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STUDY OF P-DELTA EFFECT ON HIGH RISE RCC STRUCTURES

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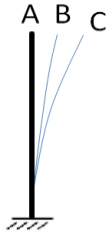
Abstract - *Nowadays with the increase in population and technology, the height of buildings is also increasing. To design high rise structure there should be advanced analysis procedures, P-Delta is one of them. P-Delta is a second order analysis in which the extra loads generated due to the deformation of structure are also included in addition to the applied lateral and vertical loads. This effect is not important for buildings up to a certain height but after a certain height and conditions this effect must be taken into account especially for areas with high risk of earthquake and wind loads. In this paper five models 10,15,20,25 and 30 storey buildings are taken for consideration and the effect of P-Delta is observed carefully.*

Key Words: P-Delta analysis, SAP 2000, linear static, nonlinear static, displacement, shear, moment, axial force.

1. INTRODUCTION

As first order analysis is very fast and famous method used by structural engineers that's why P-Delta analysis is ignored by most of the engineers. The reason behind this ignorance is lack of awareness of structural response during earthquake. We should understand that the multi storey buildings don't behave linearly during an earthquake so these buildings should be designed by a nonlinear analysis procedure. P-Delta effect is a kind of second order effect also called as geometric nonlinearity which is suitable for nonlinear analysis procedures.



A. Stable straight structure

B. Slightly displaced structure

C. Highly displaced structure

Fig -1: Showing three position of a structure

First order analysis gives smaller displacement values only up to point B but in actual the structure is displaced up to point C and P-delta analysis gives more accurate values of displacement near to point C. If this extra displacement demand (from B to C) is not fulfilled then structure may collapse during an Earthquake. To fulfill this demand P-Delta analysis is required. First order analysis involving linear static analysis is done by considering small deflection behavior in which the resulting forces, stresses, moments, shear, and displacement does not account the additional effect generated due to deformation of the structure.

1.1 Meaning of p delta effect

P-Delta is coined by two terms, P and delta (Δ), P is applied axial load and Δ is horizontal displacement by lateral loads. It occurs when additional loads are generated by an axial load (P) when a vertical member is displaced by a lateral load (Earthquake load or wind load). Since EQ loads are more dominant than wind loads so this study is limited for EQ loads only.

P- Δ is more adverse in moment resisting frames than shear core or braced system because moment frames are not so stiff, they are soft system which tends to deflect more due to lateral loads which gives more value of delta and hence more deflection. Whereas in case of shear core and braced system the structure is very stiff so this type of structure are not so much influenced by P- Δ effect.

2. OBJECTIVES

1. In depth study of P-Delta effect on a high rise RCC buildings.
2. To analyse buildings with linear and nonlinear methods using SAP 2000 V 20.0.0.
3. To compare the results obtained with linear static analysis and nonlinear static analysis i.e. P-Delta analysis.
4. With the help of the results, obtain a height after which P-Delta is important according to the model's condition.

3. MODEL CONFIGURATION

Five building models of 10,15,20,25 and 30 storey are created with the following data

Plan area		=	900 m^2
No. of Bays in X&Y Dir.		=	5 @ 6m c/c
Height of each storey		=	3m
Beam	M25	=	450 × 400 mm
Column	M30	=	550 × 550 mm
Slab	M25	=	150mm

DESIGN OF BUILDINGS - RCC frame is designed according to IS 456:2000. Seismic analysis is done according to IS 1893- 2016. Beam- slab building type is used. All other data is taken as default according to IS codes and SAP 2000 V 20.0.0.

Common parameter of all buildings - Displacement and axial force values are selected from each storey @ X-Z, Y=0 from extreme left edges. Axial force (-ve) values are selected from each storey @ X-Z, Y=0 from extreme left edges from the beam diagram and highest value was chosen for comparison. Shear values were chosen @ S 2-2, and selected from each storey @ X-Z, Y=0 from extreme left columns. Moment values were chosen @ M 3-3 and selected from each storey @ X-Z, Y=0 from extreme left columns.

Table-1: Load cases that are used in SAP

Dead	Type -Linear static (Dead × 1)
EQX	Type -Linear static (EQX × 1)
LS	Type -Linear Static (Dead ×1 +EQX ×1)
Dead PD	Type -Nonlinear static with P-Delta (Dead × 1)
NL (P-Delta)	Type -Nonlinear static with P -Delta with Initial conditions continue from state at end of nonlinear case –Dead PD (Dead ×1 +EQX×1)

Table -2: Various Parameters

Frame type	Special Moment Resisting Frame
Response reduction factor, R	5
Seismic zone factor, Z	0.36 (V)
Soil type	II (Medium soil)
Importance factor	1
Time period	Programme calculated
Ecc ratio	0.05

4. COMPARISON OF RESULTS OBTAINED

Table-3: Comparison for 10 storey building

Str.	Displacement		Axial force		Shear @S		Moment	
	LS	NL	LS	NL	LS	NL	LS	NL
10	0.0366	0.038	71	136	-	-	-	-
9	0.0351	0.0365	93	179	32	48	26	56
8	0.0327	0.0341	199	374	37	54	39	65
7	0.0295	0.031	311	575	46	63	54	80
6	0.0256	0.0268	429	785	52	68	66	92
5	0.0213	0.0223	552	994	56	72	75	101
4	0.0166	0.0174	678	1209	58	74	82	108
3	0.0118	0.0124	806	1424	50	75	88	114
2	0.0069	0.0072	933	1639	51	76	94	121
1	0.0025	0.0026	1059	1850	64	79	115	144
0	0	0	1176	2050	72	80	184	197

Table-4: Comparison for 15 storey building

Str.	Displacement		Axial force		Shear		Moment	
	LS	NL	LS	NL	LS	NL	LS	NL
15	0.0911	0.0972	76	145	-	-	-	-
14	0.0891	0.0953	99	191	35	65	26	62
13	0.0861	0.0921	211	400	41	61	39	71
12	0.0819	0.0879	331	617	51	72	56	87
11	0.0769	0.0827	460	842	59	80	71	102
10	0.0711	0.0767	595	1074	65	86	83	115
9	0.0647	0.0699	736	1311	71	91	94	126
8	0.0577	0.0625	881	1553	75	94.5	103	136
7	0.0504	0.0547	1029	1797	78	97	110	143
6	0.0427	0.0465	1180	2044	81	98.6	116	149
5	0.0348	0.038	1332	2291	82	99.3	120	153
4	0.0268	0.0293	1484	2538	83	99.5	123	156
3	0.0188	0.02053	1637	2785	84	99.3	127	160
2	0.0109	0.01191	1788	3028	85	99.3	135	169
1	0.0039	0.0042	1935	3266	89	104.17	165	205
0	0	0	2069	3486	104	112.7	280	304

Table -5: Comparison for 20 storey building

Str.	Displacement		Axial force		Shear		Moment	
	LS	NL	LS	NL	LS	NL	LS	NL
20	0.1682	0.1844	82	158	-	-	-	-
19	0.1658	0.1819	104	203	36.7	73.4	27	70
18	0.1621	0.1782	222	427	43.3	67.6	41	76
17	0.1574	0.1732	350	660	54.4	79.8	58	96
16	0.1515	0.1671	487	902	63.7	88.7	74	118
15	0.1447	0.16	632	1158	71.7	96.3	88	126
14	0.1371	0.1519	784	1410	78.7	102.7	101	141
13	0.1287	0.1431	943	1674	84.7	108.1	113	153
12	0.1197	0.1334	1106	1944	89.9	112.4	123	163
11	0.1103	0.1232	1274	2217	94.2	115.8	131	172
10	0.1003	0.1125	1445	2494	97.7	118.4	138	180
9	0.0901	0.1013	1618	2773	100.6	120.24	144	187
8	0.0796	0.0897	1794	3054	102.8	121.35	149	192
7	0.0688	0.07781	1970	3336	104.5	121.8	153	196
6	0.058	0.0657	2148	3617	105.7	121.79	156	200
5	0.0471	0.0534	2325	3899	106.5	121.3	158	202
4	0.0361	0.0409	2502	4179	107.02	120.5	161	205
3	0.0253	0.0286	2679	4457	107.5	119.7	164	209
2	0.0147	0.0165	2853	4731	108.7	120.06	174	221
1	0.0052	0.0057	3022	4997	114.5	126.55	214	267
0	0	0	3173	5239	136.4	143.71	372	410

Table -6: Comparison for 25 storey building

Str.	Displacement		Axial force		Shear		Moment	
	LS	NL	LS	NL	LS	NL	LS	NL
25	0.2732	0.3083	85	170	-	-	-	-
24	0.2701	0.305	108	213	37.4	70.6	27.8	77
23	0.2656	0.3004	232	451	44.6	72.7	41.9	85
22	0.26	0.2945	368	699	56.2	85.5	60	103
21	0.2532	0.2873	510	957	66.3	95.2	75	121
20	0.2454	0.279	663	1224	75.3	103.7	91	137
19	0.2366	0.2696	824	1499	83.4	111.2	105	152
18	0.227	0.2593	992	1782	90.7	117.7	119	166
17	0.2164	0.248	1167	2072	97.2	123.3	130	178
16	0.2053	0.236	1347	2367	103	128	141	190
15	0.1936	0.223	1532	2668	108	132	150	200
14	0.1814	0.2097	1722	2974	112	135	158	209
13	0.1684	0.196	1914	3283	116	137.5	165	217
12	0.1557	0.181	2110	3595	119.2	139.2	171	224
11	0.1423	0.166	2308	3909	122	140.5	177	231
10	0.1288	0.15	2507	4225	124	141.1	181	236
9	0.1154	0.135	2708	4541	125	141.3	185	241

8	0.1012	0.119	2909	4859	127.2	141	188	245
7	0.0872	0.103	3111	5176	128.2	140.3	191	248
6	0.0733	0.086	3313	5492	128.9	140	193	251
5	0.0593	0.07	3514	5808	129.4	138	196	253
4	0.0455	0.054	3715	6121	129.8	136	197	255
3	0.0317	0.0373	3914	6432	130	135	200	260
2	0.0186	0.022	4111	6739	132	136	213	276
1	0.0066	0.0075	4301	7035	139	145	262	335
0	0	0	4469	7299	168	173	464	521

Table -7: Comparison for 30 storey building

Str	Displacement		Axial force		Shear		Moment	
	LS	NL	LS	NL	LS	NL	LS	NL
30	0.4098	0.4771	88	178	-	-	-	-
29	0.4056	0.473	111	223	37.3	81	27.3	82
28	0.4002	0.467	241	474	45	76	41.6	90
27	0.3935	0.46	379	733	56	89	59	109
26	0.3855	0.45	529	1004	67	99	76	127
25	0.3765	0.44	688	1285	77	108	93	144
24	0.3664	0.43	855	1575	86	117	103	160
23	0.3553	0.42	1031	1874	94	134	122	175
22	0.3433	0.405	1215	2181	101	130	135	189
21	0.3305	0.39	1405	2495	108	136	147	202
20	0.317	0.37	1601	2815	114	141	157	214
19	0.303	0.36	1802	3142	120	145	167	226
18	0.2881	0.344	2008	3474	124	148	176	236
17	0.273	0.327	2218	3811	127	151	184	245
16	0.257	0.309	2432	4152	131	153	191	254
15	0.2411	0.291	2648	4496	136	155	198	262
14	0.225	0.272	2867	4843	139	156.0	203	269
13	0.2081	0.252	3088	5192	142	156.5	208	276
12	0.1912	0.233	3311	5544	144	156.6	213	282
11	0.174	0.213	3535	5893	146	156.3	216	287
10	0.157	0.193	3760	6256	147	155.7	220	291
9	0.14	0.172	3985	6604	149	154.8	222	295
8	0.1229	0.151	4210	6957	150	153	225	299
7	0.106	0.13	4436	7310	150.7	152	227	302
6	0.0887	0.109	4660	7663	151.4	150	229	304
5	0.072	0.088	4884	8013	151.8	148	230	307
4	0.055	0.067	5107	8362	152.2	147	232	310
3	0.0383	0.047	5329	8708	152.9	146	236	317
2	0.022	0.027	5548	9044	155.2	148	251	337
1	0.008	0.0093	5760	9377	164	166	311	409
0	0	0	5945	9666	200.5	200.0	556	636

Note- Since all buildings are symmetric so direction of seismic force is taken only in direction X and default units during designing in SAP are KN,m,c. and in tables str. stands for storey number.

LS- Linear static

NL- Nonlinear static means P-Delta analysis.

Displacement values are taken @ U1 translation in direction 1.

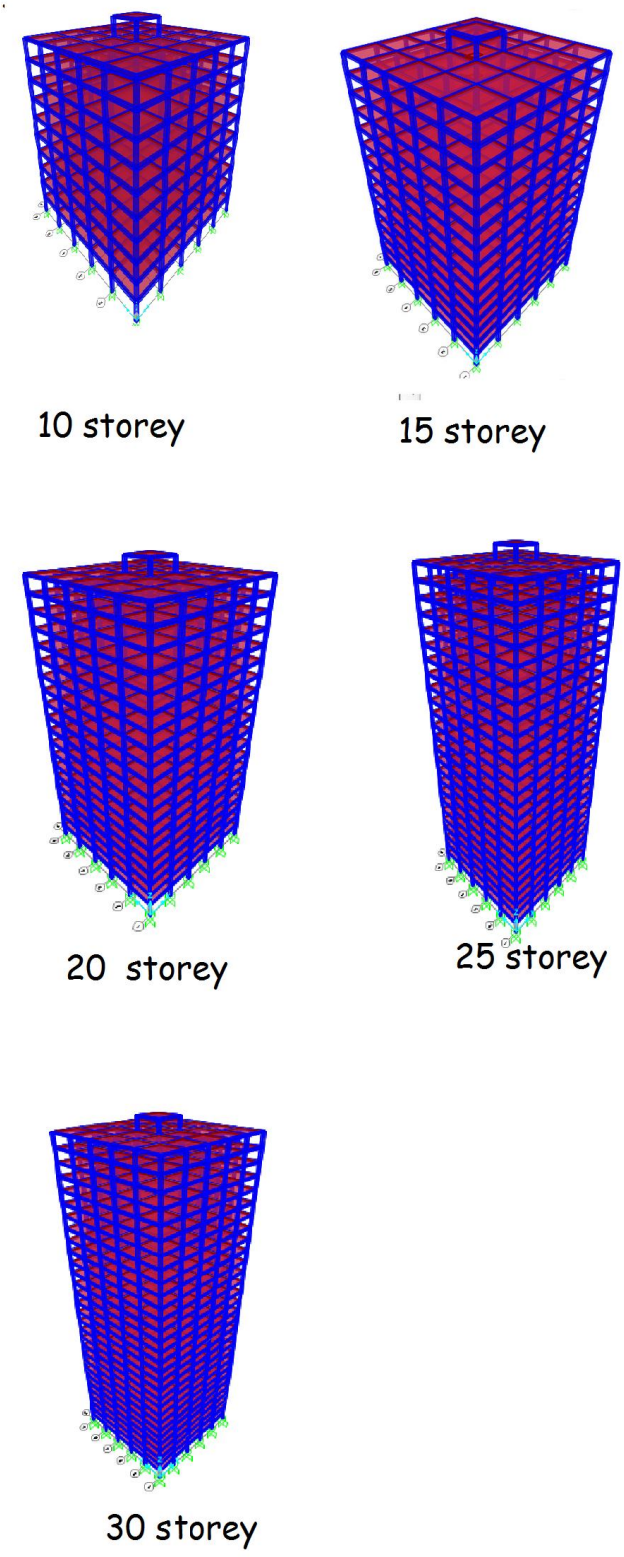


Fig-2: 3D models created in SAP 2000

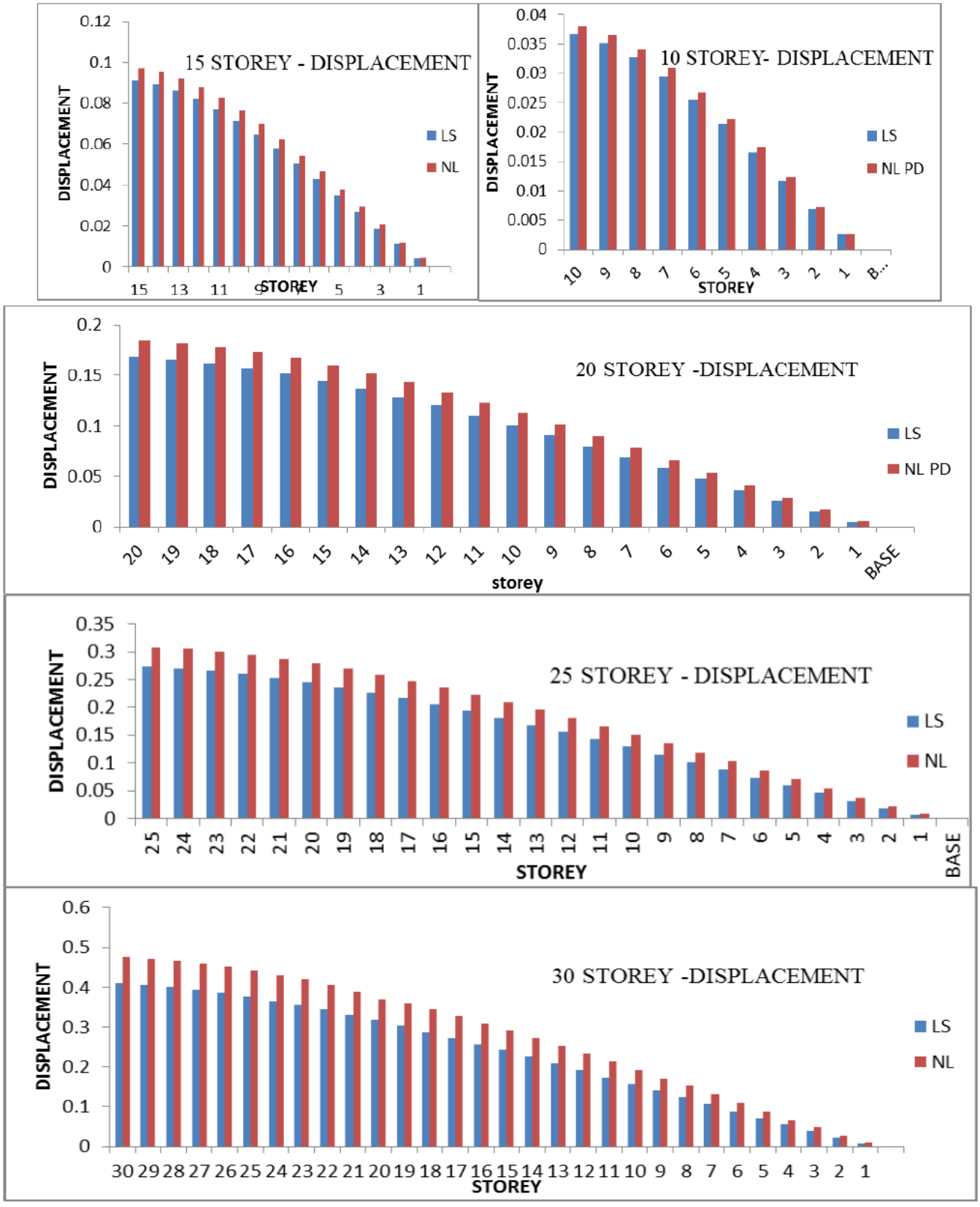
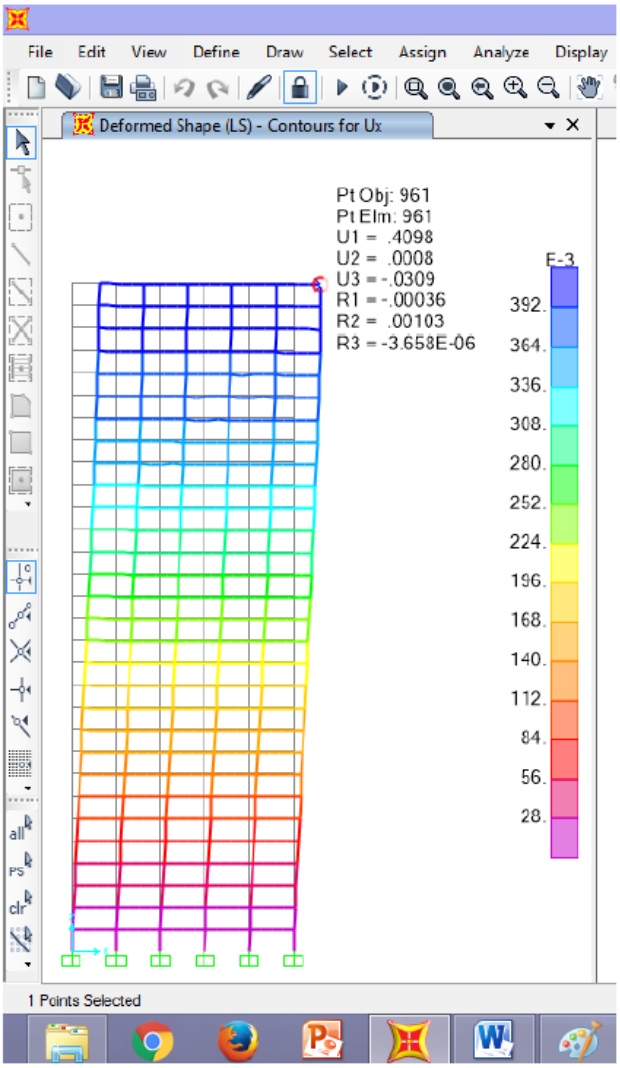
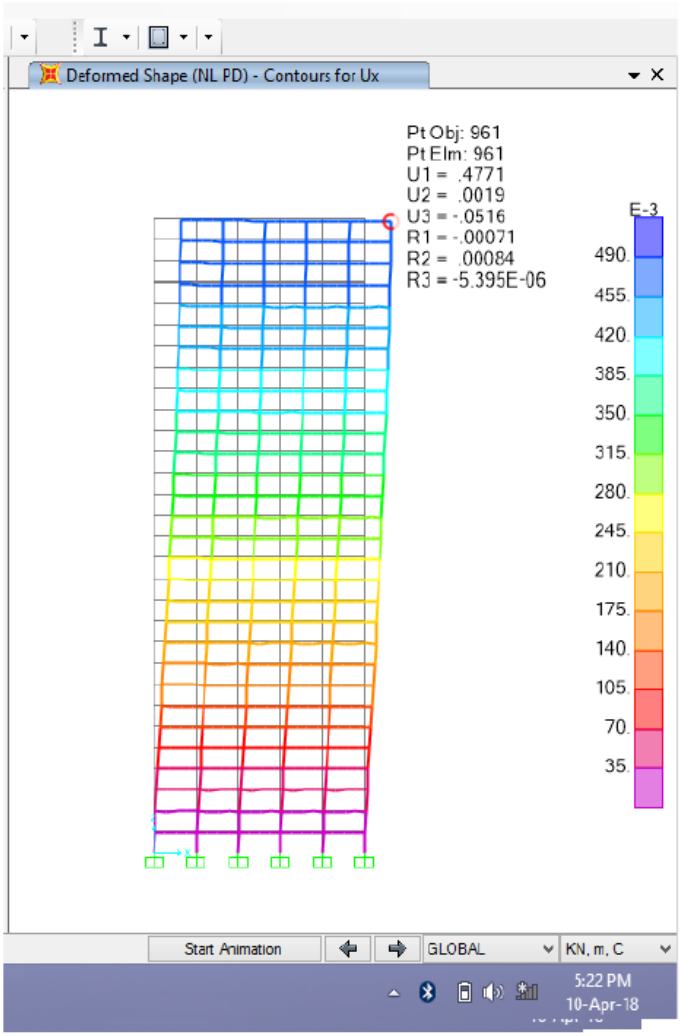


Chart -1: Showing displacement for all models of LS vs. NL (P-Delta)

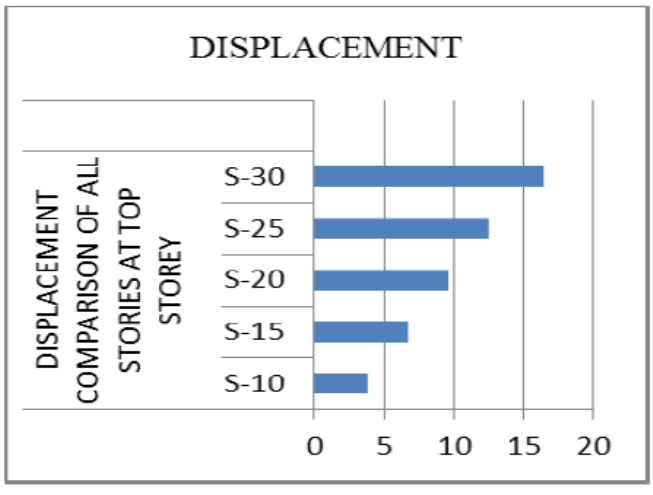


SCREENSHOT OF LS ANALYSIS



SCREENSHOT OF NL (P-DELTA) ANALYSIS

Fig -3: Screenshot of LS and NL P-Delta analysis showing displacement at top storey further results are tabulated in Table7.



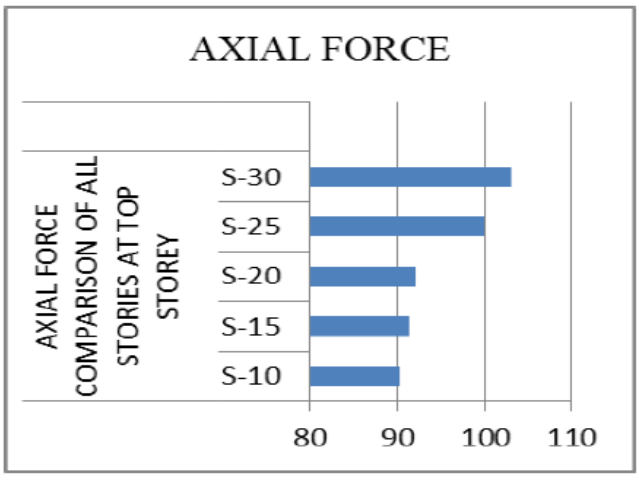


Chart-2: Percentage change between LS and NL (P-Delta) analysis for displacement and axial force of all buildings.

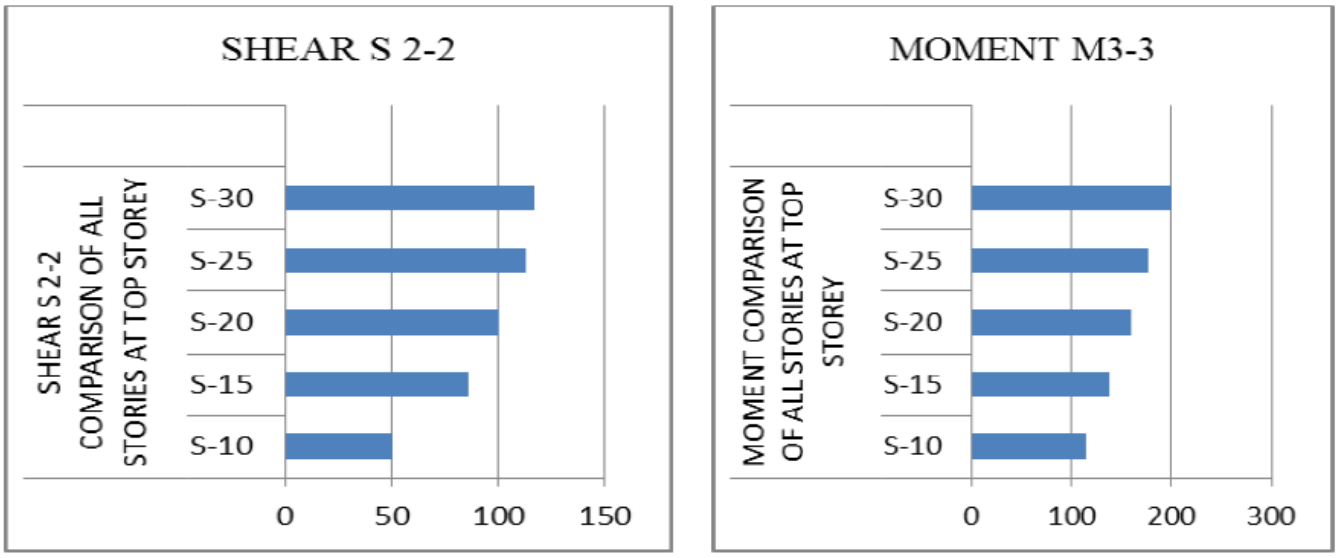


Chart-3: Percentage change between LS and NL (P-Delta) analysis for shear and moment of all buildings.

5. RESULT

The percentage change between LS and NL analysis keeping LS as initial value the changes for different stories are as follows-

Table- 8: Percentage comparison

Storey	10	15	20	25	30
Percentage change in displacement of top storey	3.8	6.7	9.6	12.5	16.4
Percentage change in axial force of top storey	90	91	92	100	103
Percentage change in shear of top storey	50	86	100	113	117
Percentage change in moment of top storey	115	138	159	177	200

6. CONCLUSION

1. The study shows that the effect of P-Delta is not significant in lower storey and for economical reasons it can be neglected but for models with storey more than 15 the change in displacement is above 9.6% so it is mandatory to include this effect.

2. The change in moment in some columns were so high that it reaches up to 200% in 30 storey model so it is very important to consider this effect.

7. FUTURE SCOPE

The models can also be analysed for large P-Delta analysis and for dynamic nonlinear case. Both of them will give larger displacement and is useful for buildings with larger plan area and slender buildings. Also non-symmetric and irregular buildings can also be analysed which will provide even higher variation.

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