Influence of Irrigation Canal Construction on the Stability of A Natural High and Steep Slope

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Abstract. The excavation and construction of the irrigation canal on a high and steep slope usually change the stress state of the original slope, which may have a serious impact on the stability of the slope. Taking the construction of irrigation canal on a high and steep slope as the research background, the stability of this high and steep slope under natural condition, construction platform excavation and construction of irrigation channel is calculated by Midas GTS NX. The results show that the stability of slope is better in natural state. The excavation of the construction platform of the irrigation canal will cause a certain displacement of the original slope, but will not affect the overall stability of the slope. With the construction of the irrigation canal, the displacement of the slope increases a lot, and the stability of the slope decreases significantly.

1. Introduction

In recent years, China has been building a large number of irrigation systems to meet the needs of agricultural production. However, due to the influence of topography, geological conditions and irrigated areas, a large number of irrigation channels have to be built on high and steep slopes with complex geological conditions [1-2]. The excavation and construction of the irrigation canal on the high and steep slope will often change the stress state of the original slope, which has a serious impact on the stability of the slope. Moreover, the seepage of the irrigation canal will reduce the geotechnical mechanics parameters of the original slope, induce more and more landslide disasters, and may cause huge casualties and economic losses [3-4]. Therefore, the excavation and construction of the irrigation canal on the high and steep slope has important social benefits and practical significance for the study of the stability of the original slope [5]. In this paper, based on the research background of the construction of a high and steep slope, Midas GTS NX, a large-scale three-dimensional numerical calculation software, is used to calculate the stability of the slope under the natural state, the excavation of the irrigation channel platform, the construction of the irrigation channel, etc. The research results are of great significance to the construction safety and subsequent safety guarantee of irrigation canal project.

2. Engineering overview

The construction area of an irrigation canal project is a high and steep, with complex geological conditions, narrow access roads and many bends, which makes the construction difficult and slow. The original design and construction of the first section of the project is 3923m long. Up to now, more than
1000 m of irrigation channel platform excavation has been completed. Due to the steep mountains, developed valleys, complex geological conditions and fragile surface ecology in the route area of the first section of the irrigation canal, the surface soil mainly consists of Quaternary silty clay mixed with gravel, gravel mixed with silty clay, etc., with low mechanical strength of rock and soil. Slope gully development, debris flow and other geological disasters occur frequently. In the process of construction, local collapse of irrigation channel platform occurs consistently.

3. The calculation model and mechanical parameters

3.1. Calculation model
The whole slope angle of the no.1 section is 60° and the irrigation channel construction platform is 80°, which is selected as the research object. The numerical simulation of slope stability under the above three conditions is carried out. Based on the field survey, the possible influence scope of landslide is analyzed, and combined with relevant data, the slope excavation model is established, which is 173m long and 300m high. The whole slope model has 8918 units and 8854 nodes. The free boundary of the model is the surface, which is constrained by normal direction and fixed at the bottom. The numerical calculation model is shown in figure 1.

Figure 1. Computational mechanics model

3.2. Recommended values of mechanical parameters of rock and soil mass
The Quaternary overburden on site is mainly composed of silty clay with gravel, gravel with silty clay and sand gravel. According to the test results of the feasibility study stage of the project, and referring to relevant specifications and similar engineering data, the recommended values of main physical and mechanical parameters of each soil layer are proposed, as shown in table 1. Mohr Coulomb elastic-plastic constitutive model is used for calculation [6].
Table 1. recommended values of main physical and mechanical parameters of overburden Table

| Lithology                   | Cohesion (kPa) | Internal friction angle (°) | Deformation modulus (MPa) | Saturation weight (kN/m³) | Bearing capacity eigenvalue(kPa) | Base friction coefficient |
|-----------------------------|----------------|-----------------------------|--------------------------|---------------------------|----------------------------------|----------------------------|
| Silty clay with crushed stone | 30             | 21°                         | 4~5                      | 20                        | 200                              | 0.3                       |
| Crushed stone with silty clay | 15             | 28°                         | 20~23                    | 21.5                      | 280                              | 0.45                      |
| Crushed stone, block stone  | 70             | 30°                         | 25~28                    | 22                        | 310                              | 0.50                      |
| Sandy cobble                | 90             | 31°                         | 30~40                    | 23                        | 400                              | 0.50                      |

3.3. Analysis content and calculation steps
The analysis content and calculation steps are as follows: (1) Based on the mechanical parameters in the engineering investigation, the initial stress field of the area is constructed; (2) The stability of irrigation canal slope under natural conditions (before excavation); (3) The stability of slope after excavation of construction platform of irrigation canal; (4) The stability of the slope after the excavation of the irrigation canal.

4. Numerical simulation analysis of slope stability of irrigation channel

4.1. Slope stability analysis in natural state
In the natural state, the distribution of the maximum principal stress field of the slope is generally controlled by the influence of the gravitational field. The maximum principal stress of the slope generally appears as compressive stress, which gradually increases from surface to interior of the slope. The maximum value can reach 4.061 MPa, and the maximum principal compressive stress is located in the lower right corner of the slope model. The minimum principal stress of the slope is still controlled by the gravity field. The minimum principal stress of the slope surface and below a certain depth range is expressed as tensile stress. Tensile stress concentration occurs in weakly weathered basalt, resulting in a maximum tensile stress of about 0.165 MPa. As the depth increases, the minimum principal stress gradually changes from tensile stress to compressive stress, and the maximum compressive stress is approximately 1.938 MPa.

4.2. Slope stability analysis after the excavation of the irrigation canal construction platform
After the excavation of the irrigation channel construction platform, the bottom of the platform rebounded due to the excavation and unloading of the platform. The maximum rebound volume was within the range of 3.207 to 3.665 cm. The main displacement of the slope occurred in the rock and soil within a certain range near the excavation. The maximum total displacement reached approximately 5.498 cm and appeared in the quaternary overburden above the excavation site. The total displacement generally shows a trend of decreasing from the front to the back of the slope. Based on the distribution characteristics of the total displacement, it shows that the impact of excavation on the cover layer is greater, and the impact on the stability of the slope is mainly caused by the deformation of the front and local deduced stability. Figures 2 and 3 are the lateral and vertical displacements of the slope after the excavation of the construction platform. It can be found that the horizontal and vertical displacements of the deep bedrock are almost zero. The maximum horizontal displacement is 4.093 cm, the maximum
vertical displacement is 3.717 cm, the distribution positions are close, and the vertical displacement mainly occurs at the bottom of the platform.

Figure 2. Lateral displacement of the slope
Figure 3. Vertical displacement of the slope

4.3. Slope stability analysis after completion of irrigation canal construction

Figure 4 shows the lateral displacement of the slope after the completion of the irrigation canal construction, and Figure 5 shows the vertical displacement of the slope after the completion of the irrigation canal. The main displacement of the slope occurred in the overburden slope of the upper part of the irrigation channel, and the total displacement of the rock and soil near the excavation showed a trend of increasing first and then decreasing from the slope surface to interior of the slope. The maximum total displacement of the slope was 2.0 m. Compared with the end of the excavation stage of the platform, it indicates that the excavation of irrigation channel has a greater impact on slope stability. Excavation of irrigation channel mainly causes the slope to generate horizontal displacement and subsidence along the free surface of the slope. The maximum horizontal displacement is 1.756 m and the maximum vertical displacement is 1.089 m, the distribution position is relatively close.
Irrigation canal construction after completion, filling presence slope canal upper body cover layer obvious maximum shear strain, the relatively high value of maximum shear strain mainly distributed to the portion of the rock and soil, a maximum value of 1.890m, to form a more internet excavation stage. At the same time, the maximum value of the maximum shear strain increases significantly, and at the same time, a sliding surface is formed at the interface between the overburden and the bedrock. The cloud diagram of maximum shear strain after excavation of the canal is shown in figure 6.

**Figure 6. Cloud diagram of maximum shear strain**

5. Conclusions

According to the numerical simulation results of the whole process of the irrigation canal construction on high and steep slope, the slope stability is better under natural condition. Excavation of the construction platform will cause a certain displacement of the original slope, but it will not affect the overall stability of the slope. With the excavation of the irrigation canal, the displacement of the slope increases significantly, and the stability of the slope decreases significantly. The excavation of the irrigation canal will have a significant adverse impact on the slope. During the operation of the irrigation canal, it is easy to get clogged and leak due to the influence of the surrounding rock and soil mass of the upper slope. The water in the irrigation canal leaks into the slope can further reduce the shear strength of the rock and soil mass, which may cause landslides and mud flow disasters.

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