WEAK STORIED CHECK FOR RESIDENTIAL BUILDING USING ETABS-2016

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A thesis submitted to the Department of Civil Engineering in partial fulfilment
For the degree of Bachelor of Science in Civil Engineering

Department of Civil Engineering

Sonargaon University

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

Section: 17B

Semester: Fall-2022

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DECLARATION

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

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Dedicated

to

"Our 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.

The base floors of the existing buildings are generally arranged as garages or offices. No walls are built in at these floors due to its prescribed usage and comfort problems. But upper floors do have walls separating rooms from each other for the residential usage. In these arrangements, the upper floors of most buildings are more rigid than their base floors. As a result, the seismic behaviours of the base and the upper floors are significantly different from each other. This phenomenon is called as the weak-storey irregularity. Weak stories are subjected to larger lateral loads during earthquakes and under lateral loads their lateral deformations are greater than those of other floors so the design of structural members of weak stories is critical and it should be different from the upper floors.

In this paper; the seismic behaviour of weak-storey is studied. Calculations are carried out for the building models which are consisting of various stories, storey heights and spans. Some weak-storey models are structural systems of existing buildings which are damaged during earthquakes. The results are compared with the current earthquake code. The ratio of buildings which have weak-storey irregularity is determined for both Ankara and Eskisehir regions. It is observed that negative effects of this irregularity can be reduced by some precautions during the construction stage. Also some recommendations are presented for the existing buildings with weak-storey irregularity**.** Soft storeys in a high-rise building have a significant impact on its seismic performance. There is a discontinuity in the rigidity of the structure at the soft storey level due to a lack of infill walls or a variation in floor height. This continuity is the cause of structural failure in multi-story buildings subjected to earthquake loads.

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NOTATIONS

BNBC	Bangladesh National Building Code
ACI	American Concrete Institute
UTM	Universal Testing Machine
GR	Gauge Reading
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
RMC	Ready Mix Concrete
PSI	Pound per Square Inch
W/C	Water Cement Ratio
PWD	Public Works Department
NSP	Nonlinear Static Procedures
RC	Reinforced Concrete
PGA	Peak Ground Acceleration
DL	Dead load
LL	Live Load
g	Gravitational Acceleration
h	Overall Thickness of Slab or Depth Of Beam In Inch
hx	Height in Feet Above the Base to Storey Level I And X Respectively
I	Structure Importance Coefficient
l	Span Length of Beam in Inch
R	Response Modification Coefficient for Structural System
S	Site Coefficient for Soil Characteristics
T	Fundamental Period of Vibration of the Structure in Second
V	Total Design Lateral Force or Shear at the Base
Kd	Directionality Factor
Kzt	Topographic Factor

CHAPTER 1

INTRODUCTION

1.1 General:

Weak Story: This irregularity refers to the existence of a building floor presenting a lower lateral structural resistance than the immediate superior floor or the rest of the floors of the building.

“Soft story” and “weak story” are irregular building configurations that are a significant source of serious earthquake damage. These configurations that are essentially originated due to architectural decisions have long been recognized by earthquake engineering as seismically vulnerable. In terms of seismic regulations their irregular condition requires the application of special considerations in their structural design and analysis. The majority of urban zoning regulations in contemporary cities, although, at present encourages and in some cases enforces the use of them not requiring special considerations. This paper analyses the architectural reasons why these configurations are present in contemporary cities and explains in conceptual terms their detrimental effects on building seismic response. These effects are presented from a multidisciplinary perspective -engineering, architecture and urban planning- because their treatment can only be achieved by an integrated approach that recognizes the interaction between these disciplines. Examples of damage due to these effects are analyzed (Taranath, July 2016).

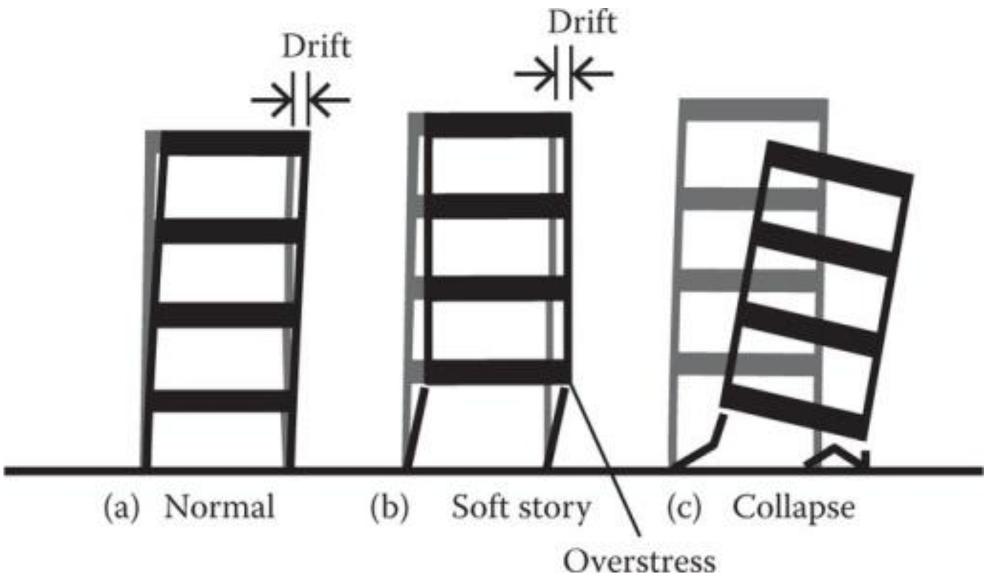


Figure 1.1: Weak Story Elevation

1.2 BACKGROUND AND MOTIVATIONS:

This study's first objective is to look into weak stories in distinct structural zones for static and dynamic testing in typical minute opposing casing. For the seismic investigation, we looked at a residential building with (G+4) stories. The fundamental requirements relating to the fundamental security of structures are attached by a method for establishing the base plan loads that must be acquired for dead loads, forced burdens, and other external loadings. ETABS software was used to examine the entire structure on a computer. An analysis of a (G+4=5) RCC building subjected to seismic loads for the Cox's Bazar District is presented in this research (Zone III). According to BNBC 2020, many load combinations are seen.

1.3 RESEARCH OBJECTIVES AND OVERVIEW

- To check a G+04 (05) Weak storied Residential building using ETABS-2016.
- Analysis the different cases of factor load for Weak storied Residential building.
- To study the wind load and Earthquake load effect on G+04 storied Residential building structures for seismic zone-III in Bangladesh according to BNBC 2020 by using ETABS.

This work aims to demonstrate the validity and efficiency of the pushover analysis method as incorporated in ETAB-2016. It will also investigate the effectiveness of pushover analysis in comparison to more rigorous nonlinear time history analysis, with a focus on the load pattern used in pushover analysis. Finally, the performance of building frames designed in accordance with BNBC 2020 will be measured against serviceability targets.

1.4 ORGANIZATION OF THE THESIS:

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

Chapter 2: Literature Review. This part discusses the previous analysis history about earthquake or seismic wave, soil properties describe, partition wall, recent research on seismic zone, seismic design requirements as per BNBC-2020, lift pit details specifications, wind load and wind load code provisions as per BNBC-2020, seismic load and seismic load code provisions as per BNBC-2020 for research of weak storied residential building using ETABS-2016.

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

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

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

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION:

Soft storey is a common building weakness. The term soft storey explains one level of a building that is appreciably more flexible than the stories above it and the floors or the foundation under it. Buildings are classified as having a soft storey if that level is less than 70% as stiff as the floor instantly above it or less than 80% as stiff as the average stiffness of the three floors above it. Open ground storey buildings are called soft storey building, whereas their ground storey may be weak or weak. The weak or soft storey commonly exists at the ground storey level, but it might be at any other storey level. Soft storey buildings have a lot of open space for example, parking garage, restaurants or floors with lots of windows. The behaviour of soft storey building in an earthquake is very crucial because the soft storey building is more flexible in seismic condition, vibration is happening in the soft storey building so we provide shear wall in a soft storey building (shear wall resists the effect of an earthquake) (K).

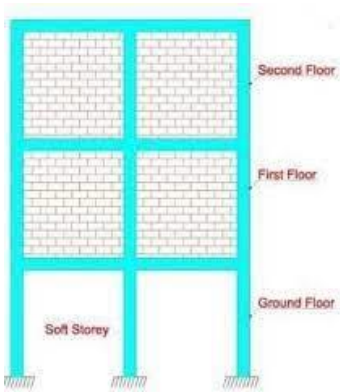


Figure 2.1: Weak Storey Building

We would like to check the structure for Vertical irregularity 5a or 5b (according to ACI) i.e., check for weak story. It is mentioned that structure has weak story if shear strength of story is less than 80%of shear strength of story above. Also, extreme weak story if shear strength of story is less than 65% of shear strength of story above (Areeb, May 14, 2018 in Seismic Design).

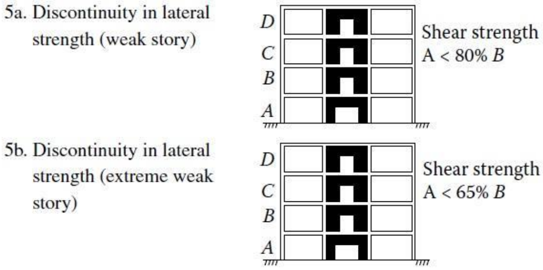


Figure 2.2: Weak Storey Strength

Reinforced concrete frame structures have become a common form of construction with masonry infill in urban and semi urban areas in the world. The infill framed structures are made and analysed by the combination of a moment resisting plane frame and infill masonry walls. The infill masonry may be of brick, concrete blocks, or stones. Ideally in present time the reinforced concrete frame is filled with bricks as non-structural wall of partition of the rooms because of its advantages such as, thermal insulation, durability, cost and simple construction technique. Nowadays, many buildings are constructed having a unique feature i.e. the ground floor remains open, which means the columns in the ground floor do not have any partition walls between them. This type of structure (Fig. 1.2) having no infill masonry walls in ground floor, but having infill masonry walls in all the upper floors, are called Open Ground Storey (OGS) Buildings. This open ground floor structure is also termed as a structure with 'soft storey at Ground Floor'. OGS buildings are also known as open first storey building (when the floor numbering starts with one from the ground floor itself), pilots, or stilted buildings. Open first storey is nowadays unavoidable feature for the most of the urban multi-storey buildings because social and functional needs for parking, restaurant, commercial use etc. are compelling to provide an open first Storey in high rise structure. Parking has become a necessary feature for the most of urban multi-storeyed buildings as the population is increasing at a very fast rate in urban areas leading to crisis of vehicle parking space. Hence the trend has been to use the ground floor of the building itself for parking purpose.

Figure 2.3: Model of a Building with Soft Storey at Ground Floor

2.2 FAILURE OF A WEAK STOREY:

Metropolitan cities' multi-story structures must have an open, taller first floor for parking vehicles and/or due to a scarcity of horizontal space and the expensive expense, a huge space for a meeting room or a banking hall. The first level has less strength and stiffness than the upper stories, which are reinforced by brick infill walls, as a result of this practical requirement. In multi-story buildings, this characteristic of building construction causes problems with weak or soft storeys. Extreme deflections caused by the first story's increased flexibility in turn cause a concentration of forces at the connections to the second storey and cause significant plastic deformation. Additionally, the soft column of the soft material dissipates the majority of the energy generated by the earthquake.

Figure 2.4: Failure of Weak storey building

2.2.1 CAUSES OF SOFT STOREY.

There are many practical reasons for having fewer walls at the ground level of a building. A building may have larger public spaces at this entry level, such as lobbies, large meeting rooms or open-plan retail space. In urban locations, residential buildings sometimes have fewer walls at the ground level to allow for parking underneath the building which is shown in figure below.

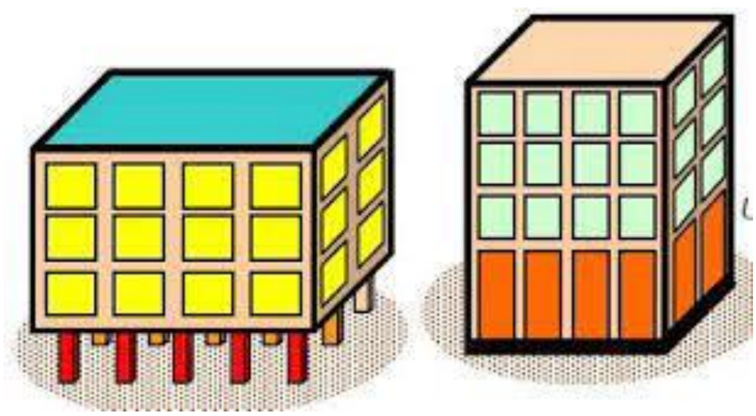


Figure 2.5: Causes of Weak storey building

2.2.2 IRREGULARITY IN STRENGTH AND STIFFNESS OF WEAK AND SOFT STOREY:

A weak storey is one in which the lateral strength of the storey is less than 80% of that of the storey above. The overall lateral strength of the storey. The shear capacity of the column or the shear wall, or the horizontal component of the axial capacity of the diagonal braces, are all seismic resistant elements that share the storey shear for the direction under discussion. The weakness that commonly causes a storey to be weak is insufficient frame column strength. A soft storey is one in which the late al stiffness is less than 70% of the stiffness of the storey above, or less than 80% of the combined stiffness of the three levels above. The primary characteristics of a weak or soft story. In case building with a flexible storey, such as the ground storey consisting of open spaces for parking that is stilt buildings. A special arrangement needs to be made to increase the lateral strength and stiffness of the soft/open storey. Dynamics analysis of building is carried out including the strength and stiffness effects of infills and inelastic deformations in the members' .particularly, those in the soft storey, and the members designed accordingly.

2.3 SOIL PROPERTIES:

The present situation, growth of multi-storey building is very high because of urbanization all over the world. Due to urbanization and increase in scarcity of space, it is becoming imperative to provide open-ground storey in commercial and residential buildings. Open-ground storey (OGS) is generally provided for parking, reception lobbies, communication hall, or for any other purpose. Soft storey is an irregularity which affects the behavior of construction during earthquake. A study of structural performance of building during the past earthquakes has clearly indicated that latest trends of constructions such as soft storey are not earthquake resistant. Soft storey during earthquake plays an important role in seismic performance of the building. At the soft storey level, there is discontinuity in rigidity of structure due to lack of infill walls. Due to this discontinuity of rigidity between the floors, causes progressive collapse of structure. Present the trend is to provide multiple soft storeys in RC frame structures (Al-Obaidi, Tikrit University (January,2018).

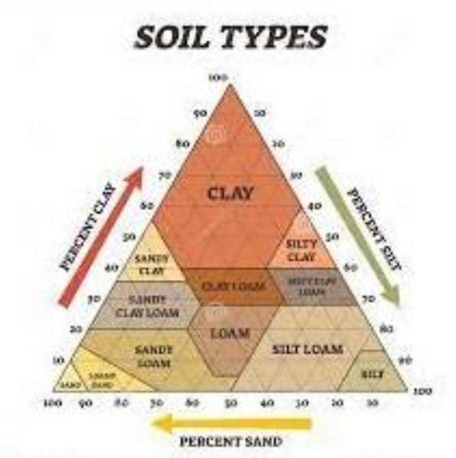


Figure 2.6: Soil layer (Ref.: https://rb.gy/teila4)

Multiple soft storeys are the buildings with soft storey at multiple levels. Multiple soft storey is adopted in many buildings because it provides open space to meet architectural demands and economical demands. In this study, behaviour of RC frame building with and without soft storey considering different soil conditions is discussed. The dissertation work is carried out on (G + 4) RC-framed building located in seismic zone II. In an attempt to investigate the effect of soft storey at multiple level in RC building, four different types of models are analysed considering hard soil, medium soil and soft soil conditions. Soft storey levels are altered from ground floor to top floor, and seismic analysis is performed using ETABS software. It is intended to describe the performance characteristics such as displacement, storey drift, base shear, axial force and natural period. Results show the general changing pattern of different parameters with respect to different soil conditions.

2.4 WIND LOAD:

The force on a structure arising from the impact of wind on it. In some areas, wind load is an important consideration, when designing a building or other structure. Wind load is a load, in pound per square foot, placed on the exterior structure by wind, this will depend on:

- The angle at which the wind strike the structure.
- The shape of the structure (height, width etc.)

2.4.1 WIND EXERTS THREE TYPES OF FORCES ON A STRUCTURE:

Uplift load - Wind flow pressures that create a strong lifting effect, much like the effect on airplane wings. Wind flow under a roof pushes upward; wind flow over a roof pulls upward.

Shear load - Horizontal wind pressure that could cause racking of walls, making a building tilt.

Lateral load - Horizontal pushing and pulling pressure on walls that could make a structure slide off the foundation or overturn.

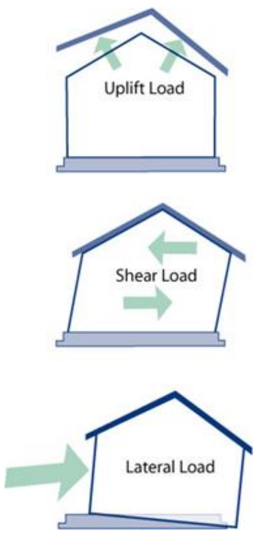


Figure 2.7: Type of wind load force (Ref.: https://rb.gy/xenbak)

2.4.2 BASIC WIND SPEED:

Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 feet (10 m) above ground for Exposure C Category. Linear interpolation between contours. Point values are provided to aid with interpolation. Islands, coastal areas, and land boundaries outside the last contour shall use the last **w**ind speed contour. Where records experience show that, wind speeds are higher than those depicted in figure (below) the fundamental wind speed shall be raised. Unusual wind conditions will be investigated in mountainous terrain, canyons and particular places. If necessary, the authority of BNBC with jurisdiction will update the values in figure (below) to accommodate for increase local wind speeds. This modification must be based on accurate weather data and relevant data.

Table 2.1: - Basic wind speeds, V for selected Location in Bangladesh

Location	Basic Wind Speeds (m/s)	Location	Basic Wind Speeds (m/s)
Angarpota	47.8	Lalmonirhat	63.7
Bagerhat	77.5	Madaripur	68.1
Bandarban	62.5	Magura	65.0
Barguna	80.0	Manikganj	58.2
Barishal	77.7	Meherpur	58.2
Bhola	69.5	Maheshkhali	80.0
Bogura	61.9	Moulavibazar	53.0
Brahmanbaria	56.7	Munsiganj	57.1
Chandpur	50.6	Mymensingh	67.4
Chapai-Nawabganj	41.4	Naogaon	55.2
Chattrogram	80.0	Narail	68.6
Chandana	61.9	Narayanganj	61.1
Cumilla	61.4	Narsinghdi	59.7
Cox's-Bazar	80.0	Natore	61.9
Dahagram	47.8	Netrokona	65.6
Dhaka	65.7	Nilphamari	44.7
Dinajpur	41.4	Noakhali	57.1
Faridpur	63.1	Pabna	63.1
Feni	64.1	Panchagahr	41.1
Gaibandha	65.6	Patuakhali	80.0
Gazipur	66.5	Pirojpur	80.0
Gopalganj	74.5	Rajbari	59.1
Habiganj	54.2	Rangamati	56.7
Hatiya	80.0	Rangpur	65.3
Ishwardi	69.5	Satkhira	61.9
Joypurhat	56.7	Sherpur	62.5
Jamalpur	56.7	Sirajganj	50.6
Jessore	64.1	Srimangal	50.6
Jhalkathi	80.0	St.Martin Island	80.0
Jhenaidah	65.0	Sunamganj	61.1
Khagrachari	56.7	Sylhet	61.1
Khulna	73.7	Sandwip	80.0
Kutubdia	80.0	Tangail	50.6
Khishorganj	64.7	Teknaf	80.0
Kurigram	65.6	Thakurgaon	41.1
Kushtia	66.9	Rajshahi	49.2
Laksmipur	51.2	Shariatpur	61.9

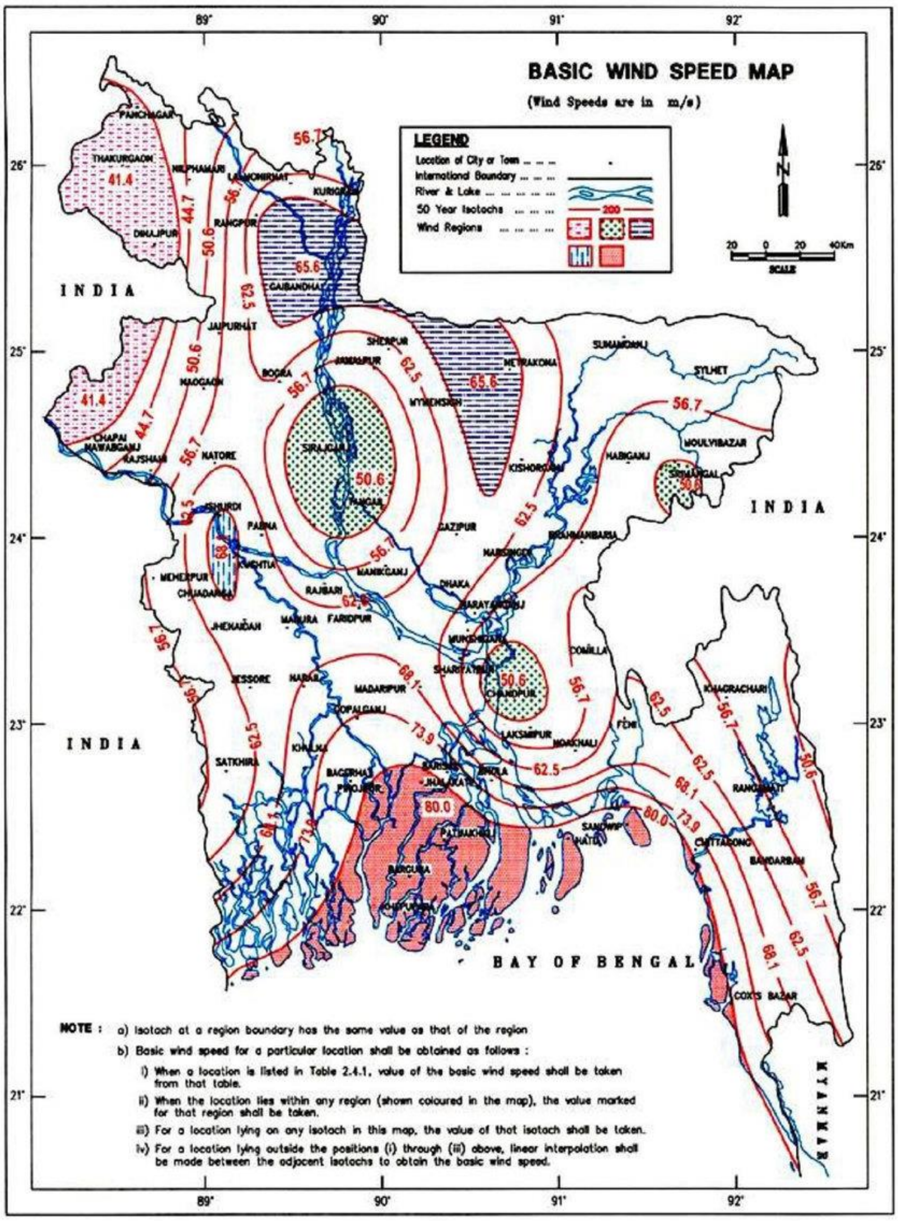


Figure 2.8: Wind Speed (Ref.: BNBC 2020 Page No: 3131)

2.4.3 EXPOSURE CATEGORY ACCORDING BNBC 2020:

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

Exposure B: Open terrain with scattered interference at heights of less than 9.1 meters. Flat open country, grassland and all water surfaces in cyclone-prone areas fall in to his Category.

Exposure C: Flat unobstructed are water surfaces outside cyclone included regions. This Category includes smooth mud flats and salt flats.

2.4.4 AFFECTING WIND PRESSURE FACTOR:

Shape: Arguably the most important concept when discussing wind effects on high-rise buildings is the atmospheric boundary layer or ABL. The ABL is the layer of atmosphere immediately above the surface of the planet, and it is here that all terrestrial human activity, including the construction and habitation of high-rises, occurs.

Opening of Building: High uplifting pressures on the roof result when stacks are at the lee side of the roof, trapping wind in the building. They can also occur when the stacks direct wind flow up against the roof, as with the step pattern. This latter pattern of storage is quite common and occurs when bales are pulled off in tiers as hay is fed.

Direction of Wind: Orientation of the building towards the wind has a logistic effect on pressure distribution, particularly at maximum section, which occurs over a small area near the leading edges of the roof.

Increase of Wind speed with Height: Wind speed generally increases with height above grade and therefore the effect on the load increases. Knowing how high you are lifting will let you know where to check the wind speed. If you are lifting a piece 400 feet into the air, then just checking the wind speed at grade isn't sufficient.

2.5 SEISMIC ZONE COEFFICIENTS:

Figure 3: Seismic Zone Coefficients (Ref.: BNBC 2020 Page No: 3117)

Observation – Above is the seismic zone coefficients figure for Bangladesh. In the legend, its color is mentioned as follows:

- Light green is Khulna District (zone I) Z = 0.12
- Yellow is Dhaka District (zone II) Z = 0.20
- Light Purple is Cox's Bazar District (zone III) Z = 0.28
- Deep Green is Sylhet District (zone IV) Z = 0.36

Table 2.2: - Seismic Zone Coefficients Z

Seismic Zone	Zone Coefficient
A	0.12
B	0.20
C	0.28
D	0.36

Table 2.3: Structure Importance Coefficients I~I'

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

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

2.6 EARTHQUAKE LOAD:

In earthquake resistant design, the soft story and the weak story irregularities are reciprocal to a significant difference between the stiffness and the resistance of one of the floors of a building and the rest of them. Both configurations are known in architectural terms as: the open floor. The number of advantages given by this concept of modern architectural design, both aesthetical as functional, is the reason why it has been encouraged all around the world since the first half of the 20th Century. These conditions are present, when either the first story of a frame structure , known in some countries as “ground floor”, is free of walls, while stiff non-structural walls are present in the upper ones, or when shear walls are located in the upper stories and they do not follow down to the foundations, but they interrupt at the second floor. The origin of this architectural configuration commonly used in modern cities is mainly derived from the three first points of the “Five points for a new architecture” published by Swiss-French architect Le Corbusier (LC) in 1926, that defines the tenets of modern architecture: (1) piloted (open first floor); (2) the free plan; (3) the free façade; (4) strip windows; and (5) roof terraces-roof gardens. These postulates were possible due to the development since the 19th Century of new construction techniques and building materials, such as the innovative "reinforced concrete frame structure"(RCFS). The load-bearing structure consisted of solid slabs that transfer the gravity loads to the columns and finally to the footings, leaving behind the brick, mortar, stone and wood structural wall system, that prevailed until early 20th Century. In 1914 LC developed the Domino System in France for economic housing, characterized by: elemental RCFS, which consisted of slender columns or piloted, and flat solid slab (cast in place or precast) that covered long spans between columns, without girders. The RC solid slabs transferred the gravity loads to the columns, and them, finally to the footings. This new structural system also allowed the use of a floor layout free of walls. Since interior partitions did not receive any load, this structural system gave the freedom for modifying the location of them (Guevara-Perez, 2009, pp. 518-519). On the left of Fig. 1.1, LC compares features of traditional architecture and the modern ones suggested by him; the three first of the five points related to the studied configurations, stand out of the shade. On the right, LC illustrates the disadvantages of traditional buildings that had functionally inflexible bearing walls with the benefits under the open first story modern proposal (Guevara 2009. p. 232). In the lower part of the figure, LC compares the design "paralyzed"(plan paralyse), unalterable, of traditional buildings, and some of its disadvantages: insalubrity, inefficiency and waste, with the open floor modern design t and some of its advantages: economy, hygiene, and, pedestrian circulation separated from vehicular traffic.

2.6.1 BEHAVIOUR DURING EARTHQUAKE:

The presence of walls in upper storeys makes them much stiffer than the open ground storey. Thus, the upper storeys move almost together as a single block, and most of the horizontal displacement of the building occurs in the soft ground storey itself. In common language, this type of buildings can be explained as a building on chopsticks.

Thus, such buildings swing back-and-forth like inverted pendulums during earthquake shaking and the columns in the open ground storey are severely stressed. If the columns are weak (do not have the required strength to resist these high stresses) or if they do not have adequate ductility, they may be severely damaged which may even lead to collapse of the building.

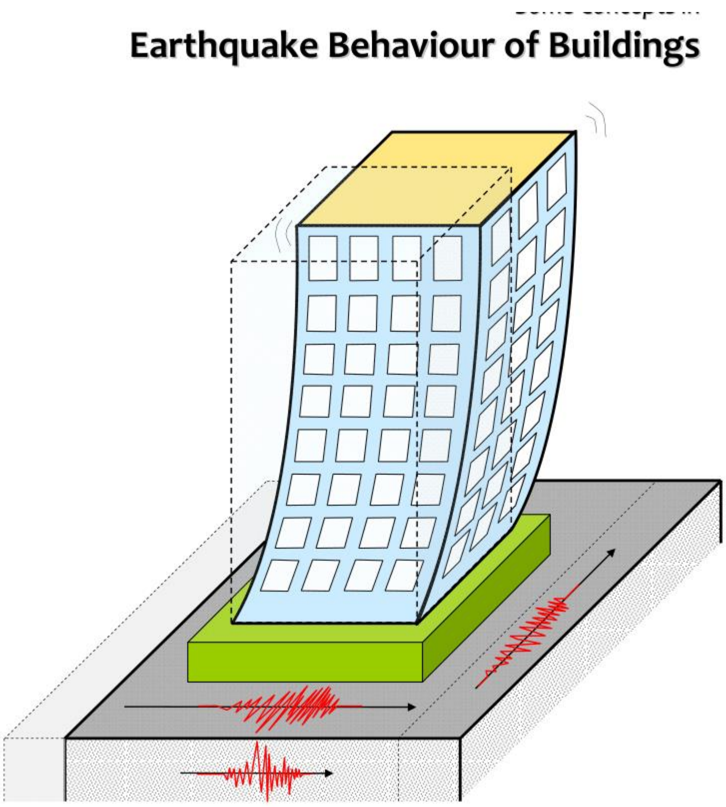


Figure 2.10: Earthquake Behaviour (Ref: https://bit.ly/3gIFc1i)

2.6.2 EARTHQUAKE MAGNITUDE:

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

- Instrumental: detected by seismograph, magnitude 13;
- weak: only perceived by sensitive people
- light: it is like the vibration of a passing truck, felt on the upper floors, size 3.5 to 4.2;
- Moderate: felt when walking, intensity 4.3;
- Strong: trees sway, hanging objects sway, fall loose, objects, magnitude 4.9 to 5.4;
- Very strong: cracked walls, plaster falls, thickness 5.5-6;
- Destructive: chimneys fall; Damaged building, magnitude 6.8;
- Ruinous: collapse of houses, cracks in the floor, broken pipes, magnitude 6.9;
- Catastrophic: The cracks in the floor move a lot. Destroyed, bent tracks, thickness 7 to 7.3;

- Very catastrophic: few buildings remain standing; Bridges destroyed, landslides and major floods, magnitude 7.4 to 8.1;
- Catastrophic: total destruction. Objects thrown into the air, the ground rises and falls in waves, magnitude 8.2 and higher.

There are three zones, mainly Zone I, which is the most active, Zone II, which is least active, and Zone III, which is the lowest possible earthquake magnitude. See figure

Zone	Richter Scale
1	7.0
2	6.5-7.0
3	6.0-6.5

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

2.6.3 EARTHQUAKE EFFECTED AREAS RECORDED IN BANGLADESH:

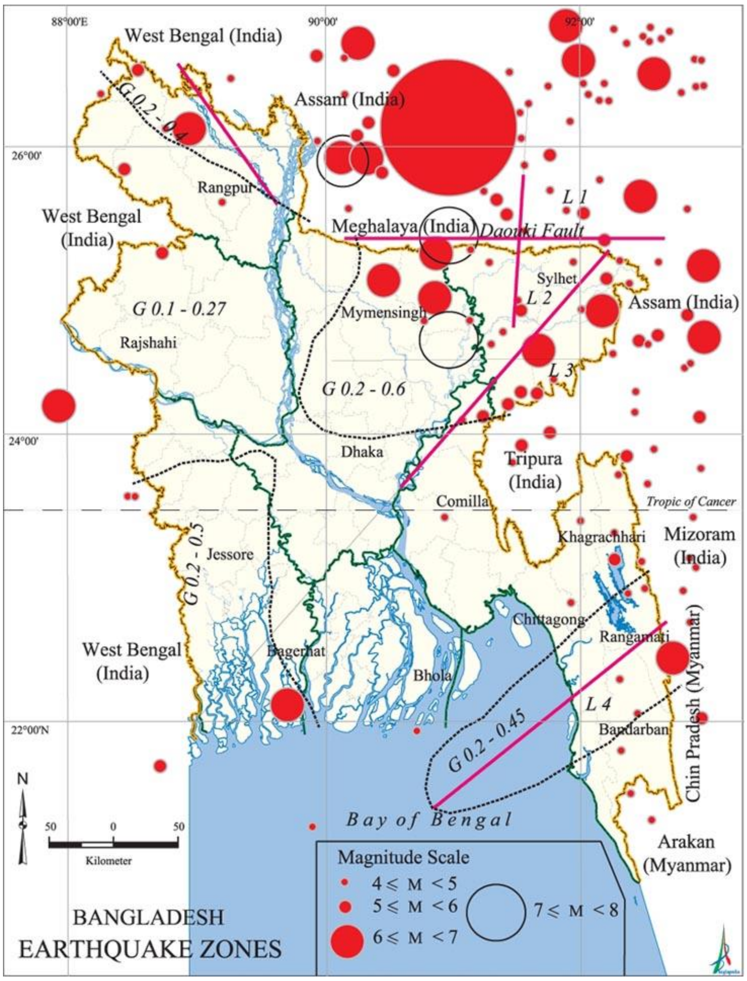


Figure 2.11: Earthquake zone (Ref.: https://rb.gy/eotuyd)

2.7 SOFT STOREY EFFECT DURING EARTHQUAKE:

In shaking a building, an earthquake ground motion will search for every structural weakness. These weaknesses are usually created by sharp changes in stiffness, strength and/or ductility, and the effects of these weaknesses are accentuated by poor distribution of reactive masses. Severe structural damage suffered by several modern buildings during recent earthquakes illustrates the importance of avoiding sudden changes in lateral stiffness and strength. A typical example of the detrimental effects that these discontinuities can induce is seen in the case of buildings with a “soft storey.” (August 28, 2013 by VINAY CHANDWANI)

2.8 SOFT OR FLEXIBLE STORY:

The soft story irregularity, refers to the existence of a building floor that presents a significantly lower stiffness than the others, hence it is also called: flexible story. It is commonly generate unconscientiously due to the elimination or reduction in number of rigid non-structural walls in one of the floors of a building, or for not considering on the structural design and analysis, the restriction to free deformation that enforces on the rest of the floors, the attachment of rigid elements to structural components that were not originally taken into consideration. Because of the effects produced by non-structural components on the seismic performance of the building, the term non-intentionally non-structural has been assigned to these components since the end of the 1980’s (Guevara, 1989). Table 12.3-2 in the ASCE/SEI 7-10 document, (p. 83) defines soft story as irregularity type 1. If the soft story effect is not foreseen on the structural design, irreversible damage will generally be present on both the structural and non-structural components of that floor. This may cause the local collapse, and in some cases even the total collapse of the building. The soft first story is the most common feature of soft story irregularity. It usually is present in modern frame buildings when a large number of non-structural rigid components, such as masonry walls, are attached to the columns of the upper floors of a reinforced concrete frame structure while the first story is left empty of walls or with a reduced number of walls in comparison to the upper floors. The rigid non-structural components limit the ability to deform of the columns, modifying the structural performance of the building to horizontal forces. In a regular building, the earthquake shear forces increase towards the first story. See Fig. 2. 1. The total displacement (ΔT) induced by an earthquake tend to distribute homogeneously in each floor throughout the height of the building. Deformation in each floor (Δn) would be similar. When a more flexible portion of the lower part of the building supports a rigid and more massive portion, the bulk of the energy will be absorbed by the lower significantly more flexible story while the small remainder of energy will be distributed amongst the upper more rigid stories, producing on the most flexible floor, larger relative displacement between the lower and the upper slab of the soft story (integratory drift) and therefore, the columns of this floor will be subjected to large deformations (Guevara-Perez, Tuesday, 4 September 2012).

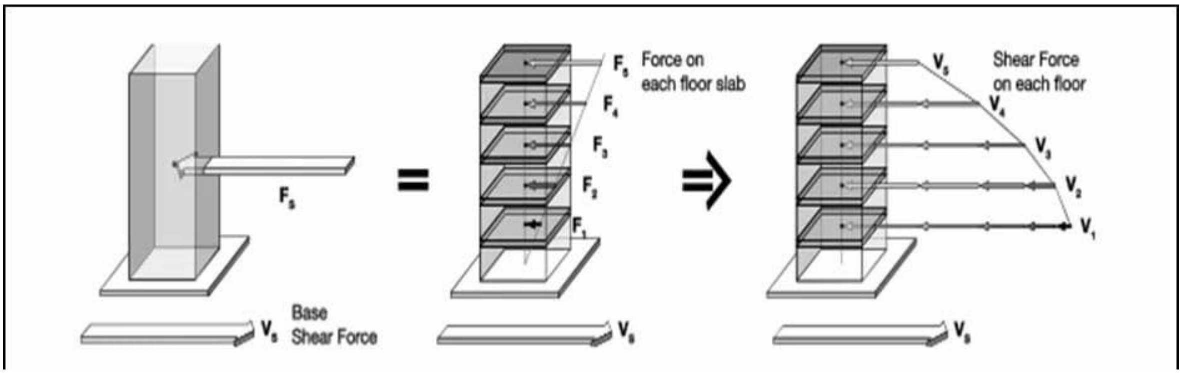


Figure 2.12: Lateral forces and shear forces generated in building due to ground motion.

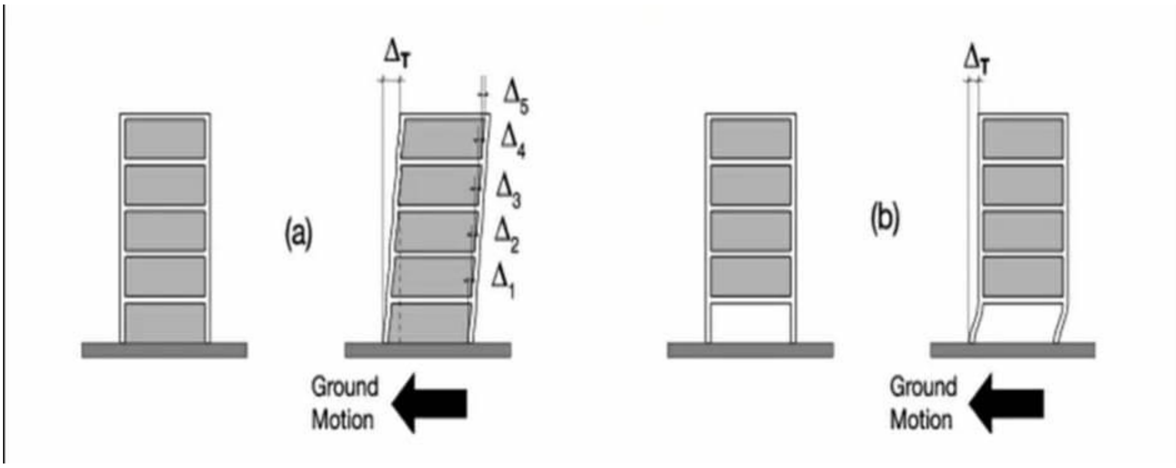


Figure 2.13: Distribution of total displacement generated by an earthquake in; (a) a regular building; (b) a building with soft story irregularity. (Ref.-https://bit.ly/3EQYGZY)

2.9 SOFTWARE USED:

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

List of software's used

1. ETABS 2016
2. Auto CAD 2021
3. Microsoft Word Document 2013

ETABS 16:

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 modelling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide-range of materials, and insightful graphic displays, reports, and schematic drawings that allow users to quickly and easily decipher and understand analysis and design results.

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

2.10 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 height of structure, whichever is greater.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION:

This chapter is mainly discuss the procedure of weak story methodology calculation. This calculation is based for etabs software. All the reference of the etabs model is based on BNBC 2020.This chapter is includes the Flow chat and steps in details also given soil test data. It has been contains the graphical presentation for weak story check. Different types of loads in structure: Structural members must be designed to support specific loads. Loads are those forces for which a given suture should be proportioned. In general, loads may be classified as 1. Dead Loads 2. Imposed loads or live load 3. Wind Loads 4. Earthquake load.

3.2 METHODOLOGY OVERVIEW:

Methodology overview is a good idea for explain the methodology step by step. It has been follow a flow chat which is given by bellow. It has also includes some table and reference.

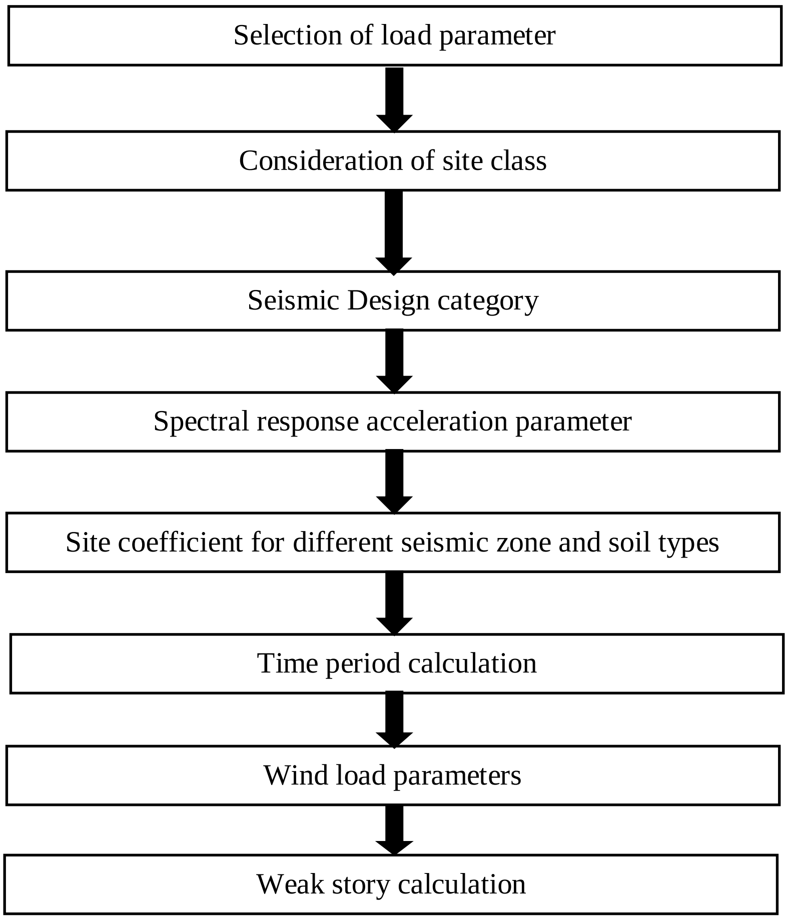


Figure 3.1: Flow chart diagram of weak storey analysis process step by step.

The present research work deals with comparative study of behavior of soft storey building frames, by considering geometrical configurations of building under wind loading and earthquake loading. The framed buildings are subjected to lateral loads and vibrations because of wind and earthquake and therefore lateral load analysis is necessary for these framed structures. The fixed base system is analyzed by employing different equivalent inclined column frame structures in seismic and wind loading by means of STAAD Pro software. The responses of the same building frames are studied and evaluated the best geometry which satisfies lateral loadings

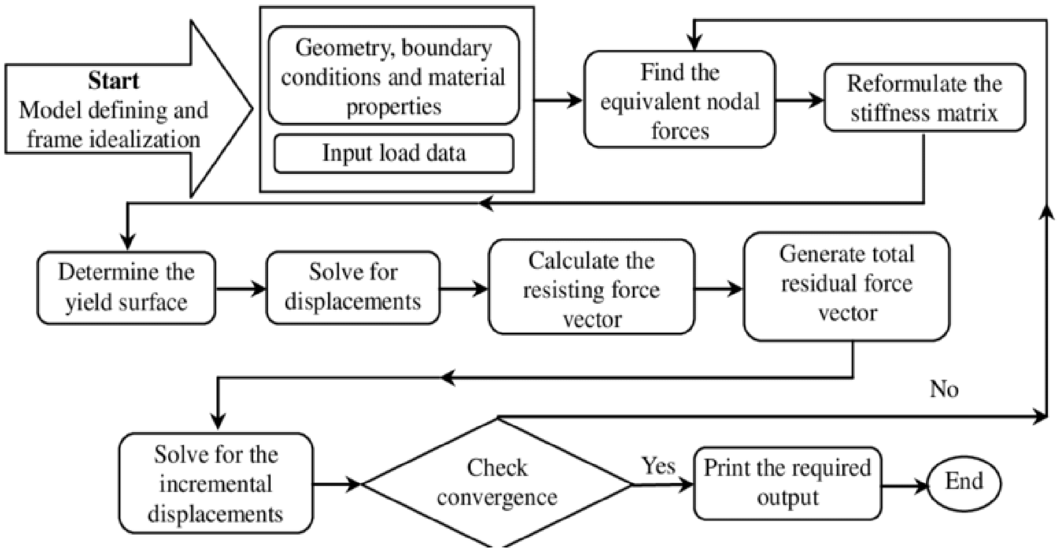


Figure 3.2: Flowchart-of-analysis-of-RC-building-using-NARCBEEEDS-finite-element-program.

3.3 METHODOLOGY STEP:

3.3.1 Step-1. This thesis mainly focuses on the weak story calculation check. We will find the weak story with the help of the software Etabs we use Etabs 16.3.2. We can show the step-by-step calculation for finding the weak story. First of all, we install Etabs software on our computer. (By following the install procedure on Etabs).Then we draw the model in Etabs. When the Etabs model is done then we go to select all the load parameters is filling up by using BNBC 2020 load combination and design procedure. In this case, we need some design parameters which are given by BNBC.

3.3.2 Step-2.

In this model, we have to need some load for checking the analysis. Live load, dead load.

Live load:

Residential: All other areas except stairs and balconies: 2 KN/m^2 or (2x20.89 = 41.78 psf ~ 42 psf). (Reference BNBC 2020 Page No: 3116)

Residential: stairs and Exit ways: 4.80 KN/m^2 or (4.80x20.89 = 100 psf). (Reference BNBC 2020 Page No: 3117)

Roof live load: 1 KN/m^2 or (1x20.89 = 20.89 psf ~ 21 psf). (Reference BNBC 2020 Page No: 3117)

Dead load:

Floor finish:

Tiles 13mm = 0.268 KN/m^2 (Reference BNBC 2020 Page No: 3111)

Plaster 10mm = 0.230 KN/m^2in this case we have used 25mm thickness plaster ($\frac{25}{10}$x0.230) = 0.575 KN/m^2 (Reference BNBC 2020 Page No: 3111-3112)

Ceiling finish:

Cement Plaster 13mm = 0.287 KN/m^2 (Reference BNBC 2020 Page No: 3112)

Total = 0.268+0.575+0.287

=1.13 KN/m^2

= (1.13x20.89)

=23.6 psf ~ 25 psf

Partition wall load calculation:

Story height = 10 ft, wall thickness = 5 inches, Beam depth= 18-inch, wall height = ($10-\frac{18}{12}$)= 8.5 ft.

Wall load = Brick unit weight x wall thickness x wall height

=120 x $\frac{5}{12}$ x 8.5

=425 lb/ft

=0.425 kip (we use in this model is 0.5 kip)

(Units weight of Brick References BNBC 2020 Page No: 3110)

3.4 LOAD COMBINATIONS:

As per BNBC 2020, Chapter 2- Part 6 (Clause 11027.5), following load cases must be considered for analysis:

1. $1.4\,D$
2. $1.2\,D + 1.6\,L + 0.5\,L_r$
3. $1.2\,D + L + 1.6\,L_r$
4. $1.2\,D + 1.6\,L_r + 0.8\,W_x$
5. $1.2\,D + 1.6\,L_r - 0.8\,W_x$
6. $1.2\,D + 1.6\,L_r + 0.8\,W_y$
7. $1.2\,D + 1.6\,L_r - 0.8\,W_y$
8. $0.9\,D + 1.6\,W_x$
9. $0.9\,D - 1.6\,W_x$
10. $0.9\,D + 1.6\,W_y$
11. $0.9\,D - 1.6\,W_y$
12. $1.2\,D + L + 0.5\,L_r + 1.6\,W_x$
13. $1.2\,D + L + 0.5\,L_r - 1.6\,W_x$
14. $1.2\,D + L + 0.5\,L_r + 1.6\,W_y$
15. $1.2\,D + L + 0.5\,L_r - 1.6\,W_y$
16. $0.9\,D + E_x + 0.3\,E_y - E_v$
17. $0.9\,D + E_x - 0.3\,E_y - E_v$
18. $0.9\,D - E_x + 0.3\,E_y - E_v$
19. $0.9\,D - E_x - 0.3\,E_y - E_v$
20. $0.9\,D + E_y + 0.3\,E_x - E_v$
21. $0.9\,D + E_y - 0.3\,E_x - E_v$
22. $0.9\,D - E_y + 0.3\,E_x - E_v$
23. $0.9\,D - E_y - 0.3\,E_x - E_v$
24. $1.2\,D + L + E_x + 0.3\,E_y + E_v$
25. $1.2\,D + L + E_x - 0.3\,E_y + E_v$
26. $1.2\,D + L - E_x + 0.3\,E_y + E_v$
27. $1.2\,D + L - E_x - 0.3\,E_y + E_v$
28. $1.2\,D + L + E_y + 0.3\,E_x + E_v$
29. $1.2\,D + L + E_y - 0.3\,E_x + E_v$
30. $1.2\,D + L - E_y + 0.3\,E_x + E_v$
31. $1.2\,D + L - E_y - 0.3\,E_x + E_v$

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

3.5 Site class:

3.6 Soil Test Documents:

<u>Client</u>

Mr. Shahalam Chowdhury

<u>Report on:</u>

Sub-soil Investigation for the Construction of proposed G+4(5) storied residential building At the B.S. Plot No.-20001, 20002, Mouza- Jilongja, Sea-Beach Road, P.S.-Cox's Bazar, Dist.- Cox's Bazar.

<u>September-2020</u>

SUB-SOIL INVESTIGATED & REPOTED BY

THE MICRO SOIL ENGINEERS

House No.-174/2, Road No.-06, Janata

Housing, Sha-alibagh, Mirpur-1, Dhaka-1216,

MOBILE: 01711-206158, 01703-990236, 01552-667818

T & T-02-55076478, Email: je.micro@yahoo.com

Table 3.1: Bearing Capacities of Shallow Foundation from field and Laboratory Tests (Values in tsf, F.S.=2.50);

Bore Hole	Depth in ft	Field SPT	Cohesion Kg/cm^2	Bearing Capacity (TSF)	
				For Raft Foundation	For Circular or Square Footing
BH-1	5	12	0.75	1.61	2.05
	10	18	1.13	2.48	3.24
	15	16	1.00	2.12	2.72
	20	32	1.94	3.87	4.68
BH-2	5	6	0.38	0.88	1.19
	10	22	1.38	3.84	3.72
	15	31	1.94	3.64	4.54
	20	23	1.44	2.96	3.88

Table 3.2: Bearing capacities of Piles from the SPT and Soil Tests parameters:

The Skin friction and the End Bearing Capacities of Piles (f.S. = 2.50).

	BH-1				BH-2			
Depth (Ft)	N	CU (Tsf)	F^s (Tsf)	F^b (Tsf)	N	CU (Tsf)	F^s (Tsf)	F^b (Tsf)
5	12	0.75	0.10	-	6	0.38	0.05	-
10	18	1.13	0.15	-	22	1.38	0.18	-
15	16	1.00	0.13	-	31	1.94	.25	-
20	32	1.94	0.26	-	23	1.44	0.19	-
25	17	-	0.14	6.62	34	-	0.27	13.2
30	20	-	0.16	9.35	14	-	0.12	6.54
35	50	-	0.32	27.2	50	-	0.32	27.2
40	50	-	0.32	31.1	50	-	0.32	31.1

*Note:

a. N = Blows/ ft, Cu: cohesion.

b. f_s= Allowable value of the skin friction.

c. f_b = Allowable value of the pile end bearing capacity.

d. SPT (N) values are corrected within calculation.

e. The values of f_s and f_b have been halved in making preliminary.

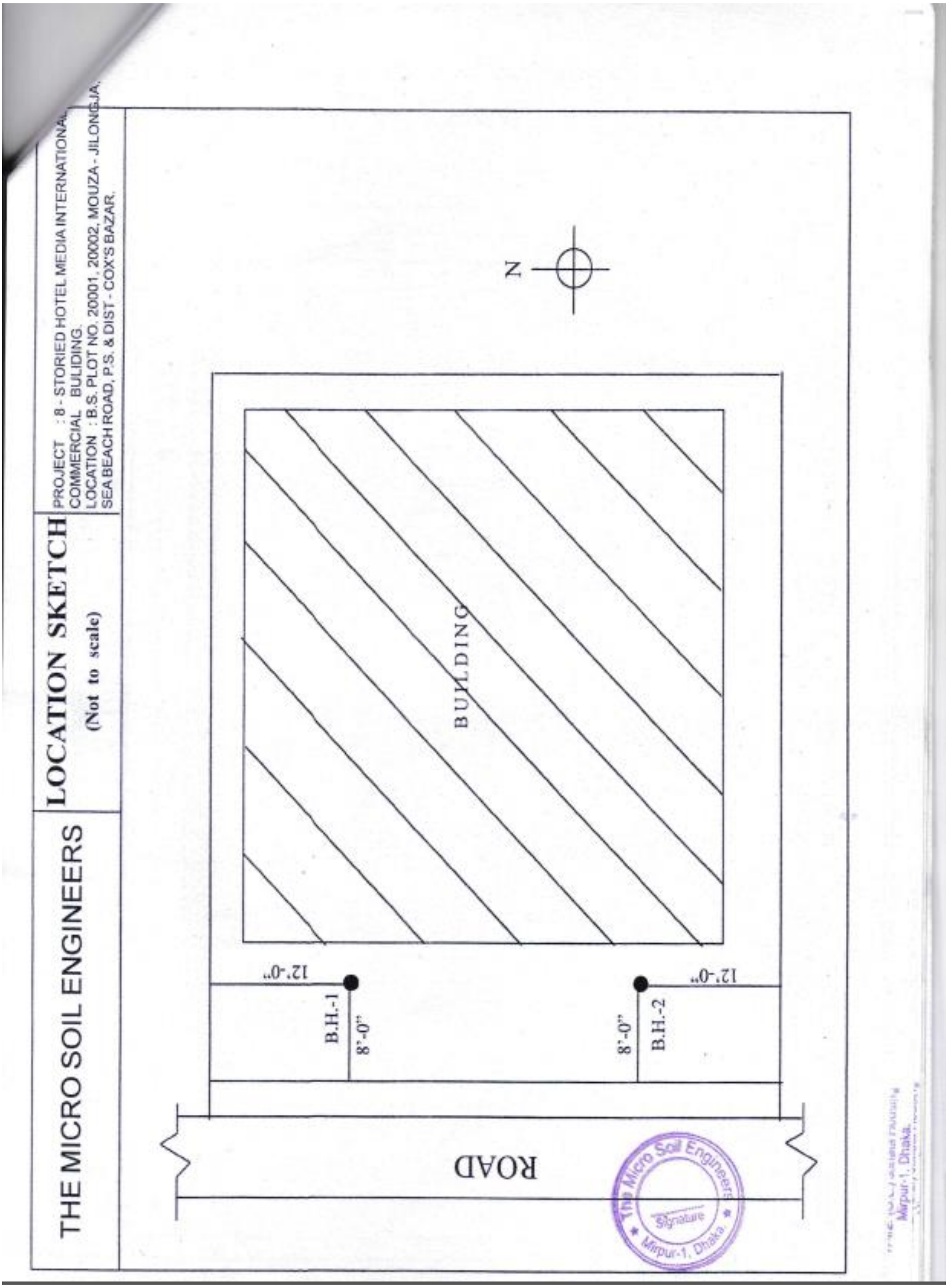
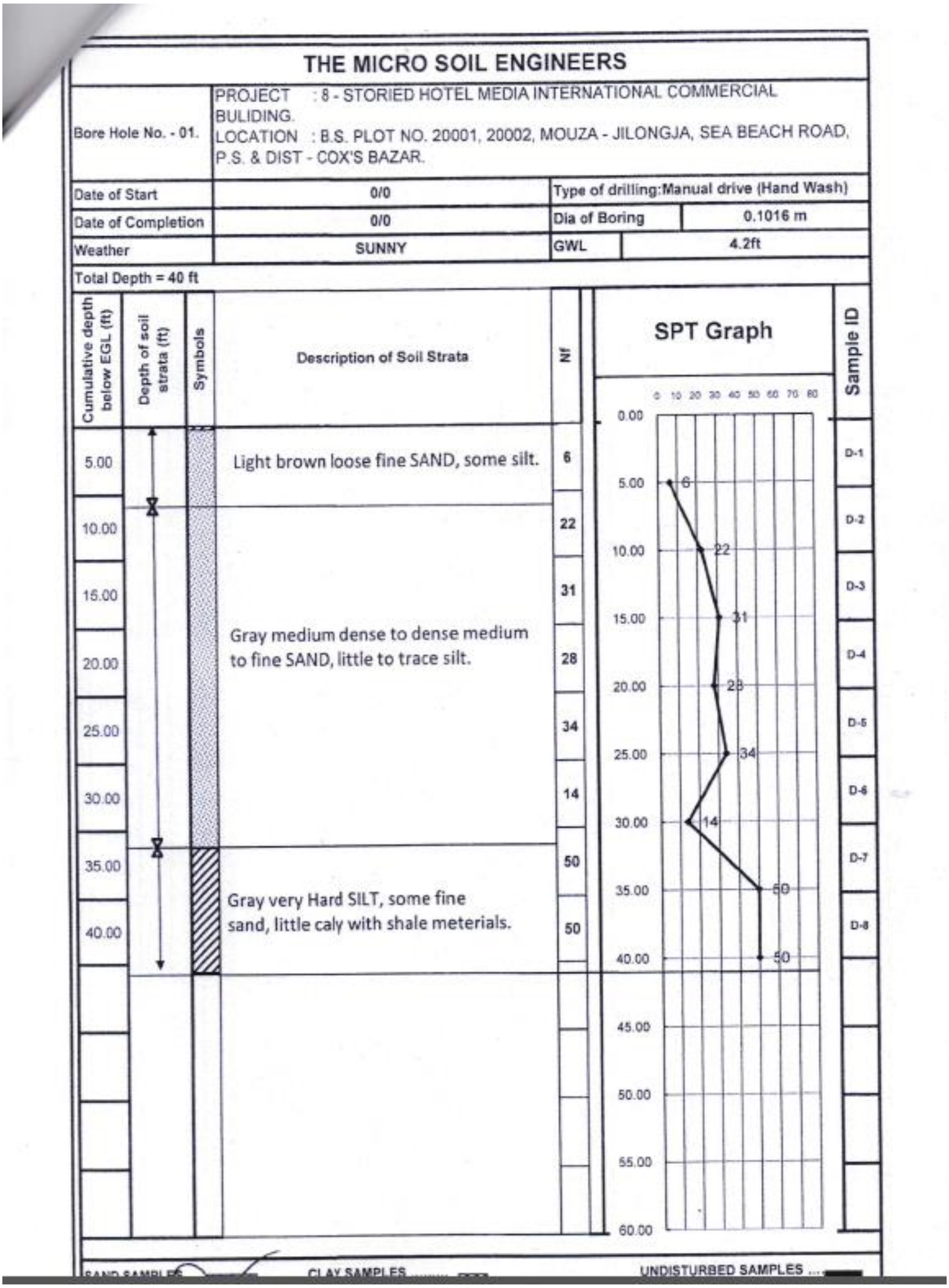


Figure 3.3: Land Layout



THE MICRO SOIL ENGINEERS

Bore Hole No. - 01.

PROJECT : 8 - STORIED HOTEL MEDIA INTERNATIONAL COMMERCIAL BULIDING.
LOCATION : B.S. PLOT NO. 20001, 20002, MOUZA - JILONGJA, SEA BEACH ROAD, P.S. & DIST - COX'S BAZAR.

Date of Start	0/0	Type of drilling:Manual drive (Hand Wash)	
Date of Completion	0/0	Dia of Boring	0.1016 m
Weather	SUNNY	GWL	4.2ft

Total Depth = 40 ft

Cumulative depth below EGL (ft)	Description of Soil Strata	Nf	Sample ID
5.00	Light brown loose fine SAND, some silt.	6	D-1
10.00	Gray medium dense to dense medium to fine SAND, little to trace silt.	22	D-2
15.00		31	D-3
20.00		28	D-4
25.00		34	D-5
30.00		14	D-6
35.00	Gray very Hard SILT, some fine sand, little caly with shale meterials.	50	D-7
40.00		50	D-8

Figure 3.4: STP Graph

Table 3.3: Bhore Hole 1: Average SPT value calculation

Layer No.	Depth Below EGL (ft.)	Thickness of Layer, d_i (ft.)	Field SPT, N_i	d_i / N_i
1	5	5	6	0.83
2	10	5	22	0.23
3	15	5	31	0.16
4	20	5	28	0.18
5	25	5	34	0.15
6	30	5	14	0.36
7	35	5	50	0.10
8	40	5	50	0.10
9	45	5	50	0.10
10	50	5	50	0.10
11	55	5	50	0.10
12	60	5	50	0.10
13	65	5	50	0.10
14	70	5	50	0.10
15	75	5	50	0.10
16	80	5	50	0.10
17	85	5	50	0.10
18	90	5	50	0.10
19	95	5	50	0.10
20	100	5	50	0.10
	$\sum d_i =$	100	$\sum \frac{d_i}{N_i} =$	3.30
	$N' = \frac{\sum d_i}{\sum \frac{d_i}{N_i}} = 30.26$			

Table 3.4: Bhore Hole 2: Average SPT value calculation

Layer No.	Depth Below EGL (ft.)	Thickness of Layer, d_i (ft.)	Field SPT, N_i	d_i / N_i
1	5	5	12	0.42
2	10	5	18	0.28
3	15	5	16	0.31
4	20	5	32	0.16
5	25	5	17	0.29
6	30	5	20	0.25
7	35	5	50	0.10
8	40	5	50	0.10
9	45	5	50	0.10
10	50	5	50	0.10
11	55	5	50	0.10
12	60	5	50	0.10
13	65	5	50	0.10
14	70	5	50	0.10
15	75	5	50	0.10
16	80	5	50	0.10
17	85	5	50	0.10
18	90	5	50	0.10
19	95	5	50	0.10
20	100	5	50	0.10
	$\sum d_i =$	100	$\sum \frac{d_i}{N_i} =$	3.11
	$N' = \frac{\sum d_i}{\sum \frac{d_i}{N_i}} = 32.18$			

Borehole 1 & borehole 2 SPT value is (30.26,32,18) now select the site class “SC”. The site location is Cox’s Bazar .so select zone 3.

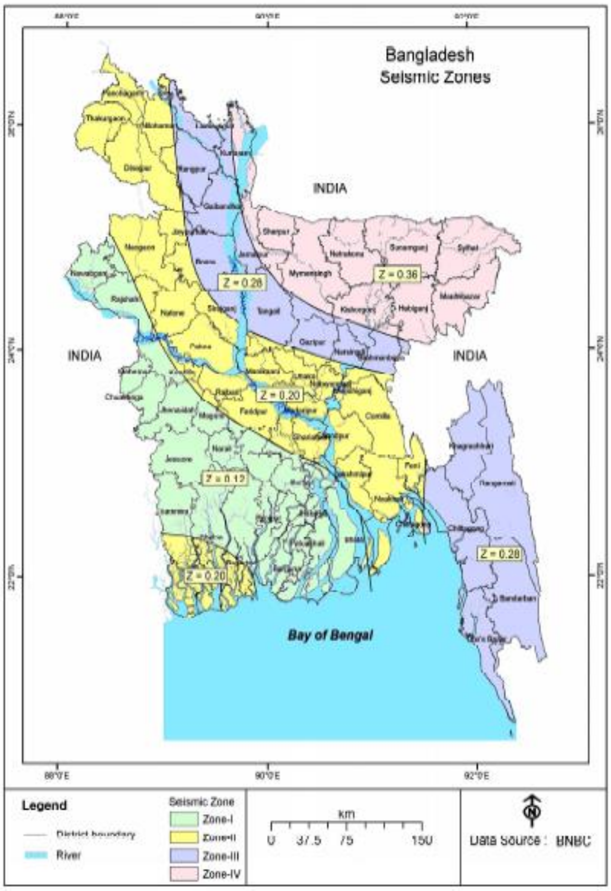


Figure 3.5: Seismic zoning map of Bangladesh (Reference; BNBC2020 Page no: 3195).

Now select the Seismic design category D.

Table 3.5: Seismic Design Category of Buildings (Reference; BNBC 2020 Page no:3198).

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

3.6.1 It has been found the seismic design category D so that the design model is a special reinforced concrete momentframe.Response Reduction Factor, R=8; system overstrength factor,Ω_0=3; Deflection Amplification Factor, C_d =5.5 (Reference;BNBC 2020 Page no:3204).

3.6.2 Spectral Response Acceleration Parameter SS =07 and S1=0.28 for Different Seismic Zone (Reference; from BNBC 2020 Appendex C,part 6, Chapter-2)

3.6.3 Site Coefficient Fa for Different Seismic Zone and Soil Types

Table 3.6: Site Coefficient Fa for Different Seismic Zone and Soil Type.

Soil Type	Zone-1	Zone-2	Zone-3	Zone-4
SA	1.0	1.0	1.0	1.0
SB	1.2	1.2	1.2	1.2
SC	1.15	1.15	1.15	1.15
SD	1.35	1.35	1.35	1.35
SE	1.4	1.4	1.4	1.4

Time period calculation: $T=C_T(hn)^m$. Where hm= Total height of the building

$T = 0.0466 \text{ x } (\frac{75}{3.28})^{0.9}$

$= 0.78$ sec

Table 3.7: Values for Coefficients to Estimate Approximate Period

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	

3.6.4 WIND LOAD PARAMETERS (Reference; BNBC 2020 Page no: 3181):

Location cox's Bazar so we found the Basic Wind Speed, V, is 80.0 m/s or (80x3.6) = 288/1.609 =178.99~179 kph. Exposure type ''C''. Importance factor "1". Gust factor "0.85". Directionality factor, kd "0.85".

1.3.8 Weak story Calculation

Formula of column strength check. Story strength of the building formula is given Vyi is.

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCK}}{H}$$

Where

V_{yi}=k are integer counters,

M is the number of columns,

MpCk is the plastic moment strength of column k under minimum factored load,

H is the story height.

3.7 COLUMN AND BEAM LAYOUT:

For Both Structures

Column Size:

Column C1 = 12x18

Column C2 = 15x18

Column C3 = 12x20

Grade Beam Size:

GB1= 12x18

GB2= 12x18

Floor Beam Size:

FB1= 12x15

FB2= 12x18

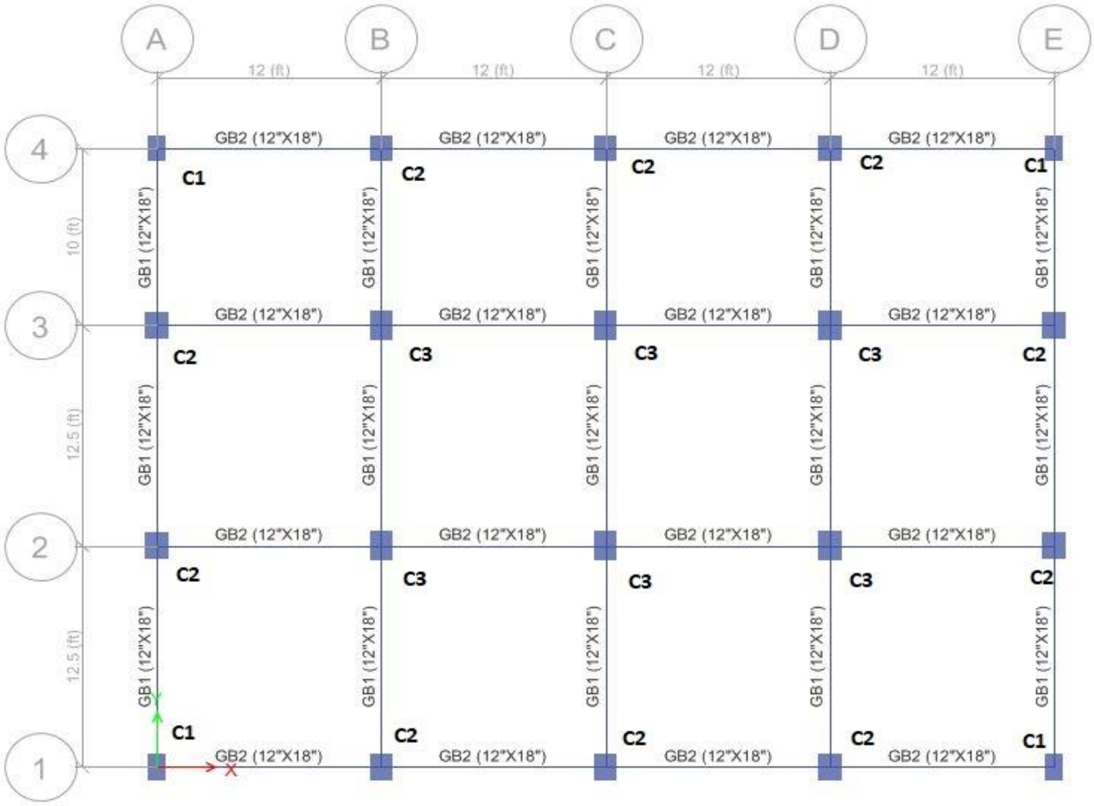


Figure 3.6: Column & Grade Beam Layout

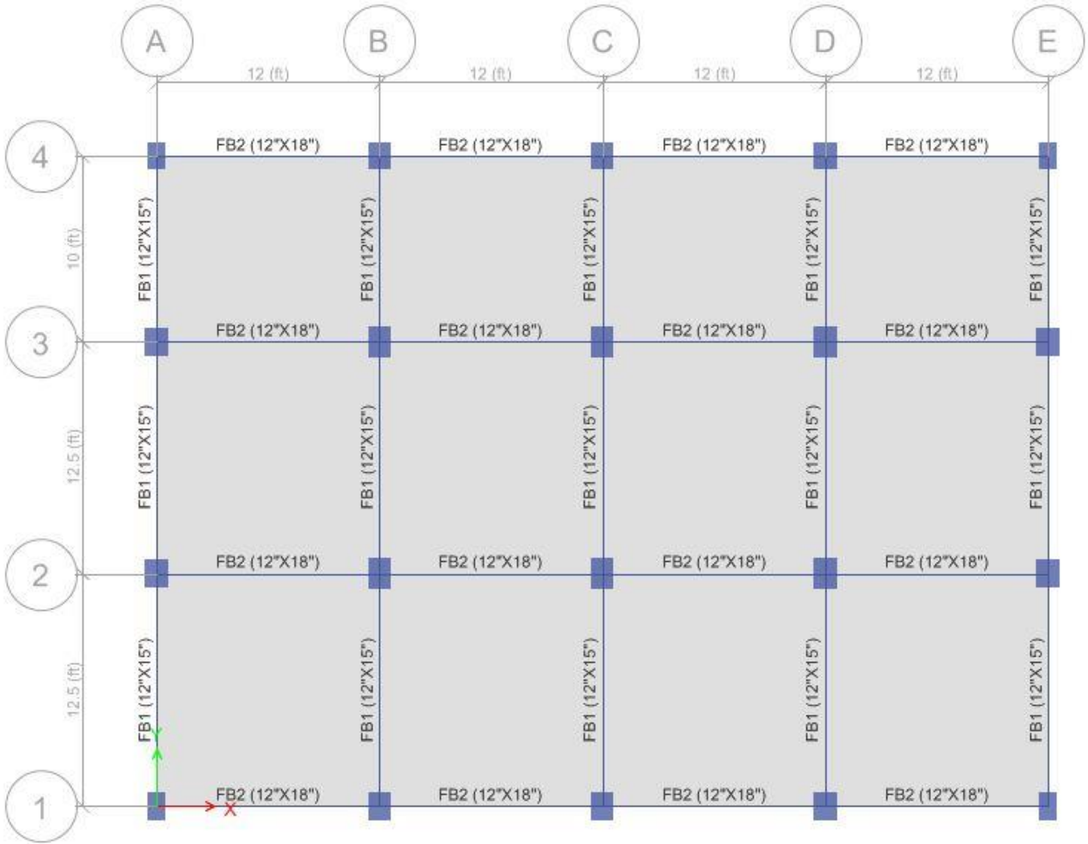


Figure 3.7: Floor Beam Layout

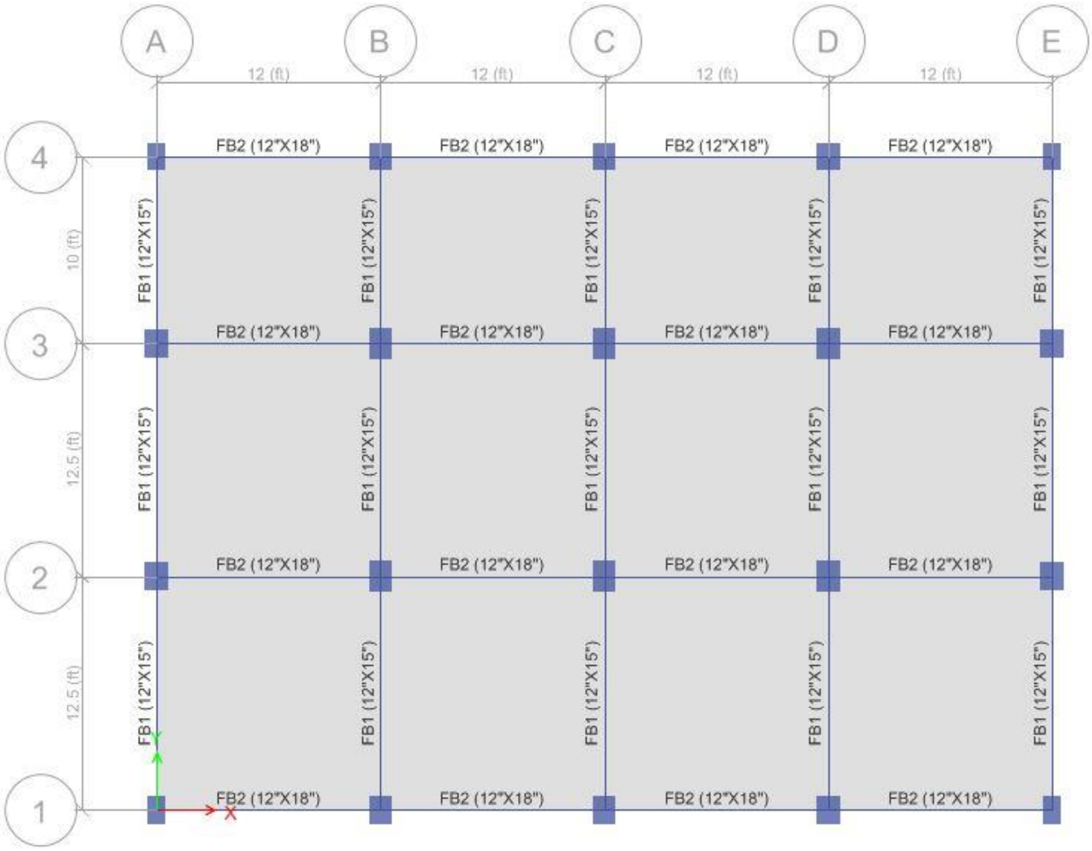


Figure 3.8: Roof Beam Layout

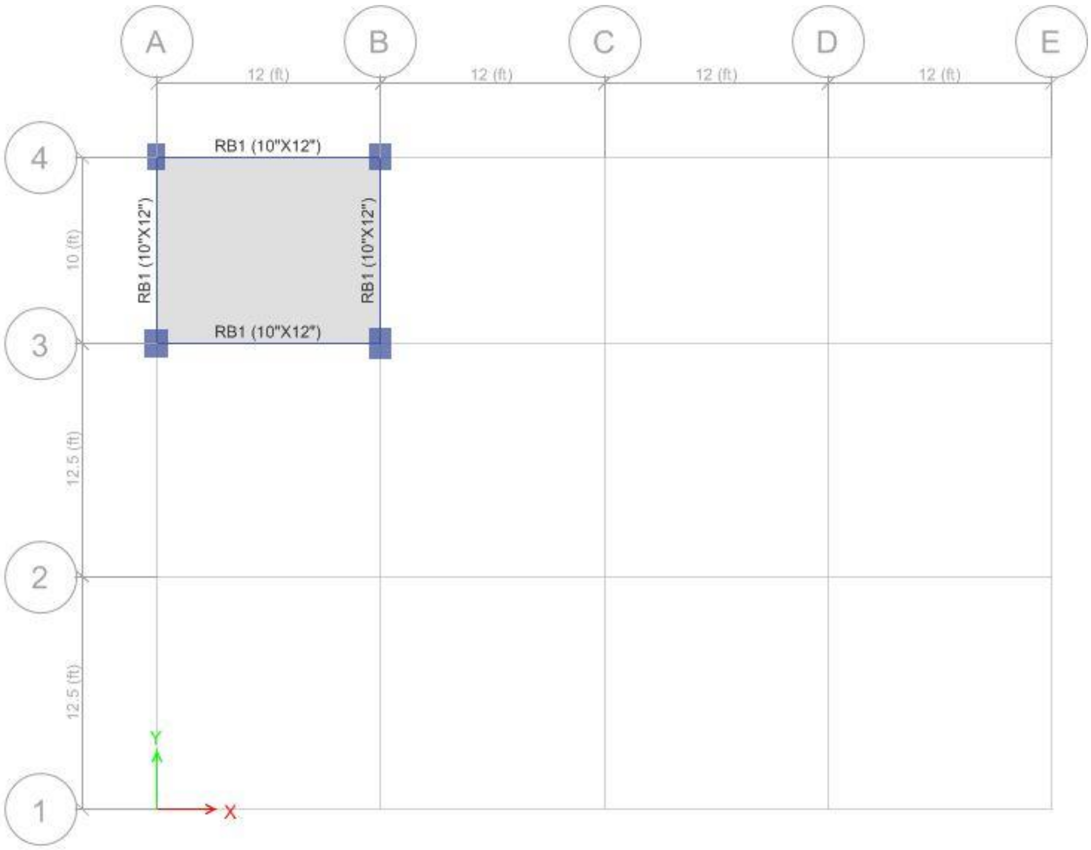


Figure 3.9: Chilekotha Beam Layout

3.8 ETABS 3D Model:

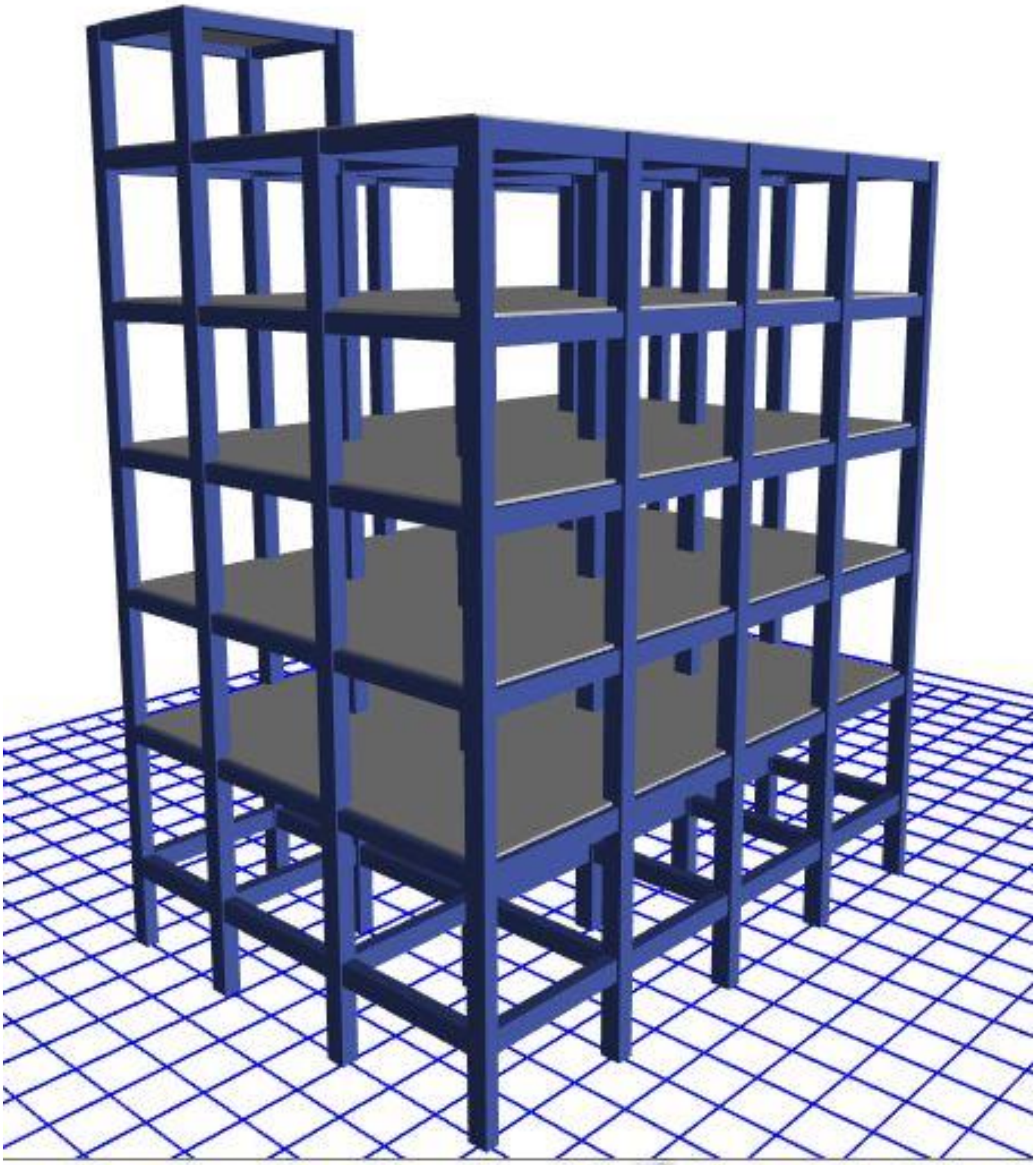


Figure 3.10: ETABS 3D Model

CHAPTER 4

RESULT AND DISCUSSION

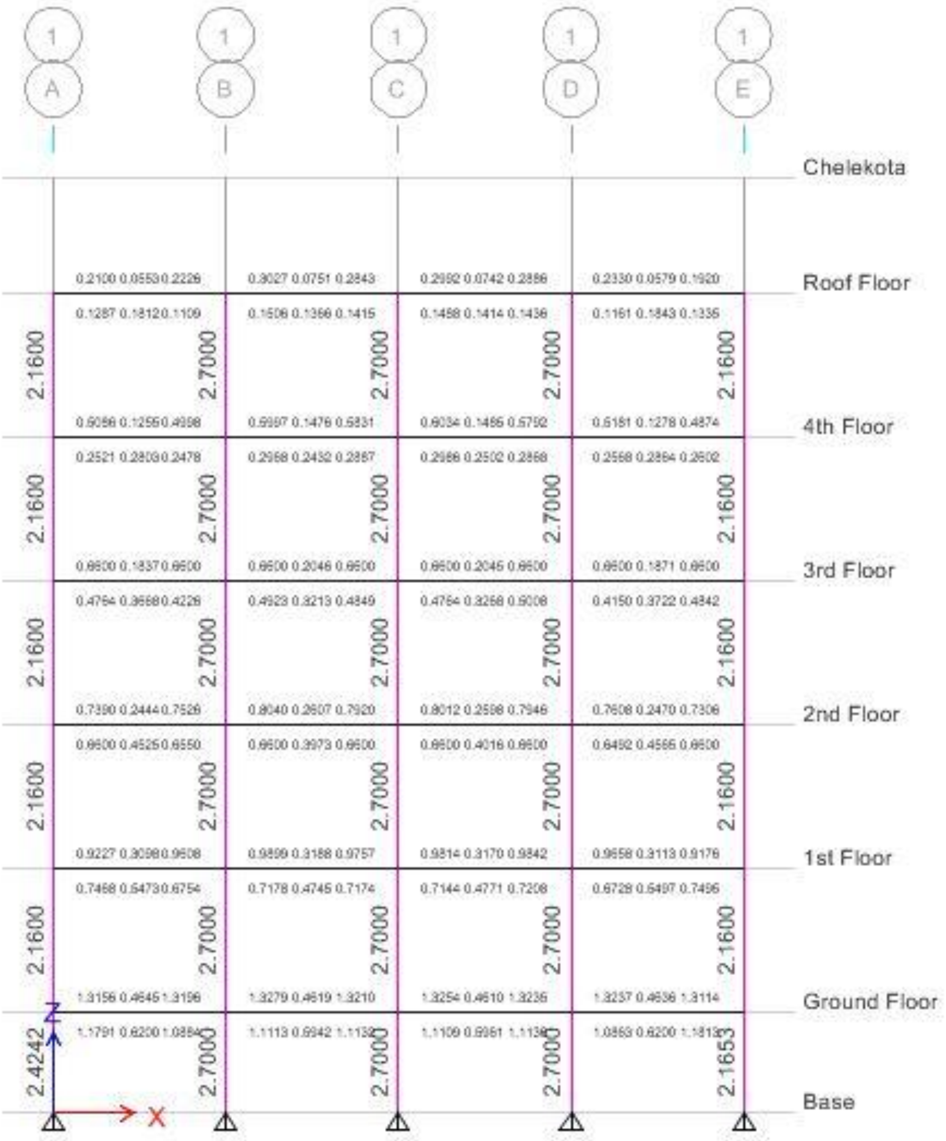
4.1 INTRODUCTION

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

4.2 ELEVATION OF COLUMN:

First of all, select the elevation of the column Grid 1, A. (Ground Floor, in etabs its show 1st floor)

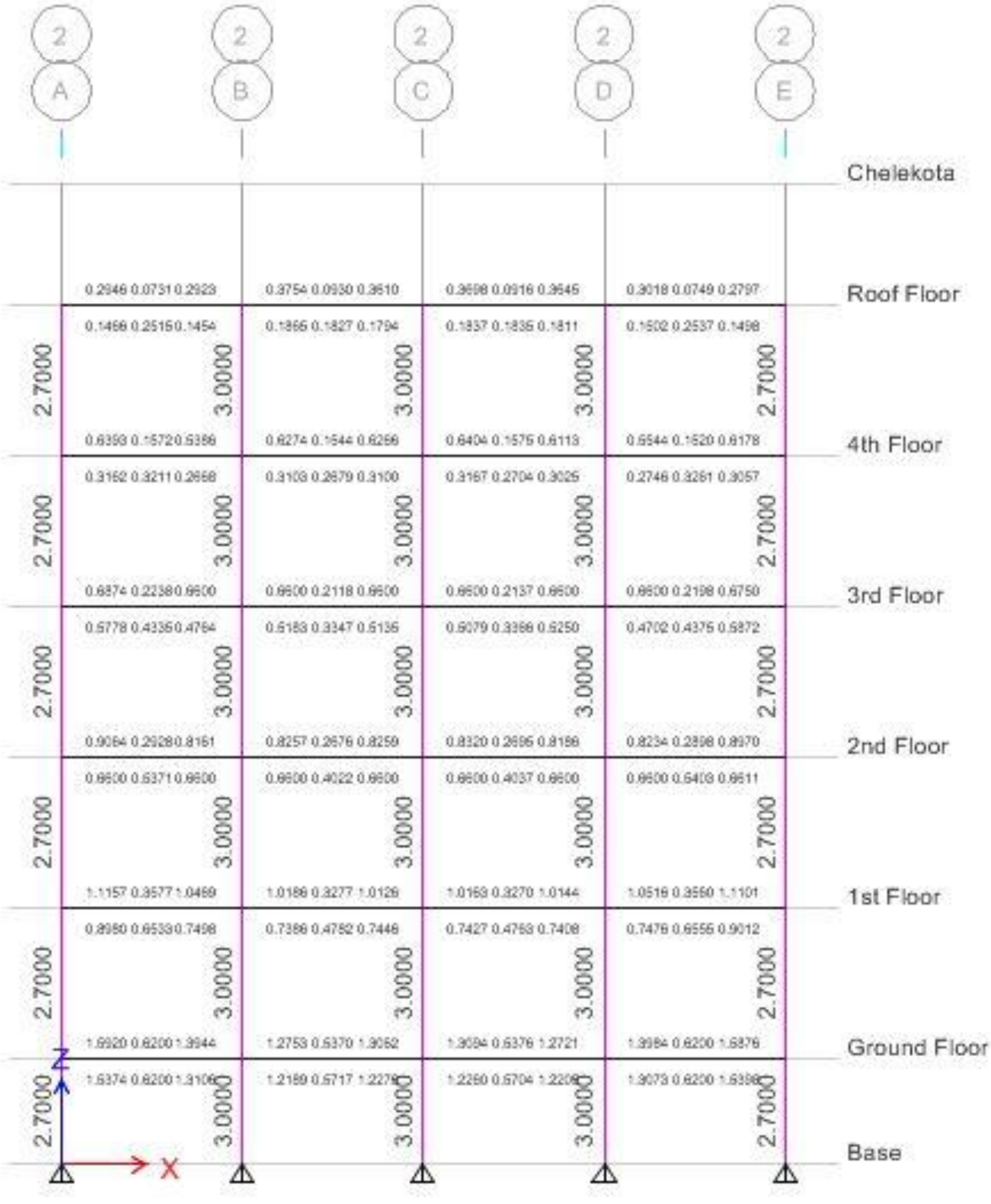
Table 4.1: Elevation of the column (1A)



From ETABS Model

First of all, select the elevation of the column Grid 2, A. (Ground Floor, In etabs its show 1st floor)

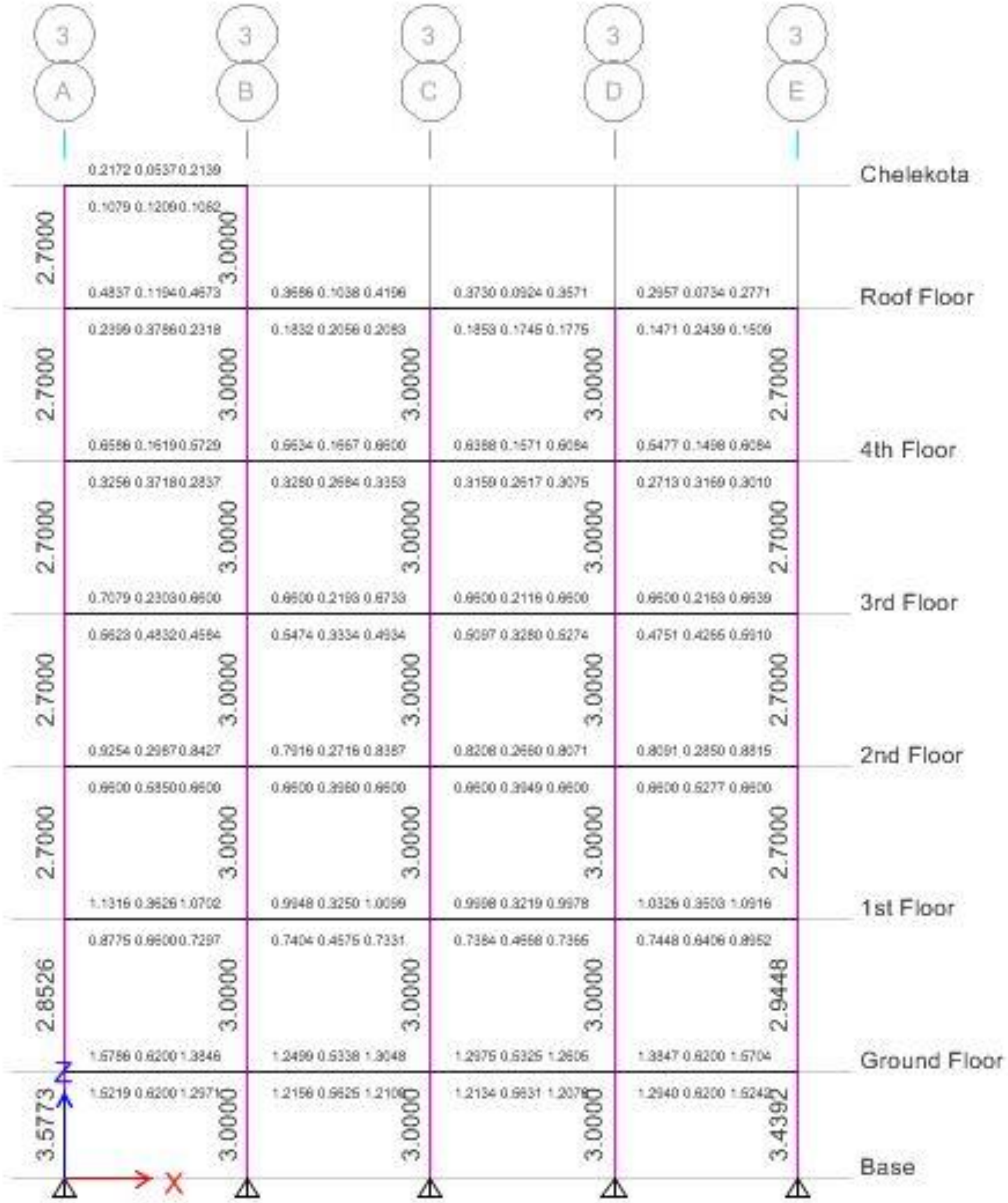
Table 4.2: Elevation of the column (2A)



From ETABS Model

First of all select the elevation of the column Grid 3, A. (Ground Floor, in etabs its show 1st floor)

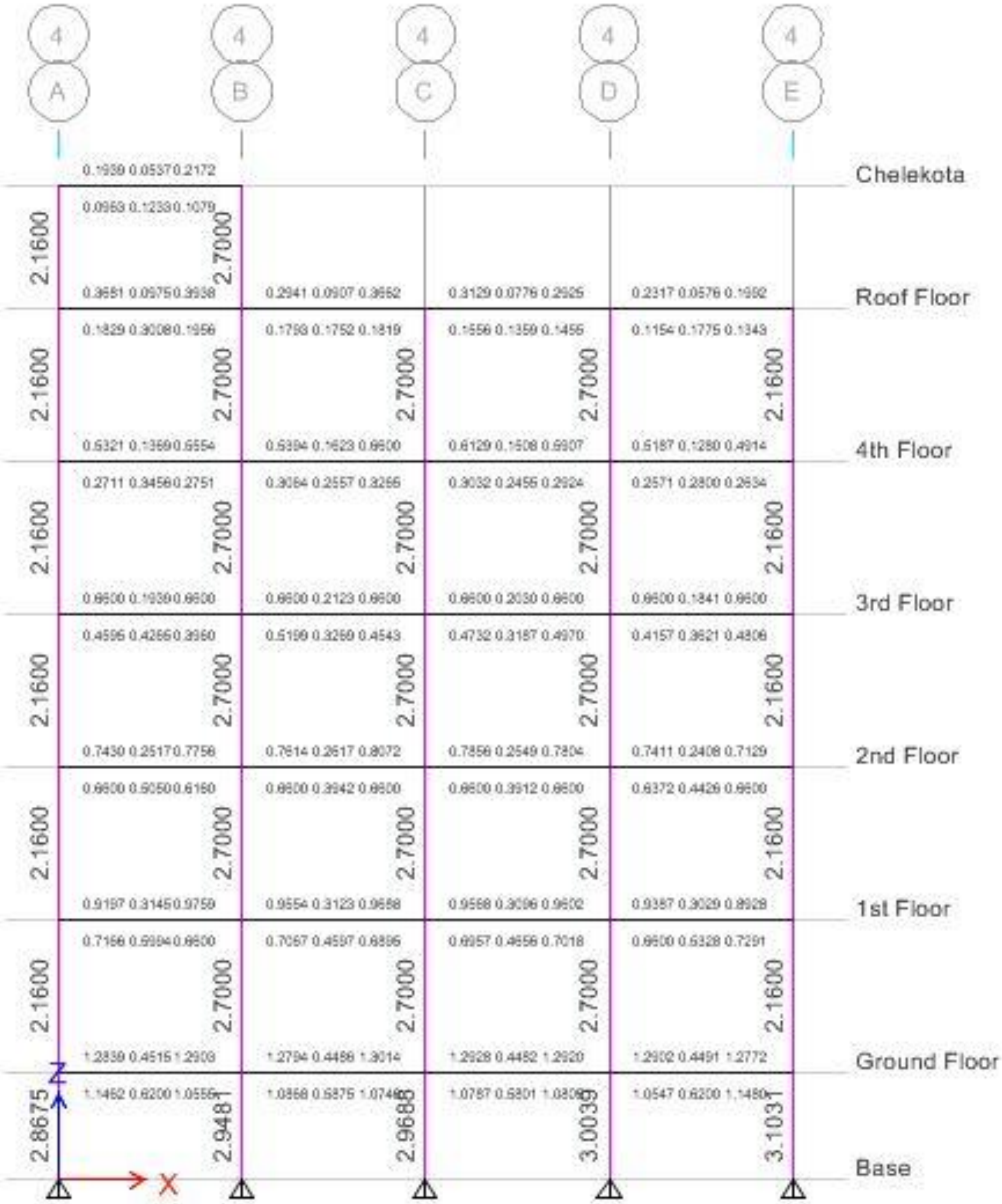
Table 4.3: Elevation of the column (3A)



From ETABS Model

First of all select the elevation of the column Grid 4, A. (Ground Floor, in etabs its show 1st floor)

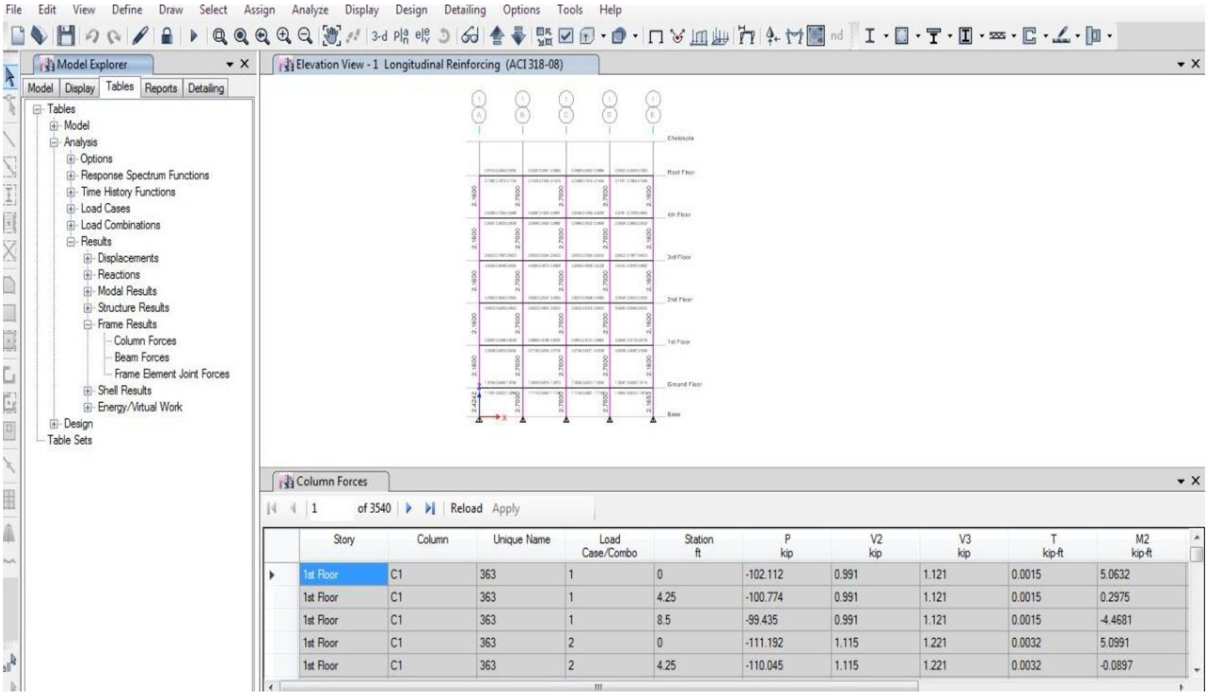
Table 4.4: Elevation of the column (4A)



From ETABS Model

4.3 FORCE OF COLUMN:

Table 4.5: Force of Column



Story	Column	Unique Name	Load Case/Combo	Station ft	P kip	V2 kip	V3 kip	T kip-ft	M2 kip-ft
1st Floor	C1	363	1	0	-102.112	0.991	1.121	0.0015	5.0632
1st Floor	C1	363	1	4.25	-100.774	0.991	1.121	0.0015	0.2975
1st Floor	C1	363	1	8.5	-99.435	0.991	1.121	0.0015	-4.4681
1st Floor	C1	363	2	0	-111.192	1.115	1.221	0.0032	5.0991
1st Floor	C1	363	2	4.25	-110.045	1.115	1.221	0.0032	-0.0897

From: **ETABS** Model

Then go the Table,Analysis,Result,Frameresult,and double click the Column force then show the display the column force in the display.Now select the story 1st floor,Column type C2 and also select all the load combination of the model.Then find the minimum column force from the force table P.Grid no 1,A Minimum column force is 37.987.

4.4 COLUMN STRENGTH:

Table 4.6: Column Strength Interpolated

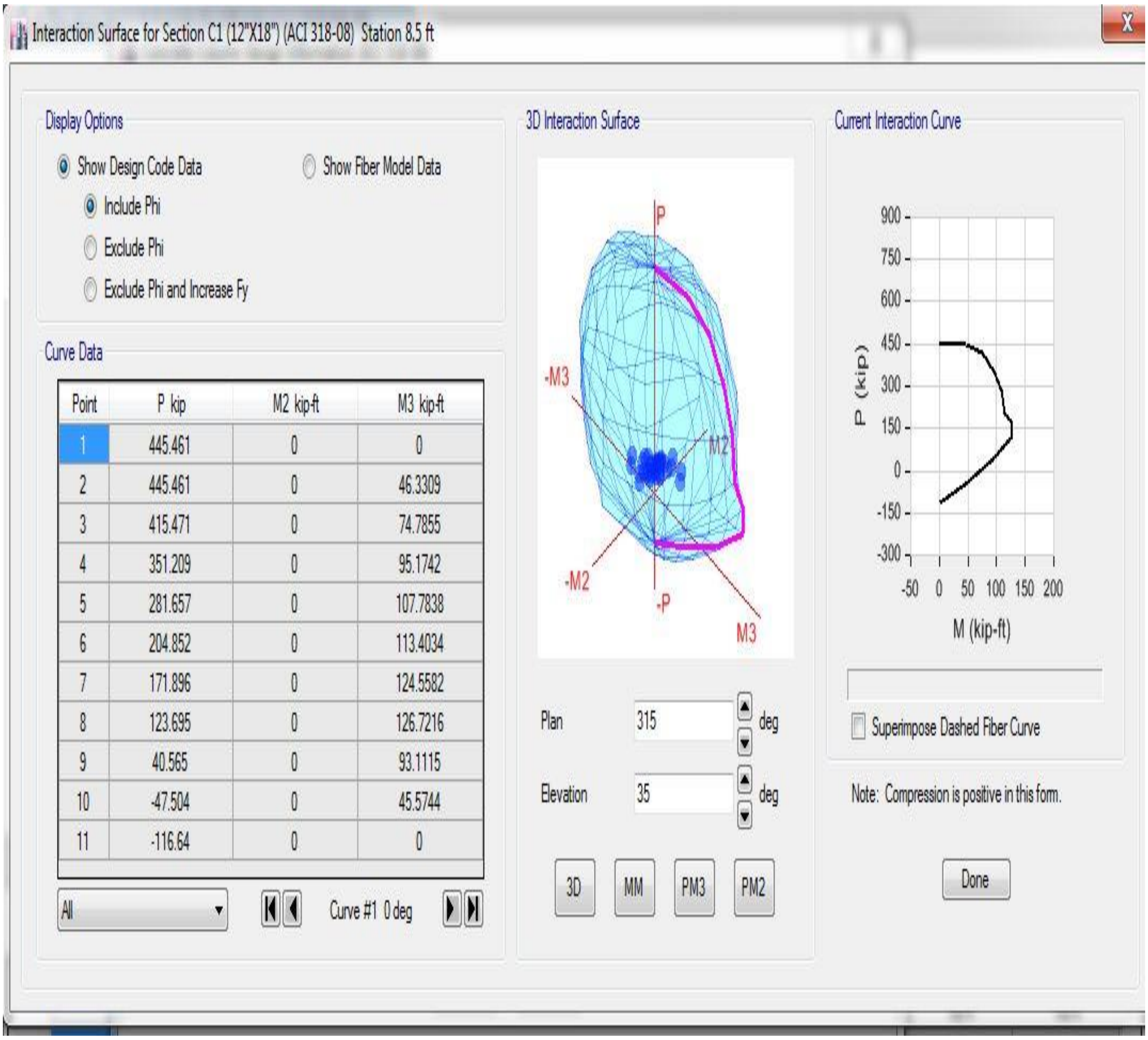
	Pu		Mu	m	c	interpolated value
	40.565	0	93.1115	0.54	71.2157	71.32 kip-ft.
	-47.504	0	45.5744			
Required	0.198		--------			

From **ETABS** Model

4.5 INTERACTION DETAILS:

Now go to the interaction diagram for 37.987 values. Copy the value is mark in the fig and past it in the previous fig. Then it has been found the interpolated value 108 kip-ft.

Table 4.7: Interaction Diagram



From **ETABS** Model

4.6 WEAK STORY CHECK:

4.6.1 Ground Floor Check:

Table 4.8: Shear strength of column, Vy from excel sheet (GF)

Weak Storey Check:
storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCk}}{H}$$

Given,
Storey height, H (ft.) = 10
1st Floor:
Total storey strength = 274.08 kips

Grid	Column Designation	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	C1	2	0.198	71.32	14.26
1B	C8	10	-29	73.37	14.67
1C	C8	9	-28.669	73.55	14.71
1D	C13	8	-30.652	72.47	14.49
1E	C13	3	-1.691	70.16	14.03
2A	C25	11	-43.322	65.64	13.13
2B	C25	20	-87.417	54.12	10.82
2C	C24	19	-84.919	55.93	11.19
2D	C3	18	-86.565	54.74	10.95
2E	C9	14	-41.922	66.39	13.28
3A	C27	12	-48.109	63.05	12.61
3B	C14	15	-89.415	52.67	10.53
3C	C14	16	-76.233	62.24	12.45
3D	C24	17	-76.383	62.13	12.43
3E	C5	13	-35.473	69.87	13.97
4A	C8	1	2.181	72.39	14.48
4B	C15	5	-18.374	79.1	15.82
4C	C17	6	-6.089	85.73	17.15
4D	C17	7	-6.477	85.52	17.1
4E	C20	4	16.343	80.04	16.01

Table: Shear strength of column, Vy from excel sheet (Ref: excel sheet)

4.6.2 FIRST FLOOR CHECK:

Table 4.9: Shear strength of column, Vy from excel sheet (1st floor)

Weak Storey Check:

storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCk}}{H}$$

Given,

Storey height, H (ft.) = 10

2nd Floor:

Total storey strength = 284.08 kips

Grid	Column Designation	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	C1	2	-7.246	67.3	13.46
1B	C8	10	-29.065	73.33	14.67
1C	C8	9	-28.903	73.55	14.71
1D	C13	8	-30.344	72.64	14.53
1E	C13	3	-8.439	66.66	13.33
2A	C25	11	-39.89	67.49	13.5
2B	C25	20	-69.218	67.33	13.47
2C	C24	19	-67.33	68.7	13.74
2D	C3	18	-68.418	67.91	13.58
2E	C9	14	-28.603	73.58	14.72
3A	C27	12	-46.498	63.92	12.78
3B	C14	15	-73.426	64.27	12.85
3C	C14	16	-61.657	72.81	14.56
3D	C24	17	-61.401	73	14.6
3E	C5	13	-33.355	71.02	14.2
4A	C8	1	-9.125	66.29	13.26
4B	C15	5	-25.556	75.23	15.05
4C	C17	6	-14.521	81.18	16.24
4D	C17	7	-14.501	81.19	16.24
4E	C20	4	3.24	72.96	14.59

Table: Shear strength of column, Vy from excel sheet (Ref: excel sheet)

4.6.3 SECOND FLOOR CHECK:

Table 4.10: Shear strength of column, Vy from excel sheet (2nd floor)

Weak Storey Check:

storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCk}}{H}$$

Given,

Storey height, H (ft.) = 10

3rd Floor:

Total storey strength = 297.29 kips

Grid	Column Designation	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	C1	2	-10.475	65.56	13.11
1B	C8	10	-25.969	75	15
1C	C8	9	-25.871	75.06	15.01
1D	C13	8	-26.901	74.5	14.9
1E	C13	3	-11.16	65.19	13.04
2A	C25	11	-33.075	71.17	14.23
2B	C25	20	-51.198	79.9	15.98
2C	C24	19	-49.853	80.7	16.14
2D	C3	18	-50.532	80.3	16.06
2E	C9	14	-32.004	71.75	14.35
3A	C27	12	-40.496	67.16	13.43
3B	C14	15	-57.328	75.96	15.19
3C	C14	16	-46.55	82.68	16.54
3D	C24	17	-46.166	82.91	16.58
3E	C5	13	-28.033	73.89	14.78
4A	C8	1	-15.092	63.07	12.61
4B	C15	5	-27.835	74	14.8
4C	C17	6	-17.805	79.41	15.88
4D	C17	7	-17.611	79.51	15.9
4E	C20	4	-4.448	68.81	13.76

Table: Shear strength of column, Vy from excel sheet (Ref: excel sheet)

4.6.4 THIRD FLOOR CHECK:

Table 4.11: Shear strength of column, Vy from excel sheet (3rd floor)

Weak Storey Check:

storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCk}}{H}$$

Given,

Storey height, H (ft.) = 10

4th Floor:

Total storey strength = 318.39 kips

Grid	Column Designation	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	C1	2	-9.334	66.18	13.24
1B	C8	10	-19.052	78.74	15.75
1C	C8	9	-18.969	78.78	15.76
1D	C13	8	-19.65	78.41	15.68
1E	C13	3	-9.67	66	13.2
2A	C25	11	-22.823	76.7	15.34
2B	C25	20	-33.378	90.57	18.11
2C	C24	19	-32.484	91.11	18.22
2D	C3	18	-32.899	90.86	18.17
2E	C9	14	-22.106	77.09	15.42
3A	C27	12	-30.335	72.65	14.53
3B	C14	15	-40.929	86.05	17.21
3C	C14	16	-30.873	92.07	18.41
3D	C24	17	-30.329	92.4	18.48
3E	C5	13	-19.699	78.39	15.68
4A	C8	1	-15.625	62.78	12.56
4B	C15	5	-24.503	75.79	15.16
4C	C17	6	-15.307	80.76	16.15
4D	C17	7	-15.085	88.88	17.78
4E	C20	4	-6.559	67.68	13.54

Table: Shear strength of column, Vy from excel sheet (Ref: excel sheet)

4.6.5 FOURTH FLOOR CHECK:

Table 4.12: Shear strength of column, Vy from excel sheet (4th floor)

Weak Storey Check:

storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCk}}{H}$$

Given,

Storey height, H (ft.) = 10

4th Floor:

Total storey strength = 343.01 kips

Grid	Column Designation	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	C1	2	-3.783	69.17	13.83
1B	C8	10	-8.211	84.59	16.92
1C	C8	9	-8.09	84.65	16.93
1D	C13	8	-8.454	84.46	16.89
1E	C13	3	-3.919	69.1	13.82
2A	C25	11	-9.194	84.06	16.81
2B	C25	20	-15.893	101.05	20.21
2C	C24	19	-15.26	101.43	20.29
2D	C3	18	-15.678	101.18	20.24
2E	C9	14	-8.86	84.24	16.85
3A	C27	12	-17.274	79.7	15.94
3B	C14	15	-24.232	96.05	19.21
3C	C14	16	-14.31	102	20.4
3D	C24	17	-14.246	102.04	20.41
3E	C5	13	-7.95	84.73	16.95
4A	C8	1	-10.513	65.54	13.11
4B	C15	5	-15.31	80.76	16.15
4C	C17	6	-6.894	85.3	17.06
4D	C17	7	-6.764	85.37	17.07
4E	C20	4	-3.014	69.59	13.92

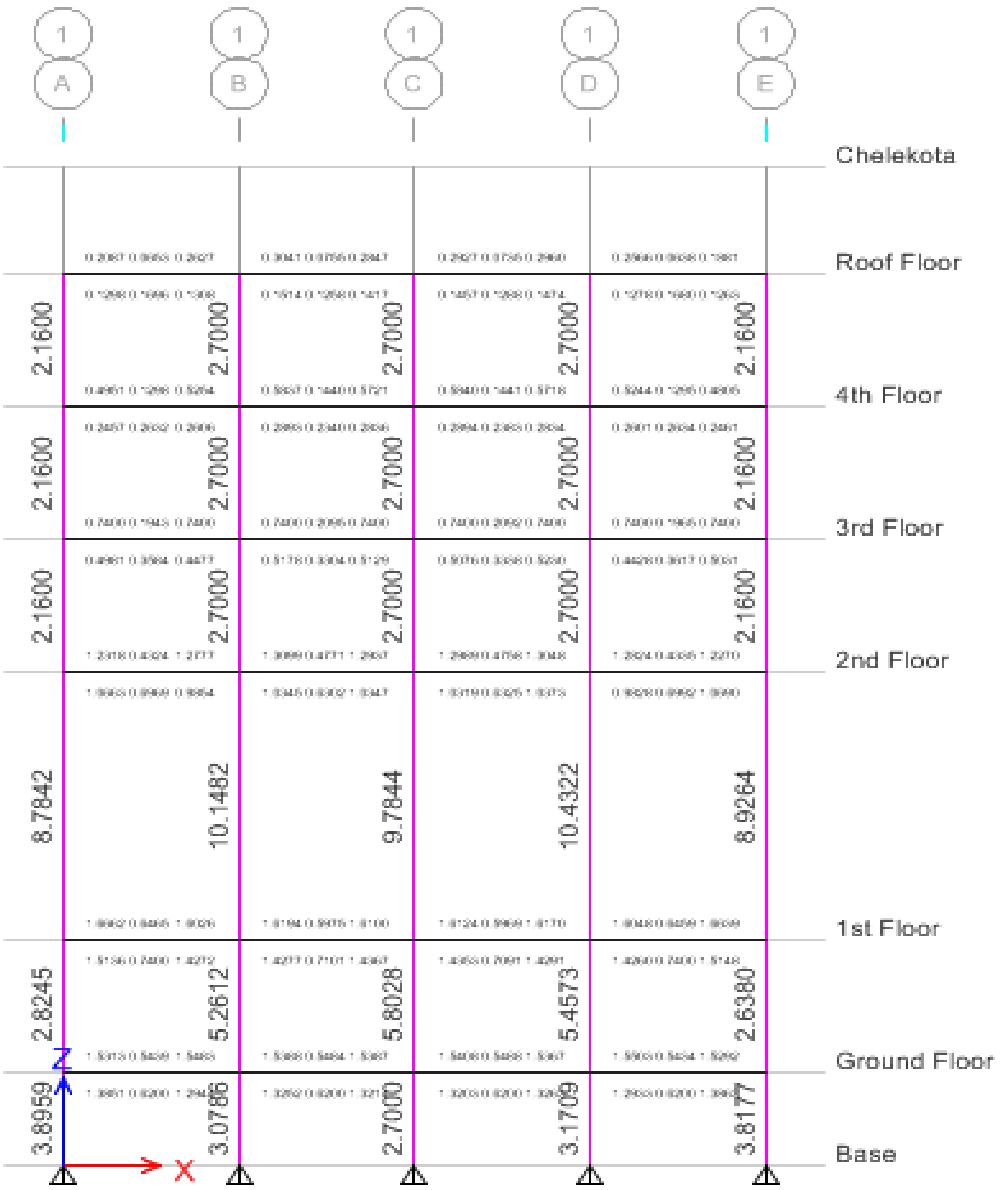
Table: Shear strength of column, Vy from excel sheet (Ref: excel sheet)

2x14.26/10=2.85.It has been found the column shear strength is 21.6.By this procedure find the total shear strength of the all column in a floor and summation all the shear strength, divide the ground floor column shear strength by the 1st floor column shear strength by percentage. Weak story is found if the ground floor column shear strength is less than 80% of the 1st floor. $\frac{274.08}{284.08}$x100 = 96.47%. So Weak story is not found for this building.

4.7 ELEVATION OF COLUMN RE-CHECK:

First of all, select the elevation of the column Grid 1, A. (Ground Floor, in etabs its show 1st floor)

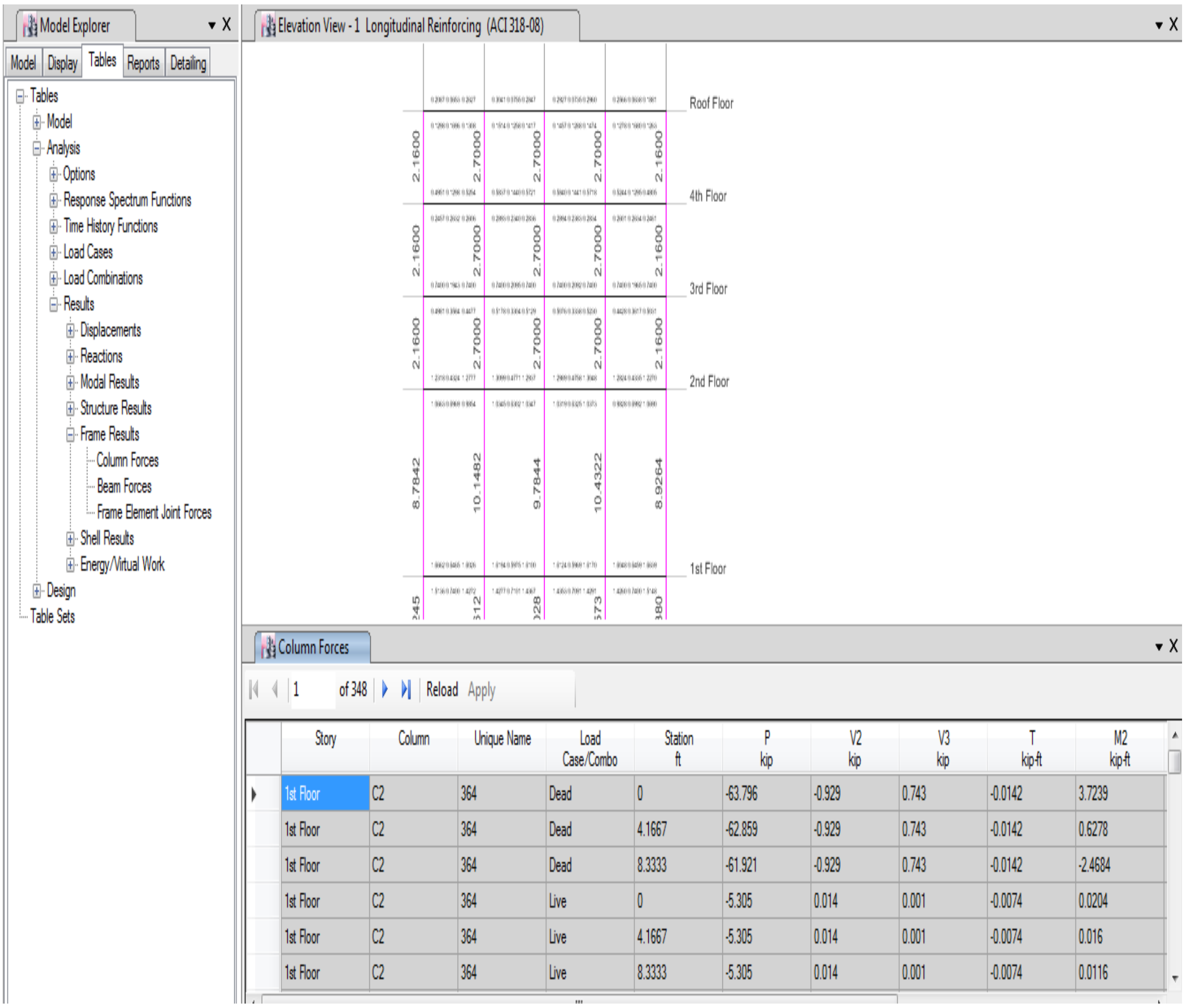
Table 4.13: Elevation of the column (1A) Re-check



From **ETABS** Model

4.8 FORCE OF COLUMN RE-CHECK:

Table 4.14: Force of Column Re-Check



Story	Column	Unique Name	Load Case/Combo	Station ft	P kip	V2 kip	V3 kip	T kip-ft	M2 kip-ft
1st Floor	C2	364	Dead	0	-63.796	-0.929	0.743	-0.0142	3.7239
1st Floor	C2	364	Dead	4.1667	-62.859	-0.929	0.743	-0.0142	0.6278
1st Floor	C2	364	Dead	8.3333	-61.921	-0.929	0.743	-0.0142	-2.4684
1st Floor	C2	364	Live	0	-5.305	0.014	0.001	-0.0074	0.0204
1st Floor	C2	364	Live	4.1667	-5.305	0.014	0.001	-0.0074	0.016
1st Floor	C2	364	Live	8.3333	-5.305	0.014	0.001	-0.0074	0.0116

From **ETABS** Model

Then go the Table, Analysis, Result, Frame result, and double click the Column force then show the display the column force in the display. Now select the story 1stfloor, Column type C2 and also select all the load combination of the model. Then find the minimum column force from the force table P.Grid no 1, A Minimum column force is 37.987.

4.9 COLUMN STRENGTH RE-CHECK:

Table 4.15: Column Strength Interpolated Re-Check

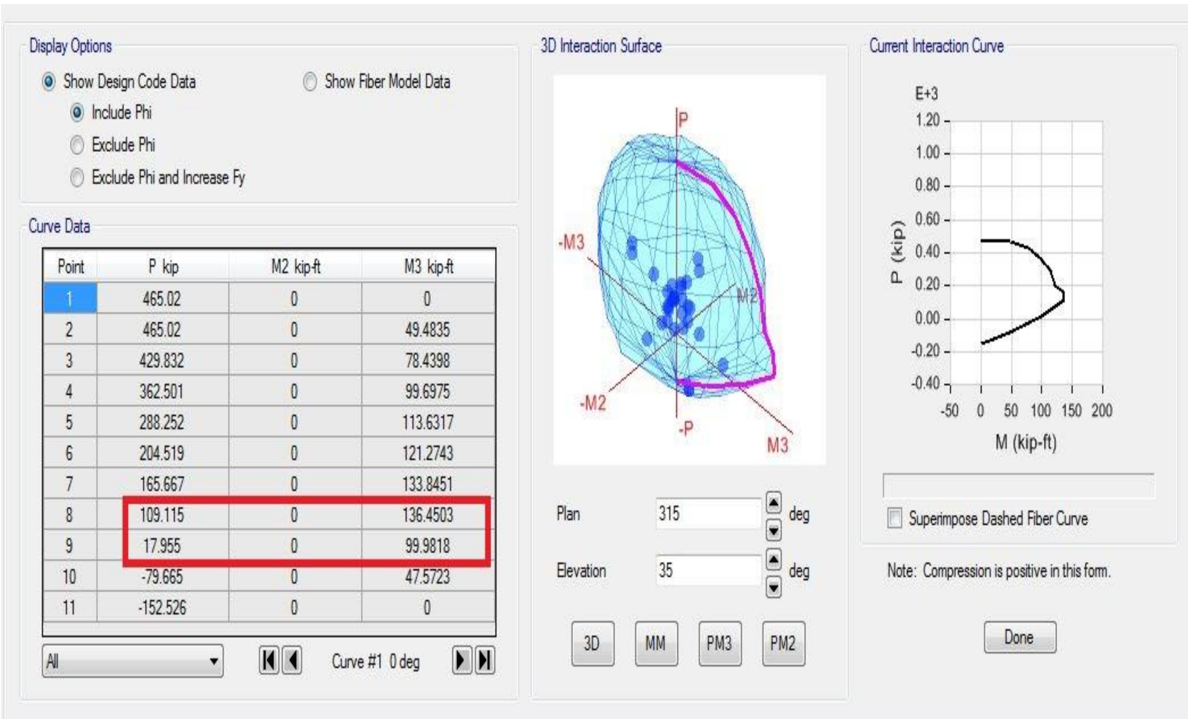
	Pu		Mu	m	c	interpolated value
	109.115	0	136.4503	0.40	92.79891	108 kip-ft.
	17.955	0	99.9818			
Required	37.987		--------			

From **ETABS** Model

4.10 INTERACTION DETAILS RE-CHECK:

Now go to the interaction diagram for 37.987 values. Copy the value is mark in the fig and past it in the previous fig. Then it has been found the interpolated value 108 kip-ft.

Table 4.16: Interaction Diagram Re-Check



Point	P kip	M2 kip-ft	M3 kip-ft
1	465.02	0	0
2	465.02	0	49.4835
3	429.832	0	78.4398
4	362.501	0	99.6975
5	288.252	0	113.6317
6	204.519	0	121.2743
7	165.667	0	133.8451
8	109.115	0	136.4503
9	17.955	0	99.9818
10	-79.665	0	47.5723
11	-152.526	0	0

From **ETABS** Model

4.11 WEAK STORY RE-CHECK:

4.11.1 Ground Floor RE-CHECK:

Table 4.17: Shear strength of column, Vy from excel sheet (GF) Re-Check

Weak Storey Check:

storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCk}}{H}$$

Given,

Storey height, H (ft.) =	10

Ground Floor:	
Total storey strength =	**515.05** kips

Grid	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	2	37.987	108	21.6
1B	10	-26.985	74.45	14.89
1C	9	-28.639	73.56	14.71
1D	8	-28.404	73.69	14.74
1E	3	28.961	114.74	22.95
2A	11	-42.619	66.02	13.2
2B	20	0	0	0
2C	19	0	0	0
2D	18	0	0	0
2E	14	-41.015	66.88	13.38
3A	12	-21.859	198.18	39.64
3B	15	-36.554	254.98	51
3C	16	-21.087	249.96	49.99
3D	17	-23.569	252.33	50.47
3E	13	-11.243	189.97	37.99
4A	1	40.066	138.26	27.65
4B	5	29.383	181.57	36.31
4C	6	41.053	195.43	39.09
4D	7	40.644	189.41	37.88
4E	4	55.16	147.79	29.56

Table: Shear strength of column, Vy from excel sheet (Ref: excel sheet)

4.11.2 FIRST FLOOR RE-CHECK:

Table 4.18: Shear strength of column, Vy from excel sheet (1st Floor) Re-Check

Weak Storey Check:

storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCk}}{H}$$

Given,

Storey height, H (ft.) =	20

1st Floor:	
Total storey strength =	**472.02** kips

Grid	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	2	6.734	221.18	22.12
1B	10	-14.388	254.93	25.49
1C	9	-15.89	240.68	24.07
1D	8	-15.828	261.64	26.16
1E	3	5.118	223.15	22.32
2A	11	-30.462	278.24	27.82
2B	25	-69.699	150.9	15.09
2C	19	-67.286	154.39	15.44
2D	18	-68.745	155.22	15.52
2E	14	-28.92	267.49	26.75
3A	12	-38.33	274.62	27.46
3B	15	-74.304	262.34	26.23
3C	16	-62.522	255.09	25.51
3D	17	-62.413	263.12	26.31
3E	13	-24.59	243.35	24.34
4A	1	6.628	217.99	21.8
4B	5	-10.308	269.47	26.95
4C	6	-0.099	257.74	25.77
4D	7	0.58	255.66	25.57
4E	4	19.431	212.96	21.3

Table: Shear strength of column, Vy from excel sheet (Ref: excel sheet)

4.11.3 SECOND FLOOR RE-CHECK:

Table 4.19: Shear strength of column, Vy from excel sheet (2nd Floor) Re-Check

Weak Storey Check:

storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pck}}{H}$$

Given,

Storey height, H (ft.) =	10

2nd Floor:	
Total storey strength =	**285.24** kips

Grid	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	2	3.446	73.08	14.62
1B	10	-29.065	73.33	14.67
1C	9	-28.903	73.55	14.71
1D	8	-30.344	72.64	14.53
1E	3	-8.439	66.66	13.33
2A	11	-39.89	67.49	13.5
2B	20	-69.218	67.33	13.47
2C	19	-67.33	68.7	13.74
2D	18	-68.418	67.91	13.58
2E	14	-28.603	73.58	14.72
3A	12	-46.498	63.92	12.78
3B	15	-73.426	64.27	12.85
3C	16	-61.657	72.81	14.56
3D	17	-61.401	73	14.6
3E	13	-33.355	71.02	14.2
4A	1	-9.125	66.29	13.26
4B	5	-25.556	75.23	15.05
4C	6	-14.521	81.18	16.24
4D	7	-14.501	81.19	16.24
4E	4	3.24	72.96	14.59

Table: Shear strength of column, Vy from excel sheet (Ref: excel sheet)

4.11.4 THIRD FLOOR RE-CHECK:

Table 4.20: Shear strength of column, Vy from excel sheet (3rd Floor) Re-Check

Weak Storey Check:

storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCk}}{H}$$

Given,

Storey height, H (ft.) =	10
3rd Floor:	
Total storey strength =	**297.29 kips**

Grid	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	2	-10.475	65.56	13.11
1B	10	-25.969	75	15
1C	9	-25.871	75.06	15.01
1D	8	-26.901	74.5	14.9
1E	3	-11.16	65.19	13.04
2A	11	-33.075	71.17	14.23
2B	20	-51.198	79.9	15.98
2C	19	-49.853	80.7	16.14
2D	18	-50.532	80.3	16.06
2E	14	-32.004	71.75	14.35
3A	12	-40.496	67.16	13.43
3B	15	-57.328	75.96	15.19
3C	16	-46.55	82.68	16.54
3D	17	-46.166	82.91	16.58
3E	13	-28.033	73.89	14.78
4A	1	-15.092	63.07	12.61
4B	5	-27.835	74	14.8
4C	6	-17.805	79.41	15.88
4D	7	-17.611	79.51	15.9
4E	4	-4.448	68.81	13.76

Table: Shear strength of column, Vy from excel sheet (Ref:excel sheet)

4.11.5 FOURTH FLOOR RE-CHECK:

Table 4.21: Shear strength of column, Vy from excel sheet (4th Floor) Re-Check

Weak Storey Check:
storey strength is calculated as follows:

$$V_{yi} = \frac{2\sum_{k=1}^{m} M_{pCk}}{H}$$

Given,

Storey height, H (ft.) =	10

4th Floor:	
Total storey strength =	**318.39 kips**

Grid	Column Label (From ETABS)	Minimum Factored Load, P_u (kips)	Plastic Strength from ETABS Interaction Diagram, M_{pck} (kip-ft.)	Shear strength of column, V_y (kips)
1A	2	-9.334	66.18	13.24
1B	10	-19.052	78.74	15.75
1C	9	-18.969	78.78	15.76
1D	8	-19.65	78.41	15.68
1E	3	-9.67	66	13.2
2A	11	-22.823	76.7	15.34
2B	20	-33.378	90.57	18.11
2C	19	-32.484	91.11	18.22
2D	18	-32.899	90.86	18.17
2E	14	-22.106	77.09	15.42
3A	12	-30.335	72.65	14.53
3B	15	-40.929	86.05	17.21
3C	16	-30.873	92.07	18.41
3D	17	-30.329	92.4	18.48
3E	13	-19.699	78.39	15.68
4A	1	-15.625	62.78	12.56
4B	5	-24.503	75.79	15.16
4C	6	-15.307	80.76	16.15
4D	7	-15.085	88.88	17.78
4E	4	-6.559	67.68	13.54

Table: Shear strength of column, Vy from excel sheet (Ref: excel sheet)

2x108/10=21.6.It has been found the column shear strength is 21.6.By this procedure find the total shear strength of the all column in a floor and summation all the shear strength, divide the ground floor column shear strength by the 1st floor column shear strength by percentage. Weak story is found if the ground floor column shear strength is less than 80% of the 1st floor.$\frac{515.05}{472.02}$x100 = 128.11%. So Weak story is not found for this building.

4.12 SUMMARY:

These results show that the design of RC buildings is quite important of weak story irregularity in terms of cost. We also specially suggest to do a key element removal check and then ensure bridging of failure of these key elements. At least this need to be done for factor load combinations to rule out accidental collapses that might also become progressive. To prevent weak story irregularity, shear walls and diagonal bracing elements can be used. Thus, it is clear that such buildings will exhibit poor performance during a strong shaking. This hazardous feature of Indian RC frame buildings needs to be recognized immediately and necessary measures taken to improve the performance of the buildings. The phenomena of soft story may arise due to many Different reasons such as change in load carrying and slab system between stories. The abrupt changes which take place in the amount of the infill walls between stories is also one of the frequent reasons of the soft storey behavior. Since infill walls are not regarded as a part of load carrying system, generally civil engineers do not consider its effects on the structural behaviour. In current TEC, concrete strength is not considered in calculations related to weak story irregularity. It is recommended that concrete strength should be included in these calculations by taking the results obtained from this study.

CHAPTER 5

CONCLUSIONS AND FUTURE WORKS:

5.1 & 5.2 CONCLUSION AND RECOMMENDATIONS:

- It is always better to design building structures keeping in mind the four virtues of seismic resistance. However sometimes, it is not possible to avoid some irregularity like that arising due to the open floors due to the requirement of parking. In such cases, careful considerations as mentioned in IS 1893 2016 shall be adopted.
- RCC frame buildings with open bottom storey are known to perform poorly during in strong earthquake shaking.
- "Soft storey" and "weak storey" are irregular building configurations that are important source of serious earthquake damage.
- Soft storey is a situation when the upper levels of a building is stiffer than the lower storey.
- The building is analyzed linearly for seismic design.
- All loads are taken according to BNBC code provided.
- The impact of earthquakes load on building design is critical.
- In conclusion it is determined that non-engineered buildings, faulty original design, lack of lateral resisting elements, frames, shear walls, inadequate detailing of reinforcement, extensions.
- Engineering Failure Analysis impacts of weak-storey irregularity during earthquakes are exacerbated by encroachment, increase in load during use, poor and inadequate construction, lack of regular maintenance, and effects such corrosion and material deterioration. This needs to be taken into account both in the design and construction phases.
- Lightweight infill wall materials can be used in upper floors of buildings with weak-storey effects to partially prevent the weak-storey effect.
- In high seismic risk zones, if possible, the existing irregular buildings must be strengthened immediately, otherwise they must be demolished.
- We can inspect the weak story once again, at which point we'll need to raise the floor, reduce the size of the columns and beams, and use an RCC frame.
- Only the ETABS software is used for analysis in this study.

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