Finite element analysis of island excavation process of foundation pit

Changyi Yu\textsuperscript{1,2,3,4}, Jie Long\textsuperscript{5}, Mingyue Lu\textsuperscript{5}\textsuperscript{*}

\textsuperscript{1} CCC-Tianjin Port Engineering Institute, Ltd., Tianjin, 300222, China
\textsuperscript{2} CCC First Harbor Engineering Company, Ltd., Tianjin, 300461, China
\textsuperscript{3} Key Laboratory of Geotechnical Engineering, Ministry of Communications, Tianjin, 300222, China
\textsuperscript{4} Key Laboratory of Geotechnical Engineering of Tianjin, Tianjin 300222, China
\textsuperscript{5} Tianjin Survey And Design Institute For Water Transport Engineering, Tianjin, 300000, China
\textsuperscript{*} Corresponding author’s e-mail: P16009@tju.edu.cn

Abstract. In the construction of foundation pit, island excavation is suitable for large-scale foundation pit because of its high speed, but it requires a higher support system. In this paper, finite element simulation is carried out for the construction process of island excavation of deep foundation pit with double-ring beam support system. The simulation process considers the construction process of island excavation and step-by-step support, and obtains the displacement field of soil around the foundation pit along with the construction progress. It provides effective guidance for the safe and smooth development of foundation pit engineering, and provides reference methods for similar engineering analysis.

1. Introduction
Excavation of foundation pit involves earthwork excavation, dewatering, construction management, on-site monitoring, construction of adjacent sites, mutual influence of existing buildings and other related issues. The construction process should not only ensure the safety and stability of the foundation pit itself, but also strictly control the movement of strata around the foundation pit to protect the surrounding environment [1]. There are three common methods of foundation pit excavation: slope excavation, basin excavation and central island excavation. Slope excavation, mainly unsupported earthwork should adopt slope digging [2]. When the depth of foundation pit excavation is not large, the surrounding environment allows, and experience can ensure the stability of soil slope, slope excavation can be used; Basin excavation method can make the surrounding soil slope support the retaining wall, which is beneficial to reduce the deformation of the retaining wall. Its disadvantage is that a large amount of earthwork can not be transported out directly; Central island excavation is generally used for excavation of supported earthwork [4,5]. As for the central island foundation pit excavation method, it is mainly suitable for the foundation pit excavation of high-rise buildings, and the supporting forms of deep foundation pit are mainly angle bracing and ring beam bracing[6,7]. In the process of construction, the construction personnel should adopt the form of enclosure structure to control the deformation of surrounding soil...
[8]. The central island excavation method can make the foundation pit excavation work have strong priority, and this method can give full play to the role of retaining structure [9]. During excavation, the earth-moving machinery can use the middle mound to go down to the foundation pit for excavation, and the earth-moving car can also be transported by means of the mound, which greatly improves the excavation speed of the foundation pit. However, the envelope of this method is formed earlier, so the structure will be greatly deformed. In addition, the excavation route of this method is complex, and it also has higher requirements for the management of the construction site.

In this paper, the finite element analysis is carried out for an island excavation scheme under the double-ring beam support system of a deep foundation pit, and the temporal and spatial changes of in-situ stress field and displacement field of soil with excavation progress are comprehensively given.

2. Excavation scheme

In order to further optimize the excavation scheme, it is necessary to carry out finite element simulation calculation on the original support form. Because of the large area and irregular shape of the foundation pit excavation model, the support of each excavation face is different, so it is necessary to take the whole foundation pit excavation as the research object to analyze the adverse effects in the process of foundation pit excavation. At the same time, the excavation scope is simplified. The excavation is divided into left and right islands, with a radius of 13.1m on the left island and 14.5m on the right island.

Construction sequence is as follows:

a. Excavate the first layer of island and the first layer of support, with an excavation depth of 2m.

b. Excavate outside the 2nd floor island and inside the 1st floor island, and support the 2nd floor with an excavation depth of 4m.

c. Excavate the third layer outside the island and the second layer inside the island, and support the 3rd floor with an excavation depth of 4m.

d. Excavate outside the 4th floor island and inside the 3rd floor island with a depth of 4m.

e. Excavate the 4th floor island with a depth of 4m.

3. Finite element model

The length, width and height of the soil model are 213*190*36m respectively, the excavation depth of foundation pit is 14m, and the depth of diaphragm wall is 26m. The support is supported by double-ring beam, which is divided into three layers. Fixed constraint is adopted at the bottom of the soil, and normal constraint is adopted around it. Soil, support and diaphragm wall are divided into solid units and hexahedron grids, and the soil is divided into 30,000 grids. Elastic-plastic model is adopted for soil, and ideal linear elastic model is adopted for support and diaphragm wall. Its parameters are shown in Table 1.

| Name     | Density (kg/m³) | Young's Modulus (Pa) | Poisson's Ratio | Cohesive Strength (Pa) | Internal Friction Angle(°) |
|----------|-----------------|----------------------|----------------|------------------------|--------------------------|
| Soil     | 1800            | 8e6                  | 0.35           | 18000                  | 15                       |
| Diaphragm Wall | 2300            | 31.5e9               | 0.2            | /                      | /                        |
| Support  | 2350            | 41.5e9               | 0.2            | /                      | /                        |
4. Simulation results

12-core CPU is used to accelerate the calculation in parallel, and the calculation time is about 2 hours. The calculation results are as follows. The excavation is divided into four layers, and the excavation depth is 2m, 4m, 4m and 4m from the surface down, and the support shall be timely supported with the excavation to prevent excessive external settlement of the foundation pit.

![Figure 1 Finite element model and grid of soil](image1)

![Figure 2 Finite element model of diaphragm wall and support](image2)

Figure 3 Settlement of topsoil with excavation
It can be seen from fig. 3 that with the increase of excavation depth, the settlement of topsoil increases continuously, and the final settlement reaches 1.65cm when the surface settlement is in the second step of excavation, the excavation depth is 4m, and the accumulated excavation depth is 6m, the surface settlement value tends to be stable, indicating that the supporting effect of the double-ring beam supporting system is obvious.

Figure 4 reflects the horizontal displacement of the surface soil after excavation. The maximum surface horizontal displacement is 3~5m outside the foundation pit, and the soil is prone to horizontal displacement at the longer position of the diaphragm wall, but not prone to lateral deformation at the shorter position.

Figure 5 shows the deformation of diaphragm wall after excavation. The deformation of diaphragm wall mainly occurs in the middle, and it is more likely to occur in places with longer horizontal direction. Because the deformation of diaphragm wall is obviously restrained by eating and supporting.

Fig. 6 shows the stress condition of horizontal bracing, the first floor bracing is stressed greatly, and the next two floors are stressed less. It shows that the top support has a great effect. It can be seen from Figure 5 that the top support has a better restraint effect. The support effect of the lower two floors is not as good as that of the top floor. During the construction, the stress monitoring of the top support and the deformation monitoring of the middle part of the long side of the diaphragm wall should be strengthened to prevent excessive deformation.
5. Conclusion
In this paper, finite element simulation is carried out for the construction process of island excavation of deep foundation pit with double-ring beam support system, and the construction process of island excavation and support step by step is considered in the simulation process. The simulation results show that the settlement of soil outside the foundation pit is about 1.6 cm at most, and the settlement of soil outside the foundation pit tends to be stable when the excavation depth is 6 m. The maximum deformation of diaphragm wall is in the middle of the long side of displacement, and the stress of support is uneven. The support on the top floor has the greatest stress and the best supporting effect. The stress monitoring of the top support and the deformation monitoring of the middle part of the long side of the diaphragm wall should be strengthened to prevent excessive deformation. The results of this paper provide reliable basis and effective reference for the safe implementation of the project.

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