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Seismic Analysis of High Rise RC Structure with Different Plan Configuration

Chetan P. Agrawal[1], Amey R. Khedikar[2]
[1]*M-Tech Research Scholar (Structure), Civil Engineering Department, Tulsiramji Gaikwad-Patil College of Engineering and Technology, Mohgaon, Nagpur, MH.*
[2]*Asst. Professor Civil Engineering Department, Tulsiramji Gaikwad-Patil College of Engineering and Technology, Mohgaon, Nagpur, MH.*
amey.khedikar@gmail.com

***Abstract**:*

Seismic analysis means determination of the behaviour of a particular structure when subjected to some action so that it will perform the function for which it is created. This project aims at studying of the structural behaviour of multi-storey building for different plan configuration such as rectangular building along with L- shape and C- shape in accordance with the seismic provisions suggested in IS: 1893-2002. Modelling of G+10 storey RC framed building is done on the ETABS 9.7.1 version for nonlinear analysis i.e. Time History Analysis (Dynamic). These analysis is carried out by considering different seismic zones (IV & V) and the behaviour is assessed by taking medium soil. Post analysis of the structure, different response like lateral force, overturning moment, story drift, displacements, base shear and design results are also computed and compared for all the cases.

Keywords
Seismic Analysis, Multi-Story Building, ETABS 9.7.1, Plan Irregularity, Nonlinear Analysis.

1. Introduction

High Rise RC Structure subjected to most dangerous earthquakes. It was found that main reason for failure of RC building is irregular geometrical configurations or irregular distributions of mass, stiffness and strength. In reality, many existing RC buildings contain irregularity due to aesthetic and functional requirements. Many past earthquake records prove that these structure shows poor seismic performance. This is because of ignorance of the irregularity aspect in the seismic design methodologies by the various seismic codes like IS 1893:2002, UBC 1997, NBCC 2005 etc. The review of seismic design codes and reported research studies show that the irregularity has been quantified in terms of magnitude ignoring the effect of location of irregularity. Therefore, understanding modern approaches to seismic analysis of High-Rise buildings may be very valuable to structural engineers and researchers.

The structural responses of all the High-Rise buildings such as story displacement, story drift, story shear and overturning moment etc. are discussed. Seismic evaluation of the buildings is carried out by Nonlinear Dynamic Time History Analysis. The primary objective of the study is to ascertain in which aspects each of the building is strong and weak and what are the effects of various shapes of the structures against seismic and other forces which adversely affect the stability and life of the structures.

2. Literature Review

In the following, a summary of the articles and paper found in the literature, about the seismic analysis of regular and irregular structures and some of the project carried out with this type of seismic analysis, is presented.

Sadjadi R., Kianoush M. R. and Talebi S. [1], (2007), presented a paper on 'Seismic Performance of Reinforced Concrete Moment Resisting Frames'. In this study a typical 5-story frame is designed as (a) ductile, (b) nominally ductile, (c) GLD, and (d) retrofitted GLD. This study presents an analytical approach for seismic assessment of RC frames using nonlinear time history analysis and push-over analysis. The analytical models are validated against available experimental results and used in a study to evaluate the seismic behavior of these 5-story frames. It is concluded that both the ductile and the nominally ductile frames behaved very well under the considered earthquake, while the seismic performance of the GLD structure was not satisfactory. After the damaged GLD frame was retrofitted the seismic performance was improved.

Mario De Stefano and Barbara Pintucchi [2], (2008), presented a paper on 'A Review of Research on Seismic Behaviour of Irregular Building

Structures Since 2002'. This paper mainly focuses on overview of the progress in research regarding seismic response of plan and vertically irregular building structures. Three areas of research are surveyed. The first is the study of the effects of plan-irregularity by means of single-storey and multi-storey building models. The second area encompasses passive control as a strategy to mitigate torsional effects, by means of base isolation and other types of devices. Lastly, the third area concerns vertically irregular structures and setback buildings.

Abhay Guleria [3], (2014), presented a paper on 'Structural Analysis of a Multi-Storeyed Building using ETABS for different Plan Configurations'. This paper mainly emphasizes on structural behavior of multi-storey building for different plan configurations like rectangular, C, L and I-shape. Modelling of 15- storeys R.C.C. framed building is done on the ETABS software for analysis. Post analysis of the structure, maximum shear forces, bending moments, and maximum storey displacement are computed and then compared for all the analyzed cases.

Girum Mindaye and Shaik Yajdani [4], (2016), presented a paper on 'Seismic Analysis of a Multi-storey RC Frame Building in Different Seismic Zones'. In this paper seismic response of a residential G+10 RC frame building is analysed by the linear analysis approaches of Equivalent Static Lateral Force and Response Spectrum methods using ETABS Ultimate 2015 software as per the IS-1893:2002 (Part-I). These analyses are carried out by considering different seismic zones, medium soil type for all zones and for zone II & III using OMRF frame type and for those of the rest zones using OMRF & SMRF frame types. Different response like lateral force, overturning moment, story drift, displacements, base shear are plotted in order to compare the results of the static and dynamic analysis.

Mohammed Rizwan Sultan and D. Gouse Peera [5], (2015), presented a paper on 'Dynamic Analysis of Multi-Storey Building for Different Shapes'. The main objective of this study is to grasp the behaviour of the structure in high seismic zone and also to evaluate Storey overturning moment, Storey Drift, Displacement, Design lateral forces. In this paper 15 storey-high building on four totally different shapes like Rectangular, L-shape, H-shape, and C-shape are used as a comparison. The complete models were analysed with the assistance of ETABS 9.7.1 version. And also, comparative Dynamic Analysis for all four cases have been investigated to evaluate the deformation of the structure.

3. Methodology

Seismic Analysis of buildings is primarily concerned with structural safety during major ground motions, but serviceability and the potential for economic loss are also of concern. Seismic loading requires an understanding of the structural performance under large inelastic deformations.

Seismic analysis is a major tool in earthquake engineering which is used to understand the response of buildings due to seismic excitations in a simpler manner. Based on the type of external action and behaviour of Structure, the analysis can be classified as,

1) Linear Static Analysis
2) Nonlinear Static Analysis
3) Linear Dynamic Analysis
4) Nonlinear Dynamic Analysis

Nonlinear Dynamic Analysis

It is known as Time history analysis. It is an important technique for structural seismic analysis especially when the Evaluated structural response is nonlinear. This technique involves the stepwise solution in the time domain of the multi degree-of-freedom equations of motion which represent the actual response of a building. It is the most sophisticated analysis method available to a structural engineer. Its solution is a direct function of the earthquake ground motion selected as an input parameter for a specific building. This analysis technique is usually limited to checking the suitability of assumptions made during the design of important structures rather than a method of assigning lateral forces themselves.

4. Modelling Of RCC Frames

Modelling means the formation of structural body in the structure software and assigning the loads to the members as per loading consideration. Here the high-rise RC structures having G+ 10 storey each are selected to model in ETABS 2016 software. In this structural analysis study, we have adopted three different shapes for the same structure, as explained below.

1. Rectangular Plan
2. L-shape Plan
3. C-shape Plan

Plan Details

The structure is 24m in x-direction & 24m in y-direction with columns spaced at 4m from center to center. The storey height is kept as 3m. Basically model consists of multiple bay ten storey building, each bay having width of 4m. The storey height between two floors is 3.0m.

The material properties and geometry of the model are described below;

1) Length X width : 24m X 24m
2) Number of stories : G+10
3) Support conditions : Fixed
4) Storey height : 3 m
5) Grade of concrete : M30
6) Grade of steel : Fe415
7) Size of columns : 500mmx500mm
8) Size of beams : 300mmx500mm
9) Slab thickness : 150mm
10) Height of parapet wall : 1m
11) Thickness of main wall : 230mm
12) Thickness of parapet wall : 115mm
13) Density of Concrete : ϒ'c= 25KN/m^3
14) Density of Brick wall : ϒ'brick= 20KN/m^3

Loading Details

The structures are acted upon by different loads such as dead load (DL), Live load and Earthquake load (EL).

A. Self-weight of the structure comprises of the weight of the beams, columns and slab of the structure.

B. Dead load of the structure consist of Wall load, Parapet wall load and floor load, according to IS 875 (Part1).

1) Wall load: weight unit of brick masonry X thickness of wall X height of the wall

= 20 KN/m^3 X 0.23m X 3m= 13.8 KN/m (acting on the beam)

2) Parapet Wall load: weight unit of brick masonry X thickness of wall X height of the wall

= 20 KN/m^3 X 0.115m X 1m= 2.3 KN/m (acting on the peripheral top beam)

C. Live load: It consist of Floor load which is taken as 4KN/m2 and Roof load as 2 KN/m2, according to IS 875 (Part 2).

D. Seismic Load: Earthquake loads have been defined and assigned on the building as per IS 1893:2002 (Part-I).

Seismic zone: IV and V
Soil type: Medium soil
Importance factor: 1
Response reduction factor: 5 (SMRF)
Damping: 5%

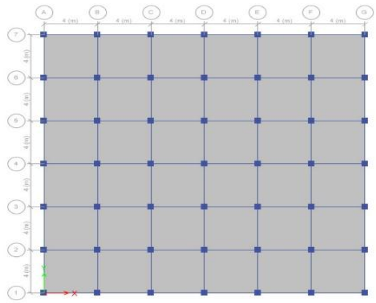
The model is divided into six cases depending on the location of seismic zones and frame type of the building as follows:

CASE-1: Rectangular Plan building located in Zone-IV CASE-4: Rectangular Plan building located in Zone-V

CASE-2: L- shape Plan building located in Zone-IV CASE-5: L- shape Plan building located in Zone-V

CASE-3: C- shape Plan building located in Zone-IV CASE-6: C- shape Plan building located in Zone-V

Plan of the building for all the cases is shown in the following figure;



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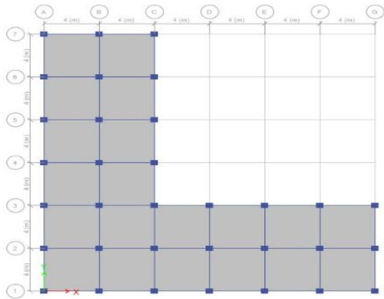

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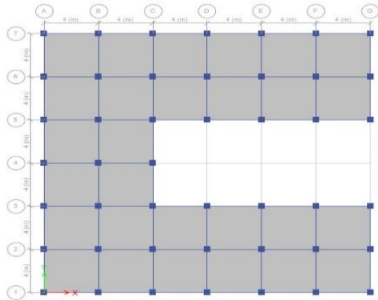
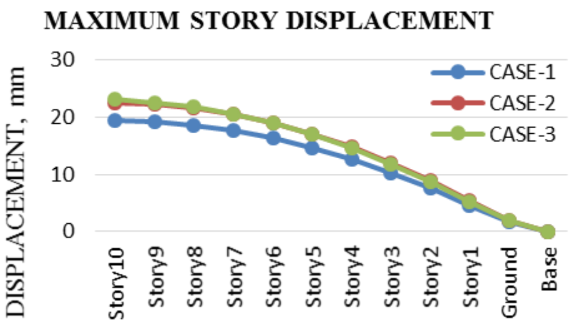


(c)

Fig. 1. Different Shapes of High Rise RC Building (a) Rectangular Plan (b) L- shape Plan (c) C- shape Plan

5. Results And Discussions

Seismic analysis carried out by the help of ETABS and the results of maximum story displacement, maximum story drift, story shear and maximum overturning moment were computed each for six cases. For determining the most stable structure among all modes that we have studied, graphs have been drawn for different shapes.



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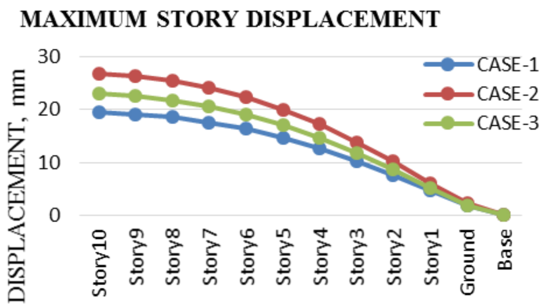

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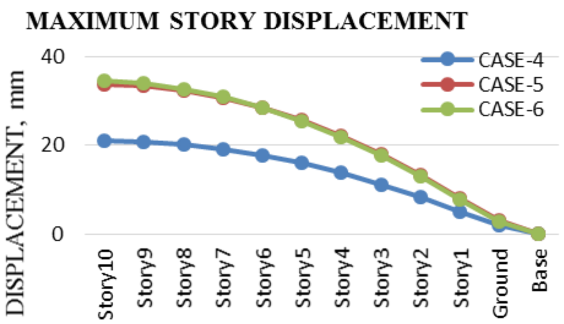
Fig. 2. Maximum Story Displacement in Seismic Zone IV (a) in X- Direction (b) in Y- Direction



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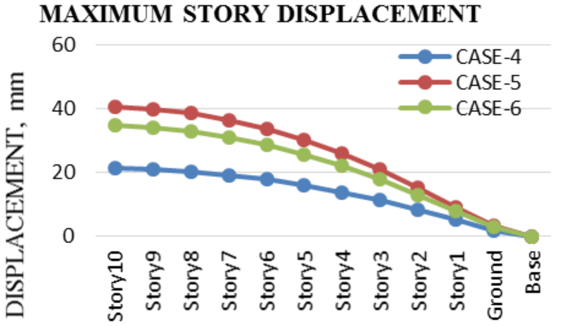
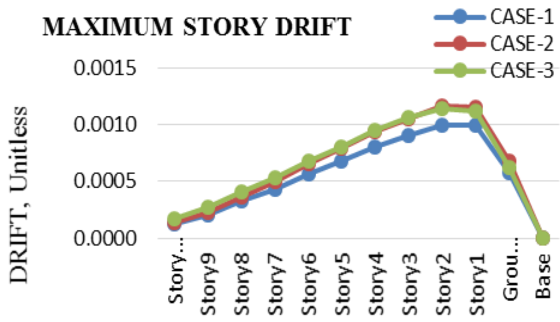


(b)

Fig. 3. Maximum Story Displacement in Seismic Zone V (a) in X- Direction (b) in Y- Direction

Above Fig. 2. and Fig. 3. shows that story displacement increases with the increase in story height. According to Codal provision, maximum or permissible story displacement should be equal to or less than 0.4% of total building height. Hence here the maximum permissible story displacement = ((0.4 / 100) x 33000) = 132 mm. Displacement in rectangular shape building is less compare to other shape of the building.



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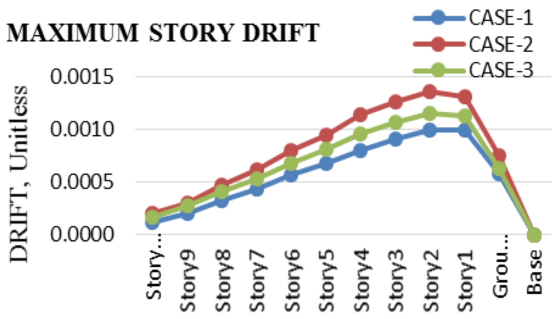
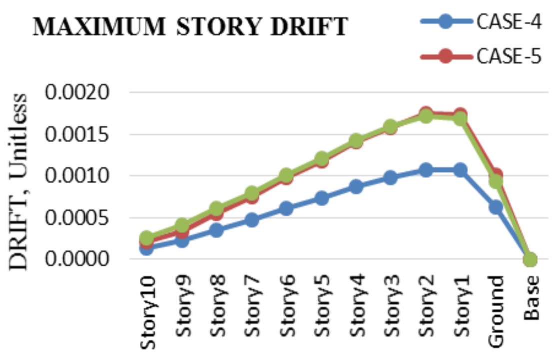


(b)

Fig. 4. Maximum Story Drift in Seismic Zone IV (a) in X- Direction (b) in Y- Direction



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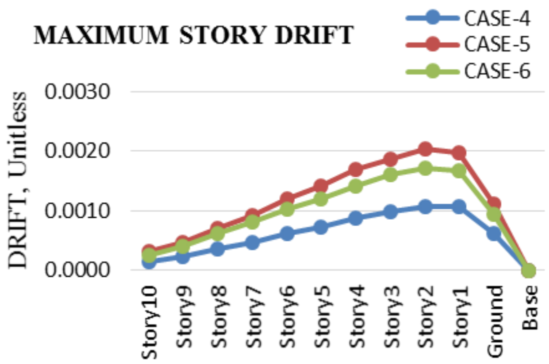
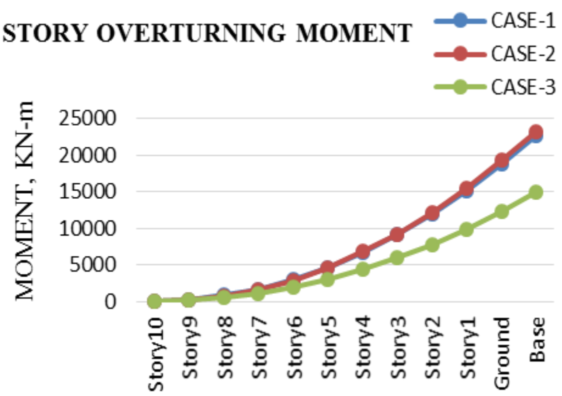


(b)

Fig. 5. Maximum Story Drift in Seismic Zone V (a) in X- Direction (b) in Y- Direction

Above Fig. 4. and Fig. 5. shows the variation of story drift between different floor of all cases. Story drift is the drift of one level of a multi-story building relative to the level below. Here the story drift varies in a similar manner for all configurations. The maximum story drift permitted is 0.004 times the story height i.e. 0.004 x 3000 = 12mm for all story. Drift in rectangular shape building is less compare to other shape of the building.



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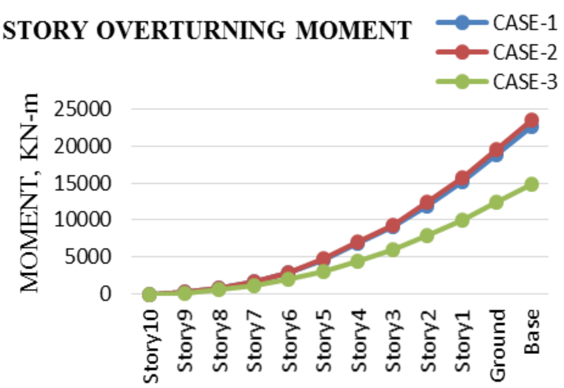
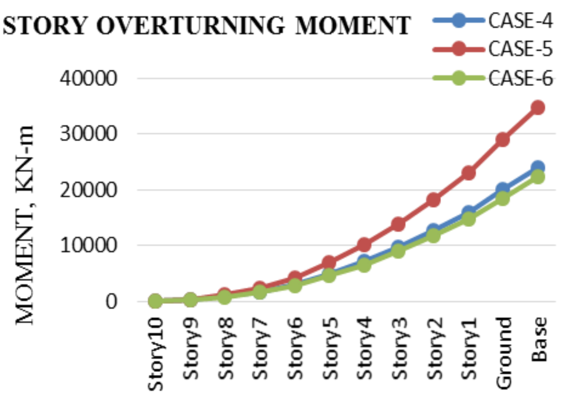


(b)

Fig. 6. Story Overturning Moment in Seismic Zone IV (a) in X- Direction (b) in Y- Direction



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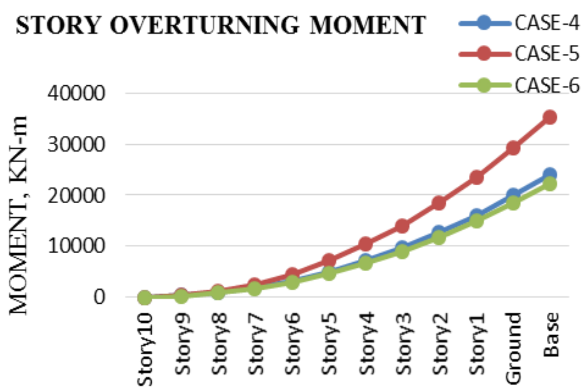
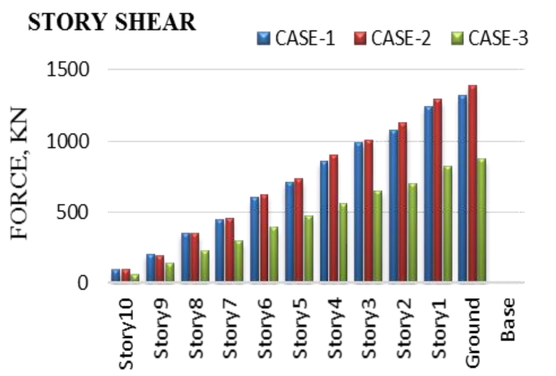


(b)

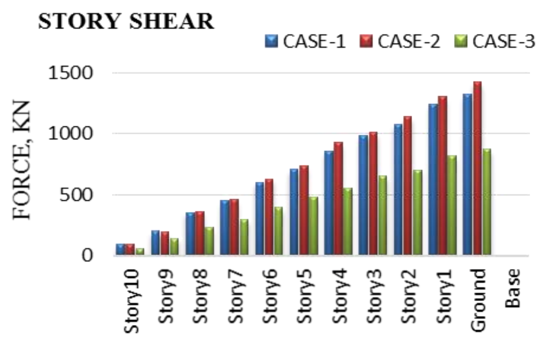
Fig. 7. Story Overturning Moment in Seismic Zone V (a) in X- Direction (b) in Y- Direction

Above Fig. 6. and Fig. 7. Shows that story overturning moment varies inversely with the story height. Story overturning moment of a building is the moment of energy capable of upsetting the story; that is the point where the story has been subjected to enough disturbances that it ceases to be stable, it overturns, capsizes, collapses, topples and eventually the structure fails. Story overturning moment decreases with increase in height of the story for all cases.

Fig. 8. and Fig. 9. Shows the Base Shear for all story for all story for different shape of the building. Story shear is a force that acts on any story in a direction perpendicular to its extension and is measured in 'KN'. It has been concluded that the story shear tends to decrease with the increase in height of the story. For all the structures it is highest at bottom and it decreases linearly towards top. L-shape building has less story shear compare to other shape of the building.

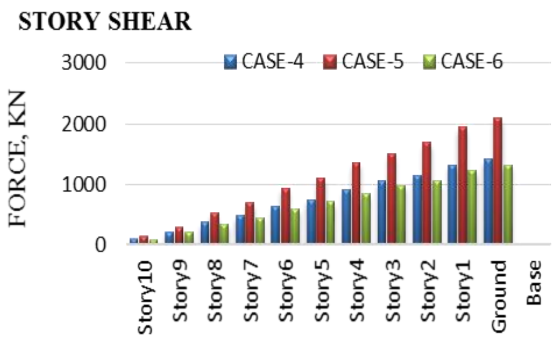


(a)



(b)

Fig. 8. Maximum Story Displacement in Seismic Zone IV (a) in X- Direction (b) in Y- Direction



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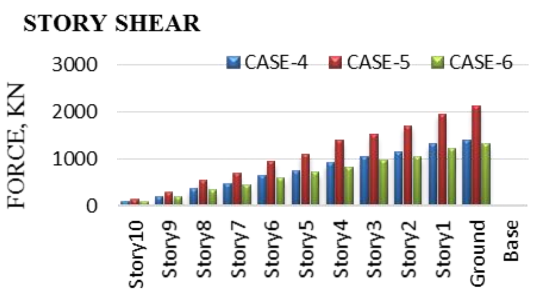

(b)

Fig. 9. Maximum Story Displacement in Seismic Zone V (a) in X- Direction (b) in Y- Direction

6. Conclusion

On the basis of the analytical results of the study, the following conclusions were drawn:

- The plan configuration of structure has significant impact on the seismic response of structure in terms of displacement, story drift, story shear and overturning moment.
- Story displacement is linearly increasing from bottom to top for all structures and is more for irregular structures.
- Story overturning moment decreases with increase in height of the story for all cases.
- It is observed that the story drift for all the stories are found to be within permissible limits. Regular shape building undergoes minimum story drift compared to the irregular shape buildings.
- Story shear decreases with increase in height of the story for all cases.
- The maximum story displacement, maximum story drift, story shear and maximum overturning moment are increased in both directions as the seismic zone goes from IV to V for the same frame type building.
- Irregular shape building undergoes more deformation and hence regular shape building must be preferred.
- Irregular shape buildings are severely affected during earthquakes especially in high seismic zones.

This proves that irregularities in buildings are harmful to the structures and it is important to have simpler and regular shapes of frames as well as uniform load distribution of load around the building.

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