# Seismic Performance of Tall Reinforced Concrete Buildings under P-Delta Analysis

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***Abstract*— Rapid growth of urbanization world over indicates that there is growing movement of population which result in high concentration of building construction activities in urban areas. This leads to ever increasing demand for land for building construction. As land is a scarce resource for developments in any urban area, there is heavy pressure on the available land. For economic reasons people tend to construct buildings with maximum floor area on the available land and consequently, construction of tall buildings is increasingly becoming inevitable in urban areas. Tall building structure is so designed to get optimum built up area to the requirements and comfort of the occupants in such a way that the structural system is economically feasible and sufficiently safe to resist all natural forces including lateral forces due to wind or earthquakes. Structures subjected to lateral loads often experience secondary forces due to the movement of the point of application of vertical loads. This secondary effect, commonly known as P-Delta effect plays an important role in the analysis of the structure. In the above context, this thesis work describes Seismic analysis of a multi-storey RC building by using ETABS structural analysis software. Building models with different number of storeys have been analyzed and the maximum response values in buildings are determined in terms of displacements and storey Drift.**

***Keywords*—Second order effect, P-Delta effect, Storey drift**

## I. INTRODUCTION

Earthquake is considered to be one of the most destructive or damaging natural calamities in the past decades. It pause serious threat to lives and damage to properties. Mostly, the causes of deaths reported after the incidence of earthquakes are eventually due to the collapse of buildings/structures. This is an indication of the necessity of developing earthquake resistant building construction techniques. Truly, there has been a growing interest among the scientific community in acquiring better knowledge on the seismic behaviour of reinforced concrete buildings in recent past. Various study reports on earthquake have revealed that under an earthquake, tall buildings will tend to have a higher magnitude of vibration as compared to short buildings. Also the buildings constructed without considering the second order P-Delta effect and appropriate characteristic seismic resistance constitute the main source of risk during an earthquake. Structures often experience secondary forces due to the movement of the point of application of vertical loads and when it is subjected to lateral loads. P-Delta effect holds an important role in the analysis of the structure. The P-Delta effect is mainly dependent on the applied loads and the building characteristics. Studying the seismic behaviour of buildings under P-Delta effect may be of growing interest to researchers.

## II. P-DELTA EFFECT

P-Delta effect refers to the abrupt changes in ground shear, overturning moment and the axial force distribution at the base of a sufficiently tall structure or structural component when it is subject to a critical lateral displacement. The P-Delta effect is a destabilizing moment equal to the force of gravity multiplied by the horizontal displacement of a structure undergoes when loaded laterally.

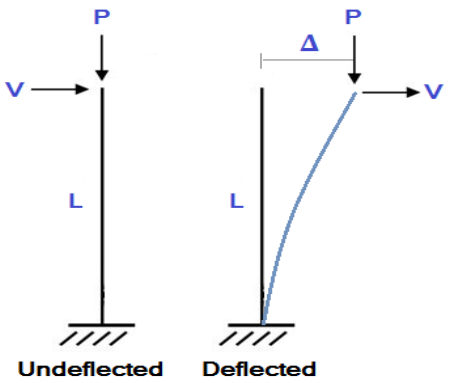


Fig.1. P-Delta effect

## III. BACKGROUND AND MOTIVATION

The inappropriate analysis and design of structures may lead to collapse of the structure. Usually the multi-storied buildings are analyzed using general one step linear static analysis assuming the full loads to be applied on the structure. But there may be lot of differences in the outcomes obtained from the analysis against practical aspect. Therefore, to briefly understand and to overcome this problem a non-linear P-Delta analysis is performed for the structure.

## IV. OBJECTIVE OF STUDY

The objective of the present work is to determine in what way the P-delta analysis influence the variation of responses of the structure such displacements and storey drift against linear static analysis. To perform the analysis ETABS 2016 software is used for all models of each case. In order to understand the trend of P-delta effects, the height of the building is gradually increased from story 5 to story 30 in 5 story intervals.

## V. MODEL DESCRIPTION

To study the effects of P-delta, six different storey cases are taken where storey variation starts from storey 5 to storey 30.

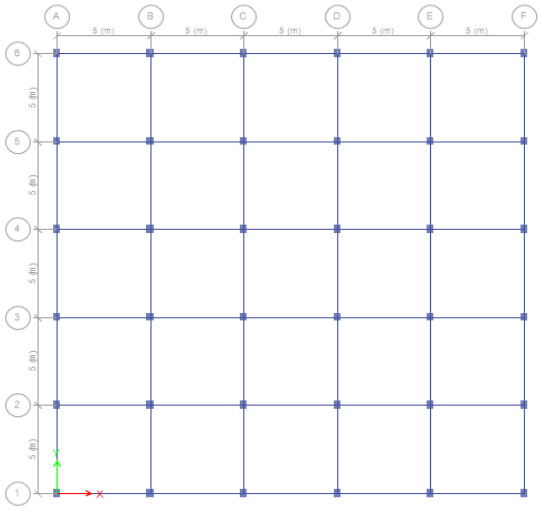

Fig.2. Typical Plan of the models

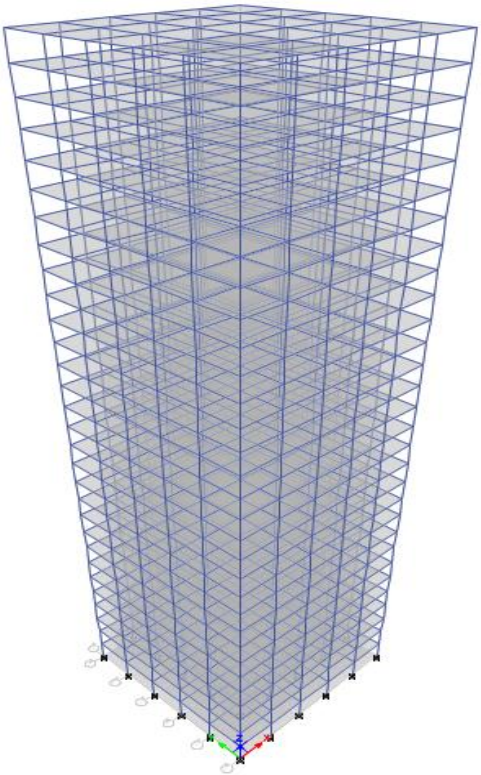

Fig.3. 3D view of 30 storey model

The detail basic specifications of the building are:

Table 1 Material Properties

| | |
|---|---|
| a) Properties of concrete | |
| Grade of concrete | M25 |
| Elasticity Modulus, Ec | 25000Mpa |
| Poisson's Ratio | 0.2 |
| Density of concrete | 25 KN/m$^3$ |
| b) Properties of reinforcement steel | |
| Grade of steel | Fe415 |
| Modulus of elasticity, Es | 210000Mpa |
| Poisson's ratio | 0.3 |
| c) Properties of masonry | |
| Density of brick wall including plaster | 20 KN/m$^3$ |
| Poisson's ratio | 0.2 |

Table 2 Geometric Properties

| | |
|---|---|
| Slab thickness | 150mm |
| Beam size | 300mm x 475mm |
| Column size | 600mm x 800mm |
| Brick wall on external beams | 230mm thick |
| Brick wall on internal beams | 150mm thick |
| Parapet wall on roof | 150mm thick |
| Storey height | 3m |

### *A.Loads on Structure*

- Live load on roof and floor : 3kN/m3
- Roof/floor finish : 1.5kN/m3
- Load from brick wall on external beams : 13.8kN/m3
- Load from brick wall on internal beams : 9kN/m3
- Load from parapet wall on roof : 3kN/m3

## VI. RESULTS AND DISCUSSION

To study the Second order or P-delta effects, with the increase in height of the structure, different building models of 5 storey, 10 storey, 15 storey, 20 storey 25 storey and 30 storey were analyzed in the ETABS software. The lateral loads, dead load and live load are considered for the design of structure as per the Indian standard code of practice for Seismic Zone V.

The comparison of maximum displacements and maximum storey drift for different models with and without P-delta effect is as shown in table-3 below.

### A. *Maximum Displacement*

Table 3 Maximum Displacement

| Model | Maximum Displacement (mm) | | Average %Increase in Displacements |
|---|---|---|---|
| | Without P-Delta | With P-Delta | |
| 5 storey model | 35.96 | 37.17 | 3.26 |
| 10 storey model | 92.23 | 98 | 5.89 |
| 15 storey model | 137.73 | 149.93 | 8.14 |
| 20 storey model | 219.6 | 242.31 | 9.37 |
| 25 storey model | 267.45 | 305.13 | 12.35 |
| 30 storey model | 321.82 | 385.1 | 16.43 |

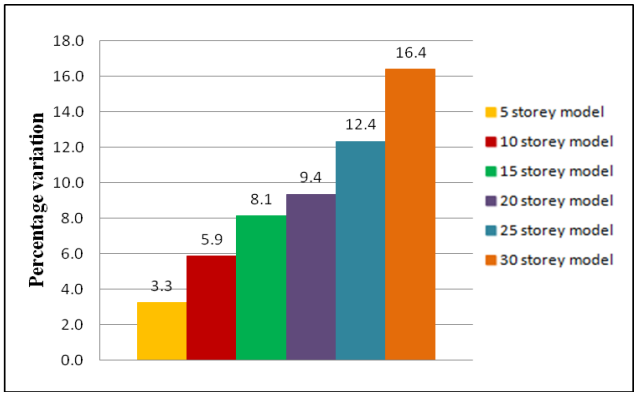


Fig.4 Variation of horizontal displacement in top

### B. *Maximum Storey Drift*

Table 4 Maximum Storey Drift

| Model | Maximum Storey drift | | Average %Increase in Storey Drift |
|---|---|---|---|
| | Without P-Delta | With P-Delta | |
| 5 storey model | 0.001729 | 0.001738 | 0.52 |
| 10 storey model | 0.002162 | 0.002202 | 1.82 |
| 15 storey model | 0.002319 | 0.002409 | 3.74 |
| 20 storey model | 0.002338 | 0.00249 | 6.10 |
| 25 storey model | 0.002481 | 0.002706 | 8.31 |
| 30 storey model | 0.002949 | 0.003419 | 13.75 |

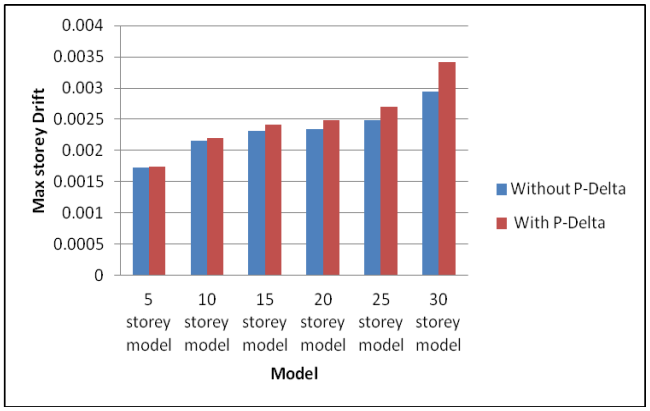


Fig.5 Variation of maximum storey drift

The second order effect in the 5 storey model is around 3%, which increases to 16% in the 30 storey model. In case of storey drift, the percentage of increase in storey drift due to P-Delta effect in the 5 storey model is about 0.52% which increased to 13.75% in the 30 storey model. Therefore 5 story models are least affected while the 30 story models are most affected by second order effect indicating the second order effects need to be considered for tall structures. P-Delta effect is negligible up to 10 storey buildings. While increasing height from 10th storey, there is considerable increase in displacement with P-Delta effect.

## VII. CONCLUSION

The structural performance of buildings with different heights, 5, 10, 15, 20, 25 and 30 stories is studied. The buildings are modelled and analysed using standard ETABS 2016 software. On the bases of results of analysis, the following conclusions are drawn:

- It is seen that the seismic parameter of building models without P-Delta is less than corresponding building models with P-Delta effect.
- Displacement value increases with increase in height, but it is more severe for P-Delta analysis.
- The change in displacement, and storey drifts due to P-Delta effect increases with increase in number of storey or building height.
- Both Llinear static and P-Delta both are necessary for RC structures.
- Due to wide displacement variation with increase in slenderness P-Delta analysis is required for the structures higher than 10 storeys.

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