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EFFECTIVE BRACING SYSTEM FOR HIGH RISE BUILDING

Khushboo khandelwal[1],M.M.Murudi[2]

[1]*Structual EngineeringEngineering department, Sardar Patel College of Engineering,*
[2]*Structural EngineeringEngineering department, Sardar Patel College of Engineering,*

Abstract*— *The design of high rise building should involve the good lateral load resisting system along with the vertical loads acting on the building as wind load will govern in high rise buildings. This paper is presented to show the variation of shear force, axial force, bending moment and deflection that would be developed in high rise buildings with different bracing systems at different locations subjected to wind and seismic loading. For this purpose the G+20 storied reinforced concrete building model is used with a constant configuration and with different bracing system such as diagonal bracing, X-bracing, V-bracing, chevron bracing at different locations. A structural analysis is performed by using software STAAD-Pro V8i and different parameters are studied and compared. The sections of such as beams, columns, bracings sare as per IS 800:2007 based on the limit state parameters. Based on the study it can be concluded that along with the type of bracing the locations of bracings is also of great importance in resisting lateral load.

Keywords*— *Wind load, high rise building, wind analysis, different brace system and different locations, shear force, bending moment, weight of structure

I. INTRODUCTION

When a tall building is subjected to lateral or torsional deflections under the action of fluctuating wind or seismic loads, the resulting oscillatory movement can induce a wide range of responses in the building's occupants from mild discomfort to acute nausea. As far as the ultimate limit state is concerned, lateral deflections must be limited to prevent second order p-delta effect due to gravity loading being of such a magnitude which may be sufficient to precipitate collapse. To satisfy strength and serviceability limit stares, lateral stiffness is a major consideration in the design of tall buildings. The simple parameter that is used to estimate the lateral stiffness of a building is the drift index defined as the ratio of the maximum deflections at the top of the building to the total height. Different structural forms of tall buildings can be used to improve the lateral stiffness and to reduce the drift index. In this research the study is conducted for braced frame structures. Bracing is a highly efficient and economical method to laterally stiffen the frame structure against wind loads. A braced bent consists of usual columns and girders whose primary purpose is to support the gravity loading, and diagonal bracing members that are connected so that total set of members forms a vertical cantilever truss to resist the horizontal forces. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing the stiffness and strength against horizontal shear.

TYPES OF BRACED FRAME SYSTEM

Braced frames categorize into two different types, concentric and eccentric which have specific characteristics and design requirements. Braced frames provides open space and design flexibility. These are a very common form of construction, being economic to construct and simple to analyze. Economy comes from the inexpensive, nominally pinned connections between beams and columns. Bracing which provide stability and resists lateral loads, may be from diagonal steel members or from a concrete core. In Braced construction, beams and columns are designed under vertical load only, assuming the bracing system carries all lateral loads.

Braced frames provide resistance to lateral forces acting on a structure. The member of a braced frame act as a truss system and are subjected primarily to axial force. Depending on the diagonal force, length, required stiffness and clearances, the diagonal members can be made of double angles, channels, tees, tubes or even wide flange shape. Besides performance, the shape of the diagonal is often based on connection considerations. The braces can also be joined to form a closed or partially closed three dimensional cell so that torsional loads can be resisted effectively.

There are two types of bracing systems

1) Concentric Bracing System

2) Eccentric Bracing System.

Concentrically braced frames In CBF the axes of all the members i.e column, beams and braces intersect at a common point such that the member forces are axial.These are class of structures resisting lateral loads through a vertical concentric truss system. The concentric bracings increase the lateral stiffness of the frame and usually decrease the lateral drift. However, increase in the stiffness may attract a larger inertia force due to earthquake. They have high strength and suitable lateral stiffness to prevent relative drift due to lateral load impacts resulting from earthquake. Such braces are part of relatively stiff systems and compatible with common needs of architecture with varied forms . Concentrically braced frames are used in different forms such as cross, diametric and chevron are shown in figure 1.1.

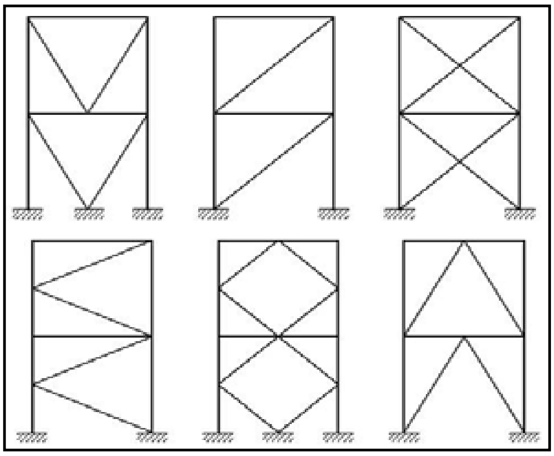

Figure: 1.1 Different types of concentrically braced frames

Eccentrically braced frames: The bracing member in EBE is connected to the beam so s to form a short link between the braced and the column or between two opposing braces as shown in figure. Thus, the eccentric bracing is unique system that attempts to combine the strength and stiffness of a braced frame with the inelastic behaviour and energy dissipation characteristics of a moment frame. The link beam acts as fuse to prevent buckling of the brace due to large overloads that may occur during major earthquakes. After the elastic capacity of the system is exceeded, shear or flexural yielding of the link provides a ductile response in contrast to that obtained in a special moment resisting frame. In addition, eccentrically braced frames may be designed to control frame deformations and minimize damage to architecture finishes.

The web buckling is prevented by providing adequate to stiffness in the link. Links longer than twice the depth of the beam tend to develop plastic hinges, while shorter links tend to yield in shear. Building using EBF is lighter than moment resisting frames. Premature failure of the link does not cause the structure to collapse, since the structure continues to retain its vertical load carrying capacity and stiffness.

EBFs utilize axial offsets to deliberately introduced flexure and shear into framing beams to increase ductility. For example the knee bracing the end parts of beam are in compression and tension with entire beam subject to double curvature bending. EBF reduces the lateral stiffness of the system and improve the energy dissipation capacity. The lateral stiffness of the system depends upon the flexural stiffness property of the beams and columns, thus reducing the lateral stiffness of the frame. The vertical component of the bracing forces due to earthquake causes lateral concentrated load on the beams at the point of connection of the eccentric bracings.

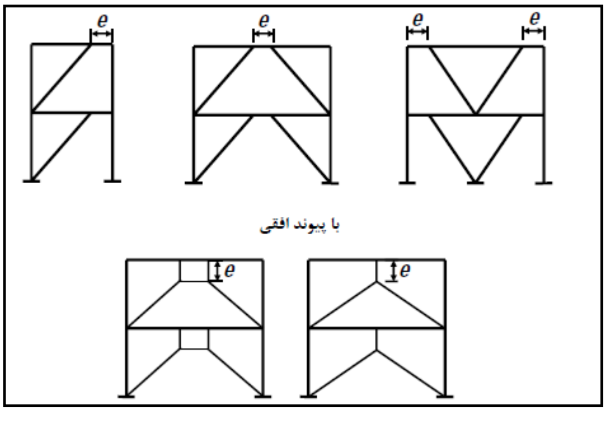

Figure: 1.2 Types of eccentrically braced frames depending on the location of the link beam

Moment Resisting Frames: These frames are rectilinear assemblages of beams and columns, with the beams rigidly connected to the columns. Resistance to lateral forces is provided primarily by rigid frame action that is by the development of bending moment and shear force in the members and the joints By the virtue of the rigid beam column connection, a moment frame can displace laterally without bending the beams or columns depending on the geometry of the connection. The bending rigidity and strength of the frame members is therefore the primary source of lateral stiffness and strength for the entire frame.

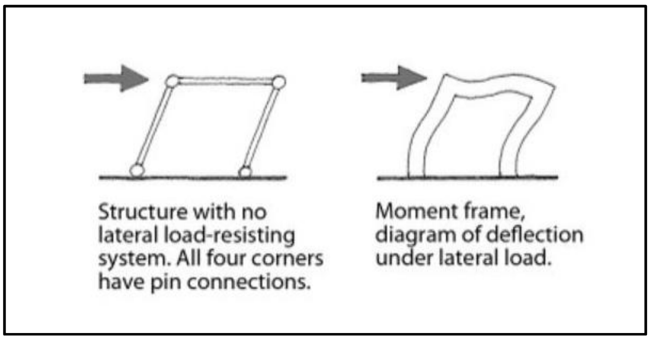

Figure 1.3 shows the deflection pattern of pinned frame and moment frame respectively

II. DETAILS OF THE STRUCTURE

A. Modeling and Analysis

The main aim to carry out analysis on different models is to study different bracing system placed at various location and their behavior. STAAD Pro V8i has been used for the analysis of different models. Initially, G+20 stories model is used with a constant configuration and with different bracing system such as diagonal bracing, X-bracing, V-bracing, chevron bracing at different locations. Results of different types of bracing system for buildings at various locations are discussed below. All the building models are subjected to gravity load, wind load and earthquake loads. The comparison is made between the diagonal bracing, X-bracing, V-bracing, chevron bracing at different locations as shown in figure

Full forms of the terms used for representing various bracing system configurations

1	MF	Moment Frame
2	OMOS	One Shear and One Moment Frame
3	SF	Shear frame without Bracing
4	CBCO	Chevron Bracings Corner
5	CBC	Chevron Bracings Center
6	VBCO	V Bracings Corner
7	VBC	V Bracings Center
8	CVBO	Chevron & V Bracing Corner
9	CVB	Chevron & V Bracing Corner
10	DBCO1	Diagonal Bracings Corner Config.
11	DBC1	Diagonal Bracings Center Config.1
12	DBCO2	Diagonal Bracings Corner Config.2
13	DBC2	Diagonal Bracings Center Config.2
14	DBZ	Diagonal Bracings Config. Zigzag
15	DBX	Diagonal Bracings Corner X
16	DBCO3	Diagonal Bracings Corner Config. 3
17	DBC3	Diagonal Bracings Center Config.3
18	XBCO	X Bracings Corner
19	XBC	X Bracings Center
20	XBX	X Bracings configuration X
21	XBZ	X Bracings Configuration Zigzag

B. Assumptions

The building is assumed to be a industrial building (TG Building) of a power plant in Delhi Region.The plan of the building is 24 m x 20m with 4 bays in x- direction and 4 bays in z-direction as shown in figure. The floor to floor height is 3m.The following assumptions are:

GRID SIZE: 24 M X 20 M

Total Height: 100 m

Size of Columns: UC 356

Size of Beams at each floor: ISMB 300

All supports were assumed to be fixed.

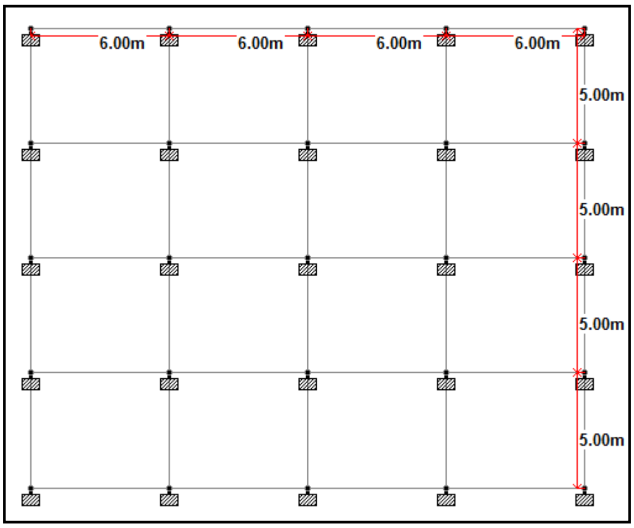

Figure: 2.1 Plan of the Building

III. LOADING DESCRIPTION

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A. **Gravity loads**

It includes the dead load, live load and floor finish. Floor loads and member loads are considered with reference to the specifications given in IS 875: Part 1 [7]. Live load is considered according to the specifications given in IS 875: Part 2[8] for residential building. The live load intensity is 3 kN/m2 for all the floors.

B. **Wind loads**

Static wind load is given as per IS 875-part3 [9].
Following assumptions are used for calculations.
Location :Delhi
Wind speed : 47m/s
Terrain category : 3
Class : C
K1 : 1
K2 : Depending upon the variation of height.
K3 : 1.0(flat topography)

C. **Seismic loads**

Dynamic earthquake load is given as per IS 1893: 2002.Following assumptions are used for calculations:

Zone Factor :0.24
Importance Factor :1-
Response Reduction Factor : 5
Soil Type : Medium Soil
Damping Coefficient :0.02

D.LOAD COMBINATION

The different load combinations as per IS 875-2007 for strength and serviceability are as follows:

1 Load Combinations for Strength
1.5DL + 1.5LL
1.5DL + 1.5WL/SL
1.2DL + 1.2LL + 1.2WL/SL
0.9DL + 1.5WL/SL
2 Load Combinations for Serviceability
DL + LL
DL + WL/SL
DL + LL + WL/SL

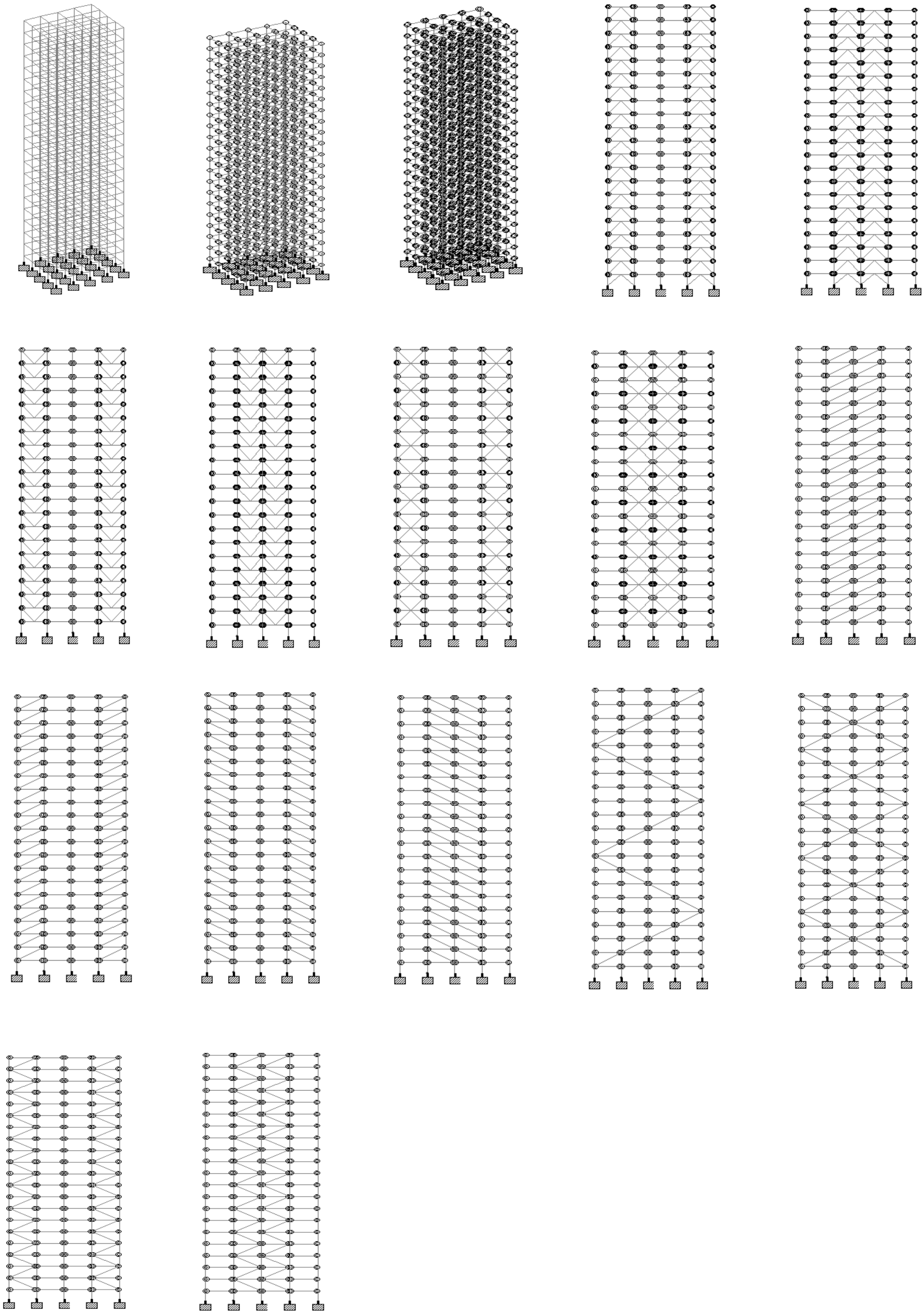


Figure 1 showing different bracing pattern with different configuration and at different location

IV. RESULTS

Following are the table 1 to 7 and graphs for bending moment, shear force , axial force deflection of the structure.

TABLE 1

	Moment in X direction		% increase/decrease	
Types of Bracing Systems	Wind	Seismic	Wind	Seismic
Moment frame	234.6	365		
Chevron at corner	159	212	-32.2	-41.9
Chevron at center	161	217	-31.4	-40.5
V at corner	149	218	-36.5	-40.3
V at center	162	216.4	-30.9	-40.7
Chevron and V at Corner	152	203	-35.2	-44.4
Chevron and V at Center	151	207	-35.6	-43.3
Diagonal Bracing corner Config. 1	257	331	9.5	-9.3
Diagonal Bracing center Config. 1	251	328	7.0	-10.1
Diagonal Bracing corner Config. 2	225	326	-4.1	-10.7
Diagonal Bracing center Config. 2	249	323	6.1	-11.5
Diagonal bracing Zigzag config.	278	366.6	18.5	0.4
Diagonal bracing X config.	197	268	-16.0	-26.6
Diagonal Bracing corner Config. 3	213.7	277	-8.9	-24.1
Diagonal Bracing center Config. 3	214	278	-8.8	-23.8
X Bracing corner	146	197	-37.8	-46.0
X Bracing center	149	202.6	-36.5	-44.5
X Bracing zigzag config.	318	375	35.5	2.7
X Bracing X config.	187.6	250	-20.0	-31.5

TABLE 2

	Moment in Z direction		% increase/decrease	
Types of Bracing Systems	Wind	Seismic	Wind	Seismic
Moment frame	197.6	547		
Chevron at corner	146	343	-26.1	-37.3
Chevron at center	101	259	-48.8	-52.7
V at corner	147	344	-25.6	-37.1
Vat center	145	347	-26.6	-36.6
Chevron and V at Corner	129	324	-34.7	-40.8
Chevron and V at Center	135	329	-31.7	-39.9
Diagonal Bracing corner Config. 1	232	527	17.4	-3.7
Diagonal Bracing center Config. 1	210.5	521	6.5	-4.8
Diagonal Bracing corner Config. 2	221	515	11.8	-5.9
Diagonal Bracing center Config. 2	220.5	512	11.6	-6.4
Diagonal bracing Zigzag config.	258	566	30.6	3.5
Diagonal bracing X config.	183	430.4	-7.4	-21.3
Diagonal Bracing corner Config. 3	188.6	438	-4.6	-19.9
Diagonal Bracing center Config. 3	188	439	-4.9	-19.7
X Bracing corner	141	336	-28.6	-38.6
X Bracing center	141	332.6	-28.6	-39.2
X Bracing zigzag config.	265	576	34.1	5.3
X Bracing X config.	187	443.5	-5.4	-18.9

TABLE 3

	Shear in X direction		% increase/decrease	
Types of Bracings	Wind	Seismic	Wind	Seismic
Model without brace	47	99		
Chevron at corner	78.6	160	42.9	13.5
Chevron at center	90.8	218	65.1	54.6
V at corner	56.5	138	2.7	-2.1
Vat center	61.7	142.8	12.2	1.3
Chevron and V at Corner	80.6	161	46.5	14.2
Chevron and V at Center	86	208	56.4	47.5
Diagonal Bracing corner Config. 1	91.7	209	66.7	48.2
Diagonal Bracing center Config. 1	197	295.8	258	109.8
Diagonal Bracing corner Config. 2	90.5	200	64.5	41.8
Diagonal Bracing center Config. 2	98.4	212	78.9	50.4
Diagonal bracing Zigzag config.	98	219	78.2	55.3
Diagonal bracing X config.	80	178	45.5	26.2
Diagonal Bracing corner Config. 3	73.7	158	34.0	12.1
Diagonal Bracing center Config. 3	77	174	40.0	23.4
X Bracing corner	69.5	151.8	26.4	7.7
X Bracing center	87.5	208.7	59.1	48.0
X Bracing zigzag config.	101	224	83.6	58.9
X Bracing X config.	71.3	158.6	29.6	12.5

TABLE 4

	Shear in Z direction		% increase/decrease	
Types of Bracings	Wind	Seismic	Wind	Seismic
Model without brace	59.7	89.5		
Chevron at corner	130	169	68.8	21.6
Chevron at center	149	254	93.5	82.7
V at corner	123.8	186	60.8	33.8
Vat center	146.5	195.8	90.3	40.9
Chevron and V at Corner	136	176	76.6	26.6
Chevron and V at Center	176	246	128.6	77.0
Diagonal Bracing corner Config. 1	193	252	150.6	81.3
Diagonal Bracing center Config. 1	281	339.7	264.9	144.4
Diagonal Bracing corner Config. 2	185	245	140.3	76.3
Diagonal Bracing center Config. 2	196	256	154.5	84.2
Diagonal bracing Zigzag config.	226	315	193.5	126.6
Diagonal bracing X config.	175.6	235.6	128.1	69.5
Diagonal Bracing corner Config. 3	163	212	111.7	52.5
Diagonal Bracing center Config. 3	166	220	115.6	58.3
X Bracing corner	129	172	67.5	23.7
X Bracing center	193	245	150.6	76.3
X Bracing zigzag config.	214	324	177.9	133.1
X Bracing X config.	124.7	161.8	61.9	16.4

TABLE 5

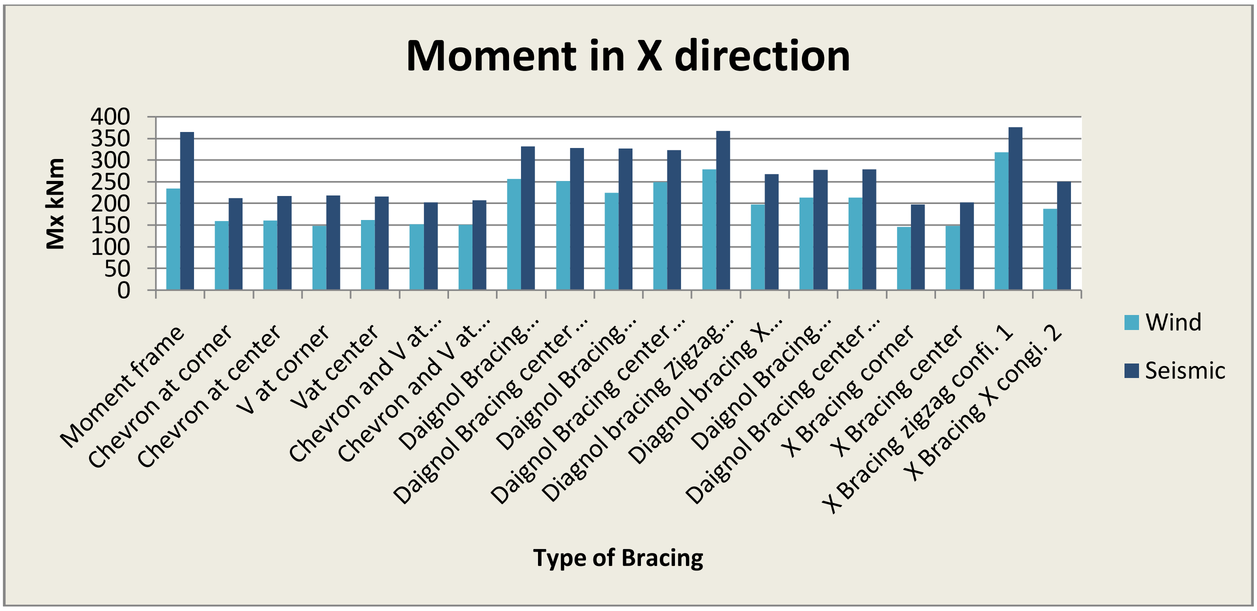
	Drift in X direction	
Types of Bracings	Wind	Seismic
Moment Frame	50.80	161.80
Chevron at corner	34.2	78.4
Chevron at center	30.8	69
V at corner	35.2	78
V at center	29	68.8
Chevron and V at Corner	26.9	73.9
Chevron and V at Center	23.5	63.3
Diagonal Bracing corner Config. 1	48	118
Diagonal Bracing center Config. 1	44.2	108.4
Diagonal Bracing corner Config. 2	46.1	117.5
Diagonal Bracing center Config. 2	42.8	108
Diagonal bracing Zigzag config.	61	155.8
Diagonal bracing X config.	33	90.7
Diagonal Bracing corner Config. 3	41.9	106
Daigonol Bracing center Config. 3	38	96.8
X Bracing corner	26.9	71.4
X Bracing center	23.5	60.4
X Bracing zigzag config.	59	142
X Bracing X config.	26.6	75.2

TABLE 6

	Drift in Z direction	
Types of Bracings	Wind	Seismic
Moment Frame	101.00	162.20
Chevron at corner	82.6	99.5
Chevron at center	70.67	85.6
V at corner	64	98.5
V at center	72.5	85.6
Chevron and V at Corner	66.7	93.5
Chevron and V at Center	56.7	79
Diagonal Bracing corner Config. 1	100.6	137
Diagonal Bracing center Config. 1	87.2	121
Diagonal Bracing corner Config. 2	101	136.4
Diagonal Bracing center Config. 2	88	120.8
Diagonal bracing Zigzag config.	122.5	173.5
Diagonal bracing X config.	64.8	96.8
Diagonal Bracing corner Config. 3	90.9	186
Daigonol Bracing center Config. 3	77.6	108
X Bracing corner	57.5	84.2
X Bracing center	62	86.8
X Bracing zigzag config.	118	169
X Bracing X config.	37.5	55.6

TABLE 7

	Axial Force		% increase/decrease	
Types of Bracings	Wind	Seismic	Wind	Seismic
Moment Frame	7477	7477	18.3	-5.3
Chevron at corner	7478	9347	18.4	18.4
Chevron at center	7476	9344	18.3	18.3
V at corner	7478	9345	18.4	18.3
V at center	7669	9586	21.4	21.4
Chevron and V at Corner	7669	9586	21.4	21.4
Chevron and V at Center	6719	8399	6.3	6.4
Diagonal Bracing corner Config. 1	6719	8398	6.3	6.3
Diagonal Bracing center Config. 1	7478	9344	18.4	18.3
Diagonal Bracing corner Config. 2	7476	9344	18.3	18.3
Diagonal Bracing center Config. 2	8052	10655	27.4	34.9
Diagonal bracing Zigzag config.	8052	10065	27.4	27.5
Diagonal bracing X config.	7478	9344	18.4	18.3
Diagonal Bracing corner Config. 3	7478	9344	18.4	18.3
Daigonol Bracing center Config. 3	6912	8640	9.4	9.4
X Bracing corner	6719	8398	6.3	6.3
X Bracing center	8100	10054	28.2	27.3
X Bracing zigzag config.	7859	9824	24.4	24.4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200
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0
Moment frame
Chevron at corner
Chevron at center
V at corner
Vat center
Chevron and V at...
Chevron and V at...
Daignol Bracing...
Daignol Bracing center ...
Daignol Bracing...
Daignol Bracing center ...
Diagnol bracing Zigzag...
Diagnol bracing X...
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X Bracing corner
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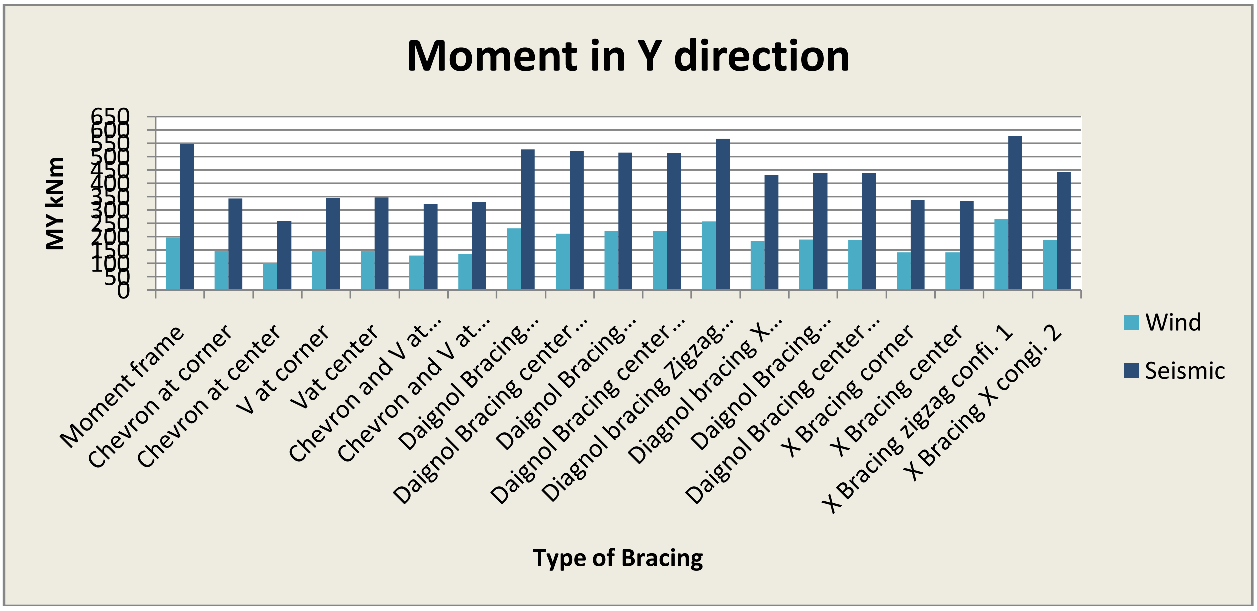
X Bracing zigzag confi. 1
X Bracing X congi. 2
Type of Bracing
Wind
Seismic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MY kNm
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Moment frame
Chevron at corner
Chevron at center
V at corner
Vat center
Chevron and V at...
Chevron and V at...
Daignol Bracing...
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Daignol Bracing center ...
Diagnol bracing Zigzag...
Diagnol bracing X...
Daignol Bracing...
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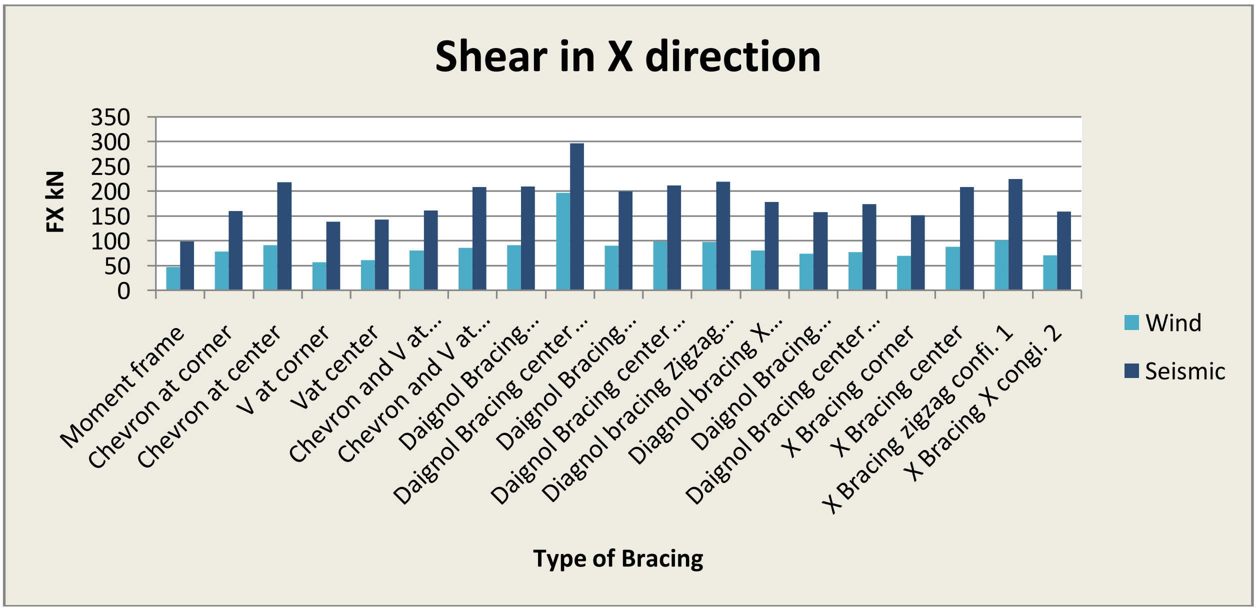
X Bracing corner
X Bracing center
X Bracing zigzag confi. 1
X Bracing X congi. 2
Type of Bracing
Wind
Seismic


Shear in X direction
FX kN
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100
50
0
Moment frame
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Chevron at center
V at corner
Vat center
Chevron and V at...
Chevron and V at...
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Daignol Bracing center ...
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Diagnol bracing X...
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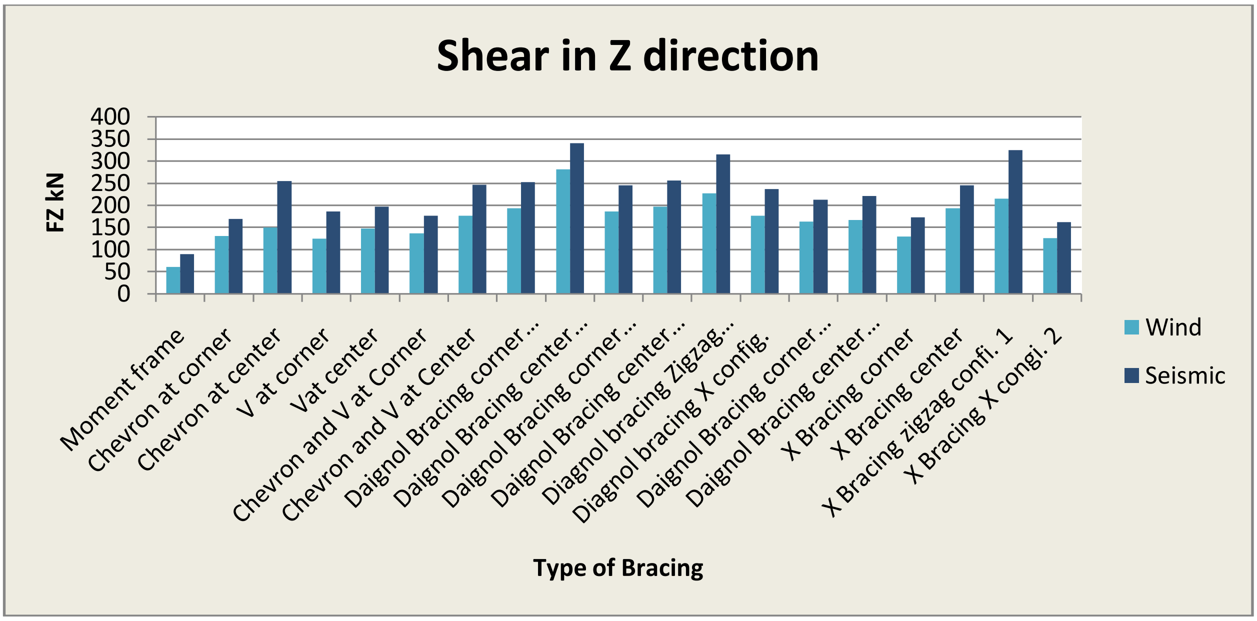
X Bracing center
X Bracing zigzag confi. 1
X Bracing X congi. 2
Type of Bracing
Wind
Seismic


Shear in Z direction
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V at corner
Vat center
Chevron and V at Corner
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Daignol Bracing corner...
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Diagnol bracing Zigzag...
Diagnol bracing X config.
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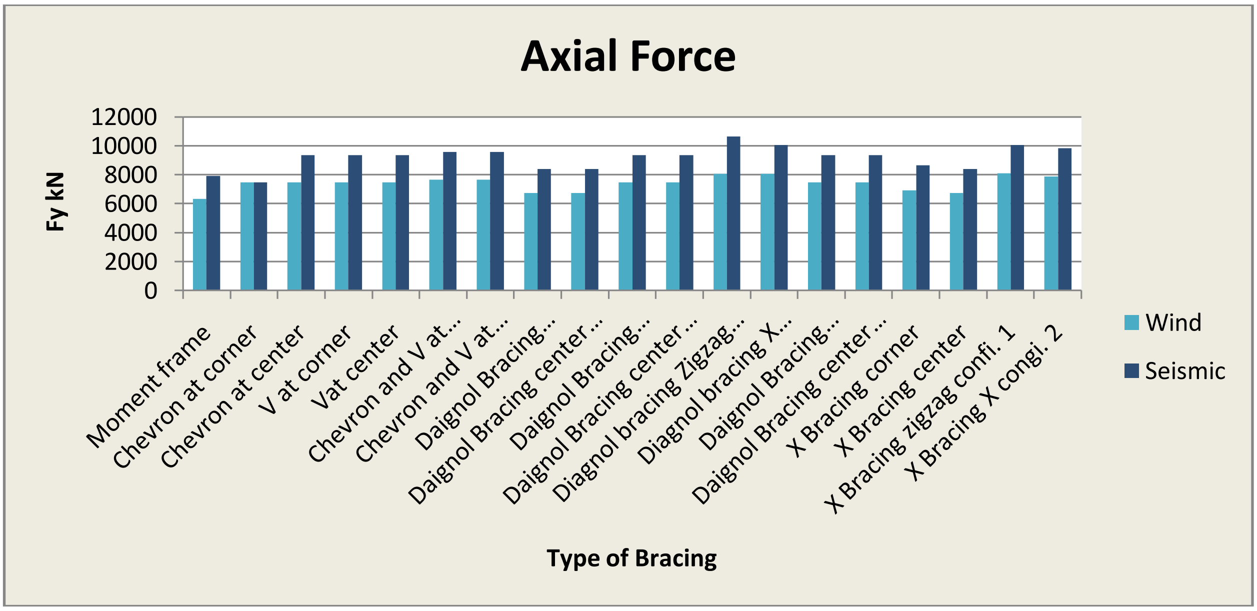
X Bracing zigzag confi. 1
X Bracing X congi. 2
Type of Bracing
Wind
Seismic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Fy kN
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Chevron and V at...
Daignol Bracing...
Daignol Bracing center...
Daignol Bracing...
Daignol Bracing center...
Diagnol bracing Zigzag...
Diagnol bracing X...
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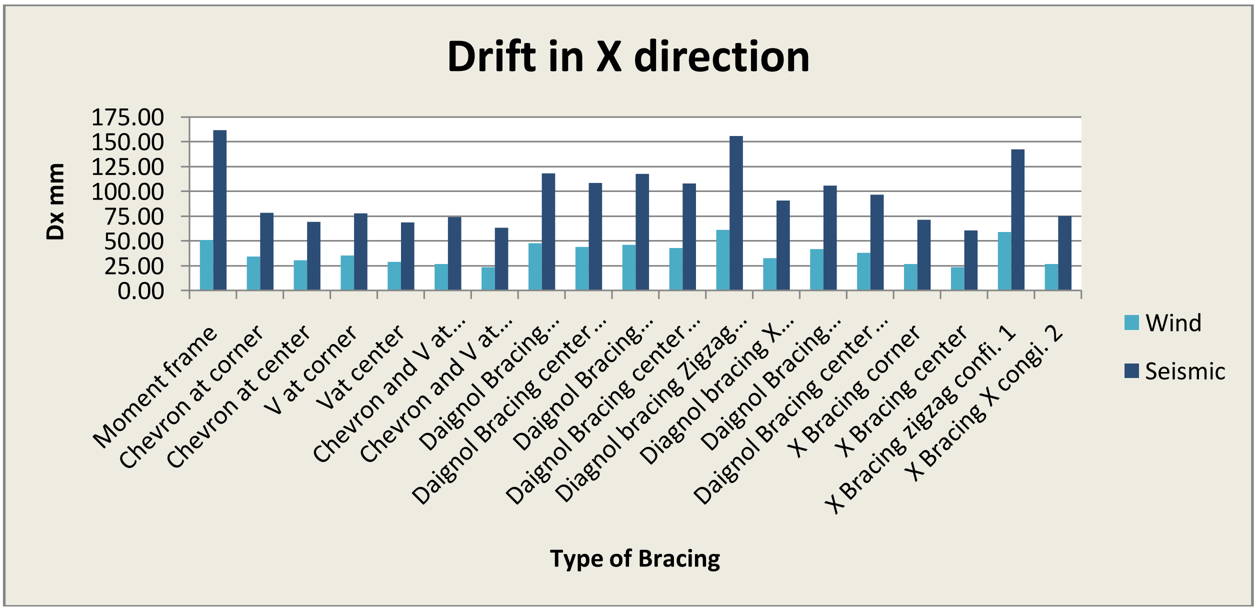
X Bracing X congi. 2
Type of Bracing
Wind
Seismic


Drift in X direction
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125.00
100.00
75.00
50.00
25.00
0.00
Moment frame
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Chevron at center
V at corner
Vat center
Chevron and V at...
Chevron and V at...
Daignol Bracing...
Daignol Bracing center...
Daignol Bracing...
Daignol Bracing center...
Diagnol bracing Zigzag...
Diagnol bracing X...
Daignol Bracing...
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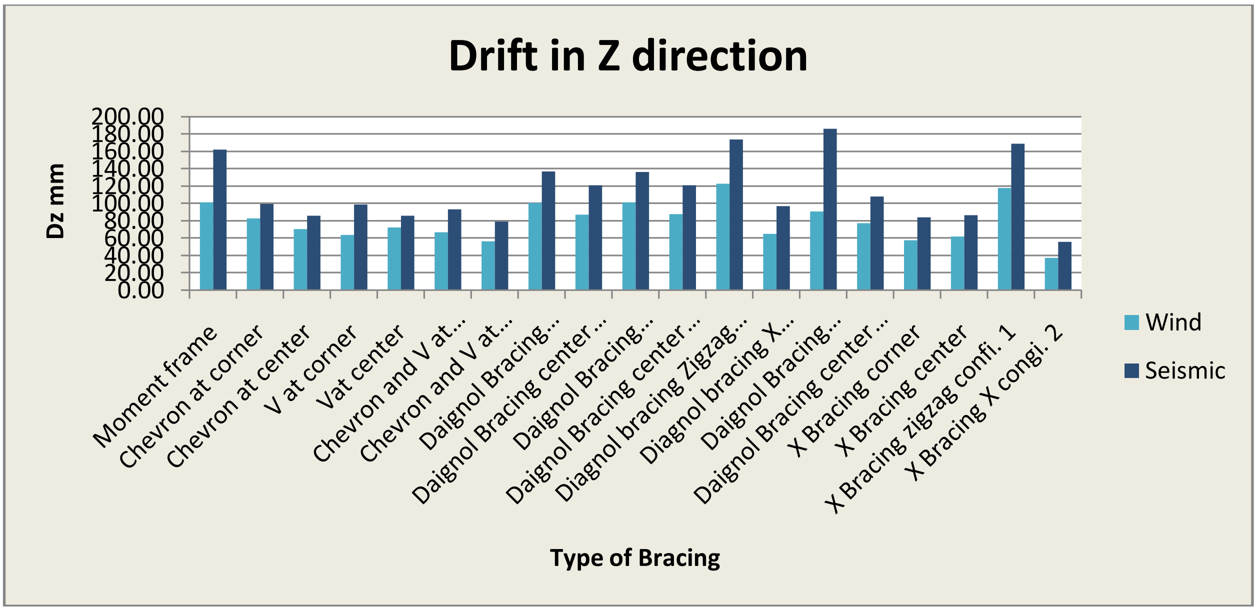
X Bracing corner
X Bracing center
X Bracing zigzag confi. 1
X Bracing X congi. 2
Type of Bracing
Wind
Seismic



V CONCLUSION

On the basis of results of different bracing systems obtained it can be concluded that different bracing systems at different location of the structure can be effectively used to reduce excessive bending moment in column due to lateral (Wind/ Seismic) loading.

From the observations made above it can be concluded that Chevron and V at corner and center as well as X bracing at corner and center bays is most effective in reducing bending moment due to lateral (wind/ Seismic) loading and Diagonal bracing and X bracing in Zigzag performs worst.

On the basis of results of different bracing systems obtained it can be concluded that the V bracing performs best and diagonal bracing config.1 at center has the maximum shear force at the base.

There is no significant variation in Axial Force in both X and Z direction.

For deflection X bracing at center and X bracing in X configuration gives the minimum deflection in X direction and zigzag configuration gives the maximum deflection.

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