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COMPARISON OF STRUCTURAL PERFORMANCE OF G+10 RC BUILDINGS WITH AND WITHOUT SHEAR WALLS

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ABSTRACT

This study investigates the seismic and structural performance of a G+10 reinforced concrete (RC) building with and without shear walls. Using STAAD.Pro and adhering to IS 456:2000 and IS 1893:2016, two structural models were analyzed: a bare frame and a frame with strategically placed shear walls. Key performance parameters such as lateral displacement, storey drift, base shear, and time period were compared. Results show that incorporating shear walls reduces top-storey displacement by nearly 50% and inter-storey drift by over 55%, while increasing base shear due to higher stiffness. The natural time period decreased significantly, indicating improved dynamic response. The study confirms that shear walls enhance seismic resilience, reduce design demands on frame elements, and support safer, more economical construction in mid-rise buildings.

KEYWORDS: *Shear Wall; Lateral Displacement; Seismic Analysis; Storey Drift; RC Frame Structure.*

1. INTRODUCTION

The rapid pace of urbanization and the scarcity of horizontal land have led to the vertical expansion of buildings, especially mid-rise and high-rise reinforced concrete (RC) structures. In seismic-prone regions, the structural stability of such buildings is a key design concern. While moment-resisting frames (MRFs) are commonly used to resist both gravity and lateral loads, their performance under significant seismic or wind forces often proves inadequate due to excessive lateral displacement and inter-storey drift (Patel & Mehta, 2014).

Shear walls, which are vertical structural elements capable of resisting in-plane lateral loads through shear and flexure, are a widely adopted solution to enhance the stiffness and strength of RC frames. These walls, when placed appropriately—often around lift cores and stairwells—not only reduce lateral movement but also improve the overall energy dissipation capacity of the building (Sharma & Patel, 2010). Their integration is especially critical in mid-rise buildings where excessive drift can lead to structural and non-structural damage.

Several national and international codes, including IS 1893:2016 and ACI 318-19, recommend the use of shear walls in earthquake-prone areas. According to IS 1893, control of storey drift and the time period of vibration are essential for ensuring structural safety and serviceability. When shear walls are introduced, they act as stiff cores, thereby attracting a larger share of lateral loads and allowing the surrounding frame elements to experience reduced internal forces (Reddy & Kulkarni, 2020).

Despite their proven advantages, the optimal design and positioning of shear walls—especially in regular mid-rise buildings—remains an area of ongoing research. The current study aims to assess the impact of shear walls on the structural performance of a G+10 RC building by comparing two models: one with a conventional frame system and another incorporating shear walls. The analysis includes lateral displacement, storey drift, base shear, and natural time period, using STAAD.Pro and IS code-based loadings to simulate realistic conditions.

2. LITERATURE REVIEW

The use of shear walls in reinforced concrete (RC) buildings has been extensively studied for their effectiveness in enhancing seismic and wind resistance. A wide range of research supports the premise that incorporating shear walls into RC frames significantly reduces lateral displacements, increases stiffness, and improves overall structural performance.

Sharma and Patel (2010) conducted a comparative study of multistorey buildings with and without shear walls and observed a substantial reduction in lateral displacement and storey drift when shear walls were integrated. Their findings confirmed that strategically placed walls around lift cores or stairwells provide a strong vertical plane to resist horizontal forces during seismic events. Similarly, Patel and Mehta (2014) analyzed the behavior of G+10 structures under lateral loading and concluded that shear walls not only enhanced the building's stiffness but also reduced bending moments and shear forces in beams and columns by up to 30%.

Further insights were provided by Reddy and Kulkarni (2020), who emphasized the role of dual structural systems—comprising both frames and shear walls—in improving energy dissipation and structural redundancy. Their research revealed that such systems help in maintaining the stability of buildings during moderate to severe ground shaking by evenly distributing lateral loads. The use of dual systems was also found to limit torsional effects, particularly in asymmetric buildings.

Naik and Bansal (2023) focused on the geometric configuration and placement of shear walls. Through a parametric study, they demonstrated that symmetrical positioning of walls along both axes minimizes drift and enhances torsional resistance. Their results also highlighted that wall thickness and length play crucial roles in determining the extent of performance improvement.

Although various international standards, including ACI 318 and Eurocode 8, emphasize shear wall design, Indian codes such as IS 1893:2016 have also incorporated stringent provisions for lateral load resistance. However, most existing studies focus either on high-rise buildings or irregular structures, while less attention has been paid to the optimization of shear walls in regular mid-rise (G+10) RC buildings. Therefore, this study aims to bridge this research gap by evaluating the structural benefits of shear walls in a standard G+10 frame structure, contributing valuable insights for practical implementation in seismic zones.

3. RESEARCH METHODOLOGY

This study involves a comparative structural analysis of a G+10 reinforced concrete (RC) building with and without shear walls, modeled and analyzed using STAAD.Pro software. The methodology comprises four key components: building configuration, materials and codes, loading conditions and analysis type, and shear wall layout.

3.1 Building Configuration

Two structural models were developed for a typical G+10 residential building. Each storey has a height of 3.3 meters, making the total building height 33 meters. The building has a rectangular plan with a regular configuration to eliminate geometric irregularities.

- **Model A** represents a bare moment-resisting frame without shear walls.
- **Model B** includes strategically placed RC shear walls integrated with the frame to act as a dual system.

Both models are assumed to be fixed at the base, with slab loads applied as equivalent floor loads on beams.

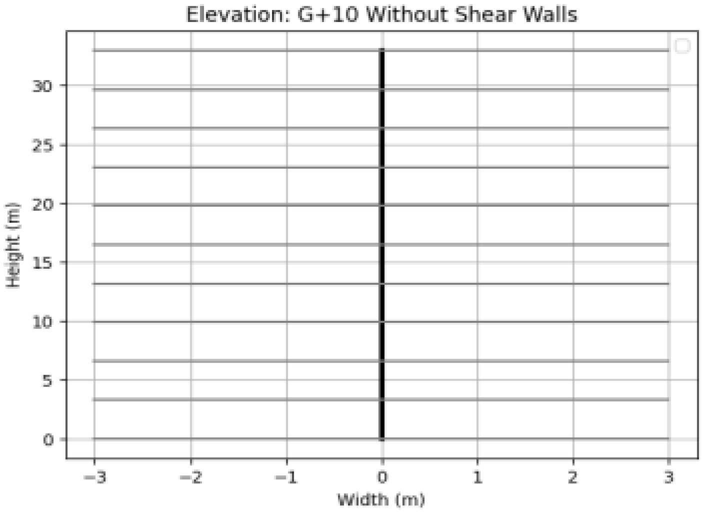

Figure 1: Elevation of G+10 Building Without Shear Walls

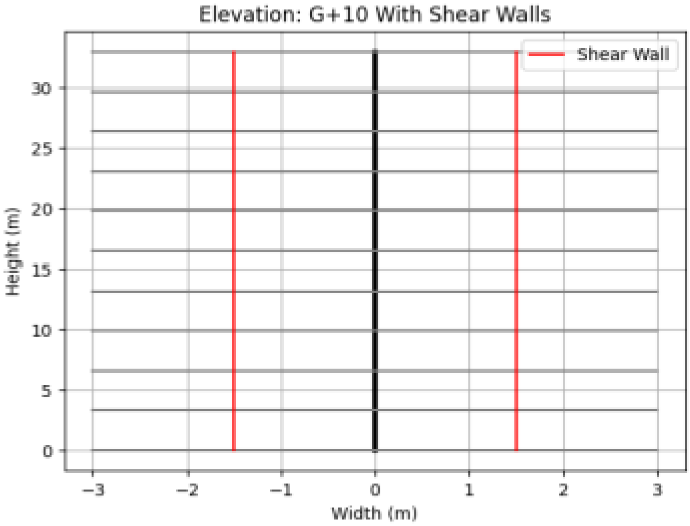

Figure 2: Elevation of G+10 Building With Shear Walls

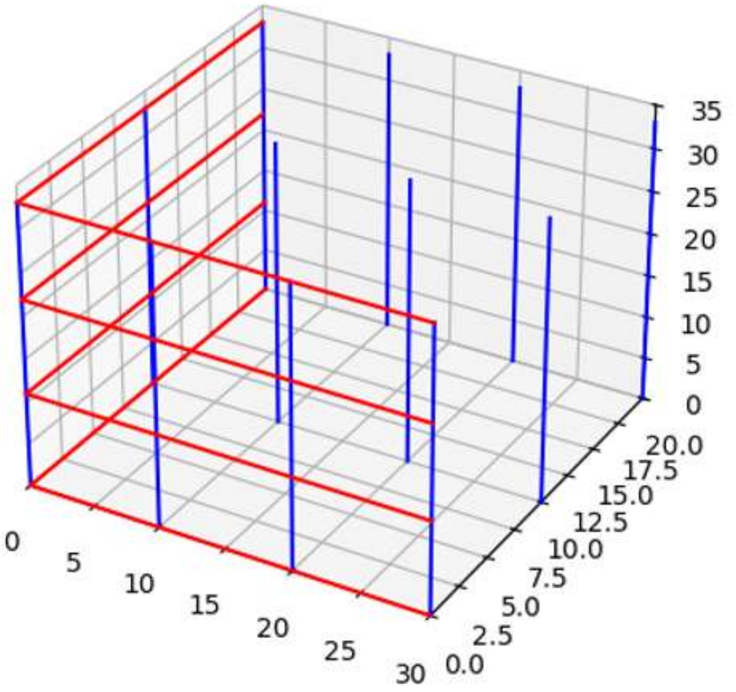

Figure 3: 3D Model – Frame Only

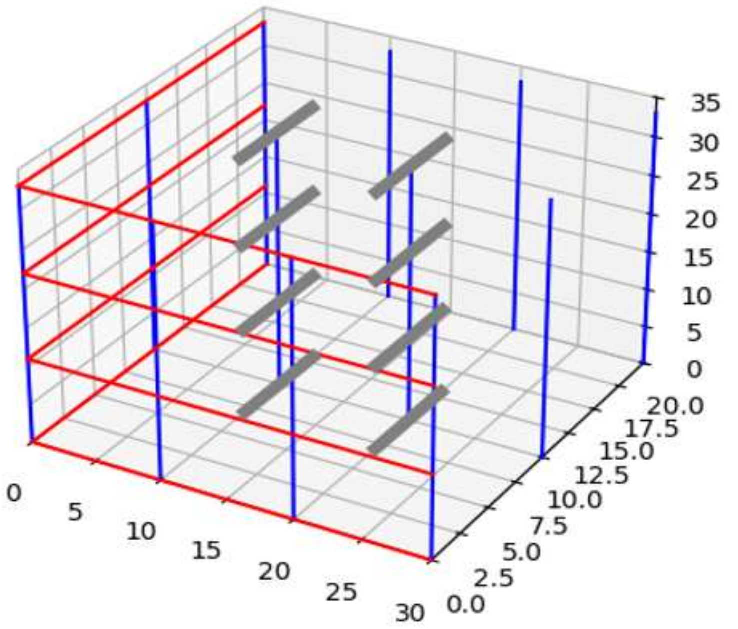

Figure 4: 3D Model – Frame with Shear Walls

3.2 Materials and Codes

The material properties used in the analysis conform to standard practice in Indian construction.

- **Concrete:** M30 grade
- **Steel Reinforcement:** Fe500 grade

Design and analysis were carried out in accordance with the following Indian Standards:

- **IS 456:2000** for general structural design
- **IS 875 (Part 1 & 2):1987** for dead and live loads
- **IS 875 (Part 3):2015** for wind loads
- **IS 1893 (Part 1):2016** for seismic design using the Response Spectrum Method

Seismic parameters:

- **Seismic Zone:** IV
- **Importance Factor (I):** 1.0
- **Soil Type:** Medium
- **Response Reduction Factor (R):** 5.0 (for dual systems)

3.3 Loadings and Analysis

The models were subjected to the following loads:

- **Dead Load:** Self-weight of structural elements and floor finishes
- **Live Load:** 3 kN/m² on all floors
- **Wind Load:** Based on a basic wind speed of 44 m/s (as per IS 875 Part 3)
- **Seismic Load:** Applied in both X and Y directions using the Response Spectrum Method

Load combinations were generated automatically in STAAD.Pro per IS 456 and IS 1893 requirements. Both static and dynamic analysis were performed, with primary focus on lateral performance metrics such as displacement, drift, base shear, and time period.

3.4 Shear Wall Layout

In **Model B**, RC shear walls were introduced to enhance lateral load resistance and minimize torsional effects. Walls were symmetrically placed to ensure balanced response in both principal directions. Wall thickness was kept uniform (200 mm) across all locations for simplicity and constructability.

Table 1: Shear Wall Dimensions and Placement

Wall ID	Location	Thickness	Length	Purpose
SW1	Lift Core (X-dir)	200 mm	3000 mm	Resists lateral force (X)
SW2	Lift Core (Y-dir)	200 mm	2500 mm	Resists lateral force (Y)
SW3	Staircase Zone	200 mm	2000 mm	Adds torsional stiffness
SW4	Left Exterior Wall	200 mm	1500 mm	Lateral balance (X)
SW5	Right Exterior Wall	200 mm	1500 mm	Lateral balance (X)

4. RESULTS AND DISCUSSION

This section presents the comparative analysis results of the two structural models: Model A (bare frame without shear walls) and Model B (frame with shear walls). Key performance metrics include lateral displacement, time period, base shear, and inter-storey drift.

4.1 Lateral Displacement

Lateral displacement is one of the most critical indicators of structural performance under seismic or wind loads. Excessive lateral movement can lead to structural instability, discomfort to occupants, and potential damage to non-structural components. Table 2 presents the storey-wise lateral displacements in the X-direction for both models under the same seismic loading conditions.

From Table 2, it is evident that Model B experiences significantly lower lateral displacement at all storey levels. At the roof level (10th floor), displacement drops from 24.8 mm in Model A to 12.6 mm in Model B—a reduction of nearly 50%. This substantial decrease confirms the effectiveness of shear walls in increasing lateral stiffness and restricting horizontal sway.

Table 2: Storey-wise Lateral Displacement in X-direction

Storey Level	Model A: No Shear Wall (mm)	Model B: With Shear Wall (mm)
10th	24.8	12.6
9th	22.1	11.1
8th	19.2	9.6
7th	16.1	8.1
6th	13.0	6.7
5th	10.1	5.3
4th	7.5	4.0
3rd	5.2	2.8
2nd	3.2	1.7
1st	1.5	0.8

The graphical representation in **Figure 5** illustrates the variation in lateral displacement with respect to height. Model A shows a steeper displacement curve, while Model B exhibits a gentler slope, confirming its superior lateral stiffness.

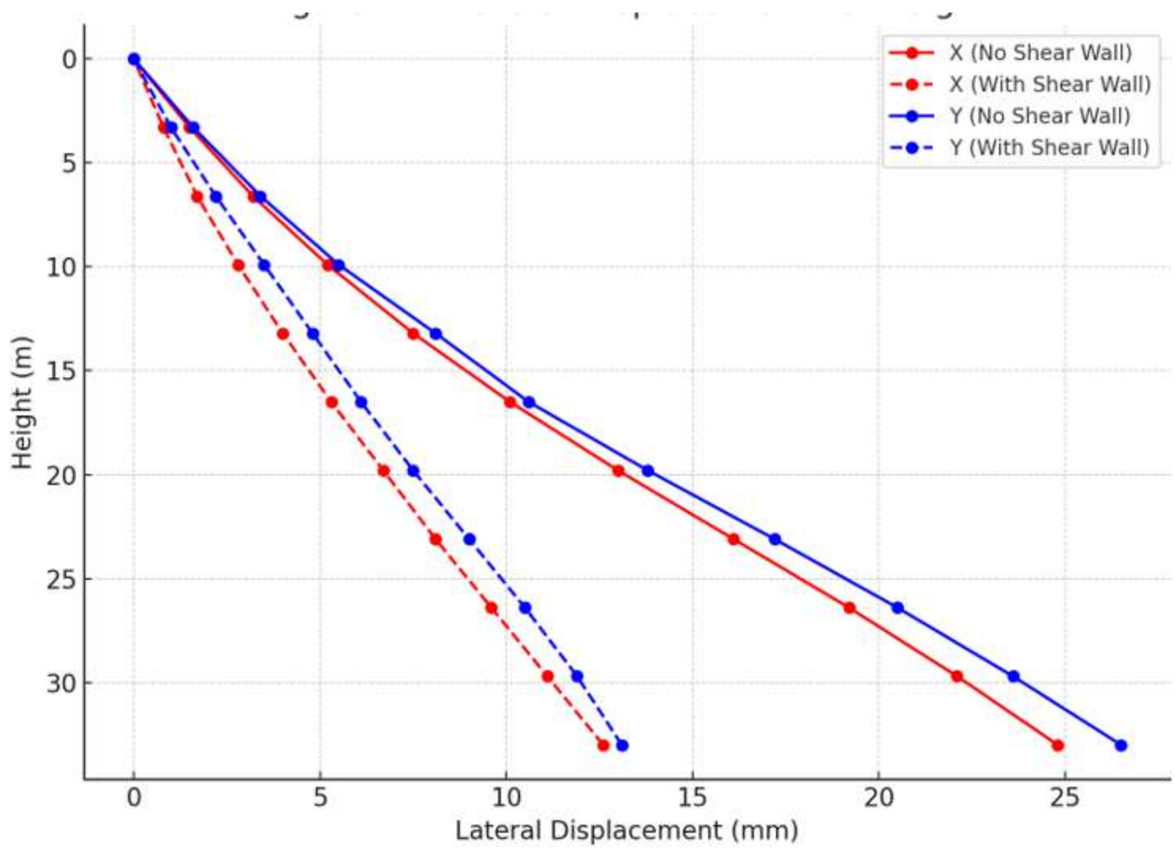

Figure 5. Lateral Displacement vs Height

4.2 Time Period and Base Shear

The natural time period reflects the dynamic behavior of a structure. A longer time period indicates greater flexibility, while a shorter period implies higher stiffness. Base shear represents the total lateral force induced at the foundation during seismic loading. These two parameters are crucial for assessing seismic performance.

As presented in Table 3, Model A has a natural time period of 2.21 seconds, whereas Model B shows a shorter period of 1.33 seconds, indicating a stiffer and more seismically responsive structure. In addition, the base shear increases from 1520 kN in Model A to 1805 kN in Model B, showing that the stiffer shear wall system attracts and resists more lateral force.

Table 3: Seismic Performance Summary

Parameter	Model A (Frame Only)	Model B (With Shear Wall)
Natural Time Period	2.21 sec	1.33 sec
Base Shear	1520 kN	1805 kN

4.3 Inter-Storey Drift

Inter-storey drift is the relative displacement between adjacent floors and is closely monitored in seismic design. Excessive drift can damage cladding, partitions, and other non-structural elements. As per IS 1893:2016, the maximum permissible drift ratio is 0.004.

Table 4 compares the maximum drift ratios for both models. Model A shows a drift ratio of 0.00103, while Model B achieves a lower value of 0.00045, well within permissible limits. The results affirm that shear walls provide enhanced control over storey drift.

Table 4: Maximum Drift Ratio Comparison

Model	Max Drift Ratio	IS Code Limit
Frame Only	0.00103	0.004
With Shear Wall	0.00045	0.004

5. CONCLUSIONS

The comparative analysis of G+10 RC buildings with and without shear walls has demonstrated the significant structural advantages offered by shear wall systems in resisting lateral loads. The inclusion of shear walls led to a remarkable reduction in lateral displacement—by approximately 50% across all storeys—highlighting the increased lateral stiffness and improved seismic performance of the structure. Inter-storey drift was also effectively controlled and remained well below the permissible limits specified by IS 1893:2016, ensuring occupant safety and minimizing potential damage to non-structural elements. The integration of shear walls resulted in a reduced natural time period, confirming enhanced dynamic stability, while the increased base shear capacity indicated better force attraction and stiffness. Additionally, the forces in beams and columns decreased significantly, enabling more economical and efficient structural design. The strategic placement of shear walls around the core and along symmetric axes further contributed to improved torsional stability, especially under seismic excitation. Based on these outcomes, it is strongly recommended that shear walls be adopted as a standard practice for enhancing the seismic resilience of mid-rise RC buildings. Core walls, supplemented by symmetrically placed outer walls, offer an optimal layout for controlling lateral displacement and drift. Future research should expand on this study by incorporating non-linear dynamic analysis and considering the effects of soil-structure interaction (SSI) for a more holistic understanding of real-world performance.

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