Construction technology of static bolt-pile reinforcement with pressure grouting combined with galvanizing steel pipe based on computational science

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Abstract. Combined with practical engineering experience, this paper summarizes the construction technology of static bolt-pile reinforcement with pressure grouting combined with galvanizing steel pipe, which can be used for the reinforcement of multi-layer industrial and civil building foundation, and has great value of popularization and application prospect.

Keywords: pressure grouting, static pressure pile, reinforcement, computational science

1. Introduction
In the process of building construction, if the foundation is not properly constructed, the building will appear differential settlement, cracks and so on. Once such problems occur, that will seriously affects the normal use of the building, it is necessary to take reinforcement measures to ensure the safety of the building foundation.

2. Overview of project case
The project for a new airport Terminal area movement command center is a two-storey frame building on the ground floor, with a 4.2m storey height on the ground floor, which is regularly rectangular. The ground strata can be divided from top to bottom: (1) plain fill; (2) tillage soil; (3) Hard plastic-like silty clay (locally without such layer of soil type); (4) clay breccia.

This project adopted independent column foundation, the size of which was 2600×2600mm. The supporting layer was a hard plastic silted clay or clayey breccia layer, whose surface is located in the outdoor floor of -3.4m ~ -4.9m. When the main body of the project is to be decorated after the completion in December 2014, it is found that the (1) ~ (6) axis members of the building appeared cracks of different degrees, where the upper concrete structural members are with severe pull crack and shear failure with 45° stepped cracks in the filling wall. It endangers the safety of the structure.

3. Method of pressure grouting combined with galvanizing steel pipe anchor pile

3.1. Construction preparation
The investigation and analysis of original data are done to master relevant written data. Combined with field survey and investigation for geological exploration report, obtaining the first-hand
information of data, and carrying on the investigation and analysis of engineering site on natural, technical and economic conditions are done in order to formulate a reasonable, practical, advanced construction organization design.

Be familiar with construction drawings and relevant technical specifications (design and acceptance specifications), operating procedures, technical standards, etc. and master the design intention. According to the drawing content to prepare practical special construction plan. Technicians should carefully study the drawings and participate in the joint review of the drawings. They must fully understand the design intention and be familiar with the contents of the drawings to guide the construction.

Before the construction, the person in charge of engineering technology and safety shall make detailed explanations to the construction work team and operators, make written disclosure of the technology and safety work, clarify the design requirements, understand the characteristics of the project and grasp the key points of construction, and both parties shall sign for confirmation.

Construction personnel and mechanical equipment (assemble and debug the equipment) are arranged to ensure all the equipments are well-prepared.

Prepare the materials for use, calculate the usage amount of the reinforced screw according to the drawing design, and processes it on site for spare in advance. Inspection and acceptance of steel pipes, rods, members, fittings and reinforcement according to acceptance are done.

According to the requirements of design and specification, the bolt processing and fabrication, prefabrication of pile segment, etc were done.

Carrying out the testing pile as required, determining the construction parameters are to form the formal construction of the control index. And the results of the test pile were feed backed to the design and supervision units.

3.2. Construction process of grouting reinforcement

(1) Layout of grouting holes: four holes were evenly arranged around the 4/A axis and the independent foundation of 6/A axis, and the reinforcement depth is 4.0-10.5m. The bottom of the deep hole entered into the clayey breccia layer. Low pressure, slow irrigation and multi-volume grouting process were adopted to inject more slurry.

(2) Repeated grouting: in order to enhance the grouting effect in the hole section with thick soft soil, an irregular curtain is formed within the scope of grouting action in the first grouting usually, , and then the grouting hole was rinsed for the second grouting, so that the slurry was fully and effectively filled.

(3) Stratified grouting (from bottom to top) is adopted: the grouting pipe dropped to the bottom of the hole after the hole is formed, and grouting begins from the bottom of the hole, while the grouting pipe is pulled out at the rear side of the grouting, so that the slurry diffuses from the bottom of the hole, which is conducive to the reinforcement of soft soil.

(4) Grouting material is 42.5 ordinary Portland cement, water, early strength agent, etc. The water cement ratio of cement slurry is 1.5, 1.0, 0.5 three grades, and add early strength agent according to the cement dosage 0.3%-0.5%, according to the total grouting and flow control, add less at first, then more. The mixing time of slurry should not be less than 5min. It is required that the setting time can be adjusted for different strata with high strength and water stop effect.

(5) Grouting pressure is controlled at 0.2-0.5mpa and grouting flow is controlled at 7-10L/min. According to the water-cement ratio from thin to thick grading perfusion, when the injection volume of a water-cement ratio reaches or exceeds 200L, the grouting pressure and injection rate are unchanged or not significantly changed, then the first-grade slurry consistency is enhanced. When the injection volume is greater than 20L/min, it is further enhanced, and so on, until the grouting is finished. When the grouting amount of a certain section exceeds 1-1.5 times of that of the adjacent section, the grouting should be stopped and re-injected several hours later intermittently to prevent the slurry from expanding beyond the strengthened section.
3. Measurement and placement of axes and piles
According to the control points and design drawings, the axis and control points of the pile foundation shall be measured and properly protected by the surveyor, so as to guide, control and check the pile position during pile pressing. After checking the site axis and the control point are correct, the surveyor shall measure the pile position and mark it so as to drill the pile hole and anchor hole. During the construction process, special attention should be paid to prevent damage marks from causing incorrect pile position, and check at any time.

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3.4. Dig pile holes and make anchor rods embedded
The pressure pile hole should be made into a bell mouth with small upper and large lower diameter. Generally, the upper opening is +50mm and the lower opening is +100mm. After the pile position is measured, the pile whole size is determined according to the design and specification requirements, and the pile hole is drilled on the original foundation.

3.5. Fabrication of prefabricated piles
The production of anchor pile should meet the design and specification requirements, and the length of each pile segment should be reasonably configured according to the design length, and then made on site. The pile is made of galvanized steel pipe DN100, material Q235. The inner diameter and outer diameter of galvanized steel pipe are 100mm and 114mm respectively. The material is Q235 and the length of each pile section is 2m. Butt welding is used for pile extension, and the welded parts are strengthened locally. The length of the pile section should be determined according to the construction clearance height and the conditions of the machine and tools, of which difference after the combination can be 25cm or 50cm, so as not to cut too many piles. During the construction, it should be reasonably prepared according to the designed pile length. The length of the first pile section of this project is 2.0m, and the length of other piles is 2.0m. Butt welding is used for pile extension, and the welded parts were strengthened locally. Drill holes on the side wall of steel pipe piles with diameter of 3-6mm and spacing of 400-500mm are arranged in the shape of plum. In order to prevent whole clogging during pile pressing, pack them with electrical tape. The pile section should be made with regular section shape, flat end face and no bending of the pile section.

3.6. Making of bolt
Anchor rod is the core force member in the construction process of anchor rod static pile. Whether the design choice of anchor rod is reasonable and the anchor rod is embedded firmly is critical to that the pile can be implemented. The bolt is buried in the rear hole with smooth straight bar or thick bolt. According to the vertical bearing capacity of a single pile to determine the number and type of bolts, the general use of four bolts, bolts are processed by bar.

3.7. Anchor bolt embedded
Firstly, the embedment position of anchor bolt should be determined accurately. For the spacing between anchor bolt and pile hole, the minimum spacing between anchor bolt and surrounding structure, and the minimum spacing between the edge of anchor bolt or pile hole and the edge of foundation cap according to the structural requirements of the arrangement of anchor bolt and pile whole. The anchorage depth of bolt bolts is generally 10 ~ 12 times the diameter of bolt, which should not be less than 300mm. The length of top surface of bolt exposed cap should meet the requirements of pile pressing machine, which should not be less than 120mm in general. The anchorage method of
anchor rod: for the anchor rod buried after the hole is formed, the air drill is used to make the hole on the original basis in advance, to ensure the anchor hole is clean and dry, before it is anchored. The reinforcement is planted in the bolt hole.

3.8. Mounting of reaction frame
The concrete screwing around the anchor rod is to facilitate the installation of the reaction rack. The installation of the reaction frame must be vertical and stable, the nuts of the anchor bolt should be tightened evenly. The loose nuts should be tightened at any time during the piling process, and multiple nuts should be used superposition when the bolt is under heavy load.

3.9. Position of pile section
Before the placement of the pile segment, the debris in the pile hole should be cleared. The placement of the pile segment must be vertical, especially to ensure the vertical degree of the first section of the pile, so that the axes of the jack, the pile segment and the pile hole coincide to prevent the occurrence of eccentric compression. The vertical degree of the pile body can be checked and corrected with a wire hammer. The plane deviation of pile position shall not exceed ± 20mm, and the vertical deviation of pile segment shall not exceed 1% of the length of pile segment.

3.10. Piling
When piling, the top of the pile can be filled with 3 ~ 4cm thick wood or multi-layer gunny bags, and then put on the steel pile cap before piling. It is not suitable for several piling machines to be built on a single column foundation at the same time. During construction, the total pile pressure shall not exceed the weight of the foundation and superstructure, so as to prevent structural damage caused by foundation cap. The whole pile should be pressed to the design level in one time. The pile should not be stopped during construction, but should be put in place once to avoid the dissipation of excess hydrostatic pressure of soil consolidation and the increase of friction resistance. If the pile must be stopped during construction, the pile tip should stay in the soft soil layer, and the stopping time should not exceed 24 hours. In case of a sharp increase in pressure, underground obstacles may be encountered or pressed into a hard soil layer, at this time, the hydraulic system can be slightly pressed in, load holding, re-pressure, re-load holding, until the design depth or bearing capacity. During construction, the length of pile section should be adjusted at any time according to the design requirements or the pressure of the pile, so as to avoid cutting the pile as far as possible. The control standard of pile construction should be based on the design of the final pile pressure, supplemented by the depth of the pile into the soil. In case of any abnormal situation, it should be reported to the designer and timely take countermeasures. The pile is controlled by hydraulic pressure, and the load of the pile is controlled between 45-55Mpa. When the pile is pressed to a predetermined depth and reaches the pressure of design penetration, the settlement control standard is that the load of the pile should be maintained at 50MPa, impacted once every 5min, impacted for three times in total, and the settlement amount should be no more than 3mm. It should be stable for 1h, and the allowable settlement amount should be kept no more than 1mm.

3.11. Pile extension
The pile type is steel pipe pile, and electric welding pile is adopted. The perpendicularity of the pile should be adjusted during welding to ensure that the perpendicularity of the upper and lower joints of the pile meets the requirements of the specification, and the welding part should be strengthened.

3.12. Sealing pile
The construction of pile sealing is another key link in the process of pile pressing. Whether the pile can be firmly connected with the pile cap and concrete floor, whether the bearing capacity can meet the requirements, and whether the form of joint is reasonable are all the keys to whether the pile can play a role after the pile sealing. Before sealing the pile, the elevation of pile top should meet the
design requirements, and the pile head should be extended into the pile foundation cap 50 ~ 100 mm. The pile hole must be carefully checked and the debris and water must be cleared away. To strengthen the connection of piles and pile caps, especially when the original foundation slab thickness is less than 350 mm, application 2 Ф 16 reinforced cross welding on the anchor rod. And when pouring concrete pile whole pressure above the top of the pile hole pouring pile cap, the thickness is not less than 150 mm. In order to form a whole pile and pile foundation cap, C35 micro-expansion early strength concrete is generally used to seal the pile. The cement, yellow sand, crushed stone and admixture needed to make concrete should be measured strictly according to the proportion of concrete. When the amount of concrete is very small, artificial mixing can be used to strictly control the water-cement ratio.

4. Conclusion
Pressure grouting combined with galvanizing steel pipe anchor pile reinforcement treatment method, with the building weight as the counterforce, the pile is pressed into the soil with the jack to form the pile-soil joint action to share the superstructure load. Compared with the cast-in-place pile, the comprehensive cost is low. It can be constructed in indoor, outdoor, basement or semi-basement, with light and flexible construction equipment, simple operation, convenient construction, and small operation surface, flexible and convenient, and moderate cost. It does not affect the construction of superstructure, short construction period, low energy consumption, low vibration, low noise, no pollution. It can be made in the precision instrument workshop and residential building, or workshop without stopping production, to move to pressure pile construction. And it is suitable for the large machine cannot enter and do not allow the foundation reinforcement without environmental pollution, it also be applied to the foundation uneven settlement caused by the upper structure cracking or tilted, buildings and plant expansion of foundation reinforcement.

References
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