Analysis and Research on excavation deformation of deep foundation pit support engineering of metro station

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Abstract: With the rapid economic and social development, the construction of urban underground rail transit is in full swing, and even many second and third tier cities are starting to build. In order to control the environmental impact of the excavation team and control the deformation, this paper takes a deep foundation pit project of a station in Wuhan Metro as the research object, combining with theoretical analysis, field monitoring and Midas GTS Nx numerical software simulation and other methods are used to discuss the ground settlement around the foundation pit, the impact on the adjacent bridge pile foundation, and the deformation control analysis.

1. Preface

In recent years, with the rapid development of economic construction, the acceleration of urbanization process, the expansion of city scale, the construction of subway promotes the progress of building science and technology to a certain extent, but the development and challenge always emerge at the historic moment. When the subway construction improves the public living standard, we also realize that the location of deep foundation pit of subway station is mostly distributed in the population and buildings concentrated The municipal pipe network and traffic trunk road around the foundation pit are complex. In addition, the construction quantity of foundation pit is relatively large, the construction period is relatively short, the surrounding environment is complex, and there are some unpredictable risks in the construction process, which lead to serious economic losses, even threaten the life safety of construction personnel. The alarm bell of safe production of engineering construction has been ringing for a long time.

Therefore, it is an important means to fully understand the deformation law of foundation pit to prevent the occurrence of foundation pit accidents. In the concrete construction, it is of great significance for the design and construction of the foundation pit to not only strengthen the preliminary investigation and field detection in the construction process, but also give full consideration to the economic benefits of the project, correctly understand the deformation mechanism, influencing factors and deformation control measures of the foundation pit project.
2. Project overview

The project is located in Hankou District, Wuhan City, to the east of the intersection of Houhu Avenue and Jianshe Avenue, and is set along the east-west direction of Houhu Avenue. Houhu Avenue station is the starting station of Wuhan Metro Line 21 (Yangluo line) project. It intersects with Metro Line 3 as a transfer station, as shown in Figure 6. The size of the foundation pit is about 292m × 20.7m, the excavation depth is 16.5m, and the safety level is level I. The main body of the station is a box shaped frame system on the second underground floor. The viaduct is located at the bottom of a road for crossing. The location between the bridge pile foundation and the foundation pit is shown in Figure 1. In order to ensure the most basic traffic during the construction of the station, a 28m long temporary overpass is installed in the north direction of the bridge. Symmetrical excavation is used in the excavation process.

Houhu Avenue red line is 60m wide and Jianshe Avenue red line is 60m wide. Houhu Avenue station of Yangluo line is located at the east side of the intersection of Houhu Avenue and Jianshe Avenue and is arranged along Houhu Avenue. The ground elevation of the station is 20.2-20.7m.

Figure 1 location relationship between bridge pile foundation and foundation pit

3. Analysis of influence of foundation pit excavation on pile foundation of adjacent bridge

3.1 Analysis of the influence of distance between pile foundation and foundation pit

Through the 3D numerical analysis software MIDAS GTS NX modeling, respectively set the distance between the deep foundation pit and the bridge pile foundation as 5m, 10m, 15m, 20m excavation horizontal and vertical displacement for parameter analysis, and finally summarize the impact. If shown in Fig. 2:

Fig.2 Horizontal displacement of pile foundation under different distance and Vertical displacement of piers at different distances
3.2 Analysis on the influence of excavation depth of foundation pit

The excavation depth of the foundation pit is 5m, 10m and 15m respectively for parameter analysis. Finally, the influence of the excavation depth of the foundation pit on the mechanical performance of the pile foundation is summarized. As shown in Figure 3:

![Horizontal displacement of pile foundation under different excavation depth](image)

Fig. 3 Horizontal displacement of pile foundation under different excavation depth

3.3 Analysis of the influence of foundation pit retaining stiffness

The rigidity of enclosure structure is 10GPa, 15gpa, 20GPa and 40gpa respectively. Finally, the influence of the stiffness of the retaining structure on the mechanical properties of the pile foundation is summarized. As shown in Figure 4:

![Horizontal displacement of pile foundation under different rigidity of retaining structure](image)

Fig. 4 Horizontal displacement of pile foundation under different rigidity of retaining structure

3.4 Analysis of the influence of the dimension of foundation pit support

Through Midas GTS NX, 600mm, 800mm, 1000mm and 1200mm size diaphragm walls are set respectively, and other conditions remain unchanged for parameter analysis. Finally, the influence of enclosure size on the mechanical properties of pile foundation is summarized. As shown in Figure 5:

![Horizontal displacement of pile foundation under different thickness of retaining structure](image)

Fig. 5 Horizontal displacement of pile foundation under different thickness of retaining structure
3.5 Summary of impact analysis

Based on different construction conditions, the finite element numerical simulation is carried out for different foundation pit distance, excavation depth and support rigidity of foundation pit, and the following conclusions are drawn:

(1) The closer the foundation pit is to the adjacent pile foundation, the greater the horizontal displacement of pile foundation and the vertical displacement of pier, on the contrary, the smaller the displacement is;

(2) The excavation of foundation pit has certain influence on the lateral displacement of pile foundation and the vertical displacement of pier top: there is a positive correlation between the excavation depth of foundation pit and the vertical displacement of pier top and the lateral displacement of pile foundation;

(3) When the rigidity and thickness of the retaining structure increase to a certain limit, there is a limit value on the vertical displacement of the pier and the lateral displacement of the pile foundation.

4. Deformation control analysis of deep foundation pit excavation

4.1 Influence of surrounding environment on excavation deformation of foundation pit

(1) Analysis of the influence of soil elastic modulus

In order to study the influence of the change of soil model on the surface settlement outside the pit, different elastic moduli of soil are taken for analysis, and the elastic moduli e, 0.6e, 0.8E and 1.2e of the original case are taken for calculation respectively, and other parameters remain unchanged. According to the change of soil elastic modulus calculated by numerical simulation, the corresponding curve of ground settlement and horizontal lateral displacement of retaining structure is drawn as shown in Figure 6:

![Figure 6. Surface settlement under different elastic modulus of soil and Horizontal displacement of enclosure structure under different elastic modulus of soil](image)

(2) Analysis of the influence of internal friction angle of soil

The internal friction angle of the original case, 0.6, 0.8 and 1.2 are taken respectively for calculation, and other parameters remain unchanged. According to the change of soil internal friction angle calculated by numerical simulation, the corresponding curve of surface settlement and horizontal lateral displacement of retaining structure is drawn as shown in Figure 7:

![Figure 7. Analysis of the influence of the surface settlement and the horizontal displacement of the retaining structure when the internal friction angle of the soil changes](image)
4.2 Influence of foundation pit excavation on deformation

In order to study the influence of ground overload on foundation pit deformation, three different ground overload values of 20KN, 50kN and 80KN are selected for calculation and analysis, and other conditions remain unchanged. According to the change of ground overload calculated by numerical simulation, the corresponding curves of ground settlement and horizontal lateral displacement of retaining structure are drawn as shown in Figure 8:

![Figure 8. Analysis of the influence of surface subsidence and horizontal lateral displacement of retaining structure](image)

4.3 Influence of engineering design on excavation deformation of foundation pit

(1) Influence of horizontal support spacing (quantity)

Select 0.5s, 1s and 1.5s respectively, and keep other parameters unchanged. Draw the corresponding curve according to the surface settlement and horizontal lateral displacement of retaining structure when the horizontal support spacing calculated by numerical simulation changes, as shown in Figure 9:

![Figure 9. Analysis of the influence of horizontal support distance and enclosure structure](image)

5. Conclusions

Through the above deformation simulation analysis, the following conclusions are drawn:

(1) In the process of deep foundation pit excavation, the maximum horizontal displacement of the pile basically appears around the excavation face, the deformation will increase with the advance of excavation, and the maximum horizontal displacement of the pile appears at the completion of bottom slab pouring;

(2) The change of internal force of pile body is combined with the change of horizontal displacement of pile body. With the increase of excavation depth of foundation pit, the maximum internal force gradually moves down, which is located near the excavation surface of foundation pit and near the surface of bridge pile on the side of foundation pit;

(3) The excavation depth of the deep foundation pit obviously increases the horizontal displacement of the pile foundation and the vertical displacement of the pier. The distance between the deep foundation pit and the pier pile foundation has a negative correlation with the horizontal displacement of the pile foundation and the vertical displacement of the pier. The stiffness and thickness of the retaining structure can reduce the horizontal displacement of the pile foundation and the vertical displacement of the pier to a certain extent, but when the support stiffness increases to a certain limit, the deformation has a limit value.
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