A Review : Retrofitting of Multi-Storey Structures in Seismic Zone IV Using Dampers

Abhishek K. Muley, Deepak B. Gaidhane, Akram S. Pathan
Govind H. Dake and Sunil D. Shinde

Department of Civil Engineering, Deogiri Institute of Engineering and Management Studies, Chhatrapati Sambhajinagar-431005, Dr. Babasaheb Ambedkar technological University, Lonere-402103, Maharashtra, India

ABSTRACT : In light of rapid urbanization and the constraints on horizontal expansion in densely populated cities, the development of high-rise buildings has become a practical necessity. With the increasing demand for vertical construction, it is imperative to assess the structural performance of tall buildings under seismic forces. Earthquakes represent one of the most critical natural hazards, often imposing highly destructive loads on built infrastructure. Structures located within high seismic risk zones are especially susceptible to severe damage or total collapse. To mitigate these risks and enhance structural resilience, various retrofitting techniques and supplemental damping systems are employed. These interventions aim to improve the building's capacity to withstand seismic events. This study specifically undertakes a seismic analysis of a multi-storey building situated in Seismic Zone-II and Zone-IV, in accordance with relevant design standards, to evaluate its dynamic response and structural behavior under earthquake loading conditions.
KEYWORDS : Earthquake, Response Spectrum Method, Viscous Damper, ETABS

I INTRODUCTION

The primary purpose of the review is structural analysis and design in earthquake engineering is to ensure the development of a stable and resilient structure capable of withstanding all potential lateral forces induced by ground motion throughout its intended service life. Structural design involves evaluating the stability, strength, and rigidity of a building to ensure it performs safely under various loading conditions. Failure to adhere to established design provisions can result in catastrophic consequences, including structural failure. Therefore, performing comprehensive seismic analysis and incorporating appropriate design strategies is essential to safeguard structures against collapse.
This review focuses on evaluating the seismic performance of multi-storey buildings using the Response Spectrum Method, which is a widely accepted approach for estimating the structural response to short-duration, non-deterministic, dynamic events such as earthquakes and shocks. The analysis takes into account the effects of dead loads, live loads, and lateral forces, including wind and seismic loads. All design parameters and load considerations are aligned with the guidelines specified in IS 1893:2016 (Part 1), which governs the seismic design of structures in India and varies based on the designated seismic zone.

II REASEARCH REVIEW

[1] D Chaudhary.et.al (2014), has summarized performance-based seismic design methodology for RC frame buildings incorporating metallic and friction dampers. The method follows a non-iterative, step-by-step procedure aimed at controlling inter-storey drift and plastic hinge rotations. A ten-storey building, designed for Immediate Occupancy (IO) under MCE in Seismic Zone IV, was analyzed using nonlinear time history analysis. The inclusion of dampers significantly enhanced seismic performance. Roof displacements and drifts were reduced by 1.5 to 2 times, while shear forces and moments in columns dropped by 30–35%. Although axial

forces increased by around 30%, the overall structural response improved, confirming the effectiveness of the proposed method.

[2] Kusuma. S et al. (2020), have done in this study, a seismic analysis of a G+10 multi-storey reinforced concrete building located in Seismic Zone-II was performed using ETABS software. Two widely used dynamic analysis methods the Response Spectrum Method (RSM) and the Time History Method (THM) were applied to evaluate the building's seismic response.The results revealed that the base shear values obtained using RSM were slightly higher compared to those from THM. Additionally, storey deflections were greater in RSM, particularly in the upper storeys. However, in the lower storeys, both methods produced nearly identical displacement results, indicating similar structural behavior under lower-level seismic forces. As the height of the building increases, the difference in structural displacement between the two methods becomes more pronounced, with THM generally providing a more accurate and detailed representation of the dynamic response. Therefore, Time History Analysis is recommended for in-depth studies, especially when precise evaluation of structural performance is required. Nonetheless, Response Spectrum Analysis remains a valid and efficient method for preliminary or simplified seismic assessments.

[3] Mayuri D. Bhagwat et.al (2014), had done dynamic analysis of a G+12 reinforced concrete (RCC) building was carried out to assess its seismic performance using ETABS software. The building was evaluated under earthquake loading conditions using both the Time History Method and the Response Spectrum Method. To perform the analysis, two actual ground motion records Koyna and Bhuj earthquakes were utilized.The study focused on key seismic response parameters, including base shear, storey displacement, and storey drift, enabling a comparative assessment of the building's behavior under the two different analysis approaches. This comparative evaluation provided valuable insights into the performance of high-rise RCC buildings during seismic events.

[4] Wakchaure and Ped (2013), has investigates the impact of masonry infill panels on the seismic response of reinforced concrete (RC) frames. In the analysis, infill walls are modeled using the equivalent strut method, where the infill acts as a compression member transferring forces between beams and columns. Various empirical formulas developed by researchers are applied to determine the strut width for accurate modeling.A G+9 RC framed structure was modeled in ETABS, and linear dynamic analysis was conducted under earthquake loading conditions using time history data. Multiple configurations of infill arrangements were considered to evaluate their influence on key response parameters, including base shear, storey displacement, and storey drift.The results indicate that the presence of masonry infill walls leads to a reduction in displacement and time period, while simultaneously causing an increase in base shear. This highlights the importance of accounting for infill wall effects in the seismic analysis of moment-resisting RC frames.Additionally, the study addresses the limited research available on the use of Viscoelastic (VE) dampers for retrofitting buildings—particularly those located in upgraded seismic zones in India. A retrofitting methodology using VE dampers is proposed and demonstrated on both a low-rise and a high-rise structure, aiming to enhance seismic performance in buildings with and without infill walls.

[5] Albert Philip et al. (2017), has performed seismic analysis on a G+12 reinforced concrete building featuring both regular and irregular plan configurations, located in Seismic Zone III in India. The study utilized CSI ETABS software and adopted the Response Spectrum Method for evaluating the building's dynamic behavior under seismic loading. Key parameters such as storey displacement, storey drift, storey shear, and storey stiffness were analyzed and compared between the two structural configurations. The results indicated that storey displacement increases linearly with the height of the building. For the irregular structure, the maximum

storey drift occurred at the second floor, while for the regular structure, it was observed at the fourth floor.The maximum storey shear force was found between the ground and second floor in the regular structure, and at the ground floor in the irregular structure. Additionally, storey stiffness exhibited a non-linear variation across the height in both configurations.

[6] Weng et al. (2012), has proposed a simplified seismic retrofit procedure for RC frames damaged during earthquakes using viscous dampers. The study focused on developing a methodology where the main frame and damping system are designed independently, with damping forces optimized based on storey shear requirements. The technique was validated through a real-life retrofit of a school building damaged in the 2008 Wenchuan earthquake. The results confirmed that the simplified approach is efficient and applicable for both retrofit of damaged structures and design of new constructions with damping systems.

[7] Symans et al. (2008), has presented a comprehensive review of Passive Energy Dissipation Devices (PEDs) and their application in seismic engineering. The study examined devices such as viscous dampers, viscoelastic solid dampers, friction dampers, and metallic dampers, highlighting their energy dissipation principles and mechanical behavior. Mathematical modeling techniques for each system were discussed in detail. The authors emphasized the importance of PEDs in improving seismic resilience of buildings, especially in areas prone to frequent or severe earthquakes.

[9] Sahil Arora et al. (2019), has conducted a comparative performance analysis between bracing systems and fluid viscous dampers in a 20-storey reinforced concrete structure modeled in ETABS 2016. Six configurations were tested, including bare frames and different types of bracings and dampers. The diagonal FVD model with 250 kN capacity showed superior performance, with a 58.98% reduction in base shear and 14.4% decrease in lateral deflection compared to conventional systems. The results suggest that fluid viscous dampers provide greater stability and energy dissipation capacity in tall buildings.

[10] J. Chiranjeevi Yadav et al. (2017), had evaluated the seismic behavior of RC buildings using ETABS, focusing on earthquake zones II and V under Indian conditions. The analysis included detailed modeling of soil characteristics, structural geometry, and seismic parameters. Key performance criteria such as storey displacement, acceleration, inter-storey drift, and structural stresses were examined to assess safety and stability. The findings highlighted the importance of zone-specific dynamic analysis for reliable earthquake-resistant design in both low and high seismic risk regions.

[10] X.L. Lu et al. has analyzed an 8-storey RC building retrofitted using three different types of dampers: viscous dampers (VD), steel dampers (SD), and viscoelastic dampers (VED). These dampers were evaluated under equivalent seismic energy conditions to compare their effectiveness. The study demonstrated that each damper type influenced shear forces and inter-storey drift differently, with variations in performance based on earthquake intensity. The results confirmed that strategic damper selection and placement significantly improve a building's seismic resistance, particularly during retrofitting after damage.

III CONCLUSION

The reviewed literature collectively emphasizes the effectiveness of various damping systems such as metallic, friction, viscous, and viscoelastic dampers in improving the seismic performance of reinforced concrete buildings. Performance-based and simplified design methodologies have been proposed and successfully demonstrated on buildings of different heights, showing notable improvements in controlling inter-storey drifts, reducing plastic hinge rotations, and minimizing structural forces like shear and moments. Comparative analyses using both time history and response spectrum methods indicate that structures equipped with dampers experience significant reductions in displacements and drifts, especially in higher stories and irregular configurations. The use of dampers also proves beneficial in mitigating seismic pounding between adjacent buildings and enhancing structural stability under dynamic loads. Infill walls, when modeled appropriately, further contribute to increased stiffness and base shear resistance. Overall, the integration of damping devices in both new constructions and retrofitting applications consistently leads to enhanced seismic performance, confirming their value in achieving desired safety and serviceability levels during earthquakes.

REFERENCES

[1] Deepiskha Chaudhary, Yogendra Singh, (2014) "Performance Based Design Of RC Frame Buildings With Metallic And Friction Dampers" Journal of Earthquake Engineering And Engineering Vibrations, Springer, Vol, No 5,239-247.
[2] Kusuma S and Dr. E. Ramesh Babu, (2020) "Seismic Analysis And Design Of Multi-storey Building Using ETABS With Comparison Of Response Spectrum Method And Time Method'' journal of emerging technologies and innovation research (Volume- 7, Issue- 5),ISSN -2349-5162.
[3] Mayuri D. Bhagwat, Dr. P.S. Patil, (2014) "Comparative Study of Performance of RCC Multistorey Building for Koyna and Bhuj Earthquakes" in IJATES, Vol: 02, Issue: 07, pp.67-72.
[4] Wakchaure, M.R and Ped, S.P, (2013) "Earthquake analysis of high rise building with and without in filled walls", International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 2.
[5] Albert Philip and Dr. S. Elavenil, (2017) " Seismic Analysis Of High Rise Building With Plan Irregularity', International Journal of Civil Engineering And Technology (Volume -8,Issue -4) , pp.1365-1375.
[6] Weng, D.G., Zhang, C., Lu, X.L., Zeng, S and Zhang, S.M, (2012) "A simplified design procedure for sesmic retrofit of earthquake damaged RC frames with viscous dampers", Journal of Structural Engineering and Mechanics, Vol.44, No.5.
[7] Symans M.D., Charney F.A., Whittaker A.S., Constantinou M.C., Kircher C.A., Jhonson M.W. and McNamara R.J, (2008) "Energy Dissipation System for Seismic Application: Current Practice and Recent Development", Journal of Structural Engineering, ASCE, Vol. 134, No. 1, pp. 3-21.
[8] Sahil Arora and Amanullah, (2019) "Optimization of bracing and viscous damper and comparison of fluid viscous damper and bracing system for stabilization of high rise building" International Journal of Civil Engineering and Technology (IJCIET). Scopus indexed Volume 10, Issue 03.
[9] J. Chiranjeevi Yadav, L. Ramaprasad Reddy, (2017) "Dynamic Analysis of G + 20 Residential Building in Zone-2and Zone-5 By Using ETABS, "International Journal of Professional Engineering Studies, Vol. 8, Issue 3, pp. 333-348.
[10] XL. Luetal "Comparative Study on Seismic Behaviour of RC Frame Structure Using Viscous Dampers, Steel Dampers and Viscoelastic Dampers" 15th World Conference on earthquake Engineering.