Influence of Staircase and Elevator Core Wall Location on the Seismic Capacity of Plan Irregular Structure

S C Manohar and Eshwar H N Reddy

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INFLUENCE OF STAIRCASE AND ELEVATOR CORE WALL LOCATION ON THE SEISMIC CAPACITY OF PLAN IRREGULAR STRUCTURE

Manohar S C[1] and Eshwar Reddy H N[2]

Email: manoharsc.37@gmail.com and eshwar.ce.et@msruas.ac.in

Department of Civil Engineering, M.S. Ramaiah University of Applied Sciences, Peenya, Bangalore - 560 058, INDIA

Abstract: *The increased frequency and intensity of earthquakes demand more seismic resistance in buildings. One of the effective approach to control deflection during an earthquake is via a shear wall. This research primarily focuses on several potential positions of the elevator core wall and staircase in an irregularly shaped structure where the mass and stiffness are concentrated at particular locations. Eccentricity in the mass and stiffness distributions causes a torsion reaction with a translation response. The location of the staircase and elevator core wall plays a vital role and changing the location of the staircase and core wall leads to torsional irregularity in the regular building.*

In this study, the analysis is made to understand the seismic behaviour of regular and irregular RC buildings with and without the effect of staircase and elevator core walls with varying locations. Five models (10-storey RC structure) of various asymmetric ratios are compared, with the staircase and elevator core walls in various locations, such as ideal frame, centre, and opposite corners. The modelling and analysis are done using ETABS v19 software according to the Indian standard codes. A parametric study is conducted for the following parameters: storey displacements, storey drift, storey shear, and base shear by performing response spectrum analysis and time history analysis. According to the results obtained it is observed that the structure with a staircase and elevator core wall positioned at an opposite corner provides better performance than other structures.

Keywords: *Plan irregularity, Torsional irregularity, Staircase, Elevator core wall.*

1. INTRODUCTION

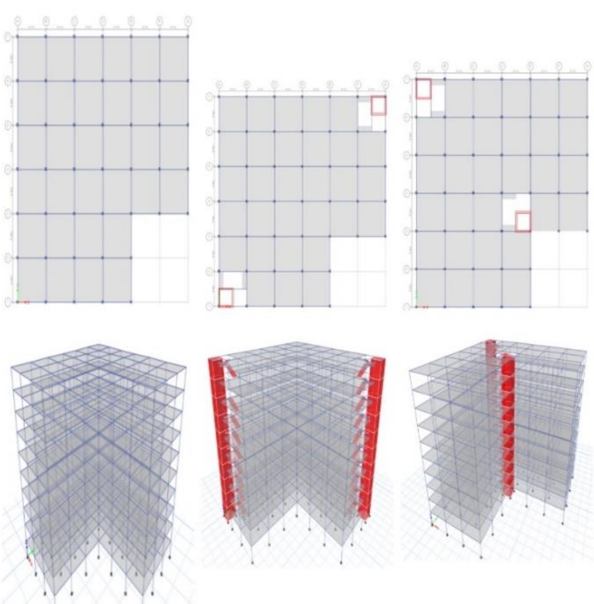
India's growing population and widespread unscientific constructions, such as multi-storey luxury flats, large manufacturing structures, large malls, supermarkets, warehouses, and masonry buildings, place the country at risk. Ten large earthquakes have struck the nation in the previous 15 years, killing nearly 20,000 people. According to the country's current seismic zone map (IS 1893: 2016), more than 59% of India's geographical area is under risk of moderate to significant seismic hazard—that is, it is prone to shaking of MSK Intensity VII and higher (BMTPC, 2006). The location of the staircase and elevator core during an earthquake is a significant component that affects how the multi-story building reacts. In a staircase, the mid-landing and floor landing levels are supported by beams that are supported by inclined firm slabs. When an earthquake shakes, the inertial force created by the staircase causes unequal stiffness in both directions because it concentrates stiffness at one specific spot. Such an imbalance in the distribution of mass or stiffness across the building plan may cause the structure to torsionally respond, which could increase the seismic demand on structural elements. Any positioning of the elevator core that is not in a symmetrical position in the building plan is likely to result in an imbalance in the distributions of mass and stiffness. This may have effects comparable to those mentioned in relation to a staircase.

Plan irregularity includes torsional irregularity, which develops in the structure as a result of the eccentricity between the centre of mass and the centre of stiffness. Torsional impacts can severely damage structures, according to damage reports from previous earthquakes. Srinivasa Rao bosta et al. (2017) investigated the impact of the staircase and shear wall in a building's lift core wall. A five-story RC structure was simulated, and nonlinear static analysis was done for models with simply a staircase and models having both a staircase and an elevator core at various locations

[6]. Chandana. S et al. (2017) used STAAD-Pro V8i software to perform linear dynamic analysis on G+20 RC building models with both symmetric and asymmetric in plan with shear walls at different places. The study demonstrates that the symmetric plan model with a shear wall along the circumference performs better [12].

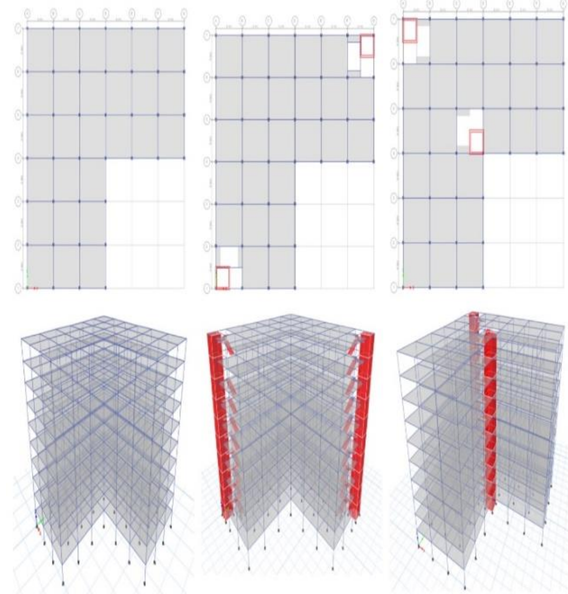
2. STRUCTURAL DETAILS

In this study, the seismic behavior of ten-storey L-shaped RC irregular structures with and without staircase and elevator core wall at different locations in plan for different irregularity ratios i.e., A/L ratio of 0.33, 0.5 and 0.67 are analysed using ETABS software, to determine the optimum location of staircase and core wall by response spectrum analysis and time history analysis. The overall dimensions of the building is 36m × 36m, the columns have cross sections of 450mm × 450mm and beams have cross sections of 300mm × 450mm, throughout the height of the building. The thickness of the RC core wall is assumed to be 250mm and the thickness of the slab is 125mm and the dead and live loads are considered from IS 875 Part 1 and 2 respectively. The grade of concrete is M25 and the reinforcing steel grade is Fe415. For the rocky stratum, all possible translational and rotational degrees of freedom at the bottom nodes of the building are restrained.



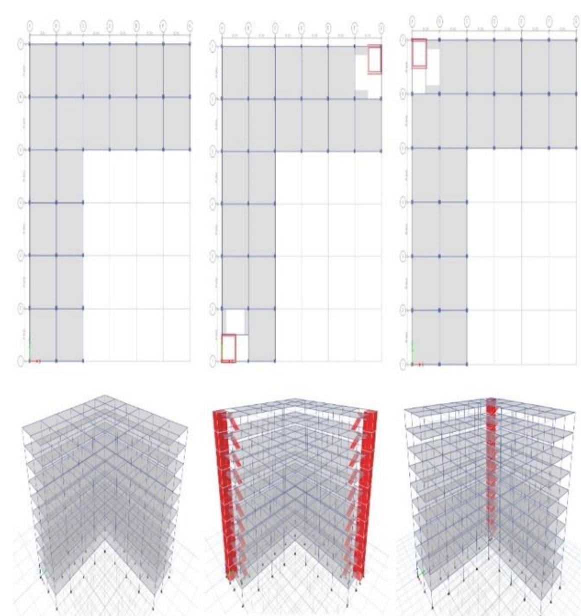
(a) (b) (c)

Figure 1 Plan and elevation of structure with irregularity ratio 0.33 (a) without staircase and core wall (b) with staircase and core wall at corner (c) with staircase and core wall at centre



(a) (b) (c)

Figure 2 Plan and elevation of structure with irregularity ratio 0.5 (a) without staircase and core wall (b) with staircase and core wall at corner (c) with staircase and core wall at centre



(a) (b) (c)

Figure 3 Plan and elevation of structure with irregularity ratio 0.67 (a) without staircase and core wall (b) with staircase and core wall at corner (c) with staircase and core wall at centre

3. ANALYSIS

Dynamic response spectrum analyses of the building models are performed by considering the seismic zone V, seismic factor is 0.36, soil type as type II and damping ratio is 5%. Time history analysis is performed by considering north-south component of Bhuj earthquake.

4. RESULTS AND DISCUSSION

The results obtained from the analysis are discussed in this section. The parameters like time period, base shears, story displacements and story drifts are discussed.

4.1 Parametric study of plan irregular structure with and without staircase and elevator core wall for different irregularity ratios using response spectrum method

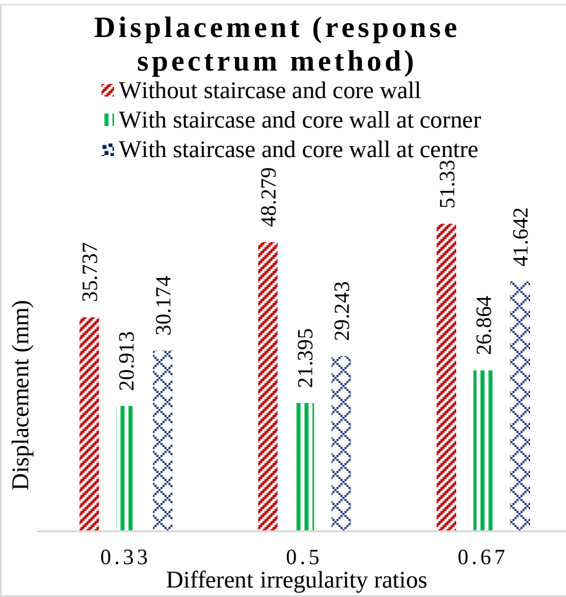


Figure 4 Displacement graph for response spectrum analysis

The maximum storey displacement results are shown in Fig. 4 it is observed that model with staircase and elevator core wall at corner and A/L ratio 0.33 has minimum storey displacement of 20.9mm and model without staircase and core wall for A/L ratio 0.67 has maximum storey displacement of 51.33mm when compared with other models. The percentage of reduction of storey displacement for staircase and elevator core wall at centre and at corner is 15.5% and 41.5% respectively when compared with model without staircase and elevator core wall.

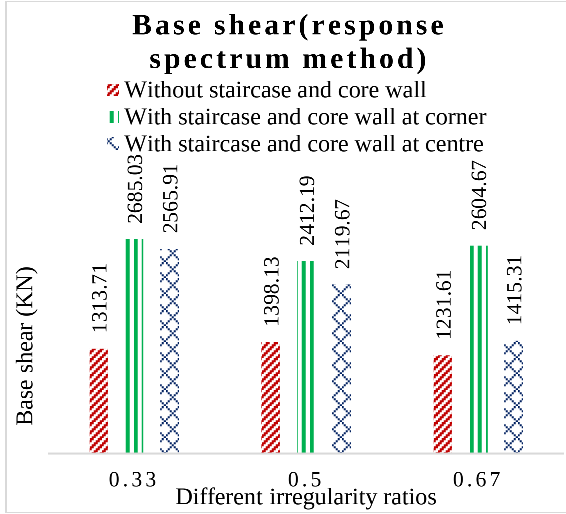


Figure 5 Base shear graph for response spectrum analysis

The base shear results are shown in Fig. 5 and base shear is minimum in the model without staircase and elevator core wall building. It is observed that when compared to the model without stair case and core wall base shear varies by large values in the building models with staircase and elevator core wall.

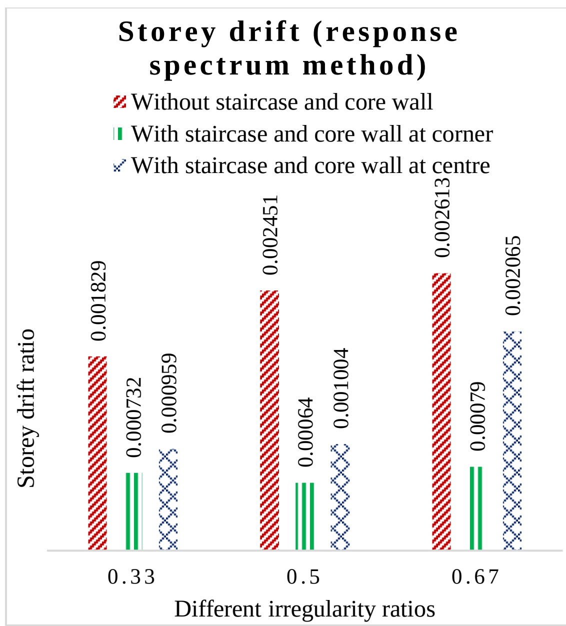


Figure 6 Storey drift ratio graph for response spectrum analysis

From Fig. 5 it is observed that model with staircase and elevator core wall at corners has minimum storey drift of 0.0007 with respect to A/L ratio 0.5 and model without staircase and elevator core has maximum storey drift of 0.0026 with respect to A/L ratio 0.67, when compared with other models.

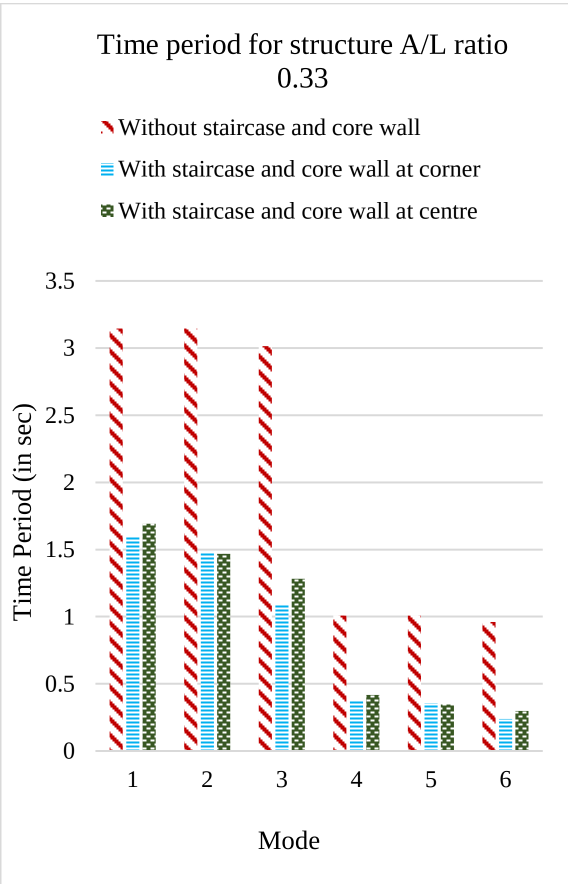


Figure 6 Time period graph for irregular structure of A/L ratio 0.33

From Fig. 6, it observed that time period for the model without staircase and core wall has shown the maximum time period of 0.96 sec and time period for building model with staircase and elevator core wall at corner has the minimum time period of 0.24 sec, compared to other building models. Building models without staircase and elevator core wall has a maximum time period because it is flexible.

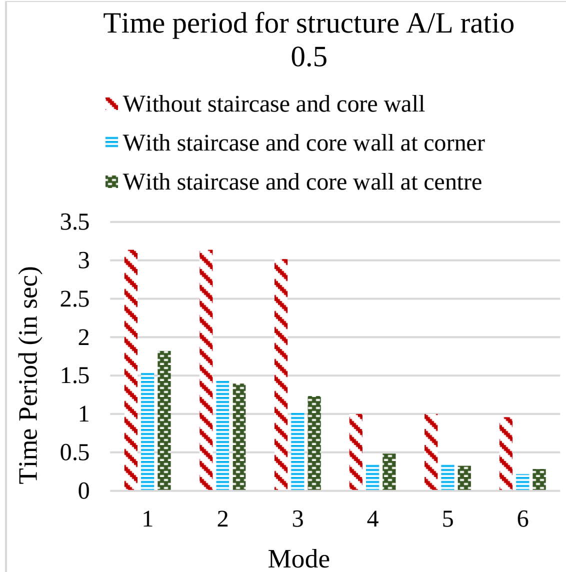


Figure 7 Time period graph for irregular structure of A/L ratio 0.5

From Fig. 7, it observed that time period for the model without staircase and core wall has shown the maximum time period of 0.96 sec and time period for building model with staircase and elevator core wall at corner has the minimum time period of 0.22 sec, compared to other building models. Building models without staircase and elevator core wall has a maximum time period because it is flexible.

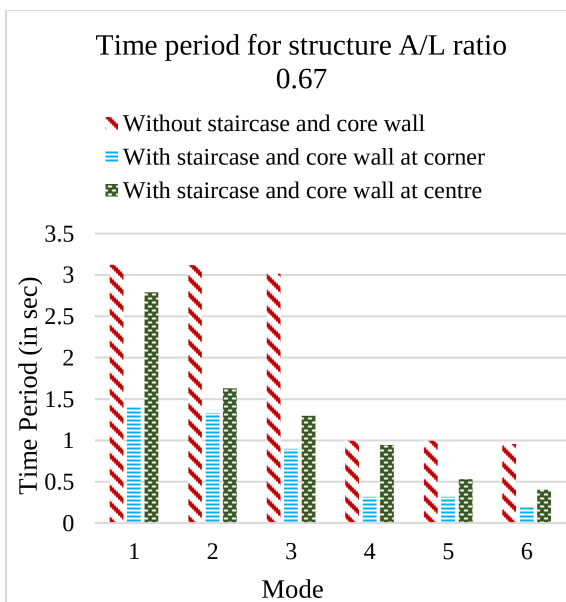


Figure 8 Time period graph for irregular structure of A/L ratio 0.67

From Fig. 8, it observed that time period for the model without staircase and core wall has shown the maximum time period of 0.95 sec and time period for building model with staircase and elevator core wall at corner has the minimum time period of 0.19 sec, compared to other building models. Building models without staircase and elevator core wall has a maximum time period because it is flexible.

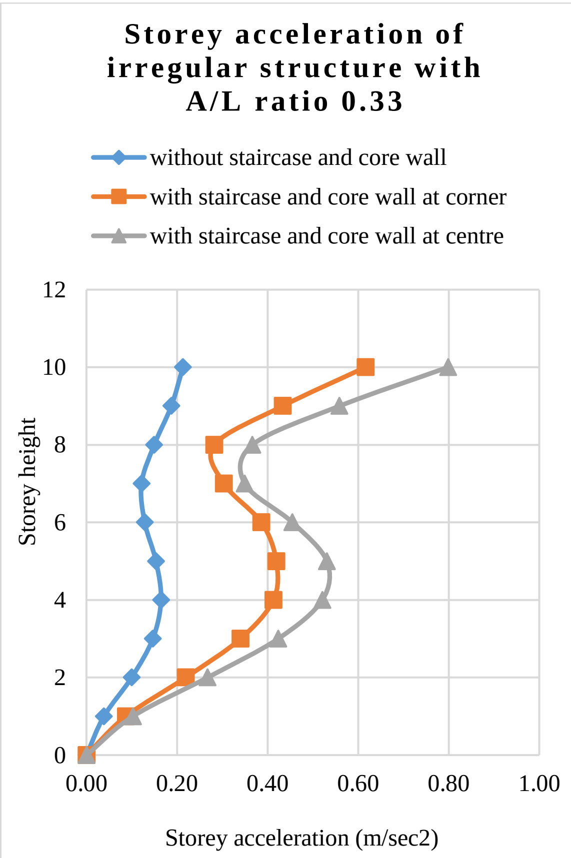


Figure 9 Storey acceleration graph for irregular structure with A/L ratio 0.33

The maximum storey acceleration results are shown in Fig. 9 it is observed that model with staircase and elevator core wall at corner has less storey accelerations when compared with a model with staircase and elevator core wall at centre when compared with other models.

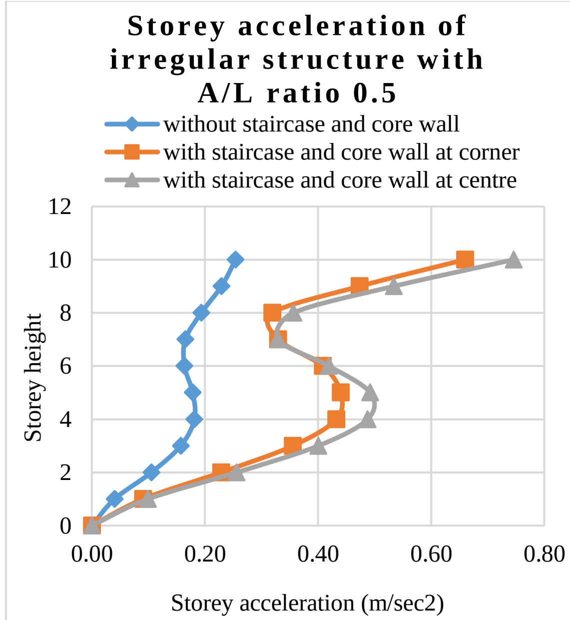


Figure 10 Storey acceleration graph for irregular structure with A/L ratio 0.5

The maximum storey acceleration results are shown in Fig. 10 it is observed that model with staircase and elevator core wall at corner has less storey accelerations when compared with a model with staircase and elevator core wall at centre when compared with other models

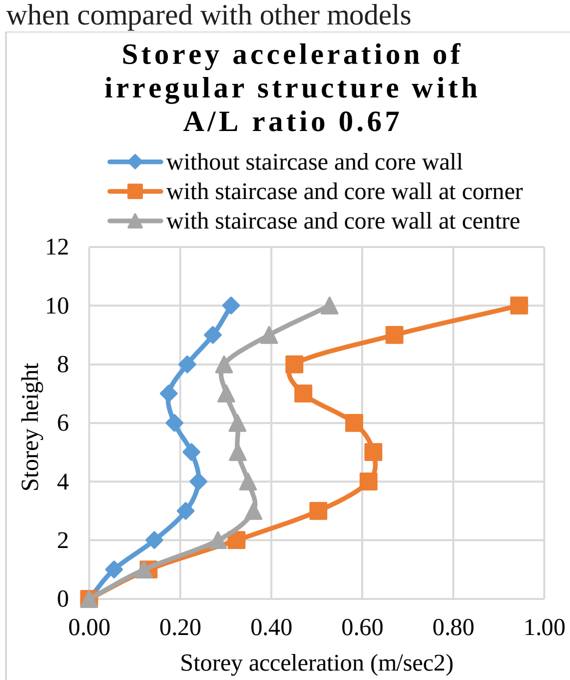


Figure 11 Storey acceleration graph for irregular structure with A/L ratio 0.6

The maximum storey acceleration results are shown in Fig. 11 it is observed that model with staircase and elevator core wall at centre has less storey accelerations when compared with a model with staircase and elevator core wall at corner when compared with other models

4.2 Parametric study of plan irregular structure with and without staircase and elevator core wall for different irregularity ratios using time history method

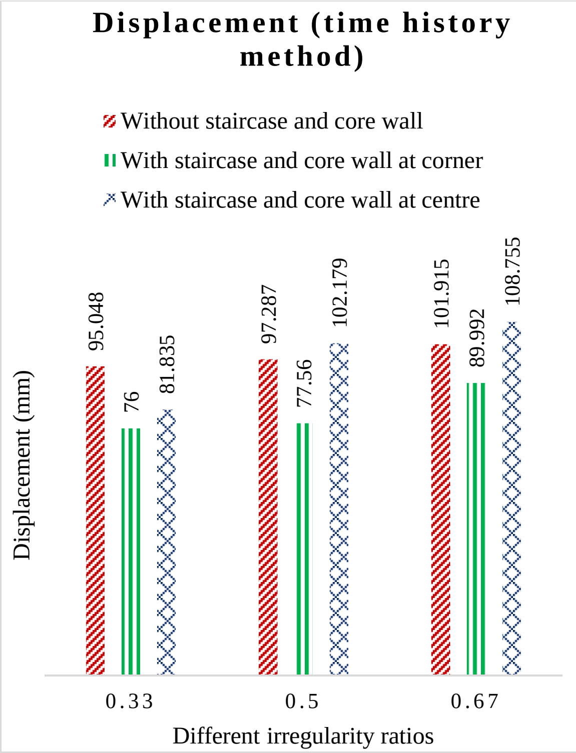


Figure 12 Displacement graph for Time history analysis

The maximum storey displacement results are shown in Fig. 12 it is observed that model with staircase and elevator core wall at corner and A/L ratio 0.33 has minimum storey displacement of 76mm and model without staircase and core wall for A/L ratio 0.67 has maximum storey displacement of 108.75mm when compared with other models. The percentage difference of results is about 72.42% between the two methods of loading condition (response spectrum method and time history method) for storey displacement.

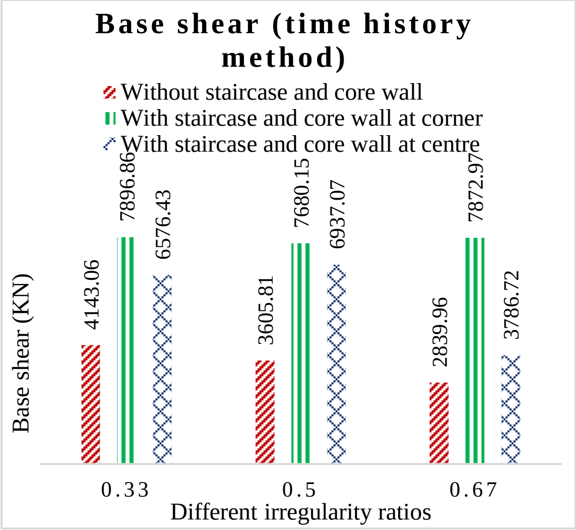


Figure 13 Base shear graph for Time history analysis

The base shear results are shown in Fig. 13 and base shear is minimum in the model without staircase and elevator core wall building. It is observed that when compared to ideal frame base shear varies by large values in the building models with staircase and elevator core wall. The percentage difference of results is about 68.59% between the two methods of loading condition (response spectrum method and time history method) for base shear.

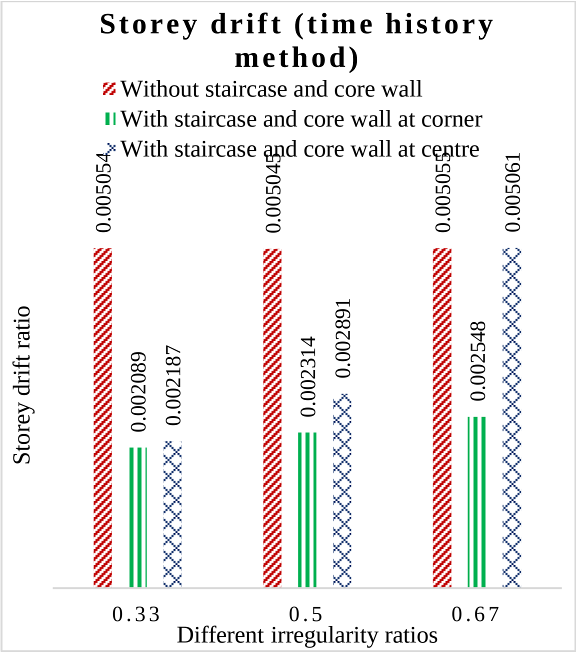


Figure 14 Storey drift ratio graph Time history analysis

From Fig. 14 it is observed that model with staircase and elevator core wall at corners has minimum storey drift of 0.002 with respect to A/L ratio 0.33 and model without staircase and elevator core has maximum storey drift of 0.005 with respect to A/L ratio 0.67, when compared with other models. The percentage difference of results is about 97.23% between the two methods of loading condition (response spectrum method and time history method) for storey drift ratio.

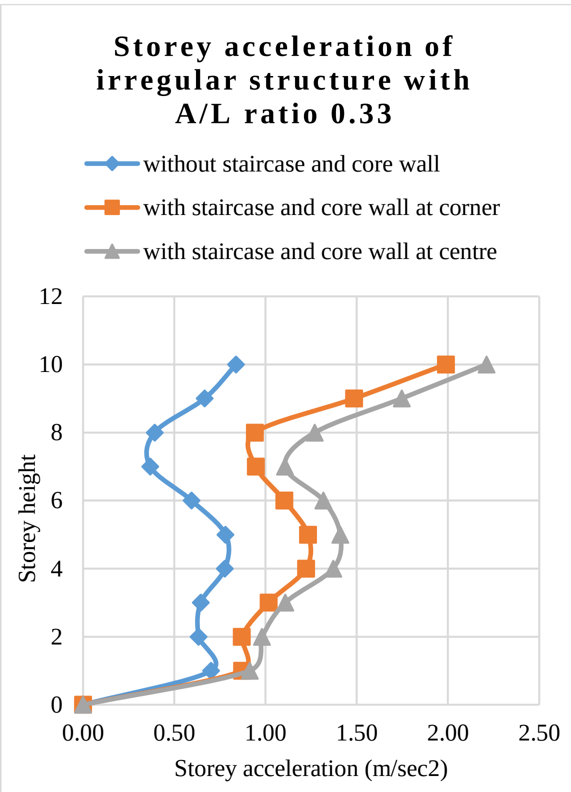


Figure 15 Storey acceleration graph for irregular structure with A/L ratio 0.33

The maximum storey acceleration results are shown in Fig. 15 it is observed that model with staircase and elevator core wall at corner has less storey accelerations when compared with a model with staircase and elevator core wall at centre when compared with other models.

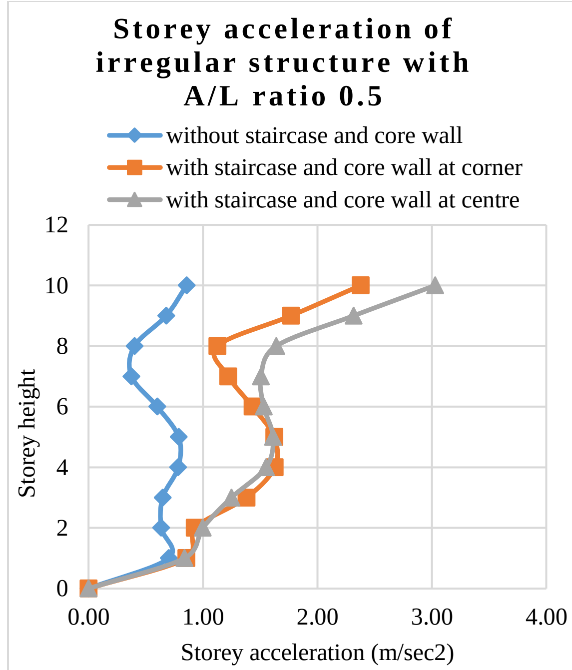


Figure 16 Storey acceleration graph for irregular structure with A/L ratio 0.5

The maximum storey acceleration results are shown in Fig. 16 it is observed that model with staircase and elevator core wall at corner has less storey accelerations when compared with a model with staircase and elevator core wall at centre when compared with other models.

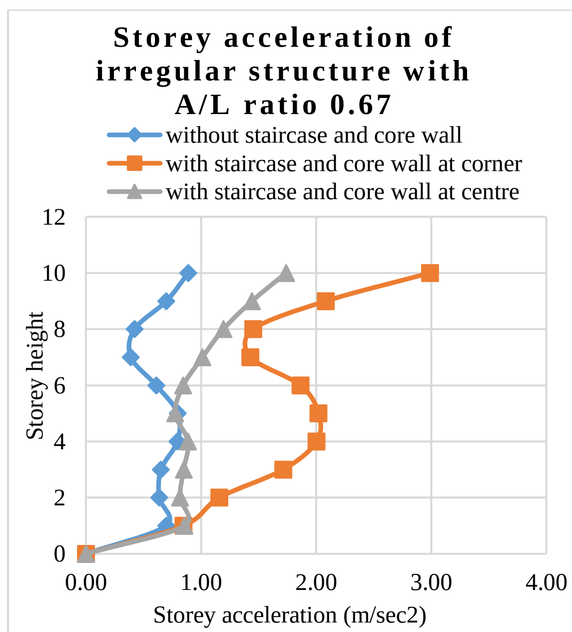


Figure 17 Storey acceleration graph for irregular structure with A/L ratio 0.67.

The maximum storey acceleration results are shown in Fig. 17 it is observed that model with staircase and elevator core wall at corner has less storey accelerations when compared with a model with staircase and elevator core wall at centre when compared with other models.

5. CONCLUSIONS

1. In this study, the seismic behaviour of RC irregular buildings with the effect of the staircase and elevator core wall at varying locations for different irregularity ratio has been carried out.

2. Time period changes with respect to the location of the staircase and elevator core wall for the same building model. The time period is minimum in building with staircase and elevator core wall at corner position when compared to other Building models.

3. In the presence of staircase and elevator core wall in the building, the base shear values have been increased for about 45.7%.

4. In the presence of staircase and elevator core wall Storey displacement values have been decreased for about 20-50% with respect to the varying location of staircase and elevator core wall.

4. It concludes that the position of building with staircase and elevator core wall at the corner performs better when compared to building models with staircase and elevator core wall at the centre positions for L-shaped irregular building.

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