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EFFECT OF WIND SPEED ON STRUCTURAL BEHAVIOUR OF MONOPOLE AND SELF-SUPPORT TELECOMMUNICATION TOWERS

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ABSTRACT

Monopole and Self-Supporting Towers are the most common types of Telecommunication Towers adopted in construction industry. This paper presents a comparison between Monopole and Self-Support type Towers with different heights of 30m, 40m and 50m for basic wind speeds of 33m/sec, 47m/sec and 55m/sec. Dead loads and Wind loads are considered for analysis of the tower using STAAD(X) Tower software which is tailor made for analyzing Telecommunication Towers. It is concluded from this study that Self-Support Towers have lower lateral displacements compared to the Monopole Towers of same height for same amount of loading. This is because they have higher stiffness. But, the steel quantity required for Self-Support Towers is about 2 times more than the Monopole Towers for a given tower height, wind speed and loading. However, due to their rigidity, Self-Support Towers have more load carrying capacity than Monopoles. For towers of height below or equal to 40m, Monopoles might be preferred. But, with the increase in height beyond 50m, Self-Support Towers are recommended. This is because, in case of any unexpected and abnormally high wind speeds during cyclones, the structural rigidity will be intact and the damage and repair for the structure may not be so high unlike Monopole.

Keywords: STAAD(X) tower; monopole tower; self-supporting tower; lateral displacements.

1. INTRODUCTION

With the rapid and exponential increase in the usage of mobiles, a lot of attention is being paid on the telecommunication industry and telecommunication towers in the recent past. Each and every individual is carrying a mobile with him/her nowadays and the demand for

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telecommunication services has increased. Telecommunication Towers are the only means for coverage area and network reliability. Civil Engineers are involved in the analysis and design of the towers that support the panel antennas, telecommunication equipment, platforms and their foundations. All the equipments like mounts, antennas etc. are mounted on the tower which requires Civil engineering expertise. Tower structural calculations include Applied Loads like wind load, dead load, seismic load and design strength of structural steel member on superstructure including connections and foundation.

Telecommunication Towers are classified into different types based upon their structural action, their cross-section, the type of sections used and on the placement of tower. They are classified as Monopole, Self-Support and Guyed Towers based on their structural action.

2. LITERATURE REVIEW AND MOTIVATION FOR THIS WORK

2.1 Review of literature

Several authors have done the experimental (Harikrishna [1], and Hiramatsu [2]) and analytical investigations by Finite Element Software's (Shehata [3], Silva [4], Lanville [5] and Murtagh [6] on non-linear analysis of towers, joint effects (Knight and Santhakumar [7]), bolt slippage, buckling mechanisms in members (Kalyanaraman [8]), effect of bracing arrangements and other aspects of steel lattice towers. Konno and Kimura [9] conducted dynamic analysis of lattice telecommunication towers (on top of buildings) and concluded that the member forces due to earthquake were greater than those due to wind. A stick model of the tower using lumped masses with a viscous damping ratio of 1% was adopted for modelling the tower. Wyatt [10] considered dynamic effects of wind for design of lattice towers in GFM (Guest Factor Method). In this approach, the equivalent wind loading is equal to the mean wind force multiplied by a Gust Factor. This load is applied as an equivalent static loading on structures. This factor is a function of wind, terrain and structural characteristics. The Gust present in strong winds are caused by mechanical disturbance to the flow resulting from the roughness of the ground surface. Mikus [11] studied the seismic response of six numbers of three legged self-supporting telecommunication towers with heights varying from 20 to 90 meters without considering the antennas and other accessories and concluded that modal superposition with the lowest four modes of vibration would ascertain adequate correctness. Two 4-legged telecommunication towers with square transversal cross-sections are considered for dynamic analysis (one supported on rooftop of single storey building and other on ground. Different types of bracings, such as X-bracing, have been adopted in each tower. The cross-section of the tower members is made-up of single equal-legged angles. Holmes [12] opined that the structures like towers and masts are sensitive to dynamic wind load and hence there is a need to design a lattice tower considering resonant dynamic response to wind loads that arises when their natural frequencies are low enough to be excited by the turbulence in the natural wind. Gomathinayagam [13] observed that the triangular towers are less affected by wind loads compared with square towers although they are adopted for small heights (due to difficulty in joint detailing and fabrication using angle sections). Prasad Rao [14] reduced the unsupported length and increased the buckling strength of the main compression members. The main legs and the bracing members are laterally supported at intervals in between their end nodes, using secondary bracings or redundants. K and X bracing with secondary bracings are commonly used in microwave towers. Amiri and Boostan [15] carried out the dynamic analysis of 10 existing self-supporting telecommunication towers of varying height from 18 to 67m. A scaled response spectrum analysis using spectra of some of the major earthquakes of Iran (Tabas, Naghan and Manjil) with respect to Iranian 2800 seismic code was performed along with wind analysis.A comparison was made between the results of wind and seismic loading and it was observed that wind is critical to earthquake in case of telecommunication towers. McClure et al. [16] explored the correlation between the building accelerations, maximum seismic base shear and base overturning moment of two self-supporting telecommunication lattice towers of height 30m and 40m, mounted on the rooftop of two medium-rise buildings by conducting time-history analysis. Abraham [17] observed that Lattice structures are vulnerable to wind induced oscillations and have to be design against dynamic effects of wind. Further, the structural loads produced by wind gusts depend of the size, natural frequency and damping of the structure in addition to the inherent wind turbulence. One approache used for evaluating the dynamic response of lattice towers is the GFM. Ghodrati [18] investigated the overall seismic response of 4-legged self-supporting telecommunication towers. For this he considered ten of the existing 4-legged self-supporting telecommunication towers in Iran and studied them under the effects of the design spectrum from the Iranian seismic code of practice and the normalized spectra of Manjil, Tabas, and Naghan earthquakes. Based on the results obtained he observed that, for smaller towers, the first three flexural modes were sufficient for their dynamic analysis and the first five modes would enhance the analysis precision for taller towers. Bryan Keith Lanier [19] proposed a retrofitting mechanism for strengthening monopole telecommunication towers by utilizing high-modulus carbon fibre polymers. In this experimental program, Flexural Strength enhancement of the existing towers was tested by considering three larger than practical monopole towers using intermediate-modulus strips, high-modulus strips and high-modulus sheets. Prasad Rao et al. [20] and Prasad Rao et al. [21] investigated the reasons behind many untimely failures found during full scale testing of Transmission line towers at Tower Testing and Research Station, Structural Engineering Research Centre (SERC). Siddesha [22] compared square hollow section and angle towers to study the tower displacement at its top most point using Static and Gust Factor Method. The analysis is also done for different configuration by removing one member as present in the regular tower at lower panels. Klinger et al. [23] presented Forensic analysis to observe the types of failures caused by wind and heavy snowfall in the region Münsterland, north-western part of Germany. Harsha Jatwa [24] compared Indian code IS: 802 (Part l/Sec 1): [25] and ASCE 10-97 (2000) [26]. For this, comparative study, towers with different types of base width, height and bracings were considered. From the study he concluded that the Indian IS: 802 (Part l/Sec 1): [25] code available for the design of tower requires certain modification so as to make design structurally safe and economical when compared to the ASCE 10-97 (2000) [26]. Through this study certain recommendations have been made to the Indian Code. Keshav kr. Sharma [27] has compared 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 members of the towers were compared. Riya Joseph [28] dealt with the analysis of monopole mobile towers. ANSYS software was utilized for this analysis. The behaviour of monopole when used as a communication tower is simulated within the ANSYS software. Evaluation of the efficiency of the monopole tower is based on ANSYS's finite element results.It can be observed from the review of literature that comparison of the performance of different types of tower is not possible.

2.2 Objective and scope of the study

The objective of this study is to compare the performance of Monopole and Self-Support type Towers with respect to lateral displacements and quantity of steel required. Analysis and design of Monopole and Self-Support Towers were performed using STAAD(X) Tower software for three different heights with three different wind speeds and compared.

The problem is assumed to be a linear-static problem and analysis was performed for basic wind speeds of 33m/sec, 47m/sec and 55m/sec and heights of 30m, 40m and 50m. The study does not include seismic forces. Further, for the scope of study considered, the connections are neither designed nor evaluated. The geometrical configurations for all these towers are maintained so that the towers are passing for the respective heights and basic wind speeds. Comparison of lateral displacements at the top of towers is made between the similar sized Monopole and Self-Support Towers.

3. METHODOLOGY

3.1 Material properties

Table 1 shows the material properties adopetd for analysis and design of Monopole and Self-Supporting Towers. For all calculation purposes Young's Modulus of steel is adopted as 205000 MPa and Density of the steel is 7850 kg/m^3.

Table 1: Material properties adopted for analysis of towers

Monopole (IS: 1161-1998) [29]	Self-Support (IS: 2062-2011) [30]	
Steel grade for shaft – YST -240	Steel grade for legs – E410	Steel grade for bracing – E250
Yield stress – 240 MPa	Yield stress – 410 Mpa	Yield stress – 250 MPa
Tensile strength – 410 MPa	Tensile strength – 540 Mpa	Tensile strength – 410 MPa

3.2 Geometry of monopole and self-support towers

An 18-sided polygon structured Monopole Tower model and a 4-sided Self-Support Tower were considered for STAAD(X) analysis. Fig. 1 shows geometrical configuration of Monopole and Self-supporting Towers for 50m height subjected basic wind speed of 55m/sec.

3.3 Loads considered for the study

3.3.1 Dead load

Dead load consists of self-weight of the structure and telecommunication equipment mounted on top of the tower. Typical equipment on a Monopole Tower consists of T-Arm Mount with 3 Andrew SBNH-1D6565B panel antenna and Andrew HP4-44 Dish. Typical equipment on a Self-Supporting Tower consists of T-Frame Mount with 3 Andrew SBNH-1D6565B panel antenna at and Andrew HP4-44 Dish.

3.3.2 Wind Parameters considered for the study (as per IS:875 (Part 3) - [31])

Probability Factor [k_1] is considered treating the Telecommunication Towers as "Important builings and structures" category. The structure under consideration is used for Telecommunication purposes. Here, there should not be any break-down in the services. Therefore, the structure class is considered as Important. Structure Classification is Class B since all the tower models analyzed within the scope of this project are between the heights of 20m to 50m (including 50m). Terrain Category [k_2] is Category 2. The tower is designed for coastal areas that receive tropical cyclones. This may, pose danger to the performance as there are trees that could be blown off damaging the structure. Thus Category 3 conditions may not be maintained effectively. Further Category 2 is more conservative. Topography Factor [k_3] is taken as Factor 1 assuming that the structure is on level ground and there will be no wind speed up due to rasied crest level or topographic features nearby.

3.4 Load combinations considered for the study (as per IS:875 (Part 5) - [32])

Load combinations considered for design are

0.9 DL +1.5 Wind 0^0
0.9 DL + 1.5 Wind 45^0
0.9 DL + 1.5 Wind 90^0

Load combinations considered for serviciabilty are

1.0 DL + 1.0 Wind 0^0
1.0 DL + 1.0 Wind 45^0
1.0 DL + 1.0 Wind 90^0

3.5 Analysis and design

Linear static analysis is performed for all the towers within scope of the study and sectional properties are obtained from the design as per IS: 800-2007 [33]. Table 2(a), 2(b) and 2(c) present the sectional properties of monopole towers of heights for 30m, 40m and 50m respectively (subjected to basic wind speed of 33m/sec., 47 m/sec. and 55 m/sec.). Table 3(a), 3(b), 4(a), 4(b), 5(a) and 5(b) present geometrical configuration with member notation andsectional properties of Self-Supporting Towers of heights for 30m, 40m and 50m subjected to basic wind speed of 33m/sec., 47 m/sec. and 55 m/sec.

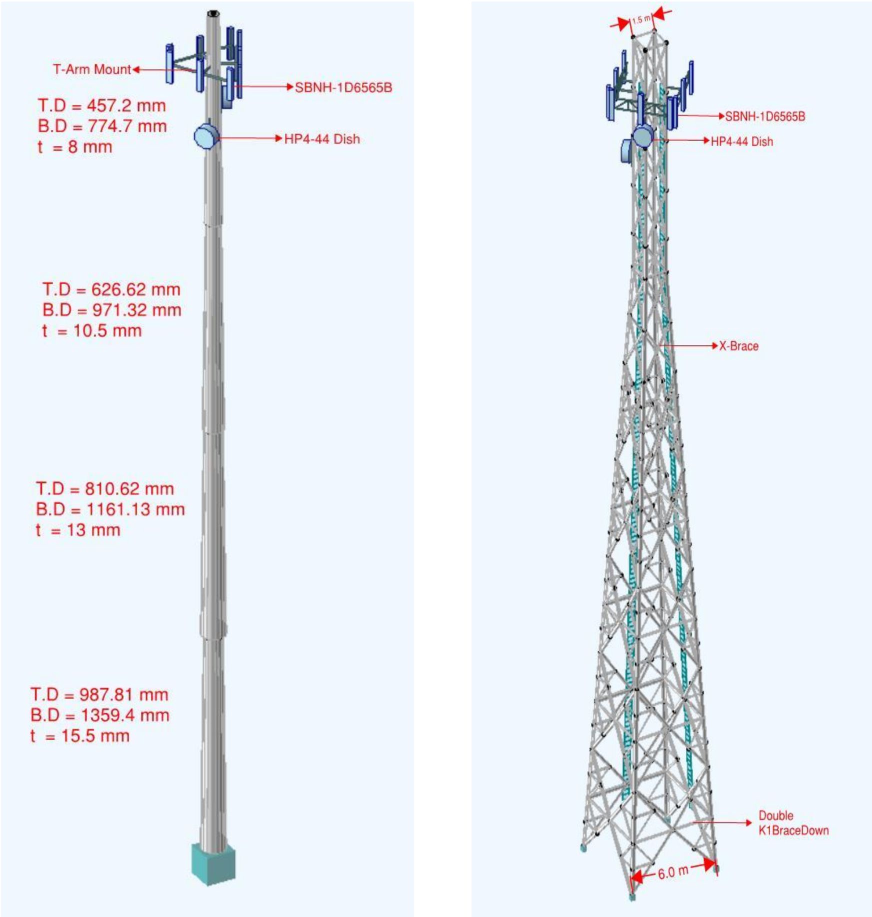

Figure 1. Geometrical configuration of monopole and self-supporting towers (height = 50m and basic wind speed = 55m/sec.)

Table 2 (a): Sectional properties of 30m height monopole tower

Section No.	Elevationabove base (m)	LapSplice (m)	Top Dia.(mm)	Bottom Dia.(mm)	ThicknessT (mm)
		For basic wind speed of 33m/sec			
1.	30	1.07	457.2	711.2	5
2.	20	1.27	572.4	847.3	7.75
3.	10.25	0	697.97	990.5	10.5
		For basic wind speed of 47m/sec			
1.	30	1.07	457.2	711.2	6
2.	20	1.27	570.4	845.3	8.75
3.	10.25	0	693.9	986.5	11.5
		For basic wind speed of 55m/sec			
1.	30	1.07	457.2	711.2	7
2.	20	1.27	568.42	843.3	9.75
3.	10.25	0	689.97	982.5	12.5

Table 2 (b): Sectional properties of 40m height monopole tower

Section No.	Elevationabove base (m)	LapSplice (m)	Top Dia.(mm)	Bottom Dia.(mm)	ThicknessT (mm)
For basic wind speed of 33m/sec					
1.	40	1.18	457.2	795.87	6
2.	26.67	1.52	652.33	1020.93	8.75
3.	13.33	0	863.34	1240.5	11.5
For basic wind speed of 47m/sec					
1.	40	1.18	457.2	795.87	7
2.	26.67	1.52	650.33	1018.93	9.75
3.	13.33	0	859.34	1236.5	12.5
For basic wind speed of 55m/sec					
1.	40	1.18	457.2	795.87	8
2.	26.67	1.52	648.33	1016.93	10.75
3.	13.33	0	855.34	1232.5	13.5

Table 2 (c): Sectional properties of 50m height monopole tower

Section No.	Elevationabove base (m)	LapSplice (m)	Top Dia.(mm)	Bottom Dia.(mm)	ThicknessT (mm)
For basic wind speed of 33m/sec					
1.	50	1.2	457.2	774.7	6
2.	37.5	1.5	630.62	975.32	8.5
3.	25.13	1.8	818.62	1169.13	11
4.	12.83	0	999.81	1371.4	13.5
For basic wind speed of 47m/sec					
1.	50	1.2	457.2	774.7	6
2.	37.5	1.5	628.62	973.32	9.5
3.	25.13	1.8	814.62	1165.13	12
4.	12.83	0	993.81	1365.4	14.5
For basic wind speed of 55m/sec					
1.	50	1.2	457.2	774.7	8
2.	37.5	1.5	626.62	971.32	10.5
3.	25.13	1.8	810.62	1161.13	13
4.	12.83	0	987.81	1359.4	15.5

Table 3 (a): Geometrical configuration with member notation of self-supporting tower of height 30m for all considered basic wind speeds

Section No.	Tower Elevation (from top) (m)	No. of bays	Bracing Pattern	Member Notation		Face width(m)
1	0-4	2	X-Brace	Leg	1a	Top – 1.5
				Bracing	1b	Bottom – 1.5
2	4-10	2	X-Brace	Leg	2a	Top – 1.5
				Bracing	2b	Bottom – 1.5

3	10-12	1	X-Brace	Leg Bracing	3a 3b	Top – 1.5 Bottom – 1.85
4	12-18	2	X-Brace	Leg Bracing	4a 4b	Top – 1.85 Bottom – 2.9
5	18-24	1	X-BraceSH1	Leg Bracing	5a 5b	Top – 2.9 Bottom – 3.95
6	24-30	1	X-BraceSH1	Leg Bracing	6a 6b	Top – 3.95 Bottom – 5.0

Table 3 (b): Sectional properties of self-supporting tower of height 30m

Member Notation	Member Description (IS Angel Sections) for basic wind speed of		
	33 m/sec.	47 m/sec.	50 m/sec.
1a	90×90×10	90×90×10	90×90×10
1b	90×90×10	90×90×10	90×90×10
2a	130×130×10	130×130×10	130×130×10
2b	90×90×10	90×90×10	90×90×10
3a	130×130×10	130×130×10	130×130×10
3b	110×110×12	110×110×12	110×110×12
4a	150×150×15	150×150×15	150×150×15
4b	130×130×10	130×130×10	130×130×10
5a	180×180×15	180×180×15	180×180×15
5b	150×150×10	150×150×10	150×150×10
6a	180×180×15	180×180×15	180×180×15
6b	150×150×10	150×150×10 /90×90×10	150×150×10 /90×90×10

Table 4 (a): Geometrical configuration with member notation of self-supporting tower of height 40m for all considered basic wind speeds

Section No.	Tower Elevation (from top) (m)	No. of bays	Bracing Pattern	Member Notation		Face width(m)
1	0-12	4	X-Brace	Leg Bracing	1a 1b	Top – 1.5 Bottom – 1.5
2	12-16	2	X-Brace	Leg Bracing	2a 2b	Top – 1.5 Bottom – 2.143
3	16-22	1	X-Brace	Leg Bracing	3a 3b	Top – 2.143 Bottom – 3.107
4	22-28	1	X-BraceSH1	Leg Bracing	4a 4b	Top – 3.107 Bottom – 4.071
5	28-34	1	X-BraceSH1	Leg Bracing	5a 5b	Top – 4.071 Bottom – 5.036
6	34-40	1	X-BraceSH1	Leg Bracing	6a 6b	Top – 5.036 Bottom – 6.0

Table 4 (b): Sectional properties of self-supporting tower of height 40m

Member Notation	Member Description (IS Angel Sections) for basic wind speed of		
	33 m/sec.	47 m/sec.	50 m/sec.
1a	150×150×12	150×150×12	150×150×12
1b	90×90×10	90×90×10	90×90×10
2a	180×180×20	180×180×20	180×180×20
2b	130×130×10	130×130×10	130×130×10
3a	180×180×20	180×180×20	180×180×20
3b	130×130×10	130×130×10	130×130×10
4a	200×200×25	200×200×25	200×200×16
4b	130×130×10	130×130×10	130×130×10
5a	200×200×25	200×200×25	200×200×25
5b	150×150×12	150×150×12	150×150×12 / 90×90×10
6a	200×200×25	200×200×25	200×200×25
6b	150×150×12	150×150×12 / 90×90×10	150×150×12 / 90×90×10

Table 5 (a): Geometrical configuration with member notation of self-supporting tower of height 50m for all considered basic wind speeds

Section No.	Tower Elevation (from top) (m)	No. of bays	Bracing Pattern	Member Notation		Face width (m)
1	0-12	4	X-Brace	Leg Bracing	1a 1b	Top – 1.5 Bottom – 1.5
2	12-14	1	X-Brace	Leg Bracing	2a 2b	Top – 1.5 Bottom – 1.5
3	14-20	2	X-Brace	Leg Bracing	3a 3b	Top – 1.5 Bottom – 2.25
4	20-26	1	X-BraceSH1	Leg Bracing	4a 4b	Top – 2.25 Bottom – 3.0
5	26-32	1	X-BraceSH1	Leg Bracing	5a 5b	Top – 3.0 Bottom – 3.75
6	32-38	1	X-BraceSH1	Leg Bracing	6a 6b	Top – 3.75 Bottom – 4.5
7	38-44	1	X-BraceSH1	Leg Bracing	7a 7b	Top – 4.5 Bottom – 5.25
8	44-50	1	X-BraceSH1	Leg Bracing	8a 8b	Top – 5.25 Bottom – 6.0

Table 5 (b): Sectional properties of self-supporting tower of height 50m

Member Notation	Member Description (IS Angel Sections) for basic wind speed of		
	33 m/sec.	47 m/sec.	50 m/sec.
1a	150×150×10	150×150×10	150×150×10
1b	90×90×10	90×90×10	90×90×10
2a	180×180×15	180×180×15	180×180×15
2b	90×90×10	90×90×10	90×90×10
3a	200×200×16	200×200×16	200×200×16
3b	110×110×12	110×110×12	110×110×12
4a	200×200×25	200×200×25	200×200×25
4b	130×130×10	130×130×10	130×130×10 / 90×90×10
5a	200×200×25	200×200×25	200×200×25
5b	130×130×10	130×130×10	130×130×10 /90×90×10
6a	200×200×25	200×200×25	200×200×25
6b	150×150×10	150×150×10	150×150×10 /90×90×10
7a	200×200×25	200×200×25	200×200×25
7b	150×150×15	150×150×15 /90×90×10	150×150×15 / 90×90×10
8a	200×200×25	200×200×25	200×200×25
8b	150×150×15	150×150×15 /90×90×10	150×150×15 /90×90×10

4. RESULTS AND DISCUSSIONS

4.1 Results of monopole and self supporting towers of 30m Height

A comparison of lateral displacements and quantity of steel between monopole and Self-Support Towers was performed and the results are presented in Fig. 2 to Fig. 19.

4.1.1 Lateral displacement and quantity of steel of 30m monopole tower and 30m self-support tower for 33m/sec basic wind speed

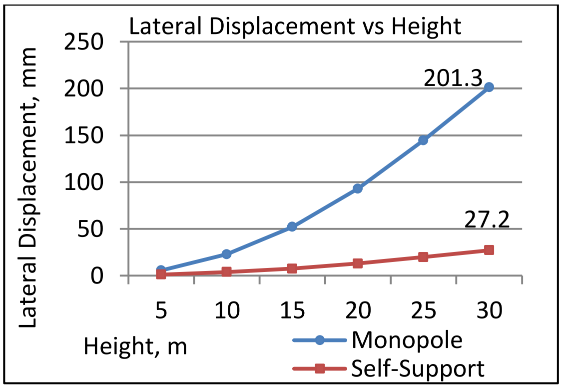

Figure 2. Lateral Displacement Vs Height for Monopole and Self supporting tower (Height = 30m and basic wind speed = 33m/sec)

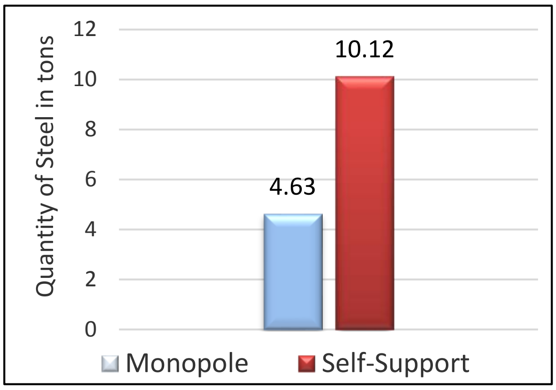

Figure 3. Quantities of Steel for Monopole and Self supporting tower (Height = 30m and basic wind speed = 33m/sec)

From Fig. 2 and Fig. 3 it was observed that for a 30m tower height with 33m/sec basic wind speed, lateral displacement for Monopole Tower is 7.4 times higher than Self-Support Tower and quantity of steel required for Self-Support tower is 2.19 times higher than Monopole tower.

4.1.2 Lateral displacement and quantity of steel of 30m monopole tower and 30m self-support tower for 47m/sec basic wind speed

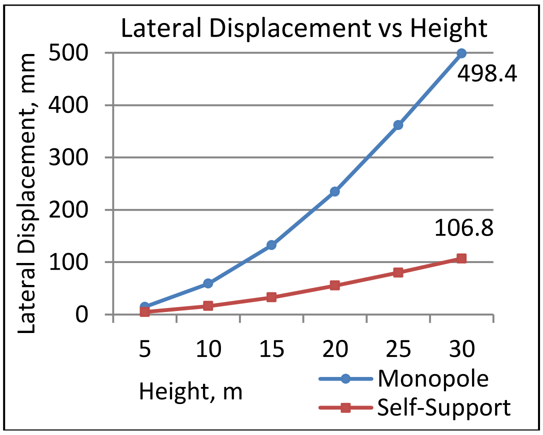

Figure 4. Lateral displacement Vs height for monopole and self supporting tower (height = 30m and basic wind speed = 47m/sec)

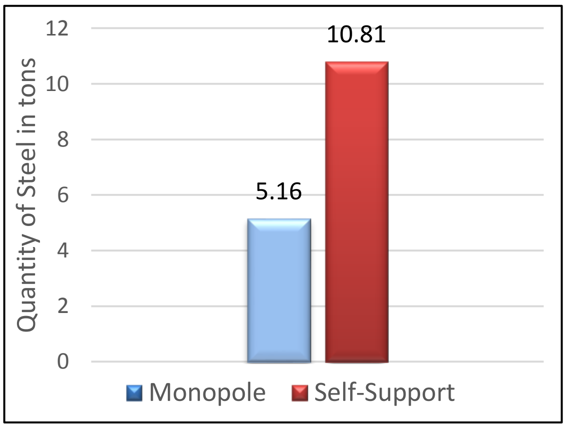

Figure 5. Quantities of steel for monopole and self supporting tower(height = 30m and basic wind speed = 47m/sec)

4.1.3 Lateral displacement and quantity of steel of 30m monopole tower and 30m self-support tower for 55m/sec basic wind speed

From Fig. 6, 7 it was observed that for a 30m tower height with 33m/sec basic wind speed, lateral displacement for Monopole tower is 4.67 times higher than Self-Support tower and quantity of steel required for Self-Support tower is 2.01 times higher than Monopole tower.

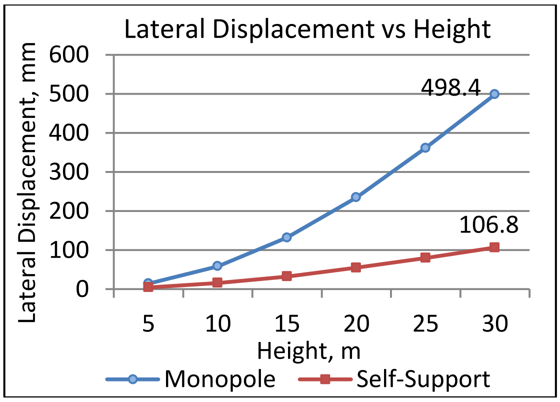

Figure 6. Lateral Displacement Vs Height for Monopole and Self supporting tower (Height = 30m and basic wind speed = 55m/sec)

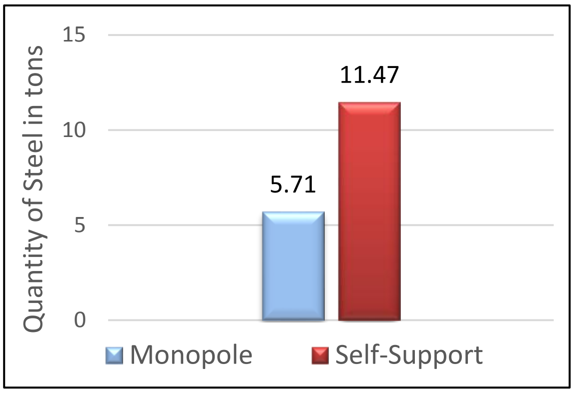

Figure 7. Quantities of Steel for Monopole and Self supporting tower (Height = 30m and basic wind speed = 55m/sec)

4.2 Results of monopole and self supporting towers of 40m height

4.2.1 Lateral displacement and quantity of steel of 40m monopole tower and 40m self-support tower for 33m/sec basic wind speed

From Fig. 8, 9 it was observed that for a 40m tower height with 33m/sec basic wind speed, lateral displacement for Monopole Tower is 6.42 times higher than Self-Support Tower and quantity of steel required for Self-Support tower is 2.27 times higher than Monopole Tower.

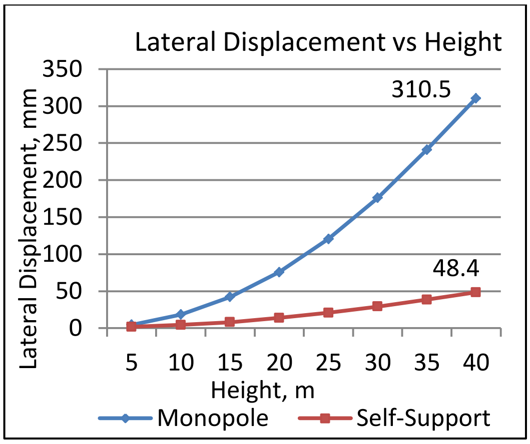

Figure 8. Lateral Displacement Vs Height for Monopole and Self supporting tower (Height = 40m and basic wind speed = 30m/sec)

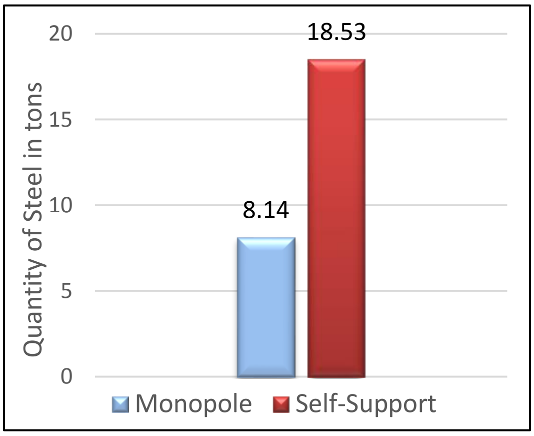

Figure 9. Quantities of steel for monopole and self supporting tower(height = 40m and basic wind speed = 33m/sec)

4.2.2 Lateral displacement and quantity of steel of 40m monopole tower and 40m self-support tower for 47m/sec basic wind speed

From Fig. 10,11 it was observed that for a 40m tower height with 47m/sec basic wind speed, lateral displacement for Monopole Tower is 5.88 times higher than Self-Support Tower and quantity of steel required for Self-Support Tower is 2.15 times higher than Monopole Tower.

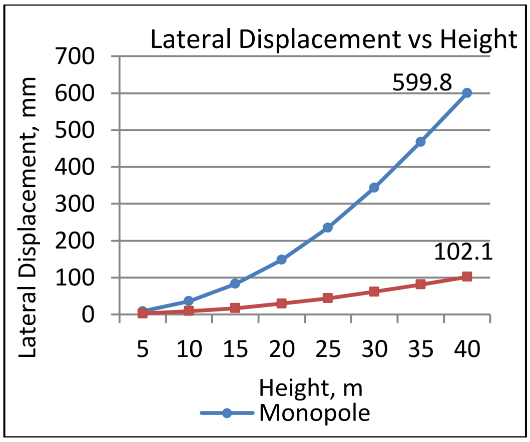

Figure 10. Lateral displacement Vs height for monopole and self supporting tower (height = 40m and basic wind speed = 47m/sec)

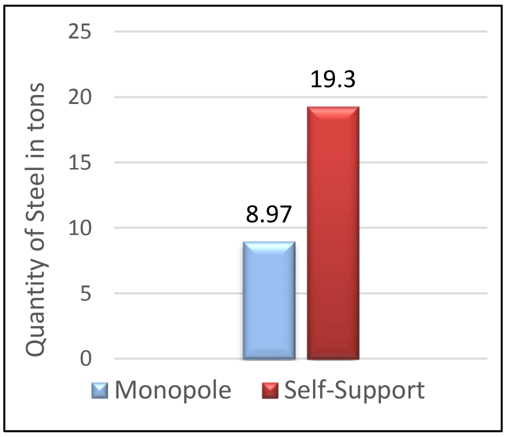

Figure 11. Quantities of Steel for Monopole and Self supporting tower (Height = 40m and basic wind speed = 47m/sec)

4.2.3 Lateral displacement and quantity of steel of 40m monopole tower and 40m self-support tower for 55m/sec basic wind speed

From Figs. 12 and 13 it was observed that for a 40m tower height with 47m/sec basic wind speed, lateral displacement for Monopole Tower is 5.05 times higher than Self-Support Tower and quantity of steel required for Self-Support Tower is 2.04 times higher than Monopole Tower.

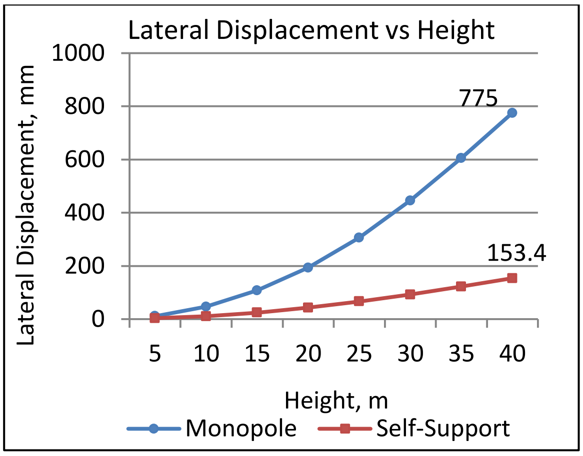

Figure 12. Lateral displacement Vs height for monopole and self supporting tower (height = 40m and basic wind speed = 55m/sec)

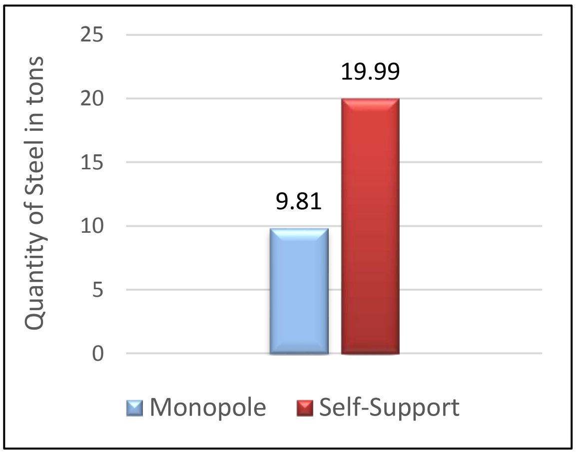

Figure 13. Quantities of steel for monopole and self supporting tower (height = 40m and basic wind speed = 55m/sec)

4.3 Results of monopole and self supporting towers of 50m height

4.3.1 Lateral displacement and quantity of steel of 50m monopole tower and 50m self-support tower for 33m/sec basic wind speed

From Fig. 14, 15 it was observed that for a 50m tower height with 33m/sec basic wind speed, lateral displacement for Monopole Tower is 4.39 times higher than Self-Support Tower and quantity of steel required for Self-Support Tower is 1.93 times higher than Monopole Tower.

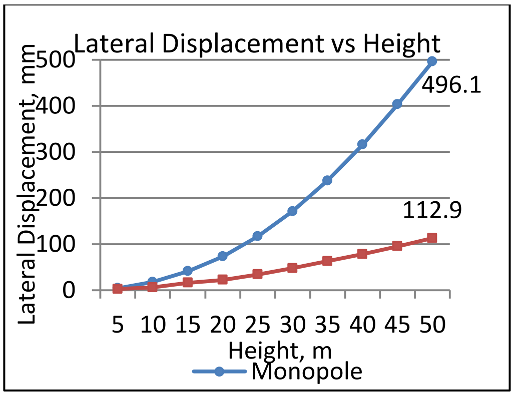

Figure 14. Lateral displacement Vs height for monopole and self supporting tower (height = 50m and basic wind speed = 33m/sec)

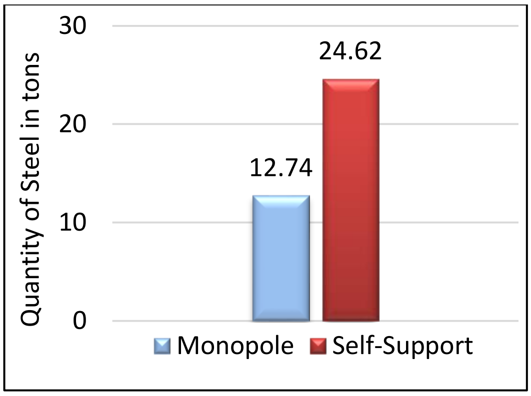

Figure 15. Quantities of steel for monopole and self supporting tower (height = 50m and basic wind speed = 33m/sec)

4.3.2 Lateral displacement and quantity of steel of 50m monopole tower and 50m self-support tower for 47m/sec basic wind speed

From Fig. 16, 17 it was observed that for a 50m tower height with 47m/sec basic wind speed, lateral displacement for Monopole Tower is 4.08 times higher than Self-Support Tower and quantity of steel required for Self-Support Tower is 1.89 times higher than Monopole Tower.

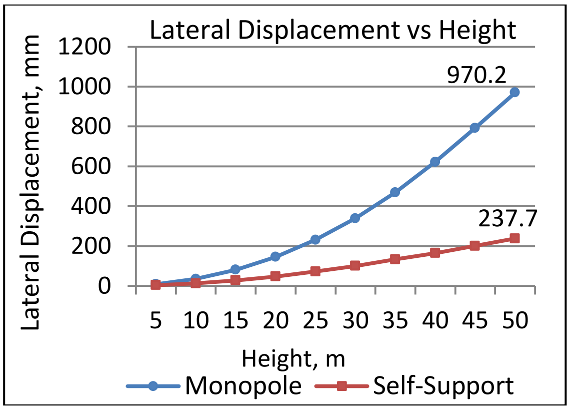

Figure 16. Lateral displacement Vs height for monopole and self supporting tower (height = 50m and basic wind speed = 47m/sec)

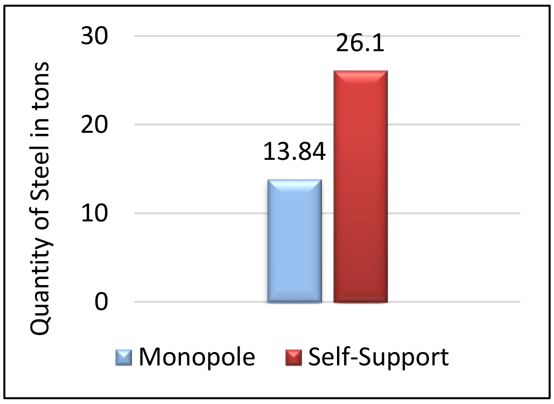

Figure 17. Quantities of steel for monopole and self supporting tower (height = 50m and basic wind speed = 47m/sec)

4.3.3 Lateral displacements of 50m monopole tower and 50m self-support tower for 55m/sec basic wind speed

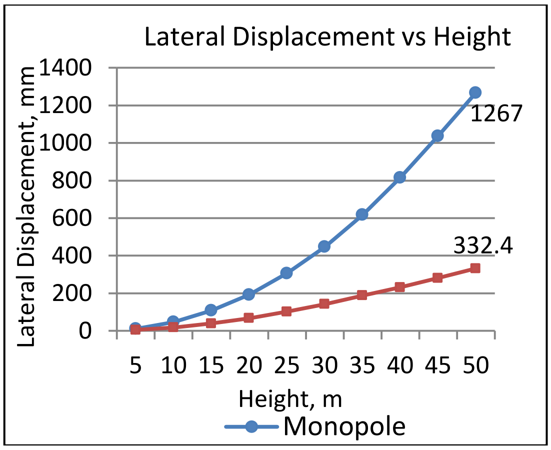

Figure 18. Lateral displacement Vs height for monopole and self supporting tower (height = 50m and basic wind speed = 55m/sec)

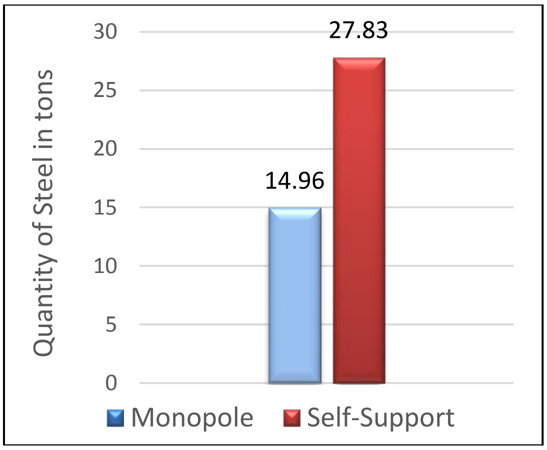

Figure 19. Quantities of steel for monopole and self supporting tower (height = 50m and basic wind speed = 55m/sec)

From Fig. 18, 19 it is observed that for a 50m tower height with 3m/sec basic wind speed, lateral displacement for Monopole Tower is 3.82 times higher than Self-Support Tower and quantity of steel required for Self-Support Tower is 1.86 times higher than Monopole Tower.

5. CONCLUSION

From the study it can be concluded that Self-Supporting Towers have lower lateral displacements compared to Monopole Towers of same height and same amount of loading due to the fact that they have higher stiffness. However, the steel quantity required for Self-Supporting Towers is approximately two times more than the Monopole Towers for a given tower height, wind speed and loading.

But due to their rigidity, Self-Support Towers have more load carrying capacity than Monopoles. For towers of height less than or equal to 40m, Monopoles may be preferred but with the increase in height beyond 50m and above Self-Supporting Towers are more suitable. This is because, during unexpected higher wind speeds due to cyclones (like Hud-Hud), the structural rigidity will be intact and the cost of damage and the repair of the structure may not be so high unlike Monopole.

It should also be noted that strengthening a monopole is difficult compared to Self-Support Tower. Unlike Self-Supporting Towers, where reinforcement is as simple as replacing a smaller, over-stressed member with a larger, stronger one, a monopole has only one member, thus replacement means installing a new pole. Finally, monopoles have lower lateral stiffness as compared to Self-Supporting Towers. Although the monopole may be structurally stable, its lack of stiffness may exceed the twist and sway tolerances of some antenna or dish equipment.

Based on the above mentioned observation & conclusions, it is recommended to adopt Self-Support Tower as they can support more equipment. Further greater heights, higher stiffness and easiness for modifications in case of member failure make Self-Supporting Towers more suitable for adoption by telecommunication industry.

Improvement: A future study can be extended for studying effects of mounting solar panels on the towers that can help generation of electricity for ground equipment.

REFERENCES

1. Harikrishna P, Annadurai A, Gomathinayagam S, Laxman N. Full scale measurements of the structural response of a 50 m guyed mast under wind loading, *Engineering Structures*, **25**(2003) 859-67.
2. Hiramatsu K, Akagi H. The response of latticed steel towers due to the action of wind, *Journal of Wind Engineering and Industrial Aerodynamics*, **30**(1988) 7-16.
3. Shehata AY, EI Damatty AA, Savory E. Finite element modeling of transmission line under down burst wind loading, *Finite Elements in Analysis and Design*, **42**(2005) 71-89.
4. Silva G S da, Vellasco P C G da S, Andrade S A L de, Oliveira M I R de. Structural assessment of current steel design models for transmission and telecommunication towers, *Journal of Constructional Steel Research*, **61**(2005) 1108-34.

5. Glanville M J, Kwok K C S. Dynamic characteristics and wind induced response of a steel frame tower, *Journal of Wind Engineering and Industrial Aerodynamics*, **54**(1995) 133-49.
6. Murtagh P J, Basu B, Broderick B M. Simple models for natural frequencies and mode shapes of towers supporting utilities, *Computers and Structures*, **82**(2004) 1745-50.
7. Knight GMS, Santhakumar AR. Joint effects on behaviour of transmission towers, *Journal of Structural Engineering, ASCE*, **119**(1993) 698-712.
8. Prasad Rao N, Kalyanaraman V. Non-linear behaviour of lattice panel of angle towers, *Journal of Constructional Steel Research*, **57**(2007) 1337-57.
9. Konno T, Kimura E. Earthquake effects on steel tower structures atop building, *Proceedings of the 5th World Conference on Earthquake Engineering*, Rome, Italy, **1**(1973) 184-93.
10. Wyatt T A. An assessment of the sensitivity of lattice towers to fatigue induced by wind guts, *Journal of Structural Engineering*, **6**(1984) 262-7.
11. Mikus J. Seismic analysis of self-supporting telecommunication towers, M. Eng. Project Report G94-10. Department of Civil Engineering and Applied Mechanics, McGill University, Montreal, Canada, 1994.
12. HolmesJD. Along wind response of lattice towers: Part I Derivation of expressions for gust response factors, *Engineering Structures*, **16**(1994) 287-92.
13. Gomathinayagam S, Shanmugasudaram J, Harikrishna P, Lakshmanan N, Rajasekaran C. Dynamic response of lattice tower with antenna under wind loading, *Journal of The Institution of Engineers (India)*, **81**(2000) 37-43.
14. Prasad Rao N, Kalyanaraman V. Non-linear behaviour of lattice panel of angle towers, *Journal of Constructional Steel Research*, **57**(2001) 1337-57.
15. Amiri G, Boostan A. Dynamic response of antenna-supporting structures, *4th Structural Specialty Conference of the Canadian Society for Civil Engineering*, (2002) pp. 1-9.
16. McClure G, Georgi L, Assi R. Seismic considerations for telecommunication towers mounted on building rooftop, *13th World Conference on Earthquake Engineering*, Vancouver, Canada, Paper No. 1988, 2004.
17. Abraham Harikrishna P, Gomathinayagam S, Lakshmanan N. Failure investigation of microwave towers during cyclones A case study, *Journal of Structural Engineering*, **32**(2005) 147-57.
18. Ghodrati A. Seismic behaviour of 4-legged self-supporting telecommunication towers, *World Applied Sciences Journal*, **2**(2007) 1818-4952.
19. Lanier Keith B. Study in the improvement in strength and stiffness capacity of steel multi-sided monopole towers utilizing carbon fiber reinforced polymers as a retrofitting mechanism,*Thin-Walled Structures*,(2009) 1037-47.
20. Prasad Rao N, Samuel Knight G M, Lakshmanan N, R Iyer N. Investigation of transmission line tower failures, *Engineering Failure Analysis*, **17**(2010) 1127-41.
21. Prasad Rao N, Samuel Knight G M, Seetharaman S, Lakshmanan N. Failure analysis of Transmission line towers, *Journal of Performance of Constructed Facilities*, **25**(2011).
22. Siddesha H. The wind analysis of microwave antenna tower with static and gust factor method (GFM), *International Journal of Applied Engineering Research*, Dindigul, **1**(2010) 0976-4259.
23. Klinger C, Mehdianpour M, Klingbeil D, Bettge D, Hacker R, Baer W. Failure analysis

on collapsed towers of overhead electrical lines in the region Münsterland (Germany) 2005, *Engineering Failure Analysis*, **18**(2011)1873-83.
24. Jatwa H. Comparative study of Indian and ASCE codes provision for design of transmission tower, *International Journal of Innovations in Engineering and Technology*, **4**(2014) 18-29.
25. IS: 802 (Part l/Sec 1):1995. Indian Standard Use of Structural Steel in Overhead Transmission Line Towers - Code of Practice Part 1 Materials, Loads and Permissible Stresses Section 1 Materials and Loads (Third Revision), Bureau of Indian Standards, New Delhi 110002.
26. ASCE 10-97 (2000).Design of Latticed Steel Transmission Structures (10-97), American Society of Civil Engineers, Standards ASCE 10-97, p. 88.
27. Sharma K K, Duggal S K. Comparative analysis of steel telecommunication tower subjected to seismic & wind loading, *Civil Engineering and Urban Planning:An International Journal (CiVEJ)*, **2**(2015) 15-33.
28. Joseph R, Varghese J. Analysis of monopole communication tower, *International Journal of Engineering Studies and Technical Approach*, **1**(2015) 23-34.
29. IS 1161 – 1998. Indian Standard Steel Tubes for Structural Purposes – Specification, (Fourth Revision), Bureau of Indian Standards, New Delhi 110002.
30. IS 2062 – 2011. Indian Standard Hot Rolled Medium and High Tensile Structural Steel - Specification (Seventh Revision), Bureau of Indian Standards, New Delhi 110002.
31. IS 875 (Part 3)-1987. Indian Standard Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures, Part 3 (Wind Loads), (Second Revision), Bureau of Indian Standards, New Delhi 110002.
32. IS 875 (Part 5)-1987 Indian Standard Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures Part 5 Special Loads. And Combinations Bureau of Indian Standards, New Delhi 110002.
33. IS 800-2007, Indian Standard, General Construction in Steel - Code of Practice (Third Revision), Bureau of Indian Standards, New Delhi 110002.