Original Research Article

Application of Full-rotation Complete Tube Technology in the Construction of Pile Foundation in Medium-coarse Sand Geology

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Abstract: The full-rotation complete tube technology is to drive the flower tube and the steel casing to be fastened by connecting pins, drive the steel casing to rotate 360 degrees, and apply torque and vertical load to the steel casing in the hole, with the help of the steel casing pipe to cut and drill the boulder and medium-coarse sandstone layer with strong force, make full use of the role of the steel casing to protect the wall, and then use the auger and sand drill to grab the confined water and the soil in the steel casing, and then clear thelobstacles inside of the steel casing. Controlling the slump of concrete and the amount of concrete poured each time can more effectively control the construction quality, which has obvious effects on speeding up the construction progress and improving efficiency, and at the same time avoiding environmental pollution.

Keywords: Full-rotation; Complete tube; Technology; Medium-coarse sand geology; Pile foundation construction; Application.

1. Engineering Background

The research project in this paper is located in the capital of Belarus. From the perspective of geographical characteristics, it is located in the Eastern European plain. The foundation soil within the exploration depth of the proposed site is mainly composed of medium coarse sandy soil, silt and interlayers in each layer, etc. The geomorphic unit is a moraine plain. Medium coarse sand layer, groundwater and isolated rock have adverse effects on construction. This project is designed in China and is designed according to the common practice of pile foundation in China. The existing local construction conditions and construction technology are different from the domestic construction, so the construction cannot be carried out according to the domestic conventional practice, and the construction scheme suitable for this project can only be selected by combining the domestic and foreign methods.

2. Piling Design Parameters

(1) Pile foundation type: end-bearing friction pile - bored pile;

(2) Concrete label: C35/P8;

(3) Pile body requirements: the pile length is 20m, the pile diameter length is about 600mm, and the distance between the pile top and the cap is about 50mm;

(4) Reinforcement connection: welding or mechanical connection;

(5) The characteristic value of compressive capacity: 1000kN, and the depth of the whole section of the pile end into the fourth layer of coarse sand should not be less than 2m;

(6) Other requirements: the thickness of sediment should not exceed 50mm, and the corresponding filling coefficient of concrete should not be less than 1.1.

Pile position arrangement is shown in Figure 1.

3. Selection of Construction Programme

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There are two main ways of drilling in Belarus according to the field investigation of the project by the parties:

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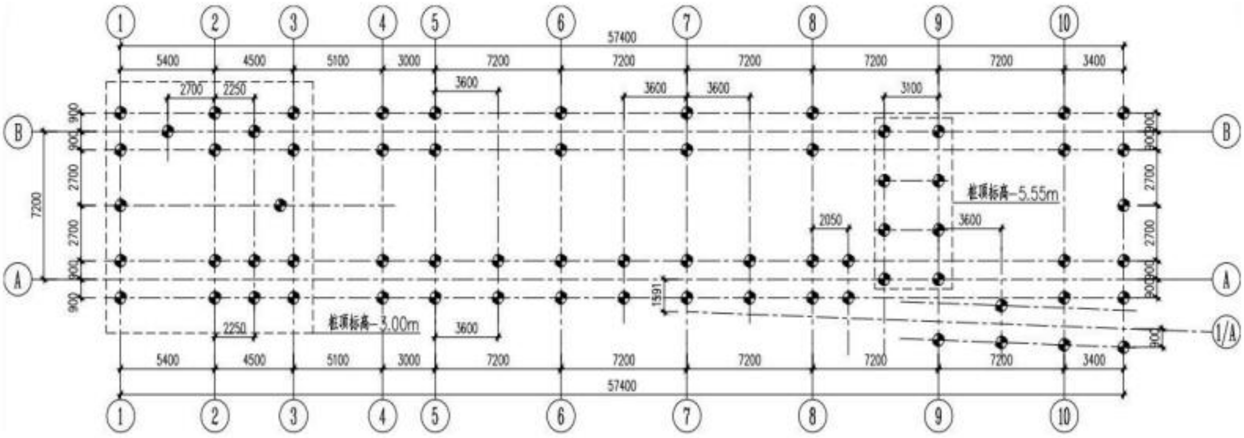

Figure 1 Pile position layout.

Option 1: The hole is drilled by auger, and the concrete is injected while the drill bit is slowly raised after the hole is formed. When the concrete is poured to the predetermined elevation, the steel bar cage is pressed into the concrete with the drill. This method is widely used in local pile foundation construction. The construction speed of this method is fast, but the actual construction quality is difficult to control, and it needs to ensure that the steel itself has sufficient strength and stiffness. The main reinforcement with a diameter of 14mm in this project cannot meet the construction requirements, so it is necessary to change the design and adjust the diameter of the main reinforcement.

Option 2: Using the full-rotating full-casing technology, the equipment drive cylinder and steel casing are tightened through the connection pin, and the cylinder casing itself is rotated and promoted in a 360 degree way. At the same time, vertical load and torque are applied to the casing in the hole, and the high-strength drill bit of the casing itself is used to cut and drill the isolated stone, soil and medium coarse sandstone layer, etc., and the seismic degree is drilled to the bottom elevation position. In addition, the wall protection function of the casing is fully utilized, and then materials such as pressurized water and medium coarse sand existing in the casing are extracted with the help of auger and old sand drilling, and the obstacles within the steel casing are removed. Then the steel cage is placed inside the casing and concrete is used for placement. This method is easy to ensure the construction quality, but the construction speed is relatively slow, and there are specific requirements for the performance of concrete itself.

After the research and discussion of relevant parties, it is decided to adopt the full-rotating full-casing construction technology that can better control the construction quality. The site investigation is shown in Figure 2 and Figure 3.

Figure 2 On-site field visits.

Figure 3 Full Turning Sleeve.

4. Overview of Piling Equipment

4.1 Introduction to Hole Forming Equipment

The construction technology of the full rotary casing drill is roughly the same as the mud wall protection construction method of the traditional rotary drilling rig, the difference mainly lies in the hole forming equipment and the hole forming method, and the key equipment is the main body of the hole forming drill and the tube pulling equipment equipped with the corresponding casing. For the whole set of pipe drilling, the pipe drill is mainly used to target the vertical load and torque of the casing family, so that the casing with the drill bit is drilled in the formation and the drilling tool is used to drill the soil inside the casing, so as to reduce or eliminate the resistance effect to the maximum extent. The drilling resistance of the casing is mainly from the resistance of the soil outside the casing. During drilling, full-hole casing was used to protect the wall while avoiding circulating fluids and mud, and casing joints were used to connect multiple casing lines until the target design height was reached. The concrete is then poured. The concrete is poured and the casing is pulled alternately. When the casing is pulled, the single casing is removed by removing the joint pins. All the casing is removed after all the concrete is poured.

4.2 Introduction to Hole Forming Equipment

Figure 4-7 shows the pictures of the hole forming equipment.

Figure 4 Casing bit.

Figure 5 Extubation equipment.

Figure 6 Concrete conduit.

Figure 7 Sleeve drives the cylinder.

5. Construction Process

The construction process is shown in Figure 8.

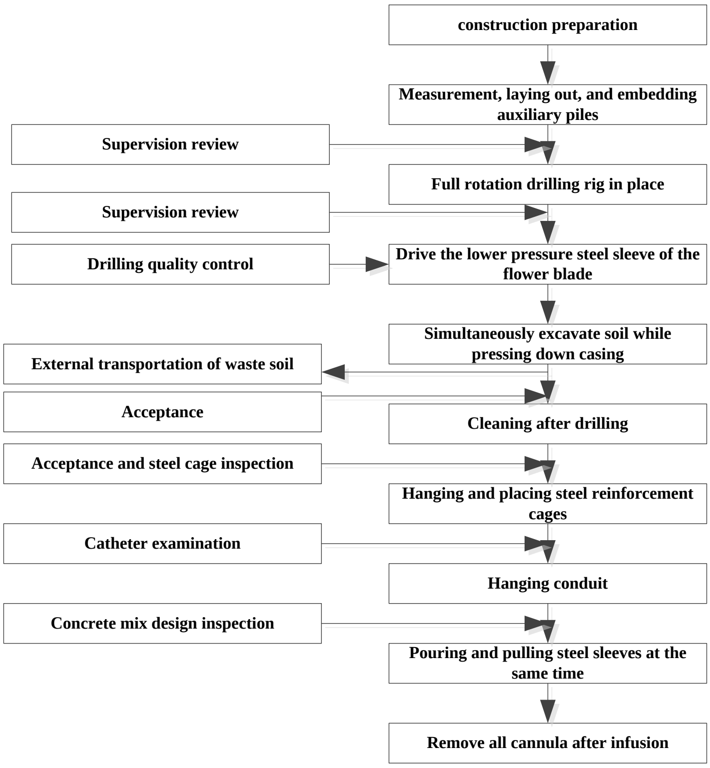

Figure 8 Construction process.

5.1 Current Situation

The procedures of lofting positioning, drilling rig positioning, hole opening, hole clearing, final hole acceptance and so on are the same as the domestic conventional practices.

5.2 Casing Follow-up and Drilling

The starting drilling position of the casing is fixed, the corresponding pipe boots are installed for the first casing, and the connection between the casing and the drive cylinder is checked. If the connection is not in place, it will be easy to have the problem of selling out. In addition, it is necessary to check the deviation of the casing position from time to time during drilling. Ensure that the distance between the casing and the positioning pile is more than 1m to avoid deviation of the positioning pile due to the effect of drilling agent. Use the horizontal ruler to check the vertical degree of the casing. If there is deviation, it needs to be adjusted manually in time. If the first casing drilling reaches 800 to 1000 above the ground, it needs to be stopped, at this time the connection pin between the casing and the drive cylinder is disconnected, and the specific drilling tool is selected to carry out the excavation work according to the geological situation. Then repeatedly carry out casing connection, drilling and excavation work until the height meets the design requirements.

The whole drilling process needs to be inspected from time to time, and the bit wear condition and bit verticality are checked. If there is any abnormality, it needs to be replaced as soon as possible. In the process of drilling, it is necessary to formulate the corresponding construction plan according to the pile, and record many parameters involved in the process. In addition, special personnel are required to direct the drilling process and make timely adjustments to the vertical of the drill pipe.

5.3 Cage Fabrication and Lifting

Since it is full casing drilling, it will not collapse the hole and shrink the neck, so the protective layer of the steel cage can not be welded to avoid affecting the casing pulling out, and the diameter of the sleeve should be increased if necessary. The other processes are the same as the traditional domestic processes.

5.4 Concrete Pouring

When concrete is poured, it is necessary to pay attention to the amount of the first pouring as shown in Figure 9. In other cases, the distance between the conduit and the bottom of the hole is generally maintained within the range of 0.3m to 0.5m, and the depth of the first embedment of the conduit should be kept above 1m. The first pouring volume is calculated as follows:

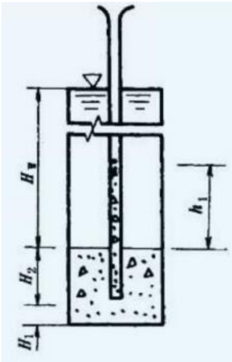

Figure 9 Sketch of the calculation of the first concrete quantity.

$$V = \frac{\pi D^2}{4}\left(H_1 + H_2\right) + \frac{\pi d^2}{4} h_1$$

Where: V -- Quantity required for first concrete placement (m^3);

D -- Pile hole diameter (M);

H_1 -- The corresponding proximity between the conduit and the bottom of the pile hole generally needs to be controlled in the range of 0.3m to 0.5m;

H_2 -- Depth distance of the first embedded catheter (m);

d -- Catheter inner diameter (M);

h_1 -- The height corresponding to the equilibrium conduit pressure when the concrete reaches the embedment depth H2 (m), and:

h= $h_1 = H_w \gamma_w / \gamma_c$

γ_c -- The weight of the concrete mix (take 24kN/ m^3);

γ_w -- The weight of water or mud in the pile hole (kN/ m^3);

H_w -- Depth of water or mud in pile hole (m).

Known: Pile depth is 20.6m

The mud weight is 11kN/ m^3

$h_1 = 20.6 \times 11 / 24 = 9.44m$

$V = 3.14 \times 0.6^2 / 4 \times (0.4 + 1) + 3.14 \times 0.12^2 / 4 \times 9.44 = 0.496m^3 \approx 0.5m^3$

5.5 Casing Removal

(1) After the concrete pouring is completed, the casing should be pulled out by the tube extractor or sleeve driven by the rotary excavator. With the help of the extractor, the extractor is operated with the help of the rotary excavator. The upper part of the casing is suspended with the hoist of the rotary excavator. When the casing is pulled to the joint part of the casing, the corresponding bolts of the casing are removed and the casing is lifted away.

(2) It is necessary to remove the casing at a constant speed to avoid the change of concrete density caused by too fast speed, which eventually causes problems in the quality of the whole pile.

(3) The casing needs to be pulled out in a vertical manner, and the entire process needs to be equipped with

command personnel to ensure perpendicularity. The concrete part on the casing should be cleaned and placed neatly for next use.

6. Piling Inspection

According to the requirements of the construction quality of the drawings, the testing of the cast-in-place pile:

The pile foundation adopts the vertical compressive static load test of single pile and the low strain or acoustic transmission method;

The number of static load tests shall not be less than 1% of the total number of piles under the same condition, and not less than 3 piles;

The number of piles tested by low strain method shall not be less than 30% of the total number, and not less than 20 piles;

The number of ultrasonic detection is not less than 30% of the total number of piles, and not less than 20.

6.1 Integrity Test

According to the actual conditions of the resident country, the project uses the low strain method to conduct the integrity test. Part of the sampling data are shown in Table 1, Figure 10 and Figure 11, and the testing figures are shown in Figure 12 and Figure 13.

Table 1 Effective pile length, pile diameter, pile integrity.

Pile number	7	13	29	42	68
Effective pile length m	20.5	21.0	20.5	19.8	21.5
Pile diameter	Qualified	Qualified	Qualified	Qualified	Qualified
Integrity of pile body	Class 1	Class 1	Class 1	Class 1	Class 1

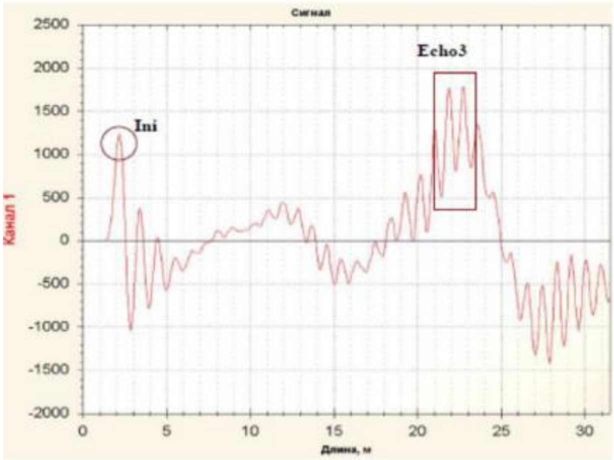

Figure 10 Schematic diagram of acoustic acceleration at pile 13.

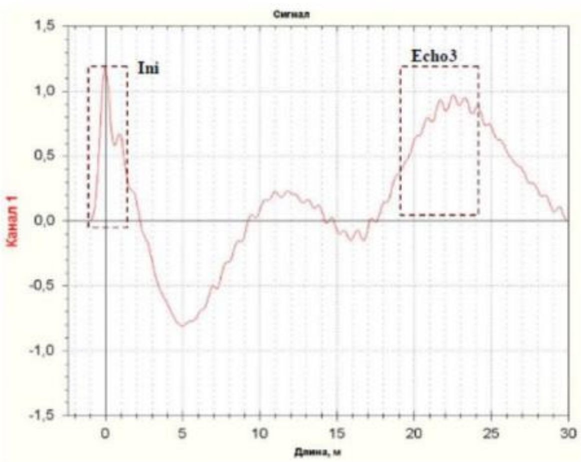

Figure 11 Schematic diagram of sonic velocity at pile 13.

Figure 12 Pictures of on-site testing (I).

Figure 13 Pictures of on-site testing (II).

6.2 Single Pile Static Load Test

The maximum attached load at the pile end, local ultimate stress of the pile, bearing performance of the pile, allowable load strength of the soil at the pile end, and subsidence are shown in Table 2, and the field test is shown in Figure 14 and Figure 15.

All the test items of this project are qualified and the test data are stable, which indicates that the construction method of full rotating casing has reliable quality assurance.

Table 2 Maximum attached load at the pile end, local ultimate stress of the pile, bearing performance of the pile, allowable load strength of the soil at the pile end, and subsidence.

Pile number	Maximum attached load at pile end kN Sinking amount MM	Local ultimate stress of pile, kN Sinking amount MM	Pile bearing capacity sinking amount MM	The allowable load strength of the soil at the pile end and the settlement amount MM
2	1200	1200	1200	1050
	3.80	3.80	3.80	2.60
3	1200	1200	1200	1050
	5.00	5.00	5.00	3.20
23	1200	1200	1200	1050
	19.90	19.90	19.90	14.70
35	1200	1200	1200	1050
	19.90	19.90	19.90	13.80
63	1200	1200	1200	1050
	19.20	19.20	19.20	13.70

Figure 14 Pictures of on-site testing (III).

Figure 15 Pictures of on-site testing (IV).

7. Comparative Analysis of Concrete Consumption and Duration

7.1 The analysis of concrete dosage is shown in Figure 16

According to the calculation of drawings and actual construction statistics, the planned concrete consumption is 387.6 m^3, the actual concrete consumption is 436 m^3, and the filling coefficient is 1.12, which meets the design requirements and the concrete consumption is reasonable.

7.2 The comparative analysis of the construction period is shown in Figure 17

In the actual construction, the practice has proved that the construction technology has a remarkable effect on saving the construction period, which is completed ahead of the planned construction period.

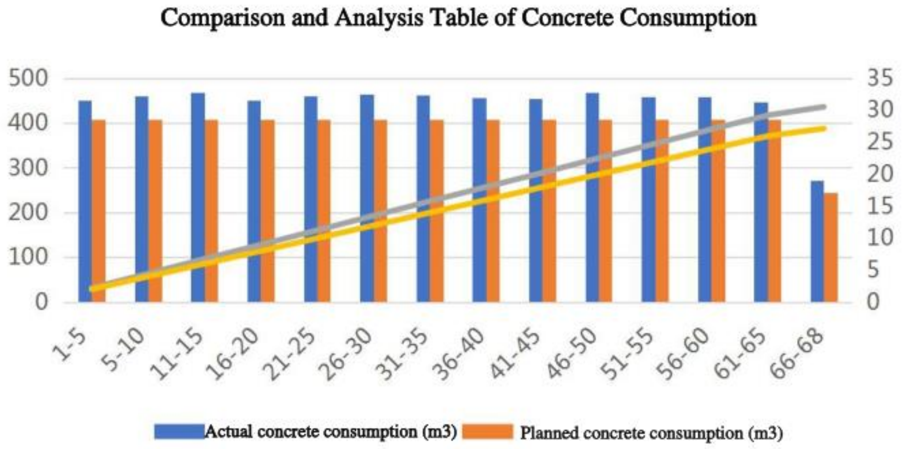

Figure 16 Concrete dosage comparative analysis diagram.

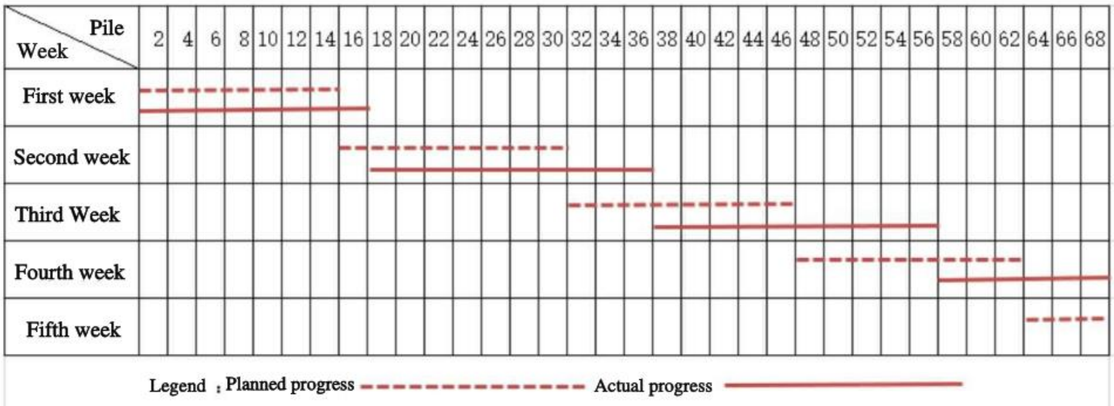

Figure 17 Time limit comparative analysis table.

8. Concluding Remarks

In summary, in the construction of medium-coarse sand and other geological pile foundations that are not easy to form holes, the construction process of full-rotating full-casing is fast, efficient, safe and reliable, and can ensure both quality and construction period by controlling concrete collapse, the amount of concrete each time injected, the depth of pipe drawing, and the strength of steel cage. At the same time, it also has a certain effect on the control of concrete excess control, and energy saving, environmental protection and pollution-free, which has been successfully applied in the actual construction of Belarus.

References

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