

Model Test Study on the Influence of Supporting Structure on the Long-Term Stability of Tunnel Surrounding Rock

Zou Xin¹, Lin Guoqiang¹, Niu Qun²

¹China Railway Liuyuan & Xi'an Survey, Design and Research Institute Co., Ltd, of CREC, Xi'an, Shaanxi Province, China

²Institute of Geotechnical Engineering, Xi'an University of Technology, Xi'an, Shaanxi Province, China

1246675979@qq.com

Abstract: *Objective: To explore the influence of different supporting structures on the long-term stability of tunnel surrounding rock. Methods: establish the mechanical model of tunnel surrounding rock, and explore its influence on the model shape by changing the support structure parameters. Results: different supporting structures will affect the shape of tunnel surrounding rock model, indicating that it has a certain impact on the long-term stability of tunnel surrounding rock. Conclusion: when carrying out tunnel surrounding rock support, four reasonable support parameter design schemes, such as 0.5m structural plane spacing and 75 °~90 ° inclination angle, can be selected to ensure the safety and stability of tunnel surrounding rock to the greatest extent.*

Keywords: Supporting structure; Impact model; Stability; long-term; Tests; Tunnel surrounding rock

1. Introduction

Most of the tunnel projects have the characteristics of deep, large and long. Under unfavorable geological conditions, the surrounding rock of the tunnel often has engineering disasters such as mud intrusion and water inrush. The tunnel surrounding rock is supported by means of protective structure [1]. In order to give full play to the effectiveness and value of the support structure in tunnel engineering, the influence of the support structure on the stability of the tunnel project should be clearly defined. Impact model test studies.

2. Materials and methods

2.1. Test objects

In order to explore the influence of support structure on the long-term stability of tunnel surrounding rock, the surrounding rock in the area of a tunnel construction project is selected as the research object. Aiming at this surrounding rock structure, its mechanical model is constructed. It is known that the surrounding rock in the area where the tunnel construction project is located is mainly dolomitic limestone and limestone. The mountain karst is developed vertically, and the ground is widely distributed in depressions and sinkholes. At the same time, the karst development in this area is obvious, and there is more fissure water. When carrying out the construction in this area, it is necessary to implement the advance geological prediction in time to ensure the construction safety. Using the method of numerical analysis, when the tunnel surrounding rock contains large-scale structural planes in the rock mass, it is abstracted as a continuum model [2]. When modeling, it is assumed that the surrounding rock of the tunnel is homogeneous and the elastoplasticity in all directions is the same. On this basis, the changes in the simulation process of each element in the model are determined. BEAM6 curved beam element is used as the basic structure of tunnel surrounding rock model in FINAL. At the same time, the following formula can also be used to describe the stress of the tunnel surrounding rock model:

$$\sigma_{\max} = \frac{3q}{B'h^2} D^2 + \frac{q}{5} \quad (1)$$

In the formula: σ_{\max} represents the maximum normal stress in the surrounding rock of the tunnel; q represents the additional load; B' represents the effective span of the surrounding rock of the tunnel; h represents the thickness of the surrounding rock of the tunnel; D represents the span of the surrounding rock of the tunnel. Figure 1 shows the mechanical model of the roof structure of the surrounding rock tunnel.

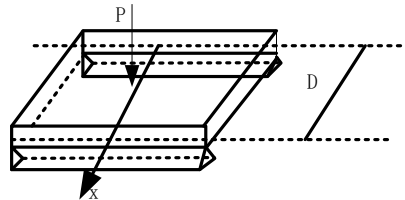


Figure 1: Mechanical model of roof structure of surrounding rock tunnel

In Figure 1, P is the sum of the additional load and hydrostatic pressure generated by the filler in the tunnel surrounding rock. The mechanical model of surrounding rock tunnel roof structure constructed above is a relatively simple constitutive model, which includes two variables: elastic modulus and Poisson's ratio, in addition to load and hydrostatic pressure. When the roof structure of surrounding rock tunnel is subjected to external force, its structure may deform. At this time, when the applied external force is removed, the material will gradually return to its original state without residual deformation. This model can be used to simulate the relevant parameters when the support structure affects the long-term stability of tunnel surrounding rock, and the impact analysis can be realized by observing the specific changes of the model.

2.2. Test method

Based on the above mechanical model, in order to explore the influence of support structure on the long-term stability of tunnel surrounding rock, a variety of different support structures are selected as test conditions to explore the stress changes of tunnel surrounding rock mechanical model when the support structure changes. The test is carried out on MIDAS-GTS numerical simulation software, and the simulation of specific working conditions is realized by using the application advantages of this software, such as simple modeling and comprehensive analysis of working conditions. In MIDAS-GTS numerical simulation software, the mechanical model of the above surrounding rock tunnel roof structure can be established according to the following process: Step 1, build the solid model, and obtain the constitutive parameters required for model establishment in the software through the solid model; Step 2, complete the division of the model from one-dimensional to three-dimensional meshes in the software; Step 3: according to the test needs, impose corresponding constraints on the boundary position of the model; Step 4: apply gravity and fixed load according to the actual surrounding rock conditions of the tunnel; Step 5: according to the above selected tunnel construction project, set each stage of the project, and make a specific analysis for the working conditions of each stage; Step 6: generate the final mechanical model through post-processing technology, and extract the data required for the subsequent analysis of the test. According to the above six steps, the mechanical model of surrounding rock tunnel roof structure is modeled in MIDAS-GTS numerical simulation software. On this basis, the change of the support structure can be fully reflected in its structural plane spacing and inclination. Therefore, four different spacing conditions of 0.5m, 0.8m, 1.5m and 2.0m and three inclination conditions of $75^\circ \sim 90^\circ$, $15^\circ \sim 30^\circ$ and $0^\circ \sim 40^\circ$ are set to analyze and judge the shape of the tunnel surrounding rock model, so as to explore the impact on its long-term stability.

3. Analysis and discussion of test results

After clarifying the test object and test method, record the influence of the support structure on the mechanical model of the surrounding rock of the tunnel under the conditions of different spacing and inclination, and draw it as shown in Table 1.

Table 1: Effects of different support structures on the long-term stability of tunnel surrounding rock

Support structure		Model form
Structural surface spacing (m)	Inclination (°)	
0.5	75~90	Intact
0.8	15~30	
1.5	0~40 75~90	
0.5	0~40	Drop block
2.0	15~30	
0.5~0.8	0~40	Collapse

The shape of the model has gone through three stages, from intact to falling blocks, and then to collapse. In this process, it is obtained through the mechanical model constructed above that the σ_{\max} value shows a gradually decreasing trend. Combining with the data in Table 1, it can be seen that when the structural plane spacing and inclination angle change, the shape of the model will gradually change, and the maximum normal stress it can withstand also changes. Based on the results obtained in Table 1, in order to ensure the long-term stability of the tunnel surrounding rock, the first four support structure parameter schemes in Table 1 can be selected to ensure the quality of the tunnel surrounding rock and construction work. In addition, during the test, it is also found that the stability of tunnel surrounding rock has also changed by changing the distance between bolts on the support structure. When the distance between the bolts increases, the axial force of the bolt at the arch foot of the corresponding support structure will gradually decrease and then increase, and the higher the value increases later. At the top of the tunnel surrounding rock, the axial force of the supporting structure will increase with the increase of the distance between the bolts. With the decrease of the distance between the axes of the anchor rods, the concentration range of the axial force of the anchor rods is further expanded. At this time, the value of the axial force gradually decreases. For the tunnel surrounding rock, under the long-term action, it can significantly change the reverse impact of the karst cave on the tunnel support structure at the arch waist of the tunnel surrounding rock. Based on the above tests and the test results obtained, with the reduction of the distance between bolts, the settlement and convergence deformation of tunnel surrounding rock can be improved to a great extent, which has a more positive effect on the long-term stability of tunnel surrounding rock; On the contrary, with the increase of the distance between the bolts, the settlement and convergence deformation of the tunnel surrounding rock will gradually increase, which has an adverse impact on the long-term stability of the surrounding rock. When the distance between bolts increases to a certain level in Chengdu, excessive bolt spacing will cause the deformation trend of tunnel surrounding rock, and certain deformation will occur in the longitudinal and transverse directions of tunnel surrounding rock. Therefore, when setting the support structure, the spacing distance between bolts cannot be increased. Through more in-depth analysis, it is concluded that for the construction project on the surrounding rock of the tunnel, when setting the support structure, the best distance between the anchor rods should be within the range of 0.6m~0.8m. According to the actual construction conditions and project scale, the specific value of the distance between the anchor rods should be reasonably selected within this range. During the actual tunnel surrounding rock support construction, in order to ensure that the quality of the tunnel construction project can meet the ideal requirements, the whole scope of the construction project should be monitored by means of monitoring, and detailed sequencing should be carried out according to the obtained monitoring data, so as to avoid irreversible engineering problems caused by the influence of the support structure during the construction process. At the same time, in view of the existing engineering problems, we need to find them in time and take effective remedial measures. Combined with the results of the above tests in this paper, we can achieve better guidance for the engineering practice.

4. Conclusion

In this paper, the influence of different supporting structures on the long-term stability of tunnel surrounding rock is studied by constructing the mechanical model of tunnel surrounding rock. Through the research results, it can be seen that during the tunnel surrounding rock construction, the supporting structure should be reasonably set, and the details should be adjusted according to the actual situation on site, so as to ensure the overall stability and safety of the surrounding rock to the greatest extent.

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