Comparative study of flat slab and conventional slab in various seismic zones using E-Tabs

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Abstract: In present era, flat slab buildings are commonly used for the construction as it has many advantages over conventional RC frame building in terms of architectural flexibility, use of space, [easier formwork and shorter construction time. In the present work a G+12 multistoried building having flat slab with column head and conventional slab has been analyzed using E-TABS software for the parameters like storey displacement, storey drift, storey shear, base shear and time period. The main objective of the present work is to compare the seismic behavior of multistory buildings having conventional RC frame, flat slab with column head and conventional slab in seismic zone II, III, IV, V and to study the effect of height of building on the performance of these types of buildings under seismic forces. Linear dynamic response spectrum analysis was performed on the structure to get the seismic behavior.

Index Terms- **Conventional RC frame building, flat slab with column head building, Response spectrum analysis, overturning moment, storey drift, base shear, displacement, time period**.

I. INTRODUCTION

Reinforced concrete, or RCC, is concrete that contains embedded steel bars, plates, or fibers that strengthen the material. The capability to carry loads by these materials is magnified, and because of this RCC is used extensively in all construction. In fact, it has become the most commonly utilized construction material. Reinforced materials are embedded in the concrete in such a way that the two materials resist the applied forces together. The compressive strength of concrete and the tensile strength of steel form a strong bond to resist these stresses over a long span. Plain concrete is not suitable for most construction projects because it cannot easily withstand the stresses created by vibrations, wind, or other forces. Concrete consists of a cement and stone aggregate mixture that forms a rigid structure with the addition of water. When steel that has a high tensile strength is embedded in concrete, the composite material withstands compression, bending, and tensile stresses. Such a material can be used for making any size and shape, for utilization in the construction. The main quality of reinforced concrete is similarity of its coefficient of thermal expansion with that of steel, due to which the internal stresses initiated due to variation in thermal expansion or contraction are eliminated. Secondly, on the hardening of the cement paste inside the concrete, it corresponds to the surface features of the steel, allowing the stresses to be efficiently transmitted between the two materials. The cohesive characteristics between the steel and concrete are enhanced by the roughening of steel bars. If moisture is present, then corrosion of steel embedded in the steel reinforced concrete will be an important concern that would require serious attention, since it has extensive financial implications. Damage due to corrosion of rebar may occur in large structures such as residential buildings, bridges, tunnels, due to which these may also become dangerous if appropriate remedial actions are not taken. Therefore, techniques have been developed that can measure the gravity of rebar corrosive effects in the existing structures, and also to foresee their residual life. Measurements are carried out on the rebar, or on embedded rebar probes, and useful information concerning the extent of corrosive damage can be obtained.

Slabs, used in floors and roofs of buildings mostly integrated with the supporting beams, carry the distributed loads primarily by bending. Slabs are constructed to provide flat surfaces, usually horizontal, in building floors, roofs, bridges, and other types of structures. The slab may be supported by walls, by reinforced concrete beams usually cast monolithically with the slab, by structural steel beams, by columns, or by the ground. The depth of a slab is usually very small compared to its span. So Slab is a large, thick, flat piece of stone or concrete, typically square or rectangular in shape structure which transfers live load (varying load or movable loads) and dead Load(structure members loads like walls ,beam, column) ,and many other forces like wind load show load (at terrace).

The flat plate is a two-way reinforced concrete framing system utilizing a slab of uniform thickness, the simplest of structural shapes. The flat slab is a two-way reinforced structural system that includes either drop panels or column capitals at columns to resist heavier loads and thus permit longer spans. Flat slab is a reinforced concrete slab supported directly by concrete columns without the use of beams. Flat slab is defined as one sided or two-sided support system with sheer load of the slab being concentrated on the supporting columns and a square slab called 'drop panels'.

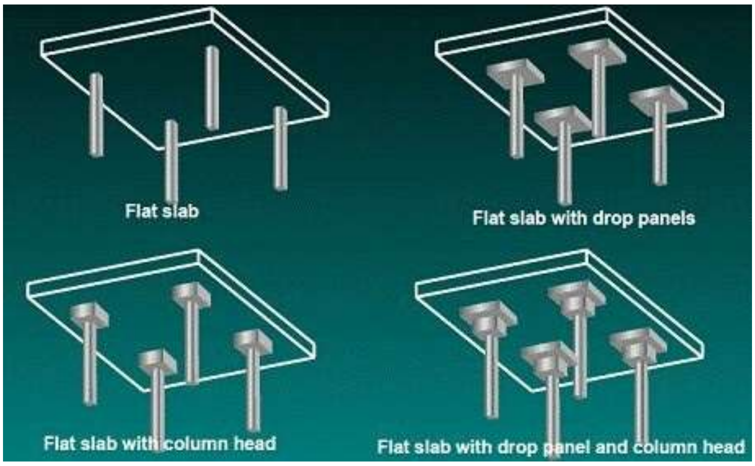

Fig No: - 1.1 Flat slab types

Drop panels play a significant role here as they augment the overall capacity and sturdiness of the flooring system beneath the vertical loads thereby boosting cost effectiveness of the construction. Usually the height of drop panels is about two times the height of slab. Flat Slabs are considered suitable for most of the construction and for asymmetrical column layouts like floors with curved shapes and ramps etc. The advantages of applying flat slabs are many like depth solution, flat soffit and flexibility in design layout. Even though building flat slabs can be an expensive affair but gives immense freedom to architects and engineers the luxury of designing. Benefit of using flat slabs are manifold not only in terms of prospective design and layout efficacy but is also helpful for total construction process especially for easing off installation procedures and saving on construction time. If possible, try to do away with drop panels as much as possible and try to make the best use of thickness of flat slabs. The reason is to permit the benefits of flat soffits for the floor surface to be maintained, ensure drop panels are cast as part of the column.

- **Types of Flat Slab Construction**

1. Simple flat slab
2. Flat slab with drop panels
3. Flat slab with column heads
4. Flat slab with both drop panels and column heads

- **OBJECTIVES**

➢ Objectives for the project work are as follows:

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- To analyze different form of slab arrangement for example conventional slab and flat slab for the given plan area and their comparative study.
- To make analysis of multistoried RCC buildings with flat slab and conventional slab (G+12 storey) having regular geometry, with response spectrum analysis, taking into account earthquake zone II, III, IV, V as per the Indian standard code of practice IS 1893-2002 part -1, criteria for earthquake resistance structure.
- To evaluate the seismic behavior of different regular moment resisting flat slab & conventional slab structure.
- To model different structures with aforementioned configuration and compare them using design aids like ETABS.
- To study comparative costing of various types of slab system.
- To evaluate base shear, overturning moment, storey displacement, storey shear etc.

2. LITERATURE REVIEW

Comparative Study of Post Tensioned and RCC Flat Slab in Multi-Storey Commercial Building, JNANESH REDDY et.al. **June-2017**
In the present study an attempt is made to compare the cost effectiveness of Post- Tensioned flat slab systems with respect to reinforced concrete flat slab system. Both the systems are analyzed using RAPT and ETABS respectively which is based on the design methodology. There are many other benefits of using PT slab. As the thickness of the slab is much lesser than the R.C.C flat slab, aesthetic look of the building may get enhanced leading to a clear height for a longer distance. Hence, using a PT Slab is more advisable for a commercial building than using a R.C.C Flat Slab. Construction of a structure using PT Slab also leads to a lighter structure as the Dead Load gets reduced.

Design Considerations for Reinforced Concrete Flat Slab Floor System, HARSHAL DESHPANDE et.al **December**-2014
The purpose of this paper is to present the use of flat plate/slab construction in India followed by a review of design methods for flat plate/slab structure designs based on Indian Standard 456:2000[1] and American Concrete Institute ACI-318[2]codes. Flat plate/slab can be designed and built either by conventional RCC or post-tensioning, conventional RCC design should be the preferred choice for spans up to 10 meters. Design of conventional RCC flat plate/slab in India, utilizing Indian codes, has many shortcomings, which have to be addressed and revised soon.

Post-Tensioned Building Analysis and Design RAHUL SINGH et.al, **March 2018,** in this paper, the emphasis is to design a post-tensioned building using ETABS and SAFE. . The main purpose of this software is to design multi-storied building in a systematic process which will be in accordance with Indian Standard design codes. This project deals with provision of earthquake and wind resistance structure. Minimum sizes of column and beam provided was C500*500 and B300*500. Seismic analysis was done by using ETABS software. As building is post tensioned one, it proves to be economical.

Comparative Analysis of Flat Slab and Post-Tensioned Flat Slab Using SAFE, V. G. Desai et.al **August-2016,** a study on analysis and behavior of Post-tensioned flat slab is been done in this thesis. Modeling and analysis of flat slab and PT flat slab is done using SAFE. Results are compared with flat slab and PT flat slab with respect to deflection, punching, moment and stresses. The following conclusions are drawn from the present case study.
Deflection for PT flat slab is about 80% to 90% in Case I, 65% to 75% in Case II and 55% to 65% in Case III. The punching shear capacity ratio is within permissible limits for Case I and Case III, whereas it higher than permissible limits for Case II. Positive and negative moments in case of PT flat slab are less, i.e. About 75% to 85% in Case I, 60% to 70% in Case II and 50% to 60% in Case III. Stresses in case of PT flat slab are within the permissible values as per guidelines provided by IS: 1343-1980. In case of PT flat slab Case I –A, Case II – B and Case II –C have given better results with respect to deflection, punching, moment and stresses compared to flat slab. In all the Cases, PT flat slabs are economical and cost effective than flat slab. In Case II –A there was no much difference in cost. Case II -B proves to be more economical than other cases. About 7% to 8.5 % of cost saving could be observed for PT flat slab in Case III by reducing thickness of slab and drop.

Flat Slab Construction in India, S.S. Patel et.al **April-2014**, the objective of this paper is to present the use of flat plate/slab construction in India. The applications in buildings followed by a comparative description of flat plate/slab structure designs based on Indian Standard 456:2000[1] and American Concrete Institute ACI-318[2] codes. In practical it was observed that the PT structure doesn't reduce thickness of slab and also doesn't reduce in the cost of structure. Due to issues related with pt construction in India and its higher cost, conventional RCC should be the preferred choice for spans up to 10 meters. Design of conventional RCC flat plate/slab in India, utilizing Indian codes, has many shortcomings, which will be addressed and revised soon.

Analysis of Post-Tensioned Flat Slab by using SAFE, S. MALVADE et.al **March-2017,** the main objective of this paper is to give a review on the response and behavioral properties of Post tensioned flat slab during earthquake and compare with normal flat slab. A study on analysis and behavior Of Post-tensioned flat slab is been done in this thesis. Modeling and analysis of flat slab and PT flat slab is done using SAFE. Stretching one cable produces secondary moment and hence strip moments in both direction changes drastically. Hyper static moments are affecting during the construction stage. In stage wise construction hyper static moments play important role. In the flat plate varying eccentricity is not very much possible due to small thickness of slab but force can be worked out for new moments. Due to post-tensioning of flat plates slab there is no much effect on axial force but shear and moment on column increases.

Study of Flat Slab, K.N.MATE et.al **2015,** this study present a complete detail procedure of analysis and design of flat slab structure with is 456:2000. Flat slab gives the advantage over beam slab structure. This slab increases efficiency of structure and requires less construction cost as compared to beam slab construction. This paper gives the guideline for selection of drop, panel width, slab thickness and gives the reinforcement details.

Use of flat slabs in multi-storey commercial building situated in high seismic zone, NAVYASHREE et.al **2013,** in the present work six number of conventional RC frame and Flat Slab buildings of G+3, G+8, and G+12 storey building models were considered. The performance of flat slab and the vulnerability of purely frame and purely flat slab models under different load conditions are studied and analyzed considering seismic zone IV. The analysis is done with using E-Tabs software. After second level moments decreases and increases at the top storey. The column behavior changes as height of the building increases. The columns have been designed for the combination of dead load and earthquake load for all cases and the load combination 1.5 [DL ± EX] is the most critical. The column moments are more in flat plate compared to conventional R.C.C building. Column moments in flat plate vary from 10 to 20 (%) as compared to that of conventional R.C.C frames depending upon the storey. The base shears is Maximum at plinth level for all types of column. After plinth level the base shear decreases as the height of the building increases. The base shear will increase drastically as the height increases. Base shear of flat plate building is less than the conventional R.C.C building. The difference between the two varies from 8-13(%). The lateral displacement is Maximum at terrace level for all types of column. Lateral displacement increases as the storey level increases. The lateral displacement will increase drastically as the height increases. Lateral displacement of conventional R.C.C building is less than the flat plate building. The difference between the two varies from 28-57(%). The natural time period increases as the height increases (No of stories). In comparison of the conventional R.C.C building and flat slab building, the time period is more for flat slab building than conventional building. The difference between the two varies from 14-33(%).

Analysis and Design of Flat Slab and Grid Slab and Their Cost Comparison, AMIT A. SATHAWANE et.al **August-2016,** the main objective of this paper is to determine the most economical slab between flat slab with drop, Flat slab without drop and grid slab. The proposed construction site is Nexus point apposite to VIDHAN- BHAVAN and beside NMC office, Nagpur. The total length of slab is 31.38 m and width is 27.22 m and total area of slab is 854.16 m2. It is designed by using M35 Grade concrete and Fe 415 steel.

- **METHODOLOGY**

To carry a relevant literature review by going through journal papers conference proceedings, text/reference books, standard handbooks etc.

Dynamic analysis shall be performed to obtain the design seismic force, and its distribution in different levels along the height of the building and in the various lateral loads resisting element.

Modeling in E-Tabs and Assigning of various properties

Analysis of both types of Structures under seismic zones

Discussion and Result

- **METHODS OF ANALYSIS**

The analysis can be performed on the basis of external action, the behavior of structure or structural materials, and the type of structural model selected. Based on the type of external action and behavior of structure, the analysis can be further classified as.

- **Equivalent static analysis:**

All design against seismic loads must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings. This procedure does not require dynamic analysis, however, it account for the dynamics of building in an approximate manner. The static method is the simplest one-it requires less computational efforts and is based on formulate given in the code of practice. First, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The lateral forces at each floor levels thus obtained are distributed to individual's lateral load resisting elements.

- **Response spectrum method**

In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions.

This chapter deals with response spectrum method and its application to various types of the structures. The codal provisions as per IS: 1893 (Part 1)-2002 code for response spectrum analysis of multi-storey building is also summarized.

Response spectra are curves plotted between maximum response of SDOF system subjected to specified earthquake ground motion and its time period (or frequency). Response spectrum can be interpreted as the locus of maximum response of a SDOF system for given damping ratio. Response spectra thus helps in obtaining the peak structural responses under linear range, which can be used for obtaining lateral forces developed in structure due to earthquake thus facilitates in earthquake-resistant design of structures.

Usually response of a SDOF system is determined by time domain or frequency domain analysis, and for a given time period of system, maximum response is picked. This process is continued for all range of possible time periods of SDOF system. Final plot with system time period on x-axis and response quantity on y-axis is the required response spectra pertaining to specified damping ratio and input ground motion. Same process is carried out with different damping ratios to obtain overall response spectra.

3. ANALYTICAL DATA OF BUILDING

Table 3.1: Material Properties and Geometric Parameters

Sr. No.	Design Parameter	Value
1	Characteristic strength of concrete	M30
2	Characteristic strength of steel	Fe-500
3	Modulus of elasticity of steel	200 Gpa

4	Plan area	30x30m
5	Slab thickness of Flat Slab	150mm
6	Slab thickness of Conventional Slab	125mm
7	Drop thickness	200x200mm
8	Floor height	3.2m

Table 3.2: Load Considered For Analysis of Building

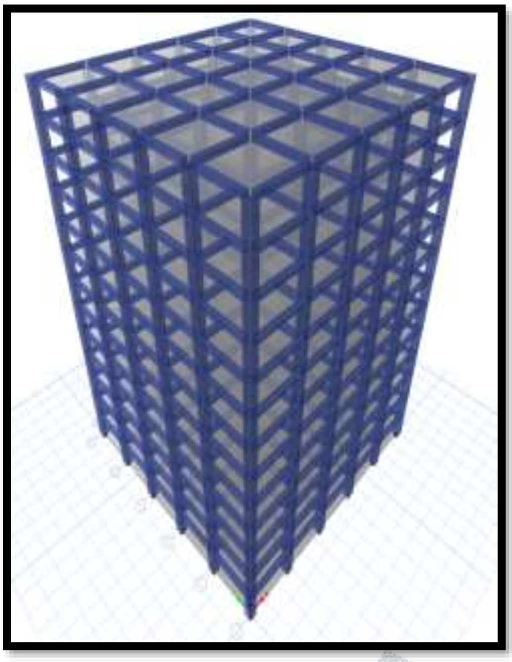
Sr.No.	Load Type	Value
1	Self-weight of Slab and Column	As per Dimension and Unit weight of concrete
2	Dead load of structural components	As per IS 875 Part-1
3	Live Load	As per IS 875 Part -2
4	Live load : on Roof and Typical floor	3.0 kN/m^2
5	Floor Finish	1.0 kN/m^2

Table 3.3: Seismic Design Data

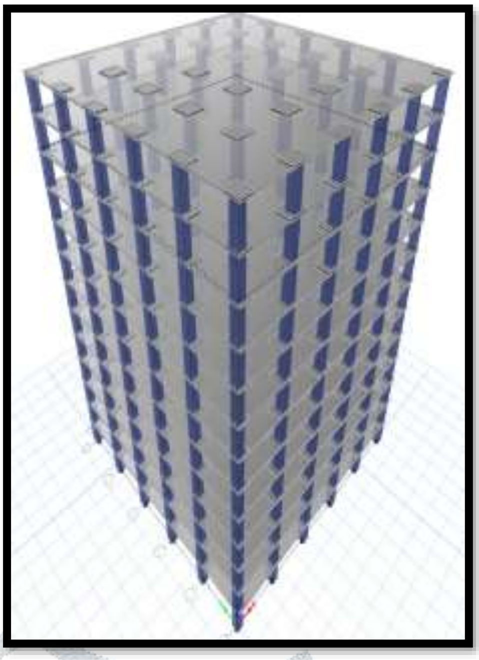
Sr.No.	Design Parameter	Value
1	Type Of Foundation	Isolated
2	Type Of Soil	Medium
3	Seismic Zone	II, III, IV, V
4	Zone factor (Z)	0.10, 0.16, 0.24, 0.36
5	Response reduction factor (R)	5
6	Importance Factor	1

Table 3.4: Cross Sectional Dimension for Column and Beam

Sr. no.	**Type of structure**	**Size**
1.	Column size	800x800mm
2.	Beam size	500x500mm



Conventional slab system



Flat slab system

4. RESULTS

In the present study a RCC Multistoried buildings of G + 12 heights subjected to the earthquake load imposed in the all four zone i.e. Zone II, Zone III, Zone IV and Zone V. To design the components of the flat slab multistory building, after the literature survey, to make the building more economical, the different parameters should be checked as per the selection of different model cases:

Table No: - 4.1 Model Nomenclatures

Sr. No.	Building Descriptions	Seismic Zone	Model Nomenclatures
1	Flat Slab Building	II	M11
2	Flat Slab Building	III	M12
3	Flat Slab Building	IV	M13
4	Flat Slab Building	V	M14
5	Conventional Building	II	M21
6	Conventional Building	III	M22
7	Conventional Building	IV	M23
8	Conventional Building	V	M24

Table 4.2: Material Properties and Geometric Parameters – Flat Slab

Sr. No.	Design Parameter	Value
1	Unit weight of concrete	25 KN/m^3
2	Characteristic strength of concrete	30 MPA
3	Characteristic strength of steel	500 MPA
4	Modulus of elasticity of steel	2×10^5 MPA
5	Plan area	900 M^2
6	Slab thickness	150 mm
7	Drop thickness	200 x 200 mm
8	Depth of foundation	3.5 m
9	Floor height	3.2 m

Table 4.3: Preliminary Data for the Conventional Slab

1	Type Of Structure	Multistoried RCC Moment Resisting Frame
2	Size Of Columns	0.8 X 0.8 M
3	Size Of Beams	0.5 X 0.5 M
5	Live Load	3 KN/M^2
6	Floor Finish Load	1 KN/M^2
7	Thickness Of Slab	125 MM
8	Specific Weight Of RCC	25 KN/M^3
9	Zone	II, III, IV, V
10	Type Of Soil	Soil Medium II
11	Response Reduction Factor	5
12	Importance Factor	1
13	Zone Factor	0.10, 0.16, 0.24, 0.36

Table 4.4: Load Considered For Analysis of Building

Sr. No.	Load Type	Value
1	Self-weight of Slab and Column	As per Dimension and Unit weight of concrete
2	Dead load of structural components	As per IS 875 Part-1
3	Live Load	As per IS 875 Part -2
4	Live load : on Roof and Typical floor	3KN/M^2
5	Floor Finish	1KN/M^2

- All the selected 8 building models with constant plan aspect ratio and slenderness ratio are analyzed using commercial ETABS 16 software. This chapter presents the analysis result and relevant discussion based on analysis. According to objectives of present study, the results presented here are focused on displacement, force and moments. The horizontal earthquake force shall be assumed to act alone in one lateral direction at a time. The effects due to vertical component of winds are generally small and can be ignored.
- The design of a building has the following stages:
- Physical dimension, Load calculation, Analysis for wind and Member design
  The following loads are considered for the analysis and design of the building:

1. Dead loads
2. Live loads
3. earthquake loads

Table No:-4.5 Tabular Comparison of Joint Displacement

Sr. No.	Building Descriptions	Model Nomenclatures	Joint Displacement MM
1	Flat Slab Building	M11	592.94
2	Flat Slab Building	M12	948.71
3	Flat Slab Building	M13	1423.06
4	Flat Slab Building	M14	2134.60
5	Conventional Building	M21	239.94
6	Conventional Building	M22	383.90
7	Conventional Building	M23	575.85
8	Conventional Building	M24	575.85

Fig No:-4.1Graphical Comparison of joint displacements

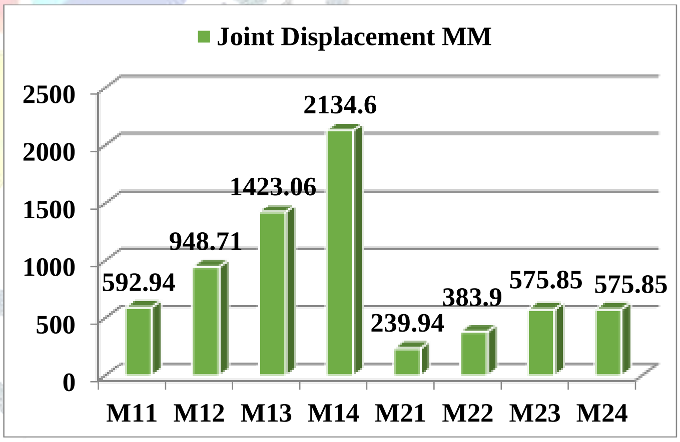


Table No:-4.6 Tabular Comparison of Base Reactions and Moments

Sr. No.	Building Descriptions	Model Nomenclatures	Base Reactions KN	Base Moments KN-M
1	Flat Slab Building	M11	8068.34	209594.29
2	Flat Slab Building	M12	12909.45	335969.88
3	Flat Slab Building	M13	19364.14	503954.00
4	Flat Slab Building	M14	29046.21	755931.00
5	Conventional	M21	19489.69	498992.14

	Building			
6	Conventional Building	M22	31183.50	798387.42
7	Conventional Building	M23	46775.25	1197581.12
8	Conventional Building	M24	46775.25	1197581.12

Fig No:-4.2 Graphical Comparison of Base Moments

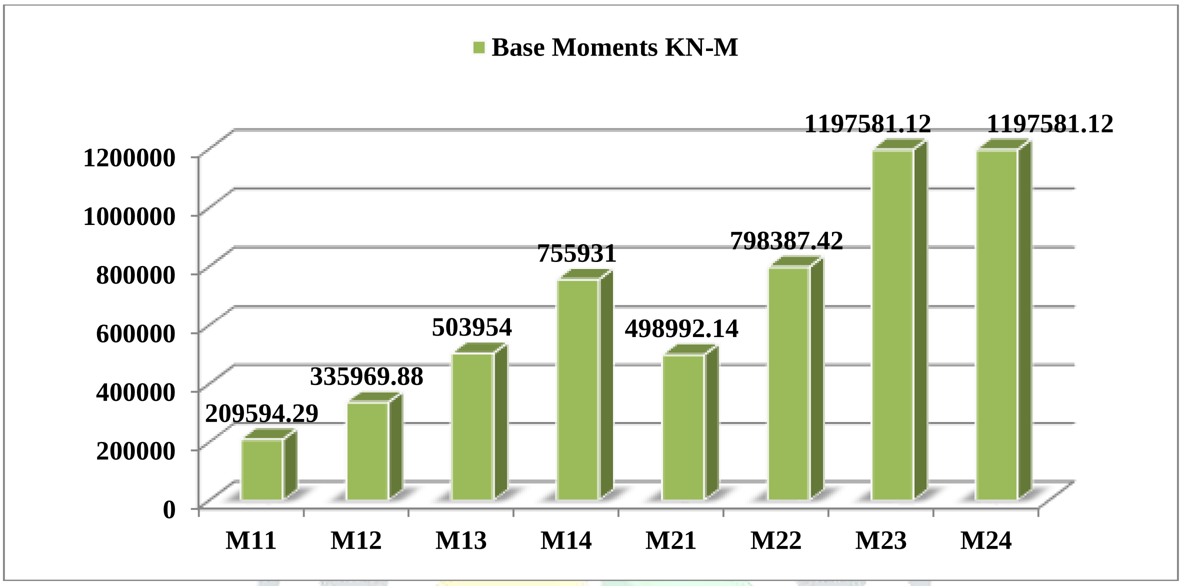


Table No:-4.7 Tabular Comparison of Joints Reactions and Moments

Sr. No.	Building Descriptions	Model Nomenclatures	Joints Reactions KN	Joints Moments KN-M
1	Flat Slab Building	M11	6691.25	2276.50
2	Flat Slab Building	M12	6691.24	3648.51
3	Flat Slab Building	M13	6824.52	5472.29
4	Flat Slab Building	M14	8791.02	8207.99
5	Conventional Building	M21	7678.41	2698.55
6	Conventional Building	M22	9178.79	4317.51
7	Conventional Building	M23	11929.66	6476.13
8	Conventional Building	M24	11929.66	6476.13

Fig No:-4.3 Graphical Comparison of Joints Reactions

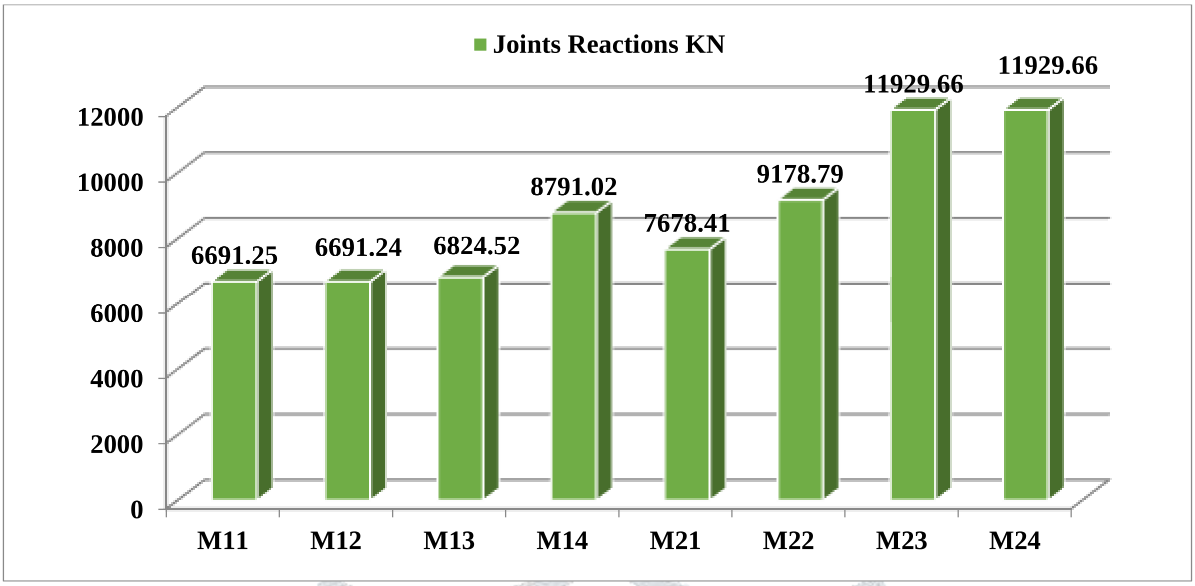


Fig No:-4.4 Graphical Comparison of Joints Reactions

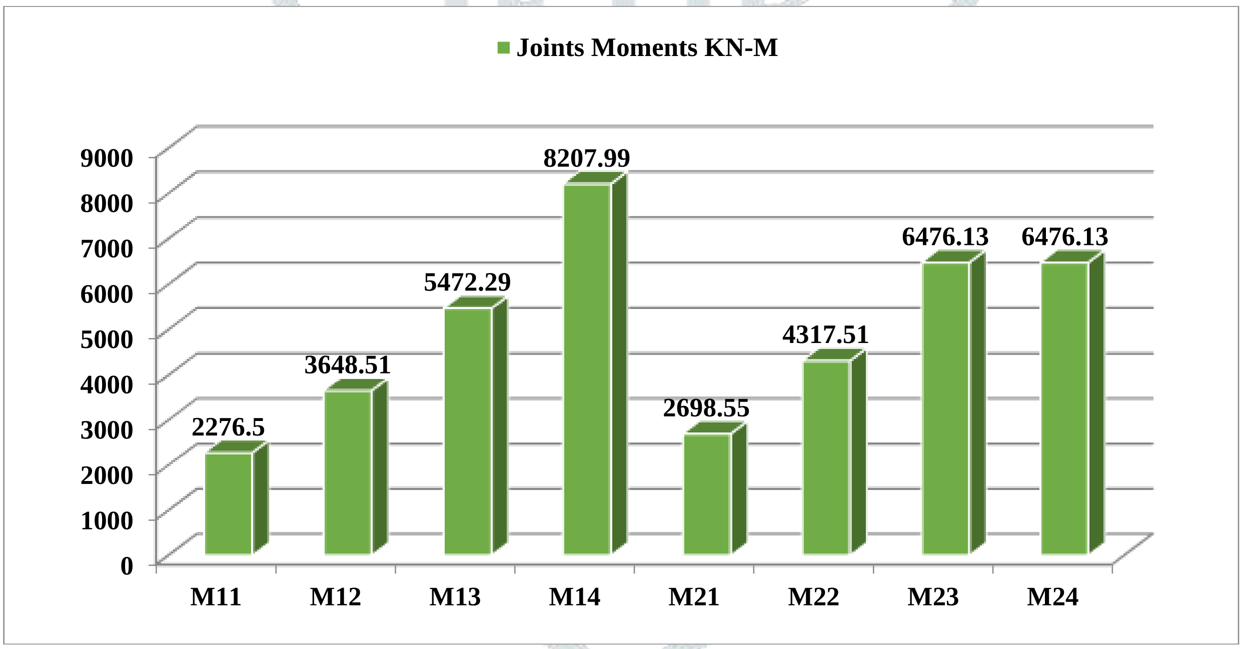


Table No:-4.8 Tabular Comparison of Column Forces and Moments

Sr. No.	Building Descriptions	Model Nomenclatures	Column Forces KN	Column Moments KN-M
1	Flat Slab Building	M11	1092.50	2343.65
2	Flat Slab Building	M12	1748.00	3749.29
3	Flat Slab Building	M13	2621.99	5623.49
4	Flat Slab Building	M14	4208.00	8434.78
5	Conventional Building	M21	2319.39	2698.55
6	Conventional Building	M22	4030.11	4317.51
7	Conventional Building	M23	6813.38	6476.13
8	Conventional Building	M24	8813.38	11476.13

Fig No:-4.5 Graphical Comparison of Column Forces

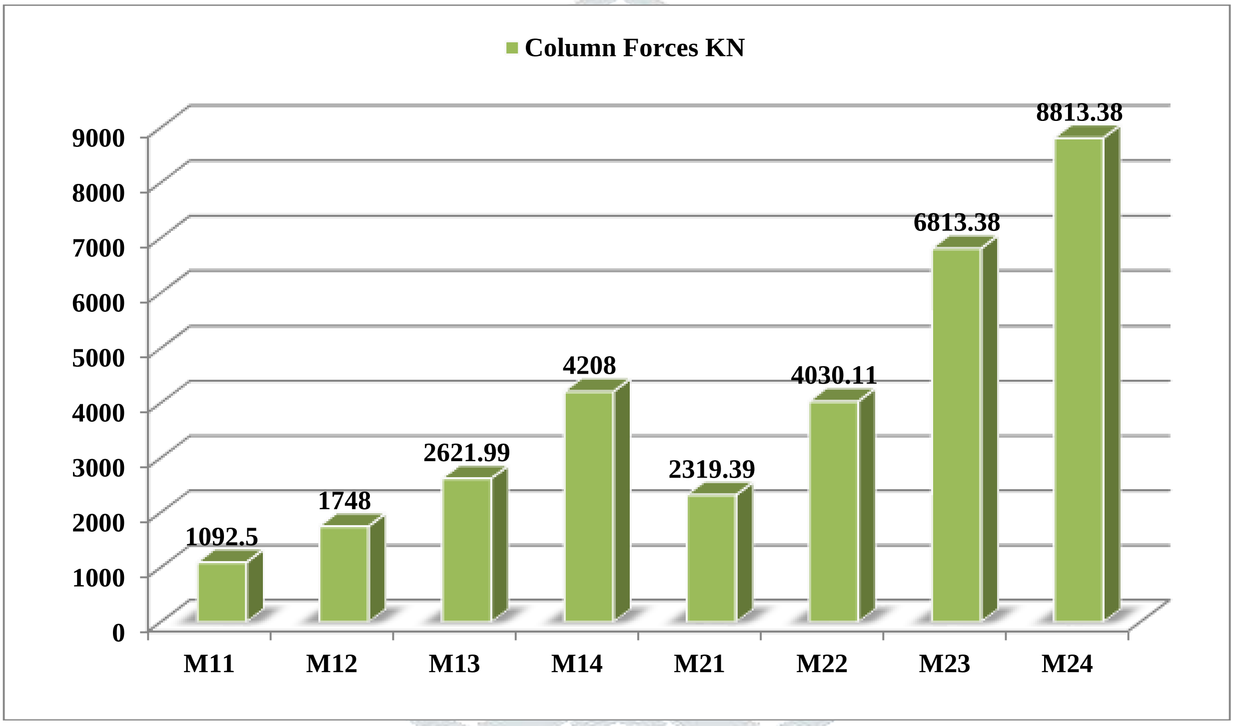
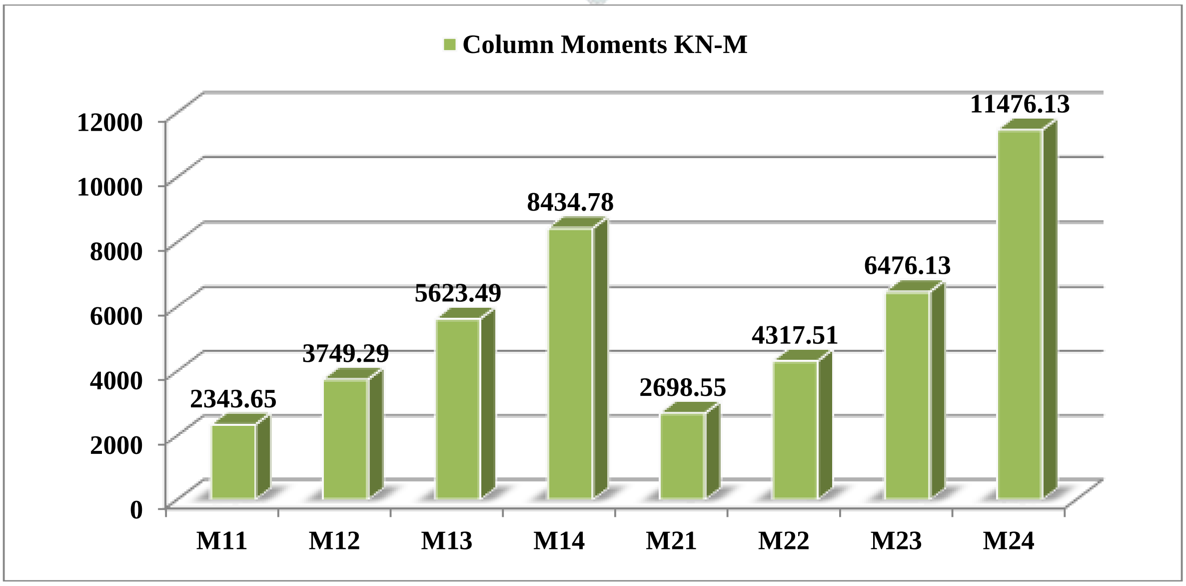


Fig No:-4.6 Graphical Comparison of Column Moments



5- CONCLUSION

In the current learning RCC Multistoried buildings of G + 12 heights i.e. flat slab building and conventional building subjected to the Earthquake load imposed in the all Earthquakes zone are considered for the analysis. To design the components of the flat slab multistory building, after the literature survey, to make the building more economical, the different parameters should be checked as per the selection of different model cases. All the selected 8 building models with constant plan aspect ratio and constant slenderness ratio are analyzed using commercial ETABS 16 software. This chapter presents the analysis result and relevant discussion based on analysis. According to objectives of present study, the results presented here are focused on displacement, force and moments. The horizontal Earthquake force shall be assumed to act alone in one lateral direction at a time. The effects due to vertical component of Earthquakes are generally small and can be ignored.

- ✓ The joint displacements of both buildings increasing with respect to Zone II to Zone V. Flat slab multistoried building shows Maximum joint displacements 2134.60 mm and another hand conventional building shows less joint displacements 575.85 mm.
- ✓ In joint displacements point of view traditional design building is good when we compare flat slab building.
- ✓ The Base Reactions of both buildings increasing with respect to Zone II to Zone V. Flat slab multistoried building shows less Base Reactions 29046.21 KN and another hand conventional building shows maximum Base Reactions 46775.25 KN.
- ✓ In Base Reactions point of view traditional design building is not good when we compare flat slab building.
- ✓ The Base Moments of both buildings increasing with respect to Zone II to Zone V. Flat slab multistoried building shows less Base Moments 755931.00 KN-M and another hand conventional building shows maximum Base Moments 1197581.12 KN-M.
- ✓ In Base Moments point of view traditional design building is not good when we compare flat slab building.

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