IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Double layer load cell test of self-balanced method for bearing capacity of super-long bored piles

To cite this article: Yuzhu Cheng 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **295** 042038

IOP Conf. Series: Earth and Environmental Science **295** (2019) 042038 doi:10.1088/1755-1315/295/4/042038

Double layer load cell test of self-balanced method for bearing capacity of super-long bored piles

Yuzhu Cheng[1,a]

[1]Zhejiang Provincial Institute of Communications Planning, Design & Research, 310015 Hangzhou, China

[a]Corresponding author: 37767126@qq.com

Abstract. The large diameter super-long bored pile's bearing capacity is generally very high. The self-balanced method is a new type of static load test method, and it is suitable for the test. At Yueqing Bay No. 1 Bridge, a pile with diameter of 2500 mm and length of 112.0 m was discussed in detail. The post grouting technology at pile bottom was used. The self-balanced method was carried out before and after post grouting. The double layer load cell test method was introduced. The ultimate bearing capacity of the upper, the middle, and the lower part piles were obtained. The test results were converted to the traditional top-down method. The ultimate bearing capacity before grouting was 46932 kN, and it was 70680 kN after grouting. The increment percentage was 50.6%.

1. Introduction

Large diameter super-long bored piles are used widely as bridge foundations in China. To ensure the structural safety, the bearing capacity of the pile should be checked. The most reliable test method is the static load test. Traditional static load tests include the kentledge method and the anchor pile method. However, these methods are sometimes unsuitable for certain conditions, for example, piles in water or on slope, piles of high loading capacity([1]).

Recently, a new type of static load test, the self-balanced method, has been developed. This method can be used in the bearing capacity test of bored piles, PHC piles, steel pipe piles, even caissons and diaphragm walls. The self-balanced method has the advantage of time saving, less expensive, unlimited to the loading capacity, and it is especially suitable for tests in water or on slope([1-4]).

In this paper, the tests of large diameter super-long piles in Yueqing Bay No. 1 Bridge are introduced. The post grouting technology in construction is reviewed. The double layer load cell test of self-balanced method is performed before and after post grouting. The test results are compared and discussed.

2. Test piles and site conditions

The Yueqing Bay No. 1 Bridge is a sea cross bridge. 3 test piles are selected and tested. The main parameters of the test piles are shown in Table 1. In this paper, the representative test pile YZ02-4# is introduced in detail.

The positon of load cell for the test pile YZ02-4# is shown in Fig. 1. The below load cell is at 2.0 m above the pile bottom, and the above load cell is at 27.0 m above the pile bottom.

Table 1. Test pile parameters

No.	Diameter/mm	Length/m	Load cells
YE31-2#	2000	88.0	2
YZ01-5#	2500	89.0	1
YZ02-4#	2500	112.0	2

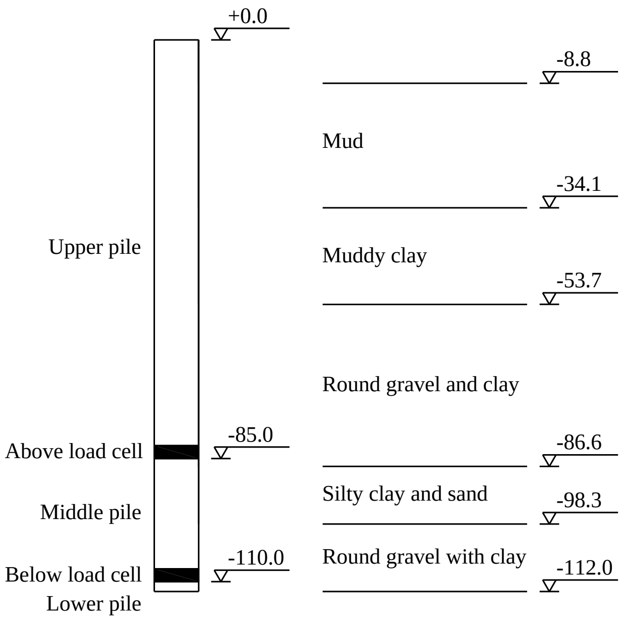

Figure 1. Load cell position and soil layer for test pile YZ02-4#.

For the soil layers at the test pile YZ02-4#, the mud surface elevation is -8.8 m. From mud surface to the depth of about 45 m, it is mainly mud and muddy clay. The soil layers below are mainly rounded gravel and clay. See Fig. 1 for the details.

3. Post grouting

To increase the bearing capacity of the bored pile, the post grouting technology at the pile bottom were used. For test pile YZ02-4#, 3 U-shaped grouting pipe system were used, see Fig. 2([5-6]).

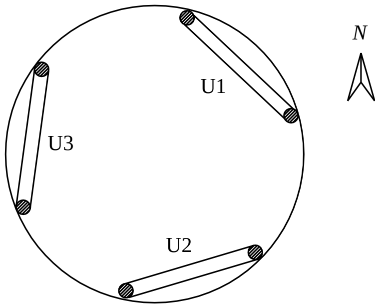

Figure 2. U-shaped grouting pipe system.

IOP Conf. Series: Earth and Environmental Science **295** (2019) 042038 doi:10.1088/1755-1315/295/4/042038

Totally 7.59 t cement was grouted into the soil layer below the pile bottom in 3 times, at the grouting pressure of 3.91-4.96 MPa.

4. Self-balanced method

4.1 Principle of the test method

The principle of the test method is shown in Fig. 3([1]).

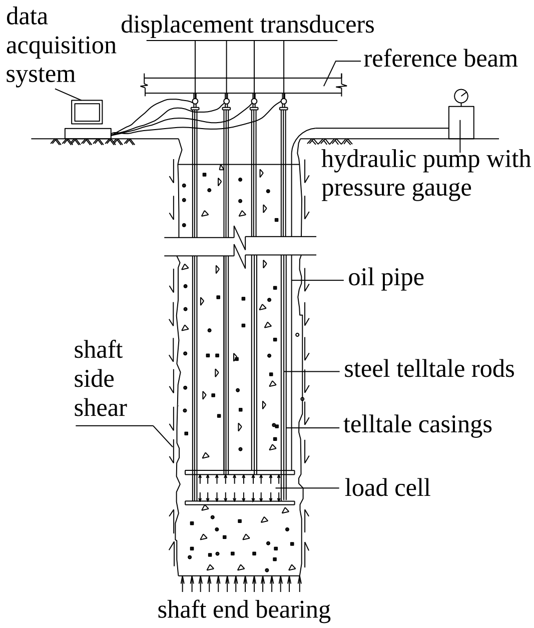

Figure 3. Principle of self-balanced method.

The load cell is installed in the pile, and the pile is separated into two parts by the load cell. The load cell works in two directions, upward mainly against shaft side shear and self-weight, downward mainly against shaft side shear and shaft end bearing. So the upper part pile and the lower part pile's bearing capacity are tested against each other([1-4]).

The displacement of the upper and lower part piles are recorded through steel telltale rods by the computer, and the load applied can be controlled by the hydraulic pump. Thus, the two part's bearing capacity can be obtained([1]).

4.2 Double layer load cell test

For large diameter super-long bored piles, the double layer load cell test is often used, as shown in Fig. 4([7-9]).

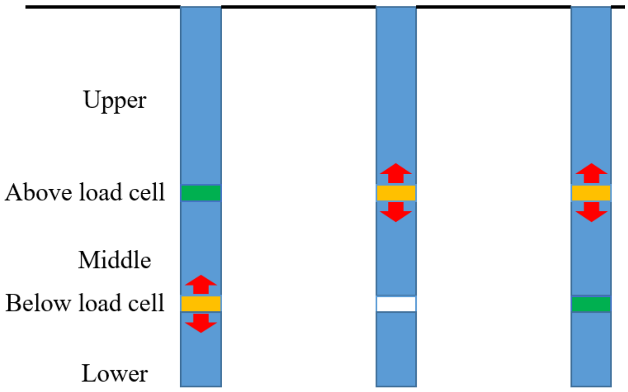

Figure 4. Double layer load cell test.

The test pile is divided into the upper, middle and lower parts by the load cells. Be well designed, the bearing capacity of three part piles should satisfy([7-9]):

$$Q_{upp}+Q_{mid}>Q_{low} \quad (1)$$

$$Q_{upp}>Q_{mid} \quad (2)$$

$$Q_{upp}<Q_{mid}+Q_{low} \quad (3)$$

Firstly, loading the below load cell, the lower part pile's bearing capacity Q_{low} can be tested. Secondly, keeping the below load cell open and loading the above load cell, the middle part pile's bearing capacity Q_{mid} can be tested. Thirdly, keeping the below load cell closed and loading the above cell, the upper part pile's bearing capacity Q_{upp} can be tested.

The load cells used in the test pile are shown in Fig. 5 and Fig. 6.

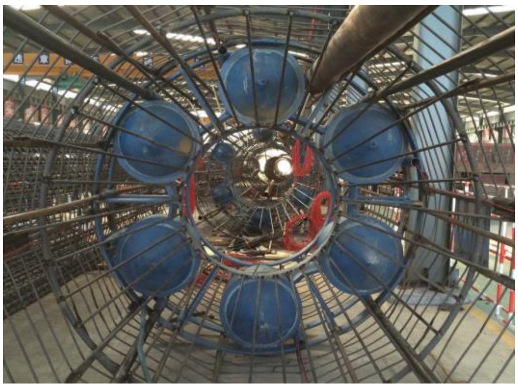
Figure 5. Load cells welded to the steel cage.

IOP Publishing
doi:10.1088/1755-1315/295/4/042038

Figure 6. Lowering down of steel cage with load cell.

5. In situ test

On Oct 31, 2014, the below load cell test was started before grouting. When loaded to 2×17333 kN, the lower part pile failed, and the Q_{low} was 16000kN. On Nov 8, 2014, the above load cell test was started. When loaded to 2×13333 kN, the middle part pile failed, and the Q_{mid} was 11667 kN. Then the middle and the lower part piles were connected together. When loaded to 2×23333 kN, the upper part pile failed, and the Q_{upp} was 21667 kN.

The in situ test pictures were shown in Fig. 7 and Fig. 8. The test curves before grouting were shown in Fig. 9.

Figure 7. In situ test platform.

Figure 8. Test controlling system.

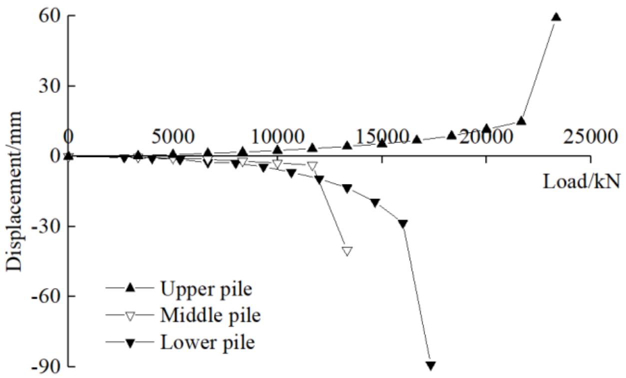

Figure 9. Test curves before grouting.

On Nov 26-27, 2014, the post grouting at pile bottom was carried out, see “3 Post grouting”.

On Dec 27, 2014, the below load cell test was started after grouting. When loaded to 2×32000 kN, the lower part pile failed, and the Q_{low} was 29333 kN. On Dec 28, 2014, the above load cell test was started. When loaded to 2×21667 kN, the middle part pile failed, and the Q_{mid} was 20000 kN. Then the middle and the lower part piles were connected together. When loaded to 2×25000 kN, the upper part pile failed, and the Q_{upp} was 23333 kN.

The test curves after grouting were shown in Fig. 10.

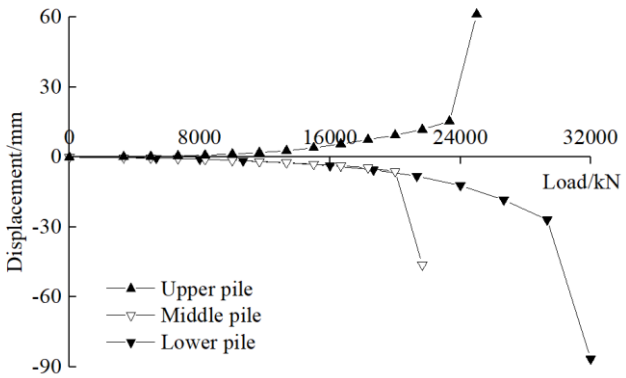

Figure 10. Test curves after grouting.

6. Test results and analysis

6.1 Bearing capacity

According to the test standard, the bearing capacity of the test pile can be calculated by([3-4]):

$$Q_u = \frac{Q_{upp} - W}{\gamma} + Q_{mid} + Q_{low} \quad (4)$$

Where Q_u is the total ultimate bearing capacity; Q_{upp}, Q_{mid} and Q_{low} are the tested ultimate bearing capaicty for the upper, middle, lower part piles; W is the self-weight of the upper part pile; γ is the correction factor, for clay and silt γ=0.8, for sand γ=0.7, for rock γ=1.0, for multi-layered soil, weighted average value could be used([3]).

The bearing capacity results before and after grouting of the test pile YZ02-4# are shown in Table 2.

Table 2. Bearing capacity results

Grouting	Q_{upp}/kN	Q_{mid}/kN	Q_{low}/kN	W/kN	γ	Q_u/kN
Before	21667	11667	16000	6255	0.8	46932
After	23333	20000	29333	6255	0.8	70680

From Table 2, the ultimate bearing capacity after grouting has increased 23748 kN, and the increment percentage was 50.6%. It means that the post grouting technology is very effective, even for the large diameter super-long bored piles.

6.2 Equivalent curve

According to the test standard, the tested curves obtained from self-balanced method can be converted to the traditional top-down curve([3-4]). The equivalent curve of the test pile YZ02-4# is shown in Fig. 11.

Fig 11 shows that the ultimate bearing capacity of the pile after grouting has increased significantly, and the settlement corresponding to the same load value is also reduced. This means that the post grouting can both increase the bearing capacity and reduce the settlement of the pile.

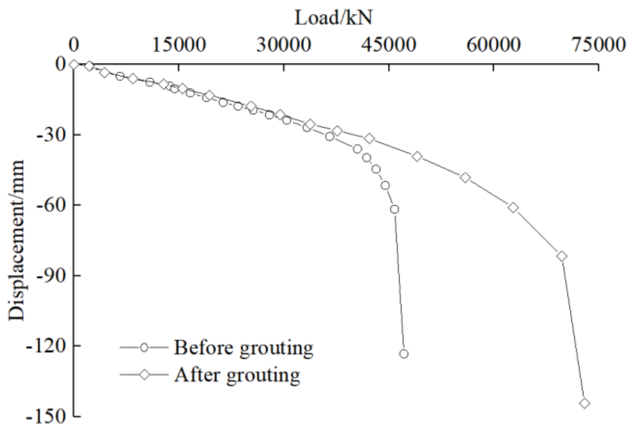

Figure 11. Equivalent curve of test pile.

6.3 Bottom bearing capacity

Strain gauges were installed along the pile, and the bottom bearing capacity of the test pile was obtained before and after grouting.

The tested results were shown in Fig. 12.

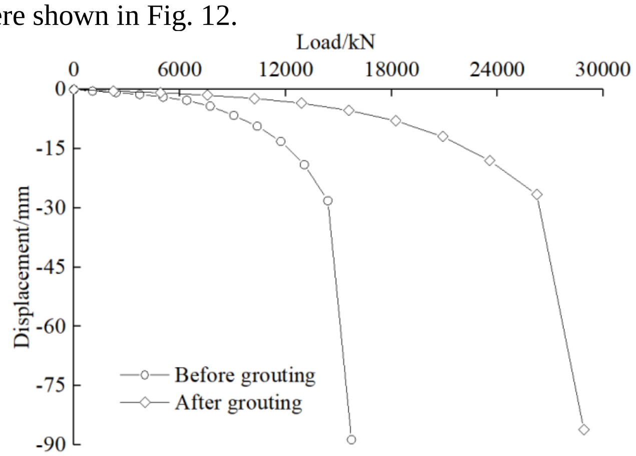

Figure 12. Tested curve of bottom bearing capacity.

IOP Conf. Series: Earth and Environmental Science **295** (2019) 042038 doi:10.1088/1755-1315/295/4/042038

From Fig. 12, the bottom ultimate bearing capacity before grouting is 14397 kN, corresponding to the displacement of 28.18 mm. The after grouting value is 26233 kN and 26.57 mm. The bottom bearing capacity has increased 11836 kN, and the increment percentage is 82.2%.

The bottom support layer for the test pile YZ02-4# is rounded gravel with clay. The tested post grouting increment factor is 1.82. According to the pile design code, the increment factor for gravel is 2.2-2.5, and 1.5-1.8 for clay([10]). It reveals that the increment factor is much more close to the clay. For practical, the design value for rounded gravel with clay should take the upper value of clay.

7. Conclusion

Large diameter super-long piles were used in Yueqing Bay No. 1 Bridge. Double layer load cell tests of self-balanced method were carried out. The following conclusions could be drawn on the test results and analysis.

1. The self-balanced method is suitable for site conditions which is difficult for traditional static load test. It can be used for the test of large loading capacity bored piles.
2. The double layer load cell test can get the upper, middle, lower part piles' ultimate bearing capacity precisely, and it is suitable for super-long bored pile's test.
3. The post grouting technology can significantly increase the bearing capacity of the bored pile, and it can reduce the settlement at the same time.
4. The tested post grouting increment factor is 1.82 for rounded gravel with clay. The design value should take the upper value of clay for practical usage.

References

[1] W.M. Gong, and G.L. Dai. *Pile bearing capacity Testing Self-balanced Technology—Research and Application*(China Architecture & Building Press, 2016)
[2] W.M. Gong, G.L. Dai, Y.S. Jiang, et al. Theory and practice of self-balanced loading test for pile bearing capacity. Journal of Building Structures, 82-88(2002)
[3] JT/T 738-2009. *Static loading test of foundation pile - Self-balanced method*(2009)
[4] JGJ/T 403-2017. *Technical specification for static loading test of self-balanced method of building foundation piles*. (2017)
[5] Z.C. Wang, L. Wang, Y.L. Xia, et al. Pile bottom post grouting technology and effect analysis of pile foundation of Yueqing Bay Bridge. China Water Transport. **17**, 198-200(2017)
[6] Y.H. Ruan. *Research on pile-end post grouting of bridge in Taizhou Coastal Freeway*.(2016)
[7] X.H. Ouyang. Study on application of double load box self-balance method for measuring the bearing capacity of super long pile foundation. Construction Technology. **47**, 88-91(2018)
[8] C.Z. Gong, C.L. He, J. Hong. Application analysis of dual-load cell testing method based on self-balancing technology. Building Science. **26**, 75-78(2010)
[9] Y. Hu. Self-Balanced Approach for bearing capability of major diameter long piles using double load cell. Highway Engineering. **35**, 128-133(2010)
[10] JTG D63-2007. *Code for design of ground base and foundation of highway bridges and culverts*(2007)