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Research on Effectiveness of Complex Supporting System of Deep Foundation Pit Based on Numerical Method

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Abstract. With the development of urban construction, in order to alleviate the impact of foundation pit excavation on the surrounding environment, some complex support forms have been adopted. In order to reduce the risk of these supports, numerical method is a very effective method. In this paper, numerical analysis is carried out on the complex supporting form of a deep foundation pit. The supporting system structure is regarded as a whole structure by using the three-dimensional finite element method, and the space-time evolution law of the surrounding soil and structure during the foundation pit construction process is obtained. It provides an effective means for the analysis of complex supporting system of foundation pit.

1. Introduction

The advantage of three-dimensional model is that the soil, the wall of the ground connecting wall and the supporting system are analysed and calculated as a unified whole, which can avoid the defect of uncoordinated deformation among various components in the previous calculation and the deformation results obtained by the calculation are more in line with the actual situation[1-3].

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. In this paper, the influence of foundation pit excavation on the surrounding environment is mainly concerned with the following issues: horizontal displacement of the diaphragm wall and surface settlement around the foundation pit.

The length, width and height of the foundation site of this project model are 680 m, 500 m and 70 m respectively.

Around the foundation pit, a ground connection wall is set up. In the process of establishing the model, a continuous wall with consistent stiffness is established for analysis and calculation. When modelling, take wall depth 35m and thickness 1m;

Divide the soil body and conduct seed distribution and mesh division. In order to calculate quickly, the soil grids inside the foundation pit and around the ground connecting wall are finely divided, and with the increase of distance from the foundation pit edge, 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. As shown in figure 1~ figure 3, the mesh of soil, ground connecting wall and support are as follows.

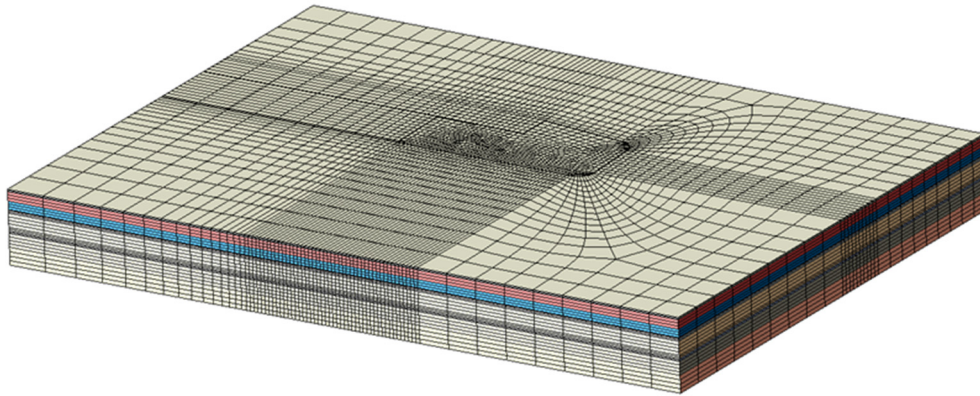


Figure 1. Soil mesh.

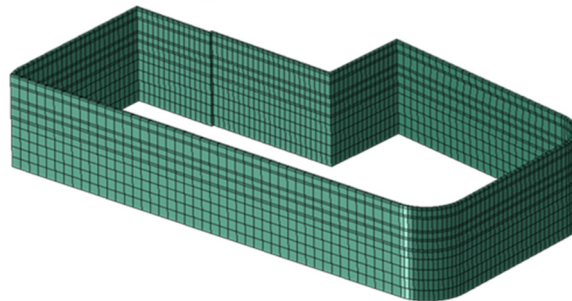


Figure 2. Diaphragm wall mesh.

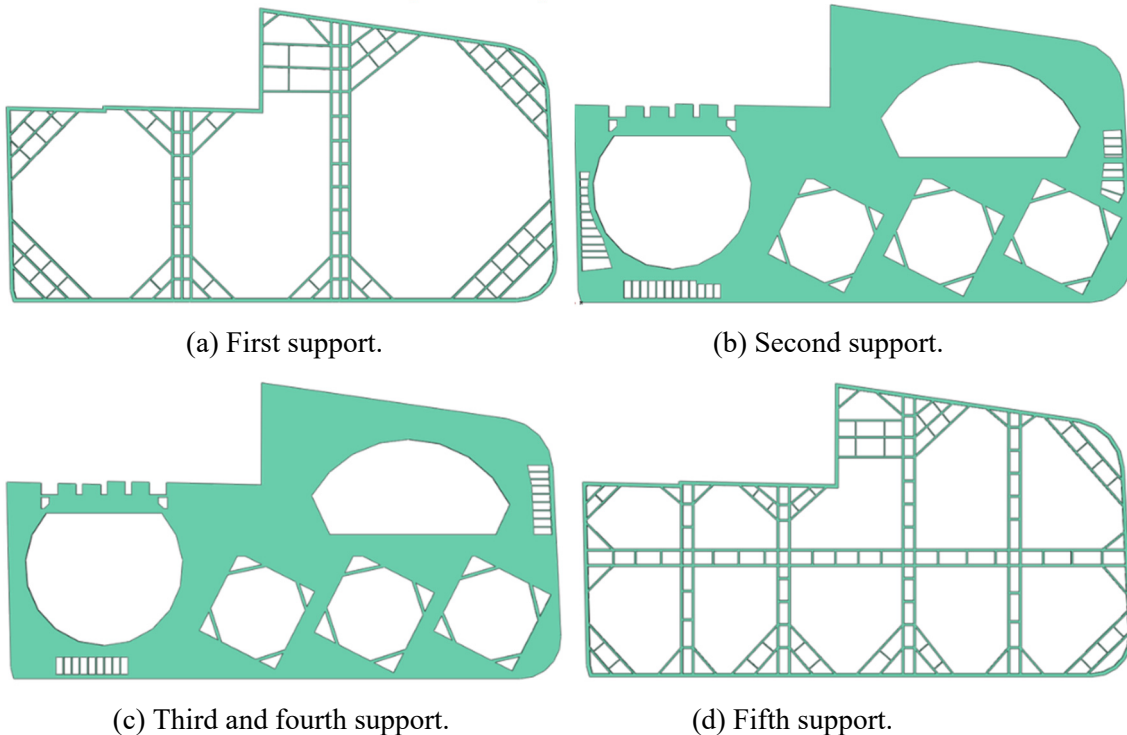


Figure 3. Horizontal support mesh.

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.

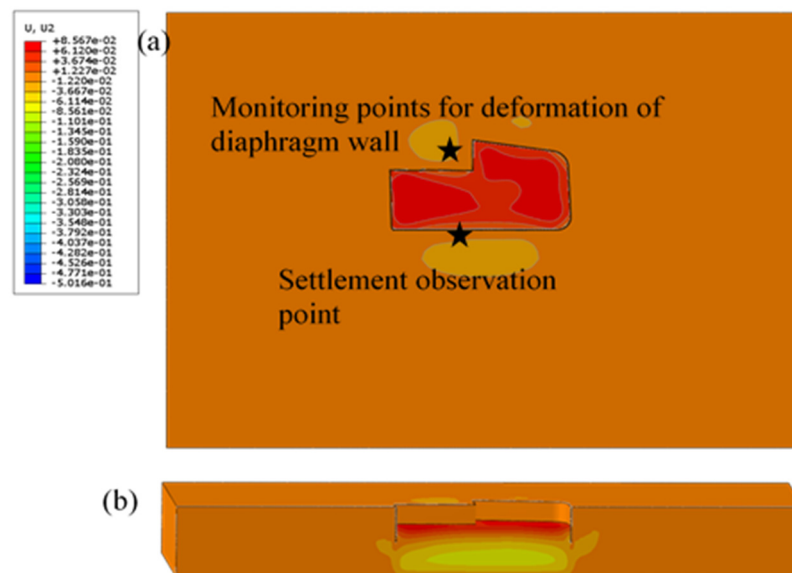
Table 1. Calculation parameters of soil layer selected by finite element method

Solum	Thickness (m)	Severe (kN/m ³)	$\phi(^{\circ})$	c(kPa)	Elastic modulus (MPa)	Poisson's ratio
Miscellaneous fill	1.47	18.13	4.9	4.9	5.88	0.245
Prime fill	3.43	19.012	10.2704	13.3574	7.84	0.245
Silty clay	3.43	18.522	17.934	12.544	15.68	0.294
Muddy clay	8.33	17.542	6.7326	9.1042	2.94	0.32
Silty clay	1.96	19.894	22.9026	12.3578	9.8	0.32
clay	2.45	18.816	14.5922	17.2382	12.74	0.32
Silty clay	2.94	19.796	16.8462	14.4648	11.76	0.32
Silt	1.96	20.188	24.696	9.212	17.64	0.32
Silty clay	2.45	19.404	18.081	16.562	14.7	0.32
Silt	2.45	20.384	27.9006	9.7216	18.62	0.32
Silt	22.54	19.992	30.1252	0	23.52	0.32

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 result

Due to the excavation of the foundation pit, the inherent balance state of the soil body is destroyed, and the soil body at the bottom of the foundation pit rebounds upward and bulges. At the same time, due to the lateral unloading of the soil body, the supporting wall body moves towards the foundation pit, and the soil body behind the wall moves, causing the surface settlement. Therefore, the deformation of foundation pit excavation mainly includes wall deformation and surface settlement behind the wall.



(a) Vertical displacement of ground surface and foundation pit bottom.

(b) Vertical displacement of foundation pit section.

Figure 4. Vertical deformation nephogram of soil.

From the above calculation results of soil deformation, it can be seen that after foundation pit excavation, the surrounding soil has significantly settled, and the maximum settlement is located in the

middle of the contact between the diaphragm wall and the soil outside the pit. The bottom of the foundation pit is uplifted, and the maximum uplift amount is approximately in the middle of the pit bottom. The calculated results are in good agreement with the actual situation[4-5].

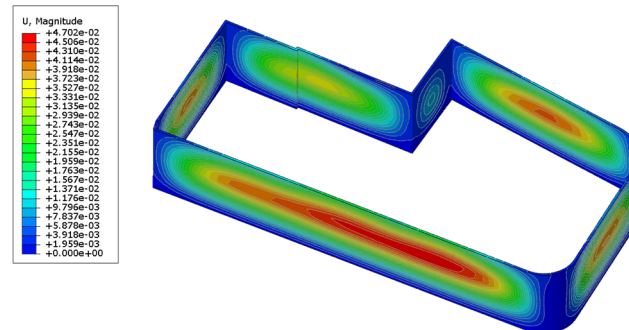


Figure 5. Deformation nephogram of enclosure structure.

When the foundation pit is excavated, the original earth pressure is removed from the inner side of the ground joint wall, and the outer side of the foundation pit is subjected to active earth pressure. The inner side of the bottom wall of the pit is subjected to all or part of the passive earth pressure, and the unbalanced earth pressure causes deformation and displacement of the wall. . When the foundation pit is shallow, the displacement of the top of the wall is the largest[6]. However, with the increase of the excavation depth of the foundation pit, after the horizontal support construction is completed, the displacement of the top of the wall remains unchanged or even moves outside the foundation pit, and the middle part of the wall protrudes into the pit and the displacement is the largest.

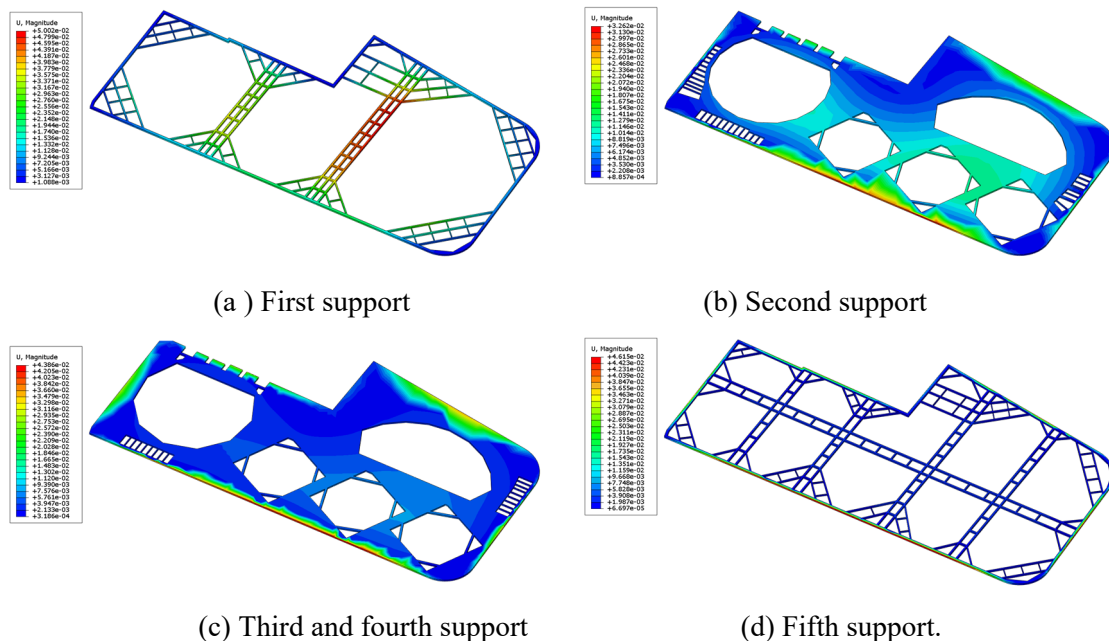


Figure 6. Deformation nephogram of horizontal support.

From the calculation results of the above horizontal support, it can be seen that the support has a significant displacement in both the horizontal direction and the vertical direction. The force of the ring beam support is good, and there is no place where excessive stress concentration occurs. Explain the superiority of the ring beam support form in the application of foundation pit support.

3. Comparative Analysis of FEM and Measured Values

From the comparison of the above data, it can be seen that the settlement of the soil at each monitoring point follows the same rule: the maximum settlement is located at the surface, and the deeper the

distance from the surface, the smaller the drop value, and gradually it will be zero. The maximum surface settlement calculated by the model is 2.7 cm, and the measured maximum settlement is 2.3 cm. The finite element calculation results are basically consistent with the measured results.

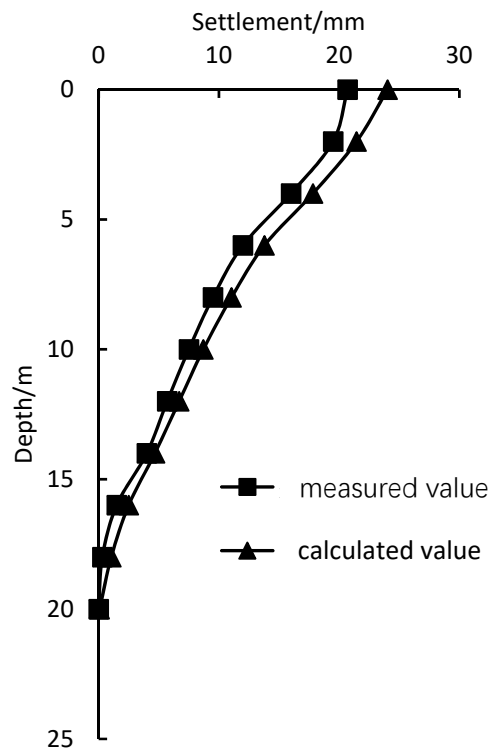


Figure 7. Comparison of calculation structure and measurement results of settlement outside pit.

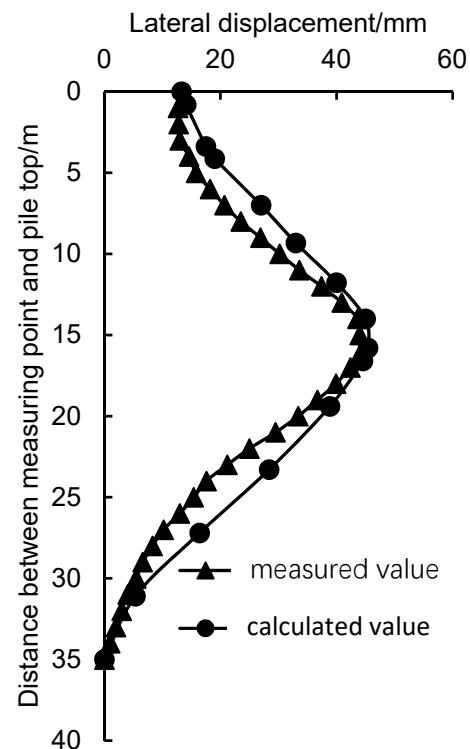


Figure 8. Comparison between calculation results and measured values of enclosure deformation.

The x axis coordinates are the horizontal displacement of the diaphragm wall toward the inside of the foundation pit, and the y axis coordinates are the depth of the diaphragm wall from the ground surface. Among them, the measured value is the measured horizontal displacement value of the diaphragm wall, and the calculated value is the horizontal deformation value of the model calculation result.

From the data comparison of the above paths, in figure 8, it can be seen that the horizontal displacement of the diaphragm wall along the path follows the following rule: the maximum displacement value is located in the middle of the diaphragm wall and gradually decreases toward the top and bottom of the wall. The finite element calculation results are basically consistent with the measured results.

4. Conclusion

The supporting system in complex situation not only has reasonable stress and avoids large stress concentration, but also has less impact on the surrounding environment compared with other supporting systems[7]. The numerical simulation results are in good agreement with the measured data. This complex support system can better control the surface settlement around the foundation pit, the uplift of the pit bottom and the lateral deformation of the ground connecting wall, which shows the feasibility of the large-diameter ring beam support structure system in the application of deep foundation pit excavation.

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