iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** V **Month of publication:** May 2025

DOI: https://doi.org/10.22214/ijraset.2025.71317

Seismic Analysis of Multistorey Building for Different Zone

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Abstract: This study evaluates the seismic performance of a G+7 multistorey building under varying seismic conditions across India's designated seismic zones (II to V). A comparative structural analysis was conducted to assess key response parameters, including base shear, floor displacement, support reactions, and steel reinforcement requirements. The results clearly indicate that Zone-V imposes the most severe seismic demands on the structure. Specifically, the base shear in Zone-V is significantly higher than in other zones, with an increase of up to 72.2% over Zone-II. Similarly, maximum floor displacements, support reactions, and required steel quantities were observed to be highest in Zone-V, reflecting a direct correlation with the increasing seismic zone factor. The findings emphasize the critical importance of zone-specific seismic considerations in structural design, particularly in high-risk areas like Zone-V, to ensure safety, stability, and compliance with earthquake-resistant design standards.

Keywords: Seismic Analysis, Multistorey Building, Earthquake Zones, Base Shear, Floor Displacement, Support Reactions, Reinforcement Steel

I. INTRODUCTION

The behavior of buildings under seismic forces has emerged as a critical field of research and practice in civil engineering, especially considering the devastating consequences of earthquakes witnessed across the world. The design and construction of structures have traditionally been influenced by static loads such as dead loads and live loads; however, dynamic loads, such as those generated during earthquakes, introduce complex inertial forces that can critically affect the stability and safety of structures. Earthquakes produce unpredictable ground motions that impart lateral forces, causing additional stresses and deformations in the structure, which can lead to severe damage or collapse if not properly accounted for during the design phase. Over the past few decades, numerous catastrophic seismic events, including those in Bhuj (2001), Latur (1993), Nepal (2015), and more globally such as Kobe (1995) and Haiti (2010), have underscored the vulnerability of buildings not designed for seismic forces. Consequently, there has been a growing emphasis on integrating seismic analysis into structural design practices. Modern building codes, including IS 1893 (Part 1): 2016 in India, now mandate that structures be analyzed and designed for potential earthquake effects based on their location, importance, and usage. In this context, understanding how buildings respond differently in various seismic zones becomes essential for optimizing design and ensuring resilience. By conducting a seismic analysis of a multistorey building across different zones, we can systematically assess how changes in seismic demand influence structural performance and stability, leading to improved safety, optimized design parameters, and better resource utilization in construction. Therefore, the background of this study is rooted in the urgent necessity to develop a deep, practical understanding of the seismic behavior of structures to create safer urban environments.

II. LITERATURE REVIEW

B. Ramakrishna et al. (2021) carried out an analysis of a G+5 multistorey building using STAAD Pro software, considering different seismic zones of India. In their study, they applied all major types of loads like dead load, live load, wind load, and seismic load based on Indian Standards. The seismic analysis was performed for Zone II, Zone III, Zone IV, and Zone V as per IS 1893:2002 (Part-1). They included important parameters such as self-weight, member weight, floor loads, damping ratio, importance factor, and response reduction factor. By observing the results like shear force, bending moment, and deflection, they found that the building's behavior changes significantly from one seismic zone to another. Their study highlights that in higher seismic zones, the forces acting on the building increase, which requires careful design. They concluded that to ensure the safety and stability of buildings under earthquake forces, it is very important to properly consider all loads, zone factors, and structural parameters during the design stage.

[1] Umamaheswara Rao Tallapalem et al. (2019) studied the effect of earthquakes on a G+7 multistorey building by analyzing it in different seismic zones of India using STAAD Pro software. In their work, they considered all important earthquake-related parameters and applied different load combinations. They analyzed the structure in Seismic Zones II, III, IV, and V as per IS 1893:2002. Their study focused on important results like base shear, floor displacements, support reactions, and changes in the quantity of steel used from one zone to another. They pointed out that while the IS 1893-2002 code provides guidelines for earthquake design, it does not mention how steel requirements vary between zones, and their study fills this gap. Their analysis shows that when the seismic zone changes, the base shear and displacement increase, and more reinforcement (steel) is needed to ensure the structure's safety. Their research highlights the importance of careful earthquake analysis and design, especially for tall buildings in high-risk zones.[2] P. Rajeswari and A. Koti Neelakantam (2019) carried out a study on the seismic analysis and design of a G+10 multistorey residential building using ETABS software. They focused on making the structure earthquake-resistant by analyzing both static and dynamic behavior. In their work, they used the static equivalent method to understand how the structure responds to earthquake forces and calculated all important factors like support reactions and joint displacements. They considered various seismic zones (Zone II, III, IV, and V) of India and included the effect of wind loads and seismic loads during the design. Their study emphasized that proper design and detailing of structural members help to achieve ductile behavior during earthquakes, reducing the chances of sudden failure. Their analysis ensures that the building is safe against lateral forces like earthquakes and wind, and highlights the importance of considering both static and dynamic loading in structural design.[3] Tejaswini Wagh et al. (2021) studied the seismic analysis and design of a G+9 reinforced concrete (RCC) building using STAAD-Pro software. They emphasized the importance of designing structures that can safely withstand earthquakes by ensuring proper detailing for ductile behavior. Their project involved applying dead loads and live loads, and designing structural elements like beams, columns, slabs, and footings. The seismic analysis was done using the Equivalent Static Method, a commonly used approach in STAAD-Pro for earthquake resistance design. The study highlighted that STAAD-Pro is highly effective for evaluating the earthquake behavior of multistorey buildings and for designing structures that perform better during seismic events compared to conventional methods. Their results showed how the building responded to seismic forces and helped understand the role of seismic design in preventing major structural damage.[4] Mahanthesh Naik K.P and Dr. H. Eramma (2023) studied the seismic analysis of a G+12 RCC multistorey building constructed on sloping ground. Due to the increasing scarcity of flat land, construction on sloped terrains has become more common, making seismic analysis for such conditions very important. In their study, buildings with ground slopes of 0°, 5°, 10°, and 15° were analyzed under earthquake loads using ETABS software. The analysis was performed using both the response spectrum method and time history method, considering seismic zones II and V. Their results showed significant differences in building behavior, including variations in base shear, bending moments, and storey displacements depending on the slope and seismic zone. This study highlights the importance of considering slope angles in seismic design to ensure the safety and stability of structures.[5] Anamika Singh, Rajeev Singh Parihar, Abhay Kumar Jha, Barun Kumar, and Rajesh Misra (2022) conducted a study on the seismic analysis of a G+14 multistorey reinforced concrete building using STAAD Pro software. The structure, built with M30 grade concrete and Fe415 steel, was analyzed with and without different bracing systems across seismic Zones III, IV, and V. The study compared several models: a bare frame RCC building, and frames with various bracing arrangements such as along the X-direction, Y-direction, both directions, and at corners. The introduction of metallic bracing significantly improved the seismic performance of the structure by reducing the building’s response to lateral forces. The building was modeled as a 3D space frame with six degrees of freedom at each node. Their findings emphasized that bracing systems are a simple and effective way to enhance the seismic resistance of multistorey structures.[6] Kiran Devi and Subhankar Petal (2023) carried out a comparative study on the seismic analysis of G+8 storey reinforced concrete structures located in different seismic zones. The research emphasized the necessity of designing multi-storey buildings to resist lateral forces generated by earthquakes, especially given the increasing urban population and limited land availability. The study considered both regular and special moment-resisting frames, examining the structural behavior in seismic Zones III, IV, and V following IS 1893 (Part 1): 2016 guidelines. Parameters such as the percentage of longitudinal reinforcement, reinforcement detailing, and base shear were compared across zones. The findings revealed that base shear values significantly increased as the seismic zone intensity increased from Zone III to Zone V, highlighting the critical influence of seismic zone on structural design requirements.[7] Pardeshi Sameer and Prof. N. G. Gore (2016) focused on the seismic analysis and design of multi-storey symmetrical and asymmetrical buildings using ETABS software. The study was motivated by the requirements outlined in IS 1893-2002, which mandates that multi-storey buildings be analyzed as three-dimensional systems due to seismic risks, especially in hilly regions of India. The research involved creating 3D models for G+15 storey buildings, both symmetric and asymmetric, to assess their seismic responses.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

The study emphasized the significance of mass and stiffness in determining the dynamic behavior of buildings and explored the impact of various vertical irregularities, including foundation types and soil conditions. By conducting Response Spectrum Analysis (RSA) and Time History Analysis (THA) on regular and irregular RC buildings, the study aimed to evaluate the effects of structural irregularities on seismic performance. The results of the comparison between regular and irregular buildings highlighted the importance of addressing irregularities in structural stiffness and mass distribution for earthquake-resistant design.[8] Gupta Arvind Kumar and Baig Mirza Aamir (2017) presented a comprehensive study on the seismic analysis and design of multi-storey reinforced concrete buildings across different seismic zones in India. The objective was to compare the design outcomes of a G+21 multi-storey building, modeled as a 3-dimensional frame, under varying seismic conditions using STAAD Pro software. The analysis considered various parameters including economic factors, material requirements, stability under seismic loads, construction supervision levels, and the need for special tools and equipment. The design adhered to the Limit State Design approach, following Indian Standard Codes IS 456, IS 1893, IS 13920, and IS 875. The building was subjected to various loads such as self-weight, dead load, live load, wind load, and seismic loads. The seismic load calculations were based on IS 1893-2005, while wind load values were generated according to IS 875. The results focused on evaluating the structure's bending moment, shear force, and deflection under the specified loading conditions. This study emphasizes the importance of adhering to minimum safety requirements outlined in Indian Standards to ensure the structural integrity of multi-storey buildings under seismic conditions.[9] Verma Kavita and Rabbani Ahsan (2018) conducted a study focusing on the seismic analysis of a G+6 multi-storey building using static analysis under different seismic zones in India. The primary objective of the study was to understand the behavior of reinforced concrete (RCC) structures subjected to seismic forces, particularly in the context of regions prone to earthquake damage. The building was modeled and analyzed in three dimensions using STAAD Pro software, with load calculations performed for various seismic zones as per IS 1893:2002. The Limit State Method of design was adopted for the entire analysis. The study highlights the importance of considering seismic loads in structural design to ensure the safety and stability of buildings, as evidenced by the damages caused by recent earthquakes, not only to non-engineered structures but also to engineered ones. The paper emphasizes the need for structural detailing and analysis in different seismic zones to mitigate earthquake damage. The focus was on static analysis, particularly examining lateral forces and the structural behavior under seismic conditions.[10]

III. PROPOSED METHODOLOGY

A. *Selection of Building Parameters*

In this study, an investigation is carried out to evaluate the variation in the seismic response of a multi-storey building situated in different seismic zones. To achieve this objective, a G+7 reinforced concrete structure is considered, with accurately defined dimensions for all structural elements, ensuring realistic modeling. The analysis is conducted using STAAD. Pro, a widely used structural analysis and design software, wherein the building is assessed under the seismic loading conditions corresponding to all seismic zones as classified by the Indian Standards (Zone II to Zone V). The primary focus of the study is to compare key structural parameters such as base shear, floor displacements, and support reactions across the different zones. Additionally, the study aims to observe the variation in the quantity of steel required for reinforcement, as influenced by the increasing seismic demand in higher zones. By quantifying these parameters, a comprehensive comparison is made to understand how seismic zone classification impacts the structural performance and material requirements of the building. The findings from this analysis serve to highlight the critical considerations necessary for the safe and economic design of multi-storey buildings in seismically active regions.

Table 3.1 Building Details

Parameters	Description
Storey	G+7
Size of the beam	0.6m×0.35m
Size of the column	0.45m×0.45m
Slab thickness	150mm
Height of floor	3m
Exterior wall	350mm
Interior wall	200mm
Parapet wall	100mm

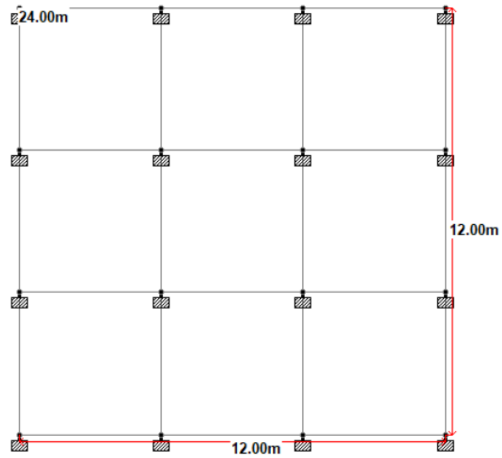

Fig.3.1: Plan of proposed G+7 structure

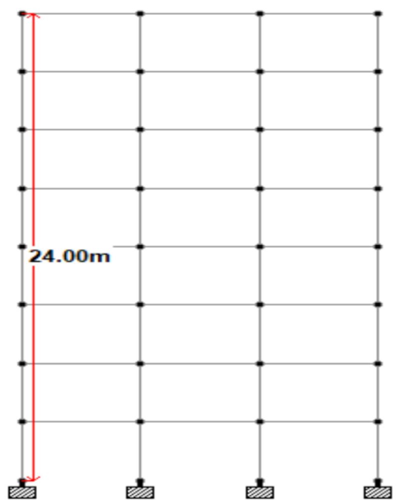

Fig.3.2: Elevation of proposed G+7 structure

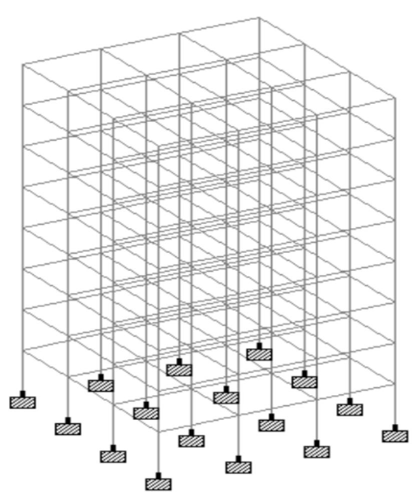

Fig.3.3: Isometric view of proposed G+7 structure

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

IV. RESULTS AND DISCUSSION

A. Base Shear Comparison

Base shear is the total lateral force experienced at the base of a structure due to seismic activity. This force originates from ground motion during an earthquake and is transmitted upward through the structure because of the fixed or restrained nature of its supports. As the base of the building is anchored, any lateral seismic forces result in relative displacement between floors, which can induce stresses and lead to structural damage or failure if not properly accounted for. Understanding base shear is therefore critical for the seismic design and analysis of structures. By estimating the magnitude of base shear acting on each floor, engineers can evaluate how the lateral force is distributed throughout the building height. This assessment helps in identifying vulnerable areas and ensuring that the structural components are designed to resist these forces adequately. The variation of base shear from one floor to another, along with its dependency on seismic zone classification, should be carefully considered in structural design.

Table 4.1: Floor - Base Shear for Zone-II

Floor	1	2	3	4	5	6	7	8
Base Shear (KN)	2.466	9.810	22.154	39.370	61.511	88.589	120.577	62.00

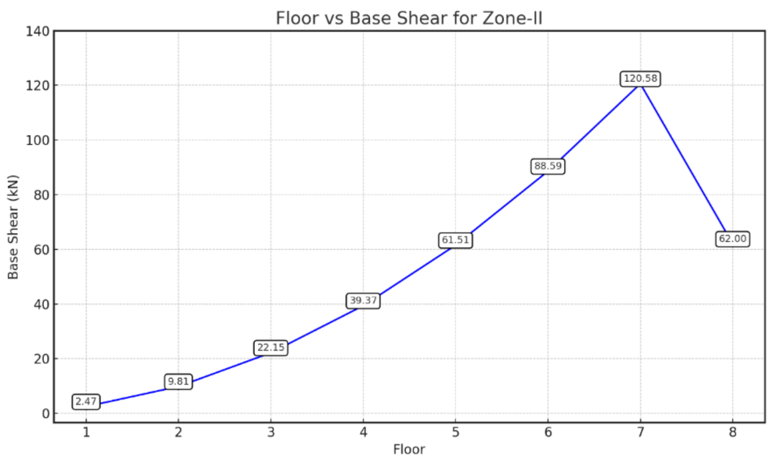

Fig.4.1: Floor - Base Shear Graph for Zone-II

Table 4.2: Floor - Base Shear for Zone-III

Floor	1	2	3	4	5	6	7	8
Base Shear (KN)	3.940	15.756	35.430	62.990	98.425	141.731	192.910	99.332

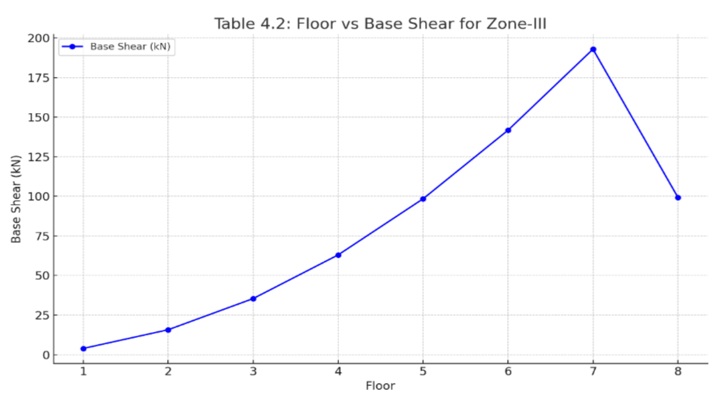

Fig.4.2: Floor - Base Shear Graph for Zone-III

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Table 4.3: Floor - Base Shear for Zone-IV

Floor	1	2	3	4	5	6	7	8
Base Shear (KN)	5.910	23.625	53.155	94.499	147.632	212.590	289.365	149.00

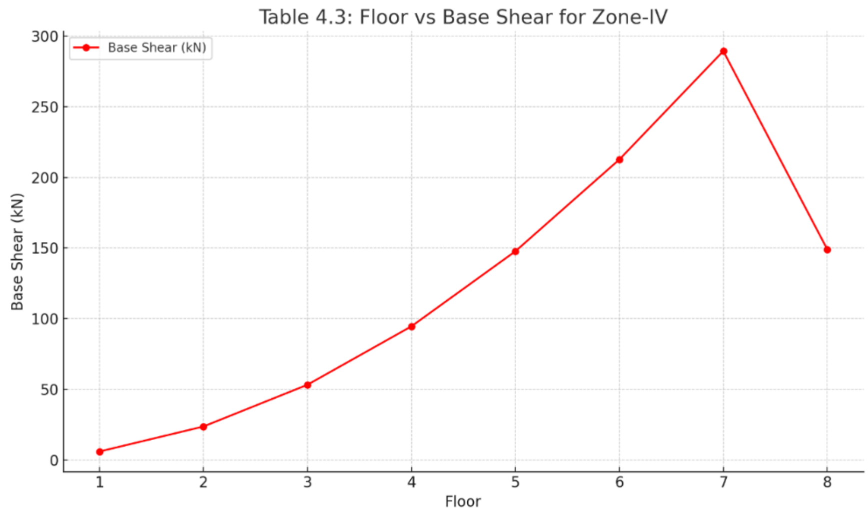

Fig.4.3: Floor - Base Shear Graph for Zone-IV

Table 4.4: Floor - Base Shear for Zone-V

Floor	1	2	3	4	5	6	7	8
Base Shear (KN)	8.866	35.433	79.725	141.730	221.450	318.890	434.044	223.500

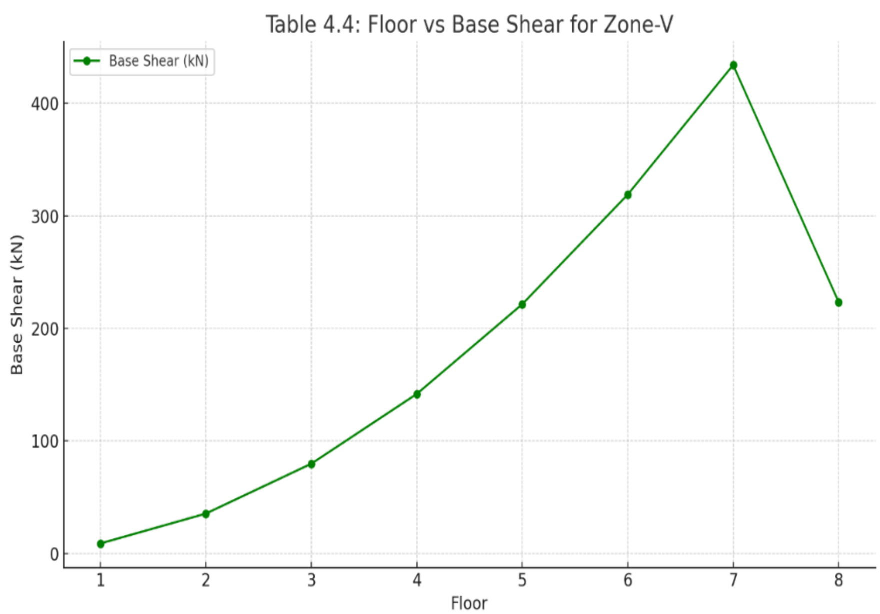

Fig.4.4: Floor - Base Shear Graph for Zone-V

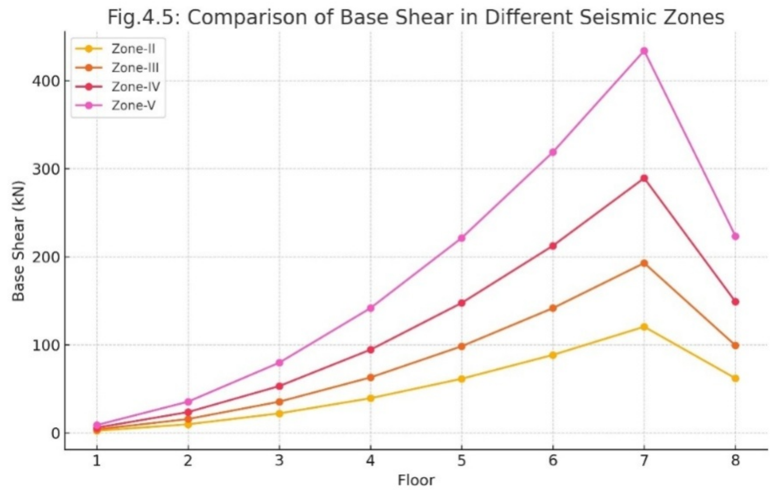

Fig.4.5: Comparison of Base Shear in Different seismic zones

B. Storey Displacement Comparison

The comparison of storey displacements across different seismic zones provides critical insight into the structural response and overall stability of a building during an earthquake. Storey displacement refers to the lateral movement experienced by each floor level relative to its original position due to seismic forces. When the G+7 structure was analyzed under varying seismic zones of India, it was observed that the magnitude of storey displacement significantly increased with the severity of the seismic zone. Seismic Zone-V, being the most severe, exhibited the highest storey displacements at every floor level when compared to Zone-II, Zone-III, and Zone-IV.

Table 4.5: Floor - Displacement for Zone-II

Floor	1	2	3	4	5	6	7	8
Displacement (mm)	2.280	5.011	7.734	10.280	12.570	14.461	15.799	16.456

Fig.4.6:Floor - Displacement Curve for Zone-II

Table 4.6: Floor - Displacement for Zone-III

Floor	1	2	3	4	5	6	7	8
Displacement (mm)	3.288	7.470	11.625	15.667	19.260	22.266	24.399	25.470

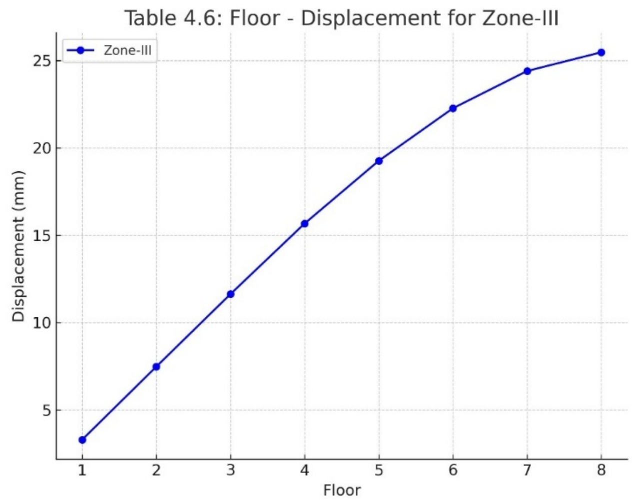

Fig.4.7:Floor - Displacement Curve for Zone-III

Table 4.7: Floor - Displacement for Zone-IV

Floor	1	2	3	4	5	6	7	8
Displacement (mm)	4.699	10.870	17.088	23.022	28.390	32.885	36.089	37.725

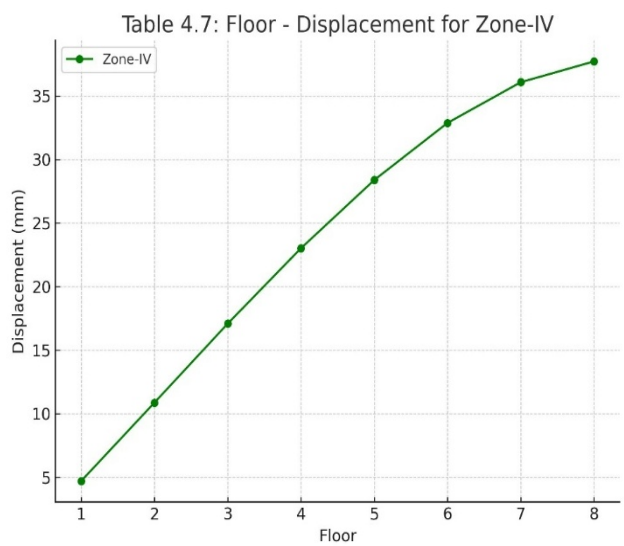

Fig.4.8:Floor - Displacement Curve for Zone-IV

Table 4.8: Floor - Displacement for Zone-V

Floor	1	2	3	4	5	6	7	8
Displacement (mm)	6.877	16.056	25.312	34.188	42.335	48.945	53.745	56.245

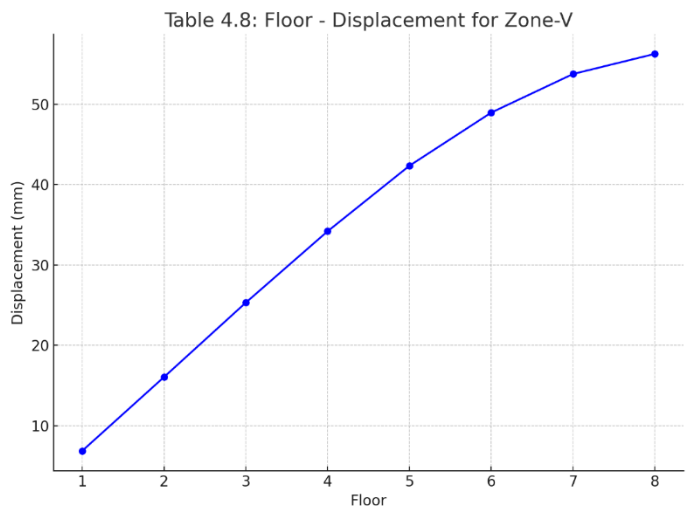

Fig.4.9:Floor - Displacement Curve for Zone-V

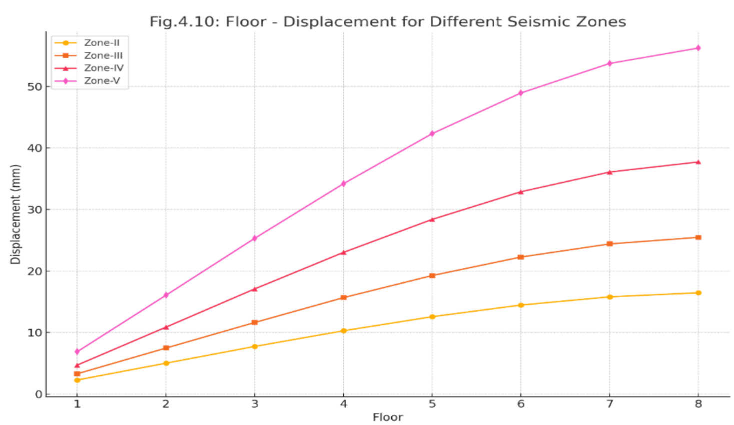

Fig.4.10: Floor - Displacement for Different seismic zones

C. *Support Reactions*

From the analysed results of support reactions, it has been observed that the different types of supports exhibit varying magnitudes of reactions under seismic loading conditions. These support reactions have been systematically divided into three distinct groups based on their numerical values. This categorization is essential as it aids in understanding the distribution and intensity of forces transmitted to the foundation system of a building. Grouping the supports based on their reactions enables engineers to design more efficient and stable foundations, taking into consideration the varying load intensities. The categorization not only streamlines the foundation design process but also ensures structural safety and cost-effectiveness, particularly in earthquake-prone areas.

Table 4.10: Support Reactions for Proposed G+7 Structure

Group	Joint(s)	ZONE-II	ZONE-III	ZONE-IV	ZONE-V
Group-1	1, 4, 109, 112	1946.08	2059.64	2222.90	2467.79
Group-2	2, 3, 37, 40, 76, 110, 111, 38, 39	2562.26	2562.00	2705.08	2952.10
Group-3	34, 74, 75	3137.86	3137.86	3137.86	3137.86

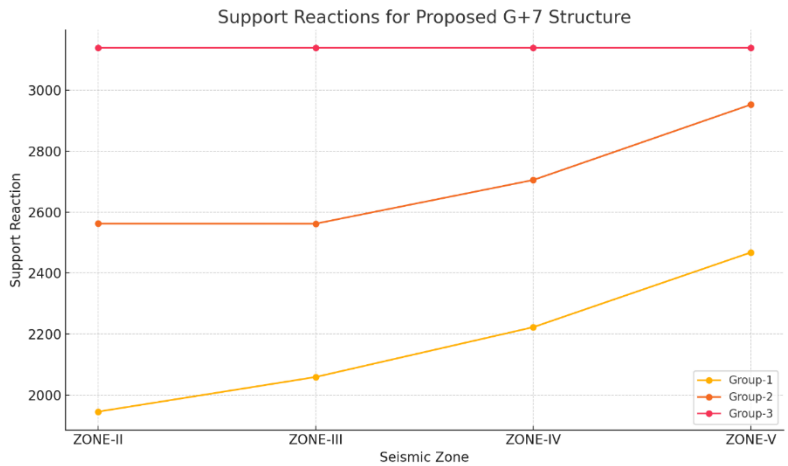

Fig.4.11: Support Reactions for Proposed G+7 Structure

D. *Steel Quantity Variation*

Table 4.11: Steel Quantity Variation from Zone to Zone

Zones	Steel (Tons)
Zone-II	14.78
Zone-III	27.57
Zone-IV	29.36
Zone-V	32.02

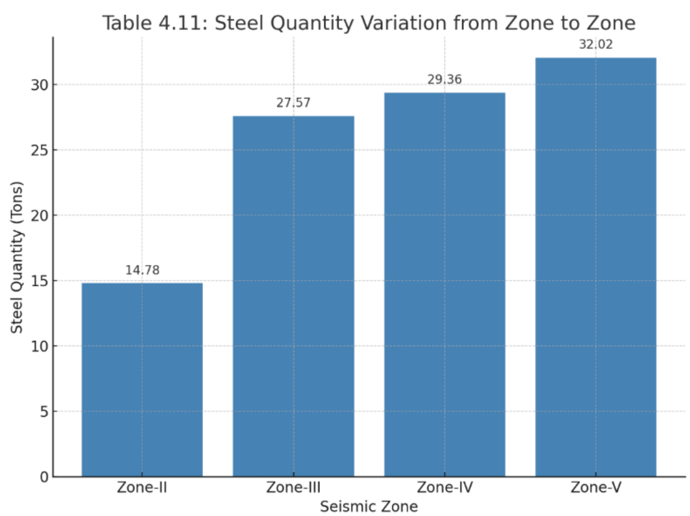

Fig.4.12: Steel Quantity Variation from Zone to Zone

V. CONCLUSION

1) The structure was analyzed under different seismic zones of India to assess the variation in structural response due to seismic loading.
2) The analysis revealed that base shear experienced by the building is highest in Seismic Zone-V when compared to Zones II, III, and IV.
3) Specifically, the base shear in Zone-V is higher by approximately 72.2%, 55.56%, and 33.33% when compared to Zone-II, Zone-III, and Zone-IV respectively.

4) In terms of floor displacements, Zone-V again exhibits the maximum displacement values among all zones, indicating a greater degree of structural movement during seismic events.
5) The maximum floor displacements in Zone-V exceed those in Zone-II, Zone-III, and Zone-IV by 39.79 mm, 30.77 mm, and 18.52 mm respectively.
6) The support reactions (forces at the base supports due to seismic loading) are also highest in Zone-V, reflecting the increased seismic demand in this region.
7) When evaluating the quantity of steel required, it was found that Zone-V requires more reinforcement steel compared to the other zones. Specifically, the steel quantity in Zone-V is higher by 53.84%, 13.89%, and 8.31% than in Zone-II, Zone-III, and Zone-IV respectively.
8) These findings clearly indicate that Zone-V is the most critical seismic zone for the considered G+7 structure, requiring greater attention in design for safety and performance.
9) The reason for this critical behavior is due to the higher seismic zone factor associated with Zone-V. A higher zone factor leads to greater seismic forces acting on the structure.
10) As a result, parameters such as base shear, floor displacements, support reactions, and steel quantity are directly influenced by the seismic zone factor—with significantly higher values observed in Zone-V compared to other zones.

VI. ACKNOWLEDGMENT

The authors are grateful to the Civil Engineering Department of Kavikulguru Institute of Technology and Science, Ramtek, for providing the necessary facilities and environment to carry out this review study.

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
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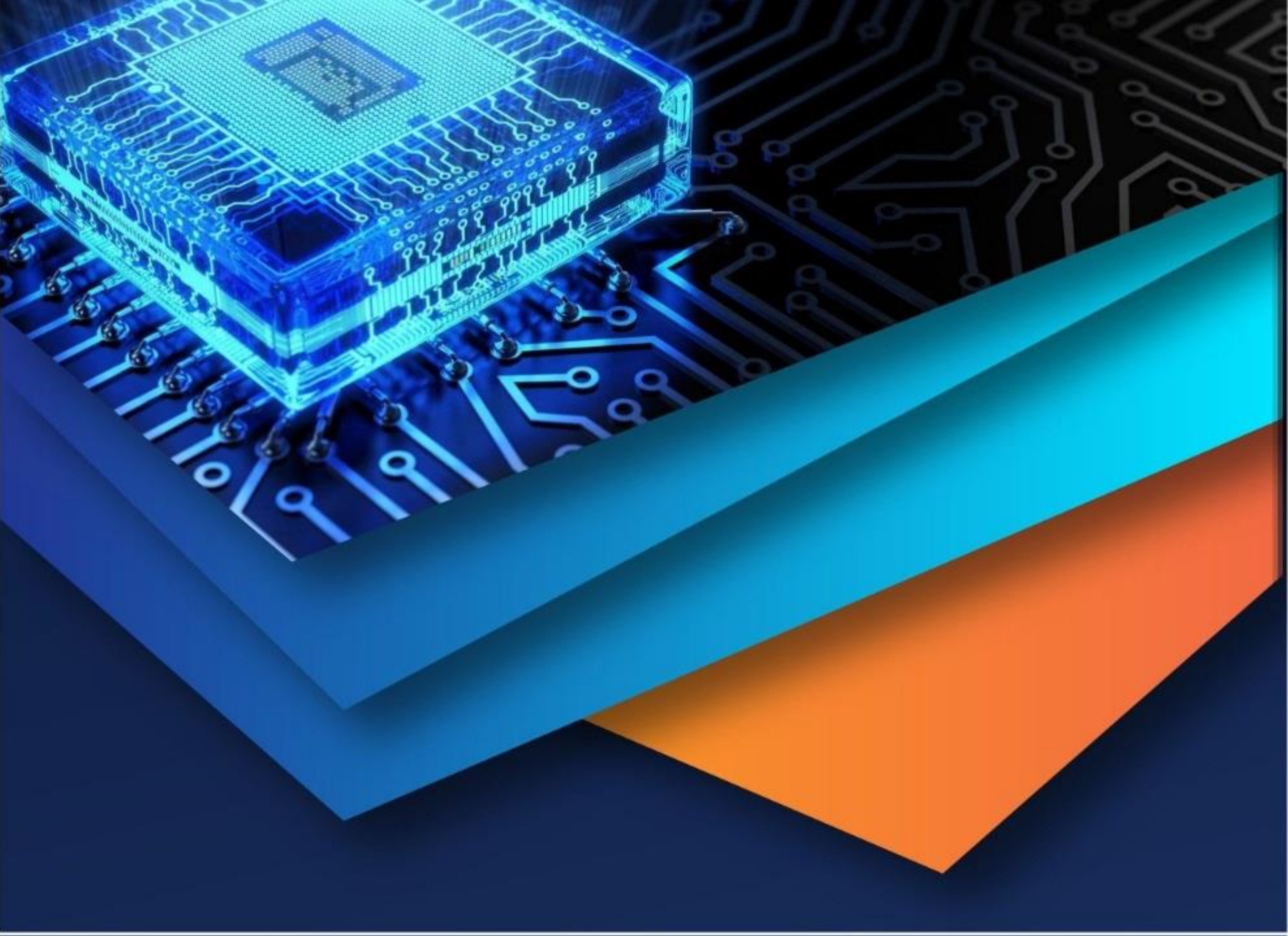

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