Practical Analysis of Pile Foundation Technology in Civil Engineering Construction of Building Projects

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Abstract: In the field of civil engineering construction of building projects, pile foundation technology is of great significance for ensuring the stability of building structures, especially widely applied in soft soil foundations and high-load building projects. Its core function is to transfer the loads from the superstructure to the stable underground soil or rock layers, thereby avoiding problems such as foundation settlement and uneven deformation. This paper first briefly describes pile foundation technology. Then, it analyzes the construction value of pile foundation technology while discussing its application principles, and provides a detailed analysis of the application of pile foundation technology, hoping to offer certain references for the development of the industry.

1. Introduction

With the continuous acceleration of China's urbanization process, the scale of building projects has been continuously expanding. There are an increasing number of high-rise buildings, large-scale factories, bridges, and other types of buildings with high loads and complex structures, which pose higher requirements for the bearing capacity and stability of foundation foundations. In civil engineering construction, the foundation is an important part of the building structure, and its quality directly determines the safety and durability of the entire building. Pile foundation technology, with its advantages of effectively transferring loads and adapting to various complex geological conditions, has become a key technical means for solving foundation problems in soft soil foundations and high-load buildings. In this context, an in-depth analysis of the practical application of pile foundation technology in civil engineering construction of building projects has important practical significance.

2. Pile Foundation Technology in Civil Engineering Construction

2.1Core Functions and Values of Pile Foundation Technology in Civil Engineering Construction

In the civil engineering construction system, pile foundation technology is not just a simple foundation support structure but a key hub connecting the upper structure of the building with the underground geological environment. The realization of its core functions directly determines the overall safety and long-term stability of the building. From the perspective of structural load transfer, pile foundation technology effectively transfers the vertical loads, horizontal loads, and seismic actions from the upper part of the building to the deeper soil or rock layers with higher bearing capacity underground, avoiding the concentration of loads on the shallow soft foundation. This significantly reduces the risks of foundation settlement and uneven deformation, which is particularly important for high-load buildings such as high-rise buildings and large-scale industrial factories. If such buildings rely on shallow foundations for direct bearing, they are prone to structural tilting, wall cracking, and other problems due to the high compressibility of the foundation soil, and may even threaten the overall safety of the building.

From the perspective of geological adaptability, pile foundation technology can break through the limitations of different complex geological conditions and provide a stable foundation guarantee

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for civil engineering construction. In adverse geological environments such as soft soil foundations, silty soil foundations, and sand layer foundations, traditional shallow foundation technologies often fail to meet the bearing requirements. Pile foundation technology can adapt to different geological characteristics by adjusting the length, diameter, and construction process of the pile: For example, in soft soil foundations, the pile can penetrate the soft soil layer and reach the stable soil layer below; in sand layer foundations, the risk of hole collapse can be reduced by optimizing the hole-forming process to ensure the adaptability between the foundation structure and the geological environment[1].

2.2 Selection Logic and Influencing Factors of Pile Foundation Technology

In civil engineering construction, the selection of pile foundation technology is not simply based on the advantages and disadvantages of the technology itself but requires the construction of a systematic selection logic by considering multiple factors such as the actual project requirements, geological conditions, and environmental constraints to ensure that the selected technology can not only meet the bearing requirements but also take into account economic efficiency and feasibility. Among them, geological conditions are the core basis for the selection of pile foundation technology, and different geological characteristics pose different requirements for the construction process, pile materials, and structural design of pile foundations. For example, in cohesive soil foundations with low groundwater levels and stable soil layers, manual dug piles can be a candidate option due to their advantages of low cost and easy visual inspection of quality; while in geological environments with high groundwater levels and widespread sand layers, manual dug piles need to be excluded due to the high risk of collapse, and bored piles or static pressure precast piles can be selected instead. Bored piles can ensure the quality of hole formation through mud slurry protection, and static pressure precast piles can reduce the disturbance to the surrounding soil layers, adapting to the construction requirements of sand layer geology.

In addition, environmental constraints and project costs are factors that cannot be ignored in the selection of pile foundation technology. In projects located in urban core areas or surrounded by sensitive buildings and residential areas, the control of noise, vibration, and pollution during the construction process is particularly important. At this time, technologies such as hammer-driven precast piles that are prone to generate strong vibrations and noise need to be excluded, and bored piles or static pressure precast piles can be selected instead; in projects in remote mountainous areas where it is difficult for machinery to enter, manual dug piles can reduce the cost of equipment transportation and entry since they do not require large-scale construction equipment, making them a better choice. From the perspective of cost control, it is necessary to comprehensively consider the material costs, construction costs, maintenance costs, and post-construction inspection costs of pile foundations: Although precast piles have relatively high material and transportation costs, their fast construction speed can shorten the construction period and reduce labor costs; although bored piles have a long construction period and high mud treatment costs, they can adapt to complex geological conditions and reduce the rework costs caused by technical mismatches. It is necessary to select the most cost-effective technical solution through full-cycle cost calculations.

3. Application Principles of Pile Foundation Technology

3.1 Principle of Geological Adaptability

The principle of geological adaptability is the primary principle for the application of pile foundation technology, with the core being to make the technology selection and construction plan fit the geological characteristics of the project to ensure that the pile foundation forms a stable force-bearing system with the underground environment. Geological conditions determine the pile type, construction process parameters, and pile design direction. Different soil layer distributions, groundwater levels, and geotechnical mechanical properties have different requirements for the bearing capacity, anti-deformation ability, and construction feasibility of pile foundations. Blindly selecting technology without considering geological conditions may lead to ineffective load transfer, increased construction difficulty, and even safety accidents. During technology application, it is necessary to grasp geological information through systematic geological surveys and dynamically adjust process parameters. If the actual geological conditions are found to be inconsistent with the survey results, additional surveys should be carried out in a timely manner and the plan should be adjusted accordingly.

3.2 Principle of Full-Cycle Economic Efficiency

The principle of full-cycle economic efficiency requires that technology selection takes into account both short-term construction investments and long-term engineering benefits, breaking away from the "low-price first" mindset and focusing on comprehensive cost-effectiveness. It is necessary to coordinate the full-cycle costs of survey and design, construction, inspection, and maintenance, and also consider potential costs such as rework and safety accidents as well as social benefit costs. Some technologies may have high initial costs but low later maintenance costs and strong anti-risk capabilities; some technologies may have low short-term costs but may increase later reinforcement costs due to defects. Therefore, it is necessary to calculate costs comprehensively in all dimensions during technology selection, incorporate environmental protection into consideration, and give priority to low-pollution and low-interference technologies to achieve the unity of economic and social benefits.

3.3 Principle of Giving Priority to Quality and Safety

The principle of giving priority to quality and safety is the bottom line for the application of pile foundation technology. It is necessary to give priority to ensuring quality and construction safety, meet standards first, and then coordinate efficiency and cost. As a concealed project, the quality and safety of pile foundations directly affect the stability of the building structure, and it is difficult and risky to repair problems once they occur. Quality control needs to run through the entire process: determine the plan based on survey data during the design stage, inspect materials and equipment and train personnel during the preparation stage, detect core processes during construction, and carry out scientific inspections later.

4. Application Analysis of Pile Foundation Technology

4.1 Manual Dug Piles

Manual dug piles rely on manual excavation and wall protection construction section by section during application. Their core advantage lies in the low requirements for the construction site, without the need for large-scale machinery to enter the site, and the ability to visually inspect the quality of pile holes, reducing the risk of concealed defects. During application, it is necessary to focus on controlling wall protection construction and safety protection. The wall protection should be poured in a timely manner as the excavation progresses to ensure tight overlap between the upper and lower sections and prevent soil layer collapse; at the same time, ventilation in the hole, low-voltage lighting, and emergency protection should be well implemented to avoid the accumulation of harmful gases or the risk of personnel falling.

From the perspective of adaptability, manual dug piles are more suitable for environments with low groundwater levels and stable soil layers. If they encounter high groundwater levels or sand layer geology, problems such as water inrush and hole collapse are prone to occur, and pre-dewatering or reinforcement measures need to be taken in advance. However, due to the limitation of construction efficiency by manual operations, they are more suitable for projects with medium and low loads and small engineering volumes. They can play a unique advantage in sites where cost control is emphasized and machinery is difficult to enter, but it is necessary to balance labor costs and construction periods to ensure that the overall project progress is not affected[2].

4.2 Static Pressure Piles

Static pressure piles press precast piles into the ground section by section through a static pressure pile driver. The core of their application lies in relying on the pressure provided by the self-weight of the equipment and the hydraulic system to achieve pile sinking, with no strong vibration and noise during the construction process and less interference with the surrounding environment. The key to their application is to control the pile sinking pressure and the verticality of the pile body. It is necessary to dynamically adjust the pile pressing speed according to geological characteristics to avoid pile body fracture caused by a sudden increase in pressure, and at the same time ensure the verticality of the pile through precise measurement to prevent uneven force later.

In terms of adaptation scenarios, static pressure piles are suitable for areas with high environmental protection requirements, such as projects in urban residential areas or surrounded by sensitive buildings. In terms of geological conditions, they are more suitable for soil layers such as cohesive soil and silty soil. If there are hard inclusions or boulders, pre-treatment is required to reduce the resistance to pile sinking. In addition, although static pressure piles have high construction efficiency and can shorten the construction period, they have high requirements for equipment tonnage, and it is necessary to select equipment reasonably according to the bearing capacity of the site to avoid equipment subsidence affecting construction.

4.3 Precast Piles

Precast piles need to be produced in a standardized manner in a factory before application and then transported to the site for pile sinking operations. Their core characteristic is that the quality of the pile body is stable and controllable, and the construction process is highly standardized, which can reduce quality fluctuations in on-site construction. During application, it is necessary to focus on the transportation of the pile body and the quality of pile connection. Protection measures should be taken during transportation to prevent damage to the pile body due to collisions; during pile connection, it is necessary to ensure that the joint welding is full or the connection is firm to avoid joint failure under later force.

In terms of adaptability, precast piles are suitable for projects with tight construction periods and high requirements for pile body strength. They can give full play to their advantages in sites with relatively uniform soil layer distribution. However, their application range is easily affected by transportation conditions due to transportation limitations, and if the hammer-driven method is used for pile sinking, noise and vibration will be generated, and the pile sinking process should be selected according to environmental requirements[3].

4.4 Bored Piles

Bored piles form pile bodies by drilling holes on site, lowering steel reinforcement cages, and pouring concrete. Their core advantage lies in their ability to adapt to complex geological conditions and adjust the pile length and pile diameter according to actual needs, with strong flexibility. The key to their application lies in controlling the quality of hole formation and concrete pouring. During hole formation, it is necessary to stabilize the hole wall through mud slurry protection to prevent hole collapse, and at the same time control the accuracy of the drilling depth and hole diameter; during concrete pouring, it is necessary to ensure that the buried depth of the tremie is reasonable to avoid defects such as pile breakage and mud inclusion.

In terms of adaptation scenarios, bored piles are suitable for projects with complex geological conditions, such as sites containing sand layers, gravel layers, or rock layers, and are widely used in high-rise buildings, large-scale structures, and other projects with high bearing capacity requirements. Their construction process has no obvious vibration and noise, with good environmental protection performance, but it is necessary to treat mud waste to avoid environmental pollution. In addition, bored piles have a long construction period, and it is necessary to plan the construction period well, and at the same time strengthen the quality control of the production and installation of steel reinforcement cages to ensure the overall force-bearing performance of the pile body.

5. Application Cases and Quality Control Measures of Pile Foundation Technology

5.1 Application Cases

The application cases of pile foundation technology are mostly concentrated in building scenarios that need to solve complex foundation problems or meet high-load requirements, and different pile types form differentiated application logics according to the core requirements of the project and geological conditions. In urban low- and medium-rise residential projects, if the site has low groundwater levels, stable soil layers, and limited machinery entry, manual dug piles are often used, relying on their advantages of low requirements for the site and controllable costs to adapt to medium and low-load requirements; in building projects surrounded by high-density residential areas in urban areas, due to high requirements for environmental protection and noise control, static pressure piles become the preferred option due to their characteristics of low vibration and low interference, which can reduce the impact of construction on the lives of surrounding residents.

In the construction of factory buildings in industrial parks with tight construction periods, precast piles can quickly complete foundation construction due to their characteristics of standardized production in factories and high on-site construction efficiency, adapting to the progress requirements of industrial projects; in high-rise buildings or large-scale bridge projects, due to complex geological conditions and high bearing capacity requirements, bored piles become the core foundation solution due to their ability to flexibly adjust pile length and pile diameter and adapt to complex geological conditions. The commonality of these cases is that they all select adapted pile foundation technologies based on project geological conditions, load requirements, environmental protection requirements, and construction period planning to ensure foundation safety and overall project benefits[4].

5.2 Quality Control Measures for Pile Foundation Technology

The quality control of pile foundation technology needs to run through the entire construction process, forming a closed-loop control from pre-construction preparation to post-construction inspection. In the early stage, it is necessary to strengthen the quality of geological surveys to ensure that the survey data accurately reflect the soil layer distribution, groundwater levels, and adverse geological conditions, providing a reliable basis for technology selection and parameter design. At the same time, the construction plan should be strictly reviewed, with a focus on checking the adaptability of the process and the feasibility of emergency measures.

During the construction stage, it is necessary to focus on the control of core processes and formulate special measures according to the characteristics of different pile types: for manual dug piles, it is necessary to strictly control the quality of wall protection pouring and safety protection in the hole; for static pressure piles, it is necessary to monitor the pile sinking pressure and the verticality of the pile body in real-time; for precast piles, it is necessary to ensure the protection of pile body transportation and the quality of pile connection; for bored piles, it is necessary to focus on controlling the effect of mud slurry protection and the buried depth of the concrete pouring tremie. At the same time, a "self-inspection - mutual inspection - special inspection" three-level inspection mechanism should be established, and the next process cannot be carried out if the previous process fails to meet the standards to avoid the accumulation of quality hazards.

In the later stage, it is necessary to verify the quality through scientific inspections, using methods such as static load tests and low-strain reflection wave methods to detect the bearing capacity of the pile foundation and the integrity of the pile body. For pile bodies that fail the inspection, a rectification plan should be formulated in a timely manner, and on this basis, construction data should be archived comprehensively, recording parameters and inspection results at each link to form a complete quality traceability system, providing a basis for subsequent project acceptance and maintenance.

6. Conclusion

In summary, in the civil engineering construction system of building projects, pile foundation technology has always been a key support for ensuring the stability of building structures. The scientificity and rationality of its practical application are directly related to the overall quality and safety of the project. With the expansion of civil engineering construction to higher-rise and more complex scenarios, as well as the in-depth application of green and intelligent concepts, the practical direction of pile foundation technology will also continue to upgrade, and its reliability will be ensured through quality control. In the future, it is necessary to further explore the integration of environmentally friendly processes and new materials and promote the application of intelligent monitoring methods in construction on the basis of existing technologies to lay a solid foundation for the high-quality development of building projects.

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