Study on the Bearing Capacity of Post Grouting Bored Pile with Hole Dry Drilling by Rotary Rig Based on the Self-Balanced Method

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Abstract: Based on a project of high level middle pile foundation in Karst area of Guizhou, this paper carries out the self-balanced static load test on post grouting bored piles with holes dry drilling by rotary rig. Through the test and the analysis of 6 bored piles in the construction site, it is found that in Karst areas, the bearing capacity of rotary drilling bored piles improves after post-grouting; the deformation resistance capacity improves significantly.

1. Introduction

Holes drilling by rotary rig have the advantages of accurate alignment, high verticality and flexible positioning. When placing the pile casing, pile casing drivers can be used, which make the process faster with small deviation and accurate positioning. The time of dry hole forming is short, leading to merits of thin mud cake, small slurry proportion and good wall protection effect. The friction resistance of the pile can be increased to a certain extent.

However, when the bored pile is drilled by rotary drilling machine, it often has low quality and reliability, which are mainly reflected in the relatively thick sediment at the pile end. It greatly affects the bearing capacity of the pile. The post grouting technology can be used for the pile body, especially for the bottom of the pile after the pile is completed. It can effectively consolidate the sediment at the pile end and improve the side friction of the rock socketed section, thus greatly improves the bearing capacity and the deformation resistance performance of the pile.

In order to verify the influence of post grouting method on the bearing capacity and the deformation performance of the pile body, we tested six piles in a practical project. The self-balanced method was used in the experiment.

Conditions of the stratum where the piles located are obtained through the site investigation report.

The plastic red clay: average load-bearing: γ=17.9kN/m^3; compression modulus: Es=4.33MPa; characteristic value of bearing capacity: fak=170kPa; cohesion: C_k=27.7kPa;

The moderately weathered limestone: characteristic value of pile end bearing capacity: qpa=5000kPa; characteristic value of bearing capacity: fak=5000kPa; average load-bearing: γ=24.55kN/m^3.

2. Post Grouting Dry Bored Pile

Three steel pipes are evenly arranged along the reinforcement cage as grouting pipes, which are bound and connected with the reinforcement bars of the reinforcement cage. The top of grouting pipe is 60cm higher than the ground to facilitate grouting. The grouting pipes are bound at the outside of the stiffening hoop and trapped with the hoop of the reinforcement cage; the bottom of the longitudinal reinforcement shall be flush. After the final setting of concrete, the grouting pipes are split with clear water. Grouting at the pile bottom has two important functions. First is to dredge the grouting channel; second is to press fine grains in the sediment and mud layer into the grouting range. The grouting slurry is prepared by PO 42.5 ordinary silicate cement; the water cement ratio is 0.5-0.6. The diluted slurry is first grouted, and then the concentrated slurry is grouted. The grouting pressure should reach the required final pressure, and the final pressure should be maintained for 10

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minutes to 15 minutes. The final pressure should be 2-3 times of the initial pressure. After the grouting, the end of the grouting pipe is sealed mechanically. The slurry should be sealed for at least 24 to 48 hours before evacuation, so as to prevent the local dilution of groundwater to the slurry, resulting in the reduction of the consolidation strength.

3. The Test Method

The self-balanced method was founded and patented by the Afar Vasela company. The detection principles are as follows. A special loading device is embedded in the corresponding position of the pile together with the reinforcement cage before the concrete placement (the specific position depends on the different purposes of the test). The pressure pipe of the loading box and other required testing devices (such as the displacement) are introduced from the pile body to the ground, and then the filling pile is made. The pressure pump presses and loads the load box on the ground; the load box generates forces in the upper and lower directions, and transmits them to the pile body. The self-counter forces can provide data equivalent to two static load tests. For the part above the load box, we can obtain corresponding reaction parameters of the upper part of pile under the reverse load; for the part below the load box, we can obtain corresponding reaction parameters of the lower part of pile under the forward load. Through the calculation and analysis of the relationship between the loading forces and these parameters (such as the displacement), we can not only obtain the bearing capacity of the pile foundation, but also obtain a series of data such as the lateral resistance coefficients of each layer of soil, the lateral resistance of the pile, as well as the bearing capacity of the pile end.

4. Results of the Test

During the self-balanced test of pile foundation, the pile body below the load box moves downward, while the pile above the load box moves upward. The situation cannot effectively represent the phenomenon of pile foundation sinking under the load. Therefore, it is necessary to transform the data of pile foundation settlement obtained from the self-balanced test into the traditional load settlement curve.

The formulas which convert settlement data obtained from the balance test into traditional load settlement curve are as follows.

$$Q = KQ^{+} + Q^{-} \tag{1}$$

$$\Delta S = \Delta S_1 + \Delta S_2 \tag{2}$$

In the formulas:

Q : traditional bearing capacity of statically loaded piles;

Q^{+} : friction resistance of the part of pile above the load box (the self weight of the upper part of pile has been deducted);

Q^{-} : friction resistance of the part of pile below the load box;

K : collateral resistance correction coefficient of the part of pile above the load box;

ΔS_1 : displacement of the part of pile above the load box;

ΔS : settlement displacement of the pile;

ΔS_2 : displacement of the part of pile below the load box;

The six piles are numbered as E5-11, E5-101, E5-58, E5-77, S-129 and E5-88. The load settlement data obtained from the field pile foundation self-balanced test are transformed to obtain the traditional load settlement curves. Specific data are as follows.

Table 1 E5-11 Pile Top Load Equivalent Conversion Data (Self-Balanced Static Load Test of Foundation Pile)

No	Pile-top equivalent load, P (kN)	Displacement corresponding to pile-top equivalent load (mm)
0	0	0.00
2	1917	1.03
3	2985	2.23
4	4054	3.24
5	5123	5.16
6	6192	7.85
7	7260	11.85
8	8329	14.22
9	9398	18.73
10	10467	26.09

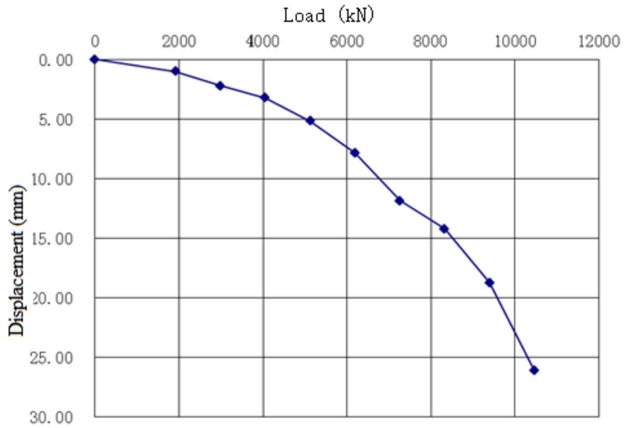

Fig.1 E5-11 Pile Top Equivalent Conversion Curve

Table 2 E5-101 Pile Top Load Equivalent Conversion Data (Self-Balanced Static Load Test of Foundation Pile)

No.	Pile-top equivalent load, P (kN)	Displacement corresponding to pile-top equivalent load (mm)
0	0	0.00
2	2640	0.72
3	4170	1.20
4	5700	1.80
5	7230	2.39
6	8760	3.16
7	10290	3.87
8	11820	4.84
9	13350	5.70
10	14880	6.77

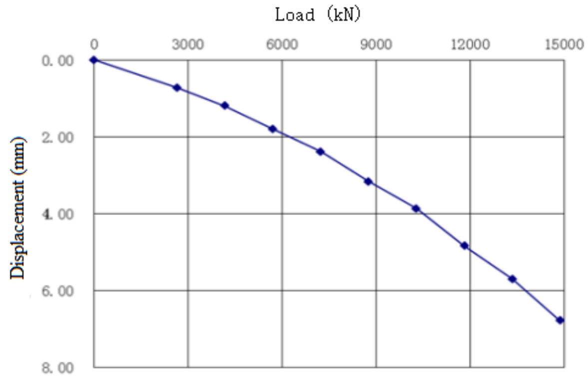

Fig.2 E5-101 Pile Top Equivalent Conversion Curve

Table 3 E5-58 Pile Top Load Equivalent Conversion Data (Self-Balanced Static Load Test of Foundation Pile)

No.	Pile-top equivalent load, P (kN)	Displacement corresponding to pile-top equivalent load (mm)
0	0	0.00
2	2397	1.40
3	3781	2.44
4	5165	3.63
5	6548	5.28
6	7932	6.63
7	9316	8.62
8	10700	10.69
9	12083	13.57
10	13467	16.08

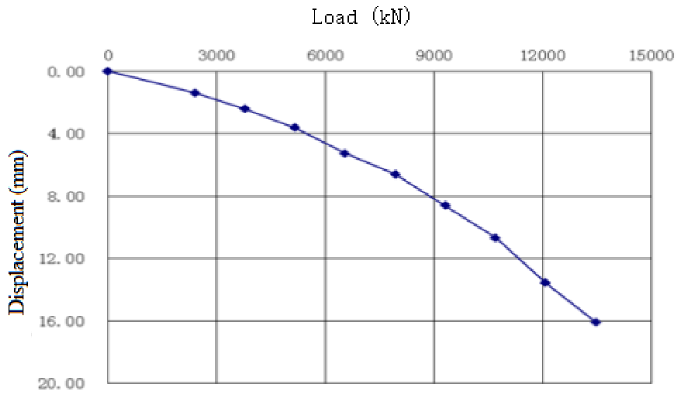

Fig.3 E5-58 Pile Top Equivalent Conversion Curve

Table 4 E5-77 Pile Top Load Equivalent Conversion Data (Self-Balanced Static Load Test of Foundation Pile)

No.	Pile-top equivalent load, P (kN)	Displacement corresponding to pile-top equivalent load (mm)
0	0	0.00
2	3580	1.44
3	5571	2.49
4	7562	3.84
5	9554	5.86
6	11545	7.61
7	13536	11.08
8	15527	15.05
9	17519	17.89
10	19510	22.22

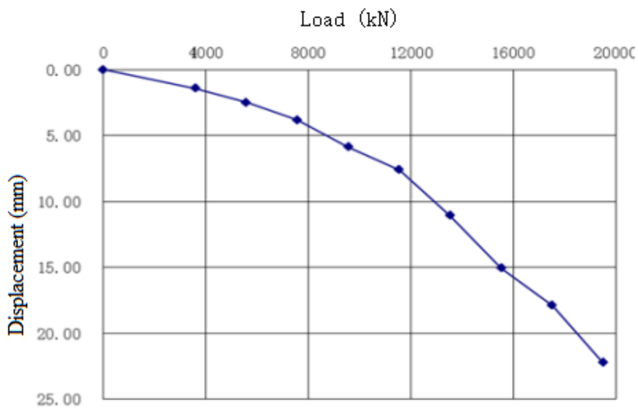

Fig.4 E5-77 Pile Top Equivalent Conversion Curve

Table 5 s-129 Pile Top Load Equivalent Conversion Data (Self-Balanced Static Load Test of Foundation Pile before and after Grouting)

No.	Pile top equivalent load, P (kN)	Displacement corresponding to pile-top equivalent load before grouting (mm)	Displacement corresponding to pile-top equivalent load after grouting (mm)
0	0	0.00	0.00
2	2603	1.07	0.99
3	3987	2.72	1.89
4	5371	5.09	3.33
5	6754	9.17	4.73
6	8138	13.60	6.66
7	9522	20.68	8.36
8	10906	26.61	10.35
9	12289 34.64	13.05	
0	13673	41.71	16.52

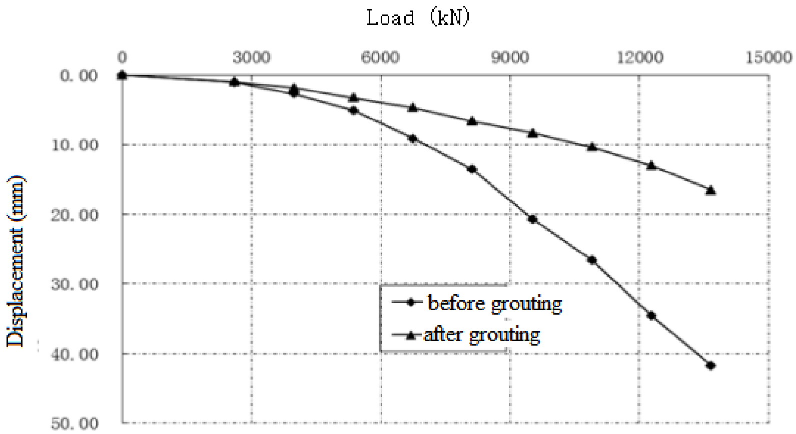

Fig.5 S-129 Pile Top Equivalent Conversion Curves Before and after Grouting

Table 6 E5-88 Pile Top Load Equivalent Conversion Data (Self-Balanced Static Load Test of Foundation Pile Before and after Grouting)

No	Pile top equivalent load before grouting, P (kN)	Displacement corresponding to pile-top equivalent load before grouting (mm)	Pile top equivalent load after grouting, P (kN)	Displacement corresponding to pile-top equivalent load after grouting (mm)
0	0	0.00	0	0.00
2	3407	2.77	3407	1.47
3	5398	5.56	5398	2.49
4	7389	7.88	7389	3.60
5	9380	12.02	9380	4.76
6	11372	17.59	11372	6.08
7	13363	22.86	13363	7.70
8	15354	27.39	15354	9.40
9	17345	35.58	/	/
10	19337	42.91	/	/

From the test results shown in figures, it can be seen that the displacement of the test pile in this project is smaller after grouting at the pile end. Except for the reason that the pile end is compacted by secondary loading, the grouting consolidation at the pile bottom also has a very obvious effect. It can effectively reduce the differential settlement among piles. Under the same loading level, the displacement of pile end is reduced by 75.49%, 73.6%, 64.77% and 81.1%.

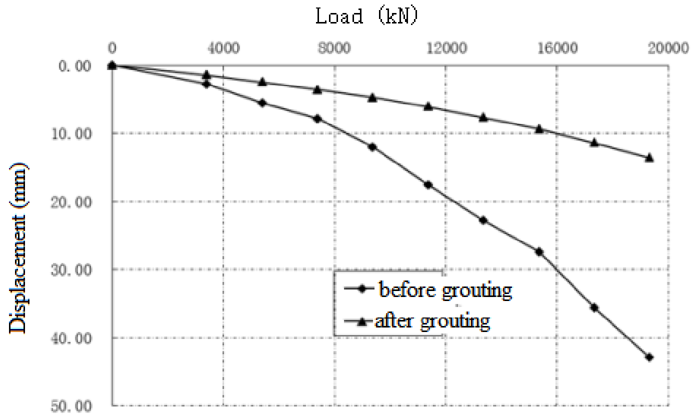

Fig.6 E5-88 Pile Top Equivalent Conversion Curves Before and after Grouting

5. Conclusion

First, based on actual test data and analysis, it can be seen that the ultimate bearing capacity of the pile can be significantly improved by grouting at the bottom of the pile.

Second, grouting at the bottom of pile can play a certain role in reducing the differential settlement among piles.

Third, for bored cast-in-place piles, due to the long pile bodies and difficulties in hole cleaning, there are some sediments at the bottom of the pile. Post grouting at the pile end can solidify the sediment, improve the compression characteristics of the supporting layer at the pile end and the friction characteristics of the soil layer at the pile side, increase the load on the top of the pile and reduce the settlement of pile-top.

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