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Study On Vertical Irregularities In RC Building Controlled By Finding Exact Position Of Shear Wall

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ABSTRACT

Shear walls are key elements in tall buildings for resisting earthquake loads, with lateral beams often connecting them to enhance ductility. Earthquake-induced dynamic loads are a major cause of building damage, making it essential to understand a structure's dynamic characteristics. Asymmetric tall buildings, combining frames, shear walls, and cores, often face torsional effects from lateral forces such as wind, seismic action, and uneven settlement. This study uses the Response Spectrum Method in ETABS to analyse a vertically unsymmetrical structure with varying shear wall locations. The objective is to reduce torsion through four concentric shear wall configurations.

Keywords: Torsion, concentric, shear wall, positioning, thickness.

1. Introduction

Irregularities in building geometry, such as asymmetrical floor plans, sudden changes in stiffness, and non-uniform mass distribution, can significantly amplify torsional responses during seismic events. This torsional amplification leads to uneven displacement demands across the structure, potentially causing damage or collapse of critical members.

Globally, post-earthquake reconnaissance reports (e.g., Bhuj 2001, Nepal 2015) have shown that buildings with poor torsional control experience higher damage ratios than regular structures of similar height and material properties.

Shear walls, when properly located, enhance lateral stiffness, reduce storey drift, and provide torsional restraint. However, the efficiency of shear walls depends heavily on their placement relative to the centre of mass and stiffness. This research focuses on quantifying the influence of shear wall positioning in a vertically irregular RC structure under severe seismic loading.

2. Literature Review

Torsional irregularity in buildings has been recognised as a critical factor influencing seismic performance. When the centre of mass and the centre of stiffness do not coincide, seismic forces induce rotational motion in addition to translation, resulting in uneven displacement demands across the structure.

Agarwal & Shrikhande (2012) analysed torsional responses in plan-irregular buildings and reported that centrally located shear walls reduce torsional irregularity indices by up to **40%** compared to edge or corner placements. This is due to the alignment of stiffness and mass centres, which minimises eccentricity.

IS 1893:2016 explicitly recommends minimising eccentricity between the centre of mass and stiffness to limit torsion. The code mandates consideration of **accidental eccentricity** of at least ±5% to account for uncertainties in mass distribution and construction tolerances.

Meena et al. (2018) examined the role of shear wall thickness and found that while increasing wall thickness improves stiffness and reduces lateral displacements, the gains diminish beyond 200 mm. This implies that optimal positioning of walls often has a greater effect on torsional control than increasing thickness alone.

Sarkar et al. (2010) classified plan irregularities and demonstrated that uneven stiffness distribution significantly amplifies torsional demand. They suggested that in high-seismic zones, careful placement of shear walls can be more effective than simply increasing the size of columns or walls.

Paul & Agarwal (2019) studied vertically irregular buildings and found that discontinuities in stiffness — such as setbacks or irregular mass distribution — exacerbate torsional effects. They concluded that dual-orientation wall placement can help counteract these effects by providing balanced stiffness in both orthogonal directions.

Despite these advances, comparative studies focusing specifically on torsional performance in vertically irregular RC structures with multiple wall configurations are still limited**. Most research addresses plan irregularities, whereas vertical irregularities present different stiffness-distribution challenges.**

This study addresses that gap by analysing five different shear wall configurations**, each in** two thicknesses (150 mm and 200 mm)**, using** Response Spectrum Analysis **under IS 1893 seismic loading conditions.**

3. Methodology

This study was carried out using a systematic approach involving structural modelling, load application, analysis, and comparative evaluation of results.

3.1 Structure Modelled

The prototype building chosen for this research is an **11-storey reinforced concrete (RC) frame structure** with vertical irregularity. The total height is **33 m**, with each storey measuring **3.0 m**. The building plan is irregular in shape, leading to eccentricities between the centre of mass and centre of stiffness.

Material Properties:

- **Concrete grade:** M-20 (fck = 20 MPa)
- **Steel grade:** Fe-415 (fy = 415 MPa)
- **Modulus of elasticity of concrete:** 25 GPa
- **Modulus of elasticity of steel:** 200 GPa
- **Poisson’s ratio:** 0.2 for concrete, 0.3 for steel

Member Dimensions:

- **Columns:** 600×600 mm at base, tapering to 500×500 mm above the 6th storey
- **Beams:** 300×450 mm throughout
- **Slabs:** 150 mm thick RCC slabs with rigid diaphragm action

3.2 Loads Applied

Dead Load (DL):

- Self-weight of structural members as calculated by ETABS based on assigned material densities
- Additional floor finish load of **1.0 kN/m²** on all floors

Live Load (LL):

- 2.0 kN/m² on typical floors
- 1.5 kN/m² on the roof as per IS 875 (Part 2)

Seismic Load (EQ):

- **Code:** IS 1893 (Part 1):2002
- **Seismic Zone:** V (Zone factor, Z = 0.36)
- **Soil type:** Medium (Type II)
- **Importance factor (I):** 1.0
- **Response reduction factor (R):** 5 (Special Moment Resisting Frame, SMRF)
- **Damping ratio:** 5%
- **Spectrum scaling:** As per IS 1893 design spectrum for medium soil

Load Combinations Used (IS 875 + IS 1893):
1.5 (DL + LL)
1.2 (DL + LL ± EQX)
1.2 (DL + LL ± EQY)
1.5 (DL ± EQX)
1.5 (DL ± EQY)
0.9 DL ± 1.5 EQX
0.9 DL ± 1.5 EQY

3.3 Analysis Method

The analysis was carried out using **ETABS v18** structural analysis software. The **Response Spectrum Method** was used to determine peak structural responses under dynamic seismic loading, as it accounts for the contribution of multiple vibration modes.

Modelling Considerations:

- **Accidental Eccentricity:** ±5% of plan dimension as per IS 1893 recommendations
- **Rigid Diaphragm Constraint:** Applied at every floor level to simulate in-plane rigidity of the floor slab
- **Meshing:** Slab mesh size ≤ 0.5 m to ensure accuracy of load distribution
- **Modal Analysis:** At least 90% modal mass participation was ensured in both X and Y directions

3.4 Configurations Studied

Five structural models were analysed:

1. **No shear wall** – Baseline irregular RC frame structure without additional lateral load-resisting walls.
2. **Four concentric shear walls** – Symmetrically positioned around the geometric centre to align stiffness and mass centres.
3. **Shear walls at lift core** – Enclosing the central stair and elevator shaft, providing high stiffness in the core.
4. **Two walls parallel to X-axis** – Located on opposite exterior faces, improving stiffness in the X-direction.
5. **Two walls parallel to Y-axis** – Located on opposite exterior faces, improving stiffness in the Y-direction.

4 Analytical Work

4.1 Overview

An 11-storey unsymmetrical RC structure was analysed in ETABS to evaluate shear wall placement effects on torsional response. Four shear wall configurations were tested:
1. Four concentric shear walls.
2. Shear wall at lift core.
3. Two shear walls parallel to X-axis.
4. Two shear walls parallel to Y-axis.

Two wall thicknesses (150 mm and 200 mm) were considered, along with a baseline model without shear walls.

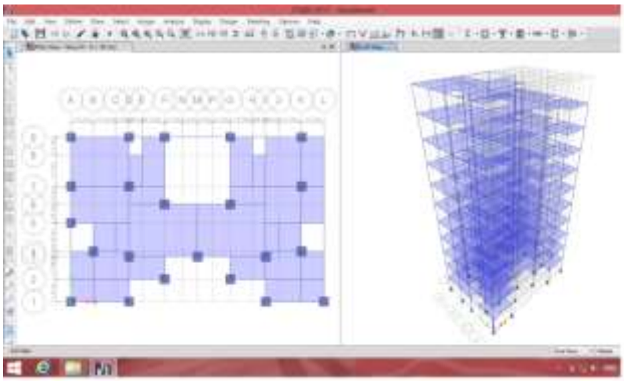


Fig. 4.1: Window of ETABS showing plan and 3D view of structure

4.2 Structural Model and Loading

- Plan size: 11 m × 16.95 m, storey height = 3 m, total height = 33 m
- Members: Columns 600×600 mm, beams 300×450 mm, slab 150 mm
- Materials: M-20 concrete, Fe-415 steel
- Loads:
  - Dead load: slab finish = 1 kN/m², beam load = 9.5 kN/m
  - Live load: 2 kN/m²
  - Seismic load: IS 1893:2016, Zone V, R = 5, I = 1, Soil type II, Z = 0.36
- Analysis method: 3D response spectrum analysis

4.3 ETABS Modelling Procedure

1. Define materials and sections
2. Assign gravity and seismic loads
3. Perform 3D response spectrum analysis in EQ-X and EQ-Y
4. Extract torsional values, base shear, and displacements for each storey

4.4 Key Results from Analysis

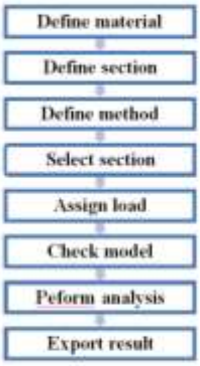


Fig. 4.2 : Flow diagram for ETABS steps

Table 4.1 – Torsion reduction for different shear wall cases (EQ-X)

Storey	Without SW	Concentric SW (150 mm)	Concentric SW (200 mm)	Lift SW (200 mm)	SW Y (150 mm)
11	809.09	803.15	800.90	731.58	752.78
7	4760.48	4503.26	4486.11	5929.46	3485.46
1	7357.07	6916.47	6877.67	9140.27	5329.13

4.5 Observations

- Concentric shear walls consistently reduced torsion.
- Lift-core placement increased torsion in certain storeys due to eccentricity.
- Thickness increase from 150 mm to 200 mm provided minor additional benefit.
- Two shear walls parallel to the Y-axis gave lowest torsion among non-concentric cases.

4.7 Building under Consideration

The study examines an 11-storey residential RC building with shear walls in various positions. ETABS 3D analysis was performed for both gravity (dead and live) and lateral (seismic) loads. Seismic loads were computed as per IS 1893 and applied to evaluate torsional behaviour for different shear wall placements.

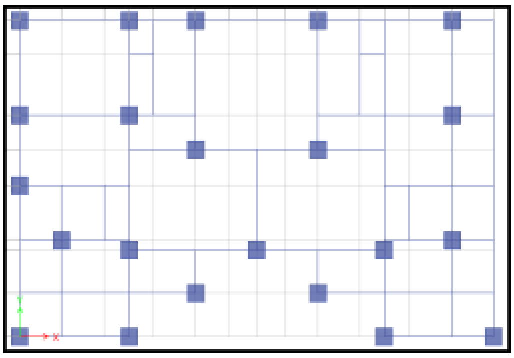


Fig. 4.3 : Plan showing structure without shear wall

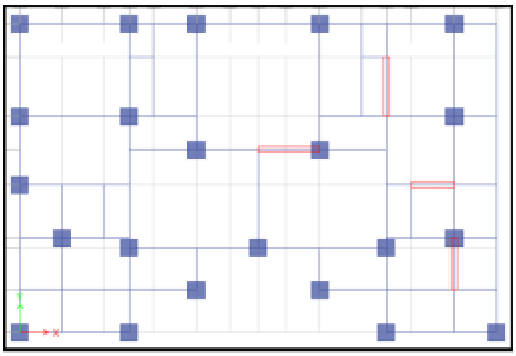


Fig. 4.4 : Plan showing structure with Four concentric shear wall

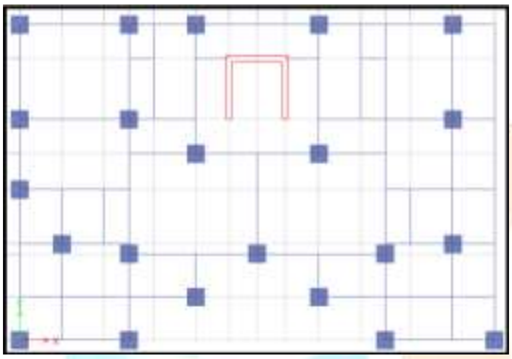


Fig. 4.5 : Plan showing structure with shear wall at lift

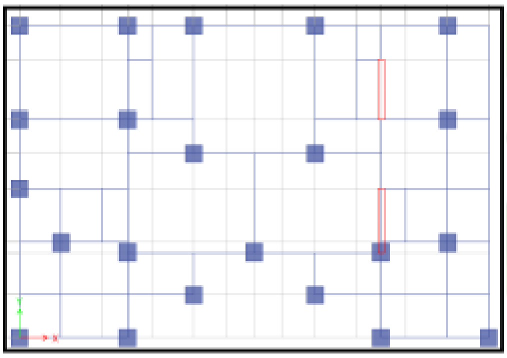


Fig. 4.6 : Plan showing structure with two shear wall parallel to Y- axis

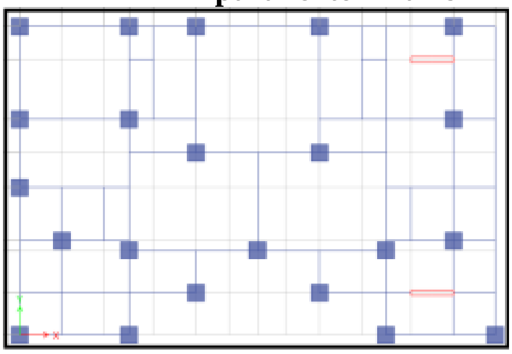


Fig. 4.7 : Plan showing structure with two shear wall parallel to X-axis

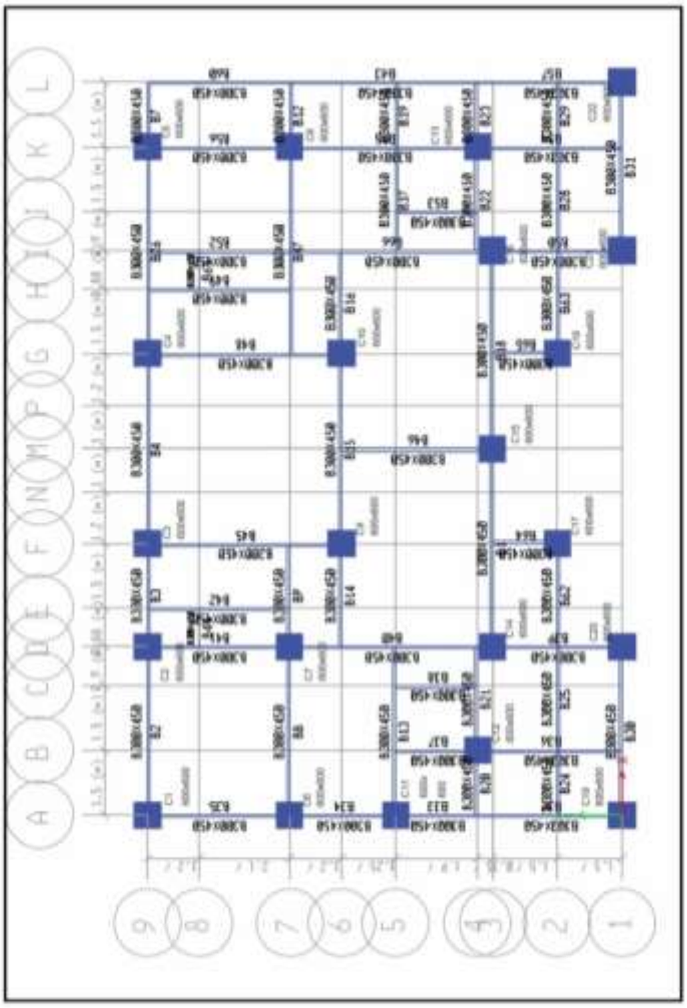


Fig. 4.8 : Plan showing position of column and Beam

5. Results and Discussion

This section presents the key findings from the ETABS analysis of the 11-storey unsymmetrical RC structure under various shear wall configurations. For brevity, results are summarised in comparative tables, highlighting torsional performance for two wall thicknesses (150 mm and 200 mm) across different placements. Only representative data from critical storeys are shown.

Table 5.1 – Torsion values for 150 mm shear walls (EQ-X)

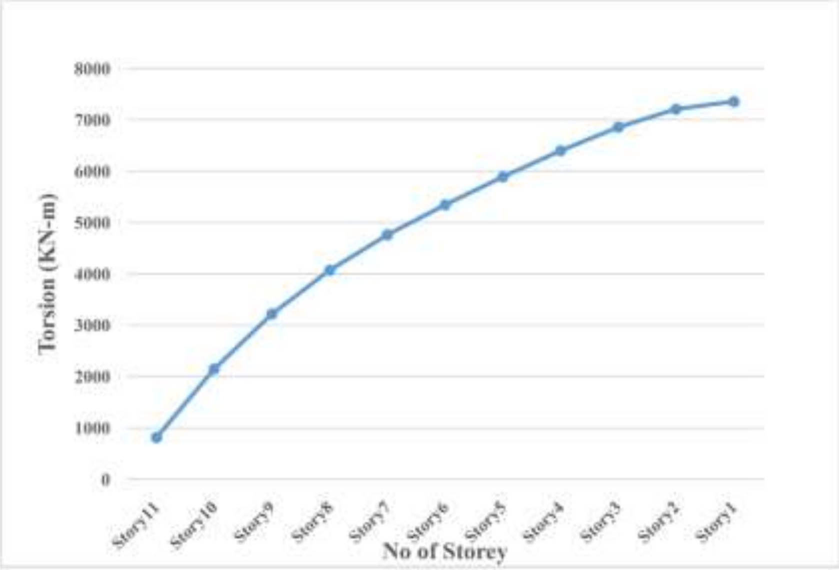
Storey	Without SW	Concentric	Lift	SW ∥ X	SW ∥ Y
11	809.09	803.15	730.44	773.98	752.78
7	4760.48	4503.26	5722.64	4265.32	3485.46
1	7357.07	6916.47	8851.32	6555.84	5329.13

Table 5.2 – Torsion values for 200 mm shear walls (EQ-X)

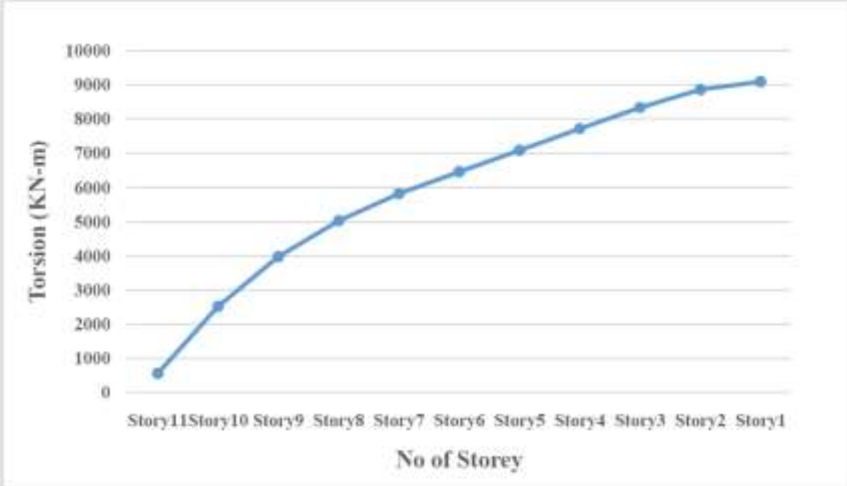
Storey	Without SW	Concentric	Lift	SW ∥ X	SW ∥ Y
11	809.09	800.90	731.58	787.73	761.94
7	4760.48	4486.11	5929.46	4378.82	3538.85
1	7357.07	6877.67	9140.27	6726.85	5410.54

5.1 Observations

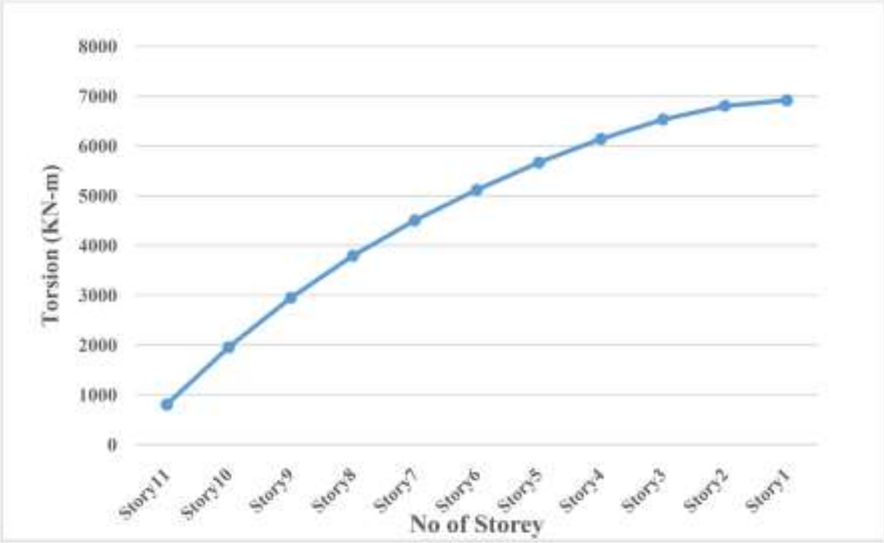
- Concentric shear walls provided the highest torsion reduction in both thickness cases.
- Lift-core placement significantly increased torsion at lower storeys due to eccentricity.
- Increasing thickness from 150 mm to 200 mm offered only marginal improvement.
- Two shear walls parallel to the Y-axis were most effective among non-concentric arrangements.



Graph 5.1: Torsional values per storey without shear wall for EQX



Graph 5.2: Torsional values per storey without shear wall for EQY



Graph 5.3 : **Torsional Values per Storey Due to Four Concentric Shear Wall of 150mm for EQ-X**

Chapter 6 – Conclusion

An 11-storey RC building was analysed in ETABS for four shear wall positions and two thicknesses (150 mm, 200 mm) under gravity and seismic loads. Key findings:

- Torsion increases with greater eccentricity between the building's centroid and centre of mass.
- Shear wall at lift core increases torsion (EQX) compared to no shear wall, failing to serve its intended purpose.
- Two shear walls ∥ X-axis performed poorly for both EQX and EQY.
- Four concentric walls and two walls ∥ Y-axis significantly reduced eccentricity; the latter gave best EQX results, while concentric walls reduced torque for both directions.
- Four concentric walls of 150 mm thickness provided the most effective torsion reduction

Chapter 7 – Future Scope

- Extend the study to taller buildings.
- Examine horizontal-plane asymmetry in addition to vertical.
- Study symmetrical shifting of shear walls toward the centre.
- Include effects of soft storeys.
- Analyse varying shear wall thickness along building height.
- Compare results using other analysis software or methods.

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