Response of Reinforced Concrete Structures to Gravity and Lateral Loads

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***Abstract*— The present investigation is to study the behaviour of multi-storey R. C. frames under various loading conditions, namely dead load, live load, earthquake load and wind loads. Three load cases have been considered and the design forces are obtained as per Indian Standards in each load case for various load combinations. Earthquake loads and Wind loads were evaluated and design forces for various load combinations has calculated. A software has been used for analysis of buildings. The severity of earthquake load and Wind load with respect to dead load and live load combination in various zones of earthquake is studied. It was concluded that except in seismically very active zone, in all other regions wind analysis is sufficient.**

***Index Terms*— Earthquake and Wind zones, Design Column Moments, Column Displacements**

I. INTRODUCTION

The trend of people to migrate into urban areas has made life in the cities more troublesome. This has led to the development of tall buildings and study of various structural systems. In tall buildings, lateral loads are the premier ones, which increases rapidly with increase in height. The structural system designed for vertical load may not have the capacity to resist the lateral loads and the cost increases substantially with the increase in number of storeys. One of the most used structural systems is the rigid frame structure. In analyzing and designing a structure, it is necessary to have a clear picture of the nature and magnitude of loads acting on the structure. The different types of loads are static loads such as dead load, live load etc., and dynamic loads such as wind load, earthquake load etc., The probability that all these loading will occur with maximum intensity at the same time and at the same point is remote. Usually, multiple types of loading condition will be considered and the structure is designed to carry the worst possible combination.

II. RELATED WORK

Many researchers have worked on the effect of wind load and earthquake load on structure.

Gambir studied a qualitative study of the behaviour of some of the commonly used structural systems employed in high rise buildings subjected to lateral load due to earthquake and has given the recommendations regarding the suitability of a system for buildings of various heights. [6]

Agarwal investigated wind resistance design of structural components and contributed provisions to Indian standards. [7]

Jain investigated an overview of the Indian Standard code requirements for earthquake resistance design of buildings. [8]

III. PROPOSED METHODOLOGY

A type of structure commonly used in industrial or residential buildings is a framed structure. Frames are characterized by moment resisting member at some or all the joints. Out of various loads acting on the buildings, only the effect of dead load, live load, earthquake load and wind loads are considered in the present study. Static wind load method of load estimation which implies a steady wind speed, which is proved to be satisfactory for normal and medium height structure is used. Basic wind speeds in different regions are modified to include risk level, terrain roughness, height of structure and local topography to get the design wind pressure. The procedure given in IS:875 (part-3)-1987 is used to estimate the wind pressure on the structure

In Seismic analysis, the buildings were analyzed, RC frames are assumed as shear structures i.e., floor systems are considered infinitely rigid as compared to the columns. Physical lumping is adopted and the masses are assumed to be concentrated at floor level. Response spectrum method is used to calculate the lateral earthquake forces. It calculates the average acceleration coefficient for a particular period and for the given damping. The individual forces obtained from each period will be summed up to obtain the maximum shear or distribution forces at various storey levels. The first six modes are considered for computation of horizontal shears. It is justified because the forces produced in the first few modes are pre-dominant and their participation factors are higher. The procedure given in IS:1893-2002 is adopted for evaluating lateral loads

As the structure is subjected to dead load, live load, earthquake load and wind load, it is necessary to combine these forces to obtain the maximum effects on structure. Simultaneous occurrence of earthquake load and wind loads will have negligible statistical probability. Thus, three separate load cases are considered and in each load case all possible load combinations are considered taking the worst effect as design forces. The three load cases considered are,

1) Case 1: Dead Load (DL) and Live Load (LL) combination.
2) Case 2: Dead Load (DL), Live Load (LL) and Earthquake Load (EL) combinations.
3) Case 3: Dead Load (DL), Live Load (LL) and Wind Load (WL) combinations.

The load combinations in each load case along with partial safety factors are

1.5 x (DL + LL)
1.2 x (DL + LL ± EL)
1.2 x (DL + LL ± WL)
1.5 x (DL ± EL)
1.5 x (DL ± WL)
0.9 DL ± 1.5 EL
0.9 DL ± 1.5 WL

The buildings were analyzed using STAAD Pro. Software to evaluate internal forces such as beam shear, beam moment, column axial forces and column moments for dead load, live load, wind load, earthquake load separately. Then in each load case, considering all the load combinations and partial safety factors, the worst effect has been taken as the design forces for each member.

TABLE I: Wind velocities and Earthquake zones in different cities

City	Earthquake Zone	Wind Zone (Wind Speed in m/s)
Bengalooru	2	1 (33)
Chennai	3	6 (50)
Delhi	4	4 (47)
Kolkata	3	6 (50)
Mumbai	3	4 (44)
Vishakhapatnam	2	6 (50)

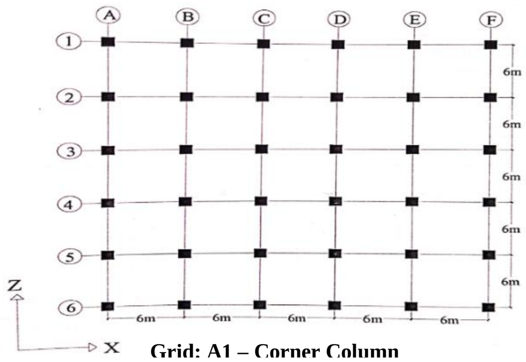

Figure 01: Plan

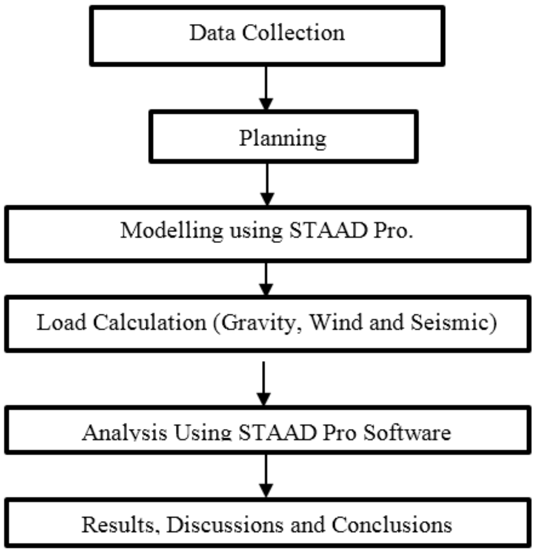

Figure 02: Methodology

IV. RESULTS AND DISCUSSIONS

To study the effect of dead load, live load, earthquake load and wind load, two buildings of different heights were considered. A four storey (14.0m) and fifteen storey (52.0m) of two buildings were considered. Plan of the buildings as shown in Figure 1. Live load intensity of 1.5 kN/m^2 at roof and 2.0 kN/m^2 at floors dead load intensity of 2.0 kN/m^2 were applied on all floors. Earthquake loads in four different zones are considered and wind forces are obtained at a particular place in the corresponding earthquake zone. For this purpose, five cities in different earthquake zone were considered and corresponding wind speed as per Indian Standards requirements in these cities were used and are shown in Table 1. In each case, taking all the corresponding loading combinations, worst effect is considered as design forces

To study the effect of earthquake load (case-2) and wind load (case-3) on conventional dead and live load (case-1), the internal forces are plotted in the normalized form i.e., normalizing design forces of case-2 and case-3 forces with respect to design forces obtained from case-1 loading. To study the variations of design forces and to identify the load case governing the design in each zone of earthquake, column displacements were plotted in Fig. 3 to Fig. 7 and normalized column moments were plotted in Fig. 8 to Fig. 12. Each curve shows the variation of design forces at various levels for a particular zone of earthquake and shows which load case the design governs.

It is found that the normalized design moments in beams and columns in all the zones are very large in the lower storeys and gradually decreases towards the top storeys and almost converges to case-1 loading at the top storey. This indicates that the forces in the top storey due to case-1 loading are almost same as that of design forces due to either case- 2 or case- 3 loading. This study verifies that care should be taken while designing the column for wind and earthquake forces particularly for tall structures. The effect of wind and earthquake forces will not have significant effect on beam shear and column axial forces in all zones of earthquake.

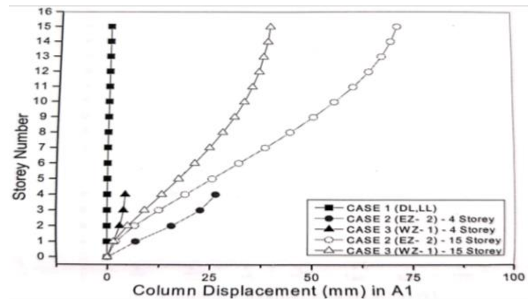

Figure 3: Column Displacement v/s Number of Storey in Bengalooru Region

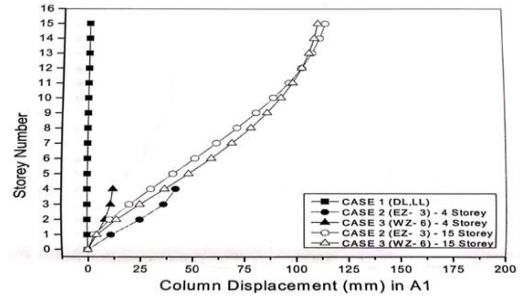

Figure 4: Column Displacement v/s Number of Storey in Chennai and Kolkata region

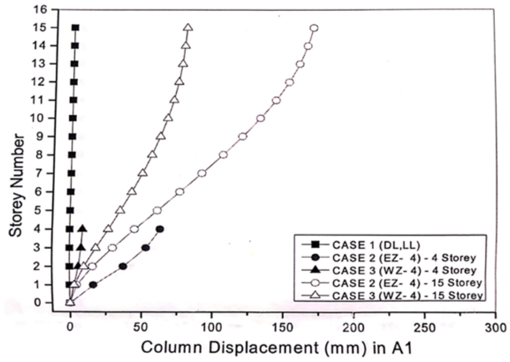

Figure 5: Column Displacement v/s Number of Storey in Delhi Region

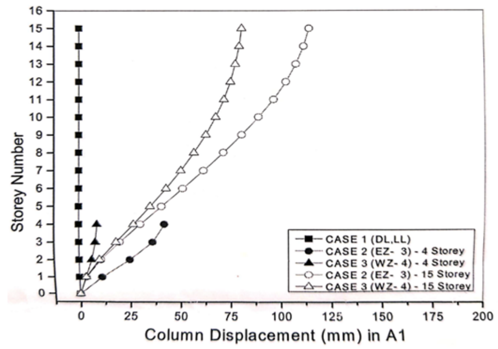

Figure 6: Column Displacement v/s Number of Storey in Mumbai Region

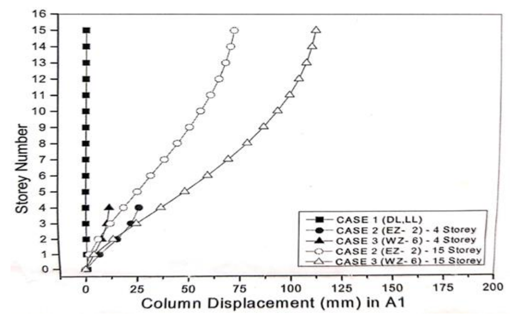

Figure 7: Column Displacement v/s Number of Storey in Vishakhapatnam Region

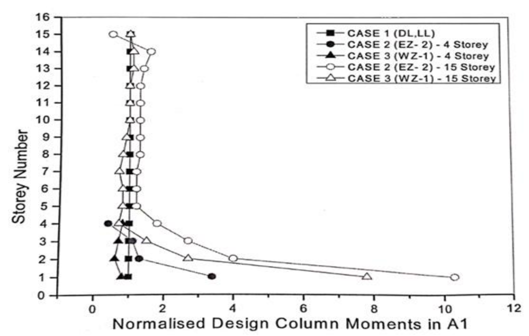

Figure 8: Column Moments v/s Number of Storey in Bengalooru Region

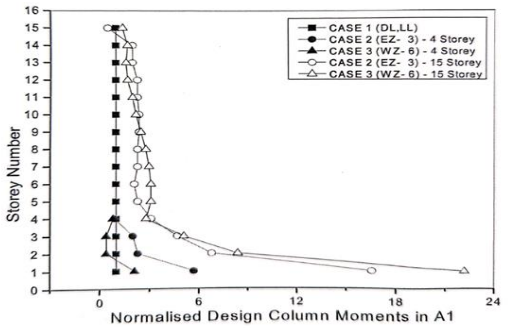

Figure 9: Column Moments v/s Number of Storey in Chennai and Kolkata region

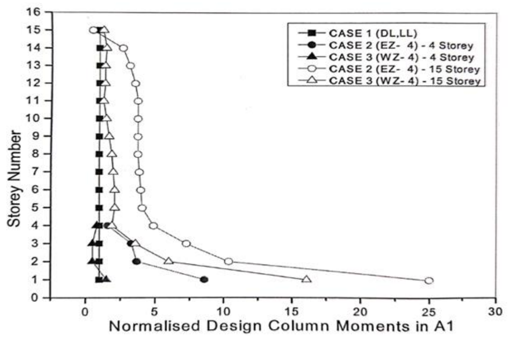

Figure 10: Column Moments v/s Number of Storey in Delhi region

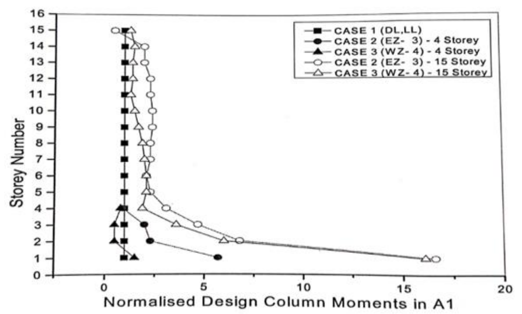

Figure 11: Column Moments v/s Number of Storey in Mumbai Region

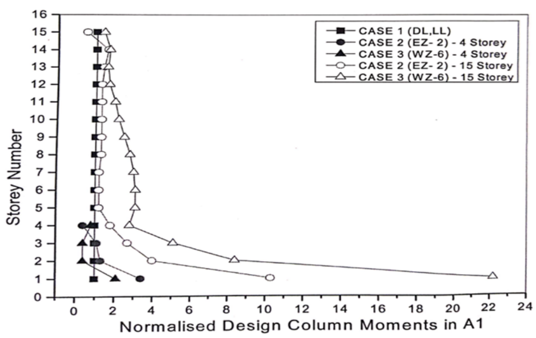

Figure 12: Column Moments v/s Number of Storey in Vishakhapatnam Region

V. CONCLUSION

It was observed from the present study that the design forces are critical in case-3 loading in all the zones except in zone 4. In zone-4, the effect of case-2 loading is predominant. This indicates that up to zone-3, earthquake analysis need not be carried out in design, provided wind load analysis is made. Study shows that there is considerable increase in beam moments, beam shear, column axial forces and column moments due to the inclusion of wind and earthquake loading. The effect of earthquake forces and wind forces on column moments is more significant. Also, increase in the number of storeys causes increase in design forces and the column moments are found to be more sensitive to increase in the number of storeys. It is found that the normalized design moments in beams and columns in all the zones are very large in the lower storeys and gradually decreases towards the top storeys and almost converges to case-1 loading at the top storey. This indicates that the forces in the top storey due to case-1 loading are almost same as that of design forces due to either case -2 or case - 3 loading.

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