ANALYASIS AND DESIGN OF HIGH RISED BUILDING FOR DIFFERENT SESMIC ZONES BY USING ETABS SOFTWARE

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Abstract:

In densely populated urban centers, the construction of high-rise buildings with standard configurations is often hindered by uneven site proportions, aesthetic criteria, and practical requirements. However, irregularly designed structures with erratic horizontal or vertical arrangements are more vulnerable to earthquake and wind impacts, leading to building collapses, property damage, and human casualties. This study focuses on investigating which types of high-rise structures with irregular configurations exhibit superior responses to earthquake forces, minimize damage caused by seismic events, and are economically viable. Specifically, we examine the effectiveness of incorporating shear walls, placed at the core of the building, in improving the structural response to lateral stresses. Using ETABS software, we developed four different building models representing stilt+G+18-story structures with vertical irregularity. The shear walls were strategically placed at the center of each building. The models were created to cater to various seismic zones, ensuring a comprehensive analysis of their performance under different seismic Zones. The findings of this study will provide valuable insights for structural engineers and architects involved in the design of high-rise structures with irregular configurations.

Keywords: Shear wall, seismic activity, Storey drift, Base shear, time period, building torsion.

1. Introduction

The field of structural engineering encompasses the design and construction of various buildings, ranging from homes to commercial complexes. Since early human history, the need for shelter has driven the evolution of dwellings, from primitive caves to sophisticated structures made of wood and other materials[2]. Modern living standards have elevated the significance of well-designed residences, making construction a vital indicator of socioeconomic development. The responsibility for safety and the aspiration for comfortable homes motivate individuals to invest their hard-earned savings in quality housing.Structural analysis plays a central role in understanding how a system responds to external forces[22]. These forces, including the weight of objects such as appliances, people, and environmental elements like wind, snow, and dust, influence the structural behaviour[14]. Seismic loads, arising from events like earthquakes, are integrated into the overall weight of a structure since they were not originally present. Differentiating between dynamic and static analysis is crucial based on the acceleration of the applied forces in comparison to the building's natural frequency. Slowly applied loads can be analysed statically, neglecting inertia forces[7]. In contrast, dynamic analysis considers the complex loads resulting from human actions, wind, tides, vehicles, explosions, and other factors. Dynamic modelling techniques allow for the evaluation of displacements, historical data, and modal information, enhancing our understanding of structural dynamics. This research focuses on the placement of shear walls within the building core[1], a recognised solution for improving a structure's response to lateral forces. By strategically incorporating shear walls, engineers aim to enhance the building's ability to resist seismic stresses effectively[8]. The study compares different building models, considering factors such as storey drift and storey displacement. Through this analysis, the research aims to evaluate the performance of various shear wall configurations and their impact on the structural behaviour of buildings.The findings of this investigation will provide valuable insights into the effectiveness of shear wall placement and its role in improving the seismic performance of high-rise structures[10]. It is important to note that specific conclusions and comparisons between the models will depend on the detailed analysis and data presented in the research, including factors such as the specific design, site characteristics, seismic zones, and analysis methodologies employed [3]. These findings will contribute to the ongoing development of cost-effective and resilient building design strategies, enhancing the safety and sustainability of our built environment.

2. Literature Review

The need to build high-rise buildings and the need to address many challenges in the field of modern construction have led researchers to make several attempts over the years to reduce the seismic effect and lateral forces. research done recently to reduce the lateral stresses and seismic effect on high-rise buildings. We have some technicalities in that adopting shear walls is being researched to reduce the consequences such as deflection, storey drift, and storey displacements. Many studies have been conducted on buildings using shear wall, such as providing shear wall with and without openings [15], different shapes of staggered openings [21], and without openings in shear wall [15], using different slab arrangements [20], using bracings [19] using the Hexagrid system [24], and with and without shear wall [28], and different positions of shear wall [26].These are some of the studies on the shear wall. We can see from all the articles that adding shear walls reduces the seismic effects and lateral forces on tall buildings.

3. Objectives and study parameters

This study's goal is to pinpoint the irregular configuration structure for the examined models that works effectively under lateral loads. It is not always possible to have a structure with a regular design, despite the IS-code book's recommendation to always choose a regular layout for the building. When structures are constructed with or without shear walls in high earthquake zones and any irregular layout is necessary, this study helps to guarantee that the optimum model is chosen to account for the behaviour of the structure. The objective of the study is to compare the values of storey stiffness, story drift, displacement, and shear for the four zones. Constructions using ETABS software with shear wall placing at core of the building

4. Methodology

The entire methodology is explained in the flow chart which is as shown in Figure 1, In this paper we considered different seismic zones for shear wall placing at core of high rise buildings for this we have considered buildings details as shown in Table 1 for stilt+g+18 floors [1].

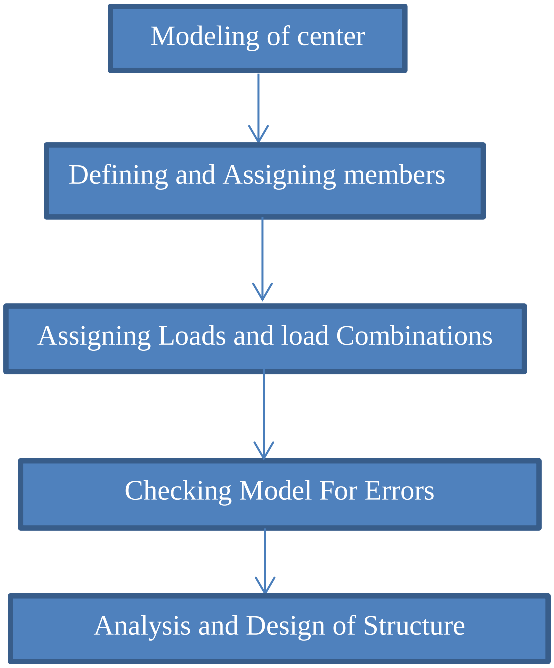


Figure 1. Detailed Methodology

This study focuses on conducting a comparative analysis of the structural behaviour of STILT+G+18 buildings for different seismic zones. The analysis is performed using the widely-utilised and versatile software ETABS. Known for its user-friendly interface and extensive capabilities, ETABS offers a comprehensive suite of features, including static and dynamic analysis[1], non-linear dynamic analysis, and non-linear static pushover analysis.

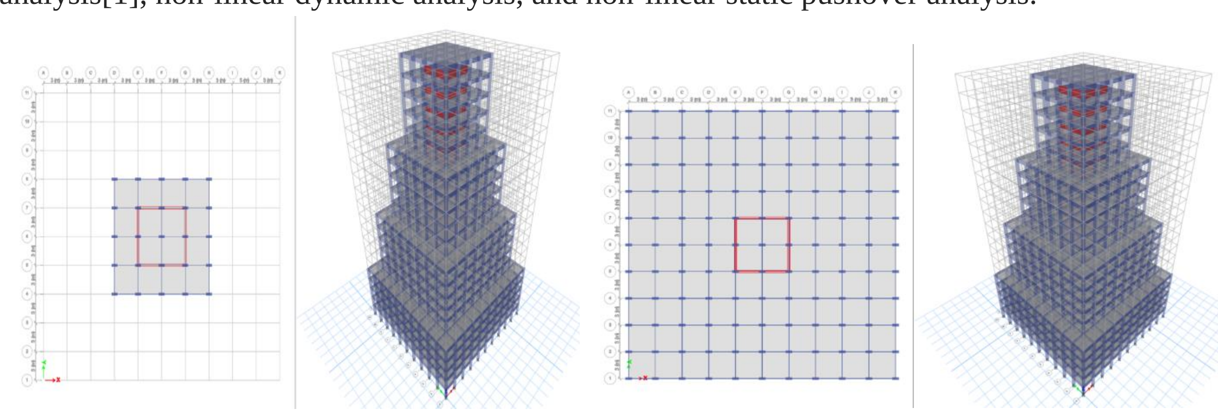


Figure 2. Shear walls at various corners

4.1 Details of structure

Parameters	Value	Remarks
Height of the building	60m	-
No of floors	stilt+g+18 floors	-
Floor to floor height	3m	-
Slab thickness	150mm	For all stories
Column dimension	750mmX300mm	For all floors
Beam dimension	600mmx300mm	-
Seismic zone	zone II,III,IV,V	-
Grade of steel	HYSD 500	-
Grade of concrete	M30	For all RC and concrete components
Thickness of shear wall	230	
Wind speed	50m/s	For all reinforcing bars
Response reduction factor	3	For all floors
Analysis method	Equivalent static method	-
R.c.c design code	IS 456 :2000[39]	-
Steel design code	IS 800: 2007	-
Wind design code	IS 875 :2016	-
Earth quake design code	IS 1893 : 2015[35]	-
Software	ETABS software[1]	-
Dead load	2.5 kN/m^2	-
Live load	3 kN/m^2	-
		For all floors
		For all floors

Table 1. Sample details of building considered for analysis

5. Results

5.1 Storey displacement

Storey displacement refers to the relative movement of each floor or storey with respect to the building's foundation or ground level. It is expected that the overall displacement values will increase as one moves higher up the structure. The shape of the deflected structure can be visualised through a graph illustrating the relationship between floor displacement and the height of the building. This graph provides valuable insights into the distribution of displacements throughout the structure, highlighting the deformation pattern and allowing for a better understanding of the building's response to external loads[1].

We have noticed from Figure 3 that in x and y direction story displacement is greater in zone 4. The maximum floor displacement occurs at story 20. We have placed a shear wall at the core of the building by [1] so that we have more storey displacement in zone 4.

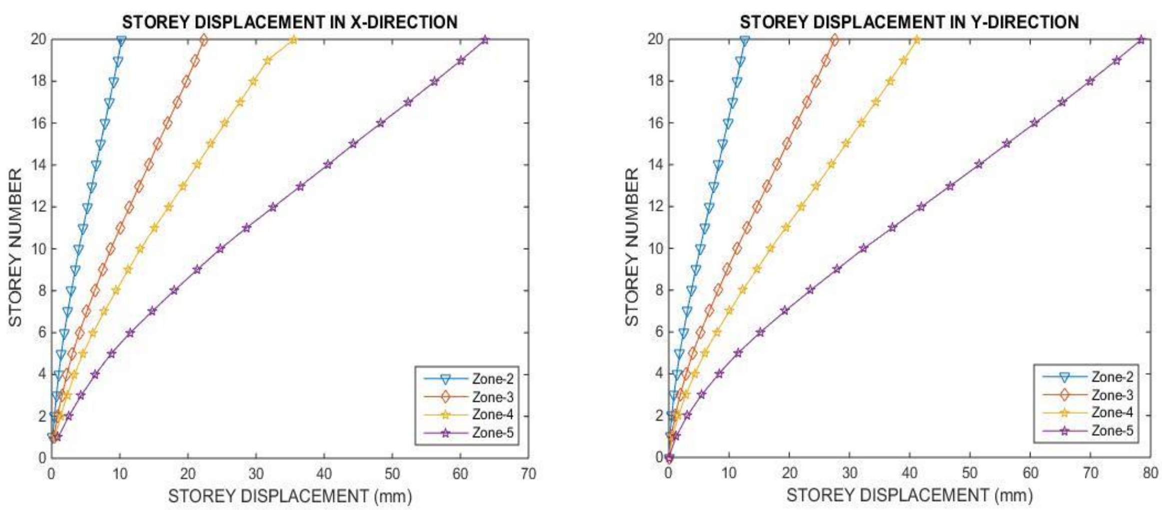


Figure 3. Storey Displacement in both X and Y Direction for various Zones

5.2 Story drift

Controlling lateral movement is essential to ensuring the structural integrity of multistory buildings and minimising damage. Among the critical parameters to be managed for seismic resilience is the storey drift ratio, which quantifies the difference in storey displacements between adjacent floors divided by the storey height. Controlling this ratio is crucial to mitigating damage when structures are subjected to ground accelerations during earthquakes. Storey drift demands have reached historically high levels, particularly in skyscrapers. One effective solution to enhance the structural response and reduce story drift is the incorporation of shear walls. Shear walls provide increased stiffness, leading to significant reductions in story drift. Studies have shown that the addition of shear walls can successfully reduce story drift by up to 75% when implemented according to appropriate design guidelines. In the absence of shear walls, buildings often experience story drift exceeding allowable code limits, which typically range from 1% to 2% depending on the construction type and occupancy. However, incorporating shear walls into various building designs subjected to the same ground motion has demonstrated remarkable reductions in maximum story drift values. Graphical representations of these designs consistently show significantly lower maximum drift values (often in the range of 1-2%) compared to conventional buildings without shear walls. The findings highlight the effectiveness of shear wall systems in reducing story drift and improving the overall seismic performance of structures. By implementing proper design practices and incorporating shear walls, engineers can enhance the safety and resilience of multistory buildings subjected to seismic forces.

We have noticed that in x and y direction storey drift is greater in zone 4 which is as shown in Figure 4. The maximum storey drift occurs at storey 11, when we place the shear wall at the core of the building. Shear wall placement at the centre has less storey drift when compared to other positions like shear wall placement at corners and sides [1].

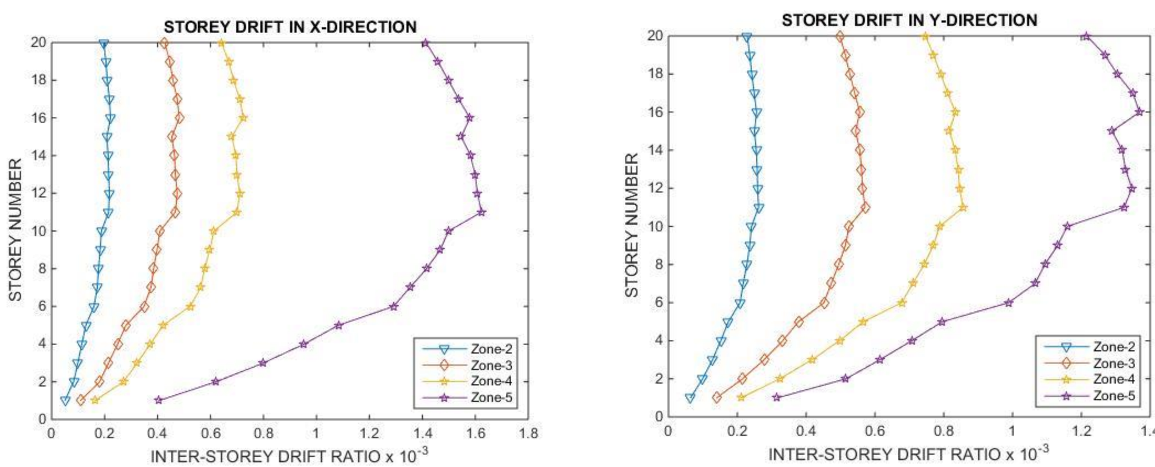


Figure 4. Storey Drift in both X and Y Direction for various Zones

5.3 Time period

A building will oscillate during an earthquake according to its inherent frequency for a predetermined period of time. The building is represented as being subject to harmonic oscillation, and the time period is computed similarly.

$$T = 2\pi\sqrt{(k/m)}$$

where total mass is m and total stiffness is k. The total lateral stiffness of all vertical parts that provide stiffness and resist moments is used to compute k. (columns, moment-resisting frames, shear walls, etc.) The total mass of each member on the shelf is used to compute the value of m.

We have noticed that the time period is longer in building in zone 4 which is as shown in Figure 5. The maximum time period occurs in mode 1. When we placed the shear wall at different positions, we got Shear wall placement at the centre has a shorter time period when compared to other positions, like shear wall placement at corners and sides. [1]

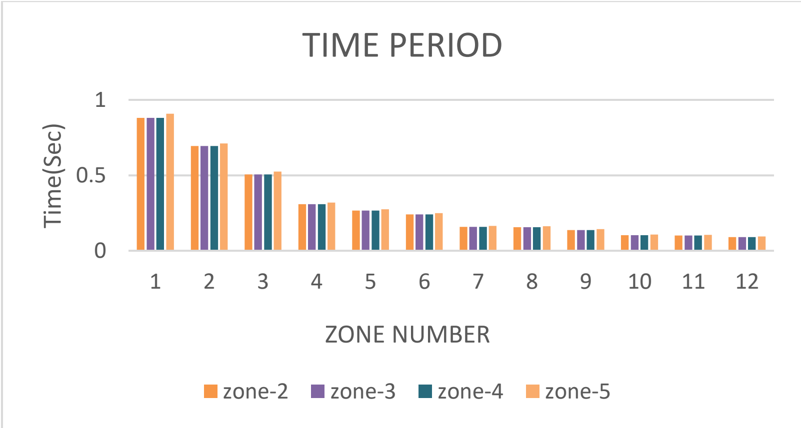


Figure 5. Time Period at various Zones

5.4 Shear force

The force exerted on a material that acts in a direction opposite to its extension and parallel to the cross-sectional plane of a body. It arises from shear stress acting over a surface and often leads to shear strain within the material. In the design of structural elements, it is crucial to calculate both the bending moment and shear force accurately. Shear force is also commonly referred to as shearing force, reflecting its nature of causing shearing or cutting effects within the material.

We have noticed from Figure 6 that in x and y direction shear force is greater in zone 4. The maximum shear force occurs at stories 1 and 2. When we placed shear walls at different positions, we got shear walls that had less shear force when compared to other positions, like shear walls placed at corners and sides [1].

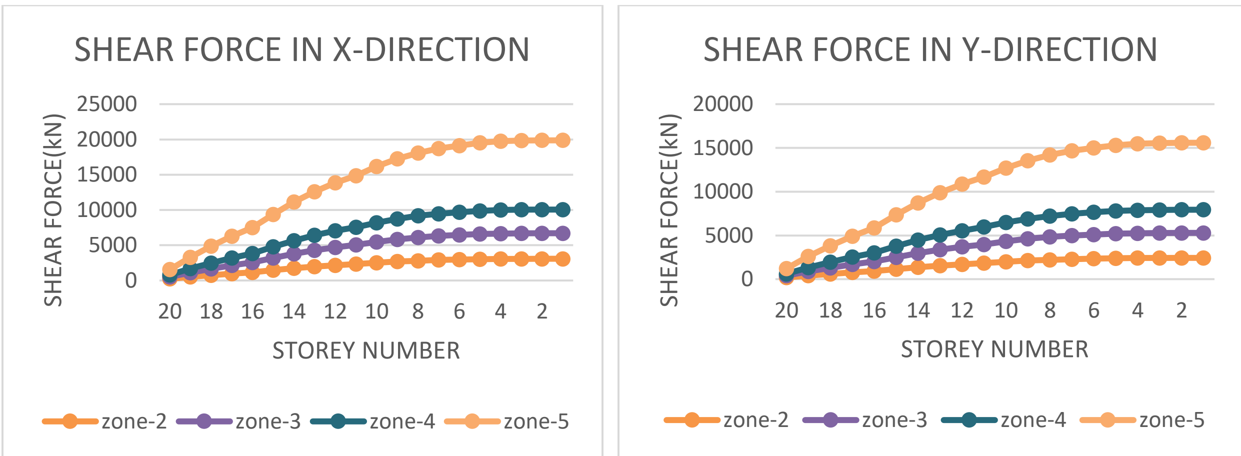


Figure 6. Shear Force in both X and Y Direction for various Zones

5.5 Bending moment

The moment created by the applied force or beam bend, which varies throughout the length of the beam or bar, is known as the bending moment in a beam. It is the algebraic sum of all moments taken in a beam or bar section in any direction, from either the left or right side of the section. KNm is the bending moment in SI units.

We have noticed that in x direction bending moments are higher in buildings in zone 4 which is as shown in Figure 7. The maximum bending moment occurs at story 1. When we placed shear walls at different positions, we found that shear walls without shear walls had less bending moments when compared to other positions like shear walls placed at corners and sides [1].

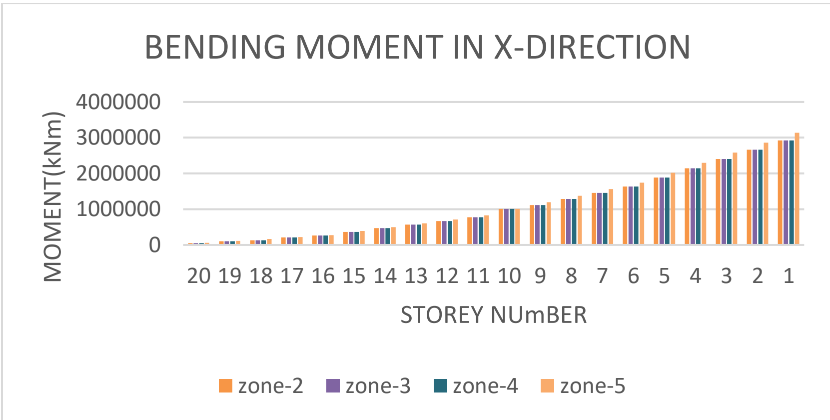


Figure 7. Bending Moment in Y Direction for various Zones

5.6 Torsion

Torsion is a state of strain that occurs when a material is subjected to an applied torque, causing it to twist. This phenomenon occurs whenever a structural element undergoes twisting forces. To illustrate this, consider holding a rubber bar with a circular cross-section and a rectangle inscribed on it. When one end of the bar is held fixed and the other end is twisted, the rectangular markings on the bar begin to tilt or deform. This deformation is a result of torsion, which is a type of strain that involves shear forces without any accompanying normal forces. Torsion causes the rubber bar to exhibit a tendency to return to its original shape due to the torsional stresses it experiences. These stresses are analogous to tension and compression but act perpendicular to them, resulting in shear stresses. Just as tension and compression cause elongation and contraction along the axis of a structural element, torsion induces shear deformation, leading to the twisting or shearing of the material.

We have noticed that torsion is more common in buildings in zone 4 which is as shown in Figure 8. The maximum torsion occurs at floors 1 and 2. When we placed shear walls at different positions, we found that shear walls without shear walls had less torsion when compared to other positions, like shear walls placed at corners and sides [1].

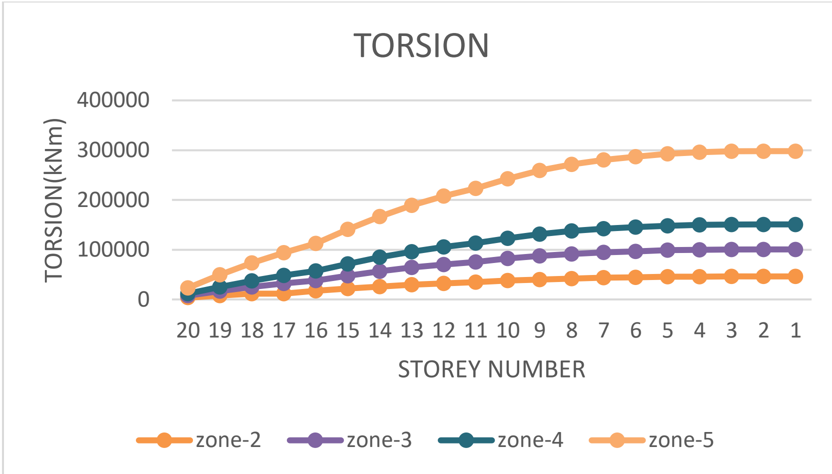
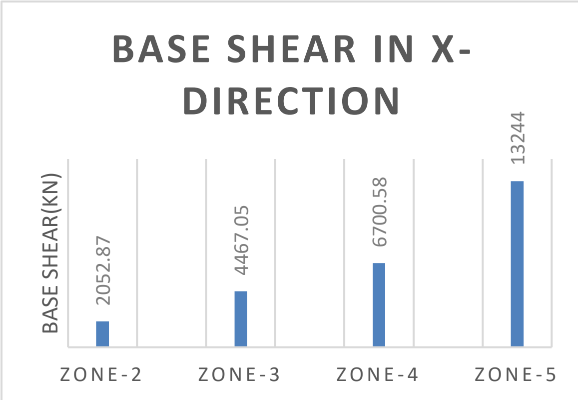


Figure 8. Torsion at various Zones

5.7 Base shear

Base shear refers to the maximum expected lateral force exerted on the base of a structure due to earthquake-induced ground motion. During seismic activity, the ground begins to move, generating lateral forces in the opposite direction of motion. This lateral force induced by seismic motion at the base of the structure is known as base shear. When designing a structure, engineers consider a range of shear values, from zero up to the base shear value. The structure is designed to withstand lateral loads or earthquake-induced loads that are equal to the base shear of the building. By designing for the base shear value, the structure is adequately prepared to withstand the expected lateral forces. It is crucial to ensure that the design of the structure accounts for the base shear and effectively resists the lateral loads. Failure to withstand the lateral forces above the base shear can result in structural collapse. Therefore, the base shear plays a critical role in designing and evaluating the seismic resistance of a building, ensuring its stability and safety during earthquakes.

We have noticed from Figure 9 that in x and y direction base shear is higher in building zone 4. When we placed shear walls at different positions, we got Shear wall placement at the centre has less base shear when compared to other positions like shear wall placement at the corners and sides [1].



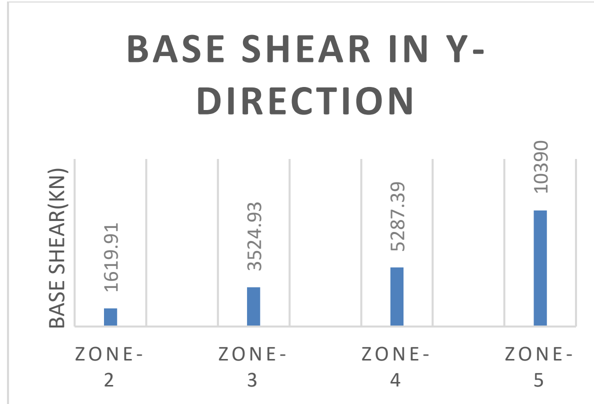


Figure 9. Base Shear in both X and Y Direction for various Zones

6. Conclusions

i. We found that the modal frequency is higher at mode 1 and minimum at mode 12. By comparing the modal frequencies of zone 2 and zone 5, we found that the modal frequency increases by changing the zone factor.

ii. We found that the base shear is higher in zone 5 when compared to zone 2, so we can conclude that the base shear increases by changing the zone factor.

iii. We found that the storey displacement in zone 5 is higher than in zone 2, zone 3, and zone 4, so we can conclude that changing the zone factor increases the storey displacement.

iv. We can see that the storey drift of the building is higher in the middle of the building and lower at the base of the building, and by comparing the storey drift of zones 2 and 5, it was found that the storey drift increased by changing the zone factor.

So from the above results, we can conclude that zone 5 is very critical for constructing high-rise buildings.

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9. Ethical Statements

i. This material is the authors' own original work, which has not been previously published elsewhere.
ii. The paper is not currently being considered for publication elsewhere.
iii. The paper reflects the authors' own research and analysis in a truthful and complete manner.
iv. The paper properly credits the meaningful contributions of co-author.
v. The results are appropriately placed in the context of prior and existing research.
vi. All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.
vii. All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.