Comparative study of transmission line tower with Staad-Pro Software

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Abstract- Transmission line towers (TLTs) carry high voltage electric power lines and conductors to keep a safe distance from the ground. These cables also carry very heavy currents, to the tune of several hundred amperes. The towers must withstand the weight of themselves and also endure strong winds and earthquakes. Transmission line towers are widely used for carrying electric power due to the growing need for electricity and the need to reduce environmental impact during production and transportation of electricity. Angle sections are the most widely utilized and dominant structural arrangement for transmission line towers. Channel, square tube, and pipe sections have many advantages over angle sections, including higher load-bearing capacity, structural integrity, uniform shape, and versatility. STAAD.Pro is used to simulate and analyses a transmission tower with two distinct heights (20 and 30 meters) and a combined X and K bracing system. All models consider the loads specified in IS 802 Part-1/sec 1: (2015) for each wind zone. The structures will be analyzed using different methods such as wind analysis, the linear static analysis (LSA), linear dynamic analysis (LDA) and nonlinear dynamic analysis (NDA). A comparison is made among different steel tower sections based on parameters such as joint displacement. This research helps bridge the gap between theory and real-world use, providing a better understanding of TLT's practicality and performance. The current study aims to compare and analyses transmission line towers made of different steel sections according to Indian standards and conditions. From this study we have concluded that the angle section is economic and resilient to withstand any type of load when compared to channel, hollow square and pipe section.

Keywords: Transmission line tower, Steel sections, Wind load, Linear static analysis (LSA), Linear dynamic analysis (LDA), Nonlinear dynamic analysis (NDA), STAAD.Pro

I. Introduction

Transmission line towers (TLTs) are tall structures of various sizes and shapes used for the transmission of high-voltage electricity. The demand for electricity is increasing worldwide, making electrical transmission towers essential for the transportation of electricity. The construction of transmission towers can account for 25-40% of the total project cost. The aim of this study is to reduce the amount of steel used to reduce costs while meeting the necessary strength requirements. The main focus is on optimizing the quantity, as other costs such as labor and transportation etc. are already fixed. When designing TLTs, it is important to take various factors into account. This includes cross-sections, ground clearance, insulation and conductor spacing etc. Transmission line towers (TLT) are also prone to earthquakes, so seismic design is essential for their structural integrity. Transmission towers can be designed and built in various shapes, types, sizes, configurations and materials

II. Reaserch Methodology

2.1 Numerical Modelling

A 3D moment resisting frame TLT structures with height of 20m and 30m were considered using finite element analysis-based software STAAD.Pro V8i. The structures of the study models under consideration are shown in the fig. no. 1 for 20 and 30 meters, respectively, and Table Nos.1 and 2 provide descriptions of their configurations. All the structures are check for lateral load by wind according to Indian standard (IS 875-Part III: 2015), (IS 802-Part 1-Section 1:2015). Seismic lateral loads calculated for all seismic zones as per IS 1893:2016. The members have been designed in accordance with the steel design code (IS 800:2007). The all steel sections designed considering elasticity E = 205 GPa, density ρ=7833.41 kg/m^3 and Poisson ratio ν = 0.3.

Table-1 General details of 20m TLT.

Tower type	Suspension Type
Circuit type	Double Circuit
Overall, height of tower	20m
Top cross arm width	6m
Bottom cross arm width	7.3m
Top cross arm height	18.2m
Bottom cross arm height	13.6m
Minimum ground clearance	10.5m
Vertical spacing of conductors	4.6m
Tower base width	4m
Insulator string size	225mm x 145mm
Insulator string length	2.3m
Ground Wire diameter	16mm
Type of bracing used	X & K
The Wire + Insulator disk dead load	6 Kn
The distance between two consecutive towers	150m
Angle Sections used	ISA100x100x8 & ISA 50x50x5
Channel Sections used	ISMC125H & ISMC75
Square Tube Sections used	TUB70703.3 & TUB35352.6
Pipe Sections used	PIP761M & PIP337L

Table-2 General details of 30m TLT.

Tower type	Suspension Type
Circuit type	Double Circuit
Overall, height of tower	30m
Top cross arm width	5.2m
Middle cross arm width	7.4m
Bottom cross arm width	9.4m
Top cross arm height	28.5m
Middle cross arm height	22.9m
Bottom cross arm height	17.6m
Vertical Spacing of Conductors	5.3m
Minimum Ground Clearance	14.9m
Tower base width	5m
Insulator string size	225mm x 145mm
Insulator string length	2.3m

Ground Wire Diameter	16mm
Type of bracing used	X & K
The Wire + Insulator disk dead load	6 Kn
The distance between two consecutive towers	150m
Angle Sections used	ISA120x120x15 & ISA 60x60x4
Channel Sections used	ISMC250H & ISMC75
Square Tube Sections used	TUB1101104.9 & TUB35352.6
Pipe Sections used	PIP1397H & PIP337H

The TLT design is mostly influenced by wind loads. In accordance with IS 802 (Part 1-Set 1): 2015, we have conducted wind load analyses on TLTs with various steel sections in all wind zones for this study. We also analyzed TLTs in each of the four seismic zones according to IS 1893 Part 1:2016. For the purpose of conducting a seismic study of a structure at any place, real-time historical records must be obtained. It's not possible to create data for every place, so these records are often missing. In these situations, response spectrum analysis is used. This approach calculates the maximum values of forces and displacements for each mode using specific design spectra. These spectra can be a useful tool for applying ground movements during earthquakes. A response spectrum shows the maximum response of a system for different natural frequencies. It can represent displacement, velocity, or acceleration. The primary drawback of RSA is that it is only generally recognized for linear systems. THA is used for nonlinear analysis. The study analyzed how TLT behaved in seismic zone 5 under different soil conditions which included soft, medium, and hard soil, with both linear and nonlinear aspects. IS 802 (Part 1-Set 1) is used for different load calculations and analysis of transmission line tower. For this study we have also considered different load combination for the analysis such as reliability, security (with broken wire), safety (construction and maintenance check) and anti-cascading load condition. Also, as per IS 802 (Part 1-Set 1): 2015 we have considered different failure containment load such as ant cascading loads, torsional and longitudinal loads and narrow front wind loads for the comparative analysis. IS 802 (Part 1-Set 1) is used for different load calculations and analysis of transmission line tower.

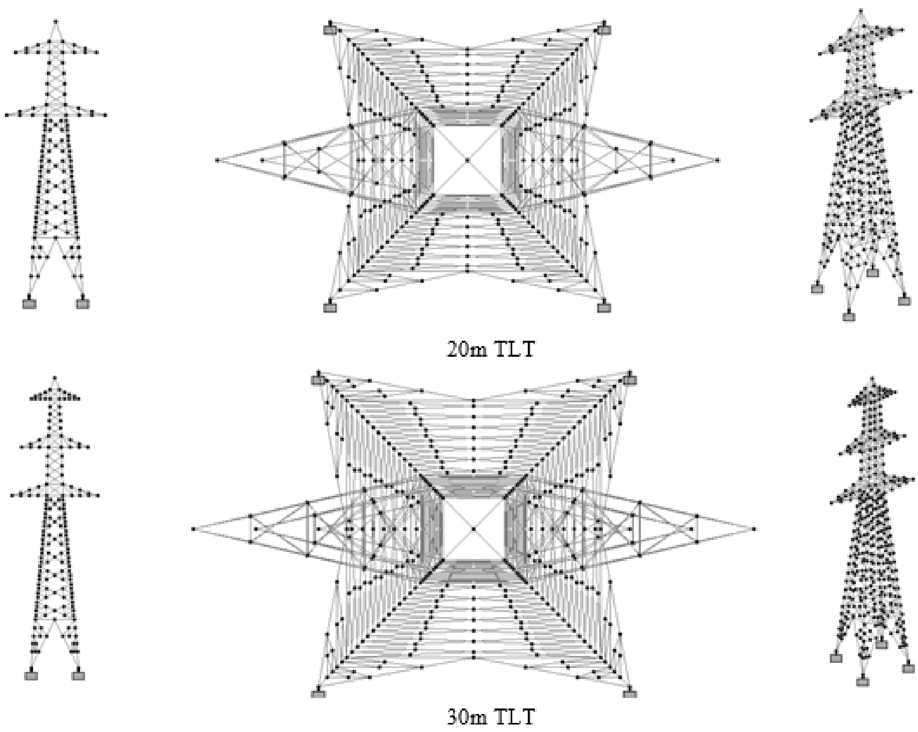
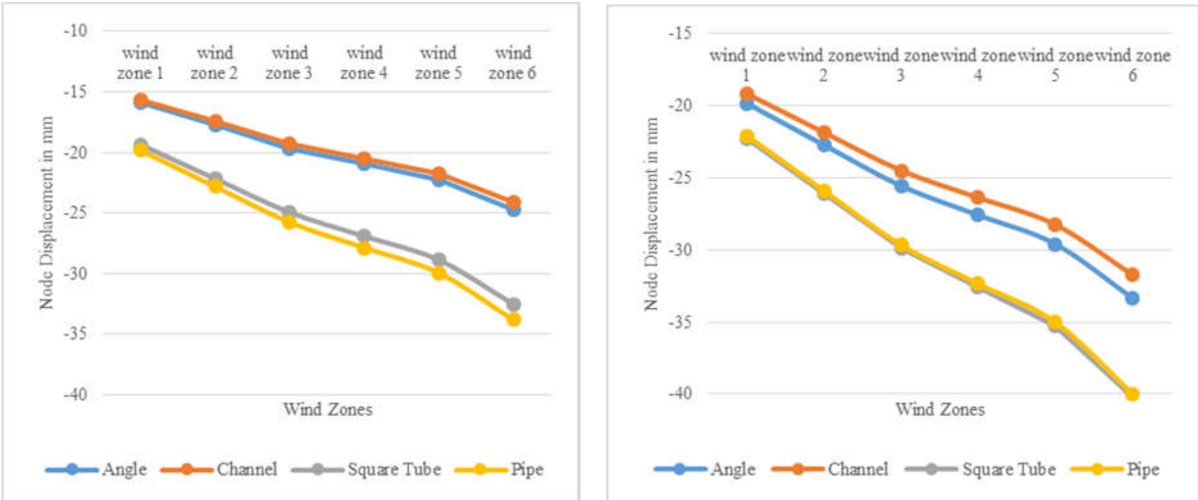


Figure 1. Bird eye view, elevation and plan of 20m and 30m TLTs.

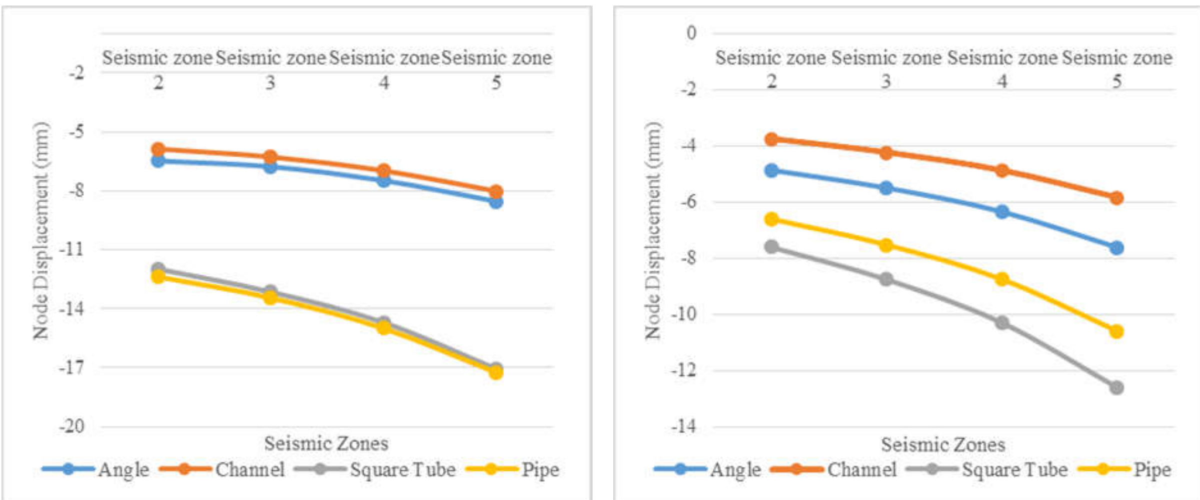
III. Experiment and Result

Node displacement analysis helps determine how a structure or component will deform under loads, ensuring that it can withstand the applied forces without failure. Excessive displacement may lead to material fatigue, cracking, or collapse. We can optimize designs by analyzing node displacements to ensure that they use materials efficiently. This analysis can help reduce weight, minimize material usage, and lower costs while maintaining safety and performance standards. By analyzing displacements, engineers can predict the areas where stresses are highest and ensure that materials are strong enough to handle them. Overall, understanding node displacement is key to ensuring the safety, efficiency, and longevity of structure.



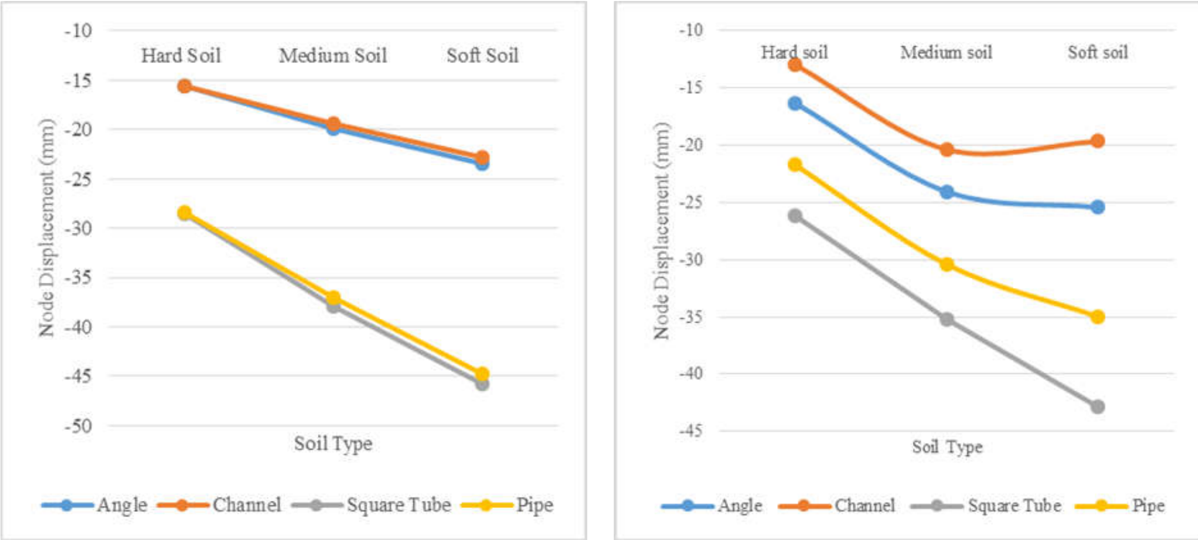
(a) (b)

Figure 2. Joint displacement in Y-direction (a) for 20m TLTs (b) for 30m TLTs due to wind analysis.



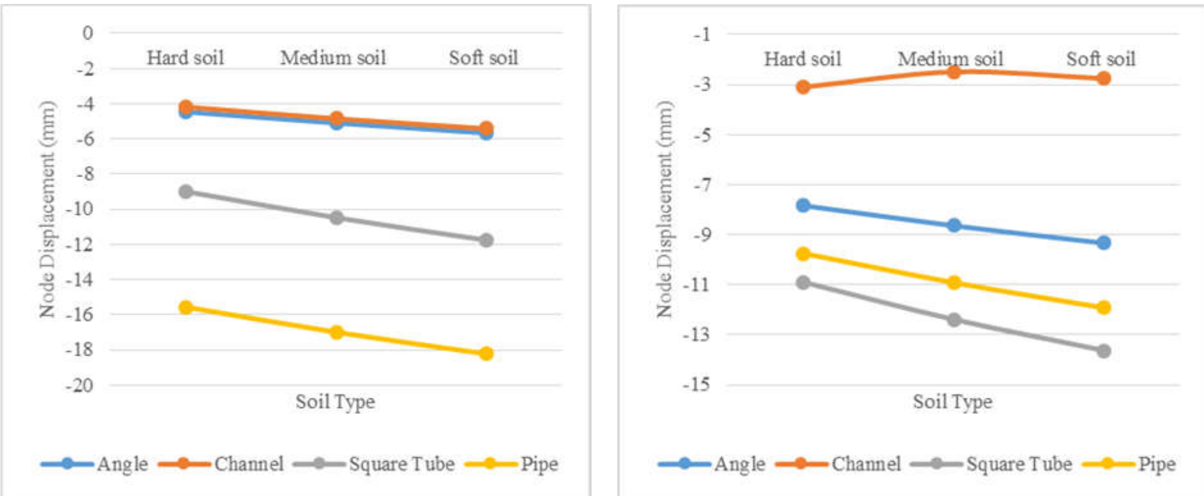
(a) (b)

Figure 3. Joint displacement in Y-direction (a) for 20m TLTs (b) for 30m TLTs due to linear static analysis.



(a) (b)

Figure 4. Joint displacement in Y-direction (a) for 20m TLTs (b) for 30m TLTs due to RSA.



(a) (b)

Figure 5. Joint displacement in Y-direction (a) for 20m TLTs (b) for 30m TLTs due to THA.

IV.CONCLUSION

This study investigates the comparative analysis of moment resisting frames for 3D transmission line tower structures with different steel sections. For this study, all wind zones as per IS 802 (Part 1-Set 1):2015 and all seismic zones as per IS1893 (Part 1):2016 were used. Wind analysis, static analysis, RSA, and THA were conducted for comparison, as per the guidelines. Crucial parameters like joint displacement, axial force, natural frequency, time period, base shear and self-weight are considered for comparison. This study has led to the conclusion that pipe and square tube sections are more venerable to joint displacement in all wind and seismic zones and in all soil conditions. Channel and angle sections exhibit reduced joint displacement

It can be seen in the data presented above that channel and angle sections are more effective and resilient to earthquake loads compared to square tube and pipe sections. But angle sections have an advantage in fabrication other than channel, square tube and pipes also it can be placed back-to-back to create virtual T-shape section. The study concludes that angle sections are more cost-effective and produce better results than other steel sections in all parameters.

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