Construction Technology for Foundation Reinforcement with Cement-Soil Mixed Piles in Municipal Road Projects

Jun Jin

Baohe Construction and Development, Hefei, Anhui, 230000, China

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Abstract: As a crucial component of urban transportation systems, municipal roads have their foundation treatment quality directly related to road service life and operational safety. Taking a municipal road project as an example, this paper details the application of cement-soil mixed piles in soft soil foundation reinforcement under complex geological conditions such as loose strata, high water content, and insufficient strength. Firstly, the basic principle of cement-soil mixed piles is expounded, emphasizing that they improve foundation bearing capacity and stability by forming a well-integrated and appropriately strong consolidated soil layer through physicochemical reactions between cement and soft soil. The latter then analyzes these core technical points from four dimensions of construction preparation, process flow, quality inspection and construction precautions respectively to provide a technical basis for high-quality construction in municipal road projects.

1. Introduction

The quality of construction performs a significant function in city transportation networks, equivalent to municipal roads will not be solely vital for the effectivity of the vehicle visitors but additionally affect on the security and safety of residents touring by them it should step-up future developments at each metropolitan space. Foundation treatment for municipal road construction is a very important link, foundation stability determines the length of time to maintain good performance of the road. Cement-soil mixed piles, as a new foundation reinforcement technology, has been continuously implemented in municipal road projects due to its high efficiency and significant effects among the various commonly used foundation reinforcement technologies. As the trend of urbanization accelerates, it is of great significance to carry out rational popularization and optimization research on cement-soil mixed pile foundation reinforcement technology for municipal road engineering projects which can effectively improve their construction quality and long-term safe operation.

2. Project Overview

A certain municipal road project has a total length of 998.7 m, with a standard red line width of 60 m. Preliminary geological surveys reveal that the site's soil layers primarily consist of interbedded marine and terrestrial deposits, rendering the soil loose and unstable. The surface is covered with plain fill soil, approximately 2.4–4.3 m thick, filled within the last three months, with relatively high water content, insufficient strength, and inadequate compaction. Some areas are replenished by groundwater, with widespread soft soil layers. Beneath the plain fill soil, there is mainly silty clay interbedded with silt, while deeper layers consist of clay interbedded with silt or silty sand. The stratigraphic structure is complex, with poor soil uniformity, interbedded silty sand and thin silt layers, and overall poor engineering geological conditions unsuitable as a qualified subgrade bearing layer. Without reinforcement, post-construction settlement, cracking, and even damage to the pavement are likely, severely affecting its safety and durability. Therefore, based on project (actual conditions) and technical feasibility analysis, the project ultimately decided to adopt cement-soil mixed pile construction technology for soft foundation reinforcement to enhance

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foundation bearing capacity, improve stability, and ensure the successful completion and long-term safe operation of the road project.

3. Principles of Foundation Reinforcement Technology with Cement-Soil Mixed Piles

3.1 Basic Concepts of Cement-Soil Mixed Piles

Cement-soil mixed piles are an effective technology for soft soil foundation treatment, which is more suitable to strengthen the saturated soft clay layer in municipal road construction hugely employed as a method of the Civil Engineering project. The general principle is to use cement as the solidifying agent and a special mixing equipment to inject cement slurry or powder into deep soft soil layer and fully mix them, thus it produces physiochemical reactions with the soil. This converts the low strength and very stability soft soil into a combination of high-stability, high-strength substance base in addition to h2o-stable foundation layer.

The cement selection is critical in this technology system. Common Portland cement is generally selected because of the advantageous setting and hardening characteristics it exhibits that facilitate beneficial chemical interactions with soft soil to form robust cement-soil piles. Soil conditions vary considerably which is critical to construction processes and treatment effectiveness. As an example, silty soils contain a lot of water in the soil as well as permeable and generally porous, but tend to be weak, so when in construction there is no dependence on cement content and consumption path mixing that bad cause the quality of pile greatly affect it. For less sticky silt and sandy soils dominated by coarse, high-permeability particles, more care needs to be taken with regards to slurry penetration and diffusion throughout operational work in order to achieve uniform mixing.

Construction techniques are essentially the most important steps that basically determine whether cement-soil mixed pile construction is successful. As you operate mixing machinery, rotating blades must thoroughly mix cement and soil together so that the solidifying agent can fully bond with soil particles to create a solid structure pile. Construction parameters like mixing depth, rotational speed and blade structure should be regulated and controlled in engineering geological conditions. To maximize the reinforcement effects of cement-soil mixed piles, it is necessary to control construction methods accurately as well as evenly mix the materials [1].

3.2 Reinforcement Technology with Cement Mixed Piles

Cement mixed-pile is one of the commonly used foundation reinforcement methods in saturated soft soil foundation treatment. It uses lime or cement as a solidifying agent, and employs mechanical mixing power to operate on silicon soft soil at deep foundation layers. The soft soil undergoes physical and chemical reactions with the solidifying agent, and it becomes a high-strength, well-structured and water-stable reinforced soil through this process. Structurally, cement mixed piles can be considered as composite piles having compressive strength, lateral pressure resistance and overall stiffness values between flexible ones and rigid piles. Because of the limitations associated with the pile rigidity, possible deformation problems may emerge when vertical loads are outside a certain range. As a result, flexible composite foundational forms have come to be utilized increasingly in engineering practice as a method of improving bearing performance and dealing with complex geological conditions.

4. Construction Techniques

4.1 Construction Preparation

1) Based on thorough preparation of the main technical data before construction such as pile top elevation, pile length and reinforcement depth, pile layout drawings and mix proportions. The pile layout is a square shape and the spacing of the piles is controlled at 1.3 m in roadbed sections and 1.6 m in green belt areas, respectively. The construction pile is 15 m long (effective pile length 14.5 m), and the minimum required cement content does not require less than 18%.

2) Before the formal operation of the construction site, leveling must be done at the place.

Concurrently, an extensive underground pipeline survey should be performed to remove any obstacle up to a buried depth of 2 m and harden areas of soft soil with plenty of capacity for pile layout and machinery. All in all, scientific planning of equipment layout, transmission pipelines and power lines to meet the specifications to achieve orderly overall construction.

3) The cement slurry mixing system, including mixing devices, storage units and conveying equipment shall be pre-assembled and tested. Proper layout and process connection contribute to construction efficiency.

4) The construction of the cement mixing pile must strictly follow the design plans. Strict adherence to test standards for pile strength, uniformity, and compliance is essential.

5) The overall use of qualified products in terms of raw materials On the other hand, it is necessary for construction staff to receive systematic safety training and specific technical disclosure, effectively cultivating the awareness of norms and operational abilities, which can provide effective guarantee for project quality and construction safety [2].

4.2 Construction Techniques

In this project, with a complete process flow: Surveying and setting out → drill positioning → equipment inspection — cement slurry mixing → initial descent with spraying and mixing of the slurry→ pile body rising to mix → Secondary Descent with slurry spraying and mixing further rise for Mixing Pile Body Formation→ Equipment Relocation in this project Adopted two-spray four-mix wet method.

1) Surveying and Setting Out. Review measurement control points supplied by the owner before building work, accurately stake and position individual piles as per design drawings. Sign off each pile in turn before you sign off to the next stage.

2) Drill Positioning. The drill bit center must exactly align with the designed pile position, because only this can ensure that the vertical direction of the pile machine will not tilt and slip or turn to form inclined or offset piles that may adversely affect foundation bearing capacity. Just to confirm whether the drill and other construction equipment are operational, a full test should be conducted before operation.

3) Cement Slurry Mixing. Background Preparation of slurry in advance prior to drill descent operations Selection of P·O42. 5 commercial ordinary Portland cement containing 18% (equivalent to 79 kg per linear meter) and mixing with strictly controlling a water-cement ratio of 0.55 in preparation stage. In case the injection radius is greater than drain based storage devices should be applied in appropriate places for continuous slurry supplied.

4) Descent with Slurry Spraying and Mixing Once the motor is started, the mixer will continuously falling along the direction of pile frame in such a way that measured by an ammeter for ensuring its descend speed do not settle down exceeding 1.2 m/min while controlling the slurry spray volume according to design requirement. Keep on with the mixing while the drill rod is vertical during descent.

5) Elevation and Mixing. Immediately after ascending to the predetermined height, hatch — opening-junction should be opened and mixing should begin— keeping stirring speed at 0.8 m/min for even mixing of cement-soil paste within pile body.

6) Process Repetition. Correlatively, descend again for slurry spraying and mixing followed by another elevation and repeat once more for a total of four elevation-mixing operations. When the mixing reaches the designed pile stopping elevation, qualified pile body can be formed.

7) Equipment Cleaning. When construction stops or is interrupted for more than three hours, water must be fed into the slurry mixing system to mix the residual soft soil within the mixing head in order to flush through the pipelines, prevent equipment blockage, and ensure smooth subsequent construction [3].

4.3 Construction Quality Inspection

In order to guarantee the quality of cement mixed piles, it is necessary for many projects to control the original data and construction site records, and the pile quality can be comprehensively evaluated by a variety of detection methods. First is the inspection of the pile digging and finishing

stage, that is, according to the design requirements randomly into some finished piles for inspection, mainly checking whether everything meets the standards and whether cement slurry or soft soil mixture has been mixed thoroughly Bonding to determine if you meet specifications. At the same time, drilling and coring shall be carried out to reflect the internal structure of the pile body in a visual manner, and it should also also check whether the mixing depth reached during construction meets design requirements and whether the total length of pile meets design requirements.

As well as indoor test block strength tests, the correlations and analyses of coring samples and relevant test results can provide estimates on its real bearing capacity under typical in-situ conditions, which is important for verifying it meets design bearing requirements. Secondly, in suit test means should also be used to detect the pole strength and homogeneity such as light dynamic penetration tests and standard penetration tests, with provision of real-time monitoring of pile traits [4].

During the construction of soft soil foundation reinforcement, monitoring lateral displacement and settlement is also an indispensable aspect, with specific detection measures including:

1) Three days after pile formation, excavate shallow pile heads to a depth of 50 cm below the gray surface; adopt visual evaluation for uniform mixing degree and actual measurement for pile diameter, with a sampling inspection ratio of no less than 1/20 of the total number of piles.

2) On the 10th day after pile formation, conduct N10 tests using a lightweight dynamic penetration device to verify pile length and pile body uniformity, with a test quantity requirement of 1/100 of the total number of piles.

3) On the 28th day after pile formation, clean the pile tops and conduct drilling and coring as well as mechanical tests. The coring rate should exceed 85%, and pile position detection should be random and uniform, with a sampling frequency of 0.5% of the total number of piles. The unconfined compressive strength of the pile body should preferably be greater than 0.6 MPa; for foundation bearing capacity tests, the green belt area should meet 80 kPa, and the roadbed section should meet 100 kPa.

5. Construction Precautions

5.1 Strict control over pile diameter and pile length is essential

Before drill operation, the length of the mixing pile should be precisely set to avoid construction depths exceeding design standards. Regularly check the diameter and mixing state of the formed mixing pile while keeping the drill bit intact. Once wear exceeds 10 mm, you must put them out of service and replace immediately to prevent an impact on the quality of the pile body and/or a drop in stability.

5.2 During pile body construction, the verticality of the pile must be maintained

The angle between the workbench and ground and how level the lifting device It can keep getting calculated in operation. Re-inspect each pile position at least two times and arrange personnel to supervise and record the entire process of operations during site inspection. The deviation of verticality is not more than 1 degree. A real-time monitoring lever should be used for the drill rod as a plumb bob and correction measures against inclination of the drill rod should be taken at that point in order to prevent calcareous capacity.

5.3 Must ensure the forming quality of pile ends, pile bodies and pile tops

END GRINDING: For end grinding, spend about 1 minute at the pile bottom during the first drill lifting The remainder of slurry at the bottom must be uniformly spray into the pile body during repair lifting, and take 30 s in top for head grinding. Construction should leave slurry spraying on a pile-by-pile basis without stopping. In case of slurry spraying interruption (for instance, power failure or equipment failures), the stopping depth will be precisely recorded, and an initial spray after no more than 12 hours has passed from the stop point along a section of at least 100 cm; construction suspension for over 12 hours must be followed by stack reconsolidation operations.

6. Conclusion

Cement-soil mixed pile is one of the mature and efficient technologies for soft soil foundation treatment, which shows great advantages in municipal road construction. On the other hand, they solve insufficient bearing capacity and low deformation modulus of soft soil layers, but also guarantee overall foundation stability and long-term road operational safety by controlling process reasonably and inspecting quality strictly. It has been demonstrated in practice that reasonable promotion and optimization of construction technology of cement-soil mixed pile can improve the quality of municipal road projects, reducing later maintenance costs as well as avoiding safety accidents. With a rapid pace of urbanization, the practical value and promotional importance of this technology will be more and more evident, thus giving strong backing to the sustainable development of urban road infrastructure.

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