SEISMIC EVALUTION OF IRREGULAR STRUCTURE USING STAAD PRO

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ABSTRACT: During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. For example structures with soft storey were the most notable structures which collapsed. So, the effect of vertically irregularities in the seismic performance of structures becomes really important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the regular building. The aim of this project is to carry out Time history Analysis (THA) of vertically irregular RC. Regular and irregular buildings of G+10 modelled and analysed in Staad pro software. Comparison of the results of analysis and design of irregular structures with regular structure was carried out.

1. INTRODUCTION

1.0 General

During an earthquake, collapse of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure.

Vertical irregularities are one of the main reasons of collapse of structures during earthquakes. For example structures with soft storey were the most prominent structures which collapsed. So, the effect of vertically irregularities in the seismic performance of structures becomes really important. Height-wise changes in stiffness render the dynamic characteristics of these buildings different from the regular building. IS 1893 definition of Vertically Irregular structures: The irregularity in the building structures may be due to irregular distributions in their mass, strength and stiffness along the height of building. When such buildings are constructed in high seismic zones the analysis and design becomes more complicated.

There are two types of irregularities-

1. Plan Irregularities.

2. Vertical Irregularities.

Vertical Irregularities are mainly of five types-

 a) Stiffness Irregularity — Soft Storey-A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

b) Stiffness Irregularity — Extreme Soft Storey-An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above. ii) Mass Irregularity-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. In case of roofs irregularity need not be considered.

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

iv) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force-An in-plane offset of the lateral force resisting elements greater than the length of those elements.

v) Discontinuity in Capacity — Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above.

1.2 Back ground of irregular building

Vertical irregularities in structure are very common attribute in urban area. In most of situation, buildings become vertically irregular at the planning phase itself due to some architectural and functional reasons. This type of buildings verified more vulnerability in the past earthquakes. The topics related to of vertical irregularities have been in centre of research for a long time. Many studies have been carried out in this area in deterministic domain. Hence the centre of present study is to assess the relative performance of typical vertically irregular buildings in a Probabilistic domain.

This type of irregularities arises due to unexpected decline of stiffness or strength in a particular storey. For high seismic zone area, irregularity in building is

perhaps a great challenge to a good structural engineer. A large number of vertical irregular structures exist in present urban infrastructures. Among them Open ground storey as well as stepped types of buildings are very general in Urban India. A typical Open Ground Storey and a Stepped irregular framed building are shown in Figure.

Figure 1 Irregular buildings

1.3 Scope of the study

1. RC buildings are considered.

2. Vertical irregularity was studied.

3. Linear elastic analysis was done on the structures.

4. Column was modelled as fixed to the base.

5. Ductility based design of the buildings as per the analysis results

1.3 Criteria for vertical irregularity in buildings

In the past code of IS 1893, there was no plan suggestions especially for OGS outlines said for vertical anomaly. However in the repercussions of Bhuj earthquake was modified in 2002. In late form of code IS 1893 (2002) (part1), joined another plan proposal for OGS structures. It needn't to plan the light emissions delicate story likewise to outline for higher story shears as suggested by the above provision. Fortifying of pillars will additionally build the request on the sections, and deny the plastic development in the bars. Suggestions

have met with some protection in outline and development rehearses because of blockage of overwhelming support in the section. According to IS 1893 (2002) code, five sorts of inconsistencies for structures are drilled down as takes after:

a) Stiffness Irregularity - Soft Story: is characterized to exist when there is a story in which the parallel firmness is under 70% of that in the story above or under 80% of the normal solidness of the three stories above.

b) Weight (Mass) Irregularity - It is considered to exist where the viable mass of any story is over 150% of the compelling mass of an adjoining story.

c) Vertical geometric anomaly - It might be considered to exist where the flat measurement of the parallel power opposing framework in any story is over 130% of that in a nearby story.

d) In-plane Discontinuity - In Vertical Lateral-Force-Resisting Elements is characterized to exist where an in-plane counterbalance of the parallel power opposing components is more prominent than the length of those components or where there is a decrease in firmness of the opposing component in the story beneath.

e) Discontinuity in Capacity - The powerless story is one in which the story sidelong quality is under 80% of that in the above story. The story horizontal quality is the aggregate parallel quality of all seismic-opposing components sharing the story shear in the thought heading.

2. LITERATURE REVIEW

Sadjadi et al. (2007) presented an analytical approach for seismic assessment of RC frames using nonlinear time history analysis and push-over analysis. The analytical models were validated against available experimental results and used in a study to evaluate the seismic behaviour of these 5-story frames. It was concluded that both the ductile and the less ductile frames behaved very well under the earthquake considered, while the seismic performance of the GLD structure was not satisfactory. The retrofitted GLD frame had improved seismic performance.

Kim and Elnashai (2009) observed that buildings that are seismically designed to contemporary codes would have survived the earthquake. But, the vertical motion would have significantly reduced the shear capacity in vertical members.

Duan et al. (2012) According to the numerical results, the structures designed by GB50011-2010 provides the inelastic behaviour and response intended by the code

and satisfies the inter-storey drift and maximum plastic rotation limits recommended by ASCE/SEI 41-06. The push-over analysis indicated the potential for a soft first story mechanism under significant lateral demands.

Poonam et al. (2012) Results of the numerical analysis showed that any storey, especially the first storey, must not be softer/weaker than the storeys above or below. Irregularity in mass distribution also contributes to the increased response of the buildings. The irregularities, if required to be provided, need to be provided by appropriate and extensive analysis and design processes. Moehle found that standard limit analysis and static inelastic analysis provide good measures of strength and deformation characteristics under strong earthquake motions.

Sarkar et al. (2010) proposed a new method of quantifying irregularity in vertically irregular building frames, accounting for dynamic characteristics (mass and stiffness). The salient conclusions were as follows:

(1)A measure of vertical irregularity, suitable for stepped buildings, called ‗regularity index', is proposed, accounting for the changes in mass and stiffness along the height of the building.

(2) An empirical formula is proposed to calculate the fundamental time period of stepped building, as a function of regularity index.

Karavasilis et al. (2008) studied the inelastic seismic response of plane steel moment-resisting frames with vertical mass irregularity. The analysis of the created response databank showed that the number of story's, ratio of strength of beam and column and the location of the heavier mass influence the height-wise distribution and amplitude of inelastic deformation demands, while the response does not seem to be affected by the mass ratio.

3. METHODOLOGY AND MODELING

3.1 Equivalent Static Method

The equivalent static method is the simplest method of analysis because the forces depend on the code based fundamental period of structures with some empirical modifiers. The design base shear is to be computed as whole, and then it is distributed along the height of the building based on some simple formulae appropriate for buildings with regular distribution of mass and stiffness. The design lateral force obtained at each floor shall then be distributed to individual lateral load resisting elements depending upon the floor diaphragm action.

Inherently, equivalent static lateral force analysis is based on the following assumptions,

- Structure is rigid.

- Perfect fixity exit between structure and foundation.
- During ground motion every point on the structure experience same accelerations
- Dominant effect of earthquake is equivalent to horizontal force of varying magnitude over the height.
- Approximately determines the total horizontal force (Base shear) on the structure.

3.1 Time History Analysis

Regular and various types of irregular buildings were analyzed using THA and the response of each irregular structure was compared with that of regular structure as per IS code Ground motion. The IS code ground motion used for the analysis had PGA of 0.2g and duration of 40 seconds.
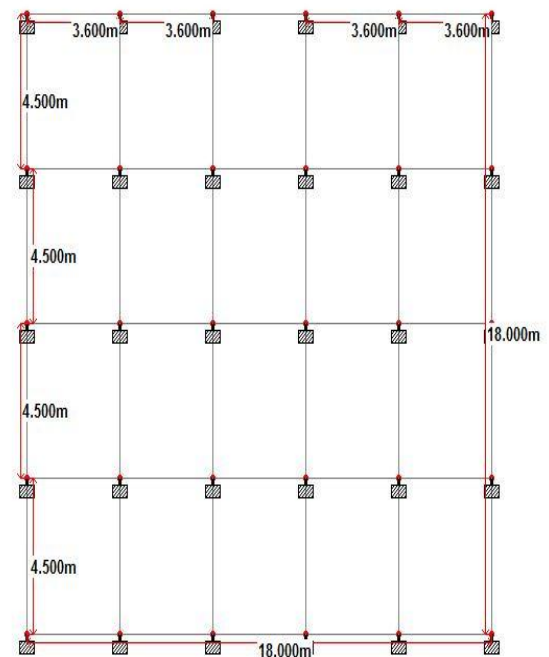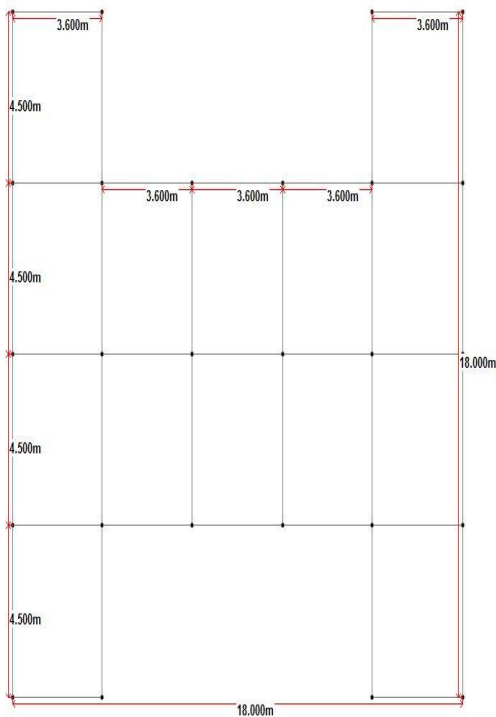

Figure 1. Regular Building
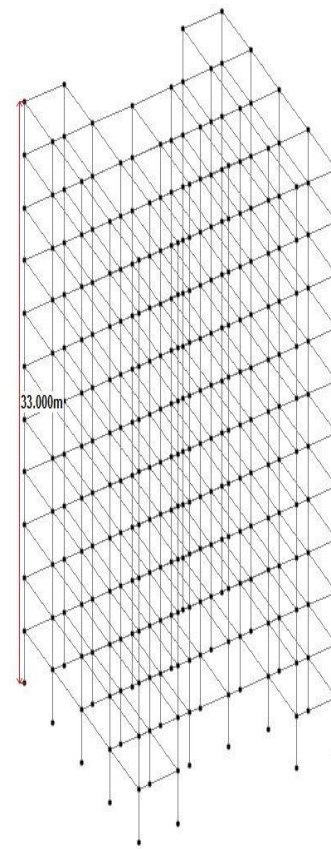
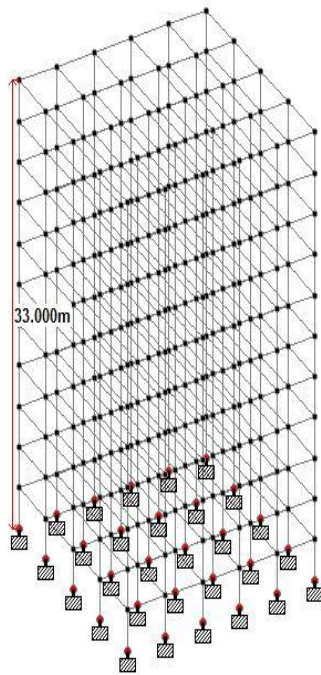**Figure 2. Irregular H type Irregular Building**

Figure 4. Elevation of Irregular Structure

3.3 Preliminary Data

Type of frame: Ordinary RC moment resisting frame fixed at the base

- Seismic zone: III
- Number of storeys: 10
- Floor height: 3 m
- Plinth height: 3 m
- Depth of Slab: 125 mm
- Spacing between frames: 3.6 m along x directions 4.5 along y direction.
- Live load on floor level: 2 KN/m2
- Live load on roof level: 1.5 KN/m2
- Floor finish: 1.0 KN/m2
- Thickness of outer wall: 230mm (Exterior walls)
- Thickness of inner wall: 115mm (Interior walls)
- Density of concrete: 25 KN/m2
- Type of soil: Medium
- Time History Analysis: As per IS 1893(Part1):2002
- Damping of structure: 5 %

Figure 3. Elevation of Regular Structure

Live load on floor level and roof level are taken from IS-875 (Part-)

3.4 Member and Material Properties:

Dimensions of the beams and columns are determined on the basis of trial and error process in analysis of Staadpro software by considering nominal sizes for beams and columns and safe sizes are as show in the table below.

Beams: 350mmx400mm

Columns: 450mmx600mm

Material properties of the building are like M_{30} grade of concrete, FE415 steel in the buildings.

Dead Load:

Floor finish: 1. 0 kN/m2

Internal wall load: = 6 KN/m

External wall load: 12 KN/m

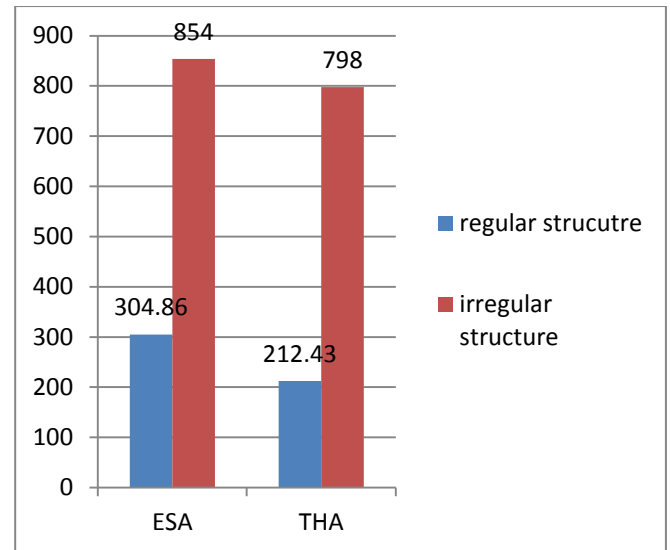Parapet Wall: 3KN/m

Live Load:

For typical floors: 2 kN/m2

For top floor: 1.5 kN/m

4. RESULTS AND DISCUSSION

4.1 Comparison of Base Shear

Table 1: Comparison of Base Shear

Model	ANALYSIS	Base Shear (KN)
Regular	ESA	304.86
Irregular		212.43
Regular	THA	854
Irregular		798

Graph 1. Comparison of Base shear for regular and irregular Building

4.2 comparison of Bending Moment, Shear Force for Regular structure.

Table 2: Comparison of Bending and shear forces

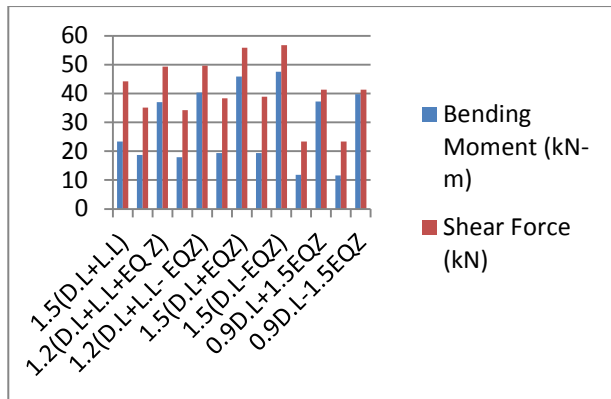| Load Combinations	STAADPRO	
	Bending Moment (kN-m)	Shear Force (kN)
1.5(D.L+L.L)	23.40	44.15
1.2(D.L+L.L+EQ X)	18.71	35.13
1.2(D.L+L.L+EQ Z)	37.03	49.32
1.2(D.L+L.L- EQX)	17.93	34.25
1.2(D.L+L.L- EQZ)	40.32	49.62
1.5(D.L+EQX)	19.41	38.34
1.5(D.L+EQZ)	45.91	55.8
1.5(D.L-EQX)	19.32	38.91
1.5(D.L-EQZ)	47.49	56.68
0.9D.L+1.5EQX	11.83	23.34
0.9D.L+1.5EQZ	37.18	41.3
0.9D.L-1.5EQX	11.55	23.36
0.9D.L-1.5EQZ	39.78	41.29

Figure 5. Bending Moment, Shear Force, for Regular structure under different load combination

4.3 Comparison of axial force of regular structure.

Table 3: Comparison of Axial force of regular structure

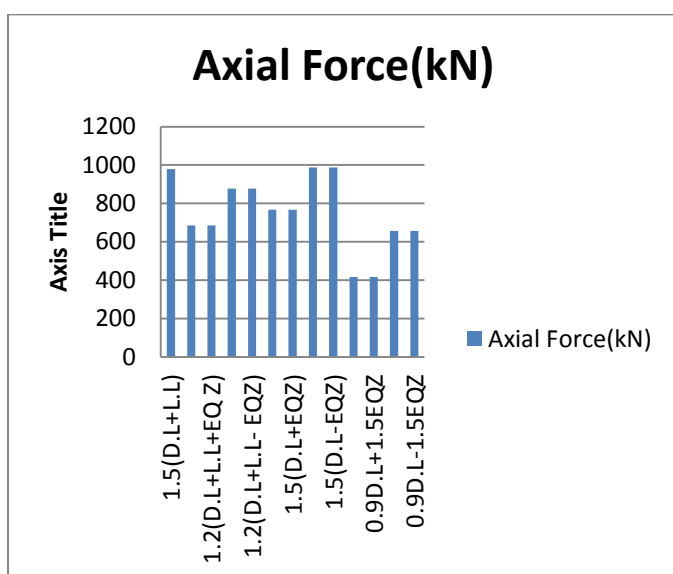| Load Combinations	Axial Force(kN)
1.5(D.L+L.L)	979.5
1.2(D.L+L.L+EQX)	685.59
1.2(D.L+L.L+EQZ)	685.59
1.2(D.L+L.L-EQX)	877.73
1.2(D.L+L.L-EQZ)	877.73
1.5(D.L+EQX)	767.66
1.5(D.L+EQZ)	767.66
1.5(D.L-EQX)	987.8
1.5(D.L-EQZ)	987.8
0.9D.L+1.5EQX	416.5
0.9D.L+1.5EQZ	416.5
0.9D.L-1.5EQX	656.7
0.9D.L-1.5EQZ	656.7

Figure 6. Axial force of regular structure under different load combination

4.4 Comparison of axial force of irregular structure.

Table 4: Comparison of Axial force of irregular structure

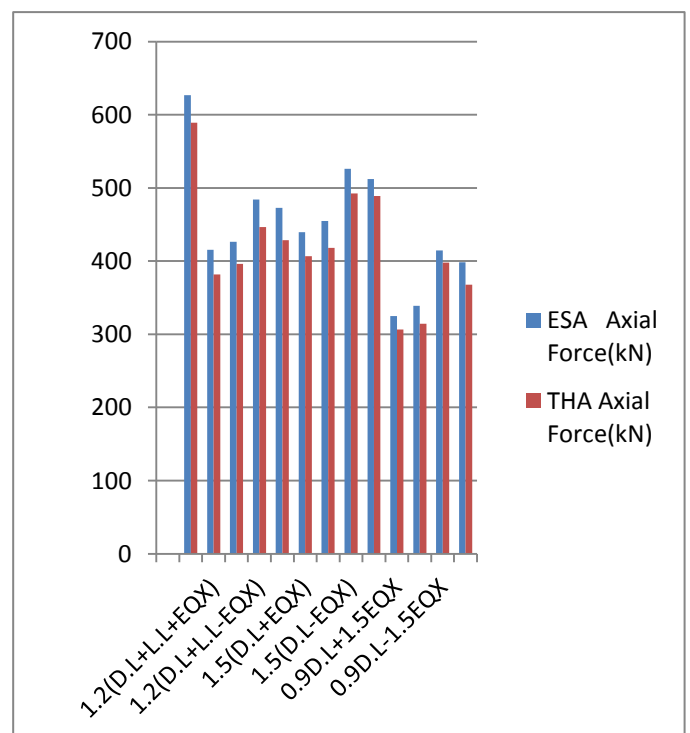| Load Combinations	ESA	THA
	Axial Force(kN)	Axial Force(kN)
1.5(D.L+L.L)	626.89	589.3
1.2(D.L+L.L+EQX)	415.6	381.78
1.2(D.L+L.L+EQZ)	426.2	396.14
1.2(D.L+L.L-EQX)	484.24	446.4
1.2(D.L+L.L-EQZ)	472.53	428.61
1.5(D.L+EQX)	439.34	406.75
1.5(D.L+EQZ)	454.92	418.17
1.5(D.L-EQX)	525.9	492.48
1.5(D.L-EQZ)	512.2	489.13
0.9D.L+1.5EQX	325.04	306.55
0.9D.L+1.5EQZ	338.7	314.32
0.9D.L-1.5EQX	414.6	397.89
0.9D.L-1.5EQZ	398.21	367.56

Figure 7. Axial force of irregular structure under different load combination

4.5 Comparison of axial force of irregular structure.

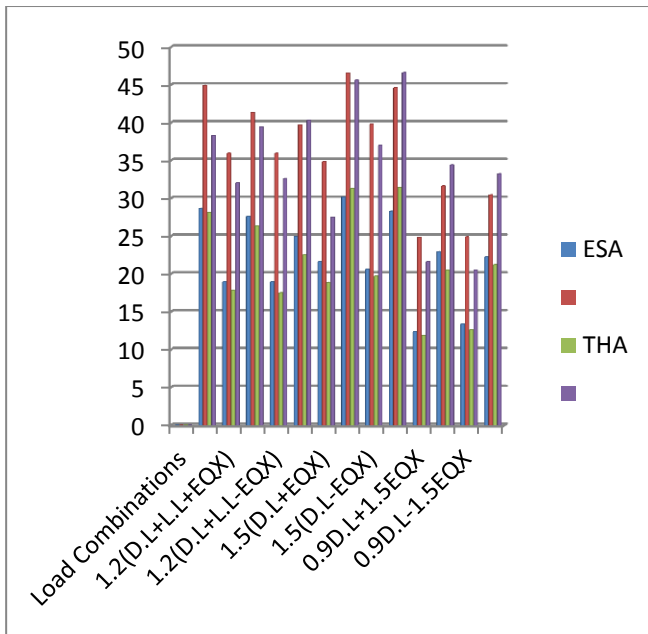### Table 5: Comparison of Bending and shear force of irregular structure

Load Combinations	ESA		THA	
	Bending Moment (kN-m)	Shear Force (kN)	Bending Moment (kN-m)	Shear Force (kN)
1.5(D.L+L.L)	28.66	44.92	28.12	38.3
1.2(D.L+L.L+EQX)	18.93	35.94	17.85	32.01
1.2(D.L+L.L+EQZ)	27.59	41.32	26.36	39.4
1.2(D.L+L.L-EQX)	18.92	35.93	17.5	32.6
1.2(D.L+L.L-EQZ)	24.96	39.69	22.5	40.3
1.5(D.L+EQX)	21.6	34.81	18.87	27.5
1.5(D.L+EQZ)	30.17	46.53	31.3	45.6
1.5(D.L-EQX)	20.59	39.8	19.7	37.02
1.5(D.L-EQZ)	28.29	44.6	31.4	46.6
0.9D.L+1.5EQX	12.36	24.84	11.85	21.6
0.9D.L+1.5EQZ	22.94	31.61	20.5	34.4
0.9D.L-1.5EQX	13.35	24.88	12.6	20.5
0.9D.L-1.5EQZ	22.22	30.45	21.2	33.24

Figure 7. Bending and shear force of irregular structure under different load combination

5. CONCLUSION

Two types of structures were modelled one regular and one irregular. THA was conducted for regular and irregular and the storey bending, axial and shear forces obtained were compared with that of regular structure. Three types of ground motion with varying frequency content, i.e., low (imperial), intermediate (IS code), frequency were considered. Finally, design of above mentioned regular and irregular building frames was carried out corresponding to ESA and THA and the results were compared. Our results can be summarized as follows-

- It has been seen that base shear for THA analysis model structure is more compare to ESA analysised structure.
- Axial force values for regular structure under ESA analysis is more than the irregular structure in the same time the ESA analysis on the irregular structure is 1-2 % more than THA analyzed model.
- Bending and shear force values of irregular structure under THA analysis is lesser than ESA.
- Dynamic analysis gives lesser values for all parameters than static analysis. Hence, dynamic analysis is economical.

6. REFEERNCES

- Comparison of design results of a Structure designed using STAAD and ETABS Software, International Journal of Civil and Structural Engineering, Volume 2, No 3, 2012

- Design and Practical Limitations in Earthquake Resistant Structures and Feedback. International Journal of Civil Engineering and Civil Engineering (IJCIET), Volume 5, Issue 6, June (2014), pp. 89-93

- Bahador Bagheri, Ehsan Salimi Firozabad, and Mohammadreza Yahyaei., "Comparative Study of the Static and Dynamic Analysis of Multi-Storey Irregular Building"

- Dr. S.K. Dubey, "Seismic Behavior of Asymmetric RC Buildings" Department of Civil Engineering, MANIT, Bhopal

- K.S. Babu Narayan and M.H. Prashanth, "Seismic Performance Evaluation of RC Buildings with Vertical Irregularity" Department of Civil Engineering, National Institute of Technology Karnataka, Surathkal, Karnataka, India