Application of the large-diameter and extra-long rotary bored pile in the thick sand layer area

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Abstract. The large-diameter and extra-long rotary bored pile is a common foundation used in civil structures, while the sand layer may influence the quality of the rotary bored pile. This paper analysed the forming of the rotary bored pile in the sand layer based on an engineering case. The testing data of the practical pile forming process were recorded, and the difficulties and key points are highlighted to provide experience for other cases.

1. Introduction
With the development of society and economy, more and more long span bridges and extreme deep foundation pits are built [1]. The main section of the reformed Sanli bridge used three-span prestressed concrete single-box and double-chamber continuous box girder with variable cross-section, and the length of the major span reaches over 150m [2]. The 1.8 m wide diameter and 100 m long bored pile was chosen to be the foundation of the pier of the major span [3]. The bearing capacity of large-diameter and extreme-long pile should be tested in-site, but the in-site testing in engineering area with high underground water level and thick sand layer is very difficult [4]. The testing in sand layer usually meet the accidents of quick-sand and slumping hole, reducing the quality of pile forming. What’s more, the soil layer, which is 10 to 35 m deep below the mudline, should be excavated away in the in-site bearing capacity testing of deep-embedded piles to obtain the true bearing capacity of the piles [5]. Therefore, the in-site bearing capacity testing of the large-diameter and extreme-long pile should be improve first [6]. This paper aims to solve this problem and proposes a novel in-site testing method to broaden the application of the large-diameter and extreme-long pile in thick sand layer based on an engineering case.

2. The problem of drilling hole wall and suitable protection method in the rotary excavation process
The rotary excavation technology has the following four major benefits: (1) The drilling machine can moves conveniently without disturbing with each other and can be used in narrow grounds; (2) The noisy sound of drilling machine is relatively low, with little disturbing on the nearby residential and office areas, and can be used in urban area; (3) Less slurry is requested for the drilling machine, and
therefore the drilling construct can meet higher environmental request; (4) Multiple outer diameters can be satisfied in one drilling machine with high construction speed, and therefore the drilling machine can be used widely and effectively.

Since the cohesion of the sand is very small and the inner friction is the main force to remain the stable of sand layer, and the underground water and water in the protecting slurry reduce the inner friction of sand, the drilling in the sand layer with high underground water level may meet unstable wall of hole, slowing down the drilling speed and causing more environment pollution. The rotatory drilling machine can solve the problem of protecting hole wall with slurry in sand layer, but it also be challenged by the exist of thick sand, since the rotatory drill will be buried in thick sand.

The common protection of hole wall protected with slurry, which is mainly prepared by bentonite, cannot work as well as expected in thick sand layer. The sedimentation rate of drilling slag is slow, and the thickness of sediment is larger than 1.0 m at the stage of secondary hole cleaning, disturbing the quality of the pile forming. Therefore, new protecting slurry is wanted in drilling in thick sand layer, and the high-performance polymer chemical slurry is proposed. This chemical slurry is very sticky, and therefore the sediment generated in rotatory drilling can be sticked and drawn down to the bottom of hole fast. The viscosity of this chemical slurry increases with the rotation of drill, and the chemical slurry applies positive pressure on the hole wall, avoiding the collapse of the hole wall.

3. Improved in-site bearing capacity testing method
In order to solve the collapse of hole wall for deep embedded pile in thick sand layer, the rotatory drilling with pile casing is used. The standard procedure can be divided into 8 major parts as shown in Fig. 1.

3.1. The preparation before construction and setting drilling machines
The geotechnical and hydrologic conditions should be tested before construction. The engineering area should be prepared to be flat and free of obstructions. A right-sized slurry preparation tank should be excavated. All materials and machines should be move into right places of the engineering case. The steel reinforcement cage should be fabricated. The waterproofing drainage facilities should be finished. The drills should be chosen according to the properties of the soil, and the straight auger bit (see Fig. 2) is used in this test due to the existing of the thick sand layer.

Figure 1. Construction technology of rotary excavation

Figure 2. The straight auger bit
3.2. Setting pile casing
Setting drilling machines and drills in piling place, making sure that the inner diameter of the pile casing is 10 cm larger than the outer diameters of drills. The center of pile casing should be coincided with the center of drills. The vertical gradient of the pile casing should not be larger than 1%. The pile casing is hanged and located by a crane, and then be pressed vertically into the soil by the rotatory drilling machine as the following steps shows (see Fig. 3). The top of the pile casing should be 0.5 m higher than the surface of the ground, and the minimum depth buried in sand should not less than 1.5 m after the pile casing was totally be pressured into soil. The stabilizing fluid should be injected into the soil inside of the pile casing, and the upper surface of the stabilizing fluid should be 1 m higher than the upper surface of the underground water in engineering area.

![Figure 3. Pile casing for in-site testing of rotary drilling piles](image)

3.3. Slurry preparation
The chemical slurry should be prepared with the air compressor. The water is firstly be poured in the slurry preparation tank, and mixed with 20% NaOH to adjust the pH of the liquid to be 8 to 10. The air compressor is used to mix the liquid uniform, and then pumping the polymer mud powder into the liquid. The viscosity of the mixed liquid should reach 22 s, as shown in Fig. 4.

![Figure 4. The mixed chemical slurry](image)

3.4. Slurry preparation
After all preparations are finished, the rotatory drilling can be conducted. The soil is excavated by the rotation, shearing, and lifting motions of the drills. The upper surface of the protecting slurry should not be lower than the bottom of the pile casing. The collapse of hole wall is sometimes observed in-site testing. Further studies show that it is because of the negative pressure generated in the lifting of the drills. The improved solution is to tie 4 hyperboloid and no more than 2 cm thick steel wall plate in the
pile casing. After taking the improvement on the pile casing, the shrink of the piling hole is almost vanished.

3.5. Hole cleaning
The remoulded soil in the bottom of the piling hole should be cleaned after the piling process, and a drill bucket with baffle is used in this test to clean the hole. The hole after the cleaning should satisfy all the following rules. The diameter of the sediment in the slurry extracted from the hole should not be larger than 2-3 mm; the weight of slurry should not be larger than 1; the ratio of sand in slurry should be less than 2%; and the viscosity of the extracted slurry should be with the range from 18 to 22 s.

3.6. Manufacturing and setting steel reinforcement cage
The rebar in the steel reinforcement cage is selected based on the requested strength and the lifting capacity of crane, and the length of one single section of the steel reinforcement cage is 9 m in this test. The steel cage is formed by rolling welding, containing 3 seamless steel tube with inner diameter of 50 mm and thickness of 3 mm for ultrasonic testing.

4. Analysis of the in-site testing results
There are three 63 m-long rotatory drilling piles with outer diameter of 800 mm are used in this in-site bearing capacity testing. The testing results are shown in Fig. 4.

![Figure 5. Q-S curves of testing piles](image)

As it is shown in Fig. 5, the deformation of piles under the action of the vertical load increases slowly and no action of sudden sinking is observed, indicating that the qualities of all three testing piles are good. The settlements of all three piles starts when the load reaches 3000 kN, and increases with an obvious speed when the load reaches 6000 kN. The maximum settlements of the three piles are 29.38 mm, 30.55 mm, and 32.12 mm, which are all smaller than the limit value in the code (40 mm).

5. Conclusion
This paper brings the details process of how to conducting the in-site bearing capacity testing of the rotatory drilling pile in thick sand layer with high underground water level. The monitor of the construction quality is the key point for the guarantee of the success of testing. The advantage of the application of the high-performance polymer chemical slurry in the piling is also be highlighted.

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