Parametric Study of Various Bracing Systems in Steel Structures

[1]Mehul J. Bhavsar [2]Kavita N. Choksi [3]Digant A. Pastagia
[1,2,3]Assistant Professor
[1,2,3]Department of Civil Engineering
[1,2,3]SSASIT, Surat, Gujarat, India

Abstract

This study is basically concentrated on use of bracings in steel buildings. Here many parameters like bending moment, axial force, joint displacement, utility ratio etc. will be assessed under lateral loads generated from earthquake particularly. Bracings are to be placed in variety of mode in the typical frame, and from them attempt is to be made to find best bracing configuration considering minimum possible weight. The study is carried out on computer software SAP 2000.
Keyword- Axial Force, bracing systems, parameters, steel frame, software SAP 2000

I. INTRODUCTION

Building frames are most common structural format, an analyst/engineer encounters in practice. Generally, in steel structures, Moment Resisting frames or rigid frames are widely used than any other types against lateral forces. Performance of rigid frames against lateral loads is acceptable up to certain extents. Moreover, only frames are not efficient against the lateral forces. As the height or width or bay of the frame increases, pure rigid or unbraced frames are not efficient to withstand against the lateral forces i.e. earthquake or wind, which causes the buckling or bending or deflection or drift of the entire or part of the structure, which leads the partial or complete failure of the structure. This can be complied by providing an additional stiffness & ductility to the frames. In steel structures bracings are commonly used for enhancing the lateral stability. Various bracing configurations like single diagonal type, cross or X type, V type, K or knee type etc. are utilized in steel structures according to structural and architectural requirements. This study includes 1) Parametric study of various bracing systems 2) A study of effect of bracing configuration on internal columns of the frame.

A. Parametric Study of Various Bracing Systems

Various parameters like bending moment, axial force, joint displacement, utility ratio, Inter storey drift, fundamental time period under various mode shapes and weight of structures are studied. Plan and 3-D view of the building is shown below. For comparison corner column A1, Edge column F4 and Interior column C5 is considered.

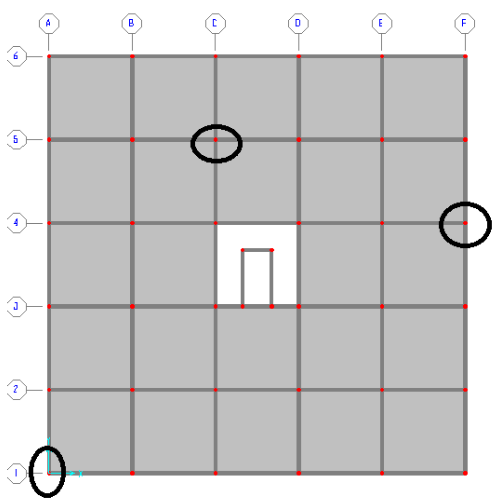

Fig. 1a: Plan of the typical building

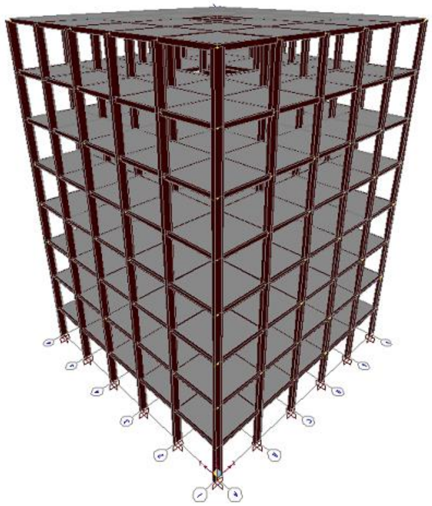
Fig. 1b: A 3-D view of the building

Following bracing systems are taken for study.

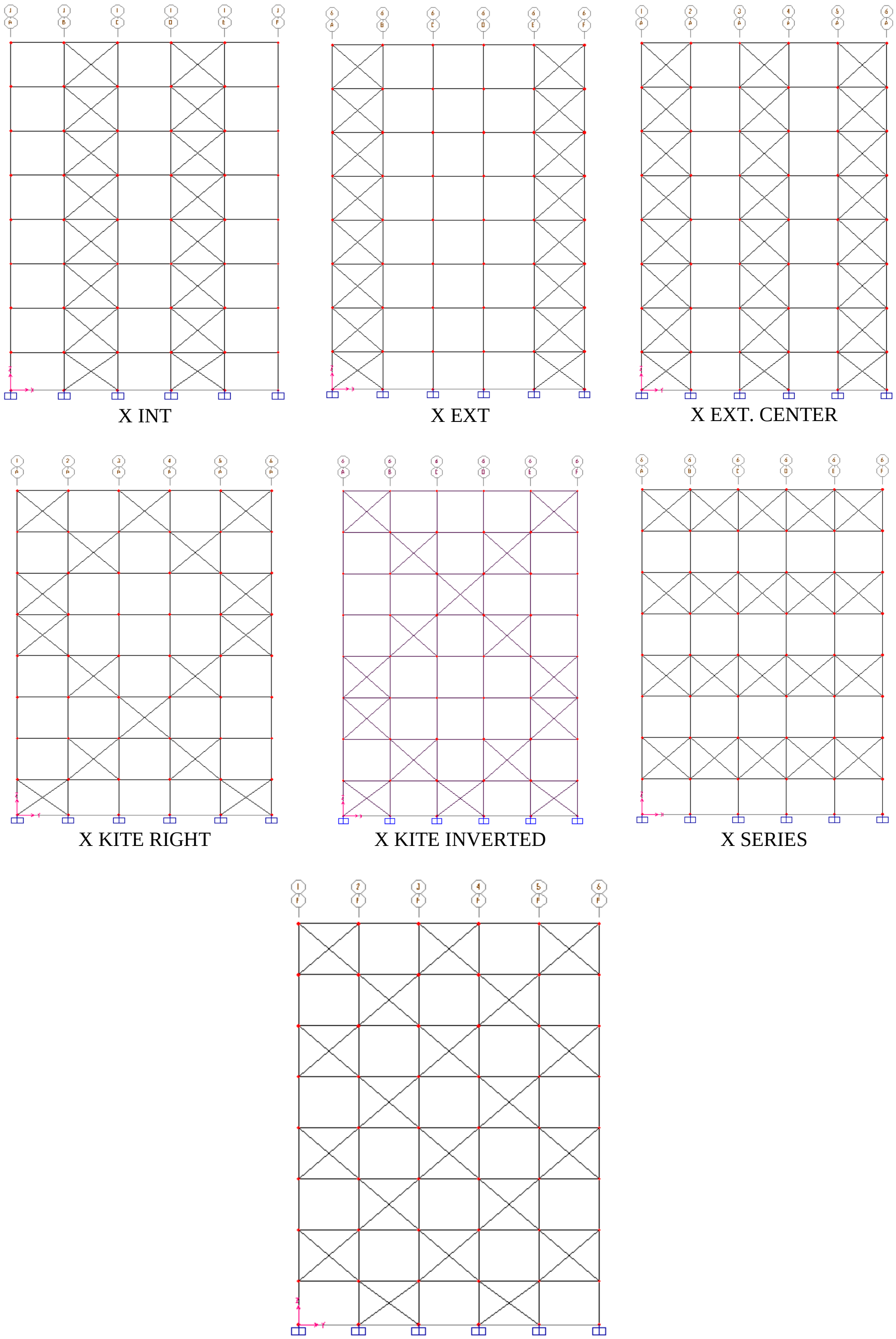

Fig. 2: bracing systems

Number of bracing pair in, X INT, X EXT, X KITE RIGHT & X KITE INVERTED are same i.e. 16 in one face of the structure, X ALT and X SERIES have 20, X EXT CENTER has 24.

B. Corner Column: A1

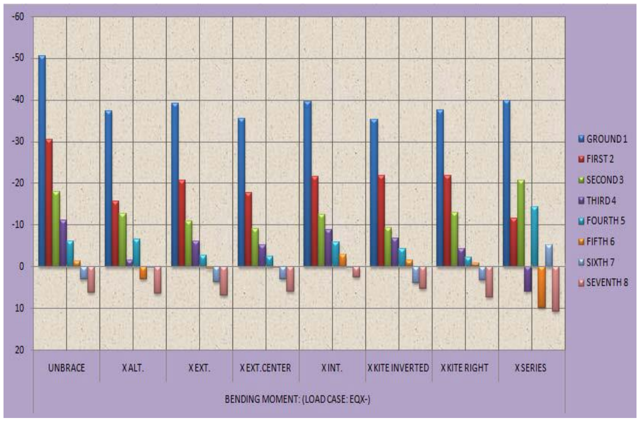

Fig. 3: Comparison of Bending Moment for Corner Column A1

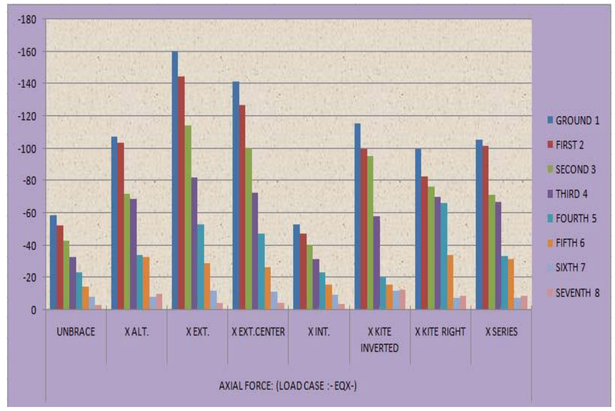

Fig. 4: Comparison of Axial Force for Corner Column A1

Figure 3 reveals that though X Kite inverted frame has same number of bracing elements as compared to X int. and X ext., it shows lesser value, moreover X kite inverted has less number of bracing elements than X alt. and X ext. center, it gives almost same or lesser value. Figure 4 reveals that X int. frame has lowest value as compared to other frames even it has almost same value of axial force as unbraced frame has.

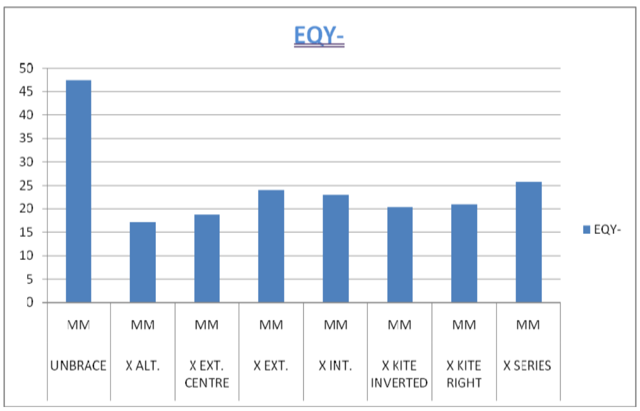

Fig. 5: Comparison of value of Joint Displacement for Corner Column A1

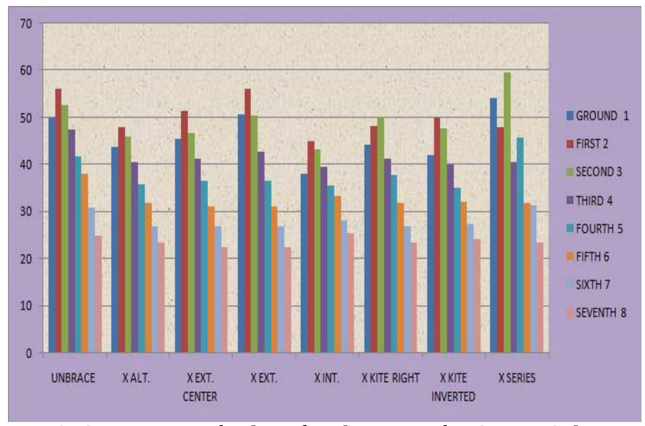

Fig. 6: Comparison of value of Utility Ratio for Corner Column A1

Figure 5 shows X kite inverted frame shows lesser value as compared to the frames have same number of bracing elements. Moreover, X alt. frame which has less number of bracing elements as compared to X ext. centre, shows lesser value of displacement at the top. Figure 6 illustrates that X int. frame has shown lowest value of utility ratio up to fourth floor, and then onwards X ext. centre has lesser value.

C. Edge Column: F4

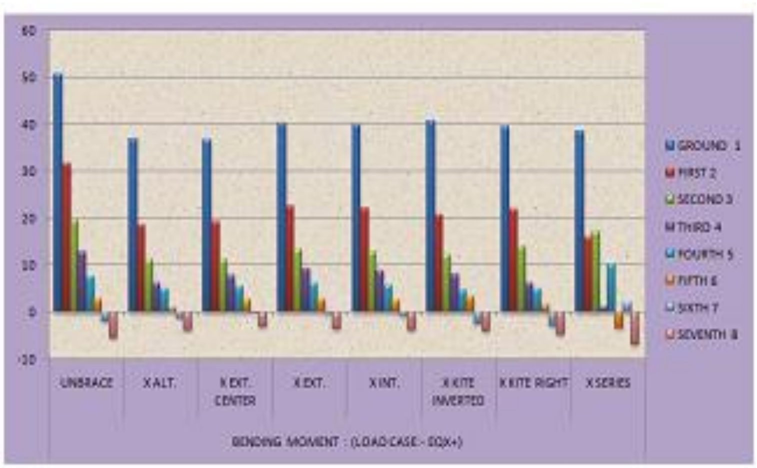

Fig. 7: Comparison of value of Bending Moment for Edge Column F4

Figure 7 reveals that though X alt. frame has shown lesser value as compared to X ext. center, moreover except ground floor X kite inverted has shown lesser value than X ext., X int and X kite right frame.

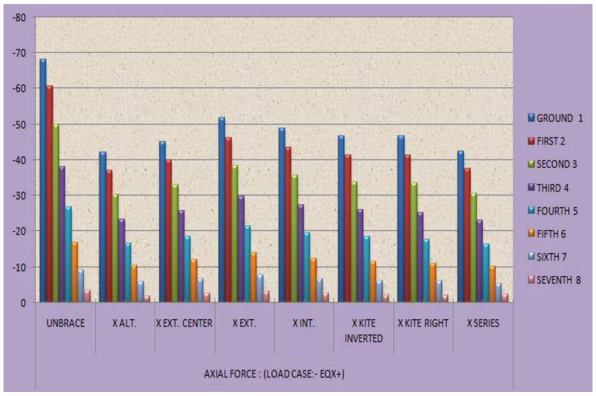

Fig. 8: Comparison of value of Axial Force for Edge Column F4

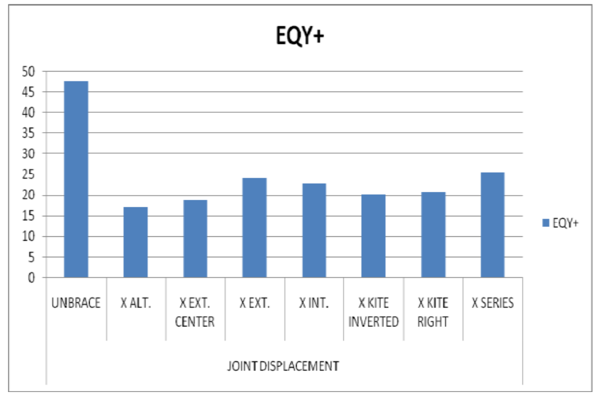

Fig. 9: Comparison of value of Joint Displacement for Edge Column F4

Figure 8 shows X alt. frame shows lesser value of Axial force as compared to others, moreover X kite inverted and X kite right have shown lesser value than X ext. and X int. on each floor. In Figure 9, X kite inverted frame shows lesser value as compared to the frames have same number of bracing elements. X alt. frame shows lesser value as compared to X ext. center.

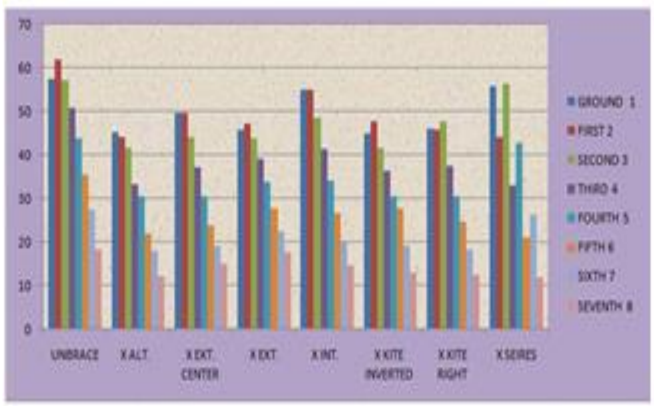

Fig. 10: Comparison of value of Utility Ratio for Edge Column F4

It has been seen from chart that average value of utility ratio of X kite inverted frame as compared to other frame except X alt. has less.

D. Interior Column:C5

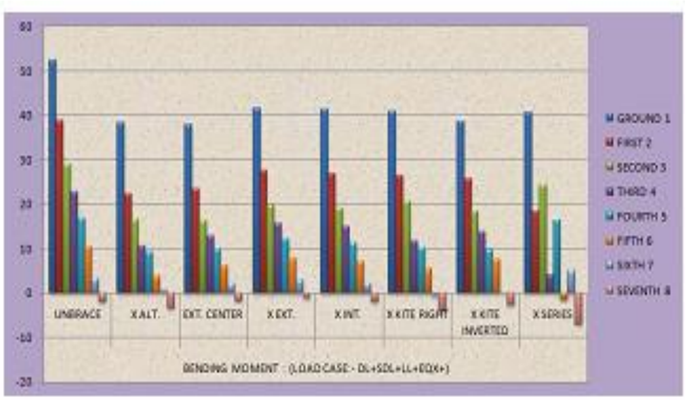

Fig. 11: Comparison of value of Bending Moment for Interior Column C5

Here X kite inverted frame shows lesser value as compared to the frames have same number of bracing elements. X alt. frame shows lesser value than X ext. centre. There is almost no change in the value in any system. It means if bracings are provided on outer periphery of the system, particularly for axial force there is no effect of bracing on interior column.

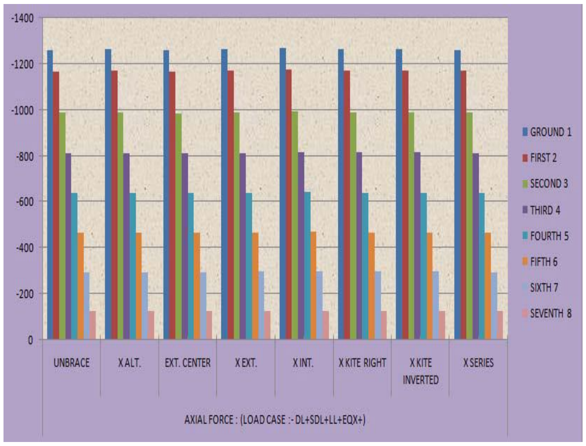

Fig. 12: Comparison of Axial Force for Interior Column C5

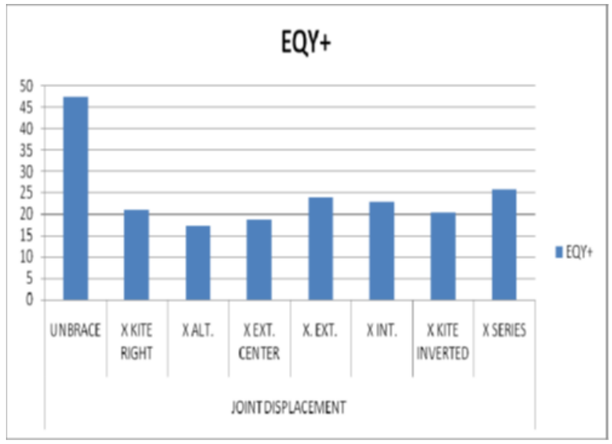

Fig. 13: Comparison of Joint Displacement for Interior Column C5

X kite inverted frame shows lesser values as compared to the frames have same number of bracing elements. X alt. frame shows lesser value as compared to X ext. center. All frames with bracing elements show almost same value of utility ratio. It is further concluded that effect of bracings (located on periphery only) on interior column is same in all bracing configuration but value as compared to unbraced frame is lesser in all case.

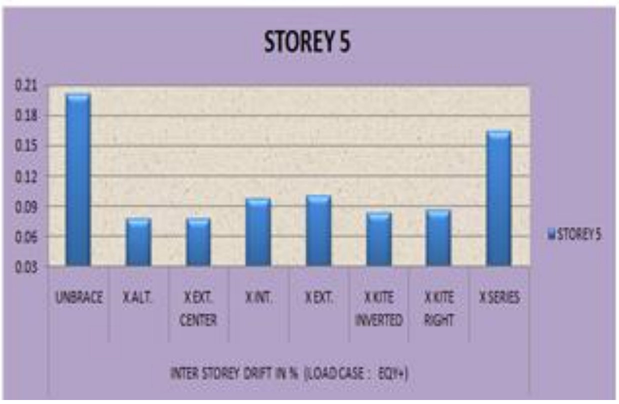

Fig. 14: Comparison of value of Inter Storey Drift

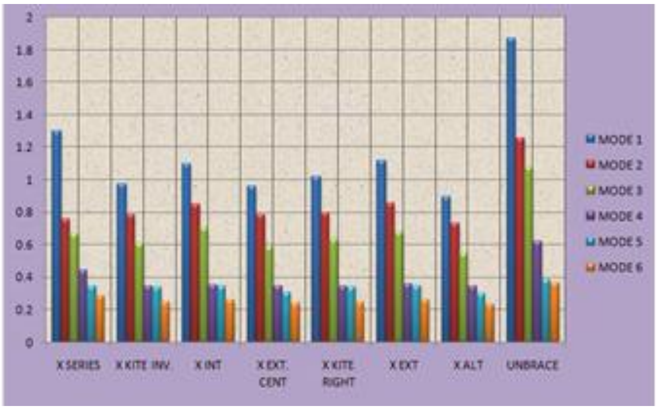

Fig. 15: Comparison of value of Fundamental Time Period

X kite inverted frame has lesser value as compared to any other frames which have same number of bracing elements. X alt. frame shows lesser value of inter storey drift as compared to X ext. centre. X kite inverted frame has lesser value as compared to any other frames which have same number of bracing elements. Even it has almost same value as compare to X ext. center frame which has almost 30% more bracing elements. Chart also reveals that X alt. frame which has less number of bracing elements as compared to X ext. centre, shows lesser value.

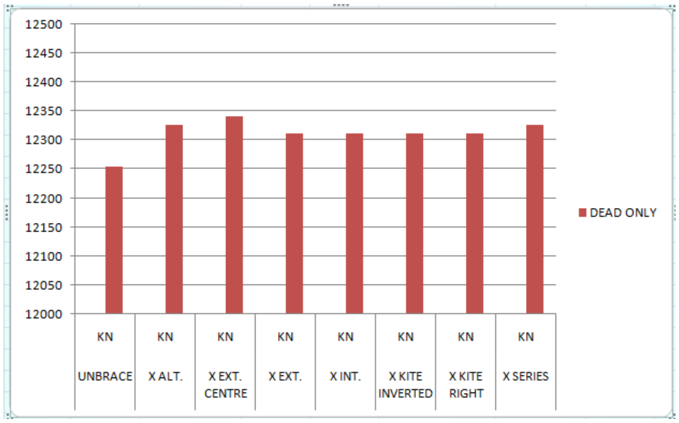

Fig. 16: Comparison of self-weight of frames

E. A Study of Effect of Bracing Configuration on Internal Columns of the Frame

Typical unbraced frame as shown in figure 1a and 1b is compared with fully braced frame having cross bracing on periphery except centre bay of bottom floor. For comparison we have taken results of axial load & utility ratio of column C5. Data is shown in table 1 and 2.

COLUMN	Combo	P	MMajor	MMinor	TotalRatio	PRatio	MMajRatio	MMinRatio
ID	Text	KN	KN-m	KN-m	Unitless	Unitless	Unitless	Unitless
GROUND	DL+SDL+LL-EQY	-1275.807	-0.3613	-23.3751	0.835304	0.515305	0.000472	0.319527
FIRST	DL+SDL+LL-EQY	-1179.697	-1.3506	-27.2293	0.91276	0.519277	0.002009	0.391474
SECOND	DL+SDL+LL-EQY	-997.2	-2.2251	-26.908	0.802419	0.436415	0.003226	0.362778
THIRD	DL+SDL+LL-EQY	-818.362	-2.5933	-25.3785	0.685827	0.358148	0.003694	0.323985
FOURTH	DL+SDL+LL-EQY	-637.376	3.0285	23.2956	0.565406	0.278942	0.004239	0.282225
FIFTH	DL+SDL+LL-EQY	-463.278	3.1963	19.7732	0.435498	0.202749	0.0044	0.228348
SIXTH	DL+SDL+LL-EQY	-291.026	3.1908	14.6081	0.292924	0.127365	0.004322	0.161238
SEVENTH	DL+SDL+LL-EQY	-120.72	4.9486	7.9332	0.154408	0.051002	0.007552	0.095854

Table 1: Data of Column C5 of unbraced frame subjected to lateral loading

COLUMN	Combo	P	MMajor	MMinor	TotalRatio	PRatio	MMajRatio	MMinRatio
ID	Text	KN	KN-m	KN-m	Unitless	Unitless	Unitless	Unitless
GROUND	DL+SDL+LL	-1257.275	0.9738	0.5699	0.690397	0.677093	0.001712	0.011592
FIRST	DL+SDL+LL	-1163.619	1.9029	1.2295	0.713831	0.682934	0.003929	0.026968
SECOND	DL+SDL+LL	-988.896	-2.2704	-1.2929	0.607423	0.577041	0.004535	0.025847
THIRD	DL+SDL+LL	-812.813	-2.6374	-1.0577	0.49898	0.474293	0.005143	0.019544
FOURTH	DL+SDL+LL	-638.882	-2.9572	-0.8809	0.39358	0.372801	0.005635	0.015144
FIFTH	DL+SDL+LL	-466.674	-3.1781	-0.7188	0.289798	0.272314	0.005922	0.011562
SIXTH	DL+SDL+LL	-295.67	-3.3264	-0.5732	0.187261	0.172529	0.006066	0.008666
SEVENTH	DL+SDL+LL	-121.029	4.9959	0.5354	0.086968	0.068178	0.010166	0.008625

Table 2: Data of column C5 of fully braced frame selected to lateral loading

COLUMN	Combo	P	MMajor	MMinor	TotalRatio	PRatio	MMajRatio	MMinRatio
ID	Text	KN	KN-m	KN-m	Unitless	Unitless	Unitless	Unitless
GROUND	DL+SDL+LL	-1258.123	0.9689	0.5723	0.690898	0.67755	0.001703	0.011645
FIRST	DL+SDL+LL	-1164.455	1.8914	1.2384	0.714505	0.683424	0.003906	0.027174
SECOND	DL+SDL+LL	-989.693	-2.2498	-1.4195	0.610387	0.577506	0.004494	0.028387
THIRD	DL+SDL+LL	-813.542	-2.6158	-1.2244	0.502452	0.474718	0.005102	0.022632
FOURTH	DL+SDL+LL	-639.514	-2.927	-1.1453	0.398443	0.373169	0.005578	0.019696
FIFTH	DL+SDL+LL	-467.174	-3.1437	-1.0688	0.295658	0.272606	0.005859	0.017194
SIXTH	DL+SDL+LL	-296.009	-3.2882	-0.998	0.193813	0.172728	0.005996	0.015089
SEVENTH	DL+SDL+LL	-121.179	4.9403	1.1271	0.096472	0.068262	0.010052	0.018158

Table 3: Data of column C5 of unbraced frame subjected to gravity loading

Table 1 shows that on first floor of column C5, the utilization of column is almost nearer to 1 i.e. 100% utilization. It means column section will get fail if extra loading is provided to the frame/column. While table 2 shows that utility ratio is about 70%. It means it has still capacity to take 30% extra loading. Now in next case fully braced frame is compared with unbraced frame subjected to only gravity loads. Data of fully braced frame is given in table 2. Data of unbraced frame subjected to only gravity loads are shown in table 3.

Data of table 2 and 3 shows that values of axial force and utility ratio are almost same. It means if the fames are fully braced from outer periphery then we can control the loading as well as utilization of internal columns and we can also design internal columns in such a way that it can only take gravity loads and lateral loads i.e. earthquake loads are taken by outer columns and bracings. But at the same time total weight of the structure is also a key parameter as it directly deals with cost of project. Comparison of weight is shown in below table 4.

load	Unbrace	Full Brace
	KN	KN
Dead only	12253.646	12395.97

Table 4: Comparison of weight of frames

From above data it is seen that weight in fully braced frame is increased by 142.324 KN. Now from table 2 we have seen that column C5 has still 30% capacity to take extra loading. It means it is still not utilized to its full swing. In view of this to compensate that 30%, we have adopted lesser size of column. Therefore, all internal columns are resized by ISWB 500 instead of ISWB 600 (I). Again the frame having ISWB 500 column ID C5 is compared with unbraced frame subjected to gravity loads. Data of fully braced frame with ISWB 500 columns is shown in table 5.

COLUMN	Combo	P	MMajor	MMinor	TotalRatio	PRatio	MMajRatio	MMinRatio
ID	Text	KN	KN-m	KN-m	Unitless	Unitless	Unitless	Unitless
GROUND	DL+SDL+LL	-1211.8	-0.4329	-0.1804	0.942811	0.934202	0.001341	0.007268
FIRST	DL+SDL+LL	-1121.386	-1.6316	-0.3598	0.940386	0.91906	0.005779	0.015547
SECOND	DL+SDL+LL	-946.124	-2.6629	-0.1249	0.78606	0.772316	0.009113	0.004631
THIRD	DL+SDL+LL	-772.187	3.3828	-0.5021	0.658063	0.630332	0.011286	0.016445
FOURTH	DL+SDL+LL	-604.813	3.7732	-0.8599	0.53131	0.493705	0.012292	0.025312
FIFTH	DL+SDL+LL	-443.315	-3.935	1.0673	0.403031	0.361875	0.012534	0.028621
SIXTH	DL+SDL+LL	-280.25	-4.1163	1.339	0.274537	0.228767	0.012824	0.032946
SEVENTH	DL+SDL+LL	-115.44	5.7956	-1.5849	0.152387	0.091982	0.02022	0.040185

Table 5: Fully braced frame having interior columns ISWB 500

Table 5 reveals that value of utility ratio at ground and first floor of column C5 is nearer to 1 i.e. 100% utilization. Now same frame is compared for weight with unbraced frame and fully braced frame having ISWB 600(I). Below table shows comparison.

Load	Unbrace frame	Fully brace frame ISWB 600 (I)	Fully brace frame ISWB 500
	KN	KN	KN
DEAD ONLY	12253.646	12395.97	12226.171

Table 6: Comparison of weight of frames

It has been seen from above table that Fully braced frame with ISWB 500 columns have lighter than any other frame.

II. CONCLUSION

In view of above study, we come to conclusion in following manner;

A. Bending Moment

- X kite inverted and X kite right frame shows 5% to 10% lesser value as compare to X ext. and X int. frame. All said frames have same number of bracing elements. Values of X alt. frame, which has less number of bracings as compare to X ext. centre, shows 4 to 6% reduction.
- In some cases, values of X kite inverted frame are almost same as of X alt. and X ext. centre. Both later frames have more number of bracings 20% to 30% than X kite inverted frame.

B. Axial Force

- Values of X kite inverted frame for edge column shows 3% to 5% reduction as compare to X ext. and X int. frames. X alt. frame has 5% to 7% reduction in values as compare to X ext. centre frame.
- In case of interior column, there is almost no change in values above seated parameter for all frames.

C. Joint Displacement

- In all cases, X kite inverted frame shows 10% to 20% lesser value as compare to X ext. and X int. frame. X alt. frame has lowest value of joint displacement as compare to other frames.

D. Utility Ratio

- In case of corner column X int. frame shows 15% to 20% lesser value as compare to X ext. frame, X kite right frame and X kite inverted frame.
- In case of edge column X kite inverted frame shows 10% to 15% lesser value as compare to other frames having same number of bracing elements.

E. Inter Storey Drift

- Results reveals that X kite inverted frame has shown 15% to 20% lesser value as compare to X int. and X ext. and even it has less value than X kite right frame.

F. Fundamental Time Period

- X kite inverted frame has lesser value as compared to any other frames which have same number of bracing elements. Even it has almost same value as compare to X ext. centre frame which has around 30% more bracing elements. X alt. frame which has less number of bracing elements as compared to X ext. centre, shows lesser value.
- If the frame is unbraced, in such case all interior columns under lateral loads are utilized to its full capacity.
- If the frame gets fully braced from periphery, then all interior columns can be designed for gravity loads only as lateral loads are governed by outer columns and bracings, moreover sizes of interior columns can also be reduced to take only gravity loads for its full capacity.
- Finally, it has been concluded that even by using bracing to periphery of frame, total weight of the structure can be minimized as compare to unbraced frame subjected to lateral loads.

REFERENCES

[1] Bosco, M. Rossi, P.P., 2009, Seismic behaviour of eccentrically braced frames, Engineering Structures 31 (2009) 664_674
[2] Canney, N., Dr. Roeder, C., Dr. Lehman,D., 2003,Performance of concentrically braced frames under cyclic loading
[3] Cook, A.J., 2005, Structural Steel Framing Options for Mid and High Rise buildings
[4] Goel, S.C., Lee, H.S., 1990, Strengthening of RC Structure with ductile steel bracing
[5] Ho, C. Y., Schierle, G. G., 1992, High-rise Space Frames: Effect of configuration and lateral drift
[6] Jason M., 2005, seismic performance of a concentrically braced frame with an innovative bracing system, CBE Institute
[7] Kasal, B., Hankin Chair, Jay Crandell, 2006, Wall Bracing. Part 1: Basic Components for Code Compliant Bracing, The Pennsylvania Housing Research/Resource Center
[8] Moghaddam, H., Hajirasouliha,I., Doostan,A., 2005, Optimum seismic design of concentrically braced steel frames: concepts and design Procedures, Journal of Constructional Steel Research 61 (2005) 151–166
[9] Mofid, Massood, Lotfollahi, Mehrdad, 2006, On the characteristics of new ductile knee bracing systems, Journal of Constructional Steel Research 62 (2006) 271–281
[10] Naeemi, Mina, Bozorg, Majid, 2009, Seismic Performance of Knee Braced Frame, World Academy of Science, Engineering and Technology 50
[11] Patil, H.S., Modhera, C. D., Deulkar,W. N., Trends in Passive Vibration Control and Some Studies of Braced Frame
[12] Paul M., 2009, Steel Moment Frames – History and Evolution, Structural Engineer magazine, Simpson Strong-Tie
[13] Popov, Egov P.,1982, Seismic Steel Framing Systems for Tall Buildings, Engineering Journal/ American institute of steel construction, third quarter
[14] Richard M. D., 2005, Steel Structures: Not Just Buildings, Modern Steel Construction
[15] Timoshenko S., 1974, Vibration problems in engineering, Wiley
[16] Whittaker, A., Constantinou, M., 2004, Seismic energy dissipation systems for buildings, In: Bertero VV, Bozorgnia Y, editors, Earthquake engineering, from engineering seismology to performance-based engineering. CRC Press