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Analysis of the Influence of Tunnels on the Ground Disturbance under the Excavation of Multiple Construction Methods

JIANG Zhenlv[2] FU Helin[1] ZHAOYibo[21] SU Zhaoqian[2] AI Guoping[2]

(1 Bridge and Tunnel Company of First Highway Engineering Co., Ltd, , Hunan Changsha 4100315； 2 Central South university, Hunan Changsha 41007)

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ABSTRACT: Using the MIDAS GTS NX finite element analysis software, the vertical and parallel combination of the step method, CD method and CRD method are simulated, and the impact of the tunnel on the stratum under the excavation of different construction methods is analyzed. The results show that: the effect of longitudinal combined construction method is greater than that of parallel combined construction; when the longitudinal construction method is combined, the surface settlement displacement of the transition from small section to large section is slightly smaller than that of large section to small section; when parallel combined construction, The settlement value is similar to the superposition of the ground settlement values at the corresponding positions caused by the excavation of the two tunnels. Taking the large hole as the first tunnel excavation tunnel is conducive to controlling the construction disturbance deformation.

Keywords: mine tunnelling method; numerical simulation; multi-method combined tunnel; stratum settlement

I. INTRODUCTION

With the development of underground traffic, underground traffic has put forward more and more complex and changeable requirements. Many geological conditions are complex, there are many risk sources, high construction control requirements, or tunnel construction needs a combination of multiple construction methods in a short distance due to special needs, Simply using a certain construction method to replace the disturbance caused by excavation under various working conditions will often lead to conservative and unnecessary economic waste or risk in practical engineering, and can not carry out disturbance control well, resulting in unexpected problems.

Many scholars have studied the problems of stratum settlement caused by tunnel excavation. Ding Zhenyi [1] established a three-dimensional model of tunnel excavation by using Midas GTS NX, and discussed the influence of different construction measures on stratum settlement; Zhao Huilong, song Zhanping [2] simulated the tunnel crossing the highway and studied the law of highway subsidence under tunnel excavation; Shi Xiangfeng, Zhang Lihua, et al. [3] used FLAC 3D finite element software to model and analyze a mine tunnel, and explored the influence law of the later tunnel on the first tunnel; Zhao Qiaolan, Wu Ze [4] analyzed the impact of different excavation methods and combined auxiliary measures on buildings by establishing three-dimensional and two-dimensional tunnel underpass models; Zhong Guang [5] used ADINA for numerical simulation analysis, and combined with the field measured data, analyzed the stability of surrounding rock when the tunnel passes under; Xu Jianguo [6] used FLAC 3D software to establish an analysis model, focusing on the impact of excavation step size and excavation method on stratum settlement and settlement tank.

There is almost no relevant research on stratum disturbance caused by different excavation construction schemes in the existing research, and the combined construction of multiple construction methods in a short distance is often accompanied by frequent construction method conversion, and due to the differences of excavation methods, the magnitude of stratum disturbance caused by different construction sequences is often different. Therefore, it is necessary to analyze the influence of different construction methods on stratum disturbance, so as to provide some reference for similar projects.

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II. ANALYSIS OF INFLUENCE OF TUNNEL EXCAVATION ON STRATUM DISTURBANCE

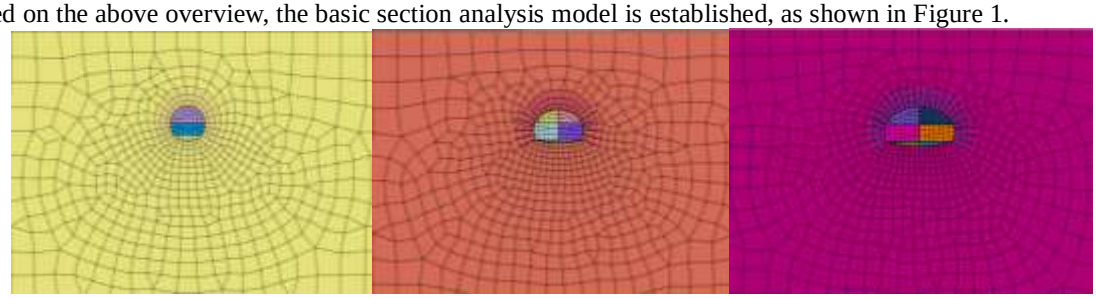
Relying on the background of a project, it is proposed to carry out fine simulation of each excavation construction method with the help of MIDAS GTS NX finite element analysis software, analyze the disturbance mechanism of different excavation construction methods on the stratum, and summarize the deformation disturbance law under the same geological condition under each excavation method.

For a double track tunnel project, the surrounding rock grade of the tunnel is grade VI. The buried depth of the tunnel top is about 19 ~ 21m. Five different types of sections are set in the concealed excavation section of the section, and 8 tunnel sections change from small section to large section and from large section to small section. See Table 1 for other stratum physical parameters.

Table 1 recommended values of geotechnical physical indexes and design parameters

Parameters	Natural density	Shear test				Compression modulus	deformation modulus	Static side pressure coefficient	Poisson's ratio	Permeability coefficient
		Direct shear quick		Consolidated quick shear						
	density	Friction angle		Cohesion	Friction angle					
	ρ	c	φ	c	φ	Es_{1-2}	E_0	K_0	μ	K
	g/cm^3	kPa	°	kPa	°	MPa	MPa			m/d
value	2.51	100	35	/	/	/	120	0.25	0.20	0.2

Based on the above overview, the basic section analysis model is established, as shown in Figure 1.



(a) Step method (b) CD method (c) CRD method

Fig. 1 Calculation Model

2.1 impact of different construction methods on surface disturbance

In order to find out the stratum overlapping disturbance caused by the combined construction of different construction methods, firstly, the stratum disturbance caused by the separate construction of each construction method shall be studied and analyzed, and the numerical simulation analysis shall be carried out with the help of the auxiliary calculation software MIDAS GTS NX. Table 2 shows the statistics of stratum disturbance caused by the three construction methods.

Table 2 Comparison of tunnel displacement with different construction methods

Construction method		Maximum vertical displacement/mm		Maximum horizontal displacement/mm		Maximum surface settlement/mm
		vault	Arch bottom	left	right	
Step	Upper	-3.61		-4.12	3.12	-6.23

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method	bench excavation					
	Bench excavation		2.56	-6.31	5.42	-7.02
	Left heading excavation	-4.12	3.34	2.96	-2.91	-16.12
CD method	Right heading excavation	-4.83	3.59	2.88	-4.08	-16.93
	Removal of temporary support	-10.12	6.15	3.32	-3.73	-18.76
	Left heading excavation	-7.06	5.4	1.68	-2.32	-22.41
CRD method	Right heading excavation	-10.61	7.83	2.03	-2.89	-23.52
	Removal of temporary support	-15.73	8.39	4.63	-5.87	-25.36

From the above numerical simulation results:

For bench method: each construction stage of bench method construction has little impact on the influence range of stratum, the surface settlement range and settlement law of each stage are basically the same, and the position of maximum displacement value is also the same; The excavation of lower bench and inverted arch has limited impact on surface settlement deformation, and the excavation of upper bench has a greater impact on surface settlement. Therefore, in order to effectively control the surface deformation caused by construction during construction, advance support shall be carried out for upper bench excavation according to the situation, and arch roof lining shall be carried out in time; The stratum deformation caused by excavation is greater than the vertical deformation in the horizontal direction. It can be seen that the horizontal direction of soil is sensitive to excavation disturbance. CD method or CRD method is recommended for construction of long-span section, which has reduced the span ofexcavation section and strengthened the horizontal support strength during construction.

For CD method: the horizontal convergence in the whole process of section excavation is greater than the vertical settlement. In the process of section excavation, due to the large horizontal convergence value on the right side, the strength and flexibility of temporary vertical support shall be ensured. If necessary, diagonal bracing shall be added or CRD method shall be used for construction; The amount of soil excavation in the inverted arch is small, and the disturbance to the stratum is limited. Finally, the inverted arch support can be applied to improve the construction efficiency; The temporary support has a certain supporting effect on the tunnel section. The removal of the temporary support will not only increase the vertical deformation, but also increase the horizontal convergence value.

For CRD method: due to the restriction of cross bracing, the stratum influence range caused by the excavation of the first part of soil is slightly smaller than that of CD method, which is only within 3.5D above the excavation surface, and due to the temporary cross bracing, the stratum influence range of the tunnel during subsequent excavation does not show obvious expansion; Due to the action of cross bracing, the deformation of the tunnel changes to

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occur on the left side of the tunnel centerline. This is mainly because the left part of the tunnel is excavated first, and the disturbance caused by the first is obviously stronger than that caused by the later. In addition, the temporary cross bracing has been applied during the excavation on the right side, which limits the horizontal development of the stratum. Therefore, the tunnel displacement, especially the horizontal displacement, slightly deviates to the left side of the tunnel centerline, When the temporary cross brace is removed, the tunnel deformation returns to the normal symmetrical state along the tunnel center line under the action of in-situ stress;

The tunnel excavation section is large, but due to the action of temporary cross bracing, the influence range of deformation caused by tunnel excavation is limited, the vertical deformation of the stratum is constrained in a small range, and the stratum deformation shows the characteristics of "narrow and deep".

2.2 influence of stratum stacking disturbance caused by combined construction of different construction methods

According to the above analysis, when different construction methods are used for tunnel construction, due to the difference in technology, there are also differences in the disturbance characteristics of the stratum. During combined construction, special attention should be paid to the combination form and excavation sequence between different construction methods. The numerical simulation is carried out with the aid of the auxiliary calculation software MIDAS GTS NX, and the specific construction method combination and construction excavation sequence of the mining method section of a project are compared and analyzed. The following results are obtained, as shown in table 3-table 4

Table3 Comparison of displacement of tunnel constructed by longitudinal combination of different construction methods

Construction method		Maximum vertical displacement/mm				Maximum horizontal convergence value/mm		Maximum surface settlement/mm
		Advance hole		Backward hole				
		Arc top	Arc bottom	Arc top	Arc bottom	Advance hole	Backward hole	
Longitudinal combined construction of bench method and CD method	Excavation by bench method	-3.83	2.71	-11.32	8.65	10.56	9.63	-18.63
	CD method excavation first	-10.56	6.12	-4.02	10.63	8.65	10.67	-19.03
Longitudinal combined construction of bench method and CRD method	Excavation by bench method	-3.78	2.63	-15.13	9.63	10.63	9.52	-26.33
	CRD method excavation first	-15.42	8.34	-3.89	8.98	9.63	11.21	-27.42
Longitudinal combined construction of CD method and CRD method	CD method excavation first	-10.32	6.33	-15.62	9.57	8.98	9.63	-27.89
	CRD method excavation first	-15.47	8.63	-10.43	6.56	9.57	9.03	-28.13

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Table 4 Comparison of tunnel displacement under parallel combined construction of different construction methods

Construction method		Maximum vertical displacement/mm				Maximum horizontal convergence value/mm/mm		Maximum surface settlement/mm/mm
		Advance hole		Backward hole				
		Arc top	Arc bottom	Arc top	Arc bottom	Advance hole	Backward hole	
Longitudinal combined construction of bench method and CD method	Excavation by bench method	-4.23	3.21	-12.35	7.08	11.52	10.73	-23.63
	CD method excavation first	-11.78	6.69	-4.38	3.56	10.23	11.88	-23.98
Longitudinal combined construction of bench method and CRD method	Excavation by bench method	-5.32	3.11	-16.21	8.32	11.8	9.32	-31.63
	CRD method excavation first	-15.32	8.23	-3.08	2.56	9.01	12.21	-30.23

According to the results of numerical simulation analysis:

For the combined construction of bench method and CD method in the tunnel excavation direction: since the excavation section has been completely disturbed in the horizontal direction, the subsequent CD method excavation has little impact on the previous excavation. No matter the surface vertical settlement or horizontal displacement caused by excavation disturbance, the main impact is still the size and construction method of the excavation section. For the interface of different excavation methods, The superimposed disturbance of stratum displacement caused by different construction methods can be almost ignored. Therefore, in the construction process, the selection of different construction methods and the superimposed disturbance caused by parallel construction of different construction methods should be mainly considered. In the longitudinal direction along the tunnel excavation direction, the soil has been completely disturbed after excavation, The combination of different construction methods superimposes each other, and the influence of disturbance is very limited, which can be ignored; Similar to bench excavation, the disturbance superposition effect of excavation at the interface is not obvious. The stratum disturbance deformation caused by tunnel excavation is mainly affected by the excavation section and construction method.

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For the combined construction of bench method and CRD method in the tunnel excavation direction: since the excavation section has been completely disturbed in the horizontal direction, the subsequent CRD method excavation has little impact on the previous excavation. Whether the surface vertical settlement or horizontal displacement caused by excavation disturbance, the main impact is still the size and construction method of the excavation section, However, different from the above combination of bench method and CD method, the maximum vertical displacement of the ground surface at the construction method conversion is about 1 / 3 larger than that of the bench method, which shows that the disturbance influence of the width of the excavation section at the construction method conversion surface is positively correlated. In order to reduce the influence of superimposed disturbance at the construction method conversion surface, appropriate transition surface transition shall be adopted, or cross passage shall be excavated in advance and supported in time, Avoid large section difference at the transition; Similar to bench excavation, it is worth noting that the surface displacement at the construction method conversion surface increases compared with bench excavation. Therefore, it is recommended to transition from small section excavation to large section excavation as far as possible on the premise of reasonable construction layout.

For the combined construction of CD method and CRD method in the tunnel excavation direction: because the excavation section has been completely disturbed in the horizontal direction, the subsequent CRD method excavation has little impact on the previous excavation. Whether the surface vertical settlement or horizontal displacement caused by excavation disturbance, the main impact is still the size and construction method of the excavation section. For the interface of different excavation methods, The subsequent construction method has little impact on the secondary disturbance of the previous excavation. Therefore, in the construction process, for the conversion from small excavation section to large excavation section, the selection of different construction methods and the superposition disturbance caused by parallel construction of different construction methods should be mainly considered. In the longitudinal direction along the tunnel excavation direction, the soil has been completely disturbed after excavation, The combination of different construction methods superimposes each other, and the influence of disturbance is very limited, which can be ignored; Similar to the CD method excavation, it is worth noting that the surface displacement at the construction method conversion surface increases compared with the CRD method excavation. Therefore, it is recommended to transition from small section excavation to large section excavation as far as possible on the premise of reasonable construction layout.

For the combined construction of bench method and CD method in parallel: the disturbance range of excavation construction to the stratum is significantly increased, and the maximum surface displacement is between the bench method section and the CD method section, slightly inclined to the CD method section, which is mainly because the CD method section is larger than the bench method section, which is also consistent with our understanding, The maximum settlement displacement is close to the superposition value of the settlement displacement at this point of bench method and CD method excavation, so the disturbance effect between parallel excavation is obvious, and due to the large buried depth, the transmission of settlement displacement to the surface can be simply regarded as the superposition of two-line excavation; Different from the combined construction of different longitudinal construction methods, there is little difference between bench method and CD method for parallel combined construction. The maximum surface settlement and horizontal displacement of CD method are only slightly larger than that of bench method. Therefore, the construction efficiency and convenience should be considered in the working hours of parallel combined construction.

For the combined construction of bench method and CRD method in parallel: similar to the parallel construction of bench method and CD method, the disturbance range of excavation construction to the stratum is significantly increased, the maximum surface displacement is between the bench method section and CRD method section, slightly deviates from CRD method section, and the maximum settlement displacement is close to the superposition value of settlement displacement at this point of bench method and CRD method excavation; Different from the advanced bench method, the surface displacement during the construction of CRD method is greater than that during the construction of bench method. During the excavation of large section, due to the large section will cause great disturbance to the stratum, direct excavation will often lead to large surface displacement. Therefore, it is often necessary to avoid this situation during the construction, If necessary, one side of the pilot tunnel shall be excavated first, and the other side shall be excavated after it reaches a certain "pre disturbance" effect; The horizontal convergence value of CRD method is small due to the support effect of temporary cross bracing. The horizontal

convergence value can be effectively controlled by applying horizontal cross bracing for large section tunnel excavation.

III. CONCLUSION

With the help of MIDAS / GTS NX finite element calculation software, this paper simulates the disturbance impact on the stratum under different construction methods, i.e. different combination construction, and obtains the following conclusions:

(1) During tunnel excavation, the combined excavation of different construction methods has a great impact on stratum settlement, and the impact of longitudinal combined construction of construction methods is greater than that of parallel combined construction. For complex double track variable section tunnel construction, the combination mode of construction methods shall be reasonably arranged and the reasonable construction and excavation sequence shall be formulated;

(2) For the combined construction of longitudinal construction method, the surface settlement displacement of the transition from small section to large section is slightly smaller than that of the transition from large section to small section, and the maximum settlement value is basically close to the surface settlement value caused by single construction method. It is recommended to transition from small section to large section during construction, and excavate the side directly connected with the small section during large section excavation;

(3) During parallel combined construction, due to the excavation disturbance of the first tunnel, the in-situ stress is released first, and the horizontal convergence value of the second tunnel increases significantly. The surface settlement value is similar to the superposition of the surface settlement value caused by the excavation of the two tunnels at the corresponding position. In order to facilitate the construction control of the tunnel deformation value, it is recommended to use the large tunnel as the first tunnel for tunnel excavation, and excavate one side of the pilot tunnel first, After excavation, the small tunnel shall be excavated. After one side of the large tunnel reaches a certain "pre disturbance" effect, the pilot tunnel on the other side shall be excavated.

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