Effectiveness of P-Delta Analysis In The Design of Tall RCC Structures

Baria Riddhi M.[1], Chetan Machhi[2], Dr. Vinu. R. Patel[3]
[1]Dept of Civil Engineering
[2]Associate Professor,Dept of Civil Engineering
[1, 2] Sardar Patel College of Engineering, Bakrol
[3]Structural Consultant, Zarna Associates, Vadodara

Abstract- *As urbanization rises worldwide, the available land for buildings is becoming lower and lower, and the cost of land is increasing day by day. Thus, the demand of high-rise structures is increasing now a days to facilitate growing population in metro cities. In this era, we focus on the effectiveness of p-delta analysis in the design of high rise reinforced concrete structures. P Delta is a second order analysis in which the additional loads is generated due to deformation of structure are also included in addition to the applied lateral and vertical loads. This effect is not observed in certain height buildings but after some heights in some areas where earthquake loads are at high risk, we considered this effect. In the current study seismic analysis of a Tall RCC building with or without P-Delta effects is analyzed by using ETABS structural analysis software. The seismic zone factor of 0.36 is consideredunder Zone-V. From this analysis, the P-delta effects is minimum, with compared to linear static analysis.*

Keywords- Linear Static,P-delta, displacement, ETABS, bracings, and lateral load.

I. INTRODUCTION

1.1 What is Tall Structure?

Strictly Speaking any building having more than one floor is a Multi Storied Building and a building to which provision of lift is essential is Tall building. Various nomenclatures used for tall buildings are high rise buildings, sky scrapers, vertigoes, anthills, concrete castles etc. From architectural considerations any building higher than two floors, needing use of staircase or lift is called as tall building. From firefighting view, a tall building is one from where emergency escape is not practicable. From structural engineering aspect, a tall building would be one whose structural elements directly or indirectly are affected by wind forces. From physical planning a tall building is one which by its height begins to affect its light, ventilation and climate of other surrounding buildings.

1.2 Loads design philosophy

In contrast to vertical load, lateral load effects on buildings are quite variable and increase rapidly with increases in height of the building, and lateral deflection varies as the fourth power of the height of the building, other things being equal.

There are three major factors to consider in the design of all structure: strength, rigidity, and stability. In the design of the tall buildings, the structural system must also meet these requirements. The strength requirement is the dominant factor in the design of low height structures. However, as height increases, the rigidity and the stability requirements become more important, and they are often the dominant factors in the design. There are basically two ways to satisfy these requirements in a structure. The first is to increase the size of the members beyond and above the strength requirements. However, this approach has its own limits, beyond which it becomes either impractical or uneconomical to increase the sizes. The second and more elegant approach is to change the form of the structure into something more rigid and stable to confine the deformation and increases stability.

1.4 Analysis of Structure

The reinforced concrete building can be damage during earthquake and due to these damages, our structures needs to be retrofitted of existing buildings in sub-continents in India, these practices are usually used because of lack of awareness of regarding structural behavior during earthquake. There are two types of analysis can be done.

1) Linear Static and Dynamic analysis
2) Non-linear Static and Dynamic analysis

Linear Static Analysis: Linear static analysis is kind of analysis in which we cannot give response to the building with respect to time.

In this analysis we can check the small deflections, bending moments and shear forces of the applied load over the structure.

The results of different load cases can be combined with each other and with other linear load cases, such as response spectrum analyses.

Non-Liner Static Analysis

Nonlinear static analysis is of two types:

1) Geometrical non-linearity
2) Material non-linearity

P-Delta is geometrical non-linearity because when the deflection increases, we have to test the against the additional forces which are generated by P-Delta effects. The word p is the force and Delta gives the deflection of the particular member on which force p applied. It generates additional shear and bending moment in column and we must design against that. There is one more case for this analysis is Push-over analysis to calculate ultimate load and deflection capability.

Material nonlinearity is defined as when the material goes beyond its yield strength and it no longer behaves in linear fashion due to this the material gets cracked, dissipates energy, permanent deformation and beam rotations

1.3 What is P-Delta?

Generally Structural designers are prone to use the 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 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.

The term P-delta refers to the additional actions induced by an axial force (P) when there is a horizontal displacement (delta) on a vertical element. 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 and not by the linear static analysis. This effect may reduce significantly the flexural capacity of a structure.

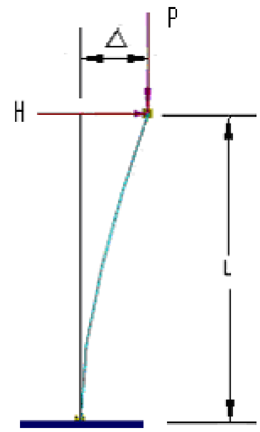

Fig 1: P-Delta Analysis

P-delta is second order effects. Second order effects can arise in every structure where elements are subject to axial load. When a model is loaded, it deflects. The deflection may give rise of an additional moment – a second order moment. It is of notable importance to consider this as additional moment may incur additional deflections which in turn again can incur additional moment, a third order, and so on until the loads can eventually exceed the capacity.

1.4 P-Delta Analysis Parameters

There are two ways to specify the initial p-delta analysis in ETABS V8 as follows:

- Non-iterative Based on Mass: The load is computed automatically from the mass at each level as a story-by-story load upon the structure. This approach is approximate, but does not require an iterative solution. This method is identical to p-delta analysis in ETABS V6.

- Iterative Based on Load Cases: The load is computed from a specified combination of static load cases. This is called the P-Delta load combination.

II. OBJECTIVE AND SCOPE OF STUDY

2.1 Objective:

The main objectives of this study are to understand the P- Delta analysis in tall structure underseismic loading conditions as per Indian standard code:

- To perform linear static analysis of Symmetric tall structure by using ETABs Software.
- To perform Non-linear (P-Delta) effect on Symmetric tall structure by using ETABs software.
- To understand the behavior of p-delta analysis in tall structure under seismic loadings.
- To study the effect of Bracing system on tall RCC structure for P-Delta.

2.2 scope of study

- Learning of ETABs software and preparing a model of tall RCC structure using software.
- Comparative study of tall Structure with different height of stories.
- To understand the trend of P-Delta and its effects.
- Analysis the Structure for Linear and Nonlinear analysis.
- Determination of P-Delta analysis of the structure such as bending moment, Displacements, and Base Shear.
- Analyzing the structure for P-Delta analysis with Bracing system.
- Comparison of Bare frame, and Braced frame Structure.

III. PROBLEM FORMULATION

For comparingRCCtall building with G+99 stories, G+129 stories, G+149 building is modeled in the ETABS software.

3.1 Building data

- Floor height:3m
- Column size: 500*600mm for G+99
  550*700mm for G+129
  650*850mm for G+149
- Beam size:500*600mm
- Slab thickness:200mm
- Wall thickness: 300mm
- Braces

Fully External Braced system (FEBS)

X Bracing ISWB550 for G+99
ISWB550 for G+129
ISWB600 for G+149

- Grade of steel: Fe 550
- Concrete grade: M-30
- Dead Load on floors: 9kN/m2
- Live load: 6kN/m2
- As per IS 1893:2002, for Zone 5,

Zone factor: 0.36
Soil type: II
Importance Factor: 1

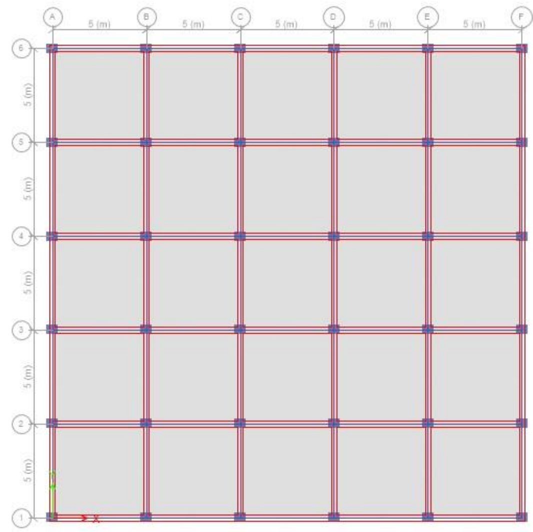
Fig 2: Plan for all models

3.2 Analysis Methods

- Linear Static Analysis or Equivalent StaticAnalysis

The linear static analysis for (G+99), (G+129) and(G+149) storey building is carried out without consideringthe P-delta effect in ETABS v17.1 program.

- Non-Linear Static or P-Delta Analysis:

The nonlinear static analysis for (G+99), (G+129) and(G+149) storey building is carried out considering the P-deltaeffect in ETABS v17.1 program.

3.3 To study the effect of P-Delta Analysis on a Bare frame tall RCC Structure:

3.3.1 Case 1 Model 1 G+99 Bare Frame

Table 3.1 Displacement for G+99

No of stories	Displacement	
	Linear Static Analysis	P-Delta Analysis
Story100	1545.07	1857.03
Story90	1333.55	1602.61
Story80	1122.52	1348.75
Story70	914.81	1098.8
Story60	714.58	857.73
Story50	527.01	631.83
Story40	358.01	428.35
Story30	213.98	255.19
Story20	101.67	120.60
Story10	28.00	32.85

The variation of Displacement obtained form Linear Static Analysis and P-Delta Analysis are plotted in Graph as shown in fig:3

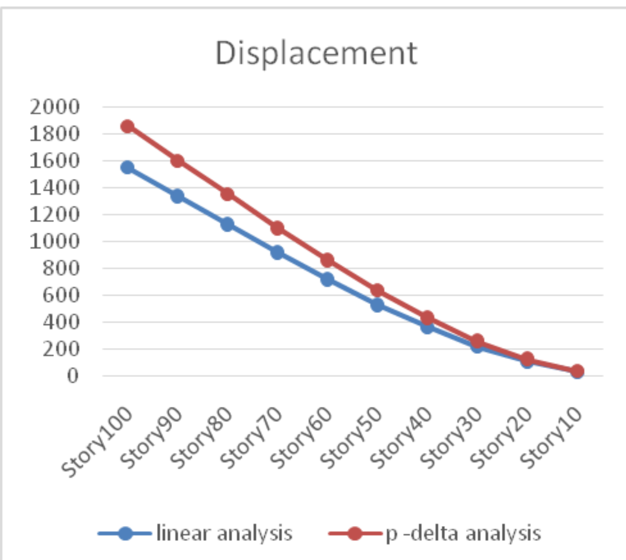

Fig 3: Graph for Displacement

From fig 2, The Maximum Displacement of G+99 is 1545.07mm and 1857.03mm obtained from Linear Static Analysis and P-Delta Analysis and their maximum difference is 18.33%

3.3.2 Case 1 Model 2 G+129 Bare Frame

Table 3.2 Displacement for G+129

No of Stories	Displacement	
	Linear Static Analysis	P-Delta Analysis
Story130	4280.28	6655.78
Story120	3827.52	5950.61
Story110	3375.21	5246.09
Story100	2926.20	4546.41
Story90	2484.81	3858.13
Story80	2056.53	3189.82
Story70	1647.86	2551.79
Story60	1266.02	1955.76
Story50	918.84	1414.49
Story40	614.58	941.43
Story30	361.78	550.30
Story20	169.17	254.62
Story10	45.59	67.24

The variation of Displacement obtained from Linear Static Analysis and P-Delta Analysis are plotted in Graph as shown in fig:4

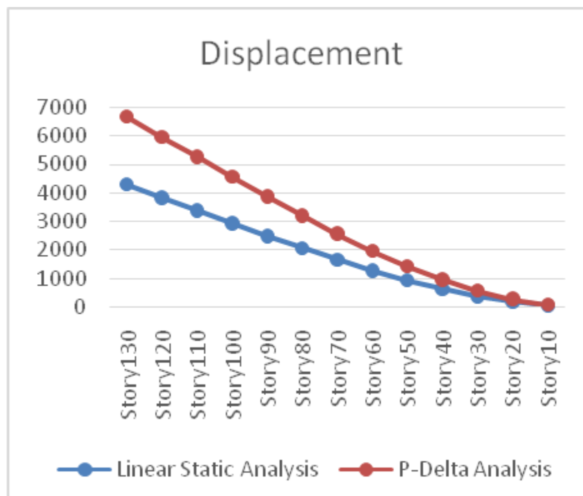

Fig 4: Graph for Displacement

From fig 3, The Maximum Displacement of G+129 is 4280.28mm and 6655.78mm obtained from Linear Static Analysis and P-Delta Analysis and their maximum difference is 43.44%

3.3.3. Case 1 Model 3 G+149 Bare Frame

Table 3.3Displacement for G+149

No of Stories	Displacement	
	Linear Static Analysis	P-Delta Analysis
Story150	7244.59	15147.29
Story140	6579.54	13753.38
Story130	5914.86	12360.18
Story120	5253.34	10973.00
Story110	4599.21	9600.30
Story100	3957.93	8253.38
Story90	3336.04	6946.11
Story80	2740.94	5694.59
Story70	2180.68	4516.78
Story60	1663.91	3432.03
Story50	1199.68	2460.60
Story40	797.34	1623.12
Story30	466.45	939.89
Story20	216.73	430.25
Story10	57.94	111.85

The variation of Displacement obtained from Linear Static Analysis and P-Delta Analysis are plotted in Graph as shown in fig:5

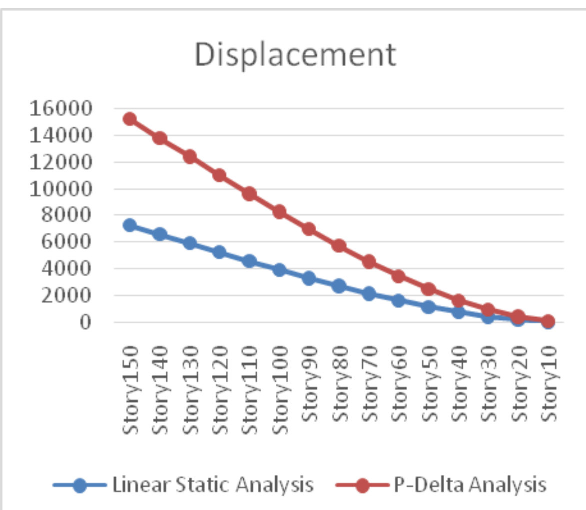

Fig 5: Graph for Displacement

The maximum Displacement of G+149 is 72244.59mm and 15147.29mm obtained from Linear Static Analysis and P-Delta Analysis and their Maximum Difference is 70.58%

3.3.4 To study the effect of P-Delta Analysis on a Braced tall RCC Structure:

3.4.1 Case 2 Model 1 G+99 Braced Frame

Table 3.4 Displacement for G+99

No of Stories	Displacement	
	Linear Static Analysis	P-Delta Analysis
Story100	1625.808	1985.029
Story90	1403.054	1712.829
Story80	1180.861	1441.29
Story70	962.206	1173.968
Story60	751.463	916.184
Story50	554.069	674.658
Story40	376.241	457.151
Story30	224.735	272.126
Story20	106.647	128.404
Story10	29.262	34.83

The variation of Displacement obtained fromLinear Static Analysis and P-Delta Analysis with bracing system are plotted in Graph as shown in fig:6

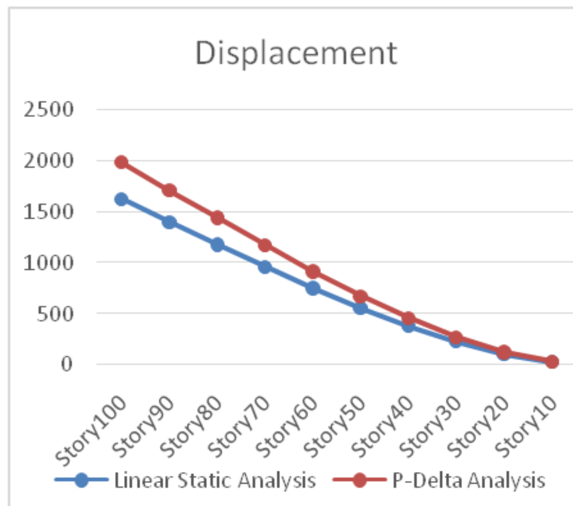

Fig 6: Graph for Displacement

The maximum Displacement of G+99 is 1625.80mm and 1985.02mm obtained from Linear Static Analysis and P-Delta Analysis with Bracing System and their Maximum Difference is 19.89%

3.4.2 Case 2 Model 2 G+129 Braced Frame

Table 3.5 Displacement for G+129

No of stories	Displacement	
	Linear Static Analysis	P-Delta Analysis
Story130	4291.62	7516.27
Story120	3837.60	6719.31
Story110	3384.03	5923.18
Story100	2933.79	5132.58
Story90	2491.20	4354.9
Story80	2061.77	3599.79
Story70	1652.00	2878.94
Story60	1269.15	2205.62
Story50	921.06	1594.33
Story40	616.01	1060.31
Story30	362.57	619.08
Story20	169.5	285.90
Story10	45.64	75.18

The variation of Displacement obtained from Linear Static Analysis and P-Delta Analysis with bracing system are plotted in Graph as shown in fig:7

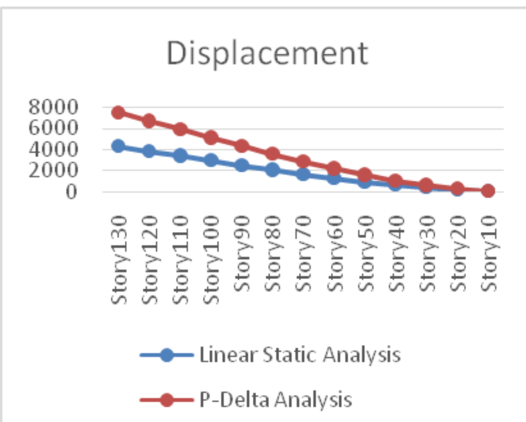

Fig 7: Graph for Displacement

The maximum Displacement of G+129 is 4291.62mm and 7516.27mm obtained from Linear Static Analysis and P-Delta Analysis with Bracing System and their Maximum Difference is 54.61%

3.4.3 Case 2 Model 3 G+149 Braced Frame

Table 3.6: Displacement for G+149

No of Stories	Displacement	
	Linear Static Analysis	P-Delta Analysis
Story150	7269.19	15386.48
Story140	6601.74	13970.22
Story130	5934.70	12554.73
Story120	5270.85	11145.41
Story110	4614.42	9750.83
Story100	3970.93	8382.47
Story90	3346.90	7054.43
Story80	2749.76	5783.06
Story70	2187.60	4586.61
Story60	1669.09	3484.75
Story50	1203.31	2498.1
Story40	799.65	1647.57
Story30	467.71	953.81
Story20	217.22	436.45
Story10	58.01	113.36

The variation of Displacement obtained from Linear Static Analysis and P-Delta Analysis with bracing system are plotted in Graph as shown in fig:8

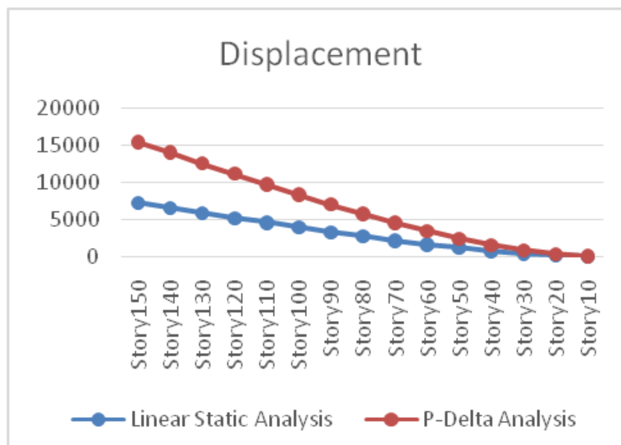

Fig 8: Graph for displacement

The maximum Displacement of G+149 is 7269.19mm and 15386.48mm obtained from Linear Static Analysis and P-Delta Analysis with Bracing System and their Maximum Difference is 71.65%

IV. CONCLUSION

1. From the above results of displacements obtained from G+99, G+129, G+149 Bared frame analyzed with P-Delta effect shows 70.58% more than that from Linear Static Analysis.
2. From the above results of displacements obtained from G+99, G+129, G+149 Braced frame model, analyzed with

P-delta effect shows 71.65% more than Linear static Analysis.

3. The Bare Frame R.C.C structure are more vulnerable to P-delta effect rather than Braced frame structure.
4. Fully external Braced system is more efficient structure rather than Bare frame with P-delta analysis.

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