Application of Bored Pile Anchor Cable Technology in Foundation Pit Construction

Zhengwei Feng 1, Peicheng Guo 1*

1Department of Engineering Management, Xiamen University Tan Kah Kee College, Zhangzhou, Fujian Province, 363105, China

*Corresponding author’s e-mail: guopeich@xujc.edu.cn

Abstract. With rapid development of the city, demands for civil air defense, underground commercial and underground parking in human society have increased. Development of the construction space towards the underground is enhanced, and foundation pit excavation is widely used. Bore pile + anchor cable supporting model has been used more and more in deep foundation pit supporting. Based on engineering examples, this essay expounds the construction scheme of deep foundation pit support for a residential area project, introduces the construction technology of bore pile, crown beam and waist beam, and analyzes in detail the construction technology of the installation, grouting and tension anchoring of anchor cable in prestressed anchor cable construction. The quality control points in the construction are discussed and summarized in depth, which could provide powerful reference for the implementation of civil engineering construction tasks and ensure smooth progress of the project to achieve the expected results.

1. Project profile
This project is located in Longyan Road, the arterial road of Longyan city. The residential community consists of four buildings, 7#, 8#, 9# and 10#, with two storeys underground and 26 storeys above the ground. The heights of the buildings are respectively: 79.8m for 7# and 8#, 78.3m for 9# and 10#. The overall floor space is 1914.7 ㎡, the above ground floor area is 40374.7 ㎡, the underground floor area is 12619.9 ㎡ and the gross building area is 52994.6 ㎡. The cellular structure is frame-shear wall structure and the structure of the upper part adopts shear wall structure. It is class A high-rise building.

The basement is parking lot and could be used as civil air defence basement. ±0.000 is Yellow Sea elevation of 336.30m. Punch filling pile is adopted as the foundation. Since the depth of the foundation pit bottom bedding is 9.40m, it could be considered as deep foundation pit. The field was originally lotus field and fish pond. Now it has been refilled and leveled as required by the construction. The ground elevation is -0.5m.

2. Foundation pit construction scheme
The current ground level surrounding the foundation pit is about -0.5m, the bottom elevation of the foundation pit floor is -9.90m and the earth excavation depth is 9.4m. The security level of the foundation pit side wall is grade 2 and the importance factor of the side wall is 1.0. Site surrounding condition: The basement edge at the east side is 9m from the red line of land acquisition; 405m outside the red line are built residential communities; the north side is 14m from the red line of land acquisition.
The underground water is divided into two layers, respectively upper pore phreatic water and lower limestone karst water. The former is reserved in plain fill, round-stone (argillaceous and chiltern fill), argillaceous gravelly sand and pebbly silty clay, all of which belongs to aquitard with poor watery. Generally, the clearing within in the red line at the west and north sides is open, while that in the east and north is relatively narrower.

Figure 1. Diagrammatic cross-section of the bored pile and anchor cable support

Considering comprehensively the composite factors mentioned above, natural slope could not be achieved surrounding the foundation pit, so this foundation pit supporting scheme sets the slope at the ratio of 1:0.8 within the scope of 500mm at the top, while at the bottom joint support with support pile with the diameter of 1000@1600 + pre-stressed anchor cable is adopted, the profile of which as shown in Fig. 1. Soil before pile in the pit is supported by 1:0.8 slope ratio + net spraying concrete surface. At the west is the entrance of the basement and the design adopts slope + spraying concrete support, which is used as the passage to carry out the earth during the period of excavation. The support pile top is designed as closed reinforced concrete crown beam. It is required the main reinforcement of the bored pile is connected by welding with the main reinforcement of the crown beam and that the anchorage length of the pile bars into the reinforcement of the crown beam is larger than 35d (d is the diameter of the bar).

The field condition surrounding the foundation pit is complex. Power pipelines are buried under local places; in the east, the west and the south there are residential communities with numerous residents and vehicles. So, certain technical measures and safety emergency plans must be taken in
construction to guarantee civilization construction and smooth progress of the project. The construction is right in the rainy season and appropriate drainage measures should be taken for the foundation pit; meanwhile, supervision of the foundation pit should be strengthened and timely alarm should be guaranteed to make sure safe construction of the foundation pit [1].

3. Construction technique of bored pile and anchor cable

3.1. Construction of bored pile

Concrete bored pile is adopted, with the diameter of 1,000mm, the spacing of @1600mm, (elevation of the pile top is -1.70m). There are three types of pile lengths: 17.3m, 16.7m and 15.7m respectively. Number of the piles N°=212. Strength grade of the concrete for the pile is C30. The longitudinal main reinforcements of the reinforcement are respectively 20C20, 23C20. The strengthened stirrup is C16@2000, the spiral stirrup is Φ10@120 and the single-pile vertical endurance value feature is 6000kN. The design adopts post-grouting technology to cast the steel pipe after setting 3 Φ25 in symmetry along the circumference of the reinforcement cage.

Pore-creating is the focus of the pile construction. Hoist with cross impact hammer is used to punch the pore, during which the wall is protected with mud. Considering the geological condition of the project sandy gravel strata has good water permeability, sealing of the holes with rubble and clay should be down well to guarantee slurry in the holes is 1.0~1.5m higher than the stage of river or the groundwater level. Moreover, slag specimen should be taken at the place where the soil changes to identify the soil layer is corresponding to the map of geological cross section[2].

3.2. Construction of pre-stressed anchor cable

Soil layer aperture in pre-stressed anchor cable is 180mm. During the construction, the pores are filled with high pressure cement slurry and the material for anchor cable rod adopts steel strand. The elevation of pre-stressed anchor cable is at 3.0 meters and 6.0 meters underground (i.e., at the breast beam). One pile one anchor is adopted, with the interval of 1,600mm, altogether 412. Inclination of the anchor cable is 30°. The anchor tie rod adopts 3 bunches ofφS15.2 steel strand, with the length varying between 19~22.5m. The anchor head of the anchor cable is anchored to the breast beam, with the tensioning force of 100kN. The pre-stressed anchor cable is of 3 bunches, each of which is Φ15.2mm steel strand. The anchor cable is connected to the breast beam with over 1m allowance to guarantee late tension. Guiding cone is welded at the ends. Pre-stressed anchor cable is divided into anchoring part and free part in the soil layer. Rust-proof treatment is done to the anchoring part and a centering bracket is installed every 1.5m. The free part is protected with polyethylene plastic pipe and within the pipe antiseptic grease is filled (especially for unbonded pre-stressed tendon). At last, numbers are sprayed on the pre-stressed anchor cable according to the hole number.

3.2.1. Anchor cable installation and grouting. Before the anchor cable is installed, it is necessary to check whether it is blocked or buried with foreign matters. If so, measures should be taken for clearing before installation, such as blowing with air compressor.

The anchor cable and grouting pipe could be installed at the same time. The anchor cable uses Φ15.2mm steel strand and the grouting pipe uses Φ20mm plastic pipe. It is advisable to insert the grouting pipe at a position 5 cm away from the bottom of the hole, and bottom-regrouting method is adopted for slip casting. The pushing process of the anchor cable should be slow with uniform strength; in case obstacles are encountered, the causes should be analyzed by checking the conditions of the
protection layer and the grouting pipe of the anchor cable. If it is found the fittings of the anchor cable fall out or stuck with too much mud, it is necessary to fix the fittings and clear the holes if necessary. It is forbidden to rotate arbitrarily the anchor cable. Moreover, the grouting pipe should be checked continuously to guarantee the grouting pipe is smooth [3].

The anchor eye is filled with M25 cement mortar, with the water-cement ratio of 0.40-0.50. The water-cement ratio can be adjusted on the site according to the hydrophilicity of the stratum. Appropriate amount of early strength agent can be mixed, with the dosage of 2% of the cement. The grouting pressure should be no less than 5Mpa, and the cement is P.O42.5 ordinary Portland cement.

3.2.2. Tension locking of anchor cable. The objective of anchor cable tensioning is to hoist the anchor cable with tensioning equipment, making the free part of the anchor rod have elastic deformation to exert required pre-stress value to the anchoring structure[4].

The tensioning should be conducted till the concrete strength of the anchorage section, the pressure-bearing platform (or beam) reaches 3/4 of the consolidating strength of the cement paste. Meanwhile, the surface of the pressure-bearing supporting member should be leveled and the platform seat and the anchorage devices are installed well to guarantee they are vertical to the axis direction of the anchor cable. The tensioning process is carried out according to the corresponding procedure, for example, the design tensioning speed is 40kN/min. The anchor cable tensioning is divided into secondary pre-tensioning and formal tensioning. Pre-tensioning is to pre-stretch the single steel strand of each bunch of anchor cable with jack before the anchor cable is officially tensioned with 10%~20% of the designed pull-out resistance, the aim of which is to make the steel strands straight and contacting with one another closely[5].

The formal tension load should be applied step by step and shouldn't be added to the locked load at one time. Pre-stress should be applied in five-grade loading method (It is required no less than 4 grades.) and the load-keeping time after each grade of load should be more than 5min. When the tensioning reaches the last grade of load, it should be 1.3 times of the standard axial tensile force and the load should be kept steadily over 10min. Then, it is locked according to the designed locking force till it is stable.

The axis of the anchor cable should be consistent with the direction of the tension, that is, it is consistent with the axial direction of the jack, to ensure that the tension is not lost. There shall be no mud and other pollutants on the tensioning device such as anchor ring, anchor body and clips. Before final locking, it is necessary to observe whether the pre-stress of the anchor cable is attenuated and then lock it. 2 days after the tension is locked, observe loss of the pre-stress. When the loss value is more than 10% of the design value, the tensile force must be compensated, and the remaining anchor cable should be cut off for final locked[6].

3.3. Construction of crown beam and breast beam

The crown beam is located at the top of the support pile, bearing mainly the vertical shear force and certain horizontal force. To connect the pile foundations together and limit the horizontal displacement of each pile top is the key to ensure the support piles can form an entire shared load. Dimension of the cross-section is 1200×800, the main reinforcement is C20 rebar and the stirrup is Φ8@130; there is one outer hoop, one inner hoop and three single limb hoop (drage hook)[7].

The breast beam is to pad the anchor plate and nut at the end of the inclined anchor. The section has only one trapezoidal hoop, the section is 450×450, the main reinforcement is C20 steel bar, and the stirrup is Φ8@200.

4. Quality control points

The quality control points should be formatted as follows:

- When the anchor cable is drilled, dry drill instead of water drill should be used to avoid the water deteriorate the side slope rock, so as to ensure the bonding performance of the hole wall when
constructing the anchor cable; when installing the anchor cable, it is forbidden to pull repeatedly the anchor cable. Make sure that all of the anchoring agent is delivered to the bottom of the hole.

- When the upper soil layer is a thick silty clay stratum and the lower part has rocks, the inclination angle of the anchor cable can be increased appropriately during the installation. Extending the anchoring end into the lower rock stratum could improve the reliability of the anchor cable effectively.
- The 3-5m from the anchoring end, an enlarged head is formed at the anchoring end by increasing the spray pressure or increasing the number of sprays, with the aim to reduce plastic deformation of the anchor cable and to improve the anchoring force.
- During the construction, it is necessary to monitor the axial force of the anchor cable, the displacement of the top of the exterior protected construction, and the displacement of the surrounding pipe pile, especially the maximum displacement of the anchor cable. After it is excavated to the designed depth, the anchor cable tension will increase within 3-5 days slowly and then tend to be stable.

5. Conclusion

It is a complex system engineering for deep foundation pit support engineering. With the development of construction engineering toward high and deep direction, the forms of foundation pit support are more and more. Because of the adjacent buildings around the foundation pit, the deformation of the foundation pit will have a great impact on the surrounding environment. In addition, the geological conditions in the site are complex and groundwater is abundant. The selection and construction of supporting scheme is a crucial link in order to ensure the safety of foundation pit.

This deep foundation pit project adopts the combined support of top slope and bottom supporting pile and prestressing anchor cable. This paper expounds the construction methods of cast-in-place pile, crown beam and waist beam in the process of foundation pit support, analyses in detail the construction process of prestressing anchor cable, and puts forward the corresponding quality control points, reduces the construction risk of the project and ensures the construction smoothly, it provide references for similar engineering construction.

References

[1] Feng Z.W. (2016) Discussion on the Construction scheme of shotcrete -bolt support for the slope and foundation pit. Building Technology Development. pp.23-25.
[2] Zhang Wei. (2018) Application of Prestressed Anchor Slope Support in Deep Foundation Pit Engineering. Fujian Building Materials. PP. 76-78.
[3] Cai L.M, Mo Bing, Xie Xiang, Peng G.X. (2009) Analysis of problems in deep foundation pit support of Taiguhui, Guangzhou. Sichuan Architecture. PP. 65-66.
[4] Sun Zheng, Zhu Yalin. (2017) Application of Prestressed Anchor Flexible Support in Deep Foundation Pit Engineering. Journal of Anhui Architectural University. PP. 56-58.
[5] Yang X.P. (2005) Application of Prestressed Anchor in Railway Slope Protection . Journal of Railway Engineering. PP. 91-95.
[6] Miao Z.R. (2013) Key technology for vertical construction of anchor cables in tunnels under soft rock conditions. Construction technology. PP. 76-79.
[7] Xiong Z.X, Liu H.Y, Li H.M, Tao L.J. (2015) Numerical test of working mechanism of composite soil nailing with prestressing anchor cable in Sandy and pebble stratum. Building technology. PP. 68-71.