

Stability Analysis and Reinforcement Effect Evaluation of Highway Slope

Jihui Deng

CCTEG Chongqing Engineering (Group) Co., Ltd., Chongqing, 400042, China

Abstract

In the process of highway engineering construction, it is inevitable to meet the slope management, slope stability is the premise of safe construction, this paper uses the finite element strength reduction method to analyze the stability of the slope, the calculated plastic penetration zone clearly shows the potential sliding surface of the slope. Based on the engineering background of a highway slope in Chongqing, this paper analyzes the slope stability before and after treatment, and compares the results. The results show that the treatment scheme can effectively improve the slope stability and provide reference value for similar projects.

Keywords

Slope strength; Reduction method; Stability analysis.

1. Introduction

In recent years, With the rapid development of China's economy, China vigorously develops infrastructure. In the construction process, in order to facilitate construction and transportation, it is inevitable to excavate the slope, which inevitably produces the slope. Many slopes even with tree roots, its stability is not reliable, light cause landslides, resulting in property losses, heavy cause debris flow, causing heavy casualties, so it is difficult for us not to pay attention to the slope. The stability of slope is of great significance for engineering construction and prevention of geological disasters. Currently, the analysis methods commonly used in engineering include limit balance method, stress limit balance method and strength reduction method [1].

The ultimate equilibrium method takes into account the forces of gravity, friction, cohesion and water pressure held by the failure body above the failure surface of the slope and decomposes them into the shear force along the failure surface upward and the shear force along the failure surface downward. The ratio of shear force to shear force is the stability coefficient [2]. In this way, we can know how much additional load the slope can bear, which is a relatively traditional slope stability analysis method.

With the rapid development of computers and finite element theory in the last century, the field of geotechnical engineering numerical simulation has also developed accordingly [3]. Although the most commonly used slope stability method in slope design is the limit equilibrium method, but this method has a defect, is unable to solve the slope stress change problem, the finite element method can also deal with this kind of problem, is too time-consuming, too much calculation, because it involves a lot of nonlinear analysis. Therefore, for the slope problem, a stress limit equilibrium method is derived, which is derived from the hypothesis of slip surface of limit equilibrium method combined with the results of finite element stress analysis. The stress analysis method can assume multiple slip surfaces, calculate the safety factor, and find out the slip surface with the lowest safety factor. The material of soil supports more-Coulomb model, Drucker - Prager model and modified More-Coulomb model.

Strength subtraction principle of shear strength of soil is decreased gradually, until at a certain point calculation convergence, we can think at this point and Mohr circle tangent, in a state of damage, then the biggest strength reduction rate can be considered as the minimum safety factor, this kind of method and limit equilibrium method does not need to assume different failure surface [4].

2. Project Summary

This project is a highway slope in Chongqing, the rock layer of the slope is relatively gentle, the length is about 120 meters, the slope height is about 15 meters, the width is about 50 meters, the slope safety grade is one level, the stability safety factor is 1.35.

Previously, slope release + anti-slide pile treatment has been carried out on the slope, and this time, comprehensive treatment of slope protection with anchor rod + shotcrete is adopted [5]. In combination with geotechnical characteristics and laboratory tests, the values of parameters of each rock and soil layer and retaining structure are shown in Table 1.

Table 1. Materia parameter

The name	E/MPa	Poisson's ratio	Volumetric weight /($\text{kN}\cdot\text{m}^3$)	φ /($^\circ$)	c /(kPa)
Grain filling	50	0.30	20.0	25	7
Strongly weathered mudstone	400	0.30	24.0	28	250
Moderately weathered mudstone	849	0.34	25.0	30.6	459
Moderately weathered sandstone	2280	0.20	24.3	35.9	1240
anchor	30000	0.25	78.0		
Shotcrete	20000	0.25	23.0		

2.1. The Establishment of Finite Element Model

Using the finite element analysis software to management before and after the analysis of numerical simulation of slope, aims to find out safety factor and potential slip surface [6], in this paper, the slope model to analysis the middle period of 24 meters length, due to the dimension of rock gently, so simplifying the sloperock level to level modeling, geotechnical constitutive model using Moore -coulomb constitutive, Anti-slide pile, anchor bolt and shotcrete adopt elastic constitutive, and the soil layer from top to bottom is plain fillstrongly weathered mudstone, moderately weathered mudstone and moderately weathered sandstone. Specific unit division is shown in Figure 1 and Figure 2.

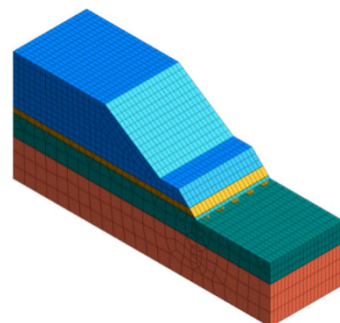
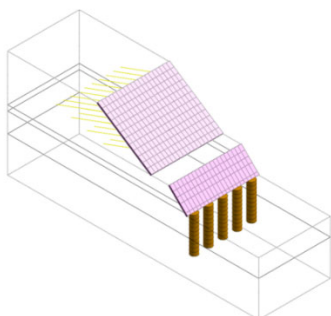


Figure 1. Grid division before slope treatment **Figure 2.** Grid division after slope treatment

2.2. Page Numbers

In order to verify the feasibility of the slope treatment scheme, strength reduction analysis and linear static analysis were carried out on the slope before and after treatment. Working condition two: after treatment.

2.3. Results Analysis

According to the calculation, the safety factor of condition 1 is 1.19, which is less than the 1.35 required by The Technical Code for Construction Slope Engineering (GB50330-2013). At this time, the slope is in a basically stable state. As can be seen from Figure 3, arc-shaped plastic through-through zone appears in the slope soil [7], indicating that the potential sliding surface is located in this zone, and there is a risk of arc-shaped sliding along the soil before slope treatment.

As can be seen from Figure 4, after the treatment of bolt + shotcrete slope protection, the safety factor of slope is 1.5, which is greater than the 1.35 required by The Technical Code for Construction Slope Engineering (GB50330-2013). At this time, the slope is in a stable state [8]. By comparison with Figure 3, it can be seen that the plastic zone inside the slope is controlled and develops to a deeper level, the potential slip surface is relatively gentle, and there is no breakthrough zone.

Governance through the linear static analysis of slope displacement is compared before and after the figure 5 shows that governance slope before the maximal displacement of 120 mm, the figure 6 shows that governance after the slope is the maximal displacement of 35 mm, by the results of the maximal displacement, the displacement of slope control measures can effectively control, further supporting the effectiveness of the slope governance program.

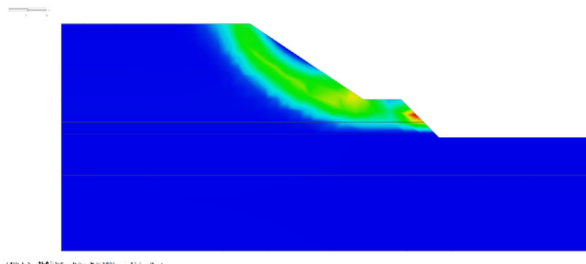


Figure 3. Slope model before treatment

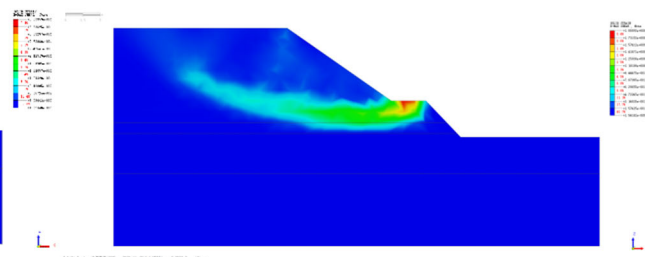


Figure 4. Slope model after treatment

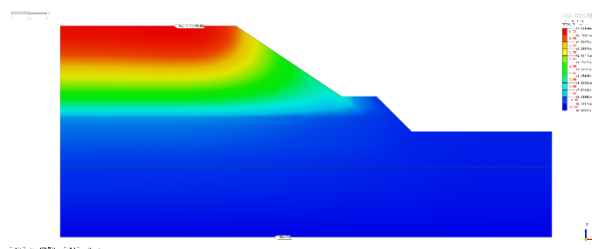


Figure 5. Cloud map of slope displacement before treatment

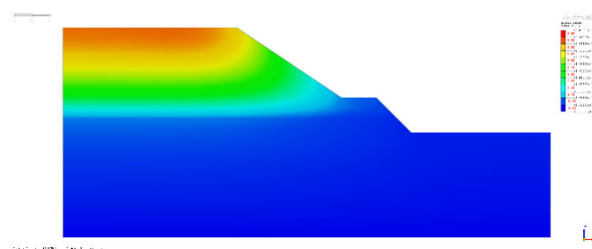


Figure 6. Cloud map of slope displacement after treatment

3. Conclusion

In this paper, numerical simulation software is used to conduct three-dimensional finite element simulation of a highway slope treatment project in Chongqing, and strength reduction method is used to analyze the slope before and after the treatment. By analyzing the stability of the slope under two working conditions, conclusions are drawn as follows:

- 1) According to the slope model before treatment, a circular arc plastic through-through zone appears on the surface of the slope soil, and the safety factor is 1.19. At this time, the slope is in a basically stable state, and there is a risk of circular sliding along the soil.
- 2) The results show that the slope needs to be treated in time, so the slope is treated with bolt + shotcrete protection. The simulation results show that the treatment scheme can effectively control the formation of the sliding surface inside the slope, and the treatment scheme is effective.

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