Monitoring analysis of a deep foundation pit construction adjacent to old buildings

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Abstract. The deformation and surface settlement need more attentions when a foundation pit is adjacent to old buildings. The foundation pit of Liangyuan Garden museum project was used as the background, and author analyzed the monitoring data which gathered from beginning to end. The results show that the lateral deformation of foundation pit mainly occurs in the excavation stage, and the influence of surrounding buildings on deformation needs to be considered. The retaining structure with inner support system shows a good deformation coordination ability and obvious spatial deformation characteristics. Entering the impervious layer makes the dewatering curtain effectively block the connection between inside and outside water system. This measure reduces the excavation impact on the groundwater level outside the pit and prevents excessive consolidation settlement in the surrounding soil layer.

1. Introduction
With the rapidly development of society, numerous foundation pits are building in many cities. The safety of foundation pit has caught many scholar’s focus, such as the stability of foundation pit [1,2], the influence of foundation pit excavation on adjacent buildings or projects [3,4], application effect of different support structure in different projects [5,6]. In this paper, the deformation law of support structure was studied based on the data of construction monitoring.

2. Engineering survey
Liangyuan Garden museum is located in the south side of Gaoji street, the west side of Songfeng road. The total length of the foundation pit is about 88.0 m, the width is about 50.0 m, and the excavation depth is 8.3 - 11.8m. About 6.8 m away from the foundation pit east boundary, there is Shi ‘anli ancient architecture group, all of which are 2-storey brick houses, built in the early 20th century [7].

The retaining structure of the foundation pit adopts the diaphragm wall, concrete grouting pile, three-axis mixing pile waterproof curtain and concrete internal support system. Two reinforced concrete support are set. The upper’s section size is 0.8m * 0.8m, and the lower’s section size is 1.0m * 1.0m. The layout of foundation pit support structure is shown in figure 1.
Figure 1. Layout of foundation pit support structure.

Figure 2. Support arrangement profile.

According to the survey report of the project, the soil layer distributed in the site is generally divided into 8 layers \([1-8]\), and the interlayer is divided into one sublayer \([2-1]\). \(1\) is miscellaneous fill soil, \(2-5\) layers are quaternary interfacial alluvial soil, and \(6-8\) layers are weathered bedrock of the paleogene Eocene baoyue formation. The bottom of foundation pit is located in \(4\) gravel sand layer. The depth of retaining structure is about 23.5m, and the wall toe is located in the highly weathered rock zone of the \(7\) layer. The maintenance structure section and geological conditions on the east side of the foundation pit are shown in figure 2.

The groundwater of this project mainly includes pore water and fissure water. Pore water occurs in \(2\) Medium sand and \(4\) gravel sand layers, with wide distribution, large thickness, medium water
permeability and good groundwater runoff conditions. The fissure water mainly exists in the ⑧ layers, and the water volume is generally poor. Comprehensive evaluation of the groundwater in this site is rich in water.

The monitoring contents of the foundation pit of Liangyuan Garden museum include: (1) deep horizontal lateral displacement (slope measurement) monitoring of the enclosure, measuring point category CX. (2) horizontal/vertical displacement monitoring of the top of the pile, and measuring point category WY. (3) Support axial force monitoring, measuring point category QYL. (4) Column settlement monitoring, measuring point category LCJ. (5) Groundwater level monitoring outside the pit, measuring point category SW. (6) Building vertical displacement monitoring, measuring point category SC. The layout of the pit measurement points is shown in figure 3.

3. Analysis of monitoring results

3.1 Settlement analysis of foundation pit retaining structure
Four sets of settlement data of WY3, 5, 7, and 13 are selected for analysis. It can be seen from figure 4 that the sedimentation curves of the four measuring points have the same trend. The settlement values of these measuring points are not much different at the same time, and they are not more than 3 mm, which is much smaller than the design alarm value (20mm). It shows that the enclosure structure used in this project has a good integrity and high safety reserve.

3.2 Displacement analysis of foundation pit retaining structure
It can be seen from figure 5 that the deformation curve changes significantly before the foundation pit is excavated to the bottom surface. After the excavation of the foundation pit finished, the lateral deformation of the retaining structure becomes stable. It is indicated that the lateral deformation of the retaining structure mainly developed during the period of foundation pit excavation. After the excavation of the foundation pit completed, the subsequent construction behavior has no significant influence on the lateral deformation of the retaining structure.
Compared with the cumulative deformation values of WY3, 9 and WY5, 13, the displacement values of points 3 and 9 on the east and west sides of the foundation pit are significantly larger than the other two sides. This is because the east and west sides of the foundation pit have adjacent buildings, provides large loads on the two sides, so the displacement value is larger.

It can also be seen from the cumulative deformation curve that the in the initial stage of foundation pit excavation, the deformation of the north and south sides is still mainly displaced into the pit. As the excavation progresses, the deformation gradually turns into the outside, which reflects the internal support system has obvious spatial deformation characteristics. When a researcher analyzes the deformation of the retaining structure, he or she should not only analyzes a certain section, but the whole structure, so that the actual engineering situation can be more accurately reflected.
3.3 Groundwater level analysis

Figure 6 takes SW1, 3, 7, and 8 to plot the groundwater level change. It can be seen that the curves at the four monitoring points are not significantly reduced, indicating that the dewatering curtain of the project has effectively limited the connection between the internal and external water systems, and stabilized the groundwater level outside the pit. This will help prevent large-scale consolidation settlement due to the drop of groundwater level in the soil outside the pit, and ensure the safety of the use of the pit-side buildings.

![Groundwater level](image)

Figure 6. Groundwater level.

4. Conclusions

1) The lateral deformation of the foundation pit is mainly developing during the excavation process. After the excavation process completed, the lateral deformation becomes stable. At the same time, the influence of the side buildings on the lateral deformation of the foundation pit should be noted.

2) The retaining structure with inner support system shows a good deformation coordination ability and obvious spatial deformation characteristics. When a researcher analyzes the structural deformation, he should consider it as a three-dimensional problem.

3) The three-axis mixing pile has a good performance when used as a dewatering curtain. Entering the impervious layer makes the dewatering curtain effectively block the connection between inside and outside water system. This measure reduces the excavation impact on the groundwater level outside the pit and prevents excessive consolidation settlement in the surrounding soil layer. The using safety of the pit-side buildings has been ensured.

4) The foundation pit retaining structure of this project has reached the design expectation, effectively guaranteed the safety of the foundation pit. It can provide a case for the same type engineering project.

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