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MODEL ANALYSIS OF HIGH-RISE STRUCTURES FOR WIND AND EARTHQUAKE FORCES

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The objective of the present work is to study and analyze the effect of wind and earthquake loads on a chosen symmetrical plan of a multi-storied building to assess the behavior of the structure in all the seismic zones based on IS 1893 and subjected to different wind velocities based on IS 875 codes. For the present study, six cases (6 floors, 9 floors and 12 floors each for earthquake and wind) are considered under which 30 structures are modelled in ETABSv16.0 software and static analysis is carried out. Structural parameters like story drifts, story displacements and story shears are studied. Finally, it is found that story drifts are found to be maximum at 2nd floor (i.e., at 6 m) and 40% increase is observed in parameters when wind speed is increased from 33 to 39 m/s and by 21% when wind speed is increased from 50 to 55 m/s. With increase in wind speed on moving to higher seismic zones, with increase in number of stories from 6 to 9 story drifts increased by 109%, story displacements increased by 185% and increased by 15% and 62% on moving to higher seismic zones. Also, wind forces on the structure subjected to variation in increasing wind speeds and increasing heights in zone II and zone III but in no case are they greater than the earthquake forces in zone IV and V.

Keywords: Lateral loads, Wind forces, Story drifts, Story displacements shears.

1 INTRODUCTION

Considering the ever-increasing population as well as limited space, horizontal expansion is no longer a viable solution especially in metropolitan cities. As there has been a considerable increase in the number of tall buildings in recent times, effects of lateral loads like wind loads and earthquake forces are attaining increasing importance (Reddy and Sandip 2014). The Indian sub-continent is highly vulnerable to natural disasters such as earthquakes, draughts, floods, cyclones, landslides, and avalanches. Hence, the response of structures under wind and earthquake effects is a very important area where the researchers should concentrate and bring out effective disaster mitigating techniques, so that the structures remain functional. As height of buildings increases, the effects of both earthquakes and wind increases can be found out by analyzing buildings for earthquake and wind forces (Suchita and Magadum 2014). Architectural re-interpretations of the building type, the high cost of land in urban areas, the need to preserve agricultural production, the concept of skyscrapers, and the influence of cultural significance have all contributed to forcing buildings upward (Rajmani 2015). Dynamic actions are caused on buildings by both wind and earthquakes, but design for wind forces and for earthquake effects are distinctly different (Narla and Vardhan 2017). By the study of past earthquakes occurred in multistoried building shows that if they are not well designed and constructed with adequate strength it leads to the complete collapse of the structure. So, to acquire safety against additional deformations there is need to study of detailed considerations to design earthquake resistance structures. Generally structural engineers traditionally use linear static analysis to compute design forces, moments and displacements of a structure resulting from loads acting on it (Radha Devi and NagaSai 2018). The basic intent of analysis for earthquake resistant structures is that buildings should be able to resist minor earthquakes without damage.

2 NEED FOR THE PRESENT STUDY

Lateral loads can develop high stresses, produce sway moment or cause vibration. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces. Wind and earthquake loads are random in nature and it is difficult to predict them. They are estimated based on a probabilistic approach. Therefore, it is necessary to know which force is governing on the chosen structure for design.

For a design of case when a building is situated in a particular wind and earthquake zone, the major designing loads for such a building can be adopted directly from the analytical conclusions of the present work subjected to parameters chosen for deciding the final design of structure. For the analysis, 30 models were created and subjected to wind and earthquake loads separately.

3 OBJECTIVES

The primary objective of our study was to understand behavior of the chosen structure under the action of seismic loads and wind loads in different seismic zones II, III, IV, and V (IS 1893 Part-1 2002) subjected to different wind speeds 33m/s, 39m/s, 44m/s, 47m/s, 50m/s and 55m/s (IS 875 Part 3 1987) respectively and to find the governing force among wind and earthquake on the structure through model analysis.

4 ANALYTICAL METHODOLOGY

For the present study, a symmetrical plan is considered and modelled for performing the wind analysis and seismic analysis separately on different floors (varying heights) of model at various locations (different zones).

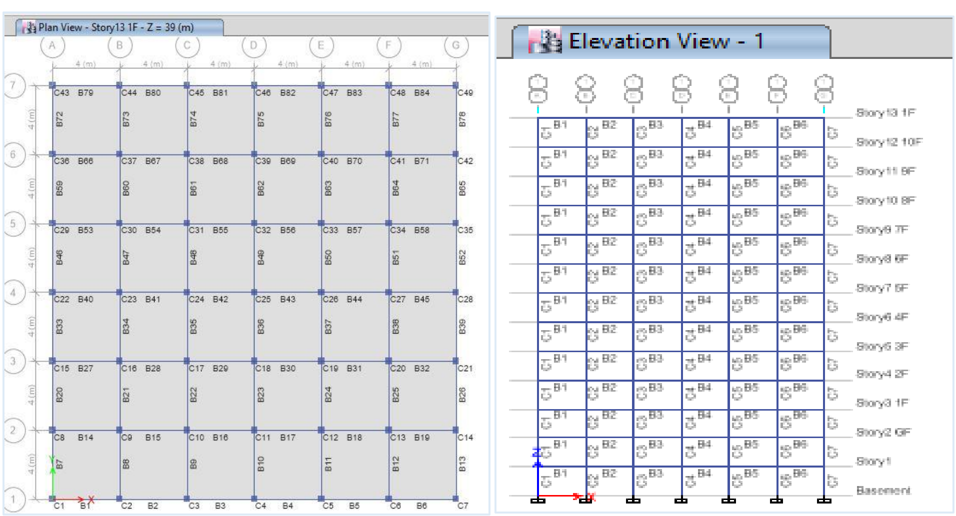

Figure 1. Plan and elevation of the model chosen for analysis with labels.

The selected plan of building consists of 49 columns. Models with different stories (6, 9 and 12) are modelled with floor height of 3.0m each and slab thickness of 0.125m with grade of concrete chosen to be M40 and steel Fe500. Soil under foundation is taken as medium soil. Loads considered for study are dead load, live load (3kN/m^2), seismic load and wind load.

Figure 1 shows the plan and elevation of the 12-floor symmetrical model with labels, which is modelled in ETABS for present study on which different loads considered are applied.

4.1 Seismic Load

Seismic base shear is given by Eq. (1),

$$V_B = A_h x W \tag{1}$$

where $\boldsymbol{A_h}$is the Design horizontal acceleration spectrum value using fundamental natural period in the considered direction of vibration is given by Eq. (2)

$$A_h = \frac{z}{2} * \frac{I}{R} * \frac{s_a}{g} \tag{2}$$

4.2 Wind Load

Design wind pressure is calculated by Eq. (3)

$$P_z = 0.6\, V_z^2,\ Where\ V_z = V_b * K_1 * K_2 * K_3 \tag{3}$$

where $\mathbf{V_z}$: design wind speed.

$\mathbf{V_b}$: basic wind speed.

All the parameters required for calculating wind loads are taken from Indian Standard Code IS 875-Part 3 (1987) and these wind loads and wind pressure coefficients are applied on to model and analyzed using method of exposure from shell objects in ETABS v16.0.

5 ANALYTICAL TEST RESULTS

The numerical models were carried out using ETABS v16.0 software. A total of 30 different structures were modeled in ETABS separately, and then analyzed for all the wind and earthquake zones. The safety of structures was then checked against allowable limits prescribed using inter-story drifts.

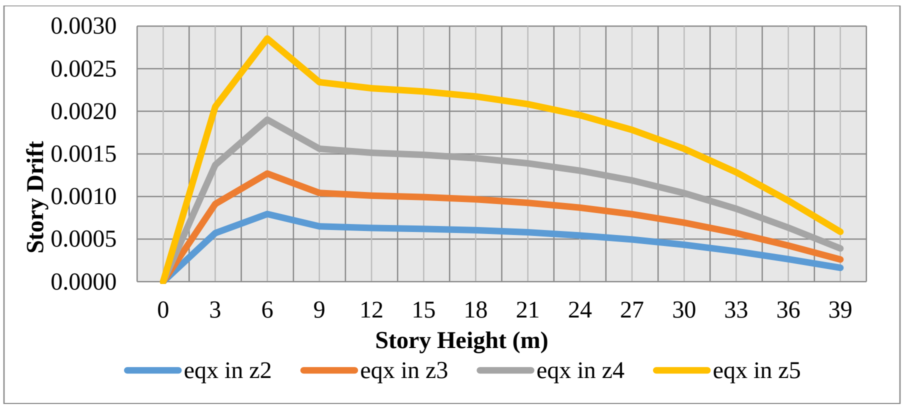

Figure 2. 12th Floor model with earth quake load.

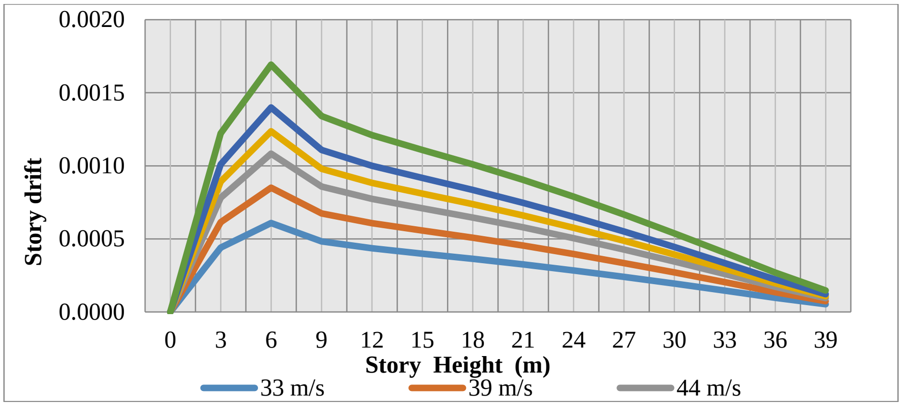

Figure 3. 12th Floor model with wind load.

From the analytical results' obtained parameters considered for study story drifts, displacements and shears are tabulated and compared in aspects of increasing height of the models, increasing seismic zones and wind velocities for which graphs are drawn and conclusions were inferred. Figures 2 and 3 show the behavior of 12-story building subjected to different earthquake zones and wind speeds, respectively. With an increase of wind velocity or seismic zone, the magnitude of story drift increases, and the maximum story drift is observed at the second floor.

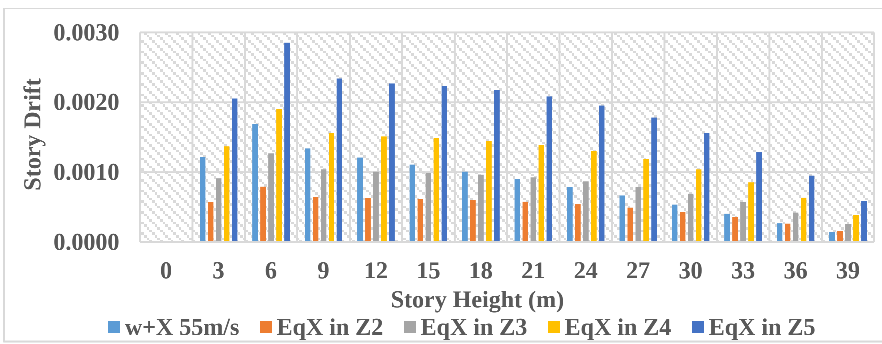

Figure 4. Story drift for earthquake with wind speed of 55m/s on 12 floor model.

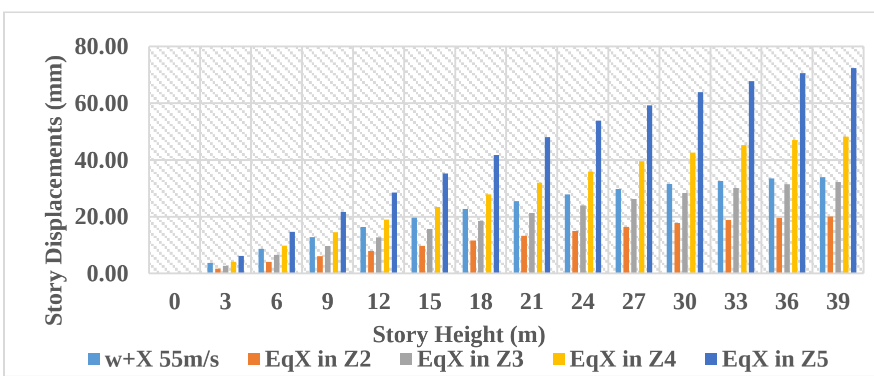

Figure 5. Story displacement for earthquake with wind speed of 55m/s on 12 floor.

In Figures 4 and 5, story drifts and displacements of 12 floor building subjected speed of 55m/s are compared with 12 floor building in all the earthquake zones to find the governing force among the both on 12 floor building and found that story drift and displacement on model due to wind forces are dominating the earthquake at all floors in zone II and zone III but in no case greater than earthquake forces in zone IV and zone V.

6 CONCLUSIONS

The effective parameters for wind forces affecting any building are the area subjected to wind as well as the intensity of wind defined by the code according to location. The effects of both earthquake forces and wind forces on multi-story buildings increase with increase in height of building. In the present study, with the increase of stories from 6 (21 m) to 9 (30 m), story drift, story shear and story displacements increase by 109%, 109% and 185%, respectively. When number of stories increase from 9 (30 m) to 12 (39 m), story drift, story shears, and story displacement increase by 53%, 53%, and 96%, respectively, with the increase in wind speed. Similarly, moving on to higher earthquake zones, story drift, story shears and story displacements increase by 15%, 15% and 62%, and increase by 9%, 9% and 42% respectively with increase in number of stories from 6 (21 m) to 9 (30 m) and 9 (30 m) to 12 (39 m).

On comparing the effect of wind forces with the effect of earthquake forces on performance of 12 story building subjected to wind speed of 55 m/s, we found that wind is the governing force in zone II and III and earthquake is the governing force in zone IV and V. Similarly, the effect of wind and earthquake forces is compared with regards to the performance of 6 story, 9 story and 12 story models subjected to different wind speeds. It was found that for medium height of the buildings subject to higher intensity of wind speeds, wind is the governing force over earthquake in zone II and to considerable height of the building in zone III. Thus, it can be presented that although seismic zone II is not severe for considering the structure to be designed for seismic forces, structures with moderate heights are to be designed for safety against wind loads compared to earthquake loads in zone II and zone III, considering the wind speed the structure is likely to experience.

The percentage increase in the parameters story drift, story displacement and story shear for same height of the building (models chosen 21 m, 30 m, 39 m) is 40% when wind speed is increased from 33 to 39m/s and 27%, 14%, 13%, and 21% when wind speeds are increased from 39 to 44 m/s, 44 to 47 m/s, 47 to 50 m/s and 50 to 55 m/s respectively. Similarly, the parameters increased by 60% when earthquake zone is changed from zone II to zone III and increased by 50% when changed from zone III to zone IV and zone V. Magnitude of the parameters on the same building increased with increase in wind speed and on moving to higher seismic zones (increase in zone factors). All the parameters considered in the study on a building increased by 178% when speed on the building is increased from 33m/s to 55m/s and increased by 260% when moved from zone II to zone V.

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