Pit-retaining Structure Construction Technique of H-shaped Steel Anchor Composite Pile- Prefabricated Wallboard Adopting Compaction Grouting Method of a High-rise Building in Guangzhou

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Abstract. Taking the deep excavation engineering of a tall building in Guangzhou as an example, this paper introduces the pit-retaining structure construction technique of H-shaped steel anchor composite pile- prefabricated wallboard adopting compaction grouting method. The main construction process of this technique includes: (1) surveying setting-out to fix piles’ locations, (2) hoisting piles into place and adjustment, (3) H-shaped steel piles driving, (4) layered and segmented excavation and pile body treatment, (5) layered and segmented drilling anchor stocks one by one from top to bottom, (6) hoisting prefabricated wallboard in position, (7) inserting reinforcement and binding firmly with protruding bar of precast wallboard, (8) layered and segmented high pressure grouting, (9) pouring expansive concrete at joints,(10) repeated step(4) to step (9), (11) steel bar binding of middle beams, framework supporting and concrete grouting, (12) acceptance check. This method utilizes the integral foundation pit enclosure structure formed by the H-shaped steel pile, anchor rod and precast wallboard and the construction follows the principle of layered and segmented excavation, setting anchors step by step and grouting immediately after hoisting, which realize the assembly construction of the foundation pit enclosure structure and can effectively saving time, retain soil and seal water.

1. Project Overview
The deep foundation pit project of a high-rise building in Guangzhou is located in Tianhe District, Guangzhou, and assembled with an integral frame shear wall structure. The building has 3 floors underground and 18 floors above ground, among which B1~B3 underground are commercial parking lots and the floors 1~2 above ground are large-scale shopping malls, and all of them are shear wall structures of cast-in-place reinforced concrete. The floors 3~18 above the ground are assembled integral frame shear wall structure, involving comprehensive office areas, hotels, cinemas, KTV and training service institutions.

The prefabrication rate of the whole project is 65.8%, and the assembly rate is 91.6%. The prefabricated components include prefabricated columns, laminated beams, laminated plates, prefabricated wall panels, prefabricated stairs and prefabricated balcony panels. The prefabrication
rate of the entire project stairs and balcony panels has reached 100%. The excavation area of the foundation pit is 3927.51m², the excavation depth is 11.9m. The underground soil layer of -0.320~5.780 in the excavation area is silty clay, and that of -5.70~22.22 is sand. The design adopts “a type of deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method. The effective combination of enclosure and underground structure construction has realized the construction of the assembled foundation pit enclosure structure, and the technical scheme has been proved to be feasible and effective by experts.

2. Construction methods

The construction technology of the deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method, follows the principle of layered and segmented excavation, layered and segmented anchoring one by one, on-site hoisting followed by grouting immediately. The construction of the assembled foundation pit enclosure structure system is realized, effectively saving time. It is safe and reliable, and has the dual effects of retaining soil and stopping water.

2.1. Deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard

Deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard, includes foundation pit soil, H-shaped steel pile, prefabricated slab wall, high pressure grouting hole, seepage layer slurry, anchor rod, etc. Some H-shaped steel piles are separately hoisted and evenly spaced on the surface of the foundation pit. Two adjacent H-shaped steel piles are provided with prefabricated laminated wall, and an anchor rod is arranged thereon the surface of the H-shaped steel pile flange plate on the soil side of the foundation pit. The anchor rod fixes the H-shaped steel pile and the foundation pit soil. The bottom of the prefabricated wallboard is provided with a high-pressure grouting hole, through which high-pressure mechanical grouting form seepage layer slurries. The slurries of the seepage layer is located between the foundation pit soil and the H-shaped steel pile and the prefabricated slab wall.

A number of anchor rods make the H-shaped steel pile effectively bind with the foundation pit soil firmly and reliably, which realizes the construction of the assembled foundation pit enclosure structure system, effectively save time and has the dual functions of retaining soil and stopping water. The deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard is shown in Figure 2, where 1 represents the foundation pit soil, 2 represents the H-shaped steel pile, 3 represents the prefabricated wallboard, 4 represents the high pressure grouting hole, 5 represents the seepage layer slurry, and 6 represents the anchor.
Figure 2. Deep foundation enclosure structure of H-shaped steel and anchor composite pile-prefabricated wallboard adopting compaction grouting method.

(1) The width of flange plate of the H-shaped steel pile 2 is $\geq 350$ mm, the thickness of the flange plate is $\geq 20$ mm. The height of the web of H-shaped steel pile 2 is 60 mm larger than the thickness of the prefabricated wallboard 3, and the thickness of the web of H-shaped steel pile 2 is $\geq 30$ mm.

(2) The thickness of the prefabricated wallboard 3 is $\geq 100$ mm, and the width of the prefabricated wallboard 3 of each section is smaller than the distance between the webs of two adjacent H-shaped steel piles 2 $(0.5 \times \text{the flange width of H-shaped steel pile } 2 + 50)$ mm.

(3) The high-pressure grouting hole 4 is a steel sleeve structure, and the high-pressure grouting hole 4 has a diameter of 18 to 22 mm. The high-pressure grouting hole 4 is integrally formed with the prefabricated wallboard 3; The high pressure grouting holes 4 are set at 300 mm above the bottom of each prefabricated wallboard 3.

(4) The interval between two adjacent high pressure grouting holes 4 is 1.2 m, and at least two high pressure grouting holes 4 are provided at the bottom of the prefabricated wallboard 3 of each section.

(5) The anchor rod 6 has a diameter of $\geq 12$ mm, and the anchor rod 6 is set at the middle of each side of the flange plate surface of the H-shaped steel pile 2. Some anchor rods 6 are evenly arranged along the length direction of the H-shaped steel pile 2 with an interval of $\geq 1.5$ m.

(6) The anchor rods 6 are closely arranged within 2000 mm of the pile body at the upper and lower joints of the prefabricated wallboard 3 of each section.

(7) The upper and lower joints of the prefabricated wallboards 3 of each section are connected by post-casting concrete, and the width of the post-cast concrete section is 2.5 times of the thickness of the prefabricated wallboard 3.

2.2. Construction technology

The construction technology of the deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method includes the below steps:

Surveying and setting out to fix piles’ locations→hoisting piles into place and adjustment→H-shaped steel piles driving→layered and segmented excavation and pile body treatment→layered and segmented anchoring one by one from top to bottom, and hoisting prefabricated wallboard in position→inserting reinforced steel bar and binding firmly with protruding bar of precast wallboard→layered and segmented high pressure grouting→pouring micro-expansive concrete at joints→Repeat step(4) to step (9)→steel bar binding of middle beams, framework supporting and concrete grouting→acceptance check.

(1) Surveying and setting out to fix piles’ locations: Before the construction of the foundation pit enclosure system, the plane position of the H-shaped steel pile is accurately measured, and the plane error is controlled within 5 mm. After the completion of each pile position measurement, the protection measures for the pile position are carried out to prevent the human factors from affecting the positional deviation after the piles are installed.

(2) Hoisting piles into place and adjustment: Before the H-shaped steel piles driving, the piles are first lifted in place according to the designed pile segments by factories, and the plane positions of the
piles are reviewed, waiting for the piles to be set up. The pile position exceeding the designed and specification requirements shall be corrected in time.

3) H-shaped steel piles driving: The H-shaped steel piles used are produced in the factory. When the H-shaped steel pile is driven onsite, static pressure pile method is utilized to construct. The deviation between the driving plane and the verticality of the pile is checked one time each 2m of the pile driving. The verticality deviations are controlled within 1%, and the piles with the vertical deviation of more than 1% are corrected. If it is difficult to correct, the piled hole will be re-drilled.

4) Layered and segmented excavation and pile body treatment: After the H-shaped steel pile is driven completely, layered and segmented excavation is conducted in the founda\n\n\n\n5) Layered and segmented anchoring one by one from top to bottom: The anchor rod is set up from top to bottom, layer by layer, section by section, and one by one. During the construction process, the soil layer excavation and the pile anchoring work are well coordinated, and the excavation depth of the soil layer is strictly controlled, no over-exca\n\n\n6) Layered and segmented active high pressure grouting: During the construction, the high-pressure grouting is carried out layer by layer from the high-pressure grouting hole at the bottom of the prefabricated wallboard. The prefabricated wallboard on each section is grouted symmetrically from the middle of the high-pressure grouting hole at the bottom of the prefabricated wallboard to the left and right directions, that is, symmetrically grouting "from the middle to the two sides", at the grouting pressure less than 0.6 MPa. The pressure grouting adopts multiple pressure-compensation and step-by-step pressuring method, and the final grouting degree ensures that the slurries between the prefabricated wallboard and the soil layer are dense, making the slurries penetrate into the soil layer by not less than 100 mm.

7) Pouring micro-expansive concrete at joints: During the construction process, the micro-expansive concrete is poured at the joints between the H-shaped steel pile and the prefabricated wallboard. The strength of the micro-expansive concrete at joints is not less than C40, with at least one grade higher than the strength of the precast wallboard concrete.

8) Steel bar binding of middle beams, framework supporting and concrete grouting: When the construction in upper and lower sections of the prefabricated wallboard is completed, a cast-in-place
reinforced concrete waist beam is arranged between the upper and lower prefabricated wallboards. The waist beam steel bar is connected with the protruding bar of the prefabricated wallboard. The longitudinal steel bars of the waist beam adopt not less than 4 above third-grade steel bars with a diameter of 20mm, and the stirrups adopt above second-grade steel bars with a diameter of 8mm, with the stirrup interval of not more than 200mm. During the process of binding the waist beam steel, the anchored length of the protruding bar of the upper and lower prefabricated wallboards into the waist beam is not less than 1.5Lae, and the waist beam steel is connected with the web of the H-shaped steel pile at the H-shaped steel pile by welding method.

(12) Acceptance check.

2.3. Key technical points
(1) A construction technique of deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method, has the characteristic that, under the premise that the calculation of the bearing capacity of the foundation pit is satisfied in the step (3), the width of the flange plate of the H-shaped steel pile is not less than 350 mm, the thickness of the flange plate is not less than 20 mm, and the web height of the H-shaped steel pile is 60mm larger than that of the prefabricated plate used, so as to facilitate the hoisting of the prefabricated wallboard. The thickness of the web of the H-shaped steel pile is not less than 30mm.

(2) A construction technique of deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method, has the characteristic that, the pile segments in the step (3) are connected by welding.

(3) A construction technique of deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method, has the characteristic that, in the step (5), in order to facilitate the construction of the anchor rods, the anchor rods adopt a steel strand instead of the traditional anchor rod, and the diameter of the anchor rods is at least 10 mm smaller than the reserved hole on the inner flange plate of the H-shaped steel pile. Or the reserved holes for anchor construction are placed at the relative positions of the inner and outer flange plates of the H-shaped steel pile to facilitate the driving of the later anchor rods. The reserved holes on the inner and outer flange plates are at least 10 mm larger than the diameter of the anchor rods; Wherein, the diameter of the anchor rods is not less than 12mm, and the length of the rod is determined according to the bearing calculation. They are arranged in the middle of each side of the flange plate surface of the H-shaped steel pile, along the length direction of the H-shaped steel pile, with the interval of not more than 1.5m. The anchors are compacted at 2000mm of the pile body at the lower and upper joints of each prefabricated wallboard, with the compacted interval of not more than 0.6m.

(4) A construction technique of deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method, has the characteristic that the diameters of the reinforced steel bars are not less than 20 mm in the step (7), and there are not less than two reinforced steel bars.

(5) A construction technique of deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method, has the characteristic that in the step (8), the high-pressure grouting holes are provided at a distance of 300 mm above the bottom of each prefabricated wallboard. A high-pressure grouting hole is set every 1.2m, and there are no less than 2 high-pressure grouting holes at the bottom of each prefabricated wallboard. The high-pressure grouting holes are made of steel sleeves, which are integrated with the prefabricated wallboard in the centralized production of the factory, with a preferably diameter of 20 mm.

(6) A construction technique of deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method, has the characteristic that, at the position of the post-casting concrete of two adjacent prefabricated wallboard in the step (11), the waist beam stirrups are compacted, and the compacted zone is not less than 600 mm. The stirrup interval in encryption zone is not more than 100 mm.
(7) A construction technique of deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method, has the characteristic that in the step (11), the waist beam steel bars at the H-shaped steel pile adopt the method of reserved roles on the web of the H-shaped steel pile, and the perforated steel bar with a diameter of not less than 16 mm is fixedly connected with the protruding bar of the prefabricated wallboard. The number of the perforated steel bars is determined by calculation according to the specific situation of the actual project.

3. Conclusions
This paper takes the deep foundation pit project construction of a tall building in Guangzhou as an example, emphatically introduces the structural design and construction technology of deep foundation pit enclosure structure of H-shaped steel anchor composite pile-prefabricated wallboard by compaction grouting method, utilizes H-shaped steel piles, anchor rods and prefabricated wallboards to form a integral foundation pit enclosure structure. The construction follows the principle of layered and segmented excavation, layered and segmented anchoring one by one, on-site hoisting followed by grouting immediately. The construction of the assembled foundation pit enclosure structure system is realized, effectively saving time. It is safe and reliable, and has the dual effects of retaining soil and stopping water.

Acknowledgment
Fund Project: 1. project with financial aids offered by Nantong Scientific Planning Project in 2018, named “The Research and Application of Key Technology in Enclosure Structure’s Assembly Constraction in High-rise Building Engineering”; 2. the training project of key members of the outstanding young teacher in Jiangsu Qing-lan Project(experienced teachers guide the new teacher) in 2018; 3. the key project of Natural Science Foundation in Jiangsu College of Engineering and Technology (GYKY/2018/4).

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