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Analysis Of Guyed Transmission Tower Under Wind And Seismic Loads

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***Abstract*—This paper presents the structural performance analysis of a guyed transmission tower under combined wind and seismic loading using STAAD.Pro software. The study considers different seismic zones based on Indian standards to evaluate displacement, stress distribution, and overall stability. Results indicate that the guyed tower exhibits minimum lateral displacement of 0.0013 mm, confirming its superior resistance against dynamic loads. The inclusion of guy wires effectively reduces bending moments and axial stresses in the main tower members, enhancing overall stability. Displacement values increase with seismic zone intensity, with the maximum observed in Zone V, demonstrating the influence of seismic activity on tower behavior. The analysis concludes that guyed towers are efficient for moderate-height installations, ensuring material economy and structural safety. The findings highlight the importance of proper guy wire tensioning, bracing, and joint detailing to achieve optimal performance under combined loading conditions.**

***Index Terms*—Guyed Transmission Tower, Wind Load, Seismic Load, Structural Stability, STAAD.Pro, Displacement Analysis.**

I. INTRODUCTION

Transmission towers form an essential part of power transmission infrastructure, supporting overhead conductors and maintaining the safe clearance of electrical lines under various environmental and mechanical loads. Depending on design requirements and site conditions, transmission towers are generally categorized into self-supporting and guyed types. Among these, guyed transmission towers are considered advantageous for moderate-height installations due to their lightweight design, reduced material consumption, and superior resistance to lateral loads. This makes them particularly efficient in regions where both wind and seismic forces are prominent. However, the structural response of guyed towers is complex due to the interaction between the tower frame and guy wires, especially under dynamic loading. Understanding the displacement pattern, stress distribution, and overall stability under combined loading conditions is crucial for ensuring safety and reliability. The present study focuses on the comparative analysis of a guyed transmission tower subjected to combined wind and seismic loading using STAAD.Pro software. The analysis is carried out as per Indian Standards (IS 875 and IS 1893) for different seismic zones. The findings provide valuable insights for optimizing the design parameters, member configuration, and guy wire arrangement, ensuring both structural efficiency and economic feasibility for power transmission applications in varying seismic conditions.

Fig 1: Guyed Tower

II. METHODOLOGY

The present study involves the structural analysis of a transmission tower using STAAD.Pro software to simulate and evaluate its performance under various loading conditions.

Geometry creation

The analysis was carried out using STAAD.Pro, following IS 875 (Part 3):2015 and IS 1893 (Part 1):2016. The model was developed as a three-dimensional lattice structure with appropriate geometric and material parameters.

Type: Guyed Tower Height: 25m

Base Width: 3m

Material: Structural Steel (Fe500) Section: ISA 200X200X25

Support: Fixed at Base

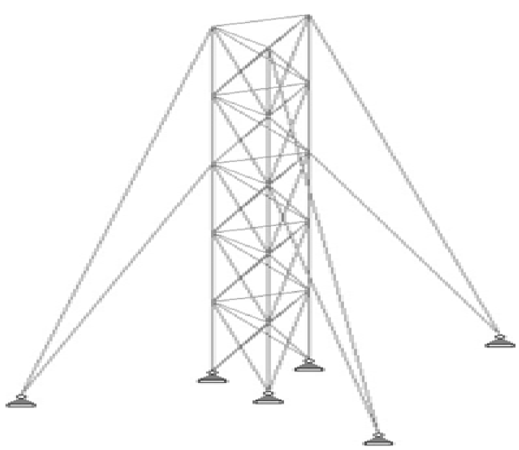

Fig 2: 3D Model of the Guyed Tower

Material Properties

The guyed transmission tower was analyzed using structural steel (Fe 500) in accordance with IS 800:2007 and IS 802:1995. The material properties considered in the analysis are: modulus of elasticity = 2.0×10^5 N/mm², Poisson's ratio = 0.3, density = 7850 kg/m³, and coefficient of thermal expansion = 12×10^{-6} /°C. The yield strength and ultimate tensile strength were taken as 500 MPa and 610 MPa, respectively. A damping ratio of 5% was adopted for seismic analysis as per IS 1893 (Part 1):2016. Tower members were modeled using ISA 200×200×25 angle sections of structural steel, ensuring adequate stiffness and strength under combined wind and seismic loading.

Loading and Analysis

The transmission tower was analyzed under the combined effect of dead, wind, and seismic loads as per IS 875 (Part 3): 2015 and IS 1893 (Part 1): 2016. The total load considered includes self-weight of members, wind pressure acting on tower surfaces, and equivalent static seismic forces. The structural model was created in STAAD.Pro as a 3D space frame with beam elements for tower members and cable elements for guy wires.

Self-Weight Modelling in STAAD.Pro

In STAAD.Pro, the self-weight of the structure is incorporated automatically through the self-weight command within the dead load case. After completing the geometry modelling, assigning material properties, and defining member sections, STAAD computes the weight of each structural member based on its volume and the density of the assigned material. For steel structures, the density is predefined in the software library.

LOAD 1 DEAD LOAD SELFWEIGHT Y -1

Overall, using the self-weight command provides a clean, reliable, and consistent method for modelling the dead load of a transmission tower in STAAD.Pro, making it highly suitable for analytical accuracy in engineering research and practice.

Live Load

Live load on transmission towers is specified in IS 5613, which provides uniformly distributed load (UDL) values to be considered on tower members for design and analysis. For guyed towers, live load represents temporary forces such as maintenance loads or additional service loads acting along the length of the member. The live load is treated as a uniformly distributed load applied over the effective length of the tower leg.

According to IS 5613, the UDL on the tower leg is taken as:

$w=10$ kN/m

For a tower leg of length:

$L=25$ m

the total live load acting on the member is calculated using:

$W=w\times L$

Substituting the values:

$W=10$ kN/m×25 m $W=250$ kN

Thus, the total live load considered for the guyed tower leg is 250 kN, applied as a uniformly distributed load along the 25 m length of the member. This value is incorporated in the load case for live load during the structural analysis in STAAD.Pro.

Wind Load

The design wind speed at height z was obtained using:

$V_z = V_b\, k_1\, k_2\, k_3\, k_4$

where Vb = basic wind speed (as per IS 875 map), k1 = risk coefficient, k2 = terrain and height factor, k3 = topography factor, and k4 = importance factor.

The design wind pressure was calculated from: $p_z = 0.6\, V_z^2$

The wind load was distributed as equivalent lateral forces on the tower nodes, proportional to the exposed area and pressure at each height. Dynamic gust effects were included through appropriate gust factors.

k1=1.07, k3=1.36, k4=1.30, Vb=44m/s

k2(Category 1)=1.13 Vz=87.90, Pd=4.36Kn/m^2

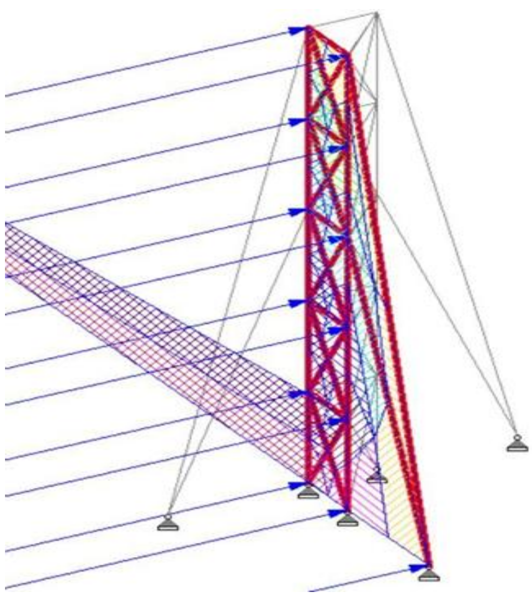

Fig 3: Wind Load in X+ direction

Temperature Load

The fundamental relationship between temperature change and axial elongation is:

$\Delta L = \alpha\, L\, \Delta T$

Rearranging to find temperature change: $\Delta T = \Delta L \alpha\, L$

Where:

ΔT = temperature change (°C) ΔL = change in length (m)

α = coefficient of linear thermal expansion (/°C) L = original length (m)

ΔT = 0.015/23×10^−6×25 23×10^−6×25 = 0.000575 0.015/0.000575 = 26.09∘C ΔT = 26.1∘C

That means a temperature rise of 26°C would cause the 25 m member to elongate by 15 mm.

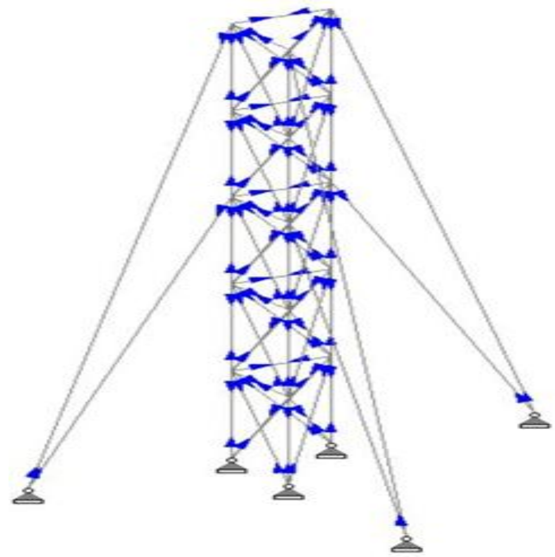

Fig 4: Temperature Load of the Structure

Seismic Load

Seismic forces were determined using the Equivalent Static Method as per IS 1893 (Part 1). The horizontal seismic coefficient is given by:

$A_h = Z\, I\, S_a / 2R\, g$

where Z = zone factor, I = importance factor, Sa/g = average response acceleration coefficient, R = response reduction factor.

The total base shear was computed as:

$V_b = A_h \times W$

where W is the total seismic weight. The lateral forces were then distributed along the tower height based on the mass and elevation of each node.

Table 1: Seismic Parameters taken into account

Seismic zone co-efficient	0.10
RF (Response Reduction Factor)	4 (typical for braced lattice steel towers)
I (Importance factor)	1.5
SS (Rock or Soil factor)	1
ST (Type of structure)	2 (Lattice Steel Tower)
DM (Damping Ratio)	5

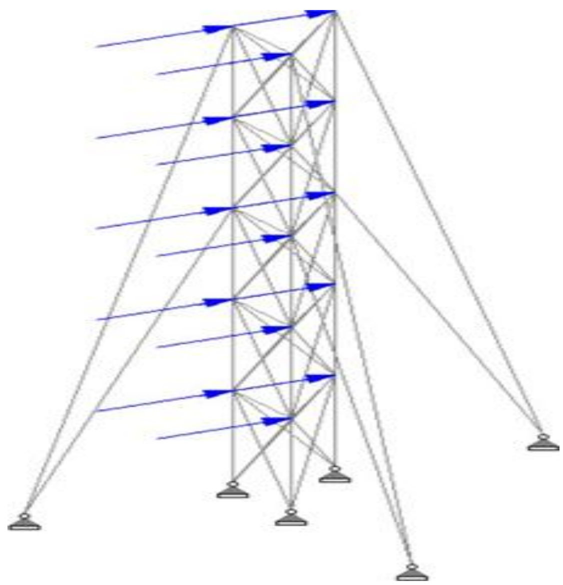

Fig 5: Seismic loads in the X direction acting on the structure

Load Combinations

The analysis considered the following load combinations:

1.5(DL+WL)

1.2(DL+WL+EL)

0.9DL±1.5EL

These combinations ensure that both ultimate strength and serviceability conditions are satisfied under combined actions.

Analysis

The transmission tower was analysed in STAAD.Pro under combined wind and seismic loading as per IS 875 (Part 3): 2015 and IS 1893 (Part 1): 2016. The complete 3D tower model was generated with appropriate material properties, member sections, and fixed-base supports. Dead load, live load, wind load, and seismic load were applied as per code requirements. Wind load was computed using design wind speed and pressure, while seismic load was assigned using the response spectrum method. After applying all loads, linear static analysis was performed to obtain member forces, bending moments, nodal displacements, and support reactions, which were used to evaluate the safety and performance of the tower.

Table 2: Maximum Values of Guyed Tower

Parameter	Maximum Value	Location (Node/Beam)
Maximum Bending Moment (kNm)	0	-
Maximum Shear Force (Kn)	422.793	Node 2
Maximum Axial Force (Kn)	279.803	Beam 2
Maximum Vertical Deflection (mm)	6.857	Node 14
Maximum Displacement (mm)	0.0013	Beam 28

Height Vs Displacement of Guyed Tower

The chart shows that the Displacement (mm) exhibits a robust periodic trend as a function of Height (m). It sharply alternates between a maximum value 0f approximately 0.0020 mm (at 10 m and 20 m) and a minimum value of 0.0010 mm (at 15 m and 25 m), thereby specifying regular height intervals for maximum and minimum movement.

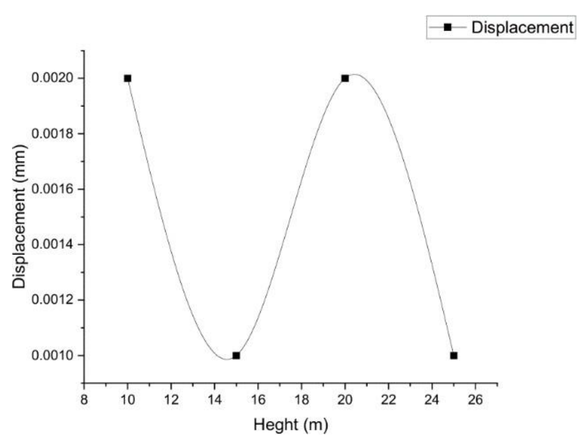

Fig 6: Variation of Height vs Displacement

Comparative Analysis of Guyed Transmission Tower under Different Seismic Zones (Zone II–V)-

In this section, the transmission tower will be evaluated under specific seismic levels related to Seismic Zone II, III, IV, and V according to IS 1893 (Part 1): 2016. This comparative analysis is performed with an objective to evaluate the structural performance and stability of the transmission tower with varying levels of earthquake hazard. Lateral displacement, base shear, and forces in the members were checked for the purpose of observing how level of seismic zone affects the response of the structure. This evaluation worth's to classify the transmission tower's safety and serviceability under various earthquake-prone areas.

Seismic Parameter Details

The seismic parameters used in Computing specified seismic loads acting on the structure are listed below:

Zone Factor (Z) as per IS-1893:2002 Part - 1, for different Zone as per clause 6.4.2.

Importance factor (I) – varies based on fundamental use. For this study, we have assumed I as 1.5.

Average Response acceleration Coefficient Sa/r - for hard soil site

Sa/g = 1+15T; 0.00 <= T <= 0.

2.50; 0.10 <= T <= 0.40

1.00/T; 0.40 <= T <= 4.00

Table.3: Seismic zone with zone factor

Seismic Zones as per IS 1893:2002(Part – 1)	Zone Factor
II	0.10
III	0.16
IV	0.24
V	0.36

Variation of Node Displacement of Guyed tower under different Seismic zones (zone ii–v)

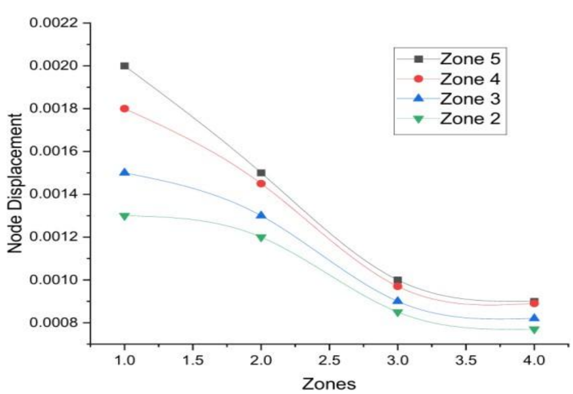

Fig 7: Variation of Node Displacement of Guyed Tower under Different Seismic zones (Zone II–V)

III. CONCLUSION

From the results, it is concluded that the node displacement of the guyed transmission tower increases with the increase in seismic zone intensity.

The analysis indicate that the Guyed Tower has the least displacement (0.0013mm), indicating the highest stability and shows that a guyed tower structure is more effective at resisting lateral loads (such as wind or seismic forces) due to the additional support provided by guy wires.

The most significant displacement is recorded in Zone V and the least is recorded in Zone II, highlighting the tendency for towers in higher seismic zones to experience larger lateral displacements due to greater ground motion. This highlights the need for enhanced structural stability and design considerations in higher seismic regions.

The study concludes that guyed towers are a reliable and economical choice for moderate-height transmission line installations. Proper guy wire tensioning, bracing, and joint detailing are essential to maintain optimal tower performance.

The minimum displacement of 0.0013 mm indicates that the guy-wire system effectively transforms lateral loads into axial tension, minimizing bending demand on tower legs.

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