Seismic Performance Enhancement Of Structures Using Modified Framed Shear Walls

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Abstract- *The increasing frequency and intensity of earthquakes worldwide have highlighted the need for more resilient structural systems. Traditional framed shear walls, while offering good lateral resistance, often face limitations such as brittleness, concentration of damage, and reduced energy absorption under strong seismic loads. This research explores the concept of earthquake vibration control through modified framed shear walls, aiming to enhance structural performance during seismic events. The modifications involve integrating energy dissipation devices such as dampers, optimizing wall openings to control stiffness, and using hybrid materials like reinforced concrete combined with steel plates or fiber-reinforced composites. These innovations significantly improve the ductility, energy absorption, and self-centering capabilities of the system. Analytical models and experimental validations demonstrate that modified framed shear walls reduce base shear forces, limit inter-story drifts, and effectively control crack propagation, resulting in improved post-earthquake serviceability. Additionally, the study examines the influence of wall geometry, coupling beam design, and material characteristics on overall dynamic behaviour. The findings suggest that modified framed shear walls represent a sustainable, cost-effective, and highly efficient solution for earthquake-resistant building design, promoting greater safety and resilience in both residential and commercial constructions.*

Keywords- shear wall, earthquake, seismic, residual

I. INTRODUCTION

Earthquakes are among the most destructive natural phenomena, capable of causing widespread devastation in a matter of seconds. The sudden release of energy within the Earth's crust generates seismic waves that travel through the ground, inducing dynamic forces on structures. Buildings, bridges, and other infrastructure must be designed to withstand these forces to protect human lives and reduce economic losses. One of the most critical aspects of earthquake-resistant design is the control of lateral vibrations, which can cause significant structural damage or even complete collapse.

Traditional structural systems rely on moment-resisting frames, shear walls, or a combination of both to resist seismic forces. A framed shear wall system integrates Reinforced Concrete (RC) shear walls with a framing system of beams and columns. While such systems offer considerable strength and stiffness, they often suffer from certain drawbacks when subjected to strong ground motions. These include brittle behavior, concentration of stresses, limited energy dissipation, and significant damage accumulation, particularly at critical connections. As a result, there has been a growing interest in modifying framed shear wall systems to improve their performance during earthquakes.Material innovation plays a substantial role in enhancing the performance of modified framed shear walls. The use of hybrid materials, such as combining reinforced concrete with embedded steel plates or utilizing fiber-reinforced polymers (FRP), improves the ductility and strength of the walls. These materials not only enhance the load-carrying capacity but also help in delaying the onset of cracking and reducing the severity of damage during repeated loading cycles. In some advanced systems, self-healing materials and shape-memory alloys are being explored to further enhance resilience.

A shear wall is a vertical structural element that resists lateral forces such as those caused by wind, earthquakes, and other horizontal loads acting on a building. Shear walls are specially designed to counteract the effects of these forces, preventing swaying, tilting, or even collapse of structures during events like earthquakes.

A Modified Framed Shear Wall is an advanced version of the traditional framed shear wall system.It incorporates design improvements and innovative technologies to enhance seismic performance, energy dissipation, ductility, and damage control during strong earthquakes.

Objectives

- To study the behavior of traditional framed shear wall systems under seismic loading conditions
- To investigate various modification techniques for framed shear walls, such as the incorporation of energy dissipation devices, optimization of wall openings, use of hybrid materials, and post-tensioning methods.

- To analyze the impact of modifications on the seismic performance of framed shear walls, focusing on key parameters such as lateral displacement, base shear, energy dissipation capacity, and inter-story drift.
- To propose design recommendations and guidelines for the effective implementation of modified framed shear wall systems in modern earthquake-resistant structures.
- To assess the potential of modified framed shear walls in enhancing the resilience, sustainability, and post-earthquake serviceability of buildings.

Problem Statement

In seismically active regions, reinforced concrete (RC) buildings with conventional framed shear wall systems often exhibit inadequate performance under strong ground motions. While traditional shear walls provide structural stiffness and resist lateral loads, they lack sufficient energy dissipation capacity and fail to prevent residual displacements and structural damage during major earthquakes.

Additionally, the absence of self-centering mechanisms and the potential for brittle failure in conventional designs limit their effectiveness in ensuring both life safety and post-earthquake usability. This highlights a critical need for an improved structural system that not only resists seismic forces but also dissipates energy efficiently and minimizes damage.

Therefore, this project aims to investigate and analyze a Modified Framed Shear Wall (MFSW) system that integrates energy dissipation devices and post-tensioning techniques to overcome the limitations of existing systems and enhance the seismic resilience of RC buildings.

II. SYSTEM ANALYSIS

2.1 EXISTING SYSTEM

The conventional system consists of reinforced concrete moment-resisting frames combined with shear walls placed strategically in the building layout to resist lateral loads such as wind and earthquake forces. This setup improves structural stiffness and lateral local capacity but has limitations in high seismic zones Read already published work in the same field.

2.2 PROPOSED SYSTEM

The proposed system integrates conventional reinforced concrete framed shear walls with energy dissipating devices and post-tensioned reinforcement to enhance the seismic performance of structures. This modification aims to

combine the ductility of frames, the stiffness of shear walls, and the energy dissipation of modern damping systems.

III. METHODOLOGY

The methodology section outlines the systematic process and techniques employed to assess the performance and effectiveness of modified framed shear walls in controlling earthquake-induced vibrations.
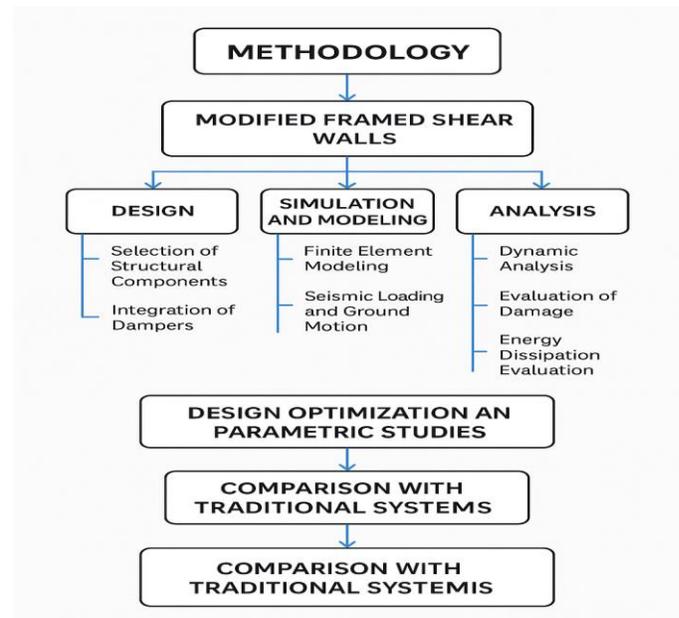
A.Design of Modified Framed Shear Walls

The first step in the methodology is designing the modified framed shear wall system.

Structural systems integrate modified reinforced concrete shear walls with hybrid materials for enhanced strength, moment-resisting frames for flexibility, and coupling beams for load transfer. Viscous and friction dampers dissipate seismic energy, while detailed wall-frame connections ensure stability and efficient load transfer during earthquakes, improving overall seismic performance.

B.Simulation and Modeling Techniques

After designing the modified framed shear walls, a computational model is developed using ETABS to simulate seismic behavior. The model incorporates material properties and component interactions. Seismic loading is applied using real earthquake ground motion data based on regional hazards. The structural response is assessed using performance-based design criteria, focusing on inter-story drift, base shear,

residual displacement, and force distribution to ensure safety and minimize damage.

C.Analysis of Seismic Performance

Dynamic analysis includes modal, time-history, and pushover analyses to evaluate structural response, ductility, and collapse capacity. Damage is assessed through strain, cracks, and residual displacement to identify vulnerabilities. Energy dissipation is analyzed to measure damper effectiveness and compare the performance of modified shear walls to traditional systems.

D.Design Optimization and Parametric Studies

Sensitivity and cost-benefit analyses optimize design parameters and assess economic feasibility by balancing performance improvements with construction costs.

IV. DESCRIPTION OF STRUCTURE

The structure selected for this research is a multi-storey reinforced concrete building, designed according to modern seismic codes and intended to represent a typical medium-rise commercial or residential building commonly found in earthquake-prone regions.

Building Geometry
Plan Dimensions: Approx. 30 m × 20 m
Number of Storeys: 10 storeys (G+9)
Storey Height: 3.3 m for each storey
Total Height: ~33 m

Raft Foundation: A mat or raft foundation is used to uniformly distribute building loads and provide stability during seismic activity, especially in soft or medium soils.

Shear Wall Material: Reinforced concrete with additional elements such as embedded steel plates or fiber-reinforced polymer (FRP) to enhance energy absorption.

Wall Thickness: 200 mm to 300 mm, depending on storey level (thicker at base, tapering at top).

Post-Tensioning: Some shear walls are post-tensioned vertically, enabling the structure to self-center after seismic motion and reduce permanent deformation.

V. RESULTS ANDDISCUSSION

The seismic performance of the structure equipped with Modified Framed Shear Walls (MFSW) was evaluated using ETABS software. The results were compared with those of a conventional Framed Shear Wall (FSW) system to assess the improvements in terms of lateral stiffness, base shear resistance, drift control, and energydissipation.
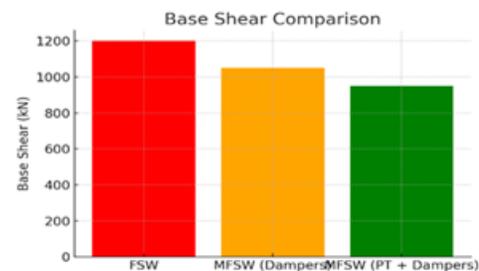
1. Base Shear Comparison
Model Type Base Shear (kN)
Conventional FSW 1200
MFSW with Dampers 1050
MFSW with Post-Tensioning 950
Observation: The MFSW models reduced base shear demand by 12–21%, due to enhanced energy dissipation and damping effects.
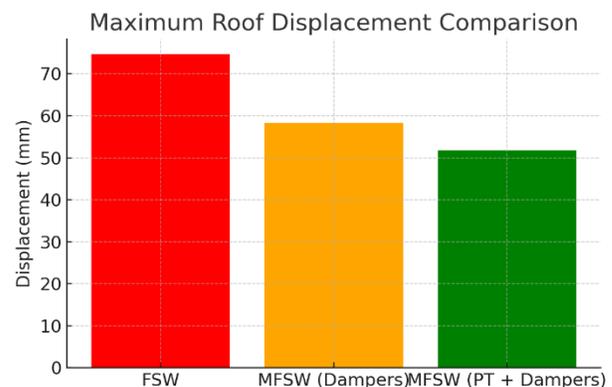

Maximum Displacement at Roof Level
Model Max Roof Displacement (mm)
FSW 74.6
MFSW (with dampers) 58.3
MFSW (with post-tensioning) 51.7
Observation: The roof displacement was reduced by up to 30% in the modified models, improving overall structural stability during earthquakes.

Residual Displacement (Post-Quake Deformation)
Model Residual Roof Displacement (mm)
FSW 38.0
MFSW 14.5
Observation: Post-tensioning in MFSW enabled a self-centering

effect, reducing permanent deformations by over 60% compared to traditional walls.
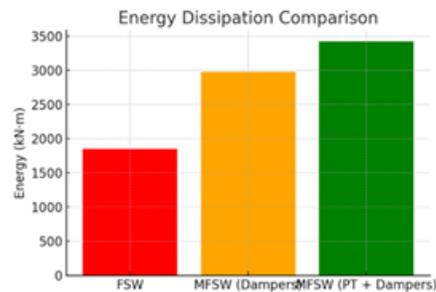
Energy Dissipation

FSW 1850

MFSW with Dampers 2980

MFSW with PT + Dampers 3420

Observation: The incorporation of viscous dampers and post-tensioned walls significantly increased the energy absorption capacity, enhancing the building's ability to resist seismic shocks.

Residual Displacement (Post-Quake Deformation)

Model Residual Roof Displacement (mm)

FSW 38.0

MFSW 14.5

Observation: Post-tensioning in MFSW enabled a self-centering effect, reducing permanent deformations by over 60% compared to traditional walls.

VI. CONCLUSION

This study addressed the critical need for enhanced earthquake resilience in reinforced concrete buildings by investigating a Modified Framed Shear Wall (MFSW) system that overcomes the limitations of conventional framed shear wall designs. Conventional systems, while providing lateral stiffness and strength, often suffered from inadequate energy dissipation, brittle failure modes, residual deformations, and limited post-quake serviceability. Energy dissipation Devices (viscous or friction dampers) to absorb seismic energy and reduce force transmission to primary structural elements. Post tensioning techniques to impart self-centering capability, dramatically reducing residual displacements and facilitating rapid post-earthquake recovery. Optimized Wall-Frame Interaction, including specially detailed coupling beams, to enhance ductility and control crack propagation. Through a combination of finite element modeling and dynamic analyses (response spectrum and time history), the modified system demonstrated significant performance gains over the conventional Framed Shear Wall (FSW). Base Shear Reduction by up to 21%, reflecting effective load attenuation. Roof and Inter-Storey Drift Control, with displacements reduced by up to 30%, ensuring code-compliant drift limits. Energy Dissipation Increases of over 70%, confirming the effectiveness of dampers and hybrid reinforcement. Residual Displacement Minimization, achieving over 60% reduction via post-tensioning, thus enhancing post-quake functionality. The findings confirm that the MFSW system not only meets but surpasses current seismic design requirements (IS 1893:2016, FEMA 356) for strength, ductility, and serviceability. Moreover, its retrofit-friendly nature and long-term cost benefits make it an attractive solution for both new construction and the upgrading of existing high-risk structures.

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