Seismic Performance of RC Buildings with Different Lateral System Using Etabs

Shilpa S[1], Umair Misbah [2], Dr. Gopinath Nayak[3], Dr. Uday Kumar[4]

[1]Assistant Professor of structural engineering, Department of Civil Engineering at Srinivas University Institute of Engineering and Technology, Mukka, Mangalore, Karnataka, India.
[2]Structural Engineering graduate pursuing M. Tech, Department of Civil Engineering at Srinivas University Institute of Engineering and Technology, Mukka, Mangalore, Karnataka, India.
[3]Associate Professor, Department of Civil Engineering MIT, MAHE, Manipal, Udupi, Karnataka, India
[4] Research Professor, Srinivas University Institute of Engineering and Technology, Mukka, Mangalore, Karnataka, India.

Abstract

Earthquakes pose a serious threat to reinforced concrete (RC) buildings, particularly multistorey structures in seismic regions. Conventional moment-resisting frame systems often suffer from excessive lateral displacement and inter-storey drift due to inadequate stiffness and limited energy dissipation. To improve seismic performance, lateral load–resisting systems such as shear walls, bracing systems, and supplemental damping devices are widely adopted in modern structural design.

In this study, the seismic performance of a G+20 RC building is evaluated using shear walls, X-bracing, friction dampers, and fluid viscous dampers. Nonlinear Time History Analysis is performed in ETABS using Bhuj (2001) and Northridge earthquake records. Structural response is assessed in terms of displacement, drift, base shear, and time period. The results show that all lateral systems enhance seismic performance compared to the bare frame, with fluid viscous dampers providing the most effective control of displacement and drift due to superior energy dissipation, thereby improving the seismic resilience of high-rise RC buildings.

Keywords: Nonlinear Time History Analysis, Shear Wall, X-Bracing, Friction Damper, Fluid Viscous Damper, ETABS

1.Introduction:

Earthquakes are among the most destructive natural phenomena, frequently causing severe damage to reinforced concrete structures. Multistorey RC buildings are particularly vulnerable due to high lateral flexibility, irregular distribution of mass and stiffness, and inadequate energy dissipation mechanisms. Past seismic events have revealed that conventional moment-resisting frame systems often fail to meet acceptable performance limits, resulting in excessive lateral displacement and inter-storey drift.

To mitigate seismic damage, engineers incorporate lateral load–resisting systems that enhance stiffness, strength, and energy dissipation capacity. Shear walls provide high lateral stiffness and strength, while steel bracing systems improve load transfer efficiency through axial action. In contrast, damping devices such as friction dampers and fluid viscous dampers dissipate seismic energy without significantly increasing structural stiffness.

Nonlinear Time History Analysis (NLTHA) is recognized as the most reliable method for evaluating seismic performance, as it captures inelastic behavior, dynamic interaction, and realistic ground motion effects. Indian seismic design codes, including IS 1893 (Part 1): 2016 and IS 13920: 2016, emphasize the importance of ductile detailing and appropriate selection of lateral systems to ensure life safety.

The objective of this study is to evaluate and compare the seismic performance of a multistorey RC building with different lateral load–resisting systems using nonlinear time history analysis and to identify the most effective configuration for seismic resilience.

1.1 Objectives

- ❖ To evaluate the seismic performance of a G+20 multistorey reinforced concrete building using nonlinear dynamic analysis under real earthquake ground motion records.
- ❖ To compare the effectiveness of different lateral load–resisting systems, namely shear walls, X-bracing, friction dampers, and fluid viscous dampers, in controlling seismic response parameters such as storey displacement, inter-storey drift, and base shear.

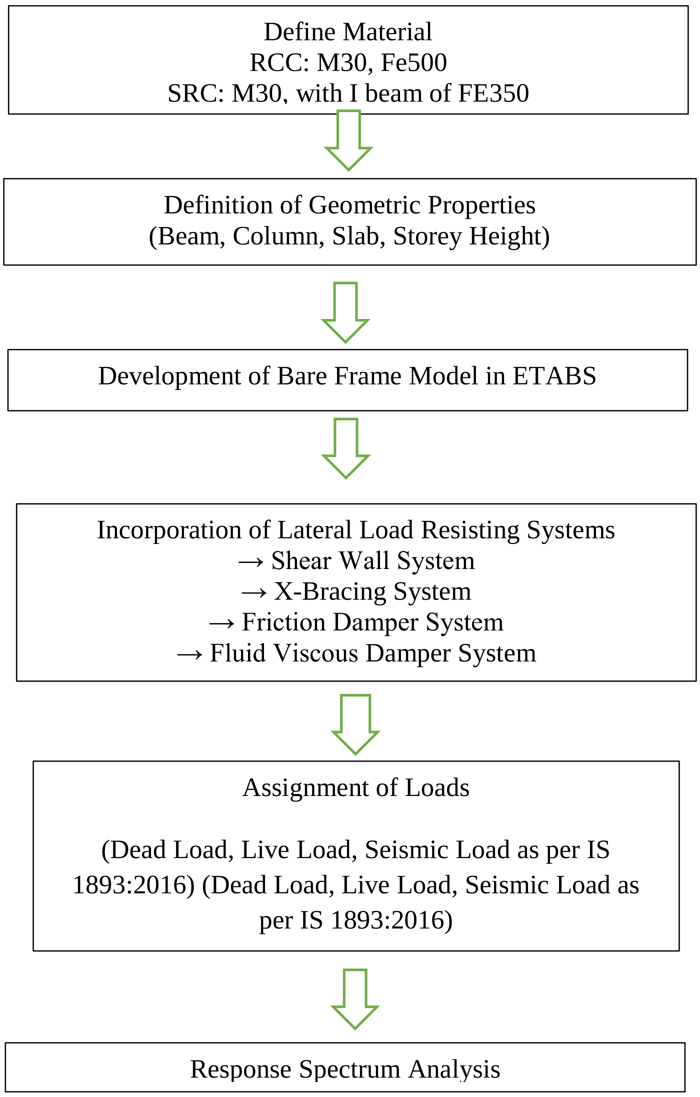
2.Literature Review

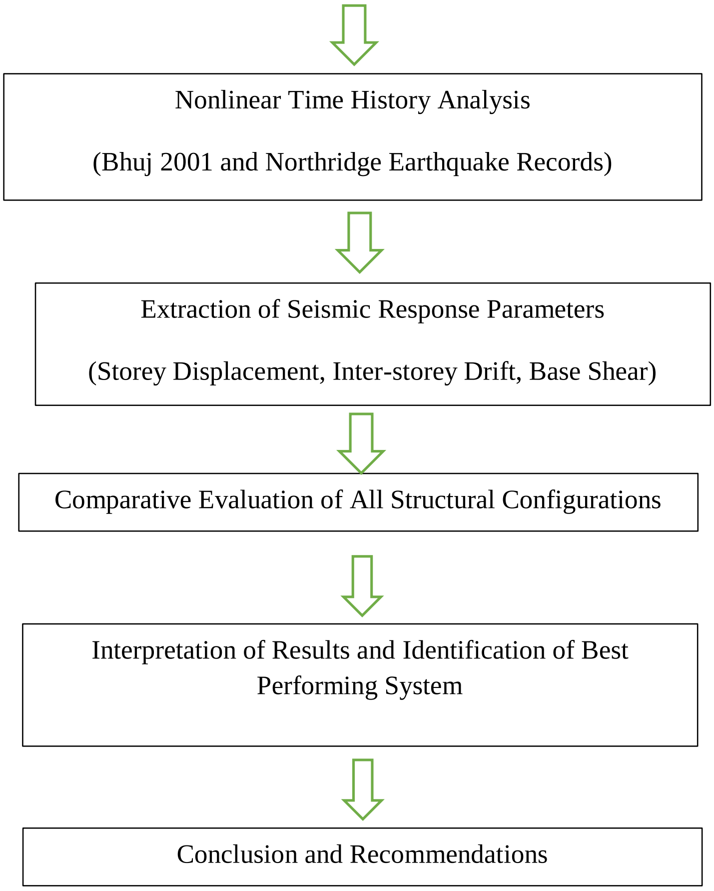
Tobber, L. (2025) This numerical study used nonlinear time-history simulations to assess reinforced-concrete (RC) shear-wall towers that had been modified with damped outriggers. Under certain earthquake occurrences, models contrasted traditional shear-wall cores with layouts that incorporate viscous/viscoelastic dampers at outrigger levels. According to the findings, damped outriggers improve modal energy dissipation and lessen the pressure on lower-story elements while significantly reducing roof and upper-story displacements and inter-story drifts. The authors come to the conclusion that damped outriggers are a useful tactic for managing dominant mode responses in tall reinforced concrete structures. Limitations include the lack of field or experimental validation for full-scale structures and the dependence on model assumptions (idealized connections and damper models).

Dang, L. (2023) This study used parametric finite-element time-history analysis to investigate precast shear-wall panels integrated with lead-viscoelastic dampers (LVED). In order to assess the reduction of inter-story drift and residual deformation, the study changed damper parameters and connection details. Important results demonstrated that properly sized LVEDs significantly lower peak drift and residual displacements and enhance precast systems' post-event stability. The authors come to the conclusion that precast walls with LVEDs can reduce damage while maintaining construction speed. Idealized joint modeling and a lack of investigation into long-term durability and manufacturing tolerances in precast connections were identified as limitations.

3.Methodology

The methodology adopted in this study involves nonlinear dynamic analysis of a G+20 multistorey reinforced concrete building using ETABS software to evaluate seismic response under different lateral load–resisting systems. The building is modeled as a moment-resisting frame with a regular rectangular plan, using M30 grade concrete for structural elements and Fe415 grade reinforcement steel, with fixed base conditions assumed. The structural modeling and analysis are carried out in accordance with IS 1893 (Part 1): 2016 and IS 13920: 2016 provisions. A three-dimensional bare frame model is first developed, followed by modified configurations incorporating shear walls, X-bracing, friction dampers, and fluid viscous dampers to study their influence on seismic behavior. Shear walls and bracing systems are provided to enhance lateral stiffness, while friction and viscous dampers are modeled using nonlinear link elements to simulate energy dissipation mechanisms. Nonlinear Time History Analysis is performed using appropriately scaled Bhuj (2001) and Northridge earthquake records, enabling assessment of inelastic behavior, damping effects, and overall seismic performance of the structure.





4.Results and Discussion:

4.1General

This section presents and discusses the seismic response of a G+20 storey reinforced concrete building analysed using Response Spectrum Analysis and Nonlinear Time History Analysis in ETABS. Four structural configurations are investigated to evaluate the influence of different lateral load–resisting systems on seismic performance:

1. Bare RC moment-resisting frame
2. RC frame with X-bracing system
3. RC frame with shear wall system
4. RC frame with fluid viscous dampers

The seismic response is evaluated primarily in terms of storey displacement, inter-storey drift, base shear, and overall comparative performance in both principal directions (X and Y). The results are interpreted by comparing each configuration with the bare frame to quantify performance enhancement and identify the most effective seismic control system.

4.2 Storey Displacement Behaviour: A comparison of the Demand Capacity ratio for both the bridges are carried out by tabulating the DC ratio of both the bridge as well as graph is also represented.

Bare Frame Response

The bare RC frame exhibits the highest storey displacement among all configurations in both X and Y directions. The displacement profile shows a near-linear increase from base to roof level, indicating dominant first-mode participation. The maximum roof displacement is significantly higher in the Y-direction compared to the X-direction, highlighting directional stiffness asymmetry within the structural system.
The absence of any supplemental stiffness or damping mechanism causes the bare frame to rely solely on inherent material damping and frame action, which proves insufficient under design-level seismic excitation. This behaviour confirms the vulnerability of conventional moment-resisting frames when subjected to strong ground motions.

X-Bracing System Response

The introduction of X-bracing leads to a noticeable reduction in storey displacement across the height of the building. The reduction is relatively uniform, with roof displacement decreasing by approximately 18–32% compared to the bare frame in both principal directions.
The displacement profile retains a similar shape to that of the bare frame but with reduced magnitude, indicating that bracing primarily contributes additional axial stiffness rather than altering dynamic characteristics. While X-bracing effectively restrains lateral deformation and reduces inter-storey drift, its efficiency is limited due to the absence of velocity-dependent energy dissipation. As a result, performance improvement plateaus beyond mid-height levels.

Shear Wall System Response

Shear walls provide a greater reduction in storey displacement compared to X-bracing, particularly in the lower and mid-storey regions. The roof displacement is reduced by approximately 12–53% depending on storey level and direction of excitation.
The displacement curves exhibit a pronounced stiffening effect near the base, consistent with coupled wall–frame behaviour. The increased lateral rigidity provided by shear walls effectively controls deformation and torsional effects, especially in the more flexible Y-direction. However, at upper storeys, the absence of supplemental damping limits further displacement reduction, as the system primarily resists seismic forces through stiffness enhancement rather than energy dissipation.

Fluid Viscous Damper Response
Among all configurations, fluid viscous dampers demonstrate the most significant reduction in storey displacement. Roof displacement reductions reach up to 82% in the X-direction and over 83% in the Y-direction at lower storeys.
Viscous dampers provide velocity-dependent damping forces, enabling effective dissipation of seismic energy across multiple vibration modes. Unlike stiffness-based systems, dampers act directly on relative

velocity, making them highly efficient in both flexible and stiff directions. The steep reduction in lower-storey displacement confirms that damper forces are fully mobilized where inter-storey drift and relative velocities are highest.

Inter-Storey Drift Behaviour

Inter-storey drift is a critical parameter governing structural damage and non-structural performance. The bare frame exhibits drift values approaching or exceeding permissible limits at mid and upper storeys.
X-bracing reduces drift moderately by increasing axial stiffness, but higher-mode effects remain noticeable. Shear walls significantly reduce drift at lower storeys due to enhanced stiffness concentration. Fluid viscous dampers provide the most uniform and substantial drift reduction across all storeys, effectively controlling both fundamental and higher-mode responses.

Base Shear Behaviour

The base shear demand varies across configurations due to differences in stiffness and damping mechanisms:

- The bare frame attracts lower base shear due to higher flexibility and longer natural period.
- Shear wall systems attract higher base shear because of increased stiffness and reduced time period.
- X-bracing systems exhibit moderate base shear demand.
- Fluid viscous dampers reduce effective seismic demand by dissipating energy rather than increasing stiffness, resulting in controlled base shear without excessive force amplification.

This behaviour highlights the advantage of damping-based systems in managing seismic demand efficiently.

Comparative Performance Evaluation
Comparative Discussion – X Direction

The graph indicates that the bare frame exhibits the highest lateral displacement across all storeys, reflecting poor seismic performance due to the absence of additional stiffness or damping mechanisms. The introduction of bracing reduces displacement by increasing lateral stiffness; however, the reduction is limited, particularly at higher storeys. The shear wall system provides greater displacement control than bracing, especially in the lower and mid-storeys, owing to its significant contribution to lateral rigidity. The updated viscous fluid damper system demonstrates the maximum reduction in displacement throughout the building height, highlighting the effectiveness of energy dissipation in controlling seismic response. Overall, the graph clearly shows that damping-based systems outperform stiffness-based systems in reducing seismic displacements.

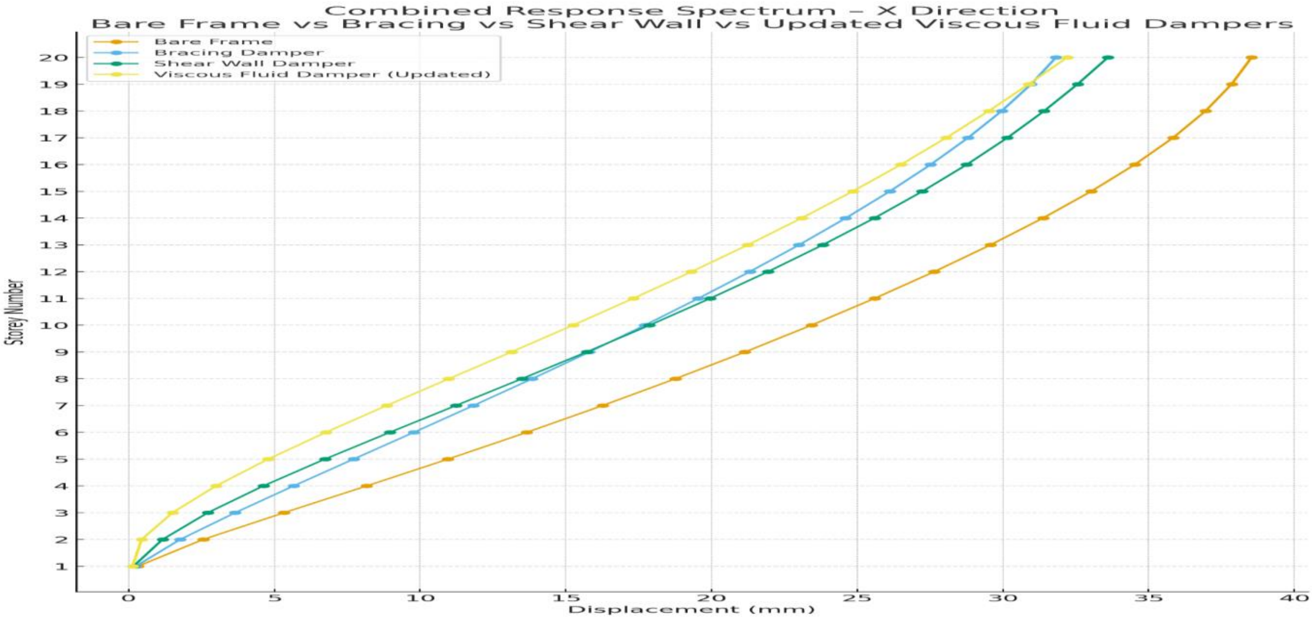


Figure 2: Combined X-Direction Displacement Response for Different Structural Control Systems

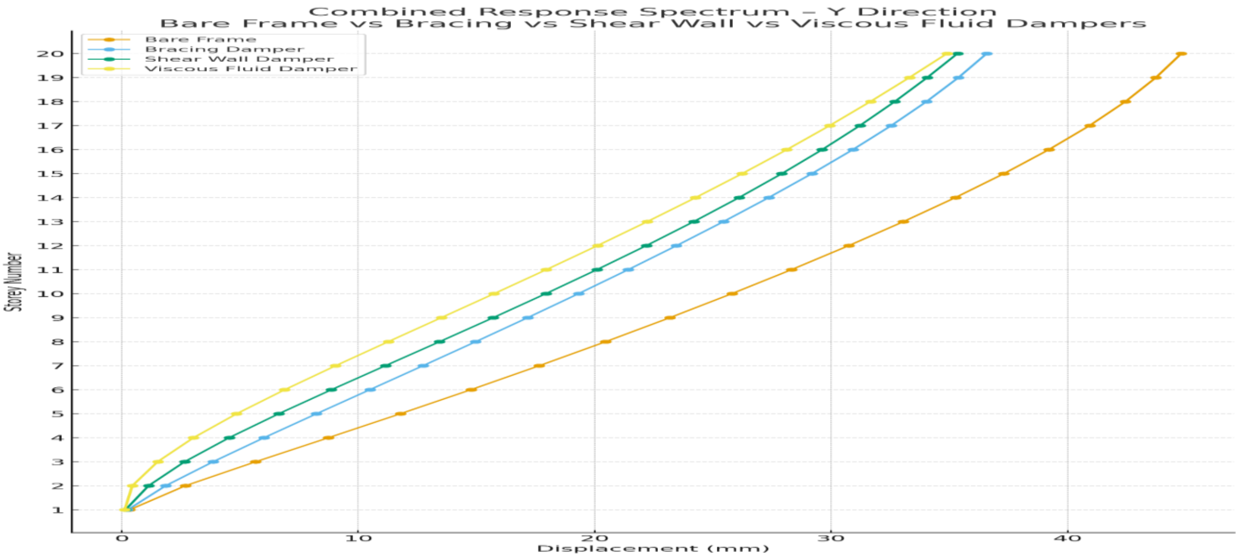


Figure 3: Combined Y-Direction Displacement Response for Different Structural Control Systems

Comparative Discussion – Y Direction

The graph shows that the bare frame experiences the highest lateral displacement in the Y-direction, indicating greater flexibility and higher seismic vulnerability in this direction. The introduction of bracing reduces displacement by improving lateral stiffness, but the reduction remains moderate across the building height. The shear wall system provides better displacement control than bracing, particularly at lower and mid-storeys, due to increased lateral rigidity. The viscous fluid damper system achieves the maximum reduction in displacement throughout all storeys, demonstrating superior seismic performance by effectively dissipating earthquake energy. Overall, the Y-direction response confirms that damping based systems are more efficient than stiffness-based systems in controlling seismic displacements.

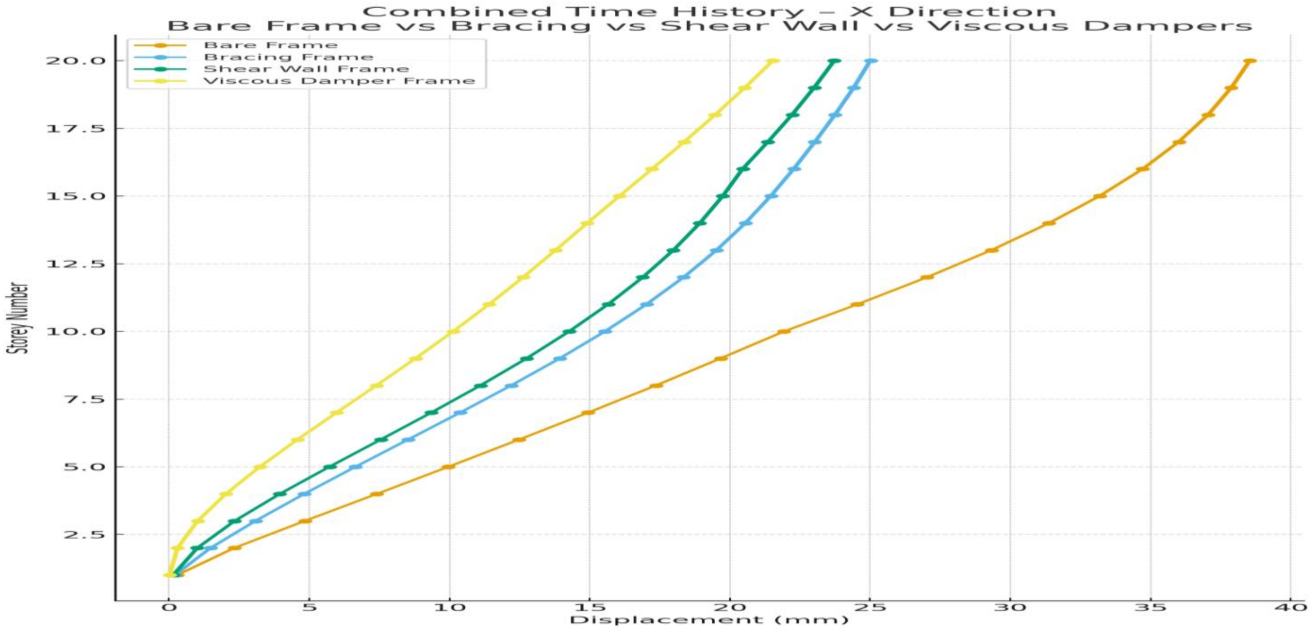


Figure 4: % Reduction Compared to Bare frame X-Direction

A progressive decrease in displacement from the bare frame to bracing, shear wall, and eventually viscous damper systems is evident in the combined X-direction response. By adding stiffness, bracing enhances performance, although its usefulness is diminished at higher elevations. Stronger rigidity from shear walls leads to much smaller displacements throughout the height. Because of their better energy-dissipation capacity, viscous dampers produce the greatest decrease in storey displacements, frequently surpassing 80% when compared to the bare frame construction. Among all setups, viscous fluid dampers provide the most effective seismic control in the X direction.

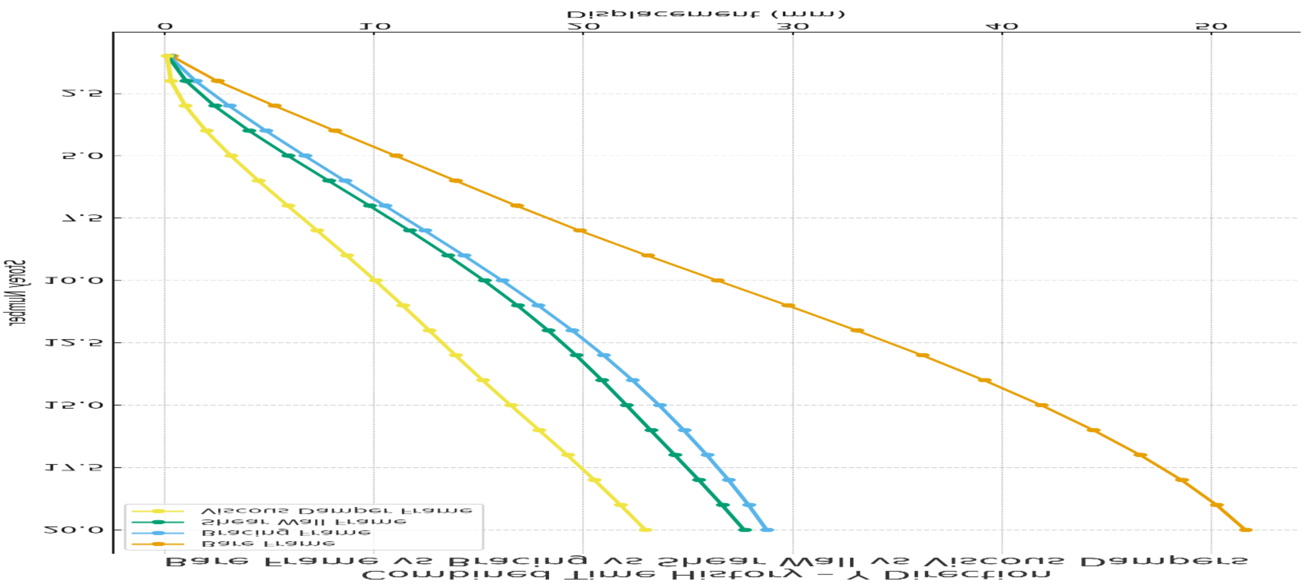


Figure 5.: % Reduction Compared to Bare frame vs Bracing vs Shear wall vs Viscous Damper in Y-Direction

The graph illustrates the time history response of the building in the Y-direction, where the bare frame exhibits the highest lateral displacement across all storeys, indicating severe seismic vulnerability under dynamic loading. The bracing system reduces displacement compared to the bare frame due to increased stiffness; however, the reduction remains limited at higher storeys. The shear wall system shows improved displacement control over bracing, particularly in the lower and mid-storey levels, owing to enhanced lateral rigidity. The viscous damper frame demonstrates the lowest displacement throughout the building height, confirming its superior performance in dissipating seismic energy under time history loading. Overall, the results indicate that damping-based systems are significantly more effective than stiffness-based systems in controlling seismic response during real earthquake excitations.

Fluid Viscous Dampers > Shear Walls > X-Bracing > Bare Frame

- Bracing systems offer stiffness-based control with limited energy dissipation.
- Shear walls provide strong stiffness enhancement but limited damping capability.
- Fluid viscous dampers combine effective energy dissipation with minimal stiffness addition, resulting in superior seismic performance.

The Y-direction consistently shows higher displacement demand, and consequently greater percentage improvement with damping systems, emphasizing the importance of direction-specific seismic control.

Conclusions:

The nonlinear time history analysis carried out in this study indicates that bare frame reinforced concrete buildings are highly vulnerable to seismic excitation due to excessive lateral displacement and inter-storey drift. The incorporation of lateral load–resisting systems significantly enhances the seismic performance of the structure by improving stiffness and energy dissipation capacity. Shear walls effectively increase lateral stiffness and reduce displacement demands, particularly at lower storeys, while X-bracing systems contribute to improved lateral rigidity and drift control through axial load transfer mechanisms. Friction dampers provide stable energy dissipation and result in a moderate reduction in seismic response. Among all the systems studied, fluid viscous dampers exhibit superior seismic performance by efficiently dissipating earthquake energy and effectively controlling displacement and drift. Based on the comparative results, fluid viscous dampers are recommended as an efficient and practical solution for enhancing the seismic resilience of high-rise reinforced concrete buildings.

Authors' Biography:

Author 1: SHILPA S., is Assistant Professor of structural engineering at Department of Civil Engineering at Srinivas University, Mukka, Mangalore. Guiding M. Tech thesis on earthquake – resistance design. Expertise in IS standards and software-based analysis. Supervised this projects modelling, load combination and theoretical validation. Email ID: shilpa.s@srinivasuniversity.edu.in

Author 2: UMAIR MISBAH, is a Structural Engineering graduate pursuing M. Tech, in Department of Civil Engineering at Srinivas University, Mukka, Mangalore. Holds a BE in Civil Engineering from VTU, Belagavi. Research interest includes Bridge Engineering; dynamic analysis as per IS 1893: 2016. Email ID: umairmisbah98@gmail.com

Author 3: DR. GOPINATH NAYAK, Associate Professor ,Department of Civil Engineering MIT, MAHE, Manipal, Udupi, Karnataka, India. Email:nayak.gopinath@manipal.edu

Author 4: DR. UDAY KUMAR, Research Professor, Srinivas University Institute of Engineering and Technology, Mukka, Mangalore, Karnataka, India. Email: uday.iet@srinivasuniversity.edu.in

References:

1. Bhardwaj, S., Singh, P. and Dixit, S. (2022) ‘Linear dynamic analysis of high-rise irregular structures with or without LFRS & frictional damper’, *Materials Today: Proceedings*, 69, pp. 499–507. doi: 10.1016/j.matpr.2022.09.256.
2. Prashar, K. and Gahir, J.S. (2018) ‘Seismic analysis of RCC structure with different types of bracing system’, *International Journal of Civil Engineering and Technology*, 9(8), pp. 496–503.
3. Pathan, S.S., Kakade, D.N. and Wadekar, A.P. (2018) ‘Seismic response control of asymmetric building using friction damper and shear wall’, *Journal of Structural Technology*, 2(2), pp. 1–5.
4. Tobber, L. (2025) ‘Seismic performance of reinforced concrete (RC) shear walls with damped outriggers’, *Engineering Structures*, 253, 113722.
5. Dang, L. (2023) ‘Seismic performance assessment of precast RC shear wall structure with lead viscoelastic damper’, *Journal of Building Engineering*, 45, 103622.
6. Soleymani, A. (2024) ‘A novel hybrid strong-back system to improve the seismic performance of RC buildings’, *Journal of Building Engineering*, 42, 103019.
7. Salameh, M. (2020) ‘Estimation and development of innovative hybrid coupled shear wall system’, *Journal of Building Engineering*, 29, 101122.
8. Ramezandoust, Z. (2024) ‘Seismic performance evaluation of hybrid coupled shear walls in RC buildings’, *Journal of Vibration and Control*, 30(3-4), pp. 567–580.
9. Zouatine, M. (2024) ‘Seismic performance and design of an innovative structure with ring springs in controlled rocking shear walls’, *Soil Dynamics and Earthquake Engineering*, 167, 107598.
10. Sharma, S. (2021) ‘Analysis of multi-Storey buildings with hybrid shear wall and steel bracing structural system’, *Structures*, 31, pp. 101658–101668.
11. Kant, R. (2024) ‘Seismic load analysis of shear wall, damper, and bracing systems in RC buildings’, *AIP Conference Proceedings*, 3188, 070004.
12. Najam, F. (2021) ‘The use of linear time history analysis in seismic design of high-rise RC buildings’, *International Journal of Structural Engineering*, 12(4), pp. 345–358.
13. Singh, R. (2022) ‘Non-linear time history analysis of G+15 RC frame building with shear wall’, *International Journal of Research in Engineering and Technology*, 11(3), pp.123
14. Razzouk, Y. (2023) ‘Optimal bracing type of reinforced concrete buildings with soil-structure interaction’, *International Journal of Civil Engineering and Technology*, 9(6), pp. 1371–1384.
15. Yıldız, Y. (2025) ‘A new approach to improving the seismic performance of RC buildings using glulam braces’, *Sustainability*, 17(17), 7690.
16. Perera, N.J. (2006) ‘Mitigating seismic response of shear wall structures using embedded dampers’, *Journal of Structural Engineering*, 132(1), pp. 1–10.
17. Hadidi, S. (2024) ‘Enhancing the seismic performance of concentrically braced RC frames using LYP steel dampers’, *Journal of Earthquake Engineering*, 28(4), pp. 567–580.

18. Sohail, M.T. (2013) *Control of lateral drift of medium to high-rise buildings using concrete bracings*. Master's Thesis. University of Engineering and Technology, Lahore.
19. Odikamnoro, I. (2022) 'Seismic collapse risk of RC-timber hybrid building with dampers', *Journal of Infrastructure Preservation and Resilience*, 3(1), pp. 61–75.
20. Perera, N.J. (2006) 'Placement of dampers within shear walls', *Proceedings of the 8th International Conference on Structural Engineering*, 1, pp. 1–10.
21. Perera, N.J. (2006) 'Seismic performance enhancement using lead viscoelastic coupling beams', *Journal of Structural Engineering*, 132(1), pp. 11–20.
22. https://dailycivil.com/shear-wall-1/
23. https://civilwale.com/types-of-bracing-systems/
24. https://www.civillead.com/types-of-bracing-system/
25. 139,400+ Earthquake Resistant Structures Stock Photos, Pictures & Royalty-Free Images - iStock
26. Viscous Fluid Damper - EarthQuake Dampers
27. https://www.researchgate.net/figure/a-Sumitomo-type-friction-damper-1-b-its-installation-2_fig1_329662558
28. https://fity.club/lists/suggestions/tuned-mass-damper/
29. https://www.researchgate.net/figure/D-models-of-symmetric-plan-3-story-Figure-3-structure-and-story-RC-structure-is-12-m-by_fig3_325579739
30. https://ar.inspiredpencil.com/pictures-2023/earthquake-building-damage
31. https://www.gettyimages.in/photos/bhuj-earthquake
32. https://www.nist.gov/image/photo-taken-after-northridge-earthquake-highlighting-