# Finite Element Analysis of A Segment of Fiber Reinforced Polymer Guyed Tower

**Sangam Yadav[1], Yatendra Saraswat[2], Hemant Singh Parihar[3]**

***Abstract*: The trending demand and necessity of telecommunication towers it is required to keep analysing the guyed towers with different materials and cross-section to get efficient sustainability. This research work involves the analysis of an 8.6m segment with guys as a bottom segment of telecommunication guyed tower made up of Fiber-reinforced polymer. In this research, the analysis is performed for FRP material with 40.6% and 65% fiber volume fraction to get the comparative results regarding deformation, stresses and strains. In this study, the guyed segment is analysed for Darbhanga location of India that has higher wind intensity according to IS code of wind loads 1987 part-3 by using Finite Element Analysis on ANSYS workbench. After performing analysis we conclude that the deformation occurred in guys, and stresses and strains can be seen in segment only after applying wind load on one face of a segment upto 8.6m height. The results obtained confirm that the segment made up of FRP with 65% fiber volume fraction is demonstrating viable results as compared to 40.6% fiber volume fraction.***

***Key Words: FRP, ANSYS Workbench, Finite Element Analysis, Fiber volume fraction, Telecommunication guyed tower.***

## I. INTRODUCTION

During the past few decades, a number of researchers have investigated the behaviour of steel guyed cable structures. Corrosion takes place in conventional steel that leads to deterioration of structure and FRP is the provision to such type of materials due to its corrosion resistive, light weighted, easy installation and other advantageous properties over steel. In this research, an 8.6m guyed segment of monopole structure is analysed by the finite element method on ANSYS [1]. In this study, the fiber reinforced polymer guyed tower is analysed for FRP with 40.6% and 65% fiber volume fraction. The material properties for 40.6% and 65% fiber volume fraction are taken from the polyzois research, in his research he had performed the burn-off test and coupon testing to estimate the mechanical properties of the material [2]. And the cross-section of the tower segment is also defined on the basis of previous researches to get efficient results with fiber reinforced polymer material by polyzois [3]. In this research the analysis is done for Darbhanga city of India that have higher wind load intensity according to IS : 875 (part 3)-1987 [4]. The goal of the study is to explore the effects for material FRP with fiber volume fraction 40.6% to 65% on various structural analysis output quantities such as displacement, von-misses stress and von-misses strain.

Here in figure 1 we have the cross-section of the segment that has taken on the basis of D. Polyzois research [3], he analysed the 81m FRP guyed tower with this cross-section and geometry on ANSYS apdl to get efficient results. In this study a segment of 8.6m height with guys is analysed on ANSYS workbench, the guys attached as line bodies of stainless steel material and the solid body of the tower made up of FRP. The connections and supports made in the tower in ANSYS workbench are, at the base the segment is supported by displacement supports and the set of three guys is fixed to ground and vertices of the tower.

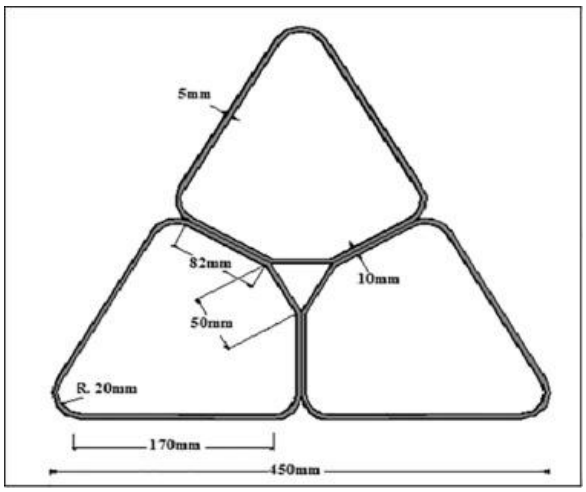


**Fig.1.** Triangular cross-section of the segment.

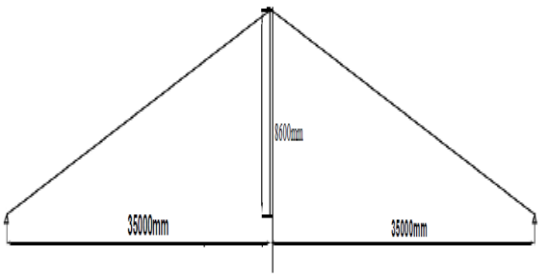


**Fig.2.** Elevation of the guyed segment.

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## II. MATERIAL PROPERTIES

The guyed tower is analysed for FRP and the mechanical properties of FRP with fiber volume fraction 40.6% and 65% is defined from study of D. Polyzois 2017 [2], in his research he has been defined the mechanical properties for material FRP with fiber volume fraction 40.6% and 65% after performing burn off test and coupon testing. The material properties and their coefficient of variations are given below in table1.

**Table 1.** Properties of FRP material.

| Property | Mechanical Properties at $V_f$ = 40.6% (obtained through coupon testing using ASTM material standard) | Coefficient of Variation (%) (Obtained through testing) | Mechanical Properties at $V_f$ = 65% (Obtained using various equations) |
|---|---|---|---|
| $E_1$ (GPa) | 29.67 | 1.4 | 47.71 |
| $E_2$ (GPa) | 7.31 | 2.9 | 7.38 |
| $G_{12}$ (GPa) | 2.21 | 14.8 | 4.15 |
| $\vartheta_{12}$ | 0.29 | 5.79 | 0.30 |
| ρ (g/mm$^3$) | 0.00173 | – | 0.0022 |

## III. CALCULATION OF WIND PRESSURE

The calculation of wind pressure for location Darbhanga according to IS-875 (Part-3) clause 6.3 [4] is given below:

Location = Darbhanga

$V_Z = V_b k_1 k_2 k_3$

$P_Z = 0.6 V_Z^2$

Where,

$V_b$ = wind speed (55 m/s) for Darbhanga

$V_Z$ = design wind speed at any height z in m/s

$k_1$ = probability factor (risk coefficient)

$k_2$ = terrain, height and structure size factor

$k_3$ = topography factor

$P_Z$ = design wind pressure in N/m$^2$ at height z

Here, z = 8.6m then calculated $P_Z$ = 1753.10 N/m$^2$

## IV. MODELLING AND LOADING

For getting accurate results of the analysis, the Finite element software ANSYS Workbench is used. The highlights and details for modelling and load application are explained here.

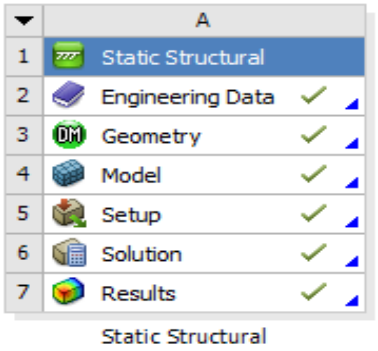


**Fig.3.** Schematic chart of analysis.

### A. Modelling

The schematic procedure for Finite element analysis of 8.6m segment on ANSYS Workbench is given below:

Step-1: Preparation of geometry

Step-2: Connections

Step-3: Meshing

Step-4: Boundary conditions and load application

Step-5: Solutions and results.

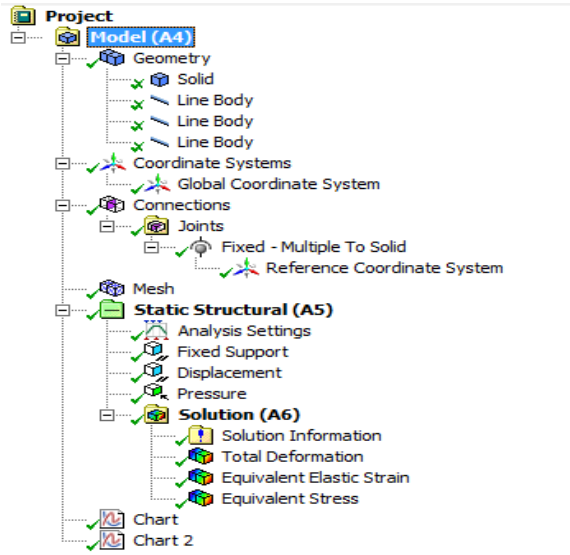


**Fig.4.** Schematic procedure

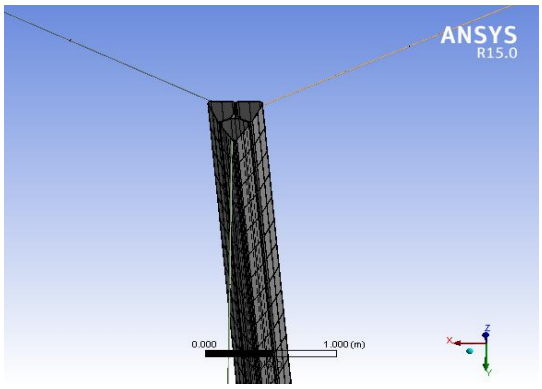


**Fig.5.** Meshing

### B. Loading

As we calculated above acc. To IS-875(part-3) clause 6.3 [4]the designed wind pressure for location Darbhanga is 1753.10 N/m$^2$. To check the sustainability of FRP guyed tower segment with fiber volume fraction 40.6% and 65%, the analysis is done for one of the highest wind speed location (Darbhanga) in India.

1. The guys are fixed to the ground surface.
2. The base of the tower is supported as ( X=0, Y=0, Z=free).
3. The Pressure of 1573.10 N/m$^2$ is acting normal to the face of the tower.

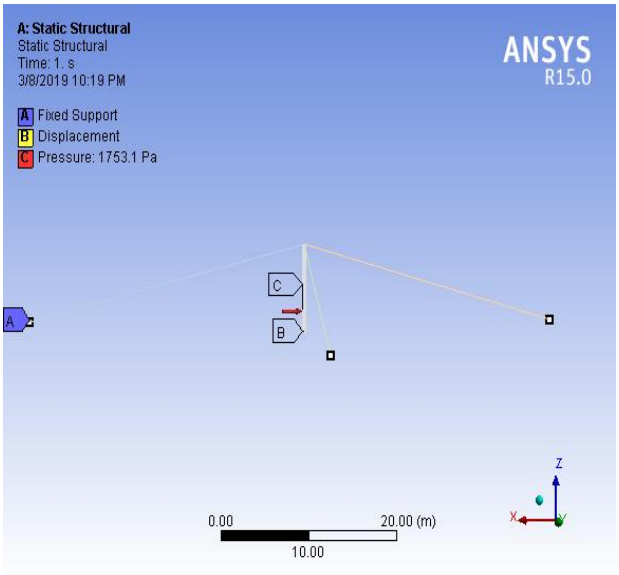


**Fig.6.** Representation of loading and boundary conditions.

## V. RESULTS AND COMPARISON

Several results are available after simulation of fiber reinforced polymer guyed tower segment with 40.6% and 65% fiber volume fraction for Darbhanga location in ANSYS workbench. The main focus was the total deformation, equivalent von-misses stress and equivalent elastic strain.

**Results obtained are as follows:-**

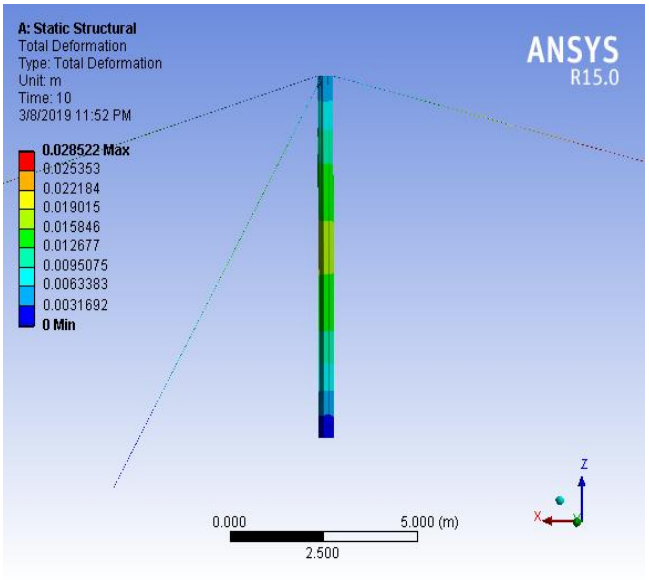


**Fig.7.** Total deformation in 40.6% $V_f$ guyed segment.

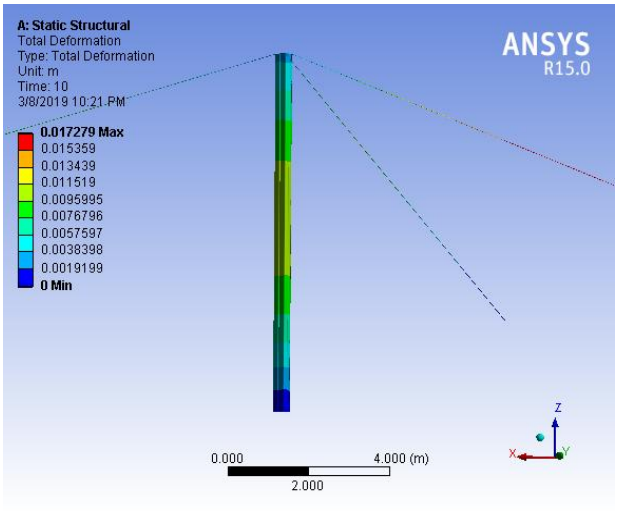


**Fig.8.** Total deformation in 65% $V_f$ guyed segment.

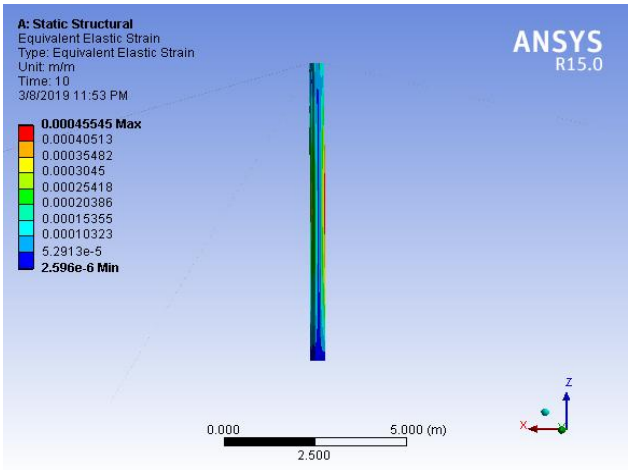


**Fig.9**. Equivalent elastic strain in 40.6% $V_f$ guyed segment.


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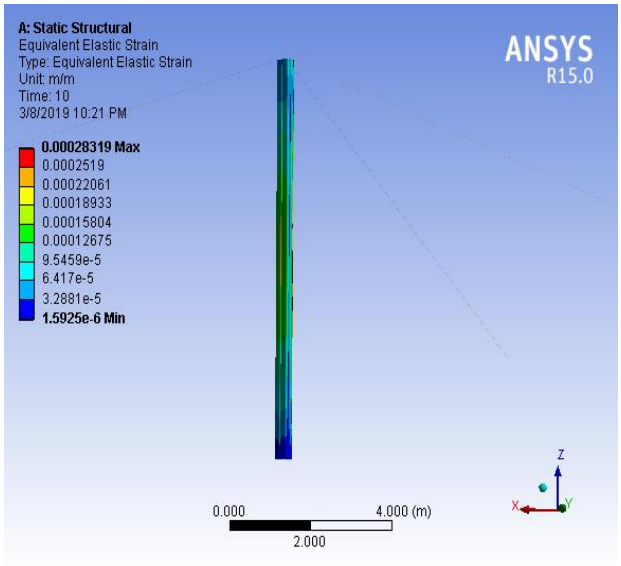


**Fig.10**. Equivalent elastic strain in 65% $V_f$ guyed segment.

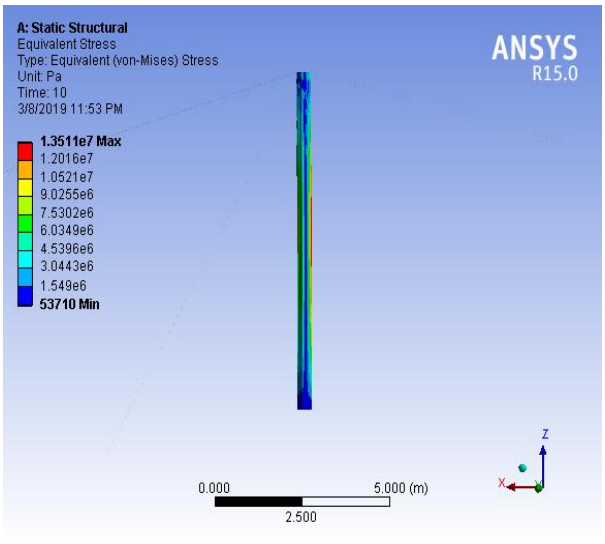


**Fig.11.** Equivalent stress in 40.6% $V_f$ guyed segment.

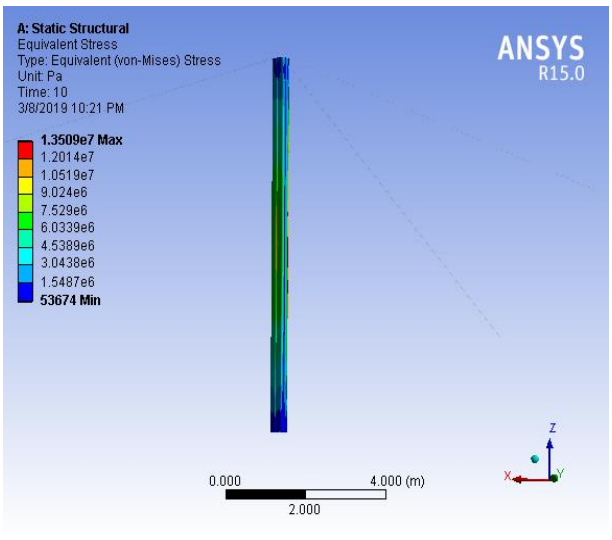


**Fig.12.** Equivalent stress in 65% $V_f$ guyed segment.

**Table 2.** The results are as follows:

| | FRP with 40.6% fiber volume fraction | | FRP with 65% fiber volume fraction | |
|---|---|---|---|---|
| | In guys | In segment | In guys | In segment |
| **Pressure (Pa)** | 1753.10 | | 1753.10 | |
| **Total deformation max (m)** | 2.852e-2 | – | 1.727e-2 | – |
| **Equivalent (von-misses) stress max (Pa)** | – | 1.3511e+7 | – | 1.3509e+7 |
| **Equivalent (von-misses) stress min (Pa)** | – | 53710 | – | 53674 |
| **Equivalent elastic strain (max) m/m** | – | 4.554e-4 | – | 2.8319e-4 |
| **Equivalent elastic strain (min) m/m** | – | 2.59e-6 | – | 1.5925e-6 |

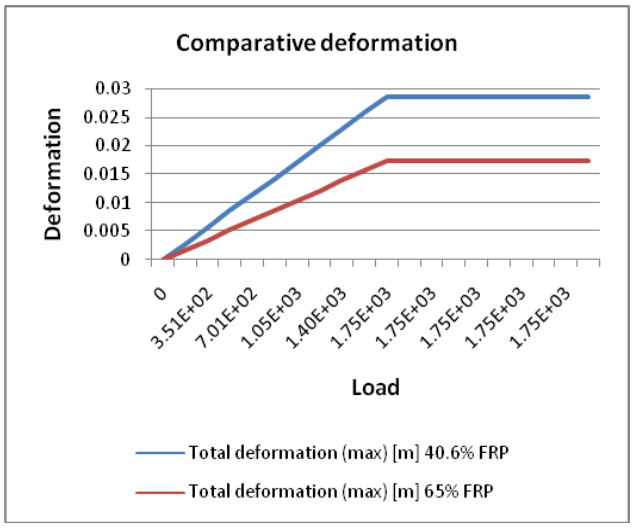


**Fig.13.** Comparative representation of deflection.

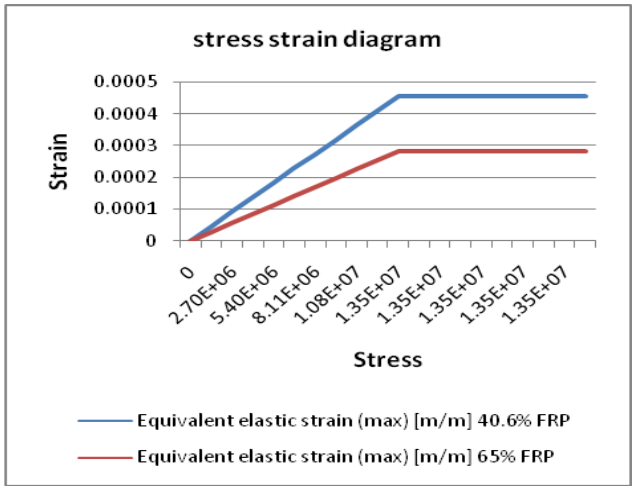


**Fig.14.** Comparative stress strain diagram.

## VI. CONCLUSION

On the basis of the above results, it is concluded that:

- Maximum deformation occurred in guys and equivalent von-misses stresses developed in the segment in both 40.6% and 65% fiber volume fraction.
- The deformations, stresses, and strains developed in the guyed segment of FRP with 40.6% fiber volume fraction are higher than 65% fiber volume fraction.
- The comparative results obtained for FRP with 40.6% and 65% fiber volume fraction declares that fiber reinforced polymer with 65% fiber volume fraction is showing more efficient and sustainable results.

So, considering these results we can estimate the mechanical behaviour of FRP guyed tower for the location with wind intensity similar or lesser to Darbhanga. It would be beneficial to use the FRP with 65% fiber volume fraction for future construction FRP guyed tower.

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