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Study on Calculation Method of Stability of Damaged Sliding Dangerous Rock on Reservoir Bank

-- Taking Jianchuandong Dangerous Rock in Wushan County as An Example

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Abstract: The rapid destruction of dangerous rock produces a large amount of energy, causing heavy casualties and economic losses every year. There are various failure modes and stability calculation methods of dangerous rock. The common failure modes of dangerous rock are tipping mode, sliding mode and falling mode. For large tower pillar dangerous rock with degraded foundation, it is unreasonable to use conventional stability calculation methods to calculate the stability of dangerous rock. This paper takes Jianchuandong dangerous rock in Wushan County as the research background, considering the expansion of rock cavity of damaged dangerous rock base and the deterioration of rock mass in the base of large tower column reservoir bank, and establishes the stability calculation method of dangerous rock suitable for the damage deterioration of the base. It is innovative on the basis of the traditional stability calculation method of dangerous rock, which has important practical significance and theoretical basis for the calculation of the stability of unconventional dangerous rock.

Keywords: Damaged dangerous rock, Deterioration of the base, Stability, Cavern extension.

1. Introduction

The formation and failure of dangerous rock is a long process. From the macroscopic concept of time, because the weathering of rocks is certain, so is the movement of geological structures, all the unstable dangerous rock mass will be unstable and fail no matter whether it is treated or not. The dangerous rock mass in the stable state at the present stage will gradually become unstable until it becomes unstable and fails, and the unstable failure of dangerous rock is inevitable. However, since the instability and failure of dangerous rock in the macroscopic time concept are often measured in thousands or even millions of years, the formation and failure process of dangerous rock is not inevitable from the microscopic time perspective. The prevention and control of dangerous rock is of great significance to the protection of human production and life and property safety. Many scholars have studied dangerous rocks, Zhang Zhihua et al [1] According to the standard method, the stability of dangerous rock under different working conditions is calculated. The calculation shows that the dangerous rock is in a basically stable to stable state, and the stability coefficient is reduced to 1.081 when the shear strength of the base rock mass is used to calculate the stability after the dry and wet cycle, and the dangerous rock mass may suffer the collapse of the base fracturing slip. Ran Tao et al [2] Combined with field investigation, the development form, volume and failure mode of the dangerous rock mass in the four-layer rock scarp belt of Wanzhou District are investigated in detail, and the stable state of the rock mass is evaluated through qualitative and quantitative analysis. Hu Mingjun et al [3] In this paper, the carbonate bank slope in the fluctuation zone of the Three Gorges reservoir is studied, and the data of rock mass deterioration and damage under periodic water level changes are obtained by means of experiments. Zhou Yuntao et al [4] When calculating the stability of dangerous rock, the influence of receding rock cavity of dangerous rock base on the stability of near horizontal hard soft rock interbed is considered. Zhou Peng [5] In this paper, the stability of 3D geological body bounded by structural plane is studied from the perspective of 3D, and a calculation method of 3D stability of sliding dangerous rock considering the boundary of structural plane is proposed. Deng Yue et al [6] Through the dynamic time-history curve of seismic wave attenuation under dynamic action, the function of equivalent blasting dynamic load with time is obtained. Combined with fracture mechanics, several conventional stability calculation methods of dangerous rock under dynamic action are established. Li Xiangqing et al [7] In order to study the stability of high slope in alpine region, the temperature field was established considering frost heave force, gravity and crack water pressure, and the stability calculation method was established based on fracture mechanics.

Current research on the stability of dangerous rock, the evaluation method is numerous, for the special dangerous rock mass, the traditional calculation method of the stability of dangerous rock is not fully applicable to the pillar of dangerous rock mass base damage type dangerous rock stability calculation, such as ZengZi Yan dangerous rock crushing destruction, longmen for whole village and dangerous rock coffin ridge may occur such as dangerous rock crushing destruction, Jianchuandong dangerous rock is a typical tower pillar rock cut by structural fissure. The lower bedrock is deteriorated by dead weight load and long-term circulation soaking of reservoir water. Therefore, it is of great significance and practical effect to establish a new calculation method for the stability of damaged damaged rock in reservoir bank.

2. Study Area Profile

2.1. Background of study area

The study area is located in the joint belt of several tectonic systems, such as the arcuate structure of Daba Mountain, Sichuan-Hubei Hunan-Guizhou uplift fold belt and eastern Sichuan fold belt. The lowest point is the side of Peishi Yangtze River with an altitude of 175m, and the highest point is Taiping Mountain on the southern slope of Daba Mountain with an altitude of 2680m, which is a typical karst landform. The maximum mountain area in Wushan Mountain is more than 97%, and the mountain area is divided into middle mountains, low mountains and hills accounting for 60%, 36% and 4%, respectively. Overall, the terrain is high and low in the middle. The middle mountain area is interspersed with the strip of low mountain area with hills scattered between them. Jianchuandong dangerous rock body is located on the west side of Shennv Peak and on the left bank of the Yangtze River in the Wuxia section. It is only 12km away from the county town and 112.3km downstream is the Three Gorges Dam. The whole base of the dangerous rock mass is immersed in the water of the Yangtze River. Once the dangerous rock mass becomes unstable and breaks down and falls into the waterway of the Yangtze River to form a surge wave, it will pose a fatal threat to the life and property safety of downstream residents and the safety of the entire waterway transportation, wharves and scenic spots.

Figure 1. Overall picture of dangerous rock pierced by Arrows (picture from the Internet)

2.2. Geological environment of the study area

Jianchuandong dangerous rock mass is located in the turning section of the axial part and southeast wing of Shennv anticline. There is neither fault nor active fault in the axial rock mass. The occurrence of the axial rock mass is NE255°-265°∠5°-7°, and the dip of the southeast wing rock strata is NE150°-160° ∠ 10°-24°. Three fissures developed in Jianchuandong dangerous rock mass are in the southeast, northwest and northeast, and the fissures have been all through, showing irregular long strips. Three main structural cracks occur in dangerous rock mass: the boundary cracks (NE300°-315°∠78°-85°) on the southeast side. The upper part of the cracks is not filled, but locally filled with rubble soil and residual gravel soil. From top to bottom, the cracks gradually converge and point out at the elevation of 153m. North west boundary crack (NE325°-335°∠85°-88°); The fissure in the northeast side (NE255°-265° ∠ 70°-80°) is basically filled by gravel, and the fissure has a large opening degree, with the maximum reaching 3.15m.

In terms of spatial form, the engineering geological conditions of Jianchuandong dangerous rock show irregular hexahedron in geometric form. In addition to the dangerous rock being divided by three fissures, Jianchuandong dangerous rock also has three adits that were used as defensive rock in Wuxia during the Anti-Japanese War, with elevations of 157m. The section size and size of the three adits are the same. The fractured fissure formed by the dead weight of the dangerous rock mass in the upper part of the foundation rock mass and the existing adit destroy the integrity of the dangerous rock mass and reduce the stability of the dangerous rock mass. When the river water level rises and inundate the foundation, the river water's erosion, erosion and dissolution on the foundation will further soften the argillous strip limestone of the foundation, thus further damaging the stability of the dangerous rock mass.

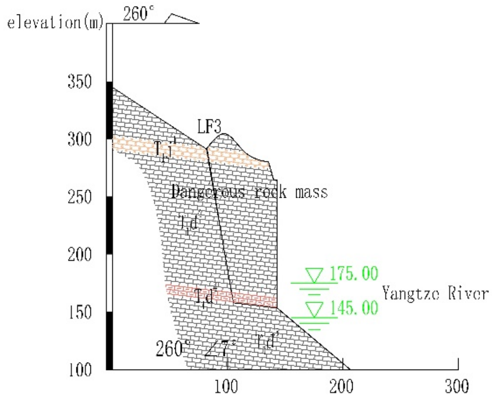

Figure 2. Geological profile of dangerous rock in Arrow hole

3. Stability Calculation Method of Damaged Sliding Dangerous Rock on Reservoir Bank

The development of dangerous rock is influenced by internal and external factors. Different lithologic combinations, topographic conditions, stratigraphic lithologic conditions and hydrological conditions will affect the failure mode and development characteristics of dangerous rock. The rock of dangerous rock mass base is damaged and deteriorated under the action of river water and weathering, and the rock strata peel off to form rock cavity. The gravity of dangerous rock mass acts on the undamaged base rock and the damaged part of base rock, forming the damaged dangerous rock on the reservoir bank. The dangerous rock mass is subject to seismic force (P), dead weight of dangerous rock mass (W), support force of undamaged rock at the base (N1), support force of damaged rock at the base (N2), shear force of rock mass (T) and support force of main control structural plane (N). The damaged sliding mechanical model of dangerous rock at the reservoir bank is as follows:

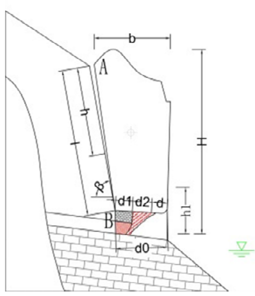

Figure 3. Physical model of dangerous rock

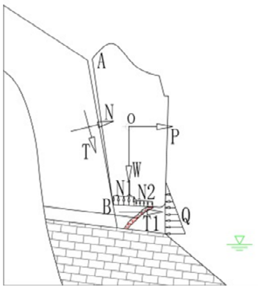

Figure 4. Mechanical model of dangerous rock

Due to the large opening degree of the main control structural plane at the back of the rock pierced by arrows, the influence of the water pressure on the fracture of the rear reinforced structural plane can be ignored. Chen Hongkai et al [8] According to the rule, the pore water pressure of dangerous rock is mainly affected by the height of fissure water under the natural state of hydrostatic pressure and the state of rainstorm. The hydrostatic pressure formula can be expressed as follows:

Natural state:

$$Q = \frac{1}{2}\xi\gamma_w(\frac{1}{3}e\sin\beta)^2 \quad (1)$$

State of rainstorm:

$$Q = \frac{1}{2}\xi\gamma_w(\frac{2}{3}e\sin\beta)^2 \quad (2)$$

Where: (Q) is the hydrostatic pressure of the crack in dangerous rock. For the dangerous rock with the opening degree of the main control structural plane of 0.2-0.5cm, (e) is the length of the crack through dangerous rock, (β) is the dip Angle of the main control structural plane of dangerous rock, (ξ) is the damage coefficient of the crack water pressure, and (γ_w) is the bulk density of water. Due to the large opening degree of the crack in dangerous rock, the maximum is 3.15m. Therefore, the hydrostatic pressure of crack in dangerous rock is not considered.

For the wharf type dangerous rock, different from the water pressure calculated by the general dangerous rock mass in the posterior structural plane fracture, the wharf type dangerous rock has hydrostatic pressure in the sliding direction of the dangerous rock, that is, the hydrostatic pressure at the sliding open surface can be expressed as:

$$Q = \frac{1}{2}\xi\gamma_w h_1^2 \quad (3)$$

Where: (h_1) represents the height of the dangerous rock mass immersed in water in the direction of the free face, and other symbols have the same meaning as the above formula.

The dead weight of dangerous rock mass is the product of the volume of dangerous rock mass and the bulk weight of dangerous rock. Generally, if the unit thickness is 1m, the dead weight of dangerous rock can be expressed as:

$$W = \gamma V \quad (4)$$

Where: (W) represents the gravity of dangerous rock mass, (γ) represents the bulk density of dangerous rock mass, and (V) represents the volume of dangerous rock mass.

The seismic force of dangerous rock mass can be divided into horizontal seismic force and vertical seismic force. In general, the horizontal seismic force is mainly considered in the calculation of the stability of dangerous rock mass. It is the product of the dead weight of dangerous rock mass and the seismic force coefficient, which can be expressed as:

$$P = \mu W \quad (5)$$

Where: (P) represents the horizontal seismic force of dangerous rock, (W) represents the gravity of dangerous rock, and (μ) represents the horizontal seismic force coefficient.

After rock damage, the internal microstructure of the rock is damaged and deteriorated, the physical and mechanical properties of the rock are damaged, and the strength is damaged. By setting the damage stress function, the damage stress of the rock can be expressed as the damage coefficient of the rock and the rock:

$$\sigma' = k\sigma_c \quad (6)$$

Where: (σ') represents the damage stress of rock damaged by river water, (σ_c) represents the standard value of rock compressive strength, and (k) represents the damage coefficient of rock that can be obtained through test fitting.

The regression velocity of rock cavity is introduced into the function ($d(t)$), which can be expressed as:

$$d(t) = wt \quad (7)$$

Where: ($d(t)$) represents the correlation between the receding velocity of rock cavity and time and the average receding velocity of rock cavity; (w) represents the average receding velocity of rock cavity after rock damage; (t) represents time.

Failure criterion of rock foundation conforms to Mohr-Coulomb strength criterion, and shear force of foundation (T_t) is expressed by Mohr-Coulomb strength criterion as:

$$T_t = d_1\tau + d_2\tau' \quad (8)$$

$$d_1 + d_2 = d_0 - d \quad (9)$$

Where: (T_t) represents the shear force of dangerous rock mass base, (d_1) represents the depth of rock cavity in undamaged part of the base, (d_2) represents the depth of rock cavity in damaged part of the base, (d_0) represents the depth of rock base, (d) represents the depth of rock cavity in rock base, (τ) represents the shear strength of undamaged rock and (τ') represents the shear strength of damaged rock.

Mohr-Coulomb strength criterion can be used to express the shear strength of undamaged rock and damaged rock as follows:

$$\tau = \sigma \tan\varphi + c \tag{10}$$

$$\tau_t = k\sigma \tan\varphi_t + c_t \tag{11}$$

The meaning of symbols in the formula is the same as above

By substituting equations (11) and (10) into equations (8), the shear force of rock base (T_t), can be expressed as:

$$T_t = (d_0 - d - d_2)(\sigma \tan\varphi + c) + d_2(k\sigma \tan\varphi_t + c_t) \tag{12}$$

Where: (T_t) represents the interface shear stress between rock base and dangerous rock mass, (c) represents the interface cohesion between rock base and dangerous rock mass, (φ) represents the internal friction Angle between base and dangerous rock mass, (σ) represents the interface normal stress between base and dangerous rock mass, (φ_t) represents the internal friction Angle between damaged rock base and dangerous rock mass, (c_t) represents the interface cohesion between damaged rock base and dangerous rock mass, The other symbols have the same meaning.

Similarly, the supporting force between the base of dangerous rock pierced by arrows and the main control structural plane can be expressed as:

$$N_t = d_1\sigma + d_2\sigma^{'} + l\sigma\cos\beta \tag{13}$$

Where: (N_t) represents the supporting force between the hazardous rock mass base and the main control structural plane; (l) represents the distance between the interface between the hazardous rock mass and the main control structural plane; (β) represents the dip Angle of the main control structural plane of the hazardous rock mass; other formulas have the same meaning as before.

By substituting equation (6) into equation (13), the supporting force of damaged rock base can be expressed as:

$$N_t = d_1\sigma + d_2 k\sigma + l\sigma\cos\beta \tag{14}$$

The meaning of the symbol is the same as before.

Along the main structural plane, the main structural plane of dangerous rock can be decomposed into normal stress and tangential stress according to the stress of dangerous rock in unit length. It can be expressed as:

Tangential component:

$$T = (W - N_t)\sin\beta + (P + T_t - Q)\cos\beta \tag{15}$$

Normal component:

$$N = (W - N_t)\cos\beta - (P + T_t - Q)\sin\beta \tag{16}$$

Assuming that the normal stress and tangential stress on the main control structural plane of dangerous rock are evenly distributed, the average normal stress and average shear stress on the main control structural plane are:

$$\tau = T / l \quad (17)$$

$$\sigma = N / l \tag{18}$$

When equations (16), (18) and (10) are combined, the shear force borne by the main control structural plane can be expressed as:

$$\tau = \frac{(W - N_t)\cos\beta - (P + T_t - Q)\sin\beta}{l}\tan\varphi + c \tag{19}$$

The shear strength of the main control structural plane of the dangerous rock mass is:

$$\tau_f = k\sigma \tan\varphi + c \tag{20}$$

The stability coefficient of sliding dangerous rock with damage on reservoir bank is expressed by shear force and shear strength as:

$$F_S = \frac{\tau_f}{\tau} \tag{21}$$

Equation (21), Equation (20) and equation (19) are combined to obtain the stability coefficient of damaged sliding dangerous rock on the reservoir bank:

$$F_S = \frac{k\sigma\tan\varphi + c}{\frac{(W - N_t)\cos\beta - (P + T_t - Q)\sin\beta}{l}\tan\varphi + c} \tag{22}$$

Equation (22) is the calculation method of stability coefficient of damaged sliding dangerous rock on reservoir bank.

Where: (FS) represents the stability coefficient of damaged sliding dangerous rock on the reservoir bank, (τ) represents the shear stress of the rock master structural plane, (τ_f) represents the shear strength of the rock master structural plane, (β) represents the dip Angle of the rock master structural plane, (l) represents the distance from the interface between the base and the dangerous rock mass to the bottom of the master structural plane, and the other symbols have the same meanings as before.

4. Conclusion

Jianchuandong dangerous rock is a typical tower pillar rock cut by tectonic fissure, and the dangerous rock mass has a huge volume. Once it falls into the waterway of the Yangtze River, it will inevitably cause surging waves and threaten the safety of ships in the waterway of the Yangtze River and cities in the lower reaches of the Yangtze River. This paper takes arrow-pierced dangerous rock as the research background and draws the following conclusions:

(1)The physical and mechanical model of Jianchuandong dangerous rock is established based on previous studies and Jianchuandong dangerous rock geological profile. The water pressure distribution of Jianchuandong dangerous rock is different from that of traditional dangerous rock, and its influence on the stability of dangerous rock is also different. The water pressure of reservoir bank dangerous rock exists in the direction of dangerous rock instability and failure surface, and the water pressure of dangerous rock fracture may exist. So we don't consider the air surface water pressure.

(2)The traditional calculation method of the stability of dangerous rock is unreasonable because of the different stress conditions and the different damage conditions of the base. By considering the depth of rock cavity and the influence of damaged rock mass on the stability of damaged rock mass, a method for calculating the stability of damaged damaged rock mass is established to calculate the stability of damaged rock mass. Calculation methods and verification of other failure modes of damaged dangerous rock on reservoir bank are presented in a separate paper.

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