficient

Ci = Structure importance coefficient
C_z = Combined height and exposure coefficient (calculate based on height)
q_z = Sustained wind pressure at height z, kN/m^2
V b = Basic wind speed, km/h

Velocity pressure:
Velocity pressure, q_z evaluated at height z shall be calculated by the following equation:

$q_z = (0.\ 0006130\ v^2) K_z K_{zt} K_d I$ …. (kN/m^2), V in m/s………………. (ii)

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

P_z = CGCpq$_z$ .... (If Vb=km/h) ……………………………. (iii)

P_z = CtCGCpq$_z$ .... (If Vb=mile/h) …………………………... (iv)

P_z =Design wind pressure at height z, kN/m^2

Co = Gust coefficient (calculated based on building height)

Cp = 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:

$F_z = \{P_z A_z\}$………………………………………………………………… (v)

F_z =Total wind force, KN P_z = Design wind pressure (kN/m^2)

A_Z = Projected frontal Area,

Basic Wind Equation p= q x G x Cp ………………………………………. (vi)

p = Wind Pressure

q = Velocity Pressure

G = Gust Effect Factor

Cp = Pressure Coefficient / Shape Factor

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 m2 shall 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:

$p= q\, GC_p – qi\, (GC_{pi})\ (kN/m^2)$ …………………………………….. (vii)

Where,

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

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

$q_i = q_h$ for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative 16 internal pressure evaluation in partially enclosed buildings. Internal pressure evaluation in partially enclosed buildings.

$q_i = q_z$ for positive internal pressure evaluation in partially enclosed buildings where height Zis 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 Second.

For positive internal pressure evaluation, qi may conservatively be evaluated at h= (qi= q_h)

G = gust effect factor

C_p = external pressure coefficient G

GC_{pi} = internal pressure coefficient

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

$P = q_h\, [(G\, C_{pf} -(GC_{pi})]\ (kN\, /m^2)$ ………………………………….. (viii)

Where,

q_h = velocity pressure evaluated at mean roof height h using exposure G

C_{pf} = external pressure coefficient G

C_{pi} = internal pressure coefficient

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

$P = qG_fC_p\text{-}q_i\ (GC_{pi})\ (kN/m^2)$ …………………………… (ix)

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:

$Pp = q_pGC_{pn}\ [kN/mm^2]$ …………………………………… (x)

Where,

Pp = 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 G

C_{pn} = Combined net pressure coefficients

= +1. 5 for windward parapet

= -1. 0 for leeward parapet

Table 3. 1: Basic Wind Speeds, V, For Selected Locations in Bangladesh (BNBC 2020)

Location	Basic Wind Speed (m/s)	Location	Basic Wind Speed (m/s)
Angarpota	77.5	Lalmonirhat	63.7
Bagerhat	47.8	Magura	65.0
Bandarban	62.5	Manikganj	58.2
Barguna	80.0	Meherpur	58.2
Barisal	78.7	Maheshkhali	80.0
Bhola	69.5	Moulvibazar	530.
Bogra	61.9	Munshiganj	57.1
Brahmanbaria	56.7	Mymensingh	67.4
Chandpur	50.6	Naogaon	55.2
Chapai Nawabganj	41.4	Narail	68.6

Chittagong	80.0	Narayanganj	61.1
Chuadanga	61.9	Narsinghdi	59.7
Comilla	61.4	Natore	61.9
Cox’s Bazar	80.0	Netrokona	65.6
Dahagram	47.8	Nilphamari	44.7
Dhaka	65.7	Noakhali	57.1
Dinajpur	41.4	Pabna	63.1
Faridpur	63.1	Panchagarh	41.4
Feni	64.1	Patuakhali	80.0
Gaibandha	65.6	Pirojpur	80.0
Gazipur	66.5	Rajbari	59.1
Gopalganj	74.5	Rajshahi	49.2
Habiganj	54.2	Rangamati	56.7
Hatiya	80.0	Rangpur	65.3
Ishurdi	69.5	Satkhira	57.6
Jamalpur	56.7	Shariatpur	61.9
Jessore	64.1	Sherpur	62.5
Jhalakat	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. 2. 4 Earthquake Load (BNBC-2020)

Earthquake loading as per BNBC-2020 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.

Design Base Shear:

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

V=Sa W

Where,

Sa = Lateral seismic force coefficient calculated

W = Total seismic weight of building defined.

Alternatively, for building with natural period less than or equal to 2. 0 sec, the seismic design base share can be calculated using ASCE 7 -05 with seismic design parameters as given in Appendix C. However, the minimum value of Sa should not be less than 0. 044 SDSI. The values of SDS are provided in Appendix C.

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:

C=Ct (h_n) m

Where,

Ct = 0. 0724 for steel moment resisting frames

= 0. 0731 for reinforced concrete moment resisting frames, and eccentric braced steel frames.

= 0. 0466 for reinforced concrete moment

= 0. 0488 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 maybe taken as0. 031/√Ac. The value of Ac shall be obtained from the relation:

Ac = $\sum A$ [0. 2+ (De/ h_n)^2] ……………………………(xi)

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

Method B:

The fundamental period I 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

$T = \sqrt{\sum \omega.\ \delta\ 2/g \sum f.\ \delta\ n\ i{=}1\ n\ i{=}1\ 2\pi}$ …………………… (xii)

Table 3. 2: Seismic Zone Coefficient, Z

Seismic zone	Zone co efficient
1	0. 12
2	0. 20
3	0. 28
4	0. 36

Table 3. 3: Structural Importance Coefficient, I

Structure importance category	Structure importance co efficient	
	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

Design response spectrum: The earthquake ground motion for which the building has to be designed is represented by the design response spectrum. The spectral acceleration for the design earthquake is given by the following equation:

$$Sa=\frac{2}{3}\frac{ZI}{R}CS$$

Where,

Sa= Design spectral acceleration (in units of g) which shall not be less than 0. 67βZIS

β=Coefficient used to calculate lower bound for Sa. Recommended value for β is 0. 11

Z= Seismic zone coefficient

I=Structure importance factor

R=Response reduction factor which depends on the type of structural system. The ratio of $\frac{I}{R}$ cannot be greater than one.

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

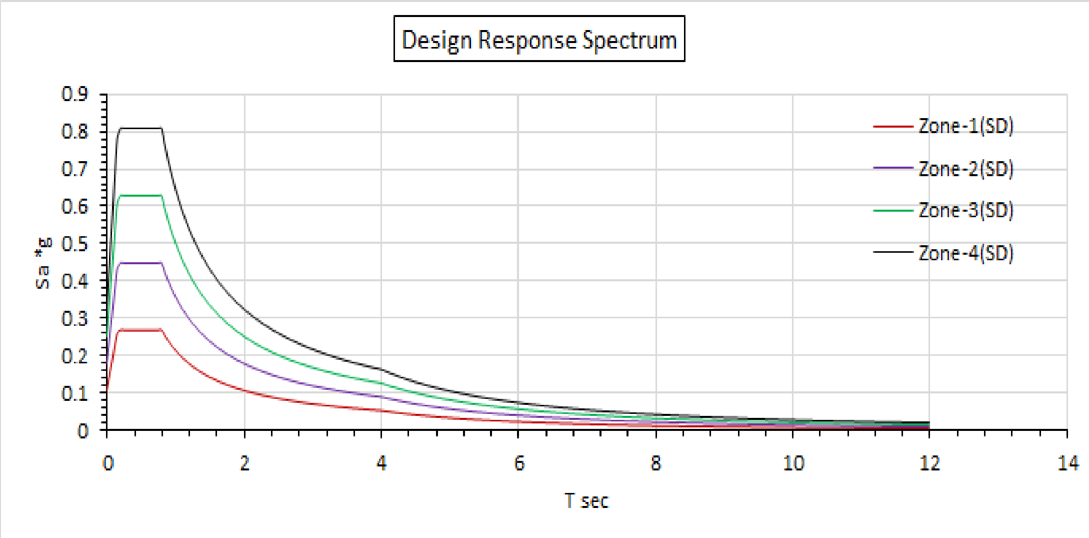


Figure 3. 1 (a): Normalized design acceleration response spectrum for different site classes.

Table 3. 4(a): Description of Seismic Zones

Seismic Zone	Location	Seismic Intensity	Seismic Zone Coefficient, Z
1	Southwestern part including Barisal, Khulna, Jessore, Rajshahi	Low	0. 12
2	Lower Central and Northwestern part including Noakhali, Dhaka, Pabna, Dinajpur, as well as Southwestern corner including Sundarbans	Moderate	0. 20
3	Upper Central and Northwestern part including Brahmanbaria, Sirajganj, Rangpur	Severe	0. 28
4	Northeastern part including Sylhet, Mymensingh, Kurigram	Very Severe	0. 36

Table 3. 4(b): Seismic Zone Coefficient Z for Some Important Towns of Bangladesh

Town	Z	Town	Z	Town	Z	Town	Z
Bagerhat	0.12	Gaibandha	0.28	Magura	0.12	Patuakhali	0.12
Bandarban	0.28	Gazipur	0.20	Manikganj	0.20	Pirojpur	0.12
Barguna	0.12	Gopalganj	0.12	Maulvibazar	0.36	Rajbari	0.20
Barisal	0.12	Habiganj	0.36	Meherpur	0.12	Rajshahi	0.12
Bhola	0.12	Jaipurhat	0.20	Mongla	0.12	Rangamati	0.28
Bogra	0.28	Jamalpur	0.36	Munshiganj	0.20	Rangpur	0.28
Brahmanbaria	0.28	Jessore	0.12	Mymensingh	0.36	Satkhira	0.12
Chandpur	0.20	Jhalokati	0.12	Narail	0.12	Shariatpur	0.20
Chapainababganj	0.12	Jhenaidah	0.12	Narayanganj	0.20	Sherpur	0.36
Chittagong	0.28	Khagrachari	0.28	Narsingdi	0.28	Sirajganj	0.28
Chuadanga	0.12	Khulna	0.12	Natore	0.20	Srimangal	0.36
Comilla	0.20	Kishoreganj	0.36	Naogaon	0.20	Sunamganj	0.36
Cox's Bazar	0.28	Kurigram	0.36	Netrakona	0.36	Sylhet	0.36
Dhaka	0.20	Kushtia	0.20	Nilphamari	0.12	Tangail	0.28
Dinajpur	0.20	Lakshmipur	0.20	Noakhali	0.20	Thakurgaon	0.20
Faridpur	0.20	Lalmanirhat	0.28	Pabna	0.20		
Feni	0.20	Madaripur	0.20	Panchagarh	0.20		

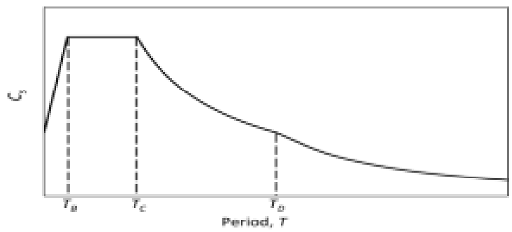


Figure 3. 1 (b): Typical shape of the elastic response spectrum coefficient Cs

Table 3. 5: Site Dependent Soil Factor and Other Parameters Defining Elastic Response Spectrum (BNBC, 2020)

Soil Type	S	T_B (sec)	T_C (sec)	T_D (sec)
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

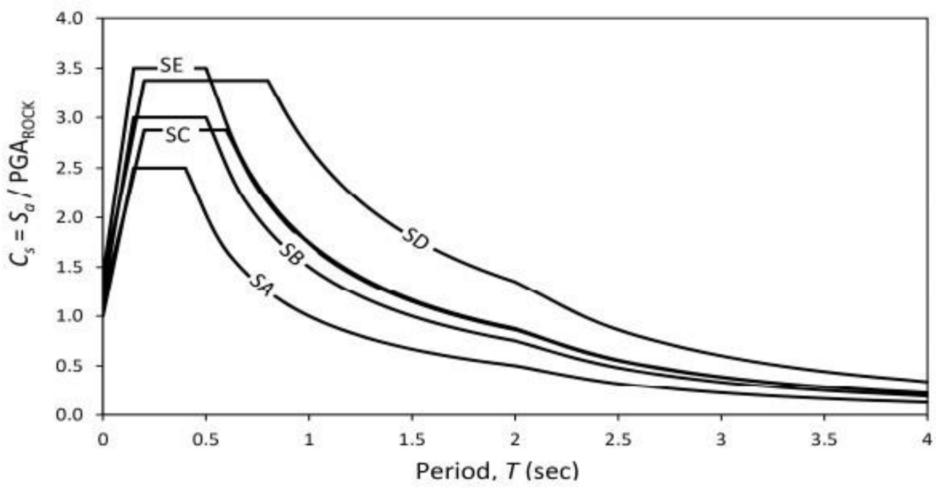


Figure 3. 2: Normalized design acceleration response spectrum for different site classes.

Building Categories

In construction and architecture, buildings are often categorized based on various criteria such as their use, size, design, occupancy, and structural characteristics. Some common building categories include:

1. Residential Buildings

Single-Family Homes: Detached houses designed for one family. Multi-Family Dwellings: Buildings or complexes with multiple separate housing units, like apartments, condominiums, townhouses, or duplexes.

2. Commercial Buildings

Office Buildings: Designed for professional and administrative work. Retail Buildings: Spaces used for selling goods and services, such as shops, malls, and storefronts.

Hotels and Hospitality: Accommodation facilities for travelers, including hotels, motels, resorts, and bed-and-breakfast establishments.

Restaurants and Food Service: Buildings designed for food preparation and dining, including restaurants, cafes, and eateries.

Manufacturing Plants: Facilities for production, assembly, or fabrication of goods.

Warehouses and Storage Facilities: Buildings for storing goods, materials, or equipment.

Factories and Processing Plants: Facilities for industrial processing, refining, or manufacturing.

3. Institutional Buildings

Educational Buildings: Schools, universities, colleges, and other educational facilities.

Healthcare Facilities: Hospitals, clinics, nursing homes, and medical centers.

These categories are often used to define building types for zoning, construction regulations, and urban planning purposes. They represent a broad classification of buildings based on their intended use and function within communities and urban environments.

According to BNBC-2020: Buildings are classified in four occupancy categories.

Table 3. 6: Building Classification Based on Height, Floor Area and Occupancy Type: (BNBC, 2020)

Building Category	Height of Building	Floor Area	Type of Occupancy
I	Up to 2 Stories or 8 m height (without basement) applicable only for areas beyond the jurisdiction of Development Authority, City Corporation and Pourashava	Up to 250 m^2	A (A1-A2)
II	Up to 5 Stories (with or without basement)	Up to 1000 m^2	A (A1-A5)
III	Up to 10 stories or 33 m height for engineering design and supervision and any height for land survey, sub-soil investigation and architectural design	Up to 7500 m^2	A, B, C, E1, E2, F1, F2 and H1
IV	Any height	Any Size	All Occupancy Type

Table 3. 7: Importance Factors for Buildings and Structures for Earthquake design (BNBC, 2020)

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

Table 3. 8: Site Dependent Soil Factor and Other Parameters Defining Elastic Response Spectrum (BNBC, 2020)

Soil type	S	T_B(s)	T_C (s)	T_D (s)
SA	1.0	0.15	0.40	2.0
SB	1.2	0.15	0.50	2.0
SC	1.15	0.20	0.60	2.0
SD	1.35	0.20	0.80	2.0
SE	1.4	0.15	0.50	2.0

Figure 3. 3: Seismic Zoning Map

Table 3. 9: Seismic Design Category of Buildings (BNBC-2020)

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, S_1, S_2	D	D	D	D	D	D	D	D

Table 3.10: Values for Coefficients to Estimate Approximate Period(BNBC 2020)

Structure type	C_t	m	
Concrete moment-resisting frames	0.0466	0.9	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.
Steel moment-resisting frames	0.0724	0.8	
Eccentrically braced steel frame	0.0731	0.75	
All other structural systems	0.0488	0.75	

Table 3. 11: Response Reduction Factor, Deflection Amplification Factor and Height Limitations for Different Structural Systems (BNBC, 2020)

Seismic Force–Resisting System	Response Reduction Factor, R	System Overstrength Factor, Ω_o	Deflection Amplification Factor, C_d	Seismic Design Category B	Seismic Design Category C	Seismic Design Category 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

Seismic Force–Resisting System	Response Reduction Factor, R	System Overstrength Factor, Ω_o	Deflection Amplification Factor, C_d	Seismic Design Category B	Seismic Design Category C	Seismic Design Category D
				Height limit (m)		
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, non-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

Seismic Force–Resisting System	Response Reduction Factor, R	System Overstrength Factor, Ω_o	Deflection Amplification Factor, C_d	Seismic Design Category B	Seismic Design Category C	Seismic Design Category D
				Height limit (m)		
4. Special reinforced concrete moment frames	8	3	5.5	NL	NL	NL
5. Intermediate reinforced concrete moment frames	5	3	4.5	NL	NL	NP
5. Ordinary reinforced concrete moment frames	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

Seismic Force–Resisting System	Response Reduction Factor, R	System Overstrength Factor, Ω_o	Deflection Amplification Factor, C_d	Seismic Design Category B	Seismic Design Category C	Seismic Design Category D
				Height limit (m)		
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 5 No height restriction, NP 5 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 BNBC-2020 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.

Table 3. 12: Parameters Ss and S1 for Different Seismic Zones (BNBC 2020 Table 6. C. 1)

Parameters	Zone 01	Zone 02	Zone 03	Zone 04
Ss	0. 3	0. 5	0. 7	0. 9
S1	0. 12	0. 2	0. 28	0. 36

S1= 0. 4 Ss, not independent of Ss, as in ASCE 7-05

S1=MCE level PGA = Z, Seismic Zone Coefficient

Shear Wall

A shear wall in building construction is a structural element that provides lateral resistance against horizontal forces such as wind, seismic activity, or other loads that can cause the building to sway or deform. These walls are designed to withstand and transfer these lateral forces to the building's foundation, thereby stabilizing the structure and ensuring its overall stability and safety.

Shear walls play a vital role in ensuring the structural integrity and safety of buildings, particularly in areas prone to seismic activity or high wind loads. Their proper design and implementation are essential aspects of the overall structural engineering of a building.

We have used shear wall in our model’s lift core to provides lateral resistance against horizontal forces such as wind, seismic activity that can cause the building to sway or deform.

3. 3 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

- **Load Group 1:** Uniformly distributed live loads arising from the Occupancies and 2 uses of assembly occupancies or areas with Uniformly distributed live load of 5. 0 kN/m or less, machinery and equipment for which specific live load allowances have been made, Special roof live load and printing plants, vaults, strong room and armories, shall be classified under Load Group 1. Reduction of live load shall not be allowed for members or portions thereof under This load group and a reduction factor, R-1. 0 shall be applied for 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.

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.

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:

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.

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.

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 eight of structure, whichever is greater.

3. 4 Load Combinations

As per BNBC 2020, 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+EL+ 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. 7 must be considered. All 26load combinations are analyzed using software.

Vertical Earthquake Loading, Ev (sec. 2. 5. 13. 2 of BNBC 2020)

The maximum vertical ground acceleration shall be taken as 50 percent of the expected horizontal peak ground acceleration (PGA). The vertical seismic load effect Ev may be determined as:

Ev = 0. 5(a_h)D Eqn. (6. 2. 56 of BNBC2020)

Where,

a_h = expected horizontal peak ground acceleration (in g) for design

= (2/3) ZS if Z corresponds to MCE (2500 yr return period)

D = effect of dead load, S = site dependent soil factor (see Table 3. 9).

Definition of Seismic Load, E Total load effects of earthquake that include both horizontal and vertical, or related internal moments and forces.

Table 3. 13(a) Strength Design Load Combination

Load Effect Combinations for LRFD/USD (Sec. 2. 7. 3 of BNBC 2020):

Strength Design Load Combination (without F,H,T)
1. 1.4 D
2. 1.2D+ 1.6L+ 0.5(L_r or R)
3. 1.2D+ 1.6(L_r or R)+ (L or 0.8w)
4. 1.2D+ 1.6W+L+ 0.5(L_r or R)
5. 1.2D+ 1.0E + 1.0L
6. 0.9D+ 1.6W
7. 0.9D+ 1.0E
Strength Design Load Combinations
1. 1.4 (D+F)
2. 1.2(D+F+T)+ 1.6(L+H)+ 0.5(L_r or R)
3. 1.2D+ 1.6(L_r or R)+ (L or 0.8w)
4. 1.2D+ 1.6W+L+ 0.5(L_r or R)
5. 1.2D+ 1.0E + 1.0L
6. 0.9D+ 1.6W+1.6H
7. 0.9D+ 1.0E+ 1.6H As per BNBC 2020

Expanded Combinations for 3D Analysis of Typical Buildings

Vertical seismic effect considered

Ev = 0. 5(Expanded Combinations for 3D Analysis of Typical Buildings Vertical seismic effect considered)

Ev = 0. 5(a_h)D Eqn. (6. 2. 56)

Let Ev = λ D where λ = 0. 5(a_h)D Eqn. (6. 2. 56 of BNBC 2020)

Table 3. 13(b) Expanded Combination of BNBC-2020

Expanded Combinations for ETABS **Vertical seismic effect considered (SDC B)**	Expanded Combinations for ETABS **Vertical seismic effect considered (SDC C&D)**
1. 1. 4D 2. 1. 2D + 1. 6L 3. 1. 2D + L 4. 1. 2D + 0. 8Wx 5. 1. 2D - 0. 8Wx 6. 1. 2D + 0. 8Wy 7. 1. 2D - 0. 8Wy 8. 1. 2D + L + 1. 6Wx 9. 1. 2D + L - 1. 6Wx 10. 1. 2D + L + 1. 6Wy 11. 1. 2D + L - 1. 6Wy 12. 1. 2D + L + Ex+ λ D 13. 1. 2D + L - Ex + λ D 14. 1. 2D + L + Ey + λ D 15. 1. 2D + L -Ey + λ D 16. 0. 9D + 1. 6Wx 17. 0. 9D - 1. 6Wx 18. 0. 9D + 1. 6Wy 19. 0. 9D - 1. 6Wy 20. 0. 9D + Ex - λ D 21. 0. 9D - Ex- λ D 22. 0. 9D +Ey- λ D 23. 0. 9D - Ey- λ D	1. 1. 4D 2. 1. 2D + 1. 6L 3. 1. 2D + L 4. 1. 2D + 0. 8Wx 5. 1. 2D - 0. 8Wx 6. 1. 2D + 0. 8Wy 7. 1. 2D - 0. 8Wy 8. 1. 2D + L + 1. 6Wx 9. 1. 2D + L - 1. 6Wx 10. 1. 2D + L + 1. 6Wy 11. 1. 2D + L - 1. 6Wy 12. 1. 2D + L + Ex + 0. 3Ey + λ D 13. 1. 2D + L + Ex- 0. 3Ey + λ D 14. 1. 2D + L - Ex + 0. 3Ey + λ D 15. 1. 2D + L - Ex- 0. 3Ey + λ D 16. 1. 2D + L + Ey + 0. 3Ex + λ D 17. 1. 2D + L + Ey- 0. 3Ex + λ D 18. 1. 2D + L - Ey + 0. 3Ex + λ D 19. 1. 2D + L - Ey- 0. 3Ex + λ D 20. 0. 9D + 1. 6Wx 21. 0. 9D - 1. 6Wx 22. 0. 9D + 1. 6Wy 23. 0. 9D - 1. 6Wy 24. 0. 9D + Ex + 0. 3Ey- λ D 25. 0. 9D + Ex- 0. 3Ey- λ D 26. 0. 9D - Ex + 0. 3Ey- λ D 27. 0. 9D - Ex- 0. 3Ey- λ D 28. 0. 9D + Ey + 0. 3Ex- λ D 29. 0. 9D + Ey- 0. 3Ex- λ D 30. 0. 9D - Ey + 0. 3Ex- λ D 31. 0. 9D - Ey- 0. 3Ex- λ D

3. 5 Design data

Load Consideration: BNBC 2020 for Zone 2.

3. 5. 1. Dead Load: (for Zone -2)

Floor Finish (FF): 25 psf

Partition wall (PW): 85 psf (1kip/ft)

Super Imposed Dead Load (SDL)=150 psf

3. 5. 2. Live Load

Floor: 2KN/m^2 or 42 psf (Table 6. 2. 3)

Stair: 4.8KN/m^2 or 100 psf (Table 6. 2. 3)

Roof Over: 4. 8KN/m^2 or 100 psf (Table 6. 2. 3)

Over Head Water Tank: 312 psf (6 ft)

3. 5. 3 Wind Pressure (BNBC 2020)

Basic Wind speed V: 149. 651 mph (Kushtia)

Structural Important Coefficient: 1.0

Exposure Category: A, (In ETABS,21: B)

Gust Factor: 0. 85

Directionally Factor, KD: 0. 85

3. 5. 4. Earthquake Category Base Shear (BNBC 2020)

Seismic Zone factor (Z): 0. 20 (Zone II-Kushtia)

Site Classification: SC

Occupancy Category: II

Structural Importance Factor (I): 1. 0

Seismic Design Category: C

Response Modification Coefficient, R: 5

System Over strength. 'Ω (omega): 3

Deflection Amplification, Cd: 4. 5

Spectral Response Acceleration, Ss’: 0. 5

Spectral Response Acceleration, S1: 0. 2

Site Coefficient, Fa: 1. 15

Site Coefficient, Fv: 1. 725

For 6 Story (74 ft):

Time Period, T: 0.77 sec

Lateral Seismic Force Acceleration, Sa =0.0597

K=1. 135

For 12 Story (134ft):

Time Period, T: 1.314 sec

Lateral Seismic Force Acceleration, Sa =0.035

K=1.407

Material Properties:

Unit weight of concrete: 150 lb/ft

Compressive Strength:

For slab, fc': 4000 psi

For beam, fc': 4000 psi

For Column: fc': 4000 psi

Steel: Yield strength of Steel, fy: 60 ksi

Design Load Combination:

Table 3. 14 Expanded Combinations for ETABS Model

Expanded Combinations for ETABS Vertical seismic effect considered (SDC C)	
1. 1. 4D	14. 1. 277D+L-Ey+0. 3Ex
2. 1. 2D + 1. 6L	15. 1. 277D+L-Ey-0. 3Ex
3. 1. 2D + L	16. 0. 9D + 1. 6W
4. 1. 2D + 0. 8W	17. 0. 9D - 1. 6W
5. 1. 2D - 0. 8W	18. 0. 823D+Ex+0. 3Ey
6. 1. 2D + L + 1. 6W	19. 0. 823D+Ex-0. 3Ey
7. 1. 2D + L - 1. 6W	20. 0. 823D-Ex+0. 3Ey
8. 1. 277D+L+Ex+0. 3Ey	21. 0. 823D-Ex-0. 3Ey
9. 1. 277D+L+Ex-0. 3Ey	22. 0. 823D+Ey+0. 3Ex
10. 1. 277D+L-Ex+0. 3Ey	23. 0. 823D+Ey-0. 3Ex
11. 1. 277D+L-Ex-0. 3Ey	24. 0. 823D-Ey+0. 3Ex
12. 1. 277D+L+Ey+0. 3Ex	25. 0. 823D-Ey-0. 3Ex
13. 1. 277D+L+Ey-0. 3Ex	

Note:

Ev = 0. 5(a_h)D

Let Ev = λ D where, λ = 0. 5(a_h)D,

[$\lambda = 0.5\times \frac{2}{3} zs = 0.5 \times \frac{2}{3} \times 0.2 \times 1.15 = 0.077$] [W= Wx=Wy]

3. 6 Auto CAD Model

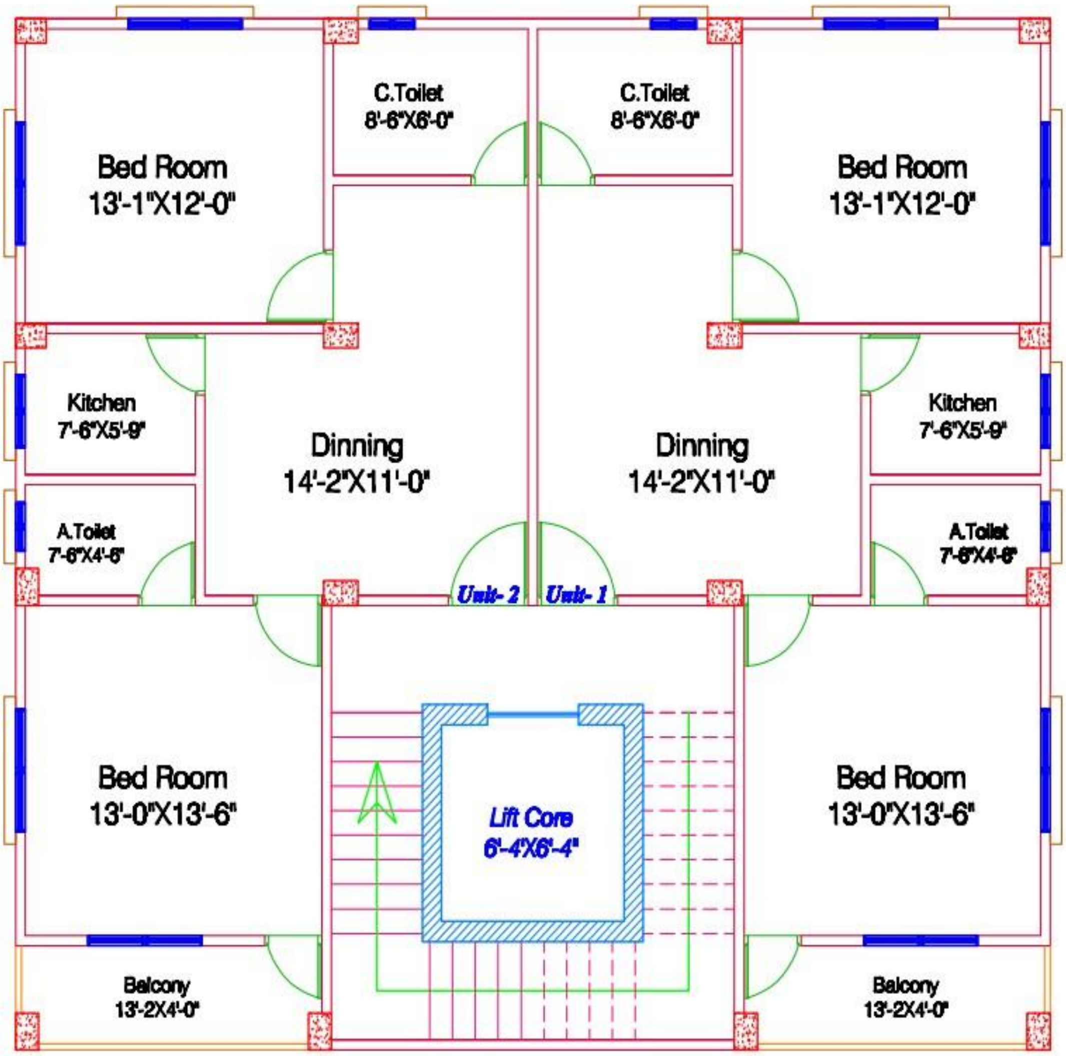


Figure 3. 4(a): Architectural Plan for both option (Typical Floor Plan)

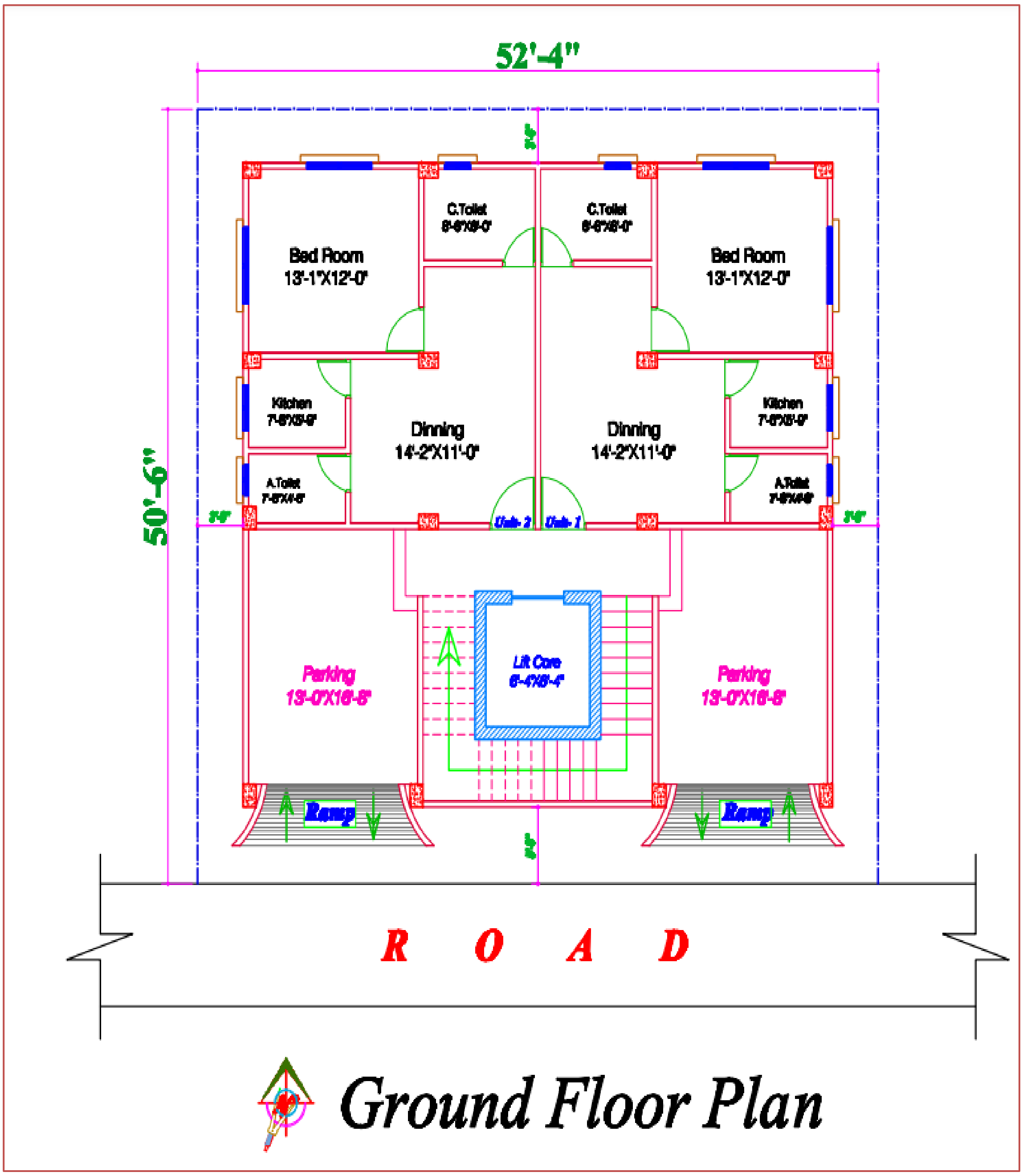


Figure 3. 4(b): Architectural Plan for both option (Ground Floor Plan)

3. 7 Column & Beam Layout

Model 01: low-rise building (6story)

<u>Column & Beam size</u>

Column 01: 12x16

Column 02: 12x18

Beam (GB): 12x15

Beam (FB): 12x16

Beam (FB): 12x18

Beam (SB): 10x16

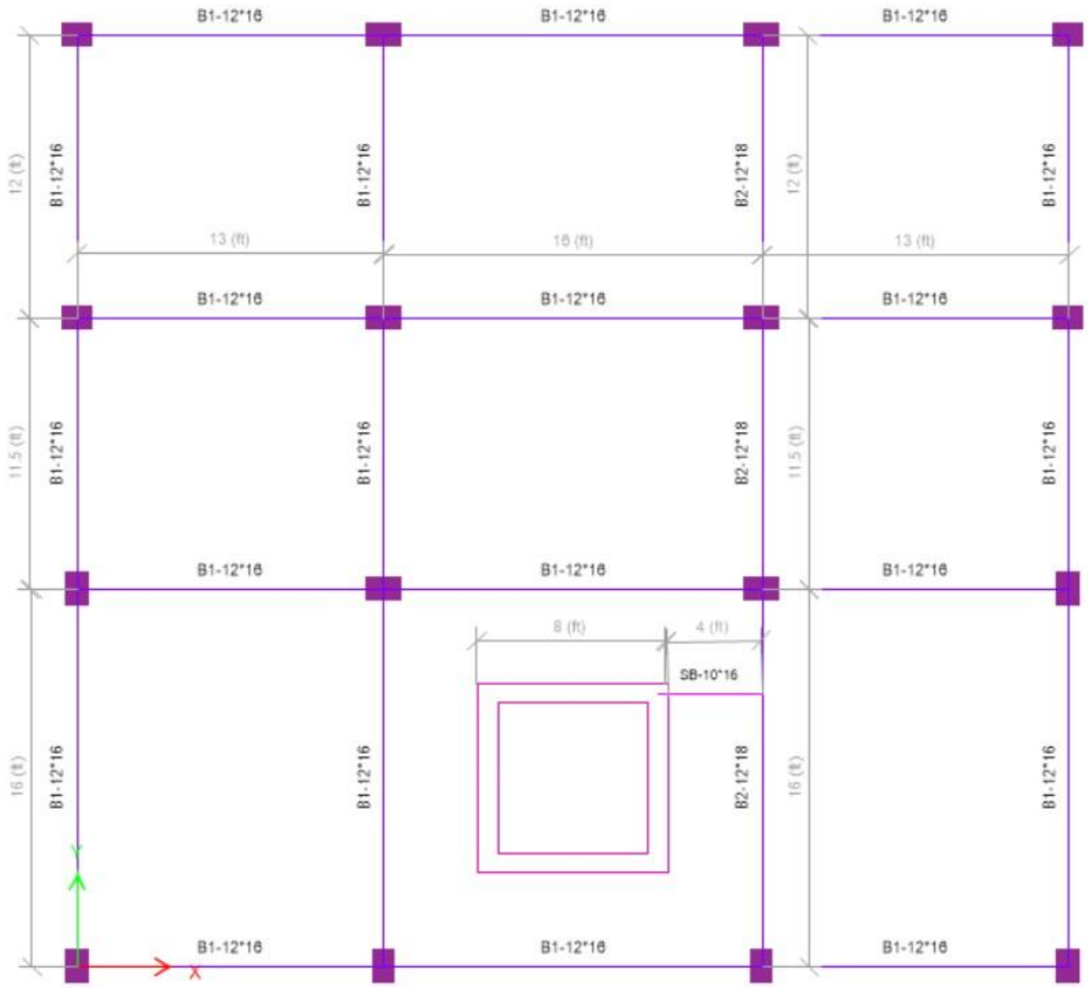


Figure 3. 5: Column & Beam Layout (low-rise)

3. 7. 1 Column & Beam Layout

Model 02: High-Rise building (12story)

<u>Column & Beam size</u>

Column 01: 12x21

Column 02: 12x18

Beam (GB): 12x16

Beam (FB): 12x16

Beam (FB): 12x18

Beam (SB): 10x16

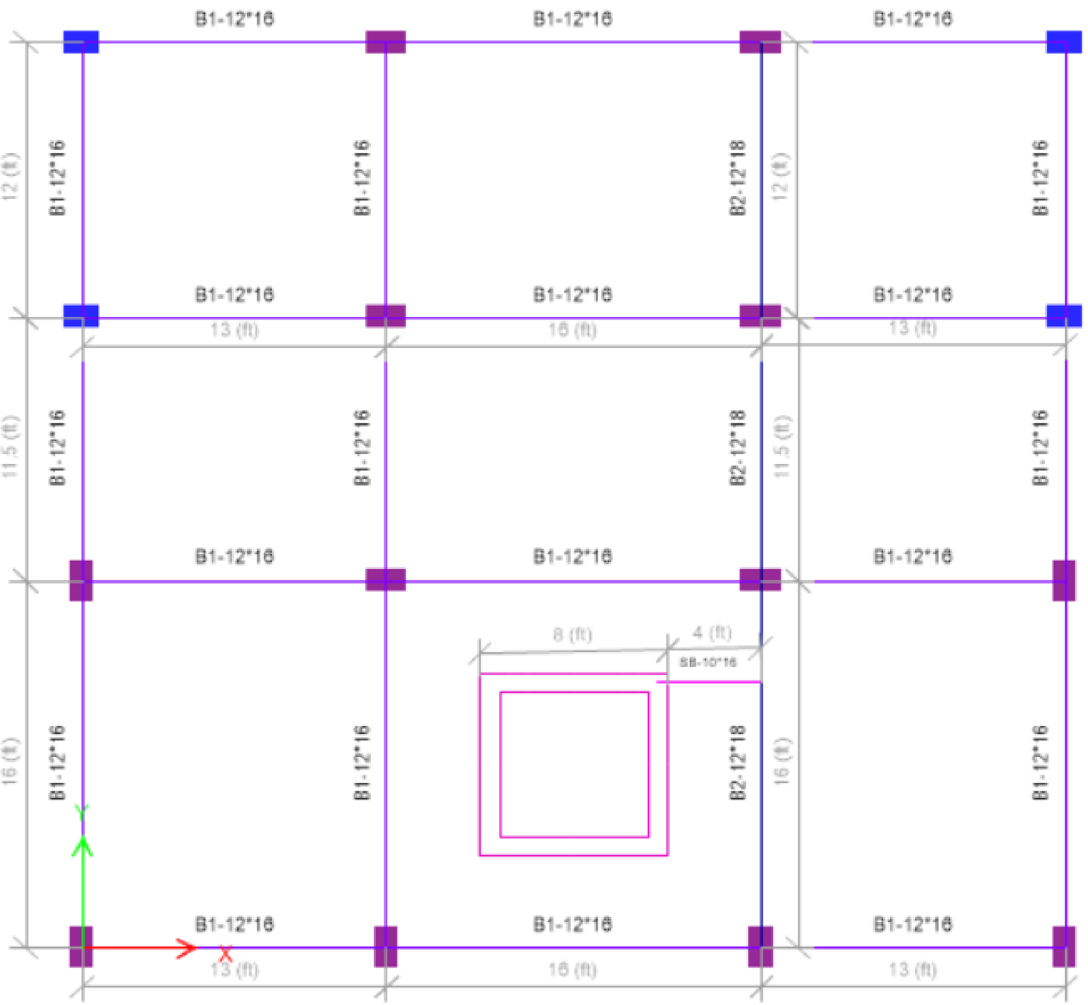
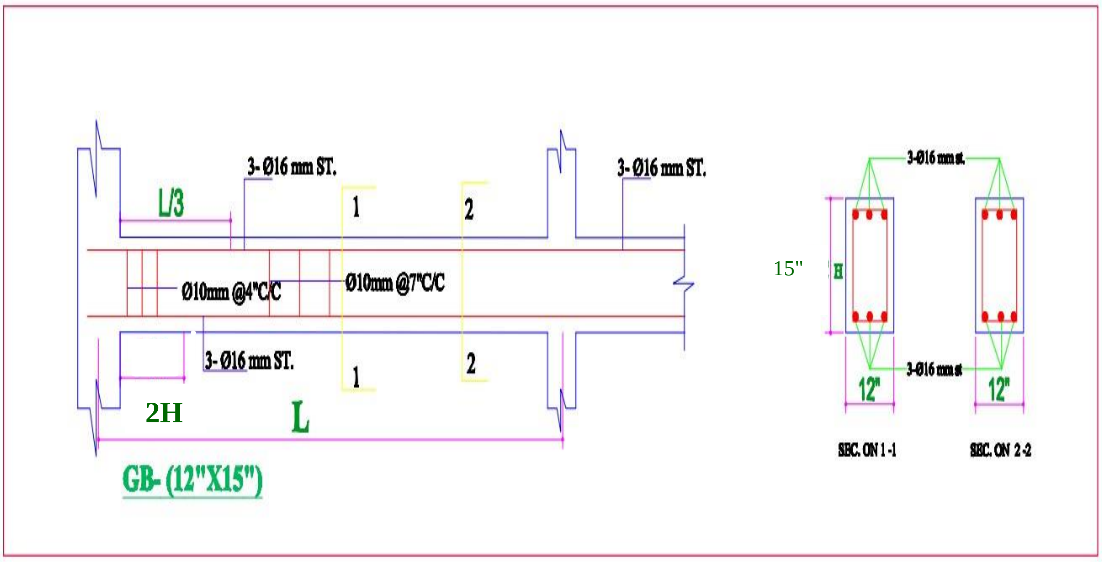


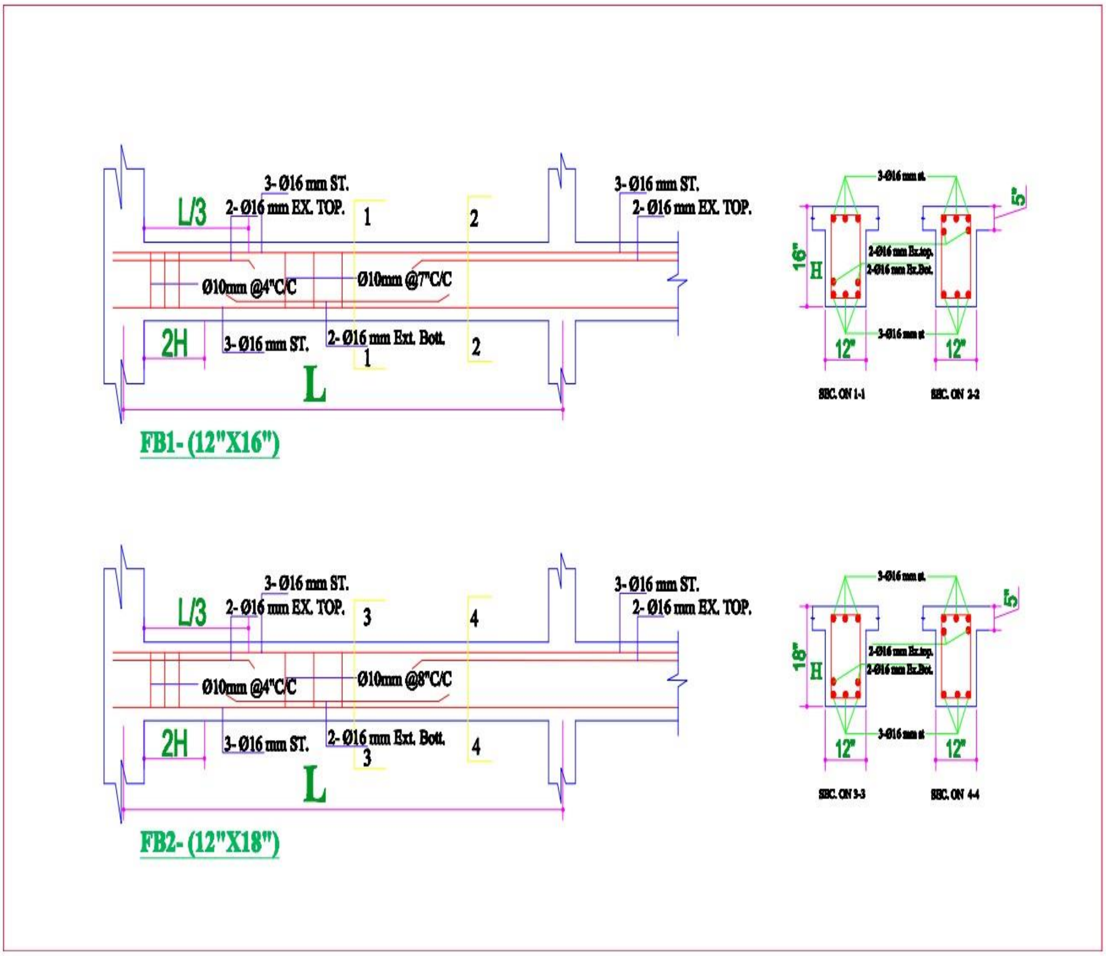
Figure 3. 6: Column & Beam Layout (High-Rise)

3. 8 Beam Section

Model 01: Low-rise Building (6Story) Beam Section:



Long Section of GB (12” ×15”)

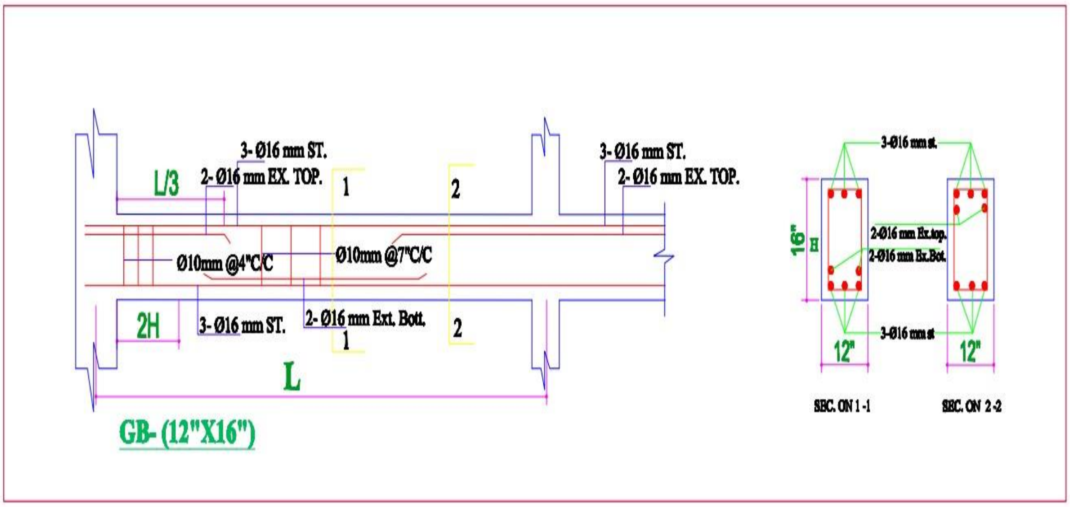


Long Section of FB

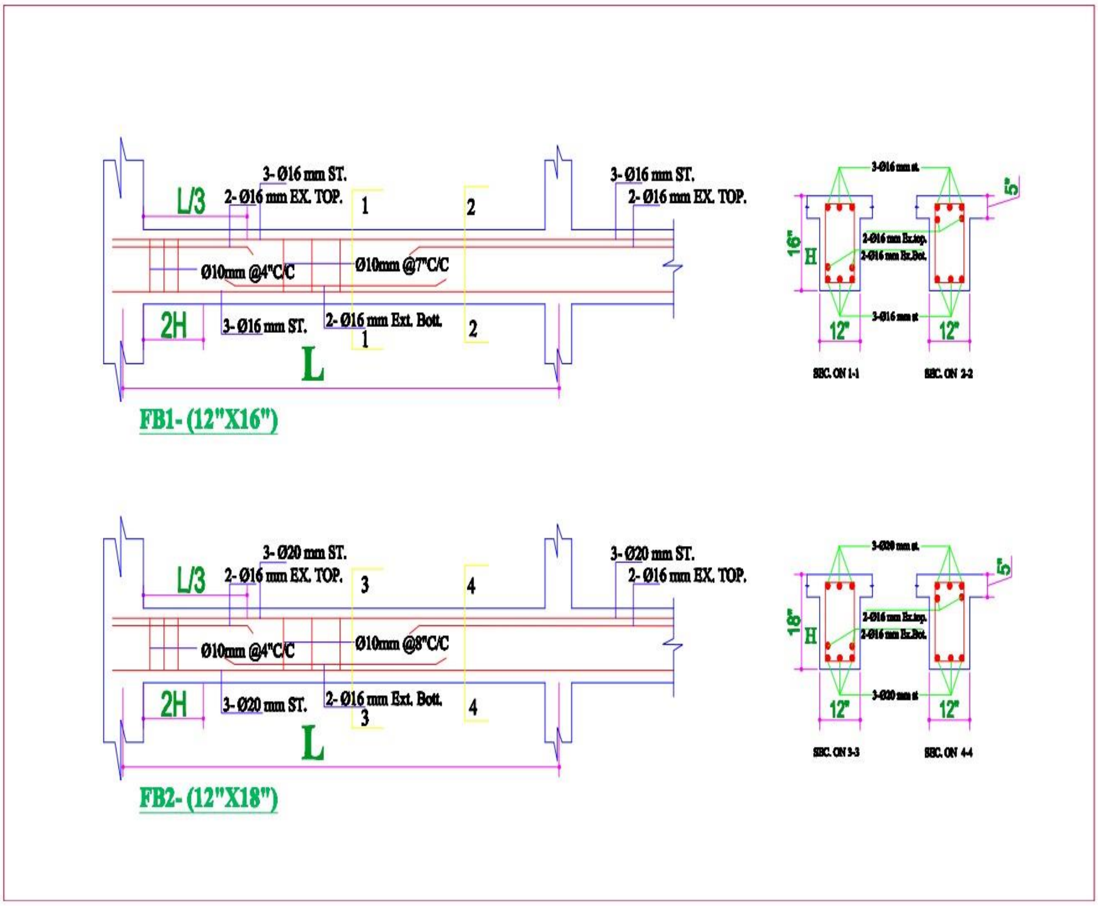
Figure 3. 7: Low-rise Building beam section

3. 8. 1 Beam Section

Model 02: High-Rise Building (12Story) Beam Section



Long Section of GB (12” ×16”)



Long Section of FB

Figure 3. 8: High-Rise Building beam section

3. 9 Modelling with EATBS

3. 9. 1 Model Initialization

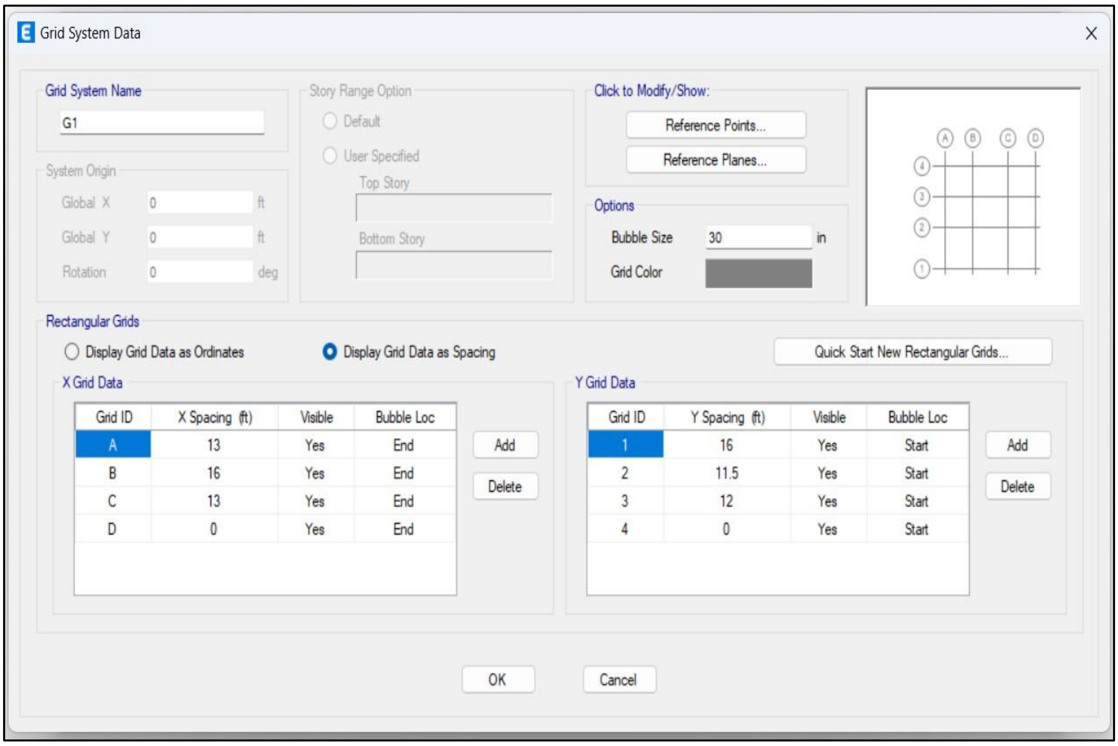


Figure 3. 9: Grid selection of the Model

- 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 of stories
- Input bottom story height
- If the grid is not uniform, then go to the Custom Grid Spacing
- Edit Grid
- Check Spacing
- Check glue to grid lines
- Input spacing of grid in X, Y direction
- OK

3. 9. 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. Select Reinforcement
  - vi. Then select beam
  - vii. Define all frame section in this process

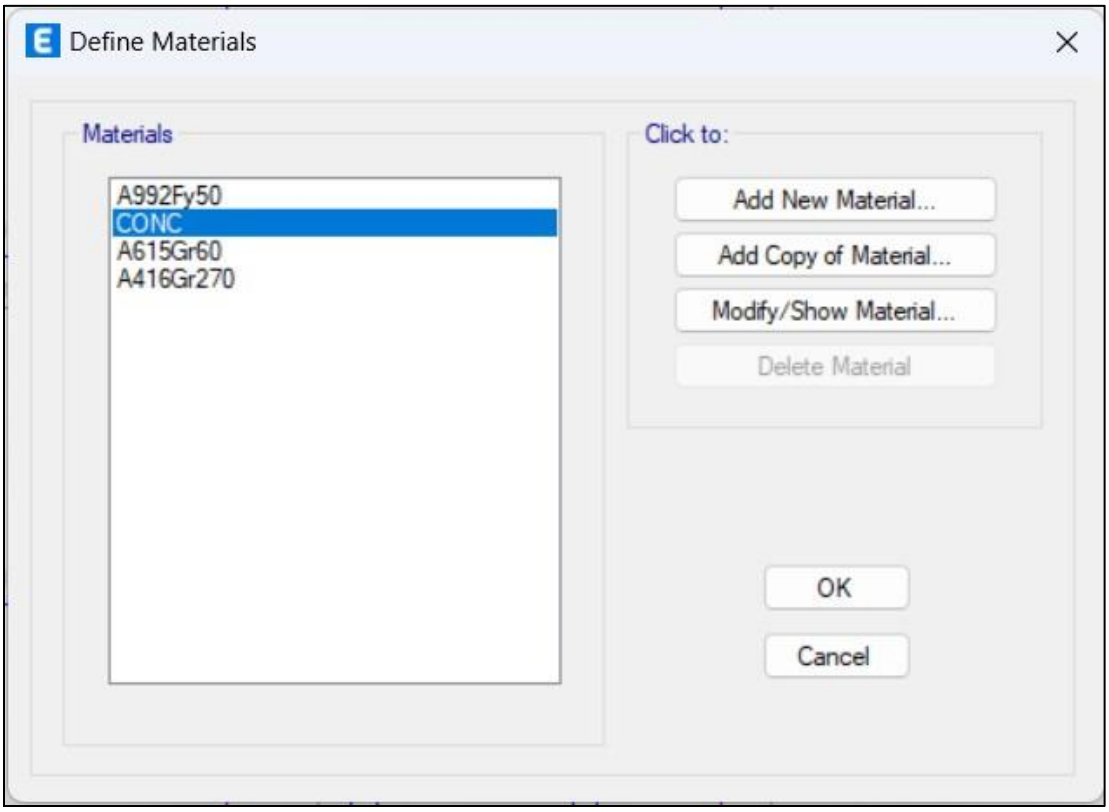


Figure 3. 10: Define Materials Dialog Box

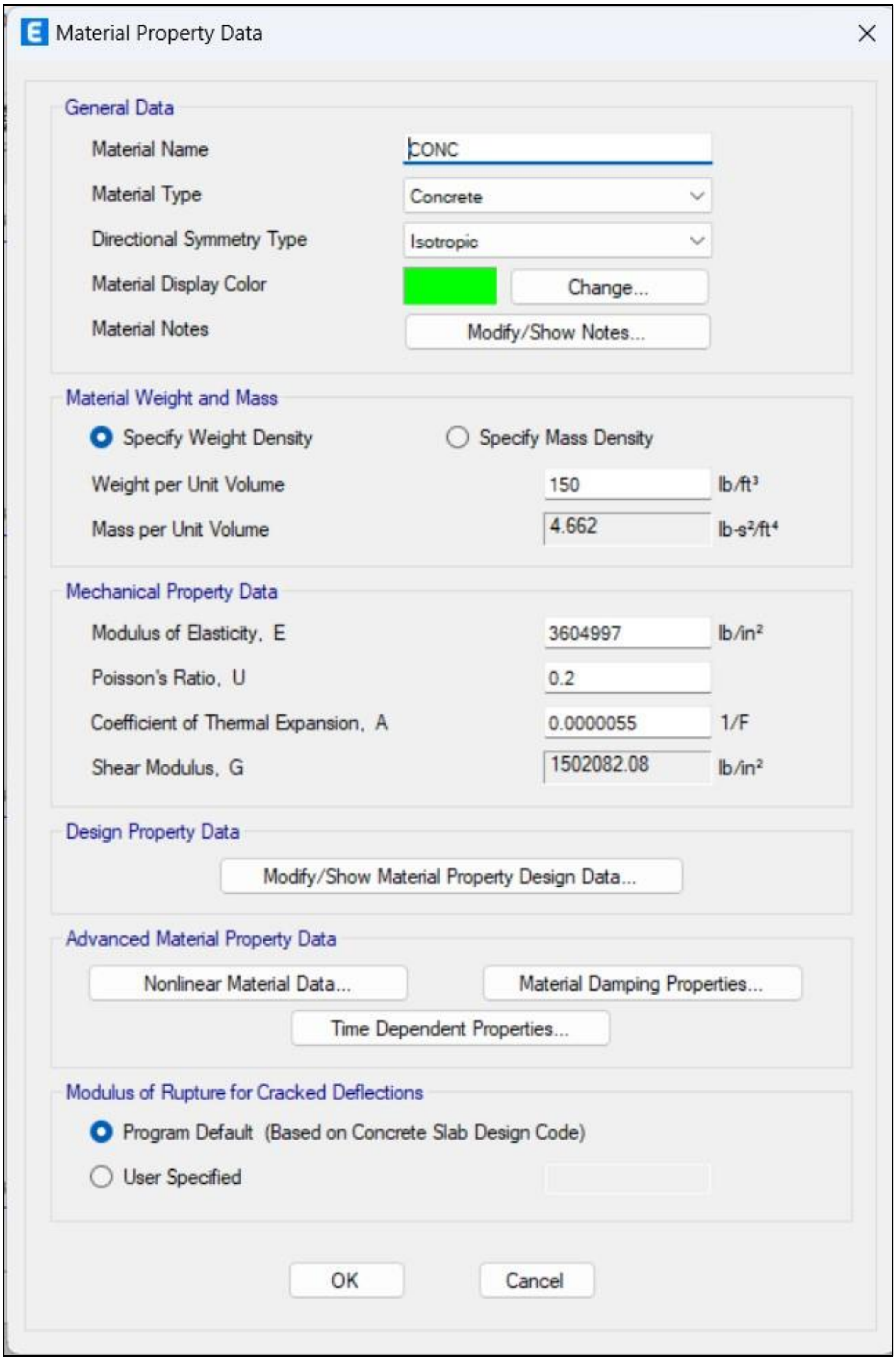


Figure 3. 11: Define Materials

3. 9. 3 Frame Properties

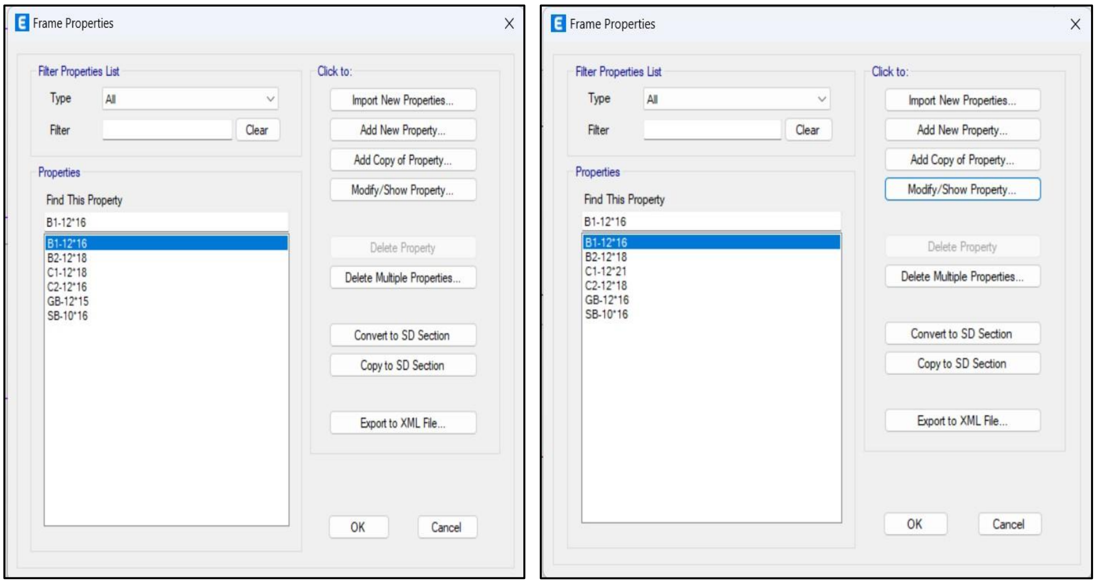


Figure 3. 12: Frame property initialization for both section

3. 9. 4 Frame Section Property of Columns for Low-rise Building

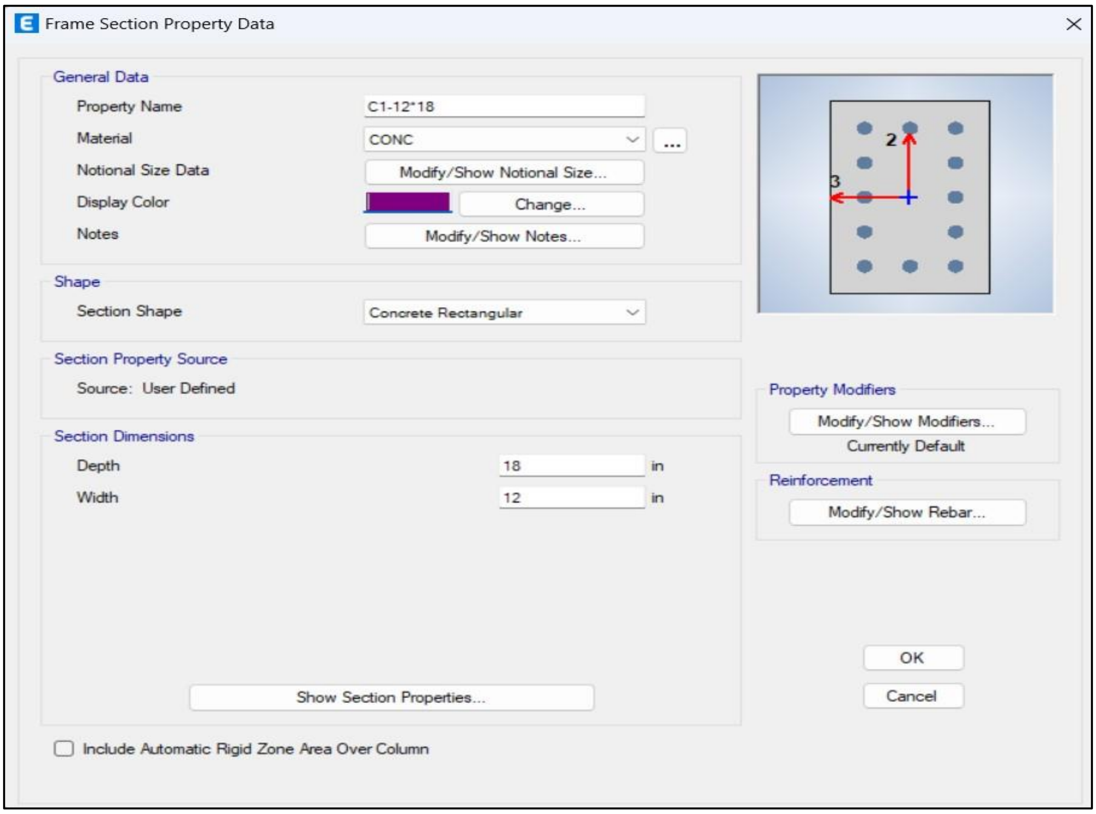


Figure 3. 13(a): Frame Section Property of Columns for Low-rise Building.

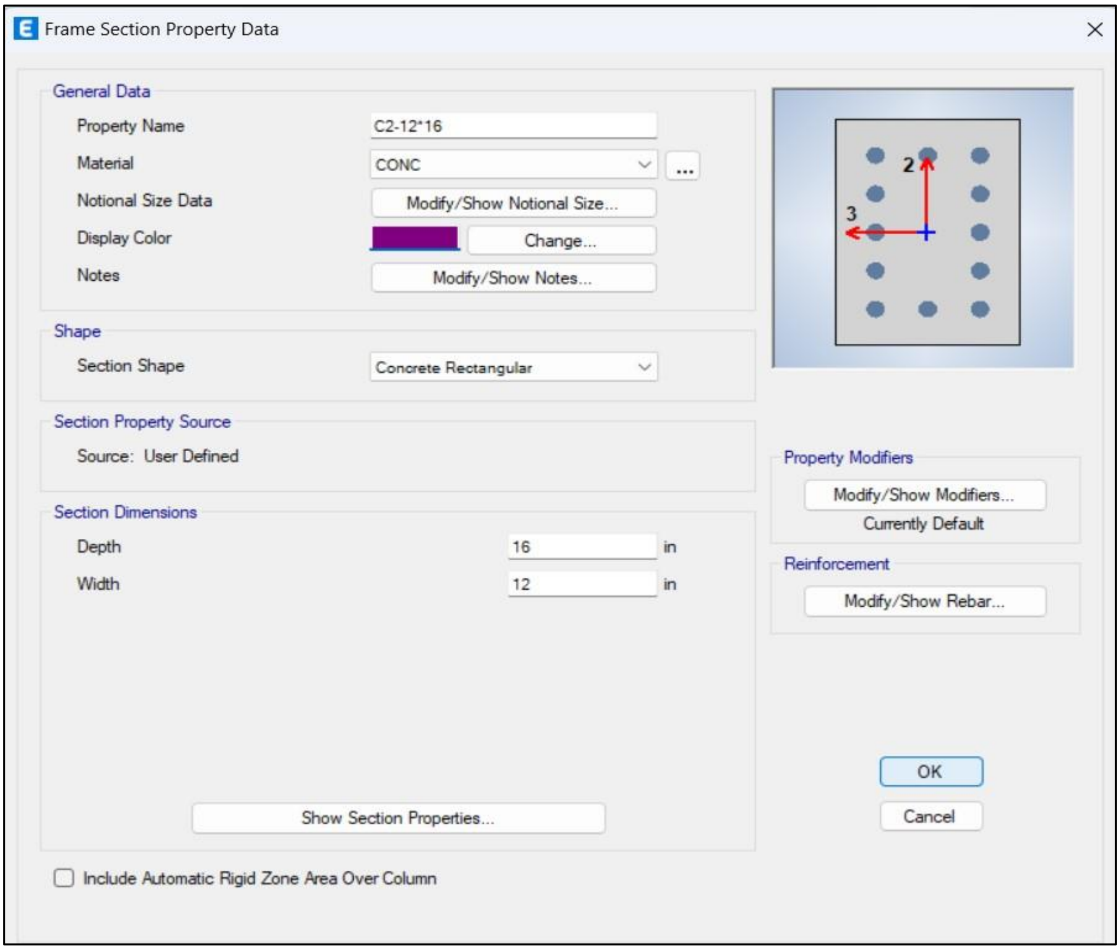


Figure 3. 13(b): Frame Section Property of Columns for Low-rise Building

3. 9. 5 Frame Section Property of Beams for Low-rise Building

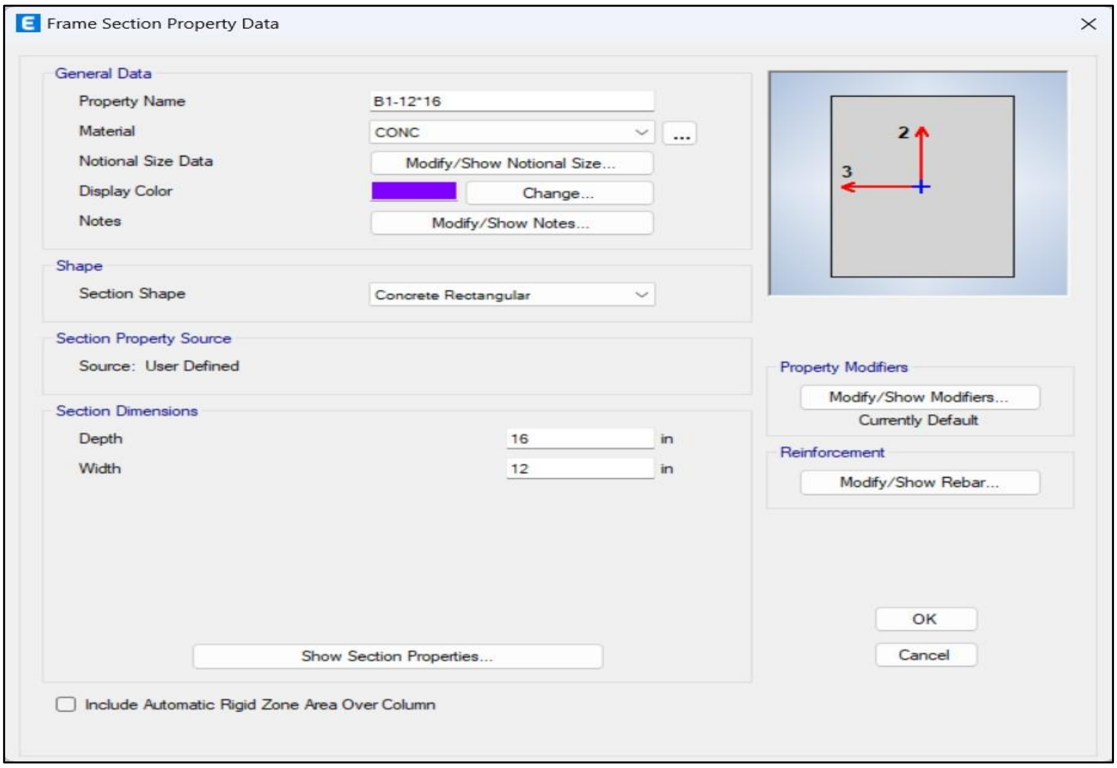


Figure 3. 14(a): Frame Section Property of Beams for Low-rise Building

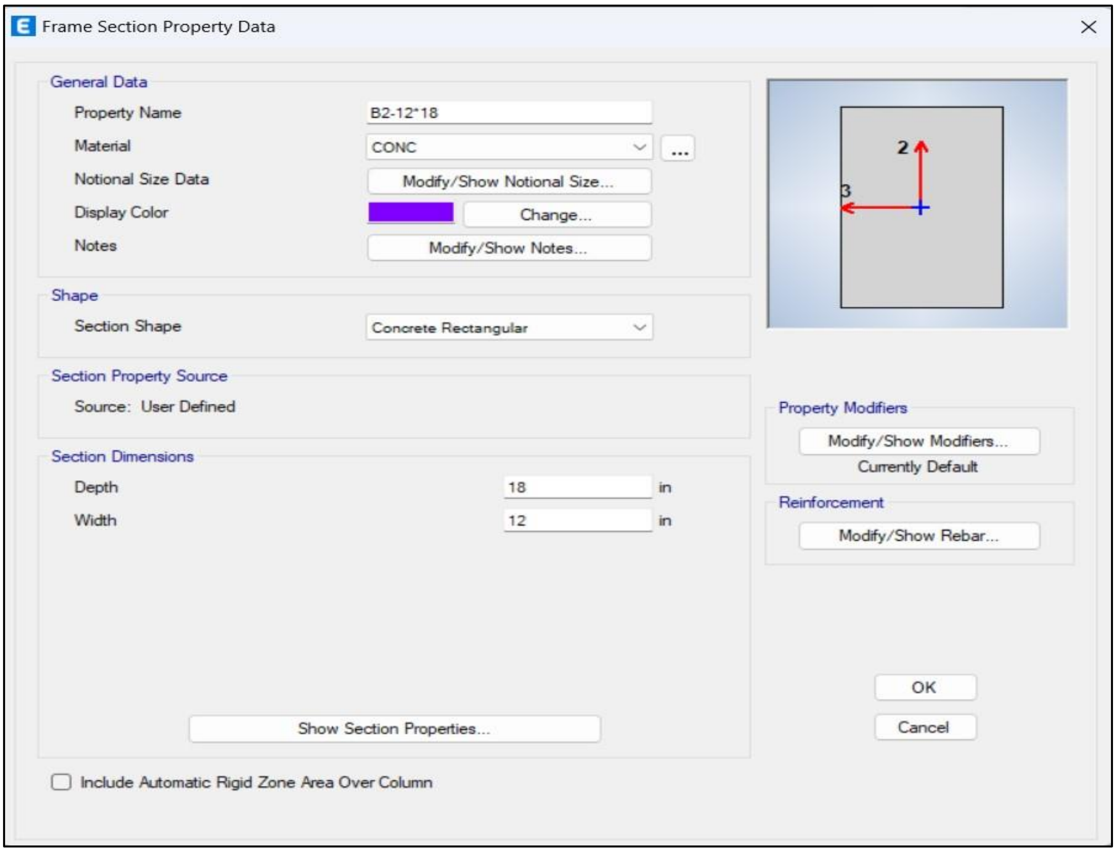


Figure 3. 14(b): Frame Section Property of Beams for Low-rise Building

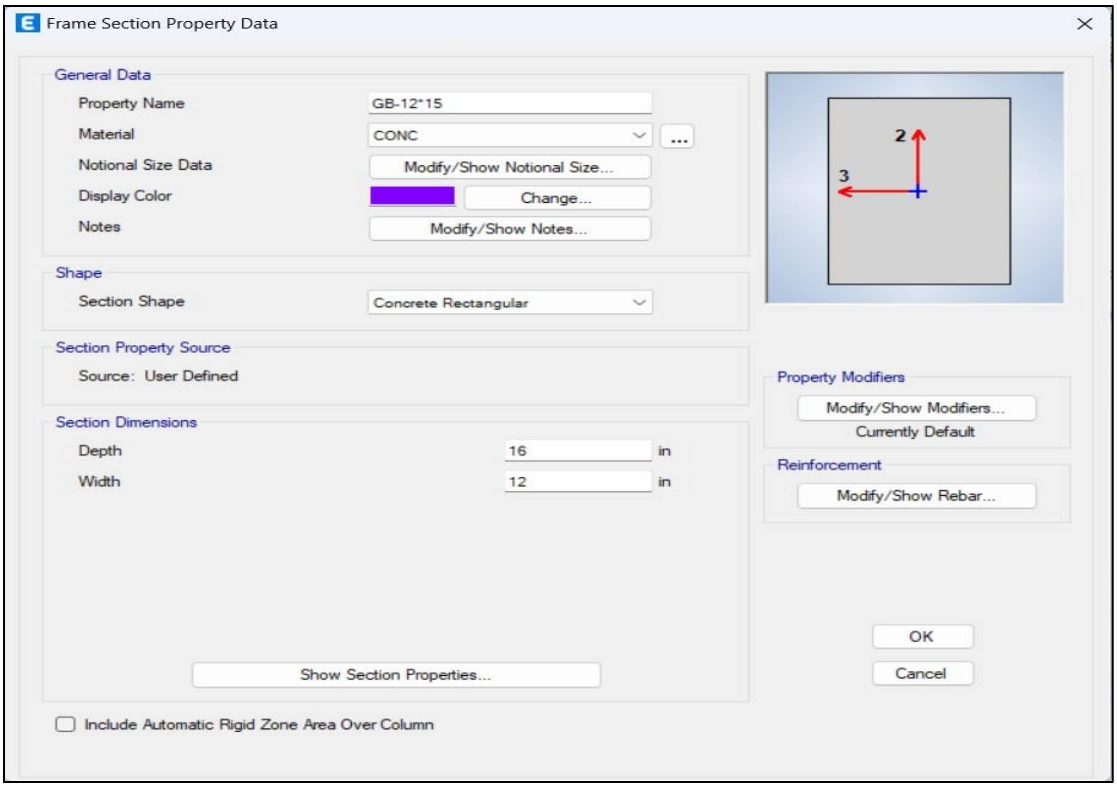


Figure 3. 15: Frame Section Property of Grade Beams for Low-rise Building

3. 9. 6 Frame Section Property of Columns for High-Rise Building

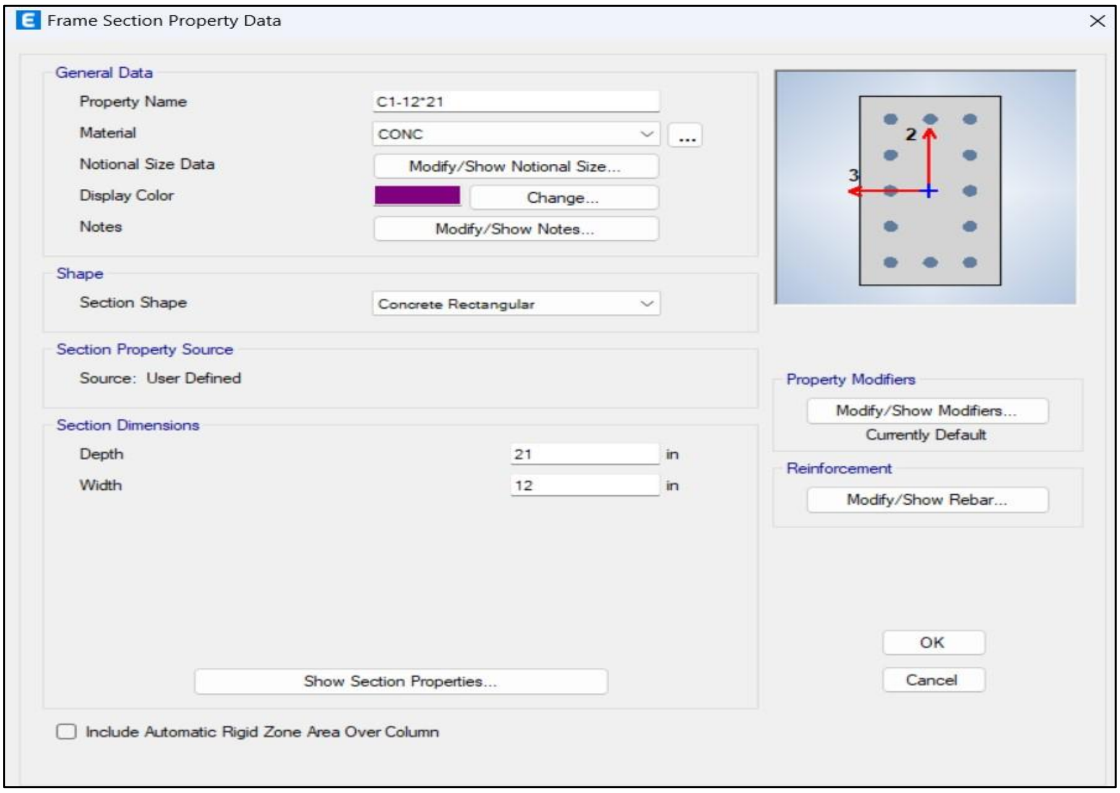


Figure 3. 16(a):Frame Section Property of Columns for High-Rise Building

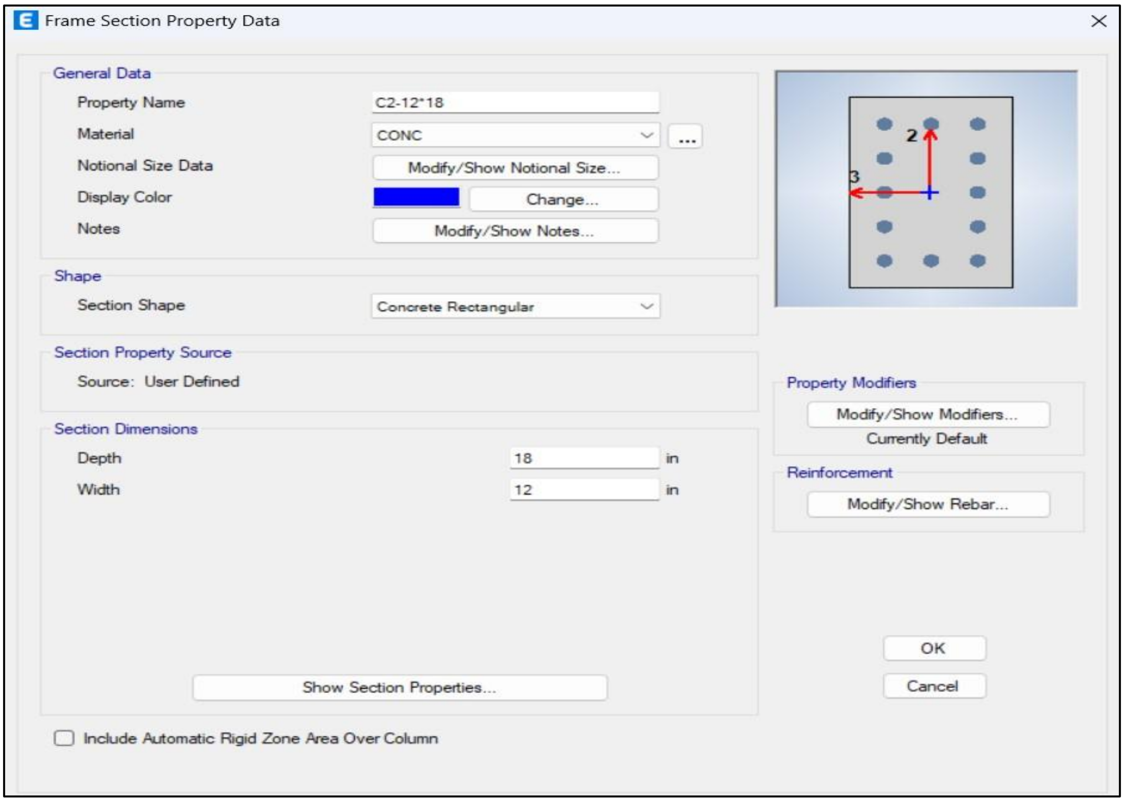


Figure 3. 16(b): Frame Section Property of Columns for High-Rise Building

3. 9. 7 Frame Section Property of Beams for High-Rise Building

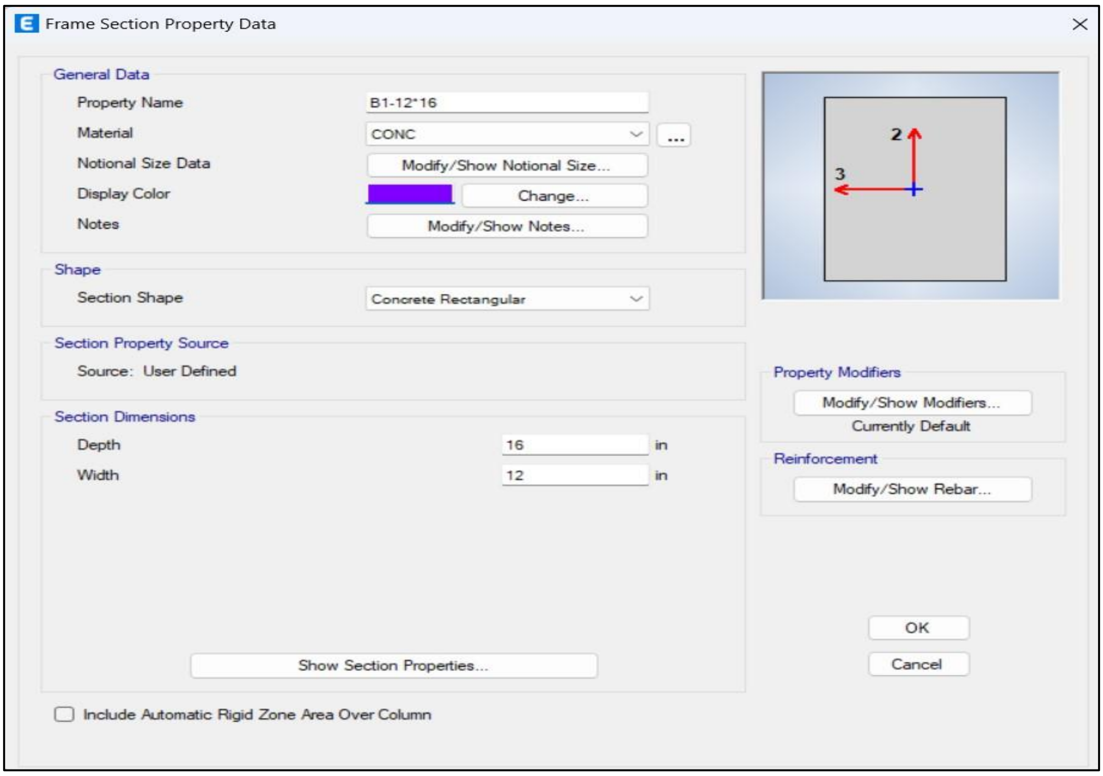


Figure 3. 17(a): Frame Section Property of Beams for High-Rise Building

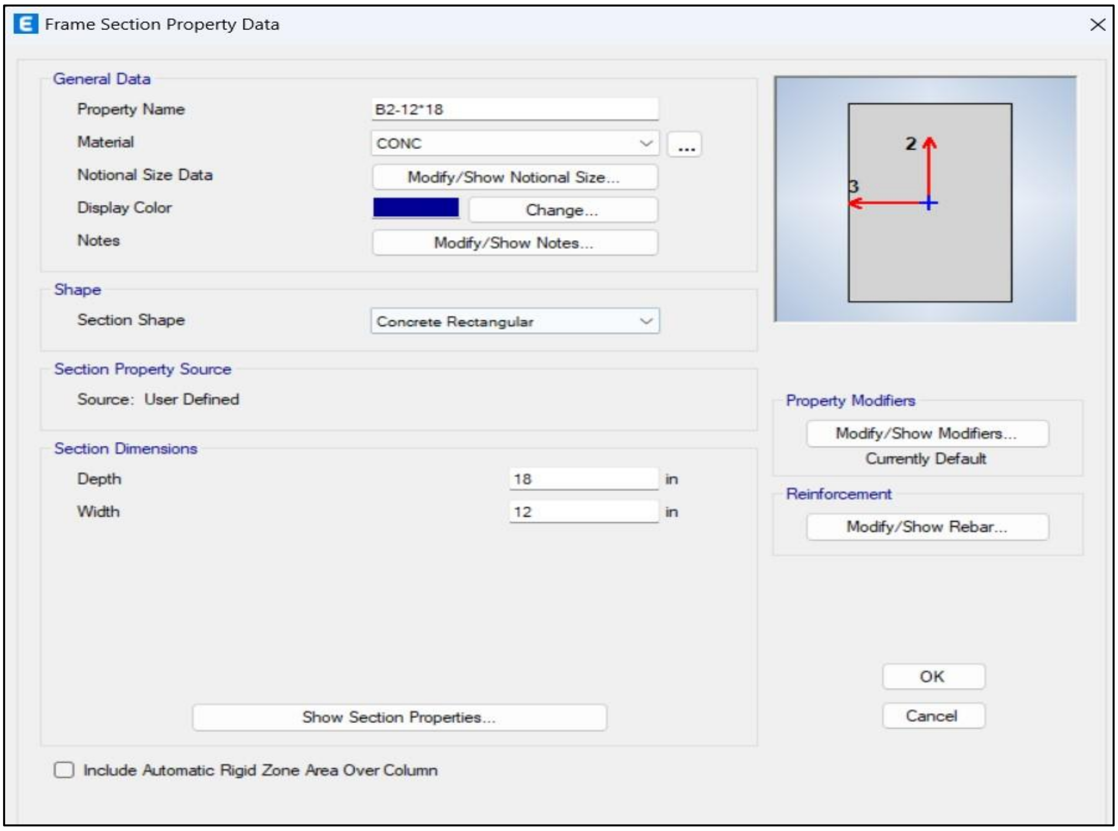


Figure 3. 17(b): Frame Section Property of Beams for High-Rise Building

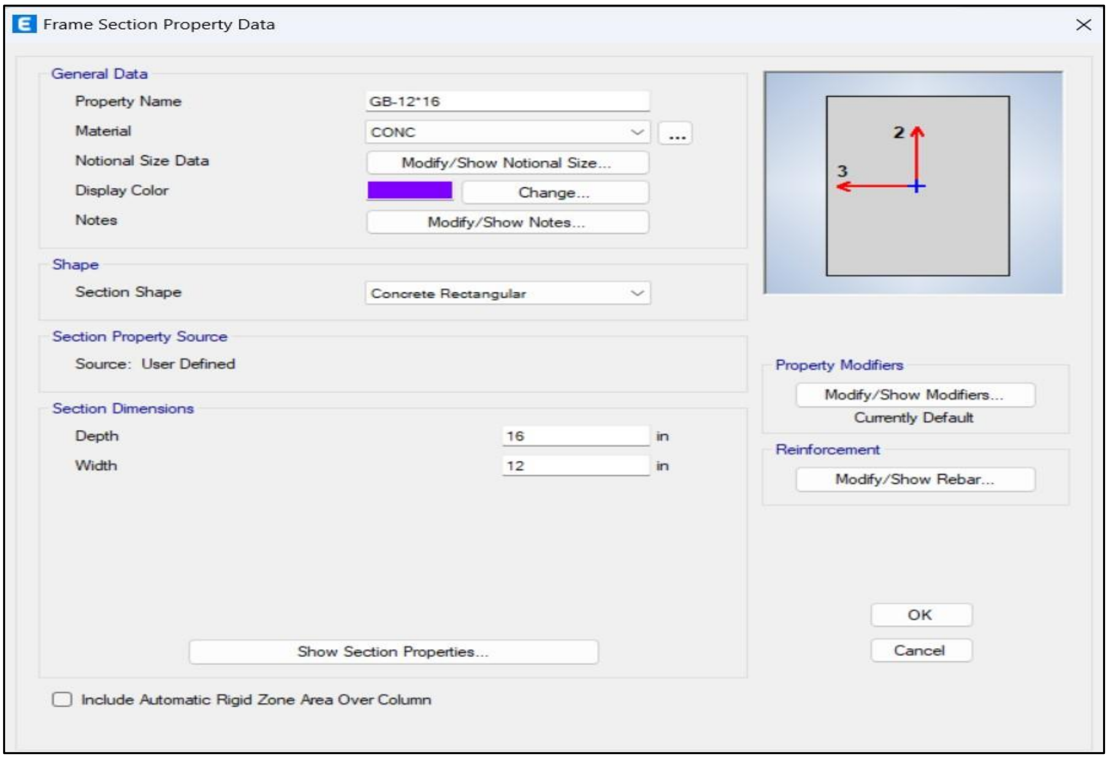


Figure 3. 18: Frame Section Property of Grade Beams for High-Rise Building

3. 9. 8 Display Grid Data

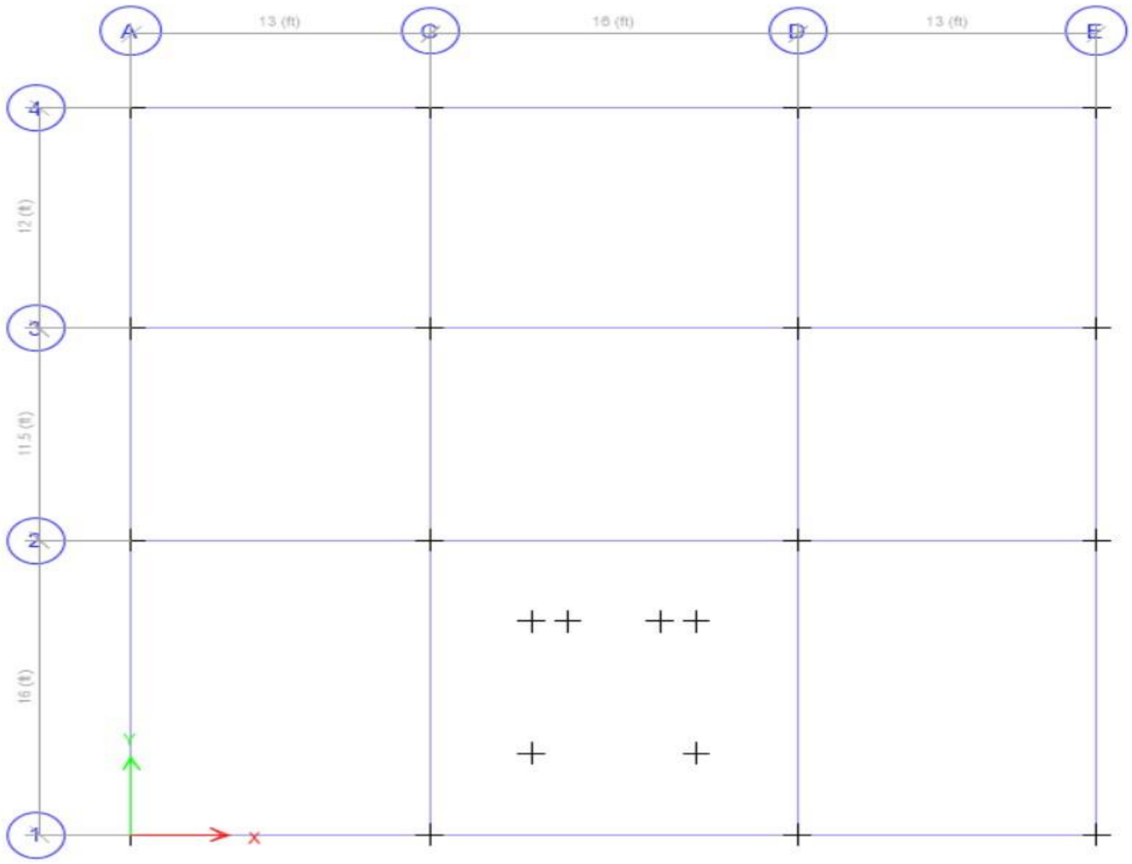


Figure 3. 19: proposed Grid Data of the model for Both Structure

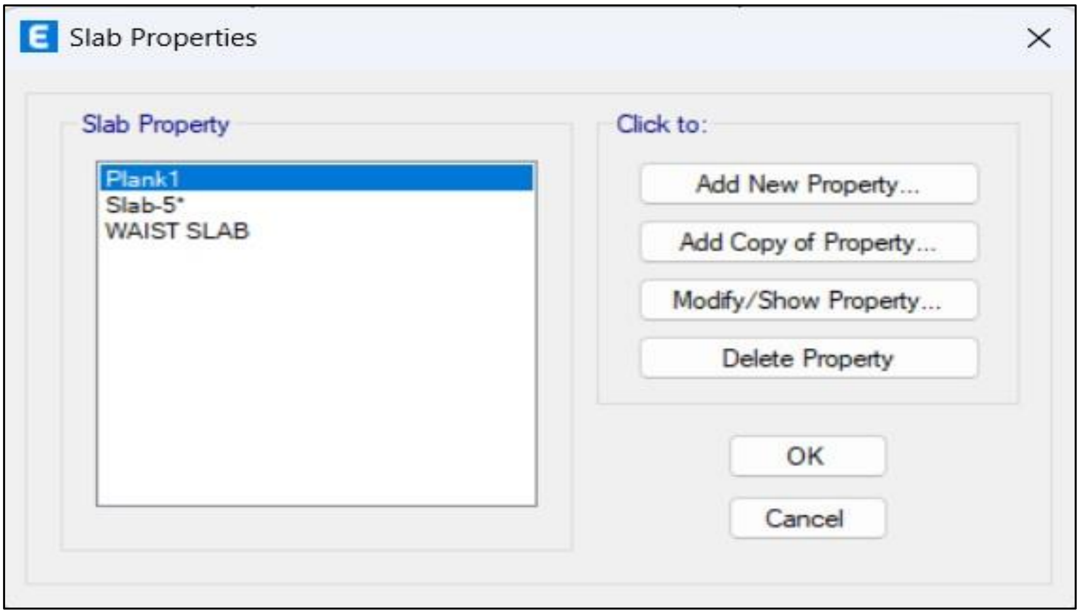


Figure 3. 20: Define Slab property

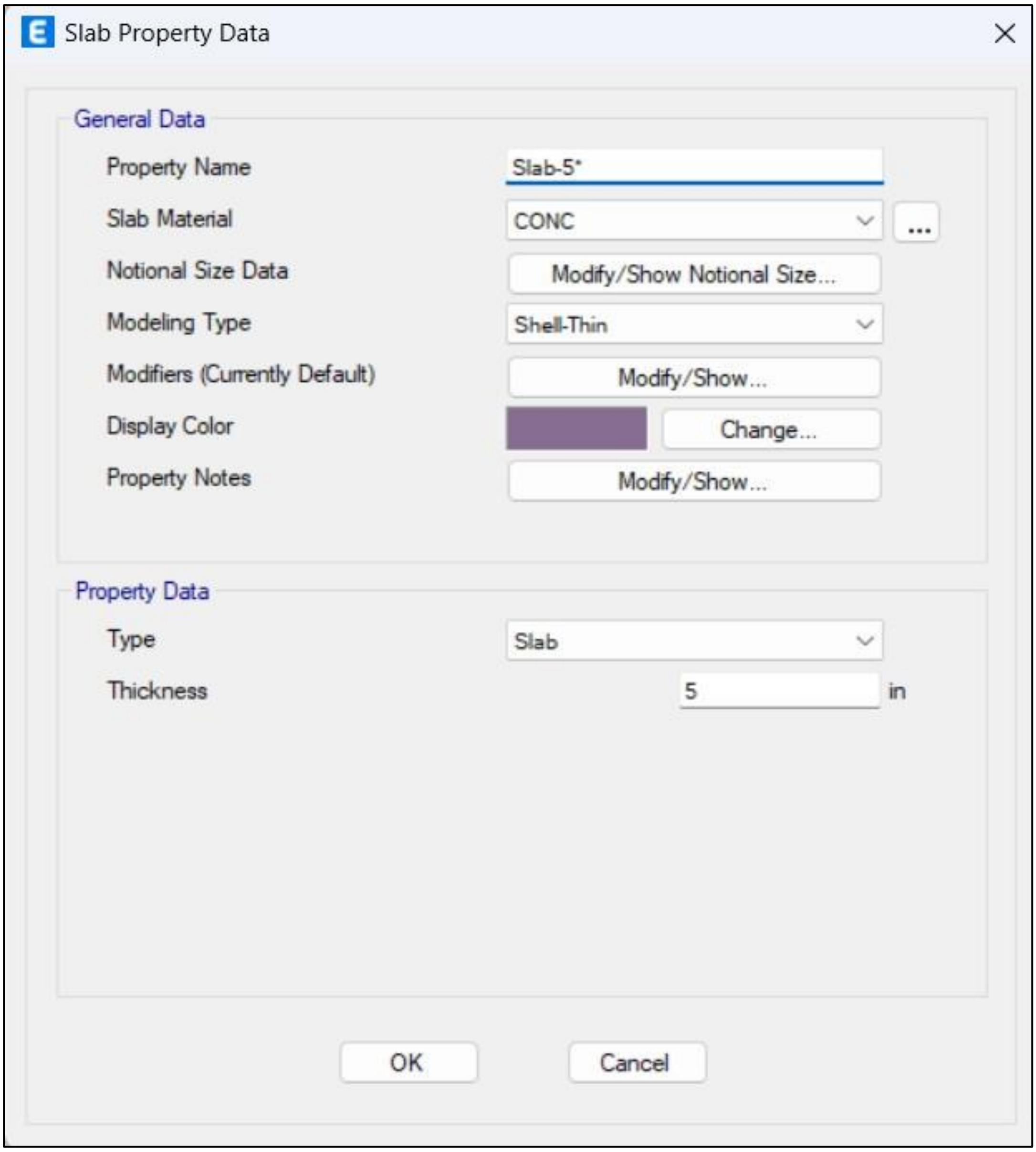


Figure 3. 21: Slab property

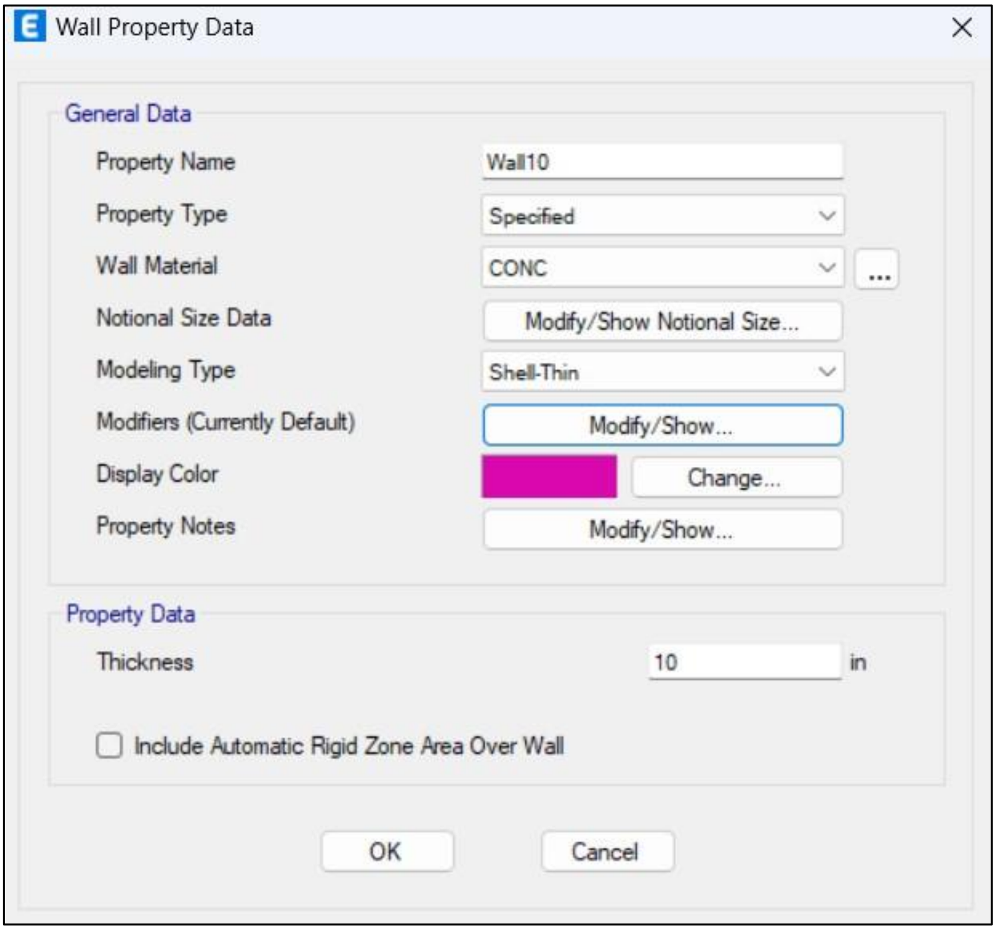


Figure 3. 22(a): Wall property

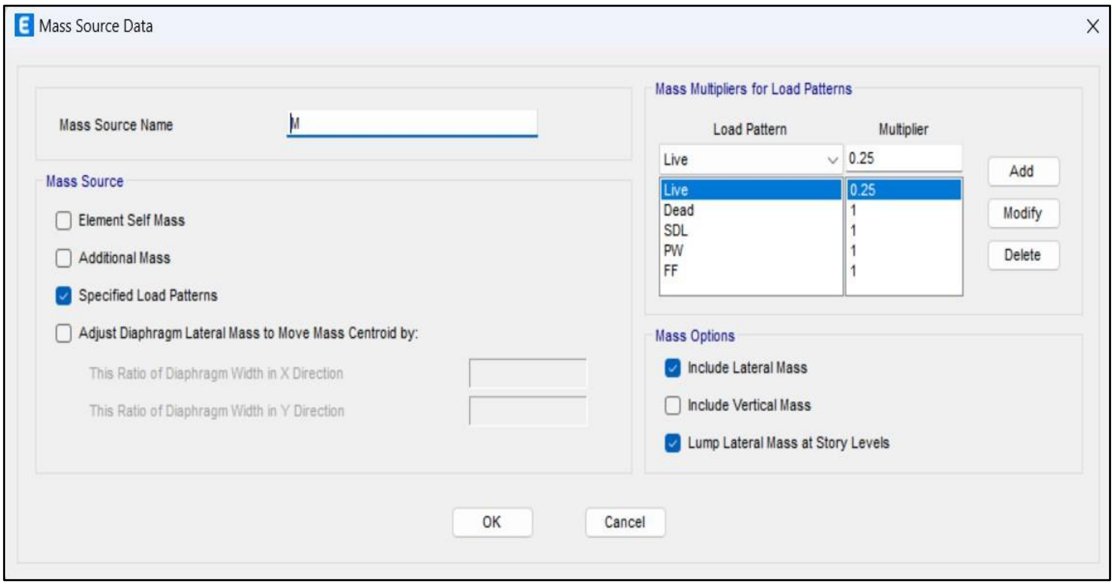
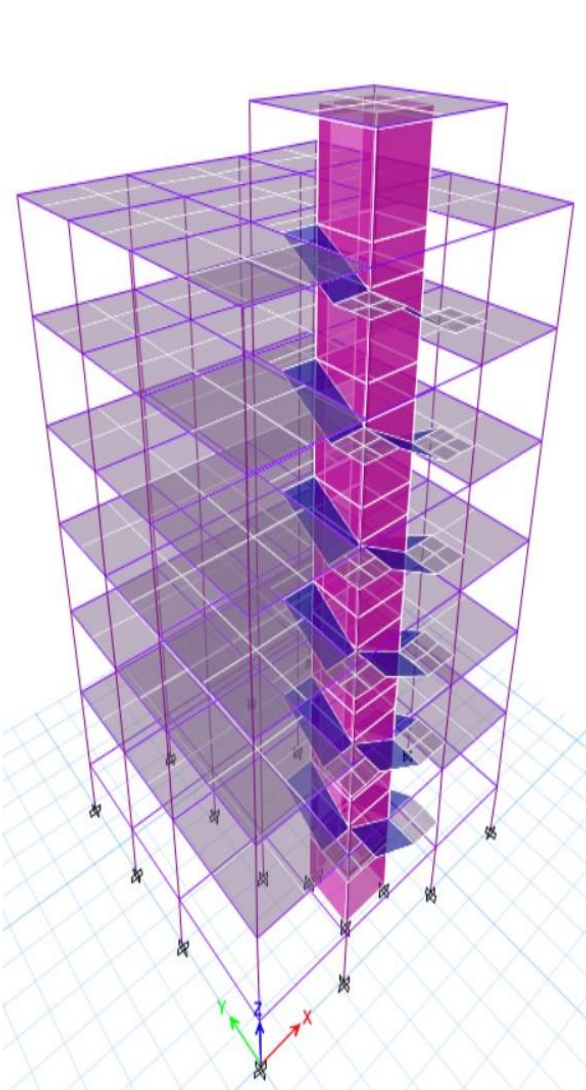


Figure 3. 22(b): Mass Source



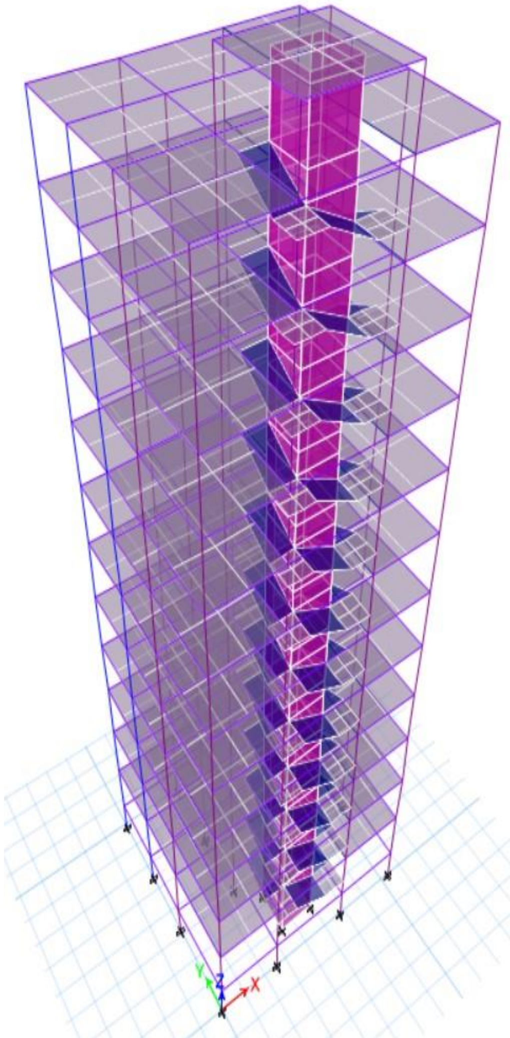


Figure 3. 23: 3D Model (6 Story) **Figure 3. 24: 3D Model (10 Story)**

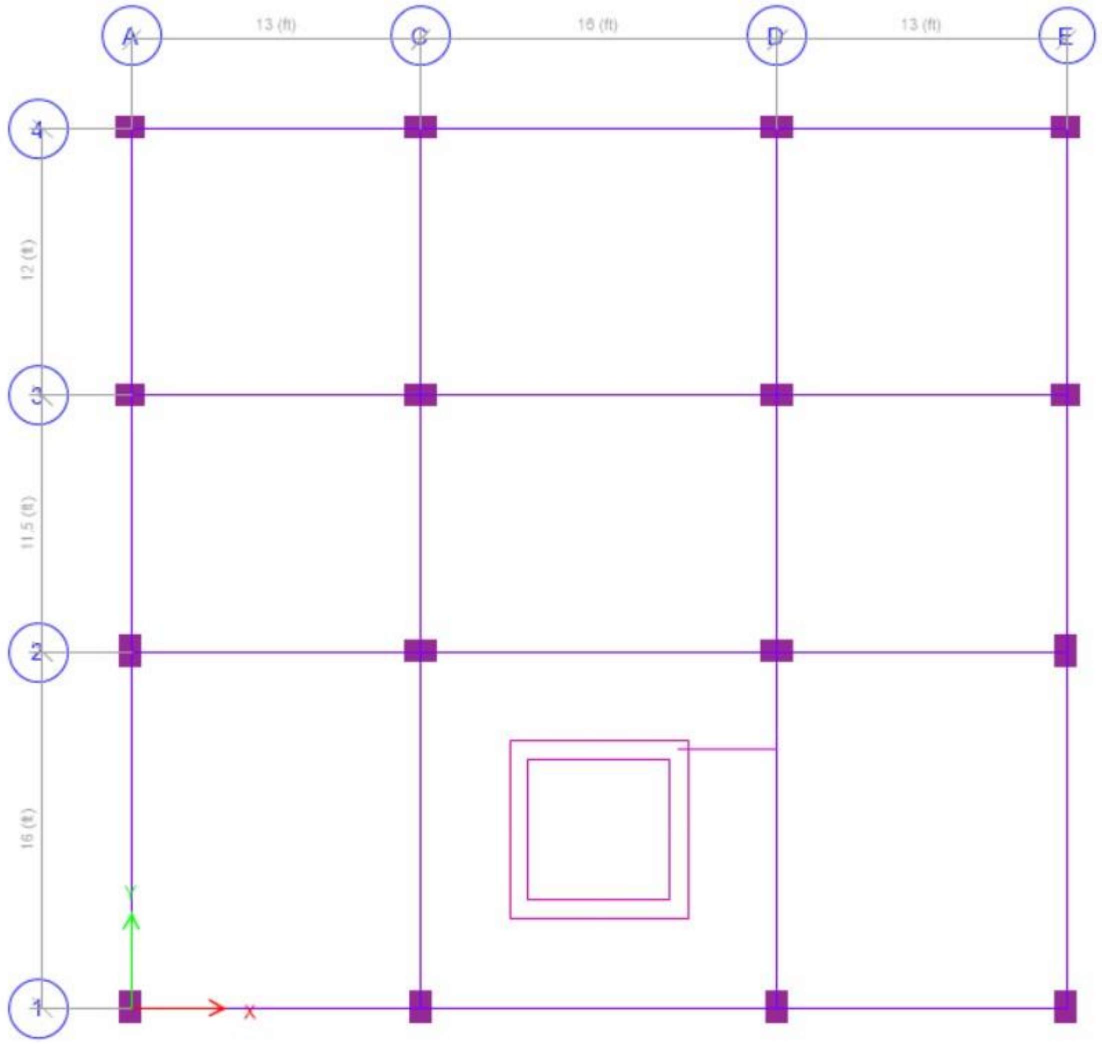


Figure 3.25: Plan for the 2D Model

3. 9. 7 Structure Need to complete the following steps.

1. Open the ETABS window
2. Click new 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 frame main toolbar and select plan view
6. Define load cases

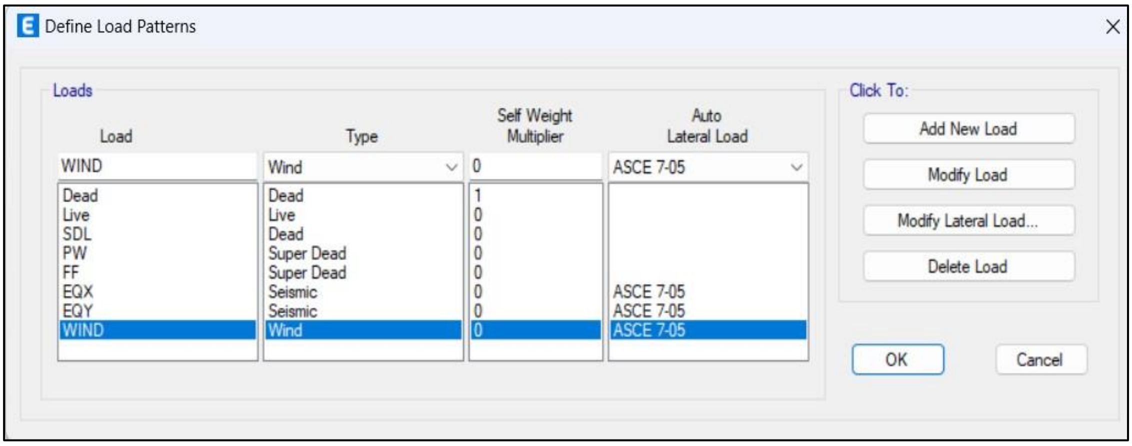
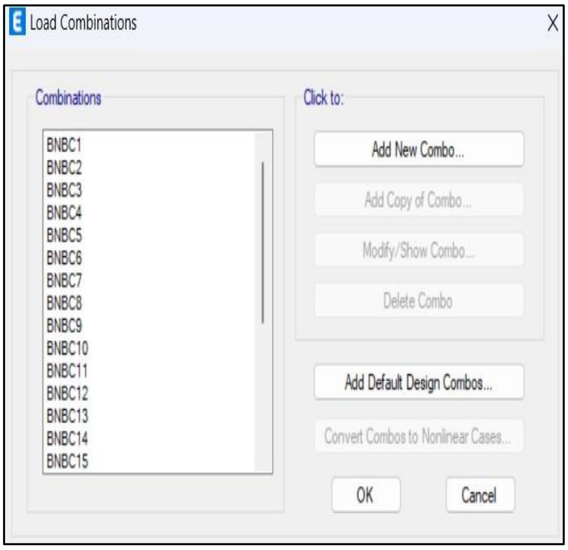


Figure 3. 26: Load pattern Assign for the model.



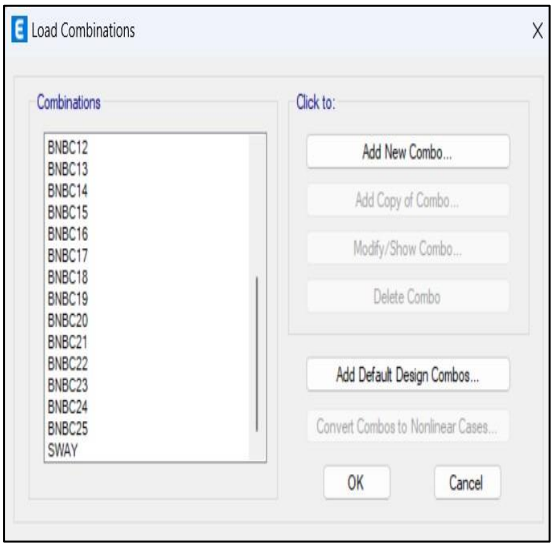


Figure 3. 27: Load Combination Assign for the model.

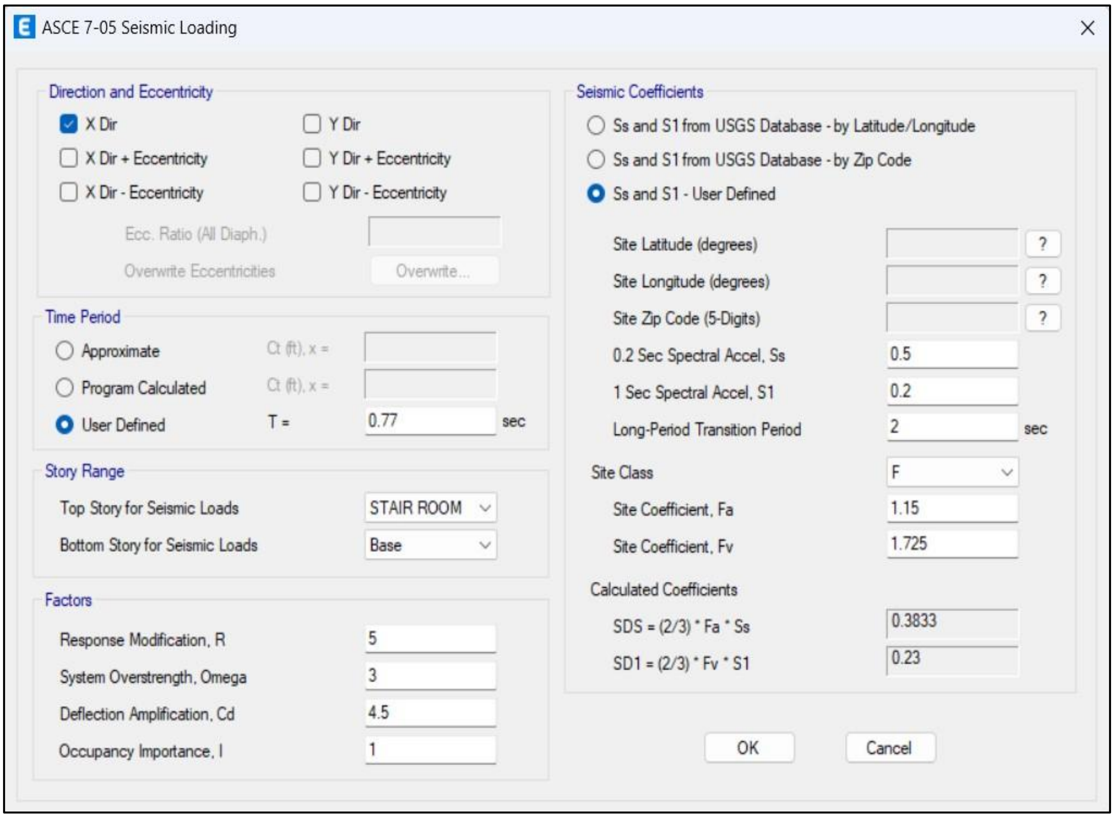


Figure 3. 28 (a):Define seismic load pattern –ASCE 7-05 For 6 Stories

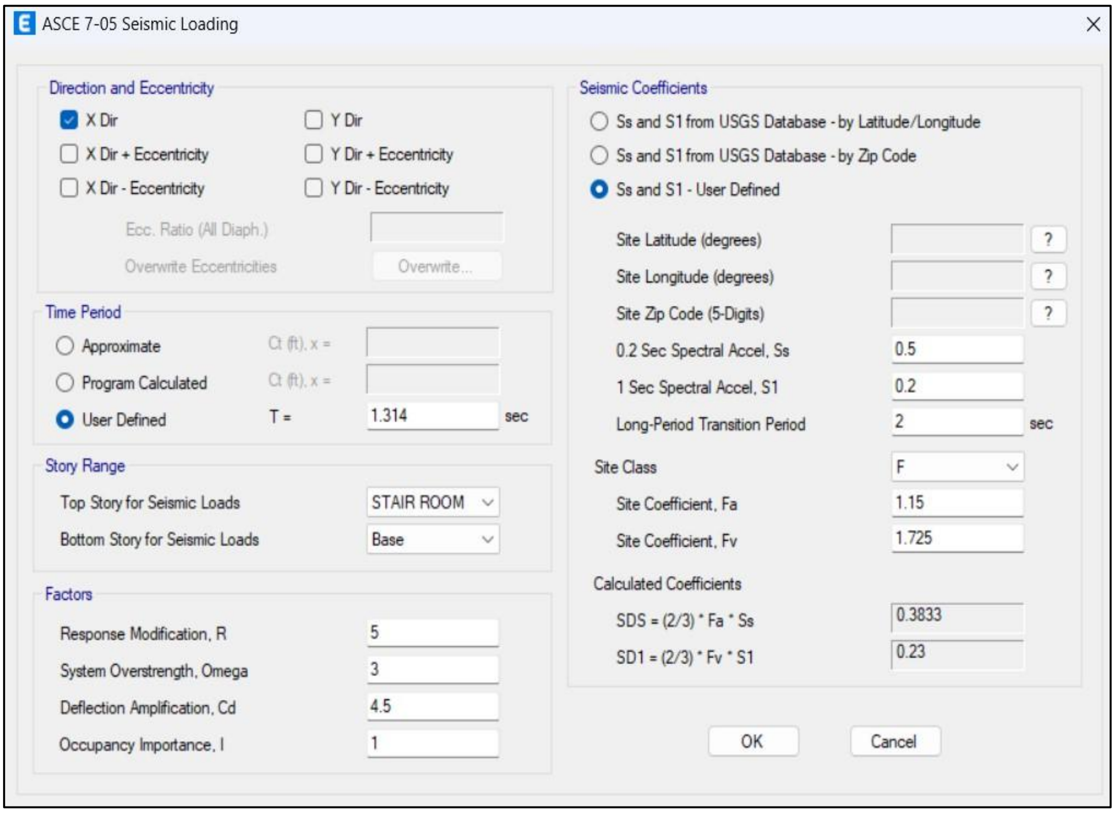


Figure 3. 28 (b): Define seismic load pattern –ASCE 7-05 For 12 Stories

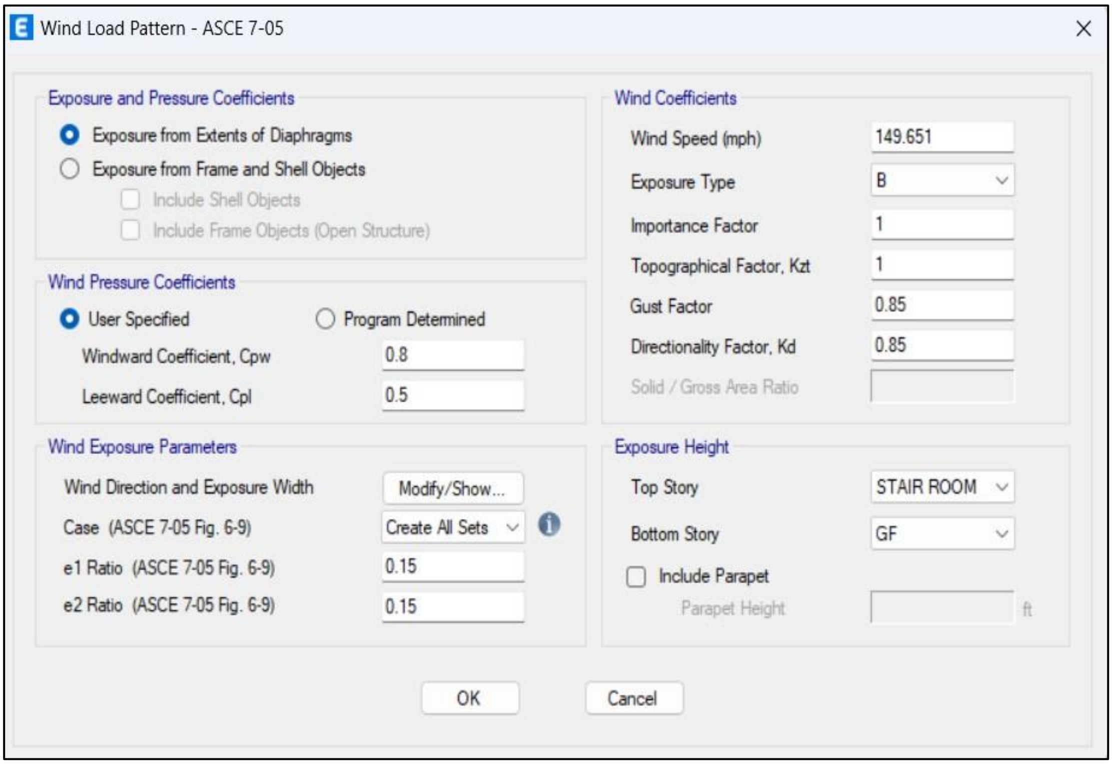


Figure 3. 29(a): Define Wind load pattern –ASCE 7-05 for 6 Stories

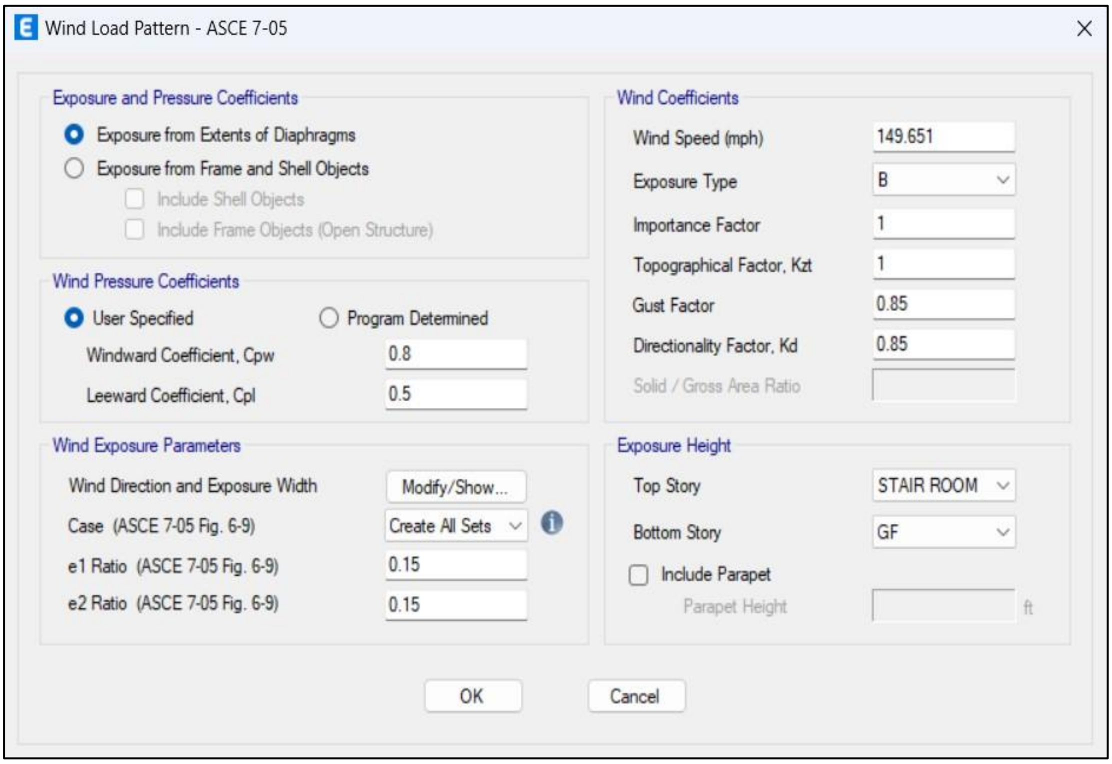
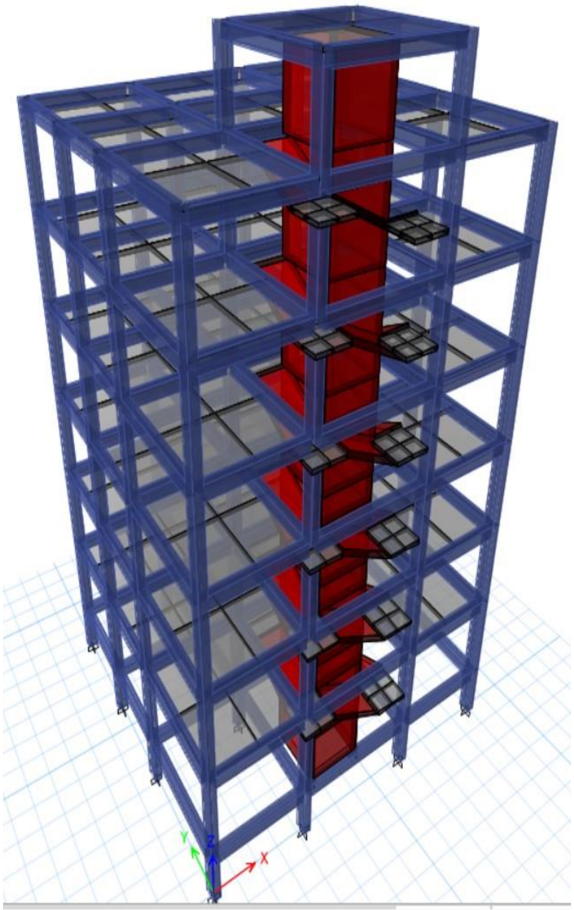


Figure 3. 29(b): Define Wind load pattern –ASCE 7-05 for 12 Stories

ETABS 3D MODEL:



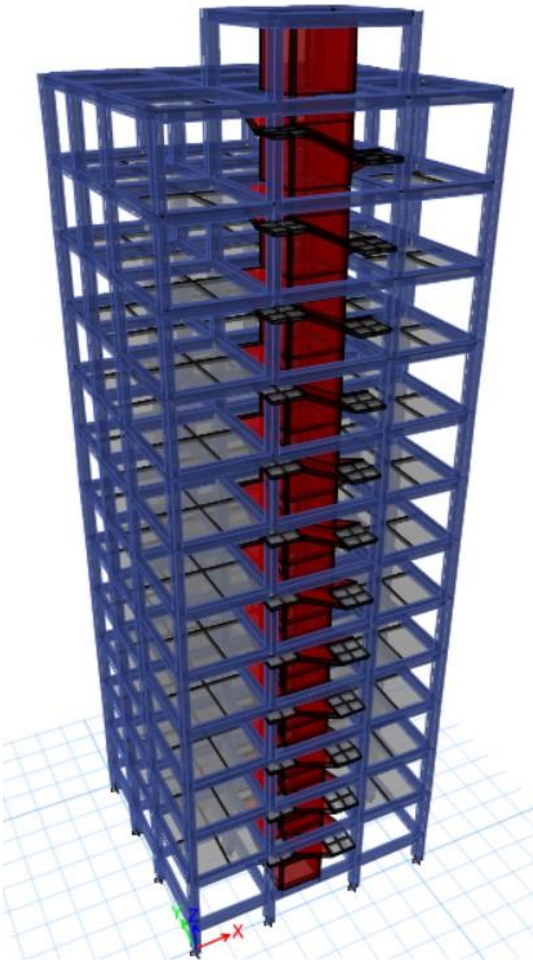


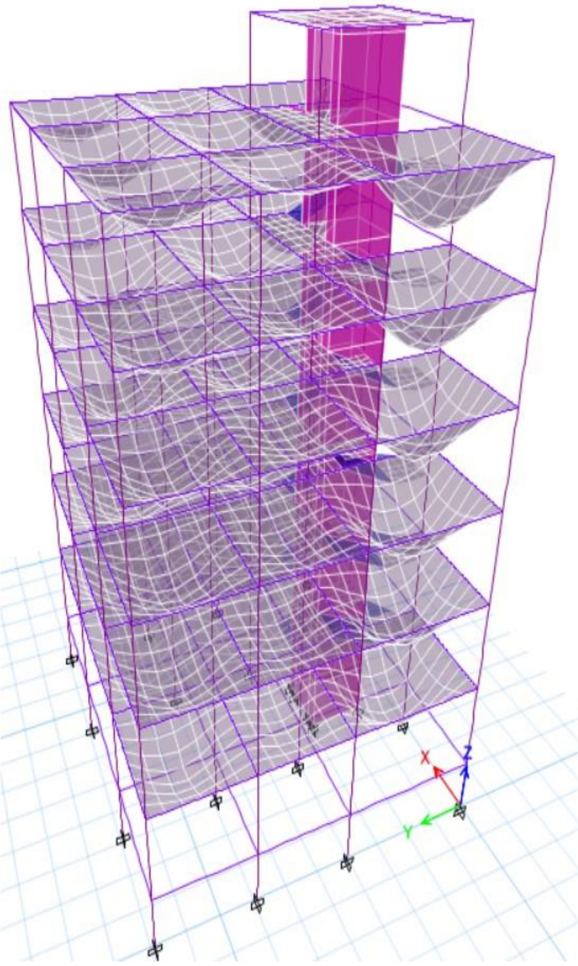
Figure 3. 30: Final 3D Model For 6 Stories

Figure 3. 31: Final 3D Model For 12 Stories

3. 9. 6 DEFLECT SHAPE OF THE MODEL:

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

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



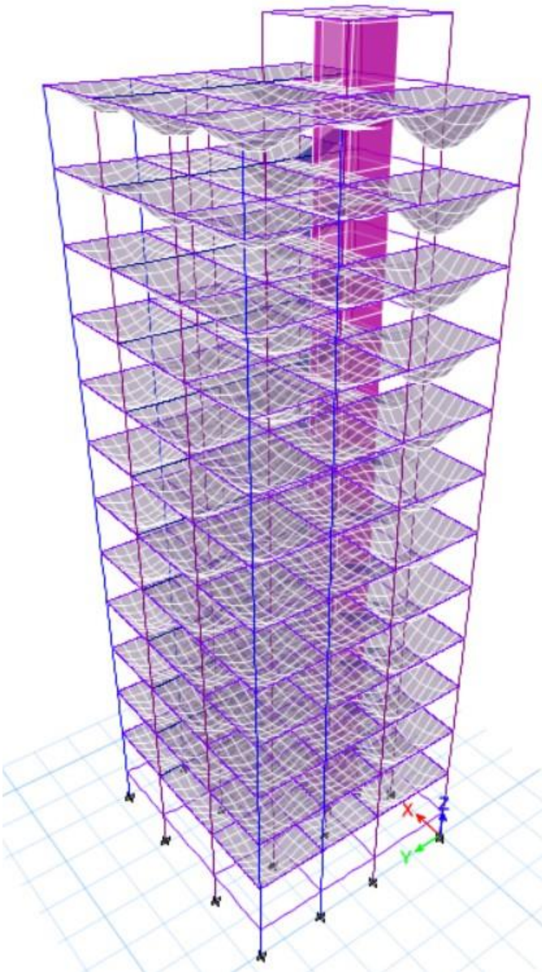


Figure 3. 32: Deflected Shape of the model low-rise

Figure 3. 33: Deflected Shape of the model High-Rise

CHAPTER 04

RESULT AND DISCUSSION

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4. 1 Introduction

In this chapter result output of the model has been shown and discussed. From the result comparison it is seen that comparisons of low-rise & High-Rise building according to BNBC 2020 using by ETABS have huge difference in designing methods and formulas.

4. 2 Drift and Building Separation (BNBC-2020)

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:

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

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

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

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

Table 4. 2. 1: Maximum Story Displacement

Load Type	Low-rise	High-Rise
	in	in
EQX	1. 291199	3. 835932
EQY	1. 138788	3. 962444
WX	0. 453412	2. 511097
WY	0. 415863	2. 696241

Table 4. 2. 2: Increase of Displacement Due to BNBC 2020

Load Type	Increase of Displacement (%)
EQX	197. 08
EQY	247. 95
WX	453. 82
WY	548. 35

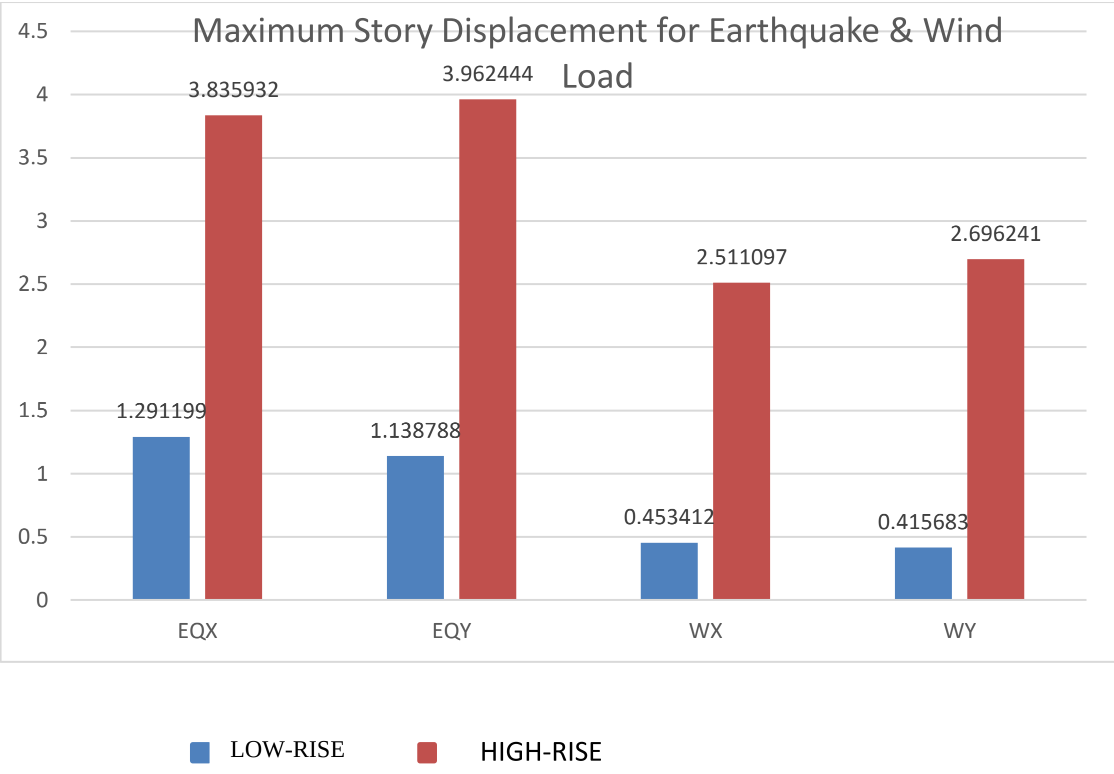

Figure 4. 1: Maximum Story Displacement for Earthquake and Wind-load .

4. 3 Drift and Building Separation (BNBC-2020)

Drift the 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 force (e. g., wind and earthquake loads). Calculate story drift shall include both translation and torsional deflections and confirm to the following requirements:

a) Story drift, A for loads other than earthquake loads, shall be limited as follows:

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

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

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

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

b) The deflections (δx) of level x at the center of the mass shall be determined in accordance with the following equation: $\delta_x = \frac{C_d \delta_{xe}}{I}$

Where, Cd = Deflection amplification factor

δ_{xe} = Deflection determined by an elastic analysis

I = Importance factor defined

The design story drift at story x shall be computed as the difference of the deflections at the centers of mass at the top and bottom of the story under consideration:

$\Delta_x = \delta_x - \delta_{x-1}$

Table 4. 3. 1: From BNBC-2020, Allowable Story Drift Limit (Δa)

Structure	Occupancy Category		
	I and II	III	IV
Structures, other than masonry shear wall structures, 4 stories or less with interior walls, partitions, ceilings and exterior wall systems that have been designed to accommodate the story drifts.	$0.025h_{sx}$	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

Notes:

1. h_{sx} is the story height below Level x.
2. There shall be no drift limit for single-story structures with interior walls, partitions, ceilings, and exterior wall systems that have been designed to accommodate the storey drifts.
3. Structures in which the basic structural system consists of masonry shear walls designed as vertical elements cantilevered from their base or foundation support which are so constructed that moment transfer between shear walls (coupling) is negligible.
4. Occupancy categories are defined in Table 6.1.1

Table 4. 3. 2: Maximum Story Drift (From ETABS)

Load Type	Low-rise	High-Rise
EQX	0. 002043	0. 003133
EQY	0. 001623	0. 003132
WX	0. 000757	0. 002129
WY	0. 00058	0. 002135

Table 4. 3. 3: Increase of Displacement Due to BNBC 2020

Load Type	Increase of Displacement (%)
EQX	53. 35
EQY	92. 98
WX	181. 24
WY	268. 10

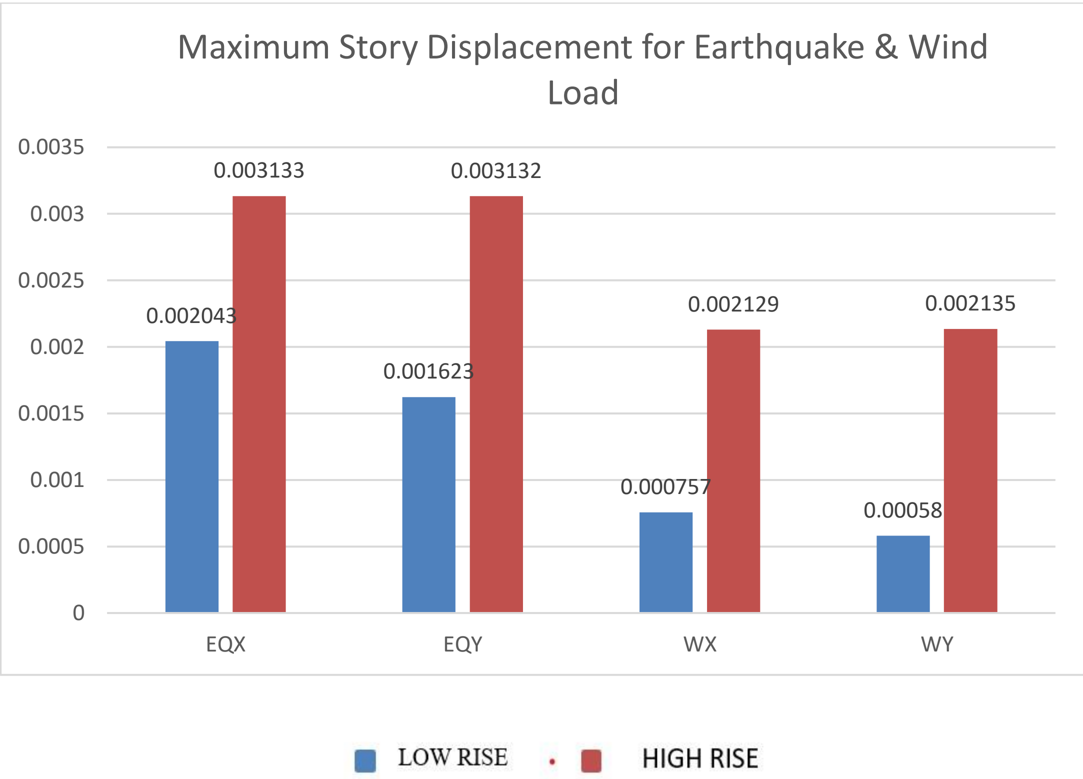

Figure 4. 2: Maximum Story Drift for Earthquake and Wind-load (Kushtia)

Table 4. 3. 4: Maximum Story Drift Calculation & Justification

For Earthquake Load:

Load Type	Low-rise	High-Rise	Deflection(δx)		Limit(δa)	Result
EQX	0. 002043	0. 003133	0. 00919	0.014098	0. 020	ok
EQY	0. 001623	0. 003132	0. 0073	0.014094	0. 020	ok

For Wind Load:

<table>
<tr><td>Load Type</td><td>Low-rise Δ/h</td><td>High-Rise Δ/h</td><td>Limit</td><td>Result</td><td rowspan="2">T= 0. 77 sec for Low-rise</td></tr>
<tr><td rowspan="2">WX</td><td rowspan="2">0. 000757</td><td rowspan="2">0. 002129</td><td rowspan="2">0. 004</td><td rowspan="2">ok</td></tr>
<tr><td rowspan="2">T=1. 314 sec for High-Rise</td></tr>
<tr><td>WY</td><td>0. 00058</td><td>0. 002135</td><td>0. 004</td><td>ok</td></tr>
</table>

4. 3. 1 Hand Calculation Result and ETABS Result of Earthquake Load and Wind Load:

<u>For Earthquake Load (For 6 Story, Height-74 Ft)</u>

<u>Step 01:</u>

Site Class: SC,

S=1. 15, Tb(S)=0. 2 sec, Tc=0. 6 sec, Td=2sec

Zone: Kushtia, Z=0. 2,

Occupancy Category: II=1

SDC=C,

<u>Step 02:</u>

Frame System= IMRF,

So, R=5, Ω_0 =3, Cd=4. 5

So, I/R=1/5=0. 2<1 ok

<u>Step 03:</u>

$T=Ct\ (hn)^m$

$=0.466\times (22.56)^{0.9}$

=0. 77 Sec

K=1. 135(By Interpolation)

Hn=6+60+8=74 Ft=22. 56 m
Ct=0. 0466
M=0. 9

<u>Step 04:</u>

$C_s=2.5S\eta\ \mathbf{(}Tc/T\mathbf{)}$ For $T_C \leq T \leq T_D$

=2. 5×1. 15×1× (0. 6/0. 77)=2. 24

Step 05:

S_a= (2/3) (ZI/R) C_s

= (2/3) (0. 2×1/5) ×2. 24=0. 0597 (ok)

0.67βZIS=0.67×0.11×0.2×1×1.15
=0. 01695
0. 044S_DSI=0. 044×0. 383×1
=0. 01685

Step 06:

FF= 207. 375 Kip

SDL=1262. 7Kip

PW=835. 69 Kip

Self Wt. =1576KiP

Total Dead Load: 3881. 765 Kip

Total Live Load: 630 Kip

Step 07:

Base Shear V, =Sa ×W

V=0. 0597× (3881. 765+0. 25× 630) =241. 14 Kip

From ETABS:

Table 4. 3. 5: EQ Result FOR Six Story from ETABS

Base Reactions

File Edit Format-Filter-Sort Select Options

Units: As Noted Hidden Columns: No Sort: None Base Reactions

Filter: None

Output Case	Case Type	Step Type	Step Number	FX kip	FY kip	FZ kip	MX kip-ft	MY kip-ft	MZ kip-ft
Dead	LinStatic			0	0	1576.795	27855.4065	-33297.9328	0
Live	LinStatic			0	0	643.451	11179.2102	-13512.4616	0
SDL	LinStatic			0	0	1262.701	27645.5757	-26516.7183	0
PW	LinStatic			0	0	867.14	18884.1799	-18288.1456	0
FF	LinStatic			0	0	201.037	4016.1289	-4106.4038	0
EQX	LinStatic			-241.694	0	0	6.656E-07	-11763.6464	4751.5055
EQY	LinStatic			0	-241.694	0	11763.6464	0	-5080.8615

For Earthquake Load (For 12Story, Height-134 Ft)

Step 01:

Site Class: SC,

S=1. 15, Tb(S)=0. 2 sec, Tc=0. 6 sec, Td=2sec

Zone: Kushtia, Z=0. 2,

Occupancy Category: II=1

SDC=C,

Step 02:

Frame System= IMRF,

So, R=5, Ω_0 =3, Cd=4. 5

So, I/R=1/5=0. 2<1 ok

Hn=6+120+8=134 Ft=40. 85 m
Ct=0. 0466
M=0. 9

Step 03:

$T=Ct(hn)^m$

$=0.466\times(40.85)^{0.9}$

=1. 134 Sec

K=1. 407(By Interpolation)

Step 04:

$C_s=2.5S\eta\,(Tc/T)$ For $T_C \leq T \leq T_D$

=2. 5×1. 15×1× (0. 6/1. 134)

=1. 312

Step 05:

$S_a= (2/3)\,(ZI/R)\,C_s$

= (2/3) (0. 2×1/5) ×1. 312=0. 035 (ok)

0. 67βZIS=0. 67×0. 11×0. 2×1×1.15
=0. 01695
0. 044S_DSI=0. 044×0. 383×1
=0. 01685

<u>Step 06:</u>

FF= 513. 825 Kip

SDL=2525. 4 Kip

PW=1714. 22 Kip

Self Wt. =3048 Kip

Total Dead Load: 7801 Kip

Total Live Load: 1098. 75 Kip

<u>Step 06:</u>

Base Shear V, =Sa× W

V=0. 035× (7801+0. 25×1098. 75)=282. 6 Kip

From ETABS:

Table 4. 3. 6: EQ Result FOR Twelve Story from ETABS

Base Reactions

File Edit Format-Filter-Sort Select Options

Units: As Noted Hidden Columns: No Sort: None Base Reactions

Filter: None

Output Case	Case Type	Step Type	Step Number	FX kip	FY kip	FZ kip	MX kip-ft	MY kip-ft	MZ kip-ft
Dead	LinStatic			0	0	3049.949	54560.5711	-64448.8484	-2.034E-06
Live	LinStatic			0	0	1125.655	19937.8397	-23638.7545	-6.942E-07
SDL	LinStatic			0	0	2525.402	55291.1514	-53033.4367	-3.639E-06
PW	LinStatic			0	0	1675.628	35742.3606	-35385.8027	-1.895E-06
FF	LinStatic			0	0	435.849	8784.5901	-8899.0078	0
EQX	LinStatic			-278.094	0	0	4.617E-06	-25724.8667	5527.3406
EQY	LinStatic			0	-278.094	0	25724.8669	-4.011E-06	-5848.4599

For Wind Load (For 6 Story, Height-74 Ft or 22. 56m)

Wind Speed:66. 9m/s or 149. 651 mile/hr

I=1, Exposure -A, G_F=0. 85, K_d= 0.85, K_{zt}= 1

$K_z = 2.01(z/z_g)^{(2/\alpha)}$ 4. 57m≤z≤z_g

$K_z = 2.01(4.57/z_g)^{(2/\alpha)}$ z<4. 57m

z_g =1200 ft=365.76m, α=7,

For windward: C_p=0. 8

For Leeward: C_p=0. 5

Table 4. 3. 7: K_z, q_z, p_z value for six story

Height m	Floor	K_z	For Windward		For Leeward	
			q_z	p_z	q_h	p_z
0	GF	0. 5746	1.340	0. 911	2.064	0.88
3.050	1F	0. 5746	1.340	0. 911		
6. 097	2F	0. 6240	1.455	0. 989		
9. 146	3F	0. 7006	1.633	1. 110		
12. 195	4F	0. 7606	1.770	1. 200		
15. 240	5F	0. 8107	1.8905	1. 285		
18. 290	Roof	0. 8541	1.990	1. 350		
20. 730	Stair room	0. 8852	2.064	1. 400		

Formula: $q_z = 0.00613\ K_z\ K_{zt} K_d V^2 I$ kN/M^2

$P_z = q_z G_F C_p$

Table 4. 3. 8 Design Force For six Story

Floor	Force in x Direction		Force in y Direction	
	Hand Calculation-KN	ETABS	Hand Calculation-KN	ETABS
GF	32. 88	32. 83	34. 96	34. 92
1F	65. 77	65. 80	69. 92	69. 96
2F	68. 63	68. 50	72. 97	72. 86
3F	73. 08	72. 92	77. 69	77. 54
4F	76. 38	76. 45	81. 20	81. 29
5F	79. 50	79. 38	85. 52	84. 40
Roof	81. 89	73. 58	87. 06	78. 24
Stair room	13. 56	13. 47	13. 5685	13. 47

Calculation for 1st floor

Force in x Direction: $(P_{zw} + P_{zl}) \times 12.04 \times 3.05 = (0.911 + 0.88) \times 12.04 \times 3.05$

$= 65.77 KN$

Force in y Direction: $(P_{zw} + P_{zl}) \times 12.8 \times 3.05 = (0.911 + 0.88) \times 12.8 \times 3.05$

$= 69.92 KN$

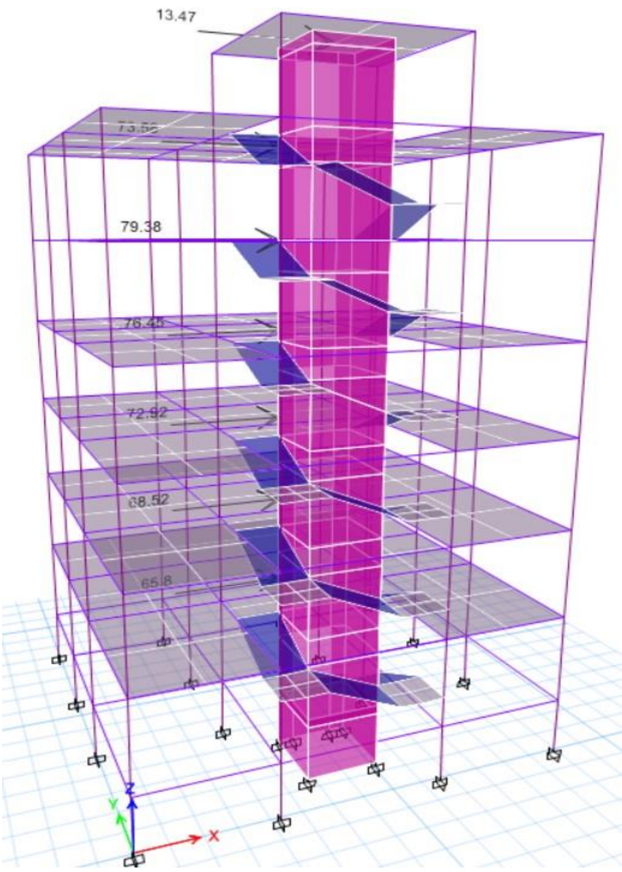

Figure 4. 3. 1 Force in x Direction

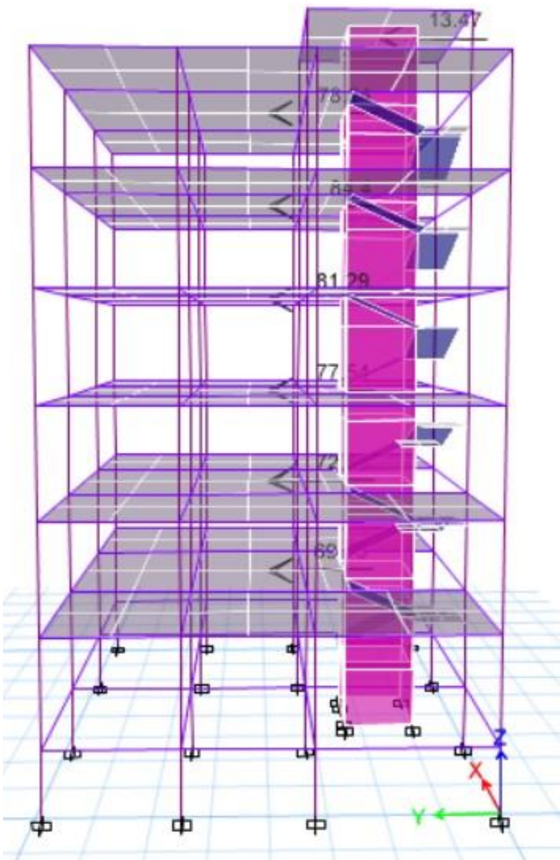

Figure 4. 3. 2 Force in y Direction

For Wind Load (For 12 Story, Height-134 Ft or 40. 85 m)

Wind Speed:66. 9m/s or 149. 651 mile/hr

I=1, Exposure -A, G_F=0. 85, K_d= 0.85, K_{zt}= 1

$K_z = 2.01(z/z_g)^{(2/\alpha)}$ 4. 57m≤z≤zg

$K_z = 2.01(4.57/z_g)^{(2/\alpha)}$ z<4. 57m

z_g =1200 ft=365.76m, α=7,

For windward: C_p=0. 8

For Leeward: C_p=0. 5

Table 4. 3. 9 K_z, q_z, p_z value for twelve story

Height m	Floor	K_z	For Windward		For Leeward	
			q_z	p_z	q_h	p_z
0	GF	0. 5746	1. 34	0. 911	2. 47	1. 05
3. 05	1F	0. 5746	1. 34	0. 911		
6. 097	2F	0. 6240	1. 455	0. 989		
9. 146	3F	0. 7006	1. 633	1. 11		
12. 195	4F	0. 7606	1. 77	1. 20		
15. 24	5F	0. 8107	1. 8905	1. 285		
18. 29	6F	0. 8541	1. 99	1. 35		
21. 34	7F	0. 8925	2. 08	1. 41		
24. 39	8F	0. 927	2. 161	1. 469		
27. 44	9F	0. 959	2. 236	1. 52		
30. 49	10F	0. 988	2. 3	1. 564		
33. 54	11F	1. 02	2. 378	1. 617		
36. 59	Roof	1. 04	2. 425	1. 649		
39. 02	Stair room	1. 06	2. 471	1. 68		

Formula: $Q_z = 0.00613\ K_z\ K_{zt} K_d V^2 I$ kN/M^2

$P_z = q_z G_F C_p$

Table 4. 3. 10 Design Force for Twelve Story

Floor	Force in x Direction		Force in y Direction	
	Hand Calculation-KN	ETABS KN	Hand Calculation-KN	ETABS KN
GF	36.006	36.09	38.28	38.37
1F	72.012	72.18	76.56	76.75
2F	74.88	74.90	79.60	79.64
3F	79.32	79.30	84.32	84.32
4F	82.62	82.83	87.84	88.07
5F	85.75	85.76	91.16	91.19
6F	88.13	88.29	93.70	93.88
7F	90.33	90.54	96.04	96.27
8F	90.50	92.56	98.34	98.42
9F	94.38	94.41	100.33	100.39
10F	95.99	96.19	102.05	102.20
11F	97.94	97.71	104.12	103.89
Roof	99.11	89.19	105.37	94.84
Stair room	16.24	16.20	16.24	16.20

Calculation for 1st floor

Force in x Direction**:** (P_{zw} + P_{zl}) ×12. 04 ×3. 05= (0. 911+1.05) ×12. 04 ×3. 05

=72.012 kN

Force in y Direction**:** (P_{zw} + P_{zl}) ×12. 8 ×3. 05= (0. 911+1.05) ×12. 8 ×3. 05

=76.56 kN

Stair Room= (1. 68+1. 05) ×4. 88×2. 439=32.49 kN/2=16. 24 kN

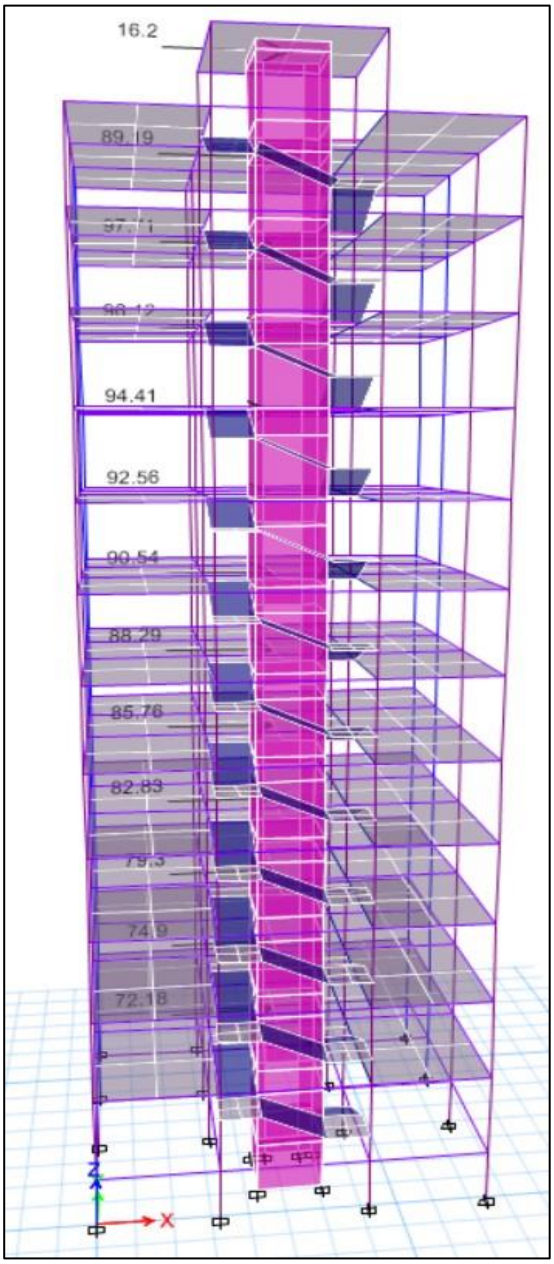

Figure 4. 3. 3 Force in x

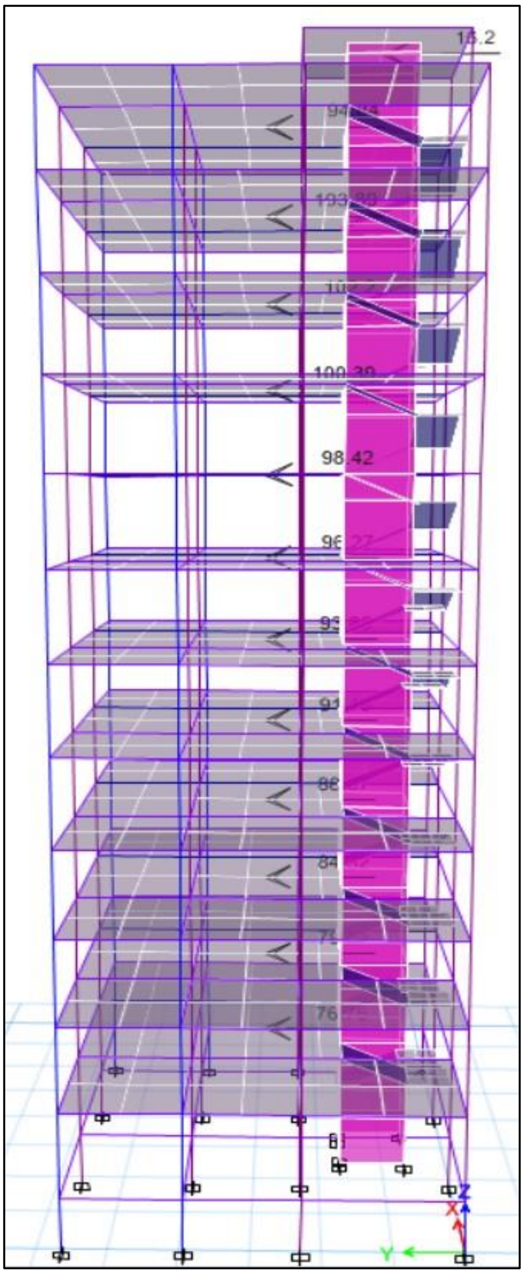

Figure 4. 3. 4 Force in y

4. 4 Result Comparison and Discussion

Finally, we get this result for lateral load

- Earthquake effect on X-direction of High-Rise Building is greater than Low-rise Building.
- Earthquake effect on Y-direction of High-Rise Building is greater than Low-rise Building
- Wind effect on X-direction of High-Rise Building is greater than Low-rise Building.
- Wind effect on X-direction of High-Rise Building is greater than Low-rise Building.
- Earthquake effect on X-direction is greater than earthquake effect on Y-direction.
- Wind effect on X-direction is greater than Wind effect on Y-direction.
- Earthquake effect on X-direction is greater than wind effect on Y-direction.
- Earthquake effect on X-direction is greater than Wind effect on Y-direction.
- Low-rise multi-story structures are about 2.7 times more affected due to earthquake than wind forces.
- High-Rise stories are equally influenced by the wind and earthquake forces. The wind influence increases three times more if the height increases further.
- The low-rise structure are equally vulnerable as much as High-Rise structures from earthquake forces.
- Story drift goes on decreasing as height of building increases whereas story Displacement increases as height of building increases.

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. In this study, the maximum story displacement of low-rise to High-Rise multi-story structure is 197. 08%, 247. 95%, 453. 82% and 548. 35% for load EQX, EQY, WX and WY respectively. And the maximum story drift of low-rise to High-Rise multi-story structure is 53. 35%, 92. 98%, 181. 24%, and 268. 10% for load EQX, EQY, WX and WY respectively.

The comparison of the aforesaid design parameters is depicted graphically, and relevant tables are presented in this research article. In comparison of wind load and seismic effect on low-rise and high-rise multi-story structures, the requirements of BNBC 2020 usually result in a less cost-effective design with a higher safety margin.

CHAPTER 05

CONCLUSION AND RECOMMANDATION

---

5. 1 Conclusions and Future Works From the study is observed that.

- Effects of wind and earthquake are very important for building design.
- The wind and earthquake load increases with height of structure.
- The lateral displacement due to the earthquake of the structure analysis in high-rise buildings is more than the lateral displacement of the structure analysis in low-rise buildings by the BNBC-2020 code.
- lateral displacement due to the wind load of the structure analysis in high-rise buildings is more than the lateral displacement of the structure analysis in low-rise buildings by the BNBC-2020 code.
- The value of inter-story drift is slightly greater than the structural analysis in high-rise buildings compared to the low-rise buildings by the BNBC-2020 code.
- The building is analyzed linearly for seismic design.
- The building does not analyze non-linearly for seismic loads
- All loads are taken according to BNBC code provided and Calculated from the model.
- The analysis data and Hand Calculated data have been compared. They are about similar.
- It is observed that, the lateral forces excited on the structure have shown increasing severity with increase in the wind speed and earthquake zone factor.

5.2 Limitations and Recommendations

5. 2.1 Limitations

- The buildings is fully analyzed for seismic loads and wind loads by preliminary and detailed design procedure.
- In this study, only the ETABS software is used for the analysis.
- The building is not designed for any expansion (Horizontally or vertically) in future.
- Reinforcement details are not calculated for slab & shear wall.
- Construction cost is not calculated.
- In this study, wind load and seismic effect is compared only for zone 2.
- The study has not considered any adjacent building.

5. 2.2 Recommendations

- The section design, estimating and costing can also be compared.
- BNBC should develop its own concrete, steel design code like ACI, AISC, IS, so that it can be directly inputted into ETABS. Then we will get exact result.
- Only zone 02 was analyzed. Analysis of all zones including the remaining three zones will give a complete comparison.
- It can be possible to build high-rise multi-storey building in seismic zone -02. but for this we have to extend reinforcement size than low-rise building's reinforcement size. And also have to extend column and beam size too. We should use shear wall in high-rise to reduce seismic effect.

5.3 Recommendations for Future Works

- The study can be used as a reference before designing a building in kushtia.
- The research has not considered any nearest building. But pounding effects between adjacent buildings should be checked if there are adjacent building.
- The study has been performed for a concrete moment resisting frame for seismic zone 2 and wind force 66.9 m/s. Other building types in a different wind and seismic zone, such as conventional moment resistant frames, structural steel, masonry buildings and so forth can benefit from a similar analysis.
- The case study conducted in this research is, it is possible to do a parallel investigation for other types of occupancy category and exposure category.
- The two building is analyzed for only zone 2. Thus, why zone to zone load effect comparison, stability comparison hasn't done. In future, zone to zone comparison of wind load and seismic effect on low-rise and high-rise multi-story structures should be analyzed.

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