

Design and Analysis of a New Type Transmission Tower

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Keywords: power industry; bamboo transmission tower; numerical Analysis; environment

Abstract: The design and construction level of power grids are increasing rapidly with the development of China's power industry. The tower of Transmission line has become an important forced fulcrum. Safety and economy are basic requirements of conventional structural design. However, making the transmission lines and the environment in harmony and unity challenges structural designers. In this paper, a new-type transmission tower--bamboo transmission tower is designed and researched on the basis of a practical project. It can be found that the new-type of transmission tower makes the tower and the environment in harmony and unity when it meets the safety and economy requirements.

Introduction

With the acceleration of urban construction, the stress of land resources, the compression of power corridors and the improvement of environment requirements, the transmission steel tower implied widely due to its beautiful appearance and small floor space. And the transmission steel tower is often used in the area where there are many residents and narrow sidewalks^[1,2]. In the past 20 years, The steel tube towers have got a considerable development since they were produced and used in China. There is a tendency that steel tube towers replace traditional cement pole and angle iron tower where the hoisting machinery can be used. It can be found that the steel tube towers have great advantages in the convenience and the rate of progress. In China, there are nearly 2000000 base towers which are practical, safe, economical and reasonable and the mileage of extra-high/ultra-high voltage transmission have nearly 100000 km^[3]. As the city appearance is attracting more and more attention, structural designers pay more attention to the harmony and unity between buildings and environment. Coordination design of power transmission tower and the main colors of city or landscape around is becoming a new challenge^[4].

In this paper, bamboo transmission tower is designed which bases on the landform and landscape characteristics of the bamboo forest according to a practical project. The finite element method is used to analyze its stress condition, which is aimed at ensuring the safety of the new-type power transmission tower. It has certain reference value to the landscape design of transmission line in the future.

Design Principles and Requirements

The optimization design principles of steel tube towers are as follows. Firstly, determine the basic tower type based on the electrical parameters. Secondly, consider the high strength steel from the material point of view. Thirdly, consider compact layout of towers to reduce the width of the corridor. At last, design the slope and internal layout for different types of tower.

The requirements which the steel tube towers should meet are as follows: (1) The structure type is concise, the force of bar member is clear and the transmission path is distinct; (2) The structure is simple, the joints treatment is reasonable and it should be easy to install and operation security. (3) Compact structure layout and minimize the width of the corridors to save limited land resources; (4) Give full play to the carrying capacity of components by reasonable division of internodes and arrangement of components; (5) Choose reasonable materials to reduce the consumption of steel and the cost.

The bamboo transmission tower which is as shown in Fig.1 is designed according to the topography and geomorphology of the area which this engineering line locates in. The form of the

lines hanging is in the shape of Chinese characters——“上”. High-strength steel is used in tower foot and tower body. E - glass fiber/epoxy resin composite material is used in crossarm. The bottom of the tower is fixed to the foundation by using triangular base. The force and the transmission path of the tower is distinct and the appearance is concise and beautiful.

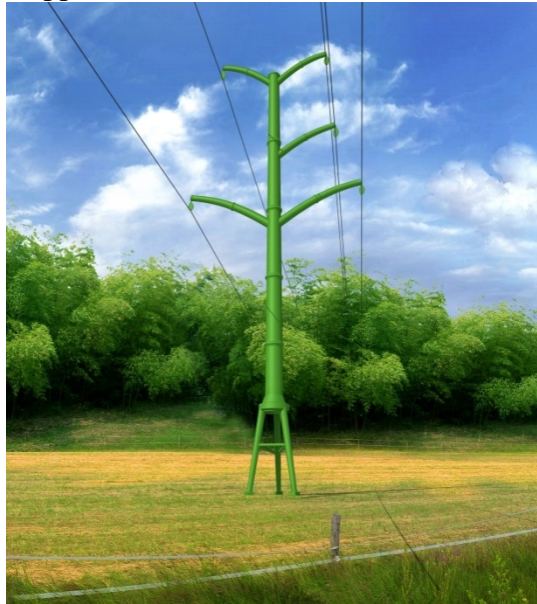


Fig.1 The bamboo transmission tower

Design Parameters

The probability model of extreme type I distribution is adopted when determining the maximum design wind speed of the 110kV ~ 330kV transmission line according to the domestic specification^[5]. Take the actual voltage level of this project and the probability of strong winds is of 30 years' frequency, and the height of the reference wind is 15m above the ground. According to the load code^[6], the partial factor γ is taken as 1.4, the partial factor for resistance ϕ includes the structural importance coefficient and the material strength coefficient. In this paper, the structural importance coefficient is temporarily taken as 1.0, ϕ taken as $1 / 1.087$ for Q235 and $1 / 1.111$ for Q345, Q390, Q420, Q460. The tower single line diagram is established according to the requirements of clearances and the stipulation of domestic specification^[5]. In this paper, consider 4 operating conditions (0°wind, 45°wind, 90° wind and long term operating conditions) when calculating the force of the tower. The force of 5 crossarms is shown in Table 1.

Table 1 the force under different operating conditions (kN)

| operating conditions | Name of mounting point | Fx | Fy | Fz |
|--------------------------------|------------------------|---------|---------|---------|
| 0° | DI1 | 0 | 0.58952 | 2.37996 |
| | DI2 | 0 | 0.58952 | 2.37996 |
| | DAO1 | 0 | 1.01438 | 4.50951 |
| | DAO2 | 0 | 0.97533 | 4.50951 |
| | DAO3 | 0 | 0.97533 | 4.50951 |
| 45° | DI 1 | 1.17904 | 0.35371 | 2.37996 |
| | DI 2 | 1.17904 | 0.35371 | 2.37996 |
| | DAO 1 | 2.02875 | 0.60863 | 4.50951 |
| | DAO 2 | 1.95067 | 0.5852 | 4.50951 |
| | DAO 3 | 1.95067 | 0.5852 | 4.50951 |
| 90° | DI 1 | 2.35807 | 0 | 2.37996 |
| | DI 2 | 2.35807 | 0 | 2.37996 |
| | DAO 1 | 4.05751 | 0 | 4.50951 |
| | DAO 2 | 3.90134 | 0 | 4.50951 |
| | DAO 3 | 3.90134 | 0 | 4.50951 |
| long term operating conditions | DI 1 | 0 | 0.03143 | 2.37996 |
| | DI 2 | 0 | 0.03143 | 2.37996 |
| | DAO 1 | 0 | 0.05358 | 4.50951 |
| | DAO 2 | 0 | 0.05152 | 4.50951 |
| | DAO 3 | 0 | 0.05152 | 4.50951 |

Numerical Analysis

In this paper, ABAQUS is used to establish model and calculate the force to the landscape tower and element SHELL is used. Gravity is applied on the whole structure, then loading according to Table 2. The height of the tower is 27m. The size, the thickness and the actual location of the steel tube of the tower body, tower foundation and the crossarm are all arranged according to the design. There are 40033 elements in the model. The tower foot is clamped which is shown in Fig. 2(a).

Table 2 Material parameters and model plastic parameters

| | | | |
|--------------------|------------------------|-----------------|-------|
| Strength | 345MPa | Poisson's ratio | 0.3 |
| Density | 7800kg/m ³ | Expansion angle | 30° |
| Elasticity modulus | 2.1e11N/m ² | Element type | SHELL |

The Reinforced constitutive model adopts the broken line model. Material parameters and model plastic parameters are shown in Table 2.

According to the results of finite element analysis, it can be found in Figure 2(b) that the maximum Mises stress of the crossarm appears when the wind direction is 0° and the Mises stress of the joint of the crossarm and the vertical pole is 79.52MPa. It can be found in Figure 2(c) that the maximum Mises stress of the vertical pole appears when the wind direction is 90° and the joint of the vertical pole and the disc-shaped base is 177MPa. It can be found in Figure 3(a) that the maximum lateral displacement of the transmission tower which is perpendicular to direction of line is 166mm appears when the wind direction is 0°. It can be found in Figure 3(b) that the maximum vertical displacement of the transmission tower which is parallel to direction of line is 489mm appears when the wind direction is 90°. Under the most unfavorable conditions, the maximum stress ratio of the tower is less than 0.5 and the maximum deformation is less than 0.02, which can meet the limit requirements of the specification.

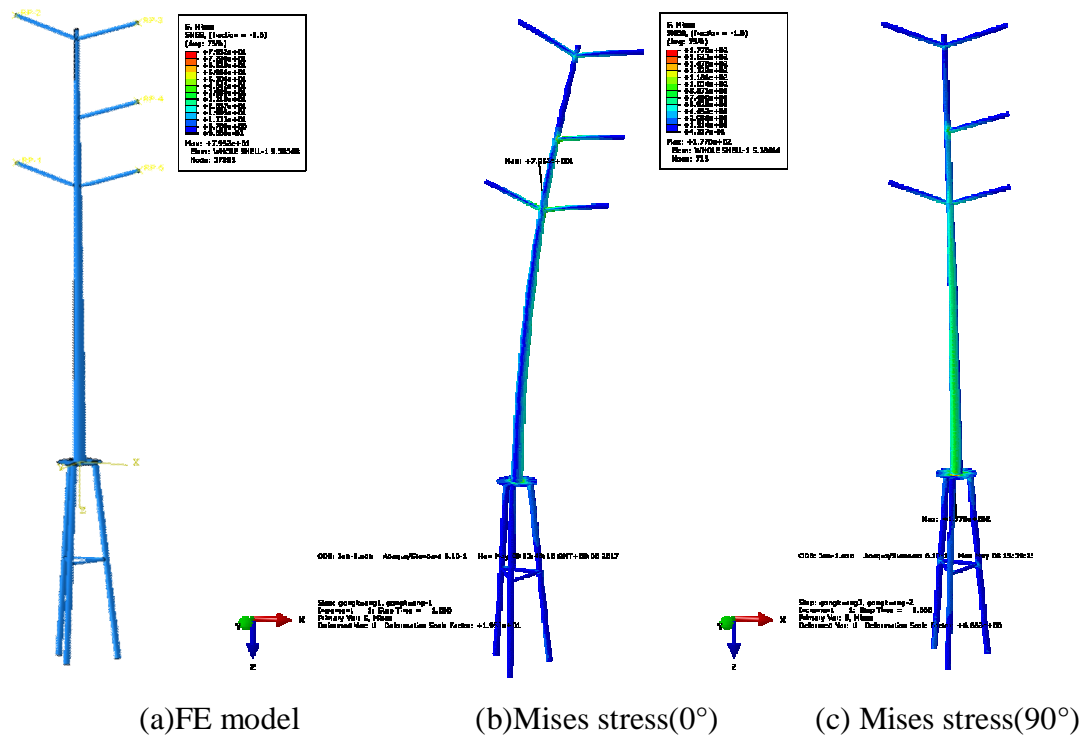


Fig.2 FE model and Mises stress nephogram

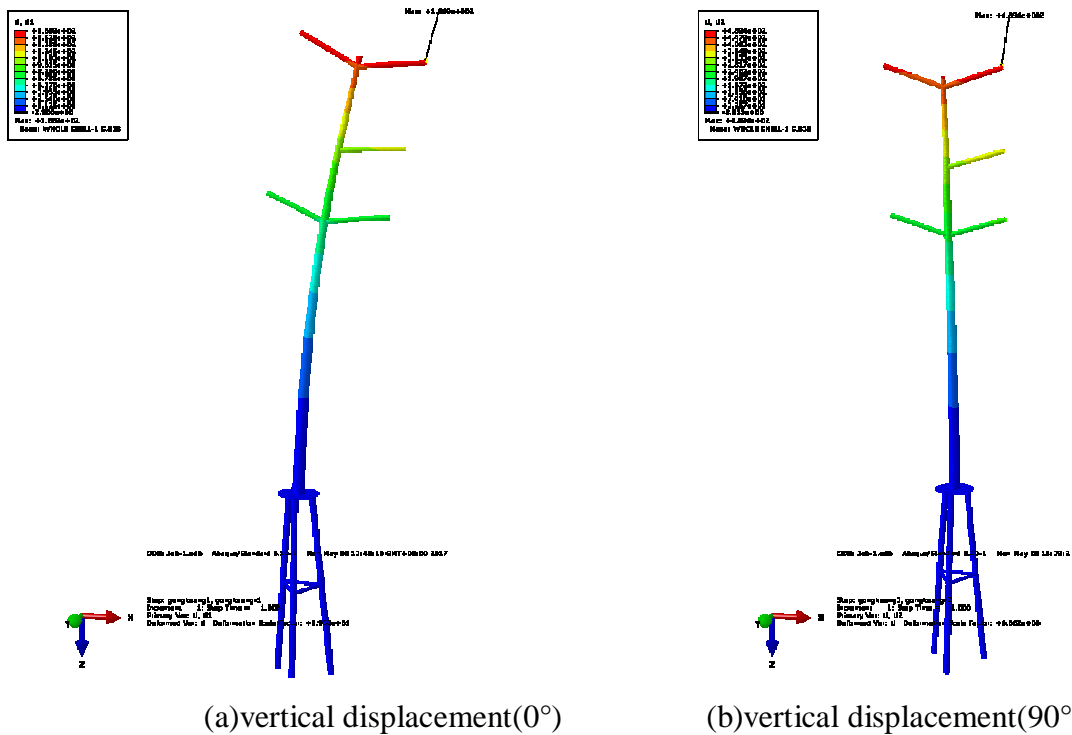


Fig.3 the maximum vertical displacement nephogram

The weight of the bamboo transmission tower increases by 5.8% comparing with the angle iron tower when the working conditions is same. There is almost no increase in project cost while considering the beauty of design.

As a towering building, the tower structure is very sensitive to the load of earthquakes and wind. Six lowest order modals and frequencies are shown in Fig.4 and Table 3, which can be used as a reference to further structural design and vibration isolation.

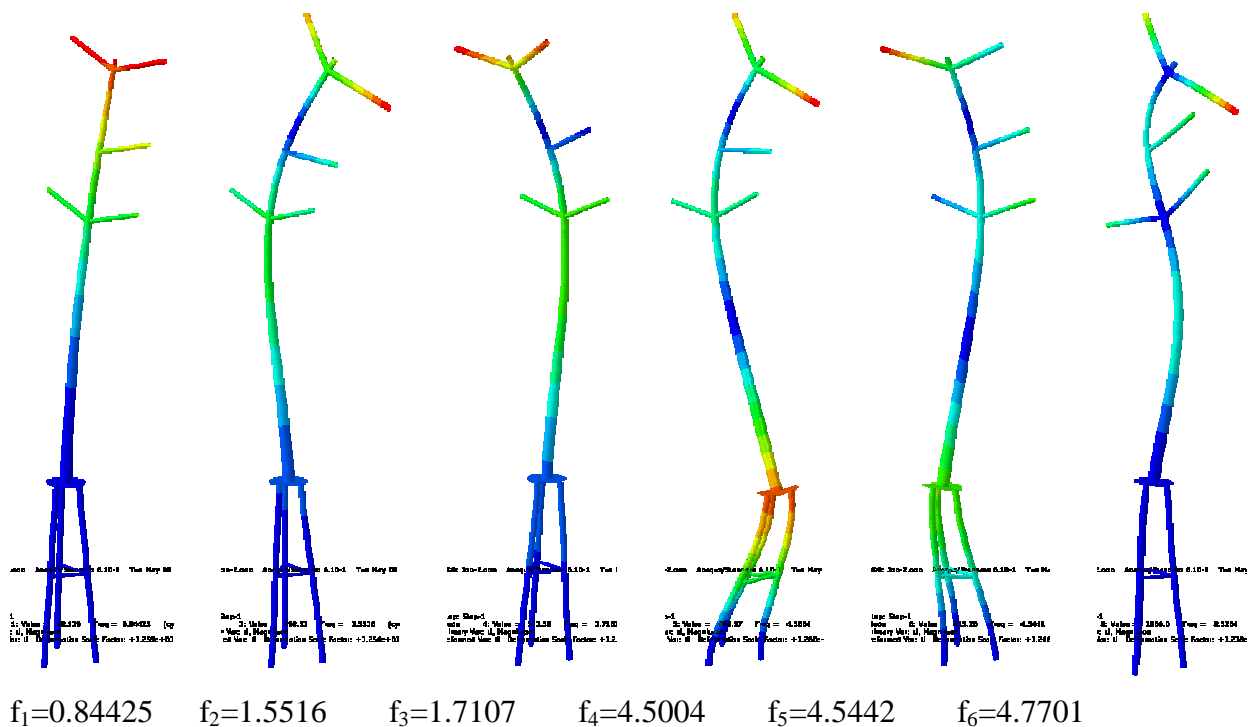


Fig.4 Six lowest order modals and frequencies(Hz)

Conclusions

In this paper, the bamboo transmission tower is proposed according to practical project. At the same time, the research on the value of body factor, the modal analysis and the numerical analysis under different operating conditions are completed. The conclusions are as follows:

(1) It can be found that the deflection of the pole increases with the increase of the height of the tower under the same operating condition, and the closer to the top of the tower, the greater the deformation rate is. So the width and the specifications of component at the top of the tower can be appropriately increase to reduce the displacement and deformation in the post-construction drawing design.

(2) The maximum displacement of the tower is 489mm under three different wind directions, while the maximum displacement of the tower is 7mm under long term operating conditions, which can meet the limit requirements of the specification.

(3) Stress concentration appears on the connection between the tower leg and the pole rod body. It needs to be strengthened in the subsequent design.

(4) It is suggested that the connecting between the steel structure legs and the composite tower body can be appropriately strengthened in the post-construction drawing design according to the six lowest order modals of the tower.

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