

## Cost comparison of a RC framed structure (Building subjected to vertical loads and earthquake resisting design)

Gaurav Jain, Lokendra Singh Karnawat, Praveen Rajani  
Department of Civil Engineering, MITRC Alwar, Rajasthan, India

### Abstract

At the time of Earthquake RC (Reinforced Concrete) framed structures are subjected to lateral loadings. Most of the RC structures are design to resist the gravity loading only by neglecting the effect of lateral loading on it at the time of earthquake. This study is concentrated on the comparison of cost for both earthquake resistant building (Special Moment Resisting Frame, SMRF) and Non-earthquake resisting building (Ordinary Building). This study has been carried out using STAAD PRO software, IS 1893:2002, IS456:2000 and IS13920:1996 for designing of structure and SOR for analysis of rates for cost comparison of both structures. The building under analysis consist of 5 floors and has 4 bays along both X and Z direction with a span of 3m each, floor to floor height is 3m throughout the structure height. The building has been located in seismic city AGRA, Uttar Pradesh.

**Keywords:** seismic force, IS1893, staad Pro v8i, grade of material, ADA, SOR

### 1. Introduction

A Building or edifice is an RC framed structure mainly consists of Beam, Column and Slabs standing more or less permanently in one place. Buildings have different shapes, size and functions and have been adapted throughout history for a wide numbers of factors such as Weather condition, Ground condition (Seismic Zone, Bearing Capacity of Soil, Availability of material), Specific use and aesthetic appearance. Normally building is designed to withstand against the vertical of loads but there are so many loads which have to be exerts in lateral direction on a structures. Earthquake resistant structures are the structures designed to withstand earthquakes, while no structure is completely immune to damage due to earthquake. The specified goal of earthquake resistant construction is to erect structure that behaves better during seismic activity and their conventional counterparts. According to IS 1893 Part-I:2000, earthquake resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location, which means that the loss of life should be minimized by preventing the collapse from earthquake. Currently there are several design philosophies for designing of structures but in INDIA IS 456:2000 is generally used for design of structural elements like Beams, Columns and Slabs while IS 1893:2000 is used for design of structure for earthquake considerations. In this Study we use STAAD Pro v8i for the designing of structure as per Indian Standards by BIS and determine the change in the value of Quantity of material used for the structure in both cases as follows:

- Structural Design of Building due to Vertical loads only
- Structural Design of Building due to Vertical and Lateral Load ( Earthquake Loading)

Finally, we analyze the rate of material used in both structures as per SOR (Schedule of Rates) by ADA (Agra Development Authority).

### 2. Structural properties of RC (Reinforced Concrete) framed building

- No. of Stories: G+4
- Storey Height: 3.0 m
- Beam Dimensions: 230mm x 450mm
- Column Dimension for Ground and First Stories: 450mm x 450mm
- Column Dimension for above Stories: 300mm x 300mm
- Grade of Concrete: M20
- Grade of Steel: Fe415
- $F_{ck}$  : 25N/mm<sup>2</sup>
- $F_y$  : 415N/mm<sup>2</sup>
- Slab Thickness: 120mm
- Zone Factor: 0.16
- Importance Factor: 1.0
- Response reduction Spectrum: 5.0
- Rock/Soil factor: 1.0
- Damping Ratio: 5%

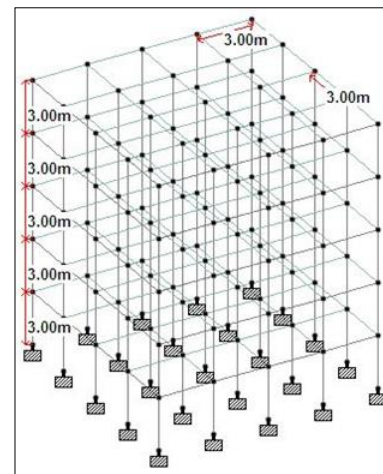


Fig 1: Structural dimensions

### 3. Loading specification used

As we consider the structure is a residential one, so there are following loadings which we consider as per IS 875 (Part 1, Part 2, Part 3). IS875 Part 1 for Dead Loads, IS875 Part 2 for Imposed Loads and IS875 Part 3 for Earthquake considerations.

Here Loading is as Follows:

- a. Dead Load
  - 1. Self Weight of Frame
  - 2. UDL due outer walls – 12.42 kN/m
  - 3. UDL due inner walls – 6.21 kN/m
  - 4. UDL due to Parapet walls – 3 kN/m
- b. Live Load
  - 1. Floor load of intensity – 3.5 kN/m<sup>2</sup>
- c. Seismic Load as per IS875 Part 3 for city AGRA in Zone III including all accidental loads.

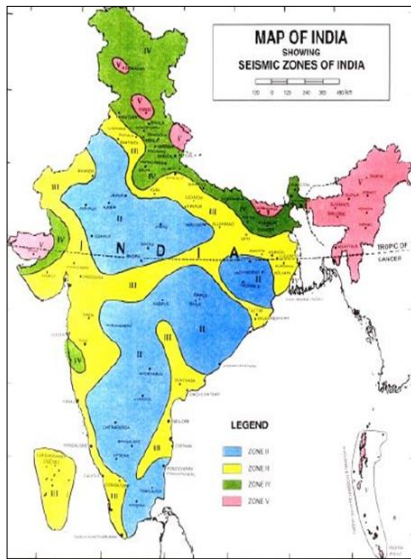


Fig 2: Seismic Zones in India

### 4. Terminologies used for analysis of earthquake

Analysis of Structure for vertical structures load only and for both vertical load and earthquake considerations is done by STAADPRO v8i software. Data used in software for earthquake analysis as per IS 1893 part 1.

- a. Horizontal acceleration coefficient ( $A_h$ )
- b. Modal Mass
- c. Modal Participation factor
- d. Zone Factor
- e. Moment resisting frames
  - OMRF (Ordinary moment resisting Reinforced Concrete frame)
  - SMRF (Special moment resisting Reinforced Concrete frame)
- f. Design eccentricity( $e_d$ )
- g. Design Spectrum (Clause 6.4 IS1893 PartI:2002)
- h. Zone Factor (Z): Clause 6.4.2 IS1893 Part I:2002

Table 1

Seismic Zone	2	3	4	5
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

### 4.1 Dynamic Analysis as per IS 1893 :2002

To obtain the design seismic force and their distribution to different levels along the height of the building and to various load resisting elements Dynamic analysis is performed as per IS1893 Part I for the following buildings:

- a. **Regular Buildings:** Buildings those have heights greater than 40m in Zone IV and V, and those whose height is greater than 90m in Zone II and III. Modeling is done as per Clause 7.8.4.5 of IS1893 Part I.
- b. **Irregular Buildings:** ( as Per Clause 7.1 IS 1893:2002) - All RC Framed Building having height greater than 12m in Zone IV and V, and for frames having height greater than 30m in Zone II and Zone III.

### 4.2 Building with Soft Storey

- a. Buildings those have Flexible storey consisting of an open space for parking needs special arrangements to increase the lateral strength and the stiffness of soft/open storey.

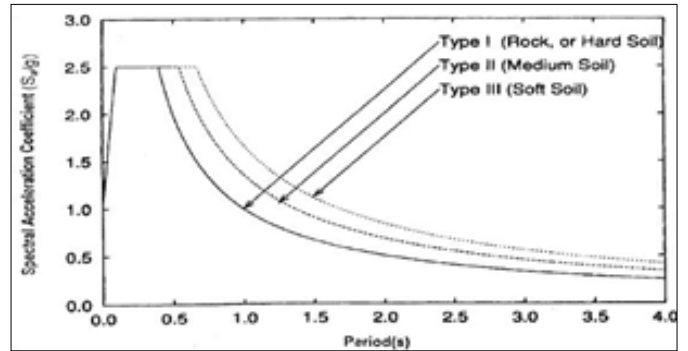


Fig 3

- b. In Dynamic analysis as per IS 1893 part 4 is carried out by considering the strength and stiffness effects of infills and deformation which is inelastic in nature, particularly members designed accordingly in case of soft storey.
- c. Design criteria which is going to be adopted to carrying out the analysis due to earthquake, which is already a function in STADD PRO v8i. This software analyze the structure for earth quake as per IS 1893 also by considering accidental loads.
- d. Following design criteria is to be adopted after analysis of earthquake by neglecting the effect of infill as follows:
- e.
  - Columns and beams of soft storey is designed for 2.5 times the shear and moment calculated under seismic loading.
  - Shear wall placed symmetrically in both direction of the building as feasible from the centre of the building.

### 5. Design of structure without earthquake

In this analysis by STAAD PRO, structure of specified dimension is to be designed only for vertical loadings consist of Dead loads and Live load only( No Lateral forces is considered while designing the structure).

Here due to application of live load and dead load following load combinations is generated as per IS456:2000 for designing of structure as follows:

- a. Dead Load + 1.5 Live Load
- b. 1.2 Dead Load + 1.2 Live Load
- c. 1.5 Dead Load
- d. 0.9 Dead Load

The above load combination with is generated by STAAD PRO v8i is as per IS456:2000, which is auto generated for general structures.

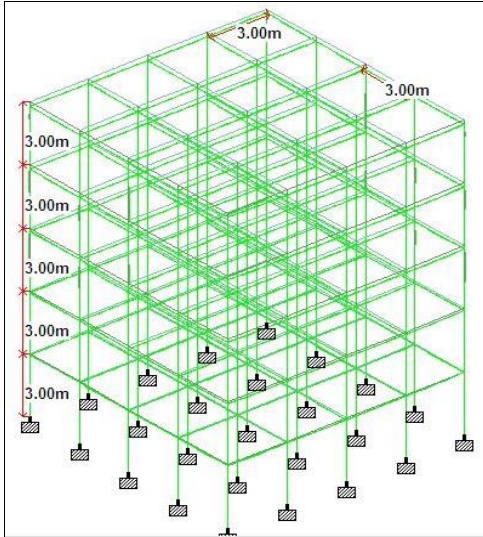


Fig 4: Deflected shape of structure

**6. Design of structure with earthquake**

In this analysis by STAAD PRO, structure of specified dimension is to be designed only for vertical loadings consist of Dead loads and Live load and Seismic loads for City AGRA which is in Zone III as specified by GOI.

Here due to application of dead load, live load ans seismic load following load combinations is generated as per IS456:2000 for designing of structure as follows:

- a. 1.5 Dead Load + 1.5 Live Load
- b. 1.2 Dead Load + 1.2 Live Load
- c. 1.2 Dead Load + 1.2 Live Load + 1.2 Earthquake load
- d. 1.2 Dead Load + 1.2 Live Load - 1.2 Earthquake load
- e. 1.5 Dead Load
- f. 1.5 Dead Load + 1.5 Earthquake Load
- g. 1.5 Dead Load - 1.5 Earthquake Load
- h. 0.9 Dead Load + 1.5 Earthquake Load
- i. 0.9 Dead Load - 1.5 Earthquake Load

The above load combination with is generated by STAAD PRO v8i is as per IS456:2000, which is auto generated for general structures and includes all repeat load cases.

Here, in the Seismic analysis we see the deflection of large magnitude in comparison to the design of structure for only Dead Loads and Live Load. Fig 4 shows the deflected shape of the structure which is designed only for vertical loads, while Fig 5 shows the deflection of the same structure when it is designed for vertical loads and lateral load(Seismic) both. In comparative analysis we consider the same scale for the representation of Deflection, BMD, SFD etc. Here we also compare with the design of a column (Fig 6) which is at ground floor and see the variation in reinforcements.

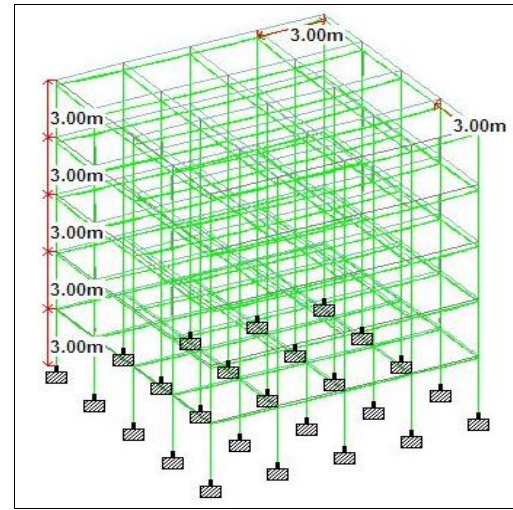


Fig 5: Deflected shape of structure

**7. Comparision of reinforcement specifications**

As we know that by analyzing the structure for different load conditions, there is a change in reinforcement and amount of concrete for the same geometry of the sections. Here we Compare the change in area of reinforcement for both conditions section 5 and section 6. Here we choose a single column then see the variation in the reinforcement for different load conditions.

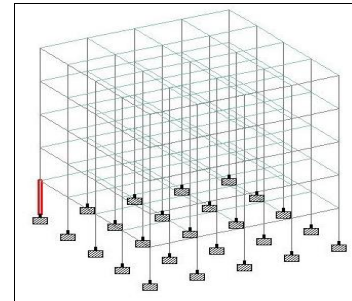


Fig 6: Selected Column

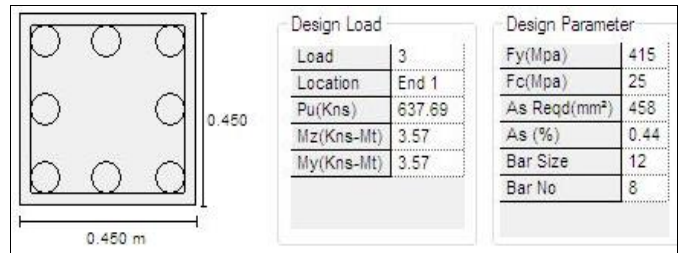


Fig 7: As required without EQ analysis

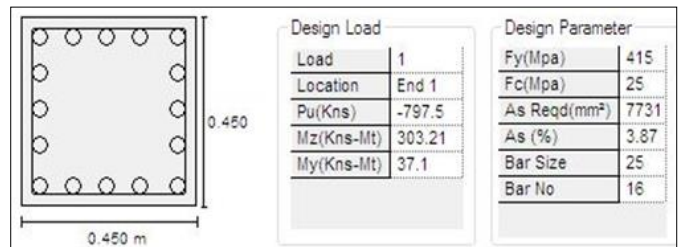


Fig 8: As required without EQ analysis

Here we see from Fig 7 and Fig 8 that for the same geometry of the section but for the different load conditions there is a diverse change in the quantity of the reinforcement. When we analyze only for vertical loads total area of reinforcement required  $A_s$  is 458 mm<sup>2</sup>, so we provide 8-12 mm dia. But in case of earthquake analysis (combination of vertical loads and earthquake load) total area of reinforcement required  $A_s$  is 7731 mm<sup>2</sup>, so we provide 16-25 mm dia. as main reinforcement.

### 8. Comparison of quantity and cost

As seen in the previous section that even in a single element there is a huge change in quantity of the steel reinforcement, as on large scale the amount of the material required is of a large value which directly affects the cost of the structure. Here for designing of the structure we use M25 grade of concrete from LAFARGE CEMENTS which costs Rs. 5640 per cubic meter, and Fe415 grade of steel from Amba Shakti TMT which costs Rs. 30500 per 930 Kgs. Following is the Quantity analysis for both structures (Normal Building subjected to vertical loads and Earthquake resisting building).

**Table 2:** Quantity and Rate analysis for the Building subjected to vertical loads only.

Material	Total Quantity	Cost per unit	Total Cost
Concrete (M25)	112.7 m <sup>3</sup>	Rs. 5640/m <sup>3</sup>	Rs.692028
Steel (Fe415)	64927 Kgs	Rs.30500 per 930 Kgs	Rs.2129327
Total Cost of structural material		Rs. 2821355	

**Table 3:** Quantity and Rate analysis for the Building subjected to vertical loads and Earthquake loads.

Material	Total Quantity	Cost per unit	Total Cost
Concrete (M25)	89.6 m <sup>3</sup>	Rs. 5640/m <sup>3</sup>	Rs.505344
Steel (Fe415)	136486 Kgs	Rs.30500 per 930 Kgs	Rs.4476154
Total Cost of structural material		Rs. 4981498	

### 9. Result and Conclusion

Finally we know the total amount of reinforcement for both the structures and see the variation in cost for the structures. But we also see the variation in the values of deflection which is the basic need for the stability of the structure at the time of earthquake. Here cost is nearly increased by 1.76 times the cost of the building subjected to the vertical loads only, which concludes that Ductility of the framed structure is high because increase in cost is generally lies between 33% to 87% as the ductility of the structures varies from low to high respectively. So, finally after results we says that the structure designed for earthquake is DCH (High Ductility).

Finally we have to work for reducing the cost of the structures having capability to resist the Earthquake loadings.

### 10. References

1. IS:1893(Part1): Criteria for earthquake resistance design of the structures,Part1, general provisions and buildings, Fifth revision, Bureau of Indian Standards, Manak Bhavan, Bahadur Shah Zafar Marg, New Delhi, 2002.
2. A Comparative Study of different configurations of Shear wall location in soft storey building subjected to seismic load, by R.S. Mishra, V. Kushwaha and S. Kumar. me:

2015; 2(7).

3. A comparative study of OMRF and SMRF structural system for tall and high rise buildings subjected to seismic load, Volume: 2 Issue:09/09/2013 by G.V.S. Siva Prasad and S. Adishesu.
4. IS: 875 (Part2)-1987 (Reaffirmed), Code of Practice for design loads for buildings and structures, Part-2 Imposed Loads, 2008.