Digital simulation research of construction risk at the entrance of Shanchongjing tunnel

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Abstract. The tunnel section of the highway tunnel is an important part of tunnel construction. Once accidents such as instability of the side slope and collapse of the palm face occur, it will affect the construction progress at a slight level, and will result in unpredictable economic losses and even casualties. Therefore, in the construction of highway tunnels, the opening section has always been taken as the key point of tunnel construction. Carrying out safety risk assessment on the construction stage of the tunnel section can discover the risks in time, so as to propose reasonable and feasible countermeasures to reduce the risks and reduce the consequences of the risks.

1 Introduction

This simulation is based on the original construction plan using a three-stage construction method for modeling using the MIDAS / GTS finite element software to divide the reservoir into hex meshes. In accordance with the Saint-Venant principle, when stress is redistributed, the stress distribution changes significantly at a location very close to the load. Locations farther from the load have minimal impact, and locations with minimal impact are usually distributed 3-5 diameters from its center of the tunnel. Consequently, the volume of this model is determined as follows: the width of the reservoir model is 100 m, the longitudinal length is 30 m, the tunnel span is 16 m, the lower part of the tunnel is 40 m. The reservoir consists of red alluvial soil, completely weathered sandstone, and sandstone layers with moderate weathering from top to bottom. The size of the one-off cut is 3m, the bed mesh is divided into 3m, and the tunnel mesh is divided into 1~1.5m[1,2].

Figure 1 shows the mesh separation of the three-stage methodical model of the entrance to the Shanchongjing Tunnel. Figure 2 shows the supporting structure of the three-stage method, and Figure 3 shows the three-stage excavation model.

Fig.1 Three-step method to simulate meshing

Fig.2 Supporting structure diagram

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Fig.3 Three-step excavation model

2 Analysis of digital simulation results

In accordance with the original construction plan, a three-stage method was chosen to excavate the entrance of the Shanchongjing tunnel. Using MIDAS / GTS to digitally simulate the diagram, once the calculation is complete, the displacement and stress cloud diagrams can be generated for each stage of the construction of the three-stage calculation mode[3].

(1) Vertical displacement of enclosing rock

Vertical displacement (Z direction) of the enclosing rock after excavation of the first stage and the entire excavation of the portal section of the Shanchongjing tunnel, perpendicular to the plane of the tunnel. Details are shown in fig. 4-5.

[DATA] 三台阶段, S2, INCR=1 (LOAD=1.000), [UNIT] kN, mm

Fig.4 Vertical displacement diagram after the first step of the three-step method is completed (mm)

[DATA] 三台阶段, S13, INCR=1 (LOAD=1.000), [UNIT] kN, mm

Fig.5 Vertical displacement after the completion of all excavations with the three-step method (mm)

It can be seen that the deformation of the enclosing rock gradually increases as the initial stress is removed and subsequent construction steps are taken to excavate the portal section of the tunnel using the three-stage method. After completing the first step of the three-stand method, the maximum vertical displacement (along the Z-axis) occurs directly above the tunnel roof, the value is 10.79 mm, and the maximum deformation of the arch bottom is 18.28 mm. After the completion of the digging of the tunnel, the maximum settlement value also occurs just above the tunnel roof, which is 46.05 mm, and the maximum deformation of the rise of the arch bottom is 69.11 mm.

(2) Horizontal displacement of enclosing rock

The horizontal displacement (X direction) of the enclosing rock after the first stage of excavation and the entire excavation of the Shanchongjing tunnel portal is vertical with respect to the tunnel axis. Details are shown in fig. 6-7.

[DATA] 三台阶段, S2, INCR=1 (LOAD=1.000), [UNIT] kN, mm

Fig.6 Horizontal displacement after the first step of the three-step method is completed (mm)

[DATA] 三台阶段, S13, INCR=1 (LOAD=1.000), [UNIT] kN, mm

Fig.7 Horizontal displacement after the completion of all excavations with the three-step method (mm)

It can be seen that when excavating the portal section of a tunnel with the three-shoulder method, the maximum horizontal displacement (x-direction) is 4.81 mm after the first stage of excavation using the three-shoulder method, which occurs on both sides of the upper bench. After excavation, the maximum displacement in the horizontal direction (x direction) is

21.28 mm, which occurs at the arch chord and arch foot.
(3) Stress analysis of enclosing rock

The tunnel has certain disturbances in the enclosing rock during excavation and tunnel construction. After the initial support is completed, the stress of the enclosing rock will be redistributed to achieve a new equilibrium state. The stress characteristics and distribution law of the enclosing rock can be understood through digital simulations using finite element software, which can provide the necessary basis for tunneling engineers to determine the stability of the enclosing rock. The portal section of the Shanchongjing tunnel is excavated by the three-girder method. The maximum main stress diagram is shown in Figure 8 and the minimum main stress diagram is shown in Figure 9.

Fig.8 Three-step method maximum principal stress diagram (KPa)

Fig.9 Three-step method minimum principal stress diagram (KPa)

It can be seen from this that the stress concentration of the tunnel portal after excavation mainly occurs in the arch, belt and bottom of the arch, the effective tensile stress is 10.85 kPa in the arch and bottom of the arch, and the effective compressive stress is at the level of the hance arch and the arch of the foot. and the above stress values are within the allowable stress range.

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Tab.1 Allowable relative displacement values around the tunnel (%)

Type of enclosing rock	Overburden cover/m		
	<50	50~300	>300
III	0.10~0.30	0.20~0.50	0.40~1.20
IV	0.15~0.50	0.40~0.12	0.80~2.00
V	0.20~0.80	0.60~1.60	1.00~3.00

When monitoring the surrounding tunnel displacement, the distance between the two peripheral convergence measurement points is about 17 m. Therefore, according to the peripheral relative displacement early warning value, the permissible convergence displacement value around the tunnel and the permissible vault settlement displacement are shown in Table 2[5].

Tab. 2 Peripheral maximum displacement value (mm)

Type of enclosing rock	Overburden cover/m		
	<50	50~300	>300
III	25	40	100
IV	40	100	160
V	60	120	240

The actual measurement and the maximum allowable displacement are written as u and U_n respectively. Based on the dynamic construction monitoring scheme, the portal section of the tunnel is effectively controlled and the construction is managed and guided according to the following safety criteria, as shown in Table 3.

Tab. 3 Displacement management level

Managerial class	Management displacement	Construction status
III	$U < (U_n/3)$	Normal construction
II	$(U_n/3) \leq U \leq (2U_n/3)$	Reinforced mount required
I	$U > (2U_n/3)$	Excavation works must be stopped immediately and special measures must be taken

3 Conclusions

The portal section of the tunnel is designed with a depth of 10.5 m, which is less than 50 m, and its enclosing rock has a degree of v . According to table 3 of the tunnel, it can be seen that the maximum allowable displacement of the surrounding convergence of the draft of the tunnel roof is 60 mm. Based on the analysis of the digital simulation results, it can be seen that during the

excavation process, the horizontal displacement has a maximum value in the hance of the arch, which is 21.28 mm, and the result is between $U_n/3 \sim 2U_n/3$, which refers to the level of level movement control II, and support needs to be strengthened; the maximum vertical subsidence of the enclosing rock occurs at the top of the arch of 46.05 mm, and the result exceeds $2U_n/3$, which is related to the level of displacement control of the 1st degree. Therefore, earthworks should be stopped immediately and special measures should be taken. To summarize, it can be seen that the portal section of the tunnel faces serious potential safety hazards during the construction process, so earthworks should be stopped immediately and a number of tunnel strengthening measures should be taken to provide a reliable guarantee for the safety of tunnel construction.

References

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