Comparative Study of Seismic Behavior of Flat Slab and Conventional RC Framed Structure

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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+5, G+8 and G+11 multistoried building having flat slab with drop, flat slab without drop and conventional slab has been analyzed using ETABS 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 multi storey buildings having conventional RC frame, flat slab with drop and flat slab without drop in seismic zone III with type II medium soil 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.**

Keywords*— Conventional RC Frame Building, Flat Slab With Drop Building, Flat Slab Without Drop Building, Response Spectrum Analysis, ETABS.

I. INTRODUCTION

The scarcity of space in urban areas has led to the development of vertical growth consisting of low-rise, medium-rise and tall buildings. Generally framed structures are used for these buildings. They are subjected to both vertical and lateral loads. Lateral loads due to wind and earthquake governs the design rather than the vertical loads. The buildings designed for vertical load may not have the capacity to resist the lateral loads. The lateral loads are the premier ones because in contrast to vertical load that may be assumed to increase linearly with height; lateral loads are quite variable and increase rapidly with height. Under a uniform wind and earthquake loads the overturning moment at the base is very large and varies in proportion to the square of the height of the building. The lateral loads are considerably higher in the top storey rather than the bottom storey due to which building tends to act as cantilever. These lateral forces tend to sway the frame. In many of the seismic prone areas there are several instances of failure of buildings which have not been designed for earthquake loads. All these reaction makes the study of the effect of lateral loads very important. [1]

Pure rigid frame system or frame action obtained by the interaction of slabs, beam and column is not adequate. The frame alone fails to provide the required lateral stiffness for buildings taller than 15 to 20 (50m to 60m) stories. It is because of the shear taking component of deflection produced by the bending of columns and slab causes the building to deflect excessively. There are two ways to satisfy these requirements. First is to increase the size of members beyond and above the strength requirements and second is to change the form of structure into more rigid and stable to confine deformation. First approach has its own limits, whereas second one is more elegant which increases rigidity and stability of the structure and also confine the deformation requirement. In earthquake engineering, the structure is designed for critical force condition among the load combination. [1]

Flat slab is a system of construction in which slab is directly rest on the column. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation. To support heavy loads, the thickness of slab near the support is increased and these are called drops and columns are generally provided with enlarged heads called column heads or capitals. [2] These increasing thickness of flat slab in the region supporting columns provide adequate strength in shear and to increase the amount perimeter of the critical section, for shear and hence, increasing the capacity of the slab for resisting two-way shear and to reduce negative bending moment at the support. Flat slab structure is preferred over conventional structure in construction due to their advantages in reducing storey height and construction period as compared with conventional structure leading to reduction of construction costs. [3]

Because of absence of deep beam flat slab building structures are more significantly flexible than conventional concrete structures, thus becoming more vulnerable to seismic loading. Thus the seismic analysis of these structures is necessary to know the vulnerability of these structures to seismic loading. [1]

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II. REVIEW OF LITERATURE

M. Altug Erberik, Amr S. Elnashai [2004] focused on the derivation of fragility curves using medium rise flat slab buildings with masonry infill walls. The study employed a set of earthquake records compatible with the design spectrum selected to represent the variability in ground motion. Inelastic response-history analysis was used to analyze the random sample of structures subjected to the suite of records scaled in terms of displacement spectral ordinates, whilst monitoring four performance limit states. The fragility curves developed from this study were compared with the fragility curves derived for moment-resisting RC frames. The study concluded that earthquake losses for flat-slab structures are in the same range as for moment-resisting frames. Differences, however, exist. The study also showed that the differences were justifiable in terms of structural response characteristics of the two structural forms. [4]

S.W.Han [2009] told about the effective beam width model (EBWM) used for predicting lateral drifts and slab moments under lateral loads. They also studies on slab stiffness with respect to crack formation. This studies developed equations for calculating slab stiffness reduction factor by conducting nonlinear regression analysis using stiffness reduction factors estimated from collected test results. [5]

A.B.Climent [2012] investigated about the effective width of reinforced concrete flat slab structures subjected to seismic loading on the basis of dynamic shaking table tests. The study is focused on the behavior of corner slab column connections with structural steel I- or channel-shaped sections (shear heads) as shear punching reinforcement. To this end, a 1/2 scale test model consisting of a flat slab supported on four box-type steel columns was subjected to several seismic simulations of increasing intensity. It is found from the test results that the effective width tends to increase with the intensity of the seismic simulation, and this increase is limited by the degradation of adherence between reinforcing steel and concrete induced by the strain reversals caused by the earthquake. Also, significant differences are found between the effective width obtained from the tests and the values predicted by formula proposed in the literature. These differences are attributed to the stiffening effect provided by the steel profiles that constitute the punching shear reinforcement. [6]

Saraswati Setia [2015] discussed about flat plate slabs exhibit higher stress at the column connection and are most likely to fail due to punching shear rather than flexural failure. To avoid shear failure, parameters influencing the punching strength need to be clearly investigated by realistic analytical or experimental studies. The present analytical study investigates the influence of some of the parameters governing the behavior of connections under punching shear, which are concrete strength, column aspect ratio, slab thickness and gravity loading. Computer program Structural Analysis Program 2000 V14 is used to model columns and slabs as frame and shell elements, respectively. Parametric studies on aspect ratio and depth-to-span ratio have been carried out using displacement control non-linear static pushover analysis to investigate the influence of these parameters on punching shear capacity of the intermediate and corner column connections, which proved to be the governing criteria to prescribe drift limits for flat plate systems in seismic zones. [7]

Prof. P. S. Lande [2015] discussed about flat slab structure is most vulnerable to the seismic excitation therefore the careful analysis of flat slab is important. In this paper the seismic analysis on flat slab is performed and compared it with the conventional RC building. To improve the performance of flat slab system shear wall and beam at periphery is applied and the seismic response of the same is determined and compared it with the flat slab building. [9]

K.S.Sable [2012] analyzed seismic behavior of building for different heights to see what changes are going to occur if the height of conventional building and flat slab building changes. It was concluded that story drift in buildings with flat slab construction is significantly more as compared to conventional R.C.C building. As a result of this, additional moments are developed. Therefore, the columns of such buildings should be designed by considering additional moment caused by the drift. [14]

K. Venkatarao [2016] studied the seismic behavior of conventional RC framed building, flat slab with drop and without drop building in all seismic zones of India. Different parameters like lateral drift, base shear, time period and axial force are compared. It was concluded that lateral displacement of conventional RC frame is less as compared to flat slab without drop building. [15]

V.K.Tilva [2011] studied about a cost comparison between flat slab panel with drop and without drop in four storey lateral load resisting building for analyzing punching effect due to lateral loads. On the basis of permissible punching shear criteria according to IS: 456-2000, economical thickness of flat slab with drop and without drop are selected and cost comparison is done by using S.O.R. [8]

A.A.Sathawane [2012] studied about 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. total area of slab is 854.16 sq m. It is designed by using M35 Grade concrete and Fe415 steel. Analysis of the flat slab and grid slab has been done both manually by IS 456-2000 and by using software also. Flat slab and Grid slab has been analyzed by STAAD PRO. Rates have been taken according to N.M.C. C.S.R. It was observed that the flat slab with drop is more economical than flat slab without drop and grid slabs. [12]

III. PROBLEM STATEMENT OF STUDY

In present work in order to determine dynamic response of flat slab with drop, flat slab without drop and conventional reinforced concrete framed structure for different height in seismic zone III, it will be modeled and analyzed in ETABS software. Linear dynamic response spectrum analysis will be performed on the structure. In present work 9 numbers of conventional RC frame building, flat slab with drop building and flat slab without drop building of G+5, G+8 and G+11 storey models are considered.

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A. Models of building

1. Conventional RCC building (G+5, G+8, G+11)
2. Flat slab without drop with perimeter beams (G+5, G+8, G+11)
3. Flat slab with drop with perimeter beams (G+5, G+8, G+11)

B. Building configuration, loading data and earthquake data

TABLE 1.DESIGN DATA OF BUILDING

Design data of building	Dimension
Plan dimension	49 m x 25 m
No. of bay in X direction	7 (Bay size 7m each)
No. of bay in Y direction	5 (Bay size 5m each)
No. of storey	G+5, G+8, G+11
Typical storey height	3.5 m
Bottom storey height	3.5 m
Thickness of slab	150 mm for conventional RC Frame building 230 mm for flat slab building
Thickness of drop	115 mm
Size of drop	3 m x 3 m
Column size	700 mm x 700 mm
Beam size	300 mm x 600 mm
Wall thickness	230 mm for external wall 115 mm for internal wall
Live load	4 kN/m^2 for typical floor 2 kN/m^2 for terrace
Floor finish	1 kN/m^2
Terrace water proofing	1.5 kN/m^2
Earthquake data	Zone III (Type II medium soil) Importance factor = 1 Response reduction factor = 5 Damping ratio = 0.05
Grade of concrete	M 25
Grade of steel	Fe 415

C. Grid and 3D view of building

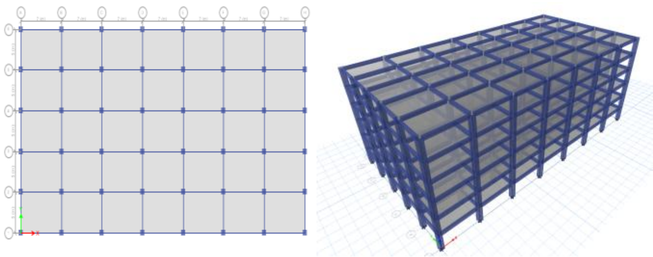

Figure 1.Grid and 3D view of conventional RC Frame building (G+5)

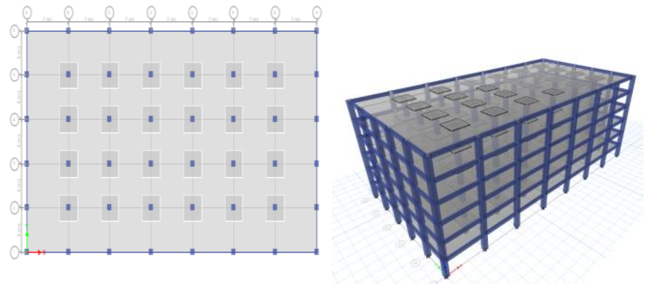

Figure 2.Grid and 3D view of flat slab with drop building (G+5)

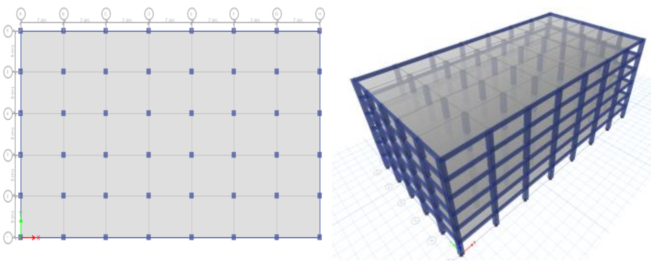

Figure 3.Grid and 3D view of flat slab without drop building (G+5)

IV. RESULTS AND DISCUSSION

Dynamic analysis for conventional RC Frame building, flat slab with drop building and flat slab without drop building was done by using response spectrum analysis for earthquake zone III as per Indian standard code. The effect of height of building on these building is evaluated. There is significant change in seismic parameters like storey displacement, storey drift, storey shear, time period and base shear is noticed and discussed below.

A. Storey displacement

Storey displacement is important when structures are subjected to lateral loads like earthquake and wind loads. Displacement depends on height of structure and slenderness of the structure because structures are more vulnerable as height of building increases by becoming more flexible to lateral loads.

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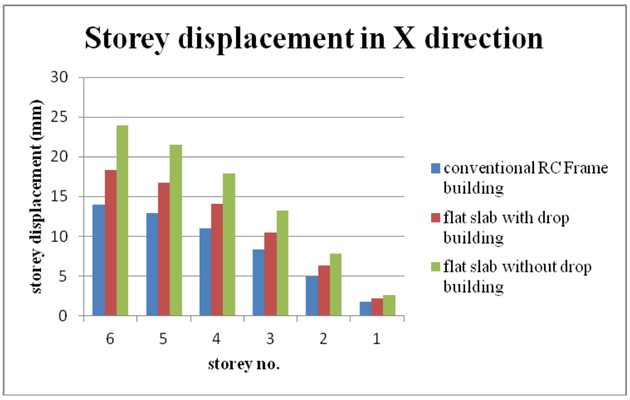

Chart 1.Storey no. vs. storey displacement in x direction (G+5)

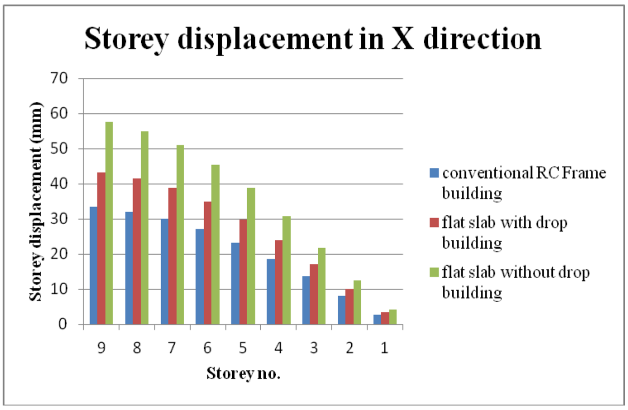

Chart 2.Storey no. vs. storey displacement in x direction (G+8)

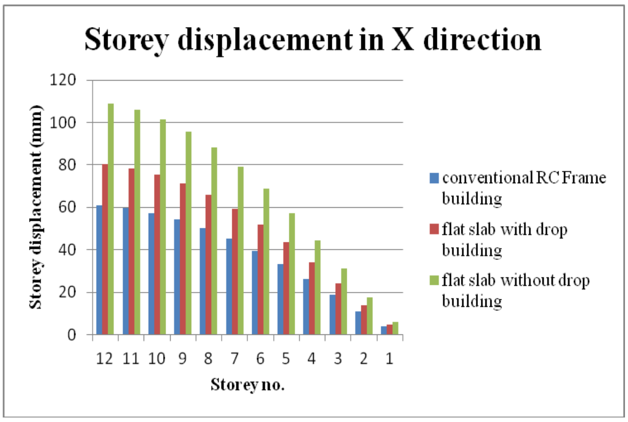

Chart 3.Storey no. vs. storey displacement in x direction (G+11)

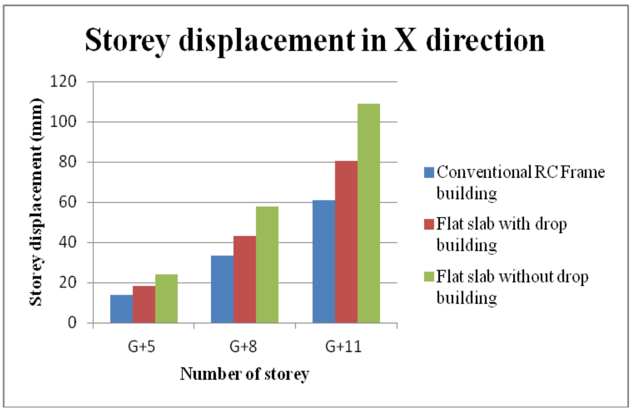

Chart 4.Storey displacement of 6, 9 and 12 storey building

Storey displacement is high at top storey and least at the base of the structures. From the above charts it was observed that storey displacement of flat slab without drop building is more than flat slab with drop and conventional RC Framed building. As height of the building increases the value of displacement also increases. The displacement value of flat slab without drop building is about 44.11 % higher compared to conventional RC Frame building and 26.19 % higher compared to flat slab with drop building.

B. Storey drift

Storey drift is defined as difference between lateral displacements of one floor relative to the other floor. Total storey drift is the absolute displacement of any point relative to the base. As per IS.1893-2002 cl.7.11.1 the storey drift in any storey due to the minimum specified design lateral force with partial load factor 1.00 shall not be exceeding 0.004 times the storey height. In this case storey height is 3500 mm. Therefore limited storey drift is calculated as = storey drift /3500 =0.004.

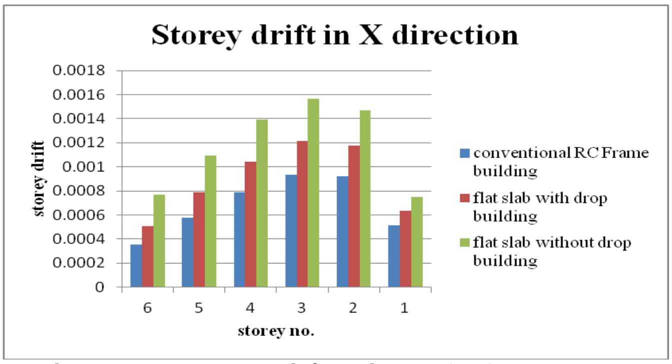

Chart 5.Storey no. vs. storey drift in x direction (G+5)

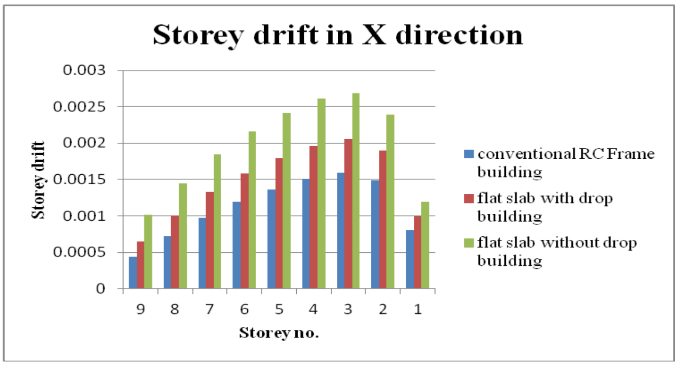

Chart 6.Storey no. vs. storey drift in x direction (G+8)

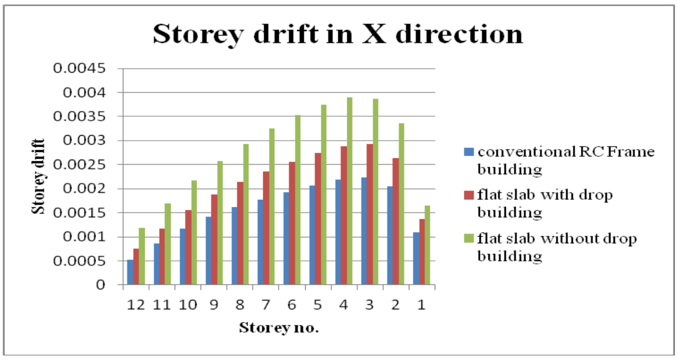

Chart 7.Storey no. vs. storey drift in x direction (G+11)

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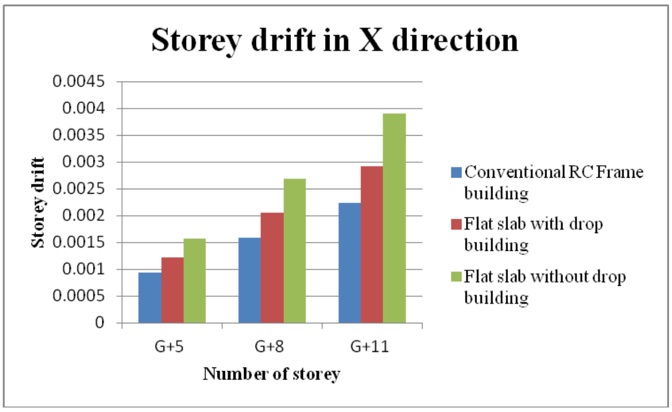

Chart 8.Storey drift of 6, 9 and 12 storey building

Storey drift follows a parabolic path along storey height with maximum value lying somewhere near the middle storey. From the above charts it was observed that storey drift of flat slab without drop building is more than flat slab with drop and conventional RC Framed building. As height of the building increases the value of storey drift also increases. The storey drift of flat slab without drop building is about 42.56 % higher compared to conventional RC Frame building and 25.12 % higher compared to flat slab with drop building.

C. Storey shear and base shear

Seismic forces are lateral loads (external force) which intern will create total reactive forces at column base in direction opposite to that of lateral load i.e. (sum of lateral loads = base shear) this overall reactive force is base shear. But the load is not applied on base alone, as the lateral load is applied along the height of building and building in turn has different stiffness and masses along its height in different storey, so the reactive force in each storey due to lateral load varies and this reactive force is storey shear. Roughly storey shear can also be seen as distribution of base shear along its storey based on its stiffness and mass.

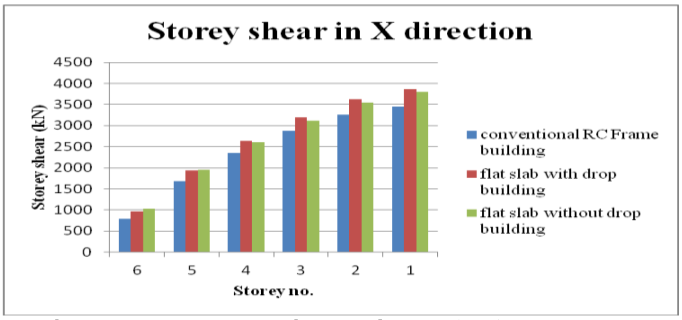

Chart 9.Storey no. vs. storey shear in x direction (G+5)

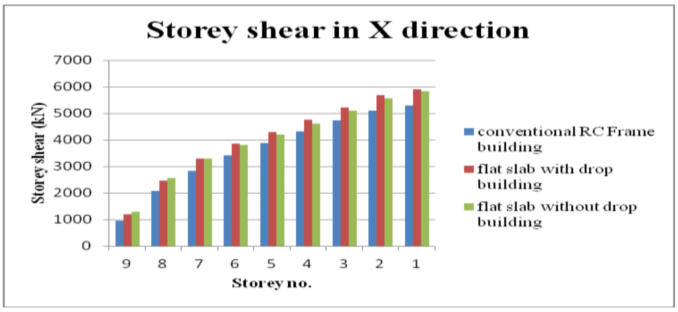

Chart 10.Storey no. vs. storey shear in x direction (G+8)

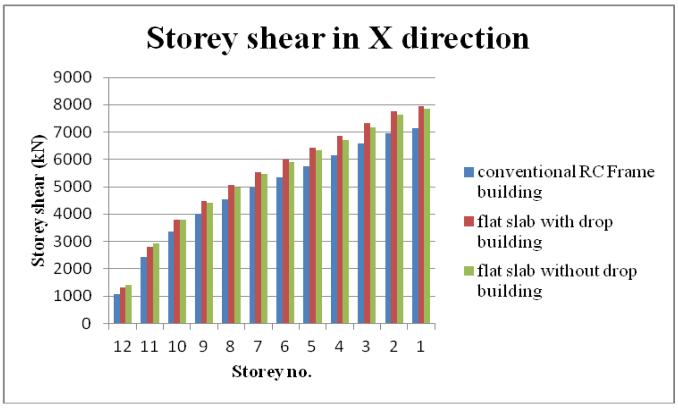

Chart 11.Storey no. vs. storey shear in x direction (G+11)

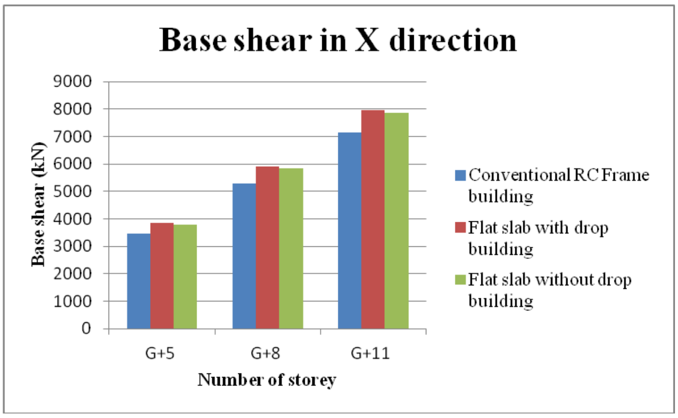

Chart 12.Base shear of 6, 9 and 12 storey building

The storey shear is maximum at ground level and keeps on decreasing towards the top storey of the structure. From the above charts it was observed that storey shear and base shear of flat slab with drop building is more than flat slab without drop and conventional RC Framed building. As height of the building increases the value of storey shear and base shear also increases. The base shear of flat slab with drop building is about 10.37 % higher compared to conventional RC Frame building and 1.24 % higher compared to flat slab without drop building.

D. Time period

Time required for the undamped system to complete one cycle of free vibration is the natural time period of vibration of system in unit of second.

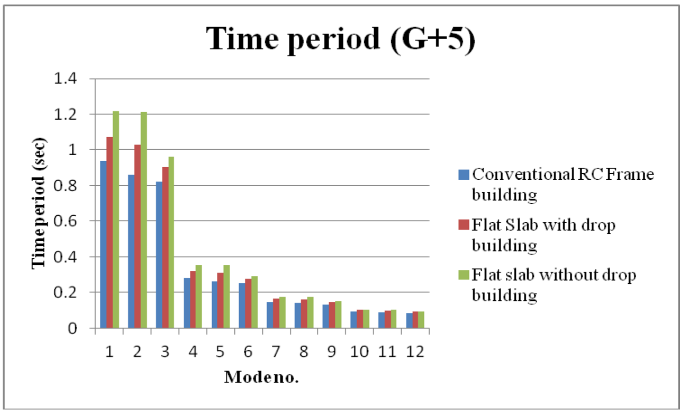

Chart 13.Mode no. vs. time period (G+5)

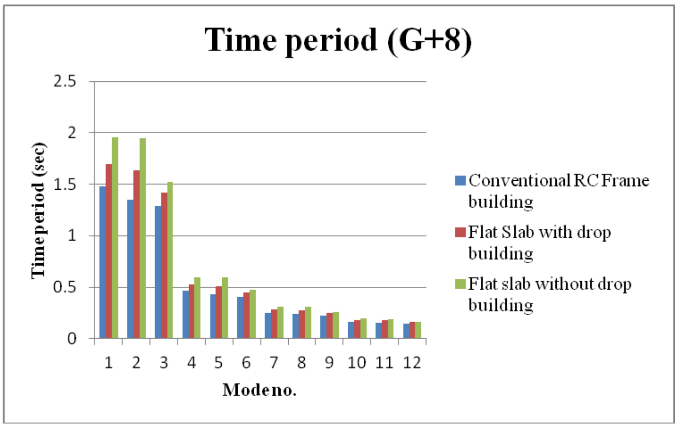

Chart 14.Mode no. vs. time period (G+8)

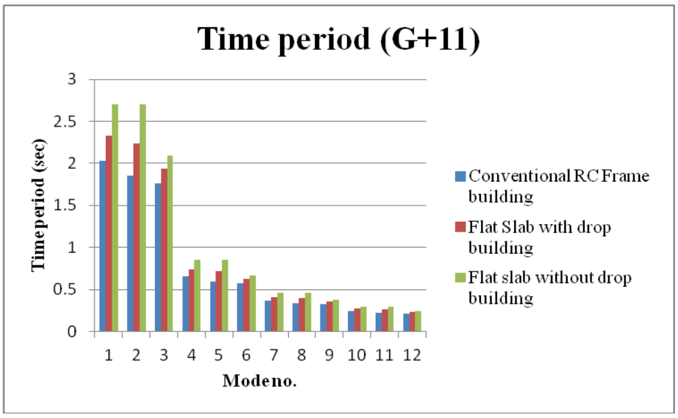

Chart 15.Mode no. vs. time period (G+11)

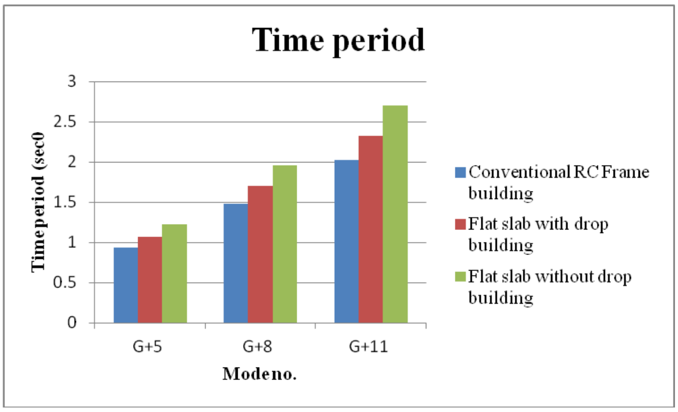

Chart 16.Time period of 6, 9 and 12 storey building

There are 12 number of mode in building, each mode has different value of time period. Time period depends on mass of building and it indicates flexibility of building. The number of mode increases, the value of time period decreases. From the above charts it was observed that time period of flat slab without drop building is more than flat slab with drop and conventional RC Framed building. As height of the building increases the value of time period also increases. The time period of flat slab without drop building is about 25.17 % higher compared to conventional RC Frame building and 14.04 % higher compared to flat slab with drop building.

V. CONCLUSION

This is the summary of project work for conventional RC Frame building, flat slab with drop building, flat slab without drop building for different height of building in seismic zone III with type II medium soil. From the above charts following conclusions have been drawn:

1. Storey displacement is high at top storey and least at the base of the structures. As the height of the building increases the value of displacement also increases. The displacement value of flat slab without drop building is about 44.11 % higher compared to conventional RC Frame building and 26.19 % higher compared to flat slab with drop building.
2. Storey drift follows a parabolic path along storey height with maximum value lying somewhere near the storey three. After storey three, storey drift decreases as the height of building increases. The storey drift of flat slab without drop building is about 42.56 % higher compared to conventional RC Frame building and 25.12 % higher compared to flat slab with drop building.
3. The base shear is maximum at ground level and keeps on decreasing towards the top storey of the structure. As height of the building increases the value of storey shear and base shear also increases. The base shear of flat slab with drop building is about 10.37 % higher compared to conventional RC Frame building and 1.24 % higher compared to flat slab without drop building.
4. The time period is maximum at mode 1, 2 and 3. After mode 3 time period reduces drastically. As height of the building increases the value of time period also increases. The time period of flat slab without drop building is about 25.17 % higher compared to conventional RC Frame building and 14.04 % higher compared to flat slab with drop building.
5. By comparing all above parameters it was found that conventional building has superior performance in earthquake against flat slab with drop and flat slab without drop.
6. Flat slab is provided with drop and column head to reduce large shear force and negative bending moment and flat slab is also provided with shear wall or bracing or damper as lateral load resisting system to reduce seismic effect.

VI. FUTURE SCOPE OF STUDY

- The structure can be analyzed in different seismic zones with different soil types.
- The structure can be analyzed with shear wall or bracing or damper.
- Comparison of pretension and post tension flat slab with and without drop.
- Cost comparison of conventional RC Frame building, flat slab with drop building and flat slab without drop building.
- Comparative study of seismic performance of multistoried RCC building with flat slab and grid slab.
- Fragility analysis of flat slab structure can be done.
- Non linear pushover analysis of flat slab building can be performed using ETABS.

REFERENCES

[1] Navyashree K, Sahana T.S, "Use of flat slabs in multi-storey commercial building situated in high seismic zone", International Journal of Research in Engineering and Technology (IJRET) Vol.3, Issue 8, pp. 439-451, August 2014.

[2] Dr. U. Gupta, S. Ratnaparkhe, P. Gome, " Seismic behavior of buildings having flat slabs with drops", International Journal of Emerging Technology and Advanced Engineering (IJETAE) Vol. 2, Issue 10, October 2012.

[3] S.Pahwa, V. Tiwari. M. Prajapati, "Comparative Study of Flat Slab with Old Traditional Two Way Slab" Internatinal Journal of Latest Trends in Engineering and Technology (IJLTET), Vol. 4, Issue 2, pp. 252-260, July 2014.

[4] M. Altug Erberik., Amr S. Elnashai, "Fragility analysis of flat-slab structures", ELSEVIER, 23 February2004.

[5] Sang Whan Han, Young Mi Park, Seong Hoon Kee, "Stiffness reduction factor for flat slab structures Under lateral loads - A literature review on experimental study", Journal of structural Engineering © ASCE / JUNE 2009 / 743.

[6] A.B. Climent, D.Z. Sánchez, J.F. Gil-Villaverde, "Experimental study on the effective Width of flat slab structures under dynamic seismic loading ", ELSEVIER, April 2012.

[7] Saraswati Setia, Shakti Kalyani "Seismic Behavior of Connections Subjected to Punching Shear in Flat Slab Systems" Journal of Engineering and Technology (JET) Vol.5, Issue 1, pp. 45-51, June 2015.

[8] V.K. Tilva, A.B.Vyas, P. Thaker, "Cost comparison between flat slabs with drop and Without drop in four storey lateral load resisting building", National Conference on Recent Trends in Engineering & Technology, 13-14 May 2011, B.V.M. Engineering College, V.V.Nagar, Gujarat,India.

[9] Prof. P. S. Lande, Aniket B. Raut, " Comparative Study of Flat Slab Building with Traditional Two Way Slab Building under the Seismic Excitation " International Journal of Pure and Applied Research in Engineering and Technology (IJPRET), Vol.3, Issue 8, pp. 51-58, April 2015.

[10] Widianto, Ying Tian, Jaime Argudo, Oguzhan Bayrak, James O. Jirsa, "Rehabilitation of earthquake-Damaged reinforced concrete flat plat slab column connections for two way shear", Proceedings of the 8th U.S.National Conference on Earthquake Engineering, April 18-22, 2006, San Francisco, California, USA.

[11] Kiran S. Patil, N.G. Gore, P.J. Salunke, "Optimum design of reinforced concrete flat slab with drop panel", International Journal of Recent Technology and Engineering (IJRTE), Vol.2, Issue 4, pp. 37-39, September 2013.

[12] A.A. Sathawane, R.S. Deotale, "Analysis and design of flat slab and grid slab and their Cost comparison" International Journal of Engineering Research and Applications, Vol. 1, Issue 3, pp.837-848.

[13] Ramos, A., Lúcio, V., "Safety on punching of prestressed flat slabs", Proceedings of the 2nd International Congress June 5-8, 2006 – Naples, Italy.

[14] K.S. Sable, V.A. Ghodechor, S.B. Kandekar, "Comparative Study of Seismic Behavior of multistory flat slab and conventional reinforced concrete framed structures", International Journal of Computer Technology and Electronics Engineering, Volume 2, Issue 3, pp. 17-26, June 2012.

[15] K.Venkatarao, N.Nageswarao " Seismic Behavior of Reinforced Concrete Framed structure with Flat and Conventional floor slab system" International Journal and magazine of Engineering, Technology, Management and Research (IJMETMR) Vol.3, Issue 4, pp. 536-545, April 2016.