Research and Application of Leakage Control Technology for the Secant Pile Waterproofing Curtain in Complex Environments

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Abstract. This paper analyzes the difficulties in construction and the reasons for the leakage of biting piles in engineering, and proposes anti leakage treatment plans, including groundwater level control technology, construction process control technology, leakage blocking scheme between biting piles, and an-chor hole leakage blocking treatment scheme. At the same time, the charac-teristics of two sealing and plugging schemes, cement+water glass dual liquid slurry and fast hardening cement sealing+polyurethane grouting, were com-pared. It was found that the cement+water glass dual liquid slurry sealing and plugging scheme has a significant impact on the horizontal deformation of the biting pile body, and the amount of sealing is large and the cost is high. Through the implementation of leak prevention measures, the problem of water leakage in the interlocking pile has been effectively solved, ensuring the safety of the foundation pit project.

Keywords: Deep Foundation Pit; Biting Pile; Leakage Treatment

1 Introduction

With the development and utilization of urban underground space, there are more and more deep excavation projects with complex geological conditions and limited construction space. When the depth of the foundation pit exceeds the groundwater level, measures need to be taken to control the groundwater level, and the requirements for controlling the settlement of the surrounding strata in the construction area are also stricter. Due to the high cost of underground continuous walls and their advantages only when combined with internal supports, the interlocking pile waterproofing technology is widely used [1-6]. However, due to complex geological conditions and engineering technical defects, water leak-age between interlocking piles often occurs [7-8]. It is urgent to explore water-proofing measures for interlocking piles in deep foundation pits, which has important practical significance for the stability of foundation pits and the safety of the surrounding environment.

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2 Project Overview

A certain project is located in a densely populated area of urban buildings, sur-rounded by mostly old-fashioned residential buildings. The foundation pit is 76.9m long, 36m wide, 19.1m deep, and has an area of approximately 2768.4m2. Based on the geological survey results and hydrogeological data of the construction area, it can be concluded that the groundwater type in the construction area is pore groundwater, with a depth of about 6.9~8.4m. The strata from top to bot-tom are artificial fill, loess, ancient soil, silty clay, medium sand, and silty clay.

The foundation pit adopts a drilling interlocking pile+anchor cable support system, and the anchor cable is made of prestressed steel strands with a tensile strength of 1860MPa and a diameter of 15.2mm; The plain concrete pile in the interlocking pile is made of C20 concrete, while the reinforced concrete pile is made of C35 concrete. The overlap width between the plain pile and the rein-forced concrete pile is 250mm. The schematic diagram of the interlocking pile is shown in Figure 1.

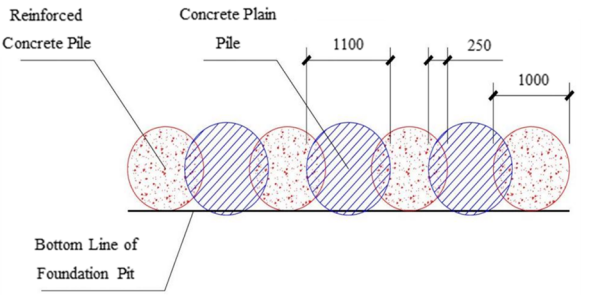

Fig. 1. Schematic diagram of overlapping of interlocking piles

Due to the shallow groundwater level and high water pressure at the construction site, the main difficulty in construction is to control the seepage of the inter-locking pile waterproofing curtain. The powder soil layer and sand soil layer below the groundwater level have large and relatively loose particles. When the rotary spray anchor cable is constructed below the groundwater level, the drill pipe penetrates the interlocking pile water stop curtain, and the groundwater vol-ume is large and easily mixed with formation particles flowing out of the anchor cable hole, causing soil erosion in the outer layer of the foundation pit, which can cause significant settlement and tilting of the building and affect its normal use. When the leakage is severe, it can also cause the water stop curtain to be dam-aged, affecting the safety of the foundation pit and existing buildings.

3 Analysis of the Causes of Water Leakage in Interlocking Piles

The leakage points of the project are mostly located on the northwest side of the foundation pit where the fourth to fifth anchor cables are applied, with a depth of about

15m. The main manifestations of water leakage in the support structure are:

(1) Leakage between interlocking piles

The leakage of water between the interlocking piles on the construction site is mostly caused by the inclination of the interlocking pile body, resulting in insufficient overlap length between the plain pile and the reinforced concrete pile, and the overall pile body is in a "forked" phenomenon. The leakage between the interlocking piles is shown in Figure 2. This phenomenon is mostly located deep in the geological strata, extending all the way to the bottom of the column. This phenomenon has a large water inflow and makes it difficult to seal the leak. There are three main reasons for the leakage between interlocking piles. Firstly, the verticality of the mechanical drill rod does not meet the standard, resulting in a large vertical deviation of the pile body, and the deeper the geological depth, the greater the deviation of the pile body; Secondly, due to inaccurate positioning of the pile body, the interlocking depth between the plain pile and the reinforced concrete pile does not meet the requirements; The third reason is that the construction interval between adjacent piles exceeds the preset time due to materials, machinery, climate, and other factors. When reinforced concrete construction is carried out, the curing strength of the plain piles is too high, and the pile body deviates towards the soil side, resulting in insufficient interlocking between the reinforced concrete piles and the plain piles, and even inability to overlap.

(2) Anchor hole leakage

Due to the shallow burial depth of the groundwater level in the construction area, the liquid index of the loess layer located below the groundwater level is 0.84, which is in a soft plastic and locally flowing plastic state, and is highly prone to consolidation deformation due to groundwater loss. The leakage of anchor holes in the foundation pit is shown in Figure 3. When the rotary jet anchor cable is installed below the groundwater level, the drill rod penetrates the water stop curtain behind the interlocking pile. Under the action of water pressure, a large number of soil particles mixed with groundwater flow out from the hole, causing a large amount of soil loss outside the foundation pit and significant geological settlement deformation, seriously threatening the safety of the foundation pit and surrounding environment.

Fig. 2. Water seepage between interlocking piles

Fig. 3. Anchor Cable Hole Leakage

4 Construction Technology for Sealing Leakage with Interlocking Piles in Foundation Pit Engineering

4.1 Groundwater Level Control

To ensure the normal operation inside the foundation pit and the stability and safety of the outer layer of the foundation pit, this project adopts the method of "dewatering and drainage inside the pit+backfilling outside the pit" to control groundwater, ensuring the stability of the groundwater level outside the foundation pit, and effectively reducing the occurrence of water leakage problems in the foundation pit support structure.

4.2 Verticality of Pile Body and Control of Adjacent Pile Construction Time

Reasonably arrange the construction process of interlocking piles, and try to avoid factors such as imbalanced material and mechanical resource allocation that may affect the construction time of interlocking piles. At the same time, con-struction should be carried out in accordance with the design standards of the interlocking pile waterproofing curtain, ensuring the verticality of the pile body from three aspects: checking the straightness of the casing, verticality of the drilled pile body, and construction correction. The vertical deviation of the pile body should not exceed 0.3%.

4.3 Anti leakage Measures Between Interlocking Piles

(1) For the leakage point at the opening of the foundation pit, heavy loading is applied at the opening, and recycled cotton is filled into the internal space of the opening. A grouting rig is used for post pile grouting to seal the leakage. After the sealing is completed, slurry is used for reinforcement grouting.

(2) The high split part of the interlocking pile is reinforced by planting steel bars and hanging steel mesh and spraying concrete to prevent the soil behind the split from being washed out with water.

(3) In areas where there are many “forks” in the interlocking piles, a grouting rig is used to vertically inject deep holes into the inner side of the foundation pit close to the supporting piles. The grouting reinforcement depth is 15m to compensate for the loss of water stop curtain length caused by the “forks” of the interlocking piles, and to increase the seepage path of groundwater from outside the foundation pit into the foundation pit. At the same time, a grout-ing rig was used to inject grout diagonally at a depth of about 8.0m at the “fork” leakage point of the blocked interlocking pile, with a post pile inclination of 30-45 °. Pre grouting reinforcement was carried out on the soil behind the pile at the "fork" point of the interlocking pile.

4.4 Anchor Cable Hole Plugging Control

(1) After the completion of the pile formation by the rotary jet grouting anchor, the flexible permeable materials (such as geotextiles, burlap bags, black cot-ton, etc.) and the water guide pipe are immediately pushed into the rotary jet grouting anchor hole using the anchor drill bit, exerting the filtering effect of the flexible permeable materials, preventing the loss of cement slurry and sand in the anchor hole, and achieving the guidance and drainage of water seepage in the anchor hole.

(2) Based on the experience of plugging in neighboring projects, two sealing and plugging schemes are developed for the leakage of water in this project. 1、Cement+water glass dual liquid slurry sealing and plugging scheme. When using cement+water glass double liquid slurry for sealing, the pressure of the grouting slurry directly acts on the outer side of the biting pile wall, causing horizontal deformation of the support pile inclined towards the inner side of the foundation pit, which has an adverse impact on the stability of the foun-dation pit support system under stress. 2、Quick hardening cement seal-ing+polyurethane grouting sealing scheme. When using fast hardening ce-ment sealing and polyurethane grouting sealing, polyurethane is mainly in-jected into the anchor hole of the plain pile, and the grouting pressure is small, which has little impact on the stress stability of the foundation pit support system. Moreover, polyurethane foam material and fast hardening cement are only used for sealing at the end of the anchor hole, with small dosage and low cost. Therefore, the anchor hole plugging scheme for this project adopts fast hardening cement sealing+polyurethane grouting sealing, and the specific implementation is as follows:

① Quick hardening cement material sealing. Mix the quick setting plugging material and water in a ratio of 1:6.6-4 to form a wet salt like body. When the plugging material heats up and becomes slightly hard, insert it into the an-chor hole and compact it layer by layer with a hammer or wooden rod. The clumps of quick setting plugging material immediately expand and solidify slightly in the hole, and react with the anchor hole to form a solid whole. Af-ter the layered and staged sealing is completed, the clear water is discharged by the water guide pipe, the water pressure is reduced, and a layer of quick setting material (quick setting plugging material: water=1:0.5-0.6) is applied.

② Polyurethane foam material sealing. Inject the polyurethane foam material through a hydraulic injection needle until the polyurethane foam material flows out from the support surface, completing the injection work. After the anchor cable is tensioned and locked, polyurethane foam waterproofing ma-terial is used for the second

grouting sealing.

5 Conclusion

To address the problems of "split" leakage and anchor hole leakage in the biting pile body of the project, anti leakage measures such as arranging precipitation wells, reinjection wells, controlling the verticality of the pile body, controlling the construction time of plain concrete pile reinforced concrete pile, heavy loading, hanging net spraying and mixing, deep hole grouting, and fast hardening cement sealing+polyurethane grouting are taken to fully play the role of water stopping in the biting pile anchor support system below the groundwater level. The sealing and plugging scheme adopted in this project can complete the sealing of the anchor hole within 20 minutes after the anchor cable construction is completed, ensuring the overall dryness of the foundation pit wall, improving the safety and stability of the foundation pit project, and creating good construction conditions for subsequent construction.

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