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ANALYSIS OF P-DELTA EFFECT ON HIGH RISE BUILDINGS

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Abstract— P-delta effect is secondary or second order effect on structure. It is also known as 'Geometric Nonlinearity effect'. As number of storey increases, P-delta effect becomes more important. If the change in bending moments, shear forces 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) and nonlinear static analysis (with P-delta effect) on high rise buildings having different number of storey is carried out. For the analysis G+19, G+24, G+29 (i.e. 20, 25, 30 storey) R.C.C. framed buildings are modeled. Earthquake load is applied on model of structure as per IS-1893(2002) for zone III in SAP2000-12 software. Load combinations for analysis are set as per IS-456(2000). All analysis is carried out in software SAP 2000-12. Bending moment, story displacement with and without P-delta effect is calculated and compared for all models. The results show that it is essential to consider the P-delta effect for 25 storey 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 25 storey building, it is not necessary to consider P-delta effect in design and first order analysis is sufficient for design.

Keywords: P-delta effect, high-rise building, Static nonlinear analysis, displacements, bending moments, SAP2000-12, second order effect

INTRODUCTION

Engineers today typically use linear elastic static (first order) analysis to determine design forces and moments resulting from loads acting on a structure. First order analysis assumes small deflection behavior; 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 two effects to reach a solution:-

- Large displacement theory; the resulting forces and moments take full account of the effects due to the deformed shape of both the structure and its members.
- "Stress stiffening"; the effect of element axial loads on structure stiffness, tensile loads stiffening an element and compressive loads softening an element.

As the structure becomes more slender and less resistant to deformation, it is necessary to consider 2nd order and to be more specific, P-delta effects arises. As a result, Codes of Practice are referring engineers more and more to the use of 2nd order analysis in order that P-delta and "stress stiffening" effects are accounted for when appropriate in design. This is as true in concrete and timber design as it is in the design of steelwork.

P-DELTA EFFECTS:-

P-Delta is a non-linear effect that occurs in every structure where elements are subject to axial load. P-Delta is actually only one of many second-order effects. There are two P-Delta effects:-

- P-"BIG" delta (P-Δ) - a structure effect
- P-"little" delta (P-δ) - a member effect

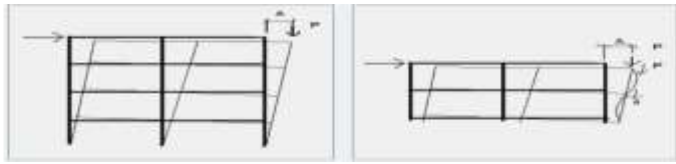

Fig.1 P-delta effects

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The P-Delta Effect Example:

The P-Delta effect refers specifically to the nonlinear geometric effect of a large tensile or compressive direct stress upon transverse bending and shear behavior. A compressive stress tends to make a structural member more flexible in transverse bending and shear, whereas a tensile stress tends to stiffen the member against transverse deformation.

The basic concepts behind the P- Delta effect are illustrated in the following example.

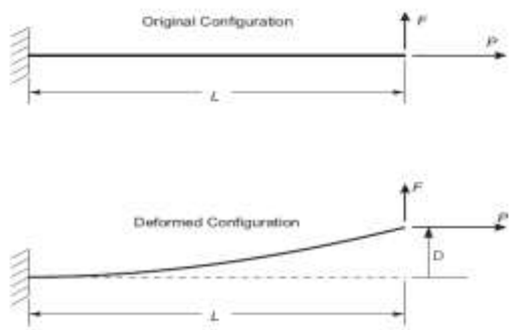


Fig.2 P-delta effect on cantilever beam

If equilibrium is examined in the original configuration (using the undeformed geometry), the moment at the base is *M =FL*. If, instead, equilibrium is considered in the deformed configuration, there is an additional moment caused by the axial force *P* acting on the transverse tip displacement Δ. The moment no longer varies linearly along the length; the variation depends instead upon the deflected shape. The moment at the base is now M =FL −PΔ. The moment diagrams for various cases are shown in Figure.

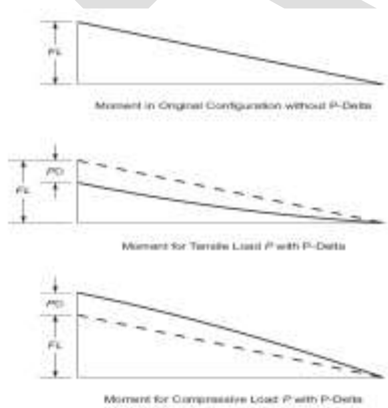


Fig.3 Change in B.M. of cantilever beam due to

P-delta effect

The key feature is that a large axial force, acting upon a small transverse deflection, produces a significant moment that affects the behavior of the member or structure.

Consideration of P-delta effect:

As per 'National Building Code, Technical Standard of Building E.030 Earthquake-Resistant Design', clause 4.1.5, page 19: The second order effects (P-delta effect) must be considered when an increase of more than 10% occurs in internal force

AIM AND OBJECTIVE OF STUDY

Scope of this study includes analysis of 20, 25 and 30 storey R.C.C. building with and without considering P-delta effects. Analysis can be done using SAP 2000. Lateral load is Earthquake load for zone III. If the change in the values of deflections, forces, and bending moments considering P-delta effect is not more than 10%, they can be neglected. From this analysis we can decide whether it is necessary to include P-delta effect for the buildings up to 30 stories.

Analysis of High rise buildings in SAP 2000:-

Buildings having same plan but with different number of stories are analyzed in SAP2000 with and without considering P-delta effect and their results are compared.

1) 20 storey
2) 25 storey
3) 30 storey

Plan of building:-

1) Residential building, RCC framed structure.
2) Storey height is 3m.
3) Length of building in X-direction = 18.8m
4) Length of building in Y-direction = 30.35m

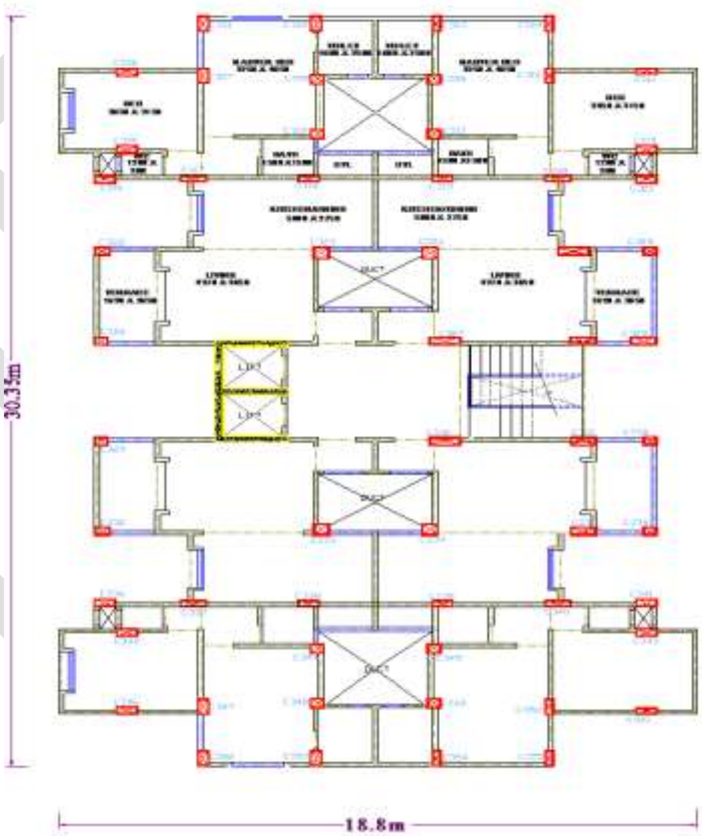


Fig.4:-Typical floor plan of building

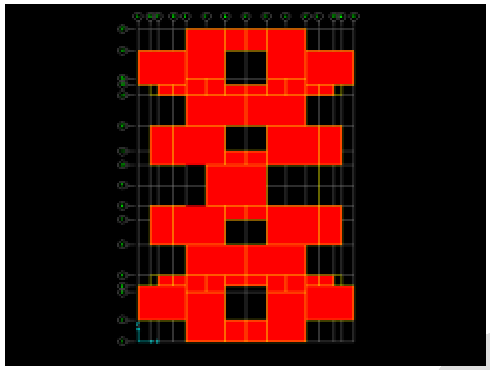


Fig.5 SAP Model (Plan View)

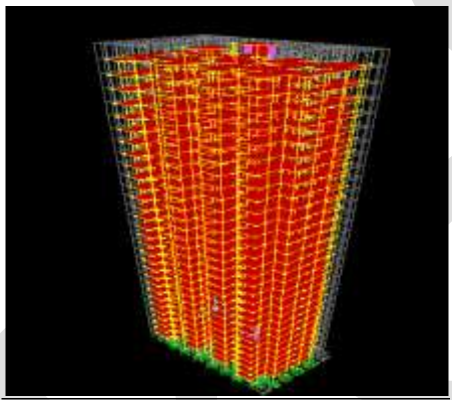


Fig.6:- SAP Model (3D View)

Material properties:-

1) **Concrete:** M30
   Density: 25 KN/m^3
   Modulus of Elasticity: 27386 N/mm^2
   Poissons ratio: 0.2
2) **Steel:** Fe500
   Density: 7850 Kg/m^3
   Modulus of Elasticity: 2.1 X 10^5 N/mm^2
   Poisson's ratio: 0.3
3) **Masonry:** Brick
   Density= 20 KN/m^3

Section Properties:-

1) **Beam:** 230X450, 230X600, 230X750
2) **Column:**
   230X825, 300X825, 375X900.
3) **Slab:** various sections with thickness varying from 150.
4) **Shear wall:** with thickness of 200mm.

Loads:-

1) **Dead load:**
a) Self weight
b) Floor finish: 1.25 KN/m^2

c) Wall load:

Load = Height x thickness x density of masonry

For 3m height of wall:

For 150mm thick wall, Load = 10 KN/m^2

For 1.2m height of wall (Parapet wall):

Load = 5 KN/m^2

2) Live load:

i) Floor = 2 KN/m^2

ii) Roof = 1.5 KN/m^2

3) Earthquake loads: As per IS1893:2002 for Zone III

EQX: Earthquake load in X-direction

EQY: Earthquake load in Y-direction

Zone factor = 0.16

Soil = Type II

Importance factor = 1

Response reduction factor = 3

LOAD CASES:-

As per IS-456(2000) in which both gravity and lateral loads are included.

1)1.2 (DL + LL + EQX)
2)1.2 (DL + LL – EQX)
3)1.2 (DL + LL + EQY)
4)1.2 (DL + LL - EQY)
5)1.5(DL + EQX)
6)1.5(DL - EQX)
7)1.5(DL + EQY)
8)1.5(DL - EQY)
9)0.9DL + 1.5EQX
10) 0.9DL - 1.5EQX
11) 0.9DL + 1.5EQY
12) 0.9DL - 1.5EQY

ANALYSIS RESULTS

1) For 20 storey building:-

Sr. No.	Load Case	B.M. at base (KNm)		
		Without P-delta	With P-delta	% Difference
1)	1.2 (DL + LL + EQX)	-201.82	-206.4	**2.27**
2)	1.2 (DL + LL – EQX)	159.7	162.46	**1.73**
3)	1.2 (DL + LL + EQY)	67.75	71.7	**5.83**
4)	1.2 (DL + LL – EQY)	-65.26	-69.36	**6.28**
5)	1.5(DL + EQX)	-249.8	-256.15	**2.54**
6)	1.5(DL - EQX)	202.1	206.2	**2.03**
7)	1.5(DL + EQY)	84.7	90.3	**6.61**
8)	1.5(DL - EQY)	-81.5	-87.4	**7.24**
9)	0.9DL + 1.5EQX	-240.6	-243.87	**1.36**
10)	0.9DL - 1.5EQX	211.63	214.24	**1.23**
11)	0.9DL + 1.5EQY	84.07	87.26	**3.79**
12)	0.9DL - 1.5EQY	-82.2	-85.7	**4.26**

Table 1: B.M. at joint at base with and without

P-delta effect (20 storey building)

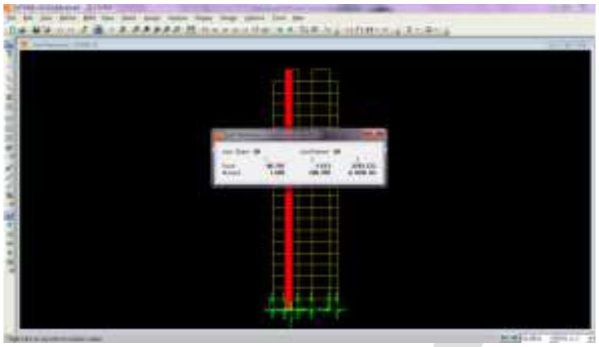


Fig. 8: B.M. at joint 60 due to load case 1 (with P-delta)

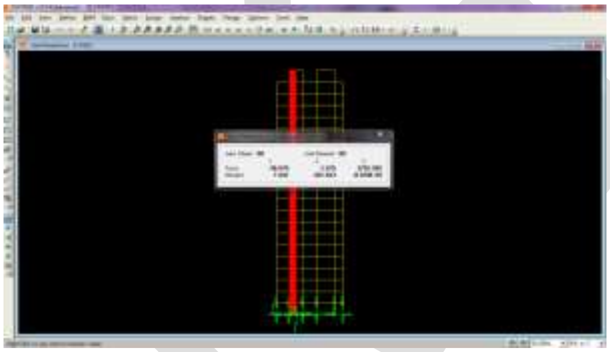


Fig 7.: B.M. at joint 60 due to load case 1 (without P-delta)

Sr. No.	Load Case	Deflection at top(mm)		
		Without P-delta	With P-delta	% Difference
1)	1.2 (DL + LL + EQX)	73.4	76.6	**4.36**
2)	1.2 (DL + LL – EQX)	-62.9	-64	**1.75**
3)	1.2 (DL + LL + EQY)	105.3	115.6	**9.78**
4)	1.2 (DL + LL – EQY)	-103.24	-113.43	**9.87**
5)	1.5(DL + EQX)	91.5	95.8	**4.70**
6)	1.5(DL - EQX)	-78.9	-80.6	**2.15**
7)	1.5(DL + EQY)	131.5	146.3	**11.25**
8)	1.5(DL - EQY)	-129.17	-143.85	**11.36**
9)	0.9DL + 1.5EQX	89	91.5	**2.81**
10)	0.9DL - 1.5EQX	-81.4	-82.5	**1.35**
11)	0.9DL + 1.5EQY	131.05	139.55	**6.49**
12)	0.9DL - 1.5EQY	-129.6	-138.06	**6.53**

Table 2: Deflection at joint at top storey with and without P-delta effect (20 storey building)

Storey no. Member no.	B.M. (KNm)	Load case No.					
		1	2	3	4	5	6
5	Initial	78.0	-107.9	39.3	-61.2	98.2	-134.2
1053	With P-delta	82.4	-110.8	46.4	-68.2	104.4	-139.0
	%	**5.6**	**2.6**	**18.1**	**11.5**	**6.2**	**3.6**
10	Initial	66.6	-104.2	25.5	59.8	84.5	-129.1
2323	With P-delta	70.7	-106.5	30.3	64.8	90.1	-132.4
	%	**6.0**	**2.1**	**18.9**	**8.4**	**6.6**	**2.6**
15	Initial	-37.4	83.0	20.4	47.7	-48.1	102.3
798	With P-delta	-39.9	83.9	18.9	49.0	-51.6	103.3
	%	**6.7**	**1.2**	**-7.5**	**2.8**	**7.1**	**1.0**
20	Initial	-6.8	32.3	-16.1	-14.1	-7.5	39.2
3091	With P-delta	-6.3	31.9	-16.8	-13.1	-6.9	38.7
	%	**-6.9**	**-1.3**	**4.7**	**-6.9**	**-7.7**	**-1.2**

Storey no. Member no.	B.M. (KNm)	Load case No.					
		7	8	9	10	11	12
5	Initial	50.1	-75.6	105.4	-126.9	55.2	-70.5
1053	With P-delta	60.4	-85.7	109.0	-129.5	61.1	-76.1
	%	**20.7**	**13.5**	**3.4**	**2.1**	**10.7**	**8.1**
10	Initial	33.4	73.1	93.4	-120.2	41.1	65.0
2323	With P-delta	40.4	80.3	96.7	-122.2	45.3	69.1
	%	**20.8**	**9.8**	**3.5**	**1.7**	**10.2**	**6.3**
15	Initial	24.1	57.5	-59.0	91.5	13.2	47.8
798	With P-delta	22.1	59.4	-61.0	92.1	12.1	49.0
	%	**-8.3**	**3.3**	**3.4**	**0.7**	**-8.4**	**2.4**
20	Initial	-18.6	-16.1	-3.4	30.2	-11.6	-9.2
3091	With P-delta	-19.7	-14.8	-3.9	30.0	-12.3	-8.4
	%	**6.1**	**-8.4**	**12.6**	**-0.9**	**5.5**	**-8.5**

Table 3: B.M. in members with and without P-delta effect (20 storey building) continued

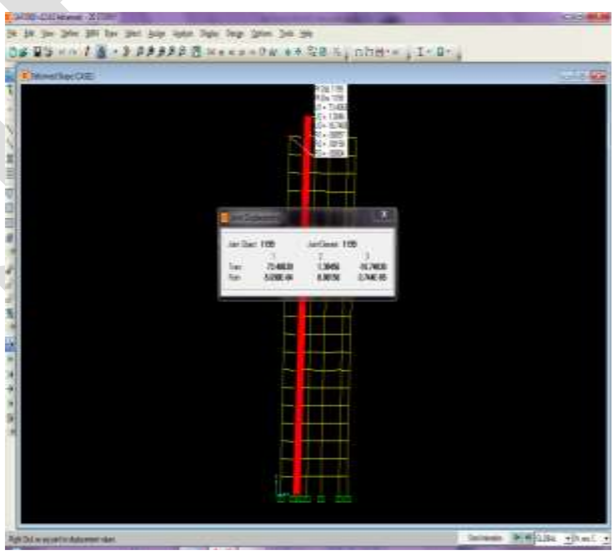


Fig.9: Deflection at joint 1199 due to load case1 (Without P-delta)

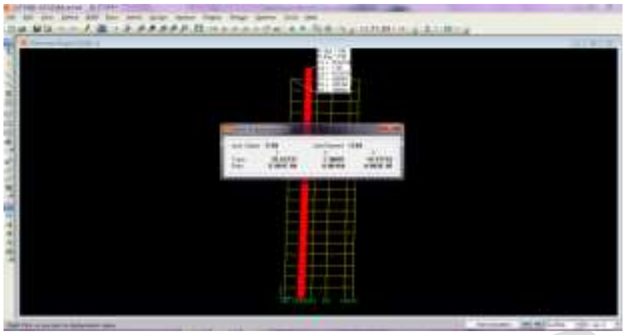


Fig. 10:Deflection at joint 1199 due to load case 1 (with P-delta)

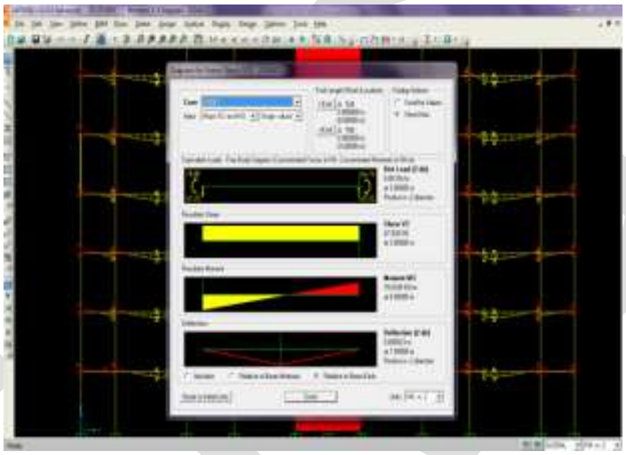


Fig. 11: B.M. of member 1053 due to load case 1 (without P-delta)

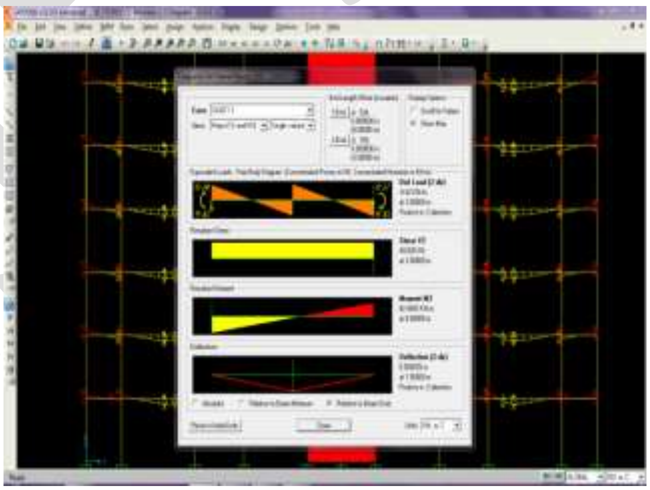


Fig. 12:- B.M. of member 1053 due to load case 1 (with P-delta)

2) For 25 storey building:-

Sr. No.	Load Case	B.M. at bottom (KNm)		
		Without P-delta	With P-delta	% Difference
1)	1.2 (DL + LL + EQX)	-234.4	-240.7	**2.69**
2)	1.2 (DL + LL – EQX)	183.9	187.52	**1.97**
3)	1.2 (DL + LL + EQY)	83.79	87.9	**4.91**
4)	1.2 (DL + LL – EQY)	-80.5	-84.7	**5.22**
5)	1.5(DL + EQX)	-290.16	-298.9	**3.01**
6)	1.5(DL - EQX)	232.8	238.17	**2.31**
7)	1.5(DL + EQY)	104.72	110.58	**5.60**
8)	1.5(DL - EQY)	-100.64	-106.68	**6.00**
9)	0.9DL + 1.5EQX	-278.68	-283.64	**1.78**
10)	0.9DL - 1.5EQX	244.26	247.7	**1.41**
11)	0.9DL + 1.5EQY	103.9	107.25	**3.22**
12)	0.9DL - 1.5EQY	-101.45	-105.04	**3.54**

Table 4: B.M. at base with and without P-delta effect (25 storey building)

Sr. No.	Load Case	Deflection at top(mm)		
		Without P-delta	With P-delta	% Difference
1)	1.2 (DL + LL + EQX)	93.19	98.8	**6.02**
2)	1.2 (DL + LL – EQX)	-73.35	-75.05	**2.32**
3)	1.2 (DL + LL + EQY)	124.65	139.42	**11.85**
4)	1.2 (DL + LL – EQY)	-122.18	-136.77	**11.94**
5)	1.5(DL + EQX)	130	138.51	**6.55**
6)	1.5(DL - EQX)	-106.22	-109.65	**3.23**
7)	1.5(DL + EQY)	173.18	196.87	**13.68**
8)	1.5(DL - EQY)	-170.38	-193.86	**13.78**
9)	0.9DL + 1.5EQX	125.3	130.19	**3.90**
10)	0.9DL - 1.5EQX	-111	-113.12	**1.91**
11)	0.9DL + 1.5EQY	172.62	186.07	**7.79**
12)	0.9DL - 1.5EQY	-170.94	-184.26	**7.79**

Table 5: Deflection at joint at top storey with and without P-delta effect (25 storey building)

Storey no. / Member no.	B.M. (KNm)	Load case No. 1	2	3	4	5	6
5	Initial	82.79	-110.3	38.67	-71.76	101.18	-137.1
1053	With P-delta	88.65	-114.3	45.04	-78.4	112.43	-143
	%	**7.08**	**3.63**	**16.47**	**9.25**	**11.12**	**4.24**
10	Initial	69.51	-111.4	29.56	67.54	88.24	-137.9
2323	With P-delta	75.31	-115.1	39.01	76.16	96.39	-143.3
	%	**8.34**	**3.26**	**31.97**	**12.76**	**9.24**	**3.87**
15	Initial	53.38	-95.24	16.27	-59.92	68.24	-117.9
798	With P-delta	58.09	-97.85	21.14	-64.96	74.81	-121.4
	%	**8.82**	**2.74**	**29.93**	**8.41**	**9.63**	**2.93**
20	Initial	29.65	56.88	12.77	-42.06	-37.97	70.19
3091	With P-delta	32.38	57.27	11.18	-43.2	-41.7	70.91
	%	**9.21**	**0.69**	**-12.45**	**2.71**	**9.82**	**1.03**
25	Initial	-7.61	29.84	-19.72	-16.74	-8.42	36.06
4546	With P-delta	-6.97	29.32	-20.6	-15.58	-7.6	35.42
	%	**-8.41**	**-1.74**	**4.46**	**-6.93**	**-9.74**	**-1.77**

Storey no. / Member no.	B.M. (KNm)	Load Case No. 7	8	9	10	11	12
5	Initial	49.7	-88.28	110.77	-130.6	57.46	-80.58
1053	With P-delta	58.98	-97.82	115.57	-134	62.76	-88.97
	%	**18.67**	**10.81**	**4.33**	**2.67**	**9.22**	**10.41**
10	Initial	38.8	82.46	98.18	-128	47.42	73.39
2323	With P-delta	52.51	95.03	102.91	-131.2	55.08	80.4
	%	**35.34**	**15.24**	**4.82**	**2.52**	**16.15**	**9.55**
15	Initial	22.43	-72.82	78.18	-107.6	32.5	-62.74
798	With P-delta	29.45	-80.06	81.97	-110.1	36.5	-66.84
	%	**31.30**	**9.94**	**4.85**	**2.34**	**12.31**	**6.53**
20	Initial	15.5	-50.43	-44.42	63.75	10.45	-40.44
3091	With P-delta	12.94	-52.03	-46.55	64.24	11.17	-41.39
	%	**-16.52**	**3.17**	**4.80**	**0.77**	**6.89**	**2.35**
25	Initial	-22.86	-19.15	-1.81	27.49	-14.46	-10.74
4546	With P-delta	-24.18	-17.5	-2.4	27.13	-15.18	-9.77
	%	**5.77**	**-8.62**	**32.60**	**-1.31**	**4.98**	**-9.03**

Table 6: B.M. in members with and without P-delta effect
(25 storey building)

3) For 30 storey building:-

Sr. No.	Load Case	B.M. at base (KNm) Without P-delta	With P-delta	% Difference
1)	1.2 (DL + LL + EQX)	-255.84	-264.13	**3.24**
2)	1.2 (DL + LL – EQX)	204.75	209.59	**2.36**
3)	1.2 (DL + LL + EQY)	105.19	110.29	**4.85**
4)	1.2 (DL + LL – EQY)	-101.63	-106.83	**5.12**
5)	1.5(DL + EQX)	-316.97	-328.49	**3.63**
6)	1.5(DL - EQX)	258.77	266.05	**2.81**
7)	1.5(DL + EQY)	131.49	138.78	**5.54**
8)	1.5(DL - EQY)	-127.04	-134.55	**5.91**
9)	0.9DL + 1.5EQX	-305.33	-311.86	**2.14**
10)	0.9DL - 1.5EQX	270.4	275	**1.70**
11)	0.9DL + 1.5EQY	130.6	134.75	**3.18**
12)	0.9DL - 1.5EQY	-127.9	-132.37	**3.49**

Table 7: B.M. at base with and without P-delta effect
(30 storey building)

Sr. No.	Load Case	Deflection at top(mm)		
		Without P-delta	With P-delta	% Difference
1)	1.2 (DL + LL + EQX)	131.65	141.01	**7.11**
2)	1.2 (DL + LL – EQX)	-108.32	-111.87	**3.28**
3)	1.2 (DL + LL + EQY)	170.72	192.64	**12.84**
4)	1.2 (DL + LL – EQY)	-167.78	-189.46	**12.92**
5)	1.5(DL + EQX)	164.2	177.16	**7.89**
6)	1.5(DL - EQX)	-135.76	-141.28	**4.07**
7)	1.5(DL + EQY)	213.23	245.06	**14.93**
8)	1.5(DL - EQY)	-209.9	-241.44	**15.03**
9)	0.9DL + 1.5EQX	158.51	166	**4.73**
10)	0.9DL - 1.5EQX	-141.45	-144.85	**2.40**
11)	0.9DL + 1.5EQY	212.5	230.4	**8.42**
12)	0.9DL - 1.5EQY	-210.57	-228.29	**8.42**

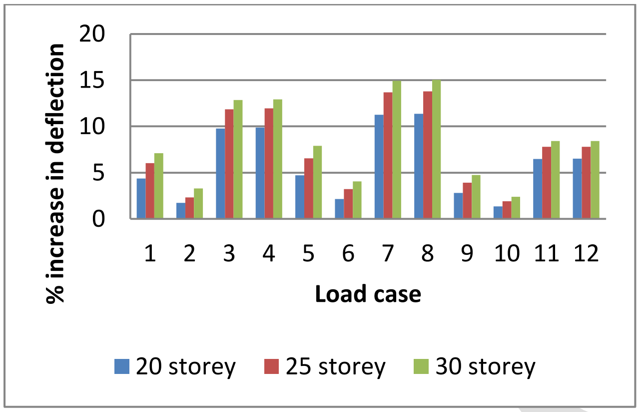
Table 8: Deflection at joint at top storey with and without P-delta effect (30 storey building)

Storey no. / Member no.	B.M. (KNm)	Load case No.					
		1	2	3	4	5	6
5	Initial	88.02	-116.6	39.23	-77.13	110.75	-145
5548	With P-delta	95.27	-121.6	44.94	-83.31	121	-152.3
	%	**8.24**	**4.30**	**14.56**	**8.01**	**9.26**	**5.03**
10	Initial	78.87	-119.7	25.43	-77.32	100.03	-148.2
1053	With P-delta	86.28	-124.8	32.5	-84.09	110.5	-155.6
	%	**9.40**	**4.20**	**27.80**	**8.76**	**10.47**	**4.96**
15	Initial	64.74	-112.3	25.66	74.43	82.65	-138.6
2323	With P-delta	71.55	-116.3	35.42	84.18	92.24	-144.7
	%	**10.52**	**3.56**	**38.04**	**13.10**	**11.60**	**4.34**
20	Initial	47.74	92.06	12.23	62.92	61.38	113.31
798	With P-delta	53.08	94.61	17.3	68.24	68.82	117.14
	%	**11.19**	**2.77**	**41.46**	**8.46**	**12.12**	**3.38**
25	Initial	-25.72	52.68	5.52	-43.3	-33.1	64.89
3091	With P-delta	-28.85	52.85	4.45	-44.48	-37.35	65.36
	%	**12.17**	**0.32**	**-19.38**	**2.73**	**12.84**	**0.72**
30	Initial	-8.65	28.28	-21.44	-18	-9.69	34.09
4546	With P-delta	-7.85	27.56	-22.35	-16.66	-8.67	33.21
	%	**-9.25**	**-2.55**	**4.24**	**-7.44**	**-10.53**	**-2.58**

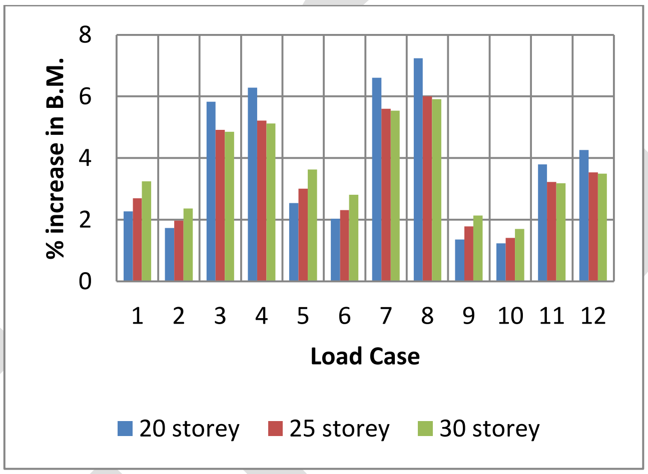
Storey no. / Member no.	B.M. (KNm)	Load case No.					
		7	8	9	10	11	12
5	Initial	50.6	-94.8	117.6	-138.1	59.45	-86
5548	With P-delta	58.9	-103.7	123.54	-142.6	64.24	-91.05
	%	**16.40**	**9.39**	**5.05**	**3.19**	**8.06**	**5.87**
10	Initial	34.17	-94.27	109.67	-138.6	46.19	-82.25
1053	With P-delta	44.49	-105.2	115.75	-143	52.04	-88.38
	%	**30.20**	**11.64**	**5.54**	**3.18**	**12.67**	**7.45**
15	Initial	34.4	90.61	93.85	-127.4	45.45	89.1
2323	With P-delta	48.74	104.92	99.39	-131.1	53.36	86.96
	%	**41.69**	**15.79**	**5.90**	**2.86**	**17.40**	**-2.40**
20	Initial	17.74	76.14	71.72	-102.7	29.26	64.35
798	With P-delta	25.11	83.84	76.01	-104.9	33.4	68.69
	%	**41.54**	**10.11**	**5.98**	**2.14**	**14.15**	**6.74**
25	Initial	4.09	-51.7	-39.46	58.33	7.54	-40.66
3091	With P-delta	3.01	-53.34	-41.89	58.89	8.25	-41.64
	%	**-26.41**	**3.17**	**6.16**	**0.62**	**9.42**	**2.41**
30	Initial	-24.84	-20.53	-1.66	25.6	-15.76	-11.46
4546	With P-delta	-26.22	-18.64	-1.07	25.1	-16.5	-10.35
	%	**5.56**	**-9.21**	**-35.54**	**-1.95**	**4.70**	**-9.69**

Table 9: B.M. in members with and without P-delta effect
(30 storey building) continued

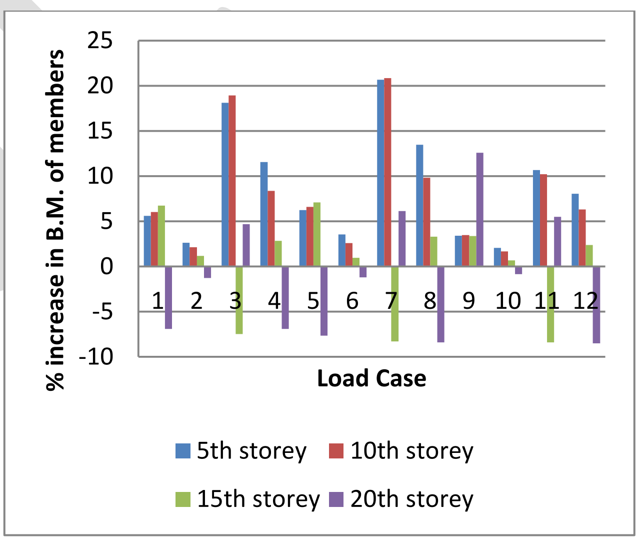
DISCUSSION OF RESULTS



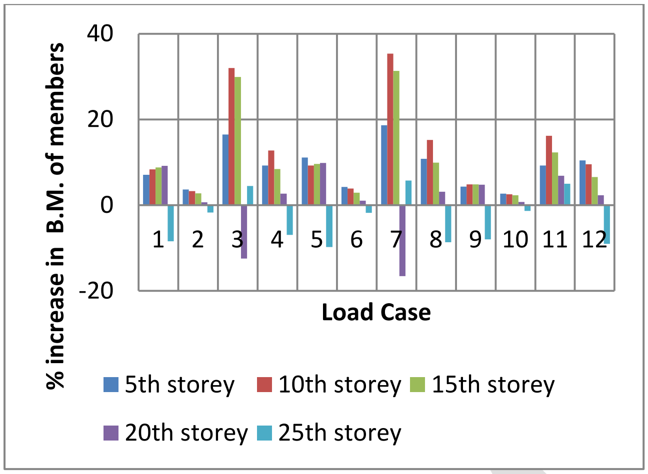
Graph 1: % increase in deflection due to P-delta effect for all load cases



Graph 2: % increase in B.M. at base due to P-delta effect for all load cases

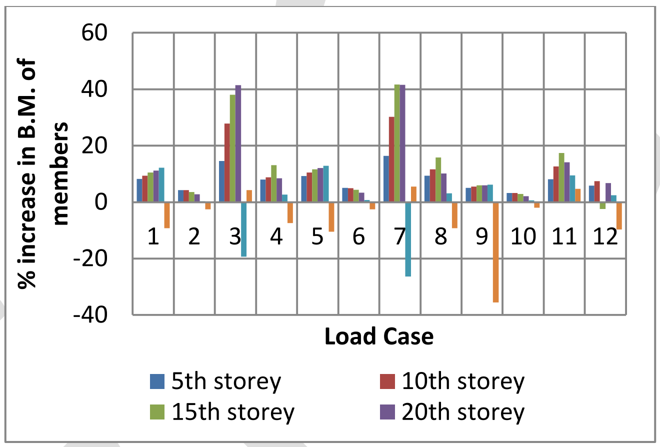


Graph 3: % increase in B.M. of members due to P-delta effect at different storey levels for all load cases (For 20 storey building)



Graph 4: % increase in B.M. of members due to P-delta effect at different storey levels for all load cases

(For 25 storey building)



Graph 5: % increase in B.M. of members due to P-delta effect at different storey levels for all load cases

(For 30 storey building)

Discussion:

1) For 20 storey building:-

1. Change in B.M. at base is 2-6%.
2. Change in the deflection is 1-11%.
3. Change in the B.M. of beams is less than 10%.
4. Change in the B.M. of 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 20 storey building, it is not necessary to consider P-delta effect. So building can be designed by performing 1st order analysis.

2) For 25 storey building:-

1. Change in B.M. at base is 2-4% .
2. Change in the deflection is 2-14%.
3. Change in the 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 25 storey building.
6. So it is necessary to consider P-delta effect while designing a 25 storey building.

3) For 30 storey building:-

1. Change in B.M. at base is 2-4%.

2. Change in the deflection is 3-15%.
3. Change in the B.M. of some beams is up to 15%.
4. Change in B.M. of some 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 for designing a 30 storey building.

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CONCLUSION

In this study, the three building models with different number of stories are analyzed with and without considering P-delta effect for seismic loads. By studying the results of analysis, following conclusions are 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 25 and 30 storey buildings and mostly in 30 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 with 25 stories (height = 75m).
- Iterative P-delta analysis method is used. Building is analyzed for 10 numbers of iterations. But it is found that the results are converged after 2 iterations. So there is no change in the results by increasing the number of iterations.
- Also the analysis is performed by considering the seismic loading in other zones in India. Similar results are observed in the form of increase in internal forces.
- So we should perform P-delta analysis for designing a minimum of 25 storey building. And buildings up to 25 stories can be designed by conventional primary analysis or linear analysis.
- This conclusion is valid for regular RCC residential buildings and may not be applicable for commercial, educational or industrial buildings.

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