Influence of Rock Quality and Excavation Mode on Horizontal Displacement of Crushing-zone Tunnel

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Abstract. In order to simulate the tunnel excavation of super-long broken rock zone, finite element analyses using Plaxis3D are carried out along with the construction, in which the influence of grade of surrounding rock, are excavation method on the deformation of tunnel are specially considered. Before numerical calculation, the parameters are reasonably simplified. The calculation results show that the CD method can efficiently reduce the deformation of rock in the broken zone to keep the stability. In the practical construction, it is recommended that the CD method is preferred when entering the broken zone.

1. Background

With the rapid development of domestic economy and traffic construction, the high-level expressway is continuously planned and constructed. Some of the expressways go through the mountain ridge where the fracture rock and the fracture water develop very well and the weight of the soft rock occupies greatly. The methods for stability analysis of enclosing rock of highway tunnel are listed in Table 1. For the construction method of the broken enclosing rock, there are plenty of researches. Yuan and Yang[1] analysed the distribution of displacement field and stress field under three different construction methods to analyse the influence factors on the safety and economy. Huang et al. [2] carried on a series of finite difference simulation for broken-zone tunnel using various construction methods. Wang and Bi [3] summarized the characteristics of stress and strain with different methods. Due to the multiple categories of tunnel enclosing rock and the construction methods, a numerical calculation is carried out using finite element method to analyses the influence of rock stability [4-7]. Several numerical models are built to observe the detailed displacement and stress. The comparison among the excavation method and the rock level is made to guide the practical construction.

Table 1 Stability analysis method of tunnel

| Method             | Advantage                      | Applicable condition       |
|--------------------|--------------------------------|-----------------------------|
| analytical method  | High precision, rapid analysis | for circle tunnel           |
| FEM                | easy to apply, abundant results| for elastic, elasto-plastic |
| discontinuous deformation | integrated block theory       | for discontinuous problem  |
2. Engineering profile and finite element model
The proposed new tunnel is a separated tunnel which includes the left part and the right part. The length of the left part is 2440m and the maximum depth of embedment is 128.85m. The length of the right part is 2425m and the maximum depth of embedment is 137.81m. The geological condition is mainly structural corrosion erosion landform. The shallow buried depth of the tunnel is 21-24m. The basic quality index (BQI) is about 204.37 and the level of the surrounding rock is classified into V2. The rock is mainly conglomerate with medium-strong cementation. The fracture contains block stone and gravel and its ingredient is limestone and dolostone. The particle size is between 10 and 30cm.

According to the design drawing of the tunnel section, the skeleton line is built using the multiple-line function. The research object is the left part of the tunnel and the classification of the enclosing rock is V2 level, where the CD method is used and the advanced support uses the advanced leading conduit with diameter of 42mm. The stratum is divided into two layers. The upper layer is filling and the broken zone is located at the lower layer. Considering the boundary effect of the model, the horizontal calculation magnitude is 30m distance to the right and left boundary from the centre of tunnel face. The magnitude in the drilling direction is 50m and the depth is 60m.

3. Calculation results
In the numerical calculation, there is great influence of the choose of the parameters on the calculation results. The perfect calculation procedure should be the comparison between the calculation and practical monitoring at the initial stage. The continual adjustment of the parameters should be carried out the make the difference between the calculation and the monitoring is very small. Then, the
adjusted parameters are used to make further analysis. However, most of the calculation are carried out far before the construction and there is no monitoring data to refer. In order to evaluate the influence factors of construction method and surrounding rock classification on the deformation of the tunnel, the qualitative analyses are carried out and the calculation scheme is listed in Table 2.

Table 2 Calculation scheme of finite element

| Elastic modulus/excavation method | CD method | three-step method |
|-----------------------------------|-----------|-------------------|
| 600MPa                            | Case 1    | Case 2            |
| 100MPa                            | Case 3    | Case 4            |

Figure 2. Comparison of horizontal displacement for four schemes

Figure 3 demonstrates the distribution of the horizontal displacement of the left part of the tunnel. As can be seen, with the excavation of the tunnel keeping on, there is obvious horizontal displacement on the left and right boundary of the tunnel. Due to the asymmetry of the CD support method, the maximum settlement and uplift is not located at the centre of the tunnel axial line, which is different from the three-step method. The maximum horizontal displacement for four schemes are 5.25mm, 5.88mm, 21.66mm, 30.57mm respectively. When the elastic modulus of the enclosing rock is 600MPa, the maximum horizontal displacement of CD method decreases about 12% compared with
the three-step method. In addition, due to the asymmetry of CD excavation, the influence area is larger at the right side and the maximum horizontal displacement also locates here. Therefore, the anchor-ejection support should be carried on timely to shorten the exposing time.

| E (MPa) | Excavation method | CD method | Three-step method |
|--------|-------------------|-----------|------------------|
| 600    | 5.25              | 5.88      |                  |
| 100    | 21.66             | 30.57     |                  |

4. Conclusions
The paper carried out a series of numerical calculation to evaluate the excavation method and elastic modulus of enclosing rock on the deformation of the ultra-long broken-zone tunnel. The conclusion are as follows:

(1) During the numerical analysis of stability and deformation of tunnel excavation, the calculation parameters should be simplified to some extent to improve the calculation efficiency.

(2) The maximum horizontal displacement for four schemes are 5.25mm, 5.88mm, 21.66mm, 30.57mm respectively.

(3) When the elastic modulus of the enclosing rock is 600MPa, the maximum horizontal displacement of CD method decreases about 12% compared with the three-step method.

(4) It is recommended that CD method is used to decrease the deformation of enclosing rock during excavation effectively and to keep the stability of the rock. During the practical excavation construction, CD method can be used when the tunnel is excavated at the initial stage.

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