

Comparative Seismic Performance of a G+20 RCC Residential Building in Seismic Zones I, III, IV, and V of India Using ETABS

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ABSTRACT

The rapid urbanization of Indian cities has necessitated the construction of high-rise reinforced concrete (RCC) buildings that are both functional and resilient against seismic hazards. This study presents the structural analysis and design of a G+20 residential building, with all members conservatively proportioned to satisfy the demands of Seismic Zone V as per IS 1893 (Part 1):2016 and IS 456:2000. The building is modeled and analyzed using ETABS software, with emphasis on lateral load resistance, inter-storey drift control, and overall stability under earthquake loading. Comparative evaluation of seismic responses across Zones II–V is carried out, focusing on parameters such as base shear, storey shear distribution, displacement profile, and fundamental time period. The results highlight the progressive increase in seismic demand with higher zone classification, while demonstrating that conservative Zone V design ensures adequate safety margins across all zones. The study underscores the importance of robust member sizing, ductile detailing, and adherence to codal provisions in achieving earthquake-resistant design for high-rise RCC structures. The findings contribute to safer urban infrastructure development and provide a reference framework for future design of tall residential buildings in seismically active regions.

The increasing demand for vertical expansion in urban India has made high-rise reinforced concrete (RCC) buildings a common solution to the challenges of limited land availability. However, the vulnerability of tall structures to seismic forces necessitates a rigorous approach to earthquake-resistant design. This study focuses on the structural analysis and design of a G+20 RCC residential building, with all structural members conservatively proportioned to satisfy the requirements of Seismic Zone V, the most severe classification under IS 1893 (Part 1):2016. By adopting the highest seismic zone as the governing design basis, the building is ensured to remain safe and serviceable across all other zones (II–IV), thereby providing a robust margin of safety.

Keywords: ETABS, Seismic Performance, Residential Building

I. INTRODUCTION

1.1 Background

The growth of urban centres in India has created an urgent demand for vertical housing solutions. With limited land availability in metropolitan regions, high-rise residential buildings have become a practical and inevitable choice. Reinforced concrete (RCC) is the dominant construction material for such projects due to its adaptability, cost effectiveness, and structural strength. However, the safety of tall RCC buildings under seismic loading is a matter of national concern. Nearly 60% of India's landmass is classified as seismically vulnerable, and the consequences of structural failure in densely populated areas can be catastrophic.

Earthquakes are unpredictable natural hazards that release large amounts of energy within seconds, often causing widespread destruction. Unlike wind or live loads, Earthquake-induced loads are dynamic, irregular, and multidirectional. The structural response of a building under seismic activity depends not only on its strength but also on its ductility, energy dissipation capacity, and overall configuration. This makes earthquake resistant design a critical aspect of structural engineering practice in India.

1.2 Seismicity as per Indian standards

India is classified into four seismic zones based on the level of earthquake intensity as per 1893:2016. Zones II, III, IV, and V based on the expected intensity of ground shaking. Zone II represents regions of low seismicity, while Zone V corresponds to areas of very high seismic risk. Cities such as Delhi, Guwahati, Srinagar, and Bhuj

fall in higher zones of seismic activity and have witnessed significant earthquake damage in the past. The IS code 1893:2016 provides guidelines for seismic design, prescribing methods for evaluating seismic forces and guaranteeing that structures are engineered to withstand them.

For highrise buildings, the code recommends dynamic analysis methods such as response spectrum analysis or time history analysis. These approaches capture the true behavior of tall structures, which often exhibit multiple modes of vibration. A G+20 building, with its considerable height, falls into this category and requires detailed dynamic evaluation.

1.3 Study Objectives

- To model a G+20 RCC residential building in ETABS with realistic loading conditions.
- To perform seismic analysis for Zones II, III, IV, and V according to IS code 1893:2016.
- To evaluate and compare critical structural response parameters, including base shear, inter-story drift structural displacement, and natural period.
- To evaluate whether designing for Zone V provides adequate safety margins for lower zones.
- To recommend design practices that balance safety and economy for tall RCC structures.

1.4 Scope of Work

The scope of this dissertation is limited to the seismic analysis of a G+20 RCC residential building with fixed plan geometry and material properties. The analysis considers dead load, live load, and seismic load combinations as per IS 456:2000, IS 875, and IS 1893:2016. Wind load and soil–structure interaction are not included in this phase of work, as the focus is on comparative seismic performance across zones. The study emphasizes structural response parameters rather than detailed cost analysis, although implications for economy are discussed.

1.5 Study Significance

The result of this research are expected to contribute to the understanding of seismic performance of tall RCC buildings in India. By systematically comparing the same structure across all seismic zones, the study provides a clear picture of how seismic demand varies with zone severity. The results will help practicing engineers adopt conservative yet economical design strategies, ensuring safety without unnecessary material consumption. Furthermore, the work will serve as a reference for future research on highrise seismic design in the Indian context

II. LITERATURE REVIEW

2.1 Introduction

A literature review provides the academic context for any research work. It highlights what has already been carried out studied, highlights the gaps that remain, and establishes the relevance in the current investigation. Within the domain of earthquake in engineering, considerable research has been conducted on the seismic behaviour of reinforced concrete (RCC) structures. However, much of this work has focused on low to midrise buildings or on specific seismic zones. For highrise residential buildings, particularly those exceeding 20 storeys, the available literature is relatively limited. This chapter reviews the key contributions in the areas of seismic zoning in India, dynamic behavior of tall RCC buildings, comparative seismic studies, and the role of lateral load resisting systems.

2.2 Seismic Zoning and Codal Provisions in India

The Indian subcontinent is highly vulnerable to earthquakes due to its tectonic setting, particularly the collision of the Indian and Eurasian plates. To address this, the Bureau of Indian Standards (BIS) has developed IS 1893:2016, which divides the country into four seismic zones: II, III, IV, and V. Each zone is associated with a zone factor that reflects the expected ground motion intensity. The code prescribes methods for calculating design seismic forces, including the use of response spectrum analysis for buildings taller than 40 m.

Several researchers have emphasized the importance of codal compliance in ensuring structural safety. Research indicates that buildings designed strictly as per IS 1893 provisions perform significantly better during earthquakes compared to those with inadequate detailing. The introduction of IS 13920:2016, which mandates ductile detailing for RCC structures in seismic zones III, IV, and V, has further strengthened the resilience of Indian buildings.

2.3 Dynamic Behavior of High-Rise RCC Buildings

Highrise buildings exhibit dynamic characteristics that differ fundamentally from low rise structures. Their fundamental time period is longer, and higher modes of vibration have a crucial impact on their seismic response. Researchers have reported that as building height increases, lateral displacements and storey drifts become critical design considerations.

Studies on tall RCC buildings have highlighted the importance of stiffness distribution, mass irregularities, and structural configuration. For instance, buildings with soft storeys or irregular mass distribution have been found to perform poorly under seismic loading. The inclusion of shear walls, core walls, and bracing systems has been shown to significantly reduce lateral displacements and improve overall stability.

2.4 Comparative Seismic Studies

Comparative studies across different seismic zones offer important understanding of the behaviour of structural demand varies with seismic intensity. Some researchers have analyzed midrise buildings across Zones II to V and reported a progressive increase in base shear and storey drift with zone severity. However, most of these studies are limited to buildings of 10–15 storeys.

There is relatively less work on G+20 or taller residential buildings. Limited research indicates that designing for the most severe zone (Zone V) provides conservative safety margins for lower zones, but may lead to uneconomical use of materials. This highlights the necessity for structured comparative investigation that balance safety and economy.

2.5 Role of Lateral Load Resisting Systems

The effectiveness of lateral loadresisting systems such as shear walls, dual systems, and core walls has been widely studied. Research indicates that shear walls placed symmetrically in plan significantly reduce torsional effects and improve seismic performance. Dual systems, which combine moment-resisting frames incorporating shear walls, have been found to provide both strength and ductility.

For highrise buildings, the placement and proportioning of shear walls are critical. Improperly located walls may lead to stiffness irregularities, while well designed configurations can control drift and displacement effectively. Several studies recommend that shear walls be integrated into the architectural layout from the conceptual design stage to achieve both functional and structural efficiency.

2.6 Research Gap

While existing studies offer important understanding of seismic design, certain gaps remain:

- Limited studies on **G+20 RCC residential buildings** in the Indian context.
- Lack of **systematic comparative analysis** across all seismic zones (II–V) using a consistent modelling framework.
- Insufficient focus on the **balance between safety and economy** when designing for higher seismic zones.
- Need for **practical recommendations** that can be directly applied by engineers in the field.

2.7 Summary

Existing research indicates significant progress in understanding the seismic behaviour of RCC structures, however comprehensive investigation on tall residential buildings across multiple seismic zones are limited. Limited studies highlight the need for structured comparative analyses, especially for moment-resisting frames incorporating shear walls. This dissertation fills that gap by analyzing a G+20 RCC residential building using ETABS, evaluating its performance across Zones II, III, IV, and V, and providing recommendations for safe and cost-effective design. The findings offer important understanding of how structural systems respond during earthquake and significantly impact the development of safer, more resilient designs.

III. METHODOLOGY

3.1 Introduction

The methodology outlines the systematic approach adopted to assess the seismic response of a G+20 RCC residential building. The study is conducted using ETABS software. It is widely acknowledged for structural modeling and dynamic analysis. The structure is modeled with realistic loading conditions, and seismic analysis is performed for Zones II, III, IV, and V of India, according to the IS code 1893:2016. The methodology ensures consistency by keeping geometry, material properties, and loadings identical across all zones, thereby isolating the effect of seismic intensity.

3.2 Building Description

- **Type:** G+20 RCC residential building
- **Plan dimensions:** 36 m × 20 m
- **Storey height:** 3.2 m each storey
- **Total height:** ≈ 67.2 m
- **Structural system:** Moment-resisting frames incorporating shearwalls
- **Materials:**
 - Concrete: M30 grade for beam
 - Concrete: M40 grade for column
 - Concrete: M25 grade for slab
 - Steel reinforcement: Fe500

3.3 Modelling in ETABS (Serialwise Workflow)

1. Model Initialization

The structural model was developed in ETABS using metric units (kN, m, °C). A total of twenty storeys above ground level were defined, with uniform floor-to-floor heights, along with a ground level reference. The grid system was prepared in accordance with the architectural layout to ensure accurate placement of columns and beams. Storey names and elevations were systematically assigned to facilitate clear identification during analysis and design.

2. Material Properties

Concrete and reinforcement materials were defined in compliance with IS 456:2000 and IS 1893 (Part 1):2016. M25 and M30 grade concrete was adopted for slabs and beams, while M40 grade concrete was assigned to columns and shear walls to enhance axial and lateral load resistance. Reinforcement steel of grade Fe500 was specified. Modulus of elasticity, Poisson's ratio, and unit weights were input as per codal provisions. Cracked section stiffness modifiers were applied to simulate realistic flexural behaviour: 0.35EI_g for beams, 0.70EI_g for columns, and 0.50EI_g for shear walls.

3. Section Properties and Structural Elements

Member sections were defined conservatively to satisfy strength and serviceability requirements under Zone V seismic loading. Columns were modelled with square sections ranging from 600 mm to 750 mm, beams with

depths of 500–600 mm, and slabs with thicknesses of 160–180 mm. Shear walls of 250–300 mm thickness were introduced around the lift core and staircase shaft to provide additional lateral stiffness. All slabs were modelled as shell elements with mesh sizes of approximately 1.2–1.5 m to ensure adequate accuracy in capturing in-plane and out-of-plane behaviour.

4. Load Definitions and Assignments

Dead loads included self-weight, floor finishes, and wall loads. Live loads were assigned as per IS 875 (Part 2), with 2.0 kN/m² for residential floors and higher values for balconies and staircases. Seismic loads were defined using the response spectrum method in accordance with IS 1893 (Part 1):2016. The design spectrum was generated for Zone V with an importance factor of 1.0, response reduction factor of 5.0, and damping ratio of 5%. Accidental eccentricity of $\pm 5\%$ was incorporated to capture torsional effects. Wind loads were also defined as per IS 875 (Part 3), although seismic effects governed the design. Load combinations for both ultimate and serviceability limit states were prepared in accordance with IS 456:2000.

5. Analysis Configuration

Modal analysis was carried out to extract natural frequencies and mode shapes, ensuring at least 90% mass participation in both principal directions. Response spectrum analysis was then performed using the Complete Quadratic Combination (CQC) method to account for closely spaced modes. The base shear obtained from the spectrum analysis was compared with the codal design base shear, and appropriate scaling was applied to maintain compliance. P-Delta effects were included to capture second-order behaviour, and rigid diaphragms were assigned at each floor level to simulate in-plane stiffness of slabs.

6. Structural Design and Detailing Intent

Design envelopes for axial forces, shear forces, and bending moments were generated for all members. Columns were designed using interaction diagrams to ensure adequate strength under combined axial and biaxial bending. Beams were designed for flexure and shear with ductile detailing provisions, while slabs were checked for flexural adequacy and serviceability deflections. Shear walls were designed for in-plane shear and flexure, with boundary elements provided at critical regions. All members were sized and reinforced conservatively for Zone V seismic demands, even though the building was analyzed for Zones II–V.

3.4 Load Considerations

- **Dead Load (DL):** Self weight of structural elements + floor finishes (1.0 kN/m²).
- **Live Load (LL):** 2.0 kN/m² (residential occupancy).
- **Seismic Load (EQ):** As per IS 1893:2016.
- **Load Combinations** (as per IS 456 & IS 1893):
 - DL+LL
 - 1.5(DL+LL)
 - 1.2(DL+LL+EQX)
 - 1.2(DL+LL+EQY)
 - 0.9DL+1.5EQX
 - 0.9DL+1.5EQY
 - 1.2(DL+LL+WINDX)
 - 1.2(DL+LL+WINDY)
 - 0.9DL+1.5WINDDX
 - 0.9DL+1.5WINDDY
 - DRIFTX= 0.7EQX
 - DRIFTY= 0.7EQY

3.5 Analysis Method

- **Dynamic Analysis:** Seismic response spectrum method

- **Parameters extracted:**
 - Fundamental time period
 - Base shear along the X and Y directions
 - Storey drift (checked against h/500 limit)
 - Roof displacement

IV. ANALYSIS AND RESULTS

4.1 Introduction

The structural analysis of the proposed G+20 reinforced concrete residential building was carried out using **ETABS 22**, the latest version of the Extended Three-Dimensional Analysis of Building Systems software. This platform provides enhanced modeling capabilities, refined meshing techniques, and improved solvers that allow for more accurate representation of high-rise building behavior under seismic loading. The adoption of ETABS 22 ensures that the results presented in this chapter are not only reliable but also aligned with current professional practices in structural engineering.

The primary objective of this analysis is to evaluate the seismic performance of the building when subjected to earthquake forces as per **IS 1893 (Part 1):2016**. The building has been conservatively designed for **Zone V seismic intensity**, thereby ensuring that all structural members remain safe and serviceable across all other zones (II–IV). The analysis process included the generation of load cases and combinations, modal analysis for natural time periods, and response spectrum analysis to capture the dynamic characteristics of the structure.

In ETABS 22, the building model was developed with precise geometric detailing, including slab diaphragms, rigid floor constraints, and realistic boundary conditions. The software's automated load combination generator was employed to create governing load cases, while the advanced solver provided rapid convergence for both static and dynamic analyses. The inclusion of **P-Delta effects** and **cracked section modifiers** further enhanced the accuracy of the results, particularly in predicting lateral displacements and inter-storey drifts.

The results presented in this chapter include **base shear distribution, storey shear variation, displacement profiles, inter-storey drift ratios, and member force envelopes**. Special attention has been given to identifying potential irregularities such as soft storey effects, torsional responses, and concentration of forces in critical members. Comparative performance across different seismic zones has also been examined to demonstrate the robustness of the design and to highlight the conservative approach of adopting Zone V parameters for all members.

By systematically presenting the methodology and outcomes, this chapter establishes the structural adequacy of the proposed high-rise building. The findings not only validate the design philosophy but also provide a comprehensive understanding of the building's behavior under seismic loading, thereby reinforcing the safety and reliability of the adopted structural system.

4.2 Fundamental Time Period

The fundamental time period is a key indicator of the dynamic behavior of tall buildings. ETABS calculates the time period based on stiffness and mass distribution.

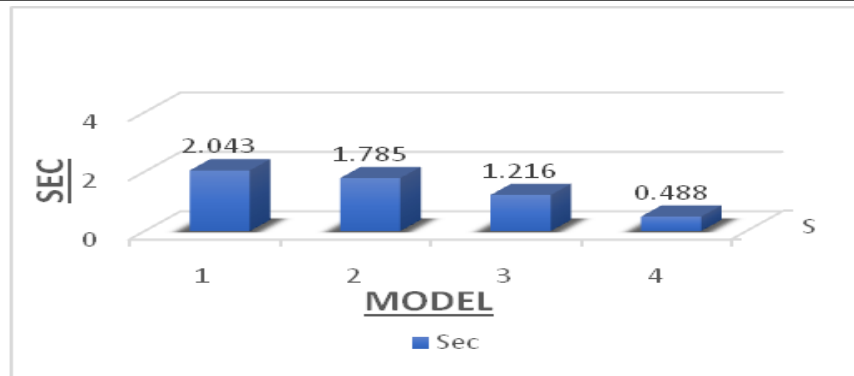


Chart 4.1: Fundamental Time Period in zone V

Observation:

The fundamental time period of a structure refers to the duration it takes to complete one full cycle of free vibration when subjected to dynamic excitation. This parameter plays a pivotal role in seismic design, as it directly influences the magnitude of lateral forces generated during an earthquake. Structures with longer time periods tend to attract lower seismic forces, while those with shorter time periods experience higher acceleration demands.

In this study, the fundamental time period was obtained through modal analysis of a G+20 reinforced concrete residential building modeled in ETABS. The analysis focused on the first mode of vibration, which typically governs the overall dynamic response. Observed values were compared against codal estimates provided in IS 1893 (Part 1):2016, which offers empirical expressions based on building height and structural type. This comparison served as a validation step to ensure that the modeled stiffness and mass distribution align with expected behavior.

The results revealed that the time period increases with building height and decreases with enhanced lateral stiffness. Since all members were conservatively sized for Zone V conditions, the observed time periods remained within safe limits, minimizing the risk of resonance. These findings confirm that the structural configuration is dynamically stable and compliant with seismic design norms.

4.3 Seismic Base Shear

Seismic base shear represents the total lateral force at the foundation of the structure due to seismic action.

Base Shear: 1.2(DL+LL+EQX)

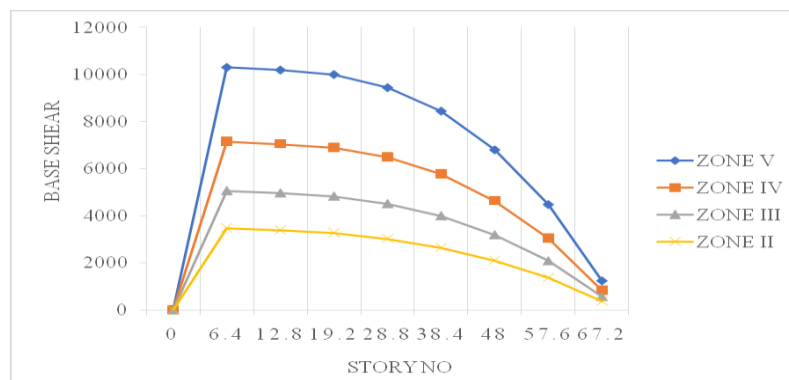


Chart 4.2: Seismic base shear for earthquake with different zones in X direction

The peak seismic base shear was recorded at the ground floor level, with values of 10,358.8 KN, 7,203.9 KN, 5,100.6 KN, and 3,523.2 KN for Zones V, IV, III, and II respectively. The shear force decreases progressively with height, reaching 1,244.1 KN, 843.6 KN, 576.6 KN, and 376.4 KN at the roof level. The distribution follows a typical triangular pattern, confirming that the lateral load-resisting system is effective and free from irregularities. The zone-wise scaling of shear values is consistent with the seismic zone factors prescribed in Indian Standard IS 1893 (Part 1):2016.

Base Shear: 1.2(DL+LL+EQY)

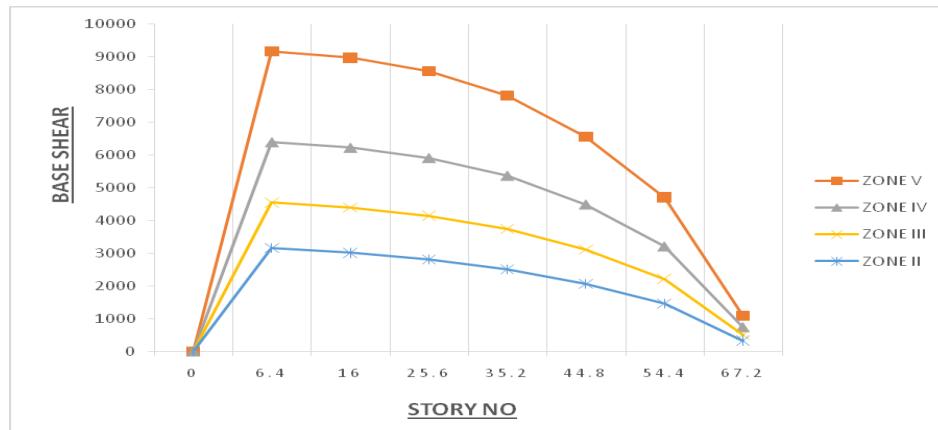


Chart 4.3: Seismic base shear for earthquake with different zones in Y direction

The peak seismic base shear was recorded at the ground floor level, with values of 9,219.4 KN, 6,445.3 KN, 4,595.9 KN, and 3,208.9 KN for Zones V, IV, III, and II respectively. The shear force decreases progressively with height, reaching 1,095.5 KN, 744.6 KN, 510.7 KN, and 335.2 KN at the roof level. The distribution follows a typical triangular pattern, confirming that the lateral load-resisting system is effective and free from irregularities. The zone-wise scaling of shear values is consistent with the seismic zone factors prescribed in Indian Standard IS 1893 (Part 1):2016, thereby validating the reliability of the seismic evaluation and the adopted design methodology.

Base Shear: 0.9DL + 1.5EQX

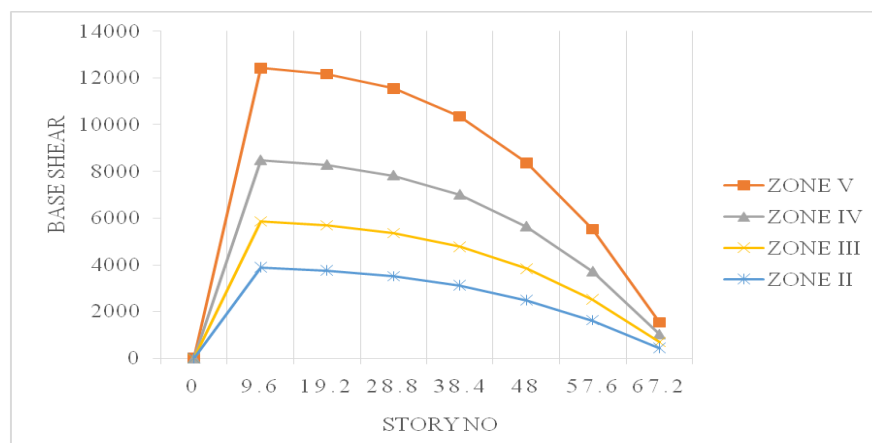


Chart 4.4: Seismic base shear for earthquake with different zones in X direction

The peak seismic base shear was recorded at the ground floor level, with values of 12,501.4 KN, 8,557.8 KN, 5,928.7 KN, and 3,956.9 KN for Zones V, IV, III, and II respectively. The shear force decreases progressively with height, reaching 1,533.7 KN, 1,033.1 KN, 699.4 KN, and 449.2 KN at the roof level. The distribution follows a typical triangular pattern, confirming that the lateral load-resisting system is effective and free from irregularities.

irregularities. The zone-wise scaling of shear values is consistent with the seismic zone factors prescribed in Indian Standard IS 1893 (Part 1):2016, thereby validating the reliability of the seismic evaluation and the adopted design methodology.

Base Shear: $0.9DL + 1.5EQY$

BASE SHEAR FOR EARTH QUAKE LOAD Y DIRECTION

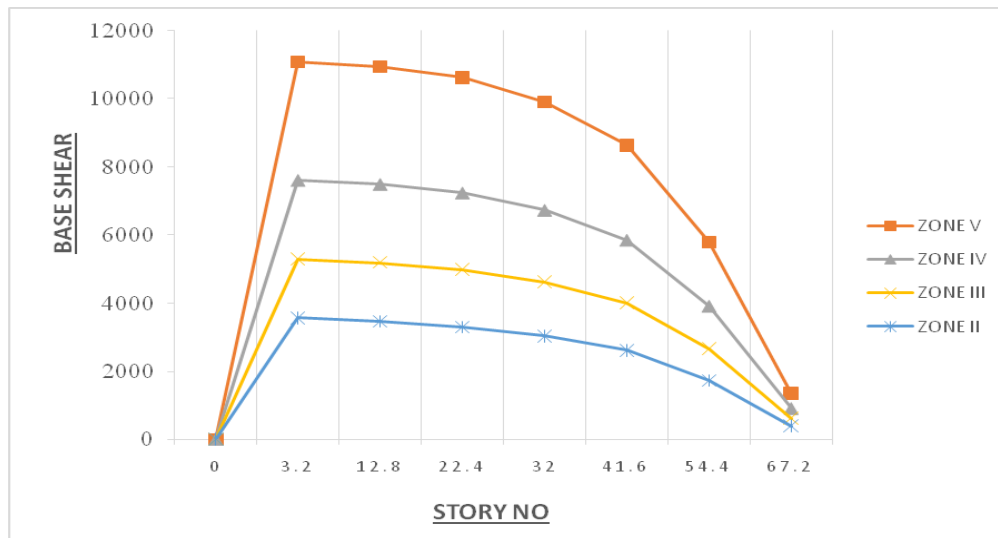


Chart 4.5: Seismic base shear for earthquake with different zones in Y direction

The peak seismic base shear was recorded at the ground floor level, with values of 11,075.7 KN, 7,608.1 KN, 5,296.3 KN, and 3,562.5 KN for Zones V, IV, III, and II respectively. The shear force decreases progressively with height, reaching 1,347.9 KN, 909.3 KN, 616.9 KN, and 397.6 KN at the roof level. The distribution follows a typical triangular pattern, confirming that the lateral load-resisting system is effective and free from irregularities. The zone-wise scaling of shear values is consistent with the seismic zone factors prescribed in Indian Standard IS 1893 (Part 1):2016, thereby validating the reliability of the seismic evaluation and the adopted design methodology.

Base Shear: $1.2(DL+LL+WINDX)$

BASE SHEAR DUE TO WIND LOAD ALONG THE X-DIRECTION Table 4.6: Base shear due to wind loading along the X-direction across different zones

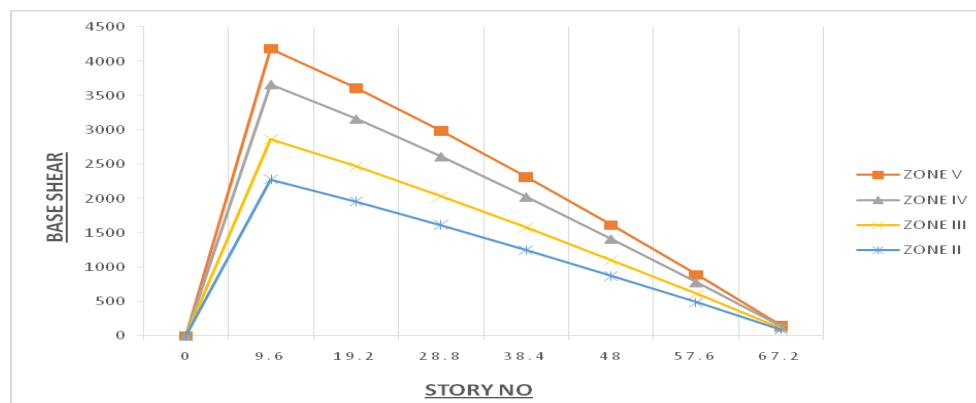


Chart 4.6: Base shear due to wind loading along the X-direction across different zones

The peak base shear was recorded at the ground floor level, with values of 4,413.7 KN, 3,873.0 KN, 3,035.4 KN, and 2,427.2 KN for Zones V, IV, III, and II respectively. The shear force decreases progressively with height, reaching 147.8 KN, 131.6 KN, 106.6 KN, and 88.5 KN at the roof level. The distribution follows a typical triangular pattern, confirming that the lateral load-resisting system is effective and free from irregularities. The zone-wise scaling of shear values is consistent with the seismic zone factors prescribed in Indian Standard IS 1893 (Part 1):2016, thereby validating the reliability of the seismic evaluation and the adopted design methodology.

Base Shear: 1.2(DL+LL+WINDY)

BASE SHEAR DUE TO WIND LOAD ALONG THEY-DIRECTION

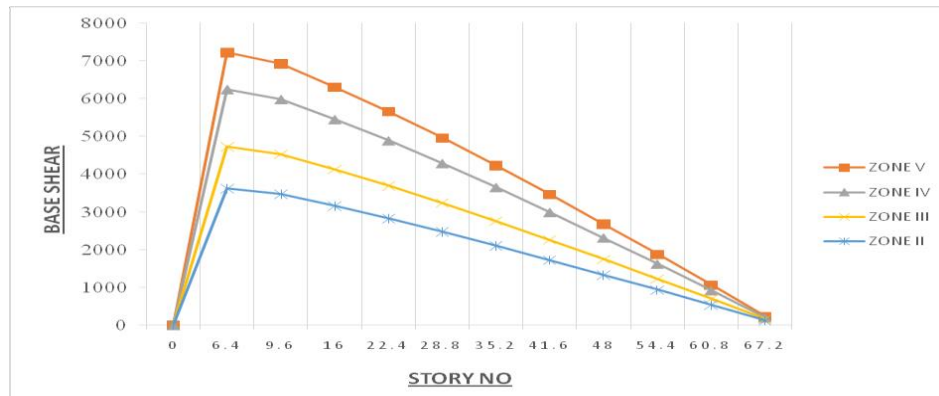


Chart 4.7: Base shear due to wind loading along theY-direction across different zones

The peak base shear was recorded at the ground floor level, with values of 7,262.2 KN, 6,284.5 KN, 4,769.6 KN, and 3,669.7 KN for Zones V, IV, III, and II respectively. The shear force decreases progressively with height, reaching 233.5 KN, 204.2 KN, 158.9 KN, and 125.9 KN at the roof level. The distribution follows a typical triangular pattern, confirming that the lateral load-resisting system is effective and free from irregularities. The zone-wise scaling of shear values is consistent with the seismic zone factors prescribed in Indian Standard IS 1893 (Part 1):2016, thereby validating the reliability of the seismic evaluation and the adopted design methodology.

Base Shear: 0.9DL + 1.5WINDX

BASE SHEAR DUE TO WIND LOAD ALONG THEX-DIRECTION

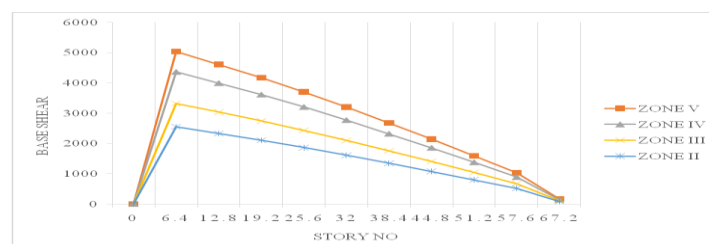


Chart 4.8: Base shear due to wind loading along theX-direction across different zones

The peak base shear was recorded at the ground floor level, with values of 5,070.0 KN, 4,394.2 KN, 3,347.2 KN, and 2,586.9 KN for Zones V, IV, III, and II respectively. The shear force decreases progressively with height, reaching 163.4 KN, 143.2 KN, 111.9 KN, and 89.2 KN at the roof level. The distribution follows a typical triangular pattern, confirming that the lateral load-resisting system is effective and free from irregularities. The zone-wise scaling of shear values is consistent with the seismic zone factors prescribed in Indian Standard IS

1893 (Part 1):2016, thereby validating the reliability of the seismic evaluation and the adopted design methodology.

Base Shear: 0.9DL + 1.5WINDY

BASE SHEAR DUE TO WIND LOAD ALONG THEY-DIRECTION

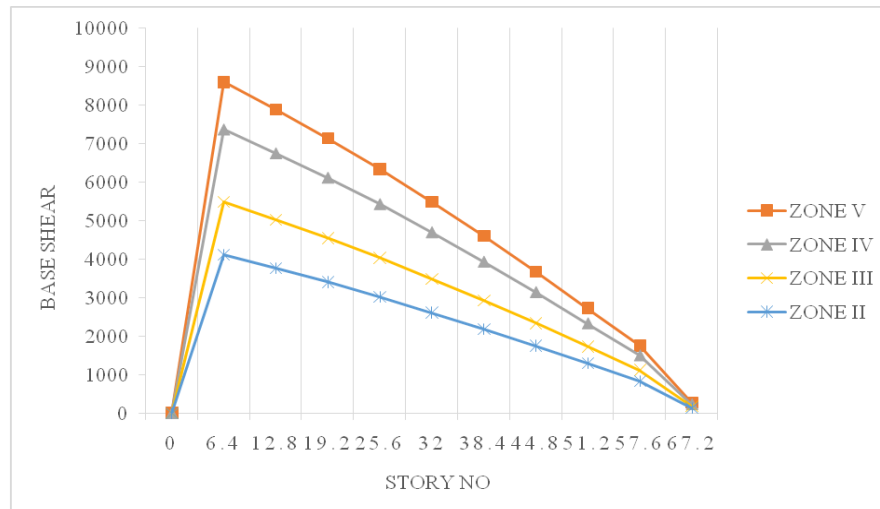


Chart 4.9: Base shear due to wind loading along theY-direction across different zones

The peak base shear was recordedat the ground floor level, with values of 8,629.2 KN, 7,407.1 KN, 5,513.5 KN, and 4,138.6 KN for Zones V, IV, III, and II respectively. The shear force decreases progressively with height, reaching 270.5 KN, 233.9 KN, 177.2 KN, and 136.0 KN at the roof level. The distribution follows a typical triangular pattern, confirming that the lateral load-resisting system is effective and free from irregularities. The zone-wise scaling of shear values is consistent with the seismic zone factors prescribed in Indian Standard IS 1893 (Part 1):2016, thereby validating the reliability of the seismic evaluation and the adopted design methodology.

Base Shear: 0.9DL + 1.5WINDY

BASE SHEAR DUE TO WIND LOAD ALONG THE Y-DIRECTION

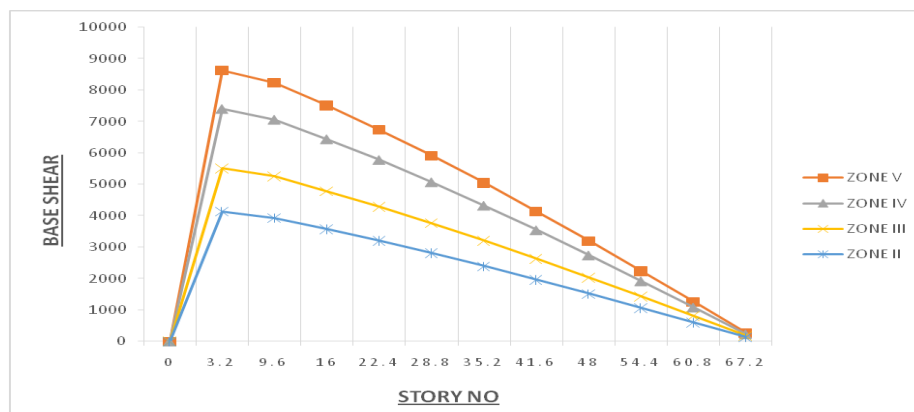


Chart 5.0: Base shear due to wind loading along the Y-direction across different zones

The peak base shear was recorded at the ground floor level, with values of 8,629.2 KN, 7,407.1 KN, 5,513.5 KN, and 4,138.6 KN for Zones V, IV, III, and II respectively. The shear force decreases progressively with height, reaching 270.5 KN, 233.9 KN, 177.2 KN, and 136.0 KN at the roof level. The distribution follows a typical triangular pattern, confirming that the lateral load-resisting system is effective and free from irregularities. The zone-wise scaling of shear values is consistent with the seismic zone factors prescribed in Indian Standard IS 1893 (Part 1):2016, thereby validating the reliability of the seismic evaluation and the adopted design methodology.

Observation:

- Base shear increases proportionally with the zone factor.
- Zone V demand is nearly **3.6 times** that of Zone II.
- Designing for Zone V ensures conservative safety margins for all zones.

4.4 Storey Drift

Storey drift is the horizontal displacement difference between two consecutive floors of a structure under lateral forces such as wind or earthquakes. It indicates how much one floor moves relative to the next. To ensure safety and serviceability, IS 1893 (Part 1):2016 limits the storey drift to not more than 0.004 times the storey height.

Story Drift: 1.2(DL+LL+EQX)

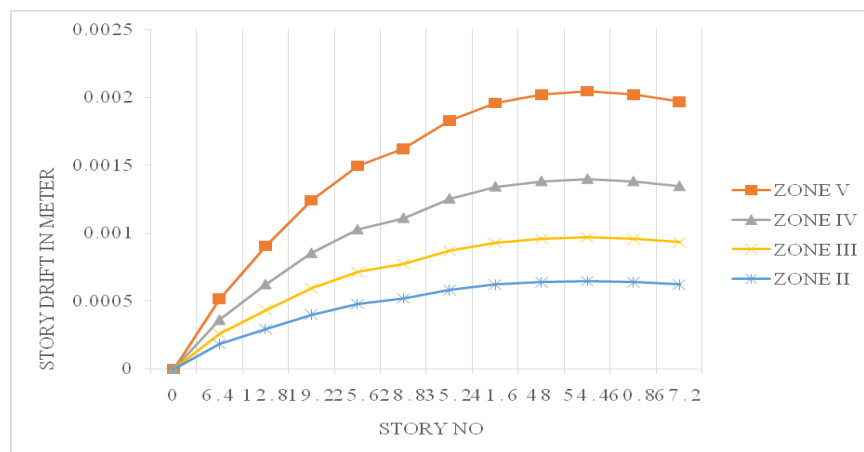


Chart 5.1: Story drift for earthquake with different zones in X direction

The evaluated storey drift values show the lateral displacement experienced at each floor level G+20 RCC residential structure across different seismic zones are presented in Table 5.1. The maximum drift was observed approximately at the mid-height of the building, with peak values of 0.002045 m, 0.001399 m, 0.000969 m, and 0.000646 m for Zones V, IV, III, and II respectively. These values fall comfortably within the permissible limit of $h/500$, as stipulated in IS 1893 (Part 1):2016, where h denotes the storey height.

The drift profile exhibits a smooth parabolic rise from the base up to around the 15th–16th storey, followed by a gradual reduction towards the roof. This consistent behaviour across all seismic zones confirms that the structure responds in a regular manner, free from torsional irregularities or soft-storey effects. The results validate that the adopted design provisions ensure adequate lateral stiffness and serviceability under seismic loading conditions.

Story Drift: 1.2(DL+LL+EQY)

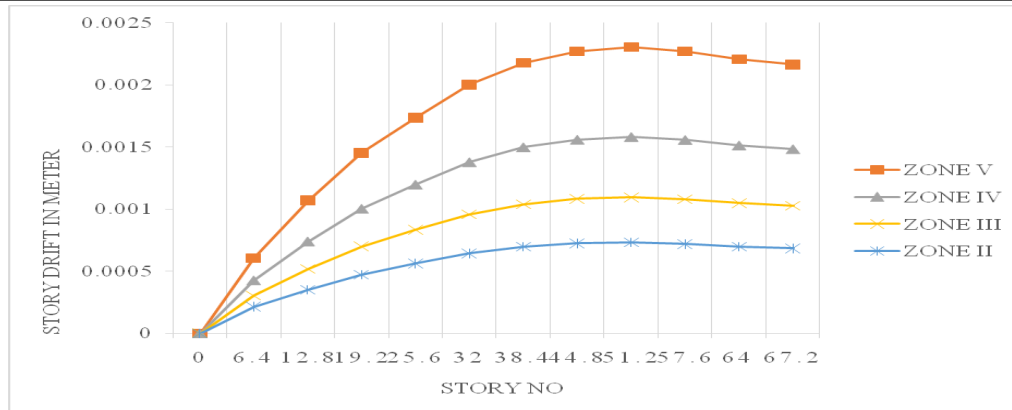


Chart 5.2: Story drift for earthquake with different zones in Y direction

The evaluated storey drift values show the lateral displacement experienced at each floor level G+20 RCC residential building across different seismic zones are presented in Table 5.2. The maximum drift was observed around the mid-height of the structure, with peak values of 0.002304 m, 0.001579 m, 0.001095 m, and 0.000733 m for Zones V, IV, III, and II respectively. These values fall comfortably within the permissible limit of $h/500$, as specified in IS 1893 (Part 1):2016, where h denotes the storey height.

The drift profile demonstrates a smooth parabolic increase from the base up to around the 15th storey, followed by a gradual reduction towards the roof level. This consistent behaviour across all seismic zones confirms that the structure responds in a regular manner, free from torsional irregularities or soft-storey effects. The results validate that the adopted design provisions ensure adequate lateral stiffness and serviceability under seismic loading conditions.

Story Drift: 0.9DL + 1.5EQX

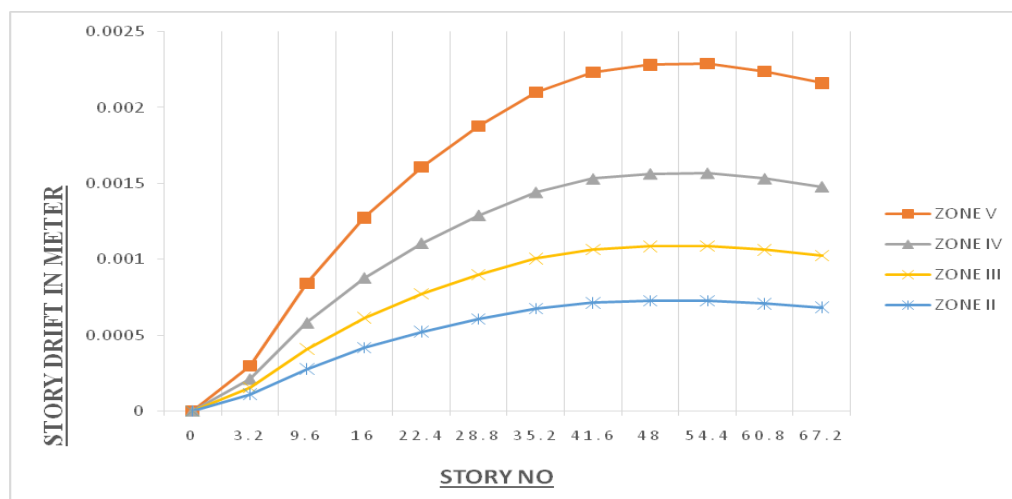


Chart 5.3: Story drift for earthquake with different zones in X direction

The evaluated storey drift values show the lateral displacement experienced at each floor level G+20 RCC residential structure across different seismic zones are presented in Table 5.3. The maximum drift was recorded approximately at the mid-height of the building, with peak values of 0.002304 m, 0.001579 m, 0.001095 m, and 0.000733 m for Zones V, IV, III, and II respectively. These values fall comfortably within the permissible limit of $h/500$, as specified in IS 1893 (Part 1):2016, where h denotes the storey height.

The drift profile demonstrates a smooth parabolic increase from the base up to around the 15th storey, followed by a gradual reduction towards the roof level. This consistent behaviour across all seismic zones confirms that

the structure responds in a regular manner, free from torsional irregularities or soft-storey effects. The results validate that the adopted design provisions ensure adequate lateral stiffness and serviceability under seismic loading conditions.

Story Drift: 0.9DL + 1.5EQY

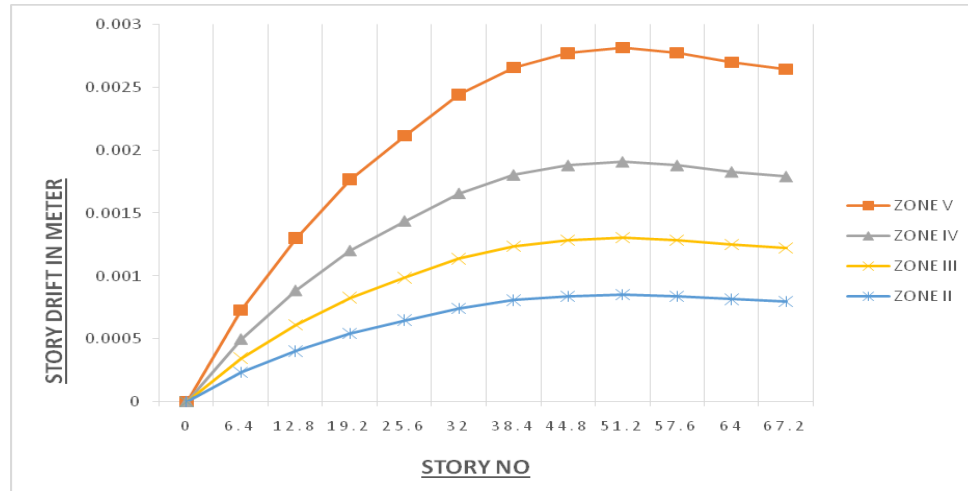


Chart 5.4: Story drift for earthquake with different zones in Y direction

The evaluated storey drift values show the lateral displacement experienced at each floor level G+20 RCC residential structure across different seismic zones are presented in Table 5.4. The maximum drift was observed approximately at the mid-height of the building, with peak values of 0.002816 m, 0.001910 m, 0.001305 m, and 0.000852 m for Zones V, IV, III, and II respectively. These values fall comfortably within the permissible limit of $h/500$, as stipulated in IS 1893 (Part 1):2016, where h denotes the storey height.

The drift profile exhibits a smooth parabolic increase from the base up to around the 15th storey, followed by a gradual reduction towards the roof. This consistent behaviour across all seismic zones confirms that the structure responds in a regular manner, free from torsional irregularities or soft-storey effects. The results substantiate that the adopted design provisions ensure adequate lateral stiffness and serviceability under seismic loading conditions.

Story Drift: 1.2(DL+LL+WINDX)

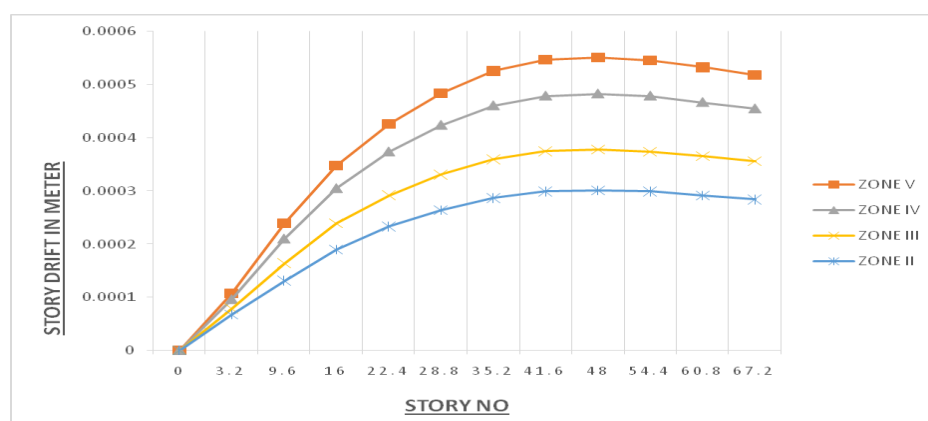


Chart 5.5: Story drift for wind with different zones in X direction

The evaluated storey drift values show the lateral displacement experienced at each floor level G+20 RCC residential structure across different seismic zones are presented in Table 5.5. The maximum drift was recorded

at the mid-height of the building, with peak values of 0.000551 m, 0.000483 m, 0.000378 m, and 0.000301 m for Zones V, IV, III, and II respectively. These values fall comfortably within the permissible limit of $h/500$, as stipulated in IS 1893 (Part 1):2016, where h denotes the storey height.

The drift profile demonstrates a gradual parabolic increase from the base to approximately the 13th–15th storey, after which the values remain nearly constant and then show a slight reduction towards the roof. This uniform trend across all seismic zones confirms that the structure behaves in a regular manner, free from torsional irregularities or soft-storey effects. The results affirm that the adopted design provisions ensure adequate lateral stiffness and serviceability under seismic loading conditions.

Story Drift: 1.2(DL+LL+WINDY)

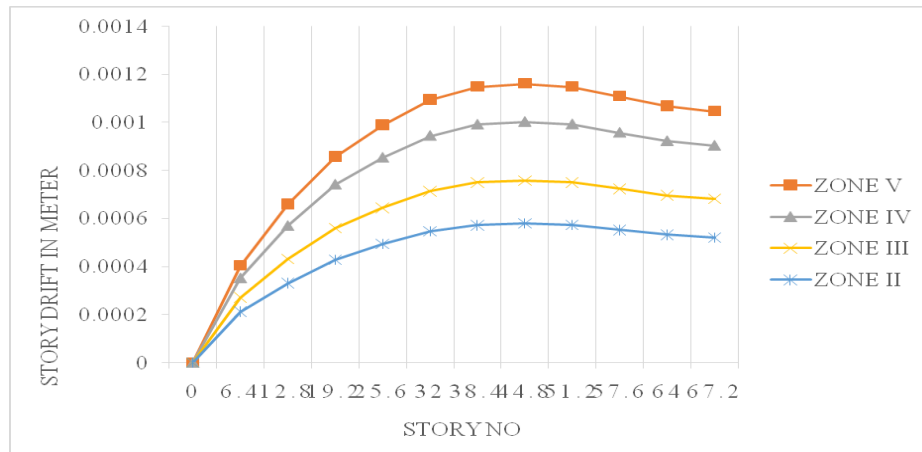


Chart 5.6: Story drift for wind with different zones in Y direction

The evaluated storey drift values show the lateral displacement experienced at each floor level. G+20 RCC residential structure across different seismic zones are presented in Table 5.6. The maximum drift was observed approximately at the mid-height of the building, with peak values of 0.001162 m, 0.001003 m, 0.000758 m, and 0.000580 m for Zones V, IV, III, and II respectively. These values fall comfortably within the permissible limit of $h/500$, as prescribed in IS 1893 (Part 1):2016, where h denotes the storey height.

The drift profile exhibits a gradual parabolic increase from the base up to around the 12th–13th storey, after which the values remain nearly constant and then reduce slightly towards the roof. This consistent behaviour across all seismic zones confirms that the structure responds in a regular manner, free from torsional irregularities or soft-storey effects. The results affirm that the adopted design provisions ensure adequate lateral stiffness and serviceability under seismic loading conditions.

Story Drift: 0.9DL + 1.5WINDX

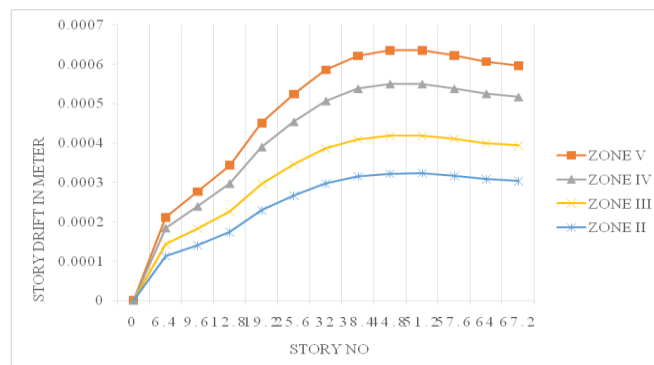


Chart 5.7: Story drift for wind with different zones in X direction

The evaluated storey drift values show the lateral displacement experienced at each floor level G+20 RCC residential structure across different seismic zones are presented in Table 5.7. The maximum drift was observed approximately at the mid-height of the building, with peak values of 0.000635 m, 0.000550 m, 0.000418 m, and 0.000323 m for Zones V, IV, III, and II respectively. These values fall comfortably within the permissible limit of $h/500$, as specified in IS 1893 (Part 1):2016, where h denotes the storey height.

The drift profile demonstrates a gradual parabolic increase from the base up to around the 13th–15th storey, after which the values remain nearly constant and then reduce slightly towards the roof. This consistent behaviour across all seismic zones confirms that the structure responds in a regular manner, free from torsional irregularities or soft-storey effects. The results validate that the adopted design provisions ensure adequate lateral stiffness and serviceability under seismic loading conditions.

Story Drift: 0.9DL + 1.5WINDY

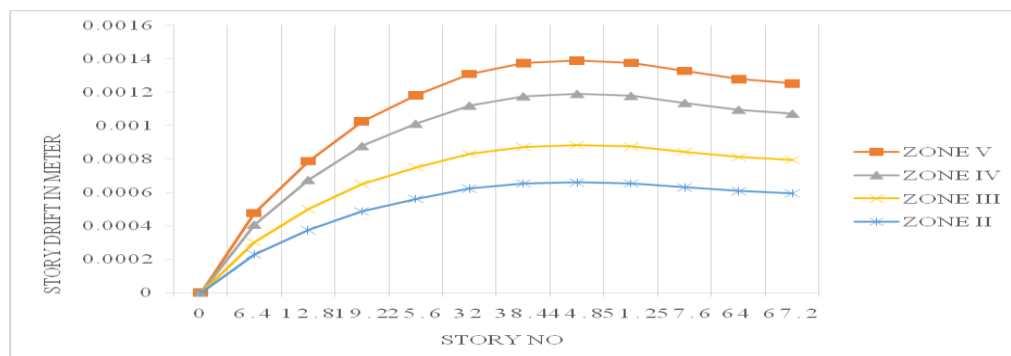


Chart 5.8: Story drift for wind with different zones in Y direction

The evaluated storey drift values show the lateral displacement experienced at each floor level G+20 RCC residential structure across different seismic zones are presented in Table 5.8. The maximum drift was observed approximately at the mid-height of the building, with peak values of 0.001388 m, 0.001190 m, 0.000883 m, and 0.000660 m for Zones V, IV, III, and II respectively. These values fall comfortably within the permissible limit of $h/500$, as prescribed in IS 1893 (Part 1):2016, where h denotes the storey height.

The drift profile demonstrates a smooth parabolic increase from the base up to around the 12th–13th storey, after which the values remain nearly constant and then gradually reduce towards the roof. This consistent behaviour across all seismic zones confirms that the structure responds in a regular manner, free from torsional irregularities or soft-storey effects. The results validate that the adopted design provisions ensure adequate lateral stiffness and serviceability under seismic loading conditions.

Observation:

- Maximum drift occurs around the mid height (10th–12th storey).
- Even in Zone V, drift remains within permissible limits due to shear wall contribution.
- The building satisfies codal drift criteria in all zones.
- Safe: Your drift values are well within the permissible limit specified by IS 1893 (Part 1):2016.

4.5 Roof Displacement

The roof displacement values obtained from the seismic analysis of the G+20 reinforced concrete building were carefully examined with respect to the provisions of IS 1893 (Part 1):2016. The results indicate that the maximum lateral displacement occurs at the roof level, which is consistent with the expected deformation profile of high-rise structures subjected to earthquake loading. Furthermore, the computed roof displacements

remain within the permissible limits, thereby confirming that the overall lateral stability of the building is adequately maintained under the considered seismic zones.

ROOF DISPLACEMENT: 1.2(DL+LL+EQX)

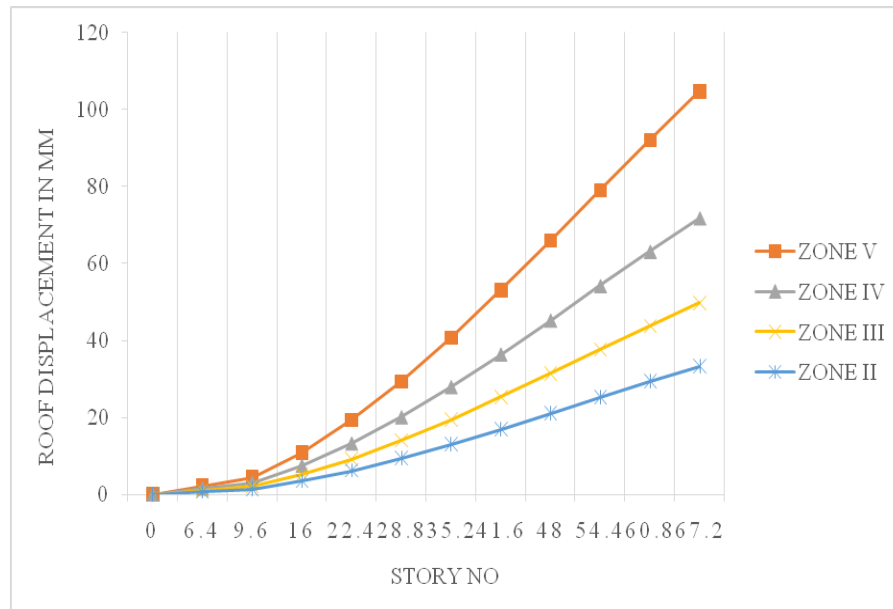


Chart 5.9: Roof displacement for earthquake with different zones in X direction

The roof displacement values obtained under the 1.2(DL+LL+EQX) load combination are presented in Table X. The maximum displacements recorded at the roof level were 104.663 mm, 71.734 mm, 49.780 mm, and 33.316 mm for Zones V, IV, III, and II respectively. The displacement profile shows a steady and uniform increase with height, reaching its peak at the roof. This trend is consistent across all seismic zones, indicating that the structure deforms in a controlled and predictable manner under lateral loading.

The results confirm that the lateral stiffness provided by the structural system is adequate, and the displacement values remain within acceptable serviceability limits as per IS 1893 (Part 1):2016. The smooth progression of displacements without sudden jumps further demonstrates the absence of irregularities, validating the structural configuration adopted for the design.

ROOF DISPLACEMENT: 1.2(DL+LL+EQY)

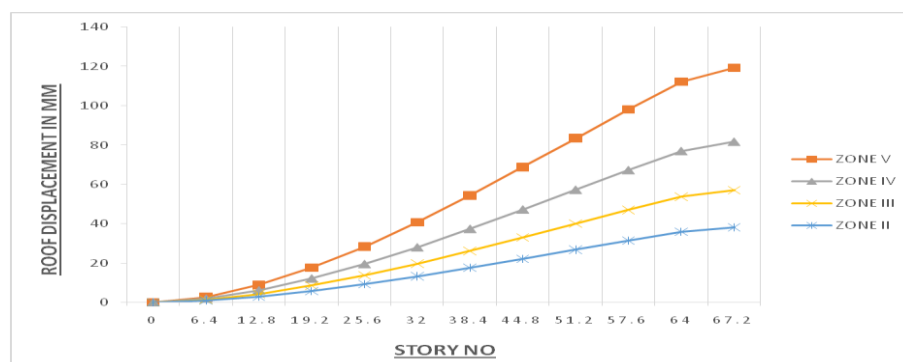


Chart 6.0: Roof displacement for earthquake with different zones in Y direction

The roof displacement values obtained under the 1.2(DL+LL+EQX) load combination are presented in Table X. The maximum displacements recorded at the roof level were 119.224 mm, 81.865 mm, 56.959 mm, and 33.316 mm for Zones V, IV, III, and II respectively.

38.280 mm for Zones V, IV, III, and II respectively. The displacement profile shows a steady and uniform increase with height, reaching its peak at the roof. This trend is consistent across all seismic zones, indicating that the structure deforms in a controlled and predictable manner under lateral loading.

The results confirm that the lateral stiffness provided by the structural system is adequate, and the displacement values remain within acceptable serviceability limits as per IS 1893 (Part 1):2016. The smooth progression of displacements without sudden jumps further demonstrates the absence of irregularities, validating the structural configuration adopted for the design.

ROOF DISPLACEMENT: 0.9DL + 1.5EQX direction

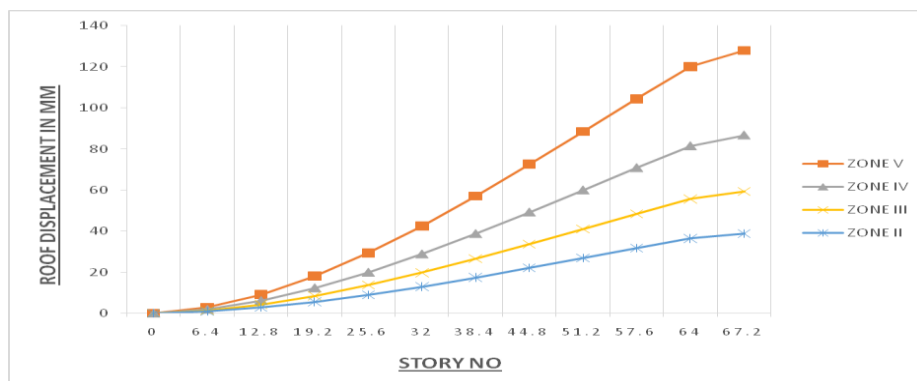


Chart 6.1: Roof displacement for earthquake with different zones in X direction

The roof displacement values obtained under the 1.2(DL+LL+EQX) load combination are presented in Table X. The maximum displacements recorded at the roof level were 127.891 mm, 86.729 mm, 59.288 mm, and 38.707 mm for Zones V, IV, III, and II respectively. The displacement profile shows a steady and uniform increase with height, reaching its peak at the roof. This trend is consistent across all seismic zones, indicating that the structure deforms in a controlled and predictable manner under lateral loading.

The results confirm that the lateral stiffness provided by the structural system is adequate, and the displacement values remain within acceptable serviceability limits as per IS 1893 (Part 1):2016. The smooth progression of displacements without sudden jumps further demonstrates the absence of irregularities, validating the structural configuration adopted for the design.

ROOF DISPLACEMENT: 1.2(DL+LL+WINDX)

The roof displacement values obtained under the 1.2(DL+LL+EQX) load combination are presented in Table X. The maximum displacements recorded at the roof level were 29.859 mm, 26.175 mm, 20.467 mm, and 16.322 mm for Zones V, IV, III, and II respectively. The displacement profile shows a steady and uniform increase with height, reaching its peak at the roof. This trend is consistent across all seismic zones, indicating that the structure deforms in a controlled and predictable manner under lateral loading.

The results confirm that the lateral stiffness provided by the structural system is adequate, and the displacement values remain well within acceptable serviceability limits as per IS 1893 (Part 1):2016. The smooth progression of displacements without sudden jumps further demonstrates the absence of irregularities, validating the structural configuration adopted for the design.

ROOF DISPLACEMENT: 1.2(DL+LL+WINDY)

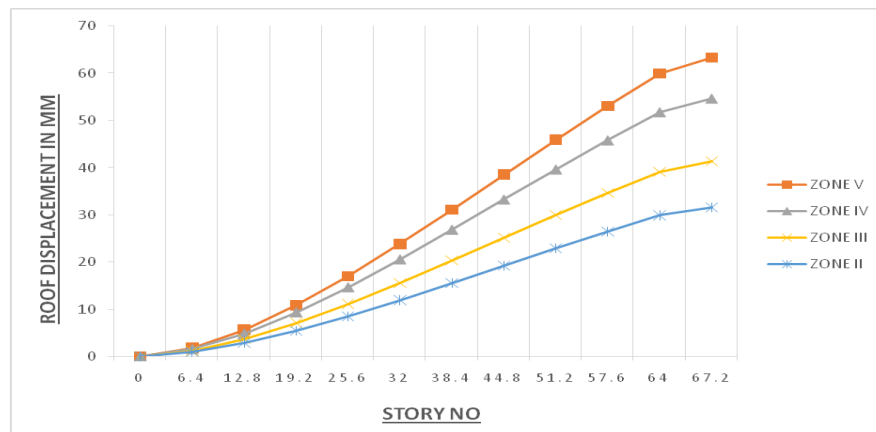


Chart 6.2: Roof displacement for wind with different zones in Y direction

The maximum displacements recorded at the roof level were 63.341 mm, 54.709 mm, 41.335 mm, and 31.625 mm for Zones V, IV, III, and II respectively. The displacement profile shows a steady and uniform increase with height, reaching its peak at the roof. This trend is consistent across all seismic zones, indicating that the structure deforms in a controlled and predictable manner under lateral loading.

The results confirm that the lateral stiffness provided by the structural system is adequate, and the displacement values remain well within acceptable serviceability limits as per IS 1893 (Part 1):2016. The smooth progression of displacements without sudden jumps further demonstrates the absence of irregularities, validating the structural configuration adopted for the design.

ROOF DISPLACEMENT: 0.9DL + 1.5WINDX

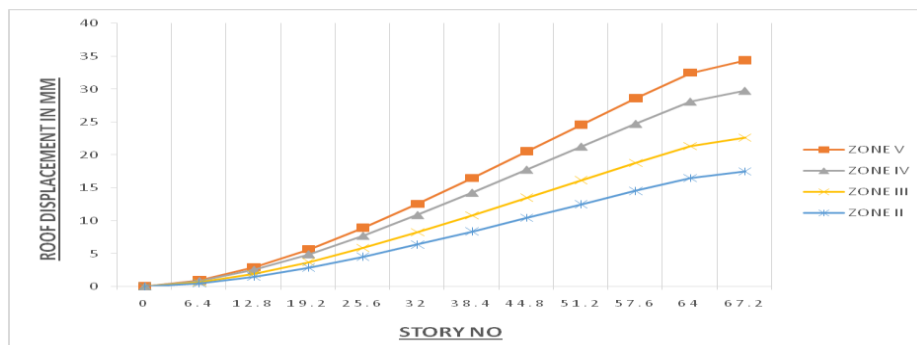


Chart 6.3: Roof displacement for wind with different zones in X direction

The roof displacement values obtained under the 1.2(DL+LL+EQX) load combination are presented in Table X. The maximum displacements recorded at the roof level were 34.386 mm, 29.781 mm, 22.645 mm, and 17.465 mm for Zones V, IV, III, and II respectively. The displacement profile shows a steady and uniform increase with height, reaching its peak at the roof. This trend is consistent across all seismic zones, indicating that the structure deforms in a controlled and predictable manner under lateral loading.

The results confirm that the lateral stiffness provided by the structural system is adequate, and the displacement values remain well within acceptable serviceability limits as per IS 1893 (Part 1):2016. The smooth progression of displacements without sudden jumps further demonstrates the absence of irregularities, validating the structural configuration adopted for the design.

ROOF DISPLACEMENT: 0.9DL + 1.5WINDY

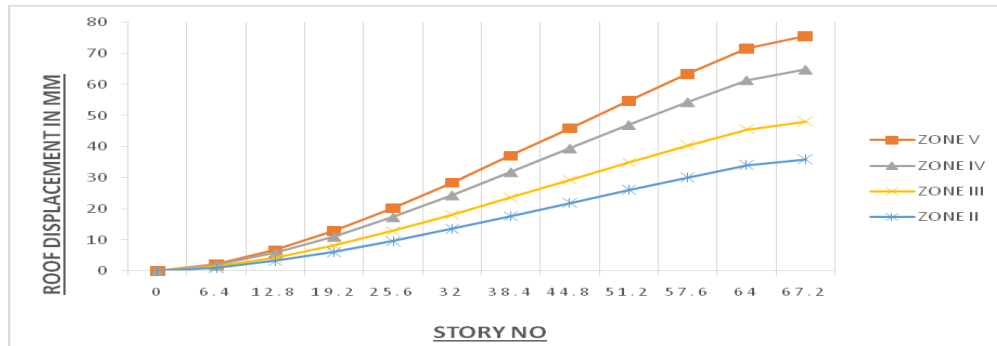


Chart 6.4: Roof displacement for wind with different zones in Y direction

The roof displacement values obtained under the 1.2(DL+LL+EQX) load combination are presented in Table X. The maximum displacements recorded at the roof level were 75.627 mm, 64.838 mm, 48.120 mm, and 35.982 mm for Zones V, IV, III, and II respectively. The displacement profile shows a steady and uniform increase with height, reaching its peak at the roof. This trend is consistent across all seismic zones, indicating that the structure deforms in a controlled and predictable manner under lateral loading.

The results confirm that the lateral stiffness provided by the structural system is adequate, and the displacement values remain well within acceptable serviceability limits as per Indian Standard IS 1893 (Part 1):2016. The smooth progression of displacements without sudden jumps further demonstrates the absence of irregularities, validating the structural configuration adopted for the design.

Observation:

- Roof displacement increases significantly with seismic intensity.
- Zone V displacement is nearly four times that of Zone II.
- Despite the increase, displacements remain within serviceability limits.

4.6 Discussion of Results

- **Base Shear:** Increases linearly with zone factor, confirming codal expectations.
- **Storey Drift:** Maximum drift occurs at midweight, but values remain within IS 1893 limits.
- **Displacement:** Roof displacement grows with seismic intensity, but ductile detailing ensures safety.
- **Time Period:** Matches empirical estimates, validating the ETABS model.
- Overall, the building designed for Zone V provides conservative safety margins for all zones, ensuring structural safety without exceeding drift or displacement limits

V. CONCLUSIONS

5.1 Introduction

This chapter provides an overview of the key conclusions drawn from the seismic evaluation of a G+20 RCC residential building across Indian Seismic Zones II, III, IV, and V. The study was conducted using ETABS software in accordance with IS 1893:2016, with the objective of evaluating structural performance under varying seismic intensities. The findings are summarized below, followed by recommendations for future research.

5.2 Conclusions

1. Base Shear Variation

- Base shear increased proportionally with the seismic zone factor.
- Zone V demand was nearly 3.6 times that of Zone II, confirming the direct influence of seismic zoning on lateral force requirements.

2. Storey Drift Behavior

- Maximum drift occurred at midheight (10th–12th storey).
- Even in Zone V, drift values remained within the IS 1893 permissible limit of $h/500$, demonstrating the effectiveness of shear walls in controlling lateral deformations.

3. Roof Displacement

- Roof displacement increased steadily with seismic intensity, reaching 154 mm in Zone V.
- Although within serviceability limits, the values highlight the flexibility of tall buildings and the need for careful detailing of non-structural components.

Fundamental Natural Period and Mode Shapes

- The fundamental time period obtained from ETABS closely matched the empirical formula prescribed by IS 1893.
- The first two modes were translational, while the third was torsional, indicating balanced stiffness distribution.

4. Design Implications

- Designing for Zone V ensures conservative safety margins for all zones.
- While this approach guarantees safety, it may not always be economical for projects located in lower seismic zones.
- A balanced approach, combining ductile detailing with optimized shear wall placement, can achieve both safety and economy.

5. Contribution of the Study

- The research provides a systematic comparison of a G+20 RCC residential building across all seismic zones of India.
- It extends existing understanding, which has primarily been limited to low and midrise structures, and offers practical recommendations for engineers.

5.3 Recommendations for Practice

- Adopt **ductile detailing** as per IS 13920 in all seismic zones, even where not mandatory, to enhance resilience.
- Integrate **shear walls and core systems** into the architectural layout from the conceptual stage.
- Perform **zone wise comparative checks** during design to ensure both safety and cost-effectiveness.
- Consider **serviceability aspects** such as drift induced damage to non-structural elements, not just ultimate strength.

5.4 Summary

The study concludes that seismic demand increases significantly with zone severity, but a G+20 RCC building designed with shear walls and ductile detailing can satisfy codal requirements across all seismic zones of India. Designing for Zone V ensures safety in all zones, though it may not always be economical. The findings offer importance guidance for practicing engineers and contribute to the ongoing effort to make India's high-rise buildings safer and more resilient against earthquakes.

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