Enhancing Seismic Performance and Material Efficiency in Multi-Storey RC Buildings Using Edge-Lined Shear Wall (ELSW) Systems

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Abstract

This research investigates the structural performance of multi-storey reinforced concrete (RC) buildings using the Edge-Lined Shear Wall (ELSW) system, in comparison to traditional solid shear walls and staircase walls. The ELSW system, strategically positioned along the building's edges, aims to optimize lateral stiffness, reduce material consumption, and enhance energy dissipation under seismic wind loads. A detailed finite element (FE) model of a multi-storey RC building was developed and subjected to lateral load analyses. Key performance metrics, particularly inter-story drift, were evaluated for each configuration. Results indicate that the ELSW system significantly reduces inter-story drift compared to staircase walls and performs comparably to solid shear walls, albeit with reduced material usage. Additionally, the ELSW system demonstrates superior energy dissipation during seismic events, underscoring its potential to enhance earthquake resistance. This research highlights the ELSW system as a sustainable, cost-effective alternative to conventional shear walls, offering a promising solution for the design of earthquake-resistant multi-storey RC buildings. The findings contribute to advancing innovative structural design methodologies focused on performance optimization and material efficiency.

Keywords: ELSW; Seismic Performance; Lateral Stiffness**;** Material efficiency

1. Introduction

ELSW represents the adapted version of traditional shear walls. These are located at the edges of RC structures, with the aim of enhancing load distribution in a building while maintaining architectural freedom and usable space to a maximum extent. However, very few investigations have been reported on how such ELSW systems impact the structural performance of a multi-story building in terms of stiffness, ductility, and stability.

The multistoried RC structure is typically designed by accounting for safety, function, and economy. As a further necessity to include more towering and complicated structures, there has also been pressure for innovations in increasing the resistance of structural systems to lateral loads like wind and forces created by earthquakes. Of these solutions, shear walls are the most widely used system because of their ability to provide effective stiffness and stability in structures [1].

Edge-Lined Shear Wall (ELSW) systems are specifically modified variants of conventional shear walls and placed along edges of RC structures. It also attempts to optimize the distribution of loads while allowing architectural flexibility and usable space. The theoretical benefits of ELSW systems, as far as the performance characteristics like stiffness, ductility, and stability of

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multistoried buildings are concerned, have never been applied. Innovative shear wall configurations have been under research that emphasized strategic placement in enhancing seismic performance [2].

2. Literature Review

The performance of multistory reinforced concrete buildings to a large extent is affected by the load-resisting systems. Popular choices of such systems are shear walls as they raise the stiffness and strength of structure, though they control the lateral displacements in case of seismic and wind loads. According to [1], shear walls are considered an essential element improving the seismic performance through drift reduction at inter-story level and energy dissipation enhancement [1]. When RC structures are built without seismic precautions, they are not as ductile or capable of withstanding lateral loads, which can lead to the gradual breakdown of the entire structure [3]. Studies have been conducted to optimize the reinforcement strategies for different components of building under seismic loads [4]. Critical structures like columns have also been strengthened using retrofitting techniques like NSM GFRP Bars [5].

Shear walls are considered in placement and configuration to maximize the performance. [6] said that shear wall placement could greatly affect the dynamic response of the building. For instance, wall placement affects load redistribution and overall ductility of a structure, which is a very crucial aspect of seismic resilience.

Recent innovative configurations are the edge-lined shear walls, ELSW. The potential of this configuration will aid in the optimization of resistance against lateral loads with architectural flexibility. According to [7], the advantage of an edge-located wall is the retention of the usable floor area, and aesthetics improved without a sacrifice in the structural integrity of such a shear wall system on an unconventional arrangement [7].

Other later studies by [8] also indicated that the seismic behavior of coupled shear wall systems was even better, thus suggesting that combining ELSW systems with coupling beams may be seen to lead to further potential improvements in performance [7]. In contrast, [9]investigated nonlinear behavior of RC buildings for various wall configurations. Edge-lined walls can appropriately stiffen buildings without any noticeable torsion effect on asymmetrical buildings, as argued by [9]

2. Methodology

The T square plan for the reinforced concrete (RC) building has a measurement of 15 m x 15 m, based on a 3x3 grid, where the bays are oriented at 5 m x 5 m. The central core of this plan is framed by the 3x3 internal grid and comprises three structural configurations for resistance to lateral loads: solid shear walls Figure 1, Edge-Lined Shear Walls (ELSW) Figure 2 and staircase walls. Columns are positioned at grid intersections and along the edge lines in a way that maintains structural symmetry and efficiency. The structural elements will be designed to the following details: beams, 250 mm x 500 mm, with 3000 psi concrete strength; columns, 305 mm x 305 mm, with 3000 psi concrete strength; and a slab thickness of 200 mm made of 3000 psi concrete. It thus ensures balanced performance under lateral, and gravity loads while optimizing the use of materials and the general stability of the structure.

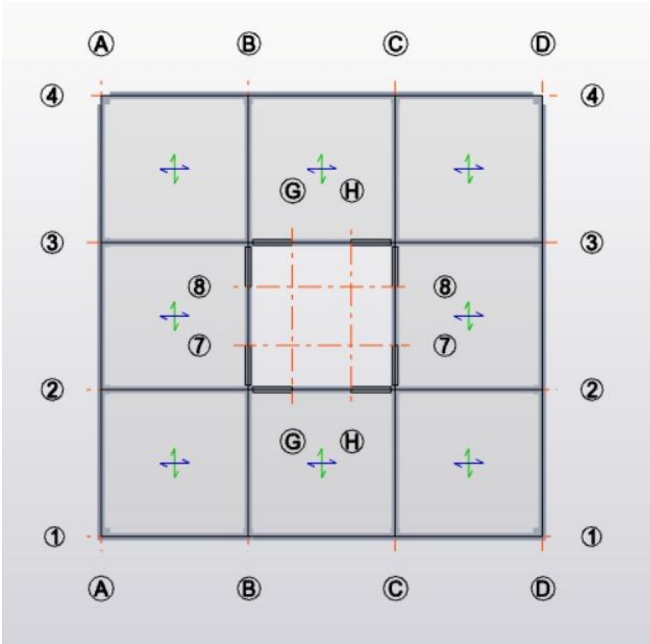

Figure 1. Building with ELSW

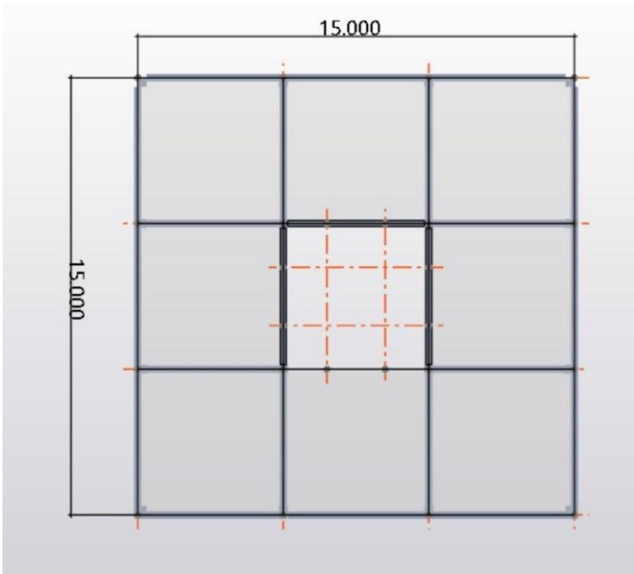

Figure 1. Building with shear Wall

3. Results

Figure 3 illustrates the drift ratios of ELSW, Stair, and Solid Shear Wall across the multi-story building show clear differences in structural behaviors. ELSW shows that it has a steady and moderate increase in drift ratios with increasing story levels. In fact, the highest drift ratios were experienced in the Stair component, which showed significant results at the intermediate and upper story levels, thereby manifesting more flexibility or susceptibility to lateral deformations. The opposite is true, where the Solid Shear Wall had the smallest drift ratios at higher story levels, proving its stiffness to be better, hence effective at reducing lateral displacement. This comparison stresses the rigid behavior of the Solid Shear Wall as compared to the more flexible behavior of the Stair and the relatively consistent performance of ELSW, which is the key to maintaining the overall structural stability.

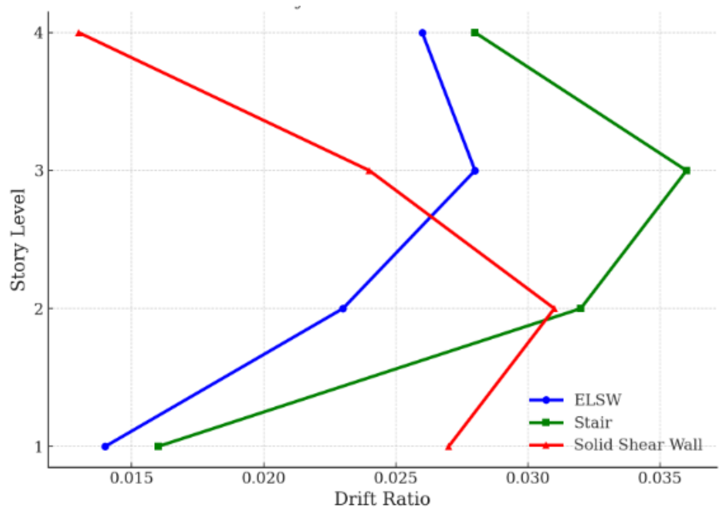

Figure 3. Drift Ratio Plot

4. Discussion and Conclusions

This study demonstrates how well the ELSW method works to improve multi-story RC buildings' lateral stiffness and reduce inter story drift. The performance comparison shows that ELSW offers superior structural behavior compared to traditional staircase walls and approaches the efficiency of solid shear walls, while also striking an ideal compromise between structural performance and material efficiency. What makes ELSW especially practical is that it is an economical and environmentally friendly option for earthquake-resistant constructions due to its capacity to maintain reduced drift ratios while maximizing architectural flexibility. These findings contribute meaningfully to the advancement of lateral load-resisting system design in seismic engineering.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ELSW	Edge-Lined Shear Wall
FEM	Finite Element Modelling
RC	Reinforced Concrete

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