

# A COMPARATIVE ANALYSIS OF THE INFLUENCE OF OPENING CONFIGURATIONS ON THE SEISMIC RESILIENCE OF SHEAR WALLS

Shubham Govardhan Babhulkar<sup>1</sup>, Dr. R. S. Londhe<sup>2</sup>

<sup>1</sup>M. Tech Student, Department of Applied Mechanics, Government College of Engineering Aurangabad, Chhatrapati Sambhajinagar, Maharashtra, India

<sup>2</sup>Professor, Department of Applied Mechanics, Government College of Engineering Aurangabad, Chhatrapati Sambhajinagar, Maharashtra, India.

**ABSTRACT** - Shear walls are essential for resisting lateral forces in high-rise buildings, especially under seismic and wind loads. This study examines the effects of varying opening sizes (1m × 2.5m to 4m × 2.5m) in shear walls on the structural performance of a 14-storey building using ETABS. Key parameters such as lateral displacement, story drift, and shell stresses were analyzed. Results indicate that larger openings increase displacement and drift by up to 35% compared to solid walls, although all models comply with IS 1893:2016 limits. Openings up to 2m × 2.5m maintain acceptable stress levels ( $\leq 11.25$  MPa), offering an optimal balance between structural integrity and architectural function in seismic zones.

**Keywords:** Shear walls, Lateral forces, Seismic performance, Structural analysis, ETABS, Opening sizes, Lateral displacement, Story drift, Shell stresses, High-rise buildings, Inter-story drift, IS 1893:2016, Structural integrity, Seismic zones.

**Author for Correspondence** E-mail: [shubhambabhulkar2001@gmail.com](mailto:shubhambabhulkar2001@gmail.com)<sup>1</sup>, [drlondhe07@gmail.com](mailto:drlondhe07@gmail.com)<sup>2</sup>

## INTRODUCTION

Shear walls, particularly reinforced concrete types, are vital in multi-story buildings for resisting lateral forces from wind and earthquakes, offering high rigidity, ductility, and load-bearing capacity. Openings within these walls affect in-plane behavior and displacement. Performance depends on factors like material, geometry, aspect ratio, and location. Proper reinforcement detailing enhances energy dissipation and prevents brittle failure. Coupled shear wall systems with connecting beams improve seismic response. Precast methods and core walls around elevators and stairwells optimize construction and space use. Finite element tools further refine designs for seismic resilience. Shear walls are critical in resisting lateral forces from wind and seismic activity, contributing to a building's strength, stiffness, and stability. These walls endure shear, axial, bending, torsional, and uplift forces. Shear and bending stresses arise from lateral loads, while axial forces result from gravity and overturning moments. Torsion occurs due to mass-rigidity offsets, and uplift forces act vertically, threatening stability. Effective design and reinforcement detailing are essential to counter these forces and ensure structural integrity. Shear walls are essential for resisting lateral forces from wind, earthquakes, and dynamic loads, particularly in seismic-prone regions. As per IS 456:2000 and IS 1893:2016, they must maintain adequate strength and stiffness under such conditions.

In modern construction, shear walls often incorporate openings for doors, windows, and mechanical ducts as demonstrated in Figure 1.1. Modern designs often incorporate openings for functional needs, which can reduce stiffness, alter load paths, and create stress concentrations. While small, symmetric openings have minimal effects, larger or asymmetrical ones can compromise performance. Proper reinforcement detailing around openings is crucial to ensure seismic resilience.



**Figure 1.1 Openings in Shear Wall**

Openings in shear walls reduce stiffness, disrupt stress distribution, and affect overall structural performance. Their size, shape, and location influence lateral displacement and seismic response. As per IS 1893:2016 and IS 13920:2016, improper openings can cause stress concentrations and instability, requiring additional horizontal, diagonal, and boundary reinforcement. Coupling beams, special boundary elements, and lintels help restore load paths and enhance ductility. IS 456:2000 further emphasizes detailed reinforcement to compensate for reduced cross-section and strength.

## LITERATURE REVIEW

Previous research shows that openings in shear walls reduce stiffness, alter load paths, and impact energy dissipation, influencing seismic performance. This review summarizes key findings on these effects.

**Bush R. C. et al. (2022)** examined the influence of staggered versus uniform openings in shear walls of high-rise structures under seismic loading. Using ETABS software, the study analyzed a 10-story asymmetric building with various shapes of vertical staggered openings, including square, rectangular, and triangular configurations. Findings indicated that staggered square and rectangular openings outperformed both uniform openings and solid walls in terms of lateral displacement, story drift, stiffness, and shear resistance. The research emphasized that strategic placement and shape of openings can enhance structural efficiency without compromising seismic performance. [1]

**G.D. Pawar, et al. (2022)** investigated how the size and placement of openings in shear walls affect the seismic performance of a 15-story RC building. Using STAAD, 32 models with inline and staggered openings were analyzed under static and dynamic loads across seismic zones III and IV with varying soil conditions. Results showed that staggered openings led to more uniform stress distribution, and optimal opening percentages varied with seismic zone and soil type. [2]

**Manoj Kumar, et al. (2022)** studied the impact of opening shape and size on lateral deformation in a 10-story building using SAP2000. Shear walls with triangular, square, and circular openings—each with 20% and 25% opening ratios—were analyzed under seismic loading. Results showed variations in top-story lateral deformation depending on the shape and size of openings. [3]

**V. Todea, et al. (2021)** conducted an experimental study on concrete structural walls with regular openings under vertical and cyclic lateral loads. Five specimens, including composite steel–concrete walls with and without openings, were tested. Results showed that using steel fiber-reinforced concrete and composite connections improved ductility and seismic performance, effectively compensating for the weaknesses introduced by openings. [4]

**Sivaguru V, et al. (2020)** performed used nonlinear finite element analysis in ANSYS 15.0 to study squat RC shear walls with utility openings under axial and lateral loads. Results showed that openings reduced shear strength, while fiber-reinforced concrete enhanced crack resistance, offering an effective strengthening approach for walls with functional openings. [5]

**V. Naresh K, et al. (2020)** analyzed medium-rise RC apartment buildings (8–12 stories) with shear walls containing openings, focusing on their impact on story drift, stiffness, shear, and internal stresses. A 3D analysis was conducted to evaluate how the size and location of openings affect structural performance, providing practical insights for engineering applications. [6]

**Mohamed Husain, et al. (2019)** developed a 3D nonlinear finite element model in ABAQUS to study shear walls with openings strengthened using CFRP wraps. Validated against experimental data, the model showed that CFRP significantly enhanced lateral load capacity, ductility, and energy dissipation in shear walls with openings. [7]

**Safoura Darabi, et al. (2018)** used ABAQUS to analyze one-story tunnel-form buildings with and without openings. Results showed that openings reduced structural performance, with lower base shear, ductility, and resistance factors compared to the solid wall structure. [8]

**Ehsan Montazeri et al. (2018)** utilized ABAQUS software to analyze reinforced concrete (RC) shear walls featuring vertically staggered openings under progressively increasing lateral loads. The study modeled 1:4 scale, four-story wall specimens with varying opening angles to explore their impact on structural response. Results, which were corroborated with experimental observations, revealed that different opening arrangements significantly affect failure mechanisms and the overall seismic performance of RC walls. The study also highlighted the critical role of opening geometry in dictating lateral stiffness and energy dissipation capacity. [9]

**M. Vatandoust, et al. (2018)** proposed a simplified method to determine optimal shear wall opening dimensions using the continuous method, based on wall displacement at roof level. The study established relationships between opening size and displacement, and validated findings through two case studies using ETABS. Comparisons between optimal and non-optimal openings demonstrated the method's effectiveness in minimizing lateral displacement. [10]

**Daniel Dan, et al. (2018)** investigated the behavior of hybrid walls with centered and staggered openings using nonlinear finite element analysis (ATENA). Based on previous experimental tests on 1:3 scale steel-concrete composite elements, the study compared the performance of hybrid walls with openings to solid walls, focusing on maximum load, deformation capacity, and stiffness degradation. [11]

**S. H. Jagadale, et al. (2016)** analyzed the performance of shear walls with varying thicknesses and types of openings (vertical, staggered, and no openings). The study found that shear walls with staggered openings performed better in seismic zones compared to those with vertical openings or no openings. [12]

**G. Muthukumar, et al. (2015)** examined the behavior of shear walls with and without openings under monotonic and dynamic loading using nonlinear finite element analysis. The study found that shear walls with central openings exhibited less displacement than those with other openings. It was recommended that openings should be placed away from the boundary to improve performance during seismic events. [13]

**Bing Lia, et al. (2015)** tested six one-third scaled RC walls with regular and irregular openings to investigate the impact of opening size, arrangement, and irregularities on seismic behavior. The study revealed that flanges increased ultimate strength but reduced deformation capacity, potentially changing the failure mode from ductile to brittle shear failure. Concrete crushing and rebar fracture were concentrated in the flanges. [14]

**Abdul Kadir M. Et Al. (2015)** proposed adding haunches to the corners of rectangular openings to enhance the strength of coupled shear walls. Using nonlinear finite element analysis (NLFA) and continuous connection method (CCM), the study found that octagonal openings significantly increased the ultimate load of shear walls with minimal impact on the overall structure weight. [15]

## AIM AND OBJECTIVES

The specific objectives of the research are,

1. To study irregularities in structural analysis and analysis of 14 storeys structure as per Indian standard code.
2. To evaluate the impact of different opening sizes in reinforced concrete shear walls on the seismic performance of regular buildings.
3. To analyses the critical parameters of shear wall such as base shear, story drift, story stiffness and maximum displacement.

## METHODOLOGY

Shear walls are crucial for enhancing the seismic resilience of structures, providing lateral stiffness and strength. However, openings in shear walls, required for architectural and functional purposes, can affect their seismic performance. This study explores the effect of varying opening sizes (1 m x 2.5 m, 2 m x 2.5 m, 3 m x 2.5 m, and 4 m x 2.5 m), along with different structural parameters outlined in Table 1.1, on the seismic performance of buildings using response spectrum analysis in ETABS-V21, in accordance with Indian seismic design standards. The research aims to identify the optimal opening configuration that balances structural performance, safety, and economy. Key parameters such as lateral deflection, drift, shear forces, and moments are analysed, along with the influence of symmetrical and asymmetrical placements on torsional behaviour. The study also compares solid and open shear walls to assess the trade-offs between structural efficiency and architectural needs, providing design recommendations for buildings in seismic zones.

**Table 1.1 Building Description**

SR. NO.	BUILDING DATA	PARAMETERS
1	Type of Building	Commercial Building
2	Building Frame Type	SMRF with Shear Wall
3	Plan Dimension	14 m X 22 m
4	Number of Stories	14
5	Height of Building	49 m
6	Floor to Floor Height	3.5 m
7	Support Condition	Fixed
8	Grade of Concrete	M25
9	Grade of Steel	HYSD Reinforcement of Fe500
10	Column Size	600 mm X 600 mm
11	Beam Size	600 mm X 350 mm

12	Length of Shear Wall in Plan	6 m	
13	Thickness of Shear Wall	300 mm	
14	Opening Size in Shear Wall	1	1 m X 2.5 m
		2	2 m X 2.5 m
		3	3 m X 2.5 m
		4	4 m X 2.5 m
15	Thickness of Slab	150 mm	
16	Thickness of Wall	230 mm	
17	Density of Concrete	25 kN/m <sup>3</sup>	
18	Density of Brick	20 kN/m <sup>3</sup>	

According to IS 1893 (Part 1):2016, a 5% damping factor is applied in the response spectrum analysis. Shear wall models with various opening configurations are evaluated using ETABS-V21 and compared in terms of storey displacement, drift, shear, and time period. Each model includes a conventional structure with peripheral shear walls and variants featuring different opening arrangements. Load values, derived from Table 1.2, consider structural geometry, material properties, usage, and site location to ensure realistic load combinations for safety under service and seismic conditions.

**Table 1.2 Loding Condition and Parameters**

Sr. No.	LOADS	SPECIFICATION	VALUE	REFERENCES
1	Dead Load	Self-Weight Factor	1.0 kN/m <sup>2</sup>	IS 875 (Part-1) 1987
		Outer Wall Load	14 kN/m	
		Internal Wall Load	9 kN/m	
		Parapet Wall Load	5 kN/m	
		Floor Finish + Ceiling Plaster	1.5 kN/m <sup>2</sup>	
2	Live Load	Live Load	4 kN/m <sup>2</sup>	IS 875 (Part-2)
		Roof Live	2 kN/m <sup>2</sup>	
3	Earthquake Load	Seismic Zone	Zone IV	IS 1893 (Part-1) 2016
		Zone Factor (Z)	0.24	
		Soil Type	Medium	
		Damping Ratio	5%	
		Response Reduction Factor (R)	5	
Importance Factor (I)	1.2			

Structural elements are illustrated in both plan and 3D views using ETABS V21, as depicted in Figures 1.2 to 1.7.

- 1) **Model I** - Shear Wall Structure without Opening.
- 2) **Model II** - Shear Wall Structure with Opening of Size (1m X 2.5m).
- 3) **Model III** - Shear Wall Structure with Opening of Size (2m X 2.5m).
- 4) **Model IV** - Shear Wall Structure with Opening of Size (3m X 2.5m).
- 5) **Model V** - Shear Wall Structure with Opening of Size (4m X 2.5m)

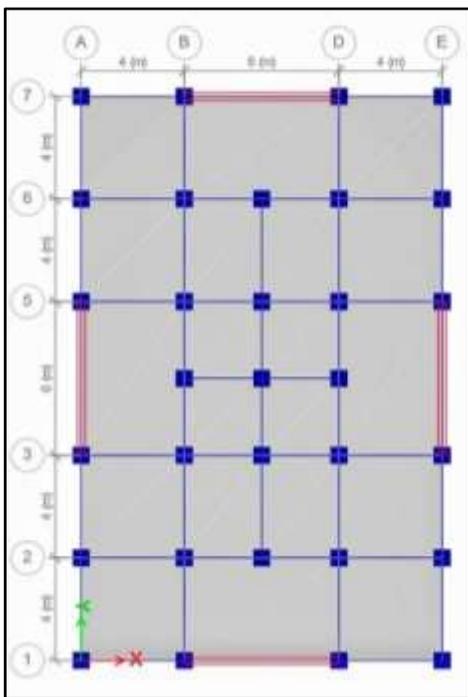


Figure 1.2 Plan of Structure

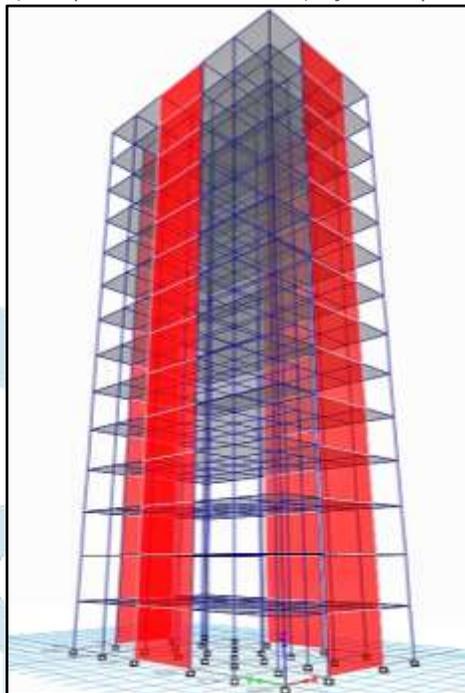


Figure 1.3 Model I - Shear Wall Structure without Opening.

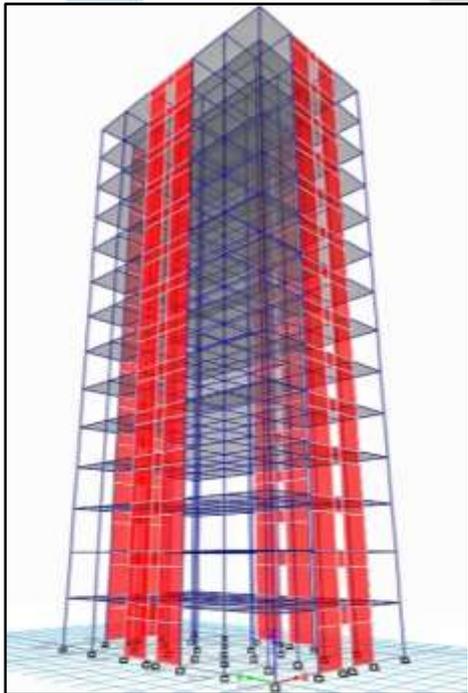


Figure 1.4 Model II - Shear Wall Structure with Opening of Size (1m X 2.5m)

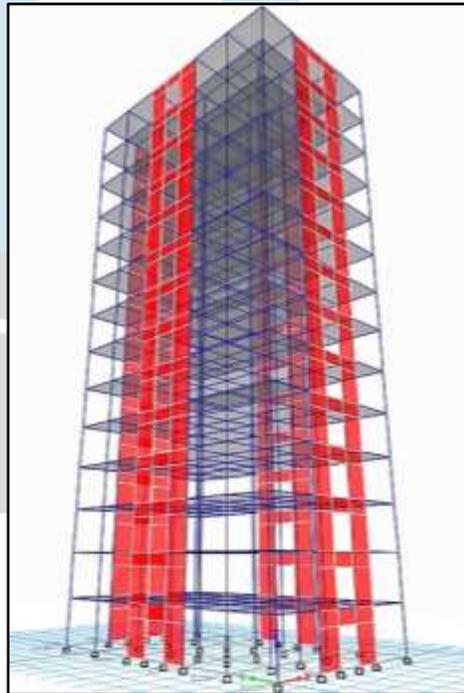
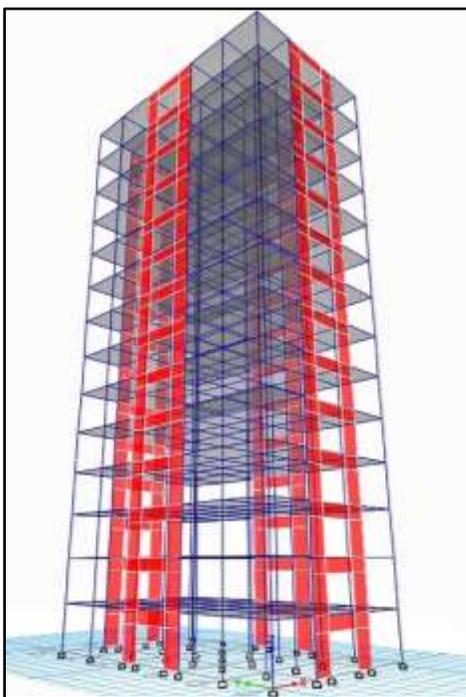
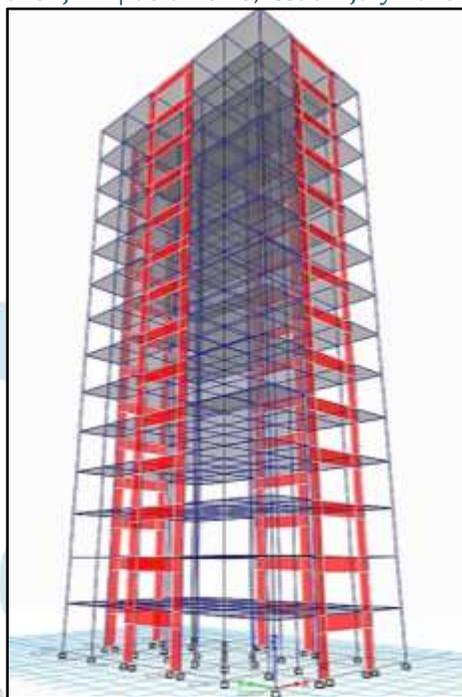


Figure 1.5 Model III - Shear Wall Structure with Opening of Size (2m X 2.5m)



**Figure 1.6 Model IV - Shear Wall Structure with Opening of Size (3m X 2.5m)**



**Figure 1.7 Model V - Shear Wall Structure with Opening of Size (4m X 2.5m)**

## RESULT AND DISCUSSIONS

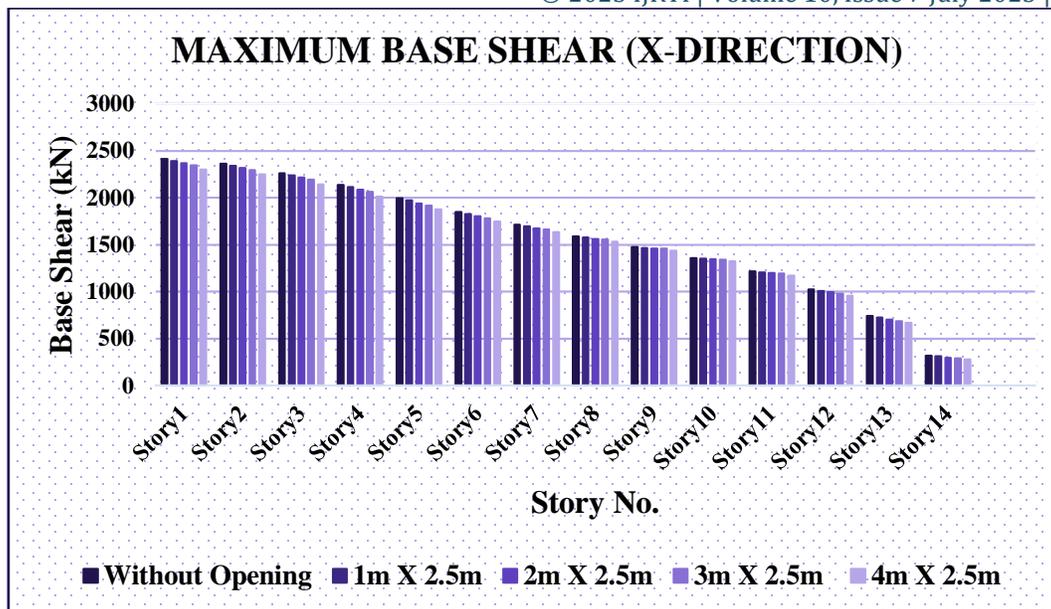
Key results on story shear, lateral displacement, drift, and shear stresses demonstrate the influence of shear wall configurations on seismic behavior.

### STORY SHEAR

Storey shear analysis in the X-direction shows that shear wall openings reduce lateral load capacity, especially at lower storeys. A  $4\text{ m} \times 2.5\text{ m}$  opening decreased base shear from 2412.46 kN to 2303.13 kN, indicating reduced seismic performance. In line with IS 1893:2016 (Clause 7.1), smaller openings ( $1\text{ m} \times 2.5\text{ m}$ ) had minimal effect on lateral strength.

**Table 1.3 Comparison of Story Shear in X-Direction (kN)**

Sr. No.	No. of Floors	Story Height (m)	Without Opening	1m X 2.5m	2m X 2.5m	3m X 2.5m	4m X 2.5m
1	Story14	49	317.079	312.297	297.145	287.66	278.188
2	Story13	45.5	740.303	723.848	703.678	686.761	665.824
3	Story12	42	1025.08	1008.43	993.086	979.312	956.63
4	Story11	38.5	1217.8	1206.39	1197.51	1190.93	1170.56
5	Story10	35	1359.56	1350.83	1343.76	1341.77	1323.32
6	Story9	31.5	1476.9	1467.31	1458	1456.52	1437.6
7	Story8	28	1590.04	1577.38	1562.78	1557.3	1534.42
8	Story7	24.5	1712.48	1695.85	1675.04	1662.93	1633.12
9	Story6	21	1848.62	1828.04	1801.92	1783.48	1745.94
10	Story5	17.5	1993.11	1970.4	1941.34	1918.48	1874.29
11	Story4	14	2135.8	2112.41	2084.57	2060.69	2012.61
12	Story3	10.5	2263.27	2240.41	2214.78	2192.41	2143.73
13	Story2	7	2361.85	2339.57	2316.94	2296.85	2250.09
14	Story1	3.5	2412.46	2388.2	2367.01	2347.92	2303.13



**Figure 1.8 Base Shear in X-Direction**

Storey shear analysis in the Y-direction shows a decline in shear capacity with increasing opening size in shear walls, similar to the X-direction. Detailed values are summarized in Table 1.4, and the corresponding variation is illustrated in Figure 1.9, at the base, shear reduces from 2409.51 kN (no opening) to 2299.41 kN (4 m × 2.5 m opening), indicating reduced seismic resistance due to larger openings.

**Table 1.4 Comparison of Story Shear in Y-Direction (kN)**

Sr. No.	No. of Floors	Story Height (m)	Without Opening	1m X 2.5m	2m X 2.5m	3m X 2.5m	4m X 2.5m
1	Story14	49	312.655	305.084	290.101	278.124	267.94
2	Story13	45.5	729.243	712.366	691.148	671.468	650.192
3	Story12	42	1014.29	998.581	980.89	963.784	940.109
4	Story11	38.5	1215.84	1202.89	1191.36	1180.35	1157.45
5	Story10	35	1369.96	1356.94	1348.74	1342.6	1320.64
6	Story9	31.5	1498.58	1482.68	1473.58	1468.57	1445.5
7	Story8	28	1620.18	1600	1587.81	1580.24	1553.18
8	Story7	24.5	1745.97	1721.5	1704.55	1692.04	1658.83
9	Story6	21	1879.9	1851.98	1830.09	1812.22	1772.11
10	Story5	17.5	2019.22	1989.74	1965.53	1943.95	1898.1
11	Story4	14	2153.45	2124.9	2100.61	2077.85	2028.81
12	Story3	10.5	2272.48	2246.2	2223.06	2201.33	2152.04
13	Story2	7	2364.59	2340.14	2318.7	2298.81	2251.68
14	Story1	3.5	2409.51	2385.62	2363.88	2344.54	2299.41

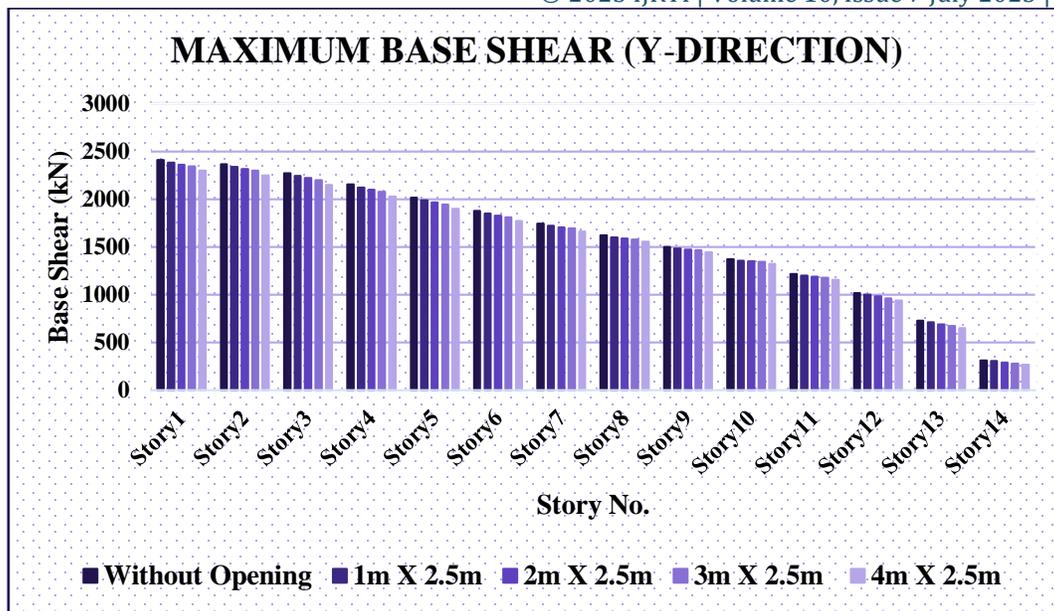


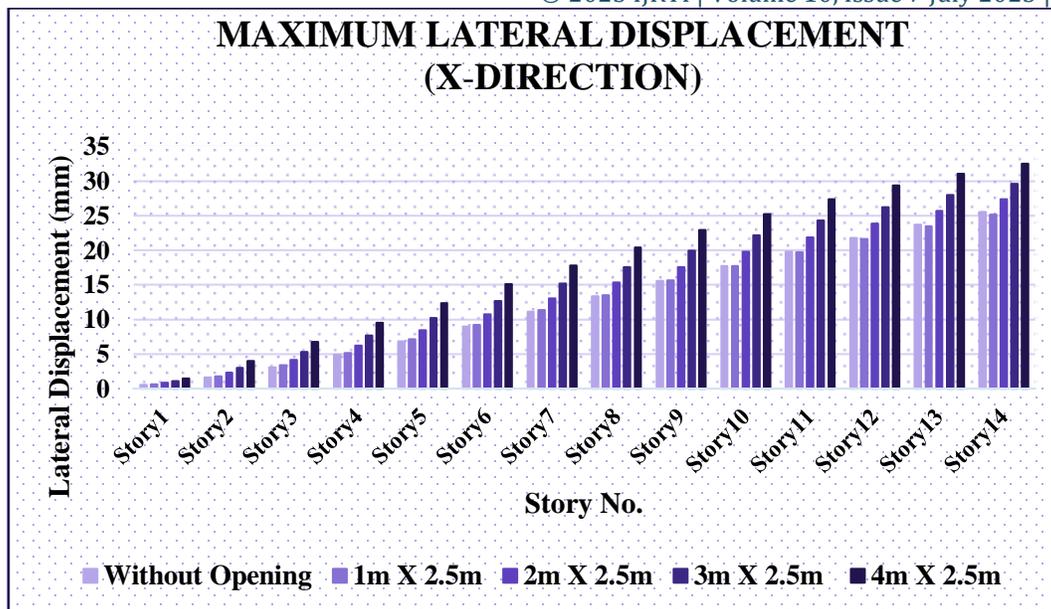
Figure 1.9 Base Shear in Y-Direction

## LATERAL DISPLACEMENT

Lateral displacement in the X-direction increases with larger shear wall openings due to a reduction in structural stiffness. For the 14-storey, 49 m tall building analyzed, none of the configurations exceed the IS 1893:2016 displacement limit of 196 mm. Displacement values are presented in Table 1.5. However, openings of 3 m × 2.5 m and 4 m × 2.5 m result in significantly higher displacements, raising concerns about inter-storey drift and potential non-structural damage. The displacement trends are illustrated in Figure 1.10.

Table 1.5 Comparison of lateral Displacement in X-Direction (mm)

Sr. No.	No. of Floors	Story Height (m)	Without Opening	1m X 2.5m	2m X 2.5m	3m X 2.5m	4m X 2.5m
1	Story14	49	25.558	25.159	27.366	29.602	32.512
2	Story13	45.5	23.727	23.452	25.66	28.013	31.055
3	Story12	42	21.791	21.635	23.82	26.242	29.349
4	Story11	38.5	19.782	19.724	21.853	24.292	27.4
5	Story10	35	17.697	17.724	19.769	22.18	25.238
6	Story9	31.5	15.548	15.65	17.588	19.934	22.902
7	Story8	28	13.358	13.524	15.334	17.584	20.423
8	Story7	24.5	11.154	11.373	13.036	15.156	17.826
9	Story6	21	8.974	9.233	10.726	12.676	15.132
10	Story5	17.5	6.864	7.146	8.441	10.175	12.363
11	Story4	14	4.886	5.164	6.231	7.691	9.547
12	Story3	10.5	3.111	3.355	4.158	5.278	6.727
13	Story2	7	1.631	1.802	2.306	3.02	3.978
14	Story1	3.5	0.547	0.614	0.814	1.087	1.484

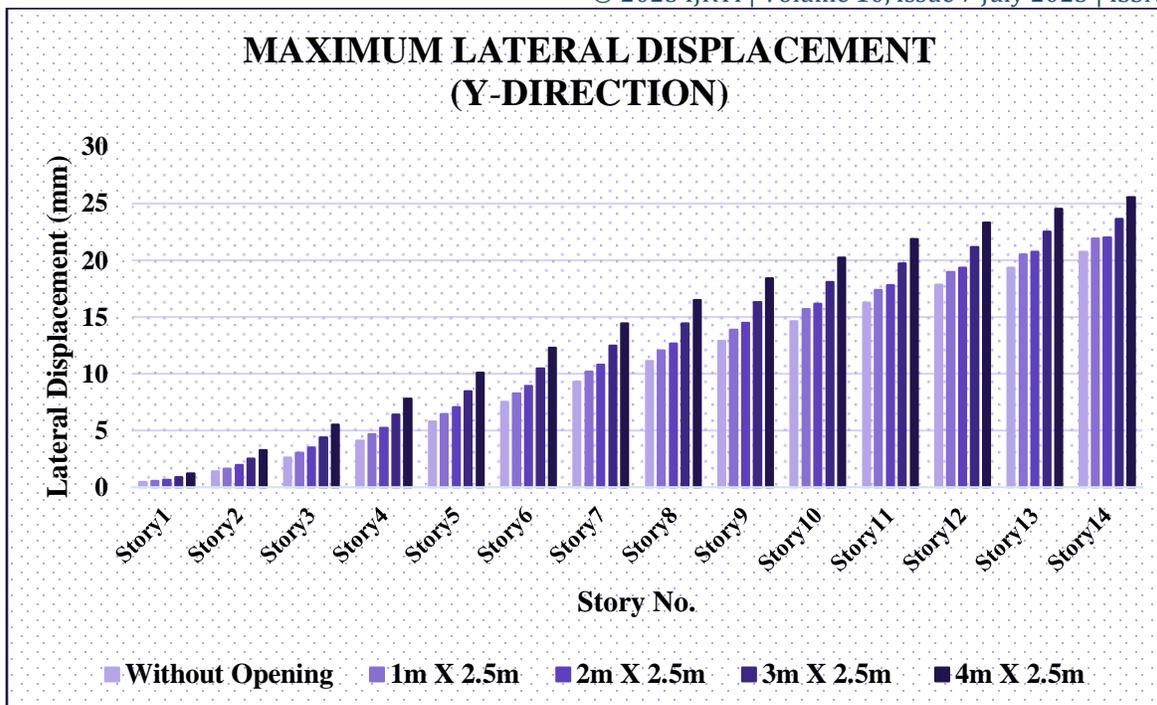


**Figure 1.10 Lateral Displacement in X-Direction**

All displacement values in both X and Y directions are below the 196 mm limit specified by IS 1893:2016, as shown in Table 1.6. Larger openings lead to increased displacement, potentially reducing stiffness and affecting inter-storey drift and non-structural elements, as depicted in Figure 1.11.

**Table 1.6 Comparison of lateral Displacement in Y Direction (mm)**

Sr. No.	No. of Floors	Story Height (m)	Without Opening	1m X 2.5m	2m X 2.5m	3m X 2.5m	4m X 2.5m
1	Story14	49	20.732	21.911	21.992	23.639	25.546
2	Story13	45.5	19.345	20.503	20.732	22.496	24.536
3	Story12	42	17.838	18.988	19.332	21.174	23.3
4	Story11	38.5	16.261	17.38	17.816	19.691	21.852
5	Story10	35	14.61	15.679	16.189	18.061	20.218
6	Story9	31.5	12.891	13.898	14.467	16.304	18.422
7	Story8	28	11.122	12.056	12.669	14.442	16.491
8	Story7	24.5	9.325	10.177	10.816	12.496	14.446
9	Story6	21	7.534	8.292	8.936	10.49	12.302
10	Story5	17.5	5.787	6.44	7.062	8.45	10.081
11	Story4	14	4.137	4.671	5.235	6.409	7.806
12	Story3	10.5	2.648	3.046	3.508	4.414	5.514
13	Story2	7	1.398	1.643	1.955	2.535	3.267
14	Story1	3.5	0.47	0.563	0.692	0.915	1.22



**Figure 1.11 Lateral Displacement in Y-Direction**

### STORY DRIFT

As per IS 1893:2016 (Clause 7.11.1), the maximum storey drift is limited to 14 mm (0.004 times storey height). Table 1.7 shows that all models comply with this limit. Analysis in the X-direction reveals that maximum drift occurs at mid-height, with larger openings leading to increased drift values demonstrated in Figure 1.12. The 4m × 2.5m opening configuration shows the highest drift, indicating reduced stiffness and increased lateral deformation.

**Table 1.7 Comparison of Story Drift in X-Direction (mm)**

Sr. No.	No. of Floors	Story Height (m)	Without Opening	1m X 2.5m	2m X 2.5m	3m X 2.5m	4m X 2.5m
1	Story14	49	0.000543	0.000505	0.00051	0.000482	0.000449
2	Story13	45.5	0.000574	0.000542	0.000555	0.000546	0.000541
3	Story12	42	0.000597	0.000573	0.000599	0.00061	0.00063
4	Story11	38.5	0.00062	0.0006	0.000636	0.000662	0.0007
5	Story10	35	0.000636	0.000619	0.000663	0.0007	0.000751
6	Story9	31.5	0.000645	0.000631	0.000679	0.000725	0.000785
7	Story8	28	0.000645	0.000634	0.000686	0.000739	0.000807
8	Story7	24.5	0.000634	0.000626	0.000683	0.000744	0.00082
9	Story6	21	0.00061	0.000606	0.000669	0.00074	0.000826
10	Story5	17.5	0.00057	0.000573	0.000643	0.000726	0.000826
11	Story4	14	0.00051	0.00052	0.000599	0.000699	0.000818
12	Story3	10.5	0.000424	0.000445	0.000533	0.000649	0.00079
13	Story2	7	0.00031	0.00034	0.000428	0.000554	0.000714
14	Story1	3.5	0.000156	0.000176	0.000232	0.000311	0.000424

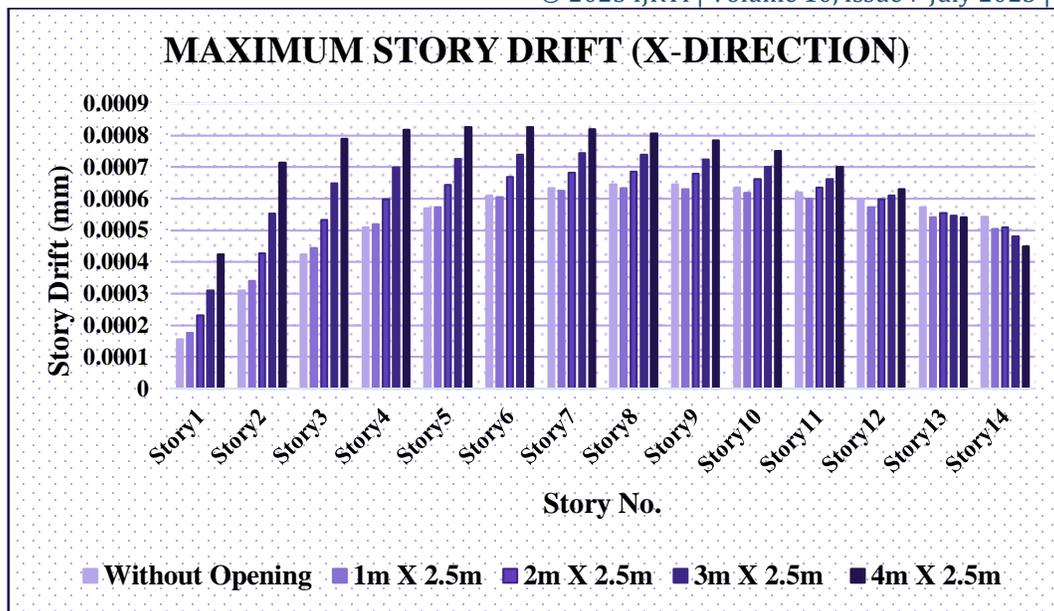


Figure 1.12 Story Drift in X-Direction

The analysis of story drift in the Y-direction shows that all models, including those with openings, are well below the permissible drift limit of 0.004 (IS 1893:2016). Table 1.8 confirms that all configurations meet the code requirements. The model without openings exhibits the lowest drift, while larger openings lead to higher drift values, with the 4m × 2.5m opening showing the maximum drift of 0.000666 at Story 5. All results are within the 14 mm (0.014 m) limit.

Table 1.8 Comparison of Story Drift in Y-Direction (mm)

Sr. No.	No. of Floors	Story Height (m)	Without Opening	1m X 2.5m	2m X 2.5m	3m X 2.5m	4m X 2.5m
1	Story14	49	0.000417	0.000417	0.000383	0.000352	0.000317
2	Story13	45.5	0.000448	0.000453	0.000425	0.00041	0.000395
3	Story12	42	0.00047	0.000484	0.000464	0.000465	0.00047
4	Story11	38.5	0.000492	0.000511	0.000497	0.000512	0.00053
5	Story10	35	0.00051	0.000532	0.000524	0.000547	0.000576
6	Story9	31.5	0.000521	0.000547	0.000542	0.000573	0.000609
7	Story8	28	0.000526	0.000553	0.000553	0.00059	0.000633
8	Story7	24.5	0.000521	0.000551	0.000555	0.0006	0.00065
9	Story6	21	0.000505	0.000538	0.000548	0.000602	0.000661
10	Story5	17.5	0.000475	0.000511	0.000531	0.000595	0.000666
11	Story4	14	0.000428	0.000467	0.000499	0.000577	0.000664
12	Story3	10.5	0.000358	0.000402	0.000447	0.00054	0.000646
13	Story2	7	0.000266	0.000309	0.000363	0.000465	0.000587
14	Story1	3.5	0.000134	0.000161	0.000198	0.000262	0.000349

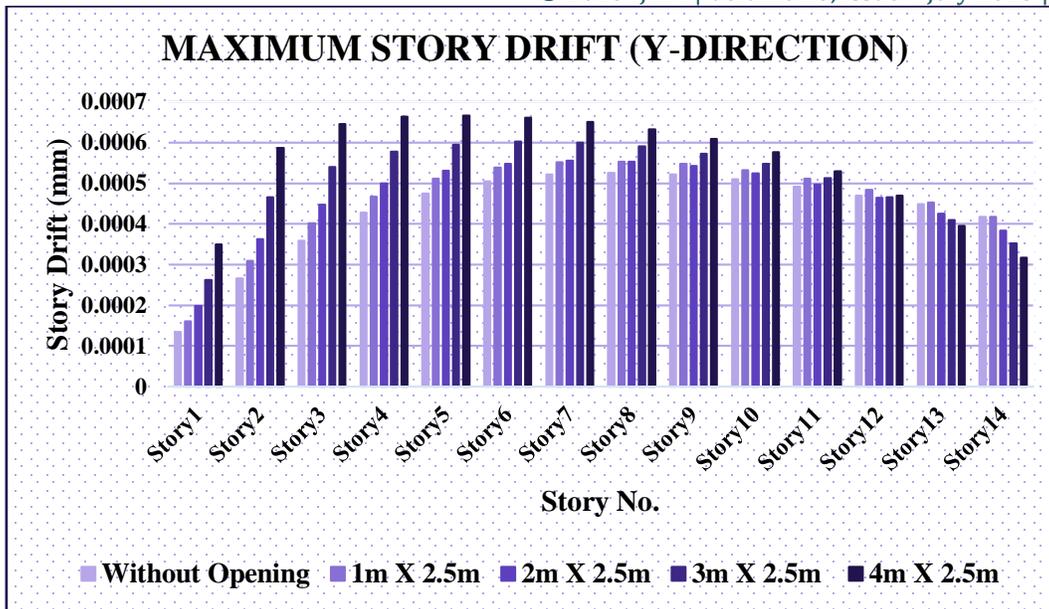


Figure 1.13 Story Drift In Y-Direction

**SHEAR STRESSES (MPa)**

Larger openings in shear walls, as demonstrated in Figures 1.14 to 1.18, lead to increased shell stress concentrations, indicating a reduction in structural efficiency under lateral loads.

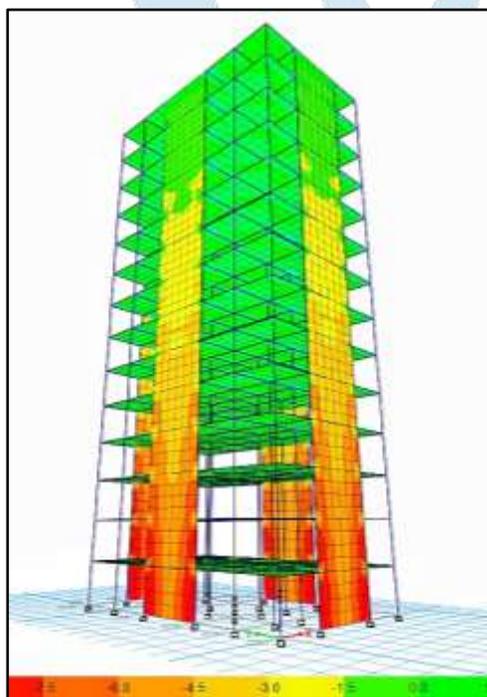
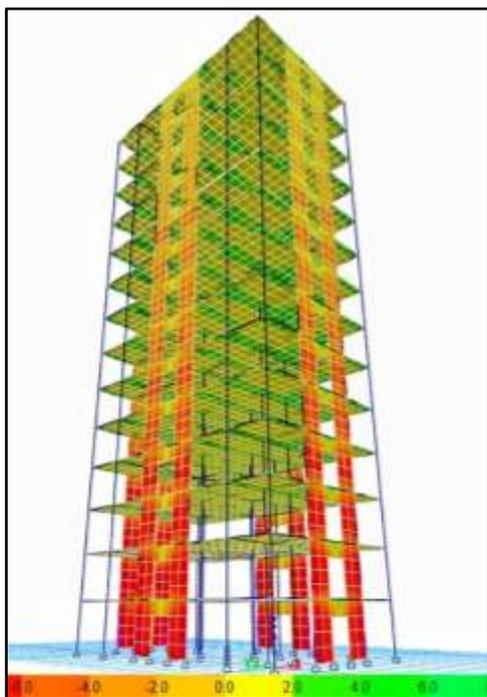


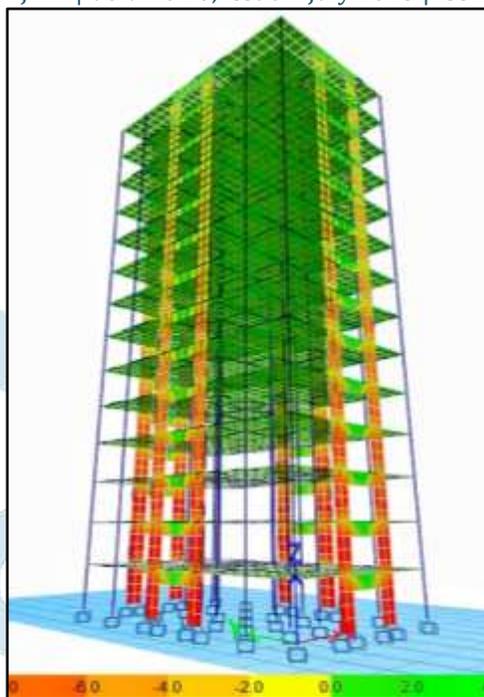
Figure 1.14 Model I - Shear Wall Structure without Opening.



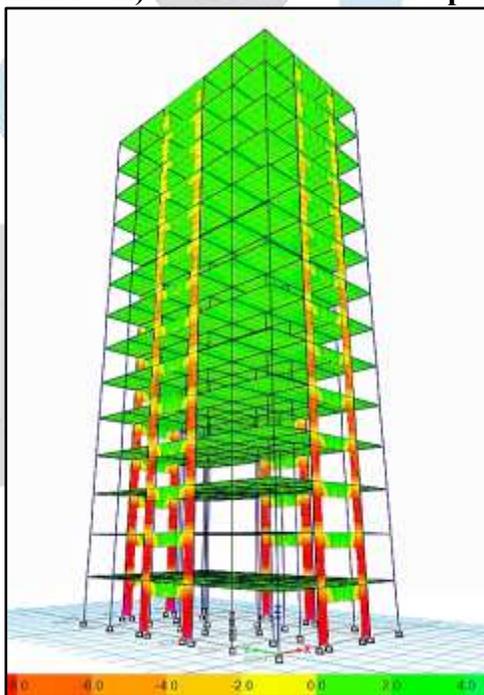
Figure 1.15 Model II - Shear Wall Structure with Opening of Size (1m X 2.5m)



**Figure 1.16 Model III - Shear Wall Structure with Opening of Size (2m X 2.5m)**



**Figure 1.17 Model IV - Shear Wall Structure with Opening of Size (3m X 2.5m)**



**Figure 1.18 Model V - Shear Wall Structure with Opening of Size (4m X 2.5m)**

Shell stress values in the shear wall models increased with the size of the openings. The model without openings (Model I) exhibited the lowest stress at 10.01 MPa, whereas the model with the largest opening (4 m × 2.5 m) experienced the highest stress of 13.54 MPa. These results suggest that larger openings concentrate stress within the wall, potentially reducing its efficiency under lateral loading.

## CONCLUSIONS

The structural analysis of RC shear walls with varying opening sizes (1m x 2.5m, to 4m x 2.5m) and a solid wall (without openings) leads to the following conclusions:

1. All models, including those with openings, show displacement values within the 196 mm limit of IS 1893:2016.
2. Lateral displacement increases with opening size, with the solid wall showing the lowest and the 4m x 2.5m configuration the highest values.
3. Inter-storey drift ratios remained under the 0.004 limit, but larger openings resulted in higher drift values, with the 4m x 2.5m model reaching the highest drift at 0.000666.
4. Story stiffness decreased with larger openings, with the solid wall exhibiting the highest stiffness and the 4m x 2.5m model the lowest.
5. Larger openings reduce seismic resistance and increase vulnerability to non-structural damage.
6. The 1m x 2.5m and 2m x 2.5m configurations provide a balanced performance, maintaining stiffness, controlling displacement, and minimizing drift.

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