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Summary of Research on Horizontal Bearing Capacity of Pile Foundation in Soft Ground

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Abstract

Based on the research theory and existing research methods of the horizontal bearing capacity of pile foundation in soft ground, this paper describes the current situation of the theory used to study the horizontal bearing capacity of pile foundation in soft ground at home and abroad, and then describes the current situation of the CPTU test method, DPP-BOTDA technology and numerical simulation methods applied to pile foundation monitoring, These research methods are proposed to provide some guidance for the follow-up research of similar projects.

Keywords

Weak Stratum; Bearing Capacity of Pile Foundation; Monitor.

1. Introduction

In recent years, urban infrastructure projects have developed rapidly, and the structural systems of these infrastructures will be subjected to various loads during their use. When the pile foundation is subjected to large horizontal loads, it is easy to cause the permanent horizontal deformation of the pile and the instability of the foundation soil. At present, most of the research on the horizontal bearing capacity of pile foundation in China is based on the nonlinear and elastic-plastic pile-soil interaction theory, but there is no unified specification to solve the problem of horizontal bearing capacity of pile foundation in soft ground. Its "large deformation", "large diameter pile" and other characteristics make the cost of on-site pile test relatively high, Therefore, it is an urgent need to put forward and improve a suitable theory and method for horizontal bearing capacity of pile foundation in weak stratum.

2. Project Overview

This study is based on the new project of S325 Lu'an Matou-Changji Section. Due to the low grade of the overall highway in Lu'an City and the low quality of the highway access, it is unable to meet the growing traffic needs and meet the needs of economic development and the national poverty alleviation work requirements. This project is a newly added project of Lu'an Matou to Changji Section of Provincial Highway S325, which aims to improve the quality demand of transportation lines in the region and greatly improve the travel conditions of the people in the region. At the same time, it actively responds to the national call for targeted poverty alleviation. As the infrastructure to support poverty alleviation, the implementation of this project is imminent. The main difficulty in the site is that the filling is high-pressure compressible soft soil with poor engineering geological properties. It is necessary to check the settlement of the soft soil area, and the foundation treatment is required for the area that does not meet the design requirements to meet the engineering needs. In addition, expansive soil is widely distributed in the area. According to the indoor geotechnical test of the project, the free expansion rate is 42%~50%, and the expansive soil is weak expansive soil. Corresponding measures shall be taken in the design of subgrade and abutment, which can be treated by excavating 0.30m expansive soil and replacing it with non-expansive soil or adding ash. The

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project team received the notice from the Lu'an Transportation Bureau that the construction drawing design of the new project of S325 Lu'an Matou-Changji Section is divided into three sections, of which the first section is the section from Matou-Danwang X017, with chainage of K0+000~K10+611.685, a total of 10.612km: the construction drawing design documents have been submitted for this section; The second bid section is from Danwang X017 to K28+000, with chainage of K10+611.685 to K28+000, 17.388 km in total; The third bid section is from K28+000 to Changji, with chainage of K28+000 to K45+358.963, 17.359km in total.

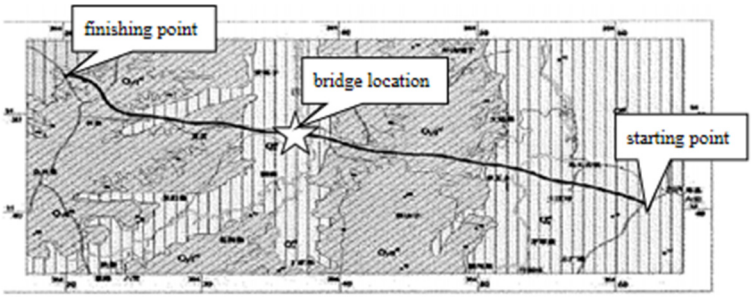

Figure 1. Starting and ending of S325 route

3. Existing Theoretical Research Methods

3.1. P-Y Curve Method

P-y curve method is one of the most commonly used methods to analyze the mechanical action of pile-soil system under horizontal load. This method is based on the assumption that the pile body is an elastic foundation beam in the vertical direction of the foundation, which is regarded as an independent nonlinear spring to simulate the influence of the foundation soil on the pile foundation. However, this method is not applicable to "large diameter" pile foundation.

Zhang Xiao-ling put forward a solution method of p-y curve based on Vesic expansion theory. The method has been verified by engineering practice and can cope with large horizontal displacement with pile foundation; Xiaochao Tang et al. studied the weathered rock slope between piles by using the p-y curve method under the rock-pile interaction, and analyzed the effect of the force formed under the interaction of passive earth pressure and pile foundation; Wenjun Lu et al. established a p-y curve model of pile foundation considering horizontal and vertical combined loading in sandy soil suitable for offshore pile foundation, and verified the accuracy of the p-y curve model and its parameters through numerical simulation; Xiaoyan Liu et al. proposed a p-y curve method based on CPTU data. This method can be used for large-diameter and super-long cast-in-place piles, and verified the rationality of this method by combining numerical simulation and field test; Djillali Amar Bouzid studied and proposed a new p-y formula, which aims to simulate the rigid behavior of large-diameter single pile, and used the semi-analytic finite element method to establish the force expression of soil for rigid movement. Finally, the effectiveness of the new p-y formula was verified by applying it to three previous practical engineering cases; Teng Wang et al. created a p-y curve model based on in-situ cyclic T-frame test, and considered the softening of soil under horizontal cyclic load. Finally, the accuracy of the p-y curve was verified by numerical simulation. In an environment similar to soft ground, Chunyan Wang conducted multiple sets of comparative tests to explore the horizontal bearing capacity of pile foundations with different diameters under coral sand and silica sand and other foundation conditions. The p-y curve of his research shows that the horizontal stiffness of coral sand is greater than that of silica sand. The destruction behavior of coral sand on the squeezed side of the pile is mainly distributed in the range of 10 times the depth of the pile diameter and 5 times the width of the pile diameter. In coral sand, the influence

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of the pile size is more obvious. Many of the above scholars have analyzed the pile-soil interaction through the improved p-y curve, and can be better applied to engineering practice.

3.2. Limit Equilibrium Method

The limit equilibrium method is generally applicable to short piles with not very deep burial depth. This theory is based on the conditions when the pile and soil reach the limit equilibrium state and uses this as the limit state to solve the equation combination, and simplifies the force of the foundation to the existing distribution form, and calculates the stability coefficient of the rock and soil according to the ratio of the shear force along the failure surface and the shear force along the failure surface of the rock and soil around the pile foundation. Because the buried depth of pile foundation in soft stratum is generally large, the limit equilibrium method is generally not applicable to the study of horizontal bearing capacity of pile foundation in soft stratum.

3.3. Elastic Foundation Beam Method

The elastic foundation beam method regards the pile foundation as the beam foundation on the elastic foundation, and takes the soil resistance at any point of the beam body as the theoretical solution in direct proportion to the displacement at that point. The winkler theory method is mostly used in engineering. Xiao-ling Zhang et al. take the elastic foundation beam as the theoretical basis, comprehensively consider the friction effect of pile and soil and the influence of vertical load on soil resistance, and use matlab software to program the mechanical response of pile. Finally, the applicability of the method is verified by comparing the theoretical calculation results with the experimental results. Hui Hu et al. took a station of Metro Line 7 as an example, used the improved Peck formula and winkler elastic foundation model to study the additional displacement and interior of the pile, and finally concluded that the permanent pile foundation should use the small diameter pile as much as possible, especially when the small diameter pile can not meet the stress requirements, it should be replaced with the design scheme of group pile.

4. Analysis of Bearing Capacity of Pile Foundation In Weak Stratum

4.1. Bearing Capacity Analysis of Pile Foundation based on CPTU Test

The total length of the Jihe Grand Bridge in the second section of the new project from Matou to Changji section of S325 Lu'an City is 5235.62m. According to the geological structure division of Lu'an City, the regional deep faults mainly include Lu'an Fault, Jinzhai Fault, and the southern section of Tanlu Fault. The proposed area has a slightly undulating terrain. The overall terrain is high in the east and low in the west, and the elevation along the Macao River is relatively low. The overall ground elevation is 27.0~34.0m, and the elevation difference is 7m. Due to the large compressibility and high-water content of the soil layer in the soft stratum area it contains, its engineering properties are relatively poor, and the accuracy measured by common test methods is low. The multifunctional pore pressure static penetration test (CPTU) technology can directly obtain the change of pore water pressure with the depth of the pile foundation, and it is fast, efficient and accurate [1]. The cone tip resistance and side friction resistance of the pile foundation with the change of depth can be obtained through CPTU, and the horizontal bearing capacity of the pile foundation can be calculated on the basis of the above theory. Therefore, CPTU test technology has a relatively broad application prospect in China [2], Especially for "large diameter" and "large deformation" pile foundation detection in weak stratum area.

Liu Dongming [3] and others used the CPTU test to calculate the undrained shear strength and internal friction angle of soil and other important parameters, and summarized some methods for testing the bearing capacity of pile foundation based on the CPTU test, such as LCPC method,

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European method and other methods. Cai Guojun [4] and others predicted the vertical bearing capacity of the pile foundation through CPTU test, carried out 8 groups of in-situ tests on the original site and calculated the classification and deformation of the soil layer and other parameters through CPTU software, and finally evaluated the engineering properties of the original foundation. Li Hongjiang [5] et al., taking the engineering project in the soft soil stratum area of the Taihu Lake Lake as the background and starting from the classical p-y curve, put forward a method to evaluate the horizontal bearing capacity of improved pile foundation based on CPTU test. The horizontal bearing capacity obtained by three test piles was compared with the horizontal bearing capacity of pile foundation tested by CPTU, and the results showed that the predicted results were in good agreement with the actual test results, this shows that the method has a high degree of coincidence when applied to practical projects. Parisa Heidari, a foreign scholar, used 25 methods to calculate the horizontal bearing capacity of pile foundation to calculate a large number of field data collected by CPTU. Finally, four different statistical methods were used to evaluate the accuracy of these 25 calculation methods. Finally, the accuracy ranking of calculation methods applicable to different soil types was given.

4.2. Bearing Capacity Analysis of Pile Foundation based on DPP-BOTDA Technology

DPP-BOTDA is a method based on differential pulse pair Brillouin optical time domain analysis, which can accurately measure the strain of pile foundation in a large range, and has been well applied to the monitoring of large domestic infrastructure. Zhaohui Zhang et al. applied BPP-BOTDA technology to the monitoring of offshore wind turbine pile foundation, and calculated the maximum horizontal load on the pile foundation using the distributed displacement calculation method based on the distributed strain data through the comparison of the collected data. The average error value finally obtained is very small, which indicates that DPP-BOTDA technology can be better applied to the monitoring field of large pile foundation, This also provides a new technical guidance for the monitoring of the horizontal bearing capacity of pile foundation in the harsh foundation environment such as soft ground.

4.3. Bearing Capacity Analysis of Pile Foundation based on Numerical Simulation Research

By means of computer technology such as numerical simulation, the stress of pile foundation can be restored to the maximum extent and the bearing capacity characteristics of pile foundation in soft ground can be intuitively analyzed. Kazimierz J ó zefiak et al. used Abaqus finite element software to simulate the stress of the pile foundation on the soft soil foundation, and verified the numerical simulation results of the horizontal bearing capacity of the pile foundation with the static test results. The results show that the numerical simulation can accurately predict the settlement of the pile foundation and the bearing capacity of the pile foundation; S. Karthigeyan et al. used FLAC 3D numerical simulation software to restore the effect of vertical load on the horizontal bearing capacity of pile foundation in clay and sand environment respectively. The results showed that the vertical load in the sand environment has a great impact on the horizontal bearing capacity of pile foundation with a length of 30 times the width, while the effect of clay on the horizontal bearing capacity of long pile foundation with a length of 15 times the width is not obvious; Rusal S. Huissen et al. used FLAC 2D software to study the vertical displacement of pile top under seismic load and the variation of soil displacement with pile body. The results provide reliable guidance for future research on pile top displacement in liquefied soil.

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5. Conclusion

Based on the background of the new project from Matou to Changji section of S325 Lu'an City, this paper mainly discusses the theoretical research foundation of pile foundation under soft ground, as well as the research status of in-situ test and numerical simulation based on CPTU. In view of the problems of "large diameter" and "large deformation" faced by the pile foundation in the existing weak stratum, more theoretical results are still needed to provide guidance for the engineering construction, especially for the effective method of improving the horizontal bearing capacity of the pile foundation in the deep soft stratum area, which still needs to be improved. The existing numerical simulation and other means can quickly and effectively simulate the stress environment and stress status of pile foundation in soft soil areas. On this basis, more advanced pile bearing capacity and pile displacement prediction technology can greatly improve the construction efficiency and reduce the construction cost. I hope that the development of information technology and theoretical research on pile bearing in soft soil areas in the future can change this situation. This paper combines and expounds many researches on the bearing capacity of pile foundation in soft ground, hoping to provide some guidance and suggestions for the research of similar projects.

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