Performance of Flat Slab Systems For Seismic

Sneha N. Mahure[1], Vinay C. Mehta [2]
[1]Dept of Civil Department
[2]Assistant, Professor, Dept of Civil Department
[1, 2] BIT Bamni, Maharashtra, india

Abstract- *Flat plate system is approving in various buildings construction asset of the decreased floor height to meet the economical and architectural demands. Flat-slab RC buildings model asset over conventional beam column building. However, the structural effectiveness of flat-slab construction is delay by its so-called lesser performance under earthquake loading. flat-slab systems broadly used in earthquake prone country in the world. Unfortunately, earthquake experience had proven that this form of construction is defenceless to extra illness and collapse, when not designed and detailed properly. Therefore careful investigation of flat slab building is important.*

In current study a parametric analysis was drifting out in order to identify the seismic response of systems a) flat slab building b) flat slab with perimetric beams c) flat slab with shear walls d) flat slab with drop panel. e) Conventional building the aforementioned hypothetical systems were studied for two different storey heights located in zone v. and analyzed by using ETABS Nonlinear version 9.7.3. Linear dynamic analysis i.e. response spectrum analysis is performed on the system to get the seismic behaviour.

Keywords- flat slab, perimetric beam, shear wall, response spectrum analysis etc.

I. INTRODUCTION

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 slabs. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation. Flat slabs have been widely used in building construction due to their advantages in reducing storey height and construction period (compared with RC frames with beams and columns), leading to a reduction of construction costs. Two- way slab, the slab is supported by beams, the load of both slab and beams is conveyed to columns and footings. Flat slabs are extensively used to resist wind and seismic forces in low-to-moderate seismicity regions compare to two way slab. The behavior of this type of structural system under gravitational loads is well established. The flat slab is often thickened closed to supporting columns to provide adequate strength in shear and to reduce 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 Building structures are significantly more flexible than traditional concrete slab under seismic excitations. The slab that satisfies architectural demand for better illumination, requires simple formwork that can be removed faster (than other slabs) and guarantees open vision while making optimum use of the available space leads to an admired concept in field of structural engineering i.e. reinforced concrete flat slab.

The flat slab system used since its inception in the USA by Turner in 1906 has been gained popularity all over the world, as evidence of the large portion of the newly constructed buildings which employ that system. Flat slab systems in current construction practice are commonly used for relatively light residential loads and for spans from 4.5m to 6m. For heavy industrial or office building loads and/or for larger spans, flat slabs are used with drop panels or column capitals. The flat slab type of construction provides architectural flexibility, more clear space, less building height, easier formwork, and consequently, shorter construction time. However, flat slabs are susceptible to significant reductions in stiffness as a consequence of slab cracking that can arise from construction loads, service gravity loads, temperature and shrinkage effects, and lateral loads. Flat slab/plate systems (especially in multi-story high-rise buildings) experience excessive lateral drifts (displacement) when subjected to wind loads or seismic excitations. Also they possess non-ductile

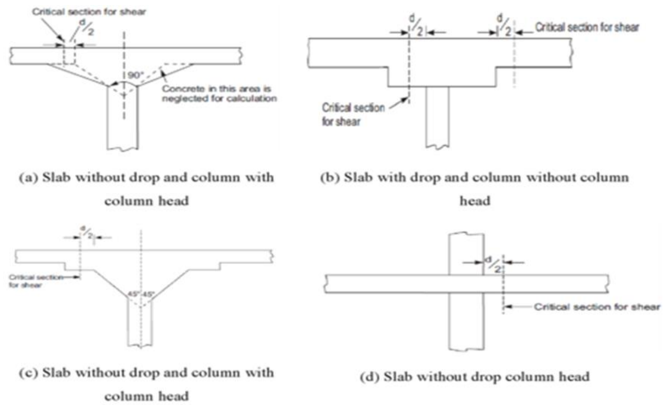

Fig.1. Different Types of Flat Slab System

Overall response, local seismic hysteretic response, and poor energy dissipations. Furthermore, their potential of brittle punching failure at the slab-column connections. Therefore in regions of high seismic risk, modern seismic design codes prohibit the use of flat slab/plate as a lateral load resisting system, but allow its use as a vertical (gravity) load resisting system. Flat slab without drop is more vulnerable to seismic behavior as there is shear failure at the slab column joint as compared slab with drop and column head. Hence the careful seismic analysis and design of flat slab building is important.

The main objective of this Paper is to determine the seismic behaviour of the flat slab building under the seismic excitation and compare it with the conventional building using ETABS software. The behavior of flat slab structure under seismic excitation will be studied by using ETABS software.

1. To evaluate the seismic bahaviour of flat slab building with and without shear wall, drop panel and peripheral beam and compare it with conventional beam column building
2. To mitigate or reduce the lateral displacement and storey drift, of flat slab building using shear wall, peripheral beam and drop panel.
3. To investigate the effect of shear wall, drop panel, peripheral beam on the flat slab building.
4. To employ design & analysis software ETABS Non-linear version 9.7.3 and to study the static and dynamic analysis of flat slab building and conventional beam column building.

II. LITERATURE REVIEW

Paper [1] performed a pushover analysis on the four story building using SAP2000 software (Ver.14) and equivalent static method according to UBC 97. The purpose of pushover analysis is to evaluate the expected performance of structural systems by estimating its strength and deformation demands in design earthquakes by means of static inelastic analysis, and comparing these demands to available capacities at the performance levels of interest. The main output given by a pushover analysis is in terms of response demand versus capacity. If the demand curve intersects the capacity envelope near the elastic range, then the structure has a good resistance. If the demand curve intersects the capacity curve with little reserve of strength and deformation capacity, they concluded that the structure will behave poorly during the imposed seismic excitation and need to be retrofitted to avoid future major damage or collapse.

In [2] carried out the analysis in STAAD Pro V8i software. Results of conventional building, flat slab with drop and flat slab without drop for different heights with and without masonry infill wall are considered in the analysis. Conventional building, flat slab with drop and flat slab without drop different height are modelled and analyzed for the different combinations for Dynamic loading. The comparison is made between the Conventional buildings, flat slab with drop and flat slab without drop Buildings with and without masonry infill wall is situated in seismic zone III. Dynamic analysis for different types of building is done by using Response Spectrum method for earthquake zone III as per Indian Standard code and they discussed the results. The results shows that The Fundamental Natural Period increases as the number of stories increases, irrespective of type of building viz. conventional structure. The Fundamental Natural Period value is much higher in Flat Slab without Drop Buildings Compared to Flat slab with Drop and Conventional R.C.C building. The Displacement and Fundamental Natural Period value of the buildings with masonry infill wall is lesser compared to without masonry infill wall. The Axial Force and Design Base Shear value of the buildings with masonry infill wall is lesser compared to without masonry infill wall.

In [3] the application of design procedure an office building is considered as a case study the plan of the office building (G+4) is considered. This building is designed by considering four cases with different floor systems. The quantities of reinforcing steel, prestressing steel, concrete required for the slab, beam and column is calculated for the same and are presented in tabular form. Along with this total cost of the building per square meter is found and comparison of all the four cases with respect to cost is done.

Paper [4] used the nonlinear finite element method of analysis using layered finite element modeling technique various parameter namely aspect ratio of connection, depth to span ratio, spacing of the stirrups, governing the punching shear capacity of the flat plate column connection is highlighted. Pushover analysis is used to monitor the response of a structure. Aspect ratio span to depth ratio and confining connection showed significant influence on the punching shear capacity of the flat plate column connection. [5] studied the comparative effect of earthquake on the flat slab and grid slab consisting of beam spaced at regular interval. The results show that the grid slab has a less drift as compared to flat slab [6] this paper investigates the comparison of conventional reinforced concrete building system i.e. slab, beam & column to the flat slab building. These results are compared for different heights of building. The main objective this analysis was to study the different forces acting on a building. The analysis was carried out in STAAD Pro2007 software. Results of conventional R.C.C structure i.e. slab, beam and column and flat slab R.C.C structure for different heights are discussed. The results shows that In comparison of the conventional R.C. building to flat slab building, the time period is more for conventional building than flat slab building because of monolithic construction. For all the structure, base shear increases as the height increases. This increase in base shear is gradual up to 9th -storey, thereafter, it increases significantly gives rise to further investigation on the topic. Base shear of conventional R.C.C building is less than the flat slab building.

Paper [7] the paper displays the results from analyses of six types of structural systems of a residential building in Skopje for the purpose of defining the seismic behavior and resistance of flat-slab Structural systems. The analyses were performed by using the finite element method and the SAP2000 v10.0.9Advanced computer program. Seismic analysis has been carried out in compliance with the regulations for design of high rises in seismically prone areas. The horizontal loads have been defined in the form of a design spectrum of acceleration in accordance with Eurocode 8, scaled in such a way that it generates the total shear force at the base to the amount of 10% of the weight of the structure. Dynamic analysis has been carried out for selected structural systems exposed to the effect of the El Centro earthquake with amax=0.32g. The purely flat-slab RC structural system is considerably more flexible for horizontal loads than the traditional RC frame structures which contributes to the increase of its vulnerability to seismic effects.

In [8] carried out an experimental program at the ELSA Laboratory, with the aim of assessing the seismic behaviour of flat-slab structures. The program consisted in pseudo-dynamic tests on a full-scale three storey RC flat-slab building structure, representative of flat-slab buildings in European seismic regions. The paper presents the experimental results obtained from the two tests, performed using Eurocode 8 compatible accelerograms of increasing intensity, together with the comparison with analytical evaluations. Some considerations are drawn regarding the deficiencies of the behaviour of these structures..

Paper [9] developed the fragility curve for flat-slab structural systems, a mid rise flat slab building is designed and modeled using the structural characteristics typical of the construction type under investigation. ADAPT IC and INDYAS software program was used to perform a static inelastic (pushover) and a dynamic time history analysis. The ten ground motion records are selected for time history analysis. An Eigen value analysis was performed with the software to yield the periods of vibration of the structure.

In [10] used an efficient analytical method in their study to obtain accurate results in significantly reduced computational time using the finite element approach. The proposed method employs super elements with fictitious beams. 20-story flat plate structure with regular plan is taken for study and Static and dynamic analyses were performed using the Equivalent frame method, finite element method.

Paper [11] analyzed the tree model with and withoutthe shear wall and with drop panel for earthquake zone III, IV and V for three different storey height. They conclude that Use of flat slabs with drop results in increase in drift values in shorter plans and decrease in larger plans, marginally in a range of 0.5mm to 3mm. Still they found all drift values are within permissible limits even without shear walls. In zone III and IV use of flat slabs with drop in place of beam slab arrangements, though, alters the maximum lateral displacement values, however, these all were well within permissible limits, even without shear walls.

Paper [12] studied flat plate structures designed only for gravity load were retrofitted against earthquake load using various methods and their seismic performances were evaluated to verify the effect of the seismic retrofit. Their nonlinear static and dynamic analysis results showed that both strength and stiffness were enhanced as a result of the seismic retrofit. They carried out the non linear static and dynamic analysis on the two different story building three and 6 storey building. According to their analysis results the unretrofitted model structures failed by punching shear of column-slab connections. However after the seismic retrofit both the strength and stiffness were significantly enhanced enough to satisfy current seismic design codes.

Paper [13] deals with the comparison between three dual lateral load resisting systems in the multistory buildings. Dual system which used in the multistory building to resist lateral loads (wind/earthquake) are used in their study are Moment resisting frame with shear wall (MRSW), Moment resisting frame with bracing (MRBR) and Flat slab with shear wall (FSSW).[14] examine the seismic response of typical high rise flat plate reinforced concrete residential structures. this class of structures is frequently Constructed by using flat plate structures, where lateral force resistance is provided by Shear walls in stairs and elevator cores, and occasionally by additional rigid frames on the Perimeter, Two existing buildings were chosen for their study, which contain most of the typical and relevant features of these classes of structures in the New York City area.[15] The lateral force resistance of the structures satisfies building code requirements with respect to wind. The report compares the response to seismic excitation with that of static wind response. Depending on the intensity of the postulated seismic excitation (response spectrum), the amplitude of the seismic response were found generally to be much larger than that due to wind. On the other hand, because wind design is governed not by strength, but by drift requirements, (i.e. stiffness) it was observed that the required lateral force resistance against seismic excitation, which is sensitive to the input spectrum, is frequently well within the capacity of the structure. The implication of these findings is significant for future consideration in the evaluation of the economic impact of seismic design requirements in the New York region. The seismic analysis was executed by taking into account the non-linear response of the structure. [16] A simple non-linear model was used for this purpose and they were found that the ductility factor method provides reliable results, thereby simplifying the analysis of this class of structures. They used the public domain computer code ETABS for their study. The program is specialized for the linear static and dynamic analysis of multi-story structures. Paper [17] performed Modal analysis as Well as seismic spectral and time history analysis. They concluded that direct wind vs. seismic responses for the class of buildings under consideration show that the seismic responses are considerably higher than wind responses. Seismic capacity ratios of buildings were found to be sensitive to the choice of input seismic spectra [18].

From the literature survey it can be conclude that the seismic performance of flat slab building is complicated as it depends upon the seismic zone, plan dimension, storey height etc. hence a careful analysis of flat slab building is needed. Most of the author perform a seismic analysis on flat slab building and compare with it a conventional building to get the comparative behaviour of flat slab building.

III. SYSTEM DEVELOPMENT MODELLING

This Paper presents methodology for static and dynamic analysis of structure. A detailed description of equivalent static analysis and response spectrum analysis is presented in this chapter. ETABS version 9.7.3 computer program is used for the analysis purpose. The program is specialized for the linear static and dynamic analysis of multi-story structures. It has a Wide range of structural modeling capabilities, including the ability to model shear walls, Columns and beams it can handle static wind and vertical loads, modal analysis as Well as seismic spectral and time history analysis, three dimensional modeling of buildings is a standard feature of the program. A three dimensional mathematical model was prepared for each of the two buildings under consideration. All shear Walls, columns, beams and structural slabs were included in the model of each building. The reinforced concrete structural elements were assumed to be uncracked, and the steel reinforcements were ignored, which is the customary way of modeling reinforced concrete buildings for linear analysis.

A. Computational Model

For determining the seismic performance of flat slab building two different height hypothetical structure (G+6 and G+12) are considered and five models is analyzed viz. flat slab building, flat slab with shear wall, flat slab with drop panel and conventional beam column building. The model must ideally represent the mass distribution, strength, stiffness and deformability. Material properties and Modeling of the structural elements used in the Present study is discussed below.

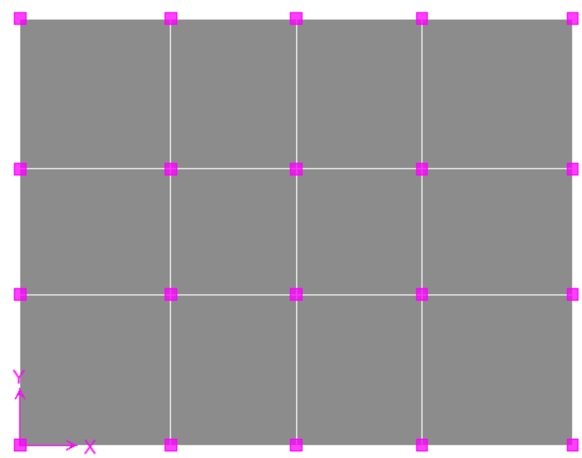

Fig.2. plan of flat slab building

B. Material Properties

M-25 grade of concrete and Fe-415 grade of reinforcing steel are used for all the frame models used in this study. Elastic material properties of these materials are taken as per Indian Standard IS 456: 2000. The short-term modulus of elasticity (Ec) of concrete is taken as.

fck is the characteristic compressive strength of concrete cube in MPa at 28-day (25 MPa in this case). For the steel rebar, yield stress (fy) and modulus of elasticity (Es) is taken as per IS 456 (2000).

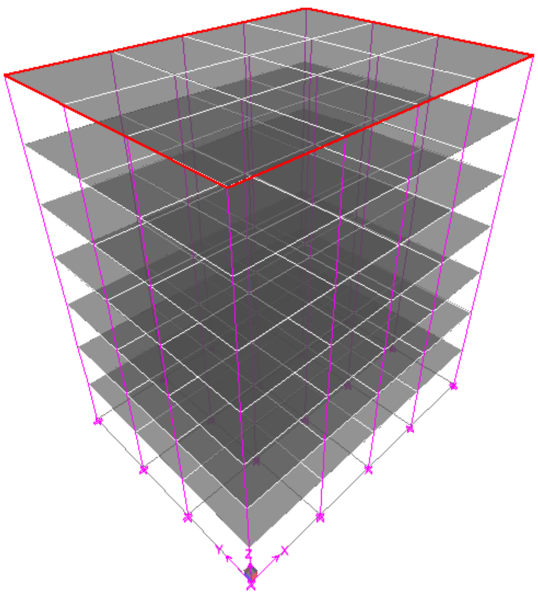

Fig.3 3D view of flat slab building in ETABS

Structural element sizes:-

For G+6 building
Column size 450 x 450 mm.
Beam size 230 x 400 mm.
Thickness of flat slab 150 mm.
Thickness of convectional two way slab 120 mm.
Thickness of shear wall 150 mm
Thickness of wall 230 mm
Thickness of interior wall 115 mm
For G+12 building
Column size 650 x 650 mm.
Beam size 230 x 500 mm.
Thickness of flat slab 150 mm.
Thickness of convectional two way slab 120 mm.
Thickness of shear wall 150 mm
Thickness of wall 230 mm
Thickness of interior wall 115 mm

Description for Loading:

A. Dead load:

1. Wall load with 230 mm thickness = 0.23 x 3 x 18 = 12.42 kN/m
2. Wall load with 115 mm thickness = 0.115 x 3 x18 =6.21 kN/m
3. Floor finish = 1.8 kN/m2
4. Self-weight of the building is automatically considered by ETABS software.

B. Live load:

Live load of 4 kN/m2 is considered on the building.

C. Earthquake force data:

Earthquake load for the building has been calculated as per IS-1893-2002:

i. Zone (Z) = V
ii. Response Reduction Factor (RF) = 5
iii. Importance Factor (I) = 1
iv. Rock and soil site factor (SS) = 2
v. Type of Structures = 1
vi. Damping Ratio (DM) = 0.05

Loading Combination:

1. 1.5 (DL+LL)
2. 1.2(DL+LL±EQX)
3. 1.2(DL+LL±EQY)
4. 1.5(DL±EQX)
5. 1.5(DL±EQY)
6. (0.9DL±1.5EQX)
7. (0.9DL±1.5EQY)

IV. RESULTS AND DISCUSSION

The linear dynamic analysis *i.e.* response spectrum analysis is carried out on the aforementioned building on two different height of buildings i.e. G+6 and G+12 storey buildings. And the response is compared in terms of displacement, storey drift and acceleration. The results of response spectrum analysis are shown in below figures.

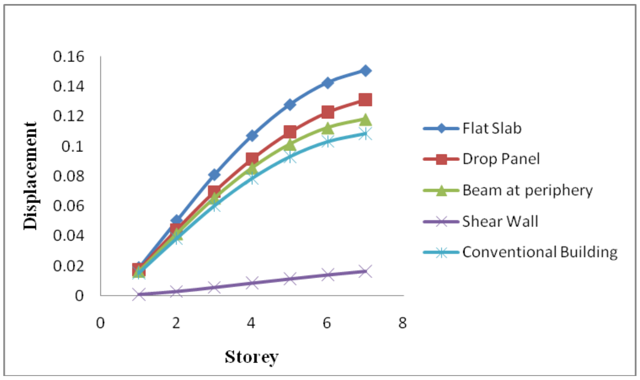

Fig.4. storey verses displacement (G+6)

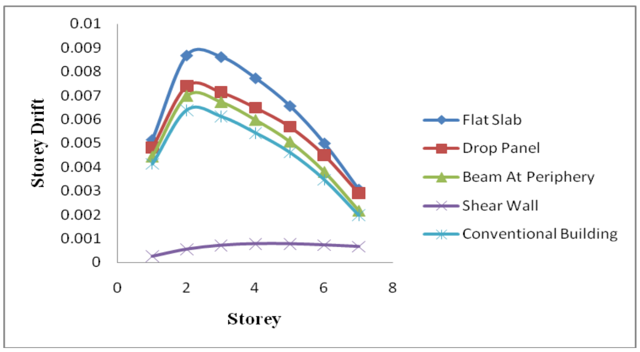

Fig.5. storey verses storey drift (G+6)

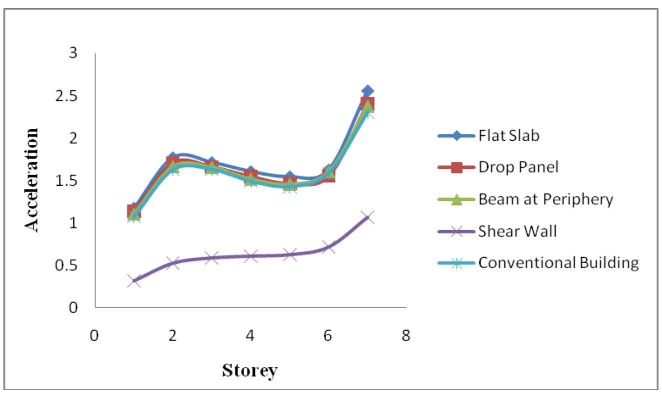

Fig.6. storey verses acceleration (G+6)

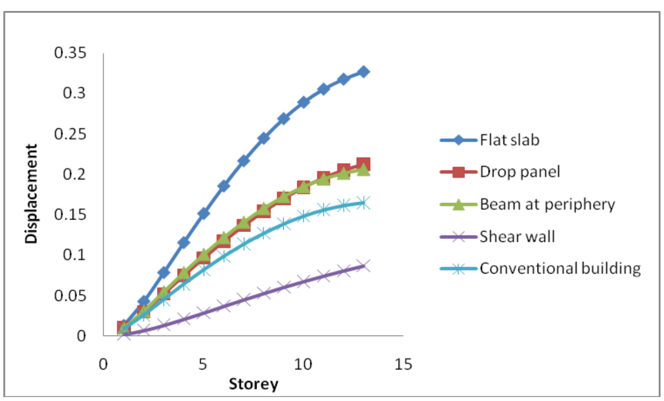

Fig.7. storey verses displacement (G+12)

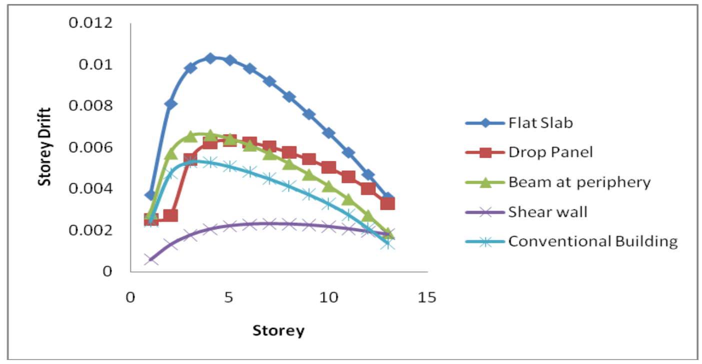

Fig.8. storey verses storey drift (G+12)

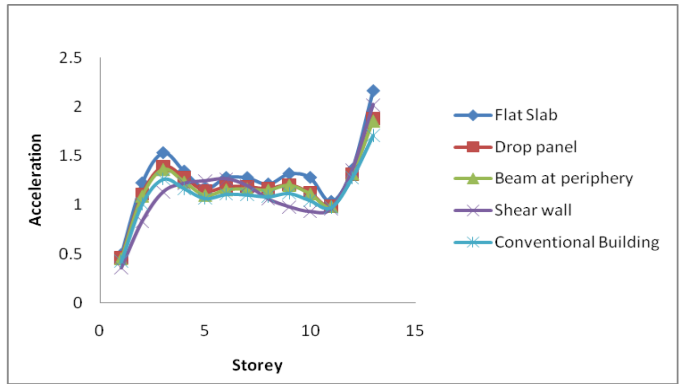

Fig.9. storey verses acceleration (G+12)

From the response spectrum analysis it is found the maximum displacement for flat slab and the maximum storey drift also found for flab slab. Min displacement found for flat slab with shear wall. Flat slab displacement is found 28% more than of conventional building for G+ 6. And 49.49% for G+12 building. Therefore it is advisable for tall building to use the shear wall.

V. CONCLUSION

This Paper presents a summary of the study, for conventional R.C.C building and flat slab building with and without shear wall, flat slab with drop panel and building with beam at periphery for seismic zone v. The effect of seismic load has been studied for these five types of buildings. On the basis of the results following conclusions have been drawn:

1. The storey displacement is found maximum for the flat slab building as compared to conventional RC building and flat slab with shear wall the maximum displacement of the flat slab building is due to the absence of lateral load resisting system.
2. The maximum storey drift found for G+6 building having a flat slab
3. The storey displacement is found least for the flat slab with shear wall. Displacement of the flat slab building is 50% larger than the conventional RC slab

G+ 12 and 30 % percent for G+ 6 building therefore in the seismically active region the shear wall is advisable.

4. For all the cases considered drift values follow a parabolic path along storey height with maximum value lying somewhere near the middle storey.
5. It is found that flat slab structures exhibit higher flexibility compared to traditional frame structures. In order to limit deformation demands under the seismic excitations, combination with other stiffer structural systems as shear-walls is advisable.
6. Base shear is found maximum for flat slab with drop panel.
7. For static analysis the displacement, storey drift and base shear came maximum as compared with dynamic analysis.

VI. ACKNOWLEDGMENT

The authors would like to thank the Department of Civil Engineering of BIT Bamni, MH, and India for their generous support.

REFERENCES

[1] Sharad P. Desai , Swapnil B. Cholekar "Seismic Behaviour Of Flat Slab Framed Structure With And Without Masonry Infill Wall", International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 7, July – 2013 ISSN: 2278-0181

[2] E. Hassaballa , M. A. Ismaeil , A. N. Alzead, Fathelrahman M. Adam, "Pushover Analysis of Existing 4 Storey RC Flat Slab Building", International Journal of Sciences: Basic and Applied Research (IJSBAR)(2014) Volume 16, No 2, pp 242-257

[3] Boskey Vishal Bahoria, Dhananjay K. Parbat "Analysis and Design of RCC and Post-tensioned Flat Slabs Considering Seismic Effect", IACSIT International Journal of Engineering and Technology, Vol. 5, No. 1, February 2013

[4] Abhijeet Kashliwal, Kaustush Dasgupta, "Parametric Study on Seismic Behaviour of Exterior Reinforced Concrete Flat plate Column Connection",15 WCEE Lisboa 2012

[5] Sandesh D. Bothara, Dr.Valsson Varghese, "Dynamic Analysis Of Special Moment Resisting Frame Building With Flat Slab And Grid Slab", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 2, Issue 4, July-August 2012, pp.275-280

[6] Prof. K S Sable, Er. V A Ghodechor, Prof. 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 (IJCTEE) Volume 2, Issue 3, June 2012

[7] R. P. Apostolska , G. S. Necevska-Cvetanovska , J. P.Cvetanovska3 and N. Mircic, "Seismic Performance of Flat-Slab Building Structural Systems", The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China

[8] Ema COELHO, Paulo CANDEIAS, Giorgios ANAMATEROS, Raul ZAHARIA, Fabio TAUCER, Artur V. PINTO, "ASSESSMENT OF THE SEISMIC BEHAVIOUR OF RC FLAT SLAB UILDING STRUCTURES", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 2630

[9] M. Altug Erberik, Amr S. Elnashai, "Fragility analysis of flat-slab structures", sciencedirect Elsevier Ltd. All rights reserved. doi:10.1016/j.engstruct.2004.02.012, Engineering Structures 26 (2004) 937–948

[10] Mohamed A. A. El-Shaer " Seismic Load Analysis of different R.C. Slab Systems for Tall Building" Vol.3, No.5 (December 2013) International Journal of Current Engineering and Technology ISSN 2277 – 4106.

[11] Dr. Uttamasha Gupta1, Shruti Ratnaparkhe, Padma Gome, "Seismic Behaviour of Buildings Having Flat Slabs with Drops", International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2, Issue 10, October 2012

[12] Woo-Seung Shin1, Jinkoo Kim"Seismic Retrofit of Flat Plate Structures", Civil Engineering and Architecture 1(1): 7-19, 2013 DOI: 10.13189/cea.2013.010102

[13] Ms. Kiran parmar , prof. Mazhar dhankot, "Comparative study between dual systems For lateral load resistance in buildings of variable heights", journal of information, knowledge and research in computer engineering", ISSN: 0975 – 6760 NOV 12 TO OCT 13 volume – 02.

[14] Paul Weidlinger and Mohammed M. Ettouney, "SEISMIC BEHAVIOR OE FLAT SLAB HIGH-RISE BUILDINGS IN THE NEW YORK CITY AREA" National Center For Earthquake Engineering Research State University of New York at Buffalo, Technical Report NCEER-88-0039 October 15, 1988

[15] David T. Finley, Ricky A. Cribbs. "Equivalent Static vs. Response Spectrum A Comparison of Two Methods", VertexRSI, 1700 International Parkway, Suite 300, Richardson, TX, USA 75081 HLA Engineers, Inc., 7267 Envoy Ct., Dallas, TX, USA 75247

[16] CSI Analysis Reference Manual for SAP2000®, ETABS®, and SAFE™.

[17] I.S. 1893-1984, Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures

Subjected to Seismic Forces. Bureau of Indian Standard, New Delhi.

[18] I.S. 875-1987, Indian Standard Code of Practice for Structural Safety of Buildings: Loading Standards (other than Earthquake) Bureau of Indian Standard, New Delhi