

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

XU LINA ^{1,2*}, GUO XUEDONG ¹

¹School of Transportation, Jilin University, Changchun, 130022, China

²School of Civil Engineering, Jilin Jianzhu University, Changchun, 130118, China

xulina0958@126.com

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 Mindlin. The variation characteristics of single pile settlement coefficient was analyzed by Chen Zhuchang^[3] based on the elastic theory. Yang Min et



al.^[4] used the elastic theory to analyze group pile system. Zou Chunhua et al.^[5], Li Suhua et al.^[6], Hong Xin et al.^[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.^[8], Jaehwan et al.^[9], Ye Qiuyu et al.^[10] carried out the load transfer analysis of rock-socketed piles based on load transfer theory. Xie Xinyu et al.^[11] analyzed the load transfer law of single pile in layered foundation. Xiao Hongbin et al.^[12], Jiang Zhenchun^[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^[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^[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.^[16], Hong Ke et al.^[17], Xu Xiankun et al.^[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^[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.^[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.^[22], Zhu Xiangrong et al.^[23], Jong-Sub et al.^[24] studied the equivalent transformation of load-settlement curve.



Fig.1 Photo of static load test



Fig.2 Load box and steel cage in self-balance test

Chen Renpeng^[25], Qiu Rendong^[26], Zhang Yongliang et al.^[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^[28] and Feng Dakuo et al.^[29] carried out in-depth study on the mechanical properties and deformation characteristics of coarse grained soil and structure interface. Liu Fangcheng et al.^[30] conducted an in-depth study on the mechanical properties of clay and structural contact surfaces. Zhao Chunfeng et al.^[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.

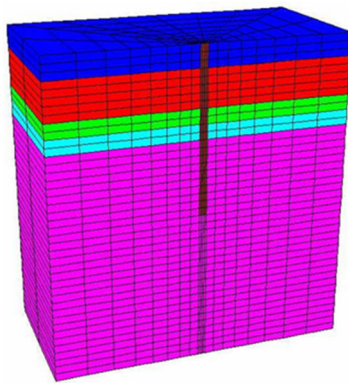


Fig. 3 Numerical simulation model

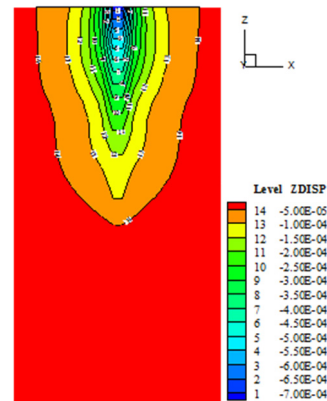


Fig. 4 Numerical simulation analysis of soil displacement

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.

Acknowledgement

This paper is supported by the innovation training program of students in Jilin Jianzhu University (2017S11084).

References

- [1] Poulos, H.G., Randolph, M.F., Pile group analysis study of two methods [J]. Journal of the geotechnical engineering division, ASCE, 1983,109(3):355-372.
- [2] Geddes, J.D., Boussinesq-based approximation to the vertical stresses caused by pile-type subsurface loading [J]. Geotechnique, 1969, 19(4):509-514.
- [3] Chen Zhuchang, Wang Jianhua. The study on performance of mixing pile by elastic theory [J]. Journal of Tong Ji University, 1993, 21(1):17-25.
- [4] Yang Min, Wang Shu Juan, Wang Bojun, Zhou Ronghua. On analysis of single pile by using Geddes' formula [J]. Journal of Tong Ji University, 1997, 25(4):379-385.
- [5] Zou Chunhua, Wang Changdan, Dai Renping, Ji Zhaohong. An improved elastic theory of single pile calculation [J]. Urban road bridge and flood control, 2009, (10):117-121.
- [6] Li Suhua, Yang Weiguan. A study on vertical load bearing performances of prefab pile [J]. Chinese Journal of Rock Mechanics and Engineering, 2001, 20(2):256-261.
- [7] Hong Xin, Yang Min. A new calculation method for single pile load and settlement in layered soils [J]. Chinese Journal of Underground Space and Engineering, 2008, 2(3):431-435.
- [8] Hoonil Seol, Sangseom Jeong, Yongmin Kim. Load transfer analysis of rock-socketed drilled shafts by coupled soil resistance [J]. Computers and Geotechnics, 2009, 36(3):446-453.
- [9] Jaehwan Lee, Kwanglo You, Sangseom Jeong, Jaeyoung Kim. Proposed point bearing load transfer function in jointed rock-socketed drilled shafts [J]. Soil and foundations, 2013, 53(4):596-606.
- [10] Qiu Yu, Hu Xuehui, Liu Songyu. A formula for calculating the settlement of long rock-socketed single pile [J]. China Civil Engineering Journal, 2001, 34(5):72-75.
- [11] Xie Xinyu, Wang Zhongjin, Wang Jinchang. Calculation method for settlement of super-long pile considering nonlinearity of pile and soils [J]. Journal of Central South University(Science and Technology), 2013,11:4664-4671.
- [12] Xiao Hongbin, Zhong Huihong, Zhang Yijing, Wang Yonghe. Numerical iteration method for determining load-settlement relationship of a single pile [J]. Rock and Soil Mechanics, 2002,23(5):592-596.
- [13] Jiang Zhenchun. Experimental study of vertical bearing behaviors of super-long prestressed high-strength concrete pipe pile in soft clay [J]. Rock and Soil Mechanics, 2012,33(9):2639-2646.
- [14] Zhai Jinmin. Semi-Analytical and Semi-Numerical Method for Analyzing Nonlinear Interaction of Pile Group-Soil-Pile Cap System [J]. Journal of Building Structures, 1996, 17(1):63-73.
- [15] Gao Meng, Gao Guangyun, Yang Chengbin, Feng Shijin, Ji Yujun. Analytical solution for settlement of group piles in layered ground based on shear displacement method [J]. Rock and Soil Mechanics, 2010, 31(4):1072-1077.
- [16] Li Yonghui, Wu Jiangbin. Bearing behavior study of larger-diameter and super-long pile based on full-scale field test [J]. Chinese Journal of Underground Space and Engineering, 2011,7(5):895-902.
- [17] He Hong, Wu Xiang, Wang Jihua, Zeng Yunchuan, Zhao Chunhong, Feng Qinggao. Research on vertical beating capacity of single super-long bored pile in thick stratum of Tianjin [J]. Rock and Soil Mechanics, 2011,32(9):2821-2826.
- [18] Xu Xiankun, Shui Weihou, Chen Guodong. Vertical bearing capacity of super-long bored piles in soft soil area [J]. Chinese Journal of Geotechnical Engineering, 2011, 33(Supp.2):502-507.
- [19] Shi Peidong. Further discussion on the Osterberg static load test method [J]. Industrial Construction, 1998, 28(2): 56-58.
- [20] Gong Weiming, Jiang Yongsheng, Zhai Jin. Pile bearing capacity self-balancing test method [J]. Chinese Journal of Geotechnical Engineering, 2000, 22(5): 532-536.
- [21] Gong Chengzhong, He Chunlin, Gong Weimin, Dai Guoliang. Analysis of size effect on large diameter rock-socketed pile based on self-balance method [J]. Rock and Soil Mechanics, 2012,33(8):2403-2407.
- [22] Hoonil Seol, Sangseom Jeong. Load-settlement behavior of rock-socketed drilled shafts using

- Osterberg-Cell tests[J]. Computers and Geotechnics, 2009, 36:1134-1141.
- [23] Zhu Xiangrong, Wang Shengzhong, Ye Junneng, Wang Wenjun. Load transfer model and improved transition method for load-settlement curve under O-cell pile testing method [J]. Chinese Journal of Geotechnical Engineering, 2010, 32(11): 1717-1721.
- [24] Jose Leo C. Mission, Hyeong-Joo Kim. Design charts for elastic pile shortening in the equivalent top-down loading-settlement curve from a bidirectional load test[J]. Computers and Geotechnics, 2011, 38:167-177.
- [25] Chen Renpeng, Ren Yu, Chen Yunmin. Experimental investigation on a single stiff pile subjected to long-term axial cyclic loading [J]. Chinese Journal of Geotechnical Engineering, 2011,33(12):1926-1933.
- [26] Qiu Rendong, Liu Jinli, Gao Wensheng, Qiu Mingbing. Large scale model tests on load transfer mechanism of long piled group foundation [J]. Chinese Journal of Geotechnical Engineering, 2012,34(12):2233-2242.
- [27] Zhang Yongliang, Chen Xingchong, Sun Jianfei. Nonlinear static calculation model and pseudo-static test of pile group bridge foundations [J]. Chinese Journal of Rock Mechanics and Engineering, 2013, 32(9):1799-1806.
- [28] Zhang Ga, Zhang Jianmin. Unified modeling of soil-structure interface and its test confirmation [J]. Chinese Journal of Geotechnical Engineering, 2013,32(9):1799-1806.
- [29] Feng Dakuo, Hou Wenjun, Zhang Jianmin. Large-scale direct shear test investigation of the 3D behavior of a gravel-structure interfaces [J]. China Civil Engineering Journal, 2012, 45(5): 169-176.
- [30] Liu Fangcheng, Shang Shouping, Wang Haidong. Study of shear properties of silty clay-concrete interface by simple shear tests [J]. Chinese Journal of Rock Mechanics and Engineering, 2011, 30(8):1720-1728.
- [31] Zhao Chunfeng, Gong Hui, Zhao Cheng, Miu Qianxu. Elastoplastic analysis of interface between clay and concrete considering effect of normal stress history [J]. Chinese Journal of Rock Mechanics and Engineering, 2012,31(4):848-855.
- [32] Yangmiao, Zhang Zhongmiao, Liu Nianwu, Shi Maofei, Zhang Rihong. Numerical simulation of compressive mechanical characters of new bored grouting PHC nodular pile [J]. Rock and Soil Mechanics, 2013,34(7):2119-2126.
- [33] Hong Xin. Theoretical simulation and factors for static loading tests on a single pile [J]. Chinese Journal of Geotechnical Engineering, 2012,34(1):176-183.
- [34] Zhou Jian, Chen Xiaoliang, Wang Guanying, Zhou Kaimin. Experimental and numerical analysis of open-ended pipe piles during jacking into sand [J]. Journal of Tong Ji University, 2012,40(2):173-178.
- [35] Sheng Zhiqiang, Shi Yucheng, Sun Junjie, Qiu Rendong, Lu Yuxia, Liu Kun, Wang Xiuhong. Three-dimensional FEM analysis of settlement and deformation of pile-soil system under vertical load using ABAQUS [J]. Chinese Journal of Geotechnical Engineering, 2013, (S1):366-371.
- [36] Du Jiangqing, Du Shouji, Zhao Danlei, Tang Wenyong. Numerical analysis of interaction of pile group-soil-raft under vertical load [J]. Rock and Soil Mechanics, 2013,34(8):2414-2420.
- [37] Wang Chenghua, Liu Qingchen. Numerical analysis of vertical bearing behavior of group pile foundation considering pit excavation effect [J]. Rock and Soil Mechanics, 2012,33(6):1851-1856.
- [38] Zhao Jianli, Feng Xu. Numerical simulation of compaction effects of single driven pile using thin-layered element technique [J]. Journal of Shanghai University(Natural Science), 2013,19(2):60-63.
- [39] Liu Tao, Peng Huazhong, Wang Yong, Wang Yanli. Research progress in static and dynamic characteristics of pile-soil interface [J]. Journal of Yangtze River Scientific Research Institute, 2013,(12):74-81.