Research on self balance test method and numerical simulation of bearing capacity of pile foundation

Huifeng Su*, Renzhuang Lia and Yujie Lvb

School of Transportation, Shandong University of Science and Technology, Shandong China

*Corresponding author e-mail: skd991970@sdust.edu.cn, a409768738@qq.com, b1358279377@qq.com

Abstract. In order to check whether the pile foundation meets the requirements of bearing capacity and set the position of the test load box reasonably, this paper takes the bearing capacity test of the test pile of the large-scale high-speed railway station as the breakthrough point, and carries out the self balance test on three test piles. At the same time, MIDAS / gtsnx was used to simulate the test process. The axial force and displacement values of three test piles under different loads are measured through the test, and the compressive bearing capacity and the best load box position of the pile foundation are obtained by analyzing and processing the experimental data.

1. Introduction
As a new testing method of pile foundation bearing capacity, the self balance testing method of pile foundation bearing capacity [1] [2] has the advantages of simple testing device, large loading tonnage and high testing accuracy. It has low requirements for the environment and strong adaptability to the site [3] [4]. The loading capacity can be specially designed according to the requirements of pile test [5].

In this paper, based on the theoretical research of self balance detection method in China [6] [7], the influence of load box position, pile top load and self balance load on ultimate bearing capacity is analyzed and discussed by changing the load box.

2. Geological conditions
The lithology of the station building where the test pile is located is mainly quaternary alluvial proluvial rock, tertiary marl and Cretaceous argillaceous sandstone, conglomerate, etc. From top to bottom, they are: (0) arable soil, (1-3) silt clay, (4-3) fine sand, (5-2) medium sand, (6-2) coarse sand, (8-2) Coarse Round gravelly soil, (1-2) marlstone, (4-2) conglomerate, (2-2) argillaceous sandstone. As the cultivated soil and silty clay in the upper layer of the station building have been largely removed after preliminary excavation, the test piles 1, 2 and 3 are mainly distributed in the soil layers of fine sand, Coarse Round gravel soil, marl, conglomerate and argillaceous sandstone. The specific geological longitudinal section is shown in Figure 1. The main parameters of three test piles are shown in Table 1.
Table 1. The pile model main parameters

| Pile number | Experimental pile foundation 1 | Experimental pile foundation 2 | Experimental pile foundation 2 |
|-------------|--------------------------------|--------------------------------|--------------------------------|
| Pile top elevation (m) | 52.01 | 59.55 |
| Pile bottom elevation (m) | 4.51 | 11.55 |
| Pile length (m) | 47.5 | 48 |
| Pile diameter (m) | 1.5 | 1.2 |
| Main reinforcement of reinforcement cage | \( \phi 32 \) |
| Corresponding geological hole No | Jz-Ill16-141 | Jz-Ill16-142 | Jz-Ill16-116 |
| Buried position of load box | Pile bottom up 19m | Pile bottom up 20m | Pile bottom up 15m |
| Concrete | C45 |
| Compressive ultimate bearing capacity (kN) | 28500 | 36000 |
| Pile type | Test pile and engineering pile | Test pile |

Figure 1. Geological profile of the test pile

3. Numerical simulation and field test

3.1. Field test

When the placement position of load box and reinforcement meter is determined and the load box and reinforcement meter are transported to the site, it is necessary to weld the load box and reinforcement cage together in the reinforcement plant, and weld the reinforcement meter on the reinforcement cage according to the preset position. After the welding of the load box and the reinforcement meter is completed, the acoustic pipe and the displacement pipe for measuring the upper and lower displacement shall be placed evenly in each section of the pile. As shown in Figure 2.
3.2. Numerical simulation

In the test, the ground elevation is 52.01 as the horizontal point of the model, and the five soil layers from top to bottom are fine sand, Coarse Round gravel, strongly weathered marl, strongly weathered conglomerate and moderately weathered sandstone. After defining the relevant parameters of each soil layer, the same sowing line is used to control the geometry and the size of test pile 2, so as to ensure the mutual coupling of each node when meshing.

After setting the boundary conditions of the model and defining the relevant construction stage, the simulation calculation is carried out to get the cloud chart of axial force calculation and displacement calculation in different loading stages. As shown in Figure 3 below.

4. Data analysis and comparison

4.1. Test data analysis

Three test piles were tested for self balance 30 days after pouring concrete. Load according to the corresponding oil pressure classification, and record the upper and lower displacement of test pile 1, test pile 2 and test pile 3 and the numerical change of reinforcement meter during loading and unloading. After dealing with the change of the frequency of the reinforcement meter measured by the test pile 1, 2 and 3, the axial diagram of each section of the pile body is obtained and plotted as a curve. [8] As shown in Fig. 4, 5 and 6.
It can be seen from the axial force distribution diagram of three test piles under various loads that the axial force of pile shaft decreases with the increase of the distance between the pile section and the load box. The axial force of the upper pile shaft decreases gradually from the load box to the top of the pile, and the axial force of the lower pile shaft decreases gradually from the load box to the end of the pile, and the axial force of the pile shaft reaches the maximum value at the load box. After obtaining the axial force of test pile 1, test pile 2 and test pile 3 under various loads, the side friction of the test pile is obtained. The data of test pile 2 is shown in Table 2. [9]

| Soil name                | Elevation range(m) | Correction of measured value(kPa) | Geological parameters(kPa) |
|-------------------------|--------------------|----------------------------------|---------------------------|
| Fine sand               | 52.01~50.26        | 30.6                             | 50                        |
| Coarse gravel soil      | 50.26~46.99        | 149.7                            | 135                       |
| Strongly weathered marl | 46.99~16.39        | 210.3                            | 150                       |
| Strongly weathered conglomerate | 16.39~13.29   | 186.9                            | 150                       |
| Argillaceous sandstone  | 13.29~4.51         | 202.5                            | 200                       |

The maximum downward displacement of test pile 2 is 7.38mm, the residual displacement after unloading is 2.83mm, and the rebound rate is 61.6%; The maximum upward displacement is 3.85mm, the residual displacement after unloading is 1.71mm, and the rebound rate is 60.7%. Finally, the Q-S curve, S-lgt curve and S-lgQ curve of test pile 2 are obtained. Then the Q-S curve, S-lgt curve and S-lgQ curve of test pile 2 are processed by the precise transformation method to obtain the equivalent transformation curve of test pile 2, [10] as shown in Figure 7 below.
4.2. Comparison between test value and calculated value

The axial force test values of each section obtained by numerical simulation are extracted and compared with the test values measured by field test to get figure 8. Figure 9 is obtained by comparing the displacement of the upper section and the lower section of test pile 2 obtained by numerical simulation with the displacement of the upper section and the lower section measured by self balance test.

5. Conclusion

The results of numerical simulation are smaller than those of self balance test, but larger than that of design. It is verified that the compressive bearing capacity of test pile 2 is not less than 28500kN.

The maximum axial force of pile body is positively correlated with the compressive bearing capacity of pile body. The best position of the load box is 0.5m upward from the original position of the load box, so it is more practical to determine the position of the load box by numerical calculation combined with theoretical calculation when determining the position of the load box.

The ultimate bearing capacity of pile top is slightly larger than that of self balanced load, and the ultimate bearing capacity of pile top is about 1.2 times of that of self balanced load. Therefore, when the test conditions permit, the pile top surcharge method is preferred to calculate the ultimate bearing
capacity of the pile body. When the test conditions are harsh and the surcharge strength is large, the pile top surcharge method cannot be used to calculate the ultimate bearing capacity of the pile body, the self balance method can be used to calculate the ultimate bearing capacity of the pile body.

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