

# Numerical Simulation and Monitoring of Surface Environment Influence of Waterless Sand Layer Shield Tunneling

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**Abstract:** The development of urban subway is becoming more and more rapid and plays an increasingly important role. The shield tunneling method has become the first choice for the construction of urban subway tunnel in the construction of urban subway. The paper takes the interval of Shijiazhuang Metro Line 3 Administrative Center Station and Garden Park Station as the engineering background. The establishment of double shield finite difference model by considering the thickness of covering soil, tunnel excavation and excavation at the same time, distance and other factors, the surface deformation, and soil thickness. The ground deformation law is obtained, the surface settlement is inversely proportional to the overburden thickness and the double line spacing, and the gradual excavation is smaller than the synchronous excavation.

## 1. Introduction

The numerical simulation analysis method is cheap and efficient. With the deepening of PC [1]technology and soil constitutive relation[2][3], it is more and more recognized. In order to study the law of surface deformation during shield construction.[4–9] In order to study the law of surface deformation during shield construction, this paper relies on the Shijiazhuang Administrative Center Station - Garden Expo Station Shield Tunnel Project, and establishes a three-dimensional numerical model for different working conditions. The numerical simulation method is used to establish shield tunneling .The interaction between the process and the surrounding soil, the thickness of the shield layer, the double line spacing, the excavation and so on are considered respectively. Finally, the numerical simulation results are analyzed.

## 2. Project Overview

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 wear 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 soil layers in the exploration scope of the project are divided into 4 layers: artificial accumulation layer (Qml), recent sedimentary layer (Q4al), quaternary Holocene flushing deposit (Q4al+pl), and quaternary Pleistocene flush alluvium (Q3al+pl).

### 3. Establishment of Three - Dimensional Numerical Model of Shield Crossing Construction

In view of the deep groundwater depth in Shijiazhuang, the influence of groundwater is not considered; In accordance with the Garden Expo station section of EPB shield machine administrative center station, selection of construction parameters. In this paper, FLAC3D software is used to model the construction process of shield tunneling. Su Xiaokun <sup>[10]</sup> through numerical simulation of the multi cavity span, it is considered that in general, the net distance of double track tunnel is 3-5 times of the span of the tunnel, and can be modeled as a single hole which is independent and independent of each other. For the model, the upper boundary is the free surface, the rest is set to the normal constraint, and the model size is 48 m × 48 m × 48 m. The initial stress calculation only considers the soil weight.

The sight lining is a seamless torus. Segment material and grouting material are considered as linear elastic material. The surrounding rock follows the Mohr-Coulomb criterion.

#### 3.1 Calculate Parameter Selection

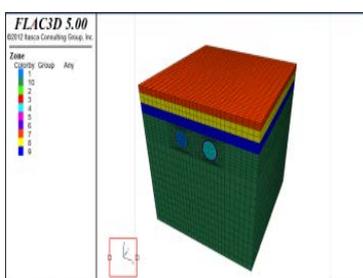
The parameters of the material are mainly based on the results of the geological survey of the administrative center station - garden garden station. The parameters of each material are shown in Table 1 .

**Table 1.** Parameters of the stratum of the tunnel

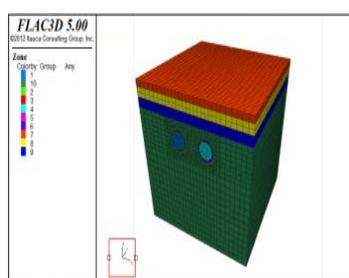
material type	$\gamma/(\text{kN}\cdot\text{m}^{-3})$	E/MPa	$\mu$	c/kPa	$\varphi/^\circ$
Miscellaneous soil	16.5	5.36	0.35	0	8
Fine sand	19.0	26.7	0.32	0	20
Loess-like silty clay	20.0	25.7	0.3	18.3	25
Silty clay	20.5	26.6	0.3	22.9	17

#### 3.2 Establishment of Calculation Model for Shield Tunnel with Different Overburden Thickness

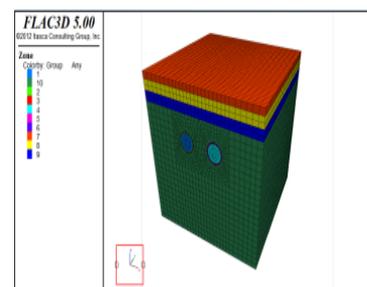
Respectively, the shield depth of 14m, 16m, 18m model, each model grid a total of 43 360 units, 43 excavation steps. The completed model is shown in Figure 1 to figure 3.



**Figure 1.** Shield depth (14 m)



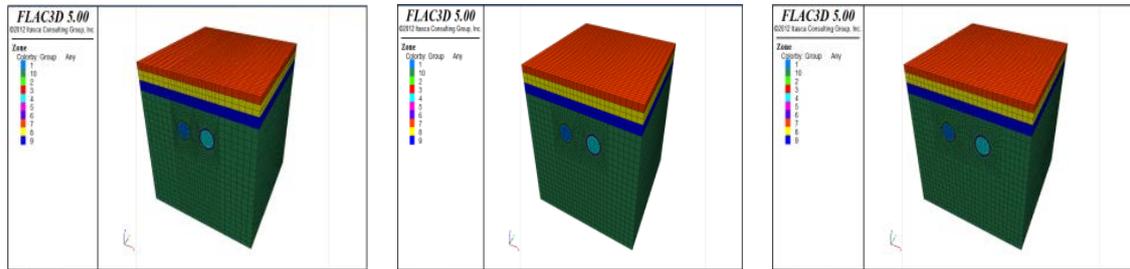
**Figure 2.** Shield depth (16 m)



**Figure 3.** Shield depth (18 m)

#### 3.3 Establishment of Shield Tunnel Calculation Model with Different Horizontal Spacing

Respectively, the establishment of the tunnel spacing of 12m, 14m, 16m numerical model, each model grid a total of 43 360 units, 43 excavation steps. The built model is shown in figure 4 to figure6.



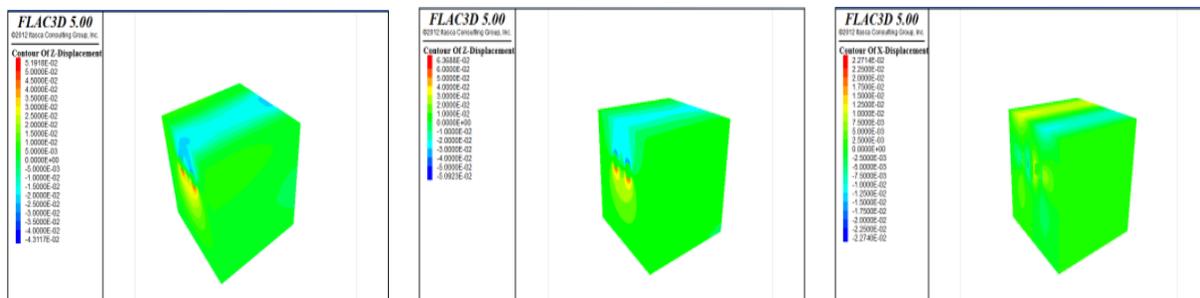
**Figure 4.** Shield spacing (12 m) **Figure 5.** Shield spacing (14 m) **Figure 6.** Shield spacing (16 m)

#### 4. Calculation Results and Analysis

Based on calculation results, the paper analyzes the law of surface deformation and overburden thickness, double line spacing and synchronous excavation and step excavation during shield tunnel construction

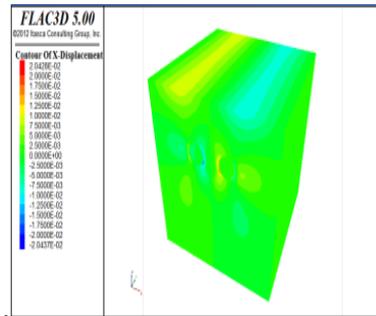
##### 4.1. Analysis on Influence of Shield Tunnel Construction on Different Overburden Thickness

Figure 7 shows the vertical displacement of the soil after the completion of shield tunneling with a depth of 18 m. It can be seen from the figure7 that the maximum settlement of the surface is 16.1 mm due to the construction of the shield, the settlement of the formation and the formation of the settling tank. Figure 8 shows the horizontal displacement of the soil after the depth of the shield is 18 m. As can be seen from the figure8, the horizontal horizontal displacement of the surface is 5.39 mm. Figure 9 shows the vertical displacement of soil after completion of shield tunneling with a depth of 16 m. It can be seen from the figure9, due to shield construction, formation settlement, the formation of sedimentation trough, the maximum settlement of the surface is 20.3 mm.

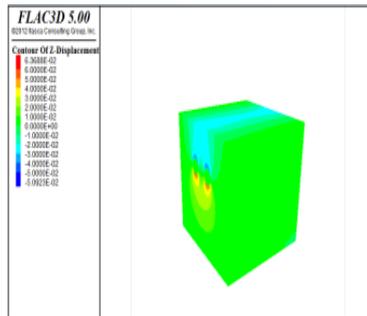


**Figure7.** Vertical displacement (18m) **Figure8.** Horizontal displacemen (18 m) **Figure9.** Vertical displacement (16 m)

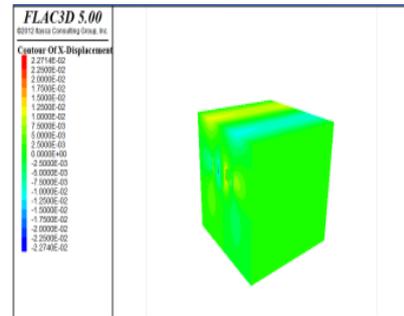
Figure 10 shows the horizontal displacement of the soil after the completion of the shield tunneling. As can be seen from the figure10, the horizontal horizontal displacement of the surface is 7.33 mm. Figure 11 shows the vertical displacement of the soil after the completion of shield tunneling with a depth of 14 m. It can be seen from the figure11, due to shield construction, formation settlement, the formation of sedimentation tank, the maximum settlement of the surface of 21.7 mm. Figure 12 shows the horizontal displacement of the soil after the excavation of the shield is completed. As can be seen from the figure12, the horizontal horizontal displacement of the surface is 6.57 mm.



**Figure10.**Horizontal displacement (16 m)



**Figure11.** Vertical displacement (14 m)

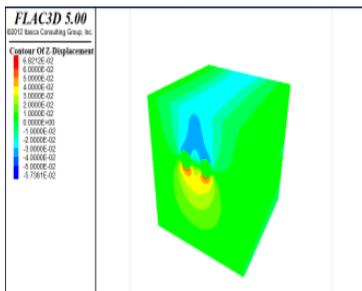


**Figure12.** Horizontal displacement (14 m)

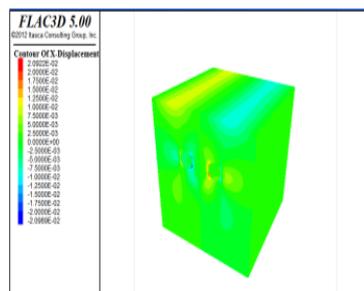
According to the pre-arranged monitoring point, you can get the top of the tunnel center vertical displacement along with the excavation step curve, the left line and the right line settlement the same. The larger the buried depth, the smaller the settlement, the monitoring points on both sides due to the boundary effect of the model, the vertical displacement is rising.

*4.2. Analysis on the Influence of Shield Tunnel Construction with Different Tunnel Spacing*

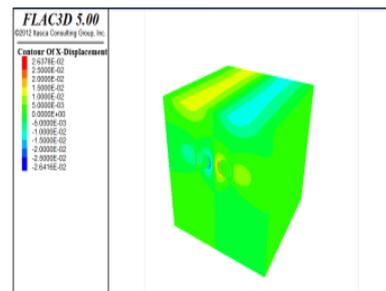
Figure 13 shows the vertical displacement of the soil after the completion of 12 m boring distance. It can be seen from the figure13, due to shield construction, formation settlement, the formation of sedimentation trough, the maximum settlement of the surface is 26.16 mm. Figure 14 shows the horizontal displacement cloud diagram of the soil after the boring distance of 12 m. As can be seen from the figure14, the horizontal horizontal displacement of the surface is 11.6 mm. Figure 15 shows the vertical displacement of the shield after the completion of the shield tunneling distance of 14 m. It can be seen from the figure15, due to shield construction, formation settlement, the formation of sedimentation tank, the maximum settlement of the surface is 22.18 mm.



**Figure13.** Vertical displacemen (12m)

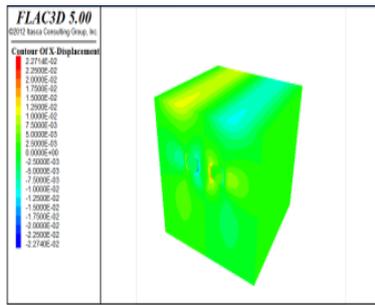


**Figure14.** Horizontal displacement (12m)

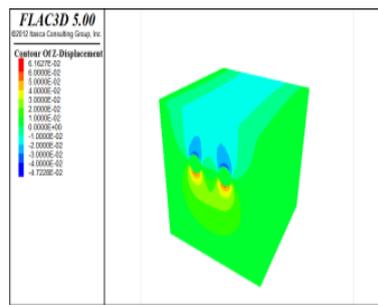


**Figure15.** Vertical displacement(14 m)

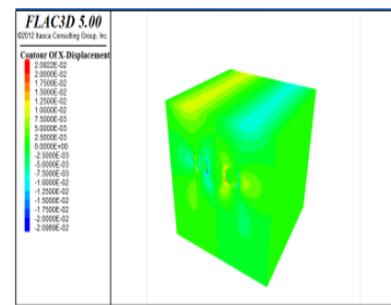
Figure 16 shows the horizontal displacement of the double-line shield at a distance of 14 m. It can be seen from the figure16 that the horizontal horizontal displacement of the surface is 9.6 mm. Figure 17 shows the vertical displacement of the shield after the completion of the shield tunneling distance of 16 m. It can be seen from the figure17, due to shield construction, formation settlement, the formation of sedimentation trough, the maximum settlement of 16.68 mm. Figure 18 shows the horizontal displacement of the double-line shield at a distance of 16 m. As can be seen from the figure18, the horizontal horizontal displacement of the surface is 8.1 mm.



**Figure16.** Horizontal displacement (14 m)



**Figure17.** Vertical displacement (16 m)



**Figure18.**Horizontal displacement (16 m)

According to the monitoring point laid in advance, the vertical displacement of the surface of the tunnel above the center of the tunnel will change with the excavation step, because the settlement of the left line and the right line will be the same. As can be seen, the greater the spacing between the two lines, the smaller the settlement

## 5. Conclusion

This paper mainly through the establishment of three-dimensional numerical simulation (FLAC3D) method to simulate and analyze the influence of shield tunneling on the deformation of the central area of the Administrative Center Station ~ Garden Park Station. And through the numerical simulation, the thickness of the upper cladding layer Spacing and shield synchronous excavation and asynchronous excavation under the conditions of the impact of the law, the main conclusions are as follows:

(1) the surface subsidence is inversely proportional to the thickness of the shield soil. When the thickness of the overlying soil is 14 m, the maximum surface subsidence is 21.7 mm.

(2) the surface subsidence is inversely proportional to the spacing of the two tunnels. When the tunnel spacing is 12 m, the maximum surface subsidence is 26.16 mm.

## 6. Acknowledgements

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