The Influence of Steel Bracing on the Stability of Foundation Pit Excavation under Dewatering Condition

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Abstract. In order to analyze the stability of under the condition of rainfall in tunnel excavation, a Phase of foundation pit in Fuchun River as the research object, according to the engineering quality condition and the excavation depth, using ABAQUS to the groundwater seepage of foundation pit, the process for the process of the change of the bearing capacity of foundation pit excavation, foundation pit precipitation is analyzed under the condition of using steel support and steel support in both cases the stability of foundation pit, to the wall and the interaction of surrounding soils including even the wall deformation of ground surface subsidence It is necessary to set steel support in large deformation area to provide certain basis for the smooth implementation of similar projects.

Keywords. Foundation pit, numerical simulation, dewatering, stability, settlement.

1. Introduction

In recent years, major cities in southern my country have high population density but limited space above ground. As a result, urban underground space projects have developed rapidly. However, the complex underground environment has led to a steep increase in the complexity of foundation pit engineering design and construction [1-3]. Large area and complex support also have to consider external factors such as the decrease in soil bearing capacity caused by rainfall, the decrease in shear strength and other unfavorable factors, which may even lead to partial collapse. At present, there are a large number of long and narrow deep foundation pits and supports in the city. Failures also occur from time to time. At present, the research of scholars has focused on the study of rainfall on unsaturated soil slopes, but there are few studies on the deformation and stability of foundation pits under the action of rainfall under the condition of support [4-8]. In addition, there are relatively few studies on support performance considering the influence of groundwater level. Li Yanlong et al. [9] calculated the seepage field value under rainfall conditions based on the abaqus finite element software, and analyzed the stability of the foundation pit slope. Cui Fengzhan [10] used FLAC3D numerical simulation and analysis and engineering actual detection methods to analyze the comparison of supporting excavation with unsupported excavation design under heavy rainfall conditions, and analyzed the stability of the foundation pit and put forward feasibility opinions. Song Yaya [11] and others used GeoStudio software to perform seepage calculation and stability analysis on slopes of different schemes, and discussed the influence of soil-water characteristic curve and saturated permeability coefficient under rainfall conditions, as well as the stability of slopes in unsaturated. In this paper, combined with the EPC project of Fuchun Bay Avenue (Phase I), the stability analysis
under the conditions of unsupported and steel support in foundation pit excavation under ABAQUS precipitation conditions is used.

2. Project Overview
Hangzhou is located on a flat and open alluvial plain with low-lying terrain and numerous lakes. Its soil quality is typical of Eastern China geological soft soil, with poor soil self-reliance. Thick layered soft soils are widely distributed, with a natural void ratio greater than or equal to 1, and natural water content. The rate is greater than or equal to the liquid limit, and it has the characteristics of high compressibility, low strength, high sensitivity, and low water permeability. The stratum that the tunnel traverses is mainly silty sand, silty clay, clay silt mixed with silty soil, and cohesive soil and gravel. The groundwater types of the site within the scope revealed by the survey are mainly Quaternary loose rock pore water and pore confined water. The soil layer profile is shown in tables 1:

| Soil       | ω/%  | γ/KN·m⁻³ | φ/°  | c/kPa | Es/MPa |
|------------|------|----------|------|-------|--------|
| Plain      | 30.4 | 18.6     | 10   | 3     | —      |
| Silty clay | 45.4 | 16.4     | 10   | 21    | 4.06   |
| Clay silt  | 26.8 | 17.6     | 15   | 25    | 3.7    |

This article mainly explores the stability analysis of steel support to foundation pit excavation under dewatering conditions. Due to the existence of groundwater, foundation pits also face the problem of foundation pit precipitation. Therefore, in order to analyze the stability of the foundation pit, the influence of groundwater on the stability of the foundation pit should be fully considered. The steel supports are Φ609 mm×16 mm steel supports, and the four corners of the ends of the foundation pit are inclined supports.

3. Finite Element Calculation Model
Through the establishment of two-dimensional finite element numerical simulation of the foundation pit system, there are mainly two types of material constitutive models widely used in the field of geotechnical engineering. One is the elastic nonlinear model, such as the Duncan-Chang model. The material parameters of the model are easy to obtain. There are many applications in actual engineering; the other type is elastoplastic model, mainly represented by Mohr-Coulomb model, Drucker-Prager model and modified Cam-clay model, although Drucker-Prager model and modified Cam-Clay clay model are in the simulation results in soft soil are more accurate than the Mohr-Coulomb model. However, due to the excessive number of parameters and difficulty in obtaining, the soil material adopts the Mohr-Coulomb constitutive model.

4. Introduction to the Model
Considering that the foundation pit is almost symmetrical in all directions, a part of the foundation pit is studied in order to simplify the calculation results. The model size is 100 m×200 m×60 m. The foundation pit size is 80 m×20 m×20 m. The soil layer is 16 meters. The soil layer uses three layers: miscellaneous fill, silty clay, and clay silt. The soil is simulated by an eight-node hexahedral C3D8P pore pressure element, and the underground continuous wall is simulated by an eight-node hexahedral C3D8R element. All layers of soil adopt an ideal elastoplastic model with Moore-Coulomb yield condition as the failure criterion. The material properties of the underground continuous wall are set to an elastic model, and the elastic modulus is 30 Gpa. The elastic modulus of steel support is 209 GPa.

4.1. Boundary Conditions
The horizontal displacement is restricted around the model, that is, the horizontal displacement is 0, the bottom of the model is restricted to the vertical and horizontal displacement, that is, the
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displacements in the x, y, and z directions are all 0, the ground wall is set as impervious and the bottom is permeable boundary conditions. Model contact setting: The contact surface between the ground wall and the surrounding soil adopts surface-to-surface contact, the normal contact adopts the form of "hard contact", and the tangential direction adopts the Coulomb friction law of limited slip for simulation, and the friction coefficient is taken as 0.3.

4.2. Dation Pit Precipitation Simulation
The foundation pit is excavated in four steps. The initial water level for precipitation of the foundation pit is the ground surface. In the first step, the groundwater level is lowered to 5 meters when the excavation is 4 meters, and the groundwater level is lowered to 1 meter below the soil body with each excavation. Ensure that the pore water pressure on the top and bottom of the soil in the dewatering area of the foundation pit is 0. Because the ground wall is set to be impervious, the pore water pressure outside the foundation pit is 0, and the pore pressure at the bottom of the foundation pit is obviously different from inside and outside.

5. Results and Analysis of Foundation Pit Deformation
The horizontal displacement of the bottom of the foundation pit under dewatering excavation is greater than the horizontal displacement of the bottom of the foundation pit without dewatering excavation. This is because the groundwater has a horizontal force on the soil during the precipitation process. Due to the existence of groundwater, as the construction progresses, groundwater may seep from the inside of the foundation pit and cause soil damage. Therefore, precipitation must be carried out during the excavation process. After the excavation of the foundation pit, the ground subsidence within 35 meters outside the pit was caused, and the soil at the bottom of the foundation pit was uplifted. The excavation process of the foundation pit is the process of unloading the excavation surface of the foundation pit, and the soil at the bottom of the pit is displaced mainly upward due to the unloading.

5.1. Analysis of Horizontal Displacement of Ground Wall
As shown in figures 1 and 2, the top displacement of the unsupported ground connecting wall increases significantly as the excavation progresses, and the maximum is about 48 cm. It has obviously collapsed (the ground connecting wall has not been damaged, so a large horizontal displacement is generated). During reinforcement, the horizontal displacement of the ground connecting wall is significantly reduced, and the maximum value is about 13 mm, indicating that the support can significantly reduce the horizontal displacement of the ground connecting wall and meet the design requirements. As the excavation progresses, the horizontal displacement of the ground connecting wall continues to increase, and the increase rate gradually decreases as the excavation progresses.

Figure 1. Horizontal displacement of connecting wall in unsupported excavation.
Figure 2. Horizontal displacement of the supported excavation diaphragm wall.
5.2. Analysis of Foundation Pit Settlement Results
The settlement value of the ground surface around the foundation pit keeps increasing, and the settlement around the foundation pit keeps increasing with the progress of excavation, but the settlement value decreases during the fourth step of excavation, which is related to the continuous drop of the groundwater level. As shown in figure 3, there is a support 12 meters away from the foundation pit, the maximum settlement is about 30 mm, and the impact range of the surrounding soil settlement is about 30 m. Meet the requirements for the maximum settlement and range of the foundation pit design. The surface settlement of the unsupported excavation is significantly greater than that of the excavation with support (the amount of damage settlement is not limited), indicating that the support can significantly reduce the surface settlement.

![Figure 3. Soil settlement diagram of mid-point section of long side.](image)

5.3. Analysis of Foundation Pit Heave Value
Foundation pit uplift is the phenomenon that the bottom of the foundation pit bulges during the excavation of the foundation pit. The uplift of the foundation will drive the support up and affect the stability of the foundation pit excavation. As shown in figure 4, as the pit bottom uplift value continues to decrease, the maximum uplift value appears in the middle of the foundation pit, and the uplift value on both sides of the foundation pit is significantly smaller than the middle of the foundation pit.

![Figure 4. Base uplift curve of different excavation depths without steel support.](image)
6. Conclusion
In this paper, by creating a finite element model, using steel supports and non-steel supports during the excavation of foundation pits under dewatering conditions mainly analyzes the settlement of the soil and the uplift of the bottom of the foundation pit.

(1) As the excavation progresses, the groundwater level in the foundation pit continues to drop, and the pore water pressure in the foundation pit decreases due to precipitation, and the effective stress on the soil increases, resulting in surface settlement in the area around the foundation pit. Each excavation will lower the groundwater level to 1 meter from the bottom of the foundation pit, which can effectively simulate the process of foundation pit precipitation and save calculation time, which is a good reference.

(2) Under support conditions, as the excavation depth increases, the active earth pressure on the ground connecting wall increases, and the deeper the excavation, the greater the horizontal displacement of the ground connecting wall, which is located on the surface of the foundation pit near the wall embedded depth. The stress concentration and uplift of the soil in the passive zone are more obvious. The steel support can fix the surrounding soil, so the surface settlement in a small area is small.

(3) Supporting excavation can significantly reduce the horizontal displacement of the ground connecting wall and the final settlement of the ground surface, and has no obvious impact on the final settlement of the base. The steel support provides a certain degree of protection for the smooth excavation of the foundation pit.

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