Application and Research of Multiple Support Types in the Combination of Deep Foundation Pits

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Abstract. We are studying the foundation pit support technology is currently the most common engineering problem in foundation pit engineering, and this is very important for the selection of support structure. We found that construction techniques such as soil-nailed walls, cast-in-place piles, triaxial cement mixing piles, row piles, anchors (rods), deep well dewatering, and internal support in foundation pits are more common construction methods in deep foundation pit support technology. During the design and construction process, according to the different environmental conditions, engineering geological conditions and support requirements of the construction site, we can flexibly adopt a variety of support types to form a safe and reliable support system. Using this method can ensure the foundation pit is opened. Safety during digging. We found in the project an example of the design of the full-type technology of the support group of "filled pile + internal support". We applied the rational foundation pit algorithm to the excavation process of the soft soil deep foundation pit under the row pile support. The variation of the moment of the pile body, the lateral deformation of the pile body and the ground settlement around the foundation pit due to excavation were analyzed. In the project, we combined the monitoring information of the foundation pit, and the experimental results resulted in this type of support combined support technology. In the foundation pit support technology, the limited deformation results are good, and the impact on the surrounding foundation is small. Studies have proved that this technology can provide a reference for similar engineering practices, and the technology has practical research significance.

1. Introduction
With the rapid development of China's economy, urbanization construction is getting faster and faster, and the land for construction is becoming increasingly tight. As a result, the higher and higher the building is, the deeper and deeper the basement is. The geological conditions of coastal cities generally have soft soils, such as silt, which are relatively thick and poor in soil quality. This puts forward higher requirements and challenges for foundation pit support technology. In foundation pit support technology, commonly used support types are soil-nailed walls, cast-in-situ piles, and triaxial cement mixing piles, row piles, anchors (rods), deep well precipitation, and internal support in foundation pits. How to comprehensively use these commonly used support types is a hot topic discussed in foundation pit support technology now [1].
Therefore, based on previous studies, this article analyzed the deformation laws and mechanisms of soft soil foundation pits under the action of multiple combined types of support based on the foundation pit support technology project of a residential district in Fuzhou. The deep foundation pit support technology for soft soil under the same engineering geological conditions in coastal areas has practical guiding significance [2].

2. The project overview

2.1. The site Overview
The proposed site for this project is located east of Lianjiang South Road and north of Shuanghu Third Road in Cangshan District, Fuzhou City. The west side of the proposed site is the built Shuanghu Second Road, with a minimum clear distance of about 5m from the basement. The north side is a residential building with an 11-story frame-shear structure, and the east side is a 6-story frame-shear structure. It is a kindergarten teaching building with a three-story frame-shear structure, and the minimum clear distance from the proposed underground outdoor wall is about 13.26m [3].

A two-storey basement is set up on the west side of the project, and a basement is set up on the east side. The basement pit excavation depth of the basement is about 9.6m, the basement excavation depth of the first basement is 5.65m, and the perimeter of the foundation pit support technology is about 397m. With an area of about 8466 square meters. The security level is Level 1. The plan view of the foundation pit support technology is shown in Figure 1.

![Figure 1. Layout of excavation](image)

2.2. Engineering geological conditions
The proposed site for this project is a geomorphic unit of alluvial plains, which is overlaid with Quaternary artificial accumulation layers, silting layers, alluvial deposits, and underlying granite weathering layers. According to the geotechnical engineering survey report, the site soil from top to bottom is:

| Stratum number | Name of rock and soil layer | Natural bulk density (Kn/m³) | Straight Cut Quick Cut Cohesion C (Kpa) | Internal friction angle φ (°) | Consolidation quick shear Cohesion C (Kpa) | Internal friction angle φ (°) |
|----------------|-----------------------------|-----------------------------|----------------------------------------|-------------------------------|----------------------------------------|-------------------------------|
| ①              | Miscellaneous fill          | 17.5                        | 5.0                                    | 13.0                          | --                                     | --                            |
| ②              | Silty clay                  | 18.3                        | 30.0                                   | 10.0                          | 32.0                                   | 16.5                          |
| ③              | Mud                         | 15.16                       | 7.8                                    | 1.6                           | 9.7                                    | 7.9                           |
| ④              | Silty clay                  | 18.49                       | 30.4                                   | 11.2                          | 32.5                                   | 17.0                          |
| ⑤              | Gravel                      | 20.0                        | 5.0                                    | 20.0                          | --                                     | --                            |
| ⑥              | Mucky soil                  | 16.51                       | 12.1                                   | 2.8                           | 10.0                                   | 8.0                           |
2.3. Hydrogeological conditions
The groundwater in the excavation depth of this foundation pit is mainly: an inland river next to the proposed site, the width of the inland river is about 18m, and there is a bank revetment. Desilting and bank protection are being carried out. The water depth during the survey is 0.5-1.5m [4]. There are no other surface water systems in the surrounding area. Groundwater in the site is mainly recharged by vertical infiltration of atmospheric precipitation and lateral aquifers of adjacent aquifers and inland rivers, and is discharged through evaporation and lateral seepage. Groundwater replenishes groundwater during the dry season, and groundwater replenishes inland river water during the rainy season, and is discharged through evaporation and lateral flow [5]. During the survey, the site initially found that the water level was buried at a depth of 0.13 to 1.74 meters, and the mixed stable water level was buried at a depth of 0.33 to 2.12 meters. According to the survey, the groundwater level of the proposed site changes by about 1.00-2.00 meters, the highest water level elevation in the past 3-5 years is 6.5 meters, and the historical highest water level elevation is about 6.90 meters [6].

3. Foundation pit support technical scheme
Based on the engineering overview of the foundation pit, the foundation pit has the following main features: The basement pit is designed with a two-story basement on the west side, and the excavation depth is relatively large. The excavation depth is 9.6m; the east side is designed with a basement. The excavation depth is 5.65m. According to the specifications, the safety level of the foundation pit belongs to the first level. The soil properties in the excavation area are relatively poor, the water permeability is weak, the clay layer is very unevenly distributed, the thickness of the silt layer is large, and the lying layer below the pit is silt; the surrounding environment is poor, and the west side is a municipal road with a distance of only 5m; the north, east, and south are all built buildings, and the distance from the proposed underground outdoor wall is about 13m. Basically no natural grading conditions [7].

Figure 2. Foundation supporting section 2-2
According to the above characteristics, the surrounding retaining pile on the west side of the foundation pit is a rotary excavated bored pile with a cross section of φ800 and a distance of about 1200m, which is compatible with the two internal support structures. It is φ800 and the distance is about 1200m. It is matched with an internal support structure [8]. The horizontal internal support adopts cast-in-situ reinforced concrete structure, the upper part of the supporting column adopts steel lattice column, and the φ1000 rotary excavated bored pile is used as the lower foundation of the column [9]. A high-pressure rotary jet pile of φ700 is used between the retaining piles for water retention and soil retention [10]. A typical section view of the foundation pit support technology is shown in Figure 2 for the foundation pit support technology 2-2, and Figure 3 for the foundation pit support technology 3-3.

Figure 3. Foundation supporting section 3-3

4. Analysis of lateral deformation of retaining piles
Figure 3 shows the lateral deformation change process of the rotary excavated cast-in-situ pile in the section 3-3 of the foundation pit according to the working conditions. It can be seen from Figure 4 that when the excavated rotary pile was excavated to 2.45m, lateral deformation occurred within 15m from the top of the pile, and the maximum deformation was about 4.51mm; with the first reinforcement, deformation of the pile side has not changed further, it is still 4.51mm; when the excavation continues to 6.45m, the deformation of the pile side further expands, and the maximum lateral deformation amount increases to 22.67mm; subsequently, the second pass is reinforced, and the lateral deformation is still 22.67mm; finally excavated to the bottom of the foundation pit, the lateral deformation reached a maximum of about 30.03mm.
We can know from the deformation of the pile side of the rotary excavated cast-in-situ pile that the lateral deformation of the retaining pile gradually increases with the excavation depth as the excavation and reinforcement processes of the foundation pit proceed. According to the Fuzhou Interim Provisions on the Management of Deep Foundation Pits and Building Slope Engineering, the design limit for the deep horizontal displacement of the foundation pit retaining piles belonging to Class I is the minimum value of the foundation pit depth of 20mm and 0.2%. Many scholars have concluded through research and statistics that the maximum lateral deformation of general sheet pile support systems in soft soil areas is about 0.01H [7], and the foundation pits using bored cast-in-situ piles or underground continuous walls are generally less than 0.01H, which basically falls between 0.20% H and 0.90% H [8]. Therefore, the rotary excavation cast-in-place pile can basically meet the requirements of lateral deformation in the foundation pit support technology, which indicates that the foundation pit support technology scheme of this project is reliable and the excavation scheme is reasonable. The environment around the pit is better, which basically meets the requirements for deformation control of the foundation pit.

5. Analysis of vertical settlement around the foundation pit

The observation map of surrounding ground settlement after excavation is shown in Figure 5. From the settlement map, it can be seen that the surface settlement around the foundation pit is relatively small. Three different algorithms, limit equilibrium method, elastic resistance method, and numerical method, are used to calculate the settlement of the surrounding surface, and the average maximum settlement of the surrounding surface is obtained. The amount is only 27mm, which can prove that the support form and construction scheme used in the foundation pit project of this project are more reasonable. According to the parabolic method, the maximum settlement of the foundation pit appears at a location about 15 m from the edge of the foundation pit, which indicates that the wall of the foundation pit is not the location of the largest settlement, and the location between the location of the largest settlement and the distance from the edge of the foundation pit There is a certain relationship.
Figure 5. The surface subsidence curve

6. Conclusion

In this paper, taking the support of the community's foundation pit as an example, the rationality calculation software is used to analyze the deformation of the pile structure of the retaining structure and the characteristics of the ground settlement around the foundation pit during the different construction stages of the foundation pit. The main conclusions are as follows:

(1) The horizontal displacement of the support and support in the rotary excavation cast-in-place pile during the excavation of the foundation pit is arched. The maximum horizontal displacement is near the bottom of the pit. As the excavation depth increases, the maximum lateral horizontal displacement of the pile body also changes Increase

(2) The ground settlement outside the foundation pit caused by the excavation of the foundation pit under the support of the rotary excavated cast-in-situ pile has a certain relationship with the distance from the pit edge, which basically increases first and then decreases. A parabolic relationship;

(3) The internal support and support method of the rotary excavated cast-in-situ pile used in this project, the lateral deformation of the pile body complies with the local code of Fuzhou, and is less than the minimum limit of the underground continuous wall support method; It is 0.1% H-0.3% H, which is far less than the statistical results of surface subsidence under the same geological conditions.

Therefore, the support and support system in the rotary excavation cast-in-situ pile can effectively control the displacement of the foundation pit and the surrounding settlement, and the support effect is safe and stable, which meets the requirements of relevant technical specifications and is an effective and safe form of support.

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