

Comparative Study of the Effects of Earthquake and Wind Loads on High-Rise Buildings

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Abstract— The importance of earthquake engineering and wind engineering is emerging in India ever since the need for more taller buildings. Considering the ever increasing population as well as limited space, horizontal expansion is no more a feasible solution especially in metro cities. There is number of technology to build super-tall and super slender buildings today, but in India we are yet to come up with the technology which is already established in other parts of the world. Analysis of high rise building structures subjected to earthquake acceleration is often a complex task. This study addresses the performance of high rise reinforced concrete building with the Comparison on the effect of earthquake and wind loads. A computer program E-TAB is used to analyze the structural buildings behaviour under wind pressure defined as well as equivalent static loads for earthquakes considering all factors in the IS 456:2000, IS 1893:2002 & IS 875:1987 (part3). Estimation of Wind load will be studied with the gust factor method, as it is more precise. This paper describes mathematical study and relation between wind and earthquake and its effects on building as a whole with respect of moment and shear force.

Key words: High-Rise Buildings, Indian Code, Wind Pressure, Gust Factor, Earthquake, Zone Factor, Response Reduction Factor, Soil Factor, Importance Factor

I. INTRODUCTION

Now a days there has been a considerable increase in the number of high rise buildings, both residential and commercial, and the modern trend is towards more taller and slender structures because of scarcity and value of land. Thus the effects of lateral loads like winds loads, earthquake forces are acquiring increasing importance and almost every structural designer is faced with the problem of providing adequate strength and stability against lateral loads. High rise reinforced concrete buildings need more attention and more concern while designing so that in case of high winds or any earthquake event they can stand with a lesser amount of damage. For this reason in recent years wind and earthquake loading have become determining factors in high-rise building design.

In this paper a computer program E-Tab has been used to analyze the reinforced concrete high rise buildings under wind and earthquake loads taking into account. This paper explain briefly the effect of wind and earthquake loads on reinforced concrete tall buildings. Application example for building with different floor weights, heights for both winds & Earthquakes such as intensity of wind pressure, gust factor (G), seismic zone coefficient (Z), the importance factor (I), Response reduction factor(R) and Average response acceleration coefficient (Sa/g) are analysed and discussed for the purpose of comparison by using IS 456:2000, IS 1893:2002 & IS 875:1987 (part3).

Present study is attempted in following steps

- 1) To determine the earthquake forces
- 2) To determine wind forces, and
- 3) To compare Earthquake and Wind Forces.

II. DESIGN EXAMPLE

A. Architectural Details:

In present study, analysis of multi storey building in moderate zones for earthquake and wind forces is conducted. Here the buildings situated at wind zone II and earthquake zone III are taken for analysis. Building has typical plan size 39m×30m. Fig.1 shows position of beams and columns in plan of building for all the floors.

The basic parameters considered for the analysis.

- Typical storey height: 3m
- Foundation: column is fixed at support
- Slab depth: 130 mm thick
- Live load: 3 kN/sq m
- Floor finish load: 1 KN/ sq m
- Earthquake parameters considered
- Zone: III
- Soil type: Medium soil
- Importance factor: 1.5
- Seismic zone factor: 0.16 for zone III
- Wind parameters considered
- Zone: II
- Basic wind speed: 39 m/s
- Terrain category: 2

B. Material Properties:

In India the design of Reinforced concrete buildings are based on IS 456, IS 1893 & IS 875. A typical value of concrete compressive strength (fck) and reinforcing yield stress (fy) is 25 N/mm² & 500 N/mm². The concrete modulus elasticity (E) 25000 N/mm² and shear modulus (G) 9615.38 N/mm² were taken in the design consideration.

C. Load Consideration:

There are two types of loads that are considered in this study; i) Gravity load ii) Lateral load. Gravity loads carried the dead load and live load while lateral loads considered wind and earthquake loads.

1) Gravity Load:

This loading represents all tributary dead loads and live loads. The dead load included concrete self weight with concrete density equal to 25kN/m³. Based on IS 875:1987 (part3) the live load was taken as 3.0kN/m² for building which is categorized under institutional occupancy class. The loads were distributed uniformly on all beams between of column lines.

2) *Lateral Load:*

In order to compare the performance of wind and earthquake loads on the reinforced concrete buildings, the static lateral loads of wind and earthquake forces were analysed.

III. ANALYSIS PROCEDURE

A. *Calculation of Earthquake Loads:*

In equivalent lateral force procedures the magnitude of force is base on an estimate of the fundamental period and on the distribution of force. The total design lateral force or design seismic base shear (VB) along any principal direction shall be determined by the following formula

$$VB = Ah W$$

Where, Ah = Design horizontal seismic coefficient, W = Seismic weight of the building.

Design horizontal seismic coefficient (Ah) is given by

$$Ah = (Z/2).(I/R).(Sa/g)$$

Where, Z = Zone factor (Table No.2), for zone-III Z = 0.24, I = Importance factor, R = response reduction factor and Sa/g = Average response acceleration coefficient.

The fundamental natural period (Ta) is taken for moment resisting frame building without brick infill panels as

$$Ta = 0.09h / \sqrt{d}$$

Where, h = Height of the building in m.

d = Base dimension of the building in m. along the considered direction of the lateral force.

Distribution of design force (Qi) is give as follow,

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^n W_j h_j^2}$$

Where, Qi = Design lateral force at floor i, Wi = Seismic weight of floor i, hi = height of floor i measure from base, and n = Number of stories.

B. *Calculation of Wind loads:*

1) *Static Method:*

The basic wind speed (Vb) for any site shall be obtained IS 875 (part 3) and shall be modified to get the design wind velocity at any height (Vz) for a given structure is given by

$$Vz = Vb k_1 k_2 k_3$$

Where, Vz = design wind speed at any height z in m/s, Vb = Basic wind speed in, k1 = probability factor (risk coefficient), k2 = terrain roughness and height factor and k3 = topography factor.

The basic wind speed map of India is applicable at 10 m height above mean ground level for different zones of the country taken from the code. The design wind pressure above mean ground level is given by

$$Pz = 0.6 Vz^2$$

Where, Pz = wind pressure in N/m2 at height z and Vz = design wind speed in m/s at height z.

2) *Gust Factor Method:*

Computation of Wind Load by Gust Factor Method, Hourly Mean Wind (Vz'): Hourly mean wind speed is maximum wind speeds averaged over one hour.

$$Vz' = Vb. K_1.K_2'.K_3$$

Where, Vb= Regional basic wind speed, K1= Probability factor, K2' = Terrain and height factor and K3 = Topography factor.

Design Wind Pressure (Pz')

$$Pz' = 0.6 (Vz')^2$$

Along-wind Load,

$$Fz = Cf. Ae. Pz'. G$$

Where,

Fz = along-wind load on structure at any height z;

Cf = Force Coefficient;

Ae = Effective frontal area;

Pz' = Design wind pressure;

G = the Gust Factor = (peak load/mean load); and is given by,

$$G = 1 + gf . r \sqrt{[B(1 + \phi)^2 + SE/\beta]}$$

Where,

gf = peak factor defined as the ratio of the expected peak value to the root mean value of a fluctuating load;

r = roughness factor;

gf . r is given by [Fig. 8 of IS 875 (III)]

B = background factor [Fig. 9];

SE/β = measure of the resonant component of the fluctuating wind load;

S = size reduction factor [Fig. 10];

E = measure of available energy

In the wind stream at the natural frequency of the structure [Fig. 11];

β = damping coefficient of the structure [Table 34]; and

$$\phi = \frac{gf . r . \sqrt{B}}{4}$$

And that is to be accounted only for buildings less than 75 m high in terrain category 4 and for buildings less than 25 m high in terrain category 3, and is to be taken as zero in all other cases.

B. *Across-Wind Loads:*

The Code points out that the method of evaluating across-wind and other components of structural response to wind loading are fairly complex and have not as yet reached a stage where successful codification can be attempted. It recommends use of wind tunnel model studies and specialist advice in cases where significant across-wind loads are anticipated.

IV. MODELING

3-D models are prepared for G+10, G+15, G+20, G+25, G+30 and G+35 multi storey building in ETABS.



Fig. 1: Plan of Building

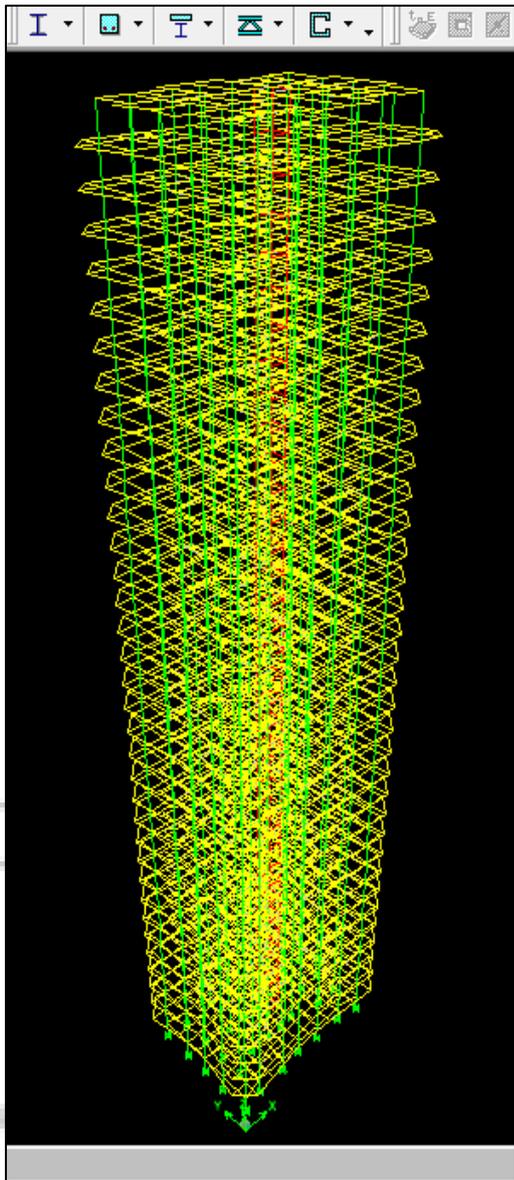
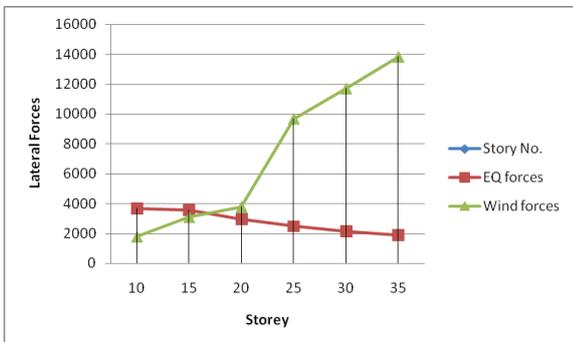


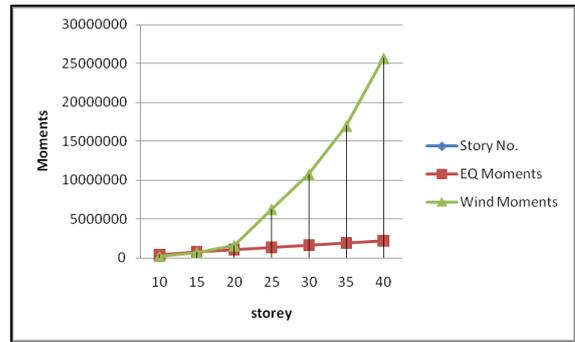
Fig. 2: Elevation in 3D

V. ANALYSIS RESULTS

From E tabs models for different stories, followings results are drawn.



Graph 1: Earthquake and Wind Forces Distribution



Graph 2: Earthquake and Wind Moments at Base

From the above graphs it is observed that height of building affects the structural behavior of multi storey building under earthquake and wind excitation.

A. Effect on Base Shear

For G+10 multi storey building, base shear obtained from earthquake analysis is 2 times greater than that obtained from wind analysis. For G+15 multi storey building, base shear obtained from earthquake analysis is 1.35 times more than that obtained from wind analysis. However, the base shear obtained from wind analysis for G+20 is 1.19 times more than that obtained from earthquake analysis. For G+25 multi storey building, base shear obtained from wind analysis is 3.67 times more than that obtained from earthquake analysis. G+ 30 storeys, wind pressure is 5.34 times more than Earthquake forces. For G+35, wind pressure is 7.56 times more than Earthquake Forces.

B. Effect on Moments At Base

For G+10 multi storey building, moments at base obtained from earthquake analysis is 1.64 times more than that obtained from wind analysis. For G+15 multi storey building, moment at base obtained from earthquake analysis is 1.25 times more than that obtained from wind analysis. However, the moments at base obtained from wind analysis for G+20 is 1.46 times more than that obtained from earthquake analysis. For G+25 multi storey building, moments at base obtained from wind analysis is 4.1 times more than that obtained from earthquake analysis. For G+30 storey, wind moment is 6 times more than Earthquake moment. And for G+35, wind moment is 8.5 times more than Earthquake moment.

VI. CONCLUSION

It is observed that base shear and base moment is less in case of wind analysis for G+10 and G+15 building whereas for G+20, G+25, G+30, and G+35 building it is more in case of wind analysis.

In present example, Gust factor is acting above the 25th story due to this wind forces become dominant than Earthquake forces.

As a height of structure increases Average Response Acceleration Coefficient (Sa/g) gets decreases and Wind Effective Area (Ae) gets increases. Because of this Wind forces become more dominant as compared to Earthquake after 20th storey.

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