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Study on seismic behavior of dual systems in high seismic zones

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Abstract— In present days flat slab buildings are widely used due to the advantage of reduced floor heights to meet the economical and architectural demands. Analysis and design of flat slab buildings for gravity loads are well established. These structures are more vulnerable to seismic and other lateral loads. Performance of flat slab buildings is unsatisfactory**.** However flat slab buildings are also being constructed in high seismicity region which can cause collapse of the buildings under seismic loading. Shear walls are added to the structures to improve its behaviour in seismic loading. In this paper, performance of shear wall provided at different positions of flat slab structure is studied. The analysis is done in Etabs. G+3, G+8, G+12 storeyes are considered for the analysis. Seismic zone IV and soil type II is considered. The response parameters such as lateral displacement, time period, storey drift, and base shear were evaluated.

Index Terms—Drop panel,Dual systems, Etabs 9.7.2,Flat slab, Response spectrum, Shear walls.

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1 Introduction

In general, RC frame construction consists of columns, beams and slabs. 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 use of flat slab building provides many advantages over conventional RC Frame building in terms of architectural flexibility, use of space, easier formwork and shorter construction time. This system is very simple to construct, and is efficient in that it requires the minimum building height for a given number of stories. Flat slab building structures are significantly more flexible than traditional concrete frame/wall or frame structures, thus becoming more vulnerable to seismic loading. In high seismic regions, the structural efficiency of flat slab system poses a significant risk due to lowly-ductile. The collapse of the structure is due to brittle punching shear due to transfer of shearing forces and unbalanced moments between slab and columns.

Moments in the slabs are more near at the column. So flat slab is often thickened closed to supporting columns to provide adequate strength in shear and to reduce the amount of negative reinforcement in the support region. The thickened portion i.e. the projection below the slab is called drop or drop panel. The column is sometimes widened at the sections below slab to reduce the punching shear in flat slabs to reduce the punching shear in the slab. The widened portions are called column heads**.**

Mainly the structures are built to resist the gravity loads. Other than these vertical loads, lateral loads due to wind loads and earthquake loads coming on the structures are resisted by the structural systems are called lateral load resisting systems. Lateral loads resisting system may be on or more of the following systems: Moment resistant frames, Braced frame, Infilled frame, Shear walls, Wall frame, Frame tube, Outrigger braced, Suspended, Space structures, and Core system. In this paper, flat slab with shear walls in different positions are considered.

Dual systems, as the name indicates it's a combination of two systems. So two load resisting systems are combined together to resist the lateral loads. Moment resisting frame and shear wall, frame and infill walls, frame and bracings are the examples of dual systems. Since it's a combination of two load resisting systems, it resists the lateral loads effectively. Dual system may combine the advantages of the constituent elements. Shear walls are most commonly used structures which act like vertical cantilevers to resist the lateral loads effectively, such an element when combined with frames will give a good performance.

Shear walls are specially designed structural walls included in the buildings to resist combination of shear, moment and axial load induced by lateral load and gravity load transfer to the wall from other structural member horizontal forces. They are mainly flexural members and usually provided in high rise buildings to avoid the total collapse of the high rise buildings under seismic forces. When walls are situated in advantageous positions in a building, they can be very efficient in resisting lateral loads originating from wind or earthquakes. Shear wall resolves the lateral (wind and earthquake) forces and directs those forces to the foundation, where they are resisted by the concrete and the ground. During an earthquake, the shear forces acting on the structure increases So shear walls are important in seismically active zones. Shear walls should have more strength and stiffness to control the

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lateral stiffness.

Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large. Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings. They could be placed symmetrically along one or both directions in plan.

2 MODELLING AND ANALYSIS

2.1 Analysis Software

For the present study the software ETABS is used and the salient features of the same is presented.

The modeling of the structure is being done by Finite Element package. The beams and columns are modeled as the concrete frame elements. The slabs and the shear walls are modeled as the shell elements. The frame element consists of six degrees of freedom at a node which are three rotations and three displacements.

Shell Element: The shell is the combination of the membrane and the plate elements i.e. a shell can behave as plate and as well as membrane. The shell has six degrees of freedom at each node, by restraining the normal translation and bending rotations the shell acts as a membrane and when the in plane translations and the bending about the normal are restrained the shell acts as a plate element.

Beam element: The frame element internal forces are:P the axial force, V2 the shear force in the 1-2 plane, V3 the shear force in the 1-3 plane, T the axial torque (about the 1-axis), M2 the bending moment in the 1-3 plane (about the 2-axis), M3 the bending moment in the 1-2 plane (about the 3-axis)

Floor Constraints: The diaphragm constraints are used to restrain the deformation of the membranes by making the membrane rigid for in plane deformations and to ensure that all joints in plane move in the same pattern. The joint connectivity of the floor should be in the same plane. Plate constraints are also kind of constraints in which even the out of plane bending that is allowed in the diaphragm constraints. The joint connectivity shall be on any points in space.

2.2 Method of Analysis

In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions.

This paper deals with response spectrum method. Analysis is carried out as per IS 1893:2002(PART1), total design lateral force or design base shear along any principal direction is given in terms of design horizontal seismic coefficient and seismic weight of the structure. Design horizontal coefficient depends on the zone factor of site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental natural time period of the structure

2.3 Modelling Details

The structures are modelled in 3D in the commercial structural analysis and design software. X and Y axis are considered as the global horizontal axis and Z as global vertical axis .The buildings are analysed as space frames. The modelled space frame is analysed for dead loads, live loads, earthquake loads and their combinations. In this study both RC framed building and flat slab buildings are considered.

G+3, G+8, G+12 storey buildings with a storey height of 3m in each floor. The buildings have five bays of 6m in X direction and five bays of 6m in Y direction with the plan dimension 30m × 30 m. The columns are oriented in such a way that the depth is along the longest span.

The building symmetric in both mutually perpendicular directions in plan to avoid torsional effects. The orientation and size of column is kept same throughout the height of the structure. The building is considered to be located in seismic zone IV. The building is founded on medium strength soil. In seismic weight calculations, 50 % of the floor live loads are considered to get the graphical plot of input functions, base functions, Joint displacement/Forces, Frame Forces.

2.4 Structure Details

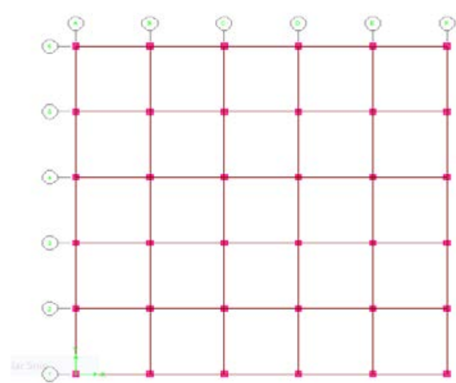

Fig.1Plan of Building Modelled in Etabs

TABLE1: Geometric details

Number of storeys	G+3,G+8,G+12
Storey height	3m
Size of beam	0.3m x 0.6m
Size of column	0.35mx0.35m (G+3)
	0.5mx0.5m (G+8 , G+12)

Slab	0.2m
Drop panel	2m x 2m
	0.45m thick
Shear wall	0.25 m thick

TABLE 2: Earthquake datas

Seismic zone	IV
Importance factor	1
Response reduction factor	5
Soil type	medium (2)

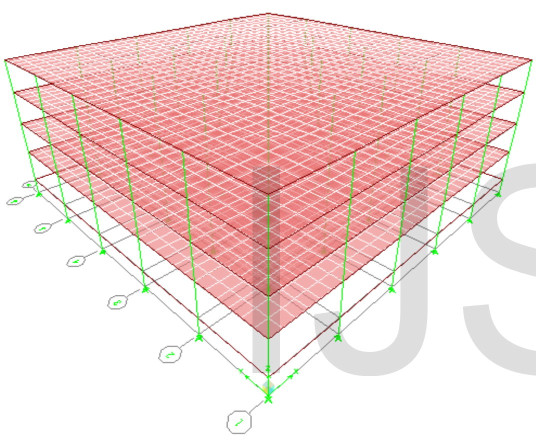

Fig.2 Flat slab structure with G+ 3 storeys modelled in Etabs

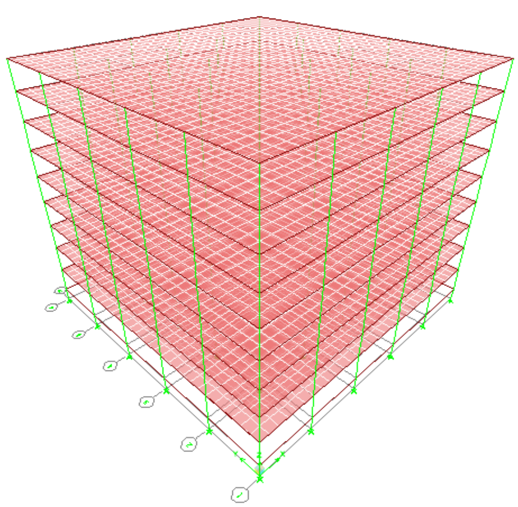

Fig.3Flat slab structure with G+ 8storeys modelled in Etabs

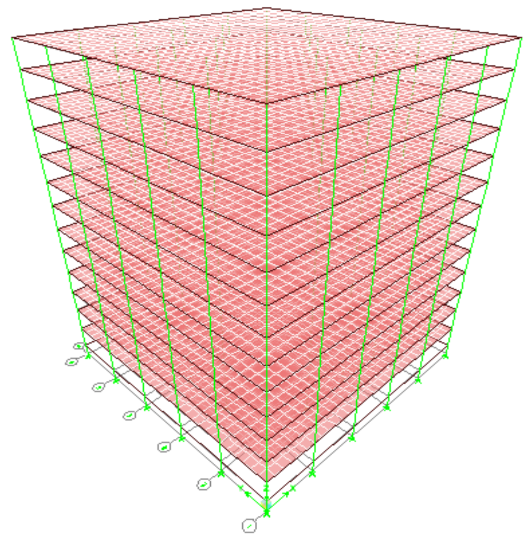

Fig.4Flat slab structure with G+ 12storeys modelled in Etabs

Shear walls are provided in four different positions of the structure to obtain the most desirable position to resist the seismic loads safely. Positions of shear walls are

1. At the centre core of the structure
2. At the mid section of perimeter beams
3. At the edges of perimeter beams
4. At the corners of the building

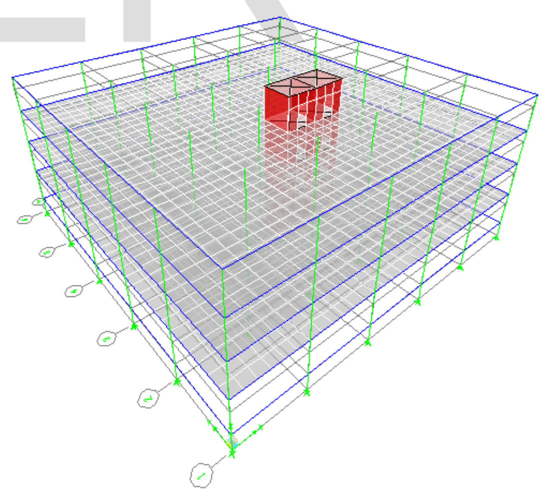

Fig.5 Shear wall positioned at centre core of building

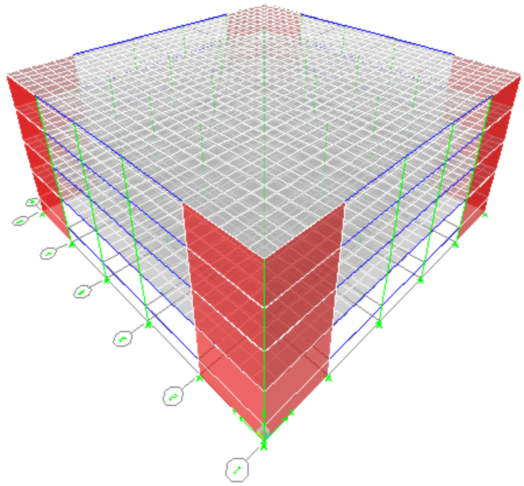

Fig.6 Shear wall positioned at corners of building

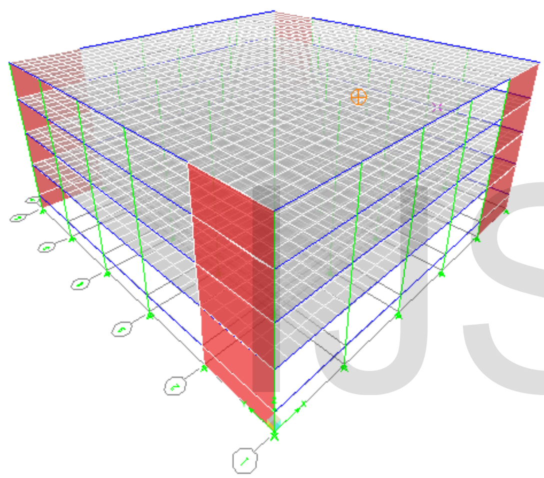

Fig.7 Shear wall positioned at edges of building

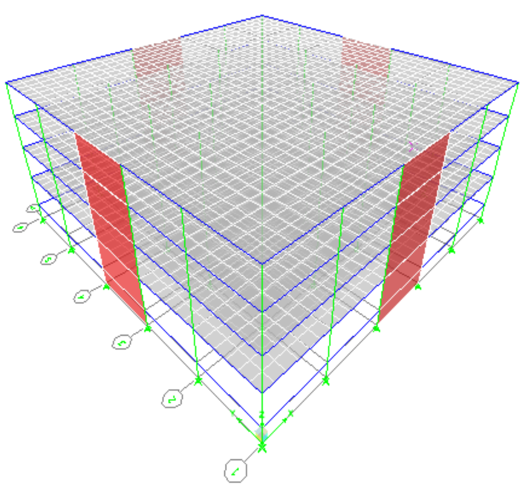

Fig.8 Shear wall positioned at mid section of perimeter beams of building

Loads Considered

Materials

Grade of concrete – M35
Grade of steel – Fe500

Dead Loads

Self weight of slab =0.2 x 1 x 1 x 25
= 5 kN/m2
Load due to Unknown partition =1 kN/m2
Load due to floor finish= 1 kN/m2
Load due to wall: 0.2x (3.0-0.6) x22 = 10.56 kN/m2

Imposed loads

Live load on floor slab and roof: 4kN/m2

3RESULTS AND DISCUSSION

3.1 Displacement

Results have been represented in the charts shown below. From the fig 9it is clear that lateral displacement is maximum at terrace level for all columns. Lateral displacement increases as storey height increases. Minimum is at base level. When shear wall is introduced, the value of lateral displacement decreases due to increased stiffness. From fig 10, 11, 12, results shows that lateral displacement is minimum when the shear wall is at corners for all models in both conventional and flat slab structures. Maximum when shear wall is at centre core.

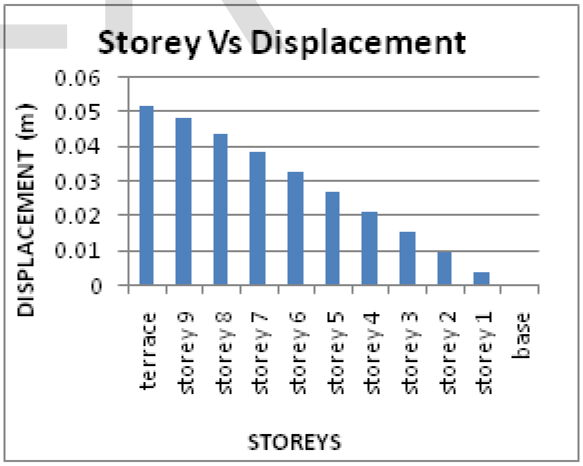

Fig.1Effect of lateral displacement on behaviour of column of G+8 storey with shear wall a centre core

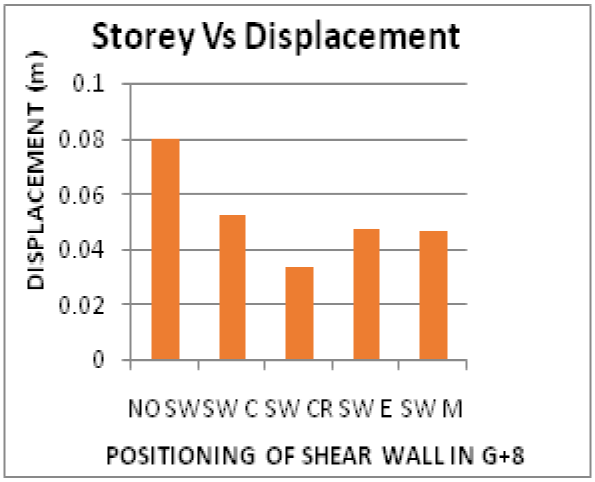

Fig.2 Effect of lateral displacement on behaviour of column of G+ 8 storeys with shear wall at different positions

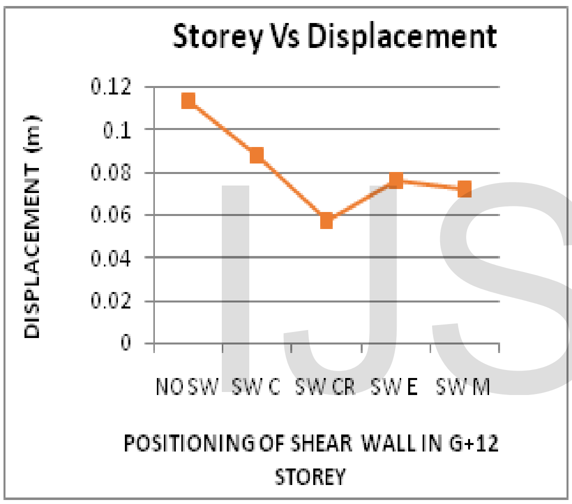

Fig.3 Effect of lateral displacement on behaviour of column of G+ 12 storeys with shear wall at different positions

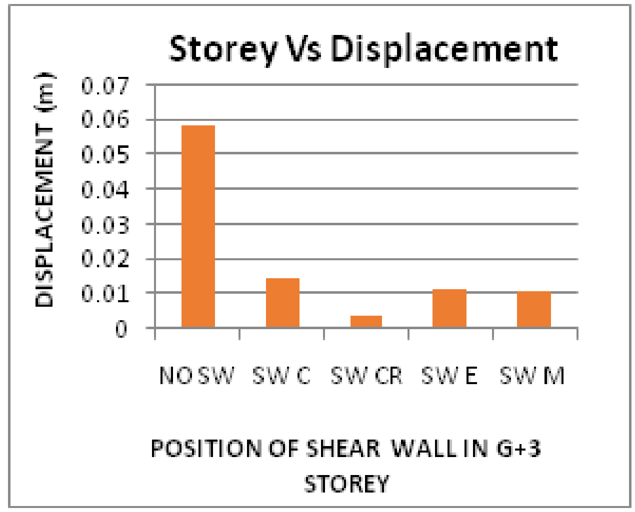

Fig.4 Effect of lateral displacement on behaviour of column of G+3 storeys with shear wall at different positions

3.2 Base Shear

From the results base shear is maximum for shear wall at corner in G+8 and G+12. In G+3 storey building, base shear is maximum is when shear wall is at centre core. In G+8 and G+ 3 minimum value is when shear wall placed at mid section of beams. In G+12, minimum is when shear wall is at edge.

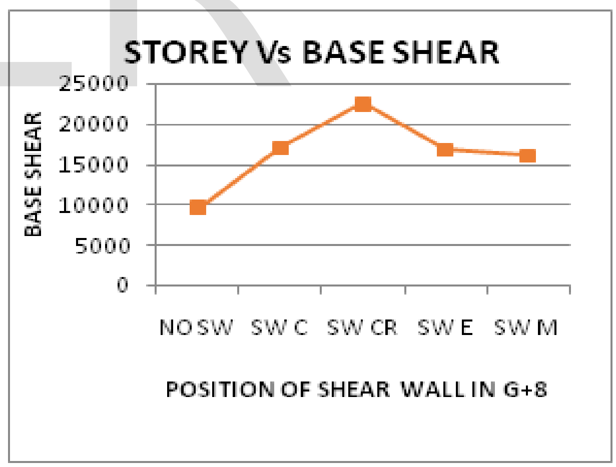

Fig.5Effect of storey shear on behaviour of column of G+8 storeys building

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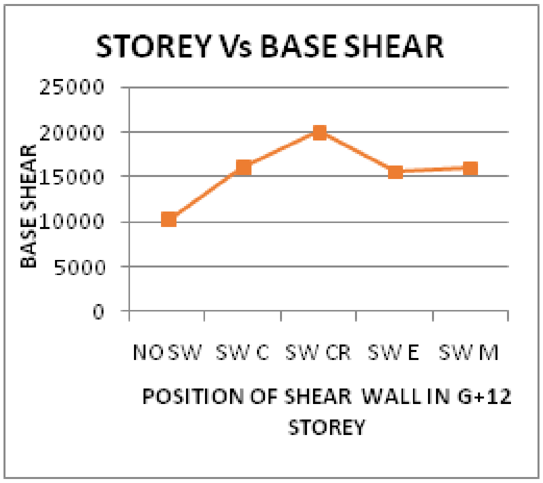

Fig.6Effect of storey shear on behaviour of column of G+12 storeys building

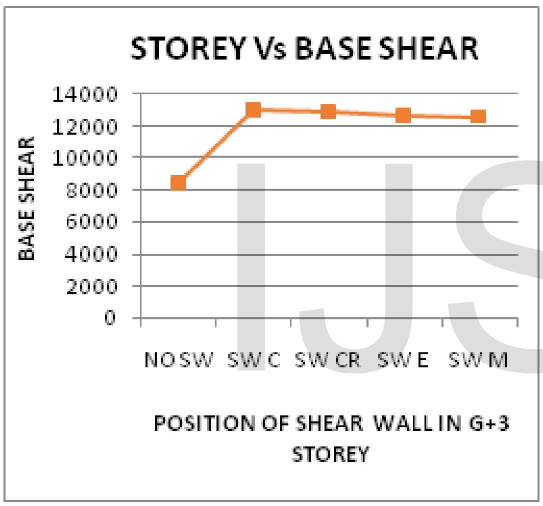

Fig.7Effect of storey shear on behaviour of column of G+3 storeys building

3.3StoreyDrift

Results have been represented in the graphs shown below. Due to the symmetry of the building the lateral displacement will be same in both directions (X and Y).Storey drift is minimum when the position of shear wall is at the corners. Among that G+3 storey have the minimum value than G+8 and G+12. Maximum value of drift is when the shear wall is provided at the centre core of the structures.

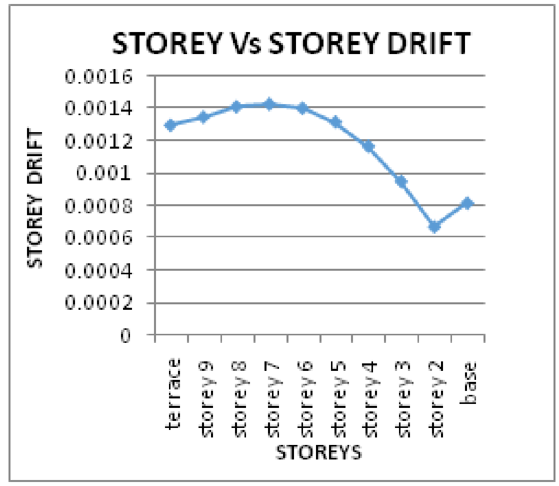

Fig.8Effect of storey drift on behaviour on G+8 storey building with shear wall placed in edge position

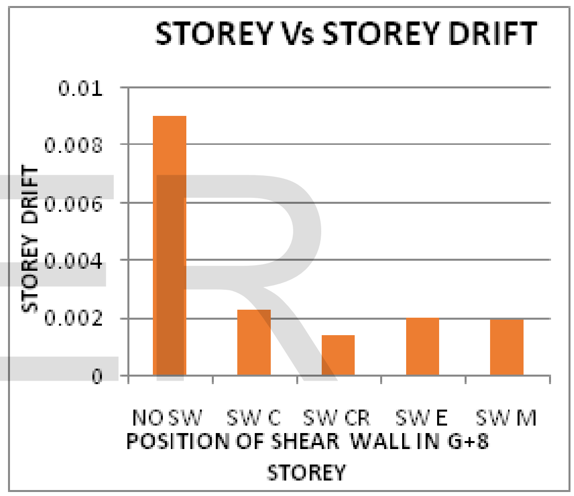

Fig.9Effect of storey drift on behaviour on G+8 storey building with shear wall placed in different positions

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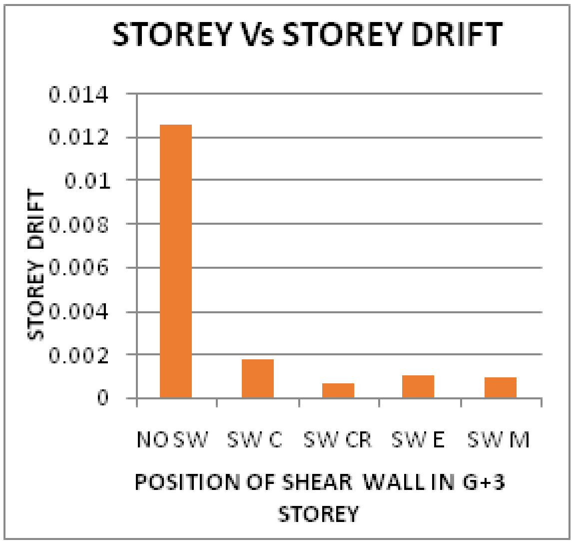

Fig.10Effect of storey drift on behaviour on G+3 storey building with shear wall placed in different positions

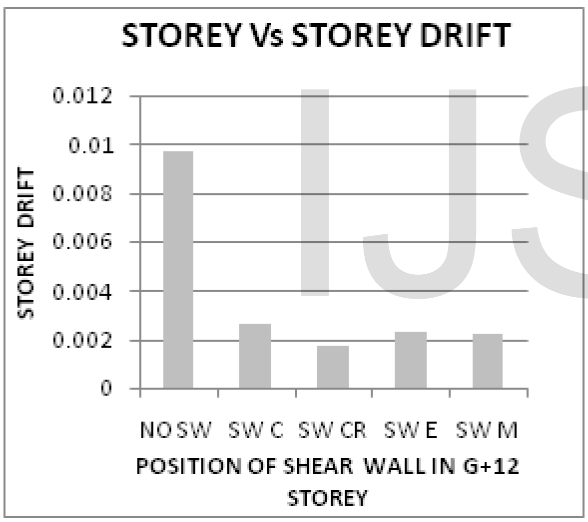

Fig.11Effect of storey drift on behaviour on G+12 storey building with shear wall placed in different positions

3.4Time Period

The results have been represented in graphs shown below. From the Chart it is observed that the time period (both Tx and Ty) is maximum at mode 1 and 2. The natural time period increases as the height increases. Due to the symmetric of the building the time period will be same in both directions (Tx and Ty). When shear walls are considered, time period is more when wall is placed at centre core. Minimum value of time period is when shear walls are at corners

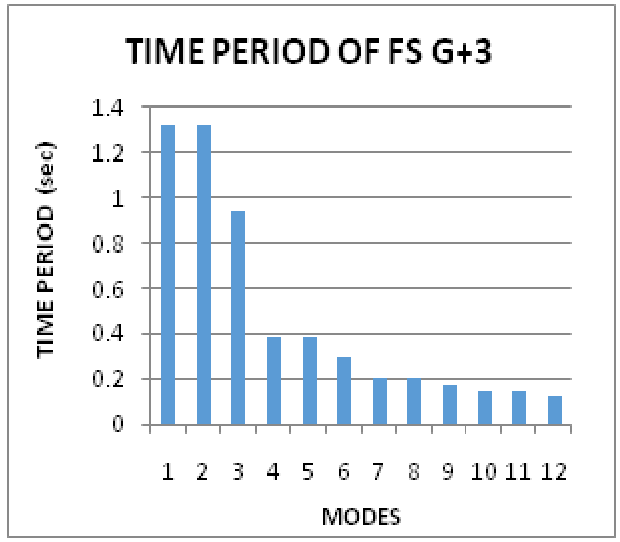

Fig.12Effect of time period on behaviour of modes shapes on G+3 storey building

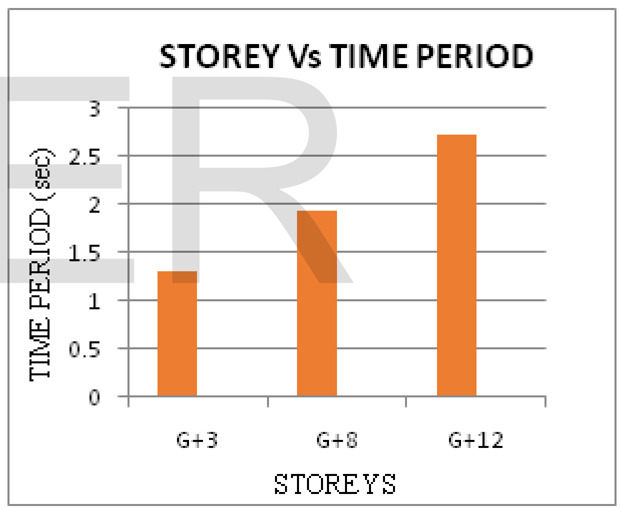

Fig.13Effect of time period in flat slab on fourth, nine and thirteen storey building

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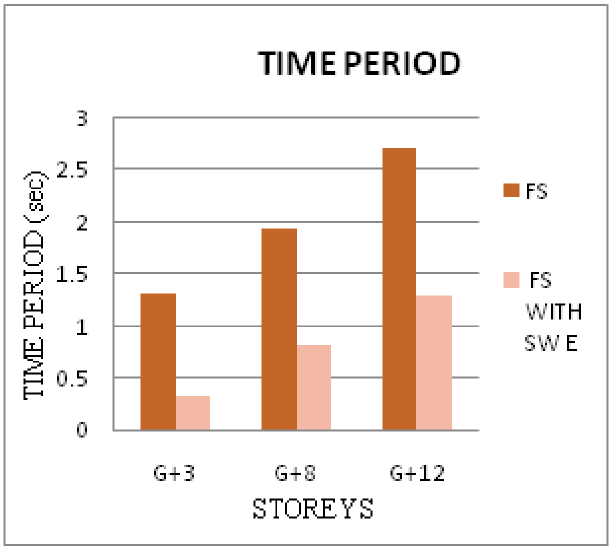


Fig.14 Effect of time period in building with shear wall positioned at edges

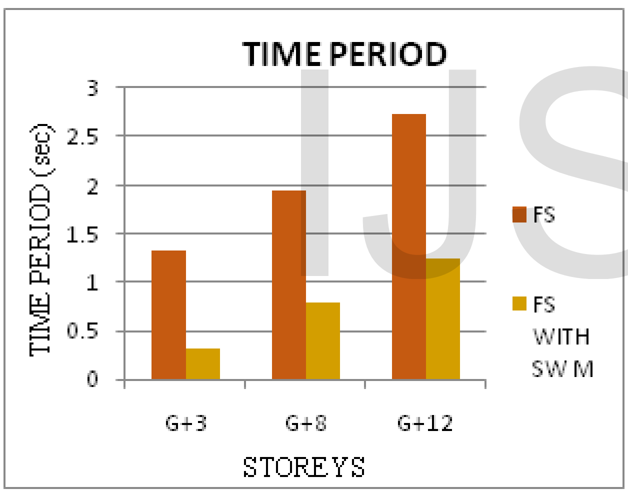
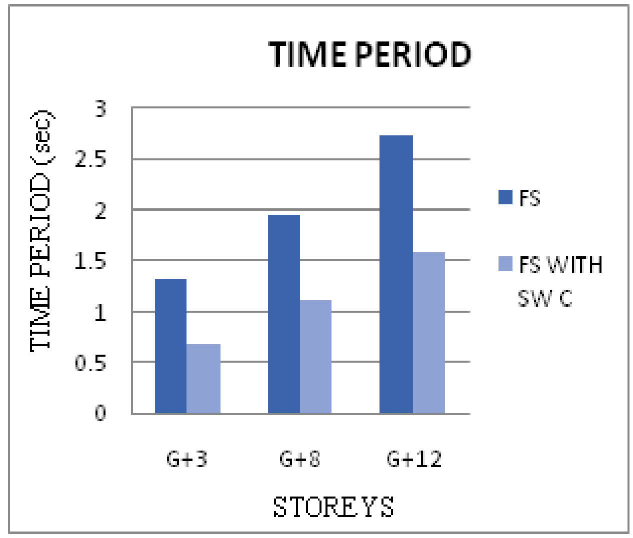


Fig.15Effect of time period in building with shear wall positioned at mid section of beams

Fig.16Effect of time period in building with shear wall positioned



at centre core

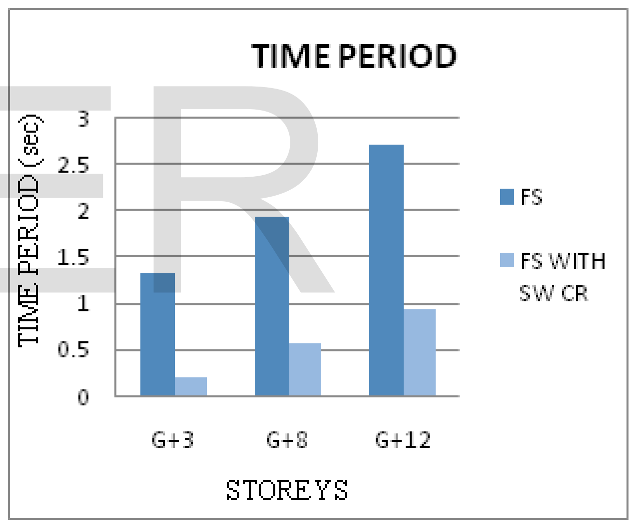


Fig.17Effect of time period in building with shear wall positioned at corners

4 CONCLUSION

Flat slab structures are more flexible than conventional RC framed structures, so it is more vulnerable to seismic loads. To resist these structures from the lateral loads, some lateral load resisting structures are incorporated to withstand safely. Shear walls are the commonly used lateral load resisting system. Here shear walls are provided at different positions of the structure. Four positions are considered. At the centre core of the structure, At the mid section of perimeter beams, At the edges of perimeter beams, At the corners of the building. Among these four positions, shear walls at the corners gives the better results.

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