Study of Seismic Response of Multi-Storied Vertical Irregular Building Due to Stiffness Irregularity

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Abstract: There are various types of irregularities in the buildings depending upon their location and scope, but mainly they are divided into two groups plan irregularities and vertical irregularities. Nowadays, as in the urban areas the space available is limited for the construction of buildings. So, in that limited space we have to construct such type of buildings which can be used for the multiple purposes such as parking, lobbies etc. Irregular structures contribute a large portion of urban infrastructure. The attempt is made to investigate the proportional distribution of lateral forces evolved through seismic action in each story level due to changes in stiffness of frame on vertically irregular frame. In This Project Study of Seismic Response of Multi-Storied Vertical Irregular Building due to Stiffness Irregularity was carried. Objective of this project was to study Seismic Response of Multi-Storied Vertical Irregular Building due to Stiffness Irregularity. To evaluate lateral load behavior of special moment resisting frame structure with vertical stiffness irregularities by studying the following parameters Storey Deflection, Storey Drift and Storey Shear under dynamic analysis by using response spectrum method. Comparison between building without stiffness irregularity and building with stiffness irregularity was observed. For the analysis and modeling of the structure Finite element based ETABS 2016 (V 16.0.2) software was used.

Keywords: Stiffness, Storey Deflection, Storey Drift, Storey Shear, ETABS 2016 (V 16.0.2).

1. Introduction

Irregular buildings constitute a large portion of the modern urban infrastructure. The group of people involved in constructing the building facilities, including owner, architect, structural engineer, contractor and local authorities, contribute to the overall planning, selection of structural system, and to its configuration. This may lead to building structures with irregular distributions in their mass, stiffness and strength along the height of building. When such buildings are located in a high seismic zone, the structural engineer’s role becomes more challenging. Therefore, the structural engineer needs to have a thorough understanding of the seismic response of irregular structures. 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 render the dynamic characteristics of these buildings different from the regular building. As per IS 1893(Part1):2002 vertical 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.

2. Methodology

A. Response spectrum analysis

Earthquake is a random and time variant process. During earthquake shaking inertia forces are induced in the structure. These earthquakes induced inertia forces as the net effect in the form of design equivalent static lateral force. This force is called as the seismic design base shear (V₁₀) and this is primary quantity involved in force based earthquake resistant design of building. This force depends on the seismic region where the building located represented by the seismic zone factor (Z). Also, increasing design forces to increase the elastic range of the building and therefore to reduce the damage in the building, codes tend to adopt the importance factor (I). Further, the net shaking of a building is a combined effect of the energy carried by the earthquake at different frequencies and the natural periods of the building. To form relationship between frequencies and natural period the code introduces an average response acceleration coefficient (Sa/g). Finally, to make normal buildings economical, design codes allow some damage for reducing cost of construction. This philosophy is introduced with the help of response reduction factor (R), which is larger for ductile buildings and smaller for brittle ones. Each of these factors are discussed in below as per IS 1893(Part1):2002.

B. Design of horizontal seismic coefficient (A₀)

The design horizontal seismic coefficient A₀ for a structure shall be determined by the following expression:

\[ A₀ = \frac{Z}{2} \cdot \frac{1}{R} \cdot \frac{Sₐ}{g} \]

Where,

- \( Z \) = Zone factor for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 in
the denominator of $Z$ is used so as to reduce the MCE zone factor to the factor for Design Basis Earthquake (DBE).

$$I = \text{Importance factor, depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance.}$$

$$R = \text{Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.}$$

$$S_a/g = \text{Average response acceleration coefficient}\,$$

For medium soil,

$$S_a/g = 1 + 1.5T \quad \text{when} \quad 0.00 < T < 0.10$$

$$S_a/g = 2.50 \quad \text{when} \quad 0.10 < T < 0.55$$

$$S_a/g = 1.36/T \quad \text{when} \quad 0.55 < T < 4.00$$

Where, $T = T_a = \text{Fundamental natural period of vibration in seconds,}$

$$T_a = 0.075h^{0.75} \quad \text{for R.C frame building without brick infill panels, and}$$

$$T_s = \frac{0.09h}{d} \quad \text{for all building with brick infill panels.}$$

Where, $h = \text{Height of building in m, and}$

$d = \text{Base dimensions of the building at the plinth level, in m.}$

**C. Design seismic base shear ($V_B$)**

The total design lateral force or design seismic base shear ($V_B$) along any principle direction shall be determined by the following expression:

$$V_B = A_h \times W$$

Where, $A_h = \text{Design horizontal acceleration spectrum value,}$

and $W = \text{Seismic weight of the building.}$

**D. Distribution of design force**

The vertical distribution of the base shear to different floor levels along the height of the building is given by:

$$Q_i = V_B \times \frac{W_i h_i}{\sum_{j=1}^{n} W_j h_j}$$

Where, $Q_i = \text{Design lateral force at floor } i,$

$W_i = \text{Seismic weight of floor } i,$

$h_i = \text{Height of the } i^{th} \text{ floor from the base, and}$

$n = \text{Number of storeys in the building.}$

### 3. Modelling

**A. Modal configuration**

1) **Frame 1 – base model**

The basic model consists of (G+20) vertically geometric irregular structure with stilt at basement. It has 11 bays of 5 m in both X and Y directions. After each four consecutive stories, the size of model is reduced by 5 m in both X and Y directions as shown in Figure. The typical storey height is 3.0 m, ground storey height is 3.5 m, and foundation height below the plinth level is 3.0 m. Preliminary data for building is mentioned in article 3.2.1.

2) **Base model with stiffness irregularity at ground storey**

The preliminary data for this frame is same as frame 1. The typical storey height is 3.0 m, ground storey height is 5 m and no wall load on beam at ground floor.
3) **Frame 3 – base model with stiffness irregularity at 10th storey**

The preliminary data for this frame is same as frame 1. The typical storey height is 3.0 m, tenth storey height is 5 m and wall load on periphery beam only.

4) **Frame 4 – base model with stiffness irregularity at 20th storey**

The preliminary data for this frame is same as frame 1. The typical storey height is 3.0 m, 20th storey height is 5 m and wall load on periphery beam only.
Table 5

<table>
<thead>
<tr>
<th>Floor</th>
<th>Frame 1</th>
<th>Frame 2</th>
<th>Frame 3</th>
<th>Frame 4</th>
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</table>

5. Conclusion

The behavior of G + 20 storeyed building stiffness irregularity has been studied using four frames. Frame-1 is an irregular vertical building which is considered as the base model. Frame-2 is vertical irregular building having ground storey height 5m and no wall load on beam on that floor. Frame-3 having tenth storey height of 5m and wall load on only periphery beams. Frame-4 having uppermost storey height 5m and wall load on only periphery beams. After analyzed all the frames results in the form of storey displacement, storey drift and storey shear are evaluated and compared. The following conclusions are made from the obtained results.

- Vertical stiffness irregularity at a storey in a building causes increase in storey drift at that storey, while buildings without stiffness irregularity perform well for lateral loads.
- Sudden change in storey height causes change in structure results.
- Storey displacement in particular floor where stiffness irregularity introduced at that floor sudden change in displacement value.
- The analysis proves that irregularities are harmful for the structures and it is important to have simpler and regular shapes of frames as well as uniform load distribution around the building.
- Frame 4 i.e. stiffness irregularity at uppermost floor performs better as compared to the frame 2 and frame 3.
• So, when there is stiffness irregularity in the model of a structure, it should not be provided at ground floor and for the intermediate floor. Stiffness irregularity may be provided in top floor levels.

References


