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Stability Analysis of Tunnel Upward-slope in Marshy Soil Layer of High Altitude and Cold Region

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Abstract

It is very important to control the stability of upward-slope during excavation. In this paper, finite element numerical simulation software is used to analyze the distribution of plastic zone and the increment of horizontal and vertical displacement of upward-slope during excavation, so as to evaluate the stability of slope during excavation. The results show that as the plastic zone area of the upward-slope continues to expand, the plastic zone area reaches the maximum after the completion of the upward-slope excavation, and the upper and lower parts of the slope tend to be transfixed from the high terrain to the low terrain plastic zone. After the completion of the upward-slope excavation, a new face is formed, and a large displacement is generated from the upward-slope to the direction of the face. The maximum displacement is mainly concentrated in the upper left of the upward-slope, and a large uplift occurs at the bottom of the slope platform. The maximum horizontal displacement of the left slope is mainly concentrated near the second and third grade slopes, and the maximum horizontal displacement is about 4cm. The maximum horizontal displacement of the right slope is mainly concentrated at the first grade slope, namely the foot of the slope, and the maximum horizontal displacement is about 4cm.

Keywords

High Altitude Cold Region; Marshy Soil Layer; Transfixion of Plastic Zone; Stability.

1. Introduction

With the development of western China and the continuous promotion of the "One Belt and One Road" strategy, the construction of tunnel engineering has been greatly developed, the construction of tunnels often need to pass through mountains, shallow buried bias, loose rock fragmentation, including weak interlayer and other bad geological phenomena occur. In accordance with the principle of "early entry and late exit", an open tunnel should be built at the entrance to make the tunnel enter safely and smoothly. It is necessary to study the influence of slope excavation on the stability of side slope.

Many scholars have studied the influence of slope excavation on the stability of side sloping slope. B XIONG [1] et al. calculated the stress field and displacement field of the slope under the natural state and excavation and support condition respectively by combining the large finite element software ANSYS with geotechnical engineering calculation, analyzed the calculation results in detail, and made a qualitative evaluation of the slope stability. C Zhao [2] et al. took the high and steep slope of the cable platform of Jinping Hydropower Station as an example and carried out numerical simulation calculation of its graded excavation and support process by using the finite element method, and analyzed the influences of different single-stage excavation heights, rock mass strength parameters and support time on the deformation and stability of the high and steep slope. The results showed

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that: The deformation and safety factor of slope are greatly affected by the strength parameters of rock mass. Under the condition of good rock mass, the single-stage excavation height and support time have little influence on the deformation and safety factor of slope, while under the condition of poor rock mass, the single-stage excavation height and support time have significant influence on the deformation and safety factor of slope. X J Li[3]et al. conducted a numerical simulation study on the layered excavation of the foundation pit inverted slope, analyzed the deformation rules and characteristics of surrounding rock caused by the excavation of the inverted slope under different supporting modes, and conducted safety analysis on the excavation process of deep foundation pit combined with real-time monitoring data on site.

2. Analysis of Influencing Factors of Upward-slope Stability

(1) Influence of the water

As the saying goes, "treat slope first and treat water first", many side slope instability slip are closely related to the action of water. Water penetrates into the rock and soil body through cracks or joints in the rock and soil body of the slope, which increases the weight of the rock and soil, increases the sliding force and reduces the shear strength of the slip surface, and forms the seepage channel, thus causing the slip of the slope body.

(2) Influence of climate

Climatic conditions mainly include temperature conditions and humid conditions. Due to the change of temperature, the freezing of water in rock and soil produces frost heaving effect on soil, and the high temperature in summer melts the ice-filled body. This repeated freezing-thawing cycle will greatly reduce the strength parameters of rock and soil, thus affecting the overall stability of slope.

(3) Landform

There is a close relationship between the slope and its stability. The larger the slope is, the more unstable the slope is. The slower the slope is, the more stable the slope is.

(4) The construction disturbance

The natural side slope basically maintains a relatively stable state under the action of dead weight, and human engineering activities will destroy this natural balance. When the slope body is excavated, the original stress balance state in the slope body will be changed, and a series of engineering geological disasters will be induced.

3. Method for Upward-slope Stability Analysis

MIDAS/GTS is used to analyze the stability of inverted slope during excavation. MIDAS/GTS is developed by Visual C++ in Windows environment under the joint efforts of domestic and foreign professional and technical personnel and experts in geotechnical tunnel field, and taking into full consideration the needs of actual engineering designers. It not only has the analysis function of general software, but also has the latest development analysis program technology in the field of geotechnical and tunnel engineering. It also provides powerful functions including static analysis, response spectrum analysis, construction stage analysis, time history analysis and eigenvalue analysis, stable flow analysis and unstable flow analysis. It can also be used for seepage analysis, stress analysis, dynamic analysis and stress-seepage coupling analysis, lining analysis and slope stability analysis. The steps of problem analysis can be summarized as follows:

(1) The model is discretized and divided into several small elements. (2) the relationship between node force and node displacement is solved. (3) The balance equation is established for each small element (4) Applying load (5) introducing boundary conditions (6) result calculation.

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4. Analysis of Simulation Results

4.1 Plastic Zone Distribution

The plastic zone can directly reflect the failure degree of rock and soil mass and has a great influence on the stability of side slope. The following figure 1-6 shows the distribution cloud of plastic zone under graded excavation of slope. Figure 1-6 shows that:

The plastic zone area of the whole slope is small under the gravity stress state, and mainly concentrates on the upper part of the slope. With the continuous expansion of the plastic zone area of the inverted slope, a large plastic zone also appears in the lower part of the slope. After the completion of the slope excavation, the plastic zone area reached the maximum, and the upper and lower parts of the slope showed a trend of transconnecting from high terrain to low terrain plastic zone, and a certain range of plastic zone also appeared in the middle of the slope[4]. The results show that the excavation of slope toe slope will have damage effect on rock and soil mass in a large range, and the penetration of plastic zone indicates that the slope body has the risk of sliding or even large-scale landslide.

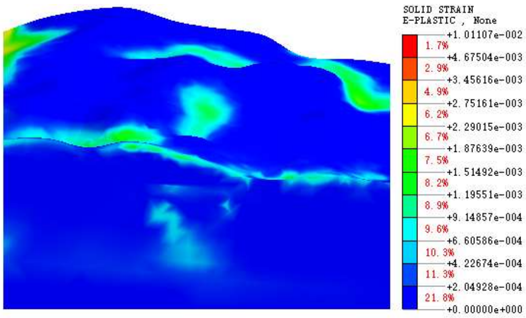

Figure 1. Initial state

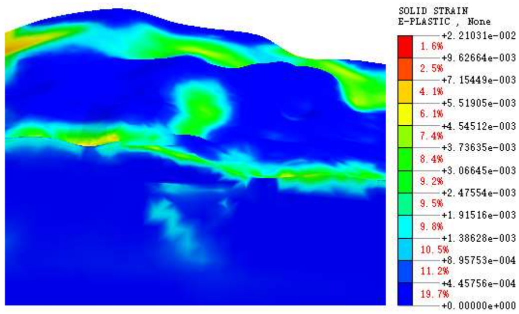

Figure 2. Five-stage inverted slope excavation

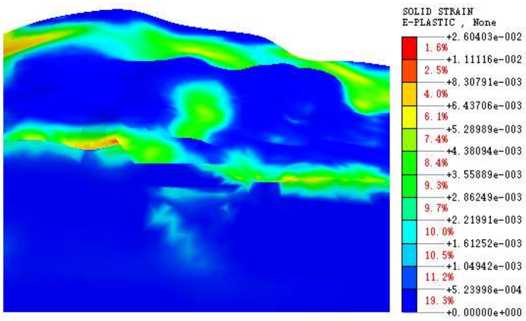

Figure 3. Four-stage elevation slope excavation

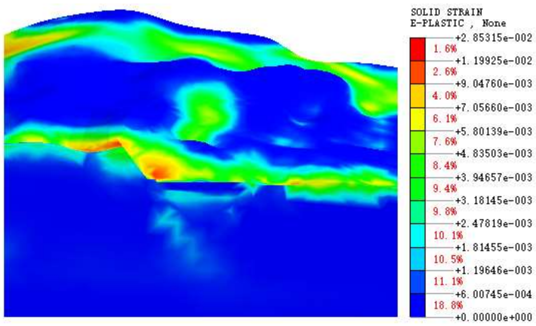

Figure 4. Three-stage elevation slope excavation

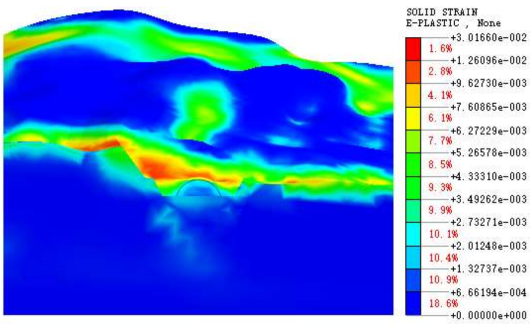

Figure 5. Secondary elevation slope excavation

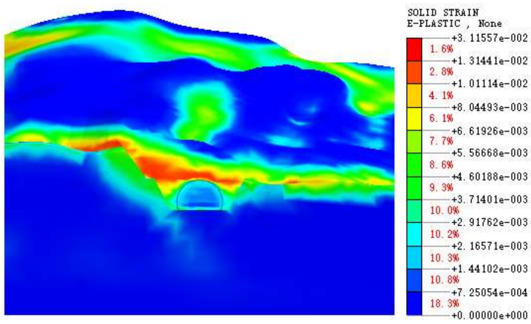

Figure 6. Primary elevation slope excavation

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4.2 Analysis of Upward-slope Displacement

The displacement increment of the slope after excavation can reflect the influence degree of construction disturbance. Figure. 7-8 are the cloud diagrams of the displacement increment in Y direction and Z direction of the inverted slope after the completion of the excavation. As can be seen from the figure:

It can be seen from Figure. 7 that a new open face is formed after the excavation of the slope is completed, and a large displacement is generated in the direction of the open face. The maximum displacement is mainly concentrated in the upper left of the slope, and the maximum value is as high as 12cm, which is highly likely to lead to collapse and instability[5]. The figure 8 shows that after the completion of the back slope excavation near rock mass produce larger pile displacement, maximum uplift is mainly concentrated in the slope at the bottom of the platform, the maximum value of up to 13.2 cm, the reason for this phenomenon is mainly of upward slope excavation near broken rock mass stress state of equilibrium, the internal stress redistribution in geotechnical engineering, and because a excavation earthwork quantity is larger, The serious unloading of rock and soil mass resulted in large uplift displacement.

The above analysis shows that the excavation of the slope will cause uncontrollable deformation of the slope body, which is almost unstable. If the slope body is not supported in time after excavation, the slope body will slide along the direction of the open surface.

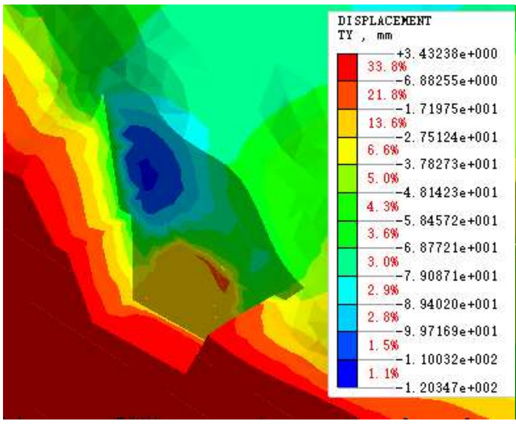

Figure 7. Displacement increment in Y direction

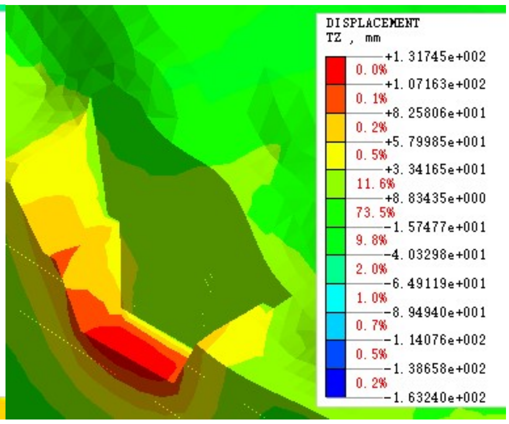

Figure 8. Displacement increment in Z direction

4.3 Slope Displacement Analysis

Figure 9-10 shows the slope displacement cloud in the X direction before and after slope excavation. Before the excavation, the overall horizontal displacement of the slope is small, and the maximum horizontal displacement is mainly concentrated at the right position in the middle of the slope, with the maximum value of about 6cm. The maximum horizontal displacement of the left slope is mainly concentrated near the second and third grade slopes, and the maximum horizontal displacement of the right slope is mainly concentrated at the first grade slope, namely, the foot of the slope, and the maximum horizontal displacement of about 4cm. It can be seen that the most dangerous area of slope after slope excavation is near the second and third grade slopes of the left slope and at the foot of the right slope[6]. During construction, support should be strengthened in these parts and monitoring frequency should be increased[7,8].

Based on the above analysis, it can be concluded that the excavation of the slope will cause great disturbance to the rock mass within a certain range, and the plastic zone area of the slope keeps expanding and has a trend of penetration. The upward-slope, the left slope and the right slope all have a trend of sliding towards the air surface, and the slope body has the risk of large-scale instability and slide.

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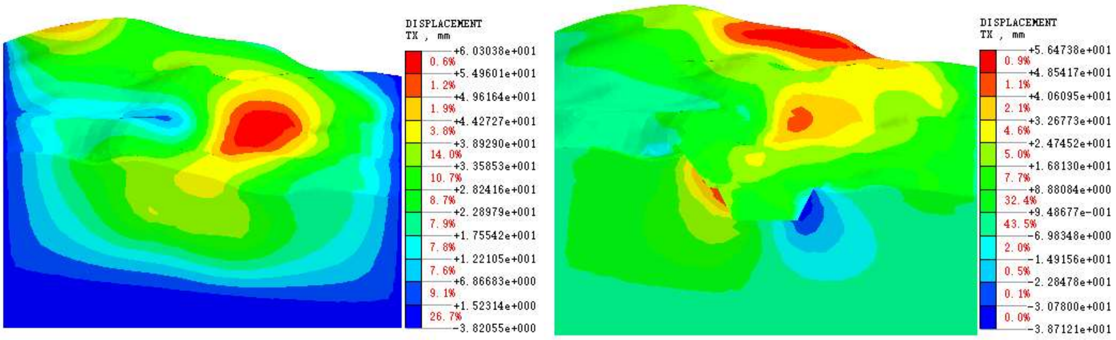

a.Displacement in X direction under gravity stress

b.Displacement in X direction after completion of slope excavation

Figure 9. Displacement in X direction

5. Conclusion

(1) After the completion of the slope excavation, the plastic zone area reached the maximum, and the upper and lower parts of the slope showed a trend of penetrating from the high terrain to the low terrain plastic zone, and a certain range of plastic zone also appeared in the middle of the slope, so the slope has the risk of slipping or even large-scale landslide.

(2) After the completion of the elevation slope excavation, a new elevation surface is formed, and a large displacement is generated from the elevation slope to the elevation surface direction. The maximum displacement is mainly concentrated in the upper left of the elevation slope, and a large uplift occurs at the bottom of the slope platform.

(3) The maximum horizontal displacement of the left slope is mainly concentrated near the second and third grade slopes, and the maximum horizontal displacement is about 4cm; the maximum horizontal displacement of the right slope is mainly concentrated at the foot of the first grade slope, and the maximum horizontal displacement is about 4cm.

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