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Study on Stability of Surrounding Rock of Mechanized Construction in Tunnel Entrance Section

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Abstract. With the development of tunnel construction technology and mechanical equipment, the mechanized drilling and blasting construction of mountain tunnels has gradually developed, but there are still certain problems in the mechanized tunnel entry. Relying on a tunnel project in Yunnan, this article uses FLAC3D software to study the stability of surrounding rock under the condition of mechanized large-section construction of shallow buried section of the tunnel entrance. When the shallow buried section of the cave entrance is constructed by the micro-step method, the surrounding rock displacement and plastic zone changes of the surrounding rock before and after the use of different cyclic footage and the tunnel face reinforcement when the tunnel face is used are compared and analyzed. The results of the study show that when the tunnel face is not reinforced, in order to ensure the safety of construction, the mechanized excavation cycle footage of the tunnel entrance section should be controlled within 1.2m, and the overlap length of the leading pipe shed should be greater than 5m; if the circulation is to be increased for footage, the tunnel face must be reinforced. Under the condition that the tunnel face is reinforced with glass fiber anchors with a length of 10m and a pitch of 1.5m, the cycle footage can be increased to 1.8m at most.

1. Introduction

In recent years, experts and scholars have carried out relevant research work on mechanized large-section tunnel construction. Wang Zhijian[1] relied on the tunnel project of the Hubei section of the Zhengzhou-Wanzhou high-speed railway to study the stability measures of the tunnel face, the optimization of supporting structure parameters, the selection of mechanized construction methods and the selection of construction process parameters during the mechanized construction of the tunnel. Yu Li et al[2]. through monitoring and measuring the surrounding rock pressure of a large-scale mechanized tunnel on the Zhengwan high-speed railway, clarified the change law and distribution characteristics of surrounding rock pressure during the mechanized construction of deep-buried tunnels under the conditions of level IV and V. Relying on the Xinhua Tunnel Project, Tian Jia and others[3] proposed a new construction organization mode for the tunnel construction production line through field experiments, which solved the problem of continuous mechanized large-section construction under the conditions of grade IV and V weak surrounding rock. Wang ming nian et al.[4] through the initial support site measurement and the classified statistics and regression analysis of the monitoring



measurement data, obtained the function expression of the initial support displacement along the longitudinal direction of the tunnel and the ratio of the segment displacement to the limit displacement under each working condition, under the condition of mechanized large-section excavation with different mechanized large-sections in the depth and shallow burial of grade IV and V surrounding rock. Liu Jiang et al.[5]. successfully applied the expanded shell prestressed hollow bolt to the Zhengwan high-speed railway tunnel project, which solved the problem of rapid support after the mechanized large-section tunnel excavation under the condition of soft surrounding rock. Li Pengfei et al.[6]concluded that the deformation of tunnel surrounding rock can be divided into advance deformation of tunnel face, extrusion deformation of tunnel face and rear deformation of tunnel face. For tunnel face extrusion deformation, literature[7-9] all proposed that the use of glass fiber anchors to strengthen the face of the tunnel has a significant effect. Through theoretical analysis, literature[10] proposed a method for determining the density, length, and reinforcement range of the face fiberglass anchor rod, and determined the effectiveness of the method through numerical simulation. Literature[11] summarized the optimal parameters of fiberglass anchors on the tunnel face from the perspective of engineering applications. Literature[12] determined through experiments and numerical simulation that the anchor density has the greatest impact on the reinforcement effect of the fiberglass anchor on the face.

According to the current research results, the current research mainly focuses on the tunnel construction method, surrounding rock displacement characteristics, auxiliary reinforcement parameters and other issues under the conditions of large-section mechanized large-section surrounding rock construction for the deep-buried section of the main tunnel of the tunnel. However, it does not involve the study of the stability of the surrounding rock in the shallow buried section of the tunnel, the geological conditions of the surrounding rock in the tunnel entrance section are often worse, and the safety risk of mechanized large-section construction is higher. Based on this, the article takes an actual engineering tunnel as an example through three-dimensional numerical simulation analysis to study the stability of the surrounding rock of the shallow tunnel entrance section under mechanized construction conditions, and proposes a reasonable excavation cycle footage, auxiliary reinforcement measures etc, under the premise of ensuring the safety of tunnel construction, providing technical support for tunnel construction of similar projects.

2. Project Overview

The entrance section of the relying tunnel project is a natural slope section, and the terrain slope is generally 18-29°. The strong weathering intensity of the rock mass is strong, the differential weathering is strong, the joints are developed, and the rock mass is extremely broken. The depth of the side of the tunnel entrance is shallow, and the arch is prone to collapse when there is no support, and the sidewall is prone to lose stability. The type of groundwater is bedrock fissure water, and dripping water is easy to appear during the rainy season. The rock mass of the upside slope at the entrance of the tunnel is strongly weathered, mostly in fragments, and the formed upside slope has poor stability.

3. Numerical analysis

3.1. Calculation model and working conditions

According to the design data, when the general construction method is adopted, the shallow buried section of the tunnel entrance is generally designed with pipe shed support. In order to adapt to mechanized excavation, the construction and excavation method of micro-steps needs to be adopted, and the stability of the tunnel face and reinforcement measures need to be studied. The numerical model is shown in Figure 1, and the calculation conditions are as shown.

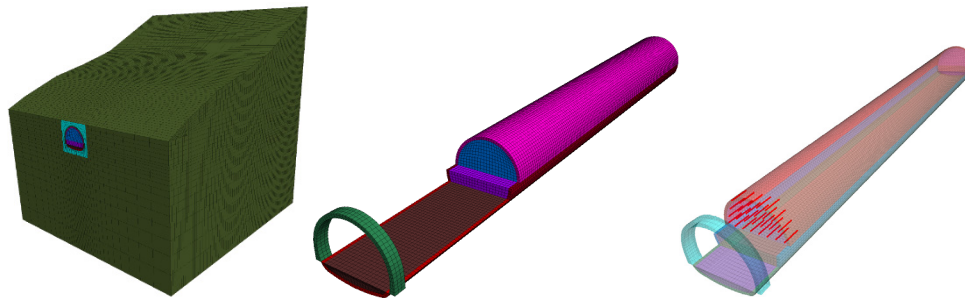


Figure 1 Numerical model

Table 1 Numerical calculation conditions

Working condition	Strengthening of the tunnel face	Cycle footage /m
1	Not reinforced	0.6
2	Not reinforced	1.2
3	Not reinforced	1.8
4	Not reinforced	2.4
5	reinforced	0.6
6	reinforced	1.2
7	reinforced	1.8
8	reinforced	2.4

3.2. Selection of calculation parameters

According to the general situation of the supporting project, the surrounding rock level of the shallow buried section of the tunnel entrance is V2, and the surrounding rock and lining structure parameters are selected according to the “Highway Tunnel Design Rules”(JTG/T D70-2010).

Table 2 Parameters of surrounding rock and support

Material name	Elastic Modulus (GPa)	Poisson	density (kN/m ³)	Friction (°)	Cohesion (MPa)
Surrounding rock	1.15	0.42	1750	21	0.085
Initial support	22.95	0.2	22	50	0.2

4. Study on the stability of surrounding rock

4.1. Without reinforcement of the tunnel face

4.1.1. Analysis of surrounding rock displacement state. In order to facilitate comparison and analysis, extract the surrounding rock deformation rate values under different cyclic footage conditions, and further analyze the impact of cyclic footage on the deformation rate. From Figure 2 and 3, we can see that the larger the footage of the face of the tunnel, the greater the rate of convergence and deformation of the surrounding rock and the extrusion deformation of the tunnel face. The settlement convergence rate of the surrounding rock is greater than the horizontal convergence rate and greater than the extrusion deformation rate of the tunnel face. When the single-cycle footage is greater than or equal to 1.8m, the deformation rate of rock is more obviously affected by the increase of cyclic footage, and the average settlement deformation rate of surrounding rock is greater than 2.5mm, and the single settlement deformation rate during surrounding rock excavation is bound to be greater than 2.5mm, which is taken as 2~3 times the average deformation rate. If the value is greater than 5mm, there is a greater risk of safety accidents of surrounding rock instability, that is the control angle of surrounding rock deformation. When the micro-step construction is adopted, the single-cycle footage should be controlled at 1.2m.

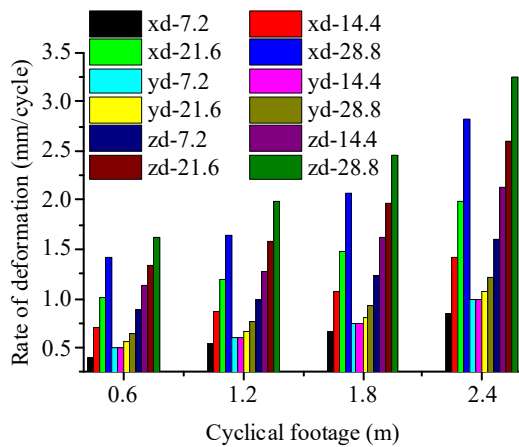


Figure 2 Variation rules of surrounding rock deformation with the burial depth

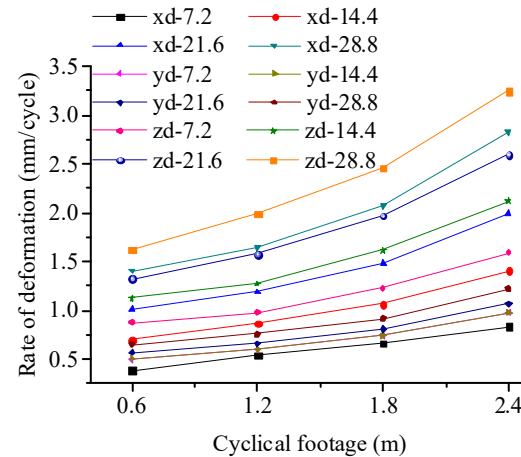


Figure 3 The variation rules of the deformation rate of the surrounding rock with the circular footage

4.1.2 Analysis of plastic state of surrounding rock. The plastic zone distribution map of surrounding rock after tunnel construction and excavation under different working conditions is extracted, as shown in Figure 4~Figure 7, comparative analysis of the stability state of surrounding rock, and reasonable cyclic excavation footage is proposed.

From Figures 4 to 7, it can be seen that after the shallow buried section of the tunnel entrance is constructed with micro-steps, with the increase in the depth of the tunnel face, the buried depth increases, the pipe shed moves outward, and the plastic zone of the tunnel surrounding rock shows a gradually increasing trend. In the initial stage of tunnel entry, the plastic zone at the bottom of the invert is larger than the arch. As the tunnel face advances, the depth of the plastic zone at the bottom of the invert gradually stabilizes, and the arch plasticity gradually expands outward, and at the same time the tunnel face plasticity also changes from the bottom moves upward and forward. When the tunnel face footage is different and the tunnel buried depth is different, the cyclic footage has different effects on the distribution of the plastic zone of the surrounding rock.

In summary, for the shallow buried section of the tunnel entrance, when the micro-step construction is adopted and the tunnel face is not reinforced and stabilized, the maximum circulating footage of the tunnel face is 1.2m. To ensure the effectiveness of the pipe shed, the overlap length of the shed should not be less than 5m.

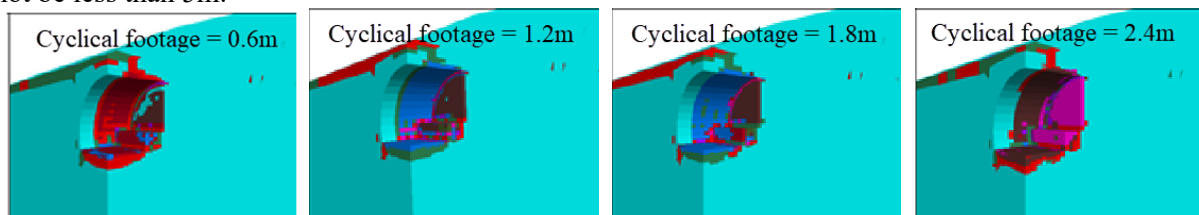


Figure 4 Distribution diagram of plastic zone of surrounding rock under different circular depth(tunnel-face depth is 7.2m)

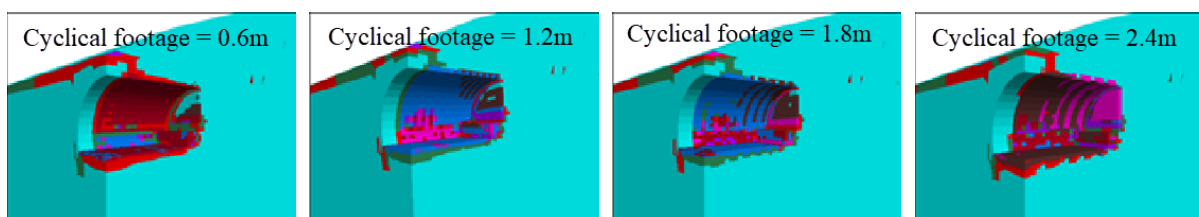


Figure 5 Distribution diagram of plastic zone of surrounding rock under different circular depth(tunnel-face depth is 14.4m)

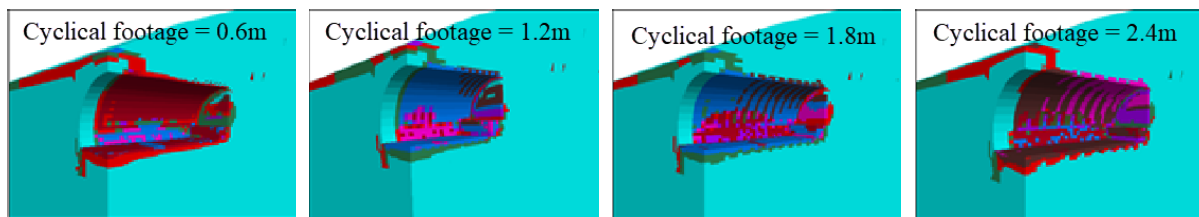


Figure 6 Distribution diagram of plastic zone of surrounding rock under different circular depth(tunnel-face depth is 21.6m)

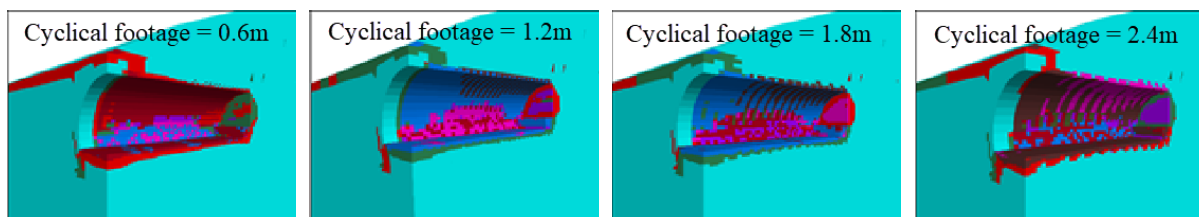


Figure 7 Distribution diagram of plastic zone of surrounding rock under different circular depth(tunnel-face depth is 28.8m)

4.2. With reinforcement of the tunnel face

According to the calculation results in the previous section, the tunnel is constructed by the micro-step method, and the stability of the tunnel face affects construction safety. When the circular footage is greater than 1.2m, the plastic zone of the tunnel face penetrates, and the maximum plastic zone depth in front of the tunnel face is 2.4m. The tunnel face is easy to lose stability and collapse, and the construction safety risk is high. It is proposed to use the up-stair glass fiber anchor to strengthen the tunnel face. The length of the glass fiber anchor is 10m, the spacing is 1.5m, the lap length is 2.8m ($>2.4\text{m}$) and plum blossom arrangement. The numerical analysis model is shown in figure 1.

4.2.1 Comparative analysis of surrounding rock displacement status. In order to facilitate comparative analysis, the typical characteristic values of surrounding rock deformation before and after face reinforcement under different working conditions are extracted and drawn into histograms, as shown in Figure 8~Figure 13. It can be seen from Figure 8~Figure 13 that the face reinforcement has a certain effect on the control of various deformation indexes of the surrounding rock. The larger the cyclic footage, the more obvious the control effect. Among them, the extrusion deformation of the face is more prominent, and the control effect of settlement convergent is second, and it has almost no effect on the horizontal convergence. Some working conditions still have a slight increase, but it does not affect the construction safety. In short, from the results of the deformation comparison analysis, reasonable measures for reinforcement of the tunnel face are taken. It is beneficial to control the excessive deformation of the tunnel face, thereby reducing construction safety risks.

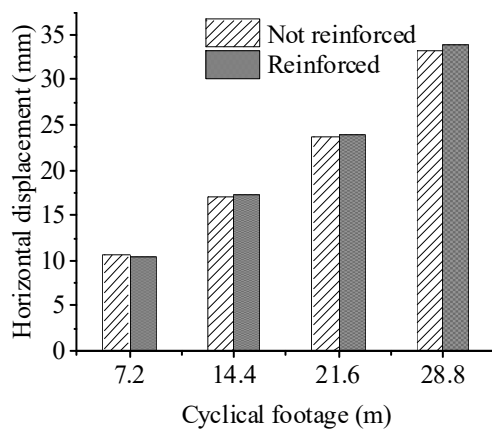


Figure 8 Comparative analysis histogram of the influence of the tunnel face reinforcement on horizontal displacement (cyclical footage: 1.8m)

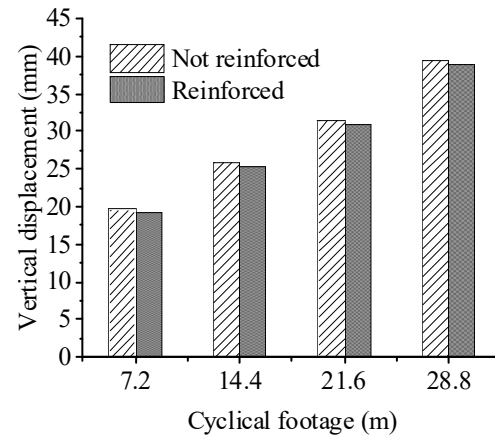


Figure 9 Comparative analysis histogram of the influence of the tunnel face reinforcement on vertical displacement (cyclical footage: 1.8m)

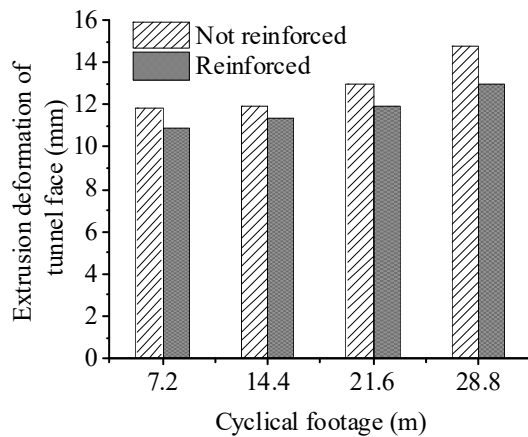


Figure 10 Comparative analysis histogram of the influence of the tunnel face reinforcement on extrusion deformation (cyclical footage: 1.8m)

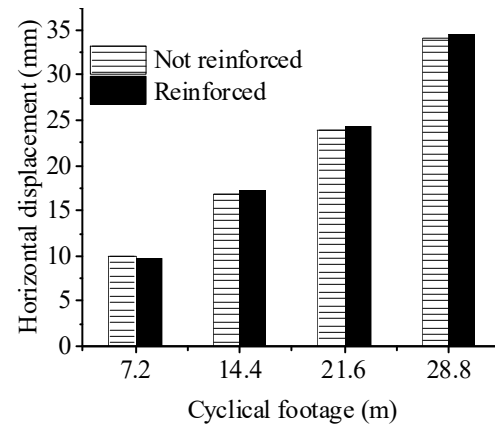


Figure 11 Comparative analysis histogram of the influence of the tunnel face reinforcement on horizontal displacement (cyclical footage: 2.4m)

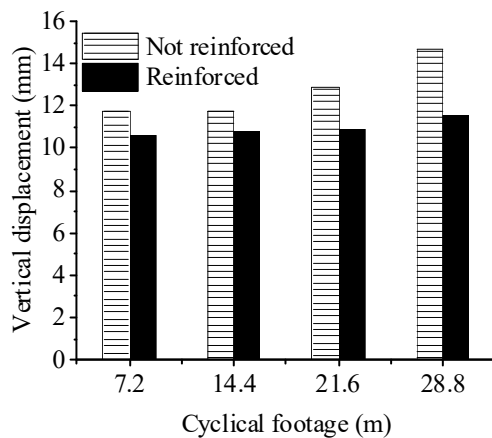


Figure 12 Comparative analysis histogram of the influence of the tunnel face reinforcement on vertical displacement (cyclical footage: 2.4m)

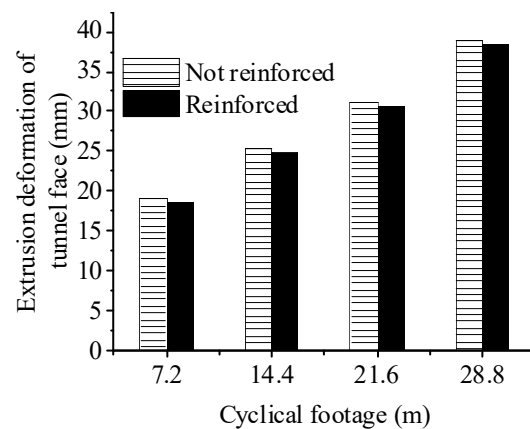


Figure 13 Comparative analysis histogram of the influence of the tunnel face reinforcement on extrusion deformation (cyclical footage: 2.4m)

4.2.2 Comparative analysis of plastic state of surrounding rock. Extract the plastic zone distribution map of the surrounding rock of the tunnel under the conditions of two working conditions (the cyclic footage is 1.8m and 2.4m) when the footage is different at the tunnel face, compare and analyze them, shown in Figure 14~Figure 17.

It can be seen from Figure 14 and Figure 15 that when the cyclic footage is 1.8m and the tunnel face is reinforced, the tunnel face plastic zone is significantly improved during the tunnel entry construction process, and the plasticity shown by the calculation results of the four tunnel face footages is not penetrated. The maximum plastic zone depth in front of the tunnel is also reduced from 3.0m before reinforcement to 1.8m, and the reinforcement effect is more obvious. As shown in Figure 16 and Figure 17, when the circular footage is 2.4m and the tunnel face is reinforced, the tunnel enters the tunnel. During the process, the plastic zone of the tunnel face was significantly improved. The calculation results of the two working conditions of the tunnel face with footage of 7.2m and 14.4m showed no penetration. When the tunnel face footage was 21.6m, the plastic zone of the tunnel face is about to be penetrated and is in a critical state of instability. When the tunnel face is 28.8m in length, the plastic zone of the tunnel face penetrates, and the surrounding rock of the tunnel face should be unstable. The construction safety risk is high, but the maximum plastic zone depth in front of the tunnel face was also reduced from 3.0m before reinforcement to 1.8m, and the face reinforcement played a certain role.

In summary, when the steps on the tunnel face are reinforced with glass fiber anchors, the reinforcement effect is good, which reduces the tunnel face and the development of tunnel face plasticity. When the cycle footage is less than or equal to 1.8m, the tunnel face plastic zone is smaller. , Without penetration, the maximum plastic zone depth in front of the tunnel is 1.8m, the surrounding rock stability is good, and the construction safety risk is low.

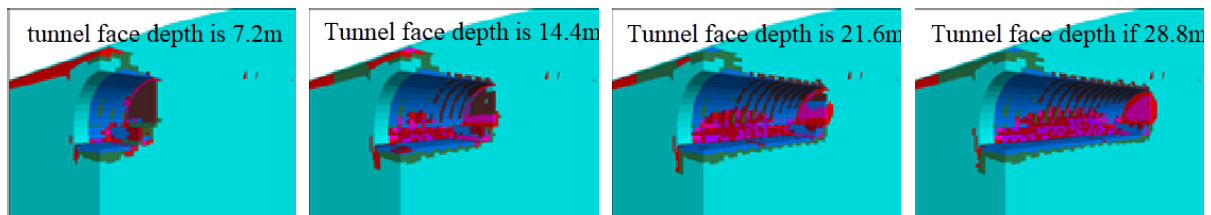


Figure 14 Distribution map of plastic zone of surrounding rock before tunnel face reinforcement (cyclical footage is 1.8m)

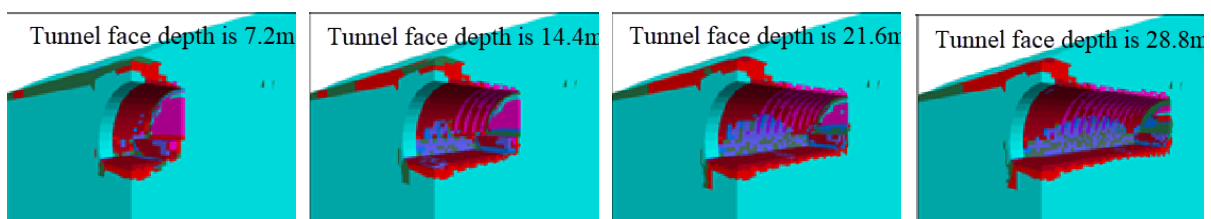


Figure 15 Distribution map of plastic zone of surrounding rock after tunnel face reinforcement (cyclical footage is 1.8m)

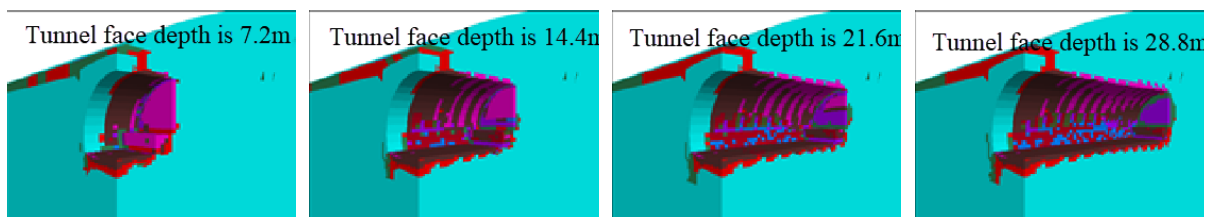


Figure 16 Distribution map of plastic zone of surrounding rock before tunnel face reinforcement (cyclical footage is 2.4m)

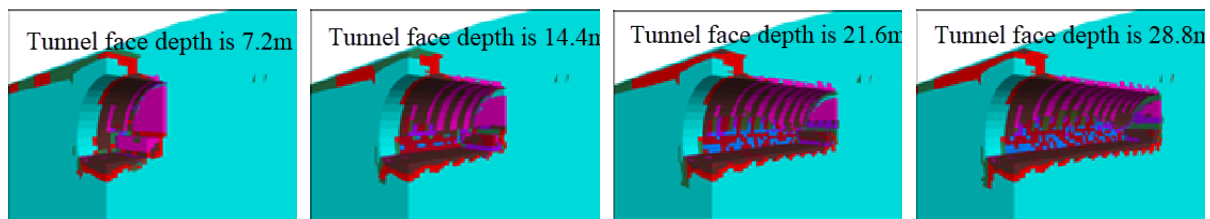


Figure 17 Distribution map of plastic zone of surrounding rock after tunnel face reinforcement (cyclical footage is 2.4m)

5. Conclusion

Through numerical analysis, this paper compares and analyzes the different circular footage (0.6m, 1.2m, 1.8m and 2.4m) in different face (7.2m, 14.4m, 21.6m and 28.8m) when the shallow buried section of the cave entrance is constructed with micro steps, the surrounding rock displacement and plastic zone change of surrounding rock before and after the face reinforcement is adopted, and a reasonable cyclic footage and auxiliary reinforcement measures are proposed. The research results show that:

1) Without reinforcement of the tunnel face, in order to ensure the safety of construction, the circular footage of the mechanized excavation of the tunnel opening section should be controlled within 1.2m, and the overlap length of the leading pipe shed should be greater than 5m.

2) The stability of the tunnel face has a great impact on construction safety. If the efficiency of mechanized construction is to be improved, and the cyclic footage of the excavation of the tunnel opening section is to be increased, the tunnel face must be reinforced.

3) The reinforced effect of fiberglass anchors on the tunnel face is obvious. Under the condition of using fiberglass anchors with a length of 10m and a plum-shaped arrangement of 1.5m to reinforce the tunnel face, the cyclic footage of the tunnel opening section can be increase to 1.8m.

Acknowledgments

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References

- [1] Zhijian Wang, (2018) Research on Key Technologies of Large Section Mechanized Construction of Zhengwan High-speed Railway Tunnel[J]. Tunnel construction ., 38 (8):1257-1270.
- [2] Li Yu, Zhi., Zhilong Wang., Nie Yang., (2018) Study of Measurement and Distribution Characteristics of Surrounding Rock Stress of Large Cross-sectional High-speed Railway Tunnel with Mechanized Construction[J]., Tunnel Construction., 38 (8):1303-1310.
- [3] Jia Tian.,Jinpeng Li, (2018) Application of Mechanized Construction Method to Large Cross-sectional Tunnel with Soft Surrounding Rocks[J]., Tunnel Construction, 38 (8):1350-1360
- [4] Mingnian Wang,Siguang Zhao,Xiao Zhang., (2018) Study of Displacement Control Criterion for Large-scale Mechanized Construction of Tunnels on Zhengzhou-Wanzhou High-speed Railway[J], Tunnel Construction , 38 (8):1271-1278.
- [5] Jiang Liu,Jun Wang,Tenghui Xu, (2018) Research of Swelling Prestressed Bolts Using in Mechanized Excavation of Large Section Tunnel[J]. Tunnel Construction, 38 (S2):324-329.
- [6] Langfeng Bai, (2019) Mechanized Construction Parameters Optimization of Long-Span Highway Tunnel[J]. Journal of Water Resources and Architectural Engineering, 17 (5): 199-202+208.
- [7] Pengfei Li,Yong Zhao,Jianyou Liu, (2014) Deformation Characteristics and Control Method of Tunnel with Weak Surrounding Rock[J]. CHINA RAILWAY SCIENCE, 35 (5):55-61.
- [8] Zheng chen,Ping He,Dumin Yan,et al, (2019) Upper-Bound Limit Analysis of Tunnel Face Stability under Advanced Support[J]. Rock and Soil Mechanics, 40 (6):2154-2162.
- [9] Rourou Cui,Qixin Yang,Yajun Jiang, (2015) Study on Reinforcement Parameters of Fiber Glass

- Anchor Bar at Soft-rock Tunnel Face[J]. RAILWAY STANDARD DESIGN., 59 (11):79-83.
- [10] Bin Li,Taiyue Qi,Zhanrui Wu,et al, (2012) Method for Determination of Reinforcement Parameters of Fiber Glass Anchor Bar for Tunnel Face[J]. JOURNAL OF THE CHINA RAILWAY SOCIETY, 34(10):115-121.
- [11] Xiuying Wang,Weihan Zheng,Jianguo Zhang,et al, (2017) Study on the influence of face stability with pre-reinforcement by glass fiber anchor in soft ground tunnel[J]. CHINA CIVIL ENGINEERING JOURNAL, 50(S1):53-V8.
- [12] Wei Liu, (2013) Research on the effect of pre-reinforcement to the stability of soft rock tunnel face[D], Beijing Jiaotong University.