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Review on Analysis of an RCC Irregular and Setback Building under Dynamic Loading Using ETABS

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Abstract: Vertical irregularities such as setbacks, abrupt changes in stiffness, mass distribution, and geometric discontinuities are increasingly common in reinforced cement concrete (RCC) buildings due to architectural and functional requirements. However, these irregularities significantly influence the seismic response of structures and often lead to concentration of damage during strong ground motions. This paper presents a comprehensive review of research studies published between 2015 and 2025 on the seismic analysis of vertically irregular and setback RCC buildings subjected to dynamic loading. Emphasis is placed on analytical investigations conducted using ETABS, including response spectrum analysis, time history analysis, and nonlinear performance-based approaches.

The reviewed literature highlights the impact of different types of vertical irregularities on key seismic response parameters such as natural period, storey displacement, inter-storey drift, base shear, torsional effects, and damage distribution. Comparative insights from code-based studies, experimental investigations, and seismic vulnerability assessments are also discussed. The review identifies consistent trends indicating increased seismic demand and reduced performance in irregular buildings compared to regular configurations. Furthermore, existing research gaps related to combined irregularities, nonlinear dynamic analysis, and mitigation strategies are summarized. The findings of this review aim to support researchers and practicing engineers in understanding the seismic behavior of irregular RCC buildings and in adopting appropriate analysis and design approaches.

Keyword: Vertical irregularity; Setback buildings; Reinforced concrete structures; Seismic response; Dynamic analysis; ETABS; Response spectrum analysis; Time history analysis

I. INTRODUCTION

Contemporary building design increasingly incorporates architectural and functional variations along the height of structures, particularly in densely populated urban areas. Such variations often result in non-uniform distribution of stiffness, mass, and geometric properties, which are collectively classified as vertical irregularities. These irregularities may arise due to setbacks, soft or weak stories, transfer floors, or abrupt changes in structural systems, and they can exist either independently or in combination. From a seismic engineering perspective, vertical irregularities are critical because they alter the dynamic characteristics of buildings and can lead to localized concentration of seismic demands.

Evidence from past earthquakes has consistently shown that buildings with vertical irregular configurations are more susceptible to severe damage than their regular counterparts. Discontinuities in stiffness and mass along the height tend to amplify inter-story drift, increase force demand at irregular levels, and adversely affect overall structural stability. Recognizing these vulnerabilities, numerous researchers have examined the seismic response of vertically irregular buildings through analytical modeling, numerical simulations, and experimental investigations.

These studies have explored various performance indicators, including base shear distribution, displacement patterns, energy dissipation capacity, and failure mechanisms under different seismic intensities.

However, the outcomes reported in the literature are dispersed across diverse structural configurations and analysis methodologies. To facilitate a clearer and more integrated understanding, this paper presents a comprehensive review of existing studies on vertically irregular buildings, highlighting key findings, comparative trends, and unresolved research challenges.

II. LITERATURE REVIEW

Rapid urbanization and the increasing demand for high-rise structures have led to the widespread adoption of architecturally complex buildings. These structures often exhibit discontinuities in mass, stiffness, and geometry along their height, commonly referred to as vertical irregularities. Among various forms of vertical irregularity, setback configurations are frequently employed to satisfy architectural, functional, and zoning requirements. However, such irregularities significantly alter the seismic response of reinforced concrete (RCC) buildings, making their behavior under dynamic loading highly complex and nonlinear. Consequently, extensive research has been conducted over the past decade to understand the seismic performance of vertically irregular and setback RCC buildings using analytical, numerical, and experimental approaches.

A. General Seismic Behavior of Vertically Irregular RCC Buildings

Vertical irregularities disrupt the uniform distribution of lateral stiffness and mass, leading to concentration of seismic demand at specific levels of a building. Several researchers have demonstrated that these discontinuities cause amplification of inter-story drift, base shear, and localized damage during seismic events. Usta et al. [1] proposed irregularity-based indices to quantify the severity of vertical irregularity and correlate them with seismic response parameters. Their study showed that irregular buildings exhibit significantly higher displacement and drift demands compared to regular structures, particularly when irregularity indices exceed threshold values prescribed by seismic design codes. Prayuda et al. [2] investigated combined vertical and horizontal irregularities in multi-storey RCC frame structures and highlighted that buildings with multiple irregularity types experience compounded adverse effects. Their dynamic analysis revealed that combined irregularities not only increase lateral displacement but also modify modal participation, resulting in higher energy demand during strong ground motion. These findings emphasize the necessity of dynamic analysis for irregular buildings, as static approaches often underestimate seismic demand.

B. Vertical Setback Irregularities and Dynamic Response

Vertical setback irregularity is one of the most common geometric irregularities encountered in urban buildings. Several studies have specifically focused on evaluating the seismic performance of setback RCC buildings using ETABS-based dynamic analysis. Sri Hari and Rani [3] conducted a response spectrum analysis of RCC frames with a single vertical setback and observed a significant increase in lateral displacement and base shear concentration at the setback level. Their results indicated that abrupt changes in building width create stiffness discontinuities, leading to localized deformation demands. Further investigations by Sai Kumar and Rani [4] examined RCC buildings with symmetric and asymmetric setbacks. Contrary to conventional assumptions, their study revealed that even symmetric setback configurations can lead to unfavorable seismic response due to sudden changes in mass and stiffness distribution. The authors reported notable variations in fundamental time period and storey drift, emphasizing that geometric symmetry alone does not guarantee improved seismic performance. Meena and Hora [5] extended the analysis of setback buildings by employing nonlinear dynamic analysis under mainshock–aftershock sequences. Their findings demonstrated that setback RCC buildings experience cumulative damage when subjected to successive seismic events, with drift demands significantly exceeding those predicted by single-event analysis. This study highlighted the limitations of linear analysis methods and underscored the importance of performance-based seismic evaluation for setback structures.

C. ETABS-Based Dynamic Analysis of Vertically Irregular Buildings

The use of ETABS software has become prevalent in seismic analysis due to its robust modeling capabilities and compatibility with international design codes. Manoj and Varghese [6] utilized ETABS to compare the seismic response of regular and vertically irregular RCC buildings through response spectrum analysis. Their results indicated that irregular buildings exhibit higher storey drift ratios and increased displacement demands, particularly at irregular floors. The study also showed that modal mass participation differs significantly between regular and irregular configurations, influencing seismic force distribution.

Pandey et al. [7] conducted a comparative study of vertically irregular RCC buildings using Indian Standard IS 1893 and Eurocode 8 provisions. Their findings revealed that code-specific assumptions regarding response reduction factors and modal combinations lead to considerable variation in predicted seismic demands. This study emphasized the need for careful interpretation of code-based results when designing irregular buildings, particularly in high seismic zones.

D. Effect of Vertical Geometric Irregularity on Seismic Parameters

Vertical geometric irregularity affects key dynamic characteristics such as natural period, mode shape, and damping. Sandeep et al. [8] studied the influence of vertical geometric irregularity on RCC buildings of varying heights and bay configurations.

Their analysis demonstrated that irregularity leads to elongation of the fundamental time period, resulting in increased displacement demand under seismic loading. The effect was found to be more pronounced in taller buildings, where higher-mode participation becomes significant. The interaction of vertical irregularity with site conditions was examined by Chauhan and Banerjee [9], who analyzed RCC buildings with setbacks located on sloping ground. Their time history analysis revealed complex torsional effects and uneven force distribution caused by the combined influence of geometric irregularity and topographical variation. The study concluded that conventional design approaches may be inadequate for such configurations and recommended detailed dynamic analysis for accurate seismic assessment.

E. Influence of Mass and Stiffness Irregularities

Mass and stiffness irregularities are often introduced unintentionally due to functional requirements such as mechanical floors, heavy equipment, or open storeys. Prajapati and Grover [10] investigated the seismic behavior of vertically mass-irregular RCC buildings under different seismic zones. Their study showed that mass irregularity leads to increased storey shear and displacement, particularly when heavy masses are concentrated at intermediate or upper floors. Raj et al. [11] examined RCC buildings with combined mass and stiffness irregularities using nonlinear static analysis. Their results indicated that combined irregularities result in significant force concentration at irregular levels, increasing the likelihood of structural damage. Raagavi and Sidhardhan [12] supported these findings through a comprehensive parametric study, concluding that buildings with multiple irregularity types exhibit the poorest seismic performance among the configurations studied.

F. Mitigation Measures for Vertically Irregular Buildings

Several researchers have explored mitigation strategies to improve the seismic performance of irregular RCC buildings. Srikanth and Vishnu [13] analyzed the effectiveness of shear walls in vertically irregular buildings and found that strategically placed shear walls significantly reduce lateral displacement and storey drift. However, their study emphasized that discontinuous or improperly located shear walls may introduce additional irregularities, negating their beneficial effects. Material-level studies and hybrid structural systems have also been proposed to enhance seismic resilience. Research published in Materials Today: Proceedings [6] demonstrated that the combination of infill walls and shear walls improves stiffness distribution and reduces deformation demands in irregular buildings. These findings suggest that an integrated design approach is essential for achieving optimal seismic performance.

G. Experimental and Vulnerability-Based Studies

While numerical studies dominate the literature, experimental investigations provide valuable insights into actual damage mechanisms. Lee et al. [15] conducted shake table tests on vertically irregular RCC frames and observed early crack initiation and damage concentration at irregular storeys. Their experimental results validated analytical predictions and confirmed that vertical irregularities significantly influence failure patterns. Vulnerability and fragility studies further support these observations. Paudel et al. [14] performed seismic vulnerability assessment of vertically irregular residential buildings and reported higher fragility indices compared to regular structures. Their probabilistic analysis demonstrated that irregular buildings are more likely to experience moderate to severe damage even under moderate seismic intensity.

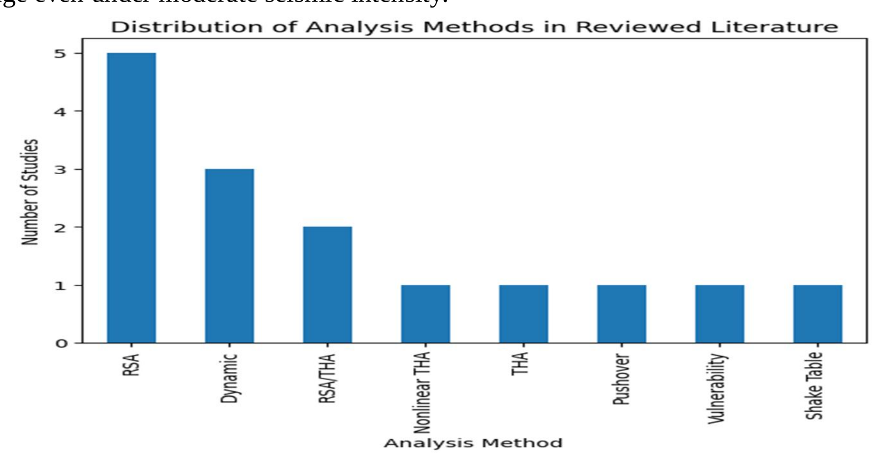


Figure 1 Distribution of Analysis Methods Used in Reviewed Studies

III. SUMMARY AND RESEARCH GAP

The reviewed literature clearly establishes that vertical irregularities—particularly setback configurations—have a profound impact on the seismic performance of RCC buildings. Dynamic analysis methods, especially those implemented using ETABS, have proven effective in capturing the complex response characteristics of irregular structures. However, significant variation exists in reported results due to differences in modeling assumptions, irregularity definitions, and analysis techniques as shown in Table 1.

Most existing studies focus on specific irregularity types or individual case studies, with limited comparative evaluation across multiple configurations. Furthermore, the majority of research relies on linear dynamic analysis, while nonlinear and performance-based approaches remain relatively underexplored for setback RCC buildings. These gaps highlight the need for a comprehensive review and systematic comparison of analytical approaches to better understand the seismic behavior of irregular RCC buildings under dynamic loading.

Table 1 Comparative Summary of Reviewed Literature on Vertically Irregular RCC Buildings

Ref.	Year	Type of Vertical Irregularity	Analysis Method
[1]	2022	Vertical irregularity	Response Spectrum & Time History
[2]	2025	Combined vertical and horizontal irregularity	Dynamic analysis
[3]	2025	Single vertical setback	Response Spectrum Analysis
[4]	2025	Symmetric setback	Dynamic analysis
[5]	2025	Setback irregularity	Nonlinear Time History Analysis
[6]	2022	Vertical irregularity	Response Spectrum Analysis
[7]	2025	Vertical irregularity	Response Spectrum Analysis
[8]	2024	Vertical geometric irregularity	Dynamic analysis
[9]	2025	Vertical irregularity on sloping ground	Time History Analysis
[10]	2025	Mass irregularity	Response Spectrum Analysis
[11]	2025	Combined mass and stiffness irregularity	Pushover analysis
[12]	2025	Combined vertical irregularities	RSA & THA
[13]	2025	Vertical irregularity with shear walls	Response Spectrum Analysis
[14]	2024	Vertical irregularity (fragility-based)	Vulnerability assessment
[15]	2024	Vertical irregularity (experimental)	Shake table testing

IV. DISCUSSION AND CONCLUSION

The tabulated comparison indicates that most studies focus on vertical and setback irregularities using linear dynamic approaches. Only a limited number of investigations incorporate nonlinear dynamic or experimental methods, indicating a research gap in performance-based evaluation of irregular RCC buildings.

This review paper has presented a detailed synthesis of recent research on the seismic analysis of vertically irregular and setback RCC buildings under dynamic loading, with particular emphasis on studies employing ETABS as the primary analysis platform. The literature clearly demonstrates that vertical irregularities, including setbacks, mass discontinuities, and stiffness variations, significantly alter the dynamic characteristics of RCC buildings and result in amplified seismic demand compared to regular structures. Increased storey drift, higher displacement concentration at irregular levels, and unfavorable force redistribution are commonly reported consequences of such irregular configurations.

The reviewed studies indicate that linear static analysis methods are often inadequate for accurately capturing the complex behavior of irregular buildings. Dynamic analysis techniques, such as response spectrum and time history analysis, provide more reliable insight into seismic performance, while nonlinear and performance-based approaches offer a deeper understanding of damage mechanisms and collapse potential. Research findings also show that buildings with combined irregularities exhibit the most critical seismic response, emphasizing the need for careful modeling and comprehensive evaluation during the design stage.

Although several mitigation measures, including the use of shear walls and infill walls, have been proposed to improve seismic performance, their effectiveness largely depends on proper placement and continuity. Despite significant progress, gaps remain in the systematic comparison of different irregularity types, the use of nonlinear dynamic analysis for setback buildings, and the assessment of cumulative damage under multiple seismic events. Future research should focus on these aspects to develop more robust design guidelines and enhance the seismic resilience of irregular RCC buildings.

REFERENCES

[1] P. Usta, Ö. Bozdağ, and Ö. Onat, "Seismic performance evaluation of reinforced concrete buildings using irregularity-based indices," Tehnički Vjesnik, vol. 29, no. 4, pp. 1362–1371, 2022,doi: 10.17559/TV-20210720195034.

[2] H. Prayuda, T. I. Maulana, S. R. Anzelina, A. A. Hermawan, and M. N. Ikhsan, "Seismic performance of multi-story RC frame structures due to vertical and horizontal irregularities," Semesta Teknika, vol. 28, no. 1, pp. 12–29, 2025, doi: 10.18196/st.v28i1.25184.

[3] A. Sri Hari and B. P. Rani, "Seismic performance of RC framed structures with vertical single setback irregularity," International Journal for Research in Applied Science & Engineering Technology, vol. 13, no. 11, pp. 241–247, 2025, doi: 10.22214/ijraset.2025.75676.

[4] S. Sai Kumar and B. P. Rani, "Seismic performance of RC framed structures with equal and single setbacks on both sides," International Journal for Research in Applied Science & Engineering Technology, vol. 13, no. 11, pp. 310–317, 2025, doi: 10.22214/ijraset.2025.75706

[5] T. Meena and M. S. Hora, "Nonlinear structural response of RC building with setback irregularity subjected to mainshock–aftershock sequences," in Engineering Research: Perspectives on Recent Advances, vol. 10. New Delhi, India: Book Publisher International, 2025, pp. 98–128, doi: 10.9734/bpi/erpra/v10/6153.

[6] M. Manoj and J. Varghese, "Seismic behavior of vertically irregular reinforced concrete buildings using ETABS," Materials Today: Proceedings, vol. 56, pp. 2132–2138, 2022, doi: 10.1016/j.matpr.2021.11.502.

[7] V. Pandey, R. Gupta, and S. Jain, "Comparative seismic assessment of vertically irregular RC buildings as per IS 1893 and Eurocode 8," Structures, vol. 63, pp. 1125–1136, 2025,doi: 10.1016/j.istruc.2024.11.036

[8] S. Sandeep, K. R. Rao, and A. Prasad, "Effect of vertical geometric irregularity on seismic response of reinforced concrete buildings," Journal of Building Engineering, vol. 85, 2024, Art. no. 108662, doi: 10.1016/j.jobe.2023.108662.

[9] R. Chauhan and S. Banerjee, "Dynamic analysis of vertically irregular buildings on sloping ground," Asian Journal of Civil Engineering, vol. 26, no. 1, pp. 77–92, 2025, doi: 10.1007/s42107-024-00841-3.

[10] M. Prajapati and A. Grover, "Seismic behavior of vertically mass-irregular RC structures," Journal of King Saud University – Engineering Sciences, vol. 37, no. 2, pp. 101–111, 2025, doi: 10.1016/j.jksues.2024.02.006.

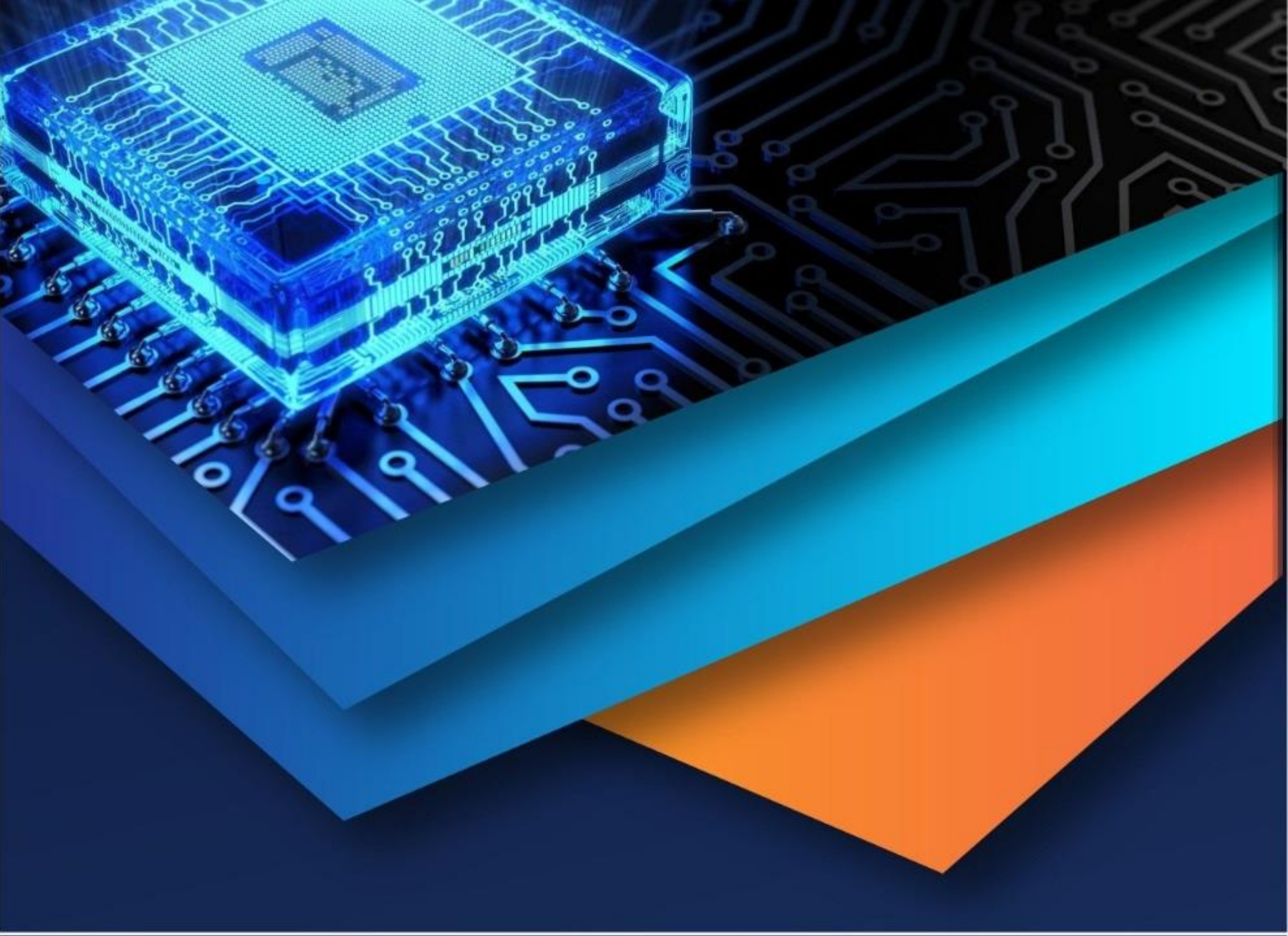
[11] P. Raj, S. Kumar, and R. Mishra, "Nonlinear seismic analysis of reinforced concrete buildings with combined vertical irregularities," Earthquake Engineering and Engineering Vibration, vol. 24, pp. 421–435, 2025, doi: 10.1007/s11803-024-2267-9.

[12] M. T. Raagavi and S. Sidhardhan, "Seismic performance of irregular reinforced concrete structures," International Journal for Research in Applied Science & Engineering Technology, vol. 13, no. 11, pp. 155–162, 2025, doi: 10.22214/ijraset.2025.75812.

[13] K. Srikanth and R. Vishnu, "Effect of shear walls on seismic response of vertically irregular reinforced concrete buildings," Structures, vol. 60, pp. 948–960, 2025, doi: 10.1016/j.istruc.2024.10.058.

[14] A. Paudel, S. Chaulagain, and H. Rodrigues, "Seismic vulnerability assessment of vertically irregular reinforced concrete buildings," Bulletin of Earthquake Engineering, vol. 22, no. 6, pp. 3191–3212, 2024, doi: 10.1007/s10518-024-01845-6.

[15] Y. Lee, J. Kim, and H. Park, "Experimental investigation of vertically irregular reinforced concrete frames under dynamic loading," Journal of Structural Engineering, vol. 150, no. 4, 2024, doi: 10.1061/JSENDH.STENG-12456.



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