Comparative Study of Three Pole Structure with Steel and FRP using Finite Element Analysis

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Abstract: ***Three pole structures are usually placed on the roof top of the building in order to enhance network coverage. Today`s world every structure started changing to composite due to its less weight and reliability. Orthotropic property of the composite material plays the vital role in determining the strength of composite structure. The modeling of a three dimensional three pole structure done in CATIA V5R21.Then it is imported to ANSYS. This study intend to implement the finite element analysis via software (ANSYS) to simulate the structure that are subjected to dead load (self-weight and communication system weight) and wind load which are apparent at high rise building. The analysis of structure with steel and FRP done in this software (ANSYS) and compare the results.***

Keywords: Three pole structures, Orthotropic property, CATIA V5R21, ANSYS, FRP

1. Introduction

Today`s world every structure started changing to composite due to its less weight and reliability. Structural poles carrying lighting fixtures and traffic signs as well as those supporting power and communication lines are traditionally made of timber, metals and steel-reinforced concrete. However, corrosion and aging problems deteriorate their structural integrity and architectural appearance. Recently, the tubes made of Fibre Reinforced Polymers (FRP) with their non-corrosive nature and high strength to weight ratio have been a favorable option for structural poles. Yet, the back ground about their structural behavior, in general, and their performance under seismic conditions, in particular, is quite limited. In this paper the structural behaviour of three pole mast structure with steel and FRP material are studied and compared.

2. Components of the Three Pole Structure

The components of three pole structure are shown below

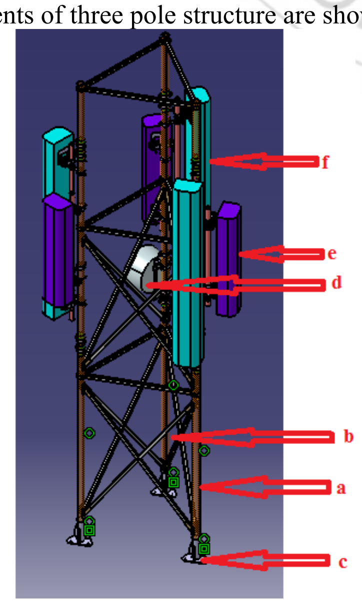

Figure 1: Components of the Three Pole Structure

a) Poles
b) Bracings
c) Triangular base frame
d) Micro wave antenna
e) 3G antenna
f) 2G antenna

3. Material Used

Steel and Fibre Reinforced Polymer(FRP) are used for the structure .All clamps are SS 316.The coupler is Aluminum FRP has high weight-strength ratio, noncorrosive nature and low weight.

Table 1: Material properties

S.I. No.	Material	Young's Modulus (MPa)	Poisson's Ratio	Density (kg/m^3)
1	SS 316	193000	0.279	8000
2	Aluminum	69000	0.334	2700
3	FRP	17926.376	0.33	1937.6

Table 2: Orthotropic Stress Limits of FRP

Tensile Stress (MPa)			Compressive Stress(MPa)			Shear Stress (MPa)		
36	36	405	140	140	158	31	31	31

4. Load Calculation

Loads considering in the analysis are dead load and wind load. The self-weight of structure excepting the antennas are applied as gravity.

4.1Self Weight of Antennas

3G Antenna-10kg=98.06N
2G Antenna-20kg=196.12N
MW Antenna-15kg=147.09N
The wind is acting in Y direction. Effect of wind on each component of the structure is calculated below. For that the projected area is calculated .Projected area of each component

$3G_1$=0.587m^2
$3G_2$=0.375 m^2
$3G_3$=0.587m^2
$2G_1$=0.958m^2
$2G_2$=0.945m^2
$2G_3$=0.958m^2
Micro Wave Antenna=0.945m^2
Tower=0.945m^2

4.2 Basic Wind Speed

Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean heights above ground level in an open terrain. Basic wind speed for some important cities/towns is also given in IS Code [3].

4.3 Design Wind Speed

The basic wind speed (Vb) for any site shall be obtained from IS code [3] and shall be modified to include the following effects to get design wind velocity at any height (Vz) for the chosen structure:
a) Risk level
b) Terrain roughness, height and size of structure; and
c) Local topography.

It can be mathematically expressed as follows:

$$V_z = V_b\ k1\ k2\ k3 \quad (1)$$

Where,
Vz = design wind speed at any height z in m/s
k1 = probability factor (risk coefficient)
k2 = terrain, height and structure size factor and
k3 = topography factor

$$\text{Drag Force, DF} = \frac{1}{2}\rho {V_z}^2 A C_d \quad (2)$$

Density of air =1.22kg/m^3
C_d=Drag coefficient=1.2

Table 3: Drag Force due to 39m/s wind speed

Unit	*Area(m^2)*	*Drag Force(N)*
2G 1	0.958	1066.6104
3G 1	0.587	653.54936
2G 2	0.945	1052.1305
3G 2	0.375	417.5145
2G 3	0.958	1066.6104
3G 3	0.587	653.54936
M W Antenna	0.283	315.08428
Tower	5.402	6014.4355

5. Finite Element Analysis

The static analysis is performed by using three-dimensional (3D) finite element models created with Finite Element Analysis (FEA) program ANSYS. In static analysis dead loads and wind load is considered. The analysis results includes Von Mises stresses, deformations and shear stresses

Fixed boundary conditions are assumed at the lower end of the three poles for all analyses. The yield strength of the FRP material and SS 316 is 40MPa and 206MPa respectively.

6. Result

Case 1 Three Pole Structure with Structural Steel

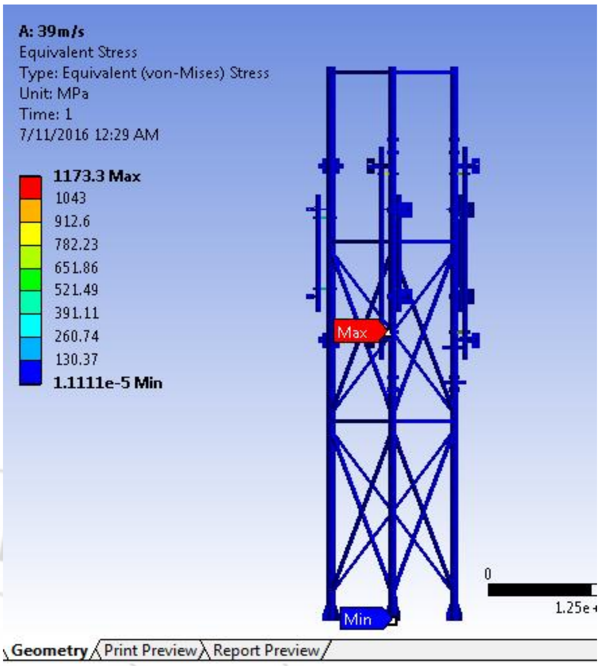

Figure 2: Von-Mises Stress Plot for the Whole Assembly

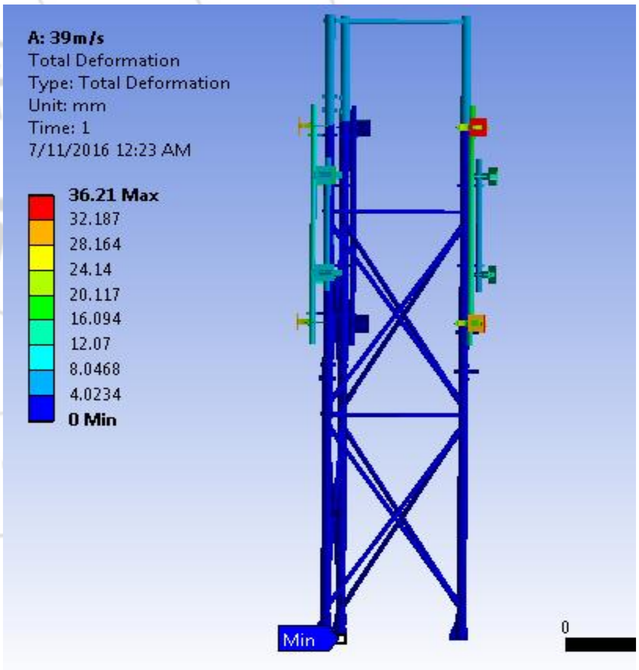

Figure 3: Deformation Plot for the Whole Assembly

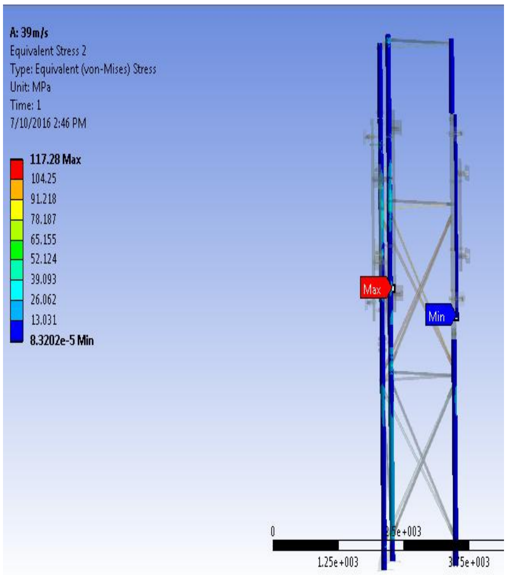

Figure 4: Von-Mises Stress Distribution for the Pole alone

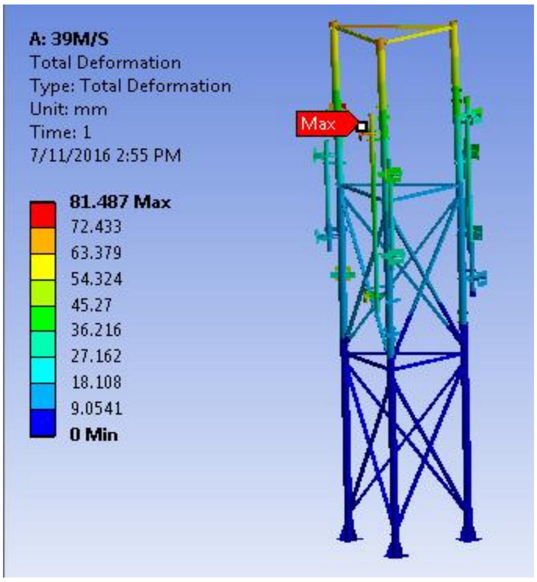

Figure 7: Deformation Plot for the Whole Assembly

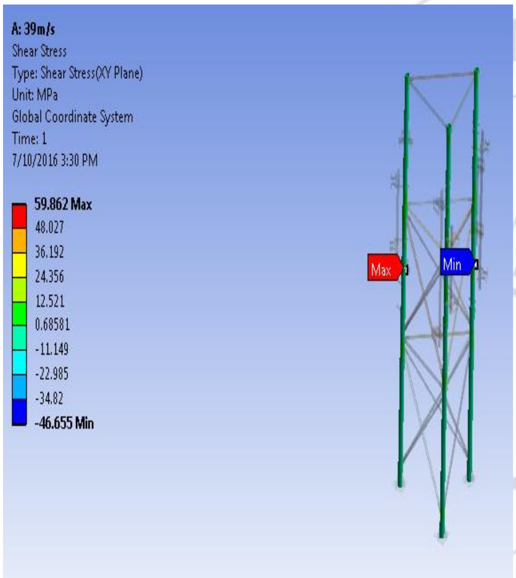

Figure 5: Shear Stress Plot (XY Plane) for the Pole alone

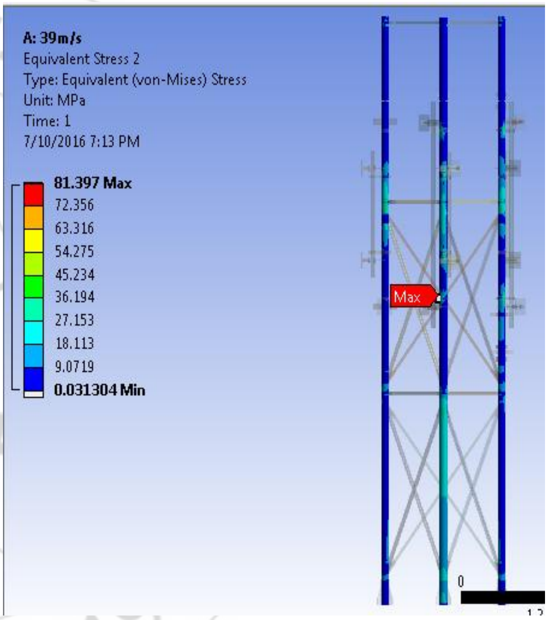

Figure 8: Von-Mises Stress Distribution for the Pole Alone

Case 2 Three Pole Structure with FRP

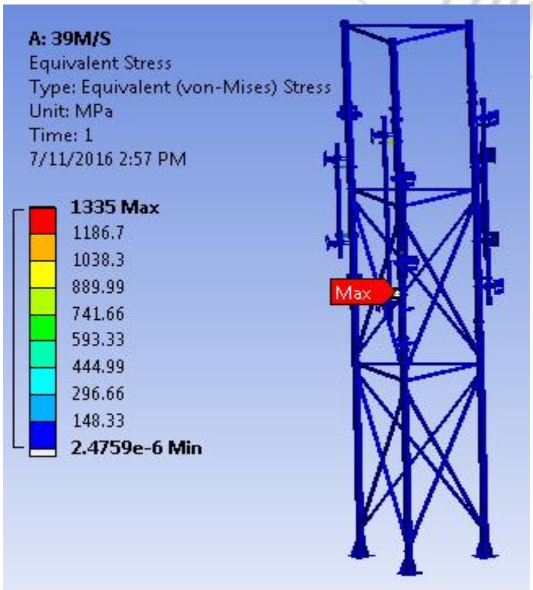

Figure 6: Von-Mises Stress Plot for the Whole Assembly

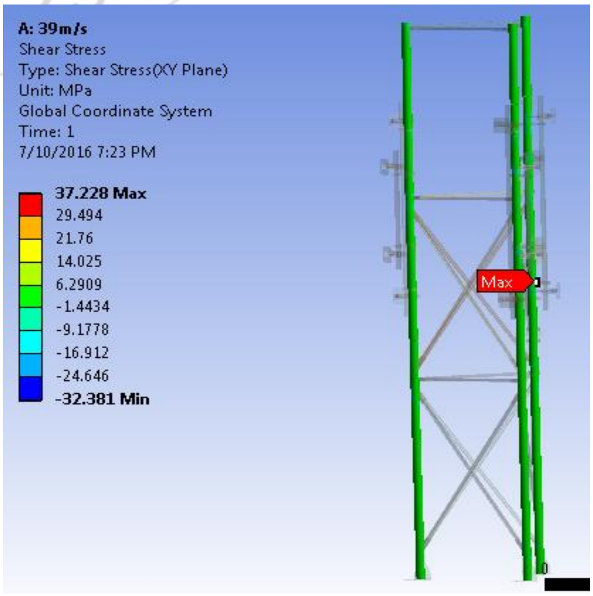

Figure 9: Shear Stress Plot (XY Plane) for the Pole alone

7. Conclusion

From the analysis results it is found that the maximum stress in case of steel structure 1173.3Mpa is at the clamps that connect the main pole with the adjacent small pole and it is found that the maximum stress of 1335 Mpa is at same point in FRP structure. The maximum deformation is 36.21 mm and 81.487 mm at 3G antenna clamp in steel and FRP structure respectively. From the Stress Distribution plot for the three Pole alone the maximum stress is at the clamps that connect the main pole with the adjacent small is 117.29 Mpa and 37.228 Mpa in steel and FRP structure respectively. From the shear stress plot on the pole alone in XY plane, the maximum shear stress of 59.862 Mpa occurs at the 3G clamp in steel structure. And the maximum shear stress of 28.337 Mpa occurs at the 3G clamp in FRP structure.

From this it is concluded that the stress distribution along the pole is very minimum compared with the whole three pole assembly. The clamps that connect the main pole with the adjacent small pole is having the maximum stress, which to be strengthened or altered. Only Very small portions of all other Clamps (2G, 3G, star clamps, bracing clamps, aluminum coupler clamps) are over stressed and can be neglected.

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