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Research on Interaction of Pile - Anchor Retaining Structure and Proposed Pile-Raft Foundation

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Abstract. During the excavation of the foundation pit, the interaction between the foundation pile anchor support structure and the proposed pile group raft foundation will affect the passive earth pressure of the support pile and the foundation pit uplift. In this paper, the finite element software ABAQUS was used to establish a foundation pit excavation model for two foundation pits with and without group piles. Through comparative analysis, the interaction between the pile-anchor support structure and the pile-slab foundation will affect the passive earth pressure of the supporting structure. As the depth of excavation increases, the earth pressure in the passive zone of the supporting structure gradually increases. Results have shown that the variation of the spacing between the pile foundation and the supporting structure will have a greater impact on the passive earth pressure. The research results in this paper summarize the experience of foundation pit construction and provide a numerical theoretical basis for the construction of similar deep foundation pits, which is of great significance for optimizing the design and construction of deep foundation pits.

1. Introduction

Nowadays, the rapid development of China's high-rise and super-tall buildings, in which the foundation pit construction has become a topic of great concern in the geotechnical engineering community. Among them, group pile raft foundation and pile anchor support structure are important research contents.

In the previous study of support structure, Rowe [1] conducted a pile-slot model test, and found that there was a significant difference between the distribution of earth pressure and the distribution of classical earth pressure. Terzaghi [2] studied the relationship between the limit state of soil and the displacement of retaining structure through model test. Yu Jianlin and Gong Xiaonan [3] used three-dimensional finite element analysis to study the deformation of the retaining structure, the spatial distribution of earth pressure and the geometric size effect of the foundation pit during excavation. Vaziri [4] analyzed the factors of the “soil arch effect” that affect the redistribution of earth pressure in the foundation pit support structure. Shi Wei [5] analyzed the stress characteristics of the pile-anchor support system during the excavation of deep foundation pits, and obtained the distribution law of the horizontal displacement of the retaining pile and the pile side soil with the excavation conditions. Peng Sheqin [6] discussed the interaction between the super-deep foundation pit supporting structure and the soil, and studied the relationship between the horizontal displacement of the supporting structure, the ground subsidence outside the foundation pit and the earth pressure of the pit wall.

In the past research on group piles, foreign research mainly aimed at reducing differential settlement of foundation pits. Padfield and Sharrock [7] discussed that the central group pile could reduce the settlement difference of the piled raft foundation. Randolph [8] believed that even though it was a relatively flexible raft foundation, it could withstand a relatively low settlement difference. Through the relevant series of centrifuge tests, Horikoshi and Randolph [9] proved that the installation of fewer piles in the central part of the raft foundation could reduce the settlement value of the piled raft foundation. In China, Chen Renpeng [10] used elastic theory and finite element method to study the stress distribution law of pile group foundation, and analyzed the influence of parameters on the stress distribution, such as stiffness. Zhang Jianhui et al. [11] established a new analytical method for the pile-raft foundation and the foundation on the layered foundation for the pile-raft foundation with irregularly shaped rafts and non-uniform piles. Qin Xiangwei [12] used the finite element method to analyze the stress distribution, settlement distribution and the variation of stress field and displacement field of pile and raft after the pile foundation.

In the past research, the main research of scholars was mainly based on the separate study of foundation pile anchor support structure and group pile raft foundation, which is also the main trend of previous research. In this paper, the interaction between the foundation pile anchor support structure and the proposed pile-slab foundation is studied to make up for the interaction between the foundation pit structures that have been neglected in the early research. This paper makes up for the blank of research and provides a more accurate basis for foundation pit construction.

2. Finite element calculation

2.1. Finite element model

This paper applyed ABAQUS to simulate using 3D model. The Mohr-Coulomb model was used to numerically analyze the passive earth pressure of the rigid support structure. The pile group, the soil body and the support pile all adopted the solid element, the anchor rod adopted the beam unit; the group pile and the support pile adopted the axisymmetric total integral unit (CAX4), and the soil body adopts the four-node axisymmetric flat strain reduction integral unit (CAX4R), The anchor rod adopted a linear beam unit (CAX1), and the foundation pit simulation diagram is shown in Figure. 1.

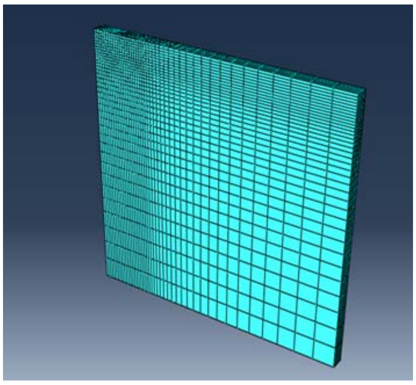

Figure 1. Foundation pit model meshing.

2.2. Engineering case

This project case in this paper used an example of foundation pit construction in an engineering project in Jinan, China. The proposed site is flat, the groundwater level is about 8.00 meters underground, and the groundwater depth is large, which has no adverse impact on the foundation and construction. The foundation pit depth is 12.5m and the foundation pit area is 26.4×43.2m (Figure. 2). In order to simplify the calculation, this paper taked half of the foundation pit for numerical simulation.

In this paper, four models were established to compare the results of foundation pit excavation models with group piles and no pile groups. The soil calculation parameters are shown in Table 1, and the calculation parameters of the pile group and support structure are shown in Table 2 and Table 3.

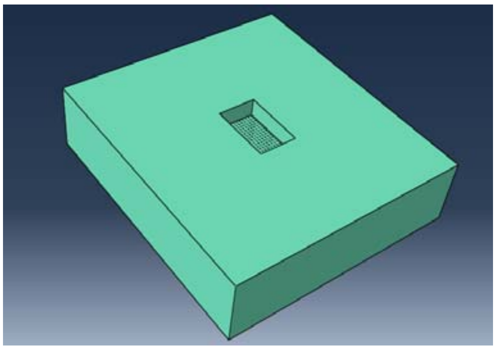

Figure 2. Two or more references.

Table 1. Soil mechanics index.

Soil	Soil thickness/m	$\gamma / KN \cdot m^{-3}$	ν	E / MP_a	c_q / KP_a	φ_q
1	5.0	19.8	0.3	6.07	123	18.8
2	5.8	19.8	0.3	6.07	644	18.8
3	3.1	19.9	0.3	9.24	649	26.9

Table 2. Structural mechanics index.

Structural	material	$\gamma / KN \cdot m^{-3}$	ν	E / MP_a
Support pile	C30	456	123	123
Engineering pile	C40	654	649	649

Table 3. Prestressed anchor cable mechanical index.

Number	Pole type	Horizontal spacing	Free segment length	Anchor length	Prestress
MG1	3Φs15.2	1600	6000	12000	180KN

3. Results and discussions

Figure. 3 shows the passive earth pressure distribution curve obtained from the data calculated by the finite element of the model. It can be seen from the analysis that the passive earth pressure does not increase linearly with the increase of depth, but gradually approaches the static earth pressure and even the distance pit. There is a cross at a distance from the bottom. It is mainly due to the limited excavation space of the foundation pit, the rebound of the soil caused by the excavation of the foundation pit, the extrusion caused by the lateral displacement of the supporting structure and the vertical displacement of the supporting structure. These factors make the stress state changes of the soil relatively Complex, the calculated passive earth pressure distribution curve is not strong. Different from the active earth pressure, the passive earth pressure value at the same depth from the bottom of the pit gradually increases with the increase of the excavation depth. As the depth of excavation increases, the passive earth pressure at the bottom of the support structure is almost constant, which is basically equal to the static earth pressure. With the increase of the number of excavation stages, the lateral displacement of the supporting structure gradually increases, and the passive earth pressure distribution curve gradually changes from a triangle to a trapezoid. The earth pressure at the bottom of the supporting structure is roughly equal to the static earth pressure. The pressure is gradually increasing.

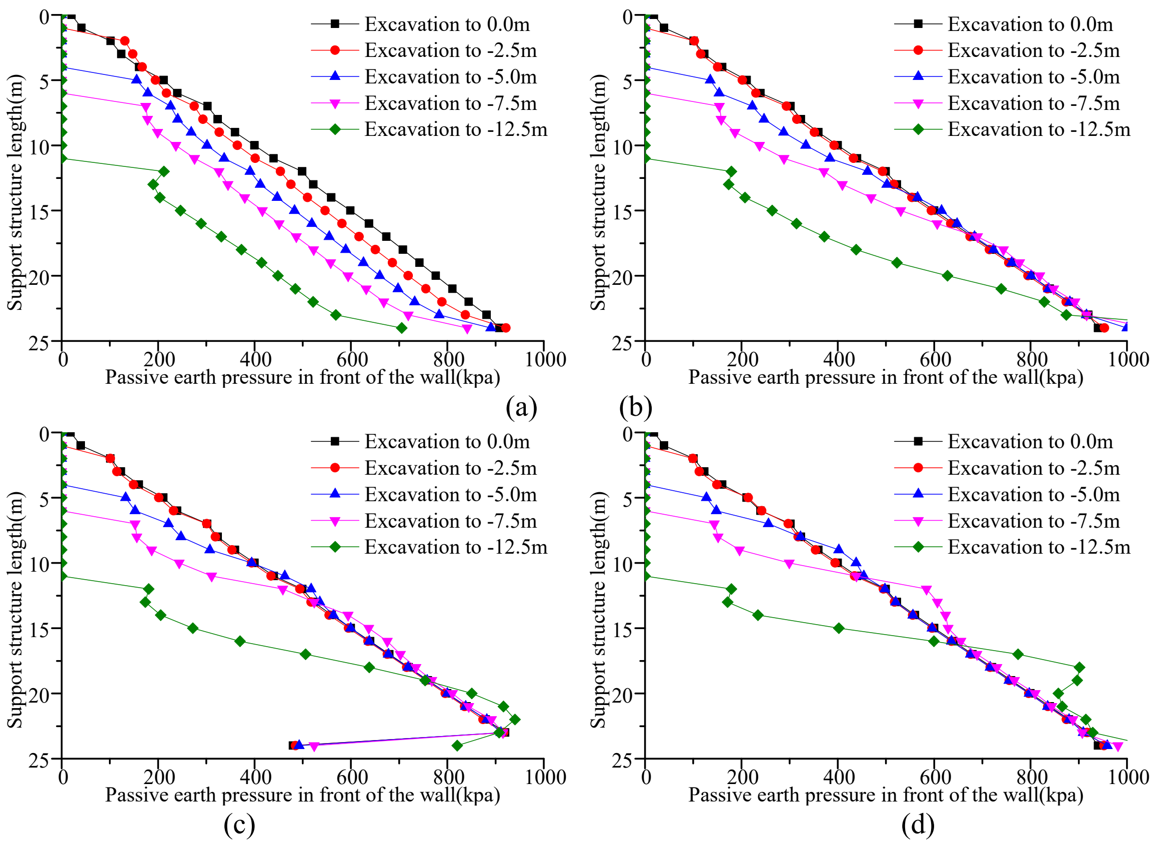

Figure 3. Passive earth pressure of support structure.

It can be seen from the Figure. That with the addition of engineering piles, the earth pressure in the passive zone of the supporting structure generally shows an increasing trend, indicating that the supporting structure is affected by the engineering during the interaction between the supporting structure and the group pile raft foundation. The co-extrusion of the pile and the soil increases the passive earth pressure of the supporting structure. According to the force analysis of the passive zone, the influence of the engineering pile on the passive earth pressure of the supporting structure is great. We can obtain through analysis that the earth pressure in the passive zone of the supporting structure reaches the limit equilibrium state only in a small range below the excavation face. The earth pressure in most of the range is in the non-limit equilibrium state, and the earth pressure of the passive zone in the supporting structure Between the static earth pressure of the supporting structure and the passive earth pressure of the supporting structure, there is a nonlinear distribution, and the strength of the soil in front of the wall is not fully exerted.

4. Conclusion

Through the simulation considering the engineering pile and the foundation pit excavation case without considering the engineering pile, the variation of the earth pressure in the passive zone of the supporting structure and the uplift of the foundation pit are obtained.

During the excavation of the foundation pit, the passive earth pressure increases with the depth is not a simple linear growth, but is far from the Langken passive earth pressure close to the static earth pressure or even at a distance from the bottom of the pit. During the interaction process between the supporting structure and the group pile raft foundation, the supporting structure is co-extruded by the group pile and the soil body, so that the passive earth pressure of the supporting structure increases, and the engineering pile is obtained according to the force analysis of the passive zone. The impact on the passive earth pressure of the supporting structure is large. The earth pressure in the passive zone of the supporting structure reaches the limit equilibrium state only in a small range below the excavation face. The earth pressure in most of the range is in a non-limit equilibrium state, and the strength of the soil in front of the wall is not fully exerted.

Acknowledgments
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References
[1] Allen Lunzhu Li, R.Kerry Rowe. Effects of viscous behavior of geosynthetie reinforcement and foundation soils on the performance of reinforced embankments [J]. Geotextiles and Geomembranes, 2008, 26(4): 317-334.
[2] Terzaghi K, Peek R B. Soil Mechanics in Engineering Practice, 2nd ed, John Wiley & Sons, Inc, New York, 1967, 729.
[3] Yu Jianlin, Gong Xiaonan. Spatial behavior analysis of deep excavation [J]. Chinese Journal of Geotechnical Engineering.
[4] Vaziri H H. Numerical study of parameters influencing the response of flexible retaining walls. Canadian Geotechnical Jounal. Vol.33, 1996:290-308.
[5] Shi Wei, Liu Jiming, Zhang Wei. Testing study on horizontal displacement of anchor-pile bracing structure for deep foundation pit [J]. Chinese Journal of Rock Mechanics and Engineering, 2003,22(51):2355-2358.
[6] Peng Sheqin. Study on interaction between super deep foundation pit supporting structure and soil [D]. Chengdu: Chengdu University of Technology, 2009.
[7] Padfield, C. J. and Sharrock, M. J. Settlement Of structure on clay soils [J]. Construction Industry Research and Information Association, Special Publication, 1983, 27.
[8] Randolph, M. E. Design methods for pile groups and piled rafts [A]. Proc. 13th ICSMFE [C]. 1994: 61～82.
[9] Horikoshi, K. and Randolph, M. E Centrifuge modelling of piled raft foundation on clay [J]. Geotechnique, 1996, 46(4): 74l～752.
[10] Chen Renpeng. Research on Working Behavior and Analysis and Design Method of Piled Raft Foundation in Soft Soil Foundation [D]. Zhejiang: Zhejiang University, 2001.
[11] Zhang Jianhui, Deng Anfu. New analytical method for piled raft foundation [J]. China Civil Engineering Journal, 2002, 35(4): 103～108.
[12] Qin Xiangwei. Research on Foundation Working Behavior of Piled Raft and Variable Stiffness Leveling Design [D]. Zhejiang: Zhejiang University, 2004