SEISMIC PERFORMANCE OF REINFORCED CONCRETE BUILDINGS WITH SHEAR WALLS UNDER STRUCTURAL IRREGULARITIES

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Abstract

Structural irregularities can significantly alter the seismic response of reinforced concrete buildings by modifying stiffness, mass distribution and load paths. This study evaluates the influence of structural irregularities and shear wall placement on the seismic performance of mid-rise reinforced concrete buildings in Sri Lanka. A detailed literature review identifies a limited body of experimental and numerical research addressing the combined effects of shear wall arrangement and structural irregularity within the Sri Lankan construction context. To address this gap, a finite element (FE) model of a five-storey reinforced concrete building is developed in ETABS software and assessed using the seismic provisions of Eurocode EN 1998-1:2004. Different shear wall arrangements and horizontal and vertical irregular configurations are investigated through response spectrum analysis, with a particular emphasis on the fundamental period, lateral displacement, inter-storey drift, and torsional response. The results indicate that the introduction of shear walls significantly improves lateral stiffness and reduces both the fundamental period and lateral displacement, with reductions exceeding 40% across the configurations investigated. Furthermore, irregular configurations involving corner-placed shear walls and discontinuities in the structural grid produce less favourable responses, primarily due to increased eccentricity and torsional effects. These results provide a strong foundation for future work, emphasising that scaled-down experimental testing is essential to bridge the gap between numerical predictions and physical structural behaviour.

Keywords: Shear walls, Seismic performance, Torsional response, Structural irregularity

1. Introduction

Earthquakes are among the most destructive natural hazards, causing severe losses to life, economic productivity, and social stability. Infrequent occurrence in many regions often leaves preparedness inadequate, resulting in catastrophic damage. This has driven researchers to prioritise advances in seismology and earthquake engineering, with experimental, numerical, and machine learning-based approaches now key to understanding structural behaviour under seismic loading. Growing urban density and high-rise construction have heightened seismic risk awareness: over the past two decades, 313 earthquakes exceeding magnitude 7.0 have been recorded worldwide, mostly in developing countries [1]. Sri Lanka has traditionally been classified as a low-seismicity region within the northern Indian Ocean, with hazards linked to tectonic activity along the Indo-Australian Plate boundaries [2]. However, its documented seismic history and increasingly frequent recent tremors suggest an evolving risk profile [3].

Shear walls are central to seismic-resistant design, providing the lateral stiffness and strength needed to resist earthquake forces and limit inter-storey drift. Research has optimised their effectiveness through geometric modification, improved material use, and energy-dissipation mechanisms such as dampers, improving seismic energy dissipation by around 45% over conventional RC frames [4]. Beyond wall quantity, strategic placement is often more cost-

effective than increasing wall numbers [5]. Symmetrical distribution is particularly effective at mitigating torsional effects, giving buildings with well-distributed shear walls superior seismic behaviour and structural efficiency. Since perfectly symmetrical building configurations are not always feasible in practice, the combined effects of shear wall functionality and spatial arrangement on seismic performance remain insufficiently explored. This study addresses this gap through a numerical investigation of a five-storey building representative of Sri Lanka's urban mid-rise residential construction.

1.1 Aim and Objectives

The aim of this research is to evaluate the influence of shear wall configurations and structural irregularities on the seismic performance of mid-rise reinforced concrete buildings in Sri Lanka and to identify suitable shear wall arrangements for improving their seismic response. This aim will be achieved by undertaking the objectives below.

1. Review existing research and relevant seismic design provisions related to shear wall configurations and structural irregularities in reinforced concrete buildings.
2. Develop numerical models of representative mid-rise reinforced concrete buildings with different shear wall arrangements and structural irregularities under seismic loading conditions relevant to Sri Lanka.
3. Evaluate and quantify the effects of different shear wall configurations on key seismic response parameters, including lateral stiffness, storey displacement, inter-storey drift, natural period, and torsional response.
4. Identify suitable shear wall arrangements for improving the seismic performance of mid-rise reinforced concrete buildings and provide recommendations for their effective placement in buildings relevant to Sri Lankan conditions.

2. Methodology

To evaluate the influence of shear wall arrangement and structural irregularities on seismic performance, a numerical case study was carried out on a representative mid-rise residential building using ETABS software. The model captures typical Sri Lankan construction practice while incorporating European seismic codes, enabling a systematic comparison of different shear wall configurations and irregularity types under earthquake loading. The different arrangements used are summarised in Figure 1.

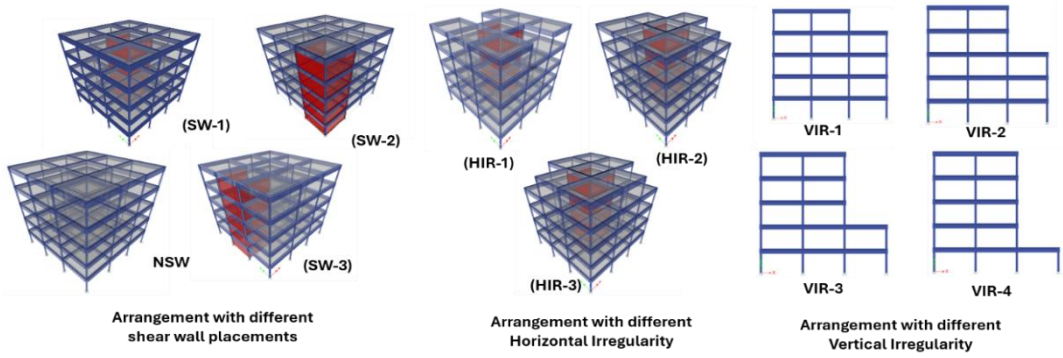


Figure 1: Arrangement used in numerical analysis.

3. Key Findings and Conclusions

The horizontal and vertical irregularity results reveal a consistent pattern: geometric irregularities mainly redistribute torsional demand rather than significantly altering overall stiffness, though the two types affect dynamic behaviour differently. The summarised displacement and drift ratio values are presented in Figure 2. The following conclusions can be drawn from the numerical study:

- Adding a centrally located shear wall system significantly improved lateral stiffness, cutting the fundamental period by 59% and maximum displacement by 80%; all tested configurations achieved over 40% reductions, with the central core arrangement giving the most balanced seismic performance and recommended where architecture allows.
- Corner-located shear walls performed worst, showing greater eccentricity and torsional effects (25.1% torsional mass participation); horizontal plan irregularities showed a similar trend, so eccentric shear wall placement should generally be avoided unless torsion is actively controlled through balanced stiffness or supplemental damping.
- Removing corner sections of the floor plan (horizontal irregularity) did not trigger significant torsional behaviour in the first two vibration modes, though the resulting increase in eccentricity did affect translational response, producing the highest lateral displacement among the irregular cases tested.
- Vertical irregularities from removing upper storeys had little effect on the fundamental period but reduced lateral displacement due to the building becoming shorter and lighter; however, torsion accounted for over 25% of mass participation, showing increased torsional sensitivity that requires careful design of vertical setbacks.

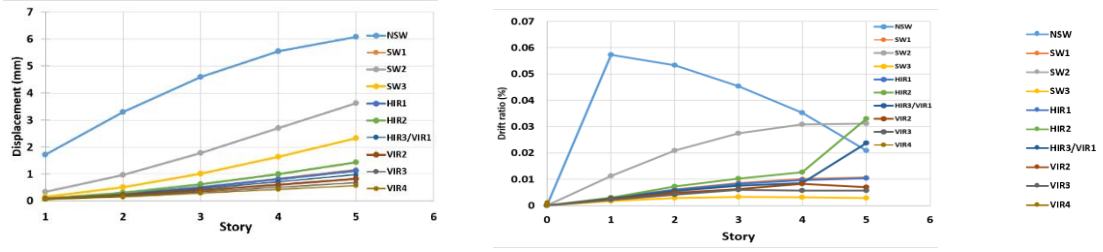


Figure 2: Displacement and drift ratio (%) behaviour of different

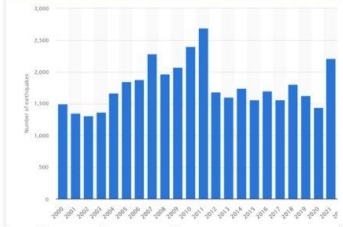
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[3] Krishnan, R., & Sivakumar, V. L. (2023). Profound impact of shear wall on stability of regular and irregular reinforced concrete structures–a review. Materials Today: Proceedings.

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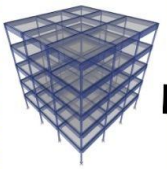


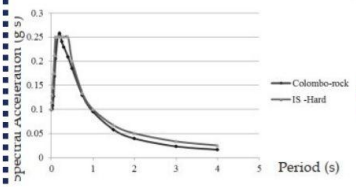
Earthquake and tremors are rising



- Frame shear wall systems enhance seismic energy dissipation
- Numerical studies conclude that the strategic positioning of shear walls is a more cost-efficient design strategy

Research methodology



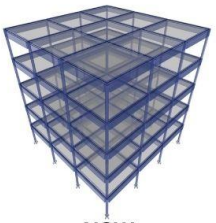


Response spectrum for Colombo

Numerical modelling

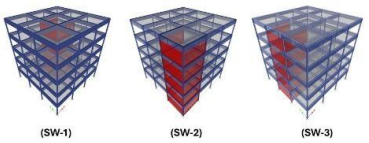
Since experimental testing of physical models is highly time-consuming and costly, the development of accurate numerical models is essential for efficiently evaluating structural behaviourt

Parametric study

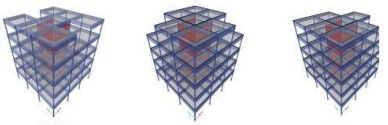


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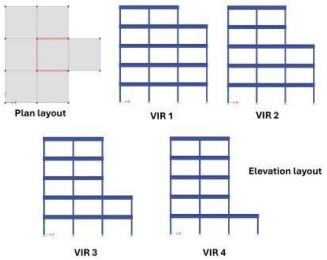
Control set up



shear wall configurations

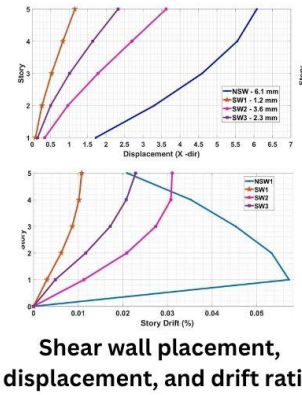


Horizontal irregularity

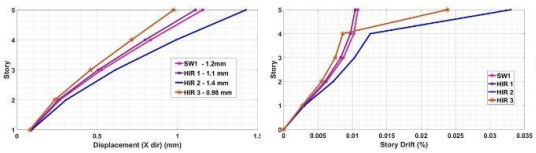


Vertical irregularity

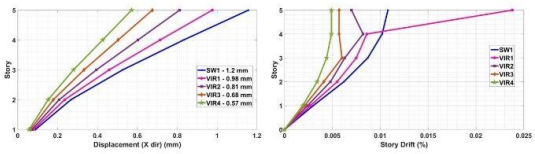
Comparative Study



Shear wall placement, displacement, and drift ratio



Horizontal irregularity displacement and drift ratio



Vertical irregularity displacement and drift ratio