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Comparative analysis of multistorey building with and without Floating Columns

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Abstract. The use of floating columns (FCs) in multistorey buildings has become increasingly common because of their functional advantages, particularly in urban areas where space optimization is essential. FCs free up ground-level space for open parking and vehicle access, which is a growing concern in cities. A floating column is a vertical element that rests at its lower end on a beam rather than transferring its load directly to the foundation. In seismically active regions, however, this feature poses a significant challenge, as it can make a building more vulnerable to failure. This study investigates the effect of FCs on the structural response of a multistorey building across different seismic zones. Building models with and without FCs were developed, and linear dynamic analysis was performed in ETABS, with storey drift, base shear, and storey displacement as the main parameters. The analysis followed an iterative approach: the initial beam and column dimensions were adjusted based on the results, illustrating the need for an adaptive design process to improve both performance and cost-effectiveness. The study also considered different seismic zones, including Zone III, and Type II soil conditions, which significantly influence a building's response to seismic forces. The results showed little difference in the values for Zone II, whereas this difference increased with higher seismic zones.

1 Introduction

Floating columns occupy a special place in contemporary architecture [1-2]. Unlike conventional columns, which transfer their load vertically to the foundation, floating columns are vertical members that terminate at a certain level and rest on a beam or other structural member [3-4]. They are commonly used in buildings that require open space on the lower floors for architectural and functional reasons, particularly in parking areas, banquet halls, and shopping malls. Rather than transferring load directly to the foundation, these columns transmit it indirectly through supporting beams or transfer girders [5-8].

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As much as floating columns offer a lot of flexibility as far as architectural planning is concerned, they present also a challenge to structure stability.As the load is being transferred to the members, the instability can lead to high bending moments and shear forces in the members of support, and these need to be taken into account during design, otherwise the members will not meet the demands for performance and safety [9-10]. Couple of studies on seismic performance of buildings with floating columns have been studied including building structure response, ductility and energy dissipation [11]. However, a systematic comparative study on the building with floating columns and without them under various earthquake conditions is not yet available. In addition, the effects of floating columns on the seismic sensitivity of buildings with heterogeneous architectures like those of setback and irregular buildings need to be examined more.

1.1 Objectives

1. To Perform the Seismic, Analyze of the Multistorey Building with and Without FC in different Seismic Zones in India.
2. Analyze the structural implications of FC on the overall seismic performance, focusing on parameters like base shear, story drift, and displacement.
3. Compare the structural responses of buildings in different seismic zones, highlighting the variations in performance due to increasing seismic intensity.

2. Literature Review

This study was done based on the previous research work and with the help of the following Indian standards which play an important role during the design and analysis of multi-story buildings, especially in seismic zones, which are mandatory for the design procedure in earthquake prone zones: IS 1893-part2:2002 and IS 456:2000. The study indicates that the concrete used is M40 and rebars of HYSD500. It is important that the properties of materials are accurately determined to ensure structural integrity. The iterative procedure for the structural analysis is explained; preliminary dimensions of the beams and columns were changed according to the analysis results, where adaptive design was shared to achieve better results and economy. In addition, the study is conducted within several types of seismic zones especially Zone III and soil conditions, in this case type-II soil that has a significant impact on the responsiveness of the building in relation to the seismic factors. Finally, the authors emphasize on the optimization of structural dimensions in order to maximize the use of materials as well as maximizing the safety requirement which is especially important in areas prone to earthquakes, therefore coming up with significant information regarding good building design [7-8].
A comparative study was carried out to examine the difference in structural performance between buildings with and without FCs, in terms of lateral displacement, storey drift, time period, and base shear, using Response Spectrum Analysis (RSA) in ETABS 2016. The results showed that the buildings with FC do respond differently to dynamic responses against the traditional buildings. To be more specific, storey forces of common buildings are larger than those of buildings with FC and the largest of them are attained at the lower storeys. It also becomes evident through the study that the storey drift of structures using

floating columns is higher than that of the ones without which indicates that the seismic design needs to be careful, regarding this. The FC structures also have lower storey shear values that could mean that there will be less risk of structural failure in situations involving seismic activity. Additionally, FC buildings take a longer time in the building periods, and this is an indication of the vibrational behaviour that may interfere with the performance of the building in seismically prone regions. Small-scale models that are used in experimentation may also be helpful in getting information on how FC structures behave when subjected to simulated earthquake motions. Overall, the literature suggests that while FC offer significant architectural benefits, their impact on structural integrity and performance under seismic conditions warrants comprehensive analysis and design considerations [4,6]

The construction of multi-storey buildings with FC has gained popularity in urban areas due to space constraints and aesthetic considerations. However, this design poses significant challenges in seismic regions, as the load transfer path becomes discontinuous, leading to poor structural performance during earthquakes. These later researches have shown that FC leads to a large, and increased, lateral displacement as well as storey drift of the building especially in zones with higher seismicity where the forces of an earthquake are denser. Three cases of multistorey buildings, comprising 8, 12, and 16 storeys, were analysed in this study to examine the influence of shear walls on structural behaviour under seismic loads. Accordingly, the results tend to show that although architectural assets Floating columns could improve the FSI, it also elevates the building's response to earthquakes. Computations also showed that the presence of shear walls eliminated or at least minimized most of the negative impacts by decreasing both the lateral displacement and storey drift in all the models evaluated. This research offers viable information on the effectiveness stability standard design with FC in the building structures for seismic condition; this shows that future construction involving building structures with FC need to adopt a stable design so as to be safe during earthquakes [8].

Keeping up with the recent architectural trends warranting column-free areas in high-rise building structures in major cities has seen architects introduce what is known as floating columns, though they aesthetically appealing, are structurally very dangerous, more so in region prone to earthquakes. This research is concerned with the dynamic behavior of high-rise steel buildings with irregularities with particular reference to buildings with floating columns. The implication of the study is of seismic performance estimations as measured by two crucial measures of storey displacement and storey drift and base shear. Using structural analysis software, the shear and moment diagrams for different configurations of the high-rise building were analysed and compared under seismic loads. The observations seek to contribute to the understanding of the performance of the floating columns concerning lateral loads, orientation of the buildings on central shear core and expose the continuous load transfer paths for enhancing the building's resistance to earthquakes. The study finally aims at identifying recommendations for design modifications which would improve the building's response to an earthquake, in a bid to increase safety where such zones are present [9]. Thus, the presented work is crucial for overcoming the existing difficulties of contemporary architectural requirements and protecting tall buildings in seismically sensitive areas.

3. Methodology

3.1 Structural Modelling

3.1.1 Building without Floating Columns Geometry

Figure 1 and Figure 2 shows the plan and front view of building adopted for the study.

- No. of Storeys– G+15
- Beam– 400 x 600 mm
- Column-1– 400 x 600 mm
- Column-2– 500 x 700 mm
- Slab– 200 mm thick
- Grade of Concrete– M40
- Re bars Grade- HYSD 500
- Total No. of Columns- 53

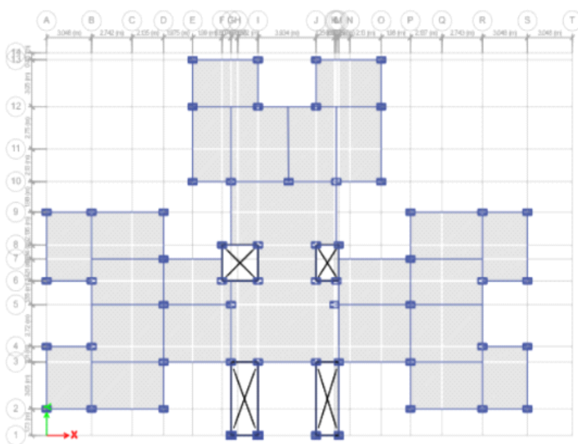

Fig. 1 Building without floating Column Top View

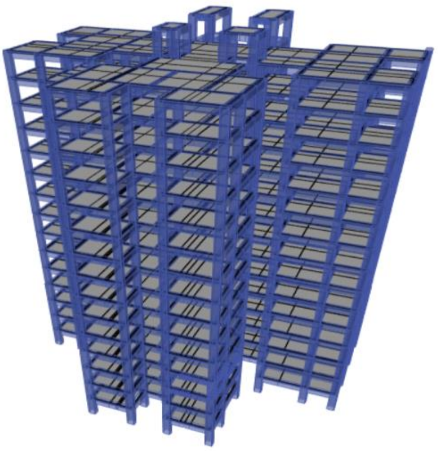

Fig. 2 Building without floating Column front View

3.1.2 Building with Floating Columns Geometry

Figure 3 and Figure 4 shows the plan and front view of building adopted for the study.

- No. of Storeys– G+15
- Beam– 400 x 600 mm
- Column-1– 400 x 600 mm
- Column-2– 500 x 700 mm
- Slab– 200 mm thick
- Grade of Concrete– M40
- Re bars Grade- HYSD 500
- Total No. of Columns- 53
- No. of Floating Columns- 2

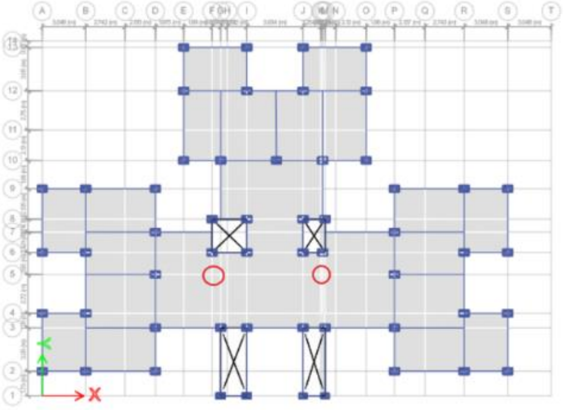

Fig.3 GF plan of Building floating Column

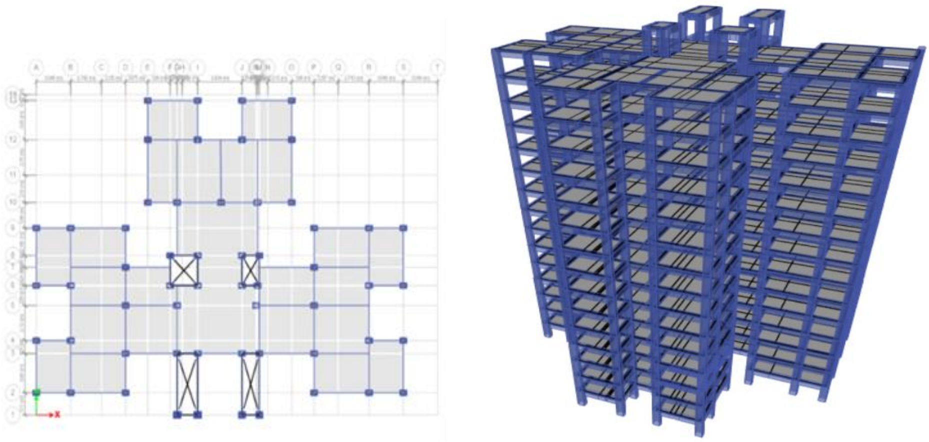

Fig. 4 1st-floor plan of building with floating columns and front view

3.2 Types of Loads applied on the structure

Dead Load of the structure
Live load of 3kN/m
Floor finish load of 1kN/m
Wall Load of 13.11kN/m was calculated by considering the wall thickness as 230mm and floor height as 3m. Parapet wall load of 4.37kN/m only on the top floor was calculated by considering the wall thickness as 230mm and height as 1m. Seismic Loads Eqx and Eqy for Zone-II, Zone-III, Zone-IV, Zone-V.

4. Results and Discussions

Table.1 Results of the Storey Drift, Displacement, Base shear of both the structures

Storey drift	**Without Floating Columns Building**	**With Floating Columns Building**
Zone-II	0.000269	0.00029
Zone-III	0.000431	0.000493
Zone-IV	0.000649	0.000798
Zone-V	0.000899	0.00121
Displacement(mm)	**Without Floating Columns Building**	**With Floating Columns Building**
Zone-II	9.077	9.972
Zone-III	15.106	18.311
Zone-IV	22.142	28.296
Zone-V	30.989	42.897
Base Shear(kN)	**Without Floating Columns**	**With Floating Columns**

	Building	**Building**
Zone-II	1.10E-06	1.168E-06
Zone-III	-1615.7162	-1766.8761
Zone-IV	7.89E-07	9.01E-07
Zone-V	1.18E-06	1.45E-06

Table 1 shows the results of the Storey Drift, Displacement, Base shear of both the structures. The percentage increase in the storey drift values from zone-II to V are 7.8%, 14.385%, 22.96%, and 34.59% was observed, with a variation of 6.585%, 8.575%, and 11.63%. The percentage increase in the displacement values from zone II to V are9.86%, 21.22%, 27.79%, and 38.43%was observed, with a variation of 11.36%, 6.57%, and 10.64%. The percentage increase in the displacement values from zone II to V are 6.18%, 9.35%, 14.19%, and 22.88% was observed, with a variation of 3.17%, 4.84, and 8.64%.

5. Conclusions

Response Spectrum analysis was performed onto the structure in order to assess the seismic performance of the structure. In ETABS, response spectrum analysis is a core functionality for analyzing the seismic behavior of structures. It is a dynamic analysis method that considers the structure's natural frequencies, mode shapes, and the characteristics of ground motion defined by a seismic response spectrum. This method is particularly useful for multistorey buildings where dynamic effects are significant. As the zones change, fluctuations are observed in the values of base shear, displacement, and Storey Drift. There was not much difference in the values observed in the case of zone II, as the zones increased there was an increase in the difference in the values of the results was observed. Much difference in the displacement values was observed when compared with storey drift and base shear. Clearly there are effects of providing the floating columns on the structural performance of the building under seismic loads.

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