Study of Wind Loads on Steel Building with and Without Different Braced System Using Tekla Structures

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Abstract - *This study analyzes the load-bearing capacity of a steel building with different systems. In this study we use different types of bracing systems. The wind load properties of buildings are usually better with the braced system. They are extracted most efficiently from these structures. Build a structure that performs well under wind loads. For this study, a 40-story residential building was designed and measured under the wind load conditions. The structural properties of the steel building were studied using different types of bracing such as X Bracing, Chevron Bracing and V Bracing, and structural analysis was performed using TEKLA software. This study assumes wind speed as a zone of 50 m/s. Therefore, in this study, the wind load parameters such as period, drift and floor displacement dominate for a steel building with a different combination of bracing system and no bracing system. Wind load analysis according to Indian Code of Standards IS875:2015 (Part III) by Diaphragm Analysis Method. Finally, the chevron bracing design is perhaps the best structural performance of any design type considered here in such conditions.*

Key Words: Steel Building, TEKLA Software, V-Bracing, X-Bracing, Chevron Bracing (Inverted V-Bracing), Natural Time Period, Story Drift, Story Displacement.

1.INTRODUCTION

India is currently a rapidly growing country that requires more infrastructure as the population grows. Due to population growth, the value of housing demand is growing day by day. The only option to meet the need for other residential and commercial space is vertical construction, which is a multi-storey building. This type of use requires security, since these apartment buildings are very sensitive to additional lateral loads from earthquakes and wind. In other countries, as a building increases in height, it responds to lateral loads. Multi-storey buildings are prone to excessive deflection, which requires special measures to reduce this deflection. Braced frames are a common type of construction, easy to analyze and economical to build. They are basically divided into two braced frames.

1.1 High-Rise Buildings Affect the Wind

When the wind stretches the wall of a building, it is deflected in all directions. Some of the wind is deflected up and around the building and has no effect on the ground. However, a significant portion of the air is deflected down the building wall, resulting in drafts and turbulence near the ground.

In general, the higher the height of a skyscraper, the greater the effect of downdraft, as a taller wall deflects more wind downward. Because the streets aren't much wider, more rotating air results in more speed and turbulence: in the same space, a larger volume of air is displaced, so it has to move faster. The angle at which the wind hits a building has a strong influence on the effect of the downdraft. In general, the effect is most pronounced when the wind hits a building wall head-on, and is significantly reduced when the wind is at an angle: more air is deflected sideways than down.

a. Concentric Braced Frames (CBF's): A class of structures that withstand lateral loads through a system of vertical concentrating worms, the members of which focus on the joints. CBF's are generally effective in withstanding lateral forces because they can offer high strength and stiffness. These properties can also lead to less favorable seismic properties, such as lower cloud strength and higher acceleration. CBF's are a general structure system or composite system for any seismicity.

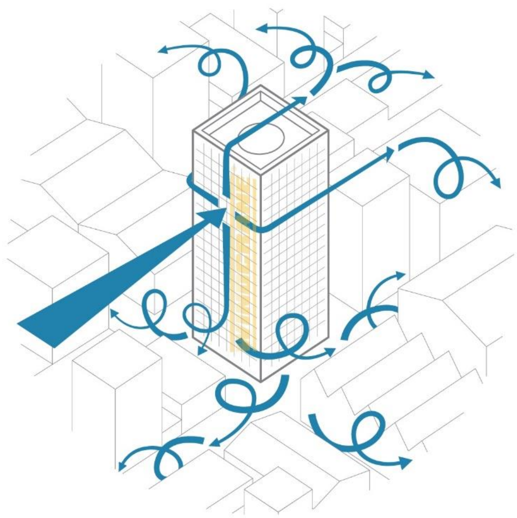


Fig 1: Wind load on building surface

b. Eccentric Brace Frames (EBF's): An eccentric bracing is more flexible than a concentric bracing. Consequently, the ability to absorb and dissipate energy during a wind loads in the eccentric bracing system is increased. The flexibility of these braced is due to the beam falling between the two braces or the beams between the bracelet post. This part of beam is called link beam. These beams are felt due to very large displacements, due to the nonlinear behavior of the communication beam, they violate the applied load of the diagonal bracing. Most difference CBF's & EBF's are, EBF's increases flexibility, but CBF's increases lateral strength.

2. OBJECTIVE OF STUDIES

The purpose of this study is analyzed of steel structure with different braced systems under gravity loads& wind loads.

a) To study the performance of steel building with different types of braced and without braced systems.
b) The compare some mainly parameters such as Natural Time Period, Story Displacements, & Story Drift on the performance of multi-story buildings with different types of bracings i.e. (V- Bracing, X-Bracing and chevron Bracing).
c) To find optimized braced system under given loads.

3. STRUCTURAL BUILDING DETAIL

The building length & width are 15m & 12m. The height of story is 3m. The building shape is uniform to X and Y axis. The columns are assumed to fixed at the level of ground. In this study of G+40 story steel building of 5 bays in X-direction & 4 bay in Y- direction both are considered for the investigation the effect of the different types of bracing system. Below the table shows details of the building that is used for the analysis of the building.

3.1 Design Wind Pressure Concept

The wind pressure at any height above mean ground level is obtained by the following relationship between wind pressure and wind speed:

$$P_z = 0.6\, V_z^2$$

Where,

P_Z = wind pressure in N/m2 at height z, and
V_Z = design for wind speed in m/s at height z.

The design wind pressure pd can be obtained as,

$$P_d = K_d.\ K_a.\ K_c.\ P_Z$$

Where,

K_d = Wind directional factor.
Ka = Area, terrain, size factor.
Kc = topography factor.

The relationship between design wind speed V_Z and the pressure produced by it assumes he mass density of air as 1.20 kg/m3, which changes as the atmospheric temperature and pressure.

In order to obtain the design wind pressure, various reductions must be made using the factors K_d, K_a and K_c. These factors are explained in the following sections.

3.2 WIND LOADS DATA as per IS 875:2015 (part 3)

1. Basic Wind Speed for Region	-	50m/sec
2. Risk Co-Efficient (K1)	-	1 (clause 6. 3. 1)
3. Terrain Category (K2)	-	Category-2 (clause 6. 3.2)
4. Topography Factor for wind (K3)	-	1 (clause 6.3.3)
5. Class of Building	-	Class-b
6. Windward direction Co-efficient (Cp)	-	0. 8
7. Leeward Co-efficient (Cv)	-	0. 5
8. Geographical Area	-	Nellore

3.3 Description of the Building in detail

1. Location	-	Nellore (Ongole)
2. Type of Building	-	Residential Building (G+40)
3. Plan Dimension	-	15m x 12m
4. Type of Structure	-	Steel Structure
5. Length In X-Direction	-	15m
6. Length in Y-Direction	-	12m
7. No. of Bays in X-Direction	-	5 bays @3.0m
8. No. of Bays in Y-Direction	-	4 bays @3.0m
9. Total Height of Building	-	123m
10. Floor to Floor Height	-	3m
11. Slab Thickness	-	110 mm
12. Beam Size	-	ISMB600
13. Column Size	-	ISWB600-1
14. Secondary Beam for Slab	-	ISMB300
15. X-Bracing	-	ISMB200
16. Chevron Bracing	-	ISMB200
17. V-Bracing	-	ISMB200

3.4 MATERIAL PROPERTIES FOR STEEL STRUCTURE

1. Steel Grade (I-section)	-	Fe345
2. Density of Steel	-	7850Kg/m3
3. Rebar	-	HYSD500
4. Young's Modulus(E)	-	2. 1*105N/mm2
5. Shear Modulus	-	80,000N/mm2
6. Poisson's Ratio	-	0.3
7. Concrete Grade	-	M30

3.5 LOADINGS CASES

a) Dead load (Self weight of building) as per IS 875-Part (I).
b) Live load = 4KN/m2 as per IS 875-Part (II).
c) Seismic loads as per IS 1893:2016(Part-I).

d) Wind loads as per IS 875:2015 Part (III).

4. BUILDING CONFIGRATION

This study is focused on wind load response of multistory steel(G+44) building with different types of bracing system. Building is located on seismic zone II and basic wind speed zone 50m/sec as per IS code guidelines using TEKLA Structures software.

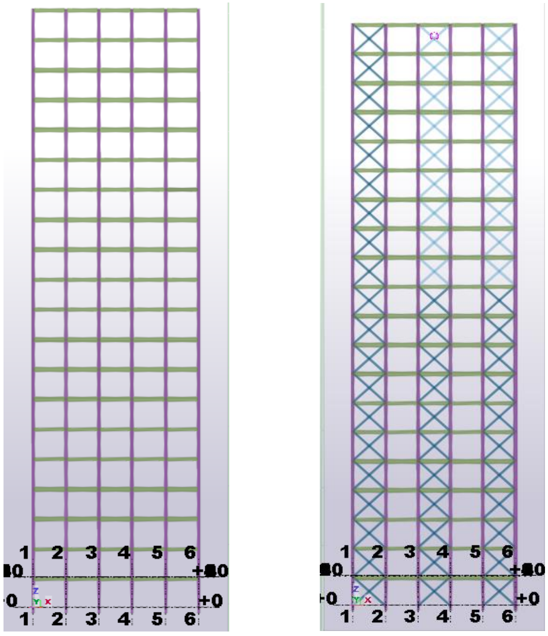


Fig 2(a): Bare Frame, X -bracing.

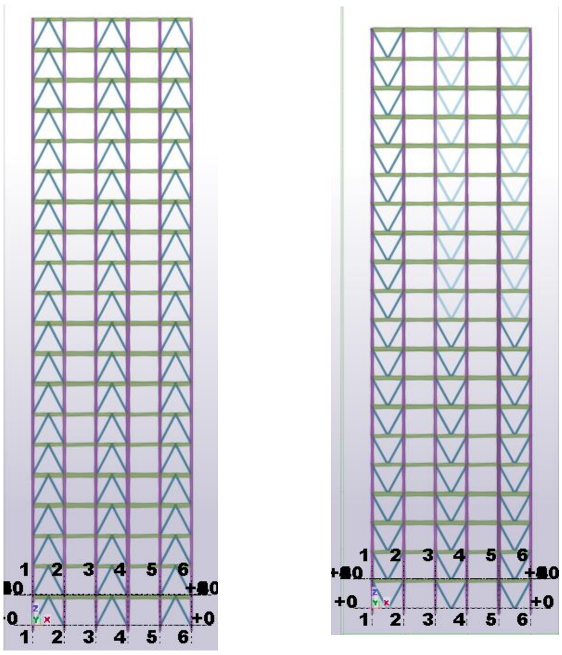


Fig 2(b): Chevron bracing, V-bracings

(a). Model 1- steel building (G+40) without Bracing.
(b). Model 2- steel building (G+40) with Chevron-Bracing (Inverted V-Bracing).
(c). Model 3- steel building (G+40) with X-Bracing.
(d). Model 4- steel building (G+40) with V-Bracing.

5. RESULT & DISCUSSION

There are various parameters defined in this study such as Natural time period, story drift and story displacement. It can be defined as:

a) Natural Time Period

The natural period (Tn) of construction is the period of a building that covers one complete cycle of fluctuations. It is determined by two main factors: the mass (m) of the building and stiffness (k). The ratio of natural period, stiffness and mass is given as:

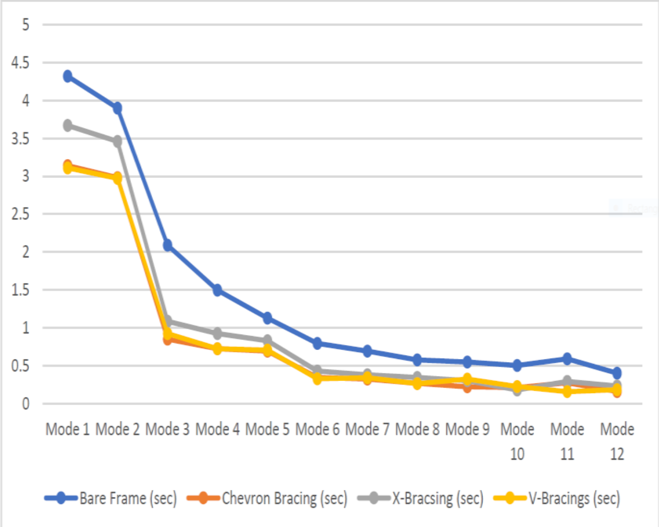
$$Tn = 2\Pi\sqrt{(m/k)} \quad \text{Its units are second (sec)}$$

This study is classified as the above Natural time period graph and table find as the Chevron bracing are most efficient bracing as compared to K-bracing, V-bracing system and without bracing.

Table 4: Natural Time Period

Mode	Bare Frame (sec)	Chevron Bracing (sec)	X-Bracings (sec)	V-Bracings (sec)
Mode 1	4.32	3.14	3.67	3.11
Mode 2	3.9	2. 98	3. 46	2.97
Mode 3	2.089	0.849	1.084	0.921
Mode 4	1.497	0.721	0.924	0.723
Mode 5	1.127	0.692	0.829	0.703
Mode 6	0.792	0.341	0.427	0.324
Mode 7	0.689	0.323	0.379	0.34
Mode 8	0.573	0.265	0.341	0.262
Mode 9	0.545	0.220	0.30	0.321
Mode 10	0.501	0.209	0.178	0.222
Mode 11	0.59	0.272	0.289	0.155
Mode 12	0.40	0.158	0.229	0.181

Chart 1: Model sway of different bracing configuration for steel structure



b) Story Displacement

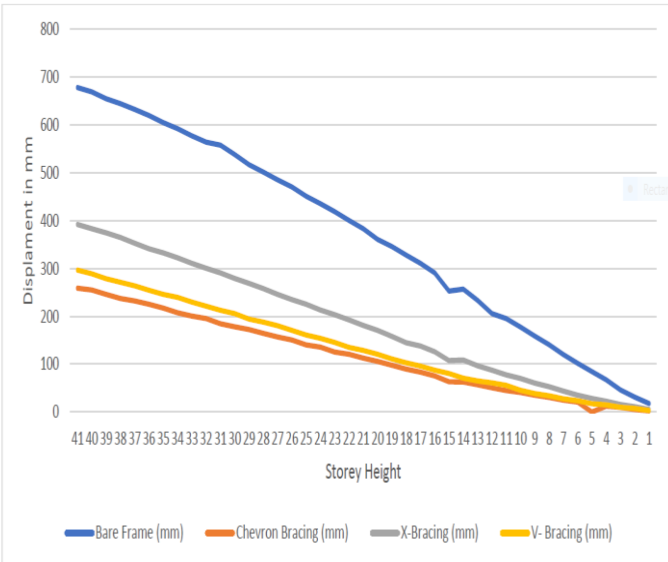
Lateral displacement means the complete displacement of the floor relative to the ground due to lateral forces acting on the building. The displacement as per IS 1893 (Part I):2016 is limited to H/250.

From above graph and table of Story displacement, it is concluded that Chevron bracing (Inverted bracing) is more efficient bracing system as compared to without and X-bracing systems.

Table 5: Storey Displacement

Storey	Bare Frame (mm)	Chevron Bracing (mm)	X-Bracing (mm)	V-Bracing (mm)	Permissible Limit
41	678.32	258.9	392.12	296.78	492
40	669.31	255.25	383.54	289.13	480
39	654.91	246.27	374.92	278.71	468
38	644.91	237.23	364.97	271.55	456
37	632.71	232.41	352.65	263.57	444
36	620.25	225.56	341.12	254.65	432
35	604.98	217.46	332.98	246.19	420
34	592.67	207.61	322.16	239.43	408
33	5787.65	200.68	310.94	230.19	396
32	564.38	195.73	300.82	221.10	384
31	558.12	184.37	290.59	212.90	372
30	538.56	178.29	279.35	205.79	360
29	517.34	172.48	268.92	194.35	348
28	501.61	164.31	157.91	187.73	336
27	485.61	157.25	245.91	180.76	324
26	470.39	150.76	235.20	170.82	312
25	450.98	140.19	225.61	160.78	300
24	435.86	135.46	213.46	154.35	288
23	418.76	125.51	203.47	145.63	276
22	400.52	120.89	192.61	1365.30	264
21	383.26	112.85	180.92	128.96	252
20	360.64	105.64	170.91	120.98	240
19	345.98	97.56	158.38	110.90	228
18	327.96	89.70	145.13	103.19	216
17	310.89	83.26	138.27	95.82	204
16	290.67	75.18	125.78	87.35	192
15	252.67	63.20	107.63	80.39	180
14	256.89	62.78	108.46	70.89	168
13	233.18	57.12	96.45	65.31	156
12	205.64	50.98	87.35	60.78	144
11	195.64	45.19	77.66	55.68	132
10	177.46	40.78	70.26	45.79	120
9	158.49	35.16	60.45	38.46	108
8	140.78	30.45	52.91	33.95	96
7	120.19	24.93	43.85	27.61	84
6	101.89	20.64	35.16	23.60	72
5	84.34	15..34	28.34	17.36	60
4	67.15	12.46	22.60	14.95	48
3	485.93	9.85	15.49	10.16	36
2	30.96	5.60	10.94	7.77	24
1	17.86	2.19	5.49	3.21	12

Chart 2: Storey displacement for different bracing configuration for steel structure



c) Story Drift

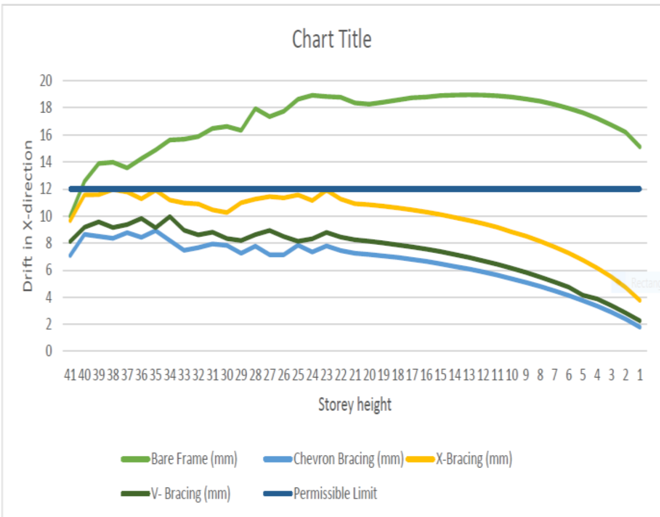
Story drift is the lateral displacement of one level relative to the upper or lower level. According to IS 1893(part I):2016(clause 7. 11. 1. 1), the level of demolition of the floor is the level of demolition divided by the height of the story. The floor drift in any case should not exceed 0. 004 times so the limited story drift value is 0.004 x 3 = 12 mm.

From above graph and table of Story drift, it is concluded that Chevron bracing (Inverted bracing) is more efficient bracing system as compared to without, K-bracing and V-bracing systems.

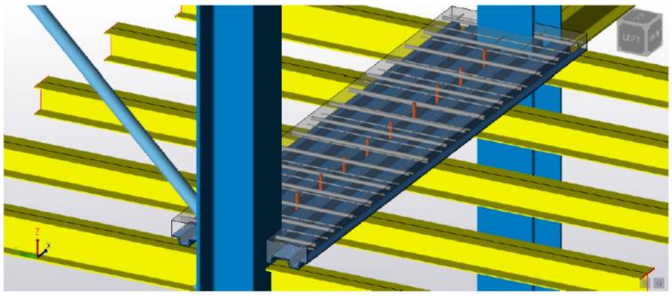
Table 6: Storey Drift

Storey	Bare Frame (mm)	Chevron Bracing (mm)	X-Bracing (mm)	V-Bracing (mm)	Permissible Limit
41	9.983	7.085	9.662	8.12	12
40	12.56	8.64	11.56	9.16	12
39	13.89	8.49	11.58	9.56	12
38	13.95	8.35	11.963	9.15	12
37	13.58	8.76	11.79	9.37	12
36	14.26	8.42	11.28	9.82	12
35	14.89	8.92	11.91	9.13	12
34	15.62	8.19	11.18	9.96	12
33	15.68	7.458	10.96	8.95	12
32	15.89	7.658	10.89	8.60	12
31	16.48	7.934	10.46	8.80	12
30	16.62	7.82	10.25	8.34	12
29	16.34	7.25	10.98	8.19	12
28	17.95	7.765	11.256	8.62	12
27	17.35	7.13	11.43	8.94	12
26	17.76	7.14	11.34	8.48	12
25	18.64	7.84	11.56	8.14	12
24	18.93	7.34	11.15	8.31	12
23	18.84	7.78	11.90	8.79	12
22	18.78	7.451	11.25	8.435	12
21	18.37	7.25	10.916	8.24	12
20	18.28	7.16	10.83	8.13	12
19	18.42	7.05	10.73	8.01	12
18	18.59	6.93	10.6	7.87	12
17	18.75	6.79	10.46	7.721	12
16	18.81	6.64	10.301	7.552	12
15	18.92	6.47	10.117	7.365	12
14	18.92	6.27	9.90	7.149	12
13	18.98	6.082	9.684	6.932	12
12	18.92	5.860	9.436	6.691	12
11	18.85	5.628	9.161	6.425	12
10	18.81	5.35	8.82	6.138	12
9	18.64	5.093	8.515	5.827	12
8	18.48	4.793	8.139	5.492	12
7	18.28	4.47	7.723	5.13	12
6	17.96	4.121	7.26	4.739	12
5	17.66	3.745	6.744	4.138	12
4	17.27	3.335	6.163	3.863	12
3	16.74	2.884	5.5	3.371	12
2	16.21	2.381	4.73	2.835	12
1	15.13	1.782	3.761	2.252	12

Chart 3: Storey drift for different bracing configuration for steel structure



d) Composite Member of Beam From Plotted 3d View



A steel concrete composite beam consists of a steel beam over which a reinforced concrete deck is cast with shear connectors. Since composite action reduces the beam depth, rolled steel sections themselves are found adequate frequently for structures and built-up girders are generally unnecessary. The composite beam can also be constructed with profiled zig zag rolled sheeting with concrete topping, instead of cast-in place or precast reinforced concrete slab.

The profiled steel sheets like rolled deck are provided with embossments to prevent slip at the interface. The shape of the curled step form, itself enhances the interlock between concrete and the steel sheet. The main advantage of using profiled deck slab is that, it acts as a shuttering form work and centering at construction stage and also serves the purpose of bottom reinforcement for the deck slab.

The studs are provided as in general it will weld with "Iron Electric Stud Type ARC Welding Machine", in order to hold the entire deck slab with respect to beam.

6. DESIGN AND DETAILING OF STEEL STRUCTURE IN TEKLA

The detailing of structures of the above steel structure is considered as the real time view in drawing, as it had best software in case of detailing steel or concrete with perfect bracing system with anchor bolt plan and Erection plans in case of top view and front view diagrams.

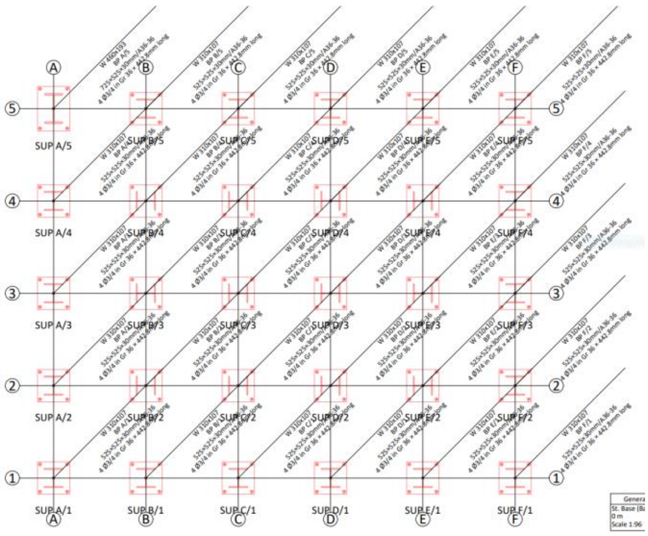


Fig 3: Anchor Bolt drawing plan

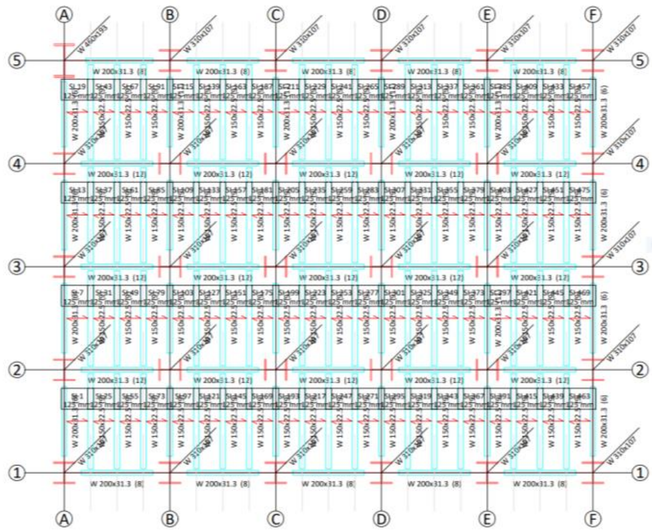


Fig 4: Erection drawings Plan

6.1 CONNECTIONS FOR STEEL CHEVRON BRACING

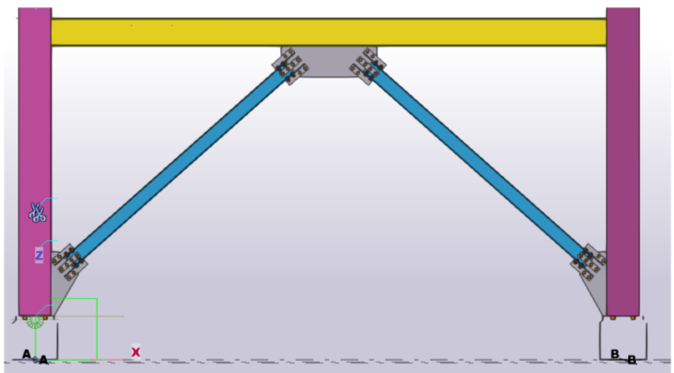


Fig 5: Chevron Bracing

7. CONCLUSIONS

The following conclusions result from the above mentioned investigations.

1. Among all the analyzed models with links, the factors taken into account are within acceptable limits.
2. Based on the real period (sec), it is estimate that the chevron model has the lowest natural period value (sec), which is a more efficient model than other models.
3. Time taken in first mode is base in Chevron braced structure and in other all with respect to braced structure, 61. 00% more in without braced, 22. 33% more in K-braced and 3. 83% and more in V-braced structure.
4. Based on the Story Displacement (mm), it is evaluated that the chevron model has the lowest Story Displacement value (mm), which is a more efficient model than other models.
5. Displacement is minimum in Chevron braced structure and in other all with respect to braced structure, 152. 21% more in without braced, 49. 89% more in Chevron braced and 14. 02% more in V-braced structure.
6. Based on the Story Drift (mm), it is estimated that the chevron model has the lowest Story Drift value (mm), which is a more efficient model than other models.

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