Determination of Optimal Support Timing for Pumped Storage Power Station Tunnels Based on Displacement Release Rate

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Abstract. The optimal timing of support is difficult to determine due to the excavation of the tunnel.This paper proposes a method for determining the optimal support timing of pumped storage power station tunnels based on the displacement release rate, using the indicator of the distance between the support and the palm face as a judgment of the support timing, and when the excavation load release rate reaches a certain value during the excavation process, the peripheral rock displacement increment will have a steep increase in the point of the excavation load release rate to reach the time of the excavation load release rate to determine the time of the optimal timing of the initial support. This method can maximize the self-supporting capacity of the surrounding rock and minimize the support load. Three-dimensional modeling simulation is used to apply this method as an example.

Keywords: Displacement release rate, support timing, perimeter rock displacement, perimeter rock, pumped storage power plant

1 INTRODUCTION

The safety of surrounding rock and supporting structure is the main content of supporting structure design, and the excavation of underground project will inevitably cause disturbance to the stress field of surrounding rock, so that stress release and unloading deformation of surrounding rock will occur[1]. For underground projects with poor geological conditions, the self-stabilizing ability of the surrounding rock is generally poor after excavation is completed, and the surrounding rock needs to be supported to ensure the stability of the surrounding rock[2]. There are many factors affecting the stability of the surrounding rock, on the one hand, due to the underground project is located in a very complex environment, the original rock stress, structural surface, rock parameters, groundwater, etc[3,4]. will affect the stability of

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the surrounding rock. On the other hand, some engineering factors, including the scale of underground engineering, construction methods, support structure, support timing, etc. will also affect the stability of the surrounding rock[5].

The stress release of the surrounding rock has an important influence on the design of the support structure, and the stress release of the surrounding rock is closely related to the application time of the support structure[6]. Support too early, the surrounding rock stress release is less, resulting in the support structure needs to share most of the excavation load with the surrounding rock, which must increase the strength of the support structure, resulting in an increase in the cost of support, and even lead to the destruction of the support structure when the load is too large[7]. Support too late and will make the surrounding rock due to the stress release is too large to make the surrounding rock stress state deterioration, the support structure can not play a proper role, resulting in a waste of support materials, so choose a reasonable support timing has become the key to support design. Most of the existing studies on the optimal support timing tend to favor the qualitative evaluation of the support effect, and fail to give effective and feasible control conditions or selection methods, which affects the application of these methods in the actual project[8]. In view of the problems faced by the current support timing theory, it is necessary to propose a simple and effective index to guide the determination of the optimal support timing for underground chambers[9,10].

2 LONGITUDINAL DEFORMATION CURVE AND DISPLACEMENT RELEASE RATE

After the tunnel excavation, the deformation of the surrounding rock in the early stage is mainly reflected in the spatial effect of the excavation surface, so the spatial effect of the excavation can be visualized by the longitudinal deformation curve of the surrounding rock (LDP).

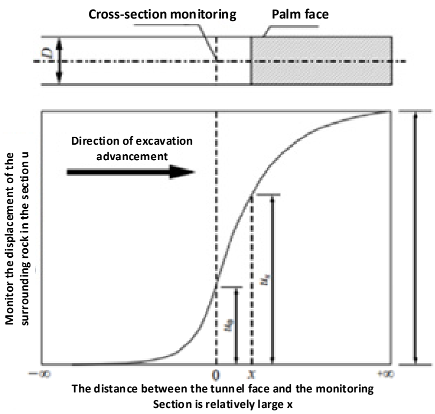

Fig. 1. Schematic diagram of longitudinal deformation curve of surrounding rock

As shown in Fig. 1, the deformation value of the surrounding rock when the palm face reaches the monitoring section is, and the deformation value of the surrounding rock when the palm face is at a distance x from the monitoring section is u_0 , and the final deformation value of this point when the palm face leaves far enough away is u_∞ . In order to reflect the degree of convergence of the surrounding rock during the advancement of the palm face, the longitudinal deformation value of the surrounding rock is normalized and the displacement release rate λ is defined as:

$$\lambda = \frac{u_x}{u_\infty} \tag{1}$$

3 BASIS FOR SELECTING THE OPTIMAL TIMING OF SUPPORT

Refuge excavation is both a stress release process and a displacement release process, and there is a very close relationship between the two. At the beginning of the excavation load release process, the deformation of the surrounding rock increases with the increase of the excavation load. At this time, because the surrounding rock stress is in an elastic state, the incremental deformation of the surrounding rock and the rate of release of the excavation load are in a linear relationship, and as the rate of release of the excavation load increases, the surrounding rock enters into a plastic state gradually, and the displacement of the surrounding rock increases steeply after reaching a certain rate of release of the excavation load. It can be determined as the time point of the best initial support timing.

4 STEPS FOR DETERMINING OPTIMAL SUPPORT TIMING

For underground tunnels, the steps for determining the optimal timing of support based on the displacement release rate are as follows:

4.1 Step 1

Firstly, a two-dimensional numerical calculation model of the tunnel is established, the tunnel is excavated at one time, and the excavation load is released in phases for calculation, and the relationship curves between the excavation load release rate and the displacement increment and displacement release rate of the monitoring points on the monitoring cross-section are plotted according to the simulation results of the different load release rates, and the excavation load release rate corresponding to the optimal time of the support is established according to the characteristics of the curve of the excavation load release rate-displacement increment as shown in Fig. 2; On this basis, the displacement completion rate corresponding to the optimal support timing was determined based on the relationship curve between the excavation load release rate and the displacement release rate.

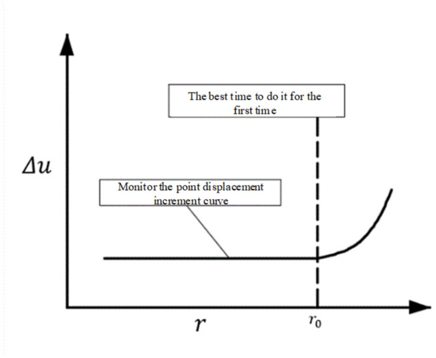

Fig. 2. Relationship between excavation load release rate and displacement increment

4.2 Step 2

Secondly, the three-dimensional numerical calculation model of the tunnel is established, and the excavation process is simulated by step-by-step excavation, i.e., starting from one end of the tunnel and gradually advancing to the other end, so as to obtain the displacement change curves of each monitoring point in the process of step-by-step excavation, and to draw longitudinal deformation curves of the tunnel, and on the basis of which, to obtain the relationship curves of distance of the palm face from the monitoring cross-section and the displacement completion rate, which is shown in Fig. 3.

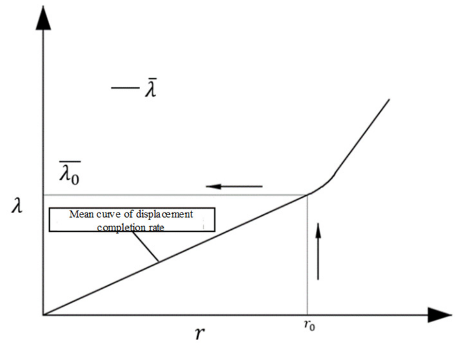

Fig. 3. displacement diagram

4.3 Step 3

Finally, according to the determined displacement release rate in step 1 and based on the distance-displacement completion rate relationship curve of the palm face from the monitoring section obtained in step 2, the distance between the corresponding support location and the palm face is checked, as shown in Fig. 4.

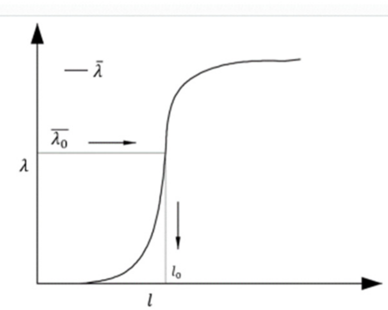

Fig. 4. Schematic diagram of longitudinal deformation curve of surrounding rock

5 EXAMPLES OF APPLICATIONS

5.1 Numerical Model

A tunnel with a burial depth of 300 m is selected, and the size of the chamber is 8.0 m×8.5 m. According to the shape and size of the chamber, Establish a three-dimensional numerical calculation model, see Fig. 5. In the numerical simulation, In order to obtain the longitudinal deformation curve of the surrounding rock, a monitoring section was arranged in the three-dimensional calculation model, and four monitoring points were placed on the section. The monitoring section is located at the center of the tunnel axis.

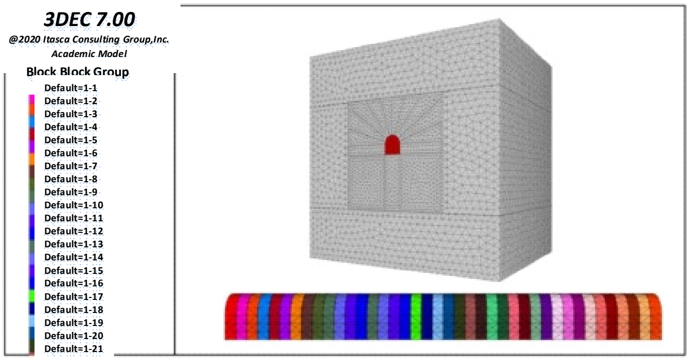

Fig. 5. Three-dimensional computational modeling and monitoring sections

5.2 Calculation Parameters

The numerical calculation model is the Moore-Cullen elastoplastic model, and the calculated parameters of the rock mass are shown in Table 1.

Table 1. Parameters for numerical calculations of rock masses

	Parameter name			
	E（*GPa*）	*υ*	*φ*(°)	*c*(*MPa*)
value	15.0	0.23	40.0	1.0

5.3 Determination of Optimal Support Timing

Determine the Excavation Load Release Rate and Displacement Release Rate Corresponding to the Optimal Support Timing.

As shown in Fig. 6, the curves of the relationship between excavation load release rate and displacement increment at different monitoring points are given. From the figure, it can be seen that there is a sudden change in the curve excavation at the monitoring point when the excavation load stress release rate is 70%, so it is determined that the excavation load stress release rate corresponding to the optimal support timing is 70%.

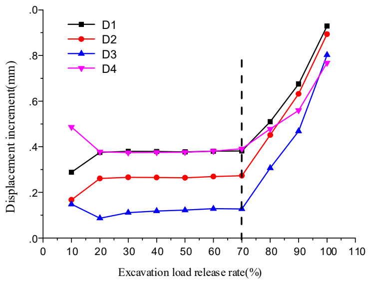

Fig. 6. Excavation Load Release Rates and Displacement Increments at Monitoring Points

As shown in Figure 7, the curves of excavation load release rate versus displacement release rate at different monitoring points are given.

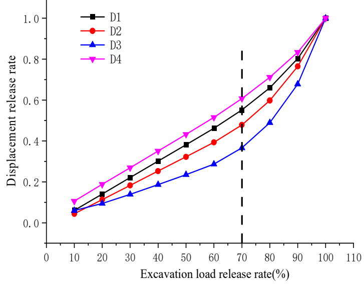

Fig. 7. Excavation Load Release Rates and Displacement Release Rates at Monitoring Points

In order to synthesize the effects of each monitoring, the displacement release rate of all monitoring points was evaluated, and the relationship curve between the excavation load release rate and the displacement release rate for the whole section was obtained, as shown in Fig. 8. As it can be seen in the figure, the displacement release rate corresponding to an excavation load release rate of 70% is about 0.6.

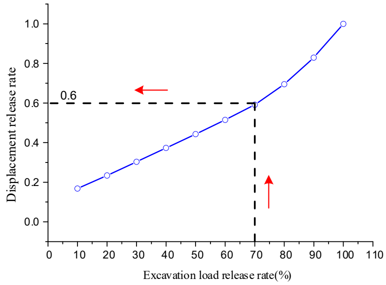

Fig. 8. Curve of load release rate versus displacement release rate for the whole section excavation

Determine the Best Time to Support.

Using 3D step-by-step excavation simulation, the longitudinal deformation curve of the surrounding rock during excavation was obtained, see Figure 9.

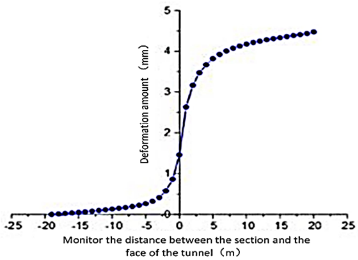

Fig. 9. Schematic diagram of longitudinal deformation curve of surrounding rock

Further by homogenization, the displacement release rate curve during excavation was obtained as shown in Fig. 10. From this figure, the distance corresponding to the best support timing can be found based on the displacement release rate determined earlier. From the figure, it can be determined that a displacement release rate of 0.6 corresponds to a distance of about 2 m from the palm face, i.e., the optimal support timing corresponds to a distance of 2.0 between the support and the palm face.

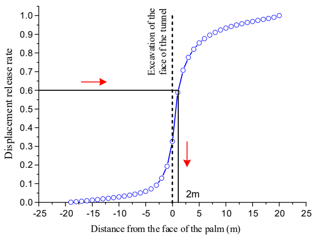

Fig. 10. Displacement release rate curves

6 CONCLUSION

Pumped storage power station tunnel excavation has been the existence of the best support time is not easy to determine the problem, support too early will lead to the support structure needs to share most of the excavation load with the surrounding rock, the need to increase the strength of the support structure, resulting in an increase in the cost of support. Supporting too late will make the support structure can not play a proper role, resulting in a waste of support materials. In view of the above problems, this paper proposes a method for determining the optimal support timing for pumped storage power station tunnels based on the displacement release rate, which can maximize the self-supporting capacity of the surrounding rock and minimize the support load. Determine the optimal support time for pumped storage power station tunnel excavation Optimal support time.

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