

Research on the Moisture Content of Fine Silty Sand Affecting the Compressive Failure Behavior of the Concrete Expanded-Plates Pile

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Abstract: The according to the results of the early theory research of concrete expanded-plates pile and the simulation analysis, discusses the influence of moisture content of fine silty sand for failure behavior and compressive bearing capacity, and put forward the tentative plan which further researches the influence of the moisture content of fine silty sand, in order to improve the calculation theory of the concrete expanded-plates pile under the action of vertical pressure, and make up the shortcomings of relevant theoretical research on the influence of the characteristics of fine silty sand for the compressive failure and bearing capacity of the concrete expanded-plates pile.

Introduction

The concrete expanded-plates pile is on the basis of the ordinary concrete filling pile, improves the bearing capacity of the concrete expanded-plates pile by changing the pile body structure and setting the bearing plate-expanded which is selected appropriate soil layer according to the geological situation. Practice shows that it has excellent characteristics, for example, the bearing capacity is high, the settlement (or uplift) deformation is small, the construction is simple and quick, and so on, the concrete expanded-plates pile is being more and more widely used in all kinds of engineering. However, the geological condition in the actual engineering is extremely complicated and ever changing, when the expanded-plates pile is used, the plates can be set in different soil layers. At present, most of the theoretical research on the MEPP pile is to put the bearing plate in the cohesive soil, the characteristics of cohesive soil are better than other soil layers, the bearing capacity is higher than other soil layer, the characteristics of high bearing capacity of cohesive soil is made full use, the influence of sandy soil layer and soil moisture content for the bearing capacity is neglected. But in the practical engineering applications, some of the soil layers can not meet the requirements because there is no cohesive soil meet the conditions we need in it and the clay soil layer is too thin. In the foundation of the middle and lower reaches of the Yangtze River in China, the thick sand layer is distributed, the sandy soil layer is a good bearing layer as pile foundation in this region, the sandy soil in this area is shallowly buried, the thickness is large, usually mixed with silt or silty clay, as the depth increases, the sand becomes dense[1]. And in present project, it has been successfully used the concrete expanded-plates pile in the fine silty sand, for example, LNG project station, in Rudong, Jiangsu carried on the test, which a pile in the sea level of 60 meters below the silty sand and fine sand layer is concreted successfully and achieve the desired effect[2].

Previous studies have indicated that the moisture content of the sandy soil and compactness has a great influence on the bearing capacity of the concrete expanded-plates pile, but the theoretical study that the bearing plate of the concrete expanded-plates pile in fine silty sand is not clear, in order to further improve the theoretical basis of the compression strength of the concrete expanded-plates pile under vertical load, in this paper, the damage effect of soil and the influence of bearing capacity are analyzed by changing the moisture content of the fine powder sand soil of the bearing plate.

Research on the status analysis

At present, due to the complexity of mechanical behavior of the concrete expanded-plates pile, people's understanding of its bearing characteristics is not sufficient. The theoretical research of the concrete expanded-plates pile is far behind the engineering practice. According to the sliding failure mode of the soil under the bearing plate, defining the calculate model about the soil stress under the pile by using the theory of sliding line, combining with plastic potential theory and the principle of virtual work and determining the ultimate bearing capacity of the soil of the plate-expanded pile, modify and improve the calculation formula of the bearing capacity of the end of the existing pile and the side resistance of the pile, Yongmei Qian put forward the new bearing force calculation formula of single pile of the concrete plates-expanded pile. And they study the failure state of the concrete expanded-plates pile under the action of the external load by a new experimental method (the half section of small model). Through the combination of theory and practice, it can illustrate the unreasonable part of calculation for bearing capacity of single pile and put forward the concept about effective length of the side-friction, which made it agree with the practical situation. Through static load test at the site of the branch and plate pile made by Xiaojuan Gao and studying the regularity of load transfer of the branch and plate pile, it indicated the location of bearing plate had been closely related with soil property, which made the shallow bearing plate play a role before the deep.

The influence of property of the sandy soil on the bearing capacity of the expanded-plates pile has been studied. Xuewen Xie, a master of Jilin Architecture University, analyzed the compression and uplift bearing capacity of the MEEP pile in different soil layers and different property of the soil by finite element simulation analysis. According to the ANSYS software, the stress and strain images were obtained, and the influence of different factors on the bearing capacity was analyzed[4]. Chengyuan Lu have studied engineering properties of branch and plate pile in different soil under repeated loading, and a double plate model pile were repeated 5 times of loading-unloading test in silt and silty clay respectively. The maximum load is less than the ultimate bearing capacity of model pile. The research results show that the bearing capacity and deformation of branch and plate pile are very different in the different soil conditions, engineering properties in silty soil is better than silty clay, the interaction mechanism between soil surrounding the pile is also different and complex in different soil layers. Minmin Jiang, from Geo-technical Engineering Research of Hohai University did an indoor model test that the effect foundation soil and change of moisture content on the quality of wet jetting piles and the influence of cohesive soil and silty soil and moisture content on the strength of wet jet pile is studied, the moisture content of the soil layer has a significant influence on the strength of wet jet pile and there exists a best moisture content ratio, under which, wet jetting piles have a maximum strength[6]. Under the condition of horizontal load, Changlin Zhou studied the effect of moisture content on the pile group by "m" method and the bending moment and shearing force of single pile were analyzed under different water content. From the analysis results that the bending moment was significantly affected by soil moisture content in top and the lower part of the pile, the peak of maximum bending moment occurred in the

middle of the pile, the bending moment of the upper and lower parts are related to the positive and negative correlation of soil water content ;and the peak of maximum shear occurred in middle and lower part of the pile, its position moves down with the increase of soil moisture content, the shear of the upper and lower parts are related to the positive and negative correlation of soil water content; the horizontal displacement of the pile is positively related to the soil moisture content, the relationship between the moisture content and the bending moment in different parts of the pile body ,the peak of maximum shear and the horizontal displacement is obtained[7]. According to the present research in China, it can be found that the influence of the properties of the soil and moisture content on pile body and pile -soil interaction can't been ignored.

The research on the pile in sandy soil layer is few in foreign counties. Ogura H. introduced the model test and full-scale test of cylinder pile in sandy soil and it was similar to the MEEP pile, which proved that the bearing capacity was much higher than the ordinary cast-in-place pile with the same diameter and also analyzed the load-settlement curve with the theory. Ergun,M. U and Akbulut, H. introduced a kind of forming of pile in the literature, which was similar to model pile of multi-branch pile what we said before. Through the comparison experiment of the model square pile which could open unequal amount flange and uniform section pile in sand, analyzing the difference of the capacity of uplift and settlement deformation of the pile which together with the flange or not. The calculation formula of uplift bearing force been put forward by Meyerhof, Das, Chattopadhyay and Prise in sand had.

Analysis of the influence of moisture content of sand on the compressive capacity of the expanded-plates pile

Effect of moisture content on the property of soil

The shear strength of soil is an important index to the mechanical properties of soil, the shear strength is mainly affected by the type, structure and moisture content of soil. In engineering practice, the texture and structure of the soil will not change greatly in a certain area. However, it will be influenced by rainfall, evaporation, irrigation and other factors under natural conditions, the soil moisture content varies greatly, and the strength of soil changes mainly by the change of moisture content. As shown in figure 2, figure 1, they are the effect of moisture content on soil cohesive force and internal friction angle of the soil in the existing research, which can be described by two segment line [8, 9].

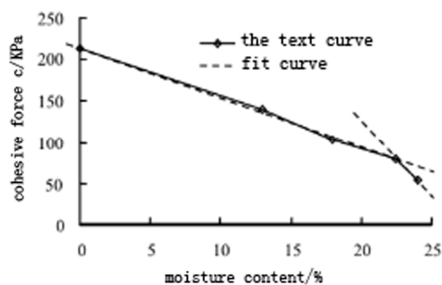


Fig. 1

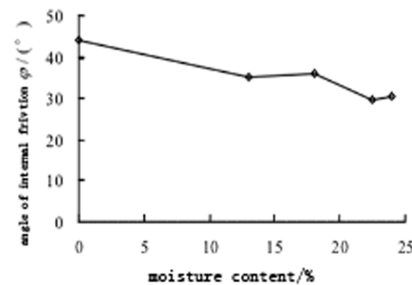


Fig.2

Fig.1 The influence of moisture content on soil cohesive force

Fig.2 The influence of moisture content on internal friction angle

Research shows that moisture content in the range of 0 ~ 25%, with the increase of moisture content, soil cohesive force and internal friction angle decreased and the influence of cohesive force on the moisture content is bigger than internal friction angle. The relationship between cohesion

force and soil moisture content is when the moisture content reaches a critical value, the cohesion force decreases sharply. So the moisture content has a great influence on the physical properties of the soil, then it will have a great influence on the bearing capacity of the pile. The influence of moisture content is more obvious, especially for the sandy soil. Therefore, the influence of the bearing capacity of the concrete expanding pile bearing plate in the sand layer on moisture content should be further discussed.

The influence caused by the change of the moisture content and soil layer to the bearing capacity of the expanded-plates pile in the existing theoretical calculation model

According to the theoretical research of JiLin Jianzhu University, the professor of Yongmei Qian, Xinsheng Yin on the concrete expanded-plates pile, we get the new theoretical results that based on the theory of slip line, it can obtain calculation model of bearing capacity of the compression strength of the end of plate[10]:

$$F_1 = F_2 + F_3 + F_4$$

F_1 -the compression strength; F_2 -the force of the end of pile; F_3 -the force of the end of plate; F_4 - the side of pile.

Among them, the calculation model of the force of the end of plate is as follows:

$$F_3 = p \frac{D+d}{2} c \cot \Phi (e^{2q \tan \Phi} - 1),$$

Formula: D , d - the diameter of the bearing plate-expanded, the diameter of the main pile; c -cohesion force of soil surrounding the pile; Φ —internal friction angle of soil surrounding the pile

c and Φ is closely related to soil moisture content of soil in the formula, and the change of moisture content will affect the strength of soil, the effect of moisture content of fine silty sand on the bearing capacity of the concrete expanded-plates pile is more obvious.

Moreover, the current studies show that bearing capacity of the concrete expanded-plates pile is provided by the end resistance of pile, the side-friction of pile and the bearing capacity of plate, at present, the research on the bearing capacity and the side-friction of pile of the concrete expanded-plates pile is aimed at the cohesive soil, the influence of the change of the side-friction of pile on the bearing capacity of the expanded-plates pile is neglected. the stress characteristics of pile foundation in sand layer is tested by Song Xu, Changhong Yan, Baotian Xu from Nanjing University. The static load test is to put the common pile in the two soil layers of clay and sand, the upper part is clay, the lower part is sand. According to the test results is calculated, the the side-friction of pile is takes the average value in length range of the pile (as shown in table 1) [2]

Table 1 Side friction of pile of different depth in sandy soil

soil layer	2	3	4	5	6	7	8	9
frictional resistance/kpa	21	35	26	37	55	48	67	70

From the table, it can be concluded that the side frictional resistance in the 9 - 6 layers of sand is much larger than that of the 5 - 2 layer of cohesive soil layer, the frictional resistance at the interface between the 5 and 6 layers of the cohesive soil and sand is obvious. It can be seen that the side frictional resistance of the sand soil was significantly greater than that of the clay layer. Therefore, the effect of property of the soil on the bearing capacity of the concrete expanded-plates pile can not be neglected.

Preliminary simulation analysis on the effect of moisture content on the damage state of the MEEP pile

The text group simulates and analyzes the results of the stress and displacement of the MEEP pile from the silty clay and fine silt in the same moisture content under the resist pressure, comparing the displacement under two types of vertical pressure in which the moisture content is 25%, according to the displacement graph, the displacement curve of the same point on the pile is extracted ,as shown in figure 3 .

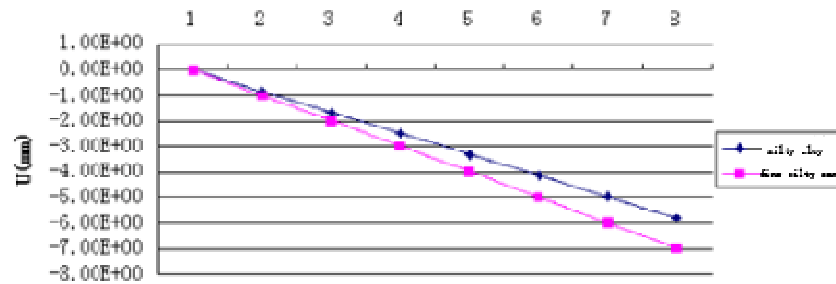


Fig 3 Displacement of a point on the pile under different loads in both soils at the same moisture content

It can be seen from the figure that the displacement of the pile in fine silty sand with the same moisture content is larger than that of the pile in silty clay under the same load, which shows that the moisture content is not ignored in the study of the vertical bearing capacity of the expanded-plates pile.

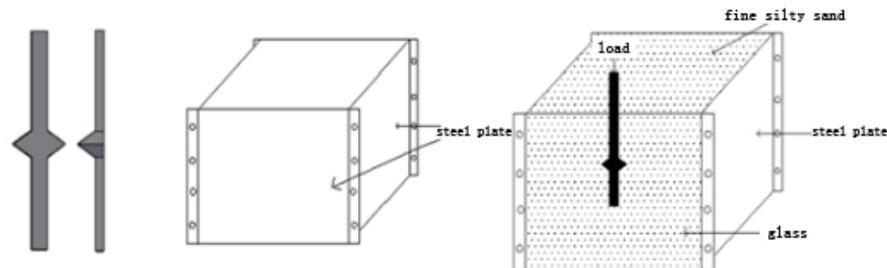


Fig 4 The model of half of the pile

Fig 5 The equipment of drawing out soil and the experimental model

Further research ideas

Tentative ideas of small model test

According to the situation of sand, summing up the previous experiences that small proportion of compression model test of the concrete plates-expanded pile and make half section of model piles (figure 4) ; according to the test requirements, making the device of drawing out soil (figure 5) and loading device (multi-functional loading attachment); observing the whole process of the changes of soil from loading to failure, describing and shooting the destruction of soil, proceeding the collection, collation, analysis of the test data; the results were compared with the current results of theoretical analysis and the bearing capacity, which in order to modify and improve the existing research results and make it more instructive and feasible. It's remarkable that ensure homogeneity of moisture content of fine silty sand in the test so as not to affect the results of the test; secondly, there is the size effect of indoor small scale model test, while the field static load test of the expanded-plates pile will be effected by the actual spot condition and the international influence of

the pile group, so it is necessary to accumulate a large number of tests to sum up reliable rule.

The assumption of finite element simulation analysis

According to the existing finite element analysis modeling method, simulating bearing characteristics of concrete expanding piles under the condition of fine silty sand by the ANSYS software. Based on a single plate, an analysis model was established by the test specimen size, under the vertical load, the model of fine silty sand of the bearing plate is analyzed with different moisture, the stress characteristics and load transfer law of the concrete plates-expanded pile under different loads is analyzed, the influence of the upper and lower stress of the plate and stress distribution of soil surrounding the pile and deformation of soil surrounding the pile are analyzed. Compared the results of the experiment analysis to the results simulation analysis, it put forward the reasonable evaluation method to bearing capacity of the concrete plates-expanded pile, so as to provide a basis for the design of piles, research and practical applications that the effect of the moisture content on the bearing capacity of the plates-expanded pile in the sandy soil play a reference role.

The preliminary simulation analysis provides a reference for this study and to put forward and modify the influence coefficient is also the key point to break through of this study. In addition, there are also some problems in the simulation analysis. Because that the interaction mechanism between pile and soil can not completely reflect in some units, so it is necessary to choose the proper form of unit to describe the contact properties between soil and pile, which is to be studied. Due to the prominent non-linearity of soil, so far, there is no constitutive model can be used to reflect the characteristics of soil. It is reasonable to choose different constitutive soil for a specific problem. Therefore, it is necessary to choose the soil structure flexibly according to the study of the problem; the selection of calculation parameters worthy of remark, due to the nature of the soil is very uneven and an-isotropic, it is difficult to select the calculation parameters.

Conclusion and Prospect

This paper discussed the failure state and bearing capacity effected by moisture content of fine silty sand and designed the idea that comparing analysis research between indoor small half pile model test and finite element simulation, which in order to improve the calculation theory of the expanded-plates pile under vertical pressure, make up the neglectful shortcoming that the effect on vertical tension capacity of the expanded-plates pile in practical engineering, and provide a theoretical basis for the application of the expanded-plates pile in fine silty sand by analyzing the current research results that the effect on the concrete expanded-plates pile by sandy soil and moisture content. At the same time, the influence of the uplift bearing capacity and the change of the moisture content on the uplift bearing capacity of the expanded-plates pile in fine silty sand is also need to be further discussed

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