

Structural Behavior of High-Rise Buildings with Shear Wall and Bracing Systems

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ABSTRACT

This study evaluates the structural behavior of a 15-storey reinforced concrete residential building strengthened using shear wall and reinforced concrete cross-bracing systems. Seven analytical configurations were considered: a conventional frame without a dedicated lateral load-resisting system, shear walls at the centre, intermediate location and exterior location, and cross-bracing at the centre, intermediate location and exterior location. The building was modelled in ETABS using a 5×5 bay square grid, 4 m storey height, M30 concrete members, 200 mm slab thickness, 400 mm shear wall thickness and 5% damping. Equivalent Static Analysis was adopted in accordance with IS 1893:2016, with gravity loads considered as per IS 875. The comparison focused on storey displacement, inter-storey drift, storey shear and overturning moment. The results show that the conventional frame records the highest lateral displacement and drift, while the introduction of shear walls and cross-bracing significantly improves seismic performance. Exterior placement of lateral systems provides the largest improvement in displacement and drift control, while the intermediate shear wall configuration produces the lowest reported overturning moment. Overall, the study confirms that appropriate placement of lateral load-resisting elements is essential for improving stiffness, reducing seismic response and enhancing the serviceability and stability of high-rise reinforced concrete buildings.

Keywords: ETABS, High-Rise Building, Shear Wall, Cross Bracing, Equivalent Static Analysis, Storey Drift, Storey Displacement, Overturning Moment

I. INTRODUCTION

1.1 Background

Rapid urbanization and limited land availability have increased the need for high-rise reinforced concrete buildings. Such structures are vulnerable to lateral forces caused by earthquakes and wind, and excessive sway or inter-storey drift can affect structural safety, occupant comfort and non-structural components. Moment-resisting frames may be adequate for low-rise and medium-rise construction, but taller buildings require additional lateral load-resisting systems to maintain displacement, stress and stability within acceptable limits.

Shear walls and bracing systems are widely adopted to enhance lateral stiffness in high-rise buildings. Reinforced concrete shear walls act as vertical plate elements that resist in-plane shear and bending, while bracing systems transfer lateral forces primarily through axial action. Their effectiveness depends strongly on location, configuration and integration with the surrounding frame. Improper placement can increase torsional response or create inefficient load transfer, while well-positioned systems can reduce displacement, drift and foundation demand.

1.2 Objectives

- To examine the structural behaviour of different lateral load-resisting systems in high-rise structures.
- To compare structural systems commonly used in conventional engineering practice.
- To evaluate the individual effects of shear walls and reinforced concrete cross-bracing systems on the overall structural response.
- To compare seismic performance measures including base shear, storey drift, lateral displacement and overturning moment.
- To identify an effective arrangement of lateral load-resisting elements for improving seismic performance in high-rise buildings.

1.3 Scope of Work

The scope of the work is limited to the structural analysis of a 15-storey reinforced concrete building using ETABS. The study compares a conventional building model with shear wall and cross-bracing configurations placed at centre, intermediate and exterior locations. The response parameters considered are storey displacement, inter-storey drift, storey shear and overturning moment under seismic loading.

II. LITERATURE REVIEW

Previous research establishes that lateral load-resisting systems are essential for improving the seismic performance of tall buildings. Agarwal and Shrikhande emphasized the importance of integrating shear walls and bracing systems into the main structural system because conventional moment-resisting frames are more vulnerable to seismic forces. Studies on concentric and eccentric bracing systems also indicate that bracing improves the load path and energy dissipation capacity of high-rise structures.

Comparative ETABS and STAAD.Pro studies have shown that shear walls generally provide strong control of displacement and drift, while bracing systems provide a cost-effective and architecturally flexible alternative. Shweta and Patel reported better lateral displacement reduction through shear walls in a G+15 building, while Patel and Mehta found that X-bracing offers the greatest reduction among several bracing layouts. Lokesh and Gopi highlighted that shear wall placement at corners or around the core improves resistance to lateral loads and reduces torsional inefficiency.

Other studies have explored combined or dual systems. Varghese and Krishna reported that hybrid systems combining shear walls, bracing or moment-resisting frames improve load distribution, drift response and torsional resistance. Kumari and Sharma observed that shear walls deliver superior structural performance but may increase cost because of higher concrete usage, whereas bracing systems provide a practical balance between economy and stiffness. The reviewed literature supports the present comparison of shear wall and bracing locations in a 15-storey RC building model.

2.1 Research Gap

Although shear walls and bracing systems have been widely investigated, prior work often treats these systems separately. The present study addresses the need for a focused comparison of their placement effects on seismic response parameters such as displacement, storey drift, storey shear and overturning moment in a common high-rise RC building model.

III. METHODOLOGY

3.1 Building and Analysis Details

The analytical model consists of a 15-storey reinforced concrete building with a 5 × 5 bay square grid layout and a uniform floor height of 4 m. Structural elements and lateral systems were modelled in ETABS. The members were designed using ACI 318-14 provisions, while gravity and seismic loading followed IS 875 and IS 1893:2016 respectively. Equivalent Static Analysis was adopted for seismic evaluation.

Table 1. Building and analysis parameters.

Parameter	Value retained from thesis
Building type	15-storey reinforced concrete residential building
Plan/grid system	5 × 5 bay square grid layout
Storey height	4 m
Column size	650 mm × 500 mm
Beam size	550 mm × 400 mm
Concrete grade	M30 for structural concrete members
Reinforcement steel	A572 Grade 50
Slab thickness	200 mm
Shear wall thickness	400 mm
Damping ratio	5%
Seismic analysis method	Equivalent Static Analysis
Seismic code reference	IS 1893:2016
Load reference	IS 875 Part 1 and Part 2
Importance factor	1.5

3.2 Analytical Model Configurations

Two primary lateral load-resisting systems were considered: reinforced concrete shear walls and reinforced concrete cross-bracing. Each system was evaluated at three locations relative to the building centre: centre, intermediate and exterior. A conventional frame without shear wall or bracing was used as the baseline model.

Table 2. Analytical configurations considered in ETABS.

Model	Configuration	Description
M1	Conventional building	RC frame without shear wall or bracing
M2	Shear wall at centre	Shear wall positioned centrally in the building footprint
M3	Bracing at centre	Cross-bracing positioned at the centre
M4	Intermediate shear wall	Shear wall positioned at an intermediate location
M5	Intermediate bracing	Cross-bracing positioned at an intermediate location
M6	Exterior shear wall	Shear wall positioned toward the perimeter/exterior
M7	Exterior bracing	Cross-bracing positioned toward the perimeter/exterior

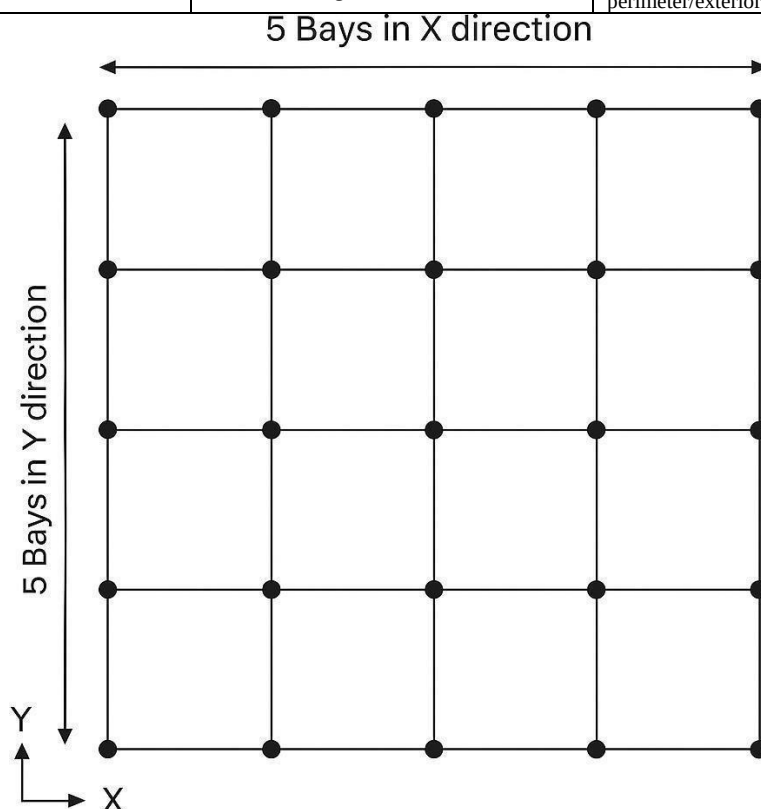


Figure 1. Plan layout of the 5 × 5 bay building retained from the thesis.

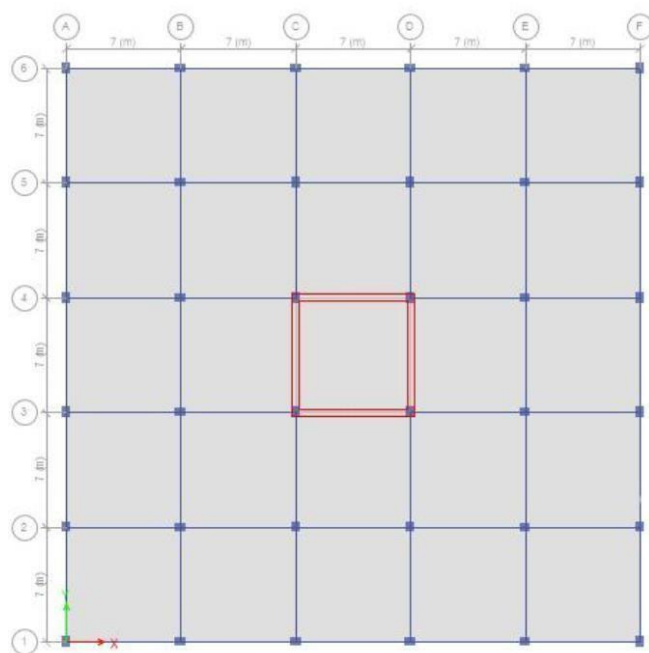


Figure 2. Representative shear wall model view retained from the thesis.

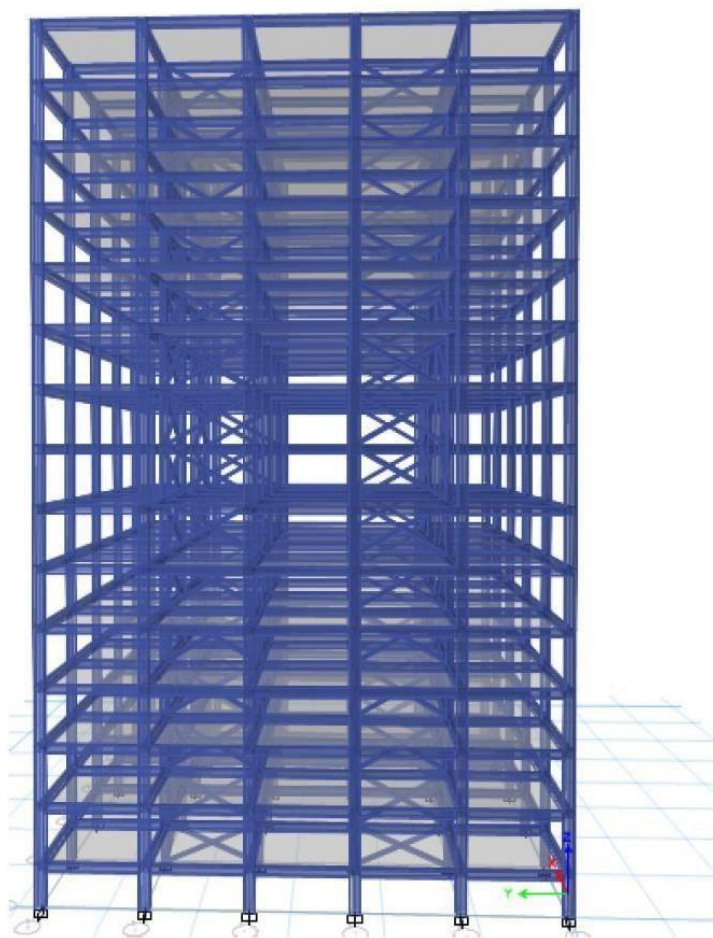


Figure 3. Cross-bracing construction at the centre retained from the thesis.

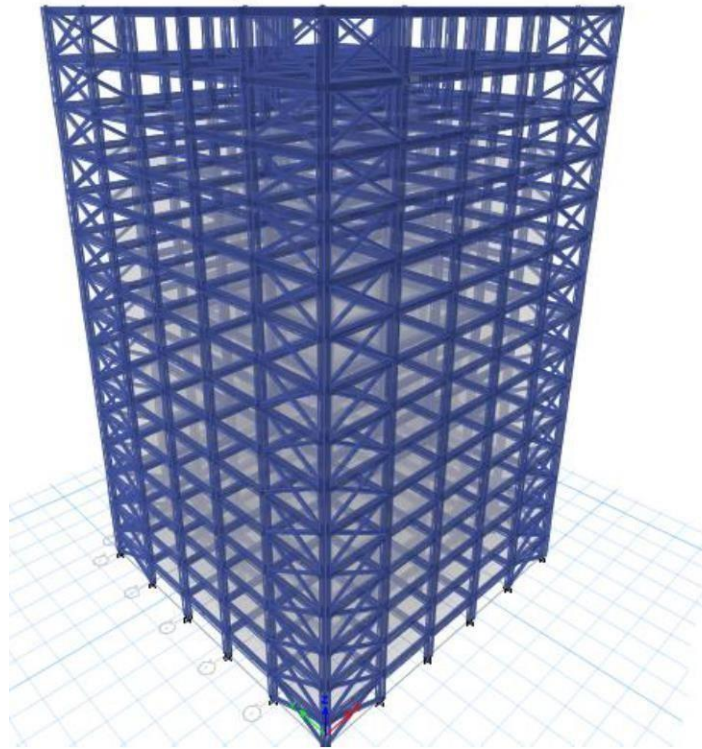


Figure 4. Representative intermediate/exterior cross-bracing model view retained from the thesis.

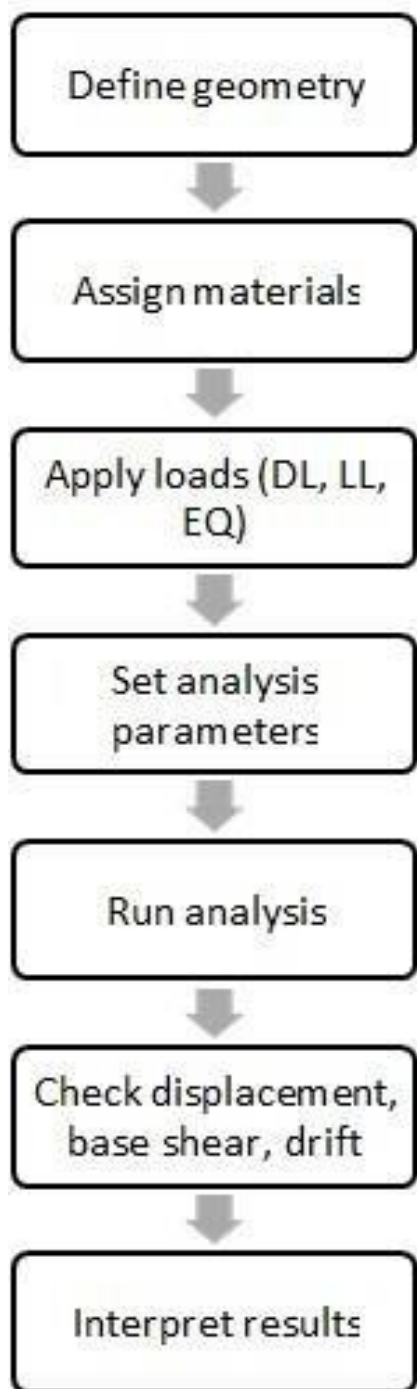


Figure 5. Equivalent Static Analysis flowchart retained from the thesis.

3.3 Output Parameters

The seismic response was evaluated through maximum storey displacement, inter-storey drift, storey shear and overturning moment. These parameters were selected because they directly indicate lateral deformation, floor-to-floor distortion, lateral force distribution and rotational demand on the building-foundation system.

IV. ANALYSIS AND RESULTS

4.1 Storey Displacement

Storey displacement represents the lateral translation of each floor under seismic loading. The conventional frame records the highest displacement, and the values increase progressively with building height. Adding shear walls or bracing reduces displacement by increasing lateral stiffness and improving the load transfer mechanism.

Table 3. Storey displacement of the analyzed models (mm).

Floor Level	Without SW & Bracing	SW at Center	Bracing at Center	Intermediate SW	Intermediate Bracing	Exterior SW	Exterior Bracing
Base	0	0	0	0	0	0	0
Storey 5	365	245	210	145	125	68	52
Storey 10	820	590	520	360	335	185	138
Storey 15	1170	875	765	550	455	285	185

At Storey 15, the conventional building reaches 1170 mm displacement. The reported table shows large reductions for exterior placements, with 285 mm for the exterior shear wall model and 185 mm for the exterior bracing model. The thesis discussion identifies exterior placement as the most effective strategy for displacement control.

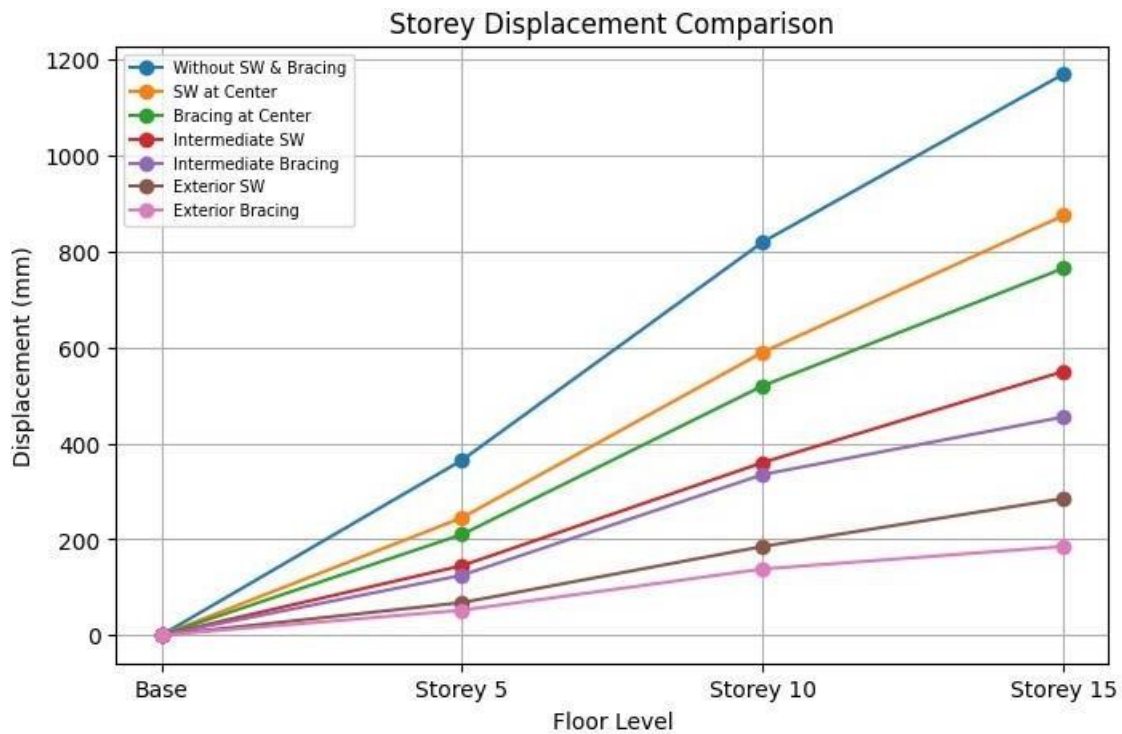


Chart 1. Storey displacement in each building model.

4.2 Inter-Storey Drift

Inter-storey drift is the relative lateral displacement between adjacent floors. Drift control is necessary to limit damage to cladding, partitions, windows and other non-structural components. The conventional model shows the highest drift values, while shear walls and bracing reduce floor-to-floor deformation.

Table 4. Inter-storey drift of the analyzed models.

Floor Level	Without SW & Bracing	SW at Center	Bracing at Center	Intermediate SW	Intermediate Bracing	Exterior SW	Exterior Bracing
Base	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Storey 5	0.0024	0.0018	0.0016	0.0012	0.0011	0.0008	0.0007
Storey 10	0.0038	0.0029	0.0026	0.0019	0.0017	0.0012	0.0011
Storey 15	0.0046	0.0035	0.0031	0.0023	0.0020	0.0015	0.0013

The drift response follows the same general trend as displacement: values increase with height and are highest in the conventional frame. Exterior bracing and exterior shear wall configurations provide the lowest reported drift values, demonstrating the effectiveness of perimeter placement in controlling lateral deformation.

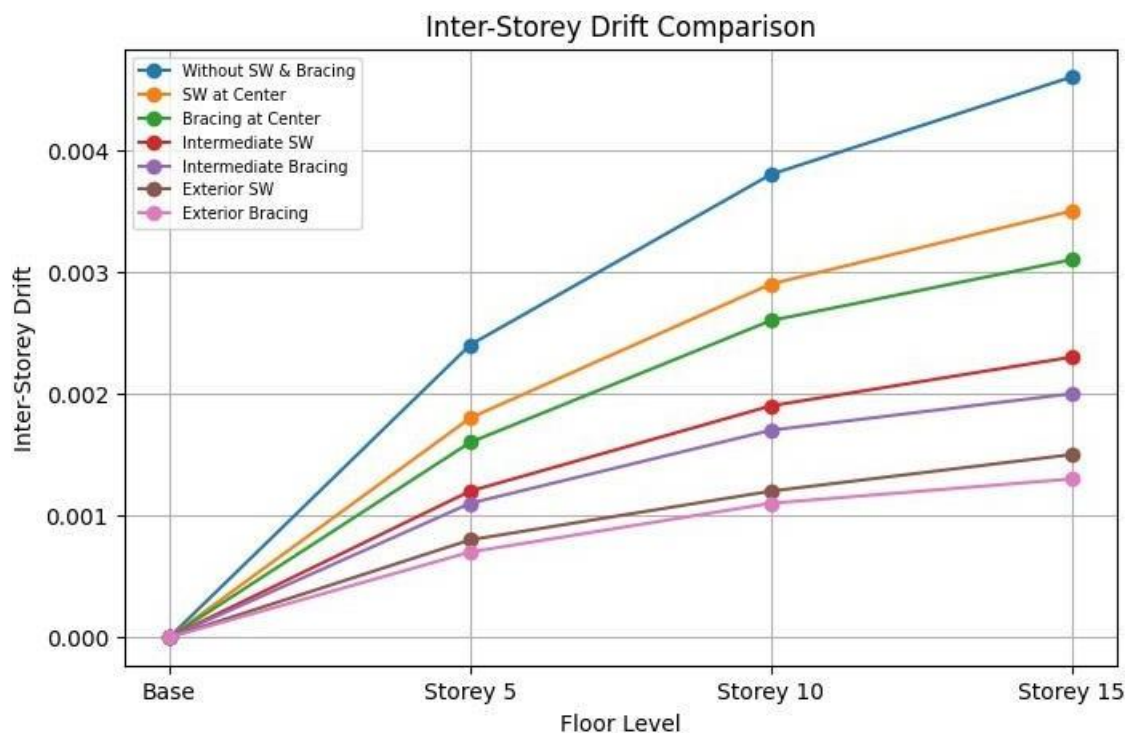


Chart 2. Inter-storey drift comparison of different structural configurations under seismic loading.

4.3 Storey Shear in Shear Wall Models

Storey shear is the cumulative lateral force acting at a given floor level. It increases toward the base because lower storeys transfer the seismic forces generated by all floors above them. The shear wall configurations show similar overall force patterns, but intermediate wall placement gives the lowest reported values.

Table 5. Storey shear in shear wall models (kN).

Floor Level	Center Shear Wall	Intermediate Shear Wall	Exterior Shear Wall
Storey 15	180	165	170
Storey 10	520	495	505
Storey 5	890	845	860
Base	1240	1185	1200

The intermediate shear wall model records the lowest base storey shear of 1185 kN, compared with 1240 kN for the centre shear wall model and 1200 kN for the exterior shear wall model. This indicates that intermediate placement provides a balanced distribution of lateral forces in the reported model.

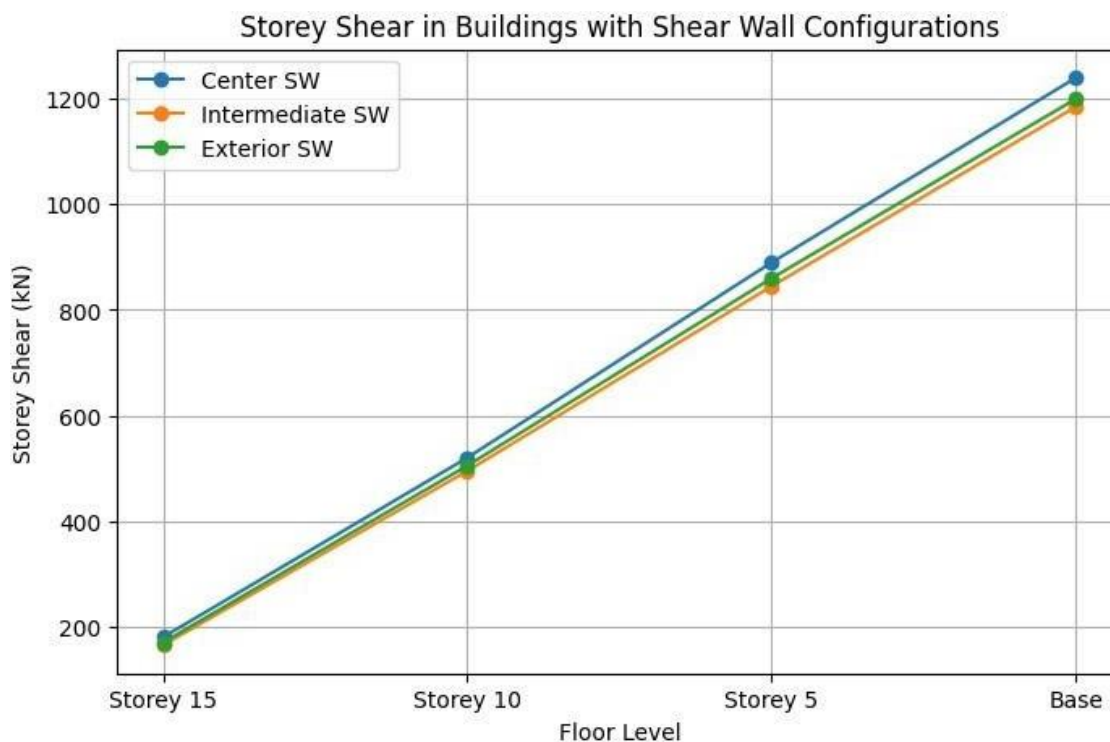


Chart 3. Storey shear variation in buildings with different shear wall configurations.

4.4 Storey Shear in Braced Models

Cross-bracing transfers lateral loads through axial compression and tension in the bracing members. The bracing models also show increasing storey shear toward the base, with exterior bracing recording the lowest values among the bracing configurations.

Table 6. Storey shear in bracing models (kN).

Floor Level	Center Bracing	Intermediate Bracing	Exterior Bracing
Storey 15	190	175	168
Storey 10	545	510	495
Storey 5	920	875	850
Base	1280	1220	1180

The exterior bracing configuration records a base storey shear of 1180 kN, lower than centre and intermediate bracing. This result indicates efficient load transfer and reduced demand on beams, columns and connections when bracing is positioned near the building perimeter.

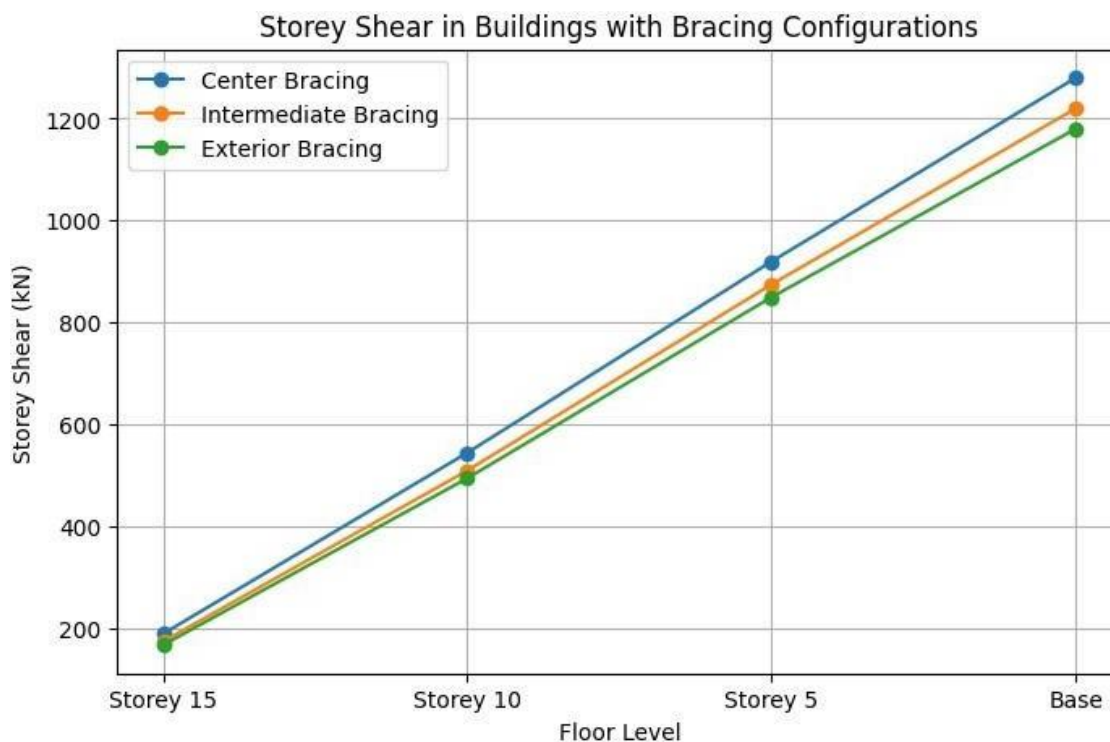


Chart 4. Storey shear variation in buildings with different bracing configurations.

4.5 Overturning Moment

Overturning moment is generated by lateral earthquake forces and tends to rotate the building about its base. It is a critical design parameter for foundations and overall structural stability. The conventional frame records the highest overturning moment, while lateral systems reduce rotational demand.

Table 7. Overturning moment in each building model.

Building Model	Overturning Moment (kN-m)
Conventional Building	48500
Center Shear Wall	38200
Intermediate Shear Wall	35100
Exterior Shear Wall	36200
Center Bracing	42100
Intermediate Bracing	39800
Exterior Bracing	38500

The intermediate shear wall model records the lowest overturning moment of 35,100 kN-m. The exterior shear wall and exterior bracing models also reduce overturning effects compared with the conventional building, confirming that lateral load-resisting elements improve the rotational stability of the high-rise structure.

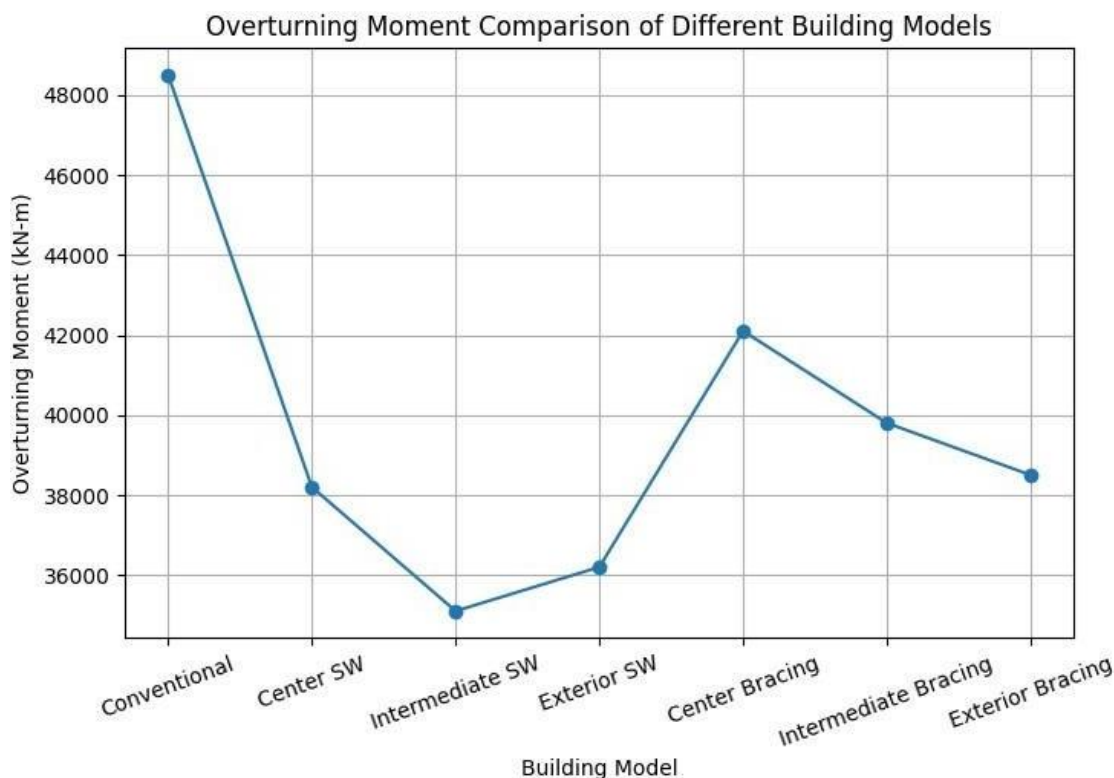


Chart 5. Overturning moment comparison of different building models.

V. DISCUSSION

The comparative results confirm that shear walls and bracing systems significantly improve seismic performance by increasing stiffness, reducing lateral deformation and improving force transfer. The conventional building without a dedicated lateral resisting system is the most flexible model and therefore exhibits the largest displacement, drift and overturning moment.

The influence of location is clear. Moving shear walls and bracing from the centre toward the perimeter improves displacement and drift control because the resisting moment arm is increased. The reported displacement and drift tables show the strongest deformation reduction in exterior configurations. For storey shear and overturning moment, however, the optimal configuration varies: intermediate shear walls provide the lowest reported overturning moment and the lowest storey shear among shear wall models, while exterior bracing provides the lowest storey shear among bracing models.

The overall efficiency ranking retained from the thesis is: exterior shear wall, exterior cross bracing, intermediate shear wall, intermediate cross bracing, centre shear wall, centre cross bracing and conventional building without a lateral system. This ranking reflects not only individual numerical values but also overall stiffness, stability, lateral deformation control and constructability considerations discussed in the thesis.

The findings are consistent with the literature review, which indicates that perimeter shear walls and bracing systems offer better resistance against lateral loads. Shear walls provide monolithic stiffness and high lateral force capacity, while bracing systems provide a practical and economical alternative where architectural or construction constraints limit wall placement.

VI. CONCLUSION

- The conventional 15-storey RC frame without shear wall or bracing records the highest storey displacement, drift and overturning moment.
- Both shear walls and cross-bracing systems significantly reduce lateral displacement and improve seismic performance compared with the conventional building.
- Exterior placement of lateral load-resisting elements is highly effective for controlling displacement and inter-storey drift.

- The intermediate shear wall model records the lowest reported overturning moment and the lowest storey shear among shear wall configurations.
- The exterior bracing model records the lowest storey shear among the bracing configurations and provides a practical alternative to shear wall systems.
- The study identifies exterior shear wall placement as the most efficient overall configuration, followed by exterior cross-bracing, based on the thesis ranking of structural efficiency.
- Appropriate placement of lateral systems is therefore essential for improving the stability, stiffness and serviceability of high-rise reinforced concrete structures under seismic loading.

6.1 Future Scope

- Future research may compare additional bracing configurations such as X-bracing, V-bracing, inverted V-bracing, K-bracing, eccentric bracing and diagonal bracing.
- Hybrid systems combining shear walls and bracing may be evaluated to determine improved control of displacement, drift and structural damage.
- Advanced analysis methods such as Response Spectrum Analysis, Time History Analysis, Nonlinear Static Pushover Analysis and Nonlinear Dynamic Analysis may be adopted for more realistic seismic assessment.
- Future work may include different seismic zones, wind loading, architectural irregularities, soil-structure interaction and optimization of member dimensions, wall thickness, bracing sections and material grades.

REFERENCES

- 1) Agarwal, P., and Shrikhande, M. (2010). Earthquake Resistant Design of Structures.
- 2) Shweta, and Patel. (2014). Comparative study using ETABS.
- 3) Lokesh, and Gopi. (2016). Optimal placement of shear walls.
- 4) Patel, and Mehta. (2017). Analysis of bracing systems.
- 5) Saranya, and Devi. (2018). Seismic analysis of RC structures.
- 6) Varghese, and Krishna. (2019). Dual systems in tall buildings.
- 7) Nisha, and Ramesh. (2020). Performance evaluation of high-rise buildings under wind loads.
- 8) Kumari, and Sharma. (2021). Cost analysis of lateral load-resisting systems.
- 9) Yadav, and Singh. (2022). Optimization techniques for lateral load-resisting systems.
- 10) Abd-el-Rahim, and Farghaly. (2010). Role of shear walls in high-rise buildings.
- 11) Moon. (2018). Performance-based design of tall buildings with braced tube systems.
- 12) IS 875. Code of practice for design loads for buildings and structures, Parts 1 and 2.
- 13) IS 1893:2016. Criteria for earthquake resistant design of structures.
- 14) ACI 318-14. Building Code Requirements for Structural Concrete.