Review Study on the Status of Bearing Characteristics of Large Diameter Pile Foundation

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Abstract. With the rapid development on the construction of the highways, high-speed railway, large bridges and other large-scale projects, large diameter piles have been widely used in various projects. Based on collecting and sorting the related research literature on the load-bearing characteristics of large diameter pile foundations at home and abroad, the present situation and problems of research on the bearing capacity of large diameter pile foundation are analysed from the theoretical analysis, experiment and numerical simulation, etc. in this paper. Through the study, it was found that there is some difference on the deformation characteristics, mechanical characteristics and law of pile soil interaction between large diameter pile foundation and small-medium diameter pile. At present, the bearing characteristics of large diameter pile theory study still lag behind the engineering application. In particular, the bearing characteristics of contact surface of large diameter pile foundation and the mechanical properties under dynamic loading should be further studied, which will provide certain support for the design and optimization of large diameter pile foundation.

1. Introduction

Along with the rapid development of highway, high-speed railway, large Bridges and other large engineering construction, the bearing capacity of pile foundation design constantly improve, the size of the single pile also constantly increase, and the large diameter pile foundation is becoming more and more widely applied in engineering construction. According to incomplete statistics, annual quantity of piles is more than 1 million in China, among them, the annual consumption of the large diameter pile is more than 20%.

2. Research status of pile bearing characteristics

2.1 Theoretical analysis method of single pile bearing characteristics

Elastic theory method, load transfer method, shear displacement method and mathematical fitting method are the main methods for the theoretical analysis of single pile bearing characteristics. Elastic theory method was used to simulate the soil around the pile by using elastic continuous medium. The vertical displacement influence coefficient of integral form was derived by Poulos and Randolph[1] according to the basic solution of Mindlin. The differential equation of pile body was applied to calculate the size and distribution of the shear stress and the size and distribution of pile end stress respectively. The stress and deformation characteristics of pile foundation under load were obtained by Geddes[2] based on the stress basic solution of Mindin. The variation characteristics of single pile settlement coefficient was analyzed by Chen Zhuchang[3] based on the elastic theory. Yang Min et
al.\cite{4} used the elastic theory to analyze group pile system. Zou Chunhua et al.\cite{5}, Li Suhua et al.\cite{6}, Hong Xin et al.\cite{7} made appropriate improvements to the classical elastic theory method, and deduced the corresponding formula of single pile theory.

The load transfer method was proposed by Seed and Reese in 1957. Hoonil et al.\cite{8}, Jaehwan et al.\cite{9}, Ye Qiuyu et al.\cite{10} carried out the load transfer analysis of rock-socketed piles based on load transfer theory. Xie Xinyu et al.\cite{11} analyzed the load transfer law of single pile in layered foundation. Xiao Hongbin et al.\cite{12}, Jiang Zhenchun\cite{13} adopted hyperbolic model to conduct simulation study on single pile bearing characteristics.

The shear displacement method was the physical model of the load transfer of friction pile proposed by Cooke. Zhai Jinmin\cite{14} proposed the generalized shear displacement method and applied it to the analysis of the nonlinear interaction between pile, pile and soil and bearing table. The settlement characteristics of group piles are analyzed by using shear displacement method by Gao Meng\cite{15}.

2.2 Experimental study of pile bearing characteristics

The experimental study is a direct method to study the bearing characteristics of single pile, which mainly includes field test and laboratory test.

The field test of single pile bearing characteristics mainly includes single pile static load test, self-balance test (Osterberg test pile method), dynamic test technique of pile and static - dynamic test pile method. Static load test of single pile and the self-balance test method (Osterberg pile test method) are widely used at home and abroad. Fig.1 is the picture of the traditional single pile static load test and Fig.2 is the photograph of load box and reinforcing cage welding in self-balance test. Li Yonghui et al.\cite{16}, Hong Ke et al.\cite{17}, Xu Xiankun et al.\cite{18} made the field static load experiment of large diameter long pile, through the analysis of field test data, the large diameter of super-long pile load transfer characteristics were studied. Shi Peidong\cite{19} has done a lot of theoretical research on the self-balancing test method, and discussed the applicability and development of the method. Gong Weiming et al.\cite{20} also carried out a lot of relevant experimental work on this method. The size effect of large diameter rock-socketed piles is studied by using the self-balancing method. Hoonil et al.\cite{22}, Zhu Xiangrong et al.\cite{23}, Jong-Sub et al.\cite{24} studied the equivalent transformation of load-settlement curve.

Chen Renpeng\cite{25}, Qiu Rendong\cite{26}, Zhang Yongliang et al.\cite{27} adopted the indoor model test to conduct in-depth research on the load transfer mechanism and bearing characteristics of single pile and group pile under the vertical pressure and tension. In recent years, the research of the mechanical properties of soil and structure interface is more and more deep by domestic and foreign scholars, through the soil and structure interface mechanical properties of indoor simulation study, it can better interpret the pile - soil contact surface mechanical properties, mechanism of action and so on. Zhang Ga\cite{28} and Feng Dakuo et al.\cite{29} carried out in-depth study on the mechanical properties and deformation characteristics of coarse grained soil and structure interface. Liu Fangcheng et al.\cite{30} conducted an in-depth study on the mechanical properties of clay and structural contact surfaces. Zhao Chunfeng et al.\cite{31} discussed the influence factors of contact surface.
2.3 Simulation study on bearing characteristics of single pile

In recent years, along with the continuous development of computer technology, simulation is also gradually developed, and continuously extend to all areas. At present, the simulation method has become a very important tool of geotechnical engineering problems. It can be seen from Fig. 3 and Fig. 4 that the numerical simulation method can not only study the bearing characteristics of piles, but also can clearly observe the change of the displacement field of the soil.

Firstly, the finite element method was applied to soil mechanics by Clough and Woodward in the United States. In 1966, these two scholars used the finite element method to analyze the earth dam. Yang Miao et al.[32], Hong Xin[33], Zhou Jian et al.[34], Sheng Zhiqiang et al.[35] respectively used different numerical simulation software for different types of single pile in the load transfer mechanism and deformation characteristics, load-bearing characteristics, the influence factors of bearing capacity between soil and pile and the mechanism of action. Du Jiaqing et al.[36], Wang Chenghua et al.[37] conducted simulation studies on the bearing characteristics and influencing factors of group piles. Zhao Jianli et al.[38], Liu Tao et al.[39] analyzed the deformation characteristics, model establishment, correlation parameters and application of contact units by the simulation method.

3. Conclusions

From the study, the following conclusions can be obtained.

(1) Comparing with the traditional medium and small diameter pile, large diameter bored piles have the advantages of high bearing capacity and convenient construction. There are a lot of differences, such as the deformation characteristics, mechanical characteristics and law of pile soil interaction.

(2) Although large diameter bored piles have been widely used in all kinds of engineering construction, the study of the theory of the large diameter bored piles is not perfect enough, still lags behind compared with the actual application.

(3) The study on mechanical properties of surface between pile and soil should be strengthened, especially the study on the shear zone distribution, mechanical properties and deformation characteristics. At the same time, the microstructure of soil around the pile can be studied, and the relationship between pile lateral friction and soil microstructure and the distribution of shear stress in the soil are analysed from the micro perspective.

(4) With the construction of high speed railway and highway, it is necessary to carry out the experiment and simulation study on the bearing characteristics of single pile under dynamic load.

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