Seismic Performance Evaluation of Reinforced Concrete Frame Building Using Incremental Dynamic Analysis (IDA)

Mohd Maseehuddin Talha[1], Imtitaz Qureshi[2]
[1]*P.G student, 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*—The increasing demand for high-rise buildings in seismic-prone regions has created the need for advanced seismic evaluation techniques capable of accurately predicting structural behaviour under strong earthquake loading. This study presents the seismic performance evaluation of reinforced concrete G+10, G+20, and G+30 buildings using Incremental Dynamic Analysis (IDA). Different lateral load resisting systems, such as Buckling Restrained Bracing (BRB), BRB-E systems, Crescent bracing, and X-bracing were incorporated to improve seismic performance. Nonlinear time history analysis was performed using incrementally scaled earthquake records ranging from 0.1g to 1.0g. Engineering demand parameters such as maximum storey displacement, inter-storey drift ratio, time period, and collapse behaviour were evaluated. The results indicate that the normal frame exhibits maximum displacement and seismic vulnerability, whereas BRB-E and BRB systems significantly improve stiffness, energy dissipation, and overall structural performance.**

Keywords: Incremental Dynamic Analysis, RCC frame, BRB, BRB-E, seismic performance, nonlinear time history analysis.

I. INTRODUCTION

Earthquakes are one of the most destructive natural hazards affecting structural systems. Traditional seismic analysis methods such as Equivalent Static Analysis and Response Spectrum Analysis are often unable to capture the actual nonlinear behaviour of buildings subjected to strong ground motions. Incremental Dynamic Analysis (IDA) is an advanced nonlinear dynamic analysis method that evaluates structural response from the elastic stage up to collapse under progressively increasing earthquake intensity levels.

IDA provides a comprehensive understanding of stiffness degradation, energy dissipation, plastic hinge formation, and collapse mechanisms. In the present study, the seismic response of G+10, G+20, and G+30 RCC buildings was evaluated using different bracing systems to understand their effectiveness in improving structural safety and seismic resilience.

II. METHODOLOGY

Three-dimensional ETABS models of G+10, G+20, and G+30 RCC buildings were developed using appropriate material properties and nonlinear hinge assignments. Five different structural configurations were considered for each height of building :

1. Normal Frame
2. BRB System
3. BRB-E System
4. Cresent System
5. X-Bracing

Incremental Dynamic Analysis was performed by applying earthquake records scaled from 0.1g to 1.0g. Nonlinear time history analysis was conducted for each intensity level. Engineering Demand Parameters (EDPs) such as storey displacement, inter-storey drift, time period, and collapse capacity were extracted and compared.

Table I. Structural Models Considered

Model	Structural System	Main Function	Performance
Normal	Bare Frame	Baseline comparison	Poor
BRB	Buckling Restrained Brace	Energy dissipation	Very Good
BRB-E	Enhanced BRB	Improved damping	Excellent
Crescent	Crescent Bracing	Lateral resistance	Moderate
X-Brace	Steel Bracing	Increase stiffness	Good

III. RESULTS AND DISCUSSION

The analytical results revealed that the normal frame experienced the highest storey displacement, drift, and time period as seismic intensity increased. The absence of supplemental bracing resulted in reduced stiffness and increased seismic vulnerability (weakness of structure).

X-bracing and Crescent bracing improved lateral stiffness and reduced overall displacement. However, BRB and BRB-E systems demonstrated superior performance due to their enhanced energy dissipation characteristics. BRB-E exhibited the least displacement and drift values, indicating improved structural stability and collapse resistance.

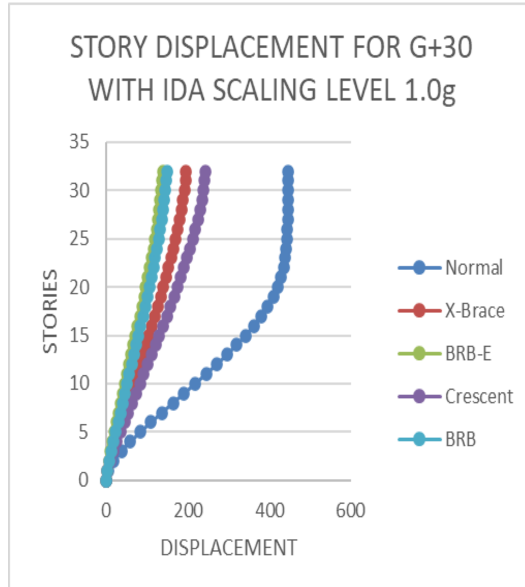

Fig. 1 : Storey displacement comparison for G+30 building.

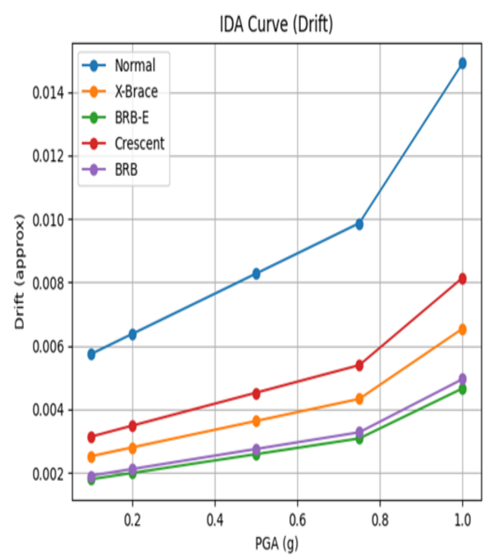

Fig. 2 : Storey drift comparison for different bracing systems.

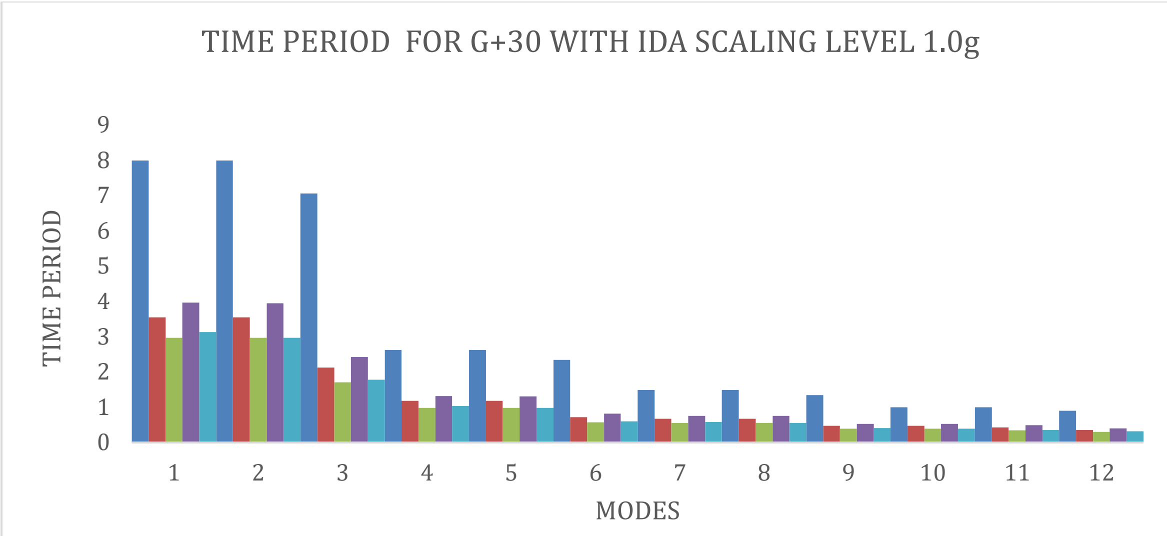

Figure. 3 : Time Period for G+30 with IDA Scaling Level 1.0g

Table II. Comparative Structural Response

System	Displacement	Drift	Overall Response
Normal	Very High	High	Severe Damage
X-Brace	Moderate	Moderate	Improved
Crescent	Moderate	Moderate	Stable
BRB	Low	Low	Very Stable
BRB-E	Very Low	Very Low	Best Performance

IV. CONCLUSION

Incremental Dynamic Analysis proved to be an effective tool for evaluating the nonlinear seismic behaviour of RCC multi-storey buildings. The study demonstrated that the incorporation of advanced bracing systems significantly improves seismic performance by reducing displacement and inter-storey drift while increasing stiffness and energy dissipation capacity. Among all systems considered, BRB-E and BRB systems showed superior seismic resistance and collapse prevention capability. The results highlight the importance of advanced lateral load resisting systems in improving the resilience and safety of high-rise buildings located in seismic zones.

V. ACKNOWLEDGEMENT

I would like to convey my sincere and deepest appreciation to the Department of Civil Engineering, Nawab Shah Alam Khan College of Engineering and Technology, for their continuous support and encouragement throughout this research work. I am truly grateful for their guidance, motivation, and constant supervision at every stage of the study. Their patience, cooperation, and valuable suggestions greatly contributed to the successful completion of this work. I also extend my gratitude for the strategic guidance and insightful advice provided during the initial stages as well as throughout the progress of the project. Finally, I would like to thank everyone who directly or indirectly supported and assisted me in completing this research successfully.

REFERENCES

[1] IS 1893 (Part 1): 2016, Criteria for Earthquake Resistant Design of Structures.

[2] Ahmed, S., Khan, M., and Ali, R. (2025). Seismic vulnerability assessment of RC residential buildings using incremental dynamic analysis. *Buildings*, MDPI.

[3] Srinath, K., Reddy, P., and Kumar, V. (2025). Effects of repeated earthquake sequences on RC frame structures using IDA. *Engineering Structures*, Elsevier.

[4] Xu, Y., Zhang, L., and Chen, H. (2024). Machine learning-based prediction of seismic response using incremental dynamic analysis. *Structures*, Elsevier.

[5] Awchat, S., Patil, D., and More, S. (2023). Seismic fragility analysis of RC frames using incremental dynamic analysis. *Civil and Environmental Engineering*.

[6] Kumar, A., and Rao, B. (2021). Seismic performance of RC buildings with soft storey irregularity using IDA. *Asian Journal of Civil Engineering*.

[7] Li, X., Wang, J., and Zhou, Y. (2022). Soil–structure interaction effects in incremental dynamic analysis of RC structures. *Soil Dynamics and Earthquake Engineering*.

[8] Zhang, Q., Liu, T., and Zhao, H. (2023). Seismic performance of high-rise RC buildings using IDA. *Engineering Structures*.

[9] Chen, W., Li, F., and Sun, J. (2024). Bidirectional seismic analysis of RC frames using incremental dynamic analysis. *Journal of Structural Engineering*.

[10] Gupta, R., and Jain, S. (2025). Seismic performance of RC buildings on sloping ground using IDA. *International Journal of Engineering Research and Technology (IJERT)*.

[11] Park, J., Kim, S., and Lee, D. (2023). Collapse probability assessment of RC frames using incremental dynamic analysis. *Earthquake Spectra*.

[12] Miao, Z., Liu, Y., and Wang, X. (2024). Deep learning-based damage prediction using IDA. *Structural Safety*.

[13] Vamvatsikos, D., and Cornell, C. A. (2025). Incremental dynamic analysis: A comprehensive nonlinear analysis method. *Earthquake Engineering & Structural Dynamics*.

[14] Sharma, P., Verma, S., and Singh, R. (2025). Seismic performance of structures with tuned mass dampers using IDA. *ISET Proceedings*.

[15] Patil, R., Deshmukh, S., and Jadhav, P. (2022). Seismic analysis of irregular RC buildings using IDA. *International Research Journal of Engineering and Technology (IRJET)*.

[16] Singh, A. (2021). Development of fragility curves for RC structures using IDA. PhD Thesis, HBNI.

[17] Karthik, R., Prasad, M., and Ramesh, K. (2024). Seismic behavior of RC buildings using nonlinear time history analysis and IDA. *International Journal of Intelligent Systems and Applications in Engineering (IJISAE)*.