Analysis of Flat Slab Structural System in Different Earthquake Zones of India

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Abstract - *Various researchers have defined the 'Flat Slab' as the slab witch is resting directly on supports (like columns & or walls) without provision of the beams. It is adopted normally for the office buildings where floor to floor height is constrain. Aesthetically this type of Structure is good but the performance of those buildings is quite poor. However, the structural efficiency of the flat-slab construction is hindered by its poor performance under earthquake loading so the emphasis is given in this research to compare the seismic performance of flat slab structural system with the change in seismic severity and to compare cost-effectiveness on the basis of required area of steel with a change in the seismic zone. In this study which is done on STAD.Pro V8i, it is found that the area of steel required in columns remains nearly constant or varies slightly by increasing from zone II to IV. The sharp increase in the area of steel required is observed from zone IV to zone V. The steel requirement is very high in zone V as compared to other zones. So it is recommended from this study to use a flat slab structure for zone II to zone IV but avoid the use of flat slab structure in seismic zone V in India.*

Key Words: Flat Slab, Story drift, later displacement, Earthquake, Seismic behaviour, STAAD.PRO

1. INTRODUCTION

Past earthquakes, in which many concrete buildings have been heavily damaged, have demonstrated that there is a need to evaluate the seismic adequacy of existing structures. Around 60% to 65% of our country's land area is susceptible to seismic hazard. We can't prevent potential earthquakes but good building practices will certainly reduce the intensity of loss and damage. However, flat slabs are vulnerable to substantial stiffness reductions as a natural consequence of slab cracking which can result from structural or construction loads, service gravity loads, temperature, shrinkage as well as lateral loads. Due to their inherent flexibility, flat slab systems, especially in high-rise multi-story buildings, experience excessive lateral sway (displacement) when exposed to seismic excitations or wind loads. They also possess non-ductile overall response, poor energy dissipations and local seismic hysteretic response. Adding to this, the potential of flat slab structure to undergo brittle punching shear failure is a serious issue to be considered. Due to this, Modern seismic design codes restrict the use of flat slab structural system in high seismic areas but permit its use as a vertical load resistant system.

As being one of the special reinforced concrete structural forms, flat-slab systems need further attention. They possess many advantages in terms of architectural flexibility, use of space, easier formwork and shorter construction time. However, under earthquake loading, the structural efficiency of the flat-slab construction is get affected leading to its poor performance. This is due to the lack of deep beams or shear walls in the flat-slab system resulted in inadequate lateral resistance. This results in excessive deformations even to the non-structural members while experiencing an earthquake motion.

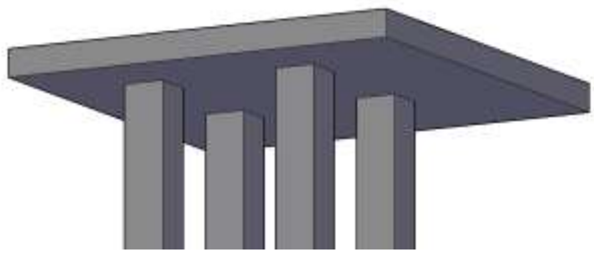


Fig -1: Flat Slab Structure directly resting on column.

The main areas of focus in this research are

• To compare the seismic performance of flat slab structural system with the change in seismic severity.

• Comparative study for change for a change in stability and strength of structure located in different seismic zone.

• To compare cost-effectiveness on the basis of the required area of steel with a change in seismic zone.

2. LITERATURE SURVEY

The seismic response of fiat slab building has been a subject of discussion science many decades. A lot of research work that taken place in this field addressing all relevant issues pertaining to the modeling analysis and construction of flat slab structures. A literature survey for seismic safety of flat slab buildings has been covered in this segment.

Bhina et al. (2013) has proposed a new technique to predict punching shear strength in the flat slab structure. The accuracy of this method to predict the failure load is somewhat good. This technique takes account of not only the size effect but also the increasing brittleness at high strength, symmetrical and unsymmetrical loading as well as reinforcement ratio. He concluded that the disadvantages can be overcome by using appropriate shear reinforcement.

H. S. Kiran and Lee (2005) have given an analytical method that can take account of stiffness degradation of the flat slab structure on the basis of lateral sway using a super element for accurate analysis. The super elements and imaginary beam were used for efficient analysis. The efficiency and accuracy of the proposed method were investigated by using three examples.

N. Subramanian (2005) has found that the shear stud reinforcement can be an economical and aesthetic solution to enhance the punching shear strength of flat slab. They enhance the shear capacity as well as result in flexural failure of the slab leading to increase in the ductility of the flat slab, which is very important in an earthquake-prone area.

Paul et al. (2013) showed that for predicting the response of two-way slab systems under lateral loads the Equivalent Frame method is not so much accurate. This method can be used as a simple approximate method.

Pradip S. Lande, Aniket B. Raut (2015) showed that the maximum storey drifts found for G+6 building having a flat slab (As compared to its maximum limit i.e. 0.04% of height). The maximum storey drifts also found for flab slab. Min displacement found for a 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 a tall building to use the shear wall. It is showed that the drift values follow a parabolic path along with storey height.

3. METHODOLOGY

The Indian Standard Codes provide some guidelines for the design of a flat slab structure. These are basically proposed on the basis of vast experiments. But these design procedures are limited in their applicability and scope as this experimentation has been carried out on standard configuration and layouts of the slabs. Currently, irregular layouts are popularly being used but standard codal procedures seem Inadequate. From the point of design philosophy, there are three methods of analysis of flat slabs which are Direct Design Method (DDM), Equivalent Frame Method (EFM) and Finite Element Method (FEM).

3.1 Finite Element Method

The structures having irregular types of plans with which the EFM has limitations in analysis can be analyzed without any difficulties by the FEM. Most finite element programs are based on elastic moment distribution and material that obey Hooke's Law. While using finite element method the considerations which are important are Choice of a proper finite element, Degree of discretization and overall computational economy.

4. NUMERICAL ANALYSIS

4.1 Numerical Modeling

The numerical modelling is done by considering a G+5 storied flat slab structure. This structure is modelled for selecting preliminary sizes of the member by manually designing adopting the guidelines given in IS 456:2000 & IS 1893:2016. The grade of concrete used for the whole structure is M35. Each panel of the flat slab is considered to be of 8m X 10m. The live load & Dead load is 5 kN/m^2 and 1.5 kN/m^2 respectively.

Table -1: Structural Properties

Size of Panel	8m X 10m
Live load	5 kN/m^2
Floor finishing load	1.5 kN/m^2
Height of floor	4.5 m
Grade of concrete	M 35
Grade of steel	Fe 415

4.2 Problem Consideration

The flat slab structural system considered in this work is modelled and analyzed which consists of a frame with 3 bays and 5 storey. Each slab consists of plate loads. The dimensions are (24m x 40 m). The dimensions and geometry are as shown below. The structure is subjected to dead load, live load, and earthquake load. (G+5) public building 24m×40m with each storey height of 4.5m which is symmetric in the plan is considered. Flat Slab thickness of 420mm is adopted. Foundation with an approximate depth of 2m from ground level on the medium type of soil is considered. The various column sizes which are taken in this work are as follows

Table -2: Column Details

Location of Column	Nomenclature	Size (mm X mm)
Corner columns	C1	600X400
Intermediate peripheral columns	C2	680X530
Interior columns	C3	680X600

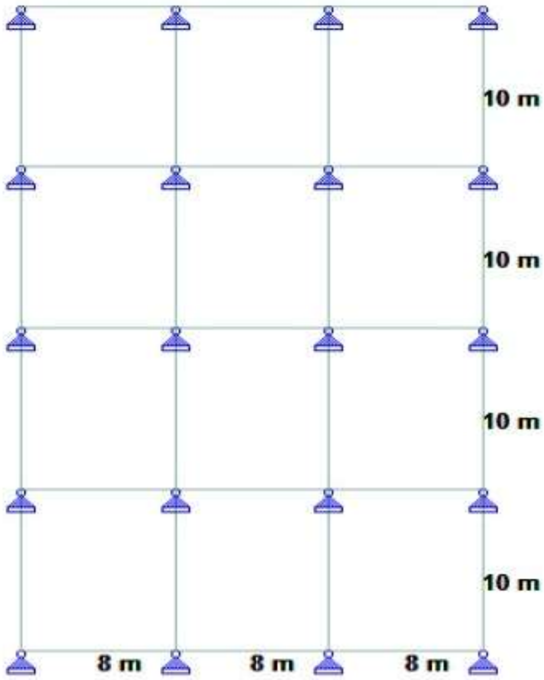


Fig -2: Plan of Flat Slab Structure.

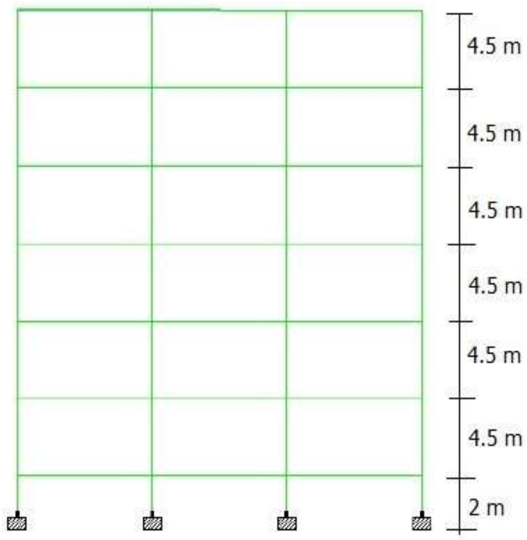


Fig -3: Elevation of Flat Slab Structure.

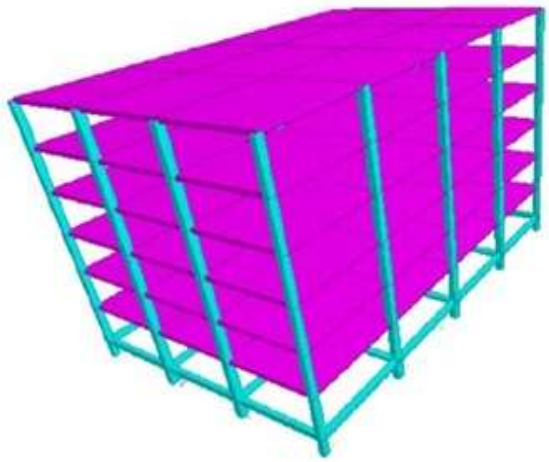


Fig -4: 3D Rendered View of Flat Slab Structure

5. DISSUCTION OF RESULTS

The study done over here with the aim to study the behaviour of flat slab structural system with the change in seismic severity has been carried out considering multistoried RCC structure with the flat slab. The modelling and analysis are done for the structure subjected to dead load, live load and earthquake load as per the criteria. The structure is analysed considering dead load, live load and earthquake loads for seismic force conditions, located in different seismic zones of India that is zone II, III, IV and V. Analysis of flat slab structure is done using STAD .Pro V8i. The seismic behaviour of the structure loaded in various seismic zones is analyzed on three benchmarks which are Steel in columns (A_{st}), Nodal displacements and Plate stresses.

5.1 Steel in Columns

Table-3 consist of steel in columns in respective seismic zones. All the columns under consideration are positioned one above the other with increasing serial number as highlighted in the following Figure-5.

Table -3: Area of steel Required

Earth quake zones	B172 Ast mm^2	B176 Ast mm^2	B180 Ast mm^2	B184 Ast mm^2	B188 Ast mm^2	B192 Ast mm^2	B196 Ast mm^2
2	6384	6055	2883	2883	1634	1085	673
3	6343	6343	2883	2883	1639	1084	1399
4	7610	7208	3607	2883	1652	1091	1734
5	25728	11491	6853	7142	9146	9743	7786

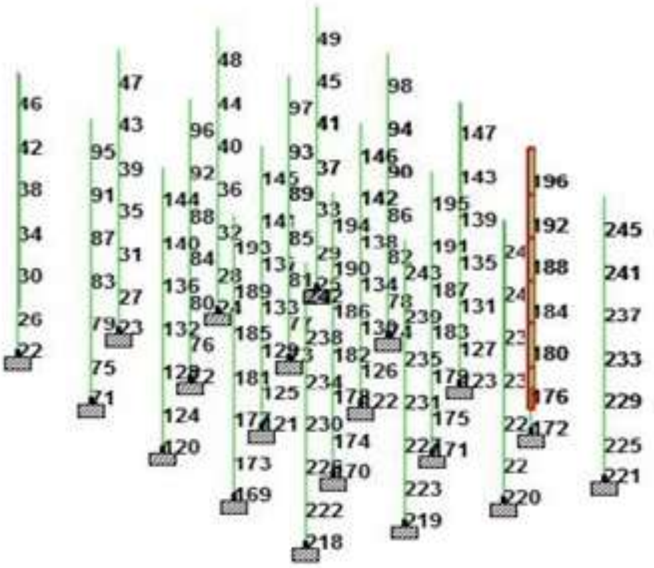
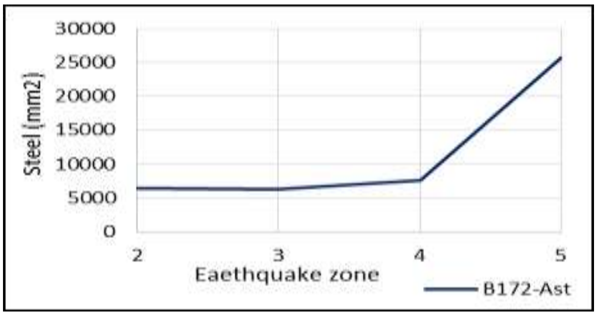
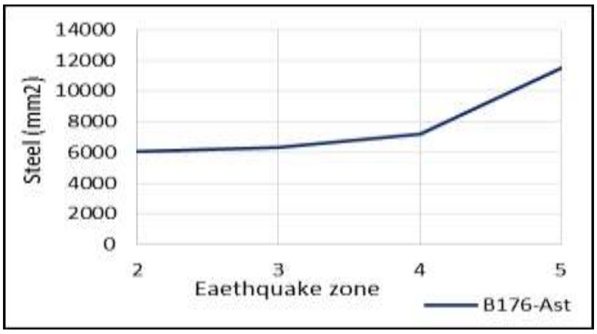
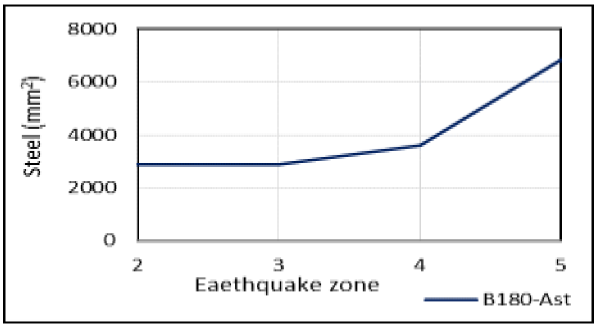


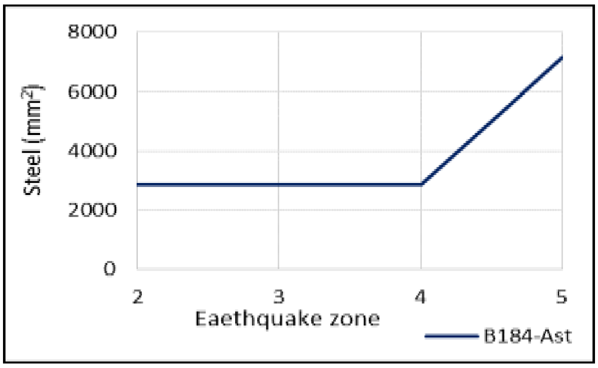
Fig -5: Column under Consideration

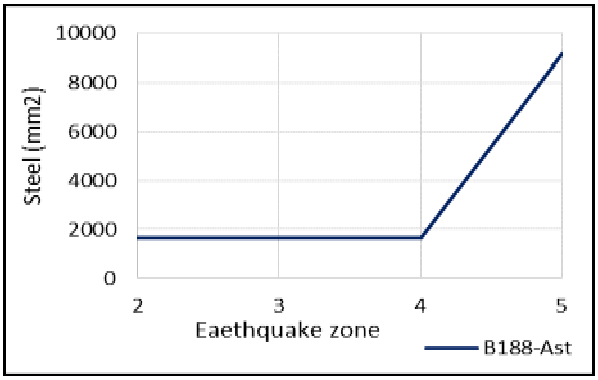
The findings of the highlighted column are tabulated below and also graphically represented in Chart below.

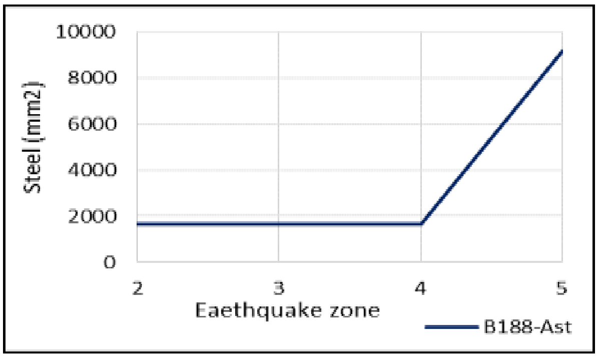












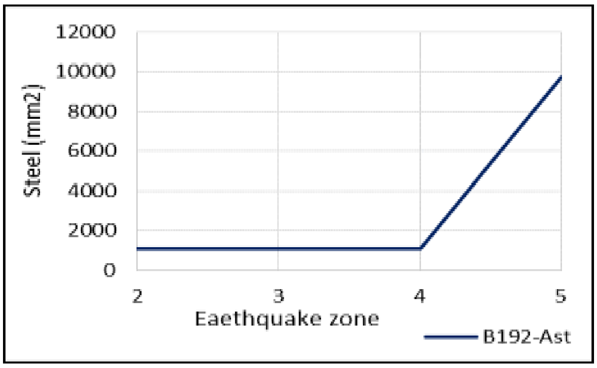


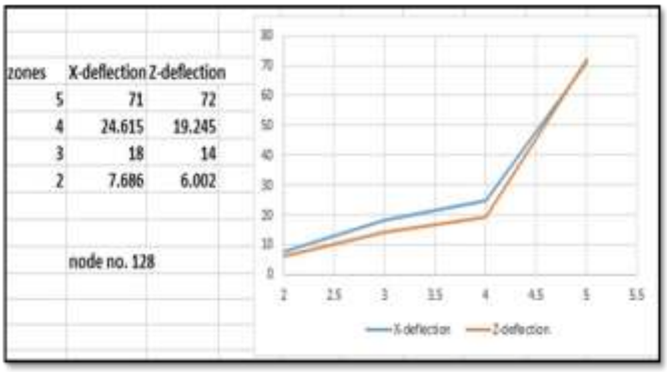
Chart -1: Graph between Steel Required Vs Seismic zones.

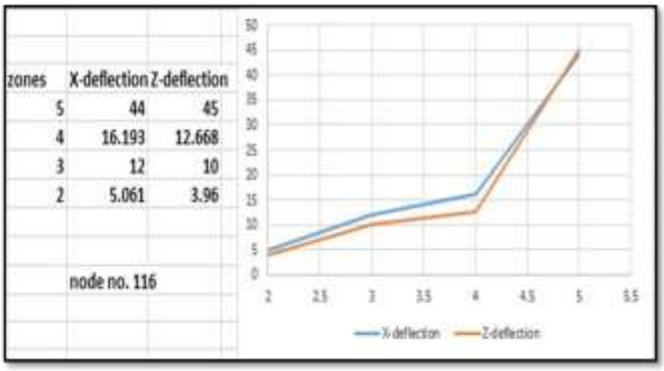
For Column B-172 the A_{st} (Area of steel required) varies slightly from zone 2-4 and from zone 4-5 there is a sharp increase in A_{st} from 7610 to 25728mm^2. The above Graph shows that for Column B-176 the A_{st} varies slightly from zone 2-3 and from zone 3-4 there is an appreciable increase. The variation in A_{st} in Column B-176 is not as sharp as in Column B-172 i.e. from 7208 to 11491 mm^2. For Column B-

180 the A_{st} remains constant from zone 2-3 and for zone 4 A_{st} increases slightly i.e. up to 3607 mm². There is a considerable increase in A_{st} from 3607 to 6853 mm². For Column B-184 the A_{st} remains constant up to zone 4. For zone 5 the A_{st} increases up to 7142mm². For Column B-188 the A_{st} remains constant from zone 2-4 and from zone 4-5 there is a sharp increase in A_{st} from 1652 to 9146 mm². Similarly from Table 3 and figure 4 the conclusions can be drawn are From Column B-172 to B-196 i.e. from the bottom column towards the top column the area of steel required goes on decreasing. For the column highlighted the area of steel required remains nearly constant or varies slightly by increasing from zone 2 to 4. There is the a sharp increase in A_{st} required is observed from zone 4 to zone 5 and The steel requirement is very high in zone 5 as compared to other zones. The area of steel required goes on decreasing from the bottom column towards the top column. The area of steel required in columns remains nearly constant or varies slightly by increasing from zone 2 to 4. The sharp increase in the area of steel required is observed from zone 4 to zone 5.The steel requirement is very high in zone 5 as compared to other zones.

5.2 Nodal Displacements

Variation of nodal displacement with respect to different seismic zone is shown below with the help of graph plotted between zones on X-axis and Nodal displacement on Y-axis. On the same graph deflection in two direction are shown i.e. in X and Z direction.





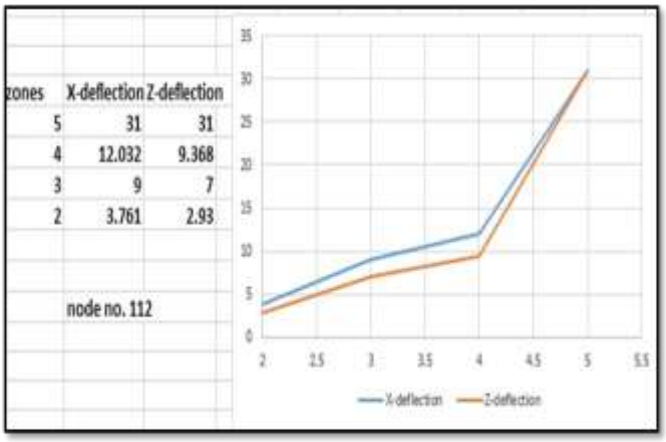
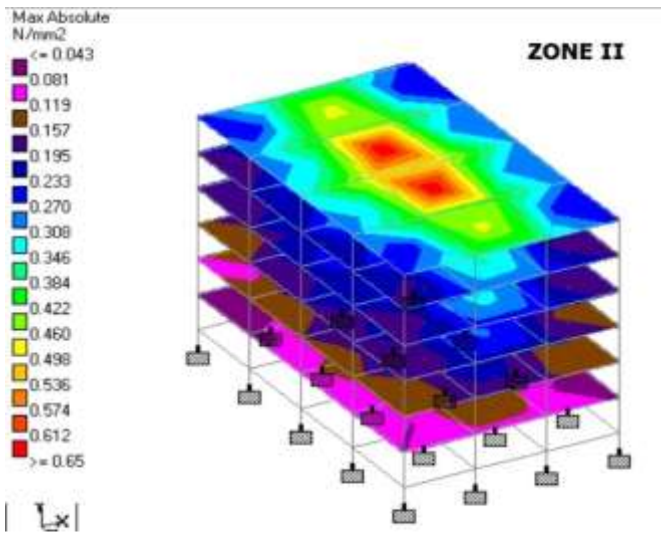


Chart -2: Graph Showing Deflection at various nodes.

From this, we can say that all three graphs are approximately the same with some variations which show that deflection is minimum at bottom and maximum at the top for the column under consideration. The above graphs show that there is a slight variation in the nodal displacement from zone 2 to zone 4 but as the zone changes from 4 to 5 the deflection changes suddenly. The graph for nodal displacement in X and Z direction is nearly parallel. Maximum displacement at the top is found to be 72 mm in both the direction which occurs in zone 5 and is very large as compare to zone 2, 3and 4. The nodal displacements are observed to be increasing from lower nodes to higher nodes.it is also observed that the increase in the nodal deflection decreases with the height of the structure. Analysis of Flat Slab structural system It is observed that the nodal deflections in X and Z directions are least in zone II and are maximum in zone V. Variation is observed very slight in zone II to zone III, zone III to zone IV, but the variation between zone IV and zone V is considerably steep.

5.3 Plate Stresses



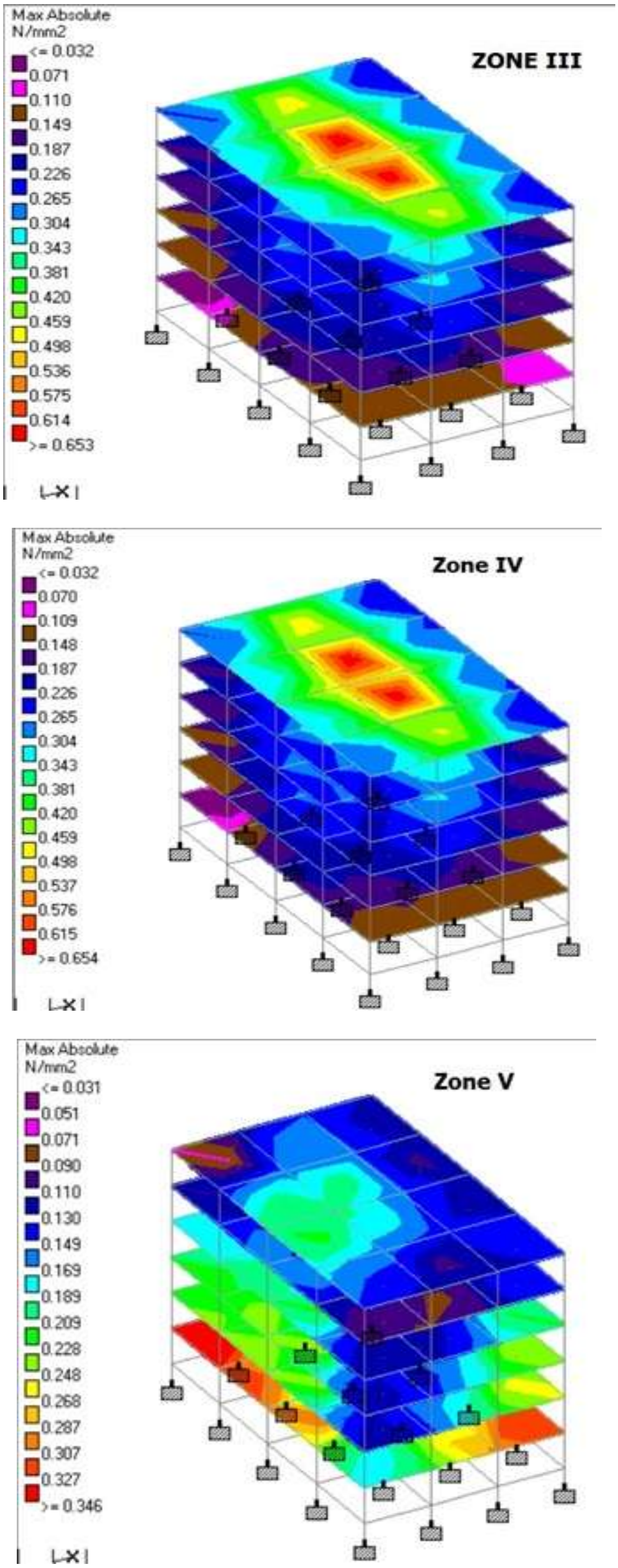


Fig -6: Plate Stresses Contours.

The variation of plate stresses is shown in the Figure for various seismic zones in India. These Figures also show the displacement of structure occurring in X and Z direction from its original position. From the stress contours, it can be stated that the plate stresses goes on increasing as the storey increases for zone 2 to 4. But for zone 5 plate stresses go on decreases as the number of storey increases. As shown in the pink colour indicate the minimum stresses in a plate and the red colour shows maximum stresses. For zone 2 to 4 maximum stresses are concentrated at the center plates when compared with the peripheral plates at each storey but for zone 5 plate stress is maximum at the periphery and minimum at the center.

6. CONCLUSION

Analysis of flat slab structure is done using STAD .Pro V8i. From the analysis, it is observed that the flat slab structure is stable in all zones II, III and IV, but found unstable and failed in zone V. From the analysis and observations drawn it can be seen that the steel requirement is very high in zone 5 as compared to other zones. Higher the storey greater is the plate stresses for zone II, III & IV but for zone V higher the storey less are the plate stresses. Stress concentration observed is not uniform in this zone (zone V). In general minimum stresses are observed at the center plates when compared with the peripheral plates at each storey. Variation is observed very slight in zone II to zone III, zone III to zone IV, but the variation between zone IV and zone V is considerably steep for nodal displacement. The overall behaviour of flat slab structural system in different seismic zones shows that it is more stable and economic in zone II while its construction is not affordable in zone V. So it is recommended from this study to use a flat slab structure for zone II to zone IV but avoid the use of flat slab structure in seismic zone V in India.

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