Dynamic Analysis of Staggered Shear Wall Structures with Different Irregularity Ratios

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DYNAMIC ANALYSIS OF STAGGERED SHEAR WALL STRUCTURES WITH DIFFERENT IRREGULARITY RATIOS

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ABSTRACT: *In India, there have been several large earthquakes with magnitudes ranging from 4.0 to 8.6 that have destroyed buildings. As a result, various techniques have been developed in the construction industry to withstand the effects of earthquakes on structures. Shear walls are one of the best ways to give earthquake protection to multistory buildings, however it is crucial to find the shear wall's most effective, efficient and optimum locations in the building. To adopt openings in the shear wall without significantly reducing the building's stiffness, a staggered shear wall is an innovative type of shear wall with effective performance. It also minimizes the weight and construction cost of the structure.*

The main goal of this study is to identify the optimum location of shear wall in irregular buildings with different irregular ratios by comparing structures with shear walls at various locations like, at the edges, at the corners and at both the corner and the edges. Further the dynamic analysis is carried out by considering optimum location of shear wall and replacing it with staggered shear wall. The effectiveness of staggered shear wall is studied by comparing the results with the shear wall structure having regular openings considering same percentage of openings in both the models using ETABS v18 software. From the study it is observed that staggered shear walls are more effective than the shear walls with regular openings. Staggered shear wall performs very well under seismic activity without affecting the stiffness of the building largely.

KEYWORDS: Irregularity; Shear wall; Staggered shear wall: Regular openings; Time history analysis.

1. INTRODUCTION

An earthquake is a natural disaster caused by movements of seismic plates inside the Earth which results in the release of energy into the lithosphere called seismic waves. India has seen some significant earthquakes with magnitudes ranging from 4.0 to 8.6, which have destroyed buildings and resulted in fatalities and injuries among people as well as significant economic losses for the nation. Irregular buildings are very prone to earth quake due to their torsional behavior. Adequate stiffness is very important in high rise buildings to resist the lateral loads brought by wind or seismic events. Reinforced concrete shear walls are designed for buildings located in seismic areas, because of their high strength, stiffness and high ductility. Shear wall performs effectively when placed in effective locations. Openings in the shear wall are in high demand for ventilation and architectural purpose. staggered shear wall is an innovative shear wall type with which openings can be provided in the shear wall without affecting the stiffness of the structure. staggered shear wall performs effectively compared to other type of openings in the shear wall.

Many researchers have studied the behavior of structures with and without shear wall under earthquake loads. The placement of shear walls in a symmetrical G+20 multi-story residential building at several places. When compared to other structures, one having shear walls at the corners produces better performances (Ahamad 2020). In seismic response on multi-storied building having shear walls with and without openings. It is reported that the presence of shear wall can increase the strength and stiffness of the structure and the width of openings plays more significant role than the height (Naresh 2020). In seismic analysis of steel plate shear walled structure least base shear is experienced by the RCC shear walled structure and the highest base shear is experienced by the Steel plate shear walled structure (Deepna 2018). Provision of shear wall generally results in reducing the storey displacements of the structure (Geetha 2016). The shear walls with staggered openings are more rigid and they record smaller top horizontal displacement than walls with regular openings (Marius 2017). The stiffness increase will alter the natural frequency of the structure with shear wall (Rajath 2017).

It was inferred from literature review that the researchers have studied the effect of shear wall and openings in symmetric buildings, however most of the structures are irregular nowadays studying the behavior of irregular building when subjected to earthquake is necessary.

2. METHODOLOGY

In the present work, the seismic behavior of irregular structures with different irregularity ratios are analyzed to determine the optimum location of shear wall using time history analysis. The north-south component of Bhuj earthquake is chosen for the same.

For analytical studies, a dynamic procedure involving time history analysis was adopted. Furthermore, a structure with shear wall at optimum location is selected, replaced with the staggered shear wall and compared with the structural parameters like storey displacements, storey drift, time period and natural frequency of shear wall structure with regular openings. Analysis of structures have been carried out using ETABS software.

3. ANALYSING THE OPTIMUM LOCATION OF SHEAR WALL IN IRREGULAR BUILDING

According to IS 1893:2016 (Part 1), A building with plan area 1200 m^2 is modelled as regular and with different plan irregular ratios. Regular, L-shape, U-shape, C-shape buildings with irregular ratios 0.5 and 0.266 are modeled by considering the dead and live loads from IS 875 Part 1 and 2 respectively. Optimum size of columns and beams are considered, i.e, 600mm ×400mm column, 400mm×400mm beams, 125mm thick slab and 200 mm thick shear wall.

Analysis was performed for all the cases to analyze the behavior of the frames with various irregularities. The effect of structural irregularities on the displacement response and storey drift was studiedand then compared. The reaction of the structure to thelateral loads is studied by placing shear wall at different locations of the building.

Dimension of regular structure is considered as 60 x 20 m.

Bay width is considered as 4 m in all type of structures considered.

Regular Building:

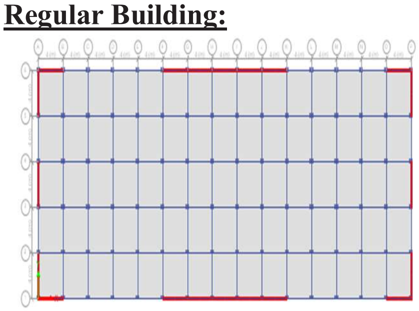

Figure 3.1: Model-2 (Regular)

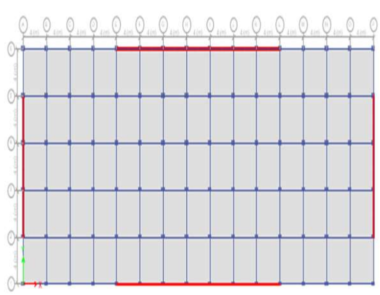

Figure 3.2: Model-3(Regular)

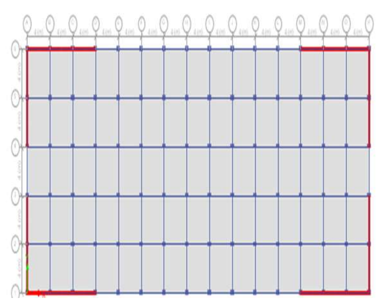

Figure 3.3: Model-4 (Regular)

L- Shaped building (A/L ratio = 0.5):

Figure 3.4: Model-2 (L-Shape)

Figure 3.5: Model-3 (L-Shape)

Figure 3.6: Model-4 (L-Shape)

C- Shaped building (A/L ratio= 0.266):

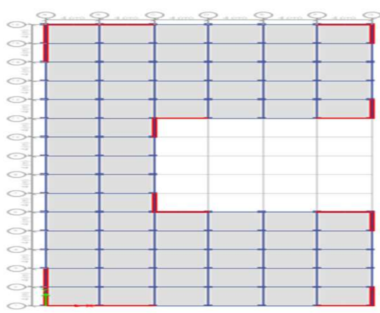

Figure 3.7: Model-2 (C-Shape)

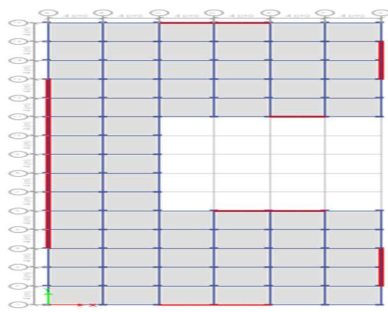

Figure 3.8: Model-3(C-Shape)

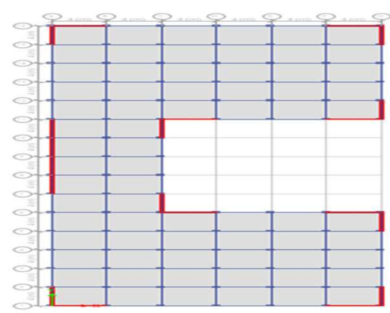

Figure 3.9: Model-4 (C-Shape)

U-Shaped building (A/L ratio=0.5):

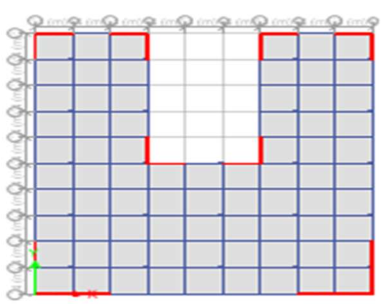

Figure 3.10: Model-2 (U-Shape)

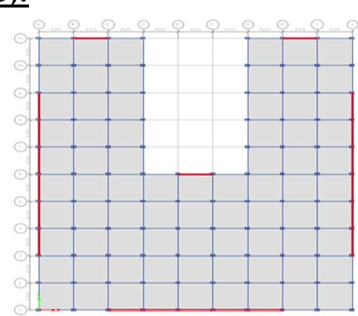

Figure 3.11: Model-3(U-Shape)

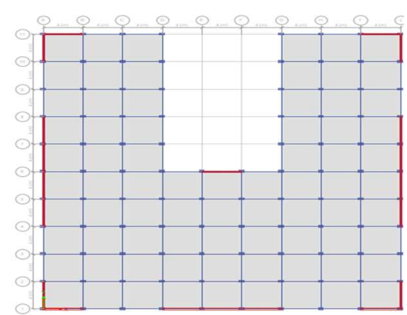

Figure 3.12: Model-4 (U-Shape)

- Model-1: Model without shear walls
- Model-2: Model with shear walls at corners.
- Model-3: Model with shear walls at edges.
- Model-4: Model with shear wall at both corners and edges.

Storey displacement and storey drift results:

Regular and irregular structures are analyzed by placing shear wall at corners, edges and both at corner and edges to find the optimum location of the shear wall by time history analysis considering Bhuj earthquake data.

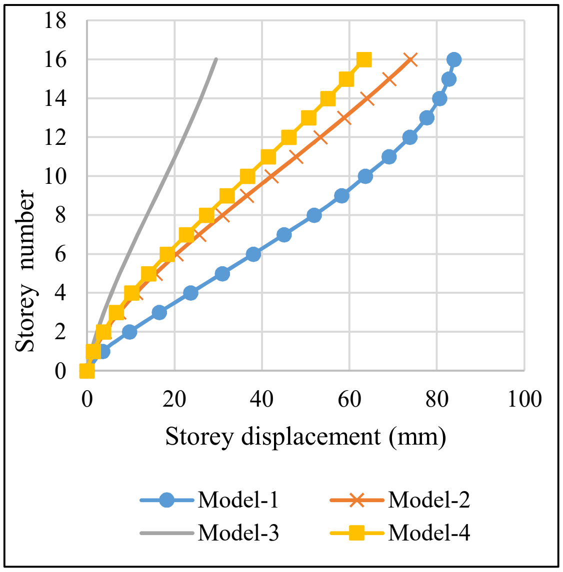

Figure 3.13: Storey displacement of regular structure

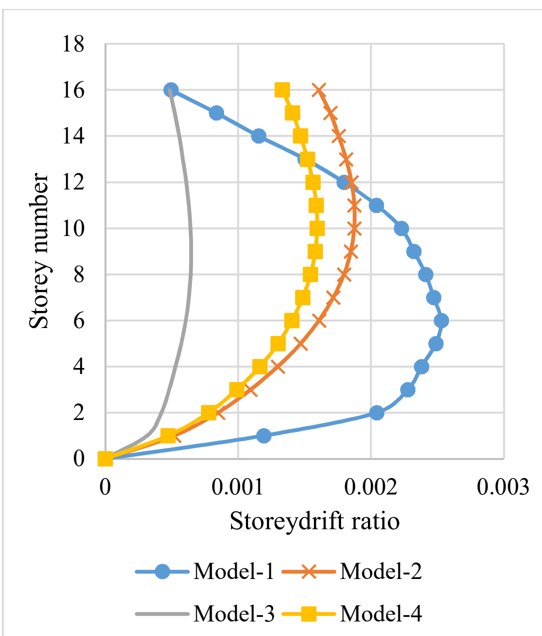

Figure 3.14: Storey drift of regular structure

Figure 3.13 and 3.14 represents the storey displacements and storey drift of regular structure in which the structure without shear wall shows high storey displacements and storey drift and structure with shear wall at the edges shows less storey displacements and storey drift.

The maximum top storey displacement is in the structure having no shear wall with displacement of 83.925 mm and minimum top storey displacement is in the structure having shear wall at the edges with displacement of 29.477 mm.

The maximum storey drift ratio is in the structure having no shear wall at 6th floor level and minimum storey drift ratio is in the structure having shear wall at the edges.

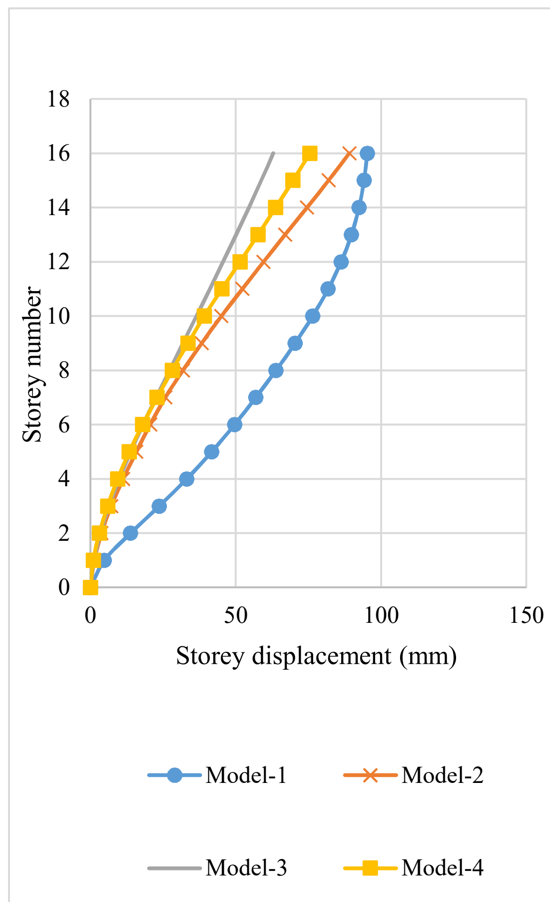

Figure 3.15: Storey displacements of L-shaped structure

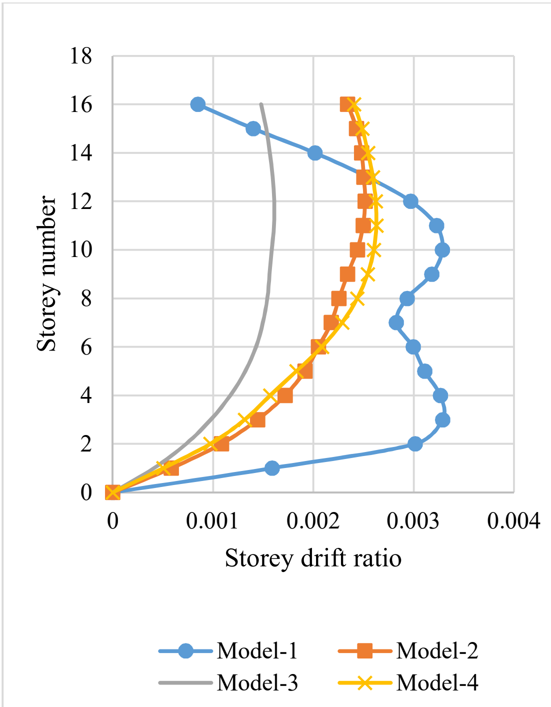

Figure 3.16: Storey drifts of L-shaped structure

Figure 3.15 and 3.16 represents the storey displacements and storey drift of L-shaped structure in which the structure without shear wall shows high storey displacements and storey drift and structure with shear wall at the edges shows less storey displacements and storey drift.

The maximum top storey displacement is in the structure having no shear wall with displacement of 95.25 mm and minimum top storey displacement is in the structure having shear wall at the edges with displacement of 62.91 mm.

The maximum storey drift ratio is in the structure having no shear wall at 3rd floor level and minimum storey drift ratio is in the structure having shear wall at the edges.

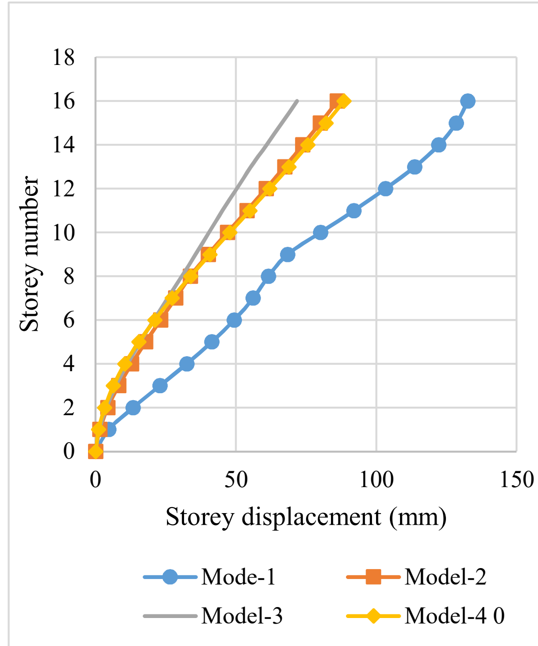

Figure 3.17: Storey displacements of C-shaped structure

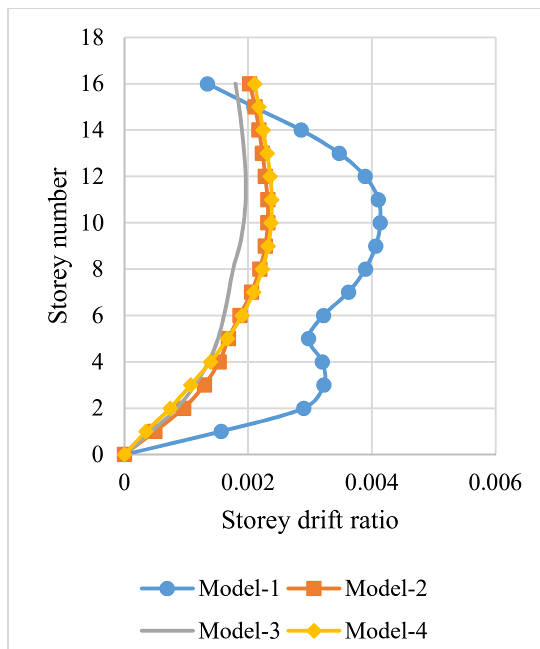

Figure 3.18: Storey drift of C-shaped structure

Figure 3.17 and 3.18 represents the storey displacements and storey drifts of C- shaped building with A/L ratio 0.26, in which the storey displacements and storey drifts are less in the structure with shear wall at the edges.

The maximum top storey displacement is in the structure having no shear wall with displacement of 132.64 mm and minimum top storey displacement is in the structure having shear wall at the edges with displacement of 71.76 mm.

The maximum storey drift ratio is in the structure having no shear wall at 10th floor level and minimum storey drift ratio is in the structure having shear wall at the edges.

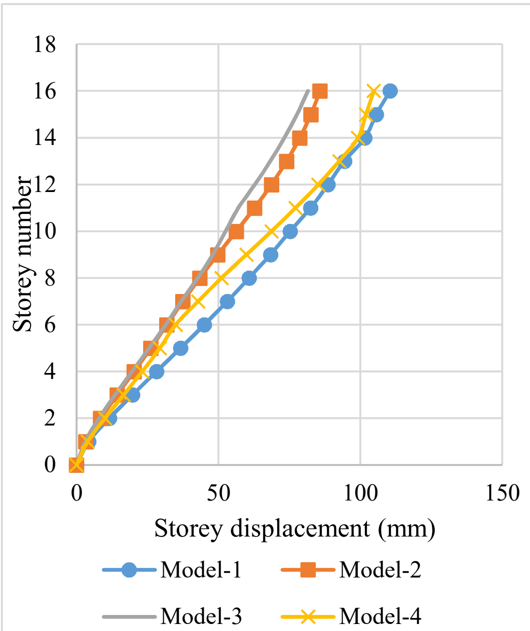

Figure 3.19: Storey displacements of U-shaped structure

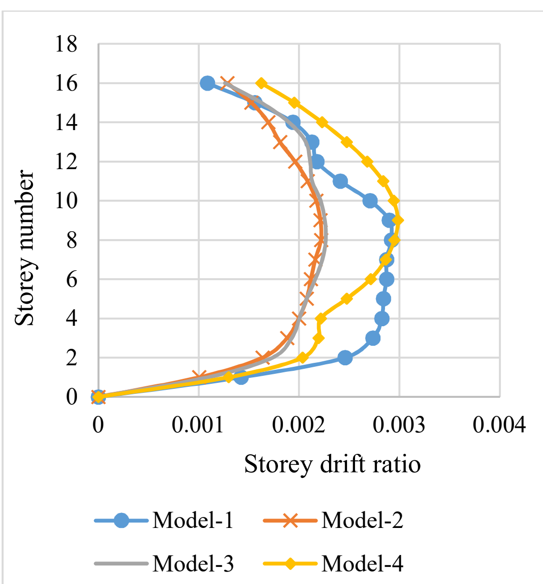

Figure 3.20: Storey drifts of U-shaped structure

Figure 3.19 and 3.20 shows the graphical representation of storey displacements and storey drifts of U- shaped building with A/L ratio 0.5, in which the storey displacements and storey drifts are less in the structure with shear wall at the edge. From the above graphs is observed that the structure is having shear wall at the edges shows the lesser storey displacements and storey drifts when compared to the models with the shear wall at corners and both at corners and edges. So, placing shear wall at edges of the building in all direction is the optimum location of the shear wall. So, the model with shear wall placed at edges in all direction is selected for the further study.

The maximum top storey displacement is in the structure having no shear wall with displacement of 110.426 mm and minimum top storey displacement is in the structure having shear wall at the edges with displacement of 81.506 mm.

The maximum storey drift ratio is in the structure having no shear wall at 9th floor level and minimum storey drift ratio is in the structure having shear wall at the edges.

The structure with shear wall shows 40-50% reduction in storey displacements and 35-45% reduction in storey drift ratio.

Irregular structures are vulnerable to earthquake, irregular structures shows 13-20 % higher storey displacements, 25-35% higher storey drifts when compared with regular structures.

Seismic response of plan irregular structures depends on both irregularity ratio and shape of the structure.

Structure with the shear wall at edges of the structure in all the direction gives the good results when it is subjected to earthquake load.

As represented in the graphs, the structures with the shear wall at sides in all the directions is very effective when compared to other structure with different location of shear wall.

Model-3 shows 70 % less displacement in regular building and up to 50% less displacements in irregular building models.

The same result has been found in all irregular models with different irregularity ratios.

4. ANALYSIS OF STRUCTURE WITH SAGGERED SHEAR WALL

After finding optimum location of shear wall the shear wall is replaced by staggered shear wall by providing 10% openings in irregular buildings of different irregularity ratios considered in previous study. Time history analysis performed to analyze the seismic behavior of the irregular structure with different irregularity ratios according to IS 1893 Part-1. The results from the staggered shear wall structure are compared with the shear wall structure with same percentage of regular openings in it

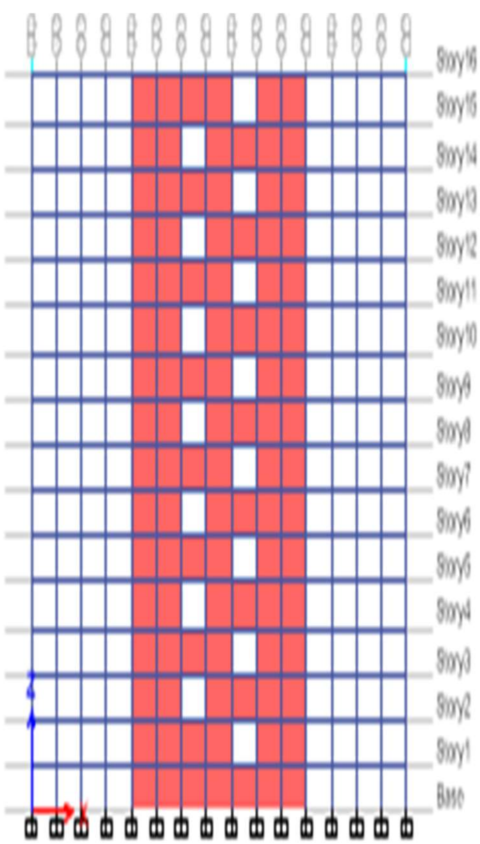

Figure 4.1:.Elevation Staggered shear wall

Figure 4.1 shows the elevation view of structure in which staggered shear wall is placed at the optimum location of the irregular structure.

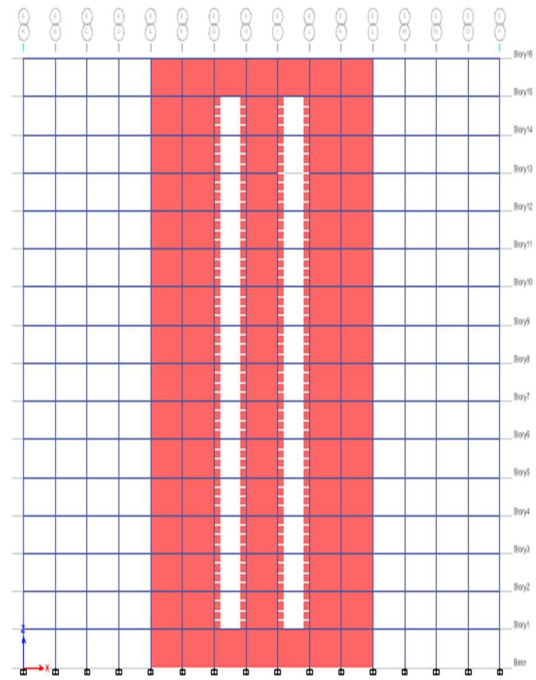

Fig4.2: Elevation of Shear wall with regular Openings.

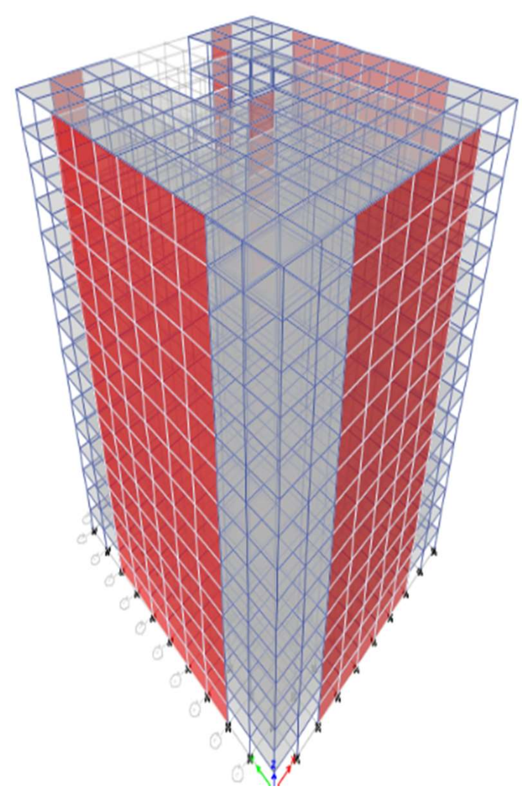

Figure 4.3: Shear wall with no opening.

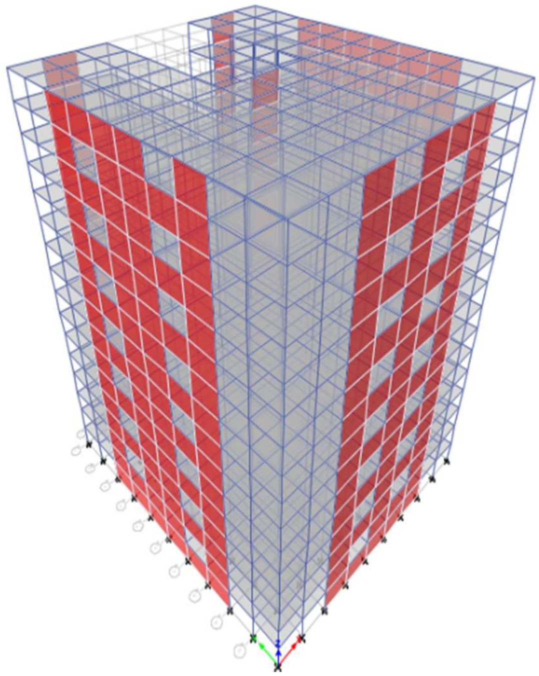

Figure 4.4:.Elevation of Staggered shear wall.

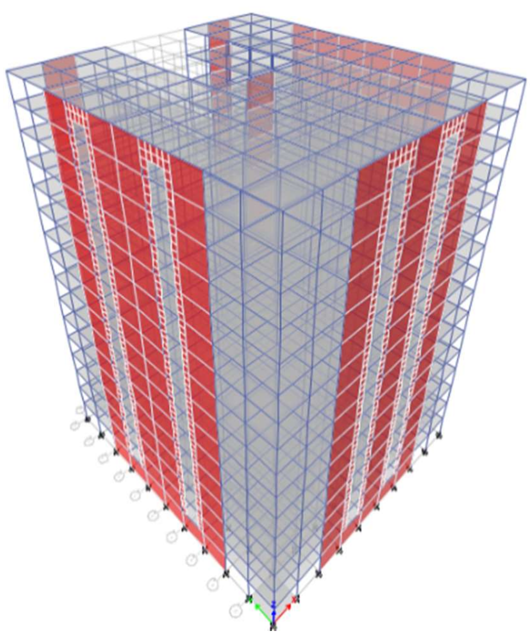

Figure 4.5: Elevation of Regular openings in shear wall.

Figures:
4.3 :3D model of shear wall building without openings.
4.4: 3D model of staggered shear wall building.
4.5: 3D model of shear wall building with regular openings.

5. RESULTS AND DISCUSSIONS

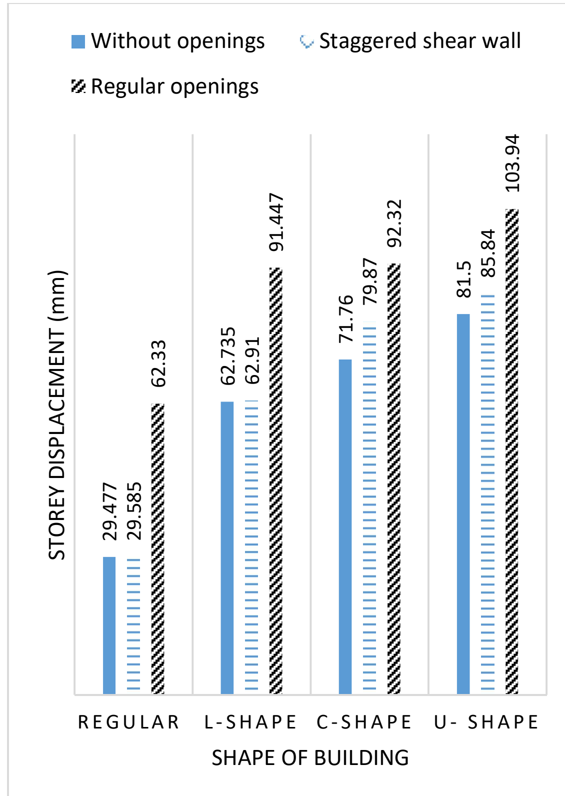

Figure 5.1: Storey displacement comparison

Figure 5.1 shows the graphical representation of storey displacements of regular building and irregular buildings of different shapes.
Staggered shear wall structure and shear wall structure with regular openings are analyzed in time history analysis considering Bhuj earthquake data by adopting 10% opening in both the models.
From the study it shows that, in comparison with the shear wall structure having no openings, staggered shear wall structure shows 1-10 % variation in storey displacements and shear wall structure having regular opening shows 15-49% variation in storey displacements in considered regular and irregular structures.
Maximum top storey displacement in regular structure is 29.47 mm, 62.735 mm in L-shaped structure, 71.76 mm in C- shaped building and 81.55 mm in U-shaped building.
From the results it shows that U-shaped structure with A/L ratio 0.5 is very much vulnerable to earthquake among considered structures in the present study.

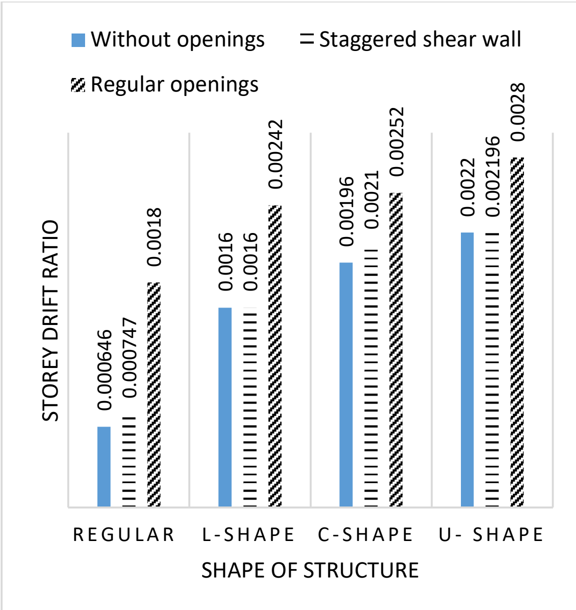

Figure 5.2: Storey drift comparison

Figure 5.2 shows the graphical representation of storey drift ratio of regular building and irregular buildings of different shapes.
From the study it shows that, in comparison with the shear wall structure having no openings, staggered shear wall structure shows 2-13 % variation in storey drift ratios and shear wall structure having regular opening shows 13-40% variation in storey drift ratios in considered regular and irregular structures.

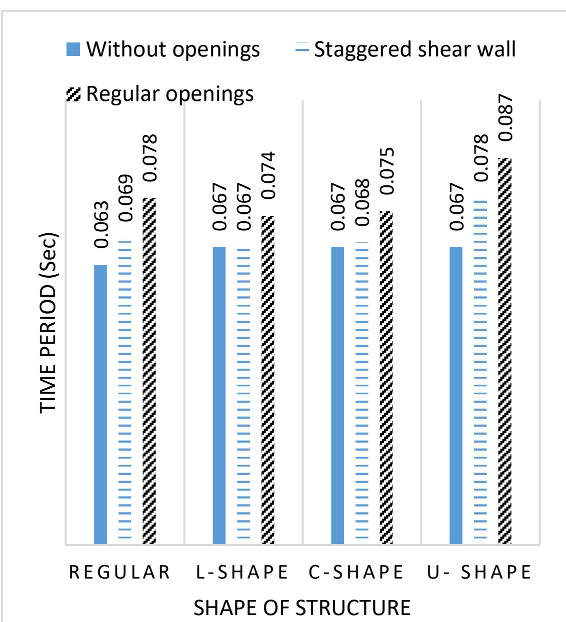

Figure 5.3: Time period comparison

Figure 5.3 shows the graphical representation of Time period of regular building and irregular buildings of different shape.
Staggered shear wall structure and shear wall structure with regular openings are analyzed in time history analysis considering Bhuj earthquake data by adopting 10% opening in both the models.
From the study it shows that, in comparison with the shear wall structure having no openings, staggered shear wall structure shows 10-20 % variation in time period and shear wall structure having regular opening shows 20-28% variation in time period in considered regular and irregular structures.

6. CONCLUSIONS

- The structure with shear wall shows 40-50% reduction in storey displacements and 35-45% reduction in storey drift ratio.
- Irregular structures shows 13-20 % higher storey displacements and 25-35% higher storey drifts when compared with regular structures.
- Model with shear wall at edges of the structure shows 70% less displacement in regular structure and up to 50% less displacements in irregular structure models.
- Staggered shear wall structure shows 1.5% variation in storey displacement and 2.8% variation in storey drift ratio in comparison with the structure having no openings in the shear wall.
- Shear wall structure having regular openings in shear wall shows 49 % variation in storey displacements and 40 % variation in storey drift ratio in comparison with the structure having no openings in the shear wall.

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