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To cite this article: Hao Wang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **295** 042081

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The Research and Control Measures of the Influence on the Complicated tie-line and the Bridge under the Shield Tunnel

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Abstract. The analysis and calculation of the influence of Shield Tunnels Crossing Existing Railways and bridges considering the time-space effect is of great significance to the risk control of shield tunnels. Taking the long-distance bus station-production Road station section of Jinan rail transit line R2 as an example, shield tunnelling method is used to construct the shield tunnels in this section, and the shield tunnels are crossed under the Beibei Bridge of Beijing-Jiaozuo Liaison Line and Beijing-Shanghai Link In order to study the influence of shield tunnelling on railway and bridge piles, three-dimensional finite element numerical analysis method is used to establish a three-dimensional finite element analysis model through MIDAS/GTS. The position relationship of shield tunnels, railways and bridge piles and the shield tunnelling distance are simulated. The stress of railway subgrade and pile foundation caused by shield tunnelling is analyzed. The result of deformation is within the allowable value of deformation control of railway and bridge. Without any reinforcement measures, through monitoring the deformation of subgrade and bridge, timely feedback of monitoring information and timely adjustment of shield tunnelling parameters, shield tunnelling can safely Cross railway and bridge. The development of similar projects will provide relevant reference.

1. Introduction

The construction of underground rail transit system is an important means to solve urban traffic problems. Subway is favored for its advantages such as large capacity, fast speed and low pollution. However, the development of subway is bound to be influenced by the existing urban buildings. The common problems in the construction of shield tunnel are as follows: underpass railway [8-10], bridge pile foundation [1-4], etc., take reasonable control measures [5-7] to reduce the existing railway in the new shield tunnel, The adverse effect of bridge pile foundation is of great significance to ensure the construction safety of new shield tunnel and ensure the safety of existing railway and bridge operation. Although many researches have been done on subway tunnel crossing the railway and bridge pile foundation at home and abroad, due to the geological conditions of underground engineering, the complexity and diversity of structure form, the existing achievements can not completely reflect the shield tunnelling to the railway. In this paper, using MIDAS/GTS NX numerical calculation software, taking a project in a section of Jinan rail transit R2 line as an example, using the numerical simulation method to study the existing railways, the Beibei Bridge of Beijing-Jiaozuo Liaison Line and the



Beijing-Shanghai third and fourth Line are used as examples. The stress and deformation law of bridge pile foundation are analyzed, and the control measures are put forward, which can be used for reference for similar projects in the future.

2. Engineering survey

2.1. Ambient environment

Jinan rail transit line R2 long-distance bus station ~ production road station between the base of Beijing-Shanghai third and fourth line and the Beibei Bridge of Beijing-Jiaozuo Liaison Line. The crossing node is located in the subgrade section of the main line of Beijing-Shanghai North Garden Station to Jinan Station (4 ‰ slope limit). The minimum net distance between the right tunnel and the bridge pile is 5.51m. The left tunnel is 6.95m from the pier of 1#. About 15.14m above the vault of the tunnel.

Beibei Bridge of Beijing-Jiaozuo Liaison Line is 902m in length. The design load of the bridge is medium to live load. The top of abutment is flat, and the supporting cushion of pier and abutment is filled with crown cap concrete.

The horizontal and cross-sectional diagrams of the piles in the new shield tunnel are shown in figs. 1, 2 and 3.

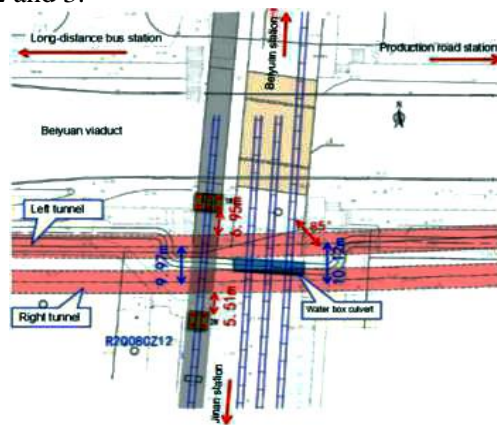


Fig. 1 The plane relation Diagram between Tunnel and tie Line and Bridge

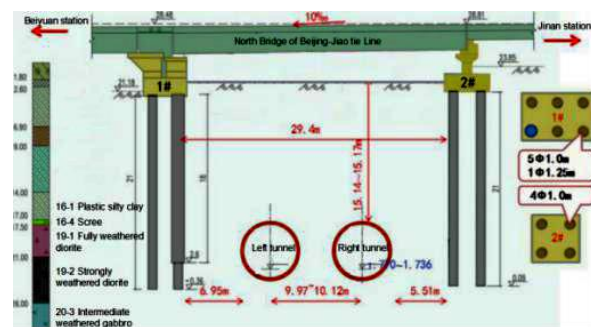


Fig.2 Section Tunnel, tie Line and Bridge Section Diagram

3. Control standard for railway and bridge piles

The determination of railway settlement control value should not only meet the requirements of railway bearing capacity, but also meet the safety of driving operation, according to the Railway subgrade Design Code (TB10001-2016). In this section, the allowable displacement of subgrade through Beijing-Shanghai railway is 15mm.

According to the basic Code for Railway Bridge and culvert Design (TB10002-2017), the settlement of the single pier of the Beibei Bridge of Beijing-Jiaozuo Liaison Line is 15mm, and the differential settlement of the pier and abutment adjacent to the pier is 5mm.

4. Numerical simulation and result analysis

4.1. Model building

(1) In this numerical simulation, the following assumptions are adopted:

1) The surrounding rock mass is homogeneous and isotropic continuum medium, and it is assumed to be an ideal elastic-plastic material.

2) The stress and deformation of the tunnel are calculated according to three dimensions.

3) When the initial stress field is simulated, the tectonic stress is not taken into account, but only the influence of the gravity stress is considered.

4) The segment is simulated according to homogeneous elastic ring, and the stiffness reduction coefficient of 90% is adopted to consider the problems of joint assembling and bolt connection.

(2) The outer and left sides of the tunnel structure are about 5 times diameter, the interval tunnel structure bottom plate is about 3 times diameter, and the model size is $X \times Y \times Z = \text{length} \times \text{width} \times \text{height} = 100\text{m} \times 100\text{m} \times 35\text{m}$, The calculation model is shown in fig. 3 and fig. 4.

According to the Design Code for Railway subgrade (TB10001-2005), rail and train loads are simplified as plane loads applied to railway subgrade. The surface load of the model is 770kN/m^2 .

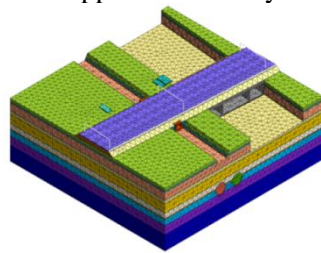


Fig.3 3D numerical modeling (1)

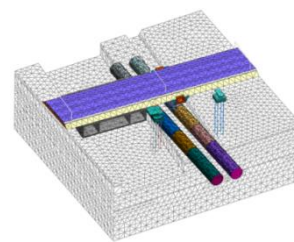


Fig.4 3D numerical modeling (2)

4.2. Calculation parameters

In the course of simulation, the physical and mechanical parameters of surrounding rock stratum, pier pile foundation, cap, pier and shield segment structure are shown in Table 1 and Table 2 .

Table 1 Geotechnical Mechanics Parameter Table

Stratigraphic lithology	Natural density (kN/m^3)	Angle of friction ($^\circ$)	Cohesive strength (kPa)	Modulus of elasticity (kN/m^2)
10-2 Ball clay	19.8	33.0	13.0	60000
16-1 Silty clay	18.8	25.0	12.0	80000
16-2 Ball clay	19.2	40.0	14.0	120000
16-4 Scree	22.5	0	35.0	250000
19-1 Fully weathered diorite	19.2	15.0	20.0	75000

Table 2 Structural Calculating Parameters Table

Structure name	Thickness (m)	Severe (kN/m^3)	Modulus of elasticity(MPa)	Poisson ratio	unit	Constitutive model
Soil body	-	-	-	-	Entity unit	Moore Coulomb model
Shield segment	0.3	25	34500	0.20	Plate element	Linear elastic model
Pile foundation	-	25	20000	0.24	Line element	Linear elastic model
Pier	-	25	20000	0.24	Entity unit	Moore Coulomb model
Catenary column	-	78	50000	0.30	Line element	Linear elastic model
Pile-stratum	-	-	-	-	-	Interface model
Segment -formation	-	-	-	-	-	Interface model

4.3. Calculation result analysis

4.3.1. Analysis on the influence of Shield Tunnel Construction on Railway subgrade

Due to the disturbance of the subgrade and the underlying stratum caused by tunnel excavation, the soil layer above the vertical area of the shield tunnel has been deformed in a certain range. When the left shield tunnel is through, the maximum vertical settlement of the stratum is -8.43mm , and the maximum vertical settlement of the subgrade of the Beijing-Shanghai Railway is -3.67mm . When the right tunnel is through, the maximum vertical settlement of the stratum is -3.67mm . The maximum vertical settlement of Beijing-Shanghai Railway Subgrade is -9.85mm , and the maximum vertical settlement of Beijing-Shanghai third and fourth Line is -6.95mm . The difference of vertical

displacement between railway subgrade and stratum is due to the difference of their own stiffness. The computed vertical displacement nephogram of subgrade and stratum of Beijing-Shanghai Railway third and fourth Line is shown in Fig. 5-8.

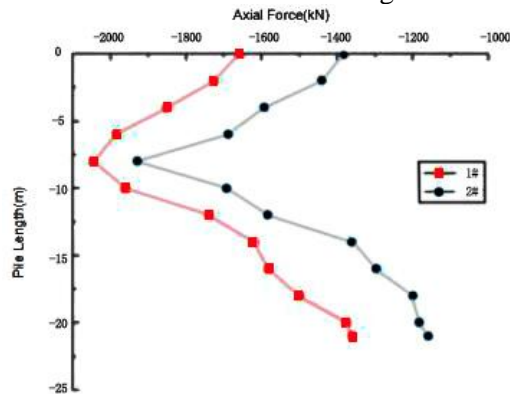


Fig. 5 Vertical Displacement of Railway Subgrade after Left Line Running through

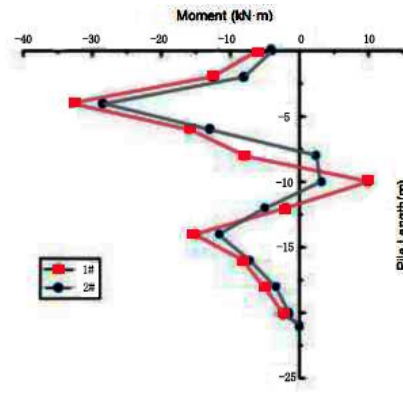


Fig. 6 Vertical Displacement of Railway Subgrade after Right Line Running through

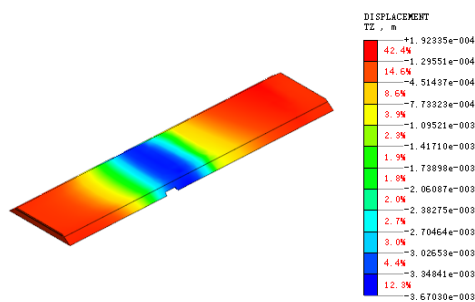


Fig. 7 Vertical Displacement of Formation after Left Line Penetration

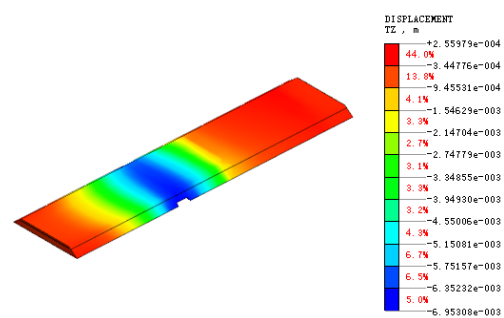


Fig. 8 Vertical Displacement of Formation after Right Line Penetration

4.3.2. Analysis of influence of Shield Tunnel Construction on Bridge pile

Vertical and horizontal displacement, axial force, bending moment, differential settlement of pier and abutment of 1# 2# pier and abutment are shown in Fig. 9-14.

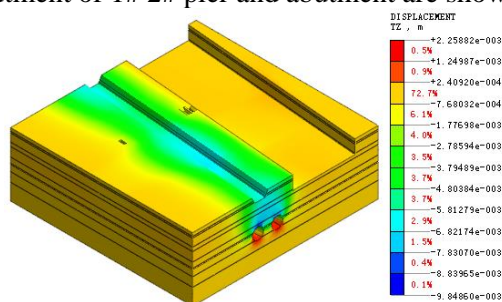


Fig. 9 Vertical Displacement of 1 # and 2 # Bridge Piles

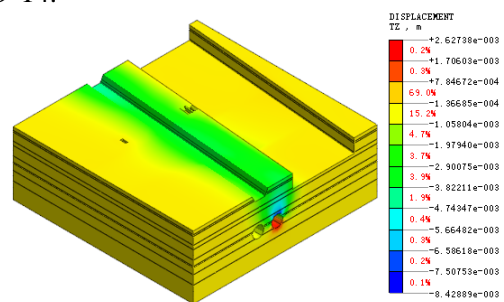


Fig. 10 Differential settlement of 1 # and 2 # Bridge Piles

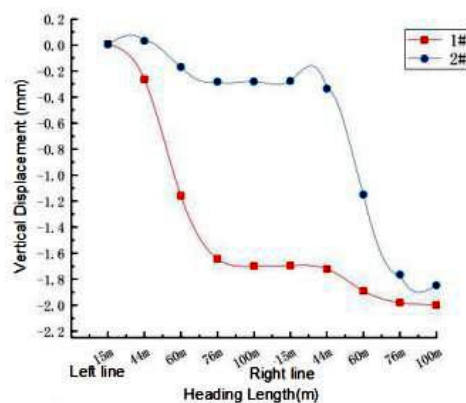


Fig. 11 Horizontal displacement of 1# bridge pile

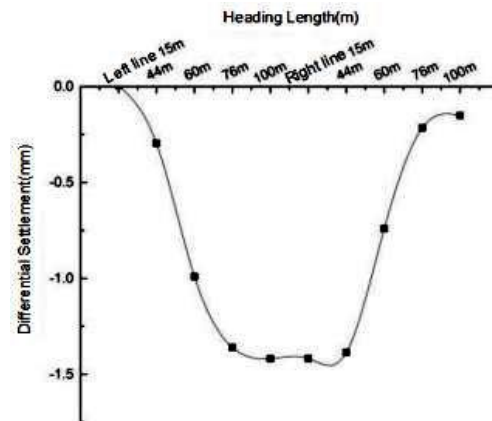


Fig. 12 Horizontal displacement of 2# bridge pile

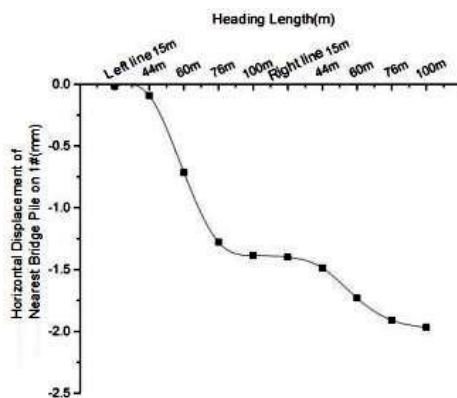


Fig. 13 Axial force of 1# and 2# Bridge Piles

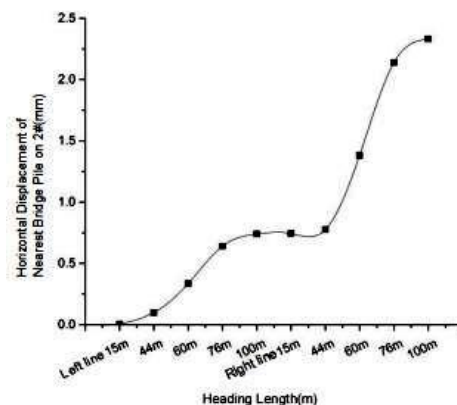


Fig. 14 Bending moment of 1# and 2# piles

From the analysis of figs. 9-14, it can be seen that the influence of shield tunnel construction on the deformation of pile foundation is mainly as follows:

1) From Fig. 9, it can be seen that the maximum vertical displacement of 1# pier abutment is -2.00mm, and the maximum vertical displacement of 2# pier abutment is -1.85mm. The settlement rate of pile foundation of 1# pier abutment increases first, then decreases gradually, and finally tends to be stable. The pile foundation of 2# pier abutment presents the opposite change state, mainly due to the following. In the right shield construction, the pile foundation of pier and abutment is the nearest to the pile foundation of pier and abutment. At the same time, because of the existence of the left tunnel, the influence of the right tunnel construction on the pile foundation of pier and abutment is weakened.

2) From fig. 10, it can be seen that the maximum differential settlement of the pier and abutment of 1# and 2# appears when the left line shield tunnelling is 100m. The pier and abutment of 1# are settled first and completed first.

3) From fig. 11 and fig. 12, it can be seen that the maximum horizontal displacement of 1# is -2.00 mm and the maximum horizontal displacement of 2# is 2.33 mm. They all displace away from the shield tunnel. The recent displacement of pier and abutment is mainly due to the squeezing of soil between piles and abutment of 1# and 2# by shield tunnelling.

4) It can be seen from fig. 13 that the axial force and bending moment produced of 1# are the largest after the right line shield tunnel is through, and the maximum axial force is -2045kN at the third position from the top of the pile, and the maximum bending moment is -33 kN·m.

5. Engineering technical measures

1. Optimizing interval lines: The minimum horizontal net distance between the line outline and the bridge piles on both sides is 6.95 m and 5.51 m, respectively.

2. In order to ensure the railway safety, we should strengthen the measures in the tunnel to minimize the settlement of subgrade and bridge pile.

3. Train speed limit: ≤ 60 km / h.

4. Reinforcement design of segment should be strengthened.

5. Fill the annular voids of tunnel excavation in time and evenly.

6. Optimize the parameters of shield tunnelling, for example: setting earth pressure reasonably and accurately, the propelling speed should be controlled in the range of 10-20 mm/min and so on.

7. According to the geological conditions of this section, the synchronous grouting materials with good permeability, strong watertight and high early strength are selected to be supplemented by double or multiple repeated grouting.

8. Strengthen the monitoring of subgrade settlement and pier settlement.

6. Conclusion

During construction, the cumulative vertical deformation of piers is -2.00mm, and the maximum settlement of Subgrade of Beijing-Shanghai third and fourth Line is 6.95mm, which meets the requirements of control standards.

In the course of construction, the safety of railway operation can be further guaranteed by means of strengthening track, speed limit and effective safety management system.

The reasonable shield excavation speed, synchronous grouting process and parameters, and a series of construction technology and reasonable protection measures are determined.

During the operation period of the metro, long-term monitoring and measurement are carried out in the tunnel of the crossing section, and corresponding treatment is carried out in the tunnel according to the monitoring situation to ensure the normal operation of the railway.

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), Major Social Projects for the People's Livelihood in Jinan City (project number 201704140).

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