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CONSTRUCTION CONTROL AND APPLICATION OF PRECAST CONCRETE INCLINED SQUARE PILES

XueMing Shi[1,2*], JinHui Cheng[1,2], ZhiChao Zeng[1,2], Liang Huang[1,2], GuangLiang Qiu[1,2], XiaoXia Zhao[1,2], ZhiCheng Bai[1,2]
[1]*China Construction Fourth Engineering Divion Corp.,Ltd., Guangdong 510000, Guangzhou, China.*
[2]*China Construction Fourth Engineering Bureau Construction Investment Co., Ltd., Shanghai 200000, China.*
[*]*Corresponding Author: XueMing Shi*

Abstract: Precast concrete inclined square piles are widely used in foundation pit support engineering, but their construction is easily affected by factors such as geological conditions, technological complexity, and on-site management, resulting in various quality defects. This article, based on actual engineering cases, systematically analyzes the common types of quality defects in the construction of precast concrete inclined square piles, explores the causes of these defects in depth, and proposes corresponding countermeasures to provide technical reference for similar projects and improve construction quality and engineering safety.
Keywords: Precast concrete inclined square piles; Quality defects; Countermeasures; Foundation pit support

1 INTRODUCTION

Precast concrete inclined square piles are widely used in soft soil foundation pit support and high-rise building foundation reinforcement projects due to their advantages such as high bearing capacity, high construction efficiency, and factory prefabrication[1-3]. However, due to complex construction processes and variable site environments, quality problems such as pile fracture, excessive tilt deviation, misalignment of waterstop steel plates, and welding defects at joints occur frequently, seriously affecting the safety and service life of the project. Therefore, in-depth research on the construction quality defects of precast concrete inclined square piles and their countermeasures has important engineering practical significance.

2 PROJECT OVERVIEW

2.1 Project and Foundation Pit Overview

The foundation pit area is approximately 38,361 m², with a length of approximately 280 m, a maximum width of approximately 145 m, and a total perimeter of 912 m. The excavation depth for the two-story basement is 9.65 m; the excavation depth for the first-story basement is 5.9 m. The safety level of the foundation pit support structure is classified as Level I for the two-story basement and Level II for the first-story basement, with a design service life of 3 years. The perimeter load of the foundation pit is considered to be 20 kPa, and the outlet load is 30 kPa.
The retaining structure type adopted is as follows: For the two-story basement: bored piles + combined steel supports. To control displacement, a prestressed anchor cable is installed on the top of the retaining piles. The water-stop curtain uses triaxial cement mixing piles[4]. For the first-story basement: HC method piles combined with inclined support piles are used for support. (Figure 1).

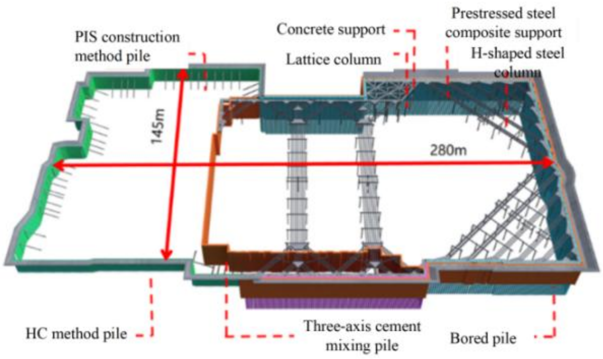

Figure 1 Three-Dimensional Schematic Diagram of the Foundation Pit Support

2.2 Overview of Precast Inclined Square Piles

The original design for this foundation pit project included 45 inclined square piles, distributed sequentially on the first floor of the basement, serving as support and maintenance in conjunction with HC method piles. The inclined square piles (solid square piles) were factory-precast, with a concrete strength grade not lower than C30. HRB400 steel reinforcement was permitted, with a minimum protective layer thickness of 20mm for the main reinforcement and an allowable error of no more than 5mm. The original design specified a pile length of 15m and a concrete strength not lower than C30. (Figure 2)

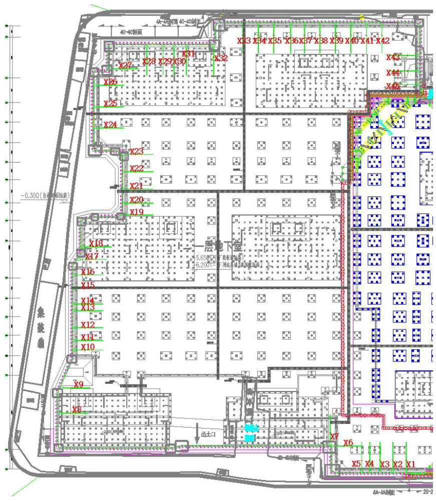

Figure 2 Detailed Diagram of Inclined Pile Distribution

3 QUALITY DEFECTS AND RECTIFICATION MEASURES DURING CONSTRUCTION

3.1 Construction Inaccuracy Leads to Lengthened Crown Beam Corbels

Due to insufficient working surface at the construction site and non-standard measurement and positioning/elevation control by on-site construction personnel, the top of the inclined support piles is far from the crown beam after construction. Supports need to be installed at the crown beam location. Furthermore, due to poor accuracy control, the original 1m length of the corbel at the crown beam needs to be lengthened to 1.5m after construction. The support easily becomes a cantilever beam structure, which is unfavorable for the stress on the inclined support piles.
(1) Strengthening Pre-Construction Measurement and Positioning
Before constructing the PIS inclined pile support system, the inclined piles need to be positioned and measured. The position of the inclined piles is determined according to the design drawings and marked on the ground. Measurement instruments are used to accurately position the inclined piles to ensure their accuracy for subsequent construction work[5].
(2) Strengthen monitoring of the construction process. The control of pile driving accuracy needs to be carried out throughout the entire process of "survey-design-construction-testing". Through high-precision measuring instruments, reasonable construction technology, real-time monitoring methods and strict management measures, the pile position deviation and verticality deviation should be controlled within the allowable range of the specifications[6].

3.2 Insufficient Working Surface Leading to Angle Deviation and Pile Splicing Issues

Due to external factors such as the high-voltage protection frame on the west side of the site and the main structure of the entrance hall, the angles of 23 PIS inclined square piles (self-numbered: XZ1~XZ6, XZ24~XZ27, XZ33~XZ45) in the original design plan needed to be adjusted, and XZ24~XZ27 required welding.

3.2.1 Angle adjustment

During construction, due to the influence of the high-voltage protection frame and main structure on the west side of the site, the working surface for the 23 PIS inclined square piles (such as XZ1-XZ6, XZ33-XZ42) was insufficient. The original design angle (such as 40°) could not meet the site conditions. Some piles needed to be adjusted to 35°, 30°, or even 25° for construction, and some piles needed to be spliced using two sections (6m+9m).

3.2.2 Rectification measures

(1) Angle Adjustment and Bearing Capacity Verification: According to the "Technical Specification for Building Pile Foundations" (JGJ 94-2008), the stress of the piles after angle adjustment was verified. The soil pressure transmission effect under different angles was simulated using the Lizheng Deep Foundation Pit software to ensure that the horizontal bearing capacity meets the design requirements. For example, when the angle is adjusted to 35°, the loss of horizontal bearing capacity is compensated by increasing the pile embedment depth.
(2) Welding Process Control for Two-Section Piles: Double-sided welding is used to connect the upper and lower pile sections. The weld length is not less than 8d (d is the diameter of the main reinforcement bar of the pile body), and the weld height is not less than 6mm. Ultrasonic testing is performed after welding to ensure welding quality. For piles such as XZ25 and XZ26 that require simultaneous angle adjustment and splicing, the corbel length is increased to 1.5m to enhance the shear resistance of the joint.

4 MISALIGNMENT OF WATERSTOP STEEL PLATES AND POTENTIAL WATERPROOFING RISKS

4.1 Defect Manifestations

The primary function of waterstop steel plates in building pile foundation construction is to prevent water penetration. They form a physical barrier at the concrete construction joint, utilizing the impermeability of the metal material and its tight bond with the concrete to block water leakage paths. Simultaneously, they enhance the structural integrity of the construction joint, disperse stress, prevent cracks caused by settlement and other factors leading to leakage, and ensure the waterproof performance and durability of the pile foundation project. They are suitable for basements and other areas with waterproofing requirements. During construction, positioning errors or pile tilting can cause deviations between the precast waterstop steel plates and the designed position of the basement floor slab, potentially leading to leakage risks.

The original design stipulated that the precast waterstop steel plates should be located in the center of the floor slab after the construction of the inclined square piles. However, due to factory design and on-site construction precision issues, the precast waterstop steel plates did not reach the original design elevation (as shown in Figures 6 and 7), and the elevation errors were all greater than 1500 mm.

4.2 Corrective Measures

A 50mm×4mm waterstop steel plate will be welded around the center of the inclined square pile penetrating the base slab. Angle steel (4L140×14) will be used for fixation, ensuring a tight weld free of air bubbles. During the welding process, care must be taken to protect the waterstop membrane of the base slab, and damage to the waterproof membrane caused by welding is strictly prohibited. (Figure 3).

(a) Pay Out (b) Carve

(c) Additional Welding of Angle Iron Batten (d) Additional Welding of Waterproof Steel Plate

Figure 3 Rectification Measures

5 CONCLUSION

This study takes the Shuangqiao Unit Foundation Pit Project in Xihu District as an example to analyze the construction quality defects and countermeasures of precast concrete inclined square piles. The main problems encountered during construction included extended cap beam corbels, pile angle deviations and splicing issues, and misalignment of the waterstop steel plate. The causes involved factors such as construction accuracy, operational limitations, and the integration of precast and on-site processes. The study proposes full-process control measures: strengthening measurement and positioning and process monitoring to control pile position deviations; verifying the bearing capacity after angle adjustment according to specifications, employing double-sided welding and testing to ensure splicing quality; and welding waterstop steel plates and fixing them with angle steel to eliminate leakage risks. The study confirms that on-site problems can be solved through technical calculations and process optimization, and standardized management throughout the entire process is key to quality assurance. The results provide a reference for similar projects, and the application of intelligent monitoring technology can be explored in the future.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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