The Charging Principle and Economic Analysis of Spiral Anchor Foundation of Transmission Line

-- Taking the application in Inner Mongolia Area as an Example

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Abstract. With the popularization of mechanized construction of transmission line engineering and the improvement of environmental and water conservancy requirements, some new types of foundations begun to be popularized and applied, and have great advantages. The spiral anchor foundation has the advantages of short construction period, fast mechanized construction speed, and can zero concrete and zero earthwork construction. According to the construction process and test requirements of the spiral anchor, the principle of cost estimation for the main body construction and test the spiral anchor foundation is proposed. Take the application of spiral anchor foundation in Inner Mongolia as an example, the economic critical point of spiral anchor foundation is obtained through cost comparison with the traditional foundation type.

Keywords: Spiral Anchor Foundation; Cost Accounting Principle; Cost Analysis.

1. Introduction

The first use of spiral anchors can be traced back to the 1833, around the English Tidal Cove, where they were used as lighthouse foundations. In 1950, people began the systematic study of screw anchors. The vertical bearing capacity, horizontal bearing capacity and combined bearing capacity of screw anchor foundation have been studied by domestic and foreign scholars. In order to study the pullout resistance of screw anchors, the assumption of cylindrical failure surface is adopted, and the influence of anchor disc spacing is considered, four models with different number of anchors and spacing ratio were tested in soft marine clay[1].Yenumula [2] has carried out the field horizontal loading test of the spiral pile with different anchor plate number in clay, and got the following conclusions: the horizontal bearing capacity of the spiral pile increases with the increase of the buried depth and the shear strength of the soil; The bearing capacity of screw pile is larger than that of single pile, and increases with the number of anchor plates. Shi Qian et al [3] carried out the model test of double-slice spiral anchor in sandy soil, and found that the uplift capacity would increase with the increase of the distance between the anchors and the depth of the anchors. By means of empirical formula method, static load test method and cone penetration test method, the influence of different variables on the reliability index of ultimate bearing capacity of single spiral pile under inclined load is studied, the calculation model of ultimate bearing capacity of spiral pile is analyzed, and the ultimate state equation is derived[4].

Although spiral anchor foundation has accumulated a large amount of experience in domestic and foreign technology research, especially in mechanical research, the cost calculation of anchor foundation is still lack of unified standards because of its initial application in power transmission line engineering. Therefore, it is imperative to explore a set of spiral anchor foundation cost principles to guide engineering practice. This paper presents the calculation principle of spiral anchor foundation unit price and model test cost on the basis of a brief introduction of spiral anchor foundation The practice of spiral anchor foundation application in power transmission line engineering in Inner Mongolia is taken as the basis. Through the cost comparison with the traditional foundation designed

under the external conditions at different voltage levels, the economic critical point of using spiral anchor foundation is calculated, which provides the cost basis for further promotion and use of spiral anchor foundation.

2. Introduction of the Spiral Anchor Foundation

The spiral anchor foundation is a kind of anchored structure composed of spiral anchor and upper bearing platform, which mainly uses the deep soil to resist the of the upper structure. Spiral anchor foundation is divided into single anchor spiral anchor foundation and group anchor spiral anchor foundation according to the number of anchor bars. Single anchor anchor foundation is divided into single oblique anchor spiral anchor foundation and single straight anchor spiral anchor foundation according to the angle between the anchor bar and the vertical direction; group spiral anchor foundation is divided into group oblique anchor spiral anchor foundation and group straight anchor spiral anchor foundation according to the angle between the anchor bar and the vertical direction, the group oblique anchor spiral anchor foundation can be divided into unequal inclination group oblique anchor spiral anchor foundation and equal inclination group oblique anchor spiral anchor foundation as shown in Figure 1.

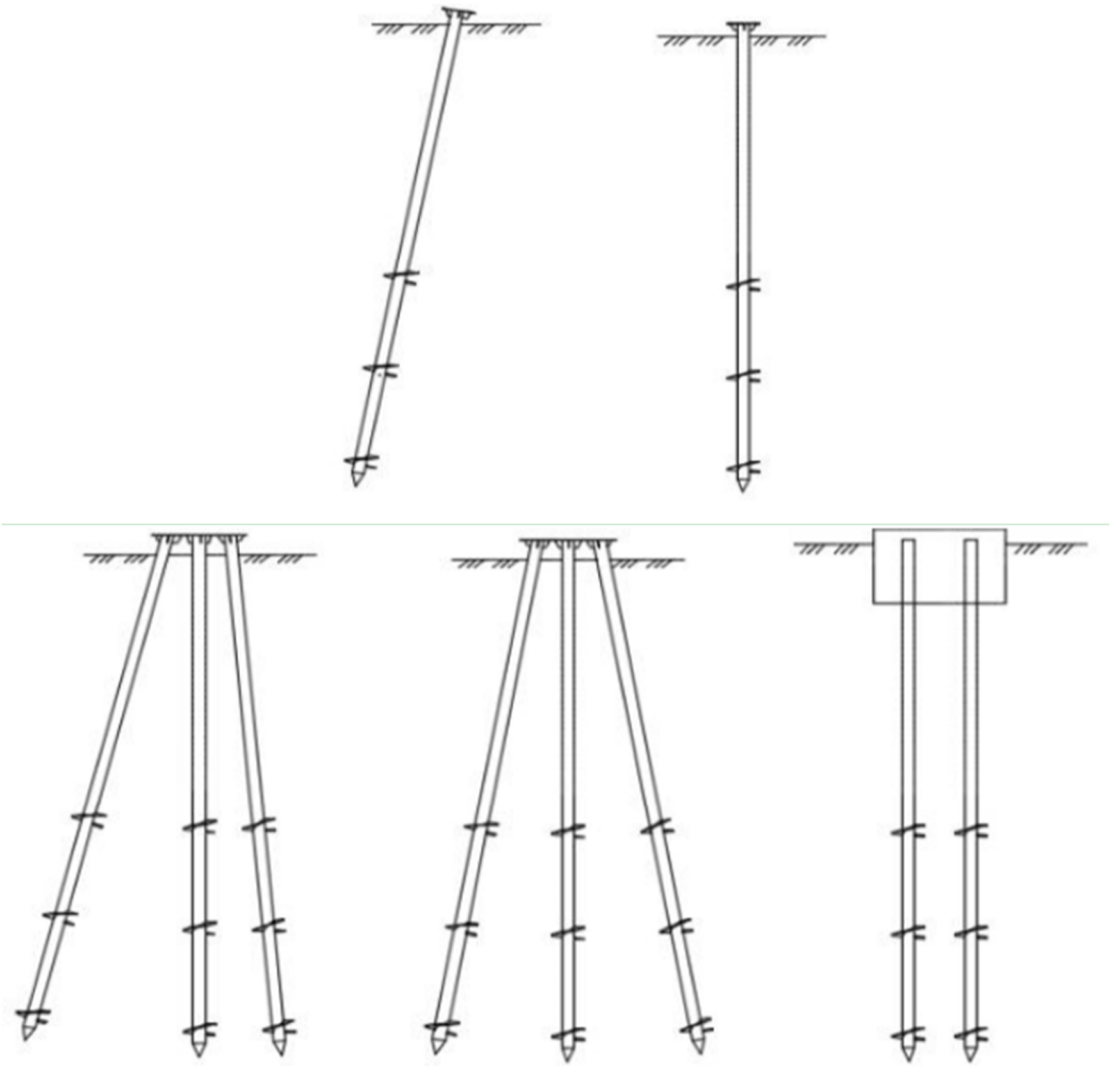


Figure 1. Screw Anchor Foundation

The single screw anchor is composed of an anchor head, an anchor plate, an anchor rod and a connecting piece, as shown in Figure 2.

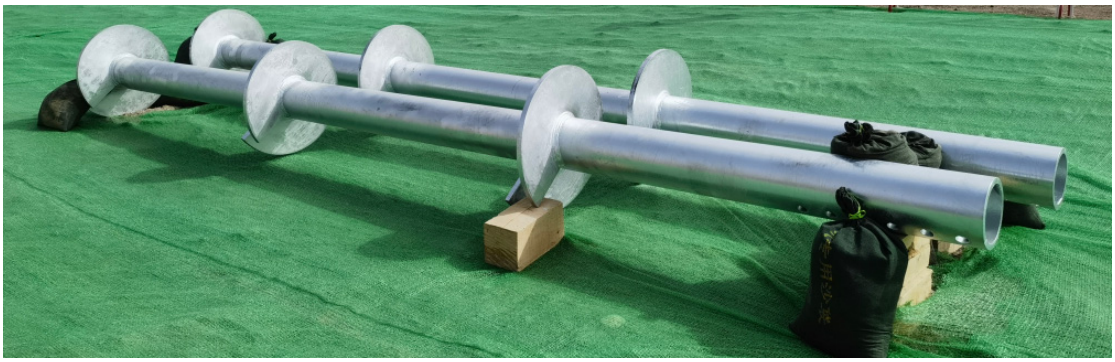


Figure 2. The composition of a single screw anchor

The construction procedure of steel spiral anchor foundation includes sub-pit measurement, drilling machine in position, spiral anchor drilling, top cutting of spiral anchor (group anchor) ,Angle Steel positioning of steel cap, steel cap welding(group anchor welding, single anchor factory welding), ultrasonic testing(group anchor),coating anticorrosive paint and basic acceptance of nine steps[5],and according to the requirements of the code, the steel screw anchor needs to do the true-type test before the construction, need to list the test cost.

3. The Principle of Cost Accounting for Spiral Anchor Foundation

According to the content of the supplementary quota(trial implementation) of the spiral anchor foundation engineering (national power grid electric rating [2020] No. 28) ,the steel spiral anchor foundation body construction needs to list the installation of the steel spiral anchor and the installation of the steel cap, the installation of screw anchors is divided into single anchors and group anchors, and the calculation is based on the number of designed anchors, taking “Root” as the unit of measurement, calculated in units of measurement. The installation work includes construction preparation, measurement, pile laying line, field transportation, steering pile and extension pile rotation, pile-to-pile connection, pile end cutting and grinding, site cleaning, tools transportation, etc. The installation work includes construction preparation, excavation and backfilling of welding working surface, lifting and positioning of steel bearing platform, welding of steel bearing platform, welding of reinforcing bar and plate, flaw detection, painting of anti-corrosion, cleaning of site, transportation of tools and instruments, etc. If steel spiral anchor foundation is used in transmission line engineering, the true test is usually used to verify the bearing capacity of foundation before construction.

According to the requirements of JGJ106-2014, the vertical compression and static load test, vertical uplift and horizontal static load test of single pile are required after construction of steel spiral anchor foundation. According to the test load grade F(unit: KN) and the diameter d(unit: mm) of the screw-anchored single pile, the corresponding prices are given respectively in the guidance on the calculation of the test fee for the foundation of power transmission and transformation projects and the Deep Foundation test fee (GDFY-2023-04) .Therefore, the total cost of the steel screw anchor includes not only the cost of the project itself, but also the material and installation cost of the single anchor and the steel accessories of the test equipment, and the material and installation cost of the foundation of the reaction pile, and the cost of vertical and horizontal static load test of pile.

4. Compared to the Cost of a Traditional Base

Since the spiral anchor foundation is suitable for soft soil areas such as ordinary soil and sandy soil, and has a high degree of mechanization, is necessary to consider factors such as the entry of the planting anchor machine and the loading device. Generally, it is required to promote the use of spiral anchor foundation when terrain is flat. Therefore, when comparing and analyzing, the traditional foundations selected include slab foundation and cast-in-place pile foundation.

Taking the data of the test site of the subject "Key technology research on the application of spiral anchor foundation of transmission line in Inner Mongolia region (Dalad Banner, Inner Mongolia) as an example. From the perspective of concrete, earthwork, and foundation cost, the superiority of spiral anchor foundation, slab foundation, and cast-in-place pile foundation under different voltage levels is compared, the data is shown in Table 1.

Table 1. Economic comparison of three basic single-based technologies

The underlying type	Inclined single helix anchor foundation			Straight Column Slab Foundation			Cast-in-place pile foundation		
Voltage level(kV)	220	500	±800	220	500	±800	220	500	±800
Concrete (m^3)	0	0	0	41.68	58.48	110.60	28.68	53.40	118.64
Steel(kg)	2040	3320	5160	3059.92	5331.24	9899	1744.1	3236.8	10489
Earth(m^3)	0	0	0	468.38	643.88	1105.03	0	0	0
Cost (10,000 yuan)	4.05	6.14	9.15	12.01	17.8	34.03	8.43	14.52	32.76

Notes: 1. The cost of steel spiral anchor foundation does not include the test cost

2.Steel without anchor bolts.

3.Geological conditions: the surface layer is filled with artificial soil, with a thickness of about 1.5m; the second layer is loose fine, with a thickness of about 1.5m; the third layer is slightly dense fine sand, with a thickness of about 0.5-1m the fourth layer is medium dense fine sand, with a thickness of about 3.5m; the bottommost layer is dense fine sand.

The magnitude of the test fee for the spiral anchor is affected by the weight of the test anchor, the size of the counterforce pile foundation, and number of test anchor roots, and generally, the higher the voltage level, the greater the test fee for the spiral anchor foundation. The test fee for spiral anchor foundation transmission lines under different voltage levels in Inner Mongolia is shown in Table 2.

Table 2. Experimental cost of spiral anchor at different voltage levels

Voltage (kV)	construction cost (10,000 yuan)
220	86
500	95
±800	113

It can be seen from Table 1 and Table 2 that the single helix anchor foundation has certain advantages over the traditional slab foundation and castin-place pile foundation in terms of cost, safety, environmental protection, and material saving if only the engineering body is considered. However, since the helix anchor needs to account for the cost of testing, from the perspective of the total cost, the helix anchor foundation has an economic advantage over the traditional foundation only when scale reaches a certain number. In the context of the regions and project data selected in this article, the economic critical point of the helix anchor foundation relative to the foundation is:

220kV project 86/(12.01-4.05)=10.80 base,

5000kV project 95/(17.8-6.14)=8.14 base,
±800kV project 113/(34.03-9.15)=4.54 base;

The economic critical point of the spiral anchor foundation relative to the cast-in-place pile foundation is:

220kV project 86/(8.43-4.05)=19.63 base,
500kV project 95/(14.52-6.14)=11.34 base,
±800kV project 113/(32.76-9.15)=4.79 base

5. Conclusion

This paper analyzes the composition of the cost of the screw anchor, puts forward the principle of calculating the cost of the steel screw anchor, and through comparing with the traditional foundation, the conclusions are as follows:

1)compared with the traditional foundation, the steel spiral anchor has the advantages of short construction period, saving earthwork excavation, saving materials, convenient and fast construction, high mechanization degree and low cost;

2)through the research on the construction process of the steel spiral anchor and the inquiry of the relevant specifications, it is found that the cost of the steel spiral anchor, in addition to the installation of the spiral anchor and the steel bearing platform, also includes the cost of vertical and horizontal static load test;

3)the steel spiral anchor is relative to the traditional foundation, there is an economic critical point under the consideration of the full cost, and different projects have different critical values due to different external conditions, which need to be measured after the Geological Survey and before the foundation design;

4)The greater the voltage level, the lower the economic critical value of the single helix anchor foundation relative to the traditional foundation, so the helix anchor should be popularized and used as much as possible in ultra-high voltage and ultra-high voltage projects when external conditions permit.

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