Research on post treatment of lock pipe fracture in diaphragm wall construction

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Abstract: Lock pipe is often used as connection joint in the construction of diaphragm wall. After pouring concrete, it often fails because of poor control of drawing time. In this paper, combined with an engineering example, the post-treatment of drawing fracture is described in detail. During the construction, it is necessary to chisel out the locking pipe on one side of the foundation pit and the nearby concrete, then cut off part of the locking pipe, make reinforcement cage in the excavation groove, weld with the original connecting wall reinforcement, and pour concrete to cover it. The possibility of rust and expansion of residual locking pipe was analyzed, and the treatment method was verified to be effective by the use of several years later.

1. Introduction

Shenzhen AVIC Plaza is located in Futian District, Shenzhen, with a total project cost of 37.9 million. The second phase is located in the south of the site near Shennan middle road and adjacent to the protection area of the underground railway, including the remaining commercial podium and basement with four floors. The construction environment is complex and the construction is difficult. Through the design, 800mm diaphragm wall is used as the foundation pit support. In the construction of diaphragm wall [1], the connection mode of locking pipe is often used. In the construction, the sinking pipe is fixed first, then the concrete is poured, and the locking pipe is used as the connection joint, which is pulled out before the final setting of concrete. When to start drawing is important. If the concrete is pulled early, the concrete will flow in the groove section and cannot be fixed and formed. If it is pulled out late, the locking pipe will not be pulled out. In the soft soil area, it is also easy to appear the failure phenomenon of locking pipe jacking [2]. If the pull-out fails, because the lock pipe is close to the groove wall, the concrete protective layer on both sides is very thin, and it is easy to rust and corrode when it is immersed in groundwater for a long time. According to the existing research data, the volume of steel bar will expand after corrosion, and the volume of rust is 2-4 times the corresponding reinforcement volume, and the compressive stress will be generated at the contact position between the concrete and the reinforcement. The concrete will crack when the main tensile stress is too large. The locking pipe is hollow steel pipe, even if the pipe is filled with concrete, it can not completely avoid groundwater seepage. If it is in the silt rich stratum, the seepage is more serious [3]. The connection between the two sides of the groove section of the lock pipe is weak, and it is prone to lateral deformation under the action of earth pressure, especially when there is no beam or floor top tight. Therefore, special treatment construction must be carried out. This happened during the construction of 9# slot section in AVIC phase II diaphragm wall project on January 25, 2010 (the locking pipe is between the 9# slot section and 8 # slot section, while the 8# groove section has not
been constructed at this time, and the diaphragm wall of this section is 35.5 m from the ground. After pouring the concrete, because the time of drawing the lock pipe is late, the lock pipe breaks during the drawing process, only 4.5 meters are pulled out, and the remaining 31 meters are still left in the groove section. The following is an example to illustrate the treatment measures.

2. Treatment method

(1) During the construction of the 8# slot section, the locking pipe is left between the 8 #~9 #groove section. Change the form of sealing bar at the joint of 8# reinforcement cage and 9# reinforcement cage from convex to concave, and modify and refine the 8# reinforcement cage. During the construction of 8# groove section, because the surface of locking pipe close to 8# groove section is round, it is difficult to completely excavate the soil at the two corners close to the side. Impact hammer and square hammer shall be used to impact and wash the lock pipe as far as possible. The earth and rock that can not be removed shall be removed manually after the lock pipe is taken.

In order to prevent the lock pipe on the upstream face from swelling and squeezing concrete due to long-term damp and rust, after the diaphragm wall is made in the 8# groove section, two rows of 600mm diameter waterproof mixing piles (9 branches in each row) are constructed on the upstream surface. The detailed distance of the mixing piles is shown in Figure 1. The pile length is 35.5m and the pile bottom elevation is - 24.0m. In order to monitor and prove the water stop effect, the gap water pressure measuring pipe and water vertical pipe are added near the 8# and 9# groove, as shown in Fig. 3. In the precipitation test, if the water stop effect is not good, it is necessary to increase the mixing water stop pile for reinforcement. In order to avoid water leakage in the process of excavation.

(2) During the reverse construction, the 2200mm wide concrete between the 8# and 9#, with a thickness of 520mm, is chiseled out. The construction is carried out in sections along the depth direction of the wall body. In order to avoid accidents, the section distance should not be too large. 1320 mm is used as a section in this project. At the same time, cut off the locking steel pipe on one side of the excavation face, as shown in Fig. 3. Then, the residual earth and rock at the position near the lock pipe in the 8 #~9 #groove section shall be removed. If the concrete is not up to the standard, it shall be removed to the complete concrete surface. At the same time, the modified waterproof asphalt shall be applied on the internal and external surface of the locking pipe, and the concrete shall be backfilled to ensure the quality and waterproof. Since the excavation face is used as support in the subsequent operation, the whole locking pipe can be backfilled with concrete.

![Fig. 1 Schematic diagram of water stop mixing pile and groove section](image-url)
If it is found that the concrete quality of this part does not meet the requirements, it shall be removed to the complete concrete surface.

(3) Lap the horizontal reinforcement at the cut-out part, as shown in Fig. 2. Weld the #20 reinforcement with the horizontal reinforcement of the reinforcement cage, and the lap length is 700mm. Within the range of 2200mm between the 8# and 9# grooves (700mm on both sides of the locking pipe), the original vertical reinforcement is cut at every interval, and the horizontal reinforcement is not cut. Smash the concrete within 2400 × 520mm. As shown in Fig. 3, the reinforcement cage is made in the original diaphragm wall with the length of 1320 mm, and the horizontal reinforcement and vertical reinforcement are welded and fixed. Lay wooden board on the horizontal bar 320mm away from the bottom of each process, lay thick paper in the gap between vertical bars to avoid mortar leakage during concrete pouring. It is better to use cushion block between the formwork and the supporting reinforcement to facilitate the removal of the formwork in the future. Finally, pouring concrete, pay attention to filling the gap. The design strength of concrete is C30, and the prepared strength is C35. Repeat the above process until the floor.

(4) Resistance calculation
Earth pressure value:
Take the diaphragm wall of four floors underground for calculation. Due to the action of three and four underground slabs, only the bending calculation of one floor diaphragm wall is considered here. The supporting section of diaphragm wall is shown in Fig. 5.
Paragraph n

Locking pile
Welding

Paragraph n+1

Board placed on horizontal bars
Reserve space for welding reinforcement in the next process. The lap length of reinforcement is 320mm.

The board plan is placed on the horizontal bar and lock pipe, and the gap between the vertical bars is paved with thick paper to prevent the concrete from falling.

Fig. 4 Schematic diagram of reinforcement welding

Fig. 5 cross section of diaphragm wall support

(a) calculate \( E_{a1} \): coefficient of active earth pressure \( K_s = 0.0998, \)
\[
E_{a1} = 1.2 \times \frac{1}{2} \times \gamma \times h^2 \times k_a = 11.24kN
\]

(b) calculate \( E_{a2} : E_{a2} = 18.65kN \), Then the maximum bending moment of diaphragm wall is:
\[
M = \frac{ql^2}{10} = \frac{14.95 \times 3.95^2}{10} = 23.33kN \cdot m
\]

The reinforcement is:
\[
x = \frac{f_y A_y - f_y' A_y'}{a_1 f_y b} = \frac{1627776}{14300} = 113.8mm
\]
\[
\alpha = \frac{f_y b h \cdot \frac{x}{2} + f_y' A_y (h - a')}{1739.36 kN \cdot m}
\]

Meet resistance requirements.

(4) When excavating to the fourth underground floor (the lowest ground), the mud in the remaining lock mouth pipe shall be removed and the concrete shall be injected.

3. Treatment effect analysis

In order to avoid rust, expansion and water seepage of the locking pipe in the later stage, the treatment method mainly adopts the following three procedures to guarantee:

(1) Two rows of waterproof mixing piles. Strengthen the monitoring, if the water stop effect is not good, add a row. Deep mixing is sufficient and grouting is even. The later use process should also be regularly monitored and strengthened measures should be taken at any time.

(2) Apply modified waterproof asphalt on the surface of locking pipe. Prevent water from seeping into the foundation pit. There is a 70mm concrete cover between waterproof asphalt and reinforcement.

(3) The reinforcement cage made in the excavation groove is welded firmly with the original reinforcement, and the concrete is poured to limit the crack expansion. According to the research of Li Yue[5] and Mou Yanjun[6], the maximum principal tensile stress of concrete is unevenly distributed due to the effect of reinforcement corrosion expansion force, and the maximum principal tensile stress of concrete at the interface between reinforcement and concrete is relatively large. On the outside of diaphragm wall (i.e. the side with groundwater), the maximum principal tensile stress of concrete first
decreases and then increases with the increase of path mapping distance. When the path mapping distance is about 13mm, the maximum principal tensile stress of concrete reaches the minimum value. It is obviously lower than the stress at the outermost of the protective layer. Therefore, with the increase of corrosion, the concrete outside the lock pipe is likely to crack. On the inner side of diaphragm wall, the main tensile stress of concrete also appears at the contact position between reinforcement and concrete, but with the increase of path mapping distance, the maximum principal tensile stress decreases, and finally almost zero. Therefore, strengthening the strength inside the diaphragm wall can limit the expansion of expansion cracks. Even if the locking pipe is seriously rusted, the inner concrete will not crack due to rust expansion.

The common building reinforcement rust is generally due to the carbonization of the protective layer. The steel bar rusts in the weak acid environment, resulting in rust expansion and cracking. This process generally takes several years to show. In the diaphragm wall, because it is under the groundwater level for a long time, if there is seepage water, the steel bar will rust much faster. Since the completion of AVIC phase II excavation project at the end of 2011, no water leakage and wall cracks have been found after long-term follow-up observation, which shows that the treatment scheme is feasible.

4. Conclusion
Because of the large buried depth of diaphragm wall, the pulling of locking pipe is one of the key steps. Attention should be paid to the drawing time during construction to reduce the drawing accidents. Once there is a problem in drawing, the locking pipe is left in the wall, and only later remedial measures can be taken. This method can not only ensure the wall supporting function, but also effectively prevent the wall cracking and water seepage caused by the rust expansion of the locking pipe.

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