Experimental Study on Base Piles Bearing Capacity of Qilu Yellow River Bridge

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Abstract. Qilu Yellow River Bridge is located in Jinan City, Shandong Province. The main bridge adopts bored pile foundation with high design bearing capacity. In order to ensure that the bearing capacity of single pile meets the requirements and ensure the safety of the bridge, the double load boxes O-cell test pile method is used to test the bearing capacity of pile before and after grouting. According to the soil layer property around pile, the double load boxes can be loaded optionally and solve the problems in the tradition pile test. The bearing capacity of each pile section is determined. The bearing capacity of pile before grouting is 75255 kN, the bearing capacity of pile after grouting is 89100 kN.

1. Introduction

Qilu Yellow River Bridge extends north of Qilu Avenue in Jinan and crosses the Yellow River. The bridge is a composite cross-river channel, including rail, bus, social vehicles, cycling and walking. The total length of the bridge is 6742 meters, the main bridge is 1170 meters long, the main span is 420 meters, and the width is 60.7 meters. The main bridge foundation adopts bored piles with a diameter of 2.0 m, 117.50 m long and a concrete strength grade of C30. The bearing capacity of base pile is very important for bridge safety. The O-cell pile test method is used to test the bearing capacity of base pile before and after grouting. As shown in Figure 1, the O-cell pile test system includes a load box which is embedded in the pile body in advance[1-3]. During the test, loads are applied to the pile bodies which above and below the load box at the same time, so the upper pile and the lower pile provide balanced reaction force to each other. The upper pile is in the upward state, the negative friction of the pile side is gradually exerted, and the lower pile is in the downward state, and the positive resistance of the pile side and the resistance at the pile end are gradually exerted. With above loading process, the bearing capacity of each pile segment can be obtained[4-7].

Fig. 1 O-cell pile test System
2. Soil layer information and equipment layout

2.1. Soil layer information

The soil layer within the exploration scope of the project area is mainly Quaternary overburden, 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 covered with miscellaneous fill, plain fill, flushing fill, etc. The soil layer thickness and mechanical parameters are shown in Table 1. Allowable value of bearing capacity of \( \text{silty clay} \) is 280kPa. 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).

| soil layer | thickness (m) | Standard value of friction resistance q(kPa) | coefficient of correction \( \gamma_i \) | Enhancement coefficient of post-grouting | \( \beta_{si} \) | \( \beta_{pi} \) |
|------------|--------------|-------------------------------------------|-----------------------------|------------------------------------------|----------------|----------------|
| ① miscellaneous fill | 2.6 | | | | | |
| ② silty clay | 4.6 | 30 | 0.8 | | | |
| ③ silty clay | 10.3 | 30 | 0.8 | | | |
| ④ silty clay | 9.0 | 45 | 0.8 | | | |
| ⑤ silty clay | 11.1 | 55 | 0.8 | | | |
| ⑥ silty clay | 3.0 | 55 | 0.8 | | | |
| ⑥1 silty fine sand | 1.6 | 50 | 0.7 | | | |
| ⑥2 silt | 1.6 | 45 | 0.8 | | | |
| ⑦ silty clay | 17.7 | 60 | 0.8 | | | |
| ⑧ silty clay | 1.9 | 70 | 0.8 | | | |
| ⑨ silty clay | 26.5 | 75 | 0.8 | | | |
| ⑩ round gravel | 1.0 | 130 | 1.0 | 3.0 | | |
| ⑪ silty clay | 4.5 | 80 | 0.8 | 1.4 | | |
| ⑫ coarse sand | 1.0 | 70 | 0.7 | 3.0 | | |
| ⑬ silty clay | 7.9 | 90 | 0.8 | 1.4 | 1.8 | | |

2.2. Equipment layout status

According to the distribution of soil around the pile, the axial force meters of pile are buried at the interface of main soil layers, ignoring the sub-layers and thin layers of soil layers. Twelve monitoring points are set up in the base pile, and the specific buried positions are shown in Figure 2.
3. Test procedure

3.1. Testing bearing capacity of base pile with O-cell pile test method before grouting

Firstly, loading the lower box by steps, the increment of each step loading 2,235*2 (kN). The first step loading 4470*2 (kN). When the lower load box gets to 31,290*2 (kN). The settlement of lower pile is stable, the bearing capacity of the lower pile is got, and the loading is terminated and unloaded. Load-
Displacement curves are shown in Figure 3. The axial force distribution curve of pile under each loading step is shown in Figure 4.

Secondly, loading the lower box by steps, the increment of each step loading 1200*2 (kN). The first step loading 2400*2 (kN), When upper load box gets to 15600*2 (kN), the settlement is stable. Close the oil outlet valve of the lower load box, the incremental step loading is 3000*2 (kN), and when the loading continues to 30600*2 (kN), the upper pile approaches the ultimate load. Then the loading is terminated and unloaded. Load-Displacement curves are shown in Figure 5. The axial force distribution curve of pile under each loading step is shown in Figure 6.

3.2. Testing bearing capacity of foundation pile by O-cell pile test method after grouting

Firstly, loading the lower box by steps, the increment of each step loading 2,500*2 (kN). The first step loading 5000*2 (kN), When the lower load box gets to 43,500*2 (kN). The settlement of lower pile is unstable, the bearing capacity of the lower pile is got, and the loading is terminated and unloaded. Load-Displacement curves are shown in Figure 7. The axial force distribution curve of pile under each loading step is shown in Figure 8.

Secondly, loading the lower box by steps, the increment of each step loading 1200*2 (kN). The first step loading 2400*2 (kN), When upper load box gets to 16,000*2 (kN), the settlement is stable. Close the oil outlet valve of the lower load box, the incremental step loading is 3000*2 (kN), and when the loading continues to 31000*2 (kN), the upper pile approaches the ultimate load. Then loading is terminated and unloaded. Load-Displacement curves are shown in Figure 9. The axial force distribution curve of pile under each loading step is shown in Figure 10.
4. Determination of static load test results

With comprehensive analysis Load-Displacement curves and experience evaluation, Vertical ultimate bearing capacity of each pile segment are determined. The data is shown in Table 2.

|                  | Upper pile | Middle pile | Lower pile | Bearing capacity |
|------------------|------------|-------------|------------|-----------------|
| Before grouting  | 30600      | 15600       | 29055      | 75255           |
| After grouting   | 31000      | 15600       | 42500      | 89100           |

5. Conclusions

The double load boxes O-cell test pile method can be used to test the bearing capacity of pile before and after grouting. The test results show that the bearing capacity of the post-grouting bored lower pile is 46% larger than that of without post-grouting.

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