Stability Analysis of Slope and Nearby Transmission Towers in a Hub project Based on Flac3D

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Abstract. Aiming at the problem that the construction process of a water conservancy and hydropower project will affect the stability of the slope and its surrounding buildings, a numerical simulation method is used to carry out a numerical analysis of the displacement and stress diffusion of a junction engineering slope and its nearby transmission tower. The results show that: the deeper the excavation depth of the slope, the greater the rebound of the excavated surface; after excavation, the horizontal displacement of the facing surface of the slope under the support of the continuous wall is small, and the slope can maintain stability. The stress ratio method determines the distance between the excavation surface and the tower foundation, and the slope excavation can be carried out smoothly while ensuring the stability of the tower foundation.

1. Introduction
In recent years, China has made greater and greater efforts in the construction of water conservancy and hydropower projects. However, during the construction process, it is easy to affect the stability of cross-strait slopes and their structures [1-3], and the environmental problems caused by these impacts have received increasing attention from the state. Among the methods for evaluating slope stability, the limit equilibrium method is widely used [4]. On the basis of fully investigating the situation at the southern end of the site, Chen Yafei [5] et al. used the limit equilibrium method to analyze the slope stability, and proposed comprehensive measures for slope deformation and destruction. Liu Handong [6] et al. used the limit equilibrium method to compare different design schemes for the high and steep slopes of a spillway in a reservoir, thereby reducing the amount of excavation for the project. Fan Lian et al. [7] evaluated the stability of a deep cut slope of a highway, and believed that natural factors such as rainfall and wet and dry cycles would affect the stability of the slope. The difficulty of the limit equilibrium method lies in the search of the potentially most dangerous sliding surface and the determination of the safety factor of soil slope stability [8]. At the same time, there is a problem that it cannot reflect the stress-strain field in the slope. With the popularization of finite difference numerical calculation methods, many scholars tend to use numerical simulation methods to study slope stability. The numerical simulation method has fewer assumptions, a wider scope of application, and can more intuitively present the calculation results. Yang Jinwang [9] etc. tried to evaluate the slope stability by using two methods of geomechanical model test and FLAC3D numerical calculation. Cheng Wei [10] and others used FLAC3D to study the stress and deformation of rock mass slopes during excavation in the Arctic.
Pavilion style area of Nanjing. Yang Tao [11] et al. used numerical simulation to evaluate the stability of a high filling in Guizhou from the perspective of displacement analysis. Reading a large amount of literature, it is found that scholars are more concerned with the impact of the construction process on slope stability, and rarely analyze the impact of the construction process on nearby structures such as transmission towers and signal towers.

The author uses FLAC3D numerical calculation software to simulate the slope excavation process of the Nianpansha Water Conservancy and Hydropower Project, and analyzes the impact of the construction process on the nearby transmission tower foundation. This analysis method can provide a reference for similar engineering stability evaluation.

2. The project overview and model establishment

2.1 Project Overview

Excavation of the right bank slope of the dam area of the Nianpanshan Water Conservancy and Hydropower Project and ground wall construction may affect the No. 103 500kV UHV large-span transmission tower. An underground continuous wall is located at the extreme edge of the shiplock excavation area to maintain slope stability. The excavation line is 43.8 meters from the edge of the existing tower base. The stratigraphic distribution of this area can be divided into 3 layers: (1) The surface soil layer is a clay layer with a thickness of about 9 meters; 2) The second layer is a strongly weathered argillaceous siltstone with a thickness of about 3.0 meters; 3) The third layer is weakly weathered argillaceous siltstone. The groundwater level is in a weak weathered rock layer 12 ~ 14m below the surface. As is shown in Figure 1. Symbols ①, ②, and ③ in the figure indicate clay layers, strongly weathered argillaceous siltstones, and weakly weathered argillaceous siltstones, respectively.

![Figure 1. Simplified relationship between slope excavation area and transmission tower](image1)

Transmission tower base is a circle with a diameter of 29.4m. Total height of the tower is 148.8m. The reinforced concrete foundation cap is located 2.5 meters below the ground. Below the platform, 58 non-squeezed reinforced concrete piles with a diameter of 1.2 meters and a buried depth of 9.0 meters are uniformly arranged along the ring. Transmission tower as shown in Figure 2 below.

![Figure 2. Transmission tower](image2)

![Figure 3. Overall model of slope before excavation](image3)
2.2 Model establishment
Based on the geological exploration results and the design of the No. 103 tower foundation, a numerical model was established using Flac3D software in conjunction with Figure 1. The length of the model along the continuous wall is 100m, and the length of the vertical continuous wall is 226m. The thickness of the clay layer is 9.0 meters, the thickness of the strongly weathered rock layer is 3.0 meters, and the thickness of the lowest weakly weathered rock layer is 55 meters. The overall numerical model is shown in the figure above. The numerical model of the pile foundation is established according to the dimensions in the design drawing, as shown in Figure 4 below.

![Figure 4. The model of transmission tower pile foundation](image)

2.3 Selection of parameters
According to the stratum information revealed by the nearest borehole from the tower base, referring to the results of laboratory tests, and comparing the engineering geology manual, comprehensively select the calculation model parameters. The specific parameters are as follows:

| Serial number | Stratum name                | Density Kg/cm³ | Elastic Modulus MPa | Poisson's ratio | Cohesion | angle of internal friction |
|---------------|-----------------------------|----------------|--------------------|----------------|----------|---------------------------|
| 1             | Clay                        | 1900           | 20                 | 0.35           | 15       | 10                        |
| 2             | Strongly weathered glutenite| 1900           | 2060               | 0.25           | 500      | 35                        |
| 3             | Weakly weathered glutenite  | 2100           | 2770               | 0.23           | 800      | 40                        |
| 4             | Concrete                    | 2400           | 20000              | 0.20           | -        | -                         |
| 5             | Ship lock                   | 2800           | 25000              | 0.2            | -        | -                         |

3. FLAC3D simulation results and analysis

3.1 Overall model displacement analysis
Assign the set physical parameters to the corresponding locations and perform calculations. After the slope is excavated, the overall vertical displacement and horizontal displacement cloud diagrams of the model are shown in Figures 5 and 6, respectively.

![Figure 5. Vertical deformation of the model after excavation](image)  
![Figure 6. Horizontal deformation of the model after excavation](image)
It can be seen from the above figure that after the slope is excavated, the maximum rebound deformation generated by the excavated part is about 5.5mm. As the rebound range gradually expands from the deepest part to the sides, the rebound value gradually decreases. And the vertical displacement of the soil near the base is very small.

It can be known from FIG. 6 that the maximum horizontal displacement of the air-facing surface formed by the excavation of the slope under the support of the underground continuous wall is about 5.7 mm. And the soil near the base of the transmission tower has almost no horizontal displacement change. Preliminary analysis shows that although the deformation of the soil caused by the slope extends to the vicinity of the base of the transmission tower, the soil near the transmission tower has not been greatly disturbed.

In order to further analyze the impact of slope excavation on the transmission tower base, the transmission tower base was taken separately for analysis. The horizontal and vertical cloud diagrams are shown in Figures 7 and 8 below.

The bottom surface of the excavated body rebounded and expanded to the vicinity of the tower foundation, which caused the tower foundation to turn over. Therefore, from the near slope side to the far slope side, the vertical deformation trend of the tower foundation gradually transitions from upward to downward. It can be seen from the figure that the tower foundation on the near slope side has an upward vertical deformation with a maximum value of about 0.136 mm; the tower foundation away from the slope side has a vertical deformation with a maximum value of about 0.175 mm.

In terms of the horizontal displacement of the tower foundation, As can be seen from the figure8, due to the tendency of the tower foundation to overturn, it generated a certain horizontal displacement away from the slope side, with a maximum value of about 0.45mm. In summary, the deformation of the horizontal and vertical displacements of the tower foundation caused by slope excavation is small, so the slope excavation has little effect on the tower foundation.

3.2 Stress analysis
After excavation of the slope, the tower foundation was subjected to a horizontal load pointing to the slope. The resistance to horizontal deformation of the pile foundation mainly depends on the rock and soil body on the side of the slope of the pile foundation, and the horizontal load in this part of the soil will cause stress diffusion. Therefore, the stress ratio method is used to study the influence range of horizontal loads, and the effect of slope excavation on the stability of tower foundation is further evaluated.
The figure 9 is a cloud diagram of the ratio of the additional stress to the horizontal load in the rock and soil near the side of the slope under the horizontal load of the pile foundation. Referring to the determination standard of the foundation compression deformation range, the position where the ratio of the additional stress to the horizontal load is 0.1 is taken as the boundary of the influence range of the pile horizontal load.

Reading the model node information, the stress diffusion range of the horizontal load of the pile foundation is about 25m outside the tower foundation wall. From the perspective of safety, considering the complexity of geological conditions, setting the distance from the excavation face to the surrounding wall of the tower foundation to 30m can ensure the stability of the tower foundation.

4. Conclusion

Using the Flac3D software, the excavation process of the dam slope was simulated, and the displacement and stress distribution of the slope and tower foundation were analyzed. The results show:

1. The maximum rebound at the bottom of the excavation area is about 5.5mm; however, the range of rebound impact is mainly concentrated in the excavation area, and the impact on the area near the foundation is relatively small.

2. The maximum horizontal deformation of the vertical excavation formed by the excavation facing the excavation area is about 5.7mm, and the tower foundation is hardly affected by the horizontal deformation of the slope.

3. Control the distance between the slope excavation surface and the surrounding wall of the foundation is not less than 30m, which can ensure the stability of the foundation.

4. The numerical calculation method simplifies the construction process and the stratum conditions, and does not consider the influence of natural factors. Therefore, the monitoring of the deformation of the tower foundation during the construction period should be strengthened, and the actual monitoring results combined with the numerical calculation results can improve the accuracy of the slope and tower foundation stability evaluation.

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