Optimization Design Research of Deformation Control in Qingyuan Xinhe Garden Foundation Pit

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Abstract. As there are many factors affecting foundation pit excavation and enclosure structure design, it is strongly necessary to carry out dynamic design and information-based construction, and to perform anti-analysis through monitoring information in deep foundation pit engineering. Taking Qingyuan Xinhe Garden foundation pit project as the engineering background and based on the deformation control optimization design theory, this paper analyzed the deformation of the foundation pit and the settlement volume of the surrounding buildings by combining on-site monitoring measurement and numerical simulation, which can provide an important reference for the safety and stability of foundation pit.

1. Influencing factors of foundation pit deformation
In the deep foundation pit excavation, must we need not only to ensure the safety and stability of the foundation pit itself, but also to effectively control the deformation of the foundation pit system and protect the surrounding environment. In order to analyze the law of foundation pit deformation quickly and accurately, the key influencing factors must be selected. For a definite foundation pit project, the surrounding environmental conditions are known, and the key factors that affect the deformation of the foundation pit include: the stiffness of the supporting structure, the depth of the supporting pile, the layout and stiffness of the supporting anchor rod, the prestress of the supporting anchor, etc.

2. Optimization design of foundation pit deformation control
In the deep foundation pit project, we should estimate the possible deformation of the foundation pit excavation according to the specific project conditions, and select the support plan based on the deformation control as a prerequisite. Supplemented by scientific monitoring methods, we also need to predict the future deformation of the foundation pit in the implementation process of the plan with the help of information construction technology, and realize dynamic design, so that the deformation of the foundation pit is always within the allowable range of the environment. Deformation control optimization design is an effective method to solve the contradiction between economic rationality and safety and reliability.

3. Qingyuan Xinhe garden foundation pit deformation control optimization design research
3.1. Project Overview
The project site covers an area of about 6,733.40 m². The proposed building is 26 stories high, 2 floors of group buildings, and two-story basements. The basement covers an area of about 5356.7 m². For the building foundation, we plan to use drilled (punched) bored piles. The foundation pit is roughly
irregularly arranged, with a circumference of about 340 m and an excavation depth of 7.20 m. The safety level of the side wall of the foundation pit design is Grade 2; the service life of the foundation pit supporting structure is 1 year from the date of completion of the supporting structure. The engineering environment is shown in Figure 1.

![Figure 1. Profile position graph of foundation supporting](image1)

![Figure 2. Foundation monitoring arrangement diagram](image2)

3.2. Engineering geological characteristics

3.2.1 Topography and landform
The original site was a paddy field, which was leveled by artificial filling. The site was flat and the site environment was relatively open, which was the alluvial terrace of Beijiang river.

3.2.2 Formation lithology
According to the geological data obtained by the drilling of the site, the rock and soil layers in the site are divided from top to bottom based on their lithological differences and burial conditions: artificial fill layer, alluvial layer, flood alluvial layer and bedrock, a total of 4 projects geological layer.

3.3. Foundation pit stability check

3.3.1 Selection of design scheme for foundation pit support
The specific foundation pit design scheme is as follows:

(1) The north side of the foundation pit: there is no sloping position on this side, and the excavation depth of the foundation pit is 8.50 m. Considering the excavation depth of the foundation pit and the surrounding conditions, it is planned to adopt the support scheme of "spray anchor net + mixing pile".

(2) The south and east sides of the foundation pit: the west section of this side has sloping position, and the excavation depth of the foundation pit is 7.20 m, so the support scheme of "grading + spray anchor net" is adopted; on the east section of this side, as there are 1 or 2 floors of residential houses and its foundation is natural foundation, which is the key supporting object on the construction of this side. The excavation depth of the foundation pit is 7.20 m, and we plan to use the support scheme of "spray anchor net + mixing pile + support". In order to reduce the displacement of the foundation pit and ensure the safety of the house, a micro steel pipe pile is set in the mixing pile to strengthen the overall rigidity of the supporting structure, and a prestressed anchor rod is provided at this place to reduce the displacement of the supporting system and ensure the house’s safety.

(3) The west side of the foundation pit: this side is close to the road and has a small sloping position. The excavation depth of the foundation pit is 7.20 m. It is planned to use the support scheme of "sloping + spray anchor net".
3.3.2 Stability calculation of anchor structure
According to the geological conditions of the site and the surrounding structures of the foundation pit, the excavation edge of the foundation pit is divided into 1-1 ~ 6-6. The detailed division is shown in Figure 1, and the calculation results of each section are shown in Table 1.

| Section | Drilling No | Foundation pit grade | Stability coefficient of supporting structure |
|---------|-------------|-----------------------|-----------------------------------------------|
| 1-1     | ZK30        | level I               | 1.365                                          |
| 2-2     | ZK29        | level II              | 1.339                                          |
| 3-3     | ZK27        | level II              | 1.341                                          |
| 4-4     | ZK23        | level II              | 1.431                                          |
| 5-5     | ZK2         | level I               | 1.341                                          |
| 6-6     | ZK5         | level I               | 1.355                                          |

3.4. Foundation pit construction plan
(1) Spray anchor net + mixing pile: Step 1: clean up the residual construction waste in the site and construct the mixing pile; Step 2: excavate the earthwork to 0.5 m below the first row of anchor rods to carry out the anchor rod construction; Step 3: wait for the strength of the first row of anchors to reach 70% of the design strength (with prestressed anchors, the anchors should be stretched before the next earthwork excavation), and then excavate the earthwork to 0.5 m below the second row of anchors, and construct the second row of anchors; Step 4: same as the previous steps, other bolts are constructed to the bottom of the foundation pit.

(2) Spray anchor network + mixing pile + miniature steel pipe pile: Step 1: clean up the residual construction waste in the site, construct the mixing pile, and then carry out the construction of the miniature steel pipe pile; Step 2: excavate the earthwork to the first row at the point 0.5 m below the anchor rod, the construction of the anchor rod is carried out. Step 3: after the strength of the first row of anchor rods reaches 70% of the design strength, excavate the earth to 0.5 m below the second row of anchor rods; Step 4: same as the previous steps, other bolts are constructed to the bottom of the foundation pit.

(3) Slope + spray anchor net: Step 1: clean up the residual construction waste in the site; Step 2: according to the slope ratio shown in the figure, excavate the earthwork to 0.5 m below the first row of anchor rods, and carry out the construction of the anchor rods; Step 3: after the strength of the first row of anchors reaches 70% of the designed strength, excavate the earthwork to 0.5 m below the second row of anchors, and construct the second row of anchors; Step 4: same as the previous steps, other bolts are constructed to the bottom of the foundation pit.

3.5. Foundation pit deformation monitoring
3.5.1 Foundation pit monitoring requirements
In order to ensure the smooth construction of the foundation pit and deal with the situation in a timely manner, during the excavation of the foundation pit and the construction of the basement, different monitoring elements are placed on the supporting structures of the foundation pit and the adjacent buildings (structures), and carrying out monitoring and analysis to their safety indicators, the detection arrangement points are shown in Figure 2.

The safety levels of foundation pit support 1-1, 5-5, 6-6 section are first class, the maximum horizontal displacement alarm value of the foundation pit is 25 mm, the early warning value is 20 mm, and the slope measurement alarm value of the foundation pit support is 25 mm, the prewarning value is 20 mm; the surrounding building settlement alarm value is 25 mm, and the prewarning value is 20 mm; the safety level of other sections is Grade 2, the maximum horizontal displacement alarm value of the foundation pit is 30 mm, the prewarning value is 25 mm, and the foundation pit support
inclinometer alarm value is 30 mm, the warning value is 25 mm; the surrounding building settlement alarm value is 30 mm, and the prewarning value is 25 mm.

### 3.5.2 Monitoring results and analysis

The initial value measurement of the project started on February 26, and a total of 30 monitorings were conducted on August 14. The graph of the horizontal displacement monitoring curve at the top of the foundation pit structure is shown in Figure 3; Figure 4 shows the relation curve between the inclinometer displacement and time in the foundation pit; the settlement curve of the buildings around the foundation pit is shown in Figure 5; the ground settlement curve around the foundation pit is shown in Figure 6. Based on the monitoring results on the construction site, the relationship between the horizontal displacement of the foundation pit, the inclinometer, the cumulative maximum deformation of the surrounding buildings, the ground settlement and the design control value of the first level of safety is shown in Table 2:

| Monitoring items                      | Alarm value (mm) | Early warning value (mm) | Measured cumulative maximum displacement point number | Measured cumulative maximum displacement (mm) |
|--------------------------------------|------------------|--------------------------|-----------------------------------------------|--------------------------------------------|
| Horizontal displacement              | 25               | 20                       | WY16                                          | 18.18                                      |
| Foundation pit inclinometer         | 25               | 20                       | CX2                                           | 8.88                                       |
| Settlement of surrounding buildings  | 25               | 20                       | SC1                                           | 1.71                                       |
| Ground settlement of surrounding foundation | 25               | 20                       | SM2                                           | 1.57                                       |

Figure 3. The top in the displacement of foundation structure monitoring cure diagram
3.6. Monitoring conclusion
According to the monitoring and measurement results, the following conclusions can be obtained:

(1) According to the horizontal displacement monitoring curve at the top of the foundation pit structure, except for the slow convergence of the measuring points wy9, wy16 and wy17, the horizontal displacement at the top of the other measuring points converges in about 20 days, and the displacement value at the measuring point of wy16 reaches the maximum. The maximum value is 18.8 mm less than the warning value 20 mm. Therefore, according to the deformation control theory, the foundation pit supporting structure is in a stable state.

(2) The maximum deflection displacement of the foundation pit is 8.88 mm and less than the early warning value of 20 mm; the foundation pit supporting structure is in a stable state.

(3) According to the settlement curve diagram of the buildings around the foundation pit, it can be obtained that due to the influence of the excavation disturbance of the foundation pit, the measurement points converge slowly, but the maximum settlement is only 1.71 mm. Therefore, based on the deformation control theory, the excavation of the foundation pit has little effect on the surrounding buildings.

(4) According to the ground subsidence curve around the foundation pit, it can be obtained that the measuring points converge slowly, but the maximum settlement is only 1.57 mm. Therefore, based on the deformation control theory, the foundation pit is stable during the excavation process.

4. Conclusion
Deep excavation is a complex systematic project, because foundation pit excavation and retaining structure design are impacted by many factors, it is very necessary to use monitoring information for anti-analysis in deep foundation pit engineering. An accurate forecast of the deformation in the foundation pit excavation system will help the effective functioning, to protect the pit surrounding environment and ensure the pit security.
The results of this study have practical value for the rational selection of foundation pit supporting structure to ensure the stability of the foundation pit and the safety of surrounding buildings; at the same time, it can also provide reference for similar projects.

Meanwhile, it should be noted that in actual construction, soil excavation is a variable that changes with time and space. Only by constantly summing up and accumulating experience in practical projects, and applying them to theoretical analysis, can the design and construction of foundation pit engineering be further improved through continuous circulating work.

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