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Unloading Mechanical Effect Analysis of Retaining Structure of Deep Foundation Pit in Soft Soil

Leiyu Zhang*, Zhenjie Hao, Shufeng Chai, Yuxin Zhou

Army Military Transportation University, Tianjin, China

*Corresponding author e-mail: dzx0413@sina.com

Abstract. The large-scale foundation pit construction site is small in area and complicated in conditions, which is easy to affect the environment. At the same time, it is prone to cracking or even collapse of nearby buildings due to uneven surface. The low-ranking official network around the foundation pit is easily damaged, and the surrounding roads are cracked. Many problems. At the same time, soft soil has the characteristics of high compressibility, low strength, large water content and small bearing capacity. It shows remarkable structural and rheological characteristics, which makes it more and more challenging to ensure the safety and stability of soft soil foundation pit engineering. In this paper, the deep foundation pit deformation of super soft soil is predicted and controlled, and the deep foundation pit engineering of soft soil is taken as the research object. The mechanical characteristics of soil unloading process are discussed, and the strength and deformation law of unloading soil are studied. The actual constitutive model and soil parameters are numerically simulated by the finite element method, which objectively reflects the mechanical state of the foundation pit excavation unloading soil, which is of great significance to ensure the safety and long-term stability of large underground engineering construction.

1. Research background

In the traditional design method of large-scale foundation pit engineering, engineering designers have not carefully considered the influence of soil unloading stress path on soil parameters in the excavation of underground space structure through the conventional “loading” soil mechanics research method. The accuracy of the soil is difficult to guarantee, and the soil mechanics parameters are directly related to the correctness of the soil pressure and the stability analysis of the foundation pit. Therefore, the correct analysis of the mechanical effects of foundation pit unloading soil is very important for the scientific design of foundation pit engineering. The analysis of deformation and stability of foundation pit engineering involves both the soil stress path problem and the groundwater seepage problem. In recent years, the seepage problem caused by foundation pit excavation has been paid more and more attention. One of the main reasons is that the engineering accidents caused by groundwater continue to occur. In the process of foundation pit excavation, due to the water level difference inside and outside the foundation pit. The increase causes the groundwater outside the foundation pit to bypass the lower end of the retaining wall and seep into the foundation pit. The resulting seepage force acts downward in the direction of the outside of the pit, and the direction of action inside the pit is upward. When the weight is heavy, it will decrease, and the soil particles will



spray upward with the water flow. When the seepage channel becomes larger, when the seepage force is greater than the soil particles, the water flow resistance seepage force increases, causing a large amount of sand particles to flow with the water flow. The phenomenon of sand flow is formed, and the influence of groundwater seepage on the safety and stability of the foundation pit cannot be ignored. Therefore, the influence of the coupling between the soil stress field and the seepage field on the deformation of the foundation pit must be considered, and the analysis of the stress field and the seepage field is related to the mechanical parameters of the soil. Therefore, the coupling effect of stress field and seepage field in foundation excavation process is analyzed, and it is of great significance to explore the stability and deformation characteristics of deep soft pit of large soft soil under seepage conditions.

2. Soil stress path and model establishment during excavation of foundation pit construction

Foundation excavation unloading breaks the original mechanical balance of the upper body. In order to study the mechanical properties of soft soil unloading,

The stress path of the soil in different parts of the foundation pit must be analyzed. For the sake of convenience, the excavation process of the deep foundation pit is simplified to the plane strain problem. The soil stress state and stress path in different areas of the foundation pit are shown in the following figure [1].

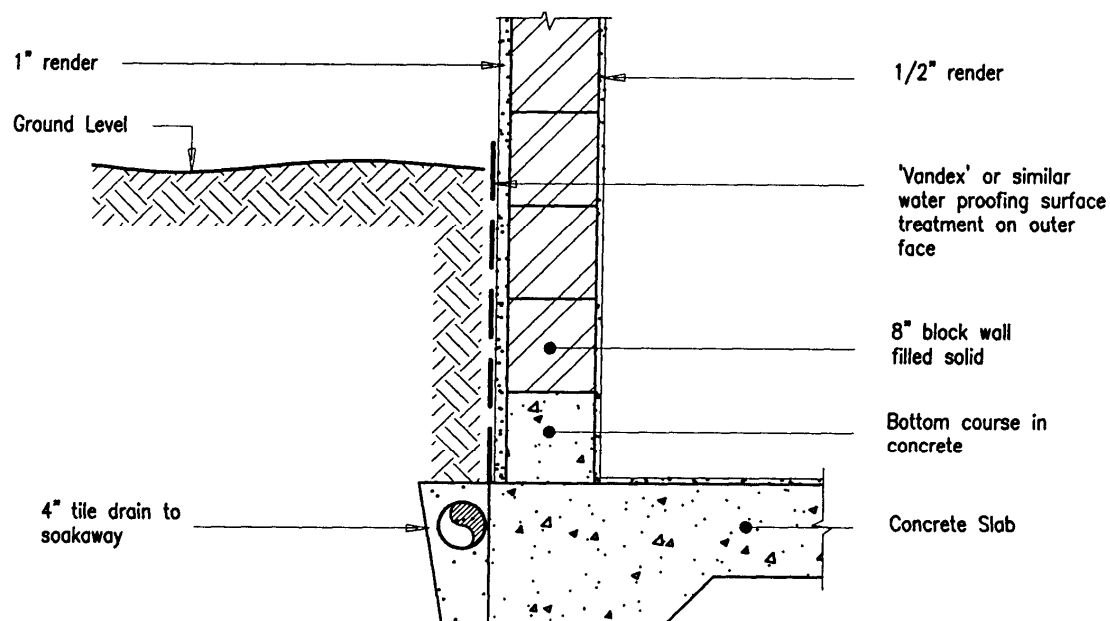


Fig. 1 Unloading effect of excavation construction of deep foundation pit engineering

2.1. Experimental research methods

2.1.1. Analysis of land stress state. In order to objectively and truly reflect the soil mechanical properties of the foundation pit sweat excavation process, the initial stress state of the soil must be simulated in the test, and the specific stress path test is carried out on this basis [2-3]. Before the excavation of the foundation pit, the soil in the natural state is consolidated under the condition of k_0 , and the stress state at any point in the soil is:

$$\begin{aligned}
\sigma_1 &= \sigma_v = \gamma z \\
\sigma_2 &= \sigma_3 = k_0 \sigma_1 = k_0 \gamma z \\
k_0 &= 1 - \sin \varphi
\end{aligned} \tag{1}$$

Where: γ : The soil is naturally heavy. z : Calculated depth of the soil. k_0 : static earth pressure coefficient. φ : effective internal friction angle of the soil. The state of stress after the soil sample is taken out.

$$\begin{aligned}
\sigma_1 &= \sigma_v = \gamma z \rightarrow 0 \\
\sigma_2 &= \sigma_3 = k_0 \sigma_1 = k_0 \gamma z \rightarrow 0
\end{aligned} \tag{2}$$

Generally speaking, the consolidation process of natural soil belongs to the k_0 consolidation process. In this test, the specimen is subjected to equal principal stress ratio consolidation, and the magnitude of the principal stress ratio can be determined by k_0 . Therefore, the initial stress state of the soil must be restored before the soil unloading triaxial test [4]. In order to simulate the initial stress state of the soil, it is necessary to minimize the lateral deformation of the specimen during the k_0 consolidation process. During the k_0 consolidation test, the axial deformation of the soil sample can be automatically adjusted by the displacement to control the lateral deformation of the soil sample.

2.1.2. Experimental soil physical and mechanical indicators. This test is for the representative black muddy soil, red clay and fine sand in the Pearl River Delta region. According to the Geotechnical Test Method Standard GB/T50123-1999, the water content, natural gravity, void ratio and liquid of the sample are tested. The physical and mechanical indicators such as the limit were measured, and the results are shown in Table 1.

Tab. 1 Physical parameters of soil samples

Soil sample	Water content (%)	Natural gravity (kN/m ³)	Pore ratio	Liquid limit (%)	Plastic limit (%)
Muddy soil	39.5	1740	1.05	49	28
Red clay	31	1840	0.95	41	22
Fine sand	29.5	2050	0.78	-	-

2.2. Mechanical properties of the soil unloading stage

Experimental studies have shown that the stress-strain relationship of the soil in the unloading test is nonlinear. Konder proposes that the hyperbolic function can be used to represent the stress-strain relationship of cohesive soil, loose sand and medium-density sand under conventional compression tests, namely:

$$\frac{\varepsilon_1 - \varepsilon_0}{(\sigma_1 - \sigma_3) - (\sigma_1^0 - \sigma_3^0)} = \frac{\varepsilon_0}{\sigma_0} = a + b\varepsilon_0 \tag{3}$$

$(\sigma_1^0 - \sigma_3^0)$: Deviation stress of soil consolidation stage; $(\sigma_1 - \sigma_3) - (\sigma_1^0 - \sigma_3^0)$: Deviation stress of soil unloading stage; Axial strain of soil; $\varepsilon_1 - \varepsilon_0$: Axial strain of soil unloading process.

2.3. Nonlinear elastic constitutive model of soil unloading in active zone

Since the Duncan-Chang model is derived based on the stress-strain relationship curve of the conventional triaxial test. The hyperbolic stress-strain relationship of soil during unloading can be transformed into a typical linear equation. Therefore, the nonlinear elastic constitutive model of soil unloading can be derived from the basic idea of Duncan-Chang model, and the ideal elasticity is analyzed by generalized Hooke's law. Body. There are expressions as follows [4-5].

$$E_0 = \frac{d(\sigma_1 - \sigma_3)_0}{d\varepsilon_0} = \frac{1}{a + b\varepsilon_0} - \frac{b\varepsilon_0}{(a + b\varepsilon_0)^2} = \frac{a}{(a + b\varepsilon_0)^2} \quad (4)$$

$$\text{Reduce } (\sigma_1 - \sigma_3)_0 = \frac{\varepsilon_0}{a + b\varepsilon_0} \text{ to } \varepsilon_0 = \frac{a}{\frac{1}{(\sigma_1 - \sigma_3)_0} - b} \text{ and substitute (5) to get:}$$

$$E_0 = \frac{1}{a} [1 - b(\sigma_1 - \sigma_3)_0]^2 \quad (5)$$

Both E_0 increases with the increase of consolidation pressure, but decrease with the increase of stress level. However, due to the different stress paths considered, for the same soil under the same confining pressure, the unloading elastic modulus of the active zone and Duncan- There is bound to be a certain gap in the elastic modulus of the Chang model.

2.4. Nonlinear elastic constitutive model for soil unloading in passive zone

The stress path of the soil in the passive zone and the active zone is quite different. The stress change of the soil in the passive zone is more complicated. With the excavation of the foundation pit, the axial load is gradually reduced, and the confining pressure may increase or decrease. The variation is related to the excavation depth of the foundation pit and the stress path of the soil in the passive zone, which is related to the nature of the soil layer, the depth and stiffness of the support structure. After the soil k_0 is consolidated, the confining pressure is graded and loaded, and the axial compression is unloaded. The absolute value of the axial pressure change is 1 times of the confining pressure. Since the unloading stress-strain relationship of the soil in the passive zone also has a hyperbolic property, the nonlinear elastic constitutive model of the unloading of the passive zone can also be derived by simulating the Duncan-Chang model.

$$E_t = \frac{3k_0 + 1}{2(1 + k_0)} E_0 = \frac{3k_0 + 1}{2(1 + k_0)} [1 - R_f S]^2 E_{0t} \quad (6)$$

Since the soil in the passive zone is not destroyed during the unloading test, only a small range of axial strain occurs. The expression of the nonlinear elastic modulus of the unloading of the soil in the passive zone, the parameters in the formula are the same as the unloading elastic modulus parameters of the active zone.

3. Example analysis

3.1. Background introduction

The depth of a garage pit is about 52000m², the excavation depth is 11.15m, and the local maximum excavation depth is 15.03m. The foundation pit construction support scheme is divided into two stages

of grading excavation after precipitation, and the slope width is 1:1.25. The platform width between the slopes is 4m. The slope is made of 150mm thick C20 spray, and the inner diameter is 10mm steel mesh, which is arranged in two directions with a spacing of 200mm. In the east, north and west directions of the Dajikeng, a three-axis cement mixing pile water-stop curtain is connected with the foundation pit maintenance structure of the southern financial square to form a large-base water-stopping ring.

3.2. Foundation pit finite element model establishment

The finite element analysis software MIDASGTS is used to simulate the foundation pit excavation process. By establishing a three-dimensional finite element analysis model, the model can be more reflected in the actual foundation pit engineering. The specific calculation model size is 100m×40m×25m, the span of the pit is 40m, the depth of the excavation depth grid is 1 along the foundation pit, and the remaining grid size is 2, using 8-node isoperimetric elements, a total of 11880 units, nodes the total number is 12,904, as shown in Figure 2.

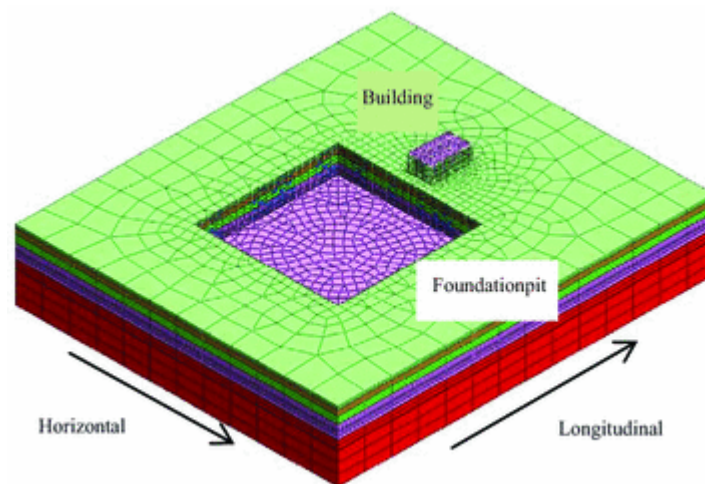


Fig. 2 finite element simulation of foundation pit

3.3. Comparative analysis of internal forces of envelope structure

Through the numerical calculation, the internal force variation law of the underground continuous wall under different excavation conditions can be obtained. The underground continuous wall with the section (x=30, y=8) is also studied. The bending moment diagram is shown in Fig. 3.

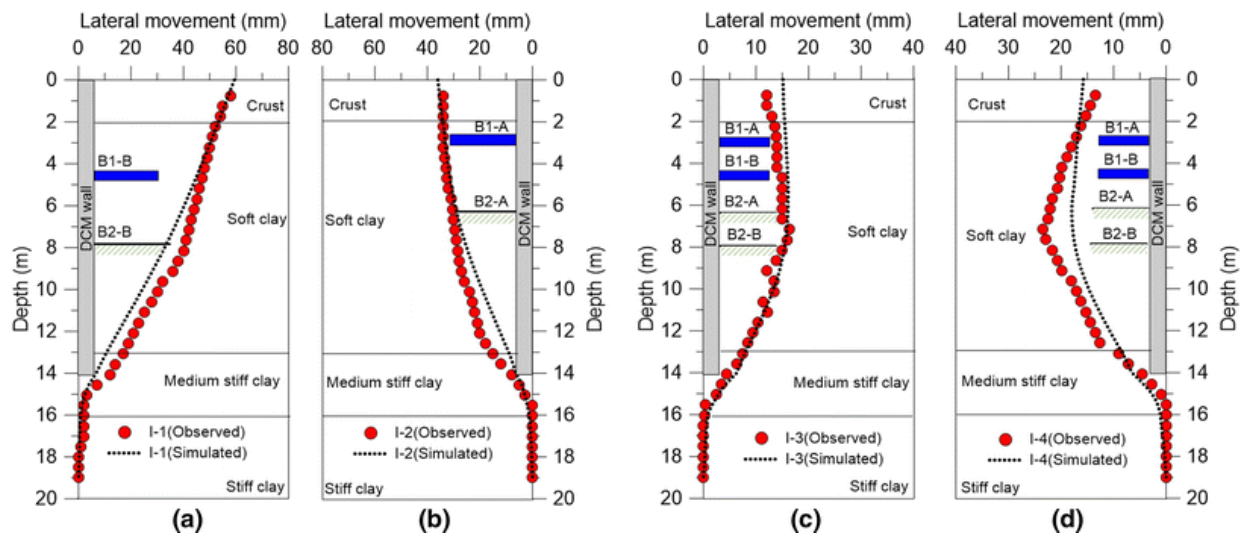


Fig. 3 Force analysis of continuous wall

4. Conclusion

According to the specific engineering geological conditions of a foundation pit engineering, the soil excavation is carried out by the conventional soil loading test parameters and unloading test parameters, and the internal forces of the foundation pit under different excavation conditions are applied. Comparative analysis shows that the calculation results using the unloading test parameters are generally larger than the conventional triaxial compression test. By comparing the finite element calculation results with the monitoring data, the calculation results using the unloading test parameters are closer to the monitoring values.

Because the mechanical behavior of deep foundation pit excavation unloading is a very complicated research topic, this paper has done a lot of useful explorations on the mechanical behavior of soil unloading, but there are still many problems to be further studied, as shown below. Several aspects: (1) In the passive zone triaxial test, due to the complexity of the stress path of the passive zone and the limitation of the test conditions, it is difficult to objectively and realistically simulate the stress state of the passive zone soil, so that the passive zone soil is derived. There is a certain difficulty in the volume of the unloading modulus. This paper has only made a preliminary discussion. Therefore, the unloading triaxial test of the soil in the passive zone still needs to be improved. (2) In the process of establishing the unloading constitutive model of the active zone, the influence of the principal stress on the Poisson's ratio is not considered. Therefore, the derivation of the unloading constitutive model of the active zone remains to be improved.

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