Environment Impact Analysis of Shield Passing Alongside Bridge Pile Platform Using Three Dimensional Numerical Simulation

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Abstract: The shield method has many advantages in the construction of urban subway, and has become the preferred method for the construction of urban subway tunnel. Taking Shijiazhuang metro line 3 (administrative center station - garden park station interval) Passing alongside bridge as the engineering background, double shield crossing the bridge pile foundation model was set up. The deformation and internal force of the pile foundation during the construction of the shield were analyzed. Pile stress caused by shield construction increases, but the maximum stress is less than the design strength; the maximum surface settlement caused by the construction of 10.2 mm, the results meet the requirements of construction.

Keywords: shield; under wear; bridge pile; deformation; internal force

1. Introduction
Shield is one important method of tunnel construction. It has many merits such as little impact on the surroundings, less ground operation, high automation degree, fast construction speed and low labor intensity. Due to the obvious advantages, shield is widely used in city subway tunnel construction. In the process of shield construction, it is a problem worth paying close attention to when it meets the surrounding structures which are sensitive to deformation. This paper takes Shijiazhuang metro line 3 (administrative center station - garden park station interval) Passing alongside bridge as the engineering background to study the surface deformation law of shield pile passing through bridge pile platform.

Administrative Center Station ~ Garden Park Station is located in Zhengding New District, starting from the administrative center station, north along the planning of Beijing South Street (formerly known as Metro Avenue) below the laying, side wear and under the comprehensive pipe gallery to park garden station. The administrative center station to park station interval by shield construction, starting mileage of the right line of the shield is K31+593.450, terminate the mileage for the K32+682.090, the total line length is 1088.640 m; the left line of the shield chainage K31+593.450, terminate the mileage for the K32+682.090, the total line length of 1088.640 M. The soils within the exploration range of the project are divided into artificial accumulation layer (Qml), newly deposited layer (Q4al), Quaternary alluvial (Q4al + pl), Quaternary system, Q3al + pl) 4 layers. Shield close to the existing Zhou Hanhe bridge bridge pile, the impact is relatively large. First of all, the outer surface
of the bridge piles and the distance between the subway tunnels is relatively close, so the control of the shield tunneling axis coordinate requirements are higher. [1~2] Second, the shield excavation squeeze the soil, and will produce friction, the two together on the pile will make the internal force increases, so the bridge under the pile when the more dangerous. Many scholars have done a lot of research [3~9]

2. Establishment of Three - Dimensional Numerical Model of Shield Crossing Construction

In this chapter, we use the method of numerical simulation to establish the model of shield tunneling through Zhouhanhe bridge The following first describes the calculation of the model assumed, shield tunneling process simulation:

(1) calculation assumption
   Pile foundation, pipe material, grouting layer as a linear elastic material.
(2) calculation parameter selection
   The parameters of segment and pile are shown in table 1.

| structure | Material name | Severeγ/ (kN·m⁻³) | Elastic ModulusE/MPa | Cohesion/kPa | Internal friction angle/° | Poisson's ratio |
|-----------|---------------|---------------------|----------------------|--------------|--------------------------|----------------|
| Segments with piles | C50 Concrete | 2 400 | 3 450 | — | — | 0.20 |

In the K32+100~K32+150 section under wear shield piles, pile depth of about 20 m, pile bottom tunnel vertical minimum distance is 5.4 m, the minimum horizontal distance is 1.5 m, the tunnel center average depth is 28 m, thickness 0.3 m, every excavation 1.2 m, the 3D model along the tunnel axis is 42 m long, 70 m wide and 50 m high, the model shown in figure 1. Figure 2 shows the relative position of the tunnel and the bridge pile. The model consists of 54844 units, 56878 nodes and 82 excavation steps. Due to the pile on the basis of the load to withstand the bridge, so set the surface of its 700 kN concentrated load.

Shield tunneling process: first simulation of the left line of shield tunneling, and other left after the end of the tunnel, the right line of shield began to dig, to the end of the excavation. Excavation first full-section excavation, and then joined the shield, simulated shield support soil, and then add the grouting layer and lining.

![Figure 1. Model of tunnel crossing pier](image1)

![Figure 2. Shield tunneling structure and bridge pile foundation structure](image2)
3. Analysis on the Influence of Shield Tunnel’s Influence on Construction of Zhouhanhe Bridge

Based on the model and calculation results of the shield tunnel and bridge pile, analysis of shield tunnel Undercrossing weeks pile surface deformation and bridge deformation and internal force characteristics of the Han River Bridge Pile foundation.

3.1 Surface Deformation

Figure 3 is the vertical displacement nephogram after shield excavation. Figure 4 horizontal displacement nephogram after excavation. As can be seen from the diagram, the maximum settlement of the ground surface is 10.2 mm, and the maximum horizontal displacement of the ground surface is 3.7 mm when the surface subsidence is formed by shield tunnelling.

Figure 5 is a pile of vertical displacement, it can be seen from the chart No. 2 pile settlement is 9.35 mm, the biggest, the other two vertical displacement of pile is small, 3 mm. Figure 6 shows the pile horizontal displacement nephogram, it can be seen from the chart the horizontal displacement of No. 2 bridge pier is less than 1 mm, the horizontal displacement of No. 1 bridge is 2.95 mm, the horizontal displacement of No. 3 pier is 2.6 mm.

According to the set of monitoring points, you can get the end of the construction and the end of the two lines are the end of the settlement. It can be seen from the figure that the subsidence is smaller and the maximum settlement is 4.52 mm after the excavation of the left line. After the excavation of the right line, the surface settlement is obviously increased and the maximum settlement is 8.74 mm.
3.2 Internal Force of Bridge Piles

In order to study the effect of shield tunneling on piles, so analysis of the internal force and displacement of pier No. 1 and No. 2 bridge pier. In the five stages of the excavation process, the internal force and displacement are monitored respectively. The stage 1 is the initial excavation of the left shield, the second stage is the left shield excavation, the stage 3 is the left line shield tunneling completion, the stage 4 is the right line Shield tunneling half, stage 5 for the right line shield tunneling end.

The internal force and displacement of five stages of No. 1 bridge piles results as shown in figure 7~8. It can be seen from Figure7 and Figure8 that the axial force of the bridge pile is proportional to the depth of the pile at the same stage. With the construction of the shield tunneling, the axial force of each part of the pile tends to increase, the value is relatively small, and so in the shield tunneling construction process, the pile shaft force has a small impact. The bending moment of the bridge pile is different. With the construction of the shield tunneling, the pile top and the pile bottom tend to decrease gradually, and the middle of the bridge pile is gradually increased with the excavation construction. 12.5M is the largest bending moment, 20.2 kN • m.

![Figure 7. Axial force diagram](image-url)
According to the relevant specifications, C50 reinforced concrete axial compressive strength design value of 22.4 MPa, calculated from the results can be seen, the bridge pile stress is much smaller than its compressive strength.

4. Conclusion
This paper mainly through the establishment of three-dimensional numerical simulation (FLAC3D) method to simulate and analyze the impact of the construction process on the bridge piles in the administrative center station and the garden road station, and evaluate the influence degree of the shield tunneling. Numerical calculation, the impact of shield excavation on the bridge pile, the main conclusions are as follows:

(1) Shield on Han River pier week case, the maximum pressure of pile shield construction caused by stress is 1.96 MPa, the stress is less than the pile of concrete strength.

(2) After the completion of the left line shield tunneling, the maximum subsidence of the surface is 5 mm. After the right line shield tunneling is completed, the maximum subsidence of the surface is 10.2 mm.

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6. References
[1] Li Hongan. Beijing Metro Line 10 shield under the bridge pile pile settlement calculation formula application [A]. China Civil Engineering Society. Underground construction and harmonious development of the environment - the fourth China International Tunnel Engineering Symposium [C]. China Civil Engineering Society: 2009: 5.
[2] Li Yigang. Finite element simulation analysis of shield tunnel under the tunnel [J]. Guangdong Building Materials, 2011, (03): 24-26.
[3] Li Song, Yang Xiaoping, Liu Tingjin. Effect of Shield Tunneling on Pile Foundation of Viaduct Bridge in Guangzhou Metro [J]. Railway Construction, 2012, (07): 74-78.
[4] Wu Yanlian. Bridge pile foundation load test [J]. Small and medium-sized enterprise management and technology (later), 2009, (10): 147.
[5] Deng Tuo. Shield tunnel under the bridge pile foundation deformation characteristics of the study [D]. Hubei University of Technology, 2015.

[6] Wang Bao, YI Dai-bing, YU Hai-ying, GAI Wen. Numerical analysis of influence of subway shield construction on Zhengxi high-speed rail multi-span high-speed bridge and its influence on surface [J]. Construction Technology, 2016,45 (S1): 443-446. [2017-08-18].

[7] Wang Meng-lin. Effects of Interference Shield Construction on Zhengzhou Special Bridge in Zhengkai Intercity Railway [J]. Construction Technology, 2016,45 (S1): 435-438. [2017-08-18].

[8] Xiao Li, Zhang Qinghe. Numerical simulation of ground subsidence caused by track shield construction [J]. Journal of Tongji University (Natural Science Edition), 2011,39 (09): 1286-1291. [2017-08-18]

[9] Liang Rongzhu, Xia Tang Dynasty, Lin Cungang, Yu Feng. Shaped Propulsion Causes Surface Deformation and Horizontal Displacement Analysis of Deep Soil [J / OL]. Chinese Journal of Rock Mechanics and Engineering, 2015,34 (03): 583-593. (January 9, 2015) [August18, 2017].

Http://kns.cnki.net/kcms/detail/42.1397.o3.20150115.1810.027.html DOI:10.13722/j.cnki.jrme.2015.03.016