# ETABS Analysis for Edge Supported and Flat Slab (With and Without) Perimeter Beam at High Seismic Zone

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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: 14A

Fall-2021

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# DECLARATION

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

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# Dedication

"This Thesis is Dedicated to our beloved PARENTS & the Faculties, Department of Civil Engineering".

# ACKNOWLEDGEMENTS

At fast, Thanks to Almighty for giving us an opportunity for the completion of the writing thesis. His blessing, strength and capability, we have achieved different type of experience. The topics on "**ETABS Analysis for Edge Supported and Flat Slab (With and Without) Perimeter Beam at High Seismic Zone**" has been conducted in fulfillments for the degree of Bachelor of Science in Civil Engineering.

We would like to give thanks and respect to our beloved parents and family for supporting us by both mentally and physically through the whole work. We our group truly admit and convey our deep expression of gratitude and respect to our honorable teacher **Mr. S.M. Yashin, Assistant Professor & Head (Acting)**, Department of Civil Engineering, also respect to we would like to **Md. Ferdous Wahid, Assistant Professor & Coordinator**, Department of Civil Engineering, SonargaonUniversity [SU].

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# ABSTRACT

Flat slab structure are more convenient, economical and provide better architectural visibility over conventional slab structure. But flat slab structures are flexible in nature and thus pose a threat to the safety of the structure which brings us to find a method to overcome this disadvantage. Therefore, perimeter beams are provided which imparts rigidity to the structure. This paper focuses on the comparative study of conventional slab structure to flat slab structure having perimeter beams.

In this study, ETABS software is used for the analysis of different structures in high seismic zones of Mymensingh (0.36) in Bangladesh having G+6 and G+11 storeys. The models taken in this study have rectangular shape configuration. On the basis the analysis results, the paper discusses the distinctions of structure's behavior under different slab in terms of maximum storey displacement, maximum storey drift and storey stiffness. The storey displacement of flat slab is approximately three times than conventional slab and two times than flat slab with perimeter beam for G+6 storey and two times than conventional slab and one-half times than flat slab with perimeter beam for G+11 storey. The storey drift is also same as storey displacement.

The stiffness of conventional slab supported structure is approximately four times than flat slab and two times than flat slab with perimeter beam for G+6 storey. The stiffness of conventional slab supported structure is approximately three times than flat slab and two times than flat slab with perimeter beam for G+11 storey. This is due to the conventional slab structure has a greater stiffness than flat slab structure and flat slab with perimeter beam structure. Lastly three data analyze of the three types of buildings showed that the conventional slab performed best in all three cases of displacement, drift and stiffness. But the flat slab with perimeter beam is giving satisfactory results. Therefore, the idea of flat slab with perimeter beam can be developed in those places where it is necessary to give flat slab in the Earthquake zone.



**KEYWORDS: Flat Slab, Conventional Slab, Seismic Analysis, Perimeter Beams, Seismic Zones, ETABS**

# CONTENTS

ACKNOWLEDGEMENTS ..... v
ABSTRACT ..... …..vi

**LIST OF ABBREVIATIONS OF TECHNICAL TERMS..... ……..viii**

LIST OF TABLES ..... ……xiii

LIST OF FIGURES..... …….xiv

CHAPTER I: INTRODUCTION..... 1

1.1 Flat Slabs ..... 3

1.2 Punching Shear ..... 4

1.2 Beam Supported Slab .....6

1.4 Scope of the Study.....7

1.5 Objectives of the study .....7

**CHAPTER II: LITERATURE REVIEW ..... 9**

2.1 Effect of Concrete Strength .....……16

2.2 Size Effect ……16

2.3 Effect of Shear Reinforcement ..... ……17

2.4 Edge Condition Effect ..... ……18

2.5 Slab-Column Connection Behavior ..... ……18

2.6 Shear Strengthening Techniques..... …….19

2.7 Miscellaneous Studies……...19

**CHAPTER III: METHODOLOGY ..... ……..……**21

3.1 Introduction ..... 21
3.2 Building Description ..... 21
3.3 Loads and other considerations ..... 22
3.3.1 Dead Loads ..... 22
3.3.2 Live Loads ..... 22
3.3.3 Wind Load ..... 22
3.3.4 Seismic Load ..... 23
3.3.5 Load Combinations ..... 23
3.4 Procedure of Modeling by ETABS ..... 24
3.4 Floor Plan ..... 30
3.5.1 Beam Supported Slab Floor Plan ..... 30
3.5.2 Flat Slab without Perimeter Beam Floor Plan ..... 31
3.5.3 Flat Slab with Perimeter Beam Floor Plan ..... 32
3.6 Render Model of structure ..... 33
3.6.1 G+6 Story Building ..... 33
3.6.1.1 Render View of Beam Supported Slab ..... 33
3.6.1.2 Render View of Flat Slab without Perimeter Beam ..... 34
3.6.1.3 Render View of Flat Slab with Perimeter Beam ..... 35
3.6.2 G+11 Story Building ..... 36
3.6.2.1 Render View of Beam Supported Slab ..... 36
3.6.2.2 Render View of Flat Slab without Perimeter Beam ..... 37
3.6.2.3 Render View of Flat Slab with Perimeter Beam ..... 38
3.7 Analysis of Modeling ..... 39
3.7.1 Procedure of Analysis by ETABS ..... 39
3.7.2 Analysis Types ..... 40
3.7.2.1 Story Displacement ..... 40
3.7.2.3StoryDrift ..... 40

3.7.2.3 Story Stiffness……42

3.7 Conclusion…… 42

**CHAPTER IV: RESULTS AND DISCUSSIONS.....43**

4.1 Introduction.....43

4.2 Results .....43

4.2.1 Comparison Based on Story Displacement for G+6.....43

4.2.2 Comparison Based on Story Drift for G+6.....45

4.2.3 Comparison Based on Story Stiffness for G+6.....47

4.2.4 Comparison Based on Story Stiffness for G+6.....50

4.2.5 Comparison Based on Story Displacement for G+11 .....52

4.2.6 Comparison Based on Story Drift for G+11……54

4.2.7 Comparison Based on Story Stiffness for G+11.....57

4.2.8 Comparison Based on Story Stiffness for G+11.....59

4.3 Discussions .....61

**CHAPTER V: CONCLUSION AND RECOMMENDATION..... ..63**

5.1 Introduction.....63

5.2 Conclusion .....63

5.2.1 Displacement.....63

5.2.2 Storey Drift……63

5.2.3 Storey Stiffness……64

5.3 Recommendation for Further Study……64

**REFERENCES ..... …65**

**NOTATIONS……68**

# LIST OF TABLES

**Table 3.1**: Preliminary data for G+11 & G+6 story building ..... 21
**Table 3.2**: Dead loads ..... 22
**Table 3.3**: Live loads ..... 22
**Table 3.4**: Preliminary data for seismic load parameters ..... 23
**Table 3.5**: Load combinations ..... 24
**Table 4.1:** The Story displacement of G+6 Story building using different slab ..... 40
**Table 4.2**: The Story Drift of G+6 story building using different slab system ..... 42
**Table 4.3**: Comparative story stiffness of different slab system of G+6 story ..... 44
**Table 4.4**: Comparative story stiffness of different slab system of G+11 ..... 46
**Table 4.5:** Comparative story displacement of different slab system of G+11 ..... 48
**Table 4.6:** Comparative story drift of different slab system of G+11 story ..... 50
**Table 4.7**: Comparative story stiffness of different slab system of G+11 story ..... 52
**Table 4.8**: Comparative story Stiffness of different slab system with load WX ..... 54

# LIST OF FIGURES

**Figure 1.1**: Earthquake zoning map of Bangladesh…..... 1

**Figure 1.2** Map of Seismic Vulnerability of Residential Neighborhoods of Mymensingh City.1

**Figure 1.3**: Flat plate slab floor system ..... 3

**Figure 1.4**: Flat slab failure due to punching shear..... 5

**Figure 1.5**: A square column tends to shear out a pyramid from a flat plate ..... 6

**Figure 3.1**: Beam Supported slab floor plan ..... 30

**Figure 3.2**: Flat slab without perimeter beam floor plan..... 32

**Figure 3.3**: Flat slab with perimeter beam floor plan ..... 33

**Figure 3.4**: Render view of the Beam Supported slab..... 34

**Figure 3.5**: Render view of flat slab without perimeter beam..... 35

**Figure 3.6**: Render view of flat slab with perimeter beam ..... 36

**Figure 3.7**: Render view of Beam Supported slab ..... 37

**Figure 3.8**: Render view of flat slab without perimeter beam..... 38

**Figure 3.9**: Render view of flat slab with perimeter beam ..... 39

**Figure 3.10**: Story Displacement……..41

**Figure 3.11**: Story Drift……..42

**Figure 3.12**: Story Stiffness……...43

# CHAPTER I

## INTRODUCTION

Now-a-days flat slab structures are replacing conventional slab structures as they are more feasible to construct, take less time and shows good aesthetic appearance. But the major disadvantage of flat slab is its high flexibility due to which many problems like motion sickness, high storey displacement etc occurs so to overcome this the concept of Perimeter beams is adopted which reduces the flexibility of the flat slab structure to a much greater extend.Due to the flexibility of Flat slab structures, they must be made stiffer or their rigidity must be increased by any means. Perimeter beams or Edge beams are provided with flat slabs for increasing their stiffness and for withstanding the lateral loads in high seismic zones.Perimeter beams are used in place of shear wall in flat slab structures because shear walls have many disadvantages such as they increase the cost of the structure, they make the structure so rigid that application of lateral forces results in cracks, if we provide shear wall then positioning of shear wall is also a critical study that's why provision of perimeterbeams as an alternative to shear wall in flat slab structures is adopted.

Generally, to reduce the amount of negative moment reinforcement over a column or to reduce shear stresses near column a drop panel of rectangular cross-section should be provided in flat slab structure

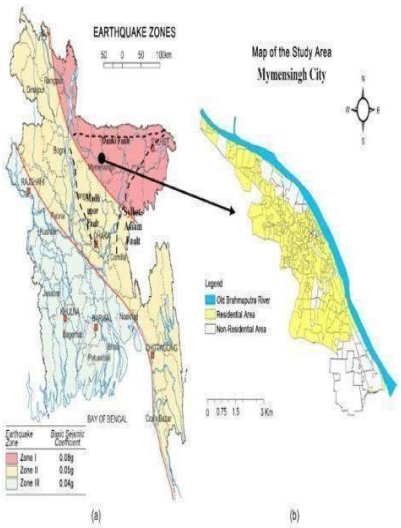



**Figure 1.1:** Earthquake zoning map of Bangladesh.

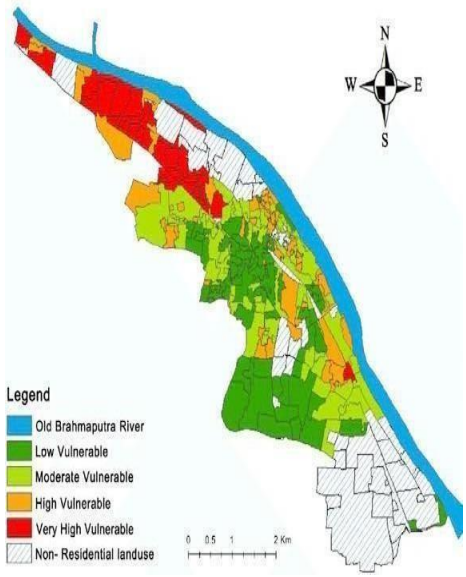



**Fig1.2:** Map of Seismic Vulnerability of Residential Neighborhoods of Mymensingh City

**Mymensingh** is on of the most earthquake-prone area of Bangladesh. Ara (2014) analyzed the impact of the sequential distribution of the population living in an earthquake-prone area to realize a pragmatic assessment. Population forecasting plays an important role to local authorities, businessmen and researchers for many purposes (Chi et al. 2011). The structural analysis software ETABS has been used to design the building. ETABS is an acronym that stands for — Extended three-dimensional analysisof building system. It is especially more efficient for building design and offers sophisticated analysis and design for steel and concrete masonry structures such as school buildings,hospitals, and hotels as well as shopping malls. Its analysis is based on direct stiffness formulation and finite element methods. The structures are modeled in 3D as residential structures buildings situated in Zone III as per Bangladesh National Building code (BNBC)-2020, is considered for the study. The buildings are studied as space frames. The designed space frames are studied for dead loads, live loads, wind loads and seismic loads. The analysis was done for the six models. G+6 and G+11 storied RCC structures with Beam Supported slabs, Flat slab with perimeter beam and without perimeter beam in ETABS software and results are tabulated and compared. All the six models were considered for finite element method. From finite element analysis the displacement, time period, story drift, lateral displacement, storey drift, shear, structuralstiffness and bending moments are obtained and compared.

Now-a-days flat slab structures are replacing conventional slab structures as they are more feasible to construct, take less time and shows good aesthetic appearance. But the major disadvantage of flat slab is its high flexibility due to which many problems like motion sickness, high storey displacement etc occurs so to overcome this the concept of Perimeter beams is adopted which reduces the flexibility of the flat slab structure toa much greater extend.Due to the flexibility of Flat slab structures, they must be made stiffer or their rigidity must be increased by any means. Perimeter beams or Edge beams are provided with flat slabs for increasing their stiffness and for withstanding the lateralloads in high seismic zones.Perimeter beams are used in place of shear wall in flat slab structures because shear walls have many disadvantages such as they increase the cost of the structure, they make the structure so rigid that application of lateral forces results in cracks, if we provide shear wall then positioning of shear wall is also a critical study

that's why provision of perimeter beams as an alternative to shear wall in flat slab structures is adopted.

Generally, to reduce the amount of negative moment reinforcement over a column or to reduce shear stresses near column a drop panel of rectangular cross-section should be provided in flat slab structure. In our thesis work, we have tried to make a analysis for edge supported and flat slab with perimeter beam at high seismic zone with comparison with analyzed flat slav building model by using ETABS.

## 1.1 Flat Slabs

Flat slabs are generally two types based on length to depth ratio as one way and two way slabs which rests on horizontal members like beams. When the ratio of length to depth is less than two then it is called two way slab and when the ratio is greater than two is called one way slab. Various types of loads acting upon the slabs are transferred from beams to columns, walls, lintels then to foundations and finally distributed over soil. Number of stories could be increased through proper design by reducing floor height while going to upper stories to maintain stability to the structure.

Flat slabs are widely implemented when there are many stories for commercial buildings inorder to reduce cost of construction along with good aesthetic view in shorter duration. Due to elimination of unnecessary beams ceiling can be used to maximum extent which leaves apleasant experience. Partitions could be made easily along with mechanical and electrical maintenance.



**Figure 1.3** Flat plate slab floor system

## 1.2 Punching Shear

Punching shear is a type of failure of reinforced concrete slabs subjected to high localized forces. In flat slab structures this occurs at column support points. The failure is due to shear. This type of failure is catastrophic because no visible signs are shown prior to failure. Punching shear failure disasters have occurred several times in this pastdecade.

Nylander (1960) measured the tangential and radial strains of slab test specimens and it was observed that the strains in the tangential direction are higher than the strains in the radial direction. As a result, the formation of radial cracks occurs prior to tangentialor circumferential cracks. These two types of cracks are shown in **Figure** for clarity.Atypical flat plate punching shear failure is characterized by the slab failing at the intersection point of the column is also shown in **Figure 1.3**.

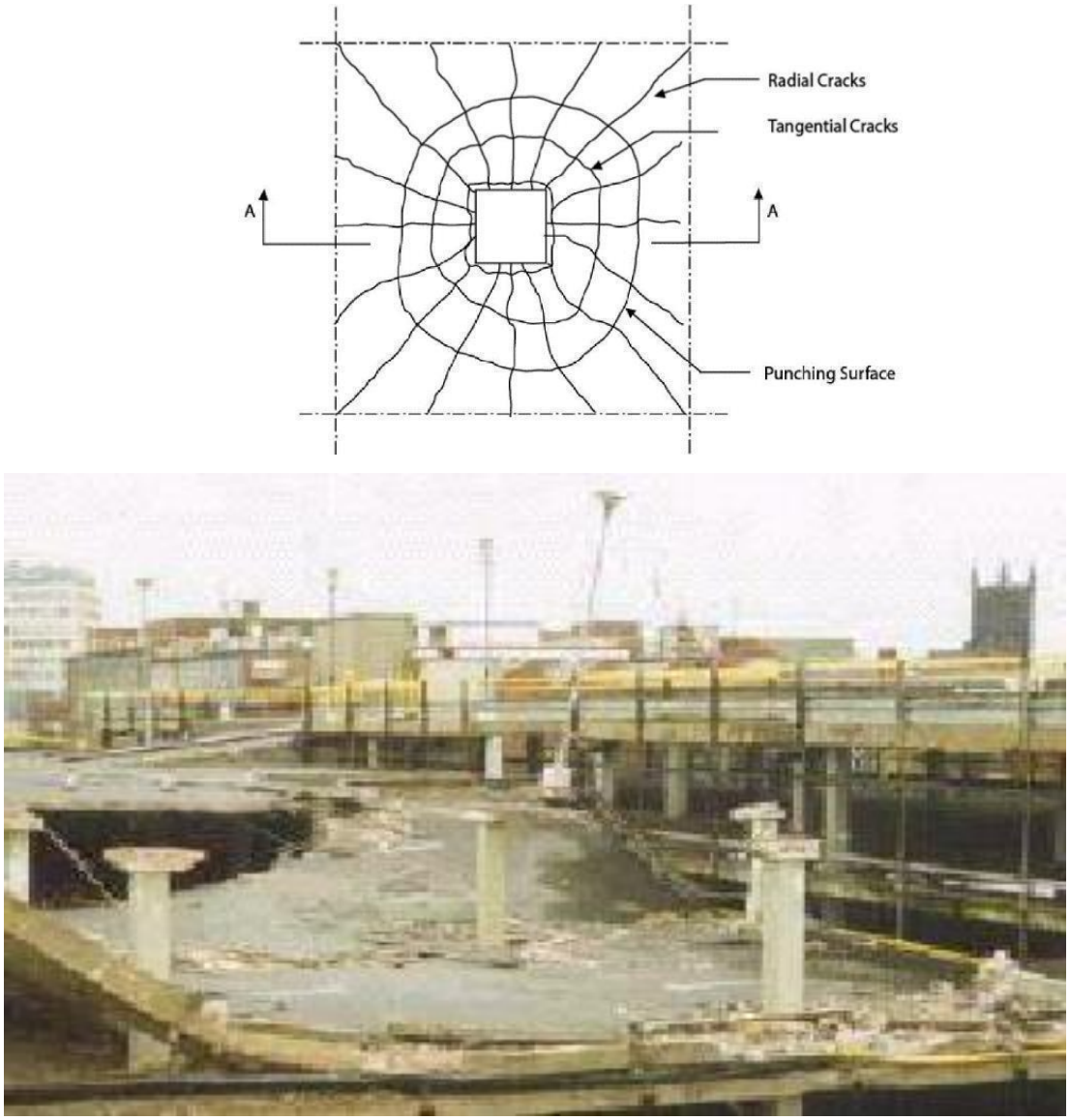



**Figure 1.4**: Piper's row car park, Wolverhampton, UK,1997 (built in 1965)

Flat slab failure due to punching shear .This results in the column breaking through theportion of the surrounding slab. This type of failure is one of the most critical problems to consider when determining the thickness of flat plates at the column-slab intersection. Accurate prediction of punching shear strength is a major concern and absolutely necessary for engineers so they can design a safe structure.

## 1.3 Beam Supported Slab

A Beam Supported slab is supported either on walls or on beams and columns.Here, the thickness of slab is small whereas depth of beam is large. In Beam Supported slab, load is transferred to either walls or beams and then from beams to columns. Beam Supported slab system is generally used in residential buildings and in small construction. The main advantage of this Beam Supported slab system is, we can design for a maximum span andmaximum load by increasing the depth of the beams and cross section of the columns without any significant increase in the depth of the slab**.**

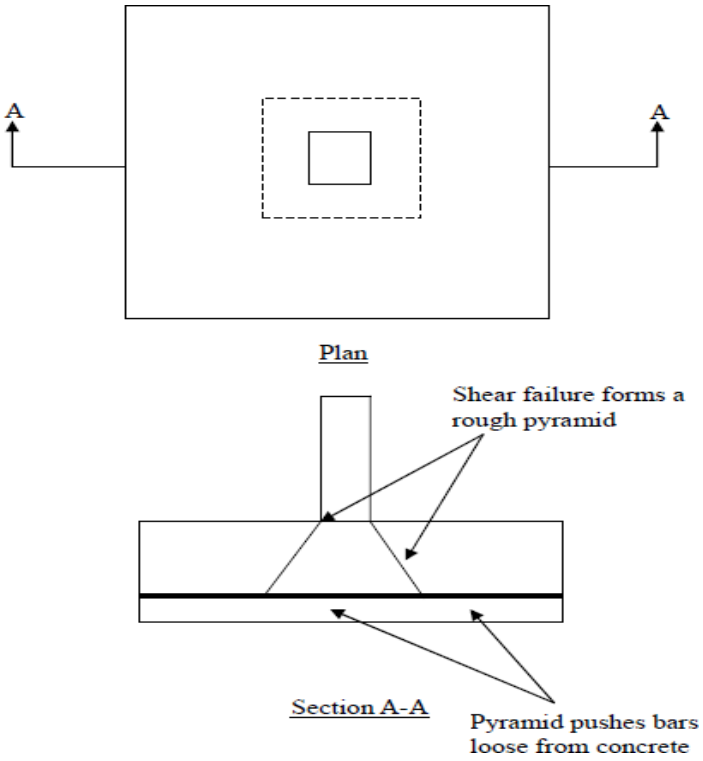



**Figure 1.5** A square column tends to shear out a pyramid from a flat plate

## 1.4 Scope of the Study

1)This study was done between flat slab with perimeter beams and conventional slab in future flat slab with perimeter beams comparison with drop and without drop can also bestudied for all seismic zones.

2)This analysis was done using ETABS software further this could be done using various different available software also.

3)In future, analysis of flat slab structure with perimeter beams can be done while considering different soil types along with different seismic zones.

4)In this study, fixed supports are considered for the analysis of the structure. In the future,it can be extended for different support conditions

## 1.5 Objectives of the study

1.To analysis a Beam Supported slab;

2. To analysis a flat slab.

3. To perform a comparative study between a Beam Supported slab and a flat slab Scopeof the Study.

Beam Supported slab reinforced concrete structure and flat slab reinforced concrete structure for different height can be modeled and analyzed for the different combinations of dynamic loading either manually or by software. Among various software, ETABS can be used for its better performance.

This cntire thesis will be covered by five chapters. The title of the chapter and it's contents are outlined here

Chapter-1: Discussed introduction is given about General description of these analysis, research significance, objectives, scope and organization of this thesis

Chapter-2: A detailed literature review of different authors included in this chapter. Topics include introduction and review of several papers regarding our works.

Chapter-3: In this chapter Methodology of this project are outlined and the detailsworking procedures are described

Chapter-4: The detailed results are evaluated and correlated with different studies.

Chapter-5: Conclusions are given in this chapter and further research needs in thisarea are recommended

# CHAPTER II

## LITERATURE REVIEW

Flat slabs are economically viable for spans range from 6 to 9 m and live loads range from 4 to 7 KN/m2. The thickness of flat slab is 10 percent smaller than that of flat plate for the same span length. It is claimed that the cost of formwork, concrete material placement and finishing, and steel placement are 47%, 36%, and 17%, respectively of overall floor cost for flat slabs.

Robertson in his study the analysis of flat slab structures subjected to combinedlateral and gravity loads. Using a three-dimensional model, analysis of a flat slab building can have done when it subjected to vertical and lateral loads which includes both slab column frame elements and the lateral framing system (shear wall) if present.This study reviews two structural analysis models and compares them to experimentaltest results. A two-beam analytical model more accurately predicts the test results withrespect to slab moment distribution and lateral drift. Three-dimensional analysis done by ETABS computer program. These models assume a uniform slab effective width coefficient and constant cracking factor for an entire span. The analytical models were unable to reproduce the slab flexural moment distribution observed in test specimen ateither 0.5 or 1.5 % drift levels. By replacing the single beam element with two-beam elements connected at the point of contra flexure, the difference between cracking in the positive and negative moment regions was incorporated in to the mode.

Altug Erberik & Elnashai discussed about Flat-slab RC buildings exhibit several advantages over Beam Supported moment resisting frames. However, the structural effectiveness of flat-slab construction is hindered by its alleged inferior performance under earthquake loading. This is a possible reason for the observation that no fragility analysis has been undertaken for this widely-used structural system. This study focuseson the derivation of fragility curves using medium-rise flat-slab buildings with masonryinfill walls. The developed curves were compared with those in the literature, derived for moment-resisting RC frames. This study also concluded that earthquake losses for

flat-slab structures are in the same range as for moment-resisting frames for low limit states, and considerably different at high damage levels.

S.W. Han [2009] told about the effective beamwidth model (EBWM) used for predicting lateral drifts and slab moments under lateral loads. They also studies on slab stiffness with respect to crack formation. These studies developed equations for calculating slab stiffness reduction factor by conducting nonlinear regression analysis using stiffness reduction factors estimated from collected test results.

A.B Climent [2012] investigated about the effective width of reinforced concrete flat slab structures subjected to Seismic loading on the basis of dynamic shaking table tests. The study is focused sections (Shear heads) as shear punching reinforcement. Tothis end, a ½ scale test model consisting of a flat slab supported on four box- type steel columns was subjected to several seismic simulations of increasing intensity. It is found the test results that the effective width tends to increase with the intensity of the seismic simulation, and this increase is limited by the degradation of adherence between reinforcing steel and concrete induced by the strain reversals caused by the earthquake. Also, significant differences are found between the effective width obtained from the test sand the values predicted by formula proposed in the literature these differences are attributed to the stiffening effect provided by the steel profiles that constitute the punching shear reinforcement.

Reichman in their paper summary flat slabs with proper design and modifications with consideration of other parameters improve resistance, durability and seismic behavior of flat slabs in construction

.

(Chowdhury et al., 2012) conducted a study on effect of openings in shear wall on seismic response of structures. In this paper, finite element modeling in analyzing and exploringthe behavior of shear wall with opening under seismic load actions, an attempt is madeto apply the finite element modeling. A shear wall in a building contains many openingsdue to functional requirements such as doors, windows and other openings. This studyis carried out using linear elastic analysis with the help of software ETABS under the earthquake loads in equivalent static analysis. This study reveals that, the sizeof the openings as well as their locations in shear walls, if will affect the stiffness as well as seismic responses of structure. If the area of openings more, the displacement increaseswith increasing story level. Thickening wall around the door openings are more effective than that of window opening as far as displacements in concerned at top moststory level.

GuptaShowed comparison between flat slab and Beam Supported structure made. The modeling and analyzing done by using STAAD Pro 2007. Analysismade for 11 storied structures. Though story increase provision of shear wall make itsame.

Chen et al. (2012) focused on tall commercial buildings are primarily a response to the demand by business activities to be as close to each other, and to the city centre as possible, thereby putting intense pressure on the available land space. Structures with a large degree of indeterminacy is superior to one with less indeterminacy, because of more members are monolithically connected to each other and if yielding takes place in any one of them, then a redistribution of forces takes place. Therefore, it is necessary to analyze seismic behavior of building for different heights to see what changes are going to occur if the height of Beam Supported building and flat slab building changes.

Sandesh & Bothara, )has worked on Dynamic Analysis of Special Moment Resisting Frame Building with Flat Slab and Grid Slab. A popular form of concrete building construction uses a flat concrete slab (without beams) as the floor system. This

system is very simple to construct, and is efficient in that it requires the minimum building height for a given number of stories. Unfortunately, earthquake experience hasproved that this form of construction is vulnerable to failure, when not designed and detailed properly, in which the thin concrete slab fractures around the supporting columns and drops downward, leading potentially to a complete progressive collapse of a building as one floor cascades down onto the floors below

Neve & Patil, 2016 studied analysis of Flat Plate Multistoried Frames with and Without Shear Walls under Wind Loads. It is seen that the column moments for flat plate floor system building with Shear walls has decreased by 69.17 % & 58.2 % when compared with flat floor system, Beam Supported beam supported slab system. The Shear walls withflat plates contribute towards reducing the column axial force even in the middle frameregion also. In the case of other building frames there is similar reduction in column axial force when wind is acting. The flat plate floor system can be further strengthenedagainst the lateral loads by providing Shear walls also. The drift becomes minimum, sothat there is 65.77% reduction in the drift in this case.

Coelho et al studied about flat slab building structures which are more significantly flexible than traditional concrete frame/wall or frame structures, thus becoming morevulnerable to seis mic loading. Therefore , the characteristics of the seismic behavior of flat slab buildings suggest that additional measures for guidingtheconception and design of these structures in seismic regions are needed. To improve the performanceof building having flat slabs under seismic loading, provision of part shear walls is proposed in the present work. The object of this work is to compare the behavior of multi-story buildings having flat slabs with drops to the two-way slabs with beams and to study the effect of part shear walls on the performance of these twotypes of buildings under seismic forces. This work provides a good source of information on the parameter's lateral displacement and story drift. Rajendran et al studied a 10 story RC building located in seismic zone III which is on medium soil. The different

Building configurations were i) Shear wall at end of Lsection ii) L Shear wall at junction of 2 flange portion iii) Two parallel L shear wall atjunction of 2 flange iv) Tube type shear wall at junction of 2 flange portion v) Two parallel shear wall atend of flange portion. From the analysis, it was observed that

compared to other models shear wall placed at end of L section is best suited for base shear since end portion of the flange always oscillate more during earthquake.

(Rasmussen, 2013)has worked on Novel Radon Sub-Slab Suctioning System. A new principle for radon protection is currently presented which makes use of a system of horizontal pressurized Air ducts located within the lower part of the rigidinsulation layerof the ground-floor slab. The function of this system is based on the principles of pressure reduction within the zone below the ground-floor construction. For this purpose, a new system of prefabricated lightweight elements is introduced. The Effectiveness of the system is demonstrated for the case of a ground-floor reinforced concrete slab situated on top of a rigid insulation layer (consisting of a thermal insulation layer located on top of a capillary-breaking layer) mounted intern on stable ground.

(M et al., 2020) studied about optimum design of reinforced concrete flat slab with drop panel according to the Indian code (IS 456-2000) is presented. The objective function is the total cost of the structure including the cost of slab and columns. The cost of each structural element covers that of material and labour for reinforcement, concrete and formwork. The structure is model and analyzed using the direct design method. The optimization process is done for different grade of concrete and steel. Thecomparative results for different grade of concrete and steel is presented in tabulated form. Optimization for reinforced concrete flat slab buildings is illustrated and the results of the optimum and Beam Supported design procedures are compared. The model is analyzed and design by using MAT LAB software. Optimization is formulated is in nonlinear programming problem (NLPP) by using sequential unconstrained minimization technique (SUMT).

(Khalotiya & Yadav, 2008) compared the performance of 15 story flat plate building with and without shear wall and diagonal bracing under wind and seismic loads on the factors such as lateral drift, displacement and column axial load. It was found that Flat plate isgood in perspective of gravity load. But it experienced that flat plate building can't stand strongly against wind, seismic or other lateral forces. As a result, more than any other structural component, the lateral force-resisting structure has on space planning. So, it is essential for a structure to have lateral resistance by providing Shearwall.

(Kvgd, 2014)found out the effect of shear wall location in buildings subjected to seismicloads. A symmetric sixteen story residential building considered for the analysis. The finite element analysis software ETABS is used to create the 3-D model and run the analysis by push over method. Eight different models were considered. Dueto the seismic ground motion at the base of the structure base shear is maximum. Maximum reduction in displacement is obtained for frame with core and corner shear wall.

(Borkar et al., 2021)discussed about the flat slab buildings in which slab is directly rested on columns, have been adopted in many buildings constructed recentlydue to the advantage of reduced floor to floor heights to meet the economical and architectural demands. Axial force in end columns of flat slab building is more compareto grid slab. Base shear of flat slab building is less than the grid slab building.

(Pahwa et al., n.d.)focused to compare behavior of flat slab with old traditional two- way slab along with effect of shear walls on their performance. The parametric studies comprise of maximum lateral displacement, story drift and axial forces generated in the column. For these case studies they have created models for two-way slabs with shear wall and flat slab with shear wall, for each plan size of 16X24 mand 15X25 m, analyzed with Staad Pro. 2006 for seismic zones III, IV and V with varying height 21m,27 m, 33m and 39 m. This investigation also tells us about seismic behavior of heavy slab without end restrained. For stabilization of variable parameter shear wall are provided at corner from bottom to top for calculation. Results comprises of study of 36models, for each plan size, 18 models are analyzed for varying seismic zone. From conclusion it is seen that part shear wall are not enough to keep displacement in limits.In case of

Damam & Damam, 2015 studied the solution for shear wall location and type ofshear wall in seismic prone areas. The effectiveness of RCC shear wall building is studied with help of four different models. Model one is bare frame system and

remaining three types are different shear wall buildings. An earthquake load is applied to 8 story building located in different zones. The performance of building is evaluatedin terms of lateral displacements of each story. The analysis is done byusing structuralfiniteelement analysis (SAP2000) software.

(J Shah & Jain, n.d.)analyzed with 12, 15, 18 story by taking into account seismic zonesusing ETABS. It is found that at terrace level base shear of flat slab is more than grid slab. The story drift and time period will be more for flat slab than thegrid slab.

(Vijayan et al., 2019)presented a study of investigations carried out in order to identify the seismic response of systems (a) flat slab building (b) flat slab with parametric beams

(c) flat slab with shear wall (d) flat slab with drop panel (e) Beam Supported building the aforementioned hypothetical systems were studied for two different story heights located in zone v. and analyzed by using ETABS nonlinear version 9.7.3. linear dynamic analysis i.e., response spectrum analysis is performed on the system to get the seismic behavior.

(Karki & Suwal, n.d.) investigated the behavior of flat slab in 4 different cases as (a) flat slab structure without drop, (b) Flat slab structure with column drop, (c) Flat slab structure with shear wall, (d) Flat slab structure with column drop and shear wall together, through response spectrum method, by using ETABS software. The behavior of the flatslab is investigated in terms of story displacements, frequency, base shear, story level accelerations. And also, most severe problem in flat slabs is punching shear failure. During the earthquake, unbalanced moments can produce significant shear stresses thatcauses slab column connections to brittle punching shear failure. This paperalso investigates on which type of combination produces less punching shear at slab columnjoint.

## Effect of Concrete Strength

Gardner (1990) presents the result of an investigation relating punching shear to concrete strength and steel ratio. It is concluded that the shear capacity is proportional to the cube root of concrete strength and steel ratio. It is also opinedthat the shear perimeter should be increased by using large columns and column capitals, if the punching shear capacity is in doubt. Elstner and Hognestad (1956) presented a researchreport on the methods and results ofexperimental work on the shearing strength of reinforced concrete slabs subjected to acentrally located concentrated load. The test findings show that the shearing strength ofslabs is a function ofconcrete strength as well as several other variables like percentageof tension reinforcement, size of column, conditions of support and loading, distributionof tension reinforcement, and amount andposition of shear reinforcement.

## Size Effect

Punching shear tests of geometrically similar reinforced concrete slabs of different sizes have been carried out by Bazant et. al.(1987). The test prediction summarized that the punching shear failure of slab without stirrup is not plastic but brittle. Results of an experimental investigation on the punching shear strength of reinforced concrete slabs with varying span to depth ratio have been summarized by McLean et. al. (1990). It is reported that the ACI Code does not recognize span to depth ratio effects or the effects of restraining action at the support when treating punching shear in reinforced concrete slabs. It is also observed that punching shear strengths are much greater than the values permitted by the ACI Code. Broms (1990) present a design method to predict the punching strength and deflectionof flat plates at interior columns. Failure is assumed tooccur when the compression zone of the slab in the vicinity of the column is distressed by either radial compression stress or by a high tangential compression strain. Size effectsand the effect of increasing concrete brittleness with increasing strength are both considered.

## Effect of Shear Reinforcement

Yamada et al. (1991) performed a research program for the determination of the effectof shear reinforcement type and ratio on the punching shear strength of monolithic slab column connections. The first type of shear reinforcement consisted of hat-shaped units, very advantageous from the points of view of prefabrication and field installation. The second type consisted of double-hooked shear bars, more difficult to install but with very efficient anchorage. Experimental results showed that the hat-shaped shear reinforcement was not effective because of lack of proper anchorage. Double-hooked reinforcement showed high effectiveness, which resulted in a considerable increment of the punching shear resistance of the connection.

Olivera et al. (2000) introduced a novel form of inclined stirrups and reported the resultsof test slabs with such reinforcement. Companion tests of slabs without shear reinforcement and slabs with vertical stirrups were also reported. The inclined stirrups were shown to function well and produced punching resistances superior to those obtained with vertical stirrups. Four reinforced concrete slab-column sub-assemblies were subjected to a high intensity shear and moment transfer at the column-slab connections by Pillai et. al. (1982). The effectiveness of shear reinforcement in increasing the shear strength and preventing punching failure and in improving the ductility of the connections were assessed. It was found that shear reinforcement in theslab at the connections prevent punching failure and generally double their ductility.

MacGregor (1994) presented the results of 19 tests of reinforced concrete plates simply supported on four edges. The plates were subjected to combine in plane compressive and lateral loads. The variables in the experimental investigation included the loading type, plate slenderness, in plane load level, aspect ratio, reinforcement ratio in the two orthogonal directions, and loading sequence. The test program was successful in providing data relating to the behavior of reinforced concrete plates under combined in plane compressive and lateral loads.

## Edge Condition Effect

Alam (1997) presented punching tests conducted on reinforced concrete slabs with their edges restrained as well as unrestrained. The significant positive effect of edge restraint on the punching failure, resulting in enhancing the ultimate punching strength, has beennoticed.

Aghayere (1990) presented the results of tests on nine reinforced concrete plates simply supported along four edges and subjected to combined uniaxial compression and uniform transverse loads. The results of the investigation led to the conclusion that the presence of an axial in plane load can lead to a reduction in the transverse load capacity of a concrete plate. This reduction depends on the in-plane load level, the width to thickness ratio, the concrete strength, the amount of reinforcement, and the aspect ratioof the plate.

Kuang et. al. (1992) tested 12 restrained reinforced concrete slabs with varying span to depth ratio, percentage of reinforcement, and degree of edge restraint. It is reported thatthe punching shear strengths are much higher than those predicted by ACI 318 and BS8110 codes. The study suggested that there is a definite enhancement in punching shear strength as the degree of edge restraint increases. The enhanced punching shear capacity was a result of compressive membrane action caused by restraining action at the slab boundaries.

## Slab-Column Connection Behavior

Hammill et. al (1994) reported test results of five full-scale reinforced concrete flat plate connections with corner columns subjected to shear-moment transfer. The tests showedthat the equations of the codes (ACI 318-89 and Canadian Standard CAN-A23.3-M84)are conservative and can be improved by addition of an appropriate equation for the fraction of the unbalanced moment resisted by eccentric shear stress. It is shown that the codes, or their commentaries, need to provide the equations necessary to determinethe extent of the shear-reinforced zone for a corner column connection.

Mortin et. al. (1991) reported test results of six full-scale reinforced concrete flat plate connections with edge columns subjected to shear moment transfer with and without

shear reinforcement, to verify the effectiveness of the shear reinforcement. The results confirmed the effectiveness of this type of shear reinforcement in improving shear strength and ductility.

#### 2.1.1.1.6 Shear Strengthening Techniques

EI-Salakawy et al. (2003) presented new shear strengthening technique for concrete slab-column connections. The aim of the program was to test a new method for strengthening existing reinforced concrete slabs for punching shear. The new strengthening technique consists of shear bolts externally installed in holes drilled through the slab thickness. It is found that the presence of shear bolts substantially increased the punching capacity and the ductility of the connections.

Elgabry et. al. (1990) presented rules to design and detail stud-shear reinforcement in accordance with the 1989 ACI Building Code (ACI 318-89). Because of the effectiveness of anchorage, design rules that reduce the amount of shear reinforcement are suggested and applied.

Shaaban (1994) carried out experimental study to determine whether addition of steel fibers to the concrete mix could significantly increase the punching shear strength of reinforced concrete flat plates. Thirteen slab specimens and their companion cylinder specimens were tested. Test results of this study indicated that the addition of steel fibers to the concrete mix did significantly enhance the punching shear strength of slabs.

Bayrak (2003) presented a strengthening technique for increasing punching shear resistance in reinforced concrete flat plates using carbon fiber reinforced polymers (CFRPs). This strengthening method employed CFRP strips in the vertical direction as

shear reinforcement around the concentrated load area in a specified pattern. The results showed that, by using a sufficient amount of CFRP strips in an efficient configuration, the failure surface can be shifted away from the column. The load carrying capacities of the strengthened reinforced concrete slabs were increased with increasing amount of vertical CFRP reinforcement used in a wider area.

#### 2.1.1.1.7 Miscellaneous Studies

Broms (2000) presented a design concept that examines the punching failure mode of flat plates, verified by test, and design recommendations are given. The system provided excellent safety against progressive collapse of flat plate buildings; a basic requirement that seems to be overlooked in many current concrete codes.

Chiang (1993) carried out a comparative study on the methods of punching shear strength analysis of reinforced concrete flat plates. It is found that the ACI and the British methods are applicable only to flat plates with torsion strips; the codes also tend to give unsafe predictions for the punching shear strength.

Mitchell (1984) investigated the slab structures after initial failure in order to determine a means of preventing progressive collapse. Analytical models for predicting the post- failure response of slabs are presented and the predictions are compared with experimental results. These analytical models along with experimental investigation enabled the development of simple design and detailing guidelines for bottom slab reinforcement, which is capable of hanging the slab from the columns after initial failures due to punching shear and flexure.

Rangan (1990) presented the background theory and the punching shear design provisions contained in the Australian Standard for Concrete Structures, AS 3600-1988. The correlation of the design equations with test data is also presented. It is believed that the Australian method could serve as a useful alternative to the ACI Building Code Provisions.

# CHAPTER III

## METHODOLOGY

### 3.1 Introduction

To examine the seismic behavior of conventional and flat slab structures without shear wall comparative study has been carried out between the models using response BNBC- 2020 method. The analysis has been performed using ETABS software for Mymensingh region. In response BNBC-2020, for the calculation of different parameters like displacement, drift shear, stiffness only maximum values are considered. All the model plan has 2 plats, that is a rectangular shape, above 2545 square feet areaand floor height 10 feet.

### 3.2 Building Description

The rectangular Residential building of G+6 & G+11 story are consider in Mymensinghregion. In This research total six model buildings have been designed to compare displacement, story drift and story stiffness of RC Beam Supported slab and with and without perimeter flat slab. A residential building is considered as model building for the plan .in this section different types of slab floor plan and render model are viewed. All the model plan has 2 plats, that is a rectangular shape, above 2545 square feet areaand floor height 10 feet.

**Table 3.1**: Preliminary data for G+11 & G+6 story building

| STORY Type | PARAMETER | BEAM SUPPORTED SLAB | FLAT SLAB | PERIMETER BEAM SLAB |
|---|---|---|---|---|
| G+6 & | Slab thickness | 7 inches | 7 inches | 7 inches |
| | Column 1 | 12 inch*20 inch | 12 inch*20 inch | 12 inch*20 inch |
| | Column 2 | 14 inch*24 inch | 14 inch*24 inch | 14 inch*24 inch |
| | Beam 1 | 14 inch*26 inch | 14 inch*26 inch | 14 inch*26 inch |

| | | | | |
|---|---|---|---|---|
| G+11 | Beam 2 | 14 inch*28 inch | 14 inch *28 inch | 14 inch*28 inch |
| | Grade Beam | 12 inch * 22 inch | 12 inch *22 inch | 12 inch*22 inch |

## 3.3 Loads and other considerations

To analyze the model building structure according to BNBC-2020 occupancy-A, the following loads are considered.

### 3.3.1 Dead Loads

Dead load is the gravitational load due to the self-weight of structural and nonstructural components of a building, i.e., columns, beams, structural wall, floors, ceilings, floor finishing, permanent partitions and fixed service equipment, etc. These are the loads which acts vertically downward and arises due to the self-weight of the structure. Dead load is evaluated as per its cross-sectional area multiply with the density of material used. Permanent Dead loads are showed in **Table 3.2**.

**Table 3.2**: Dead loads

| | |
|---|---|
| Floor finish | = 20psf |
| Loads from permanent periphery wall (125mm thick wall) | = 0.52 kip/ft |
| Partition wall | = 45 psf |
| Parapet wall | = 0.2 kip/ft |

### 3.3.2 Live Loads

Live loads are those which may change in position and magnitude. According to BNBC 2006, Live load are given as in **Table 3.3**.

**Table 3.3**: Live loads

| | |
|---|---|
| a) Floor Slab | = 40 psf for each floor |
| b) Roof slab | = 60 psf |
| c) Stair & exit | = 100 psf |

### 3.3.3 Wind Load

This section discusses the wide-area hourly average wind vector (speed and direction) at 10 meters above the ground. The wind experienced at any given location is highly dependent on local topography and other factors, and instantaneous wind speed and direction vary more widely than hourly averages. These wind loads are evaluated from ASCB 7-16 for the seismic zone III (BNBC-2020) in Mymensingh region.Wind velocity (according to BNBC-2020) = 61.1 m/s

### 3.3.4 Seismic Load

When a structure is subjected to ground motion or ground vibration it responds in shaking fashion. The random stirring of structure is possible in all possible directions i.e., in Horizontal (X) and (Y) direction and also in Vertical (Z) direction. This motion causes the structure to vibrate in all three directions. These seismic forces are evaluated from ASCE 7-16 for the seismic zone III (BNBC-2020) in Mymensingh region. Seismic load parameters are showed in **Table 3.4**.

**Table 3.4**: Preliminary data for seismic load parameters

| SL. No | Seismic load parameters | Zone III |
|---|---|---|
| 1 | Zone factor | 0.36 |
| 2 | Response reduction factor | 8 |
| 3 | Importance factor | 1 |
| 4 | Type of soil strata | SC |
| 5 | Damping | 5% |

### 3.3.5 Load Combinations

The Load combinations are considered as per Bangladesh National Building Code-2006 to design the model building showed in **Table 3.5**.

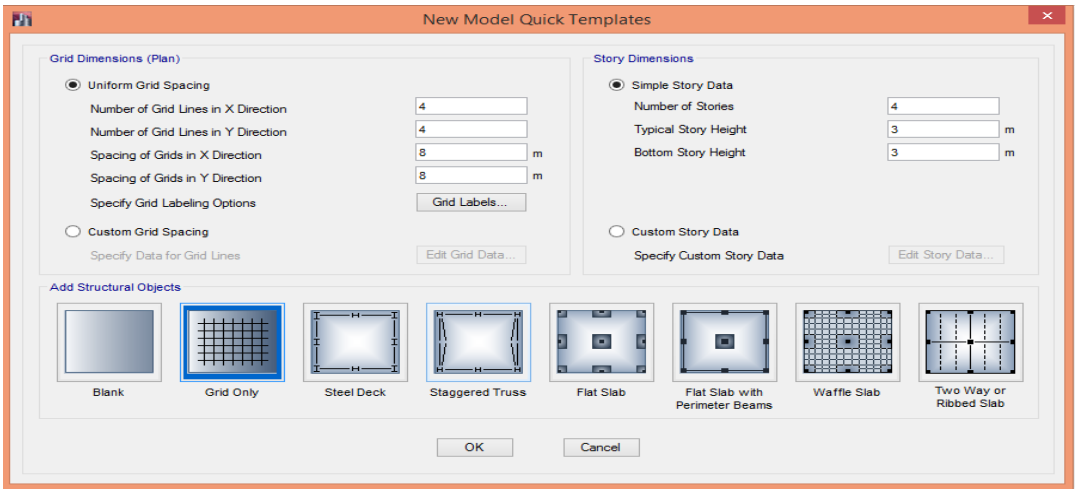
**Table 3.5**: Load combinations

| SL. No. | Load Combination | SL .No. | Load Combination |
|---|---|---|---|
| 01 | DL+LL | 14 | 1.05DL-1.4025EY |
| 02 | 1.4DL+1.7L.L | 15 | 1.05DL+1.275WX |
| 03 | 1.05DL+1.275LL+1.275WX | 16 | 1.05DL-1.275WX |
| 04 | 1.05DL+1.275LL-1.275WX | 17 | 1.05DL+1.275WY |
| 05 | 1.05DL+1.275LL+1.275WY | 18 | 1.05DL-1.275WY |
| 06 | 1.05DL+1.275LL-1.275WY | 19 | 0.9DL+1.3WX |
| 07 | 1.05DL+1.275LL+1.4025EX | 20 | 0.9DL-1.3WX |
| 08 | 1.05DL+1.275LL-1.4025EX | 21 | 0.9DL+1.3WY |
| 09 | 1.05DL+1.275LL+1.4025EY | 22 | 0.9DL-1.3WY |
| 10 | 1.05DL+1.275LL-1.4025EY | 23 | 0.9DL+1.43EX |
| 11 | 1.05DL+1.4025EX | 24 | 0.9DL-1.43EX |
| 12 | 1.05DL-1.4025EX | 25 | 0.9DL+1.43EY |
| 13 | 1.05DL+1.4025EY | 26 | 0.9DL-1.43EY |

## 3.4 Procedure of Modeling by ETABS

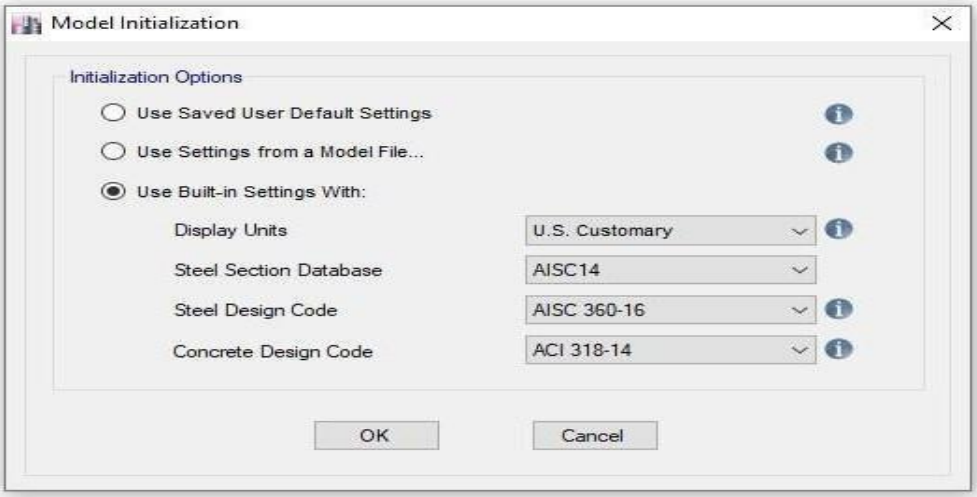
- File > New model

Use built in setting as below OR use settings from a model file which is already set as



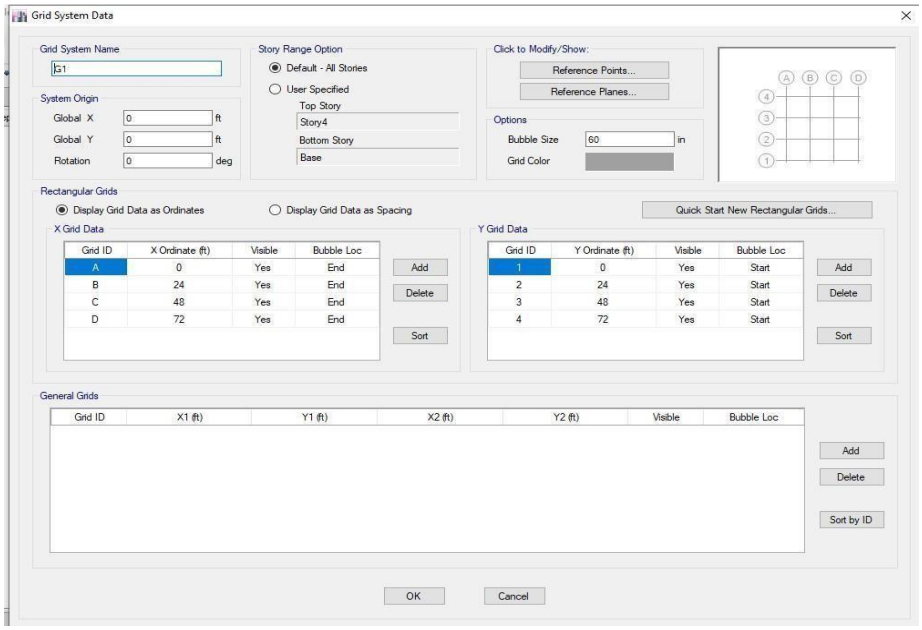

a standard template. Using first option may have a different unit system (Depends on the ETABS default)

- Model Initialization > Quick template

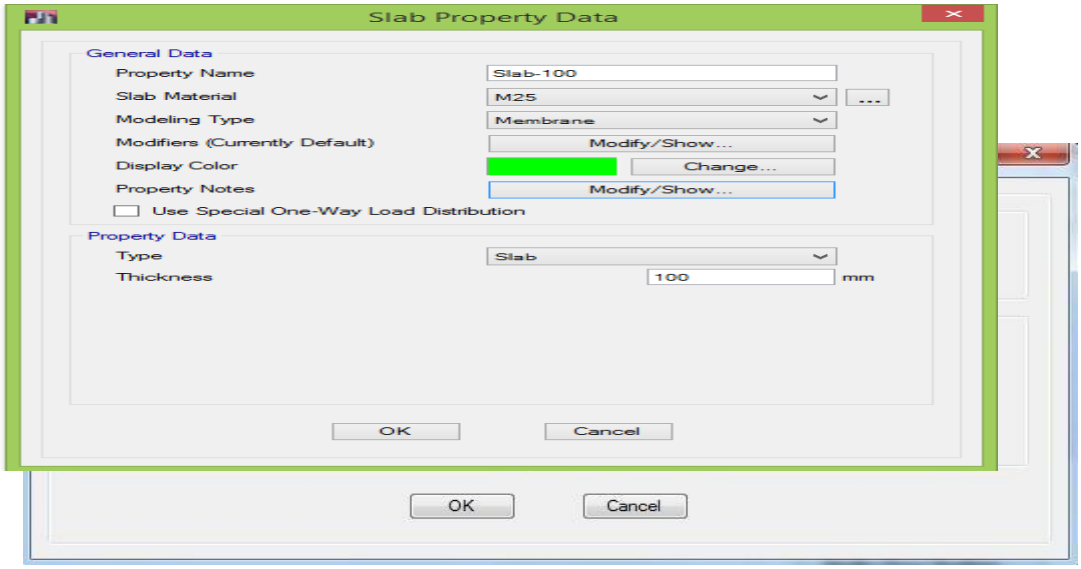



Grid spacing and story data should be defined as required .Custom grid spacing can be used to have non uniform spacing .Add Structural objects as required. For normal structures, blank or grid only options are handy.

- Go to Edit > Edit Story and Grid System

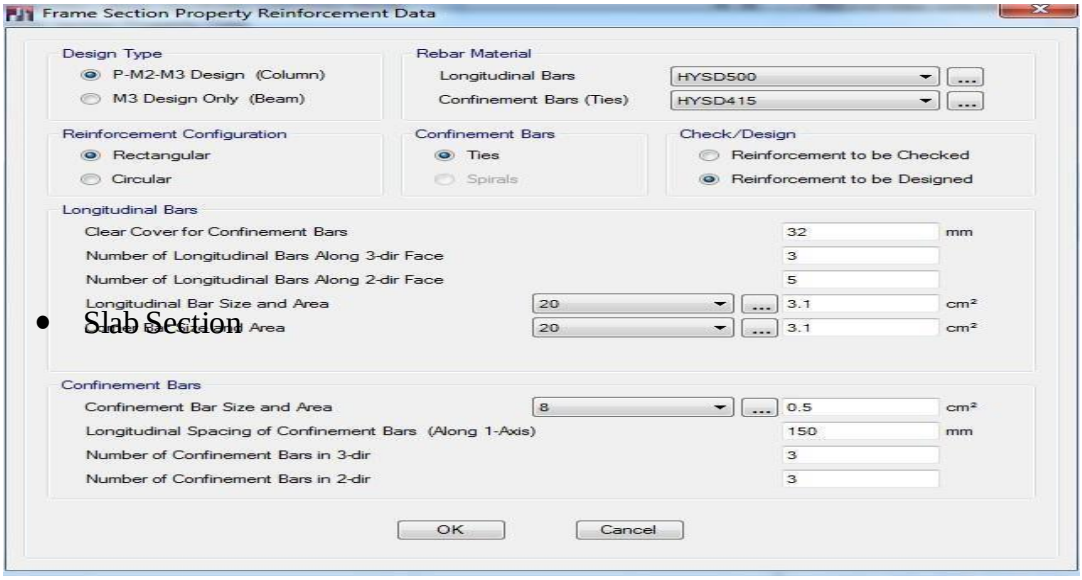


- Define material Properties




- Define section properties

- Beam Section and Column Section



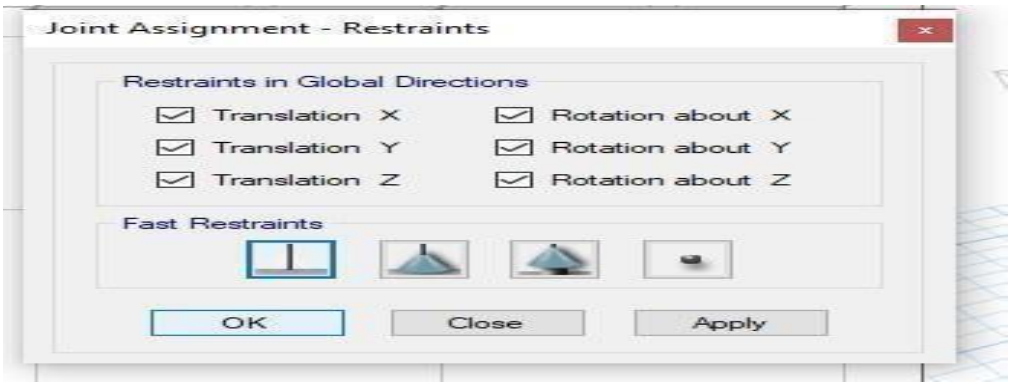

- Slab Section

- After modelling, assign member properties to the members as required. Select bases then go to Assign >joint > restrained > pinned or fixed as required.

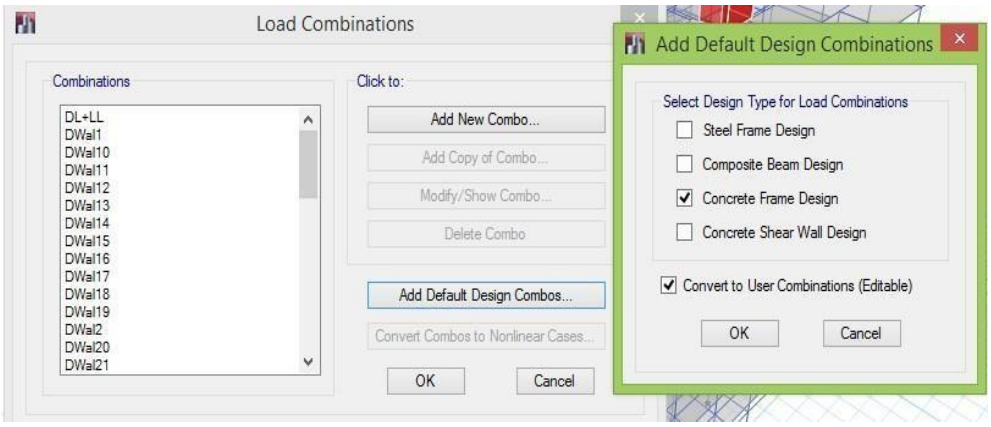
- Define load pattern

  Only Dead load to have a self-weight multiplier of

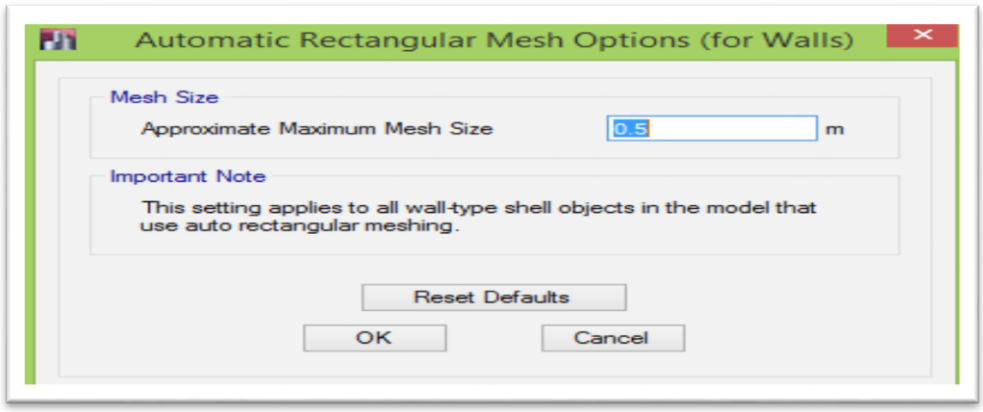
  Define mass source



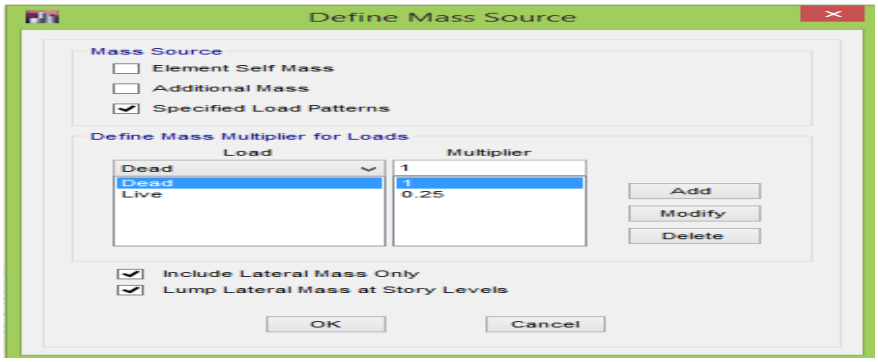

- Define load combination

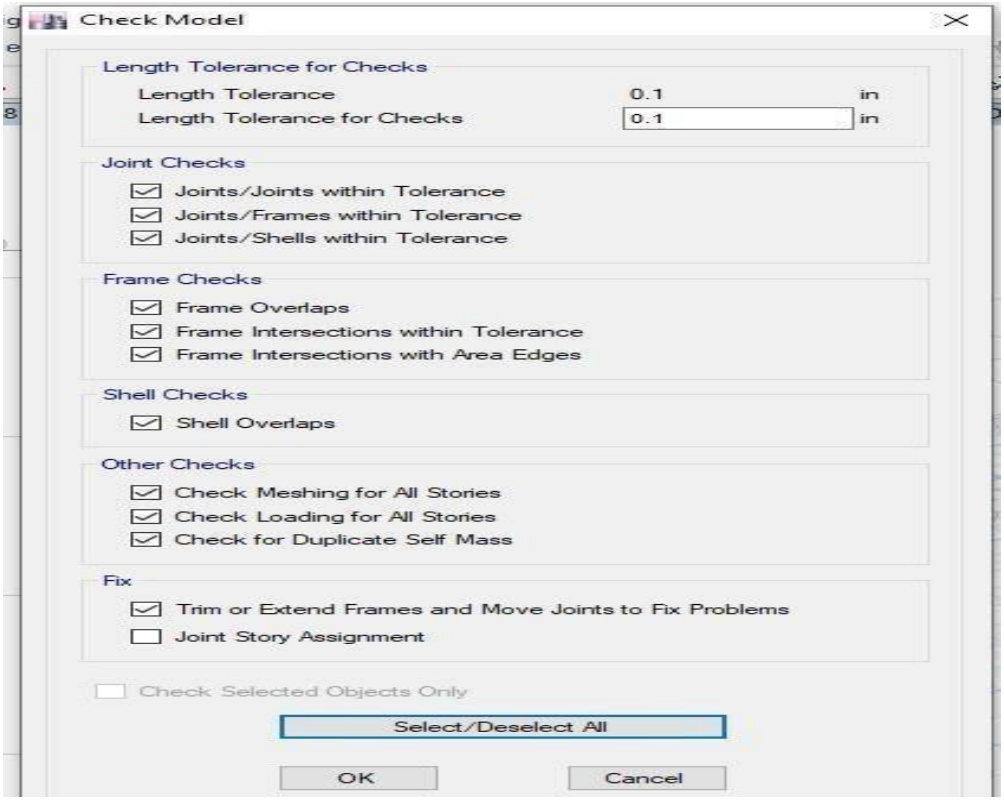


- Analyse – Auto mesh for slab and rectangular mesh setting of wall




- Check model




Check Model
Length Tolerance for Checks
Length Tolerance
0.1
in
Length Tolerance for Checks
0.1
in
Joint Checks
Joints/Joints within Tolerance
Joints/Frames within Tolerance
Joints/Shells within Tolerance
Frame Checks
Frame Overlaps
Frame Intersections within Tolerance
Frame Intersections with Area Edges
Shell Checks
Shell Overlaps
Other Checks
Check Meshing for All Stories
Check Loading for All Stories
Check for Duplicate Self Mass
Fix
Trim or Extend Frames and Move Joints to Fix Problems
Joint Story Assignment
Check Selected Objects Only
Select/Deselect All
OK
Cancel


Warning
Model has been checked. No warning messages were generated.

## 3.4 Floor Plan

In architecture and building engineering, a floor plan is a drawing to scale, showing a view from above, of the relationships between rooms, spaces, traffic patterns, and other physical features at one level of a structure. The floor plan has seven grid line in X direction and four grid line in Y direction with rectangular shape with different span length. Plan and elevation views are automatically generated at every grid line to allow for quick navigation of the model. Users can also create their own elevation sections by using our developed elevation feature.

### 3.4.1 Beam Supported Slab Floor Plan

In a Beam Supported slab, slab is supported on Beams and columns. Here load from slab is transferred to beam and from beam to column. The Beam Supported slab floor plan is shown in **Figure 3.1**.

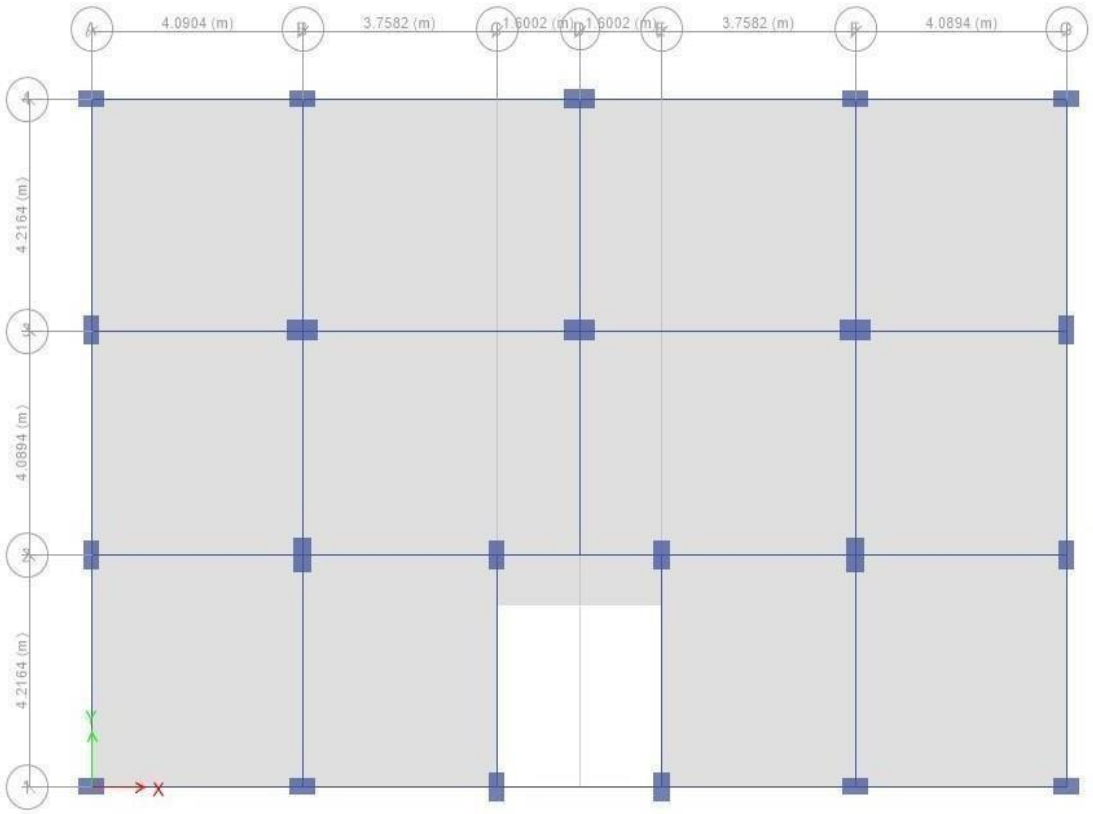



**Figure 3.1**: Beam Supported slab floor plan

### 3.4.1 Flat Slab without Perimeter Beam Floor Plan

In flat slab system without perimeter beam, the floor/roof consists of slabs and there are no beams. The load is transferred directly from slab to column in the flat slab Ratioof Longer span to shorter span is not more than 2.2. A floor plan of flat slab without perimeter beam for G+6 and G+11 buildings is shown in **Figure 3.2** clarify**.**

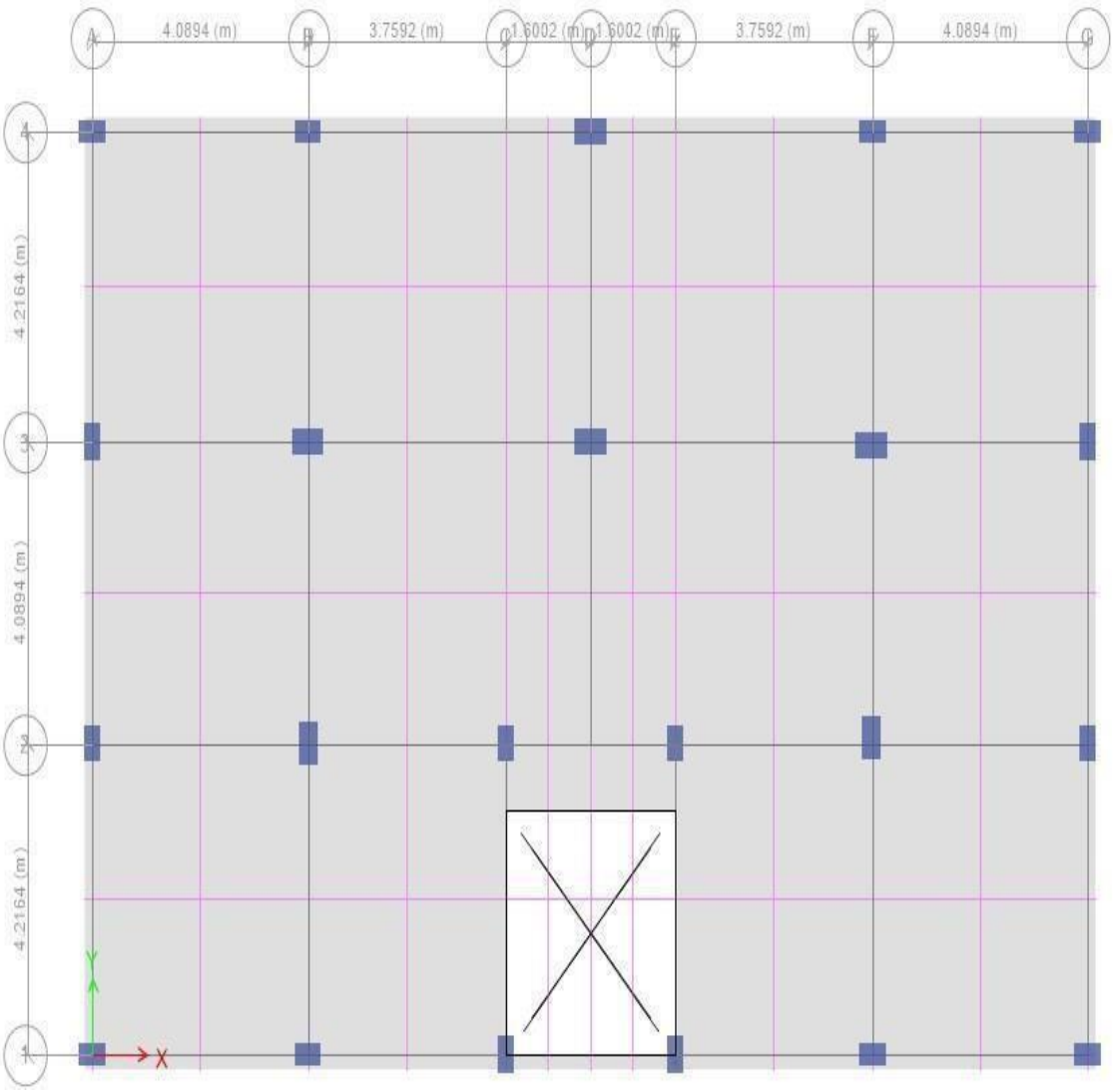



**Figure 3.2**: Flat slab without perimeter beam floor plan

### 3.4.2 Flat Slab with Perimeter Beam Floor Plan

Perimeter beams or Edge beams are provided with flat slab for G+6 and G+22 is shownin **Figure 3.3**. The cross section of perimeter/edge beam is used is 14 inch X 26 inch.

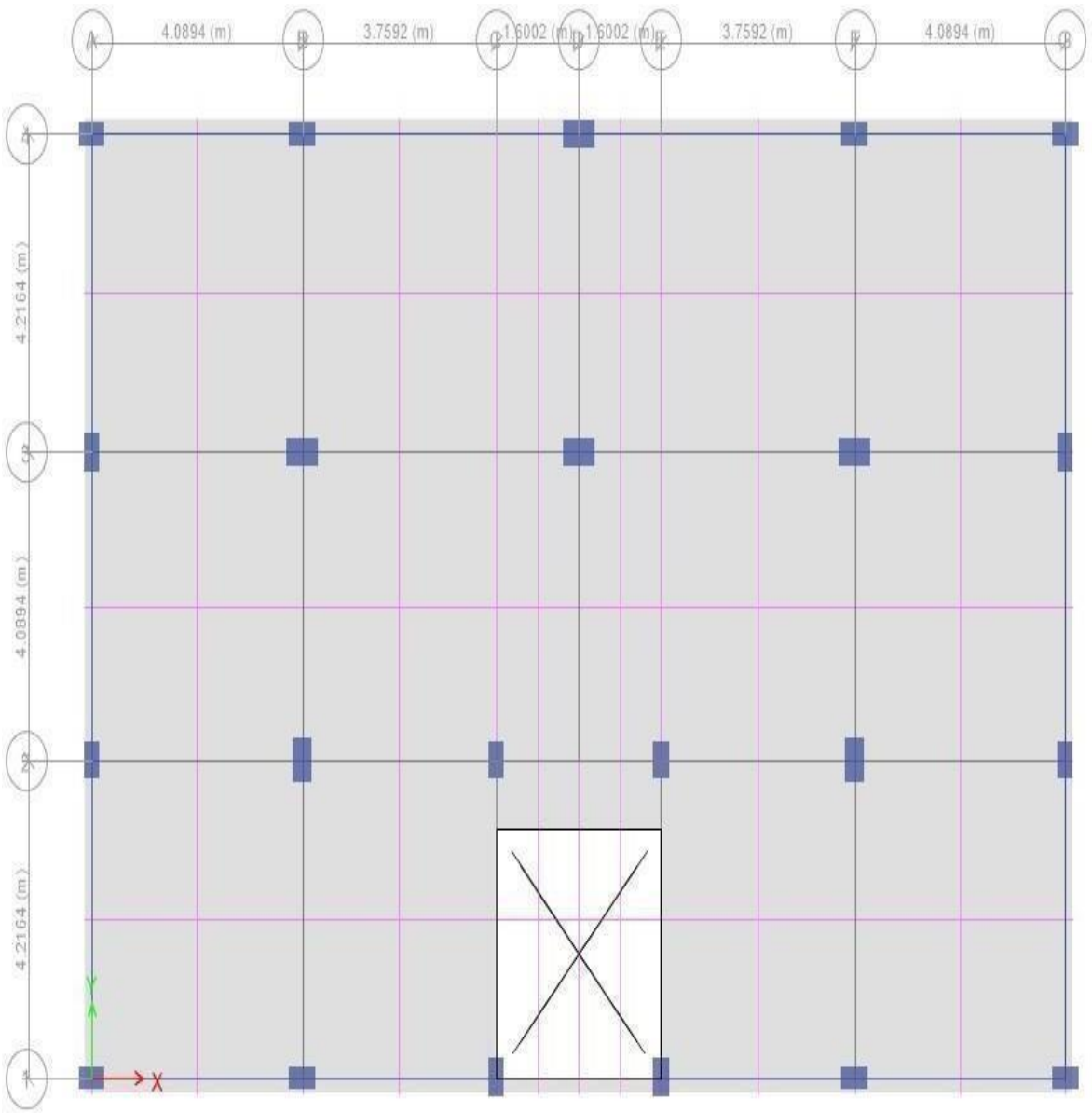



**Figure 3.3**: Flat slab with perimeter beam floor plan

## 3.5 Render Model of structure

Rendered views can used to create images to include in our reports. ETABS has multiple lighting options, shadows, and texture options to create life-like images of ourstructures.

### 3.5.1 G+6 Story Building

The render view of G+6 story buildings with Beam Supported slab and flat slab with perimeter beam and without perimeter beam have been snapshotted to preview in this section.

#### 3.5.1.1 Render View of Beam Supported Slab

The render view of the Beam Supported slab for G+6 building is as **Figure 3.4**.

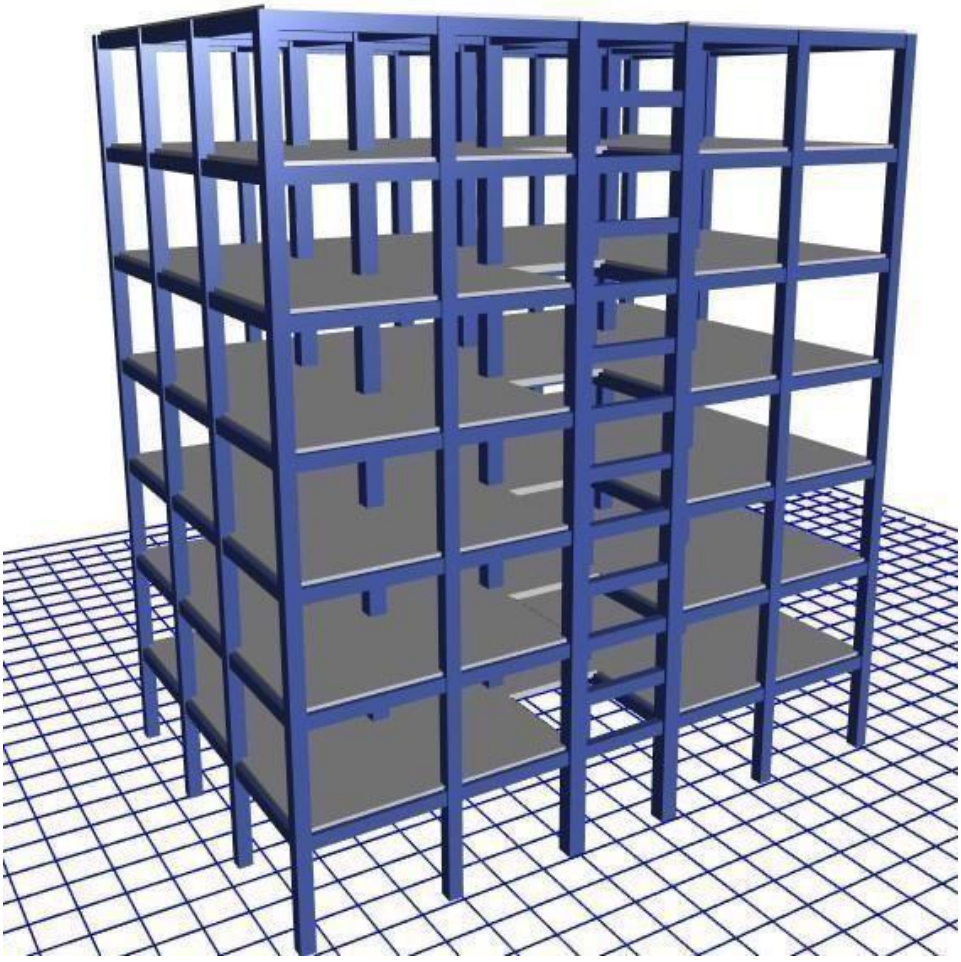


**Figure 3.4**: Render view of the Beam Supported slab

### 3.5.1.2 Render View of Flat Slab without Perimeter Beam

In **Figure 3.5**, the render view of the flat slab without perimeter beam is shownclearly.

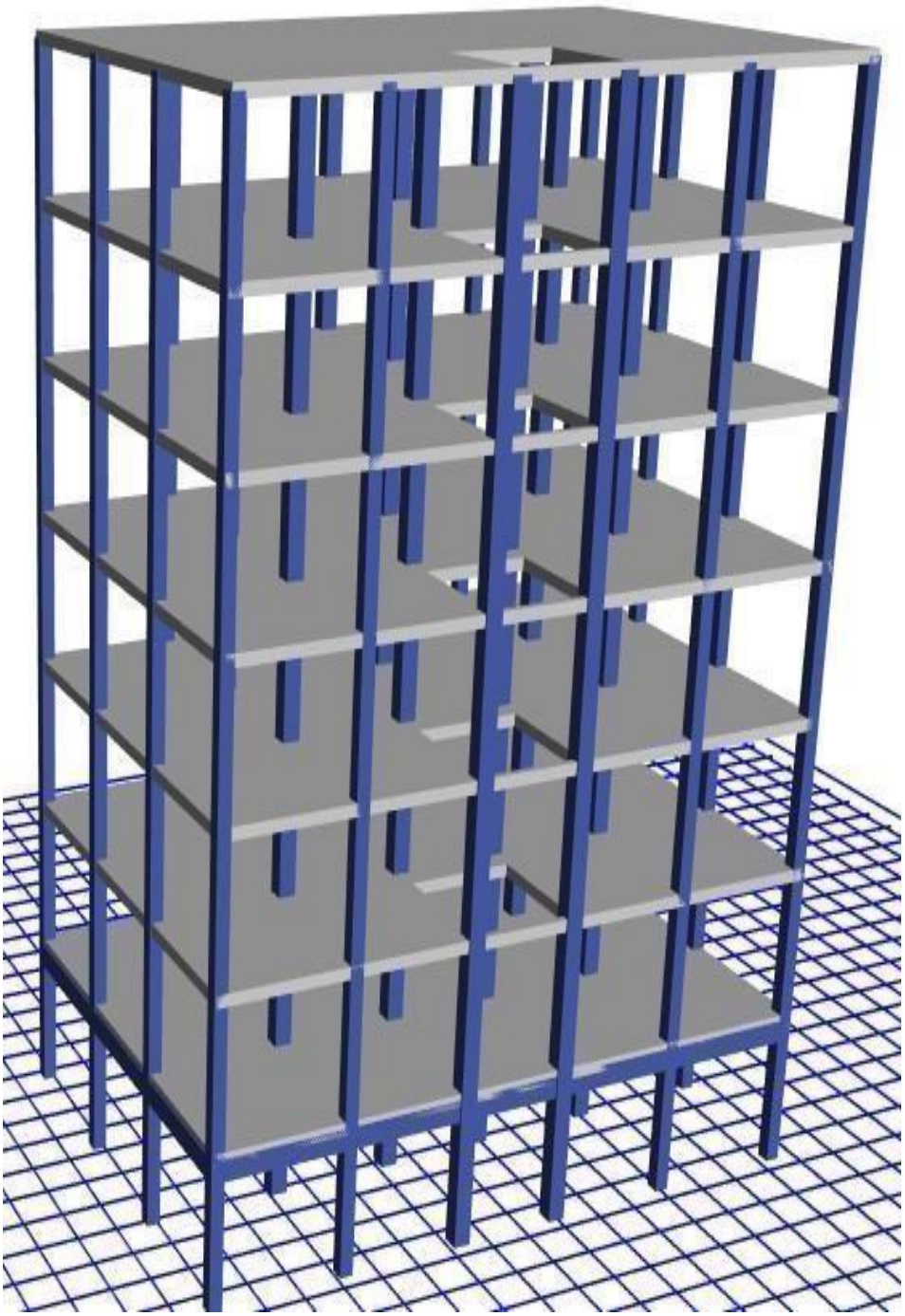


**Figure 3.5**: Render view of flat slab without perimeter beam

### 3.5.1.3 Render View of Flat Slab with Perimeter Beam

The render view of the flat slab with perimeter beam for G+6 building is as **Figure 3.6**

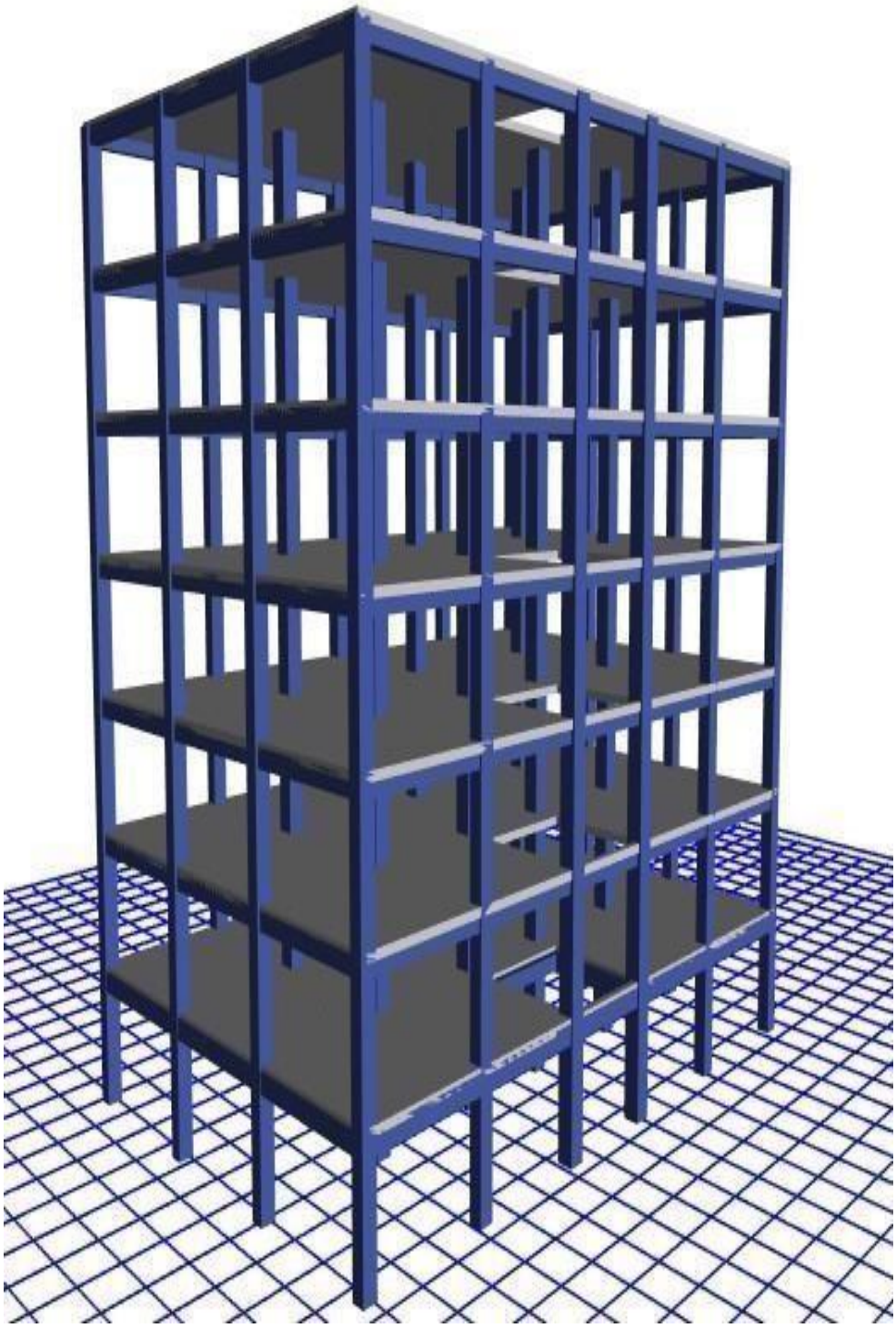


**Figure 3.6**: Render view of flat slab with perimeter beam

### 3.5.2 G+11 Story Building

The render view of G+6 story buildings with Beam Supported slab and flat slab with perimeter beam and without perimeter beam have been snapshotted to preview in this section.

#### 3.5.2.1 Render View of Beam Supported Slab

In **Figure 3.7**, the render view of the flat slab without perimeter beam is shown clearly.

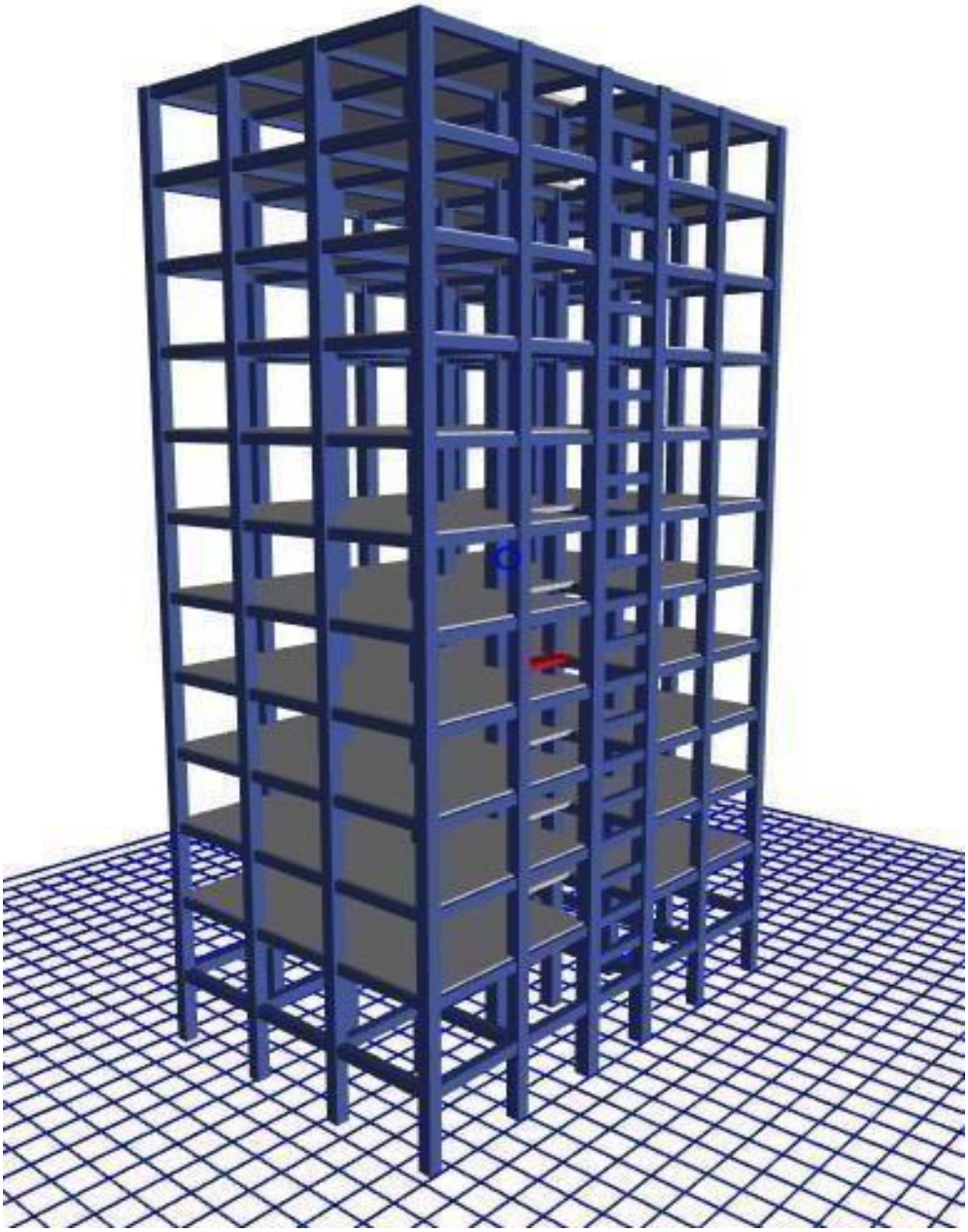


**Figure 3.7**: Render view of Beam Supported slab

### 3.5.2.2 Render View of Flat Slab without Perimeter Beam

The render view of the Beam Supported slab for G+11 building is as **Figure 3.8**.

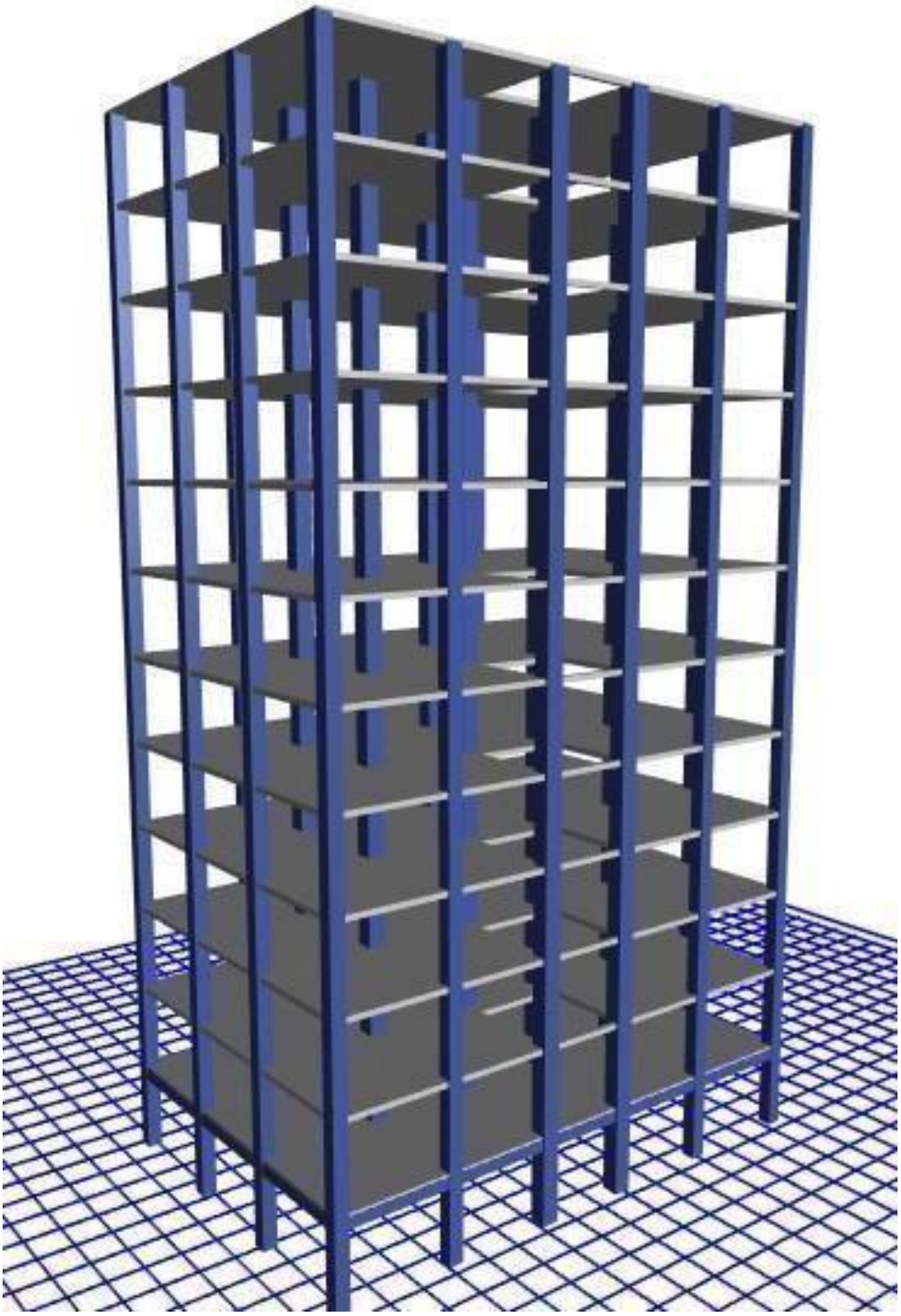


**Figure 3.8**. Render view of flat slab without perimeter beam

### 3.5.2.3 Render View of Flat Slab with Perimeter Beam

The render view of the flat slab with perimeter beam for G+11 building is as **Figure 3.9**.

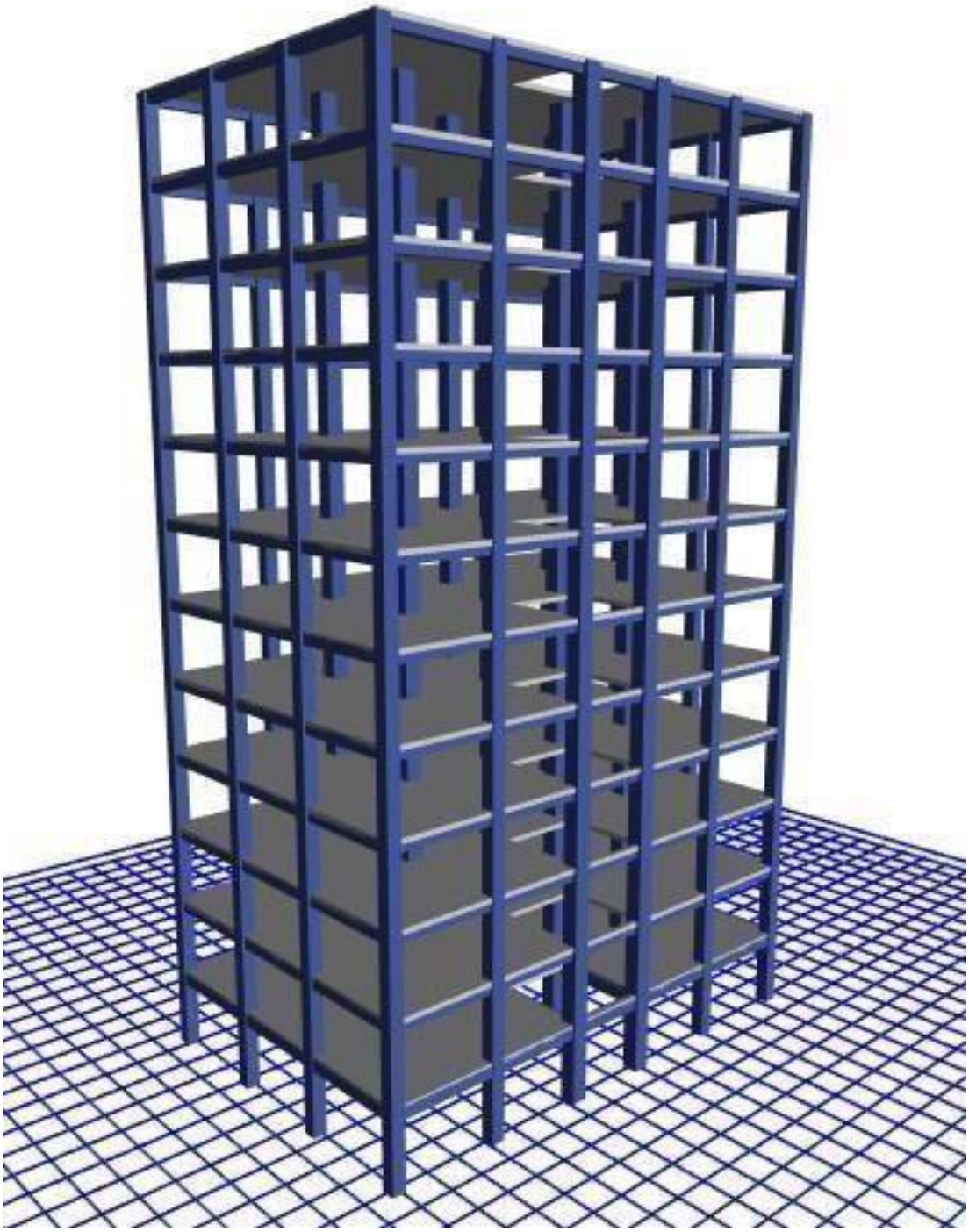


**Figure 3.9**: Render view of flat slab with perimeter beam

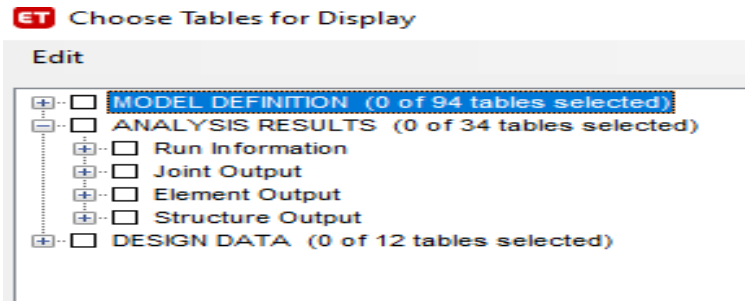
## 3.6 Analysis of Modeling

The first would apply gravity load to the structure, the second would apply another distribution of lateral load over the height of the structure, and the third would apply another distribution of lateral load over the height of the structure. The distribution of load along it may start from the results at the end of a previous case. The distribution of load along the height of the buildings is obtained from BNBC 2006 as the seismic loads and wind loads on the buildings at different beam column joints. In the analysis the loads are increased as multiple of the applied loads. The displacement at the top ofthe buildings is recorded at each incremental load.

### 3.6.1 Procedure of Analysis by ETABS

The following general sequence of steps is involved in performing a analysis:

1. A model is created just like for anyother analysis.
2. RC concrete structure is considered for the study having G+6 & G+11stories of height 70' &120' each floor is considered as 10' height.
3. The regular concrete moment resisting frame of square plan is consideredas base or reference model.
4. The load pattern are defined, if any that are needed for use in the analysis(Define>*load* pattern).
5. The load cases are defined, if any that are needed for use in the analysis (Define>*load* case).
6. The mass source are defined, D.L, F.F, P.W, WALL and Parapet Wall aredefined as dead load, factor is 1 and L.L is define as live load, facto is o.25
7. Any other static and dynamic cases are defined that may be needed for steelor concrete design of frame element.
8. The basic linear and dynamic analysis are run (analyze >run).
9. View the result (Display>story response plot or display >show result >analyze result> result).
10. The model should be revised as necessary and repeated until it satisfy theBNBC code.




### 3.6.2 Analysis Types

The model is analyzed and different type of parameter are evaluated like as story displacement, story drift and stiffness.

#### 3.6.2.1 Story Displacement

A single monitored Displacement component (of the conjugate Displacement). The magnitude of the load combination is increased or decreased as necessary until the control should be used when specified drifts are sought (such as in seismic loading) where the magnitude of the applied load is not known in advance or when the structurecan be expected to lose strength or become unstable.

Check displacement as **Figure 3.10**, Display>Story Response Plot>Show>Max Story displacement >EQ> Select 'Step Number' '1' for X dir., & '2' for Y dir.

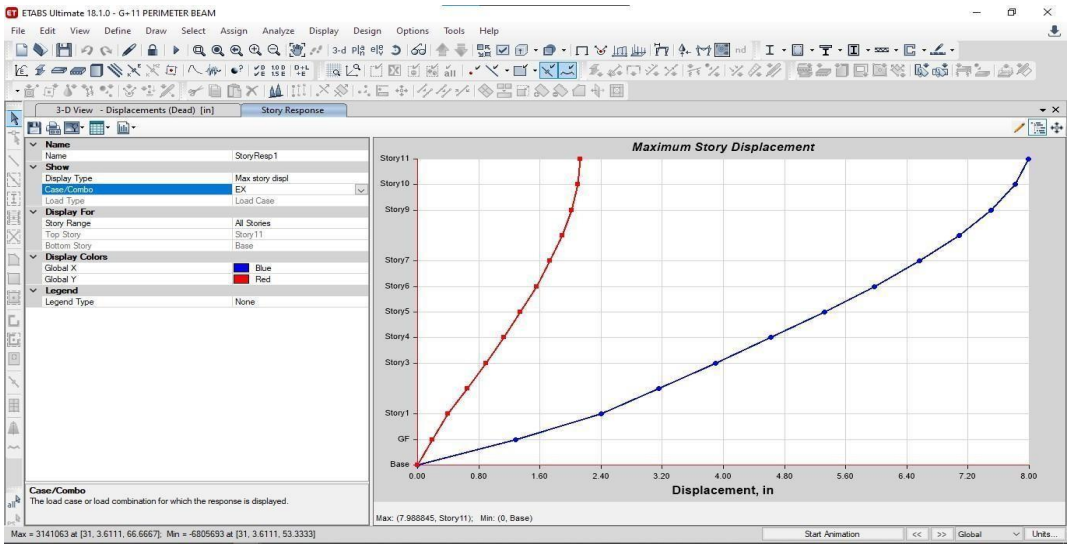



**Figure 3.10**: Story Displacement

### 3.6.2.2 Story Drift

Drift is a very complex topic in structural engineering. It involves too many factors to arrive at a suitable decision. It involves engineering judgment; the phenomenon fresh engineers might not feel. I have tried to explain what is building drift, allowable limits,ways and means to check in ETABS models and to control the excessive drift. Please keep in mind, this article is not about the building drift as far as structural science is concerned, rather this topic of drift is related to ETABS software.

Check displacement as showed in **Figure 3.11**,

Display>Story Response Plot>Show>Max Story drift>EQ>Select 'Step Number' '1' forX dir, & '2' for Y dir.

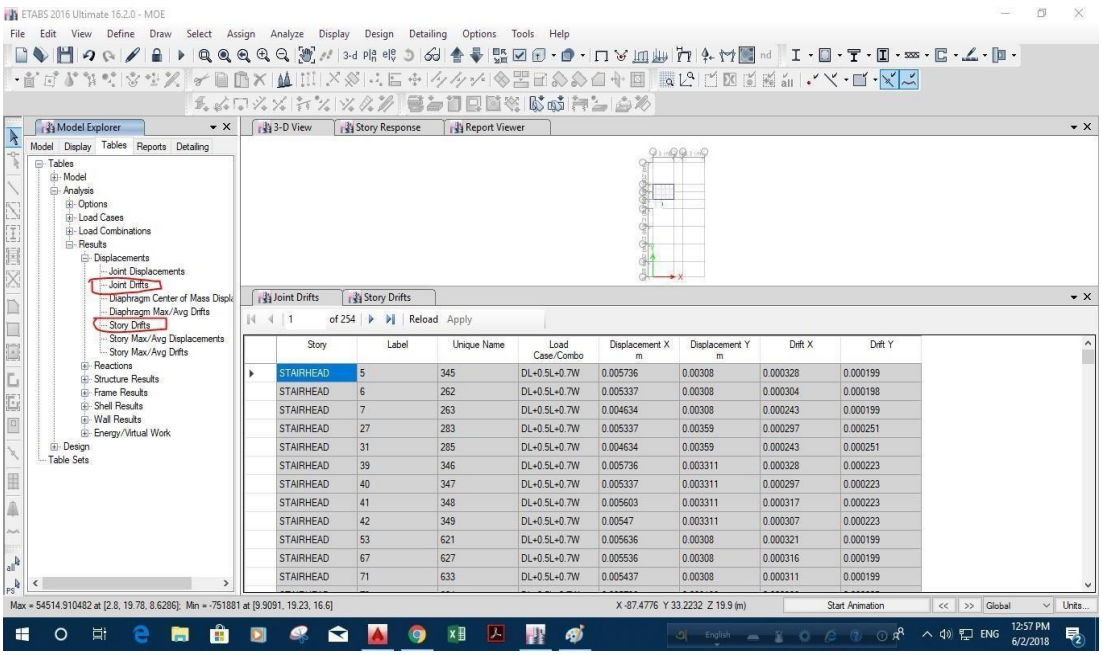



**Figure 3.11**: Story Drift

### 3.6.2.3 Story Stiffness

Equivalent story stiffness of a story is estimated as the lateral force that results in unit lateral translational deformation in that story showed in **Figure 3.12**.

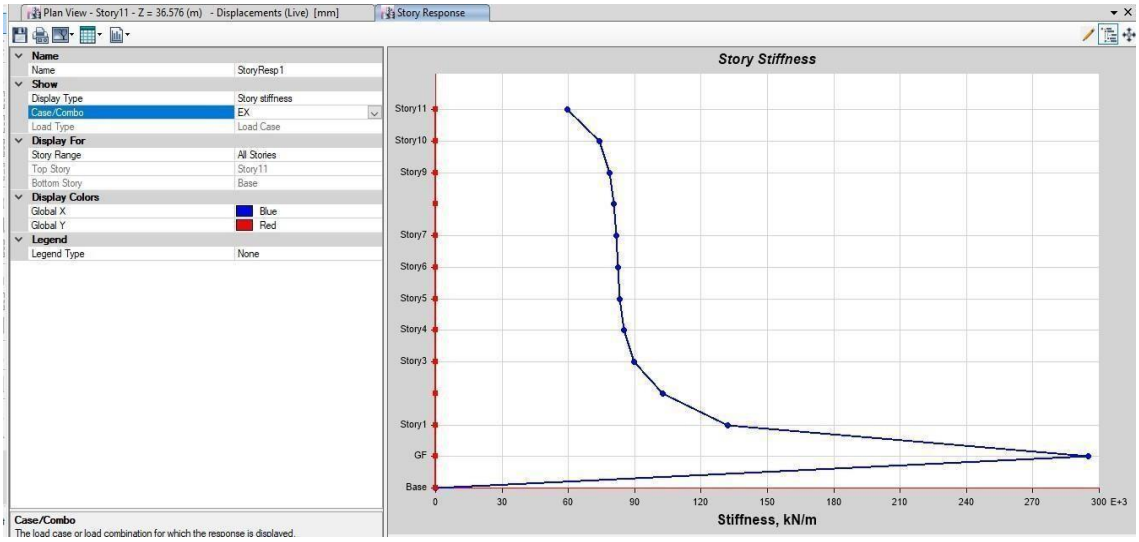



**Figure 3.12**: Story Stiffness

Thus, this method requires an-additional analyses to estimate story stiffness of an n- story building. Presence of stiffness irregularity, in conjuncture with strength irregularity, along building height leads to undesirable behavior during severe earthquake shaking, including localization of lateral deformations in select stories and initiation of story collapse mechanism.

## 3.7 Conclusion

Total six numbers of model building are analyzed to prepare the project paper for comparative study and to obtain results. Beam Supported slab and flat slab with and without perimeter beam RC structure are analyzed by ETABS. In this chapter three type of floor plan are used and analyzed to obtain proper result. The process of modeling and analyses are thus describing in this chapter.

# CHAPTER IV

## RESULTS AND DISCUSSIONS

### 4.1 Introduction

A G+6 & G+11 story Residential building was analyzed by ETABS. Comparison of thevariation of analysis result like as story displacement, story drift and stiffness are discussed in this section. After analyzing all 6- structures in the ETABS, the constrainsare given bellow from all load combinations considered, the 2 - maximum load combinations selected, those are 0.9DL + 1.43EX and 0.9DL + EY for the story displacement and story drift. For the story stiffness consider the maximum load combination EX and WX. In this chapter all over result found from analysis are described. The section properties are same for all model structure.

### 4.2 Results

The above cases are analyzed and their results on the basis of various parameters are shown below

#### 4.2.1 Comparison Based on Story Displacement for G+6

Maximum displacement in X direction occurred for load combination is
= (0.9DL+1.43EX).

**Table 4.1:** The Story displacement of G+6 Story building using different slab

| STORY | BEAM SUPPORTED SLAB (mm) | FLAT SLAB (mm) | PERIMETER BEAM SLAB (mm) |
|---|---|---|---|
| Story6 | 43.659 | 139.357 | 65.755 |
| Story5 | 41.238 | 127.564 | 61.513 |
| Story4 | 37.031 | 109.846 | 54.567 |
| Story3 | 31.288 | 86.077 | 45.205 |
| Story2 | 24.328 | 58.027 | 33.948 |

| | | | |
|---|---|---|---|
| Story1 | 16.428 | 30.024 | 21.361 |
| GF | 7.706 | 9.883 | 9.033 |

The **Table 4.1** indicated that the Story displacement of Beam Supported slab is less than the flat slab with and without perimeter beam. The story displacement of flat slab indicated the maximum displacement at top story than the Beam Supported slab and flat slab with perimeter beam i.e., Flat slab with perimeter beam>flat slab without perimeter beam> Beam Supported slab.

In the **Figure 4.1** indicated the story displacement of different slab supported structurewith the load combination 0.9DL+1.43EX in X direction for G+6 story building.

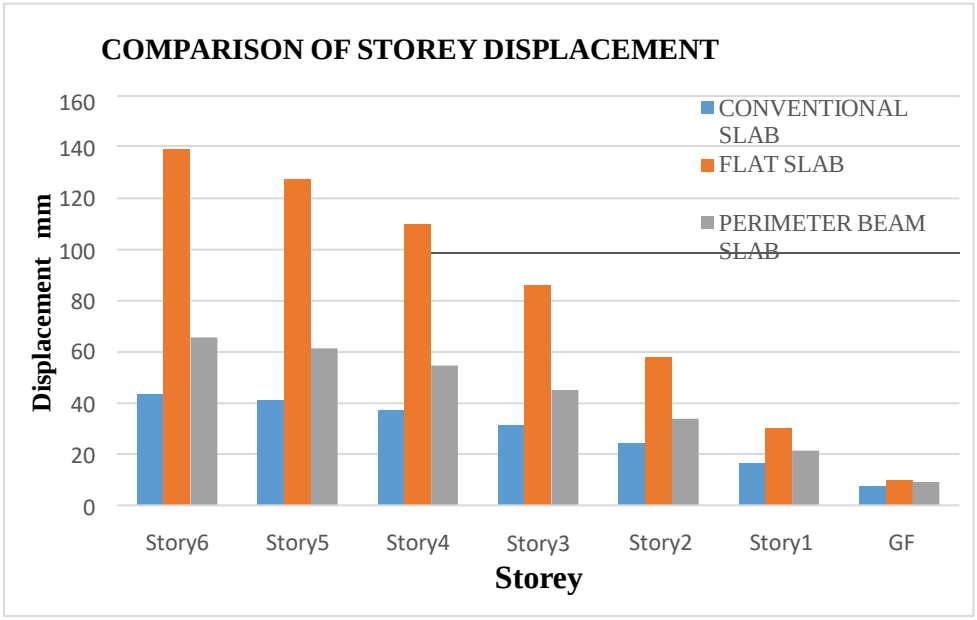



**Figure 4.1**: The Story displacement vs story number

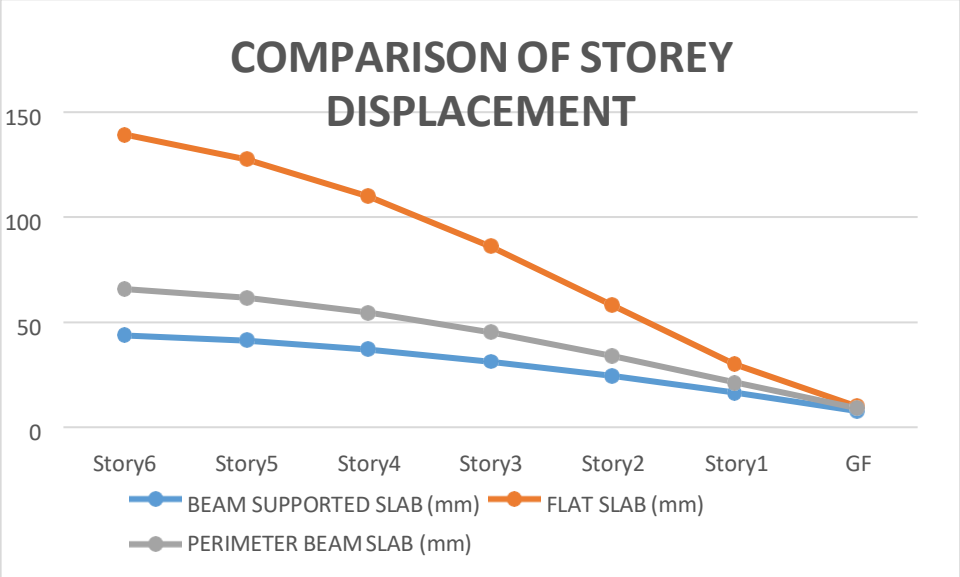



**Figure 4.1**: The Story displacement vs story number

The maximum story displacement of Beam Supported slab is 31% of flat slab without perimeter beam and the maximum displacement of flat slab with perimeter beam is 48% of flat slab without perimeter beam. Story displacement is more at top story and less at base of the structure. With increase in building height displacement also increases. It is less resistant to earthquake as it is less flexible than slab beam system. It is more resistant to earthquake as it is flexible than flat slab system. In a flat slab system, the floor/roof consists of walls/slabs and there are no beams. In a slab-beam system, the floor/roof consists of beam and slab.

### 4.2.2 Comparison Based on Story Drift for G+6 Story

Story drift is defined as difference between lateral displacements of one floor relative to the floor below. Maximum story drift in X direction (mm) for load combination = (0.9DL+1.43EX) is showed in **Table 4.2**.

**Table 4.2**: The Story Drift of G+6 story building using different slab system

| **STORY** | | **FLAT SLAB** | |
|---|---|---|---|

| | BEAM SUPPORTED SLAB | | PERIMETER BEAM SLAB |
|---|---|---|---|
| Story6 | 0.000794 | 0.003869 | 0.001392 |
| Story5 | 0.00138 | 0.005813 | 0.002279 |
| Story4 | 0.001884 | 0.007798 | 0.003071 |
| Story3 | 0.002283 | 0.009203 | 0.003693 |
| Story2 | 0.002592 | 0.009346 | 0.00413 |
| Story1 | 0.003027 | 0.007022 | 0.004045 |
| GF | 0.002528 | 0.003239 | 0.002961 |
| Base | 0 | 0 | 0 |

In the **Table 4.2** indicated the comparison of story drift of different slab supported building. Since the displacement of flat slab without perimeter beam is maximum thanthe flat slab with perimeter beam and Beam Supported slab building so the story drift of flat slab without perimeter beam is maximum. Flat slab with perimeter beam is morestable than flat slab without perimeter beam because the displacement and story drift is less and among three slab Beam Supported slab is more stable.

In this **Figure 4.2** indicated the comparative story drift of different slab supported building. Storydrifts are maximum in the middle stories. That means columns are stifferin bottom and top stories and weaker in the midlevel of the structure. The story drift is maximum in flat slab without perimeter beam and less in Beam Supported slab supported building. The maximum story drift of Beam Supported slab is 28% of flat slab without perimeter beam and flat slab with perimeter beam is 44% of flat slab without perimeter beam.

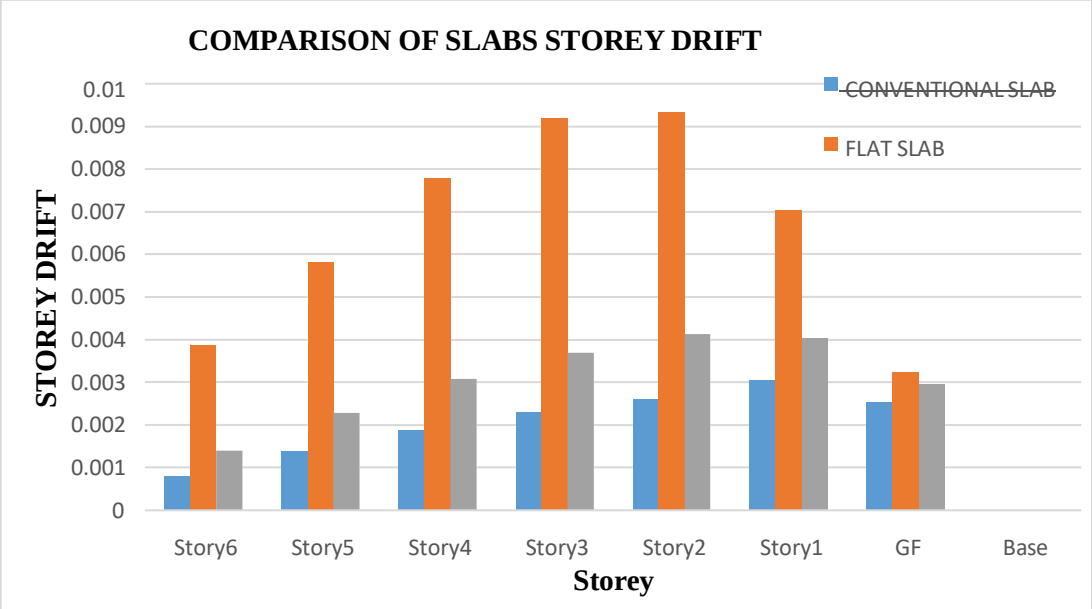
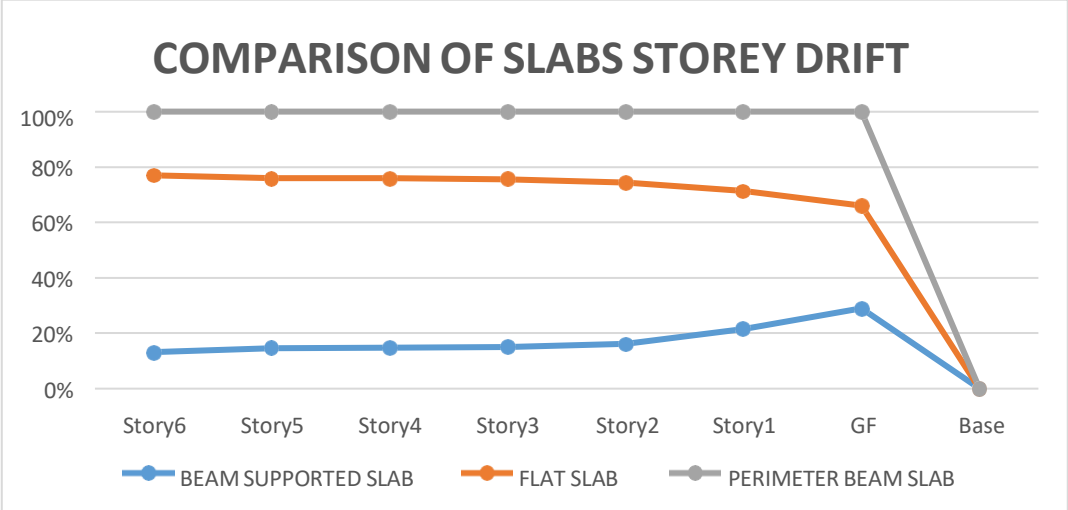



**Figure 4.2**: The Story drift vs story number



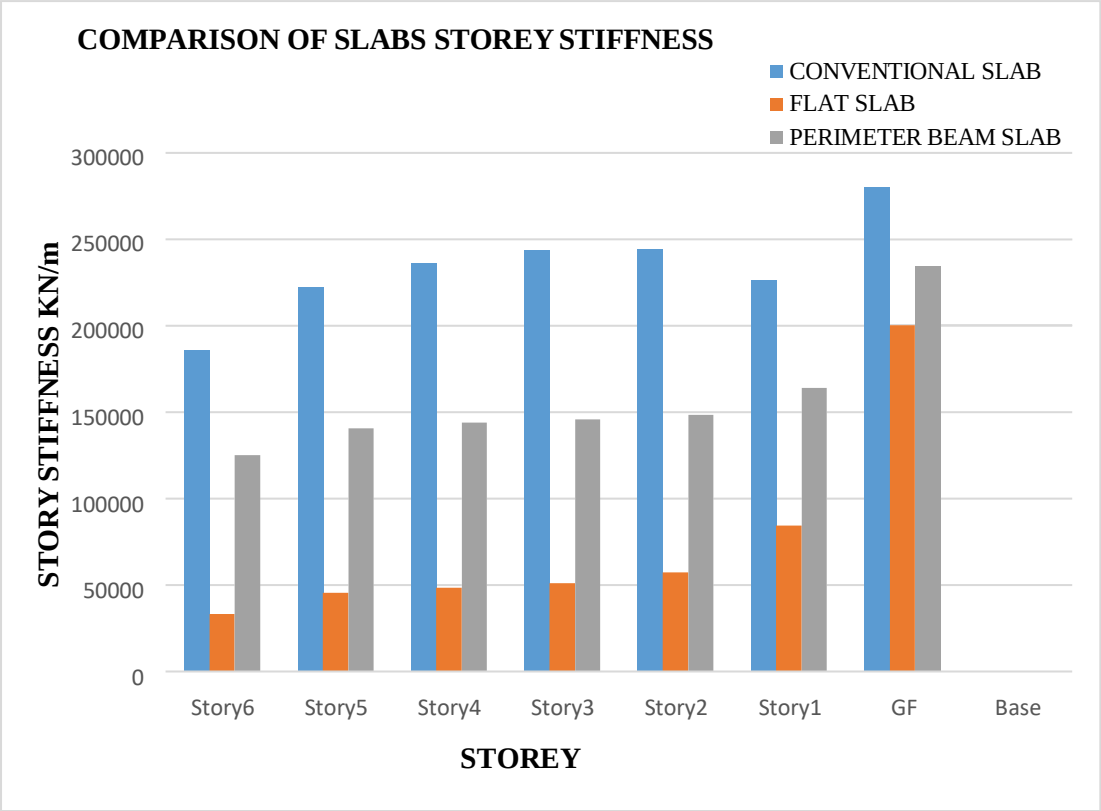

### 4.2.3 Comparison Based on Story Stiffness for G+6

story stiffness of a story is estimated as the lateral force that results in unit lateral translational deformation in that story. Maximum story stiffness occurred in X direction for EX showed in **Table 4.3.**

**Table 4.3**: Comparative story stiffness of different slab system of G+6 story

| STORY | BEAM SUPPORTED SLAB(KN/m) | FLAT SLAB (KN/m) | PERIMETER BEAM SLAB (KN/m) |
|---|---|---|---|
| Story6 | 186223.887 | 33408.127 | 125187.991 |
| Story5 | 222167.025 | 45621.769 | 140681.997 |
| Story4 | 236096.572 | 48576.797 | 143903.909 |
| Story3 | 244185.648 | 50981.466 | 145970.965 |
| Story2 | 244428.953 | 57248.536 | 148299.728 |
| Story1 | 226166.69 | 84501.009 | 163968.197 |
| GF | 280156.236 | 200292.459 | 234318.641 |
| Base | 0 | 0 | 0 |

In this **Table 4.3** indicated the story stiffness of different slab supported structure withthe load combination EX in X direction for G+6 story building. Story Stiffness is the ratio of story force to average drift experienced by each story. And also Beam Supported slab and flat slab with and without perimeter beam is compared for this parameter. If structures are stiff then it's suitable for long period of sites. Story stiffness of Beam Supported slab building is stiffer than Flat slab with and without perimeter building. As the story no decreases stiffness goes on increasing. The maximum story



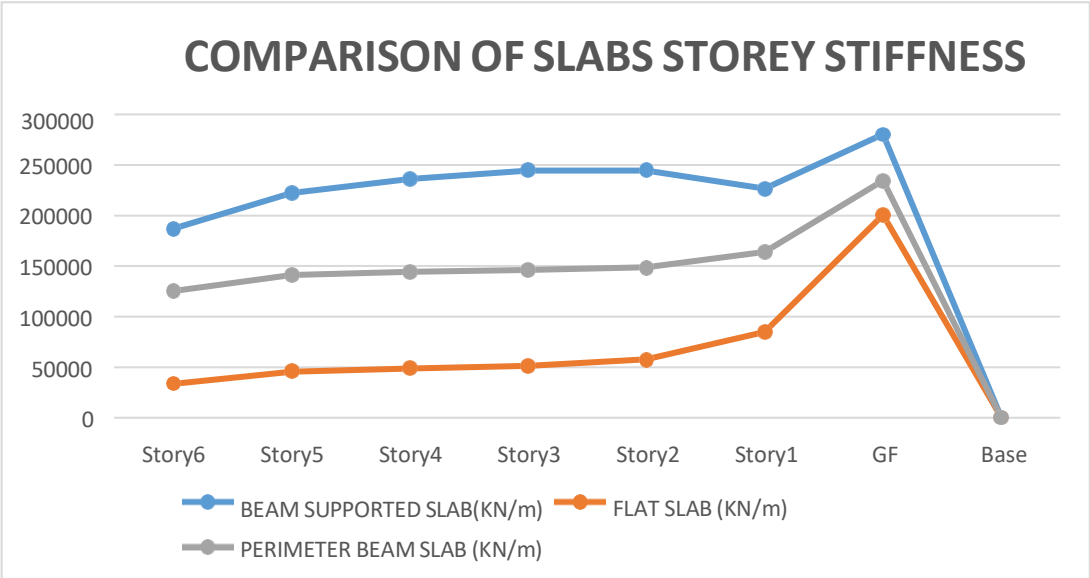




**Figure 4.3:** The Story stiffness vs story number

slab. The maximum story stiffness of flat slab with perimeter beam is 83% of Beam Supported slab or 17% less than the Beam Supported slab. In the **Figure 4.3** indicated the comparative maximum story stiffness of G+6 story with load EX in X direction. stiffness of flat slab is 72% of Beam Supported slab or 28% less than Beam SupportedThe Story stiffness of Beam Supported slab is more than the flat slab with

| STORY | BEAM SUPPORTED SLAB(KN/m) | FLAT SLAB (KN/m) | PERIMETER BEAM SLAB (KN/m) |
|---|---|---|---|
| Story6 | 168142.821 | 31237.945 | 112265.131 |
| Story5 | 213799.877 | 43994.789 | 137490.551 |
| Story4 | 231082.637 | 47740.161 | 142893.087 |
| Story3 | 240218.29 | 50609.865 | 145493.214 |
| Story2 | 239830.225 | 57510.406 | 148002.493 |
| Story1 | 226887.341 | 87206.507 | 165619.623 |
| GF | 282517.818 | 198189.288 | 236740.98 |
| Base | 0 | 0 | 0 |

and without perimeter beam. The stiffness is higher at GF compare to the upper floor. The story stiffness of Beam Supported slab is maximum compare to the other type of slab. i.e., Beam Supported slab>flat slab with perimeter beam>flat slab without perimeter beam. Story stiffness of Beam Supported slab building is stiffer than Flat slab building. As the story no decreases stiffness goes on increasing. For use of beam in Beam Supported slab it shows more stiffness than flat slab without perimeter beam andthe stiffness of flat slab is less than the flat slab with perimeter beam because the flat slab has no beam.

### 4.2.4 Comparison Based on Story Stiffness for G+6

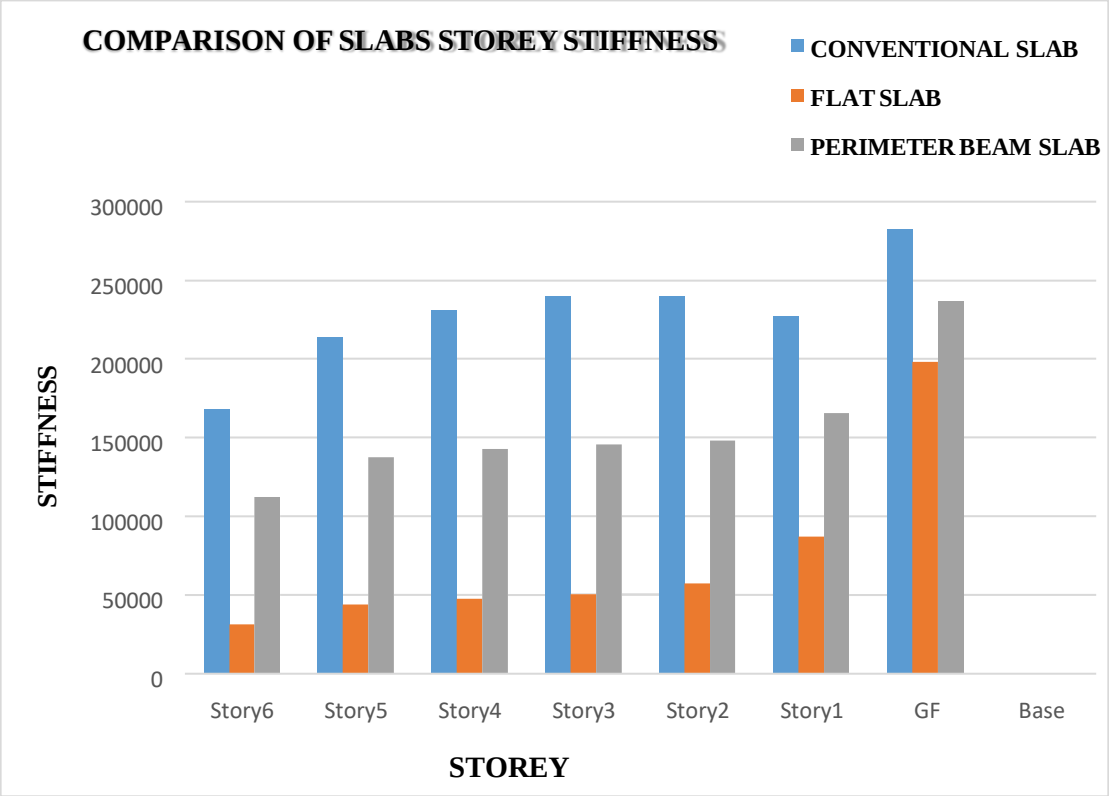
Maximum story stiffness in X direction occured for WX is showed in **Table 4.4**

**Table 4.4**: Comparative story stiffness of different slab system of G+11

**Table 4.4** indicated the story stiffness of different slab supported structure with the load combination WX in X direction for G+6 story building. Story Stiffness is the ratio of story force to average drift experienced by each story. And also, Beam Supported slab

and Flat slab with and without perimeter beam is compared for this parameter Story stiffness of Beam Supported slab building is stiffer than Flat slab with and without perimeter building. As the story no decreases stiffness goes on increasing. The maximum story stiffness of flat slab is 70% of Beam Supported slab or 30% less than Beam Supported slab. The maximum story stiffness of flat slab with perimeter beam is84% of Beam Supported slab or 16% less than the Beam Supported slab.

In the **Figure 4.4** indicated the comparative maximum story stiffness of G+6 story with load WX in X direction. The Story stiffness of Beam Supported slab is more than the flat slab with and without perimeter beam. The stiffness is higher at GF compare to theupper floor. The story stiffness of Beam Supported slab is maximum compare to the other type of slab. i.e., Beam Supported slab>flat slab with perimeter beam>flat slab without perimeter beam. Story stiffness of Beam Supported slab building is stiffer than Flat slab building. As the story no decreases stiffness goes on increasing. For use of beam in Beam Supported slab it shows more stiffness than flat slab without perimeter beam and the stiffness of flat slab is less than the flat slab with perimeter beam becausethe flat slab



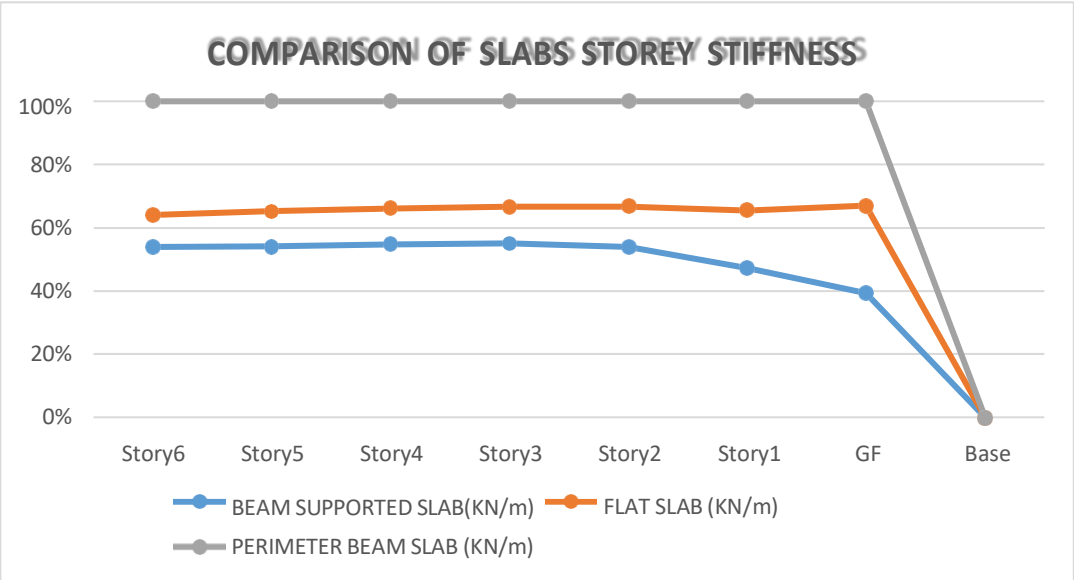



**Figure 4.4**: The Story stiffness vs story number

Beam Supported slab is beam supported slab which can resist more lateral load than the flat and perimeter beam flat slab and perimeter beam flat slab is stiffer than flat slab because of perimeter beam.

### 4.2.5 Comparison Based on Story Displacement for G+11

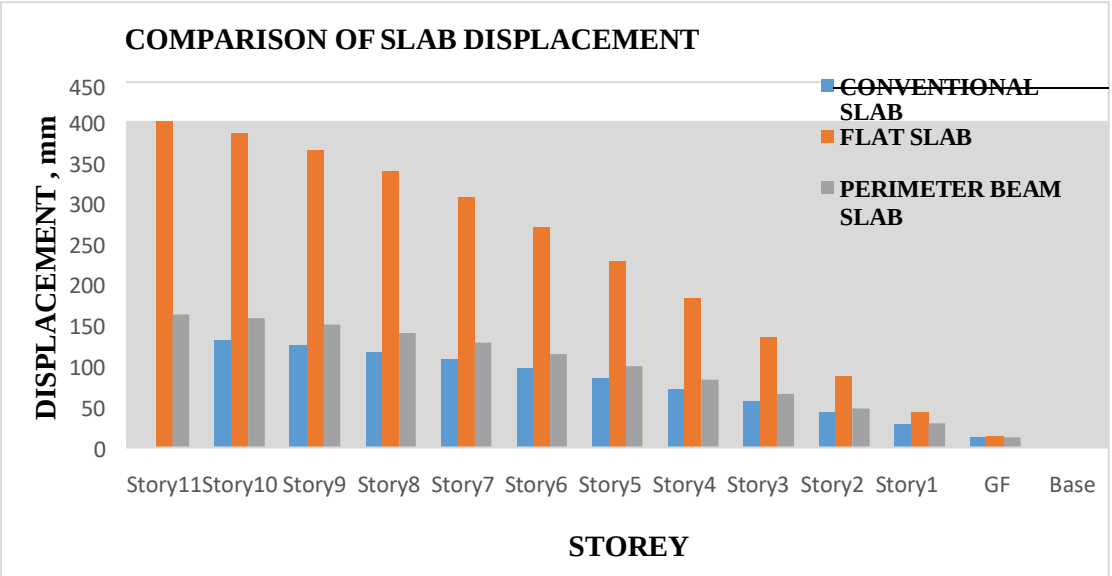
Displacement in x direction (mm) for maximum load combination = (0.9DL+1.43EX) is as **Table 4.5**. Displacement of residential structure constructed using flat slab system is more than the Beam Supported slab system. The **Table 4.5** indicated that The Story displacement of Beam Supported slab is less than the flat slab with and without perimeter beam. The story displacement is increased with the increase of story height. The story displacement of flat slab indicated the maximum displacement at top story than the Beam Supported slab and flat slab with perimeter beam. i.e., Flat slab with perimeter beam>flat slab without perimeter beam> Beam Supported slab. The maximum story displacement of Beam Supported slab is 34% of flat slab or 66% less than flat slab and 83% of flat slab with perimeter beam or 17% less than the perimeter beams flat slab.

**Table 4.5:** Comparative story displacement of different slab system of G+11

| STORY | BEAM SUPPORTED SLAB | FLAT SLAB | PERIMETER BEAM SLAB |
|---|---|---|---|
| Story11 | 136.507 | 400.663 | 163.891 |
| Story10 | 132.174 | 386.338 | 158.454 |
| Story9 | 125.86 | 366.391 | 150.653 |
| Story8 | 117.745 | 340.272 | 140.628 |
| Story7 | 108.026 | 308.297 | 128.617 |
| Story6 | 96.903 | 271.052 | 114.866 |
| Story5 | 84.579 | 229.264 | 99.628 |
| Story4 | 71.262 | 183.807 | 83.164 |
| Story3 | 57.162 | 135.873 | 65.738 |
| Story2 | 42.496 | 87.473 | 47.646 |
| Story1 | 27.491 | 43.368 | 29.218 |
| GF | 12.583 | 13.819 | 12.15 |
| Base | 0 | 0 | 0 |

Story displacement is total displacement of 11 story with respect to ground. The story displacement is increased with the increase of story height.

**Figure 4.5** indicated that The Story displacement of Beam Supported slab is less than the flat slab with and without perimeter beam.



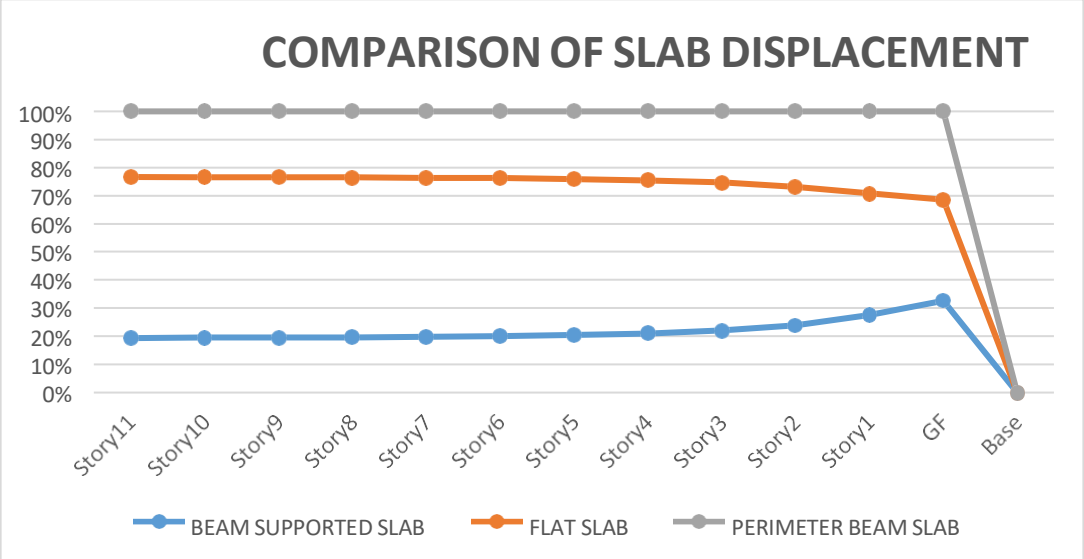



**Figure 4.5**: The Story displacement vs story number

The story displacement of flat slab indicated the maximum displacement at top story than the Beam Supported slab and flat slab with perimeter beam. Since the beam is used in Beam Supported slab this slab can resist more lateral load than flat slab with and without perimeter beam and flat slab showing more displacement because of column supported slab. Perimeter beam flat slab showing less displacement than flat slab because of added perimeter beam in this slab.

### 4.2.6 Comparison Based on Story Drift for G+11

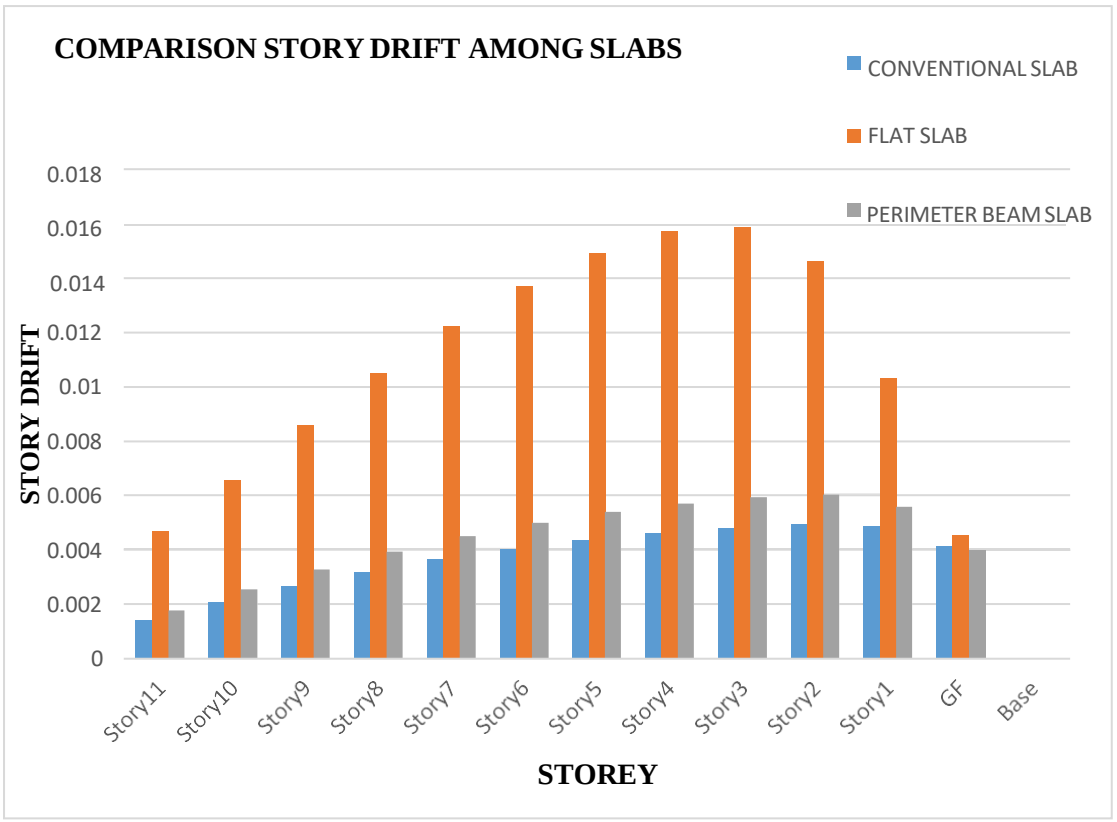
Story drift in x direction (mm) for max. load combination = (0.9DL+1.43EX) is shownin **Table 4.6**. **Table 4.6** indicated the comparison of story drift of different slab supported building. Since the displacement of flat slab without perimeter beam is maximum than the flat slab with perimeter beam and Beam Supported slab building so the story drift of flat slab without perimeter beam is maximum.

**Table 4.6:** Comparative story drift of different slab system of G+11 story

| STORY | BEAM SUPPORTED SLAB | FLAT SLAB | PERIMETER BEAM SLAB |
|---|---|---|---|
| Story11 | 0.001421 | 0.0047 | 0.001784 |
| Story10 | 0.002071 | 0.006544 | 0.002559 |
| Story9 | 0.002662 | 0.008569 | 0.003289 |
| Story8 | 0.003189 | 0.01049 | 0.003941 |
| Story7 | 0.003649 | 0.01222 | 0.004512 |
| Story6 | 0.004043 | 0.01371 | 0.004999 |
| Story5 | 0.004369 | 0.014913 | 0.005402 |
| Story4 | 0.004626 | 0.015727 | 0.005717 |
| Story3 | 0.004812 | 0.015879 | 0.005936 |
| Story2 | 0.004923 | 0.014621 | 0.006046 |
| Story1 | 0.004891 | 0.010286 | 0.005599 |
| GF | 0.004128 | 0.004529 | 0.003984 |
| Base | 0 | 0 | 0 |

Flat slab with perimeter beam is more stable than flat slab without perimeter beam because the displacement and story drift is less and among three slab Beam Supported slab is more stable. Story drift is defined as difference between lateral displacements of one floor relative to the floor below. The maximum story drift of Beam Supported slab is 30% of flat slab without perimeter beam or 70% less than the flat slab and flat slab with perimeter beam is 37% of flat slab without perimeter beam or 63% less than the flat slab

**Figure 4.6** showing the comparative story drift with load combination of 0.9DL+1.43EX



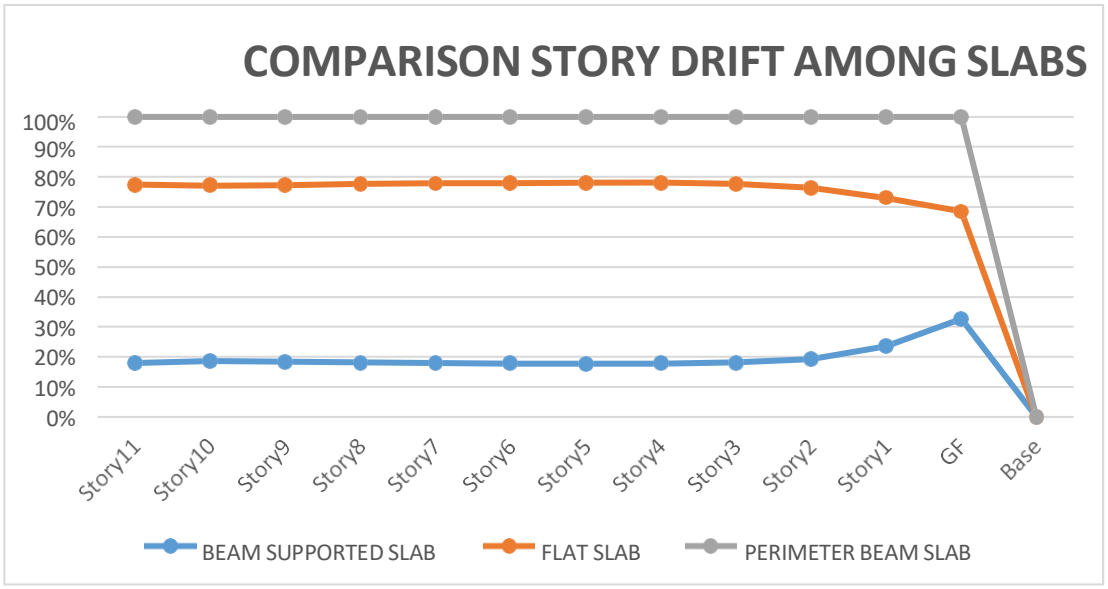




**Figure 4.6**: Story drift vs Story number

In X direction from this **Figure 4.6**, we see that middle stories indicated the maximum storydrift because of maximum displacement. That means columns are stiffer in bottom and top stories and weaker in the midlevel of the structure. It is seen that story drift is maximum for the flat slab compared to the Beam Supported slab and very less for the

Beam Supported slab for using beam with slab . Flat slab with perimeter beam is more stable than flat slab without perimeter beam because the displacement and story drift isless and among three slab Beam Supported slab is more stable.

### 4.2.7 Comparison Based on Story Stiffness for G+11

Story stiffness in x direction (KN/m) for EX is as **Table 4.7**.

**Table 4.7** indicated the story stiffness of different slab supported structure with the load combination EX in X direction for G+11 story building. Story Stiffness is the ratio of story force to average drift experienced by each story. And also, Beam Supported slab and Flat slab with and without perimeter beam is compared for this parameter. If structures are stiff then its suitability stands for long period of sites. Story stiffness of Beam Supported slab building is stiffer than Flat slab with and without perimeter building. As the story no decreases stiffness goes on increasing. The maximum story stiffness of flat slab is 81% of Beam Supported slab or 19% less than Beam Supported slab at GF. The maximum story stiffness of flat slab with perimeter beam is 84% of Beam Supported slab or 16% less than the Beam Supported slab.

**Table 4.7**: Comparative story stiffness of different slab system of G+11 story

| STORY | BEAM SUPPORTED SLAB (KN/m) | FLAT SLAB (KN/m) | PERIMETER BEAM SLAB (KN/m) |
|---|---|---|---|
| Story11 | 142091.486 | 34404.847 | 101873.154 |
| Story10 | 160923.333 | 41726.411 | 118260.61 |
| Story9 | 170282.305 | 43756.146 | 125473.273 |
| Story8 | 176047.218 | 44560.713 | 129844.736 |
| Story7 | 180111.571 | 45000.925 | 132903.838 |
| Story6 | 183316.854 | 45360.937 | 135319.968 |
| Story5 | 186095.836 | 45806.666 | 137432.506 |
| Story4 | 188706.381 | 46617.477 | 139444.507 |
| Story3 | 191361.879 | 48561.415 | 141708.255 |
| Story2 | 194325.082 | 54477.853 | 144668.954 |

| | | | |
|---|---|---|---|
| Story1 | 200648.316 | 80758.289 | 160588.317 |
| GF | 237666.556 | 195065.477 | 231561.762 |
| Base | 0 | 0 | 0 |

**Figure 4.7** indicated the comparative maximum story stiffness of G+11 story with load EX in X direction. The Story stiffness of Beam Supported slab is more than the flat slab with and without perimeter beam. The stiffness is higher at GF compare to the upper floor.

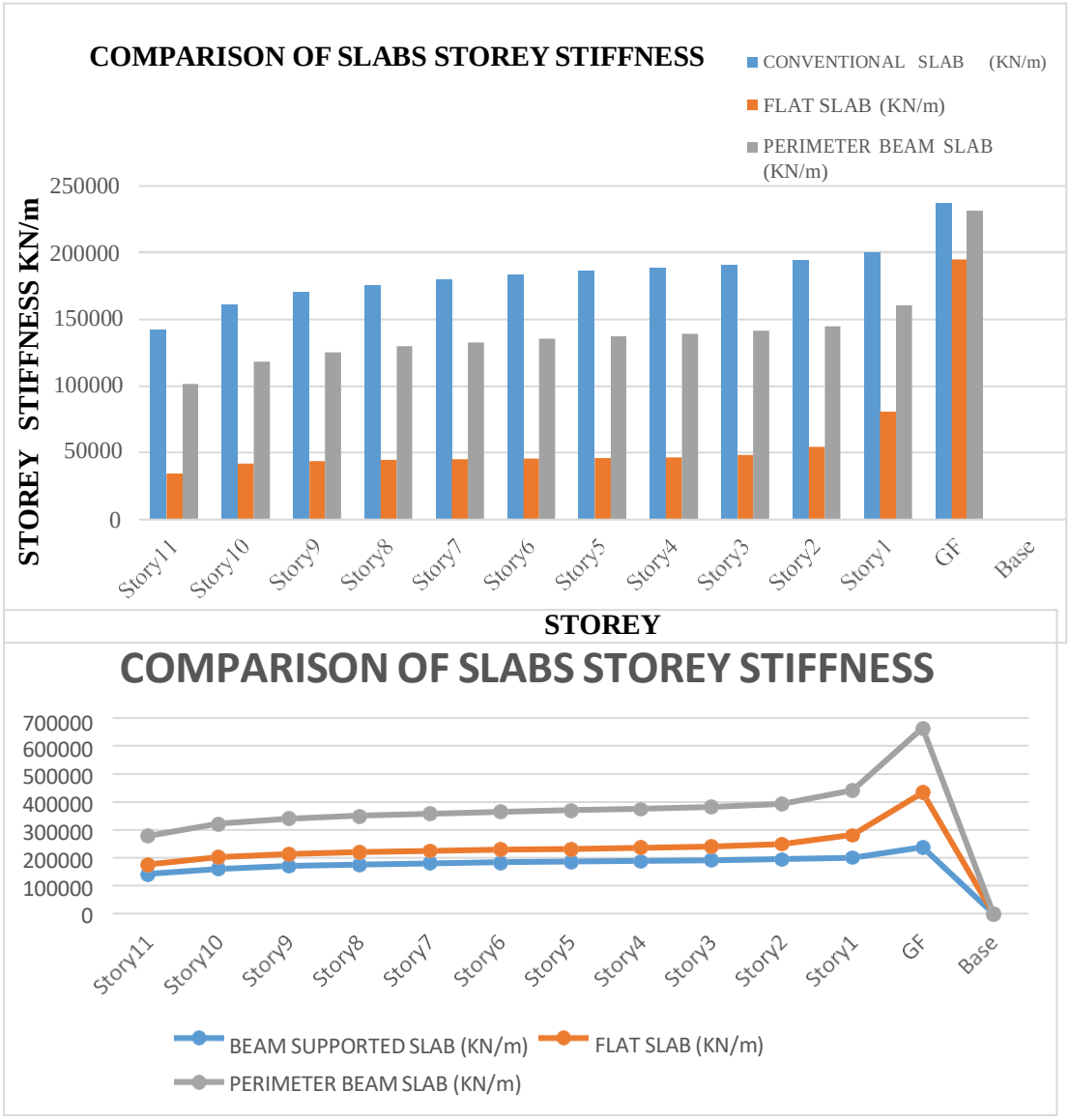



**Figure 4.7:** Comparative Story stiffness of G+11

The story stiffness of Beam Supported slab is maximum compare to the other type of slab. i.e., Beam Supported slab>flat slab with perimeter beam>flat slab without perimeter beam. The story stiffness of flat slab is 24% of Beam Supported slab at top story and 81% at GF. The story stiffness of flat slab is 34% of perimeter beam flat slab at top story. Story stiffness of Beam Supported slab building is stiffer than Flat slab building. As the story no decreases stiffness goes on increasing. For use of beam in Beam Supported slab it shows more stiffness than flat slab without perimeter beam andthe stiffness of flat slab is less than the flat slab with perimeter beam because the flat slab. Beam Supported slab is beam supported slab which can resist more lateral load than the flat and perimeter beam flat slab and perimeter beam flat slab is stifferthan flatslab because of perimeter beam.

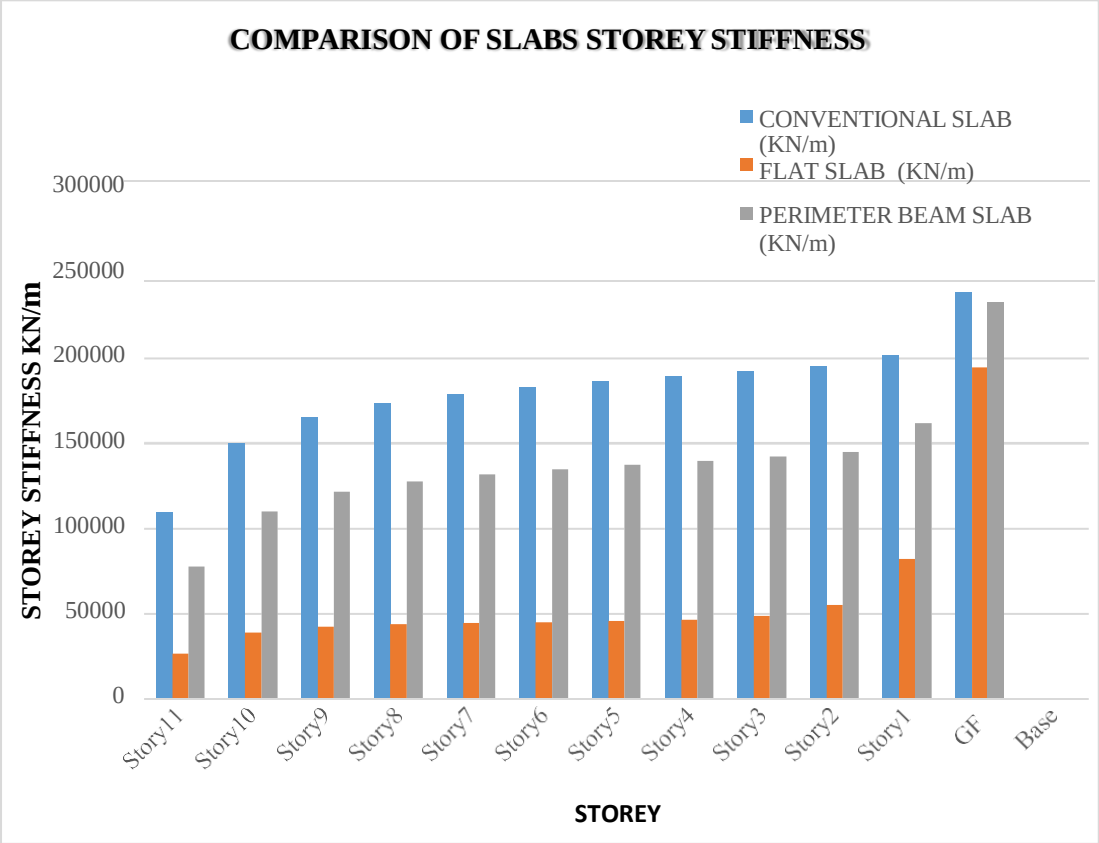
### 4.2.8 Comparison Based on Story Stiffness for G+11

Story stiffness in x direction ((KN/m) for WX is shown in **Table 4.8**.

**Table 4.8** represented the comparative story stiffness for G+11 story building with WX lateral load in X direction. The story stiffness is decreased with the increase of story height. The story stiffness of different slab is maximum at GF but minimum at top floor.The Beam Supported slab represented the maximum story stiffness than the other slab at GF to top floor and flat slab represented the less stiffness than another slab at GF to top floor. Beam Supported slab and Flat slab with and without perimeter beam are compared for this parameter Story stiffness of Beam Supported slab building is stiffer than Flat slab with and without perimeter building. The maximum story stiffness of flat slab is 82% of Beam Supported slab or 18% less than Beam Supported slab. The maximum story stiffness of flat slab with perimeter beam is 84% of Beam Supported slab or 16% less than the Beam Supported slab.

**Table 4.8**: Comparative story Stiffness of different slab system with load WX

| STORY | BEAM SUPPORTED SLAB (KN/m) | FLAT SLAB (KN/m) | PERIMETER BEAM SLAB (KN/m) |
|---|---|---|---|
| Story11 | 142091.486 | 34404.847 | 101873.154 |
| Story10 | 160923.333 | 41726.411 | 118260.61 |
| Story9 | 170282.305 | 43756.146 | 125473.273 |
| Story8 | 176047.218 | 44560.713 | 129844.736 |
| Story7 | 180111.571 | 45000.925 | 132903.838 |
| Story6 | 183316.854 | 45360.937 | 135319.968 |
| Story5 | 186095.836 | 45806.666 | 137432.506 |
| Story4 | 188706.381 | 46617.477 | 139444.507 |
| Story3 | 191361.879 | 48561.415 | 141708.255 |
| Story2 | 194325.082 | 54477.853 | 144668.954 |
| Story1 | 200648.316 | 80758.289 | 160588.317 |
| GF | 237666.556 | 195065.477 | 231561.762 |
| Base | 0 | 0 | 0 |



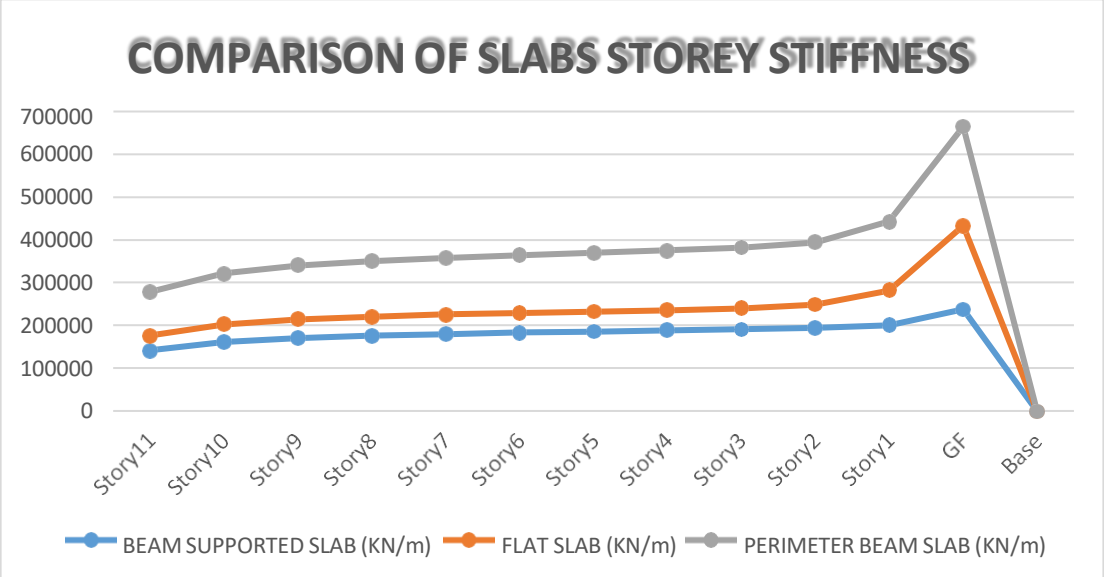



**Figure 4.8**: Story stiffness vs Story number

The story stiffness is decreased with the increase of story height. The story stiffness of different slab is maximum at GF but minimum at top floor. The Beam Supported slab represented the maximum story stiffness than the other slab at GF to top floor and flat slab represented the less stiffness than other slab at GF to top floor. Story stiffness of Beam Supported slab building is stiffer than Flat slab building. As the story no decreases stiffness goes on increasing. For use of beam in Beam Supported slab it showsmore stiffness than flat slab without perimeter beam and the stiffness of flat slab is lessthan the flat slab with perimeter beam because the flat slab. Beam Supported slab is beam supported slab which can resist more lateral load than the flat and perimeter beamflat slab and perimeter beam flat slab is stiffer than flat slab because of perimeter beam.

## 4.3 Discussions

The displacement of the flat slab is more than the Beam Supported slab and perimeter beam flat slab. The displacement is increased with the increased height of the building. The displacement of the G+11 story building is more than the G+6 story building with the same load combination and same section properties.

That's why the story drifts also increased in twelve story buildings than seven-story buildings with the same lateral load in the flat slab. The story drifts in the building usinga flat slab system are larger than in the Beam Supported slab and flat slab with perimeterbeam.

The Beam Supported slab structure has a greater stiffness than flat slab structure and flat slab with perimeter beam. As a result of this, additional moments are developed. Therefore, the columns of such buildings should be designed by considering additionalmoments caused by the drift.

The story displacement of the flat slab is approximately three times that Beam Supported slab and two times that flat slab with perimeter beam for G+6 story and two times than Beam Supported slab and one-half times than flat slab with a perimeter beamfor a G+11 story.

The story drift is also same as story displacement. The stiffness of Beam Supported slab supported structures is approximately four times than flat slab and two times that flat slab with perimeter beam for G+6 story.

The stiffness of Beam Supported slab supported structures is approximately three timesthat flat slab and two times that flat slab with perimeter beam for G+11 story. This is due to the Beam Supported slab structure has a greater stiffness than flat slab structure and flat slab with perimeter beam structure.

# CHAPTER V

## CONCLUSION AND RECOMMENDATION

### 5.1 Introduction

The main object of this thesis to analyzed G+6 and G+11 story residential building by ETABs to compare the displacement, story drift and stiffness of different slab. In this chapter overall results found from this analyzed are described. In this thesis we have developed eight data table and graph about story displacement, story drift and story stiffness vs different slab with maximum load combination.

### 5.2 Conclusion

On the basis of investigation and analysis of the results, following conclusions can be drawn here. These conclusions are grouped under following sub-headings:

#### 5.2.1 Displacement:

The maximum displacement of conventional slab is 43.659 mm and 136.507 mm for G+6 & G+11 storey which has gradually increased and graduated less towards the top. So that the maximum percentage of storey displacement of conventional slab is 31% and 34% for G+6 & G+11 storey of flat slab and 67% & 83% for G+6 and G+11 storeyof flat slab with perimeter beam. Above all, although more acceptable in the case of conventional slabs, but for the sake of convenience, if we want to omit the beam, then developing a flat slab with perimeter beam can significantly reduce the displacement compared to flat slabs.

#### 5.2.2 Storey Drift

The storey drift is maximum in flat slab and less in conventional slab. The maximum story drift of conventional slab is 28% of flat slab and 57% of flat slab with perimeter beam for G+6 Storey. On the other hand the maximum storey drift of conventional slabis 30% of flat slab or 70% less than the flat slab and flat slab with perimeter beam is 37% of flat slab without perimeter Beamor 63% less than the flat slab for G+11 storey.

**5.2.3 Storey Stiffness**: The storey stiffness is maximum in conventional slab and less in flat slab. So that's the maximum storystiffness of flat slab is 70% of conventionalslab or 30% less than conventional slab at GF and the maximum story stiffness of flat slab with perimeter beam is 81% of conventional slab at GF of G+6 Storey. For G+11 storey the maximum storey stiffness of flat slab is 78% of the conventional slab or 22% less than the conventional slab at GF and the maximum story stiffness of flat slab with perimeter beam is 81% of conventional slab or 19% less than the conventional slab.

Lastly three data analyze of the three types of buildings showed that the conventional slab performed best in all three cases of displacement, drift and stiffness. But the flat slab with perimeter beam is giving satisfactory results. Therefore, the idea of flat slab with perimeter beam can be developed in those places where it is necessary to give flatslab in the Earthquake zone.

## 5.3 Recommendation for Further Study

Some recommendations for future work in the light of the conclusions derived fromthese studies are

1. This study was done between flat slabs with and without perimeter beams and Beam Supported slab in future flat slab with perimeter beams comparison with drop and column capital can also be studied for all seismic zones.

2.This analysis was done using ETABS software further this could be done usingvarious different available software and different section properties also.

3. In future, analysis of flat slab structure with perimeter beams can be done while considering different soil types along with different seismic zones.

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# APPENDIX

## NOTATIONS

| | | |
|---|---|---|
| $A_{sw}$ | = | Cross-sectional area of a shear reinforcement |
| $Es$ | = | Modulus of elasticity of reinforcement |
| $VR_{in}$ | = | Punching shear strength (governing failure within shear-reinforced zone) |
| $VR_{out}$ | = | Punching shear strength (governing failure outside the shear-reinforced zone) |
| $b0$ | = | Perimeter of the critical section |
| $b0_{in}$ | = | Perimeter of the critical section (check of punching within the shear reinforced zone) |
| $b0_{out}$ | = | Perimeter of the critical section (check of punching shear outside theshear-reinforced zone) |
| C | = | Column size |
| $d_b$ | = | Diameter of a reinforcing bar |
| $dt$ | = | Diameter of transverse reinforcement |
| $dg$ | = | Maximum diameter of the aggregate |
| $dg0$ | = | Reference aggregate size |
| $f_y$ | = | Yield strength of flexural reinforcement |
| $f_c$ | = | Average compressive strength of concrete (measured on cylinder) |
| $f_{yt}$ | = | Yield strength of transverse reinforcement |
| $h$ | = | Depth of slab |
| $k$ | = | Second stress invariant ratio |
| st | = | Spacing of transverse reinforcement |
| $f_{ck}$ | = | Characteristic compressive strength of concrete (measured on cylinder) |
| $f_c$ | = | Specified compressive strength of concrete (measured on cylinder) |
| $\psi$ | = | Dilation angle |
| $\alpha$ | = | Angle between the critical shear crack and the soffit of the slab |
| $\beta$ | = | Angle between the shear reinforcement and the soffit of the slab |

# LIST OF ABBREVIATIONS OF TECHNICAL TERMS

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials. |
| ACI | American Concrete Institute. |
| BSI | The British Standards Institution. |
| ETABS | Extended Three-dimensional Analysis of Building Systems. |
| ASTM | American Society for Testing and Materials. |
| BNBC | Bangladesh National Building Code. |
| A.S.C | Allowable stress of concrete. |
| CBC | Crushed Brick Chips. |
| COV | Coefficient of Variance. |
| CFRP | Carbon Fiber Reinforced Polymers. |
| CC | Cement concrete. |
| RC | Reinforced Concrete. |
| RCC | Reinforced Cement Concrete. |
| TOB | Top of Beam. |
| TOC | Top of Concrete. |
| LW | Light Weight. |
| LWC | Light Weight Concrete. |
| USD | Ultimate strength design. |
| W.S.D | Working stress design. |
| MT | Metric Tons. |
| LL | Live load. |
| DL | Dead Load. |
| EQ | Earth Quack. |
| WL | Wind Load. |
| FP | Flat Plate. |
| TEMP | Temperature |