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STUDY OF EFFECTIVE LOCATION OF SHEAR WALL IN MULTI-STOREYED BUILDINGS FOR OPTIMUM SEISMIC RESPONSE

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ABSTRACT

In the seismic resistant design of high-rise structures, shear walls which are constructed along the height of the building are capable of transferring lateral forces from peripheral walls, floors, and roofs to the ground foundation. The main objective of the present study is to determine the effective location for shear walls in a multi-storey building for an optimum seismic response. The "Dynamic Response Spectrum method" of analysis of the building is done using ETABS. The effectiveness of shear walls has been studied by considering four different models. Model-I is a bare frame structural system without a shear wall and the other three models are dual-type structural systems with shear walls at different locations. In this study, a 16x16m plan with G+15 stories RC building with a total height of about 48m is analysed in zone V by providing shear walls of 250mm thick at different locations in the building. From the analysis results it is observed that the model with a shear wall placed at the centre of the building is more effective in resisting seismic forces when compared to other models.

Keywords: location of shear walls, response spectrum method, ETABS, earthquake resistant structure.

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INTRODUCTION

Shear walls are vertical elements of the horizontal force-resisting system. Shear walls are constructed to counter the effects of lateral load acting on a structure. In residential construction, shear walls are straight external walls that typically form a box that provides all of the lateral support for the building. When shear walls are designed and constructed properly, they will have the strength and stiffness to resist horizontal forces.

In building construction, a rigid vertical diaphragm is capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes. Examples are reinforced concrete walls or vertical trusses. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants; create powerful twisting (torsion) forces. These forces can tear (shear) a building apart. Reinforcing a frame by attaching or placing a rigid wall inside maintains the shape of the frame and prevents rotation at the joints. Shear walls are especially important in high-rise buildings subjected to lateral wind and seismic forces.

In the last two decades, shear walls have become an important part of mid and high-rise residential buildings. As part of an earthquake-resistant building design, these walls are placed in building plans reducing lateral displacements under earthquake loads.

LITERATURE REVIEW

Chandurkarand Pajgade [1] have done studies on determining the shear wall location of four different types of models varying with earthquake load with zones II, III, IV, and V as per IS: 1893: 2016, and calculated lateral displacement, storey drift, and total cost required for the ground floor are calculated by replacing column with the shear wall. It was found that shear walls in short spans at corners in model 4 were economical and effective in high-rise buildings. Shear walls with large dimensions are effective in high amounts of horizontal forces and by providing shear wall at suitable locations, displacements can be reduced due to earthquakes.

Varsha R Harne [2] conducted an analytical study on the dynamic response of seismo-resistant building frames. The effects of change in the height of the shear wall on storey displacement in the dynamic response of building frames were obtained. From the study, it was concluded that it is sufficient to raise the shear wall to the mid-height of building frames instead of raising to entire height of the building.

Shahabodin Zaregarizi [3] conducted a comparative investigation on using shear wall and infill to improve the seismic performance of existing buildings. Static nonlinear analysis was done to compare the effectiveness of both methods. From the results, it was observed that concrete infills have considerable strength while brick ones showed lower strength. On the contrary, brick infills accepted larger displacements than concrete ones. It was concluded that the combination of brick and concrete infills reduced the negative effects when they were both used individually.

Ugale Ashish B. and Raut Harshlata R [4] conducted an analysis on the behaviour of steel plate shear wall in a G+6 building frame located in seismic zone III using STAAD Pro and compared it with a Building frame without a shear wall. The building with steel plate shear wall showed very little deflection, shear force, and bending moment, and overall stiffness was found to be increased. It was found that Steel plate shear walls occupy less space than RCC Shear wall.

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Anshuman S., Dipendu Bhunia, and Bhavin Ramjiyani [5] have studied solutions for shear wall locations in multi-storey buildings based on both elastic and elastoplastic behaviours. An earthquake load is calculated and applied to a building of fifteen stories located in zone IV. Elastic and elastoplastic analyses were performed using both STAAD Pro 2004 and SAP V 10.0.5 (2000) software packages. Shear forces, bending moment, and storey drift were computed in both cases and the location of the shear wall was established based on the above computations.

Kameswari *et al*. [6] studied the effect of various configurations of shear walls on high-rise structure is analysed. The drift and inter-storey drift of the structure in the following configurations of shear wall panels is studied and is compared with that of bare frame: Conventional shear walls, Alternate arrangement of shear walls, Diagonal arrangement of shear walls, and Zigzag arrangement of shear walls and Influence of lift core walls. Of the configurations studied the zigzag shear wall configuration is found to be better than the other systems studied in controlling the response to earthquake loading. The diagonal configuration is found to have having significant role in controlling the response of structures to earthquakes.

Berman [7] assessed the behavior of code-designed SPSWs. A series of walls are designed and their behavior is evaluated using nonlinear response history analysis for ground motions representing different hazard levels. It is found that designs meeting current code requirements satisfy maximum inter-storey drift requirements considering design level earthquakes and have maximum inter-storey drifts of less than 5% for maximum considered earthquakes. Web plate ductility demands are found to be significantly larger for low-rise walls than for high-rise walls where higher modes of vibrations impact the response. The percentage of storey shear resisted by the web plate relative to the boundary frame is found to be between 60% and 80% and is relatively independent of panel aspect ratio, wall height, or hazard level, but is affected by transitions in plate thickness. Maximum demands in VBEs in design level shaking are found to be considerably less than those found from capacity design for SPSWs with 9 or more stories.

Dangi and Akhtar [8] presented studies on Seismic analysis of a RC building on sloping ground with shear wall at different positions. In their study, the behavior of a G+ 6 storey framed structure with a shear wall on sloping ground is analyzed for different sloping angles i.e., 15°, 30°and 45°. The analysis is carried out to evaluate the effect of sloping ground on structural forces.

Shaik Akhil Ahamad and K. V. Pratap [9] carried out dynamic analysis on type -III (i.e., soft soil) for an irregular structure in plan in all the zones as specified and it is concluded that the structure with shear walls (i.e., Case C) placed symmetrically will show better results in terms of all the seismic parameters when compared with the structures without shear wall (i.e., Case A) and with shear wall at one end (i.e., Case B)

Koshy *et al*. [10] conducted a study on multi-storeyed buildings of a symmetric plan with shear walls provided at multiple locations across the plan. The total length and thickness of walls were kept constant throughout all cases. Straight walls and L - shaped R.C.C. walls were made use of. Linear static, linear dynamic, and non-linear static analyses were performed. Comparisons were made based on roof-level displacement, drift, stiffness of structure, and ductility to find the best-performing configuration Benerjee *et al*. [11] have carried out Response Spectrum Analysis and Time History Analysis. In this study, fourteen test models with unique locations of shear wall are considered and parameters such as period, Storey Displacement, Static Eccentricity, Storey Drift, Joint Displacement, Base Shear, and Base Force, are compared with the bare model. Thus, the best location of the shear wall is suggested based on models having the least static eccentricity, minimum displacement, Minimum drift, Minimum period, Minimum joint displacement, and Maximum base shear.

Banerjee *et al*. [12] have modelled and analyzed the building with varying shear wall positions using ETAB Ver. 0.2 to discover the optimal site of the shear wall in an asymmetric, irregular, star-shaped G + 14 building in zone IV. Two models, one with a shear wall and one without, have been analyzed. The bare frame model has been compared to analytical results for top storey displacement, base shear, period, static eccentricity, storey drift, and torsional moment.

The present study aims to further strengthen the studies carried out on the optimum placement of shear walls in multi-storeyed buildings under seismic forces.

METHODOLOGY

For the comparison of various structural aspects, four different models which are shown in Figure-1 and Figure-2, have been considered viz. Model without Shear walls, Model with Shear wall along the perimeter, Model with Shear wall at centre, and Model with Shear wall at all corners.

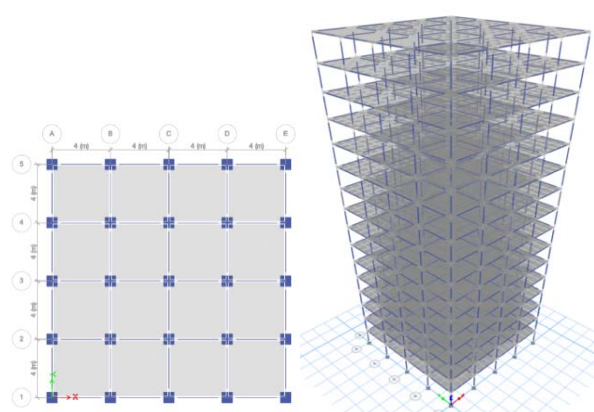

Figure-1. Plan and 3D-view of the model without Shear walls.

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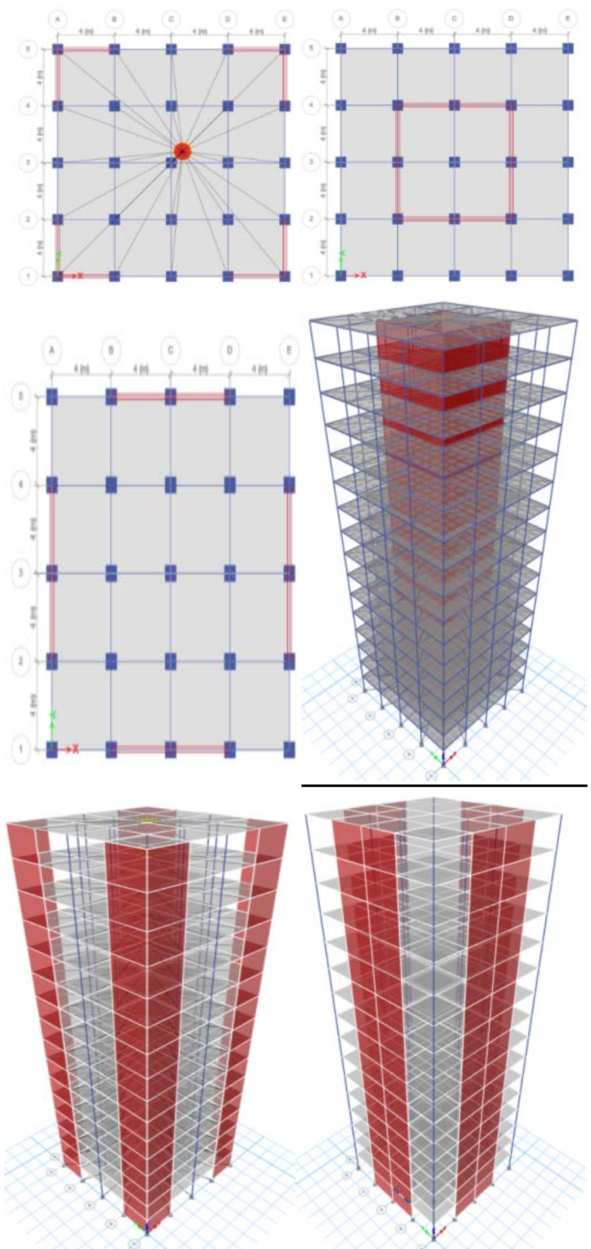


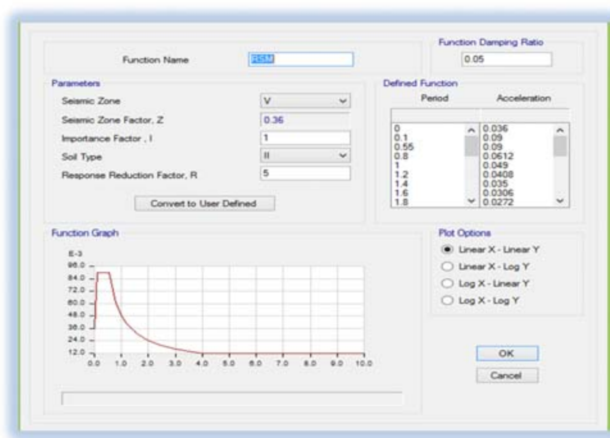
Figure-2. Plan and 3D-view models with shear walls (a). A model with a shear wall at the centre. (b). Model with The shear wall at all corners. (c). A model with a Shear wall along the perimeter.

The following properties listed in Table-1 are used for modeling the building and loads viz. dead load [13], live load [14], wind load [15], and earthquake loads [16] are applied to the structure.

Table-1. Building details.

Modelling Details	
Type of structure	Residential Building
Number of stories	G+15
Height of floor	3m
Column size	750 mm x 750 mm
Beam size	230 mm x 505mm
Slab thickness	200 mm
Loads on building	
Live load	3 KN/m2
Floor finish	1.125 KN/m2
Properties of Grade of Concrete and Steel	
Grade of concrete	M30
Grade of steel	Fe415
Grade of steel	Fe500
Shear walls thickness	250mm
Seismic Coefficient for Response Spectrum method	
Seismic Zone	V
Zone Factor	0.36
Medium soil, Soil type	II
Importance factor	1
Response reduction factor (SMRF)	5

The response spectrum shown in Figure-3 is adopted for carrying out the response spectrum method.



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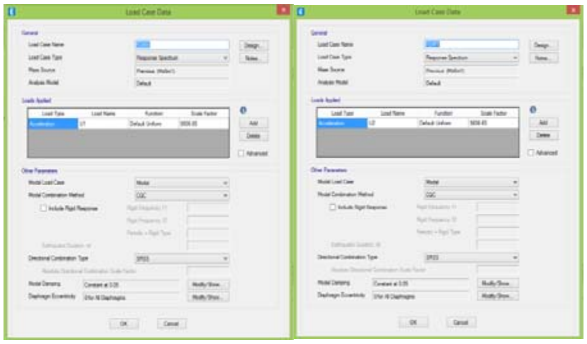

Figure-3. Response spectrum load case in X, Y directions.

RESULTS AND DISCUSSIONS

In this paper, results obtained by modeling shear walls placed at various locations for a G+15 storied structure are presented. An attempt is made to study the variations in storey displacements, storey drift, storey shear, period, mode shapes, and storey stiffness.

Storey Displacement

From Figure-4 and Figure-5 it is observed that the maximum storey displacement of a structure with a shear wall at the centre is 89.95% lesser than the structure without a shear wall in both X and Y directions, it is 80.83% for a case of the shear wall at the perimeter and it is 72.4% if the shear wall is placed at corners. This is due to an increase in mass and stiffness in the structure by introducing shear walls.

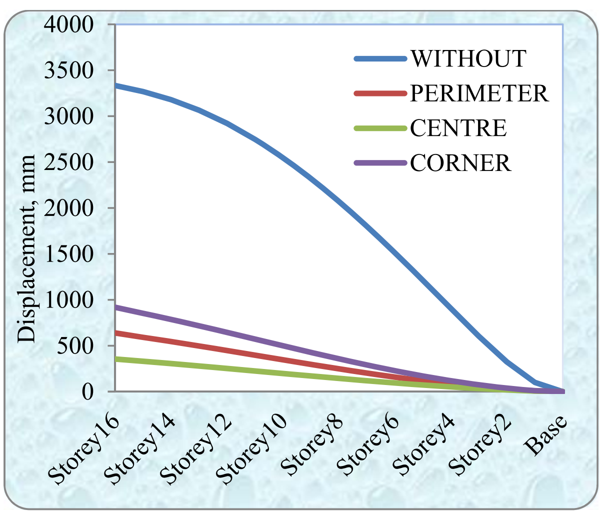

Figure-4. Storey displacement (mm) in x-direction.

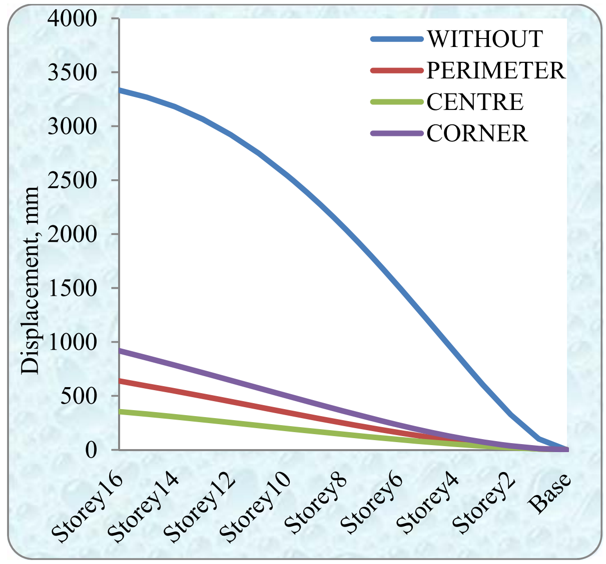

Figure-5. Storey displacement (mm) in y-direction.

Storey Drift

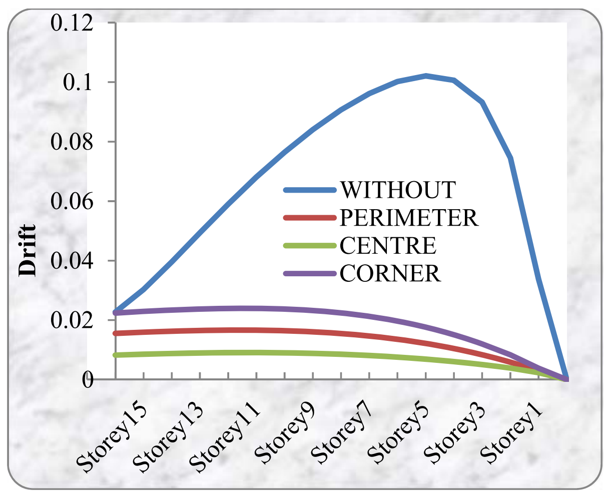

Figure-6. Storey drift in x-direction.

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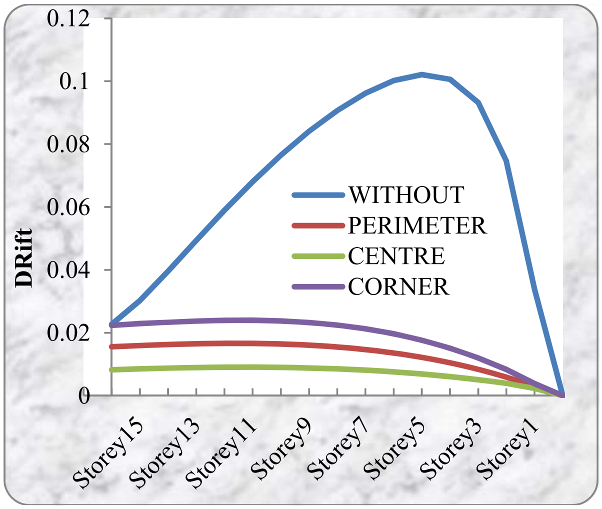

Figure-7. Storey drift in y-direction.

From Figure-6 and Figure-7 it is observed that the maximum storey drift of a structure with a shear wall at the center is 91.13% lesser than the structure without a shear wall in both X and Y directions, it is 83.71% for a case of the shear wall at the perimeter and it is 76.52% if the shear wall is placed at corners. The shear walls placed at the center contribute to more resistance towards the displacement in X and Y directions when compared to the shear walls at the perimeter and corners of the structure.

Storey Shear

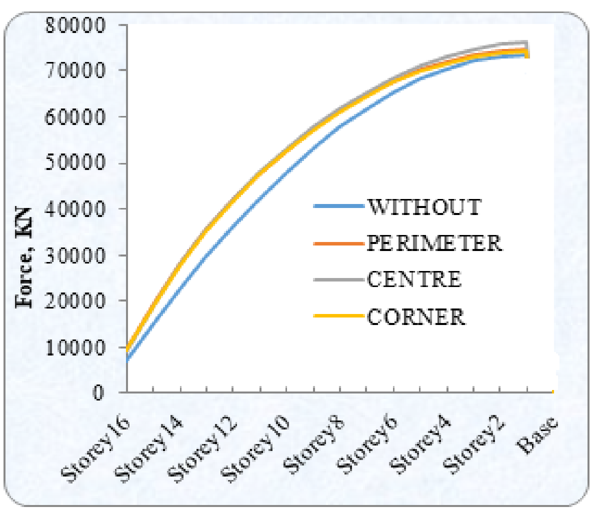

Figure-8. Storey shear in x-direction.

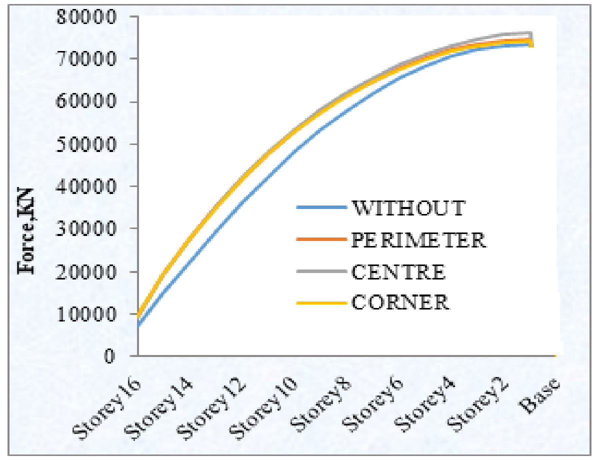

Figure-9. Storey shear in y-direction.

From Figure-8 and Figure-9 it is observed that the maximum storey shear of a structure with a shear wall at the center is 3.75% higher than the structure without a shear wall in both X and Y directions, it is 1.855% for a case of the shear wall at the perimeter and it is 1.085% if the shear wall is placed at corners. The shear walls placed at the center, perimeter, and corners of the structure contribute almost negligibly in increasing the storey shear when compared to the structure without shear walls.

Time Period

From Figure-10 it is observed that the maximum time period of a structure with a shear wall at the center is 68.4% lesser than the structure without a shear wall, it is 58.11% for a case of the shear wall at the perimeter and it is 49.41% if the shear wall is placed at corners. The shear walls placed at the center, perimeter, and corners of the structure contribute to the reduction in time period when compared to the structure without shear walls. The shear walls placed in the structure improve the stiffness of the structure which reduces the time period of vibration.

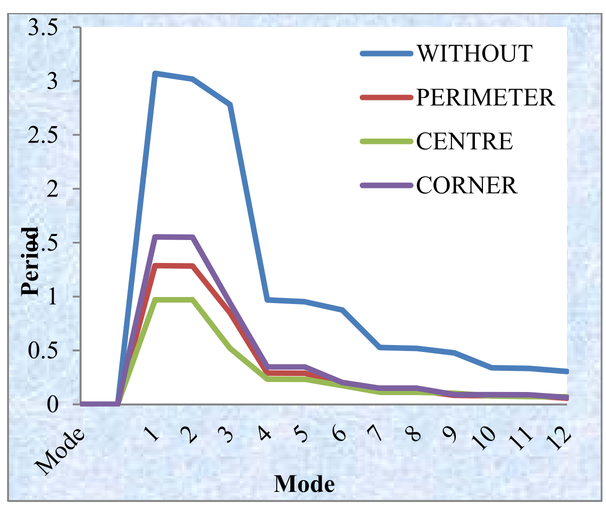

Figure-10. Time period.

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Mode Shapes

Figure-11a.

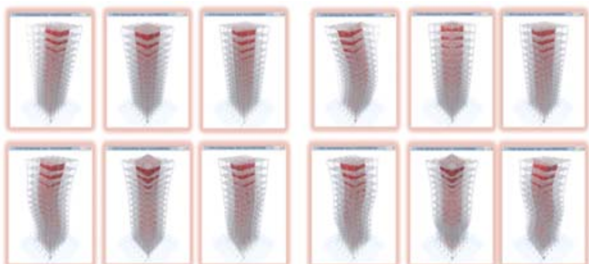

Figure-11b.

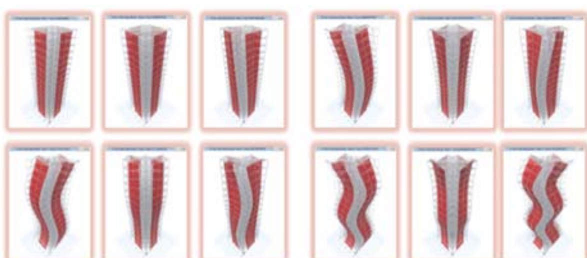

Figure-11c.

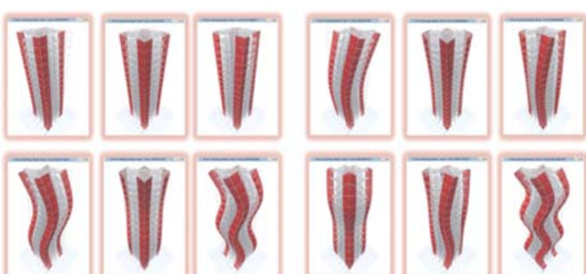

Figure-11d.

A mode shape is the deformation that the component would show when vibrating at the natural frequency. The terms mode shape or natural vibration shape are used in structural dynamics.Figure-11a to Figure-11drepresents mode shapes of the structure under various conditions viz. structure without shear walls, structure with shear wall at center, structure with shear wall at the perimeter, and structure with shear wall at corners.

STOREY STIFFNESS

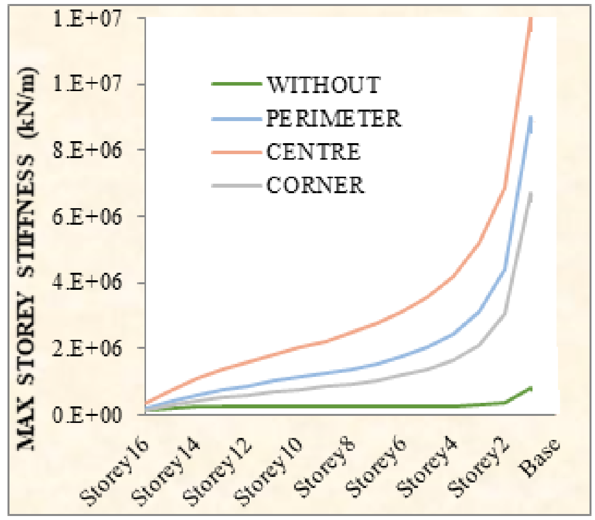

Figure-12. Storey stiffness.

Storey stiffness is estimated as the lateral force producing unit translational lateral deformation in that storey, with the bottom of the storey restrained from moving laterally, i.e., only translational motion of the bottom of the storey is restrained while it is free to rotate. From Figure-12 it is observed that the maximum storey stiffness of a structure with a shear wall at the center is 14.54 times more than the structure without a shear wall, it is 10.88 times for a case of the shear wall at the perimeter and it is 8.11 times if the shear wall is placed at corners.

CONCLUSIONS

Based on the parametric study on a G+15 storied buildings, having placed shear walls at various locations and applying the response spectrum method for earthquake loads, the following conclusions have been drawn,

- The structure with a shear wall located at the centre has lesser storey displacement values compared to all other cases of shear wall location
- The structure with a shear wall located at the centre has lesser storey drift values compared to all other cases of shear wall location
- The structure with a shear wall located at different locations has higher storey shear values compared to the structure without a shear wall. However, a structure with a shear wall at the centre has morestorey shear values compared to all other cases of shear wall locations.
- The structure with a shear wall located atcentre has lesser time period values compared to all other cases of shear wall location
- The structure with a shear wall located at the centre has more storey stiffness values compared to all other cases of shear wall location

Therefore, it is concluded that the building model with a shear wall placed at the centre has performed better in all aspects.

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