An Evaluation of P-Delta Effect in High-Rise Building

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Abstract: *High-Rise structures of rigid joint frame system are increasing day by day to accommodate growing population and infrastructural needs in metropolitan cities. However multi-storied rigid frame RC structures are prone to collapse under severe displacement, axial force and moment, if the second order effects are not included or ignored in analysis and design phase. P-Delta is one of important second-order effects. P-Delta is a non-linear effect that occurs in every structure where elements are subjected to axial load. It is associated with the magnitude of the applied axial load (P) and a displacement (delta). The second order effects are analyzed in much software's like Etabs, Staad Pro, SAP 2000 etc., this study evaluates the difference between displacements and bending moments for second order effects performed analysis by ETABS and STAAD PRO. In this research the plan with dimensions 15 x 40m was considered and varied the stories of the building 15, 20 and 25 was modeled and earthquake load is applied on model of structure as per IS-18939(2002) for zone III. 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. Bending moment and story displacement with P-Delta effect was considered and compared for all the models. The result shows that it is essential to consider the P-Delta effect for all multistoried buildings.*

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

1. Introduction

When you Engineers today typically use linear static (first order) analysis to determine design forces and moments resulting from loads acting on a low-rise structure. First order analysis assumes small deflection behaviour; the resulting forces and moments take no account of the additional effect due to the deformation of the structure under load. Second order analysis combines the effect of displacements also in the calculation of loads. When the high rise buildings are shaken by the earthquake excitation. The exterior columns are subjected not only to the lateral force but also to the fluctuation axial force both in compression and tension. Naturally the lowest part of the exterior columns are most severely subjected to the highest intensity of axial force The combine effect of storey drift in the lateral direction due to lateral force and the axial force causes the well-known P-Delta effect. The P-Delta effect becomes more severe with higher storey drift. The total effects on the exterior columns are due to the combination of the lateral force and the P-Delta effect. Some of the researchers views are explained below.

[1].Farzad Naeim et al., (2001), reported the difficulties due to drift and lateral solidity of a structure. At the early stages of design development itself the drift and lateral stability playsan important role in the designing of the structure. In tall buildings torsion is the main contributor for the structural response with respect to different load combinations.

[2].Mallikarjuna B.N et al., (2014), presented P-Delta analysis's compared with linear static analysis. In this study, a 18steel storey has been selected. The mathematical model is analysed by structural analysis software STAAD Pro 2007with P-Delta effect consideration.

[3].Yousuf Dinar et al., (2013), focused on six different types of structures for the analysis with different number of stories. Non-linear method of P-Delta analysis is used and It is carried out by P-Delta analysis both P|-delta analysis and linear static analysis are important for RC buildings.

2. P-Delta

In structure P-Delta effect generally arises due to the direct action of lateral loads where the deformed structure shape is a dominating factor in the structure at the state of equilibrium in second order analysis this kind of effects are taken care when the elements in damaged conditions. Vertical loads in the high rise buildings on their way through along the elements of the structure produces additional loads at deformed parts. This additional load is taken into consideration for the analysis of the structure is considered for analysis in order to study effects of P-Delta. Whenever a high rise building is shaken by the earthquake excitation.

The exterior columns are subjected not only to the lateral force but also to the fluctuating axial force both in compression and tension naturally the lowest part of the exterior columns are most severely subjected to the highest intensity of the axial force. The combine effect of storey draft in their lateral direction due to the lateral force and the axial force causes the well-known P-Delta effect as shown in Fig-1. The P-Delta effect induces more storey drift. Second-order analysis when accounting for P-Delta combines two effects to reach a solution:-

Theory of large displacement: In this theory both forces and moments due to deformed shape of structure and also members are considered.

Stress stiffening: In this the effect of axial load on structure stiffness is seen. Normally tensile loads straighten the geometry of an element this increases the stiffness whereas compressive loads accentuate deformation which in turn reduces the stiffness of the structure.
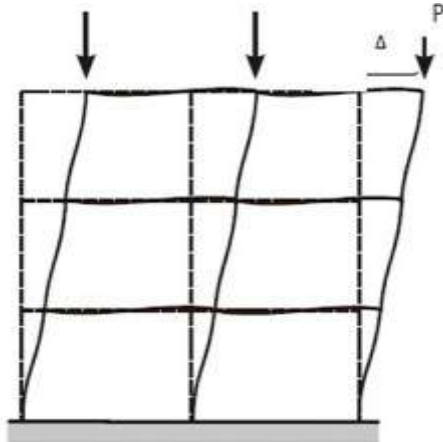
Figure 1: P-Delta

3. Objective

- The objective of this project work is to evaluate the performance of high-rise buildings by considering P-Delta effect and calculating the displacements of columns.
- Detailed study of P-Delta effect to study the effects of axial loadings on high rise buildings.
- Linear Static Analysis of 15, 20 and 25 storey R.C.C. buildings with considering P-Delta effects was done in ETABS and STAAD PRO.
- Difference in Bending moment and Storey Displacement for each storey was considered for both the software's by considering P-Delta analysis.

4. Modelling

Various structural members of the building are assumed with the following dimensions for the feasibility of load calculations. The base dimension was equal for the each building was 15 x 40 m. The structure was varied with respect to height and number of stories. The preliminary data was shown in Table – 1.

Table 1: Building Data

Parameter	Dimensions
Height of The Building	52.5m , 70m , 87.5m
Height of The Each Storey	3.5m
No. of Stories	15 , 20 , 25
Column Size	0.3mx0.6m
Beam Size Longitudinal	0.3m x 0.45m
Beam Size Transverse Beam Size	0.3m x 0.6m
Slab Thickness	0.12m
Parapet Wall Height	1m
External Wall Thickness	0.23m
Internal Wall Thickness	0.15m
Use IS 1893 Part 1 (2002) & IS 875-1987(Part-3) Code Are Used Earthquake Load & Wind Load Analysis	
Proposed Software	BOTH STAADPRO AND ETABS

5. Analysis

Buildings having same plan but with different number of stories are analyses in ETAB and STAAD PRO with considering P-delta effect and their results are compared. Following three buildings are considered for study.
Case 1 = 15 Storey Building
Case 2 = 20 Storey Building
Case 3 = 25 Storey Building
The three cases are shown in Fig – 2. Analysis result of building in case of deflection, bending moment is presented below in tabular form. The modeling and analysis of the cases are shown in Fig – 3 & 4. The Bending Moment analysis results for all three cases are shown in Table-2,3 and 4 for
 Case 1
 Case 2
 Case 3 respectively.

Table 2: Bending Moment at base for Case 1

S.no	Load Case Considered	BM at Base, KNM		Differences (%)
		STAAD	ETABS	
1	1.2(DL+LL+EQX)	159.844	163.884	2.46
2	1.2(DL+LL-EQX)	114.022	117.819	3.22
3	1.2(DL+LL+EQY)	204.600	208.884	2.05
4	1.2(DL+LL-EQY)	126.386	130.567	3.20

Table 3: Bending Moment at base for Case 2

S.no	Load Case Considered	BM at Base, KNM		Differences (%)
		STAAD	ETABS	
1	1.2(DL+LL+EQX)	173.307	178.611	2.97
2	1.2(DL+LL-EQX)	124.186	128.898	3.66
3	1.2(DL+LL+EQY)	222.436	227.659	2.29
4	1.2(DL+LL-EQY)	137.657	142.933	3.69

Table 4: Bending Moment at base for Case 3

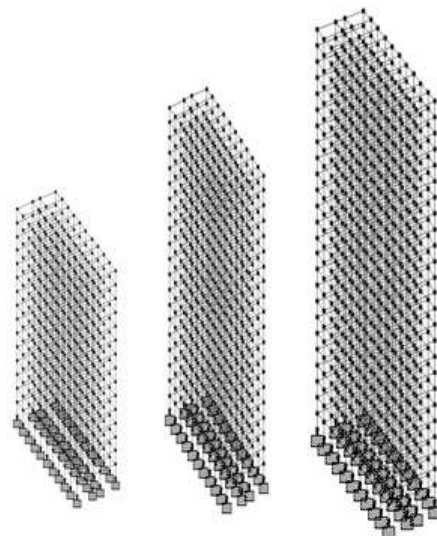| S.no	Load Case Considered	BM at Base, KNM		Differences (%)
		STAAD	ETABS	
1	1.2(DL+LL+EQX)	168.541	174.913	3.64
2	1.2(DL+LL-EQX)	120.684	126.694	4.74
3	1.2(DL+LL+EQY)	216.380	223.010	2.97
4	1.2(DL+LL-EQY)	133.873	140.615	4.79

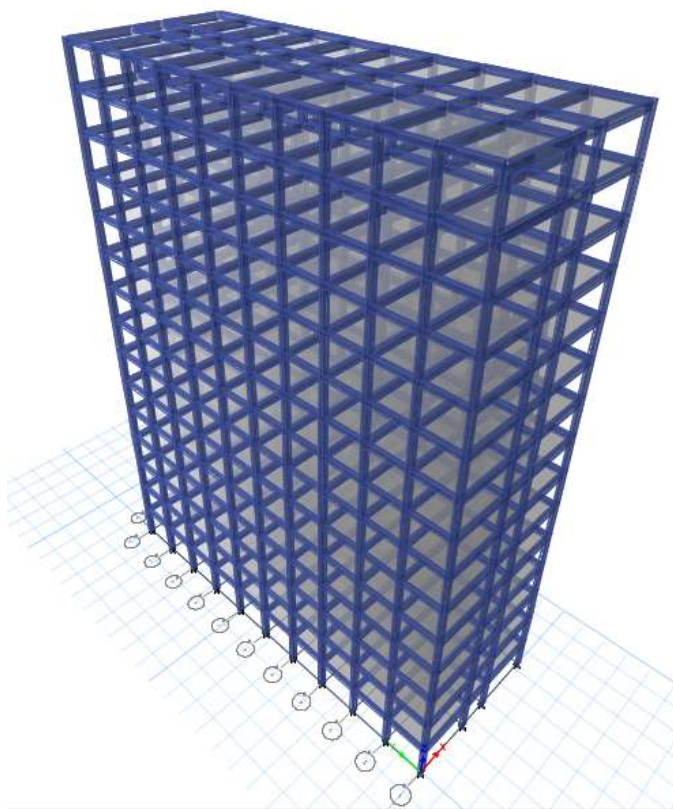**Figure 2:** 15, 20 and 25 storied buildings
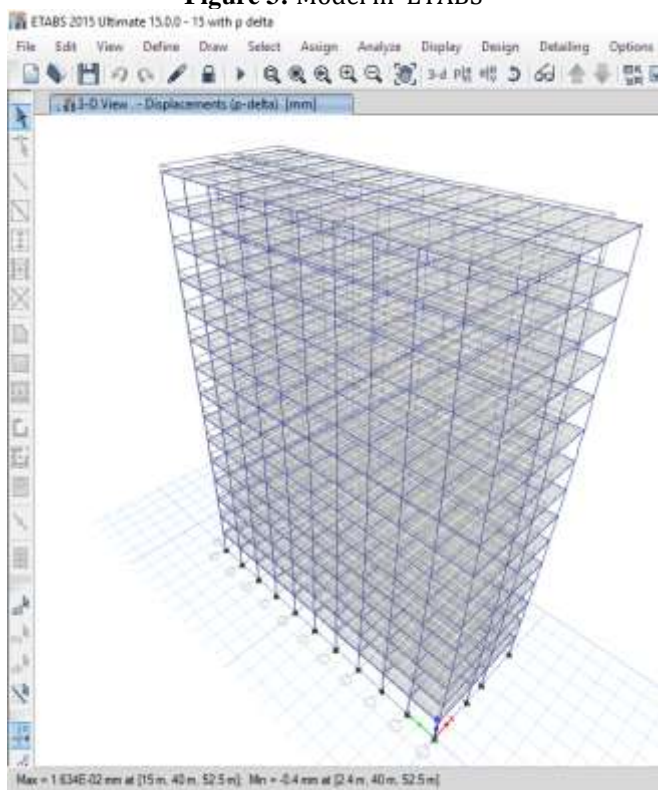
Figure 3: Model in ETABS

Figure 4: P-Delta Model

6. Results and Discussions

Figure - 5 represents % increase in deflection for various load cases for 15, 20 and 25 storey building. From graph, it is observed that increase in deflection is more as number of storey increased. Also, P-delta effect is more observed in all load cases.
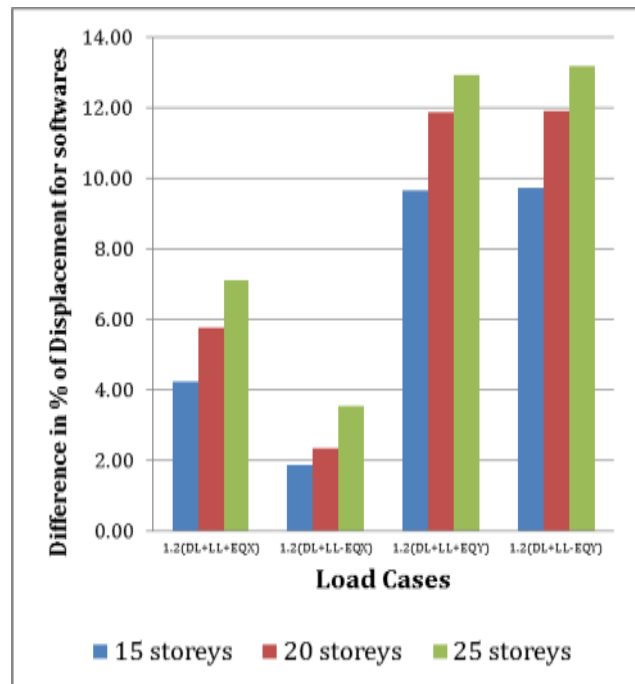

Figure 1: Difference of Displacement for P-Delta in ETABS and STAAD PRO

7. Conclusions

- P-Delta investigations and linear static analysis are carried out for 15, 20 and 25 storey RC framed structure using ETABS and STAAD PRO.
- On the basis of results obtained, Displacements with respect to earthquake load with P-Delta effects are maximum in ETABS when compared with STAAD PRO.
- This also concludes P-Delta effects have more effect in designing of a structure rather than firstorder effect.
- As number of storey increases P-Delta effect becomes more important. P-Delta effect is only observed in some of the beams and columns 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. Out of that ETABS show the accurate results.
- 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 iterations.

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