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Stability Analysis of Multi-story building with underneath Satellite Bus Stand having intermediate soft-story and Floating columns

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Abstract - *The masonry infill walls are considered as non-structural element and their stiffness contribution are ignored in the analysis when building is subjected to seismic loads, but it is considered while we studying stability analysis. RC frame building with open ground story, and similar soft story effect can be observed when soft story at different levels of structure are constructed. The method used for stability analysis of columns, shear walls, coupled and coupled components, cores, single story and multi-story structures are studying. Buildings and structures are considering stable with lateral supports by using either bracing systems or shear system or both such as wall to ensure the stability of the building. One of the problems is affected from wind load. The calculation methods are computer assisted through the use of the software, ETAB. Comparisons of results are made between the methodologies, and different models with different parameters. This is how the soft story effects are managed to overcome the future damages of the storied structures.*

Key words: Satellite Bus Stop, Soft-Story, Non-Linear Time History Analysis, P-Delta, Floating Columns.

1. INTRODUCTION

Satellite bus stop is the new term that has come in the recent years in cities like Bengaluru because, due to increasing population and the land value since the past few years' bus stands in populated cities is a matter of major problem. So that constructions of multi-Storyed buildings with open first story. Hence it has been utilizing for the

moment of the buses and people can use this as bus terminals. These type of buildings having no infill walls in ground story, but all upper storys infilled with masonry walls. Soft stories at different levels of structure are constructed for other purposes like lobbies conference halls and for the service storys. This story is known as weak story because story stiffness is lower compare to above storys. So, importance to be given for the earthquake resistant design.

2. DESCRIPTION OF STRUCTURAL MODEL

2.1 Geometry

For the study, four different models of a 12 story building are considered. The building has four bays in X direction with spacing of 11m and seven bays in Y direction with spacing of 7m. The plan dimension 44 m × 49 m. Typical story height is 3.65 m for each floor up to intermediate soft story their after that 3.2 m for remaining storys and bottom soft-story and intermediate soft-storys are of height 7m and 3m respectively. Floating columns are used after intermediate soft story as shown in figure below. This geometry remains same throughout the study. The only influencing factor is change in the models and parameters, dimensions remains same. The column size decreases from Bottom to Top.

Column size	
From Story 1 to Story 6	1.5m x 0.6m
Story 7 to Story 10	1.2m x 0.8m
Story 11 to Story 15	0.8m x 0.4m
Floating columns	0.8m x 0.4m
Beam size	
From story 1to story7	0.4m x 0.8 m
Story 7th in X direction	1m x 1m
Slab thickness	
Story 1 to 7	0.150m
Story 8 to 12	0.125m

Following 2 models are analyzed by equivalent static method, response spectrum method and Non-Linear Time History analysis using ETABS software.

- ✓ Model 1: Bare frame model, however masses of brick masonry infill walls are included in the model with and without P-Delta option for equivalent static method, response spectrum method and Time history nonlinear analysis.
- ✓ Model 2: Masonry frame model, however masses of brick masonry infill walls and stiffness are included in the model with and without P-Delta option for

equivalent static method, response spectrum method and Time history nonlinear analysis.

- ✓ Model 3: Bare frame model, however masses of brick masonry infill walls are included in the model and 'L' Type Shear wall add with and without P-Delta option for equivalent static method, responsespectrum method and Time history nonlinear analysis.
- ✓ Model 4: Bare frame model, however masses of brick masonry infill walls are included in the model and 'Swastik' type shear wall adds with and without P-Delta option for equivalent static method, response spectrum method and Time history nonlinear analysis.
- ✓ Model 5: Bare frame model, however masses of brick masonry infill walls are included in the model and 'H' Type shear wall add with and without P-Delta option for equivalent static method, response spectrum method and Time history nonlinear analysis.

2.2 Analysis Data

Following data is used in the analysis of the RC frame building models for equivalent static method and response spectrum method.

Material Properties:

E for (M20) concrete = $25.00x10^6$ KN/m^2
E for (M30) concrete = $29.58x10^6$ KN/m^2
Density of RCC = 25kN/m^3
E for brick masonry = $3500x10^3$kN/m^2
Density of brick masonry = 20kN/m^3
Floor finishes = 1.5kN/m^2
Live load intensities: = 4.0KN/ m^2

Seismic Data: (as per IS:1893-2002)

Zone factor (table 2) = 0.36(Zone–V)
Importance factor I (Table 6) = 1.5
Response reduction factor R (Table 7) = 5.0(SMRF)
Soil type (Figure 2) = Type II (Medium soil)

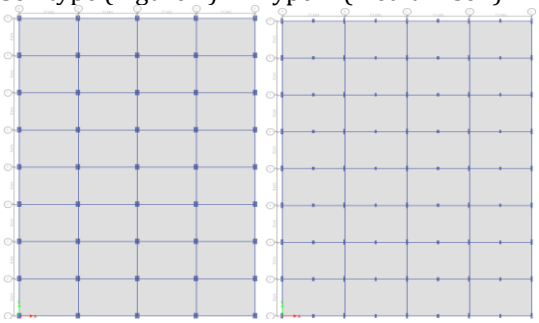

Figure 1. Floor Plan up to intermediate soft-story Figure 2. Floor Plan after intermediate soft story

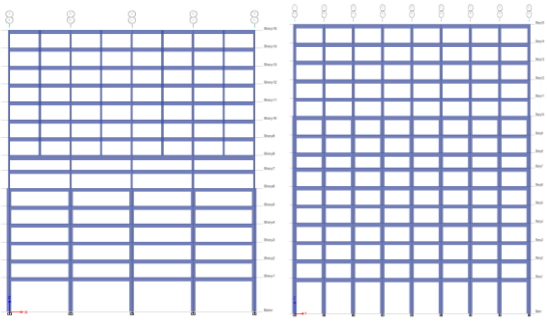

Fig 3: Elevation of Building Model-1 along y-dir. Fig 4: Elevation of Building Model-1 along x-dir.

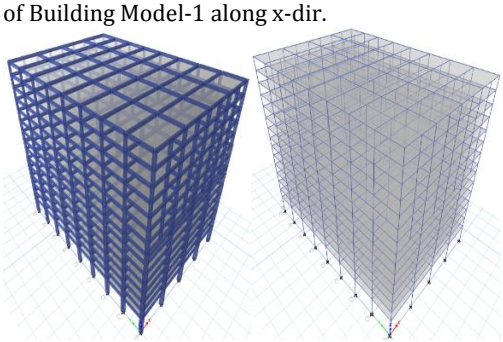

Figure 5. 3D View of Model-1

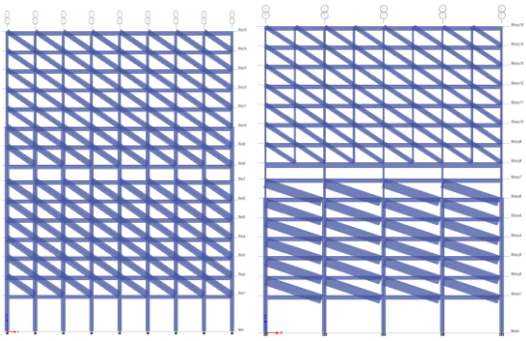

Fig 6: Elevation of Building Model-2 along y-dir.
Fig 7: Elevation of Building Model-2 along x-dir.

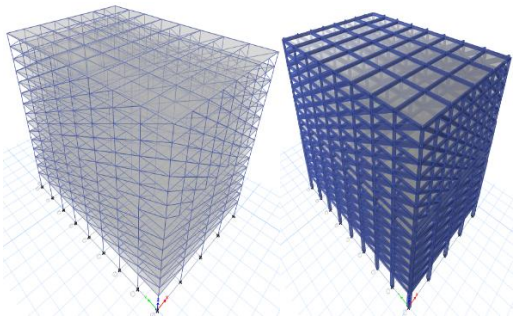

Fig 8. 3D View of Model-2

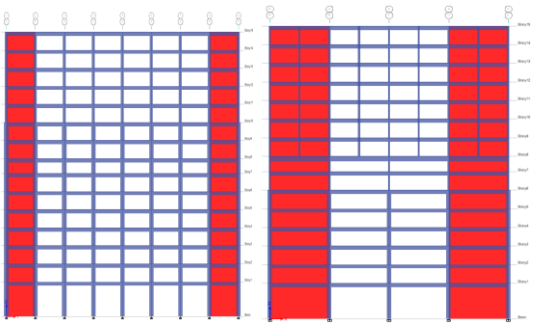

Fig 9: Elevation of Building Model-3 along y-dir.
Fig 10: Elevation of Building Model-3 along x-dir.

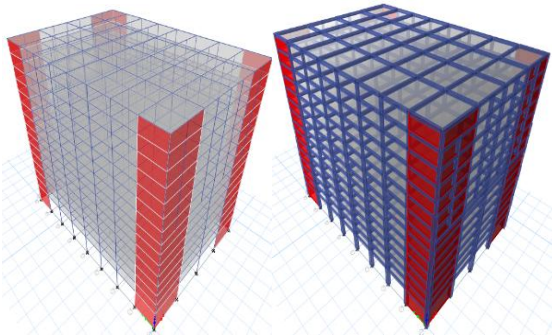

Fig 11. 3D View of Model-3

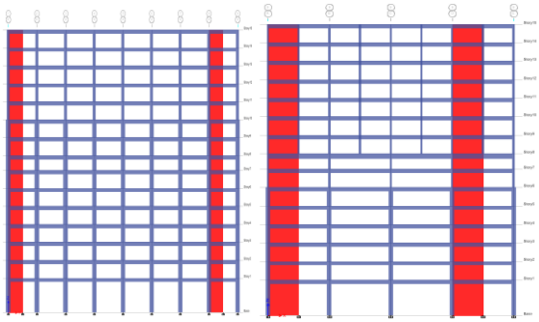

Fig 12: Elevation of Building Model-4 along x-dir.
Fig 13: Elevation of Building Model-4 along y-dir.

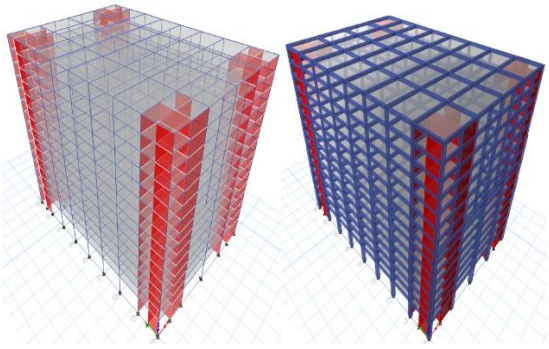

Fig 14. 3D View of Model-4

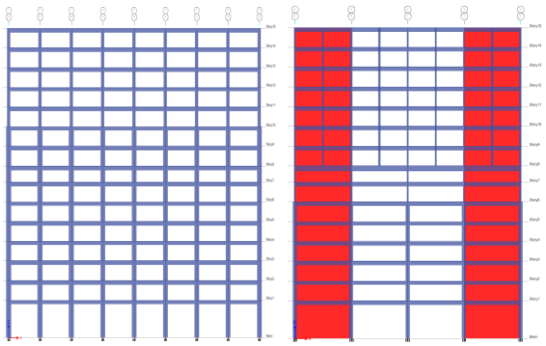

Fig 15: Elevation of Building Model-5 along y-dir.
Fig 16: Elevation of Building Model-5 along x-dir.

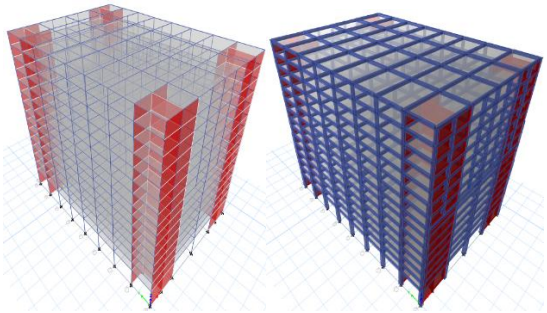

Fig 17. 3D View of Model-5

3. RESULTS AND DISCUSSIONS

Most of the past studies on different buildings such symmetrical and unsymmetrical have adopted idealized structural systems without considering the effect of concrete shear and core walls. Although these systems are sufficient to understand the general behaviour and dynamic characteristics, it would be interesting to know how real building will respond to Earthquake forces and Wind forces. For this reason, a hypothetical building, located on a plane ground having similar ground floor plan have been taken as structural systems for the study.

In this chapter, the results of natural period of vibration, base shear, lateral displacements, story drifts of different building models are presented and compared. An effort has been made to study the effect of shear wall both at Centre and corners on exterior side in longitudinal & transverse direction respectively.

3.1 Fundamental Natural Time Period

Table 3.1 shows the time period and frequency obtained by ETABS without P-delta options for analysis, time period for model 2 reduces by 61.51% as compared to bare frame model-1. Model-1 with P-Delta increases time period by

5.45% as compared to model-1 without P-delta. Similarly, for model-2, 3, 4, and 5 are 2.47%, 1.03%, 0.725 and 0.88% respectively. From that it can be clear that the presence of p-delta in the building will increases the time period and decreases the frequency of the structure. Thus it can be clearly understanding that, presence of brick infill wall stiffness and shear wall considerably reduces the time period of building.

	PERIOD IN SEC		FREQUENCY IN CYC/SEC	
MODEL	Without P-Delta	With P-Delta	Without P-Delta	With P-Delta
1	3.266	3.444	0.306	0.290
2	1.257	1.288	0.796	0.776
3	1.645	1.662	0.608	0.602
4	1.537	1.548	0.651	0.646
5	1.484	1.497	0.674	0.668

Table 3.1: Fundamental natural time period and Frequency using ETABS software for various models.

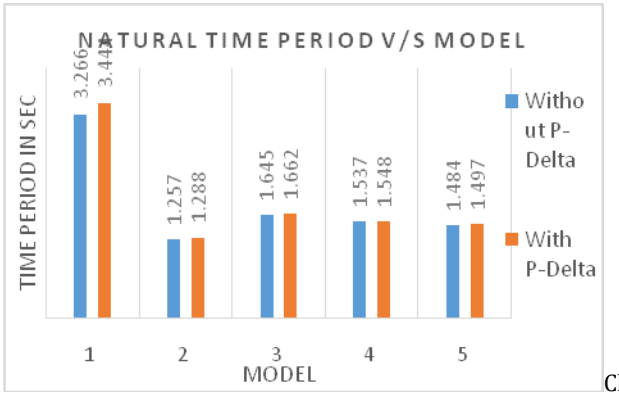

Chart 3.1.2: Model Vs Time period for Different models without and with P-delta.

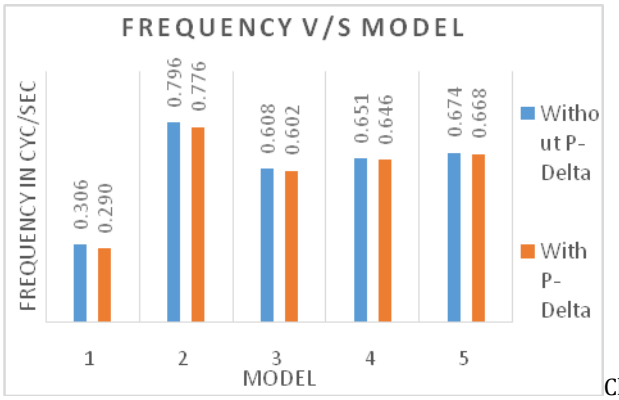

Chart 3.1.2: Model Vs frequency for Different models without and with P-delta.

3.2 Story Drifts

The permissible story drift according to IS1893(part1)-2002 is limited to 0.004 times the story height. The maximum story drifts for various building models along longitudinal and transverse direction obtained from Non-linear time history analysis from ETABS are shown in tables below, from the table 3.2.1 to 3.2.5 and chart 3.2.1 to 3.2.10. From that it can be seen that the story drift in all story for model-1 has higher values as compare to other models. The drift values gradually decrease from story 1 to 15thstory in both directions. All the values of drift are within the limit as per IS:1893-2002 i.e., 0.004x3.5=0.014m, 0.004x3=0.012m and 0.004x7=0.028m.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	0.002079	0.002235	0.002257	0.002178
2	0.002785	0.002998	0.003316	0.003170
3	0.002693	0.002931	0.003270	0.003163
4	0.002594	0.002735	0.003062	0.003081
5	0.002549	0.002413	0.002919	0.002918
6	0.002453	0.002270	0.002727	0.002775
7	0.003313	0.003099	0.002822	0.003080
8	0.002287	0.001945	0.002867	0.003066
9	0.001589	0.001347	0.003098	0.003226
10	0.001845	0.001574	0.003254	0.003335
11	0.001992	0.001709	0.003723	0.003789
12	0.001761	0.001563	0.003498	0.003527
13	0.001415	0.001355	0.002968	0.002959
14	0.000970	0.000971	0.002189	0.002163
15	0.000479	0.000480	0.001366	0.001340

Table 3.2.1: Comparison of Story Drifts for with and without P-Delta Non-Linear Time History analysis of Model-1 in x and y-direction.

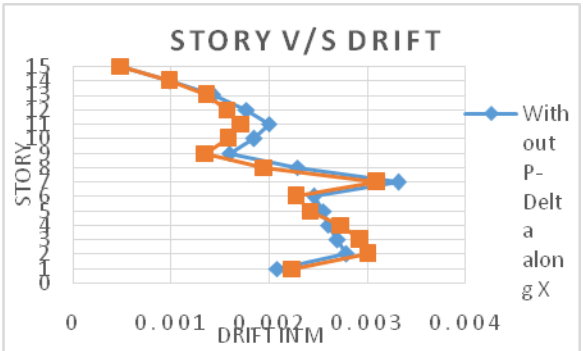

Chart 3.2.1: Story drift Vs Story for model-1 along X-direction by THNA with and without P-delta.

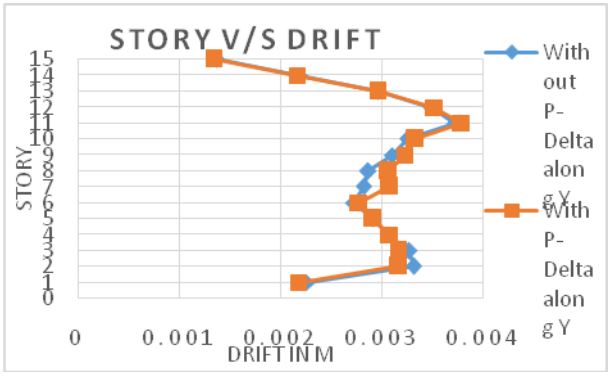

Chart 3.2.2: Story drift Vs Story for model-1 along Y-direction by THNA with and without P-delta.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	0.008407	0.008102	0.006174	0.006152
2	0.000627	0.000545	0.000691	0.000692
3	0.000426	0.000369	0.000368	0.000364
4	0.000403	0.000358	0.000348	0.000346
5	0.000392	0.000374	0.000311	0.000312
6	0.000409	0.000387	0.00031	0.000305
7	0.000423	0.000416	0.000341	0.000345
8	0.006916	0.006683	0.002136	0.002099
9	0.000302	0.000300	0.000436	0.000431
10	0.000291	0.000288	0.000318	0.000315
11	0.000287	0.000284	0.000295	0.000296
12	0.000277	0.000274	0.000265	0.000266
13	0.000268	0.000266	0.000247	0.000248
14	0.000262	0.000259	0.000233	0.000233
15	0.000258	0.000255	0.000228	0.000227

Table 3.2.2: Comparison of Story Drifts for with and without P-Delta Non-Linear Time History analysis of Model-2 in x and y-direction.

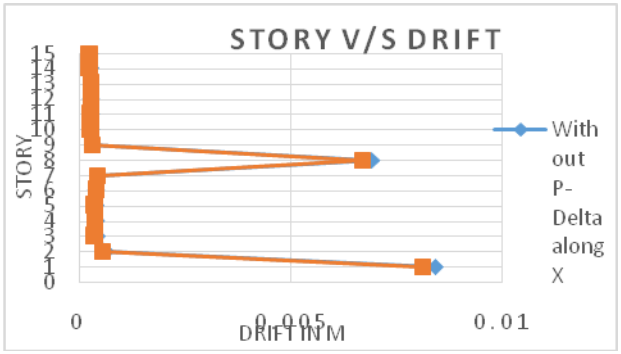

Chart 3.2.3: Story drift Vs Story for model-2 along X-direction by THNA with and without P-delta.

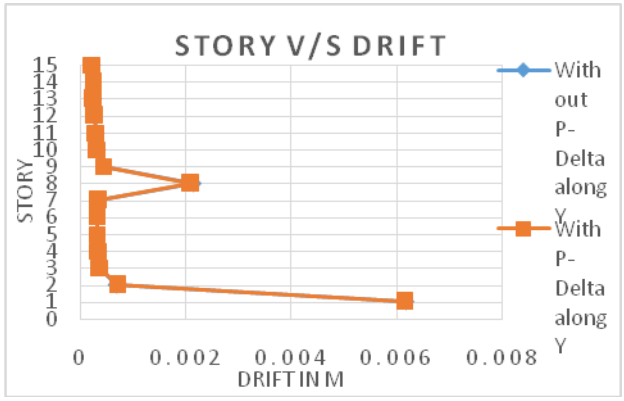

Chart 3.2.4: Story drift Vs Story for model-2 along Y-direction by THNA with and without P-delta.

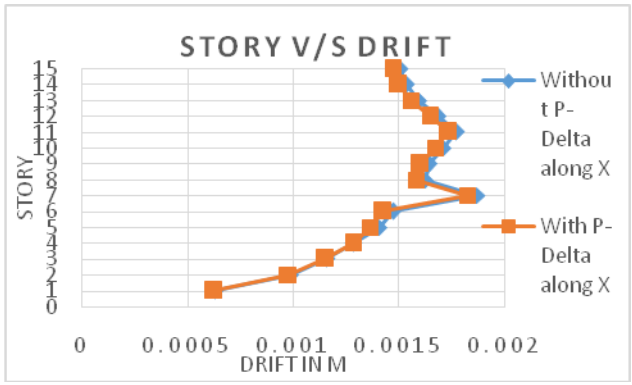

Chart 3.2.5: Story drift Vs Story for model-3 along X-direction by THNA with and without P-delta.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	0.000633	0.000626	0.000730	0.000732
2	0.000988	0.000980	0.001157	0.001160
3	0.00116	0.001155	0.001273	0.001269
4	0.001289	0.001286	0.001363	0.001392
5	0.001406	0.001363	0.001536	0.001572
6	0.001472	0.001429	0.001670	0.001710
7	0.001871	0.001825	0.001842	0.001889
8	0.001626	0.001583	0.001872	0.001920
9	0.001644	0.001603	0.001923	0.001972
10	0.00171	0.001672	0.001952	0.002002
11	0.001774	0.001736	0.002039	0.002090
12	0.001687	0.001650	0.001943	0.001992
13	0.001595	0.001559	0.001849	0.001896
14	0.001536	0.001501	0.001762	0.001805
15	0.001508	0.001473	0.001717	0.001758

Table 3.2.3: Comparison of Story Drifts for with and without P-Delta Non-Linear Time History analysis of Model-3 in x and y-direction.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	0.000907	0.000871	0.000625	0.000640
2	0.001435	0.001433	0.000953	0.000998
3	0.001658	0.001665	0.001094	0.001129
4	0.001841	0.001852	0.001254	0.001294
5	0.001993	0.002009	0.001403	0.001447
6	0.002092	0.002113	0.001507	0.001554
7	0.002300	0.002329	0.001703	0.001755
8	0.002234	0.002262	0.001729	0.001781
9	0.002226	0.002257	0.001808	0.001860
10	0.002248	0.002282	0.001817	0.001868
11	0.002241	0.002277	0.001918	0.001971
12	0.002173	0.002207	0.001865	0.001914
13	0.002098	0.002130	0.001822	0.001869
14	0.002027	0.002057	0.001744	0.001789
15	0.001978	0.002006	0.001661	0.001703

Table 3.2.4: Comparison of Story Drifts for with and without P-Delta Non-Linear Time History analysis of Model-4 in x and y-direction.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	0.000713	0.000708	0.000589	0.000575
2	0.001161	0.001165	0.000951	0.000931
3	0.001385	0.001395	0.001085	0.001064
4	0.001581	0.001597	0.001190	0.001169
5	0.001721	0.001742	0.001258	0.001236
6	0.001804	0.001827	0.001326	0.001333
7	0.002137	0.002174	0.001479	0.001487
8	0.001944	0.001977	0.001469	0.001474
9	0.001998	0.001996	0.001501	0.001505
10	0.002093	0.002030	0.001489	0.001490
11	0.002180	0.002119	0.001564	0.001566
12	0.002157	0.002099	0.001467	0.001467
13	0.002130	0.002075	0.001383	0.001382
14	0.002046	0.001992	0.00128	0.001281
15	0.002031	0.001977	0.001206	0.001207

Table 3.1.5: Comparison of Story Drifts for with and without P-Delta Non-Linear Time History analysis of Model-5 in x and y direction.

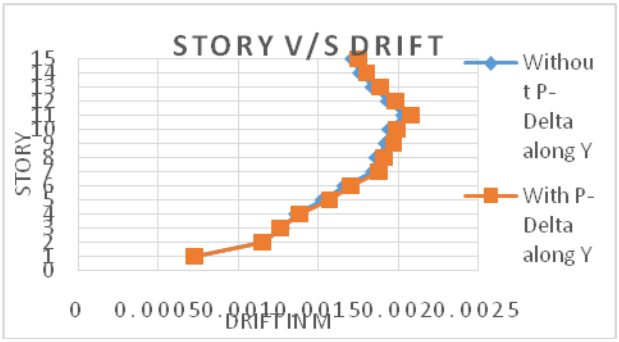

Chart 3.2.6: Story drift Vs Story for model-3 along Y-direction by THNA with and without P-delta.

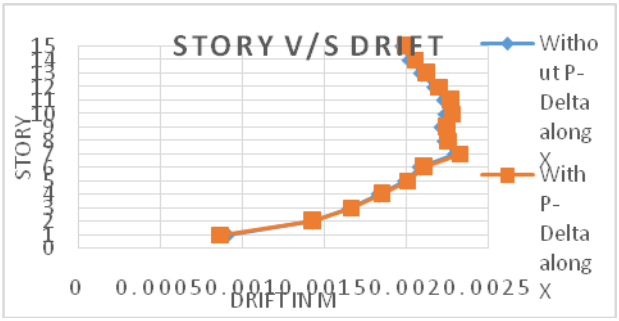

Chart 3.2.7: Story drift Vs Story for model-4 along X-direction by THNA with and without P-delta.

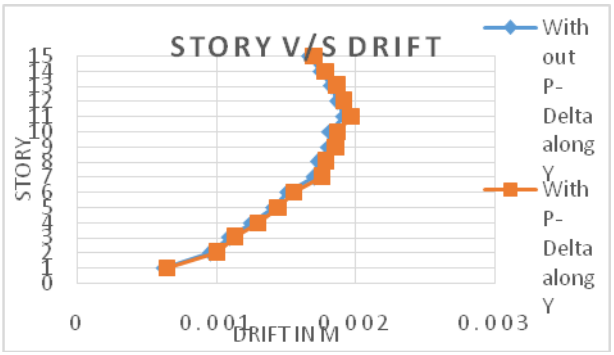

Chart 3.2.8: Story drift Vs Story for model-4 along Y-direction by THNA with and without P-

delta.

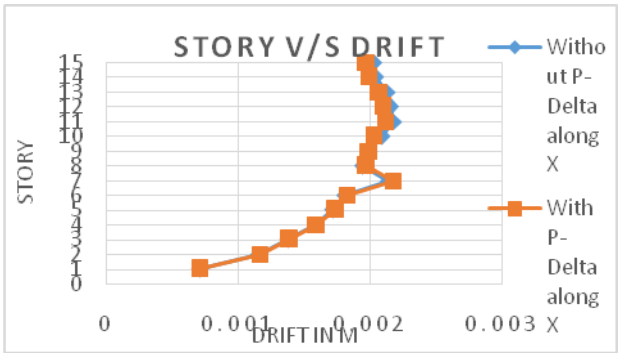

Chart 3.2.9: Story drift Vs Story for model-5 along X-direction by THNA with and without P-delta.

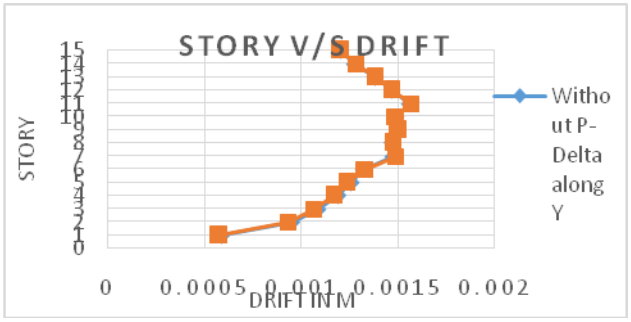

Chart 3.2.10: Story drift Vs Story for model-5 along Y-direction by THNA with and without P-delta.

3.3 Story Displacements

The maximum displacement at each story with respective to ground level are presented in tables obtained from Non-Linear Time history analysis for different models. To understand in a better way, the displacements for each model along the longitudinal direction and transverse direction are plotted in charts below. Table 3.3.1 to 3.3.5 and chart 3.3.1 to 3.3.10 shows all Model story displacements. The bare frame model-1 has highest story displacement values as compared to model-2.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
0	209.208	209.208	209.208	209.208
1	211.299	210.505	209.809	209.701
2	213.074	212.04	210.346	210.132
3	214.846	213.667	210.916	210.606
4	216.568	215.255	211.481	211.079
5	218.209	216.752	212.029	211.536
6	219.773	218.161	212.557	211.973
7	221.785	219.941	213.077	212.399
8	222.715	220.714	213.464	212.714
9	223.346	221.183	213.916	213.087
10	224.002	221.641	214.350	213.450
11	224.65	222.064	214.807	213.835
12	225.186	222.387	215.207	214.169
13	225.597	222.621	218.062	221.600
14	225.872	222.772	224.179	228.414
15	226.011	222.851	228.136	232.740

Table 3.3.1: Comparison of Story Displacement for with and without P-Delta Non-Linear Time History analysis of Model-1 in x and y-direction.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
0	209.208	209.208	209.208	209.208
1	210.424	210.477	209.349	209.349
2	210.447	210.5	209.355	209.356
3	210.474	210.527	209.359	209.361
4	210.5	210.553	209.364	209.367
5	210.525	210.578	209.369	209.372
6	210.55	210.603	209.374	209.378
7	210.576	210.628	209.38	209.384
8	211.137	211.206	209.433	209.435
9	211.161	211.231	209.44	209.442
10	211.184	211.254	209.447	209.449
11	211.209	211.279	209.453	209.455
12	211.233	211.303	209.459	209.461
13	211.258	211.328	209.465	209.467
14	211.282	211.352	209.471	209.473
15	211.306	211.376	209.477	209.478

Table 3.3.2: Comparison of Story Displacement for with and without P-Delta Non-Linear Time History analysis of Model-2 in x and y-direction.

The effect of p-delta will reduce the displacement values of all models in both x and y direction. Model-2 (full brick infill) shows considerable reduction in story displacement with a reduction compared with other models and also reduce due to use of shear walls compared to model-1. Thus it can be concluded that addition of infill wall stiffness and shear walls act as drift and displacement controlled elements in RC buildings.

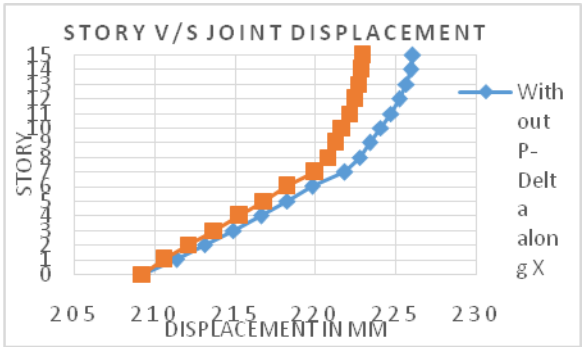

Chart 3.3.1: Story Displacement Vs Story for model-1 along X-direction by THNA with and without P-delta.

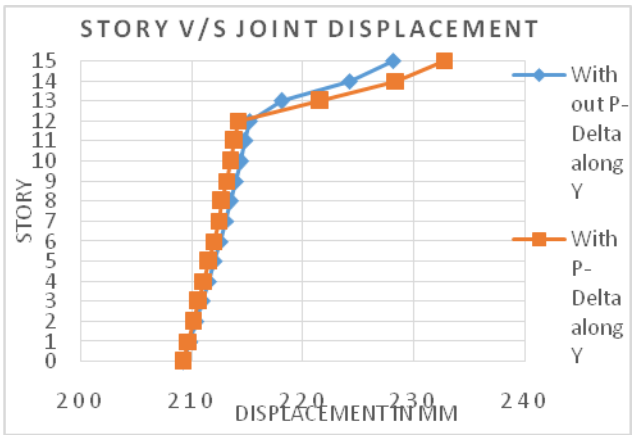

Chart 3.3.2: Story Displacement Vs Story for model-1 along Y-direction by THNA with and without P-delta.

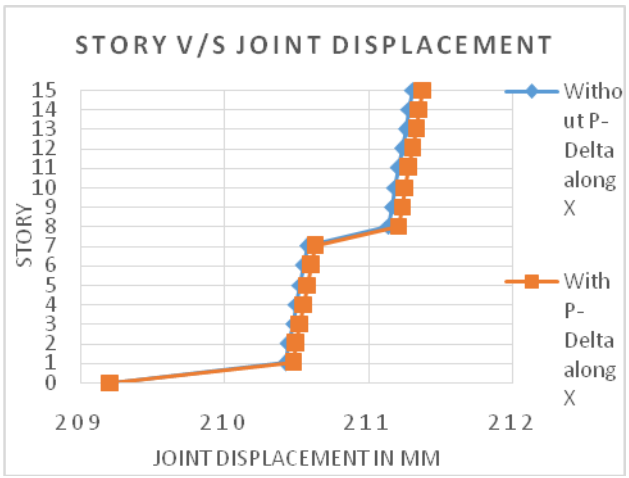

Chart 3.3.3: Story Displacement Vs Story for model-2 along X-direction by THNA with and without P-delta.

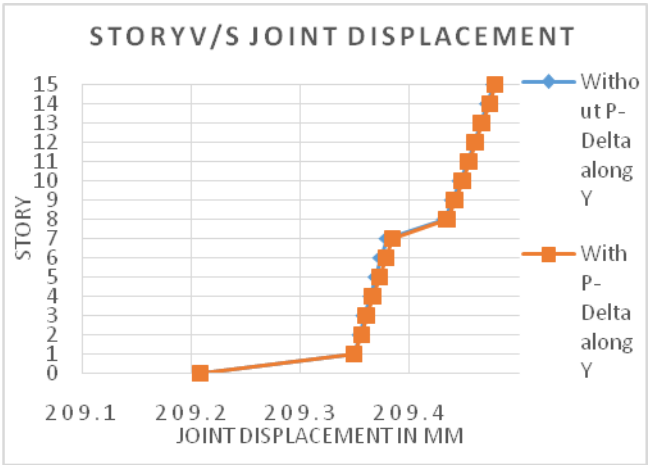

Chart 3.3.4: Story Displacement Vs Story for model-2 along Y-direction by THNA with and without P-delta.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	209.458	209.462	209.298	209.311
2	209.661	209.672	209.426	209.454
3	209.89	209.909	209.573	209.618
4	210.14	210.166	209.727	209.792
5	210.399	210.434	209.881	209.969
6	210.651	210.694	210.03	210.141
7	210.959	211.013	210.174	210.311
8	211.164	211.225	210.278	210.435
9	211.394	211.461	210.395	210.579
10	211.633	211.709	210.5	210.709
11	211.868	211.955	210.598	210.834
12	212.087	212.183	210.686	210.944
13	212.293	212.401	210.78	211.048
14	212.485	212.606	210.894	211.159
15	212.639	212.771	211.007	211.271

Table 3.3.3: Comparison of Story Displacement for with and without P-Delta Non-Linear Time History analysis of Model-3 in x and y-direction.

Story No	Without P-Delta along X in mm	With P-Delta along X	Without P-Delta along Y in mm	With P-Delta along Y
1	209.352	209.351	209.34	209.335
2	209.469	209.47	209.467	209.46
3	209.603	209.607	209.606	209.596
4	209.751	209.758	209.749	209.735
5	209.91	209.92	209.888	209.871
6	210.07	210.082	210.021	209.998

7	210.27	210.285	210.152	210.122
8	210.417	210.434	210.253	210.215
9	210.594	210.613	210.386	210.335
10	210.786	210.807	210.542	210.474
11	210.982	211.006	210.747	210.662
12	211.173	211.2	210.968	210.87
13	211.357	211.387	211.191	211.083
14	211.532	211.565	211.404	211.288
15	211.676	211.712	211.589	211.465

Table 3.3.4: Comparison of Story Displacement for with and without P-Delta Non-Linear Time History analysis of Model-4 in x and y-direction.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	209.329	209.329	209.426	209.401
2	209.438	209.439	209.627	209.586
3	209.572	209.572	209.845	209.784
4	209.724	209.724	210.067	209.986
5	209.890	209.889	210.287	210.185
6	210.058	210.057	210.500	210.376
7	210.264	210.262	210.713	210.565
8	210.418	210.413	210.872	210.708
9	210.600	210.595	211.067	210.884
10	210.796	210.788	211.257	211.062
11	210.995	210.985	211.466	211.264
12	211.189	211.176	211.678	211.473
13	211.378	211.363	211.892	211.685
14	211.561	211.544	212.100	211.889
15	211.717	211.698	212.277	212.062

Table 3.3.5: Comparison of Story Displacement for with and without P-Delta Non-Linear Time History analysis of Model-5 in x and y-direction.

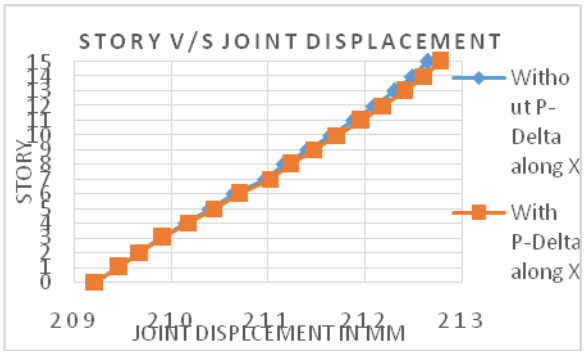

Chart 3.3.5: Story Displacement Vs Story for model-3 along X-direction by THNA with and without P-delta.

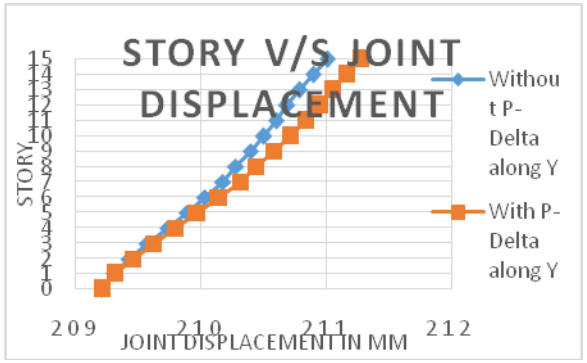

Chart 3.3.6: Story Displacement Vs Story for model-3 along X-direction by THNA with and without P-delta.

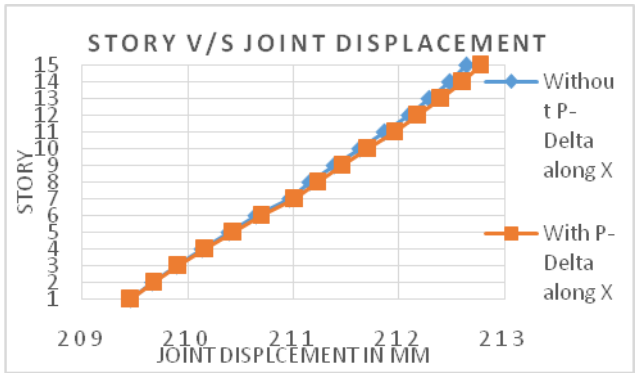

Chart 3.3.7: Story Displacement Vs Story for model-4 along X-direction by THNA with and without P-delta.

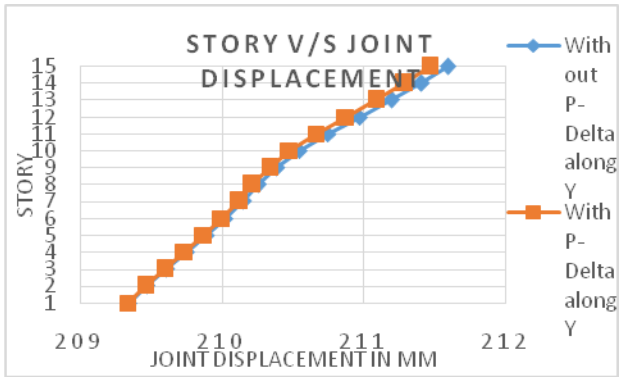

Chart 3.3.8: Story Displacement Vs Story for model-4 along Y-direction by THNA with and without P-

delta.

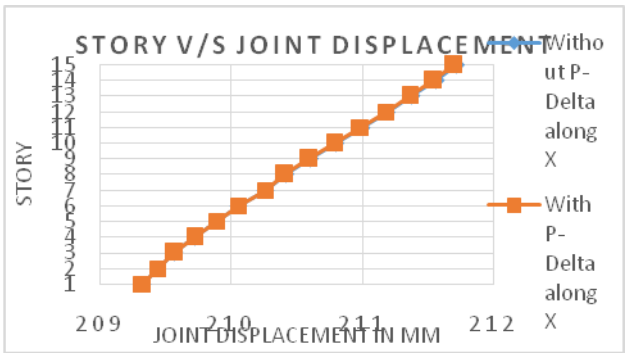

Chart 3.3.9: Story Displacement Vs Story for model-5 along X-direction by THNA with and without P-delta.

Thus it can be concluded that concrete shear wall act as drift and displacement controlled elements in RC buildings. Therefore, it can be concluded that as far as tall buildings are concerned, different types of Shear walls can be a good solution to minimize the effect of soft stories. And use of P-delta in the model is effects more for displacement values (refer tables and charts).

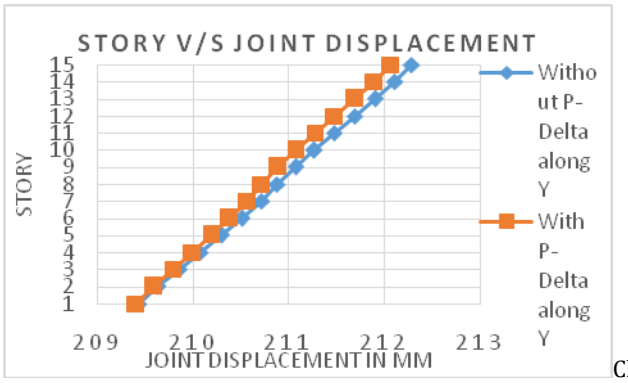

Chart 3.3.10: Story Displacement Vs Story for model-5 along Y-direction by THNA with and without P-delta.

3.4 Story Acceleration

The maximum acceleration at each floor level with respect to ground are presented in tables from 3.4.1 to 3.4.5 obtained from Non-Linear Time History Analysis along x-direction and y-direction. The acceleration value is lower for the bare frame model as compare to the other models. When masonry infill stiffness taken into consideration, Model-2 (full brick infill) shows considerable increase in story acceleration than model-1. It is observed that, the model with shear wall yields comparatively greater story acceleration which is represented in chart 3.4.1 to 3.4.10.

Hence it can be concluded that by providing shear walls at corners in X and Y direction significantly increases the story acceleration in the storys. 'L' type shear wall reduces the story acceleration compared to all other models. Andconsideration of P-delta will reduce the acceleration values in all the models.

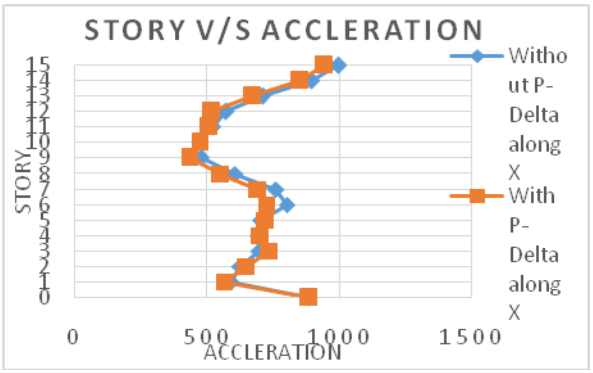

Chart 3.4.1: Story Acceleration Vs Story for model-1 along X-direction by THNA with and without P-delta.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	591.25	563.22	821.52	812.32
2	623.68	646.94	888.62	862.64
3	695.74	734.02	878.00	879.84
4	688.18	702.42	1026.46	881.8
5	699.34	719.59	1046.07	860.88
6	799.86	723.57	996.86	893.27
7	759.04	692.67	1041.48	955.3
8	605.07	551.53	1011.93	955.94
9	475.67	432.74	960.95	937.52
10	472.81	472.19	939.36	885.99
11	519.66	506.69	848.07	887.96
12	569.96	517.35	1015.53	1004.21
13	707.94	672.51	958.89	917.23
14	894.47	850.5	1246.19	1114.32
15	997.43	944.24	1484.50	1340.36

Table 3.4.1: Comparison of Story Acceleration for with and without P-Delta Non-Linear Time History analysis of Model-1 in x and y-direction

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	1705.3	1451.75	2784.01	2799.85
2	1749.62	1493.75	2834.52	2850.21
3	1775.21	1521.74	2875.79	2891.19
4	1799.42	1549.73	2912.84	2927.49
5	1821.37	1575.32	2947.38	2960.62
6	1843.62	1600.5	2979.6	2990.64
7	1874.31	1631.82	3010.75	3018.56
8	2385.78	2247.88	3095.99	3047.87
9	2405.16	2261.66	3136.23	3068.28
10	2422.11	2274.45	3176.94	3091.1
11	2438.54	2286.65	3219.04	3116.98
12	2454.43	2299.27	3262.49	3146.06
13	2470.03	2312.38	3306.79	3177.88
14	2485.08	2325.79	3352.3	3211.99
15	2499.69	2339.96	3398.25	3248.22

Table 3.4.2: Comparison of Story Acceleration for with and without P-Delta Non-Linear Time History analysis of Model-2 in x and y-direction

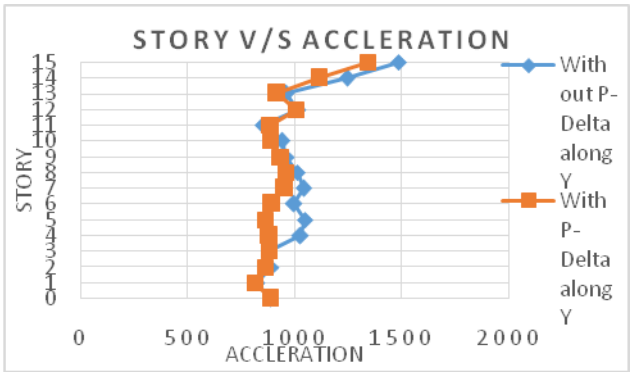

Chart 3.4.2: Story Acceleration Vs Story for model-1 along Y-direction by THNA with and without P-delta.

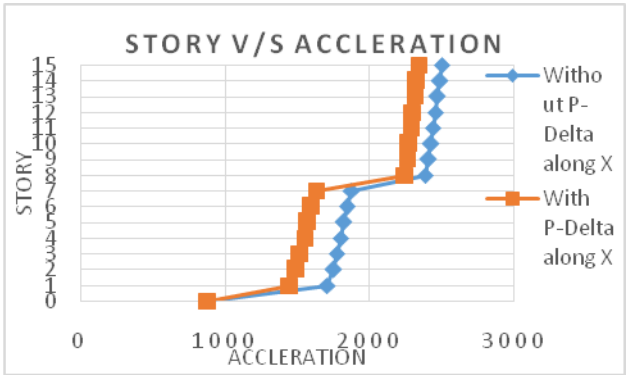

Chart 3.4.3: Story Acceleration Vs Story for model-2 along X-direction by THNA with and without P-delta.

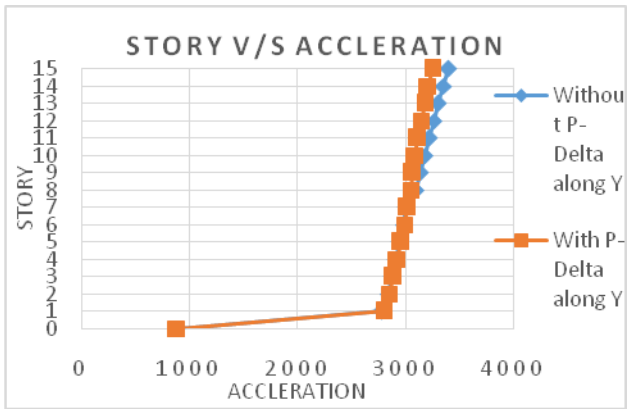

Chart 3.4.4: Story Acceleration Vs Story for model-2 along Y-direction by THNA with and without P-delta.

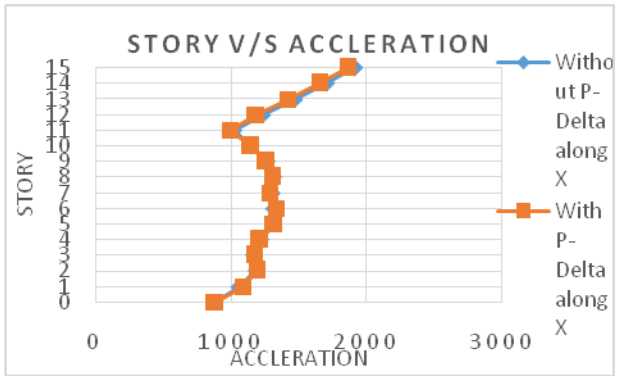

Chart 3.4.5: Story Acceleration Vs Story for model-3 along X-direction by THNA with and without P-delta.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	1065.07	1088.15	1041.79	1042.48
2	1184.81	1191.33	1223.86	1216.71
3	1162.58	1175.79	1335.02	1329.45
4	1222.07	1216.57	1188.54	1203.31
5	1317.28	1319.53	1172.79	1177.17
6	1318.9	1332.6	1288.09	1297.25
7	1304.49	1288.35	1281.5	1295.14
8	1316.69	1305.52	1213.63	1248.73
9	1268.78	1264.13	1233.91	1271.86
10	1150.91	1148.61	1139.07	1169.23
11	1022.31	996.13	993.78	989.93
12	1233.6	1187.13	1044.99	1031.87
13	1472.78	1421.42	1231.58	1224.74
14	1706.81	1654.99	1460.17	1509.05
15	1913.94	1862.17	1810.51	1859.71

Table 3.4.3: Comparison of Story Acceleration for with and without P-Delta Non-Linear Time History analysis of Model-3 in x and y-direction.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	1065.73	1077.30	1171.55	1177.18
2	1058.29	1068.29	1260.32	1269.72
3	1113.43	1124.67	1331.74	1343.82
4	1270.90	1292.63	1402.28	1421.64
5	1311.66	1319.41	1414.66	1440.58
6	1450.70	1435.23	1369.17	1398.39
7	1576.24	1565.07	1216.89	1245.36
8	1658.21	1641.37	1090.48	1111.18
9	1737.39	1717.03	1082.09	1099.38
10	1819.32	1806.83	1055.58	1077.44
11	1927.41	1921.05	987.27	1014.68
12	2093.00	2095.96	1153.88	1186.62
13	2349.45	2372.75	1413.32	1451.92
14	2695.41	2739.93	1663.11	1705.93
15	3034.78	3093.37	1924.77	1971.16

Table 3.4.4: Comparison of Story Acceleration for with and without P-Delta Non-Linear Time History analysis of Model-4 in x and y-direction.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	1107.20	1102.88	1034.67	1030.33
2	1263.00	1240.26	1170.17	1158.06
3	1605.12	1576.92	1171.42	1156.23
4	1853.08	1822.42	1149.09	1135.24
5	2047.66	2026.97	1192.08	1186.60
6	2206.70	2191.66	1130.81	1131.24
7	2206.34	2193.58	1137.61	1117.31
8	2044.42	2028.24	1090.01	1071.44
9	2126.95	2089.97	920.78	916.69
10	2198.86	2160.07	961.30	979.06
11	2088.46	2038.52	997.76	1017.99
12	2278.34	2295.84	1147.07	1125.61
13	2536.14	2568.99	1194.49	1188.06
14	3065.72	3029.34	1400.89	1390.31
15	3556.43	3497.62	1585.33	1571.64

Table 3.4.5: Comparison of Story Acceleration for with and without P-Delta Non-Linear Time History analysis of Model-5 in x and y-direction

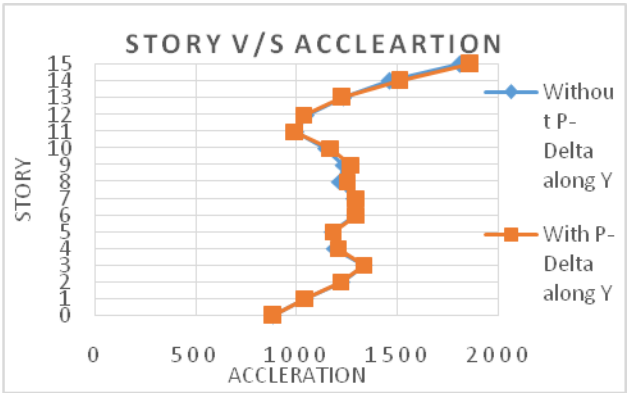

Chart 3.4.6: Story Acceleration Vs Story for model-3 along Y-direction by THNA with and without P-delta.

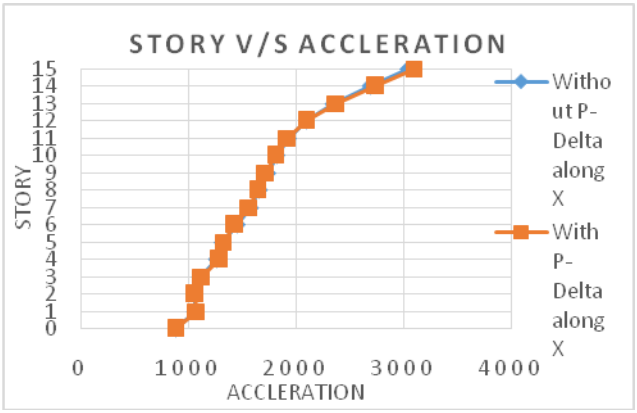

Chart 3.4.7: Story Acceleration Vs Story for model-4 along X-direction by THNA with and without P-delta.

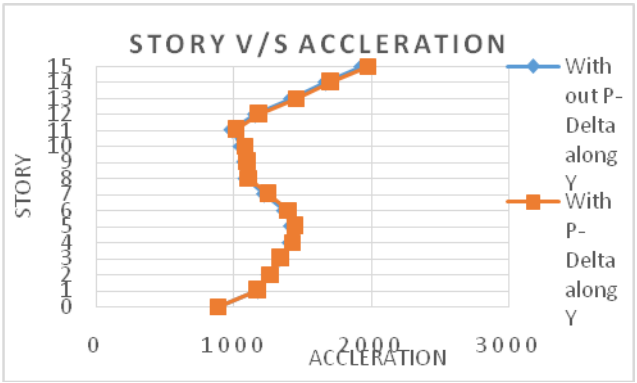

Chart 3.4.8: Story Acceleration Vs Story for model-4 along Y-direction by THNA with and without P-delta.

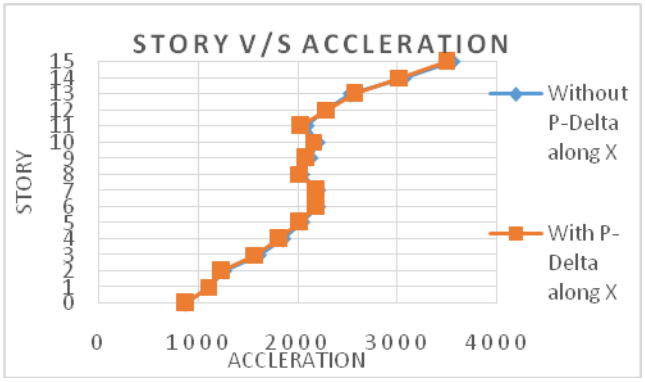

Chart 3.4.9: Story Acceleration Vs Story for model-5 along X-direction by THNA with and without P-delta.

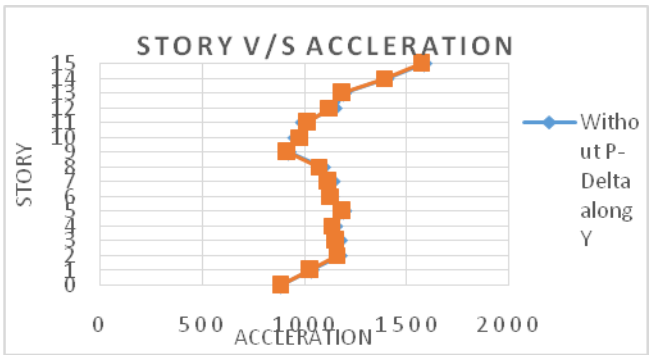

Chart 3.4.10: Story Acceleration Vs Story for model-5 along Y-direction by THNA with and without P-delta.

3.5 Seismic Base Shear

Table 3.5.1 shows comparison of highest values of seismic base shear of different models by Non-linear time history analysis using Bhuj Earthquake data. From the table it can be seen that the seismic base shear for all model-2 has larger values then model-1(bare frame).Model-2 increased by 85.9% along x-direction and 85.32% along y-direction as compared to bare frame model-1. The use of p-delta in the analysis increases the base shear value by 4.5% to 17% in longer direction and decreases 1.5% to 12% in shorter direction when compared without p-delta values.

Story No	Without P-Delta along X	With P-Delta along X	Without P-Delta along Y	With P-Delta along Y
1	13236	12353	24997	21449
2	93870	84144	131205	131828
3	29592	29488	33064	31581
4	60176	58209	32496	32810
5	78535	77176	29978	30939

Table 3.5.1: Seismic Base shear by Non-linear Time-History analysis

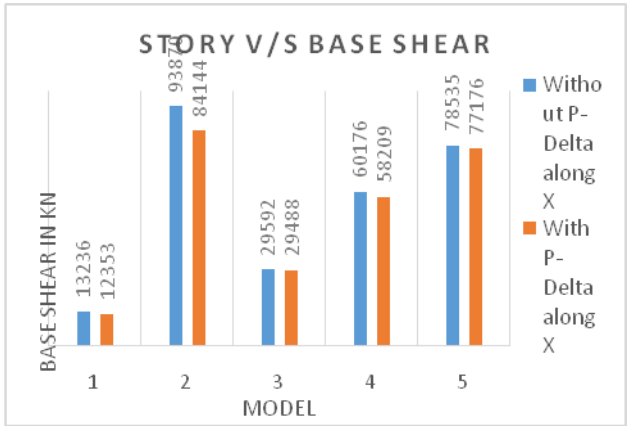

Chart 3.5.1: Model Vs Base shear for different models along x-direction by NTHA.

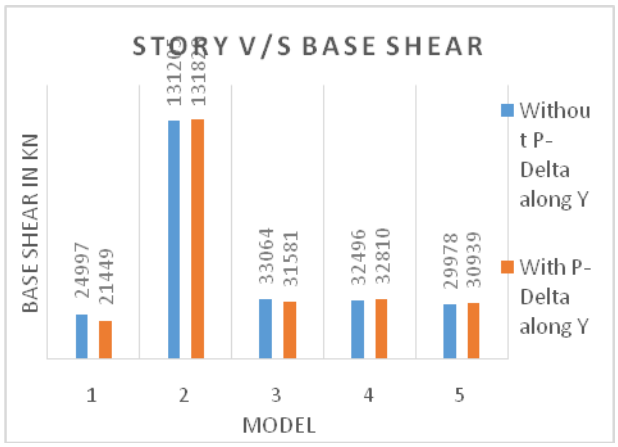

Chart 3.5.1: Model Vs Base shear for different models along y-direction by NTHA.

4. CONCLUSIONS

1) Time period of the structure increases with use of p-delta in the analysis and frequency of the structure decreases.
2) Time period decreases when the stiffness of masonry infill wall stiffness and shear wall are considered.
3) Story drift of all the storys found within the limit.
4) Story drift increases in longer direction and decreases in shorter direction when considered p-delta effect to the building. P-delta not effect more on drift, so it can be negligible.

5) Story displacement are decreases when infill wall stiffness and shear walls are considered in to the building.
6) Story acceleration are increases when infill wall stiffness and shear walls are added to the structure.
7) Base shear decreases when p-delta is considered in the building along shorter direction and increase in longer direction.
8) The soft story effect is less at intermediate location of the building. A service story of lesser height can be safer for building at higher level.
9) Models with soft stories have got highest story drift values at soft stories levels, which leads to dangerous sway mechanism. Therefore, providing shear wall is essential so as to avoid soft story failure.
10) The use of P-delta can be included in the building for the analysis and design purposes

5. REFERENCE

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