

Dynamic Response of High Rise Structures Under The Influence of Shear Walls

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Abstract

This paper will give an insight into the technique for overall seismic performance estimation of high-rise structures primarily based on a concept of the response spectrum method. Three-dimensional analytical version of high rise buildings will be generated for seismic analyses. Models were analyzed by using the structural evaluation tool of ETABS Software. The analytical model of the structure includes all essential components that have an effect on the mass, performance and deformability of the shape. To study the effect of concrete shear wall at extra ordinary positions for the duration of earthquake, seismic evaluation with the use of linear static, linear dynamic and non-linear static system has been used. The deflections at every Storey stage are compared by using response spectrum approach and influence of Shear Walls on dynamic response is established.

Keywords: Shear walls, High-rise structure, ETABS

1. Introduction

In today's urbanized world, the scarcity and high cost of available land have intensified due to increasing rural-to-urban migration driven by the industrial revolution and population growth. To accommodate the rising urban population, there is a growing need for tall buildings for residential and commercial purposes. However, constructing these towering structures poses significant challenges, particularly in ensuring their earthquake resilience. Earthquakes, being destructive and unpredictable natural disasters, pose a grave threat. While earthquakes may not directly harm individuals, they can lead to building collapses, resulting in injuries and property damage. Recent seismic events, including those in countries like India, have underscored the urgency of investigating and implementing strategies to construct buildings that can withstand earthquakes.

Designing earthquake-resistant structures entails a holistic approach, considering factors such as a building's natural motion, its resistance to movement, the choice of foundation, and most importantly, its capacity to flex without breaking. The ability of a building to flex during an earthquake is paramount as it aids in the more even distribution of forces, reducing the risk of collapse. In India, where urbanization is on the rise, the historical prevalence of shorter buildings

is evolving as more people flock to cities. As urban landscapes transform with taller structures, the focus shifts toward addressing lateral loads, the sideways forces generated during earthquakes. Various methods, including rigid frames and shear walls, are employed to effectively counter these forces. Shear wall systems, in particular, have gained prominence in tall steel buildings due to their efficacy in transferring lateral loads through a specialized design. In summary, the confluence of limited land availability and burgeoning urban populations necessitates the construction of tall buildings in cities. However, ensuring their earthquake resistance is paramount. This entails comprehensive considerations of structural dynamics, strength, foundation, and flexibility. Employing lateral load-resisting systems like shear walls is pivotal in enhancing the earthquake resilience of tall buildings, ultimately safeguarding lives and property.

1.1 SHEAR WALLS

Shear walls are special walls in buildings that make them strong and steady. They prevent buildings from shaking too much during strong winds or earthquakes. Think of them as powerful support walls that stop the building from swaying and falling over. They are made of really strong materials like tough concrete, steel, or bricks.

These walls are put in specific places inside or outside the building to keep it safe. They work like secret defenders, making sure the building stays safe even when there's lots of shaking or pushing from the sides.

Shear walls are structural elements used in buildings to resist lateral forces caused by wind, earthquakes, or other horizontal loads. They are

designed to provide stability and prevent excessive lateral movement or deformation of the building during such events. Shear walls work by transferring the lateral forces acting on the structure to the foundation, thus enhancing the building's overall stability and safety. The structure of a shear wall is presented in fig.1.

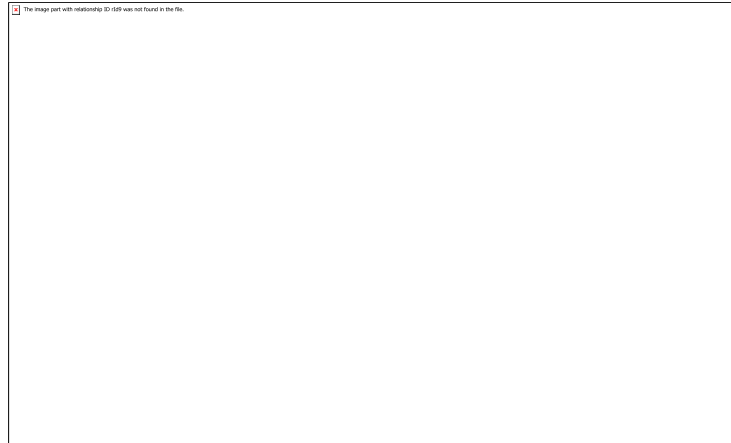


Fig.1 Shear Wall Structure

2. Literature Review

M.Jesse Leo Pragnan et.al¹. (2019). Studied Seismic Analysis Of Multi-Storied Regular Building By Response Spectrum. The analysis of a G+15 RCC building in accordance with IS 16700:2017 standards emphasized the critical role of incorporating P-Delta analysis alongside Linear dynamic analysis, particularly for structures exceeding 50 meters in height. The P-Delta effect, driven by second-order geometric nonlinearity stemming from lateral displacements, gains significance as the number of stories increases. In multi-story tall buildings, cumulative lateral displacements amplify P-Delta forces, necessitating precise consideration of these higher-order effects. A comparison between P-Delta and Response Spectrum analyses yielded important insights, revealing that P-Delta analysis resulted in larger maximum storey displacements and drifts compared to Response Spectrum analysis. This disparity was attributed to the additional deformations introduced by the P-Delta effect, which were not fully accounted for in linear dynamic Response Spectrum analysis. Response Spectrum analysis, being linear, tended to underestimate displacements, particularly in tall

structures subjected to substantial lateral loads. However, it was noted that maximum storey shear forces remained consistent in both analyses, as the P-Delta effect primarily influenced displacements and deformations, with a relatively minor impact on shear forces.

Tarun magendra et al(May ,2016) studied Optimum positioning of shear walls in multi storey building .The study of four building models underscores the vital need for evaluating seismic hazards in the construction of high-rise structures. It strongly advocates for incorporating shear walls despite their higher cost, as they greatly enhance structural stability under seismic loads. The research highlights a direct link between seismic hazard levels and the necessity of shear walls, particularly in regions with high seismic activity. Among the four cases studied, placing shear walls at the building's center or corners, especially in the form of box-type shear walls, proved most effective in ensuring stability during seismic events. While all models met Storey Drift limits according to IS:1893 (Part 1), Case 4 and Case 2 exhibited superior performance, emphasizing the importance of strategic shear wall placement for seismic resilience. This study provides a clear

mandate for the inclusion of shear walls in high-rise structures to enhance seismic resistance and safeguard occupants and assets during earthquakes.

Mindala Rohini, et al (April, 2019) studied Seismic analysis of residential building for different zones using ETABSThe comparison of storey displacement values between Zone III and Zone V reveals that both analysis methods exhibit higher displacements in the top storey, with Zone V experiencing greater displacement due to its higher seismic activity. Among the load cases, the time history method for EQX load shows maximum storey drift, particularly in the 5th storey. In Zone III, response spectrum analysis (RSZ) results in maximum storey drift in the 6th and 7th storeys, while RSX shows drift in the 4th to 9th storeys. Similarly, in Zone V, RSZ displays maximum drift in the 4th to 11th storeys, while RSX exhibits it in the 3rd to 12th storeys, indicating how different load cases can influence storey drift. Storey shear values, assessed using both response spectrum and time history methods, are highest at the ground level in all cases, with Zone V showing higher lateral forces. Overall, this analysis emphasizes the need for meticulous consideration of seismic hazards during structural design, particularly in high seismic zones like Zone V. Understanding displacement, drift, and shear behavior under varying scenarios enables engineers to create safer and more resilient structures capable of withstanding seismic challenges.

Sopna Nair, et al¹ .(2017) studied RESPONSE SPECTRUM ANALYSIS AND DESIGN OF CASE STUDY BUILDING.In the seismic analysis of the tall and irregular case study building, both the equivalent static method and response spectrum method are employed to account for seismic loads. However, given the building's complex behavior, dynamic analysis using the response spectrum method is favored for accuracy. Modal analysis is performed to determine the structure's natural frequencies and mode shapes, representing unique vibration patterns. These modal responses are then combined using the Square Root of the Sum of the Squares (SRSS) method to determine maximum responses. Vertical element design, like columns and shear walls, considers forces from the

response spectrum analysis to ensure they can withstand lateral loads. Foundation design accounts for worst load combinations of earthquake forces and uplift water pressures, considering both lateral and vertical forces to ensure foundation stability during seismic events.

Jalmindodiya et al¹, (2018) studied Analysis of Multi story building with shear wall using Etabsoftware.The dynamic analysis of the case study building revealed several significant findings. It demonstrated that seismic zone V had notably higher maximum displacement and storey drift values compared to zones II, III, and IV, indicating increased vulnerability to lateral movements. This underscores the importance of robust seismic design in high seismic zones. Additionally, the study highlighted the crucial role of uniform stiffness distribution in seismic performance, as non-uniform stiffness led to concentrated forces and greater deformations. Among the analyzed cases, Case C, featuring shear walls at all four ends of the building, exhibited superior seismic performance in terms of maximum displacement, storey drift, and base shear values. This emphasizes the importance of incorporating shear walls for enhanced seismic resistance in high-rise buildings. Overall, the analysis underscores the significance of uniform stiffness distribution and shear wall integration in seismic-prone regions, offering valuable insights for safer and more resilient tall building design in earthquake-prone areas.

Gauri G. Kakpureet al¹,(2016) studied Comparative study of static and dynamic seismic analysis of multi storied RCC building by ETABS.Comparing dynamic and static analyses for G+10 and G+25 buildings reveals several key findings. In dynamic analysis, storey drift values are consistently 22 to 25% lower than those in static analysis for both building heights, indicating greater stability and structural integrity under lateral loads. As the building height increases, displacement values also rise, with the top storey experiencing the maximum displacement. Dynamic analysis shows a 22% reduction in G+10 and a 26% reduction in G+25 building displacements compared to static analysis, particularly benefiting taller structures. The axial loads in corner and peripheral columns exhibit 7% to 8% reductions in

dynamic analysis, whereas interior columns show a 2% decrease. Additionally, bending moments in beams are 3% to 7% lower in G+10 and 3% to 4% lower in G+25 buildings in dynamic analysis, leading to more economical design outcomes. In summary, dynamic analysis consistently provides more reliable and cost-effective results, making it the preferred approach for assessing high-rise buildings under lateral loads, with reduced drift, displacement, axial loads, and bending moments compared to static analysis.

3. Methodology

3.1 RESPONSE SPECTRUM ANALYSIS

Response spectrum analysis in ETABS is a critical seismic analysis method used in structural engineering to evaluate a structure's dynamic response to earthquake ground motions. It involves the application of a spectrum curve, which represents the acceleration response of a theoretical single-degree-of-freedom oscillator subjected to a range of frequencies. In ETABS, users can define the spectrum by specifying parameters like damping, mode shapes, and target periods. The software then employs this spectrum to compute the maximum structural displacements, velocities, and accelerations for each mode of vibration. This analysis is particularly valuable in regions prone to seismic activity, as it provides engineers with essential data for designing structures that can withstand the potentially devastating effects of earthquakes.

4. Design Considerations And Modeling Of Building

In the present study, analysis of G+26 multi-story building in Zone V seismic zones is carried out. 3D model is prepared for multi-story building is in

ETABS. Basic parameters considered for the analysis are

1. Utility of building : Residential building
2. Number of stories : G+26
3. Plan dimensions : 32.25 x 19.555 m
4. Shape of building : Irregular
5. Damping ratio : 5%
6. Geometric details
7. Basement B1 : 5m
8. Silt to 26 floor : 3m
9. Building height : 78m
10. Material details
11. Concrete Grade : M30 (COLUMNS AND BEAMS)
12. All Steel Grades : HYSD reinforcement of Grade Fe415
13. Bearing Capacity of Soil : 245 KN/m², medium soil(type 2)
14. Type Of Construction : R.C.C FRAMED structure
15. Column : 500mm X 1000mm, M30
 : 750mm X 900mm ,M30
 : 1000mmX500mm ,M30
 : 1000mm X 1000mm ,M30
16. Beams : 400mm X 750mm ,M30
 : 450mm X 900mm ,M30
17. Slab : 150mm, M30
18. Shear wall : 400mm, M30
19. Supports : Fixed

To analyze the structure two models are developed and depicted in fig.2&3.

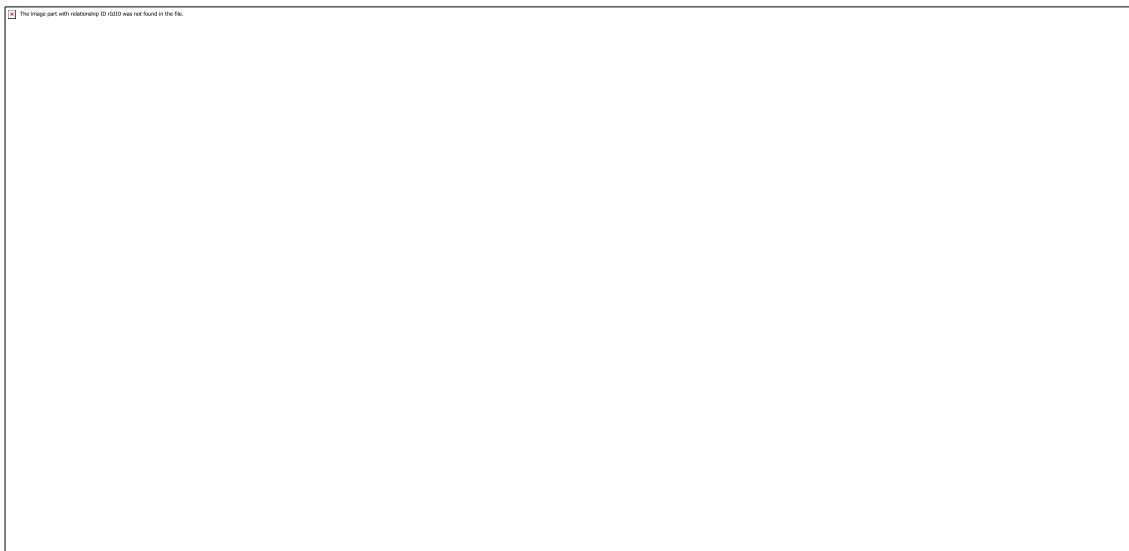


Fig 02: Model I: RCC Structure without shear walls

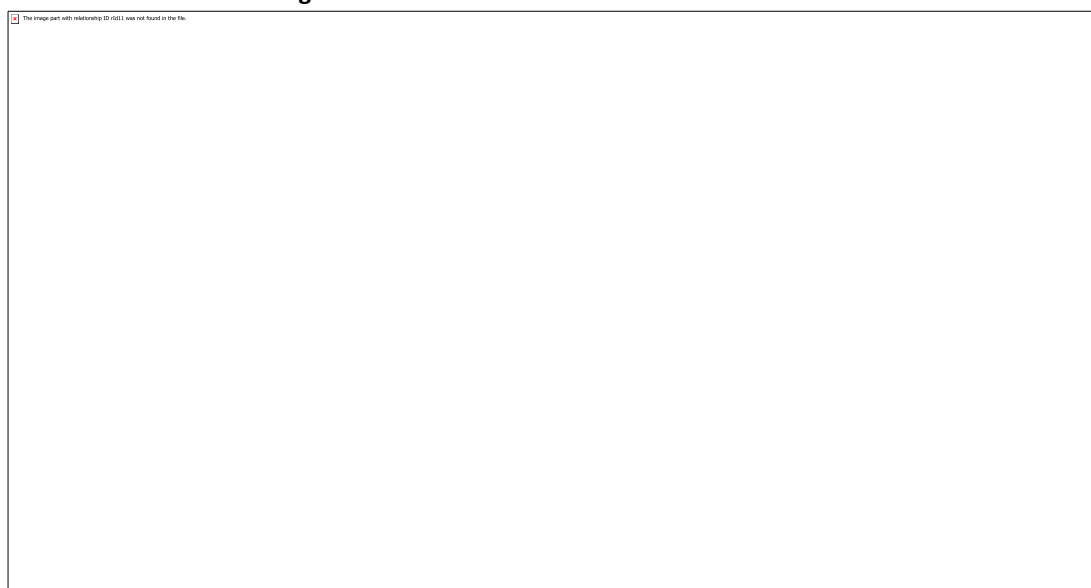


Fig03: Model II: RCC Structure with Shear wall

The various load combinations studied are presented in Table No.01

Table No. 01 Load Combinations

Combination1	1.5(DL+LL)	Combination6	0.9(DL+LL+WL-X)
Combination2	1.2(DL+LL+WL-X)	Combination7	0.9(DL+LL+WL-y)
Combination3	1.2(DL+LL+WL-Y)	Combination8	0.9(DL+LL+EQ-X)
Combination4	1.2(DL+LL+EQ-X)	Combination9	0.9(DL+LL+EQ-Y)
Combination5	1.2(DL+LL+EQ-Y)	Combination	Add all combinations

These different load combinations are taken for better analysis of structure, For the representation of different analysis results Combination 4 is taken

because earthquake forces are unpredictable when compared to wind load acting on the building.

5. Results And Analysis

5.1 COMPARISON OF TIME PERIOD AND FREQUENCY

Time period and frequency are crucial parameters in understanding the behavior of buildings during seismic events. Time period represents the duration it takes for a building to complete one oscillation or shake back and forth. On the other hand, frequency describes how quickly a structure vibrates when subjected to dynamic loads. Notably, these two factors are inversely related; as time period increases, frequency decreases.

The relationship between time period and frequency is fundamental in assessing a building's stability during an earthquake. Buildings with longer time periods and lower frequencies experience greater deflection on the top story and prolonged load impact. This can lead to an increased risk of structural element failure, rendering the structure unstable. Conversely, structures with shorter time periods and higher frequencies exhibit shorter load impact durations, reducing the likelihood of structural failure and enhancing overall stability.

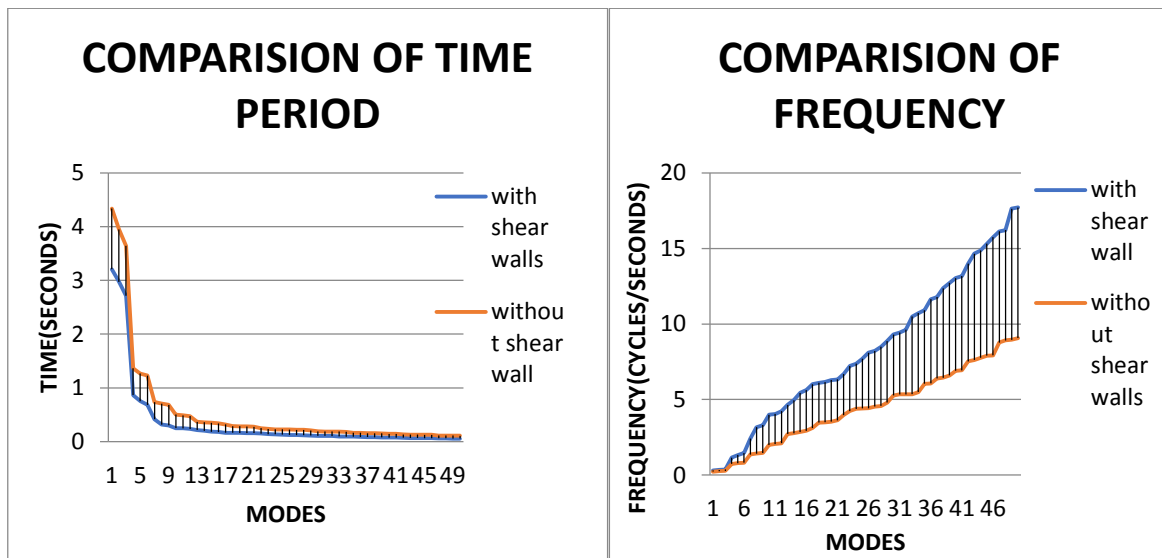


Fig No: 04 Comparison of Time Period and Frequency

Analyzing time period comparison graphs (see Fig No.4) reveals that buildings equipped with shear walls exhibit shorter maximum time periods compared to those without shear walls. This observation underscores the enhanced stability of buildings with shear walls during seismic events.

5.2 Shear force

Shear force is a critical indicator of the internal forces generated within a structure when

subjected to various loads. It plays a pivotal role in assessing a building's ability to withstand external forces under different load conditions. In practical terms, a building with a higher shear force exhibits a robust resistance to external loads, while a building with lower shear force displays reduced resistance. A comparison of shear force in X and Y direction are presented in Fig No.5

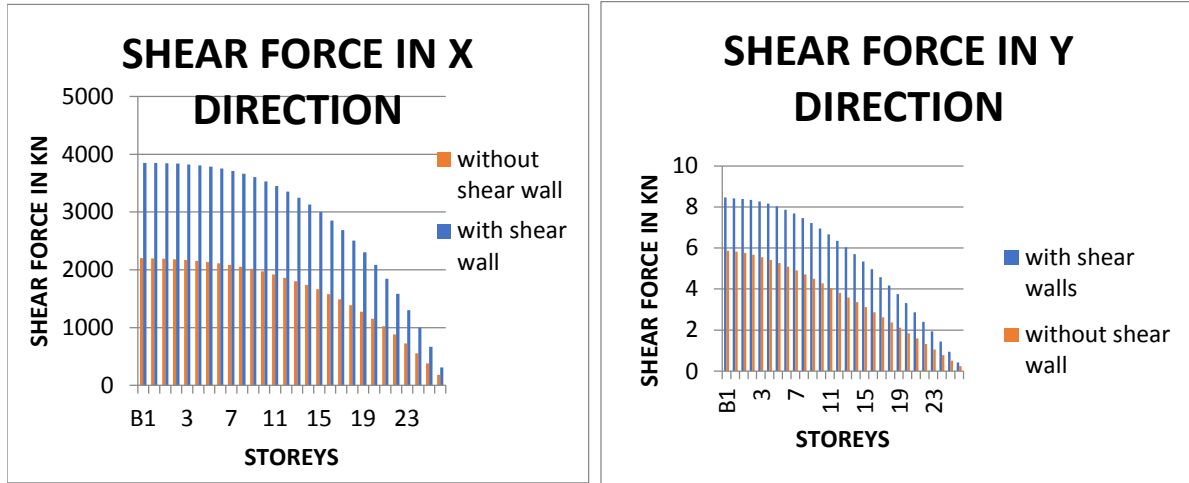


Fig No: 05 Comparison of Shear Force In X and Y Direction

When we examine shear force through comparison graphs, it becomes evident that buildings featuring shear walls typically experience significantly higher maximum shear forces compared to those without shear walls. This observation underscores the enhanced resistance of buildings with shear walls to external forces. It's also noteworthy that shear force is at its peak at the bottom floor and

gradually decreases towards the top, illustrating a gradient from top to bottom. Furthermore, in the realm of structural analysis, base shear represents the maximum internal shear force among various load combinations acting on a building. The comparison of base shear is depicted in Fig No.6.

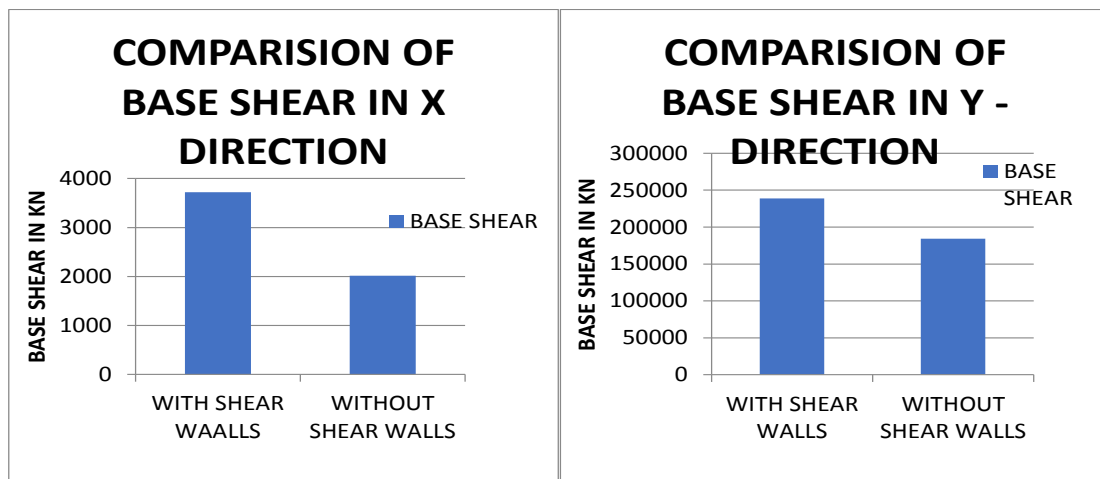


Fig No: 6 Comparison of Base Shear In Base Shear in X & Y Direction

Similar to shear force, a high base shear value signifies a structurally robust building with strong resistance to external forces. It can be observed that the base shear values of model without shear wall is comparatively lesser.

5.3 Torsion

Torsion is a critical parameter that characterizes a structure's ability to resist rotational forces caused

by lateral loads acting on the building. It provides valuable insights into how well a building can withstand various load scenarios. In the context of high-rise buildings, a higher torsion moment indicates greater resistance to external loads, while a lower torsion moment signifies reduced resistance.

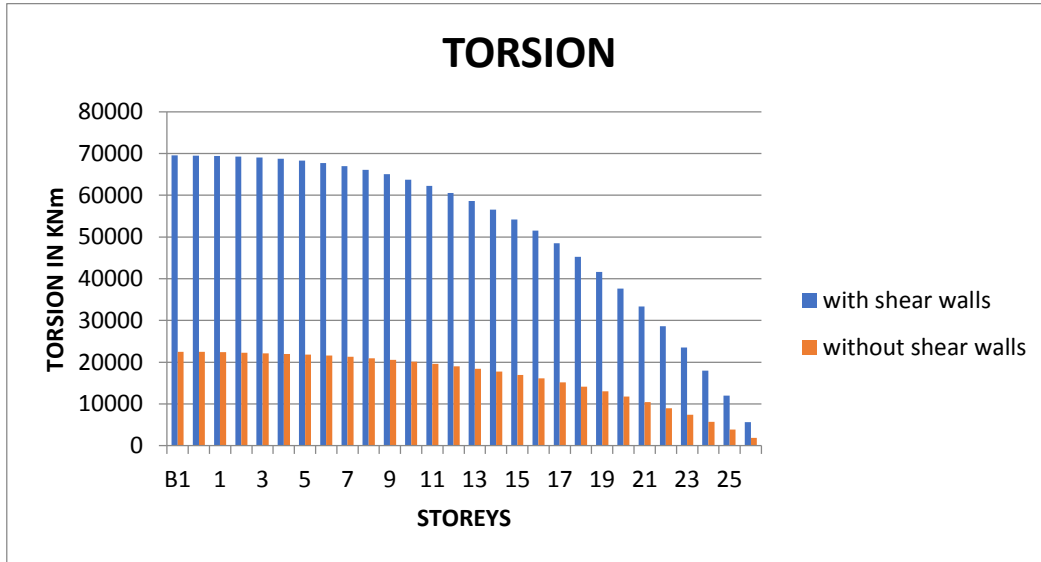


Fig No: 07 Comparison of Torsion

When examining torsion moment through comparison graphs, (see Fig.7) it becomes evident that buildings equipped with shear walls typically exhibit higher maximum torsion moments than those lacking shear walls. This observation underscores the increased resistance to external forces provided by buildings with shear walls. Additionally, it's noteworthy that torsion is at its maximum at the bottom floor and decreases as you move upward, reflecting a gradual increase in torsion moment from top to bottom. (see Fig.7)

5.4 Bending moment

Bending moment is a crucial measure of the internal resistance a structure offers against bending induced by external loads. It serves as a key tool in comprehending a building's capacity to withstand various load scenarios, particularly in high-rise structures. A higher bending moment in a building signifies a robust ability to resist external loads, whereas lower bending moments indicate reduced resistance.

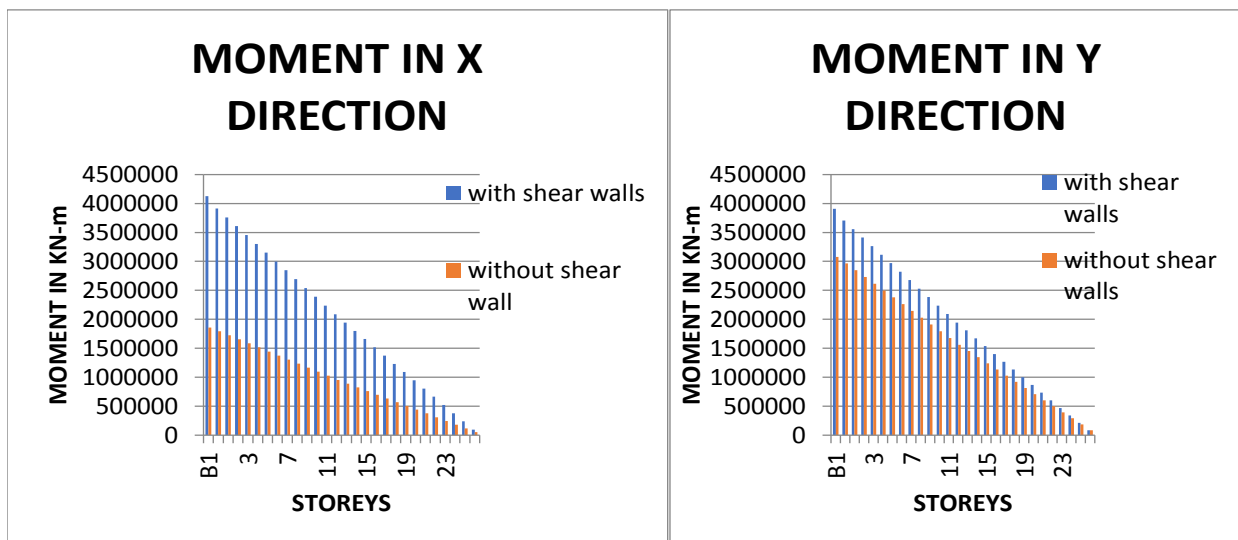


Fig No: 8 Comparison of Moment In X & Y Direction

An examination of bending moment via comparison graphs (see Fig.8) reveals that buildings incorporating shear walls generally

experience significantly higher maximum bending moments compared to those lacking shear walls. This observation underscores the superior

resistance of buildings with shear walls to external forces. Additionally, it's important to note that the bending moment is greatest at the building's bottom floor and gradually diminishes towards the top. This gradient illustrates how the structure's resistance increases from top to bottom, emphasizing the significance of this factor in structural analysis.

5.5 COMPARISON OF STORY DRIFT

Story drift, in structural engineering, signifies the horizontal displacement of one floor in relation to the floor directly below it. The extent of story drift primarily hinges on the overall deflection of the structure.

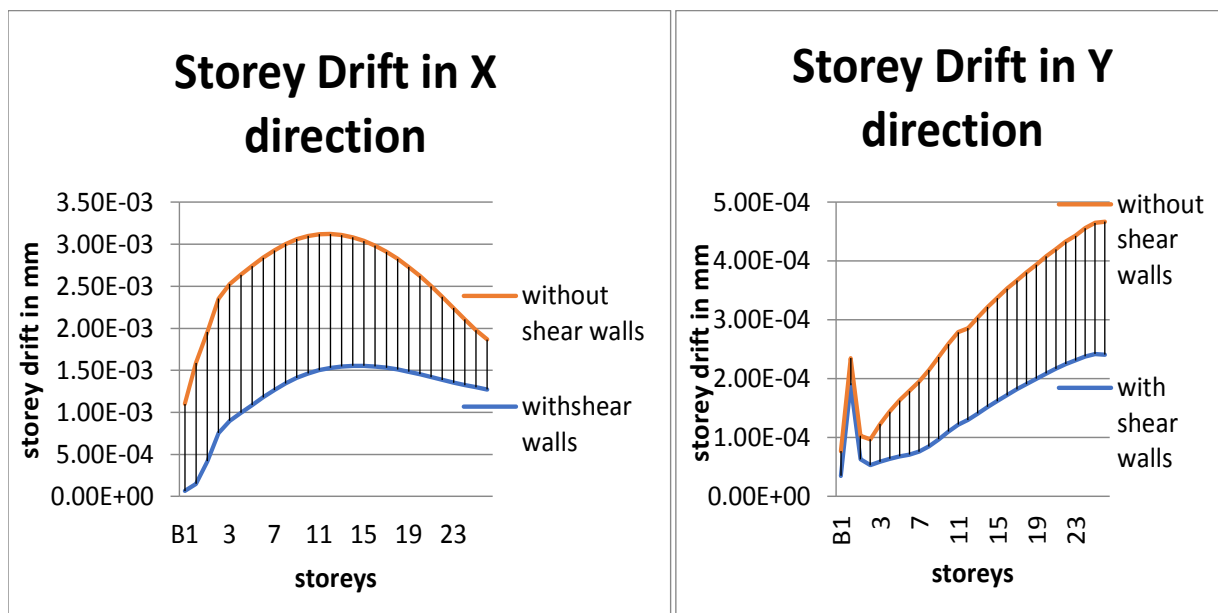


Fig No:9 Comparison of Storey Drift In X&Y Direction

Upon analyzing the graph provided, (see Fig.9) it becomes evident that structures lacking shear walls exhibit the highest levels of story drift. This observation raises concerns about the structural integrity and susceptibility to failure in such cases. Conversely, structures equipped with shear walls display the least amount of story drift. This pattern serves as a strong indicator of increased stability and enhanced resistance to lateral forces compared to structures without shear walls.

6. Conclusion

The following conclusion are drawn from the dynamic analysis:

- It is noted that structure with shear walls has shown 42.81% more resistance over shear force in x-direction and 44.26% more resistance over shear force in y-direction for the combination 4 of load case.
- It is observed that structure with shear wall recorded 84.75% & 29.44% more resistance in

base share in x-direction & y-direction max among the all combinations.

- The time period is reduced by 35.26% and frequency is increased by 95.41% for building with shear walls
- It is studied that structure with shear walls shown 114% more resistance in story drift in x-direction and 6.6% more resistance in story drift in y-direction for the combination 4 load case.
- It is observed that structure with shear walls has shown 208% more resistance in terms of torsion for the load combination 4.
- It is observed that structure with shear walls has shown 122% more resistance in terms of bending moment in x-direction & 27.10% in y-direction for the combination 4 of load case.
- It is concluded that building with shear walls have superior performance in resisting the earthquakes.

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