Research on the Construction Technology for the Reconstruction of Existing Retaining Piles under the Condition of the New and Old Foundation Pits in Close Proximity

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Abstract. In view of the development of the city and the development and utilization of underground space, the new building foundation pit is close to the existing foundation pit. In view of this problem, a common reconstruction technology of existing retaining piles under the condition that the new and old foundation pits are adjacent to each other is proposed. The main construction process includes: primary selection of common pile section, design change, bored pile inspection, construction of steel pipe pile with pilot hole, depth judgment of new and old foundation pit, construction of locking anchor rod, foundation pit construction, monitoring and acceptance, etc. The reconstruction and reuse technology of the existing foundation pit supporting pile has been applied in a foundation pit in Zhuhai, which proves that it is safe and reliable, saves the construction period, reduces the construction difficulty, and improves the construction efficiency, which can provide reference for similar projects.

1. Introduction
With the development of the city and the development and utilization of underground space, the number, depth and scale of urban foundation pit are gradually increasing. Improving the utilization rate of urban underground space has become a development trend.

In the actual construction engineering, along with the excavation and enclosure of foundation pit, the foundation pit will deform, and then the soil will produce corresponding displacement. If more than one adjacent foundation pit works at the same time, it is not only necessary to ensure the construction safety of the new foundation pit, but also to consider the structural interaction between the new foundation pit and the buildings that have been put into use. The mutual settlement difference should be controlled within the standard range, and the relevant deformation should be monitored continuously in the actual construction process [1]. The excavation of a single foundation pit will cause the external surface settlement of the foundation pit and the lateral displacement of the ground wall. Under the excavation of two adjacent foundation pits, the surrounding soil environment may be affected by the excavation of two foundation pits at the same time, and the interaction between the two foundation pits will also produce more complex stress and deformation [2]. Zhang Aiying [3] pointed out that the impact of groundwater level changes on the surrounding environment is related to the physical and mechanical properties of foundation soil and the duration of precipitation. Nicholson [4] studied the influence of many factors on the deformation, such as the depth of retaining wall, the stiffness of retaining structure, the strength of soil and so on. He thought that the depth of retaining...
wall and the relative stiffness of retaining structure have great influence, and the improvement of both can reduce the overall deformation of foundation pit. Masuda [5] analyzed and studied the deformation monitoring data of foundation pit supported by multiple diaphragm walls and considered that the horizontal displacement of diaphragm wall is related to the soil properties, whether the soil is reinforced or not, and the construction scheme. The reinforcement of soil can reduce the relative deformation of the foundation pit and improve the stability. Long m [6] study shows that the main factors affecting the settlement and deformation of retaining wall and soil outside the pit are excavation depth of foundation pit, structural form of support and longitudinal spacing between supports. Wang Xianxing and other researchers [7-9] analyzed the influence of adjacent foundation pit excavation on the mechanical deformation of retaining structure. Xue Ao and other researchers [10-12] analyzed the influence of the distance between foundation pits on the deformation of adjacent foundation pits.

Aiming at the problem that a new foundation pit is adjacent to the existing one in Zhuhai, this paper studies the common construction technology of the existing retaining pile reconstruction under the condition of the new and old foundation pit adjacent.

2. Project Overview and Construction Plan Design

2.1. Project Overview and Construction Plan Design
The YK2 + 363 ~ YK2 + 580 section of the tunnel is parallel with the existing underpass tunnel and intercity railway tunnel with small clear distance, as shown in figure 1. The intercity railway company and the consulting company found that the retaining pile of the project is too close to the existing tunnel, and the pile position of the retaining pile of the existing underpass tunnel is deviated. The construction of the retaining pile of the project will have adverse impact on the existing tunnel.

![Figure 1. Sectional view of the relative position of the foundation pit.](image)

According to the geological age, genetic type, lithologic characteristics, weathering degree and other engineering characteristics and regional stratigraphic data, the rock and soil layers in the site are divided into artificial factor fill, with thickness of 1.50~8.60 m; silt caused by land sea interaction, with a thickness of 4.65 m; coarse sand, with a thickness of 4.75 m; muddy soil, with a thickness of 7.88 m and silty clay, with a thickness of 4.91 m; sandy cohesive soil, with a thickness of 4.78 m; The thickness of completely weathered granite is 3.77 M; the thickness of strongly weathered granite is 2.64 M; the thickness of moderately weathered granite is unknown.

2.2. Construction Plan Design
The foundation pit depth of YK2 + 363 ~ YK2 + 516 section is 9.5~10.5 m, and the foundation pit retaining wall is made of 0 1200@1500 The existing retaining piles are shared by the north side of the foundation pit of YK2 + 363 ~ YK2 + 391.4 and YK2 + 424.5 ~ YK2 + 516.5. The main structure of the existing tunnel has been completed and backfilled. Since the retaining pile has been used for two
years, the actual pile length and pile integrity are not clear. Before the excavation of the foundation pit, the actual length of the existing pile and the integrity of the pile body are detected.

According to the detection results, there are a total of 20 piles for YK2 + 363 ~ YK2 + 391.4 on site, which are reinforced with 4 Ø108X6 steel pipes, as shown in figure 2. The side walls of the steel pipes need to be opened, and the steel pipes are grouted. 2m control means that the steel pipe is 16 m long. YK2 + 424.5 ~ YK2 + 516.5 are reinforced with 4 Ø108X6 steel pipes. The side walls of the steel pipes need to be opened, and the steel pipes need to be grouted, and the soil at the bottom of the existing piles should be reinforced. 2 m control, ie YK2 + 424.5 ~ YK2 + 488.5 total 39 existing piles, steel pipe length 11 m, YK2 + 488.5 ~ YK2 + 516.5 total 21 existing piles, steel pipe length 11 m.

Figure 2. Detailed drawing of steel pipe layout.

3. Construction Technology

3.1. The Site Construction

For the section adjacent to the new foundation pit and the existing foundation pit, the design is carried out according to the pile position, pile diameter, pile spacing and other parameters of the retaining pile of the existing foundation pit. The pile length is not enough to be shared after the reconstruction is checked out through the pile drilling detection, as shown in figure 3. The steel pipe pile of the pile construction approach hole that needs to be reconstructed is reinforced to ensure that the existing retaining pile in the common pile section meets the construction requirements of the new foundation pit under the condition that the new and old foundation pits are adjacent to each other. The reconstruction of existing retaining piles is shared, the site construction effect is shown in figure 4. The specific implementation steps are as follows:

Figure 3. Drilling and coring process.
Figure 4. Completion of steel pipe pile pouring.

(1) Level the site; set out the side line of foundation pit and determine the pile position according to the design requirements; excavate the slurry pit for drainage preparation when the underground is clear of obstacles; install the drilling rig to carry out the hole forming operation; after the construction is completed, the mud and core column shall be stacked together, and the earthwork shall be transported outside the construction area simultaneously.

(2) Fabrication and welding of steel pipe: blanking shall be carried out according to the depth required by the construction scheme. Single side welding of V-shaped groove with inner lining ring shall be adopted for pile joint welding of steel pipe, and multi-layer welding shall be adopted. The perpendicularity of steel pipe shall be checked, and the welding quality grade shall not be lower than grade II. Within the 3-5 M range of the lower part of the steel pipe, grout holes are arranged every 30cm plum blossom type, with a diameter of 8mm. Before grouting, the hole is sealed with transparent tape.

(3) Surveying and setting out: Surveying and setting out shall be carried out according to the spacing and row spacing required by the design and the elevation provided by the design.

(4) Hole spacing positioning: according to the designed hole diameter, spacing and row spacing, the electrode is driven into the ground for positioning.

(5) Drilling in place: place the drilling machine at the designated position, place it horizontally, prevent inclination, and drill to the designed effective depth.

(6) Grouting machine installation: the grouting machine is fixed at the designated position on site, and the power supply is connected by the specified distribution box, and the mixed cement slurry is put into the ash tank, and then the grouting machine is used for grouting.

(7) Install and lower the steel pipe: after the hole is lifted, install the pre fabricated steel pipe in the hole in time, and the steel pipe is exposed to the ground by 300 mm. Easy access to the grouting pipe. The detail drawing of grouting pipe is as follows.

(8) Installation of grouting pipe: after the fine stone filling is completed, grouting shall be carried out in time. The grouting pipe is connected by the grouting machine and goes down to the bottom of the grouting hole.

(9) Mixing cement slurry: the cement slurry is mixed with special machinery, the water cement ratio is controlled between 0.6 and 1.0, the cement is P.O42.5, and the cement consumption per meter is not less than 40kg. The mixed cement slurry is put into the grouting ash tank.
(10) Grouting slurry: the grouting pipe shall be equipped with a pressure gauge with the grouting pressure of 0.5~1.0 MPa. After grouting, the pipe shall not be pulled out until the cement slurry flows out of the pipe. The grouting pipe shall be pulled out, the end of the steel pipe shall be sealed, and pressurized for several minutes until the cement slurry flows out of the steel pipe again.

(11) After the grouting of each pile is finished, the grouting pipe should keep the pressure for 3 minutes, and then pull out the grouting pipe after the pressure dissipates. This is not only beneficial to the grouting effect and ensuring the quality of the pile body, but also avoiding the safety accident caused by too high pressure.

(12) The deviation of pile position shall not be greater than 50 mm, and the verticality shall not exceed 1%.

| Depth | This change (mm) | Initial observation | Accumulated value of last observation (mm) | Accumulated value of this observation (mm) | Deformation rate(mm/d) |
|-------|-----------------|---------------------|-------------------------------------------|------------------------------------------|-----------------------|
| -0.5  | 0.2             | 0                   | 11.3                                      | 11.5                                     | 0.2                   |
| -1    | 0.3             | 0                   | 11.5                                      | 11.8                                     | 0.3                   |
| -1.5  | 0.2             | 0                   | 11.1                                      | 11.3                                     | 0.2                   |
| -2    | 0.2             | 0                   | 11.1                                      | 11.3                                     | 0.2                   |
| -2.5  | -0.2            | 0                   | 11.8                                      | 11.6                                     | -0.2                  |
| -3    | 0.3             | 0                   | 10.6                                      | 10.9                                     | 0.3                   |
| -3.5  | -0.2            | 0                   | 11.3                                      | 11.1                                     | -0.2                  |
| -4    | 0               | 0                   | 10.8                                      | 10.8                                     | 0                    |
| -4.5  | -0.3            | 0                   | 10.9                                      | 10.6                                     | -0.3                  |
| -5    | -0.2            | 0                   | 10.9                                      | 10.7                                     | -0.2                  |
| -5.5  | -0.3            | 0                   | 10.9                                      | 10.6                                     | -0.3                  |
| -6    | -0.2            | 0                   | 10.8                                      | 10.6                                     | -0.2                  |
| -6.5  | -0.3            | 0                   | 10.7                                      | 10.4                                     | -0.3                  |
| -7    | -0.1            | 0                   | 10                                        | 9.9                                      | -0.1                  |
| -7.5  | 0               | 0                   | 8.7                                       | 8.7                                      | 0                    |
| -8    | -0.2            | 0                   | 7.5                                       | 7.3                                      | -0.2                  |
| -8.5  | -0.3            | 0                   | 7.9                                       | 7.6                                      | -0.3                  |
| -9    | -0.2            | 0                   | 8.1                                       | 7.9                                      | -0.2                  |
| -9.5  | -0.3            | 0                   | 6.8                                       | 6.5                                      | -0.3                  |
| -10   | -0.1            | 0                   | 6.5                                       | 6.4                                      | -0.1                  |
| -10.5 | 0.3             | 0                   | 5.1                                       | 5.4                                      | 0.3                   |
| -11   | 0.2             | 0                   | 5.4                                       | 5.6                                      | 0.2                   |
| -11.5 | -0.1            | 0                   | 4.6                                       | 4.5                                      | -0.1                  |
| -12   | -0.2            | 0                   | 4.1                                       | 3.9                                      | -0.2                  |
| -12.5 | 0.3             | 0                   | 3.5                                       | 3.8                                      | 0.3                   |
| -13   | 0.3             | 0                   | 2.1                                       | 2.4                                      | 0.3                   |
| -13.5 | 0               | 0                   | 1.4                                       | 1.4                                      | 0                    |
| -14   | 0.2             | 0                   | 1.3                                       | 1.5                                      | 0.2                   |

3.2. Deformation of Foundation Pit
During the construction process, the retaining pile structure of YK2 + 424.5 ~ YK2 + 516.5 section is monitored. The deformation and displacement of retaining structures on both sides near YK2 + 470 are shown in figures 5-6 and tables 1-2:
Figure 5. Horizontal displacement of deep layer far away from existing tunnel.

Table 2. Horizontal displacement of deep layer adjacent to existing tunnel.

| Depth (m) | This change (mm) | Initial observation August 26, 2019 | Accumulated value of last observation (mm) | Accumulated value of this observation (mm) | Deformation rate (mm/d) |
|-----------|------------------|------------------------------------|---------------------------------------------|---------------------------------------------|------------------------|
| -0.5      | -0.2             | 0                                  | -5.7                                        | -5.9                                        | -0.2                   |
| -1        | 0                | 0                                  | -4.8                                        | -4.8                                        | 0                      |
| -1.5      | 0.2              | 0                                  | -4.1                                        | -3.9                                        | 0.2                    |
| -2        | 0.3              | 0                                  | -3.9                                        | -3.6                                        | 0.3                    |
| -2.5      | -0.3             | 0                                  | -3                                          | -3.3                                        | -0.3                   |
| -3        | 0                | 0                                  | -3                                          | -3                                          | 0                      |
| -3.5      | -0.3             | 0                                  | -2.7                                        | -3                                          | -0.3                   |
| -4        | -0.2             | 0                                  | -2.1                                        | -2.3                                        | -0.2                   |
| -4.5      | -0.1             | 0                                  | -1.9                                        | -2                                          | -0.1                   |
| -5        | 0.1              | 0                                  | -1.9                                        | -1.8                                        | 0.1                    |
| -5.5      | 0.1              | 0                                  | -1.6                                        | -0.6                                        | 0.1                    |
| -6        | 0.1              | 0                                  | -1.9                                        | -0.9                                        | 0.1                    |
| -6.5      | 0.3              | 0                                  | -0.9                                        | -0.6                                        | 0.3                    |
| -7        | -0.2             | 0                                  | -0.7                                        | -0.9                                        | -0.2                   |
| -7.5      | 0.3              | 0                                  | -0.5                                        | -0.2                                        | 0.3                    |
| -8        | -0.1             | 0                                  | -0.4                                        | -0.5                                        | -0.1                   |
| -8.5      | 0.1              | 0                                  | -0.1                                        | 0                                            | 0.1                    |
| -9        | -0.3             | 0                                  | -0.1                                        | -0.4                                        | -0.3                   |
Figure 6. Horizontal displacement of deep layer adjacent to existing tunnel.

The monitoring results show that when the foundation pit is excavated to the specified elevation, the maximum deformation at the most unfavorable position far away from the existing tunnel is 11.8 mm, while the maximum deformation near the most unfavorable position of the existing tunnel is 5.9 mm, which is less than the required value of the specification. Meanwhile, the maximum deformation rate is 0.3 mm/d, which is also less than the specification value.

4. Conclusion
In this paper, the reuse technology of the existing foundation pit retaining pile transformation is safe and reliable by a foundation pit project in Zhuhai, which saves the construction period, reduces the construction difficulty, improves the construction efficiency, ensures the safety of the existing foundation pit, and reduces the impact on the existing underground structure.

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