Study on the position of load box for pile foundation of Qilu Yellow River Approach Bridge

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Abstract. In theory, the balance point position of O-cell pile test is determined and unique, and the load box should be located at this point. But in practical projects, it is difficult to determine the balance point position accurately. The pile foundation of Qilu Yellow River Approach Bridge bears a large load. In order to reduce the risk caused by the position of load box in O-cell pile test, the double load box technology is adopted in this pile test project. According to the pile design, the soil properties and the loading sequence, the bearing capacity of the pile foundation before and after grouting is estimated. The pile test results show that the project is a successful example for the double load box technology.

1. Introduction
At present, high capacity pile foundation has been widely used in various engineering buildings. The O-cell pile test high capacity pile has the advantages [1-3], such as high capacity pile load, simple operation, good usability, low cost, safe and reliable test. The process of O-cell pile test includes technical links. In the design stage, the balance point position needs to be estimated according to the survey data, pile length and pile diameter. In the construction stage, the load box, displacement measuring equipment and internal force testing components are need to be installed on the pile foundation reinforcing cage. Load test carries out after the concrete strength and foundation soil rest time meet the requirements. Every link in the process of O-cell pile test is very important, and the position of load box can directly affect the test data [4-7]. Because the O-cell pile test equipment is embedded in the pile foundation, the poor test data means that the cost of pile foundation construction and equipment is completely lost, the test site is abandoned and the construction period is delayed. The pile foundation of approach bridge of Qilu Yellow River Bridge has a large bearing capacity. In order to reduce the problem that the load box position deviates from the balance point position, this project adopts double load box technology to test the bearing capacity of pile foundation.

2. Engineering soil layer and pile layout information
The approach bridge of Qilu Yellow River Bridge adopts prestressed concrete continuous beam with a span of 667.2m to 680 m. The soil layer within the exploration scope of pile foundation is mainly Quaternary cover area, and the upper part is Quaternary Holocene alluvium and proluvial. The lithology is silty clay, silt, fine sand and calcareous nodules. The lower part is the Upper Pleistocene Chong proluvial, which is characterized by silty clay, silty fine sand, round gravel and calcareous nodules, with stable distribution; The surface layer is mostly covered with artificial miscellaneous fill, plain fill and flushing fill, etc. The distribution of soil layer along the depth is shown in Figure 1.
According to the geotechnical investigation report of this project, the thickness and mechanical parameters of soil layer are shown in Table 1. Allowable value of bearing capacity of silty clay is 210kPa. Grouting enhancement coefficient prefers to Specifications for Design of Foundation of Highway Bridges and Culverts (JTGD63-2007), and the value of pile side friction correction coefficient refers to Static loading test of foundation pile Self-balanced method (JTT 738-2009).

The design strength grade of concrete for the test pile body is C30, with a pile diameter of 1.2m and a pile length of 63.6m. The bearing layer of the pile foundation is silty clay. The rotary drilling reverse circulation hole-forming construction and underwater concrete pouring technology are adopted, and the pile quality is good. The drilling core of cast-in-place pile is shown in Figure 2. In order to improve the bearing capacity of piles, post-grouting technology is adopted for bored piles, with secondary grouting at the pile end, with the first grouting amount of 970L and the second grouting amount of 790L. The grouting enhancement range is 12m above the pile bottom.

Table 1. Soil thickness and mechanical parameter values

| soil layer         | thickness (m) | Standard value of friction resistance q(kPa) | coefficient of correction γi | Enhancement coefficient of post-grouting βsi βp |
|--------------------|---------------|---------------------------------------------|------------------------------|-----------------------------------------------|
| ①miscellaneous fill| 2.6           |                                             |                              |                                               |
| ②silty clay        | 4.6           | 30                                          | 0.8                          |                                               |
| ③silty clay        | 10.3          | 30                                          | 0.8                          |                                               |
| ④silty clay        | 9.0           | 45                                          | 0.8                          |                                               |
| ⑤silty clay        | 11.1          | 55                                          | 0.8                          |                                               |
| ⑥silty clay        | 3.0           | 55                                          | 0.8                          |                                               |
| ⑥_1silty fine sand | 1.6           | 50                                          | 0.7                          |                                               |
⑥ silt 1.6 45 0.8
⑦ silty clay 17.7 60 0.8 1.4
⑧ silty clay 1.9 70 0.8 1.4 1.8

3. Design of load box position and loading sequence

When the O-cell pile test is used to test the bearing capacity of foundation piles, the displacement value of the upper pile at the balance point is equal to that of the lower pile, but the direction is opposite, and the load box should be set near the balance point as much as possible. It is necessary to calculate the load box position in the pile body. The pile foundation of approach bridge of Qilu Yellow River Bridge has a high bearing capacity. In order to reduce the problem of low bearing capacity caused by the deviation of balance point position in the process of O-cell pile test, this project adopts double load box technology to test the bearing capacity of pile foundation. The load box position is shown in Figure 1. According to the Table 1, the capacity of piles are estimated, and are shown in Table 2.

Table 2. The estimated capacity of pile

| Before grouting | After grouting |
|-----------------|----------------|
| Load upper box  | Load lower box |
| 20590 (upper pile) | 11630 (middle pile) |
| +14910 (lower pile) | 30830 (upper pile) +21500 (lower pile) |
| 14910 (lower pile) | 30830 (upper pile) |
| 20590 (upper pile) | 30830 (upper pile) +21500 (lower pile) |
| 11630 (middle pile) | 21500 (lower pile) |

3.1. Loading before grouting

First, the lower load box is loaded by steps, the increment of each step loading 500×2(kN). The first step is increased by 1000×2(kN). When the lower load box loads to 7000×2(kN), the settlements are still stable, and reached the limit load, then the loading is terminated and unloaded.

Second, the upper load box is loaded in steps, the increment of each step loading 500×2 (kN). The first step is increased by 1000×2(kN), and then loading in equal steps. When the lower load box loads to 6500×2(kN), the settlements are still stable, and the middle pile has been loaded to the ultimate load. When the oil outlet valve of the lower load box is closed and the loading continues to 8500×2(kN), the upper pile body has reached the limit load, then the loading is terminated and unloaded.
3.2. Loading after grouting
First, the lower load box is loaded by steps, the increment of each step loading 750×2(kN). The first step is increased by 1500×2(kN). When the lower load box loads to 10500×2(kN), the settlements are still stable, and reached the limit load, then the loading is terminated and unloaded.

Second, the upper load box is loaded in steps, the increment of each step loading 750×2 (kN). The first step is increased by 1500×2(kN), and then loading in equal steps. When the lower load box loads to 6750×2(kN), the settlements are still stable, and the middle pile has been loaded to the ultimate load. When the oil outlet valve of the lower load box is closed and the loading continues to 8250×2(kN), the upper pile body has reached the limit load, then the loading is terminated and unloaded.

4. Q-s curve of test pile
The whole pile is divided into upper, middle and lower sections by double load boxes. The load-displacement curves of each load box before and after grouting are shown in the figure3 to figure 6. It can be seen from the figures that the upward and downward displacements of the load boxes are fully coordinated. After comprehensive analysis and evaluation, the bearing capacity of each pile section is shown in the Table 3. The pile test results show that the project is a successful example for the double load box technology.

| Table 3. Vertical ultimate bearing capacity of each pile section (kN) |
|---------------------------------|----------------|---------------|----------------|
|                                 | Upper pile     | Middle pile   | Lower pile     |
| Before grouting                 | 7500           | 6500          | 6000           |
| After grouting                  | 7500           | 6750          | 9750           |
5. Conclusions
According to the pile design, the soil properties and the loading sequence, the bearing capacity of the pile foundation before and after grouting is estimated. The Q-s curves of approach bridge pile foundation of Qilu Yellow River Bridge meet the load test requirements. The pile test project is a successful example for the double load box technology.

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