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Analysis on the influence of double-line large diameter shield tunnel orthogonally underpassing tunneling on railway track group

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Abstract. In the process of urban traffic construction and reconstruction, the number of new tunnels crossing existing railways is increasing day by day.Based on the reconstruction project tunnel of Xiangyang Road in Weifang city underpassing Jiaoji Railway passenger dedicated line and Jiaoji Railway, the outer diameter of shield tunnel is 10.7 m, and the minimum cover soil thickness is 10.5 m, and the crossing length is 60 m. The three dimensional numerical simulation analysis was carried out to study the influence of the construction of the double-line parallel shield tunnel on the existing railway track group. The results show that the final settlement of the ground settlement of the railway subgrade centerline is "bimodal shape"; the maximum value of ground subsidence in the centerline of shield tunnel is -2.29mm, and the longitudinal influence range of shield construction is approximately 20 meters in front of the face to 40 meters in the rear. This study provides a reference for the implementation of similar double-line shield tunnel underpass railway engineering.

1. Introduction

In recent years, with the expansion of underground space, there are more and more new tunnels crossing the existing railway. The shield tunnel construction will affect the surrounding soil, the railway roadbed and the surrounding subsidiary structures. When it is serious, the shield tunneling will affect the normal operation of the train.

At present, scholars at home and abroad have done a great deal of research on the influence of shield tunnel underpass railway by theoretical calculation, on-site monitoring and simulation analysis, and have obtained certain research results[1~3]. Wei na [4] studied the influence of different construction control measures on the subgrade and rail of the existing operating railway under the parallel shield tunnel by using three-dimensional numerical simulation, and external diameter of the tunnel is 6.2m; Deng Nengwei et al.[5] carried on the three-dimensional finite element numerical simulation analysis to the subgrade settlement caused by the shield tunnel under the railway track group, and its tunnel external diameter is 6.3m.

The above research is not enough to analyze the influence caused by large diameter shield tunneling under the railway, and the consideration of the construction process is not enough. Therefore, on the basis of the existing research, with consideration of construction conditions, the influence of the large diameter double line parallel shield tunnel under the railway track group is analyzed with the background of reconstruction project tunnel of Xiangyang Road in Weifang city underpassing Jiaoji Railway passenger dedicated line and Jiaoji Railway. The study can provide reference for similar engineering design and construction.

2. Engineering overview

Xiangyang Road Tunnel adopts circular cross section. Tunnel outer diameter is 10.7 m, and the center distance of the left and right tunnel is 19m. Segment thickness is 0.5 m. Reconstruction project tunnel of Xiangyang road orthogonally cross the Jiaoji Railway Passenger Dedicated Line and Jiaoji Railway from north to south. The crossing length is 60m, and the distance between the top of the tunnel structure and the rail surface of the railway is about 10.0m ~ 10.5m in the railway section.

The main soil layer in the shield tunnel crossing area is 1-1 miscellaneous fill, 2-1 silty clay, 4-12 fully weathered basalt, 4-13 strong weathering basalt, 4-14 moderate weathered basalt, and shield tunnel is mainly located in 4-14 moderate weathered basalt.

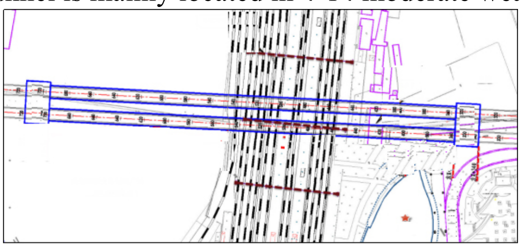


Figure 2-1. Plan of passing section.

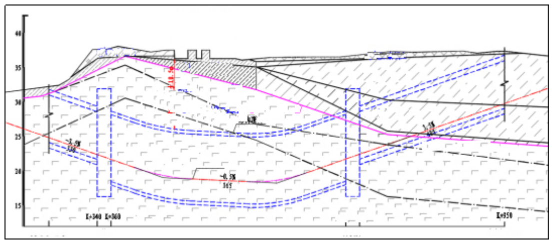


Figure 2-2. Vertical section of passing section.

According to railway line maintenance rules and the past experience of the adjacent railway engineering:

1) The subgrade settlement deformation of Jiaoji railway passenger dedicated line is controlled within 5mm;

2) The subgrade settlement deformation of Jiaoji railway is controlled within 10mm;

3) The control value of settlement deformation of catenary column is 10mm.

3. Model establishment

When the ratio of the soil model to the actual structure plane size is greater than 3~5, the boundary effect has little effect on the static and dynamic responses of the structure. Therefore, the model takes 170 m in the excavation direction of shield tunnel, 150 m width and 70 m depth. The boundary of soil model chooses ground support boundary, that is, the degree of freedom in the direction of x is restricted at the left and right boundary, the degree of freedom in the direction of y at the front and back boundary, the degree of freedom in z direction is restricted at the bottom boundary. Besides the weight of soil mass, the train and track loads of inter-city railway should be taken into account, as well as the traffic load in operation stage. The driving load is 20 kPa. According to Code for design on subgrade of railway, the equivalent load of train and track can be considered as static load by using the method of conversion soil column. The equivalent load is 60.2 kPa.

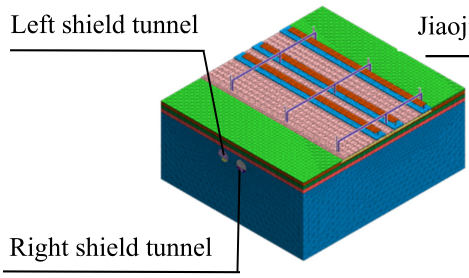


Figure 3-1. Model elevation.

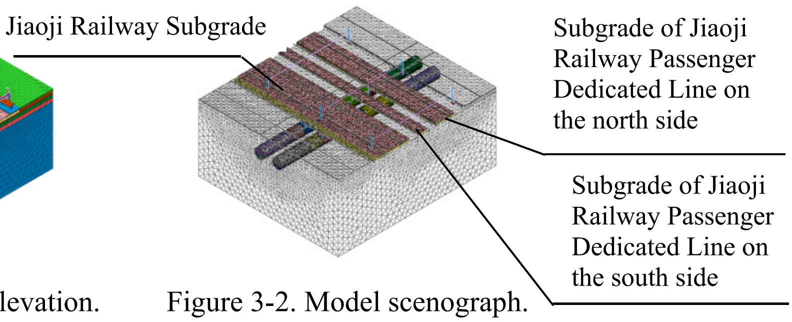
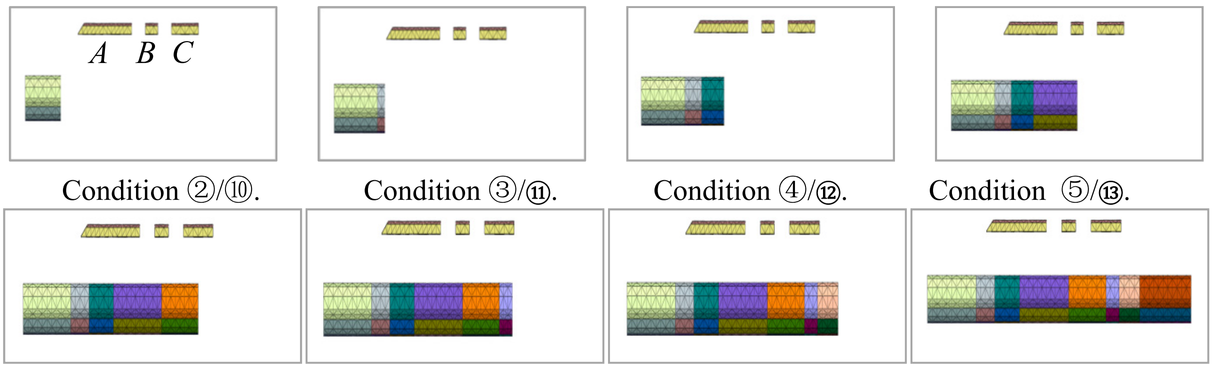


Figure 3-2. Model scenograph.

First shield tunneling the left line tunnel, then shield tunneling the right line tunnel. The model analyzes the influence of the construction of the new municipal tunnel of Xiangyang Road on the railway subgrade through the establishment of eighteen typical working conditions, as follows:

Table 3-1. Working condition table.

Working condition ①	Analysis of initial ground stress.
Working condition ②/⑩	The shield cutterhead for the left (right line) tunnel is located at the southern edge of the Jiaoji Railway Subgrade at a depth of 1 times.
Working condition ③/⑪	The shield cutterhead for the left (right line) tunnel is located at the southern edge of the Jiaoji Railway Subgrade.
Working condition ④/⑫	The shield cutterhead for the left (right line) tunnel is located directly below the middle of the Jiaoji Railway Subgrade.
Working condition ⑤/⑬	The shield cutterhead for the left (right line) tunnel is located directly below the middle of the subgrade of the Jiaoji Railway Passenger Dedicated Line on the south side.
Working condition ⑥/⑭	The shield cutterhead for the left (right line) tunnel is located directly below the middle of the subgrade of the Jiaoji Railway Passenger Dedicated Line on the north side.
Working condition ⑦/⑮	The shield cutterhead for the left (right line) tunnel is located at the northern edge of the "Jiaoji Railway Passenger Dedicated Line Subgrade on the north side".
Working condition ⑧/⑯	The shield cutterhead for the left (right line) tunnel is located at the northern edge of the Jiaoji Railway Passenger Dedicated Line Subgrade on the north side at a depth of 1 times.
Working condition ⑨⑰	The transfixion of the left line (right line).
Working condition⑱	The internal structure of the tunnel is completed and applied to vehicle loads.



Condition ②/⑩. Condition ③/⑪. Condition ④/⑫. Condition ⑤/⑬.

Condition ⑥/⑭. Condition ⑦/⑮. Condition ⑧/⑯. Condition ⑨/⑰.

Note: “A” is subgrade of Jiaoji Railway. “B” is subgrade of the Jiaoji Railway Passenger Dedicated Line on the south side. “C” is subgrade of the Jiaoji Railway Passenger Dedicated Line on the north side.

Figure 3-3. Relationship diagram between shield face and railway subgrade under typical working conditions.

4. Analysis of the influence of shield construction on existing railway subgrade

For the railway subgrade settlement and ground surface settlement caused by double-line shield tunnel construction, the analysis was carried out in the following areas:

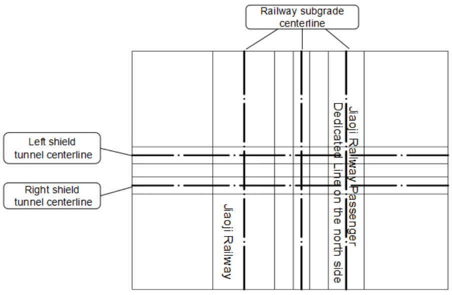
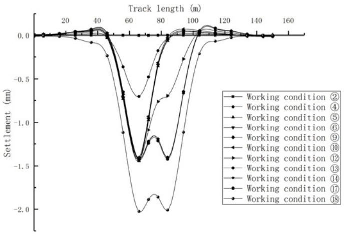


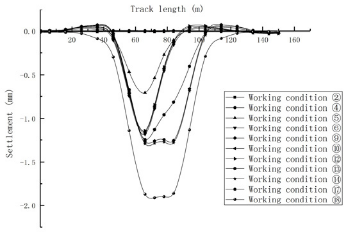
Figure 4-1. Model plane diagram.

(1) Ground surface settlement of railway subgrade centerline

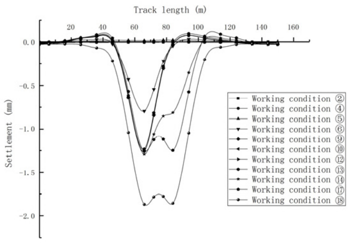
The settlement curve of a single roadbed centerline under partial typical working conditions, as shown in the following figure,



Jiaoji Railway Subgrade.



Subgrade of Jiaoji Railway Passenger Dedicated Line on the south side.

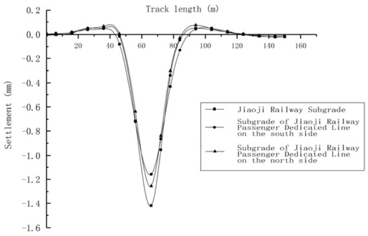


Subgrade of Jiaoji Railway Passenger Dedicated Line on the north side.

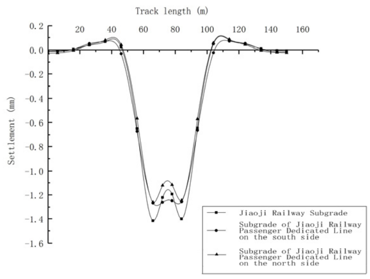
Figure 4-2. Ground surface settlement curve of subgrade centerline.

Figure 4-2 shows that the influence of shield tunnel construction on the settlement of the three subgrades is basically the same. In the second to ninth stage of the working condition, the settlement groove of the subgrade centerline is "single peak" during the construction of the left line shield tunnel; and in working condition 10, after the construction of the right line shield tunnel is started, the subgrade centerline settlement groove begins to be "double peak"; in the ten to eighteen stage of the working condition, and the subgrade centerline settlement groove is "double peak". With the development of construction condition, the settlement of subgrade centerline increases gradually, and the shape of settlement groove develops from "single peak" to "double peak". Under the working condition 18, operation stage, due to the weight of internal structure and driving load, the settlement curve of the three subgrade centerline is basically the same, the settlement trough is "double peak", and transverse range of influence is about 40 meters on both sides of the center line of the tunnel. The maximum settlement of the three subgrades is located at the center line of the tunnel, and the settlement is -2.03mm, -1.91mm, -1.87mm in turn, and meets the control standard.

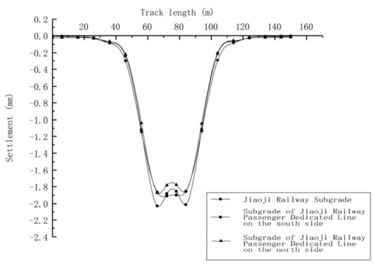
The settlement curves of the three subgrades under working conditions 9, 17 and 18 are compared, as shown in the following figure.



Subgrade centerline settlement curve of working condition 9.



Subgrade centerline settlement curve of working condition 17.



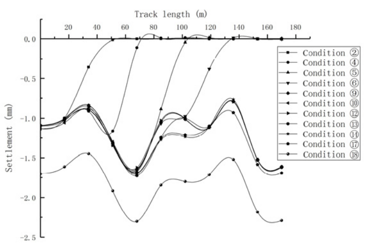
Subgrade centerline settlement curve of working condition 18.

Figure 4-3. Contrastive analysis of settlement curve of Subgrade centerline.

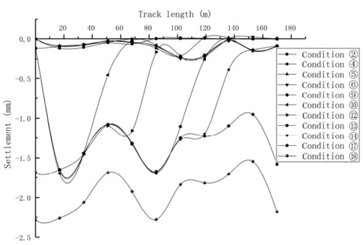
From figure 4-3, we can infer from the analysis of three typical working conditions that, under each working condition, the settlement law of each subgrade centerline is basically the same, and the maximum settlement amount is slightly different, but the difference is not obvious. It can be concluded that the influence of shield tunnel construction on the settlement of the three subgrades has no obvious difference.

(2) Ground surface settlement of center line of shield tunnel

The settlement curves of the center line of the left line shield tunnel and the center line of the right line shield tunnel under partial typical working conditions, as shown in the following figure,



Center line of the left line shield tunnel.



Center line of the right line shield tunnel.

Figure 4-4. Ground surface settlement curve of center line of the shield tunnel.

From figure 4-4, it can be seen that with the advance of construction conditions, the ground subsidence of center line of shield tunnel increases and then tends to be stable. In working condition 2, after the construction of the left line shield tunnel starts, the ground subsidence of the axis of the left line shield tunnel increases gradually; and in working condition 9, the ground surface settlement of center line of the left line shield tunnel tends to stabilize after the left line is through, but the right line shield construction has little effect on it. The surface settlement of center line of the right line shield tunnel is less affected by the construction of the left line shield tunnel; in working condition 10, the ground subsidence of center line of the right line shield tunnel increases gradually after the construction of the right line shield tunneling; in working condition 17, after two tunnels through, the ground surface settlement of center line of the right shield tunnel tends to be stable. In the operation stage, under the action of internal structure deadweight and driving load, the ground surface settlement of center line of shield tunnel appears bigger settlement again. The longitudinal influence range of shield construction is from 20 meters in front of the face to 40 meters in the rear, the surface of the ground in front of a certain range of the surface is slightly raised. The curve inflection point is the junction point between the subgrade and the ground. Because the stiffness of the subgrade soil and the surface soil is different, the curve shows a sudden change. The law of final settlement is basically the same between the two tunnels, and the maximum value of ground subsidence on the axis of the left and right shield tunnels is -2.29mm and -2.28mm, and meets the control standard.

5. Conclusion

Through the three-dimensional numerical simulation of reconstruction project tunnel of Xiangyang Road in Weifang City under Jiaoji Railway Passenger Dedicated Line and Jiaoji Railway, the following conclusions can be obtained:

(1) After the operation stage, the settlement curve of subgrade centerline is "double peak", and the influence range is approximately within 40m range of each side of the tunnel center line. The maximum settlement of the subgrade of Jiaoji railway, the south side and the north side of Jiaoji railway passenger dedicated line is -2.03mm，-1.91mm，-1.87mm in turn, which meets the requirements of the control standard.

(2) After the operation stage, the surface subsidence of the axis of the left and right shield tunnel is -2.29 mm and -2.28 mm, respectively, which meets the control standard. The longitudinal influence range of shield tunnel construction is from 20 meters in front of the face to 40 meters in the rear, and the surface of the ground in front of a certain range of the surface is slightly raised.

(3) From the comparison and analysis of subgrade settlement curves, there is no obvious difference in the influence on each subgrade by the orthogonal underpass railway group of double-line parallel shield tunnel.

(4) In this project, in the middle weathered basalt, without reinforcement measures, the settlement amount caused by the shield tunnel passing through the railway track group meets the requirements of the control standard, so it is not necessary to carry out reinforcement measures.

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