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Seismic Behavior of Multi Storied RCC Building having Vertical Mass Irregularity

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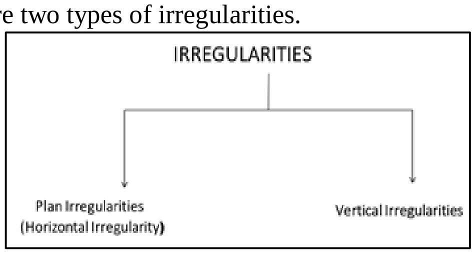
Abstract— This study presents the procedure for seismic evaluation of vertically mass irregular reinforced concrete frame buildings based on a concept of the capacity spectrum method. When the previous recent earthquakes in many parts of India and globe are concerned this reveals the issue regarding the vulnerability of existing buildings. The existing building structures which were designed and constructed according to earlier code provisions do not satisfy requirement of current seismic code and design practice. Many reinforced concrete buildings in urban regions lying in active seismic zone may suffer moderate to severe damages during future ground motion. Therefore it is essential to lessen unacceptable hazards to property and life of occupant. In this study, 3d analytical model of twelve storied buildings have been generated for vertically mass irregular buildings. Models are analyzed using structural analysis tool 'ETABS". The analytical model of the buildings includes influence of the mass at different storey of the structure i.e. at 4th floor, 8th floor and 12th floors respectively. And the results are compared for models having irregular mass at different floors with regular frame. Also the results of Linear Static (Equivalent static method) and Linear dynamic Analysis (Response spectrum Analysis).

Key words: Mass Irregularity, Lumped Mass, Time Period, Storey Forces, Storey Drifts

I. Introduction

During an earthquake, failure of structures starts at the points of weakness. This weakness may arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregularities are not avoidable in construction of buildings; however the behavior of structures with these irregularities during earthquake needs to be studied. Adequate precautions can be taken. A detailed study of structural behavior of the buildings with irregularities is essential for design and behavior. Civil engineering structures are mainly designed to resist static load. Generally the effect of dynamic loads acting on structure is not considered. This feature of neglecting the dynamic forces sometimes becomes the cause of disaster. The Indian Standard code IS-1893: 2002 (Part-I) defines a number of structural irregularities. The code suggests a different approach of analysis for irregular structures.

There are two types of irregularities.



Vertical Irregularities are mainly

A. Stiffness Irregularity

1) Soft Storey

A soft story is one in which the lateral stiffness is less than 70 percent of the story above or less than 80 percent of the average lateral stiffness of the three story's above.

2) Extreme Soft Storey

An extreme soft story is one in which the lateral stiffness is less than 60 percent of that in the story above or less than 70 percent of the average stiffness of the three story's above.

3) Mass Irregularity

Mass irregularity shall be considered to exist where the weight of any storey is more than 200 percent of that of its adjacent story's. The effective mass is the real mass consisting of the dead weight of the floor plus the actual weight of partition and equipment. Excess mass can lead to increase in lateral inertial forces, reduced ductility of vertical load resisting elements. In Case of roofs, irregularity need not be considered.

4) Vertical Geometric Irregularity

A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any story is more than 150 percent of that in its adjacent story.

II. Objectives

- To carryout analysis of a multi-storeyed RC building having vertical mass irregularity
- To perform lateral load analysis on different buildings models as per code.
- To analyse the structure using different methods such as Equivalent static method, and Response spectrum method.
- To study the effects of vertical irregularity in high rise buildings considering parameters like displacement, time period, storey drift and base shear.

III. Description of Structural Model

A. Geometry

For the study, five different models are prepared the analytical model of the buildings includes influence of the mass at different storey of the structure i.e. at 4th floor, 8th floor and 12th floors respectively.

- MODEL1: Regular Frame
- MODEL2: Frame having lumped mass at 4th floor
- MODEL3: Frame having lumped mass at 8yh floor
- MODEL4: Frame having lumped mass at 12th floor
- MODEL5: Frame having lumped masses at 4th, 8th, 12th floors respectively.

No of storey	12
Storey height	3.5m
Size of beam	300x500mm

Size of column	350x750mm
Thickness of slab	150mm
Lumped mass	15kn/m^2
Live load	3kn/m^2
Floor finish	1kN/m^2
Seismic Parameters	
Zone factor	V
Importance factor	1
Response reduction factor	5
Soil type	Rock 1

Table 1: Seismic Parameters

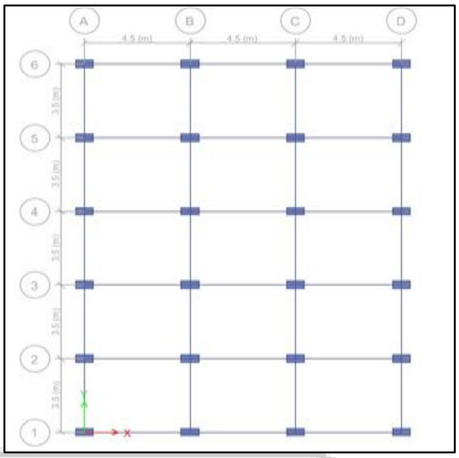


Fig. 1: Plan Layout

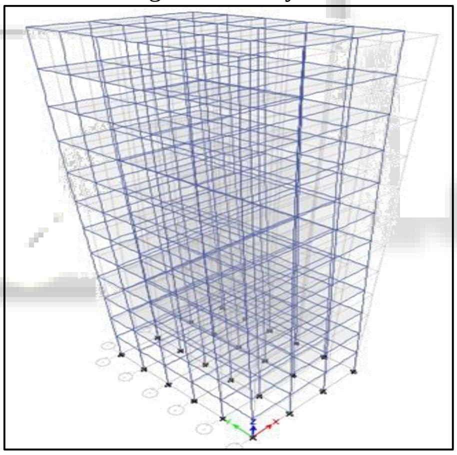


Fig. 2: 3D view of regular frame

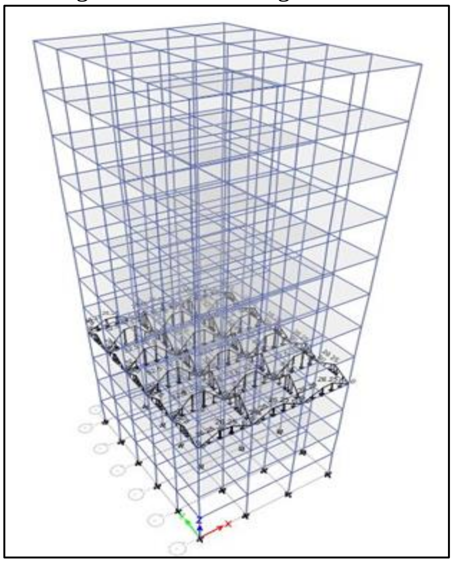


Fig. 3: 3D view of Frame with lumped mass at 4th floor

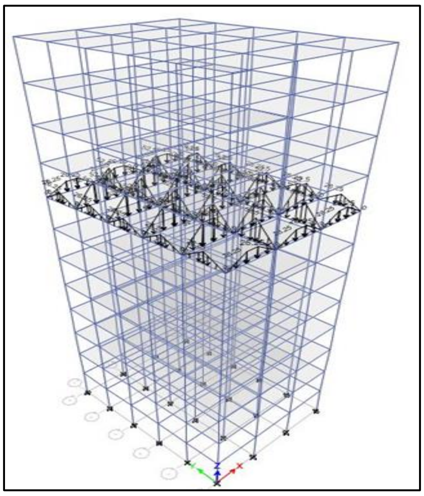


Fig. 4: 3D view of Frame with lumped mass at 8th floor

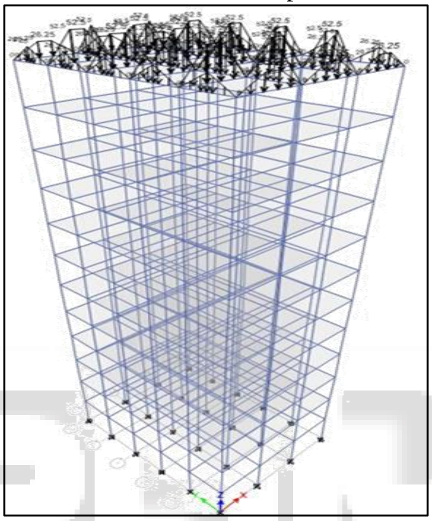


Fig. 5: 3D view of Frame with lumped mass at 12th floor

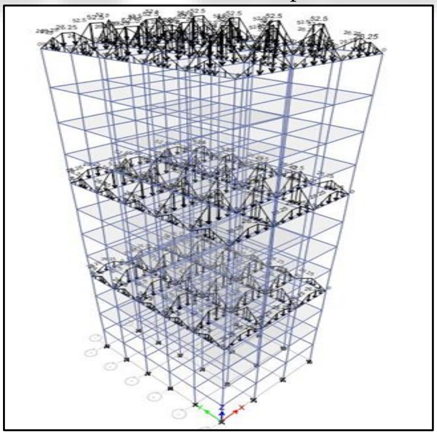


Fig. 6: 3D view of Frame with lumped mass at 4th, 8th & 12th floor

IV. RESULTS AND DISCUSSIONS

Results of the selected buildings studied are presented and discussed in detail. The results are included for building models and the response results are computed using the equivalent static and response spectrum method. ETABS software tool is used to perform the analysis of building models. In this chapter various parameters are studied such as time periods, base shear, displacements, storey drifts, storey forces etc.

A. Maximum Shear Force

Below charts represents the maximum shear force in the beams at each floor, it shows the variation of maximum shear force of regular frames with irregular frames.

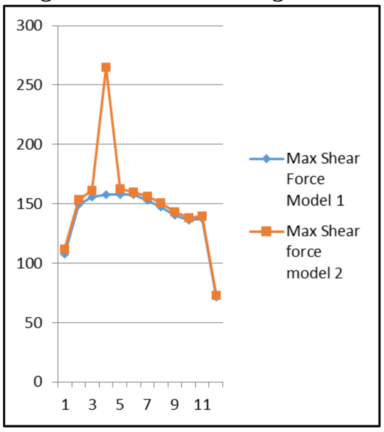


Fig. 7: Storey vs. Max SF(in kN)

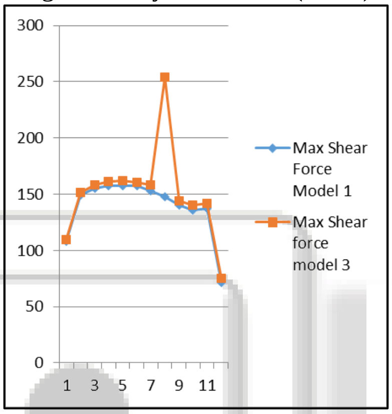


Fig. 8: Storey vs. Max SF(in kN)

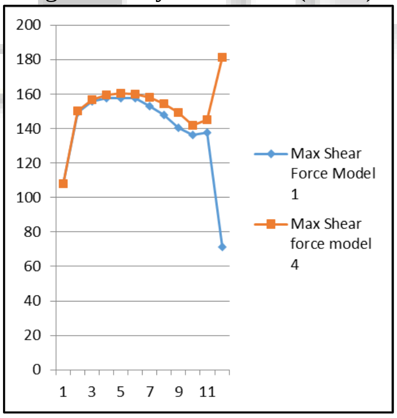


Fig. 9: Storey vs. Max SF(in kN)

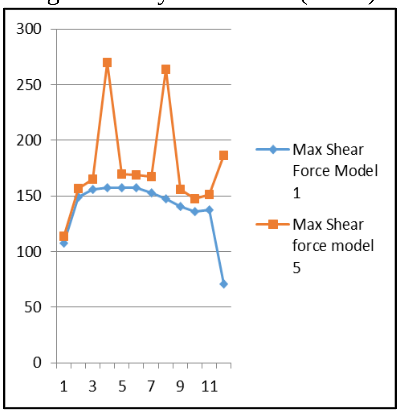


Fig. 10: Storey vs. Max SF(in kN)

B. Maximum Shear Force

Below Fig. s represents the maximum bending moments in the beams at each floor, it shows the variation of maximum bending moments of regular frames with irregular frames.

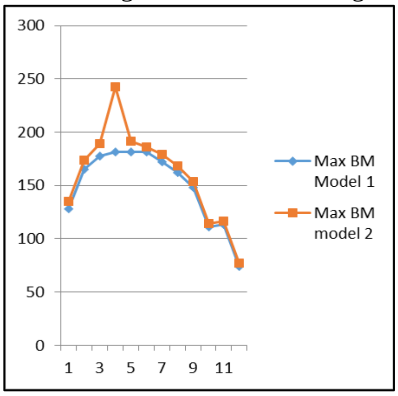


Fig. 11: Storey vs. Max BM(in kN-m)

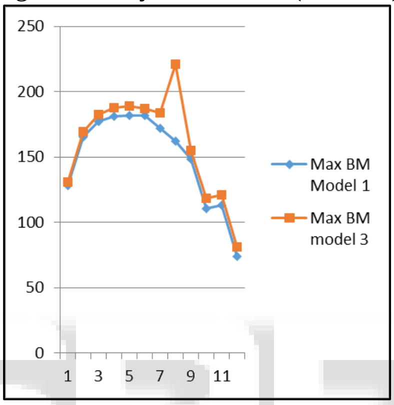


Fig. 12: Storey vs. Max BM (in kN-m)

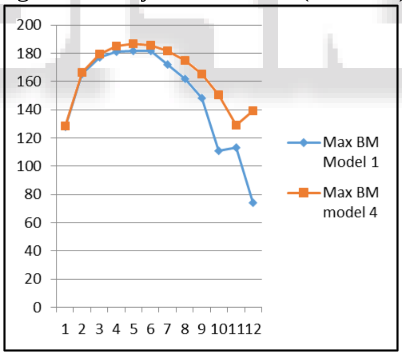


Fig. 13: Storey vs. Max BM in(kN-m)

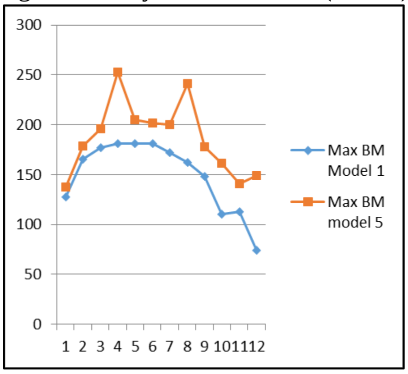


Fig. 14: Storey vs. Max BM in(kN-m)

C. Storey Drifts

The permissible storey drift according to IS1893(part1)-2002 is limited to 0.004 times the storey height, so that minimum damage would take place during earthquake.

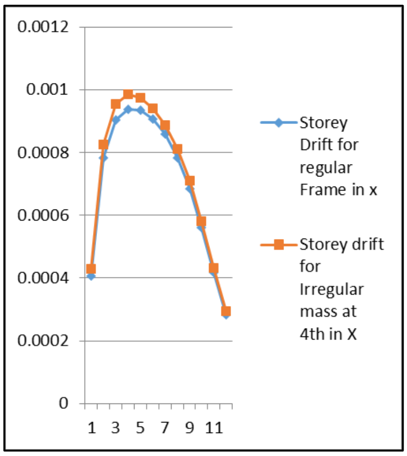


Fig. 15: Storey vs. Storey Drift in X (m)

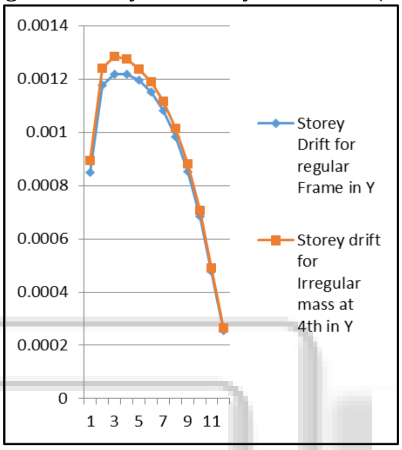


Fig. 16: Storey vs. Storey Drift in Y (m)

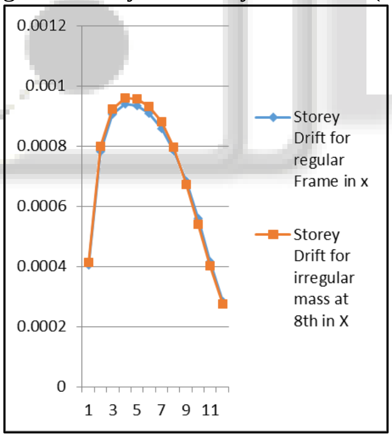


Fig. 17: Storey vs. Storey Drift in X (m)

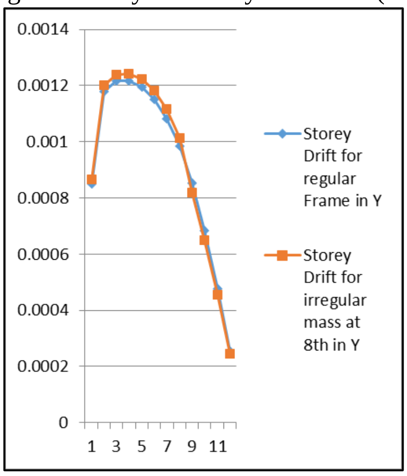


Fig. 18: Storey vs. Storey Drift in Y (m)

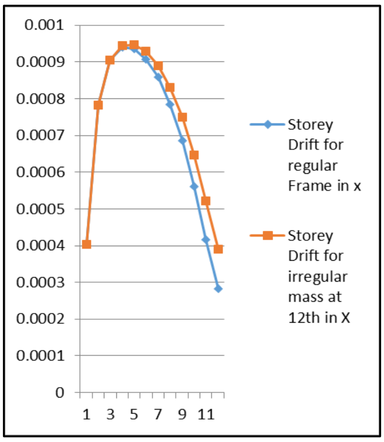


Fig. 19: Storey vs. Storey Drift in X (m)

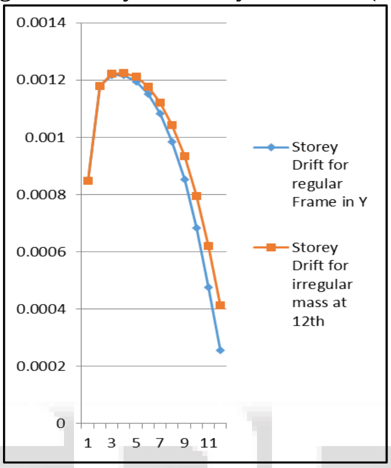


Fig. 20: Storey vs. Storey Drift in Y (m)

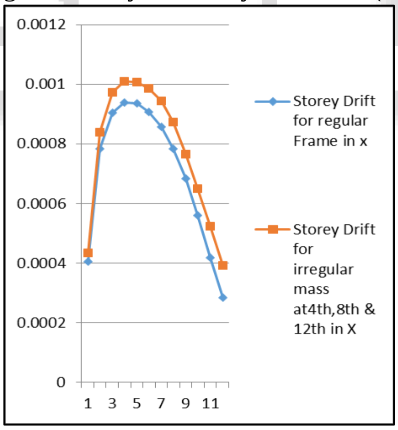


Fig. 21: Storey vs. Storey Drift in X (m)

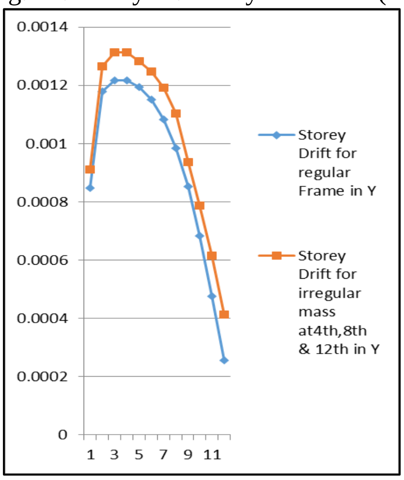


Fig. 22: Storey vs. Storey Drift in Y (m)

D. Siesmic Base Shear

The seismic force at the base of the building is called as base shear, In other words base shear is an estimate of the maximum expected lateral force that will occur due to ground motion at the base of a structure, It is depends on the soil condition at the site and geological features of the site.

Model	Base Shear in X (kN)	Base Shear in Y (kN)
Heavy mass at 4th floor	971.2	849.6
Heavy mass at 8th floor	937.643	822.07
Heavy Mass at 12th floor	914.53	805.287

Table 2: Base Shear

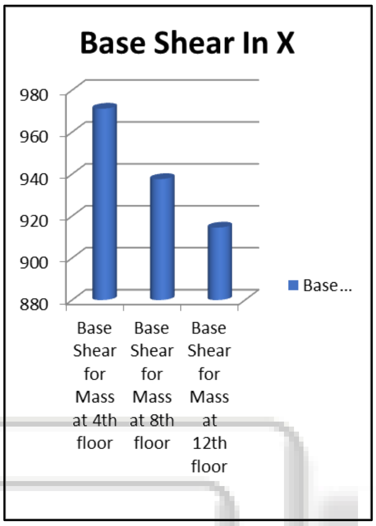


Fig. 23: Model vs. Base shear (kN)

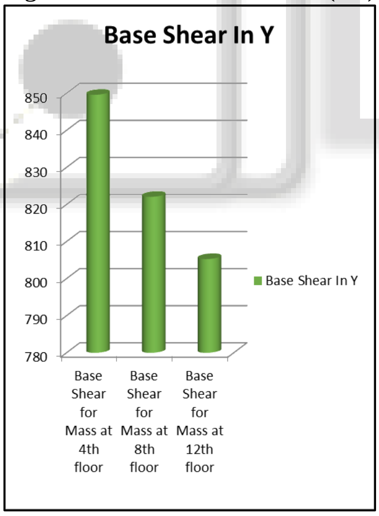


Fig. 24: Model vs. Base shear (kN)

E. Fundamental Natural Time Period

The natural period is nothing but the time it takes to swing back to its original position. If a flag pole is pushed it would sway at its natural period. The building height has dramatic effects on a structural performance of building in earthquake.

A taller building suffers more damage than a shorter building. This is the reason why some buildings are severely damaged and others are not.

Model. No	Time periods in sec
1	2.268
2	2.301
3	2.379
4	2.428
5	2.558

Table 3: Time periods

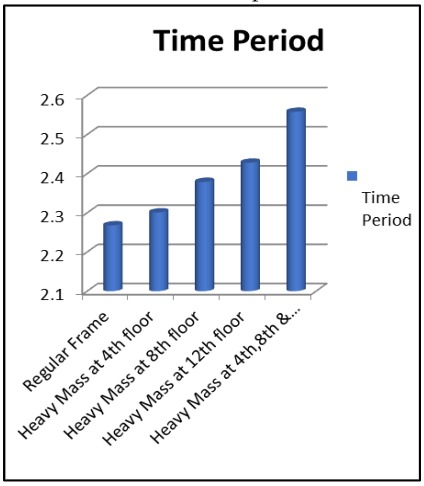


Fig. 25: Time period comparison

From the above Fig. it can be clearly seen that the value of time period is increasing as lumped mass moves toward the top, i.e. the time period will be high for the frame having mass irregularity at top floors.

F. Storey Forces

Below Fig represents the comparison of storey forces between regular and mass irregular frames.

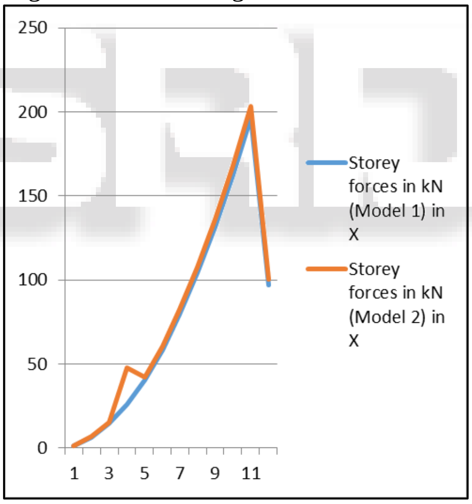


Fig. 26: Storey vs. Storey forces in X (kN)

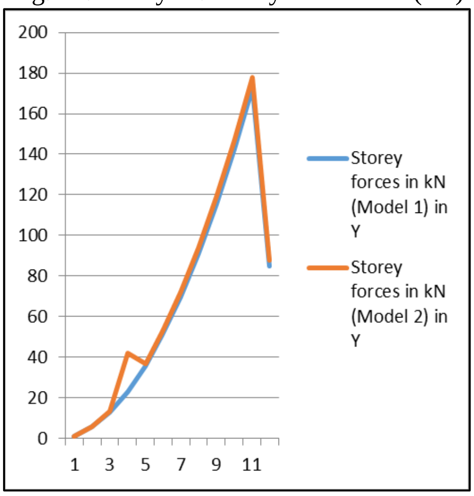


Fig. 27: Storey vs. Storey forces in X (kN)

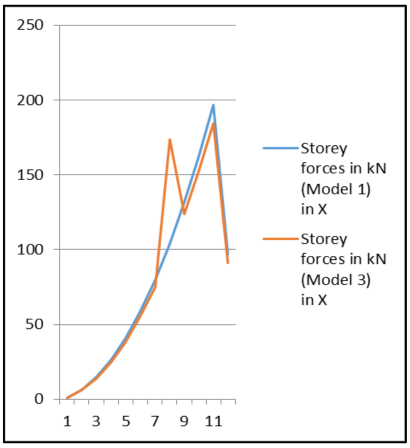


Fig. 28: Storey vs. Storey forces in X (kN)

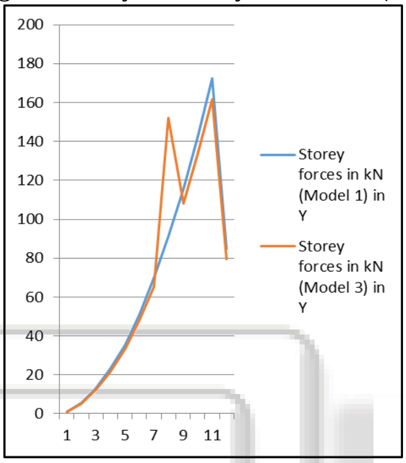


Fig. 29: Storey vs. Storey forces in Y (kN)

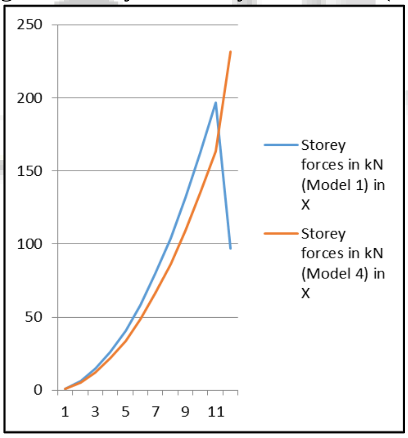


Fig. 30: Storey vs. Storey forces in X (kN)

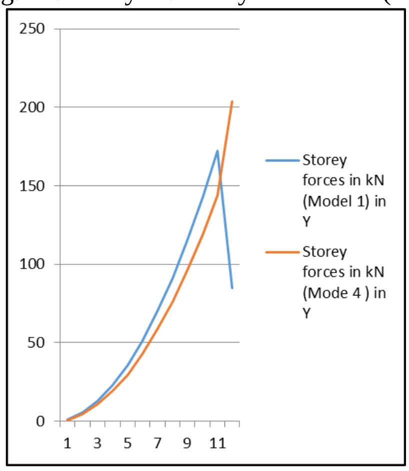


Fig. 31: Storey vs. Storey forces in Y(kN)

V. CONCLUSION

1) From the maximum shear force and bending moments Fig. s it can observed that, the beams at floors subjected to lumped masses will have very high shear force and bending moment as compare to other floors.
2) The vertical mass irregularity may result is increase in the size of structural members such as beams and column.
3) From the natural time period Fig. , it can be observed that the time period will increase as the lumped mass moves toward top
4) From the storey forces Fig. , it can be seen that the storey forces will be high at the floors which are subjected to heavy mass.
5) From the storey drifts Fig. s, it can be observed that the storey drift will be high at the adjacent floors which are subjected to heavy mass.
6) The results which are obtained from response spectrum analysis are lesser as compared to equivalent static analysis.

Finally it can conclude that, the effect of vertical mass irregularity has local as well as global effect on the various floors of a building.

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