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ANALYSIS OF MULTISTOREY STEEL SETBACK BUILDING WITH STEEL PLATE SHEAR WALLS AND BRACINGS

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ABSTRACT

Seismic force-resisting systems extending above the podium level typically consist of reinforced concrete walls connected by beams. The tower structures might also incorporate steel or concrete moment frames, or double systems that combine a moment frame with concrete walls, steel frames with dampers, or steel plate shear walls. Steel frames in these systems can be configured as braced frames, either eccentrically braced or concentrically braced. This study focuses on a multi-story building that uses steel plates in its sliding wall and bracing systems. The outcomes are evaluated in terms of displacement, moment, and stress.

Keywords: Setback building, shear wall, bracings and seismic

1. INTRODUCTION

General

According to ASCE/SEI 7-10, "Minimum Design Loads for Buildings and Other Structures" (ASCE, 2010), buildings taller than 240 feet, and in some cases 160 feet, located in high seismic zones, are required to incorporate seismic forces. These forces typically include special moment frames or a dual system that encompasses a special moment frame. Tall buildings that do not comply with these specific requirements often achieve code compliance through alternative procedures, usually involving a design process that utilizes capacity design and nonlinear response history analysis, along with a seismic expert review.

In tall buildings, not all concrete walls are situated within the primary configuration. The primary configuration is effective for buildings where service functions such as elevators, staircases, mechanical rooms, and restrooms are centrally located within the floor plan. However, buildings with displaced elements or those with irregular plan configurations, like L-shaped designs, may require a series of separate walls or multiple cores, as depicted. Architectural constraints that influence the placement and configuration of concrete walls similarly affect the layout and structure of steel frames.

Figure 1: Construction of concrete walls for a high-rise apartment building. The structural system has two individual walls, at left, and a concrete core, at right (courtesy of KPFF) [17]

Consideration of Backstay Effects

Assessing the effects of a return stay necessitates evaluating the two seismic load paths that contribute to the building's resistance to overturning. These paths are depicted in the figure, with one path representing the overturning resistance provided directly by the foundation beneath the seismic elements of the tower. The other path involves the resistance provided by the forces distributed through the plane of the diaphragms on the lower floor and the perimeter walls .

Seismic design addressing indentation effects requires: (1) evaluating the proportion of the total overturning resistance attributable to each load path; and (2) designing to ensure adequate strength in the structural components along each path. For a direct load path through the foundation, it is crucial to consider the vertical stiffness of the piles or the soil supporting the foundation. For the return stay load path, it is essential to account for the relative stiffness of the diaphragms and perimeter walls, which includes considering horizontal pressure on the walls and the vertical rocking resistance in the plane under the walls provided by the surrounding soil.

2. LITERATURE REVIEW

Kannan R. et al. explored the dynamic behavior of multi-storey structures with a base isolator, specifically those with significant plan irregularities. They employed two types of dynamic analyses: response spectrum analysis and nonlinear dynamic analysis. The findings were presented in terms of deformation, inter-storey drift at various levels, and strains, with a focus on bending moments, column and beam shear forces, and axial forces in the columns.

Kieran Yu. Naxan et al. examined a multi-storey residential building (G+4) for both regular and irregular configurations under seismic loads according to IS 1893-2002 and IS 1893-2016 in zones III and IV. The study aimed to understand the application of relevant Indian standard codes in designing different building elements using ETABS software. Both lateral loads were considered active in the structure. For both regular and irregular constructions, an equivalent static method was used for analysis. The study compared results such as bending moments, shear forces, and floor displacements. It was concluded that results based on IS 1893-2016 provisions were greater compared to those from IS 1893-2002, highlighting the updates in the new version of the IS code.

Lakshmi Subash et al. investigated the proportion of wind and seismic forces developed at each floor level due to vertical irregularities in structures. They used static and dynamic analyses to calculate the structural response in terms of shear, displacement, and drift. The results indicated that vertically irregular structures are more vulnerable in earthquake-prone areas, and such irregularities should be avoided. However, if unavoidable, they must be properly designed and detailed according to IS 1893 (Part 1): 2016 and IS 456-2000, with joints designed plastically as per IS 13920: 1993 to account for dynamic behavior.

M. S. Naidu conducted a study on a flat plate frame for a G+10 building, modeling and analyzing it for nonlinear behavior in seismic zone IV for medium-type soil. This study included sequential design, time history analysis, and construction sequence analysis. The analysis revealed that the period of the structure, when analyzed through the construction stage analysis, was greater than when analyzed through time history analysis. Thus, it is necessary to include construction stage analysis for a more accurate structural assessment.

3. METHODOLOGY

The following models were developed using STAAD-PRO software:

i. Model-I: Setback building in Earthquake Zone-II without bracing or shear wall

ii. Model-II: Setback building in Earthquake Zone-II with bracing

iii. Model-III: Setback building in Earthquake Zone-II with a shear wall

iv. Model-IV: Setback building in Earthquake Zone-III without bracing or shear wall

v. Model-V: Setback building in Earthquake Zone-III with bracing

vi. Model-VI: Setback building in Earthquake Zone-III with a shear wall

vii. Model-VII: Setback building in Earthquake Zone-IV without bracing or shear wall

viii. Model-VIII: Setback building in Earthquake Zone-IV with bracing

ix. Model-IX: Setback building in Earthquake Zone-IV with a shear wall

x. Model-X: Setback building in Earthquake Zone-V without bracing or shear wall

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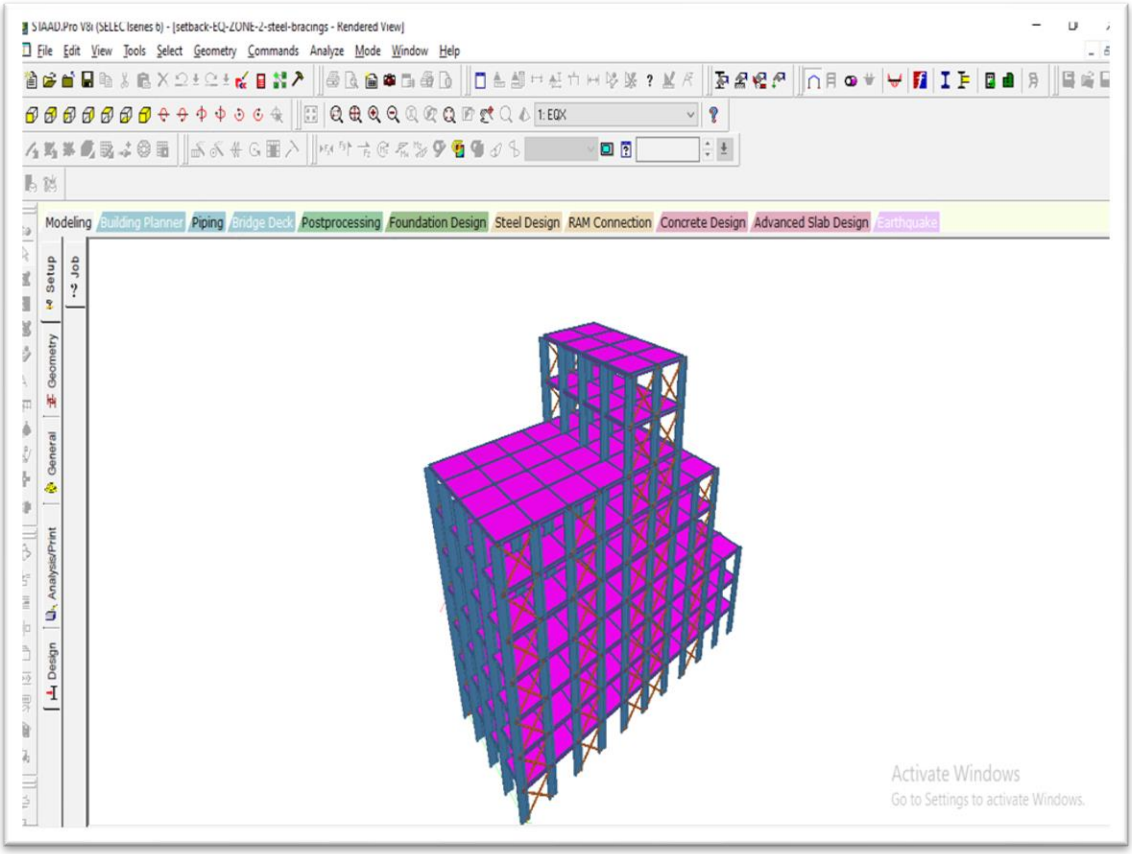

Figure 2:3D view of the setback building with the bracings

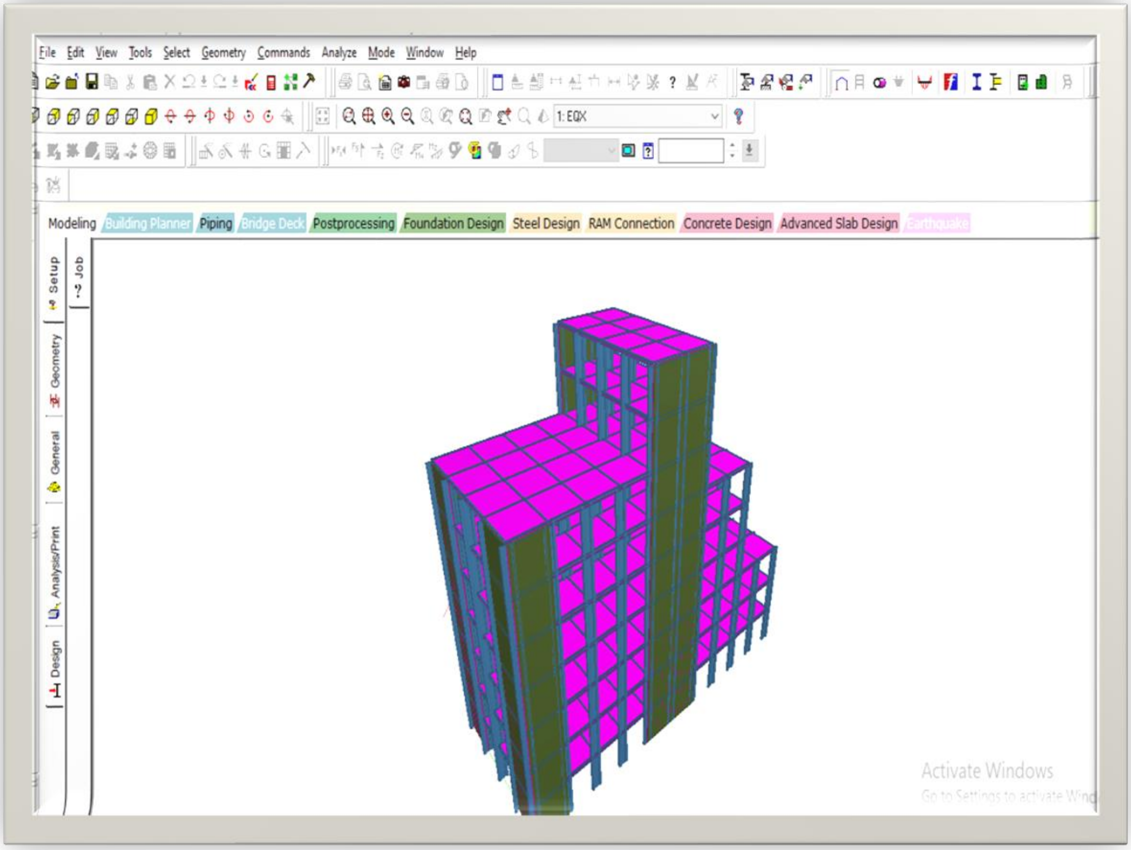

Figure 3:3D view of the setback building with the shear walls

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4. RESULTS

The results obtained in the STAAD-PRO in terms of the displacement, reactions, beam forces, plate stresses for the all models as follows.

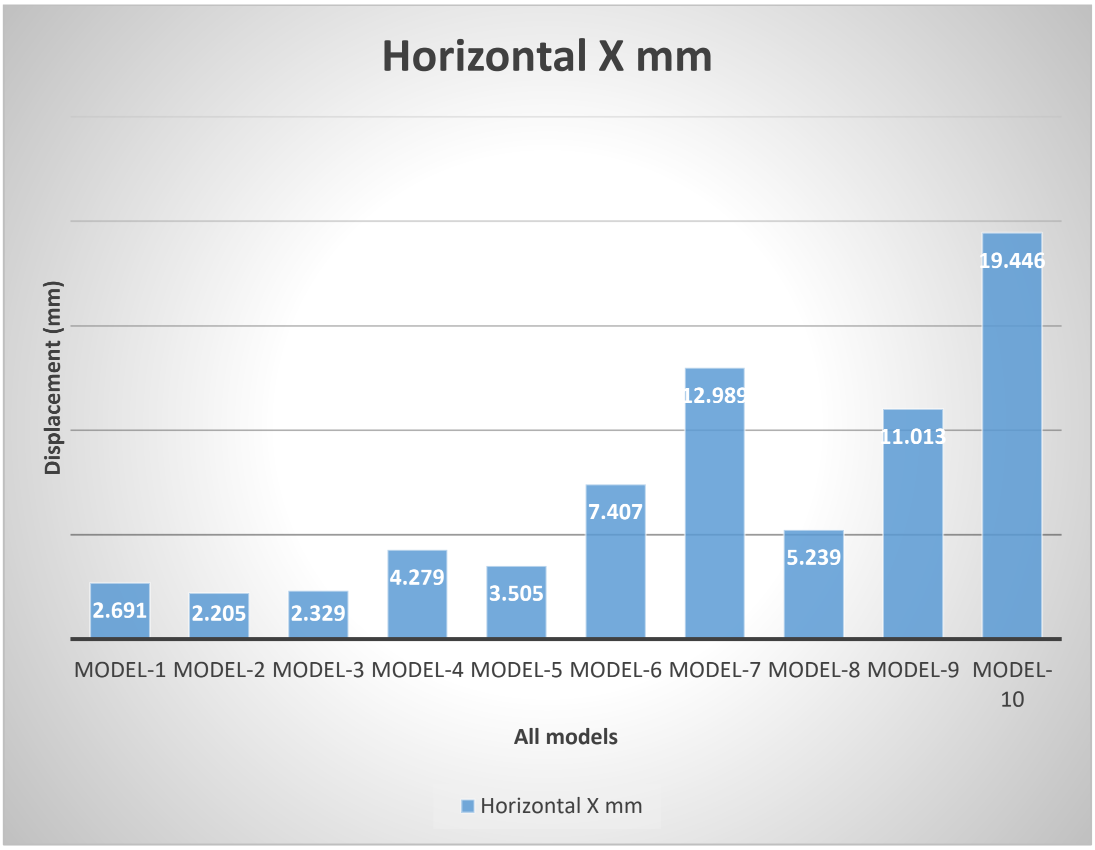

Figure 4: Horizontal (X) Displacement for all the models

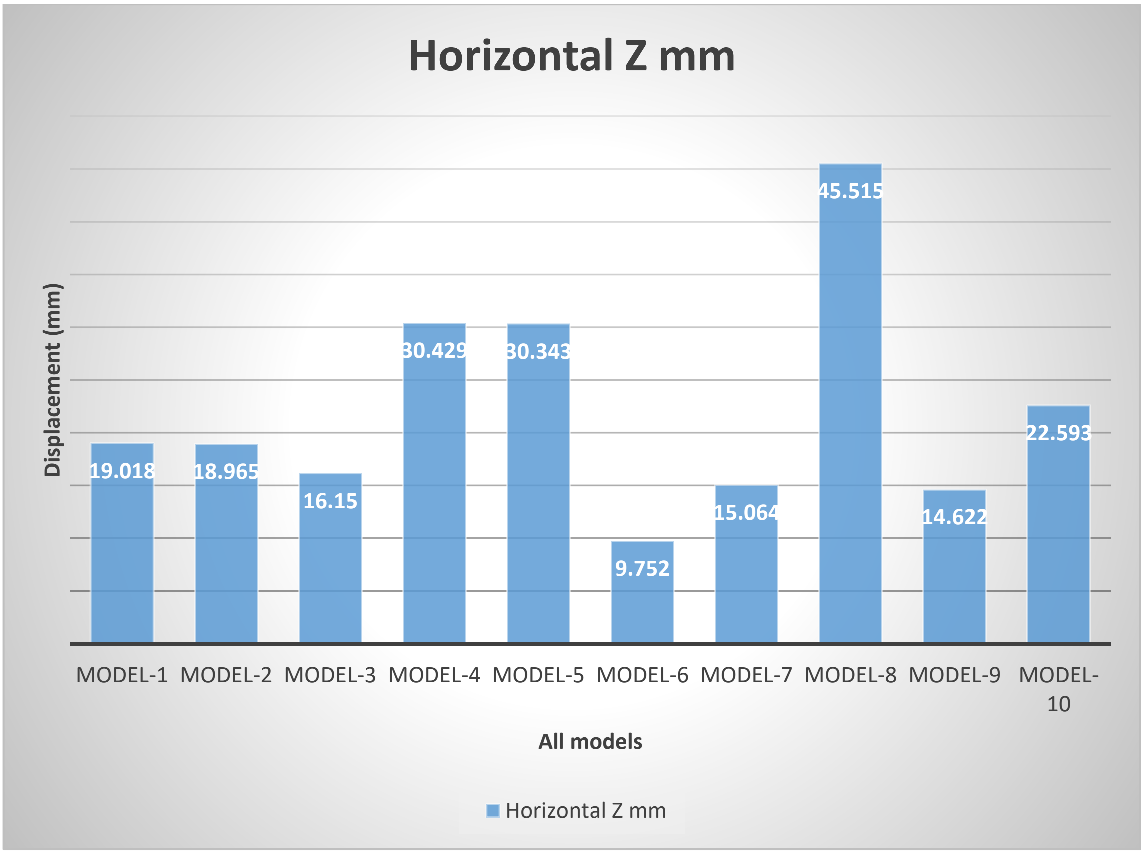

Figure 5: Horizontal (Z) Displacement for all the models

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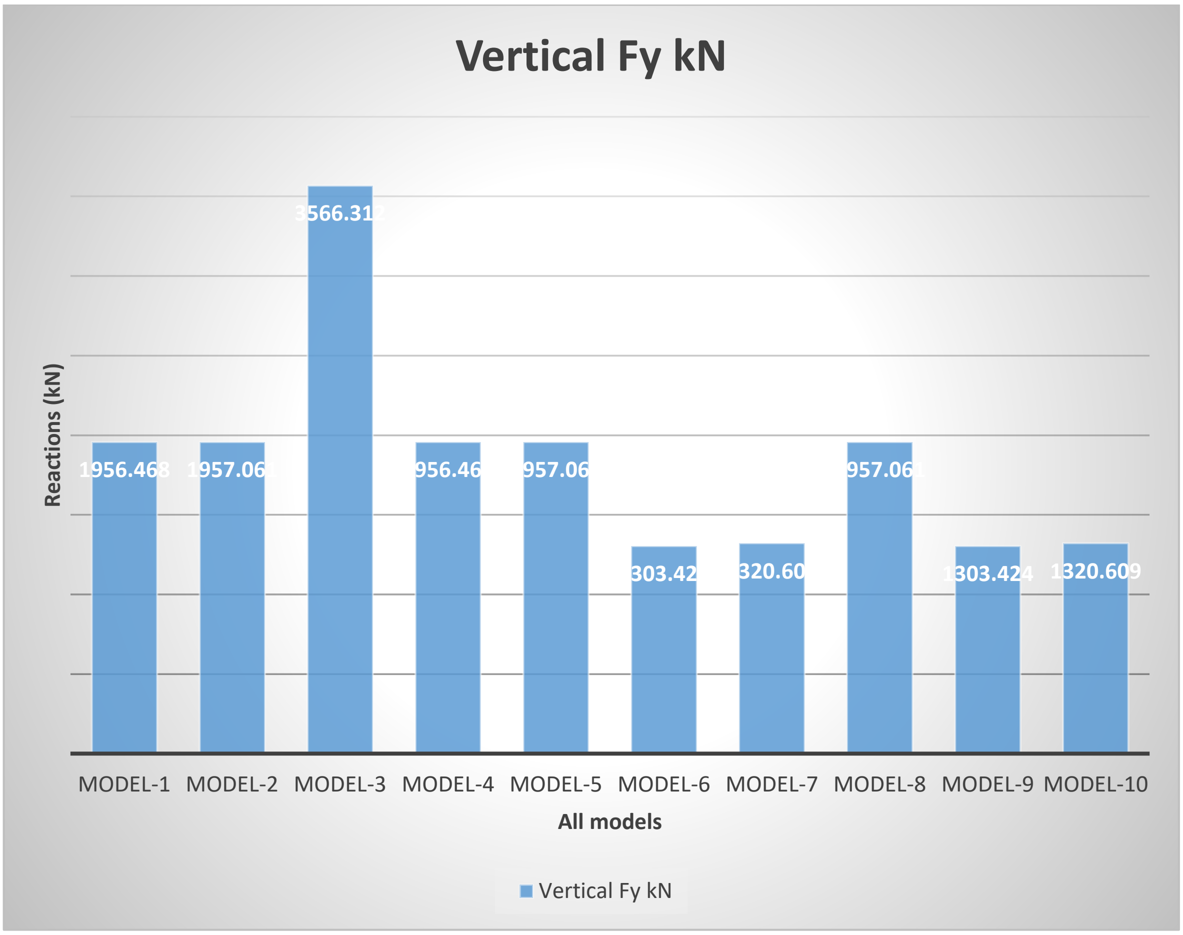

Figure 6: Vertical (Fy)-Reactions for all the models

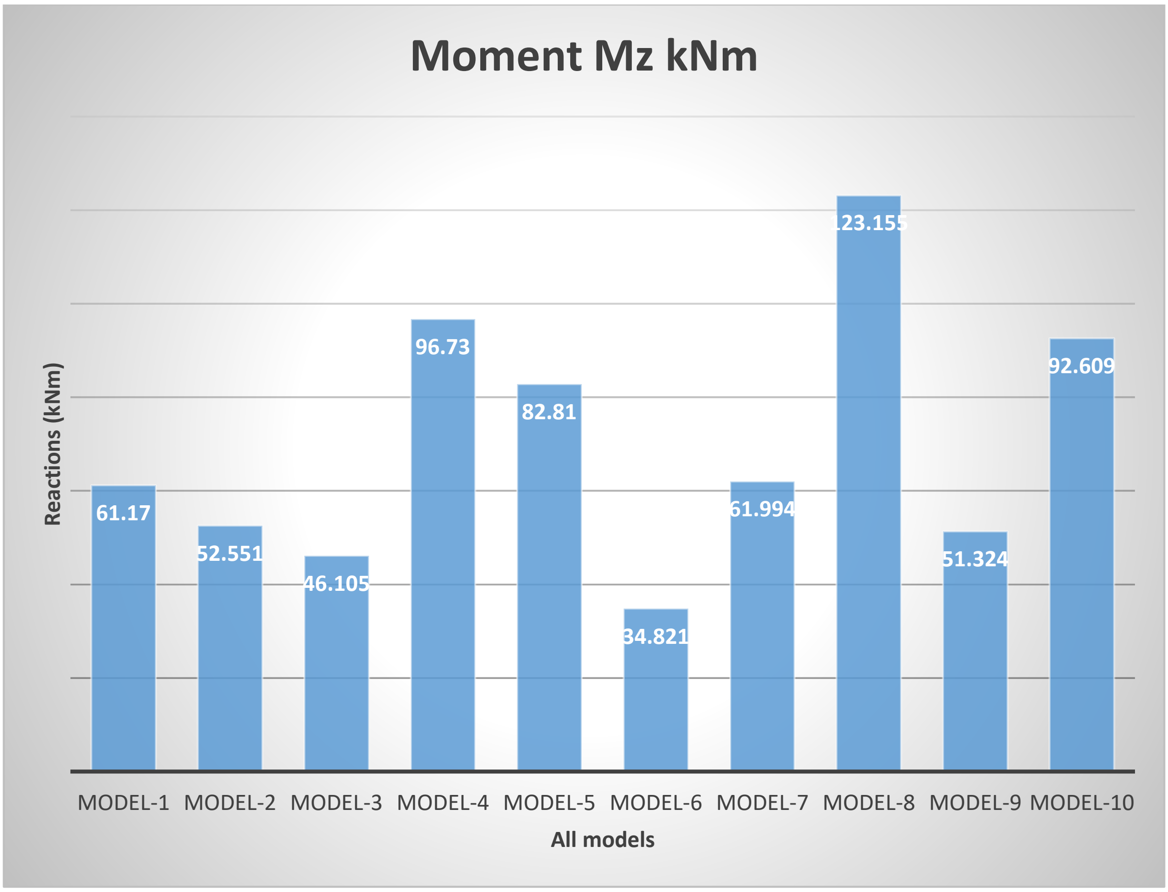

Figure 7: Moment (Mz)-Reactions for all the models

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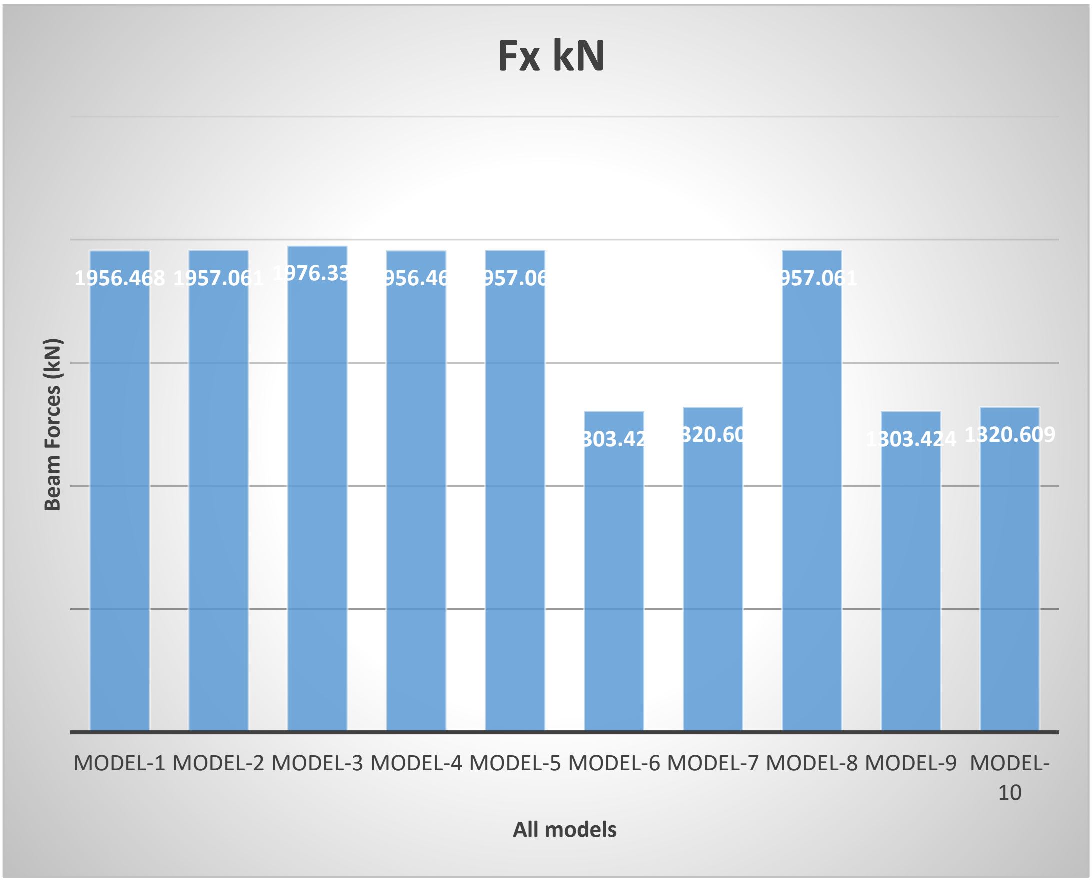

Figure 8: Beam Forces (Fx) for all the models

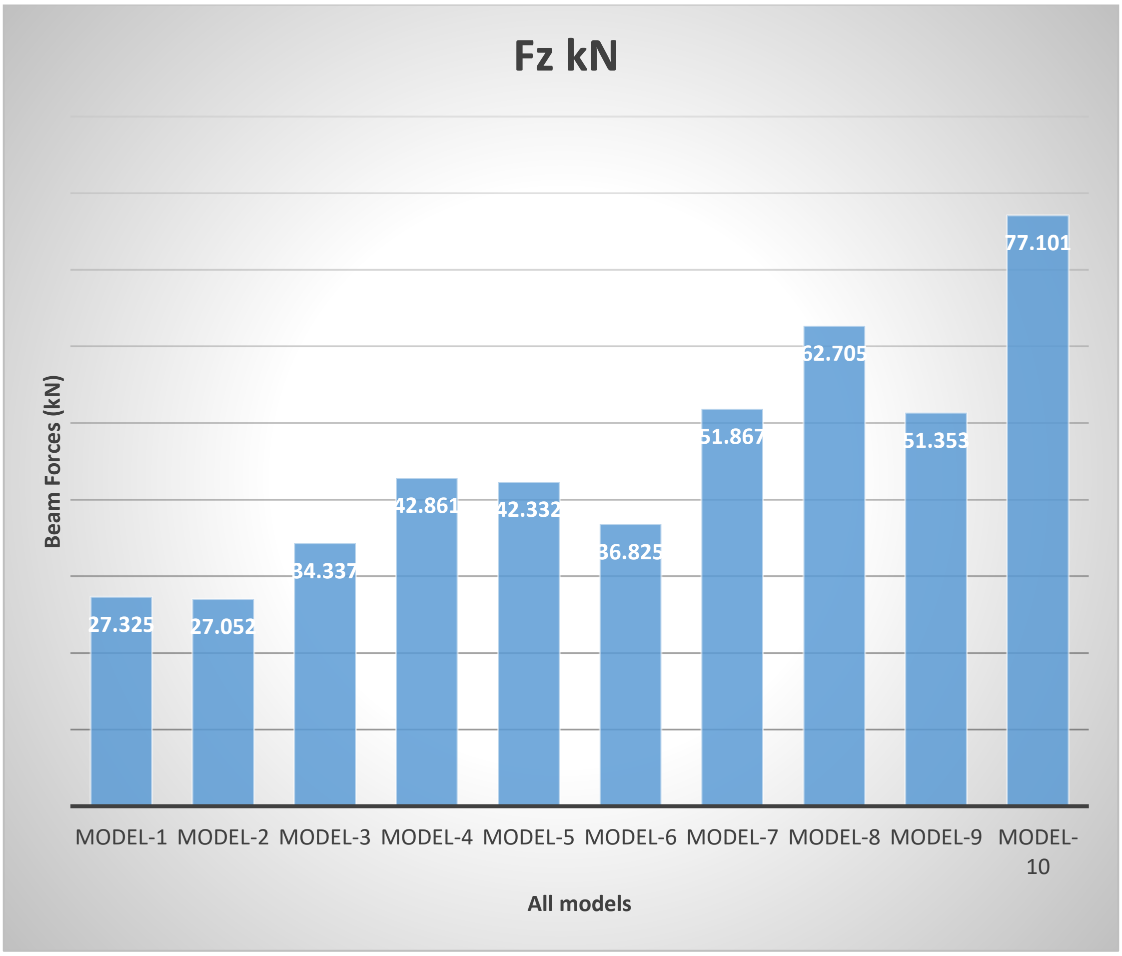

Figure 9: Beam Forces (Fz) for all the models

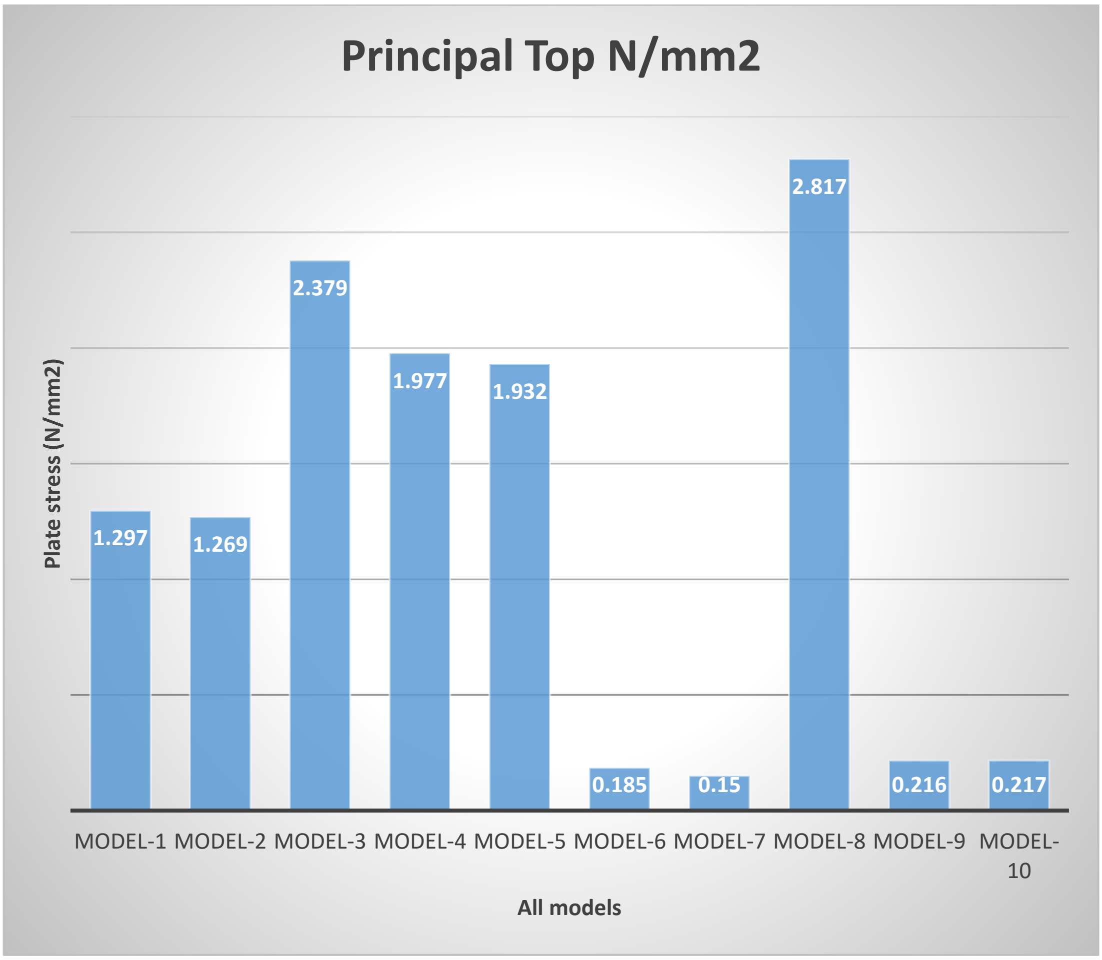

Figure 10: Principal stress (Top) for all the models

5. CONCLUSIONS

Based on the above results, the following conclusions can be drawn:

i. Model-10, which represents the setback building in Earthquake Zone V, exhibits the greatest horizontal displacement.

ii. Model-8, corresponding to the setback building in Earthquake Zone IV, shows the highest resultant displacement.

iii. Model-3 of the setback building, which includes shear walls, experiences the highest vertical reactions.

iv. The maximum moment reactions along the x-axis (Mx) are observed in Model-10 of the setback building.

v. The highest moment reactions along the z-axis (Mz) are recorded for Model-8 of the setback building.

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