Study on construction technology of percussive reverse circulation drilling hole forming squeezed branch pile

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Abstract. Taking No.65 pier of Zhongshan-Tanzhou express line as the background, the construction technology of percussive reverse circulation drilling hole forming squeezed branch pile is studied, the construction process of percussive reverse circulation drilling hole forming squeezed branch pile is defined, and through the field trial hole forming test, the points needing attention in field construction are summarized and improved: (1) The top elevation of the steel casing shall not exceed 30cm of the surface elevation, and the hole diameter of the percussion drilling hole shall be slightly larger than the designed hole diameter, so as to avoid the floating of the steel cylinder and the influence of too small hole diameter on the squeezing operation; (2) hole cleaning operation is an important factor for the success or failure of the squeezed branch pile construction, and the sediment thickness has a great influence on the bearing capacity of the pile foundation. After the expansion equipment is squeezed and the reinforcement cage is lowered, the hole cleaning is carried out, and the control points and mud parameters during each hole cleaning are clarified; (3) during the expansion process, the extrusion pressure value and the floating amount of the expansion equipment should be detailed, the geological information should be verified, and the bearing capacity of the pile foundation should be evaluated.

1. Introduction
With the continuous development of China's coastal economy, the traffic volume is increasing. In order to meet the requirements of daily traffic, more and more urban expressways are under construction or planning. Due to the effects of transgression, regression and river water in coastal areas, soft soil is widely distributed and the thickness of deposition is large[1]. In order to increase the traffic volume and improve the traffic performance of highway, the width of bridge is increasing day by day. Pile foundation is a common form of bridge foundation. Due to the dead weight of the bridge and the load on the upper part of the bridge, the length and diameter of the pile are increasing under the condition of soft soil geology, which makes the construction difficulty and project cost doubled.

On the basis of ordinary pile, the squeezed branch and disk pile forms a branch cavity or disk cavity by squeezing the surrounding soil at the corresponding position of the pile body with special equipment. After pouring concrete, the diameter of the pile body can be changed, and the side friction resistance of the pile body can be converted into the end bearing capacity, so as to greatly improve the bearing capacity and settlement control capacity of the pile body. It can effectively shorten the length of the pile and the pile foundation, which has a certain application value in clay and sand geological conditions Good economy. Through the development in recent years, the application of squeezed
branch and disk pile in bridge engineering is more and more \[^{2-5}\]. The hole forming quality of squeezed branch and disk pile is the premise and guarantee for the successful application of squeezed branch and disk pile. The conventional pile foundation hole forming technology includes reverse circulation drilling hole forming technology, positive circulation drilling hole forming technology and impact reverse circulation drilling hole forming technology. Reverse circulation drilling construction technology has the advantages of high drilling efficiency, low cost and strong slag removal \[^{6-8}\]. It can effectively remove the pile slag and the sediment and mud in the branch cavity and disk cavity. Therefore, the reverse circulation drilling construction technology is a common hole forming technology for squeezed branch disk pile.

Most of the piles in Zhongshan-Tanzhou express line are rock socketed piles, and the pile foundation drilling method is impact reverse circulation drilling. Through geological scanning survey, the basement of No. 65 pier of landscape Avenue has boulder layer. In order to shorten the construction period, reduce the project cost, and avoid penetrating Boulder, the squeezed branch pile is used as the foundation pile foundation at the bottom of the pier. Since the reverse circulation drilling drilling equipment is not equipped on site, if you buy a new type of equipment. The preparation improves the project cost, causes the waste of resources, and it is difficult to form holes on the surface of boulder by using reverse circulation drilling. Therefore, it is appropriate to use percussive reverse circulation drilling technology to form holes. At present, the hole forming technology of squeezed branch and disk pile is reverse circulation drilling, and there is no precedent of using impact reverse circulation drilling. Taking the squeezed branch and disk pile of No. 65 pier of Zhongshan-Tanzhou express line as an example, this paper introduces the construction technology and precautions of impact reverse circulation drilling and squeezed branch and disk pile, which provides a new idea and method for the later squeezed branch and disk pile under boulder geological conditions.

| Pile number | Pile length/m | Elevation/m | stratum       |
|-------------|---------------|-------------|---------------|
| 65-1        | 14.45         | Top of pile 2.05 | /             |
|             |               | Branch 1 -0.20 | silty clay    |
|             |               | Branch 2 -3.00 | silty clay    |
|             |               | Branch 3 -5.80 | silty clay    |
|             |               | Branch 1 -8.60 | silty clay    |
|             |               | Bottom of pile -12.40 | /             |
| 65-2        | 14.05         | Top of pile 2.05 | /             |
|             |               | Branch 1 -0.20 | silty clay    |
|             |               | Branch 2 -3.00 | silty clay    |
|             |               | Branch 3 -5.80 | silty clay    |
|             |               | Branch 4 -8.60 | silty clay    |
|             |               | Bottom of pile -12.00 | /             |
| 65-3        | 13.55         | Top of pile 2.05 | /             |
|             |               | Branch 1 0.18  | silty clay    |
|             |               | Branch 2 -2.32 | silty clay    |
|             |               | Branch 3 -4.82 | silty clay    |
|             |               | Branch 4 -7.32 | silty clay    |
|             |               | Bottom of pile -11.5 | /             |
2. Construction process of squeezed branch pile

The pile length of 65 pier squeezed branch pile of Zhongshan-Taizhou express line is 13.55m ~ 14.45m, the diameter of the central pile is 1.6m, four rows of eight star branches are set in the pile body, the length of the branch is 0.75m, and the spacing between each row of branches is 2.8m. The specific parameters are shown in table 1. According to the construction conditions and design drawings, a Yzj-3400 squeezed branch pile machine is used, and the maximum opening size of the bow arm is 3.4m, as shown in figure 1.

The construction technology of percussive reverse circulation drilling hole forming squeezed branch pile is as follows: construction preparation → pile position measurement and setting out → burying steel casing → rechecking pile position → drilling in place → drilling hole forming → first hole cleaning → inspection of drilling hole → hole laying dial and leveling and centering → connection of branch oil pipe and pressure pump oil pipe → lifting squeezing machine → centering and putting into hole → connecting extension rod → lowering to chassis elevation → Through the rotating rod → center the extruder → center the rotating rod to the first origin of the dial → start the oil pump extrusion → apply pressure to the design pressure value → return oil → measure the floating amount → observe the pressure gauge → record the expanding pressure value and the floating value of the pipe joint → first hole cleaning → inspection of drilling → binding and lowering the steel cage → third hole cleaning → lowering the concrete pipe → second hole cleaning → pouring underwater concrete → dismantling Except for conduit → piling, the specific flow chart is shown in figure 2.
3. Matters needing attention in construction of impact reverse circulation drilling hole forming squeezed branch pile

The construction of squeezed branch and disk pile in Tanzhou express line is the first time to adopt the impact reverse circulation drilling technology, and there are many uncertain factors. The trial hole forming test was carried out before the pile construction on site, and the trial hole forming position was selected near pier 65, with the following purposes:

- Check the geological exploration data;
- Design calculation and construction confirmation of parameters;
- Confirmation of construction technology and key points of extrusion expansion process;
- Mutual technical requirements of hole forming process and extrusion expansion process;
- Confirmation of hole forming mechanical equipment and extrusion expansion branch plate mechanical equipment;
- Confirmation of quality inspection and testing equipment for pile hole and branch plate cavity;
- Enterprise qualification and construction management personnel post requirements;
- Technical requirements for foundation pile acceptance and testing;
- Take the squeezed expansion pressure value of soil layer, and the test results are shown in table 2.
Figure 3. Hole test

(a) impact hole forming
(b) measurement of equipment floating amount

Table 2. Statistics of pressure value and equipment floating amount in trial hole forming.

| Plate of a name | Disc bit elevation (m) | Depth of the branch (m) | stratum       | Count                  | 1st | 2nd | 3rd | 4th |
|-----------------|------------------------|-------------------------|---------------|------------------------|-----|-----|-----|-----|
| Branch 1 of MI word | -0.20                  | 5.541                   | Coarse sand   | Extrusion pressure value Mpa | 5   | 5   | 5   | 5   |
|                  |                        |                         |               | Floating amount of equipment mm | 600 | 600 | 700 | 700 |
| Branch 2 of Hexagram | -2.20                  | 7.541                   | Silty clay    | Extrusion pressure value Mpa | 6   | 5   | 5   |     |
|                  |                        |                         |               | Floating amount of equipment mm | 600 | 550 | 560 |     |
| Branch 3 of MI word | -4.20                  | 9.541                   | Silty clay    | Extrusion pressure value Mpa | 6   | 5   | 6   | 6   |
|                  |                        |                         |               | Floating amount of equipment mm | 570 | 450 | 620 | 520 |
| Branch 4 of Hexagram | -6.20                  | 11.541                 | Silty clay    | Extrusion pressure value Mpa | 6   | 6   | 5   |     |
|                  |                        |                         |               | Floating amount of equipment mm | 500 | 400 | 350 |     |
| Branch 5 of Hexagram | -6.959                 | 12.30                   | Silty clay    | Extrusion pressure value Mpa | 8   | 6   | 6   |     |
|                  |                        |                         |               | Floating amount of equipment mm | 900 | 880 | 850 |     |

The value of squeezing pressure can reflect the degree of soft and hard soil, which can be used to evaluate whether the soil at the squeezing position is consistent with the design soil, and can reflect the bearing capacity of the squeezed branch pile. According to the results of hole forming test, the value of squeezing pressure in the hole forming test is between 5 ~ 6Mpa, which is slightly less than the value required in the specification. The reason is analyzed, which provides a reference for the pile foundation to clear the hole during the hole forming process Slag is not enough, resulting in sediment into the side wall, resulting in the reduction of extrusion expansion pressure value, and in the process of extrusion expansion, it is found that the steel cylinder has an upward trend in the process of extrusion expansion, which affects the extrusion expansion operation of squeezed branch and disk pile. By summarizing the problems encountered in the construction process of trial hole, the following precautions are summarized on the basis of the above process:

(1) Hole forming: 1) pile casing embedding technology: vibration sinking, pile casing length 3m ~
3.5m, pile casing top elevation not more than 30cm above the surface elevation; 2) hole forming diameter: the hole diameter above the top of boulder is 0.1m larger than the design hole diameter, the pile diameter of embedded boulder part maintains the original design hole diameter, so as to prevent borehole necking, and it is difficult to lower the squeezing equipment; 3) mud index before squeezing: relative density 1.3 ~ 1.45, viscosity 22 ~ 30, sand content < 4%. The pulp is made of clayey soil with particle size less than 0.074mm and clay content more than 50%.

(2) One time hole cleaning: 1) slag cleaning requirements before extrusion: the first slag cleaning should be completed within 3 hours after hole forming, and the sediment thickness should be less than 30cm.

(3) Branch and disk expansion: 1) after a hole cleaning, the branch and disk geotechnical engineer uses caliper to retest the hole diameter, hole depth and hole wall integrity; 2) finish the expansion operation within 10 hours after the completion of the previous construction step, and the direction of the expansion angle is consistent with the design position to meet the requirements of later detection (branch position and expansion time); 3) fill in the on-site expansion table and collect the data of each expansion. According to the relevant data in the process of squeezing expansion (squeezing expansion pressure value and equipment floating amount), the squeezing expansion pressure value in clay layer and sand shall not be less than 5MPa.

(4) Preparation before secondary hole cleaning: before secondary hole cleaning, the mud in the mud pit is transported out. After transportation, a certain amount of clean water is injected into the mud pit. After hole cleaning, the mud index is tested. The relative density of the mud is 1.15 ~ 1.2, the viscosity is 18 ~ 22, and the sand content is less than 4%.

(5) Secondary hole cleaning: 1) requirements for secondary hole cleaning: use automobile reverse circulation drilling equipment for hole cleaning (1.6m bit must be taken for slow drilling), the hole cleaning time shall not be less than 2 hours, and the hole cleaning time at the bottom support position shall not be less than 30 minutes; 2) the sediment thickness after secondary hole cleaning shall not be more than 10 cm.

(6) Caliper testing: the caliper testing shall be conducted within 1 hour after the second hole cleaning, and the testing times of each pile shall not be less than 5 times, and the testing time shall not be more than 2 hours.

(7) Lower the reinforcement cage: 1) lower the reinforcement cage within 1 hour after passing the inspection, and the plane positioning of the reinforcement cage shall ensure that the PVC pipe on the reinforcement cage, the PVC pipe outside the pile and the center of the pile are on the same axis; 2) take effective measures to ensure that the reinforcement cage will not collide with the hole wall during the lowering process, so as to prevent hole collapse due to the collision of the reinforcement cage; 3) after the reinforcement cage is lowered, the third hole cleaning must be carried out. It is necessary to use reverse circulation pump suction hole cleaning technology, and the hole cleaning standard can meet the requirements of rock socketed pile specification.

(8) Concrete pouring: underwater concrete shall be poured within 30 minutes after three times of hole cleaning.

4. Conclusion

Based on the No. 65 pier of Tanzhou express line, this paper studies the construction technology of percussive drilling and squeezed branch pile under the condition of boulder geology. This paper puts forward the construction technology and process of impact drilling hole forming and squeezed branch and plate pile, and through the trial hole forming test, summarizes and improves the key points that should be paid attention to in the field construction. In addition, the construction of three branch plate piles of pier 65 has been completed, and through the detection, the branch length is between 61.43cm ~71.54cm, which meets the design requirements. Through the implementation of this project, the construction technology of percussive reverse circulation drilling hole forming squeezed branch and disk pile is realized for the first time, which provides a new idea for the later application of squeezed branch and disk pile in Boulder or hard rock interlayer geology.
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Reference
[1] Zhou Hui. Geological and hydrological environment analysis on distribution characteristics and causes of soft soil in Pearl River Delta [J]. Civil engineering and architecture, Guangdong, 2014, 21 (07): 36-38 + 35.
[2] Li Yong, Yi Shaoping, he Quan Quan. Settlement analysis and anti deformation ability of squeezed branch pile of bridge [J]. Guangdong highway transportation, 2019, 45 (05): pp 49-54.
[3] Lu Mantang, Liang Wenbiao. Development status and application prospect of new bored pile technology [J]. Science and technology information development and economy, 2001 (01): pp 65-66.
[4] Zhao Youlong. Application of squeezed cast-in-place pile in Expressway [J]. East China highway, 2016 (02): pp 119-120.
[5] Wang xunbo. Study on the application of squeezed branch pile in bridge engineering [D]. China University of Geosciences (Beijing), 2011.
[6] Wan Jiangying. Research and application of bored pile construction method [D]. Nanchang University, 2014.
[7] Wang Qiang, Zhao Chunfeng, Zhao Cheng, Xue Jinxian, Lou Yun. Study on the influence of positive and negative circulation mud retaining wall of bored pile on pore diameter [J]. Journal of geotechnical engineering, 2011, 33 (S2): pp 205-208.
[8] Wang Shaohua, sun Keqiang, Liu Guangyu, Zhang Guoliang. Construction technology and intelligent equipment of bridge squeezed branch pile [J]. Guangdong highway transportation, 2019, 45 (05): pp 55-59.