A STUDY ON THE EFFECTS OF PLAN ASPECT RATIO ON SEISMIC RESPONSES OF RCC BUILDINGS USING ETABS

Abstract

Seismic design is a critical aspect of constructing safe and resilient buildings in earthquake-prone regions. The layout and design of a building play a significant role in determining its behavior under seismic forces. The as pectratio, defined as the ratio of a building's width to its height, is an important parameter that affects its structural response during earthquakes. The placement of the core within the building is crucial as it directly impacts the distribution of lateral forces and stiffness of the structure. Therefore, it is essential to investigate the effects of plan aspect ratio on the seismic performance of RCC buildings. This study investigates the effects of plan aspect ratio on the seismic responses of rein forced concrete (RCC) buildings using ETABS software. The research aims to assess the impact of core placement in structures with different aspect ratios and analyze various parameters such as story drift, shear forces, and other relevant factors. The findings of this study contribute to a better understanding of how the placement of the core within a building influences its response to seismic loads. The results obtained from the analysis of the seismic responses of RCC buildings with different aspect ratios and core placements indicate significant variations in their behavior. Story 7consistently exhibits the highest displacement values in both the X and Y directions across different aspect ratios, suggesting that this story is more vulnerable to seismic loads. Aspect Ratio 1:1.5 and Story 4 generally demonstrate the lowest displacement values, indicating a more favorable response to seismic forces. Additionally, Story 1 exhibits the highest

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shear force, whereas Aspect Ratio 1:2 experiences the lowest shear force in Story 1. The maximum lateral load occurs in Aspect Ratio 1:1, while Story 7 experiences the highest lateral load in both directions. These findings emphasize the influence of core placement on the impact of seismic loads on the structure.

Keywords: Aspect ratio, Core placement, RCC buildings, Seismic responses, Seismic design.

I. INTRODUCTION

Earthquakes are one of the most devastating natural disasters that can cause considerable damage to the built environment, resulting in the loss of life and property. The design of earthquake-resistant buildings is therefore of immense importance, particularly in regions proneto seismic activity. The seismic response of buildings is affected by several factors, including the characteristics of the ground motion, the properties of the building materials, and the structural configuration of the building [1,2]. One of the critical aspects of seismic-resistant design is the plan aspect ratio of the building, which is defined as the ratio of the length to the width of the building.[3] The plan aspect ratio can significantly affect the seismic response of the building, as it affects the distribution of mass and stiffness along the longitudinal and transverse direction soft he building. [4] Buildings with different aspect ratios may have different natural periods of vibration, which can lead to different responses to seismic forces.[5]The seismic response of buildings can be evaluated in terms of inter-story drift, acceleration, and displacement. Inter-story drift is the relative displacement between adjacent floors of the building, while acceleration is the rate of change of velocity of the building during an earthquake where as displacement refers to the total displacement of the building during an earthquake. [3-5] Several studies have been conducted to investigate the effect of plan aspect ratio on these is mic response of RC buildings. [6-8] Most of these studies have focused on low-rise buildings with up to four stories. [7,8] However, with the increasing demand for taller buildings, there is a need for further research to investigate the effect of plan aspect ratio on the seismic response of tall RC buildings. Theuseofcomputer-aided design(CAD) tools such as ETABS has made it easier to investigate these is mic response of buildings with different aspect ratios. ETABS is a widely used software for the analysis and design of buildings, particularly in seismic zones. The software allows for the creation of detailed 3D models of buildings, which can be used to evaluate the response of the building to seismic forces.This study aims to investigate the effect of plan aspect ratio on these is mic response of tall RC buildings using ETABS. The study will develop several building models with different plan aspect ratios and analyze their seismic response using ETABS. The study will evaluate the inter-story drift, acceleration, and displacement of the buildings and compare the results to investigate the effect of plan aspect ratio on the seismic response of tall RC buildings. The results of this study will provide valuable insights into the design of earthquake-resistant tall RC buildings and help engineers make informed decisions regarding the plan aspect ratio of the building.

II. ETABS

ETABS (Extended Three-Dimensional Analysis of Building Systems) is a widely used finite element analysis software specifically designed for the analysis and design of building structures. The ETABS software is utilized for modelling and analysis. ETABS offers several features and capabilities that make it suitable civil engineering applications are:

- Modelling Tools: ETABS provides a user-friendly interface for creating 3D models of buildings. It allows for the efficient and accurate representation of the building geometry, including the different aspect ratios considered in the study. The software supports the creation of structural elements such as columns, beams, slabs, and walls.
- Material Properties: ETABS allows the specification of material properties for concrete and reinforcement. The software accommodates the input of parameters such

as compressive strength, modulus of elasticity, Poisson's ratio, and yield strength, which are crucial for accurately simulating the behavior of RCC structures.

- Dynamic Analysis: ETABS has the capability to perform both linear and nonlinear dynamic analyses. In this research project, dynamic analysis is crucial for evaluating the seismic responses of the RCC building models with varying aspect ratios. The response spectrum analysis method available in ETABS can be employed to calculate the building's response to seismic excitation.
- modeled using a nonlinear material model, and the steel reinforcement is modeled using a plastic hinge model.
- Assigning Loads and Boundary Conditions: The gravity loads, such as dead loads and live loads, are applied to the building models according to the design specifications. The boundary conditions are defined on the support conditions and the assumptions of the structural system.
- Dynamic Analysis: The dynamic analysis is conducted using ETABS to simulate the seismic response of the building models under the applied ground motions. The response spectrum analysis method is employed to evaluate the maximum responses of the structures, such as the base shear, roof displacement, and inter-story drift.
- Results Interpretation and Comparison: The result of the dynamic analysis is interpreted and compared for the different building models with various aspect ratios. The effects of aspect ratio on the seismic responses are evaluated in terms of the maximum responses and the mode shapes.
- Sensitivity Analysis: Sensitivity analyses is performed to investigate the effects of other parameters, such as the building height, structural system, and damping ratio, on the seismic responses of the building models. The results of the sensitivity analyses are compared to the base case scenarios to assess the influence of these parameters on the research findings.
- Statistical Analysis: Statistical analyses is performed to quantify the variability and uncertainty associated with the results of the dynamic analysis. The statistical analyses include probability distribution fitting, confidence interval estimation, and regression analysis.

1. Validation:

The following steps outline the validation process:

- Comparison with Analytical Solutions: The analytical models used in the study is compared with known analytical solutions or simplified hand calculations for specific cases. This step helps validate the accuracy of the modelling assumptions, boundary conditions, and solution techniques used in the analysis.
- Comparison with Experimental Data: If available, experimental data from previous studies or shake table tests on similar building configurations is used for comparison with the analytical results. The measured responses, such as inter-story drifts, base shear, and acceleration, is compared with the predicted responses from the building models. This step helps assess the accuracy and reliability of the numerical models and their ability to capture the seismic behaviour of the buildings.
- Sensitivity Analysis: Sensitivity analysis is performed by varying input parameters and comparing the resulting responses. The sensitivity analysis involves changing

parameters such as material properties, damping ratios, or boundary conditions. The obtained responses from the sensitivity analysis are compared to expected trends or theoretical behaviour to verify the consistency and validity of the model.

- Peer Review and Expert Consultation: The research findings and methodology are shared with peers and experts in the field of structural engineering. Their feedback, suggestions, and critiques provide an external validation of the research approach and conclusions.
- Code Compliance Check: The analysis results are evaluated against the requirements and recommendations of relevant design codes and standards, such as IS 1893 or ASCE
- The building models' responses, such as inter-story drift ratios, comply with the code provisions for different plan aspect ratios and seismic hazard levels. Any discrepancies or deviations from the code requirements are carefully examined and addressed.
- Sensitivity to Modelling Assumptions: The sensitivity of the results to different modelling assumptions, such as the element types, mesh density, and modelling simplifications, are assessed. Multiple analyses with varying modelling approaches are performed to evaluate the robustness of the results and ensure that they are not overly dependent on specific modelling assumptions.
- Limitations and Uncertainties: The limitations and uncertainties associated with the analysis and the obtained results are identified and clearly stated. These include simplifying assumptions, modelling uncertainties, or limitations of the software used. Acknowledging and addressing these limitations provides a balanced perspective on the research findings.

III. CREATING 3D MODEL

Creating a 3D model in ETABS involves several steps to accurately represent the RCC building geometry. The following outlines the process for creating a 3D model in ETABS:

1. Project Setup

- Open ETABS software and create a new project.
- Define the project units (e.g., length, force, time) based on the design requirements and standards.
- Set the project preferences and analysis settings, such as seismic design codes and analysis methods as shown in Fig. 1.

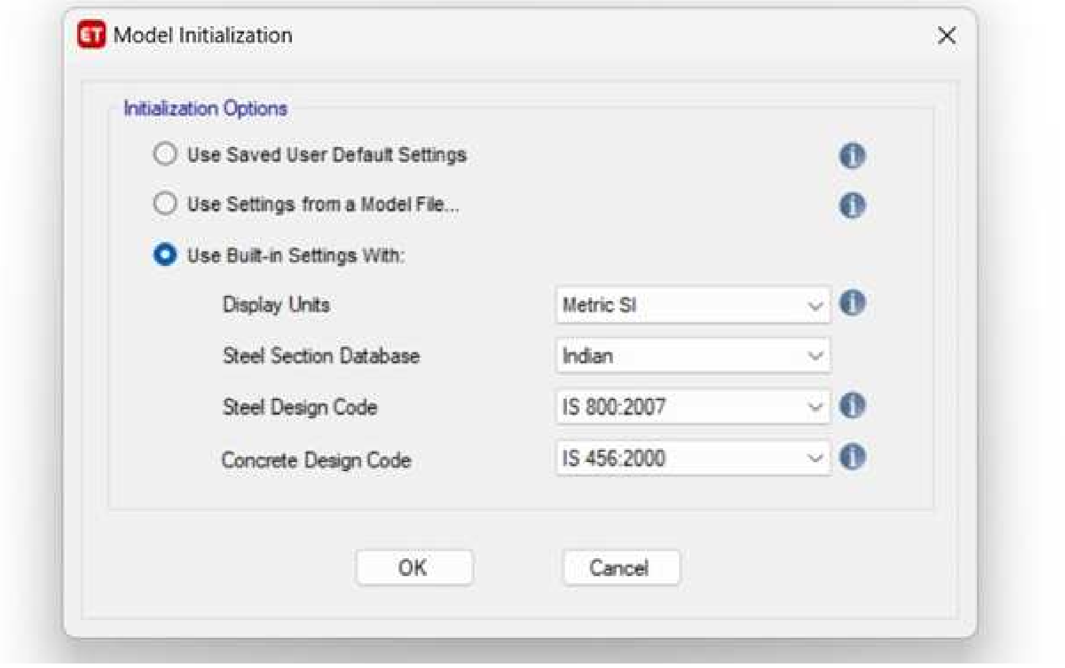


Figure 1: ETABS Model Initialization

Figure 2: Defining Material Properties.

2. Define Material properties

- Specify the material properties for concrete and reinforcement [9].
- Input the concrete compressive strength, modulus of elasticity, Poisson's ratio, and reinforcement yield strength as shown in Fig. 2.

3. Create Building Geometry

- Define the building's overall dimensions, including plan aspect ratio, number of stories, and floor-to-floor heights.
- Use the drawing tools in ETABS to create the structural elements (columns, beams, slabs, walls) in the desired layout.
- Ensure that the elements accurately represent the building's geometry, including column locations, beam depths, slab thicknesses, and wall locations as shown in Fig. 3.

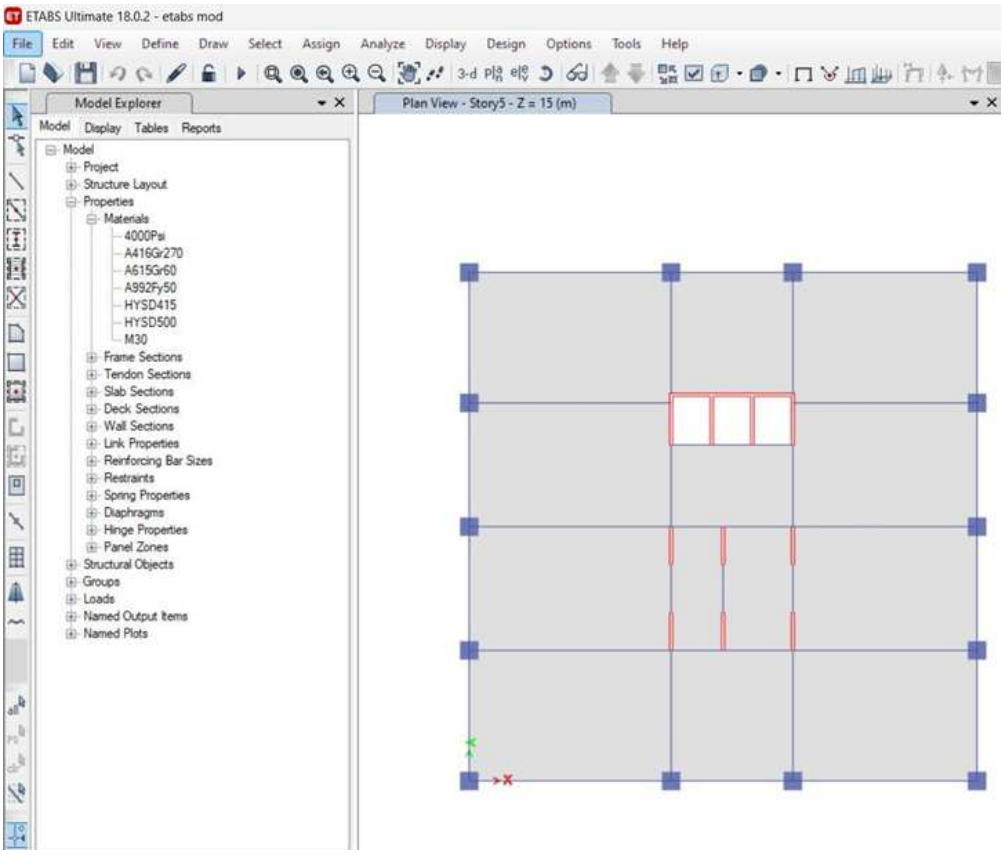


Figure 3: 2-D Plan of ETAB Model

4. Assign Material Properties

- Assign the previously defined material properties to the respective structural elements.
- Specify the appropriate concrete grade and reinforcement details for each element as shown in Fig. 4.

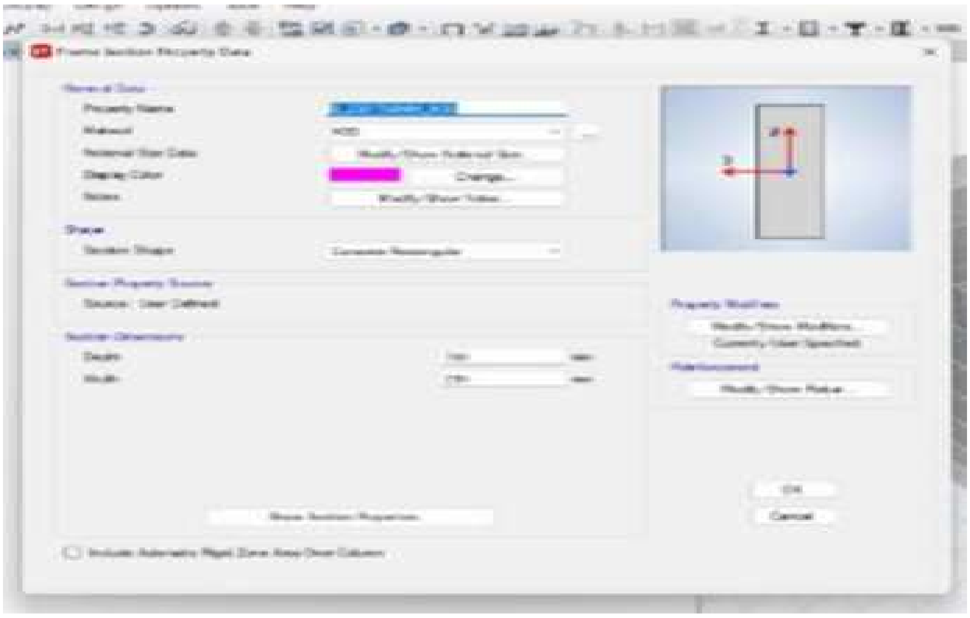


Figure 4: Defining Reinforcement Details.

5. Define Supports and Constraints

- Assign appropriate supports to the structural elements, considering the boundary conditions of the building.
- Define fixed supports at the base or other locations where the building is connected to the foundation.
- Apply rotational and translational constraints to the appropriate elements to represent their connections.

6. Apply Loads

- Define gravity loads such as dead loads (self-weight) and live loads based on the design specifications[10].
- Apply the loads to the corresponding elements (e.g., slabs, beams) based on their load-bearing capacity.
- Consider any eccentricities or load distribution factors as required as shown in Fig. 5.

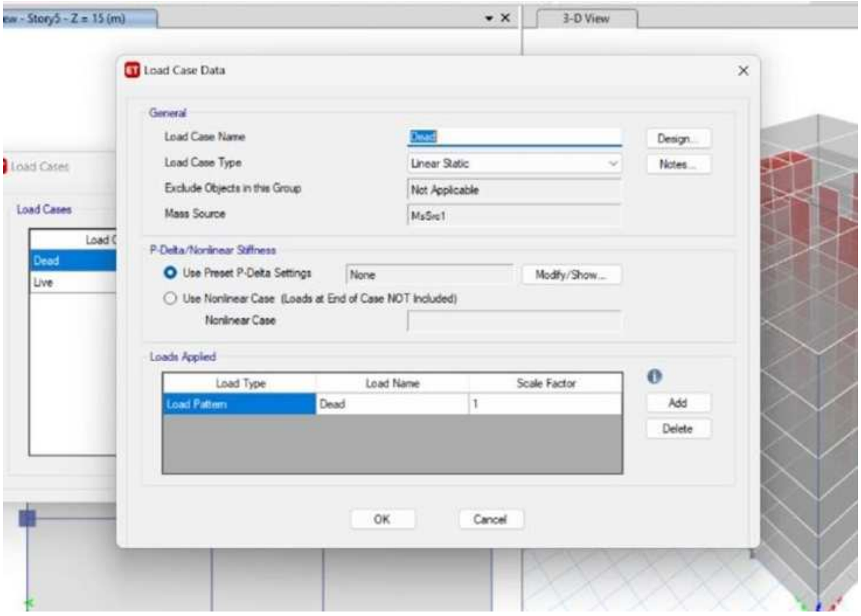


Figure 5: Defining Load Combinations.

7. Define Seismic Loads

- Specify the seismic design parameters, such as the design seismic coefficient or the site-specific design spectra.
- Assign the seismic loads to the appropriate elements, such as beams and columns, based on their lateral load-resisting capacity.
- Consider the effects of plan aspect ratio on the distribution and magnitude of seismic loads.

8. Perform Analysis

- Run the analysis using the defined load cases and combinations.
- Select the appropriate analysis method, such as response spectrum analysis or time history analysis, based on the research objectives.
- Monitor the convergence and accuracy of the analysis results

9. Review and Interpret the Results

- Evaluate the analysis results, including inter-story drifts, base shear, and other relevant response parameters.
- Visualize the results using the graphical output tools in ETABS, such as displacement plots, moment diagrams, and mode shapes.
- Compare and analyze the results for different plan aspect ratios to determine the effects on the seismic responses.
- By following these steps, a 3D model of the RCC building is accurately created in ETABS, allowing for subsequent analysis and evaluation of the effects of plan aspect

ratio on seismic responses, a sample 3 D model for model 1 has been illustrated in Fig.6.

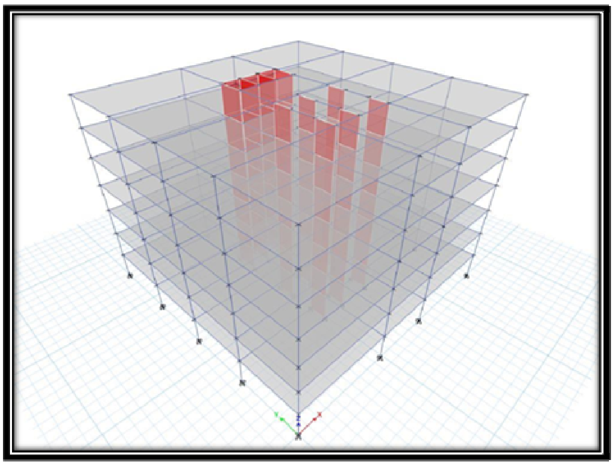


Figure 6: 3-D Model for Model 1

IV. ANALYSIS AND INTERPRETATION OF DATA

1. **Interstorey Drift:** Inter-story drift refers to the relative horizontal displacement between consecutive floors of the building. It indicates the building's flexibility and its ability to withstand lateral forces during seismic events. The inter-story drift results have been examined to assess the deformations and potential damage in different plan aspect ratios. In this case, the building has a total of seven stories, including a base level. Each story is assigned a number (Story1 to Story7) along with its corresponding elevation, X direction drift and Y direction drift values. The X direction and Y direction values represent the horizontal and vertical displacements, respectively, experienced by each story during a seismic event. These values indicate the relative movement or deformation in the respective directions for each story. Figure 7 and 8 represents the story drift of a building with a 1:1 aspect ratio for X and Y direction. The highest value of the X direction occurs at Story4, which has an X direction value of 0.001881. This signifies that Story4 experienced the greatest horizontal displacement among all the stories. It is also found that the highest Y direction value occurs at Story4, with a value of 0.000795. This signifies that Story4 experienced the greatest vertical displacement among all the stories.Fig. 9 and 10represent the story drift of a building with a 1:1.25 aspect ratio for Model 2. In the X direction it is observed that the highest value of 0.001875 occurs at Story4. This indicates that Story4 experienced the most significant horizontal displacement among all the stories. In the Y direction table, Story4 also stands out with the highest value of 0.0008. Story4 exhibited the greatest vertical displacement among all the stories.

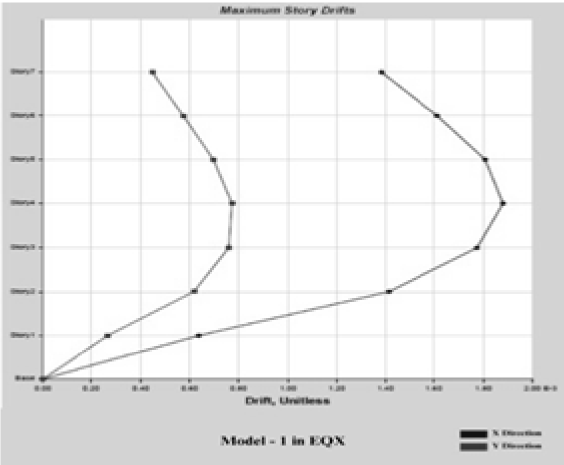


Figure 7: Story drift in X direction

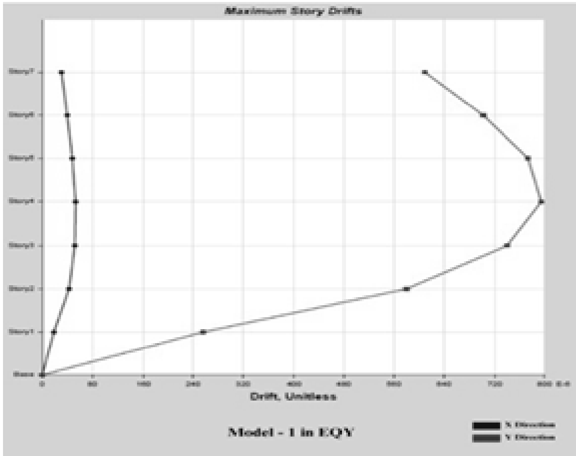


Figure 8: Story drift in Y direction

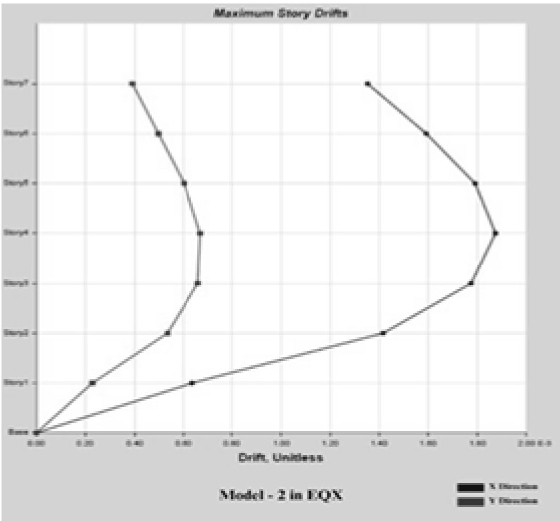


Figure 9: Story drift in X direction

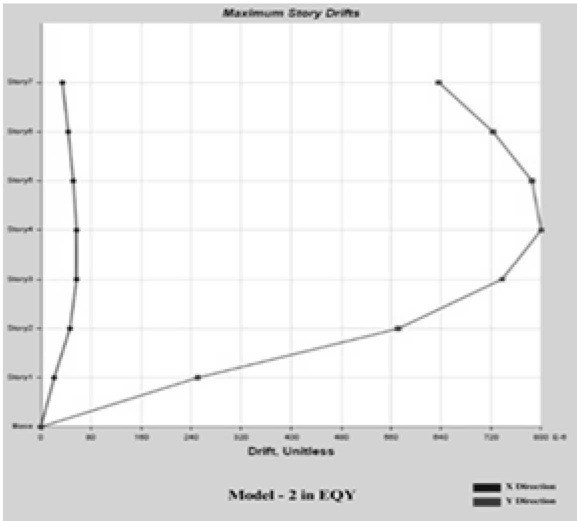


Figure 10: Story drift in Y direction

Fig. 11 and Fig.12 represent the story drift of a building with a 1:1.5 aspect ratio in X and Y direction respectively for Model 3. It is observed that the highest X direction value of 0.001284 is associated with Story4. This indicates that Story4 experienced the greatest horizontal displacement among all the stories. The highest Y direction value of 0.000692 is also attributed to Story4. This indicates that Story4 exhibited the highest vertical displacement among all the stories. Fig.13 and Fig.14represent the story drift of a building with a 1:1.75 aspect ratio in X and Y direction respectively for Model 4. Story4 has the highest X direction value of 0.001742. This indicates that Story4 experienced the greatest horizontal displacement among all the stories. Story4 also exhibits the highest Y direction value of 0.001056. This suggests that Story4 encountered the greatest vertical displacement among all the stories. Fig.15 and Fig.16represent the story drift of a building with a 1:2 aspect ratio in X and Y direction respectively for Model 5. Story4 has the highest X direction value of 0.001597. This indicates that Story4 experienced the greatest horizontal displacement among all the stories. Story4 also exhibits the highest Y direction value of

0.001136. This suggests that Story4 encountered the greatest vertical displacement among all the stories.

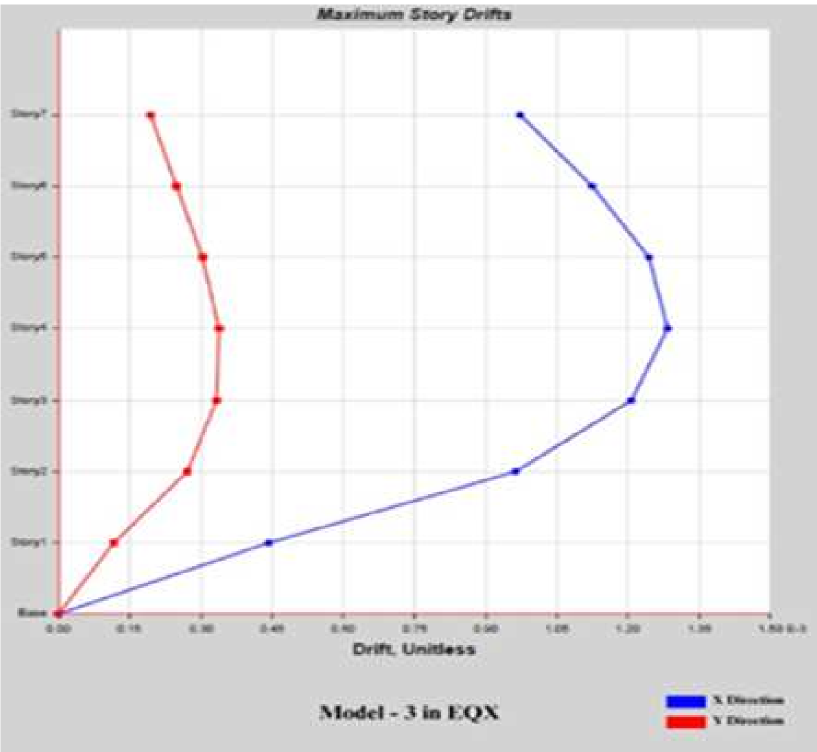


Figure 11: Story Drift in X Direction

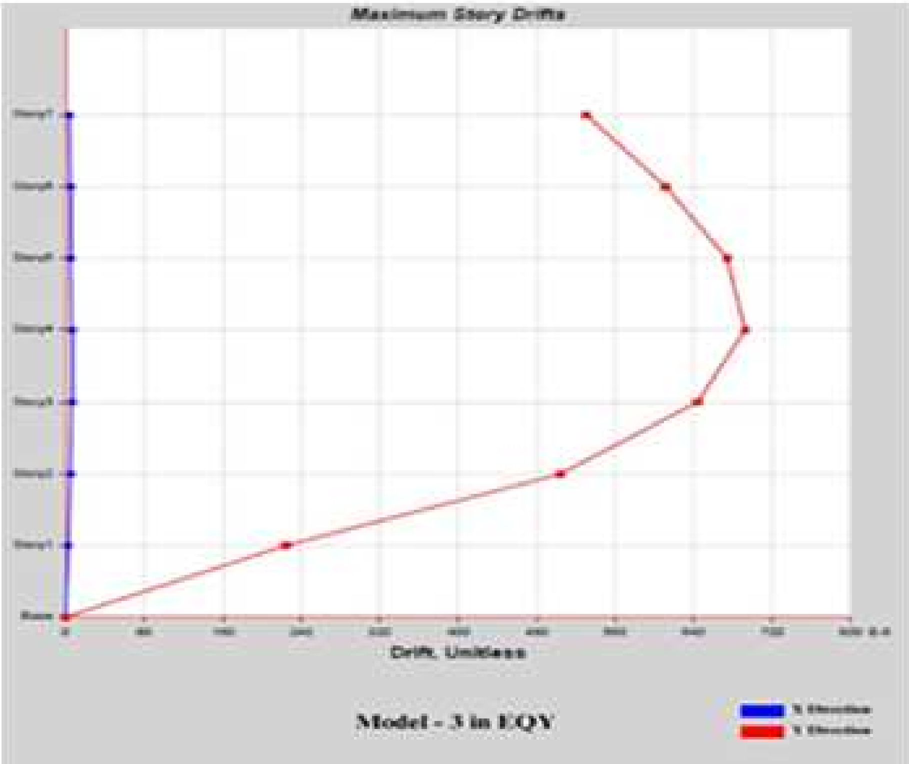
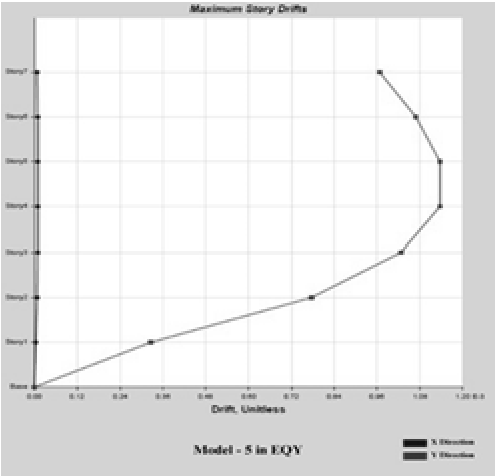


Figure 12: Story Drift in Y Direction



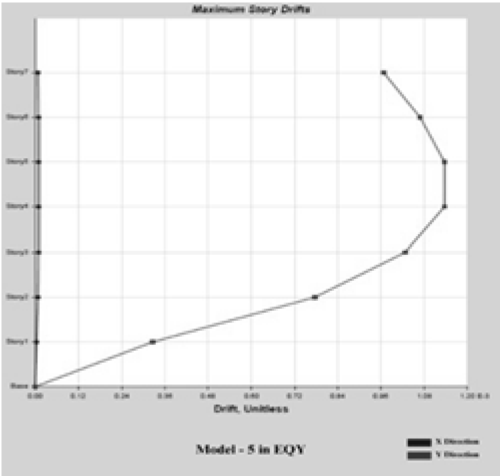


Figure 13: Story drift in X direction

Figure 14: Story drift in Y direction

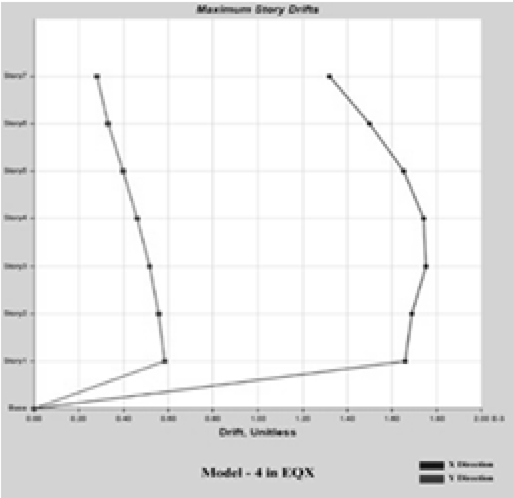


Figure 15: Story Drift in X Direction

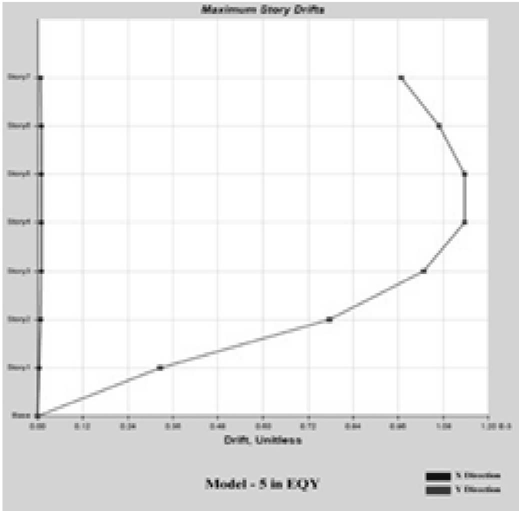


Figure 16: Story Drift in Y Direction

2. **Base Shear:** The base shear represents the total lateral force exerted at the base of the building due to seismic loading. It is a critical parameter for structural design as it determines the design requirements for the foundation and the overall stability of the building. The base shear results have been compared for different plan aspect ratios to understand the variations in lateral force distribution.In Fig. 17 with an aspect ratio of 1:1, Story7 exhibits the highest X direction value of 32.049 mm. For the corresponding Y direction, Story7 has the highest value of 13.593 mm. In Fig. 18. with an aspect ratio of 1:1.25, Story7 has the highest X direction value of 31.844 mm, and in table no.15, Story7 has the highest Y direction value of 13.743 mm. In Fig. 19 with an aspect ratio of 1:1.5, Story7 has the highest X direction value of 22.076 mm. Story7 has the highest Y direction value of 11.837 mm. In Fig. 20 with an aspect ratio of 1:1.75, Story7 demonstrates the highest X direction value of 34.476 mm. For the corresponding Y direction, Story7 has the highest value of 18.523 mm. Lastly, in Fig. 21 with an aspect ratio of 1:2, Story7 has the highest X direction value of 27.74 mm, and Story7 has the highest Y direction value of 19.63 mm.To summarize, for each aspect ratio scenario, Story7 consistently exhibits the highest direction value. Similarly, Story7 consistently has the highest Y direction value. These findings provide insights into the extent of horizontal and vertical displacement experienced by Story7 across different aspect ratios, highlighting its significance in understanding the building's structural response during seismic events.

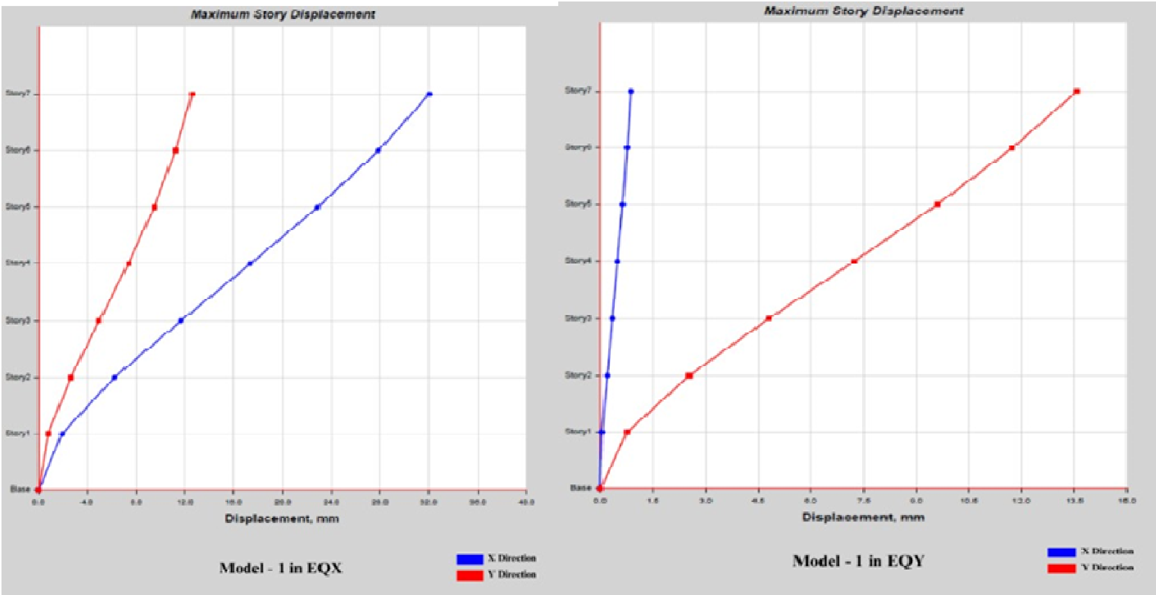


Figure 17: Story Displacement in X and Y direction for Model 1

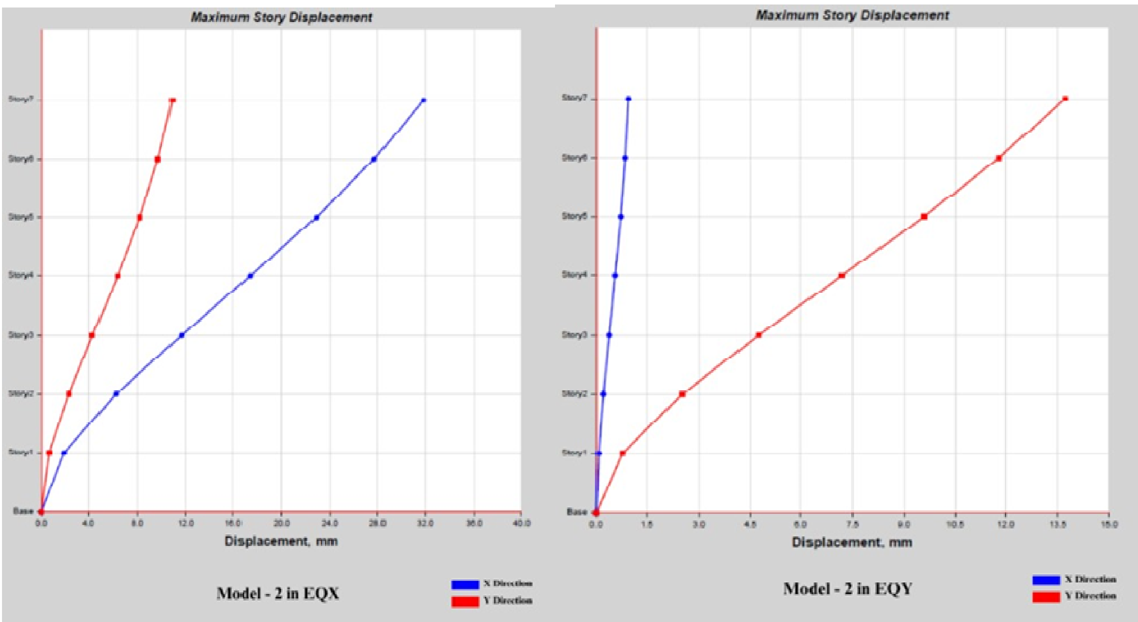


Figure 18: Story Displacement in X and Y direction for Model 2

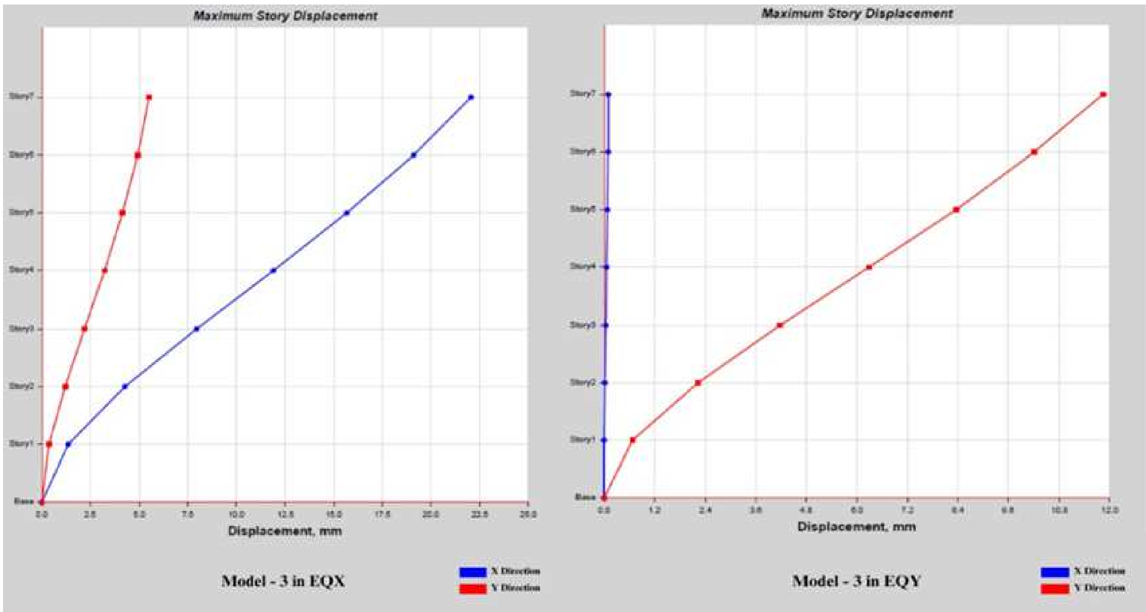


Figure 19: Story Displacement in X and Y direction for Model 3

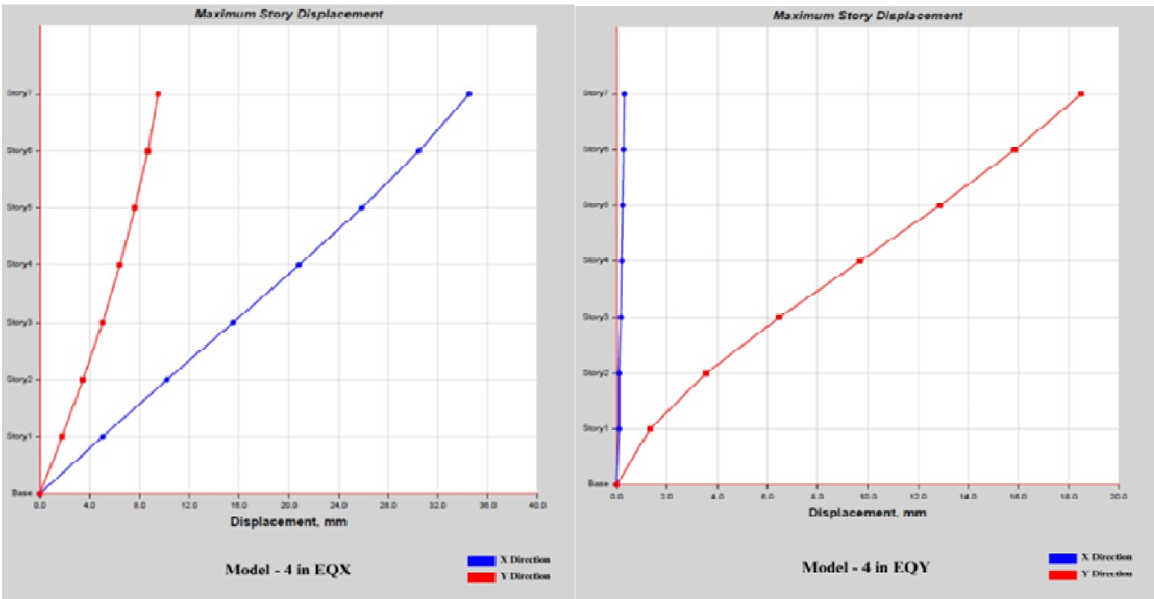


Figure 20: Story Displacement in X and Y direction for Model 4

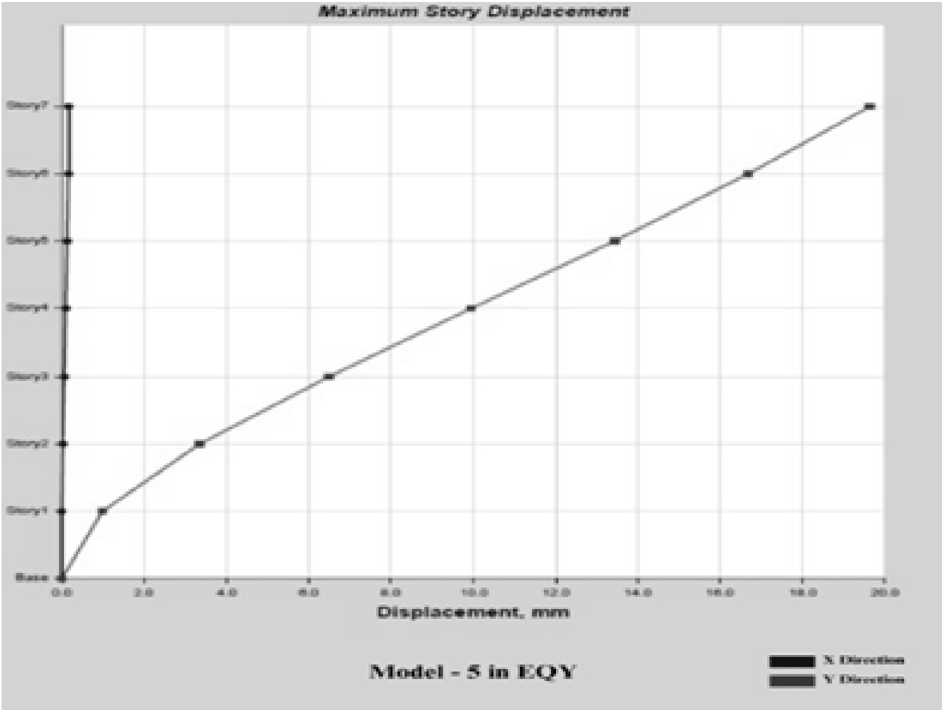


Figure 21: Story Displacement in X and Y direction for Model 5

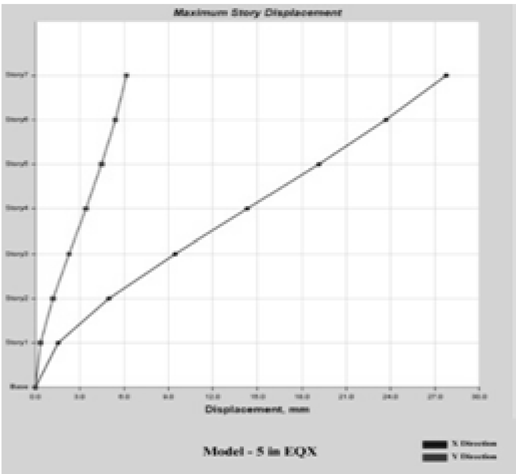


Figure 22: Story Shear in X and Y direction for Model 1

3. **Mode Shapes:** Mode shapes illustrate the vibrational characteristics of the building at different natural frequencies. Analysing the mode shapes can help identify potential modes of vibration and understand the building's dynamic behavior. The mode shapes should be examined for each plan aspect ratio to observe any significant differences in the building's response.For the buildings with an aspect ratio of 1:1 the highest X direction value is 3285.217 kN, which occurs at the top of Story1. Similarly, the highest Y direction value is 3285.217 kN, found at the bottom of Story1 as shown in Fig. 22. In the case of buildings with an aspect ratio of 1:1.25 the highest X direction value is 3203.7618 kN, located at the top of Story1. For the Y direction, the highest value is 3283.8558 kN,

observed at the bottom of Story1 as depicted in Fig.23. The building with an aspect ratio of 1:1.5 shown in Fig. 24. the highest X direction value is 3167.812 kN, present at the top of Story1. In the Y direction, the highest value is 3405.3979

kN, occurring at *the* bottom of Story1.For the buildings with an aspect ratio of 1:1.75 in the Fig. 25. the highest X direction value remains 3052.1091 kN at the top of Story1. In the Y direction, the highest value is 3357.32 kN, found at the bottom of Story1. Lastly, in building with an aspect ratio of 1:2 as shown in Fig. 26.the highest X direction value is 3178.6202 kN, located at the top of Story1. The highest Y direction value is 3496.4822 kN, which occurs at the bottom of Story1. It is important to note that for each aspect ratio, the highest X direction value is consistently found in Story1, while the highest Y direction value is also consistently found in Story1.

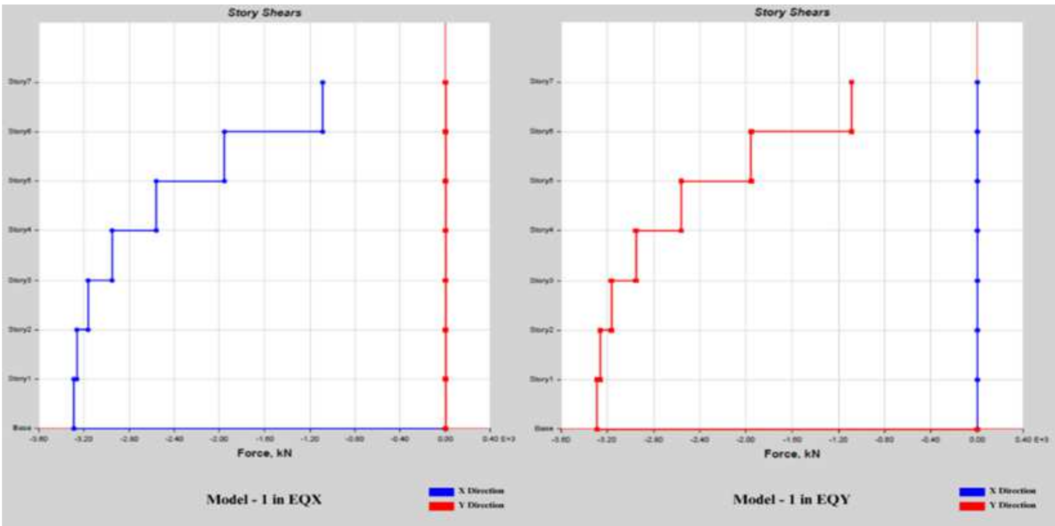


Figure 23: Story Shear in X and Y direction for Model 2

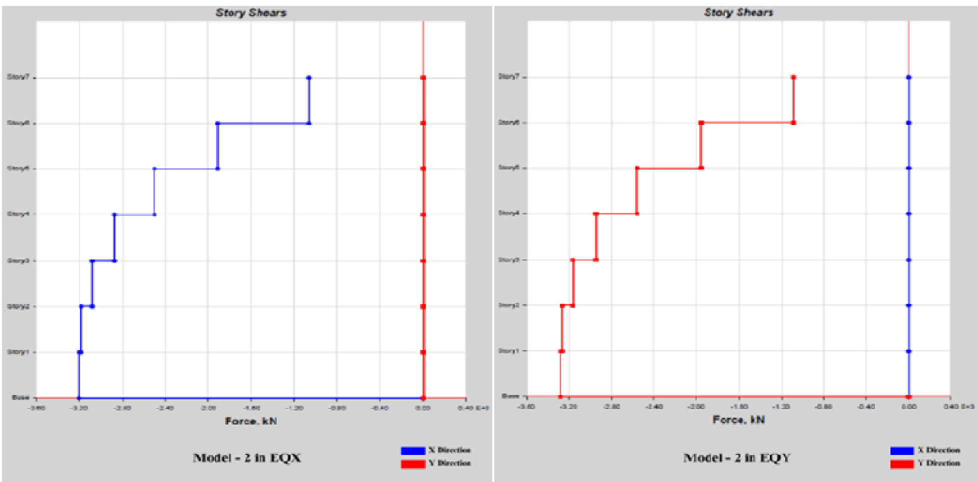


Figure 24: Story Shear in X and Y direction for Model 3

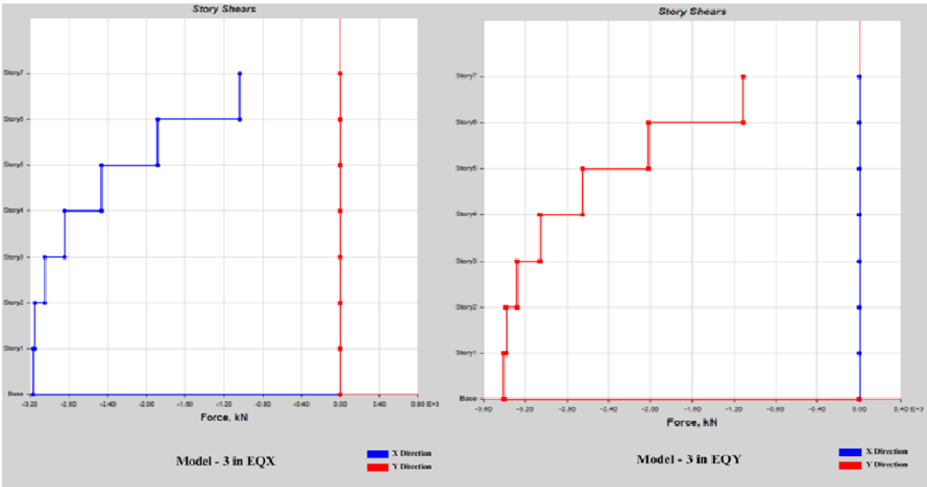


Figure 25: Story Shear in X and Y direction for Model 4

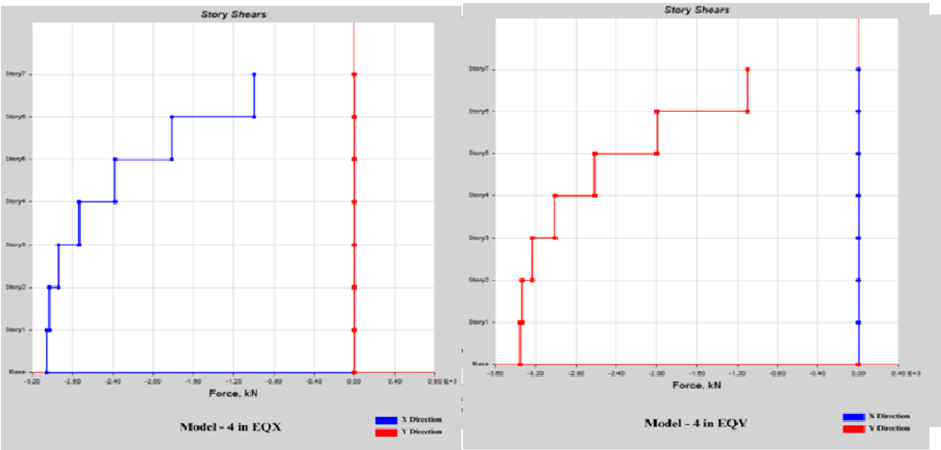


Figure 26: Story Shear in X and Y direction for Model 5

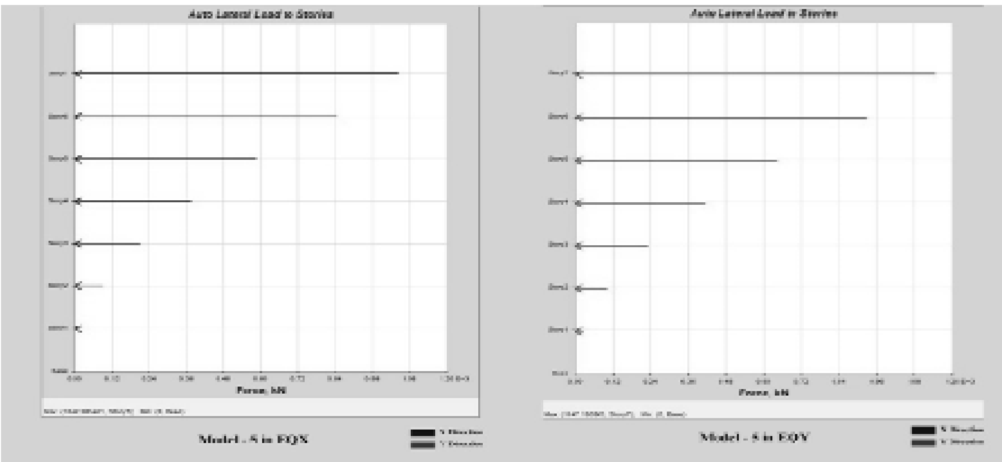


Figure 27: Lateral Load in X and Y direction for Model 1

4. **Lateral Load:** Lateral load analysis refers to the evaluation and assessment of the effects of horizontal forces or loads on a structure. These lateral loads typically result from wind, earthquakes, or other external forces that act parallel to the ground surface. Lateral load analysis is an essential step in the design of buildings and structures to ensure their stability and safety. Fig. 27. represent an aspect ratio of 1:1 for Model 1 in X and Y direction respectively. Fig. 28 represent an aspect ratio of 1:1.25 for Model 2 in X and Y direction respectively. Fig. 29 represent an aspect ratio of 1:1.5 for Model 3 in X and Y direction respectively. Fig. 30 represent an aspect ratio of 1:1.75 for Model 4 in X and Y direction respectively. Fig. 31. represent an aspect ratio of 1:2 for Model 5 in X and Y direction respectively. These values indicate the stories that experience the highest lateral loads in the X and Y directions for each respective aspect ratio. It is important to consider these findings when designing and reinforcing the structure to ensure its stability and safety.

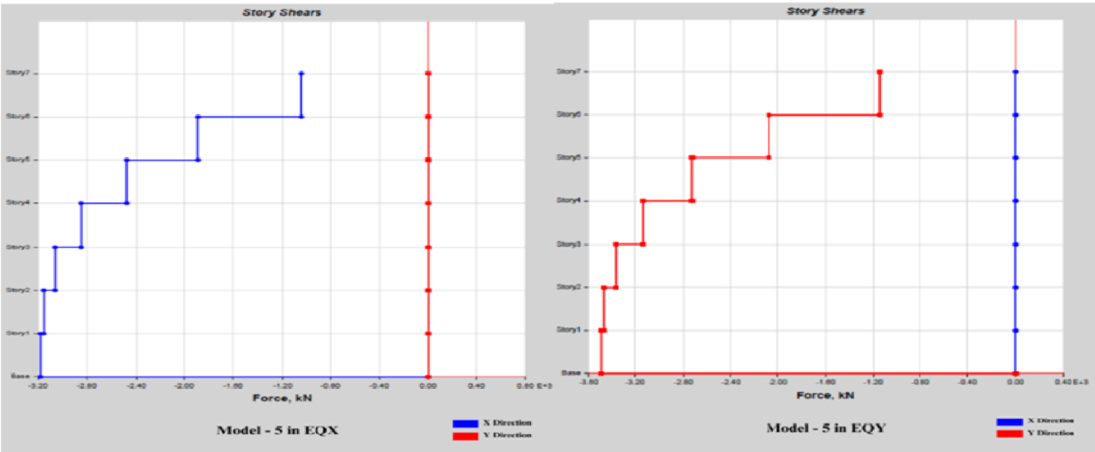


Figure 28: Lateral Load in X and Y direction for Model 2

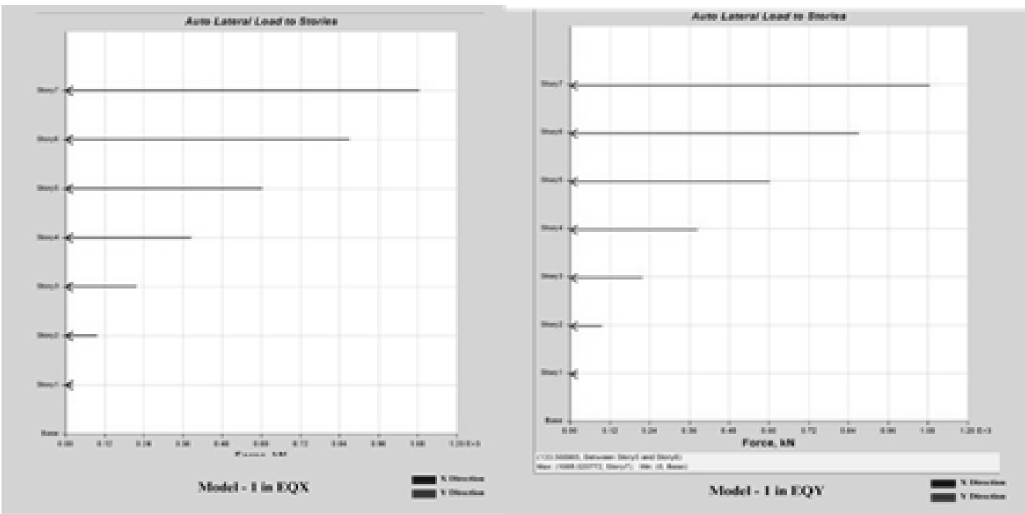


Figure 29: Lateral Load in X and Y direction for Model 3

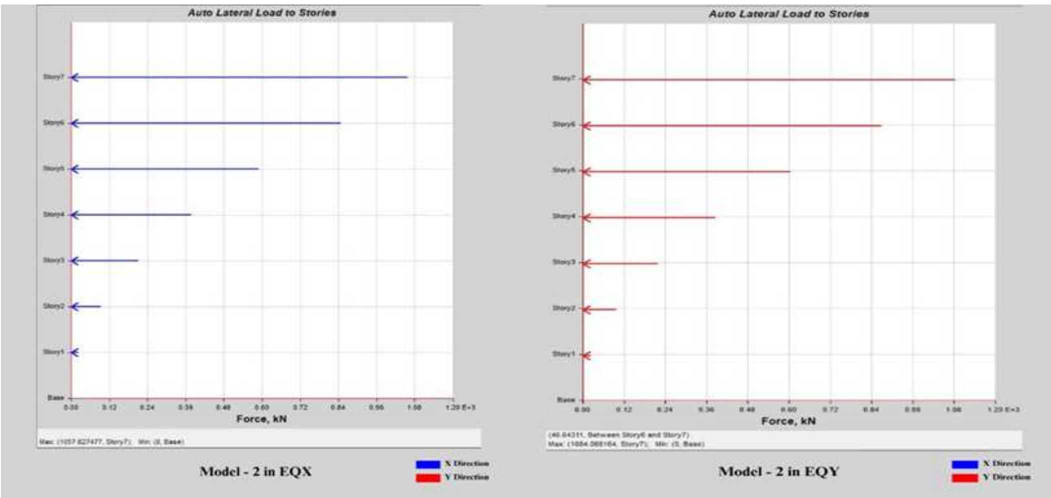


Figure 30: Lateral Load in X and Y direction for Model 4

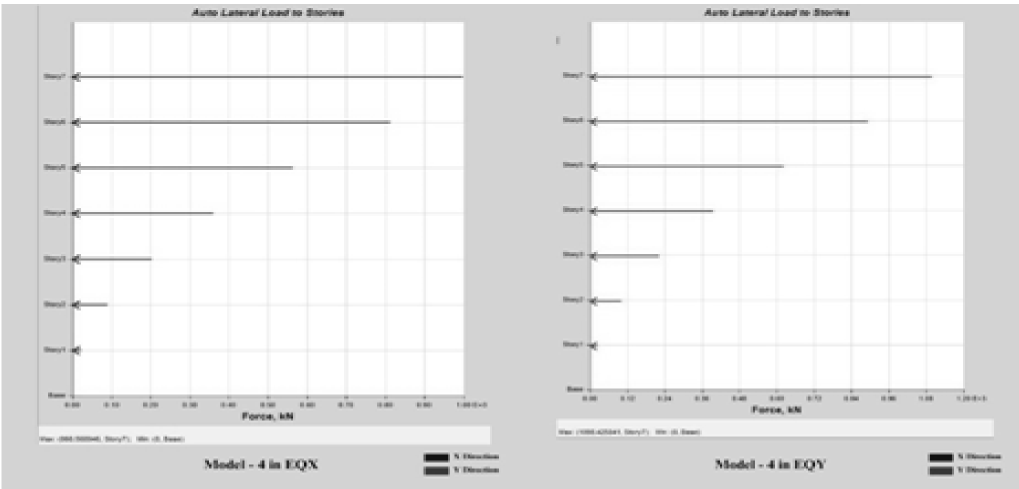


Figure 31: Lateral Load in X and Y direction for Model 5

V. CONCLUSION

Among all the stories, Story 7 has the lowest displacement in both the X and Y directions in Aspect Ratio 1:1.5 for story displacement. Aspect Ratio 1:1.5 and Story 4 exhibit the lowest drift values in both the X and Y directions for story drift. Precautionary measures need to be taken in Story 1 as it experiences the maximum shear force in all the aspect ratios. Among the aspect ratios, 1:2 exhibits the lowest story shear in Story 1 in story shear. Story 7 experiences the maximum lateral load in both the X and Y directions, indicating the need for precautionary measures. Story 7 consistently exhibits the highest displacement values in both the X and Y directions across different aspect ratios. Aspect Ratio 1:1.5 and Story 4 generally demonstrate the lowest displacement values. Story 1 shows the highest shear force, and Aspect Ratio 1:2 has the lowest shear force in Story 1. The maximum lateral load occurs in Aspect Ratio 1:1, while Story 7 experiences the highest lateral load in both directions. This implies that the core placement does affect the impact of seismic load on the structure.

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