STUDY ON EFFECTS OF P-DELTA ANALYSIS ON RC STRUCTURES

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Abstract - *In this modern era, the land value is shooting up in an exponential rate and the regions in city and towns are getting over-populated. In order to overcome this situation, there is a necessity of modern multi-storeyed building construction and this in turn leads to irregular type buildings (with irregularity in plan and elevation) which are commonly increasing, mainly because of architectural aesthetics and functional requirements. So there is a need to understand the effects of second order in high rise buildings which occurs when both horizontal and lateral forces act simultaneously. The second order effect is the additional action in the structure due to the structural deformation by virtue of the applied loads which is also known as P-delta effect. The P-Delta is a non-linear effect that occurs in every structure where elements are subjected to axial load. In slender columns or high rise structures, P-delta effect becomes more significant. In the design of high rise buildings with vertical irregularity, it is very much important to examine whether the second order P-delta effects are significant. This project consists of 6 building models with 5, 10, 15, 20, 25 and 30 stores in height and analysed with and without P-delta. In this model, zone III, Zone IV and zone V are taken as seismic zone and compared the effects of storey drift, storey displacement and time period of each individual model with and without the effects of P-delta.*

Key Words: P-Delta effect, second order effect, building models, storey drift, storey displacement, seismic zones.

1. INTRODUCTION

In General, the building analysis can be followed using linear elastic methods, which is referred as first order structural analysis. In this type of analysis, internal forces and displacements are worked out with respect to geometrically un-deformed structure, but material yielding and buckling is not taken into consideration. In this type of analysis, the internal forces and deformations are directly proportional to the load applied. But in some cases where the deflection will have the behaviour of geometric second order and it cannot be calculated with the help of first order linear method. This kind of non-geometric linearity to be calculated by doing iterative methods and this can be done with the help of computer programming and is called as analysis of second order. The internal forces and deformations in this kind are not proportional to the loads applied.

1.1 P- DELTA EFFECT

When subjected to lateral displacements, the building structure will deform which in turn produces second order overturning moments and usually these are not taken into consideration in the case of dynamic and static analysis. This type of second order behavior is known as P- Delta effect as additional overturning moments in the building is equal to the arithmetic sum of story weight "P" multiplied by lateral displacements "Delta". This P- Delta effect is depending on the factors such as load applied and characteristics of buildings and over this, it is also depending on stiffness, height, and symmetry of the structure. The symmetry of structure can be stiffness, unbalanced mass in plane. And two types of distinct P- Delta effects are P- Δ (sometimes referred to as large P Delta for P Big Delta), P- δ (sometimes referred to as "small P- Delta or P- Small Delta).

1.1.1 P Big Delta Effect (P- Δ)

P- Δ is referred to effects of gravity loads applied on structures which are laterally displaced. For reference, seismic or wind loads create horizontal displacements (Δ) and vertical loads (P) also known as gravity loads also act vertically on displaced structure at the same time. So secondary moments developed on the structure is equal to gravity load (P) multiplied by horizontal displacement (Δ)

1.1.2 P- Small Delta Effect (P- δ)

P- δ is referred to the axial load effects in a member subjected to deflection between the end points. For instance, loads on columns due to wind load, earthquake forces and self-weight results in deflection as the result of beams which are supported on it. The bending moments developed is proportional to the axial load. i.e., P multiplied by the curvature it produced during bending i.e, δ. It has to be considered that even beams which are loaded axially will also experience these kind of effects.

2 MATERIAL PROPERTIES:

Table 2.1: Structure Details

Plan dimension	28m x 15m (up to 30 storeys)
No. of storeys	5,10,15,20,25,30 storeys

Structure	R.C.C (SMRF)
Storey height	Base 4 m and typical floor 3.5 m
Base consideration	Fixed

Table 2.2: Material Properties

Concrete grade of beam and column	**M25**
Concrete grade of slab	**M25**
Density of concrete	**25kN/m³**
Grade of steel	**Fe415**
Modulus of elasticity	**2500x10³ kN/m²**

Table 2.3: Sectional Properties & load considering

Structural element	**Dimensions**
Beam	300x600mm
Column	550x1150mm
Slab thickness	125mm
Laterite wall	300mm width
Laterite parapet wall	750 mm height

Table 2.4: Load Detailing

GRAVITY LOAD		
	Typical floors	Roof
Dead load	Default values taken by ETABS	
Live load	3kN/m²	1.5kN/m²
Floor Finish	1.2kN/ m²	2kN/m²
Wall Load	16.53kN/m	3.42kN/m (parapet)

Table 2.5: Preliminary Data

Soil type	Type II (Medium)
Damping	5%
Importance factor	1.0
Reduction factor	5.0
Seismic data	Zone III, Zone IV, Zone V
Time period	Program calculated

3 ABOUT THE MODELS

- Type-1 having conventional building and analyzing using linear static analysis, i.e without considering the effect of P-delta. This consists of 6 building models with 5, 10, 15, 20, 25, 30 storeys in height and analyzed without P-delta. In this model, zone III, Zone IV and zone V are taken as seismic zone and compared the effects of storey drift, storey displacement and time period of each individual model.
- Type-2 having typical building storeys and here P delta effects are added, i.e using non- linear static analysis. Here also the same 6 models with 5, 10, 15, 20, 25, 30 storeys are analyzed with different seismic zones like zone III, zone IV, zone V. In this method, iteration done based on loads and effects of storey displacement, storey drift and time period are calculated for each individual model and comparison is done.

4. TIME PERIOD FOR DIFFERENT STRUCTURES

4.1 Time Period for 30 Storey Building Structure

Table 4.1: Comparison of Time Period for Different Models

Mode	Modal Period (Sec)		Frequencies (Cycles/Sec)	
	With pdelta	Without pdelta	With pdelta	Without pdelta
1	9.098	4.896	0.11	0.204
2	10.098	5.896	1.11	1.204
3	11.098	6.896	2.11	2.204
4	12.098	7.896	3.11	3.204
5	13.098	8.896	4.11	4.204
6	14.098	9.896	5.11	5.204
7	15.098	10.896	6.11	6.204
8	16.098	11.896	7.11	7.204
9	17.098	12.896	8.11	8.204
10	18.098	13.896	9.11	9.204
11	19.098	14.896	10.11	10.204
12	20.098	15.896	11.11	11.204

4.2 STOREY DISPLACEMENT

Storey displacement is defined as displacement that occurs laterally in each storey when related with respect to base of the structure. When base of the structure is fixed, displacement will be less at bottom and as the height increases displacement will also increase

Table 4.2: Storey Displacement for 10 storey building along X-Direction

Storey No.	ZONE III		ZONE IV		ZONE V	
	With P Delta	Without P Delta	With P Delta	Without P Delta	With P Delta	Without P Delta
10	22.134	13.96	33.201	20.94	49.801	31.41
9	21.405	13.518	32.108	20.277	48.162	30.415
8	20.171	12.724	30.257	19.086	45.385	28.629
7	18.403	11.589	27.604	17.383	41.407	26.075
6	16.171	10.179	24.256	15.269	36.385	22.903
5	13.569	8.565	20.353	12.848	30.53	19.272
4	10.694	6.81	16.041	10.215	24.061	15.323
3	7.651	4.97	11.477	7.456	17.216	11.183
2	4.588	3.107	6.882	4.66	10.323	6.99
1	1.797	1.329	2.695	1.994	4.043	2.991

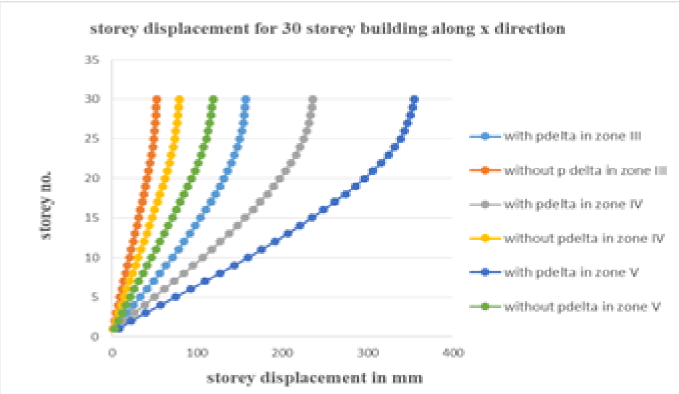

Fig 4.1: Storey Displacement for 30 storey building along X- Direction

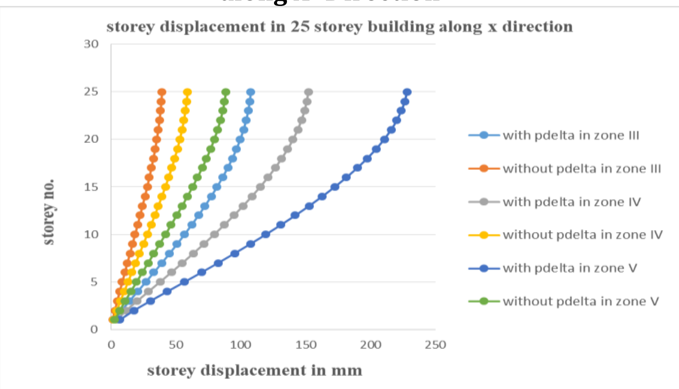

Fig 4.2: Storey Displacement for 25 storey building along X- Direction

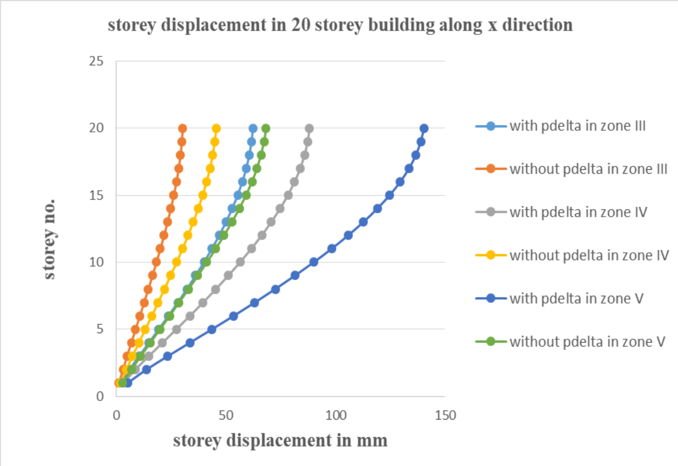

Fig 4.3: Storey Displacement for 20 storey building along X- Direction

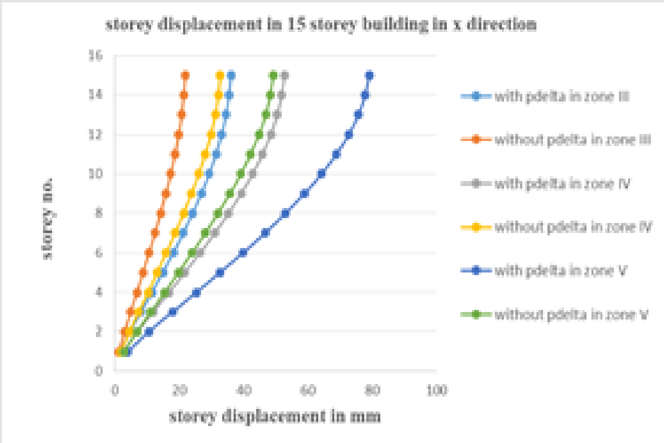

Fig 4.4: Storey Displacement for 15 storey building along X- Direction

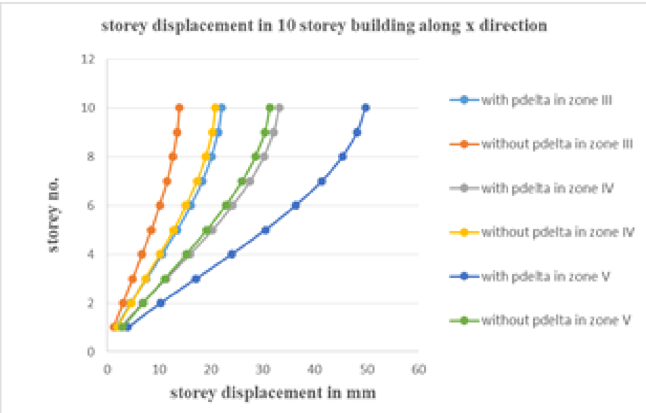

Fig 4.5: Storey Displacement for 10 storey building along X- Direction

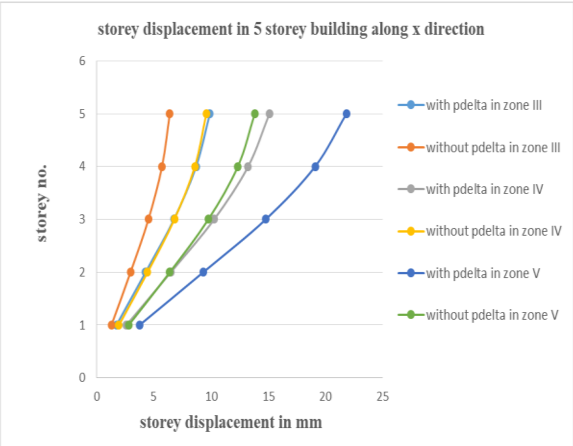

Fig 4.6: Storey Displacement for 5 storey building along X- Direction

Table 4.3: Percentage difference in storey displacement

Displacement ZONE V		
	X-direct	Y-directn
STOREY 30	63.736	65.343
STOREY 25	59.162	63.482
STOREY 20	46.695	51.792
STOREY 15	36.649	38.439
STOREY 10	36.228	37.923
STOREY 5	35.033	34.940

4.3 STOREY DRIFT

The storey drift is expressed as the ratio of displacement of two consecutive floor to height of that floor. Storey Drift is an inter storey-the storey displacement of one storey by which related to subsequent or above & below storeys. According to IS 1893-2002, storey drift cab be estimated as below.

2nd storey drift =Δ

Second storey (2nd) drift =displacement at 3rd floor level – displacement of 2rd floor level

The storey drift in any storey because of defined design lateral force i.e minimum with partial load factor of 1.0 should not cross 0.004 of storey height. In high rise structures, the larger deformations and axial forces in columns, the effects will keep on increasing as the height increases.

Table 4.4: Storey Drift for 10 storey building along X- Direction

Storey No.	ZONE III		ZONE IV		ZONE V	
	With P Delta	Without P Delta	With P Delta	Without P Delta	With P Delta	Without P Delta
10	0.000208	0.000126	0.000312	0.000189	0.000468	0.000284
9	0.000353	0.000227	0.000529	0.00034	0.000793	0.00051
8	0.000505	0.000324	0.000758	0.000486	0.001137	0.00073
7	0.000638	0.000403	0.000957	0.000604	0.001435	0.000906
6	0.000743	0.000461	0.001115	0.000692	0.001673	0.001038
5	0.000821	0.000501	0.001232	0.000752	0.001848	0.001128
4	0.000869	0.000526	0.001304	0.000788	0.001956	0.001183
3	0.000875	0.000533	0.001313	0.000799	0.001969	0.001198
2	0.000797	0.000508	0.001196	0.000762	0.001794	0.001143
1	0.000449	0.000332	0.000674	0.000499	0.001011	0.000748

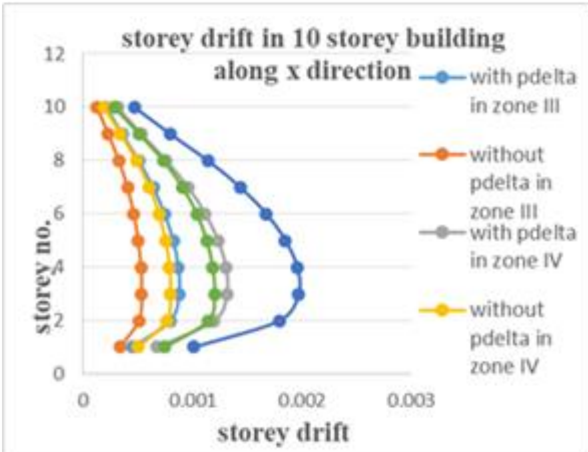

Fig 4.7: Storey Drift for 10 storey building along X- Direction

5. CONCLUSION

Analysis of 6 models of RCC different storeyed building is carried out and comparison was done for each using equivalent static analysis (without p delta) & non-linear analysis (with p delta) method. .

•The displacement of conventional building (without p delta) is less when compare to building with p delta.
•The time period i.e, modal period and frequencies also found to be more in building models with p delta effects than building models without p delta.
•The storey drift in building models with the consideration of p delta effects are more when comparing with models

using equivalent static analysis method (without p delta effects)

•As the number of storey increases, the parameters like storey displacement, storey drift and time period found to have increased when considering p delta effects.

•The storey displacement varies from 35.02% to 63.63% in x direction for models with 5 storey to 30 storey when compared with and without p-delta.

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