International Journal of Scientific Research & Engineering Trends
Volume 7, Issue 4, July-Aug-2021, ISSN (Online): 2395-566X

Performance of Telecommunications Tower During Seismic and Wind Loading Condition

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Abstract- **Four-legged self-supporting towers are commonly used in telecommunications around the world. In recent years, the communication industry has experienced considerable growth, resulting in the construction of a large number of towers to improve coverage area and network consistency. These towers play an important part in wireless communication networks, so their collapse in the event of a crisis is a big concern. As a result, when building these towers, harsh situations should be taken into account to the fullest extent possible. The effect of wind on four-legged self-supporting towers has been studied extensively in most studies. A study on models at differing heights with various bracing for earthquake and wind effects was carried out in this dissertation. Gust factor method is used to investigate the wind effect on the structure, and the modal analysis and response spectrum analysis are used to investigate the seismic effect on the structure. The results obtained from the above analysis are tabulated, compared and conclusions are drawn.**

Keywords- **Steel communication towers; Bracings; Wind analysis; Gust factor method; Modal analysis; Response spectrum analysis; STADD- Pro 2007 software.**

I. INTRODUCTION

Communication towers or lattice towers are classified into three categories that are Guyed masts, monopole and self-supporting towers. The structure engineer faces the challenging job of designing and constructing telecommunication towers to support antenna loads, platform as well as steel ladder loads in open weather with high degree of reliability.

The major cause of failures of telecommunication tower throughout the world though still remains to be high intensity winds (HIW). There have been several studies in telecommunication towers taking into consideration the wind as well as dynamic effect. Investigated the effects of wind and earthquake loads on the self-supporting antenna towers and it is reported that for towers, seismically induced member forces may exceed forces obtained from service and wind load calculations.

Self-supporting steel telecommunication towers with different heights were evaluated considering the wind and earthquake loads. A comparison is made between the results of wind and earthquake loading.

These comparisons resulted in the necessity of considering earthquake loads in tower analysis and design. Future offers a basic line of self-supporting towers that can be customised to suit any application. Light duty towers for small radio connections to heavy duty towers for major microwave and transmitting applications in cyclonic regions are all available. Future has supplied over 5,000 lattice towers in Australia and the world, and we will build a custom structure to meet your needs if necessary.

Future may have triangular or square towers with a wide range of attachments, fabricated from hollow tube, angle, or solid rod. All towers come with a site-specific base specification that is tailored to the specific soil conditions. Future offers a variety of traditional tower styles to fit the needs, as well as a large inventory of telecommunication structure towers.

II. OBJECTIVE

- To study the effect of wind load on tower structures for different wind zones using gust factor method.
- To study the seismic effect on the tower structures by carrying out the modal analysis and response spectrum analysis.
- To reduce the Displacements and steel quantity of the communication tower in the event of wind load effects by considering most suitable bracing system.

III. MODELLING AND LOADING DETAILS

1. Modelling of tower:

The Steel Communication tower is designed for heights of 25 m, 35 m and 45 m. The towers are provided with 4-different types of bracings: K type, XB-type, XX-type, and Y-type for lower portion and X-Bracing for upper portion of tower. Details of towers used for modeling are given in

Table-1 for various heights. Fig. 1 shows 30 m high towers with different types of bracings considered in the study.

Table 1. Details of different tower.

Height of Tower(m)	30	40	50
Height of Slant Portion(m)	20	28	36
Height of Straight Portion at Top of Tower(m)	10	12	14
Base Width(m)	5	5	5
Top Width(m)	2	2	2
No. of 4m Panel	5	7	9
No. of 2m Panel	5	6	7

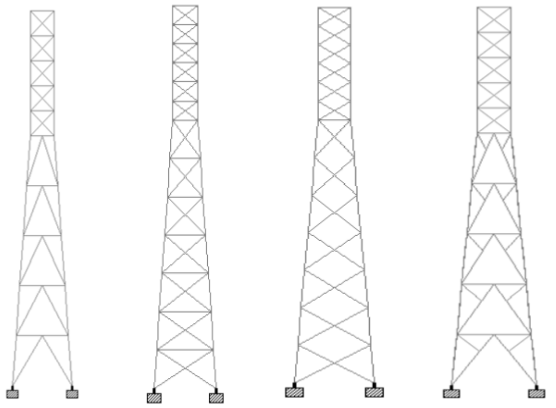


Fig 1. 30m Towers with Different Bracings Considered.

Table 2. Members details of tower.

Sr. No.	Tower Elevation (50 m)	Member Description	Section
1	0-20	Leg member	ISA 200 x 200 x 25
2		Bracing	ISA 150 x 150 x 12
3	20-36	Leg member	ISA 200 x 200 x 12
4		Bracing	ISA 130 x 130 x 12
5	36-50	Leg member	ISA 110 x 110 x 12
6		Bracing	ISA 90 x 90 x 10

2. Loads acting on tower

A platform load of 0.82 KN/m2 is applied at 26m, 36m, and 46m respectively for 30m, 40m and 50m tower. The weight of the ladder and cage assembly is assumed to be 10% of total weight. The antenna loads are summed up and distributed evenly to the nodes at the considered heights. The details of the antenna provided on the tower are given in the table 3.

Table 3. Antenna Loading for the Towers.

Sr . no	Item	Qty	Día (m) (w x d)	Location from Base (30m tower)	Location from Base (40m tower)	Location from Base (50m tower)
1	CDMA	6	0.26 x 2.5	28	38	48
2	Microwave	1	1.2	24	34	44
3	Microwave	1	0.6	24	34	44
4	Microwave	2	0.3	24	34	44

3. Wind Load:

The wind load on the tower structure is calculated by using IS 875 (part 3): 1987. For the calculation of the wind load by the gust factor method the parameters considered are as follows.

Wind zone II and V, basic wind speed is 39m/s, 44m/s, 47m/s and 55m/s, the risk coefficient factor k1 considered is 1.08 (considering design life of 100 years), topography factor k3 = 1.0 (flat terrain), the value of terrain and height factor k2 and the gust response factor G is calculated for category 1 that is open terrain category.

The table 4 shows the wind load calculated for 30m tower similarly the wind loads can be calculated for 40m and 50m tower.

Table 4. Wind load acting on 30m tower.

Panel No	Distance (m)	Case 1 (39m/s)			
		K	XB	XX	Y
1	4	11.13	12.81	10.27	13.35
2	8	12.72	14.33	11.69	15.18
3	12	14.35	15.81	13.17	17.06
4	16	15.58	16.71	14.38	18.34
5	20	12.13	12.72	12.27	14.25
6	22	6.04	6.04	6.04	6.04
7	24	5.96	5.96	5.96	5.96
8	26	5.88	5.88	5.88	5.88
9	28	5.91	5.91	5.91	5.91
10	30	5.99	5.99	5.99	5.99

4. Seismic load

The Seismic loads are applied on the tower structure using IS 1893: part 1, 2002. For the analysis purpose the acceleration spectrum have been prepared for zone II to zone V assuming soil condition as soft and damping as 2 % (For steel structure). The important factor (I) = 1.5 and response reduction factor (R) = 4.

IV. RESULT AND DISCUSSIONS

International Journal of Scientific Research & Engineering Trends
Volume 7, Issue 4, July-Aug-2021, ISSN (Online): 2395-566X

1. Wind Analysis Result:

Wind analysis carried out four wind zones of basic wind speed 39m/s, 44m/s, 47m/s and 55m/s. In the analysis gust factor method used to calculate wind load. The combination of dead load, antenna load and wind load is the load take for the analysis of the models. The joint displacement comparison is done by different wind zone in table 5 and member stress comparison is done in table 6.

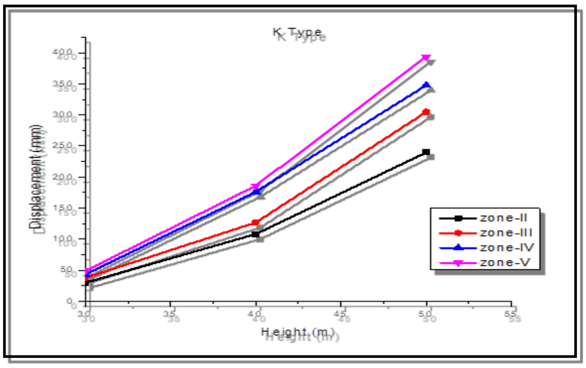
Table 5. Joint displacement(mm) at top of the tower.

Tower height (m)	Wind zone	Displacement(mm)			
		K-Bracing	XB-Bracing	XX-Bracing	Y-Bracing
30	zone-II (39m/)	29.58	36.59	39.23	37.22
40		108.0	100.3	101.9	113.2
50		239.4	258.3	279.7	285.0
30	Zone-III (44m/s)	37.65	46.57	49.93	47.37
40		126.6	126.4	126.9	143.4
50		304.7	328.7	355.9	362.7
30	zone-IV (47m/s)	42.95	53.14	56.97	54.05
40		176.0	143.6	146.9	163.3
50		347.7	375.1	367.1	413.9
30	zone-V (50m/s)	48.6	60.15	64.49	61.19
40		185.8	162.0	165.8	184.5
50		393.5	424.5	459.6	468.4

Table 6. Member stresses (N/mm2) in bottom leg with different bracing.

Tower height (m)	Wind zone	Stress(N/mm^2)			
		K-Bracing	XB-Bracing	XX-Bracing	Y-Bracing
30	zone-II (39m/s)	31.2	39.70	42.64	41.13
40		74.54	73.31	75.52	80.38
50		110.2	114.6	123.1	119.8
30	zone-III (44m/s)	39.70	50.53	54.28	52.35
40		94.66	92.80	95.82	102.0
50		140.3	145.8	156.7	152.4
30	zone-IV (47m/s)	45.30	57.66	61.93	59.73
40		107.5	105.6	109.1	116.3
50		160.1	166.4	168.8	173.9
30	zone-V (50m/s)	51.28	65.26	70.10	67.61
40		121.9	119.2	123.4	131.5
50		181.2	188.3	202.4	196.9

Graphs are plotted between displacement at the top of tower and tower height for a particular bracing pattern in all the wind zones (II to V) and are shown in Chart 1.



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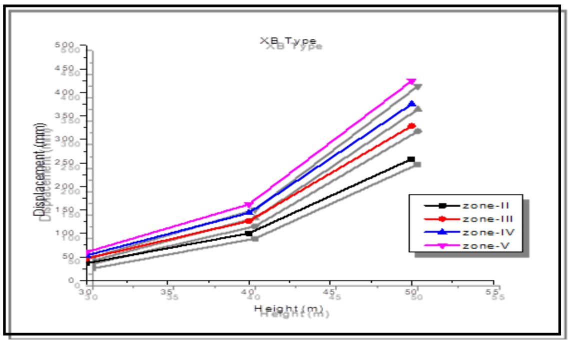

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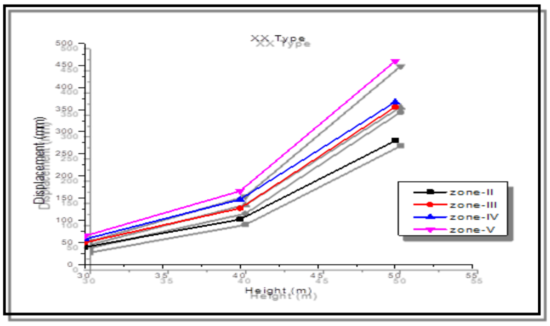

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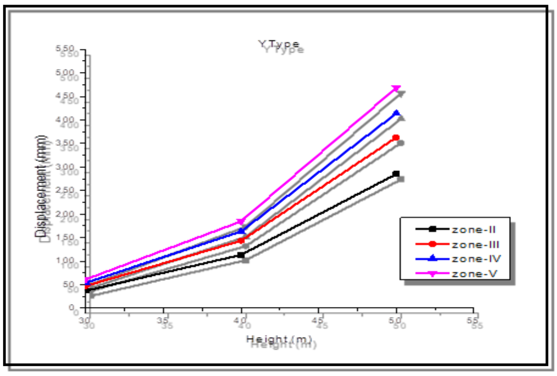

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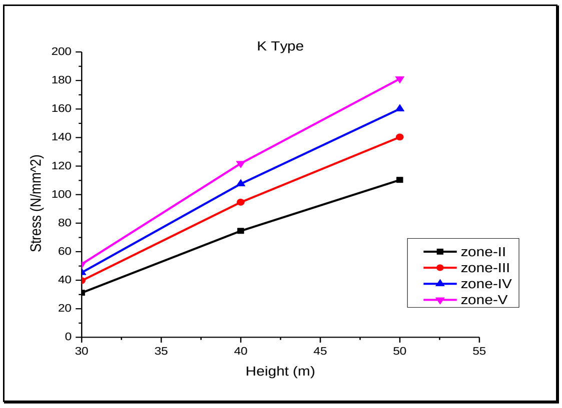
Fig 2. Chart:Comparison of displacement at the top of the tower for all wind zone.

It was concluded from Chart that displacement increases with the wind zone from II to V. Above all chart found to be maximum displacement for Y-bracing and minimum for K-bracing for wind zone II to V.

Chart shows variation of displacement at the top of the tower for different bracing patterns for all the wind zones. Tower heights between 30m to 40m with different bracing patterns; do not reveal much difference in displacement.



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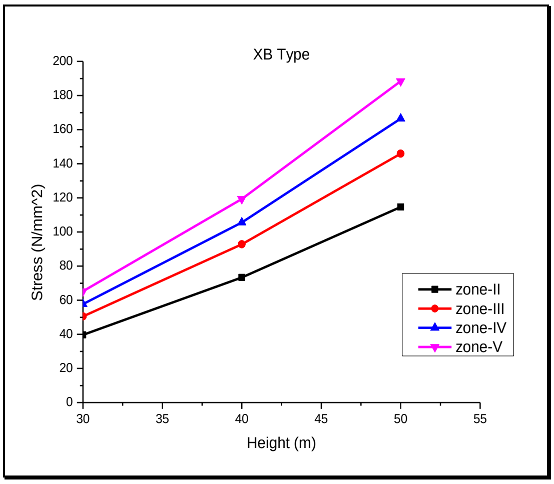

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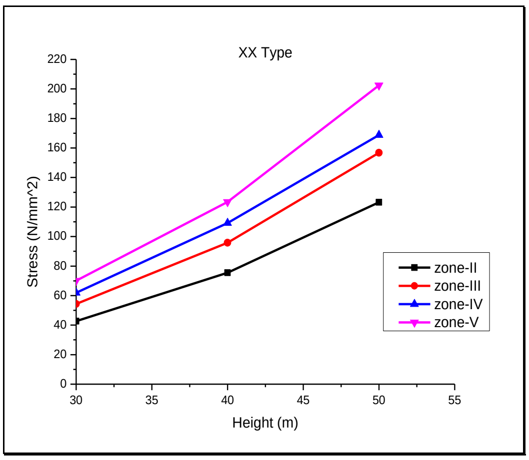

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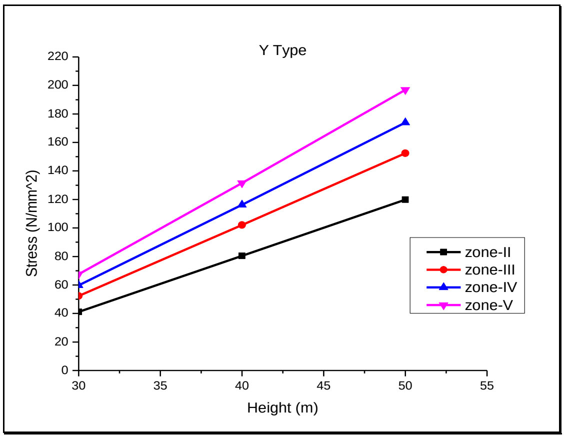

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Fig 3. Chart: Variation of stress at the bottom leg of the tower in all wind zones.

Stresses in the bottom leg members of tower vs. tower height for a particular bracing pattern in all wind zones (II to V), are shown in Chart 2.

It was concluded from Chart that stress increases with variation of wind zone from II to V and found to be maximum for XX-bracing and minimum for K-bracing.

2. Seismic Analysis Results:-

Joint displacement at the top of the tower and the member stress at the base of the tower obtained after the Response spectrum analysis of the towers of height 30 m, 40 m, and 50 m using different bracing pattern for earthquake zone II, III, IV, V are tabulated in Table 7 and Table 8 respectively.

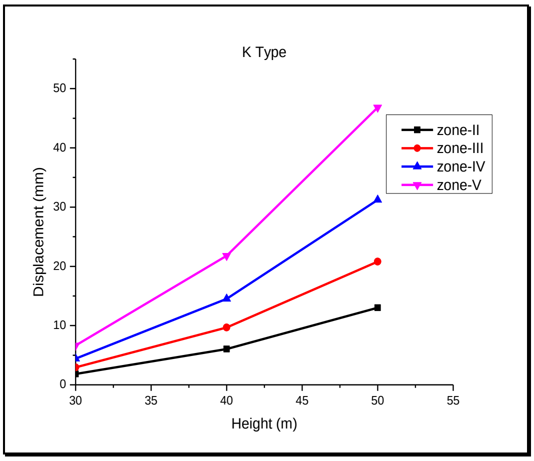
Table 7. Joint displacement at top of the tower.

Tower height (m)	EQ zone	Displacement(mm)			
		K-Bracing	XB-Bracing	XX-Bracing	Y-Bracing
30	zone -II	1.842	2.14	2.295	2.212
40		6.051	5.536	5.785	5.766
50		13.006	12.99	13.303	13.803
30	zone -III	2.947	3.424	3.672	3.54
40		9.682	8.87	9.256	9.226
50		20.809	20.784	21.282	22.377
30	zone -IV	4.42	5.136	5.509	5.31
40		14.523	13.305	13.884	13.839
50		31.214	31.176	31.924	33.126
30	zone -V	6.63	7.704	8.263	7.965
40		21.785	19.958	20.826	20.759
50		46.821	46.764	47.886	49.689

Table 8. Member stress at the base of the tower.

Tower height (m)	EQ zone	Stress(N/mm^2)			
		K-Bracing	XB-Bracing	XX-Bracing	Y-Bracing
30	zone-II	2.161	2.571	2.681	2.685
40		3.622	4.106	4.201	4.269
50		6.468	6.027	5.857	5.375
30	zone-III	3.457	4.114	4.289	4.297
40		5.795	6.569	6.721	6.83
50		10.35	9.643	9.372	8.6
30	zone-IV	5.185	6.17	6.433	6.445
40		8.692	9.854	10.082	10.245
50		15.524	14.465	14.058	12.9
30	zone-V	7.778	9.255	9.65	9.668
40		13.039	14.781	15.123	15.367
50		23.286	21.697	21.086	19.35

Graphs are plotted between displacement at the top of tower and tower height for a particular bracing pattern in all earthquake zones (II to V) and shown in Chart 3.



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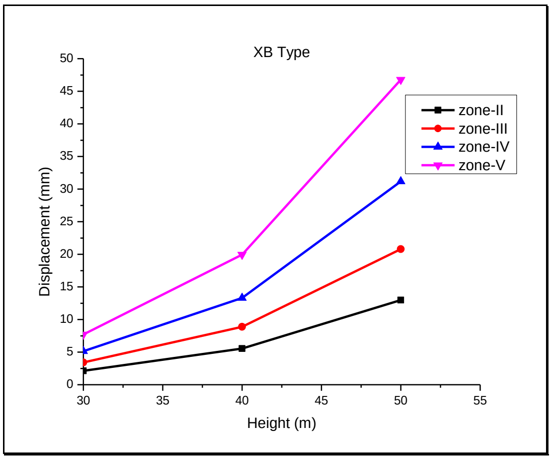

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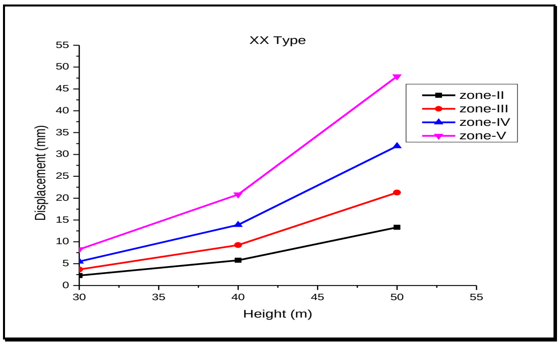

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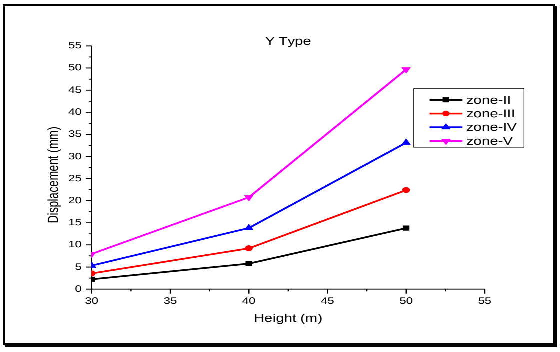

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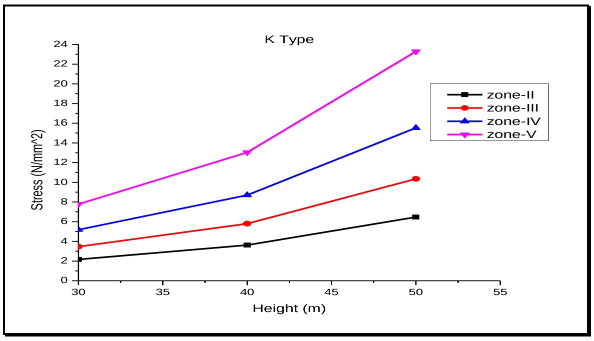
Fig 4. Chart: variation of Displacement at the top of the tower for different seismic zones.

Graphs are plotted between stress in the bottom leg members of tower and tower height for a particular bracing pattern in all EQ zones (II-V) and shown in Chart 4.



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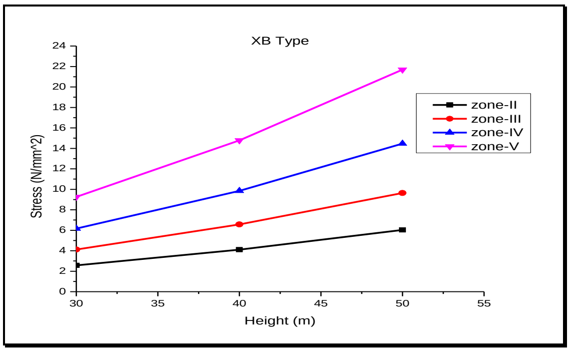

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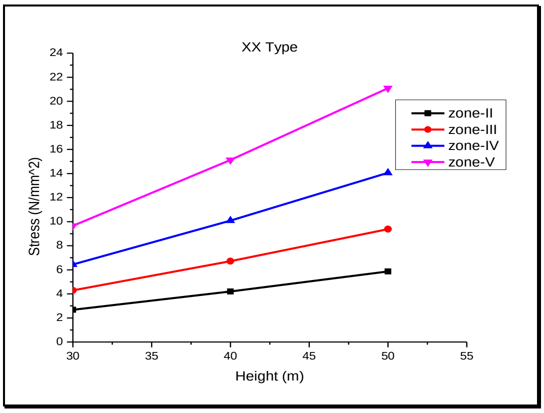
International Journal of Scientific Research & Engineering Trends
Volume 7, Issue 4, July-Aug-2021, ISSN (Online): 2395-566X



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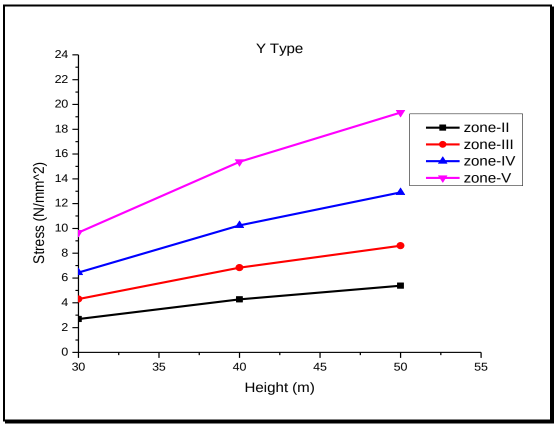

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Fig 5. Chart: variation of stress with tower height for different bracing pattern.

Chart 3 shows variation of Displacement at the top of the tower for different wind zones with the tower height. There is a steep increase in the displacement in seismic zone V for every type of bracing pattern. Change in displacement with the earthquake zone is maximum for Y-bracing and it is minimum for XB-Bracing.

Chart 4 variation of stress with tower height for all earthquake zones for different Bracing pattern shows that change in stress is maximum for earthquake zone -V for any type of Bracing pattern. Change in stress with the change in seismic zone for a particular tower height is maximum for K-Bracing and it is minimum for Y-Bracing.

Table 9. Weight with different bracing.

Tower Height (m)	Weight			
	K-bracing	XB-bracing	XX-bracing	Y-bracing
50	258.98	247.379	219.144	261.663
40	188.139	185.633	167.87	194.997
30	129.557	127.231	114.997	133.544

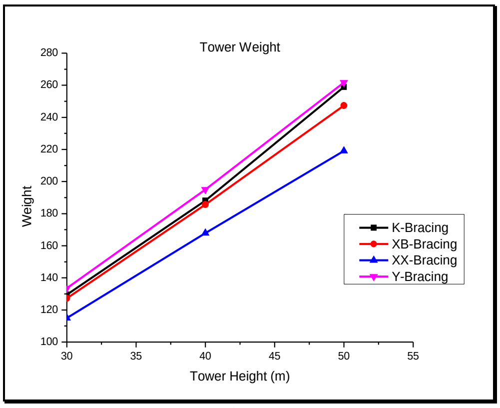

Fig 6. Chart: Comparison of Weight with Tower height for different Bracing system.

Figure indicates that weight increases as height of the tower increases. Increase in weight is 68% when height increases from 30m to 40m and increase in weight is 75% when height increases from 40m to 50m. Weight is maximum for Y-bracing and minimum for XX-bracing for the same tower height.

V. CONCLUSION

Displacement increases with the increase in wind speed. Result shows that increase displacement from increase wind zone II to V is maximum for Y-Bracing and minimum for K-Bracing. For wind zone II to V, tower height between 30m to 40m having maximum joint displacement for Y-bracing or K-Bracing and minimum value of displacement is XX-Bracing.

For wind zone II to V, tower height between 40m to 50m having maximum joint displacement for Y-bracing or XX-Bracing and minimum value of displacement is K-Bracing. Stress increases with the increase in wind speed. Result shows that increase member Stress from increase wind zone II to V is maximum for XX-Bracing and minimum for K-Bracing.

For Seismic zone II to V, tower height between 30m to 40m having maximum joint displacement for XX-bracing or K-Bracing and minimum value of displacement is XB-Bracing.

For Seismic zone II to V, tower height between 40m to 50m having maximum joint displacement for Y-bracing or XX-Bracing and minimum value of displacement is XB-Bracing.

For Seismic zone II to V, tower height between 30m to 40m having maximum member stress for XX-bracing or Y-Bracing and minimum value of member stress is K-Bracing. For Seismic zone II to V, tower height between 40m to 50m having maximum member stress for K-bracing or XB-Bracing and minimum value of member stress is Y-Bracing.

Check result for weight of tower. Increase in weight is 68% when height increases from 30m to 40m and increase in weight is 75% when height increases from 40m to 50m. Weight is maximum for Y-bracing and minimum for XX-bracing for the same tower height. Tower is light steel structure that's why wind load is more effective for telecommunication tower as compare to seismic load.

It can be observed that in response spectrum analysis the stress for tower with XX bracing is more at the change point leg than that of the bottom leg member this is due to the absence of horizontal bracing along the tower.

Check all result of joint displacement, we have to conclude that seismic load is less effect of displacement compare to wind load.

From the above analysis it can be concluded that the wind is the predominate factor in the tower modelling than the seismic forces but the seismic effect cannot be fully neglected as observed from the results.

Table 10. Recommended bracing pattern.

Wind Zone	Seismic zone			
	Zone II	Zone III	Zone IV	Zone V
Zone II	K-Bracing	XB-Bracing	XB-Bracing	K-Bracing
Zone III	XX-Bracing	XB-Bracing	Y-Bracing	XB-Bracing
Zone IV	XX-Bracing	XB-Bracing	XX-Bracing	XB-Bracing
Zone V	K-Bracing	K-Bracing	XB-Bracing	XB-Bracing

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