© May 2026 | IJIRT | Volume 12 Issue 12 | ISSN: 2349-6002

Seismic Performance of Vertically Irregular Rcc Buildings Using Mass Redistribution Techniques

Mohammed Shafeeque Ahmed[1], Mohd Rafi[2]
[1]*P. Gstudent, Department of Civil Engineering, Nawab Shah Alam Khan College of engineering*
[2]*Assistant professor, Department of Civil Engineering, Nawab Shah Alam Khan College of Engineering*

Abstract— **Vertical irregularity in reinforced concrete structures causes uneven distribution of seismic forces and significantly influences structural stability during earthquakes. This study evaluates the seismic performance of G+20 vertically irregular RCC buildings using different mass redistribution techniques and lateral load resisting systems such as concrete bracing, shear wall systems, outriggers, and dual systems. The analytical models were developed in ETABS 2021 and analyzed using Nonlinear Time History Analysis as per IS 1893:2016 provisions. Seismic response parameters, including storey displacement, inter-storey drift, time period and base shear, were evaluated and compared. The results indicated that the shear wall and dual structural systems provided improved seismic resistance, reduced lateral deformation, and enhanced overall structural efficiency.**

I. INTRODUCTION

A building is considered vertically irregular when there are significant variations in mass, stiffness, or strength along the height of the structure. Suppose it includes irregular mass distribution, intensity, and rigidity, along with the house's height. According to I.S. 1893:2016, a floor in a building contains mass anomalies if its mass reaches 200 percent of that of the adjacent floor. A storey is considered weak when its lateral stiffness is considerably lower than that of the adjacent storey. Soft storey irregularity occurs when a particular storey possesses significantly lower stiffness compared to neighboring storeys. Many existing buildings contain irregularities, and some of them were initially built irregularly to fulfill various functions. Reduce the size of beams and columns in the upper stories to meet practical requirements and other commercial uses, such as storage of large mechanical equipment, etc. This variation in the usage of a particular floor concerning the neighboring feet results in uneven mass, stiffness, and strength distributions around the building height. Several other structures are made unusual by mistake due to some factors, such as the non-uniformity of construction methods and materials used. The building may also have irregular mass, power, and rigidity distributions along with the plan. In such a case, the building can be said to have a horizontal irregularity. The detailed structural irregularity classification is shown, and code limits are established. It can be seen from the analysis of code limits that most codes recommend identical guidelines for irregularities based on severity, ignoring the unrealistic dimension of irregularity venue.

II. VERTICAL IRREGULARITIES (IS 1893:2016)

Vertical irregularities significantly influence the seismic response of multi-storey buildings. In the present study, stiffness irregularity and mass irregularity are considered due to their major effect on lateral displacement and inter-storey drift. Stiffness irregularity occurs when the lateral stiffness of a storey is significantly lower than that of adjacent storeys, resulting in soft storey behavior. Mass irregularity develops due to a sudden variation in seismic weight between adjacent storeys, resulting in uneven distribution of seismic forces during earthquake excitation. These irregularities increase structural vulnerability during earthquake excitation and therefore require suitable lateral load–resisting systems for improved seismic performance.

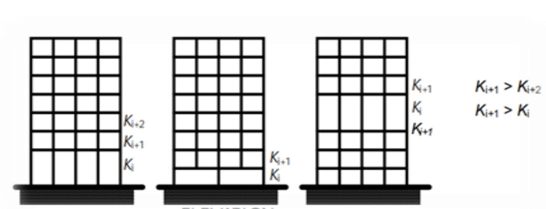

Fig. 1 Stiffness Irregularity

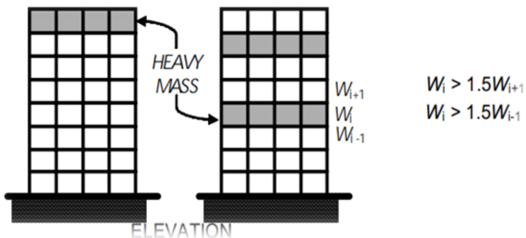

Fig. 2 Mass Irregularity

III. OBJECTIVES OF THE STUDY

The present study aims to evaluate and compare the effectiveness of various structural systems, namely the normal (bare) frame system, concrete bracing system, outrigger system, shear wall system, and dual structural system, in improving the seismic performance of vertically irregular reinforced concrete (RCC) buildings. The seismic response of irregular building configurations such as L, T, E, U, and Y shapes is analyzed using Nonlinear Time History Analysis (NLTHA) to understand their behavior under earthquake loading. The study further investigates the influence of mass redistribution techniques in reducing critical seismic response parameters such as storey displacement and inter-storey drift. In addition, a comparative assessment is conducted to identify the most efficient lateral load–resisting system that minimizes displacement, controls drift, improves overall structural stability, and enhances base shear resistance. The research also aims to determine the most suitable structural system among concrete bracing, outrigger, shear wall, and dual systems for enhancing the seismic performance of vertically irregular buildings.

IV. METHODOLOGY

A G+20 vertically irregular RCC building located in Seismic Zone IV was modeled and analyzed using ETABS 2021 in accordance with the provisions of IS 1893:2016. Five irregular plan configurations, namely L, T, U, E, and Y shapes, were considered in the study. Different lateral load–resisting systems, such as normal frame, concrete bracing, shear wall, outrigger, and dual systems, were incorporated to evaluate their seismic performance. Nonlinear Time History Analysis (NLTHA) was carried out using Bhuj earthquake ground motion data through Fast Nonlinear Analysis (FNA). Mass redistribution techniques were applied to improve the distribution of seismic forces and reduce structural irregularities. The performance of all models was evaluated based on parameters such as storey displacement, inter-storey drift, base shear, and time period.

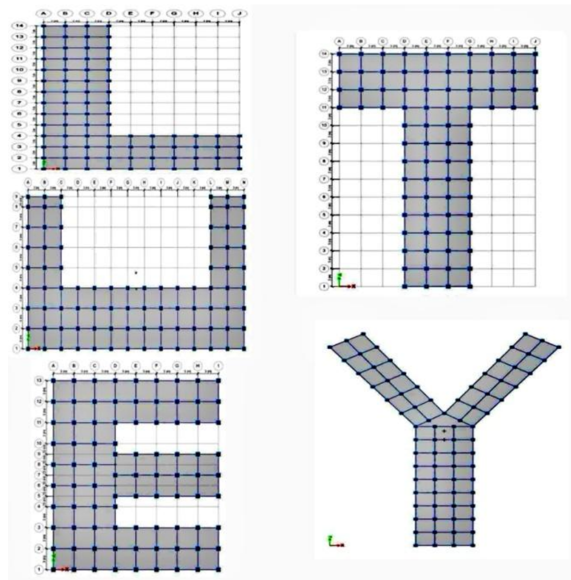

Fig. 3 Plan Configurations of Vertically Irregular Buildings (L, T, U, E, and Y Shapes)

V. RESULTS AND DISCUSSION

The results showed that the normal bare frame model exhibited maximum storey displacement and inter-storey drift due to lower lateral stiffness. The incorporation of lateral load resisting systems significantly improved seismic performance by reducing displacement and enhancing structural stability. For the L-type model, the normal frame recorded nearly 60 mm top storey displacement, whereas the dual system demonstrated superior performance with approximately 88.33% reduction in displacement compared to the normal model. In the E-type model, the normal structure exhibited nearly 76 mm displacement in the Y-direction. The dual system reduced the displacement to nearly 16 mm, achieving approximately 78.95% reduction, while the shear wall system also showed considerable improvement in controlling lateral deformation.

For the Y-type model, the normal frame recorded maximum displacement of nearly 88 mm in the X-direction and 70 mm in the Y-direction. The dual system reduced the displacement to approximately 18 mm and 5 mm in X and Y directions, respectively, indicating superior seismic resistance. The time period results indicated that the bare frame model had the highest natural time period of about 4.026 seconds, whereas the dual structural system reduced the time period to nearly 0.702 seconds due to increased stiffness. The base shear values increased considerably with the implementation of advanced structural systems.

The dual system showed nearly 90% increase in base shear compared to the normal model, indicating improved lateral load resistance and stiffness. Among all the structural systems considered, the dual system and shear wall system demonstrated superior seismic performance by effectively reducing storey displacement and drift while improving overall structural stability of vertically irregular RCC buildings.

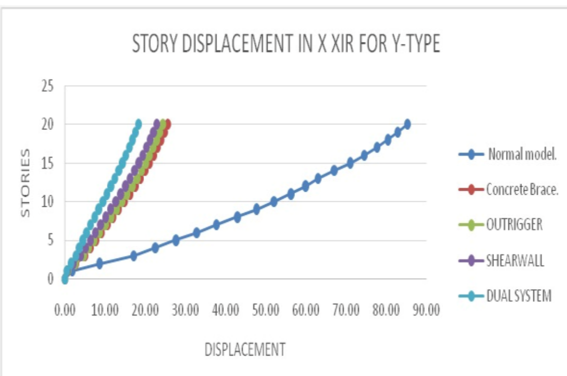

Fig. 4 Story Displacement Results for Y-Type Model in X Direction

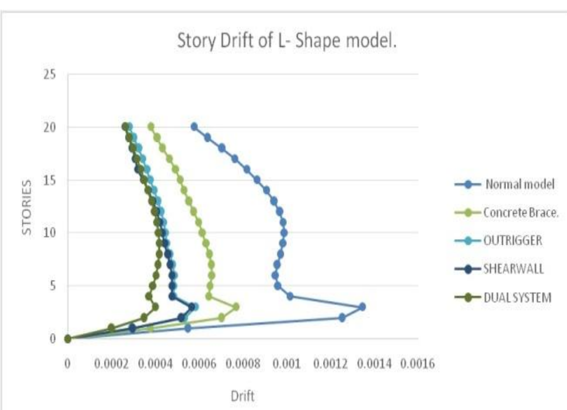

Fig. 5 Story Drift Results for L-Type Model in X Direction

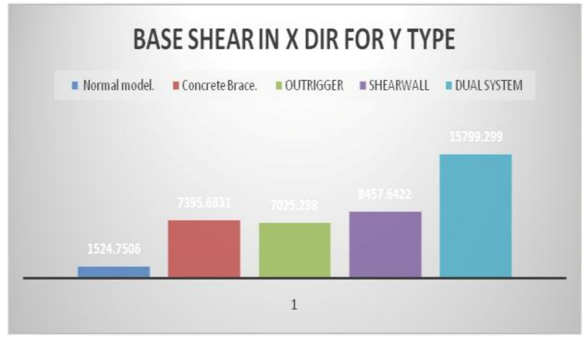

Fig. 6 Base Shear Results for Y-Type Model in X Direction

VI. CONCLUSION

This study investigated the influence of mass redistribution techniques and various lateral load resisting systems on the seismic response of vertically irregular RCC buildings subjected to earthquake loading. The analytical investigation carried out using ETABS 2021 demonstrated that structural irregularity significantly affects the dynamic behavior of high-rise buildings by increasing deformation and reducing overall stability.

The implementation of concrete bracing, outrigger, shear wall, and dual systems considerably enhanced the structural response by improving stiffness and controlling lateral movement. Among all the systems analyzed, the dual structural system exhibited the most efficient behavior due to its combined stiffness and load-sharing mechanism, which effectively minimized seismic response in both X and Y directions. The study also revealed that the use of advanced structural systems improved lateral load transfer and reduced the concentration of seismic forces at critical storeys. The reduction in displacement, drift, and time period confirmed the effectiveness of mass redistribution techniques in improving earthquake resistance of irregular structures. Based on the analytical results, it can be concluded that the integration of mass redistribution techniques with suitable lateral load resisting systems provides a reliable and efficient approach for enhancing the seismic safety and performance of vertically irregular RCC buildings.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to the Department of Civil Engineering, Nawab Shah Alam

Khan College of Engineering and Technology, Hyderabad, for providing the necessary support and facilities to carry out this research work. I would also like to thank my project guide and faculty members for their guidance and technical support throughout the study. Finally, I would like to acknowledge all those who contributed directly or indirectly to the successful completion of this work.

REFERENCES

[1] *IS 1893 (Part 1): 2016*, *Criteria for Earthquake Resistant Design of Structures*. New Delhi, India: Bureau of Indian Standards, 2016.

[2] *IS 16700:2017*, *Criteria for Structural Safety of Tall Concrete Buildings*. New Delhi, India: Bureau of Indian Standards, 2017.

[3] Karami *et al*., "Seismic behavior of steel frames with vertical mass irregularity," *Applied Sciences*, 2020.

[4] M. Wasey *et al*., "Seismic control systems in vertically irregular buildings," *Structures*, Elsevier, 2022.

[5] R. Raj *et al*., "Seismic performance of RCC buildings with vertical irregularities," *Springer Structural Engineering Journal*, 2025.

[6] Computers and Structures Inc., *CSI ETABS 2021: Integrated Building Design Software*, USA, 2021.