Seismic Analysis on A Plan of Irregular Multistory Commertial Building Using Etabs

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Abstract - ***According to the most recent edition of IS: 1893-2002, almost all multi-story buildings must be examined as three-dimensional systems. In terms of bulk, stiffness, and plan, buildings can be categorized as asymmetrical along their storeys. The majority of India's hilly areas are quite seismically active. The structural analysis tool ETABS software was used to assess the 3D analytical models of G+15-story structures that were created for both symmetric and asymmetric building models. Two fundamental metrics for assessing a structural system's dynamic response are mass and stiffness. Depending on a number of factors, including soil conditions, foundation types, and mass-stiffness distribution, multi-story buildings react differently. The 2001 Bhuj earthquake in Gujarat, India, showed how structural abnormalities in floor mass and rigidity caused buildings to fall and sustain damage. The impact of different vertical abnormalities on a structure's seismic response is the focus of this research. Response spectrum analysis (RSA) of regular and irregular RC building frames, Time history analysis (THA) of regular RC building frames, and ductility-based design using IS 13920, which corresponds to response spectrum analysis, are the project's goals. The outcomes of the examination of irregular and regular structures are compared.***

Key Words: *Symmetric and Asymmetric structures; Dynamic analysis, Storey Deflection, Storey Shear, Base Shear.*

1. INTRODUCTION

A building should possess four main attributes, mainly having simple and regular configuration, adequate lateral strength, stiffness and ductility. Buildings having simple regular geometry in plan as well as in elevation, suffer much less damage than the irregular configuration. A building shall be considered as irregular as per IS 1893-2002, if it lacks symmetry and has discontinuity in geometry, mass or load resisting elements. These irregularities may cause problem in continuity of force flow and stress concentrations.

The primary goal of structural analysis is to determine how a structure responds to various actions. Wind, waves, traffic, earthquakes, and explosions are examples of dynamic loads. Dynamic loading can be applied to any structure. Asymmetry greatly increases lateral deflections, member forces, and ultimately the collapse of the building. Structural symmetry can be a primary cause of a building's poor performance under extreme seismic loading.

The research of seismic analysis and multi-story symmetric and asymmetric building design are the focus of this project. Etabs software is used to do the structural analysis of a G+15-story reinforced concrete symmetrical and asymmetrical frame building. It is assumed that the building is a commercial structure. The current study compares the results of Response Spectrum Analysis (RSA) of regular and irregular RC building frames, performs ductility-based design, and compares Time History Analysis (THA) with Response Spectrum Analysis of regular buildings.

1.1 Concept of regular and irregular configuration

To perform well in an earth quake a building should possess four main attributes namely simple and regular configuration and adequate lateral Strength, stiffness and ductility. Current earthquake codes define structural configuration as either regular or irregular in terms of size and shape of the building, arrangement of the structural and non-structural elements within the structure, distribution of mass in the building etc. A building shall be considered as irregular for the purposes of this standard, if at least one of the conditions is applicable as per IS 1893(part1):2002

A. Plan Irregularity

Asymmetric or plan irregular structures are those in which seismic response is not only translational but also torsional, and is a result of stiffness and/or mass eccentricity in the structure. Asymmetry may in fact exist in a nominally symmetric structure because of uncertainty in the evaluation of center of mass and stiffness, inaccuracy in the measurement of the dimensions of structural elements

B. Vertical Irregularity

Vertical irregularity results from the uneven distribution of mass, strength or stiffness along the elevation of a building structure. Mass and Stiffness irregularity results from a sudden change in mass and stiffness between adjacent floors respectively.

1.2 Objectives

1. To study irregularities in structures analyze and design of G+15 storied structure as per code provision.
2. Analyze the buildings in Etabs software to carry out the storey deflection, storey drift, storey shear force and base shear of regular and irregular structures using response spectrum analysis and compare the results of different structures
3. Time history analysis subjected to intermediate frequency ground motion for the response of regular buildings and compare with response spectrum analysis.
4. Ductility-based earthquake-resistant design as per IS 13920

1.3 Definitions

a) Storey

When the multi-story building or the residential building is constructed in that when the floor to floor gap will be there that is the story.

b) Storey Shear

We will calculate all the lateral loads at each floor of the building.

c) Story Drift

Defined as the difference in lateral deflection between two adjacent stories. During an earthquake, large lateral forces can be imposed on structures; Lateral deflection and drift have three primary effects on a structure; the movement can affect the structural elements (such as beams and columns); the movements can affect non-structural elements (such as the windows and cladding); and the movements can affect adjacent structures. Without proper consideration during the design process, large deflections and drifts can have adverse effects on structural elements, nonstructural elements, and adjacent structures.

d) Center of mass

It is the unique point at the center of a distribution of mass in space that has the property that the weighted position vectors relative to this point sum to zero. In analogy to statistics, the center of mass is the mean location of a distribution of mass in space. According to IS: 1893-2002, center of mass is the point through which resultant of the masses of a system acts. This point corresponds to center of gravity of masses of system. Earthquake induced lateral force on the floor is proportional to mass. Hence, resultant of this force passes through the center of mass of the floor.

e) Center of rigidity

It is the stiffness centroid within a floor-diaphragm plan. When the center of rigidity is subjected to lateral loading, the floor diaphragm will experience only translational displacement. Other levels are free to translate and rotate since behavior is coupled both in plan and along height. As a function of structural properties, center of rigidity is independent of loading. According to IS1893-2002, Centre of stiffness, for a one story building can be defined as the point on the floor through which lateral force should pass in order that floor undergoes only rigid body translation, with no rigid body rotation.

2. ANALYSIS METHOD

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.

There are different types of earthquake analysis methods. Some of them used in the project are:

- Response Spectrum Analysis
- Time History Analysis

2.1 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 are 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)

2.2 Time history analysis

This technique involves 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 themselves.

3. PROBLEM FORMULATON

The structural analysis and design of G+15 storey reinforced concrete symmetrical and asymmetrical buildings is done with the help of Etabs software. The building is assumed as commercial building. Regular plan of the structure and irregular plan of the structures are shown in fig. The structure is assumed to be located in seismic zone V on a site with medium soil and Special Moment Resisting Frame. These buildings have approximately the same plan area of about 540m².

Table -1: Building Details

Dimension of beam	300 mm x 650mm
Dimension of column	300mm x 1200mm
Thickness of Slab	150mm
Thickness of outside wall	230mm
Thickness of inner wall	150mm
Height of each storey	3.5m
Live Load	4kN/m²
Floor Finish	1.5 kN/m²
Grade of reinforcing steel	Fe415
Grade of concrete	M 30
Density of concrete	25 kN/m³
Density of infill	20kN/m³
Seismic Intensity	Very sever
Importance factor	1
Zone factor	0.36
Damping ratio	5%

3.1 Plan irregular structures

Typical floor plans of symmetrical and asymmetrical

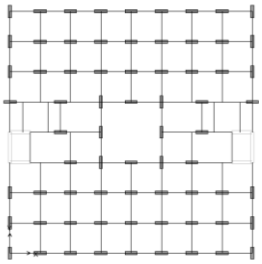

Fig -1: Regular shape

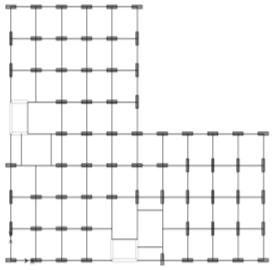

Fig -2: L shape

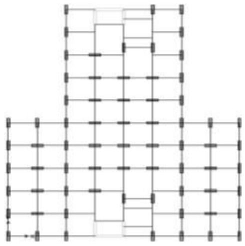

Fig -3: T shape

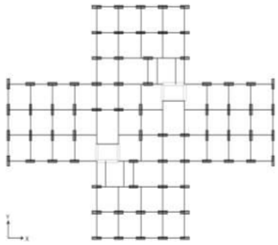

Fig -4: Plus shape

3.2 Mass irregular structure

The structure is modeled as same as that of regular structure except the loading due to swimming pool is provide in the seventh and thirtieth floor.
Height of swimming pool considered- 2m
Loading due to swimming pool -20 kN/m²

3.3 Stiffness irregular structure

The structure is same as that of regular structure but the ground storey has a height of 4.5 m. 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

3.4 Load Combinations

The gravity loads and earthquake loads will be taken for analysis. As per IS 1893 (Part I): 2002 Clause no. 6.3.1.2, the following Earthquake load cases have to be considered for analysis.

1.5(DL + LL) 0.9DL ± 1.5EQ 1.2(DL + LL ± EQ)
1.5(DL ± WL) 0.9DL ± 1.5 WL 1.2(DL+ LL ± WL)
1.5(DL ± EQ)

4. RESULTS AND DISCUSSION

Response Structure analysis was performed on regular and various irregular buildings using Etabs. The storey shear forces, storey drift, displacement and base shear were calculated for each floor and graph was plotted for each structure.

1. Comparison of Regular and Plan Irregular structure:

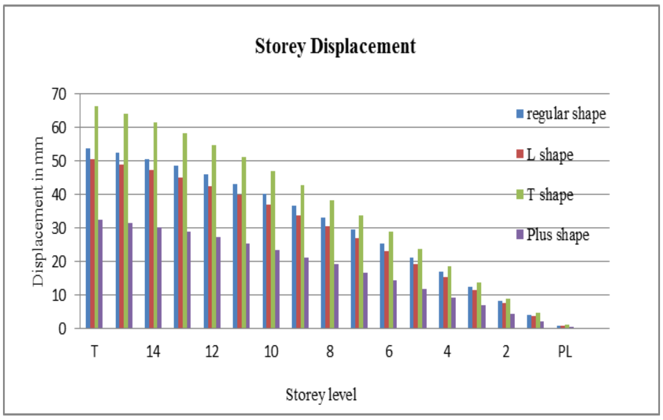

Chart -1: Storey displacement in X direction

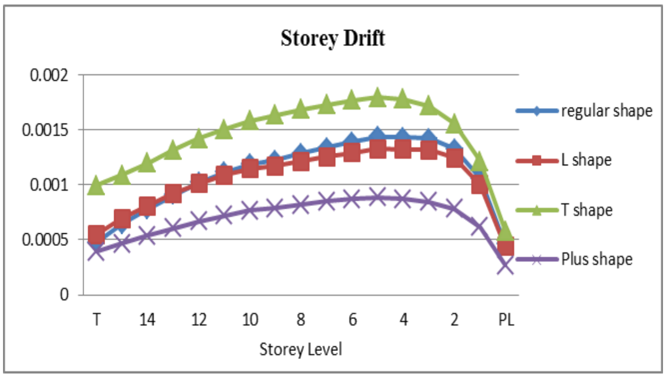

Chart -2: Storey drift in X direction

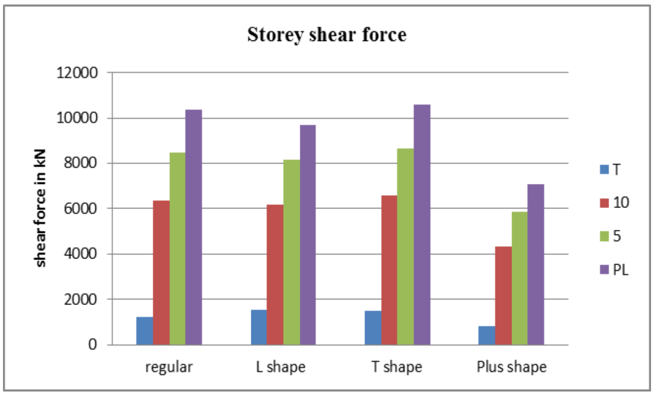

Chart -3: Storey shear force in X direction

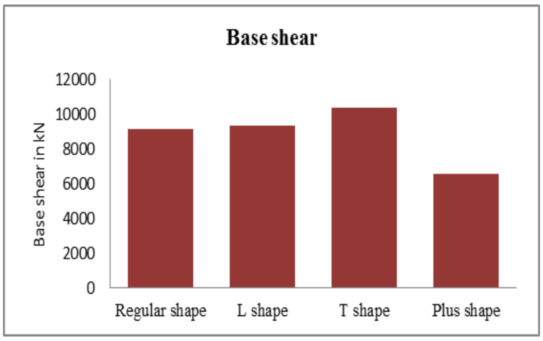

Chart -4: Base shear in X direction

2. Comparison of Regular structure and Mass Irregular structure:

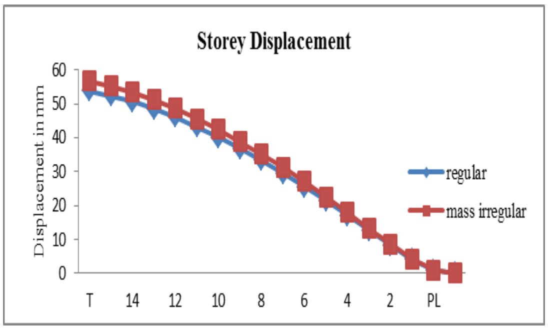

Chart -5: Displacement in X direction

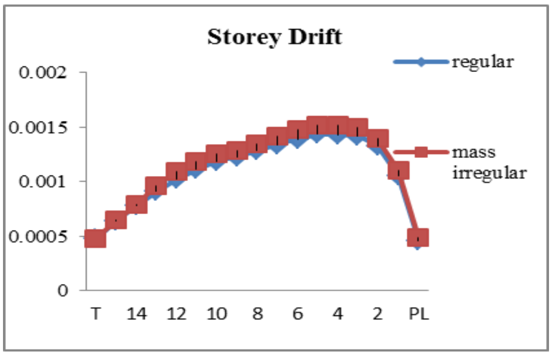

Chart -6: Storey drift in X direction

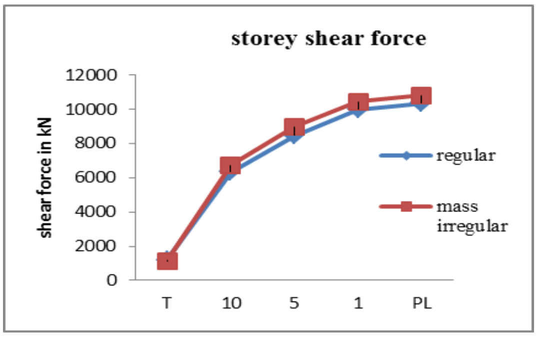

Chart -7: Storey shear force in X direction

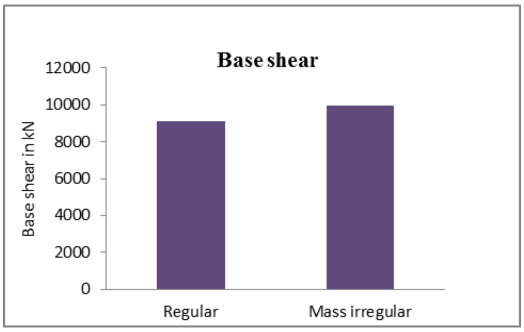

Chart -8: Base shear

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 storey 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 12th storey.

3. Comparison of Regular structure and stiffness Irregular structure:

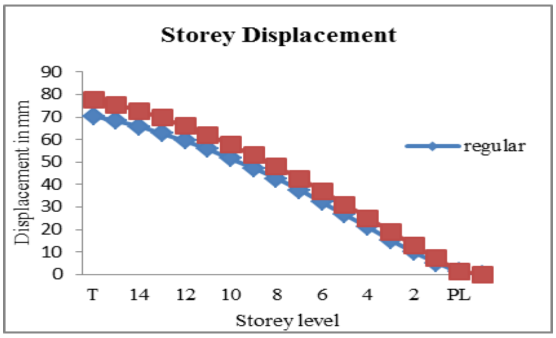

Chart -9: Displacement in Y direction

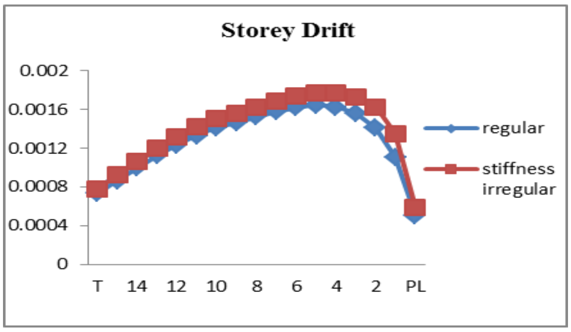

Chart -10: Storey drift in Y direction

Chart -11: Storey shear force in X direction

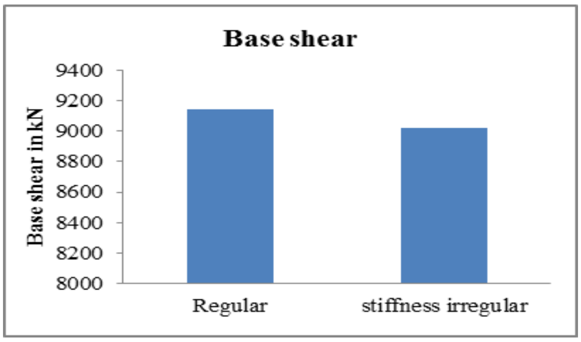

Chart -12: Base shear

The Stiffness Irregular structure has a ground storey height of 4.5m (more than height of the above storey). This makes the building less stiff than regular structure. Hence the storey shear force is more in regular structure as compared to stiffness irregular structure.

4. Comparison of response spectrum analysis and time history analysis of regular building:

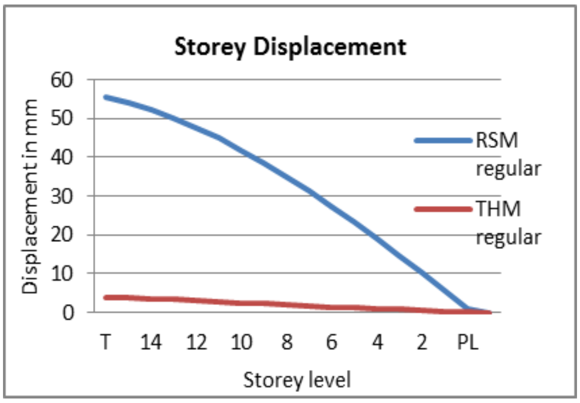

Chart -13: Displacement in X direction

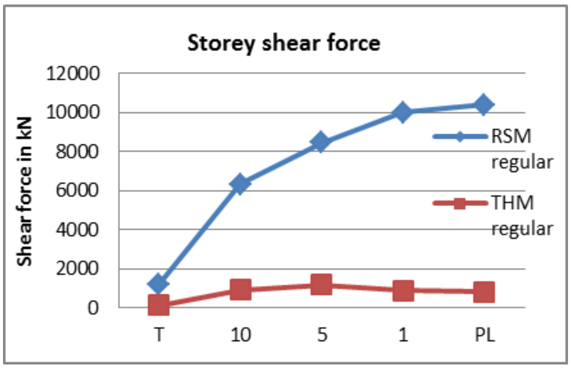

Chart -14: Storey shear force in X direction

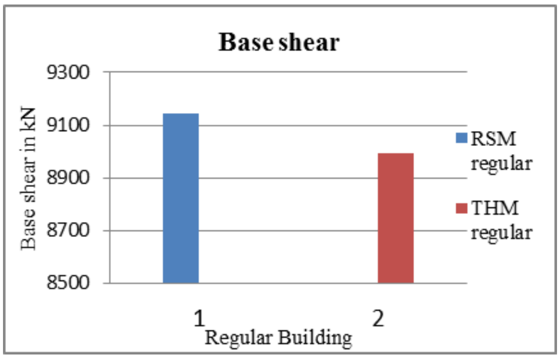

Chart -15: Base shear

5. CONCLUSIONS

1. The plan configurations of structure has significant impact on the seismic response of structure in terms of displacement, story drift, story shear
2. 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.
3. Large displacement was observed in the T shape building. It indicates that building with severe irregularity shows maximum displacement and storey drift.
4. According to results of RSA, it was found that mass irregular building frames experience larger base shear than similar regular building frames.
5. According to results of RSA, the stiffness irregular building experienced lesser base shear and has larger inter storey drifts.
6. As a result of comparison between time history method and response spectrum method it has been observed that the values obtained by response spectrum analysis of base shear and top storey displacement are higher than time history analysis.
7. It is observed that the storey drift for all the stories are found to be within the permissible limits.
8. From the results it is recommended that time history analysis should be performed as it predicts the structural response more accurately than the response spectrum analysis

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