Research on static load test of foundation piles by self-balance method

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Abstract. The pile foundation static load test is a technique for detecting pile foundation bearing capacity in engineering. In determining the ultimate bearing capacity of a single pile, it is a relatively accurate and reliable test method, which can accurately reflect the stress condition and deformation characteristics of a single pile, and determine the vertical compressive bearing capacity of a single pile. Based on the static test of pile foundation, the process of self-balancing loading method is expounded.

1. Introduction
The static load test of pile adopted in China is the most reliable method to test the bearing capacity of pile. However, for the bearing capacity of pile with large diameter and large tonnage, the equipment required is bulky and expensive, which is difficult to meet the bearing capacity test of pile with special site and large tonnage. The self-balancing test of pile bearing capacity solves the problem of pile bearing capacity test of large tonnage and special site. The self-balancing method of pile bearing capacity has the advantages of large test tonnage, free from the limitation of site conditions, and fast and convenient test. This paper analyzes the bearing capacity and displacement of foundation pile through the test of self-balancing method in a certain area of guizhou province, providing a reference for the future application of self-balancing method of pile bearing capacity.

2. Project Overview
Based on on-site geological survey and drilling data combined with regional geological data, the underlying bedrock of the site is the Triassic Lower Anshun Formation (T\textsubscript{1}a) argillaceous dolomite, which is under the red clay layer. Purplish red, gray white, gray yellow, thin - thick layer, fine crystal structure, dissolution ditch, stone bud more developed, the buried depth is generally 0.00~9.40m, the maximum buried depth is about 17.90m, and the bedrock surface is undulating.

3. Test pile determination
Corresponding to the three engineering piles of ZK2-41, ZK2-92 and ZK2-59 (construction numbers C6, C27, C34 respectively), the static load test is carried out, and the hole forming method adopts manual digging, and the test method is self-balance loading method.
Table 1. The parameters of the pile.

| No. | Pile No. | Pile diameter /mm | Enlarged head diameter/mm | Pile length /m | concrete grade/KN | Design bearing capacity/KN |
|-----|----------|-------------------|---------------------------|----------------|------------------|---------------------------|
| 1   | C6       | 1000              | 1800                      | 12.53          | C30              | 5343                      |
| 2   | C27      | 1000              | 1600                      | 14.87          | C30              | 5343                      |
| 3   | C34      | 1000              | 1600                      | 14.19          | C30              | 5343                      |

4. Test methods and experimental settings

4.1 Test principle

4.1.1 Self-balance loading method

This test was conducted using the self-balancing method. The detection principle is to put a special loading device-load box, which is embedded in the corresponding position in the pile together with the steel cage before the concrete is poured, and the pressure tube of the loading box and other required test devices are led from the pile to the ground, then infused into piles. The pressure pump is loaded on the ground facing the load box, and the load box generates forces in the upper and lower directions and is transmitted to the pile body. Due to the self-acting reaction force of the pile body and the surrounding rock mass of the pile, we will get the data equivalent to two static load tests: above the load box, we obtain the corresponding reaction series parameters of the upper part of the pile during reverse loading; In the lower part of the load box, we obtain the corresponding reaction parameters of the lower part of the pile during forward loading. This principle test pile is called the self-balance force test pile in the domestic industry. This method can be used to provide data basis for design, and can also be used to test the bearing capacity of engineering piles [1-2].

4.2 Experimental device

4.2.1 Loading system

The loading system includes a high pressure oil pump, a special jack, and a high pressure oil pipe. The jack is a professional jack with patent technology. It is characterized by: During the design, the parameters such as the shape and layout of the load box fully consider the space reserved for the tasks such as grouting and replenishing. The design of the jack diameter and the loading area fully takes into account the medium and low pressure of the loading hydraulic pressure and the high bearing capacity after the pile test. The jack is designed with built-in special supercharging technology to generate a large loading force with very low oil pressure, which can greatly reduce the failure rate of the loading system [3-5].

4.2.2 Installation of load boxes

In order to ensure the quality of the pile foundation and the success of the test pile, the following safety measures will be taken when the load box is buried: In order to avoid damage to the pile due to stress concentration during loading, the reinforcement cage stirrups near the load box are properly encrypted. The connection strength between the load box and the steel cage is appropriate to facilitate opening the load box during the test. Because the load box is placed in the middle of the pile, there is a through hole in the center. In order to ensure the thickness of the sediment at the bottom of the pile, it is recommended that the load box and the steel cage be connected into one body. After the hole is closed, the pile bottom is placed at one time.

4.2.3 Determination of vertical ultimate bearing capacity of single pile

Obtained the ultimate bearing capacity of the upper pile of the load box and the ultimate bearing capacity of the lower pile of the load box. Refer to the calculation formula of the bearing capacity in...
the Technical Code for Self-Balance Measurement Method of pile Bearing Capacity (DBJ/T14-055-2009). Vertical compressive ultimate bearing capacity of piles:

\[
Q_U = \frac{Q_{UU} - W}{\gamma} + Q_{UD}
\]  

(1)

\(Q_U\): vertical compressive ultimate bearing capacity (kN) of single pile; 
\(Q_{UU}\): measured ultimate bearing capacity (kN) of the upper pile of the load box; 
\(Q_{UD}\): the measured ultimate bearing capacity (kN) of the pile in the lower part of the load box; 
\(W\): the weight of the upper pile of the load box; 
\(\gamma\): The correction coefficient of the pile side resistance of the upper part of the load box, usually taking the value of 0.75~1.0.

5. Experimental monitoring results and analysis

5.1 Test pile C6 test process and data analysis

According to the field measured data, draw the load box bottom downward, top upward displacement curve Q-s, s-lgQ curve. The correlation curves are shown in Figures 1 and 2. Vertical compressive ultimate bearing capacity of single pile = ultimate bearing capacity of upper pile + ultimate bearing capacity of lower pile, calculated according to formula (1) is 11370kN, which is greater than 2 times of vertical bearing capacity of design single pile, ie greater than 10686kN, and the upward and downward displacements of the load box are small, 12.03mm and 14.68mm. Respectively, so the final test bearing capacity of the test pile is 11370kN.

![Figure 1. Q-s curve diagram of C6 test pile in area C of museum.](image-url)
5.2 Test pile C27 test process and data analysis

According to the field measured data, draw the load box bottom downward, top upward displacement curve Q-s, s-\lg Q curve. The correlation curves are shown in Figures 3 and 4. Vertical compressive ultimate bearing capacity of single pile = ultimate bearing capacity of upper pile + ultimate bearing capacity of lower pile, calculated according to formula (1) is 11319kN, which is greater than 2 times of vertical bearing capacity of design single pile, ie greater than 10686kN, and the upward and downward displacements of the load box are small, 13.18mm and 10.00mm. Respectively, so the final test bearing capacity of the test pile is 11319kN.

Figure 2. s-\lg Q curve diagram of C6 test pile in area C of museum.

Figure 3. Q-s curve diagram of C27 test pile in area C of museum.
5.3 Test pile C34 test process and data analysis
According to the field measured data, draw the load box bottom downward, top upward displacement curve $Q-s$, $s-\lg Q$ curve. The correlation curves are shown in Figures 5 and 6. Vertical compressive ultimate bearing capacity of single pile = ultimate bearing capacity of upper pile + ultimate bearing capacity of lower pile, calculated according to formula (1) is 11345kN, which is greater than 2 times of vertical bearing capacity of design single pile, ie greater than 10686kN, and the upward and downward displacements of the load box are small, 16.15mm,13.09mm. Respectively, so the final test bearing capacity of the test pile is 11345kN.

Figure 5. Q-s curve diagram of C34 test pile in area C of museum.
6. Conclusion
1. The self-balance method pile foundation static load test is convenient and cost-effective. The loadable range of the loading box can also achieve satisfactory experimental results for large-tonnage test installation, and the cost saving is more obvious.

2. The loading box is a one-time product, and the placement position will also have an impact. It should be considered before construction to avoid waste.

3. According to the formula of vertical ultimate bearing capacity of single pile, this paper calculates that at 5500kN, the upper and lower pile sections of loading box are basically in the elastic stage, and the bearing capacity of single pile is more than twice the vertical bearing capacity of single pile.

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