International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 07 | July 2021 www.irjet.net p-ISSN: 2395-0072

Soft Storey Mitigation Behaviour of Combined Hexa, Octa and Penta Bracing System

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Abstract - *The greatest challenge for structural engineer is to design the structure to be earthquake resistant. When a structure is designed for seismic resistance, various systems are embedded into structure so as to resist the lateral force. One of the systems adopted for resisting lateral forces, is to provide the structure with different types of bracings. There are many conventional types of bracings. Bracing is the best method to overcome soft storey effect. In this project a combined Hexa, Octa and Penta bracing system is investigated. An innovative bracing system is introduced in a G+20 building with soft storey to improve its seismic performance. G+20 building with different bracing configurations are analysed to check soft storey mitigation behaviour. To study linear and nonlinear behaviour of structure, dynamic analysis and push over analysis are performed. ETABS is used for modelling and analysing the building in this project.*

Key Words: **Bracing system, Dynamic analysis, Push over analysis, Soft storey, ETABS.**

1. INTRODUCTION

Steel structures generally need less construction time, have larger span feasibility and have better seismic resistance than reinforced concrete structures, and thereby popularity of steel structures are increasing nowadays. A Soft storey is defined as the storey in a building structure which has substantially less resistance, or stiffness, than the storeys above or below it. It has inadequate shear resistance and inadequate ductility to resist the earthquake – induced building stress. A Soft storey is one within which the lateral stiffness is smaller than 70% of storey above or less than 80% of the average lateral stiffness of the three storeys above, as per IS 1893:2002. Soft storeys may be located at top, bottom or intermediate points, so that the floor above or below may become stiffer compared to itself. In order to reduce lateral deflection, a bracing system is introduced in the structure. Bracings increase the stability of the structure by transferring lateral load sideways down to the ground and thereby preventing sway of the structure. In Seismic design of structure and in high rise structure, the provision of bracing system makes them more effective. In this project a combined Hexa, Octa and Penta bracing is introduced as shown in Fig 1, Fig 2 and Fig 3 respectively. The Main aim of the present study is to know the effect of bracings on soft storey multi-storied building. The project aims to study the overall performance of the building which different size of bracing system. Also to identify the suitable bracing system for resisting the seismic load efficiently. The simple parameters to determine the stiffness of frames are storey displacement, storey drift and storey shear. Storey displacement is defined as the displacement of a storey with respect to the base of the structure. Storey drift is the lateral displacement of one level of multi-storied building relative to the level below. The Seismic force applied at each floor level is defined as storey shear. Bracings are economical method to laterally stiffen the framed structures against wind and gravity loads. As the trend of construction of tall buildings is increasing, it is utmost importance to find cost effective bracing system.

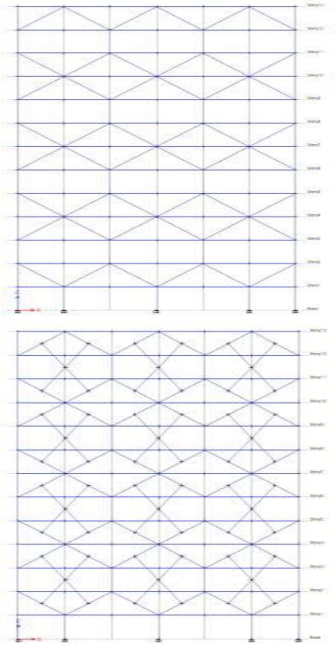


Fig-1: Elevation of Hexa, **Fig-2:** Elevation of Penta

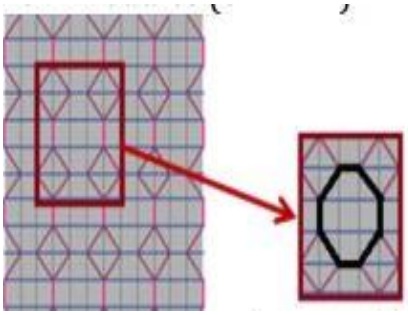


Fig-3: Octa Bracing System

1.1 Hexagrid

In the Hexagrid structure, the conventional vertical columns are eliminated. Hexagrid type structural system consists Hexagrid perimeter, manufactured of a network of multi-storey tall hex-angulated truss system. Hexagrid structure formed of intersecting the diagonal and horizontal components. And to study the structural properties of hexagonal structures and thereby to match their potential efficiency with the conventional systems.

The Hexagrid are multiple hexagonal grids at exterior perimeter surfaces of building. The Hexagrid structural system may be a particular sort of belt trusses mixed tubular system and resists it lateral loads acting in tension or compression.

1.2 Pentagrid

The Pentagrid structural system derived by smartly arranging several technically developed irregular pentagons - alternatively inverted both horizontal as well as vertical directions. This structural system developed by using multiangle concept by which all the elements share both gravity as well as lateral loads partially. Unlike most of other structural systems, this structural system is non nature inspired but it is technically devised by applying mathematics thereby it is able to resists both shear force and bending moment which are developed in the structure, due to gravity as well as lateral loads

1.3 Octagrid

The Octagrid are of multiple hexagonal grids at the exterior perimeter surfaces of building structure. Octagrid formed by intersecting the diagonal and horizontal components it is technically developed by arranging several octagons. It is able to resist lateral loads acting in tension and compression.

1.4 Objectives

The objectives of the project are,

- To study the performance of unbraced multi-storey building.
- To study the performance of multi-storey steel building with different configuration of bracing systems and to identify the effective bracing system.
- To study the seismic performance of the effective bracing system with soft storey at different levels.
- To study the performance of combined bracing system in a steel building with soft storey effect.
- The study focusses on finding building displacement, drift, base shear, time period and natural frequency.

1.5 Scope

The scope of the project is to investigate the seismic performance of combined bracing system in a multi-storey building with soft storey effect.

2. METHODOLOGY

A G+20 storeyed building of different bracing configurations is drawn and analysed using software ETABS. As per the details given below the multi-storey buildings is drawn. Figure 4 represents the detailed elevation of the Bare frame.

2.1 Salient Features and Dimensions of Building

Dimensions:

All measurements are centre line;

Height of Basement level : 3.65m

Height of Ground level : 5.49m

Height of 1^{st}-19^{th} level : 3.96m

Bay widths (all) : 6.10m

Seismic mass:

Ground level : 5.32×10^5 kg

1^{st} floor level : 5.63×10^5 kg

2^{nd}-19^{th} floor level : 5.52×10^5 kg

20^{th} floor level : 5.84×10^5 kg

Entire structure (above ground): 1.11×10^7 kg

Beams:

B-2 – 4th floor level	W30x99
5th – 10th floor level	W30x108
11th – 16th floor level	W30x99
17th – 18th floor level	W27x84
19th floor level	W24x62
20th floor level	W21x50

Columns:

Column sizes change at splices, corner columns and interior columns the same size, throughout elevation; box columns are ASTM A500 (15x15 indicates a 0.38m (15 in) square box column with wall thickness of t).

Restraints:

Columns pinned at base; structure laterally restrained ground level.

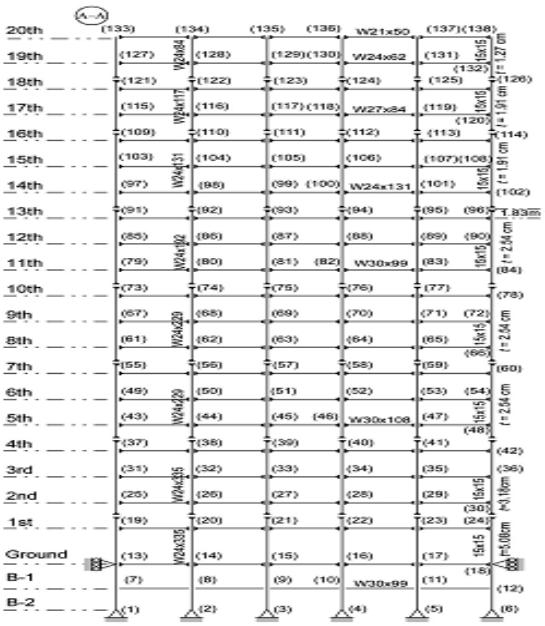


Fig -4: Elevation of Multi-Storey Building

2.2 ETABS Software

ETABS indicate Extended Three-Dimensional Analysis of Building System. ETABS is a 3 Dimensional modelling software for any kind of structural analysis and design. Using this we can analyse both steel structure and RC Structure. It is an engineering software which is used in construction field. Static and dynamic analysis of multi-storey frame is acclaimed highly. It's the popular civil designing tools used in the building industry and increases the productivity of structural engineers. It prevents the investment of unnecessary time and money.

3. MODELLING

G+20 building with and without braces is modelled using ETABS. Bracing is one of the best method used to overcome soft storey effect. Bracing is provided for the reduction of lateral deflection. The bracing system gives best result in lateral stiffness, strength capacity as well as in displacement capacity. The soft storeys are given at higher, because it give safe and best result. A soft storey has inadequate shear resistance or inadequate ductility or energy absorption capacity to resist earthquake induced building stress.

The Models considered in this project are,

Model 1: Multi-storey building without bracing system

Model 2: Multi-storey building with Hexa braced system

Model 3: Multi-storey building with Octa braced system

Model 4: Multi-storey building with Penta braced system

Model 5: Exterior Hexa Penta (HP) braced multi-storey building

Model 6: Exterior Penta Hexa (PH) braced multi-storey building

Model 7: Exterior Penta-Hexa-Penta (PHP) braced multi-storey building

Model 8: Exterior Hexa-Penta-Hexa (HPH) braced multi-storey building

Model 9: Exterior x axis Penta- y axis Hexa (XP-YH) braced building

Model 10: Exterior Penta corner braced multi-storey building

Model 11: Exterior Penta middle braced multi-storey building

Model 12: Interior Penta-Hexa-Penta just inside the periphery of building

Model 13: Interior Penta-Hexa-Penta just inside the periphery of building and corner

Model 14: Interior Penta-Hexa-Penta at corner and inside of building

Model 15: Interior Penta-Hexa-Penta at parallel position

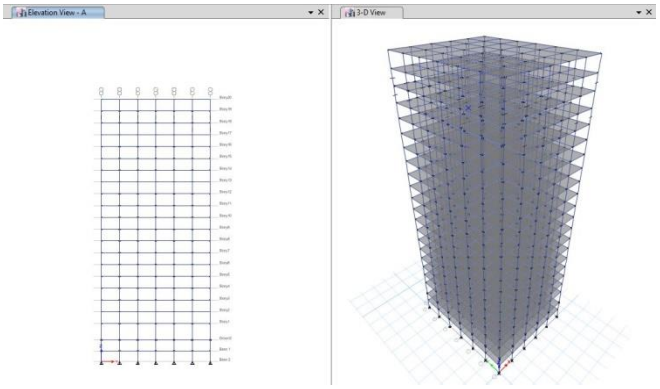


Fig-5: Elevation and 3D view of Model 1

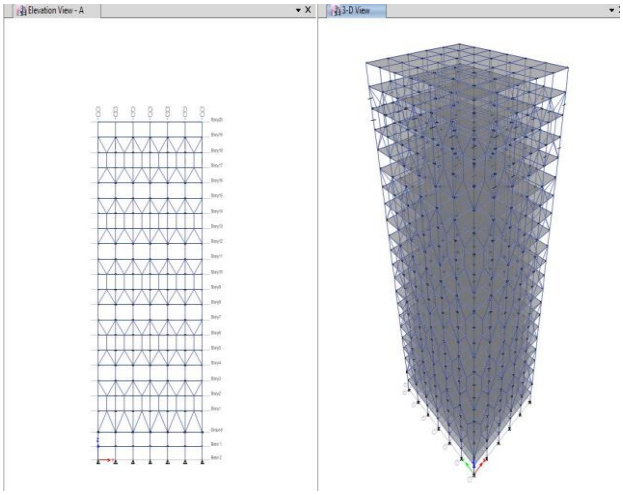


Fig-6: Elevation and 3D view of Model 2

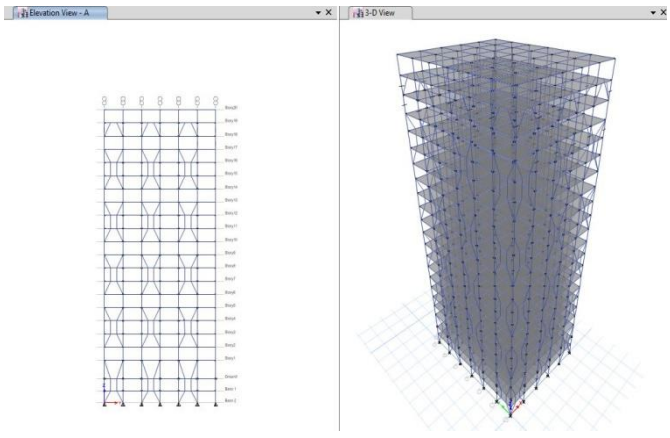


Fig-7: Elevation and 3D view of Model 3

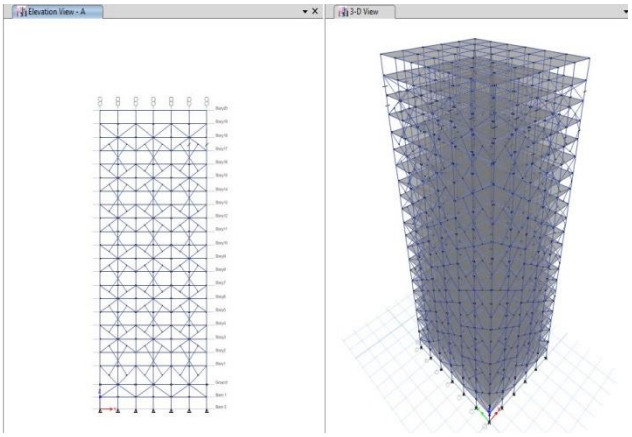


Fig-8: Elevation and 3D view of Model 4

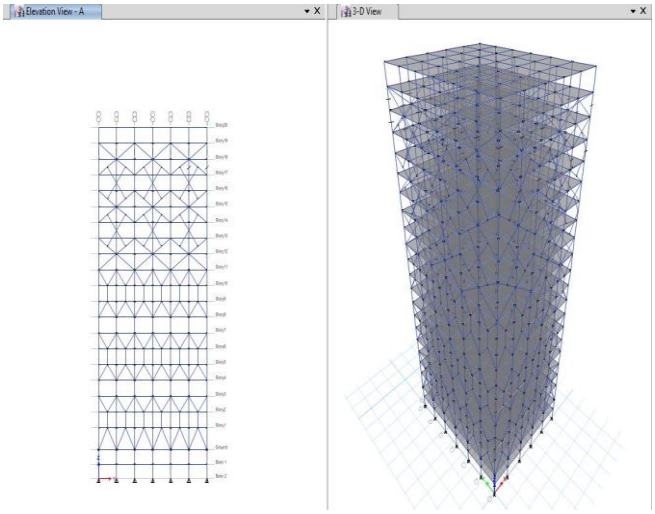


Fig-9: Elevation and 3D view of Model 5

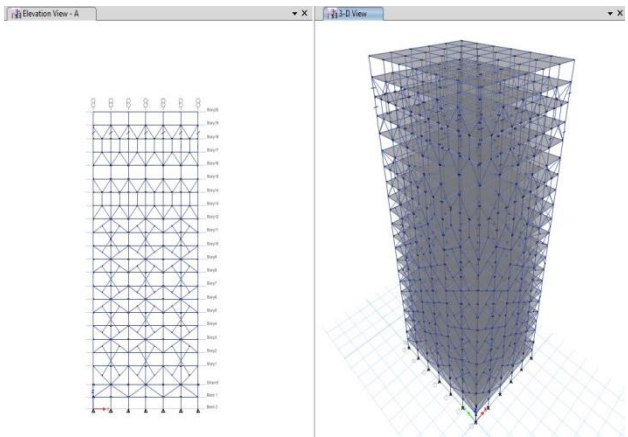


Fig-10: Elevation and 3D view of Model 6

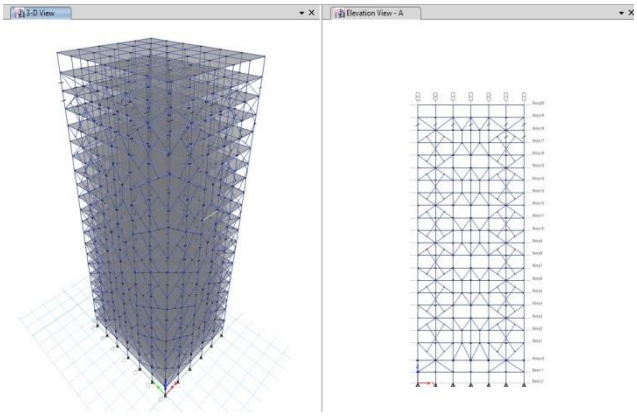


Fig-11: Elevation and 3D view of Model 7

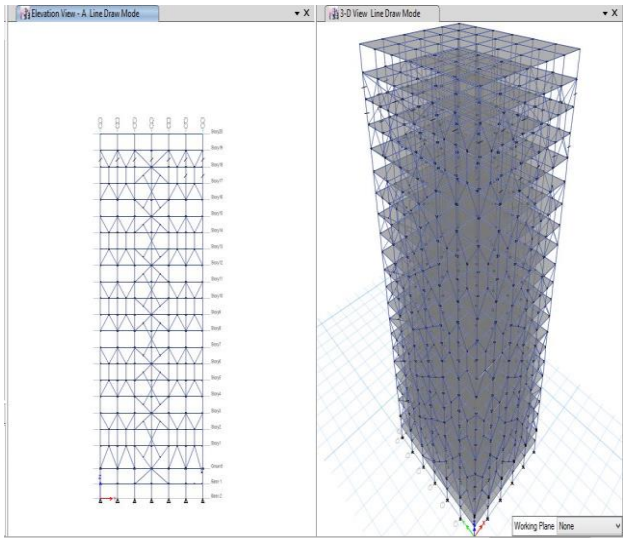


Fig-12: Elevation and 3D view of Model 8

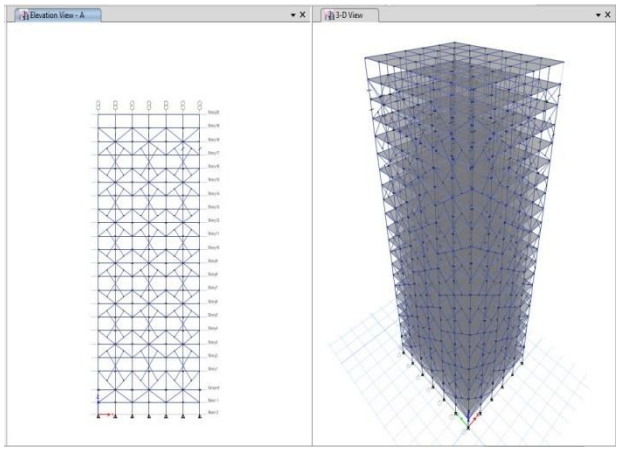


Fig-13: Elevation and 3D view of Model 9

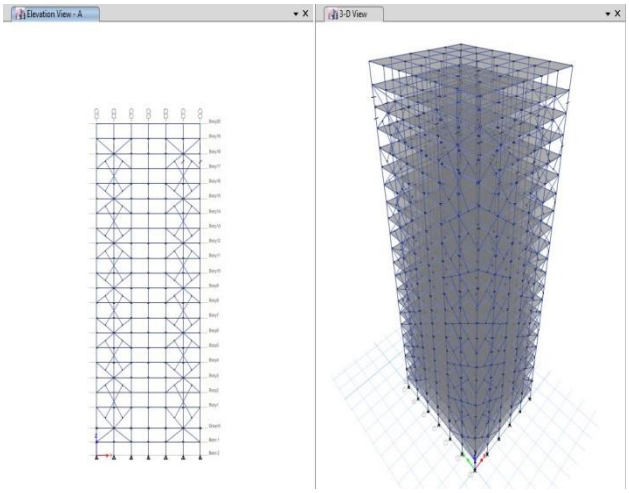


Fig-14: Elevation and 3D view of Model 10

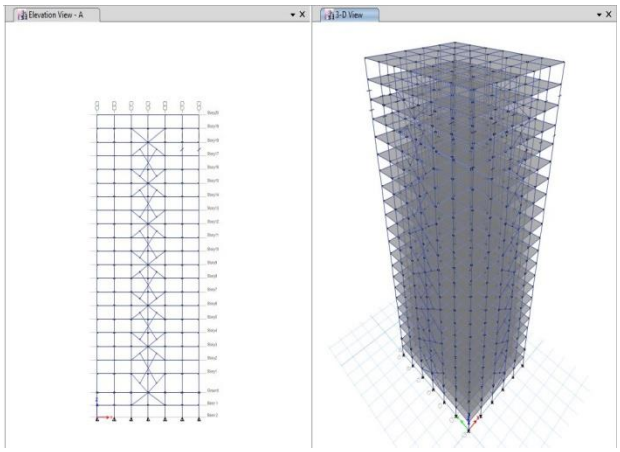


Fig-15: Elevation and 3D view of Model 11

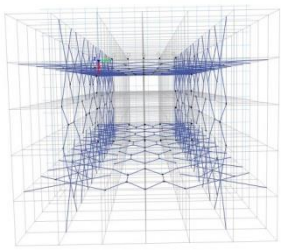


Fig-16: 3D view of Model 12

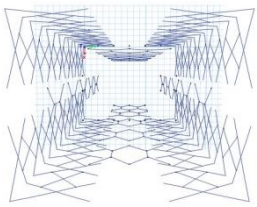
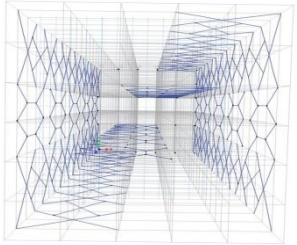


Fig-17: 3D view of Model 13



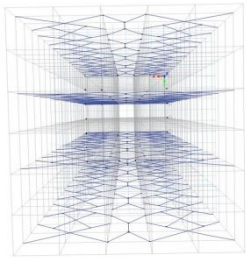


Fig-18: 3D view of Model 14 **Fig-19:** 3D view of Model 15

After the modelling of building, the material and frame properties are defined. Model 1, Model 2, Model 3, Model 4 are under different bracing configuration; in Model 5 and Model 6 bracings are provided at different storey; in Model 7, Model 8 and Model 9 bracings are varied at different bays; in Model 10, Model 11 position of bracing is varied and Model 12, Model 13, Model 14, Model 15 have interior bracing. All others are exterior bracing.

4. ANALYSIS

ETABS software was used to develop the 14 models. Modal analysis is performed to get the information regarding different modes of vibration, different shape that can be taken up by structure during vibration. For the evaluation of seismic response of frames under seismic loading in case of time history analysis or dynamic analysis, frames were subjected to earthquake ground acceleration of El-Centro. Details of El-centro earthquake are downloaded from the site peer.berkeley.edu. Before the dynamic analysis El-centro details are to be added to time history function definition file shown in Fig 20. Pushover analysis, the simplest method performed to evaluate the performance of structures in terms of structure displacement-base shear curves, yield and failure points.

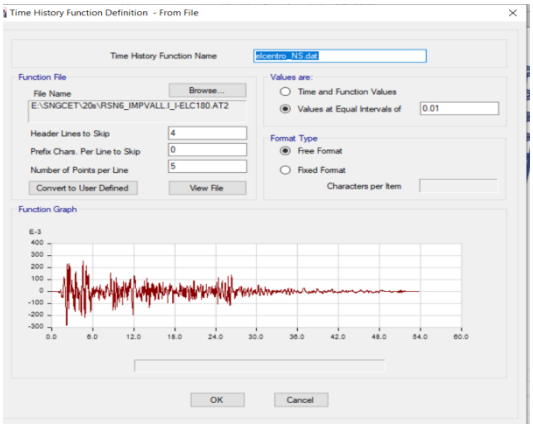


Fig -20: Defining Time History Function

The values of storey drift that is the inter storey displacement for two consecutive floors, displacement and storey shear obtained from analysis are tabulated.

After the analysis of Bare, Hexa, Penta and Octa braced multi-storey building, displacement and drift values of each storey level is obtained and are provided in Table 1 to Table 4. Table 5 compare the performance of Penta, Hexa, Octa and Bare frame model. It is found that exterior Penta braced multi-storey building is more effective. Thus Penta and Hexa bracing are selected for the combined bracing system. Selection of effective bracing system and Combined modelling of best two bracing system by,

- varying storeys
- varying bays
- varying position

Table -1: Displacement and Drift values of Bare Frame

BARE FRAME					
	X			Y	
Storey No	Displacement (mm)	Drift	Storey No	Displacement (mm)	Drift
20	154.19	0.000423	20	154.449	0.000727
19	153.953	0.000629	19	154.83	0.000571
18	152.787	0.000574	18	153.769	0.000565
17	151.126	0.000751	17	152.543	0.000859
16	148.889	0.001017	16	150.506	0.001012
15	145.661	0.00129	15	147.261	0.001172
14	141.157	0.001559	14	142.76	0.001451
13	135.398	0.001443	13	137.025	0.001354
12	130.022	0.001639	12	131.746	0.001564
11	123.726	0.001832	11	125.555	0.001777
10	116.585	0.002026	10	118.516	0.001993
9	108.598	0.002222	9	110.629	0.002202
8	99.799	0.002407	8	101.915	0.002395
7	90.268	0.00257	7	92.437	0.002568
6	80.093	0.002708	6	82.27	0.00272
5	69.37	0.002832	5	71.5	0.002862
4	58.159	0.00245	4	60.173	0.002468
3	48.459	0.002492	3	50.402	0.002529
2	38.589	0.002548	2	40.389	0.002606
1	28.511	0.005193	1	30.089	0.005478
0	0.151	0.000158	0	0.171	0.000157
-1	0.575	0.000158	-1	0.537	0.000147
-2	0	0	-2	0	0

Table -2: Displacement and Drift values of Hexa Frame

HEXA BRACE					
	X			Y	
Storey No	Displacement (mm)	Drift	Storey No	Displacement (mm)	Drift
20	112.457	0.00077	20	103.571	0.00074
19	112.37	0.000914	19	103.091	0.000597
18	111.208	0.000879	18	101.587	0.000565
17	109.796	0.001576	17	99.57	0.001292
16	107.569	0.002096	16	96.75	0.001948
15	104.534	0.001169	15	93.799	0.000961
14	100.605	0.001267	14	90.538	0.001156
13	95.872	0.001823	13	85.959	0.001653
12	91.651	0.003439	12	81.295	0.003109
11	86.773	0.001395	11	76.622	0.001321

10	81.296	0.001604	10	71.846	0.001502
9	75.332	0.00233	9	66.182	0.002074
8	68.902	0.005031	8	59.662	0.004471
7	62.028	0.001853	7	53.331	0.00168
6	54.77	0.002218	6	47.099	0.001999
5	47.27	0.002654	5	40.31	0.002307
4	39.557	0.005238	4	32.993	0.004646
3	33.02	0.001674	3	27.299	0.001433
2	26.392	0.002449	2	22.028	0.00217
1	19.638	0.003576	1	16.357	0.002979
0	0.075	0.000118	0	0.092	0.000101
-1	0.464	0.000127	-1	0.386	0.000106
-2	0	0	-2	0	0

Table -3: Displacement and Drift values of Penta Frame

PENTA BRACE					
	x			y	
Storey No	Displacement (mm)	Drift	Storey No	Displacement (mm)	Drift
20	84.764	0.000643	20	33.608	0.000552
19	86.001	0.000637	19	35.138	0.000535
18	85.948	0.000636	18	35.275	0.000402
17	85.186	0.000486	17	35.001	0.000303
16	84.451	0.000587	16	35.588	0.000362
15	83.477	0.000786	15	35.463	0.000288
14	80.516	0.000782	14	34.395	0.000317
13	77.431	0.000771	13	33.302	0.00035
12	74.645	0.001068	12	32.356	0.000468
11	70.424	0.001104	11	30.6	0.000515
10	66.062	0.001181	10	28.257	0.000592
9	61.516	0.001444	9	25.946	0.000673
8	55.807	0.001454	8	23.637	0.000692
7	50.058	0.001475	7	20.915	0.000723
6	44.233	0.001657	6	17.808	0.00075
5	37.679	0.001617	5	14.923	0.000731
4	31.282	0.001409	4	12.204	0.000646
3	25.706	0.00146	3	9.603	0.000621
2	19.925	0.001518	2	7.046	0.000696
1	13.96	0.002539	1	4.778	0.000867
0	0.27	0.000176	0	0.153	0.000101
-1	0.54	0.000148	-1	0.305	8.30E-05
-2	0	0	-2	0	0

Table -4: Displacement and Drift values of Octa Frame

OCTA BRACE

	X			Y	
Storey No	Displacement (mm)	Drift	Storey No	Displacement (mm)	Drift
20	138.538	0.001175	20	112.467	0.000736
19	135.75	0.001896	19	112.181	0.000862
18	131.766	0.001336	18	109.482	0.000892
17	127.957	0.001154	17	107.531	0.00081
16	123.76	0.001281	16	105.481	0.000899
15	118.724	0.001872	15	102.168	0.001158
14	113.174	0.003124	14	97.602	0.002549
13	107.873	0.001467	13	92.783	0.001124
12	103.047	0.001593	12	88.779	0.001261
11	97.564	0.002031	11	83.81	0.001483
10	91.496	0.003784	10	78.286	0.003212
9	84.872	0.001876	9	72.885	0.001608
8	77.682	0.001963	8	67.202	0.001704
7	70.019	0.002313	7	60.72	0.001863
6	61.956	0.004812	6	53.495	0.004359
5	53.573	0.002195	5	46.325	0.001907
4	44.882	0.001941	4	39.073	0.001815
3	37.47	0.002129	3	32.694	0.001702
2	29.951	0.004644	2	25.958	0.004287
1	22.302	0.004062	1	19.435	0.003539
0	0.104	0.000102	0	0.112	8.60E-05
-1	0.3	8.20E-05	-1	0.229	6.30E-05
-2	0	0	-2	0	0

From the result of combined bracing system shown in Table 5, PHP exterior braced model is better and exhibit smaller storey displacement and drift values than other exterior braced models. PHP model has got less time period and weight than penta model. PHP exterior braced model showed 42.47% decrease in dispalcement than other models. Thus model M7 is considered as the most effective model.

Placing PHP brace in interior in different ways as M12, M13, M14, M15 as shown in Fig 16 to Fig 19. Interior PHP M12 model performed better than other. The model exhibits low storey displacement and drift value in both x and y direction. M12 configuration controls the displacement. M12 model has got 86% decrease in displacement than M13, M14 and M15 shown in Table 8. M12 model percentage decrease in displacement for M12 model is 86.92%, whereas exterior PHP braced model has 42.47%.The weight of M1 and PHP is almost similar. Comparing exterior PHP braced model and interior braced model M12, M12 model had better performance, in terms of displacement, base shear and drift.

Table -5: Comparison different configuration of exterior braces

Model ID	Braces	Weight (kN)	% Decrease in Displacement	% Increase in Weight

M1	BARE	13395			M7	PHP	16937	42.47357157	26.4427025
M2	HEXA	16242	27.06595758	21.25419933	M8	HPH	16673	26.92781633	24.47181784
M3	OCTA	15175	10.15111226	13.2885405	M9	XP-YH	16724	30.48187301	24.85255692
M4	PENTA	17220	45.02626629	28.55543113	M10	P CRNR	16177	38.85465984	20.76894364
M5	H P	16601	30.5921266	23.93430384	M11	P MID	14438	21.67455736	7.786487495
M6	P H	17051	32.22647383	27.29376633					

Table -6: Comparison of different configuration of exterior bracing models

	Braces		Displacement (mm)		Base Shear (kN)		Drift		Time Period (s)	
			X	Y	X	Y	X	Y	X	Y
Different Bracing Configuration	M1	BARE	154.19	154.449	1570	1688	0.0076	0.0079	3.957	3.931
	M2	HEXA	112.457	103.571	1934	1896	0.0052	0.0046	2.942	2.869
	M3	OCTA	138.538	112.467	1899	1897	0.0043	0.0048	3.14	2.811
	M4	PENTA	84.764	33.608	2036	878	0.0025	0.0008	3.57	3.53
Bracing Varying @ Storeys	M5	H P	107.02	103.95	2041	2090	0.0053	0.0055	3.257	3.052
	M6	P H	104.5	64.12	2690	2099	0.0037	0.0022	3.521	3.458
Bracing Varying @ Bays	M7	PHP	88.7	45.02	2071	1167	0.0025	0.0011	3.416	3.38
	M8	HPH	112.67	78.54	2535	2293	0.0045	0.0027	3.367	3.188
	M9	XP-YH	107.19	116.04	1751	1758	0.0057	0.0062	3.587	3.511
Bracing Varying@ Position	M10	P CRNR	94.28	70.67	1787	1577	0.003	0.0022	3.654	3.641
	M11	P MID	120.77	82.095	1740	1180	0.0036	0.0021	3.912	3.83

Table -7: Comparison of different configuration of interior PHP bracing models

Model ID	Displacement (mm)		Base Shear (kN)		Drift		Time peiod (s)	
	X	Y	X	Y	X	Y	X	Y
M12	20.16	15.67	354.14	335.91	0.0006	0.00048	3.639	3.591
M13	104.23	78.79	2201.55	1874.86	0.0029	0.0031	3.506	3.466
M14	56.19	28.8	1111.14	528.76	0.0018	0.0011	3.657	3.41
M15	14.53	190.76	194.48	2368.98	0.00045	0.00666	3.765	3.432

Table -8: Comparison of different configuration of interior PHP braces

	Weight (KN)	% DECREASE IN DISPLACEMENT	% INCREASE IN WEIGHT

M12	16950	86.92	26.54
M13	16951	32.4	26.55
M14	16594	63.55	23.88
M15	16686	90.57	24.56

5. RESULT AND DISCUSSION

The outcomes obtained from ETABS after evaluating the models and results have been specified in tables and figures.

5.1 Different Bracing Configuration

After the analysis of Bare, Hexa, Octa and Penta braced multistorey building, the simple parameters used to determine the stiffness of frame like displacement, drift, baseshear, time period are evaluated. Storey displacement is the displacement of a storey with respect to the base of a structure and Storey drift is the lateral displacement of one level of multi-storied building relative to the level below. Storey displacement and drift of bare, Hexa, Octa, Penta braced frame in both x and y direction are graphically represented in chart 1to chart 4.

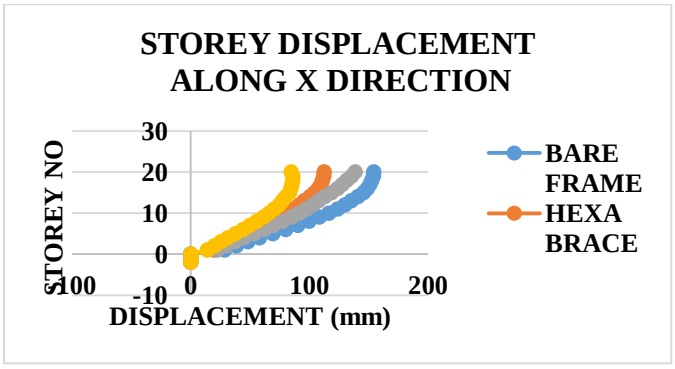


Chart -1: Storey displacement along X direction

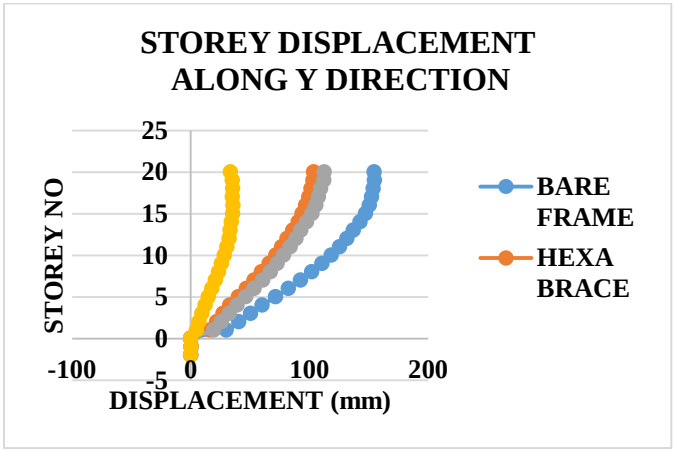


Chart -2: Storey displacement along Y direction

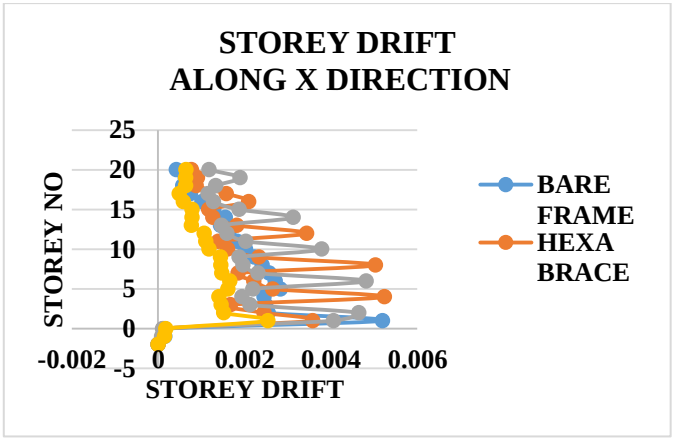


Chart -3: Storey drift along X direction

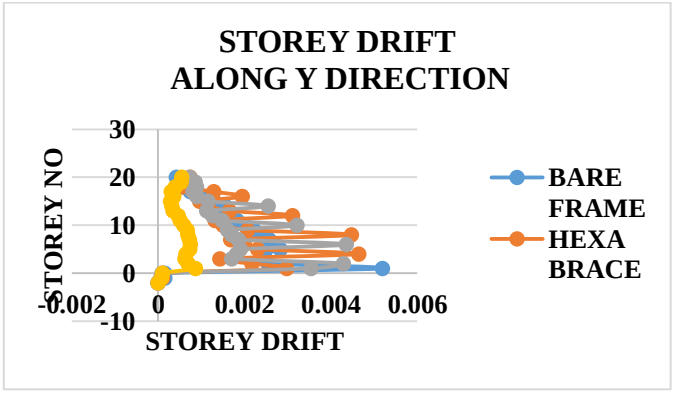


Chart -4: Storey drift along Y direction

It was observed that, from different bracing configuration model, Penta braced multi-storey building performed better than Hexa, Octa and Bare frame model. Penta braced model exhibited low displacement and drift around 45%. decrease in displacement was observed in Penta braced model.. Hence, for the combined braced system, the combination of the best two systems as Hexa and Penta were taken. Selection of effective bracing system and Combined modelling of best two bracing system by varying storeys, varying bays and varying position was carried out.

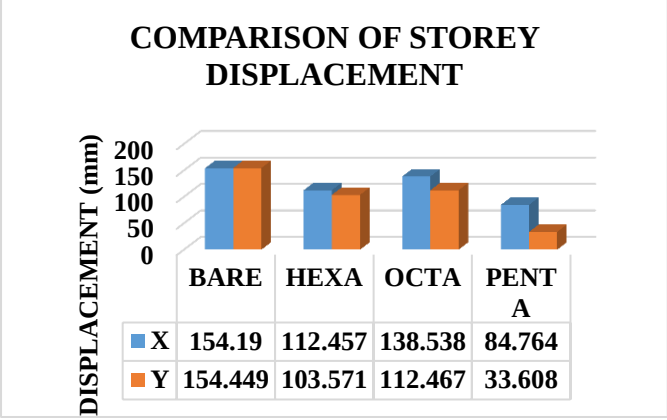


Chart -5: Comparison of storey displacement

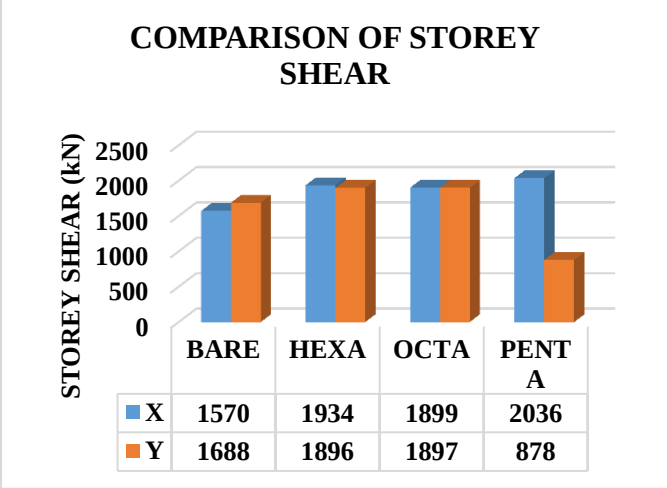


Chart -6: Comparison of storey shear

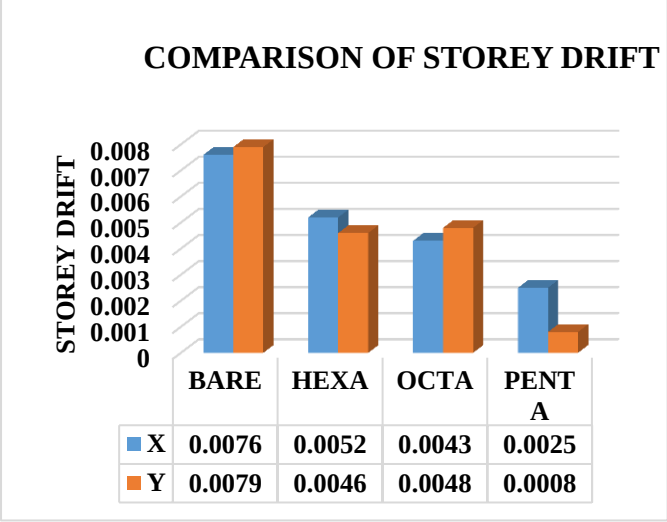


Chart -7: Comparison of storey drift

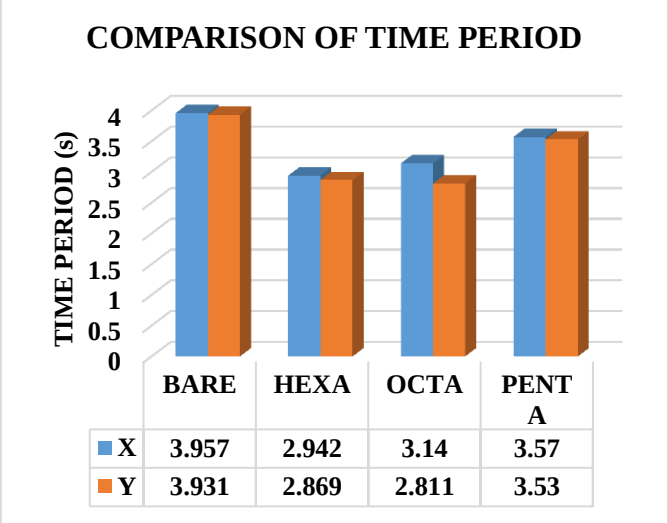


Chart -8: Comparison of time period

5.2 Bracing Varying At Storeys

In bracing varying at storeys, diplacement,drift, storey shear and time period obtained after analysis are graphically plotted. PH model performed better HP. It has got low values of storey displacement and drift in both x and y direction. PH model showed 32 % decrease in displacement than HP.

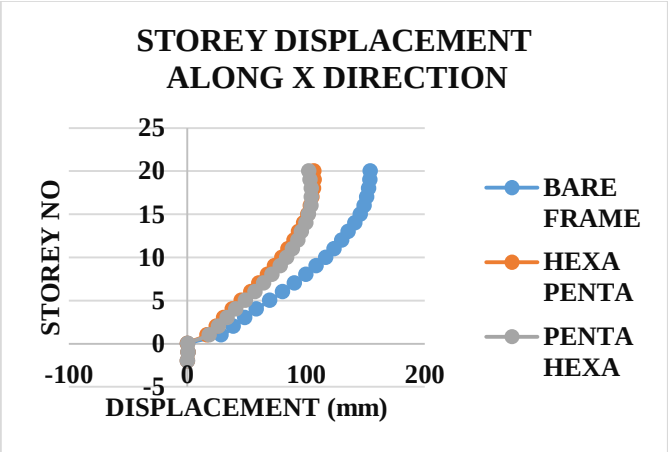


Chart -9: Storey displacement along X direction

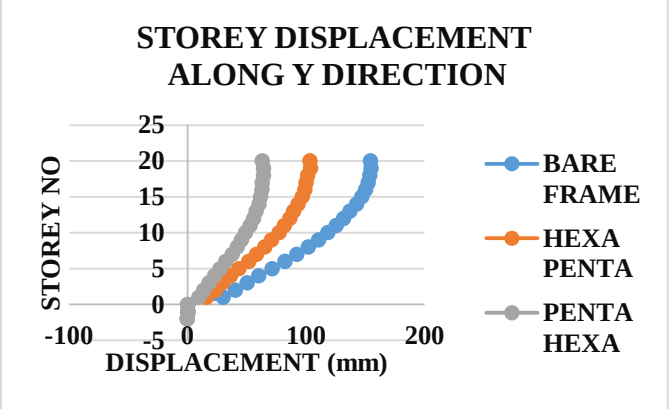


Chart -10: Storey displacement along Y direction

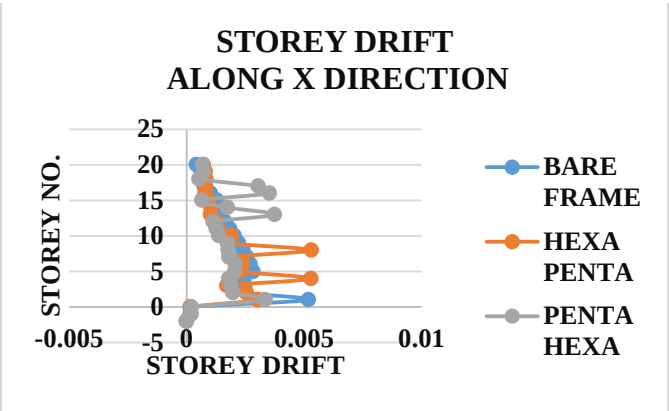


Chart -11: Storey drift along X direction

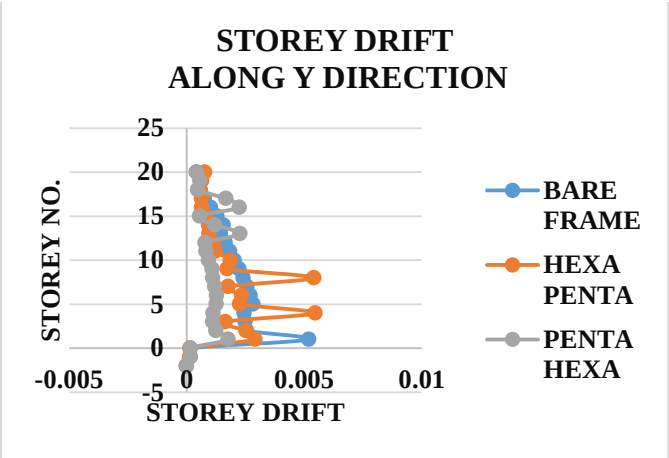


Chart -12: Storey drift along Y direction

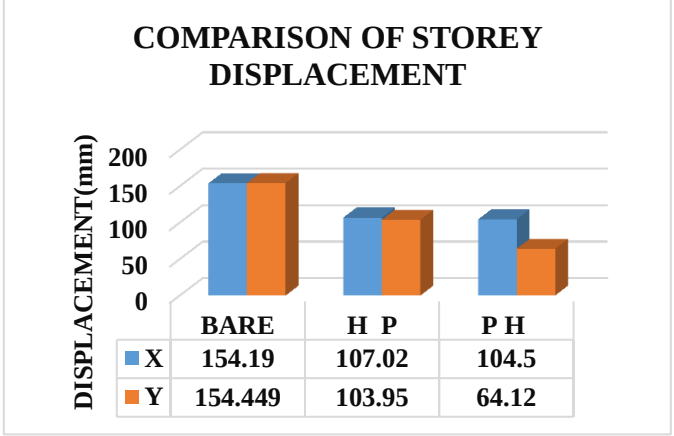


Chart -13: Comparison of storey displacement

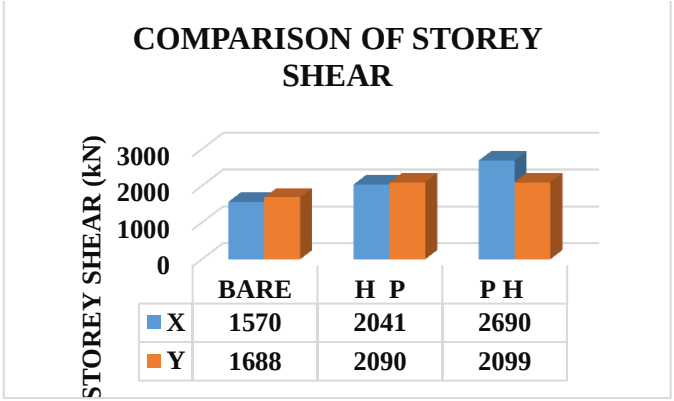


Chart -14: Comparison of storey shear

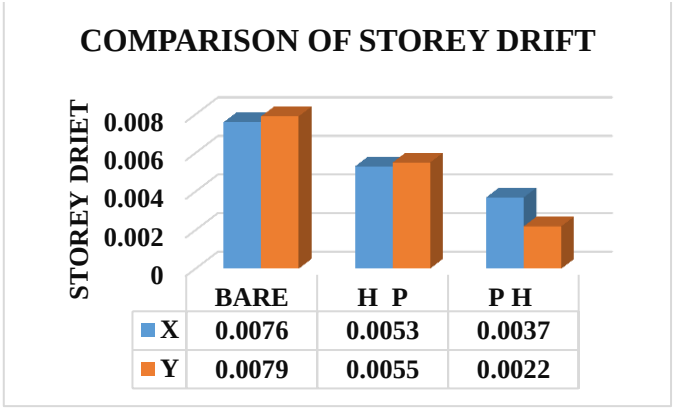


Chart -15: Comparison of storey drift

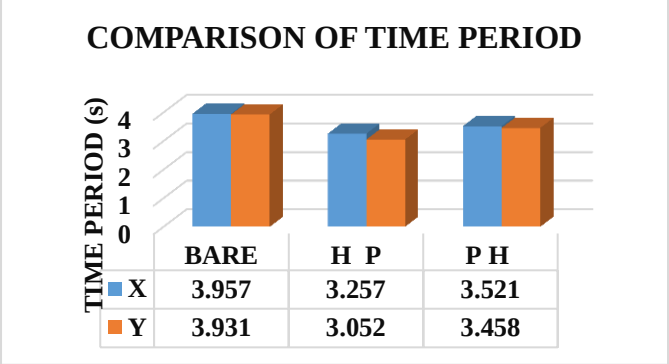


Chart -16: Comparison of time period

5.3 Bracing Varying At Bays

In bracing varying at bays, parameters obtained after the analysis is plotted in graph shown in chart 17 to chart 20.

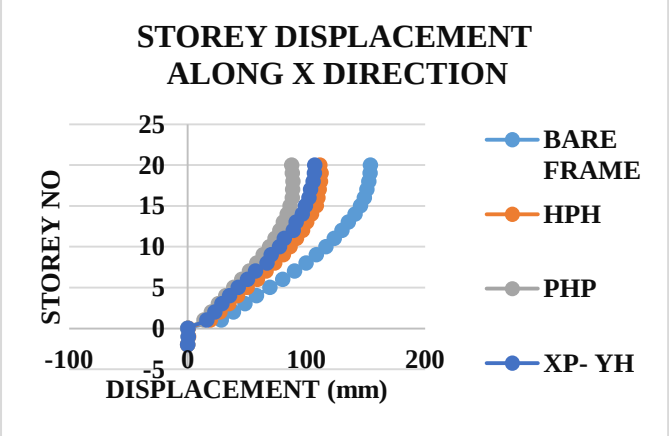


Chart -17: Storey displacement along X direction

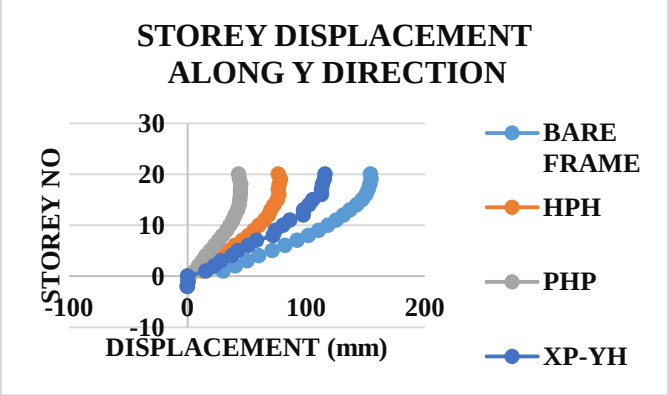


Chart -18: Storey displacement along Y direction

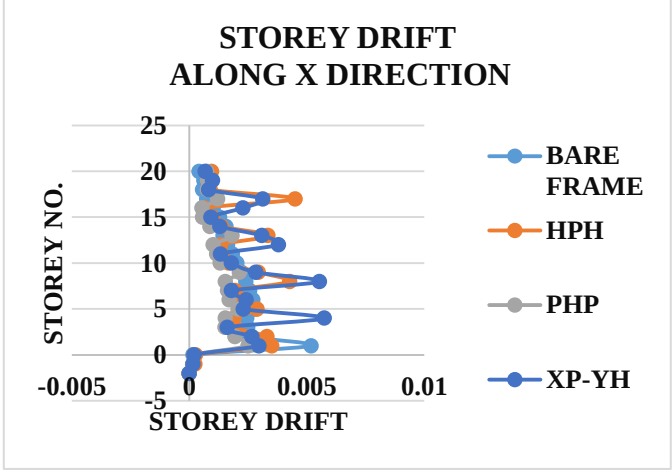


Chart -19: Storey drift along X direction

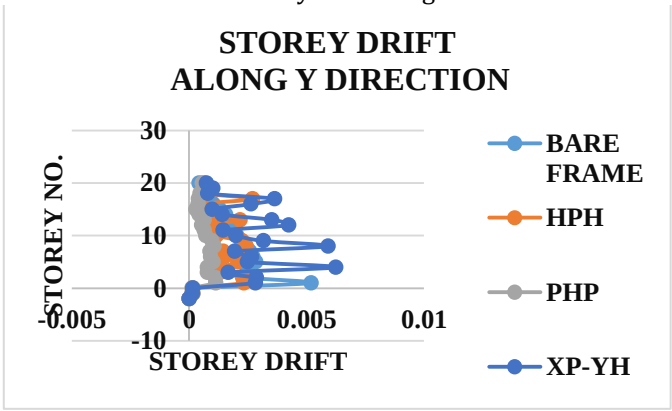


Chart -20: Storey drift along Y direction

In bracing varying at bays, PHP model is better than HPH model. It shows low displacement and drift values in both x and y directions. Also it has 42% decrease in displacement. PHP model has got less time period and weight than penta model.

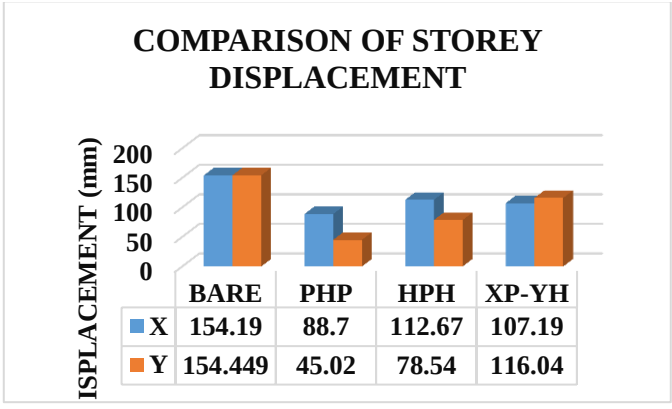


Chart -21: Comparison of storey displacement

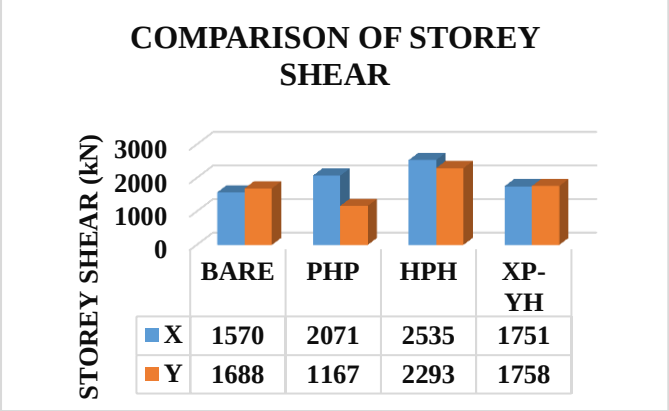


Chart -22: Comparison of storey shear

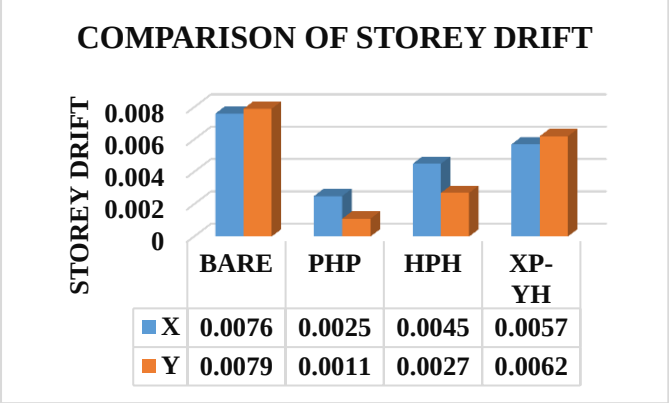


Chart -23: Comparison of storey drift

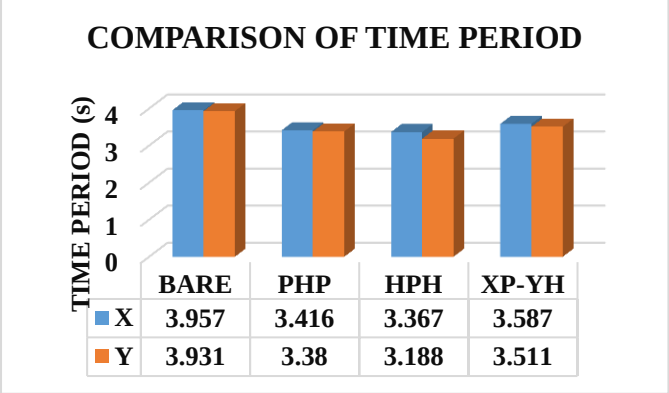


Chart -24: Comparison of time period

5.4 Bracing Varying At Position

In bracing varying at position, diplacement, drift, storey shear and time period obtained after analysis are graphically plotted in chart 25 to chart 28. Penta corner is performed better than other model. It showed low drift, displacement, time period than penta middle model. Penta corner model have 38% lesser displacement than penta middle.

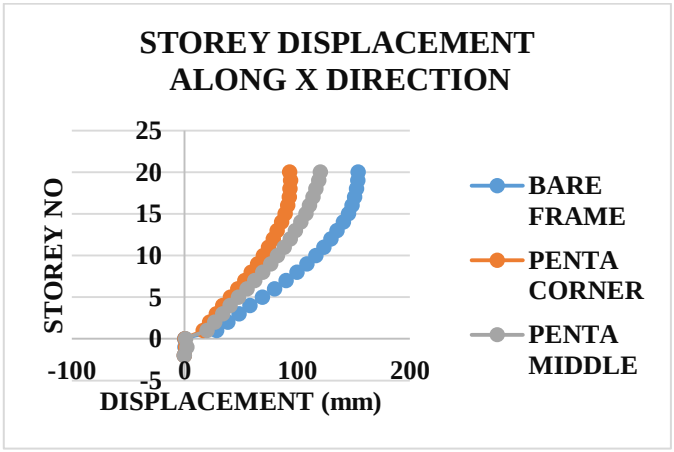


Chart -25: Storey displacement along X direction

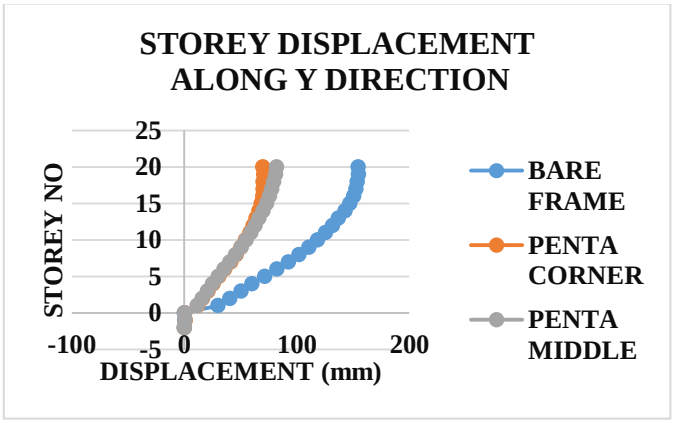


Chart -26: Storey displacement along Y direction

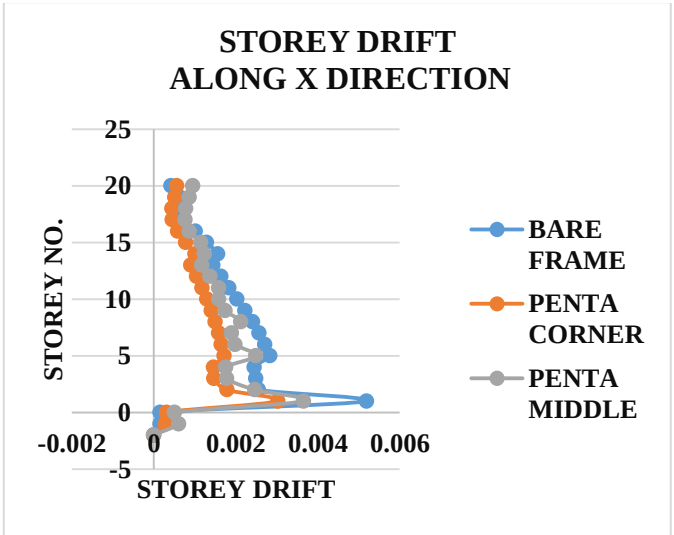


Chart -27: Storey drift along X direction

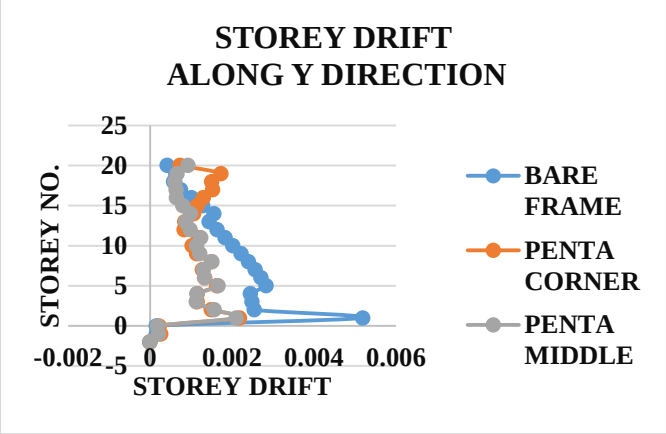


Chart -28: Storey drift along Y direction

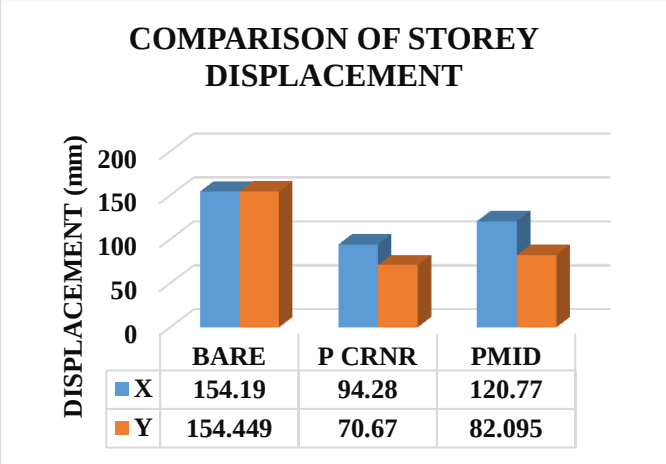


Chart -29: Comparison of storey displacement

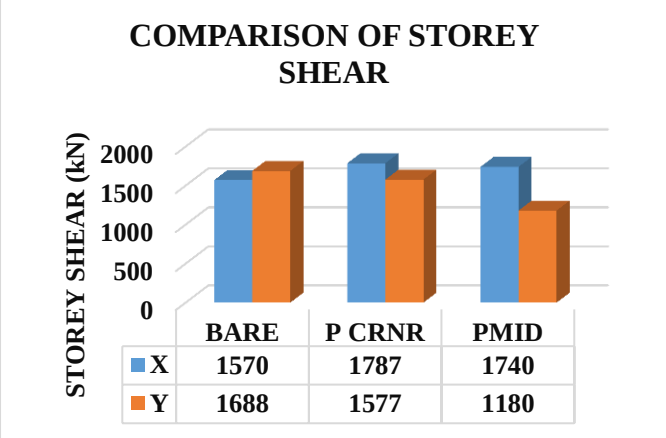


Chart -30: Comparison of storey shear

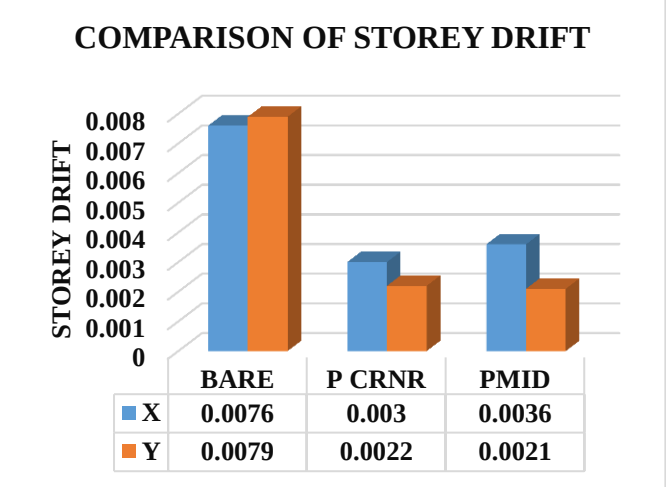


Chart -31: Comparison of storey drift

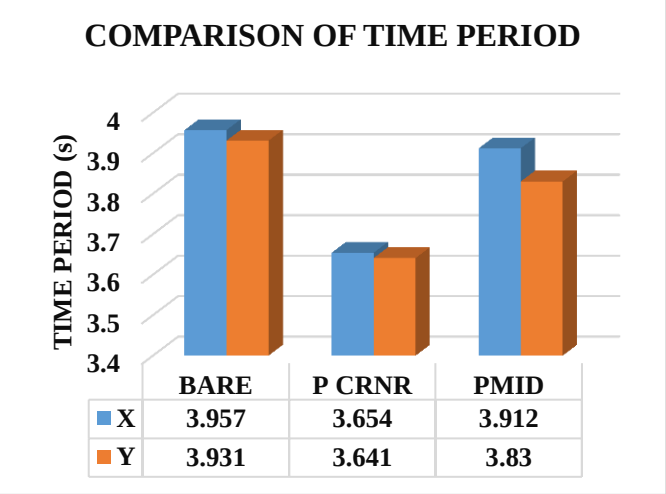


Chart -32: Comparison of time period

5.5 Interior Bracing Configuration

Placing PHP brace in interior in different ways in model M12, M13, M14 and M15. The result obtained after the analysis are graphically plotted in chart 33 to chart 36. and a comparison chart is plotted in chart 37 to 40.

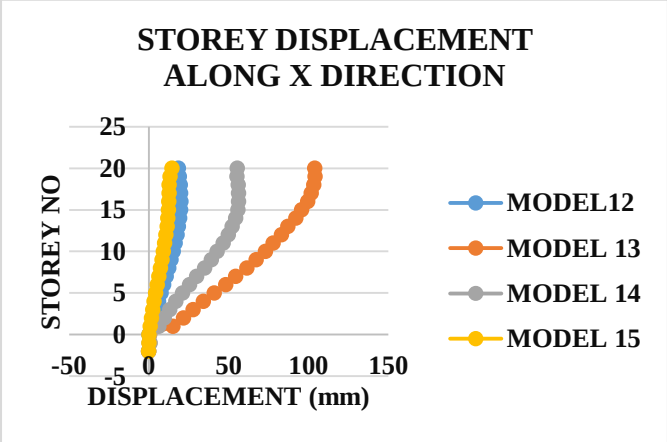


Chart -33: Storey displacement along X direction

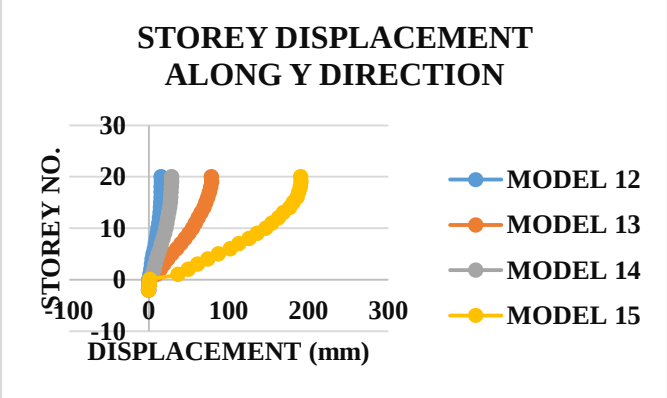


Chart -34: Storey displacement along Y direction

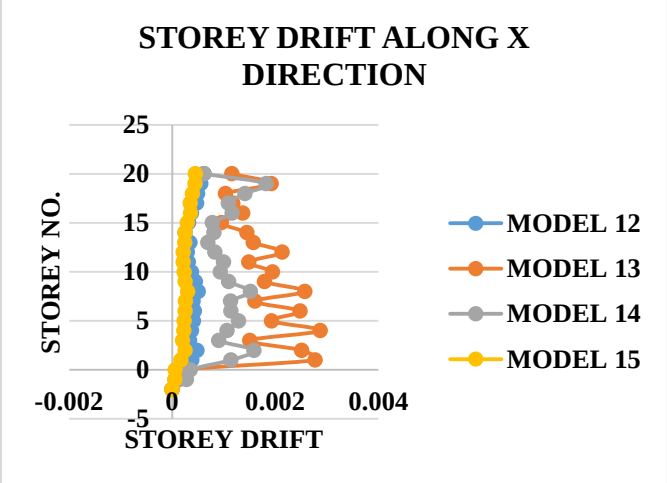


Chart -35: Storey drift along X direction

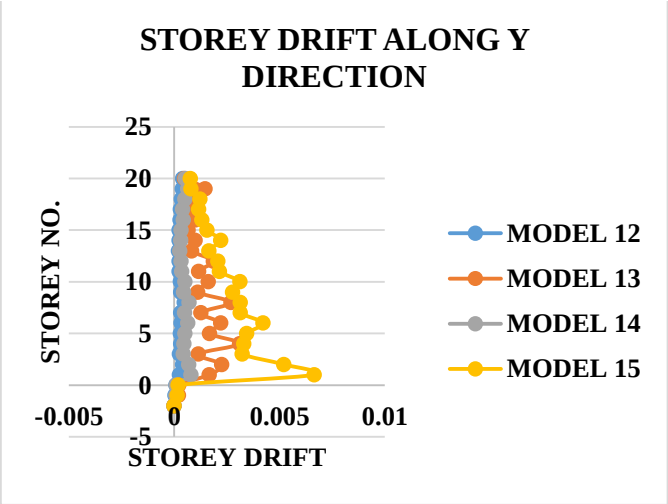


Chart -36: Storey drift along Y direction

Interior PHP M12 model performed better than M13, M14, and M15. This model exhibits low storey displacement and drift value in both x and y direction.

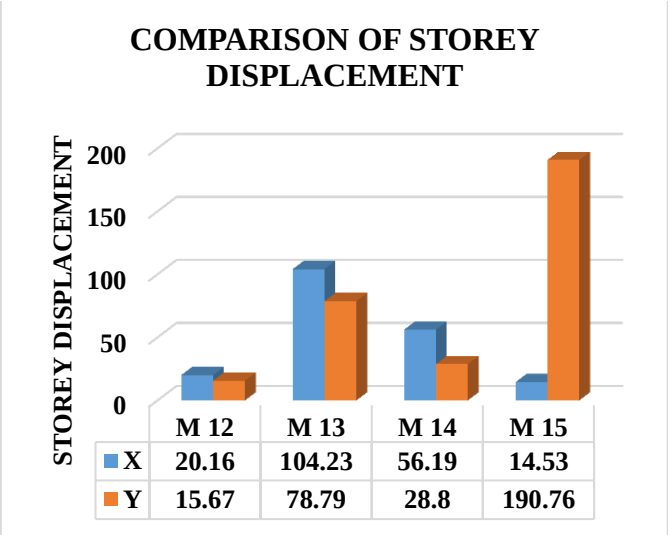


Chart -37: Comparison of storey displacement

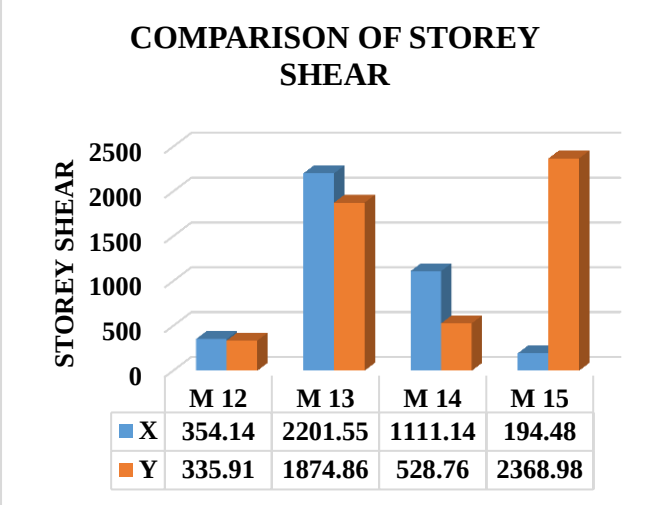


Chart -38: Comparison of storey shear

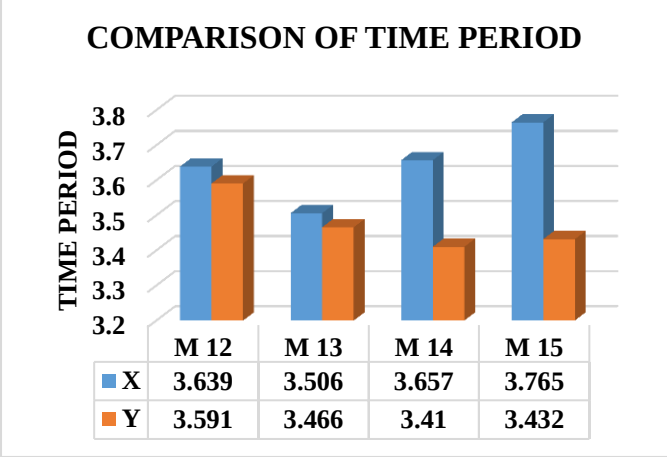


Chart -39: Comparison of time period

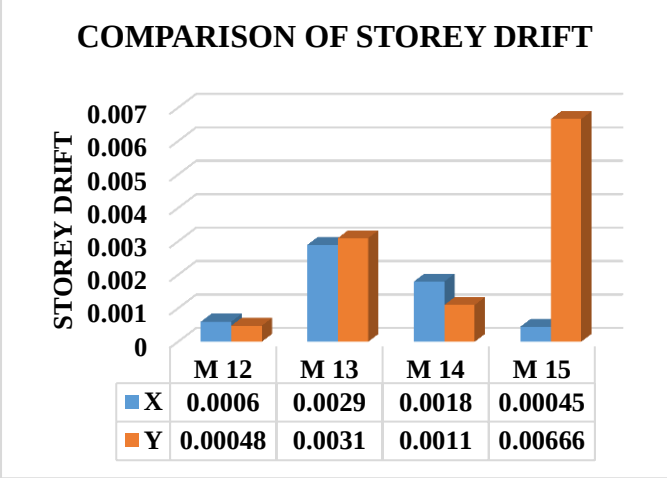


Chart -40: Comparison of storey drift

After the analysis and comparison of all the graph and tables the following result were obtained,

1. In different bracing configuration, Penta braced frame perform better than Hexa and Octa braced frame, due to lower displacement, drift and time period. Penta braced frame showed 45% decrease in displacement than other. Octa is not effective comparing the result with bare frame model. So we had taken combination of penta and hexa.
2. From bracing varying at position, penta corner model is better than penta middle model due to 38% decrease in displacement. It have low drift, displacement, time period than penta middle model.
3. From bracing varying at storeys, PH model is better than HP model. It showed low values of storey displacement and drift in both x and y direction. PH model have 32 % lesser displacement than HP.
4. From bracing varying at bays, PHP model is better than HPH model and XP-YH model. It showed low displacement, time period and drift values in both x and y directions. Also it has 42% decrease in displacement.
5. From all exterior braced model, PHP performed better.
6. Placing PHP brace in interior in different ways as M12, M13, M14, M15 model. Interior PHP M12 model performed better than M13, M14, and M15. This model exhibits low storey displacement and drift values. Thus M12 configuration controls the displacement. M12 has got 86% decrease in displacement than M13,M14 and M15. M12 model got percentage decrease in displacement as 86.92%, whereas exterior PHP braced model has 42.47%.The weight of M1 and PHP is almost similar. Comparing exterior PHP braced model and interior braced model M12, M12 model got effective.
7. Thus, we can concluded that combined PENTA-HEXA-PENTA model configuration is effective and economic.

From the study on the above models, it is concluded that bracing is one of the best method used to resist earthquake forces. It increase the strength in member and overall stiffness of the building.

6. CONCLUSIONS

In this project, ETAB Software is used to analyse the soft storey mitigation behaviour of combined Hexa, Octa and Penta bracing system. The following conclusions are arrived from the study,

1. In combined bracing form, PHP braced model is better, due to smaller storey displacement and drift values than other braced models.
2. Time period and weight of PHP is lower than other braced models.
3. Displacement and drift values Penta braced multi storey building is lesser. Whereas, Economically, PHP is better due to reduced weight.
4. Thus Combined PHP bracing is both economic and effective to overcome soft storey effect.
5. Combined PHP bracing gives better lateral stiffness, strength capacity and displacement capacity compared to other model.

Hence the study concluded that combined PHP bracing can effectively increase the seismic performance of a multi-storey building with soft storey effect.

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[2] Parasiya A.S, Parasiya A.S and Nimodiya P (2013), "A Review on Comparative Analysis of Brace Frame with Conventional Lateral Load Resisting Frame in RC Structure Using Software", International Journal of Advanced Engineering Research and Studies, pp 88-93.

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