

**ABSTRACT**

It has been said that “Earthquake don’t kill people but buildings kill people”. By taking care to make the constructions earthquake proof, we cannot only reduce economic loss but also loss of precious lives. Major earthquakes in India have damaged or destroyed numerous buildings. By monitoring how buildings respond to earthquake and applying the knowledge gained engineers are improving the ability of structures to survive major earthquakes. Designing a building is always a challenge and that challenge is compounded when they are built in earthquake prone. As earth scientists learn more about ground motion during earthquakes and structural engineers. Use this information to stronger buildings that can withstand earthquakes, engineers must and should understand the stresses caused by shaking. Every time a strong earthquake occurs, the new information gathered enables engineers to refine and improve structural design and building codes. Such loss of life and property can be reduced. Building codes provide the first line of defence against future earthquake damage and help to ensure public safety. Records of building response to earthquakes, especially those from structures that failed or damaged have led to many revisions and improvements in building codes. Earthquakes are of low permeability but high risk events. Awareness against earthquake is the need. We are the engineers to be blamed for such hazards.

**KEYWORDS:** Earthquake, building codes, damage.

**INTRODUCTION**

During severe earthquakes, the structures undergo deformations well in excess of their yield deformations and consequently suffer damage at certain locations. The location and degree of damage reflects the performance of the structure as well as its non-structural components. Consequently a deformation-based analysis and design is more rational and meaningful than a force-based analysis and design. Such an analysis helps in evaluating the location and degree of damage and thus evaluates the performance of the structure. In recent earthquakes (2001 Bhuj earthquake) many concrete structures have been severely damaged or collapsed, have indicated the need for evaluating the seismic adequacy of existing buildings. In particular, the seismic rehabilitation of older concrete structures in high seismicity areas is a matter of growing concern, since structures vulnerable to damage must be identified and an acceptable level of safety must be determined. To make such assessment, simplified linear-elastic methods are not adequate. In INDIA 2012 there are two major earthquakes occurred at koyananagar in Maharashtra and at Bahadurgarh in New Delhi, these two earthquakes are occurred with a magnitude of 4.9. Bahadurgarh in New Delhi is occurred in March 5, and koyananagar in Maharashtra was occurred in April 14. The main objectives of this paper are

1. To study the performance of storey drift under the four zones.
2. To study the performance of storey displacement under the four zones.
3. To study the performance of RC plane frames under lateral loads (EARTHQUAKE).
4. To study the bending moment and shear force variations of RC plane building under four zone.
5. To study the performance of stability indices of different storey RC framed building under four zones

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**STRUCTURAL MODELLING****1. GENERAL**

A building frame model involves the assemblage of structural elements viz., beams, columns, slabs, footing etc. To represent the structural aspects of a typical frame in a building and exhibit its behaviour under external loading. An analytical model must ideally represent its mass distribution, strength, stiffness and deformability through a full range of local and global displacements. This chapter deals with the modelling of RC plane frames of G+3 storey building.

**2. MODELLING ASPECTS**

RC plane frames of G+3 storey building were modelled at FOUR EARTHQUAKE ZONES and analyzed by using STAAD pro. The numerical model represents all components that effect the strength, stiffness and the mass of the frame.

**3. MATERIALS**

The modulus of elasticity of reinforced concrete as per IS 456:2000 is given by

$$E_c = 5000 \sqrt{f_{ck}}$$

For the steel rebar, the necessary information is yield stress, modulus of elasticity and ultimate strength. High yield strength deformed bars (HYSD) having yield strength 415 N/mm<sup>2</sup> is widely used in design practice and is adopted for the present study and medium type soils is considered.

**4. LOADS**

All loads acting on the building except wind load were considered. These are

1. Dead Load
2. Live load
3. Lateral Load due to Earthquake load

It was assumed that wind load will not govern the demands on the members and storey levels.

*a) Dead Load*

The dead load due to beams, columns, floors and slabs shall be given in STAAD pro and self weight due to external and internal walls shall be calculated as follows. The unit weights of some materials are taken from Table-1, IS 875 (part-1):1987.

Dead load due to external walls =  $0.23 \times 3.2 \times 20 = 14.72 \text{ kN/m}^2$

Dead load due to internal walls =  $0.16 \times 3.2 \times 20 = 10.24 \text{ kN/m}^2$

Unit weight of Reinforced concrete,  $\gamma_c = 25.0 \text{ kN/m}^3$

Unit weight of standard brick =  $20 \text{ kN/m}^3$

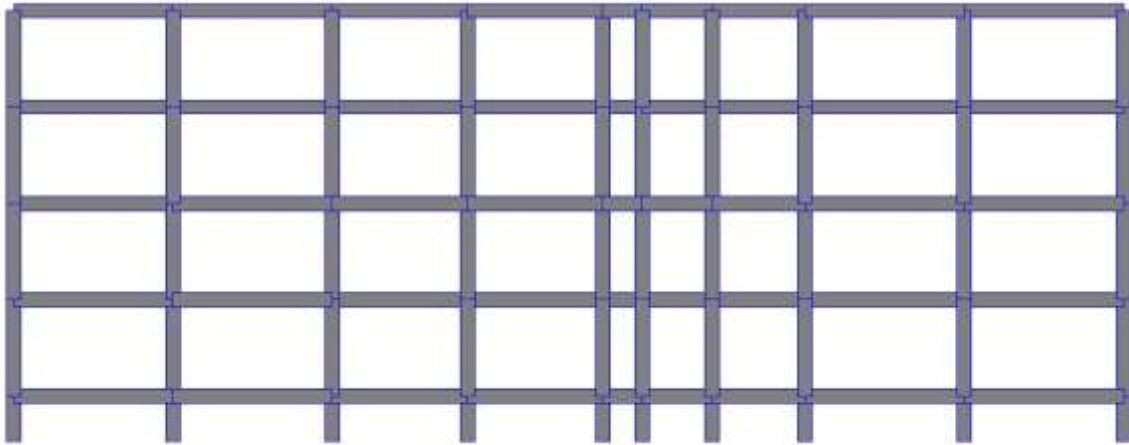
*b) Live load on floors:*

Live load on floors =  $3 \text{ kN/m}^2$

Live load on roof slab =  $2 \text{ kN/m}^2$

**5. STRUCTURAL ELEMENTS**

In this section, the details of the modelling adopted for various elements of the frame are given below.



*Section Outline Diagram*

**a) Beams and Columns**

Beams and columns were modelled as frame elements. The elements represent the strength, stiffness and deformation capacity of the members. While modelling the beams and columns, the properties to be assigned are cross sectional dimensions, reinforcement details and the type of material used.

**b) Beam-Column Joints**

The beam-column joints are assumed to be rigid. They were modelled by giving end offsets at the joints. This is intended to get the bending moments at the face of the beams and columns. A rigid zone factor of 1.0 was considered to ensure rigid connections of the beam and columns.

**RESULTS AND DISCUSSION**

**1. CALCULATION OF BASE SHEAR:**

The total design lateral force or design seismic base shear ( $V_B$ ) is calculated according to clause 7.5.3 of IS 1893:2002 (IS 1893:2002 is referred to as the Code subsequently).

The total Base shear

$$V_B = A_h W$$

Where  $A_h$  is the design horizontal seismic coefficient

$$A_h = \left( \frac{Z}{2} \right) \frac{I}{R} \frac{S_a}{g}$$

Here

Z = Zone Factor

I = Importance Factor

R = Response Reduction Factor

The values of Z, I, R are given in Tables 2, 6, 7 respectively in IS 1893 (part-1):2002.

$S_a/g$  = Spectral acceleration coefficient. It is calculated according to Clause 6.4.5 of the Code corresponding to the fundamental time period  $T_a$  in seconds is given as follows.

For a Moment Resisting Frame without infill

$$T_a = 0.075 h^{0.75}$$

For a Moment Resisting Frame with brick infill panels

$$T_a = \frac{0.09 h}{\sqrt{d}}$$

Here

h = Height of the Building Frame

d = Base dimension of the building at the plinth level in meters, along the considered direction of the lateral load.

## 2. EARTHQUAKE ANALYSIS IN STAAD Pro:

The space frame is modelled using STAAD Pro software. The basic load cases are shown in the below table where X and Z are lateral orthogonal directions.

*Basic Load Cases Used for Analysis*

| No | Load case              | Directions                                    |
|----|------------------------|---|
| 1  | DL                     | Downwards                                     |
| 2  | IL (Imposed/live load) | Downwards                                     |
| 3  | EXTP (+ Torsion)       | +X; Clock wise torsion due to earthquake      |
| 4  | EXTN (- Torsion)       | +X; Anti Clock wise torsion due to earthquake |
| 5  | EZTP (+ Torsion)       | +Z; Clock wise torsion due to earthquake      |
| 6  | EZTN (- Torsion)       | +Z; Anti Clock wise torsion due to earthquake |

EXTP: EQ load in X direction with torsion positive

EXTN: EQ load in X direction with torsion negative

EZTP: EQ load in Z direction with torsion positive

EZTN: EQ load in Z direction with torsion negative

### Load Combinations:

As per IS 1893 (Part 1): 2002 Clause no. 6.3.1.2, the following load cases have to be considered for analysis:

1.5 (DL + IL)

1.2 (DL + IL+ EL)

1.5 (DL+ EL)

0.9 DL+ 1.5 EL

Earthquake load must be considered for +X, -X, +Z and -Z directions. Moreover, accidental eccentricity can be such that it causes clockwise or anticlockwise moments. Thus, load combinations are 13 cases as given in methodology, not using negative torsion considering the symmetry of the building.

For design of various building elements (beams or columns), the design data may be collected from computer output. Important design forces for selected beams will be tabulated and shown diagrammatically where needed. In load combinations involving Imposed Loads (IL), IS1893 (Part 1): 2002 recommends 50% of the imposed load to be considered for seismic weight calculations. However, the authors are of the opinion that the relaxation in the imposed load is unconservative. This example therefore, considers 100% imposed loads in load combinations.

For above load combinations, analysis is performed and results of deflections in each storey and forces in various elements are obtained.

### Storey Drift:

As per Clause no. 7.11.1 of IS 1893 (Part 1): 2002, the storey drift in any storey due to specified design lateral force with partial load factor of 1.0, shall not exceed 0.004 times the storey height. From the frame analysis the displacements of the mass centres of various floors are obtained and are shown in Table 4 along with storey drift.

Since the building configuration is same in both the directions, the displacement values are same in either direction.

**Storey Drift Calculations:**

Maximum drift permitted =  $0.004 \times h_s$  (height of the storey). Sometimes it may so happen that the requirement of storey drift is not satisfied. However, as per Clause 7.11.1, IS: 1893 (Part 1): 2002; "For the purpose of displacement requirements only, it is permissible to use seismic force obtained from the computed fundamental period ( $T$ ) of the building without the lower bound limit on design seismic force." In such cases one may check storey drifts by using the relatively lower magnitude seismic forces obtained from a dynamic analysis.

**Stability Indices:**

It is necessary to check the stability indices as per Annex E of IS 456:2000 for all Storey's to classify the columns in a given storey as non-sway or sway columns. Using data from Table 1 and Table 4, the stability indices are evaluated as shown in Table 5. The stability index  $Q_{si}$  of a storey is given by

$$Q_{si} = \frac{\sum P_u \Delta_u}{H_u h_s}$$

Where

- $Q_{si}$  = Stability index of  $i^{\text{th}}$  Storey
- $\sum P_u$  = sum of axial loads on all columns in the  $i^{\text{th}}$  Storey
- $\Delta_u$  = elastically computed first order lateral deflection
- $H_u$  = total lateral force acting within the Storey
- $h_s$  = height of the storey

**RESULTS**

By doing analysis of the frames in all the zones (II, III, IV, V) we got the following results.

**ZONE-II**

Storey drift will be depending up on the displacement. We will consider the displacements in two principal directions i.e. X and Z directions. Generally displacements are increases from bottom to top storey as well as storey drifts also be increased from bottom to top storeys. In this earthquake zone the maximum displacements are 7.263mm and 10.788mm in X and Z directions respectively as well as the maximum storey drifts are 2.692mm and 3.896mm in X and Z directions respectively.

**Storey drift calculations**

| STOREY | DISP-X (mm) | DRIFT-X (mm) | DISP-Z (mm) | DRIFT-Z (mm) |
|--------|-------------|--------------|-------------|--------------|
| 5      | 7.263       | 2.692        | 10.788      | 3.896        |
| 4      | 5.994       | 2.433        | 9.175       | 3.616        |
| 3      | 4.173       | 2.064        | 6.577       | 3.104        |
| 2      | 2.163       | 1.868        | 3.473       | 3.031        |
| 1      | 0.295       | 0.295        | 0.442       | 0.42         |

**ZONE-III**

In this earthquake zone the maximum displacements are 15.174mm and 22.973mm in X and Z directions respectively as well as the maximum storey drifts are 5.175mm and 6.955mm in X and Z directions respectively.

**Storey drift calculations**

| STOREY | DISP-X (mm) | DRIFT-X (mm) | DISP-Z (mm) | DRIFT-Z (mm) |
|--------|-------------|--------------|-------------|--------------|
| 5      | 15.174      | 5.175        | 22.973      | 6.955        |
| 4      | 12.598      | 4.788        | 19.488      | 6.756        |
| 3      | 8.822       | 4.328        | 13.953      | 6.593        |
| 2      | 4.549       | 3.935        | 7.36        | 6.434        |
| 1      | 0.614       | 0.614        | 0.926       | 0.0926       |

#### ZONE-IV

In this earthquake zone the maximum displacements are 16.72mm and 25.337mm in X and Z directions respectively as well as the maximum storey drifts are 5.331mm and 7.912mm in X and Z directions respectively.

#### Storey drift calculations

| STOREY | DISP-X (mm) | DRIFT-X (mm) | DISP-Z (mm) | DRIFT-Z (mm) |
|--------|-------------|--------------|-------------|--------------|
| 5      | 16.72       | 5.331        | 25.337      | 7.912        |
| 4      | 13.889      | 4.971        | 21.491      | 7.427        |
| 3      | 9.729       | 4.771        | 15.384      | 7.271        |
| 2      | 5.014       | 4.337        | 8.113       | 7.093        |
| 1      | 0.677       | 0.677        | 1.02        | 1.02         |

#### ZONE-V

In this earthquake zone the maximum displacements are 25.003mm and 38.002mm in X and Z directions respectively as well as the maximum storey drifts are 7.903mm and 11.848mm in X and Z directions respectively.

#### Storey drift calculations

| storey | DISP-X (mm) | DRIFT-X (mm) | DISP-Z (mm) | DRIFT-Z (mm) |
|--------|-------------|--------------|-------------|--------------|
| 5      | 25.003      | 7.903        | 38.002      | 11.848       |
| 4      | 20.8        | 7.621        | 32.22       | 11.486       |
| 3      | 14.591      | 7.143        | 23.055      | 10.904       |
| 2      | 7.504       | 6.493        | 12.151      | 10.626       |
| 1      | 1.011       | 1.011        | 1.525       | 1.525        |

### CONCLUSION

A major purpose of the project being commented upon is to determine forces on components of a building or a structure as required for design purposes. For buildings, Earthquake force is required in order to design with supporting elements, from which the forces get transferred to the framework. Thus the building frame experiences the cumulative effect of Earthquake forces produces forces on different parts of nodal joints. These forces are used in designing the framework. This project provides values of bending moments, shear forces, storey drifts for a variety of cases covered.

It is also noted that, according to recent studies, suitable zone factors for buildings in various zones used in the India. The effects of the underestimation of basic earthquake quantity and of bending moment values for buildings, can lead in some situations to designs that do not meet intended minimum requirements for earthquake forces.

- The construction period of a structure is much than its expected life. Therefore, return period of 50 years may be considered for arriving at the zone factor for construction stages/period of a structure depending on its importance.
- The stability of a structure shall be checked both with and without the earthquake loads.
- The basic Earthquake force corresponds to certain reference conditions. Hence to account for various effects governing the design Earthquake force in any zones.
- Storey drift was considered, storey drift increase from bottom to top. We have observed that storey drift will be increased from zone II to zone V in both the directions X and Z. Amount of storey drift depends up on the amount of earthquake effect and also on the displacement of the storey.
- Bending moment and shear force values vary from one zone to another zone; these will be increased from zone II to zone V. Maximum bending moment occurred in 336<sup>th</sup> beam in the first storey and 167<sup>h</sup> column in ground floor in zone –V.

- The results of model building were design for worst earthquake combinations.

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