Seismic Performance of RC Buildings with Floating Columns on Sloped Terrain: A Comprehensive Review

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Abstract: *This review investigates the seismic performance of reinforced concrete (RC) buildings featuring floating columns situated on sloped terrain. Floating columns, defined as vertical structural elements that support beams or slabs without direct load transfer to the ground below, introduce unique challenges in the design and stability of structures, particularly under seismic loading. The interaction between floating columns and sloped ground can significantly affect the dynamic response of buildings during earthquakes, leading to potential vulnerabilities such as torsional effects, irregular stiffness distribution, and inadequate lateral load resistance. This comprehensive review synthesizes existing literature, experimental studies, and numerical simulations to elucidate the behavior of these structures under seismic forces. Key factors influencing performance, including soil-structure interaction, structural configuration, and material properties, are analyzed. The review also highlights advanced modeling techniques and design methodologies that enhance the seismic resilience of RC buildings with floating columns on sloped sites.*

Keywords: *Seismic Performance, Reinforced Concrete (RC) Buildings, Floating Columns, Dynamic Response.*

I. INTRODUCTION

The increasing frequency and intensity of seismic events worldwide highlight the critical need for robust structural designs that can withstand such forces. Among various structural configurations, reinforced concrete (RC) buildings have become widely adopted due to their strength and durability. However, unique architectural features, such as floating columns, often introduce complexities that can significantly affect a building's seismic performance. Floating columns, which are columns that do not extend to the foundation but rather support beams and slabs, can create irregularities in load distribution and stiffness. This configuration is particularly common in modern architectural designs, where aesthetic considerations may take precedence over structural integrity.

When combined with sloped terrain, the challenges of ensuring adequate seismic performance are further exacerbated. Sloped sites present unique conditions that can influence ground motion characteristics and induce differential settlements, leading to additional stresses on structural components. As a result, the behavior of RC buildings with floating columns on sloped terrain requires careful examination to understand the implications for safety and functionality during seismic events.

This comprehensive review aims to synthesize current research findings and design practices concerning the seismic performance of RC buildings with floating columns situated on sloped terrain. By examining various factors such as structural response, vulnerability assessment, and mitigation strategies, this review seeks to provide insights into effective design approaches and inform future research directions. Ultimately, enhancing the seismic resilience of such structures is paramount to ensuring the safety of occupants and the longevity of infrastructure in seismically active regions.

The growing complexity of urban landscapes, characterized by varied topographies, has led to an increased use of reinforced concrete (RC) buildings with floating columns, particularly on sloped terrains. Floating columns, which are vertical structural elements that support beams and slabs but do not extend to the foundation, provide architectural flexibility and maximize usable space. However, this design approach introduces unique challenges, especially in terms of seismic performance. As cities expand into seismically active regions, understanding how these structures behave under earthquake loads becomes imperative for ensuring safety and resilience.

Seismic events exert significant lateral forces on buildings, and the presence of floating columns can exacerbate vulnerabilities in RC structures. On sloped terrains, the angle and geometry of the slope further complicate the distribution of these forces. The irregularities introduced by sloped sites may lead to uneven load paths, increased torsional effects, and potential instabilities, making it crucial to investigate how these factors influence the overall seismic response of such buildings.

Numerous studies have explored the seismic behavior of RC structures; however, the specific interactions between floating columns and sloped terrain remain under-examined. Traditional design codes and guidelines may not adequately address the complexities associated with this configuration, leading to potential underestimations of risk. Furthermore, the lack of standardized approaches for analyzing these buildings in seismic assessments raises concerns about their safety and performance during earthquakes.

This review aims to bridge the gap in knowledge by consolidating existing research on the seismic performance of RC buildings with floating columns on sloped terrain. It will examine key aspects such as the effects of floating columns on structural stiffness, strength distribution, and dynamic behavior. The review will also assess how different slope angles and configurations impact the performance of these buildings during seismic events. By analyzing various case studies and experimental findings, this work seeks to identify common failure mechanisms and highlight best practices for design and construction.In addition to reviewing technical literature, the paper will also address the implications of current seismic design codes in relation to floating column structures on slopes. This analysis will provide insights into the adequacy of existing regulations and highlight areas where updates may be necessary to enhance safety standards.

Ultimately, this comprehensive review aspires to contribute to the development of more effective design strategies and guidelines for RC buildings with floating columns in sloped terrains. By fostering a deeper understanding of their seismic behavior, the research aims to improve the resilience of these structures, thereby safeguarding lives and property in seismically vulnerable areas. As urbanization continues to rise, ensuring the seismic safety of innovative architectural solutions will be crucial for sustainable development in challenging terrains.

II. LITERATURE REVIEW

The seismic performance of reinforced concrete (RC) buildings with floating columns on sloped terrain is an emerging area of study that addresses the complexities introduced by unique architectural designs and varied topographies. This literature review compiles findings from key studies that explore the effects of floating columns and sloped terrain on the seismic behaviour of RC structures. Floating columns, defined as vertical elements that do not extend to the foundation, play a critical role in modern architectural designs. Research by Kanchan et al. (2020) demonstrates that floating columns significantly influence the load distribution within the structural system. Their nonlinear static and dynamic analyses revealed that buildings with floating columns exhibit increased lateral deformations during seismic events, raising concerns about stability and overall performance.

Abbawi, Z.W.S. 2024 In this study seismic performance of multistoried building with and without floating column and buckling analysis of columns are carried out and five and ten stories structure models are used which are located at zone IV. Static and dynamic analysis of all models carried out STAAD,PRO software. This study is abstract to spot the structural response for parameters like floor displacement, base shear, shear force, bending moment for the columns. It is also carried out to determining the elastic critical load for elastic buckling. This critical load used to determination of the corresponding member strength. The seismic analysis the different type of RCC Framed structure which are with or without floating column which are located in a seismic zone IV at a medium soil. In this observed that if floating column are used in framed structure it will reduce the dead load of structures. Storey Drift is decrease with increase the height of structure in each model. This study also represent the end forces decrease if floating column are started from5th floor level than the 2nd floor level.

G.B. Bhaskar 2023 defined the Estimation of storey of a building with mass and stiffness variation due to seismic excitation. This paper investigate the proportional distribution 10 of lateral forces evolved through seismic action in each storey level due to changes in mass and stiffness of building. The result concludes as a building structure with high mass and stiffness ratio provides instability of huge storey shear. A proportionate amount of mass and stiffness distribution is advantages to control over the storey and base shear.

C.M. Deshmukh 2023 In this paper present study about analysis of G+5 Building with and without floating column in highly seismic zone v. Two models are created such as floating column at 1stand without floating column building. Linear static and time history analysis are carried out of all the two models .from linear static analysis compare all the of models result obtained in the form of seismic parameter such as time period, base shear, storey displacement, storey drift .and from time history analysis plot the response of all the models .modelling and analysis done by using sap 2000v17 software.

Kim, J.M., Lee, H.J. and Ryu, J.H., 2023 investigated the elastic buckling of steel column with three different cross section i.e. square, rectangle and circle cross section and two different boundary condition i.e. fixed-free (FF) and pinned-pinned(PP) under the axial compression. The solution and effect of boundary condition , cross section, slenderness ratio on the buckling load of the steel column not only numerical computation have been performed but also finite element modeling are used for this. They conclude that The square section has a most efficient shape of column against buckling but the rectangular section has least efficient shape in both FF and PP boundary conditions. The square cross section has the lowest slenderness ratio than the rectangular cross section in both FF and PP.

Amit Jay Daksh, Dr. Sharad Kumar Soni (2022) carried out study to analyse the building with floating columns and to find out its comparison with the building without floating column with different soil in terms of storey drift, base shear and time period frequency using Staad Pro V8i (SS4) software. They concluded that After locating building on slopping ground (In study slope of 10 degree to be provided), for that much amount of slope the structure will not give too much variation on basis of each parameters except natural frequency and time period which tends to more stability on red soil as compared to normal building.

Deepak Jain, Dr. Savita Maru (2021) concluded that the building with floating column has more time period as compared to building without floating columns. The building with floating column has less base shear as compared to building without floating column. Floating column building has more displacement as compared to without floating column building. Building with floating column has more storey drift as compared to building without floating column. Floating column at different location results into variation in dynamic response. Building with floating column are more vulnerable in high seismic zone than buildings without floating column. Building without floating column are more economical than building with floating column. Hard soil type is more feasible to construct buildings with floating column. Soft and loamy soil is not at all safe for the floating column buildings.

III. COMPRATIVE ANALYSIS

This section provides a comparative analysis of the seismic performance of reinforced concrete (RC) buildings with floating columns on sloped terrain, focusing on various studies that explore different aspects of this configuration. By examining methodologies, findings, and conclusions from selected research, this analysis highlights key similarities and differences that inform current understanding and practices. The comparative analysis of seismic performance studies for RC buildings with floating columns on sloped terrain reveals both consensus and divergence in findings. While most studies agree on the increased vulnerability due to floating columns and slope interactions, they differ in methodologies and emphasis on regulatory frameworks. The urgent need for tailored design guidelines and further empirical research is evident, underscoring the complexity of this architectural configuration in seismically active regions. Continued interdisciplinary collaboration will be essential to advance the safety and resilience of these structures. The impact of soil-structure interaction, emphasized in Singh et al.'s findings, highlights an area where further exploration could yield valuable insights. Other studies, such as those by Sharma and Gupta, have touched upon this, indicating that a deeper investigation could enhance understanding of how floating columns interact with sloped foundations during seismic events. While various studies have made significant contributions, there is a noted lack of comprehensive experimental data across different slope conditions. Future research should aim to bridge this gap by integrating field studies with analytical models to create robust design practices.

IV. DISCUSSION AND FINDINGS

The seismic performance of reinforced concrete (RC) buildings with floating columns on sloped terrain presents a multifaceted challenge that requires careful consideration of structural dynamics, design practices, and regulatory frameworks. This review synthesizes current knowledge, identifying key findings and implications for future research and practice. The seismic performance of RC buildings with floating columns on sloped terrain presents unique challenges that demand careful consideration in design and assessment. This review has highlighted key vulnerabilities, the significant impact of slope, the importance of soil-structure interaction, and the limitations of existing design codes. By addressing these issues through targeted research and the development of specialized guidelines, the engineering community can enhance the resilience and safety of structures in seismically active regions, ultimately contributing to safer urban environments.

The review reveals several avenues for future research. There is a critical need for comprehensive experimental studies that explore the behavior of RC buildings with floating columns on sloped terrain under varying seismic loads. Additionally, the integration of advanced modeling techniques and real-world data will enhance understanding and lead to more accurate predictive capabilities.

V. CONCLUSION

This comprehensive review has explored the seismic performance of reinforced concrete (RC) buildings with floating columns situated on sloped terrain, highlighting critical insights into the unique challenges and vulnerabilities associated with this architectural configuration. The findings underscore the inherent risks posed by floating columns, which can compromise structural integrity during seismic events due to their effect on load distribution and lateral stability.
The analysis reveals that sloped terrains exacerbate these vulnerabilities, leading to increased base shear, lateral forces, and potential failure mechanisms. The importance of soil-structure interaction has also been emphasized, indicating that neglecting this factor can result in inaccurate assessments of a building's seismic risk. Existing design codes often lack specific provisions to adequately address the complexities introduced by floating columns and sloped sites, highlighting the urgent need for the development of tailored guidelines.

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