Analysis on the Variation Rule of Aperture of the Normal Circulation Bored Pile

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Abstract. The hole formation is the most important link in the construction of bored piles. The quality of the hole formation plays a decisive role in the bearing capacity of cast-in-place piles. Combined with the field measurement data of hole formation in Changzhou Science And Technology Financial Center, combined with the time factor and the buried depth factor, the pore diameter change was analyzed. At the same time, the monitoring data was compared and analyzed by means of numerical simulation. The results show that the stress releases and the pore diameter decreases with the change of depth. With the increase of time, the pore size decreases. Due to the influence of soil structure, the pore diameter shrinkage of silty sand layer is up to 12.5%, while the silty clay layer is generally relatively small, with the maximum value not exceeding 6.25%.

1. Introduction

In the process of bored pile construction, hole formation is as important as pile formation, and the quality of pile formation directly affects the quality of cast-in-place pile [1]. Bearing capacity of foundation pile is a key factor to judge the quality of bored pile [2]–[3]. The bearing capacity of a pile consists of the lateral friction resistance of the pile and the resistance of the pile bottom, and the total lateral friction resistance of the pile is positively proportional to its surface area [4], that is, the larger the pore size of the pile is, the greater the total lateral friction resistance is. If shrinkage occurs in the process of hole formation, the side friction resistance of the pile will be reduced, and in the process of hole formation, the hole formation process, mud performance index, clearance time and hole cleaning method of the bored pile will directly affect the exertion of side friction resistance and pile tip resistance [5].

The field measurement data of hole formation in Changzhou Science And Technology Financial Center were selected to analyze the pore size variation rules and pore size characteristics under the influence of soil layer factors with time and depth changes.

2. Influence of soil layer properties on pore diameter changes

2.1 Monitoring results of soil pore size change
2.2 Numerical simulation results

Numerical simulation software PLAXIS was used to simulate it.

According to the actual size of the borehole, an axisymmetric model is adopted. The boundary surface of the soil layer is 15m wide and 100m deep. The established model is shown in figure 2. It is assumed that the model has horizontal constraint on the right boundary, vertical and horizontal constraint on the bottom boundary, free boundary on the top and axisymmetric constraint on the left boundary. The mud skin is equivalent to a 2mm thin sheet in terms of engineering parameters. The input parameters of the mud skin are shown in table 1. The mud pressure ACTS like a triangular stress from top to bottom along the board. The calculation unit adopts 15-node triangular element to simulate the rock-soil mass, the mud skin adopts 8-node quadrilateral element, the contact element adopts zero-thickness Goodman element to simulate, the failure of the soil mass adopts mohr-coulomb criterion, and the soil parameter is selected as representative soil, as shown in table 2.
Table 1. Material parameters of mud cake

| Parameter          | Name      | Value | Unit   |
|--------------------|-----------|-------|--------|
| Behavior type      | Material type | Elastic |        |
| Axial stiffness    | EA        | 3600  | kN/m   |
| Flexural rigidity  | EI        | 2.4×10⁻⁶ | kNm²/m |
| Equivalent thickness | d      | 2×10⁻³ | m      |
| Bulk density       | w         | 15    | kN/m/m |
| Poisson ratio      | ν         | 0.3   |        |

Table 2. Soil model parameters

| Layer        | $\gamma$(kN/m³) | $\gamma_{sat}$(kN/m³) | $c$(kN/m²) | $\varphi$(°) | $E$(kN/m²) | $v$ | Permeability coefficient (m/day) |
|--------------|-----------------|-----------------------|-------------|--------------|------------|-----|----------------------------------|
| Prime fill   | 19.0            | 20.279                | 29.5        | 12.5         | 14649      | 0.16| 0.003                            |
| Clay         | 19.6            | 21.123                | 55.3        | 16.1         | 16075      | 0.35| 0.001                            |
| Silty clay I | 19.1            | 20.49                 | 38.8        | 17.2         | 17160      | 0.3 | 0.001                            |
| Silty sand I | 18.4            | 19.569                | 6.2         | 34.2         | 348685     | 0.22| 2.66                             |
| Silty sand II| 18.4            | 19.526                | 5.7         | 34.5         | 37839      | 0.22| 2.66                             |
| Silty clay II| 19.7            | 21.333                | 42.6        | 16.5         | 19389      | 0.3 | 0.001                            |
The change of soil layer is shown in Figure 3.

Under the action of the mud arm, the soil layer will form a layer of mud skin on the surface of the borehole, which can be regarded as a temporary retaining structure. Different soils have different parameters and different effects on the pore wall. As shown in the figure, at the junction of soil layers, the displacement tends to be abrupt. In particular, from silty clay layer to silty sand layer, pore size changes from expansion to reduction, which is due to the small cohesion between silty sand and poor stability of soil layer, mud crust inhibits its lateral failure, thus increasing the displacement of mud crust.

Comparing silty sand layer with silty clay layer, the silty sand layer all moves toward the hole, and the borehole diameter shows as shrinkage hole, while the silty clay layer mostly shows as the movement outside the hole. Even if some soil layer moves toward the hole, its maximum displacement is smaller than that of silty sand layer. At the same time, in the 4 layers of silty clay, its lateral displacement to the hole is larger, which is because the depth of the soil layer is deep, and the changing pressure value is larger than that of the shallow soil, so its displacement is also larger, but still less than the maximum lateral displacement of the silty sand layer.
3. The influence of time on the aperture change

Hole was taken to make the variation diagram of hole diameter with time in the same buried depth in each soil layer.

![Figure4. Relation diagram of soil aperture reduction with time](image)

Can be seen from the diagram above, 1 layer and silty clay layer, silt layer 2 of the smallest aperture has a tendency to increase along with the change of time, in the first 1.5 h within the aperture size remains the same, basic stabilized at about 920 mm, and later in the 1.3 h hours, aperture increased slightly, but the change is tiny, fluctuating in 10 mm, the time of clay and silt layer and the influence of silty sand layer 2 is not very big. The minimum pore diameters of layer 1, layer 2, layer 3 and layer 4 of silty clay become smaller and smaller with time, but the difference is not large, and the variation range is within 8mm within 2.8h. With the increase of depth, the pore diameter of layer 1, layer 2, layer 3 and layer 4 of silty clay is 930mm, 920mm, 900mm and 850mm respectively, that is, the pore diameter decreases successively with the depth. Only the fine sand layer suddenly reduced its pore diameter from 820mm to 748mm within one and a half hours, reducing by 72mm, and then the pore size was reduced and then remained at 746mm.

According to formula literatures [7], [8], [9], under normal circumstances, the longer the hole formation time is, the more serious the stress release is, the stress on the hole wall should be reduced, and the displacement of the hole wall is increased. On the one hand, the increase of pore diameter of some soil layers is due to the water in the mud infiltrating into the soil layer, which makes the soil layer soft and reaming. On the other hand, due to the lack of hole forming technology, that is, too short a time to sweep the hole, will lead to the increase in pore roughness, and at the same time mud wall clay and some of its sediment fall at the bottom will also cause fine sand shrinkage.

Compared with silty sand layer, the influence of silty clay layer on pore formation is greater, the reduction of pore size will often lead to the construction of steel cage is difficult to put into the hole, of course, the increase of pore size will also produce the phenomenon of pore reaming. Therefore, it is suggested that the construction unit should control the first hole cleaning within 1h to ensure the maximum hole diameter of drilling, then place the steel cage and weld it, followed by the second hole cleaning, and the total time before pouring concrete shall not exceed 3h.
4. Conclusion

(1) Due to the cohesive force between soil particles, the cohesive force between soils with different properties is also different, resulting in different pore size yield of soils with different properties. At the same time, due to the influence of soil structure, the pore diameter shrinkage of silty sand layer is up to 12.5%, while the silty clay layer is generally relatively small, with the maximum value not exceeding 6.25%.

(2) Time is an important factor affecting the pore size. Therefore, it is suggested that the construction unit should control the first hole cleaning within 1h to ensure the maximum hole diameter of drilling, then place the steel cage and weld it, followed by the second hole cleaning, and the total time before pouring concrete shall not exceed 3h.

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