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Full Length Research Paper

Analysis of the shape of bearing push-extend reamed affecting the bearing capability of the pile of push-extend multi-under-reamed pile through the finite element method

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In the paper, through use of ANSYS software of the finite element method to establish the simulation analysis model about the stress of soil around the pile, we obtained the normal and shear stress curve when the bearing push-extend reamed have different shapes under the same loads. It qualitatively analyzed the influence of bearing capacity on the push-extend Multi-under-reamed pile raised by the different shapes of the bearing push-extend reamed, and puts forward the theoretical basis that further promotes application of the push-extend Multi-under-reamed Pile.

Key words: Push-extend multi-under-reamed pile, shape of bearing push-extend reamed, dimension of diameter, bearing capacity of pile, influence.

INTRODUCTION

Based on the theoretical and experimental study of the effects on the pile and soil of the Push-extended Multi-under-reamed Pile, it is further confirmed that many factors affect the bearing capacity of the Push-extend Multi-under-reamed Pile, and the situation is also more complex (Yongmei et al., 2013a). The main influence factors include: the diameter, location, height, form, distance and quantity of the bearing push-extend reamed, etc. It is difficult to provide quantitative conclusion for all these factors; however, we can give a qualitative conclusion. While researching on influence factors of the bearing capacity of the pile of Push-extend Multi-under-reamed Pile based on the theory of slip line, it was discovered that the shape of the bearing push-extend reamed has larger influence, which is one of the main influence factors of the bearing capacity of the pile (Yongmei et al., 2013a). In this paper, through theoretical analysis of the shape of the bearing push-extend reamed affecting the bearing capacity of the pile by establishing the finite element analysis model of the Push-extend Multi-under-reamed Pile, and in practical application, it is qualitatively put forward that the

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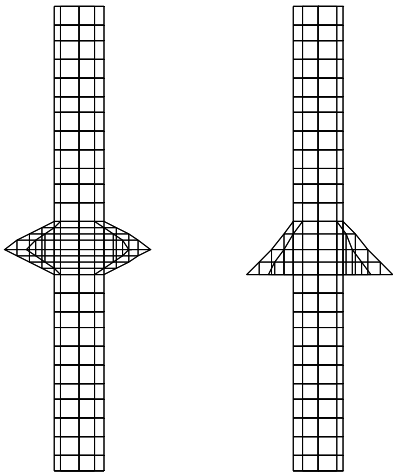

Figure 1. The perspective of unit division.

determining principle of the shape of the bearing push-extend reamed can be considered in the design and calculation of the Push-extend Multi-under-Pile.

ANALYSIS OF THE SHAPE OF THE BEARING PUSH-EXTEND REAMED AFFECTING THE BEARING CAPABILITY OF THE PILE BY USING FINITE ELEMENT METHOD

The bearing capacity of the pile of Push-extend Multi-under-reamed pile is composed of the side frictional resistance and the end-bearing force of pile. Due to existence of the bearing push-extend reamed, the soil under the bearing push-extend reamed produced large compressive stress; meanwhile, the soil on the bearing push-extend reamed produced tensile stress at a certain range; within the scope of the side frictional resistance of pile that does not exist simultaneously, the soil under the bearing push-extend reamed created slippage which led to a reduction in effective length of side frictional resistance of pile. Also the shape of the bearing push-extend reamed makes effect on it. In order to make full use of the role of the side frictional resistance of pile and the bearing push-extend reamed, further research needs to be made on the shape of the bearing push-extend reamed affecting the bearing capability of pile. The following is an analysis of the shape of the bearing push-extend reamed affecting the soil, an analysis of failure mechanism around pile and the bearing capacity of the pile through the finite element method.

ESTABLISHMENT OF THE FINITE ELEMENT MODEL

Finite element model can be set up using the 8-node space units (Yongmei et al., 2013b). The model is divided into double and single slopes of the Push-extend Multi-under-reamed Pile, as shown in Figure 1. Pile and soil around pile unit division, as well as a combination of pile and soil surface were elaborately distributed in the unit according to the stress distribution. In order to benefit from analysis and comparison of the calculation model, the establishment of the model identifies the following principles:

The concrete pile C20 (density 2.5×10^{-5} N/mm^3, elasticity modulus $E=3\times10^4$ N/mm^2, Poisson's ratio u=0.167) takes the soil around the pile as the foundation of cohesive soil (density 2.0×10^{-5} N/mm^3, elasticity modulus $E=6\times10^{4\text{-}2}$ N/mm^2, Poisson's ratio u=0.3) (Yongmei et al., 2013b).

This research focus primarily on influence of the bearing push-extend reamed on the soil failure mechanism and the bearing capacity of pile; when the distance of the push-extend reamed is suitable, soil failure above and below the push-extend reamed does not affect each other. Thus, when one push-extend reamed is set in the calculation model tentatively, the push-extend reamed will be located in the middle along the pile length.

In order to avoid the boundary condition's influence on the soil in the calculation model, the scope of soil around pile is not too small- the dimension of diameter is 7 m and the depth of pile is 12 m.

Based on the principles above, six calculation models are established. Main pile diameter D=500 mm, pile length L=5000 mm and pile top load F=300 KN, the diameter of push-extend reamed D=1500 mm, 2000 mm, 2500 mm, the form of the bearing push-extend reamed are usually two kinds - double slope and single slope. The push-extend reamed is located in the middle along the length (as shown in Figure 1). Concrete model statistics are shown in Table 1.

ANALYSIS OF CONTENT AND CALCULATION RESULTS OF FINITE ELEMENT

Through computer simulation of the model, the contour map of the principal stress σ_x, σ_z and shear stress τ_x was obtained from different models and the calculation results sorted. The related numerical value of representative model was extracted to form the normal stress curve of soil around the pile in different shapes of the bearing push-extend reamed, taking the pile of the dimension of diameter 2000 mm as an example (as shown in Figure 2, the horizontal axis for the pile length, the vertical axis for normal stress); shear stress curve (as shown in Figure 3, the horizontal axis for the pile length, the vertical axis for shear stress); the shear stress contour map of soil around pile (as shown in Figures 4 and 5); the vertical stress curve of soil under the pile (Figure 6) and the vertical stress curve of soil under the bearing push-extend reamed (as shown in Figure 7).

Table 1. Statistics of the basic parameters calculation model (F=300 KN).

Serial number	Model name	Diameter of push-extend reamed D (mm)	Form of push-extend reamed
1	H153	1500	
2	H203	2000	The double slope form
3	H253	2500	
4	P153	1500	
5	P203	2000	The single slope form
6	P253	2500	

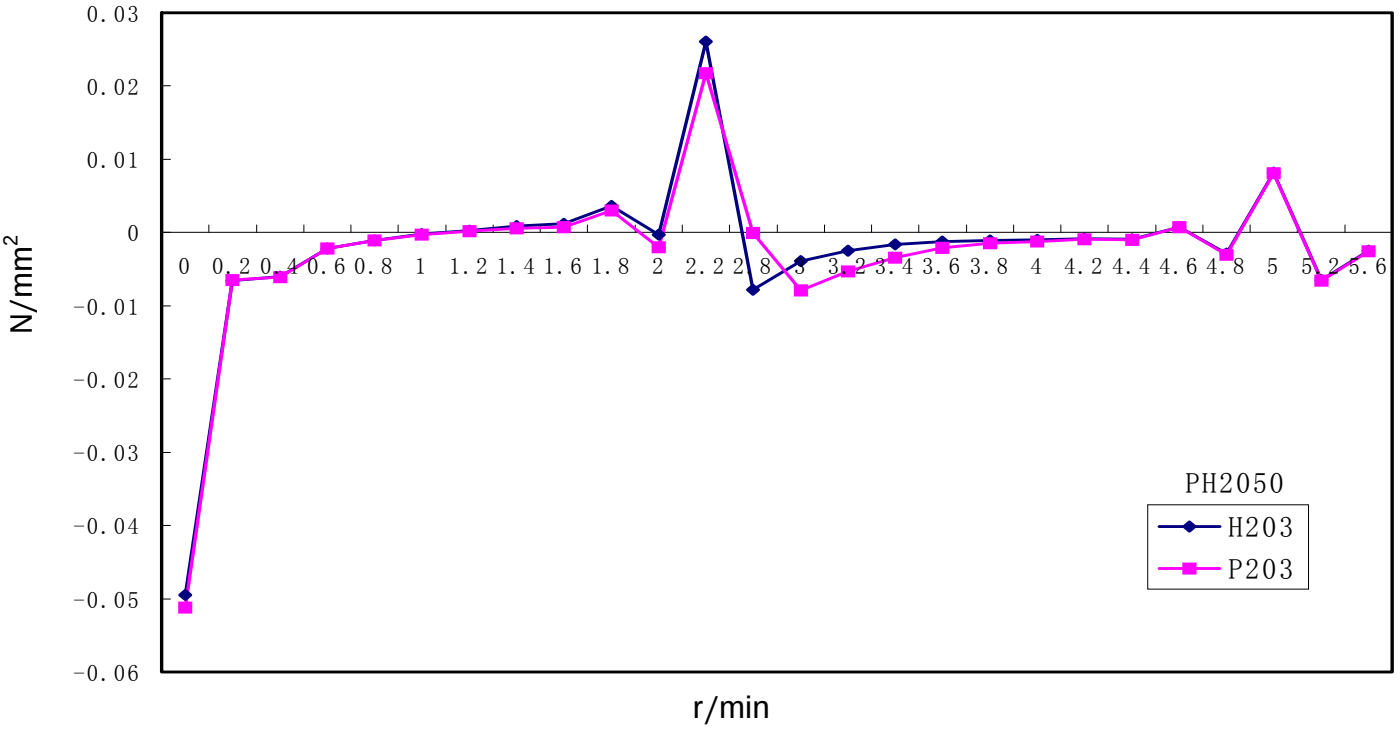

Figure 2. Normal stress curve of soil around pile (D=2000 mm).

Deductions

(1) About σ_x: It can be seen that a comparison of the double slope of the push-extend pile with the single slope of the bearing push-extend reamed pile as shown in Figure 2 revealed that for, near the bearing push-extend reamed, up the bearing push-extend reamed and under the push-extend reamed, the stress influence region are basically the same. The compressive stress under the bearing push-extend reamed is different within a certain region, but with increase in diameter of the bearing push-extend reamed, the compressive stress value approaches the same gradually.

(2) About τ_{xz}: It can be seen from the Figure 3 that the shear stress of the single slope push-extend reamed pile has a high reduction. Up the bearing push-extend reamed, the τ_{xz} of the single slope push-extend reamed pile is bigger than double slope bearing push-extend reamed pile; but σ_x is tensile stress in this region, so the τ_{xz} does not work; under the bearing push-extend reamed, τ_{xz} of single slope bearing push-extend reamed pile has more reduction than the double slope bearing push-extend reamed pile.

(3) About σ_z: It can be seen from the Figures 4 and 5 that when the vertical stress under push-extend reamed under the same diameter are compared, the double slope bearing push-extend reamed has larger influence region of soil under the push-extend reamed than the single

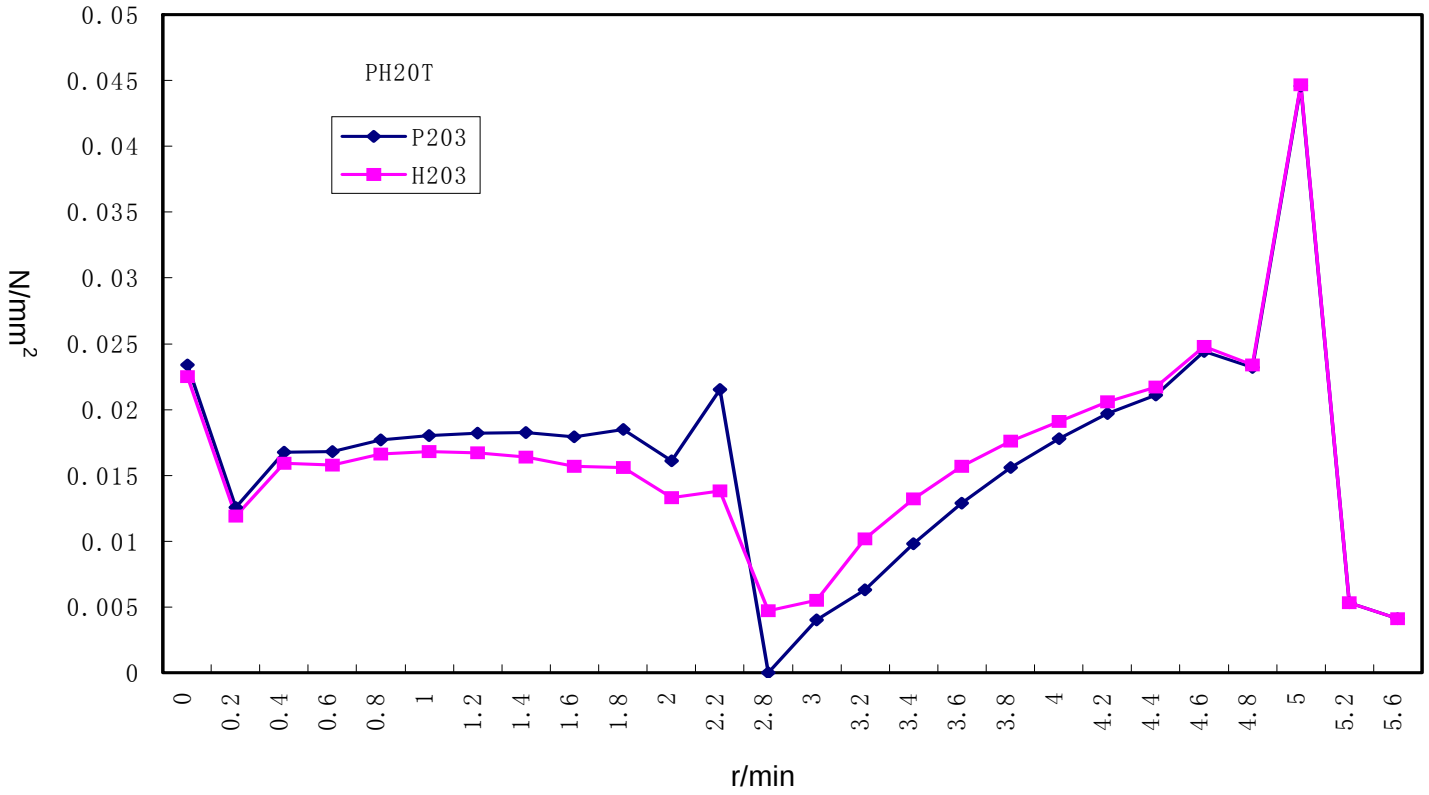

Figure 3. Shear stress curve of soil around pile (D=2000 mm).

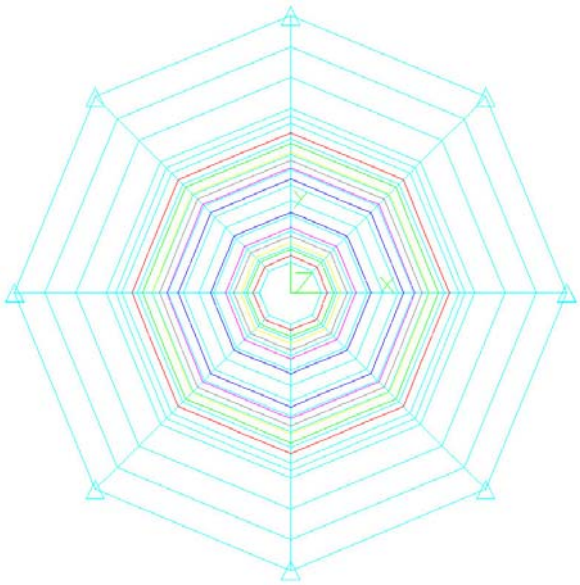

Figure 4. The contour map of vertical stress of soil under the double slope push-extend reamed (D=2000 mm).

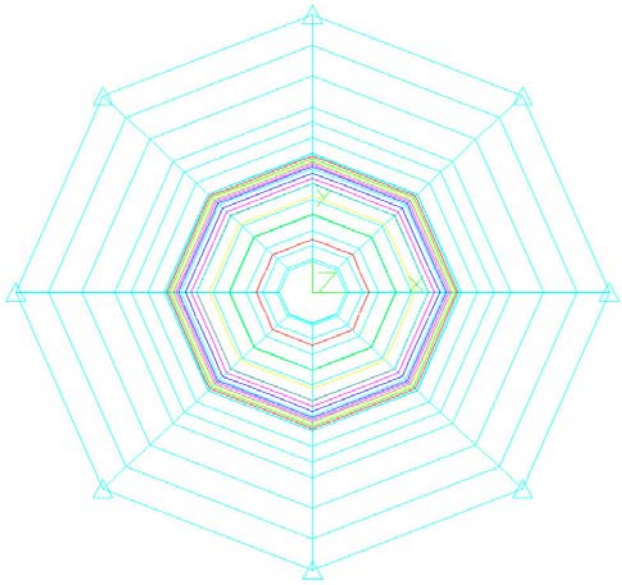

Figure 5. The contour map of vertical stress of soil under the single slope push-extend reamed (D=2000 mm).

slope bearing push-extend reamed. From Figures 6 and 7, it can be seen that the σ_z of pile tip is basically the same, but under the bearing push-extend reamed, the σ_z value of double slope bearing push-extend reamed is much larger than the single slope bearing push-extend reamed.

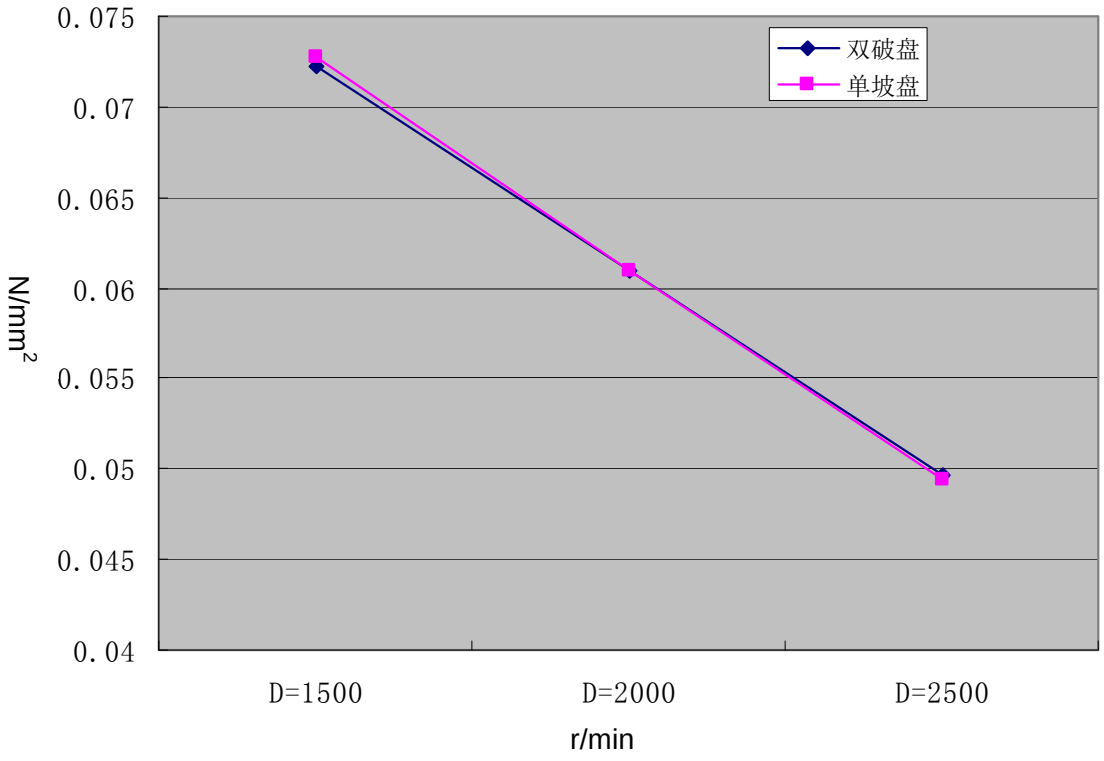

Figure 6. The vertical stress curve of pile tip soil.

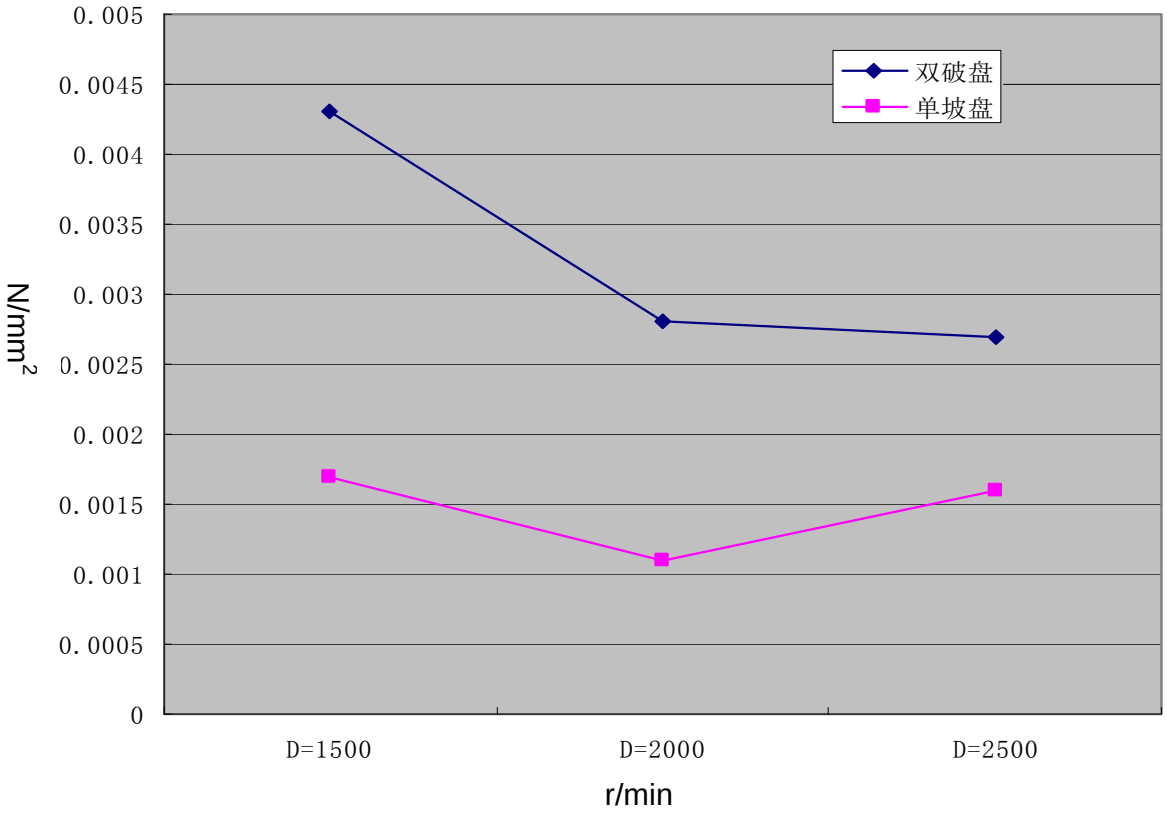

Figure 7. The vertical stress curve of soil around pile.

Conclusions

As regards selection of diameter of the bearing push-extend reamed, some qualitative conclusions can be drawn as follows:

(1) The bearing push-extend reamed can improve the end-bearing force of pile, due to the existence of the bearing push-extend reamed; and also make the failure mechanism of soil up and down the push-extend reamed change. Therefore, the influence on soil around pile, bearing capacity of pile and the shape of the bearing push-extend reamed is different. However, with increase in diameter, the difference of effect between the double slope bearing push-extend and single slope bearing push-extend reamed tends to be slight.
(2) From the deductions, it can be seen that the double slope bearing push-extend reamed pile is lesser than single slope bearing push-extend reamed pile about the bearing capacity of pile under some diameter; however the influence region is larger. Therefore, based on variation of stress for different shape of bearing push-extend reamed, when considering selecting shape of bearing push-extend reamed, if the distance between the bearing push-extend reamed is smaller, the single slope bearing push-extend reamed may be adopted; otherwise, when the distance is larger, the soil can play a significant role; using double slope bearing push-extend reamed will have better effect.
(3) Meanwhile, considering that the forms of bearing push-extend reamed can be further improved, the development will be to change the current situation of the same diameter of bearing push-extend reamed as the diameter of gradual variation. The diameter at the top of pile was largest; from pile top to pile end, the diameter is gradually diminished.

The results of the study are used in the actual design, helpful for the selection of the shape of the bearing push-extend reamed, and can better determine the bearing capacity of single pile through use of the theory of slip line. It is put forward that the theoretical foundation of the design of the Push-extend Multi-under-reamed Pile, contribute to the extensive application of this technology, so as to create greater economical and social benefits.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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