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Research on Optimization of Supporting Forms of Complex Foundation Pit Based on Finite Element Method

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Abstract. As the working conditions of foundation pit engineering become more and more complex, its requirements for supporting forms are also higher and higher. The plane excavation of a complex foundation pit in a project requires the reservation of a large plane position, a working space for machinery, and as much as possible to reduce the impact of excavation on the surrounding environment. In this paper, the support effect of the straight beam and the ring beam is simulated by finite element method according to the optimization of the straight beam form used in the design. Through comparison, it is found that the support effect of the ring beam is better. The research methods and ideas in this paper provide effective means and reference for the development of similar projects.

1. Introduction

The technology of deep foundation pit support design is a technical problem gradually encountered in China over the past 10 years [1-2]. It involves almost all aspects of geotechnical mechanics and engineering geology, such as soil mechanics, hydrogeology, engineering geology, structural mechanics, construction methods, supervision, monitoring and so on. There are many uncertain factors affecting the stability of foundation pit, which leads to a high incidence of foundation pit accidents, especially in the open cities in the southeast coast [3]. Some cities have larger foundation pit accidents accounting for about one-third of the total number of foundation pits. If the support fails, the consequences will be unimaginable. This will not only delay the construction period and cause economic losses, but also, more importantly, may have an untold adverse impact on the surrounding buildings and urban lifeline projects, and even endanger personal safety [4-5]. China's deep foundation pit project started in the 1980s, although it developed rapidly, it is still in the exploratory stage. In practical engineering, support selection and design are sometimes very conservative for safety, resulting in unnecessary waste. Sometimes, in order to pursue economy unilaterally, the requirements for stability, deformation control and design safety of foundation pit are lowered, resulting in engineering accidents and greater economic losses [6-7]. The optimal design technology of deep foundation pit engineering is based on this and is an effective means to solve the contradiction between economic rationality and safety and reliability.

The optimization method is an applied technique to solve various engineering problems based on mathematical theory. At present, the design optimization of foundation pit support mainly includes: the first is to optimize the type of foundation pit support. It mainly adopts qualitative evaluation, according to the surrounding environmental conditions of foundation pit, stratum conditions, underground water burial conditions, characteristics and applicable conditions of various support types, comprehensively optimizes the support types, and also uses a small amount of fuzzy mathematics to optimize the support types. The second is the design optimization of the supporting structure, also known as detail optimization. The simplest method for this optimization is the elastic resistance method specified in the specification, i.e. M method, which optimizes the appropriate design calculation method by calculating the displacement, maximum bending moment and shear force of the support system.

Based on the actual project, this paper simulates the supporting forms of straight beam and ring beam, compares the supporting effects of the two, and provides strong guidance for the project design and construction.
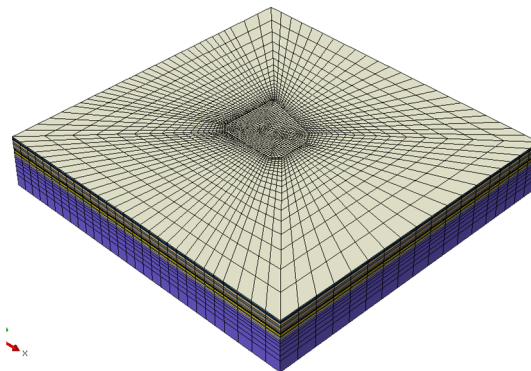

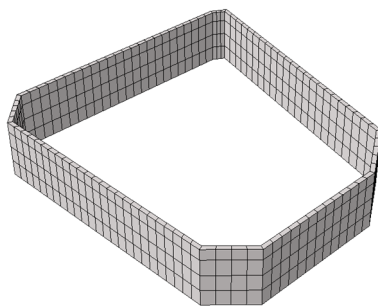Figure 1. Soil mesh.

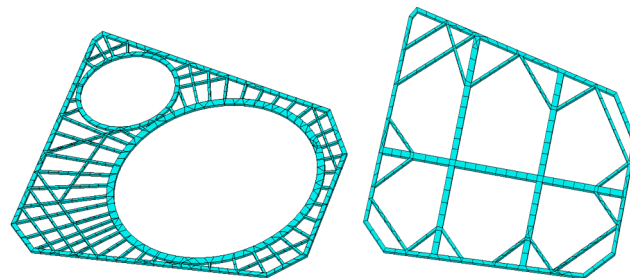Figure 2. Diaphragm wall mesh.   Figure 3. Horizontal support mesh.

Foundation pit excavation involves wall-soil, wall-support interactions. According to the actual construction experience, the boundary between the wall and the horizontal support is the binding constraint, and the friction between the ground wall and the soil is frictional. The constraints around the soil are axially constrained and the bottom constraints are three-dimensional fixed constraints. The bottom of the wall is also fixed.

ABAQUS provides a series of constitutive models for simulating geotechnical bodies. The model soil established in this chapter uses the Cambridge model. The Cambridge model, also known as the critical state plasticity model, is a representative elastoplastic model of soil established by Roscoe et al., University of Cambridge, England, which uses elliptical yield surfaces and adaptive flow criteria and is plasterer. The strain is a hardening parameter and has been widely accepted and applied internationally. ABAQUS made some promotion to the Cambridge model proposed by Roscoe et al., but it is essentially the same.

According to the distribution of the soil layer in the survey report, various parameters required for finite element calculation can be obtained, as shown in Table 1.

Table 1. Calculation parameters of soil layer selected by finite element method

Solum	Thickness (m)	Severe (kN/m³)	φ(°)	c(kPa)	Elastic modulus (MPa)	Poisson's ratio
Miscellaneous fill	1.5	18.5	5	5	6	0.25
Prime fill	3.5	19.4	10.48	13.63	8	0.25
Silty clay	3.5	18.9	18.3	12.8	16	0.3
Muddy clay	8.5	17.9	6.87	9.29	3	0.3
Silty clay	2	20.3	23.37	12.61	10	0.3
clay	2.5	19.2	14.89	17.59	13	0.3
Silty clay	3	20.2	17.19	14.76	12	0.3
Silt	2	20.6	25.2	9.4	18	0.3
Silty clay	2.5	19.8	18.45	16.9	15	0.3
Silt	2.5	20.8	28.47	9.92	19	0.3
Silt	23	20.4	30.74	0	24	0.3

Considering reinforced concrete as linear elastic material, the grade is calculated as C30. The underground continuous wall and horizontal support adopt a completely elastic model.
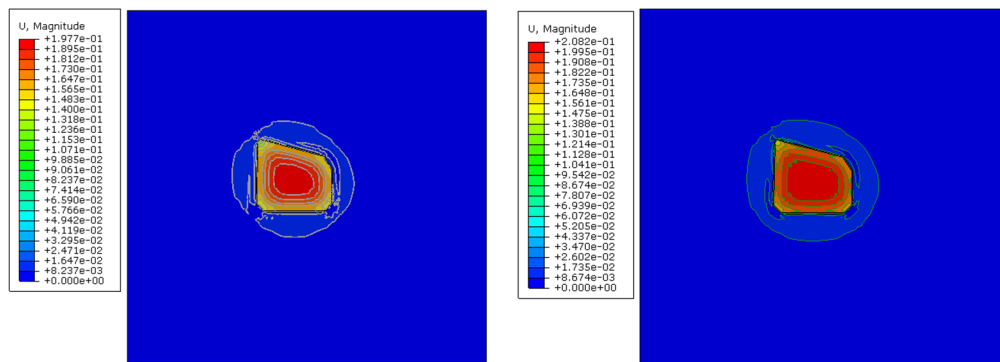
2. Calculation results

Figure 4. displacement deformation of soil mass.

Figure 4. shows the vertical deformation of the foundation pit, from which it can be seen that the soil mass within a certain depth at the bottom of the foundation pit has produced upward displacement, and the maximum displacement is located in the center of the bottom of the foundation pit, i.e. the center of the bottom of the foundation pit has the largest uplift. The soil outside the retaining wall structure will move downward, i.e. the surface settlement around the foundation pit will be uneven, and the maximum settlement value will be located near the retaining wall outside the retaining wall.

Therefore, the soil deformation law of the straight beam foundation pit excavation model is basically consistent with the calculation result of the ring beam support.

The retaining wall produces horizontal displacement to the inside of the foundation pit. For each side wall, the middle part has the largest displacement and the corner is smaller. For a single supporting pile, the middle part of the pile body has a larger displacement and the two ends are smaller, showing a " convex" shape as a whole.

Compared with the calculation results of the support form of the straight beam and the ring beam, the deformation and stress distribution of the retaining wall structure are consistent.
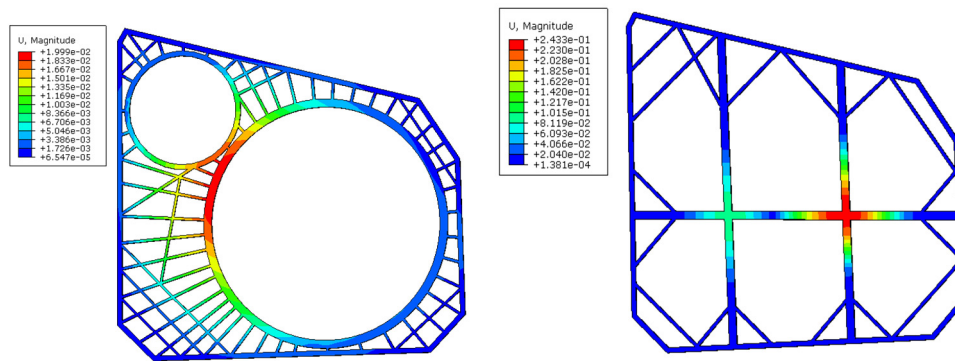
Figure 5. Horizontal support deformation

The deformation result of horizontal support is shown in figure 5. It can be seen from the figure that the displacement value at the intersection of the two main beams is the largest, and the displacement of the ring beam around the enclosure wall is smaller.
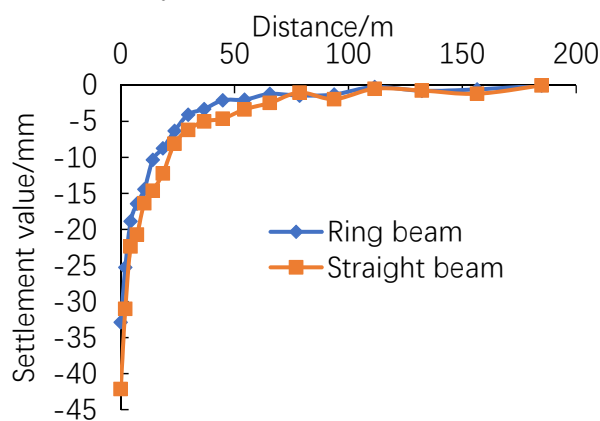
3. Result analysis
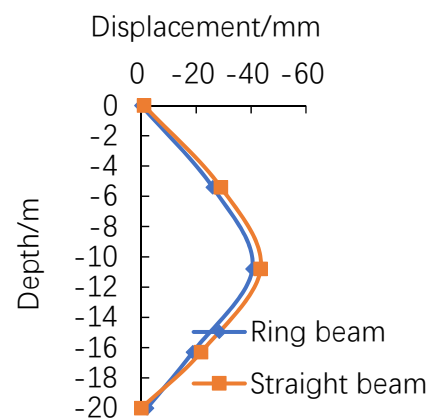

Figure 6. Comparison of land subsidence values

Figure 7. Comparison of pile deformation of retaining structure

Figure 6 shows the contrast curves of the surface settlement values around the foundation pit along the same path, and all four pairs of contrast curves show the same regularity. Through the comparison and analysis of the calculation results, it can be seen that the settlement value of the soil outside the pit under the ring beam support is smaller than that under the straight beam support for the same position. When using large diameter ring beam support, the maximum surface settlement around the foundation pit is 3.3cm, while when using straight beam support, the maximum surface settlement around the foundation pit is 3.6cm, which indicates that using ring beam support can better control the settlement deformation of soil outside the pit.

Figure 7 is a comparison curve of horizontal displacement value of foundation pit retaining structure pile on the same path, and all four pairs of comparison curves show the same regularity. Through the comparison and analysis of the calculation results, it can be seen that the horizontal displacement value of the pile body in the case of ring beam support is smaller than that in the case of straight beam support for the same position. When using large-diameter ring beam support, the maximum horizontal displacement of pile body of foundation pit retaining structure is 4.5cm, while when using straight beam support, the maximum horizontal displacement of pile body of foundation pit retaining structure is 4.2cm. For the same position, the deformation value of pile body under ring beam support is smaller than that under straight beam support. This shows that the ring beam support can better control the deformation of the retaining structure pile body.
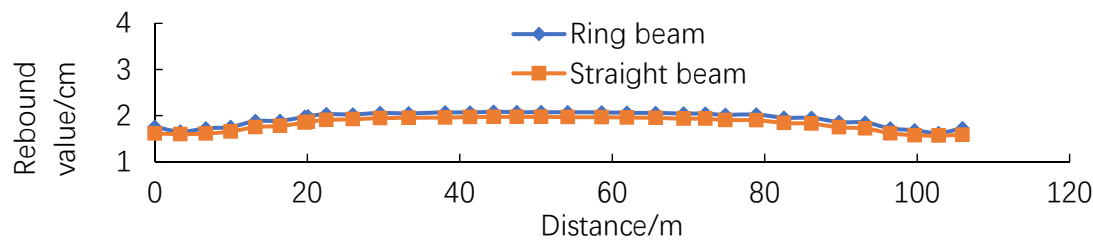
Figure 8. Comparison of displacement values on kengdi-01 path under different working conditions

Figure 8 is a comparison curve of soil uplift values at the bottom of the foundation pit along the same path. both pairs of comparison curves show the same regularity. Through the comparison and analysis of the calculation results, it can be seen that for the same position, the pit-bottom uplift value under the ring beam support is smaller than that under the straight beam support. When using large diameter ring beam support, the maximum uplift at the bottom of the foundation pit is 1.9cm, while when using straight beam support, the maximum uplift at the bottom of the foundation pit is 2.4cm, which indicates that the supporting structure with ring beam support can better control the uplift deformation of soil in the pit.

4. Conclusion

In this paper, the finite element method is used to simulate the different support forms of complex deep foundation pit, and the following conclusions are obtained through comparison: the effect of large diameter ring beam support structure in foundation pit excavation support is obviously better than that of straight beam support structure. Under the same working conditions, the internal force distribution of the ring beam support itself is reasonable without obvious stress concentration. After the foundation pit excavation is completed, the surface settlement around the foundation pit is small, the horizontal displacement of the retaining structure is small, and the uplift at the bottom of the pit is also small. Therefore, this form of ring beam support is worthy of reference and promotion.

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