Influence of retaining method of reservoir foundation pit on construction deformation of surrounding soil

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Abstract. In order to avoid the summer rainfall flood peak and improve the efficiency of rainwater utilization, many cities have put the construction of storage ponds on the agenda. However, the design of the foundation pit of the storage tank mostly adopts the design method of building foundation pit, that is, the foundation pit supporting structure will be dismantled after the main structure construction to a certain extent, so this has resulted in a greater waste of resources. In view of the above reasons, this paper proposes an economical foundation pit supporting structure of underground storage pond. This structure can be used as both retaining structure and pool body structure in the process of foundation pit excavation, which can reduce the waste of materials in the construction process and reduce the project cost. Through the calculation results of MIDAS-GTS software, it can be seen that the optimized structure has a good supporting effect in the process of foundation pit excavation, and can completely replace the temporary supporting structure in the original design scheme. The calculation results can provide reference for similar engineering construction.

1. Introduction
In recent years, although the vast majority of plain cities in China have made remarkable achievements in economy, the attention to urban water environmental pollution and its treatment is relatively backward. Therefore, many plain cities have planned many underground storage tanks and other water treatment projects. Compared with building foundation pit, the foundation pit of underground storage pond has the following characteristics: (1) The structure is relatively simple, and the investment cost of foundation pit construction in the construction process takes a relatively large proportion in the total engineering cost. (2) When the pool structure is constructed, the temporary supporting structure of the foundation pit will be dismantled and abandoned in an orderly manner, resulting in a certain degree of waste of funds. Therefore, it is of practical significance to propose a relatively economical method for the foundation pit protection of large underground monomer structures involved in the water environment control project of plain city.

Zhang Yi [1] proposed two schemes of separation design and combination design of foundation pit and main structure of the storage pond for the underground storage pond built under the condition of soft bottom layer, and compared them from many aspects. Li Guirong, Ping Wenmin et al. [2] proposed three kinds of excavation and seepage prevention schemes for the problems of leakage and underwater excavation in the construction of storage pond in the permeable layer or strong permeable layer. Wang
Zhidong, Song Lijun et al. [3] adopted the new optimized drill bit and other construction technologies to improve the construction efficiency and ensure the construction period in the anchor cable construction of the deep foundation pit support of the storage pond. Wu Longshun [4] established a calculation model for an underground storage pond project, and compared it with structural three-dimensional analysis and spatial finite element calculation methods. Liu Jinglin [5] described the technical measures of the foundation pit retaining structure adopted in the civil engineering construction of the storage pond along Jiangsu Road along Suzhou River. Wang Jianhua and Xu Zhonghua [6] introduced the way, general process and application scope of the combination of supporting structure and underground structure. Xu Zhonghua [7] systematically studied the displacement shape of deep foundation pit combined with supporting structure and underground main structure in Shanghai area by using three-dimensional finite element modeling, analyzing a large number of measured data of foundation pit and combining with the practice of three large foundation pit projects.

According to the research contents of many scholars and experts, "integration of underground engineering support structure" has become an important direction of underground geotechnical engineering construction, which combines temporary structure with permanent structure in underground engineering. It can not only shorten the construction period and reduce the cost, but also avoid the secondary stress and deformation of the supporting structure. This paper studies the optimization of the foundation pit supporting structure and the pool body structure of the underground storage pond in the comprehensive improvement project of urban water system proposed by Fuyang City in recent years, and analyzes the soil displacement rule in the optimization scheme with the help of finite element software, and discusses the feasibility of the underground "continuous wall + structure inner bracing" scheme.

2. Project overview and optimization design
Quanbei No.1 Regulation and Storage Pond, a comprehensive renovation project of urban water system in Fuyang City, is planned to be built in Ningtang Village, Quanying Community, Yingquan District, Fuyang City, east of Taihe Road and north of Yingdong Road. The main pool structure of this project is the underground storage pond and the subsidence sand pond (the main body discussed in this paper is the storage pond). The underground storage pond has a plane size of 91.0m×46.0m and a depth of 12.4m. The overall structure is reinforced concrete structure, using buttress + beam + column + slab reinforced concrete frame shear wall structure, shear wall thickness of 600mm. In addition, the internal beam-column of the storage pond (hereinafter referred to as the "internal support of the structure") is divided into two layers, and a continuous beam is set above the collecting tank. The foundation pit retaining structure adopts the form of "cement mixing pile + bored cast-in-place pile + crown beam (or enclosing purlin) + internal support" to support, in which the specification of bored cast-in-place pile is 900mm×1200mm.

Fig1. The layout of the original design of foundation pit support
Fig. 2 The original design profile of foundation pit support

According to the introduction, "the structure of the water conservancy facilities such as the storage pond and the pumping station is relatively simple. During the construction process, the foundation pit construction input cost takes a relatively large proportion in the total engineering cost. After the completion of the construction, the enclosure structure should be dismantled "and so on. Cement mixing piles, bored cast-in-place piles and internal supports in the existing design structure are all temporary structures. This part of the structure will not be reused to a large extent after the completion of the masonry of the reservoir body. Therefore, the original support scheme is now adjusted and optimized as "underground continuous wall + internal support in the structure". As shown in Fig. 3, when this scheme is adopted, the diaphragm wall can be used for "one wall with three uses", that is: (1) The replacement of cement mixing pile plays the role of water stop. (2) Instead of bored pile, it plays the role of retaining soil, moreover, the rigidity of diaphragm wall is large, and the effect of controlling soil displacement is better. (3) The underground diaphragm wall and the internal support of the structure can be used as a part of the structure of the storage pond in the later stage. It can be seen that this optimization scheme has the following characteristics: I shorten the construction period; II reduce the cost; III reduce waste of materials and resources.

Fig. 3 Optimized scheme

3. Calculation and analysis of the original design scheme

MIDAS-GTS software was used for calculation and analysis. In the calculation process, solid element is used for soil, beam element is used for crown beam and enclosing purlin, implantable truss element is used for internal support, and pile element is used for cast-in-place pile simulation. The modified Mohr-Coulomb model developed from the Mohr-Coulomb constitutive model is applied to various types of subsoil. The shear yield surface of the model is the same as the yield surface of the Mohr-Coulomb model, and the compression surface is an elliptical cap constitutive. The double hardening model is used
The calculation model is 120m long, 60m wide and 50m high. According to the actual construction process, a number of construction stages are divided into numerical simulation. ① Initial in-situ stress balance; ② pile foundation, crown beam construction; ③ the first soil excavation; ④ the second soil excavation; ⑤ the third soil excavation; ⑥ the fourth soil excavation and enclosing purlin construction; ⑦ the fifth soil excavation; The sixth soil excavation; ⑧ The seventh soil excavation. The calculation parameters are determined according to the geological prospecting report, as shown in Table 1.

| material          | Thickness/m | Density/(kN·m³) | Cohesive /KPa | Angle of internal friction(°) | The compression modulus/(MPa) |
|------------------|-------------|-----------------|---------------|-------------------------------|-------------------------------|
| Miscellaneous    | 4.45        | 17.5            | 10            | 8                             | 3                             |
| Silty clay I     | 4.1         | 19.5            | 40            | 18                            | 10                            |
| Silt I           | 6.8         | 19.9            | 8             | 25                            | 9                             |
| Silt             | 2.7         | 20.58           | 2             | 28                            | 15                            |
| Silty clay II    | 6.1         | 19.4            | 25            | 18                            | 6.8                           |
| Silt II          | 3.5         | 19.5            | 10            | 27                            | 10                            |

The soil displacement after the completion of the excavation is shown in Fig. 4, which presents an inwardly convex deformation on the whole. The maximum displacement of the soil on the side wall of the foundation pit is 10.6mm, and the displacement of the soil on the lower side wall is significantly greater than that on the upper side wall. In addition, the vertical displacement of the surface soil presents a funnel distribution with a maximum value of 5.2mm.

In addition to the above analysis, according to the analysis of the excavation process can be seen: The crown beam at the top of cast-in-place pile foundation and its internal support play a very positive role in controlling the displacement of pile top and avoiding the possibility of cantilever failure. The displacement of the soil is also controlled by the position of the enclosing purlin and its internal support. In this calculation process, enclosing purlin and its internal support are located 5.5m below the pile top, but they are still at the upper part of the maximum displacement area of soil, so the height of enclosing purlin and its internal support still has room for optimization.

4. Optimization scheme introduction and calculation analysis
This calculation involves two models: (1) Optimization model: ground wall + structural support. (2) Comparison model: ground wall (no internal support). Among them, the position of the structural support in the optimization model is the same as the support elevation inside the pool structure in the original design scheme, and the section size is the same (800mm*1000mm). Considering the need of working space for construction, the spacing of structural support is adjusted to 15m*15m.
4.1 Horizontal displacement of surface soil
The calculation results of the two calculation models are shown in Figure 5. In the optimization model, the maximum horizontal displacement of surface soil was 4.4mm. The large horizontal displacement of soil on the surface is located within a range of 12m from the excavation boundary of the foundation pit, and the horizontal displacement of soil within this range is all greater than 4mm. In the comparison model, the maximum horizontal displacement of surface soil is 19.1mm (located at the edge of excavation). The farther the distance from the excavation boundary, the smaller the horizontal displacement.

Fig. 5 Horizontal displacement of surface soil.

4.2 Vertical displacement of surface soil
It can be seen from Fig. 6 that the vertical displacements of surface soil obtained by the two models are all distributed in a funnel-shaped manner. The maximum vertical displacement calculated by the optimization model is 2.2mm, and the maximum vertical displacement calculated by the comparison model is 5.4mm. In addition, the following conclusions can be drawn from the analysis in Figure 6: the structural support inside the foundation pit not only has a good effect in controlling the horizontal displacement of the surface soil, but also plays a significant role in controlling the vertical settlement of the surface soil.

Fig. 6 Vertical displacement of surface soil.

4.3 Lateral displacement of diaphragm wall
It can be seen from Fig. 7 that the diaphragm wall in the optimization model is internally convex lateral deformation, in which the lateral displacement at the top of the diaphragm wall is 3.6mm, and that at the bottom of the foundation pit is 8.8mm (which is the maximum lateral displacement of the wall). In the comparison model, because there is no structural support to control the soil deformation, the maximum horizontal displacement of the diaphragm wall is located at its top and reaches 20.9mm.
5. Conclusion
In the design and construction of many underground storage ponds, the temporary supporting structure of the foundation pit and the pool body are designed separately. After the completion of the pool body structure, the temporary supporting structure of the foundation pit will be removed, resulting in a large amount of material waste. The significance of this work is to reduce the total cost of such projects and reduce the waste of resources.

Through numerical calculation and analysis, the following conclusions are drawn.
(1) When the original design scheme is adopted, the vertical displacement of the surface soil is distributed in a funnel-shaped manner, and the row pile and its adjacent soil are internally convex deformation.
(2) The displacement of soil mass and the lateral deformation of the diaphragm wall can be better controlled by using the optimized scheme (i.e., the diaphragm wall + the internal support). Through the analysis and comparison of the "optimization model" and "comparison model", it can be seen that the structural support inside the foundation pit plays a non-negligible role in controlling the soil deformation. "Integration of supporting structure" has become a development trend, and I believe that there will be more research in this field in the future. The author suggests that future research should focus on how to optimize construction space and the design parameters of diaphragm wall.

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