A Study on Seismic Analysis and Design of High Rise Irregular Structures and Regular Structure By Using STAADPro

K. Raju[1], Mr.V L D Prasad Reddy[2]
[1, 2] Department of Civil Engineering
[1, 2] Kakinada Institute of Technology and Science, Divili.

Abstract- *Three Models of irregularity high rise (G+15Storeys) buildings namely mass irregularity, stiffness irregularity and vertical geometry irregularity And one Regular High Rise (G+15 storeys) building in the seismic Zone II at the location of Kakinada were considered. The project is to carry out Response spectrum analysis (RSA) and Time history Analysis (THA) of vertically irregular RC buildings and to carry out the ductility based design using IS 13920 corresponding to Response spectrum analysis and Time history analysis. I want to study on Comparison of the results of analysis and design of irregular structures with regular structures in the parameters of peak storey shears and Displacements. Comparison of Peak storey shear forces of regular structure and mass irregular structure, Comparison of Peak storey shear forces of regular structure and stiffness irregular structure, Comparison of displacements of regular structure and stiffness irregular structure, Comparison of displacements of regular structure and mass irregular structure, Comparison of displacements of regular structure and Geometry irregular structure, Comparison of design based on RSA and THA. If we will do so much calculation for a high rise building manually then it will take more time as well as human errors can be occurred. So the use of STAAD-PRO will make it easy. STAAD-PRO can solve typical problem like Static analysis, Seismic analysis and Natural frequency. These type of problem can be solved by STAAD-PRO along with IS-CODE.*

Keywords- Response spectram analysis, Time History Analysis, Base Shear, Peak storey shear, Displacement etc.

I. INTRODUCTION

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.

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-

i 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

II. LITERATURE RIEVIEW

Rajeeva and Tesfamariam (2012) Fragility based seismic vulnerability of structures with consideration of soft -storey (SS) and quality of construction (CQ) was demonstrated on three, five, and nine storey RC building frames designed prior to 1970s. Probabilistic seismic demand model (PSDM) for those gravity load designed structures was developed, using non-linear finite element analysis, considering the interactions between SS and CQ. The response surface method is used to develop a predictive equation for PSDM parameters as a function of SS and CQ. Result of the analysis shows the sensitivity of the model parameter to the interaction of SS and CQ.

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 storeys, 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. Athanassiadou (2008) concluded that the effect of the ductility class on the cost of buildings is negligible, while performance of all irregular frames subjected to earthquake appears to be equally satisfactory, not inferior to that of the regular ones, even for twice the design earthquake forces. DCM frames were found to be stronger and less ductile than the corresponding DCH ones. The over strength of the irregular frames was found to be similar to that of the regular ones, while DCH frames were found to dispose higher over strength than DCM ones. Pushover analysis seemed to underestimate the response quantities in the upper floors of the irregular frames.Lee and Ko (2007) subjected three 1:12 scale 17-story RC wall building models having different types of irregularity at the bottom two stories to the same series of simulated earthquake excitations to observe their seismic response characteristics. The first model had a symmetrical moment-resisting frame (Model 1), the second had an infilled shear wall in the central frame (Model 2), and the third had an infilled shear wall in only one of the exterior frames (Model 3) at the bottom two stories. The total amounts of energy absorption by damage are similar regardless of the existence and location of the infilled shear wall. The largest energy absorption was due to overturning, followed by the shear deformation.

Devesh et al. (2006) agreed on the increase in drift demand in the tower portion of set-back structures and on the increase in seismic demand for buildings with discontinuous distributions in mass, strength and stiffness. The largest seismic demand was found for the combined stiffness and strength irregularity. It was found out that seismic behavior is influenced by the type of model.

Shahrooz and Moehle (1990) undertook an experimental and analytical study to understand the earthquake response of setback structures. The experimental study involved design, construction, and earthquake simulation testing of a quarter-scale model of a multistory, reinforced concrete, setback frame. The analytical studies involved design and inelastic analysis of several multistory frames having varying degrees of setbacks. Among the issues addressed were:

(1) The influence of setbacks on dynamic response;
(2) The adequacy of current static and dynamic design requirements for setback buildings; and
(3) Design methods to improve the response of setback buildings.

Valmundsson and Nau(1997) evaluated the earthquake response of 5-, 10-, and 20story framed structures with non-uniform mass, stiffness, and strength distributions. The response calculated from TH analysis was compared with that predicted by the ELF procedure embodied in UBC. Based on this comparison, the aim was to evaluate the current requirements under which a structure can be considered regular and the ELF provisions applicable. Das (2000) found that most of the structures designed by ELF method performed reasonably well. Capacity based criteria must be appropriately applied in the vicinity of the irregularity.Sadjadi et al. (2007) presented an analytical approach for seismic assessment of RC frames using nonlinear time history analysis and push-over analysis.

III. METHODOLOGY

Building Type	:	High rise RC frames
Floor area	:	20.00m x 24.00m
Storey Height	:	3m
No. of Stories	:	G+15

Section details

MEMBER	SIZE (mm)
Plinth Beams	300 X 300
Floor & Roof Beams	300 X 450
Columns	450 X450
External Walls	230, 150 & 115
Internal Walls	115
Slab	150

1. Review of existing literatures by different researchers.
2. Selection of types of structures.
3. Modelling of the selected structures.
4. Performing dynamic analysis on selected building models and comparison of the analysis results.
5. Ductility based design of the buildings as per the analysis results.

IV. OBJECTIVES

1. To calculate the design lateral forces on regular and irregular buildings using response spectrum analysis and to compare the results of different structures.
2. To study three irregularities in structures namely mass, stiffness and vertical geometry irregularities.
3. To calculate the response of buildings subjected to various types of ground motions namely low, intermediate and high frequency ground motion using Time history analysis and to compare the results
4. To carry out ductility-based earthquake-resistant design as per IS 1893 corresponding to equivalent static analysis and time history analysis and to compare the difference in design.

V. ANALYSIS METHODS

SEISMIC ANALYSIS: 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. In the past the buildings were designed just for gravity loads and seismic analysis is a recent development. It is a part of structural analysis and a part of structural design where earthquake is prevalent. There are different types of earthquake analysis methods. Some of them used in the project are-

I. **Equivalent Static Analysis**
II. **Response Spectrum Analysis**
III. **Time History Analysis**

EQUIVALENT STATIC ANALYSIS:

The equivalent static analysis procedure is essentially an elastic design technique. It is, however, simple to apply than the multi-model response method, with the absolute simplifying assumptions being arguably more consistent with other assumptions absolute elsewhere in the design procedure. The equivalent static analysis procedure consists of the following steps:

1. Estimate the first mode response period of the building from the design response spectra.

2. Use the specific design response spectra to determine that the lateral base shear of the complete building is consistent with the level of post-elastic (ductility) response assumed.

3. Distribute the base shear between the various lumped mass levels usually based on an inverted triangular shear distribution of 90% of the base shear commonly, with 10% of the base shear being imposed at the top level to allow for higher mode effects.

RESPONSE SPECTRUM ANALYSIS:

This approach permits the multiple modes of response of a building to be taken into account. This is required in many building codes for all except for very simple or very complex structures. The structural response can be defined as a combination of many modes. Computer analysis can be used to determine these modes for a structure. For each mode, a response is obtained from the design spectrum, corresponding to the modal frequency and the modal mass, and then they are combined to estimate the total response of the structure. In this the magnitude of forces in all directions is calculated and then effects on the building is observed. Following are the types of combination methods:

- absolute **-** peak values are added together
- square root of the sum of the squares (SRSS)
- complete quadratic combination (CQC) **-** a method that is an improvement on SRSS for closely spaced modes.

The result of a RSM analysis from the response spectrum of a ground motion is typically different from that which would be calculated directly from a linear dynamic analysis using that ground motion directly, because information of the phase is lost in the process of generating the response spectrum.

In cases of structures with large irregularity, too tall or of significance to a community in disaster response, the response spectrum approach is no longer appropriate, and more complex analysis is often required, such as non-linear static or dynamic analysis.

TIME HISTORY ANALYSIS:_ Time history analysis techniques involve 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.

VI. TYPES OF LOAD USED

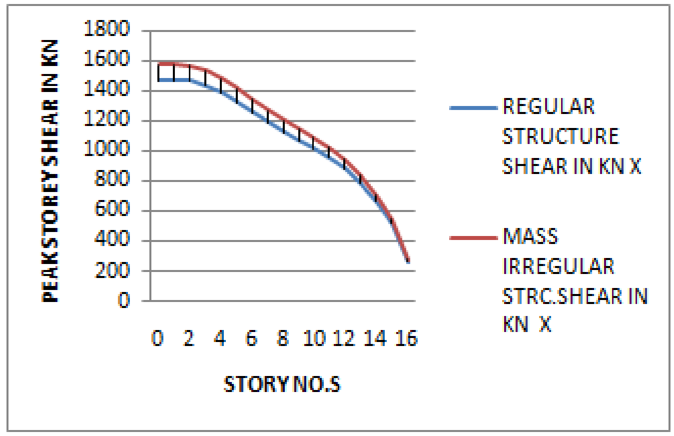
1. DEAD LOAD (DL):-DEAD LOAD is defined as the the load on a structure due to its own weight (self-weight). It also added other loads if some permanent structure is added to that structure.

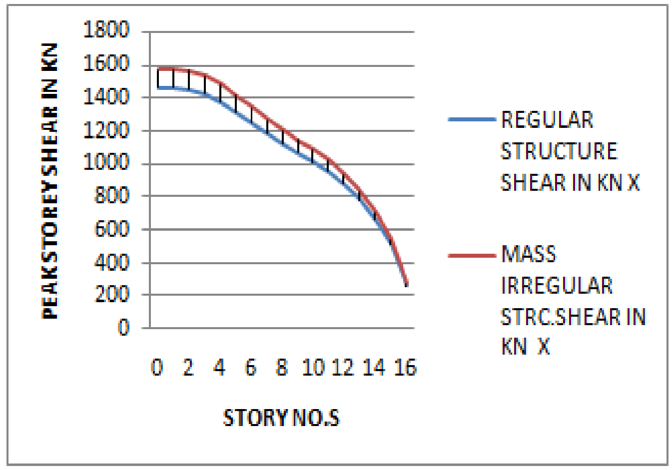
2. LIVE LOAD (LL):-LIVE LOAD Or IMPOSED LOAD is defined as the load on the structure due to moving weight. The LIVE LOAD varies according to the type of building. For example generally for a Residential Building the LIVE LOAD is taken as 4kN/m2.

3. SEISMIC LOAD (SL):-SEISMIC LOAD can be calculated taking the view of acceleration response of the ground to the super structure. According to the severity of earthquake intensity they are divided into 4 zones.
   Zone I and II are combined as zone II.
   Zone III.
   Zone IV.
   Zone V.

VII. RESULTS AND DISCUSSION

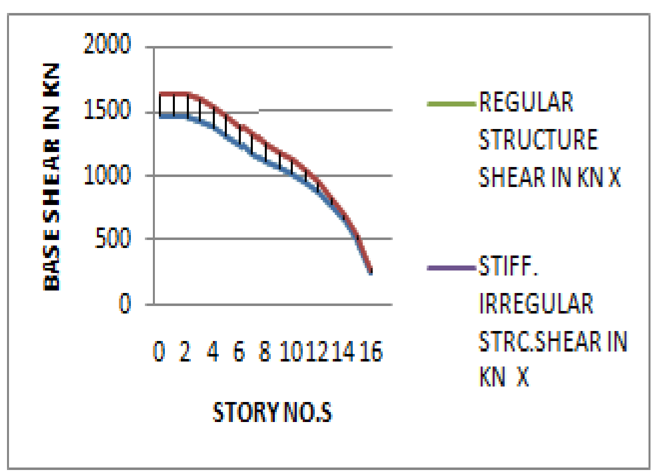
1. Comparison of Peak storey shear forces of Regular structure and Mass Irregular structure:

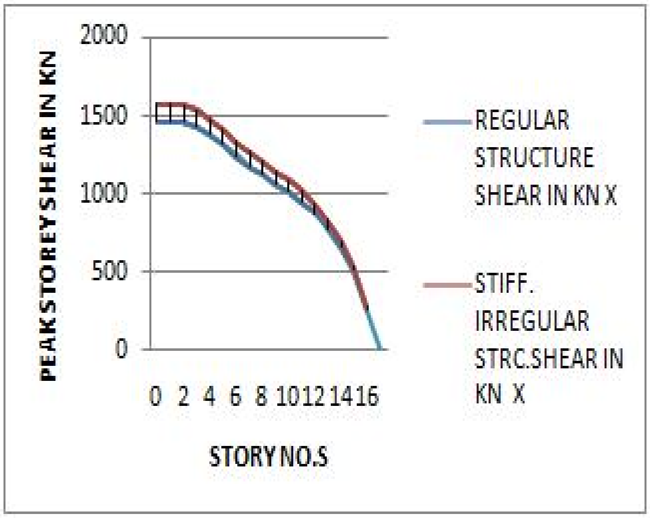




The storey shear force is maximum in ground storey and it decreases as we move up in the structure. Mass irregular storey shear force is more in lower storeys as compared to regular structure. The graph closes in as we move up the structure and the mass irregular storey shear force becomes less than that in regular structure above 15th storey.

2. Comparison of Peak storey shear forces of Regular structure and Stiffness Irregular structure

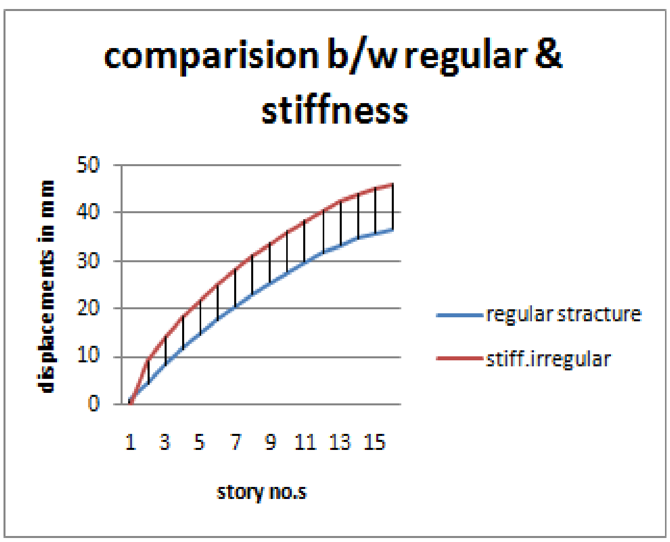




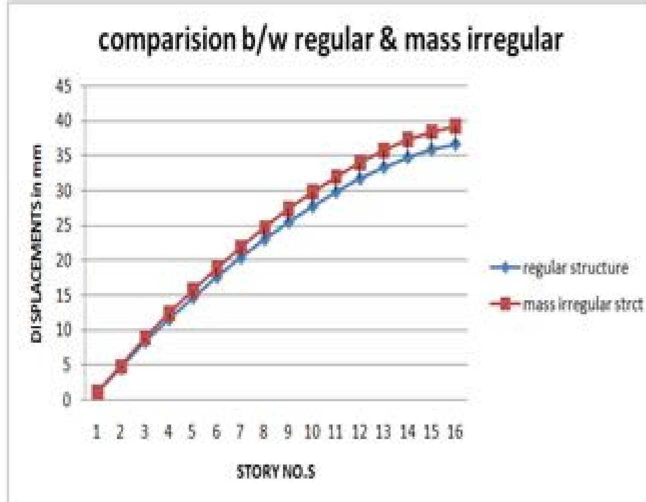
The Stiffness Irregular structure has a ground storey height of 5.0m(more than height of the above storeys). This makes the building less stiff than regular structure. Hence the interstorey drift is observe to be more in stiffness irregular structure. And hence, the storey shear force is more in regular structure as compared to stiffness irregular structure.

3. Comparison of displacements of different floors of Regular structure and Stiffness Irregular structure

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



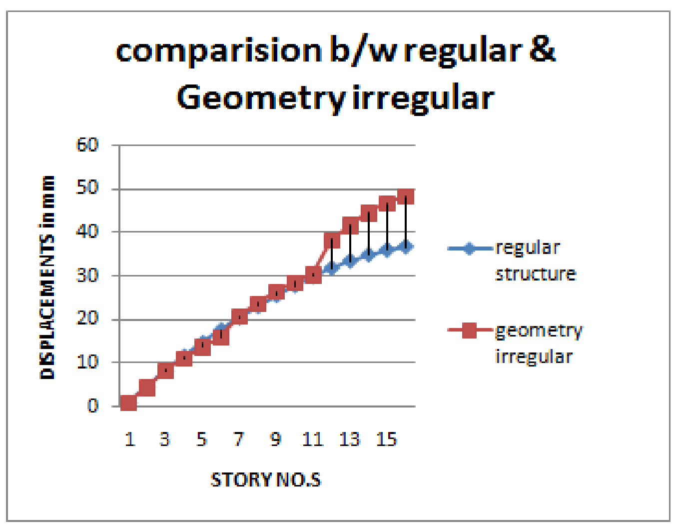
4. Comparison of displacements of different floors of Regular structure and Mass Irregular structure



Mass irregular structure has swimming pool in 5th,10th and 16th floor hence the 5th, 10th storey displacement is more in mass irregular structure. The effect of extra mass is found to be more in 16th 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

5. Comparison of displacements of different floors of Regular structure and Geometry Irregular structure

In geometry irregular structure the stiffness upto 5th storey is far more than that of regular structure. So the displacement in lower storeys 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.



VIII. CONCLUSION

Three types of irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were considered .All three kinds of irregular RC building frames had plan symmetry. Response spectrum analysis (RSA) was conducted for each type of irregularity and the storey shear forces obtained were compared with that of a regular structure. Time history analysis (THA) was conducted for each type of irregularity corresponding to the above mentioned ground motions and and nodal displacements were compared. Finally, design of above mentioned irregular building frames was carried out using IS 13920 corresponding to Response spectrum analysis (RSA) and Time history analysis(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 maximum for the first storey and it decreased to a minimum in the top storey in all cases.
- According to results of RSA, it was found that mass irregular building frames experience larger base shear than similar regular building frames.
- According to results of RSM, the stiffness irregular building experienced lesser base shear and has larger inter storey drifts.
- The absolute displacements obtained from time history analysis of geometry irregular building at respective nodes were found to be greater than that in case of regular building for upper stories but gradually as we move to lower stories displacements in both structures tended to converge. This is because in a geometry irregular structure upper stories have lower stiffness (due to L-shape) than the lower stories. Lower stiffness results in higher displacements of upper stories.
- In case of a mass irregular structure, Time history analysis yielded slightly higher displacement for upper stories than that in regular building, whereas as we move down, lower stories showed higher displacements as compared to that in regular structures.
- When time history analysis 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 compared to respective stories in regular building.

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