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Analysis of a High-Rise Building Frame Considering Lateral Load Using Analysis Tools

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ABSTRACT

Buildings must be able to safely withstand any significant ground motions that could happen during construction or regular operation in order to be considered earthquake resistant. The impacts that ground motions have on structural reactions, however, are special. The time-history analysis is the analytical method that is most accurate for structures that are subjected to severe ground vibrations. For this analysis, a stepwise solution is used to integrate the pushover analysis of a multi-degree-of-freedom system, or MDOF, in the time domain in order to depict the real reaction of a structure. Although it can be applied to all practical uses, this method takes time. The pushover analysis was developed because it was necessary to develop quicker techniques that would nevertheless provide a trustworthy structural assessment or design of structures subjected to seismic loading.
The foundation of pushover analysis is the presumption that during a seismic event, structures vibrate primarily in the first mode or in the lower modes. As a result, the multi-degree-of-freedom system is reduced to a single-degree-of-freedom system that has attributes that are predicted by the nonlinear static analysis of the multi-degree-of-freedom system, or SDOF system. The ESDOF system is then subjected to a response spectrum analysis with constant-ductility spectra, or damped spectra, or a nonlinear time history analysis. Through modal connections, the seismic demands for the MDOF system are converted from the ESDOF system's computed seismic demands.
To illustrate the overall effects of the RCC frame building, a model was made. In seismic zone II, four G+11 concrete planar frames with four bays in each of the X and Y directions were built in accordance with Indian codes. Each frame is subjected to five unique loading situations. Pushover analysis is used to evaluate the different frames after they have been created with varied elevational irregularities but the same loading conditions. The outcomes of each frame are compared. The outcome

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consists of a pushover curve between base shear and displacement as well as capacity spectrum, which are performed and evaluated for each frame. This study used STAAD.Pro v8i to analyse the non-linear response of RCC frames under stress with the aim of determining the relative weights of various parameters in the non-linear analysis of RCC frames in seismic zone II, taking into account comparisons of the case with bare frame and infill wall.

Keywords: RCC frame, Irregular building, FEMA hinge, capacity spectrum, pushover analysis, seismic reaction.

I. INTRODUCTION

Modern high rise building construction began to address a variety of objectives, including the need to accommodate a growing population, the high cost of land, and even to demonstrate the state of the economy in the case of corporate structures. Earlier, these structures were regular in shape, but with modern technology and materials, it is now feasible to build structures with a variety of plans, shapes, and sizes. Due to their practical and aesthetically pleasing qualities, these atypical structures are quite prevalent all over the world. Different story heights, excess mass in one or more storeys that may be caused by the presence of public meeting areas like gyms, halls, etc., abrupt changes in stiffness made in accordance with architectural considerations, and other factors can all contribute to irregularity. The majority of apartments favour soft-storey structures with sizable parking areas. Irregular buildings are those that have discontinuities in their bulk and rigidity in their layout or elevation. Performance level describes the state of the building's damage, providing information on whether it is safe for occupants to occupy it or how much repair work will be required, as well as its serviceability following an earthquake. Different design requirements are needed at various performance levels. Therefore, it is impossible for a single design parameter to achieve all performance goals. Even though these performance goals could place competing demands on stiffness and strength, one shouldn't sacrifice life safety.

II. PUSHOVER ANALYSIS

Pushover analysis is a technique by which a computer model of the building is subjected to a lateral load of a certain shape (i.e., inverted triangular or uniform). The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded. Pushover analysis can provide a significant insight into the weak links in seismic performance of a structure. Pushover analysis is a simplified nonlinear analysis whose central focus is generation of the pushover curve or capacity curve. This represents the lateral displacement as a function of force applied to the structure. This capacity curve is representation of the structures ability to resist the seismic demand. To generate the capacity curve, the structure is pushed in a representative lateral load pattern which is applied monotonically while the gravity loads are in place. Any type of representative lateral load pattern can be defined but the load pattern similar to first mode shape amplitude of the structure is the most commonly used to determine the capacity. The A predefined lateral load pattern.which is distributed along the building height is then applied. The lateral forces are increased until some members yield. The structural model is modified to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable. The roof displacement is plotted with base shear to get the global capacity curve.

Objectives of the Research

- To study the effect of vertical geometric irregularity in G+20 3D buildings.
- To analyse the buildings using Pushover Analysis.
- To calculate the maximum Monitered Displacement of the different buildings.
- To calculate the maximum Base Shear at maximum Monitered Displacement and performance point.
- To analyse these RCC buildings in seismic zone II.
- Comparison of the different parameters of different models considering displacement as common.

III. LITERATURE REVIEW

D J Zavala et.al (2022) author analyzed the influence of the stiffness irregularity and the p-delta effect on the structural behavior of a reinforced concrete building. The main objective was to determine the impact of the stiffness irregularity and the p-delta effect on the structural behavior in regular and irregular buildings. The linear dynamic analysis procedure was performed in order to determine the structural response in terms of drifts, shear force and moments per floor. A comparative analysis of the responses from the linear and nonlinear analysis was carried out to determine the percentage variation of the results. When analyzing the structures that consider the stiffness irregularity and the p-delta effect, variations of up to 16.50%, 11.00% and 14.00% was obtained in drifts, shear force and moments per floor respectively, which are considerable values. When the p-delta effect was considered in structures with the presence of stiffness irregularity, there was a variation in stiffness of up to 59.85%. Conclusion stated that p-delta effect produces a greater degradation of the overall stiffness of the structure.

Thokala Brahmendra Rao et.al (2022) in the research paper, p- delta (P-Δ) effect on high- rise building was investigated for the analysis of G+29 RCC framed building and models were done by ETABS2016. Seismic and wind loads were applied to model as per IS-1893 (2002) and IS-875 (PART-III). The displacements, storey drifts, Bending Moments and Shear Forces are compared to the different models by considering with and without P-delta effect and by providing shear walls at different locations.

Results stated that displacements of conventional building models (without p-delta) is less when compare to building with p- delta. The storey drifts in building models with p-delta effect are more when comparing with models analysed using equivalent static analysis method(without p-delta effect). The bending moment (BM) in shearwall 18% increases after p-delta effect. Shearwall placed at centre of frame shows more effectiveness when comparing with shear wall placed at corner and without shear wall of the structure.

IV. Methodology

Steps of the Modelling and Analysis

Step 1: Research paper from different authors was summarized in this section who have focused towards analyzing multi storey high rise structures considering seismic loads with different zones and soil condition

Step 2: In order to initiate the modelling of the case study, firstly their's need to initialize the model on the basis of defining display units on metric SI on region India as STAAD.Pro supports the building codes of different nations. The steel code was considered as per IS 800:2007 and concrete design code as per IS 456:2000.

Step 3: STAAD.Pro provides the option of modelling the structure with an easy option of Quick Template where the grids can be defined in X, Y and Z direction. Here in this case, 6 bays in considered in both X and Y direction with a constant spacing of 3.5m making the model symmetrical in nature. G+11 storey structure is considered with typical storey height of 3.2 m and Bottom storey height of 2 m.

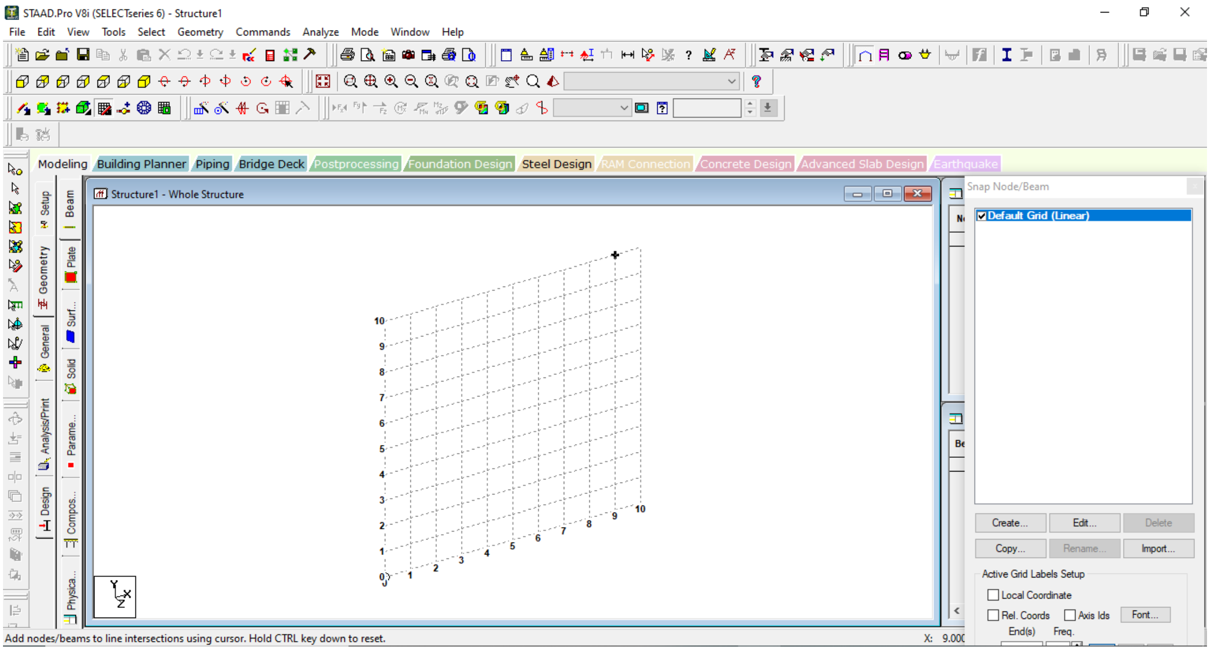


Fig 1 New Model Quick Template

Step 4: Next step is to define the material properties of concrete and steel. Here in this case study, M30 concrete and rebar HYSD 550 is considered and its predefined properties are available in the STAAD.Pro application considering section properties for Beam, Column and Slab.

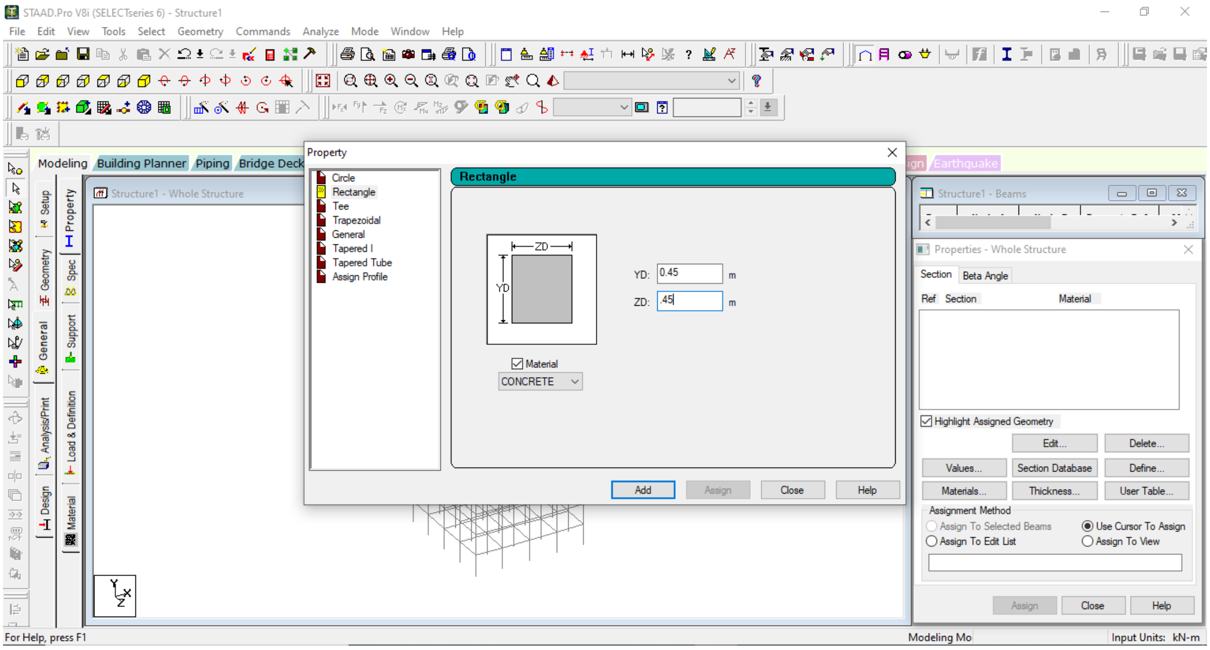


Fig 2 Defining Properties of Column

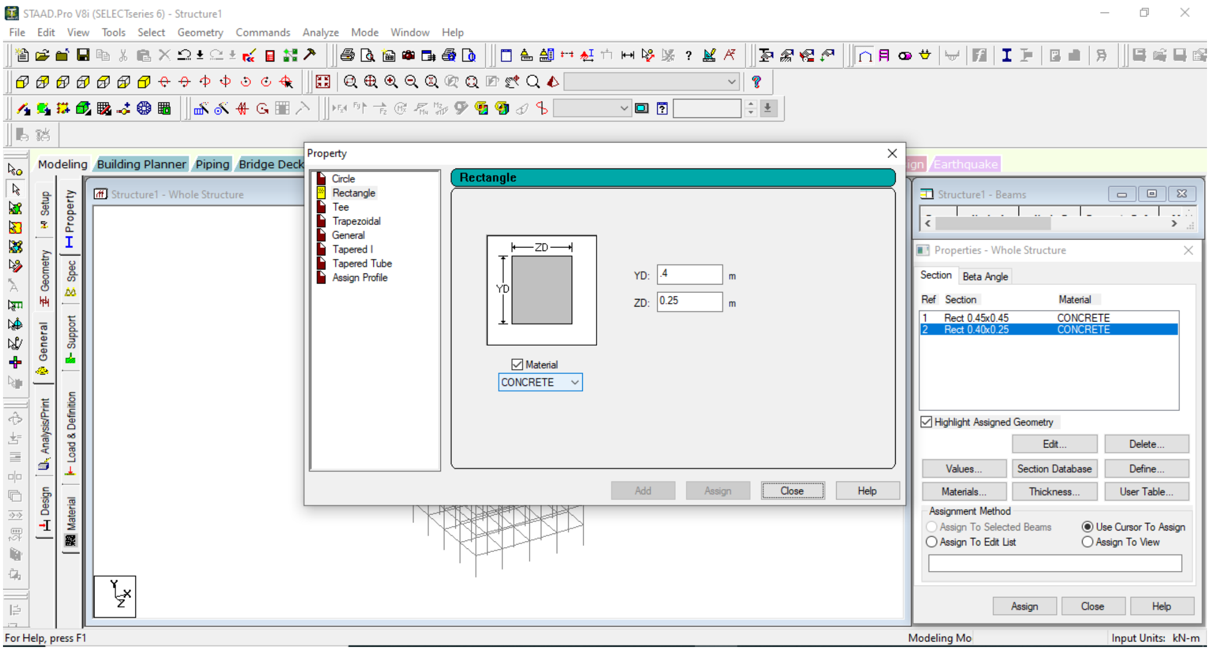


Fig 3 Defining Properties of Beam

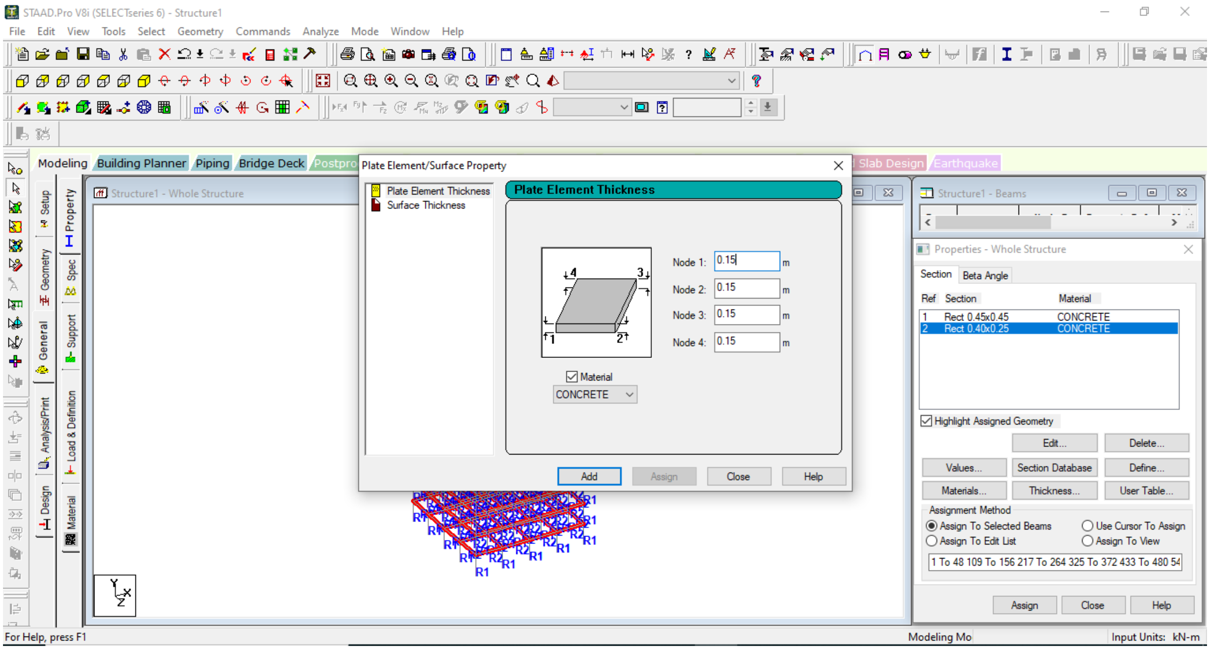


Fig 4 Defining Slab Properties

Step 5: Assigning Fixed Support at bottom of the structure in X, Y and Z direction in both the considered cases.

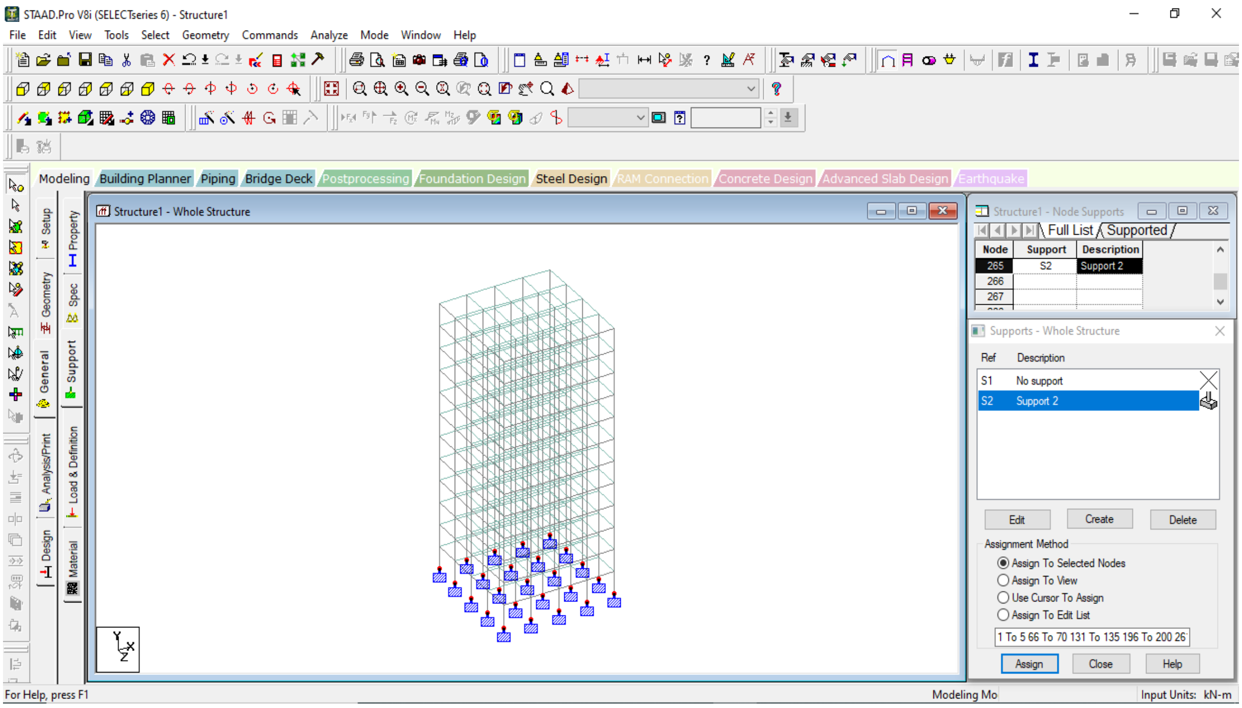


Fig 5 Assigning Fixed Support

Step 7: Defining Load cases for dead load, live load and seismic analysis for X and Y Direction.

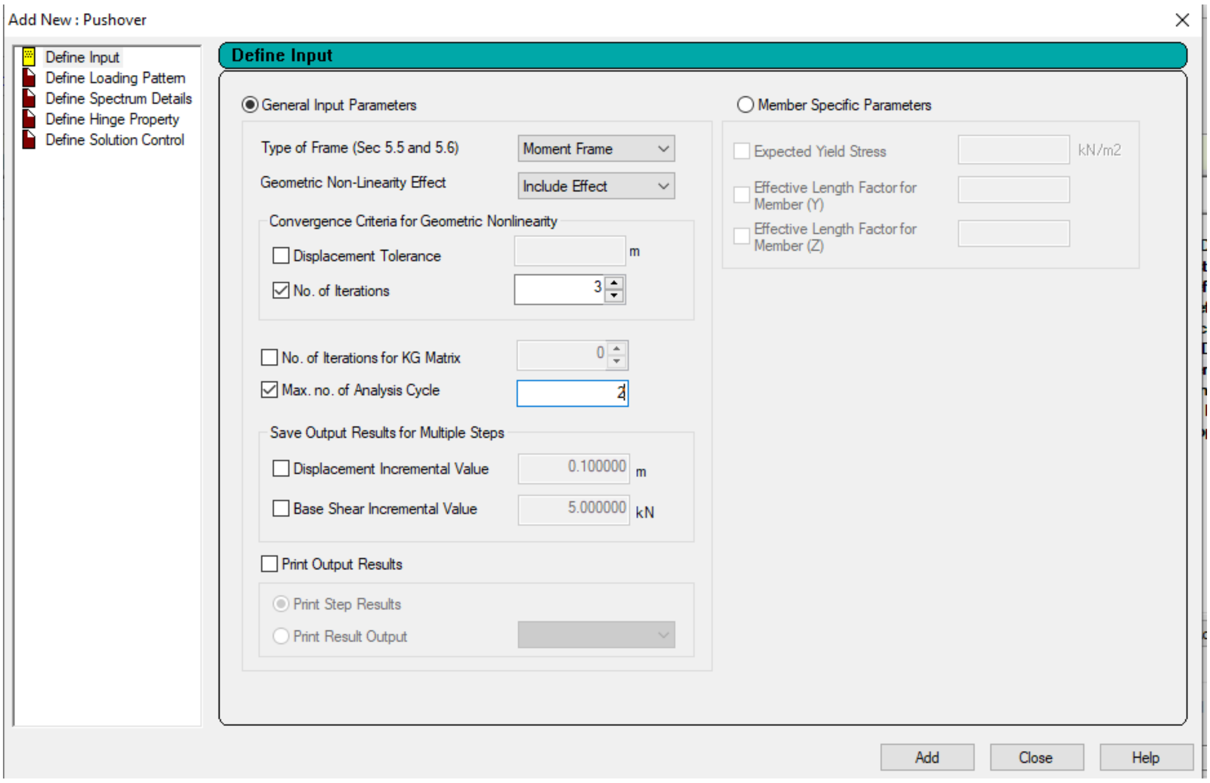


Fig 6 Defining Input

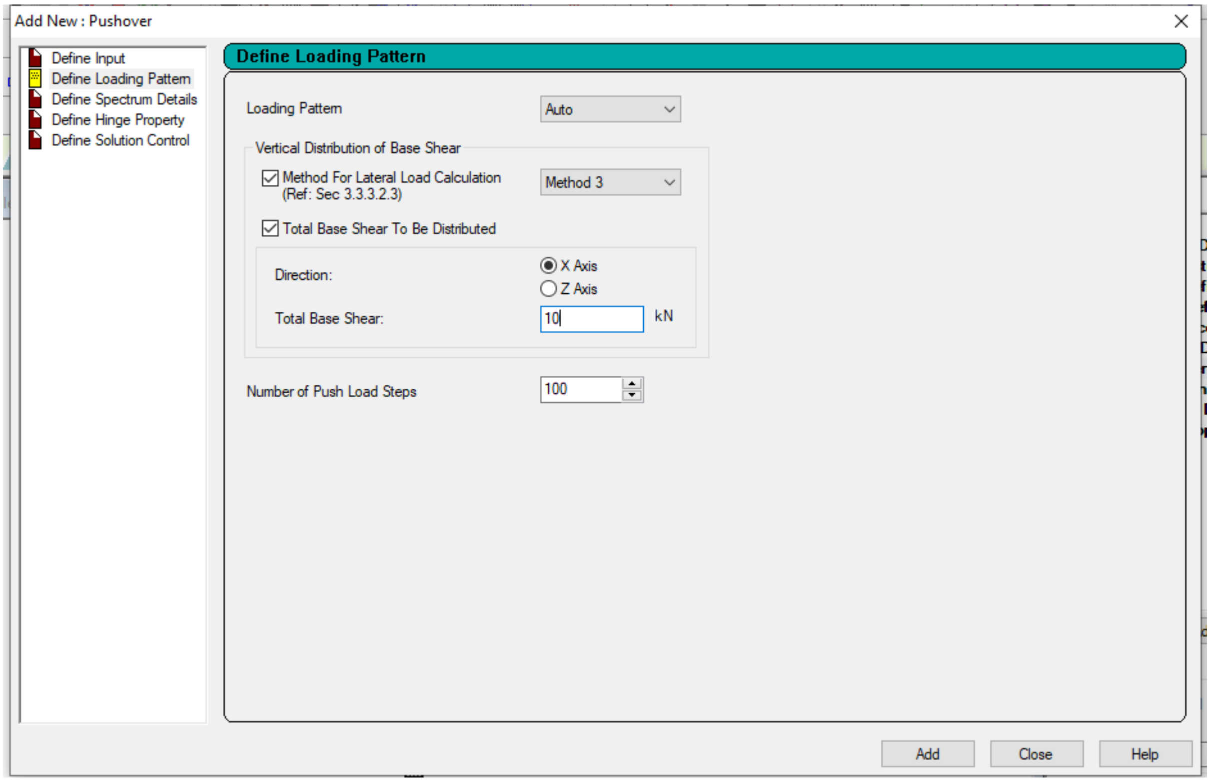


Fig 7 Defining Loading Pattern

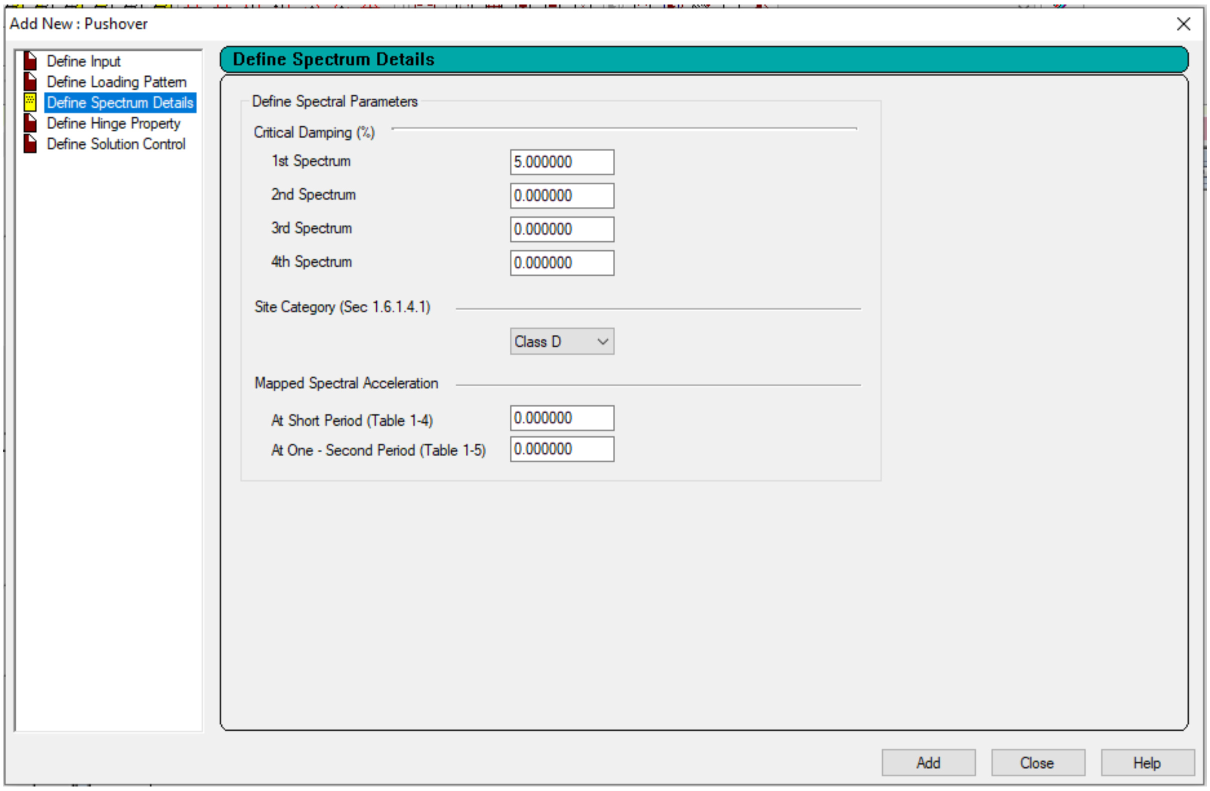


Fig 8 Defining Response Spectrum Analysis

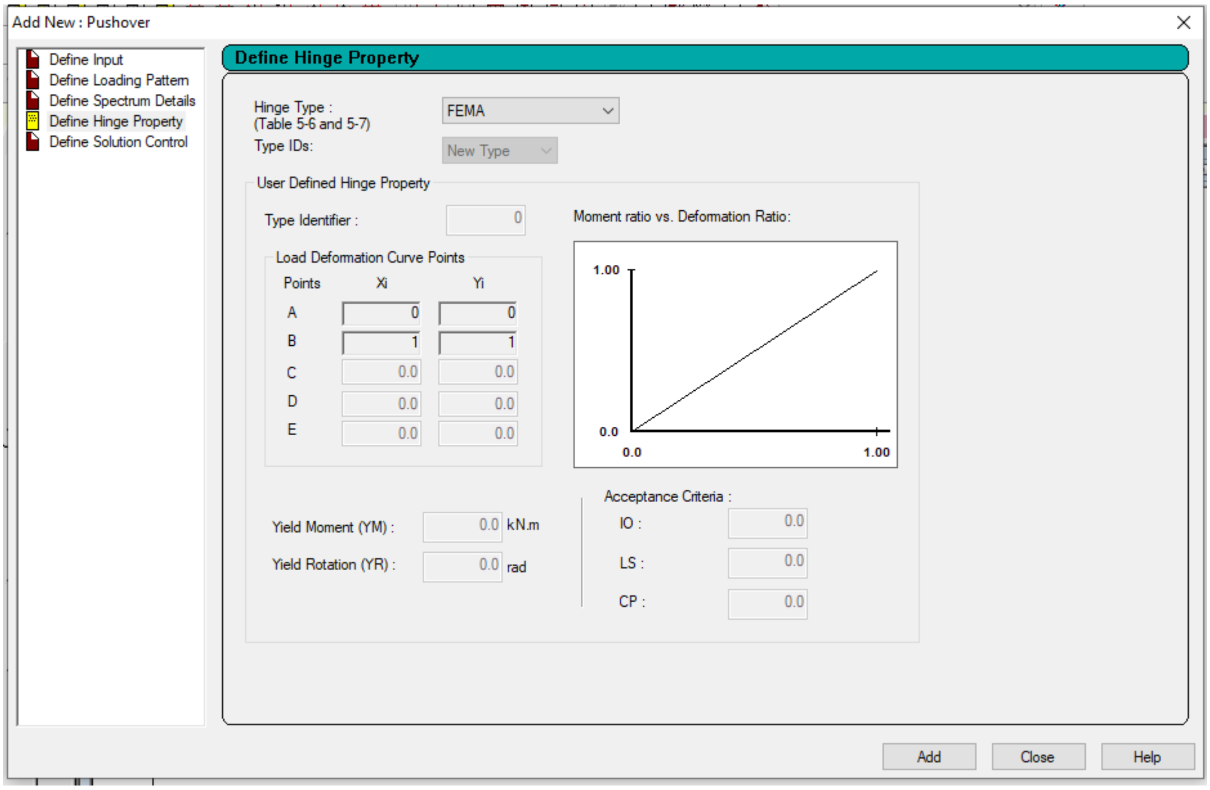


Fig 9 Defining Hinge Property

Step 8 Defining Seismic Loading as per IS 1893: 2016 Part I.

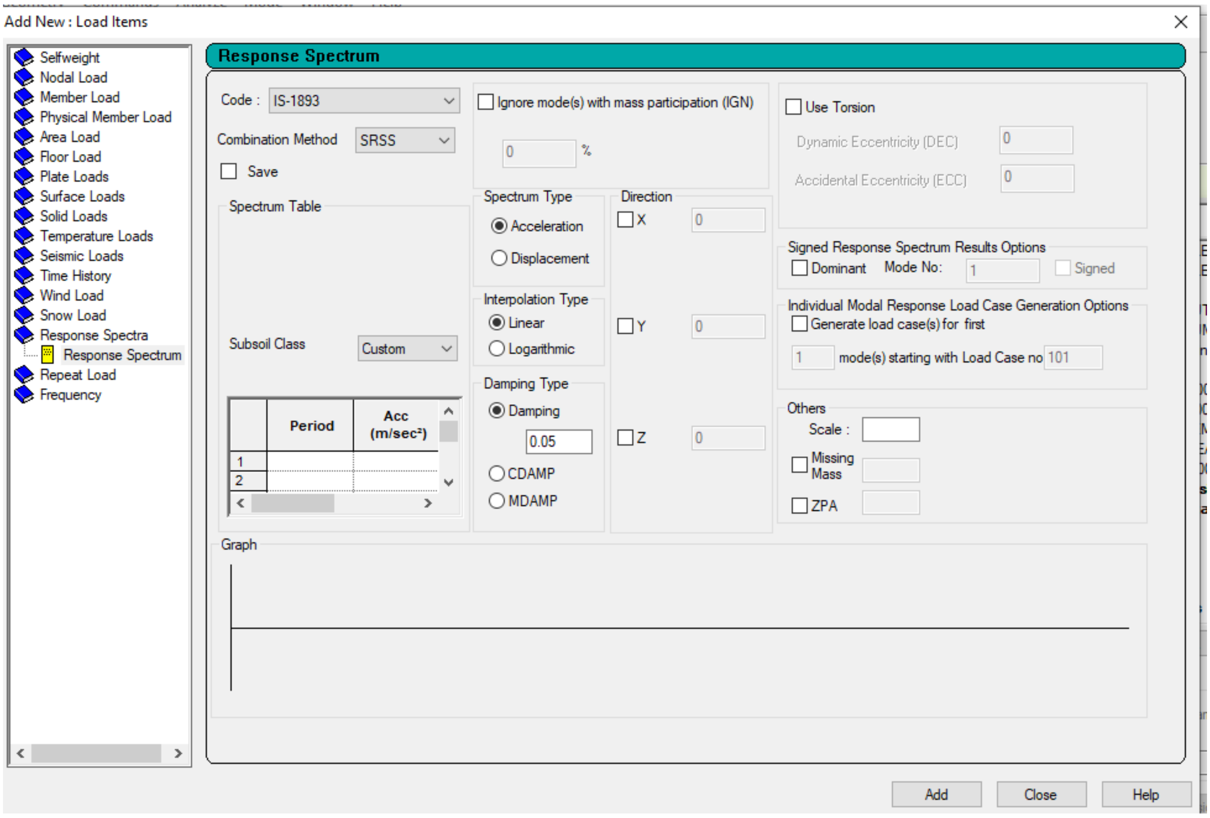


Fig 10 Response Spectrum as per IS 1893-2016

Step 10: Analyzing the structure for dead load, stress analysis and displacement.

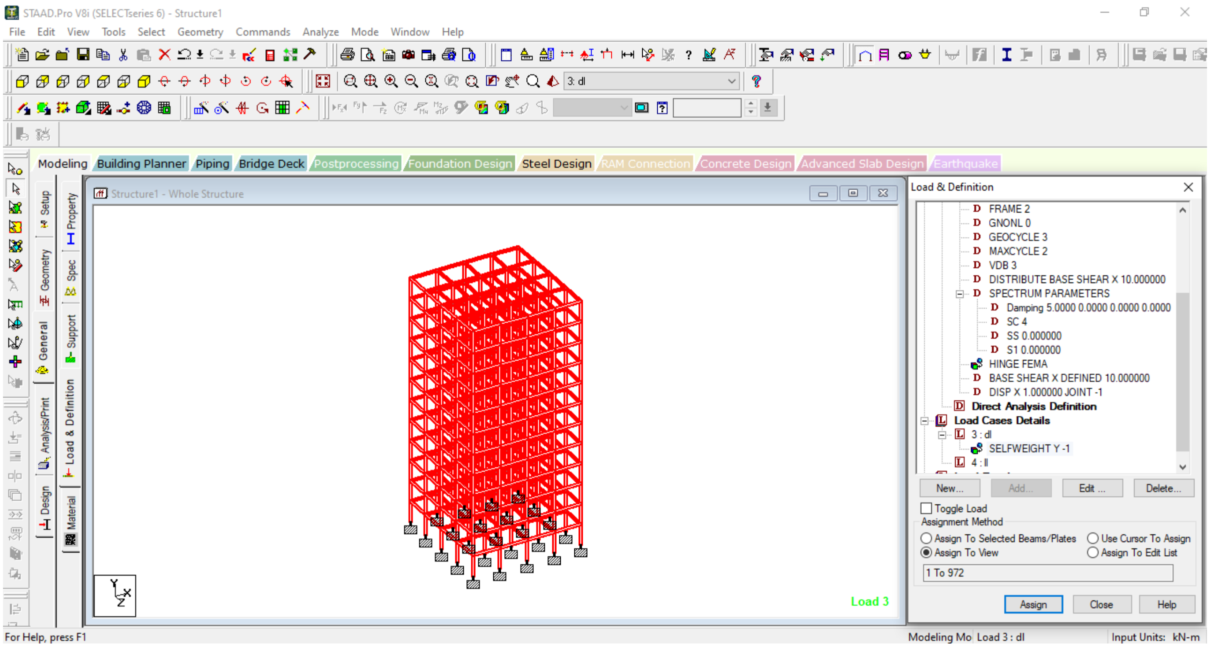


Fig 11 Stress Analysis for Dead Load

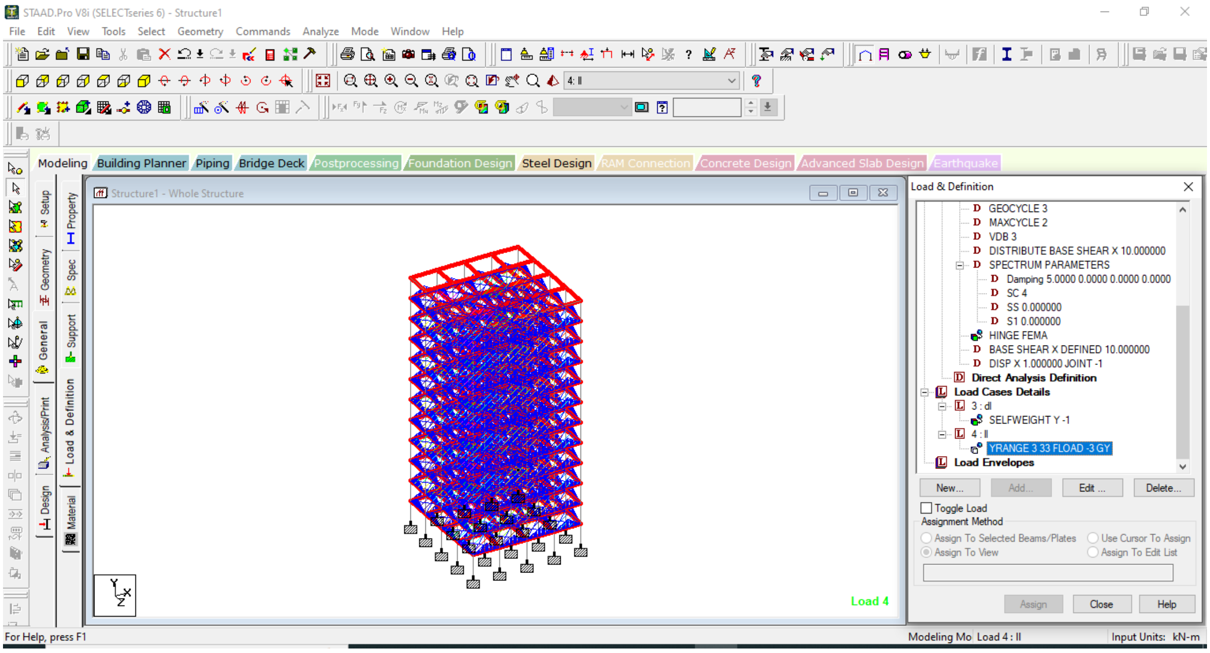
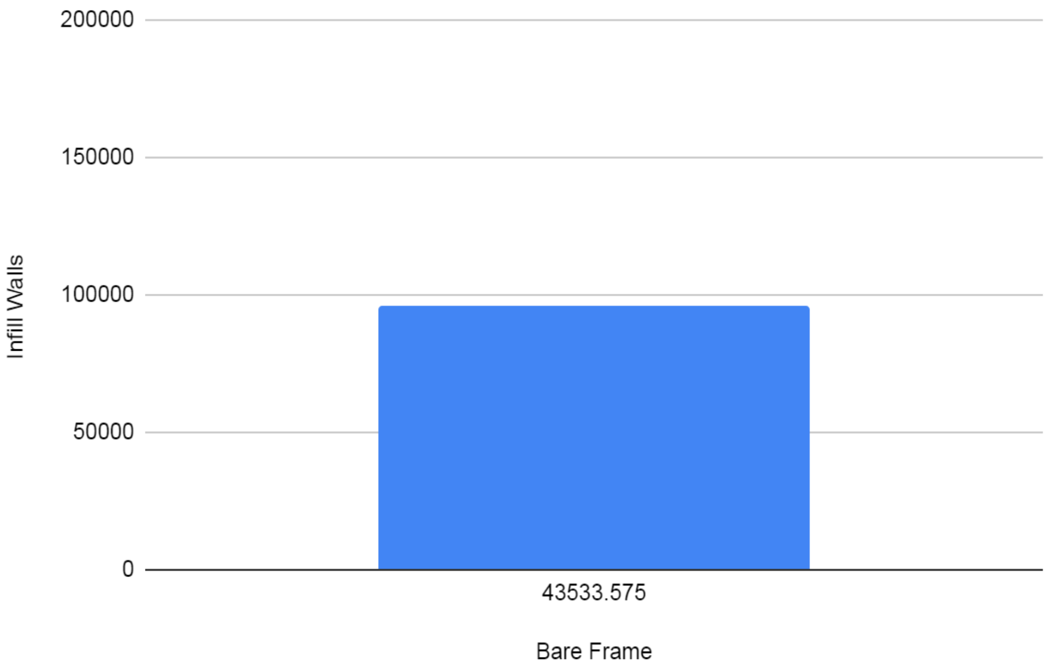
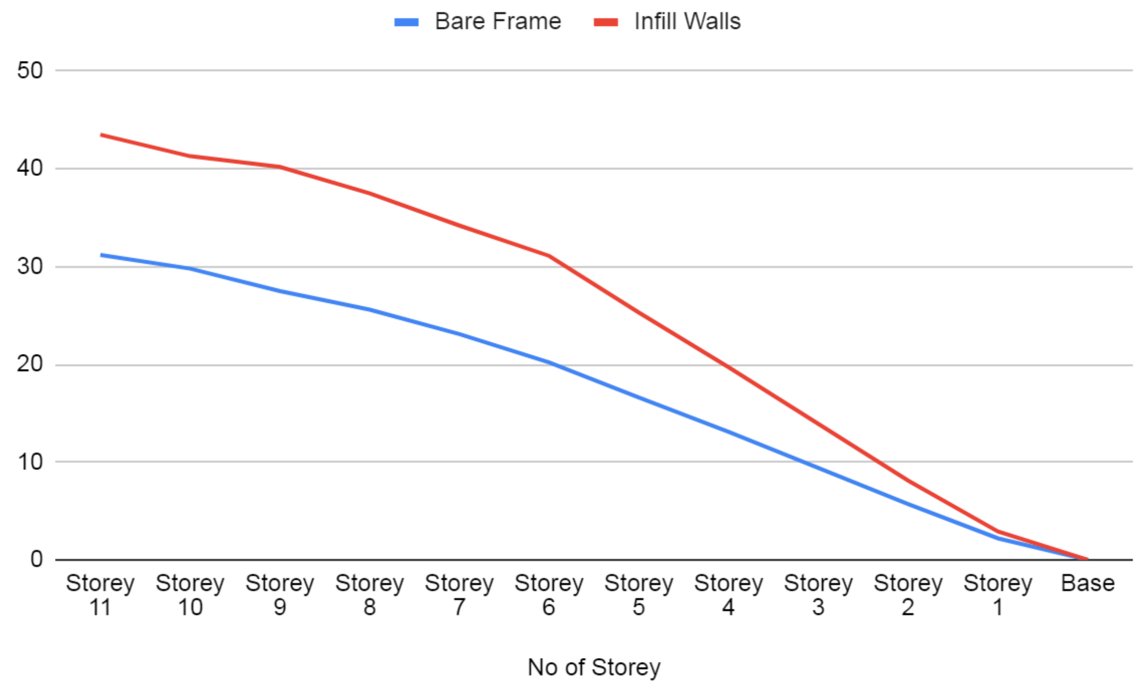
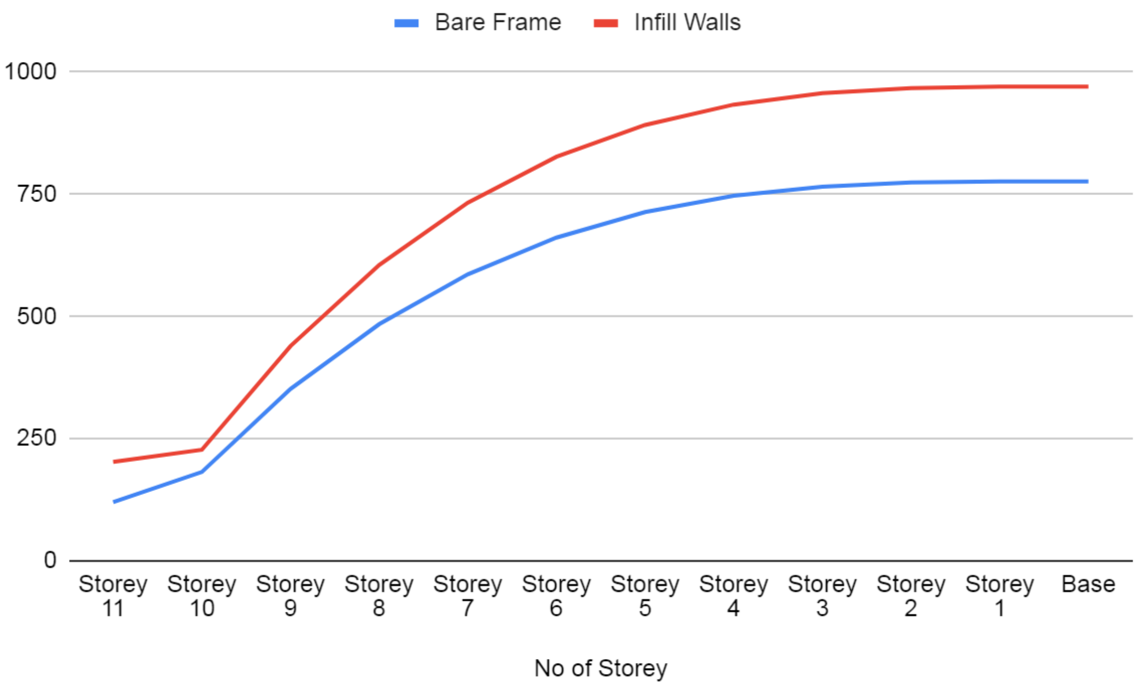


Fig 12 Storey Analysis with Live Load

V. ANALYSIS RESULT




Bare Frame
Infill Walls
50
40
30
20
10
0
Storey 11
Storey 10
Storey 9
Storey 8
Storey 7
Storey 6
Storey 5
Storey 4
Storey 3
Storey 2
Storey 1
Base
No of Storey


Bare Frame
Infill Walls
1000
750
500
250
0
Storey 11
Storey 10
Storey 9
Storey 8
Storey 7
Storey 6
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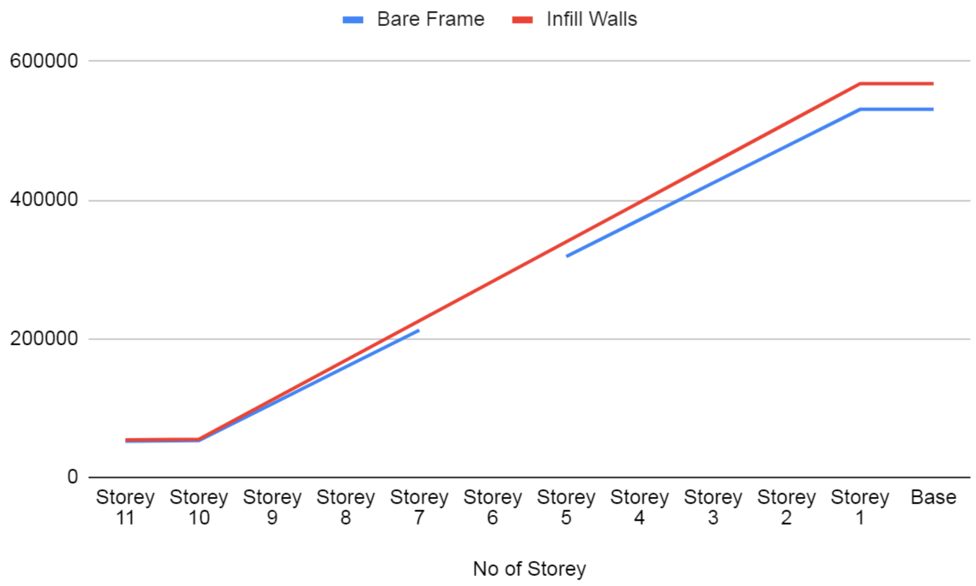
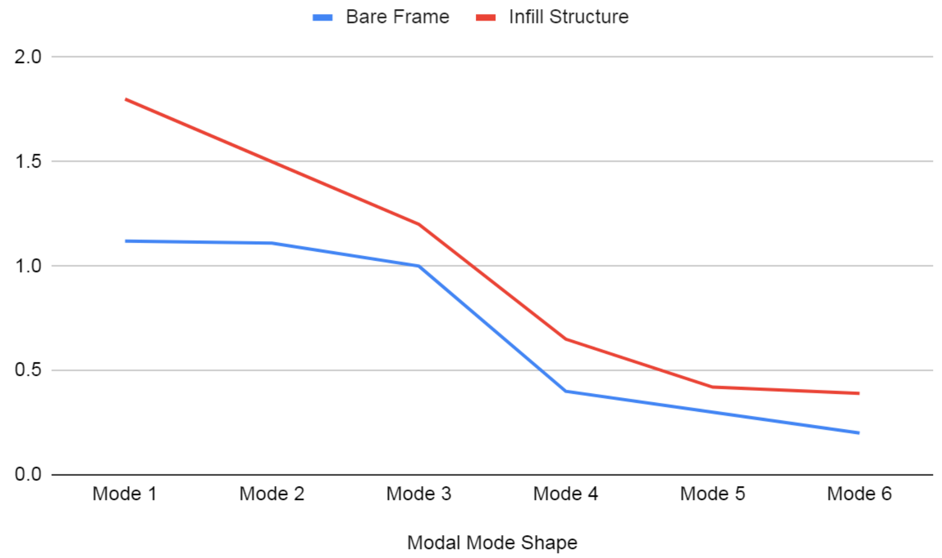
Storey 2
Storey 1
Base
No of Storey





VI. CONCLUSION

Base Shear

Base shear is a calculation of the greatest lateral stress that seismic activity is likely to exert on the foundation of the structure. It is determined using the lateral force formulae for the seismic zone, soil type, and building code. Base shear is the maximum expected lateral force that will occur due to seismic ground acceleration at the base of the structure. The base shear was found to be 96004.672 kN for Infill structure whereas 43533.575 kN for bare frame structure.

Storey Displacement

Story displacement is the lateral displacement of the story relative to the base. The lateral force-resisting system can limit the excessive lateral displacement of the building. The acceptance lateral displacement limit for wind load case could be taken as H/500 (some may take H/400). Displacement was minimum at the bottom of the structure but maximum comparison between the results were visible by 8.2%

at the top of the structure in bare frame structure and infill wall.

Storey Shear

Storey shear was the lateral force acting on a storey due to the forces such as seismic and wind force. Buildings having lesser stiffness attract lesser storey shear and vice versa. Storey shear used to decrease from bottom to top of the structure. The storey shear was found to be 2.3% on higher side fro the structure with infill wall when compared to bare frame structure.

Storey Moment

Variation of 5.2 % variation was visible for Structure with infill wall and bare frame. As number of storey increases P-delta effect becomes more important. P-delta effect is only observed in some of the beams and columns (Exterior columns and their adjacent beams) in some load cases. If these load cases are governing load cases for design of member, it is considerable.

Modal Period

The natural time period is found for building with pdelta effect where natural period of a building is simply a time taken by it to undergo one complete cycle of oscillation. The natural period is one of the properties or building which is controlled by mass and stiffness. The results were evaluated till mode 6 where the maximum results were visible for infill structure at mode 1.

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