

# Study on deformation influence of shield tunnel passing through existing railway bridge piles

Fanen Lv<sup>1,a</sup>, Feng Ren<sup>1,2</sup>, Liangliang Zhang<sup>3</sup>

<sup>1</sup> School of Civil Engineering and Architecture, University of Jinan, Jinan 250022, China

<sup>2</sup> The engineering technology research center for urban underground engineering supporting and risk monitoring of Shandong Province

<sup>3</sup> China Railway Siyuan Survey and Design Group Co., LTD.

<sup>a</sup>lvfanen@163.com

**Abstract.** Based on the rail transit of Xuzhou city and considering the actual engineering geological conditions, this paper studies the deformation effect of bridge piles across the railway bridge of shield tunnel. In this paper, the finite element numerical analysis software Midas GTS/NX is used to analyze the influence of the shield tunnel crossing bridge on the deformation of the bridge pile, and the change law of the displacement of the bridge pile under the condition of unreinforcement and reinforcement is obtained. The calculated results show that under the condition of no reinforcement, the settlement deformation of the bridge pile exceeds its own displacement limit due to the side crossing of shield tunnel. The reinforcement scheme of the bridge pile is used to enlarge the size of the original bearing platform section and add the foundation pile, and the simulation is carried out. The results show that the settlement of the bridge pile decreases significantly under the condition of reinforcement. The results prove the rationality of the reinforcement scheme to a certain extent, and provide a certain theoretical basis for the design of similar shield tunnel lateral pier pile.

## 1. The introduction

Due to the development of urban construction in China, available ground space is gradually reduced, so the development and utilization of underground space should be increased. With the acceleration of underground infrastructure construction, there are more and more underground engineering projects such as shield tunnel. The surrounding environment of most shield tunnels is complex, for example, there are existing buildings near the shield tunnel. Most urban high-rise buildings and railway viaducts adopt pile foundations. The advance of shield tunneling will inevitably cause disturbance to surrounding soil, which will adversely affect the pile foundation, resulting in settlement of the building, affecting its normal use and safety and stability.

Ma Weibin<sup>[1]</sup>, Peng Kun<sup>[3]</sup>, Xu Gancheng<sup>[4]</sup> have studied the influence of tunnel underpass on railway bridge deformation and treatment measures, Liu Chunyang<sup>[2]</sup>, Huang Xinmin<sup>[5]</sup> have studied the safety analysis and protection scheme of tunnel underpass railway. Xu Youjun<sup>[6]</sup> studied the influence of shield tunnel on urban overpass. How to ensure the safety of railway bridge above the tunnel is the research focus of shield tunnel at home and abroad. Taking Xuzhou rail transit as an example, the finite element numerical analysis software Midas GTS/NX, is used to add the subway shield tunnel underpass railway bridge. The reliability of the reinforcement measures is verified by the



simulation analysis of the two working conditions before and after the solidification, which has certain reference value for the design of similar project.

## 2. Engineering survey

A shield tunnel in a section of Xuzhou Rail Transit passes through a railway bridge with a thickness of about 22m and a net distance of 5.5m. The diameter of shield tunnel is 6.2 m and the thickness of segment is 0.35 m. Before reinforcement, the distance from the outer side of the tunnel segment to the pile foundation is 5.8 m, the height of the cap is 2 m, and the pile length is 11.5 m. The reinforcement scheme is to expand the cross-section size of the original pile cap and add the foundation pile to reinforce the pile. The original pile is 0.8m diameter bored pile, the design and reinforcement scheme adds 1.0m diameter bored pile and 1.25m diameter manually excavated pile. The reinforcement of the cap adopts the way of partially outsourcing the section of the existing cap. Supplementary borehole perfusion The minimum horizontal net distance between pile and tunnel is 4.5 m.

## 3. geological conditions

The geomorphologic type to the south of the site is alluvial high ground, which is mainly composed of silt and silt brought by the Yellow River, with a elevation of 38.00 ~ 40.0 m, and a natural dike on both sides, which is 3 ~ 5 m high above the alluvial plain, and to the north is a alluvial plain. The shallow part is composed of brown red calcareous core clay of the middle and upper Pleistocene of Quaternary and brown red and brown yellow clay of the new series.

The physical and mechanical parameters of the soil layer through which the shield tunnel passes are obtained from the detailed survey report of this section, as shown in the table below:

Table1.physical and mechanical parameters of soil layer

order number	project	thickness (mm)	unit weighty(kN/m <sup>3</sup> )	compression modulusEs (MPa)	Poisson's ratio	Cohesive force(kPa)	Angle of internal friction(°)
1	Miscellaneous fill	3.8	16.8#	-	-	15#	12#
2	Sandy silt	5.2	19.2	6.5	0.25	13.6	27.6
3	Plastic clay	2.5	18.9	5.4	0.25	35.5	12.2
4	Hard plastic clay	2.0	19.5	12.1	0.30	63.1	13.2
5	Hard plastic clay	3.0	19.1	13.0	0.25	72.5	14.0
6	Medium weathering limestone	13.3	24	70#	0.25#	-	60#
7	Plastic clay	2.7	18.9	5.4	0.25	35.5	12.2
8	Medium weathering limestone	5.5	24	70#	0.25#	-	60#

Note: "#" indicates that the value takes an empirical value.

## 4. Establishment of numerical model

### 4.1. Modeling principle

Moor-Coulomb strength criterion for soil materials.

The engineering geological conditions such as the thickness of the soil layer and the mechanical parameters of the soil layer are selected according to the parameters provided in the detailed survey report of this section.

The cap, pile foundation, tunnel segment and so on are made of solid element, and the material is based on elastic constitutive model.

The model has displacement constraints, horizontal displacement constraints on the side of the model, and horizontal and vertical displacement constraints on the bottom of the model.

#### 4.2. three-dimensional model

According to the stratum parameters provided by the detailed investigation report of this section, the process of shield tunnel passing through the pile foundation of railway bridge in short distance is simulated by using the finite element numerical analysis software Midas GTS/NX. According to the position relationship between the pile foundation and the cap of the tunnel and the railway bridge, a 100m 80m 6550.

### 5. Analysis of numerical simulation results

From the simulation results, the top displacement of piers can be obtained under two conditions, that is, 50 #A、50 #B and 51 #A、51#B when the pile foundation of the railway bridge is crossed by the side of the shield tunnel under the condition of no reinforcement and the horizontal displacement of the horizontal bridge, and the settlement displacement of the top of the four piers is shun, the horizontal displacement of the transverse bridge. To determine whether or not to meet the deformation control standards of the railway bridge.

#### 5.1. Simulation of working conditions without reinforcement measures

Under the condition of no reinforcement, the vertical displacement settlement cloud diagram and horizontal displacement cloud diagram of 50 #A、50 #B and 51 #A、51#B bridge under shield tunnel crossing railway bridge are shown in figure 5-1below.

##### (1) 50#A bridge pier

The maximum settlement at the top of bridge pier 50 #A caused by shield tunneling is 2.2 mm, the horizontal displacement is 0.3 mm along the bridge, and the horizontal displacement is 0.05 mm in the transverse direction.

##### (2) 50#B bridge pier

The maximum settlement at the top of bridge pier 50#B caused by shield tunneling is 5.6mm, the horizontal displacement is 0.5mm along the bridge, and the horizontal displacement is 0.08mm.

##### (3) 51#A bridge pier

The maximum settlement at the top of the bridge pier 51#A is 6.1mm, the horizontal displacement along the bridge is 0.6mm, and the horizontal displacement of the transverse bridge is 0.07mm.

##### (4) 51#B bridge pier

The maximum settlement at the top of the bridge pier 51#B caused by shield tunneling is 2.6 mm, the horizontal displacement is 0.4mm along the bridge and the horizontal displacement is 0.05mm.

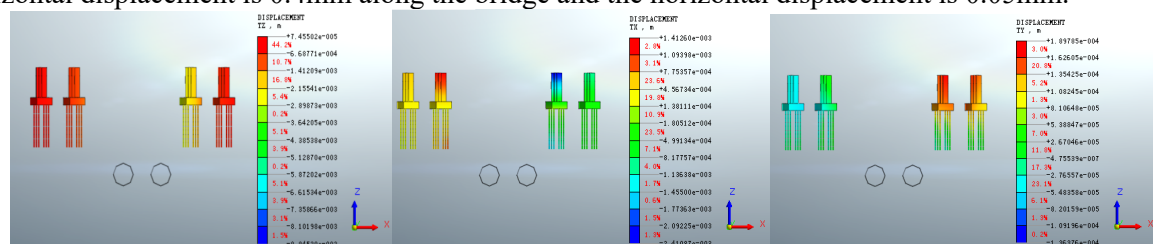


Fig.5-1. Vertical settlement and horizontal displacement of Pier and abutment

### 5.2. Simulation of working conditions with reinforcement measures

The vertical and horizontal displacement nephograms of 550 # A, 50 # B and 51 # A, 51 # B Bridgeton and the horizontal displacement nephograms of shield tunnels crossing railway bridges are shown in Figure 5-2below.

#### (1) 50#A bridge pier

The maximum settlement at the top of 50#A pier is 0.7mm, the horizontal displacement is 0.03mm along the bridge and the horizontal displacement is 0.02mm.

#### (2) 50#B bridge pier

The maximum settlement at the top of the pier of 50#B bridge caused by shield tunneling is 2.1 mm, the horizontal displacement is 0.04mm along the bridge and the horizontal displacement of the transverse bridge is 0.05mm.

#### (3) 51#A bridge pier

The maximum settlement at the top of the bridge pier 51#A caused by shield tunneling is 2.9 mm, the horizontal displacement along the bridge is 0.05mm, and the horizontal displacement of the transverse bridge is 0.04mm.

#### (4) 51#B bridge pier

The maximum settlement at the top of the bridge pier 51#B caused by shield tunneling is 0.1mm, the horizontal displacement is 0.04mm along the bridge, and the horizontal displacement is 0.03mm.

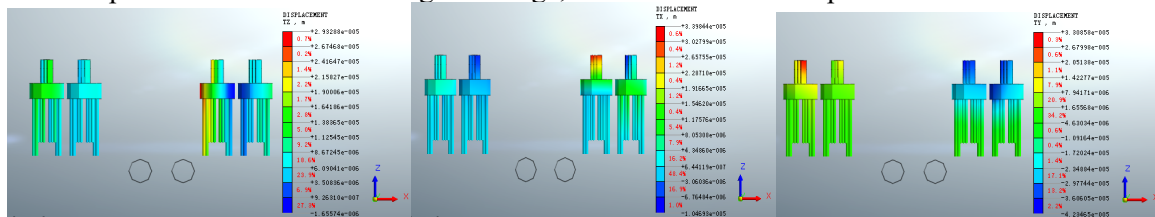


Fig.5-2.Vertical settlement and horizontal displacement of Pier and abutment

### 5.3. Simulation result analysis

Based on the analysis of the results before and after reinforcement, the displacement values at the top of the pier and abutment are obtained. According to the control criteria of the special design for iron, the vertical settlement of the single pier is 5 mm, the pier is lateral, Longitudinal displacement (3mm) is used to determine whether the displacement of the four abutments of 50 #A、50 #B、51#A、51B meets the control standard when the shield tunnel passes through the railway bridge under two conditions.

Table 2.Statistical table of pier and abutment displacement before and after reinforcement

Pier and abutment number		50#A	50#B	51#A	51#B
unreinforced	vertical settlement	2.2	5.6	6.1	2.6
	Vertical horizontal displacement	0.3	0.5	0.6	0.4
	Horizontal horizontal displacement	0.05	0.08	0.07	0.05
reinforce	vertical settlement	0.7	2.1	2.9	0.1
	Vertical horizontal displacement	0.03	0.04	0.05	0.04
	Horizontal horizontal displacement	0.02	0.05	0.04	0.03

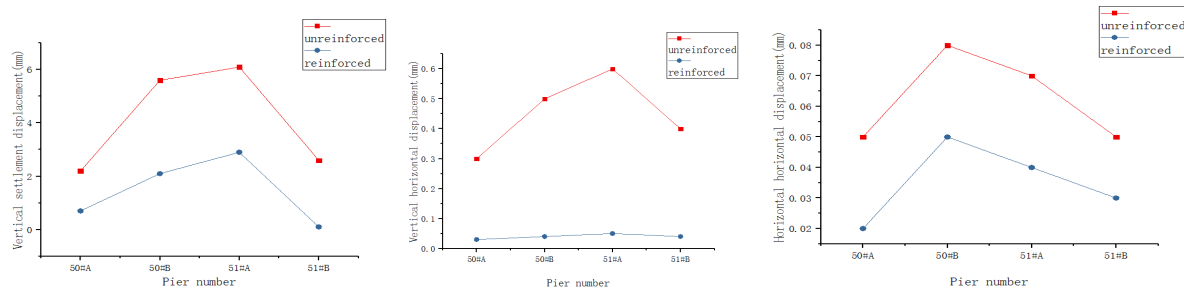


Fig.5-3. Vertical settlement and horizontal displacement profile of Pier and abutment before and after reinforcement

## 6. conclusion

In order to ensure the safety of the pile foundation and superstructure of shield tunnel in the process of crossing the railway bridge in close distance, this study carried out numerical simulation under the two working conditions of no reinforcement and reinforcement. By comparing and analyzing the vertical and horizontal displacements of the four piers of the railway bridge before and after reinforcement, the following conclusions can be drawn: The maximum settlement value of the pier is 6.1mm, the maximum vertical horizontal displacement is 0.6mm and the maximum horizontal horizontal displacement is 0.08mm without reinforcement. Although the horizontal displacement did not exceed the limit value of 3mm, the maximum settlement value exceeded the control value of 5mm settlement of the pier. Therefore, before the shield tunnel crosses the railway bridge, the pile foundation construction should be strengthened to reduce the deformation of the superstructure and reduce the risk. Under the condition of reinforcement measures, the influence on pier displacement becomes smaller when shield tunnel passes through railway bridge pile foundation at close distance. The maximum displacement settlement value of pier is 2.9 mm, which satisfies the 5mm limit value of vertical settlement of single pier and the maximum longitudinal horizontal displacement value. The maximum horizontal displacement is 0.05mm and the maximum horizontal displacement is 0.05mm. The variation of displacement is small. The limit value of 3mm is the lateral and longitudinal displacement control value of pier and abutment which can meet the special requirement of iron-related project. The scheme of strengthening pile foundation and cap is feasible.

In order to ensure the safety of pile foundation and superstructure, it is suggested that the shield tunnel should be strengthened first and then excavated in order to ensure the safety of pile foundation and superstructure.

## Acknowledgments

The author would like to thank for the support from the Key R & D project in Shandong Province (project number 2018GSF120010), Jinan Science and Technology Project (project number 201705015), Planning project of Shandong Provincial Construction Department (project number KY011), University of Jinan Student Science and Technology Innovation Project (project number 2017062).

## References

- [1] Ma Weibin, Fu Bingxian, Du Xiaoyan, Guo Xiaoxiong, Shi Cunlin. Construction deformation Analysis and treatment measures of Subway Tunnel through Railway Bridge[J]. Journal of underground space and engineering, 2013, (4): 897-901.
- [2] Liu Chunyang, Zhang Peng, Zhang Jixian. Safety Analysis of Subway Shield Tunnel under existing Railway[J]. Journal of Shijiazhuang railway university, 2013(26): 70-72.
- [3] Peng Kun, Tao Lianjin, Gao Yuchun, Wang Feng, Huang Jun. Numerical analysis of pile foundation displacement caused by underpass bridge of shield tunnel[J]. Journal of underground space and engineering, 2012, (3): 486-489.
- [4] Xu Gancheng, Li Chengxue, Wang Houyu, Zhao Yue, Hu Ping. Analysis on the influence of Metro Shield tunneling through Beijing-Tianjin Intercity High-speed Railway[J]. rock-soil

mechanics ,2009,(2):270-276.

- [5] Huang Xinmin. Research on Protection Scheme of existing Bridge pile Engineering under Shield Tunnel[J]. Journal of underground space and engineering, 2012, (3): 558-561.
- [6] Xu Youjun, Tao Lian Jin, Li Wenbo, Fan Junyi, Wang Wenpei. Analysis on subgrade settlement of Subway Double-line Shield Tunnel under High-speed Railway[J]. Journal of Beijing university of technology, 2010, (12): 1619-1622.