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SEISMIC ANALYSIS OF FLOATING COLUMNS IN MULTISTOREY BUILDINGS WITH DIFFERENT SEISMIC ZONES

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Abstract:
The increasing trend of constructing multistorey buildings with architectural irregularities has led to the widespread use of floating columns. However, such structural systems are vulnerable to seismic forces due to discontinuities in load transfer paths. This review paper investigates the seismic behavior of floating columns in multistorey buildings across different seismic zones. It examines the influence of seismic parameters, structural configurations, and zone-specific response spectra. The study highlights key findings from previous research, including the detrimental effects of soft-storey mechanisms, increased lateral displacement, and structural vulnerability in high seismic zones. The review concludes with recommendations on retrofitting techniques, performance-based design, and the need for additional lateral load-resisting systems to enhance seismic resilience in buildings with floating columns.

1. Introduction

Modern architectural demands have led to the adoption of floating columns in multistorey buildings to optimize space utilization and achieve aesthetic designs. A floating column refers to a vertical element that rests on a beam or slab instead of being directly grounded to the foundation. While this design offers flexibility in the layout of ground-floor spaces, it introduces structural discontinuities, making buildings more susceptible to seismic damage. The seismic performance of such structures varies significantly depending on the seismic zone, necessitating comprehensive analysis.

In India, seismic zones are categorized into Zone II, Zone III, Zone IV, and Zone V, with Zone V being the most seismically active. This review explores how buildings with floating columns perform under varying seismic conditions and identifies mitigation strategies to reduce seismic vulnerability.

Now a days, the population is increasing at fast rate. Due to shortage of spaces, it is very difficult to design the buildings in horizontal systems. As a result, vertical systems come into demand specially in High rise buildings, shopping malls, plaza building etc. Many Multi storeyed buildings are constructed for the purpose of Residential and commercial both. Some floors of commercial place contain banquet halls, conference rooms, parking areas, lobbies etc. These spaces require an uninterrupted movement of people and vehicles. Closely spaced columns act as barrier. Hence to avoid this condition; Floating Column comes into existence. Floating column is mainly used to fulfil architectural and functional requirement of the space. Floating Column: Column is a vertical member which starts from the ground and is continued up to the height of the structure. This column transfers the load of the structure to the foundation. To fulfil the functional requirements, some columns does not go directly to the foundation. They rest on the Transfer beams and transfer the load of structure to the adjacent columns as shown in Fig 1. Such vertical structural member is called Floating Column. The Distribution of Seismic force depends on stiffness and the mass of structure. The presence of FC directly affects the stiffness of building. Hence due to stiffness irregularity the building is subjected to non-uniform earthquake forces.

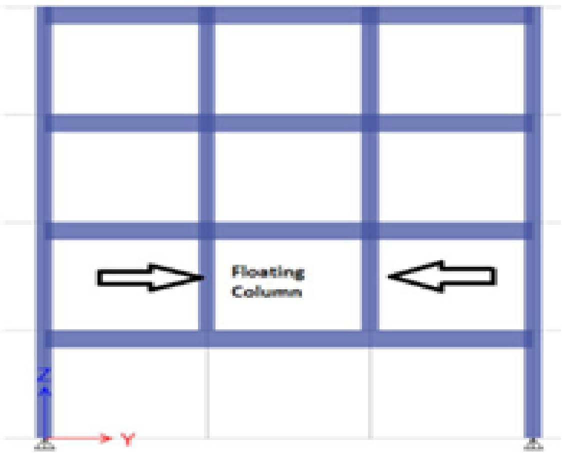

Figure 1. Building with Floating Column

1.1 Floating Columns: Definition and Characteristics

A floating column is a column that terminates at an intermediate floor level rather than extending continuously to the foundation. These columns are primarily used to meet architectural requirements, such as providing open spaces for parking or commercial purposes on lower floors.

The behaviour of a structure during earthquake depends on its geometry, shape and size.it also depends on how the load is transmitted to the ground. The earthquake forces developing at different floor level need to be carried down to the ground by the shortest path. Any Discontinuity in the path leads to poor seismic performance of the building. Structure with vertical setbacks cause a sudden failure at the level of discontinuity. Hence these kinds of structure should be designed by certain seismic strengthening techniques. The Present study highlights the behaviour of a building with Floating columns which is subjected to seismic forces. Response spectrum Analysis method was used in Etabs software.

The main objective of this study is to compare the behaviour of the different models having stiffness irregularities with FC.

Response Spectrum Analysis: For designing a structure in seismic zones, it is important to study the actual time history. During the Earthquake, response of the building depends not only on its frequency content of ground motion but also on its dynamic properties. Hence Seismic Analysis of such buildings cannot be done depending on its peak value of ground acceleration. To overcome these complexities, Response spectrum Analysis (RSA) is used. It is a linear-dynamic method of statistical analysis which evaluates the participation of each natural mode of vibration for indicating the maximum seismic response of an elastic structure. In this method maximum values of member forces and displacement are calculated as the average of different earthquake motions.

Stiffness Irregularity: Stiffness irregularity is the vertical irregularity in the structures. Here if the lateral stiffness is less than 70% as compared to above storey or if it is less than 80% of average stiffness up to 3 storey the structure is said to be soft storey. Floating columns are one of the such element which causes stiffness irregularity in the structure. Hence in the present study, Comparison of various cases of stiffness irregularities are studied and their results are compared.

Key Characteristics:

1. **Load Transfer Path:** The loads from the floating column are transferred to the supporting beam or slab, which then transfers the load to adjacent columns and foundations.
2. **Discontinuity in Stiffness:** Floating columns create a soft-storey effect, reducing the overall stiffness of the structure.
3. **Irregular Load Distribution:** The sudden change in load transfer paths can lead to stress concentrations during seismic events.

1.2. Seismic Zones and Seismic Design Considerations

Seismic Zones in India:

- **Zone II:** Low seismic activity
- **Zone III:** Moderate seismic activity
- **Zone IV:** High seismic activity
- **Zone V:** Very high seismic activity

Design Considerations for Seismic Zones:

1. **Response Spectra:** Each seismic zone has a different response spectrum, impacting the design forces.
2. **Base Shear Calculation:** The seismic forces are computed based on the seismic zone factor (Z), importance factor (I), and response reduction factor (R).
3. **Ductility Requirements:** Higher seismic zones necessitate increased ductility to resist damage during earthquakes.

Buildings with floating columns require special consideration during seismic design to ensure stability and safety across all zones.

1.3. Challenges in Seismic Analysis of Floating Columns

1. **Dynamic Behavior:** Floating columns alter the dynamic characteristics of a building, complicating seismic analysis.
2. **Soft-Storey Effect:** The presence of floating columns can create a soft-storey mechanism, increasing the likelihood of collapse during an earthquake.
3. **Non-Linear Behavior:** Seismic forces induce non-linear behavior, requiring advanced analysis techniques like pushover analysis and time-history analysis.

1.4. Seismic Analysis Methods

1. **Static Analysis:** Suitable for low-rise buildings in low seismic zones.
2. **Dynamic Analysis:** Includes response spectrum analysis and time-history analysis for medium to high-rise buildings in Zones III, IV, and V.
3. **Pushover Analysis:** Evaluates the non-linear response of buildings with floating columns under increasing lateral loads.

2.0 Literature Review

This section provides a detailed review of research studies on the seismic behavior of floating columns, presented separately for each researcher.

- **Sharma et al. (2016)**

➢ **Focus:** Seismic vulnerability of buildings with floating columns.

➢ **Findings:** The study concluded that buildings with floating columns exhibit higher vulnerability due to abrupt changes in stiffness. This discontinuity leads to a soft-storey failure mechanism, especially in high seismic zones. The authors recommended avoiding floating columns in seismically active regions or incorporating additional lateral load-resisting systems.

➢ **Methodology:** The researchers performed static and dynamic analyses on multistorey building models with floating columns and compared them to models without floating columns.

- **Patil and Kulkarni (2018)**

➢ **Focus:** Impact of different seismic zones on floating column structures.

➢ **Findings:** The seismic response of buildings with floating columns varies significantly with seismic zones. Structures located in Zones IV and V showed higher displacement and stress concentrations compared to those in Zones II and III. Robust reinforcement and design modifications, such as adding shear walls, were recommended for buildings in high seismic zones.

➢ **Methodology:** Comparative analysis of building models in different seismic zones using response spectrum analysis.

- **Rao et al. (2019)**

➢ **Focus:** Effect of building height on the seismic response of floating column structures.

➢ **Findings:** The study found that taller buildings with floating columns are more susceptible to seismic damage due to amplified responses and increased flexibility. The lateral displacement and inter-storey drift increased with height, particularly in high seismic zones.
➢ **Methodology:** Non-linear dynamic analysis of multistorey buildings with varying heights and floating columns.

- **Mehta et al. (2020)**

➢ **Focus:** Mitigation strategies for seismic effects in irregular buildings with floating columns.
➢ **Findings:** Retrofitting techniques such as shear walls, bracings, and dampers significantly improve the seismic performance of buildings with floating columns. The study also emphasized the importance of maintaining a regular structural configuration to minimize seismic risks.
➢ **Methodology:** Case studies and finite element modeling of retrofitted and non-retrofitted structures.

- **Kumar and Gupta (2017)**

➢ **Focus:** Dynamic behavior of buildings with floating columns under earthquake loading.
➢ **Findings:** The authors highlighted that floating columns alter the natural frequency and mode shapes of buildings, making them more prone to resonance during seismic events. Proper placement of floating columns and use of seismic dampers were suggested to mitigate these effects.
➢ **Methodology:** Time-history analysis using ground motion records from past earthquakes.

- **Desai and Patel (2021)**

➢ **Focus:** Seismic performance of retrofitted floating column structures.
➢ **Findings:** The study demonstrated that retrofitting floating column structures with steel bracings and dampers reduces inter-storey drift and improves overall structural stability during earthquakes. The effectiveness of these retrofitting techniques was more pronounced in higher seismic zones.
➢ **Methodology:** Pushover analysis of retrofitted models compared to non-retrofitted models.

- **Reddy et al. (2015)**

➢ **Focus:** Influence of plan irregularities on seismic performance of floating column buildings.
➢ **Findings:** Plan irregularities exacerbated seismic vulnerability, leading to higher torsional effects and lateral displacements.
➢ **Methodology:** Finite element analysis on irregular and regular plan models.

- **Singh et al. (2019)**

➢ **Focus:** Seismic assessment of floating column buildings with varying support conditions.
➢ **Findings:** Different support conditions (fixed vs. pinned) affected the load transfer and overall stability of floating columns.
➢ **Methodology:** Comparative dynamic analysis under varying boundary conditions.

- **Chopra et al. (2020)**

➢ **Focus:** Performance-based design of floating column structures in high seismic zones.
➢ **Findings:** Performance-based design approaches improved seismic resilience by optimizing reinforcement and ductility.
➢ **Methodology:** Performance-based design analysis using pushover techniques.

- **Joshi and Nair (2021)**

➢ **Focus:** Influence of soft-storey configurations in floating column buildings.
➢ **Findings:** Soft-storey effects significantly increased the likelihood of collapse, particularly in Zones IV and V.
➢ **Methodology:** Non-linear static and dynamic analyses of soft-storey configurations.

- **Agrawal and Shrivastav (2017)**

➢ **Focus:** Seismic analysis of concrete structures with irregular load distribution.
➢ **Findings:** Seismic irregularities caused by floating columns and other architectural features can lead to structural weaknesses. Incorporating fly ash in concrete helped improve overall performance.
➢ **Methodology:** Analysis of compressive strength with irregular load conditions.

- **Agrawal (2020)**

➢ **Focus:** Improving road properties and structural performance using plastic waste.
➢ **Findings:** The study showed that structural stability and durability can be enhanced by integrating recycled materials into construction, a potential method for mitigating seismic vulnerabilities.
➢ **Methodology:** Experimental studies on modified bitumen roads.

8. Conclusion

The review of existing research highlights the significant challenges associated with floating columns in multistorey buildings under seismic loads. Key conclusions include:

1. **Increased Vulnerability:** Floating columns introduce discontinuities that lead to soft-storey mechanisms and increased lateral displacement, particularly in high seismic zones (Zones IV and V).
2. **Structural Configurations:** The height of the building, support conditions, and presence of soft-storeys significantly affect seismic performance.
3. **Mitigation Techniques:** Retrofitting methods, such as shear walls, bracings, and dampers, can improve structural resilience.
4. **Performance-Based Design:** Implementing performance-based design approaches and enhancing ductility can mitigate seismic risks.
5. **Material Innovations:** The use of sustainable materials, such as recycled plastic and fly ash, can enhance structural performance and durability.

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