Compartive Study of Seismic Analysis on Structures by Using Dampers and Without Dampers

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Abstract: **Earthquakes, as one of the most destructive natural disasters, cause abrupt and severe ground motions due to the sudden release of energy within seconds. Recent seismic events highlight the vulnerability of modern society to such disasters. As a result, ensuring the safety and resilience of civil structures, along with protecting occupants and property, has become a global imperative. One of the primary challenges for structural engineers is designing buildings that can effectively withstand seismic forces and mitigate potential damage. Seismic events pose significant threats to structural stability, necessitating the adoption of advanced mitigation measures such as dampers to enhance resilience. This study conducts a comparative seismic analysis of structures with and without dampers using ETABS software. The primary aim is to assess the influence of dampers on structural performance by analyzing critical parameters, including story displacement, inter-story drift, base shear, and energy dissipation.**

This study examines the seismic performance of a reinforced concrete (RC) moment-resisting frame (MRF) building, modeled in two configurations, Model I: RC frame building without dampers and Model II: RC frame building with fluid viscous dampers (FVDs). The building, designed for commercial use, is assumed to be located in Seismic Zone IV as per Indian seismic zoning standards. Both models are developed and analyzed in ETABS software, considering all relevant design parameters.

This study emphasizes the importance of integrating advanced damping systems like FVDs in seismic design to achieve safer and more resilient structures in earthquake-prone areas. The findings reveal that incorporating dampers not only enhances seismic resilience. The analysis results demonstrate that incorporating fluid viscous dampers significantly enhances the building's seismic performance. By carefully selecting suitable damping coefficients, FVDs effectively reduce structural responses such as displacements and accelerations during seismic events. Moreover, strategically placing dampers at critical locations within the structure achieves substantial reductions in earthquake-induced responses, improving the stability and safety of the building.

Keywords: **Fluid Viscus Damper, Earthquake Performance, Seismic Responses, Structural Integrity. ETABS, Lateral displacements, Storey drifts.**

I. INTRODUCTION

Seismic activity, commonly known as earthquakes, involves ground motion that can result in structural failures and loss of life. These movements release energy in the form of primary and secondary waves, which transmit vibrations to structures through their foundations. Depending on the severity of the vibrations, they can lead to cracks, settlements, and structural damage. A structure's capacity to deform and revert to its original shape is referred to as its elastic limit. When deformation surpasses this limit, cracks develop; however, ductility can help mitigate significant damage. Greater ductility enhances structural resilience and reduces damage, though it often comes with increased costs.

The extent of damage to buildings during an earthquake is influenced by factors such as shaking intensity, duration, soil conditions, and building construction. Shaking intensity decreases with distance from the epicenter, with seismic force diminishing progressively (e.g., to one-sixteenth at 50 miles). Longer shaking durations typically cause more damage, as seen in events like the Loma Prieta earthquake (10–15 seconds) versus other magnitude 7 quakes (30–40 seconds). Soil type also plays a crucial role; loose, soft, or water-saturated soils amplify vibrations and may cause uneven settlement or sliding. Additionally, poorly designed or inadequately constructed buildings are more prone to severe damage or collapse due to their inability to withstand lateral forces.

Dampers are mechanical devices engineered to dissipate earthquake energy by undergoing controlled deformation or yielding during seismic events. Installed within structures, they enhance energy absorption, thereby reducing the seismic forces the structure must endure. When seismic energy travels through a building during an earthquake, dampers absorb a significant portion of this energy, effectively decreasing vibrations and motion. This process minimizes structural damage and enhances the building's overall seismic performance and safety.

Fluid viscous dampers (FVDs) are advanced energy dissipation devices that improve a structure's seismic performance by absorbing earthquake-induced energy through fluid motion. They work by forcing fluid through a small orifice, creating damping pressure that reduces structural stresses and deformations. FVDs can increase structural damping up to 30–50% of critical damping, significantly lowering lateral displacements and floor accelerations, often by 50% or more. Developed using aerospace technology and tested at MCEER, these compact devices effectively mitigate stress and deflection under dynamic loads.

II. LITERATURE REVIEW

Dr. Sarika J. Modak et al. (2024) compared a G+5 residential structure using ETABS and STAAD Pro, two widely utilized tools for structural design and analysis in civil engineering. The research evaluated their accuracy in predicting vertical loads and structural responses, including bending moments, axial forces, shear forces, and deflection. Following a systematic methodology that included standard code setup, grid creation, property definition, load assignment, and analysis, the study ensured a fair comparison. By identifying the strengths and limitations of each software, the findings aimed to assist engineers in selecting the most appropriate tool, thereby advancing structural engineering practices.

Prashanth et al. (2024) compared the design outcomes of multi-storey buildings using ETABS and STAAD.Pro software. The study revealed that ETABS generally requires less steel for beams compared to STAAD.Pro, which tends to produce more conservative designs. However, for columns where the required steel falls below the minimum limit, both software delivered comparable results.

Krishna Kumar Kori and Ankita Singhai (2024) investigated various energy dissipation systems, including dampers, base isolators, and shear walls, with an emphasis on their strategic placement to maximize efficiency. Through a comprehensive literature review, the study examined the performance of these systems under seismic conditions and their interaction with earthquake forces. It provided valuable insights into optimizing structural designs, focusing on improving the seismic resistance of buildings and elevated water tanks using advanced energy dissipation techniques.

Dhanapal Arunraj et al. (2023) examined the seismic performance of high-rise buildings across different seismic zones using ETABS. The study highlighted the significance of accounting for varying seismic conditions in structural design to enhance safety and meet applicable standards. By analyzing building responses to seismic forces, the research underscored the need for zone-specific design approaches to ensure structural resilience and compliance. The findings contribute to improving seismic design practices for high-rise structures in diverse seismic environments.

Umer Bin Fayaz and Gurpreet Singh (2023) conducted a design and seismic analysis of a G+5 storey building using ETABS. The study emphasized the importance of seismic analysis in creating structures that can effectively resist lateral movements caused by earthquakes. It highlighted how seismic considerations play a critical role in ensuring structural safety and stability. The research contributes to advancing design methodologies for earthquake-resistant buildings.

Shivam Gautam and Ramanuj Jaldhari (2023) focused on progressive collapse analysis, which occurs when the removal of a vertical load-bearing element causes adjacent members to fail, potentially resulting in partial or total structural collapse. Using SAP2000 V23, five 15-story RC framed structure models—one regular and four with vertical member removal—were analyzed through nonlinear static analysis, following GSA 2003 guidelines. The trapezoidal building plan (7x10 bays) in seismic zone V was evaluated for demand-capacity values, base shear versus displacement, and hinge formation. Results highlight the high potential for progressive collapse and compare structural behavior across scenarios. The study aims to mitigate failure risks and minimize life and property losses through advanced analysis and simulation.

Venkatesh and K. Janardhan (2022) conducted a comparative analysis of a G+10 residential building subjected to wind loads using STAAD.Pro V8i and ETABS 2020. The study assessed the performance and accuracy of both software in predicting structural responses to wind forces. By analyzing the building's behavior under wind load, the research highlighted the strengths and limitations of each tool. The findings contribute to informed decision-making in selecting suitable software for wind load analysis in structural engineering.

S. Sharma and R. Gupta (2021) aimed to analyze and design a G+3 commercial structure using ETABS while also manually designing beams, slabs, columns, and footings for comparison. The study evaluated manual versus ETABS results, provided AutoCAD drawings, and detailed the reinforcement of structural components to ensure accuracy and practicality in design.

Harshavardhan P. (2022) focused on the analysis and design of a G+10 residential building as per IS code methods. The structure was designed manually and verified using STAAD.PRO V8i software. With the growing availability of advanced civil engineering software, tools like STAAD.PRO and ETABS, based on finite element analysis, account for dynamic loads such as wind effects. This project evaluates the efficiency of these software applications, with drafting and detailing completed using AutoCAD 2021. The beam, column, slab, staircase, and shear wall designs were calculated using the "Limit State Method" in accordance with IS: 456-2000, and various loads were considered per IS: 875-1987 (Parts 1, 2, and 3). The residential building was meticulously planned to comply with Indian Standard Codes.

Dr. R. S. Talikoti & Mr. Vinod R. Thorat (2014) studied on effectiveness of base isolation systems and cross-bracing was analyzed for multistoried buildings. Base isolation significantly reduced seismic forces compared to non-isolated designs, demonstrating its potential for enhancing structural resilience during earthquakes.

III. METHODOLOGY

The present study focuses on the analysis of a reinforced concrete (RC) moment-resisting frame (MRF) building, modeled in two configurations to assess its seismic performance. The building, intended for commercial use, is assumed to be located in Seismic Zone IV, as per Indian seismic zoning classifications. Two models are analyzed:

•Model I: RC frame building without dampers

•Model II: RC frame building incorporating fluid viscous dampers (FVDs)

The structural models are developed and analyzed using ETABS software, with all relevant design parameters duly considered.

Table 1 Building Parameters

Parameter	Details
Type of Building	Moment Resistant Frame
Number of Storeys	15, 25, and 35
Floor Height	3 m
Live Load	3 kN/m²
Dead Load	Finishing Load: 1 kN/m²
	Wall Load: 12 kN/m²
Materials	M30 Concrete and Reinforced with HYSD Bars (Fe415)
Size of Columns	600 x 600 mm, 800 x 800 mm, 850 x 850 mm, 950 x 950 mm
Size of Beams	450 x 450 mm
Depth of Slab	150 mm
Density of Concrete	2400 kg/m³
Density of Brick Wall	1900 kg/m³
Seismic Zone	IV
Importance Factor (I)	1
Response Reduction Factor (R)	5
Soil Type	Type I (Hard Rock) or A

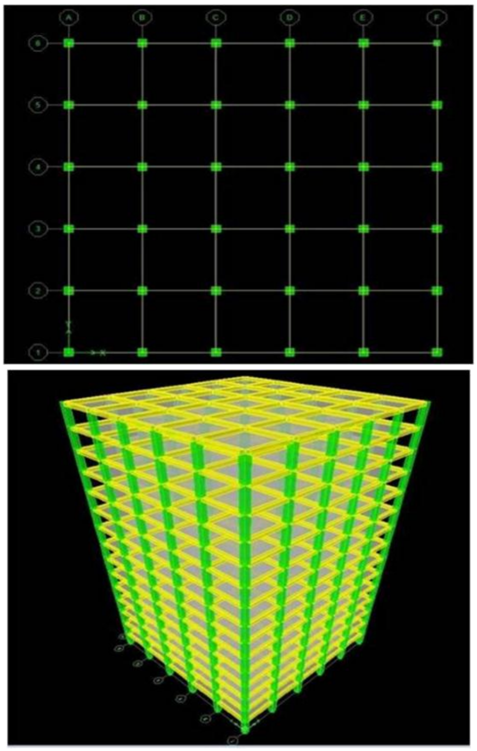

Fig. 1 Plan and 3D view of G+14 Building without dampers

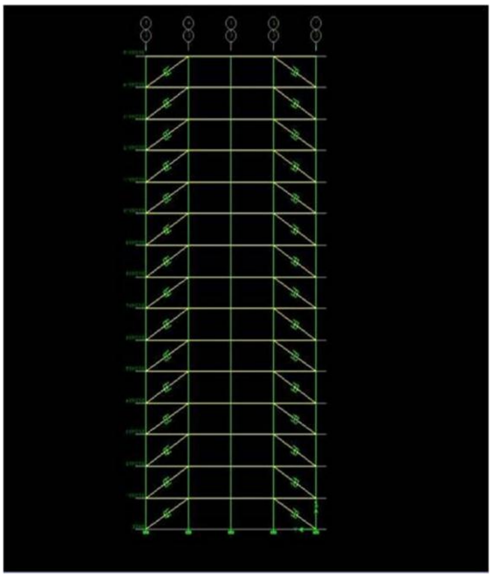

Fig. 2 Elevation view of G+14 Building with dampers

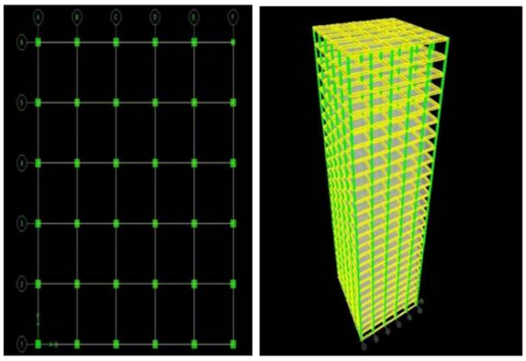

Fig. 3 Plan and 3D view of G+24 Building without dampers

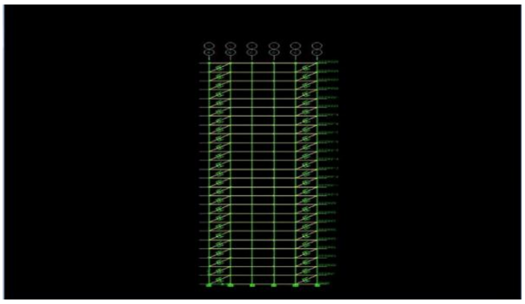

Fig. 4 Elevation view of G+24 Building with dampers

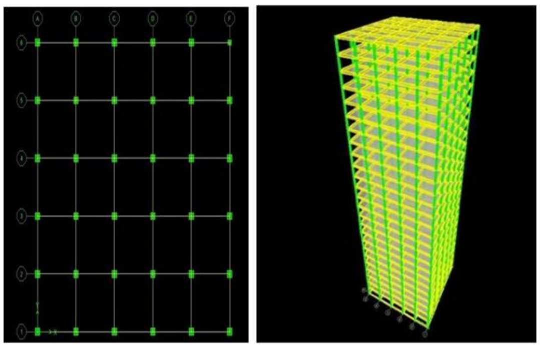

Fig. 5 Plan and 3D view of G+34 Building without dampers

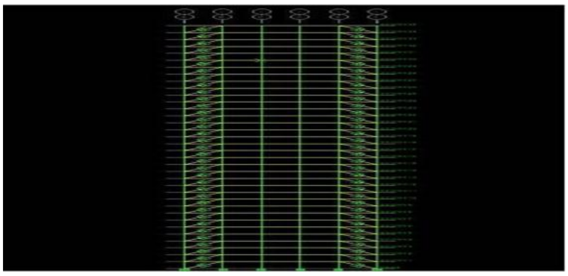

Fig. 6 Elevation view of G+34 Building with dampers

IV. RESULTS AND DISCUSSION

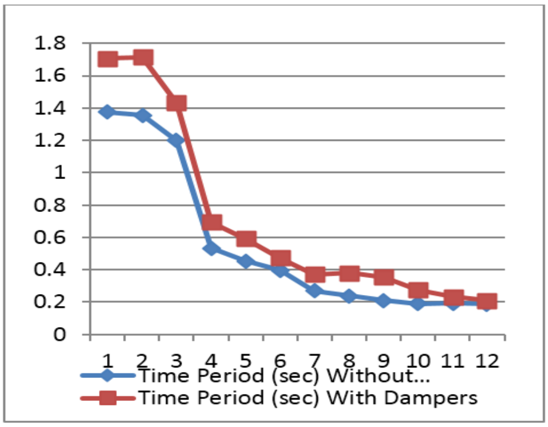

Fig. 7 Time vs mode graph of G+24 with and without dampers

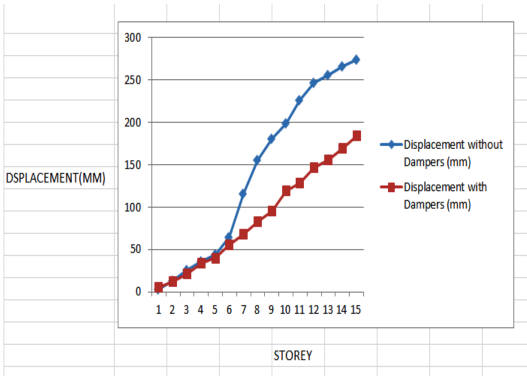

Fig. 8 Displacement vs storey graph of G+24 with and without dampers

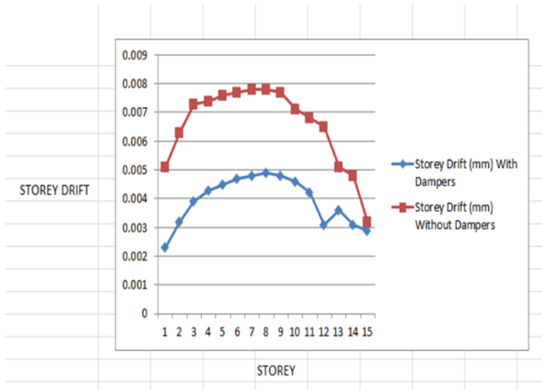

Fig. 9 Storey Drift vs storey graph of G+24 with and without dampers

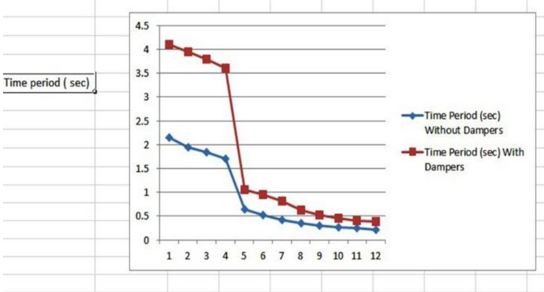

Fig. 10 Time vs mode graph of G+24 with and without dampers

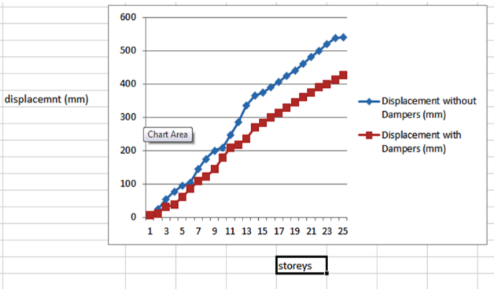

Fig. 11 Displacement vs storey graph of G+24 with and without dampers

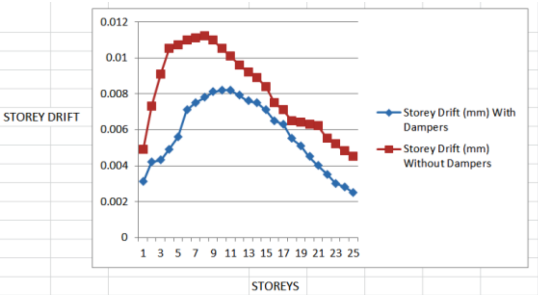

Fig. 12 Storey Drift vs storey graph of G+24 with and without dampers

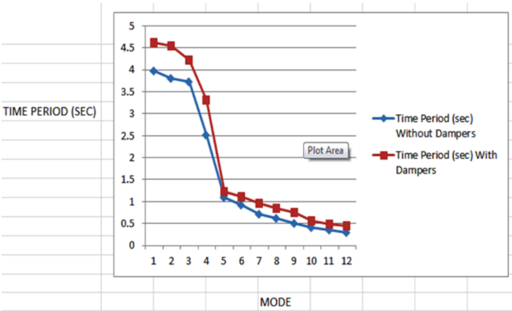

Fig. 13 Time vs mode graph of G+34 with and without dampers

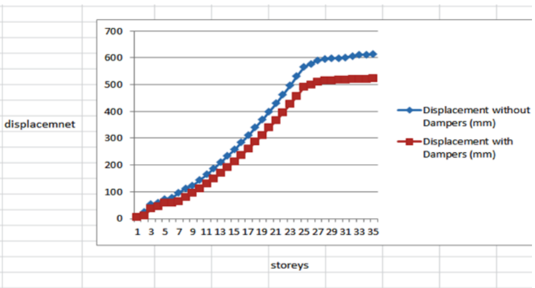

Fig. 14 Displacement vs storey graph of G+34 with and without dampers

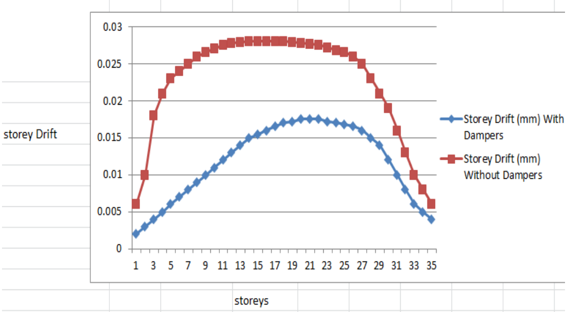

Fig. 15 Storey Drift vs storey graph of G+34 with and without dampers

V. CONCLUSIONS

Base isolation techniques significantly reduce seismic responses in both symmetric and asymmetric buildings compared to fixed-base models. These methods enhance safety, serviceability, and resilience by minimizing structural damage during seismic events.

- Reduction in Storey Drifts with Dampers:
  Dampers significantly lower storey drifts, especially in high-rise structures like G+15, G+25, and G+35 buildings. This control improves structural integrity and reduces damage to non-structural components such as facades and partitions.
- Improved Lateral Stability in All Models:
  Fixed-base models transfer all lateral loads to the superstructure, increasing stress and failure risks during earthquakes. Buildings with dampers exhibit controlled displacement, which dissipates seismic energy and enhances lateral stability, particularly in asymmetric structures.
- Effectiveness in High-Rise and Irregular Buildings:
  Dampers mitigate critical issues like lateral displacement and torsional irregularities in tall and irregularly shaped buildings. They reduce the impact of higher vibration modes, improving structural and non-structural performance under seismic loads.
- Importance of Proper Selection and Installation:
  The study highlights the need for selecting appropriate dampers based on building specifications and seismic conditions. Correct placement and installation are crucial for efficient performance; improper execution can compromise seismic safety.
- Enhanced Seismic Performance and Safety:
  Buildings with base isolators and dampers demonstrate reduced displacements, drifts, and

internal forces, enhancing structural safety. These measures ensure functionality of critical buildings like hospitals and offices after earthquakes by preventing structural and non-structural damage.

- Contribution to Disaster-Resilient Infrastructure: Incorporating base isolation and dampers promotes earthquake-resilient infrastructure, safeguarding lives and assets. These advanced solutions are vital for urban resilience, enabling buildings to withstand both moderate and severe seismic events without catastrophic failure.

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