Research on the application of Deep Foundation pit support technology in a residential area

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Abstract. With the urban development, the number of private cars has been increasing and the construction scale of the basements in the residential district is becoming larger and larger. In order to meet the requirements of the structural stability of the buildings, the requirements for the technologies of the supports for slopes and deep foundation pits are getting higher and higher in engineering. In this paper, a certain residential community project is involved. The site is adjacent to the existing municipal road to the east, the north of the site is a road which has been planned, and the west of the site is the phase II project, the topographic conditions are complex. The construction scheme of the deep foundation pit works is analyzed, and the construction technologies of the soil nailing wall support, the enclosure row pile support, the large diameter long pile and pile wall works are introduced. It puts forward the corresponding quality control points, and provides reference and information for the treatment of foundation pit support under similar environmental conditions.

1. General situation of the project

1.1 The project information
The project is located in Xinluo District of Longyan City, Lianzhuang Road is in the east, one planning road is in the north and the phase II project is in the west. It consists of 3 buildings i.e. Building #17, Building #18 and Building #12#. Each of these buildings has two underground floors. The ground floors of each of the building are 26 floors for Building #12 and 27 floors for Building #17 and Building #18. The height of each of these buildings is about 78 meters, and these buildings cover an area of 1455.73 square meters, with a total construction area of 39668.8 square meters. These buildings are all class 1 high-rise buildings, ±0.000 is the Yellow Sea elevation 343.70m. The main building adopts the raft foundation, and the pure basement part adopts the pier foundation. The structural type of the project is frame shear wall structure and the excavated earthwork depth of the foundation pits is about 5.9-7.5 meters. The foundation pits fall into the category of deep foundation pit.

1.2 The geological conditions of the project
The project site is located in the southeast of Longyan City, the geomorphology belongs to the class I accumulation terrace in rivers. The south west side is the geomorphology of the foothill slope accumulation, and the terrain is relatively flat. The site was originally a piece of root soil and asite of demolished old houses. Because of the demands for construction, it has been back filled and leveled,
with a ground elevation between -5.2 meters and 3.7 meters. For the deep foundation pit here, the soil mass of the pit wall is mainly composed of miscellaneous fill, root soil, silty clay, cobbles, silty clay, gravelly silty clay and the like. The underground water level is -4.50 meters. When the foundation pit was excavated, the measure which has been adopted was using the water collection wells for water drainage.

2. The technical scheme for construction

After considering the safety, the feasibility of the construction technology, the economic and the construction period, etc., according to the actual environment of the site, the supporting scheme for the deep foundation pit were stipulated as follows: the north side of the foundation pit was to be supported by the soil nailing wall; the west side was an open space, the conditions for grading of a slope were available, so an open slope was to be excavated and the surface of the slope was to be provided with a protective layer through spraying concrete, the row piles supports were to be adopted which was close to Lianzhuang Road.

The amount of earth excavation of this project was about 50,000 cubic meters, and the area of the foundation pit was large. The supporting structure was the rotary excavating pile and the soil nailing wall support. The conditions for excavation in parts and layers were available. It was considered to carry out the vertical soil excavation due to the enclosure pile support in east side; as to the other sides, the excavations were to be performed in layers. For the earth excavation, three backhoe excavators (1 cubic meter) were to be used; for transportation of the earthwork, 20 sets of 10t earthwork vehicles were to be adopted, which was to be subject to adjustment in real time depending on the excavation progress and the road transportation conditions.

The deep foundation pit supporting structure stage: In this project, the row pile support, the inter-pile wall support and the soil nailing wall support were adopted. The section of the crown beam was provided along the periphery of the foundation pit, and the trench was excavated to the working surface at three stages. The first stage was to construct the bored in situ piles. The construction of the crown beam was carried out after the construction of the enclosure row piles was completed. The elevation of the crown beam surface was -2.0m, the bottom elevation of the crown beam was excavated to -2.6m. The crown beam construction, pile driving head chiseling and side slope trimming shall be carried out together, and the side slope outside the foundation pit shall be sloping according to the design requirements, after completion of the crown beam, the intercepting drain was constructed and spraying of concrete was carried out. The excavation was carried out in parts and then the crown beam was constructed with the flow operation method. When the construction of the crown beam was completed, this part was excavated in layers to the bottom elevation of the foundation pit (-9.2m). A slope was set above and below the ditch. The temporary protective rails and warning signs were provided at the top of the slope. In the excavation and construction of the earthwork, attention was also paid to the protection of the supporting structure [1].

The temporary slope at the inner side of the foundation pit adopted the two-stage grading method. Since the foundation pit was a rectangle, in order to facilitate the excavation of soil reduce the effect on the soil excavation, which was caused by the slope, the soil excavation slop was arranged at the north side of the foundation pit. The ramp was of an internal ramp, with a gradient between 1:4 and 5, and a ramp width between 7 and 8 meters (taking into considering parallel driving of two vehicle).

First of all, the construction of the in situ cast concrete piles was carried out, and the earthwork excavation of Building 18# and Building 17# was carried out immediately after the construction of the in situ cast concrete piles was completed. In the process of the earthwork excavation, anchoring of the pipelines as well as the soil nailing wall support were carried out. The transportation road, which was located on the east side of the foundation pit, was excavated in layers and in the backward direction from the west side of the foundation pit to the east side. The excavation of the reserved road on the north side was carried out the latest.

The construction sequence for the foundation pit engineering was as follows: leveling of the site→survey and setting out of the control points in the construction→construction of the drainage
ditch on the top of the slope→casting of the concrete piles→excavation of earthwork→construction of the crown beam→construction of the steel pipes and the soil nailing→setting up of the meshes and spraying of concrete was carried out→excavation to the bottom of the pit→construction of the cushion layer on the pit bottom.

3. The technologies used in construction of the foundation pit support
The location of the project provided it with a complex terrain condition, the west side was an open space, so the excavation was carried out by means of an open slope, and the meshes were set up for spraying of concrete; the north side was supported by the soil nailing wall; the east side, which was close to Lianzhuang Road, was supported with the row piles and enclosure wall. In this paper, the supporting methods used for the north side and the east side were mainly studied.

3.1 The soil nailing wall support on the north side
The soil nailing wall method is a technology in which, the soil nails which are made of reinforcing steel are driven into the original soil, then the steel meshes are laid on the surface of the side slope and the concrete is sprayed, so that the soil nails, the reinforcing steel meshes and the sprayed concrete can be formed as a whole so as to maintain the stability of the side slope and ensure the stability of the slope surface after the excavation of the foundation pit[2]. The anchor rods used as the soil nailing in the project adopt HRB400C20 reinforced bars, which are set up at an interval of 1500mm, the lengths of which are 4500mm, 6000mm and 9000mm, and the diameter of the construction hole is 110mm; the arrangement of the reinforcing ribs is 4B16, the strength grade of the concrete sprayed on the surface layer is C20, the sprayed thickness is 100mm, and the 8@200x200 is made as the reinforcing mesh, and the anchoring force of the supporting anchor rod in the construction process is less than 90kN. The length of the water discharge hole is 800mm, the diameter of the pipe is 50mm, the interval is 1500mm.

The slope were drilled before the anchor rod construction was carried out. The depth of the holes was greater than the length of the soil nail reinforcement by +0.5m. Then the holes were cleaned and the anchor rods were inserted in them and then grouting was carried out. The tilting angle error of the completed hole must be within the range of ±1°, and the depth error of the hole must be within the range of ±100mm. The cement paste with the strength of M10 was used for grouting, the water to cement ratio was 0.5. The triethanolamine early strength agent of a concentration of 0.05% was added. The low-pressure grouting process with the grouting pressure of 0.5-1.0MPa was adopted. The grouting process was carried out continuously. The grouting would not be stopped until the slurry had overflowed from the hole, or the grouting pressure had reached the design requirements and had held for 3 minutes. The grouting pipe was tied to the soil nail body. A grout stopping plug, an exhaust pipe and the like were provided around the position of the hole. The distance between the grouting pipe and the hole bottom was 150mm.

3.2 The construction technology of the enclosure piles on the east side
The enclosure pile supports for the foundation pit on the east side adopted the in situ cast concrete piles, each having a diameter of 1 meter, at an interval of 2 meters. The height of pile top is 5.60 meters, the pile length is 10.1 meters, the number of piles is 35, concrete grade is C30, the main rib in the section reinforcement, which is subjected to the longitudinal force is 16C20, the arrangement of the reinforcement ribs is CC20@2000, and the arrangement of the spiral ribs is A10@120. The schematic diagram of the enclosure piles and drainage is as shown in Figure1.
3.2.1 Installation of steel guard cylinders: For the enclosure piles in the project, the holes were formed by using a rotary drilling rig. The steel casing is made of a 5mm steel plate, the diameter of the pile is 1000mm, the inner diameter of the pile casing is 1030mm, the length is 4m. The top, the middle part and the bottom of the steel casing are welded with a reinforcing ring with a thickness of 5 mm and a height of about 15 cm. The welding of the joints in the steel casing should meet the welding requirements, which should be able to resist to pull and pressure and water leakage.

The steel casing can be laid by hammering or pressurization, which should be place at a place which is 0.5m above the hard and dense soil. After determining the center of the pile, it is possible to lay the steel casing d, and the specific position of the steel casings should meet the requirements for deviations, the deviation between the center of the top surface of the steel casing and the designed pile position should not be more than 5cm, and the tilting angle deviation should be less than 1%. The drilling can be carried out only after the measurement is correct[4].

3.2.2 Construction of the large diameter long pile: Since the diameter of the main rib in the steel bar cage is relatively larger, the steel bar cage is fabricated by adopting a building platform. For the main reinforcement rib which is to be hoisted, the method for reinforcement is to arranged steel bars on the cross section in a square crossing manner. During the transportation and hoisting, two cranes should be employed, and a single crane is to be used, both of its main hook and auxiliary hook should be used to carry out simultaneous hoisting. To prevent the reinforcement cage frame from being deformed due to collisions or its own weight, welding of the main reinforcement rib should be carried out by two welders at the same time so as to ensure the verticality of the reinforcement cage after the butt joint is made meets the requirements. Before lowering the reinforcement cage, an reinforcement cage made with short steel bars, with a slightly larger diameter and carrying weights shall be lowered in advance to check the quality of the holes, and the phenomenon of a seized cage should not occur at the time when the reinforcement cage is being lowered[5].

- As to the bored pile with a larger diameter, it is possible to protect its wall with the highgrade mud, that is, the PHP mud, which is made by incorporating the polyacrylamide into the ordinary mud and is known as the PHP mud. Generally, the content of polyacrylamide is 0.003% of the amount.
of the mud. Compared with the common clay which is made with the natural pulp, the PHP mud is made by adding PHP colloid into the base slurry which is made using bentonite. It has the advantages such as: the water loss is small, the mud skin is thin, compact and flexible, and the effect of wall protection is better.

- In order to avoid the collapse of the hole or seizure of the drilling rig during the drilling operation, attention should be paid to controlling and adjusting the consistency of mud. When clay layer is encountered during the drilling operation, clean water should be injected to reduce the mud consistency. Clay should be added to a sand layer and a gravel layer in order to improve the mud consistency and ensure safety during the drilling operation.
- In case a gravel layer is encountered in the drilling operation and the drilling speed becomes slower, first a small drill of 1 meter should be used for drilling up to the designed elevation. Then the hole should be drilled once again with a drill of 1.5 meters. This method can greatly improve the working efficiency.

3.2.3 Construction of the inter-pile wall: In order to ensure the safety of the foundation pit support and ensure the stability of the soil mass between the piles, a thick concrete wall with 80mm thickness should be formed between the supporting piles by spraying C20 concrete during the earthwork excavation. The steel mesh of φ8@200mm×200mm shall be set up within the supporting piles.

- The soil between the piles should be repaired. It is required to repair the soil at the same time the excavation is carried out. It ensures the stability of the side wall under natural conditions.
- After the repair is completed, the mesh shall be hung. Two φ16@2000 reinforcement steel bars should be pressed longitudinally above the mesh, and the reinforcement shall be secured on the pile.
- The mesh can be prefabricated and fixed to its position between piles with the short steel bars (soil nails).

4. The key points in quality control of the deep foundation pit support

The foundation plan should be based on, the axis and geometric size of the foundation pit should be checked in real time during excavation. The position and elevation of each control pile should be checked regularly during the excavation process.

The large diameter hole piles are protected by high-grade mud, namely PHP mud. PHP mud is made by adding polyacrylamide into the ordinary mud. Its content shall be strictly controlled and generally it accounts for 0.003% of the mud amount.

In order to ensure the safety of the foundation pit, the steel bars and the structures. It masters the working conditions of the support system in detail to meet the requirements of information construction. This supporting work was being monitored according to the design requirements. So it was possible to know any changes in the foundation pit in time, and non safety accident has occurred.

5. Conclusion

The deep foundation pit work of the residential district project adopts the soil nailing support and the enclosure pile support technology. This support work is close to the highway and the terrain is complex, the construction technology of the soil nailing wall and the supporting wall row pile is introduced. The key points in the quality control technology used for the deep foundation pit support are put forward for the purpose of reducing the construction risk of the project, which can be used for reference to the construction of similar foundation pit engineering project.

References

[1] Wang C.D, Xia X. (2003) Application of shotcrete anchor support in deep foundation pit engineering. Journal of rock mechanics and engineering,167:83-86.

[2] Feng Z.W. (2016) Discussion on the Construction scheme of shotcrete-bolt support for the slope and foundation pit. Building Technology Development,140:62-63.
[3] LiY, Dong W.H, Huang X.F.(2013) Reinforcement and Reconstruction technology of existing foundation pit support structure under reverse operation. Construction technology, 204:55-58.

[4] Ma Y.A. (2015) Analysis of pile foundation construction technology of highway bridge. Sichuan cement, 53:98-100.

[5] Tan X.S. (2018) Research on design and construction of deep foundation pit support in geotechnical engineering. Architectural technology development, 68:121-122.