Seismic Performance Evaluation of Multi-Storey RCC Buildings with Shear Walls Using ETABS

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ABSTRACT

This study investigates the seismic performance of multi-storey reinforced concrete (RC) buildings integrated with RC shear walls, using ETABS software for structural modelling and dynamic analysis. Building models with G+3, G+13, and G+23 storeys were analysed in accordance with IS 1893:2016 provisions, representing seismic conditions of Zone V. The research examines the effect of shear wall placement on key seismic response parameters, including storey drift, base shear, fundamental time period, and hinge formation. The analytical results demonstrate that incorporating shear walls markedly increases lateral stiffness, decreases displacement, and enhances overall structural stability. The location of shear walls, whether at the corners, core, or along the periphery, significantly influences torsional response and helps achieve Immediate Occupancy (IO) performance levels. The findings confirm that shear walls provide substantial seismic resistance for low, mid, and high-rise structures compared to bare frame systems. This work offers a practical framework for designing earthquake-resilient RC buildings and guides retrofitting measures for structures in high-seismic regions.

Keywords: Shear walls; Seismic performance; Storey drift; Base shear; Fundamental time period; Lateral stiffness; Torsional response; Seismic Zone V; Earthquake-resistant design; Structural stability;

INTRODUCTION

Earthquakes are among the most destructive natural phenomena, resulting from sudden movements of tectonic plates beneath the Earth's crust [1]. The ground shaking caused by these movements poses a serious threat to life, infrastructure, and the economy. Ensuring the seismic stability of buildings during strong ground motions is therefore a major concern in structural engineering. Beyond life safety, serviceability and economic loss are also critical considerations in earthquake-resistant design [2,3]. Unlike wind or gravity loads, seismic loads induce complex dynamic behavior and significant inelastic deformations in structures, requiring advanced analytical approaches to understand their response. Previous studies have shown that structural damage during earthquakes is primarily due to excessive lateral displacement and inadequate stiffness [4,5]. To mitigate these effects, reinforced concrete (RC) shear walls are widely used as one of the most efficient lateral force-resisting elements. When strategically placed, shear walls enhance lateral stiffness, reduce storey drift, and prevent catastrophic collapse under seismic excitation. Typically, columns, beams, and load-bearing walls transfer gravity loads to the foundation, whereas shear walls resist horizontal forces generated by wind and earthquakes. In high-rise structures, their role becomes even more vital due to increased lateral demands [6,7].

According to IS 456:2000, the minimum thickness of a shear wall should not be less than 150 mm. Shear walls, often referred to as structural walls, serve a dual purpose: resisting lateral forces and acting as vertical load-bearing elements [8]. However, irregular configurations such as asymmetric placement or openings within shear walls can lead to torsional irregularities, particularly in high-seismic zones [9]. Therefore, symmetrical arrangements are generally preferred to minimize torsional effects and ensure balanced stiffness distribution [10,11,12]. This research focuses on evaluating the seismic performance of multi-storey RC buildings with shear walls placed at different locations using ETABS software [13]. Building configurations with G+3, G+13, and

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G+23 storeys are analyzed under Zone V conditions, in accordance with IS 1893:2016 guidelines [14-17]. The study investigates key response parameters such as storey drift, base shear, time period, and hinge formation using the dynamic time-history method with the 1940 El Centro earthquake record (Ms = 7.2, PGA = 0.31g) [18,19,20,21]. The findings aim to provide insights into optimal shear wall positioning to achieve improved seismic resistance and performance for RC buildings in highly seismic regions.

METHODOLOGY

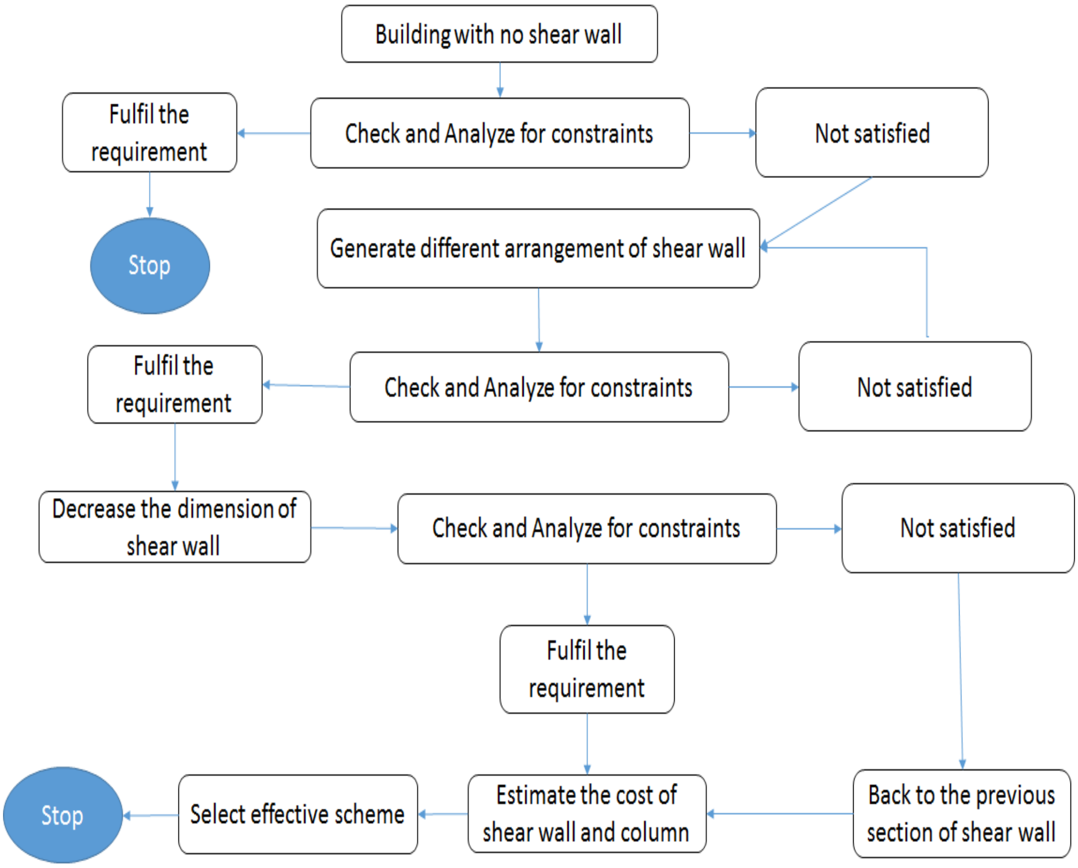
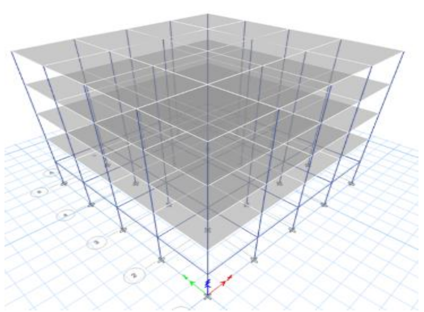
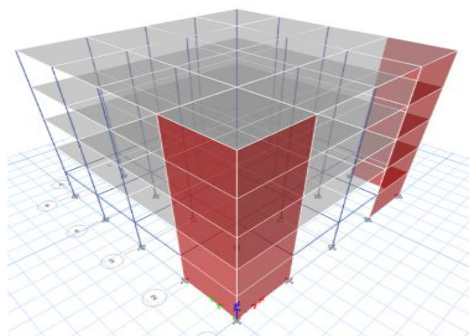


Figure 1. Flowchart for Seismic Performance Evaluation of RC Buildings with Shear Walls.

Low-rise building (G+3 storey building)

Structure specification: Material a) concrete = M30, b) steel = HYSD 550 Section property: a) column size = 300 mm x 450 mm, b) beam size = 300mm x 450mm, Area section: Slab thickness = 120mm (shell-thin); Area of plan = 16.92m x 16.92m, Number of grid lines in both direction = 5,

	
Case 1A: Without a shear wall	Case 1B: with a shear wall at two corners

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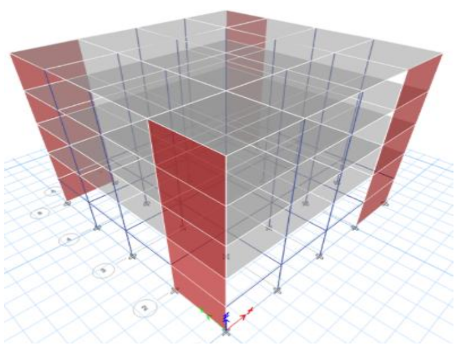
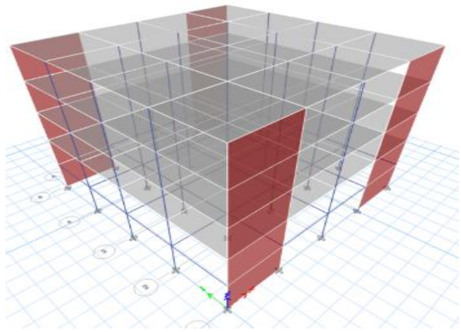
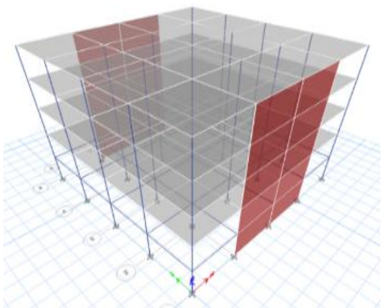
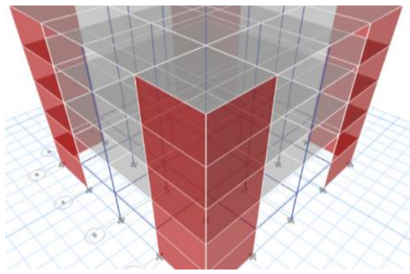
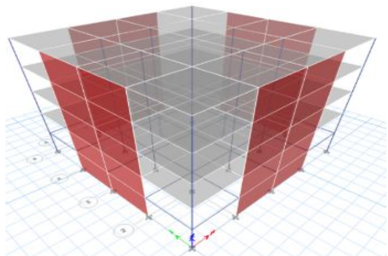
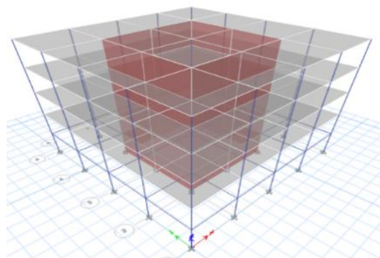
	
Case 1C: with SWat the corner unsymmetrically	Case 1D: with SW along the X dir. At Corner
	
Case 1E: with SW mid of the face in X direction.	Case1F: with a shear wall at the corners symmetrically
	
Case 1G: with SW at mid of outer face	Case 1H: with SW at the inner core

Figure 2. Cases of G+3 storey building models with shear wall

Low-rise building (G+13 storey building)

Structure specification: Material a) concrete = M30, b) steel = HYSD 550; Section property: a) column size = 300 mm x 450 mm, b) beam size = 300mm x 450mm, Area section: Slab thickness = 120mm (shell-thin); Area of plan = 16.92m x 16.92m, No of grid lines in both direction = 5, Shear wall thickness = 250mm, Spacing of grids in both direction = 4.23m, Height of the storey = 3m.

High-rise building (G+23 storey building)

Structure specification: Material a) concrete = M30, b) steel = HYSD 550; Section property: a) column size = 300 mm x 450 mm, b) beam size = 300mm x 450mm, Area section: Slab thickness = 120mm (shell-thin); Area of plan = 16.92m x 16.92m, No of grid lines in both direction = 5, Shear wall thickness = 250mm, Spacing of grids in both direction = 4.23m, Height of the storey = 3m.

Numerical Modelling and Analysis Parameters

The structural models were developed and analysed using ETABS 20 based on the finite element method. All buildings were modelled as reinforced concrete moment-resisting frames with rigid beam-column joints. Beams and columns were represented using frame elements, while slabs and shear walls were modelled using shell elements. The floor diaphragms were assumed to be rigid at every storey level to ensure uniform distribution of lateral forces. The buildings were assumed to be fixed at the foundation level, neglecting soil–structure

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interaction effects. The material properties adopted in the analysis were M30 grade concrete and HYSD Fe550 reinforcing steel. The modulus of elasticity of concrete was taken according to IS 456:2000. Dead load, live load and seismic load combinations were assigned according to IS 456:2000 and IS 1893 (Part 1):2016. The seismic analysis considered Zone V, Importance Factor = 1.2, Response Reduction Factor = 5.0, Medium Soil (Type II), and 5% damping. Dynamic time-history analysis was performed using the 1940 El Centro earthquake record (PGA = 0.31g). Eight different shear wall configurations were investigated while maintaining identical structural dimensions and loading conditions. The principal response parameters evaluated were storey displacement, inter-storey drift, base shear, lateral stiffness and natural period.

Model Validation

To verify the reliability of the numerical model, the obtained results were compared with previously published numerical investigations on reinforced concrete buildings with shear walls subjected to seismic loading. Previous studies by Ozkul et al. (2019), Saikumar and Mandava (2022), Ahamad and Pratap (2021), and Abualreesh et al. (2022) reported that introducing reinforced concrete shear walls significantly reduces lateral displacement and inter-storey drift while increasing lateral stiffness and base shear capacity. Similar trends were observed in the present investigation, confirming the reliability of the adopted ETABS modelling approach.

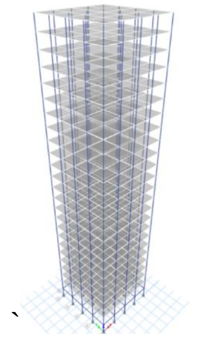
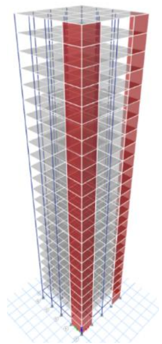
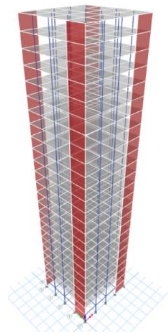
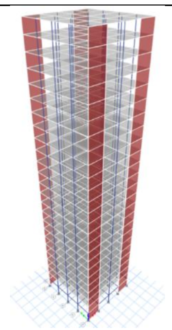
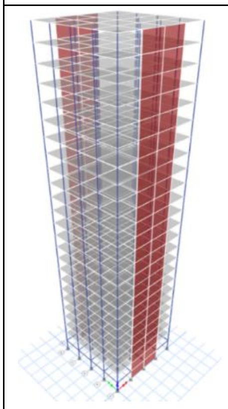
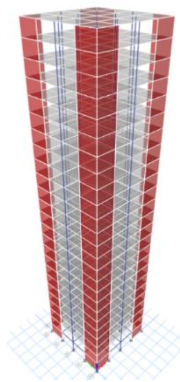
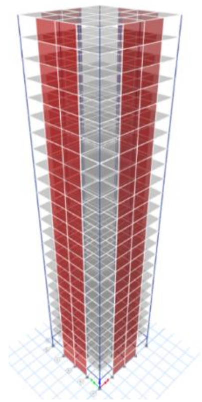
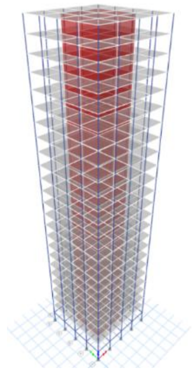
			
Case 3A	Case 3B	Case 3C	Case 3D
			
Case 3E	Case 3F	Case 3G	Case 3H

Figure 4. Cases of G+23 storey building SAP models with shear wall

RESULTS AND DISCUSSION

Results of low-rise RCC building (G+3 storey)

Table 1. Displacements (mm) of the G+3 storey with the shear wall in the Global X direction.

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STORY LEVEL	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODE L F	MODEL G	MODEL H
0	0	0	0	0	0	0	0	0
1	3.544	0.272	0.319	0.176	0.1	0.132	0.111	0.078
2	8.967	0.818	0.956	0.542	0.255	0.387	0.283	0.185
3	13.752	1.517	1.806	1.035	0.456	0.71	0.505	0.299
4	17.58	2.272	2.75	1.587	0.671	1.059	0.743	0.408
5	19.954	3.007	3.692	2.145	0.879	1.4	0.969	0.498

Figure 5. Displacements (mm) of the G+3 storey with the shear wall in the Global X direction.

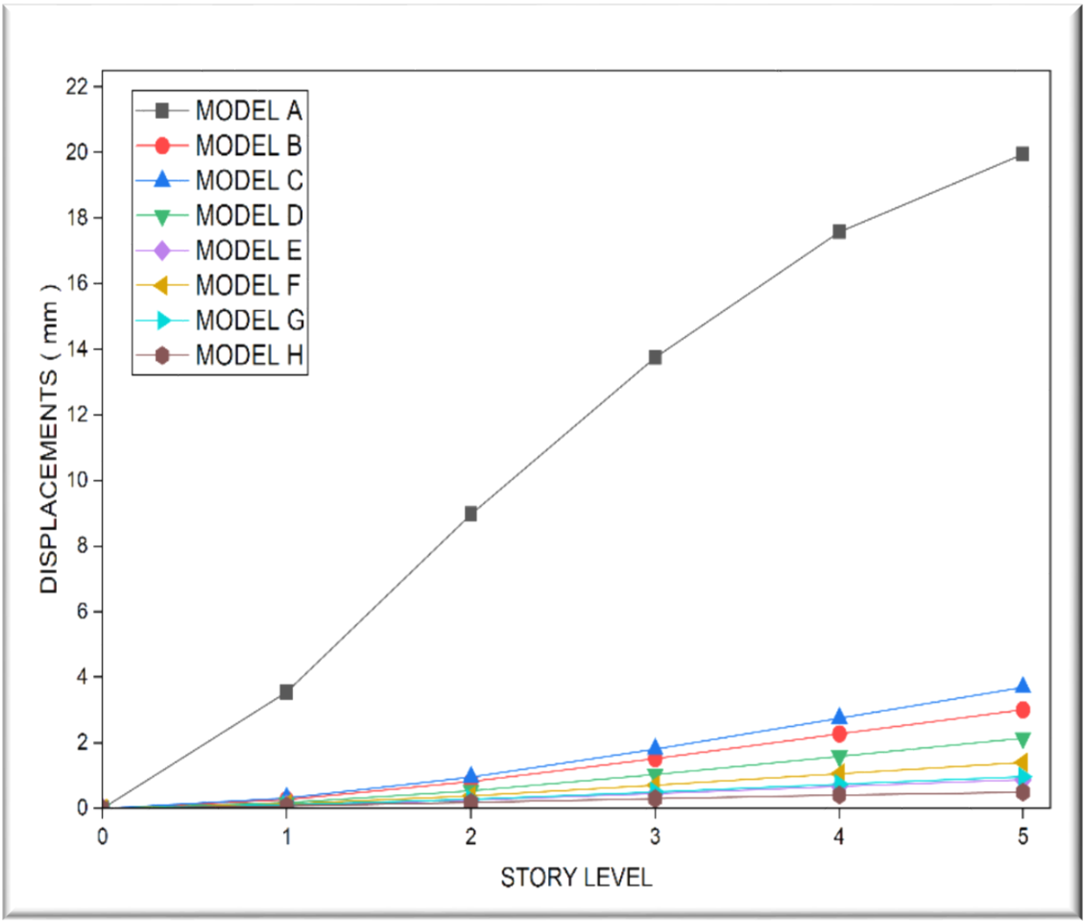

Figure 5 depicts the displacement of G+3 storey with the shear wall in the Global X direction. Model A exhibits the largest displacement values at every storey. Its curve rises steeply from the ground to the top floor, reaching nearly 20 mm at the fifth storey. This indicates that Model A is the most flexible or has the least lateral stiffness among all models. Models B, C, and D show moderate displacement growth. Their curves increase gradually with height, showing higher displacements than the remaining models but significantly lower than Model A. Models E, F, G, and H have minimal displacements, forming a cluster at the bottom of the graph. These models display much stiffer behaviour, resulting in reduced lateral movement. By the top storey, their displacements remain below roughly 2 mm. A large displacement curve (Model A) suggests low stiffness or possibly fewer lateral force-resisting elements. The remaining models show improved stiffness, with Model H and similar low-curve models being the most resistant to lateral deformation.

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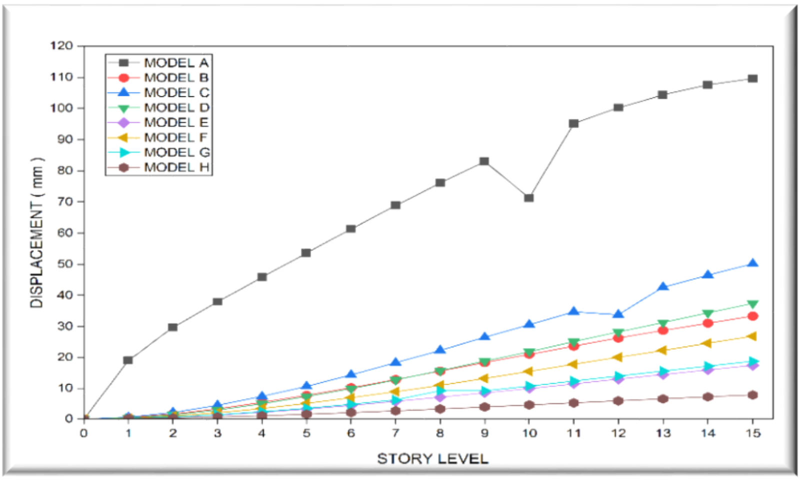
Results of medium-rise RCC building (G+13 storey)

Figure 6 illustrates the variation of lateral displacement along the height of a fifteen-storey structure for eight different analytical models (A–H). Displacement values, measured in millimeters (mm), are plotted on the vertical axis, while story levels are represented on the horizontal axis. Model A shows the highest displacement profile, with values increasing sharply from the lower to upper floors. Its curve rises almost linearly up to about the tenth storey, where a slight drop is observed, followed by another increase toward the top level. This trend suggests that Model A has the lowest lateral stiffness, resulting in greater overall drift under lateral loading. Models C and D form the next group with noticeably higher displacements compared to the remaining models. Their curves increase steadily with building height, indicating moderate stiffness characteristics. Models B, E, F, and G exhibit lower displacement magnitudes, remaining well below those of Models A, C, and D. Their responses display a more uniform and gradual increase with storey level, reflecting comparatively stiffer behavior. Model H consistently shows the smallest displacement values across all floors. Its curve remains nearly flat, indicating minimal deformation and demonstrating that this configuration possesses the highest resistance to lateral movement.

Table 2. Displacements (mm) of G+13 storeys with the shear wall in the Global X direction.

STORY LEVEL	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODEL F	MODEL G	MODEL H
0	0	0	0	0	0	0	0	0
1	1.994	0.034	0.044	0.051	0.036	0.03	0.016	0.019
2	3.085	0.014	0.129	0.128	0.059	0.038	0.035	0.031
3	3.917	0.023	0.269	0.265	0.119	0.078	0.071	0.046
4	4.715	0.029	0.448	0.441	0.195	0.129	0.117	0.061
5	5.501	0.029	0.659	0.647	0.286	0.189	0.171	0.076
6	6.272	0.024	0.896	0.879	0.387	0.258	0.232	0.09
7	7.02	0.011	1.153	1.13	0.498	0.334	0.299	0.104
8	7.736	0.01	1.424	1.394	0.616	0.414	0.37	0.118
9	8.411	0.038	1.704	1.667	0.74	0.499	0.445	0.13
10	9.034	0.074	1.989	1.945	0.866	0.587	0.521	0.142
11	9.591	0.118	2.276	2.224	0.995	0.677	0.599	0.152
12	10.07	0.168	2.561	2.5	1.124	0.767	0.677	0.161
13	10.454	0.225	2.842	2.773	1.252	0.858	0.755	0.168
14	10.729	0.287	3.12	3.042	1.379	0.948	0.908	0.173
15	10.888	0.353	3.393	3.307	1.505	1.037	0.908	0.175

Figure 6. Displacements (mm) of G+13 storeys with the shear wall in the Global X direction.



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Results of high-rise RRC building (G+23 storey)

Table 3. Displacement (mm) of G+23 storey RCC building in X direction.

STORY LEVEL	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODEL F	MODEL G	MODEL H
0	0	0	0	0	0	0	0	0
1	5.1	0.523	0.693	0.464	0.286	0.327	0.301	0.169
2	13.166	1.801	2.385	1.641	0.843	1.207	0.884	0.487
3	21.085	3.666	4.942	3.463	1.748	2.517	1.824	0.945
4	29.097	6.027	8.222	5.84	2.935	4.226	3.051	1.53
5	37.213	8.792	12.104	8.701	4.375	6.289	4.536	2.231
6	45.417	11.889	16.485	11.978	6.045	8.666	6.251	3.04
7	53.684	15.258	21.272	15.61	7.92	11.317	8.169	3.946
8	61.986	18.846	26.383	19.54	9.976	14.206	10.266	4.941
9	70.294	22.607	31.745	23.716	12.192	17.298	12.518	6.016
10	78.575	26.502	37.292	28.09	14.547	20.562	14.903	7.163
11	86.795	30.493	42.963	32.618	17.021	23.966	17.399	8.373
12	94.916	34.547	48.705	37.259	19.595	27.482	19.987	9.637
13	102.898	38.635	54.468	41.974	22.25	31.083	22.647	10.949
14	110.699	42.728	60.208	46.73	24.97	34.744	25.361	12.3
15	118.275	46.8	65.884	51.494	27.74	38.443	28.114	13.683
16	125.579	50.827	71.463	56.24	30.544	42.158	30.891	15.092
17	132.561	54.788	76.912	60.942	33.369	45.872	33.677	16.519
18	139.171	58.665	82.208	65.581	36.204	49.568	36.462	17.959
19	145.354	62.441	87.332	70.14	39.038	53.234	39.235	19.406
20	151.056	66.105	92.27	74.607	41.863	56.859	41.988	20.856
21	156.218	69.649	97.02	78.977	44.672	60.437	44.716	22.303
22	160.782	73.073	101.585	83.25	47.461	63.964	50.083	23.744
23	164.687	76.383	105.982	87.433	50.228	67.442	50.083	25.176

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24	167.877	79.595	110.242	91.54	52.973	70.876	52.725	26.598
25	170.359	82.731	114.394	95.59	55.698	74.271	55.339	28.005

Figure 7. Displacement (mm) of G+23 storey RCC building in X direction.

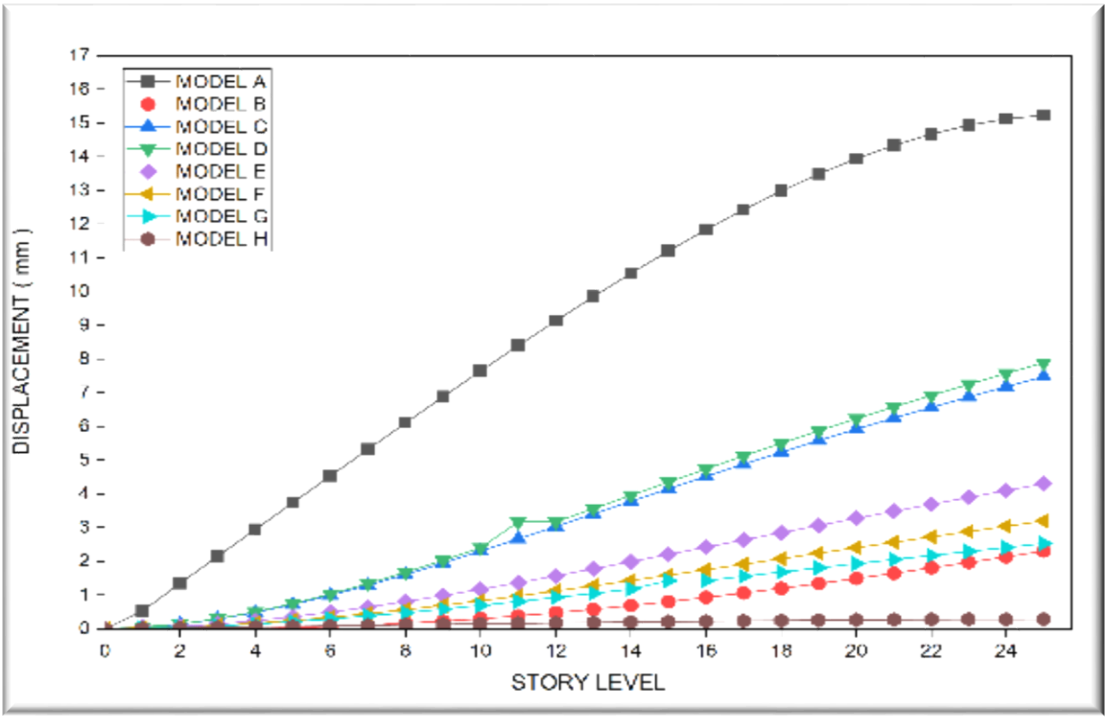

Figure 7 illustrates the distribution of lateral displacement along a 25-storey building for eight structural configurations (Models A–H). The horizontal axis denotes the storey level, while the vertical axis represents the corresponding lateral displacement in mm. Model A displays the largest displacement values throughout the height of the building, with a steadily increasing trend that reaches its peak at the top storey. This behaviour suggests that Model A has the lowest overall stiffness among the compared models, allowing greater horizontal movement under lateral loading. Models C and D form the next highest displacement group, exhibiting a consistent upward trend with height. Their curves rise more gradually than that of Model A, indicating moderate stiffness characteristics. Models E, F, and G show moderate to low levels of displacement, with each curve following a smooth, incremental pattern. These models demonstrate a stiffer response relative to Models A, C, and D, limiting lateral drift more effectively. Model B records relatively small displacement values, staying close to the lower range across all storeys. Meanwhile, Model H consistently exhibits the lowest displacement, remaining nearly flat throughout the building height. This indicates that Model H offers the highest resistance to lateral deformation, making it the most structurally stable configuration within the comparison set.

CONCLUSIONS

Across all three building heights examined—5, 15, and 25 storeys—the displacement profiles reveal a consistent performance pattern among the eight analytical models. Model A systematically exhibits the largest lateral displacements, reaching approximately 20 mm, 110 mm, and 16 mm at the top storeys of the 5-, 15-, and 25-storey structures, respectively, confirming it as the least stiff configuration. Models C and D form the next highest displacement group, with top-storey values of about 3–4 mm, 35–45 mm, and 7–8 mm, indicating moderate stiffness. Models E, F, and G show significantly lower drift levels, ranging from 1–2 mm in the 5-storey case to 2–4 mm in the 25-storey system, reflecting improved lateral resistance. Model B consistently performs within the low-displacement range, with values of roughly 1.5–2 mm, 10–15 mm, and 1–1.5 mm across the three heights. Throughout all analyses, Model H demonstrates the most favourable response, producing the

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smallest displacements—below 1 mm in the 5-storey frame, approximately 1–3 mm in the 15-storey structure, and around 0.5–1 mm in the 25-storey configuration. Overall, the comparative results establish a clear stiffness ranking of Model H > Model B > Models E/F/G > Models C/D > Model A, consistently validating Model H as the most effective system for controlling lateral drift across varying building heights.

Limitations and Future Research

The present study considered regular reinforced concrete buildings having G+3, G+13 and G+23 storeys with selected shear wall configurations under Zone V seismic loading. Soil–structure interaction, material nonlinearity, construction defects and deterioration effects were not included in the numerical models. Furthermore, only regular rectangular building geometry was considered. Future investigations should incorporate laboratory experiments, shake-table testing, or comparisons with recorded earthquake response data to further validate the numerical predictions. Additional research may investigate irregular building geometries, different shear wall shapes (L-, T-, U-, and C-shaped), dual systems combining shear walls with steel bracing or dampers, base-isolated buildings, different soil conditions and nonlinear material behaviour.

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