COMPARATIVE ANALYSIS OF STEEL TELECOMMUNICATION TOWER SUBJECTED TO SEISMIC & WIND LOADING

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ABSTRACT

Over the past 30 years, the growing demand for wireless and broadcast communication has spurred a dramatic increase in communication tower construction and maintenance. Failure of such structures is a major concern. In this paper a comparative analysis is being carried out for different heights of towers using different bracing patterns for Wind zones I to VI and Earthquake zones II to V of India. Gust factor method is used for wind load analysis, modal analysis and response spectrum analysis are used for earthquake loading. The results of displacement at the top of the towers and stresses in the bottom leg of the towers are compared.

KEYWORDS

Steel communication towers; Bracings; Wind analysis; Gust factor method; Modal analysis; Response spectrum analysis

1. INTRODUCTION

Fastest growing telecommunication market has increased the demand of steel towers. The major loads considered for design of these towers are self-weight, wind load, seismic load, antenna load, platform load, steel ladder load etc. Failure of towers is generally due to high intensity winds. Several studies have been carried out by considering wind and earthquake loads.

Jithesh Rajasekharan et al. (2014) designed the lattice tower for three heights of 30m, 40m and 50m with different types of bracings to study the effect of wind load on 4- legged lattice tower for wind zone V and VI using gust factor method. They also studied the seismic effect on the tower structures by carrying out the modal analysis and response spectrum analysis for zone II to zone V and concluded that the member stresses in bottom leg of XX braced tower are higher as compared to other tower models. The frequency of the tower with Y bracing displayed the least natural frequency since its stiffness was found to be higher due to more weight of the structure as compared to other models. It was observed that from 30m to 40m tower height, the increase in displacement is nearly linear but as the height increases from 40m to 50m there is a steep increase in the displacement in all the zones.

Siddesha. H (2010) presented the analysis of microwave antenna tower with Static and Gust factor method and compared the towers with angle and square hollow sections. The displacement at the top of the tower was considered as the main parameter. The towers with different configuration have also been analyzed by removing one member present in the regular tower in

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lower panels. Square sections were found to be most effective for legs as compared to the angle sections. Square hollow sections used in bracing along with the leg members did not show any appreciable reduction of displacement. X-type and M-type bracings in square hollow sections for legs and bracings in the lower first panel of towers showed maximum reduction in displacement as compared to the regular towers with angle sections.

A. Jesumi.et al. (2013) modeled five steel lattice towers with different bracing configurations such as the X-B, single diagonal, X-X, K and Y bracings for a given range of height. The heights of the towers are 40m and 50m with a base width of 2m and 5m respectively. The tower of height 40m has 13 panels and the tower of height 50m has 16 panels. 70-72% of the height is provided for the tapered part and 28-30% of the height is provided for the straight part of the tower. The towers have been analyzed for wind loads with STAAD Pro. V8i, to compare the maximum joint displacement of each tower. Optimized design has been carried out to estimate and to compare the weight of each tower. From the results obtained, Y bracing has been found to be the most economical bracing system up to a height of 50m.

Silva.et.al. (2005) presented paper on an alternative structural analysis modeling strategy for the steel tower design considering all the actual structural forces and moments combining three-dimensional beam and truss finite elements. Comparisons of the two above-mentioned design methods with a third method based on the use of spatial beam finite elements to model the main structure and the bracing system on two actually built steel telecommunication towers (40 and 75 m high steel towers) have been described. Generally in all the cases studied the maximum stress values for the structural tower modeling based on the three investigated methodologies were significantly modified. The lateral displacement values were not significantly changed when the usual truss model, the beam model or the combined beam and truss model were considered.

The objective of the present work is to study the effect of wind and earthquake load for different heights of the tower structures with different possible arrangements of bracing systems for all of the wind and earthquake zones of India. Gust factor method for wind loading, modal analysis and response spectrum analysis for earthquake loading have been considered. This paper helps in understanding the effect of both wind and seismic forces on the tower structures by considering different height of towers with different bracing systems.

1.1 MODELING OF TOWER

The Steel Communication tower is designed for heights of 25 m, 35 m and 45 m. The towers are provided with 5-different types of bracings: K type, XBX-type, V-type, W-type, XX-type for lower portion and X-Bracing for upper portion of tower. STAAD Pro. V8i has been used for modeling, analysis and design of towers. Details of towers used for modeling are given in Table-I for various heights. Fig. 1 shows 45 m high towers with different types of bracings considered in the study. Table II to Table IV show the member properties assigned to towers for different heights.

Table I: Details of Towers

Height of tower	45 m	35 m	25 m
Height of slant portion	38 m	31 m	22 m
Height of straight portion at top of tower	7 m	4 m	3 m
Base width	6.5 m	6.5 m	6.5 m
Top width	1.5 m	1.5 m	1.5 m

Table II: Member Details of 45m Tower

Height(45m)	**0-8**	**8-20**	**20-30**	**30-38**	**38-45**
	ISA section used				
Main leg	200×200×18	150×150×18	110×110×15	100×100×12	90×90×6
Horizontal members	80×80×10	80×80×10	60×60×10	70×70×6	60×60×10
Primary bracing	110×110×15	100×100×12	80×80×10	60×60×10	45×45×6
Secondary bracing	70×70×6	70×70×6	45×45×6	Nil	Nil
Horizontal bracing	70×70×6	70×70×6	60×60×10	70×70×6	60×60×10

Table III: Member Details of 35m Tower

Height(35 m)	**0-16 m**	**16-26 m**	**26-35 m**
	ISA section used		
Main leg	150×150×18	110×110×15	80×80×12
Horizontal members	70×70×10	70×70×10	70×70×10
Primary bracing	100×100×12	80×80×10	65×65×10
Secondary bracing	70×70×10	60×60×10	Nil
Horizontal bracing	70×70×10	70×70×10	70×70×10

Table IV: Member Details of 25m Tower

Height(25m)	0-12	12-18	18-25
	ISA section used		
Main leg	110×110×15	90×90×12	80×80×10
Horizontal members	65×65×10	65×65×10	55×55×8
Primary bracing	100×100×10	70×70×10	60×60×8
Secondary bracing	70×70×10	55×55×10	Nil
Horizontal bracing	65×65×10	65×65×10	60×60×8

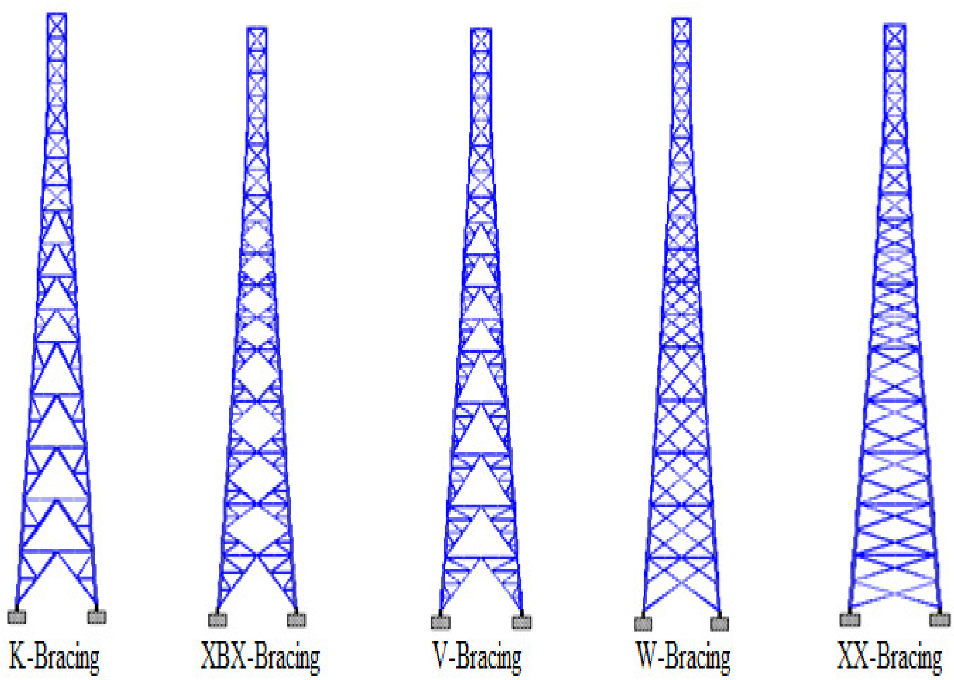

Fig. 1: 45m Towers with Different Bracings Considered

2. LOADS ON TOWER

A platform load of 0.82 kN/m2 is applied at 22 m, 32 m, and 42 m for 25 m, 35 m, and 45 m respectively. Weight of the ladder and cage assembly is assumed to be 10% of total weight.

Table V: Antenna Loading for the Towers

S. No.	Item	Quantity	Diameter (m)	Weight of antenna (kg)	Location from base (25 m-tower)	Location from base (35 m-tower)	Location from base (45 m-tower)
1.	CDMA	6	0.26 x 2.5	20	23m	33m	43m
2.	Microwave	1	1.2	77	20m	30m	40m
3.	Microwave	1	0.6	45	20m	30m	40m
4.	Microwave	2	0.3	25	20m	30m	40m

2.1 WIND LOAD

IS 875 (part 3): 1987 and IS 802 (Part 1:Sec1)-1995 are referred to estimate wind loads on the towers. Design wind speed (V_z) is expressed as:

$$V_z=V_b k_1 k_2 k_3$$

where, V_b=basis wind speed in m/s at height z, k_1= probability factor (risk coefficient), k_2= terrain, height and structure size factor, k_3= topography factor and design wind pressure is expressed as:$p_z = 0.6V_z^2$ where, p_z=design wind pressure in N/m2 at height z

Wind loads are calculated for wind zone I, II, III, IV, V and VI, for which basic wind speed is respectively 33 m/s, 39 m/s, 44 m/s, 47 m/s, 50 m/s, and 55 m/s.

Following stipulations have been made. Terrain category – 2 (Open terrain with well scattered obstruction height having 1.5 to10 m), Class – B (Greatest vertical dimension between 20 to 50 m), Risk coefficient k1=1.08 (Mean probable design life of structure = 100 years) and Topographic factor k3=1 (Up-wind slope less than 30)

2.2 DYNAMIC LOAD

IS 1893: part 1, 2002 has been used to access the dynamic load. Analysis has been carried out for Seismic zone II, III, IV, and V. Following stipulations have been made Importance factor (I) = 1.5, Response reduction factor (R) = 4 (steel frame with concentric braces), Soil condition as Medium and Damping Ratio - 2%. (For steel structure). Table-VI shows the wind pressure calculation for 45 m tower with K-Bracing for the wind speed of 50 m/s. Force coefficient is calculated by calculating solidity ratio and using table given in IS 875 (part 3): 1987. Table VII shows the wind load calculation for 45 m high tower.

Similarly wind load was calculated for other wind speeds for different height of towers with different bracing patterns.

Table VI: Design Wind Pressure Acting on 45m Tower (kN/m²) with K-type bracing

Panel no.	Bottom width	Top width	Height of panel	Height of panel from bottom	K2	Design wind speed	Design wind pressure (kN/m²)
1	6.5	5.92	4	4	0.98	52.92	1.6803
2	5.92	5.34	4	8	0.98	52.92	1.6803
3	5.34	4.76	4	12	0.996	53.784	1.7356
4	4.76	4.18	4	16	1.026	55.404	1.8417
5	4.18	3.6	4	20	1.05	56.7	1.9289
6	3.6	3.3	2.5	22.5	1.0625	57.375	1.9751
7	3.3	3	2.5	25	1.075	58.05	2.0218
8	3	2.7	2.5	27.5	1.0875	58.725	2.0691
9	2.7	2.4	2.5	30	1.1	59.4	2.1170
10	2.4	2.18	2	32	1.105	59.67	2.1363
11	2.18	1.95	2	34	1.11	59.94	2.1556
12	1.95	1.73	2	36	1.115	60.21	2.1751
13	1.73	1.5	2	38	1.12	60.48	2.1946
14	1.5	1.5	1.75	39.75	1.125	60.75	2.2143
15	1.5	1.5	1.75	41.5	1.128	60.912	2.2261
16	1.5	1.5	1.75	43.25	1.133	61.182	2.2459
17	1.5	1.5	1.75	45	1.1375	61.425	1.2638

Table VII: Wind Load Acting on 45m Tower (kN) with K-type bracing

Gross area (m^2)	Net area (m^2)	C.G of individual panel(m)	C.G from bottom (m)	Solidity Ratio	Force coefficient	Design wind pressure	Wind Force (kN)
24.84	4.247	1.967	1.977	0.178	3.1	1.680	22.214
22.52	4.267	1.966	5.967	0.184	3.2	1.680	22.971
20.2	3.851	1.916	9.966	0.198	3.3	1.735	22.074
17.88	3.654	1.949	13.962	0.262	3.3	1.841	22.203
15.56	3.451	1.903	17.955	0.226	3.28	1.928	21.879
8.625	2.367	1.284	21.953	0.273	3.1	1.975	14.432
7.875	2.272	1.259	23.738	0.287	2.9	2.025	13.219
7.125	2.177	1.207	26.216	0.302	2.8	2.038	12.451
6.375	2.086	1.229	28.727	0.304	2.6	2.117	11.283
4.58	1.475	0.988	31.229	0.398	2.8	2.134	8.476
4.13	1.342	0.987	32.989	0.3217	2.6	2.216	7.524
3.68	1.278	0.972	34.984	0.313	2.4	2.146	6.634
3.23	1.208	0.964	36.987	0.379	2.3	2.124	6.075
2.625	0.835	0.875	38.976	0.338	2.5	2.275	4.923
2.625	0.885	0.875	40.625	0.338	2.5	2.205	4.995
2.625	0.885	0.875	42.375	0.338	2.5	2.227	4.992
2.625	0.885	0.875	44.125	0.338	2.5	2.238	5.317

3. RESULTS AND DISCUSSION

3.1 FOR WIND LOAD

Joint displacement at the top of the tower and the stresses in the bottom leg of tower were obtained for towers of height 25 m, 35 m, and 45 m with different bracing arrangements for wind zones I, II, III, IV, V, VI are tabulated in Table VIII and Table IX, respectively.

Table VIII: Joint displacement (mm) at the top of the tower

Tower Height (m)	Wind zone	Displacement (mm)				
		K-bracing	XBX-bracing	V- bracing	W- bracing	XX- bracing
25	zone-I (33m/s)	7.899	8.109	7.836	8.122	8.271
35		26.459	23.204	21.872	24.854	24.583
45		64.173	53.394	53.154	64.28	55.648
25	zone-II (39m/s)	10.946	10.664	10.664	10.945	10.739
35		30.691	29.376	28.621	29.282	32.705
45		86.239	74.571	74.629	89.787	77.722
25	zone-III (44m/s)	13.934	13.573	12.573	13.931	13.669
35		37.520	41.208	36.704	37.999	42.806
45		114.493	94.913	94.082	114.293	98.927
25	zone-IV (47m/s)	15.9	15.487	15.487	16.895	20.282
35		43.67	53.018	41.021	45.075	52.135
45		137.817	108.295	107.83	130.414	112.875
25	zone-V (50m/s)	20.99	20.443	20.443	20.981	21.282
35		56.009	62.064	55.79	56.221	56.934
45		162.323	142.951	151.83	172.162	158.988
25	zone-VI (55m/s)	26.774	26.207	31.207	29.765	32.352
35		67.065	74.384	67.915	68.248	64.06
45		175.647	168.294	168.25	188.599	174.557

Table IX: Member stresses (N/mm2) in bottom leg with different bracing

Tower Height (m)	Wind zone	Stress (N/mm2)				
		K-bracing	XBX-bracing	V- bracing	W-bracing	XX-bracing
25	zone-I (33m/s)	35.466	28.076	33.076	31.862	25.165
35		53.546	47.823	50.561	51.815	43.71
45		71.576	58.425	68.657	63.28	52.051
25	zone-II (39m/s)	44.513	39.516	41.516	40.615	32.747
35		63.546	55.572	61.569	57.983	46.75
45		100.34	67.016	97.563	76.28	66.078
25	zone-III (44m/s)	53.258	46.59	50.590	48.087	39.312
35		69.05	59.737	62.813	61.988	54.99

45		84.33	68.035	78.05	74.28	67.740
25	zone-IV (47m/s)	53.992	53.002	56.013	55.47	50.412
35		77.502	66.785	75.523	71.155	55.51
45		127.829	90.259	111.47	102.975	76.018
25	zone-V (50m/s)	73.842	55.528	56.528	52.412	44.808
35		95.531	73.147	75.102	79.592	64.451
45		154.008	97.037	121.47	109.065	85.451
25	zone-VI (55m/s)	76.132	59.761	57.874	54.561	47.931
35		98.619	74.487	77.448	83.034	66.614
45		177.855	100.851	137.358	124.63	87.756

Graphs are plotted between displacement at the top of tower and tower height for a particular bracing pattern in all the wind zones (I to VI) and are shown in Fig.2 (a-e). Graphs are also plotted between displacement at the top of tower and tower height for different bracing patterns in a particular zone and are shown in Fig. 3(a-f).

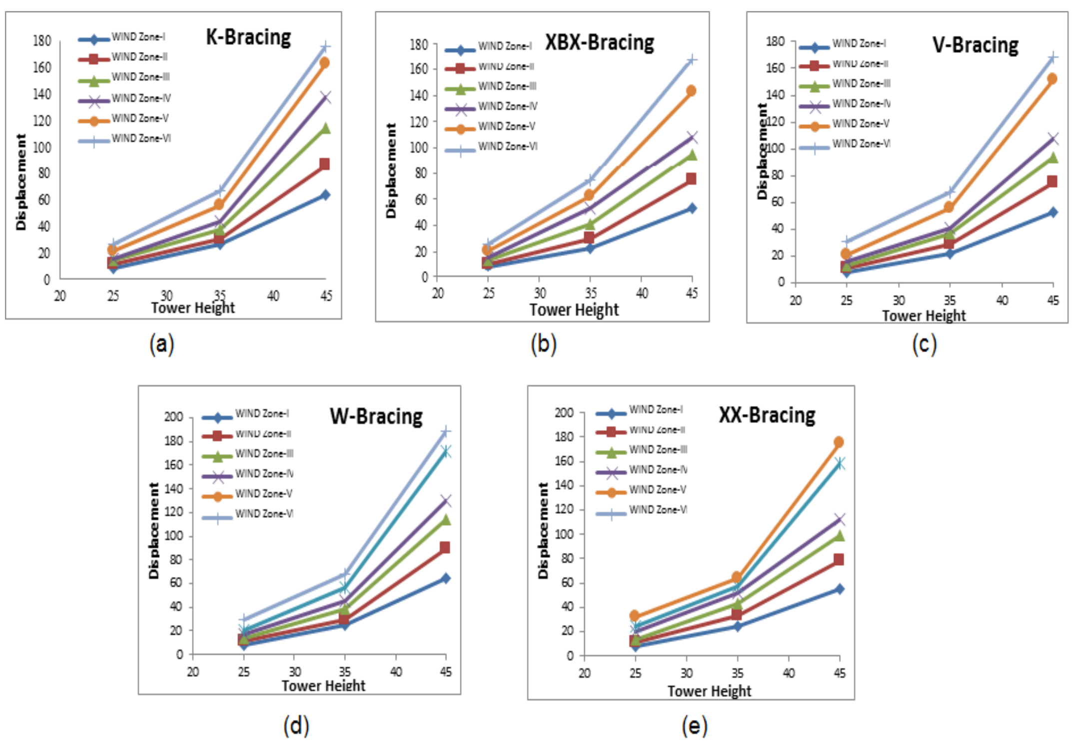

Fig. 2(a-e): Comparison of displacement at the top of the tower for all wind zone

It was concluded from Fig. 2(a-e) that displacement increases with the wind zone from I to VI and found to be maximum for W-bracing and minimum for K-bracing.

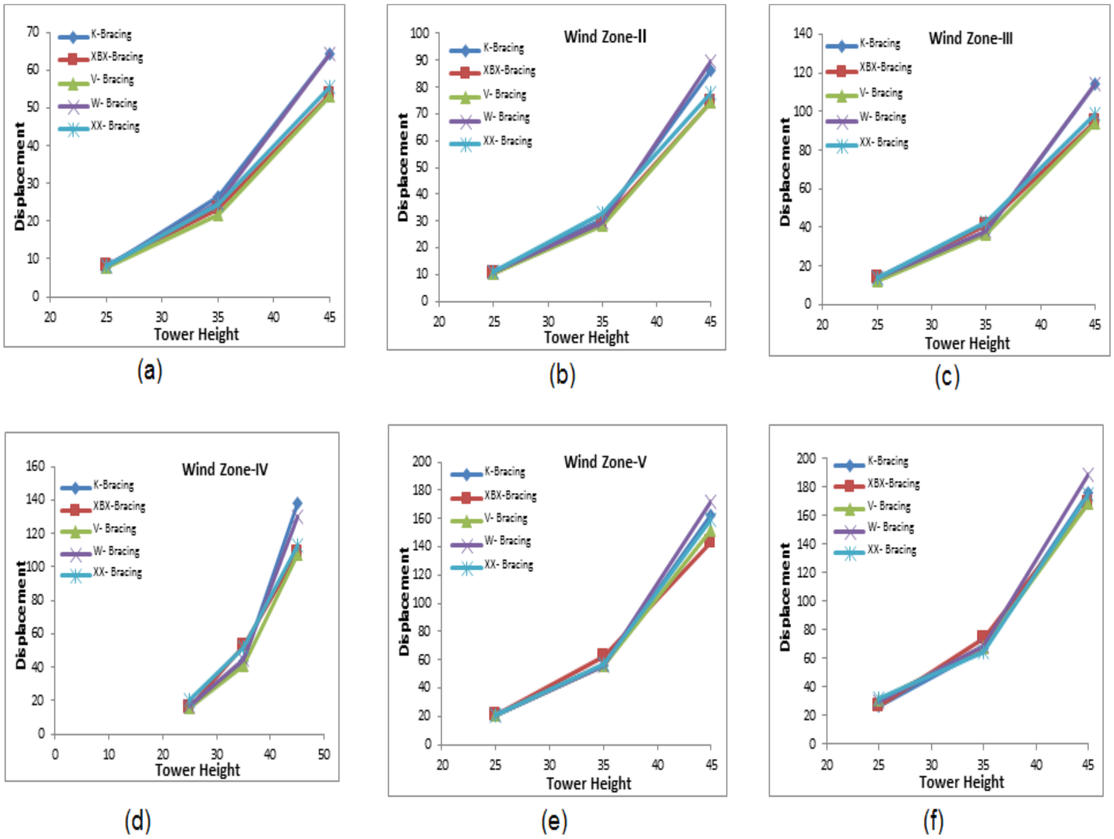

Fig 3 (a-f): Variation of displacement at the top of the tower for different bracing pattern

Fig. 3(a-f) shows variation of displacement at the top of the tower for different bracing patterns for all the wind zones. Tower heights between 25m to 35m, with different bracing patterns, do not reveal much difference in displacement.

For wind zone I to IV tower height between 35m to 45m having K-Bracing or W-Bracing gives maximum value of displacement and V-Bracing gives minimum value of displacement.

For wind zone V and VI tower height between 35m to 45m having W-Bracing gives maximum value of displacement and V-Bracing or XBX -Bracing gives minimum value of displacement. Stresses in the bottom leg members of tower vs. tower height for a particular bracing pattern in all wind zones (I to VI), are shown in Fig. 4(a-e). Graphs are also plotted between stresses in the bottom leg members of tower and tower height for different bracing patterns in a particular zone and are shown in Fig. 5(a-f).

It was concluded from Fig. 4(a-e) that stress increases with variation of wind zone from I to VI and found to be maximum for K-bracing and minimum for XX-bracing.

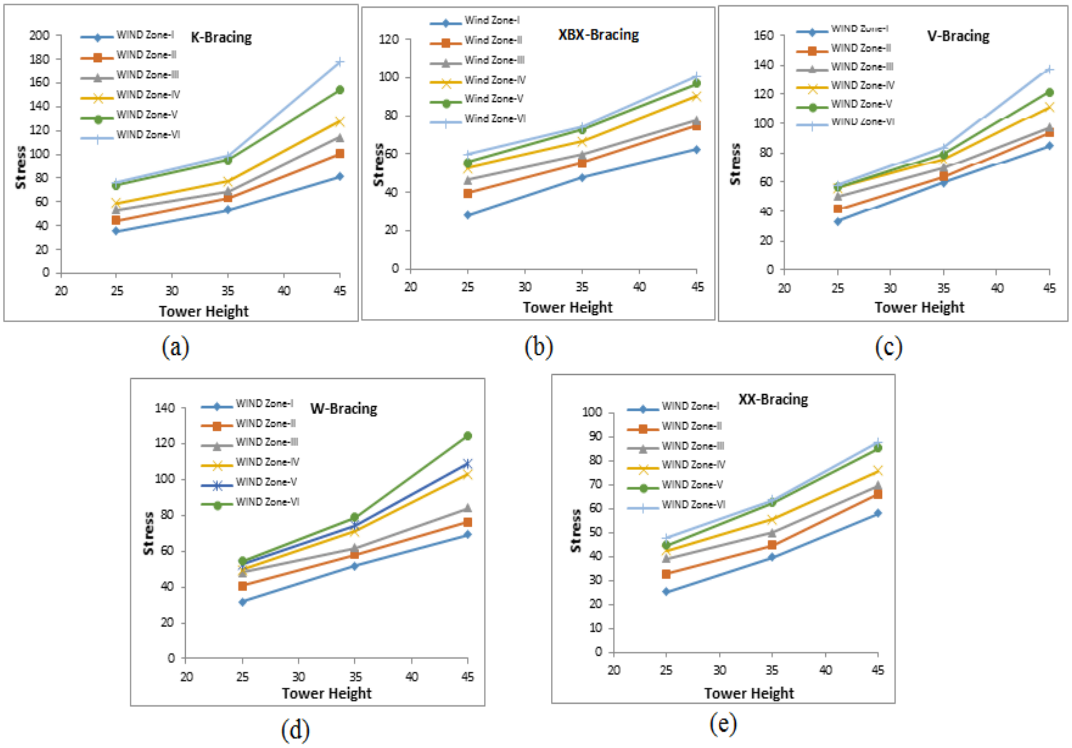

Fig 4 (a-e): Variation of stress at the bottom leg of the tower in all wind zones

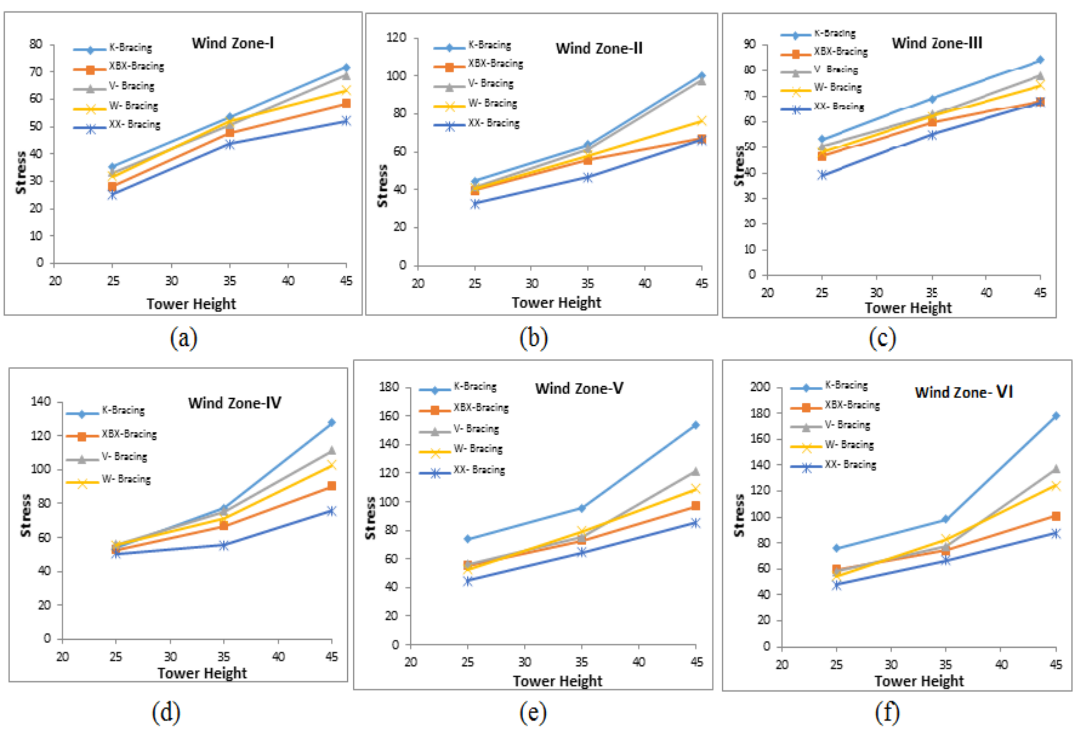

Fig 5(a-f): Variation of Stress at the top of the tower for different bracing pattern

Figure 5(a-f) shows variation of stress in the bottom leg of the tower with respect to tower height in a wind zone for different possible arrangements of bracing patterns. Stress increases with the increase in the height of the Tower. Results show that the increase in stress with height in the bottom leg members of the tower from wind zone I to wind zone VI is maximum for K-Bracing and it is minimum for XX-Bracing.

3.2 FOR SEISMIC LOADS

Modal Analysis

Modal analysis of the tower structures are carried out and the modal parameters such as natural frequency and mode shapes are obtained. The figure 6 shows the first mode shape of 45 m tower with different bracings. The natural frequencies are tabulated in table X.

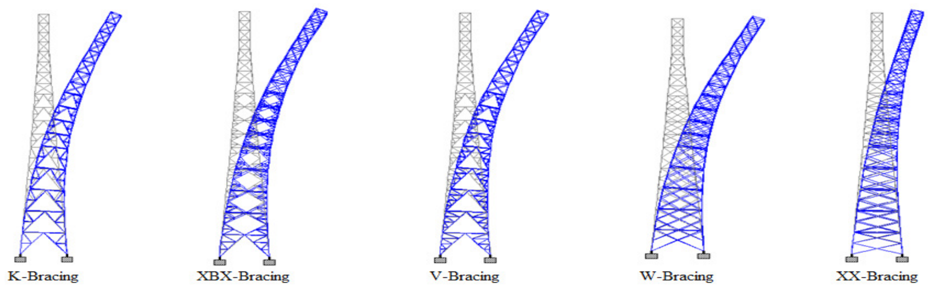

Fig 6: First Mode shape of 45 m Towers with Different Bracings Considered

Table X: Natural Frequencies of Telecommunication Towers (Hz)

Height	Mode	Bracing				
		K-Bracing	XBX-Bracing	V-Bracing	W-Bracing	XX-Bracing
		Natural frequency				
45	Mode1	3.802	3.172	2.919	2.95	3.125
	Mode2	3.802	3.172	2.919	2.95	3.125
	Torsion	9.420	8.279	7.085	8.05	8.801
35	Mode1	4.51	3.907	3.986	4.298	4.155
	Mode2	4.51	3.907	3.986	4.298	4.155
	Torsion	10.404	10.520	7.891	8.319	11.212
25	Mode1	7.392	7.439	7.042	7.536	7.274
	Mode2	7.392	7.439	7.042	7.536	7.274
	Torsion	10.063	9.097	9.522	8.028	8.238

Table X indicates that natural frequency decreases as height of the tower increases. Decrease in natural frequency is 63.9% when height increases from 25 m to 35 m and decrease in natural frequency is 18.68% when height increases from 35 m to 45 m.

As the tower height increases the mass starts to play a major role than the stiffness of the structure there by reducing the natural frequency of the structure. The frequency of the tower with Vbracing displayed the least natural frequency since its stiffness was found to be higher due to more weight of the structure as compared to other models.

Response Spectrum Analysis-

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 25 m, 35 m, and 45 m using different bracing pattern for earthquake zone II, III, IV, V are tabulated in Table XI and Table XII respectively.

Table XI: Joint displacement at the top of the tower

Tower Height (m)	Zone	Displacement (mm)				
		K-bracing	XBX-bracing	V-bracing	W-bracing	XX- bracing
25	zone-II	0.88	1.87	0.76	0.94	1.06
35		3.79	4.12	3.67	3.82	3.96
45		8.44	9.33	8.39	8.56	8.67
25	zone-III	2.67	3.58	2.58	2.91	3.15
35		6.85	7.32	6.64	6.95	7.19
45		15.26	15.86	14.97	15.37	15.46
25	zone-IV	3.85	4.38	3.58	4.06	4.19
35		9.24	10.34	9.07	9.36	9.68
45		18.57	19.34	18.34	18.74	18.95
25	zone-V	5.27	6.53	5.04	5.58	5.93
35		14.86	15.58	14.43	14.97	15.24
45		32.09	32.92	31.79	32.42	32.73

Table XII: Member stress at the base of the tower

Tower Height (m)	zone	Stress (N/mm2)				
		K-bracing	XBX-bracing	V- bracing	W-bracing	XX-bracing
25	zone-II	3.76	3.87	3.63	2.99	3.15
35		6.28	6.72	6.18	5.86	6.12
45		8.89	9.83	8.73	8.05	8.43
25	zone-III	5.27	5.98	5.15	4.81	4.95
35		7.89	8.26	7.54	7.05	7.39
45		10.89	11.46	10.57	10.37	10.43
25	zone-IV	6.56	6.88	6.38	6.08	6.26
35		9.73	9.93	9.49	9.24	9.38
45		12.57	12.84	12.43	12.22	12.35
25	zone-V	8.27	8.74	7.98	7.63	7.85
35		11.86	12.21	11.63	11.36	11.44
45		16.79	17.16	16.63	16.42	16.58

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 figure 7(a-e). Graphs are also plotted between displacement at the top of tower and tower height for different bracing pattern in a particular zone and shown in figure 8(a-d).

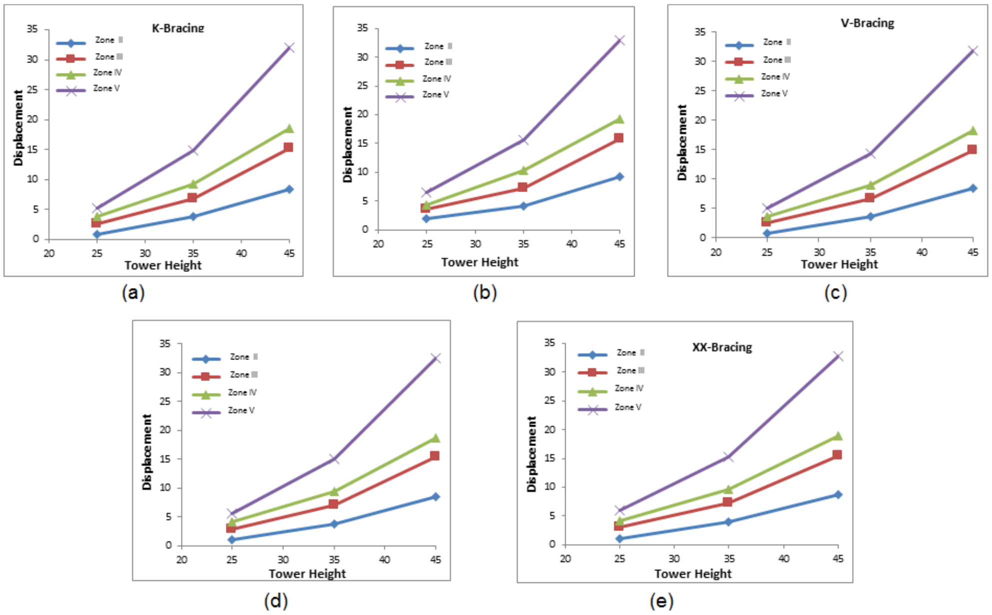

Fig 7(a-e): variation of Displacement at the top of the tower for different seismic zones

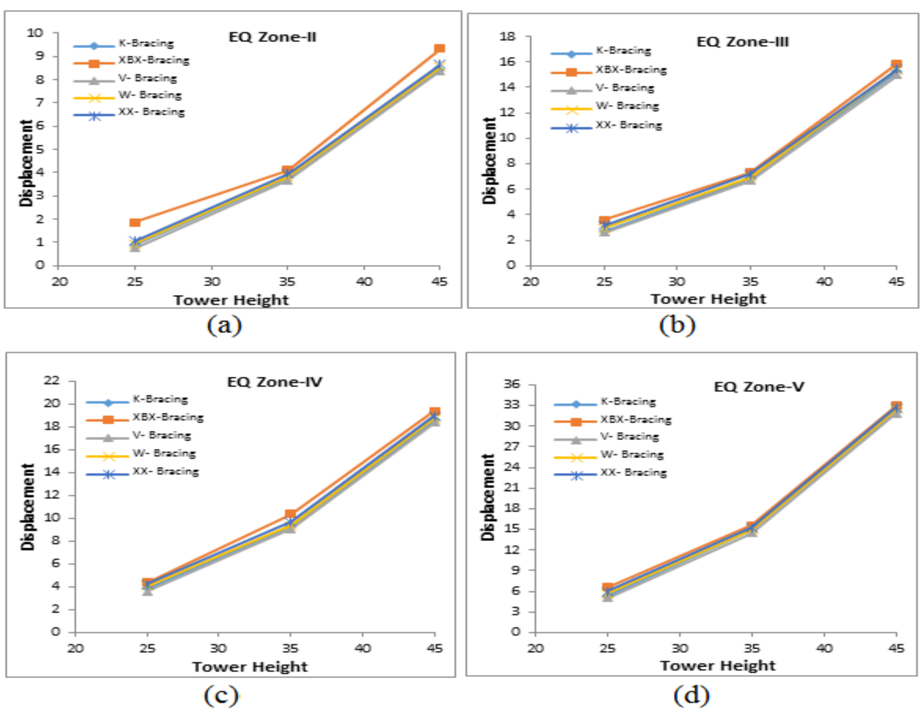

Fig 8(a-d): Variation of displacement with tower height for different Bracing Pattern

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 figure 9(a-e). Graphs are also plotted between stress in the bottom leg members of tower and tower height for different bracing pattern in a particular zone and shown in figure 10(a-d).

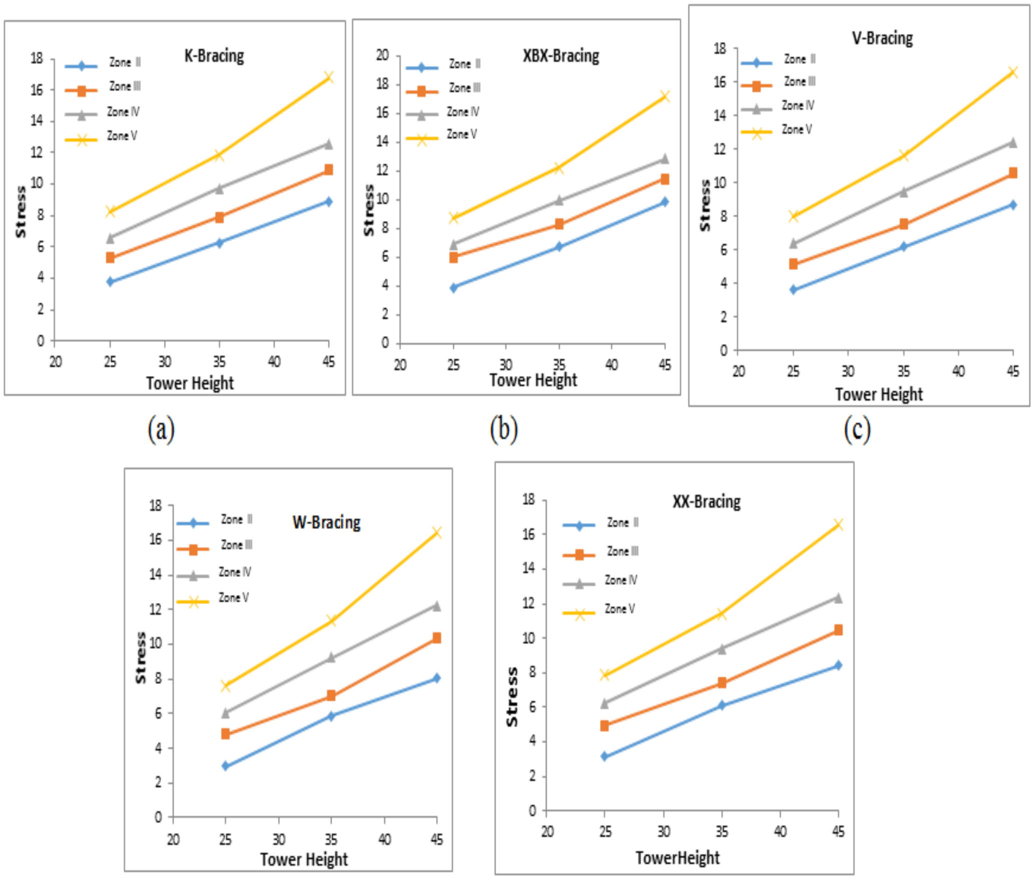

Fig 9 (a-e): variation of stress with tower height for different bracing pattern

Figure 7(a-e) 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 earthquake zone V for every type of bracing pattern. Change in displacement with the earthquake zone is maximum for W-bracing and it is minimum for K-Bracing.

Figure 8(a-d) Variation of displacement with tower height for different Bracing Pattern showes that from all the types of bracing pattern in a earthquake zone, XBX-Braced tower shows maximum value of displacement and V-braced tower shows mimimum value of displacement for the given height of the tower.

Figure 9(a-e) 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. From Zone II to zone III increase in stress is about 17%, Zone III to zone IV increase in stress is about 12% and from Zone IV to zone V increase in stress is about 24%.

Change in stress with the change in earthquake zone for a particular tower height is maximum for W-Bracing and it is minimum for K-Bracing.

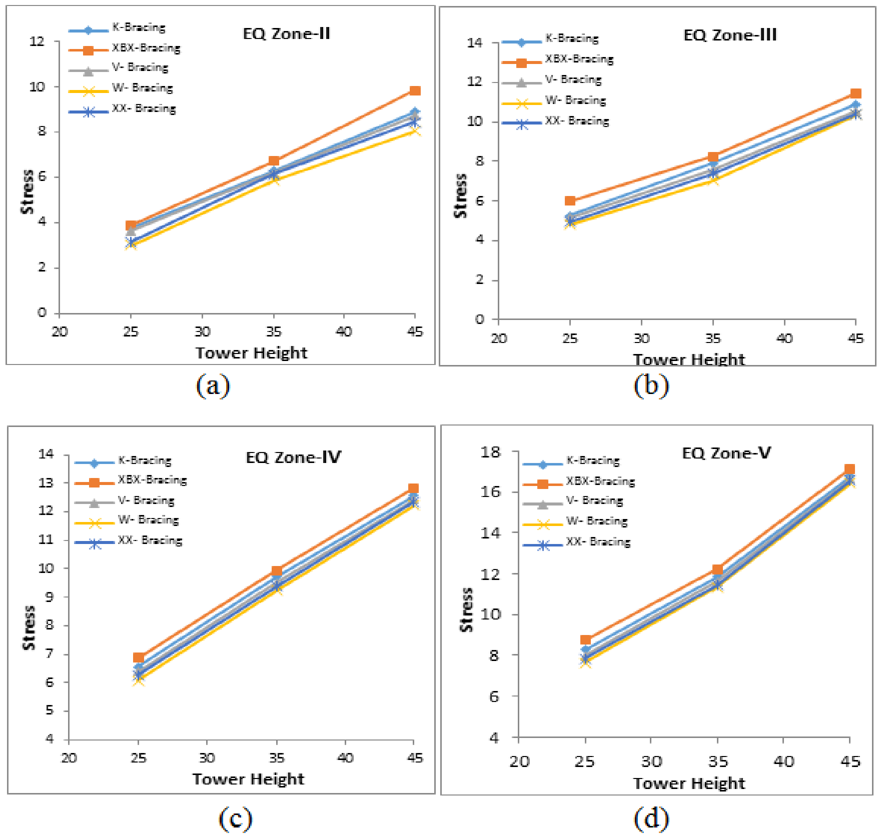

Fig 10(a-d): Variation of stress with tower height for all EQ zone

Figure 10(a-d) shows variation of stress with tower height for different bracing pattern shows that for all earthquake zones stress in the bottom leg members of the tower is maximum for XBX-Bracing and it is minimum for W-Bracing.

Weight Vs. Tower Height

Table XIII: Weight with different bracing

Tower Height (m)	Weight				
	k-bracing	XBX-bracing	V-bracing	W-bracing	XX-bracing
45	190.72	173.64	139.33	155.68	146.72
35	111.204	103.42	76.406	96.526	91.204
25	68.201	58.201	33.942	52.201	48.201

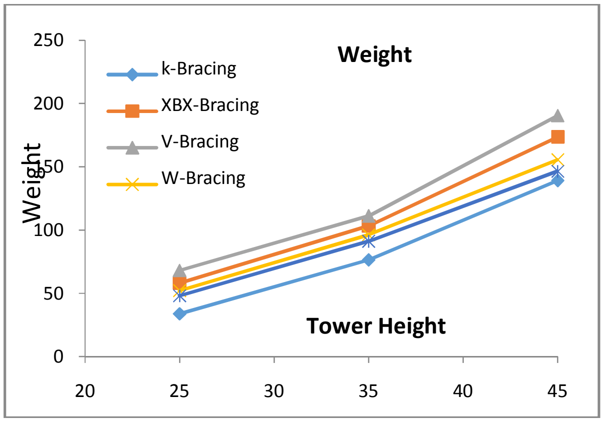

Fig 11: Comparison of Weight with Tower height for different Bracing system

Figure-11 indicates that weight increases as height of the tower increases. Increase in weight is 41.07% when height increases from 25m to 35m and increase in weight is 10.42% when height increases from 35m to 45m. Weight is maximum for V-bracing and minimum for K-bracing for the same tower height.

4. CONCLUSIONS

1). Displacement increases with the increase in speed of the wind. Results displayed that the increase in the displacement from wind zone I to wind zone VI is maximum for W-Bracing and it is minimum for K-Bracing.

2). For all wind zones tower height between 25m to 35m with different bracing patterns do not show much difference in displacement.

For wind zone I to IV, tower height between 35m to 45m having K-Bracing or W-Bracing gives maximum value of displacement and V-Bracing gives minimum value of displacement.

For wind zone V and VI tower height between 35m to 45m having W-Bracing gives maximum value of displacement and V-Bracing or XBX -Bracing gives minimum value of displacement.

3). Stress increases with the increase in speed of the wind. Results show that the increase in stress in the bottom leg members of the tower from wind zone I to wind zone VI is maximum for K-Bracing and it is minimum for XX-Bracing.

4). Stress increases with the increase in the height of the Tower. Results show that the increase in stress is maximum for K-Bracing and it is minimum for XX-Bracing.

5). There is a steep increase in the displacement in Earthquake zone V for all considered type of bracing pattern. Results show that the increase in the displacement from earthquake zone II to VI is maximum for W-Bracing and it is minimum for K-Bracing.

6). For all earthquake zones stress at the bottom leg members of the tower is maximum for XBX-Bracing and it is minimum for W-Bracing.

7). The change in weight when height increases from 25 to 35m is about 41.07% and from 35 to 45m is 26.02% .Weight is maximum for V-bracing and minimum for K-bracing for the same tower height.

8). There is a gradual decrease in the natural frequency of the structure as the height of tower increases. This is due to the influence of mass as the height increases the mass starts to play predominate role than stiffness there by reducing the natural frequency of the structure.
The comparison shows that the frequency of the tower with V- bracing have the least natural frequency since its stiffness is higher as the weight of the structure is more and as compared to others.

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

10). From the above analysis it can be concluded that sub divided V-Bracing gives satisfactory result in wind analysis, modal analysis and response spectrum analysis for all considered wind and earthquake zones mentioned in IS code.

Recommended Bracing Pattern

Wind zone	**Earthquake Zone**			
	Zone -II	**Zone -III**	**Zone -IV**	**Zone -V**
Zone-I	W-Bracing	XX- Bracing	XBX- Bracing	K- Bracing
Zone -II	W- Bracing	XX- Bracing	K- Bracing	K- Bracing
Zone -III	XX- Bracing	XBX- Bracing	K- Bracing	V- Bracing
Zone -IV	XBX- Bracing	XBX- Bracing	K- Bracing	V- Bracing
Zone -V	XBX- Bracing	K- Bracing	V- Bracing	V- Bracing
Zone -VI	XBX- Bracing	K- Bracing	V- Bracing	V- Bracing

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