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Research on foundation engineering design and construction technology in soft soil area

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Abstract: The design and construction technology of foundation engineering in soft soil areas have always been a critical issue in the field of civil engineering. This paper conducts an in-depth study on the design and construction technology of foundation engineering in soft soil areas, systematically summarizing existing theories and practical experiences. Firstly, a detailed analysis of the geological characteristics of soft soil areas is carried out, clarifying the engineering properties of soft soil and its challenges to foundation engineering. Subsequently, in conjunction with relevant research findings both domestically and internationally, a series of effective methods and technologies for the design and construction of foundation engineering in soft soil areas are proposed.

1. Introduction

The unique geological conditions in soft soil areas pose significant challenges to the design and construction of foundation engineering. Due to the rheological properties, heterogeneity, and sensitivity to moisture of soft soil, traditional design and construction techniques for foundation engineering often prove insufficient in such areas. Therefore, it is necessary to conduct an in-depth study on the design and construction technology of foundation engineering in soft soil areas to meet the specific requirements of foundation engineering in these regions.

2. Geological Characteristics Analysis of Soft Soil Areas

2.1. Definition and Classification of Soft Soil

Soft soil is a special type in geotechnical engineering, characterized by loose texture, high water content, and relatively low shear strength. This type of soil has significant potential for settlement and deformation, posing a series of challenges in foundation engineering. The definition of soft soil is based on both the physical and engineering properties of the soil, and it can be classified into various types, including organic colloidal soil, cohesive soil, and loose sandy soil, among others. Organic colloidal soil mainly contains organic matter, with fine soil particles leading to strong rheological properties and a tendency for settlement deformation. Cohesive soil exhibits strong cohesive force and plasticity, making it prone to substantial settlement. Loose sandy soil, on the other hand, has low friction between particles, resulting in relatively low shear strength that affects the bearing capacity of foundation engineering. The geological characteristics of soft soil areas require

special attention in foundation engineering. A thorough understanding of the definition and classification of soft soil contributes to a better comprehension of the engineering properties in soft soil areas, providing a scientific basis for the design and construction of foundation engineering. [1]

2.2. Geological Characteristics of Soft Soil Areas

The geological characteristics of soft soil areas encompass several aspects, with soil layer structure, water content, and deposition environment being key factors. These areas are typically formed due to the deposition processes of ancient rivers and lakes, resulting in soil with unique features such as uneven distribution, interlayer complexity, and high water content.

The soil layer structure in soft soil areas exhibits non-uniform distribution, with different depths and positions having distinct physical properties. This variability poses challenges in the design and construction of foundation engineering, requiring precise selection of appropriate treatment schemes based on actual conditions. The relatively high water content in soft soil areas is related to their ancient history of lake and river sedimentation. The high water content makes the soil sensitive to water migration, susceptible to seasonal influences, and prone to settlement deformation.

Therefore, in foundation engineering design, dynamic changes in soil water content must be thoroughly considered, and measures should be taken to maintain the stability of the project. [2]

The influence of deposition environments results in an interlayered structure in soft soil areas, indicating variations in soil properties at different locations. In the construction of foundation engineering, these differences need to be comprehensively considered, and corresponding construction schemes and ground treatment measures should be implemented to ensure the sustainability and safety of the project. These geological characteristics present complex and diverse challenges for foundation engineering in soft soil areas. Understanding and fully considering the geological features of soft soil areas are crucial for developing scientifically reasonable plans in the design and construction processes.

2.3. Impact of Soft Soil on Foundation Engineering

The impact of soft soil on foundation engineering primarily manifests in ground settlement, reduced bearing capacity, and decreased shear strength. Due to the unique properties of soft soil, foundation engineering in soft soil areas often encounters significant deformation and stability issues.

Firstly, the variation in moisture content in soft soil is a crucial factor. Soft soil is highly sensitive to changes in moisture, and seasonal rainfall or fluctuations in groundwater levels can cause significant volume changes in the soil, leading to foundation settlement. This poses severe challenges to the stability and sustainability of foundation engineering, requiring corresponding moisture control measures in design and construction.

Secondly, the low shear strength of soft soil increases the difficulty in the design and construction of foundation engineering. Foundations in soft soil are prone to significant deformation, and the low shear strength of soft soil threatens the stability of the foundation. Construction must consider the engineering characteristics of the soil, employing suitable ground treatment techniques and structural designs to ensure that the foundation engineering can withstand external loads while maintaining stability. [3]

Therefore, the design and construction of foundation engineering in soft soil areas must consider the unique properties of soft soil and employ effective technical means to address potential settlement, deformation, and stability issues, ensuring the safety and reliability of the project. This requires in-depth research into the geological conditions of soft soil areas to develop scientifically reasonable foundation engineering plans.[4]

3. Foundation Engineering Design Methods in Soft Soil Areas

In the design of foundation engineering in soft soil areas, ground treatment technology is a crucial step to ensure project stability. Different types of soft soil require different treatment methods to enhance the bearing capacity and overall stability of the foundation. The following are key aspects of ground treatment technology:

3.1. Reinforcement Techniques

The purpose of employing reinforcement techniques in soft soil areas is to increase the bearing capacity by introducing external materials or structures. Common reinforcement methods include:

3.1.1. Strengthening Techniques

Introducing rigid underground beams or walls to disperse loads and improve the overall stability of the soil. This method is suitable for soft soil areas, especially when a significant increase in bearing capacity over a large area is needed. Using methods such as underground piles or mixing piles to enhance the shear strength of soft soil, thereby reducing foundation settlement. The choice of pile type and arrangement depends on specific soil conditions. Introducing these rigid structures into soft soil effectively disperses loads, enhances the overall compressive capacity of the soil, slows down the settlement process, and ensures the stability of foundation engineering.[5]

3.1.2. Improvement Techniques

The purpose of employing improvement techniques in soft soil areas is to alter the engineering properties of the soil to make it more suitable for foundation engineering. Common improvement methods include:

Stabilizing agents can be added to solidify soft soil and increase its overall shear strength, which is useful in areas where stability improvement is needed. The selection and mixing methods of these agents require detailed design considerations based on soil characteristics and engineering requirements to ensure the desired strength and stability enhancement.

Another method involves adding improvement materials such as lime or cement to alter the physical and chemical properties of the soil, thereby increasing its bearing capacity. This approach is typically used when higher soil strength is required in soft soil areas. Precise proportions and mixing methods are crucial for effectively improving the engineering properties of the soil and enhancing overall stability.

Additionally, permeation consolidation liquids or gases can be used to alter the pore structure of soft soil, increasing its shear strength and stability. This method is suitable for local or overall reinforcement of the soil. Factors such as the selection of permeating agents, depth, and rate must be considered to ensure effective soil reinforcement. [6]

3.1.3. Preprocessing Techniques

Preprocessing techniques involve taking measures before construction to ensure that soft soil achieves good engineering performance during foundation engineering. The main preprocessing methods include:

Controlling the water content in soft soil through a drainage system can reduce the impact of moisture on the soil, thus slowing down foundation settlement. This method effectively prevents volume changes in the soil due to moisture, reduces the occurrence of settlement, and ensures the stability of foundation engineering.

Applying pre-pressure to consolidate soft soil can increase its bearing capacity and stability. This method is commonly used in soft soil areas that need to withstand heavy loads. Applying pre-pressure can improve the engineering properties of soft soil, reducing deformation and settlement during construction.

Applying a certain load before construction to precompact the soil can minimize post-construction settlement and deformation. This method is suitable for soft soil areas that need to achieve stability in a short period. Preloading can effectively control settlement during foundation engineering construction, ensuring that the project reaches the required stability in a short time.

The selection of ground treatment technology should be based on specific geological characteristics and engineering requirements in soft soil areas. A comprehensive consideration of various factors is necessary to formulate a scientifically reasonable treatment plan, ensuring the safety and reliability of foundation engineering. During implementation, strict adherence to design requirements and standards, along with effective quality control and monitoring, is essential to ensure the effectiveness of ground treatment technology.

3.2. Foundation Type Selection and Design

In the design of foundation engineering in soft soil areas, choosing the appropriate foundation type is crucial, as different types of foundations are suitable for different soft soil conditions. The following are common foundation types and their design considerations in soft soil areas:

3.2.1. Shallow Foundations

Raft foundations are suitable for low-bearing capacity soft soil areas. By increasing the foundation's base area, raft foundations can disperse loads, reduce foundation stress, and mitigate ground settlement. Slab foundations are another common shallow foundation form, using cement or steel plates on the soil surface to expand the base area, enhance overall bearing capacity, slow down ground settlement, and maintain structural stability. Cantilever wall foundations are suitable for situations requiring higher bearing capacity, increasing foundation stiffness by setting deep wall structures.

3.2.2. Deep Foundations

Pile foundations are a common form of deep foundation in soft soil areas, penetrating into more stable soil layers to increase bearing capacity. In soft soil areas, methods such as mixing piles and cast-in-place piles are commonly used to strengthen soil shear strength, achieving a stable foundation. Pier foundations are another form of deep foundation, transferring structural loads to deeper soil layers by setting pier columns in soft soil. Foundation design also needs to consider the deformation characteristics and moisture sensitivity of soft soil. Through detailed geological surveys and engineering analysis, suitable foundation types, sizes, and forms should be determined to ensure the safety and reliability of foundation engineering in soft soil areas. Such a comprehensive design and construction strategy can effectively reduce the risk of foundation engineering in soft soil areas, ensuring its long-term stable operation.

3.3. Material Selection and Quality Control

3.3.1. Ground Reinforcement and Improved Soil Materials

Selecting appropriate materials is crucial when undertaking ground reinforcement and soil improvement projects in soft soil areas. This involves material selection and quality control for

different ground treatment technologies.

For ground reinforcement projects such as reinforced piles and mixing piles, high-strength concrete or similar materials are commonly used. Key to quality control is ensuring that the concrete mix and slump meet design requirements to guarantee the piles have excellent compressive and shear performance. In soil improvement projects, soil improvement agents such as lime and cement must adhere to relevant standards. Quality control should focus on the proportion and uniformity of the improvement agent, ensuring consistent and stable enhancement of soil properties. Additionally, materials used in preprocessing techniques, including drainage equipment and consolidation materials, need to exhibit excellent durability and adaptability to soft soil environments.

3.3.2. Foundation Structure Building Materials

The building materials for foundation structures play a crucial role in the stability and durability of the project. In soft soil areas, concrete is a common building material. Attention must be paid to the mix design to ensure sufficient strength and impermeability in the soft soil environment. During construction, particular attention should be given to the uniformity and compactness of concrete pouring to prevent quality issues. Moreover, the steel used must adhere to relevant standards and possess sufficient tensile strength and corrosion resistance. In soft soil areas, the humid environment requires special attention to corrosion protection for steel, extending its lifespan.

In summary, for material selection and quality control in foundation engineering in soft soil areas, strict adherence to design standards and construction specifications, using appropriate materials, and implementing scientific quality control are essential guarantees for the long-term stability of foundation engineering.

4. Construction Techniques for Foundation Engineering in Soft Soil Areas

4.1. Pre-Construction Preparation

Prior to initiating construction in soft soil areas, thorough pre-construction preparation is a crucial step to ensure project stability and smooth execution. The following are important aspects of pre-construction preparation:

4.1.1. Comprehensive Geological Survey

Conducting a comprehensive and detailed geological survey is the primary task in pre-construction preparation. This work aims to gain in-depth knowledge of the geological conditions in soft soil areas, including factors such as soil layer structure, moisture content, and groundwater levels. These data provide a critical foundation for formulating targeted and feasible construction plans.

4.1.2. Site-Specific Foundation Investigation and Analysis

Detailed investigation and analysis of the foundation conditions at the construction site are equally essential. This step enhances the understanding of the characteristics of the foundation in soft soil areas, providing practical insights for the formulation of construction plans. It aids in accurately assessing the bearing capacity and deformation characteristics of the foundation, serving as a scientific basis for the selection of subsequent ground treatment technologies.

4.1.3. Engineering Design Review

A reasonable engineering design review is crucial during the pre-construction preparation phase. This ensures that the design takes into account the actual conditions of soft soil areas, selecting the

most appropriate ground treatment technology, foundation type, and materials. The review process helps identify and address design issues promptly, ensuring the efficiency and feasibility of construction.

4.1.4. Environmental Protection and Safety Measures

Pre-construction preparation also needs to consider factors such as environmental protection and safety in production. Formulating relevant construction management plans, specifying measures, and regulations during construction ensure environmental friendliness and worker safety. This includes planning construction areas sensibly to minimize impacts on the surrounding environment and ensuring worker safety during construction.

In summary, pre-construction preparation is the foundation for the successful construction of foundation engineering in soft soil areas. Through detailed geological surveys, site-specific foundation investigations, design reviews that consider soft soil conditions, and comprehensive considerations of environmental and safety factors, these preparations provide a solid basis for subsequent construction, ensuring the reliable implementation of the project.

4.2. Technical Points during Construction

In the construction process of foundation engineering in soft soil areas, ensuring the precise construction of ground treatment technology is crucial. For reinforcement, improvement, and preprocessing of foundation treatments, precise control of construction parameters is the key to ensuring treatment effects meet design standards and enhance overall stability in soft soil.

4.2.1. Precise Construction of Ground Treatment Technology

In the construction of foundation engineering in soft soil areas, the construction requirements for ground treatment technology demand precision and caution. For activities such as reinforcement, improvement, and preprocessing, it is crucial to accurately control parameters such as depth, density, and construction methods. Only by ensuring the accuracy of these parameters can the effects of ground treatment meet design requirements, thereby improving the overall stability of soft soil.

4.2.2. Key Points in Shallow and Deep Foundation Construction

For the construction of shallow foundations, strict requirements exist for the flatness and strength of the foundation to ensure good contact with the soft soil. In deep foundation construction, special attention is required for the quality and verticality of pile bodies to ensure the load-bearing performance of the piles. Simultaneously, appropriate technical measures should be taken promptly to address common construction issues in soft soil areas, such as mud leakage and soil squeezing, to ensure smooth construction.

4.2.3. Quality Control during Construction

Quality control during construction is the guarantee of success for foundation engineering in soft soil areas. Monitoring and testing are required for aspects such as material selection, concrete pouring, and reinforcement placement. Through comprehensive and scientific quality control, each construction phase can conform to design standards, ensuring high-level stability and reliability during the construction of foundation engineering in soft soil areas.

4.2.4. Timely Resolution of Construction Issues

Various issues may arise during the construction of foundation engineering in soft soil areas, such as mud leakage and soil squeezing. These issues need to be promptly identified and addressed with corresponding technical measures. Establishing an emergency response mechanism ensures that issues encountered during construction can be swiftly resolved, preventing them from affecting the quality and progress of the project. By addressing construction issues promptly, the smooth progress of foundation engineering in soft soil areas is ensured.

4.3. Post-Construction Monitoring and Maintenance

In the post-construction phase of foundation engineering in soft soil areas, establishing an effective monitoring system is crucial. Implementing systematic monitoring through appropriate means and frequencies provides accurate data support for subsequent maintenance, ensuring the stability and safety of the foundation project.

4.3.1. Establishment of an Effective Monitoring System

The primary task in post-construction monitoring and maintenance is to establish an effective monitoring system. This includes selecting suitable monitoring methods, such as on-site measurements and remote sensing technologies, and determining the monitoring frequency. Systematic monitoring allows timely access to various indicators of the foundation project, providing accurate data support for subsequent maintenance.

4.3.2. Regular Inspection and Problem Diagnosis

Regular inspection is a crucial component of post-construction maintenance. Developing a rational inspection plan based on the characteristics and usage of the foundation allows for a comprehensive examination. Regular inspections help identify potential problems, such as cracks or settlements, facilitating problem diagnosis. This aids in taking necessary repair measures before problems escalate, ensuring the long-term stability of the foundation project.

4.3.3. Implementation of Maintenance Measures

Based on the results of inspections and problem diagnosis, formulate corresponding maintenance plans. Maintenance measures may include cleaning drainage systems, repairing cracks, and reinforcing partially damaged areas. The implementation of these measures requires scientific methods and professional techniques to ensure that the maintenance effects meet design requirements. Through timely and targeted maintenance, the lifespan of the foundation project is extended, ensuring its long-term stable operation.

4.3.4. Analysis and Evaluation of Monitoring Data

Data obtained from the monitoring system need to undergo scientific analysis and evaluation. This includes quantitative analysis of indicators such as settlement, deformation, and shear strength to assess the overall stability of the foundation project. The interpretation of monitoring data is a critical step in providing a scientific basis for subsequent maintenance plans. Through scientifically sound monitoring and maintenance, foundation engineering in soft soil areas can maintain long-term stability and safety. This not only contributes to extending the lifespan of the foundation project but also provides strong support for future maintenance work.

5. Conclusion

Through the design and construction technology of soft soil area, this paper summarizes the key problems and solutions of foundation engineering in soft soil area. When carrying out foundation works in soft soil areas, the geological characteristics of soft soil should be fully considered, the appropriate foundation treatment technology and foundation type design should be adopted, and the technical points and monitoring and maintenance work in the construction process should be emphasized. This will provide reliable theoretical guidance and practical experience for the design and construction of foundation engineering in the soft soil area.

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