ANALYSING BEHAVIOUR OF HIGH RISE RCC STRUCTURES IN P – DELTA ANALYSIS

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Abstract – *While dealing with high rise RCC structure there is a need of advanced analysis procedure for stability design. First order analysis which is mostly practiced doesn't take into account any additional stresses occurred due to deformation of structure in axial and vertical loading scenario, to take these additional stresses into account second order analysis is very important. P-delta is a second order analysis which is used in this study to study how this affects various structural parameters & when to consider it and when not. In this paper 5 models are designed using SAP 2000 and the structural behavior is analysed with and without this effect. On the basis of the results it is concluded when it is important to consider this effect.*

Key Words: SAP 2000 structural analysis software, first order analysis, second order analysis, linear static analysis, P- Delta analysis, lateral loading, vertical loading, geometric non linearity, storey drift,

1. INTRODUCTION

This study focuses on the importance of second order analysis as it provides better structural behavior with the given loading conditions. First order analysis is based on linear static analysis which calculates deformations only by considering linear deformation in building material and geometry but in actual, structure behaves in nonlinear fashion so it under-estimates the stresses generated and hence accordingly structure with low strength is designed by this method. On the other hand P-delta analysis is a kind of nonlinear analysis (second order analysis) which provides better insight on how structure will behave in actual situation. For regions having high seismic activity and wind loads, second order analysis is very crucial as its ignorance can result in structural collapse.

1.1 Meaning of P-Delta

P- Delta is a term having two terms P and Delta or Δ, here P is the applied load and Δ is the horizontal deformation in the structure due to lateral loads generated by wind loads or earth quake loads (as shown in Fig-1), mathematically it can be expressed as

$$P \times \Delta = V \times L$$

$$\Delta = (V \times L)/ P$$

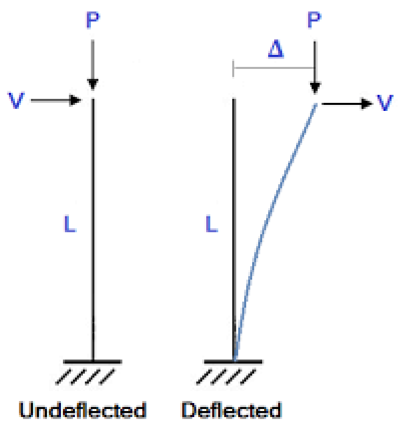

Fig -1: Deformation of a structural member in P-Δ effect.

1.2 P-Delta analysis

P-Δ analysis represents softening effects of compression and stiffening effect of tension.
P- Delta analysis includes mainly two effects –
(i) Material non linearity
(ii) Geometric non linearity
To apply these two effects for designing purpose sophisticated and well developed software is required so as to have better insight on what actually happens in a structure. For this SAP 2000 is used in designing of models.

2. OBJECTIVES

1. Analyzing behavior of RCC structures with lateral loads considering P – Delta effect.
2. Using SAP 2000 software from CSI to design models with 10,15,20,25 and 30 storeys.
3. Relative comparison of deformation results obtained from first order analysis and second order analysis.
4. To find out optimum height of building after which consideration of P- Delta effect is very important.
5. To determine the changes that is to be made while considering P- Delta effect in areas having high seismic activity or wind load.

3. STRUCTURAL PARAMETERS

Table -1: Common data for all models.

Base area	625 m^2
Storey height	3.2m
Mumty Height	3m
Mumty plan area	5m × 5m in the middles so as to maintain symmetry
No. of bays in X direction	5 at 5m centre to centre
No. of bays in Y direction	5 at 5m centre to centre
Slab	165 mm, M25
Slab for stair case	200 mm, M30
Grade of Steel	As per IS 456- 2000

3.1 Analysis method

Frame type building is modeled having beam - column - slab configuration. RCC structural design is as per IS 456:2000, seismic parameters are taken according to IS 1893: 2016 (as shown in Fig - 2). Reinforcement is taken as per default by SAP 2000.

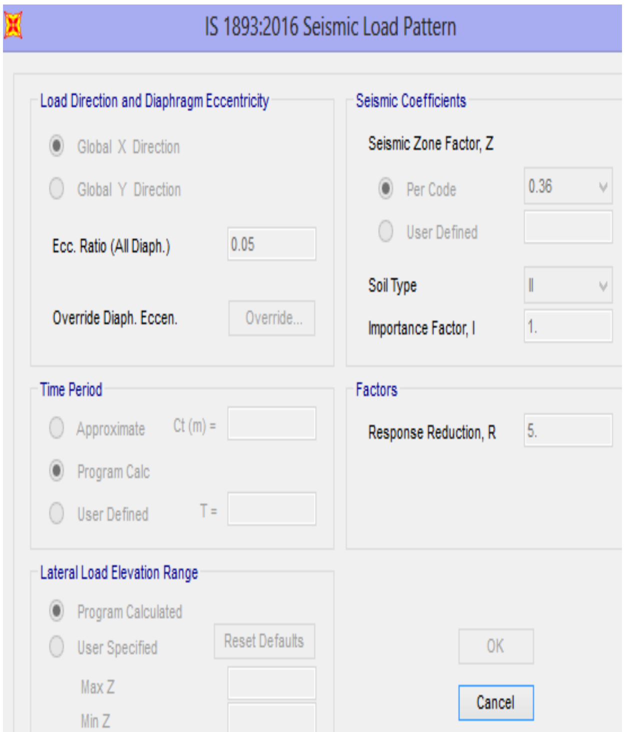

Fig -2: Seismic Design Parameters

Analysis data by SAP 2000-

Running analysis is within the GUI processor with advanced solver which provides instability information. Computation for element formation is by Newton- Raphson method. Other details of nonlinear parameters are shown in Fig – 3.

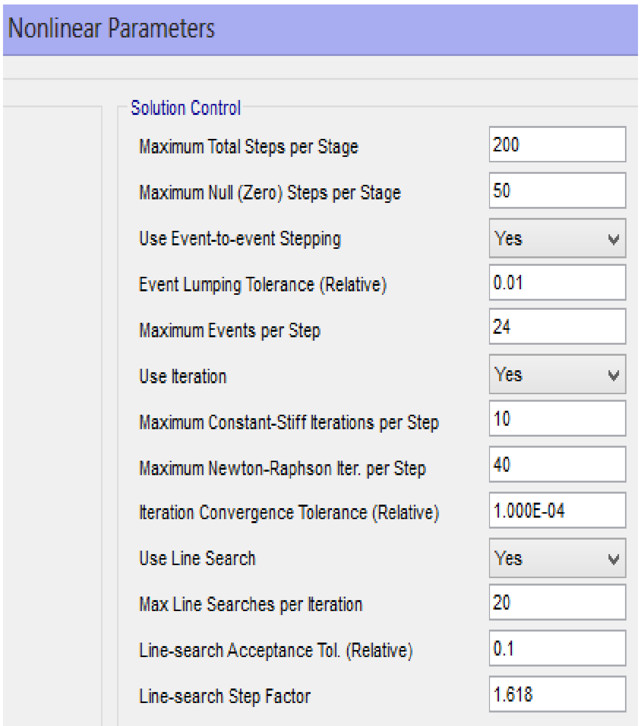

Fig -3: Nonlinear parameters in SAP 2000

Model data – 10 storey building

Height = 32 m
Beam = M25, 400× 325mm
Column= M30, 425×425mm - entire height

Model data – 15 storey building

Height = 48m
Beam = M25, 425 × 400 mm
Column= M30, 525×525mm – up to 32m
= M30, 425×425mm – 32m – 48m

Model data – 20 storey building

Height = 64 m
Beam = M25, 450 ×425mm
Column= M30, 625× 575mm – up to 32m
= M30, 425×425mm – 32m - 64m

Model data – 25 storey building

Height =	80 m	
Beam =	M25, 500×450mm	
Column=	M35, 675×600mm	– up to 32m
=	M30, 625×600mm	– 32m - 64m
=	M30, 425×425mm	– 64m – 80 m

Model data – 30 storey building

Height =	96 m	
Beam =	M25, 500×450mm	
Column=	M35, 825×825mm	– up to 32m
=	M30, 625×625mm	– 32m - 64m
=	M30, 475×475mm	– 64m – 96 m

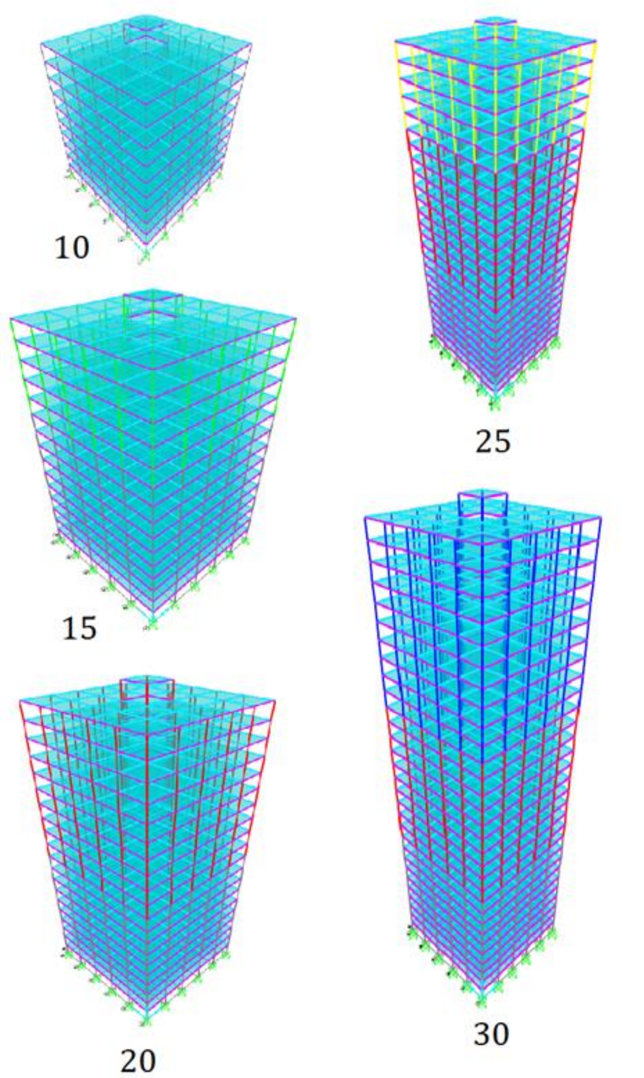

Fig -4: Screenshot of 3D models designed in SAP 2000

4. RESULT

The comparison is made by observing the behavior of buildings according to P-Delta analysis i.e. nonlinear analysis and between linear analyses without P- Delta effect. Deflection behavior of exterior left uppermost column is taken so as to have largest difference in values of structural parameters like displacement, axial force, shear force, moment and stress values.

Tabular comparison of Displacement values by Linear static analysis (LS) with P- Delta analysis (PD) is summarized of only top 10 storey of each model. Drift is also shown in the table; it is the relative displacement of upper storey with the lower one.

Table -2: Displacement in m and drift data with LS and PD for 10 storey building

STOREY	LS	PD	DRIFT LS	DRIFT PD
10	0.0514	0.0569	0.00215	0.0022
9	0.0493	0.0546	0.0042	0.0036
8	0.045	0.050	0.004	0.005
7	0.041	0.046	0.005	0.0057
6	0.036	0.0402	0.007	0.0067
5	0.029	0.0336	0.006	0.0075
4	0.022	0.027	0.007	0.008
3	0.016	0.018	0.007	0.003
2	0.009	0.0107	0.006	0.007
1	0.003	0.0039	0.003	0.0037

Table -3: Displacement in m and drift data with LS and PD for 15 storey building

STOREY	LS	PD	DRIFT LS	DRIFT PD
15	0.1074	0.1235	0.0026	0.0035
14	0.1048	0.121	0.0042	0.004
13	0.1007	0.117	0.0056	0.006
12	0.095	0.11	0.0068	0.0081
11	0.0883	0.102	0.00791	0.008
10	0.08021	0.094	0.0073	0.008
9	0.0731	0.086	0.0082	0.009
8	0.0639	0.0765	0.0091	0.01
7	0.057	0.067	0.0081	0.01
6	0.0481	0.057	0.0091	0.01

Table -4: Displacement in m and drift data with LS and PD for 20 storey building

STOREY	LS	PD	DRIFT LS	DRIFT PD
20	0.180	0.214	0.003	0.0037
19	0.178	0.210	0.00512	0.006
18	0.173	0.205	0.0061	0.0065
17	0.1661	0.1981	0.0082	0.008
16	0.159	0.191	0.0079	0.011
15	0.1522	0.180	0.011	0.0115
14	0.1423	0.17	0.011	0.012
13	0.1321	0.157	0.012	**<u>0.0129</u>**
12	0.1191	0.146	0.012	**<u>0.0130</u>**
11	0.107	0.130	0.012	**<u>0.0131</u>**

Table -5: Displacement in m and drift data with LS and PD for 25 storey building

STOREY	LS	PD	DRIFT LS	DRIFT PD
25	0.246	0.294	0.004	0.004
24	0.243	0.29	0.005	0.005
23	0.236	0.285	0.007	0.0075
22	0.231	0.277	0.0081	0.009
21	0.221	0.269	0.0092	0.015
20	0.214	0.257	0.0091	0.0099
19	0.204	0.248	0.009	0.011
18	0.196	0.238	0.01	**<u>0.0130</u>**
17	0.185	0.226	0.01	**<u>0.0131</u>**
16	0.175	0.215	0.012	**<u>0.0135</u>**

Table -6: Displacement in m and drift data with LS and PD for 30 storey building

STOREY	**LS**	**PD**	**DRIFT LS**	**DRIFT PD**
30	0.3226	0.389	0.00451	0.0041
29	0.316	0.383	0.0052	0.0062
28	0.314	0.378	0.0071	0.008
27	0.304	0.372	0.0081	0.008
26	0.296	0.359	0.0092	0.011
25	0.288	0.349	0.0112	0.011
24	0.280	0.341	0.011	**<u>0.0133</u>**
23	0.267	0.329	0.011	**<u>0.0132</u>**
22	0.256	0.315	0.0122	**<u>0.0151</u>**
21	0.241	0.303	0.0141	**<u>0.0150</u>**

From the results obtained after the analysis, the percentage change in the displacement by linear static analysis and P-Delta analysis is summarized as-
10 storeys – 9.14 %
15 storeys – 15.1 %
20 storeys – 22.1 %
25 storeys – 23.2 %
30 storeys – 24.2 %
The drift according to IS 1893:2002 should not be greater than 0.004× storey height in this study storey height is 3.2 m hence maximum drift allowed is -
0.004× storey height = 0.004 ×3.2m = 0.0128m
From the bold and underlined values in Table 4, 5, 6 for 20, 25 & 30 storey building, this is clearly understood that these models doesn't satisfy the drift criteria and hence results in unstable structure.

5. CONCLUSION

From the given study and according to the selected model configuration, it can be concluded that P-Delta analysis is not very important for 10 & 15 storey building but for 15, 20 & 25 storey building this effect is very important to consider. The Drift data shows that the same building is considered safe as per linear static analysis but the same model is not safe if we consider P- Delta analysis.

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