A Comparative Study of Beam Supported Slab and Flat Slab Structures Under Seismic Loading Using ETABS 18.1.0

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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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The thesis titled **"A Comparative Study of Beam Supported Slab and Flat Slab Structures Under Seismic Loading Using ETABS 18.1.0"** submitted by Md. Sheikh Farid, BCE1802014057, Md.Arif Shahriar, BCE1802014076, Mashuda Akter, BCE1802014148, Mst. Zannatul Ferdousi,BCE1802014041, Muhammad Noor Syeed, BCE1802014108 has been accepted as satisfactory inpartial fulfillment of the requirement for the degree of bachelor of science in civil engineering ondate-of-defense.

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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 the Faculties,
Department of Civil Engineering".

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ABSTRACT

This study undertaken to carry out comparative analysis of buildings with different slab systems by using ETABS 18.1.0 and to compare the analytical results with different slab system and also to conduct a parametric study on the lateral strength of building with different load combination. Total six models, three of G+6 and three of G+11 building was analyzed to compare the results of different parameter. This paper focuses on the comparative study of Beam Supported slab structure to flat slabstructure. In this study, ETABS 18.1.0 software is used forthe analysis of different slab supported structures with BNBC 2020 in seismic zone IV.The models taken in this study have rectangular configurations for residential building. Flat slab structure is more convenient, economical and provide better architectural visibility over Beam Supported 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. The paper discusses the distinctions of structure's behavior under different slab in terms of maximum story displacement, maximumstory drift and story stiffness. The story displacement of flat slab is approximately three times than Beam Supported slab. The story drift is also same as story displacement. The stiffness of Beam Supported slab structure is approximately four times than flat slab and two times for G+6 story. The stiffnessof Beam Supported slab supported structure is approximately three times than flat slab and two times than flat slab with perimeter beam for G+11 story. This is due to Beam Supported slab structure has a greater stiffness than flat slab structure.

Keywords: Slab Systems, Beam Supported Slab, Flat Slab, Seismic Zone-IV, Drift, Displacement, Stiffness.

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CHAPTER I

INTRODUCTION

1.1 Background

In the present world, with the increase in population growth, need for shelter and growth of country's economy demanding for infrastructure growth in the limited land area suitable for construction. The fast-growing countries are there in the world, in the context of developing country in the world. Bangladesh is one of those country at present is expeditiously growing in economic and nation developments infrastructure as population is increased day by day. Urbanization taking very fast developing and rate of urbanization rate is more, by keeping this context we are aiming to counteract those requirements to from or build the structures in the urban area. When the area comes under the earthquake zone or the high intensity of the wind and external load this are all factor affects the improvements the infrastructure. Earthquake phenomenonplays important role due to movement of tectonic plates in Earth's lithosphere. Seismicforce is the major cause for collapse of many high-rise structures. Seismic zone plays an influential role in the earthquake resistant design of building structures.

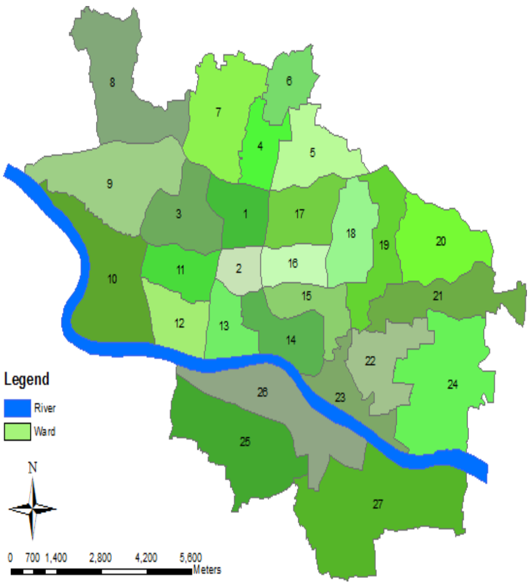


Figure 1.1 Ward map for Sylhet city

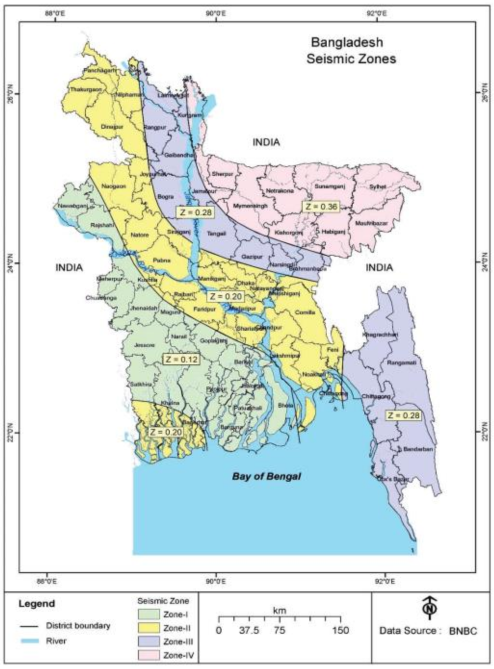


Figure 1.2 Seismic zoning map of Bangladesh.

Sylhet is the most earthquake-prone area of Bangladesh. 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 The structural analysis software ETABS 18.1.0 has been used to design the building. ETABS 18.1.0 is an acronym that stands for ― Extended three-dimensional analysis of 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 residentialstructures buildings situated in Zone IVas 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 and Flat slab in ETABS 18.1.0 software and results are tabulated and compared. All the sixmodels were considered for finite element method. From finite element analysis the displacement, time period, story drift, lateral displacement, story drift, shear, structuralstiffness and bending moments are obtained and compared. The work will help greatlyin achieving the better safety, economy and comfort in the design of the multistoried building's slab which is the need of the hour. The research examines the effect of Beam Supported slab reinforced concrete structure and flat slab with and without perimeterbeam reinforced concrete structure. The innovative and revolutionary software, ETABS 18.1.0 is the ultimate integrated softwarepackage for the structural analysis and design of buildings. Incorporating 40 years of continuous research and development, ETABS 18.1.0 offers unmatched 3D object-based modeling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide-range of materials, and insightful graphic displays, reports, and schematic drawings that allow users to quicklyand easily decipher and understand analysis.

Slabs are flat plate-shaped load bearing elements, usually in uniform thickness throughout the whole element, designed to carry lateral actions. Sometimes, in order to accommodate several services such as staircases, elevators, escalators, electrical cables, heating and ventilation systems, openings will be entailedto slabs.The slab is a structural component in a building thatfunctions to withstand the load transversely through bending action to each support. Slab is a flat, two-dimensional planar structural component of building having a very small thickness compared to its other two dimensions. It provides a covering shelter orworking flat surface in buildings. Its primary function is to transfer the load by bendingin one or two directions. Concrete slab behaves primarily as a flexural member and itsdesign philosophy is similar to that of beams.

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 istransferred 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.

A flat slab is a reinforced concrete slab supported directly on concrete columns or caps. Flat slab is also called beamless slab because it is supported on columns. Here, the loads are directly transferred to the columns. A slab with or without drops, supported generally without beams by columns with or without column heads. In flat slab buildings, floors are directly supported by columns without the use of intermediary beams.In general, normal frame construction utilizes columns, slabs and Beams. However, it may be possible to undertake construction without providing beams, in such a case the frame system would consist of slab and column without beams. These types of Slabs are called flat slab, since their behavior resembles the bending of flat plates. To increase punching shear resistance of flat slabs,columns may be flared to form a column head (column capital) or the slab may be thickened around columns as a drop panel or both. According to some research work flat slabs may have drop panels or drop panels with capitals that allow the slabs to be thinnerthan those without drop panels and capitals.

Figure 1.3 Flat slab floor system

Flat slab doesn’t have beams so it is also called a beam-less slab. They are supported on columns itself. Loads are directly transferred to columns. In this type of construction, a plain ceiling is obtained thus giving an attractive appearance from an architectural point of view. The plain ceiling diffuses the light better and is considered less vulnerable in the case of fire than the traditional beam slab construction. The most outstanding advantages of flat plates include fast construction, simple and low formwork cost, flat ceiling that reduces finishing cost. Flat plate systems are directly supported by columns and suitable for span of 6-8m with life load of 3-5KN/m^2. This type of floor system is adopted mainly for hotels, hospitals, multifamily residential buildings. Now-a-days flat slab structures are replacing Beam Supported slab structures as they are more feasible to construct, take less time and shows good aesthetic appearance. But themajor disadvantage of flat slab is its high flexibility due to which many problems like motion sickness, high story displacement etc.

1.2 Problems with Flat Slabs

Problems with flat slabs are mainly punching shear and deflection.

1.3 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 past decade.

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 tangential or circumferential cracks. These two types of cracks are shown in **Figure** for clarity.A typical 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**.

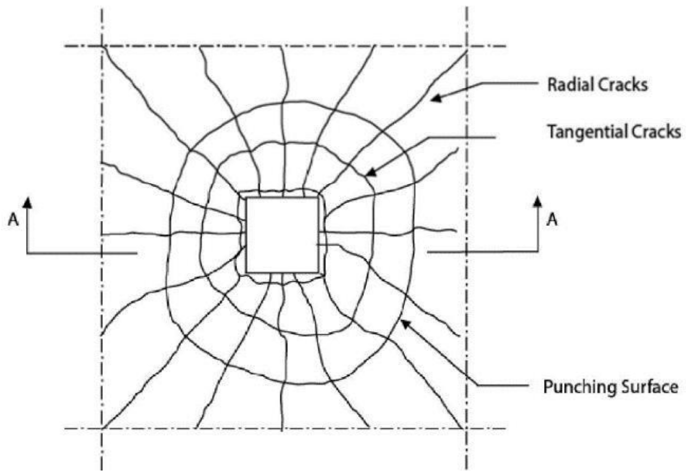


Figure 1.4: Piper's row car park,Wolverhampton,UK,1997 (built in 1965)

Flat slab failure due to punching shear. This results in the column breaking through the portion 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.

1.4 Punching Shear Mechanism

When a two-way slab is heavily loaded with a concentrated load or where a column rests on a two-way footing, diagonal tension cracks form that encircles the load or column. These cracks are not visible, except as flexural cracks. Such cracks extend into compression area of the slab and encounter resistance near the load similar to the shear-compression condition. The slab or footing continue to take load and finally the punching failure mechanism consists of the punching out a solid of revolution as a pyramid shape of concrete in the vicinity of column is adopted as indicated in **Figure. 1.4**, the surrounding slab remaining rigid. Diagonal cracks do not form further out from the load or column because of rapid increase in the failure perimeter. The initial diagonal cracks thus proceed to failure in punching shear type of failure directly around the load. The slab is reinforced in such a way that flexural failure is prevented. This implies that a punching failure mechanism forms first before the yielding of the main reinforcement. In compromising between initial cracking and the final shear condition at failure for different ratios between column (or load) dimension and slab (or footing) thickness, different codes recommend a single punching shear strength calculated at a pseudocritical distance from the column face or edge of the load.

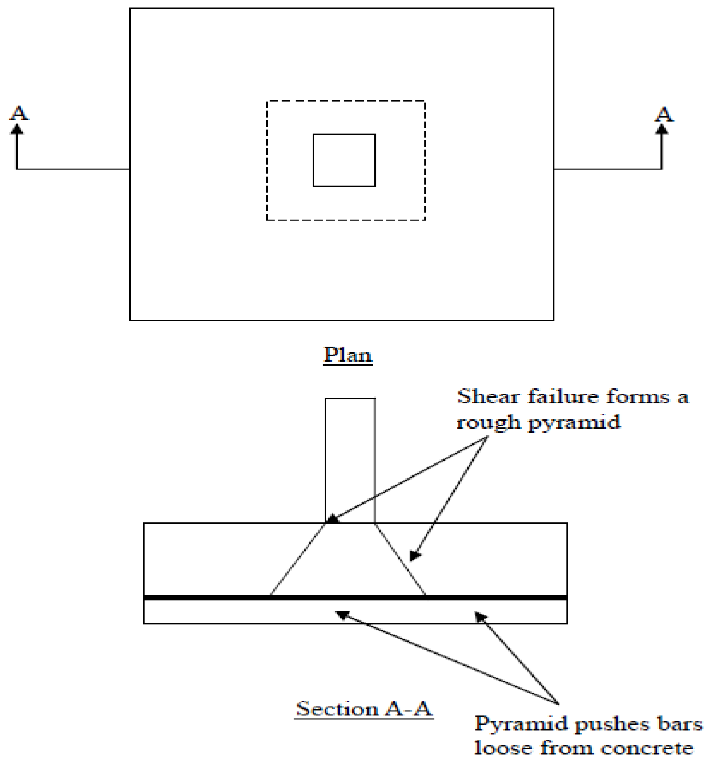


Figure 1.5 A square column tends to shear out a pyramid from a flat plate

1.5 Experimental Investigations

Several experimental investigations have been carried out to evaluate the punching shear strength of flat plates and slabs. These investigation covers both concrete material and geometric parameters like concrete strength, influence of reinforcement type and ratio, column size, plate thickness, edge conditions etc. Some of these are briefly summarized in the following subsections.

1.6 Research Significance

The goal of this research is to investigate the feasibility of flat slab with perimeter beam compared to flat slab without perimeter beam and Beam Supported slab in multi-story buildings. This is carried out through the comparison of a case study on building G +6 and G+11. In this paper, an attempt has been made to compare the study among beam supported slab and flat slab with for G+11and G+6 story buildings.

1.7 Objectives of the study

1. To analyze a Beam Supported slab;

2. To analyze a flat slab.

3. To perform a comparative study between a Beam Supported slab and a flat slab on the basis of different dynamic loading combinations.

Scope of 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 18.1.0 can be used for its better performance.

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.

I. N. Robertson [1]in his study the analysis of flat slab structures subjected to combined lateral 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 experimental test results. A two-beam analytical model more accurately predicts the test results with respect to slab moment distribution and lateral drift. Three-dimensional analysis done by ETABS 18.1.0 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.

M. Altug ERBERIK [2] 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 focuses on the derivation of fragility curves using medium-rise flat-slab buildings with masonry infill 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.

Y. Reichman [3] 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.

S. R. Chowdhury [4] conducted a study on effect of openings in shear wall on seismic response of structures. In this paper, finite element modeling in analyzing and exploring the behavior of shear wall with opening under seismic load actions, an attempt is made to apply the finite element modeling. A shear wall in a building contains many openings due to functional requirements such as doors, windows and other openings. This study is carried out using linear elastic analysis with the help of software ETABS 18.1.0 under the earthquake loads in equivalent static analysis. This study reveals that, the size of 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 increases with 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 most story level.

Gupta [5]Showed 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 and Bothara, [6]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 has proved 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 and Patil, 2016 [7]studied analysis of Flat Plate Multistoried Frames with and WithoutShear 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 % and 58.2 % when comparedwith 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 [8]studied about flat slab building structures which are more significantly flexible than traditional concrete frame/wall or frame structures, thus becoming more vulnerable to seismic loading. Therefore, the characteristics of the seismic behavior of flat slab buildings suggest that additional measures for guiding theconception and design of these structures in seismic regions are needed. To improve the performance of 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 [9] 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 L section ii) L Shear wall at junction of 2 flange portion iii) Two parallel L shear wall at junction of 2 flange portion iv) Tube type shear wall at junction of 2 flange portion v) Two parallel shear wall at end 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 [10]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 layer of 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 [11] 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. The comparative 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 and Yadav, 2008 [12]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 significant impact on space planning. So, it is essential for a structure to have lateral resistance by providing Shear wall.

Kvgd, 2014 [13]found out the effect of shear wall location in buildings subjected to seismic loads. A symmetric sixteen story residential building considered for the analysis. The finite element analysis software ETABS 18.1.0 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 [14]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. [15] 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 m and 15X25 m, analyzed with Staad Pro. 2006 for seismic zones III, IV and V with varying height 21m,27 m, 33 m 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 larger plans increase in column reinforcement is 0.6 to 1 % without shear walls and 0.2 to 0.6 % with shear walls.

Damam and Damam, 2015 [16] studied the solution for shear wall location and type of shear 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 by using structuralfinite element analysis (SAP2000) software.

J Shah and Jain, [17]analyzed with 12, 15, 18 story by taking into account seismic zones using ETABS 18.1.0. 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 [18]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 18.1.0 nonlinear version 9.7.3. linear dynamic analysis i.e., response spectrum analysis is performed on the system to get the seismic behavior.

Karki and Suwal, n.d. [19] 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 18.1.0 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 paper also investigates on which type of combination produces less punching shear at slab columnjoint.

Salim and Jaya, 2017 [20]investigated to study the seismic behavior of shear wall–flat slab connections with various reinforcement detailing at the joint region. The modelling andassessment of scaled down exterior wall–slab connection sub-assemblages subjected tostatic reverse cyclic loading is presented. Three-dimensional nonlinear finite element models with different reinforcement detailing at the joint region were developed using

ABAQUS/CAE software. The concrete damage plasticity model was used to model. It concludes that the provision of shear reinforcement in the joint core region can be an effective option for detailing exterior wall—flat slab connection in seismic risk regions.

Jamle et al., 2017 [21]investigated the combined effect of with and without shearwall of flat slab building on the seismic behavior of high rise building with various positions of shear wall studied. For that, 11 story model is created in ETABS 18.1.0. To study the effect of different location of shear wall on high rise structure, linear dynamic analysis (Response spectrum analysis) in software ETABS 18.1.0 is carried out. Seismic parameters like time period, base shear, story displacement and story drift arechecked out.

2.1.1.1.1 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 opined that 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 research report 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 of concrete strength as well as several other variables like percentage of tension reinforcement, size of column, conditions of support and loading, distributionof tension reinforcement, and amount and position of shear reinforcement

2.1.1.1.2 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 deflection of flat plates at interior columns. Failure is assumed to occur when the compression zone of the slab in the vicinity of the column is distressed by either high radial compression stress or by a high tangential compression strain. Size effects and the effect of increasing concrete brittleness with increasing strength are both considered. The method showed excellent agreement with results from punching tests reported in the literature, with conditions ranging from ductile flexural failures to brittle punching failures, from small test specimens to a full-sized structure, and from symmetrical to unsymmetrical loadings**.**

2.1.1.1.3 Effect of Shear Reinforcement

Yamada et al. (1991) performed a research program for the determination of the effect of 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 results of 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 the slab 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.

2.1.1.1.4 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 been noticed.

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 ratio of 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 that the punching shear strengths are much higher than those predicted by ACI 318 and BS 8110 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.

2.1.1.1.5 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 showed that 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 determine the 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 Structural Description

The rectangular Residential buildings of G+6 and G+11 story are consider in Sylhet region. In This research total six model buildings have been designed to compare displacement, story drift and story stiffness of RC Beam Supported 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 area and floor height 10 feet. The details of building are showed in **Table 3.1**

Table 3.1: Preliminary data for G+11 and G+6 story building (should be in result and discussion).

STORY Type	**PARAMETER**	**BEAM SUPPORTED SLAB**	**FLAT SLAB**
G+6 and G+11	Slab thickness	7 inches	7 inches
	Column 1	12 inch*20 inch	12 inch*20 inch
	Column 2	14 inch*24 inch	14 inch*24 inch
	Beam 1	14 inch*26 inch	
	Beam 2	14 inch*28 inch	
	Grade Beam	12 inch * 22 inch	12 inch *22 inch

3.1.0 Loads and other considerations

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

3.1.1 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

3.1.2 Live Loads

Live loads are those which may change in position and magnitude. According to BNBC 2020, 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 and exit	= 100 psf

3.1.3 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 ASCE 7-16 for the seismic Zone IV (BNBC-2020) in Sylhet region. Wind velocity (according to BNBC-2020) = 61.1 m/s

3.1.4 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 IV(BNBC-2020) in Sylhet region. Seismic loadparameters 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%

3.1.5 Load Combinations

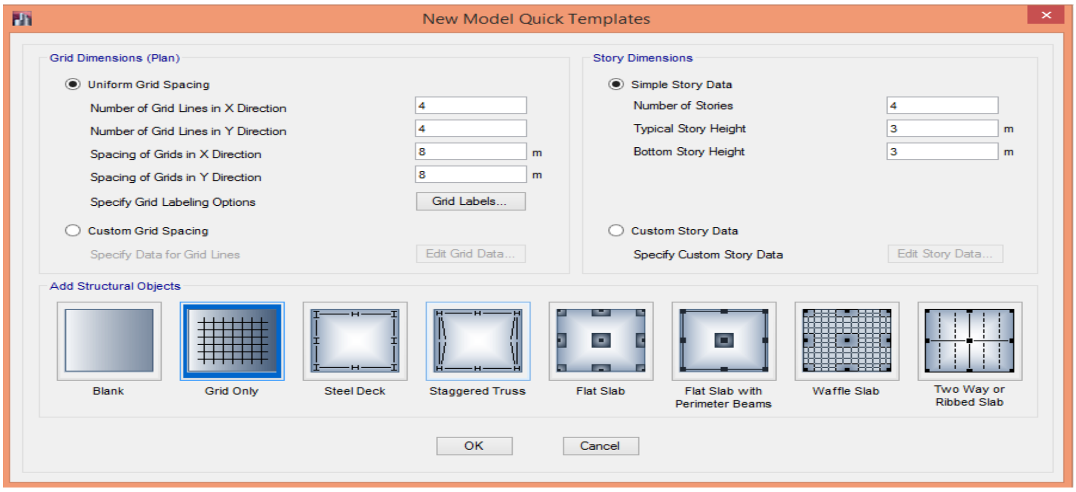
The Load combinations are considered as per Bangladesh National Building Code-2020 to design the model building showed in **Table 3.5**.

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

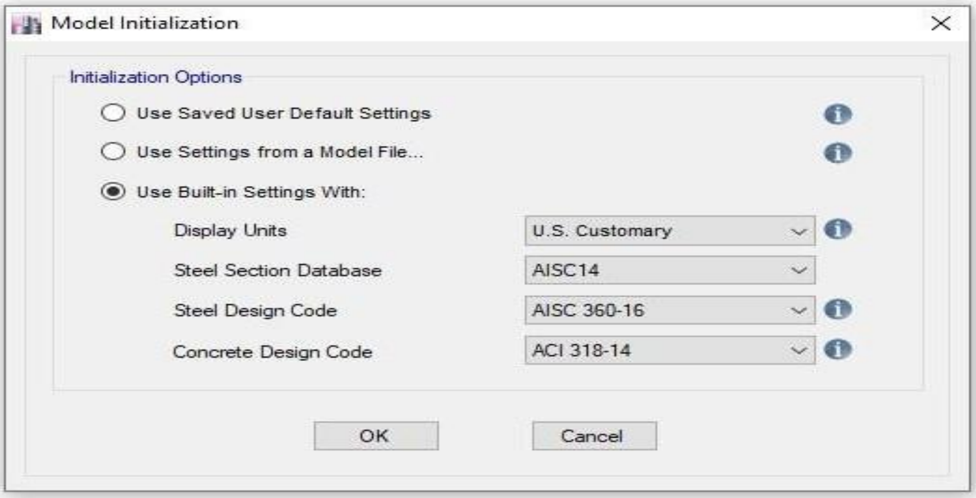
3.1.6 Procedure of Modeling by ETABS 18.1.0

- File > New model



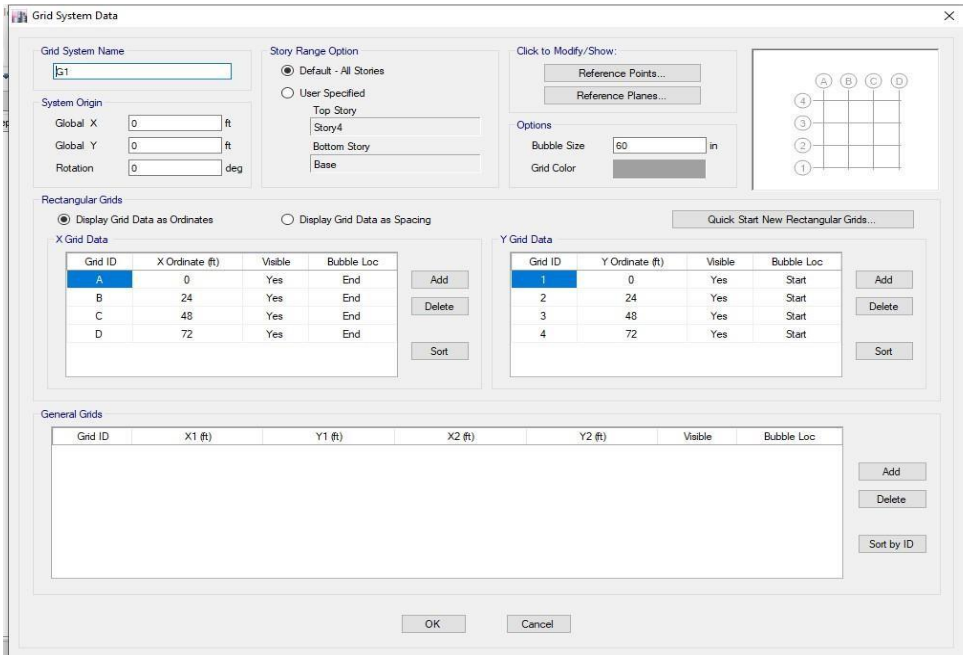
Use built in setting as below OR use settings from a model file which is already set as a standard template. Using first option may have a different unit system (Depends on the ETABS 18.1.0 default)

- Model Initialization > Quick template

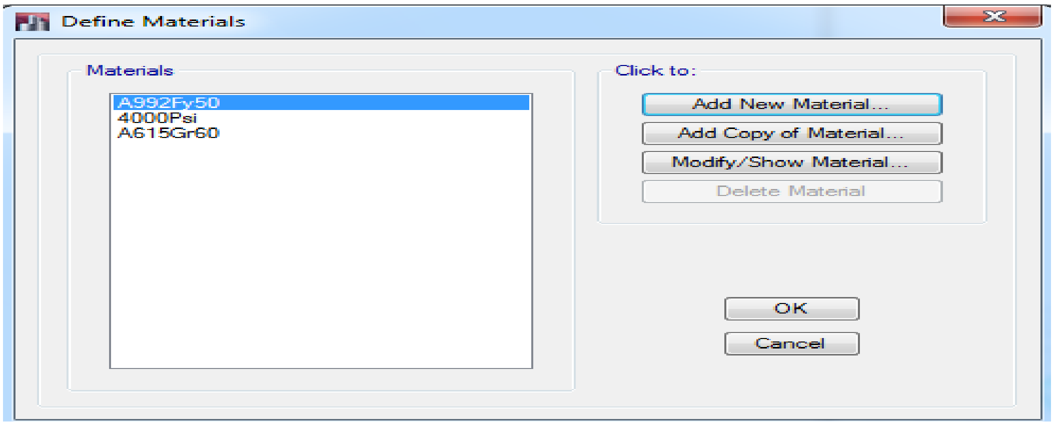


Grid spacing and story data should be defined as required. Custom grid spacing can be used to have non uniform spacing .Add Structural objects as required. For normal structures, blank or grid only options are handy.

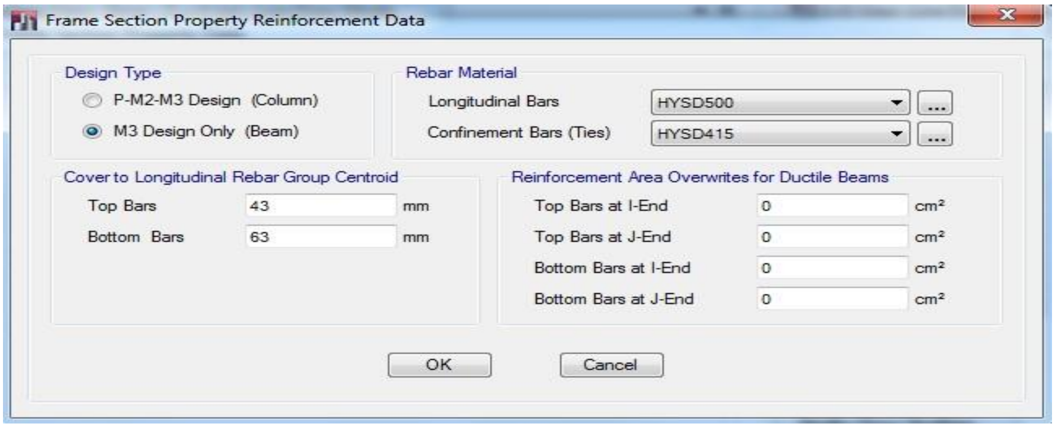
- Go to Edit > Edit Story and Grid System



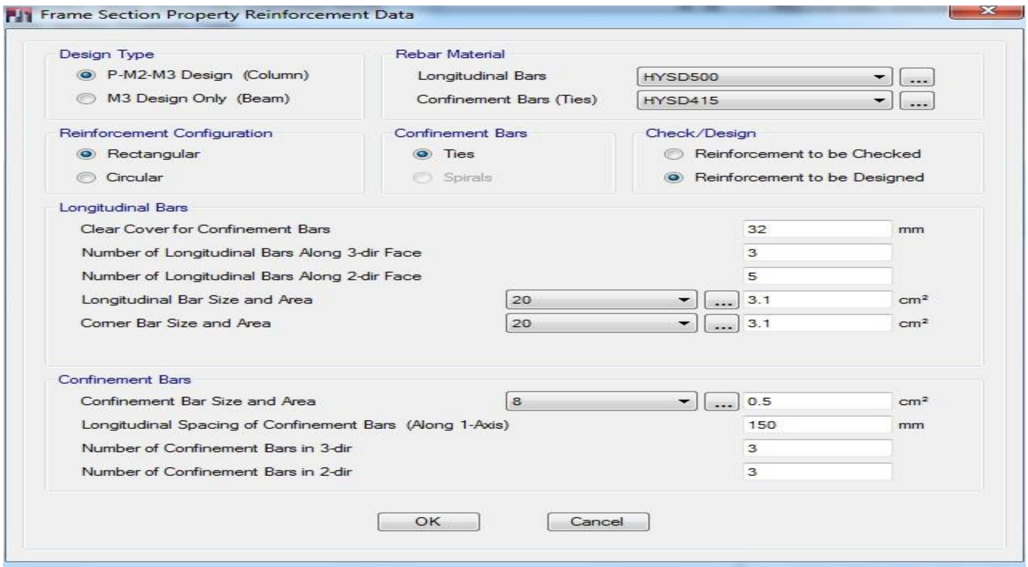
- Define material Properties



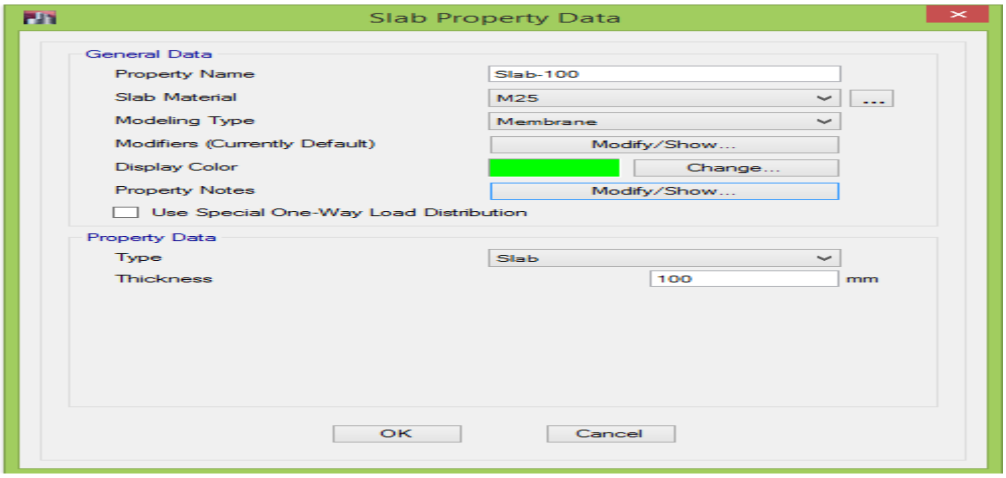
- Define section properties



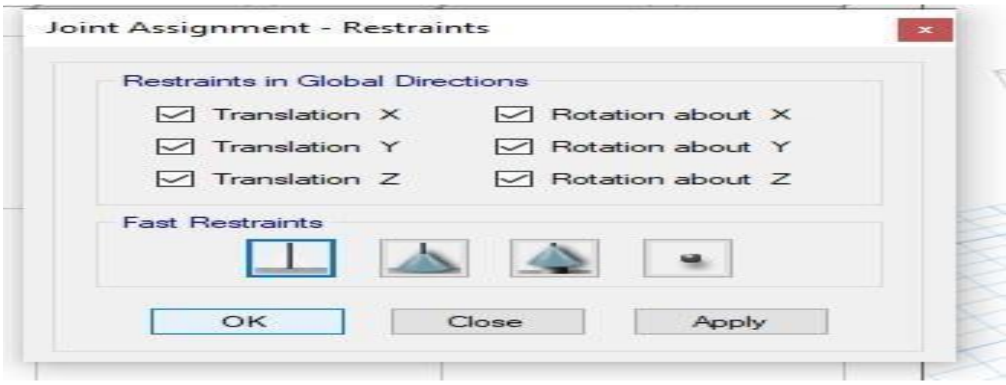
- Beam Section and Column Section



- Slab Section



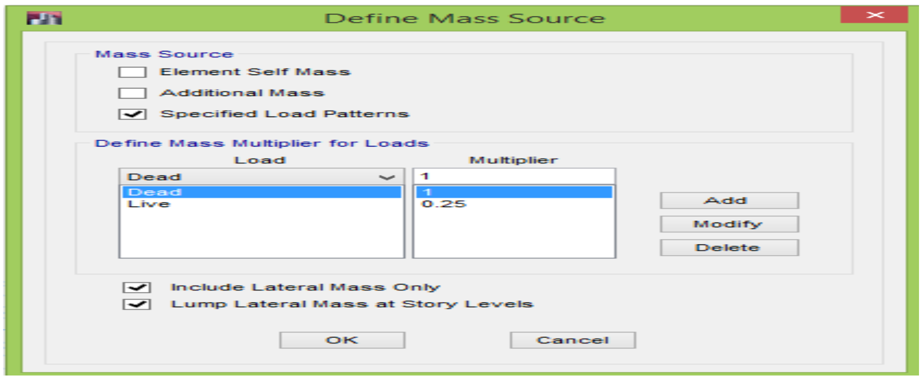
- After modelling, assign member properties to the members as required. Select bases then go to Assign >joint > restrained > pinned or fixed as required.



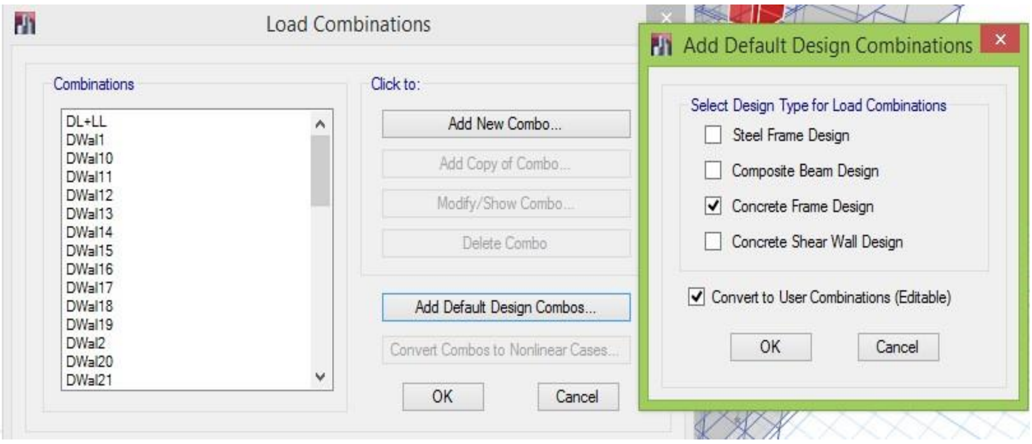
- Define load pattern

Only Dead load to have a self-weight multiplier of

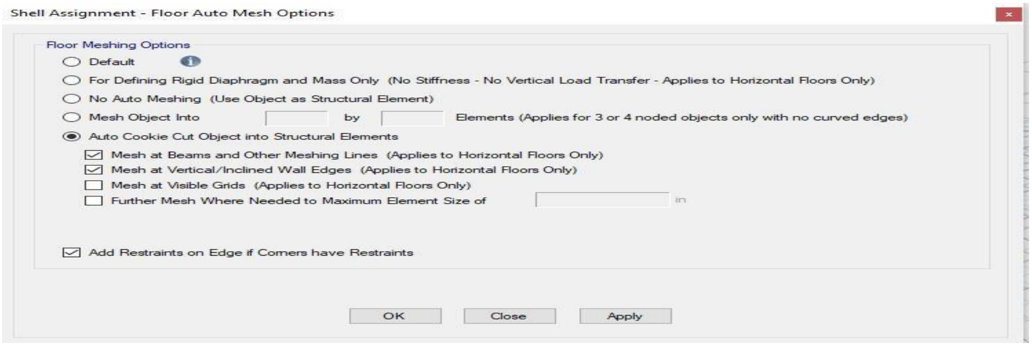
Define mass source

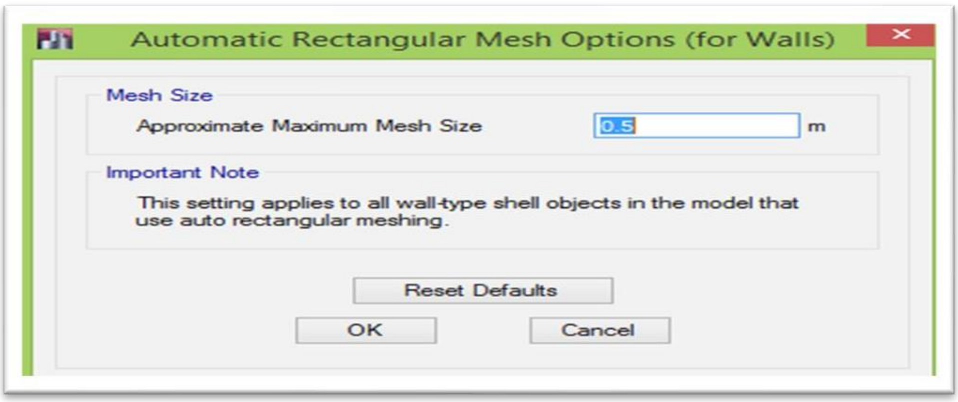


- Define load combination

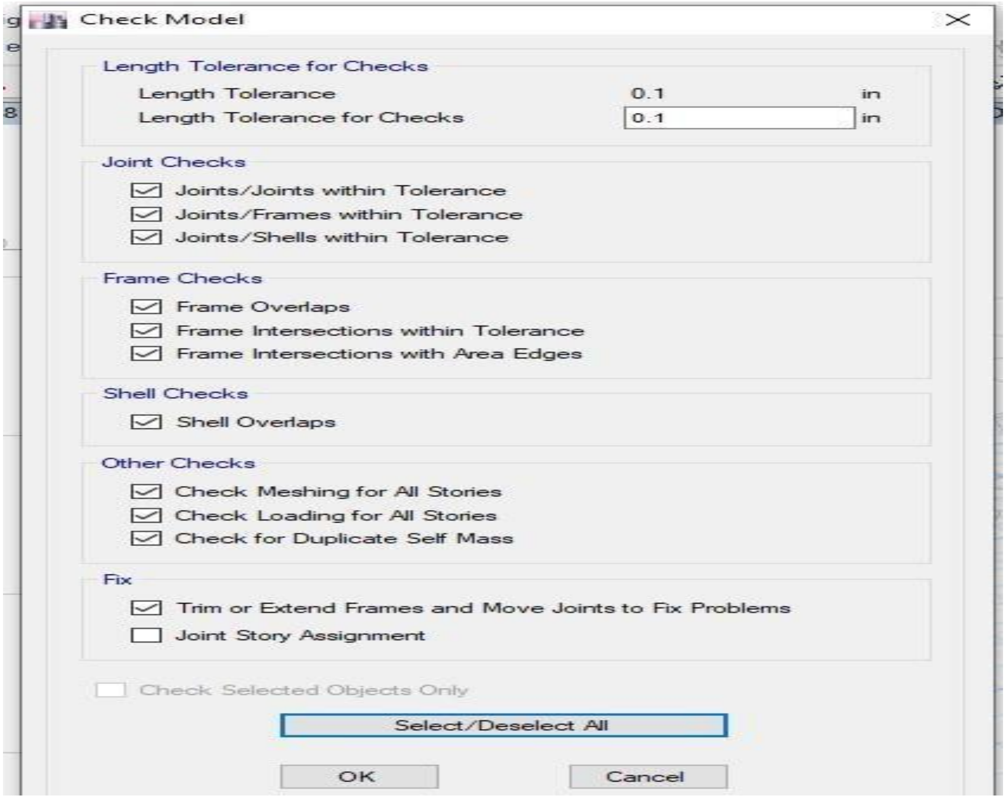


- Analyse – Auto mesh for slab and rectangular mesh setting of wall





- 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.

3.1.7 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.

3.1.8 Beam Supported Slab Floor Plan

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

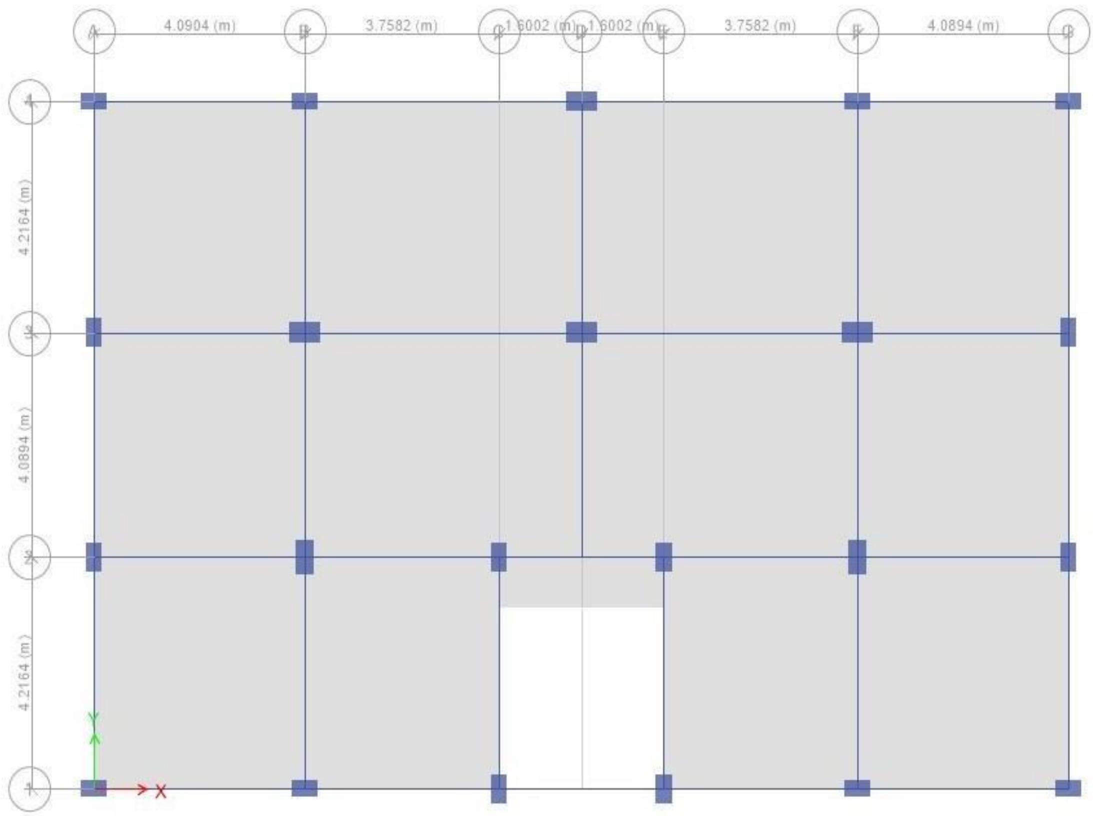


Figure 3.1: Beam Supported slab floor plan

3.1.9 Flat Slab Floor Plan

In flat slab system, the floor/roof consists of slabs and there are no beams. The load is transferred directly from slab to column in the flat slab Ratio of Longer span to shorter span is not more than 2.2. A floor plan of flat slab for G+6 and G+11 buildings is shown in **Figure 3.2** clarify**.**

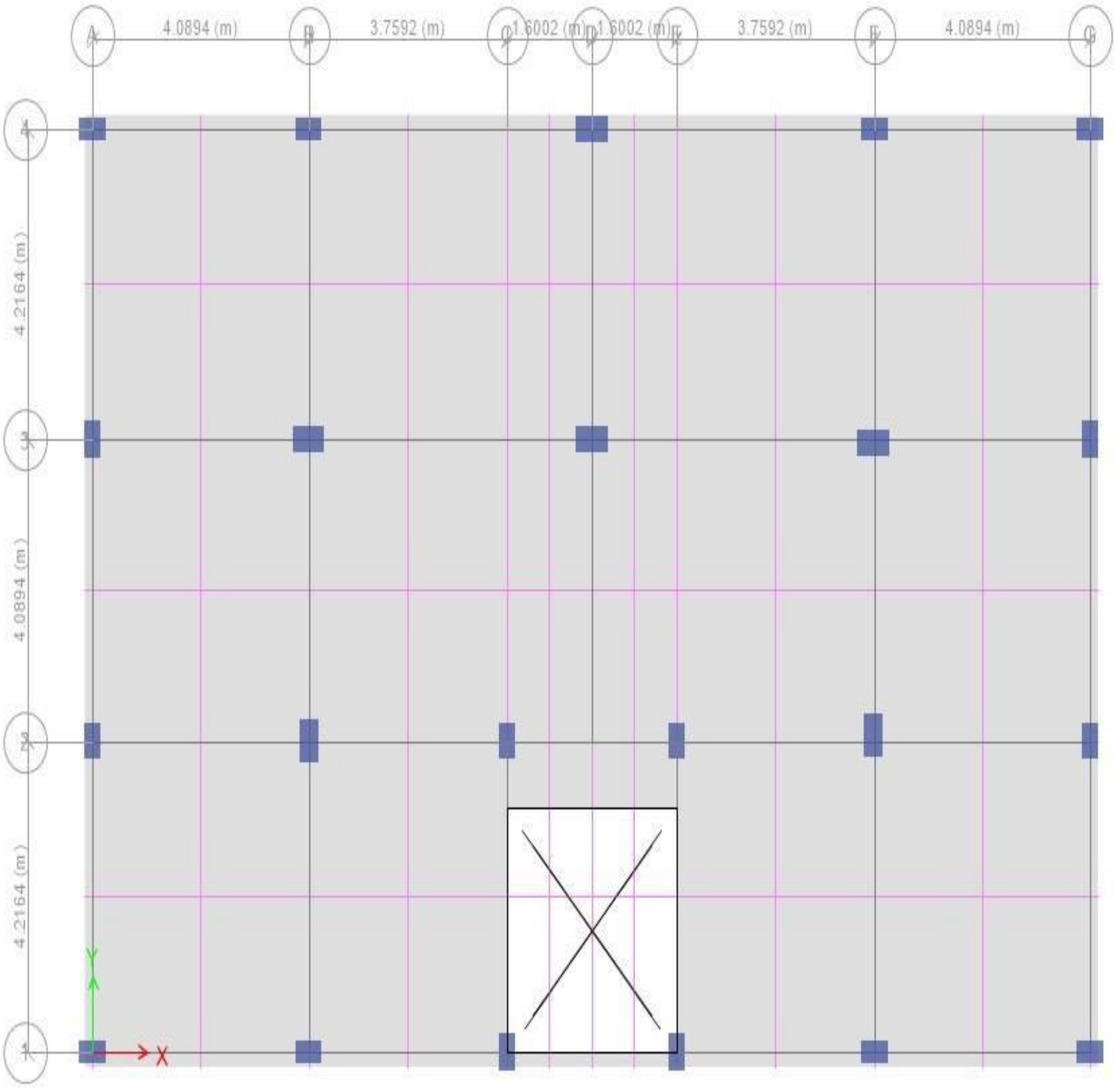


Figure 3.2: Flat slab floor plan

3.2 Render Model of structure

Rendered views can used to create images to include in our reports. ETABS 18.1.0 has multiple lighting options, shadows, and texture options to create life-like images of our structures.

3.2.1 G+6 Story Building

The render view of G+6 story buildings with Beam Supported slab and flat slab have been snapshotted to preview in this section.

3.2.2 Render View of Beam Supported Slab

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

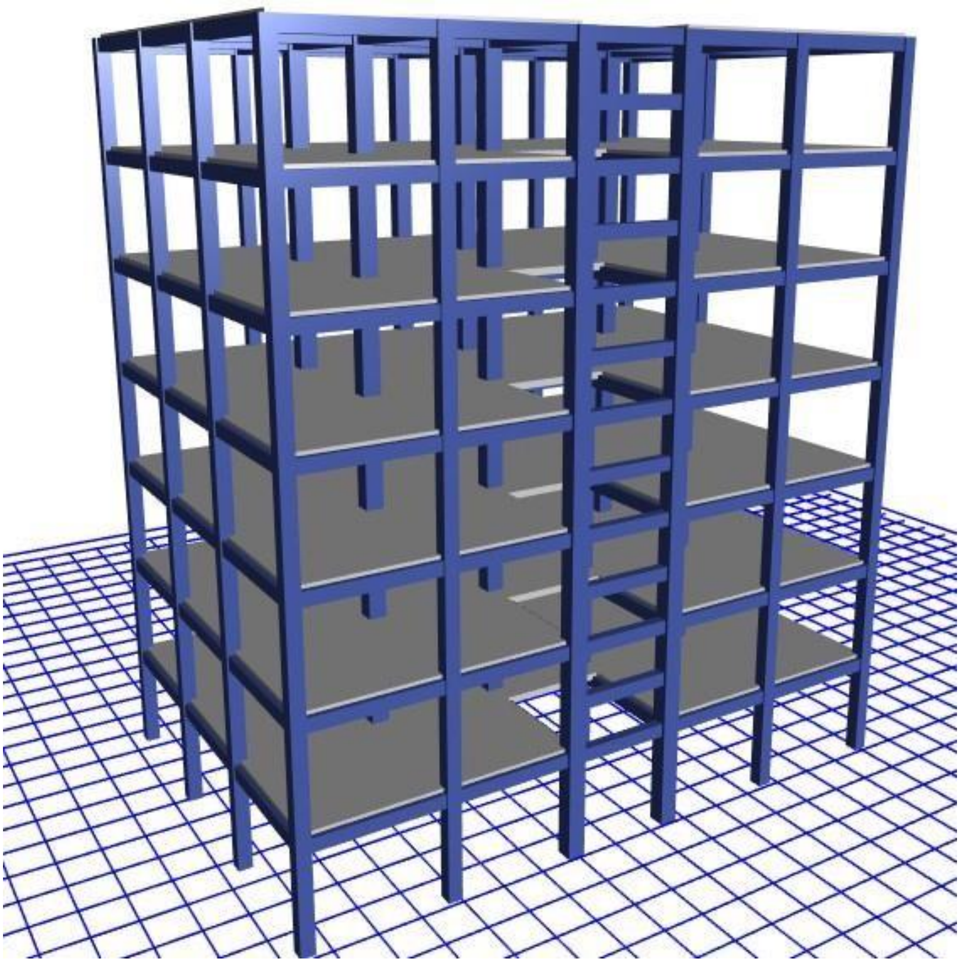


Figure 3.3: Render view of the Beam Supported slab

3.2.3 Render View of Flat Slab

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

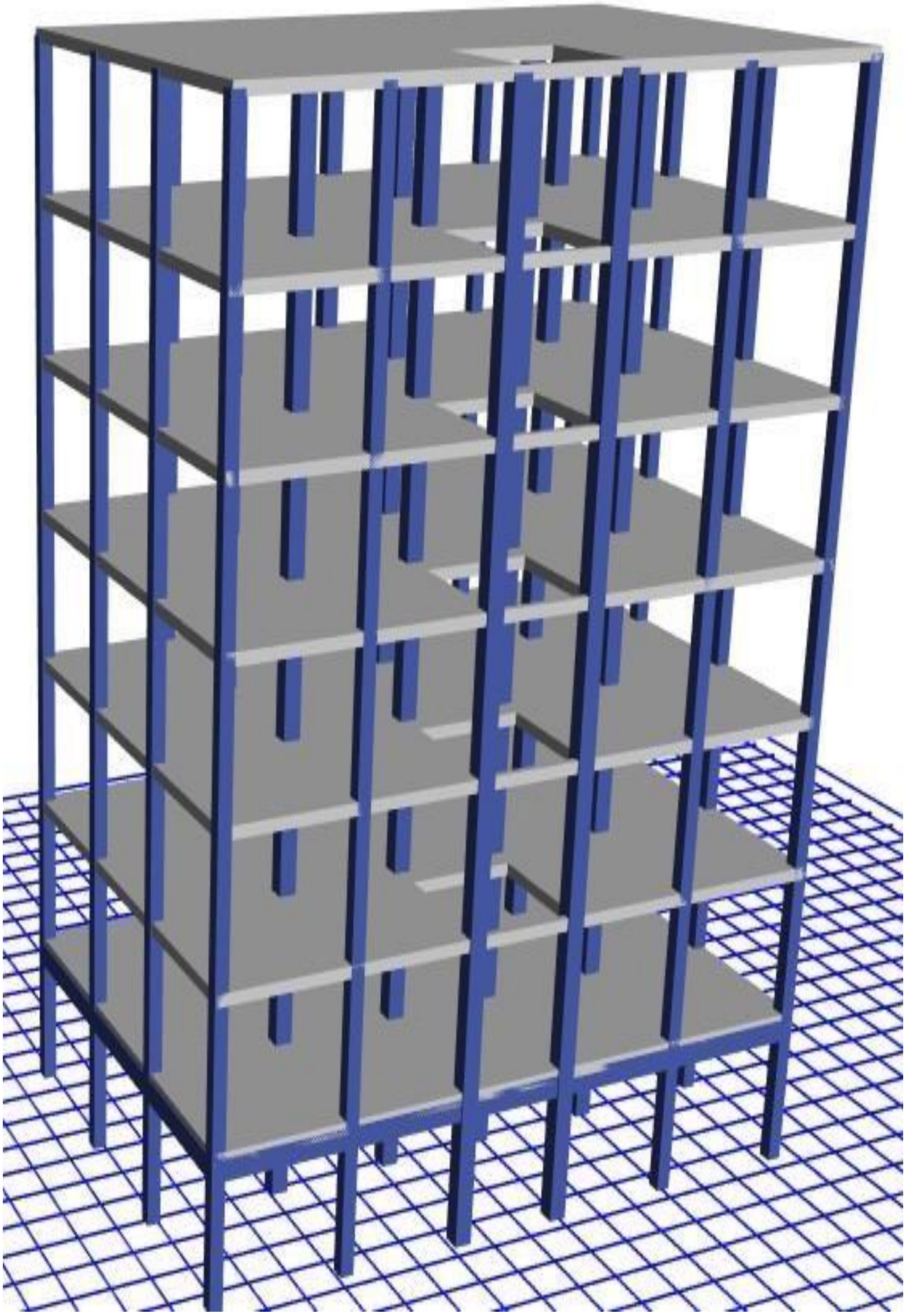


Figure 3.4: Render view of flat slab

3.2.4 G+11 Story Building

The render view of G+6 story buildings with Beam Supported slab and flat slab have been snapshotted to preview in this section.

3.2.5 Render View of Beam Supported Slab

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

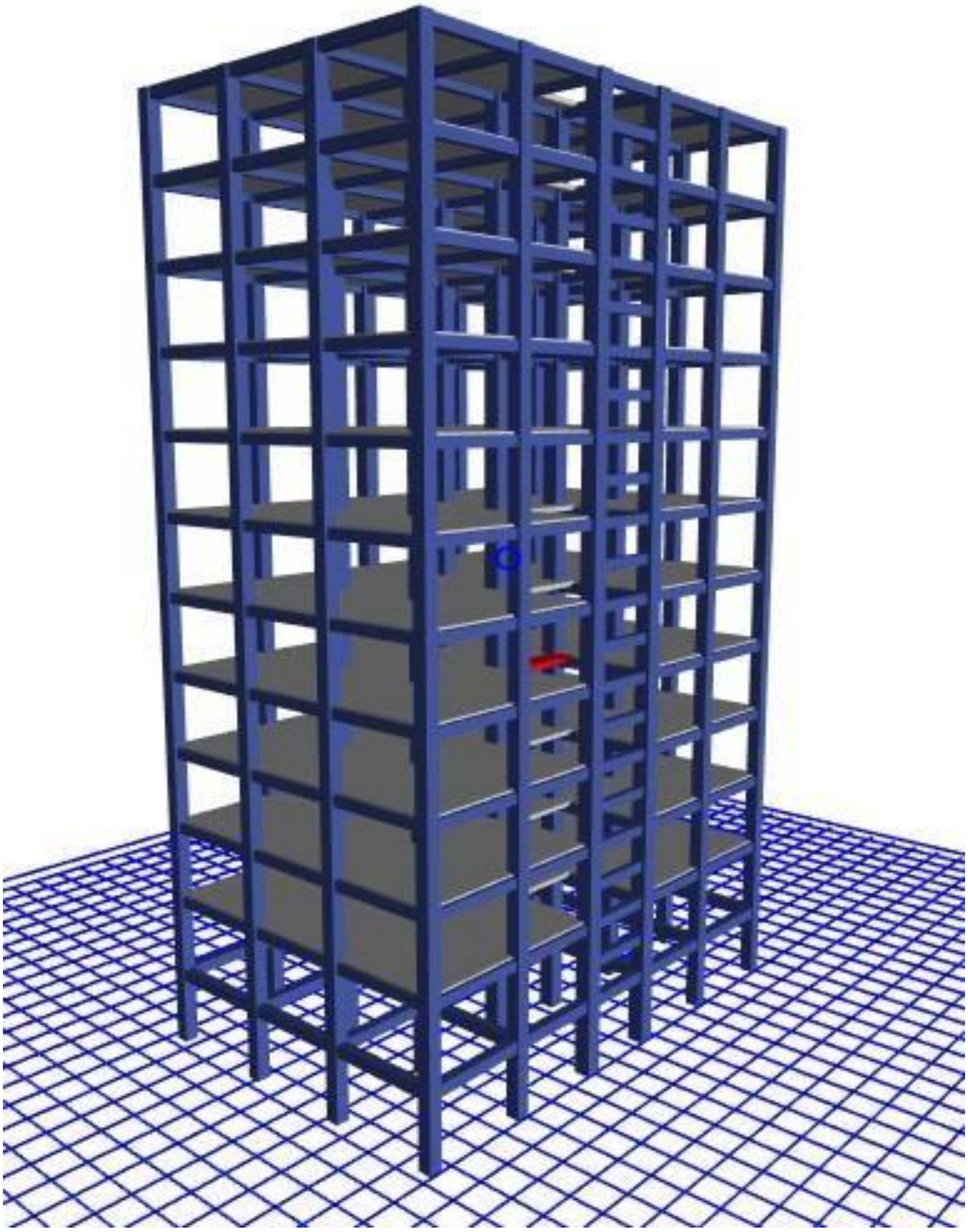


Figure 3.5 Render view of Beam Supported slab

3.2.6 Render View of Flat Slab

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

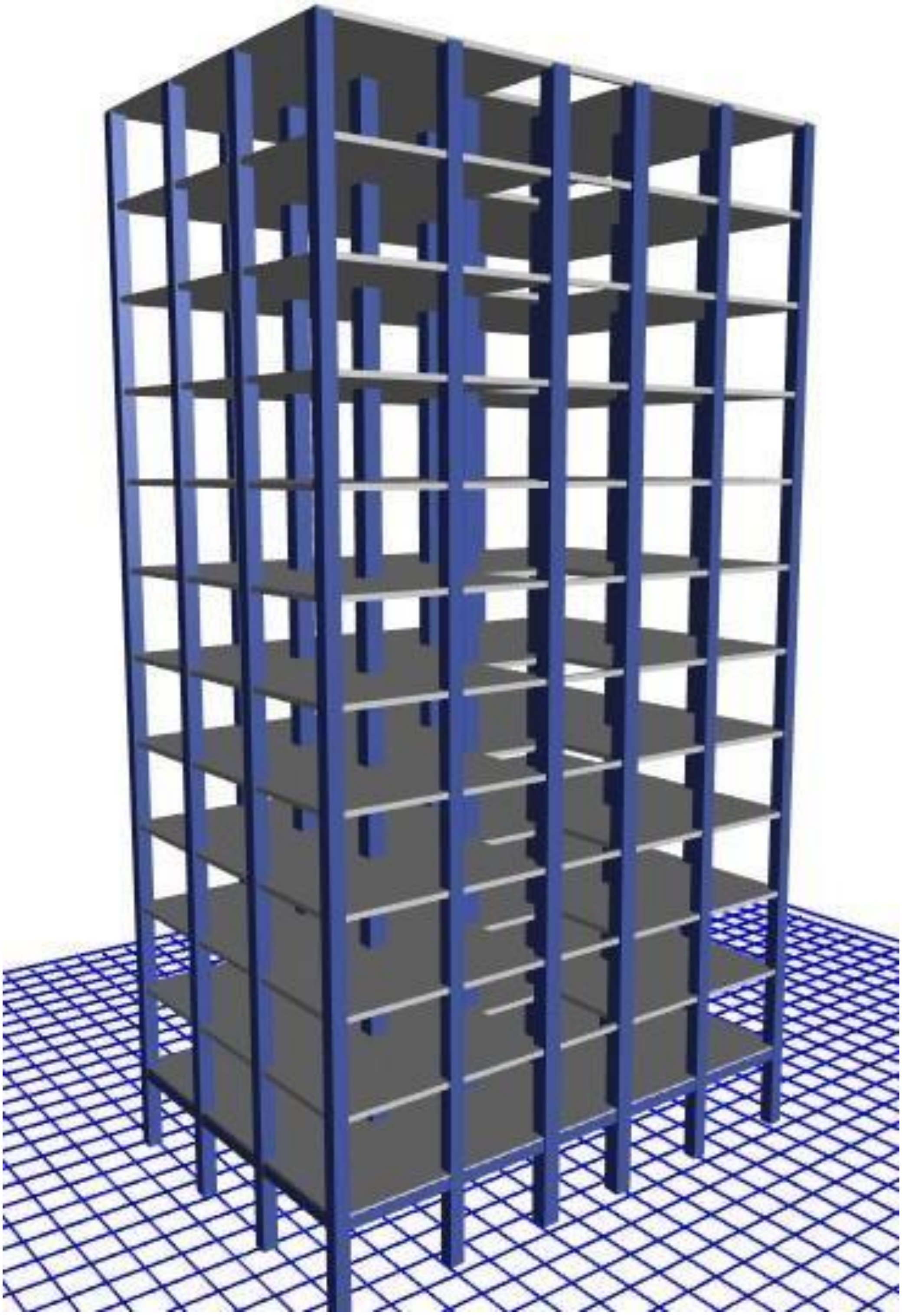


Figure 3.6 Render view of flat slab

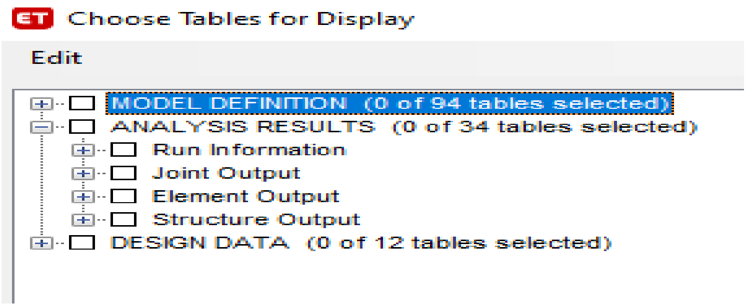
3.2.7 Analysis of Modeling

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 2020 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 of the buildings is recorded at each incremental load.

3.3 Procedure of Analysis by ETABS 18.1.0

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

1. A model is created just like for any other analysis.
2. RC concrete structure is considered for the study having G+6 and G+11stories of height 70’ and120’ each floor is considered as 10’ height.
3. The regular concrete moment resisting frame of square plan is considered as 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 are defined 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 steel or 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 the BNBC code.



3.3.1 Analysis Types

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

3.3.2 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 structure can 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., and '2' for Y dir.

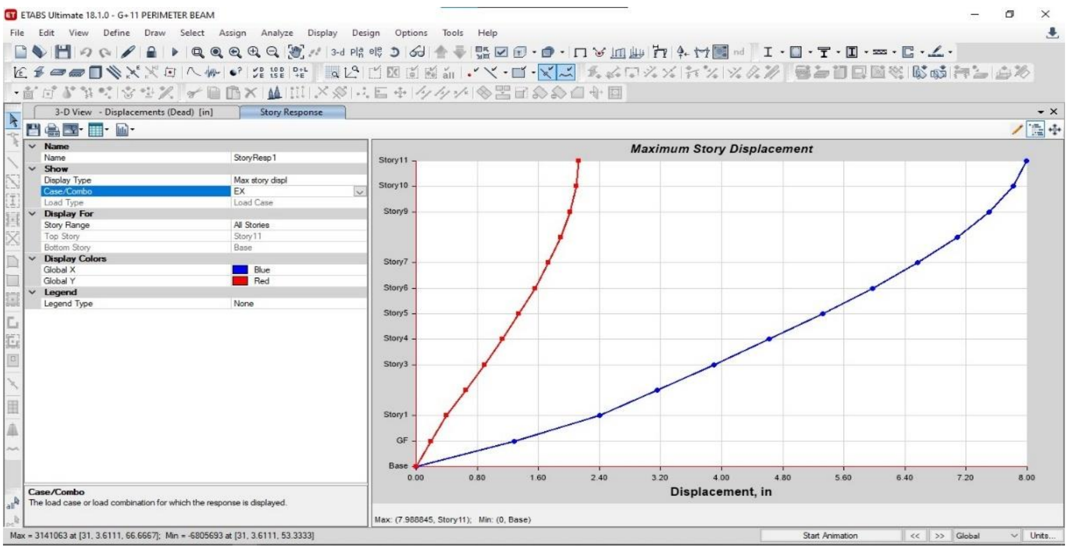


Figure 3.7: Story Displacement

3.3.3 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 18.1.0 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 18.1.0 software.

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

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

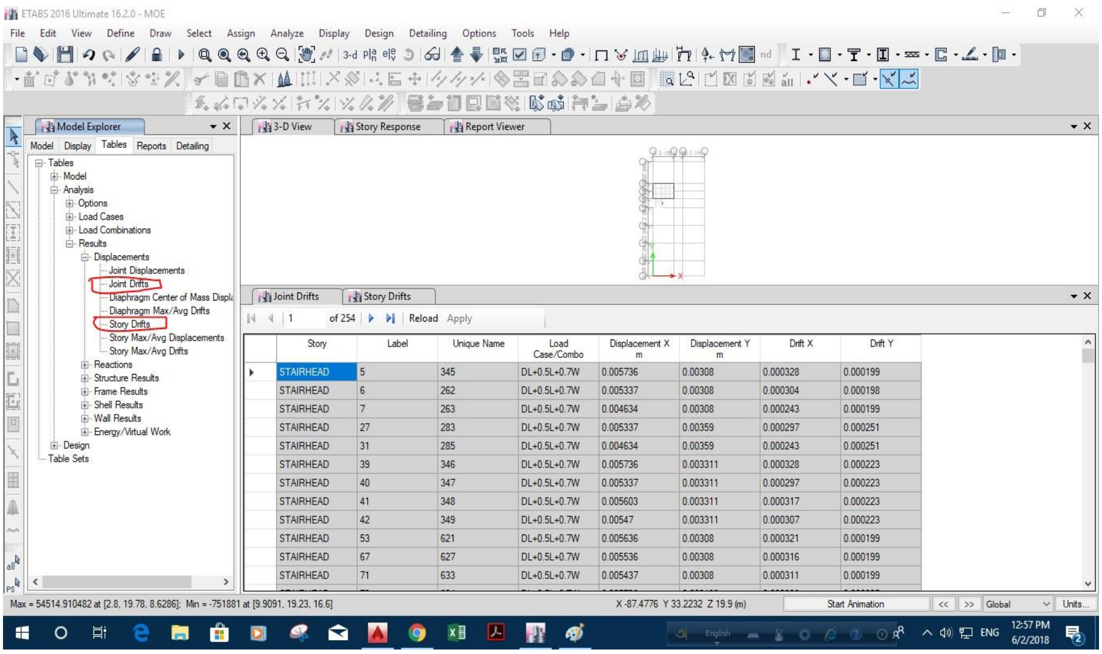


Figure 3.8: Story Drift

3.3.4 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**.

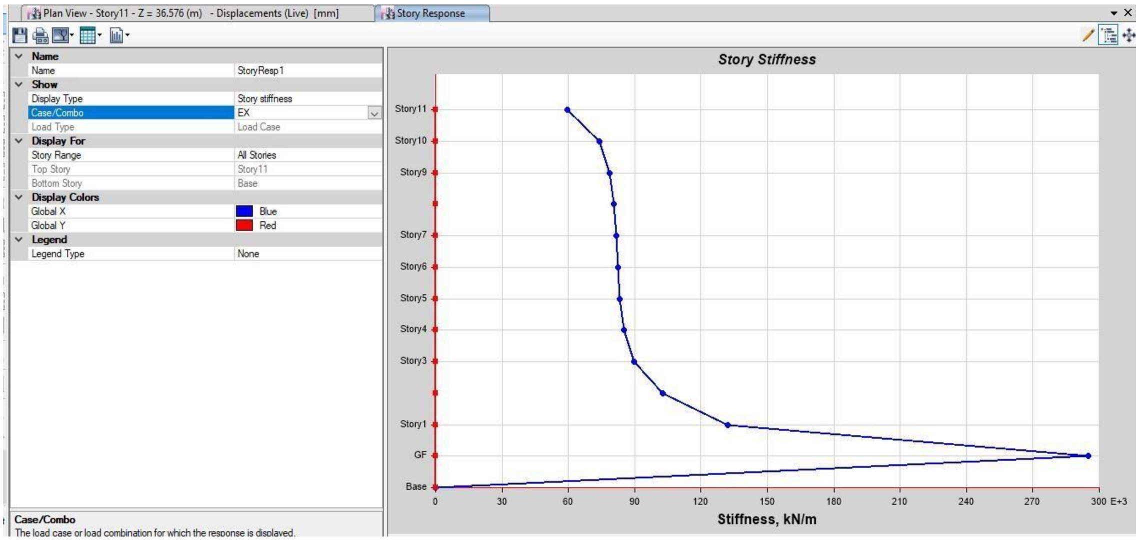


Figure 3.9 Story Stiffness

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.

3.3.5 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 RC structure are analyzed by ETABS 18.1.0. In this chapter two 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 and G+11 story Residential building was analyzed by ETABS 18.1.0. Comparison of the variation of analysis result like as story displacement, story drift and stiffness are discussed in this section. After analyzing all 6- structures in the ETABS 18.1.0, the constrains are 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)
Story6	43.659	139.357
Story5	41.238	127.564
Story4	37.031	109.846
Story3	31.288	86.077
Story2	24.328	58.027
Story1	16.428	30.024
GF	7.706	9.883

The **Table 4.1** indicated that the Story displacement of Beam Supported slab is less than the flat slab. The story displacement of flat slab indicated the maximum displacement at top story than the Beam Supported slab i.e., Flat slab > Beam Supported slab.

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

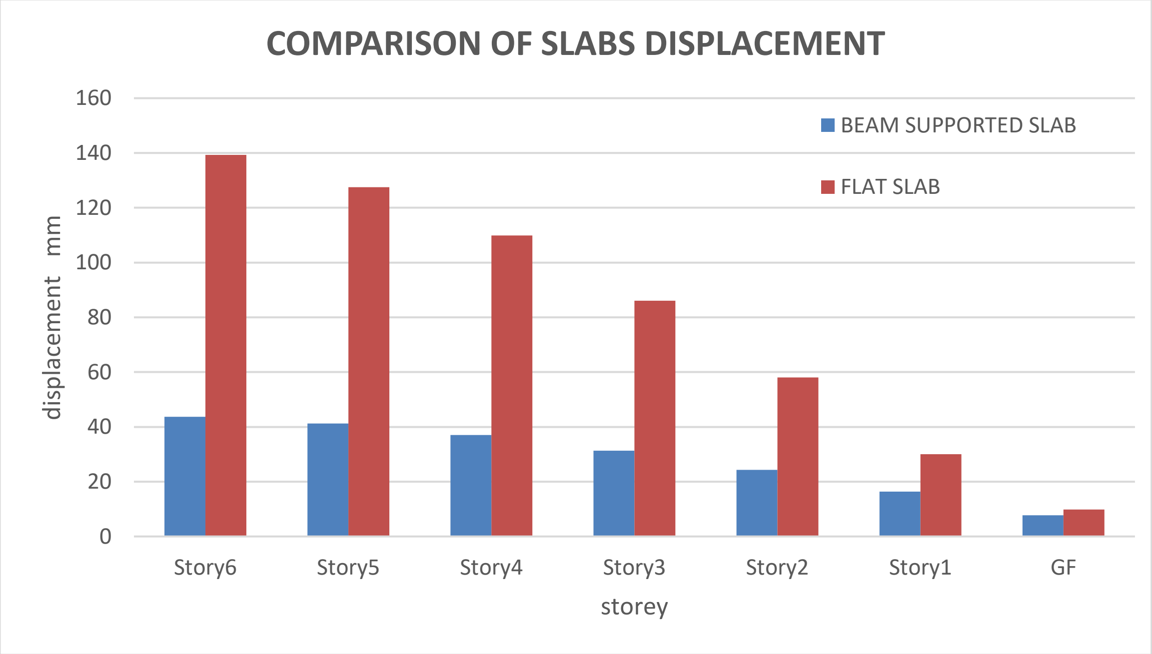


Figure 4.1: The Story displacement vs story number

The maximum story displacement of Beam Supported slab is 31% of flat slab. 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	BEAM SUPPORTED SLAB	FLAT SLAB
Story6	0.000794	0.003869
Story5	0.00138	0.005813
Story4	0.001884	0.007798
Story3	0.002283	0.009203
Story2	0.002592	0.009346
Story1	0.003027	0.007022
GF	0.002528	0.003239
Base	0	0

In the **Table 4.2** indicated the comparison of story drift of different slab supported building. Since the displacement of flat slab is maximum than Beam Supported slab building so the story drift of flat slab is maximum. Beam Supported slab is more stable than flat slab.

In this **Figure 4.2** indicated the comparative story drift of different slab supported building. Story drifts are maximum in the middle stories. That means columns are stiffer in bottom and top stories and weaker in the midlevel of the structure. The story drift is maximum in flat slab and less in Beam Supported slab supported building. The maximum story drift of Beam Supported slab is 28% of flat slab.

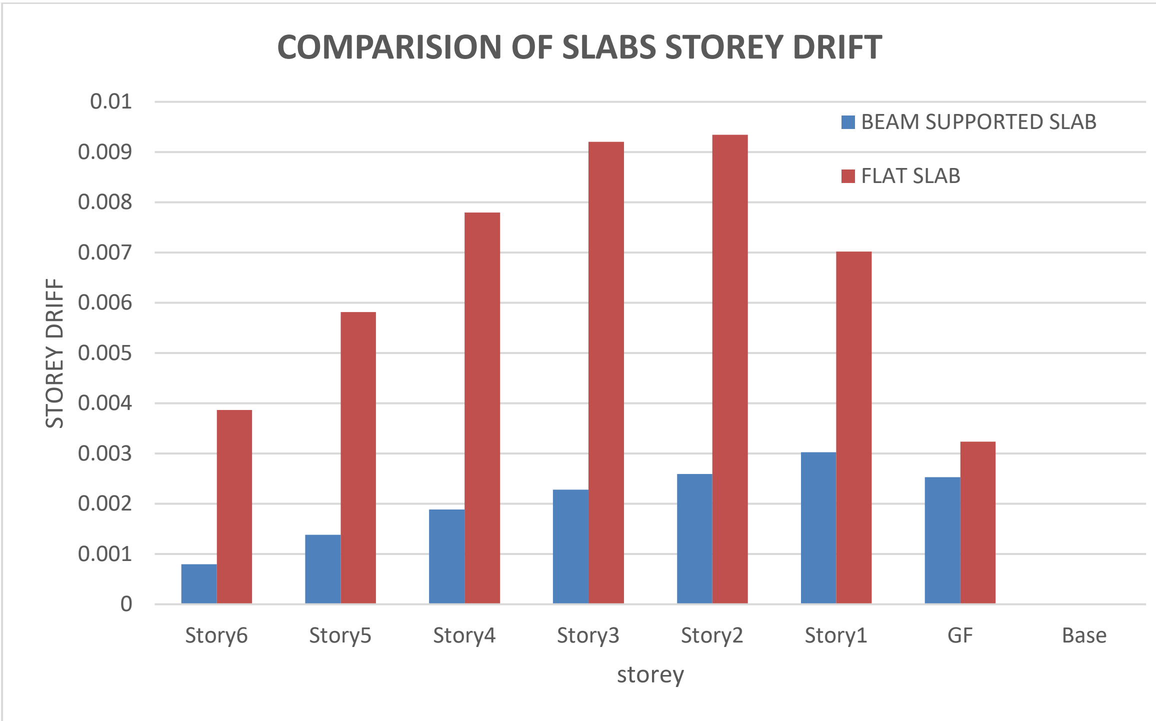


Figure 4.2: The Story drift vs story number

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)
Story6	186223.887	33408.127
Story5	222167.025	45621.769
Story4	236096.572	48576.797
Story3	244185.648	50981.466
Story2	244428.953	57248.536
Story1	226166.69	84501.009
GF	280156.236	200292.459
Base	0	0

In this **Table 4.3** indicated the story stiffness of different slab supported structure with the 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 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 building. As the story no decreases stiffness goes on increasing. The maximum story stiffness of flat slab is 72% of Beam Supported slab or 28% less than Beam Supported slab. **Figure 4.3** indicated the comparative maximum story stiffness of G+6 story with load EX in X direction.

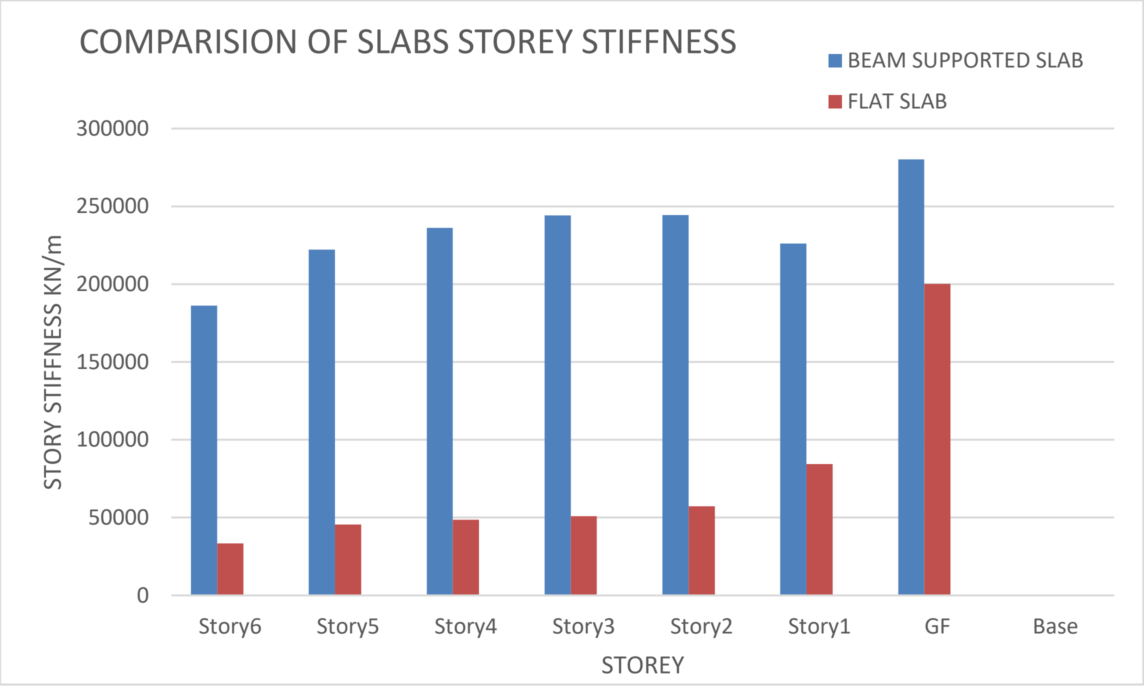


Figure 4.3: The Story stiffness vs story number

The Story stiffness of Beam Supported slab is more than the flat slab.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. 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 Supported slab it shows more stiffness than flat slab.

STORY	BEAM SUPPORTED SLAB(KN/m)	FLAT SLAB (KN/m)
Story6	168142.821	31237.945
Story5	213799.877	43994.789
Story4	231082.637	47740.161
Story3	240218.29	50609.865
Story2	239830.225	57510.406
Story1	226887.341	87206.507
GF	282517.818	198189.288
Base	0	0

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 compared for this parameter Story stiffness of Beam Supported slab building is stiffer than Flat slab 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.

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. 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. 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 Supported slab it shows more stiffness than flat slab. Beam Supported slab which can resist more lateral load than the flat slab.

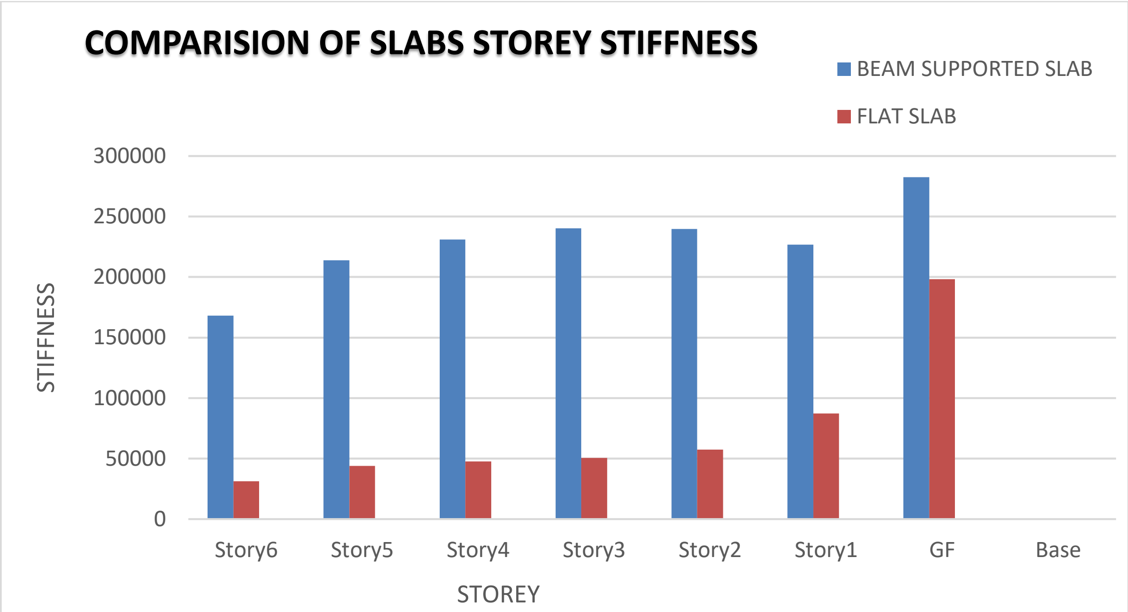


Figure 4.4: The Story stiffness vs story number

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. 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. i.e., flat slab > Beam Supported slab. The maximum story displacement of Beam Supported slab is 34% of flat slab or 66% less than flat slab.

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

STORY	BEAM SUPPORTED SLAB	FLAT SLAB
Story11	136.507	400.663
Story10	132.174	386.338
Story9	125.86	366.391
Story8	117.745	340.272
Story7	108.026	308.297
Story6	96.903	271.052
Story5	84.579	229.264
Story4	71.262	183.807
Story3	57.162	135.873
Story2	42.496	87.473
Story1	27.491	43.368
GF	12.583	13.819
Base	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.

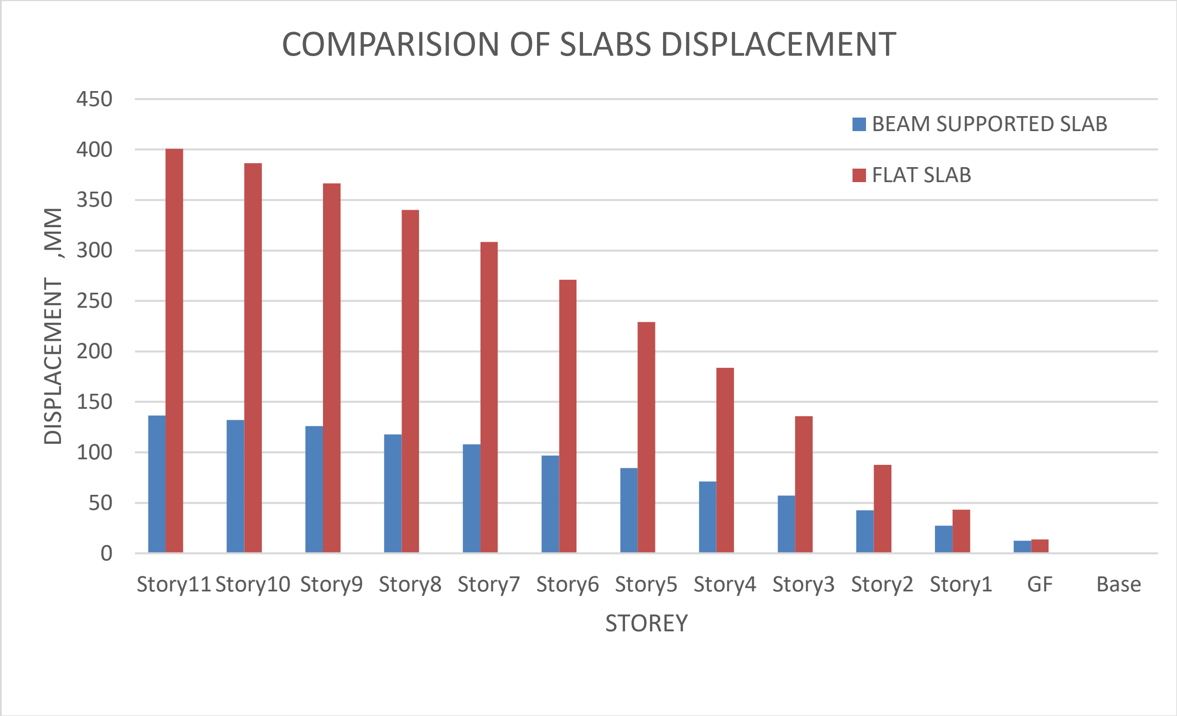


Figure 4.5: The Story displacement vs story number

The story displacement of flat slab indicated the maximum displacement at top story than the Beam Supported slab. Since the beam is used in Beam Supported slab this slab can resist more lateral load than flat slab showing more displacement because of column supported 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 shown in **Table 4.6**. **Table 4.6** indicated the comparison of story drift of different slab supported building. Since the displacement of flat slab and Beam Supported slab building so the story drift of flat slab is maximum.

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

STORY	BEAM SUPPORTED SLAB	FLAT SLAB
Story11	0.001421	0.0047
Story10	0.002071	0.006544
Story9	0.002662	0.008569
Story8	0.003189	0.01049
Story7	0.003649	0.01222
Story6	0.004043	0.01371
Story5	0.004369	0.014913
Story4	0.004626	0.015727
Story3	0.004812	0.015879
Story2	0.004923	0.014621
Story1	0.004891	0.010286
GF	0.004128	0.004529
Base	0	0

Beam Supported slab is more stable than Flat slab. 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 or 70% less than the flat slab.

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

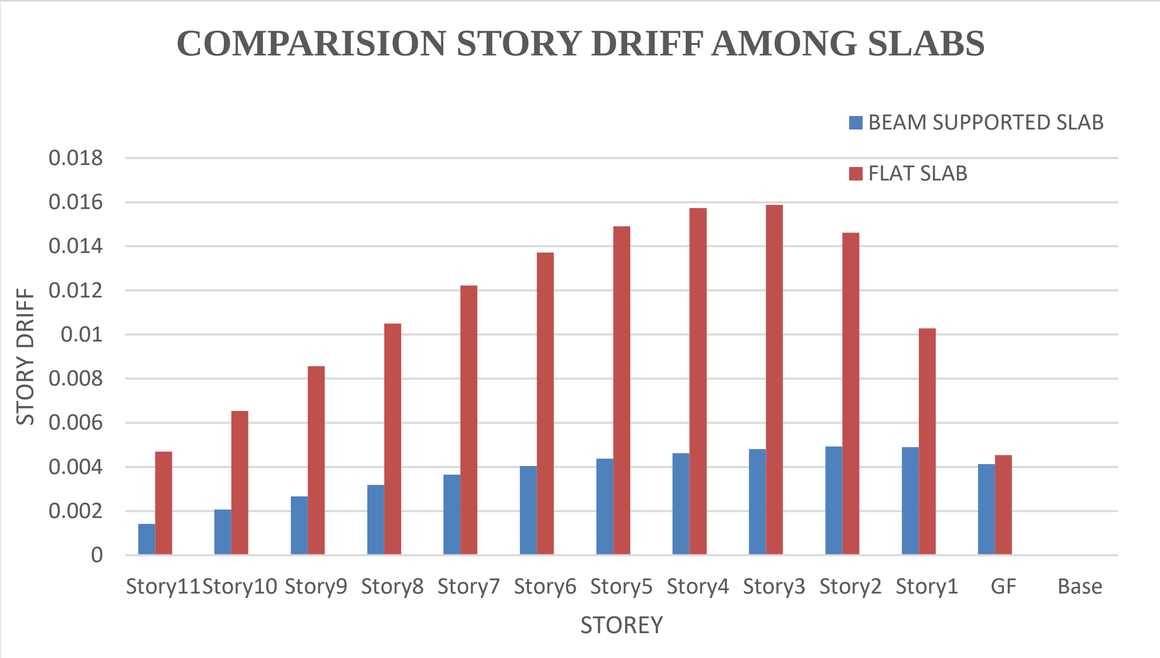


Figure 4.6: Story drift vs Story number

In X direction from this **Figure 4.6**, we see that middle stories indicated the maximum story drift 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. Beam Supported slab is more stable than Flat slab.

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 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 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.

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

STORY	BEAM SUPPORTED SLAB (KN/m)	FLAT SLAB (KN/m)
Story11	142091.486	34404.847
Story10	160923.333	41726.411
Story9	170282.305	43756.146
Story8	176047.218	44560.713
Story7	180111.571	45000.925
Story6	183316.854	45360.937
Story5	186095.836	45806.666
Story4	188706.381	46617.477
Story3	191361.879	48561.415
Story2	194325.082	54477.853
Story1	200648.316	80758.289
GF	237666.556	195065.477
Base	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. The stiffness is higher at GF compare to the upper floor.

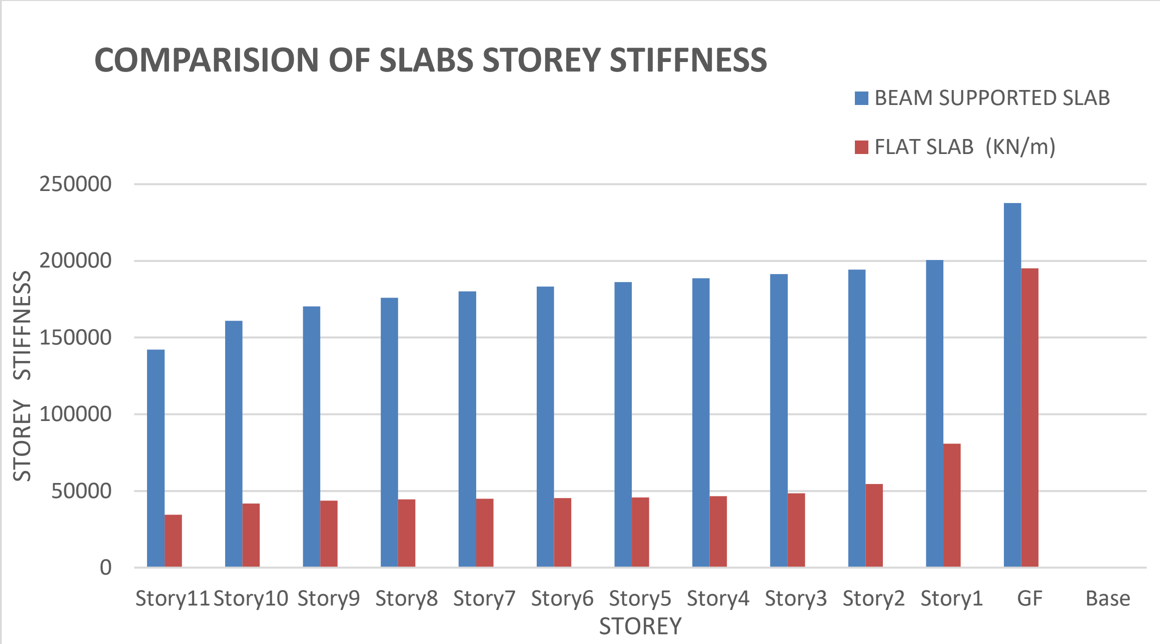


Figure 4.7: Comparative Story stiffness of G+11

The story stiffness of Beam Supported slab is maximum compare to the other type of slab. i.e., Beam Supported slab>flat slab. The story stiffness of flat slab is 24% of Beam Supported slab at top story and 81% at GF. 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. Beam Supported slab which can resist more lateral load than the flat slab.

STORY	BEAM SUPPORTED SLAB (KN/m)	FLAT SLAB (KN/m)
Story11	142091.486	34404.847
Story10	160923.333	41726.411
Story9	170282.305	43756.146
Story8	176047.218	44560.713
Story7	180111.571	45000.925
Story6	183316.854	45360.937
Story5	186095.836	45806.666
Story4	188706.381	46617.477
Story3	191361.879	48561.415
Story2	194325.082	54477.853
Story1	200648.316	80758.289
GF	237666.556	195065.477
Base	0	0

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. The maximum story stiffness of flat slab is 82% of Beam Supported slab or 18% less than Beam Supported slab.

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

Figure 4.8 represent the comparative story stiffness of different slab system with a lateral load WX in X direction.

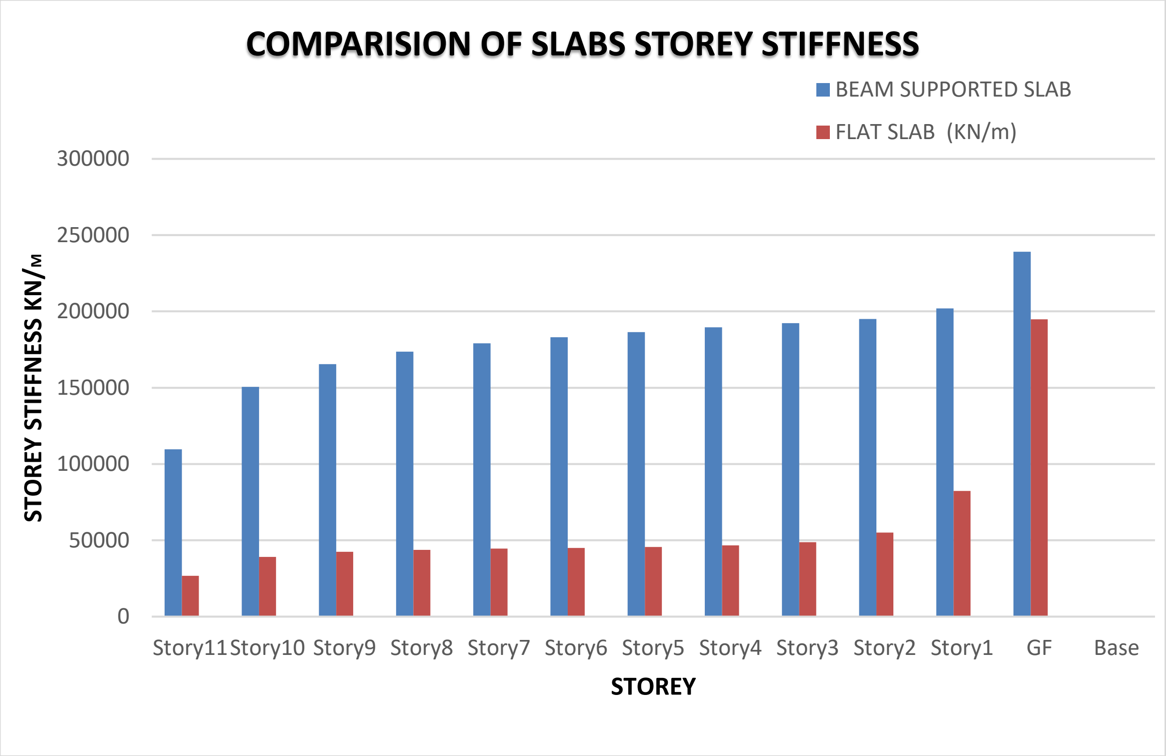


Figure 4.8: Story stiffness vs Story number

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 Supported slab it shows more stiffness than flat slab. Beam Supported slab which can resist more lateral load than the flat slab.

Discussions

The displacement of the flat slab is more than the Beam Supported 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 using a flat slab system are larger than in the Beam Supported slab and flat slab. The Beam Supported slab structure has a greater stiffness than flat slab structure. As a result of this, additional moments are developed. Therefore, the columns of such buildings should be designed by considering additional moments 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 for G+6 story and two times than Beam Supported slab and one-half times than flat slab for 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 for G+6 story.

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

CHAPTER V

CONCLUSION AND RECOMMENDATION

The main objective of this thesis is to analyze G+6 and G+11 story residential building by ETABS 18.1.0 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.

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 G+6 Story

Conclusions derived from these studies for G+6 story buildings are showed below:

1. The maximum story displacement of Beam Supported slab is 31% of flat slab Story displacement is more at top story and less at base of the structure. Displacement also increases with the increase in building height.

2. The story drift is maximum in flat slab and less in Beam Supported slab supported building. The maximum story drift of Beam Supported slab is 28% of flat slab.

3. The maximum story stiffness of flat slab is 70% of Beam Supported slab or 30% less than Beam Supported slab at GF.

5.2.2 G+11 Story

Conclusions derived from these studies for G+11 story buildings are showed below:

1. The maximum story displacement of Beam Supported slab is 34% of the flat slab or 66% less than the flat slab and 83% of the flat slab.

2. The maximum story drift of Beam Supported slab is 30% of flat slab or 70% less than the flat slab.

3. The maximum story stiffness of flat slab is 78% of the Beam Supported slab or 22% less than the Beam Supported slab at GF.

The story displacement and drift in the building using a flat slab system are larger than the Beam Supported slabs. The Beam Supported slab structure has a greater stiffness than flat slab structure. As a result of this, the Beam Supported slab is more significant than flat slab.

5.3 Recommendation for Further Study

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

1. This study was done between flat slabs and Beam Supported slab in future flat slab comparison with drop and column capital can also be studied for all seismic zones.

2. This analysis was done using ETABS 18.1.0 software further this could be done using various 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)
ψ	=	Dilation angle
α	=	Angle between the critical shear crack and the soffit of the slab
β	=	Angle between the shear reinforcement and the soffit of the slab

ABBREVIATIONS

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