# Analysis of Tall building by P-delta effect using IS 16700-2017

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*Abstract* - **As the urbanization increases worldwide , the available land for building is becoming scarer and scarer, and the cost of land is becoming higher and higher. Thus the popularity of tall structure are increasing day by day to accommodate growing population in metropolitan cities. As number of stories increases, P-Delta effect becomes more important. In this study the P-Delta effects on tall structure is studied. For the analysis three different types of structural systems will be carried out. In these structural systems 1) Moment frame structure 2) Moment frame with structural wall. Earthquake load is applied and the P-Delta analysis is consider for the analyse the structure. This analysis of multi storied RC building has been done using ETABS 2016 structural analysis software. The results of Base shear, Storey drift and storey displacement is compared and it will demonstrate the effectiveness of the above stated analysis methods on variation of storey height. The analysis of the tall structure will be carried out by considering the P-Delta effect in ETABS software using the criteria of IS 16700-2017.**

*keywords* - **Tall buildings , P-Delta effect, Seismic loads , IS 16700:2017, ETABS 2016.**

## I. INTRODUCTION

The tall structures are used as Residential, Commercial and more-over as a modern trend among the people which is growing towards the development of tall structure. Seismic analysis is carried out in this study. Earthquake ranges in size from those that areas so weak that they cannot be felt to those violent enough for people around and destroy whole cities. Buildings are susceptible to earthquake forces because of the fact that during earthquake the very ground on which building stands starts shaking. The ground motion is characterized by displacement, velocities and acceleration that are erratic in direction, magnitude, duration and sequence. The static analysis may be used to design buildings, extreme caution must be taken to render them disaster proof. This is where the dynamic analysis comes into play , modelling the seismic loads accurately and thereby providing economical design. By carrying out dynamic analysis, one obtains the design forces of the building and additionally, height wise distribution of those forces. In the traditional first order analysis of structures, the effects of change in the structure actions due to structure deformations are neglected. However, when a structure deforms, the applied loads may cause additional actions in the structure that are called second order or P-Delta effects.

The P-Delta effect is dependent on the applied load and building characteristics. In addition to parameters such as height and stiffness of a building, the degree of its asymmetry may also be of importance. The building asymmetry is often due to unbalanced distribution of its mass, stiffness or strength. The induced torsional deformations usually cause uneven displacements among lateral load resisting elements and therefore concentration of damage in some of them. Therefore, torsionally unbalanced buildings are normally more susceptible to earthquake damages. The deformations caused by torsion can affect the P-Delta consequences. As a result, it is expected that torsion and P-Delta have interaction in the seismic behavior of some buildings. A long list of parameters is likely to be effective in this interaction. Lateral and torsional stiffness of building, the level of its eccentricity, mass moment of inertia, height, the properties of loading and ground motions are some of these parameters.

**P-Delta analysis:**

It is also known as geometric nonlinearity, involves the equilibrium and compatibility relationships of a structural system loaded about its deflected configuration. Of particular concern is the application of gravity load on laterally displaced multi-story building structures. This condition magnifies story drift and certain mechanical behaviors while reducing deformation capacity. When an initial P-Delta analysis is requested on the P-Delta Options form, it is performed before all linear-static, modal, response-spectrum, and time-history analyses in the same analysis run. The initial P-Delta analysis essentially modifies the characteristics of the structure, affecting the results of all subsequent analyses performed.

There are two P-Delta effects:

- P-BIG delta (P-$\Delta$) - a structure effect
- P-little delta (P-$\delta$) - a member effect

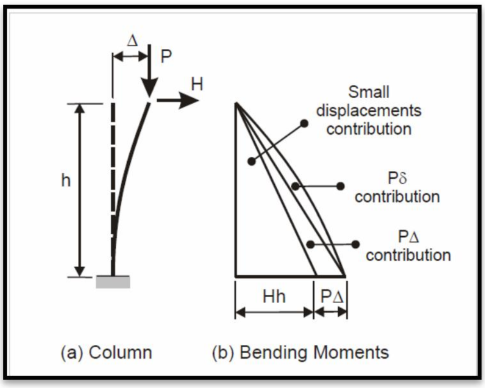


**Figure 1 P-Delta on Column**

**Progressive Collapse :**

Progressive collapse occurs when the loss or failure of one member in a structure leads to loss or failure of other members, progressing through the structure and leading to partial or full collapse. Progressive collapse analysis is a design tool that can be used to assess whether progressive collapse is likely to occur.

It is important to keep the goal in mind. A collapse analysis is a merely a design tool. Its purpose is not to provide an exact simulation of structural collapse, but to provide the designer with useful information for assessing the performance of the structure and making reasonable decisions about its safety.

U.S. General Services Administration (GSA) and Department of Defense DoD) guidelines by United Facilities Criteria (UFC) - New York, provide detailed stepwise procedure regarding methodologies to resist the progressive collapse of structure.

## II. Objectives

To analyse tall buildings by the P-Delta effect for different structural systems like Moment frame system, Moment frame with Structural wall.

To Evaluate the seismic parameters like Storey stiffness , Storey displacement and Storey drift.

To find Demand Capacity Ratio (DCR) by analytical approach for earthquake design.

To compare the buildings which are having different values of Slenderness ratio and Heights to get the most feasible one using IS 16700:2017.

## III. Building Description

- **Load Combination :**

**Table 1 Load Combinations**

| | | |
|---|---|---|
| 1.2(DL+LL+EQX) | 1.5(DL+EQX) | 0.9 (DL+ 1.5 EQX) |
| 1.2(DL+LL-EQX) | 1.5(DL-EQY) | 0.9 (DL- 1.5 EQX) |
| 1.2(DL+LL+EQY) | 1.5(DL+EQY) | 0.9 (DL+ 1.5 EQY) |
| 1.2(DL+LL-EQY) | 1.5(DL-EQY) | 0.9 (DL- 1.5 EQY) |

| Model 01 | |
|---|---|
| $H_t$ (Height) | 60m |
| B (Width) | 15m |
| L (Length) | 75m |
| H/B (Slenderness ratio) | 04 |
| L/B (Plan aspect ratio) | 05 |
| **Model 02** | |
| $H_t$ (Height) | 60m |
| B (Width) | 12m |
| L (Length) | 60m |
| H/B (Slenderness ratio) | 05 |
| L/B (Plan aspect ratio) | 05 |
| **Model 03** | |
| $H_t$ (Height) | 81m |
| B (Width) | 21m |
| L (Length) | 60m |
| H/B (Slenderness ratio) | 3.85 |
| L/B (Plan aspect ratio) | 2.85 |

**Section Properties of Moment Frame Structure**

**Beam**= 300mm X 375mm(12”X15”)
**Column**=450mm X 375mm(18”X15”), 375mm X 375mm (15”X15”), 375mm X 300mm(15”X12”) and 375 mm X 230mm (09”X15”).

**Slab**= 150mm

**Fig. 2 Configuration of Moment Frame Structure**

| Model 01 | |
|---|---|
| $H_t$ (Height) | 159m |
| B (Width) | 24m |
| L (Length) | 72m |
| H/B (Slederness ratio) | 6.625 |
| L/B (Plan aspect ratio) | 03 |
| **Model 02** | |
| $H_t$ (Height) | 168m |
| B (Width) | 24m |
| L (Length) | 84m |
| H/B (Slederness ratio) | 07 |
| L/B (Plan aspect ratio) | 3.5 |
| **Model 03** | |
| $H_t$ (Height) | 168m |
| B (Width) | 18m |
| L (Length) | 72m |
| H/B (Slederness ratio) | 9.34 |
| L/B (Plan aspect ratio) | 04 |

**<u>Section Properties of Moment Frame Structure with Structural Wall</u>**

**Beam**=675mmX600mm(27”X24”),600mmX525mm(24”X21”),525mmX450mm (21”X18”) and 525mmX375mm (21”X15”).
**Column** = COMP(21”X30”), COMP(21”x27”), COMP(21”x24”) AND COMP (21”x21”).
**Slab** = 150mm
**Shear wall** = 200mm

**Fig. 3 Configuration of Moment Frame Structure With Structural wall**

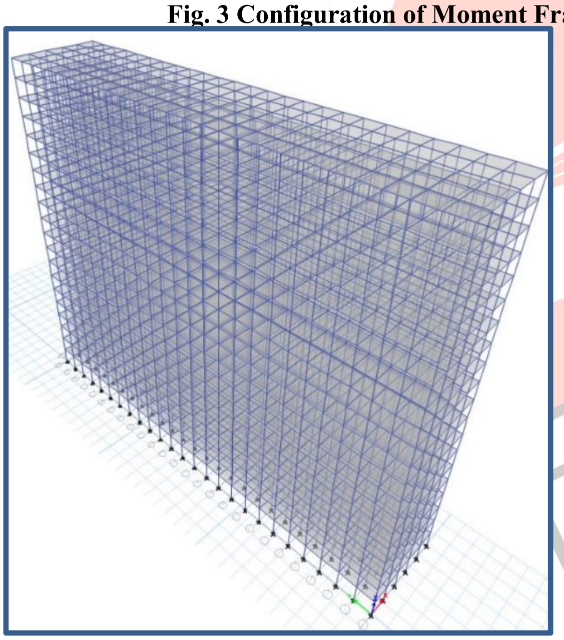

**Fig.4 3-D View of Moment Frame Structure**

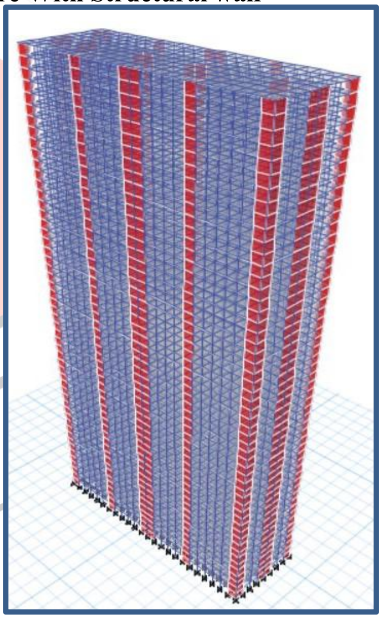

**Fig. 5 3-D View of Moment Frame Structure with Structural wall**

## IV. RESULTS

**<u>Moment Frame Structure :</u>**

1. **Storey Displacement**

| | |
|---|---|
| Model 01 | 42.96mm (Non P-Delta) |
| | 46.93mm (P-Delta) |
| Model 02 | 76.56mm (Non P-Delta) |
| | 84.01mm (P-Delta) |
| Model 03 | 103.39mm (Non P-Delta) |
| | 116.201mm (P-Delta) |

2. **Storey Drift**

| | |
|---|---|
| Model 01 | 0.00364 (Non P-Delta) |
| | 0.000384 (P-Delta) |

| | |
|---|---|
| Model 02 | 0.000728 (Non P-Delta) |
| | 0.000779 (P-Delta) |
| Model 03 | 0.000623 (Non P-Delta) |
| | 0.000675 (P-Delta) |

3. **Storey Stiffness**

| | |
|---|---|
| Model 01 | 3331417 kN/m (Non P-Delta) |
| | 2479510 kN/m (P-Delta) |
| Model 02 | 1763458 kN/m (Non P-Delta) |
| | 1618674 kN/m (P-Delta) |
| Model 03 | 2978879 kN/m (Non P-Delta) |
| | 2652136 kN/m (P-Delta) |

**Moment Frame Structure with Structural Wall :**

1. **Storey Displacement**

| | |
|---|---|
| Model 01 | 72.52 mm (Non P-Delta) |
| | 79.85 mm (P-Delta) |
| Model 02 | 79.651 mm (Non P-Delta) |
| | 85.686 mm (P-Delta) |
| Model 03 | 99.023 mm (Non P-Delta) |
| | 107.28 mm (P-Delta) |

2. **Storey Drift**

| | |
|---|---|
| Model 01 | 0.000517 (Non P-Delta) |
| | 0.000549 (P-Delta) |
| Model 02 | 0.000539 (Non P-Delta) |
| | 0.000575 (P-Delta) |
| Model 03 | 0.000706 (Non P-Delta) |
| | 0.000768 (P-Delta) |

3. **Storey Stiffness**

| | |
|---|---|
| Model 01 | $5.38 \times 10^7$ kN/m (Non P-Delta) |
| | $5.22 \times 10^7$ kN/m (P-Delta) |
| Model 02 | $5.54 \times 10^7$ kN/m (Non P-Delta) |
| | $5.36 \times 10^7$ kN/m (P-Delta) |
| Model 03 | $4.44 \times 10^7$ kN/m (Non P-Delta) |
| | $4.28 \times 10^7$ kN/m (P-Delta) |

## V. CONCLUSION

From the analysis of tall building under P-Delta effect the following concluding remarks can be made

- For the Height up to 60 m, Special Moment Resisting Frame structure should be used but after then up to 160 m, Structural wall Moment Resisting Frame structure should be used.
- For the 160 m height composite columns are used due to large displacements. The storey stiffness in this composite structure is nearly half as compared to RC Structure, which will increase the ductility of the structure.
- As per the criteria of the Storey stiffness (IS: 16700-2017) i.e., "The stiffness of any storey shall not be 70 % less than the above storey. "has been satisfied.
- Increasing the beam size will be more effective in avoiding or delaying collapse rather than increasing column sizes.

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**Codes**

1. IS 16700:2017 : Criteria for Structural safety of Tall Concrete Buildings
2. IS 456 (2000): Plain and Reinforced Concrete – Code of Practice
3. IS 1893-1 (2016): Criteria for Earthquake Resistant Design of Structures, part-1: General Provision and buildings
4. IS 875-1 (1987) : Code of Practice for Design Loads (other than earthquake) for Buildings and Structures : Part 1 Dead Loads – Unit weights of building material and stored materials
5. IS 875-2 (1987) : Code of Practice for Design Loads (other than earthquake) for Buildings and Structures : Part 2 Imposed Loads
6. IS 875-5 (1987) : Code of Practice for Design Loads (other than earthquake) for Buildings and Structures : Part 5 Special Loads and Loa Combination