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Stiffness Analysis of Multi-Storey Structure With and Without Infill Walls in Regular & Irregular Building

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ABSTRACT: This paper is concerned with the effects of various vertical irregularities on the seismic response of a structure. The objective of the project is to carry out Response spectrum analysis (RSA) and Time history Analysis (THA) of vertically irregular RC building frames and to carry out the ductility based design using IS 13920 corresponding to Equivalent static analysis and Time history analysis. Comparison of the results of analysis and design of irregular structures with regular structure was done. The scope of the project also includes the evaluation of response of structures subjected to high, low and intermediate frequency content earthquakes using Time history analysis. Three types of irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were considered. According to our observation, the storey shear force was found to be maximum for the first storey and it decreases to minimum in the top storey in all cases. The mass irregular structures were observed to experience larger base shear than similar regular structures. The stiffness irregular structure experienced lesser base shear and has larger inter-storey drifts. The absolute displacements obtained from time history analysis of geometry irregular structure at respective nodes were found to be greater than that in case of regular structure for upper stories but gradually as we moved to lower stories displacements in both structures tended to converge. Lower stiffness results in higher displacements of upper stories. In case of a mass irregular structure, time history analysis gives slightly higher displacement for upper stories than that in regular structures whereas as we move down lower stories show higher displacements as compared to that in regular structures. When time history analysis was done for regular as well as stiffness irregular structure, 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 structure. Tall structures were found to have low natural frequency hence their response was found to be maximum in a low frequency earthquake. It is because low natural frequency of tall structures subjected to low frequency earthquake leads to resonance resulting in larger displacements. If a high rise structure (low natural frequency) is subjected to high frequency ground motion then it results in small displacements. Similarly, if a low rise structure (high natural frequency) is subjected to high frequency ground motion it results in larger displacements whereas small displacements occur when the high rise structure is subjected to low frequency ground motion.

KEYWORDS: Masonry infill, bare frame, response spectrum, seismic response.

I. INTRODUCTION

During an earthquake, failure of structure begins at points of weakness. This weakness emerges because of irregularity in mass, stiffness and geometry of structure. The structures having this discontinuity are named as Irregular structures. Irregular structures contribute a huge part of urban infrastructure. Vertical irregularities are one of the significant reasons of failures of structures during earthquakes. For example, structures with soft story were the most notable structures which collapsed. In this way, the impact of vertically irregularities in the seismic performance of structures turns out to be extremely essential. Height-wise changes in stiffness and mass render the dynamic characteristics of these structures not quite the same as 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 become more complicated.

There are two types of irregularities-

1. Plan Irregularities
2. Vertical Irregularities.

II. RESEARCH PROBLEM

RC framed structures with infill walls are a common form of buildings of more than two stories high in state like Punjab, where the seismicity of the region is considered to be high. Infill walls, however, are treated as non-structural components even though they provide significant improvement in lateral stiffness of the frame structures. This leads to random selection of infill materials. The Indian Seismic Standard (IS 1893: 2002) which is currently being used for the analysis and design of new buildings in Punjab does not make any specific reference to in-fill walls. However, cracks on the infill wall do appear even under mild earthquakes and thus there is a need to know the strength limit of infill material under the action of credible earthquakes. Besides, some buildings are given higher importance factor even though the use of infill material is the same irrespective of how important the structure is. Thus, there is no information on the strength of infill wall for all categories of structures at different performance levels.

Moreover, there are many buildings which were not designed for seismic resistance. Although such buildings would not fulfil the requirements of the modern seismic codes, it is important to address the seismic resistance level of these buildings and to know the future course of action from the disaster management point of view.

III. METHODOLOGY

The steps undertaken in the present study to accomplish the above-mentioned objectives are as follows:

- Review of existing literatures by different researchers
- Selection of types of structures
- Select an irregular and regular building frame model with heights (G+7 stories) assuming equal bay width of 4m along X and Y direction bays
- Performing dynamic analysis i.e response spectrum analysis and push over analysis on selected building models using STAAD.Pro V8i and SAP2000.
- Detailed discussion on the results with the help of graphs and tables considering all the included parameters.

IV. RESPONSE SPECTRUM ANALYSIS

Response Structure analysis was performed on regular and various irregular buildings using STAAD-Pro. The storey shear forces were calculated for each floor and graph was plotted for each structure.

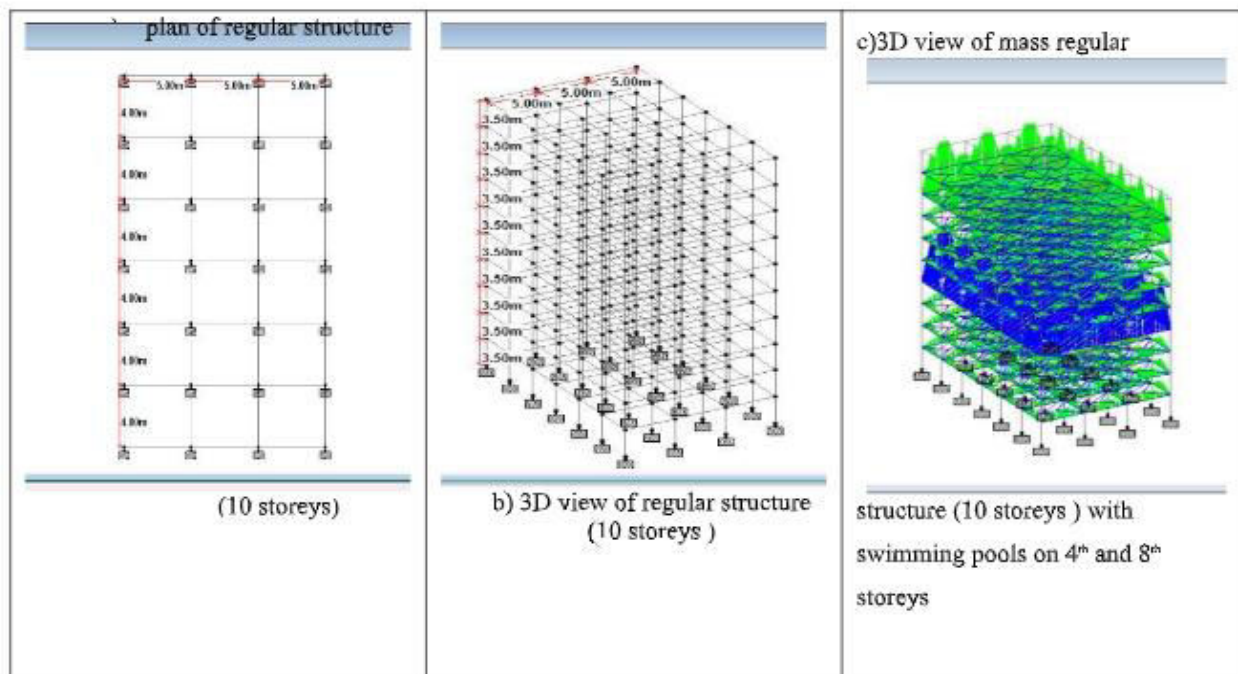
Live Load	3kN/m ²
Density of RCC considered:	25kN/m ³
Thickness of slab	150mm
Depth of beam	400mm
Width of beam	350mm
Dimension of column	400x400mm
Density of infill	20kN/m ³
Thickness of outside wall	20mm
Thickness of inner partition wall	15mm
Height of each floor	3.5m
Earthquake Zone	IV
Damping Ratio	5%

Importance factor	1
Type of Soil	Rocky
Type of structure	Special Moment Resisting Frame
Response reduction Factor	5

V. STRUCTURAL MODELLING

SPECIFICATIONS: Four types of Irregular buildings were considered, Regular structure, Mass irregular structure, structure with ground storey as the soft storey and vertically geometric irregular building. The first three structures were 10 storeyed.

1. Regular structure (10 storeys):



Mass Irregular Structure(10 storeys): The structure is modeled as same as that of regular structure except the loading due to swimming pool is provide in the fourth and eighth floor. Height of swimming pool considered- 1.8m Loading due to swimming pool -18kN/m² **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 have brick infill. Stiffness of each column= $12EI/L^3$ 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.

VI. CONCLUSION

We 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. 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 using IS 13920 corresponding to Equivalent static analysis (ESA) 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.
- Tall structures have low natural frequency hence their response was found to be maximum in a low frequency earthquake.

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