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Study on the measures of tunnels side-crossing bridge based on sheltering effects of isolation piles

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Abstract. Based on the transit line 3, we studied the effect of the bridge piles crossed closely from the side by the shield tunnel. Using the three-dimensional finite element numerical analysis software Midas GTS/NX, we analyzed the effect of shield tunnel on pile deformation, statistics are obtained that under the condition of pile, subgrade reinforcement and ground changes. The calculation results show that in the condition of reinforcement, the new tunnel shield crossing through the pile caused longitudinal disturbance of the tunnel surrounding strata along the tunnel, where the soil over the area is within a certain range of pile and settlement deformation of surface subsidence occurs, changing the surface roughly to the shape of "V". The maximum value appears above the shield tunnel and the value is high. In combination with engineering geology, hydrogeology and environment factors, this paper adopted isolation pile reinforcement to the pile, and the simulated results show that, pile settlement was significantly reduced under the condition of pile reinforcement. The calculation results show the rationality of the reinforcement scheme to a certain extent, which provides a theoretical basis for the similar tunnel.

1. Introduction

With the rapid development of Chinese urban construction, urban available land is gradually reduced. In order to meet the needs of people for transportation and travel, the subway is becoming more and more favored. However, the development of the subway is bound to be restricted by the existing urban construction environment, which makes more and more new tunnel have to be constructed close to the existing (omitted) underground structure. How to ensure the safety and normal use of the bridge construction in the subway tunnel construction is a hot and challenging problem in the design and construction of metro tunnel shield. Although a lot of research of the subway tunnel crossing the bridge pile foundation has been done both at home and abroad, they can not reflect the effect of shield tunneling on adjacent pile foundation because of the complexity of underground geological conditions and the diversity of engineering structure. This paper uses MIDAS/GTS NX numerical calculation software of rail transit line 3 short distance crossing Jiaoji railway passenger line and roadbed to simulation analysis. The simulation of non-reinforcement and reinforcement conditions, through the comparative analysis of two kinds of calculation results, verify the feasibility and effectiveness of the reinforcement, and provide scientific basis for the bridge, adjacent subway excavation process in the safe use of the building, has important application value in engineering.



2. Background.

Transit line 3 project in the range XK10+220 ~ 265 successively through the Jiaoji railway, railway passenger dedicated line. The interval risk source is Jiaoji passenger dedicated railway and Railway Roadbed. As shown in Fig.1.

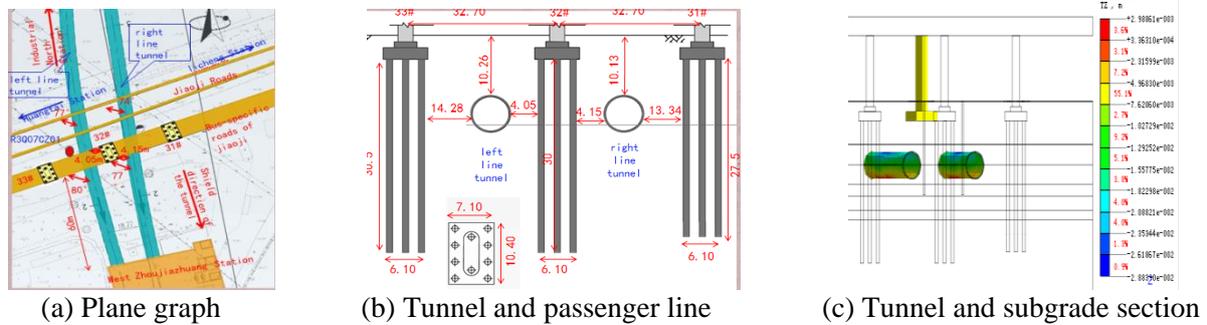


Fig. 1 Relationship between R3 line and passenger line and subgrade section

The main physical and mechanical parameters of strata are shown in Tab. 1.

Tab. 1 Formation parameter value

Serial number	Item	Thickness (m)	Bulk density γ (kN/m ³)	Compression modulus Es (MPa)	Poisson ratio ν	Cohesive force c(kPa)	Internal friction angle ϕ ($^{\circ}$)
1	Miscellaneous fill (1-2)	9.1	16.8#	-	-	15#	12#
2	Plastic sandy silt(10-1)	4.3	19.6	4.8	0.31	27	15
3	Plastic clay(14-2)	4.1	19.2	7.5	0.39	48	20
4	Spall silty clay (15-3)	2.5	18.6	5.8	0.37	40	18
5	Hard plastic clay (15-5)	3	18.9	8.5	0.44	43	18
6	Compact calcareous cemented conglomerate (15-2)	2	22	60	0.23	35	35
7	Spall silty clay (15-3)	18.5	18.6	5.8	0.37	40	18
8	Plastic clay(16-2)	4	17.9	4.9	0.30	29	17
9	Shield segment	0.3	25	34500	0.2	-	-

(Notice: “#” Indicates that the value takes empirical value.)

2.1 Simulation of non-reinforcement condition (case 1)

Computational models and basic assumptions:

In the process of modelling and calculation, the main factors should be considered and the secondary factors should be neglected: [5-7]

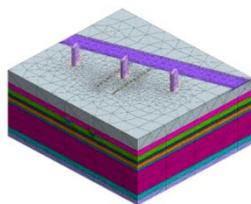
1)The material of the surrounding rock is a homogeneous and isotropic continuous medium, which is assumed to be an ideal elastic-plastic material. Based on the macroscopic material behaviour, the soil and rock mass is simulated by using the Mohr-Column elastoplastic model. The model has high efficiency in numerical calculation, fast convergence and relatively stable calculation. It can be used to describe the mechanical behaviour of geotechnical materials, and has been widely used in the field of geotechnical engineering.

2) The soil is simulated by solid element, the segment is simulated by shell element and the pile foundation is simulated by line element.

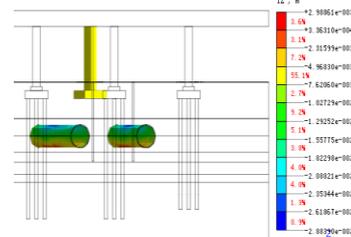
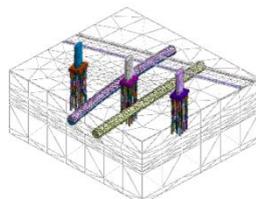
3)The segments are simulated by a homogeneous elastic ring, taking the stiffness reduction factor of 90% into account.

4)Boundary conditions: horizontal and vertical constraints are used at the bottom of the model, horizontal and vertical displacements are not allowed. The upper surface is the free surface.

The choice of stratigraphic range: tunnel structure on both sides of a range of about 5 times the diameter of the tunnel, under the structure, about 5 times the tunnel diameter. Model size: X * Y * Z = length * width * height = 109m * 96m * 51.4m. The calculation model is shown in Fig. 2.



(a)



(b)

Fig. 2 three-dimensional numerical model

Fig. 3 vertical displacement of pier No. #32

2.2 Analysis of deformation characteristics of Bridge Foundation--32 # pier

1) After the construction of the double shield tunnel, the maximum settlement value of the pier 32# is 5.6mm induced by the tunnel construction.

2) After the construction of the double shield tunnel, the horizontal displacement of the pier top 32# is 0.75mm, and the horizontal displacement of the bridge is 0.02mm.

Analysis of stratum settlement deformation characteristics

In the case of non-active protection, the vertical displacement nephogram of surrounding rock around the tunnel during the construction of shield tunnel is shown in Fig. 4

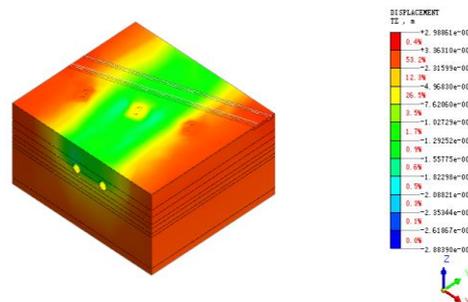


Fig. 4 Vertical deformation nephogram under non active protection condition

The surface subsidence caused by tunnel construction of left line is completed, the location of the maximum settlement of shield tunnel is just above the surface, the surface subsidence is roughly the shape of "V", because line spacing is about 15m and with the completion of the right line of the shield

tunnel construction, the values and the range of surface subsidence has improved to a certain extent. The maximum settlement of double shield tunnel is 16.18mm when the tunnel is accomplished.

2.3 Simulation of active reinforcement (Case II)

It is recommended to use the root pile as isolation pile. Making two rows of $\Phi 350 @ 500$ root piles between the tunnel and the bridge pier. The distance between the pile and the tunnel is 0.8m, the minimum clearance of the isolation pile on the left and right line tunnel side and the pile foundation of 32 # bridge pier are 2.40m and 2.45m respectively.

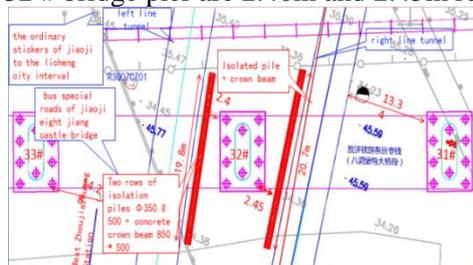


Fig. 5 Micro isolation pile layout

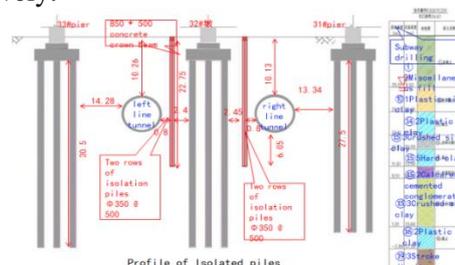


Fig. 6 Profile layout of mini isolation pile

2.4 Analysis of deformation characteristics of Bridge Foundation--32 # pier

- 1) After the construction of the double shield tunnel, the maximum settlement value of the pier 32# is 1.9mm induced by the tunnel construction. The overall sedimentation value is small. It can be seen that the excavation of double-line shield tunnel has little effect on the pier foundation of 32 #.
- 2) Double-line shield tunnel through the pile foundation, causing 32 # bridge pier to the horizontal displacement of 0.02mm, causing 32 # bridge pier to the longitudinal displacement of 0.01mm.

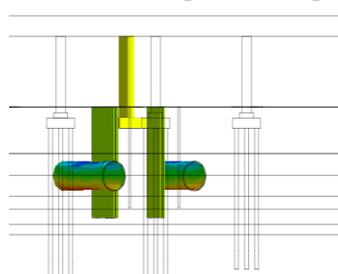


Fig.7 32# pier settlement

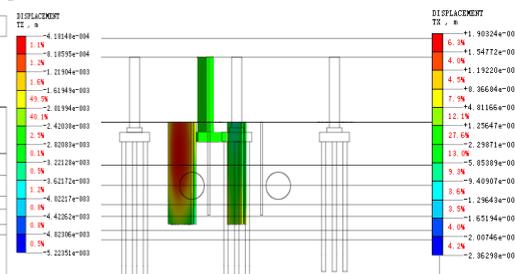


Fig.8 32# vertical pier displacement

Analysis of stratum settlement deformation characteristics

In the construction of shield tunnel under active reinforcement condition, the nephogram of the settlement and displacement of surrounding rock of tunnel is shown in Fig.9

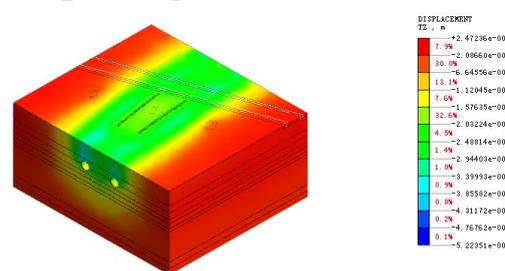


Fig.9 Vertical deformation nephogram of shield caused by shield tunneling in case 2

The surface subsidence caused by tunnel construction of left line is completed, the location of the maximum settlement of shield tunnel is just above the surface, the surface subsidence is roughly the shape of "V", because line spacing is about 15m and the completion of the right line of the shield tunnel construction, the values and the range of surface subsidence has improved to a certain extent. The maximum settlement of double track shield tunnel is 5.2mm when the tunnel is accomplished.

2.5 The shielding effect between isolation piles and displacement decreases

As we can see from Fig. 3 and Fig. 7, the vertical displacement of pier 32# decreased from 5.63mm to 1.9mm, the double isolation pile to reduce displacement is obvious, namely double isolation piles on pile displacement have been obviously.

3. Result analysis

Combined with the previous numerical simulation of the calculation, the two-lane tunnel cross through 33#, 32#, 31#, three piers of the total exchange analysis, we can see from Tab. 2~3.

Tab. 2 The displacement of the bridge pier and the settlement difference (without isolation pile)

Monitoring point \ Items	Settlement	Settlement difference	Longitudinal displacement	Lateral displacement
	mm	mm	mm	mm
33#	-0.28	5.35	0.18	-2.47
32#	-5.63		0.75	0.02
31#	-0.40	5.23	-0.37	-2.54

Tab. 3 The displacement of the bridge pier and the settlement difference (double row piles)

Monitoring point \ Items	Settlement	Settlement difference	Longitudinal displacement	Lateral displacement
	mm	mm	mm	mm
33#	-0.26	1.64	0.114	1.24
32#	-1.9		0.02	-0.01
31#	-0.35	1.55	-0.01	-1.35

4. Summary

Through the above research, we can draw the following conclusions:

(1) Under the condition of non-reinforcement, the maximum settlement of the bridge at the top of the pier is 5.63mm, the maximum settlement difference is 5.35mm, the maximum lateral displacement is 2.54mm, the maximum longitudinal displacement is 0.75mm.

(2) The ground water is low, The ground is more uniform and the parameters of the formation are better, the construction of shield method, the main protection scheme with the control measures, the maximum settlement is 5.63mm, the settlement value is too high, beyond the ballastless track railway bridge pier 5mm corresponding deformation control standard requirements. So we should take corresponding engineering measures to reduce railway bridge deformation and crossing project risk. It will reduce the effect of shield tunnel construction for passenger line.

(3) In the use of double row isolation pile reinforcement measures (case two), the maximum settlement of the bridge pier top is 1.90mm, the maximum settlement difference is 1.64mm, the maximum lateral displacement is 1.35mm, the maximum longitudinal displacement is 0.14mm. All the indexes are small, the maximum settlement at the top of the pier is 1.90mm, which meets the requirements of the 5mm standard for the deformation control standard of the railway bridge pier.

(4) According to the above research conclusion and the simulated results show that pile settlement was significantly reduced under the condition of pile reinforcement .

(5)The simulation results show that the double row isolation pile can effectively reduce the displacement of the pile foundation, so the protection measures of the isolated pile have important engineering application value.

References

- [1] Ministry of Railways of People's Republic of China. TB10002D1 - 2005 railway bridge and culvert design basic code [S]. Beijing: China Railway Press, 2006
- [2] People's Republic of China Ministry of railways. Trains [2006]146 railway repair rules [S]. Beijing: Chinese Railway Press, 2006
- [3] Xiao Li, Zhang Qinghe. Analysis of [J]. Journal of Shanghai Jiao Tong University, ground settlement caused by shield tunneling long distance across multi tracks: Natural Science Edition, 2011, 45 (5): 672-676.
- [4] Wang Guodong, Xiao Li, Zhang Qinghe. Study on the settlement of shield driven by road and railway [J]. railway building, 2010 (10): 57-60.
- [5] Lv Peilin, Zhou Shunhua. Analysis of the settlement of the line caused by the shield tunnel passing through the railway main line in soft soil area [J]. China Railway Science, 2007, 28 (in Chinese): 12
- [6] Xia Yuanyou, Zhang Liangliang, Wang Kejin. Numerical analysis of construction displacement of Subway Shield Crossing building [J]. rock and soil mechanics, 2008, 29 (): 1411-1414.
- [7] Guo Qinghao, Kui Kui, Zhang Zhiyong. Analysis of the influence of shield tunneling on existing subway station [J]. urban rail transit research, 2008 (11): 82-86.