STAAD Pro Based Seismic Analysis and Design of Step-Up Buildings

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ABSTRACT

Stepped building with vertical geometric irregularity is now increasingly encountered in modern urban areas. During an earthquake, collapse of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of Building. The Building having this discontinuity is termed as Irregular structures. The behaviour of a structure during an earthquake depends on several factors such as stiffness, adequate lateral strength, ductility and configuration. The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less harm compared to those of irregular configurations. Irregular building contributes a large portion of urban infrastructure. The aim of this study is to carry out Response spectrum analysis (RSA) and Time history Analysis (THA) of vertically irregular RC structure and to carry out the ductility based design by using IS 13920 corresponding to Equivalent static analysis and Time history analysis. Regular and irregular buildings (stepped buildings) are modelled and analysed in staad pro software. Comparison of the results of analysis and design of irregular building with regular building was carried out.

I. INTRODUCTION

Vertical irregularity is one of the major reasons of failure of structures during earthquakes. For example building with soft storey be the most notable building which collapsed. So, the effect of vertically irregularities in the seismic performance of structures becomes actually 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 structures 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-

I. Stiffness Irregularity
II. Stiffness
III. Mass Irregularity
IV. Vertical Geometric Irregularity
V. In-Plane Discontinuity.
VI. Discontinuity in Capacity

1. 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&2 Irregular buildings

2. Scope of the study

- RC buildings are considered.
- Vertical irregularity was studied.
- Linear elastic analysis was done on the structures.
- Column was modelled as fixed to the base.
- The contribution of infill wall to the stiffness was not considered. Loading due to infill wall was taken into account.
- Ductility based design of the buildings as per the analysis results

II. METHODOLOGY AND MODELING

1. Response spectrum analysis

RSA analysis was performed on regular and various irregular buildings using Staad-Pro. The storey shear forces were considered for each floor and graph was plotted for each structure.

Regular structure (10 storeys):

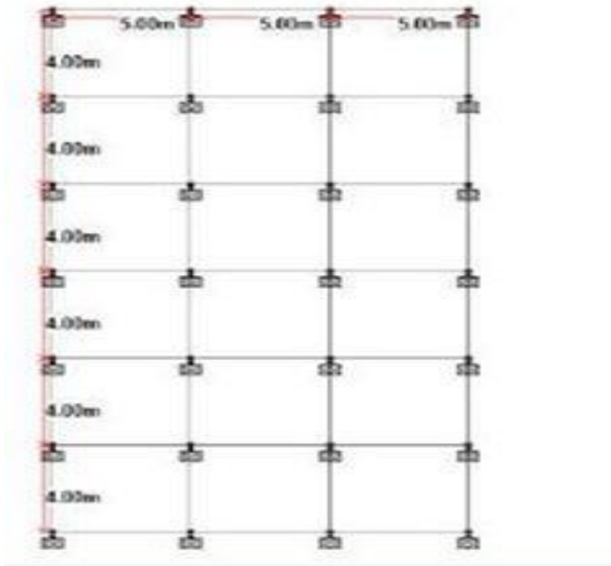


Figure 3 plan of regular structure

Mass Irregular Structure : The structure is modelled as same as that of regular structure except the loading due to swimming pool is provide in the 4th and 8th floor.
Height of swimming pool considered- 1.8m
Loading due to swimming pool - 20 kN/m2

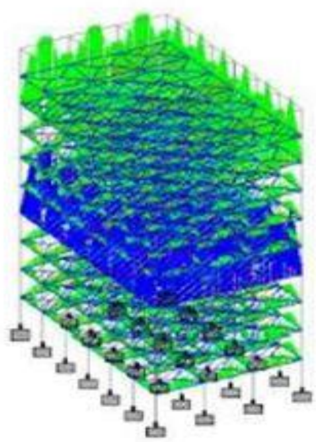


Figure 4. 3D view of mass regular structure with swimming pools on 4th and 8th storeys

Stiffness Irregular Structure (Soft Storey): The structure is same as that of regular structure but the ground storey has a height of 4.5 m and doesn‘t has brick infill.
Stiffness of each column= 12EI/L3
Therefore,
Stiffness of ground floor/stiffness of other floors= (3.5/4.5)3 =0.47<0.7
Hence as per IS 1893 part 1 the structure is stiffness irregular.

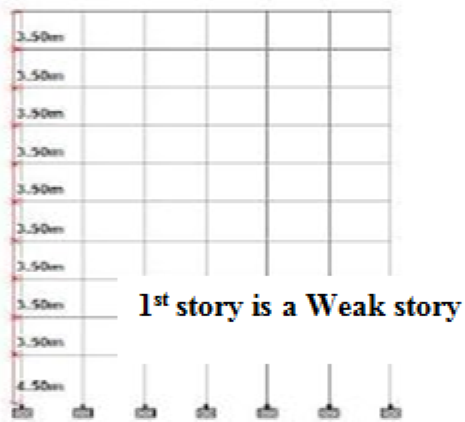


Figure 5. Stiffness irregular structure

Vertically Geometric Irregular: The structure is 14 storied with steps in 5th and 10th floor. The setback is along X direction.
Width of top storey= 20m
Width of ground storey=40
40/20=2>1.5
Hence, as per IS 1893, Part 1 the structure is vertically geometric irregular structure.

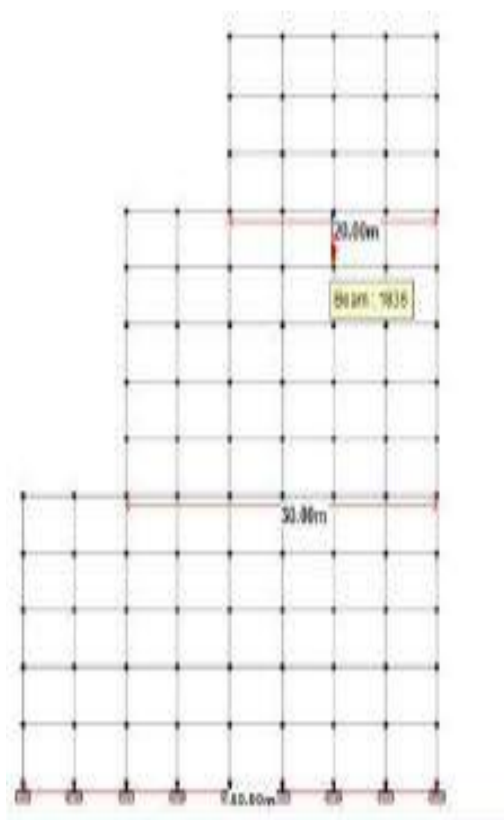
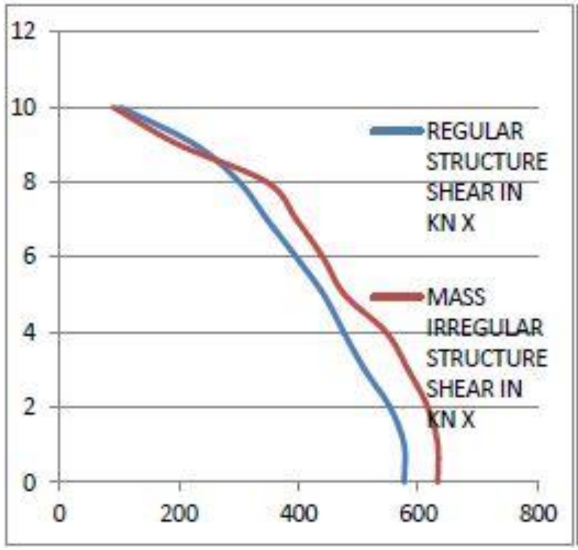
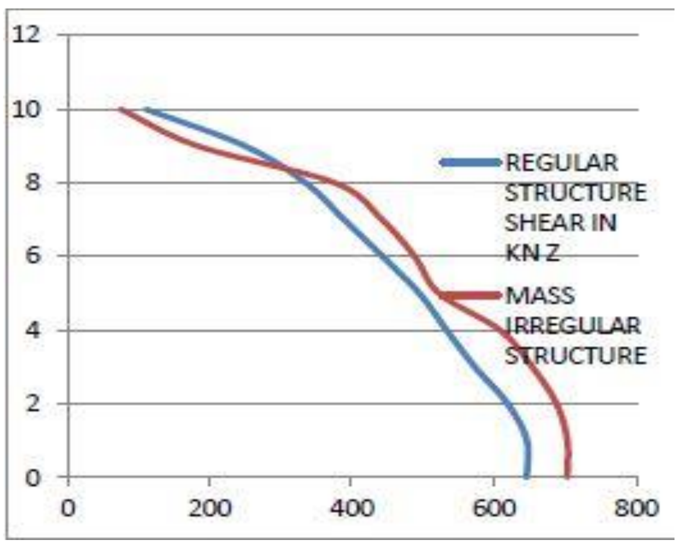


Figure 6.Vertical Geometric irregular structure

2. Results

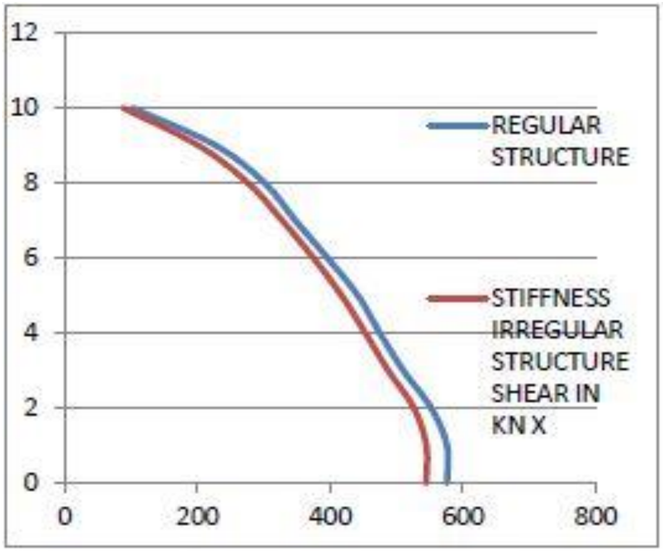


Graph1.Evaluation of Peak storey shear forces of Regular structure and Mass Irregular structure in KN X

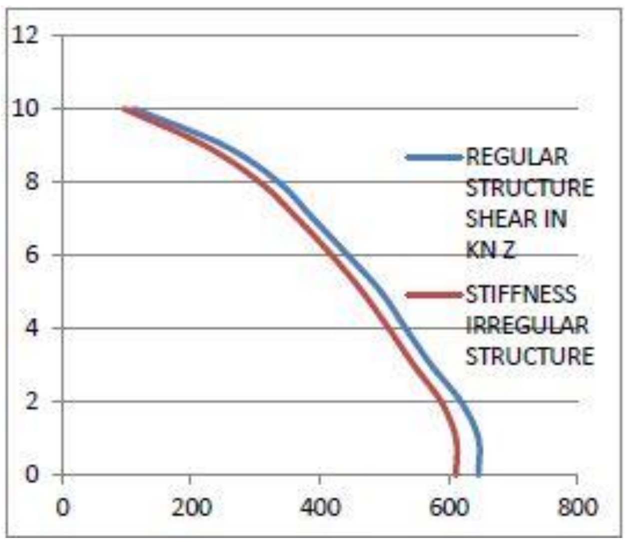


Graph 2. Evaluation of Peak storey shear forces of Regular structure and Mass Irregular structure in KN Z.

The storey shear force is Moree in ground storey and it decreases as we move up in the structure. Mass irregular storey shear force is more in lower storeys as compared to regular structure. The graph closes in as we move up the structure and the mass irregular storey shear force becomes less than that in regular structure above 8th storey.



Graph 3. Evaluation of Peak storey shear forces of Regular structure and Stiffness Irregular structure in KN X



Graph 4. Evaluation of Peak storey shear forces of Regular structure and Stiffness Irregular structure in KN X.

The Stiffness Irregular structure has a ground storey height of 4.5m (more than height of the above storeys). This makes the building less stiff than regular structure. Hence the inter storey drift is examine to be more in stiffness irregular structure. And hence, the storey shear force is more in regular structure as compare to stiffness irregular structure.

III. 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.

Regular structure

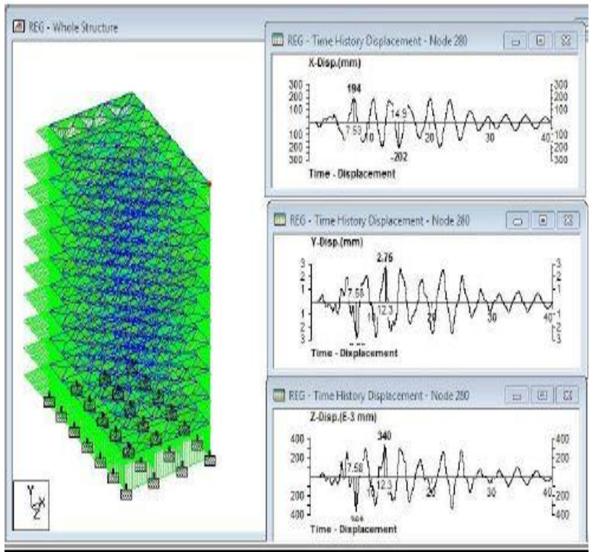


Figure7.THA displacement of the highlighted node of regular structure

Stiffness irregular structure

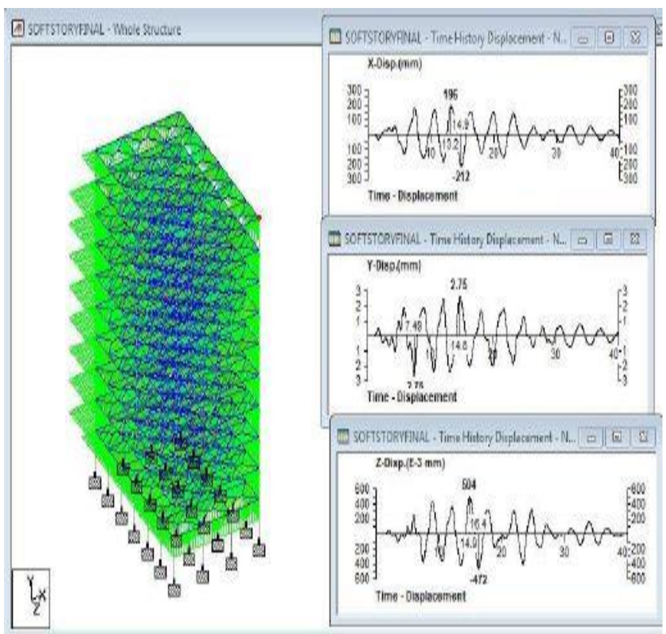


Figure 8.THA displacement of the highlighted node of stiffness irregular structure

Mass irregular structure

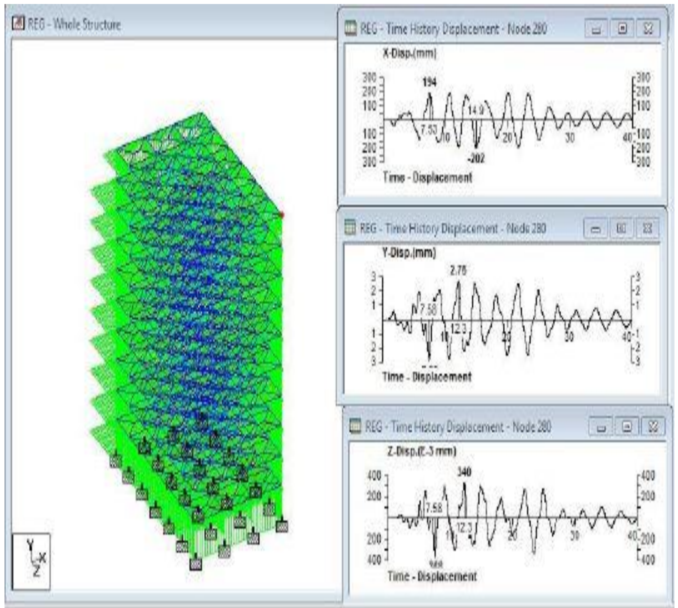


Figure 9.THA displacement of the highlighted node of mass irregular structure

Vertically geometric irregular structure

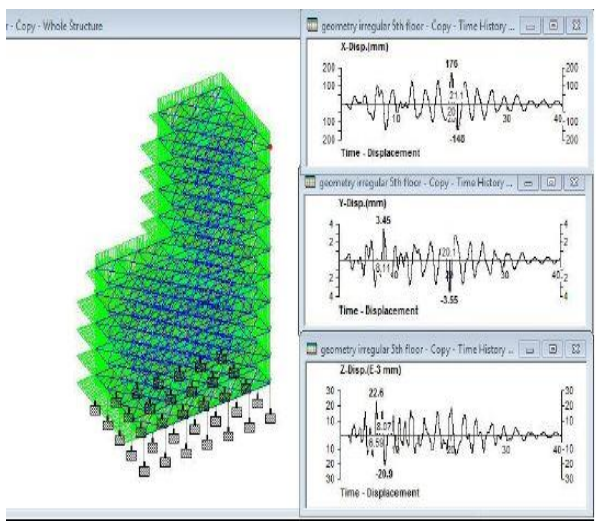
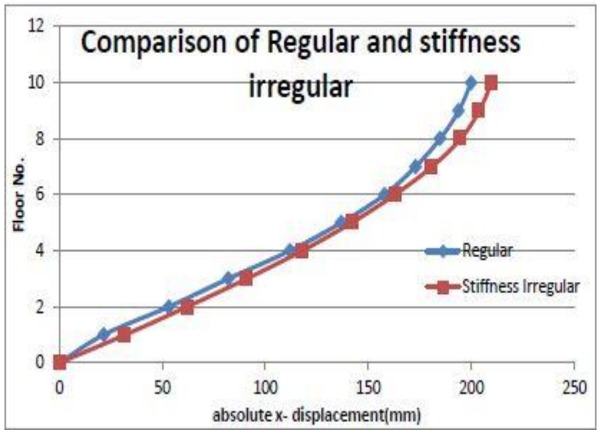


Figure 10. THA displacement of the highlighted node of geometry irregular structure

The above figures show that THA displacements of the topmost node of regular, stiffness irregular and geometry irregular structure respectively. Similarly THA displacements were obtained for other floors in the structure and the maximum displacement was plotted in the graph. The graphs of Irregular structure were compared with that of Regular structure.

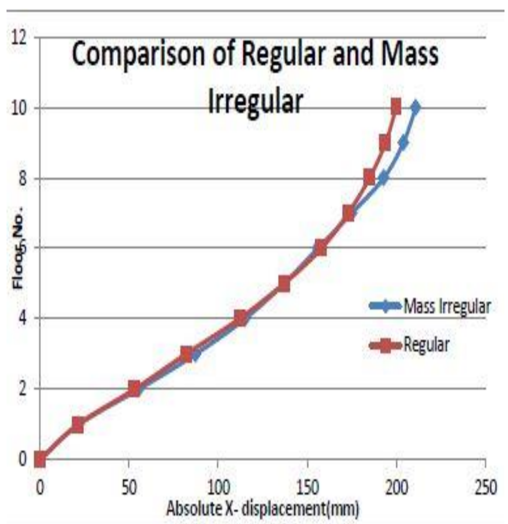
1. Results



Graph 5.Evaluation of displacements along x-direction of regular and stiffness irregular structure.

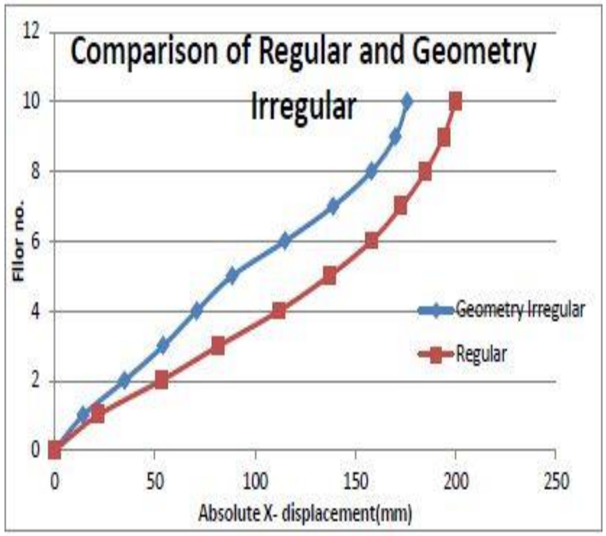
Due to less stiff ground storey the inter storey drift is found to be more in stiffness irregular structure. Hence, the floor displacement is more in stiffness irregular structure than regular structure.

Comparison of Time history displacements of different floors of Regular structure and Mass Irregular structure



Graph 6. Comparison of displacements along x-direction of regular and mass irregular structure

Mass irregular structure has swimming pool in 4th and 8th floor hence the 4th storey displacement is more in mass irregular structure. The effect of extra mass is found to be more in 8th storey where higher inter storey drift is observed. Higher the position of extra mass the moment of the inertial force is more leading to larger displacement.



Graph 7. Evaluation of displacements along x-direction of regular and geometry irregular structure

In geometry irregular structure the stiffness up to 5th storey is more than that of regular structure. So the displacement in lower storey's of geometry irregular structure is very less as compared to regular structure. But at 5th storey due to setback there is a sudden increase in the displacement and hence there is decrease in slope of the graph. The mass, stiffness and vertical irregularties are comparing with regular and irregular buildings and the reinforcement details are calculated.

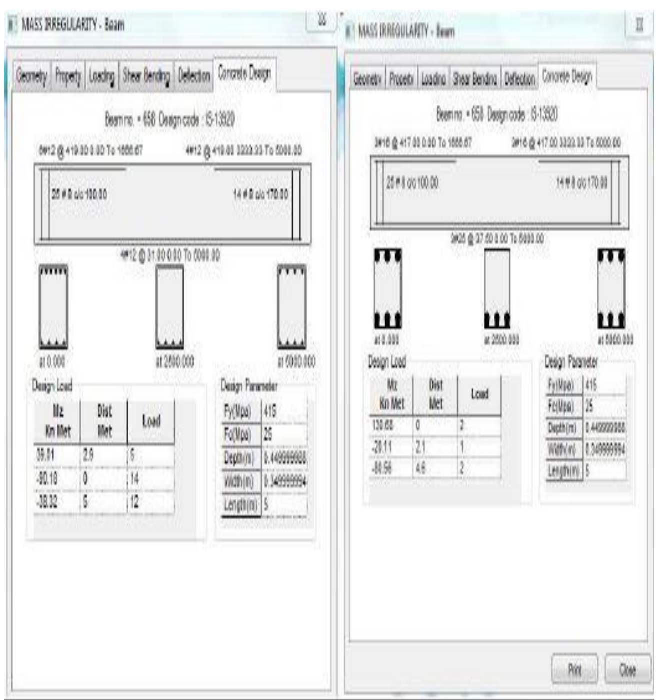


Figure 11.Design of beam as per ESA and THA

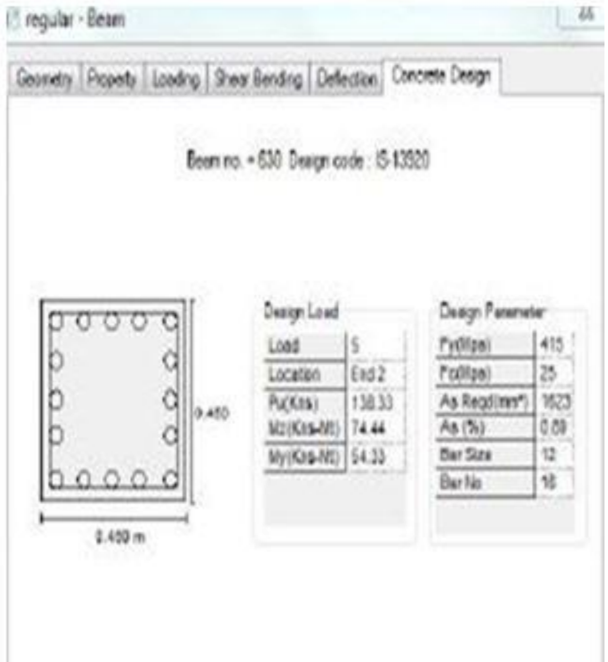


Figure 12. Design of Column as per ESA and THA

IV. CONCLUSION

Three types of irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were considered. RSA was conducted for each type of irregularity and the storey 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), high (San Francisco) frequency were considered. Time history analysis (THA) was conducted for each type of irregularity corresponding to the above mentioned ground motions and nodal displacements were compared. Finally, design of above mentioned irregular building frames was carried out corresponding to ESA and THA and the results were compared. Our results can be summarized as follows-

- According to results of RSA, the storey shear force was found to be more for the first storey and it decreased to a minimum in the top storey.
- According to results of RSA, mass irregular building frames experience larger base shear than related regular building frames.
- According to results of RSM, the stiffness irregular building experienced lesser base shear and has larger inter storey drifts.
- In case of a mass irregular structure, THA yielded slightly higher displacement for upper stories than that in regular building, When THA was done for regular as well as stiffness irregular building (soft storey),it was found that displacements of upper stories did not vary much from each other but as we moved down to lower stories the absolute displacement in case of soft storey were higher in regular building.
- Tall structures have low natural frequency hence their response was found to be maximum in a low frequency earthquake

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