



Analysis on Foundation Selection of Mechanized Construction for Ultra-High Voltage Transmission Line

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Abstract.This paper analyzes the limitations of conventional foundations such as hole foundation, grouting pile foundation and rock anchor foundation in the mechanized construction of UHV transmission line projects, summarizes the boundary conditions applicable to conventional foundations, and selects new foundation types such as micro-pile foundation, variable section pile foundation and sheet pile foundation with wings to adapt to the mechanized construction of UHV foundation in mountainous areas. Increase the mechanized construction rate of UHV transmission line project, save project time and investment cost.

Keywords: KEY WORDS:Foundation Selection,Mchanized Construction,Ultra-High Volatge

1 Introduction

The common foundation types of UHV line engineering mainly include dig hole foundation, rock anchor foundation, pile foundation, excavation and backfill foundation, micro pile foundation and so on. Because there are few foundation types suitable for mechanized construction in mountainous areas, the proportion of mechanized construction of transmission line foundation in mountainous areas is low. Li Ran and Shi Wenfei discussed the feasibility of the whole process of mechanized construction of transmission lines through the mechanization of construction equipment and the optimization of design methods [1]. By comparing the traditional overhead transmission line construction technology with the whole process of mechanized construction technology, Wang Shengbing proposed the whole process of mechanized construction scheme in the field exploration stage and the interior construction drawing design stage [2]. Wang Yonghua carried out technical and economic analysis of different foundation types of the same tower type, based on different influencing factors and characteristics of foundation types, combined with the actual situation of the project, reasonable selection of foundation types.[3-5]. S.M.Takalkar and A.P.Monhite discussed the mechanized construction of transmission line tower foundation in hilly area[6],and analysis the technical economy of transmission line tower foundation design and construction[7].Zhou Tiejun

Foundation selection is an important measure to improve the mechanized construction rate of UHV transmission lines. At present, UHV line projects are mostly routed in mountainous areas, and the foundation types are mainly dug holes and rock anchor foundation. In the process of promoting mechanized foundation construction, the mechanized construction of rock bolt foundation does not need large-scale road construction, but only applies to the rock foundation with high basic quality grade of rock mass. Excavating basic machinery equipment has higher requirements for approach conditions. In view of the above problems, it is necessary to carry out in-depth research on the selection of UHV transmission line engineering foundation according to the conditions of mechanized construction.

2 Key factor of the foundation type restricts Mechanization construction

In the foundation design stage of UHV transmission line engineering, the designer should reasonably select the foundation type suitable for mechanized construction according to the comprehensive consideration of geological conditions, terrain slope, approach road, traffic conditions, environmental protection requirements, green compensation and forest felling, which is conducive to improving the mechanized construction degree of UHV transmission line engineering.

2.1 Foundation type adapt mechanized construction

According to the topographic and geological conditions of the tower, combined with the practical experience of mechanization construction of UHV transmission line engineering, the applicability of different foundation types is analyzed, as shown in Table 1.

Table 1. A table with Foundation type adapt mechanized construction

Foundation type	Foundation type selection principle
Excavation foundation	Water-free soil foundation or rock foundation with deep overburden.
	Anhydrous general soil foundation or overburden thick rock foundation (Rock hardness of 40 Mpa or less) .
Mountain micro-pile foundation	Rock geological conditions below 120 Mpa and topographic gradient below 40 °
	Rock geological conditions below 120 Mpa and topographic gradient below 15 °
	40MP and strong weathering rock geological conditions
Rock bolt foundation	(1) It is suitable for the rock foundation with the basic quality grade of I-V, the soft rock foundation with the grade of V should be comprehensively judged according to the groundwater, and the very soft rock and broken rock with the grade of V should not be adopted; It is not suitable to use the steep outdip weak structural plane (sand-mudstone interbedded and bedding slope) .

	(2) It is not suitable to have karst trough, semi-rock and semi-soil geology and groundwater in the design depth. For the area where the rock fissure water is developed, the comprehensive judgment should be combined with the field water quantity and lithology. (3) The thickness of overburden (without strongly weathered rock) should not exceed 3.5 m, and the slope of tower should not exceed 35 °. The covering layer should not exceed 1.5m when the slope of the tower is 35 °, and 3.5m when the slope of the tower is 10 °, when the slope height is less than 5m and the slope is stable, the Rock Bolt Foundation can be chosen.
Excavation backfill foundation	General soil foundation that can not be dug or drilled or that is not convenient for drilling machine.
Pile Foundation	Water general soil or soft soil foundation

2.2 Key factor of the foundation type restricts mechanization construction

The key factors that impede mechanized construction are evident from Table 1:

(1) Geological conditions. Different geological conditions determine different foundation selection. The rock foundation is mainly suitable for rock anchor foundation and micro pile foundation. Soil foundation is mainly suitable for digging foundation, cutting foundation, excavation and backfilling foundation.

(2) Topographic slope. General mechanized construction equipment has certain requirements for the slope and flatness of the site. Topographic slope not only determines the calculated outcrop and buried depth of the foundation, but also has a great influence on the operation of mechanical equipment. If the terrain slope is too large, it does not meet the operation requirements of mechanized construction equipment, and it is very unfavorable to the mechanized construction of the foundation.

(3) Thickness of covering layer. Overburden refers to the thickness of the soil layer above the rock foundation, which has a great influence on the configuration and calculation of the rock anchor foundation. Especially the rock anchor foundation, if the cover layer is too thick, it will cause the rock anchor length is too long, the cap size is too large, which is not conducive to the mechanized construction of the foundation.

(4) Hole forming equipment. Foundation hole forming equipment has a very important influence on the mechanized construction degree and efficiency of foundation. The selection of lightweight, detachable and easy to operate hole forming equipment can improve the mechanization of the foundation.

(5) Approach road. The traffic condition is an important factor affecting the approach of mechanized foundation construction equipment. Especially in the mountainous areas, the traffic conditions in some areas are poor, the road environment is poor, and the mechanical construction approach is very difficult, which is not conducive to the mechanized construction of the foundation.

3 Foundation boundary conditions adapt to the mechanical construction

The applicable boundary conditions for foundation types applicable to mechanized construction are summarized, as shown in Table 2.

Table 2. A table with applicable boundary conditions of the foundation

Foundation name	Scope of application
Excavation foundation	<p>Topographic conditions: flat land, hills, mountains; Geological conditions: Soil Foundation; Groundwater situation: no groundwater; Structural requirements: column diameter not less than 0.6 m and not more than 2 m, modulus 0.2 m, the base spreading angle is not more than 45.</p>
Dig Hole Foundation	<p>Topographic conditions: flat land, hills, mountains; Geological conditions: cover layer thickness requirements; for saturated uniaxial compressive strength of not more than 30 mpa bedrock, one-time hole technology pile diameter not more than 2m; For bedrock with saturated uniaxial compressive strength greater than 30 Mpa, the diameter of the primary hole-forming pile should not be greater than 1.4 m; combined with the construction method, the maximum diameter of the pile should not be greater than 2.6 m; Groundwater situation: no groundwater; Structural requirements: not suitable for bottom expansion, the diameter of pile should not be less than 0.6 m and the modulus of pile should be 0.2 m.</p>
Rock Bolt Foundation	<p>Topographic conditions: flat land, hills, mountains; Geological conditions: the cover layer thickness is not more than 4 m, the basic Quality Grade I ~ IV rock foundation. Ground water situation: no pressure groundwater.</p>
Excavation backfill foundation	<p>Topographic conditions: flat, part of the bearing capacity is high (fak not less than 100 kpa) River Network Bog area; Geological conditions: Soil Foundation; Groundwater situation: no requirement.</p>
Pile Foundation	<p>Topographic conditions: flat land, river network and marsh; Geological conditions: Soil Foundation; Groundwater conditions: no requirements.</p>

4 New Foundation for mechanical construction

On the basis of fully considering the characteristics of mechanized construction of UHV transmission line engineering, by studying and drawing on the engineering experience of other industries, three types of foundations, such as micro-piles, variable cross-section piles and sheet piles with wings, were selected as supplementary foundations for mechanized construction of UHV line in mountain area.

4.1 Micro-pile Foundation

Micro pile foundation is a new type of pile foundation with pile diameter of 200~400mm, using drilling, strong reinforcement and pressure grouting construction technology, which is suitable for mountain and flat terrain. At the same time, due to its excellent drilling ability, it can adapt to various geological conditions of rock hardness, weathering degree and integrity. Compared with excavation foundation, it has the characteristics of small pile diameter, light equipment and small field disturbance. Compared with rock anchor foundation, it has the characteristics of high bearing capacity, low requirement of covering layer thickness and rock integrity. When rock bolt foundation cannot be used due to terrain and geological conditions, micro pile foundation is the most important supplementary scheme for rock bolt foundation.

The advantages of micro-pile foundation are as follows:

- The diameter of the micro-pile foundation is suitable, and the bearing capacity of the single pile is higher than that of the anchor foundation, and the scope of application is wider.
- The requirements for geological conditions and rock integrity in mountain area are not high, which can meet the needs of foundation selection of about 3M overburden, soft rock and broken rock foundation.
- Adopting micro-pore-forming machine, it can adapt to different terrain, low safety risk, high pore-forming speed and high mechanization degree.

4.2 Variable Section Pile Foundation

The variable section pile foundation is an optimized excavation foundation designed for special geological conditions in mountainous areas. It is characterized by having different diameters for the upper and lower sections of the pile body, making it suitable for layered foundation rock masses with "upper soil and lower rock" or "upper soft and lower hard" characteristics. Practical engineering experience has shown that when dealing with strong to moderately weathered rock foundations with a saturated uniaxial compressive strength exceeding 30MPa and a pile diameter larger than 1.4m, traditional rotary digging mechanical equipment faces difficulties in hole excavation. However, by implementing the variable section pile foundation technique, the pile diameter can be reduced to less than 1.4m, effectively overcoming construction capacity limitations imposed by design schemes while improving mechanical excavation efficiency and reducing overall costs associated with this particular aspect of foundation construction.

Compared with the conventional equal section pile, The variable section pile foundation has the following advantages:

- The pile foundation with variable cross-section has obvious soil compaction effect in the bearing process, which increases the pile side friction resistance.
- According to the behavior of the pile, the stepped variable cross-section pile has the characteristics of large and small axial force passing down the pile body. Especially in layered soil, this kind of pile can bring the bearing potential of each layer of soil into full play.

- The variable-section pile foundation makes full use of the characteristics of bending moment and shear force under horizontal load, which not only saves material, but also reduces project cost.

4.3 Wing-sheet Pile Foundation

Wing sheet pile foundation refers to a foundation type which is used to increase the force area of soil resistance on the side of the pile by setting wing plates with a certain width and height at a certain depth of the pile body, so as to improve the horizontal bearing capacity. Similar to variable section pile, it is also an optimization type of excavation foundation under special geological conditions. When the soil cover thickness is not less than 5 meters and the slope is less than 20°, the pile diameter controlled by the structure or the horizontal displacement of the overlying soil layer can be reduced moderately, which has good economic benefits.

4.4 Boundary conditions of new foundation

According to the topographic and geological conditions of the tower, combined with the characteristics of mechanized construction, the applicability of micro pile foundation, variable section pile foundation and sheet pile foundation with wing in the project is demonstrated, the selection principles of the above three types of foundation are determined from a macro perspective, and the applicability boundary conditions of the foundation applicable to mechanized construction are summarized as shown in Table 3.

Table 3. A table with applicable boundary conditions of the new foundation

Foundation name	Scope of application
Micro-pile Foundation	<p>Topographic conditions: flat land, hills, mountains;</p> <p>Geological conditions: Soil Foundation (suitable for soft soil and loess) ; overburden thickness not less than 4 m, no requirements for the integrity of Bedrock, weathering degree, it can be applied to saturated rock foundation with uniaxial compressive strength of 70MPa and below.</p> <p>Groundwater status: no groundwater.</p>
Variable Section Pile Foundation	<p>Topographic conditions: flat land, hills, mountains;</p> <p>Geological conditions: the bedrock is saturated uniaxial compressive strength of more than 30 mpa strong-medium weathered rock mass; Groundwater situation: no groundwater.</p> <p>Construction requirement: the pile diameter of rock-entry part should be controlled within 1.4 m</p>
Wing-sheet pile foundation	<p>Topographic conditions: flat land, hills, hills, slopes less than 20 ° mountain;</p> <p>Geological conditions: calculated cover soil thickness of more than 5 meters, the bedrock is saturated uniaxial compressive strength of more than 30 Mpa of strong-medium weathered rock mass.</p> <p>Ground water condition: no ground water;</p>

	Structure requirement: the pile diameter of the rock-entering part should be controlled within 1.4 m, and the setting depth of the wing plate should not exceed 2 m.
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5 Conclusion

The research on the selection of UHV transmission line foundation suitable for mechanized construction focuses on the analysis of the limitations of existing foundation types in the process of mechanized construction, so as to obtain the applicable boundary conditions of conventional foundation, and propose a new foundation type suitable for mechanized construction, so as to improve the mechanization rate of UHV transmission line:

(1) Conventional excavation foundation, excavation foundation, rock anchor foundation, grouting pile foundation, excavation and backfill foundation have certain limitations in terms of terrain, geological conditions and traffic, environmental protection, tree felling and compensation, etc., which are applicable to UHV transmission lines in high mountain areas, and new foundation types need to be developed and studied. Make up for the shortcomings of conventional foundation in adapting to mechanized construction.

(2) By summarizing the boundary conditions applicable to the conventional foundation, the performance parameters of different construction machinery are counted, and the reference parameters of mechanized construction in high mountain area are given.

(3) Based on the analysis of the limitations of conventional foundation mechanization and the performance of different construction equipment, a new type of foundation, such as micro pile foundation, variable section pile foundation and sheet pile foundation with wing, is selected to adapt to the mechanized construction of UHV transmission line projects in high mountain areas.

(4) The research on the selection of the foundation for the mechanized construction of UHV transmission lines can better solve the mechanized construction of the difficult transportation sections such as high altitude and few people in the future, improve the mechanized construction rate, shorten the construction period of UHV transmission lines, and save construction costs.

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