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# STUDY ON BEHAVIOR OF TALL STRUCTURES UNDER P-DELTA EFFECT

[1]Mr. S N Abhishek, [2]Mrs. Nishigandha Mandekar
[1]Lecturer, [2]Lecturer
[1]Department of Civil Engineering
[1]Thakur Polytechnic, Kandivali (E), Mumbai, INDIA

***Abstract:*** As urbanization increases worldwide, the available land for buildings is becoming scarcer, and the cost of land is becoming higher. Thus, the popularity of high-rise structures are increasing day by day to accommodate growing population in metropolitan cities. A tall structure is defined as the one in which the height is between 35-100 m, or a building with 12-39 floors. And it is designed to resist lateral forces due to wind or earthquake within the prescribed standard for drift, strength and provide comfort for the occupants. P-Delta effect is secondary effect on structure it is also known as “Geometric nonlinearity effect”. As number of stories increases, P-delta effect becomes more important. If the change in bending moments and displacements is more than 10%, P-delta effect should be considered in design. The present study focuses on the P-Delta effect in the design of tall reinforced concrete structures. The building models with different storey heights i.e., G+9, G+14, G+19 and G+ 24 have been analyzed to investigate the maximum response of the building in terms of displacement, moment and storey drift. The analysis of multistoried RC building has been done using ETABS 2015 structural analysis software.

***IndexTerms* - RC Structures, Linear static analysis, P-Delta analysis, Displacements, ETABS-2015**

## 1. INTRODUCTION

A tall structure is defined as the one in which the height is between 35-100 m, or a building with 12-39 floors. And it is designed to resist lateral forces due to wind or earthquake within the prescribed standard for drift, strength and provide comfort for the occupants. Tall buildings are the structures that require stability because it consists a lot of framed structures. Generally, structural engineers are likely to use linear static analysis or first order analysis to compute the forces, displacements and moments due to loads acting on the structure. [1] This First order analysis is carried out by assuming small deflection behavior where the resulting displacements, forces and moments will won’t take part in additional effects due to deformation of the structure. In this first order analysis the effects due to deformation of the structure are neglected. This deformation due to the loads will impose additional effects in the structure that are called as P-Delta or second order effects.

## 2. LATERAL LOADS ON STRUCTURES

Most of the lateral loads are live loads; the main component is horizontal force acting on a structure. Some of lateral loads are listed below:

i. Earthquake Load
ii. Wind Load

### 2.1 EFFECT OF EARTHQUAKE ON STRUCTURE

Earthquake loads are very complex, potentially damaging and uncertain compared to other lateral loads. It is quite fortune that it does not occur regularly. An earthquake creates ground movements that are generally categorized into rattle, shakes and roll. Every structure needs to resist all the three of these loadings. Although the soil under a structure can move in any direction, only the horizontal component of the movement is considered critical in a structural analysis. Seismic strength and surface waves create inertial forces in the building. When a building trembles, it is subjected to inertial forces. Inertial force is a product of mass and the acceleration. Most of the earthquake-related deaths are caused due to the collapse of structures. Construction practices have a huge role in earthquake resistant buildings. When the ground shakes, buildings will react to the accelerations transferred from the ground through the structure's foundation. The inertia of the building can cause shearing of the structure which can concentrate stresses on the joints and weak walls in the structure causing failure or possibly total collapse. [2]

### 2.2 EFFECT OF DEFORMATIONS IN STRUCTURES

The inertial forces experienced by the roof are transferred to the ground via the columns, causing forces in columns. These forces generated in the columns can also be understood in another way. During an earthquake shaking, the columns undergo relative movement between their ends. It is as shown in Figure 1 and 2. In the straight vertical position, the columns carry no horizontal earthquake force through them. But when forced to bend they develop internal forces. The larger is the relative horizontal displacement between the top and bottom of the column, the larger this inertial force in columns. [3]

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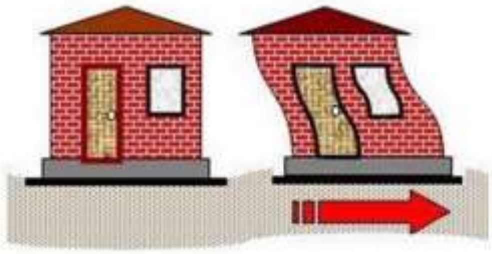

Figure 1: Effect of earthquake

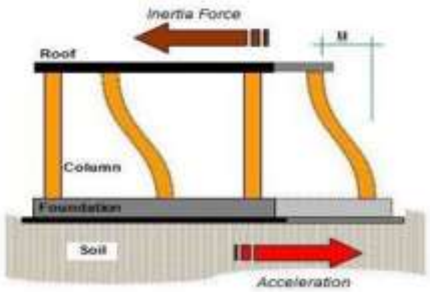


**Figure 2:** Inertia forces in structures

**2.3 EFFECTS OF WIND ON STRUCTURE**

It plays a vital role in the design of tall structures because it exerts loads on buildings. The response depends on characteristics of wind flow. Wind is caused by air flow from high pressure to low pressure area. Wind loads differ throughout the world. Weather data collected by national weather services are one of the most reliable wind source data. Factors that influence wind load are exposure, relationship with the nearby structure, height and size of the building, prevailing wind direction, wind speed dominant pressures, elevation, architectural design feature, geographic location. All these are taken into account when the wind loads are calculated. Often it is necessary to look at more than one wind load case. [4]

Wind effects on structures are classified into:

- Static wind effect: primarily causes elastic bending and twisting of structures.
- Dynamic wind effect: causes fluctuating forces on the structures which induce large dynamic motions and oscillations.

**3. TYPES OF ANALYSES**

**3.1** Linear static analysis

The procedure, also referred to as the equivalent static method, involves several key steps. Initially, the design base shear for the entire building is calculated. Subsequently, this base shear is distributed across the entirety of the structure. The lateral forces at each floor level are then determined and allocated to individual lateral load resisting elements. The specific formulas for computing the base shear are typically outlined in the relevant code of practice. However, it's important to note some limitations associated with this approach. Firstly, its applicability may be restricted based on the seismic zone and height of the structure. Additionally, buildings with higher modes of vibration than the fundamental mode, as well as structures featuring significant discontinuities in mass and stiffness along their height, may encounter challenges when utilizing this method.

**3.2 NONLINEAR STATIC ANALYSIS**

The method referred to as pushover analysis serves as a valuable tool in structural engineering. Its primary purpose is to evaluate the strength and drift capacity of existing structures, as well as to assess the seismic demand placed upon them during designated earthquakes. Additionally, pushover analysis can be utilized to verify the adequacy of new structural designs. This analysis involves the creation of a mathematical model that incorporates the nonlinear load deformation characteristics of individual components and elements within the building. Through pushover analysis, engineers can obtain crucial response characteristics of the structure, including its strength and displacement capacities, the order of failure of various components, and the subsequent impact on the overall integrity of the structure. Furthermore, this analysis aids in identifying critical regions within the building, providing invaluable insights for structural evaluation and retrofitting efforts.

**3.3 LINEAR DYNAMIC ANALYSIS**

The response spectrum serves as a valuable tool in structural analysis, particularly in seismic design. This method, a linear dynamic analysis technique, incorporates multiple mode shapes, considering the response across various frequencies and masses within the structure. By referencing the design spectrum, the response spectrum analysis enables engineers to estimate the total structural response based on modal frequency and modal mass. This estimation is achieved through modal combination methods, including the Absolute Sum Method, Square Root Sum of Squares, and Complete Quadratic Combination. One critical aspect of response spectrum analysis involves comparing the design base shear, denoted as Vb, obtained from dynamic analysis, with the base shear calculated using static analysis, represented as $\bar{V}b$. If the base shear from static analysis is less than $\bar{V}b$, adjustments must be made to response parameters such as member forces and displacements. However, it's important to note that irregular buildings may not be suitable for modeling using the dynamic analysis method. Despite this, for structures with a height less than 40m in seismic zones II and III, dynamic analysis is recommended, though not mandatory, to ensure adequate seismic performance and safety.

**3.4 NONLINEAR DYNAMIC ANALYSIS**

Time history analysis, also known as dynamic analysis, is a widely used method in structural engineering for assessing the response of structures to seismic events. Unlike response spectrum analysis, time history analysis involves subjecting the structural model to actual accelerations recorded from seismic events. This approach is applicable for both elastic and inelastic analysis scenarios. In elastic analysis, the stiffness of the structure remains constant throughout the duration of the earthquake, providing insights into the structure's response under ideal conditions. However, in inelastic analysis, the stiffness varies over time, reflecting the structure's behavior as it experiences nonlinear effects during seismic events. Here, the stiffness remains constant only for specific durations, corresponding to incremental time intervals during the earthquake. Time history analysis allows engineers to accurately capture the dynamic behavior of structures, considering factors such as material properties, damping, and nonlinear behavior, providing valuable insights into structural performance under seismic loading conditions.

**4. P-DELTA EFFECT**

P-Delta is a non-linear effect that occurs in every structure where elements are subject to axial loads. It is a genuine effect that is associated with the magnitude of applied axial load „P" and displacement „delta". If a P-Delta affected member is subjected to lateral load then it will be prone to more deflection which could be computed by P-Delta analysis not the linear static analysis. Although the development of knowledge and advancement of technology is quite advanced today, there are a very few practical experimental studies on the P-Delta effects of the structure. The most used structural analysis for reinforced concrete design is linear static analysis, where P-Delta effect is omitted which is very important to include in analysis and design phase. Because of that, high rise structures may show potential vulnerability against lateral loads. P-Delta analysis may bring the second order loading effects in the structure and design the structure with its effects. This analysis is no more a matter of time consuming paper work but easy and simple which could be performed by engineers and researchers. Nowadays many software have the capability to do analysis and design with P-Delta effects. [5]

## 5. IMPORTANCE OF STUDY

P-Delta is coined from "P" that is load and "Delta" is the lateral displacement. So now columns which are supposed to carry axial gravity loads, during earthquake these columns displace laterally, now the tip of the column displaced by the amount "Delta" as compared to the bottom of the column. This drift adds upon an accidental moment in the column along with axial force by the amount P-Delta. We have to check columns for this additional moment so that it does not fail. The below Figure 3 represents the P-Delta effect.

Effects of P-Delta

- It generates additional shear and additional bending moment in column due to its deformed shape.
- It is also called as Force Follower Analysis when member losses its stability the force follows the deformed member and creates further more instability quickly.
- This effect is more adverse in soft lateral force resisting systems like moment resisting frames as compared to core wall systems and braced frames.

The following expressions are used to define the effect of P-Delta:

Where,

| | | |
|---|---|---|
| $M_{total}$ | = | Total moment generated, including P-Delta effect |
| $V \times L$ | = | Primary moment |
| $P \times \Delta$ | = | Secondary moment |
| V | = | Lateral force due to wind and earthquake |
| L | = | Height of the column |
| P | = | Axial load on top of the column |
| Δ | = | Displacement due to the lateral force |

Let us assume the total lateral force is Ū, and then the above expression can be written as

$$M\ total = \bar{U} \times L \qquad \textbf{Equation 1}$$

$$\bar{U} \times L = V \times L + P \times \Delta \qquad \textbf{Equation 2}$$

$$\bar{U} = V + [\frac{P \times \Delta}{L}] \qquad \textbf{Equation 3}$$

$$\frac{\bar{U}}{V} = 1 + [\frac{P \times \Delta}{V \times L}] \qquad \textbf{Equation 4}$$

$[\frac{P \times \Delta}{V \times L}]$ The value shouldn't exceed 10%, if the value exceeds more than 10%, then the P-Delta Effect must be considered in the analysis part. $[\frac{P \times \Delta}{V \times L}] \le 10\%$

## 6. OBJECTIVE OF STUDY

The objective of the present work is to determine in what way the P-delta analysis influences the variation of responses of the structure such as bending moments, displacements and storey drift against linear static analysis. To perform the analysis ETABS 2015 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 10 to story 25 in 5 story intervals. After comparing the performance of RC structure with respect to displacement, storey drift and moment between two analyses mentioned above, necessity of P-delta analysis over linear static analysis will be understood clearly and also to decide the minimum height of building for which it is necessary to included P-delta effect in analysis.

## 7. METHODOLOGY

As mentioned earlier, to observe the effects of P-delta, four different storey cases are taken where storey variation starts from storey 10 to storey 25. Each of the storey case is performed with linear Static and P-delta analysis separately with appropriate command. Each storey is 3 metre in height.

### 7.1 DESCRIPTION OF MODEL

Four three-dimensional building models are used as the basic models in the study. The buildings have 10, 15, 20 and 25 stories. Bay length of buildings in each direction is 3 m and their typical storey height is 3 m and bottom storey height is 3 m. The floors are assumed to be semi-rigid in their plane. The seismic lateral load is considered in both directions of the structure using IS 1893:2002 (Part - 1) by providing seismic coefficient of seismic zone II to perform both linear static and P-Delta analysis separately. The beams and columns sizes are mentioned in "Table 1". The concrete grade for beams and columns is M45, and for slabs it is M25. The thickness of slab is 150 mm. The loads acting on the building other than earthquake loads has been provided as per IS 875 and the load combinations are as per IS 456:2000.

In the analysis of structures, neglecting the second order effects may overestimate the strength and stiffness of a member or a frame. The elastic forces generated within a member can be more accurately predicted with the use of an elastic second order analysis. The second order effects are of increasing importance as lighter and more flexible structures are constructed. The building model has been analysed for 10 to 25 storeys with 5 storey intervals. The analysis has been carried out without P-Delta effect to locate maximum responses and then same has been analysed considering P-delta effects. The maximum response values are compared to notify the P-delta effect. The plan and three-dimensional frame models of four different storeys (G+9, G+14, G+19, and G+ 24) is shown in Figure 4 and 5.

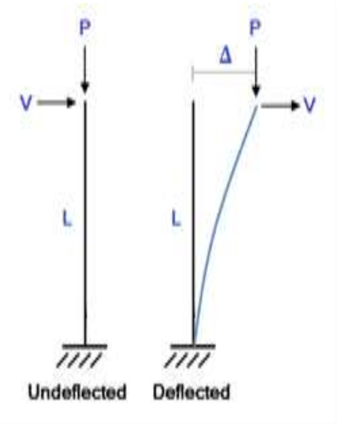


**Figure 3: Effect of P-Delta**

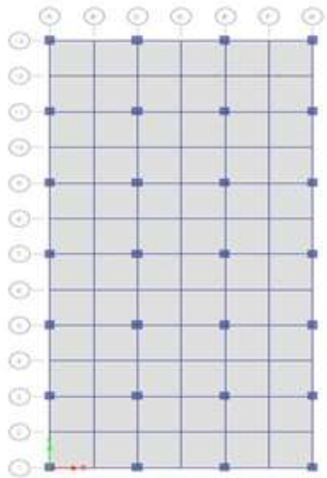

**Figure 4:** Plan

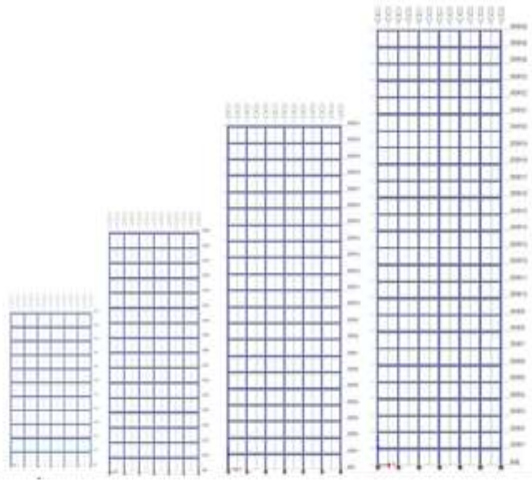

**Figure 5:** Three-dimensional frame models of four different storeys (G+9, G+14, G+19, and G+ 24

## 8. Steps Used for Modelling in ETABS

Geometry of structure: Grid system data, number of storeys, similar storeys, drawing columns, beams and roof etc..

Material property: Defining materials for members like steel and concrete, Defining sections properties for beams, columns, roofs and defining loads and load combinations are done in this step.

Assign property to members: Assigning properties to beams, columns, roof sections, supports and assigning point loads, area loads, line loads for all storeys.

Analysis: Check the model for all seismic inputs and analyse the model created with and without considering P-Delta.

Control of results: Extract the analysis results in terms of storey displacement, storey drift and moments.

Load Combinations Considered

- 1.5 Dead Load + 1.5 Live Load
- 1.5 Dead Load + 1.5 Earthquake in X direction
- 1.5 Dead Load - 1.5 Earthquake in X direction
- 1.5 Dead Load - 1.5 Earthquake in Y direction
- 1.5 Dead Load + 1.5 Earthquake in Y direction
- 1.2 (Dead Load + Live Load + Wind Load in X direction)
- 1.2 (Dead Load + Live Load - Wind Load in X direction)
- 1.2 (Dead Load + Live Load + Earthquake Load in X direction)
- 1.2 (Dead Load + Live Load - Earthquake Load in X direction)
- 1.2 (Dead Load + Live Load + Earthquake Load in Y direction)
- 1.2 (Dead Load + Live Load - Earthquake Load in Y direction)

Generally maximum values are obtained for:

1.2 (Dead Load + Live Load + Earthquake Load in X direction)

**Table 1:** Sizes of beams and columns for different storeys

| Storeys | Beam Size (mm) | Column Size (mm) |
|---|---|---|
| 25 storey | 450 X 300 | 700 X 700 |
| 20 storey | 450 X 300 | 650 X 600 |
| 15 storey | 450 X 300 | 550 X 550 |
| 10 storey | 400 X 300 | 450 X 450 |

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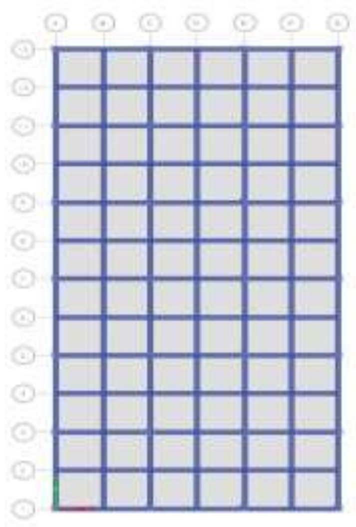

**Figure 6:** Floor plan

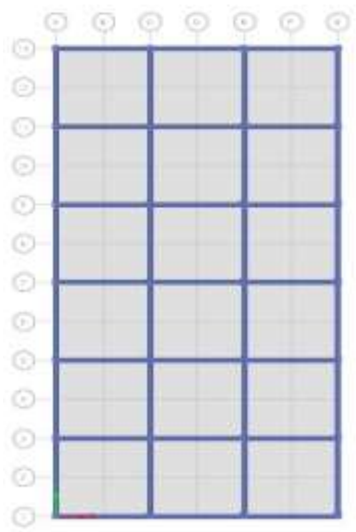

**Figure 7:** Roof plan

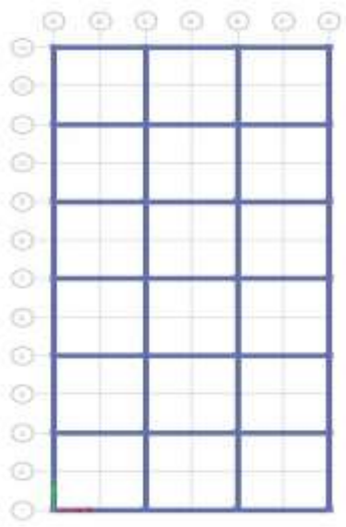

**Figure 8:** Plinth beam plan

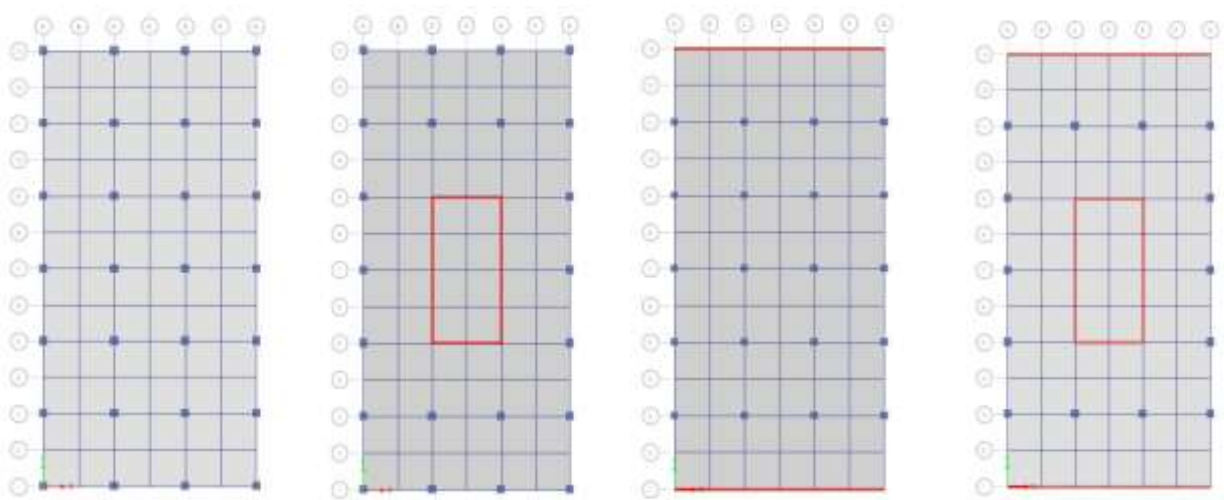

**Figure 9:** Plan of simple RC frame, core wall, external shear wall, combined system

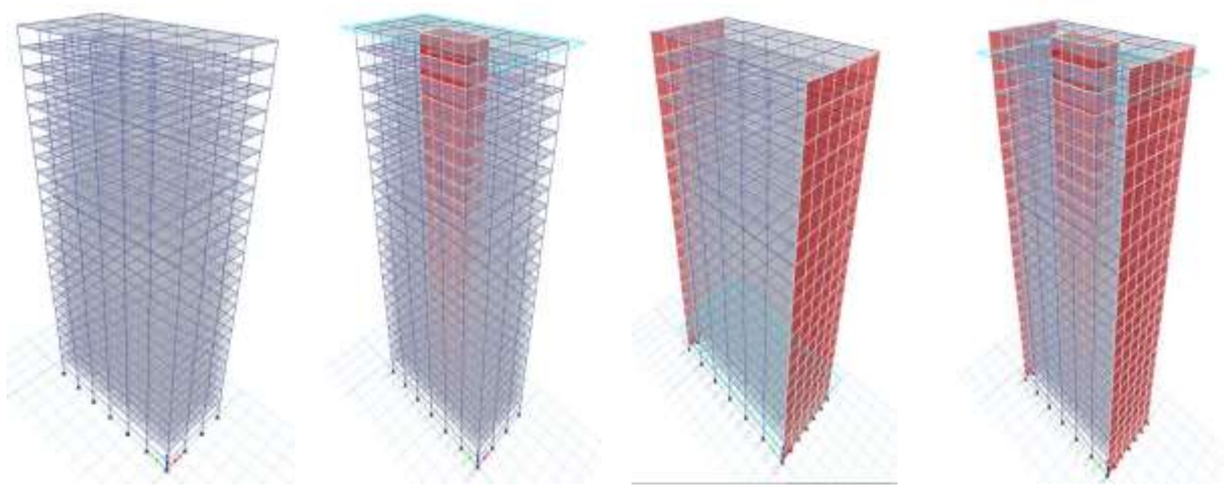

**Figure 10:** 3D view of simple RC frame, core wall, external shear wall and combined system

## 9. RESULTS AND DISCUSSIONS

P-Delta and Linear static analysis of all the models reveals that P-Delta effects significantly influences the behaviour of structure and have higher value than linear static analysis. Results of all the different types of analysis such as linear static analysis and P-Delta analysis for reinforced concrete structures are obtained and mentioned here.

**9.1 STOREY DISPLACEMENT OF DIFFERENT STOREY CASES**

The variation in displacement is mainly due to the lateral forces like earthquake and wind loads, this variation in displacements is studied for 10, 15, 20 and 25 storeys with external shear wall, core wall and combined system, considering linear static and P-Delta analysis.

**9.1.1 10 STOREY BUILDING**

- It is concluded that the percentage change in displacement at 10$^{th}$ storey with and without considering P-Delta for simple RC frame structure is 10.88.
- It is concluded that the percentage change in displacement at 10$^{th}$ storey with and without considering P-Delta 10 storey RC frame with core wall is 1.09%.
- It is concluded that the percentage change in displacement at 10$^{th}$ storey with and without considering P-Delta 10 storey RC frame with external shear wall is zero.
- It is concluded that the percentage change in displacement at 10$^{th}$ storey with and without considering P-Delta 10 storey RC frame with external combined systems is zero.

**9.1.2 15 STOREY BUILDING**

- It is concluded that the percentage change in displacement at 15$^{th}$ storey with and without considering P-Delta for simple RC frame structure is 11.522%.
- It is concluded that the percentage change in displacement at 15$^{th}$ storey with and without considering P-Delta 10 storey RC frame with core wall is 3.39%.
- It is concluded that the percentage change in displacement at 15$^{th}$ storey with and without considering P-Delta 10 storey RC frame with external shear wall is 1.65%.
- It is concluded that the percentage change in displacement at 15$^{th}$ storey with and without considering P-Delta 10 storey RC frame with external combined systems is 1.02%.

**9.1.3 20 STOREY BUILDING**

- It is concluded that the percentage change in displacement at 20$^{th}$ storey with and without considering P-Delta for simple RC frame structure is 15.3%.
- It is concluded that the percentage change in displacement at 20$^{th}$ storey with and without considering P-Delta 10 storey RC frame with core wall is 5.34%.
- It is concluded that the percentage change in displacement at 20$^{th}$ storey with and without considering P-Delta 10 storey RC frame with external shear wall is 2.50%.
- It is concluded that the percentage change in displacement at 20$^{th}$ storey with and without considering P-Delta 10 storey RC frame with external combined systems is 2.343%.

**9.1.4 25 STOREY BUILDING**

- It is concluded that the percentage change in displacement at 25$^{th}$ storey with and without considering P-Delta for simple RC frame structure is 19.99%.
- It is concluded that the percentage change in displacement at 25$^{th}$ storey with and without considering P-Delta 10 storey RC frame with core wall is 8.15%.
- It is concluded that the percentage change in displacement at 25$^{th}$ storey with and without considering P-Delta 10 storey RC frame with external shear wall is 4.606%.
- It is concluded that the percentage change in displacement at 25$^{th}$ storey with and without considering P-Delta 10 storey RC frame with external combined systems is 3.731%.

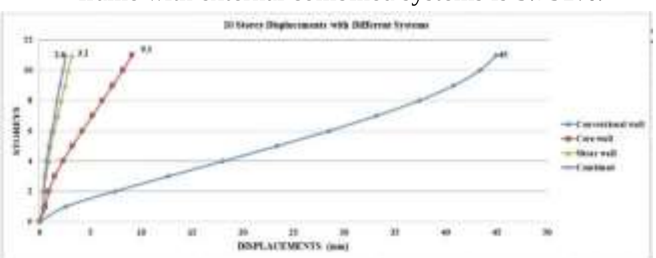

**Figure 11:** Displacements of different systems for 10 storey structure with linear static analysis

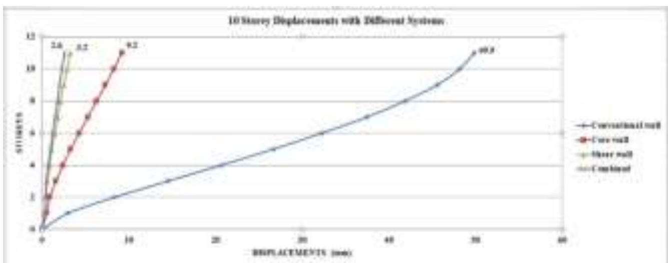

**Figure 12:** Displacements of different systems for 10 storey structure with P-Delta analysis

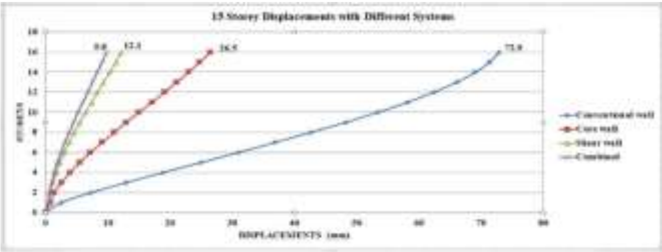


**Figure 13:** Displacements of different systems for 15 storey structure with linear static analysis

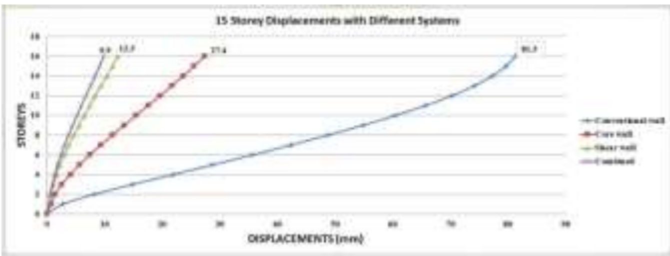


**Figure 14:** Displacements of different systems for 15 storey structure with P-Delta analysis

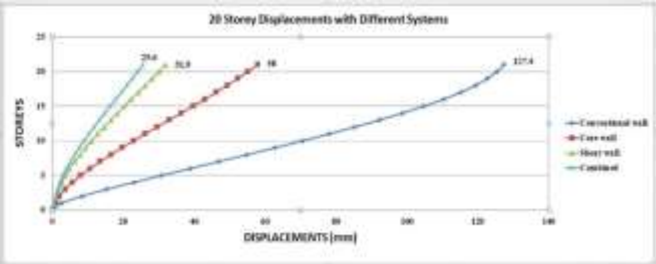


**Figure 15:** Displacements of different systems for 20 storey structure with linear static analysis

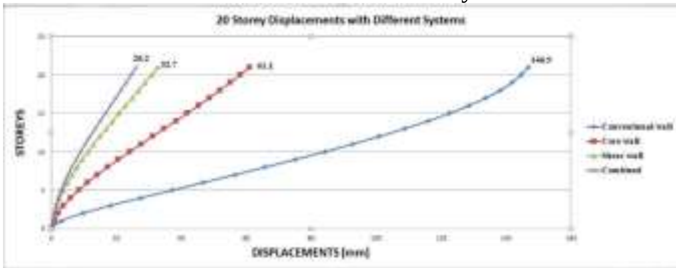


**Figure 16:** Displacements of different systems for 20 storey structure with P-Delta analysis

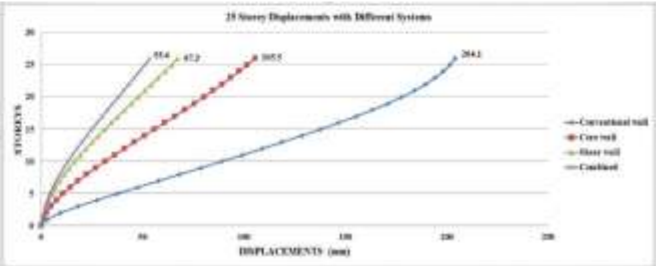


**Figure 16:** Displacements of different systems for 25 storey structure with linear static analysis

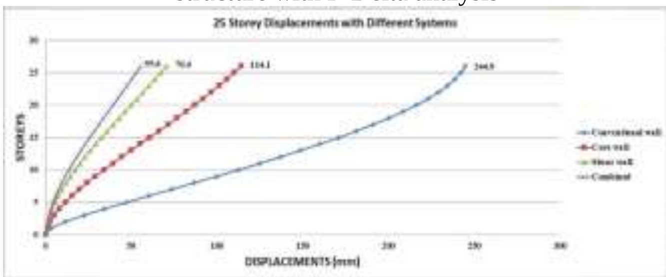


**Figure 17:** Displacements of different systems for 25 storey structure with P-Delta analysis

### 9.2 CHANGE IN BENDING MOMENT AT THE BASE OF THE COLUMNS

- Percentage variation in bending moment at base of column for 10 storey structure with and without considering P-Delta effect is 8.66
- Percentage variation in bending moment at base of column for 15 storey structure with and without considering P-Delta effect is 11.72
- Percentage variation in bending moment at base of column for 20 storey structure with and without considering P-Delta effect is 14.94
- Percentage variation in bending moment at base of column for 25 storey structure with and without considering P-Delta effect is 19.62

**Table 2:** Change in moments at the base of the columns for different storeys with and without considering p-delta effect

| Storeys | Linear static | P-Delta | Percentage Variation |
|---|---|---|---|
| 25 storey | 522.231 | 621.702 | 19.62 |
| 20 storey | 335.669 | 385.812 | 14.94 |
| 15 storey | 186.962 | 208.999 | 11.78 |
| 10 storey | 95.268 | 103.527 | 8.66 |

### 9.3 VARIATION IN STOREY DRIFT OF STRUCTURE

- Percentage variation in the storey drift for 10 storey structure with and without P-Delta analysis is 12.49.
- Percentage variation in the storey drift for 15 storey structure with and without P-Delta analysis is 15.35.
- Percentage variation in the storey drift for 20 storey structure with and without P-Delta analysis is 20.84.
- Percentage variation in the storey drift for 25 storey structure with and without P-Delta analysis is 26.6.
- The above-mentioned values for 10 storeys are nearly equal to 10% so it is not mandatory to consider P-Delta analysis for 10 storeys.
- As the number of storey increases greater than 10 the P-Delta effect becomes more important in the analysis as well as in the design part. So, we can say that, at least it is necessary to check the results with and without considering P-Delta analysis.

- This P-Delta effect is more observed in exterior columns. And it is found that, this P-Delta effect has less impact on structures with core wall, shear wall and combined systems.

**Table 3:** Variation in storey drift with and without considering p-delta effect

| Storeys | Linear static | P-Delta | Percentage Variation |
|---|---|---|---|
| 25 storey | 0.003451 | 0.004396 | 26.6 |
| 20 storey | 0.002672 | 0.003229 | 20.84 |
| 15 storey | 0.002021 | 0.002321 | 15.35 |
| 10 storey | 0.001777 | 0.001999 | 12.49 |

### 9.4 Variation in Overturning Moments With Respect to 25 storeys

- The percentage difference in overturning moments for 10 storeys is 7.81
- The percentage difference in overturning moments for 15 storeys is 19.6
- The percentage difference in overturning moments for 20 storeys is 47.3

### 9.5 Overturning moment

**Table 4:** Change in overturning moments with and without considering p-delta effect

| Storeys | P-Delta (kN-m) | Linear-static (kN-m) | Change in moments (kN-m) |
|---|---|---|---|
| 25 Storey | 2740489 | 2700349 | 40149 |
| 20 Storey | 2098934 | 2079940 | 18994 |
| 15 Storey | 1515463 | 1507590 | 7873 |
| 10 Storey | 949433 | 946270 | 3136 |

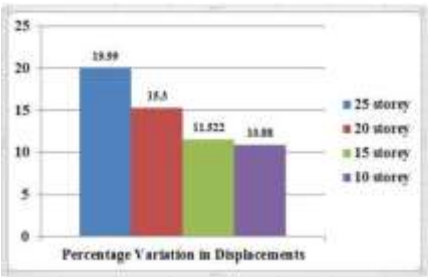


**Figure 18:** Percentage variation of displacement considered under P-Delta analysis over linear static analysis


**Figure 19:** Percentage variation in storey drift

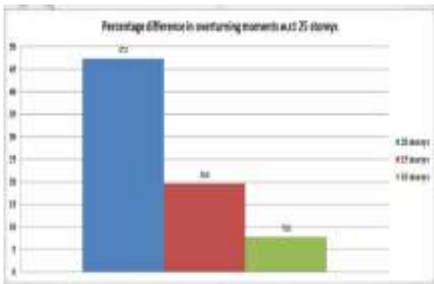

**Figure 20:** Variation in overturning moments with respect to 25 storeys

### 10. Conclusions

In conclusion, the analysis of the P-Delta effect on the structural behavior of buildings with varying numbers of storeys reveals important insights into its significance. For buildings with 10 storeys, the percentage variations in displacements, base moments, storey drift, and overturning moments are approximately 10%, indicating that the consideration of P-Delta analysis may not be mandatory for such structures. However, as the number of storeys increases, the impact of the P-Delta effect becomes more pronounced. For instance, in buildings with 25 storeys, the percentage variations in displacements, base moments, and storey drift exceed 19%, highlighting the necessity of accounting for P-Delta effects in the design process, particularly for tall structures. Moreover, the analysis underscores the importance of examining results with and without P-Delta analysis, especially for exterior columns and under certain load cases, to ensure the structural integrity and stability of tall buildings. Therefore, it is imperative to consider the P-Delta effect in the design of tall structures to accurately predict their behavior and ensure safety and performance.

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## REFERENCES

**[1]** E L Wilson, M EERI and A Habibullah "Static and Dynamic Analysis of Multi-Storey Buildings Including P-Delta Effect," Earthquake Engineering Research Institute, vol.3 Issue 3, pp 289-298, May 1987.
**[2]** A S Moghadam and A Aziminejad. "Interaction of Torsion and P-Delta Effects in Tall Buildings," World Conference on Earthquake Engineering, paper no. 799, August 2004.
**[3]** Kiran R Kaware, Sagar P Lunge, "P Delta Effect on Tall Building," International Journal of Pure and Applied Research in Engineering and Technology, vol.1 Issue 8, pp 348-355, April 2013.
**[4]** Yousuf Dinar, Samiul Karim, Ayan Barua, Ashraf Uddin, "P-Delta Effect in Reinforced Concrete Structures of Rigid joint," IOSR Journal of Mechanical and Civil Engineering, Vol.10, Issue: 4, pp 42-49, Dec 2013.
**[5]** Rafael Shehu, "The P-Delta-Ductility Effect Overview the Effect of the Second Order in the Ductile Structures," European Scientific Journal, vol.3, pp 143-155, Feb 2014.
**[6]** Saranya, S. Pillai, Namitha Chandran, "Effectiveness of P-Delta Analysis in the Design of Tall Slender RC Structures," International Journal of Science and Research, Vol.5 Issue: 6, pp 2005-2008, June 2016.
**[7]** Prashant Dhadve, Alok Rao, Atul Rupanvar, Deokate K, Admile P R, Dr. Nemade. P D, "Assessment of P-Delta Effect on High Rise Buildings," International Journal on Recent and Innovation Trends in Computing and Communication, vol.3 Issue: 5, pp 3231–3236, 2015.
**[8]** Tabassum G Shirhatti, Dr. S. B. Vanakudre, "The Effects of P-Delta And Construction Sequential Analysis of R.C.C and Steel Building with Respect to Linear Static Analysis," International Research Journal of Engineering and Technology, vol.2 Issue: 4, pp 501-504,2015.
**[9]** Juan Carlos Vielma Perez and Manuel Antonio Cando Loachamin, "Influence of P-Delta Effect on Ductility and Vulnerability of SMRF Steel Buildings," The Open Civil Engineering Journal, vol.9, pp 351-362, 2015
**[10]** ManikRao, Rajendrakumar S Harsoor, "Effect of P-Delta in Seismic Analysis of Multi-storey Buildings," International Journal of Research in Engineering and Technology, vol.5 Issue: 11, pp 195-206, 2016.
**[11]** IS 456:2000 "Plain and Reinforced concrete code of practice"
**[12]** IS: 875 (Part1) -1987 "Code of practice for design loads (other than earthquake) for buildings"
**[13]** IS: 875 (Part2)-1987 "Code of practice for Design loads (other than earthquake and structural loads) for building"
**[14]** IS: 875 (Part3)-1987 "Code of practice for wind loads on buildings and structures"
**[15]** IS 1893 (Part 1): 2002 "criteria for earthquake resistant design of structures"
**[16]** Christoph Adam, Luis F. Ibarra and Helmut Krawinkler, "Evaluation of P-Delta Effects in Non-Deteriorating MDOF Structures from Equivalent SDOF Systems", World Conference on Earthquake Engineering Vancouver, vol.3 Issue: 6, pp 366-372, 2015.
**[17]** Jose Antonio and Flores Ruiz, "Study of P-Delta Effect on Tall Steel Structure", International Journal of Allied Practice, Research and Review, vol.6 Issue: 5, pp 26-36, 2015.