

Analytical Study of Seismic Response of Double Tower Building on a Common Podium

Shivam A. Satpute^{1*}, R.S. Londhe²

Abstract

The recent surge in global population, particularly in urban areas, has led to a significant rise in the demand for tall building structures featuring multiple towers on a shared podium. Such complex configurations often result in intricate interactions between towers and podium structures, particularly under lateral loads induced by earthquakes. One of the critical structural behaviors observed in such systems is the backstay effect, which arises due to discontinuities in the lateral force-resisting systems between the podium and the towers. This study investigates the seismic performance of a double-tower 24-story commercial building connected by a common podium, with an emphasis on understanding how podium characteristics and perimeter retaining walls influence the overall seismic response. The research utilizes ETABS software to develop four structural models of the building, varying primarily in the presence and stiffness of retaining walls at the podium level. Response Spectrum Analysis is used to assess story displacements, drifts, and shears under seismic loading. The results demonstrate that models with retaining walls exhibit significantly improved lateral stiffness and reduced displacements compared to models without retaining walls. Furthermore, two models are assigned with upper-bound and lower-bound stiffness parameters. The notable outcome is the observation of shear reversal at the podium level in models with stiffer retaining walls, highlighting the manifestation of backstay effects. This demonstrates that stiffness in the diaphragm is key to how loads are re-distributed in podium-tower systems. The results of this study provide insight into how high-rise towers on podiums respond to earthquakes and help secure their stability.

Keywords: Podium, multiple towers, backstay effect, shear reversal, common podium, backstay diaphragms, seismic response

INTRODUCTION

Recent urban growth has reshaped many big cities, leading there to be a focus on creating structures that are compact and tall. Consequently, we see many high-rise buildings today because the demand for homes, businesses, and mixed areas has grown on limited land. To make good use of available land and

*Author for Correspondence

Shivam A. Satpute

E-mail: shivam.satpute04@gmail.com

¹Student, Department of Applied Mechanics, Government College of Engineering Aurangabad, Chhatrapati Sambhajanagar, Maharashtra, India

²Professor, Department of Applied Mechanics, Government College of Engineering Aurangabad, Chhatrapati Sambhajanagar, Maharashtra, India

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create attractive architecture, developers and architects now favor buildings with many towers from one common podium base. Many times, podiums function by including parking garages, shops, lobbies, and other useful spots, all while keeping the building structure stable for the towers above. Today, many cities have skyscrapers with different shapes and heights clustered around a single base. These high buildings are efficiently spaced to add a striking impact to the area.

Although it helps save land and improves city planning, this approach adds lot of engineering challenges due to how the buildings behave when there is an earthquake. In this setup, the backstay

effect is a particularly important structural phenomenon. Because lateral stiffness changes so suddenly from the flexible podium to the towers, shear stresses can sometimes flow in the opposite direction. For this reason, the modelling and analysis of these structures are key to avoiding their collapse under an earthquake and keeping the entire building safe. Designers should pay attention to backstay effects and use engineering analysis to achieve strong and visually impressive structures for high-rise projects.

OBJECTIVE OF THE STUDY

- To assess the role of podium levels in high-rise buildings.
- To observe the backstay effect in podium levels.
- To analyze the structure with different stiffness assumptions.

LITERATURE REVIEW

The story isolation technology is applied to a high-rise building with an enlarged base and multitower in a high-intensity area. Comparing different structural methods for an enlarged base and multiple tower-layer high-rise building, the authors identify an effective base isolation technique and analyze its seismic response. Results shows that story isolation method significantly reduces the seismic response of the structure and provides a good strategy for improving structural safety under any seismic activity [1].

A large chassis multitower building performs in a seismic event in an urban business area. The investigation is carried out on a structure consisting of two towers on a common podium, with steel tube frames and cores in the towers. According to the study, the dual-tower structure twists differently than expected because its towers work together and are controlled by each other's movements [2].

Jeong et al. investigated how a 49-story residential building in Seoul was performed during an earthquake. The study highlights how common basements shared by multiple towers can significantly affect the dynamic response due to unsynchronized vibrations. Through nonlinear dynamic analysis, the research illustrates that incorporating realistic basement models and SSI is required to correctly display these behaviors. The findings suggest that better modelling techniques should be used to enhance high-rise structures' reliability [3].

The way high-rise buildings react with podium spaces. This happens by investigating how towers and podiums interact, considering horizontal transfer of forces from the towers to the podiums. Experiments on different types of platforms and the addition of outriggers and tall blade walls were carried out to increase performance. The research shows that while podiums keep towers from shifting, their influence weakens in the bays that come after the first. Outriggers give good drift control, though they result in greater strutting forces, while wide blade walls work well to control drift and minimize forces on the supports [4].

The seismic response of a tall building structure composed of two towers on a shared podium and their interaction with the podium level. To represent these interaction effects, the authors apply an upper-bound and lower-bound approach to the single-tower models at the continuous boundaries. These findings suggest that while single-tower models may offer a conservative estimate, integrating the full combined model gives accurate insights into the seismic performance, improving the reliability of structural designs for similar podium-tower configurations [5].

The tall reinforced concrete buildings with large podiums. By integrating the shaking table test with numerical simulations, the research addresses surrounding floor stiffness ratios that exceed standard code provisions. The results show that using steel-reinforced concrete beams and columns can improve the performance of the transfer floor, even when the building's lateral stiffness differs from recommended limits. Despite structural differences, both single- and multi-tower models have comparable seismic responses, such as natural frequencies and mode shapes. From the results, the study advises evaluating both structural configurations during planning, using an envelope method to predict performance under different earthquake conditions [6].

The behavior of high-rise buildings that have a podium surrounding tower walls, and how important the podium restraint is for the tower walls. The research indicates that different movements in the walls of the tower when subjected to horizontal loads are the main reason for the in-plane strutting forces seen in the floors close to the podium-tower connection. The authors point out that assuming a rigid diaphragm building floors may cause errors in the design of tower walls [7].

The issues and solutions in multitower high-rise buildings that are built on podiums. Often, these types of buildings use transfer structures to bring the support from the lower podium level to the towers above. Authors present a flexible approach to supporting floors that can handle the load changes and interacting forces found in tall buildings. As part of their research, they note the effectiveness of having a flexible transfer floor for controlling vertical and sideways loads, reducing stress hotspots, and increasing the building's resistance to earthquakes [8].

A way to limit the torsional response of tall buildings that have podiums. Because of its large base, the unusual distribution of mass and stiffness occur in podium, makes it behave differently under earthquake shaking, resulting in tower rotation. The authors placed viscous fluid dampers between the podium and the main tower so that the tower's movements are dampened. Using these methods, the study shows that the dampers do an excellent job of reducing the torsional vibrations in the podium floors and making the main structure more secure in earthquakes [9].

The seismic response of buildings supported by podium structures, considering the whipping problems caused by different building stiffnesses. The system uses magnetorheological (MR) dampers to join a slender 12-story tower to a solid 3-story support base. A variety of physical tests are performed, including dynamic response and shake table tests using a scaled version of the El-Centro earthquake. Results indicate that when the tower and podium are joined by rigid connections, seismic forces, especially at the top levels, are greatly amplified, creating a whipping motion. In contrast, MR dampers help reduce these displacements and vibrations, demonstrating their effectiveness in managing stiffness variation and improving overall seismic safety [10].

ANALYTICAL APPROACH

In this study, a 24-story high-rise double tower building connected by a common podium is considered. Also, the podium structure has floors above and below subgrade level. These are modelled using ETABS software.

Building Specifications

The model specifications are provided in Table 1, and the elevation and 3D perspective of the structural model are illustrated in Figures 1 and 2.

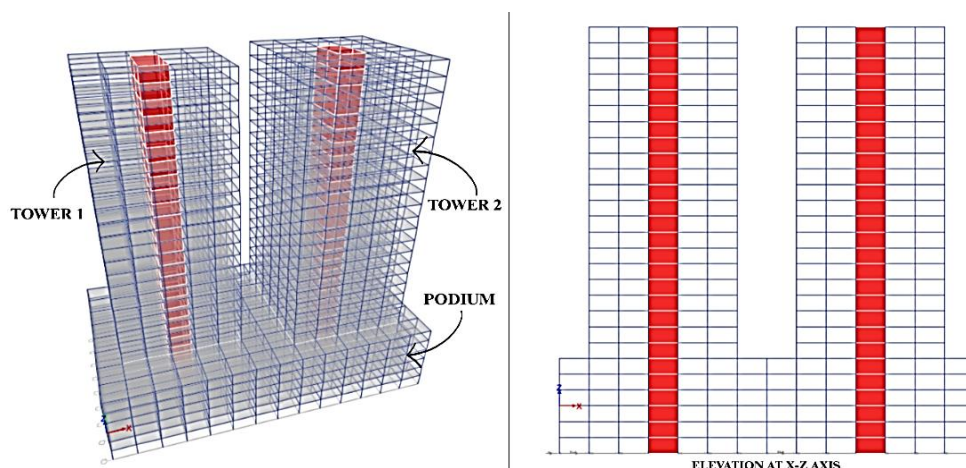


Figure 1. 3D view and elevation of model without retaining wall at basement floors.

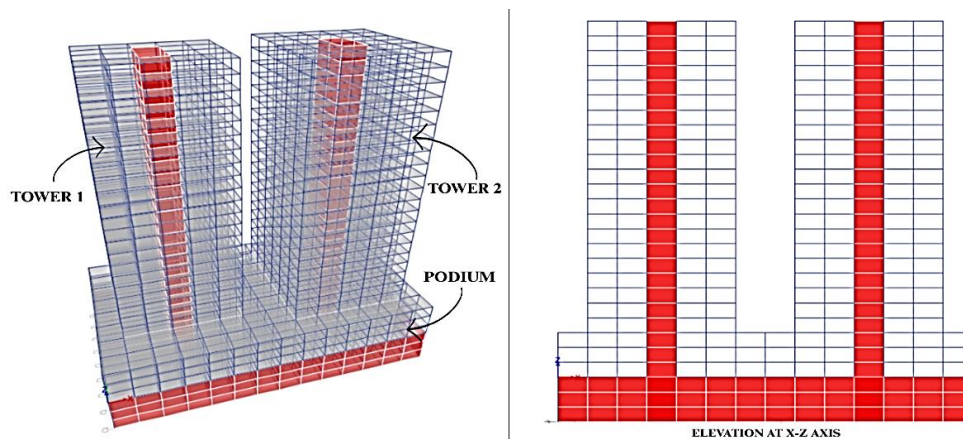


Figure 2. 3D view and elevation of model with retaining wall at basement floors.

Table 1. Building specifications.

S.N.	Building Data	Values	
1	Building use purpose	Commercial	
2	Plan Dimension	Podium	84 x 48 m
		Tower 1	30 x 24 m
		Tower 2	30 x 36 m
3	Number of stories	G+P+20	
4	Height of building	84 m (From grade level)	
5	Floor Height	3.5 m	
6	Type of building system	Dual system	
7	Grade of concrete	M45	
8	Grade of steel	HYSD Fe550	
9	Column sizes	600 x 600 mm	
		750 x 750 mm	
		900 x 900 mm	
10	Beam sizes	300 x 600 mm	
		300 x 750 mm	
11	Slab thickness	Main backstay diaphragm	380 mm
		All other diaphragm	200 mm
12	RC walls thickness	Shear wall	380 mm
		Retaining wall (Basement floors)	300 mm

Model Description

In this study, four models are considered and shown in Table 2. One without a retaining wall at the perimeter of the basement floors and the other with a retaining wall on the basement floors. Other three models, which have retaining walls at perimeter of the basement floors, vary in their stiff parameters (Figures 3-5).

Table 2. Models' description.

S.N.	Model name	Description
1	M1	Double towers without retaining wall at perimeter of basement floors (Serviceability design)
2	M2	Double towers with retaining wall at perimeter of basement floors (Serviceability design)
3	M3	Double towers with retaining wall at perimeter of basement floors (Upper bound stiffness parameter)
4	M4	Double towers with retaining wall at perimeter of basement floors (Lower bound stiffness parameter)

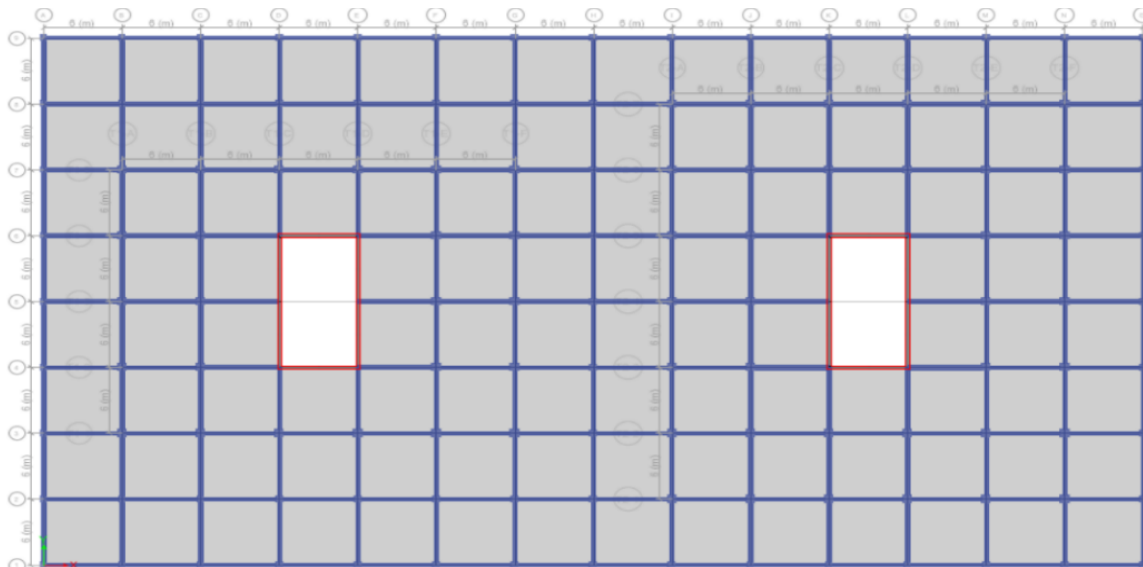


Figure 3. Plan view of podium without retaining wall at basement floors.

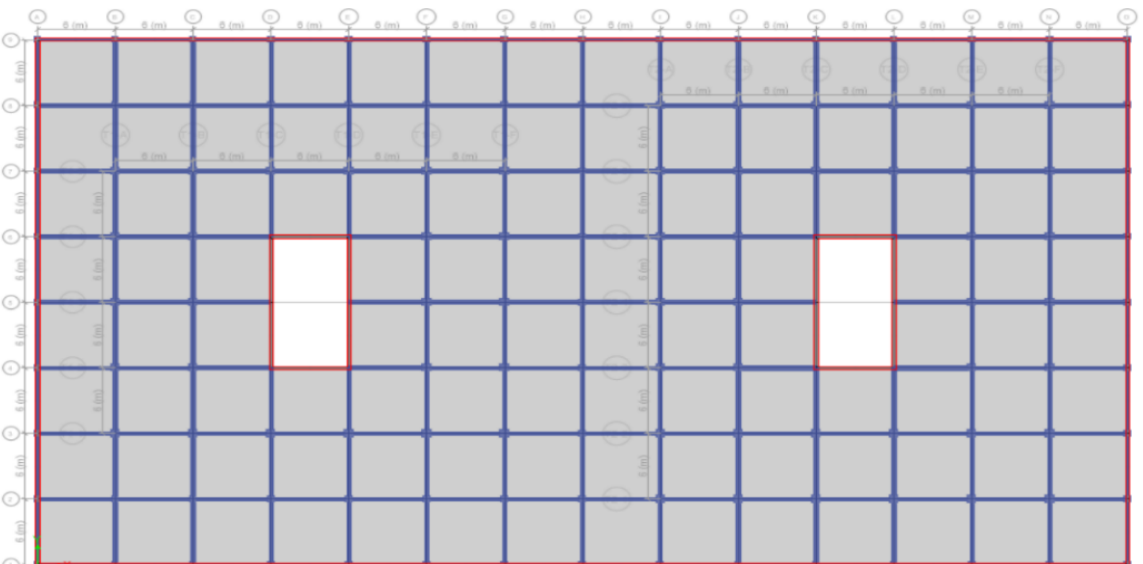


Figure 4. Plan view of podium with retaining wall at basement floors.

Loads and Seismic Data Consideration

The considered loads for this analysis are dead loads, live loads and wind loads taken from IS 875:1987 shown in Table 3.

Seismic Design Data

The earthquake loads are considered as per IS 1893:2016, presented in Table 4.

RESULT AND DISCUSSION

The research examines the seismic performance of dual-tower building connected by common podium. The analysis conducted by response spectrum method and the key parameters, such as story displacement, story drift, and story shears are discussed.

Story Displacement

Both the towers show similar trend across all four models. The story displacement response of tower 1 and tower 2 in the X-direction is represented in Figures 6 and 7, respectively. The chart shows that story displacement increases with height across all models, which is expected in tall structures.

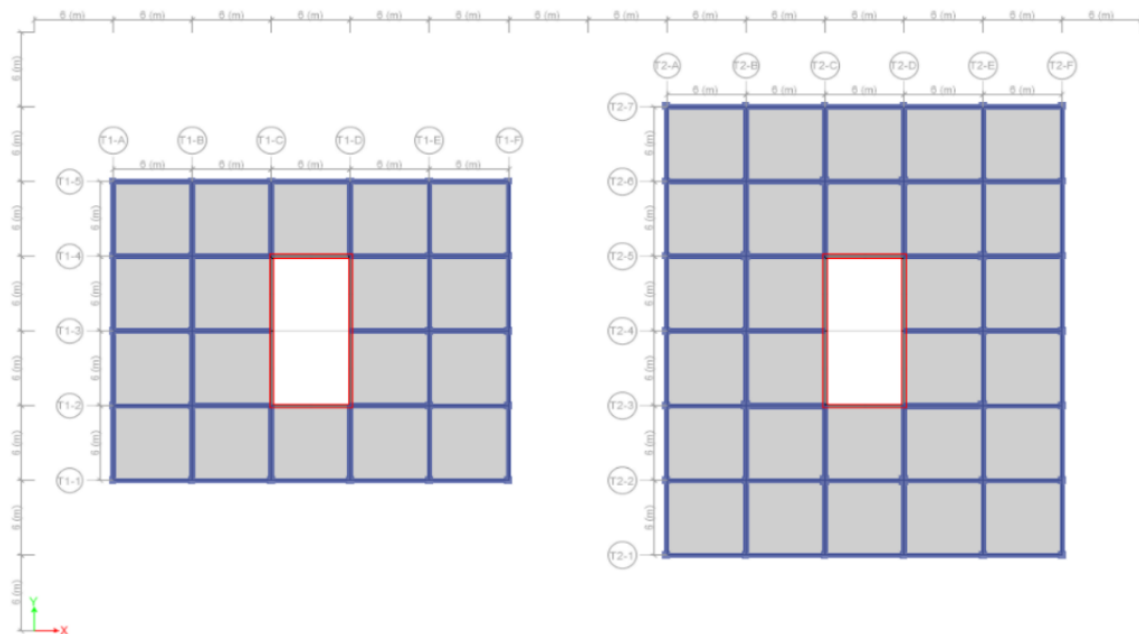


Figure 5. Plan view of tower 1 and tower 2.

Table 3. Load consideration.

S.N.	Type of Load		Values	
1	Dead load	Floor finish and ceiling plaster	1.5 kN/m ²	
		Earth pressure (non-uniform)	C	-6.27 kN/m ²
			D	65.835 kN/m ²
		Wall load	External wall	13.34 kN/m ²
			Internal wall	6.67 kN/m ²
Parapet wall	4.6 kN/m ²			
2	Live load	Floor load	Typical floors	3 kN/m ²
			Basement floors	5 kN/m ²
			Terrace floors	2 kN/m ²
		Surcharge (uniform)	3.3 kN/m ²	
3	Wind load	Wind Speed	44 m/s	
		Topography factor	1	
		Terrain Category	4	
		Risk Coefficient	1	
		Importance Factor	1	

Table 4. Seismic data.

S.N.	Parameters	Values
1	Zone factor (Z)	III (0.16)
2	Soil type	II (Medium soil)
3	Importance factor (I)	1.2
4	Response Reduction factor (R)	5
5	Grade of concrete	M45

Model M1, which lacks a retaining wall, exhibits the highest displacement throughout, indicating reduced lateral stiffness. In contrast, models with retaining walls (M2, M3, M4) show significantly lower displacements, highlighting the structural benefits of retaining walls at basement levels. As M3

& M4 is assigned with upper and lower bound stiffness parameters, respectively, M2 has the least displacement due to higher stiffness in its backstay diaphragms and basement walls compared to M3 & M4. M4 with lower bound stiffness shows slightly higher displacement than M3 but still performs better than M1. This trend underscores the role of wall stiffness and design parameters in displacement control. The difference between M3 and M4 also reveals the sensitivity of lateral response to stiffness assumptions. Overall, the results confirm that including perimeter retaining walls and optimizing their stiffness can substantially improve the structural behavior of double-tower systems.

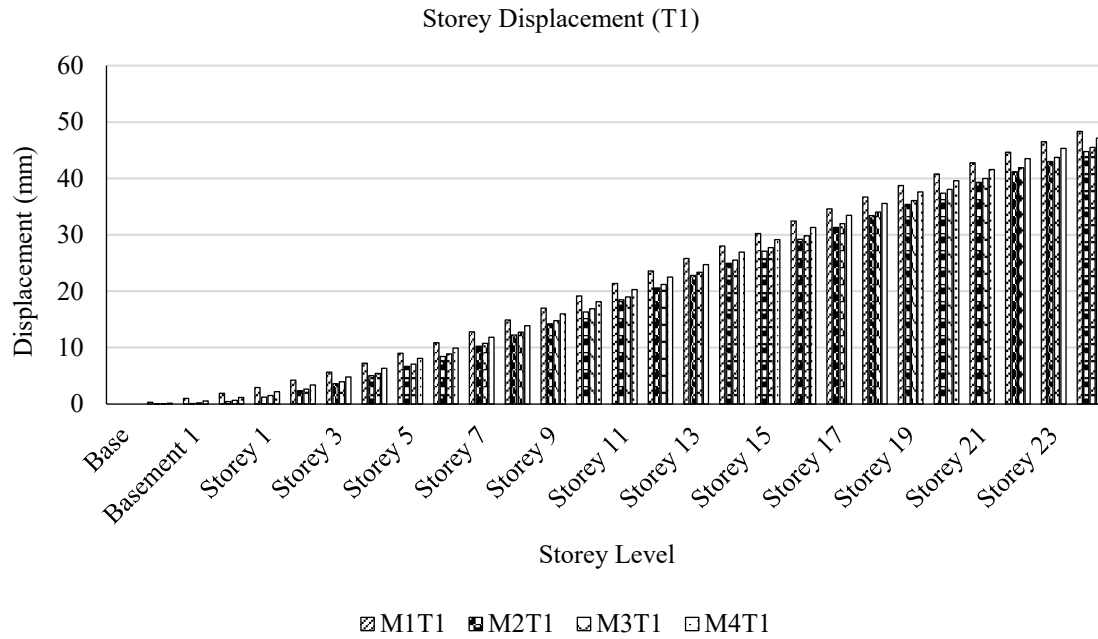


Figure 6. Story displacement comparison of tower 1.

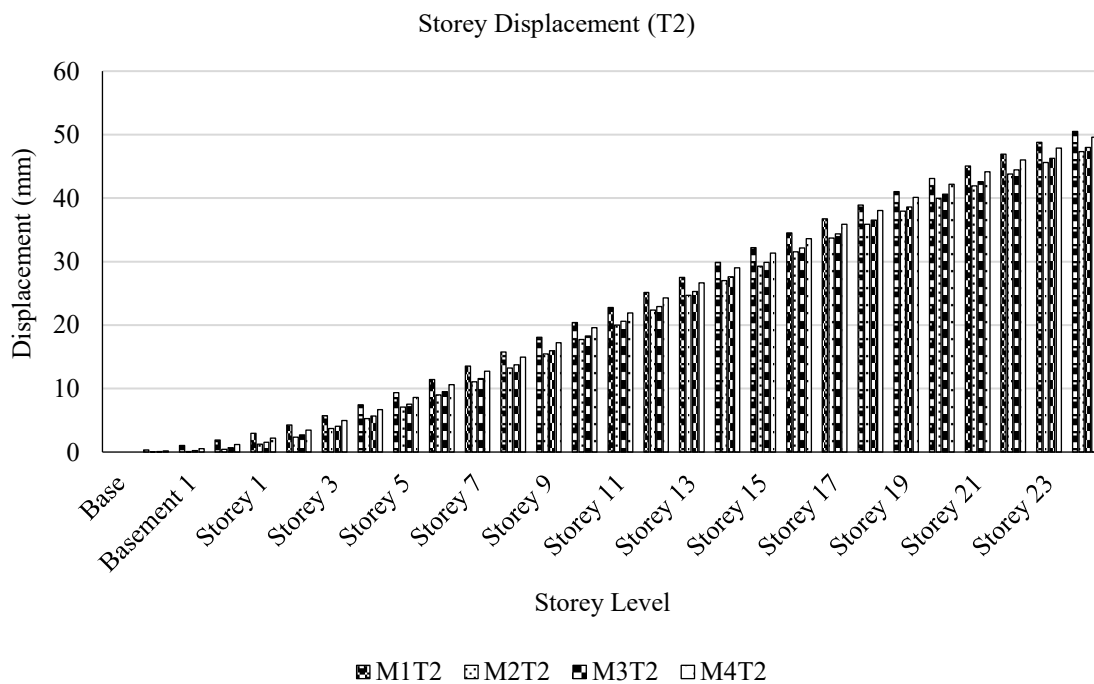


Figure 7. Story displacement comparison of tower 2.

Story Drift

Story drift refers to the lateral displacement or movement of one story of a building relative to the story below it, typically caused by seismic or wind forces. The story drift in any story should be limited to 0.004 times of story height as specified in Indian Standard Code. In both the towers the story drift values are within limit.

Figures 8 and 9 show the variation of story drift in X-direction for different structural models in tower 1 and 2, respectively. For both towers, all models show a similar trend where drift increases up to mid-height (around stories 11–14) and then gradually decreases. M1, the model without a retaining wall, exhibits the highest drift values in all stories, indicating lower lateral stiffness. Models with retaining walls (M2T1, M3T1, M4T1) show reduced drift, demonstrating their structural efficiency. Among these, M2 consistently yields the lowest drift, while M4 (lower bound stiffness) exhibits slightly higher values but still less than M1. The peak drift across all models occurs between story 11 and story 14, suggesting this zone experiences the most significant deformation under lateral loads. Overall, the inclusion of retaining walls improves drift control, and the variation in stiffness significantly influences drift performance in double-tower structures.

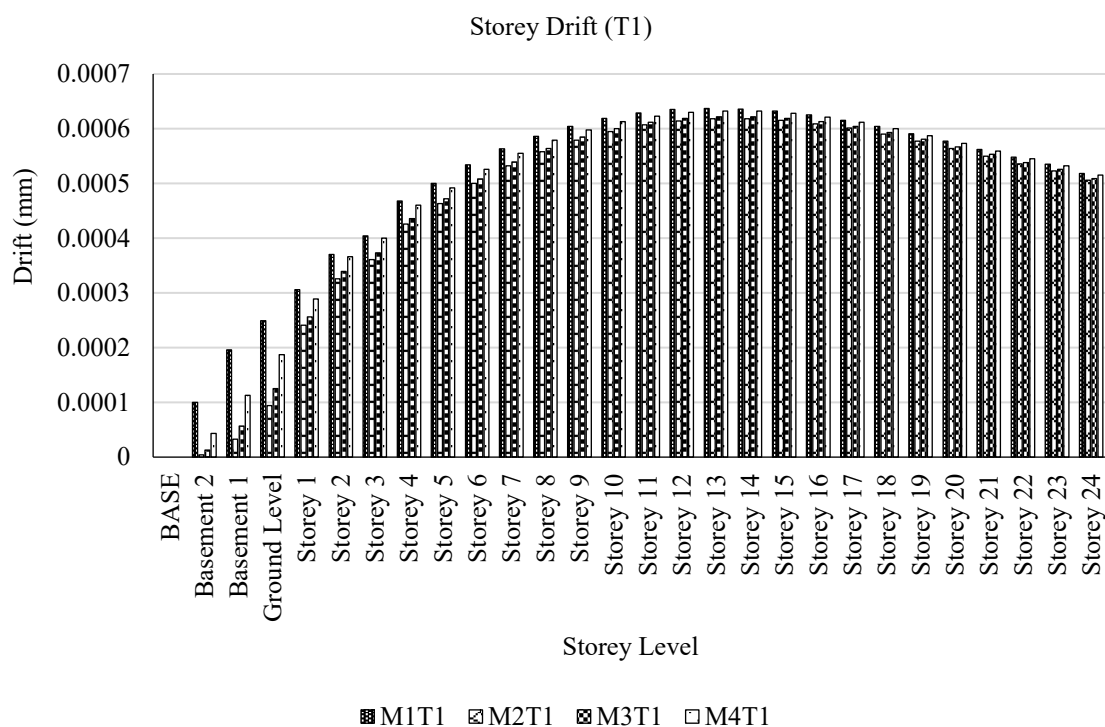


Figure 8. Story drift comparison of tower 1.

Story Shear

The backstay effect is evidently seen in the podium levels (base to story 3), particularly in models M2, M3, and M4 as illustrated in Figures 10 and 11 for tower 1 and 2, respectively.

The reversal of story shear direction observed in M2 and M3 is due to the higher stiffness and restraint offered by the retaining walls. No shear reversal observed in the model M4, which has significantly less stiffness as assigned with a lower bound stiffness assumption, compared to M2 and M3, which reflect a redistribution of forces. This reversed behavior is absent in M1, where the lack of perimeter retaining walls results. These findings clearly show that retaining walls and podium diaphragms significantly influence the lateral load path, and their presence alters both the magnitude and direction of story shear in the basement levels.

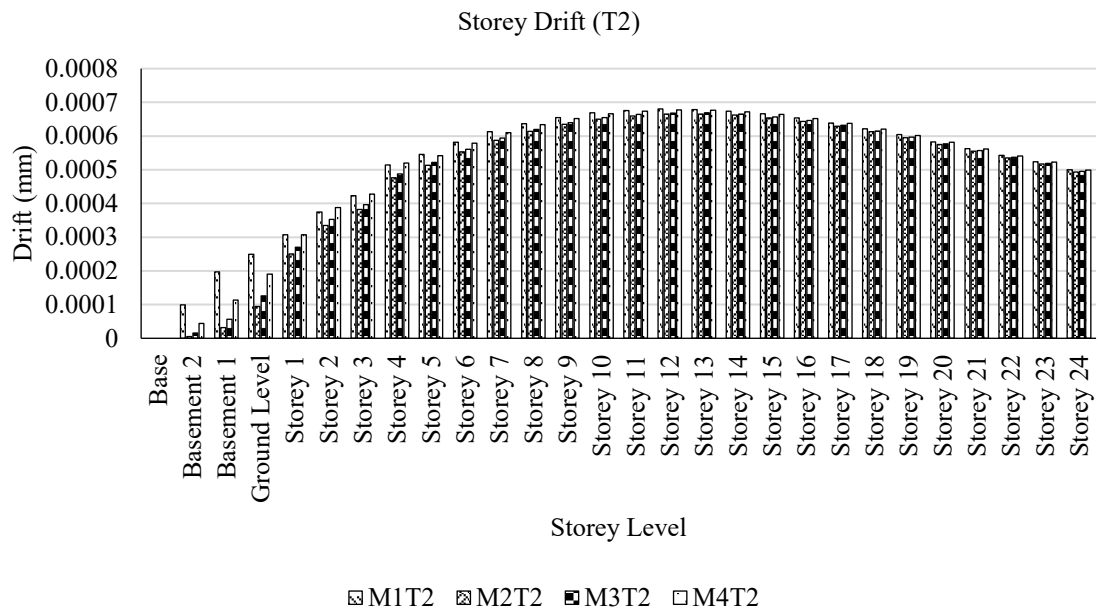


Figure 9. Story displacement comparison of tower 2.

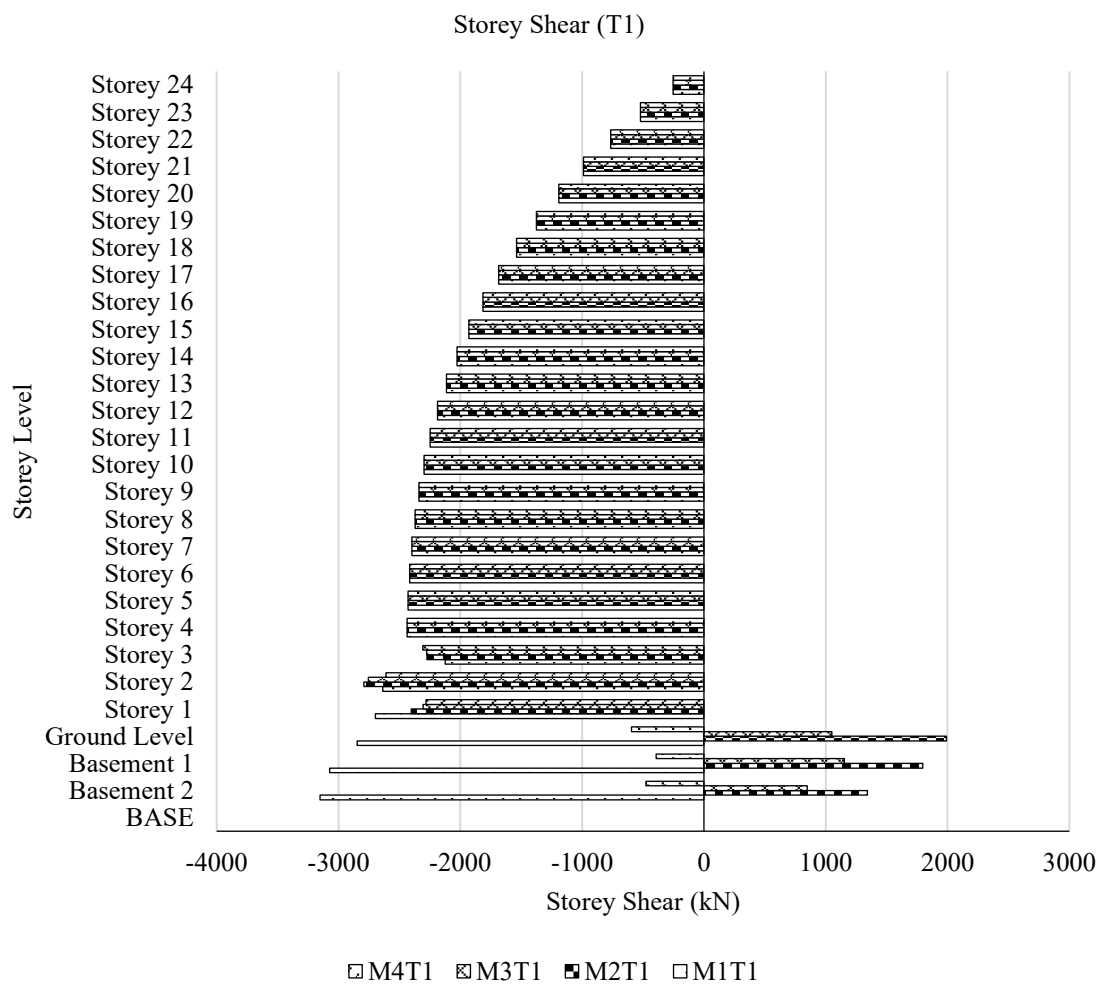


Figure 10. Story shears comparison of tower 1.

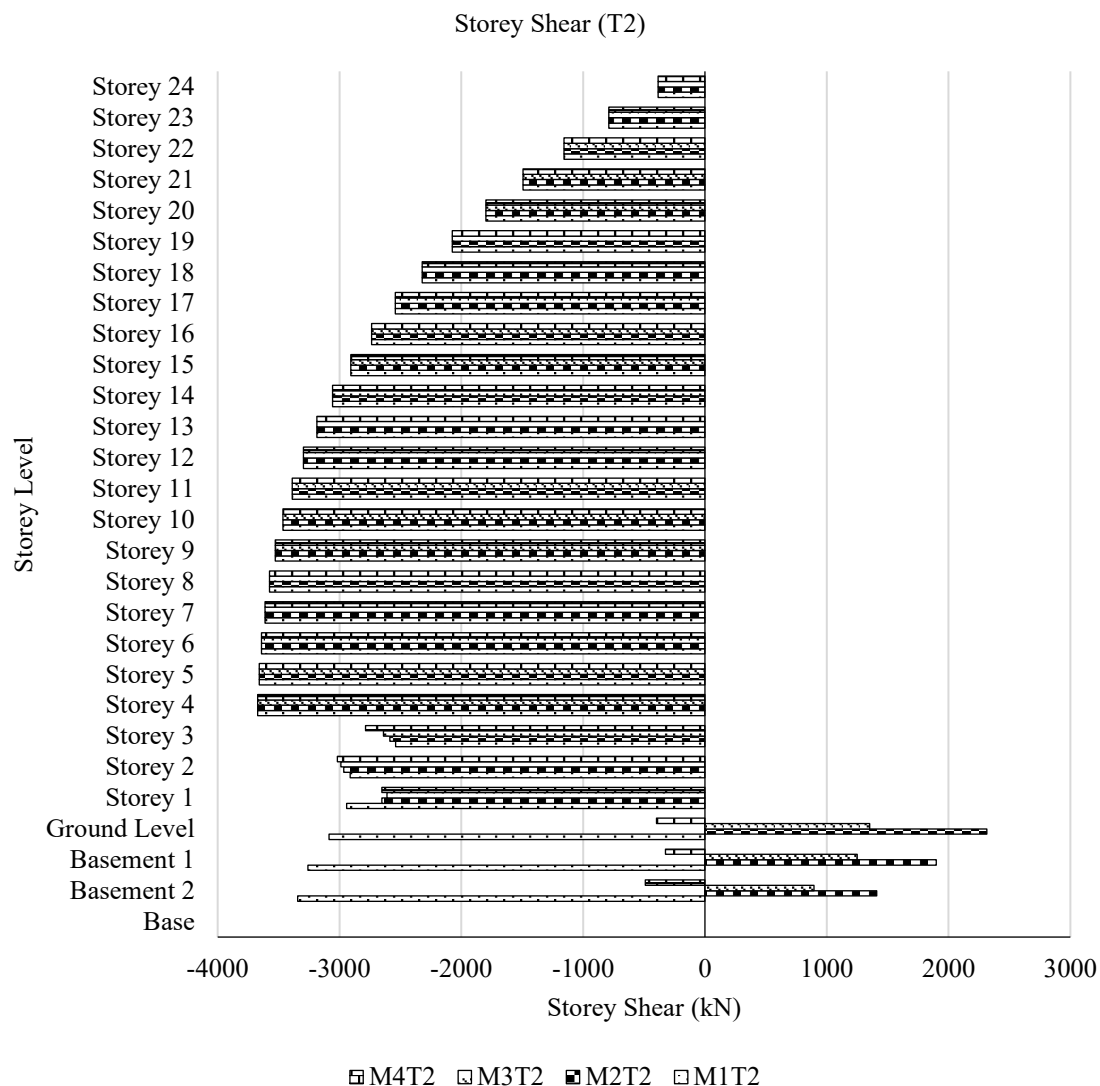


Figure 11. Story shears comparison of tower 2.

CONCLUSIONS

The seismic behavior of a 24-story tower is analyzed by variation in stiffness assumptions and retaining wall integration in ETABS software. The story displacement, story drift, and story shear and values are displayed and compared, leading to the following conclusions:

- Structural models without retaining walls display the highest displacements and drifts, underscoring the inadequacy of neglecting podium resistance in the seismic design of multitower systems.
- The inclusion of perimeter retaining walls at the basement levels significantly enhances the lateral stiffness of the structure, leading to reduced values of story displacements and drifts in both towers under seismic loading.
- The presence of stiffer retaining walls results in shear reversal at podium levels due to the backstay effect. This demonstrates that podium-tower interaction can significantly alter the lateral load paths and must be carefully considered in design.
- Models with different stiffness assumptions (upper and lower bounds) show notable variations in displacement and drift. Though using a retaining wall in the basement floor of the podium, shear reversal is absent in the model with lower bound stiffness due to the redistribution of forces occurring on the lower stories.

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