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Comparative Study on RC Frame, Flat Slab Frame, Flat Plate Frame and Pre-stressed Slab Frame with Shear Wall and Without Shear Wall in Seismic Region

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ABSTRACT - In urban areas, increase in population and scarcity of land, the horizontal development gets restricted that's why most of the owners, building contractors, engineers are adopting vertical development of buildings for the construction. Natural hazards like earthquake, affects the stability of such structures. Previous studies reveal that major failures of structures occurred due to improper design procedures. Therefore, it is the need of the time to analyze and design such hazard resisting structures so, to save human life and avoid property damage. The aim of this study is to compare the different types of multistorey frame structures subjected to seismic forces. In the present work 4 types of multistorey buildings are considered such as RC building, flat slab building, flat plate building and prestressed slab building with shear wall and without shear wall. Location of shear wall is considered at side and corner position of the building. The said building models are analyzed by response spectrum method using SAP 2000 software by considering zone IV and medium type soil. The parametric study was done by considering time period, base shear, top displacement and storey acceleration. From the study it is observed that, the time period is maximum in flat plate and minimum in flat slab structure with shear wall located at corner.

Keyword: Reinforced concrete frame; flat slab frame; flat plate frame; prestressed slab frame; shear wall; SAP 2000; response spectra analysis.

I. INTRODUCTION

India at present is a fast growing economy, which brings about demand in increase of infrastructure facilities along the growth of population. The shortage of land in urban region is increasing day by day. It is imperative that land available for forming and agriculture remains intact. To cater the land demand in these regions, vertical development is the only option. This type of development brings challenges to counteract additional lateral load due to wind and earthquake [1]. The flat-slab system is a special structural form of reinforced concrete construction that possesses major advantages over the conventional frames. The former system provides architectural flexibility, lower building height, easier formwork and shorter construction time.

A. Flat Slab

Common practice of design and construction is to support the slabs by beams and support the beams by columns. This may be called as beam-slab construction. The beams reduce the available net clear ceiling height. Hence in warehouses, offices and public halls sometimes beams are avoided and slabs are directly supported by columns. This type of construction is aesthetically appealing also. These slabs which are directly supported by columns are called flat slabs [2]. This type of construction of reinforced concrete buildings with flat slab systems has become widely used in some high seismicity European countries. This type of structures is particularly common in South European countries, such as Italy, Spain and Portugal, both for office and residential buildings.

B. Flat Plate

Flat Plates are solid concrete slabs of uniform depths that transfer loads directly to the supporting columns without the aid of beams or capitals or drop panels. Flat plates are probably the most commonly used slab system today for multi-storey reinforced concrete hotels, apartment houses, hospitals, and dormitories. Flat plates can be constructed for a thickness of 125-250 mm for spans of 4.5-6 m. Flat Plate Systems have an advantage of introducing an edge beam at the periphery of the panel to reduce the deflection of the exterior panel of the plate. The main disadvantage in Flat slabs and Flat plates is their lack of resistance to lateral loads, hence special features like shear walls, structural Walls are to be provided, if they are to be used in High rise constructions.

C. Prestressed Slab Building

As the floor system plays an important role in the overall cost of a building, a post-tensioned floor system is invented which reduces the time for the construction and finally the cost of the structure. In some countries, including the U.S, Australia, South Africa, Thailand and India, a great number of large buildings have been successfully constructed using post-tensioned floors. The reason for this lies in its decisive technical and economical advantages. According to

Park.E.H.Kim *et al* [1] and Y. H. Luo, A. Durrani [2] the most important advantages offered by post-tensioning systems are as follows -

- By comparison with reinforced concrete, a considerable saving in concrete and steel since, due to the working of the entire concrete cross-section more slender designs are possible.
- Smaller deflections compared to with steel and reinforced concrete structures.
- Good crack behavior and therefore permanent protection of the steel against corrosion.
- High fatigue strength, since the amplitude of the stress changes in the prestressing steel under alternating loads are quite small [3].

D. *Shear Wall (SW)*

Shear wall are one of the excellent means of providing earthquake resistance to multistoried reinforced concrete building**.** The structure is still damaged due to some or the other reason during earthquake. Behavior of structure during earthquake motion depends on distribution of weight, stiffness and strength in both horizontal and vertical planes of building. To reduce the effect of earthquake, reinforced concrete shear walls are used in the building. These can be used for improving seismic response of buildings. Structural design of buildings for seismic loading is primarily concerned with structural safety during major Earthquakes, in tall buildings, it is very important to ensure adequate lateral stiffness to resist lateral load [4]. Shear walls are usually used in tall buildings to avoid collapse of buildings Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents.

E. Objectives of the Work

The objective of the present work is to compare the behavior such as base shear, time period, storey acceleration and top displacement for RC frame building, flat slab building, flat plate building and prestressed slab building with shear wall and without shear wall using response spectrum analysis.

II. DESCRIPTION OF BUILDING

In the present work 8, 12 and 16 storey regular plan buildings situated in zone IV, are considered. For the study RC frame, flat slab frame, flat plate frame and prestressed slab frame with shear wall (SW) and without shear wall (SW) are taken. This study includes modeling and analysis of the models by using standard analysis software SAP 2000. Material properties and section properties are defined and assigned. Reinforced concrete frame elements are modeled as beam and column elements. Slab is modeled as an area element. Response spectrum analysis is performed. For this study, four types of building models are considered for the comparison.

A. Models Considered For Analysis

Model 1: RC frame building
Model 1 (a): RC frame building with SW at side
Model 1 (b): RC frame building with SW at corner
Model 2: Flat slab building
Model 2 (a): Flat slab building with SW at side
Model 2 (b): Flat slab building with SW at corner
Model 3: Flat plate building
Model 3 (a): Flat plate building with SW at side
Model 3 (b): Flat plate building with SW at corner
Model 4: Prestressed slab building
Model 4 (a): Prestressed slab building with SW at side
Model 4 (b): Prestressed slab building with SW at corner

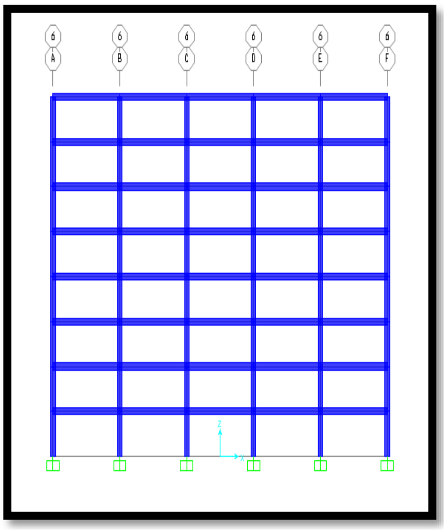

Fig.1:.Elevation of RC frame building

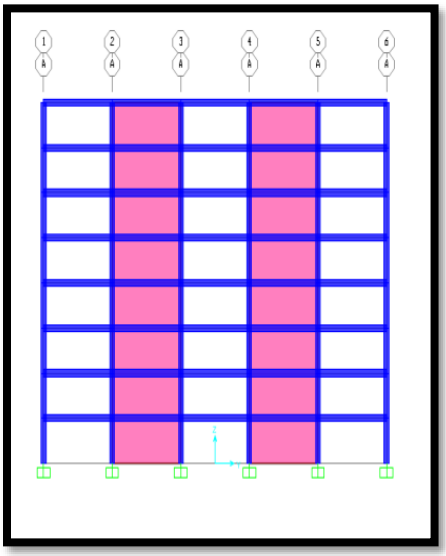

Fig.1(a): Elevation of RC frame building with SW at side

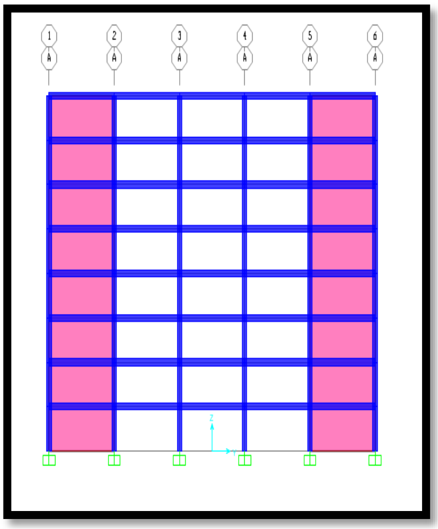

Fig.1 (b): Elevation of RC frame building With SW at corner

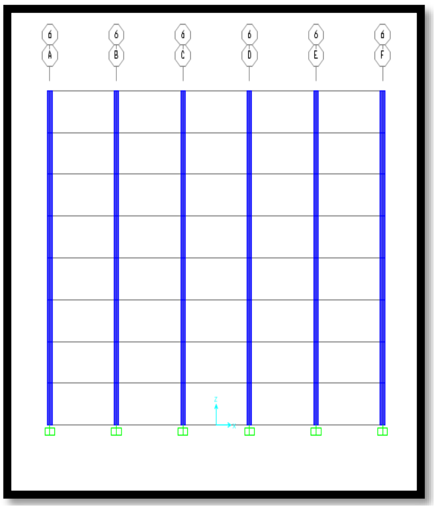

Fig.2: Elevation of flat plate frame building

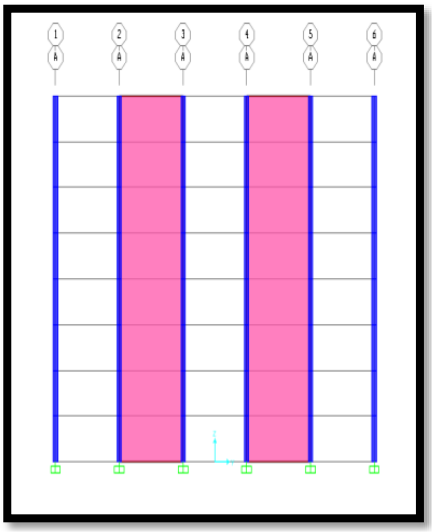

Fig.2 (a): Elevation of flat plate building with SW at side

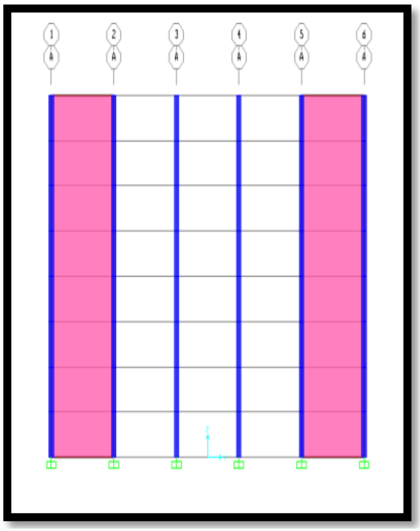

Fig.2 (b): Elevation of flat plate building With SW at corner

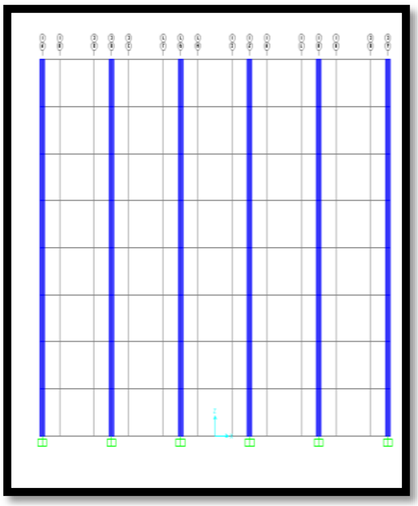

Fig.3: Elevation of flat slab building

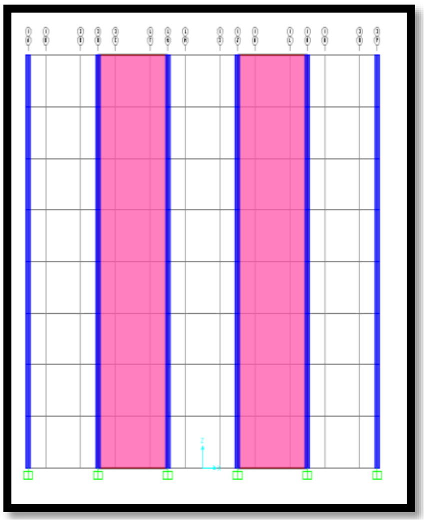

Fig.3 (a): Elevation of flat slab Building with SW at side

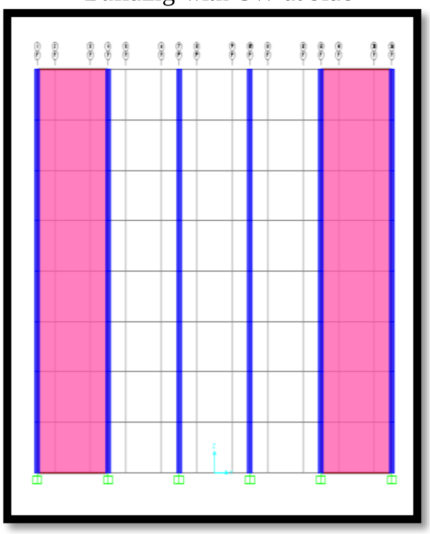

Fig.3 (b): Elevation of flat slab frame building with SW at corner

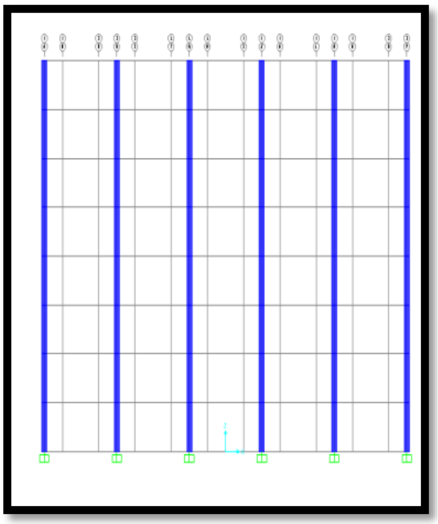

Fig.4: Elevation of prestressed slab frame building

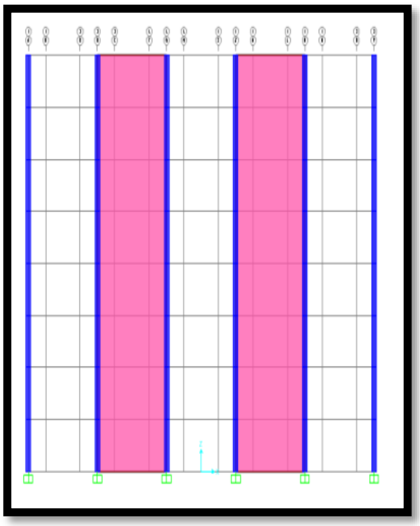

Fig. 4 (a): Elevation of prestressed building
With SW at side

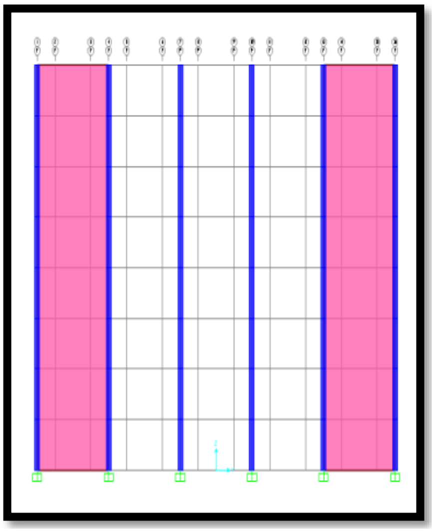

Fig.4 (b): Elevation of prestressed building
With SW at corner

The Above data considered for the building of different heights

1. G+7 Building model

2. G+11 Building model
3. G+15 Building model

B. Building Data

For all four Building models, the following data are used for analysis.

C. Details of Building

Type of structure: Multi-storey RC frame structure
Type of building: Commercial Building
Number of stories: 8 (G+7), 12 (G+11), 16 (G+15)
Floor to floor height: 3.6 m
Type of Soil: medium type

D. Materials

M30- grade concrete
Fe-500 steel

E. Member dimensions

Column size: For (G+7) building 550x550 mm, (G+11) building and 16 (G+15) building 600x600 mm.
Slab thickness: 200 mm for all the cases
Beam Size: 550 mm x 550 mm taken for NRCB
Drop size: For (G+7) building 400x400 mm, (G+11) building and (G+15) building 450x450 mm.

F. Earthquakes data

Zone (Z) = IV
Response reduction factor (R) = 3
Importance factor (I) =1.5
Rock and soil site factor (SS) = 2
Type of structures = 1
Damping ratio (DM) = 0.05

III. RESULTS AND DISCUSSION

The forces and displacements developed in each members of the structure are obtained from the analysis and discussed in this section. Further, these results have been used for understanding the behaviour of the structure for RC frame, flat slab frame, flat plate frame and prestressed slab frame with shear wall (SW) and without shear wall (SW) building, under the effects of lateral loads.

A. Base Shear

The total horizontal force on the structure is calculated on the basis of structural mass and fundamental period of vibration and corresponding mode shape. The base shear is distributed along the height of the structure in terms of lateral force. The results of models without shear wall are shown in figure 5.

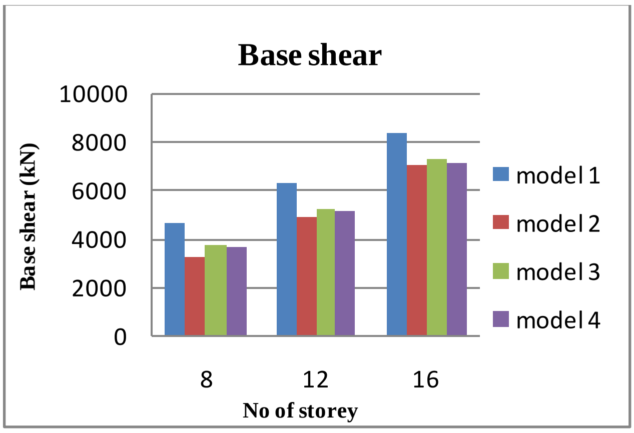

Fig. 5: Variation of No. of storey V/s Base shear

From the figure, it can be observed that, due to symmetry of the building, the base shear will be same in both the directions (V_x and V_y). From the figure, it can be seen that, on increasing the number of storeys the base shear increases. The base shear is maximum in RC frame and is minimum in flat plate compared to other models. Base shear in model 2, model 3 and model 4 is decreased by 16% , 13% and 15% compared to model 1.

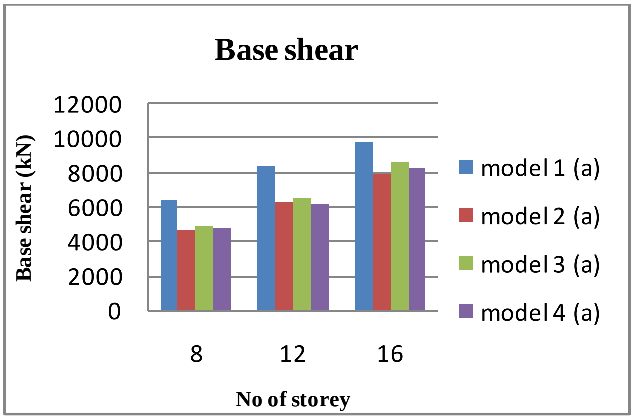

Fig. 5 (a): Variation of No. of storey V/s Base shear SW at side

Figure 5 (a) shows the base shear of models with shear wall located at the side position of the building. The base shear of flat plate building with shear wall located at sides of the building is less compared to other models. From the above figure 5 (a), it can be seen that, the base shear in model 2 (a) is decreased by 24 % as compared to model 1 (a), in model 3 (a) Base shear is decreased by 22 % compared to model 1 (a) and it is decreased by 28 % in model 4 (a) compared to model 1 (a).

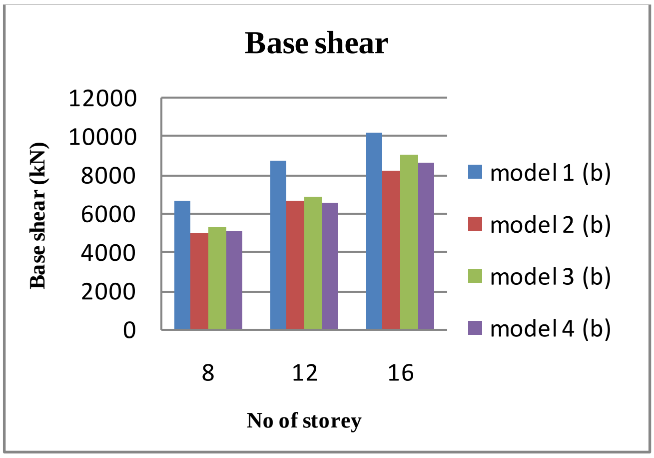

Fig. 5 (b): Variation of No. of storey V/s Base shear SW at corner

Base shear of models with shear wall placed at corner position of the building is shown in figure 5 (b). The base shear is minimum in flat plate frame with shear wall located at corner position of the building compared to other models. Figure 5 (b) shows that, the base shear is decreased by 23%, 20% and 26% in model 2 (b), model 3 (b) and model 4 (b) compared to model 1 (b).

B. Time Period

Time required for undamped system to complete one cycle of free vibration is the natural period of vibration of the system in the units of second. Figure 6 shows the variation of natural time period with number of storeys for different models.

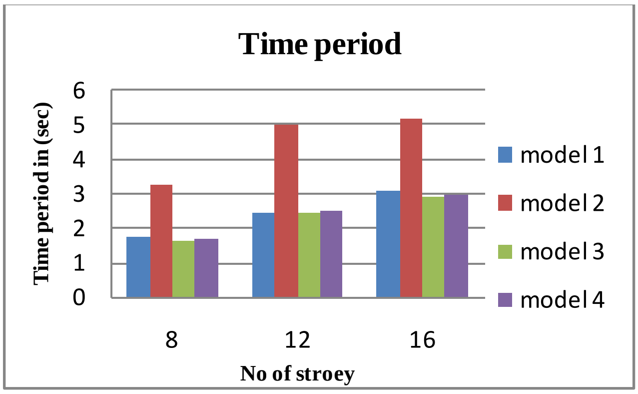

Fig. 6: Variation of No. of storeys V/s Time period

From figure 6, it is observed that, the natural time period increases as the number of storey increased. Due to symmetry of the building, the time period will be same in both the directions (T_x and T_y). Figure shows that, the time period is more for flat plate building compared to other models. From the figure it is observed that, the time period of model 2 is increased by 68% as compared to model 1, in model 3 time period is decreased by 6% compared to model 1 and it is increased by 3% in model 4 compared to model 1.

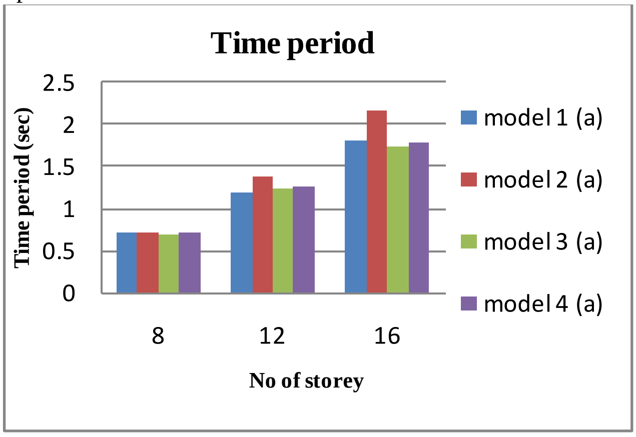

Fig. 6 (a): Variation of No. of storeys V/s Time period SW at side

Figure 6 (a) represents the time period of models with shear wall located at the side position of the building. The time period is more in the model 2 (a) compared to other models. From the figure 6 (a), it is observed that, the time period is increased by 16%, 4% and 6% in model 2 (a), model 3 (a) and model 4 (a) compared to model 1 (a).

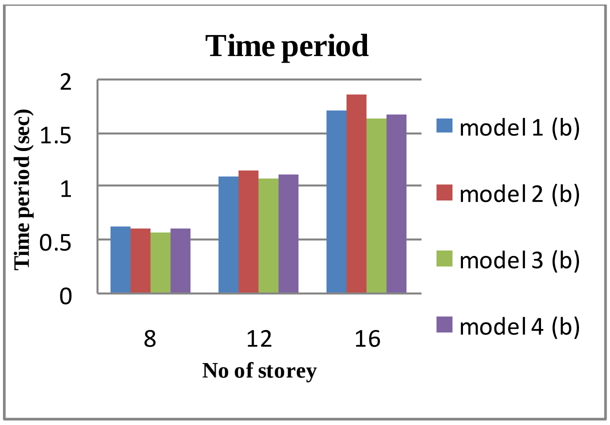

Fig. 6 (b): Variation of No. of storeys V/s Time period SW at corner

In the figure 6 (b) the time period of models with shear wall placed at corner position of the building is shown. The time period is more in flat plate building. From the figure 6 (b), it is observed that, the time period in model 2 (b) is increased by 4% as compared to model 1 (b), in model 3 (b) time period is decreased by 3 % compared to model 1 (b) and it is increased by 2 % in model 4 (b) compared to model 1 (b).

C. Lateral Displacement

Lateral displacement is the displacement of centre of mass, according to IS 456: 2000 the maximum limit for lateral displacement is H/500 where H height of building. The lateral displacement obtain by response spectrum analysis in X and Y direction for zone IV are shown in the below figure 7.

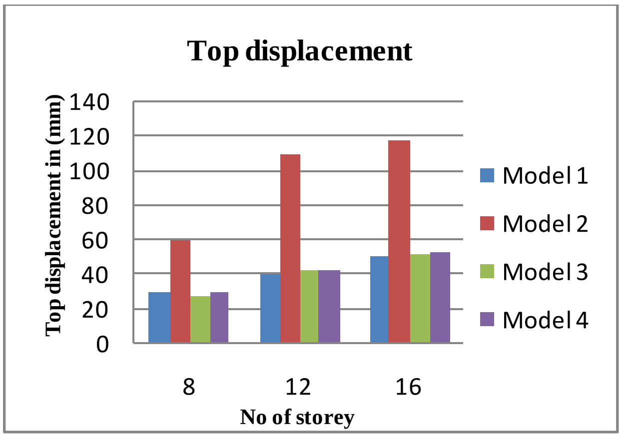

Fig. 7: Variation of No.of storey V/s Top displacement

From the figure, it can be seen that, lateral displacement increases as the storey level increases. Lateral displacement will be minimum at plinth level and maximum at terrace level. Due to symmetry of the building, the lateral displacement will be same in both the directions (U_x and U_y). From the figure, it is observed that, in flat plate (model 2) the lateral displacement increases drastically as the number of storeys increased. Top displacement is minimum in RC frame building compared to other models. Top displacement in model 2 is increased by 98% as compared to model 1, in model 3 top displacements is increased by 8% compared to model 1 and it is increased by 10% in model 4 compared to model 1.

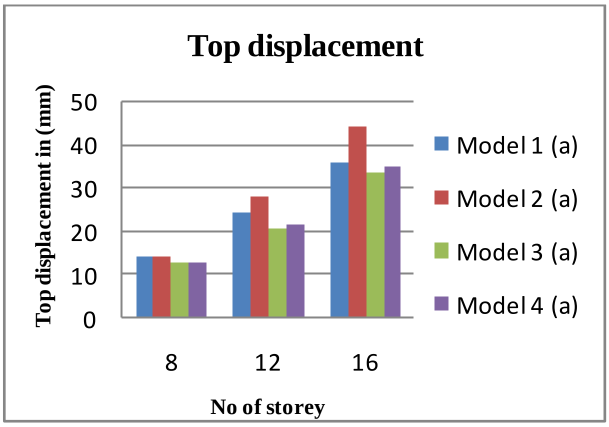

Fig. 7 (a): Variation of No.of storey V/s Top displacement SW at side

The variation of top displacement with number of storeys for different models is shown in figure 7 (a). Figure shows that, the top displacement in model 2 (a) is increased by 14% as compared to model 1 (a), in model 3 (a) top displacements is decreased by 16 % compared to model 1 (a) and it is decreased by 13 % in model 4(a) compared to model 1(a). On increasing the number of storeys, the top displacement increases. From the figure 7 (a) it is observed that, the top displacement is maximum for model 2 (a) and minimum in model 3 (a).

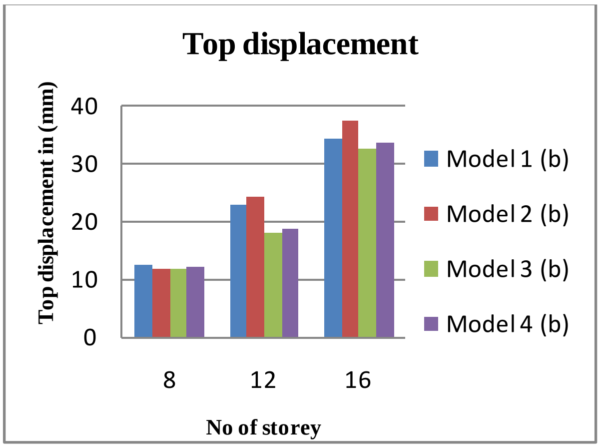

Fig. 7 (b): Variation of No.of storey V/s Top displacement SW at corner

Shear wall is considered at corner position of the building, the variation of top displacement with number of storeys for different models is shown in figure 7 (b). From the figure 7 (b) it is observed that the top displacement in model 2 (b) is increased by 6% as compared to model 1 (b), in model 3 (b) top displacements is decreased by 22 % compared to model 1 (b) and it is decreased by 18 % in model 4 (b) compared to model 1 (b). The top displacement is maximum for flat plate building.

D. Storey Acceleration

It is the factor denoting the acceleration response spectra of the structure subjected to earth quake ground vibration, and depends on the natural period of vibration and damping of the structure. The top storey acceleration obtained by response spectrum analysis for zone IV and are represented in the below figure 8.

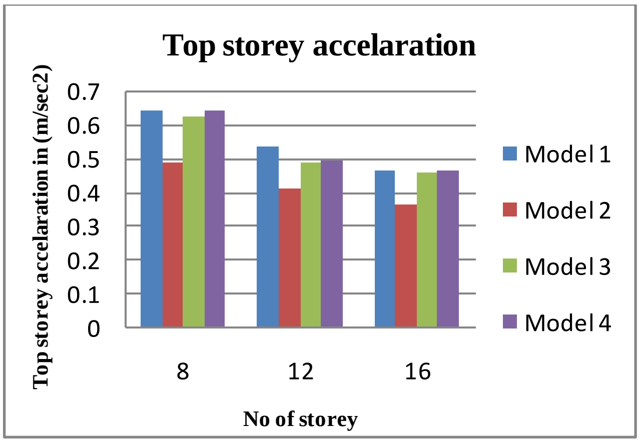

Fig. 8: Variation of No. of storey V/s storey acceleration

Figure 8, shows that top storey acceleration decreases as the storey level increases. Top storey acceleration will be maximum at plinth level and minimum at terrace level. From the figure, it is observed that, storey acceleration in model 2, model 3 and model 4 is decreased by 24%, 3% and 1 % compared to model 1. On increasing the number of storeys, the top storey acceleration decreases.

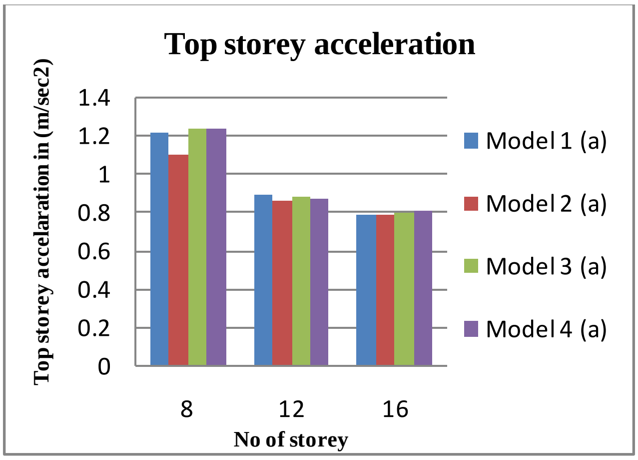

Fig. 8 (a): Variation of No. of storey V/s storey acceleration SW at side

Figure 8 (a), shows the variation of top storey acceleration with number of storeys for various models. further, it can be seen that the storey acceleration in model 2 (a) is decreased by 3% as compared to model 1 (a), in model 3 (a) storey acceleration is increased by 1.5% compared to model 1 (a) and it is increased by 3% in model 4 (a) compared to model 1 (a). From the above figure it shows that there is no much variation between different models, but on increasing the number of storeys the top storey acceleration decreases for all the models.

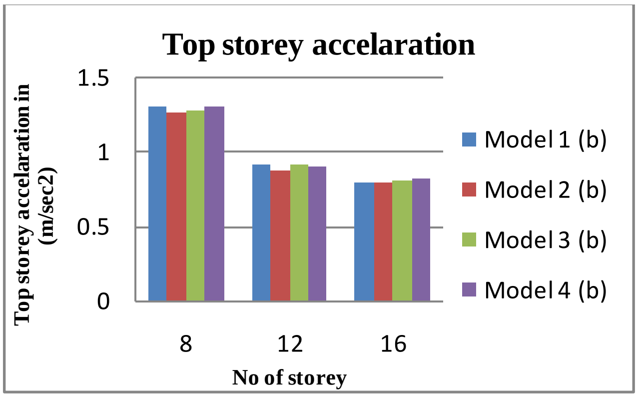

Fig. 8 (b): Variation of No. of storey V/s story acceleration SW at corner

Considering the shear wall at corner position of the building, the top storey acceleration is obtained by response spectrum analysis for zone IV is shown in the above figure 8 (b). Further, it is observed that, the storey acceleration in model 2 (b) is decreased by 4 % as compared to model 1 (b), in model 3 (b) Storey acceleration is increased by 1 % compared to model 1 (b) and it is increased by 2 % in model 4 (b) compared to model 1 (b).

IV. CONCLUSIONS

1. The base shear of RC slab building was increased by 16-22% compared to other models. Flat plate building shows the minimum base shear. The base shear increases on increasing the number of storeys.
2. Time period is maximum in flat plate building (model 2) and is increased up to 68% .
3. Top displacement is maximum in flat plate but it is within the permissible limit. On considering the shear wall the top displacement decreased by 50%.
4. When shear wall is considered there is no much variation in top storey acceleration between all the models.
5. Overall the performance of the flat plate is good compared to all the models, for with and without shear walls.

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