STUDY ON PLAN IRREGULAARITITY EFFECT ON PERFORMANCE OF HIGH RISE STRUCTURE

Anushree R[1], Dr Raghuprasad B K [2], Dr Amarnath K[3]

M. Tech. Student[1], professor[2], HOD[3]

Department of civil engineering

The Oxford College of Engineering, Bengaluru, India

Abstract-Earthquake is one of the main causes building failure and it is unpredictable and cannot be prevented. From the previous studies it is evident that damage due to earthquake is more in irregular buildings than in regular buildings. In these days due to increase in population there is growth in metropolitan cities where the cost of property and materials are high. High rise buildings are more common in the metropolitan cities and many building will have irregular structural configuration like plan or vertical irregularities. The current study is based on plan irregularities due to which the centre of mass of the structure and centre of stiffness of the structure do not coincide with each other. The difference between centre of mass and centre of stiffness is called eccentricity which induces torsion in the building which is one of the major causes of building failure.

In the current study three models of (G+30) storey buildings by varying the storey eccentricities are considered and linear static analysis, response spectrum analysis and pushover analyse are carried out for all the four seismic zones. Parameters such as storey displacement, storey drift, base shear and ductility ratio are noted and results are evaluated.

Keywords—plan irregularity, vertical irregularity, linear static analysis, response spectrum analysis, pushover analysis.

1. INTRODUCTION

High rise buildings are most common now a days, this is due to rapidly increase in cost of land, high population and also to preserve agricultural lands etc. All results in high rise residential and commercial buildings. Many structures will have irregular configurations to satisfy architectural needs or for some other reasons, which leads to both plan and vertical irregularities in the structure. These irregularities result in uneven distribution of mass, stiffness and strength along the height of the structure. High-rise building especially with irregularities constitute certain design challenges both for structural and geotechnical engineers, especially when it is situated in seismically active zones or if the soil is soft.

Torsional irregularity:

Torsion can be one of the major causes of damage in the building during strong earthquakes and may lead to damage of structures or failure of structure. Torsion in plan is rotation about a vertical axis through centre of mass, occurs when the centre of mass of a building does not coincide with the centre of stiffness. In the cases such as building plan in which the stiff elements are placed asymmetrically with respect to the mass centre of the story or when the large masses are being placed asymmetrical to the stiffness the torsion occurs.

A complex structural plan leads to irregular structural configuration when these structures are subjected to earthquake the earthquake force acts at centre of mass of the structure but the resisting force acts at centre of rigidity/centre of stiffness of the structure. Because of eccentricity between the centre of stiffness and centre of mass the torsion is induced in a structure. Fig: 1. (a) and 1. (b) Shows the symmetrical and asymmetrical structures.

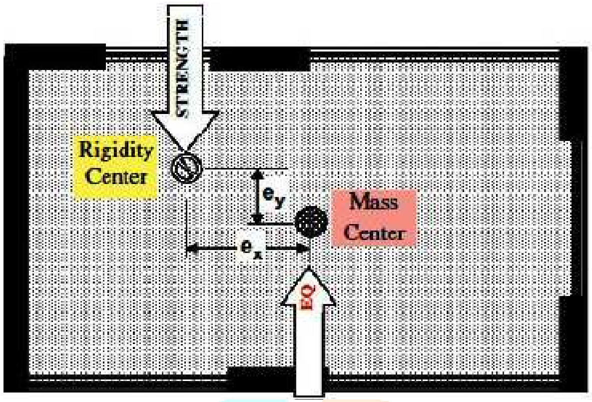
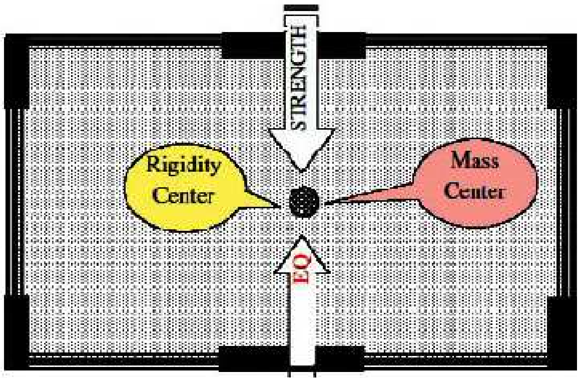


Fig. 1.(a)Asymmetric structure (Torsional irregularity)



1. (b) Symmetric structure

2. OBJECTIVES

The main objectives of the study are:

- To study the behaviour of regular and irregular plan buildings with varying eccentricities in different seismic zones
- To compare results of linear static analysis of symmetric and asymmetric buildings.
- To compare results of response spectrum analysis of symmetric and asymmetric buildings.
- To conduct push-over analysis to determine the ductility ratios.

2. LITERATURE REVIEW

Mallikadevi Palli et al.[2014] [1] conducted a study on "**analysis and design of multi-storey building with plan irregularity to opt a suitable structural framing**" In this study one regular and three irregular shape (L, U, T shape) model, both OMRF and SMRF frames for all 4 seismic zones have been considered. The results confirms the four conditions in Clause 1.1.1 of code "Ductile detailing of Reinforced Concrete Structure subjected to Seismic Forces - Code of Practice" IS- 13920:1993 and the result also shows that there is no impact of plan irregularity in the section of structural system for analysis and design. For zone IV and zone V it is ideal to consider SMRF frame as it is safe and economical.

Ashish R et al. [April-June 2015] [2] conducted a performance based study on "**Seismic Design of R.C.C. Buildings with Plan Irregularity"** In this paper a study was conducted on irregular plan building using standard and modal pushover analysis, and also to check the accuracy of these two methods Non-linear time history analysis is carried out. The result shows that in case of regular building both standard pushover analysis and modal pushover analysis gives the same results, but modal pushover analysis gives better results for irregular buildings as higher mode effects is considered. It also concludes that torsion in irregular building is 20% more than that of regular building.

Prof. Milind V. Mohod [Jul. - Aug. 2015] [3] conducted a study on "**Pushover Analysis of irregular plan structure**". A 9 models of different plan irregular shapes like regular square shape, E-shape, H-shape, T-shape, L-shape C-shape, square with core, rectangle with core and plus shape are been considered. The parameters such as storey drift, lateral displacement, base shear and pushover curves have been studied. Considering all the above parameters it was concluded that simple geometric building attracts less earthquake forces than that of complex structures and also perform well during earthquake, hence it is necessary to omit complex shapes and adopt simple ones during planning stage.

Rajalakshmi K R et al. [June 2015] [4] conducted a analytical study on "**Torsion Effects on Building Having Mass and Stiffness Irregularities**", three type of irregularities have been considered in this study which are mass irregularity, stiffness irregularity and setback buildings. The analysis is performed by Non linear dynamic analysis on mass and stiffness buildings. From the results it is seen that irregular building are subjected to more damage near the regions of irregularity and also large displacements is observed than that of regular buildings.

Dr. Y. M. Ghugal et al.[JULY, 2016] [5] conducted a performance based analysis on **"Seismic Design of R.C.C. Buildings with plan Irregularities"** A (G+6 storey regular and irregular buildings are modelled using ETABs (version 9.7.3), irregular structures such as L,C and T shapes have been considered. the analysis is done using standard pushover analysis and modal pushover analysis and the parameters such as performance curve, torsion, pushover curve and plastic hinge mechanism are studied. The results shows that estimate of seismic demand due to strong earthquake has seen to be accurate by modal pushover analysis for irregular buildings with similar degree as it was for regular building.

Desai R.M et al.[Nov – Dec 2016] [6] conducted a study on "**Behaviour of Symmetric and Asymmetric Structure in Zone 5**" . Three buildings (G+3), (G+6) & (G+9) building models with soil type medium in seismic zone II are been considered. The main aim was to study effect of eccentricity on the performance of building. From the results its been concluded that the performance of symmetrical building is better than that of the asymmetrical building for given loading and soil conditions, and the structural parameters such as storey drift. Displacement, time period and torsional moments is higher in asymmetrical building than symmetrical building.

3. METHODOLOGY AND PROBLEM DESCRIPTION

FLOW CHART OF METHODOLOGY:

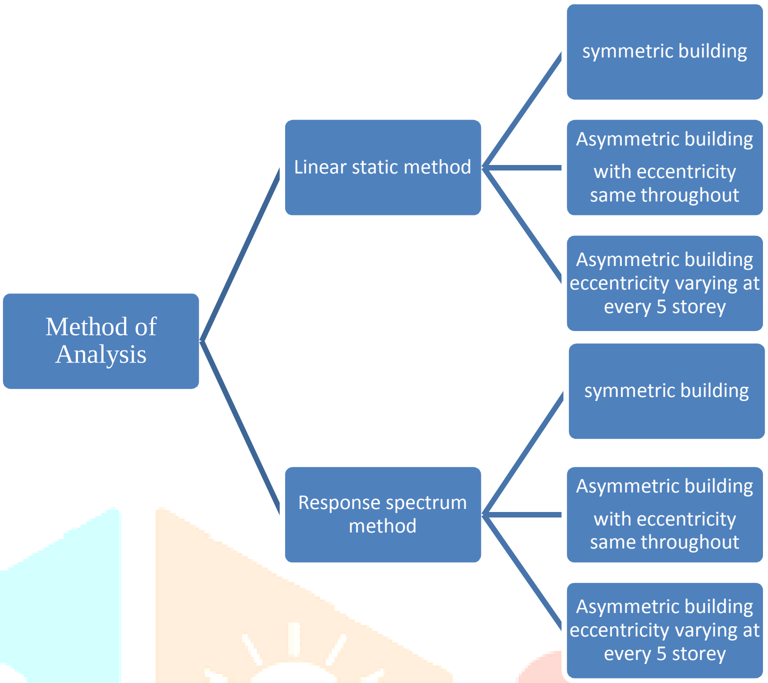


Fig.3.1. Flow chart representing the methodology

A 30 storied single frame model is taken for analysis, and the analysis is done using ETABS 2013. Tables 3.1, 3.2, 3.3, 3.4 shows the description of the model considered for study.

Table 3.1

PARAMETERS	VALUES
Seismic data	
Earthquake Zone	II , III ,IV, V
Damping ratio	5%
Importance factor	1
Type of soil	Medium soil
Responce reduction factor	5(SMRF)
Time period, sec	2.19
Dimensions of building and material properties	
Total height of building at roof level	90m
Dimension of building	4mX4m
Height of each storey	3m
Grade of concrete	M30
Grade of reinforcement steel	Fe500; Fe415

Model 1 – symmetric 30 storey building

Table3. 2: Dimensions of structural members of model 1

PARAMETERS	VALUES
Dimensions of beam	500X500 mm
Dimensions of column	800X700 mm
Thickness of slab	150mm

MODEL 2 - Asymmetric building with eccentricity same throughout the building.

Table 3.3: Dimensions of structural members of model 2

PARAMETERS	VALUES	ECCENTRICITIES
Dimensions of beam	400X450 mm	
Dimensions of column	850X800-Along Grid 2	e_y=0.06
	800X800- Along Grid 1	e_y=0.06
Thickness of slab	150mm	

MODEL 3- Asymmetric building with eccentricity varying at every 5 storey.

Table 3.4: Dimensions of structural members of model 3

PARAMETERS	VALUES		ECCENTRICITIES
Dimensions of beam	400X450 mm		
Dimensions of column	Storey 1-5	800X700- Along Grid 2	e_y=0.578
		700X600- Along Grid 1	
	Storey 6-10	700X600- Along Grid 2	e_y=0.673
		600X500- Along Grid 1	
	Storey 11- 15	600X500- Along Grid 2	e_y=0.806
		500X400- Along Grid 1	
	Storey 16-20	500X400- Along Grid 2	e_y=0.98
		400X300- Along Grid 1	
	Storey 21-25	400X300- Along Grid 2	e_y=0.285
		300X300- Along Grid 1	
	Storey 25-30	300X300- Along Grid 2	e_y=0.698
		250X250- Along Grid 1	

Eccentricity calculation:

Eccentricity of each storey is calculated manually.

Centre of mass:

CM= $[\frac{\sum M * X}{\sum M}]$

Where, M= mass of slab

Centre of stiffness:

CSx= $[\frac{\sum Ky * X}{\sum Ky}]$

CSy= $[\frac{\sum Kx * Y}{\sum Kx}]$

Where, X and Y = Distance from origin to centre of column

Kx and Ky = stiffness of column in X and Y direction

Stiffness of column K = $\frac{12EI}{L^3}$

E= $5000\sqrt{fck}$

Moment of inertia I = $\frac{bd^3}{12}$

Eccentricity e_x = CM-CSx

e_y = CM-CSy

<u>For Model 2:</u>

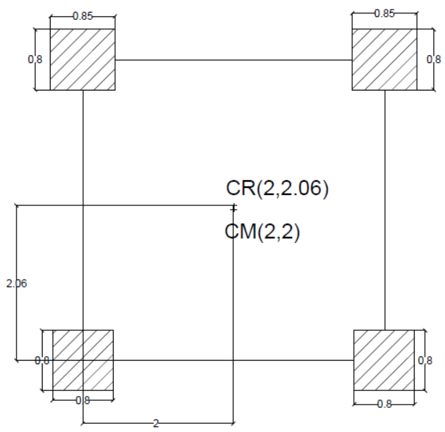


Fig 3.2: centre of mass and centre of rigidity of Model 2.

For model 2- Eccentricity e_x = CM-CSx= 2-2=0

e_y = CM-CSy=2-2.06=0.06

<u>For Model 3:</u>

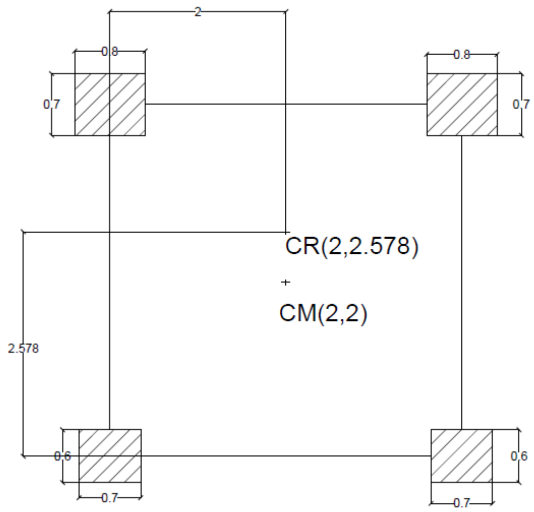


Fig 3.3:CM and CR for storey1-5 in model 3.

Eccentricity e_x = CM-CSx= 2-2=0

e_y = CM-CSy=2-2.578=0.578

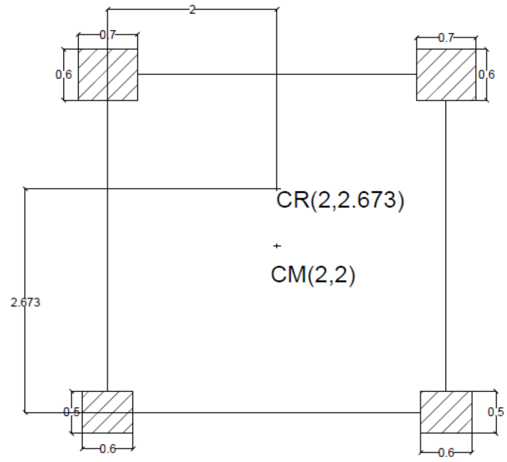


Fig 3.4:CM and CR for storey6-10 in model 3.

Eccentricity e_x = CM-CSx= 2-2=0

e_y = CM-CSy=2-2.673=0.673

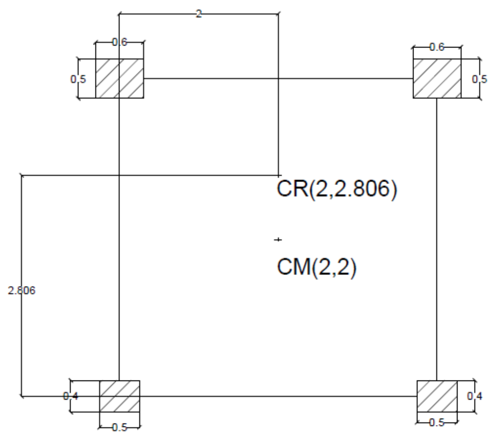


Fig 3.5:CM and CR for storey11-15 in model 3.

Eccentricity e_x = CM-CSx= 2-2=0

e_y = CM-CSy=2-2.806=0.806

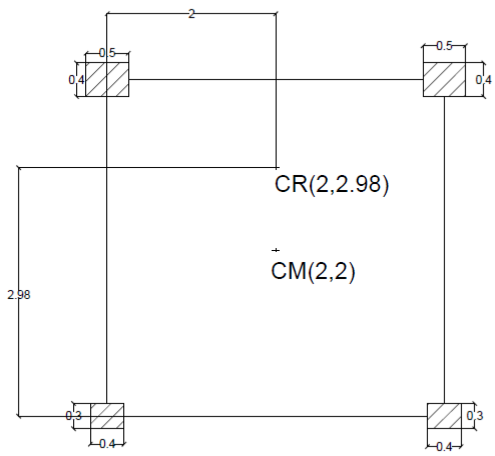


Fig 3.6:CM and CR for storey15-20 in model 3.

Eccentricity e_x = CM-CSx= 2-2=0

e_y = CM-CSy=2-2.98=0.98

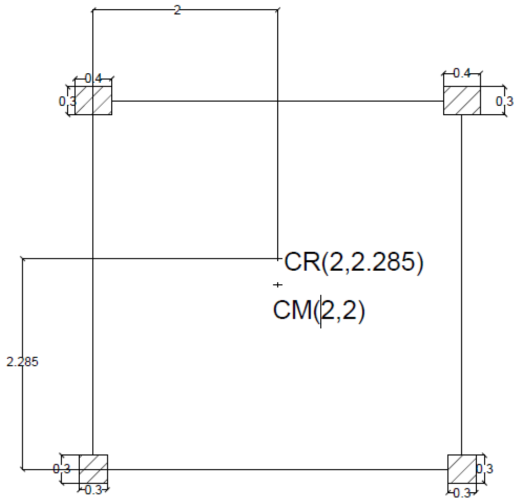


Fig 3.7:CM and CR for storey21-25 in model 3.

Eccentricity e_x = CM-CSx= 2-2=0

e_y = CM-CSy=2-2.285=0.285

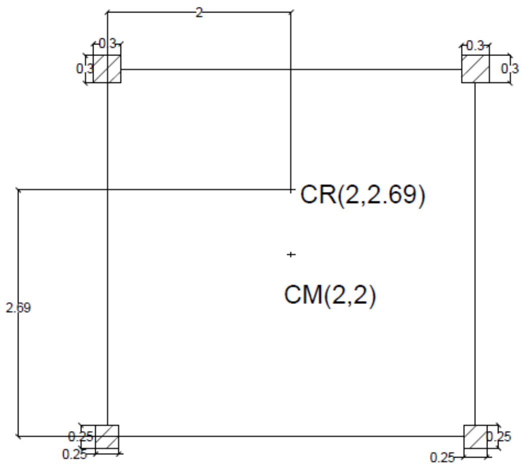


Fig 3.8:CM and CR for storey25-30 in model 3.

Eccentricity e_x = CM-CSx= 2-2=0

e_y = CM-CSy=2-2.69=0.69

4. RESULT AND DISCUSSION

a) Variations in Base Shear:

Figure 4.1, 4.2, 4.3 and 4.4 shows the comparison of base force values of all the three models in various seismic zones considered.

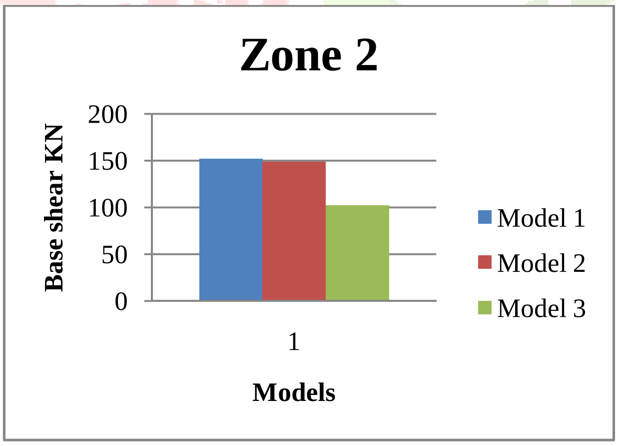


Fig.4.1Comparisons of base shear values for models in zone 2

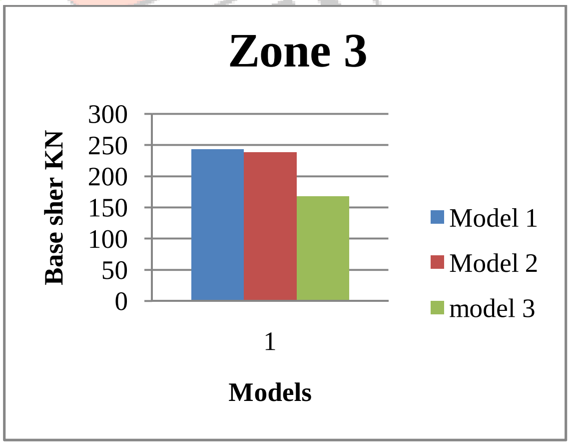
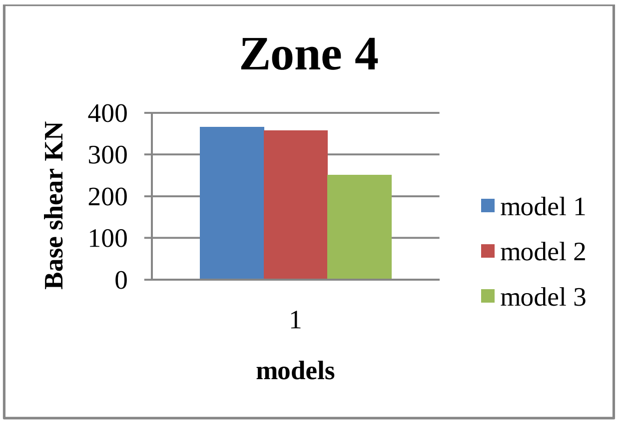


Fig.4.2Comparisons of base shear values for models in zone 3



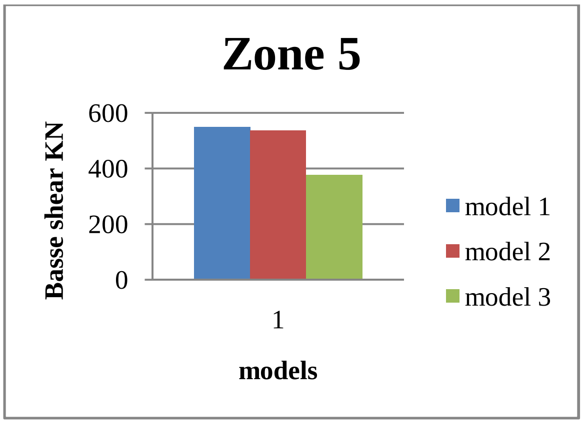


Fig.4.3 Comparisons of base shear values for models in zone 4.

Fig.4.4 Comparisons of base shear values for models in zone 5

b) Variations of storey displacements:

Figure 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, and 4.12 show the comparison of Displacements value in linear static method and response spectrum method of all the three models in various seismic zones considered.

i) Displacement results from linear static analysis:

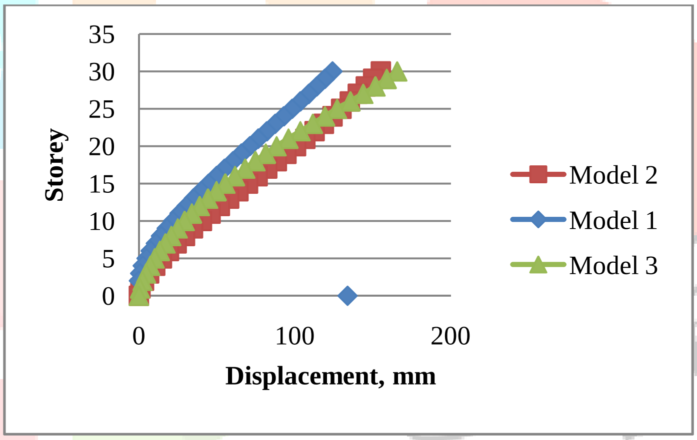


Fig4.5 Comparison of displacement for different models in Zone2

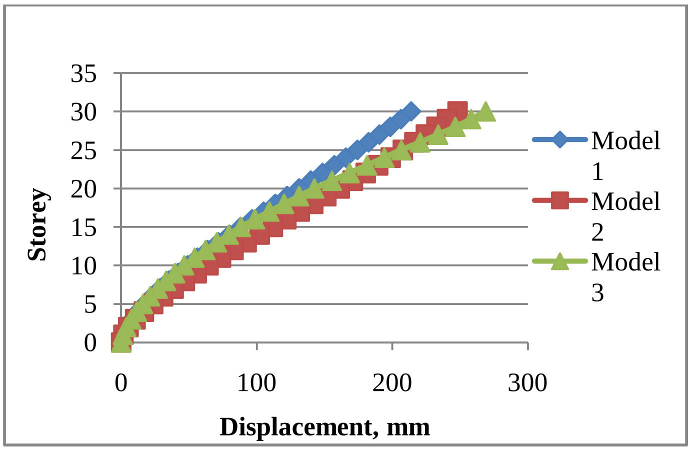


Fig.4.6 Comparison of displacement for different models in Zone3

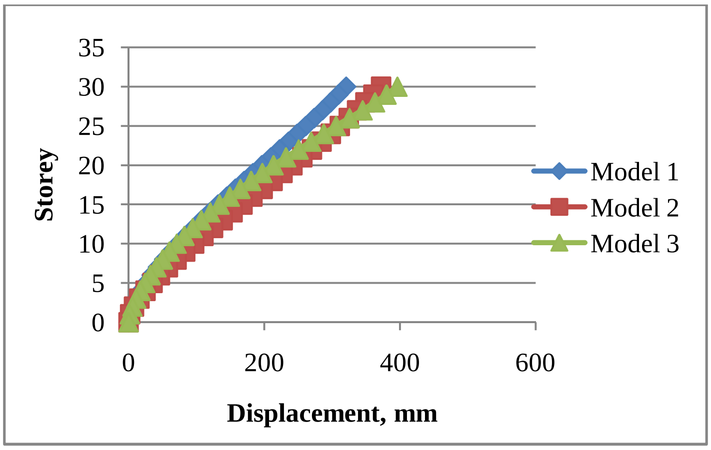


Fig.4.7 Comparison of displacement for different models in Zone4

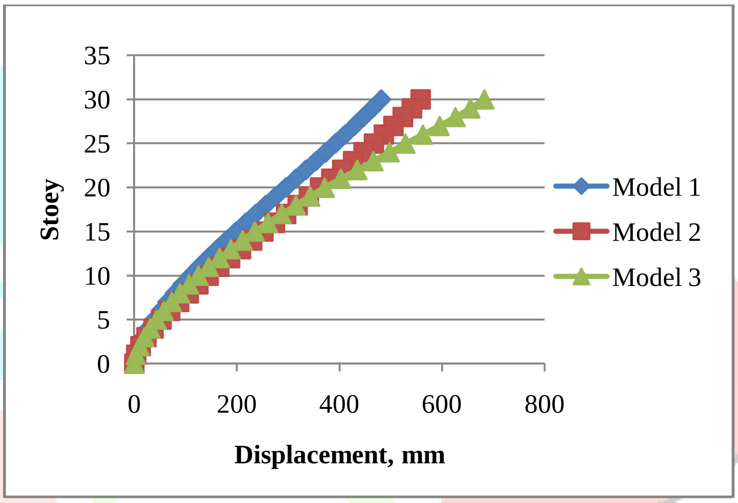


Fig4.8 Comparison of displacement for different models in Zone5

ii) Displacement results from response spectrum analysis:

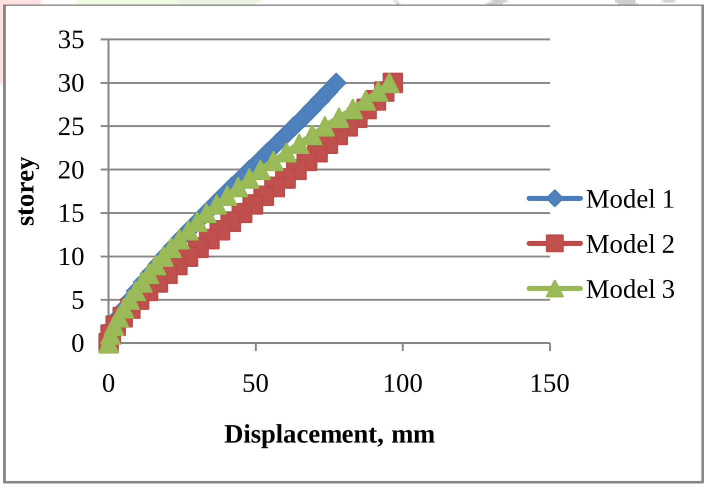


Fig.4.9Comparison of Displacement in response spectrum method for different models in Zone2

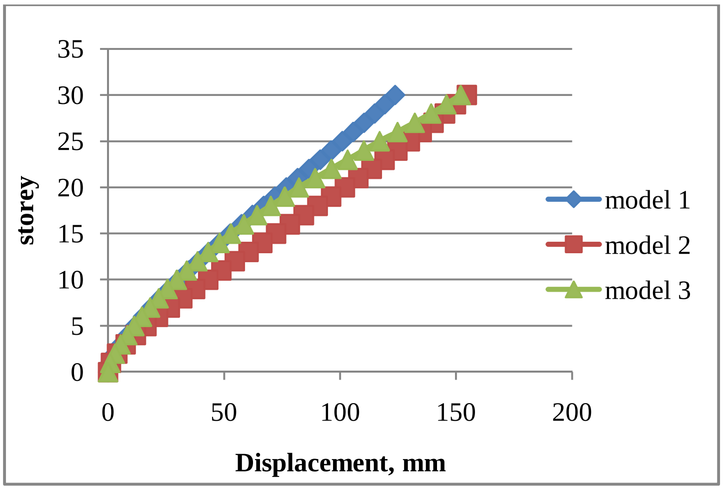


Fig4.10Comparison of Displacement in response spectrum method for different models in Zone3

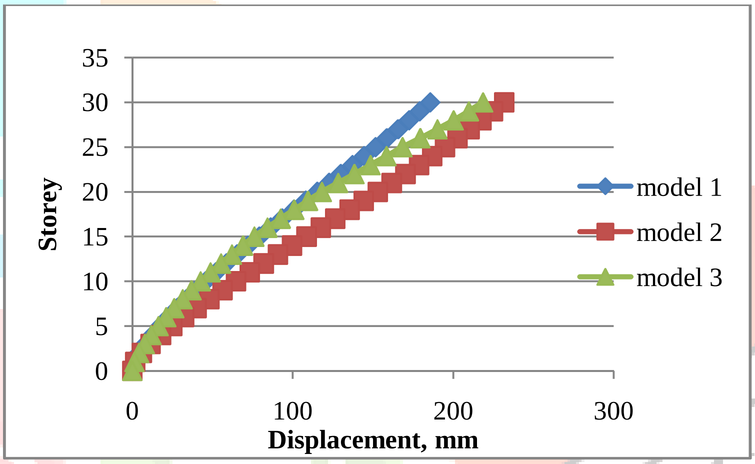


Fig4.4.11 Comparison of Displacement in response spectrum method for different models in Zone4

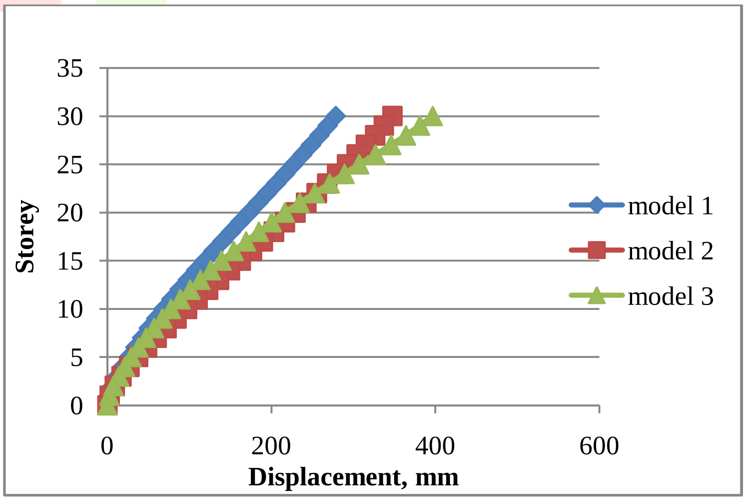


Fig4.4.12 Comparison of Displacement in response spectrum method for different models in Zone5

c) Variations of storey drifts:

Figure 4.13, 4.14, 4.15, 4.16, 4.17, 4.18, 4.19, and 4.20 show the comparison of Displacements value in linear static method and response spectrum method of all the three models in various seismic zones considered.

i) Drift results from linear static analysis:

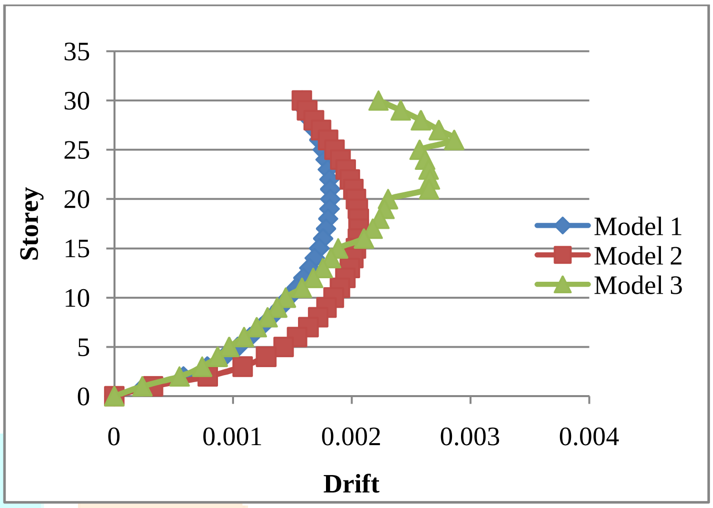


Fig.4.13 Comparison of Drifts for different models in Zone2

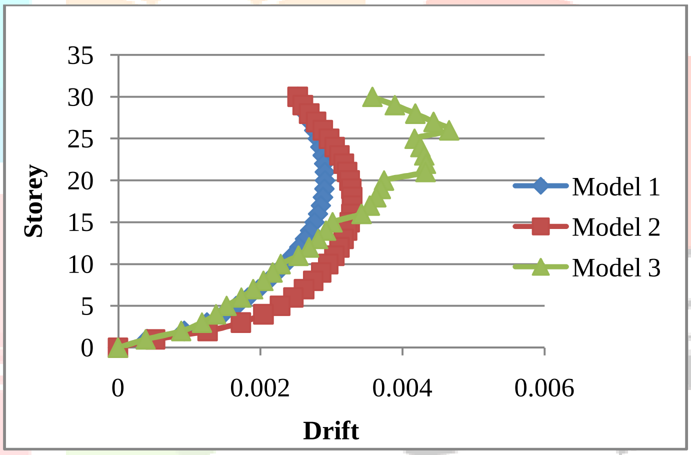


Fig.4.14Comparison of Drifts for different models in Zone

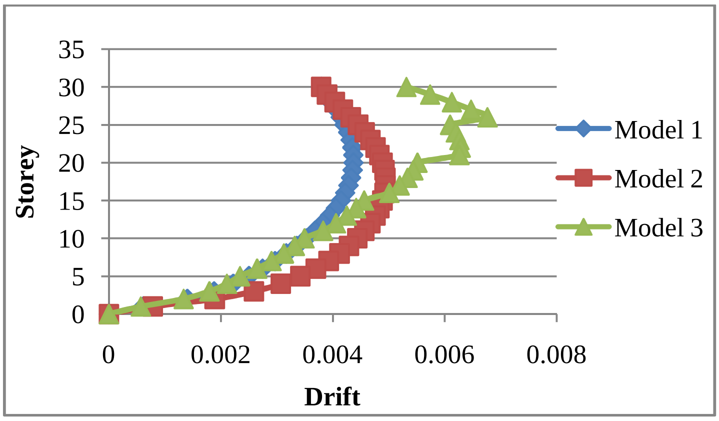


Fig4.4.15 Comparison of Drifts for different models in Zone4

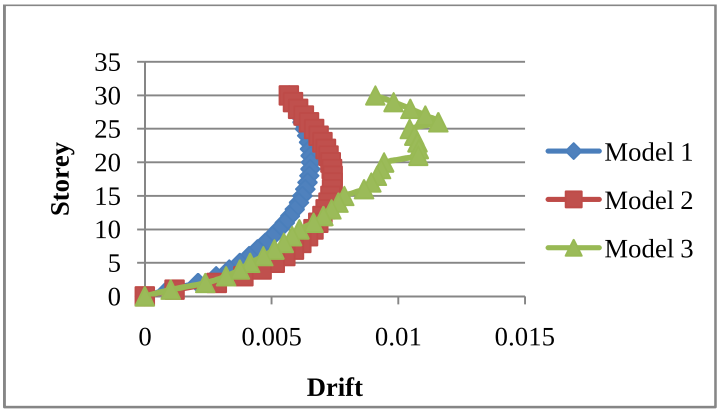


Fig4.4.16 Comparison of Drifts for different models in Zone5

ii) Drift results from response spectrum analysis:

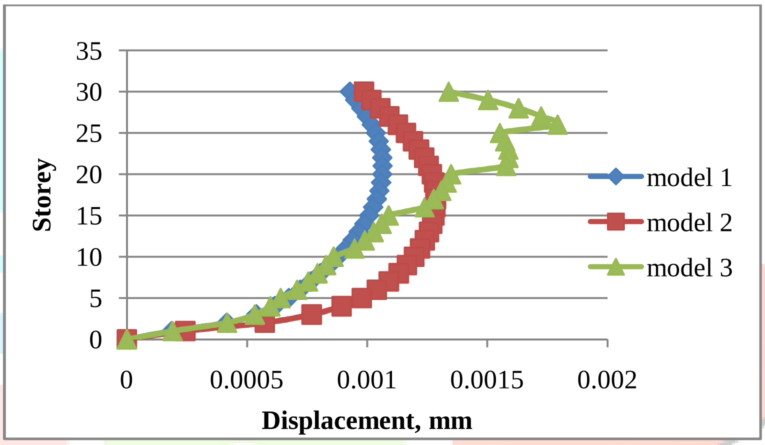


Fig.4.17 Comparison of Drifts in response spectrum method for different models in Zone2

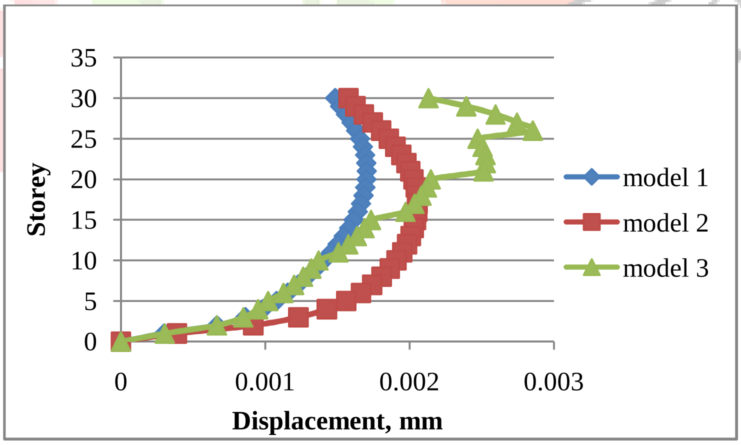


Fig4.18. Comparison of Drifts in response spectrum method for different models in Zone3

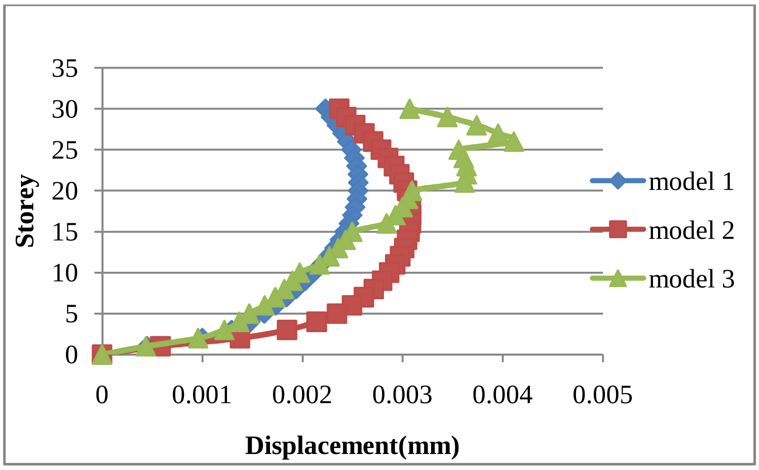


Fig.4.19 Comparison of Drifts in response spectrum method for different models in Zone4

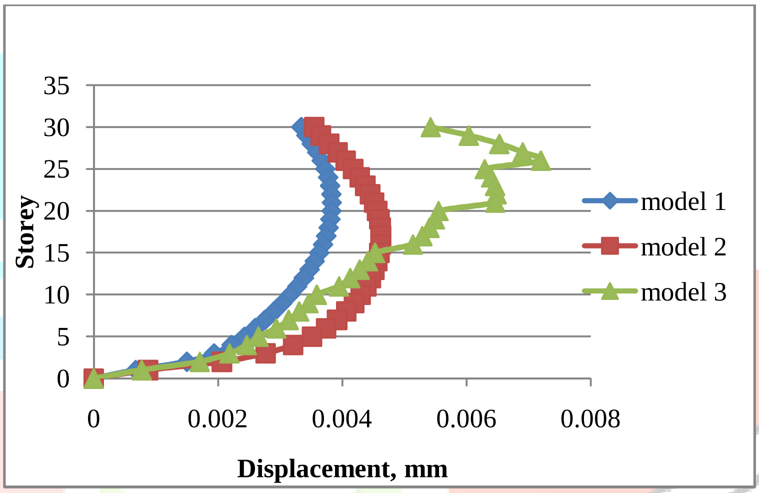


Fig4.20 Comparison of Drifts in response spectrum method for different models in Zone5

d) Pushover Analysis:

To study the non linear behaviour of structure, Model 3 is considered. 3D pushover analysis was carried out, for the simplification purpose two frames of model 3 along X direction is taken separately and analysis was carried out manually in ETABS.

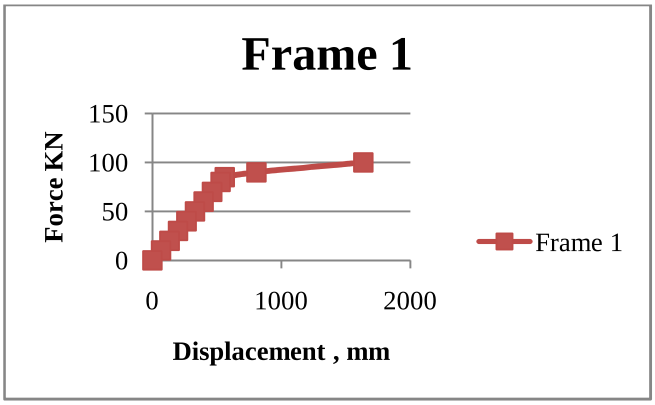


Fig4.21. force Vs displacement curves in frame 1

Ductility ratio= [1633/560.122] = 2.915

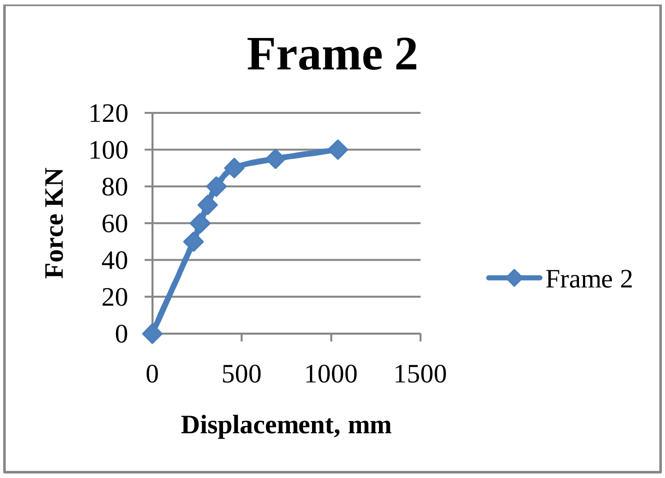


Fig.4.22. force Vs displacement curves in frame 2

Ductility ratio= [1037.57/457.73] = 2.266

5. CONCLUSIONS

- The deformation values are smaller in response spectrum analysis when compared to linear static analysis.
- Since base shear values depend upon the building height, dimensions, and building mass, there is not much difference in base shear values of linear static and response spectrum analysis.
- Base shear values of model 1 are more when compared to those of model 3.
- On comparing the displacement results of model 1, model 2, and model 3, it is seen that displacements are less in case of symmetric building when compared to those of asymmetric building.
- On comparing the storey drifts results of model 1, model 2, and model 3, it is seen that storey drifts are less in case of symmetric building when compared to those of asymmetric building.
- Ductility ratios obtained from pushover analysis are 2.915 for frame 1 and 2.266 for frame 2 of model 3.

6. REFERENCES

1) Mallikadevi Palli et al.[2014] [1] “analysis and design of multi-storey building with plan irregularity to opt a suitable structural framing”
2) Ashish R et al. [April-June 2015] [2] “Seismic Design of R.C.C. Buildings with Plan Irregularity”
3) Prof. Milind V. Mohod [Jul. - Aug. 2015] [3] “Pushover Analysis of irregular plan structure”.
4) Rajalakshmi K R et al. [June 2015] [4] “Torsion Effects on Building Having Mass and Stiffness Irregularities”,
5) K. Sandeep Kumar et al. [April 2016] [5] “Plan Irregularities with Different Shear Wall Location in a High Rise Building under Dynamic Loads”.
6) Dr. Y. M. Ghugal et al.[JULY, 2016] [6] “Seismic Design of R.C.C. Buildings with plan Irregularities”
7) Desai R.M et al.[Nov – Dec 2016] [7] “Behaviour of Symmetric and Asymmetric Structure in Zone 5” .
8) IS-875 (Part-1)-1987 code of practice for design loads (other than earthquake loads) for buildings and structures: part-1 for dead loads.
9) IS: 1893 (Part 1): 2016. “Criteria for Earthquake Resistant Design of Structures”, Bureau of Indian Standards, New Delhi.