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Assessment of P-Delta Effect on High Rise Buildings

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Abstract:- 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. In this study the P-delta effect on high rise building is studied. Linear static analysis (without P-delta effect) on high rise building having different number of stories is carried out. For the analysis G+14, G+19, G+24, (i.e 15, 20, and 25storey) R.C.C. framed building are modeled. Earthquake load is applied on model of structure as per IS-18939(2002) for zone III in E-Tab software. Load combination for analysis is set as per IS-456(2000).All analysis is carried out in software ETAB. Bending moment, story displacement with and without p-delta effect is calculated and compared for all the models. Then by trial and error method suitable cross-section are provided for unsafe building to bring within acceptable limit by increasing stiffness of a building. The result shows that it is essential to consider the P-delta effect for 25storey building. So buildings having height more than or equal to 75m, should be designed considering P-delta effect. Also we can say that up to 25storey building, it is not necessary to consider P-delta effect in design and primary or first order analysis is sufficient for design. By increasing stiffness of building by providing suitable cross section or by increasing stiffness building can bring within acceptable limit.[7]

Keywords: P-delta effect, high-rise building, static nonlinear analysis, displacement, bending moment's stiffness.

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1. INTRODUCTION

A high rise building is a structure whose architectural height is between 35 and 100 m or a structure a automatically listed as a high rise when it has a minimum of a 12 floors, whether or not the height is known .also if it has fewer than 40 floors and height is unknown, it is also classified as a high rise structure.[6]

Generally Structural designers are prone to use linear static analysis, which is also known as first order analysis, to compute design forces, moments and displacements resulting from loads acting on a structure. First order analysis is performed by assuming small deflection behavior where the resulting forces, moments and displacements take no account of the additional effect due to the deformation of the structure under vertical load prior to imposing lateral loads.P-Delta is a non-linear (second order) 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 the applied axial load (P) and a displacement (delta). If a P-Delta affected member is subjected to lateral load then it will be prone to deflect more which could be computed by P-Delta analysis not the linear static analysis.[6]

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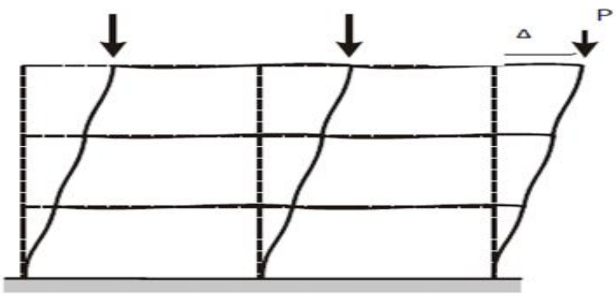


Figure 1.1 P-Delta effects

The magnitude of P-delta effect is related to the:-

- Magnitude of axial load

- Stiffness/slenderness of the structure as whole
- Slenderness of individual elements

1.1 Objectives of the present study;

- Detailed study of P-Delta effect
- To study the effects of axial loadings on high rise buildings
- To Analysis of G+9, G+14 and G+19 story R.C.C. buildings with and without considering P-delta effects.
- Linear static Analysis procedure is carried out by using E-Tab, for ascertaining the seismic Capacity of buildings.
- Nonlinear static pushover analysis procedure is carried out by using E-Tab for ascertaining the seismic capacity of building.
- To decide the minimum height of building for which it is necessary to included P-delta effect in analysis.
- To calculate the % change in the values of forces, deflections and moments considering P-delta effect and without considering P-Delta effect and without considering P-Delta effect of structures.
- To decide the minimum height of building for which it is necessary to include P-delta

effect in analysis.

- To make a structure stiffer for bringing it within acceptable limit according to the code..

2. PUSHOVER ANALYSIS

Pushover analysis is a technique by which a computer model of the building is subjected to a lateral load of a certain shape (i.e., inverted triangular or uniform). The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded. Pushover analysis can provide a significant insight into the weak links in seismic performance of a structure. Pushover analysis is a simplified nonlinear analysis whose central focus is generation of the pushover curve or capacity curve. This represents the lateral displacement as a function of force applied to the structure. This capacity curve is representation of the structures ability to resist the seismic demand. To generate the capacity curve, the structure is pushed in a representative lateral load pattern which is applied monotonically while the gravity loads are in place. Any type of representative lateral load pattern can be defined but the load pattern similar to first mode shape amplitude of the structure is the most commonly used to determine the capacity. The A predefined lateral load pattern as shown in fig.2.1.which is distributed along the building height is then applied. The lateral forces are increased until some members yield. The structural model is modified to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable. The roof displacement is plotted with base shear to get the global capacity curve.[4]

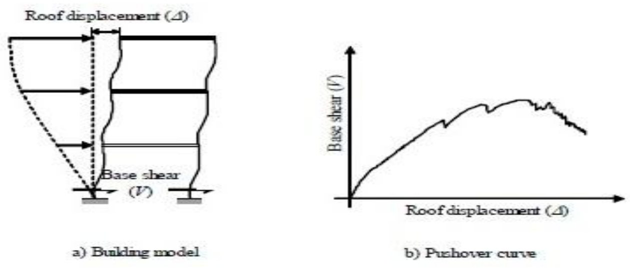


Fig. 2.1Capacity curve

3. ANALYSIS OF HIGH RISE BUILDINGS IN ETAB

Buildings having same plan but with different number of stories are analyses ETAB with and without considering P-delta effect and their results are compared. Following three buildings are considered for study.

Case1. 15storey

Case2. 20storey

Case3. 25storey.

3.1 Load calculations: Following loads are considered for the analysis of the buildings. The loads are taken in accordance with IS: 875 (Part 1) and (Part 2).

Dead load

a) Self-weight
b) Floor finish: 1.25 kN/m^2
c) Wall load

Live load

a) Live load on intermediate floors

Intensity of live load= 2 kN/m^2

b) Live load on roof

Intensity of live roof load= 1.5 kN/m^2

Lateral loads for pushover analysis:- As per IS 1893:2002 for zone3

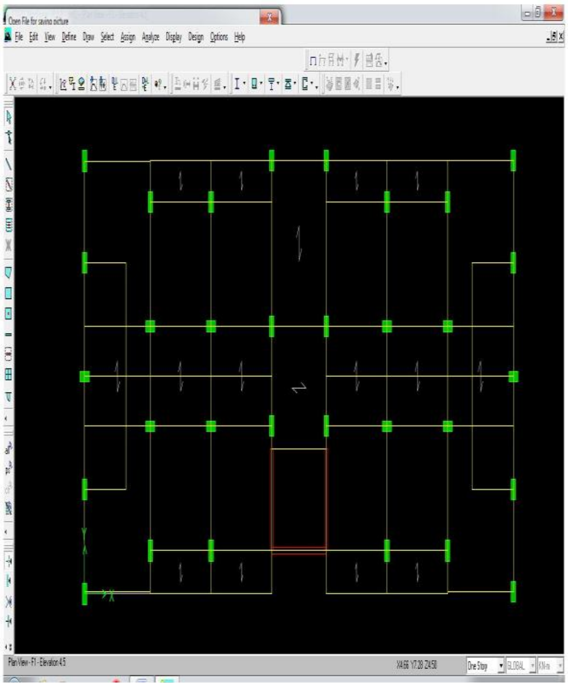
EQX: Earthquake load in X-direction

EQY: Earthquake load in Y-direction

Zone factor = 0.16

Soil: Type 2

Importance factor = 1



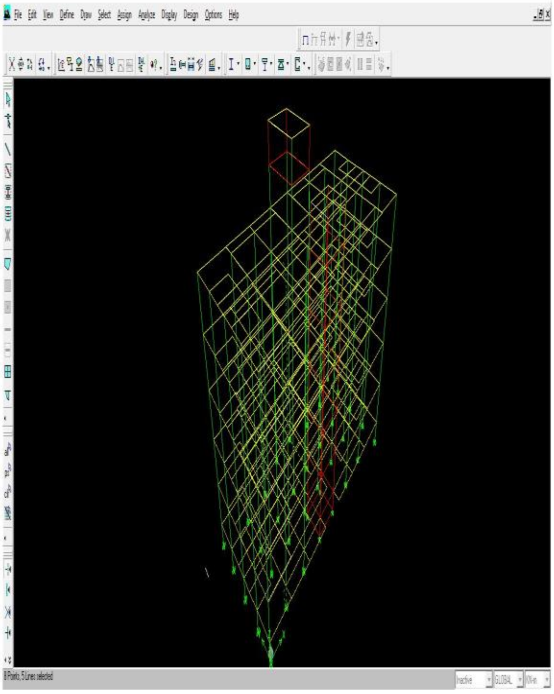


Fig. 3.1 **ETAB Model (3D view and plan)**

3.3 Analysis Result for 25 Storey building:

Analysis result of building in case of deflection, bending moment is presented below in tabular form.

Deflection at top: Table3.2: Deflection at joint at top storey with and without P-delta effect (25 storey building)

Sr. No.	Load case	B.M. at base (KNm)		
		Without P-delta	With P-delta	% Difference
1)	1.2(DL+LL+EQX)	92.23	98.78	7.11%
2)	1.2(DL+LL-EQX)	69.14	71.37	3.28%
3)	1.2(DL+LL+EQY)	75.88	85.62	12.84%
4)	1.2(DL+LL-EQY)	69.20	78.14	12.92%
5)	DL+LL+WL+EQX	-141.45	-144.85	2.40%
6)	DL+1.5LL+1.5WLX	-69.41	-75.25	8.42%

Table 3.2

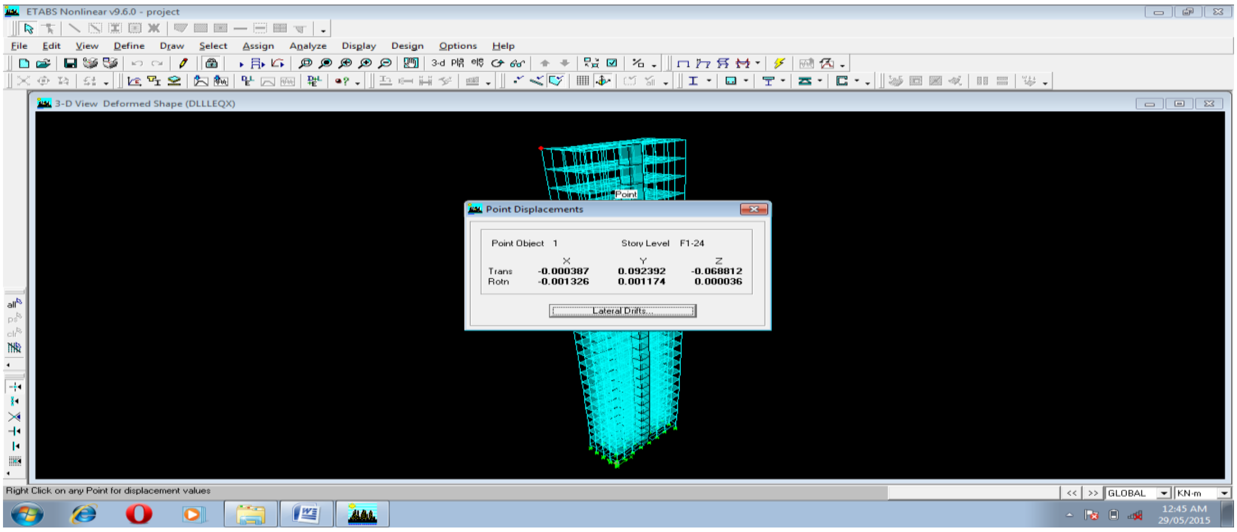


Fig 3.2: deflection at top

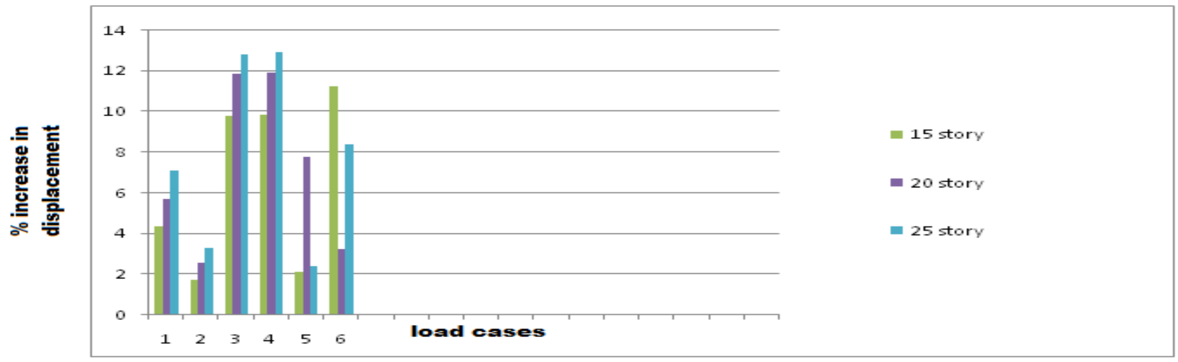
4. RESULT AND DISCUSSION

4.1: Result of 15, 20, 25storey buildings

1. Graph 6.1 represents % increase in deflection for various load cases for 15, 20 and 25 storey building.

2. From graph, it is observed that increase in deflection is more as number of storey increased.

3. Also, P-delta effect is more observed in all load cases.



Graph 4.1; % increase in deflection due to P-delta effect for all load cases

4.2. DISCUSSION

1) For 15 storey building

1. Change in B.M. at base is 2-6%.
2. Change in the deflection is 1-11%.
3. Change in B.M. of beams is less than 10%.
4. Change in the B.M of the columns is up to 20% for some members in some load cases. But it is found that their initial values are very small (i.e not more than 30KNm). So we can say that practically it is not necessary to consider P-delta effect.
5. Hence for 15 storey building, it is not necessary to consider P-delta effect, so building can be designed by 1st order analysis.

2) For 20 storey building

1. Change in B.M. at base is 2-4%.
2. Change in the deflection is 2-14%.
3. Change in B.M of beams which are parallel to y-direction is up to 15%.
4. Change in B.M of columns is 8-30%. It is more observed at the exterior columns and their nearby

beams. Also it is more observed at intermediate stories.

5. So P-delta effect is observed in some load cases for 20 storey building.
6. So it is necessary to consider P-delta effect while designing a 20 storey building.

2) For 25 storey building

1. Change in B.M. at base is 2-4%.
2. Change in the deflection is 3-15%.
3. Change in B.M of some beams is up to15%.
4. Change in B.M of columns is 10-35%. It is more observed at the exterior columns and their nearby beams. Also it is more observed at intermediate stories.
5. So it is necessary to consider P-delta effect while designing a 25 storey building.

5. CONCLUSION

This chapter presents the major conclusions and future scope of the assessment of P-delta effect for high rise buildings. Based on the second order analysis using ETAB and verification with other authors following conclusions can be drawn.

- As number of storey increases P-delta effect becomes more important.
- P-delta effect is only observed in some of the beams and columns (Exterior columns and their adjacent beams) in some load cases. If these load cases are governing load cases for design of member, then only we can say that it is considerable. This condition is observed in 20 and 25 storey buildings and mostly in 25 storey building.
- So we can say that, at least it is necessary to check the results of analysis with and without considering P-delta effect for the buildings.
- Iterative P-delta analysis method is used. Building is by default analyzed for 10 numbers of iterations in ETAB. But the same results are observed for single iteration also. So there is no change in results by increasing the iterations.
- As the cross sections of members increases stiffness of a structure also increases.
- So we should perform P-delta analysis for designing a minimum of 20 storey building considering seismic loads. And buildings up to 20 stories can be designed by conventional primary analysis or linear analysis.
- The conclusion is valid for RCC residential buildings for seismic loading in all the zones of India and may not be applicable for commercial, educational or industrial buildings.

6. FUTURE SCOPE OF THE WORK

Further work and studies on the P-delta effect on high-rise buildings is highly recommended to eliminate the risk of failures of high-rise buildings. Below are some of the recommendations for further studies:

- In this work the stiffness of structure is increased by the concept "The more uniform the internal force distribution, the stiffer the structure" further study can be carried out for the remaining concepts i.e. X bracing for achieving economical design.

- In this work nonlinear behavior of building was studied by static pushover analysis method further study can be carried out by using nonlinear dynamic analysis.

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