# Analytical Study of Flat Slabs for High Seismic Zones

Jayant Awasthy[1], Dhruv Sharma[2]

[1]*Ujjain Engineering College, Ujjain, Madhya Pradesh, India*
[2]*SKITS Indore, Madhya Pradesh, India*

***Abstract:*** **Flat slab systems are rapidly in use under recent advancement in construction practices. Since the Flat slab systems are more vulnerable to seismic effects, hence a comparative analysis is desired to know about actual behavioral response to seismic actions. In this research paper, using different techniques four modelling cases are modelled and analyzed using software STAAD PRO V8i SS6 keeping few parameters of the flat slab systems same. In the first case, Flat Slab structure with interior rectangular drop panel is modelled and analyzed for a four storeyed building having equal cantilever projection and column heads are not provided. In the Second case, flat slab resting on column with no beams is modeled and analyzed for the same building. Modelling for conventional RCC framed structure with beam & column are modeled and analyzed as the third case where slab is provided as plate element of some thickness while for the fourth case, RCC framed structure with floor load considered as slab load is modeled and analyzed for the same building. This research aims to study the effect of axial and shear forces and bending moments produced in the different elements of the framed structures for two different seismic zones. During analysis, different types of loads and load combinations along with seismic zone factors have been considered for all the cases. Peak storey lateral displacement, column forces and bending moment has been obtained and a graphical comparison for the different parameters of study. Earthquake forces are determined for Zone III and Zone V accounting IS 1893(Part-1):2002. Finally it has been concluded that Zone V parameters results are higher than Zone III. As well as in both zones flat slab systems are more flexible and also time period of vibration is less in such structures. This shows that Zone V structure needs provision of shear wall or bracing etc to avoid flexible behaviour to appropriate extent under seismic actions.**

***Keywords:*** **Flat Slab Systems, Zone III and Zone V, STADD Pro 2008Vi SS6 *SS6*, Seismic Analysis.**

## I. INTRODUCTION

Primarily purpose of all types of structural systems is to support gravity load such as dead load, live load and snow loads. Besides these vertical loads, the buildings are also subjected to lateral loads caused by wind, blasting or earthquake. Lateral loads can develop very high stresses, as well as sway movement or cause vibrations. Therefore, it is important for the structure to have adequate stiffness and sufficient lateral strength to resist lateral forces. Flat slab systems involving either drop pannel or directly resting on column are considerably more flexible for horizontal loads than the traditional RCC framed structures.

If flat slabs are provided with cantilever projections and even with variable storey heights, the behaviour of flat slabs needs to be analysed. The ductility of such structural systems is generally limited by the deformation column-slab joint. To improve the bearing capacity of the flat-slab structure under horizontal loads, adding structural elements are necessary as well as lumped mass of model is required. A flat-slab building structure is found to be useful over traditional slab-beam-column structures because of the free design of space, shorter construction time and architectural functional and economical aspects.

Framed structure modelling requires modelling techniques considering lateral stiffness for the building because the shear taking components produced by the bending of columns and slab causes the building to deflect excessively. While modelling, detailed finite element model of such building the technique of modelling includes as many as nodes and finite elements or plates or beams, special types etc. It is natural that there are technical difficulties in creating a single design model that would both comply with all design /analysis stages and enable one to allow for all important factors. It is commonly known that a design model of a structure is only an approximation of the real structure and what can be indeterminate to a great extent is the set of stiffness properties of a model.

## II. MODELLING AND NUMERICAL ANALYSIS

In this report, four different modelled structures have been analyzed using STADD pro V8i 2008Vi SS6 for Earthquake Zone-IV. Same configuration of building is used for all cases. Master slave approach is used for rigidity of floors.

*Structural Data Used*

1. Number of Storey's = 4
2. Height of Storey (GF+FF) = 4m
3. Height of Storey (SF+TF) = 3m
4. Width of building = 5m
5. Length of building = 15m
6. Cantilever projections = 1m all sides.
7. Foundation column size= 0.6 x0.6m

8. Storey column size = 0.6x0.4m (case1 &2)
9. Storey column size = 0.5x0.3m (case3 &4)
10. Size of Roof beam=0.4x0.3m
11. Size of Drop Pannel=3x2x0.25
12. Depth of Slab=200 mm.
13. Grade of Concrete= M30
14. Grade of Steel= Fe415

*Loadings Consideration:*

1. Dead Load-

a) Self Weight- Assigned via software.

b) Wall Load- Wall thickness taken for all theperipheries is 200 mm thick and a uniform load of 16 KN/m for 4m height of storey and a uniform load of 12 KN/m for 3m height of storey. Also, a uniform load of 4 KN/m for 1m height of the paraphet wall.

2. Live Load- 2.0 KN/$m^2$ for all storey& terrace.

3. Earthquake Load- As per IS 1893 (Part-I) 2002.

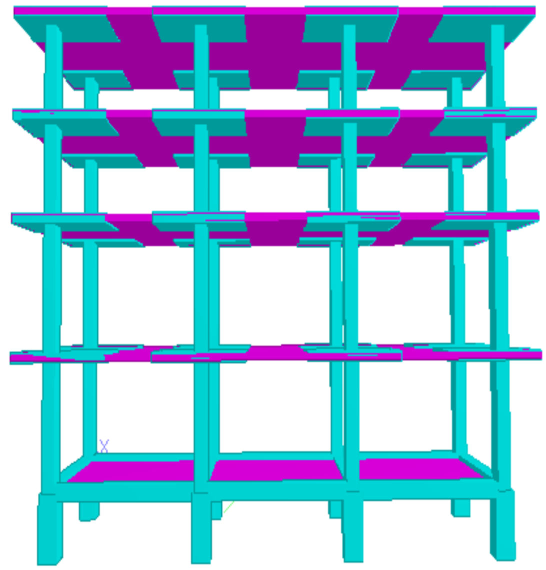
**Load Combinations Used:** As per IS 1893 (Part 1): 2002 Clause no. 6.3.1.2, the following load cases have been considered for analysis of all cases of different modelled framed structures. Also earthquake load must be considered for +X, -X, +Z and –Z directions.

- 1.5 (DL + IL)
- 1.2 (DL + IL ± EL)
- 1.5 (DL ± EL)
- 0.9 DL ± 1.5 EL

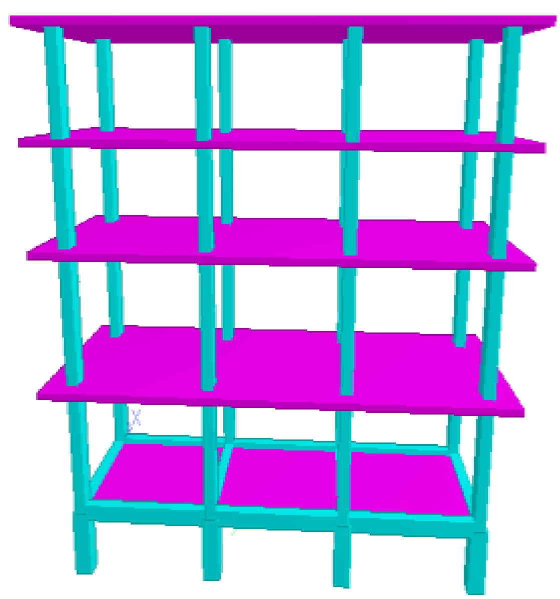
*Modelling & Problem Formulation:*

The process of modelling a framed structure consists of iterations and different techniques for accuracy in the analysis of the structure. The correct analysis of the structure will depend upon the proper modelling of the behaviour of materials, elements, connection and structure.

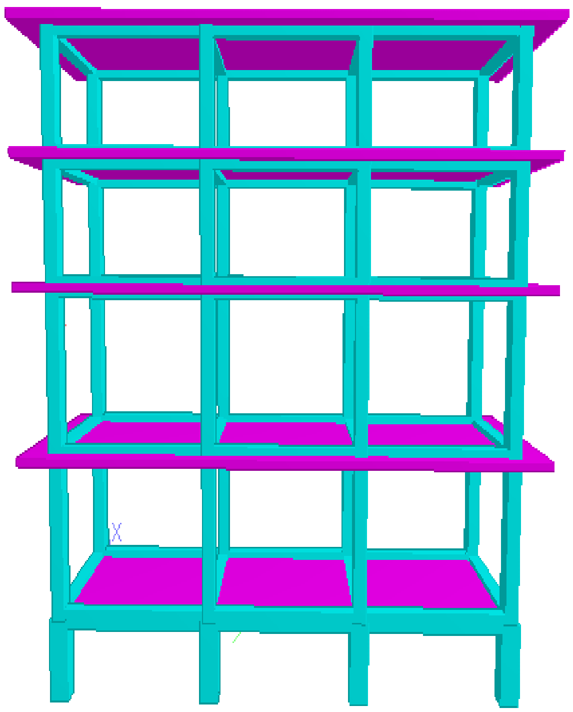
**Case 1**:- Flat Slab structure with drop panel is modeled and analyzed for a four storeyed building having cantilever projections on each side. The plan of the building is a symmetrical rectangular plan. The size of the building at ground level is 5m x 15m. The height of the ground and first storey is 4m and height of other storey is kept same equal to 3m. The size of the column provided at foundation level is 600 mm x 600 mm and the size of column at all other storey is 600 mm x 400 mm. The size of the plinth beams is 500mm x 600mm. The overall depth of the slab on all storeys is taken as 150mm. The size of the drop pannel provided is 3.0 m x 2.0 m x 0.25 m. The foundation level is kept equal to 2.0m.



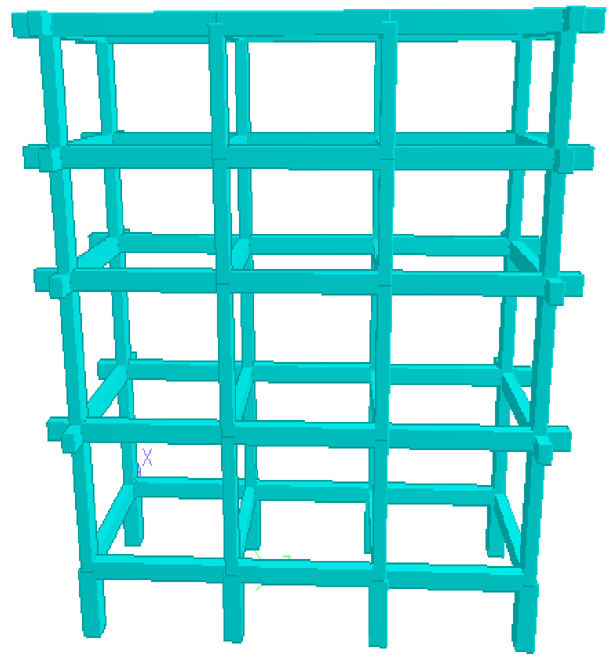
**Case 2**:- Modelling of Flat Slab resting on Columns. Flat Slab structure without drop panel and directly resting on columns is modeled and analyzed for a four storeyed building having cantilever projections on each side. A flat plate as slab element is provided resting directly on columns. The plan of the building is a symmetrical rectangular plan with same dimensions at ground level as 5m x 15m. The height of the ground and first storey is 4m and height of other storey is kept same equal to 3m. The size of the column provided at foundation level is 600 mm x 600 mm and the size of column at all other storey is 600 mm x 400 mm. The size of the plinth beams is 500mm x 600mm. The overall depth of the slab on all storeys is taken as 150mm. The foundation level is kept equal to 2.0m.



. **Case 3:-** Modelling of Conventional RCC Framed structure with plate element as slab. Conventional RCC framed structure with slab resting on beam and beam resting on column is modeled and analyzed for the same four storeyed building having cantilever projections on each side. A plate element as slab element is defined for the framed structure. The dimensions of the conventional RCC building and its components are kept same as flat slab structure.The size of the column provided at foundation level is 600 mm x 600 mm and the size of column at all other storey is 500 mm x 300 mm. The size of the roof beams provided is 400mm x 300mm. The size of the plinth beams is 500mm x 600mm.



**Case 4:-** Modelling of Conventional RCC Framed structure with floor load as slab load. Conventional RCC framed structure with slab resting on beam and beam resting on column is modeled and analyzed for the same four storeyed building having cantilever projections on each side. The slab thickness is kept 150 mm and the slab element is not provided but floor load is taken instead of slab element. The dimensions of the conventional RCC building and its components are kept same as flat slab structure The size of the column provided at foundation level is 600 mm x 600 mm and the size of column at all other storey is 500 mm x 300 mm. The size of the roof beams provided is 400mm x 300mm. The size of the plinth beams is 500mm x 600mm.

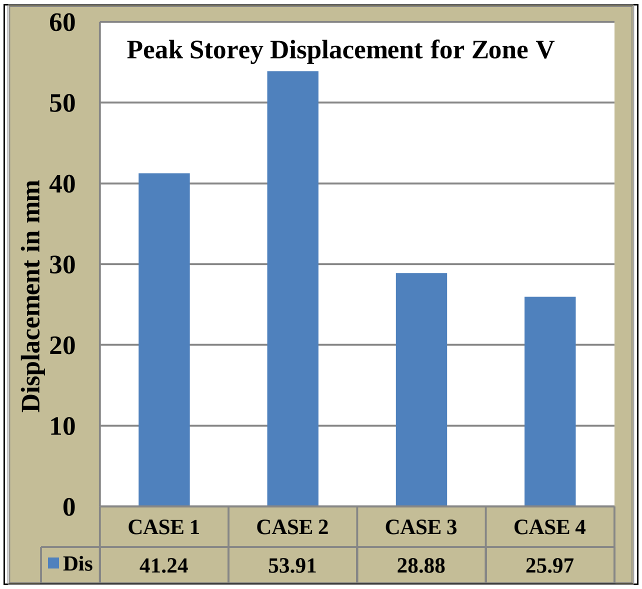


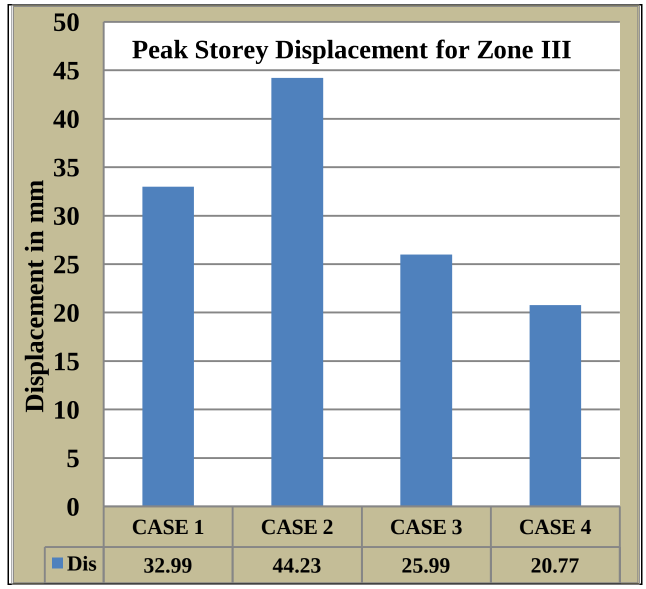
## III. RESULT AND DISCUSSIONS

This chapter describes the experimental results of analysis and design of flat slabs systems and conventional RCC framed structure by software analysis using STADD Pro v8i. The study aims at understanding the behaviour of different flat slab systems and how they behave differently from in each system and with other framed structure A comparison based on different structural parameter is madein the graphical form

*Effect of parameters studied on peak storey displacement:*

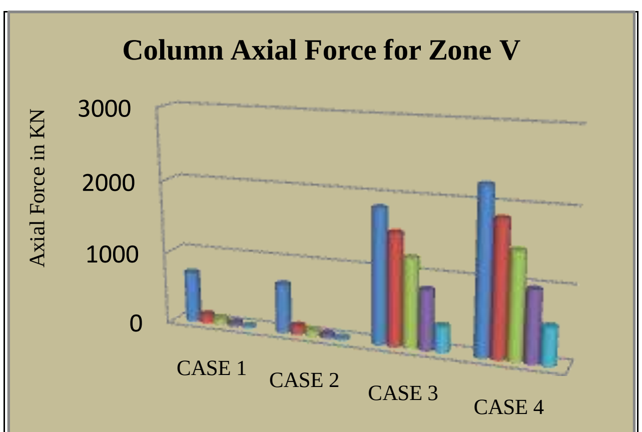
A comparative study for peak storey displacement is made and the variation in the results has been determined to conclude for the behaviour of flat slab systems. For Zone V and Zone III, it is found that flat slab systems results in increase in maximum lateral displacement for peak storey while conventional RCC framed structures are more resistant in this direction. At the same time, also it is observed that lateral displacement increases with the increase in storey height. In case of flat slab resting on columns (case2), peak storey lateral displacement (node displacement) is found to be 53.91 mm for Zone V and 44.23 mm for Zone III which is maximum. Within flat slab systems it is found that in flat slabs directly resting on columns (case 2), the lateral displacement is more then flat slab with drop pannel (case1) for both Zones. When comparative analysis is made for Zone V and Zone III the results are on safer side for both zone and still the flat plate systems undergo higher displacement. But Zone V suffers relatively higher peak storey displacement (about 21.8%higher).



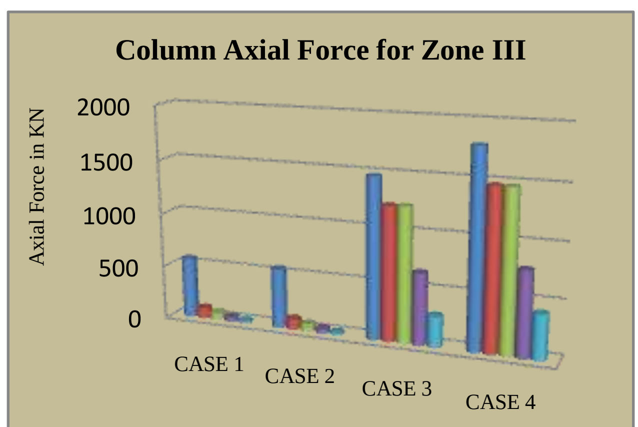




*Effect of parameters studied on Column Axial force, Shear forces and Moments:*

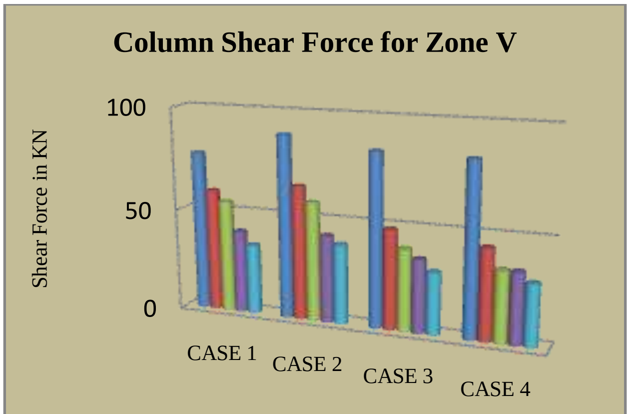
In case of flat slab systems the axial force in the columns are minimum then conventional RCC framed structures Also, it is found that axial forces decrease with the increase in the storey height. But in case of flat slab resting on columns (case2), axial force has a small variation then flat slab with drop pannel (case1). But Zone V suffers relatively higher axial forces (as in case4) and results are about 25.17% higher. In flat slab system, shear force in columns of flat plate systems are more than conventional RCC framed structures for all storeys except in foundation. The value of shear force is maximum for Zone V as compared to Zone III. Also In case of flat plate system the results are invariably higher i.e. case 2. When shear force is compared it is revealed that flat slab resting on columns (case 2) the percentage variation in Zone V is about 15.65% higher than Zone III value. When column shear is compared for interior (center corner) columns and exterior (corner) columns it is found that interior column undergoes more shear then exterior columns.



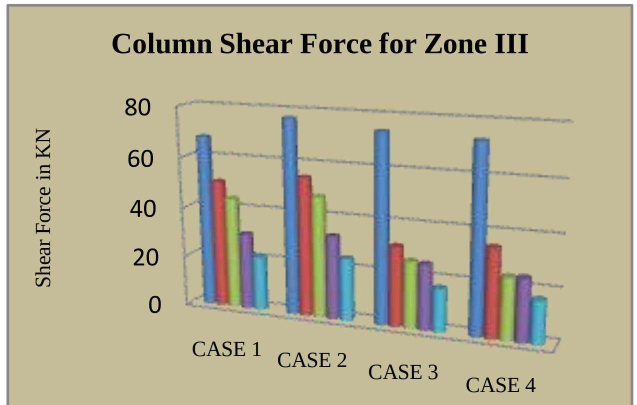

| | CASE 1 | CASE 2 | CASE 3 | CASE 4 |
|---|---|---|---|---|
| Foundation | 707.01 | 680.5 | 1847.9 | 2251.59 |
| GF | 118.75 | 118.75 | 1538.04 | 1842.77 |
| FF | 84.82 | 84.82 | 1227.62 | 1456.39 |
| SF | 50.89 | 50.89 | 826.01 | 978.81 |
| TF | 25.44 | 25.44 | 359.28 | 522.49 |




| | CASE 1 | CASE 2 | CASE 3 | CASE 4 |
|---|---|---|---|---|
| Foundation | 564.7 | 556.8 | 1478.32 | 1798.7 |
| GF | 98.7 | 98.7 | 1230.43 | 1474.21 |
| FF | 67.76 | 67.12 | 1235.4 | 1474.21 |
| SF | 41.67 | 41.67 | 660.8 | 783.2 |
| TF | 22.92 | 22.92 | 287.43 | 417.56 |

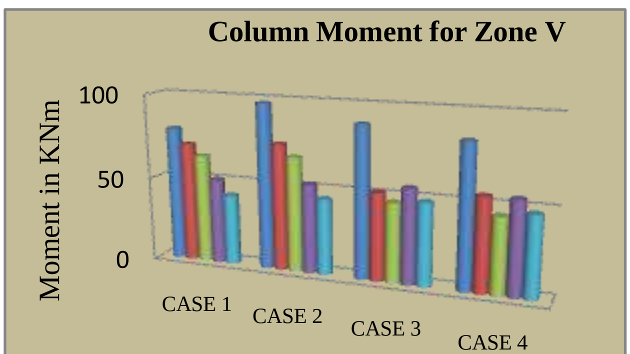



| | CASE 1 | CASE 2 | CASE 3 | CASE 4 |
|---|---|---|---|---|
| Foundation | 77.67 | 89.1 | 84.22 | 83.8 |
| GF | 59.67 | 65.27 | 48.57 | 44.32 |
| FF | 54.67 | 57.96 | 39.98 | 34.58 |
| SF | 40.45 | 42.45 | 35.67 | 34.56 |
| TF | 34.23 | 38.85 | 30.33 | 30.1 |

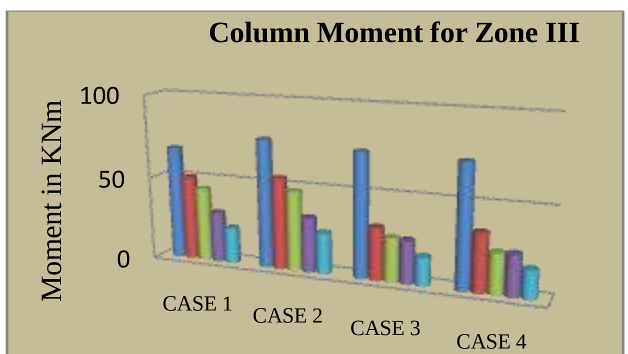



| | CASE 1 | CASE 2 | CASE 3 | CASE 4 |
|---|---|---|---|---|
| Foundation | 67.98 | 77.04 | 74.12 | 73.08 |
| GF | 50.59 | 54.89 | 31.52 | 34.83 |
| FF | 44.13 | 47.86 | 26.32 | 24.38 |
| SF | 30.31 | 32.87 | 25.77 | 24.62 |
| TF | 21.56 | 24.71 | 17.13 | 17.03 |

In case of flat slab systems, column moments in flat plate systems in Zone V are much higher than Zone III Values as well are higher from conventional RCC framed structures i.e about 26.6% higher in case II. Within the systems, Moment in flat slab systems shows that flat slab resting on columns (case 2) undergoes higher moment then flat slab with drop pannel (case 1). This is due to the effect of drop pannel. However in case of conventional RCC framed structures, moment in column is less in RCC framed structure with plate element as slab (case 3) then RCC framed structure with floor load (case 4). The column moment for more height of storey as in flat slab system shows a remarkable increase in moment then conventional RCC framed structures.



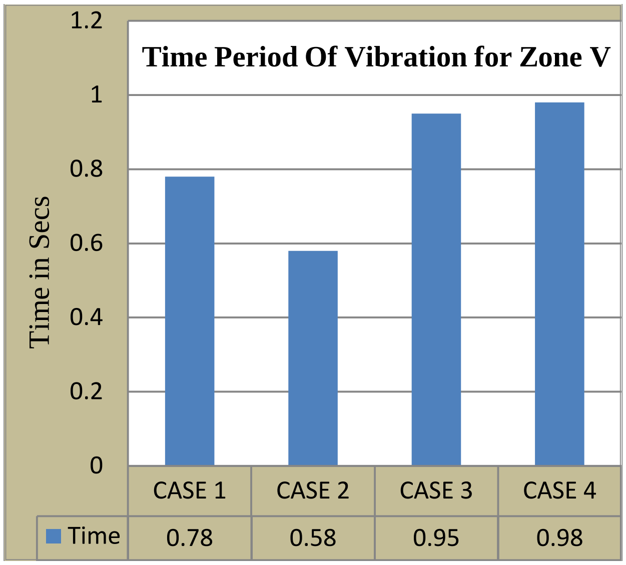

| | CASE 1 | CASE 2 | CASE 3 | CASE 4 |
|---|---|---|---|---|
| Foundation | 79.62 | 97.59 | 89.12 | 83.96 |
| GF | 70.59 | 74.67 | 51.58 | 54.89 |
| FF | 64.13 | 67.67 | 46.68 | 44.68 |
| SF | 50.58 | 52.68 | 55.59 | 54.78 |
| TF | 41.68 | 44.79 | 48.56 | 47.68 |

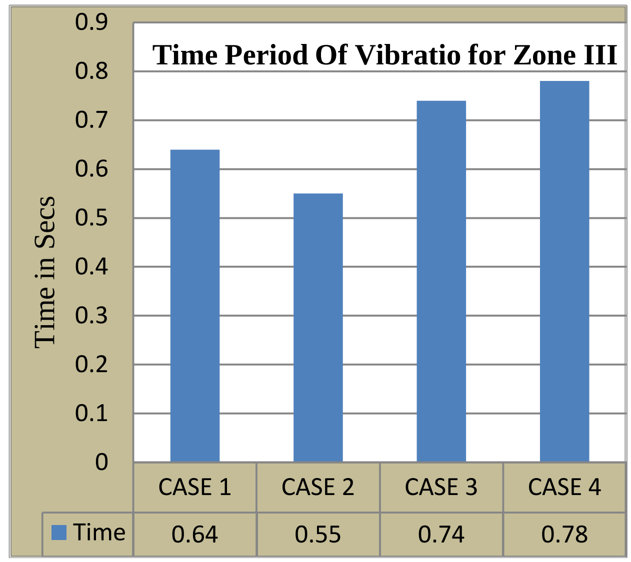



| | CASE 1 | CASE 2 | CASE 3 | CASE 4 |
|---|---|---|---|---|
| Foundation | 67.98 | 77.04 | 74.12 | 73.08 |
| GF | 50.59 | 54.89 | 31.52 | 34.83 |
| FF | 44.13 | 47.86 | 26.32 | 24.38 |
| SF | 30.31 | 32.87 | 25.77 | 24.62 |
| TF | 21.56 | 24.71 | 17.13 | 17.03 |

*Effect of parameters studied on Time Period of Vibration:*

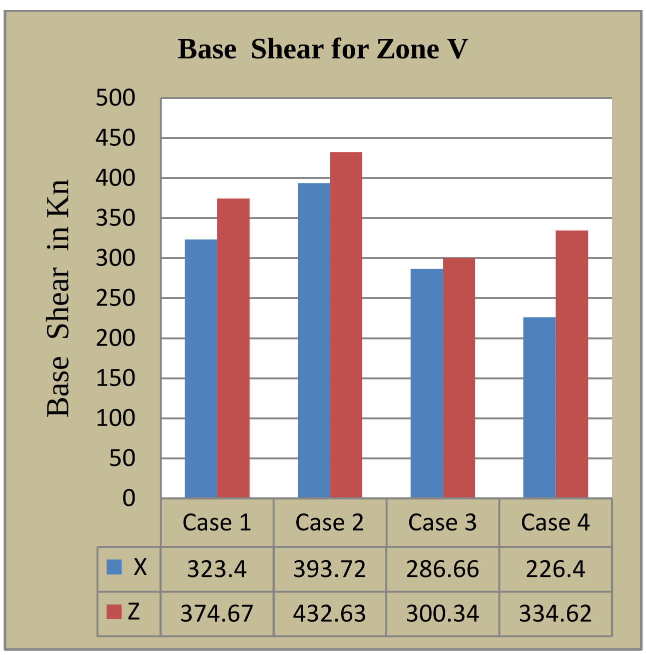
The time required for the undamped system to complete one cycle of free vibration is the natural period of vibration of the system in units of seconds. In case of Zone V of flat slab systems the time period of vibration is more than Zone III values by 25.64%.

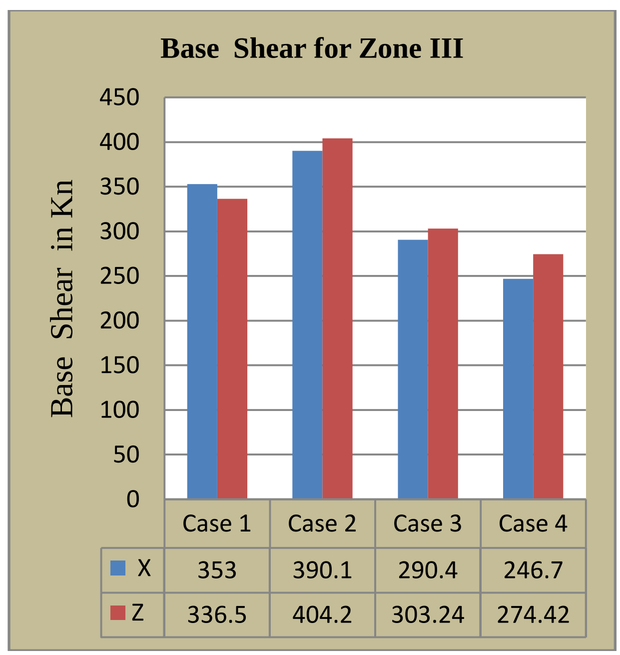



*Effect of parameters studied on Base Shear:*

The total design lateral forces or design seismic base shear (Vb) along any principal direction shall be determined by the following expression. $Vb = AhW$ .Base Shear in case of Zone V values are higher than Zone III values. Also in both zones the base shear of conventional R.C.C framed structure is found to be less than flat plate slab systems. The results for Zone V are approximately 75 higher than Zone III results



## IV. CONCLUSIONS

1. For Flat slab systems, the peak storey lateral displacement (node displacement) is found to be maximum in Zone V rather than Zone III and also maximum in the conventional RCC framed structures and also it is observed that lateral displacement increases with the increase in storey height. This study concludes that flat slab structures with cantilever projections are much more flexible in Zone V. This is due to lack of stiffness and more flexibility in flat slabs. However, cantilever projections must be provided with shear walls to avoid flexibility of structure.
2. When flat slab systems are compared within Zone V and Zone III values the axial forces, shear forces and column moments are relatively higher. This leads to the conclusion that mass difference in both structures and seismic response of the structure plays an important role during the analysis and with modelling of the structural components.
3. Base Shear of Zone V results higher values than Zone III and also in flat slab systems is rather more than Conventional R.C.C framed structure. This may be due to lack of stiffness and lateral instability of flat slab systems.
4. 4. Time period of vibration in Zone V are higher than Zone III values and also flat slab systems in both zone suffers less vibration as compared to conventional RCC framed structures. This is due to monolithic construction in RCC framed structures.

## REFERENCES

[1]. I.S. 456-2000, Indian Standard Code of Practice for Plain and Reinforced Concrete. Bureau of Indian Standard, New Delhi.

.

[2]. 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.
[3]. IS 1893 -2002: Criteria for Earthquake Resistant Design of Structures (Part 1) General Provisions and Buildings
[4]. 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.
[5]. IS 875(Part 1)-1987: Indian Standard Code of practice for design loads (Other Than earthquake) For buildings and structures, Part 1:- Dead Load, Bureau of Indian Standard, New Delhi.
[6]. Analysis and Design of Flat Slab and Grid Slab & their Cost Comparison: Amit Sathawane, R Deotale: Civil Engg Deptt, Y Chavhan College of Engg Nagpur, India
[7]. Shear stress distribution of flat-plate using Finite Element Analysis Viswanathan T, Mohan Ganesh G Santhi A Velammal Engineering College, Chennai.
[8]. Seismic Performance of Flat Slab Building Structural SystemsR. P. Apostolska, G. S. Necevska-Cvetanovska, J. P.Cvetanovska and N. Mircic
[9]. Experience of design and analysis of multistory buildings Eduard Z. Kryksunov, Mykhailo A. Mykytarenko* Oleg V. Kabantsev
[10]. Analysis and Design of RCC and Flat Slabs considering Seismic Effect (2013) Vishal Bahoria and Dhananjay Parbat
[11]. Seismic Behaviour of Buildings Having Flat Slabs with Drops Dr. Uttamasha Gupta, Shruti Ratnaparkhe, Padma Gome
[12]. Punching Shear Behaviour of Flat storey Assessment of Seismic Behaviour of RCC Flat Slab Building Structure Ema Coelho, Paulo Candeias, Giorgios Anamateros, Raul Zaharia, F Taucer, Artur V
[13]. Seismic Behaviour of Beam Column Joints in RCC Frame R Uma and A Meher Prasad
[14]. Agrawal Pankaj and Shrikhande Manish, "Earthquake resistant design of structures", Prentice Hall of India Private Limited
[15]. SP 16, "Design Aids for Reinforced Concrete", Bureau of Indian Standards, 1980.
[16]. Agrawal Pankaj and Shrikhande Manish, "Earthquake resistant design of structures", Prentice Hall of India Private Limited
[17]. Punmia B.C., Jain A.K, "RCC Designs", Laxmi Publications, 1998.
[18]. STADD pro V8i 2008Vi SS6 guide