EFFECT OF STEEL BRACING ON SEISMIC PERFORMANCE OF REINFORCED CONCRETE (RC) FRAMED BUILDINGS

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Abstract - *This research examines the seismic analysis of a 15-storey reinforced concrete structure using various bracing techniques. Using SAP 2000 software, a G+14 building is assessed for seismic zone V in accordance with IS 1893: 2016. To assess the impact of the bracings in various stories, a non-linear time history analysis was performed. Lateral displacement, story drift, base shear, and time period are the primary factors taken into account in this seismic study of buildings. According to the investigation, the X-type of steel bracing greatly increases a building's stiffness and decreases its maximum story drift and lateral displacement. In accordance with the findings, steel angle section outperforms steel I section and steel tube section in terms of performance.*

***Key Words*: Retrofitting, Steel Bracings, Steel sections, Time history analysis, Displacement, Storey drift, Base Shear, Time periods.**

1. INTRODUCTION

Reinforced concrete framed buildings are commonly used in construction due to their strength and durability. However, they can still be vulnerable to lateral forces induced by earthquakes. One approach to mitigate these forces and improve the seismic performance of such buildings is to introduce steel bracing systems.

Steel bracing consists of steel members strategically placed within the structure to provide additional strength and stiffness. These braces can absorb and redistribute the energy generated during seismic events, reducing the lateral displacements and improving the overall structural response.

1.1 TYPES OF BRACING

There are several types of bracing commonly used in structural engineering to improve the seismic performance of buildings. These bracing systems are designed to resist lateral forces induced by earthquakes and enhance the overall stability of the structure. Here are brief explanations of three commonly employed types of bracing:

1. **Diagonal Bracing:** Diagonal bracing consists of inclined structural members that form diagonal patterns within the building frame. These braces are typically installed in the form of X-shaped or V-shaped configurations. Diagonal bracing effectively transfers lateral forces between different parts of the structure, providing stiffness and reducing deformations during seismic events. It offers good overall stability and is often used in steel and timber structures.

2. **Chevron Bracing:** Chevron bracing is a type of diagonal bracing that involves a series of V-shaped braces arranged in parallel. The braces are connected at their vertices, forming a zigzag pattern across the frame. Chevron bracing provides efficient load transfer and stiffness while offering architectural flexibility. It is commonly used in steel structures and can be aesthetically pleasing, as the pattern can be visible on the building's exterior.

3. **Buckling-Restrained Bracing (BRB):** Buckling-restrained bracing is a specialized type of bracing that utilizes steel members encased in a ductile material, such as concrete or steel tubes filled with concrete. This bracing system is designed to prevent buckling and maintain its load-carrying capacity during seismic events. BRBs offer excellent energy dissipation capabilities, allowing them to absorb and dissipate seismic forces effectively. They are commonly used in both steel and reinforced concrete structures.

1.1.1 ADVANTAGES OF STEEL BRACING

1. Steel bracing significantly enhances the lateral strength and stiffness of a structure, making it more resistant to seismic forces.
2. These bracings are economic to use.
3. Easy to erect and occupies less space.
4. Does not significantly add to the structural weight of the building.

5. Lateral resistance of buildings can be significantly improved by the addition of a bracing system.

1.2 TYPES OF STEEL SECTIONS USED

There are three types of steel sections used in the study – steel angle sections, I sections, and tube sections - each have their own distinct characteristics and applications. Understanding their properties and structural behavior is essential for selecting the appropriate section for a given bracing system.

2. OBJECTIVES

1. To assess RC-framed buildings with and without steel bracing and determine the maximum displacement, base shear, inter-storey drift, and time period using SAP2000 software in accordance with IS: 1893-2016.

2. To evaluate the impact of various bracing types on the structure and choose the bracing that minimises lateral displacement and inter-storey drift.

3. To compare the impact of various steel sections on the structural response to earthquakes and select the most effective steel section to be employed in the bracing system.

3. MODLLING AND ANALYSIS

Table -1: Building Data

Type of building	Residential
No. of Stories	G+14
Height of each floor	3.5 m
No. of bays in X-direction	7
No. of bays in Y-direction	7

Table-2: Material Properties

Grade of concrete	M30
Grade of steel	Fe500
Young's modulus of M30 concrete	27386.12 N/mm^2
Modulus of elasticity of steel	$2x10^5$ N/mm^2
Density of concrete	25 KN/m^3

Table -3: Member Properties

Slab Thickness	150 mm
Size of Beam	400 mm x 400 mm
Size of Column	600 mm x 600 mm (1st and ground floor) 500 mm x 500 mm (remaining stories)
Steel Section properties	
Steel angle Section	ISA 200X200X25
Steel Beam (I) Section	ISMB 300
Steel Tube Section	ISB 172X92X5.4

Table -4: Seismic Parameters

Seismic Zone	V
Seismic Zone Factor, Z (Table 3 of IS 1893:2016)	0.36
Importance Factor, I (Table 8 of IS 1893:2016)	1.2
Response Reduction Factor, R (Table 9 of IS 1893:2016)	5
Soil Type (Table 4 of IS 1893:2016)	II

3.1 MODEL OF BUILDING WITHOUT BRACING

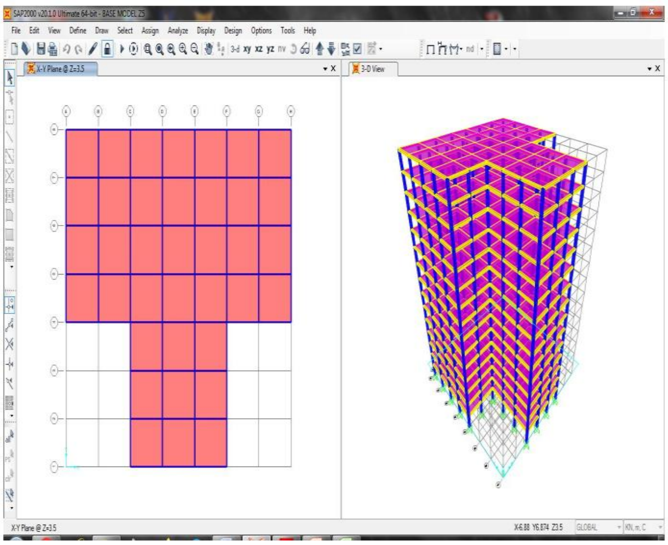


Figure-1: Plan and 3D view of building without braces

3.2 MODEL OF BUILDING WITH BRACING

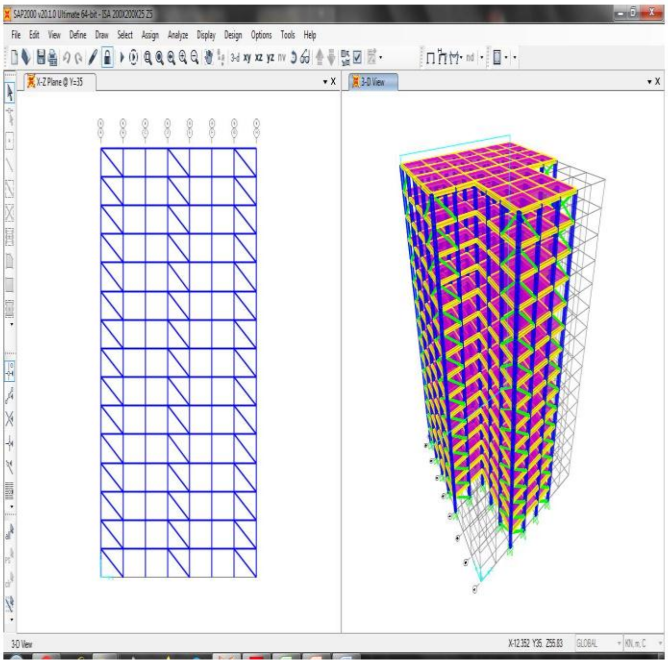


Figure-2: Elevation and 3D view of building with Single Diagonal bracing

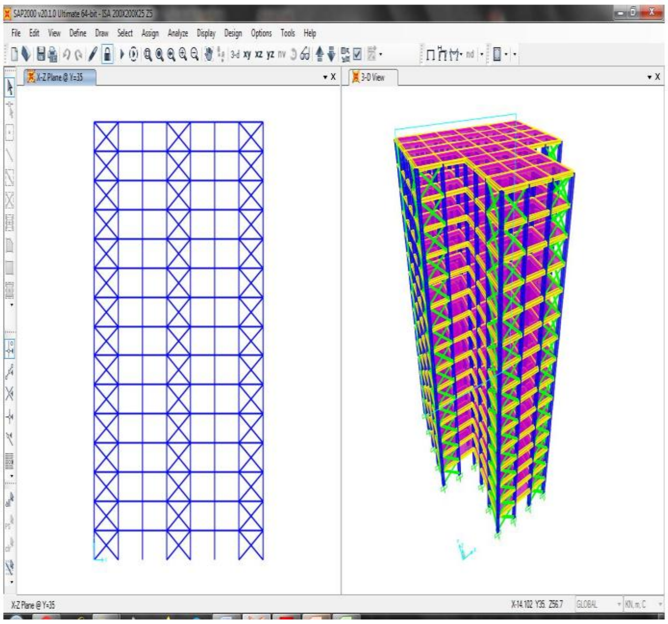


Figure-3: Elevation and 3D view of building with X-bracing

4. RESULTS AND DISCUSSION

4.1 Maximum Displacement

The value of the storey's greatest lateral displacement caused by a lateral load is known as the storey displacement. Using time history analysis, the building's maximum displacement in the X direction is determined.

4.1.1 X-Bracing

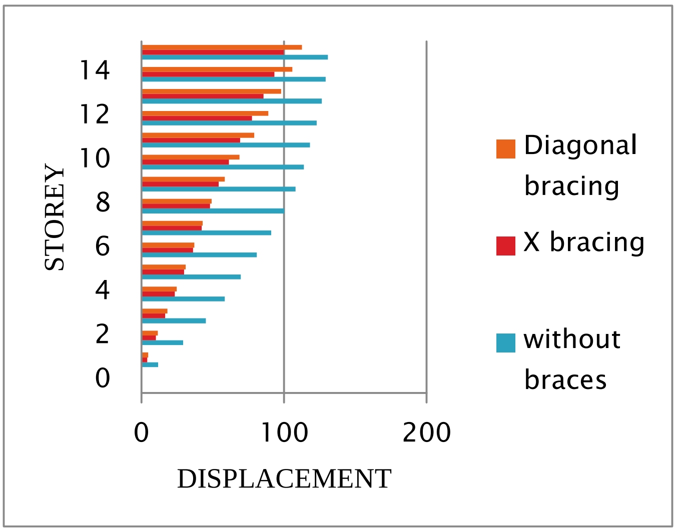
Table-5: Maximum displacement using X-bracing with different steel sections

Storey	Elevation	Without braces	Steel I section	Steel tube section	Steel angle section
	m	mm	mm	mm	mm
15	52.5	130.724	120.79	118.58	99.777
14	49	129.147	112.921	112.979	93.192
13	45.5	126.575	104.444	106.023	85.701
12	42	122.933	95.071	97.709	77.656
11	38.5	118.19	86.355	88.156	69.372
10	35	113.986	78.202	77.739	61.365
9	31.5	108.083	70.177	67.003	54.287
8	28	100.223	62.628	56.829	48.038
7	24.5	91.156	56.261	48.931	42.21
6	21	80.907	49.917	43.203	36.229
5	17.5	69.806	42.673	36.772	29.962
4	14	58.588	34.346	30.032	23.421
3	10.5	45.278	25.167	22.187	16.754
2	7	29.242	15.63	13.973	10.231
1	3.5	11.681	6.414	5.497	4.159
0	0	0	0	0	0

4.1.2 Diagonal Bracing

Table-6: Maximum displacement using diagonal bracing with different steel sections

Storey	Elevation	Without braces	Steel I section	Steel tube section	Steel angle section
	m	mm	mm	mm	mm
15	52.5	130.724	123.962	116.292	112.586
14	49	129.147	120.422	112.716	105.813
13	45.5	126.575	115.975	107.681	97.946
12	42	122.933	110.379	100.838	88.992
11	38.5	118.19	103.378	92.146	79.197
10	35	113.986	94.789	83.672	68.896
9	31.5	108.083	84.892	78.386	58.484
8	28	100.223	74.403	72.299	49.17
7	24.5	91.156	65.594	65.792	42.983
6	21	80.907	59.675	59.004	37.113
5	17.5	69.806	53.457	51.227	31.121
4	14	58.588	44.851	41.456	24.822
3	10.5	45.278	33.401	29.695	18.177
2	7	29.242	19.929	17.086	11.423
1	3.5	11.681	7.029	5.813	4.832
0	0	0	0	0	0



Graph-1: Maximum Lateral Displacements (mm) for different types of bracings with steel angle section

Table-7: percentage reduction in top storey displacement

Model	Steel angle section	Steel Tube section	Steel I section
X Bracing	23.67%	9.28%	7.59%
Diagonal Bracing	13.87%	11.04%	5.17%

It has been found that bracings made of the X type of steel angle section reduce displacement.

When compared to a system without braces, the top floor displacement for the system with X bracing is reduced by 23.67% with steel angle sections, 9.28% with steel tube sections, and 7.59% with steel I sections.

4.2 Storey Drift

A multi-story building's story drift is the movement of one level in relation to the level below. It is the difference between any particular story's two floor displacements as the building sways due to an earthquake.

As given in clause no. 7.11.1.1 of IS 1893:2016, Storey drift in any storey shall not exceed 0.004 times the storey height.

i.e. 0.004x3.5x1000=14mm

So, in our case storey drift should not exceed 14mm

4.2.1 X-Bracing

Table-8: Storey Drift using X-bracing with different steel section

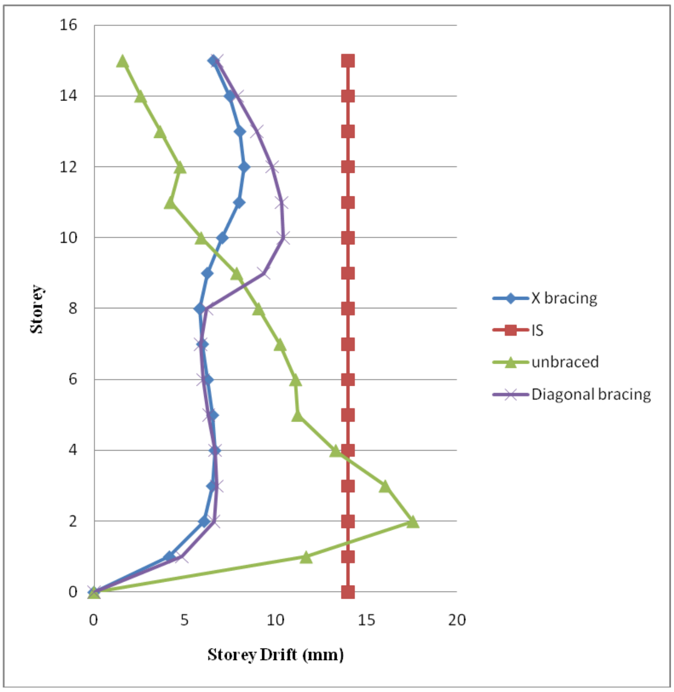
Storey	Elevation	Without braces	Steel I section	Steel tube section	Steel angle section
	m	mm	mm	mm	mm
15	52.5	1.577	7.869	5.601	6.585
14	49	2.572	8.477	6.956	7.491
13	45.5	3.642	9.373	8.314	8.045
12	42	4.743	8.716	9.553	8.284
11	38.5	4.204	8.153	10.417	8.007
10	35	5.903	8.025	10.736	7.078
9	31.5	7.86	7.549	10.174	6.249
8	28	9.067	6.367	7.898	5.828
7	24.5	10.249	6.344	5.728	5.981

6	21	11.101	7.244	6.431	6.267
5	17.5	11.218	8.327	6.74	6.541
4	14	13.31	9.179	7.845	6.667
3	10.5	16.036	9.537	8.214	6.523
2	7	17.561	9.216	8.476	6.072
1	3.5	11.681	6.414	5.497	4.159
0	0	0	0	0	0

4.1.2 Diagonal Bracing

Table-9: Storey Drift using Diagonal bracing with different steel section

Storey	Elevation	Without braces	Steel I section	Steel tube section	Steel angle section
	m	mm	mm	mm	mm
15	52.5	1.577	3.54	3.576	6.773
14	49	2.572	4.447	5.035	7.867
13	45.5	3.642	5.596	6.843	8.954
12	42	4.743	7.001	8.692	9.795
11	38.5	4.204	8.589	8.474	10.301
10	35	5.903	9.897	5.286	10.412
9	31.5	7.86	10.489	6.087	9.314
8	28	9.067	8.809	6.507	6.187
7	24.5	10.249	5.919	6.788	5.87
6	21	11.101	6.218	7.777	5.992
5	17.5	11.218	8.606	9.771	6.299
4	14	13.31	11.45	11.761	6.645
3	10.5	16.036	13.472	12.609	6.754
2	7	17.561	12.9	11.273	6.591
1	3.5	11.681	7.029	5.813	4.832
0	0	0	0	0	0



Graph-2: Storey drift for different types of bracings with steel angle section

Maximum interstorey drift is decreased and distributed more evenly along the height of the building with the inclusion of steel bracings.

Storey drift values in unbraced buildings are clearly beyond the limit specified in IS 1893:2016.

Table-10: percentage reduction in storey drift

Model	Steel angle section	Steel Tube section	Steel I section
X Bracing	65.42%	51.73%	47.52%
Diagonal Bracing	65.42%	35.81%	26.54%

Utilising steel angle section, the maximum storey drift in the x-direction is reduced by 65.42% as compared to an unbraced building.

By minimising lateral displacements, the X type of bracings prevents collapse by lowering story drifts in the building.

4.3 BASE SHEAR

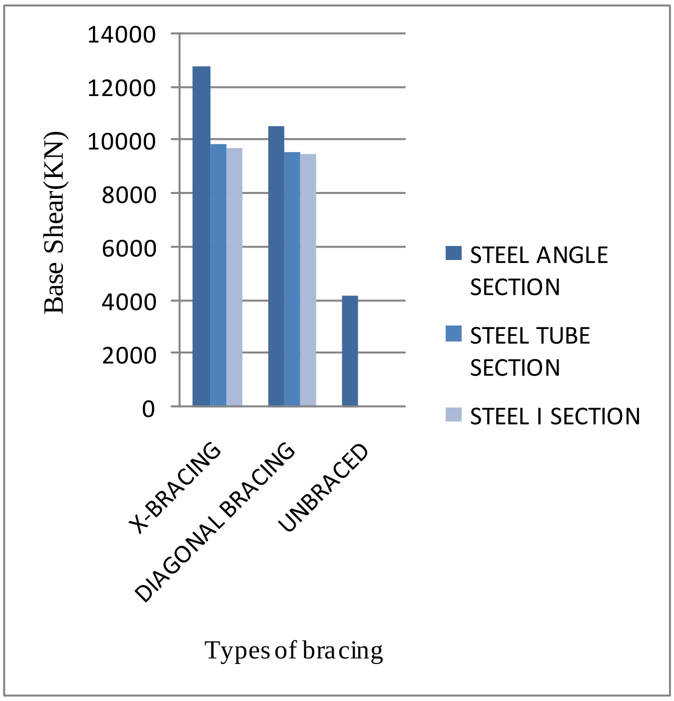
Table-11: Base shear using X and diagonal bracing with different steel sections

Base Shear (KN)	Unbraced	Steel Angle Section	Steel I Section	Steel Tube Section
X-Bracing	4193.595	12777.85	9758.91	9869.729
Diagonal Bracing	4193.595	10584.83	9504.268	9553.129

In contrast to buildings with diagonal bracing and without bracing, it is clear that the base shear of X-braced buildings with steel angle sections increased the highest, indicating an increase in the stiffness of the building.

The X-bracing with steel angle section building exhibits the greatest rise in base shear. This is due to an increase in the horizontal seismic coefficient (Ah) with increasing spectral acceleration.

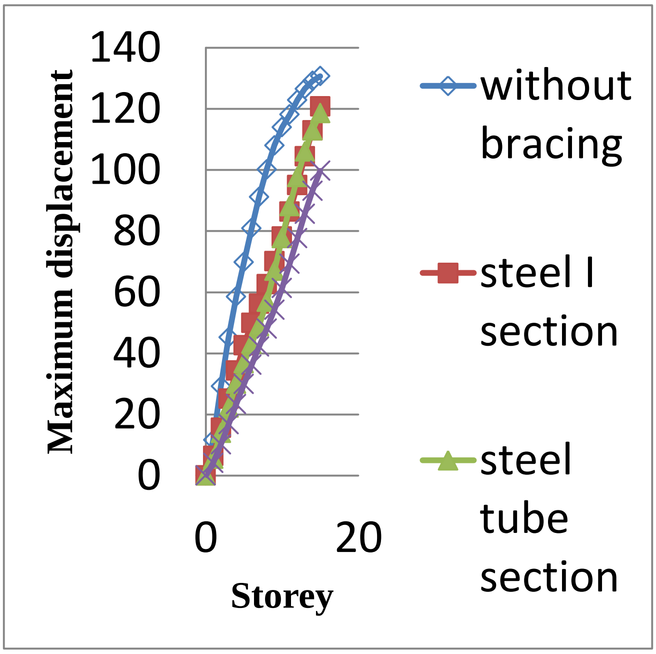
Because the base shear and seismic coefficient are directly correlated, base shear rises as horizontal seismic coefficient (Ah) rises.



Graph-3: Base shear using X and diagonal bracing with different steel sections

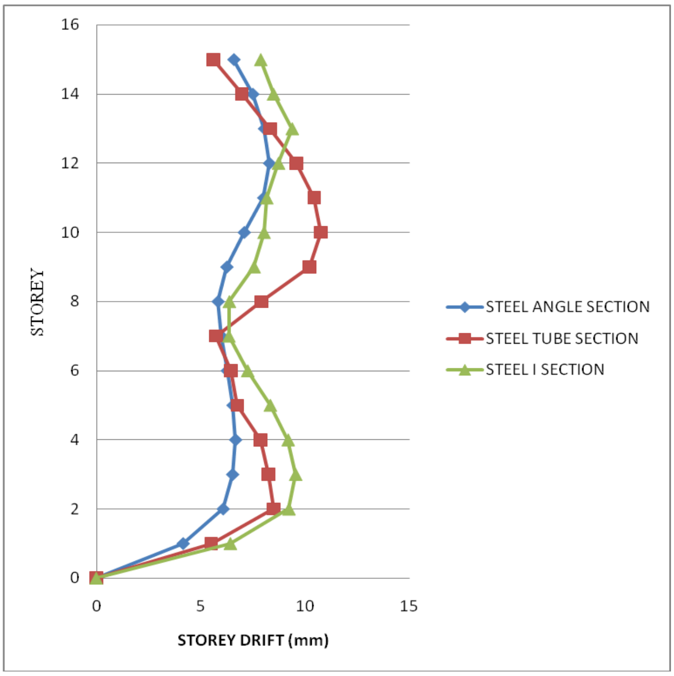
4.4 COMPARISON OF DIFFERENT STEEL SECTIONS

4.4.1 IN TERMS OF DISPLACEMENT



Graph-4: Comparison of steel sections in terms of displacement

4.4.2 IN TERMS OF STOREY DRIFT



Graph-5: Comparison of steel sections in terms of storey drift

5. CONCLUSIONS

- X type of bracing is found to be more effective than diagonal bracings.
- The reduction in the displacement along X direction is about 23.67% by use of steel angle section.
- Comparative to unbraced building, there is 65.42% reduction in maximum storey drift in x-direction using X-Bracing with steel angle section.
- The base shear of X-braced buildings with steel angle section increased most as compared to building with diagonal bracing and without bracing which indicates that the stiffness of building increases.
- The performance of steel angle section braced frame is better than steel I section frame and steel tube section frame.

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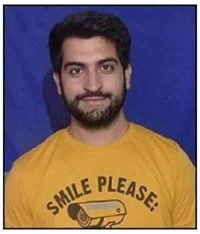
BIOGRAPHIES



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