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Lateral Load Analysis of Steel Building with and without Braced System

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Abstract—*This study is devoted to the study of the structural characteristics of a steel building with various fastening systems. The effectiveness of different types of bracing systems on the structure has also been studied and most efficient is being obtained from these structures. It is very essential to design a structure that will work well under the effect of wind loads. A G+44 story residential steel building was designed and analysed for this study under lateral loads conditions i.e. wind loads & seismic forces. The structural characteristics of the steel building have been studied by various types of bracing systems, such as X-bracing, without bracing & Chevron Bracing and analysis of structure using ETAB'S 17 software are done. A comparative study is being carried out on the bouquet of unrelated, unconnected and unconnected structures. This study consider seismic zone-II and wind speed zone 50m/sec, so this study most dominating factor are wind loading parameters such as Natural Time period, story displacement, story drift and axial forces for steel building with different combination of braced system & without braced system are studied. Finally, it can be said that a structure with Chevron Bracing connections shows the best structural characteristics of all such structures, which are considered here in such conditions.*

Keywords: *Steel Building, ETAB'S 17 Software, X-Bracing, Chevron Bracing (Inverted V-Bracing), Natural Time Period, Story Drift, Story Displacement.*

I INTRODUCTION

Braced system are a very common type of construction, easy to analyze and construct economically. The savings are achieved through beams and columns, through cheap, nominally pinned joints. Reinforcement, which provides stability and resistance to lateral loads, can be made of diagonal steel elements or concrete "core". In the case of steep construction, the beams and columns are intended for vertical loads only, provided that the fastening system takes all lateral loads. The columns and beams are usually arranged in an orthogonal manner, both in height and in plan. There are basically categorized into two brace systems.

1. **Concentric Brace system**:It is a type of mountain whose central axis coincides with each other. They especially increase the lateral stiffness of the frame, which in turn increases the natural frequency, and it also reduces the lateral clouds on the floor. In addition, the reinforcement increases the key compression in the columns, which is related to the bending moments in the column and reduces the lateral forces.

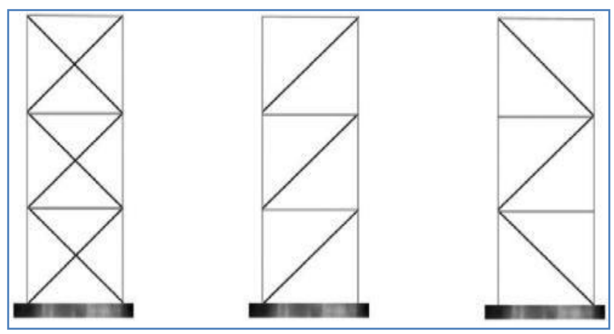


Fig. 1: X-Bracing Fig.2: Single Bay of Diagonal Bracing

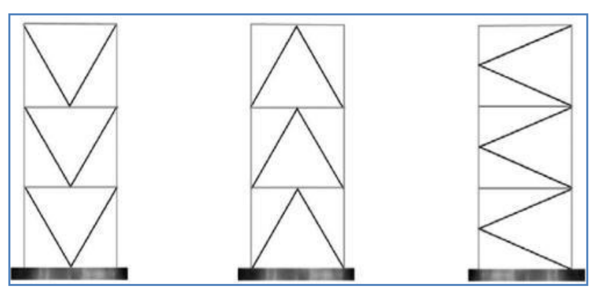


Fig. 3: V-Bracing, Chevron Bracing, K Bracing

2. **Eccentric Brace system:** It is a type of attachment whose central line braces are compensated by the intersection of the columns and the central line of the beams. This mainly improves the power extravagance and reduces the lateral stiffness of the system. The vertical component of the force exerted by the earthquake at the point of

connections of the eccentric bonds on the beams generates a concentrated.

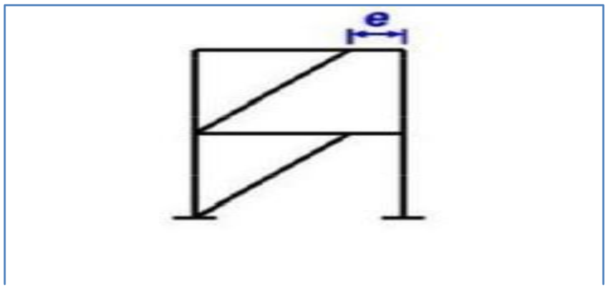


Fig. 4: Eccentric Bracing

II OBJECTIVE OFSTUDIES

The purpose of this study is analyze of steel structure with different braced systems under seismic forces & wind loads.

1. To study the performance of steel building with different types of braced and without braced systems.
2. 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. (X- Bracing and chevron Bracing).
3. To find optimized braced system under given loads.

III STRUCTURAL BUILDINGDETAIL

The building length & width are 27m & 27m. The height of story is 3m. The building shape is symmetrical to X and Y axis. The columns are assumed to be fixed at ground level. In this study, A G+44 story steel building of 7 bays in X-direction &7 bay in Y- direction have been considered for the investigation the effect of the different types of bracing system. Below table shows details of the building that is used for the analysis of the building.

Table 1: Description of the Building

S. No.	Structural Parts	Dimensions
1.	Location	Vishakhapatnam(A.P)
2.	Type of Building	Residential Building(G+44)
3.	Plan Dimension	27m*27m=729sq.m
4.	Type of Structure	Steel Structure
5.	Length In X-Direction	27m
6.	Length in Y-Direction	27
7.	No. of Bays in X-Direction	7No@4.5m
8.	No. of Bays in Y-Direction	7No@4.5m
9.	Total Height of Building	132m
10.	Floor to Floor Height	3m
11.	Slab Thickness	125mm
12.	Beam Size	ISMB600
13.	Column Size	ISWB600-1
14.	Secondary Beam For Slab	ISMB300
15.	X-Bracing	ISMB600
16.	Chevron Bracing	ISMB600

Table 2: MaterialProperties

S. No.	Material	Grade
1.	Steel Grade	Fe345
2.	Density of Steel	7850Kg/m^3
3.	Rebar	HYSD500
4.	Young's Modulus(E)	2.1*10^{5}N/mm^2
5.	Shear Modulus	80000N/mm^2
6.	Poisson's Ratio	0.3
7.	Concrete Grade	M30

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

S. No.	Factors	Details
1.	Basic Wind Speed	50m/sec
2.	Risk Co-efficient(K_1)	1(clause 6.3.1)
3.	Terrain Category(K_2)	Category-2(clause 6.3.2)
4.	Topography Factor(K_3)	1(clause 6.3.3)
5.	Class of Building	Class-b
6.	Windward Co-efficient($C_{p)}$)	0.8
7.	Leeward Co-efficient(C_v)	0.5

LOADINGS:

a) Dead load (Self weight of building) as per IS875-Part (I).
b) Live load= 4KN/m^2 as per IS875-Part (II).
c) Seismic loads as per IS1893:2016(Part-I).
d) Wind loads as per IS 875:2015 Part (III).

IV PROBLEMFORMULATION

This study is focused on wind load response of multistory **steel(G+44) building** with different types of bracing system. Building are located on seismic zone II & basic wind speed zone 50m/sec as per IS code guidelines using ETAB'S-2017 software.

(a). Model -1 steel building(G+44) without Bracing wind/seismic
(b). Model -2 steel building (G+44) with Chevron-Bracing (Inverted V-Bracing).
(c). Model -3 steel building (G+44) with X-Bracing.

Model 1: Steel Building (G+44) Without Bracing system

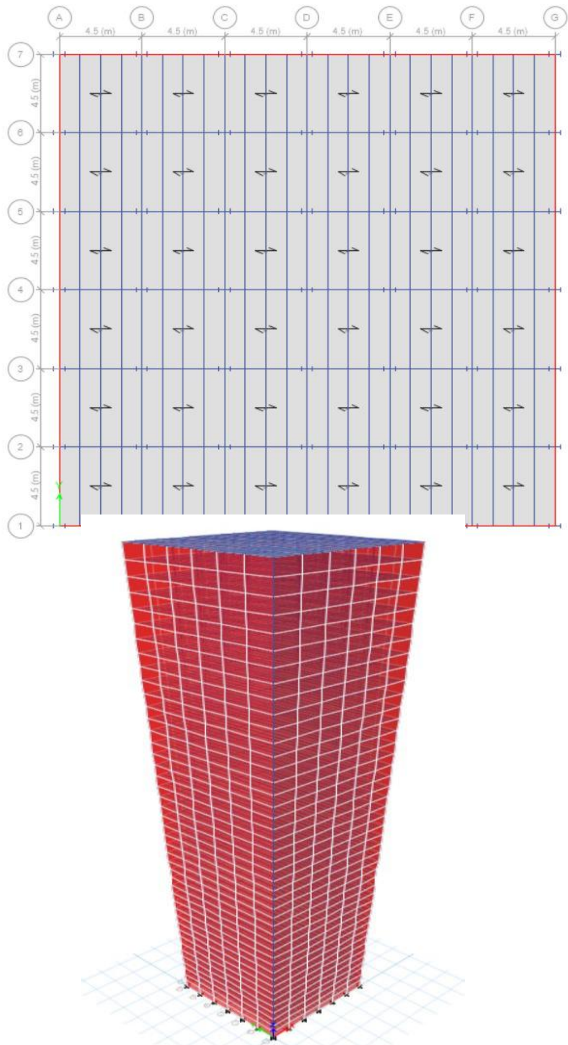
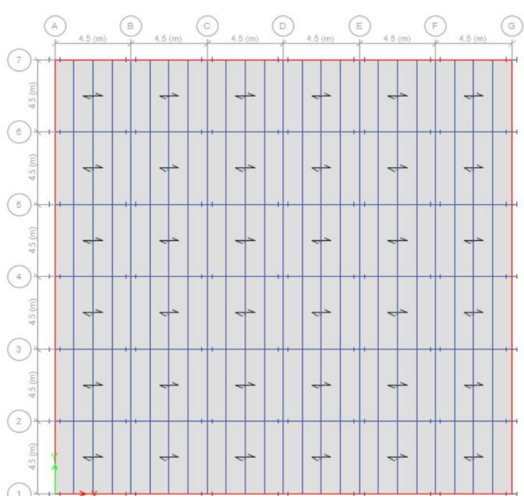


Fig. 5: Plan & 3D view

Model 2: Steel Building (G+44) with Chevron Bracing system



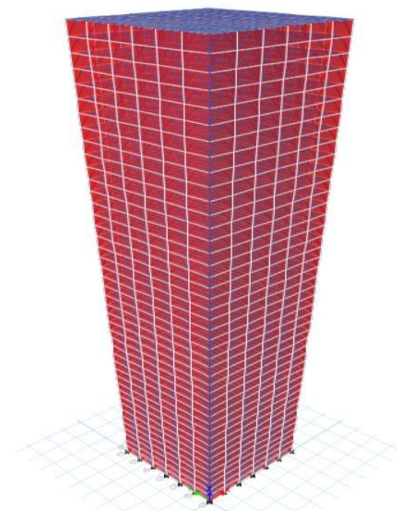
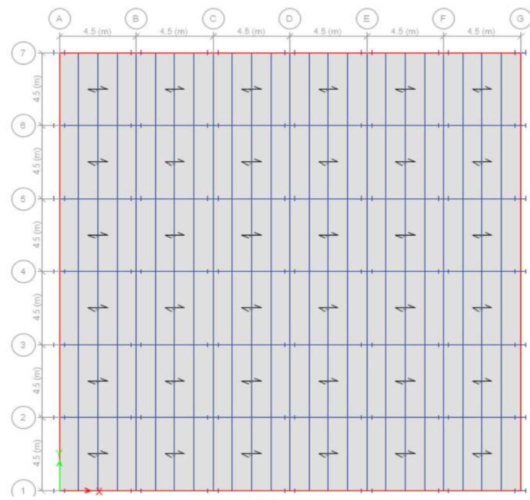


Fig. 6: Plan & 3D view

Model 3: Steel building (G+44) with X-Bracing



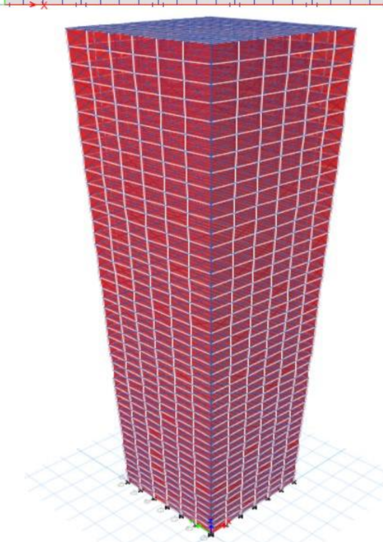


Fig. 7: Plan & 3-D view

V 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 ($T_{n)}$ 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 the stiffness (k). The ratio of natural period, stiffness and mass is given as,

$T_n = 2\Pi\sqrt{(m/k)}$ It's units are second (sec)

Table 4: Natural Time Period

Mode	Without Bracing(sec)	Chevron Bracing(sec)	X-Bracing(sec)
Mode 1	4.83	3	3.101
Mode 2	3.973	2.985	3.066
Mode3	2.064	0.769	0.692
Mode 4	1.485	0.706	0.682
Mode 5	1.118	0.682	0.663
Mode 6	0.789	0.333	0.313
Mode7	0.687	0.319	0.302
Mode 8	0.566	0.257	0.231
Mode 9	0.549	0.218	0.201
Mode 10	0.419	0.207	0.193
Mode 11	0.41	0.162	0.148
Mode 12	0.387	0.154	0.141

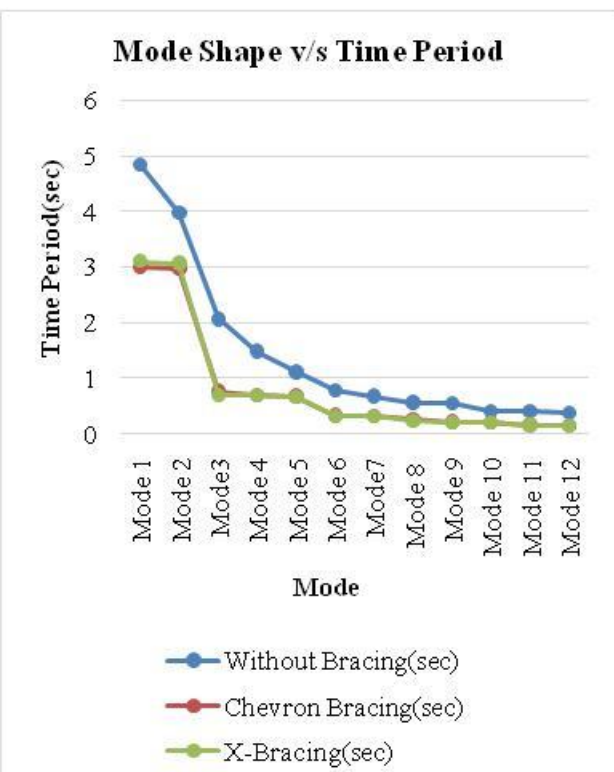


Fig. 8: Comparison of Time period

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

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**.

Table 5: Story Displacement

Story	Without Bracing WIND (mm)	Without Bracing SEISMIC (mm)	Chevron Bracing (mm)	X-Bracing (mm)	Permissible Limit
44	709.528	50.795	281.316	296.212	528
43	699.544	49.986	274.23	288.423	516
42	689.154	49.137	267.094	280.595	504
41	678.35	48.25	259.906	272.726	492
40	667.13	47.327	252.665	264.817	480
39	655.49	46.369	245.372	256.867	468
38	643.433	45.379	238.029	248.88	456
37	630.96	44.379	230.637	240.857	444
36	618.074	43.311	223.201	232.801	432
35	604.78	42.237	215.722	224.717	420
34	591.082	41.138	208.207	216.609	408
33	576.989	40.016	200.659	208.482	396
32	562.507	38.873	193.084	200.342	384
31	547.647	37.711	185.488	192.196	372
30	532.419	36.532	177.878	184.05	360
29	516.835	35.338	170.262	175.913	348
28	500.908	34.13	162.647	167.792	336
27	484.65	32.909	155.041	159.698	324
26	468.075	31.676	147.454	151.638	312
25	451.2	30.434	139.895	143.623	300
24	434.04	29.182	132.374	135.665	288
23	416.611	27.924	124.901	127.773	276
22	398.932	26.659	117.488	119.961	264
21	381.021	25.39	110.146	112.239	252
20	362.898	24.118	102.888	104.622	240
19	344.583	22.843	95.726	97.122	228
18	326.509	21.567	88.673	89.755	216
17	307.464	20.291	81.743	82.533	204
16	288.706	19.016	74.95	75.474	192
15	269.851	17.744	68.311	68.592	180
14	250.925	16.476	61.839	61.905	168
13	231.958	15.213	55.553	55.429	156
12	212.981	13.923	49.468	49.183	144
11	194.026	12.711	43.602	43.186	132
10	175.128	11.473	37.974	37.456	120
9	156.323	10.246	32.604	32.013	108
8	137.654	9.03	27.511	26.879	96
7	119.165	7.827	22.719	22.077	84
6	100.907	6.636	18.249	17.629	72
5	82.931	5.46	14.128	13.56	60
4	65.295	4.303	10.383	9.896	48
3	48.068	3.168	7.048	6.668	36
2	31.324	2.062	4.163	3.911	24
1	15.123	0.993	1.782	1.666	12

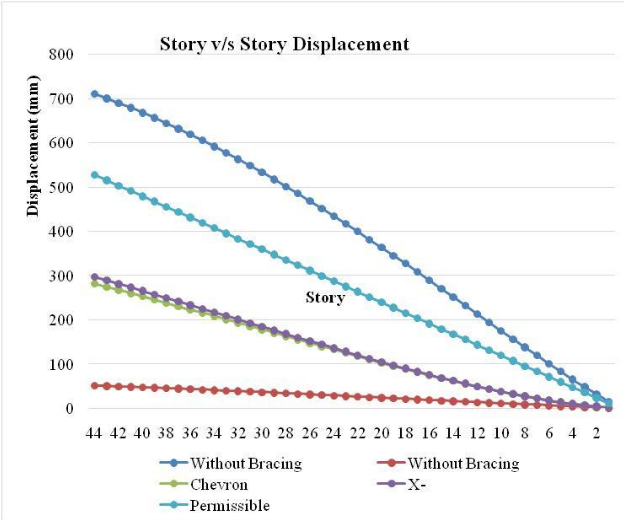


Fig. 9: Comparison of Story Displacement

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.

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**.

Table 6: Story Drift

Story	Without bracing WIND (mm)	Without bracing SEISMIC (mm)	Chevron Bracing (mm)	X-Bracing (mm)	Permissible Limit
44	9.985	0.839	7.085	7.789	12
43	10.389	0.895	7.136	7.828	12
42	10.804	0.95	7.188	7.869	12
41	11.221	1.003	7.241	7.909	12
40	11.639	1.052	7.293	7.949	12
39	12.057	1.096	7.343	7.988	12
38	12.473	1.135	7.392	8.023	12
37	12.886	1.169	7.437	8.056	12
36	13.294	1.199	7.478	8.095	12
35	13.697	1.226	7.516	8.108	12
34	14.093	1.25	7.548	8.127	12
33	14.482	1.272	7.575	8.14	12
32	14.86	1.299	7.596	8.146	12
31	15.228	1.309	7.61	8.146	12
30	15.584	1.324	7.616	8.137	12
29	15.928	1.337	7.615	8.12	12
28	16.258	1.348	7.606	8.095	12
27	16.574	1.357	7.587	8.06	12
26	16.875	1.363	7.559	8.014	12
25	17.16	1.368	7.521	7.959	12
24	17.429	1.371	7.473	7.892	12
23	17.679	1.373	7.413	7.813	12
22	17.911	1.373	7.342	7.721	12
21	18.123	1.371	7.258	7.617	12
20	18.315	1.369	7.162	7.5	12
19	18.486	1.364	7.053	7.368	12
18	18.633	1.359	6.93	7.221	12
17	18.758	1.352	6.792	7.059	12
16	18.856	1.345	6.64	6.882	12
15	18.926	1.336	6.471	6.687	12
14	18.967	1.326	6.287	6.476	12
13	18.977	1.315	6.085	6.246	12
12	18.955	1.301	5.866	5.998	12
11	18.898	1.285	5.628	5.73	12
10	18.805	1.267	5.37	5.442	12
9	18.669	1.248	5.093	5.134	12
8	18.488	1.229	4.793	4.803	12
7	18.258	1.208	4.47	4.448	12
6	17.976	1.187	4.121	4.069	12
5	17.636	1.164	3.745	3.663	12
4	17.227	1.138	3.335	3.228	12
3	16.744	1.107	2.884	2.758	12
2	16.201	1.07	2.381	2.245	12
1	15.123	0.993	1.782	1.666	12

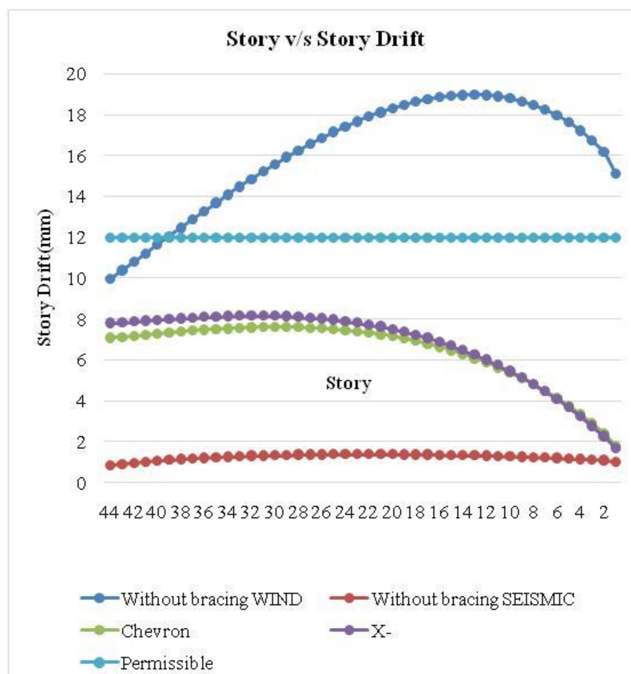


Fig. 10: Comparison of Story Drift0

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 and X- bracing systems.

VI CONCLUSIONS

From the above study the following conclusion are given below:

- Among all the analysed models with links, the factors taken into account are within permissible limits.
- Based on the natural time period (sec), it is evaluated that the chevron model has the lowest natural period value (sec), which is a more efficient model than other models.
- Time taken in first mode is minimum in Chevron braced structure and in other all with respect to braced structure, 61.00% more in without braced system and 3.36% and more in X-braced structure.
- 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.
- Displacement is minimum in Chevron braced structure and in other all with respect to braced structure, 152.21% more in without braced system and 5.29% more in X-braced structure.
- Based on the Story Drift (mm), it is evaluated that the chevron model has the lowest Story Drift value (mm), which is a more efficient model than other models.
- Drift is minimum in Chevron braced structure overall comparisons shows with respect to braced structure, 149.17% more in without braced system and 6.95% more in X-braced structure.

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