CHAPTER 14
THE EFFECT OF FLOATING COLUMNS ON SEISMIC PERFORMANCE

14.1 THE CONCEPT OF FLOATING COLUMNS

After the Bhuj earthquake in the year 2001, it was observed that a lot of RC framed structures in the city of Ahmedabad got damaged. One of the major discrepancies found in the framing of low to medium rise buildings, G+4 to G+7 structures, was the concept of floating columns. The local building byelaws stipulated that the allowable projection of a building beyond the building periphery should not be considered in the allowable floor space index (FSI) calculations. This fact led to the construction of RC framed buildings where the columns on the corner of building in the ground floor was shifted on the outer edge of the periphery making it float over a beam. Thus, the concept of using a floating column got popular to increase the usable area of the floor. Sometimes, the columns are omitted from the framing at a particular level and the load transferred from the column above on to a transfer girder is distributed to the columns of the floor below.

To study the effects of seismic loads on the framing containing a transfer girder is proposed in the present chapter. Usually, providing a floating column on a transfer girder is not preferred by a structural engineer especially when it is subjected to lateral loads. So, in order to quantify the difference in the seismic performance between a frame without floating column is proposed to be compared with one having a floating column. The study is limited to G+7 storey low rise RC framed structures with a regular grid spacing of 3m.

The number of floors above the transfer girder also affects the seismic performance of a frame. In order to study the effect of omitting a column in the peripheral framing of a G+7 storey building, one column is omitted at the first floor designated by F1 to sixth floor designated by F6. It is also proposed to compare the seismic performance of a frame having all the columns as square against a space frame having all the columns having an equivalent rectangular cross section. The analytical tool of push over analysis is proposed to be used in order to identify the effectiveness of the framing in resisting the seismic forces. The factors which decide the performance of the structure are the roof displacement and the base shear at performance point. A further indication of seismic performance is also given by the effective damping at performance point. The number and category of plastic hinges developed are also useful in deciding the relative performance of a particular framing as against the other. It is obvious that development of plastic hinges in the beam element is preferred over that in the column element. For better performance, plastic hinges should develop in beam elements rather than in column elements. The performance of a frame can be verified by comparing the number and category of hinges developed in the column element at performance point.

One more criteria for judging the seismic performance of a framing is the comparison of drift induced. Thus, it is proposed to compare the storey drift for the structures under consideration when they are subjected to the lateral push in both the lateral directions.

14.2 MATHEMATICAL MODELS WITH FLOATING COLUMNS

The problem selected for the performance evaluation of structures having floating columns is a G+7 storey space frame with an overall plan dimension of 6m x 6m having four panels of 3m x 3m each. Total nine columns are considered at each panel points forming a space frame with columns extending to 3m below plinth level where foundation level is assumed. The storey height is considered as 3m for all storey and the cross section of the columns is considered as

230mm x 450mm for all columns with the longer side parallel to global Y axis in plan. Another model with equivalent square section of 322mm x 322mm is also considered for comparing it's performance with the rectangular one. The column section is increased by 50mm in both the lateral directions below plinth level. A typical isometric view and the typical plan views of the frame is shown in **Fig. 14.1**. The size of all the beams is considered to be 230mm x 450mm. The size of the transfer girder is considered as 300mm x 750mm when the column is omitted on the first floor level whereas it is considered as 230mm x 600mm for all other levels.

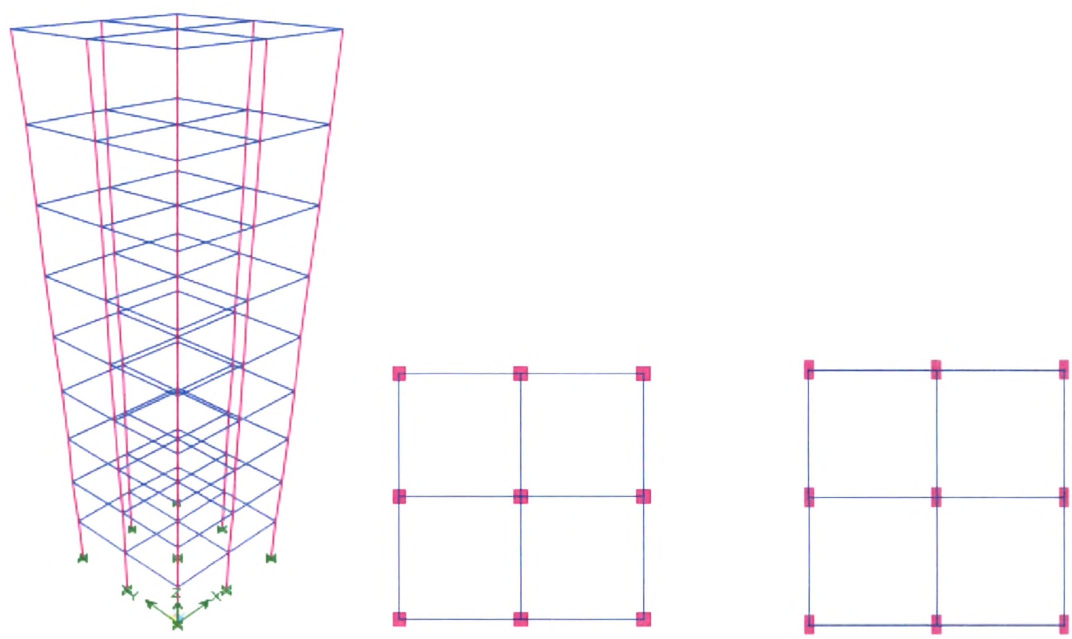
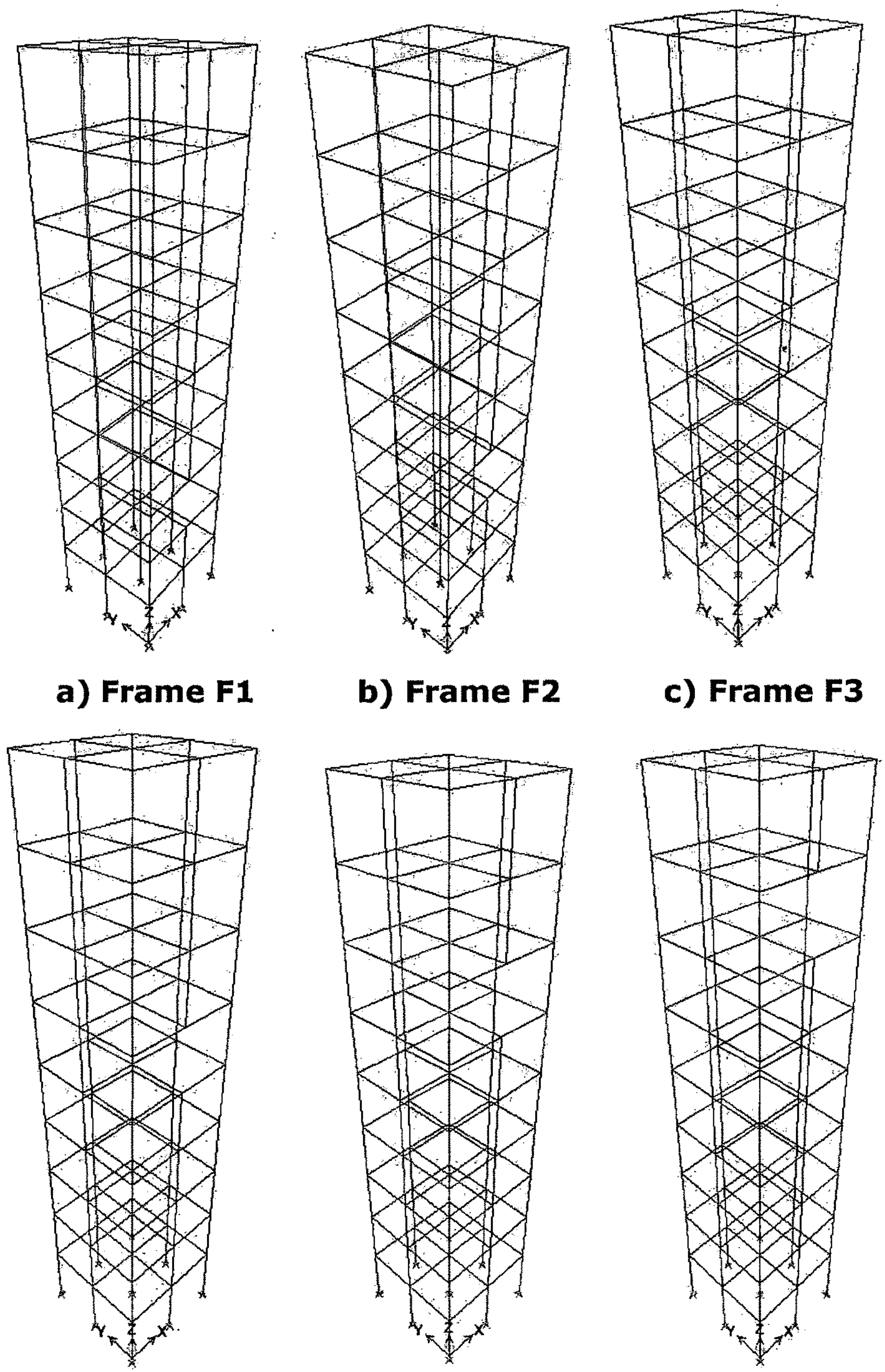


Fig. 14.1 Typical Isometric and Plan Views of the G+7 Frame

The six space frame models with one of the central columns omitted at the y=0 face at first floor level to sixth floor level are generated and analyzed for the two variations in column cross sections. The line diagrams of the models designated as F1 to F6 are shown in **Fig. 14.2**.



a) Frame F1 **b) Frame F2** **c) Frame F3**

d) Frame F4 **e) Frame F5** **f) Frame F6**

Fig. 14.2 Space Frame Models Considered

The loading considered for the analysis is an area load applied to the diaphragms at the floor levels. The dead load of 1.5 kN/m^2 and a live load of 3 kN/m^2 is considered on all typical floors along with a uniformly distributed dead load of 13 kN/m on the peripheral beams to account for the 230mm thick brick walls. The loads considered on terrace are a dead load of 2 kN/m^2 with a live load of 1.5 kN/m^2 along with a uniform dead load of 6 kN/m on peripheral beams to account for the parapet walls. The self weight due to slabs and beams is calculated by the program and applied as a dead load. The earthquake loads are defined in the lateral X and Y directions as per IS 13920 **[27]** calculated by the program for zone factor Z=0.16 , medium soil and importance factor of 1 with response reduction factor of 5 with initial damping as 5%. The time period is specified as 0.8132 calculated as per IS 1893, part 1, 2002 **[24]**. Thus, in all there are 4 static load cases which are defined.

For carrying out the concrete design of all the elements as per IS 456, 2000 **[28]**, 13 standard load combinations are considered for the four basic static load cases. The push over analysis is considered only after carrying out the concrete design.

For carrying out the push over analysis, default PMM plastic hinges are defined at the two ends of all columns and also at 5% and 95% span length of all beams. Default M3 hinges are also defined at the mid span of all beams. The first typical push over case defined for the analysis is PUSH1 in the vertical (gravity) direction wherein the full dead load and 50% of live load is applied up to their full magnitude to push the structure in the gravity (global Z) direction. The second push over case defined is PUSH2 which is the lateral push in the global X direction. This is a displacement controlled push in which displacement of the central node at the roof level is monitored up to a target displacement of 4% of the height of the building. The pattern of load to be applied is selected as per the earthquake load in the X direction and a geometric nonlinearity due to P-delta effects is considered. The method of unloading adopted in case of a hinge dropping load is considered as local redistribution. This push over case is started with the stresses in the hinges already there due to the gravity push – PUSH1. The conjugate displacement option is selected to adjust the push so that the target displacement is achieved. Since the structure is symmetric about the Y axis, there is only one lateral push defined in the X direction.

The next push to be applied in order to obtain the performance point for the same structure is the push in the lateral Y direction. Thus, PUSH3 is defined as a push over case in the lateral Y direction where the Y displacement of central node at terrace level is monitored when a push is given as per the load pattern of earthquake load defined in the Y direction. All the parameters applied for PUSH2 are applied to this push over case also. As the column is omitted on one of the faces parallel to the X axis, another push over case termed as PUSH4 is also required to be defined where the push is given in the negative Y direction.

14.3 THE RESULTS OF ANALYSIS

Various parameters like base shear, roof displacement, effective time period and effective damping are noted at performance point and presented in the form of results. These parameters are reported in **Table 14.1**. The results also consist of the number of hinges developed at performance point with category of hinges in each case. These values are presented as **Table 14.2**.

It is difficult to compare these parameter especially when there is no marked difference between the two compared category. One of the criteria to judge the seismic performance of a frame is to identify the location of the plastic hinges. As the plastic hinges forming in column elements of the frame are indicative of a general failure of a structure, the number of hinges developing in the columns is particularly noted in the present study. These values are presented in **Table 14.3**.

Table 14.1 Various Parameters at Performance Point for the Frames Considered

Frame Designation	Parameter	Rectangular columns			Square columns		
		PUSH X	PUSH +Y	PUSH -Y	PUSH X	PUSH +Y	PUSH -Y
Regular	V in kN	655	962	-	842	-	-
	D in m	0.224	0.168	-	0.194	-	-
	Teff in sec	2.382	1.657	-	1.924	-	-
	βeff %	9	7.4	-	7.3	-	-
F1	V in kN	638	959	919	793	840	815
	D in m	0.216	0.171	0.176	0.181	0.196	0.202
	Teff in sec	2.348	1.702	1.682	1.898	1.97	1.946
	βeff %	9	6.8	7.9	8.3	6.8	7.6
F2	V in kN	702	671	673	815	848	826
	D in m	0.205	0.181	0.172	0.186	0.195	0.199
	Teff in sec	2.09	2.288	2.095	1.908	1.95	1.927
	βeff %	7.7	12.3	14.7	7.8	6.9	7.6
F3	V in kN	644	1063	888	825	847	827
	D in m	0.222	0.187	0.163	0.189	0.195	0.196
	Teff in sec	2.354	1.696	1.639	1.916	1.941	1.924
	βeff %	9.1	5	8.9	7.6	7	7.7
F4	V in kN	657	967	941	827	871	852
	D in m	0.225	0.17	0.17	0.192	0.192	0.192
	Teff in sec	2.37	1.673	1.656	1.924	1.881	1.865
	βeff %	8.6	7	7.8	7.5	6.8	7.5
F5	V in kN	661	966	950	844	834	835
	D in m	0.226	0.169	0.169	0.195	0.195	0.193
	Teff in sec	2.372	1.667	1.654	1.926	1.934	1.921
	βeff %	8.5	7.1	7.7	7.4	7.1	7.5
F6	V in kN	664	964	957	842	839	839
	D in m	0.227	0.169	0.169	0.194	0.195	0.194
	Teff in sec	2.372	1.661	1.655	1.926	1.929	1.922
	βeff %	8.5	7.3	7.5	7.3	7.3	7.4

V – Base shear, D – Roof displacement, Teff – Effective time period, βeff – Effective damping

Table 14.2 Plastic Hinges Developed at Performance Point for the Frames Considered

Frame Designation	Hinge Category	A-B		B-IO		IO-LS		LS-CP		TOTAL
	Column	Rect	Square	Rect	Square	Rect	Square	Rect	Square	
Regular	PUSH X	414	397	54	71	16	16	0	0	484
	PUSH Y	388	397	64	71	32	16	0	0	484
F1	PUSH X	418	398	50	66	13	17	0	0	481
	PUSH Y	388	387	74	73	19	21	0	0	481
	PUSH -Y	382	381	76	79	23	21	0	0	481
F2	PUSH X	414	397	49	66	18	18	0	0	481
	PUSH Y	382*	391	78	70	10	20	8	0	481
	PUSH -Y	379	386	87	82	11	13	4	0	481
F3	PUSH X	382	393	71	69	26	19	2	0	481
	PUSH Y	358	388	80	75	41	18	2	0	481
	PUSH -Y	364	383	90	81	25	17	2	0	481
F4	PUSH X	410	395	51	66	20	20	0	0	481
	PUSH Y	389	391	71	72	21	18	0	0	481
	PUSH -Y	379	385	73	78	29	18	0	0	481
F5	PUSH X	411	389	53	76	16	16	1	0	481
	PUSH Y	386	387	65	77	30	17	0	0	481
	PUSH -Y	379	394	70	67	32	20	0	0	481
F6	PUSH X	408	387	57	77	15	17	1	0	481
	PUSH Y	383	387	65	77	33	17	0	0	481
	PUSH -Y	382	392	70	70	29	19	0	0	481

* For rectangular column model, 3 hinges develop in the category D-E.

Table 14.3 Plastic Hinges Developed in Columns at Performance Point for the Frames Cconsidered

Frame Designation	Hinge Category	A-B		B-IO		IO-LS		D-E		TOTAL	
	Column	Rect	Square	Rect	Square	Rect	Square	Rect	Square	Rect	Square
Regular	PUSH X	4	1	3	0	0	0	0	0	**7**	**1**
	PUSH Y	1	1	0	0	0	0	0	0	**1**	**1**
F1	PUSH X	1	0	3	0	0	0	0	0	**4**	**0**
	PUSH Y	0	3	0	0	0	0	0	0	**0**	**3**
	PUSH -Y	0	1	0	0	0	0	0	0	**0**	**1**
F2	PUSH X	0	2	0	0	0	0	0	0	**0**	**2**
	PUSH Y	6	1	0	0	0	0	3	0	**9**	**1**
	PUSH -Y	0	2	6	0	3	0	0	0	**9**	**2**
F3	PUSH X	6	1	3	0	0	0	0	0	**9**	**1**
	PUSH Y	4	1	0	0	0	0	0	0	**4**	**1**
	PUSH -Y	2	2	0	0	0	0	0	0	**2**	**2**
F4	PUSH X	1	1	6	0	3	0	0	0	**10**	**1**
	PUSH Y	0	1	0	0	0	0	0	0	**0**	**1**
	PUSH -Y	2	1	0	0	0	0	0	0	**2**	**1**
F5	PUSH X	1	1	5	0	4	0	0	0	**10**	**1**
	PUSH Y	2	2	0	0	0	0	0	0	**2**	**2**
	PUSH -Y	2	2	0	0	0	0	0	0	**2**	**2**
F6	PUSH X	1	1	5	0	3	0	0	0	**9**	**1**
	PUSH Y	2	1	0	0	0	0	0	0	**2**	**1**
	PUSH -Y	2	1	0	0	0	0	0	0	**2**	**1**

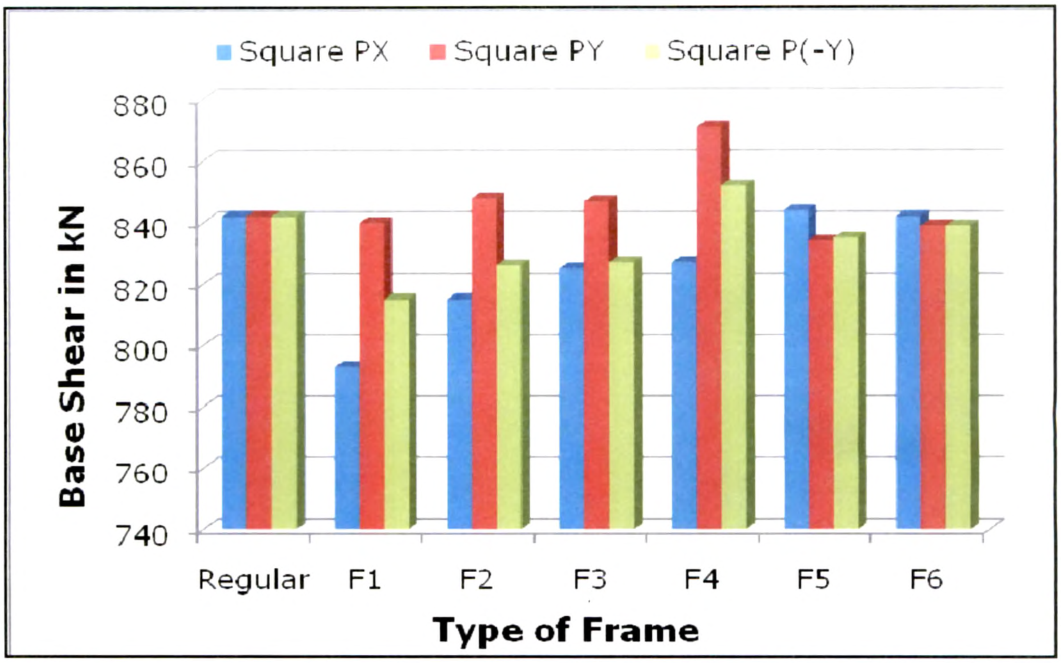


Fig. 14.3 Variation in Base Shear for Frames with Square Columns

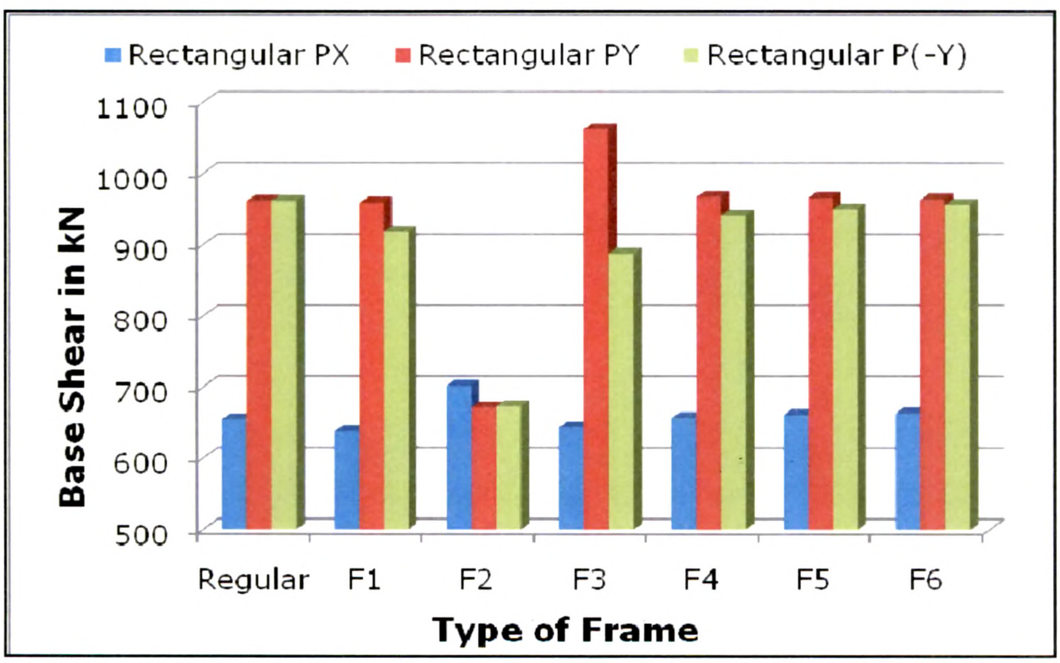


Fig. 14.4 Base Shear for frames with Rectangular Columns

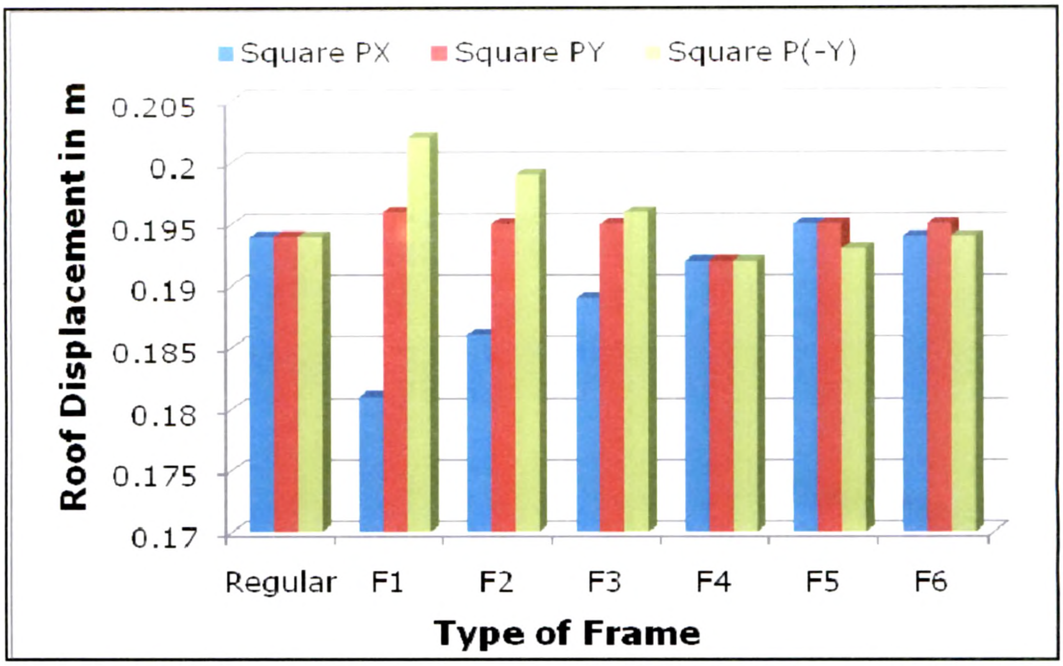


Fig. 14.5 Variation in Roof Displacement - Square Columns

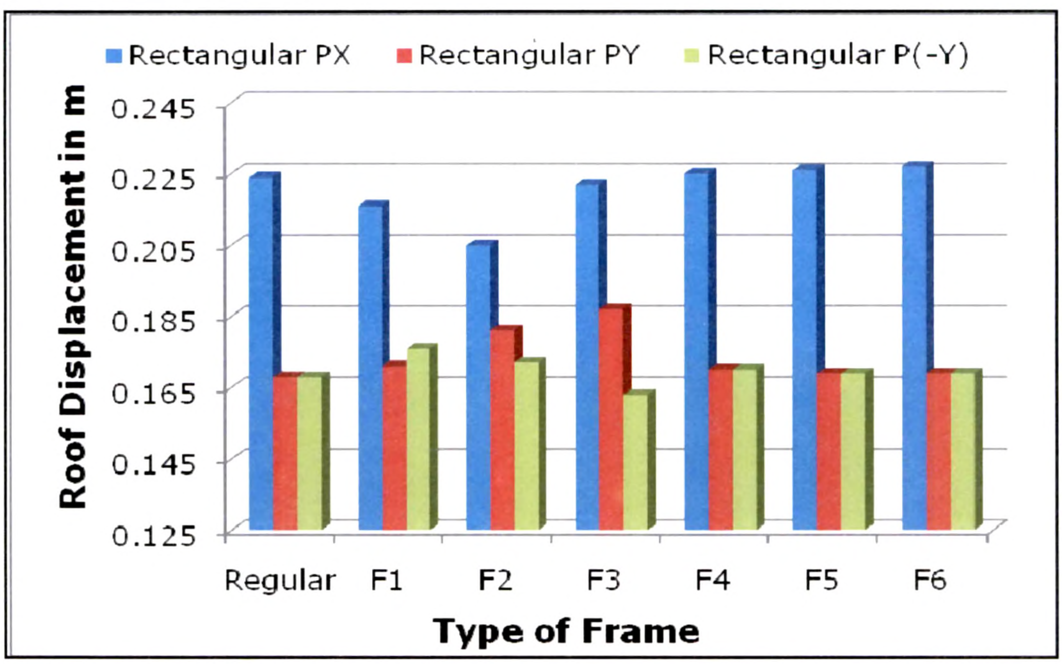


Fig. 14.6 Variation in Roof Displacement - Rectangular Columns

One more important parameter for judging the seismic performance of a structure is the storey drift. The storey drift under the lateral push is noted and presented for regular G+7 frame with square and rectangular columns in **Table 14.4** and the corresponding graphical representation shown in **Fig. 14.7** is more convenient to review.

Table 14.4 Drift in m at Performance Point for G+7 Storey Frame

Storey	Rectangular Columns		Square Columns
	PUSH X	PUSH Y	PUSH X
9	0.0029	0.0033	0.0029
8	0.0049	0.0047	0.0046
7	0.0065	0.0060	0.0059
6	0.0075	0.0068	0.0068
5	0.0082	0.0073	0.0074
4	0.0086	0.0075	0.0076
3	0.0087	0.0075	0.0076
2	0.0097	0.0083	0.0085
1	0.0196	0.0123	0.0139

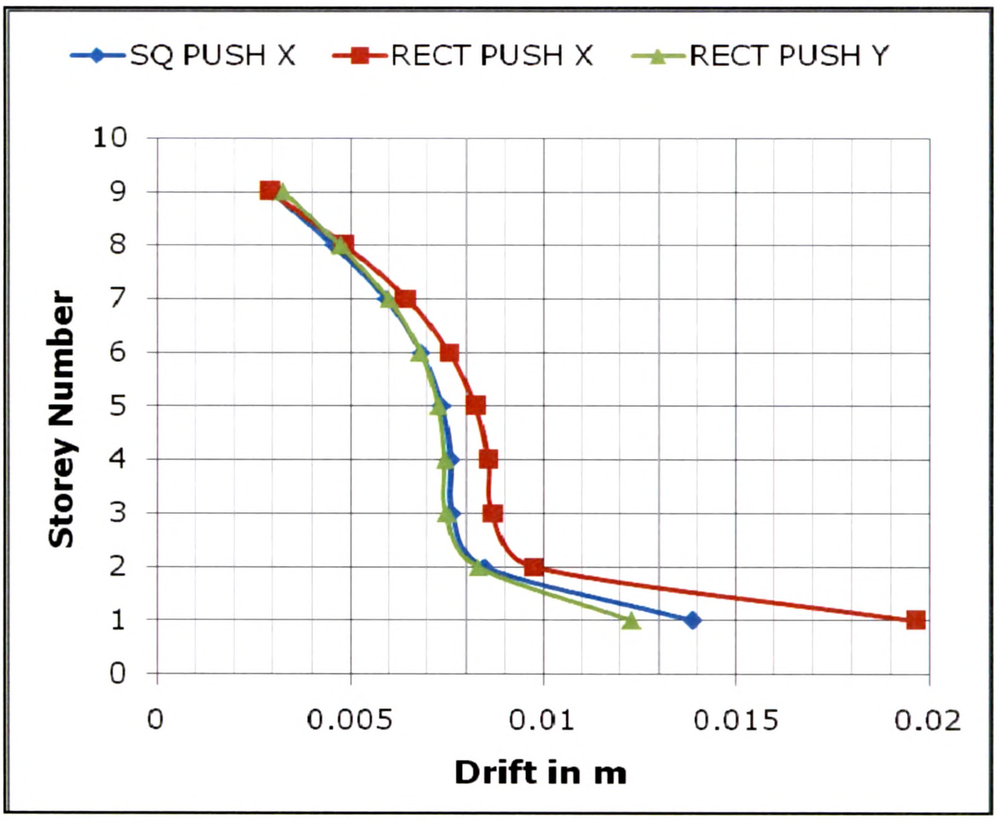


Fig. 14.7 Storey Drift for G+7 Storey frame

Table 14.5 presents the storey drift in m for the space frames F1 to F6 with floating columns. The results are presented in graphical format in various figures. **Figures 14.8** and **14.9** represent the drift variation in G+7 storey space frames with square and rectangular columns respectively subjected to push in the lateral X direction. The variation in storey drift for frame F1 under the three lateral push PUSHX, PUSHY and PUSH -Y with square and rectangular columns is shown in **Fig. 14.10**. Similar graphs are presented for G+7 storey frames with floating columns designated as F2 to F6 in **Fig. 14.11** to **Fig. 14.15.** All the storey drifts are presented to compare the behavior of a particular frame having rectangular columns and equivalent square columns under lateral push up to performance point.

Table 14.5 Storey Drift Values in m for Space Frames

Frame Type	Storey	Rectangular Columns			Square Columns		
		PUSH X	PUSH Y	PUSH -Y	PUSH X	PUSH Y	PUSH -Y
F1	9	0.0029	0.0030	0.0037	0.0029	0.0029	0.0037
	8	0.0047	0.0044	0.0050	0.0045	0.0045	0.0054
	7	0.0063	0.0055	0.0061	0.0058	0.0059	0.0068
	6	0.0073	0.0062	0.0069	0.0067	0.0068	0.0077
	5	0.0080	0.0066	0.0073	0.0072	0.0073	0.0083
	4	0.0081	0.0068	0.0074	0.0073	0.0075	0.0085
	3	0.0095	0.0072	0.0075	0.0083	0.0081	0.0088
	2	0.0096	0.0075	0.0074	0.0084	0.0083	0.0087
	1	0.0178	0.0111	0.0110	0.0136	0.0137	0.0144
F2	9	0.0033	0.0024	0.0027	0.0030	0.0031	0.0035
	8	0.0056	0.0034	0.0035	0.0047	0.0048	0.0052
	7	0.0073	0.0042	0.0043	0.0061	0.0063	0.0065
	6	0.0086	0.0048	0.0048	0.0070	0.0072	0.0074
	5	0.0091	0.0051	0.0050	0.0074	0.0074	0.0077
	4	0.0110	0.0055	0.0051	0.0086	0.0083	0.0082
	3	0.0101	0.0055	0.0046	0.0079	0.0080	0.0076
	2	0.0105	0.0069	0.0054	0.0087	0.0089	0.0084
	1	0.0087	0.0288	0.0232	0.0146	0.0149	0.0139
F3	9	0.0029	0.0033	0.0035	0.0030	0.0030	0.0035
	8	0.0048	0.0048	0.0048	0.0047	0.0046	0.0051
	7	0.0072	0.0063	0.0060	0.0060	0.0060	0.0065
	6	0.0084	0.0074	0.0066	0.0068	0.0067	0.0072
	5	0.0096	0.0079	0.0068	0.0082	0.0077	0.0079
	4	0.0087	0.0077	0.0063	0.0079	0.0077	0.0076
	3	0.0088	0.0077	0.0063	0.0078	0.0077	0.0077
	2	0.0099	0.0086	0.0070	0.0087	0.0086	0.0085
	1	0.0192	0.0127	0.0104	0.0145	0.0140	0.0140

Table 14.5 Storey Drift Values in m for Space Frames

Frame Type	Storey	Rectangular Columns			Square Columns		
		PUSH X	PUSH Y	PUSH -Y	PUSH X	PUSH Y	PUSH -Y
F4	9	0.0031	0.0030	0.0040	0.0030	0.0030	0.0035
	8	0.0050	0.0044	0.0055	0.0046	0.0047	0.0052
	7	0.0066	0.0056	0.0068	0.0060	0.0061	0.0066
	6	0.0091	0.0067	0.0077	0.0082	0.0075	0.0078
	5	0.0086	0.0068	0.0075	0.0076	0.0075	0.0075
	4	0.0088	0.0069	0.0076	0.0077	0.0077	0.0077
	3	0.0090	0.0070	0.0077	0.0078	0.0077	0.0077
	2	0.0101	0.0077	0.0085	0.0086	0.0084	0.0084
	1	0.0238	0.0114	0.0127	0.0141	0.0133	0.0133
F5	9	0.0031	0.0034	0.0039	0.0030	0.0029	0.0033
	8	0.0050	0.0049	0.0054	0.0046	0.0046	0.0050
	7	0.0077	0.0065	0.0068	0.0070	0.0064	0.0066
	6	0.0079	0.0071	0.0071	0.0071	0.0069	0.0069
	5	0.0085	0.0076	0.0075	0.0075	0.0075	0.0075
	4	0.0089	0.0078	0.0077	0.0077	0.0077	0.0077
	3	0.0090	0.0078	0.0078	0.0078	0.0078	0.0077
	2	0.0101	0.0086	0.0086	0.0086	0.0086	0.0086
	1	0.0239	0.0128	0.0128	0.0142	0.0142	0.0141
F6	9	0.0030	0.0033	0.0037	0.0030	0.0029	0.0032
	8	0.0058	0.0052	0.0053	0.0054	0.0049	0.0051
	7	0.0068	0.0063	0.0063	0.0061	0.0060	0.0060
	6	0.0078	0.0071	0.0071	0.0070	0.0070	0.0070
	5	0.0085	0.0076	0.0076	0.0075	0.0075	0.0075
	4	0.0089	0.0078	0.0078	0.0077	0.0077	0.0077
	3	0.0090	0.0078	0.0078	0.0078	0.0078	0.0078
	2	0.0101	0.0087	0.0087	0.0086	0.0086	0.0086
	1	0.0240	0.0129	0.0129	0.0142	0.0142	0.0142

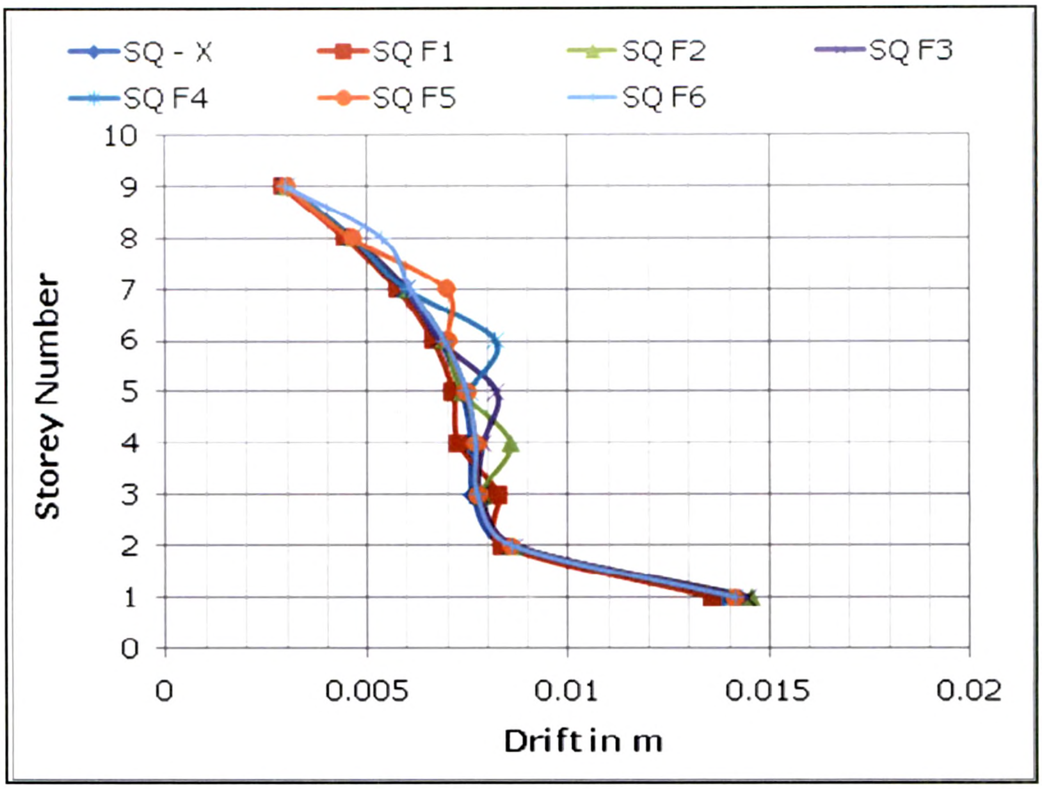


Fig. 14.8 Variation in Drift for Frame with Square Columns - PUSHX

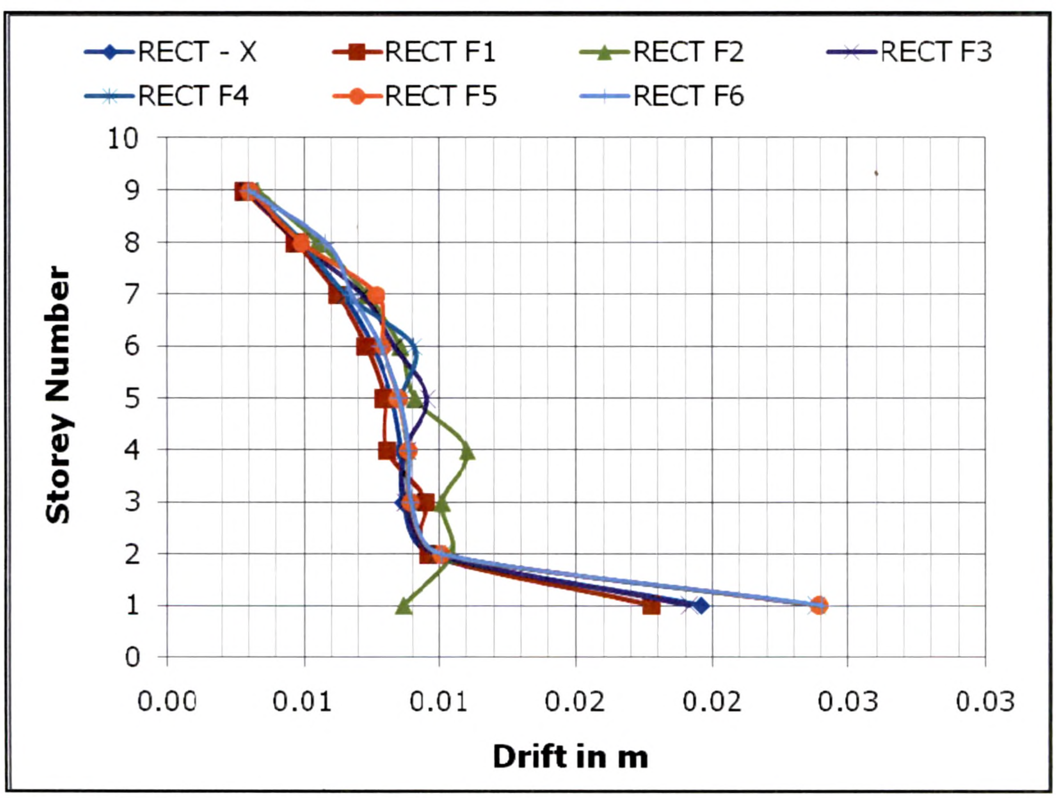


Fig. 14.9 Drift Variation with Rectangular Columns under PUSHX

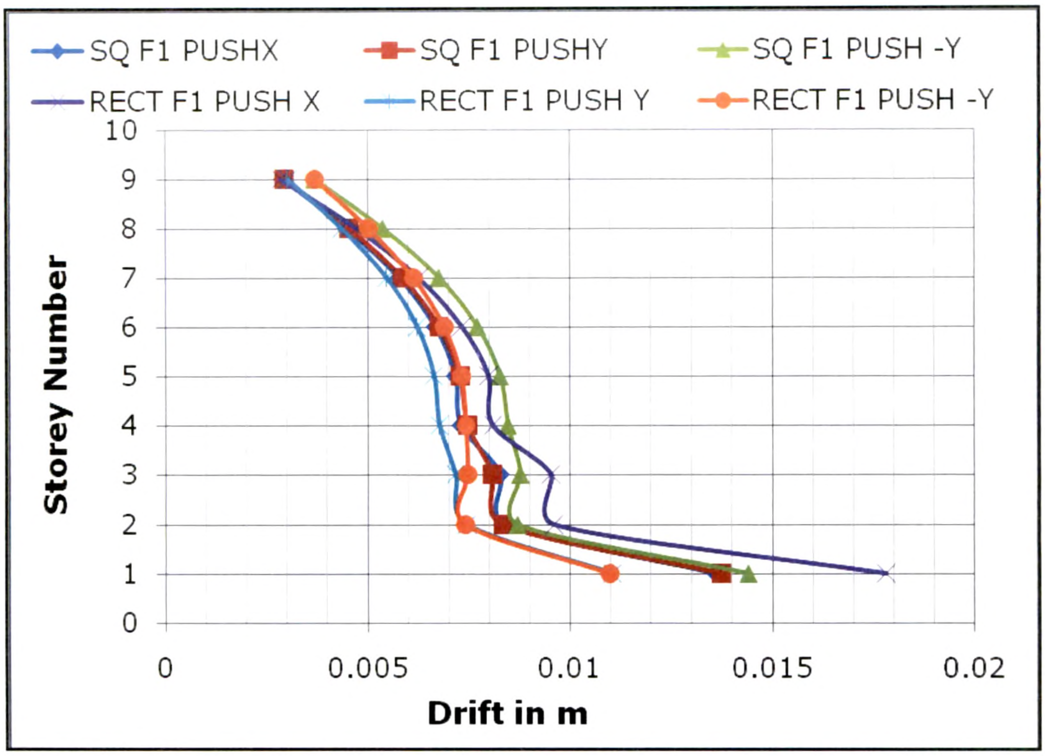


Fig. 14.10 Drift Variation for G+7 Storey Frame Designated as F1

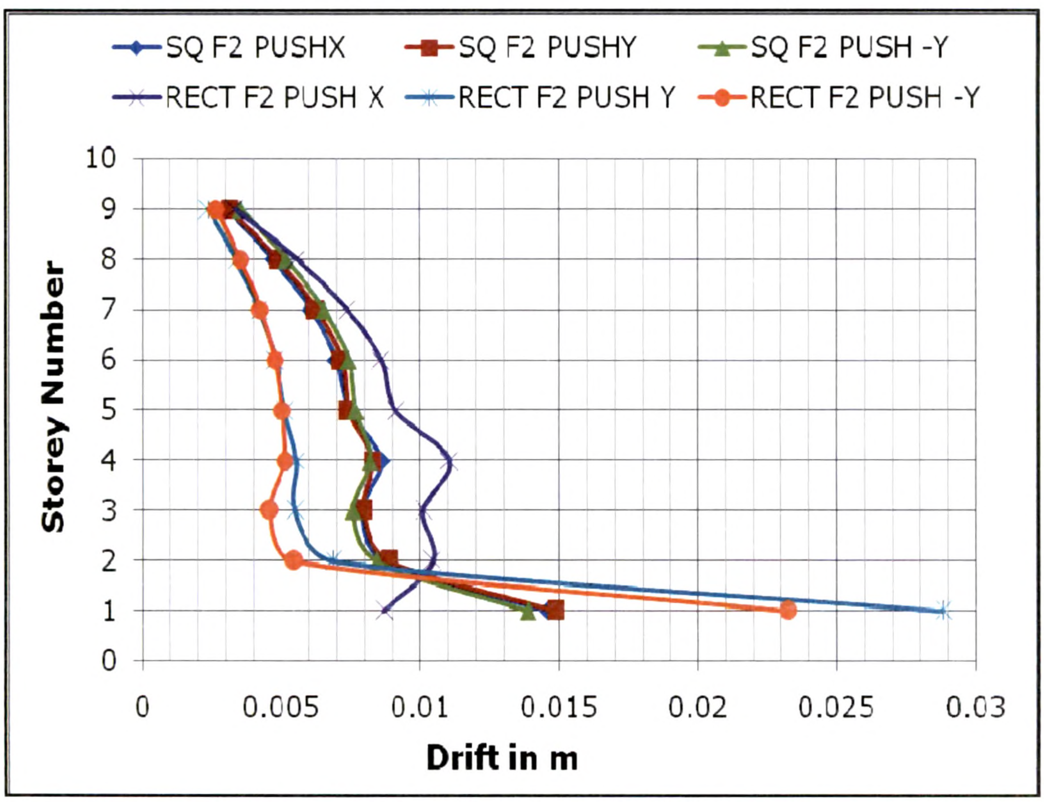


Fig. 14.11 Drift Variation for G+7 Storey Frame Designated as F2

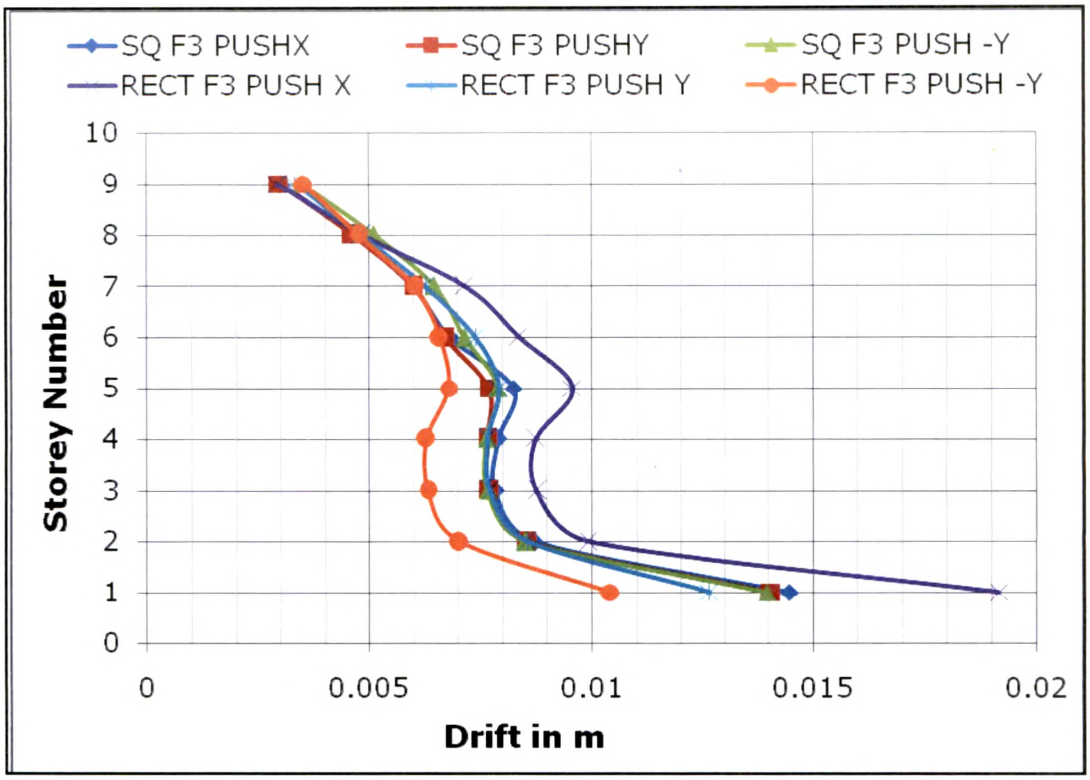


Fig. 14.12 Drift Variation for G+7 Storey Frame Designated as F3

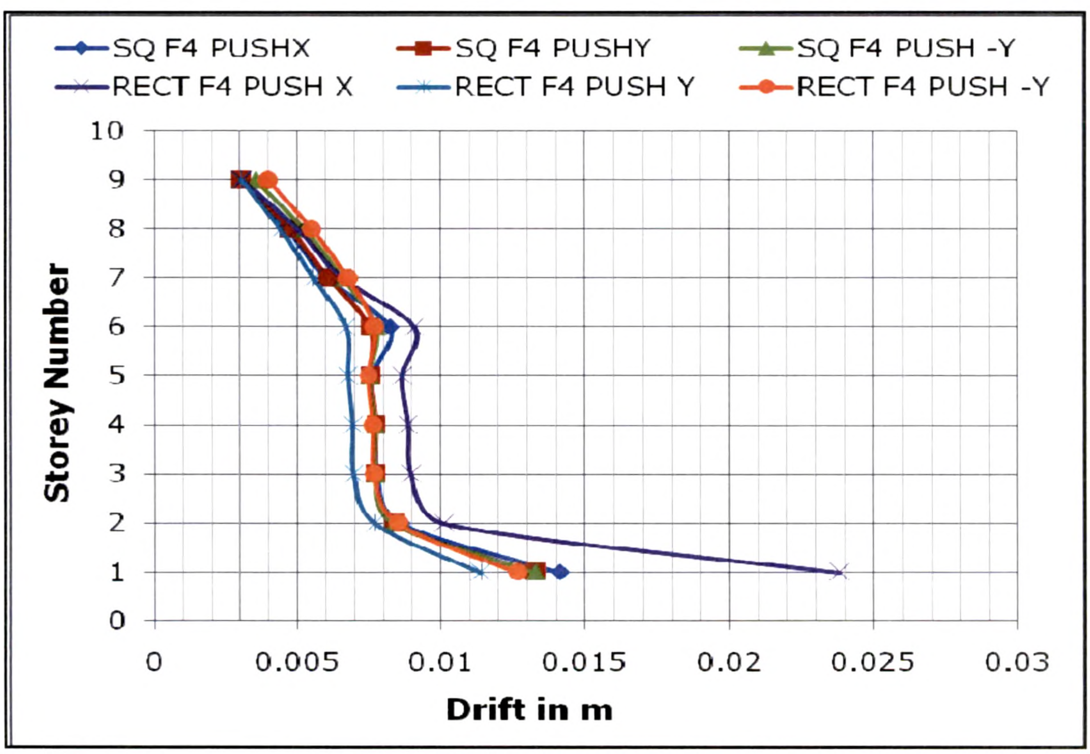


Fig. 14.13 Drift Variation for G+7 Storey Frame Designated as F4

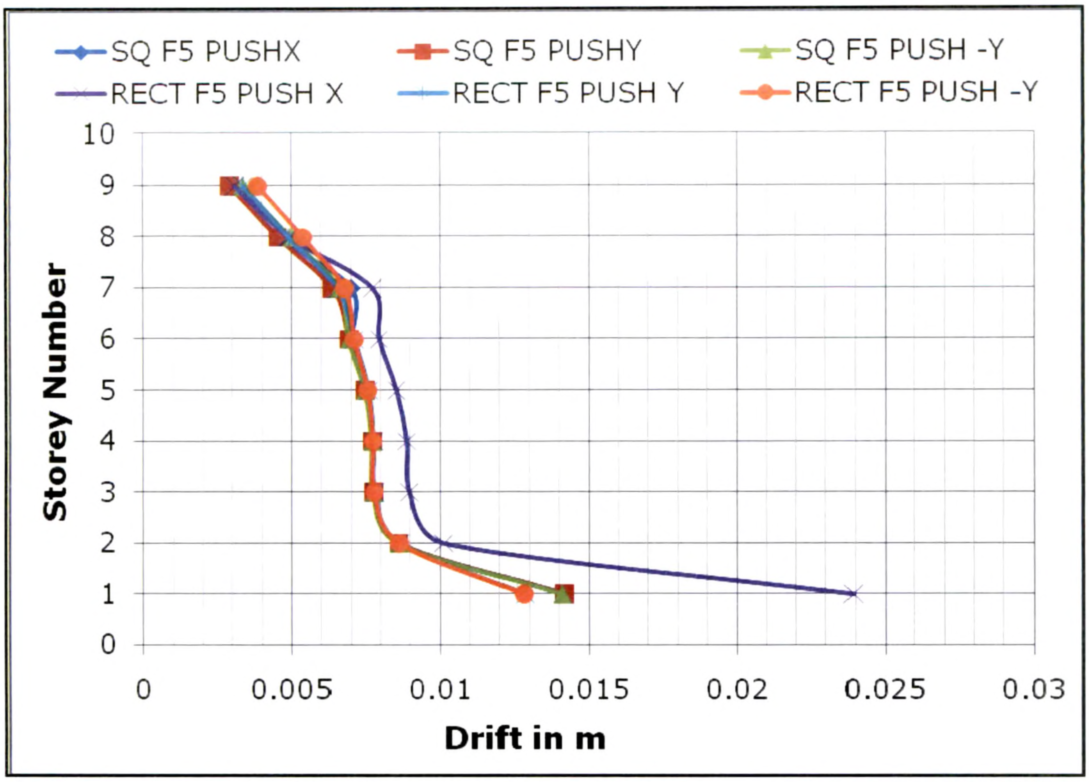


Fig. 14.14 Drift Variation for G+7 Storey Frame Designated as F5

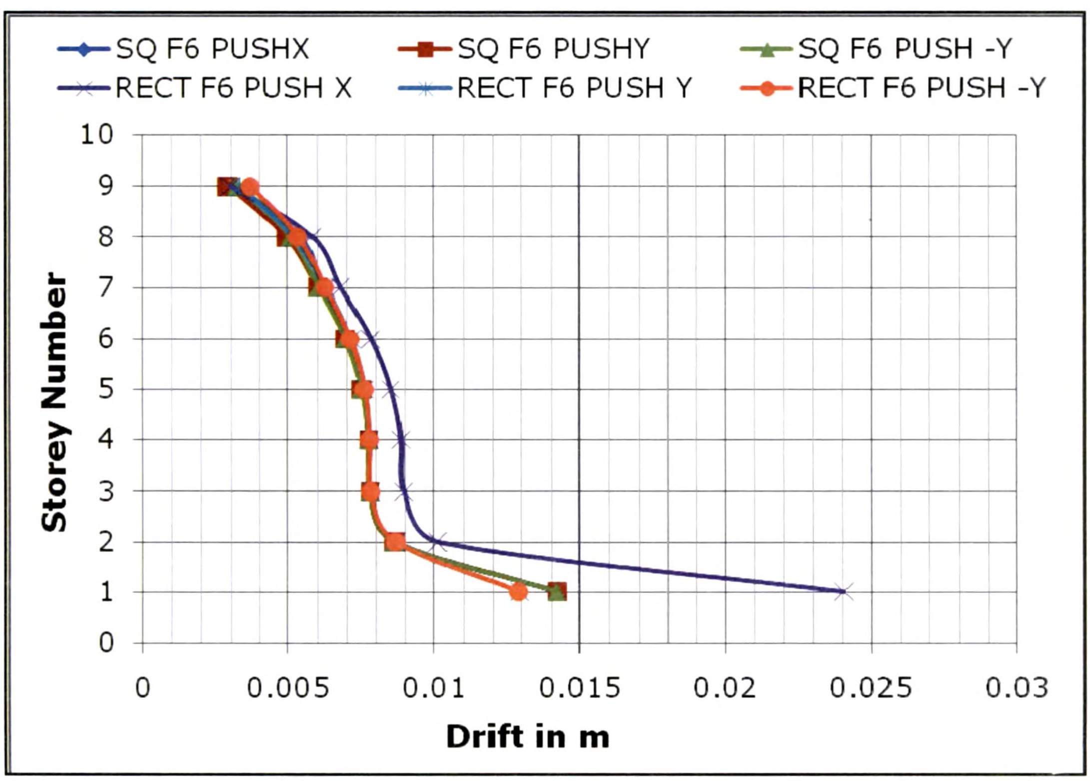


Fig. 14.15 Drift Variation for G+7 Storey Frame Designated as F6

14.4 IMPORTANT OBSERVATIONS

1. **Table 14.1** clearly indicates that for regular frames with square and rectangular columns, the frame with square columns is showing a better performance as it resists more base shear at a lower roof displacement at performance point compared to that having rectangular columns.
2. **Figures 14.3** and **14.4** shows that the minimum base shear resisted by all G+7 frames with square columns is 793 kN and the highest value is 871 kN. Thus, there is a variation of 9.8% in the base shear value resisted at performance point. The same variation in case of frames with rectangular columns is seen to be from 638 kN to 1063 kN which is as huge as 66.6%. The lowest value of base shear resisted by F1 frame under PUSH in the X direction is 24.29% less for rectangular columns as compared to square columns under same PUSH.
3. **Figure 14.3** further indicates that the base shear resisted at performance point by frames with square columns drops by 49 kN for PUSH in the X direction when a column is removed from the first storey which is a variation of only 5.8% compared to a regular frame with square columns. This variation further decreases as the omitted column is shifted towards upper storey designated by F2, F3, F4 etc.
4. It can also be observed from **Fig. 14.3** that the omission of column in the fifth and sixth storey (F5 and F6 frames) has no effect on the base shear resisted at performance point for frames with square columns. The same is observed for frames with rectangular columns (**Fig. 14.4**).
5. The base shear variation in case of frames with rectangular columns is in the Y PUSH which reduces considerably for frame F2 to 671 kN as compared to 962 kN for a regular frame without floating columns.
6. From **Figs. 14.5** and **14.6** it can be observed that for frames F4, F5 and F6, the roof displacement values are almost unchanged for square as well as rectangular columns. It is also observed that the roof displacement at performance point is more for frames F1, F2 and F3

under PUSH in –ve Y direction for square columns and for + Y PUSH for rectangular columns.

7. It can be seen from **Table 14.1** that the value of effective damping which is a measure of damage in the frame due to PUSH ranges between 6.9% and 8.3% for frames with square columns. The same value ranges from 5% to 14.7% for models with rectangular columns. This indicates a consistent performance of square shaped columns compared to rectangular columns under seismic effects.
8. The effective time period at performance point for all frames with square columns is around 1.9 sec as indicated in **Table 14.1**, whereas the same varies between 1.65 and 2.38 sec for rectangular columns. This fact implies the consistency of seismic performance of square shaped columns.
9. The number of plastic hinges developed in various categories at performance point is definitely an indication of seismic performance of a structure. From the study of **Table 14.2**, it can be seen that for frames with square columns, no hinges are developed in the category beyond life safety (LS) stage. As against this, in case of frame F2 with rectangular columns under PUSH Y, 3 plastic hinges develop stress beyond collapse stage. This indicates a better performance of square columns in general.
10. The development of hinges in column elements is more serious as compared to beam elements in a frame. This data of number and category of hinges developed only in the column elements out of the totally developed hinges is presented in **Table 14.3**. This table once again shows better performance of square shaped columns as against rectangular columns for the same frame. It is also clear from the same table that for square columns, the category of hinges is in the lowest stress level i.e. up to the immediate occupancy (IO) stage. If the performance of the frames with floating columns is compared to that of one without floating columns, there is not much difference in the hinges developed in the column elements for square columns.

11. One fact which was observed from the push over analysis of frames with floating columns is that plastic hinges develop under the gravity push itself when the transfer girder is not stiff enough, which is otherwise not observed in regular frames. Thus, floating columns are not advisable even from the point of view of resisting gravity loads which may not be reflected effectively in the seismic performance criteria. Also, the hinges developed due to gravity loads may further deteriorate the performance of the frame under vertical component of earthquake motion which is not considered in the current analysis.
12. From **Table 14.4** and **Fig. 14.7** included for regular frames without floating columns under the lateral push in X and Y directions, it is clear that the square columns show less storey drift as compared to the rectangular columns pushed along their weaker axis.
13. **Figures 14.8** and **14.9** show the plots of storey drift for G+7 frames with square and rectangular columns respectively under PUSH in the lateral X direction. These plots indicate that the storey drifts for all the frames closely match the basic curve of regular frame without floating column accept for the fact that there are local peaks in the drift values at the specific storey level where a column is omitted. This fact is observed in both square as well as rectangular columns.
14. **Figures 14.10** to **14.12** indicate that in case for frames F1, F2 and F3, the variation in drift is significant between frames with square columns and rectangular columns. It is observed that the storey drift curves for frame with square columns for all the three lateral push are close to each other indicating consistent performance. The curves for frames with rectangular columns are wide spread and on either side of those for frames with square columns.
15. **Figures 14.13** to **14.15** depicting the storey drift curves for frames F4, F5 and F6 show very less variation. This fact indicates that the floating columns in the upper storey of G+7 frame do not have any significant effect on the seismic performance for both the column shapes.