Dynamic Performance of a G+28 Reinforced Concrete Residential Building in Seismic Zone V

Author-Ms. Sanija Patil, Student,
Master's in Structural Engineering, Dr. Vishwanath Karad's MIT WPU, Pune

Co- Author- Dr. Mrudula Sanjay Kulkarni, Professor of Civil-Structural Engineering,
Dr. Vishwanath Karad's MIT WPU, Pune

ABSTRACT

This study investigates the dynamic performance of a G+28 reinforced concrete residential building situated in Seismic Zone V, an area prone to intense seismic activity. As high-rise structures become more common in urban environments, especially in seismically sensitive zones, ensuring their stability and safety is critical. A detailed 3D model of the building was developed using ETABS software, incorporating realistic loading conditions and material specifications. Dynamic analyses, including response spectrum and modal analysis, were performed in accordance with IS 1893 (Part 1): 2016. Key performance indicators such as natural time periods, base shear, inter-storey drift, and mode shapes were examined. The results demonstrate that the integration of structural system significantly enhances the building's lateral stiffness, effectively minimizing drift and maintaining displacements within permissible limits. The study emphasizes the importance of well-planned lateral load-resisting systems in the seismic design of tall buildings. These findings can serve as a valuable reference for structural engineers and researchers aiming to improve the resilience of high-rise residential buildings in high-risk seismic zones.

Keywords: High-rise buildings; Seismic Zone V; Dynamic analysis; ETABS; Response spectrum analysis; Modal analysis; Shear walls; Lateral stiffness; Base shear; Inter-storey drift; Structural performance; Earthquake-resistant design; IS 1893:2016

1. GENERAL

Urbanization has led to a dramatic increase in the demand for residential and commercial spaces in metropolitan cities worldwide. With limited land availability and soaring population densities, vertical expansion through the construction of multi-storeyed buildings has become an indispensable solution. High-rise buildings not only optimize land use but also contribute significantly to the modern urban skyline and infrastructure development. However, the design and construction of tall structures come with unique challenges. As buildings grow taller, they become increasingly vulnerable to lateral forces generated by wind and seismic activities. While wind-induced forces are often predictable and relatively constant, seismic forces are highly dynamic and unpredictable, posing a significant threat to the stability and safety of tall structures.

India's diverse geological setting makes it prone to frequent seismic activities, with several regions classified under high seismic risk zones as per IS 1893 (Part 1): 2016. Seismic Zone V, which includes parts of the northeastern states, Jammu and Kashmir, and the Andaman and Nicobar Islands, is the most critical zone in the country in terms of seismic hazard. Structures located in this zone must be designed with utmost caution to ensure they can withstand severe ground motions without compromising the safety of occupants. For high-rise residential buildings in such zones, it becomes essential to evaluate how the structural system responds under dynamic loading conditions. Conventional static analysis is often inadequate for capturing the real behavior of tall buildings subjected to earthquake excitations. Therefore, it is necessary to employ advanced dynamic analysis methods to gain a realistic understanding of the structural response.

1.1 Core and Outrigger System

The core and outrigger system is widely recognized as one of the most effective structural systems for enhancing the lateral stiffness of high-rise buildings. As the demand for taller and more slender structures increases in urban areas, this system has gained prominence due to its structural efficiency and practicality in resisting both wind and seismic loads.

In a typical core and outrigger system, a central reinforced concrete or composite core is employed as the primary vertical and lateral load-resisting element. This core often accommodates essential building services such as lift shafts, stairwells, and utility ducts, making it a functionally integrated component of the building design. While the core alone can resist a significant portion of lateral forces, its effectiveness diminishes as building height increases, especially in regions with high seismic activity.

To address this limitation, outrigger elements — usually in the form of deep beams or steel trusses — are introduced at one or more strategic levels, often coinciding with mechanical or service floors. These outriggers connect the stiff central core to the perimeter columns, thereby creating a coupled system that mobilizes the exterior columns to act as additional moment-resisting components. When the building is subjected to lateral loads, such as those generated by an earthquake, the outriggers transfer part of the overturning moment from the core to the outer columns. This interaction effectively widens the structural "base," increases the overturning resistance, and significantly reduces overall lateral deflections and inter-storey drifts.

One of the notable advantages of the core and outrigger system is that it allows for greater architectural flexibility and usable floor space. Unlike braced frames that may obstruct floor layouts, outriggers are typically confined within mechanical floors, thereby minimizing their impact on usable areas. Furthermore, this system can be tailored to specific design requirements by varying the number, location, and configuration of outrigger levels.

In the context of this study, the core and outrigger system has been adopted for the G+28 residential building to achieve an optimal balance between structural performance and functional efficiency in Seismic Zone V. By integrating a rigid core with strategically placed outrigger levels, the building's lateral stiffness is enhanced, ensuring that displacements and drifts remain within acceptable limits as prescribed by relevant design codes. This system is particularly suitable for sites located in high seismic regions, where both strength and ductility are critical for maintaining the structural integrity and safety of occupants during strong ground motions.

Overall, the core and outrigger system provides an effective solution for addressing the challenges associated with the design of modern high-rise buildings, combining structural efficiency, economy, and adaptability within demanding urban and seismic environments.

1.2 Structural Wall System

A **structural wall system**, often referred to as a shear wall system, is one of the most widely adopted lateral load-resisting systems for medium- and high-rise buildings, particularly in regions prone to seismic or high wind loads. In this system, reinforced concrete walls — known as shear walls — are strategically positioned throughout the building plan to provide significant lateral stiffness and strength.

Shear walls act primarily by resisting lateral forces through in-plane shear and bending action, effectively transferring horizontal loads from floors and roofs down to the foundation. Due to their high in-plane stiffness, these walls significantly reduce lateral displacements and inter-storey drifts, which is critical for occupant comfort and structural safety during seismic events.

Typically, structural walls are integrated with the building's architectural layout by aligning them with corridors, lift shafts, stairwells, or external facades. This makes them efficient both structurally and functionally, as they do not occupy additional floor space beyond what is already needed for vertical circulation or partitioning.

In high-rise construction, structural walls are often combined with frames or core systems to form dual systems, further enhancing the building's seismic performance. The walls resist the majority of lateral loads, while the frames provide ductility and help redistribute forces in the event of local damage.

The main advantages of a structural wall system include:

- **High lateral stiffness and strength**, which helps control drift and sway.

- **Effective seismic performance**, due to their ability to dissipate energy through controlled cracking and plastic deformation.
- **Efficient use of space**, as walls double up as partitions and structural elements.

However, the placement and detailing of shear walls require careful consideration to avoid torsional irregularities and to ensure that the building's center of mass and center of rigidity are aligned as much as possible. Proper reinforcement detailing is essential to prevent brittle failure and ensure adequate ductility during strong earthquakes.

In summary, the structural wall system provides a reliable, cost-effective, and practical solution for resisting lateral loads in tall buildings, making it a preferred choice in seismic design, especially for residential and mixed-use towers in high-risk zones.

2. Literature Review

Dileshwar Rana et al. [1] studied on “Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building”. Researchers compared the shear force, a measure of earthquake force, across different building designs. They analyzed each floor individually and compared buildings of the same height but varying shapes. Buildings with setbacks (protruding sections) experienced higher shear forces than regular buildings. This effect became more significant with increasing setbacks. The study also investigated the bending moment, the twisting force buildings experience during earthquakes. Irregular buildings, including those with setbacks, faced higher bending moments than regular ones, regardless of height. This is due to the reduced stiffness of irregular structures, making them more susceptible to twisting. As a result, irregular buildings require more reinforcement to withstand these greater forces.

Response spectrum analysis (RSA) was used to compare the earthquake response of irregular buildings to a regular one. **Ravindra N. Shelke et al. [2]** examined the seismic demand (forces the structure needs to withstand) increases with higher seismic zones, requiring stronger buildings. Response spectrum method is recommended for high-rise or irregular buildings as it provides a more realistic assessment compared to simpler methods.

Arup et al. [3] carried out the research on “Simplified analysis method found effective for base-isolated buildings, including irregular ones”. The study found that the simplified static analysis with a specific force distribution based on the first eigen mode provided results very close to the more complex response spectrum analysis, even for irregular buildings. This applies to both stiff and flexible base isolation systems. While the simplified method might slightly underestimate the forces on the top floors of tall buildings, it generally provides more accurate results compared to another simplified method (linear distribution) which tends to overestimate top floor forces.

“Effects of vertical irregularities on the seismic behaviour of multi-storey buildings with base isolation” was researched by **N.I. Doudoumis et al. [4]** where a comparison of simplified static analysis using a specific force distribution based on the building's first vibration mode with a more complex multi-modal response spectrum analysis. The results showed that the simplified method provided very close results to the complex method for both regular and irregular base-isolated buildings, regardless of the base isolation system's stiffness. However, the simplified method might slightly underestimate forces on the top floors of tall buildings. This underestimation depends on the building's inherent damping and the effectiveness of the base isolation system in damping vibrations. He first eigen ode distribution is more accurate, especially for avoiding overestimation of forces on top floors. The study suggests that the simplified static analysis using the first eigen mode force distribution can be reliably applied to determine the seismic response of both regular and irregular base-isolated buildings.

Omkar M. Todkar et al. [5] investigated on “Study of Seismic Response of Multi-Storied Vertical Irregular Building Due to Stiffness Irregularity”. Study finds irregular buildings with sudden height changes move more under lateral loads. Uniform stiffness and regular shapes are ideal for better performance. Top floor irregularity may be slightly less harmful than lower ones, but avoiding irregularities is best.

In the Comparison of Analysis and Design of Regular and Irregular Configuration of Multi Story Building in Seismic Zones various parameter such as story shear force, mass irregularity, time history analysis, stiffness irregularity and vertical geometric irregularity. Were researched. In conclusion**, El Sayed Abdel Naby et al. [6]** stated the shear force is highest in the first floor, decreasing towards the top, regardless of irregularity type. There is increase in base shear compared to regular buildings in mass irregularity. Stiffness irregularity also Reduces base shear but increases inter-story drifts. Geometry irregularity leads to higher displacements in upper stories compared to regular buildings, converging towards the lower stories.

R Ismail et al [7] studied “Seismic performance for vertical geometric irregularity frame structures”. This study investigated the stress and displacement of buildings with vertical geometric irregularities (uneven shapes) subjected to seismic forces (earthquakes). The analysis considered both the normal building load and the seismic wave to understand the combined effect. Using eigenvalue analysis, the study identified the locations of maximum stress (critical points) under seismic loading. The overall results suggest that the vertical geometric irregularity frame can withstand the variations in loading and forces due to the earthquake. Additionally, the analysis of mode shapes revealed that the frame experiences swaying movements but the displacements are not significant. In conclusion, the study suggests that the vertical geometric irregularity in this specific case seems to be safe under the applied seismic performance loading.

“Irregularity effects on the seismic performance of l-shaped multi-story buildings” was examined by **Momen M. M. Ahmed et al [8**]. When a floor is not stiff enough (like an L-shape), the distribution of earthquake forces and the building's response are significantly affected. Consequences of neglecting irregularity: Local damage: Uneven force distribution can cause torsion and damage to outer columns, jeopardizing the building's stability during earthquakes. Designing without considering irregularity can lead to miscalculations in the building's seismic performance. Impact on functionality: Irregularity can lead to increased lateral deflections (swaying) and inter-story drifts (movement between floors), compromising the building's functionality and potentially leading to performance failures.

Mohd. Swaliheen et al. [9] researched “Seismic Response of Vertically Irregular RC Frame with Stiffness Irregularity at Fourth Floor”. Frame 1: Vertically irregular (uneven floor heights). Frame 2: Stiffness irregularity on a vertically irregular frame (combination of uneven floor heights and stiffness variations). Frame 2 (combined irregularity) performed worse than Frame 1 (only vertical irregularity) under lateral loads (earthquakes): Larger story displacements: Frame 2 experienced significant changes in displacement across all floors, indicating greater movement and potential structural weakness. Higher story drifts: Frame 2 showed extreme changes in story drift (movement between floors) at the level with the increased height, suggesting higher stress concentration and potential damage. Slightly higher story shear: Frame 2 experienced slightly higher forces at each floor level compared to Frame 1.

Pravin S Patil et al. [10] studied "RCC Structure with Different Bracing Configuration on Seismic Issues". This study compared different types of bracing (like X, V, and eccentric) in two building models. They found that all bracing configurations can help control the building's behavior under different loads, including earthquakes. X-bracing was the most effective, reducing forces, bending, and vibration time. Inverted V and Eccentric Backward were also good options. Overall, X-bracing was the best at controlling horizontal movement. These findings suggest that bracing can be a valuable tool for designing tall buildings in the future.

"Analysis & design of G+20 RCC building using X-bracing system with base Isolator" was studied by **Ashish R. Kondekar et al. [11]** using X-bracing can help prevent buildings from collapsing and reduce the forces on the building during an earthquake. This makes the building more stable. However, it can also increase the displacement of each floor. Overall, X-bracing can improve a building's earthquake resistance and potentially reduce the amount of reinforcing steel needed.

Rohan Chavan et al. [12] studied "Seismic Analysis of Irregular RC Structure with Cross-Bracing System". This study analyzed the effectiveness of steel bracing in improving the earthquake resistance of a 11-story building. The results showed that adding steel bracing, even with a minimal increase in weight, significantly reduces lateral movement, bending forces, and story drift. This makes the building more stable during earthquakes. Both X-bracing and other types of bracing were found to be effective in improving structural performance. These findings suggest that steel bracing can be a valuable tool in designing earthquake-resistant buildings.

3. METHODOLOGY

This chapter outlines the methodological framework adopted to assess the dynamic performance of the proposed G+28 high-rise residential building located in Seismic Zone V. The primary objective is to ensure that the structure can adequately resist seismic forces through rigorous analysis and appropriate modeling techniques.

To begin with, **Response Spectrum Analysis (RSA)** has been employed as the principal dynamic analysis method. RSA enables a detailed evaluation of how the building responds to a range of ground motion frequencies by examining the peak responses of an equivalent set of single-degree-of-freedom systems. This approach condenses complex seismic data into a practical spectrum, which helps identify critical modes and natural frequencies that may influence structural performance. The insights gained through RSA form the basis for making informed decisions to enhance seismic resilience, ensuring compliance with safety codes while optimizing the design.

For structural modeling and analysis, **ETABS 2022** has been utilized due to its robust capabilities in simulating the behavior of modern building systems. ETABS facilitates the accurate representation of the building geometry, material properties, and support conditions. In the modeling phase, beams and columns are defined as line elements, while slabs are assigned either membrane or shell properties based on their role in force transfer and bending resistance. Diaphragm constraints are applied to replicate the rigid floor behavior typical in reinforced concrete buildings.

Loading conditions in ETABS have been defined in line with relevant IS codes, covering dead loads, live loads, and seismic loads. Automated load patterns and combinations ensure that all possible load scenarios are evaluated comprehensively. The software's capacity to generate self-weight, uniform area loads, and code-based lateral loads further enhances the reliability of the model.

The **analysis process** in ETABS involves static and dynamic evaluation to capture both steady-state and time-dependent structural responses. Modal analysis determines the building's natural periods and mode shapes, while RSA quantifies the expected seismic forces and resulting displacements. The results are reviewed through graphical outputs and numerical reports to verify structural adequacy.

In addition, ETABS provides integrated **design tools** that check all primary structural elements — including beams, columns, slabs, and foundations — against the provisions of the selected design codes. Automated checks and design iterations help ensure that strength, stability, and serviceability criteria are consistently met, while also allowing scope for design refinement where necessary.

In conclusion, this methodology combines theoretical seismic principles with advanced software tools to create a reliable and practical basis for the structural evaluation of the high-rise building. The next chapter details how these modeling strategies have been applied specifically to the core and outrigger system adopted for this project, presenting the structural configuration, applied loads, and the resulting dynamic performance insights.

CHAPTER 4

MODELLING AND ANALYSIS

This section outlines the modelling strategy and analysis procedure adopted to evaluate the seismic performance of the proposed G+28 high-rise residential building using a core and outrigger system and Structural Wall System in Seismic Zone V. The analysis was carried out using ETABS 2022, which is widely recognized for its robust capabilities in modelling complex building systems in accordance with relevant IS codes. The structural system consists of a centrally located reinforced concrete core, which accommodates vertical circulation elements such as lift shafts and staircases. To improve lateral stiffness and limit drift, outrigger beams connect the core to the perimeter columns at designated levels, creating an integrated structural system capable of efficiently resisting seismic forces. The building was modelled using beam and column elements represented as frame members, while slabs were defined as shell elements to capture both in-plane and out-of-plane behavior. Rigid diaphragm constraints were assigned at each floor level to simulate the realistic collective movement of the floor slabs during lateral loading. Design loads were defined based on IS 875 (Part 1, Part 2, and Part 3) for dead, live, and wind loads respectively, while seismic parameters were specified according to IS 1893 (Part 1): 2016 for Zone V with medium soil conditions. Load combinations were automatically generated in ETABS to ensure that all critical loading scenarios were accounted for as per codal provisions. To study the dynamic response, a modal analysis was first conducted to extract the fundamental natural periods and mode shapes of the building. This was followed by a Response Spectrum Analysis (RSA), which provides a practical means to estimate the peak structural response to seismic excitations without requiring a full time history record. The response spectrum was defined in accordance with IS 1893, considering a damping ratio of 5% for reinforced concrete structures. Key output parameters such as base shear, lateral displacements, inter-storey drift, and mode shapes were carefully reviewed. The results indicate that the core and outrigger system effectively enhances the lateral stiffness of the building and keeps storey drift within permissible limits. This confirms the suitability of the selected structural system for a high-rise building in a high seismic risk zone.

4.1 BUILDING PARAMETERS

This study primarily focuses on the dynamic analysis of a high rise building structure by considering the seismic zone V for Shillong location on the North-East of India. The overall analysis is done for a Twenty-eight storey high rise building structure in ETABS software.

Table 1 Structural Details of Building

Parameters	Details
Plinth Beam Size (mm)	300X450
Floor Beam Size (mm)	300X700
Shear Wall (mm)	300X1000

Slab Thickness (mm)	150
External Wall Thickness (mm)	300
Floor to Floor Height (mm)	3000
Height of Building (mm)	83400

Table 1 provides information about various aspects of a building, including the plan area, beam and column size, slab thickness, and height.

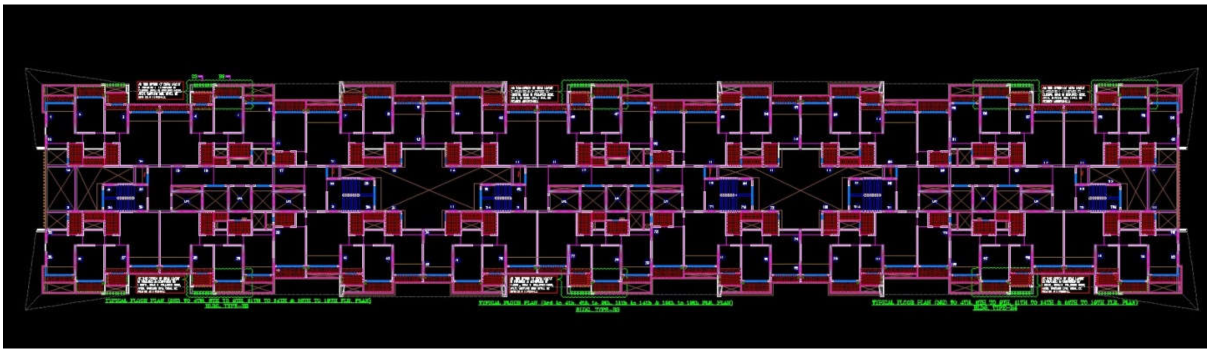

Figure 1 Typical Floor Plan

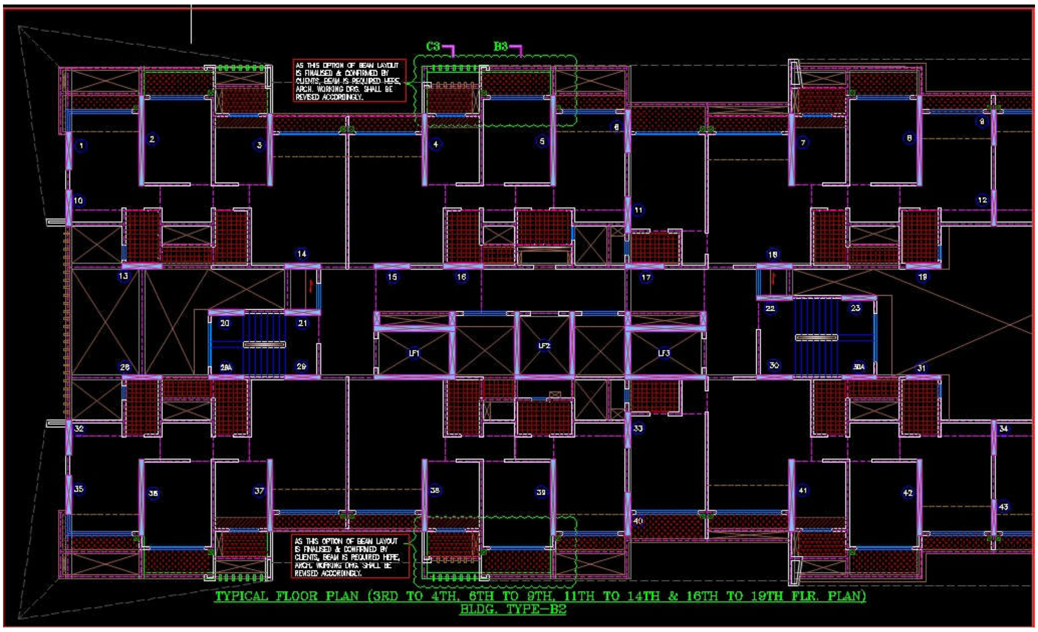

Figure 1(a) Typical Floor Plan (1/3)

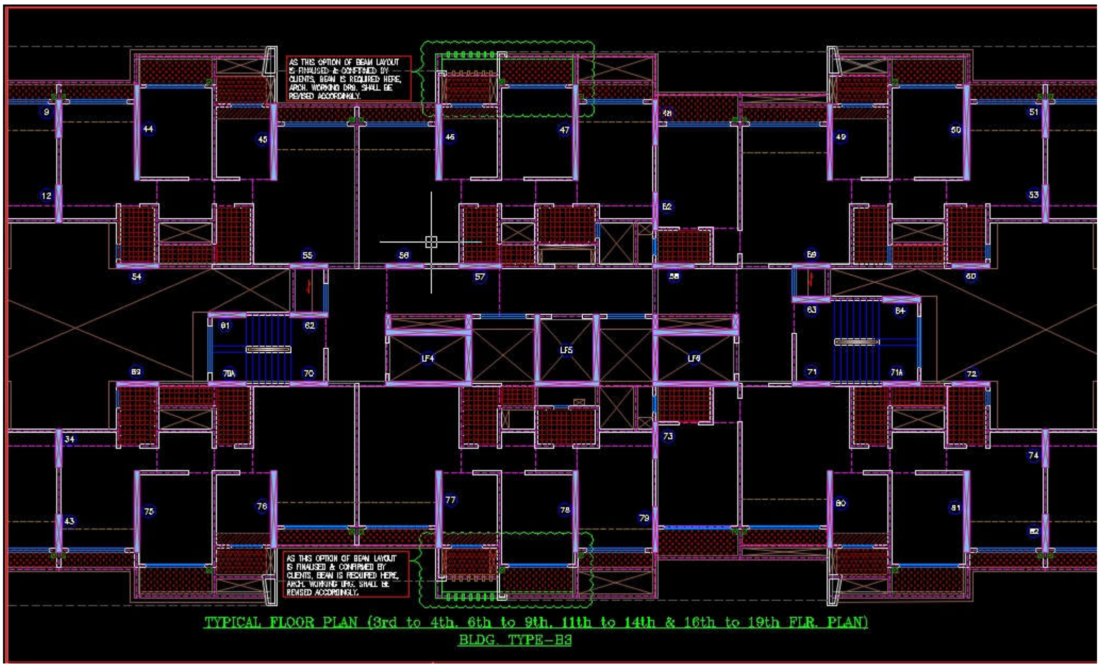

Figure 1(b) Typical Floor Plan (2/3)

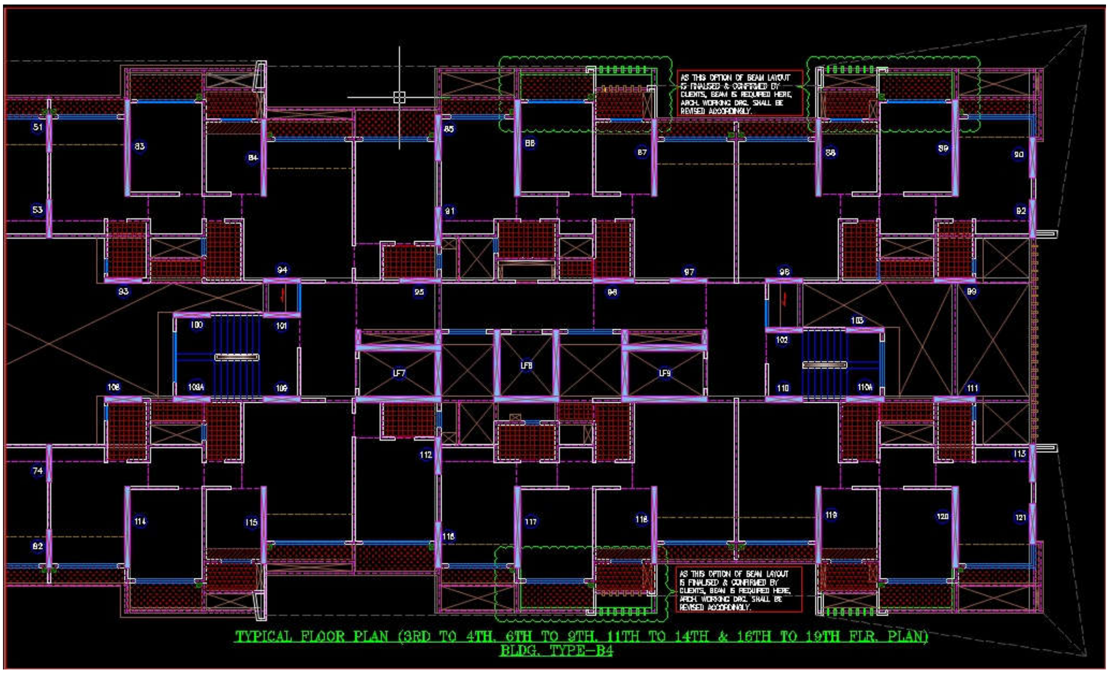

Figure 1(c) Typical Floor Plan (3/3)

The high-rise building's typical floor plan, depicted in Figure 1, is intended for analysis in the ETABS software.

4.2 LOADING PARAMETERS

Calculating loading parameters in structural analysis involves determining load types and magnitudes, combining them into load combinations, considering load distribution and application points, calculating load effects using structural mechanics principles, and comparing them to element capacities for stability and safety. Understanding load types and their effects is crucial, such as assuming concrete density as 25 kN/m³ and brick density as 18 kN/m³.

4.2.1 Seismic Load Parameters

As per IS 1893 Part I 2016, the Indian standard code for earthquake loads on buildings and structures, earthquake load parameters are defined to ensure the structural safety and stability of buildings. The soil type considered for the analysis is Type II soil (Medium – stiff). The importance factor, response reduction factor, time period, design acceleration coefficient is given in the table 4.2 below:

Table 2 Earthquake Load Details for Building

Particulars	**Details**
City	Shillong
Seismic Zone	V
Importance Factor (I)	1.20
Response Reduction Factor (R)	5
Time Period (seconds)	2.069
Design Acceleration Coefficient (Ah)	0.036

4.3 LOAD COMBINATIONS

In the limit state design of reinforced concrete structures, load combinations are determined based on the guidelines provided in IS Code 456 Table 18. These load combinations are essential for ensuring the safety and reliability of the structures. The table specifies the partial safety factors to be applied to different types of loads, such as dead load, live load, wind load, and earthquake load. By considering these load combinations, the various possible scenarios and design structures that can withstand the expected loads and forces are defined below:

Table 3 Static Earthquake Load Combinations

EQ LOAD COMBOS	NAME
0.9DL + 1.5 EQPX	D9EQPX15
0.9DL + 1.5 EQNX	D9EQNX15
0.9DL + 1.5EQPY	D9EQPY15
0.9DL + 1.5EQNY	D9EQNY15
0.9DL – 1.5 EQPX	D9EQPNX15
0.9DL – 1.5 EQNX	D9EQNNX15
0.9DL –1.5EQPY	D9EQPNY15
0.9DL – 1.5EQNY	D9EQNNY15
1.2 (DL + LL + EQPX)	EQPX12
1.2 (DL + LL + EQNX)	EQNX12
1.2 (DL + LL + EQPY)	EQPY12
1.2 (DL + LL + EQNY)	EQNY12
1.2 (DL + LL – EQPX)	EQPNX12
1.2 (DL + LL – EQNX)	EQNNX12
1.2 (DL + LL – EQPY)	EQPNY12
1.2 (DL + LL – EQNY)	EQNNY12
1.5 (DL + EQPX)	EQPX15
1.5 (DL + EQNX)	EQNX15
1.5 (DL + EQPY)	EQPY15
1.5 (DL + EQNY)	EQNY15
1.5 (DL – EQPX)	EQPNX15
1.5 (DL – EQNX)	EQNNX15
1.5 (DL – EQPY)	EQNNY15
1.5 (DL – EQNY)	EQNNY15

Table 4 Dynamic Earthquake Load Combinations

SPEC LOAD COMBOS	NAME
0.9DL + 1.5SPECX	D9SPECX15
0.9DL + 1.5SPECY	D9SPECY15
0.9DL – 1.5SPECX	D9SPECNX15
0.9DL – 1.5SPECY	D9SPECNY15
1.2 (DL+ LL + SPECX)	SPECX12
1.2 (DL + LL + SPECY)	SPECY12
1.2 (DL + LL – SPECX)	SPECNX12
1.2 (DL + LL – SPECY)	SPECNY12
1.5 (DL + SPECX)	SPECX15
1.5 (DL + SPECY)	SPECY15
1.5 (DL – SPECX)	SPECNX15
1.5 (DL – SPECY)	SPECNY15

Table 5 Serviceability Load Combinations

EQ COMBO	NAME
DL+EQPX	DEQPX
DL+EQNX	DEQNX
DL+EQPY	DEQPY

DL+EQNY	DEQNY
DL-EQPX	DEQPNX
DL-EQNX	DEQNNX
DL-EQPY	DEQPNY
DL-EQNY	DEQNNY
DL+0.8(LL+EQPX)	DLEQPX8
DL+0.8(LL+EQNX)	DLEQNX8
DL+0.8(LL+EQPY)	DLEQPY8
DL+0.8(LL+EQNY)	DLEQNY8
DL+0.8(LL-EQPX)	DLEQPNX8
DL+0.8(LL-EQNX)	DLEQNNX8
DL+0.8(LL-EQPY)	DLEQPNY8
DL+0.8(LL-EQNY)	DLEQNNY8

4.4 STRUCTURAL SYSTEMS MODELING ETABS SOFTWARE

In the ETABS software, various types of structural systems including ordinary moment resisting frame, shear wall and belt truss are modeled. These structural systems are analyzed under various load combinations mentioned in the above tables. Table 4.6 provides detailed information about all three models, including their respective structural systems. This data helps in evaluating the performance and behavior of each model under the seismic conditions under different structural systems, allowing to study various parameters such as storey displacement, storey drift and storey stiffness.

Table 6 Structural Systems Models in ETABS

Model No.	Type of Structural System
I	Shear Wall Structural System
II	Core and Out-trigger System

The figures presented below showcase the detailed comprehensive plan, 3D visualization, and loading analysis generated using the ETABS software. These figures illustrate the different types of structural systems employed in various models. The comprehensive plan outlines the project's objectives, strategies, and actions in a thorough and systematic manner. The 3D visualization offers a visual representation of the structures, allowing for a better understanding of their overall form and geometry. Additionally, the loading analysis provides insights into how different loads, such as gravity and wind forces affect the structural performance of each model.

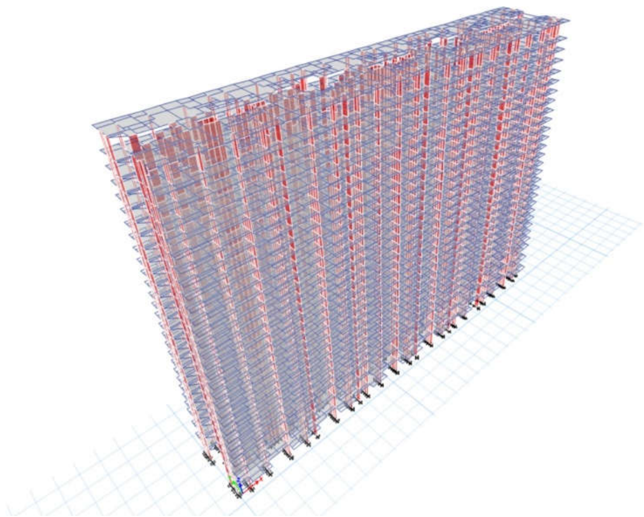

Figure 2(a) 3D View of Shear Wall System

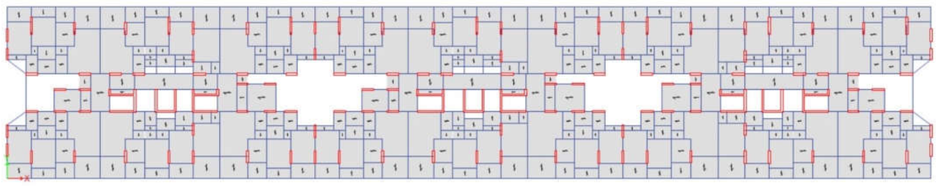

Figure 2(b) Plan View of Shear Wall System

Figure 2(a) & 2(b) Model with Shear Wall System

In Figure 2(a) & 2(b), showcase the shear wall structural system employed in this particular model. The figure visually presents the layout and arrangement of the shear walls within the model, providing insights into the structural configuration. For the analysis, a consistent thickness of 300 mm is considered for the shear walls. The structure incorporates a central core and shear walls positioned along with some walls equally distributed on the both the axes. These shear walls, including the core of the structure, share the same type and dimensions, ensuring uniformity throughout the design.

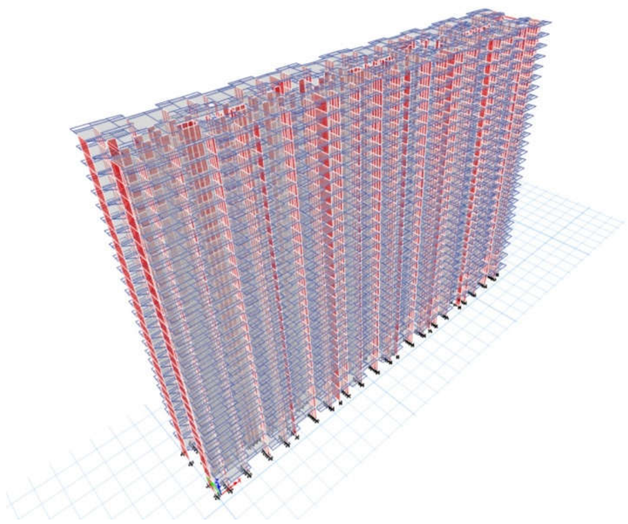

Figure 3(a) 3D view of Core & Out-trigger System

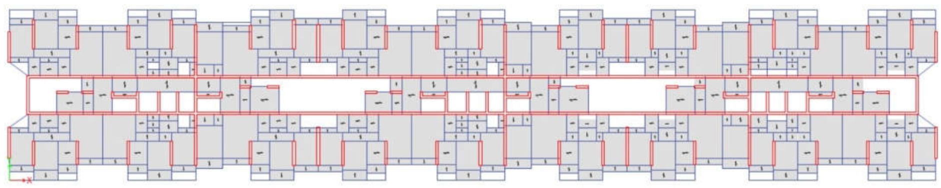

Figure 3(b) Plan view of Core & Out-trigger System

Model with Core & Out-trigger System

Figure 3 (a) & (b) provides a visual representation of the Core & Out-trigger structural system utilized in Model II. The figure showcases the arrangement and configuration of the core and outrigger elements within the model. This visual depiction shows that the Core & Out-trigger System are provided at fifteenth and twentieth storey of the structure. A central reinforced concrete or composite core is employed as the primary vertical and lateral load-resisting element. This core accommodates essential building services such as lift shafts, stairwells, and utility ducts, making it a functionally integrated component of the building design.

5. RESULTS AND DISCUSSIONS

Table 7 Modal Participating Mass Ratios

Systems	Mode	Period (sec)	UX	UY	RZ
Shear Wall System	1	4.92	0%	6%	63%
	2	4.68	0%	63%	6%
	3	3.45	76%	0%	0%
Core and Out-trigger System	1	3.99	0%	62%	10%
	2	3.82	0%	10%	63%
	3	2.43	83%	0%	0%

The time period of the shear wall structural system is below 8 seconds is significant for several reasons as per IS 16700-2023, Clause 5.5.2, Page No 5. Firstly, it indicates that the structural system has a relatively high natural frequency, which means it can better resist lateral forces generated by earthquakes. This is because structures with higher natural frequencies are less likely to resonate with external forces and experience significant damage or collapse. The comparison of time period in mode I for various structural systems is depicted in Figure

5.1 Storey Displacement

Table 8: Displacement due to Seismic Load

Structural System	Maximum Displacement	Displacement in X direction	Displacement in Y direction
Shear Wall System	333.6	148.01	325.3
Core and Out—trigger System	333.6	61.435	216.52

Table 9: Displacement due to wind Load

Structural System	Maximum Displacement	Displacement in X direction	Displacement in Y direction
Shear Wall System	166.8	23.69	264.21
Core and Out—trigger System	166.8	7.687	159.06

5.2 Storey Drift

Table 10: Lateral Storey Drift

Structural System	Maximum Drift	Drift in X direction Spec X	Drift in Y direction Spec Y
Shear Wall System	1.5	1.01	1.03
Core and Out—trigger System	1.5	1.06	1.15

6. CONCLUSION

This study presented a comparative analysis of the shear wall system and the core-outrigger structural system using ETABS, focusing on their lateral performance under seismic and wind loads in Seismic Zone V. Key structural parameters such as lateral displacement and storey drift in both X and Y directions were evaluated.

The results clearly indicate that the core-outrigger system significantly improves displacement control:

- Under seismic loading, lateral displacement reduced
- by 58.5% in the X-direction and 33.4% in the Y-direction.
- For wind loading, displacement decreased by 67.6% in the X-direction and 39.8% in the Y-direction, compared to the shear wall system.

However, in terms of storey drift, the core-outrigger system showed a slight increase: approximately 4.95% higher in the X-direction and 11.65% higher in the Y-direction. These values should be further reviewed against the drift limits specified in IS 1893:2016, but they remain within typical acceptable bounds for high-rise design.

In conclusion, the core and outrigger structural system provides significantly better control of lateral displacements, making it a more suitable choice for tall buildings in seismic-prone regions. While storey drift increased slightly, the overall reduction in displacement confirms the core-outrigger system's effectiveness in enhancing stiffness and resisting lateral forces.

6.1 FUTURE SCOPE

The present study lays the foundation for future research and exploration in the field of structural engineering. This research investigation has contributed valuable insights into the identification of an effective structural system through a comprehensive comparison of two types of structural systems however, there remain numerous avenues for further investigation and development in this area of research. The following point can be adopted for future scope of study:

i) Identifying the effective structural system considering the different horizontal and vertical irregularities of buildings.

ii) Identifying the effective structural system considering the slopping or irregular terrain.

REFERENCES

1. **B. XING, E. LUMANTARNA, NELSON T. K. LAM AND SCOTT MENEGON,"** Torsional Rigidity of Asymmetrical Multi-Storey Reinforced Concrete Buildings**",** Australian Earthquake Engineering Society**, NOV 2021**
2. **MOHD. SWALIHEEN, MIRZA AAMIR BAI, "**Comparison of Analysis and Design of Regular and Irregular Configuration of Multi Story Building in Seismic Zones"**,** International Journal for Research in Applied Science & Engineering Technology, AUG 2021
3. **MARIUS FLORIN BOTIS AND CAMELIA CERBU,"** A Method for Reducing of the Overall Torsion for Reinforced Concrete Multi-Storey Irregular Structures" Applied Sciences MDPI, Aug 2020
4. **OMKAR M. TODKAR, PADMAKAR. J. SALUNKE** "Study of Seismic Response of Multi-Storied Vertical Irregular Building Due to Stiffness Irregularity". International Journal of Research in Engineering, Science and Manage JAN 2019
5. **R ISMAIL1, N A MAHMUD AND I S ISHAK** "Seismic performance for vertical geometric irregularity frame structures". IOP Conf. Series: Earth and Environmental Science, 2018
6. **RAVINDRA N. SHELKE, U. S. ANSARI** "Seismic Analysis of Vertically Irregular RCC Building Frames", International Journal of Civil Engineering and Technology, JAN 2017
7. **MOMEN M. M. AHMED, SHEHATA E. ABDEL RAHEEM, MOHAMED M. AHMED AND ALY G. A. ABDEL-SHAFY** "Irregularity effects on the seismic performance of l-shaped multi-story buildings" Journal of Engineering Sciences, Sept 2016
8. **EL SAYED ABDEL NABY, NABY ABDEL AZIZ ABOU KHALIFA,** "Comparison of Analysis and Design of Regular and Irregular Configuration of Multi Story Building in Seismic Zones", United Arab Emirates University, 2015
9. **DILESHWAR RANA, PROF. JUNED RAHEEM** "Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building", International Research Journal of Engineering and Technology (IRJET). JULY 2015
10. **S MONISH1, S KARUNA, "**A Study on Seismic Performance of High Rise Irregular RC Framed Buildings" International Journal Of Research In Engineering And Technology, May 2015
11. **AIJAZ SHAIKH, GIRISH DESHMUKH**, "Seismic Response of Vertical Irregular RCC Frame with Irregularity At 4th Floor", International Journal of Emerging Technology and Advanced Engineering, Aug 2013
12. **N.I. DOUDOUMIS, F. GRAVALAS,** "Effects of Vertical Irregularities on The Seismic Behaviour Of Multi-Storey Buildings with Base Isolation" Research Gate, Jan 2005

13. IS 875(Part 2):1987. "Indian standard code practice for deign loads (Other than earthquake) for building and structure, Part 2: Imposed Loads".
14. I.S Code 456 : 2000. "Indian standard code of practice for plain & reinforced concrete".
15. I.S 1893(Part 1):2016. "Indian standard code Criteria for earthquake resistant design of structures".
16. **PRAVIN S PATIL, ISHWAR SONAR**, " RCC Structure With Different Bracing Configuration On Seismic Issues" Research Gate, March 2018
17. **ASHISH R. KONDEKAR, DHARTI B. DOLARE, PRAGATI V. BALANDE, DIVYA S. SHINDE, ANUJA J. ALKUNTE,** "Analysis & design of G+20 RCC building using X-bracing system with base Isolator", International Journal Of Creative Research Thoughts, May 2022
18. **Rohan Chavan, Prachi Sohoni,** "Seismic Analysis of Irregular RC Structure with Cross-Bracing System", IJSRSET 2018