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EXPLORING STRUCTURAL PERFORMANCE THROUGH SEISMIC & PUSHOVER ANALYSIS OF G+4 STOREY BUILDING

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Abstract: In this study, we utilized ETABS structural analysis software to intricately model 5-storey reinforced concrete frames (G+4) with setbacks in both X and Y directions. The analysis considered medium soil conditions and addressed seismic Zones II, III, IV, and V. We focused on parameters such as storey drift, displacement, stiffness, base shear, and Modal participation factor. Results were systematically tabulated and graphically presented for comprehensive comparative analysis. Additionally, pushover analysis using ETABS provided insights into the structure's capacity to withstand increasing seismic forces until failure or significant deformation, crucial for seismic design and structural evaluation.

Keywords: Linear analysis, base shear, story displacement, story shear, Non-Linear analysis, and Push over analysis.

I. INTRODUCTION

In civil engineering, structures are typically designed according to building codes for normal loads. However, these codes may not fully consider the behavior of structures during severe seismic events. Unlike industries such as automotive and aviation, construction faces limitations in creating large-scale prototypes and conducting extensive testing due to the unique nature of each building. In seismic-prone areas, structural design must meet two critical criteria: withstanding operational loads and ensuring resilience against earthquakes. Engineers employ two main methods for seismic calculations: the Lateral Force Method for simple structures and the Modal Response Spectrum Analysis for structures influenced by higher vibrational modes. ETABS stands out as an innovative software for structural analysis and design of buildings. It offers features like 3D modeling, fast linear and nonlinear analysis, and comprehensive design tools. ETABS facilitates a smooth transition from CAD drawings and accommodates various materials. Renowned for its user-friendly interface, compliance with Indian Standard Codes, versatility, and accuracy, ETABS provides both linear and nonlinear analysis capabilities, including pushover and P-Δ analysis. Linear static analysis assumes a linear relationship between forces and displacements, fitting for structures within the elastic range of materials. Seismic analysis is crucial in earthquake-prone regions, where preventive and mitigation strategies are paramount. Nonlinear analysis, on the other hand, establishes a nonlinear force-displacement relationship, accounting for aspects like large deformations, material behavior, and contact interactions. Pushover analysis, a component of nonlinear analysis, simulates earthquake-induced forces to identify structural weaknesses and assess performance during seismic events. It offers valuable insights into forces, deformations, load paths, and potential damage. While pushover analysis offers advantages, its accuracy hinges on factors such as estimating target displacement, defining lateral load patterns, and identifying failure mechanisms.

The study focuses on evaluating the effects of soft storey positioning in different earthquake zones, highlighting the effectiveness of shear walls in significantly reducing lateral displacement and storey drift by 98.838% and 99.86%, respectively. For regions with low seismic activity, the project recommends implementing steel bracing to improve seismic performance. Using ETABS for load calculations, the project aims to analyze the seismic response of a G+10 building across various Indian seismic zones, while ensuring compliance with IS 1893:2002 standards. Another project examines the seismic and wind analysis of a G+11 building located in Pune's seismic zone II, utilizing ETABS, as conducted by Yashashri Ankalkhope et al. The study investigates critical parameters for rectangular and circular columns, comparing outcomes from Linear Static and Linear Dynamic (Response Spectrum Analysis) methods. Performance-based earthquake engineering, which accounts for uncertainties in seismic demand and capacity, is crucial for assessing seismic design. Specifically, the study explores the impact of cracked inertia on building performance during earthquakes, with a focus on pushover analysis, as conducted by Ashwini L.K. et al.

Objectives of present study

- Analyze seismic parameters such as story drift, story displacement, story shear, story stiffness, model period, and frequency with various zones.
- To study the pushover analysis for earthquake zone V of G+4 residential building.

II. METHODOLOGY: - In this paper, we focus on analyzing a multi-story structure with four floors (G+4) based on its plan. Using the ETABS software, we model and analyze the structure using linear static analysis and pushover analysis to find earthquake-related parameters like base shear, storey drift, and maximum storey displacement. The analysis is conducted for seismic Zone V, following the guidelines of IS code 1893 (2016). The table below provides details about the building properties and configuration.

2.1 Building Description: - The Following are building Description.

- Number of bays along X- axis: 6
- Number of bays along Y- axis: 7
- Size of column: 230 x 450 mm
- Size of beam: 450 x 230 mm
- Thickness of slab: 150 mm
- Grade of concrete: M20
- Grade of steel: Fe 550

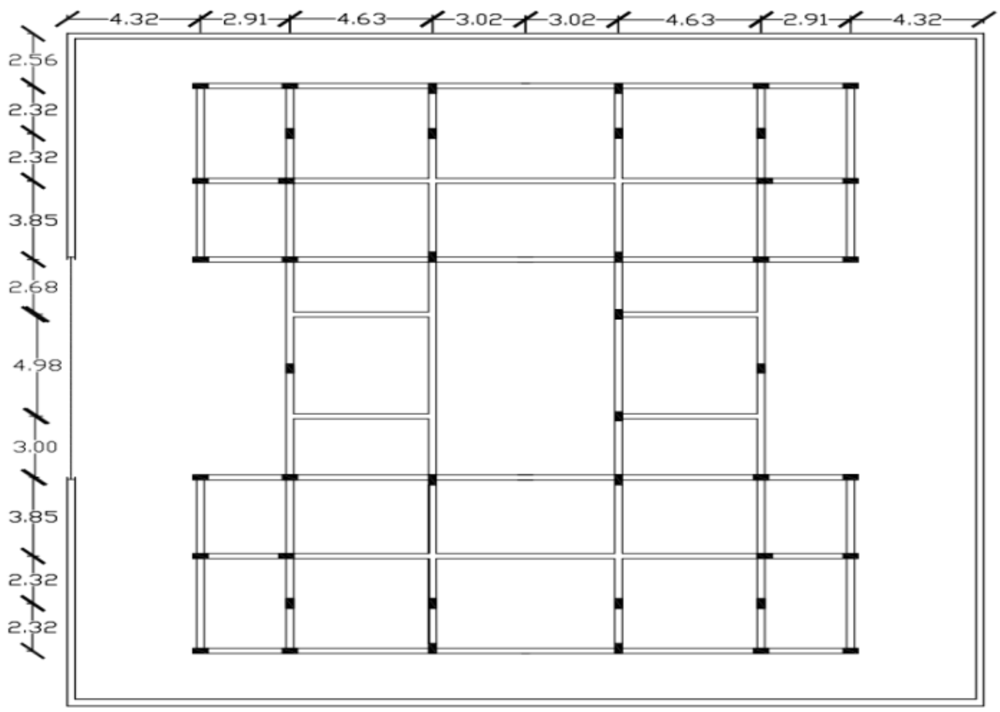

Fig: 1 Architectural Pla

2.2 Loads

The design loads considered for this analysis include the following:

- Dead load includes the weight of architectural and structural elements, calculated per IS 875 (Part I: 2015) standards, e.g., beam, slab, column, wall, and floor finish load.
- Live load, a superimposed load, is determined per IS 875 (Part II: 2015) guidelines and is specified as 4 kN/m2.
- Seismic loads are considered in the analysis, following IS 1893 (Part I: 2016) and IS 875 (Part V: 2015) codes, which offer guidance for seismic design and building details.
- Wind load The construction of the building will adhere to wind load specifications in accordance with IS 875 Part 3: 2015.

2.3 Development of Model: - Beam and column members were initially designed in AutoCAD and later imported into ETABS. In ETABS, properties and loads were assigned, and the structural model was analyzed, with results systematically tabulated. The building plan is shown below Fig 2.

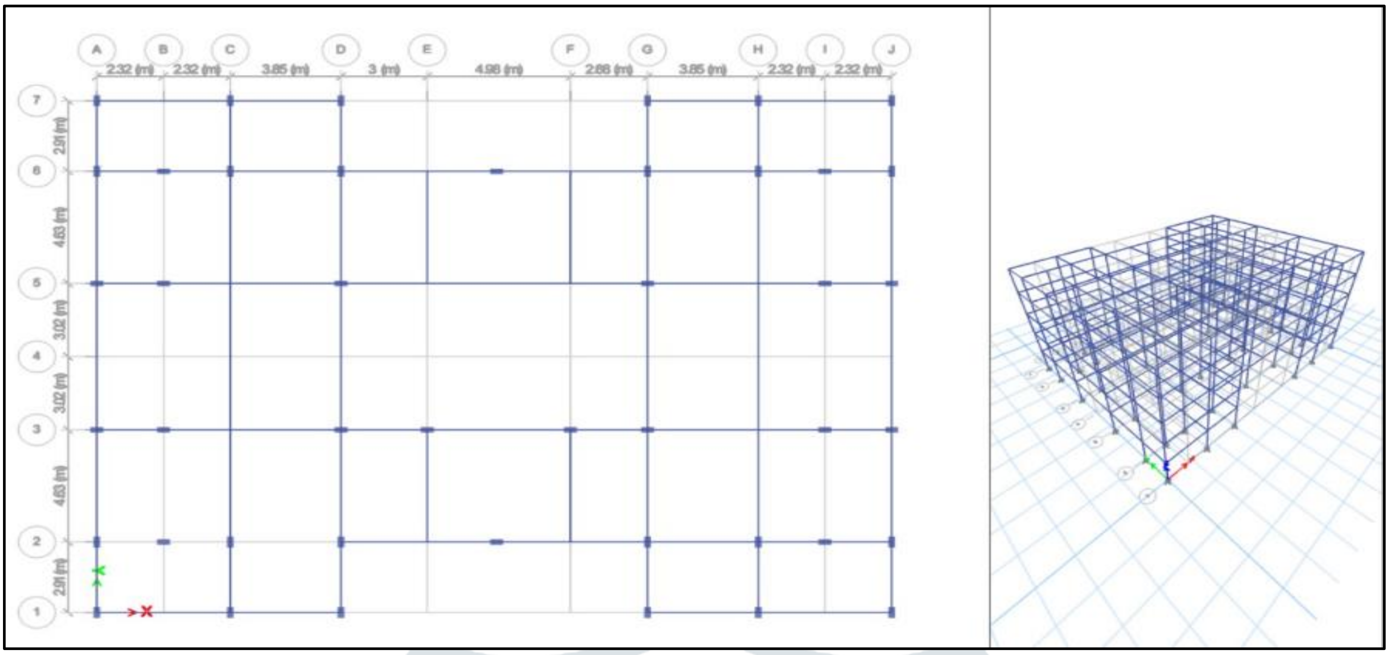

Fig: 2 Development of Model

2.4 Analyzing the model: - Analysis involves examining a structure's components, with two main types: static analysis for low to medium-rise buildings and dynamic analysis for earthquake-prone areas and high-wind locations Fig 3.

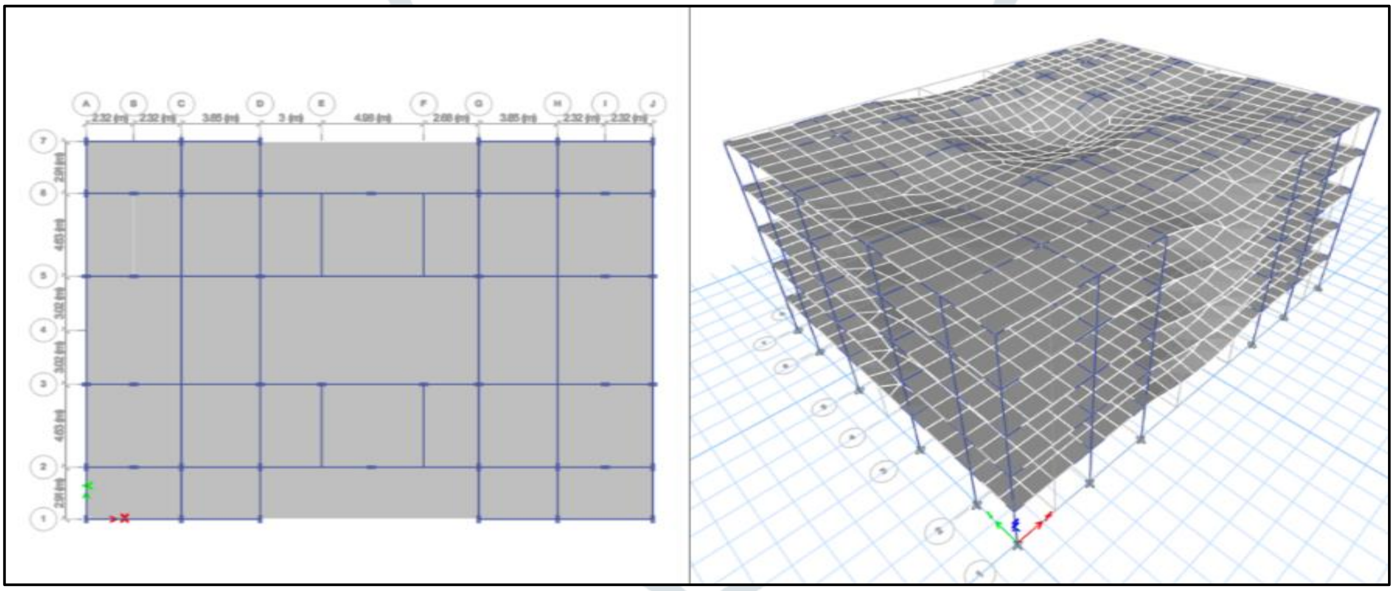

Fig: 3 Analyzing the Model

III. RESULTS AND DICUSSION

In this present study considered for various parameters base shear; story displacement, story drift story stiffness and pushover analysis are as follows in the form of fig 4-12 and table 1-2 respectively.

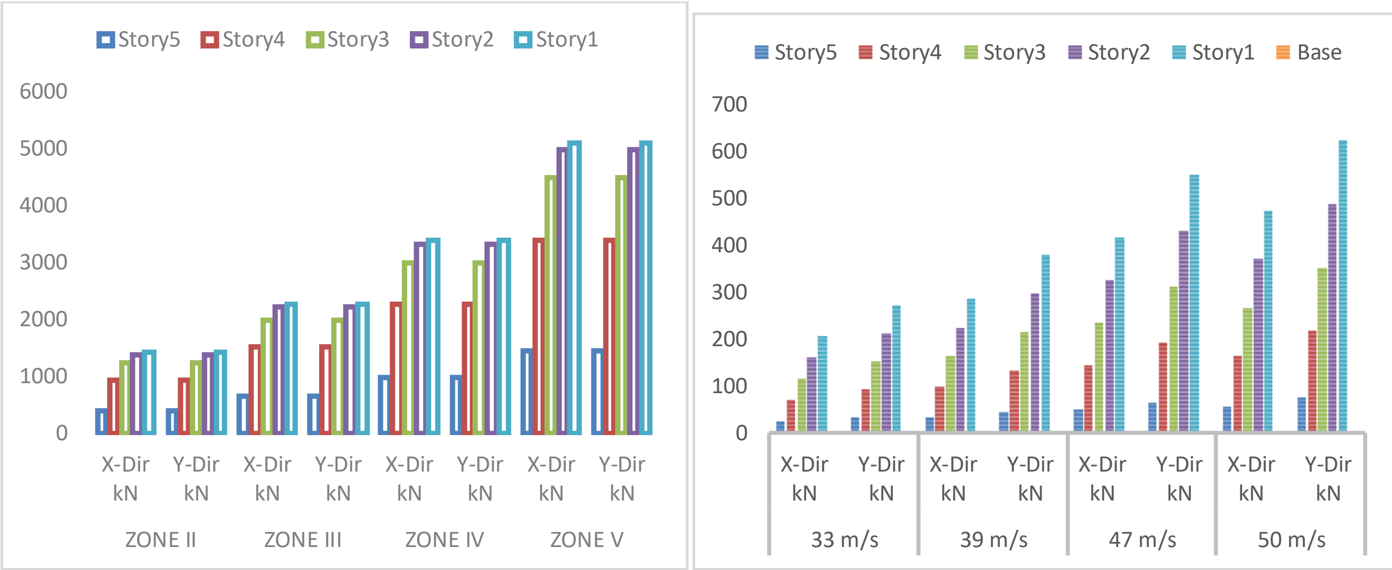

Fig: 4 Graph of Base shear due to seismic and wind force in X & Y Dir.

Observation: shear Base or storey shear, ranging from 401.624 KN to 5095.331 KN in seismic Zones II to V, peaks consistently at the building's base in response to seismic forces. Additionally, at wind speeds of 33m/s and 50m/s, base shear varies from 24.69 KN to 622.049 KN in the X and Y directions.

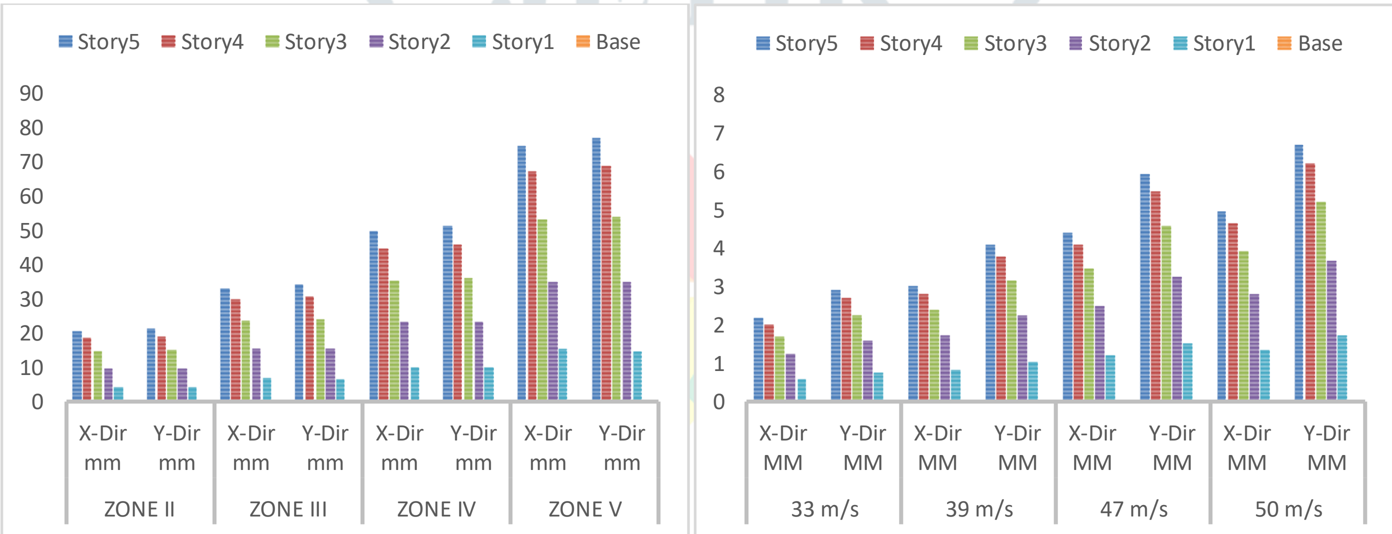

Fig: 5 Graph of Storey Displacement due to wind force in X Dir and Y Dir.

Observation: From the graph seismic forces in Zones II to V, top storey displacement remains consistent at 4.107 MM to 76.89 MM in the X and Y directions. Conversely, under wind forces at 33m/s and 50m/s, base storey displacement varies from 0.592 MM to 6.699 MM in the X and Y directions.

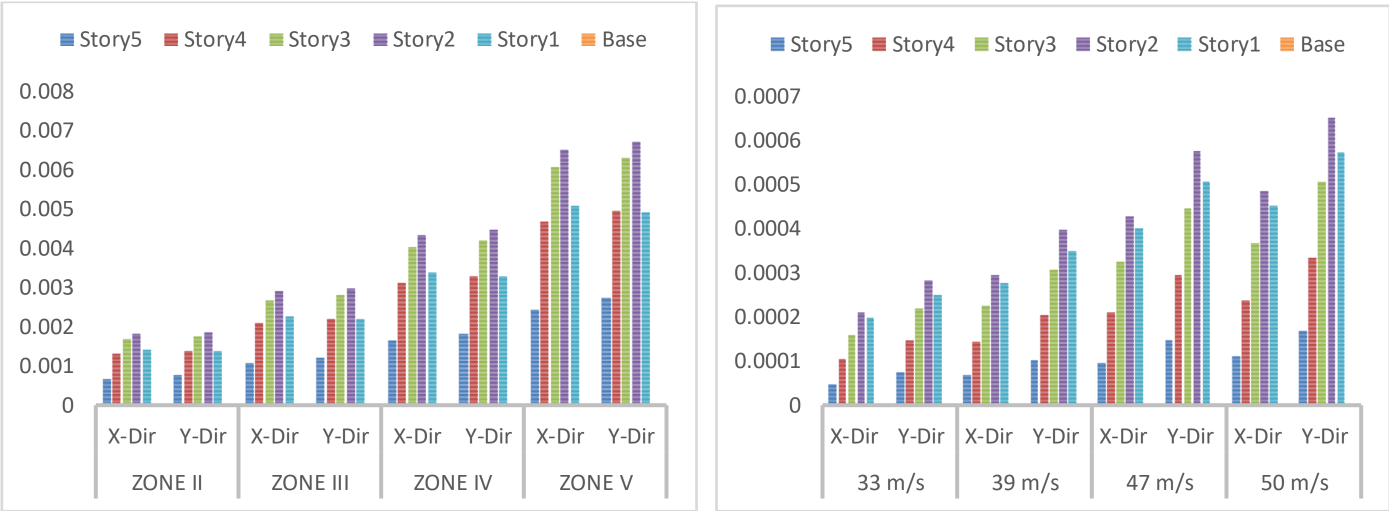

Fig: 6 Graph of Storey Drift due to wind force in X & Y Dir.

Observation: Top storey drift, influenced by seismic forces in Zones II to V, consistently peaks from 0.00068 to 0.006709 in the X and Y directions. Meanwhile, under wind forces at 33m/s and 50m/s, maximum storey drift consistently occurs at the base, ranging from 7.30E-05 to 0.000652 in the X and Y directions.

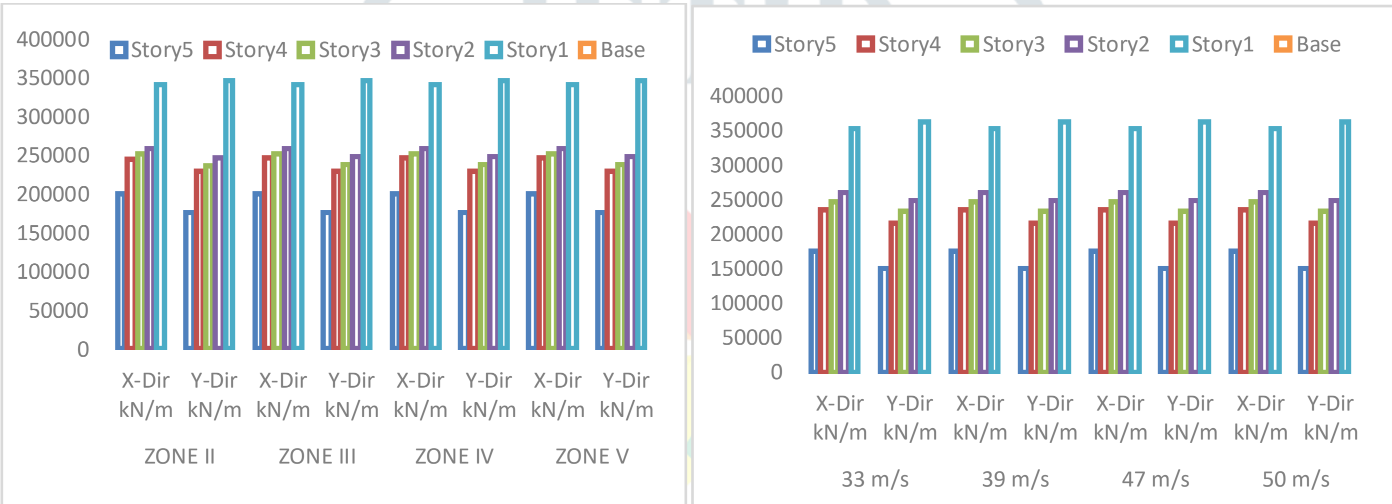

Fig: 7 Graph of Storey Stiffens due to wind force in X & Y Dir.

Observation: Influenced by seismic forces in Zones II to V, consistently ranges from 175,837 KN/M to 345,627.6 KN/M, with the lowest in Zone II and the highest in Zone V, in the X and Y directions. At the base, storey stiffness varies from 148,947 .59 KN/M to 361,671.98 KN/M, reaching the lowest at 33m/s wind speed in the X direction and the highest at 50m/s in the Y direction.

3.1 Modal participation: Modal participation, reflecting the involvement of each mode in structural response, where effective modal mass accounts for no less than 90% of the actual mass.

Table:1 Modal participation.

Case	Mode	UX	UY	RX	RY
		kN-m	kN-m	kN-m	kN-m
Modal	1	3.64E-07	4.90E-05	-0.08468	0.00061
Modal	2	-4.90E-05	4.08E-07	-0.00072	-0.0817
Modal	3	5.00E-06	4.48E-07	-0.00093	0.00798
Modal	4	-4.87E-07	-1.80E-05	-0.17557	0.00504
Modal	5	-1.70E-05	1.00E-06	0.005137	0.17734
Modal	6	-2.00E-06	-1.61E-07	-0.00164	0.01629
Modal	7	-1.00E-05	-7.32E-08	-0.0004	0.05244
Modal	8	-7.81E-08	1.00E-05	0.055086	0.00042
Modal	9	1.00E-06	9.31E-08	0.000484	-0.0044

Modal	10	6.00E-06	2.36E-08	0.000218	-0.0551
Modal	11	-2.66E-08	6.00E-06	0.056105	0.00026
Modal	12	4.59E-07	5.74E-08	0.000553	-0.0043

3.2 Pushover analysis: Pushover analysis is a nonlinear static analysis that generates a "capacity curve," plotting total base force against roof displacement. This analysis extends to failure, aiding in determining the collapse load and ductility capacity, offering insight into the building's successive damage states as it undergoes monotonically increasing lateral loads until reaching the peak response.

Table: 2 Base shear and displacement due to pushover analysis.

			Location of Hinges					
Load Case	**Maxi Disp (mm)**	**Max Base Shear (kN)**	**A-B**	**B-C**	**A-Io**	**Io-Ls**	**Ls-Cp**	**Total**
X-axis	83.635	2944.18	2299	289	2462	66	86	2640
Y-axis	70.25	2565.75	2450	190	2640	0	0	2640

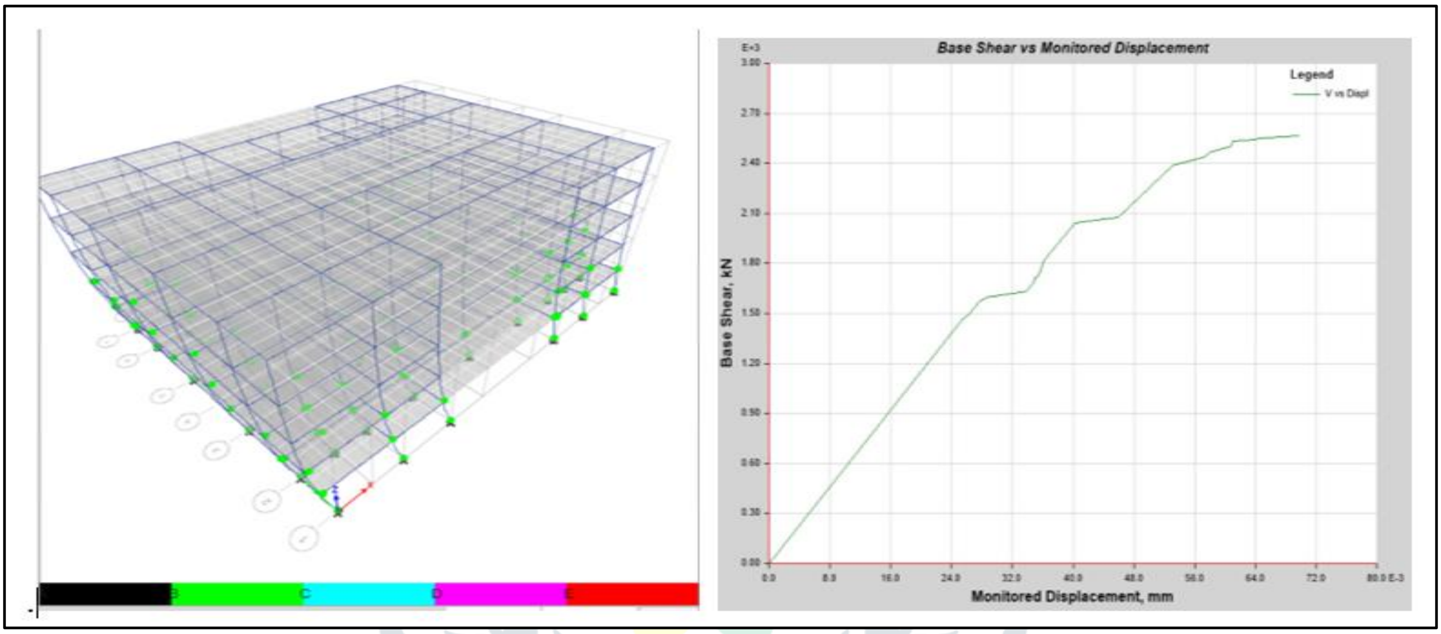

Fig: 8 Push over analyzing the model and Displacement graph.

CONCLUSION

When comparing seismic Zone V to Zone II, notable differences emerge in storey shear and displacement, with Zone V showing higher values. However, wind force analysis reveals differing shear values. Similarly, there are significant distinctions in storey drift data, with Zone V experiencing higher drift values compared to wind analysis, which indicates lower drift values. Interestingly, storey stiffness remains consistent across both seismic zones during wind analysis, suggesting similar values. Modal participation factors vary across directions, providing insights into how the structure responds to seismic and wind forces. In pushover analysis, maximum and minimum base shears are recorded, alongside the progression of hinge formation in beams across various stages, which is noteworthy. Load-moment interaction curves are pivotal in defining column hinges, with localized collapse occurring in beams before columns. Despite these observations, the building exhibits adequate base shear capacity for the assumed earthquake level, indicating a resilient structural response.

Future Scope of Work

- Push over analysis is used as a non-linear static method to predict the actual performance of the RC Frames under lateral loadings.
- The study highlights the effect of seismic zone factor in different zones and various soil conditions which is considered in the seismic performance evaluation of buildings.

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