

Research and Engineering Application of Soft Soil Unloading and Deformation Model

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Abstract. Soft soil is a multiphase medium composed of solid soil particles, pore water, pore gas and combined water film adsorbed on the surface of particle group and colloid between particles. It is widely distributed in coastal, middle and lower reaches of rivers and delta of lakes. Its physical and mechanical properties and engineering characteristics are complex and regional differences are obvious. With the rapid development of social economy and urbanization, it will inevitably lead to serious problems such as urban land tension, traffic congestion and environmental pollution. These coastal cities are the leaders of China's economic development. After more than 30 years of rapid economic development, the construction scale of these cities in China is also expanding, and the supply and demand of construction land is becoming increasingly tight. The contradiction between supply and demand is more prominent. With the scarcity of land resources and the rapid development of economy, a large number of construction projects in Qianhai area have been started, among which the construction of subway is also on a large scale. The shortage of land resources and the increase of land development make the high density and high strength building development along the subway line. The development of these building properties is bound to appear a large number of complex deep foundation pit projects, and the excavation of deep and complex foundation pit near the side of subway tunnel is a common form of excavation. In practical construction projects, due to the influence of external factors such as complex construction site conditions and urgent time requirements, people often pursue the progress of foundation pit excavation too much in actual construction, ignoring the research and application of mechanical properties of soft soil foundation, which leads to the safety accidents of subway tunnel structure from time to time. This is closely related to the mechanical properties of soft soil with high moisture content, high compressibility and low bearing capacity. Therefore, deep and large foundation pit engineering in soft soil area is prone to heavy engineering safety problems such as underground continuous wall and other retaining structures. Therefore, the further study of the unloading deformation model of soft soil, the physical and mechanical properties and engineering characteristics of soft soil has a positive and important economic value and social role in engineering in the future.

1. Analysis of main engineering geological problems in soft soil area of China

Usually, the thickness of soft soil cover in deep soft soil area is deep, most areas can reach more than 30 m in 15~20 m, or even some special areas, at the same time, it is affected by the nature of soft soil geology itself, and the amount of clay minerals is high. For example, a large deep foundation pit is excavated on the side of the adjacent subway, which leads to longitudinal through cracks in the segment of the subway tunnel, which leads to the damage of segment rupture, leakage and other diseases. Deep foundation pit excavated in soft soil area will face many complex engineering problems,



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such as on July 6, 2015, A serious safety accident occurred in the collapse of underground continuous wall in a deep foundation pit of Shenzhen Qianhai area under construction. The underground continuous wall with a length of more than 20 meters in deep foundation pit collapses as a whole, and the whole collapse and damage process lasts for nearly 1 minute, which leads to the delay of construction period and great economic loss. The inherent characteristics of soft soil determine that the existing projects in soft soil will be affected by surface construction activities, especially in the following aspects:

1.1. Problems of failure of supporting structure and obvious seepage deformation of soft soil

Under the influence of its own factors in the deep soft soil area, it is easier to appear the failure of the support during the excavation of the foundation pit, and the slope stability of the foundation pit is reduced, thus forming the safety problem and affecting the subsequent construction. In the actual construction process, under the influence of load factors, the deformation and damage of the structure are more prominent, resulting in the settlement of the foundation, resulting in flow deformation, a series of adverse consequences, and damage to the stability. Permeability deformation is also the main problem in the excavation of foundation pit in deep soft soil area at present. The main reason is that the water content of soil itself is large and it is easy to be affected by the change of water level to cause water gushing or sand gushing, which causes obvious deformation of the side wall of the project and reduces the overall engineering quality^[1].

1.2. Because of the uplift of the pit bottom caused by the opening of the foundation pit, the problem of ground subsidence is obvious

The soil itself is naturally stressed, but due to the development of foundation pit, the natural stress state of thick soil layer is destroyed. Especially in the southeast coastal area, the bearing capacity of the bottom of the foundation pit is very poor because of the thick soil layer itself. The main reason is that the failure of soil stress causes the load of the bottom and side of the foundation pit to change, and the side soil is gradually squeezed into the middle under the action of load, which produces certain damage, and finally affects the development of the project. The reason of ground subsidence is mainly due to the influence of geological structure on the latent property during the excavation of foundation pit in deep soft soil area, resulting in uneven geological settlement, such as cracking on the ground, which has an overall impact on the structure of the foundation, thus limiting the development of the project.

1.3 Soil erosion due to drainage problems

In the drainage of foundation pit, the ground around the foundation pit is settled under the force of drainage, which makes the surrounding buildings and pipes deform under the influence of settlement, and may cause cracking and damage from time to time. Because of the fluidity of the soft soil layer, it is easy to cause the ground around the foundation pit to sink under the pressure of drainage when drainage is carried out^[2].

Table 1. The main engineering geological problems of soft soil unloading.

The main engineering geological problems in soft soil area of China	Slope instability of foundation pit
1	Permeability deformation of soft soil
2	Water loss and soil erosion
3	Pit bottom uplift
4	Land subsidence

2. Analysis of influencing factors of construction in soft soil area of China

Because of the particularity of soft soil foundation, the problems and difficulties in the construction of soft soil area are relatively prominent. Therefore, the analysis of the influencing factors of excavation in soft soil area is the key to avoid the construction problems caused by engineering geology and

ensure the construction safety and quality.

Depth is one of the important factors affecting its construction safety. Because of the low strength and poor stability of the land structure in the soft soil area, the greater the excavation depth, the more difficult it is to design the foundation pit support, and the greater the risk of foundation pit support deformation. For the deep soft soil area, the mechanical properties of the soft soil structure itself and the thickness of the soft soil layer are all the factors that affect the excavation of the foundation pit in the soft soil area. The soft soil layer has higher water content, loose structure, high sensitivity to external load and action change, easy to appear thixotropic problem, and the larger the thickness of soft soil, The more prominent the deformation and thixotropic of land structure, the greater the impact on foundation pit excavation. In addition, the combination of soft soil and non-soft soil distribution in soft soil area is also an important factor affecting the excavation of foundation pit. In general, the soil layer formed by the combination of soft soil and clay, especially the clay with high hardness, has better bearing capacity and deformation resistance than the soil structure formed by soft soil and silt or fine sand. Therefore, its distribution in soft soil area will also directly affect the excavation construction of foundation pit in soft soil area^[3].

In the construction of soft soil area, the load distribution around foundation pit and the construction mode of excavation will also affect the construction and safety of foundation pit. In addition, the unloading in the pit and the loading around the pit will also cause changes in the load and performance of the land structure in the soft soil area under the sensitivity of higher load changes, while the excavation itself is a stress release process. The change of the land pressure around the excavation area will inevitably lead to the deformation or displacement of the land structure under the stress release. Under the influence of the larger action and change, the damage will occur.

3. Construction of mathematical model of unloading deformation of soft soil

3.1. The assumptions and requirements of constructing the model

In order to further optimize the simulation and prediction of soil deformation characteristics under repeated loading and unloading, according to the test results, it can be considered that the initial loading process line after exceeding the yield stress is a straight line within a certain pressure range. It is assumed that all springback processes are fully elastic. The mathematical model should meet at least the following requirements:

- (1) The reloading process is described by curve and is related to the stress state;
- (2) After each reloading and springback process is completed, the soil should be able to exhibit new plastic deformation^[4];
- (3) The above plastic deformation decreases with the number of cycles, so the model parameters should be related to the number of cycles;
- (4) The plastic deformation is not the same under loading and unloading in different pressure range, and the model parameters should be related to loading and unloading pressure range.

3.2. Construction of the model

The mathematical description of the normal isotropic consolidation curve in the Cambridge model is as follows:

$$(V - V_0) = -\lambda \left(\ln p' - \ln p'_0 \right) \quad (1)$$

The formula is expressed in the semi-logarithmic coordinate system, in which the V_0 、 p'_0 is the specific capacitance and effective consolidation stress corresponding to the starting point, and the λ is the slope of the consolidation line^[5].

The repeated "isometric loading and unloading" test process studied in this paper is drawn under the double natural logarithmic coordinate. As shown in figure 1, the relationship curve of each stage can be described as:

$$(\ln v - \ln v_0) = -\lambda' (\ln p' - \ln p_0') \quad (2)$$

The λ is the slope of the consolidation line at the corresponding point of pressure p' in the double natural logarithmic coordinate, and its absolute value is taken. The λ'_1 , λ'_s represents the slope of the initial consolidation loading section and the unloading section respectively, and the reloading process is a curve description, λ' is the slope of any point of the curve. The slope of the starting point and end point of the curve is expressed as the λ'_r , λ'_e , existence $\lambda'_e \geq \lambda' \geq \lambda'_r$ respectively.

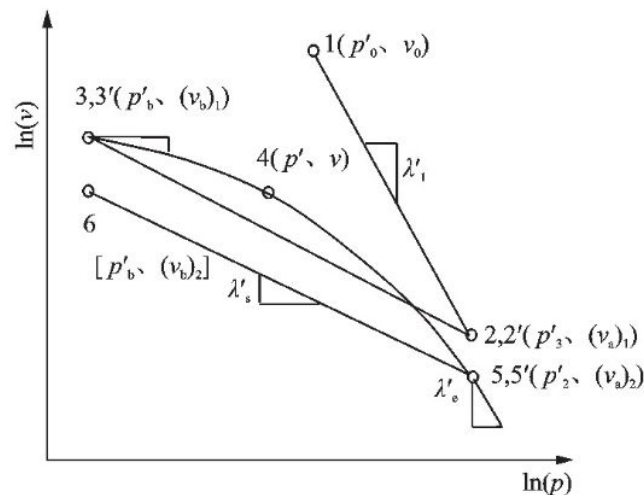


Figure 1. Experimental curves under dual natural logarithmic coordinates.

4. The main engineering geological problem solving strategy in deep soft soil area

4.1. Establish a good support system

In the actual construction process, the staff should design according to the actual situation at the present stage, combine the construction quality, innovate from many angles, and establish a perfect foundation pit excavation support system based on foundation pit excavation construction. Give full play to the advantages of the system, improve the safety of construction and reduce the probability of foundation pit stability failure. According to the actual situation at the present stage, the upper load produced in the excavation process of foundation pit is unloaded, the advanced technology is used flexibly to innovate, the current technology is optimized, and the stability of support is improved. In order to ensure the excavation safety, improve the overall engineering safety. According to the actual local construction situation, the staff can make a comprehensive analysis, select the most reasonable support protection, do a good job of foundation pit slope stability protection, improve the overall safety. Reducing the influence of excavation depth, reducing the limitation of land structure strength in deep soft soil area, reducing the construction difficulty and the risk of foundation pit support deformation, in order to meet the construction demand at the present stage^[6].

4.2. Rational design of waterproof and drainage systems

During the excavation of foundation pit in deep soft soil area, the staff should make clear the causes of seepage deformation and deal with them according to their causes. For example, the waterproof and drainage system can be designed reasonably, based on the actual demand at present. For example, according to the actual situation, the constructors can establish a reasonable intercepting curtain on the outside of the excavation foundation pit at the present stage, through which the groundwater seepage at the present stage can be reasonably prevented and the interference caused by external factors can be reduced. In the current construction process, the most common forms of water cut curtain for

excavation of soft soil foundation pit are double three-axis cement-soil mixing pile, high pressure rotary jet pile and grouting method. This kind of method can be optimized reasonably by pile support technology in the process of application to meet the development needs at the present stage and achieve the effect of water cut curtain. At the same time, in the excavation of foundation pit in deep soft soil area, the constructors can set up reasonable recharge wells according to the actual situation around the foundation pit at the present stage, and deal with them reasonably in the way of recharge, so as to reduce the occurrence of displacement or deformation. The reason for the seepage deformation is clearly defined, the factors of which are the water content of the soft soil itself, the loose structure, and the reduction of the influence of the deformation. By solving the problem from the root, the engineering quality can be improved at the present stage.

4.3. Take reasonable measures to reinforce

In view of the practical problems at the present stage, reasonable reinforcement is carried out, the excavation above the foundation pit is treated by the method of block, strip and layered excavation, and the advantages of soil itself are flexibly used to deal with it reasonably, and the deformation of the side wall and bottom of the foundation pit is reasonably controlled to improve the construction quality. Flexible use of existing technical advantages to control the uplift in the pit, reduce the damage caused by the uplift, reinforcement is the most effective method, but also the most direct protection strategy to reduce security risks. For example, the staff can reasonably deal with the actual situation, such as wooden piles, pressure plates, vertical support, etc., to give full play to the advantages of supporting body, reasonable reinforcement control, and improve the construction quality.

4.4. Effective control of deformation of pit bottom

In view of the actual situation at the present stage, reasonable construction innovation and improvement of the construction strategy at the present stage, the staff can flexibly apply the foundation pit support structure to deal with it, can choose reasonable support structure and permanent support structure, can choose continuous wall, pit wall support and so on. The staff should first analyze the causes of its deformation, clarify the influence of the surrounding factors in the excavation of foundation pit in deep soft soil area, reasonably control the influencing factors at the present stage, and improve the safety of construction, such as the surrounding load factors. To give full play to the advantages of internal support, to control the excavation and main body construction of foundation pit in deep soft soil area in an all-round way, to ensure its economy, safety, construction and information construction quality improvement, and to meet the development needs at the present stage.

5. Conclusion

In view of the theoretical research discussed in the soft soil unloading model at the present stage, the excavation project of foundation pit in soft soil area is comprehensively treated, innovated from many angles, perfected the development idea at the present stage, strengthened the application of safety measures, promoted the level of soft soil foundation pit, reduced the safety risk, controlled the influence of external factors, supported the safety, solved the uplift and deformation in foundation pit, and laid a good foundation for the development of construction industry in China. Soft soil foundation is a common condition in engineering construction. Due to the land bearing problem of soft soil foundation, and with the progress of social and economic development and the continuous improvement of construction technology, the scale and quantity of the project are expanding, the land load of soft soil foundation is increasing, and the excavation depth of foundation pit is increasing. Therefore, the research of soft soil unloading model can provide the corresponding advice and reference for the excavation of soft foundation pit, which has very significant positive effect and significance.

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