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Application Study of Self-balanced Testing Method on Big Diameter Rock-socketed Piles

Qing-biao WANG[1,2,3*], Zhen-yue SHI[1], Cong ZHANG[1] and Xiaokang WEN[1]

[1]Department of resource and civil engineering of Shandong University of Science and Technology, Taian, Shangdong province, 271019, China
[2]State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences,Wuhan, 430071, China
[3]Shandong Hualian Mining CO.,LTD, Yiyuan, Shangdong province, 251000, China

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Abstract

Through the technological test of self-balanced testing method on big diameter rock-socketed piles of broadcasting centre building of Tai'an, this paper studies and analyzes the links of the balance position selection, the load cell production and installation, displacement sensor selection and installation, loading steps, stability conditions and determination of the bearing capacity in the process of self-balanced testing. And this paper summarizes key technology and engineering experience of self-balanced testing method of big diameter rock-socketed piles and, meanwhile, it also analyzes the difficult technical problems needed to be resolved urgently at present. Conclusion of the study has important significance to the popularization and application of self-balanced testing method and the similar projects.

Keywords: Big Diameter Rock-Socketed Piles; Self-Balanced Testing Method; Bearing Capacity

Introduction

As a concealed work, quality defect of pile foundation can be easily caused by construction technology, construction machinery, testing methods as well as management level and so on. Therefore, the testing of pile foundation is very important. Compared with other testing technologies, self-balanced method for bearing capability testing of pile foundation is characterized by the following aspects[1-2]:

(1)Simple testing installation: it occupies small construction site and has little heaped material. Moreover, it needs no reaction frame and the preparation work of pile foundation testing save time and effort.

(2)Low testing costs: the testing costs can be lowered by 30% to 60% based on the difference s between piles and geological conditions, the greater the tonnage is, the more obvious saving money becomes.

(3)Shorten testing time: pile technology and quality control of test pile are consistent with engineering pile without other requirements on construction machinery and quality control. In addition, test on many piles can be carried out at the same time, as a result, the whole testing time is shortened.

(4)Reusable test pile: pile foundation can be used as engineering piles after the self-balanced testing and also can use grouting pipes give pressure grouting treatment to test pile bottom when it is necessary. Therefore, it can lower the engineering costs of the whole pile foundation.

(5)Convenience for repeatable tests: by using double load cell or multiple load cell technology, repeatable tests can be carried out at the different depth of pile bottom or the same depth of pile bottom at different time. In addition, different effects can be tested before or after the pile grouting.

1. Project summery

Broadcasting centre building of Tai'an is proposed to build in its centre, with the total construction area of about 20000 square meters, underground 2 layers, the ground 20 layers. The building height is 91m. Cast-in-site frame shear—core tube structure is proposed to use bored piles foundation. The largest single column axial force is for 22000 KN.

1.1 geotechnical engineering conditions of the site

Proposed site is located in the west part of two four tectonic unit bordering of Luxi uplift (II), Mountain Tai-Mountain Yi uplift (III), and Mountain Tai bulge. Based on the engineering drilling, the foundation soil of proposed site is divided into five layers according to the difference between formation lithology and karst development characteristics within the scope of exploration depth, including plain fill, sticky clay, clay, karst-fractured development zones and karst-fractured relatively not development zones.

1.2 investigation conclusion and suggestion

41 drilling holes are fixed up at the centre of pile foundation, with the hole's depth between 30.00 and 35.00m, regarding

* E-mail address: 1349725165@qq.com
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entering the complete or relatively complete bedrock as the basis of the final hole. The drilling workload is 1415.30m/41 hole.

(1) Proposed project should adopt big diameter bored pile foundation, taking the five layers karst-fractured relatively not development zones as the pile end's bearing stratum. Moreover, the pile end should enter the karst-fractured relatively not development zones no less than 0.50m.

(2)The formation conditions of 16#、46#、47# drilling is very complicated, and there is no pile end' s bearing stratum can satisfy with the rock-socketed piles ' requirements. It is recommended that using the high-pressure grouting to fill rock-socketed pile and giving it karst cave fracture treatment.

(3) We can know the 9# and 16# holes are key control points in the construction of pile foundation through drilling. Self-balanced method for compressive vertical bearing capacity of single pile should be carried out to man-excavated rock-socketed piles of proposed project, with the view to making sure single pile vertical bearing capacity of the two test piles (9#、16#) meet the design requirements.

2. Self-balanced test equipment installation

2.1 Choice of load cell location

The load cells which used in this project's test are both installed at the bottom of pile. It conducts pile lateral friction and pile end bearing capacity as the counterforce device by using step loading and unloading method. In addition, it takes tester to control loading and unloading quantity as well as uses displacement meter measuring the displacement under load at all levels.

2.2 features of load cells

The load cells used in this project are developed by Tomer System B.V. (see Fig. 2.1) they are characterized by the following aspects:

Fig. 2.1 The load cell

(1)The design should be carried out according to load cell shapes and layout forms. Grouting, acoustic measurement and pulp complementation etc should also be taken into full consideration.

(2)In accordance with project data, load cell end will be designed into cone conductor, which contributes to laitance diversion produced during the process of grouting.

(3)The design of load cell diameter and loading area should give attention to low pressure of loading hydraulic as well as the high bearing capacity of pile after the test.

2.3 installation and placement of load cells

(1)In order to guarantee the pile not destroyed by the stress concentration produced by loading, the stirrup of reinforcement cage nearby the load cell should be infilled appropriately.

(2)The connection strength between load cell and reinforcement cage should be properly with the view to opening the loading cell easily during the test.

(3)The joint between load cell and reinforcement cage should be welded into cone positive reinforcement with the purpose of penetrating the grouting pipe into the center of load cells.

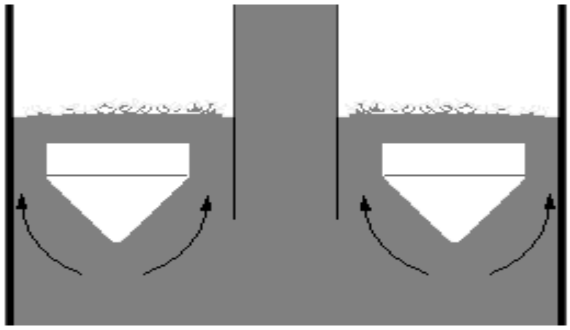
Fig.2.2 Float plasma diversion principle

2.4 data sensing device[3]

2.4.1 Displacement sensor

Faint displacement should adopt coat protection pipe so as to simplify the installation procedure and improve testing precision. Several groups of faint displacement are lead to the pile top form the monitoring point section. Special devices are used to fix these faint displacements and read the average of displacement. The displacement value is measured by the displacement sensor and its resolution reaches to 0.01mm.

2.4.2 Displacement measurement principle

Fixed structure design and installation of displacement sensor should be able to guarantee enough stiffness and stability, which shall not affect the detection results. In addition ,it should ensure that the displacement measurement value is only affected by pile displacement and datum beam movement.

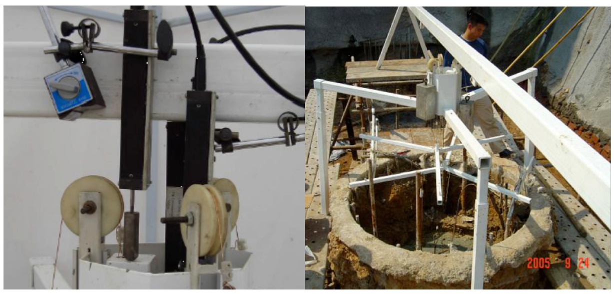
Fig.2.3 Displacement measurement principle

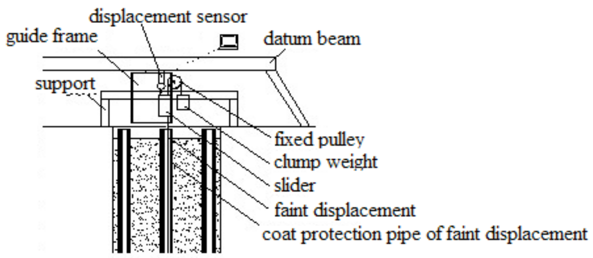

Fig.2.4 Measuring structure examples

The principle is shown as Fig.2.3, example is shown as Fig.2.4

3 self-balanced testing data analysis

3.1 Testing Data.

Specific analysis is only given to selected 1#test pile with pile diameter 1500mm,pile length 17.61m and depth of rock-socketed 3.00m.Characteristic value of the design capacity is 15890KN,The testing data are shown in Table3.1 and shown in Figure 3.1 to 3.4

Tab. 3.1 inspection data summary chart of 1# testing pile

program \ load		0	9600	14400	19200	24000	28800	33600	38400	43200	48000
time (min)	level	0.00	60	60	60	60	60	60	60	60	60
	calculation	0.00	60	120	180	240	300	360	420	480	540
Upper displacement (mm)	level	0.00	0.04	0.04	0.06	0.08	0.09	0.07	0.08	0.10	0.12
	calculation	0.00	0.04	0.08	0.14	0.22	0.31	0.38	0.46	0.56	0.68
Unloading (mm)		0.42	0.49	—	0.55	—	0.60	—	0.64	—	—
Lower displacement (mm)	level	0.00	-0.58	-0.24	-0.31	-0.39	-0.36	-0.37	-0.25	-0.28	-0.12
	calculation	0.00	-0.58	-0.82	-1.13	-1.52	-1.88	-2.25	-2.50	-2.78	-2.90
Unloading settlement (mm)		-2.51	-2.66	—	-2.73	—	-2.80	—	-2.85	—	—

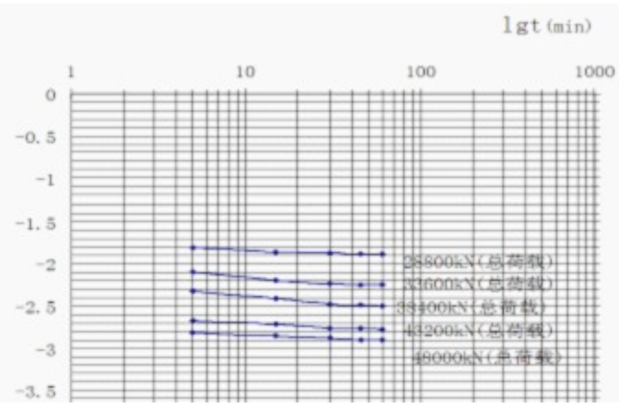

Fig.3.1 Sup－lgtcurve of 1# testing pile

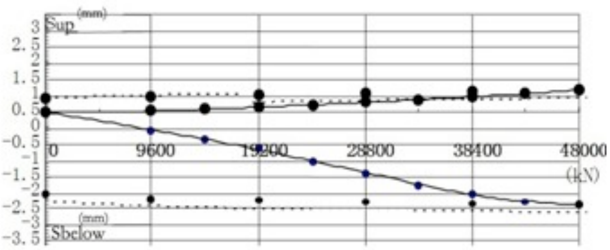

Fig.3.3 Q－S curve of 1# testing pile

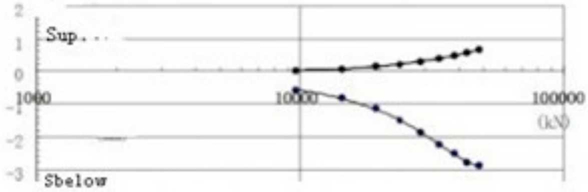

Fig.3.4 Sbelow－lgQ total curve of 1# testing pile

3.2 testing conclusion

According to the above data statistics, single pile ultimate bearing capacity of testing pile is shown in table 3.2.

Tab.3.2 single pile ultimate bearing capacity

No.	single pile ultimate bearing capacity（kN）			
	Q—S method	S—lgt method	S—lgQ method	Certain value of testing
1#	≥48000	≥48000	≥48000	48000
2#	≥26000	≥26000	≥26000	26000

Under the force of 48000kN, up displacement of 1# test pile is 0.68mm and under displacement is 2.90mm within the ultimate restriction. So we make sure that single pile ultimate bearing capacity of 1# testing pile is 48000kN. Similarly, 2# testing pile is 26000kN.

4 key technology of self-balanced testing method of big diameter rock-socketed piles

4.1 choice of balance position

To the greatest extent, the load cells are installed at the bottom of pile. It conducts pile lateral friction and pile end bearing capacity as the counterforce device, which can make the dead weight and friction resistance get full play[4].

4.2 Choices of load cells

Load cell shapes and layout forms should be paying attention to when choose the load cells. Moreover, grouting, acoustic measurement and pulp complementation etc should also be taken into full consideration. Load cell end will be designed into cone conductor, which contributes to laitance diversion produced in the process of grouting. As a result, laitance can be prevented from depositing on the load call end so as to make sure the accuracy of test displacement data. At the same time, it also can guarantee pile strength and bearing capacity after pulp complementation. Referring to the design of load cell diameter and loading area, attention should be give to low pressure of loading hydraulic as well as the high bearing capacity of pile after the test.

4.3 Load cell production

In order to ensure the accuracy, roof and floor of load cell as well as its upper and lower reinforcing cage must be welded into a strong overall. In addition, horn reinforcement is welded on the roof and floor of load cell as well as it's upper and lower reinforcing cage horn bar. The pouring of pile concrete shall be finished a time so as to avoid load cell bottom appearing loose section effectively.

4.4 Installation and placement of load cells

The stirrup of reinforcement cage nearby the load cell should be in filled appropriately. What's more, the connection strength between load cell and reinforcement cage should be properly with the view to opening the loading cell easily during the test. The joint between load cell and reinforcement cage should be welded into cone positive reinforcement with the purpose of penetrating the grouting pipe into the center of load cells.

4.5 Choices of displacement sensor and its installation
Faint displacement should adopt coat protection pipe so as to simplify the installation procedure and improve testing precision. Several groups of faint displacement are lead to the pile top form the monitoring point section and special devices are used to fix these faint displacements. Fixed structure design and installation of displacement sensor should be able to guarantee enough stiffness and stability, which shall not affect the detection results.

4.6 Determination of the bearing capacity
Single pile ultimate bearing capacity in self-balanced testing method on big diameter rock-socketed piles can be determined in accordance with the displacement load. To steep deformation Q - S curve, we should take the part which obvious changes have taken place in the curve as the starting point. For slow deformation Q - S curve, ultimate side resistance of the upper segment of a pile should take S ＋ = 40 mm load corresponding to the upward displacement, and ultimate bearing capacity of lower segment of a pile should take S - = 40 mm load. In addition, big diameter rock-socketed pile take corresponding load S = 0.05 D (D for pile end's diameter) [5,6,7,8].

5. Existing problems in self-balanced testing method on big diameter rock-socketed piles

This paper only studies on self-balanced testing technology. Many shortcomings and deficiencies are still existed owing to limited time, engineering, ability and other various factors. According to the relevant data and personal experience, further study should be carried out in the following aspects:

(1)Determination of balance point: this is still the technical problems have yet to be solved. Selection of load cell balance point is the most key technical problem in the test, so balance point of pile reaction must be calculated accurately before the test. The exact selection of balance point is of great difficulty because of diversity of geological structure, complexity of interaction mechanism between pile foundation and variety of underground water level etc. At present, the use of self-balanced mothod to determine bearing capacity of pile foundation is just the preliminary verification for the bearing capacity of engineering pile.

(2) Determination of conversion coefficient: if the value of composite conversion coefficient K does not make a reasonable determination, analyzing results will be badly affected. Value of composite conversion coefficient K has great difference in different countries, different areas and different projects. Therefore, a large number of actual engineering materials need to be analyzed and researched in order to improve the accuracy of the self-balanced data conversion.

(3)Positive and negative friction: bigger differences are existed between stress mechanism, stress and displacement of self-balanced test piles and actual load conditions of engineering piles. Piles receive top pressure load from top to bottom in the self-balanced test piles, which is different from negative friction resistance of uplift piles. Therefore, further study and deeply analysis is necessary.

(4) Pile integrity: the pile is divided into two parts (the upper part and lower part) after the test, especially on the condition of test piles using as engineering piles. How to restore the integrity of piles effectively, further exploration and research need to be done in engineering practice.

6. Conclusion

Broadcasting center building of Tai'an has been put into operation for more than 3 years. The monitoring to foundation and superstructure shows that test piles can work normally, meeting the designed bearing capacity requirements. In addition, it also verities the feasibility and reliability of self-balanced test method, as well as provides theoretical basis and support for self-balanced testing method on big diameter rock-socketed piles. It is inevitable for self-balanced testing technique to have a broad prospect of application due to its advantages in technology and economic.

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