Deformation Control Study on Foundation Pit Support by Pre-stressed Pile-anchor

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Abstract. In this paper, through the study of the optimization design of the prestressed anchor foundation pit excavation, the problems that are not considered in the design calculation of the multi-pivot pile anchor support are analyzed. At the same time, according to the design and calculation of foundation pit excavation, the optimization model of the prestressed anchor to effectively control the deformation of foundation pit is put forward under the condition of not considering the support design of foundation pit, only considering the influence of construction.

1. Introduction of prestressed pile anchor support
Among the many forms of foundation pit support, the prestressed pile anchor support is a commonly form of support used in China. Compared with soil nailing, it has a strong technical advantage in controlling soil deformation; compared with internal support, it has the advantages of low cost, convenient construction, small support space and less remaining problems; compared with cement-soil wall, it has the advantages of less material consumption, wide application range and less environmental pollution; compared with top-down method, it has the advantages of simple equipment, low technical requirements, strong promotion and wide applicability.

2. Deformation optimization control of prestressed pile anchor pit
It can be seen from the supporting regulations of foundation pit that the design manual only considers the influence of earth pressure on the calculation of internal force of anchor bolt. During the actual construction process, with the development of soil deformation, the prestress of anchor bolt will change with the construction progress. In the process of foundation pit construction, the prestress supplement tensioning bolt may have a restraining effect on the deformation of foundation pit; based on the deformation control theory of foundation pit, it is necessary to ensure the safety and stability of foundation pit itself and its surrounding buildings during the excavation process, that is to say, the deformation is controlled within a certain allowable range. Therefore, the influence of anchor prestressed supplement tension on the deformation of the foundation pit and the settlement of the surrounding buildings is particularly important.

Figure 1 shows the monitoring results of the top anchor prestress during the excavation of a certain foundation pit in Guangzhou. The foundation pit is 8.5m deep and excavated in four layers, with four anchor bolts in total. From Figure 1, it can be seen that the anchor prestress basically decreases with the excavation of the foundation pit. When the excavation reaches the bottom of the foundation pit, the anchor stress decreases by about 33%, with an average decrease of about 10% for each layer.
If the foundation pit is constructed according to the design, the prestress of anchor bolt is applied one-time without follow-up supplement, and the prestress of anchor cable decreases with the excavation of foundation pit, which will cause the stress and deformation of foundation pit support pile to be affected to some extent, and the deformation of surrounding environment will also be affected, thus endangering the safety of foundation pit and the deformation safety of surrounding environment. Therefore, it is necessary to consider the change of prestress reduction during the construction according to the design, and supplement the prestress when appropriate.

3. Numerical simulation analysis

In this paper, FLAC2D is used to simulate the excavation process of a certain foundation pit in Guangzhou. Considering the symmetry of foundation pit support and structural deformation, plane strain is used to analyze. The x-direction is 3.3 times of the excavation width of the foundation pit, and the y-direction is 3.75 times of the depth. The simulated support is 4 rows of prestressed anchor cables. In the model, the soil is divided into four layers: plain fill, silt, sandy clay and strongly weathered granite.

Figure 1. The results map of the monitoring of a pre-stressed anchor

Figure 2. Excavation FLAC2D numerical model
Figure 2 is a numerical analysis model based on FLAC2D software. The empty space in the figure is the excavated area. The excavation of soil in FLAC is simulated by model null. The support pile and soil joint share one joint, and the coupling effect is not considered.

Figure 3 shows the stress contours of the Y-displacement. It can be seen from the figure that under the action of initial geostress, the displacement of soil layer decreases gradually from top to bottom. The contour of the Y displacement is distributed according to the obvious line from top to bottom of the soil layer. The surface subsidence is the largest, about 0.25m, and the bottom subsidence is the smallest, about 0.025m. This distribution is consistent with the actual settlement distribution of the stratum, indicating that the model is established correctly. The purpose of considering the displacement change of soil layer caused by geostress is to subtract the displacement caused by initial geostress from the subsequent working conditions in the subsequent construction steps, so as to obtain the true displacement of soil layer under each working condition during the excavation of foundation pit.

![Figure 3. Stress contours of the Y-displacement](image)

4. Results of deformation optimal control scheme

4.1 Foundation pit excavation scheme

The numerical simulation of the foundation pit excavation is divided into two schemes. The first scheme is to adopt the conventional excavation scheme, that is, the prestress of the anchor cable calculated according to the design is applied to the anchor cable one-time, and construct a prestressed anchor cable for each layer of soil excavation; the second scheme is to consider the prestress loss of the anchor cable caused by the excavation deformation of the foundation pit. After each layer of excavation, the prestress is added to the previously constructed anchor cables. The specific excavation scheme is shown in Table 1.

| Excavation Program | Program 1 | Program 2 |
|--------------------|-----------|-----------|
|                    | Excavation (m) | Prestress (KN) | Excavation (m) | Prestress (KN) |
| Condition 1        | 1         | 1         | 1             | 180          |
| Condition 2        | 2         | 180       | 2             | 200          |
| Condition 3        | 2         | 200       | 2             | 20; 18       |
| Condition 4        | 2         | 200       | 3             | 200; 20; 18  |
| Condition 5        | 1.5       | 150       | 1.5           | 150; 20; 20; 18 |

① represents the first anchor cable,
①180 represents the prestress applied by the first anchor cable is 180KN, and so on.
4.2 Deformation analysis

4.2.1 Comparison of horizontal displacement
Figure 4 and Figure 5 are the curves of the horizontal displacement of the support pile with the depth of the foundation pit excavation under each working condition after the foundation pit excavation. It can be seen from the figure that the maximum horizontal displacement under the third working condition is about 1.5mm smaller than that under the normal construction after the prestressed supplementary tension; the minimum displacement is 0.5 larger than the original scheme, because the pile has a certain rigidity, under the prestressed condition at the top, the displacement at the top of the pile tends to decrease while the displacement at the bottom of the pile tends to increase. Its pivot point is about 8 m below the ground.

4.2.2 Comparison of vertical displacement
Figure 6 and Figure 7 show the surface settlement curve of foundation pit under various working conditions after numerical simulation. It can be seen from the figure that the surface settlement around the foundation pit caused by the conventional construction scheme is larger than the excavation scheme of pre-stressed supplement tensioning, and the pre-stressed supplement tensioning scheme does not have a large range of influence. In the area of 1.5 times the depth of the foundation pit, the supplement tensioning has a direct impact on the control of the surface settlement, and the impact is small when it exceeds 1.5 times the excavation depth of the foundation pit. The difference in surface settlement caused by the two schemes is small.
Fig 6. Program 1 with the excavation of surface subsidence deformation map

Fig 7. Program 2 with the excavation of surface subsidence deformation map

5. Conclusion
According to the law of prestress loss, the large-scale finite element software FLAC is used to carry out numerical simulation analysis of foundation pit excavation, establish the optimized numerical analysis model, and compare the calculation results before and after optimization. The results show that the optimization scheme can effectively control the lateral displacement and surface settlement of the foundation pit, and provide strong protection for the safety of the foundation pit and the surrounding environment. It should be pointed out, although the layered soil is considered in the process of simulating the excavation of foundation pit in this paper, the actual layered soil is not continuous or horizontal. In order to get better results, a model consistent with the distribution law of soil layer can be further established for analysis.

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