Composite Foundation Bearing Characteristics of PHC Pile

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Abstract: To study the bearing characteristics of PHC pile composite foundation, base on the analysis of soft soil characteristics, according to the design parameter, the static loading test are used to test and analyze the bearing capacity of the composite foundation. The results show that it is feasible that using PHC pile with 400mm diameter and 11.0-30.0m length to deal with soft soil which mainly composed of flow plastic muddy clay, and the pile spacing is 2.0m. The composite foundation bearing capacity can reach 680Kpa, which meet the need of the corresponding project.

Introduction

Soft soil has the characteristics of high natural moisture content, high compressibility and low bearing capacity. In general, it cannot meet the engineering requirement as a natural foundation. As a foundation, it needs to be treated to improve its bearing capability. PHC (pre-stressed high-strength concrete) pile composite foundation is a way to deal with soft soil, which has the characteristics of high pile bearing capacity, wide application range, reliable pile quality, and low engineering cost. In fact, as early as the 1990s, people had the idea of composite foundation and have made some research results^[1]. However, in actual projects, PHC pile be used to treat soft soil is later. In 2005 Wang Rui-fang and Pi Ju-hua discussed the reaction between the soil and the PHC pile^[2]. In 2006, Xu Qing-gen and others introduced the treatment technology of PHC pile in Dongguan Civic Square^[3]. In 2007, Rui Rui studied the load transfer mechanism of embankment reinforced with rigid pile for soft soil foundation rely on PHC pile to reinforce soft soil foundation of Guang-Shao Expressway^[4]. In the same year, Zhang Si-hua studied the deformation calculation of composite foundation with static pressure PHC pile^[5]. In 2009, Du Hao and others monitored and analyzed the deformation characteristics of PHC pile composite foundation of widening embankment^[6]. In 2010, Li Ying-le studied the long and short piles composite foundation of CFG pile and PHC pipe^[7]. In 2012, Xu Hai-ying and others introduced the application of PHC pile composite foundation in the bridge transition section, Tianjin-Qin passenger special project and housing construction project. In 2014, Nuan Ri-guang et al. conducted an experimental study on the settling characteristics of the composite foundation preloaded by PHC pile and CFG pile in the JiNan West Passenger Station of the Beijing-Shanghai high-speed railway^[8]. In 2015, Yan Hong-bo discussed the static load test method for multi-piles composite foundations of CFG pile and PHC pile. In 2016, Chen Hong-lei applied numerical simulation to analyze the performance of PHC pipe composite foundation of high embankment^[10]. Li Rui and others discussed the determination and detection method of bearing capacity of PHC pile composite foundation. In 2017, Wen Jiao-tan discussed the anti-liquefaction capacity of PHC pile composite foundation^[11]; Shu Yuehua numerically simulates the bearing charac-

teristics of single PHC pile and composite foundation^[12]. This paper tests the performance of PHC pile composite foundation relying on Lechang - Guangzhou expressway PHC pile soft foundation treatment project, which can provide reference and reference for similar practical projects.

Engineering geological conditions

The soft foundation project treated by PHC pipe locates at K234+400~ K234+810 of Lechang-Guangzhou expressway, Guangdong province, P.R. China. The Quaternary sediments in engineering site are silty clay and muddy clay of. The underlying bedrocks are sandstone and siltstone of the Devonian.

Site stratum structure

Site strata from top to bottom are as follows:

(1) Silty clay, it is soft plastic state and its compressibility is high compression. The soil is uneven, which distribution all engineering site. The thickness is 7.0-11.0m.

(2) Muddy clay, it is flow plastic to soft plastic state and its compressibility is high compression. The soil is uneven, which distribution all engineering site. The thickness is 2.0-11.9m.

The underlying bedrocks are Devonian sandstone and siltstone, which are fully weathered and strongly weathered.

Physical and mechanical properties

The main physical and mechanical properties of each stratum in the site as shown in table 1.

Table 1 Statistical table of physical and mechanical properties

Stratum	Statistical indicators	Water content ω_0 (%)	Porosity ratio e	Cohesion C (kPa)	Internal friction angle Φ (°)	Compression modulus E_{s1-2}
Silty clay (1)	Range value	21.6~41.7	0.596~1.124	11.3~34.3	10.1~17.6	3.83~7.67
	average value	30.3	0.834	25.6	15.1	5.13
	Number of samples	26	26	26	26	23
Muddy clay (2)	Range value	36.8~56.7	1.020~1.653	7.6~16.5	7.1~12.6	1.71~4.12
	average value	46.7	1.192	12.3	8.9	2.47
	Number of samples	31	31	31	31	28

Hydrogeological conditions

The site groundwater is mainly pore water, which is phreatic water. The site groundwater level depth is 0.40~0.60m. The main supply sources of site groundwater are atmospheric precipitation the groundwater level during the wet period is higher and the groundwater level during the dry season is lower. The groundwater level change range is 0.30-0.50m.

Natural foundation bearing capacity

The bearing capacity of each stratum in the site as follows: the silty clay bearing capacity is 65 kPa, the muddy clay bearing capacity is 50 kPa.

PHC pile composite foundation

The soft foundation project treated by PHC pipe locates at K234+400~ K234+810 of Lechang-Guangzhou expressway, Guangdong province, P.R. China. The design single pile bearing capacity is

680kPa. To achieve the above capacity requirements, the design details of PHC pile are as follows: the pile diameter is 400mm, the pile length is 11.0-30.0m, the pile spacing is 2.0m.

Composite foundation bearing capacity inspect

Test method

The test use static load method with pressure platform reaction force device. The test grading load is 1/10 of the maximum loading; however, the first test load is twice of the test grading load, so the test is divided into 9 levels of loading. The load test method is fast maintenance load method.

Ultimate bearing capacity

(1) Settlement changes characteristics with load to determine ultimate bearing capacity: for steeply descending Q-s curves, the corresponding load of the curve is obviously steeper is the ultimate bearing capacity.

(2) Settlement changes with time to determine ultimate bearing capacity: When the tail of the s-lgt curve is clearly bent downward, the front load value is the ultimate bearing capacity.

(3) For the slowly changing Q-s curve, take the load value corresponding to S=40mm is the ultimate bearing capacity

(4) When the above method determines that the pile bearing capacity has not reached the ultimate bearing capacity, the maximum test load is the pile ultimate bearing capacity.

The test results are shown in Table2 and Fig.1.

There are 19 engineering piles were tested in K234+400~810 section. Pile bearing capacity eigenvalues meet design requirements.

Table 2 Test results

Scope of test	Test No.	Project Number	Pile diameter (mm)	Pile length (m)	Design load (kN)	characteristic value (kN)	Ultimate bearing capacity (kN)	Settlement of Ultimate bearing capacity (mm)	Settlement of characteristic value (mm)
K234+400~K234+480	1	26-26	400	16	860	946	1892	5.06	1.82
	2	28-14	400	14	860	946	1892	5.24	4.16
	3	38-33	400	18	860	884	1768	14.05	2.75
K234+480~+600	4	ZK3	400	22	680	780	1560	11.98	4.15
	5	2-50	400	15	680	748	1496	9.82	3.97
	6	28-24	400	24	680	748	1496	11.69	4.24
	7	35-39	400	30	680	860	1720	12.48	5.28
	8	41-25	400	22	680	680	1360	15.96	0.51
	9	52-19	400	22	680	680	1360	16.14	3.82
	10	73-27	400	15	680	680	1360	39.56	6.51
	12	74-21	400	18	680	680	1360	29.62	5.48
	11	76-25	400	17	680	680	1360	10.54	1.85
	13	77-23	400	17	680	680	1360	30.00	5.37
K234+600~+655	14	ZK6-1	400	11	680	1200	2400	25.68	6.50
	15	3-42	400	14	680	680	1360	18.98	4.23
	16	4-24	400	14	680	680	1360	8.60	2.76
	17	8-41	400	15	680	680	1360	17.00	4.93
K234+655~+810	18	69-1	400	15	680	748	1496	14.35	2.09
	19	79-2	400	11.3	680	714	1428	5.82	1.26

Fig 1 Q-S curves

Conclusions

(1) It is feasible for using PHC pile to deal with soft strata composed mainly of silty clays with soft plastics and muddy clays with flow plastic state.

(2) The design details of PHC pile to treat soft soil are as follows: the pile diameter is 400mm, the pile length is 11.0-30.0m, and the pile spacing is 2.0m.

(3) The static load test results show that the bearing capacity is about 680 kPa, which meets the requirements of the corresponding project

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