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Stability Analysis and Design of Support Scheme for a Medium-sized Landslide on the South Slope of Xijiushui Village

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ABSTRACT. This project examines the stability of a medium-sized landslide that occurred on the south slope of Xijiushui Village, Bai'an Township, Xingtai County, using the MIDAS GTS software and the finite element strength discount method. It also examines the factors that affect the stability of this slope, as well as its deformation, destabilization mechanism, and development trend. Finally, it proposes prevention and control measures.

Keywords: slope; finite element model; strength reduction method; stability analysis

1 INTRODUCTION

Slope instability poses a serious threat to people's lives and property in the context of modern society and rapid economic development; as a result, when designing a slope support, the support structure that can ensure this safety while also preserving some degree of harmony and balance with the surrounding environment should be chosen [1]. The thorough examination of slope stability and all-encompassing management strategies promotes the logical, scientific prevention and control of geologic hazards and ensures the security of people's lives and property. There is a moderate landslide on the southern slope of Xijiushui Village in Bai'an Township, Xingtai County. The landslide area is located in the middle-low mountainous area in the west of Xingtai County, with steep slopes, and most of the landslide surfaces are in the form of strips, and the back of the landslide body is separated by a ridge, which has a poor water-storage capacity, and the post-tensioned fissure is located on the edge of the ridge, with the maximum displacement of about 3.0 m, and backslope gradient 35~45 degree, with a steeper slope gradient. A series of terraced formations with heights ranging from 1.0 to 3.0 m and

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well-developed vegetation was developed in the landslide's center. Due to the slope construction of the abatement zone, a vertical steep canyon with good overhanging conditions was formed at the canyon's leading edge, and bedrock outcrops appeared in localized areas [2].

The medium-sized landslide in the south slope of Xijiushui Village, Bai'an Township, Xingtai County is used as a prototype in this paper, which then uses MIDAS GTS NX (a professional geotechnical finite element calculation software) to examine its stability[3-5], examine how the landslide changes as a result of various factors, and propose an appropriate and reasonable support plan.

2 Calculation model

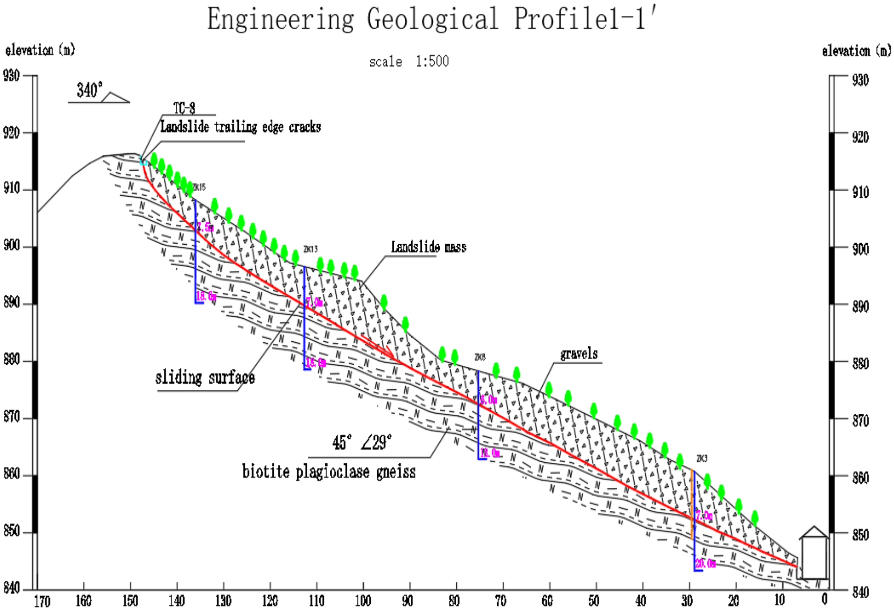
It is crucial to apply the Moore-Cullen yield criterion as well as to take into account all of the parameters and physical characteristics of the soil by this criterion while examining the stability of soil slopes in various instances utilizing the strength discount method. For instance, there is a direct relationship between the modulus of elasticity and its deformation strength; the bonding force and angle of internal friction of the soil body will not only affect the shear strength of the soil body (porosity, saturated capacity, etc.) but will also affect the permeability of the soil to some extent, which will affect the stability of slopes under rainwater conditions.

This project proposes to use the finite element method to analyze the dynamic characteristics and damage mechanism of a medium-sized landslide in a natural situation, on a mountain south of Xijiushui Village, in the south of Bai'an Township, using a combination of indoor simulation and numerical simulation, as shown in Table 1 below:

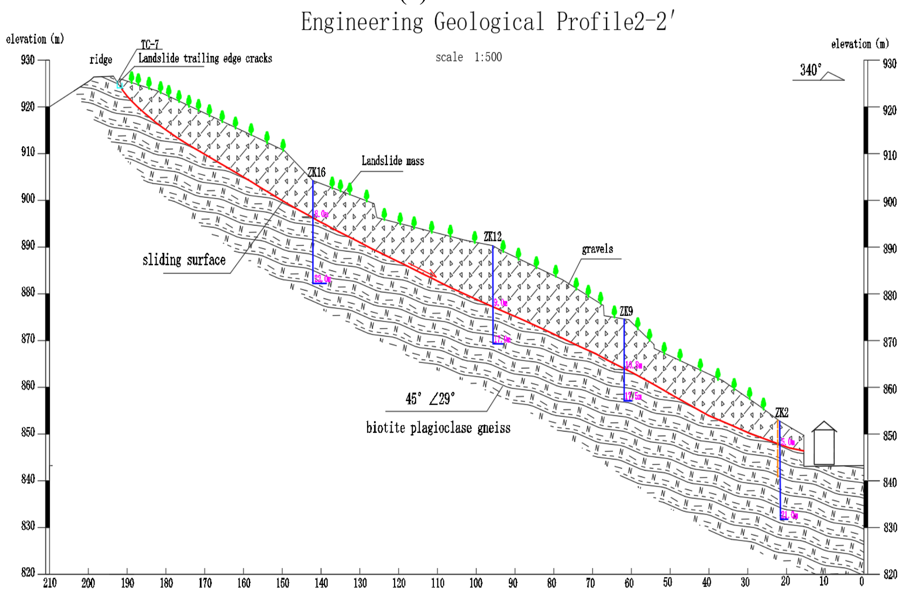
Table 1. Table of soil material property parameters (kN/m/sec)

Soil mass	Unit type	Constitutive model	Elastic modulus	Poisson's ratio	Bulk density	Saturated bulk density	Void ratio	Cohesion	Internal friction angle
Rubble soil	2D plane strain	Mohr-Coulomb	40000	0.2	16.6	19.75	0.73	21.3	15.54
Plagioclase gneiss	2D plane strain	Mohr-Coulomb	77240	0.3	24.3	24.2	0.73	12.43	43.69
Middle weathered layer	2D plane strain	Mohr-Coulomb	2800	0.32	19.92	23.12	0.5	12	33
Bedrock	2D plane strain	Mohr-Coulomb	83800	0.37	26.3	27.5	0.4	17100	43.27

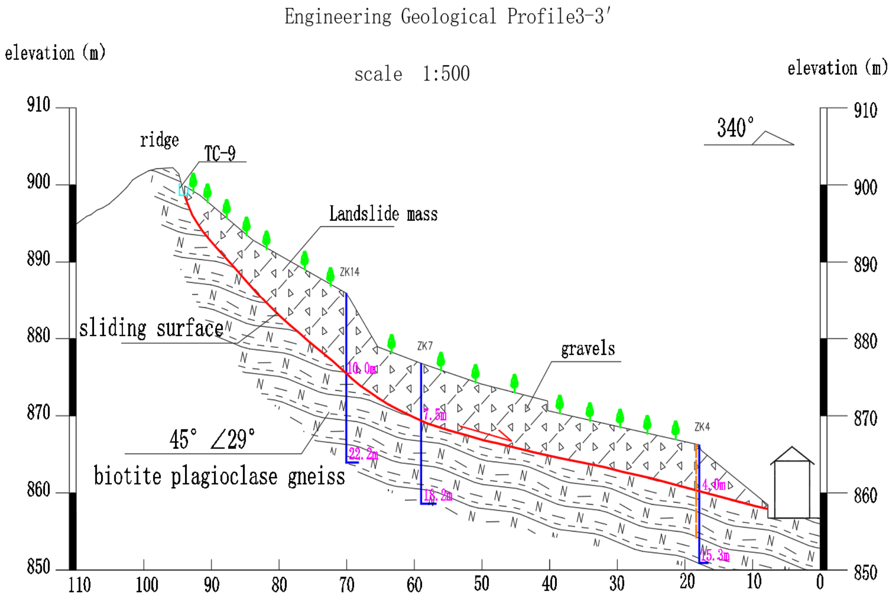
The landslide's diverse soil strata were reasonably simplified, and three representative profiles (as shown in Figure 1) were chosen to create the model, as shown in Figure 2.



(a)I-I section

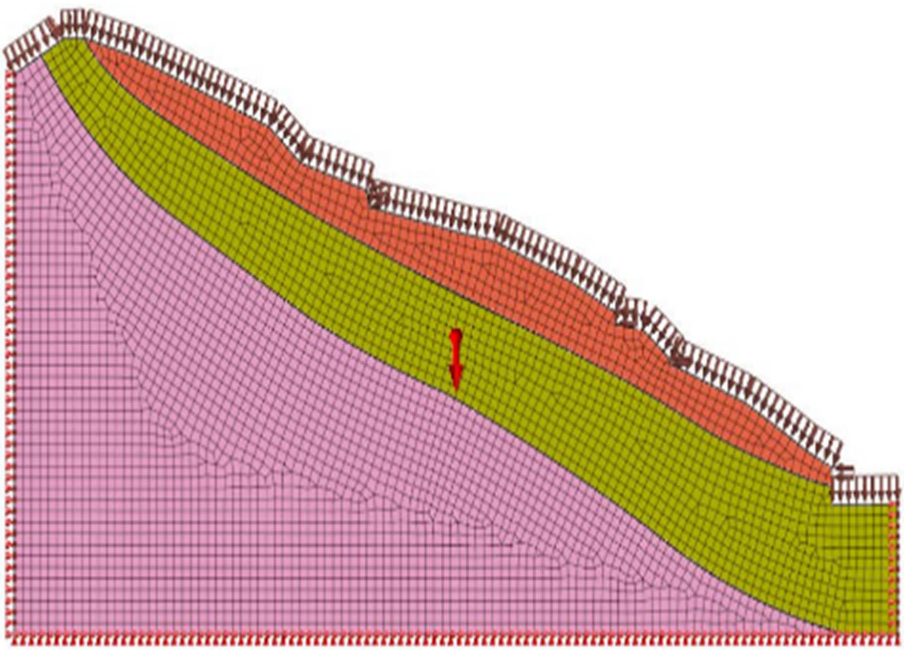


(b)II-II section

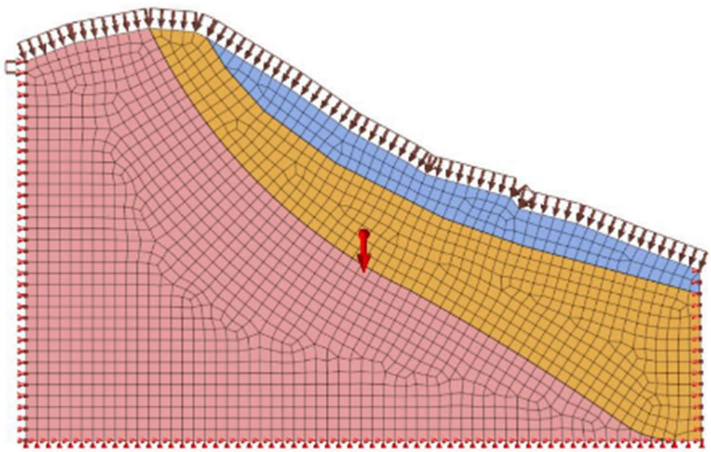


(c) III-III section

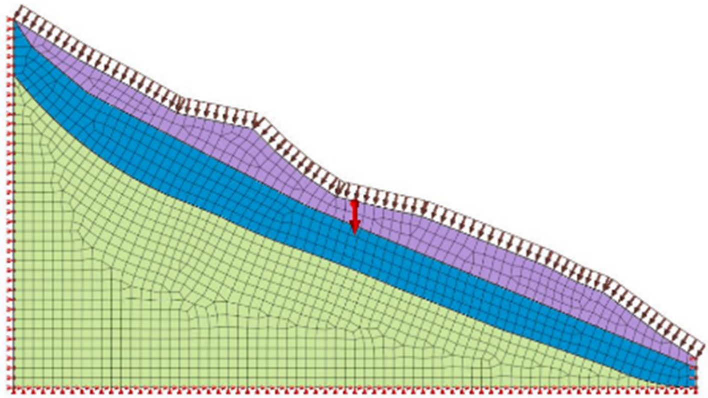
Fig. 1. Engineering geological section



(a)I-I section



(b)II-II section



(c) III-III section

Fig. 2. Profile model

3 Analysis result

3.1 Results without support

By creating a finite element model of the underground structure, establishing the boundary conditions and loading conditions, and calculating the displacement field distribution, MIDAS GTS NX may be used to analyze the displacement field using the finite element approach. The sections are all moved along the direction of gravity and the direction of the soil, as shown in Figure 3 and Figure 4 below, which also shows the displacements along the X-direction caused by the I-I section under self-weight and following rain.

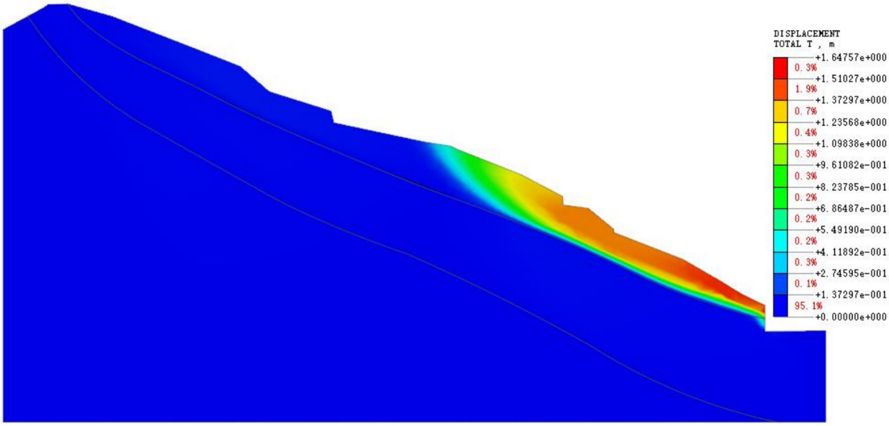


Fig. 3. Natural state I-I profile horizontal displacement map

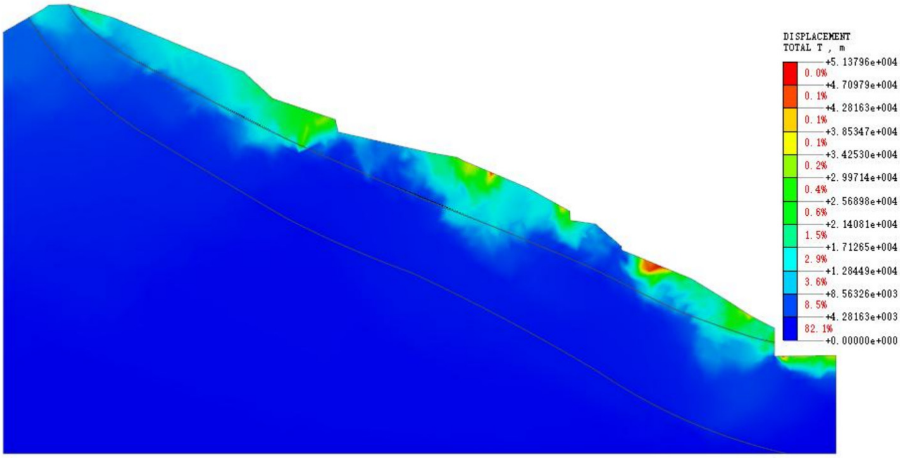


Fig. 4. Rainfall state I-I profile horizontal displacement map

3.2 Support scheme

3.2.1 Anchor rods support.

Anchor support should be designed and built by underground construction characteristics, such as the number, length, diameter, and spacing of anchors, as well as the selection of grouting materials and the determination of grouting methods. In this project, it is proposed to design 18m and 31m-long anchors for the characteristics of medium-scale landslides on the south slope of Xijiushui Village, Bai'an Township, Xingtai County, which are anchored with 500 mm caliber, 215° angle, 25mm HRB400 steel bars, and poured with 42.5 R cement mortar.

3.2.2 Anti-slide pile support.

The primary idea behind anti-slide piles is to stop soil bodies from sliding and deforming by friction between the pile body and soil bodies as well as the shear strength of the soil bodies. Anti-slide piles are chosen to be installed at the bottom and middle of the landslide, and they are made of C30 concrete with a cross-section of D=250 mm, a length of 24 m, and HRB400 and HPB300 reinforced concrete beams for the main reinforcement and hoop reinforcement, respectively.

3.2.3 Mixed support of anchor rods and anti-slide piles.

Because the two types of support mentioned above each have unique drawbacks, they will be combined to get a superior overall support result.

Anchor rods: Anchors of different lengths, 17 m, and 31 m, were planned and deployed in the tougher soil layer with 500 mm diameter boreholes and 135° inclination angle, 25 mm HRB400 steel bars were chosen for reinforcement and cast with 42.5 R cement mortar.

Anti-slide piles: Anti-slip piles must be installed in the landslide's middle and foot, with anti-slide pile diameter D = 250mm, material C30 concrete, main bar HRB400, and hoop bar HPB300 reinforced concrete beam.

3.3 Safety factor analysis

Table 2 shows that after employing the mixed support of anchors and anti-slide piles, the slope safety coefficients of sections I-I, II-II, andIII-III were enhanced, and they are still in stable condition after rain.

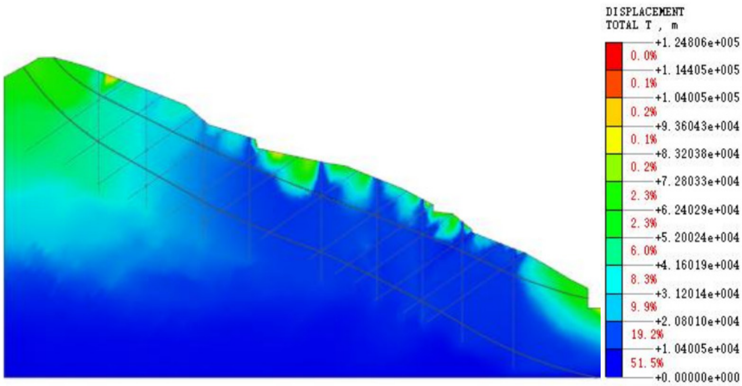
Table 2. Slope stability analysis under mixed support

Section	Working conditions	Factor of safety	Slope stability state
I-I	Mixed support	2.790	stabilize
	Mixed support+rainfall	2.000	stabilize
II-II	Mixed support	2.500	stabilize
	Mixed support+rainfall	1.862	stabilize
III-III	Mixed support	2.225	stabilize
	Mixed support+rainfall	1.426	stabilize

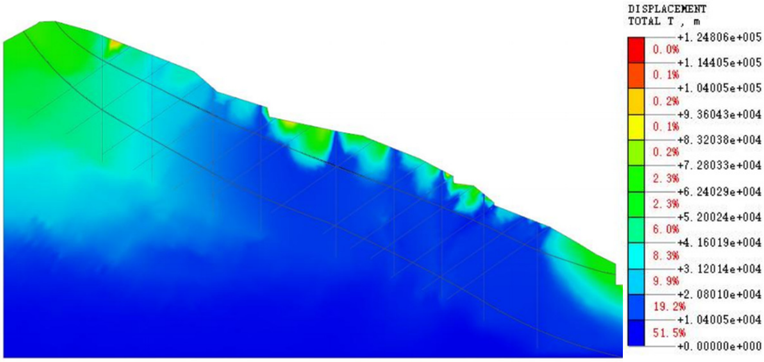
3.4 Result analysis under support conditions

3.4.1. Displacement field analysis.

After the rain, the landslide's lateral displacement changes very little and is mostly focused near the slope's base, which will reduce the slope's safety factor and influence the stability of the slope. The horizontal displacements of the I-I profile under the natural state and the state of rainfall are shown in Figure 5:



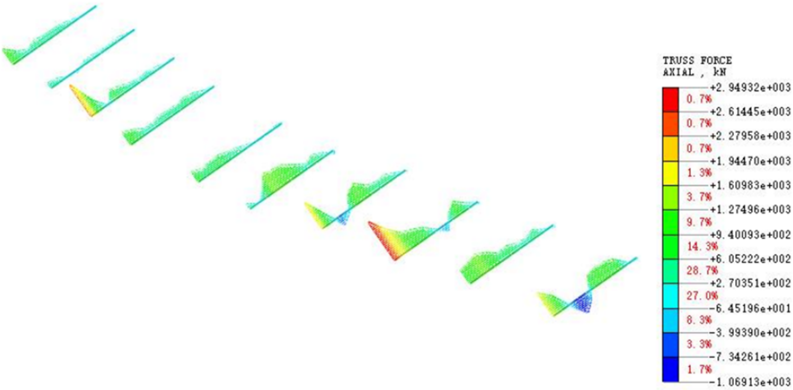
（a）Natural state



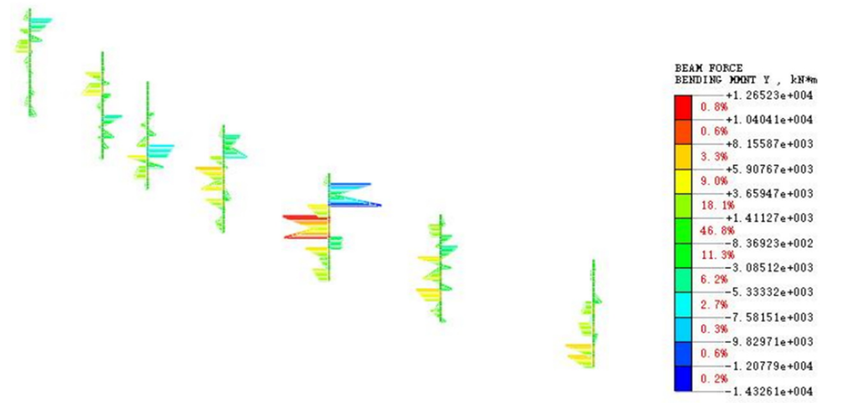
(b)After rainfall

Fig. 5. Horizontal displacement diagram of mixed support in I-I section

3.4.2. Analysis of axial force and a bending moment of the anti-slide pile.

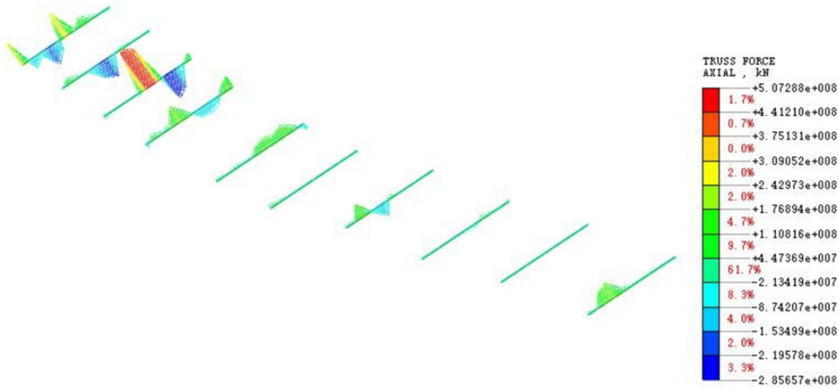


(a)Axial force diagram

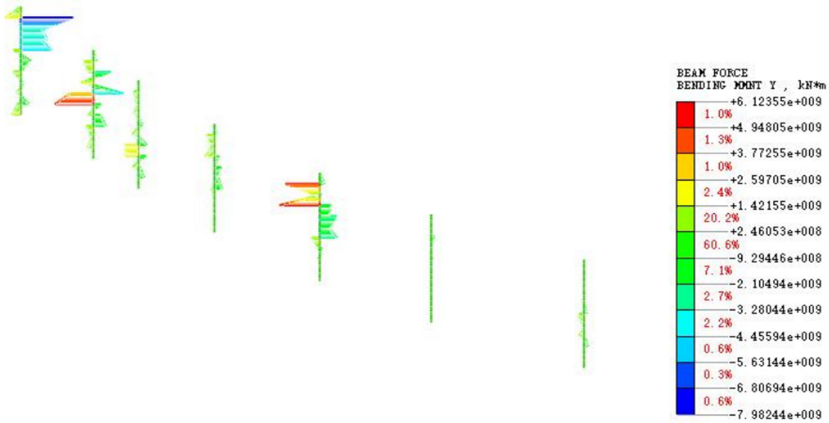


(b)Bending moment diagram

Fig. 6. Axial force diagram and bending moment diagram of II-II section in a natural state



(a)Axial force diagram



(b)Bending moment diagram

Fig. 7. Axial force diagram and bending moment diagram of II-II section after rainfall

Figures 6 and 7 show that the anchor shaft force in the rainstorm situation is much higher than the anchor shaft force in the natural state, which was previously mentioned.

4 Conclusion

In this paper, based on the management of the landslide in the south of Xijiushui Village, Bai'an Township, Xingtai County, and combined with the current development and research status of slope support, a typical cross-section model of the landslide is established based on the MIDAS GTS finite element numerical simulation software, and the stability of the landslide in the natural state under the rainfall is analyzed and evaluated in detail by using the strength reduction method. The "anchor + anti-slide pile" combination support method is produced by model analysis, and its reasonableness is validated through numerical simulation.

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