Journal of Science and Technology
ISSN: 2456-5660 Volume 5, Issue 5, Sep-October 2020

www.jst.org.in *DOI: https://doi.org/10.46243/jst.2020.v5.i5.pp35-42*

Analysis and Design of Transmission Tower with Isolated Footing

Arya S[1], Er. Sindhu A R[2]
[1](Department of Civil engineering, Saintgits College of Engineering, Kerala, India)
[2](Department of Civil Engineering, Saintgits College of Engineering, Kerala, India)
[1]Corresponding Author: aryaas.jack@gmail.com

To Cite this Article
Arya S and Er. Sindhu A R, "Analysis and Design of Transmission Tower with Isolated Footing", Journal of Science and Technology, Vol. 05, Issue 05, Sep-October 2020, pp35-42

Article Info
Received: 02-05-22020 Revised: 25-07-2020 Accepted: 28-07-2020 Published: 05-08-2020

Abstract: *A transmission tower is a tall structure, usually a steel lattice tower used to support an overhead power line. They are used in high voltage AC and DC systems. Steel tower structure resting on footings are currently becoming popular in any geographical location for electrical transmission, microwave transmission etc. It is necessary to have an understudy of the behavior of such structures and provide an economical design. To understand the performance of such high rise structures, it is necessary to know their behavior considering the soil structure interaction. Modeling of Transmission tower for the validation purpose is done. The basic soil properties of laterite were also found accordingly. Here the entire transmission tower with the isolated footing is modeled and analyzed in STAAD Pro V8i and STAAD Foundation software. The total load transmitted to each tower leg is found using STAAAD Pro and the size of isolated footing under each tower leg is determined using the STAAD Foundation software respectively. If required the soil structure interaction effects (SSI) can also be found easily.*

Keywords*: Steel Tower, Lattice Tower, Isolated Footing, STAAD Pro V8i, STAAD Foundation*.

I. Introduction

A transmission tower or power tower (alternatively electricity pylon or variations) is a tall structure, usually a steel lattice tower, used to support an overhead power line. They are used in high-voltage AC and DC systems. They come in a wide variety of shapes and sizes [1]. Typical height ranges from 15 to 55 m, though the tallest are the 370 m. In addition to steel, other materials may be used, including concrete and wood. There are four major categories of transmission towers: suspension, terminal, tension, and transposition. Some transmission towers combine these basic functions. Transmission towers and their overhead power lines are often considered to be a form of visual pollution. Methods to reduce the visual effect include undergrounding. Steel tower structure resting on piles are currently becoming popular in any geographical location for electrical transmission, microwave transmission etc [4]. It is necessary to have an understudy of the behaviour of such structures and provide an economical design. To understand the performance of such structures, it is necessary to know their behaviour considering the soil structure interaction.

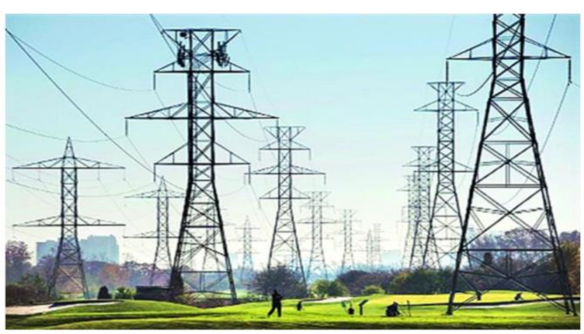

Fig no.1: Transmission Tower

II. Literature Review

An investigation on multi panel retrofitted steel transmission towers is conducted by Julie E Mills (2015) to evaluate its role in power transmission. Due to the increasing demands on power supply and telecommunication services, existing transmission towers are frequently being required to carry extra loads above their initial design limits. This paper addresses steel lattice transmission towers with main leg members retrofitted by steel angles through bolted double steel angle connectors, a method that is widely used in practice but to date with little experimental research to support it. Three unreinforced tower models and four groups of retrofitted tower models with and without preloading have been tested in the structural laboratories at the University of South Australia. The experimental results verify the effectiveness of the retrofitting method. Load sharing analysis shows that axial loads can be effectively transferred between original tower members and reinforcing members through the bolted-splice system. Preloading reduces the load sharing in reinforcing members in the early loading stage but does not have significant influence on the ultimate strength of the whole structure

A parametric study was carried out by Syed Jalaludeen et al. (2015) on steel tower structure resting on piles, which are currently becoming popular in any geographical location for electrical transmission, microwave mobile transmission etc. To understand the performance of such structures is necessary to know their behaviour considering soil structure interaction. In this work a steel tower structure resting on single pile at each leg and group of three piles embedded in soft, medium and stiff soil has been analysed to obtain their stresses and deformations. The modal analysis, static analysis and transient structural analysis considering the kobe earthquake has been considered. The result pointed out that the soil structure interaction is important and need to be accounted to reach a realistic understanding of such structures.

Chenghao et al. (2015) studied several things to meet the increased design loads from upgraded wind load standards and higher power demands, existing aging transmission towers are often in need of retrofitting. One effective way to increase the load carrying capacity of a tower structure is to reinforce its critical leg members through attaching additional elements with bolted cruciform connections. The effectiveness of the leg retrofitted method has been verified experimentally in both leg segments and tower systems. In his paper, a new modeling method for lattice transmission towers with retrofitted leg members was developed in STRAND 7 through the use of truss-beam elements to represent tower members, and spring elements to simulate bolted connections.

III. Methodology

The main supporting unit of overhead transmission line is transmission tower. In order to study the behavior of transmission tower under wind and seismic loading, the following steps are abided sequentially. Initially a validation process is carried out. Xing Fu et al (2019) in his paper (Fragility Analysis of Transmission Line subjected to Wind Loading) showed that neither structural properties nor wind loads are deterministic; accordingly, a fragility analysis of overhead transmission towers can be employed to comprehensively evaluate their strength capacity.

Here, a fragility analysis method for a transmission line under wind loading is developed that incorporates the uncertainties of structural parameters and wind loads into a numerical model. First, a simplified model with one tower and two span lines is presented to improve calculation efficiency; this model is validated via a comparison with a complete tower line system under both static and dynamic conditions. The exact tower was replicated in ANSYS and the deflection values were compared and made error free. Then the fragility analysis process for transmission towers subjected to wind loading is presented in three main steps: development of uncertainty models and wind loadings, nonlinear dynamic analysis, and regression analysis. Afterwards, the random variables and their corresponding probability distributions are determined. Finally, a case study of a real operational transmission tower under wind loading is carried out. The results indicate that the consideration of a greater number of uncertainty parameters leads to a greater dispersion of the fragility curve and that the wind attack angle has a significant influence on the fragility curve.

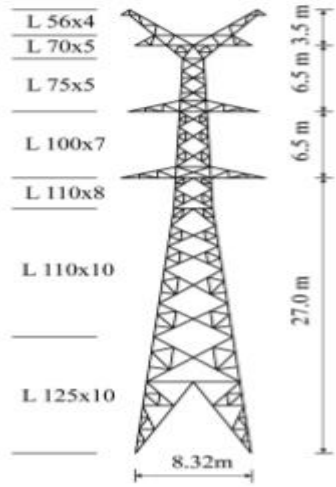

Fig no.2: Dimensions of Tower

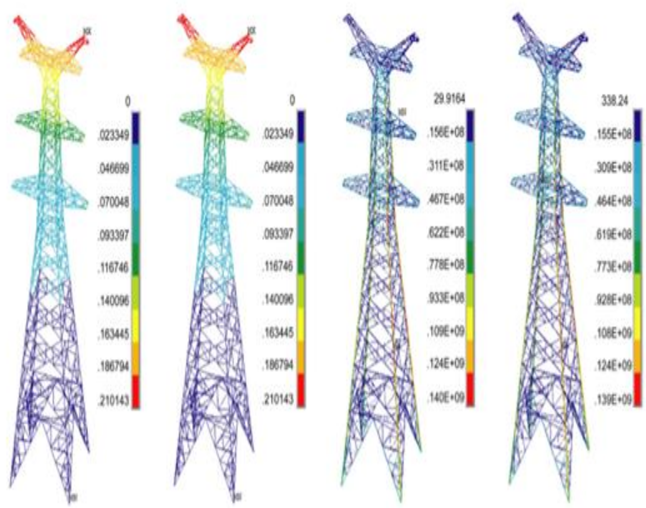

Fig no.3: Deflection and Stress plot

After validation the next step is the analysis and design of transmission tower along with isolated footing. STAAD or (STAAD Pro) is a structural analysis and design software application originally developed by Research Engineers International in 1997.

In late 2005, Research Engineers International was bought by Bentley Systems STAAD Pro is one of the most widely used structural analysis and design software products worldwide. It supports over 90 international steel, concrete, timber & aluminium design codes. STAAD can be used for analysis and design of all types of structural projects from plants, buildings, and bridges to towers, tunnels, metro stations, water/wastewater treatment plants and more. Therefore with the help of this software the total load transmitted to each tower leg has been determined easily.

STAAD foundation is standalone software with more than 50 different design modules and 5 different international codes. It is cost-saving downstream application that also enables engineers to analyze and design the underlying foundation for the structure they created in STAAD Pro. STAAD foundation can automatically absorb the geometry, loads and results from a STAAD Pro model and accurately design isolated or combined footings, true mat foundations and even perform pile cap arrangements.

Table no 1: Soil Parameters adopted for the study

SOIL PARAMETERS	VALUES
Density	18(kN/m^3)
Modulus of elasticity	20000(kN/m^2)
Soil type	Laterite
Poisson's ratio	0.2
Type of foundation	Isolated Footing

Various tests have been conducted in order to determine the properties of the soil sample. After obtaining the nature of soil sample, the selection of type of foundation under each tower leg of the transmission tower would become easier and systematic. The properties of laterite soil taken are shown in the above table.

STAAD foundation not only analyzes and designs a myriad of foundation configurations, but will also produce production quality reports, detail drawing, schedule drawing, general arrangement (GA) drawing and detailed 3D rendering of your foundation structures. With full OpenGL graphics, engineers can clearly see the displaced shape, stress distribution, reinforcement layout and force diagrams of their supporting structure..

Now the total load transmitted to each tower leg and foundation size of transmission tower is to be determined. Full structure including the foundation can be drawn in STAAD Pro and STAAD foundation software. Total load is found accordingly from the STAAD Pro V8i software and foundation size is determined from the software – STAAD Foundation respectively.

IV. Results and Discussion

The color distributions of the complete model are highly similar to those of the simplified model, and the maximum values of the displacement and stress are very close, with relative errors of less than 2%. First, a simplified model with one tower and two span lines is presented to improve calculation efficiency; this model is validated via a comparison with a complete tower line system under both static and dynamic conditions.

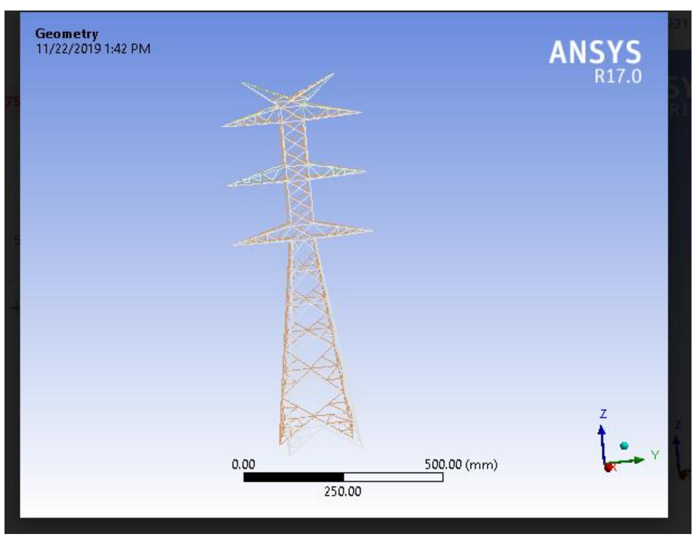

Fig no.4: Transmission Tower modeled in ANSYS

The modeling of the transmission tower in ANSYS software is depicted above. The exact dimensions as per the journal referred (Fragility analysis of transmission tower subjected to wind loading) were used to model this tower. To verify the accuracy of the simplified model, a FEM of the entire transmission line is built, and both nonlinear static and dynamic analyses are conducted. Figure below shows the stress as well as the deflection plot of the model selected accordingly. It exhibits comparisons of the displacement and stress contour plots between the entire FEM and simplified FEM under static wind loads with a basic wind speed of 25 m/s. Due to uncertainties in their structural parameters and wind loads, the structural design of transmission towers is a decision-making process involving risks and constraints on national economic conditions in addition to a balance between the initial construction costs and the potential costs of collapses in the future.

The stress results are more important than the displacement results for judging the limit state (LS), and the relative error of the maximum stress is smaller than 0.5%, indicating that the proposed simplified model can accurately simulate the static behavior. The deflection value obtained from ANSYS software is shown below and matches in accordance with the value obtained from the journal paper and is error free also.

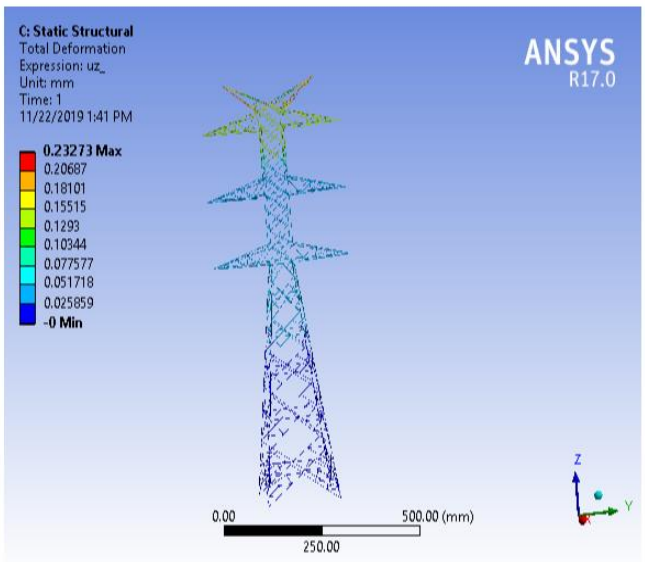

Fig no.5: Deformation value

The stress results are more important than the displacement results for judging the limit state (LS), and the relative error of the maximum stress is smaller than 0.5%, indicating that the proposed simplified model can accurately simulate the static behaviour. The deflection value obtained from ANSYS software matches in accordance with the value obtained from the journal paper and is error free also. The modelling of transmission tower with all the corresponding nodes is shown below. The picture itself shows the large number of nodes present in the tower.

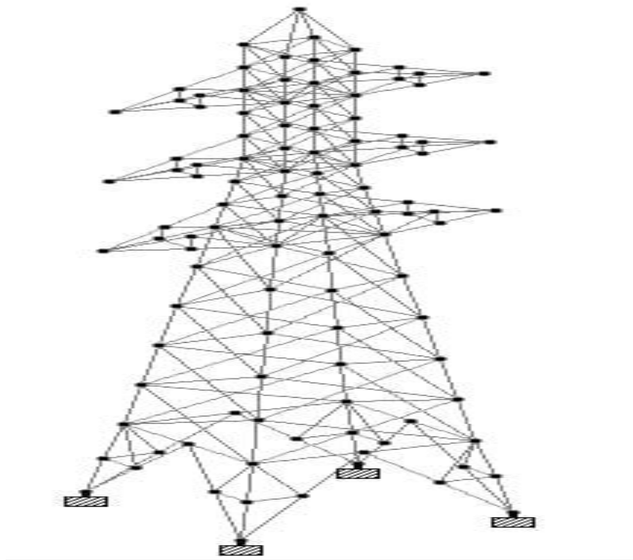

Fig no.6: Node Sketch in STAAD Pro

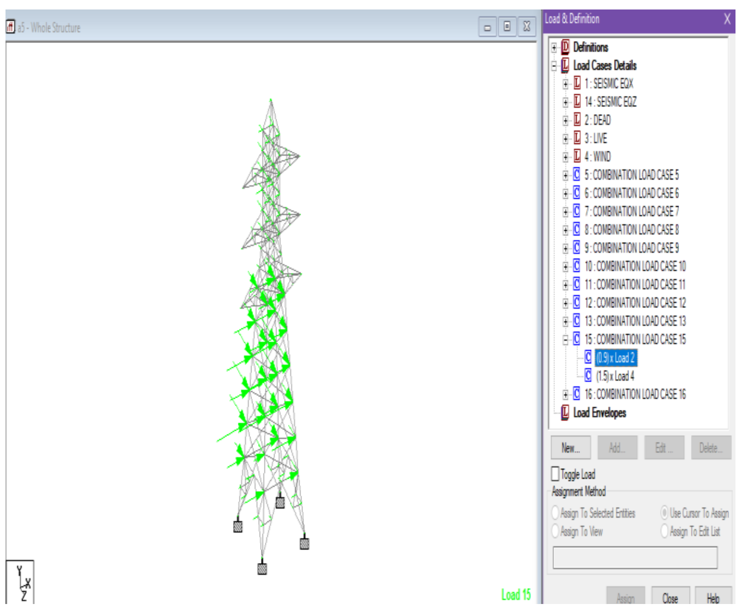

Fig no.7: Loading Values

Different loading conditions like dead load (self weight of transmission tower), live load (6 cable loads at the respective nodes), seismic loading conditions as per the code IS and wind loadings in all the four different directions is applied to the transmission tower sketched in STAAD Pro respectively. Self weight is applied through out the entire transmission tower body. The cable loads at six different nodes is found using a standard formula specified in the code (IS 875 part II) and is within the limits also. Different combinations of loading as specified in the code for transmission tower is also included appropriately.

a5 - Support Reactions:

All | Summary | Envelope

			Horizontal	Vertical	Horizontal
	Node	L/C	Fx kN	Fy kN	Fz kN
Max Fx	4	5 COMBINATI	5.639	43.601	-5.545
Min Fx	3	15 COMBINA	-106.793	647.458	-117.031
Max Fy	3	15 COMBINA	-106.793	647.458	-117.031
Min Fy	1	15 COMBINA	-104.417	-623.703	-114.205
Max Fz	2	5 COMBINATI	-5.639	43.601	5.545
Min Fz	3	15 COMBINA	-106.793	647.458	-117.031
Max Mx	1	1 SEISMIC EQ	-0.269	-1.852	-0.244
Min Mx	1	1 SEISMIC EQ	-0.269	-1.852	-0.244
Max My	1	1 SEISMIC EQ	-0.269	-1.852	-0.244

Fig no.8: Total Load and Final Reactions

After finding out the final reactions and total load from STAAD Pro, the next step is to find out the maximum load transmitted to each leg of the transmission tower. The maximum load was obtained as 648 kN under each tower leg from STAAD Pro V8i. This load is obtained after considering different loading combination as per the specified code for transmission tower. The foundation has to be proposed to withstand this 648 kN safely. A stability check is also done to make sure that each member is also safe. The above figure shows the details of a particular member in tower which is safe in design also. The figure also shows that each member in transmission tower is safe enough (passed the design criteria without failure).

STAAD Foundation is standalone software with more than 50 different design modules and 5 different international codes. It is cost-saving downstream application that also enables engineers to analyze and design the underlying foundation for the structure they created in STAAD Pro. STAAD foundation can automatically absorb the geometry, loads and results from a STAAD Pro model and accurately design isolated or combined footings, true mat foundations and even perform pile cap arrangements

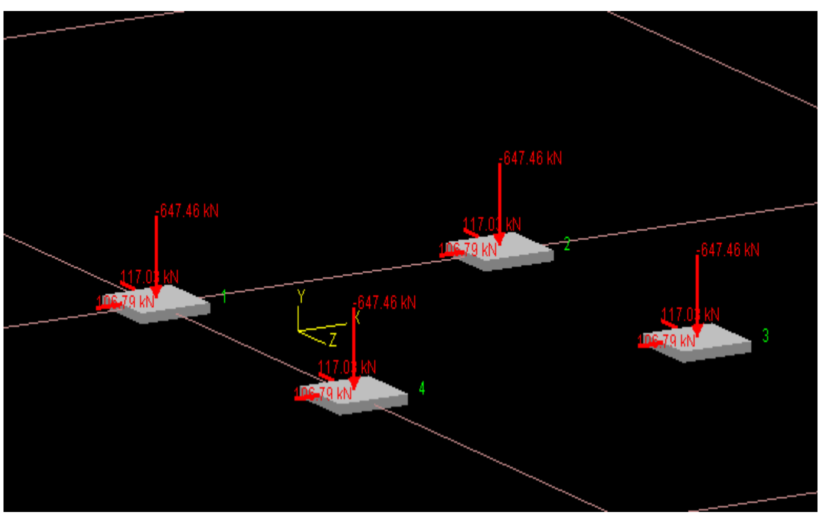

Fig no.9: Modeling of Isolated Footing in STAAD Foundation

The maximum load obtained from STAAD Pro (648 KN) was applied at each transmission tower leg as shown in fig 6.11 and an isolated footing was designed in STAAD foundation software. The size of isolated footing was found to be 2.3x2.3x 0.55 m from the STAAD foundation software. These obtained dimensions were assigned to the footing under each tower leg accordingly. In order to carry out the soil structure interaction of transmission tower ANSYS 15 software is used accordingly.

V. Conclusion

A study on Transmission Tower with isolated footing was adopted. Working with large areas of foundation requires input of exact soil properties under the foundation to produce their actual behaviour. In practice, the soil pressure under the foundation of a building is non-uniform depending upon the column loads, column spacing etc. Due to the increasing demands on power supply and telecommunication services, existing transmission towers are frequently being required to carry extra loads above their initial design limits. But in this case the structure to be considered is a transmission tower subjected to dead load, live load, wind load and seismic conditions respectively. Now the total load transmitted to each tower leg and foundation size of transmission tower is to be determined. Full structure including the foundation can be drawn in STAAD Pro and STAAD foundation software. Total load is found accordingly from the STAAD Pro V8i software and foundation size is determined from the software STAAD Foundation respectively.

The maximum load under each tower leg was obtained as 648kN from STAAD Pro V8i. All the individual tower members were found to be stable and safe. The size of isolated footing was found to be 2.3x2.3x 0.55 m from the STAAD FOUNDATION software. The maximum deformation value of transmission tower under wind loading was obtained as 13mm in STAAD Pro accordingly and was within the limits also.

References

[1]. Julie E Mills, Experimental study on multi panel retrofitted steel transmission towers, Journal of Constructional Steel Research Elsevier, Fourth Edition, 2015.
[2]. CSI, Analysis Reference Manual for STAAD and ANSYS, Computers and Structures, Berkley, California, 2015.
[3]. Dr.Jendoubi A and Dr.K. Ilamparuthi, Effect of interaction on rigid transmission towers subjected to wind and impulse loads, Electrical Transmission and Substation Structures, Vol. 2, No. 4, 2015.
[4]. G. S. Kame ,K. Borgaonkar, A Parametric Study on Isolated Foundation, International Association for Computer Methods and Advances in Geomechanics (IACMAG) 2015.
[5]. Qiang , Experimental study on the behaviour and failure mechanism of steel latticed tower , ACSE Journal of Structural Engineering, Issue 12, pp 945-949, 2016.
[6]. Kamel Bilal,Analysis and behaviour of composite transmission towers, Proceedings of the 3rd International Structural Conference on Civil Engineering for Sustainable Development (ICCESD 2016), Issue 2, pp 978-984, 2016.
[7]. Vesic A. S, Beam on elastic subgrade and the Winkler hypothesis, Proceedings of 5th International Conference on Soil Mechanics and Foundation Engineering, Paris, Issue 1, pp 845-850, 2016.