P-Delta Effects on Tall RC Buildings with and Without Shear Wall

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Abstract - *In this modern era of 21st century the urbanization increases worldwide, in heavily populated cities the availability of land is becoming less and cost of land is becoming higher. In view of popularity & less availability of land, tall structures are only solutions for overcoming the problems. A tall structure should be designed to resist the lateral load like Earthquake force within the permissible limits set by Standards. Loads are mainly of two types that are Gravity Loads & Lateral Loads likes Earthquake load. Earthquake forces are further two types, Static Forces & Dynamic Forces. It would be linear and Non-linear also. Linear static analysis can be performed for Low Rise Structure & law earthquake zones only. For tall structure it is necessary to consider nonlinearity, which is generally observed in geometry & materials. Our study is based on "P-Delta" analysis which incorporates geometric nonlinearity in the analysis. The study will be performed on structural software ETABS. In the present study seismic analysis and wind load analysis of a multi -storey RC building with and without P-Delta effects is analyzed by using ETABS structural analysis software. The seismic zone factor of 0.16 is considered which falls under Zone-III. From the analysis, the displacement respects to earthquake loads are minimum when compared with earthquake load with P-delta effects.*
P-delta effect is secondary effect on structure .it is also known as "Geometric nonlinearity effect". In this study the P-delta effect on high rise building is studied. Linear static analysis (without P-delta effect) on high rise building. For the analysis (20 storey) R.C.C. framed building are modeled. Earthquake load is applied on model of structure as per IS-1893(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 shear wall and without shear wall and p-delta effect is calculated. The P-Delta effects found to decreases the storey displacement by earthquake using shear walls and also decrease by wind loading. Axial force increases as no. of building storey increases. Bending moment is increases in column at ground floor found 9% increases and also in shear walls 5.96 % increases after P-delta effects.

Key Words: P-Delta effect, displacement, bending moment, lateral loads, liner static, shear walls, tall buildings.

1. INTRODUCTION

High-rise building is the demand of new era as it provides accommodation to a well number of people in a small place but without proper design and consider catastrophic may happen which is evident from last few decades after introduction of high-rise and Reinforced Concrete structures are prone to effected by several parameters for its self-weight and frame system.

Generally, the analysis of buildings is done by using linear elastic methods, which is first order structural analysis. In a first order analysis displacements and internal force are evaluated in relation to the geometric un deformed structure. However, in some cases, the deflection of the structure can have a geometric second order effect on the behavior of the structure. This type of geometric non-linearity can be analyzed by performing through iterative processes which is only practicable by using computer programs. It is generally known as second order analysis. In this type of analysis, the deformations and internal forces are not proportional to the applied loads.

Second-order effects are generally explained by considering the additional displacements, forces, and moments which generated from the use of actions on a deflecting structure. These are known as second-order effects. In certain situations, a first-order analysis may be used to estimate the effects of a second-order analysis by procedure, which is suitable for elastic frame analysis by computer. Second order effects introduce additional deflections, moments and forces beyond those calculated by first-order analysis. So it should be considered in the design.

1.1 P-DELTA EFFECT

P-Delta is a non-linear (second order) effect that occurs in every structure where elements are subject to axial load. It is a genuine "effect" that is associated with the magnitude of the applied axial load (P). Due to which, the structure is pushed even further developing a second order deflection. This second order effect experienced is conveniently termed as P-Delta effect. If P‟ is the gravity load, „Δ1‟ is the displacement observed through first order or elastic analysis for lateral forces (Fwind or Feq) and h‟ is the story height, the product ($P \cdot \Delta 1$) is the overturning moment experienced in addition to $F \cdot h$. The P-Delta effect is illustrated in the Figure 1, where the Δ2 is the second order deflection developed due to P-delta effect. This secondary effect is observed by two different processes. The major effect is seen due to deflection of the structure as a whole (frame instability) and also termed as P -"BIG" delta (P-Δ) and the rest is contributed by the axial deformations of individual members of the structure (member instability), also termed as P -“little” delta (P-δ) (Chen and Wang 1999; Dobson 2002). However, this thesis research is only limited to the P-delta effect seen through structural instability (P-Δ). The magnitude of P-Delta effects depends on the magnitude of axial load (P), Stiffness / slenderness of individual elements and structure as a whole (Dobson 2002). So, normally tall structures and buildings with higher number of stories will experience higher P-delta effect than others and have to be designed with adequate considerations to it. The importance of P-Delta non-linear analysis is continuously increasing as new generation high rise buildings are getting more and more popular.

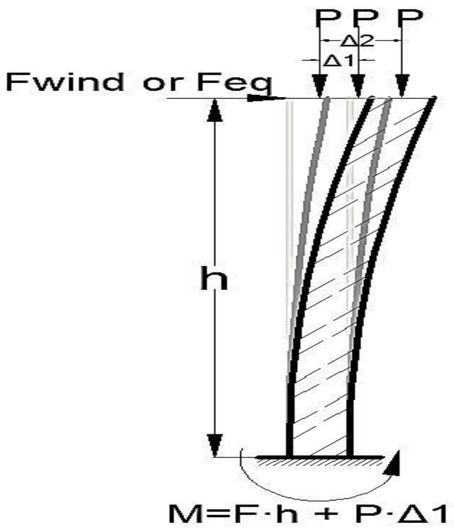

Fig.1: P-Delta Effects on a Cantilever Column

2. MODEL CONFIGURATION

The general layout of the building is shown in Figure-2. Preliminary sizes of structural components are assumed by experience and general information of building as shown in Table-1.In this direction, four identical shear walls are located along four side of the building. The shear walls are assumed to be fixed at their bases. The 3D view of building as shown in Fig.3a & b.

Table-1 Details for Building Models

Details for Building Models	
Particular	**Details**
Plan Size	70.00mx13.50m
No. of Floors	20.00
Storey Height	60.00 m
Type of soil	1.0
Grade of Concrete	M25 and M30
Grade of Steel	Fe415 (Rebar)
Column Size	500mmx500mm and 300mmx500mm
Beam Size	300mmx500mm
Slab Thickness	150mm
External Wall	200mm
Shear Wall	150mm
Zone	III
Region	Indore
Live Load	3KN/sqm
Floor Finish Load	1KN/sqm
Earthquake Load	As Per IS:1893(Part-I)-2002
Wind Load	As Per IS:875:1987(Part-3)
Response Reduction Factor	3.0
Zone Factor	0.16
Seismic Intensity	Moderate
Wind Speed	39m/s
Terrain Category	1.0
Structure Class	A

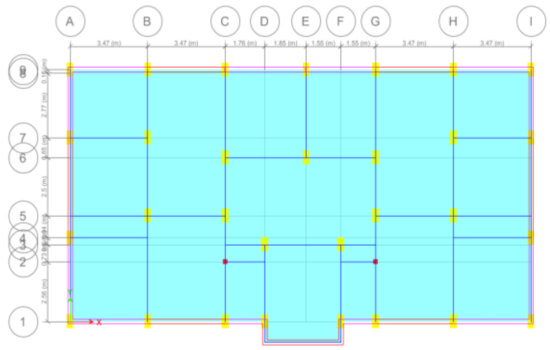

Fig.2: Plan of Building

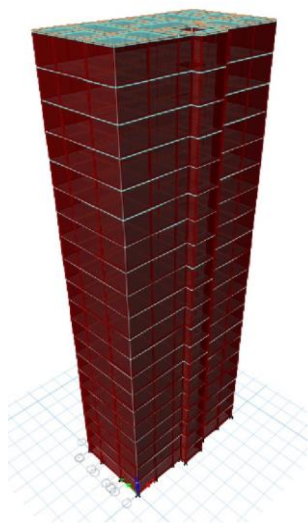

Fig.3 (a) 3D view without shear wall

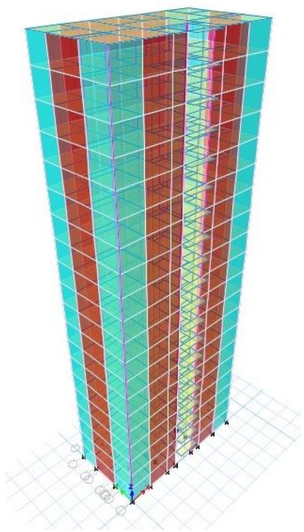

Fig.3 (b) 3D view with shear wall

3. LOAD CALULATION

3.1 Gravity Load

The loads considered for the following study are as below which are according to IS codes.

1. Dead load: The self-weight of the structural members is calculate according to the code provisions and is taken care in the software.
2. Live load on floor: 3kN/m^2 (Table 1 of IS 875(Part-2):1987)

3.2 Wind Load

Wind load calculations as per Indian code: IS 875 (Part-3)1987)

Design wind speed (V_z) can be mathematically expressed as follows

$$V_z = V_b \times K_1 \times K_2 \times K_3$$

Where, V_b = basic design wind speed
K_1, K_2, K_3 can be calculated from the IS: 875 (part3)
P_z = Design wind pressure

$$P_z = 0.6\, V_z^2$$

3.3 Earthquake Load

As per IS-1893-2002, seismic analysis of the structure is performed. The design horizontal seismic coefficient, Ah for the structure has been computed using the following:

1. Zone factor, Z = 0.16 (Zone III)
2. Importance factor I = 1.0
3. Response Reduction factor, R =3
4. Soil type = Hard Soil
5. Damping Coefficient = 0.05

4. RESULTS AND DISCUSSIONS

he results of the P-delta, displacement due to earthquake and wind load with and without shear wall calculations for each model are presented.

4.1 Displacement

For the earth quake load storey displacement with P-delta effects along the height of the building is shown in Fig.3a,b. The storey height is plotted in X-axis and Storey displacement is plotted in Y-axis. Displacement of without shear wall model is seen as shown in Table-2

Table-2: Displacement due to earthquake (without shear wall)

Storey	Without p-delta		With p-delta	
	X-dir	Y-dir	X-dir	Y-dir
Storey 20	0.192	30.922	0.193	31.191
Storey 19	0.135	29.196	0.136	29.451
Storey 18	0.108	27.441	0.109	27.681
Storey 17	0.095	25.654	0.096	25.879
Storey 16	0.088	23.833	0.088	24.044
Storey 15	0.083	21.985	0.084	22.181
Storey 14	0.079	20.119	0.080	20.299
Storey 13	0.075	18.245	0.076	18.409
Storey 12	0.072	16.376	0.073	16.524
Storey 11	0.069	14.527	0.070	14.658
Storey 10	0.066	12.711	0.067	12.825
Storey 9	0.062	10.944	0.063	11.041
Storey 8	0.062	9.240	0.063	9.321
Storey 7	0.063	7.615	0.064	7.681
Storey 6	0.064	6.085	0.064	6.136
Storey 5	0.063	4.666	0.063	4.703
Storey 4	0.060	3.374	0.060	3.399
Storey 3	0.053	2.228	0.053	2.244
Storey 2	0.058	1.273	0.059	1.280
Storey 1	0.059	0.515	0.059	0.517
Base	0	0	0	0

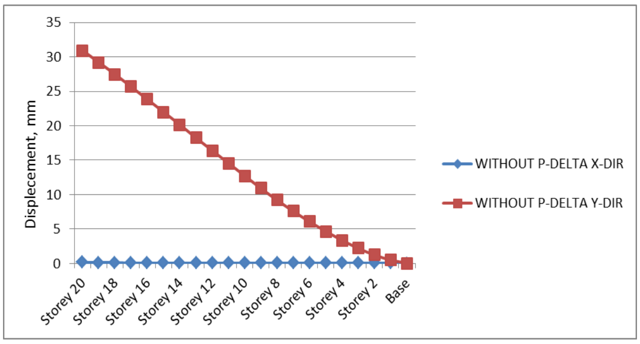

Fig.3 (A) Displacement due to Earthquake without shear wall & without P-Delta

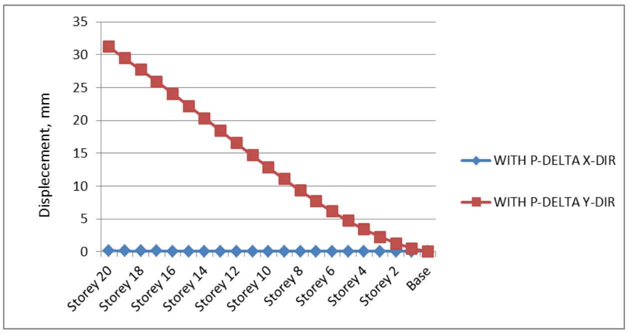

Fig.3 (B) Displacement due to Earthquake without shear wall & with P-Delta

For the earth quake load storey displacement with P-delta effects along the height of the building is shown in Fig.4a,b. The storey height is plotted in X-axis and Storey displacement is plotted in Y-axis. Displacement of with shear wall model is seen as shown in Table-3

Table-3: Displacement due to earthquake (with shear wall)

Storey	Without p-delta		With p-delta	
	x-dir	y-dir	x-dir	y-dir
Storey 20	0.248	28.643	0.250	28.86
Storey 19	0.202	26.993	0.204	27.197
Storey 18	0.176	25.315	0.178	25.507
Storey 17	0.159	23.610	0.16	23.791
Storey 16	0.146	21.882	0.148	22.050
Storey 15	0.136	20.135	0.138	20.29
Storey 14	0.127	18.377	0.129	18.519
Storey 13	0.119	16.620	0.121	16.749
Storey 12	0.112	14.876	0.113	14.991
Storey 11	0.104	13.156	0.106	13.258
Storey 10	0.098	11.475	0.099	11.563
Storey 9	0.091	9.845	0.092	9.921
Storey 8	0.084	8.283	0.085	8.345
Storey 7	0.077	6.800	0.078	6.850
Storey 6	0.073	5.412	0.073	5.450
Storey 5	0.072	4.131	0.072	4.158
Storey 4	0.069	2.972	0.069	2.990
Storey 3	0.062	1.951	0.063	1.962
Storey 2	0.051	1.101	0.052	1.106
Storey 1	0.051	0.439	0.051	0.440
Base	0	0	0	0

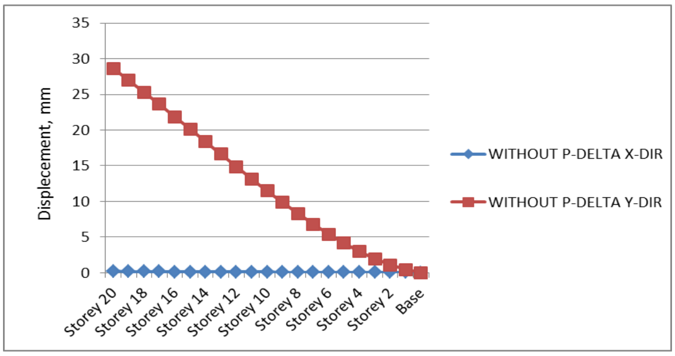

Fig.4 (A) Displacement due to Earthquake with shear wall & without P-Delta

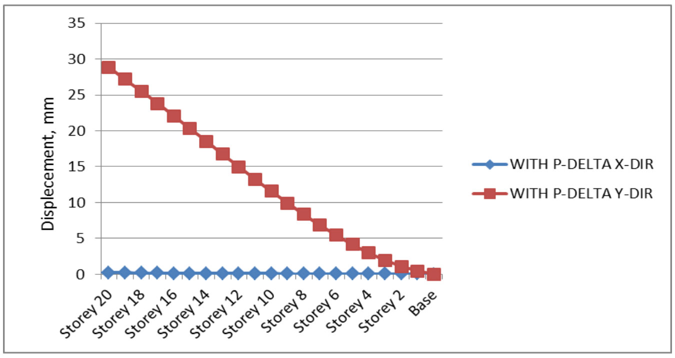

Fig.4 (B) Displacement due to Earthquake with shear wall & with P-Delta

For the wind load storey displacement with P-delta effects along the height of the building is shown in Fig.5a,b. The storey height is plotted in X-axis and Storey displacement is plotted in Y-axis. Displacement of without shear wall model is seen as shown in Table-4

Table-4: Displacement due to wind load (without shear wall)

storey	without p-delta		with p-delta	
	x-dir	y-dir	x-dir	y-dir
Storey 20	0.353	4.256	0.355	4.313
Storey 19	0.335	4.052	0.337	4.107
Storey 18	0.32	3.845	0.321	3.896

Storey 17	0.304	3.632	0.306	3.680
Storey 16	0.289	3.414	0.290	3.459
Storey 15	0.273	3.190	0.274	3.233
Storey 14	0.256	2.962	0.258	3.001
Storey 13	0.239	2.730	0.24	2.766
Storey 12	0.222	2.495	0.223	2.527
Storey 11	0.204	2.257	0.205	2.286
Storey 10	0.186	2.018	0.187	2.043
Storey 9	0.167	1.779	0.168	1.801
Storey 8	0.148	1.541	0.149	1.560
Storey 7	0.130	1.307	0.130	1.323
Storey 6	0.110	1.079	0.111	1.092
Storey 5	0.091	0.861	0.092	0.871
Storey 4	0.071	0.652	0.072	0.659
Storey 3	0.051	0.454	0.051	0.459
Storey 2	0.031	0.271	0.031	0.274
Storey 1	0.020	0.117	0.02	0.118
Base	0	0	0	0

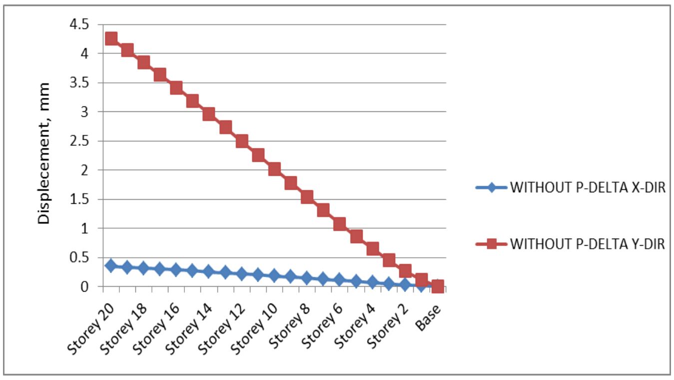

Fig.5 (A) Displacement due to wind load without shear wall & without P-Delta

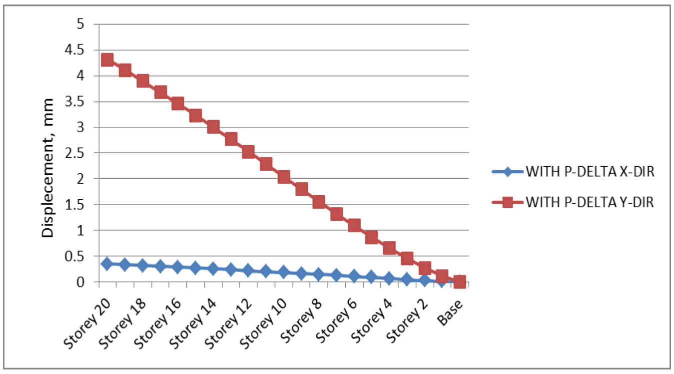

Fig.5 (B) Displacement due to wind load without shear wall & with P-Delta

For the wind load storey displacement with P-delta effects along the height of the building is shown in Fig.6a,b. The storey height is plotted in X-axis and Storey displacement is plotted in Y-axis. Displacement of with shear wall model is seen as shown in Table-5.

Table-5: Displacement due to wind load (with shear wall)

Storey	Without p-delta		With p-delta	
	x-dir	y-dir	x-dir	y-dir
Storey 20	2.524	0.652	2.529	0.654
Storey 19	2.394	0.612	2.398	0.614
Storey 18	2.261	0.572	2.265	0.574
Storey 17	2.124	0.532	2.128	0.533
Storey 16	1.986	0.492	1.989	0.493
Storey 15	1.844	0.451	1.847	0.452
Storey 14	1.700	0.411	1.703	0.412
Storey 13	1.555	0.370	1.558	0.371
Storey 12	1.408	0.330	1.411	0.331
Storey 11	1.261	0.290	1.263	0.291
Storey 10	1.114	0.251	1.116	0.252
Storey 9	0.969	0.213	0.971	0.214
Storey 8	0.827	0.177	0.829	0.177
Storey 7	0.689	0.143	0.69	0.143
Storey 6	0.557	0.111	0.558	0.111
Storey 5	0.432	0.082	0.433	0.083
Storey 4	0.317	0.058	0.317	0.058
Storey 3	0.213	0.037	0.213	0.037
Storey 2	0.124	0.021	0.124	0.021
Storey 1	0.053	0.01	0.053	0.01
Base	0	0	0	0

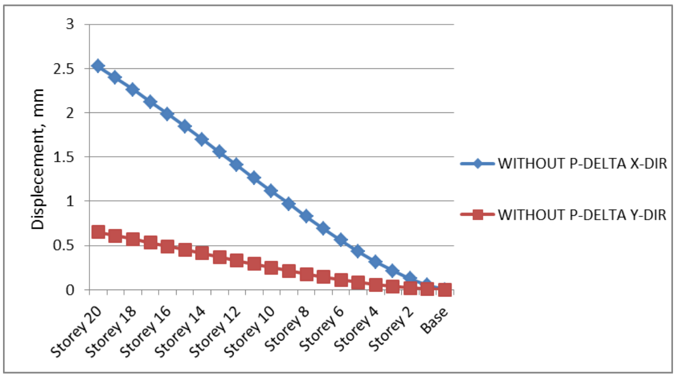

Fig.6 (A) Displacement due to wind load with shear wall & without P-Delta

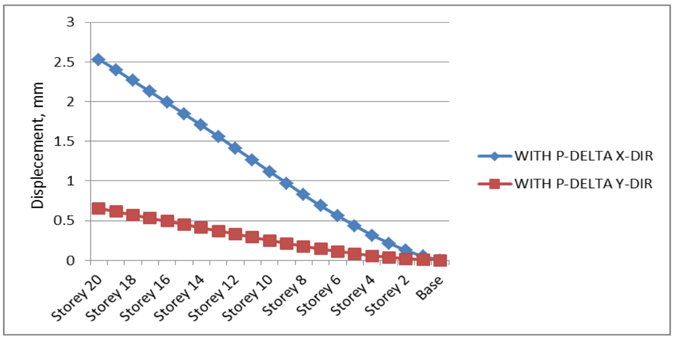

Fig.6 (B) Displacement due to wind load with shear wall & with P-Delta

Along the height of the building auto lateral load for the Earth quake load is shown in fig-7. Storey height is plotted in X-axis and lateral force is plotted in Y-axis. For Earthquake load case the value of axial force are tabulated in table 6. Maximum axial force is seen in the Storey 20 and minimum lateral force is seen at Base.

Table-6: Auto lateral load for earthquake

Storey	Elevation (m)	Lateral Load (KN)
Story20	60	589.9462
Story19	57	532.0343
Story18	54	531.7288
Story17	51	476.4421
Story16	48	424.086
Story15	45	374.6606
Story14	42	328.4858
Story13	39	285.5618
Story12	36	245.5684
Story11	33	208.5056
Story10	30	174.6936
Story9	27	143.8122
Story8	24	115.8615
Story7	21	91.1615
Story6	18	69.3921
Story5	15	50.8734
Story4	12	35.2854
Story3	9	22.628
Story2	6	13.2213
Story1	3	7.0653
Base	0	0

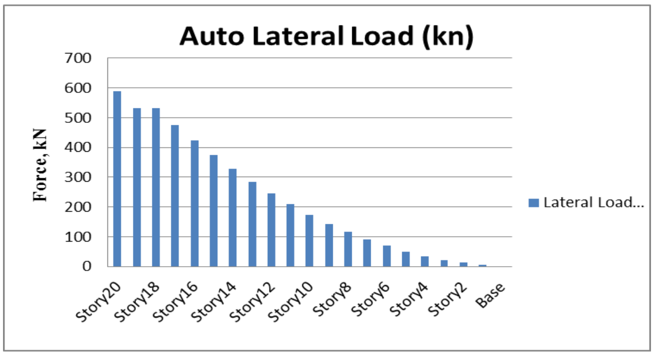

Fig-7: Auto lateral load verses storey height due to Earthquake load in general

The results for Bending Moment values of column C18 are described below in Table-7 and Fig.8.

Table-7: Bending Moment at Base of column C18

S. N	Load Case	Without P-Delta	With P-Delta	% Difference
1	1.2(DL+LL+EXQ)	300.00	306.12	2.04
2	1.2(DL+LL-EXQ)	-342.00	-347.88	1.719
3	1.2(DL+LL+EQY)	-52.89	-56.05	5.974
4	1.2(DL+LL-EQY)	25.92	28.43	9.683
5	DL+1.5LL+1.5WLX	350.35	355.29	1.41
6	DL+1.5LL+1.5WLY	-62.89	-66.12	5.135

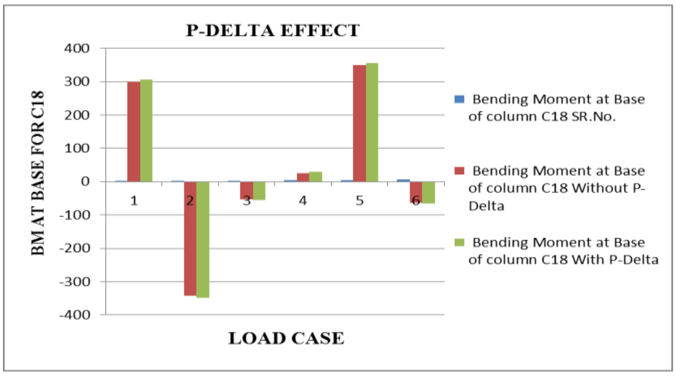

Fig-8: P-Delta Effect for C18

The results for Bending Moment values of shear wall P1 are described below in Table-8 and Fig-9. In this Table six load cases are described with P-Delta and Without P-Delta and also shown percentage difference.

Table-8: Bending moment at base of shear wall p1

SN	Load Case	Without P-Delta	With P-Delta	% Difference
1	1.2(DL+LL+EXQ)	71.65	75.92	5.968
2	1.2(DL+LL-EXQ)	-301.54	-306.24	1.558
3	1.2(DL+LL+EQY)	-58.22	-54.51	-6.368

4	1.2(DL+LL-EQY)	-180.81	-183.65	1.570
5	DL+1.5LL+1.5WLX	98.92	101.71	2.820
6	DL+1.5LL+1.5WLY	-50.32	-45.99	-8.608

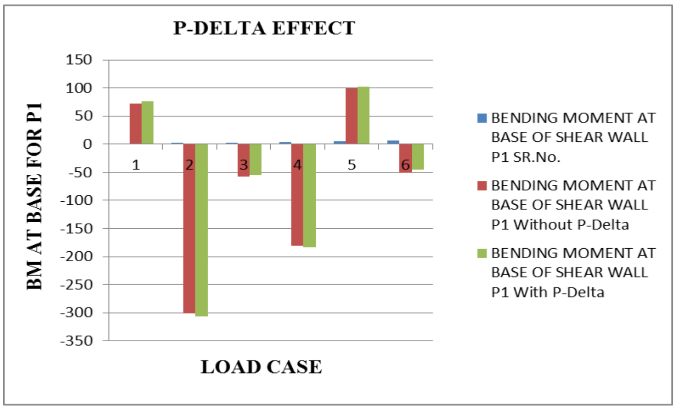

Fig-9: P-Delta Effect for Shear Wall P1

CONCLUSIONS

This chapter presents the major conclusions and future scope of the p-delta effects on Tall RC building with and without shear wall.

1. The P-Delta effects found to decreases the storey displacement by earthquake using shear walls and also decrease by wind loading.
2. The result obtained that axial force increases as no. of building storey increases.
3. Bending moment in column at ground floor found 9% increases after the P-delta analysis.
4. The results show the bending moment in shear walls 5.96 %increases after P-delta effects.
5. Displacements with respect to earthquake load with P-delta effects are higher when compared with earthquake load.
6. Storey displacement values for all the load cases are within the permissible limit.
7. This concludes P-delta effects have more effect in designing of a structure rather than linear order effects.
8. As number of storey increases P-delta effect becomes more important when shear wall provided.
9. It is necessary to check the results of analysis with and without considering P-delta effect for the buildings.
10. So, we should perform P-delta analysis for designing a 20 storey building with and without shear walls.
11. The conclusion is valid for RCC residential buildings for wind loading and seismic loading in all the zones of India.

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