Research on Optimal Design and Construction Technology of Prefabricated Load-bearing Pier Structure

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Abstract: The prefabricated pier structure has the advantages of low energy consumption, high mechanized level, which meets the green development trend of the construction industry, with broad application prospects. This paper analyzes the process and construction principle of the prefabricated pier structure and the pier and the top platform of the prefabricated bearing pier, which describes the principle of the prefabricated bearer structure, and the structural operation of the prefabricated bearer structure, and proposed a new type of prefabricated pier structure.

1. Introduction

A typical trend in the foundation treatment development in recent years is based on existing foundation treatment methods, and continuously develops new foundation treatment methods, especially in combination of a variety of foundation processing methods to form an extremely distinctive foundation composite reinforcement technology[1]. At present, domestic and foreign research results on the test performance analysis and design theory of ground treatment technology are relatively abundant. Qin Lixin[2] dealt with the inheritance of cement mixing piles in the soft soil for a certain railway soft soil project, and studied the problem of segmentation after construction. The Tai-Hua Expressway uses dry vibrating gravel piles for soft soil foundation treatment, researchers used numerical methods to simulate the development and changes of foundation settlement, excess pore water pressure and foundation plastic zone during the embankment filling process[3]. Cheng Wanzhao et al.[4] studied the consolidation deformation, pore pressure dissipation, pile-soil stress sharing and bearing capacity characteristics of the concrete-cored sand-gravel pile composite foundation through in-situ observations and experiments and analyzed the load-bearing characteristics of the variable-ridge cement-soil mixing pile under the condition of single-pile composite foundation load test. Wen Shiqiang et al.[5] studied engineering applications in Soft Subgrade in Ningbo Ring Expressway, and conducted on-site testing of the composite foundation of the crushing stone pile under the embankment. Zheng Gang et al.[6] used the finite difference numerical method to study the stability of the composite foundation on the soft foundation reinforced by rigid piles. Wu Mingsheng[7] carried out related research on the pile foundation offset caused by ground pile loading. Mo Yanyi[8] summarizes the process parameter selection, construction process and construction sequence of spinning grouting.

In summary, the current research on composite foundation treatment is mainly concentrated in the foundation load performance and calculation theory, and the construction of the prefabricated pier structure is relatively small, only a small number of scholars are for the construction flow of the prefabricated carrier and research on technical points such as pouring concrete pouring. In view of this, based on the actual needs of the current project, it proposes a preform improved mechanical performance
pier, the lift pier top platform preform combined structure bearing capacity, improving the efficiency of on-site construction of prefabricated bearing supporting structures and explain its construction method.

2. Engineering technical problems and difficulties

2.1. The length of the pier has limited impact on ability to resist pulling
Concrete pouring in prefabricated load-bearing pier structure, as the length of the pier is increasing, the number of concrete pouring is also increasing. When other factors remain unchanged, the internal friction angle between the pier and soil increases, and the pull-out ability of the single pier increases, but the increase is small. In addition, the length of the pier will affect the project planning and construction time, increase the difficulty of construction, and construction cost.

2.2. Pier side soil carrying performance is difficult to effectively
The interaction between the pile and the soil around the pile in the composite foundation, the mechanism of the cushion layer, etc. occupy an important position in the research of the composite foundation. Strengthening the mechanism of the cushion layer in the composite foundation and the interaction between the pile body and pier side soil will help to better exert the bearing capacity and settlement control of the composite foundation, and achieve better economic and social benefits.

2.3. The structural integrity of the pier needs to be improved
The connection between the prefabricated pier connecting section, the lower prefabricated pier and the top platform, directly affects the integrity of the structure. Welding, lap joint, grouting sleeve and other connection forms are often used in the prior art, but the connection segment, the prefabricated pier and the platform have not formed effective force channels, thus causing the connection between seismic performance, anti-bending performance, overall performance both are poor.

3. Principle of structure and operation

3.1. Structural design
In civil engineering, in order to effectively bear the load of the superstructure, it is often necessary to carry out foundation engineering construction. Pier foundation usually refers to a rigid foundation with a diameter greater than 800mm, a length greater than 3m and less than 6m, or a length-to-diameter ratio L/D<6. It has the advantages of high bearing capacity, strong uplift and seismic resistance, low construction cost, and small settlement.

Engineering practice shows that setting splicing joints at the connection between the precast pier structure and the cap is an effective measure to improve the insufficient connection strength of the precast pier structure. However, due to the influence of construction and many difficult to control factors, the connection section of the precast pier and the lower precast pier, the connection problem with the pier top platform is still difficult to solve. In view of this, this paper has designed a prefabricated bearing pier structure in a targeted manner. The structure is equipped with a pressure dispersing plate inside the connecting section of the prefabricated pier, and a pier bottom bearing body is installed at the bottom; the top of the lower prefabricated pier is equipped with built-in connecting ribs, transverse connecting pipes and Grouting baffle, with grouting bladder on the outside; fastening ties, flexible joint layer and connecting hooks at the junction of the prefabricated pier connecting section and the lower prefabricated pier; grouting at the bottom of the lower prefabricated pier to form the pier bottom bearing The outer grouting pocket is grouted into the pocket to form a pocket grouting body. The structure is provided in the top of the prefabricated pier connection section, and the prefabricated load-bearing pier structure is shown in Figure 1.
Figure 1 Schematic diagram of longitudinal section of prefabricated load-bearing pier structure.

In Figure 1: (Note: 1-Pier top platform; 2-Pier side hoop; 3-Pressure Dispersion Plate; 4-Connection hook; 5-Fastening lacing; 6-Pier side soil; 7-Stop grout baffle; 8-Transverse connecting Pipe; 9-Pier top prestressed tendons; 10-Prefabricated pier connecting section; 11-Flexible seam layer; 12-Built-in connecting rib; 13-Lightweight filler; 14-Pier core reserved tube; 15-Grouting bladder; 16-Capsular grout; 17-Lower prefabricated pier; 18-Pier bottom bearing body)

Figure 2 "X"-shaped prefabricated pier structure diagram.

In Figure 2: (Note: 8-Transverse connecting Pipe; 13-Lightweight filler; 14-Pier core reserved tube; 15-Grouting bladder; 16-Capsular grout; 17-Lower prefabricated pier; 19-Connection reinforcement)

The "X"-shaped prefabricated pier structure is composed of connecting reinforcing ribs, transverse connecting pipes, and grouting pockets; transverse connecting pipes: the transverse connecting pipes are steel pipes or PVC pipes. The bottom surface of the lower prefabricated pier is 10cm~15cm, and the cross-sectional schematic diagram of the "X"-shaped prefabricated pier structure is shown in Figure 2.
3.2. Working principle

(1) The prefabricated pier connection section and the lower prefabricated pier can be used in the study structure, which can also save concrete dosage, but also increase the side surface area of the prefabricated pier, which can effectively improve pier side friction.

(2) The study structure sets lightweight filler in the middle of the prefabricated pier connection section and the lower prefabricated pier, and can be prepared in the prefabricated field, not only can save the cost preparation of the prefabricated pier, but also improve the stress behaviour of prefabricated piers and increase the bearing capacity of the structure. At the bottom of the lower prefabricated pier, the dispersing plate and pier bottom bearing body are set at the bottom of the lower precast pier, and the outer side is equipped with pocket grouting body and pocket reinforcement net, which can effectively increase the bonding strength between the precast pier and the surrounding soil and improve the bearing performance of the soil on the side of the pier.

(3) The study structure is attached to the prefabricated load-bearing pier structure connection section and the lower prefabricated load-bearing pier structure to attach a tightening tribute, flexible seam layer, and linking, and connect the fastening rib with the connection replenishment, and the corresponding fastening rib passes tight Solid bolt connection and enhance the overall performance of the prefabricated pier.

(4) The study structure is equipped with pier side hoop and pier side reinforced pipes on the pier side, and pier top prestressed tendons are set in the pier top platform, which can enhance the mechanical performance of the combined structure of the precast pier and the platform on the top of the pier, and the bearing capacity of the precast pier structure.

4. Main construction program

4.1. Construction preparation

(1) Determine the cross-sectional size of the prefabricated pier connection section, the lower prefabricated pier and the top platform according to the bearing requirements of the building basics, and prepared in the prefabricated field.

(2) The inner portion of the prefabricated pier connection section provided with a dispersion plate, and the bottom of the connecting section is provided with a connecting groove at the bottom of the pier; The top of the lower prefabricated pier is provided with a built-in connecting band, and the internal setting pipe, lightweight filler, lateral connecting tube, outer side setting grouting bag; set the pier side hoop on the lower surface of the pier.

4.2. Construction process

4.2.1. Prefabricated pier hole construction.

On-site measurement determines the location of the prefabricated piers, and uses the drill pilot hole method to form the holes to form the prefabricated piers.

4.2.2. Lifting the lower prefabricated pier.

A grout pouch is provided on the outside of the lateral connecting tube of the lower prefabricated pier; the prefabricated pier bodies are set and depth, and the lower prefabricated pier is suspended in the prefabricated pier, which uses a static pressure to set the lower precast pier to set up Depending place; when the lower prefabricated pier is difficult, the pier is reserved to the prefabricated pier to provide a pier to the prefabricated pier to provide a pier-side soil.

The cross section of prefabricated piers cloth with holes is round or square, and the cross section area is 2% ~ 5% smaller than that of prefabricated piers connecting section and lower prefabricated pier.
4.2.3. The Prefabricated pier connecting section is placed in sink.
Lift the connecting section of the prefabricated pier to the top of the lower prefabricated pier, so that the connecting section of the prefabricated pier presses down the connecting hook and the built-in connecting ribs to squeeze the grout bag to form a built-in rib filling body; synchronously make the tightening ribs and connecting supplements The strong ribs are connected, and the tightening bolts are used to apply tension to the tightening ribs; the static pressure is continued to be applied to make the prefabricated pier connection section sink to the set depth.

4.2.4. Setting of the top platform.
The pier top platform is hoisted to the upper portion of the prefabricated load-bearing pier structure connection section and is firmly connected to the pier-side hoop on the lower surface of the pitch.

4.2.5. Grouting construction.
The bottom pressure of the lower prefabricated pier is formed by the pier core reserved tube; the pier should be formed by the pier-reserved pipe to form a pocket grouting body to the outer surface of the lower prefabricated pier.

| Table 1 | Grouting construction parameter table. |
|---------|-----------------------------------------|
| Diffusion radius of slurry (m) | Final grouting pressure (MPa) | Serous gel time(s) | Grouting segment length (m) |
| 0.6     | 1~1.5                                   | 90~150             | 0.4                    |

4.2.6. Pre-compression of prefabricated piers.
Before the seam grout is finally aggregated, the vertical downward pressure is applied to the pier top platform to eliminate the gaps at the joints between the pier top platform, the pier bottom bearing body and the lower prefabricated pier.

4.2.7. Tension of prestressed tendons.
After the grouting body in the pipe has formed strength, the pier top prestressed tendons inside the pier top platform are stretched, and the pier top prestressed tendons are firmly connected to the pier top platform.

4.3. Matters needing attention
(1) In order to reduce the error in the construction process, accurate calibration should be used throughout the process, preventing the error, affecting the quality of the project.
(2) When the lifting is working, it must be equipped with a unified command and set up a special person. When the crane is working, the lifting arm rod rotation radius range is strictly prohibited.

5. Conclusions
Affected by uncertain factors, the quality and duration of precast pier construction has always been a difficult point in engineering construction control. In view of the difficult problems in the construction of prefabricated load-bearing pier structures, the article carried out targeted technical research and obtained the following conclusions:
(1) The prefabricated pier adopts the overall prefabricated installation design, the structure is compared with the conventional prefabricated pier, and improve the prefabricated pier Force, enhance the prefabricated pier structure load capacity, reduce safety risks, and accelerate the construction progress and improve the construction quality of prefabricated pier structures.
(2) From the perspective of construction technology, the prefabricated pier structure has the advantages of high on-site construction efficiency, easy quality control, good structural integrity, and easy hoisting. It has certain engineering applicability.
The overall stability of prefabricated pier structure is still different from that of cast-in-place concrete structure, so it is necessary for researchers to study its local force transfer mechanism. Through numerical simulation and field test, the deformation characteristics and collapse process of prefabricated pier structure are understood, and the sound theoretical calculation formula and design principle of Precast Pier structure are established.

Acknowledgments
Thanks for the support of the National Natural Science Foundation of China (Grant No. 52068054 and 12062015) and the project supported by the graduate innovation fund of Nanchang University of Aeronautics (Grant No. YC2020-093).

References
[1] Zheng G., Gong X.N., Xie Y.L., et al. (2012) Summary of the development of foundation treatment technology. Journal of Civil Engineering, 45(02): 127-146.
[2] Qin L.X., Wang Z. (2007) Analysis of Instability of Railway Embankment in Soft Soil on Certain Line. Journal of subgrade engineering, 02: 42-44.
[3] Cao W.P, Chen Y.P. (2007) Cause Analysis and Countermeasures of Instability of Embankment of Taihua Expressway. Journal of Rock Mechanics and Engineering, 07: 1504-1510.
[4] Cheng W.Z, Le M.H, Wang F.Y, et al. (2007) Experimental study on strengthening soft foundation of embankment with concrete-cored sand-gravel pile composite foundation. Journal of Water Conservancy, (S1): 675-681.
[5] Wen S.Q, Chen Y.M, Ding X.M, et al. (2010) Field test study on composite foundation of grout-solid gravel piles under embankment. Journal of geotechnical mechanics, 31(05): 1559-1563.
[6] Zheng G., Liu L., Han J. (2010) Stability of Embankment on Soft Ground Reinforced by Rigid Piles (II)--Analysis under the Condition of Group Piles. Journal of Geotechnical Engineering;32(12): 1811-1820.
[7] Wu M.S. (2017) Treatment Method and Application of Bridge Pier Displacement Treatment on Soft Ground of Expressway Bridge. Heilongjiang Journal of transportation science and technology, 40(06): 138+140.
[8] Mo Y.H, Xie Y.G. (2020) Application of high-pressure rotary jet grouting in foundation technology treatment. China Building Materials Technology, 29(06): 171-172.