Quality Control of Bored Piles of Cross-river Bridges Pile Foundation Construction

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Abstract. Punching pile is a commonly used construction technology for pile foundation of river-crossing bridges, which has the advantages of small impact on the sur-rounding environment, strong adaptability of pile length and pile diameter, the pile end can enter the holding layer or be embedded in the rock layer, and large bearing capacity of a single pile, etc. However, the process and operation requirements are more strict and prone to quality accidents. However, the hole for-mation process and operation requirements are more stringent, and quality accidents are prone to occur. Based on the pile foundation project of Shenzhen Changchun North Road Bridge, this paper analyzes the quality con-trol requirements of large diameter bored piles in land and water construction, proposes the pile foundation application process under adverse geological con-ditions, and at the same time, also proposes the measures to prevent and deal with quality problems. Through these measures, the 36 bored piles (24 piles of 1.5m diameter and 12 piles of 1.6m diameter) of this bridge are all class I piles after testing, with good quality control effect, which can provide relevant engi-neering experience for the subsequent municipal bridges across the river with similar structures.

Keywords: bridges across rivers; pile foundations; perforated piles; waterborne construction; quality control

1 Introduction

Pile driving is a commonly used construction process for the foundation of grouted piles, which is commonly used for the foundation support of high-rise buildings and the pile foundation construction of bridge projects due to its advantages such as less impact by groundwater, less impact on the environment, strong adaptability of the pile length and diameter, the ability of the pile end to enter the holding layer or embedded in the rock layer, and the large bearing capacity of a single pile, etc.[1~3], and it is an effective construction method in some cases where the operating conditions are limited. method. Zhang Hao[4] introduced the construction method of punched piles under special geo-logical conditions by relying on the pile foundation construction of Gangu Bridge;

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Lu Binjun[5]analyzed the difficulties of large diameter punched piles under water in the complex environment and complex stratum by relying on the pile foundation construction of a river-crossing bridge in Zhuhai City and put forward the preventive and treatment measures in various situations for these difficulties, and the construction results confirmed the feasibility of the measures; Wang Yang and others[6], according to the special characteristics of gravel stratum of bridges along Jiguanshan Highway, proved that perforated piles have greater application advantages in gravel stratum construction after program selection and practical application.

Although punched piles have many advantages, there is also a disadvantage that cannot be ignored, which is the high quality control requirements for the construction process. Hertlein[7] outlined the common non-destructive and destructive testing methods for bored piles/bored wells in North America and Europe, and evaluated the implementation in the two continents through the survey results; Zheng Qixin[8] com-bined the project example of High-tech Road 2 (Jingcheng Avenue - South Inner Ring Road) in Jingcheng Park, Hi-tech Zone, Zhangzhou, with the project example of High-tech Road 2 (Jingcheng Avenue - South Inner Ring Road, which is a new high-way in Zhangzhou.) project example, the key points of construction quality supervision of bridge bored piles were elaborated in detail; Hannigan[9] outlined the latest progress of quality control of bored piles and illustrated its practical application in pro-jects through use cases. Based on the pile foundation project of Shenzhen Changchun North Road Cross-river Bridge, this paper analyzes the quality control requirements of large-diameter bored piles in land construction and water construction, proposes the pile foundation application process under adverse geological conditions, and at the same time, also proposes the measures for preventing and dealing with quality problems.

2 Project Overview

Changchun North Road Municipal Engineering 1 standard is located in Shenzhen Guangming District, Gongming Street center area, the existing bridge across the Xitian River was built in the 1990s, two-way four-lane, with the rapid development of the city, the bridge's original design width can not meet the requirements of the traffic operation, and can not meet the requirements of the flood discharge, so the project will be demolished after the demolition of the original bridge in the original position of the re-construction of the new bridge, the new bridge is the older bridge deck to be elevated and widened to two-way Eight lanes, the new bridge length of 105.6m, a total of 4 spans, the substructure for the columnar abutment and columnar piers. A total of 36 piles are required for construction, with a total length of 1020m, including 12 piles for abutments and 24 piles for piers. Among them, 0# and 4# piers are end bearing piles and 1#-3# piers are friction piles. Design requirements end bearing piles embedded in medium weathering siltstone mudstone effective embedded depth of not less than 3 times the pile diameter, friction pile bottom bearing capacity of not less than 120kPa, pile foundation using C35 underwater concrete construction, as shown in Fig. 1:

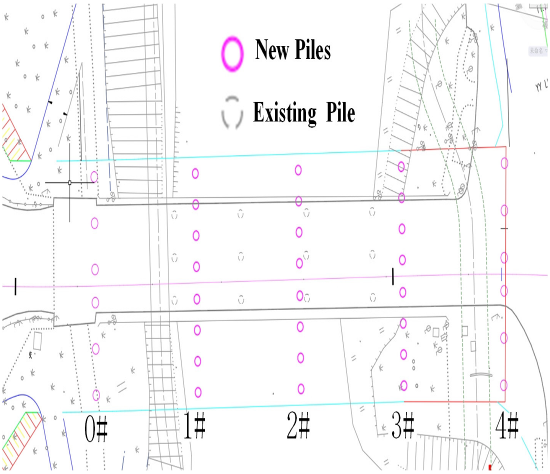

Fig. 1. Schematic diagram of existing and new bridge piles

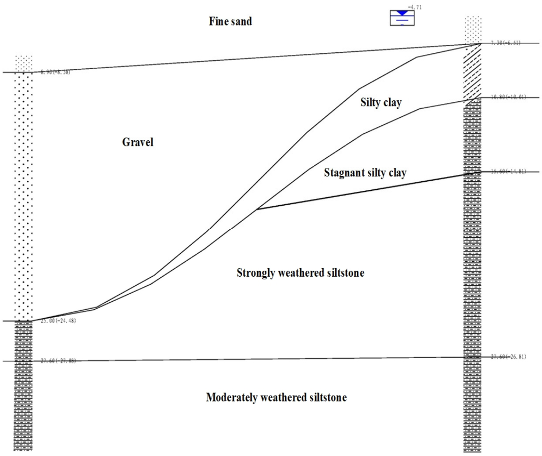

Fig. 2. Geological profile of the river channel

Before the construction, the construction unit hired a survey unit to investigate the geological and hydrological conditions of the pile foundation construction area of the new bridge, and the results are shown in Fig. 2: the upper foundation in the river channel area mainly consists of vegetal fill, silty soil, silty sandy soil, silty clay, medium-coarse sand and rounded gravel, and the lower part consists of residual soil, fully-weathered siltstone, strongly-weathered siltstone, and moderately-weathered siltstone; and at the same time, there is a significant difference in the soil layers: the upper part of the up-stream section of the river channel includes silty clay and strongly-weathered siltstone, while the upper part of the downstream section of the construction area mostly consists of rounded gravel. difference: the upper part of the upstream section of the river channel in the pile foundation construction area consists of chalky clay and strongly weathered sandy mudstone, while the upper part of the downstream section of the construction area is mostly rounded gravel. According to the investigation results, the engineering geological conditions in this area are more complicated, and the thicker chalky clay and silty mudstone in the soil layer will lead to higher impact of construction on the stability of the stratum due to its low mechanical strength, and the presence of rounded gravels and other materials will easily cause a large amount of slag on the bottom of the holes in the punching process, which will affect the efficiency of the construction as well, and thus put forward higher requirements for the construction technology of the pile foundation of the bridge.

3 Construction Control of Driven Piles

The main processes of punched pile construction are surveying and sampling, embedding shoring, setting up working platform, preparing mud, punching, clearing, making and lifting of reinforcement cage, and filling underwater concrete, etc. The construction of this project is in non-flood season. The piling work of this project is in non-flood season, the water level of the river is shallow, and before the construction of the new bridge, the demolition of the existing bridge has been constructed by building an island cofferdam to build a working platform, so the piling work of the new bridge can be utilized to carry out the construction work with the completed demolition platform. Concrete design mix such as shown in Table 1, the water-cement ratio is 0.41, of which the fineness modulus of sand for concrete is 2.6, and the mud content is 0.8%; the maximum grain size of stone for concrete is 25mm, and the content of needle flakes is 4%, and the mud content is 0.4%; the admixture is Class F, Class II fly ash; the admixture is a retarder-type high-performance water reducing agent, and the mixing amount is 1.8%.

Table 1. Concrete design mix ratio

Title	Water	Cement	Sand (dry)	Stone (dry)	Additives	Admixtures
Material consumption (kg/m^3)	161	353	784	997	8.2	57
Proportions	0.46	1.0	2.22	2.82	0.0232	0.1615

3.1 Construction Preparation

Materials used in construction, such as concrete, connecting sleeves, reinforcing steel and other raw materials, should have completed the quality inspection to ensure that the quality of materials up to the design requirements, the required machinery and equipment have been overhauled and debugging, to ensure the normal operation of the equipment. Technical briefing for the construction team to ensure that they are familiar with the construction technology and process requirements, and can better control the construction parameters in the construction process. The quality of the reinforcing cage should be sampled after processing to ensure that the construction quality is up to standard. The conduit should be test assembled and pressure tested before use, and the test water pressure can be taken as 0.6~1.0MPa.

3.2 Hole Formation Control

Before grouting pile construction, the mud material should be prepared in accordance with the actual construction requirements and standards. The Technical Specification for Highway Bridge and Culvert Construction (JTG/T 3650-2020) requires that the sand content of the mud material should be less than 2%, and the colloid rate should be more than 98%. In order to prevent the collapsed hole, the stability of the impact hammer working platform and the wear of hammer teeth should be checked regularly. In order to prevent the steel cage from floating in the process of grouting, the indexes of hole-making slurry should be ensured to meet the specification requirements when punching and clearing holes. Clearing should be carried out several times, until the bottom of the hole slag is less than the specification requirements, clearing process should strictly control the specific gravity, viscosity and sand content of the mud, and timely replenishment of mud or water, to maintain the stability of the mud surface in the pile hole. In case of deviated hole, the more serious ones can backfill the pile hole with blocks of stone and clay, and then use the low hammer to punch closely, and correct repeatedly; if the slag at the bottom of the pile is too thick, the core hole for core detection or the probe tube for ultrasonic detection can be used as a channel, and high pressure grouting can be used to strengthen the bottom of the pile.

3.3 Concrete Filling

When you start filling concrete, the distance from the bottom of the conduit to the bottom of the hole should be 300-500mm, to ensure that the initial concrete filling can cover the lower end of the conduit, so that the initial depth of the conduit is not less than 1m. the conduit should be buried below the surface of the concrete filling should not be less than 0.8m, it is appropriate to 2-6m, and control the speed of the conduit, and the special person to measure the depth of the conduit and the pipe inside and outside of the surface of the concrete filling the difference between the heights. Filling underwater concrete must be continuous construction, the filling time of each pile is controlled according to the initial setting time of concrete. Control the last filling volume, over-filling height should be 0.8 ~ 1.0m, after chiseling the height of the flooding slurry must ensure that the concrete strength of the top of the exposed pile reaches the design level. In order to prevent the steel cage from deformation and floating during the grouting process, effective positioning and anti-floating measures must be taken. If the steel cage is found to have floating phenomenon, in addition to using the steel pipe sleeve on the top of the reinforcement, the conduit should be lifted, paying attention to the depth of the conduit and slowing down the concrete pouring speed.

4 Pile Foundation Test Results

After the construction is completed, 36 bored piles need to be inspected according to the requirements, according to the requirements of SJG09-2020 "Shenzhen Building Foundation Pile Inspection Regulations", the inspection of bored piles includes ultra-sonic inspection and core drilling inspection, of which the ultrasonic inspection should not be less than 30% of the total number of piles, the core drilling inspection is not less than 15% of the total number of piles, and should not be less than 10 (the total number of piles should not be less than 5 if the number is less than 30). Less than 30, should not be less than 5), according to the project four main units (in addition to the survey unit) meeting to determine, the bridge project's ultrasonic testing of the pile foundation proportion of 100% (pile construction has been according to the design requirements of all the reinforcement cages in an equally spaced arrangement of 3 acoustic tubes for testing), the proportion of drilling core testing for the number of piles for the total number of 36, so the number of drilling core to take the minimum number of 10, drilling core testing of the The location of selected piles is shown in Fig.3.

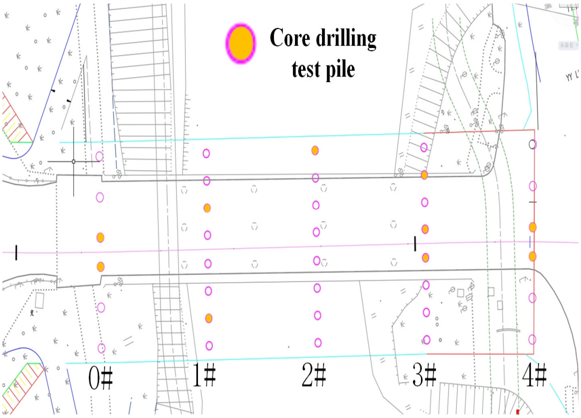

Fig. 3. Schematic diagram of core drilling test piles

The summarized data of ultrasonic testing results are shown in Table 2, the results of the average wave velocity and sound velocity dispersion rate tests for all piles are shown in Fig. 4(a). It can be seen that the measured average pile lengths are all beyond the design requirements of the pile lengths, only the No.1 pile of No.4 abutment is slightly smaller than the design pile lengths, but the error of the pile lengths is 1.2cm, which is in line with the requirement of the grouted piles with the single row of piling lengths with the error of not more than 5cm.

Table 2. Summary of results of ultrasonic testing of pile foundations

No.	Piles	Design pile length(m)	Range of measured pile lengths (m)	Average pile length (m)	Average wave speed interval (km/s)	Sound velocity dispersion range (%)

1	0#	27	28.31~28.61	28.51	4.20~4.27	1.89~3.53
2	1#	29	31.15~31.82	31.33	4.22~4.34	1.77~4.77
3	2#	29	33.15~34.31	33.98	4.21~4.28	2.19~4.78
4	3#	35	35.71~35.84	35.77	4.23~4.26	1.24~3.44
5	4#	27	26.88~27.28	27.09	4.24~4.27	2.51~3.19

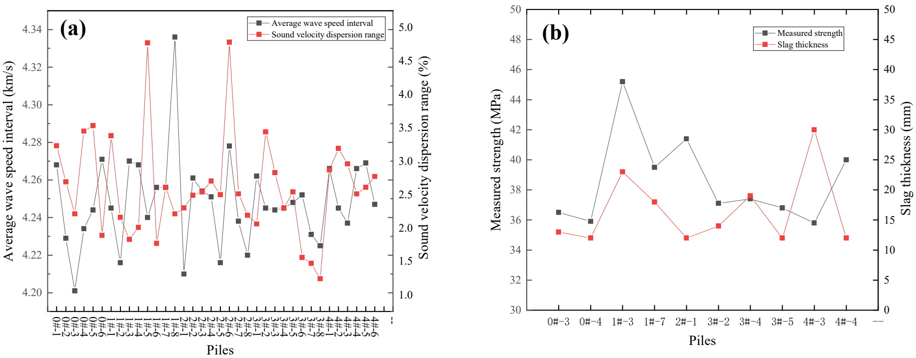

Fig. 4. Detailed data of pile foundation test results(a: average wave velocity and sound velocity dispersion rate of pile; b: strength of pile and thickness of slag at pile bottom)

The summarized data of the drilling core test results are shown in Table 3, the strength of the drilled concrete core samples and the thickness of the slag at the bottom of the pile are shown in Fig. 4(b), which can be seen that the compressive strength of the concrete body of the 10 selected punched piles is distributed in the range of 35.8MPa~45.2MPa, which is greater than the design requirement of 35MPa; the thickness of slag at the bottom of the pile is in the range of 12-30mm, which is satisfied with the specification requirement of no more than 50mm. Meanwhile, the results of core drilling show that the holding layer at the pile end has been embedded in medium weathered siltstone mudstone, which meets the design requirements.

Table 3. Summary of Pile Drill Core Testing Results

No.	Piles	Design strength (MPa)	Measured strength (MPa)	Slag thickness (mm)
1	0#-3	35	36.50	13
2	0#-4	35	35.90	12
3	1#-3	35	45.20	23
4	1#-7	35	39.50	18

5	2#-1	35	41.40	12
6	3#-2	35	37.10	14
7	3#-4	35	37.40	19
8	3#-5	35	36.80	12
9	4#-3	35	35.80	30
10	4#-4	35	40.00	12

Fig. 5. Schematic diagram of concrete core samples drilled from pile foundation

As can be seen in Figure 5, the drilled concrete core samples are continuous, complete, with smooth surface, good cementation, uniform aggregate distribution, long columnar shape, matching fracture, and only a few small air holes are seen on the side of the core samples. Combined with the ultrasonic testing and core drilling test results, the punched piles of this project are all Class I piles, which exceeds the design requirements for completing the construction of the bridge pile foundation project.

5 Conclusion

Relying on the construction process of punched grouted pile foundations for municipal bridges in the Changchun North Road Municipal Project, this paper inroduces the quality control points of the construction process of punched grouted pile foundations for bridges, including the land and water construction of pile foundations, and puts forward the preventive and treatment measures for the situation of quality problems. The feasibility of the quality control points is also verified by the results of ultrasonic testing and coring testing of the pile foundations: all 36 piles involved in the bridge are

Class I piles, which can provide relevant experience for the subsequent municipal river-crossing bridges with similar structures.

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