**Open Access Library Journal**
2025, Volume 12, e14438
ISSN Online: 2333-9721
ISSN Print: 2333-9705

# Stability Analysis of Perilous Rocks in Baiyan Mountain of Guilin

**Yanxu Yuan[1], Xinlan Tang[1], Boyang Shen[1], Haoyan Kang[2], Guanyu Chen[1], Bai Yang[1*]**

[1]School of Architecture and Transportation Engineering, Guilin University of Electronic Technology, Guilin, China
[2]School of Optoelectronic Engineering, Guilin University of Electronic Technology, Guilin, China
Email: *870655138@qq.com

**How to cite this paper:** Yuan, Y.X., Tang, X.L., Shen, B.Y., Kang, H.Y., Chen, G.Y. and Yang, B. (2025) Stability Analysis of Perilous Rocks in Baiyan Mountain of Guilin. *Open Access Library Journal*, **12**: e14438.
https://doi.org/10.4236/oalib.1114438

**Received:** October 12, 2025
**Accepted:** November 25, 2025
**Published:** November 28, 2025



## Abstract

Rockfall is a common mountain geological disaster. It has the characteristics of high release energy, sudden and strong disasters. In order to effectively prevent the occurrence of geological disasters such as rockfall. This paper takes the perilous rock mass of Baiyan Mountain in Guilin as the research object. The perilous rock mass of Baiyan Mountain is classified and numbered and the corresponding stability evaluation standard is formulated for the Baiyan Mountain perilous rock mass group. Based on the limit equilibrium method, the stability calculation methods of various types of perilous rock masses are established and the stability calculation analysis is carried out. According to the calculation results, the protective measures for different types of dangerous rock masses are proposed. The perilous rock mass mainly includes three types of perilous rock mass: overhead-type, slope-type and isolated-type. According to the calculation results, five protective measures are formulated for different types of perilous rock masses: support protection, removal project, pour mortar, anchorage-wire rope (nets) bounding and grouting and anchorage-screen. The research results are of great significance for the formulation of protective measures for perilous rock masses, as they provide a good reference for the prevention and control of geological disasters in mountainous areas.

## Subject Areas

Civil Engineering

## Keywords

Perilous Rock, Stability Analysis, Protective Measures

## 1. Introduction

Perilous rock is a kind of natural disaster. When it collapses, it has the characteristics of large energy release, high emergency and strong disaster, which is a global geological disaster [1]. Perilous rocks mostly exist on cantilevered slopes or steep cliffs, and such rock masses are divided by multiple structural surfaces, resulting in poor stability [2]. At present, many scholars have analyzed the development of perilous rocks and classified them. In 1976, P. B. Attewell [3] divided unstable rock slopes into four failure and unstable modes: collapse, plate failure, caving and spalling. In 1977, E. Hoek [4] divided slope failure into four types: plane failure, toppling failure, arc failure and wedge failure. The toppling damage is considered to be a collapse, and the toppling damage is subdivided into three types: bending toppling damage, block toppling damage and block-bending toppling damage. Yao [5] divided the types of perilous rock collapses into: columnar block perilous rock mass, wedge-shaped perilous rock mass, blocky rock mass and probe-shaped perilous rock mass. Shi [6] divided the failure modes of perilous rock mass into four types: slipping shear failure mode, shear failure mode, compression cracking failure mode and slipping failure mode. Huang [7] analyzed the rock mass structure, and divided the perilous rock mass into seven types: the slope type, the weak base type, the hanging type, the block type, the isolated type, the fragmented type and the slab type. Gao [8] analyzed the perilous rock mass and divided the perilous rock into two kinds: single perilous rocks and group perilous rocks. He further divided single perilous rocks into four types: pull-crack-compression-shear-fall type, pull-crack-fall type, pull-shear-dump type and compression-shear-rolling type, and divided the group of perilous rock masses into two types: bottom-induced type and top-induced type. Fan [9] divided the unstable modes of perilous rock collapses in Guilin into five types: pull-crack-fall mode, compression-shear-slip mode, pull-crack-dumping mode, plastic-flow-pull-crack mode, isolated-fall mode and space slip mode.

The stability evaluation of perilous rock mass can be used as the basis for controlling perilous rock mass. Chen [10] combined the research results of perilous rocks in the Three Gorges area, and established a limit equilibrium analysis method for perilous rocks. Kong [11] used the limit equilibrium method and the subtraction of discrete element strength to analyze the stability of rock mass. Liu [12]used the limit equilibrium method to evaluate the stability of perilous rock mass in cantilevered slopes. Based on laboratory test data, Wang [13] established a bedrock constitutive damage model under dry and wet conditions, and analyzed the stability of the perilous rock mass in Jianchuan Cave in the Three Gorges Reservoir area. Verma [14] analyzed the stability of a perilous rock slope based on DEM, and revealed the influence of joint shape and parameters on the failure mechanism of perilous rock. LI [15] studied the stability of perilous rocks on the slope of a hydropower station by using the general block method of fractured rock mass and the three-dimensional discontinuous deformation analysis method. Huang [16] used limit equilibrium method and numerical simulation method to study the stability of natural conditions and reinforcement measures of a perilous rock mass in Xiluodu Dam. Liu [17] used the limit equilibrium method to quantitatively check the stability of the dangerous rock mass No. 3 in Baiyan Mountain, and comprehensively analyzed and evaluated the development characteristics and stability of perilous rock masses in Guilin City. Wang [18] took Wangxia Perilous Rock as an example, and used the method of combining exponential smoothing and linear regression analysis to analyze the stability of Wangxia Perilous Rock Mass. The results show that the Wangxia perilous rock mass is mainly controlled by the special geological structure environment and the high and steep slope conditions near the sky, and the perilous rock mass has been destabilized many times under the induction of continuous rainfall.

Due to the unique geological conditions, Guilin City is basically full of karst rock peaks, and there are certain hidden dangers in them. In recent years, there have been many rock collapse accidents in various parks in Guilin city, which have caused huge economic losses. Therefore, the evaluation of the stability of perilous rock masses in the study area will be beneficial to the planning of geological disaster prevention and control in Guilin City, and provide the corresponding theoretical basis for disaster prevention and control, which has very important practical significance. Baiyan Mountain is located in Xiufeng District, Guilin City. According to the survey, there are at least 99 pieces of perilous rocks, and most of them are potential threats. This paper formulates the corresponding stability evaluation standards for the Baiyanshan perilous rock mass group. Based on the limit equilibrium method, it proposes the stability calculation methods of various types of perilous rock mass and conducts stability calculation and analysis. According to the calculation results, formulate corresponding protective measures.

## 2. Stability Calculation and Evaluation of Perilous Rock Mass

### 2.1. Type of Working Condition

The working conditions used in the calculation of the stability of perilous rock mass can include the following three situations, and the load combination considered in each working condition should meet the following regulations [19]:

Condition 1: gravity + fissure water pressure (natural condition) (toppling perilous rock is not considered);

Condition 2: gravity + fissure water pressure (rainstorm condition) (free perilous rock is not considered);

Condition 3: gravity + fissure water pressure (natural condition) + seismic force.

### 2.2. Perilous Rock Types

Classification of perilous rock masses is a prerequisite for stability research and prevention of perilous rock masses. So far, there is no unified standard for classifying perilous rock types. There are various classification schemes for perilous rocks from different research areas and different research perspectives.

The classification of perilous rock masses should consider meeting two requirements:

1) Combined with the deformation and instability mechanism;

2) Corresponding to protective measures.

Therefore, the most feasible classification method should be based on geometric characteristics, specific locations, rock mass structural characteristics, air conditions and boundary structural surfaces. In particular, the instability modes of perilous rock masses are classified based on the orientation, combination relationship and characteristics of the main control structural planes. Based on the above considerations, the results of the on-site survey were analyzed and summarized. From the perspective of the structure and state characteristics of the perilous rock mass, the perilous rock mass in Baiyan Mountain was divided into three types: overhead-type, slope-type and isolated-type, as shown in Figure 1.

The images of the above three types of perilous rock masses are simplified, and the simple diagrams are shown in Figure 2.

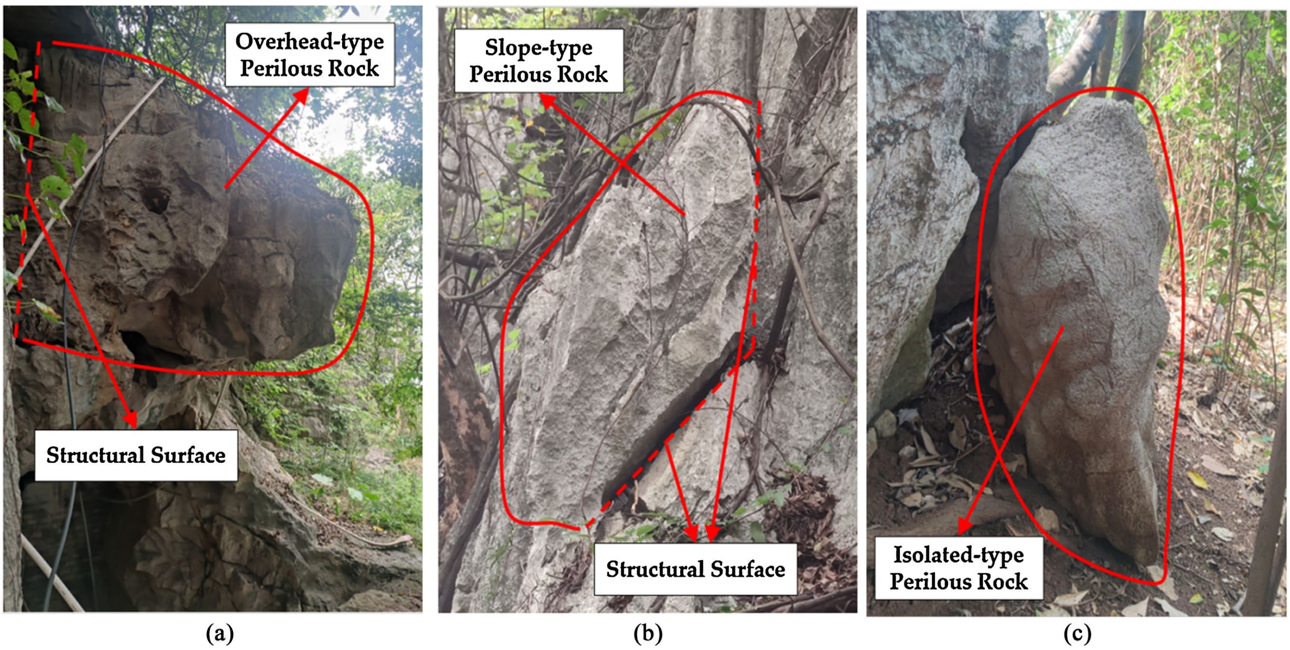


Figure 1. Three types of perilous rocks in Baiyan Mountain. (a) Overhead-type; (b) Slope-type; (c) Isolated-type.

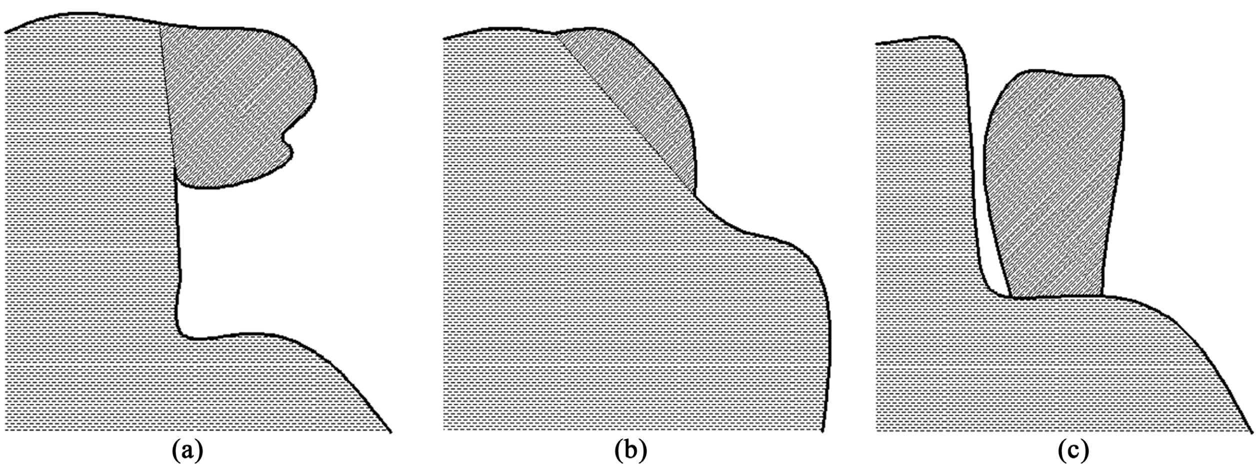


Figure 2. Simple diagrams of three perilous rock masses. (a) Overhead-type; (b) Slope-type; (c) Isolated-type.

### 2.3. Stability Evaluation Criteria

According to the evaluation criteria for the stability of perilous rocks proposed by Chen [10], the failure modes of perilous rocks are divided into three types: unstable, basically stable and stable, as shown in **Table 1**.

Kong [20] summarized the unstable modes of perilous rocks into four types: integral slip shear failure mode, block collapse failure mode, integral scattered failure mode and compression-cracking-slip failure mode, as shown in **Table 2**.

Referring to the evaluation standards of perilous rocks of the above two scholars, the corresponding stability evaluation standards were formulated for the Baiyan Mountain perilous rock mass group, as shown in **Table 3**.

**Table 1.** Evaluation criteria for the stability of perilous rocks proposed by Chen [10].

| Failure Mode of Perilous Rock | Stable State | | |
|---|---|---|---|
| | Unstable | Basically Stable | Stable |
| Slide Perilous Rock | <1.0 | 1.0~1.3 | >1.3 |
| Topple Perilous Rock | <1.0 | 1.0~1.5 | >1.5 |
| Fall Perilous Rock | <1.0 | 1.0~1.5 | >1.5 |

**Table 2.** Evaluation criteria for the stability of perilous rocks proposed by Kong [20].

| Failure Mode of Perilous Rock | Stable State | | | |
|---|---|---|---|---|
| | Unstable | Basically Stable | Less Stable | Stable |
| Integral Slip Shear Type | <1.0 | 1.0 - 1.15 | 1.15 - 1.30 | >1.3 |
| Block Collapse Type | <1.0 | 1.0 - 1.15 | 1.15 - 1.30 | >1.3 |
| Integral Scattered Type | <1.0 | 1.0 - 1.25 | 1.25 - 1.50 | >1.5 |
| Compression-cracking-slip Type | <1.0 | 1.0 - 1.25 | 1.25 - 1.50 | >1.5 |

**Table 3.** Evaluation criteria for the stability of perilous rocks in Baiyan Mountain.

| Failure Mode of Perilous Rock | | Stable State | | | |
|---|---|---|---|---|---|
| | | Unstable | Poor Stable | General Stable | Stable |
| Overhead-type Perilous Rocks | | <1.0 | 1.0 - 1.25 | 1.25 - 1.5 | >1.5 |
| Slope-type Perilous Rocks | | <1.0 | 1.0 - 1.15 | 1.15 - 1.3 | >1.3 |
| Isolated-style Perilous Rocks | Surface Embedded in Slope | <1.0 | 1.0 - 1.25 | 1.25 - 1.5 | >1.5 |
| | Surface Attached to Slope | <1.0 | 1.0 - 1.15 | 1.15 - 1.3 | >1.3 |

When the perilous rock is still in a stable situation, it is not necessary to take treatment measures. However, when the stability of the perilous rock is poor or general, the monitoring should be strengthened, and surface drainage and local engineering treatment should be adopted. When the perilous rock is still in an unstable state, surface cleaning and engineering treatment should be adopted.

## 3. Calculation Method of Perilous Rock Stability

### 3.1. Calculation of the Stability of the Overhead-Type Perilous Rock Mass

The main control structural surface at the rear edge of the overhead-type perilous rock mass is steeply inclined and has a high degree of penetration. Under the action of gravity, seismic force, fissure water pressure, vegetation root splitting and other forces, the main control structural plane is unloaded and the cracks deepen until all the main control structural planes are penetrated. As a result, the dangerous rock mass is separated from the parent rock, causing staggered instability. According to its structural characteristics, the simplified calculation model is shown in Figure 3.

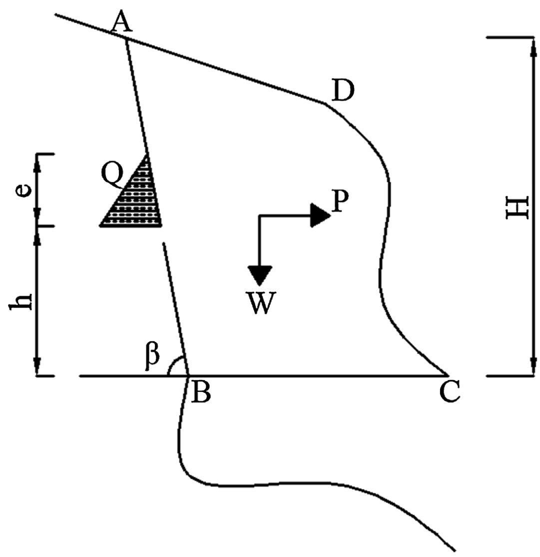


Figure 3. Simplified computational model of the overhead-type perilous rock mass.

The stability coefficient $F_s$ of the overhead-type perilous rock mass is as shown in Equation (1):

$$F_s = \frac{(W\cos\beta - P\sin\beta - Q)\tan\varphi + c\dfrac{H}{\sin\alpha}}{W\sin\beta + P\cos\beta} \quad (1)$$

$$V = \zeta_e W \quad (2)$$

$$Q = \frac{1}{2}\gamma_w h_w^2 \quad (3)$$

where: $F_s$ —the stability coefficient of the perilous rock system;

$V$ —the seismic force, KN;

$W$ —the gravity of the perilous rock, KN;

$\zeta_e$ —the seismic horizontal coefficient, which is taken as 0.05;

$Q$ —the fissure water pressure, KN/m;

$h_w$ —the fissure water height, m, which can be taken as 1/3~2/3 of the fissure depth during heavy rain. When it is difficult to drain water from the fissure at the rear edge of the perilous rock mass, the value should be determined according to the actual investigation in the recent situation. The mass of the sample used for the disintegration test in air;

$c$ —the standard value of the cohesion of the structural surface, kPa. When the fracture is not penetrated, the standard value of the internal friction angle of the penetrated section and the unpenetrated section is weighted by length, and the standard value of the cohesion of the unpenetrated section is taken as 0.4 times the standard value of the rock cohesion;

$\varphi$ —the standard value of the internal friction angle of the structural surface, ˚. When the standard value of the unpenetrated section of the crack and the unpenetrated internal friction angle are based on the length, the standard value of the internal friction angle of the unpenetrated section is 0.95 times the standard value of the internal friction angle of the rock formation;

$\beta$ —the inclination angle of the slip surface, ˚;

$H$ —the vertical distance from the top of the crack penetrating section to the end of the unpenetrated section of the fissure, m;

$h$ —the depth of the crack penetration section on the structural surface, m.

### 3.2. Calculation of the Stability of the Slope-Type Perilous Rock Mass

When calculating the stability of dangerous rock mass, the most critical thing is to determine the slip surface. Most of the instability of dangerous rock masses occurs along the main control structural surface. It can be seen that the main control structural plane of the dangerous rock mass can be used as the slip surface, and the main control structural surface is generally composed of one or two combinations.

If the slip surface of the perilous rock mass is a two-dimensional linear surface, the simplified calculation model is shown in **Figure 4**. When the slip surface is completely penetrated, it is shown in **Figure 4(a)**; When the slip surface is not completely penetrated, it is shown in **Figure 4(b)**.

The stability coefficient $F_s$ of the slope-type perilous rock mass is as shown in Equation (4):

$$F_s = \frac{F_1}{F_2} \tag{4}$$

where: $F_s$ —the stability coefficient of the perilous rock system;

$F_1$ —the anti-sliding force of the perilous rock mass, KN;

$F_2$ —the sliding force of the perilous rock mass, KN.

When the slip surface is completely penetrated (as shown in **Figure 4(a)**), the anti-sliding force $F_1$ is calculated by Equation (5):

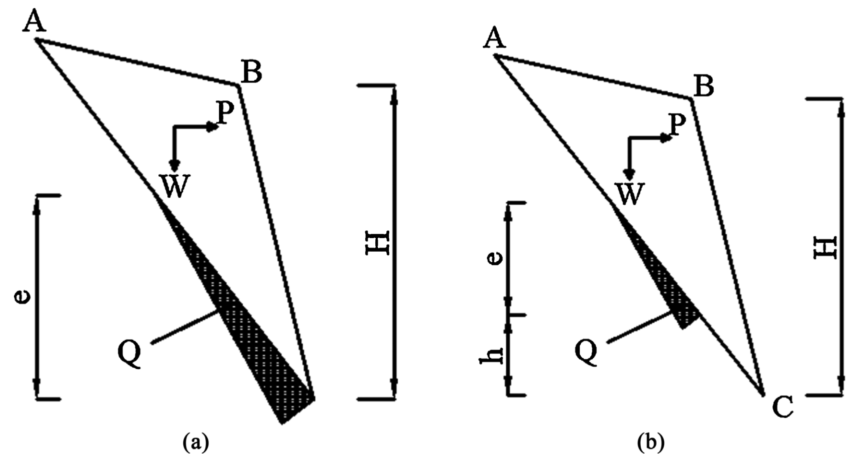


Figure 4. Calculation model of slope-type perilous rock mass with a single structural surface as the slip surface. (a) The slip surface is completely penetrated; (b) The slip surface is not completely penetrated.

$$F_1 = \left(W\cos\beta - Q - P\cos\beta\right)\tan\varphi_0 + \frac{c_0 H}{\sin\beta} \quad (5)$$

where: $c_0$ —the average cohesion of the penetrating section of the main control structural surface of the perilous rock mass, kPa;

$\varphi_0$ —the average internal friction angle of the penetrating section of the main control structural surface of the perilous rock mass, ˚;

If the slip surface is not completely penetrated (as shown in Figure 4(b)), the anti-sliding force $F_1$ is calculated by Equation (6):

$$F_1 = \left(W\cos\beta - Q - P\cos\beta\right)\tan\varphi + \frac{cH}{\sin\beta} \quad (6)$$

Whether slip surface is penetrated or not, the sliding force $F_2$ is calculated by Equation (7):

$$F_2 = W\sin\beta + P\cos\beta \quad (7)$$

When the slip surface is a combination of two structural surfaces, the calculation model is shown in Figure 5.

The stability coefficient of slope-type perilous rock mass is calculated by Equation (7) and Equation (8):

$$F_s = \frac{\left[W_1\cos\theta + T'\sin\left(\alpha-\theta\right) - W_1 - Q_1\sin\theta\right]\tan\varphi + c\dfrac{H_1}{\sin\theta}}{W_1\sin\theta + P_1\cos\theta + T'\cos\left(\alpha-\theta\right)} \quad (7)$$

$$T' = W_0\sin\alpha + P_0\cos\alpha + \frac{\left(W_0\cos\theta - Q_0 - P_0\sin\theta\right)\tan\varphi + c\dfrac{H_0}{\sin\theta}}{K} \quad (8)$$

where: $W_0$ —the gravity of the ADE block, KN;

$W_1$ —the gravity of the EDCB block, KN;

$P_0$ —the horizontal seismic force borne by the ADE block, KN;

$P_1$ —the horizontal seismic force borne by the EDCB block, KN.

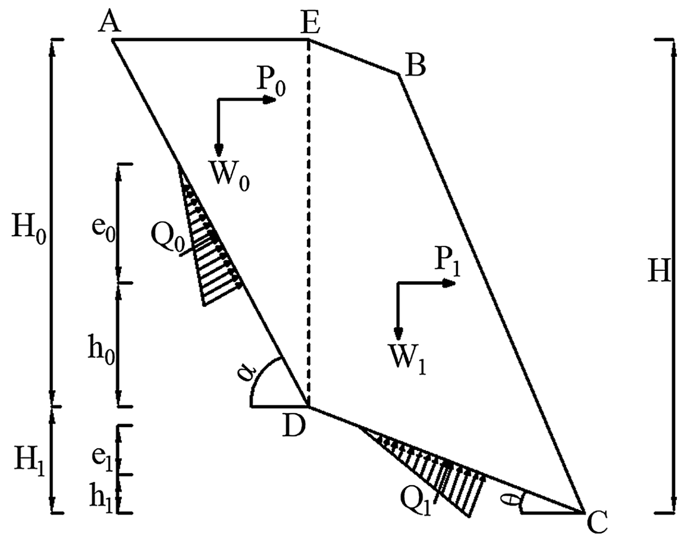


Figure 5. Calculation model of slope-type perilous rock mass with two structural surfaces as the slip surface.

$Q_0$—the hydrostatic pressure inside the slip surface of ADE block, KN;
$Q_1$—the hydrostatic pressure inside the slip surface of EDCB block, KN;
$H_0$—the height of the slip surface of the ADE block, m;
$H_1$—the height of the slip surface of the EDCB block, m;
$\alpha$—the inclination angle of the ADE block slip surface, ˚;
$\theta$—the inclination angle of the EDCB block slip surface, ˚.

### 3.3. Calculation of the Stability of the Isolated-Type Perilous Rock Mass

According to the existing form of isolated-type perilous rock mass, the isolated-type perilous rock mass is divided into two types: one is that the lower part of the rock mass is embedded in the soil and the upper part is exposed outside the ground, and the other is that it is attached to the slope surface.

For the first type of isolated-type perilous rock mass, when the moment of the horizontal seismic force on the rotation point A is greater than the force of the gravity on the rotation point A, the dangerous rock mass will undergo eccentric roll instability. The simplified calculation model of the first type of isolated-type perilous rock mass is shown in Figure 6.

The stability coefficient $F_s$ of the first type of isolated-type perilous rock mass is as shown in Equation (9):

$$F_s = \frac{W \times m}{P \times h} \tag{9}$$

where: $m$—the vertical distance from turning point A to the gravity extension line, m;

$h$—the vertical distance from turning point A to the horizontal seismic force extension line, m;

For the second type of isolated-type perilous rock mass, under the action of seismic force and other forces, when the sliding force of the dangerous rock mass is greater than the anti-sliding force of the slope surface, the slope surface will be used as the sliding surface to slide in the airborne direction. The simplified calculation model of the second type of isolated-type perilous rock mass is shown in Figure 7.

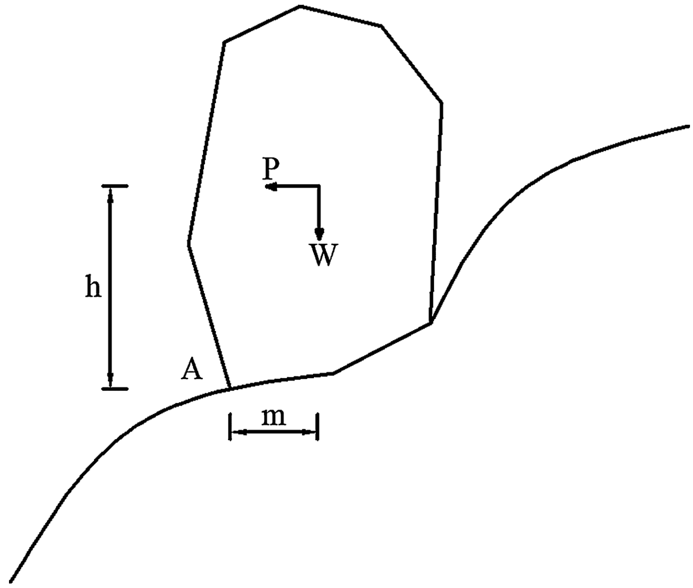


Figure 6. Simplified calculation model of an isolated eccentric rolling perilous rock mass.

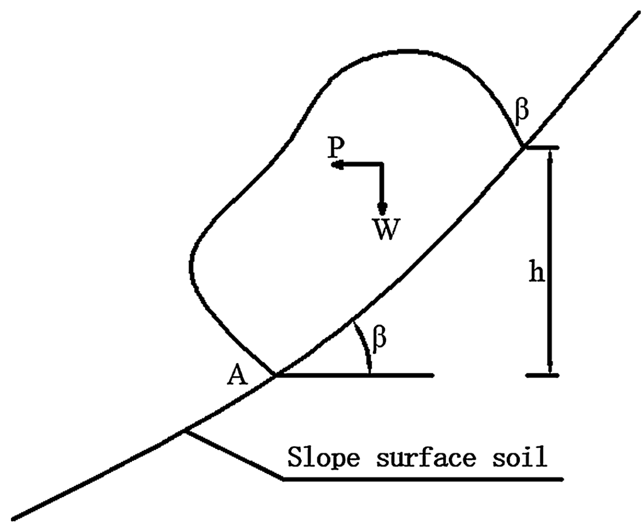


Figure 7. Simplified calculation model of an isolated eccentric slip perilous rock mass.

The stability coefficient $F_s$ of the second type of isolated-type perilous rock mass is as shown in Equation (10):

$$F_s = \frac{\left(W\cos\beta - P\cos\beta\right)\tan\varphi + \dfrac{ch}{\sin\beta}}{W\sin\beta + P\cos\beta} \tag{9}$$

where: $\beta$ —the vertical distance from turning point A to the gravity extension line, m;

$h$ —the height of the perilous rock mass, m;

$c$ —the cohesion between the perilous rock mass and the slip surface;

$\varphi$ —the internal friction angle between the perilous rock mass and the slip surface, °.

## 4. Calculation Results Analysis of Baiyan Mountain Perilous Rock Mass in Guilin

Through research and investigation [21], Baiyan Mountain is a karst mountain, and there are many perilous rock blocks around the mountain. There are many perilous rock blocks around the mountain, and these perilous rock blocks are numbered for further research, respectively B1 - B99. The free height of each perilous rock mass is about 2 - 66 m, the volume of a single piece of perilous rock is about 1.2 - 800 $m^3$ , and the total volume is 2787.95 $m^3$ . Perilous rocks are distributed on the slopes around Baiyan Mountain, basically scattered in the middle and upper part of the mountain slope, and the rocks are exposed everywhere; the slope angle usually exceeds 50°, and some are even steep cliffs. The stability of perilous rocks is poor.

Zheng Jin and others in our research group conducted on-site investigations on the perilous rock mass of Baiyan Mountain in Guilin and found that there are three main types of perilous rock mass in Baiyan Mountain, namely the overhead-type, the slope-type and the isolated-type. There are 99 perilous rock masses in Baiyan Mountain, including 8 perilous rocks of the overhead-type, 68 perilous rocks of the slope-type, and 23 perilous rocks of the isolated-type. Using the type of working condition and the calculation method for the stability of perilous rock in the previous part of this paper, the stability calculation and analysis of various types of perilous rock mass are carried out, and the results are shown below.

When calculating the stability of dangerous rock mass, the most critical thing is to determine the slip surface. Most of the instability of dangerous rock masses occurs along the main control structural surface. It can be seen that the main control structural plane of the dangerous rock mass can be used as the slip surface, and the main control structural surface is generally composed of one or two combinations.

### 4.1. Physical and Mechanical Properties of Dangerous Rock Mass in Baiyan Mountain

According to the analysis of geological survey results, the perilous rock mass in Baiyan Mountain is located in medium to thick-layered gray limestone. The bedrock is relatively complete and the surface rocks are moderately to weakly weathered. The lithology of the parent rock and dangerous rock mass is medium to thick-layered gray limestone, dolomite, and dolomitic limestone. The physical and mechanical properties of the rock masses with similar geological conditions are compared, and the recommended physical and mechanical parameters of the dangerous rock mass are shown in **Table 4**.

### 4.2. Calculation Results of Overhead-Type Perilous Rock

There are 8 overhead-type perilous rock masses in the exploration area, namely B15, B26, B29, B31, B33, B45, B85, and B86, all of which have steeply dipping cracks at their trailing edges. The calculation results are shown in Table 5.

Table 4. Design values of physical and mechanical parameters of dangerous rocks in Baiyan Mountain.

| Name | State | Uniaxial Tensile Strength $\sigma$/MPa | Deformation Modulus $E_0$/GPa | Poisson's Ratio $\mu$ | Volume Weight $\gamma$/(KN/m$^3$) | Bearing Capacity Standard Value $f_k$/kPa | Cohesion $c$/kPa | Internal Friction Angle $\varphi$/˚ |
|---|---|---|---|---|---|---|---|---|
| Limestone, Dolomite, Dolomitic Limestone | Natural State | Take 0.4 for Overhead-type | 1.2 | 0.25 | 27 | 2500 | 400 | 35 |
| Crack Structural Surface | - | - | - | - | - | - | 25 | 23 |

Table 5. Stability calculation of overhead-type perilous rock mass.

| Perilous Rock No. | Working Condition | Height $H$/m | Gravity $W$/KN | Fissure Depth $e$/m | Rupture Surface Inclination Angle $\beta$/˚ | Equivalent Cohesion $c$/kPa | Equivalent Internal Friction Angle $\varphi$/˚ | Seismic Force $P$/KN | Stability Coefficient | Stability |
|---|---|---|---|---|---|---|---|---|---|---|
| B15 | 1 | 3.0 | 324.0 | 2.5 | 86 | 62.5 | 24.2 | 0 | 1.18 | Poor |
| | 3 | 3.0 | 324.0 | 2.5 | 86 | 62.5 | 24.2 | 16.2 | 1.15 | Poor |
| B26 | 1 | 2.0 | 81.0 | 1.9 | 83 | 45.6 | 23.7 | 0 | 1.15 | Poor |
| | 3 | 2.0 | 81.0 | 1.9 | 83 | 45.6 | 23.7 | 4.1 | 1.13 | Poor |
| B29 | 1 | 8.0 | 2160.0 | 7.0 | 80 | 71.9 | 24.5 | 0 | 1.42 | General |
| | 3 | 8.0 | 2160.0 | 7.0 | 80 | 71.9 | 24.5 | 108.0 | 1.39 | General |
| B31 | 1 | 3.0 | 605.7 | 2.7 | 85 | 68.8 | 24.4 | 0 | 1.06 | Poor |
| | 3 | 3.0 | 605.7 | 2.7 | 85 | 68.8 | 24.4 | 30.4 | 1.03 | Poor |
| B33 | 1 | 4.5 | 908.6 | 3.7 | 82 | 91.7 | 25.1 | 0 | 1.08 | Poor |
| | 3 | 4.5 | 908.6 | 3.7 | 82 | 91.7 | 25.1 | 45.4 | 1.05 | Poor |
| B45 | 1 | 4.0 | 324.0 | 3.8 | 79 | 48.4 | 23.8 | 0 | 1.31 | General |
| | 3 | 4.0 | 324.0 | 3.8 | 79 | 48.4 | 23.8 | 16.2 | 1.27 | General |
| B85 | 1 | 3.0 | 907.2 | 2.6 | 79 | 75.0 | 24.6 | 0 | 1.11 | Poor |
| | 3 | 3.0 | 907.2 | 2.6 | 79 | 75.0 | 24.6 | 45.4 | 1.08 | Poor |
| B86 | 1 | 5.0 | 1967.0 | 3.9 | 88 | 103.8 | 25.5 | 0 | 1.25 | General |
| | 3 | 5.0 | 1967.0 | 3.9 | 88 | 103.8 | 25.5 | 98.4 | 1.22 | Poor |

### 4.3. Calculation Results of Slope-Type Perilous Rock

There are a total of 66 slope-type perilous rock masses in the exploration area. The fractures have good penetration and poor bonding. The calculation results of some of them are shown in Table 6.

**Table 6.** Stability calculation of slope-type perilous rock mass.

| Perilous Rock No. | Working Condition | Height $H$/m | Gravity $W$/KN | Fissure Depth $e$/m | Rupture Surface Inclination Angle $\beta$/° | Equivalent Cohesion $c$/kPa | Equivalent Internal Friction Angle $\varphi$/° | Seismic Force $P$/KN | Stability Coefficient | Stability |
|---|---|---|---|---|---|---|---|---|---|---|
| B2 | 1 | 2.0 | 121.5 | 1.88 | 67 | 47.5 | 23.72 | 0 | 1.11 | Poor |
| | 2 | 2.0 | 121.5 | 1.88 | 67 | 47.5 | 23.72 | 0 | 1.08 | Poor |
| | 3 | 2.0 | 121.5 | 1.88 | 67 | 47.5 | 23.72 | 6.1 | 1.06 | Poor |
| B3 | 1 | 3.0 | 324 | 2.81 | 71 | 48.75 | 23.76 | 0 | 1.15 | General |
| | 2 | 3.0 | 324 | 2.81 | 71 | 48.75 | 23.76 | 0 | 1.12 | Poor |
| | 3 | 3.0 | 324 | 2.81 | 71 | 48.75 | 23.76 | 16.2 | 1.11 | Poor |
| B16 | 1 | 3 | 259.2 | 2.8 | 63 | 50 | 23.8 | 0 | 0.95 | Unstable |
| | 2 | 3 | 259.2 | 2.8 | 63 | 50 | 23.8 | 0 | 0.92 | Unstable |
| | 3 | 3 | 259.2 | 2.8 | 63 | 50 | 23.8 | 12.9 | 0.9 | Unstable |
| B17 | 1 | 2.5 | 675 | 1.7 | 60 | 145 | 26.84 | 0 | 1.01 | Poor |
| | 2 | 2.5 | 675 | 1.7 | 60 | 145 | 26.84 | 0 | 1 | Poor |
| | 3 | 2.5 | 675 | 1.7 | 60 | 145 | 26.84 | 33.8 | 0.96 | Unstable |
| B19 | 1 | 4 | 486 | 3.65 | 61 | 57.81 | 24.05 | 0 | 1.17 | General |
| | 2 | 4 | 486 | 3.65 | 61 | 57.81 | 24.05 | 0 | 1.14 | Poor |
| | 3 | 4 | 486 | 3.65 | 61 | 57.81 | 24.05 | 24.3 | 1.12 | Poor |
| B28 | 1 | 2.57 | 746.01 | 2.27 | 64 | 68.77 | 24.4 | 0 | 0.95 | Unstable |
| | 2 | 2.57 | 746.01 | 2.27 | 64 | 68.77 | 24.4 | 0 | 0.94 | Unstable |
| | 3 | 2.57 | 746.01 | 2.27 | 64 | 68.77 | 24.4 | 37.3 | 0.9 | Unstable |
| B32 | 1 | 2.4 | 110.16 | 2.28 | 76 | 43.75 | 23.6 | 0 | 1.11 | Poor |
| | 2 | 2.4 | 110.16 | 2.28 | 76 | 43.75 | 23.6 | 0 | 1.07 | Poor |
| | 3 | 2.4 | 110.16 | 2.28 | 76 | 43.75 | 23.6 | 5.51 | 1.08 | Poor |
| B35 | 1 | 2.51 | 466.29 | 2.17 | 76 | 75.8 | 24.63 | 0 | 0.98 | Unstable |
| | 2 | 2.51 | 466.29 | 2.17 | 76 | 75.8 | 24.63 | 0 | 0.97 | Unstable |
| | 3 | 2.51 | 466.29 | 2.17 | 76 | 75.8 | 24.63 | 23.3 | 0.94 | Unstable |
| B38 | 1 | 4.1 | 553.5 | 4.25 | 67 | 45.83 | 23.67 | 0 | 1.05 | Poor |
| | 2 | 4.1 | 553.5 | 4.25 | 67 | 45.83 | 23.67 | 0 | 1.00 | Poor |
| | 3 | 4.1 | 553.5 | 4.25 | 67 | 45.83 | 23.67 | 26.7 | 1.01 | Poor |
| B43 | 1 | 3.5 | 234.36 | 3.33 | 65 | 43.21 | 23.58 | 0 | 1.17 | General |
| | 2 | 3.5 | 234.36 | 3.33 | 65 | 43.21 | 23.58 | 0 | 1.12 | Poor |
| | 3 | 3.5 | 234.36 | 3.33 | 65 | 43.21 | 23.58 | 11.7 | 1.13 | Poor |
| B54 | 1 | 2.7 | 437.4 | 2.5 | 71 | 52.78 | 23.89 | 0 | 1.06 | Poor |
| | 2 | 2.7 | 437.4 | 2.5 | 71 | 52.78 | 23.89 | 0 | 1.03 | Poor |

Continued

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 2.7 | 437.4 | 2.5 | 71 | 52.78 | 23.89 | 21.9 | 1.02 | Poor |
| B56 | 1 | 3.1 | 1135.81 | 2.63 | 59 | 91.8 | 25.14 | 0 | 1.48 | Stable |
| | 2 | 3.1 | 1135.81 | 2.63 | 59 | 91.8 | 25.14 | 0 | 1.46 | Stable |
| | 3 | 3.1 | 1135.81 | 2.63 | 59 | 91.8 | 25.14 | 56.8 | 1.41 | Stable |
| B57 | 1 | 2.54 | 436.05 | 2.24 | 58 | 69.29 | 24.41 | 0 | 1.18 | General |
| | 2 | 2.54 | 436.05 | 2.24 | 58 | 69.29 | 24.41 | 0 | 1.16 | General |
| | 3 | 2.54 | 436.05 | 2.24 | 58 | 69.29 | 24.41 | 21.8 | 1.12 | Poor |
| B61 | 1 | 3.75 | 1027.62 | 3.27 | 62 | 73 | 24.536 | 0 | 1.43 | Stable |
| | 2 | 3.75 | 1027.62 | 3.27 | 62 | 73 | 24.536 | 0 | 1.4 | Stable |
| | 3 | 3.75 | 1027.62 | 3.27 | 62 | 73 | 24.536 | 51.4 | 1.37 | Stable |
| B72 | 1 | 3.54 | 324.972 | 3.23 | 69 | 57.84 | 24.05 | 0 | 1.58 | Stable |
| | 2 | 3.54 | 324.972 | 3.23 | 69 | 57.84 | 24.05 | 0 | 1.53 | Stable |
| | 3 | 3.54 | 324.972 | 3.23 | 69 | 57.84 | 24.05 | 16.3 | 1.53 | Stable |
| B96 | 1 | 3.2 | 794.88 | 2.89 | 59 | 61.33 | 24.16 | 0 | 1.04 | Poor |
| | 2 | 3.2 | 794.88 | 2.89 | 59 | 61.33 | 24.16 | 0 | 1.02 | Poor |
| | 3 | 3.2 | 794.88 | 2.89 | 59 | 61.33 | 24.16 | 39.7 | 0.99 | Unstable |

### 4.4. Calculation Results of Slope-Type Perilous Rock

There are 25 isolated-type perilous rock masses in the exploration area. The calculation results of some of them are shown in Table 7.

Table 7. Stability calculation of isolated-type perilous rock mass.

| Perilous Rock No. | Height $H$/m | Gravity $W$/KN | Seismic Force $P$/KN | The distance from the turning point to the horizontal seismic force extension line $h$/m | The distance from the turning point to the gravity extension line $m$/m | Stability Coefficient | Stability |
|---|---|---|---|---|---|---|---|
| B11 | 8 | 864 | 43.2 | 4.1 | 0.203 | 0.99 | Unstable |
| B12 | 3 | 299.7 | 14.985 | 2.35 | 0.12 | 1.02 | Poor |
| B14 | 8.2 | 1467.882 | 73.39 | 5.21 | 0.3 | 1.15 | Poor |
| B34 | 1 | 25.92 | 1.296 | 0.51 | 0.03 | 1.18 | Poor |
| B40 | 3 | 607.5 | 30.375 | 2.1 | 0.11 | 1.05 | Poor |
| B50 | 4.5 | 1105.65 | 55.28 | 2.7 | 0.15 | 1.11 | Poor |
| B53 | 4 | 324 | 16.2 | 2.34 | 0.13 | 1.11 | Poor |
| B59 | 2.7 | 291.6 | 14.58 | 1.65 | 0.08 | 0.97 | Unstable |
| B62 | 3.1 | 631.09 | 31.55 | 2.01 | 0.1 | 1.00 | Poor |
| B73 | 3.4 | 367.2 | 18.36 | 1.99 | 0.08 | 0.80 | Unstable |
| B74 | 1.9 | 56.43 | 2.82 | 0.87 | 0.05 | 1.15 | Poor |

Continued

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B75 | 2.9 | 195.75 | 9.78 | 1.63 | 0.08 | 0.98 | Unstable |
| B83 | 2.4 | 228.09 | 11.40 | 1.19 | 0.06 | 1.01 | Poor |
| B84 | 4.7 | 879.41 | 43.97 | 2.32 | 0.14 | 1.21 | Poor |
| B97 | 2.1 | 183.14 | 9.16 | 1.24 | 0.07 | 1.13 | Poor |

Through the calculation of the stability of 99 perilous rock masses in the exploration area, that is, the calculation results of various types of perilous rock masses in Baiyan Mountain mentioned above in this paper, the following conclusions are drawn: 8 overhead-type perilous rock masses are in an unstable or poorly stable state. Among 66 slope-type perilous rock masses, 58 are in unstable or poorly stable states, and 8 are in a stable state; 25 isolated-type perilous rock masses are in an unstable state. In order to avoid perilous rock geological disasters threatening the lives and properties of residents in residential areas, it is necessary to take corresponding measures for various types of unstable perilous rock masses. For the perilous rock masses that are currently in a stable state, long-term monitoring should be carried out.

## 5. Treatment of Baiyan Mountain Perilous Rock Mass

According to the calculation results, a corresponding treatment plan is adopted for the perilous rock, including support protection, removal project, pour mortar, anchorage-steel wire rope (net) bounding and grouting and anchorage-screen.

### 5.1. Support Protection

For some perilous rock masses, if there are supporting conditions, flakes or reinforced concrete should be used as supports to ensure the stability of the perilous rock masses. Taking B26 perilous rock mass as an example, its length, width and height are about 2 × 1 × 1.5 m, and its volume is small. The mortar used is M7.5 grade, and the concrete is supported by C20 plain concrete, as shown in Figure 8. Among the 99 perilous rock masses, there are eight perilous rock masses that meet the above conditions, namely No. B15, B26, B29, B31, B33, B45, B85, and B86. The treatment plans all use support protection.

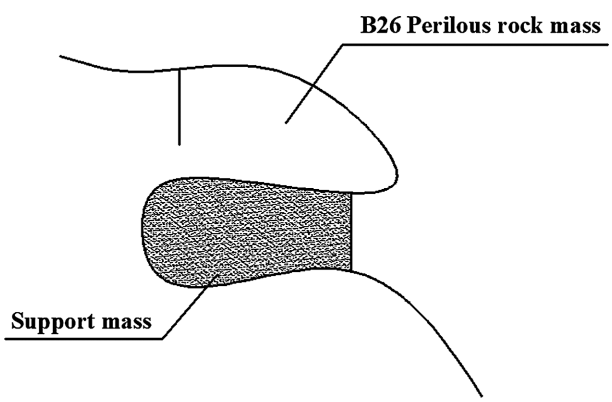


Figure 8. Support protection diagram of B26 perilous rock mass.

### 5.2. Removal Project

If the surface slope below the perilous rock mass is relatively gentle and there are no other buildings such as residential buildings below, or there are no effective protective measures under the perilous rock mass, then a removal project can be used to treat it. When removing perilous rocks, methods such as manual excavation and blasting can be used to disintegrate perilous rocks one by one and remove them gradually. During the removal of perilous rocks, monitoring should be strengthened to avoid stimulating other unstable perilous rocks. The 39 perilous rock masses including B6, B7, B14, and B50 in the Baiyan mountain perilous rock mass are protected and treated by a removal project. Take B50 as an example, as shown in Figure 9.

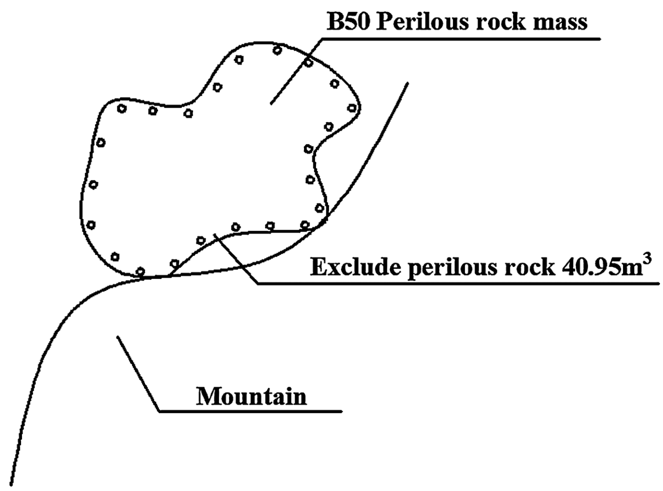


Figure 9. Removal protection diagram of B50 perilous rock mass.

### 5.3. Pour Mortar

For some perilous rock masses, if the whole is relatively broken and there are many cracks on the surface of the rock mass, pressure pour mortar can be used to fill the cracks with grout to enhance the stability of the perilous rock mass in order to protect the integrity of the rock mass, improve the overall stability of the perilous rock mass, prevent water seepage and further damage the perilous rock mass. When pouring cement mortar, the clay gravel in the joint should be cleaned up. Set pour mortar holes in the middle and upper part of the perilous rock mass, and then pour cement mortar to increase the cohesion between the rock masses. Among the 99 perilous rocks, No. B12 perilous rock body has relatively large surface cracks, so take No. B12 perilous rock body of Baiyan Mountain as an example, as shown in Figure 10. The treatment method is to use 350kPa low-pressure pouring cement mortar to fill the gaps in the structural surface.

### 5.4. Anchorage-Steel Wire Rope (Net) Bounding and Grouting

For most of the perilous rock mass separated from the parent rock, but with poor stability, anchorage-steel wire rope (net) bounding and grouting can be used. The method is mainly to lay anchor rods on the stable rock mass around the perilous rock mass. The anchorage depth is calculated according to the main control crack surface, and the distance between anchor rods is 1.5~2m. After the A15mm steel wire rope and anchor rod are tightly bound around the perilous rock mass with cold-drawn steel bars, poor mortar is applied to the cracks in the perilous rock. Take Baiyan Mountain No. B1 perilous rock mass as an example, as shown in Figure 11.

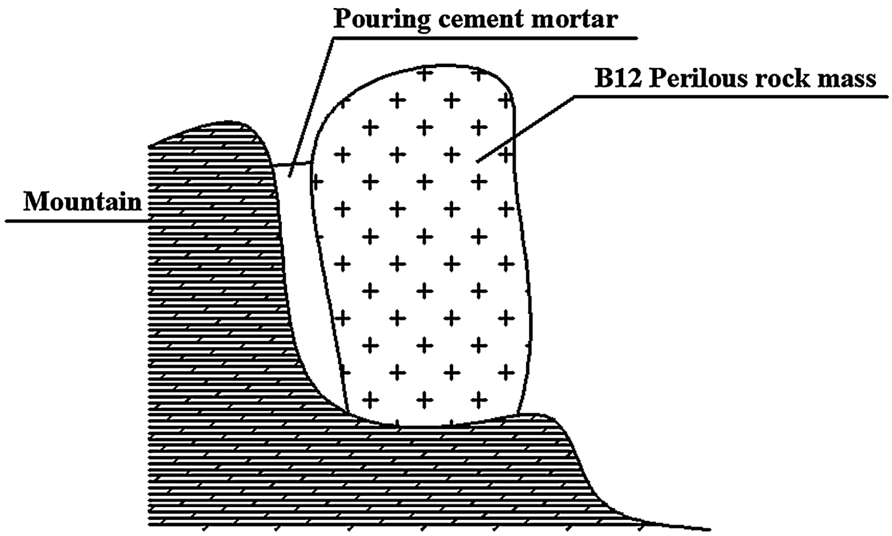


Figure 10. Fracture pour mortar diagram of B12 perilous rock mass.

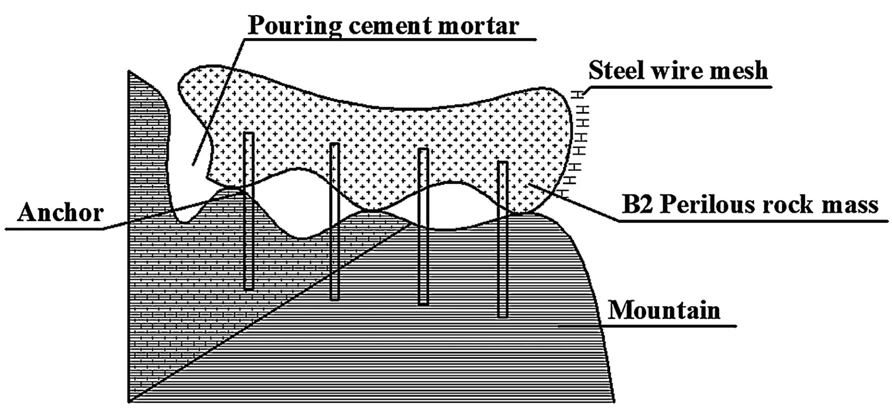


Figure 11. Protection diagram of B2 perilous rock mass.

### 5.5. Anchorage-Screen

For the overhead-type perilous rock, if the center of gravity of the support body is located outside the center of gravity of the rock, the perilous rock mass can be anchored, and the control measures are to use steel wire stone blocking nets and stone blocking walls. Take Baiyan Mountain B85 as an example, as shown in Figure 12.

## 6. Conclusion

This paper takes the perilous rock mass of Baiyan Mountain in Guilin as the research

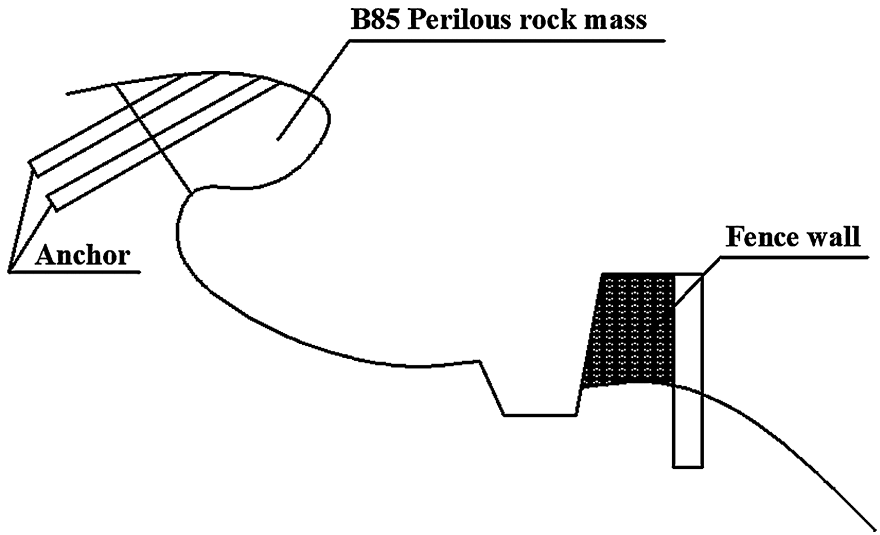


**Figure 12.** Anchorage-screen protection diagram of B85 perilous rock mass.

object and classifies the unstable modes of the perilous rock mass. It establishes a stability calculation method for perilous rock masses of different unstable modes and uses the limit rigid body balance method to calculate the stability of the perilous rock mass. According to the calculation results analysis and judgment, formulate different protective measures for different types of perilous rock mass. The main conclusions are as follows:

(1) According to the results of engineering geological survey, the perilous rock mass of Baiyan Mountain can be divided into three types: overhead-type, slope-type and isolated-type. The corresponding stability evaluation standards were formulated for the Baiyan Mountain perilous rock mass group.

(2) According to the on-site survey, there are 99 perilous rock masses in Baiyan Mountain, including 8 perilous rocks of the overhead-type, 68 perilous rocks of the slope-type, and 23 perilous rocks of the isolated-type. According to the calculation results of the stability of perilous rocks, 8 overhead-type perilous rock masses are in unstable or poor stable state; Among 66 slope-type perilous rock masses, 58 are in unstable or poor stable state, and 8 are in a stable state; 25 isolated-type perilous rock masses are in an unstable state.

(3) For different types of perilous rock mass, formulate corresponding protective measures, namely support protection, removal project, pour mortar, anchorage-steel wire rope (net) bounding and grouting and anchorage-screen. Although the environment for the development of perilous rocks is different and there are many influencing factors, through reasonable analysis, corresponding prevention and control measures have been worked out to ensure the life safety of local residents.

## Funding

This work was supported by College Students' Innovation and Entrepreneurship Project (No. S202510595192).

## Conflicts of Interest

The authors declare no conflicts of interest.

## References

[1] Chen, H.K., Tang, H.M., Hu, M. and Li, Q. (2005) Research on Anchorage Calculation Method for Unstable Rock. *Chinese Journal of Rock Mechanics and Engineering*, **8**, 1321-1327.

[2] Chen, H.K. And Qin, X. (2018) Status Quo and Trend of Unstable Rock Stability Analysis. *Journal of Chongqing Jiaotong University (Natural Science Edition*), **37**, 49-60.

[3] Attewell, P.B. and Farme, I.W. (1976) Principles of Engineering Geology. John Wiley & Sons, Inc., 75-76.

[4] Hoek, E. and Bray, J.W. (1981) Rock Slope Engineering. The Institution of Mining and Metallurgy, Vol. 7, 213-217.

[5] Yao, Y.J. (1990) The Formation Conditions, Types and Prevention Principles of Dangerous Rock Collapse. *Subgrade Engineering*, **1**, 36-39.

[6] Shi, C., Yang, B., Zhang, Y. and Yang, J. (2020) Application of Discrete-Element Numerical Simulation for Calculating the Stability of Dangerous Rock Mass: A Case Study. *International Journal of Geomechanics*, **20**, Article 04020231. https://doi.org/10.1061/(asce)gm.1943-5622.0001872

[7] Huang, L.Q. and Xu, M. (2004) Fine Description and Engineering Application of Complex Rock ass Structure. Science Press.

[8] Gao, Y.C., Meng, X.J., Qi, Y.A., Gao, J.L., Zhang, P.P., Dai, M.Y. and Yang, X.W. (2015) Characteristic and Prevention of Perilous Rock in Yuntaishan Scenic Region. *Journal of Henan Polytechnic University*, **34**, 129-135.

[9] Fan, K., Feng, Z.H., Wang, X., Jiang, M.Y., Liu, Z.K. and Cai, Y.F. (2019) Development of Rockfalls in Guilin and Its Influence Factors. *Journal of Natural Disasters*, **28**, 169-182.

[10] Chen, H.K., Tang, H.M. and Wang, R. (2004) Calculation Method of Stability for Unstable Rock and Application to the Three Gorges Reservoir. *Chinese Journal of Geotechnical Engineering*, **26**, 614-619.

[11] Kong, Y., Shi, H.P. and Yu, H.M. (2016) Analysis of Unstable Rock-Mass Stability Based on Limit Equilibrium Method and Strength Reduction Method. *Applied Mechanics and Materials*, **858**, 73-80. https://doi.org/10.4028/www.scientific.net/amm.858.73

[12] Liu, W., Dong, J., Sui, S., Xu, H., Yang, R. and Shen, Z. (2021) Stability Assessment of Dangerous Rock Mass of an Overhanging Slope in Puerdu Town, Southwestern China. *Advances in Civil Engineering*, **2021**, 1-12. https://doi.org/10.1155/2021/6526417

[13] Wang, L., Yin, Y., Huang, B. and Dai, Z. (2020) Damage Evolution and Stability Analysis of the Jianchuandong Dangerous Rock Mass in the Three Gorges Reservoir Area. *Engineering Geology*, **265**, Article 105439. https://doi.org/10.1016/j.enggeo.2019.105439

[14] Verma, A.K., Sardana, S., Sharma, P., Dinpuia, L. and Singh, T.N. (2019) Investigation of Rockfall-Prone Road Cut Slope Near Lengpui Airport, Mizoram, India. *Journal of Rock Mechanics and Geotechnical Engineering*, **11**, 146-158. https://doi.org/10.1016/j.jrmge.2018.07.007

[15] Li, H.F., Zhang, G.X., Huang, T. and Zhou, Q.J. (2013) Stability Analysis of Dangerous

Rocks on the Slope of a Hydropower Station. *Applied Mechanics and Materials*, **405**, 621-629. https://doi.org/10.4028/www.scientific.net/amm.405-408.621

[16] Huang, D., Huang, R.Q, Pei, X.J. and Liu, W.H. (2008) Study on Stability and Reinforcement Measures of An Unstable Rock Mass of Xiluodu Hydropower Station. *Geotechnical Mechanics*, **29**, 1425-1429.

[17] Liu, B.C., Pan, Z.Y. and Zheng, J. (2013) Development Characteristics and Stability Analysis of Karst Dangerous Rock Mass in Guilin City. *Journal of Natural Disasters*, **22**, 183-189.

[18] Wang, G.F., Wang, H.D., Xue, X.Q., Jin, X.H. and Le, Q.L. (2012) Failure Analysis of Wangxia Dangerous Rock Mass in Wuhan County and Prediction of Its Next Deformation and Instability. *Journal of Natural Disasters*, **21**, 164-172.

[19] Chen, H.K., Wang, S.J. and Chen, J. (2020) Theoretical Framework of Physical Development and Break Out Time of Perilous Rock and Collapse Disaster. *Journal of Chongqing Normal University*, **37**, 121-128.

[20] Kong, W. (2018) Study on the Deformation and Failure and Rockfall Movement Characteristics of Potential Unstable Rock in the Yiwan Section of Zhengwan Railway. Chengdu University of Technology,

[21] Zheng, J. (2012) Research on the Technical System and Characteristics of Prevention and Control of Perilous Rock Collapse in Guilin Area. Guilin University of Technology.