Application Research of Miniature Group Pile Foundation in a 500kV Power Transmission Project

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Abstract. This paper focuses on the application of the miniature group pile foundation in a 500kV power transmission project. It covers the project's background, challenges, and the current research on such foundations. It details the stress and bearing performance of miniature group pile foundation and construction specifics in mountainous and rocky terrain. An economic comparison with other foundations is made, and project-based suggestions for design, construction, and economic analysis are provided. The study concludes that miniature group pile foundation enhance safety, reduce time, and lessen environmental impact, offering theoretical and practical insights for similar projects.

Keywords: Miniature group pile foundation; Power transmission line project; Mountainous and hilly areas; Bearing performance; Technical and economic analysis.

1 Introduction

Economic growth and energy demand drive power transmission infrastructure. Traditional foundation methods in complex terrains like mountains face challenges of difficulty, safety, and duration. New foundation types are needed to enhance efficiency and safety in power engineering[1]. The miniature group pile foundation shows promise in these areas.

This paper takes a certain 500kV power transmission project as the background and systematically studies the stress mechanism, bearing performance, and construction technology of miniature group piles. The research content includes: design optimization of miniature group piles, analysis of stress characteristics, key points of construction technology, and technical and economic comparison, etc.

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2 Research Status of Miniature Group Pile Foundation

Internationally, research on miniature piles started relatively early[2~3], especially in Europe and North America. France's IBEX initiated a 5-year study in 1993, exploring theory, simulation, lab tests, and fieldwork. The United States has also made significant progress in the design and application of miniature piles, especially in fields such as structural reinforcement and foundation pit support.

Domestic research and use of miniature piles began later but have grown quickly. Chinese scholars have done extensive work on the bearing performance, deformation characteristics, and construction technology of miniature piles, with notable results. Particularly in soft soils, significant practical experience has been gained.

3 Force Mechanism and Design Optimization of Miniature Group Piles

3.1 Stress Mechanism of Miniature Group Piles

Miniature group piles transfer vertical loads through the cap, with friction as the main bearing mechanism due to small diameters. Compressive deformation occurs first, followed by upward frictional resistance transferring load to soil. Uplift capacity involves side friction, pile weight, and vacuum suction. Side friction is crucial, similar to compression but in opposite direction. As uplift increases, soil layer resistance reaches limits progressively.

3.2 Optimized Design of Miniature Group Piles

Targeting the characteristics of miniature group piles, optimized design can improve their bearing performance and economic benefits. Factors such as pile diameter, pile length, pile spacing, and the number of piles should be considered in the design to achieve optimal bearing performance through reasonable design.

4 Construction Machinery and Hole-Forming Technology

4.1 Selection of Construction Machinery

Selecting the construction machinery for the construction of the miniature group pile foundation is crucial[4-6]. The water well drilling rig as shown in Figure 1 selected for this project has the following characteristics:

Dimensions: 8800×2250×3100mm, suitable for complex terrain requirements; Mobility: Tracked self-propelled, with good crossing capabilities; Drilling diameter: Ranges from 135-500mm; Gradientability: Up to 21°, adapting to the slope variations of terrain.

Fig. 1. Water Well Drilling Rig

4.2 Construction Process for Miniature Piles in Rock Areas

Drilling Positioning: Ensure stability and alignment with drilling site; Drilling: Use rock-drill bits and control speeds for rock drilling; Hole Inspection: Verify and correct hole quality to meet design specifications; Reinforcement Cage Installation and Concrete Pouring: Fabricate cage per design; use funnel to pour and compact concrete. The construction process is shown in Figure 2.

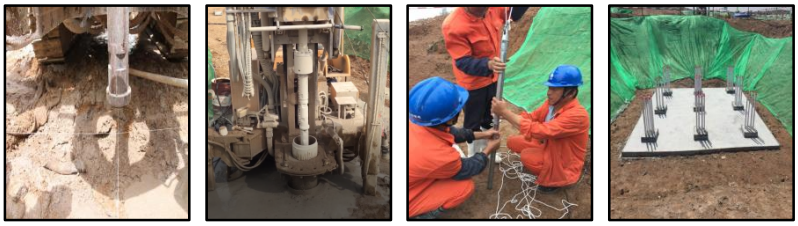

Fig. 2. Construction process

4.3 Construction Precautions

During the construction process, attention should be paid to minimizing the impact on the environment, especially in sensitive areas such as forested areas and orchards.

Ensure construction safety, particularly in high-risk operations such as rock drilling and concrete pouring.

Strictly implement quality inspection standards to ensure that every construction phase meets design and specification requirements.

5 Technical and Economic Comparison

5.1 Comparison of Technical Performance

Miniature group pile foundation construction has a high degree of mechanization, suitable for complex geological conditions, especially for rock and stiff soil, with fast construction speed and low maintenance needs. Table 1 shows the advantages of miniature group pile foundation compared to other types of foundations.

Table 1. Comparison of Technical Performance of Various Foundations

Foundation Types	Mechanization Level	Geotechnical Applicability	Construction Period	Durability
Miniature Group Piles	High Degree	Strong	Short	Good
dug hole foundations	May Require Manual Blasting	Moderate	Average	Average
Cast-in-Place Piles	High Degree	Relatively Strong	Long	Good
Slab Foundation	Relatively High Degree	Poor	Average	Fair

5.2 Material Quantity Comparison

Based on the geological survey of this project, an economic comparison is made among different foundation types as shown in Table 2.

Table 2. Comparison of Tension Tower Foundation Schemes

Item	Cast-in-Place Single Pile	Slab Foudation	Miniature Group Pile (Four Piles)	Miniature Group Pile (Two Piles)
Pile Diameter/Main Column Size/Pier (m)	1.4	1.6	0.4	0.6
Pile Length (Embedded Length) (m)	12(11.5)	\	7.5(7.5)	9.0(9.0)
Flared Bottom Width/Bottom Slab Width/Pier Slab Width (m)	\	8.1	3.3	3.0
Pier Dimensions (m)	\	\	3.3×3.3×1.1	3.0×3.0×1.1
Pier Column Size (m)	\	\	1.2×1.2×1.8	1.2×1.2×1.8
Foundation Embedment (m)	11.5	5	\	\
Pier Embedment (m)	\	\	2.4	2.4
Foundation Concrete（m^3）	73.89	273.32	86.12	88.40
Foundation Reinforcement Steel（t）	8.805	20.74	15.900	14.500
Road Conditions	\	Road widening and reinforcement 150m + new road construction 50m		
Inspection	Low Strain	-	Low Strain	Low Strain

By comparing material quantities, the difference in concrete volume between excavated pile foundations, cast-in-place single piles, and miniature group pile foundations is not significant; the concrete volume is the greatest when using slab

foundations. The amount of foundation reinforcement steel is the least for excavated pile foundations and cast-in-place single piles, while the reinforcement steel volume is relatively large for both miniature group pile foundations and slab foundations.

6 Usage Analysis and Recommendations

Miniature group piles are mainly applied in the following situations in this project: (1) Tower positions with rock strength exceeding 800 kPa; (2)Tower positions with shallowly buried rock in gentle hills and mountainous areas.

Through practical application, miniature group piles have shown the following advantages: (1)The construction safety risk is greatly reduced; (2)The construction period is shortened by 50%; (3)The mechanization application rate reaches 100%; (4)The environmental impact is significantly reduced.

7 Conclusion

7.1 Research Summary

This paper comprehensively analyzes the use of miniature group pile foundations in a 500kV power project, examining stress, performance, construction, and costs, leading to conclusive findings.

(1) Stress & Bearing: Miniature group piles show strong compressive and tensile capacity, relying on side friction and tip resistance, adaptable for complex geology. (2) Construction: Machinery like well rigs is fit for hilly terrain, with optimized processes for efficient, high-quality construction. (3) Comparison: Miniature group piles offer advantages over other foundations in performance, cost, and impact, notably in reducing time and risks. (4) Usage: The success in the project confirms benefits in safety, time reduction, and minimal environmental effect.

7.2 Research Outlook

Despite advantages, miniature group piles can still be optimized.

(1) Design: Improve design methods, considering diameter, length, spacing, and quantity. (2) Technology: Seek more efficient, eco-friendly construction to minimize environmental impact. (3) Performance: Assess long-term durability and maintenance of miniature group piles. (4) Economics: Deepen economic analysis, varying with geology and environment. (5) Environment: Evaluate long-term ecosystem impact under different conditions.

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