

Parametric Study of G+4 Storey Structure with Vertical Geometric Irregularity Subjected to Seismic Actions

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Abstract

The high rise structures are setting a trend day in and day out. Today in this era, people are fighting for building up the “tallest” high rise structure and in this fight the role of the structural design engineers comes. The scope of the paper is to understand and analyse the behaviour of high rise structures subjected to “vertical geometric irregularity”. Out of the methods prescribed by IS 1893 (Part1):2002, ESA and RSA for G+4 in all four zones with regular and irregular configurations have been taken up. To take different models in four zones was to reduce the level of inaccuracy in results. The irregularity has been adopted at all the four floors. Only linear analysis has been performed as per IS 1893.

A through study has been presented and results of comparison with regular structures have been presented. For the analysis SAP2000 v14.2.4 had been used. The scope of the paper also includes the evaluation of response of structures subjected to different seismic zones having low to very severe seismic intensity.

Keywords

Structures, Irregularities, Vertical Geometric Irregularity, Seismic, Storey Drift, Bending Moments and Shear Forces, Regular Configuration, Irregular Configuration

Introduction

An earthquake is a sudden and transient motion of the earth’s surface. According to geologists, the earth has suffered earthquakes for hundreds of millions of years, even before humans came into existence. Because of the randomness, the lack of visible causes, and their power of destructiveness, ancient civilizations believed earthquakes to be supernatural phenomena – the curse of God. In terms of the geological time scale, it is only recently (the middle of seventeenth century) that an earthquake has been viewed as a natural phenomenon driven by the processes of the earth as a planet. Thus subsequent work, especially in nineteenth century, led to tremendous progress on the instrumental side for the measurement of earthquake data.[1,13]

Seismological data from many earthquakes were collected and analyzed to map and understand the phenomena of earthquakes. Both seismologists and earthquake engineers use the seismological data for the understanding of an earthquake and its effects, but their aims are different. Seismologists focus their attention on the global issues of earthquakes and are more concerned with the geological aspects, including the prediction of earthquakes. Earthquake engineers, on the other hand, are concerned mainly with the local effects of earthquakes, which are capable of causing significant damage to structures. They transform seismological data into a form which is more appropriate for the prediction of damage to structures or, alternatively, the safe design of structures. [12,13,4]

Response spectrum analysis (RSA) is a method widely used for the design of buildings. Conceptually the method is a simplification of modal analysis, i.e., response history (or time history) analysis (RHA) using modal decomposition, that benefits from the properties of the response spectrum concept. The purpose of the method is to provide quick estimates of the peak response without the need to carry out response history analysis. This is very important because response spectrum analysis (RSA) is based on a series of quick and simple calculations, while time history analysis requires the solution of the differential equation of motion over time. Despite its approximate nature, the method is very useful since it allows the use of response spectrum, a very convenient way to describe seismic hazard. RSA is very appealing to practicing engineers because seismic loading is defined by means of a response spectrum.

Methodology and Formulation

A total of 16 models were prepared on SAP2000 v14.2.4 along with all the ESA calculations as per IS 1893(Part 1):2002. The models included both regular as well as irregular configurations, in all the zones. The irregularity considered is “Vertical Geometric Irregularity” conforming to IS 1893(Part 1):2002. In each Zone there are total 4 models, 4 regular configuration models i.e. for G+4 storey and 1 regular model (for each zone). Like this for total of 4 zones there are $4 \times 4 = 16$ models which were prepared and analysed on Finite Element Software (SAP 2000 v 14.2.4) and their ESA & RSA and analysis results were obtained.

RC Frame Building

A ground plus four stories regular RC office building of plan dimensions 19 m X 10 m located in seismic zone V on medium soil is considered. Seismic analysis is performed using the Equivalent Static Analysis Method and Response Spectrum Analysis Method.

1. Preliminary Data

Plan of the building and sectional elevations of different RC frames are shown in figure 1. The size of the beams and columns are given in the table 6.1 and other relevant data for analysis is shown in tables below.

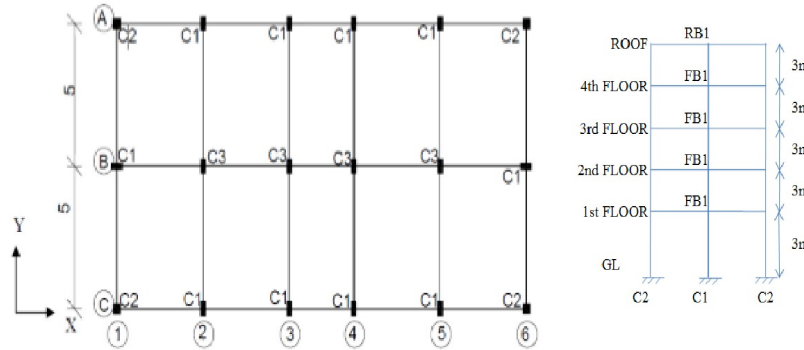


Fig 1: Plan & Elevation of Building (All Dimensions in m) (Kumbhar O. and Kumar R.)

Column (mm)	Beam (mm)
C1: 300 X 500	RB1,FB1: 300 X 600
C2: 400 X 400	RB2,FB2 300 X 500
C3: 400 X 500	SLAB THICKNESS : 125

Table 1: Table showing Dimensions of Columns and Beams

Sr. No.	General Data	Value
1	Grade of concrete	M20
2	Grade of steel	Fe 415
3	Live load on roof	1.5 kN/m ² (Nil for EQ)
4	Live load on floors	3 kN/m ² (25% for EQ)
5	Roof finish	1 kN/m ²
6	Floor finish	1 kN/m ²
7	Brick wall on internal beams	150 mm thick
8	Density of concrete	25 kN/m ³
9	Density of brick wall	20 kN/m ³

Table 2: Table showing General Data used for Analysis

2. Theoretical Calculations For Lumped Masses As Per Is 1893 (Part 1):2002

1	Dead Slab (For 1 st , 2 nd , 3 rd , 4 th , and Roof)	593.75 kN
2	Dead Beam (For 1 st , 2 nd , 3 rd , 4 th , and Roof)	83.75 kN
3	Dead Column (For 1 st , 2 nd , 3 rd and 4 th floor)	220.5 kN
4	Dead Column (For Roof)	110.25 kN
5	Wall Load (For 1 st , 2 nd , 3 rd and 4 th floor)	1331.4 kN
6	Wall Load (For Roof)	665.7 kN
7	Parapet Load (For Roof)	400.2 kN
8	Floor Finish (For 1 st , 2 nd , 3 rd and 4 th floor)	190 kN
9	Roof Treatment (For Roof)	190 kN
10	Live load Roof	0 kN
11	Live Load (For 1 st , 2 nd , 3 rd and 4 th floor)	142.5 kN

Table 3: Table for Theoretical Calculations For Lumped Masses As Per Is 1893 (Part 1):2002

3. Determination of Fundamental Natural Period

The approximate fundamental natural period of vibration (T_a), in seconds, of a moment resisting frame building with brick infill panels may be estimated by the empirical expression as given in IS 1893 (Part 1):2002

$$\text{So, } T_a = \frac{0.09h}{\sqrt{d}} \text{ (in our case it is with brick infill panels) [13]}$$

Where, $h = 15 \text{ m}$ and $d = 19 \text{ m}$ (for T_a in x-dir) and 10 m (for T_a in y-dir)

4. Determination of Design Base Shear (VB) [13]

The design base shear V_B as given by IS 1893. In order to find Design Base Shear as per IS 1893 (Part 1):2002 V_B we need A_h too. As per IS 1893 design horizontal acceleration is given by A_h

Where, $Z = 0.36$, $I = 1$, $R = 5$ and $\frac{S_a}{g} = 2.5$. So we can get the value of A_h for x and y direction both.

5. Vertical Distribution of Base Shear [13]

The design base shear computed shall be distributed along the height of the building as per the expression given in IS 1893 (Part 1):2002. So, we can calculate the values of Q_1 , Q_2 , Q_3 , Q_4 and Q_5 .

For G+4 (Zone - V Regular Configuration)

Total Seismic Weight “W” = 14291.25 kN

Base shear at different levels							
Floor level	W_i	h_i	$W_i(h_i)^2$	$(Q_i)_x$	$(Q_i)_y$	Cumulative $(Q_i)_x$	Cumulative $(Q_i)_y$
Roof	2443.65	15	549821.3	524.023	524.023	524.023	524.023
4	2961.9	12	426513.6	406.501	406.501	930.524	930.524
3	2961.9	9	239913.9	228.657	228.657	1159.181	1159.181
2	2961.9	6	106628.4	101.625	101.625	1260.806	1260.806
1	2961.9	3	26657.1	25.4063	25.4063	1286.212	1286.212
		$\Sigma W_i \cdot h_i^2$	1349534.25			$(V_B)_x$	$(V_B)_y$
<i>Fundamental natural period (sec)</i>	$(T_a)_x$	0.30971		<i>Design horizontal Acceleration (m/sec²)</i>		$(A_h)_x$	0.09
	$(T_a)_y$	0.42691				$(A_h)_y$	0.09
<i>Design Seismic base shear (kN)</i>	$(V_B)_x$	1286.21					
	$(V_B)_y$	1286.21					

Table 4: Table showing Calculations for Analysis by Equivalent Static Lateral Force Method

Note: The values of $(Q_i)_x$ and $(Q_i)_y$ from the above table are the values of EQX and EQY respectively, which are to be applied as a nodal force in X and Y directions respectively at each floor at their centre of gravities.

Analysing ESA and RSA ON SAP 2000 V14.2.4

Analysis results in SAP2000 v14.2.4 along with all the ESA and RSA calculations as per IS 1893(Part 1):2002. The analysis results obtained were for Base Shear, Lateral Displacements, Storey Drift Ratio, Shear Forces and Bending Moments. Based on the results obtained various graphs were plotted.

1. Base Shear: Table below shows base shear at different levels for a G+4 Zone-V having Irregular floors

Floor levels	$(V_B)_x$ (kN)		Floor levels	$(V_B)_y$ (kN)
4	1137.97		4	1137.97
3	1054.80		3	1054.80
2	911.71		2	911.71
1	768.63		1	768.63

Table 5: Table Base Shear at Different Levels for a G+4 Zone-V having Irregular Floors

2. Lateral Displacement for G+4 (RSA-X) and G+4 (RSA -Y)

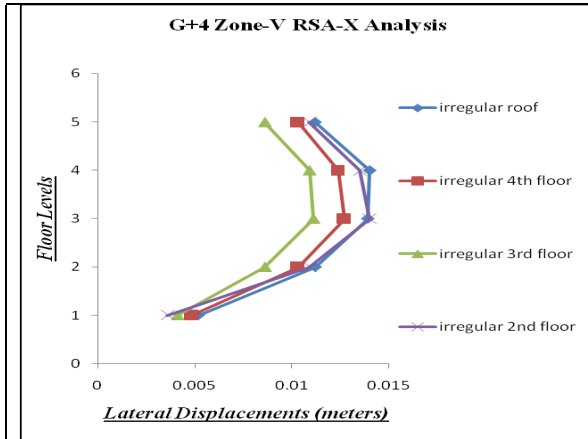


Fig 3: shows variation of Lateral Displacements at different levels for a G+4 Zone-V having Irregular floors for RSA-X

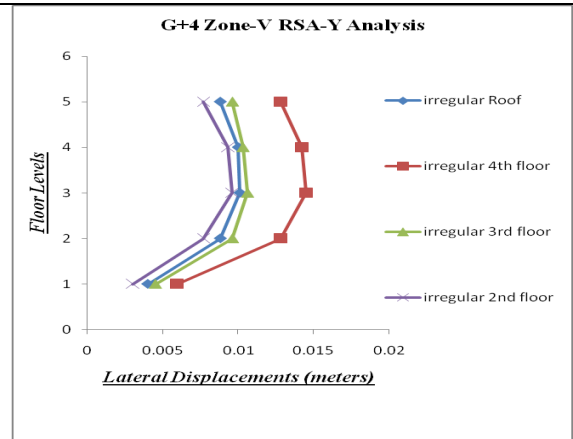


Fig 4: shows Variation of Lateral Displacements at different levels for a G+4 Zone-V having Irregular floors for RSA-Y

3. Storey Drift Ratio (SDR) for G+4

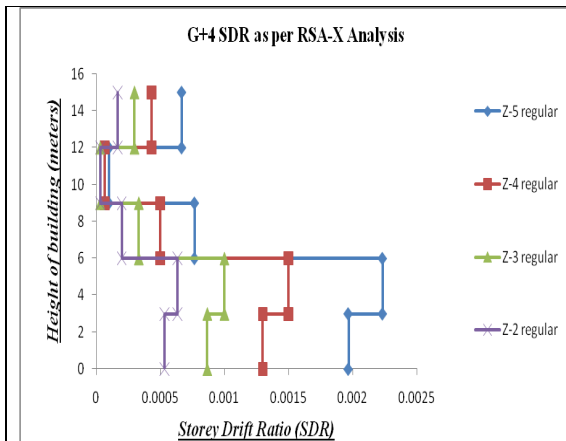


Fig 4: Variation of SDR with height of a G+4 building for RSA-X

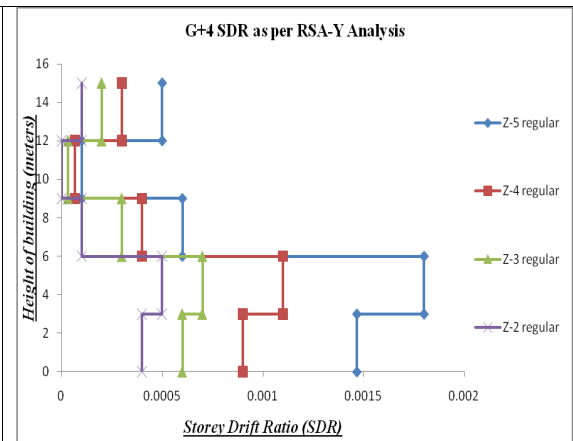


Fig 5: Variation of SDR with height of a G+4 building for RSA-Y

4. Irregularities

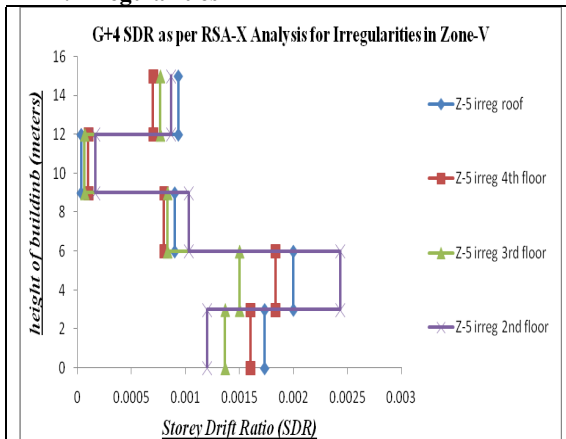


Fig 6: Variation of Storey Drift Ratio with height of a G+4 Irregular building for RSA-X in Zone -V

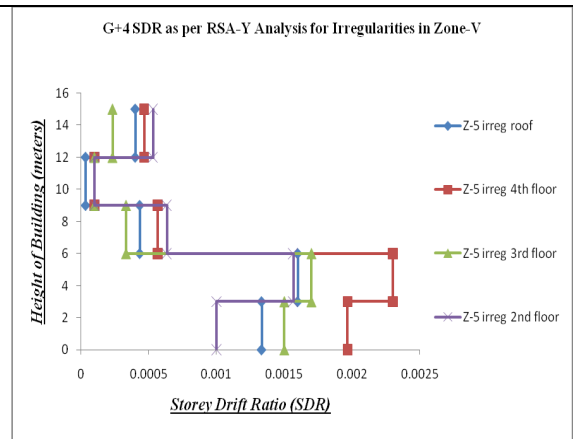


Fig 7: Variation of Storey Drift Ratio with height of a G+4 Irregular building for RSA-Y in Zone -V

5. Shear Force

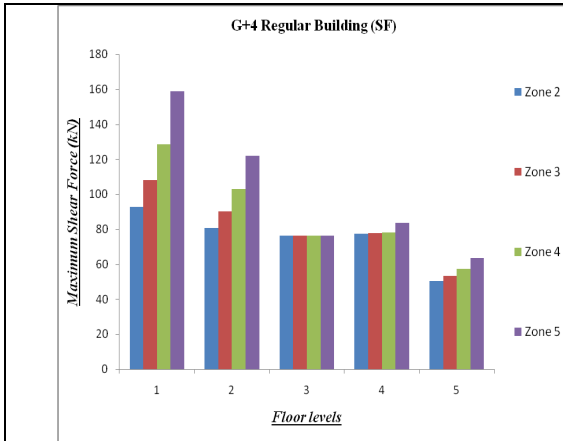


Fig 8: Variation of Maximum SF for a G+4 Regular Building for all the Zones and Floors

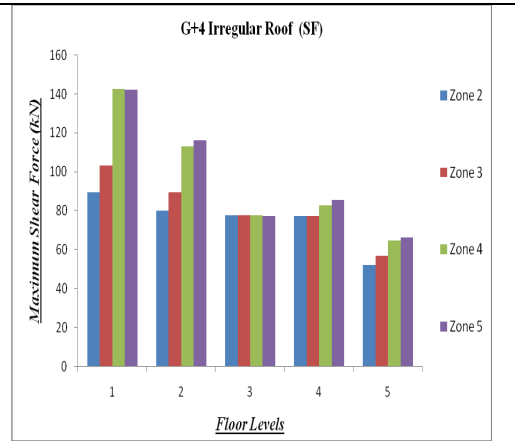


Fig 9: Variation of Maximum SF for a G+4 Irregular Roof for all the Zones and Floors

6. Bending Moment

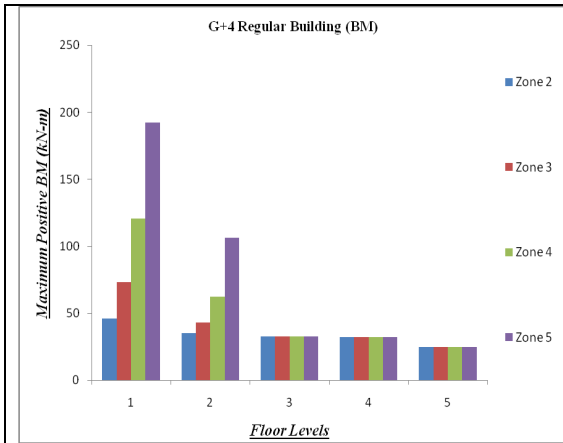


Fig 10: Variation of Maximum Positive BM for a G+4 Regular Building for all the Zones and Floors

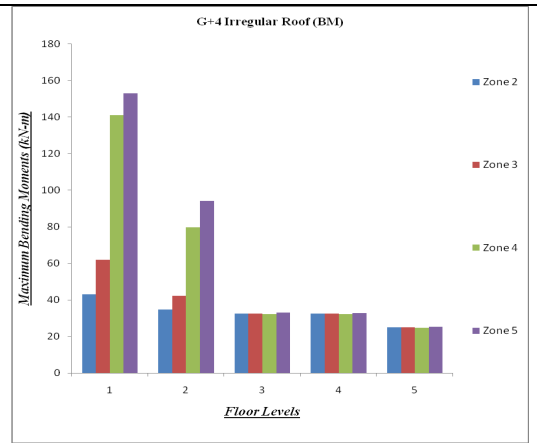


Fig 11: Variation of Maximum Positive BM for a G+4 Irregular Roof Building for all the Zones and Floors

Results

- The base shear increases with the increase in floor level of the building.
- When the irregularity in Zone-V for a low rise building, eg. G+4 (vertical geometric) is considered at the top floor only out of all the irregular floors, such buildings show the maximum lateral displacement. But as we increase the number of stories, it can be seen that with increase in story height and considering irregularity (vertical geometric) at every floor.
- It can be seen from the models of G+4 regular buildings that the G+4 regular buildings are safe in all the Zones with regards to SDR.
- It can also be seen that the shear force and bending moments decrease with increase in floor levels for both regular as well as irregular configurations.

Conclusion and Comments [2,12,13]

An attempt have been made in this paper and a G+4 storey structure in all four zones with regular and irregular configurations have been taken up. Different models in four zones were modelled to reduce the level of inaccuracy in results. Including irregularity has been adopted at all the four floors and linear analysis has been performed using SAP2000 v14.2.4 as per IS 1893 2002 (Part I).On evaluation of response of structures subjected to different seismic zones having low to very severe seismic intensity following concluding remarks can be made:

- a) It can be seen that the base shear in X-direction is more as compared to the base shear in Y-direction as the building is more flexible in Y-direction.
- b) The maximum lateral displacements are observed when the irregularity was considered at bottom floors only.
- c) Also the maximum variation in SDR is observed as we move from the 1st floor to 2nd floor in all the four zones.
- d) The soft stories are subjected to the maximum bending moments and shear forces. So accordingly such soft stories must be designed for additional Shear forces and Bending moments.

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