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Analysis of Monopole Communication Tower

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ABSTRACT:

Telecommunication towers are tall structures installed at a specific height usually designed for supporting parabolic antennas. The structure engineer faces the challenging job of designing and constructing telecommunication towers to support all loads in open weather with high degree of reliability. Free standing lattice towers are generally used in our country. As per the recent surveys, mobile towers in INDIA are likely to grow to over 5 lakh by 2020. In urban areas with high density population, great difficulties are experienced in finding land for installation of these conventional lattice towers. Steep increase in land value has necessitated finding a suitable alternative to conventional lattice towers that are unobstructive to the environment. Environmental and economic pressures have initiated to seek improved design approaches to make communication towers more environmentally acceptable and cost effective. Since pole structures have smaller dimension and require lesser space for installation, they can be used as a suitable alternate for lattice towers. The project work deals with the analysis of monopole mobile towers. Analysis is done using ANSYS finite element software. The model provided by ANSYS is used to simulate the behaviour of monopoles when used as a communication tower. Efficiency of monopole tower is evaluated based on the finite element results.

Index Terms— *Antenna Load, Communication Towers, Finite Element Method, Force Co-efficient Method, Gust Factor Method, Monopole, Wind Analysis.*

1. INTRODUCTION

TELECOMMUNICATION is an economic miracle which has transformed the lives of millions and contributed immensely towards India's socio – economic development. It is one of the prime support services needed for rapid growth and modernisation of various sectors of the economy. India's telecommunication network is the second largest in the world based on the total number of telephone users. According to the Internet and Mobile Association of India (IAMAI), the Internet user base in the country stood at 190 million at the end of June, 2013.

Telecommunication towers are tall structures usually designed for supporting parabolic antennas installed at a specific height. The telecommunication industry plays a great role in human societies and thus much more attention is now being paid to telecommunication towers than it was in the past. The direction and height of tower along with the antennas mounted on it is completely governed by the functional requirements. As telecommunication towers are the only means of enhancing both the coverage area and network reliability, more and more telecommunications towers are installed nowadays. The structure engineer faces the challenging job of designing and constructing telecommunication towers to support all loads in open weather with high degree of reliability.

Free standing lattice towers are generally used in our country. As per the recent surveys, mobile towers in INDIA are likely to grow to over 5 lakh by 2020. In urban areas with high density population, great difficulties are experienced in finding land for installation of these conventional lattice towers. Steep increase in land value has necessitated finding a suitable alternative to conventional lattice towers that are unobstructive to the environment. Environmental and economic pressures have initiated to seek improved design approaches to make communication towers more environmentally acceptable and cost effective. Since pole structures have smaller dimension and require lesser space for installation, they can be used as a suitable alternate for lattice towers. This paper deals with the analysis of monopole mobile towers.

2. MONOPOLE

Modern telecommunication structures are essential to the present society. The emergence of new technologies creates demand for additional facilities and introduction of new elements into our cities. Our vast selection of communications poles is designed and manufactured for durability, wear and corrosion resistance, and visual appeal. Monopoles are polygonal sectioned and hot dip galvanized hollow steel structures. All accessories for onsite assembly are bolted, consequent body sections are either slip jointed or bolted. Base plates, flanges and accessories are welded to the sections. Monopole towers can support all the equipments, antennas and utilities similar to that of the conventional lattice tower.

2.1 Structural Features

Monopoles are polygonal sectioned and hot dip galvanized hollow steel structures with consequent body sections either slip jointed or bolted. These are single self supporting or free standing pole and are most commonly used in cellular and personal communication service applications. They are typically constructed of different diameter steel sections either cylindrical or multi sided in shape. The individual sections are bolted or welded together with the largest diameter sections at the base and each successive section is smaller in diameter. The base costs include the tower, erection, concrete footings, painting, lighting, platforms and overhead.

2.2 Manufacturing

Computer - aided plasma and oxy - cutting allow instant changes to be made to the dimensional characteristics of shaft trapezium, base plate and flange plate. Plates are bent to realize shafts with a maximum length 13 m and 6, 8, 12, 16, 18 etc. sides. Longitudinal welds in steel pole sections should be free of cracks and undercutting and are performed with automatic processes. Quality of welds is assured by visual inspection. Longitudinal welds in the female section of the lap splice which should have 100% penetration have their quality being assured by ultrasonic inspection. The base plate telescopes the pole shaft and is circumferentially welded at top and bottom.

All handling, packing, storage and shipment of the steel work are carried out diligently and carefully to reduce the risk of damage to the articles and zinc coating to a minimum. The steel work is packed in bundles containing articles in accordance with the prepared packing lists. The parcels are bundled with polyester bands of suitable strength which are evenly distributed along the length of the parcels. The galvanized items are stacked such that water and moisture can run off them and the surfaces are able to dry out.

2.3 Significance

Due to rapid growth of telecommunication industry, the development of relevant infrastructure gains sufficient importance. In a fast developing country with high growth rate and faced with high density of population in urban areas, great difficulties are experienced in finding land for installation of conventional lattice towers for communication purpose. Steep increase in land value has necessitated finding a suitable alternative to conventional lattice towers that are harmonious, pleasing and unobstructive to the environment. Environmental and economic pressures have initiated to seek improved design approaches to make communication towers more environmentally acceptable and cost effective. Steel pole structures are used in different fields such as power transmission, communication, high way and stadium illumination. Steel tubular poles have smaller plan dimension and are composed of only few components, compared to the lattice type towers. When these poles are used as antennae supporting structures, they are more economical considering the cost of land. These poles are either slip jointed or connected using bolted flange plates. The circumferential thickness is varied along the height of the pole to obtain a lighter structure. The pole cross sections generally have rectangular, circular or 6, 8, 12, 16, 24 sided polygonal shape. Steel tubular poles having cross sections of polygonal shape is widely used. The number of sides in a polygonal shape is determined considering the circumference, thickness of pole, cross section and its diameter. The pole weight affects the overall cost of the system consisting of cumulative cost of the material, manufacturing, transportation and erection cost.

2.4 Scope

Monopole towers are gaining popularity for communication purpose around the world due to the current difficulty in finding land for installation of conventional lattice towers and hence its analysis is important in the present scenario. Monopole towers can support both CDMA and GSM antennas at heights of 30m to 50m which increases the scope of the structure. The multipurpose usage of monopole towers in the fields of power transmission, communication, illumination etc makes it versatile among structures. Structure analysis can enhance the better performance and life of the structure. Proper analysis of monopole can lead to reduction in construction cost.

3. STRUCTURE MODELLING

3.1 Description of Software Used

Finite element method is considered to be the best tool for analyzing the structures recently many software's uses this method for analyzing and designing. The most popular and the easiest to learn is ANSYS software. It is a general purpose finite element modeling package for numerically solving a wide variety of mechanical problems. All users, from designers to advanced experts, can benefit from ANSYS structural analysis software. The fidelity of the results is achieved through the wide variety of material models available, the quality of the elements library, the robustness of the solution algorithms and the ability to model every product from single parts to very complex assemblies with hundreds of components interacting through contacts or relative motions. ANSYS FEA tools also offer unparalleled ease of use to help product developers focus on the most important part of the simulation process, understanding the results and the impact of design variations on the model.

3.2 Modelling of Monopole

Tower is to be designed in such a way that the antennas can be placed at certain elevations. Signal transmission should not be obstructed in any case. The structural properties of the tower are very important as the property such as tower stiffness has a big influence on its performance and structural response.

Tubular towers can have either a round or a polygonal cross section. Modern towers are tapered tubular tower with diameter increasing towards the base. Generally, the idea is to increase the strength towards the base where high bending stresses are susceptible. Also, it saves the material and thereby reducing the cost of the tower. Usually, monopole tower has a large the ratio of height (H) to least horizontal dimension (D) that makes it a particularly more slender and wind sensitive than any other structures. On the other hand, the thickness is less than the radius of the tubular of shaft and hence the tower is more prone to buckling. The height of the tower is a site-dependent parameter such that the signal transmission is not obstructed. The design optimization for the least cost could favor tall towers in low wind areas and shorter towers in high wind areas. Taller the tower, lesser will be the effect of harmful radiation towards the living organisms.

3.3 Tower Material

ASTM 572 is most commonly used material in towers. It is a high strength, low alloy steel that finds its best application where there is need for more strength per unit of weight. Less of this material is needed to fulfill given strength requirements than is necessary with regular carbon steels. In addition, ASTM 572 is noted for its increased resistance to atmospheric corrosion and can be successfully bent or shaped but requires more force than plain carbon steel. It is commonly used in structural applications, heavy construction equipment, building structures, heavy duty anchoring systems, truck frames, poles, liners, conveyors, boom sections, structural steel shapes, and applications that require high strength per weight ratio.

3.4 Tower Dimensions

The monopole to be modeled is a tubular steel pole of 40m height. The main shaft of the monopole is having the shape of a 20 sided regular polygon. Diameter of the shaft is 900mm at the bottom and 500mm at the top. Thickness of the section is adopted in such a way that the analysis results in minimum deflection without increasing the volume and cost of material.

4. METHODOLGY

4.1 Specimen Geometry

For monopole, simulation element SHELL181 was chosen from the ANSYS element library. SHELL181 is suitable for analyzing thin to moderately-thick shell structures. It is a four-noded element with six degrees of freedom at each node: translations in the x, y and z directions, and rotations about the x, y, and z axes. The degenerate triangular option should only be used as filler elements in mesh generation.

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TABLE 1 Material Properties

ASTM 572 STEEL	
Modulus of Elasticity	2.1 x 10^{11} N/m^2
Yield stress	350 MPa
Poisson's Ratio	0.3
Density	7850 kg/m^3

4.2 Boundary Conditions

The supporting conditions of the tower was assumed that the tower is rigidly attached to the ground, fixed – free boundary condition is applied i.e. tower is fixed at the base and free at the top.

4.3 Meshing

To achieve high accuracy, the meshing of the element should be fine as possible. The results heavily depend upon the quality of mesh.

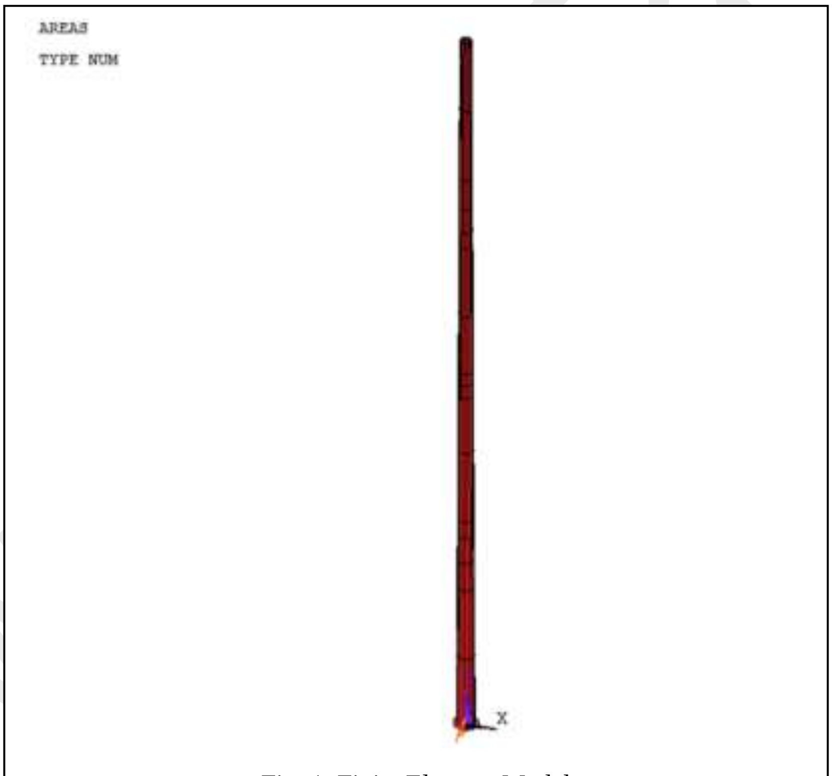

Fig. 1. Finite Element Model

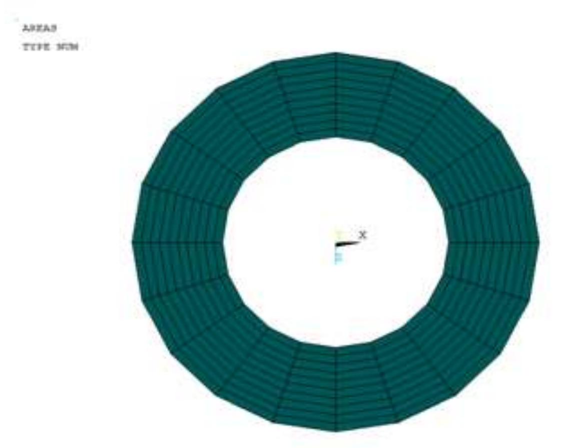

Fig. 2. Top View of the Model

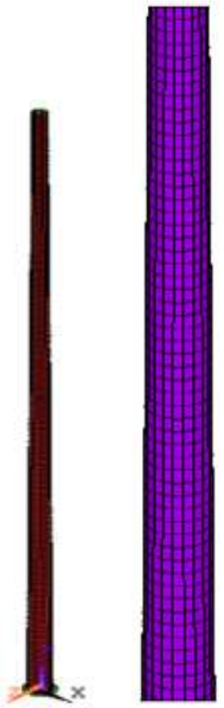

Fig. 3. Meshed View of the Model

5. LOADING

Before the response of a support structure can be obtained, it is necessary to have quantitative estimates of all significant loadings that the structure is likely to experience. For the analysis of communication towers generally wind and seismic loads are considered along with antenna loads.

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The forces exerted on a structure by wind depend on the size and shape of the structural members in the path of wind and the speed on which the wind is blowing. The wind force acting on any structure is the sum of wind forces acting on its individual parts. The design wind speed is calculated taking into account the terrain type, height of the structure, topography, risk level for the structure.

5.1 Gust Factor Method

The additional loading effects due to wind turbulence and dynamic amplification in flexible structures such as guyed towers and pole structures is calculated using gust factor. The gust factor 'G' accounts for the dynamic effects of gust on wind response towers. The values of these gust factor lies in the range of 1.5 to 2.5. The values of these gust factors changes with wind speed, decreases with height and increases with increased terrain roughness. As per literature, the frequency of the pole structures is almost less than 1Hz, the wind loads on these structures is calculated based on gust factor method. The wind loads calculated based on this gust factor method is 25-30% higher when compared to force-co-efficient method.

The wind load on monopole is calculated based on IS: 875 (Part 3) - 1987.The following design parameters are used for calculating the wind loads:

Basic Wind Speed: 33 m/s,

Risk coefficient kl=1.06,

Terrain Category: 2, Class: B,

Topography factor k3=1.0,

With the basic velocity at a height of 10 m is known, the velocities can be translated to another height with the following formula:

$$V = Vref * (\ln(z/0.002) / \ln((z\ ref)/0.002))$$

Where, V ref is the reference wind speed at reference height z ref. and V is the wind speed at any height z.

TABLE 1 Wind Loads

Height (m)	V_b (m/s)	k_2	V_z (m/s)	P_z (kN/m^2)	G x P_z (kN/m^2)
40	38	1.125	45.32	1.23	2.46
36	38	1.115	44.91	1.21	2.42
32	38	1.105	44.5	1.19	2.38
28	37	1.09	42.75	1.09	2.18
24	37	1.07	41.97	1.06	2.12
20	36	1.05	40.07	0.96	1.92
16	36	1.026	39.15	0.92	1.84
12	36	0.996	38	0.87	1.74
8	33	0.98	34.28	0.71	1.42
4	33	0.98	34.28	0.71	1.42

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5.2 Antenna Load

Both the pole and lattice structures are subjected to same antenna loads and the deflection behavior is compared. There are 4 nos. of GSM antennae of size 2.6m x 0.3m and 4 nos. of CDMA antennae of size 2.5m x 0.26m. The wind load due to these antennae on the pole and lattice structure is calculated based on the exposed area of the antenna.

TABLE 2 Antenna Loads

Item	Quantity	Size (m)	Weight (kg)	Location from base (m)	Total load (kN/m^2)
CDMA	2	0.26x2.5	20	40	0.615
CDMA	2	0.26x2.5	20	36	0.615
GSM	2	0.3 x 2.6	25	34	0.641
GSM	2	0.3 x 2.6	25	28	0.641

5.3 Effect of Wind on Monopole Towers

As per the previous studies it is found that wind pressure is the chief criterion for the analysis of towers. Majority of the tower failures were due to the effect of wind loads. Inorder to study the effect of wind on monopole towers, it was analysed under two different wind loads. The basic wind speed 33m/s was increased to 39m/s while keeping all other coefficients as constants.

6. RESULTS AND DISCUSSIONS

6.1 Defection

For monopole towers, deflection should be less than 5% of the tower height. Deflection of towers after analysis is tabulated. The results are within the permissible results.

TABLE 3 Deflection Results for 33m/s

Thickness	35m Tower	40m Tower
20	0.43	0.55
22	0.39	0.51
25	0.36	0.46

TABLE 4 Deflection Results for 39m/s

Thickness	35m Tower	40m Tower
20	0.59	0.76
22	0.55	0.7
25	0.51	0.64

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6.2 Yield Stress

It is defined as the stress at which a material begins to deform plastically. Prior to the yield point the material will deform elastically. Knowledge of the yield point is vital as it generally represents an upper limit to the load. Yield stress of the tower material is 350 MPa. All the stresses developed should be within the limit of yield stress.

TABLE 5 Stress Results for 33m/s

Thickness	35m Tower	40m Tower
20	81.3	87
22	74.23	80
25	65.76	70.8

TABLE 6 Stress Results for 39m/s

Thickness	35m Tower	40m Tower
20	113	120
22	103	110
25	92	97.5

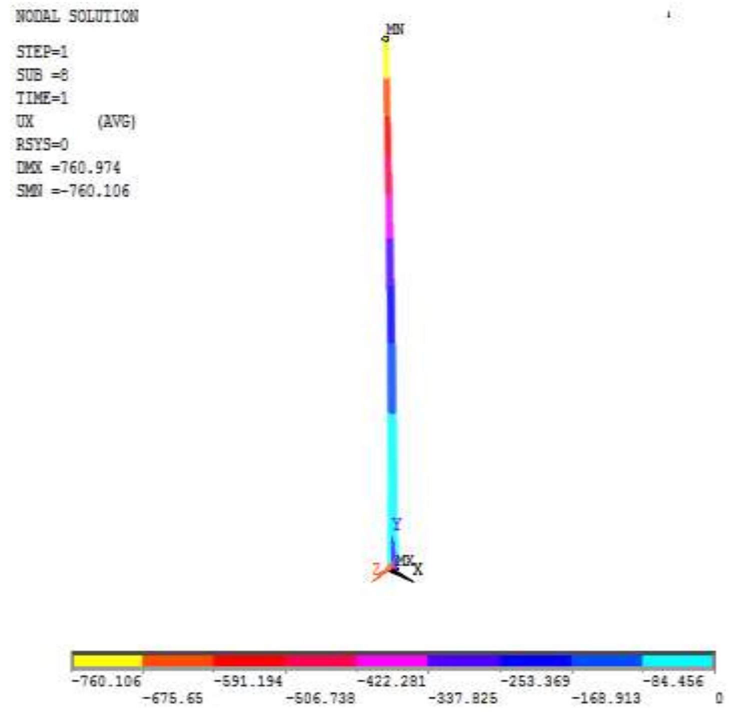

Fig. 4. Deflection contour of 40m tower with 20mm shell thickness

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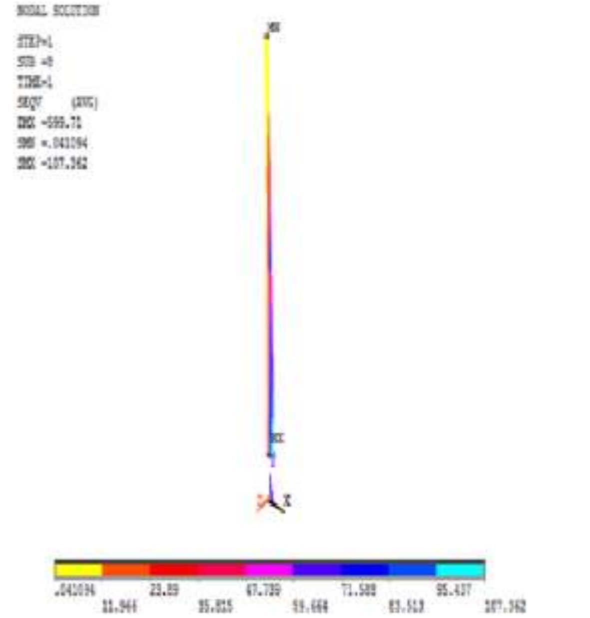

Fig. 5. Deflection contour of 35m tower with 20mm shell thickness

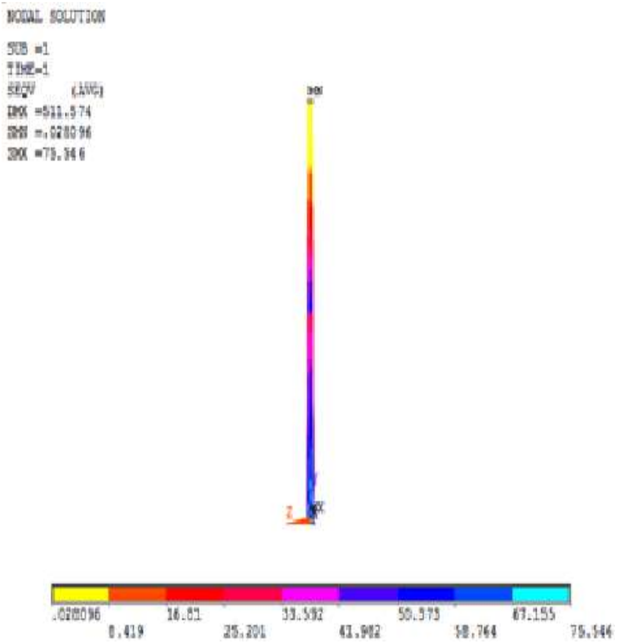

Fig. 6. Von mises stress contour of 40m tower with 20mm shell thickness

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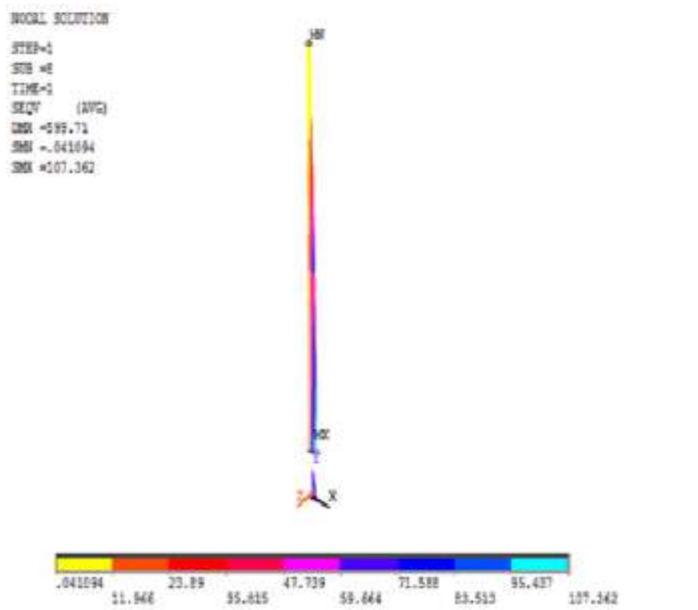

Fig. 7. Von mises stress contour of 35m tower with 20mm shell thickness

CONCLUSIONS

Steel poles structures are used in different fields. These have smaller plan dimension and are composed of only few components. These are more economical considering the cost of land. Structure was modeled in ANSYS. Load calculations were done as per IS codes. Gust factor method was adopted inorder to include the dynamic effects. Displacements and stresses were obtained within the permissible limits. Variation in the results with change in thickness was studied. Wind effect was studied by analysing the same structure to an increased wind load. Towers of two different heights were taken for the study.

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REFERENCES

i. B.M. Broderick , “Simple models for natural frequencies and mode shapes of towers supporting utilities”, Department of Civil, Structural and Environmental Engineering, Trinity College, Dublin, 18 April.

ii. B.Lanier, “Behavior of steel monopoles strengthened with high-modulus CFRP materials”, Journal of thin walled structures, 2009.

iii. Bryan Keith, Study "In The Improvement In Strength And Stiffness Capacity Of Steel Multi-Sided Monopole Towers Utizling Carbon Fiber Reinforced Polymers As A Retrofitting Mechanism", North Carolina, State University,

iv. Daniel Horn, "Design of Monopole Bases", Technical Manual 1, AISC.

v. Jeneevan, "Strength Assessment Of Steel Towers", Department of Civil Engineering, 2011C.

vi. J. Kaufman, Rocky Mountain Research Laboratories, Boulder, Colo., personal communication, 1992.

vii. R. P Rokade, "Comparative studies on conventional monopole and microwave towers", Structural Engineering Research Journal, 05 August 2011.

viii. Shen-En Chen, "Modal characteristics of two operating power transmission poles", Department of Civil and Environmental Engineering, University of North Carolina, 2010.

ix. Siddesha.H, "Wind Analysis of Microwave Antenna Towers", International Journal Of Applied Engineering Research,Volume 1, No 3, 2010.

x. Vikaskumar Pandey, "Influence Of Telecommunication Tower On Response Of Host Structure", International Journal of Students Research in Technology & Management Vol 1 (05), September 2013, pg 489-498.