Seismic Analysis of Braced and Unbraced RC Framed Building

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Abstract— Earthquakes are major natural destruction, responsible for loss of life and damage of property. For decreasing these damages in multi storied building we can apply bracing. The Bracing is attached to provide lateral support to wall framing. Metal straps, timber or sheet bracing can be used for bracing. A typical G+14th story regular RC frame building is designed for various types of bracing like X-bracing, inverted chevron, braced chevron brace, k bracing and carried out through seismic analysis. Three types of different section for same cross sectional area. i.e. ISA,ISMC,ISLB sections are used to compare for same patterns of bracing with unbraced building. The principle objective is to arriving to suitable configuration, modelling, developing models for seismic analysis and design of Multi Storey Building.

Key words: Hospital Bed Management, Hospital Capacity Planning, Decision Support Systems, Decision Support Models

I. INTRODUCTION

Earthquakes are one of the most destructive of natural hazards. Earthquake occurs due to sudden transient motion of the ground as a result of release of elastic energy in a matter of few seconds. The impact of the event is most traumatic because it affects large area, occurs all on a sudden and unpredictable. They can cause large scale loss of life and property and disrupts essential services such as water supply, sewerage systems, communication and power, transport etc. They not only destroy villages, towns and cities but the aftermath leads to destabilize the economic and social structure of the nation.

In the RC structure, reinforced concrete frames are used as part of seismic force-resisting systems in buildings that are designed to resist earthquakes. Beams, columns, and beam-column joints in moment frames are proportioned and detailed to resist flexural, axial, and shearing actions that result as a building sways through multiple displacement cycles during strong earthquake ground shaking. Special proportioning and detailing requirements result in a frame capable of resisting strong earthquake shaking without significant loss of stiffness or strength.

During earthquake bracing is reduce the deflection in the structure. It works like a Retrofitting of the structure. A bracing system can be defined as a structural system capable of resisting horizontal actions and limiting horizontal deformations. On the basis of this definition, all the systems shown in following figure can be considered bracing systems. Within one building more than one of these systems can be present. In that case some systems are more effective than others in resisting horizontal loads, the others are neglected.

II. OBJECTIVES OF THE PROJECT

The Main objective of the project is to analyse the high rise RC framed structure on STADD PRO affected by different load to resisting the element and to developed suitable seismic load factors to prevent structural collapse under earthquakes and The multi storey building is to be considered to check effectiveness of bracing system in high rise building.

III. MODELING AND ANALYSIS OF BUILDING

Different types of bracing pattern used in the study are shown in below

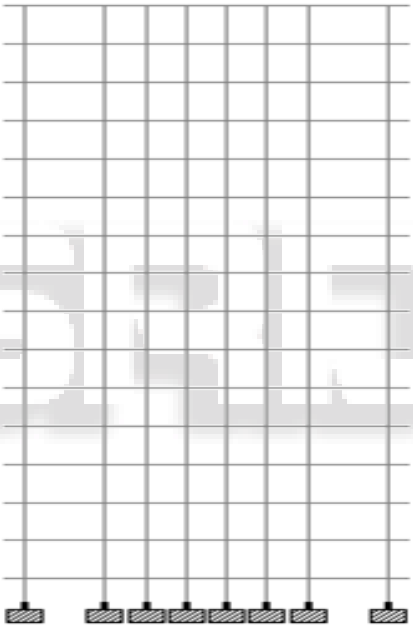


Fig. 1: Elevation of Unbraced

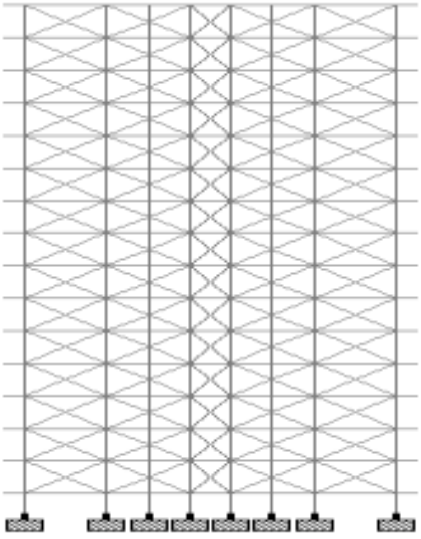


Fig. 2: Elevation of X-Bracing

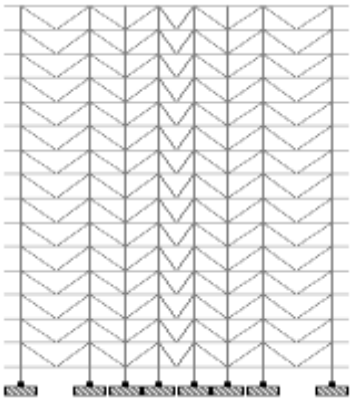


Fig. 3 : Elevation of Inverted-Chevron

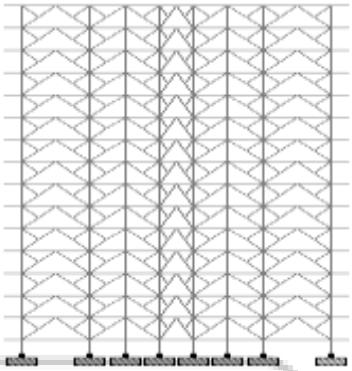


Fig. 4 : Elevation of B.C.B.

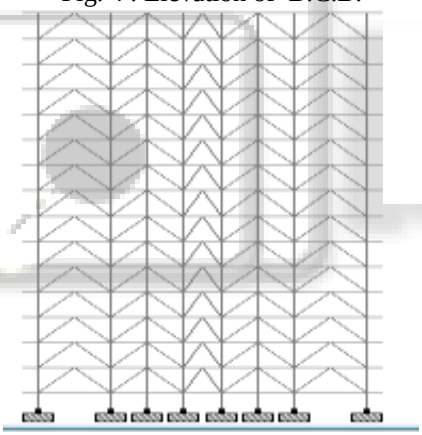


Fig. 5: Elevation of K-Bracing

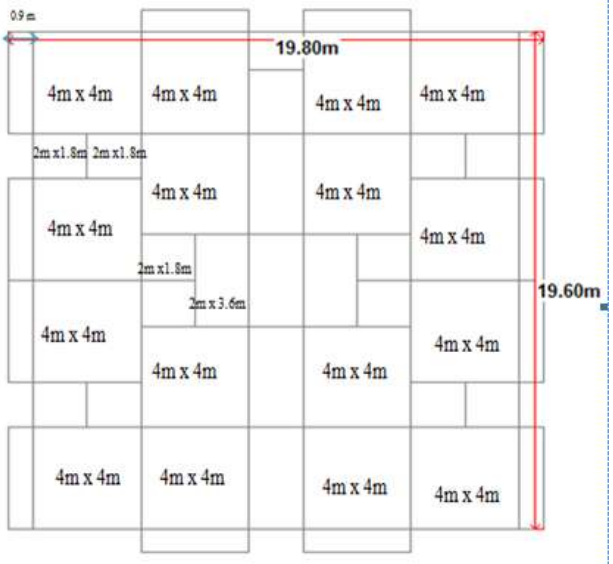


Fig. 6: plan of building

Serial Number	Building Description	
1	Zone	II
2	Zone Factor	0.1
3	Response Reduction Factor	5
4	Importance Factor	1
5	Height of Building	49.5 m
6	Column Details	0.8m x0.8m
7	Beam Details	0.35m x 0.45m
8	Bracing Details-1	ISA 200 x 200 x 16.41 (Made)
9	Bracing Details 2	ISMC 400
10	Bracing Details 3	ISLB 350
11	Thickness of Slab	125 mm
12	Floor to Floor Height	3.3 m
13	Grade of Steel Section	Fe - 415
14	Grade of Concrete	M30
15	Soil Type	Hard Strata
16	Damping Ratio	5%

Table 1: Building Description

IV. RESULTS & DISCUSSION

A. General

Seismic performance evaluation is complex phenomenon as there are several factors affecting the behaviour of the building. In this study there is a comparison of the analytical results between unbraced & braced RCC framed structure with various parameters such as Joint Displacement, base shear, storey drift, bending moment & axial force. The Response Spectrum Analysis on static approach is carried out on all the models. The results obtained from the analysis are discussed in this chapter.

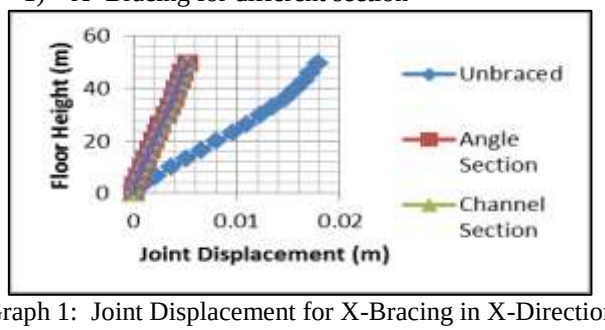
B. For G+14 Story Building

1) Joint Displacement

a) Joint displacement in X-direction

Graphs are plotted below for unbraced & braced buildings, Joint Displacement is indicate on X-axis & floor levels are indicate on Y-axis.

1) X- Bracing for different section



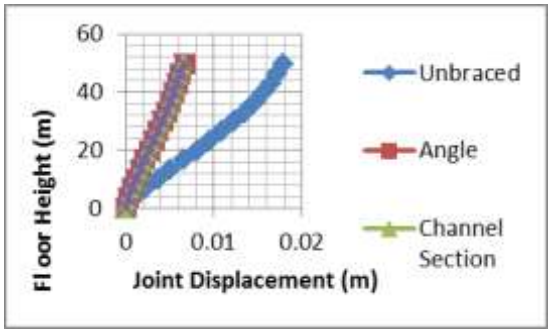
Graph 1: Joint Displacement for X-Bracing in X-Direction for G+14 Storey Building.

From the Graph1, we know that the maximum values of Joint Displacement are reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Joint Displacement in RCC frames building for

X bracing in X-direction is reduced by 70.68% using ISA, 70.67% using ISMC & 70.67% using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Joint Displacement takes place.

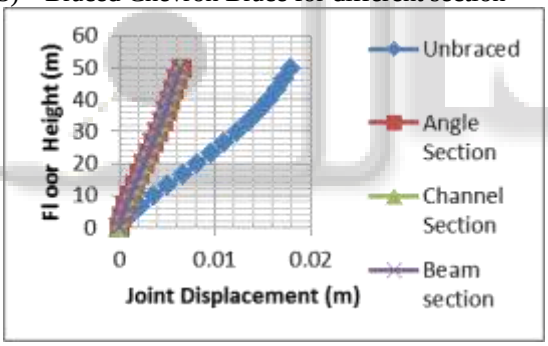
2) Inverted Chevron for different section



Graph 2: Joint Displacement for Inverted Chevron in X-Direction for G+14 Storey Building.

From the Graph 2, we know that the maximum values Joint Displacement is reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Joint Displacement in RCC frames building for Inverted Chevron in X-direction is reduced by 62.40% using ISA, 62.88% using ISMC & 62.84% using ISLB. Due to the various bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Joint Displacement takes place.

3) Braced Chevron Brace for different section

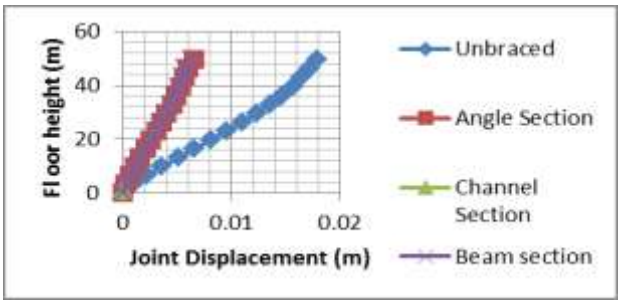


Graph 3: Joint Displacement for Braced Chevron Brace in X-Direction for G+14 Storey Building.

From the Graph no.3, we know that the maximum values Joint Displacement is reduced in comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Joint Displacement in RCC frames building for Braced Chevron Brace in X-direction is reduced by 63.36% using ISA, 64.11% using ISMC & 64.01 % using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Joint Displacement takes place.

4) Chevron Brace (K- Bracing) for different section



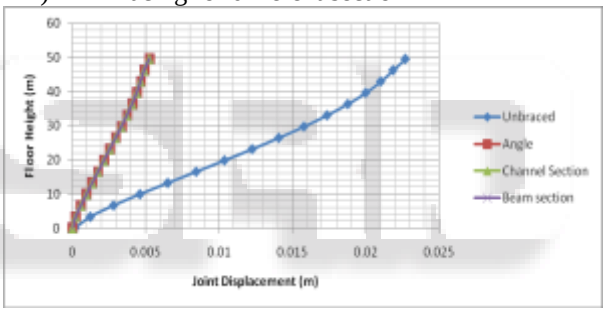
Graph 4: Joint Displacement for Chevron Brace in X-Direction for G+14 Storey Building.

From the Graph no.4, we know that the maximum values of Joint Displacement are reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Joint Displacement in RCC frames building for K bracing in X-direction is reduced by 63.46% using ISA, 63.83% using ISMC & 63.8% using ISLB. Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Joint Displacement takes place.

b) Joint displacement in Z-direction

Graphs are plotted below for unbraced & braced buildings, Joint Displacement is indicate on X-axis & floor levels are indicate on Y-axis.

1) X-Bracing for different section

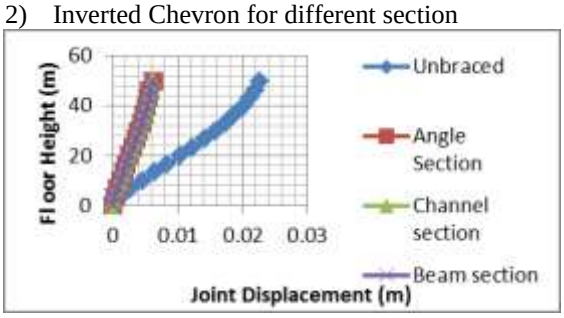


Graph 5: Joint Displacement for X-Bracing in Z-Direction for G+14 Storey Building.

From the Graph no.5, we know that the maximum values of Joint Displacement are reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Joint Displacement in RCC frames building for X-bracing in Z-direction is reduced by 76.79% using ISA, 76.89% using ISMC & 76.88% using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Joint Displacement takes place.

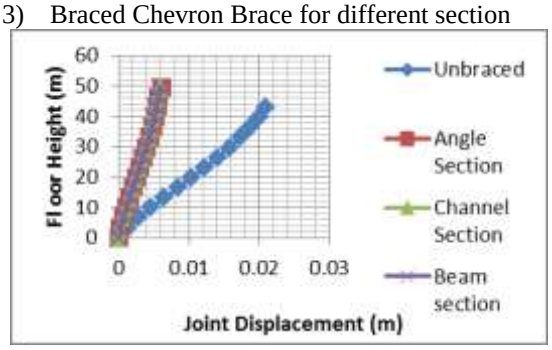
2) Inverted Chevron for different section



Graph 6: Joint Displacement for Inverted Chevron in Z-Direction for G+14 Storey Building.

From the Graph no.6, we know that the maximum values Joint Displacement is reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Joint Displacement in RCC frames building for Inverted Chevron bracing in Z-direction is reduced by 72.36% using ISA, 72.57% using ISMC & 72.56% using ISLB. Due to the various bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Joint Displacement takes place.

3) Braced Chevron Brace for different section

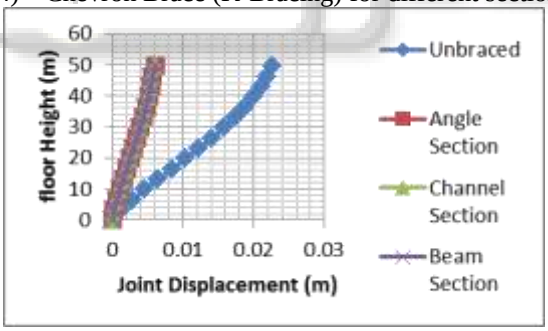


Graph 7: Joint Displacement for Braced Chevron Brace in Z-Direction for G+14 Storey Building.

From the Graph no.7, we know that the maximum values Joint Displacement is reduced in comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Joint Displacement in RCC frames building for X-bracing in Z-direction is reduced by 73.13% using ISA, 73.55% using ISMC & 73.50% using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Joint Displacement takes place.

4) Chevron Brace (K-Bracing) for different section

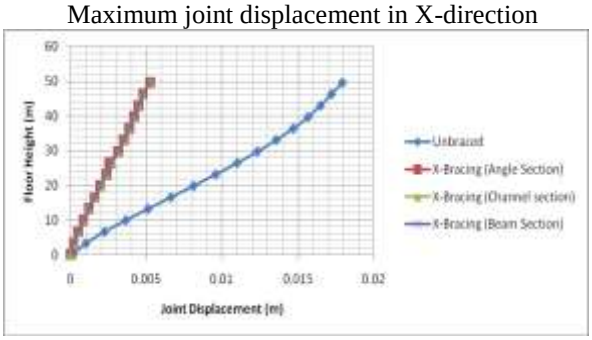


Graph 8: Joint Displacement for Chevron Brace in Z-Direction for G+14 Storey Building

From the Graph no.8, we know that the maximum values of Joint Displacement are reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Joint Displacement in RCC frames building for K-bracing in Z-direction is reduced by 73.2% using ISA, 73.36% using ISMC & 73.35% using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Joint Displacement takes place.

c) Maximum joint displacement in X-direction

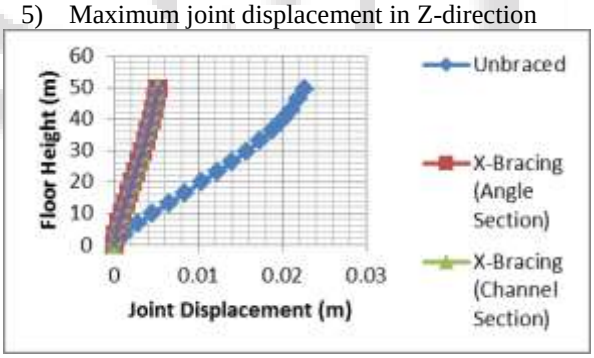


Graph 9: Maximum Joint Displacement in X Direction for G+14 Storey Building

From the Graph no.9, we know that the maximum values of Joint Displacement is reduced in comparison with unbraced building & braced building for using different bracing types with different sections such as ISA, ISMC, ISLB. The Percentage Difference Decreases i.e. reduction for X bracing is 70.68% using section ISA, for X bracing is 70.67% using section ISMC and for X-bracing is 70.67% using section ISLB.

The overall Percentage Difference Decreases i.e. reduction in the braced building occurs due to the stiffness provided to the braced building in the form of bracing system using different bracing types with different sections. The maximum Percentage Difference Decreases i.e. reduction are nearly same i.e. 70.6% can be seen for X-bracing using for different sections. Due to this result it is concluded that X-bracing for using three different sections offers maximum resistance to deflection which increases the stiffness of the building in X-direction

5) Maximum joint displacement in Z-direction



Graph 10: Maximum Joint Displacement In Z Direction for G+14 Storey Building

From the Graph no.10, we know that the maximum values of Joint Displacement is reduced in comparison with unbraced building & braced building for using different bracing types with different sections such as ISA, ISMC, ISLB. The Percentage Difference Decreases i.e. reduction for X bracing is 76.79% using section ISLB, for X bracing is 76.89% using section ISLB and for X-bracing is 76.88% using section ISLB.

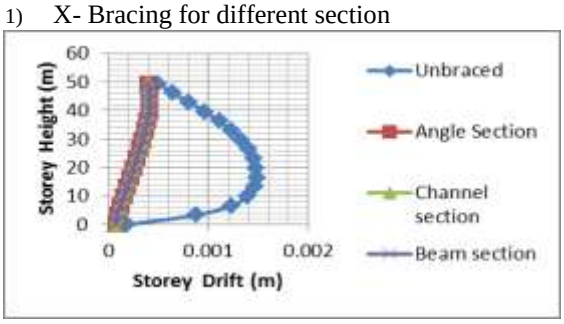
The overall Percentage Difference Decreases i.e. reduction in the braced building occurs due to the stiffness provided to the braced building in the form of bracing system using different bracing types with different sections. The maximum Percentage Difference Decreases i.e. reduction are nearly same i.e. 76.8% can be seen for X-bracing using for different sections. Due to this result it is concluded that X-bracing for using three different sections offers maximum resistance to deflection which increases the stiffness of the building in X-direction.

2) Storey Drift

a) Storey drifts in X-direction

Graphs are plotted below for unbraced & braced buildings, Storey Drift is indicating on X-axis & floor height is indicating on Y-axis.

1) X- Bracing for different section

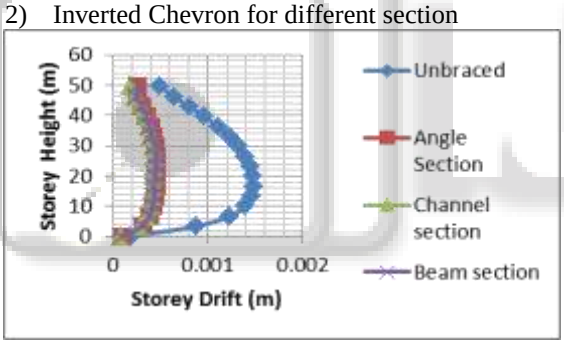


Graph 11: Storey Drift for X-Bracing in X-Direction for G+14 Storey Building.

From the Graph no.12, we know that the maximum values of Storey Drift are reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Storey Drift at storey height 16.5m in RCC frames building for X bracing in X-direction is reduced by 85.19% using ISA, 85.19% using ISMC & 85.19% using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Storey Drift takes place.

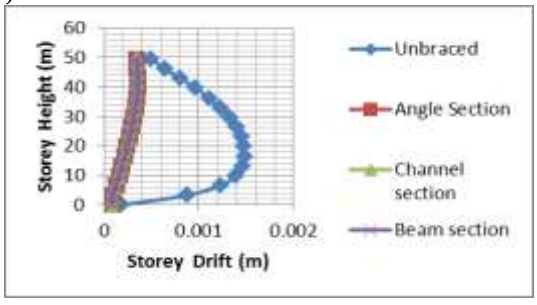
2) Inverted Chevron for different section



Graph 13: Storey Drift for Inverted Chevron in X-Direction for G+14 Storey Building.

From the Graph no.13, we know that the maximum values Storey Drift is reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Storey Drift at storey height 16.5m in RCC frames building for Inverted Chevron in X-direction is reduced by 69.16% using ISA, 70.71% using ISMC & 70.37% using ISLB. Due to the various bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Storey Drift takes place.

3) Braced Chevron Brace for different section

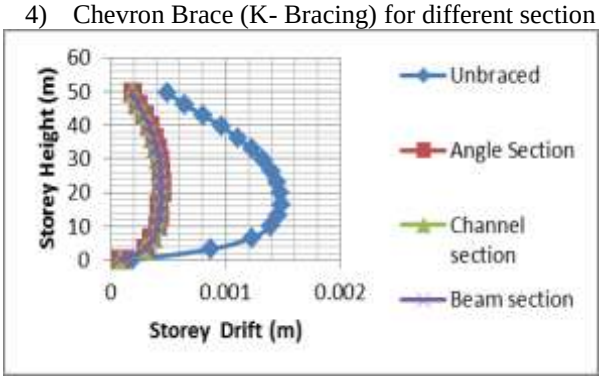


Graph 14: Storey Drift for Braced Chevron Brace in X-Direction for G+14 Storey Building.

From the Graph no.14, we know that the maximum values Storey Drift is reduced in comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, ISLB. The Storey Drift at storey height 16.5m in RCC frames building for Braced Chevron Brace in X-direction is reduced by 85.32% using ISA, 85.39% using ISMC & 85.39 % using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Storey Drift takes place.

4) Chevron Brace (K- Bracing) for different section



Graph 15: Storey Drift for Chevron Brace in X-Direction for G+14 Storey Building.

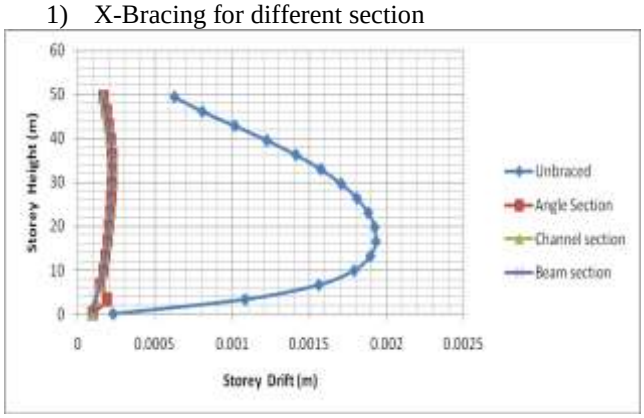
From the Graph no.15, we know that the maximum values of Storey Drift are reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Storey Drift at storey height 16.5m in RCC frames building for K bracing in X-direction is reduced by 71.58% using ISA, 70.71% using ISMC & 70.64% using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Storey Drift takes place.

b) Storey drifts in Z-direction

Graphs are plotted below for unbraced & braced buildings, Storey Drift is indicate on X-axis & floor levels are indicate on Y-axis.

1) X-Bracing for different section



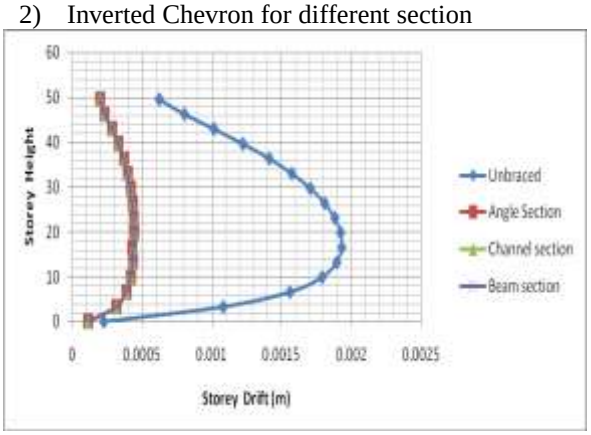
Graph 16: Storey Drift for X-Bracing in Z-Direction for G+14 Storey Building.

From the Graph no.16, we know that the maximum values of Storey Drift are reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, ISLB. The Storey

Drift at storey height 16.5m in RCC frames building for X-bracing in Z-direction is reduced by 90.05% using ISA, 90.15% using ISMC & 90.10% using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Storey Drift takes place.

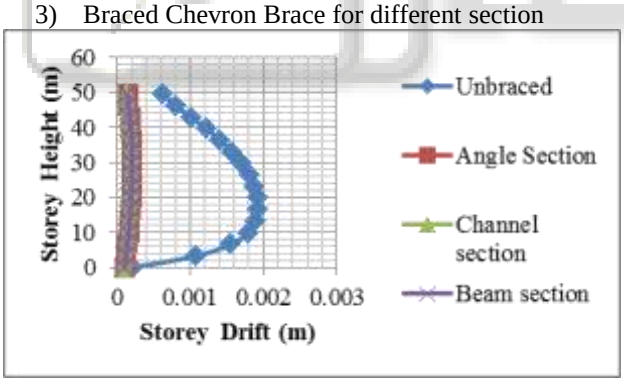
2) Inverted Chevron for different section



Graph 17: Storey Drift for Inverted Chevron in Z-Direction for G+14 Storey Building.

From the Graph no.17, we know that the maximum values Storey Drift is reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Storey Drift at storey height 16.5m in RCC frames building for Inverted Chevron bracing in Z-direction is reduced by 77.76% using ISA, 77.29% using ISMC & 77.29% using ISLB. Due to the various bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Storey Drift takes place.

3) Braced Chevron Brace for different section

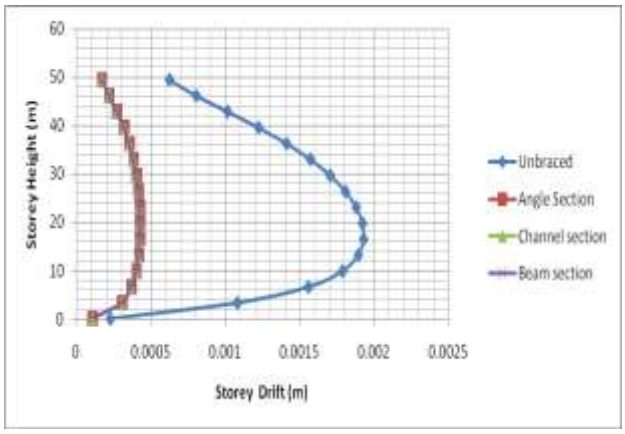


Graph 18: Storey Driftfor Braced Chevron Brace in Z-Direction for G+14 Storey Building

From the Graph no.18, we know that the maximum values Storey Drift is reduced in comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Storey Drift at storey height 16.5m in RCC frames building for X-bracing in Z-direction is reduced by 90.15% using ISA, 90.20% using ISMC & 90.20% using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Storey Drift takes place.

4) Chevron Brace (K-Bracing) for different section

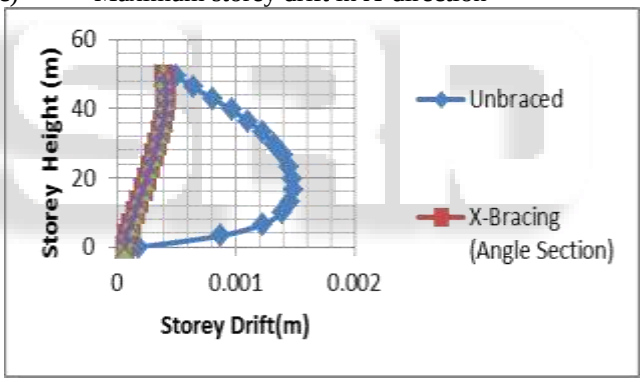


Graph 19: Storey Drift for Chevron Brace in Z-Direction for G+14 Storey Building

From the Graph no.19, we know that the maximum values of Storey Drift are reduced on comparison with unbraced building & braced building for using different bracing types with different sections i.e. ISA, ISMC, and ISLB. The Storey Drift at storey height 16.5m in RCC frames building for K-bracing in Z-direction is reduced by 77.81% using ISA, 77.02% using ISMC & 77.02% using ISLB.

Due to the different bracing systems provided, the building offers resistance to the displacement & Percentage Difference Decreases i.e. reduction of Storey Drift takes place.

c) Maximum storey drift in X-direction

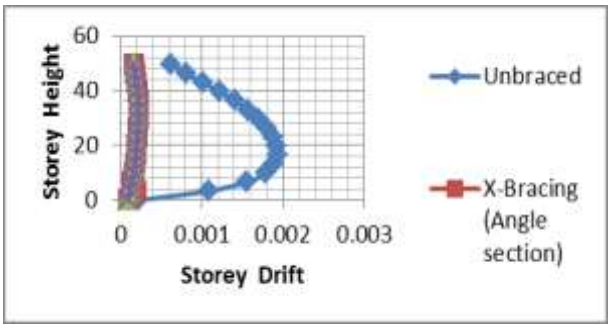


Graph 20: Storey Drift for Maximum Storey Drift In X Direction for G+14 Storey Building

From the Graph no.20, We know that the maximum values of Storey Drift is reduced in comparison with unbraced building & braced building for using different bracing types with different sections such as ISA, ISMC, ISLB. The Percentage Difference Decreases i.e. reduction for X bracing is 85.19% using section ISLB, for X bracing is 85.19% using section ISLB and for X-bracing is 85.19% using section ISLB.

The overall Percentage Difference Decreases i.e. reduction in the braced building occurs due to the stiffness provided to the braced building in the form of bracing system using different bracing types with different sections. The maximum Percentage Difference Decreases i.e. reduction are nearly same i.e. 85.19% can be seen for X-bracing using for different sections. Due to this result it is concluded that X-bracing for using three different sections offers maximum resistance to deflection which increases the stiffness of the building in X-direction.

d) Maximum storey drift in Z-direction



Graph 21. Maximum Storey Drift In Z Direction for G+14 Storey Building

From the Graph no.21, We know that the maximum values of Storey Drift is reduced in comparison with unbraced building & braced building for using different bracing types with different sections such as ISA, ISMC, ISLB. The Percentage Difference Decreases i.e. reduction for X bracing is 90.05% using section ISLB, for X bracing is 90.15% using section ISLB and for X-bracing is 90.10% using section ISLB.

The overall Percentage Difference Decreases i.e. reduction in the braced building occurs due to the stiffness provided to the braced building in the form of bracing system using different bracing types with different sections. The maximum Percentage Difference Decreases i.e. reduction are nearly same i.e. 90.1% can be seen for X-bracing using for different sections. Due to this result it is concluded that X-bracing for using three different sections offers maximum resistance to deflection which increases the stiffness of the building in X-direction.

3) Maximum Base Shear

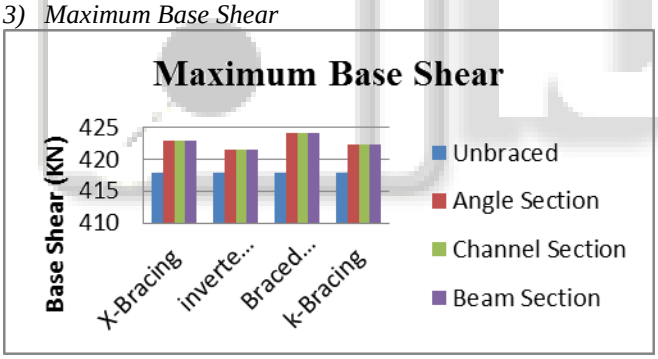


Chart 1: Maximum Base Shear for G+14 Storey Building for Different Bracing Systems.

From the Chart no.1, we know that the maximum values of base shear in the column increases for X-bracing, Inverted Chevron & B.C.B., K-Bracing respectively when compared to unbraced building, for different sections ISA, ISMC, and ISLB. The maximum percentage difference increases i.e. reduction for inverted X bracing is 1.17% using section ISA, 1.17% using section ISMC& 1.17% using section ISLB, for Inverted Chevron bracing is 0.86% using section ISA, 0.86% using section ISMC& 0.86% using section ISLB and for B.C.B. is 1.46% using section ISA, 1.46% using section ISMC& 1.46% using section ISLB and and for K-Bracing. is 1.02% using section ISA, 1.02% using section ISMC& 1.02% using section ISLB in comparison of base shear the percentage difference increases i.e. reduction takes place in braced building as compared to unbraced building. So the base shear is almost same.

Chart no.1, shows that the base shear in B.C.B.(same in each section) bracing system is more as compared to X-bracing, Inverted Chevron, K-Bracing system. The base shear produce in X and Z direction is same because stiffness of building is same in both direction. As the stiffness of bracing sections increases, the base shear in building also increases in both directions.

4) Maximum Bending Moment

The maximum bending moment for unbraced and different braced building are shown in Chart no. 2 and Chart no. 3.

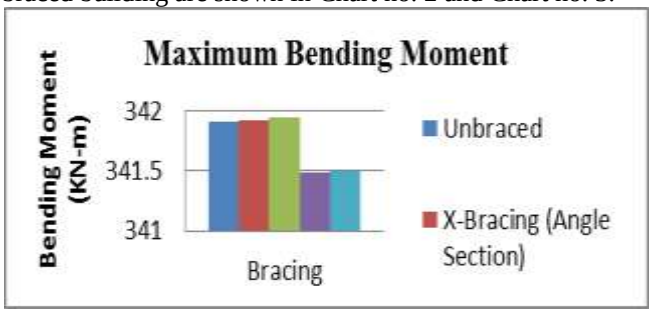


Chart 2: Maximum Bending Moment for G+14 Storey Building for Different Bracing Systems

From Chart no. 2, it can be seen that bending moment in braced building reduces in comparison of unbraced building. Bending moment in building with K-bracing system is less among of four bracing but here B.C.B. and K-Bracing shows nearly same result

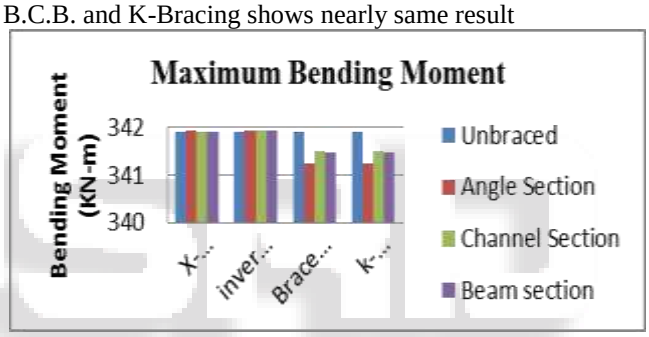


Chart 3: Maximum Bending Moment for G+14 Storey Building for Different Bracing Systems

Chart no. 3, illustrated that Bending Moment in the braced building reduces as the stiffness of brace increases.

5) Maximum Axial Force

The maximum axial force for unbraced and different braced building are shown in Chart no. 4 and Chart no. 5

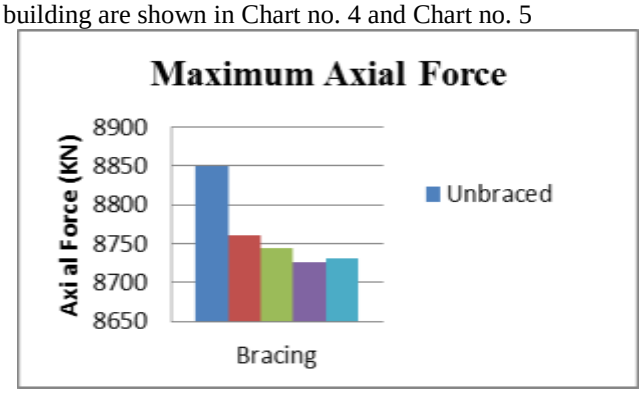


Chart 4: Maximum Axial Force for G+14 Storey Building for Different Bracing Systems

From Chart no.4, it can be seen that axial force in braced building reduces in comparison of unbraced building. Axial force in building with B.C.B. is less among of four bracing and other bracings gives suitable result as compare to unbraced building.

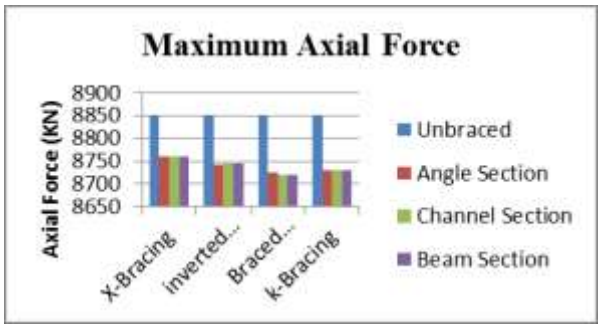


Chart 5: Maximum Axial Force for G+14 Storey Building For Different Bracing Systems

Chart no.5 illustrated that Axial force in the braced building reduce as the stiffness of brace increases.

V. CONCLUSIONS

A. General

Using STADD PRO, the analyses were carried out for unbraced & braced type of buildings. The comparison of results for the unbraced & braced building has been carried out to the suitable type of bracing system.

B. Conclusions

1) The seismic response of the building changes with inclusion of braces in structure.
2) The value of maximum base shear increases in braced structure as compared to unbraced structure. This is due to increased stiffness of building by addition of braced member.
3) Due to inclusion of bracing, the stiffness of building increases, hence vibrations caused because of earthquake reduce thus reducing joint displacement of structure.
4) By providing braces in the frame, the horizontal load at node is distributed among brace members along with beams and columns. Due to provision of the bracing system in the building bending moment comparatively reduced.
5) In seismic analysis for braced and unbraced framed building time period are same for all 13 models.
6) On the basis of reduction in joint displacement, base shear, bending moment and axial force, storey drifts. it can be observed that X bracing and Braced Chevron Brace systems are suitable. But the values of base shear and axial forces, bending moment are gives better performance in Braced Chevron Brace (B.C.B.) as compare to X-bracing and the value of joint displacement in X-bracing and Braced Chevron Brace are nearly in same range. In the case of inverted Chevron, K-bracing for joint displacement, bending moment and axial force are maximum and decrease in base shear as that of X bracing and B.C.B..Hence, comparing all the parameters, it can be concluded that, B.C.B. are more effective than any other bracing systems and it gives same performance in different section i.e. for channel, angle and beam sections.
7) From the study it is clear that use of maximum number of braces does not lead to satisfactory results.

APPENDIX

A. Joint Displacement in X Direction (mm)

Sr.no.	Floor height (m)	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.17	0.029	0.04	0.037	0.037
2	3.3	1.014	0.216	0.298	0.284	0.284
3	6.6	2.245	0.521	0.718	0.696	0.695
4	9.9	3.642	0.865	1.192	1.161	1.159
5	13.2	5.114	1.226	1.687	1.643	1.64
6	16.5	6.612	1.598	2.192	2.132	2.128
7	19.8	8.105	1.95	2.701	2.625	2.621
8	23.1	9.569	2.367	3.21	3.119	3.114
9	26.4	10.981	2.556	3.715	3.609	3.602
10	29.7	12.319	3.142	4.208	4.087	4.08
11	33	13.56	3.517	4.679	4.544	4.536
12	36.3	14.679	3.869	5.117	4.966	4.958
13	39.6	15.656	4.187	5.51	5.342	5.333
14	42.9	16.488	4.473	5.868	5.677	5.667
15	46.2	17.204	4.78	6.227	6.032	6.02
16	49.5	17.925	5.256	6.74	6.567	6.55

Table 1: For Angle section

Sr.no.	Floor height (m)	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.17	0.028	0.039	0.038	0.036
2	3.3	1.014	0.215	0.29	0.28	0.281
3	6.6	2.245	0.519	0.702	0.681	0.688
4	9.9	3.642	0.862	1.168	1.135	1.146
5	13.2	5.114	1.223	1.655	1.604	1.621
6	16.5	6.612	1.595	2.152	2.08	2.102
7	19.8	8.105	1.977	2.653	2.561	2.588
8	23.1	9.569	2.364	3.156	3.043	3.076

9	26.4	10.981	2.755	3.654	3.521	3.559
10	29.7	12.319	3.142	4.141	3.988	4.031
11	33	13.56	3.517	4.607	4.435	4.483
12	36.3	14.679	3.869	5.04	4.848	4.901
13	39.6	15.656	4.187	5.429	5.216	5.273
14	42.9	16.488	4.473	5.779	5.544	5.604
15	46.2	17.204	4.78	6.14	5.898	5.955
16	49.5	17.925	5.257	6.653	6.434	6.483

Table 2: For Channel section

Sr.no.	Floor height (m)	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.17	0.028	0.039	0.038	0.084
2	3.3	1.014	0.215	0.29	0.281	0.399
3	6.6	2.245	0.519	0.703	0.683	0.775
4	9.9	3.642	0.862	1.17	1.139	1.201
5	13.2	5.114	1.223	1.658	1.609	1.659
6	16.5	6.612	1.596	2.155	2.087	2.133
7	19.8	8.105	1.977	2.657	2.569	2.615
8	23.1	9.569	2.365	3.161	3.053	3.098
9	26.4	10.981	2.755	3.659	3.532	3.577
10	29.7	12.319	3.142	4.147	4.001	4.045
11	33	13.56	3.517	4.614	4.449	4.496
12	36.3	14.679	3.87	5.047	4.864	4.92
13	39.6	15.656	4.187	5.436	5.232	5.307
14	42.9	16.488	4.473	5.786	5.561	5.628
15	46.2	17.204	4.78	6.148	5.916	5.809
16	49.5	17.925	5.257	6.661	6.451	6.489

Table 3: For Beam Section

B. Joint Displacement in Z Direction (mm)

Sr.no.	Floor height (m)	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.194	0.022	0.088	0.029	0.028
2	3.3	1.237	0.233	0.392	0.282	0.202
3	6.6	2.818	0.596	0.765	0.744	0.708
4	9.9	4.616	0.978	1.212	1.167	1.164
5	13.2	6.515	1.367	1.686	1.635	1.631
6	16.5	8.453	1.765	2.161	2.11	2.105
7	19.8	10.383	2.167	2.632	2.587	2.58
8	23.1	12.27	2.569	3.097	3.061	3.053
9	26.4	14.084	2.97	3.553	3.529	3.52
10	29.7	15.795	3.364	3.994	3.984	3.974
11	33	17.373	3.743	4.414	4.419	4.407
12	36.3	18.79	4.099	4.802	4.821	4.809
13	39.6	20.014	4.417	5.151	5.177	5.164
14	42.9	21.026	4.681	5.452	5.468	5.455
15	46.2	21.868	4.927	5.661	5.732	5.718
16	49.5	22.708	5.271	6.276	6.102	6.086

Table 4: For Angle Section

Sr.no.	Floor height (m)	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.194	0.021	0.033	0.027	0.028
2	3.3	1.237	0.23	0.297	0.276	0.279
3	6.6	2.818	0.59	0.737	0.698	0.703
4	9.9	4.616	0.969	1.204	1.147	1.155
5	13.2	6.515	1.357	1.681	1.607	1.618
6	16.5	8.453	1.753	2.165	2.074	2.089
7	19.8	10.383	2.153	2.649	2.542	2.561
8	23.1	12.27	2.555	3.13	3.008	3.032
9	26.4	14.084	2.954	3.604	3.468	3.495
10	29.7	15.795	3.347	4.065	3.916	3.947
11	33	17.373	3.726	4.506	4.343	4.378
12	36.3	18.79	4.081	4.916	4.74	4.778

13	39.6	20.014	4.398	5.279	5.089	5.131
14	42.9	21.026	4.661	5.58	5.376	5.421
15	46.2	21.868	4.905	5.854	5.635	5.683
16	49.5	22.708	5.248	6.228	6.006	6.05

Table 5: For Channel Section

Sr.no.	Floor height (m)	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.194	0.021	0.033	0.027	0.028
2	3.3	1.237	0.23	0.297	0.277	0.279
3	6.6	2.818	0.591	0.737	0.699	0.703
4	9.9	4.616	0.97	1.205	1.149	1.155
5	13.2	6.515	1.358	1.682	1.61	1.619
6	16.5	8.453	1.754	2.166	2.078	2.09
7	19.8	10.383	2.154	2.65	2.548	2.562
8	23.1	12.27	2.556	3.131	3.015	3.033
9	26.4	14.084	2.956	3.606	3.475	3.496
10	29.7	15.795	3.349	4.067	3.924	3.948
11	33	17.373	3.728	4.508	4.352	4.379
12	36.3	18.79	4.083	4.918	4.75	4.78
13	39.6	20.014	4.399	5.282	5.1	5.133
14	42.9	21.026	4.663	5.583	5.387	5.423
15	46.2	21.868	4.907	5.856	5.646	5.685
16	49.5	22.708	5.25	6.231	6.017	6.052

Table 6: For Beam Section

C. Maximum Joint Displacement (mm)

Sr.no.	Type Of Bracing With Diffrent Section	Unbraced	Braced	% Difference Decreases
A	Angle			
1	X-Bracing	17.925	5.256	70.67782427
2	inverted chevron	17.925	6.74	62.39888424
3	Braced Chevron Brace (B.C.B.)	17.925	6.567	63.36401674
4	k-Bracing	17.925	6.55	63.45885635
B	Channel			
1	X-Bracing	17.925	5.257	70.67224547
2	inverted chevron	17.925	6.653	62.88423989
3	Braced Chevron Brace (B.C.B.)	17.925	6.434	64.10599721
4	k-Bracing	17.925	6.483	63.83263598
C	Beam section			
1	X-Bracing	17.925	5.257	70.67224547
2	inverted chevron	17.925	6.661	62.83960948
3	Braced Chevron Brace (B.C.B.)	17.925	6.451	64.0111576
4	k-Bracing	17.925	6.489	63.79916318

Table 7: Maximum Joint Displacement In Xdirection

Sr.no.	Type Of Bracing With Diffrent Section	Unbraced	Braced	% Difference Decreases
A	Angle Section			
1	X-Bracing	22.708	5.271	76.78791615
2	inverted chevron	22.708	6.276	72.36216311
3	Braced Chevron Brace (B.C.B.)	22.708	6.102	73.12841289
4	k-Bracing	22.708	6.086	73.19887264
B	Channel Section			
1	X-Bracing	22.708	5.248	76.88920204
2	inverted chevron	22.708	6.228	72.57354236
3	Braced Chevron Brace (B.C.B.)	22.708	6.006	73.55117139
4	k-Bracing	22.708	6.05	73.35740708
C	Beam Section			
1	X-Bracing	22.708	5.25	76.88039457
2	inverted chevron	22.708	6.231	72.56033116
3	Braced Chevron Brace (B.C.B.)	22.708	6.017	73.50273032
4	k-Bracing	22.708	6.052	73.34859961

Table 8: Maximum Joint Displacement In Z Direction

D. Storey Drift in X Direction (mm)

Sr.no.	Floor height	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.189	0.074	0.097	0.089	0.089
2	3.3	0.875	0.085	0.314	0.09	0.304
3	6.6	1.227	0.119	0.393	0.127	0.35
4	9.9	1.388	0.155	0.429	0.16	0.413
5	13.2	1.46	0.188	0.448	0.19	0.432
6	16.5	1.485	0.22	0.458	0.218	0.422
7	19.8	1.479	0.25	0.462	0.243	0.447
8	23.1	1.45	0.281	0.462	0.267	0.447
9	26.4	1.398	0.31	0.455	0.29	0.441
10	29.7	1.324	0.339	0.443	0.311	0.429
11	33	1.227	0.366	0.423	0.33	0.409
12	36.3	1.108	0.388	0.395	0.344	0.381
13	39.6	0.966	0.404	0.357	0.353	0.343
14	42.9	0.807	0.412	0.31	0.355	0.296
15	46.2	0.642	0.409	0.257	0.349	0.243
16	49.5	0.497	0.4	0.262	0.341	0.191

Table 9: For Angle Section

Sr.no.	Floor height	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.189	0.073	0.089	0.089	0.089
2	3.3	0.875	0.084	0.3	0.09	0.3
3	6.6	1.227	0.118	0.374	0.126	0.374
4	9.9	1.388	0.154	0.407	0.159	0.407
5	13.2	1.46	0.188	0.425	0.189	0.425
6	16.5	1.485	0.22	0.435	0.217	0.435
7	19.8	1.479	0.251	0.44	0.243	0.44
8	23.1	1.45	0.282	0.439	0.267	0.44
9	26.4	1.398	0.312	0.435	0.291	0.435
10	29.7	1.324	0.341	0.423	0.312	0.423
11	33	1.227	0.367	0.404	0.331	0.404
12	36.3	1.108	0.39	0.376	0.346	0.376
13	39.6	0.966	0.406	0.34	0.355	0.34
14	42.9	0.807	0.412	0.293	0.356	0.293
15	46.2	0.642	0.409	0.241	0.35	0.241
16	49.5	0.497	0.398	0.189	0.342	0.189

Table 10: For Channel Section

Sr.no.	Floor height	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.189	0.073	0.095	0.088	0.088
2	3.3	0.875	0.084	0.309	0.09	0.301
3	6.6	1.227	0.118	0.386	0.126	0.374
4	9.9	1.388	0.154	0.422	0.159	0.407
5	13.2	1.46	0.188	0.44	0.189	0.426
6	16.5	1.485	0.22	0.44	0.217	0.436
7	19.8	1.479	0.251	0.451	0.243	0.441
8	23.1	1.45	0.282	0.455	0.267	0.441
9	26.4	1.398	0.312	0.455	0.291	0.435
10	29.7	1.324	0.341	0.449	0.312	0.424
11	33	1.227	0.368	0.418	0.331	0.404
12	36.3	1.108	0.391	0.39	0.346	0.377
13	39.6	0.966	0.407	0.353	0.355	0.34
14	42.9	0.807	0.414	0.307	0.356	0.294
15	46.2	0.642	0.411	0.254	0.351	0.241
16	49.5	0.497	0.399	0.26	0.342	0.189

Table 11: For Beam Section

E. Storey Drift in Z Direction (mm)

Sr.no.	Floor height	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.228	0.096	0.114	0.107	0.106

2	3.3	1.081	0.188	0.318	0.121	0.308
3	6.6	1.558	0.143	0.388	0.146	0.369
4	9.9	1.788	0.165	0.421	0.166	0.404
5	13.2	1.893	0.178	0.436	0.18	0.421
6	16.5	1.929	0.192	0.429	0.19	0.428
7	19.8	1.921	0.202	0.443	0.199	0.429
8	23.1	1.879	0.21	0.44	0.203	0.427
9	26.4	1.806	0.216	0.432	0.209	0.42
10	29.7	1.704	0.221	0.419	0.211	0.406
11	33	1.572	0.222	0.398	0.21	0.386
12	36.3	1.411	0.22	0.369	0.206	0.357
13	39.6	1.223	0.213	0.332	0.197	0.32
14	42.9	1.016	0.202	0.285	0.183	0.273
15	46.2	0.805	0.185	0.233	0.165	0.221
16	49.5	0.625	0.166	0.199	0.149	0.172

Table 12: For Angle Section

Sr.no.	Floor height	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.228	0.095	0.113	0.106	0.106
2	3.3	1.081	0.116	0.314	0.121	0.306
3	6.6	1.558	0.142	0.384	0.145	0.366
4	9.9	1.788	0.163	0.417	0.164	0.402
5	13.2	1.893	0.178	0.432	0.178	0.417
6	16.5	1.929	0.19	0.438	0.189	0.424
7	19.8	1.921	0.2	0.439	0.197	0.426
8	23.1	1.879	0.208	0.436	0.203	0.424
9	26.4	1.806	0.215	0.429	0.207	0.416
10	29.7	1.704	0.219	0.415	0.209	0.399
11	33	1.572	0.221	0.395	0.208	0.383
12	36.3	1.411	0.219	0.367	0.204	0.355
13	39.6	1.223	0.212	0.329	0.194	0.318
14	42.9	1.016	0.199	0.283	0.18	0.267
15	46.2	0.805	0.182	0.231	0.163	0.22
16	49.5	0.625	0.161	0.197	0.145	0.172

Table 13: For Channel Section

Sr.no.	Floor height	Unbraced	X-Bracing	Inverted Chevron	Braced Chevron Brace	K-Bracing
1	0	0.228	0.095	0.113	0.106	0.106
2	3.3	1.081	0.116	0.315	0.121	0.306
3	6.6	1.558	0.142	0.384	0.145	0.366
4	9.9	1.788	0.163	0.417	0.164	0.402
5	13.2	1.893	0.177	0.432	0.178	0.417
6	16.5	1.929	0.191	0.438	0.189	0.424
7	19.8	1.921	0.198	0.44	0.197	0.426
8	23.1	1.879	0.209	0.437	0.203	0.424
9	26.4	1.806	0.215	0.429	0.207	0.417
10	29.7	1.704	0.22	0.415	0.209	0.399
11	33	1.572	0.221	0.395	0.209	0.383
12	36.3	1.411	0.219	0.367	0.204	0.355
13	39.6	1.223	0.212	0.329	0.195	0.318
14	42.9	1.016	0.2	0.283	0.181	0.272
15	46.2	0.805	0.183	0.231	0.163	0.22
16	49.5	0.625	0.163	0.197	0.146	0.172

Table 14: For Beam Section

Sr.no.	Type of bracing with diffrent section	Unbraced	Braced	% difference
				Decreases
A	Angle			
1	X-Bracing	1.485	0.22	85.18518519
2	inverted chevron	1.485	0.458	69.15824916
3	Braced Chevron Brace (B.C.B.)	1.485	0.218	85.31986532
4	k-Bracing	1.485	0.422	71.58249158

B	Channel			
1	X-Bracing	1.485	0.22	85.18518519
2	inverted chevron	1.485	0.435	70.70707071
3	Braced Chevron Brace (B.C.B.)	1.485	0.217	85.38720539
4	k-Bracing	1.485	0.435	70.70707071
C	Beam section			
1	X-Bracing	1.485	0.22	85.18518519
2	inverted chevron	1.485	0.44	70.37037037
3	Braced Chevron Brace (B.C.B.)	1.485	0.217	85.38720539
4	k-Bracing	1.485	0.436	70.63973064

Table 15: Maximum Storey Drift in X Direction (mm)

Sr.no.	type of bracing with diffrent section	Unbraced	Braced	% difference decreases
A	Angle			
1	X-Bracing	1.929	0.192	90.04666
2	inverted chevron	1.929	0.429	77.7605
3	Braced Chevron Brace (B.C.B.)	1.929	0.19	90.15034
4	k-Bracing	1.929	0.428	77.81234
B	Channel			
1	X-Bracing	1.929	0.19	90.15034
2	inverted chevron	1.929	0.438	77.29393
3	Braced Chevron Brace (B.C.B.)	1.929	0.189	90.20218
4	k-Bracing	1.929	0.424	78.0197
C	Beam section			
1	X-Bracing	1.929	0.191	90.0985
2	inverted chevron	1.929	0.438	77.29393
3	Braced Chevron Brace (B.C.B.)	1.929	0.189	90.20218
4	k-Bracing	1.929	0.424	78.0197

Table 16: Maximum Storey Drift in Z Direction (mm)

Sr.no.	Type Of Bracing With Diffrent Section	Unbraced	Braced	Percentage difference Increases
A	Angle Section	Unbraced	Braced	
1	X-Bracing	417.95	422.8546	1.173489652
2	inverted chevron	417.95	421.54	0.85895442
3	Braced Chevron Brace (B.C.B.)	417.95	424.04	1.457112095
4	k-Bracing	417.95	422.23	1.024045939
B	Channel Section			
1	X-Bracing	417.95	422.85	1.172389042
2	inverted chevron	417.95	421.54	0.85895442
3	Braced Chevron Brace (B.C.B.)	417.95	424.04	1.457112095
4	k-Bracing	417.95	422.225	1.022849623
C	Beam Section			
1	X-Bracing	417.95	422.86	1.174781672
2	inverted chevron	417.95	421.55	0.861347051
3	Braced Chevron Brace (B.C.B.)	417.95	424.05	1.459504725
4	k-Bracing	417.95	422.23	1.024045939

Table 17: Maximum Base Shear (KN)

Sr.no.	Type Of Bracing With Diffrent Section	Unbraced	Braced	% Of Difference	
				increases	decreases
A	Angle Section				_
1	X-Bracing	8850.25	8760.602	_	1.012943137
2	inverted chevron	8850.25	8743.279	_	1.208677721
3	Braced Chevron Brace (B.C.B.)	8850.25	8726.062	_	1.403214598
4	k-Bracing	8850.25	8728.85	_	1.371712663
B	Channel Section				
1	X-Bracing	8850.25	8759.304	_	1.02760939
2	inverted chevron	8850.25	8744.268	_	1.197502895
3	Braced Chevron Brace (B.C.B.)	8850.25	8718.987	_	1.483155843

4	k-Bracing	8850.25	8730.451	_	1.353622779
C	Beam Section				
1	X-Bracing	8850.25	8759.476	_	1.025665942
2	inverted chevron	8850.25	8744.202	_	1.198248637
3	Braced Chevron Brace (B.C.B.)	8850.25	8720.166	_	1.469834185
4	k-Bracing	8850.25	8730.355	_	1.354707494

Table 18: Maximum Axial Force (KN)

Sr.no.	Type Of Bracing With Diffrent Section	Unbraced	Braced	Percentage Reduction	
				Increases	Decreases
A	Angle				
1	X-Bracing	341.913	341.918	0.001462339	_
2	inverted chevron	341.913	341.919	0.001754802	_
3	Braced Chevron Brace (B.C.B.)	341.913	341.237	_	0.198102785
4	k-Bracing	341.913	341.235	_	0.198690052
B	Channel				
1	X-Bracing	341.913	341.915	0.000584941	_
2	inverted chevron	341.913	341.943	0.008773392	_
3	Braced Chevron Brace (B.C.B.)	341.913	341.489	_	0.124162125
4	k-Bracing	341.913	341.494	_	0.122696153
C	Beam section				
1	X-Bracing	341.913	341.916	0.000877408	_
2	inverted chevron	341.913	341.941	0.008188547	
3	Braced Chevron Brace (B.C.B.)	341.913	341.471	_	0.129439982
4	k-Bracing	341.913	341.469	_	0.130026445

Table 19: Maximum Bending Moment (KN-m)

Sr.no..	Type of Bracing With Diffrent Section	Unbraced	Braced	% difference
A	Angle			
1	X-Bracing	1.44184	1.44184	0
2	inverted chevron	1.44184	1.44184	0
3	Braced Chevron Brace (B.C.B.)	1.44184	1.44184	0
4	k-Bracing	1.44184	1.44184	0
B	Channel			0
1	X-Bracing	1.44184	1.44184	0
2	inverted chevron	1.44184	1.44184	0
3	Braced Chevron Brace (B.C.B.)	1.44184	1.44184	0
4	k-Bracing	1.44184	1.44184	0
C	Beam section			0
1	X-Bracing	1.44184	1.44184	0
2	inverted chevron	1.44184	1.44184	0
3	Braced Chevron Brace (B.C.B.)	1.44184	1.44184	0
4	k-Bracing	1.44184	1.44184	0

Table 20: Time Period (Second)

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