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A study on the Effectiveness of Steel Bracings in RCC Structure

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Abstract- *Due to inadequate lateral resistance, most of the existing reinforced concrete structures require seismic retrofitting. Thus to strengthen and stiffen the structure, one such scheme used is the use of bracings. The bracings are attached to the perimeter frame and minimize the disruptions in the structure during and after construction. Bracing system is quite efficient in increasing strength and stability of the structure by controlling lateral displacement of frame caused by various natural forces such as earthquake force. In this study, two high rise RCC structures have been analysed along with various bracing systems using STAAD.Pro V8i and ETABS software.*

Keywords- Bracing System; lateral displacement; storey drift; lateral loads

INTRODUCTION

Earthquake-resistant structures are planned to resist the largest earthquake of a certain probability that is likely to occur at their location. This means the loss of life should be lessened by preventing collapse of the buildings for rare earthquakes while the loss of functionality should be limited for more common ones. When an earthquake occurs, the structure undergoes dynamic motion because the building experience inertia force which acts in direction opposite to the direction of acceleration of earthquake vibrations. This force, which the structure undergoes, is called seismic force.

Various methods are used for retrofitting the structure and making it earthquake resistant. One such method is the use of bracing system. The bracings are attached to the perimeter frame and minimize the disruptions in the structure during and after construction. Bracing system is quite efficient in increasing strength and stability of the structure by controlling lateral displacement of frame caused by various natural forces such as earthquake force.

Bracings can be of two types:

(a) Concentric bracings increase the lateral stiffness of the frame which in return increases the natural frequency. Lateral drift is reduced n this process. But with the increase in the stiffness, inertia force due to earthquake may increase.

(b) Eccentric Bracings reduce 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.

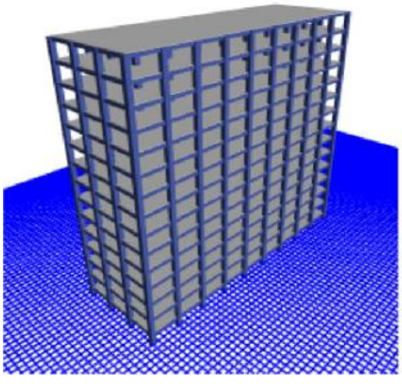
STRUCTURAL SPECIFICATION

STRUCTURE 1

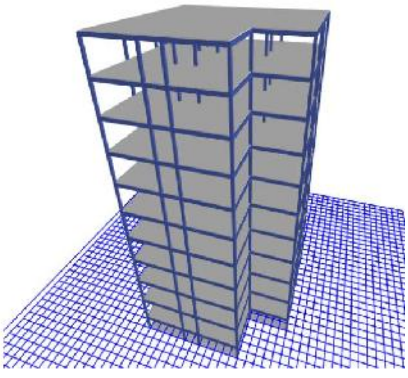
No. of stories	G+14
Beam size	500mm x 300 mm
Column size	750mm x 750mm
Dead Load Intensity	5 kN/m^2
Live Load Intensity	3 kN/m^2
Seismic zone, Z	IV
Importance Factor, I	1
Response Reduction Factor, R_f	5

STRUCTURE 2

No. of stories	G+10
Storey height (typical floors)	3.5m
Storey height (bottom storey)	2.5m
Grade of concrete	M 30
Grade of steel	Fe 415
Thickness of slab (passage)	150mm
Thickness of slab	200mm
Beam size	350mm x 250mm
Column size	250mm x 250mm
Thickness of wall	0.23 m
Dead Load	5 kN/m^2
Live Load	3 kN/m^2
Wall Load (all floors)	16 kN/m
Wall Load (top floor)	5 kN/m
Seismic Zone	IV
Zone factor, *Z*	0.36
Importance factor, *I*	1.0
Response reduction factor R_f	3.00



Structure 1



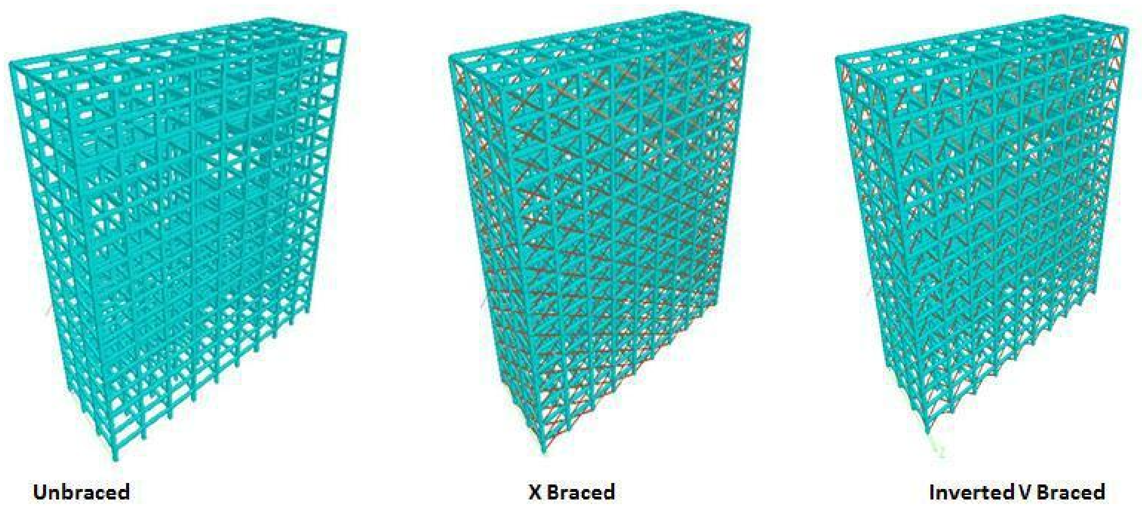
Structure 2

Fig.1 Unbraced Structure (Rendered View)

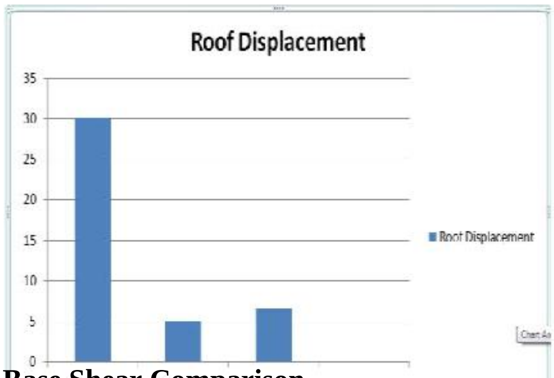
These two structures have been analysed with V bracing, inverted V bracing, X bracing and double cross bracings. Also, structure 2 has been alalysed using two different rolled sections for bracings, namely ISMC 200 and ISMC 300.

STRUCTURAL MODELING AND ANALYSIS

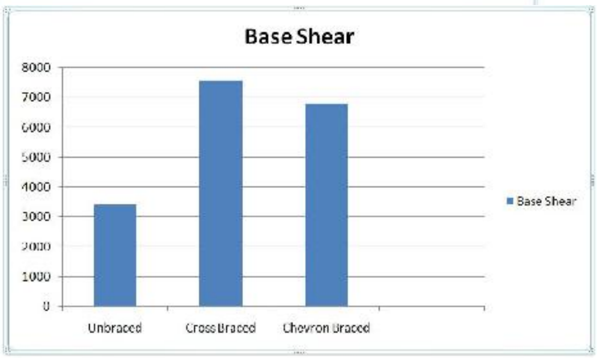
STRUCTURE 1 STAAD Analysis



Roof Displacement Comparison



Base Shear Comparison



Category 1	Unbraced
Category 2	Cross Braced
Category 3	Chevron Braced

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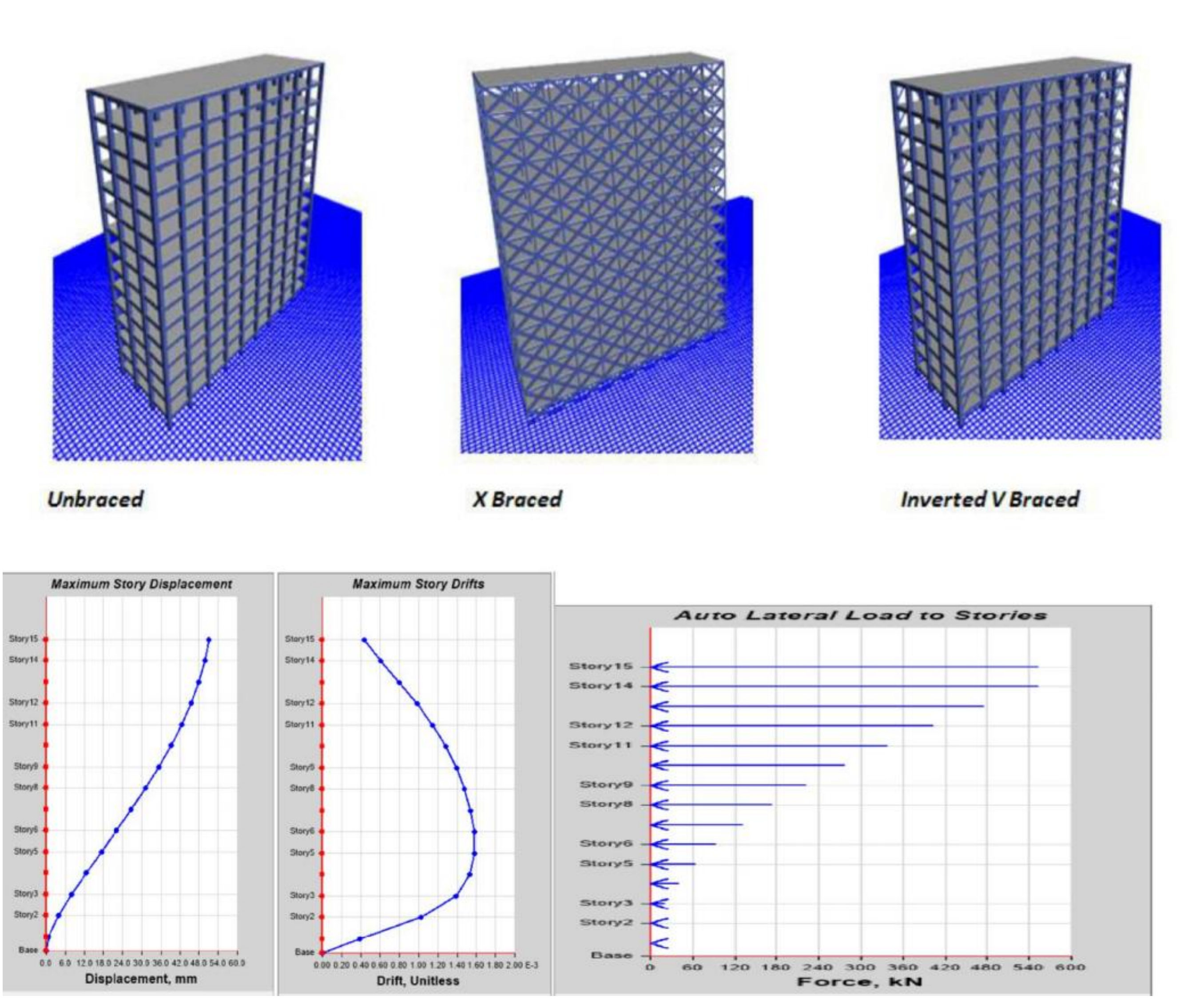
The bar charts given above represent that with the installation of bracings in structure; the roof displacement reduces and is least in cross bracings.

Also, base shear increases and it becomes maximum in cross braced structure. Thus, cross braced structure turns out to be more effective than chevron braced structure in STAAD.Pro analysis.

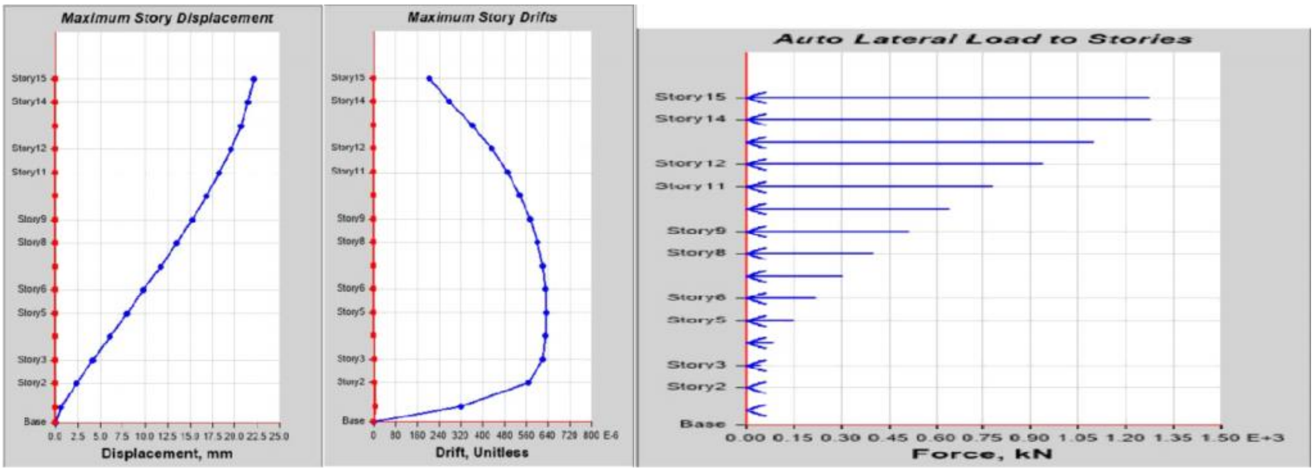
STRUCTURE 1 ETABS Analysis

The same structure was analysed with ETABS software and the results are shown below.



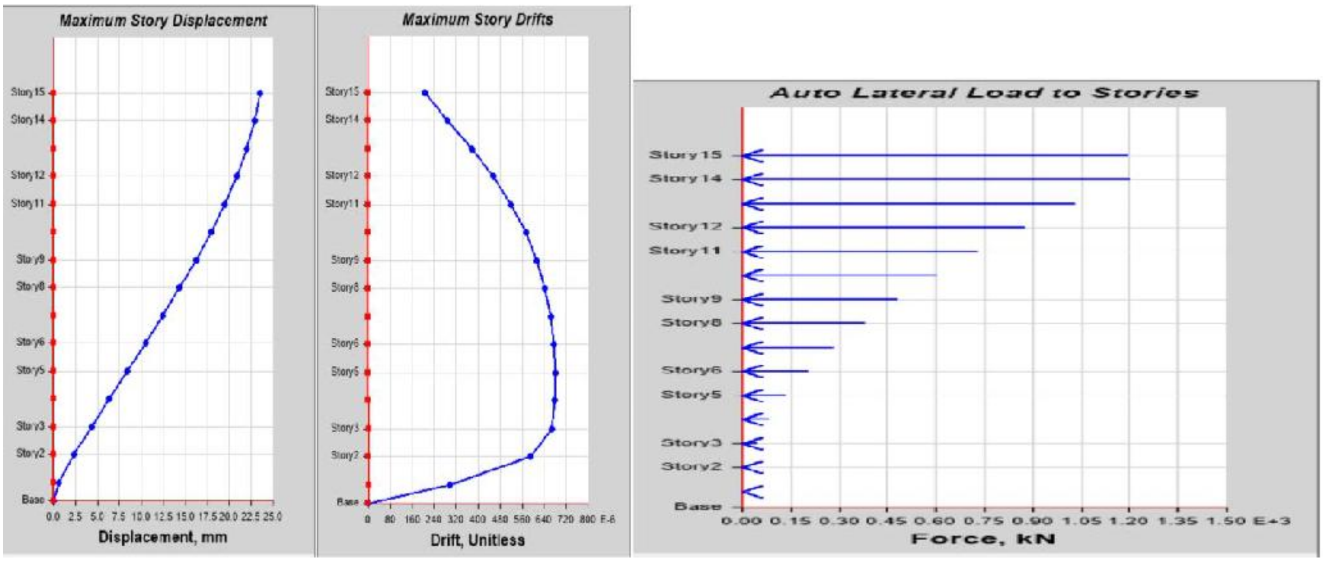
Displacement *Drift* *Lateral loads*

Fig.2 Unbraced structure



Displacement *Drift* *Lateral loads*

Fig.3 X braced structure



Displacement *Drift* *Lateral Loads*

Fig.4 Chevron braced structure

Fig 2, fig 3 and fig 4 shows the graphs of displacement, drift and lateral loads for unbraced, V braced and chevron braced structures. These graphs are obtained from ETABS analysis.

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Comparison of lateral displacement (mm) for various types of bracings in structures

Storey Number	Without Bracing	With X Bracing	With V Bracing
15	51.1	22.1	23.4
14	49.8	21.5	22.8
13	48.0	20.6	22.0
12	45.6	19.6	20.8
11	42.6	18.3	19.5
10	39.2	16.8	17.9
9	35.3	15.2	16.2
8	31.1	13.5	14.4
7	26.7	11.7	12.4
6	22.1	9.8	10.4
5	17.3	7.9	8.4
4	12.6	6.0	6.4
3	8.0	4.2	4.3
2	3.9	2.3	2.4
1	0.8	0.6	0.6
Base	0	0	0

Comparison of Storey Drift for various types of bracings in structures

Storey Number	Without Bracing	With X Bracing	With V Bracing
15	0.000432	0.000204	0.000288
14	0.000604	0.000278	0.000379
13	0.000799	0.000361	0.000456
12	0.000984	0.000432	0.000521
11	0.001146	0.000490	0.000573
10	0.001283	0.000537	0.000613
9	0.001394	0.000573	0.000643
8	0.001479	0.00060	0.000663
7	0.001541	0.000618	0.000675
6	0.001577	0.000628	0.000680
5	0.001580	0.000631	0.000678
4	0.001533	0.000628	0.000667
3	0.001386	0.000621	0.000591
2	0.001025	0.000569	0.000298
1	0.000389	0.000319	0.000243
Base	0	0	0

Comparison of Lateral Loads (kN) for various types of bracings in structures

Storey Number	Without Bracing	With X Bracing	With V Bracing
15	553.02	1277.42	1198.80
14	555.16	1285.17	1205.58
13	476.89	1104.48	1035.61
12	404.56	936.97	878.54
11	338.18	783.23	734.39
10	277.74	643.26	603.15
9	223.25	571.05	484.81
8	174.70	404.62	379.38
7	132.10	305.95	286.87
6	95.44	221.05	207.26
5	64.73	149.91	140.56
4	39.96	92.55	86.77
3	21.13	48.95	45.89
2	8.20	19.12	17.92
1	1.28	2.97	2.78

The comparison shows that lateral displacement reduces by about 50% in cross bracings when compared to unbraced structure which in turn reduces the storey drift. X bracings increase the lateral load capacity of the structure to great extent. Thus, X bracings are again proved better than chevron bracings.

STRUCTURE 2 ETABS Analysis

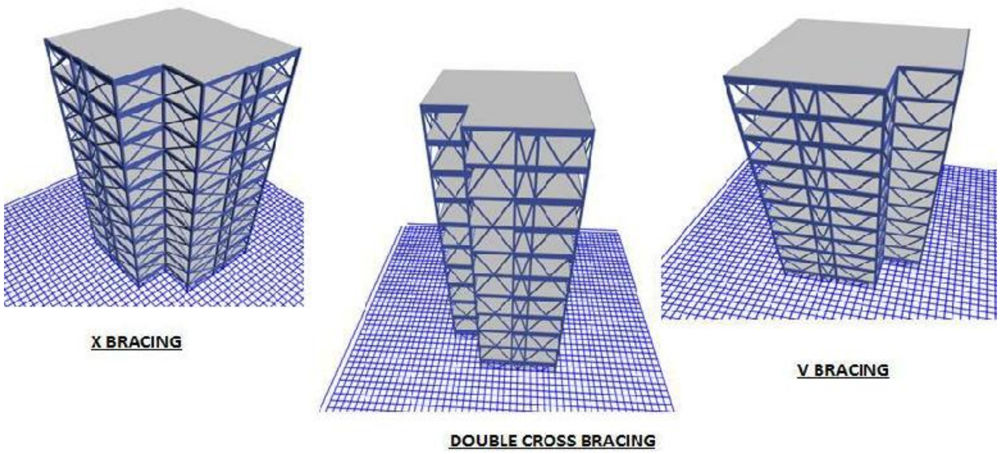

Table 1: X Direction: Maximum Lateral Displacement

LEVEL	STRUCTURE TYPE						
	Unbraced	X bracing (ISMC200)	X bracing (ISMC 300)	K bracing (ISMC 200)	K bracing (ISMC 300)	V bracing (ISMC 200)	V bracing (ISMC300)
11	199.5	72.5	64	78.1	67.7	75.2	65.3
10	191.7	66.9	58.7	72.9	62.8	70.2	60.5
9	179.3	60.5	52.7	56.5	57.1	64	54.8
8	163.3	53.4	45.2	59.3	50.6	57	48.5
7	144.4	45.8	39.4	51.3	40.7	49.3	41.7
6	123.5	38	32.4	42.9	30.3	41.3	34.7
5	101.1	30.1	25.5	34.4	29.1	33.1	27.6
4	78	22.5	18.8	25.7	21.6	24.9	20.6
3	54.5	15.2	12.6	17.8	15	17	13.9
2	31.2	8.7	7.1	9.8	8.2	9.7	7.8
1	8.5	3.1	2.5	3.5	3.2	3.1	2.5
Base	0	0	0	0	0	0	0

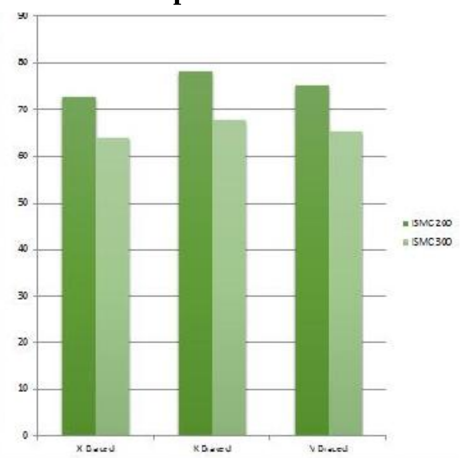

Table 2: Y Direction: Maximum Lateral Displacement

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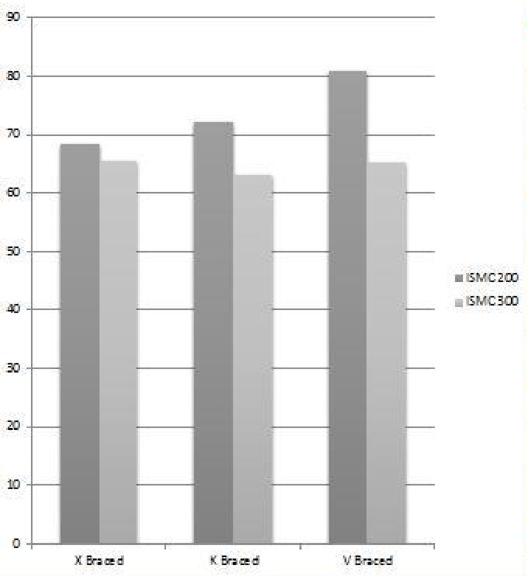

LEVEL	STRUCTURE TYPE						
	Unbraced	X bracing (ISMC 200)	X bracing (ISMC 300)	K bracing (ISMC 200)	K bracing (ISMC 300)	V bracing (ISMC 200)	V bracing (ISMC 300)
11	202.7	68.3	65.6	72.2	63.1	81	72.3
10	194.9	63	59.9	67.5	59	75	66.7
9	182.2	56.9	53.7	61.6	54	98.6	60.3
8	165.9	50.1	47	54.9	48.4	60.9	53.2
7	146.6	42.9	39.9	47.6	42.5	52.6	45.6
6	125.3	35.5	32.8	39.7	36.1	43.9	37.8
5	102.6	28.1	25.7	31.9	29.9	35.1	29.9
4	79.1	20.9	18.9	23.8	23.4	26.4	22.2
3	55.3	14.2	12.6	16.6	17.8	18	15
2	31.6	8.1	7.1	9.1	11.9	10.2	8.4
1	8.7	3	2.6	3.3	7.6	3.3	2.7
Base	0	0	0	0	0	0	0

It is evident from table 1 and 2 that use of bracings reduces maximum lateral displacement to great extent. As we switched the rolled section of bracings from ISMC 200 to ISMC 300, the lateral displacement reduced in both X and Y directions. However, the lateral displacement was least in X bracings for both ISMC 200 and ISMC 300 sections.

Table 3: Lateral Loads

LEVEL	STRUCTURE TYPE						
	Unbraced	X bracing (ISMC 200)	X bracing (ISMC 300)	K bracing (ISMC 200)	K bracing (ISMC 300)	V bracing (ISMC 200)	V bracing (ISMC 300)
11	103.12	339.61	394.43	306.55	358.54	277.73	321.03
10	99.42	329.08	383.37	296.66	347.77	268.77	311.41
9	80.01	264.82	308.50	238.73	279.85	216.28	250.60
8	62.70	207.53	241.76	187.08	219.31	169.49	196.38
7	47.49	157.21	183.14	141.72	166.13	128.39	148.77
6	34.40	113.87	132.65	102.65	120.33	93.00	107.75
5	23.41	77.50	90.28	69.86	81.90	63.29	73.34
4	14.53	48.11	56.04	43.37	50.84	39.29	45.52
3	7.76	25.69	29.96	23.16	27.15	20.98	24.31
2	3.09	10.24	11.93	9.23	10.83	8.37	9.69
1	0.53	1.76	2.05	1.59	1.86	1.44	1.67
Base	0	0	0	0	0	0	0

Table 3 shows the comparison of lateral loads for various bracing systems in RCC structure. It is evident from this table that use of bracings increases the lateral load carrying capacity of the structure. The maximum lateral load that this structure could resist is obtained in X bracing with section ISMC 300.

Comparison of Lateral loads for ISMC 200 and ISMC 300 bracings

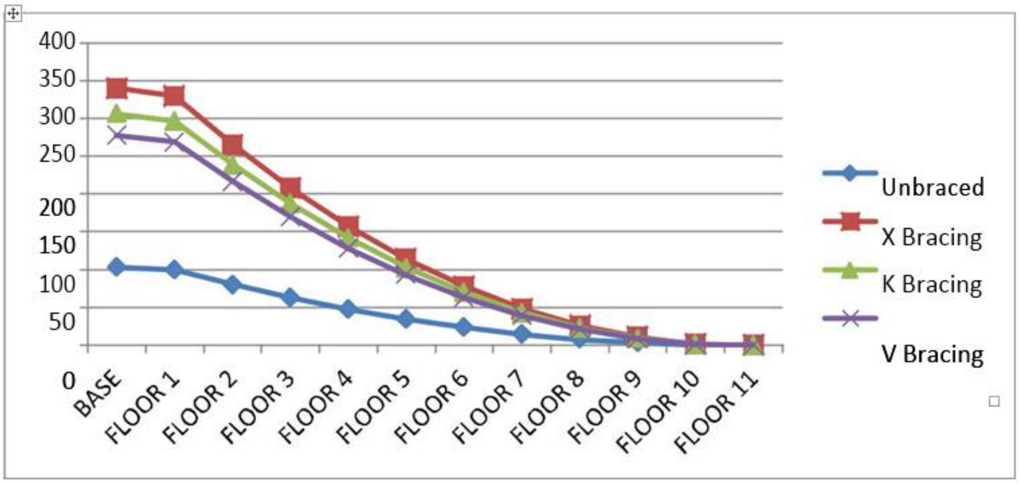

Fig 5 Lateral load comparison for ISMC 200 bracing section

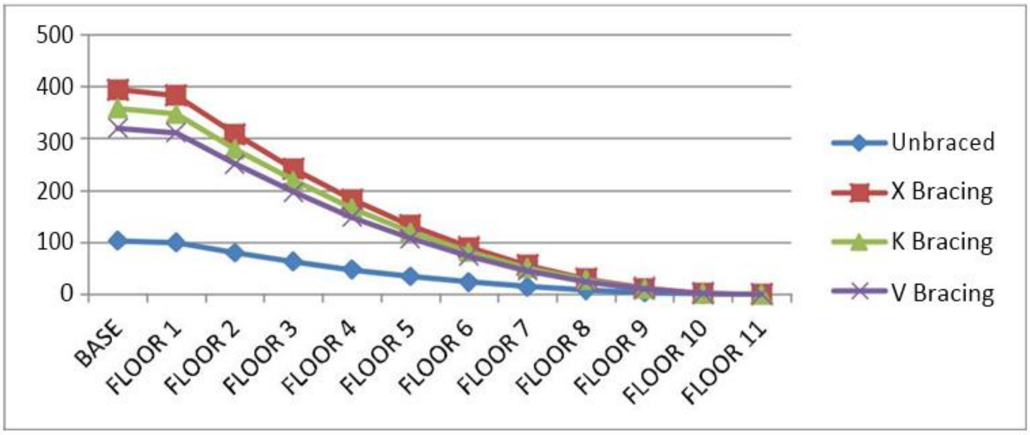

Fig 6 Lateral load comparison for ISMC 300 bracing section

Figure 5 and 6 shows the variation of lateral loads for unbraced, X braced, K braced and V braded structures. In both the cases, X braced increased the lateral load capacity to great extent and proved to be more effective than any other bracing.

RESULTS

It is evident from this research work involving both STAAD.Pro V8i and ETABS analysis that steel bracing system increases the lateral load resisting capacity of the structure and reduces the displacement and storey drift of high rise building. Thus, this is an effective retrofitting technique to resist seismic forces.

CONCLUSION

The following conclusions are derived from this research work:

1) Steel bracing system is an efficient and effective retrofitting system for high rise buildings located in high seismic regions.

2) Out of various arrangements of bracings, V bracing came out to be least efficient and X bracing was most effective bracing system.

3) X bracings are more effective in increasing lateral load capacity of structure.

4) X bracings are also proficient to reduce lateral displacement and storey drift produced due to seismic vibrations and inertia force.

5) The variation of bracing section changes the effect of seismic forces. As per this research work, ISMC 300 was found better in resisting lateral loads when compared to ISMC 200 section.

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