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Analysis on Influence of Foundation Pit Excavation Supported by Large Diameter Ring Beam on Surrounding Environment

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Analysis on Influence of Foundation Pit Excavation Supported by Large Diameter Ring Beam on Surrounding Environment

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Abstract. Excavation of foundation pit is a common engineering type in urban construction. In order to reduce the impact of foundation pit excavation on the environment, its supporting form plays a decisive role. In this paper, the finite element model of the large-diameter ring beam supporting system is established, and the settlement results of the soil around the foundation pit are obtained by simulating the construction process of the foundation pit. The comparison between the numerical simulation structure and the measured data shows that they are very close. It shows that the model simulation results are accurate and the proposed large diameter ring beam support system is effective.

1. Finite element model

A three-dimensional finite element model is established for the soil and its supporting system within the influence range of the foundation pit excavation. Because the supporting structure of the foundation pit is extremely irregular in shape, the whole range is modelled and only some minor parts are simplified[1]. In this paper, the influence of foundation pit excavation on the surrounding environment is mainly concerned with the following issues: horizontal displacement of the retaining structure, surface settlement around the foundation pit, uplift at the bottom of the pit and stress of the horizontal support.

In principle, the boundary range of the calculation model should reach the boundary where the deformation and internal force of the foundation pit excavation structure will no longer be affected by the stress, but due to the limited calculation conditions, resources and time, it often does not meet the requirements completely consistent with the actual situation[2-3]. Generally speaking, the stress and deformation of soil beyond 3 times the actual size of foundation pit can be ignored. Therefore, the length, width and height of the foundation site of this project model are 520m, 500m and 80m respectively.Although the retaining wall structure of cast-in-place bored pile has individual piles connected together, its stress form is similar to that of continuous underground wall. Since ring beams are added to the binding during construction, the integrity of the pile body is greatly enhanced. In the process of establishing the model, in order to simplify the treatment, the pile wall is equivalent to a continuous wall with uniform stiffness for analysis and calculation. Moreover, according to engineering experience, it is often safe and reasonable to design according to this equivalent method. When modelling, take the wall depth of 20m and thickness of 1.5m; the form and size of the support are given according to the design drawing. The width of the middle large-diameter ring beam is 2.5m; the width of the small-diameter ring beam is 1.5m. The width of the support beam connected with the two ring beams is 0.8m, and the width of the rest beams is 0.7m.

In order to calculate quickly, the soil grids inside the foundation pit and around the retaining wall are finely divided. As the distance from the foundation pit edge increases, the grid division is relatively sparse. The element type is a spatial 8 - node hexahedron element. Because it is a 3D stress analysis, the mesh type uses 3D stress analysis. The grid forms of soil, retaining wall and support are shown in figure 1 - 3.

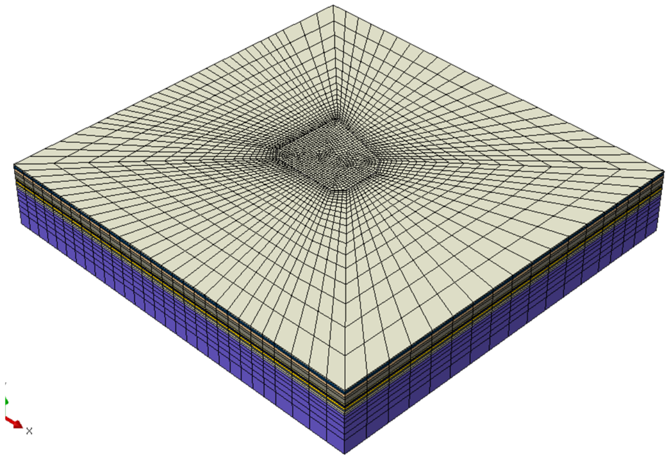

Figure 1. Soil mesh.

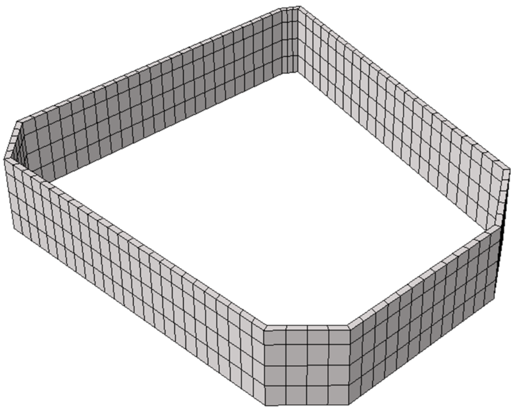

Figure 2. Diaphragm wall mesh.

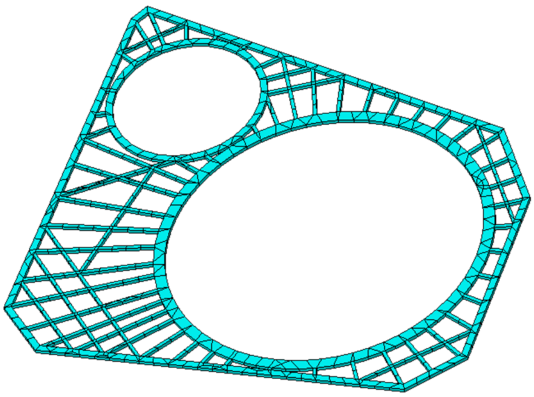

Figure 3. Horizontal support mesh.

Foundation pit excavation involves the interaction of wall - soil and wall - support. According to the actual construction experience, the binding constraint is between the connecting wall and the horizontal support, while the friction is between the connecting wall and the soil. The constraint around the soil body adopts axial constraint, and the constraint on the bottom surface adopts three-dimensional fixed constraint. Fixed constraints are also used at the bottom of the retaining wall[4].

ABAQUS provides a series of constitutive models for simulating rock and soil. The model soil established in this chapter adopts Cambridge model[5-6]. Cambridge model, also known as critical state plastic model, is a representative elastic-plastic model of soil established by Roscoe et al. of Cambridge University in England. The model has been widely accepted and applied internationally by adopting elliptical yield surface and corresponding flow criteria and taking plastic body strain as hardening parameter. ABAQUS has extended the Cambridge model proposed by Roscoe et al., but it is essentially the same.

According to the soil distribution of the site 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/m^3)	φ(°)	c(kPa)	Elastic modulus (MPa)	Poisson's ratio
Miscellaneous fill	1.5	18.5	5	5	500	6
plain fill	3.5	19.4	10.48	13.63	2511.61	8
Silty clay mixed with silt	3.5	18.9	18.3	12.8	6147.8	16
Silty clay	8.5	17.9	6.87	9.29	1185.94	3
Silty clay	2	20.3	23.37	12.61	8000	10
Clay	2.5	19.2	14.89	17.59	4704.24	13
Silty clay	3	20.2	17.19	14.76	5666.92	12
Silty soil	2	20.6	25.2	9.4	9000	18
Silty clay	2.5	19.8	18.45	16.9	6653.05	15
Silty soil	2.5	20.8	28.47	9.92	9000	19
silt	23	20.4	30.74	0	9000	24

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. Land subsidence value

Create four paths as shown in figure 4 on the soil component, extract the surface settlement displacement values on these four paths, draw curves, and compare them with the measured values, as shown in figure 5.

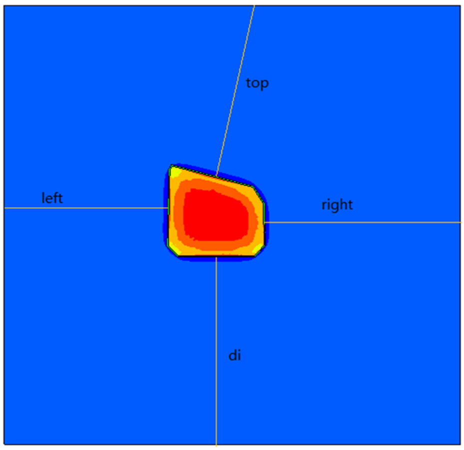

Figure 4. Path diagram.

Figure 5 is a comparison curve of surface settlement values on four paths around the foundation pit. Among them, the measured value is the measured settlement value of soil outside the pit, and the other is the calculation result of finite element model. The point 0 of the X-axis is the position where the retaining wall of the foundation pit contacts the soil outside the pit.

From the above data comparison, it can be seen that the settlement of soil outside the pit on each path follows the same rule: the maximum settlement is located at the edge of the foundation pit, and the smaller the surface settlement is as far away from the retaining wall of the foundation pit, and the outward development gradually goes to zero. The maximum surface settlement of the finite element simulation results is 3.3cm, and the measured maximum settlement is 3.5cm. The finite element calculation results are basically consistent with the measured results, so the finite element model established in this paper is accurate and effective.

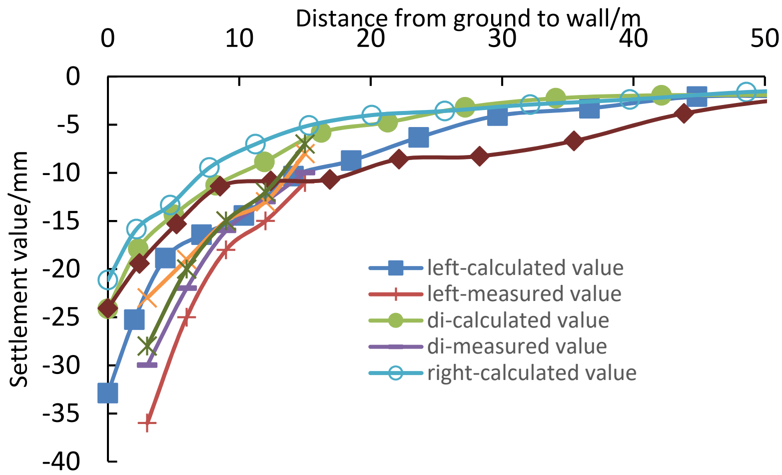

Figure 5. Comparison between numerical simulation and measured values of foundation pit lateral settlement

3. The upheaval of foundation pit bottom

Two paths as shown in figure 6 below are established on the soil components, the displacement values of the pit bottom uplift are extracted, curves are drawn, and compared with the measured values, as shown in figure 7.

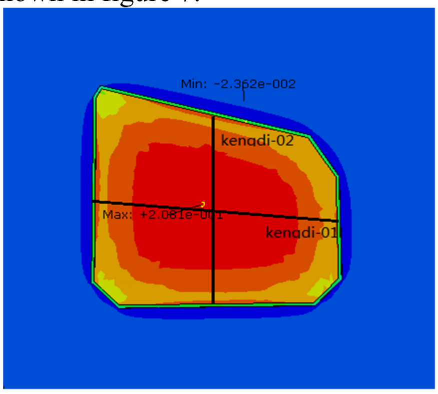

Figure 6. Path diagram.

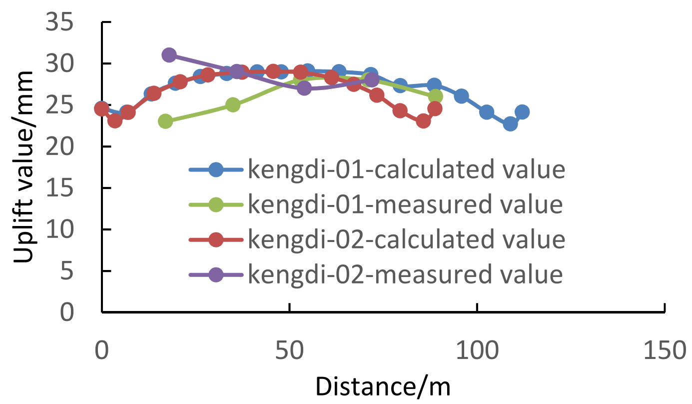

Figure 7. Comparison between numerical simulation and measured values of foundation pit rebound.

Figure 7 is a comparison curve of pit bottom uplift values along the two paths at the bottom of the foundation pit. Among them, the calculated value before strength reduction is the model calculation result without considering the unloading effect on the upper part of the pit bottom soil, the measured value is the measured uplift value of the pit bottom soil, and the calculated value after strength reduction is the model calculation result considering the unloading effect on the upper part of the pit bottom soil.

From the above data comparison, it can be seen that the settlement of soil outside the pit on each path follows the same rule: the maximum uplift is located in the center of the bottom of the foundation pit. The maximum uplift of the model without considering the strength reduction is 2.1cm, the maximum uplift of the model with considering the strength reduction is 2.9cm, and the measured maximum settlement is 3.2cm. The finite element calculation results are basically consistent with the measured results, while the model calculation results with considering the strength reduction effect are closer to the measured values. Therefore, the unloading effect of the soil at the bottom of the foundation pit should be taken into account when establishing a similar numerical calculation model for deep foundation pit

4. Deformation of retaining wall

Create four paths as shown in figure 8 below on the enclosure wall components, extract the horizontal displacement value of the diaphragm wall, and draw a graph.

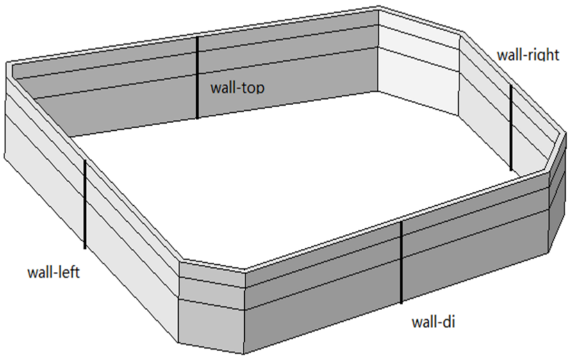

Figure 8. Path diagram

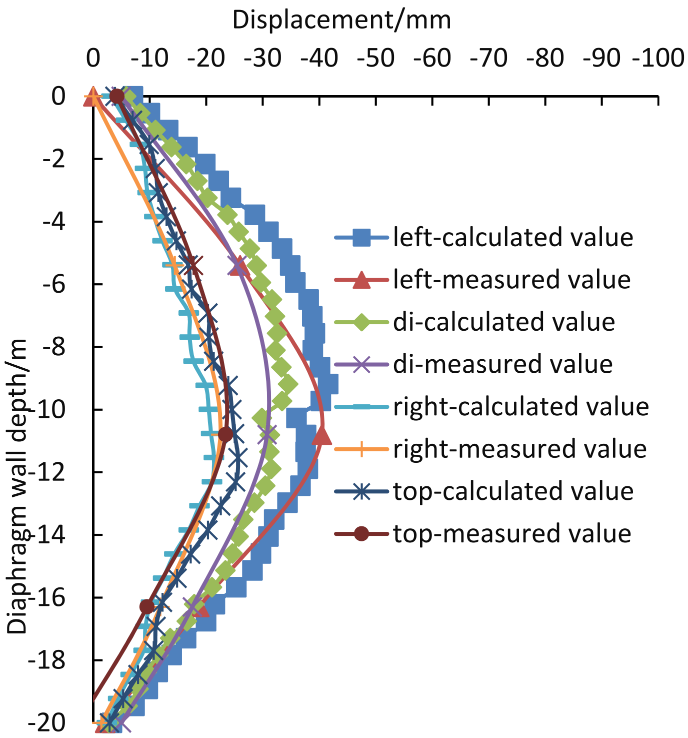

Figure 9. Comparison between numerical simulation and measured values on various paths of the ground connecting wall.

In figure 9, the coordinate origin point is the top of the retaining pile, the x axis coordinate is the horizontal displacement of the retaining wall to the inside of the foundation pit, and the y axis coordinate is the depth of the pile body from the ground surface. Among them, the measured value is the measured settlement value of the soil outside the pit, and the calculated value is the settlement value of the soil outside the pit calculated by the model. From the data comparison of the above four paths, it can be seen that the horizontal displacement of the retaining pile body on each path follows the same rule: the maximum displacement value is located in the middle of the pile body and gradually decreases toward the top and bottom of the pile. The finite element calculation results are basically consistent with the measured results.

5. Conclusion

In this paper, the large-diameter ring beam supporting system of irregular foundation pit is simulated, and the results show that: The displacement of soil outside the foundation pit near the foundation pit is large, and gradually decreases with the settlement away from the edge of the foundation pit. The law of numerical simulation model results is the same as that of actual measurement, and the two values are very close. The maximum settlement outside the pit is 3.3cm and the actual measurement is 3.5cm. The uplift rule of foundation pit is that the uplift at the center of the pit bottom is larger and the displacement near the edge of foundation pit is smaller. The numerical simulation is consistent with the measured rule[7-8]. With the increase of the depth, the deformation of the diaphragm wall increases first and then decreases. The numerical simulation is consistent with the measured law, and the numerical values of the two are also very close. It shows that the numerical simulation of large diameter ring beam support system is very accurate and effective.

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