Design of indoor model test system for Post-stiffened core lengthened concrete pile

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Abstract: The post-stiffened core lengthened concrete pile is a kind of composite foundation pile formed after the existing concrete core is inserted into the stiffened core lengthened body through the hole. Based on the pile-forming technology and testing needs of the pile structure, a set of indoor model test system is studied and determined. The system is mainly composed of model groove, loading system and measuring system, and the setting of post-stiffening core section can be realized by controlling the filling time of concrete in the existing concrete core position. The displacement test body is set up on the top of the model pile and the soil around the pile, the stress sensor is set in the pile body and the core body, and the earth pressure sensor is set in the soil around the pile. The test system can form the bearing capacity of pile body (including existing concrete pile and stiffening core section) and soil around the pile from multiple dimensions, and realize the test of pile response under different load combinations by controlling the loading process.

1. Introduction

In the old city reconstruction and other civil engineering projects, how to achieve the retention and bearing capacity improvement of existing concrete piles has become the focus of the engineering community. In this regard, the project team proposed a post core extension concrete pile structure [1], which forms a new composite foundation pile after the core of the existing concrete pile is inserted into the leading hole of the core of the existing concrete pile, which can realize the combined bearing of the core extension and the existing concrete pile. However, due to the short application time of the pile structure in engineering practice, the understanding of its performance in engineering and academic circles mainly comes from the common concrete pile [2-3] with uniform section and the special-shaped pile [4-8], many of the characteristics proved in engineering practice have not been further analyzed and deepened in theory.

Considering that the indoor test is an important method to reveal the working characteristics of foundation piles [9-10], researchers have carried out some research on the bearing capacity of special-shaped piles, such as Wu Zejun et al. [11]. Luo Zhao et al. [12], analyzed the working mechanism of variable section piles, load settlement curve and other issues. Sun Tao et al [13] revealed the influence of geometric characteristics of variable cross-section stiff cement soil pile on bearing characteristics. Yang Qingguang et al. [14], Yin Hongchun et al. [15] studied the horizontal bearing behavior of variable cross-section tubular piles. Wang Zhenbo et al. [16] analyzed the stress characteristics of stepped DX pile with variable cross-section under vertical static load. Ma Jindong et al. [17] studied the mechanical characteristics of I-shaped reinforced concrete piles with variable cross-section under horizontal load and the working performance of pile-soil interaction through scale
model test. Kong Gangqiang et al. [18-19] discussed the bearing capacity characteristics, side friction resistance and the distribution law of earth pressure on the side of the pile. The above research results play a positive role in revealing the bearing capacity of the special-shaped pile and promoting the improvement of the indoor model test device. However, the foundation piles of the above-mentioned test device are all formed in one time, which is difficult to reflect the multi-point and two-way deformation of the foundation pile and the soil around the pile, and it is difficult for the load to be stabilized by the pressure jack. In view of this, on the basis of the existing research results, combined with the need of bearing capacity test of post stiffened lengthened concrete pile, a set of indoor model test device is designed.

2. Preparation of concrete model pile

2.1 Preparation process of concrete model pile
Considering that the diameter range of existing concrete pile is generally concentrated in 600-1000mm, and the pile length is more than 6000mm. According to this, the diameter of the prototype pile is 600mm, the length of the pile is 7000mm and the concrete strength is C35. The indoor model pile is made of C20 concrete, and the specific dimensions are shown in Table 1.

| Pile serial number | Pile diameter/mm | Pile length/mm | Core growth/mm | Core diameter/mm |
|--------------------|------------------|----------------|----------------|-----------------|
| 1#                 | 150              | 600            | —              | —               |
| 2#                 | 150              | 800            | —              | —               |
| 3#                 | 150              | 600            | 200            | 60              |
| 4#                 | 150              | 600            | 200            | 90              |

Note: 1-Lateral filling soil; 2-Existing concrete pile; 3-Auxiliary erection bar; 4-Stiffener extension

The preparation of the model pile (Fig. 1) is divided into two stages: the preparation of the external concrete pile and the pouring of the extension of the core. PVC pipes are used for the model pile mould and the core mould. In order to reduce the difficulty of synchronous removal of the core mould during the pouring construction of the extension of the core, the PVC pipes of the core mould are cut along the central line in advance, then bonded with adhesive tape, and the transverse support bars are inserted inside. When the external concrete pile is poured, the core mould shall be reserved at the pile core in advance to arrange the holes.

During the pouring construction of the extension of the core, the external concrete pile shall be fixed to the set position in the model groove, and then the closed core mold at the bottom and the transverse support bar shall be inserted into the reserved channel of the external concrete pile; after the test system and the soil around the pile are set, the concrete shall be poured into the core mold and the core mold shall be taken out synchronously.
3. model test device design
The test system is mainly composed of model slot, loading system and measuring system. The measurement system is set in the model pile and soil around the pile, and the load in different directions is applied to the model pile through the loading system.

3.1 Preparation of test model tank
In the test, a 1000mm × 1000mm × 1500mm (L × w × h) rectangular model slot was used. The model groove is welded with iron plate and angle steel as a whole, three sides are fixed by fixed angle steel, one side is set with discharge door, and it is connected by bolts. At the same time, in order to improve the accuracy of soil moisture control around the pile, plastic film is laid inside and at the bottom of the model groove.

3.2 Measurement system settings
(1) Pile body strain test
Auxiliary erection reinforcement shall be set inside the external concrete pile and in the stiffening core section respectively. φ 10 plain round reinforcement shall be used as the auxiliary erection reinforcement. The reinforcement stress gauge shall be welded at both ends, bx120-2aa type reinforcement strain gauge shall be set in the middle, and the concrete strain gauge shall be set on the surface of the external concrete pile at even intervals.

(2) Test of variable section earth pressure of pile bottom and pile body
Several ly-350 micro earth pressure sensors are embedded in the lower part of the external concrete pile and the extension along the transverse direction every 1.5cm, and two to three earth pressure sensors are arranged in the lower part of the extension along the height direction. The layout of stress-strain sensor and earth pressure sensor is shown in (Figure 2):

(3) Displacement test of soil around pile top and pile
Considering that under the action of vertical and lateral loads, a certain amount of horizontal and vertical deformation will occur at different depths of pile top and soil around the pile. For this reason, the observation points of horizontal displacement and vertical displacement are respectively arranged at different depths of pile top and soil around the pile. See (Figure 3) for the specific arrangement. The displacement observation point is composed of displacement test rod and dial indicator or displacement sensor. One end is buried in the soil around the pile, and the other end is fixed on the instrument fixed bracket.

![Fig. 2 layout of measuring instruments](image-url)

Note: 1. Lateral filling soil; 2. Existing concrete pile; 3. Auxiliary erection bar; 4. Stiffener extension; 5. Steel stress meter; 6. Concrete strain gauge; 7. Steel strain gauge; 8. Earth pressure sensor
3.3 loading system

The test vertical load is loaded by slow maintaining load method, and the load is provided by hand hydraulic jack. The method of superposition weight is adopted for horizontal load. The load is iron block in the laboratory, and the weight of load is converted into transverse load by fixed pulley.

Before the test, the maximum load that can be borne shall be estimated first, and the loading shall be carried out according to 1/12 of the estimated total load. When the rate of settlement change is too large, the loading amount shall be reduced to control the rate of displacement change until the test termination condition appears.

4. test and test process

4.1 test procedure
4.2 Test process analysis

(1) The external concrete pile and the extension of the core can be respectively applied with the vertical load, the lateral load, and the combination value of the vertical load and the lateral load.

(2) The stress and strain of the external concrete pile and the extension of the stiffener can be collected respectively under the action of load, so as to analyze the bearing capacity of the composite foundation pile after the extension of the stiffener is set.

(3) By analyzing the displacement and earth pressure of the soil around the pile under the action of load, it can be clarified that the combined bearing condition of the composite foundation pile and the soil around the pile and the rationality of the design parameters of the composite foundation pile.

5. Characteristics of test system

(1) Combining closely with the pile forming process of the post stiffened lengthened concrete pile, the scheme of the model pile preparation and the arrangement of the pile body stress-strain test system are studied and determined.

(2) In the model test system, the integral reaction frame and the bottom bearing structure are set up, and the vertical and horizontal loading devices are fixed on the reaction frame, so that the vertical and horizontal loads can be applied synchronously or controlled separately.

(3) According to the response of pile under load, two-way displacement observation points and earth pressure observation points are arranged in the soil around the pile, which can meet the needs of response analysis of soil around different parts of the pile.

6. Conclusion

Based on the needs of construction and bearing capacity analysis of post stiffened extension concrete pile, this paper studies its indoor test and test system, and obtains the following conclusions:
(1) A set of preparation scheme of model pile and model groove consistent with the actual construction is proposed.

(2) A model test system is designed to effectively reflect the response of pile body and soil around the pile.

(3) A load application system that can simultaneously apply vertical and horizontal loads is formed, and a new type of lateral load application method is proposed.

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