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A Review on Investigates the Optimal Placement of Floating Columns in Multi-Story Buildings

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ABSTRACT

The presence of floating columns in multi-story buildings poses significant structural challenges, especially in earthquake-prone areas. Floating columns refer to columns that do not transfer their loads directly to the foundation but instead rest on beams or slabs at a certain level. This design creates a discontinuity in the load transfer mechanism, leading to potential structural vulnerabilities during seismic events. Floating columns in multi-story buildings situated in seismic zones and contribute valuable insights to the field of earthquake engineering and structural safety. Ground acceleration and shaking are the main effects of damage to buildings and rigid structures. The severity due to the local influence is related to a composite grouping of the magnitude of the earthquake, the distance from the epicenter and the local geological and topographic conditions. The motion of the earth is measured by the acceleration of the earth. Earthquakes can cause injuries and deaths, damage to roads and bridges, damage to property and the collapse or instability of buildings. This study investigates the optimal placement of floating columns in multi-story buildings through the analysis of three distinct scenarios using ETABS software.

Key Words:- Floating columns, Multi-story buildings, Structural vulnerabilities, Earthquake, Epicenter

Introduction

Floating columns, also known as hanging or suspended columns, are vertical members that rest on beams rather than extending down to the foundation. These columns act as point loads on the supporting beams. While this architectural feature can be essential for meeting certain design and client requirements, it can compromise the structural integrity of multi-storey buildings, particularly in earthquake-prone areas.

The seismic performance of buildings with floating columns is typically less robust compared to those with conventional column layouts. However, by carefully selecting the optimal locations for floating columns, it is possible to mitigate some of the adverse effects and enhance the earthquake.

Discontinuity in Load Path: Floating columns interrupt the continuous load transfer from the superstructure to the foundation. During an earthquake, this discontinuity can lead to significant stress concentrations and potential failure points in the building.

Soft Storey Effect: Often, the ground level of buildings with floating columns is left open for parking or other uses, creating a 'soft storey.' This storey is less rigid compared to the upper storeys, making it more susceptible to lateral movements during an earthquake. The differential stiffness between storeys can result in severe damage or collapse.

Increased Shear and Bending Moments: The beams and slabs supporting the floating columns experience higher shear forces and bending moments during seismic events. These increased forces can lead to the failure of these structural elements if not adequately designed and reinforced.

Vulnerability to Ground Acceleration: Earthquake ground acceleration and shaking exert significant lateral forces on buildings. Structures with floating columns are particularly vulnerable because the discontinuous load path and soft storey effects amplify these forces, leading to increased deformation and potential structural failure.

Literature Review

Conducting a literature survey on the earthquake response of multi-story building frames with usual columns, particularly focusing on the strengthening of existing buildings in seismic-prone regions, is essential for understanding current methodologies and advancements in this field. The performance of usual columns, including their strength and ductility, is a critical factor. Columns designed with adequate confinement and reinforcement show better performance under seismic loads.

Balsamoa et al (2005) conducted an extensive study on the effectiveness of Carbon Fiber Reinforced Polymer (CFRP) laminates in the seismic repair of reinforced concrete (RC) structures. The research involved pseudodynamic testing on a full-scale dual system at the ELSA laboratory to evaluate the potential of CFRP composites for restoring structural integrity post-seismic events. The research by Balsamoa et al. underscores the potential of CFRP composites in the seismic repair of RC structures, providing a robust basis for future design guidelines and applications. The detailed experimental analysis and positive findings reinforce the viability of CFRP laminates as a reliable solution for enhancing the seismic resilience of RC frames. The experimental data serve as a reference for developing standardized design criteria and methodologies for the seismic repair of RC structures using composite materials. The study's outcomes offer valuable insights into the design principles for using CFRP composites in seismic repairs. The experimental results indicated that the CFRP repair technique successfully restored the structural properties, enhancing the overall deformation capacity and performance of the RC frame. Comparisons between the original (pre-damage) and repaired structures highlighted significant improvements in both global and local performance metrics.

Vasilopoulos et al (2006) developed a rational and efficient seismic design methodology for plane steel frames by leveraging advanced methods of analysis within the framework of Eurocodes 8 and 3. This design approach utilizes a sophisticated finite element method that incorporates geometrical and material nonlinearities, as well as member and frame imperfections. By doing so, it effectively captures the limit states related to displacements, strength, stability, and damage of the structure.

Bardakis et al (2007) Bardakis & Dritsos conducted an evaluation of the American and European procedural assumptions for assessing the seismic capacity of existing buildings through pushover analyses. This assessment focused on a four-storeyed bare framed building, utilizing the FEMA (Federal Emergency Management Agency) guidelines from the United States and the GRECO procedures based on the Eurocode from Europe. To compare the effectiveness and accuracy of the FEMA and Eurocode-based GRECO procedures in assessing the seismic capacity of a four-storeyed bare framed building. This technique involves applying a monotonically increasing lateral load to a building model until a target displacement or structural performance level is reached. The aim is to estimate the building's seismic demand and capacity. These are detailed in guidelines such as FEMA 356 (Prestandard and Commentary for the Seismic Rehabilitation of Buildings), which provide methods for evaluating and retrofitting existing buildings to improve their seismic performance. These follow the Eurocode 8 (Design of structures for earthquake resistance), which is the European standard for assessing and retrofitting buildings to withstand seismic forces.

Mortezaei et al. (2009) examined data from recent earthquakes, revealing that ground motions near a rupturing fault exhibit significant differences compared to ordinary ground motions. Specifically, near-fault ground motions can contain a large energy "directivity" pulse, which poses a substantial risk to structures, particularly those with natural periods aligning closely with the pulse. Observations of modern engineered structures in recent earthquakes have highlighted the susceptibility of existing reinforced concrete (RC) buildings to these pulse-type ground motions. This vulnerability is attributed to the design of these structures based on standard design spectra, which are typically developed using stochastic processes that represent more distant and longer-duration ground motions.

The findings suggest that many contemporary buildings may need retrofitting to endure near-fault ground motions effectively. Fiber Reinforced Polymers (FRPs) have emerged as a promising solution due to their advantages, including ease and speed of installation, low life cycle costs, and no maintenance requirements.

William et al (2009) The study delved into the economic benefits of a specific seismic retrofit procedure using a detailed analytical framework. This research involved a parametric analysis aimed at understanding how various parameters influence the feasibility of implementing seismic retrofits. The study included a case analysis of buildings in Memphis and San Francisco, applying a modest retrofit procedure to assess outcomes in both locations. Key findings from the parametric analysis and the case study highlighted that, in most scenarios, conducting a seismic retrofit of an existing building is more financially viable in San Francisco compared to Memphis. This conclusion can be attributed to several factors, including differences in seismic risk levels, economic conditions, building codes, and construction costs between the two cities. By examining these elements, the study provided valuable insights into the cost-effectiveness of seismic retrofits, suggesting that such interventions are generally a sound financial investment in areas with higher seismic activity like San Francisco. This research underscores the importance of location-specific analyses when considering seismic retrofitting projects, as economic benefits can vary significantly based on regional characteristics.

Garcia et al. (2010) conducted experiments on a two-story reinforced concrete (RC) building with poorly detailed beam-column joints. This testing was part of the ECOLEADER project in Europe. Initially, the structure was tested on a shake table, which resulted in damage. Subsequently, the damaged frame was strengthened using carbon fiber reinforced materials (CFRPs) and re-tested. The paper aims to analyze the effectiveness of the CFRP strengthening technique in improving the seismic behavior of the RC frame. The experimental data from the initial shake table tests were utilized to calibrate analytical models. These models incorporated factors such as steel-concrete bond slip and degradation of bond strength under cyclic loading, simulating deficient beam-column joints. Analytical models were employed to evaluate how well the CFRP rehabilitation enhanced the seismic performance of the structure when subjected to a series of medium to strong seismic records. The results indicated that the CFRP intervention significantly improved the behavior of the substandard beam-column joints. Specifically, after the CFRP strengthening, it was projected that the damaged building would, on average, experience 65% less global damage compared to its original state when subjected to real earthquake excitations. The study demonstrates that CFRP strengthening effectively mitigates the seismic vulnerabilities associated with poorly detailed beam-column joints in RC structures, thereby enhancing overall structural resilience and reducing earthquake-induced damage.

Maheri et al (2010) investigated the retrofitting of an eight-storey frame that had previously been strengthened with a steel bracing system. In their research, they compared the seismic performance of this frame retrofitted with web-bonded CFRP (Carbon Fiber Reinforced Polymer) at joints, against a retrofitting method using steel X-braces.

Ductility and Over-strength Factors: Both retrofitting methods (steel X-bracing and CFRP at joints) were found to enhance the ductility reduction factor and the over-strength factor of the frame. However, CFRP retrofitting was noted to perform better in terms of enhancing ductility, while steel X-bracing excelled in improving over-strength.

Stiffness and Lateral Load Resistance: The steel bracing system used in the RC (Reinforced Concrete) frame was particularly beneficial when substantial increases in stiffness and lateral load resisting capacity were required.

Combined Retrofitting Approach: The study suggests that CFRP retrofitting at joints can complement the retrofitting of beams and columns with CFRP, allowing engineers to achieve desired increases in structural capacity and performance. The research highlights the effectiveness of both steel bracing and CFRP retrofitting methods in enhancing the seismic performance of reinforced concrete frames. The choice between these methods may depend on specific performance objectives related to ductility, over-strength, stiffness, and lateral load resistance.

KeerthiGowda B. S et al (2014) The study underscores the importance of continuous load transfer paths in the design of multistory buildings, particularly in seismic zones. While floating columns may offer architectural benefits, their impact on structural performance under seismic loads cannot be ignored. Incorporating lateral bracing provides a viable solution to mitigate these adverse effects, ensuring better safety and stability of the structures. For buildings in seismically active areas, it is advisable to avoid floating columns. If their use is unavoidable due to architectural constraints, lateral bracing should be employed to enhance seismic resilience. Structures with floating columns often exhibit increased horizontal displacement (sway) during seismic events, leading to greater instability and potential damage. The distribution of base shear (the horizontal force exerted at the base of the structure due to seismic activity) is affected by the presence of floating columns. This can lead to uneven force distribution and potential failure points. The study on the effects of floating columns in multistory RC (Reinforced Concrete) buildings under seismic excitation highlights several key points related to structural integrity and earthquake resilience:

Sasidhar T et al (2017) In urban India, multistoried buildings with floating columns are increasingly popular due to space optimization and aesthetic appeal. This study focuses on the analysis and design of a G+5 residential building with and without floating columns, utilizing static analysis. Various scenarios of column removal at different positions and floors were examined. The equivalent static analysis was performed using a 3-D mathematical model in ETABS software. Comparative results of the structural behavior with and without floating columns are presented. The demand for innovative architectural designs and efficient use of space has led to the adoption of floating columns in modern construction. These columns, which do not extend to the foundation, provide more open spaces but pose structural challenges. This study aims to evaluate the impact of floating columns on the structural integrity of a G+5 residential building. The study concludes that while floating columns offer architectural and spatial benefits, they require careful consideration in design to ensure structural safety. The results provide valuable insights for engineers and architects in optimizing the use of floating columns in multistoried buildings.

Rinkesh R Bhandarkar et al (2017) ETABS (Extended Three-dimensional Analysis of Building Systems) is widely used for the analysis and design of concrete and steel structures, including low and high-rise buildings, skyscrapers, and portal frames. In this project, we studied the structural behavior of a multi-story building with a ground floor plus seven additional floors (G+7) using ETABS. This project demonstrated the capabilities of ETABS in effectively analyzing and designing complex multi-story buildings, ensuring compliance with engineering standards and safety requirements.

Nagalaxmi D et al (2018) The seismic analysis and design of the G+6 storied building with ETABS involves comprehensive modeling of structural elements, application of seismic loads as per IS 1893:2002, identification of critical load combinations, detailed analysis of structural responses, and graphical representation of results to establish correlations and ensure structural safety under seismic conditions. Describing a detailed seismic analysis and design process for a G+6 storied building using ETABS software.

Building Description: The building is G+6 stories tall and incorporates architectural complexities such as external floating columns, internal floating columns, and combinations of both.

Seismic Analysis: The analysis considers earthquake loads as per IS 1893 (part 1): 2002, which specifies the seismic design provisions for buildings in India. Different earthquake zones have specific ground motion parameters that influence the design.

Critical Load Combinations: During the seismic analysis, critical load combinations are identified. These combinations typically involve the worst-case scenario of loads (such as earthquake loads) acting on the structure.

Parameters Analyzed: Various parameters such as displacements, moments, and forces on columns and beams at different floor levels are computed. These parameters are crucial for understanding how the structure responds to seismic forces.

Graphical Representation: To visualize and understand the results better, graphs are used to show the variations in these parameters across different load cases or floor levels. Graphical representation helps in identifying trends and correlations between different structural responses.

Software Used (ETABS): ETABS (Extended Three-Dimensional Analysis of Building Systems) is a widely used software for structural analysis and design. It can handle complex structural configurations, irregularities (like floating columns), and seismic loads efficiently. ETABS allows engineers to model the building, apply various loads including seismic loads, and analyze the structural response under these loads.

Design Process: The design process involves ensuring that the structure can safely withstand the seismic forces as per the design codes (IS 1893:2002 in this case). This includes sizing structural members (columns, beams, slabs) appropriately and detailing reinforcement to ensure ductility and resilience during earthquakes.

Harsha P V et al (2020) In recent years, the construction of multi-storey and commercial buildings with architectural complexities has become common. One such complexity is the inclusion of floating columns, which pose significant risks in seismically active areas. This study analyzes the behavior of a G+10 storey normal building and a G+10 storey building with floating columns subjected to external lateral forces. The objectives are to assess the safety of these structures in Seismic Zone III, identify the most critical and optimal positions for floating columns, and evaluate the impact of shear walls in floating column buildings. This study will provide valuable insights into the seismic performance of multi-storey buildings with floating columns, aiding in the development of safer structural designs in seismically active regions. By identifying critical positions and evaluating shear wall effectiveness, the research aims to enhance building resilience against earthquakes. Practical guidelines for architects and engineers on the design and placement of floating columns and shear walls in multi-storey buildings. Detailed understanding of how floating columns influence building behavior under seismic loads.

Venkat rao mane b.g et al (2021) Floating columns, also known as hanging or suspended columns, are vertical members that rest on beams rather than extending down to the foundation. These columns act as point loads on the supporting beams. While this architectural feature can be essential for meeting certain design and client requirements, it can compromise the structural integrity of multi-storey buildings, particularly in earthquake-prone areas.

The seismic performance of buildings with floating columns is typically less robust compared to those with conventional column layouts. However, by carefully selecting the optimal locations for floating columns, it is possible to mitigate some of the adverse effects and enhance the earthquake resistance of such structures. This study investigates the optimal placement of floating columns in multi-storey buildings through the analysis of three distinct scenarios using ETABS 2017 software. The study demonstrates that while floating columns can pose challenges to the seismic performance of multi-storey buildings, their impact can be mitigated through strategic placement. By optimizing the locations of floating columns, it is possible to enhance the earthquake resistance of buildings, ensuring safety and structural integrity while meeting architectural and client requirements.

Krishna Chaitanya Lingampally et al (2022) In recent years, the development of multi-storey and commercial buildings has seen an increase in architectural complexity, including the use of floating columns. While these designs can offer aesthetic and functional benefits, they present significant risks in seismically active areas due to disrupted load transfer paths. This study aims to analyze the lateral force response of a G+10 building with floating columns, determine its safety in seismic zone II, and identify the optimal position for floating columns within such a structure using response spectrum analysis via CSI ETABS 2018. Floating columns, which rest on beams instead of directly transferring loads to the foundation, are often used for architectural purposes. However, their presence can significantly alter the behavior of a building under seismic loads by creating points of discontinuity in the load transfer path. This study focuses on understanding the implications of using floating columns in a high-rise structure located in a seismically active zone. This paper aims to contribute to safer building practices in seismically active regions by providing detailed analysis and recommendations for the use of floating columns in high-rise structures.

Ankita R. Uplenchwar et al (2022) In urban environments, maximizing the use of space is crucial. This has led to the design of multi-storey buildings with floating columns and soft stories. Floating columns provide open ground spaces for parking or commercial use, while soft stories typically have large openings or reduced stiffness compared to other floors. This study aims to investigate the seismic performance of such buildings using ETABS software, employing Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA). In urban environments, maximizing the use of space is crucial. This has led to the design of multi-storey buildings with floating columns and soft stories. Floating columns provide open ground spaces for parking or commercial use, while soft stories typically have large openings or reduced stiffness compared to other floors. This study aims to investigate the seismic performance of such buildings using ETABS software, employing Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA).

Teena Tara Tom et al (2022) Floating columns are a type of column constructed over beams or slabs of any intermediate floors of a multistoreyed building. They are not attached to any footings or pedestal and are also known as hanging columns. This study investigates the effect of floating columns on the storey shear, displacement, and storey drift using ETABS software. Both static analysis and dynamic analysis using the response spectrum method are performed on multistoreyed buildings with and without floating columns. Floating columns are structural elements that are supported by beams or slabs instead of directly connecting to the foundation. This construction technique is often used to create open spaces on the lower floors of a building, which can be utilized for parking, lobbies, or commercial purposes. However, the inclusion of floating columns can significantly impact the structural behavior of a building. The study aims to provide a comprehensive understanding of the structural implications of floating columns in multistoried buildings. By utilizing ETABS software for static and dynamic analysis, the research highlights the potential risks and benefits associated with this construction technique. The findings are expected to inform better design practices and ensure the safety and stability of buildings incorporating floating columns.

Methodology

Case Studies

The study considers three scenarios with different distributions of commercial and residential spaces:

Analytical Approach

The analysis is performed using ETABS 2017 software, a widely used tool for structural analysis and design of buildings. The software allows for detailed modeling and simulation of the structural behavior under various loading conditions, including seismic loads.

Steps

Model Creation: Develop models for each case scenario in ETABS, incorporating the respective distributions of commercial and residential spaces.

Loading Conditions: Apply appropriate loading conditions, including dead loads, live loads, and seismic loads as per relevant standards.

Analysis: Perform structural analysis to evaluate the performance of each model under seismic loading.

Comparison: Compare the results across the three scenarios to determine the optimal locations for floating columns.

Column Reactions: Forces and moments in the floating columns and supporting beams.

Conclusion

The study demonstrates that while floating columns can pose challenges to the seismic performance of multi-story buildings, their impact can be mitigated through strategic placement. By optimizing the locations of floating columns, it is possible to enhance the earthquake resistance of buildings, ensuring safety and structural integrity while meeting architectural and client requirements. The use of floating columns in multi-story buildings in seismic zones necessitates careful consideration and advanced engineering practices to mitigate risks. By understanding the behavior of such structures under seismic loads and implementing appropriate design and reinforcement strategies, the potential for damage and collapse can be significantly reduced. Conducting thorough seismic analysis and adhering to modern building codes and standards are essential steps in ensuring the safety and stability of buildings with floating columns.

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