Study on the Uplift Resistance of Hole Digging Foundation in Strong Weathered Soft Rock for Transmission Lines

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Abstract: With the rapid development of China's electric power construction, more and more overhead transmission lines cross the mountains. The most common type of foundation for the distribution of overhead transmission lines in mountainous areas of China is the strong weathered rock foundation. For this type of foundation, hole digging foundation is often used in the project. Different from other industry foundations, the design of the overhead transmission line foundation is mainly controlled by the uplift stability, and the key parameter of the uplift stability design is the basic uplift resistance bearing capacity. In engineering, the foundation uplift bearing capacity is often obtained by the uplifting load-displacement curve. The establishment of models and parameters that accurately describe the variation characteristics of the load-displacement curve are of great significance for engineering design. In this paper, a simple analysis is made through the domestic transmission line basic engineering. Therefore, the model and parameter conclusions of the load-displacement curve variation characteristics are established based on the theory of uplift analysis of the strong weathered soft rock hole digging foundation of the transmission line.

Key words: transmission line; strong weathered soft rock; hole digging foundation; uplift resistance analysis

Introduction:

With the increasing environmental protection in the construction of domestic power grids, the application of hole digging foundation in transmission line engineering is becoming more and more extensive. The uplift bearing characteristics of digging foundation and its design and calculation are also one of the hot issues in the current research of tower foundation. The transmission line is realized by using a transformer to boost the electric energy generated by the generator, and then accessing the transmission line through the control device such as a circuit breaker. For the form of structure, the transmission line is divided into overhead transmission lines and cable lines. The overhead power transmission line is composed of a tower, wire, insulator, a line fitting, stay wire, tower foundation, grounding device, and so on, and is erected on the ground. According to the nature of the current delivered, the transmission is divided into AC transmission and DC transmission. The basic design of the transmission line tower is mainly controlled by the uplift stability, and the key parameter for the calculation of the uplift stability is the basic uplift bearing capacity. The main factors affecting the basic uplift bearing capacity include the physical and mechanical properties of the foundation rock mass, the strength of base material, the basic shape characteristics and parameters.

1 Analysis of domestic transmission line infrastructure engineering

1.1 Current status of transmission line infrastructure engineering

China has a vast territory, and the geological conditions vary greatly from region to region. The basic forms of transmission lines used are also diverse. The northwestern region is mainly loess foundation, and some are desert and rock foundations. The basic forms used in the loess foundation mainly include rigid stepped foundation and plug-in foundation, and some soft foundations mainly use bored piles. China has a vast territory and a wide variety of ground types, which distribute widely. The topography and geological conditions of different regions are different, and the basic types of regional foundations are diverse. The tower foundation is an important part of the transmission line, and its cost, construction period and labor consumption account for a large proportion of the entire line project. According to relevant statistics, the construction period of the transmission line foundation project accounts for about half of the entire construction period, and the transportation volume accounts for about 60% of the entire project, and the cost accounts for 15% to 35% of the entire project.

1.2Development trend of transmission line infrastructure engineering

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According to statistics, the tower foundation takes up about half in construction period, about 60% in the transportation volume, and about 15% to 35% in the cost of the entire the transportation volume project. It can be seen that it is imperative to reduce the volume of foundation concrete and steel bars, shorten the construction period, and reduce the construction cost. It is imperative to choose a more scientific and reasonable basic model. At present, the general development trend of transmission line infrastructure engineering at home and abroad has two aspects: first, use reasonable structure, improve the basic force performance, reduce the basic horizontal force and bending moment, so that the basic column mainly bears the axial pull pressure; on the other hand, it is to make full use of the good mechanical properties of the undisturbed soil foundation with high bearing capacity and small deformation, and to adopt the undisturbed soil foundation type, new basic types and scheme research in the construction of line engineering according to local conditions.

1.3 Problems relating to transmission line basic engineering design

Due to the particularity and complexity of the foundation engineering of transmission lines, *Technical Regulations for Basic Design of Transmission Lines* has not adopted the principle of probability limit state design, nor the partial coefficient design method, and the total safety factor method is still adopted. Many experts and scholars at home and abroad are working on the reliability of foundation engineering. The implementation of synchronous reliability design for foundation engineering and structural engineering is an international trend. If the foundation engineering of transmission lines continues to use the fixed value design method of the traditional safety factor design method for a long time later, it is obviously inappropriate; the damage of transmission line tower caused by wind load often brings serious impact on the economic construction and people's life. It takes a lot of money and time to fix it.

2 Analysis on the uplift resistance of hole digging foundation in strong weathered soft rock for transmission lines

2.1 Analysis of uplift bearing capacity and influencing factors of holes digging foundation

The foundation uplift bearing capacity refers to the maximum uplift load that is received before the foundation fails, and is the key parameter for calculating the uplift stability of the transmission line tower. According to DL/T5219—2014, 25mm uplift displacement force is taken as the limit uplift displacement, and the corresponding load value is the foundation uplift bearing capacity. The uplift bearing capacity of 10 holes digging foundation is obtained in turn, and the analysis is carried out for the test results of the prototype foundation field with the same size. The results can indicate: the test ratio (the ratio of the test value to the calculated value) is between 0.8 and 1.2, and the error between them is within 30%, which basically meets the engineering requirements.

2.2 Failure mode of uplift rock mass on the hole digging foundation and analysis of morphological characteristics of sliding surface

Because the hole digging foundation is under the action of uplift load, the foundation system eventually fails due to the destruction of the rock and soil around the foundation. In the numerical calculation, the foundation is considered to be damaged when a continuous plastic zone appears in the rock mass around the foundation. According to the above criteria, the morphological curve of the sliding surface on the experiment section of the rock mass around 10 digging holes foundation is obtained by numerical calculation. It can be seen that all the digging holes foundation is extended from the base along the opening with certain angle to the ground. Until the crack penetrates, the rock mass is destroyed, which is consistent with the field test results in the literature data. The failure modes of the rock mass on the hole digging foundation of the two structural forms are quite different, and this difference shows different characteristics with the increase of the foundation depth.

3 Load-displacement curve change analysis

3.1 Constitutive model and calculation parameters base

DL/T5219—2014 *Basic Design Rules for Overhead Transmission Lines*: The reinforcement for the foundation design of the tower is in accordance with the two-way eccentric tension member reinforcement, and the reinforcement ratio of the full section is not less than 0.6%. Under this condition, the bearing capacity of the basic section is sufficient to withstand the uplift load; at the same time, the normal stress at the variable cross section is not required to be greater

than the tensile strength of the plain concrete to ensure that the foundation body of the tower does not suffer from tensile damage. Since the strength of the foundation members is fully ensured in the foundation design, the tower foundation will not have the material damage on concrete member, but have the shear failure on the foundation rock soil mass.

3.2 Analysis of deformation characteristics of digging holes under load effect

There are great differences in the deformation and failure characteristics between rock and soil. The research on the uplift-load-displacement curve and model parameters of the hole digging foundation of the strong weathered rock foundation is rarely reported in the literature at home and abroad. Based on the data of 8 field tests, the study on the influencing factors of the uplift bearing capacity of rock foundation hole digging foundation is carried out in this paper, and the influence rule of basic dimensional parameters on load-displacement curve, uplift capacity and failure mode. However, due to the limited number of field test samples, the models and parameters describing the load-displacement curve could not be further obtained, which leads to the application of the foundation load-displacement curve is limited in determining the basic uplift capacity. It can be seen from Figure 1 that the load-displacement curves of all test foundations are “gradually variable” curves. The main feature of the “gradual variable” curve is that three characteristic stages can be used to describe the change process of load-displacement, namely the initial straight line segment oa, the intermediate curve transition segment ab and the final straight line segment bc, wherein the initial straight line segment can approximately express the elastic deformation property of hole digging foundation and the curve transition section can approximately express the plastic deformation property of the hole digging foundation, as shown in Figure 2. Based on the tower load of 220~1100kV voltage level, eight full-size digging holes foundation is designed according to the 1:1 ratio. The development of the uplift static load test on the eight test foundation fields in the strong weathered rock foundation is described in detail. Based on the data obtained from the test, the uplift bearing characteristics of the hole digging foundation in the strong weathered rock foundation are analyzed from the two aspects of load-displacement curve variation characteristics, load-displacement curve model and parameters. On this basis, the applicability of the hole digging load-displacement curve model and the influencing factors of the parameters for the strong weathered rock foundation is further studied.

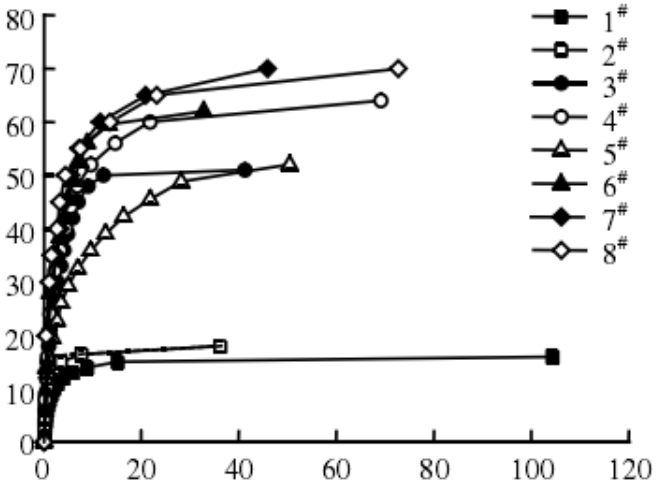

Figure 1. Load-displacement curve of 8 test bases

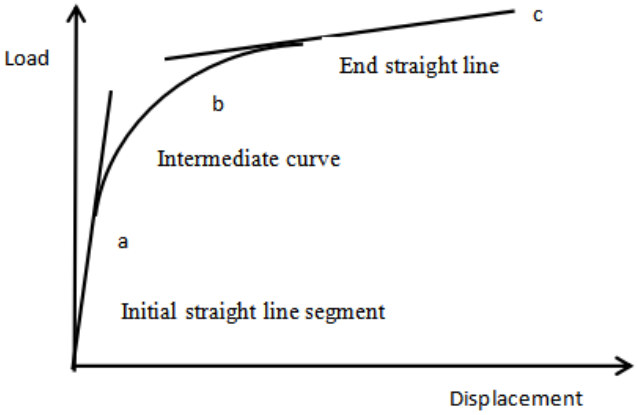

Figure 2. Three stages of “gradual variation” curve change

3.3 Analysis of load displacement curve results

The uplift load of the right cylinder hole digging foundation model, the jar-embedded solid model, the bottom-excavation model and other hole digging foundation and the vertical displacement curve of the foundation top. At the initial stage of loading, the curve presents elastic straight line segment, and the displacement is small. With the increase of load, the elastoplastic curve segment presents. The uplift displacement changes nonlinearly with the load, and the displacement rate increases obviously. As the uplift load continues to increase, the plastic zone gradually penetrates until the foundation is destroyed, and the load-displacement curve appears steeply descending segment, and the surface micro-cracks are remarkable. The law of load-displacement curves of the three types of digging holes is basically the same, and it is linearly distributed when shallowly buried. With the increase of the buried depth, the proportion of the plastic curve segments is larger, showing a slowly changing distribution.

Conclusion

The undisturbed soil foundation has higher bearing capacity, and the all-round high and low leg foundation design scheme is feasible by adopting the manual digging and expanding bottom pouring pile foundation, and the working characteristics of the cast-in-place pile are rigid short piles. The uplift bearing capacity that can be assumed by the unit volume of concrete is the economic evaluation criterion, and the hole digging foundation of the expanded-foundation and hole digging model has obvious advantages. The application of all-round high and low leg foundations in mountainous transmission lines has obvious technical and economic benefits, and should be vigorously promoted in the construction of power grids.

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