Study on the Key Points of Slope Reinforcement in Mountain Geotechnical Engineering

Yunhao Zhang *

College of Civil Engineering, Southwest Jiaotong University, Chengdu, China

* Corresponding Author Email: ddw12333@tzc.edu.cn

Abstract. Slope instability in mountain geotechnical engineering can cause great damage to the engineering structure and the surrounding environment. Therefore, it is necessary to strengthen the slope to meet the demand of environmental safety. This paper firstly analyzes the main reasons of slope instability. Then, through the analysis of the existing research results, four common slope strengthening technologies and their advantages, disadvantages and application ranges are obtained. Finally, taking the slope reinforcement of Jiazhaerjia Cave Mural protection project as an example, this paper studies the reason of using anchor cable ground beam and anchor point reinforcement method and calculates the reinforcement effect after using this method. Through the analysis, it can be found that the environment should be studied before the slope reinforcement, and the matching reinforcement method should be selected through the environment. In the slope reinforcement of Jiazhaerjia Cave Mural protection project, the rock mass is broken and easy to collapse, and the reinforcement method requires less disturbance to the mountain. Therefore, the method of anchor cable ground beam and anchor point reinforcement has the best effect. This paper can provide theoretical and practical reference for mountain geotechnical engineering slope reinforcement.

Keywords: Mountain geotechnical engineering; slope reinforcement; Jiazhaerjia Cave Mural protection project.

1. Introduction

Slope instability is one of the main disasters that endanger people's life and property safety. In particular, the geographical environment of China is complicated, and slope instability exists in many areas. Therefore, the reinforcement of the slope is a crucial link. The effective treatment of slope engineering can guarantee the quality of slope engineering and improve the stability. In slope reinforcement, it is necessary to select the appropriate reinforcement technology according to the characteristics of slope engineering. Through comprehensive consideration of various influencing factors and practical reasons, the final reinforcement method can be obtained. Based on the performance-based global optimization of the support scheme, the design scheme of the support system that can consider the safety, economy, performance and other indexes is obtained, which is a work of both theoretical value and application prospect in landslide control. Zhang pointed out that the effective remediation of the landslide should not only be based on the correct understanding of the formation conditions, causes, deformation and destruction mechanism, and the stability of the movement process, but also through the technical and economic comparison of various possible remediation schemes [1]. Wang proposed that the organic combination of engineering geology and rock and soil mechanics should be achieved in landslide control [2].

This paper mainly analyzes the main causes of slope instability, and introduces four common slope reinforcement techniques. Taking Jiazhaerjia Cave Mural protection project as an example, the slope strengthening technology suitable for this practical engineering is analyzed. This paper can provide effective references for the theoretical research and practical application of mountain slope reinforcement.

2. The Main Causes of Slope Instability

Slope instability refers to the slope under the action of various external adverse factors, resulting in the structure of the slope soil or rock mass change, loss of the original stability, sliding, collapse and other damage phenomena. The causes of slope instability in geotechnical engineering can be divided into geological structure factors, hydrological factors, natural influence and human influence.

The geological structure factor is mainly the nature of the rock mass itself. The stability of the rock slope will also be affected by the geological structure. If the slope production and rock production are poor, the smooth phenomenon occurs, the probability of slope instability will be increased. Rock mass structure is divided into two parts: structural body and structural surface. From the essential level, the direction of the structural surface will affect the stability of the slope, and it is also related to the inclination and tendency of the rock mass structure. The continuity and surface shape of the structural surface will also affect the instability of the slope.

The hydrological factors are mainly the effect of groundwater and rainfall. The lifting of the underground water level or the flow of water will flow with fine sand particles, damaging the structure of the soil and easily causing the pit wall collapse. At the same time, groundwater immersion will reduce the strength of the soil, leading to collapse. Rainfall infiltration will lead to the softening of slope rock and soil mass, the reduction or loss of shear strength, forming slope cracking and slope foot shear damage [3].

The natural impact is mainly of various natural disasters. Earthquakes are usually the most common natural disasters that lead to slope instability. The vibration caused by the earthquake may cause the stress change of the whole rock mass structure and lead to the instability of the rock mass. Other natural disasters such as flood, debris flow and other natural disasters may also have external forces on the slope, destroying the original stable structure of the rock mass and causing slope instability.

Human factor is the slope instability caused by human activities. There are mainly construction activities, excessive development, in the slope excavation, there is no reasonable control of slope ratio and slope height, do not meet the design standards, resulting in slope displacement and collapse [4]. At the same time, the destruction of slope vegetation will lead to serious weathering of surface rock and soil, which will further reduce the shear strength of soil. All of these factors may lead to slope instability.

3. Types and Key Points of Slope Reinforcement Construction Technology

3.1. Reinforcement Technology of Prestressed Anchor Cable Slope

Prestressed anchor cable slope reinforcement technology is to adopt the prestress method anchor wirethe cable support anchored inside the rock mass is used to reinforce the slope. Anchor cable anchor headpass through weak structural surface of the rock massThe hole anchors into the rock mass, linking the sliding body with the stable rock layer, thus changing the stress state of the slope rock mass and improving the unstable rock mass integrity and intensity. Zhu et al. studied the influence of the prestressed cable reinforced of the three Gorges permanent lock on the mechanical properties of surrounding rock [5]. Yang discussed the technical points of quality management and control methods in the construction of expressway in Fujian Province, and introduced the construction process [6]. When prestressed anchor cable construction, need special slack adjusterand machines and tools. In terms of high slope reinforcement, compared with other reinforcement measures, the prestressed anchor cable has unique advantages. The relevant forces can be evenly distributed in the reinforced slope, have strong adaptability to geological and topographic conditions, can meet various construction conditions, and have reliable force. Active force does not need blasting excavation, so it will not interfere with the slope, maintain the original mechanical properties of the slope, and improve the construction efficiency. In the use of the prestressed anchor cable, the drilling measurement must

be done well, and the drilling machine is used for drilling, the overall construction is more complex and the cost is relatively high.

3.2. Reinforcement Technology of Anti-skid PileSlope Protection

The anti-slide pile technology is to further insert the pile column into the slide bed and the stable rock layer under the sliding surface to effectively balance the thrust formed by the sliding pile, improve the stability of the whole landslide, and play the function of a stable slope. Song et al. reasonably simplified the resistance of the rock mass in front of the pile and the rear slope thrust in the rock high slope excavation project, and proposed that the resistance of the rock mass before the pile was calculated according to the triangular distribution load [7]. Wu et al. analyzed the pile anchor reinforcement scheme for the unstable high and steep cutting slope in detail [8]. The construction of anti-skid pile is relatively simple, which does not need too much mechanical equipment and complex process. In general, it only needs to dig certain earthwork holes around the pile, and then insert the pile into the hole, and finally fill the gap between the pile and the soil. At the same time, the pile position of the anti-skid pile is flexible, and the pile can be set in the place with the best anti-skid effect according to the actual needs of the project. Anti-skid piles can be used alone or in combination with other anti-skid measures (e. g., anchors and anchor cables) to cope with different landslide conditions. However, if the slope landslide is in the active link, it is necessary to carefully implement the piling operation to exert the slip resistance performance and prevent strong vibration Caused by the aggravated slope sliding problem. Anti-skid pile is suitable for strata with hard soil or certain clay content. For the stratum with loose soil or high-water content, the effect of anti-skid pile will be greatly reduced, and even cannot achieve the expected anti-skid effect.

3.3. Reinforcement Technology of Shotcrete

Shotcrete reinforcement technology can be divided into two forms: wet shotcrete and tidal shotcrete. In order to improve the spraying effect, it is necessary to prepare the foundation construction and select the appropriate construction method according to the site construction conditions. Zhang et al. conducted experimental research on the strength growth law of tunnel shotcrete and the influence of hardening rate on the initial support performance [9]. Zhang studied the performance of shotcrete subjected to composite salt erosion [10]. For dry foundation pit construction suitable for tidal spray technology, adding accelerant to accelerate the spray coagulation, improve the reinforcement effect. If the foundation pit contains a lot of water, you can choose the wet spray method, and do a good job of concrete allocation according to the actual situation to optimize the spray quality. Shotcrete adopts mechanical spraying, and the construction progress is more than 10 times faster than the traditional concrete construction, which significantly improves the construction efficiency. At the same time, shotcrete does not need to set up a template, saving manpower, material resources and financial resources, and further speeding up the construction progress. Shotcrete and concrete, masonry, steel and other base materials have a high bond strength, can ensure the integrity and stability of the structure. The quality of concrete injection will affect the construction quality, so it is necessary to strengthen material testing, reasonably control the strength of concrete, and conduct reasonable testing according to different component types such as non-load-bearing and load-bearing. Shotcrete will produce a lot of dust pollution in the construction process, so it is necessary to control the dust.

3.4. Soil Nail Reinforcement and Support

Soil nail reinforcement support soil nail reinforcement take the lead in earthwork excavation, to the deep soil nail actual position, after the soil nail, step 2 soil excavation, then 2 layers of soil nails, repeated cycle until the end of the last layer of soil nail construction, continue to spray the first layer of concrete, immediate anchorage, then the second layer of concrete spray. According to the basic principle of first spraying before anchor, dig to the corresponding distance below the soil nail, shop the steel mesh, and reserve the appropriate lap length reasonably. If the concrete injection meets the

corresponding strength conditions, the soil nail will be inserted successfully, dig to the corresponding distance between the second layer earthwork and the soil part of the second layer nail, effectively connect with the steel mesh of the previous stage, continue to spray concrete, and nail the second layer soil nail into. Chen and Wang analyzed the application of soil nail support technology in weathered rock slope [11]. Lou and Zhou monitored the acceptance and displacement of soil nail support structure of a soft rock high slope, studied the reinforcement mechanism of soil nail support technology, and summarized the criterion for determining the most dangerous sliding surface of soft rock high slope [12]. This construction technology is convenient to apply, can save the cost, time, improve the construction efficiency. However, the applicability of soil nails is limited in the case of loose sand, soft plastic, flow plastic clay and rich groundwater sources, which cannot be used alone, and must be strengthened with other soil combination of supporting methods. At the same time, the soil nail support is a form of passive force support. Only the soil nail is forced when the soil is deformed, so the deformation and displacement of the foundation pit is relatively big.

4. Case Analysis

In this paper, the slope reinforcement of Jiazhaljia Mountain cave fresco protection project is taken as an example. The mural paintings of Jiazhaljia Mountain Cave are located in the middle and upper part of the south side of Jiazhaljia Mountain in Aba Tibetan and Qiang Autonomous Prefecture, Sichuan Province. The location of the cave is shown in Fig. 1. The cave was originally a natural rock cave formed by different weathering of rocks in the mountain fault fracture zone, and the two walls and the ground of the cave were simply repaired by artificial later period. The cave is a Buddhist cave mural in the Ming Dynasty, which is a key national protection project. The layout of the cave is shown in Fig. 2.

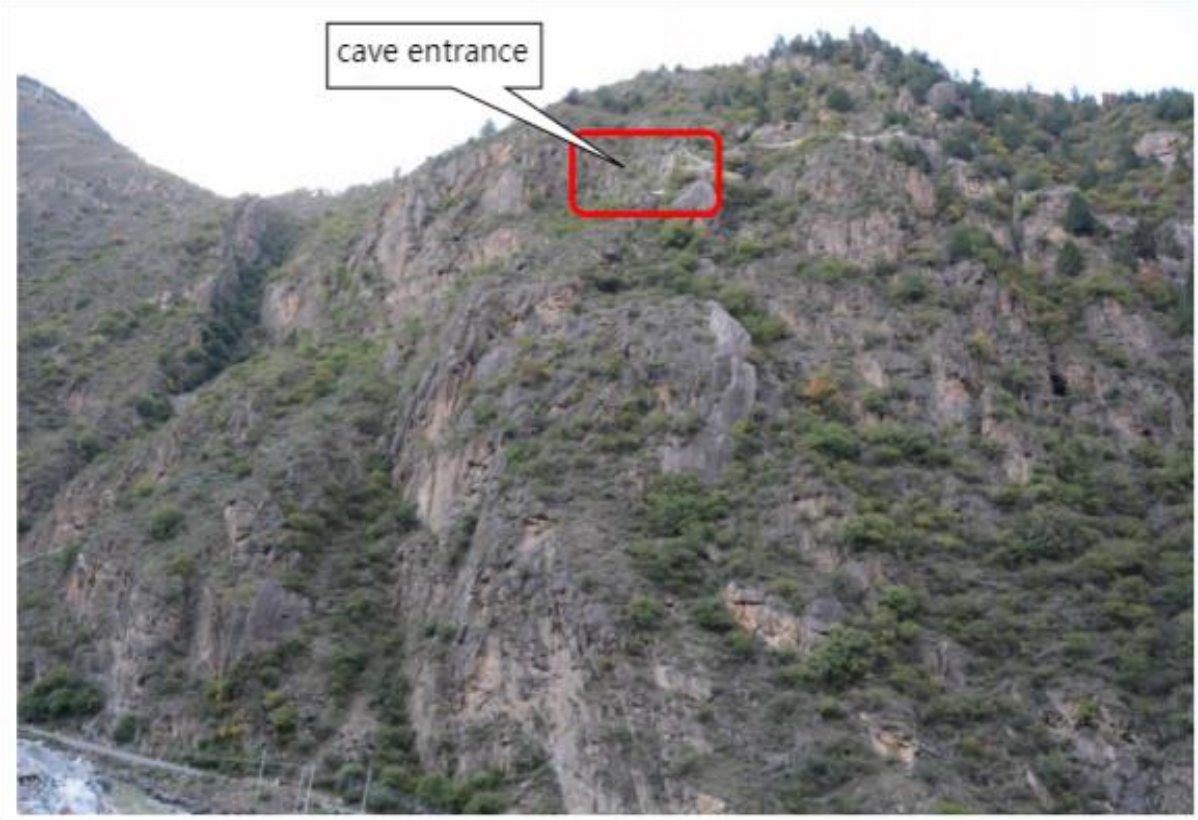

Fig 1. Location map of Jiazhaerjia Cave.
(Photo credit: Original)

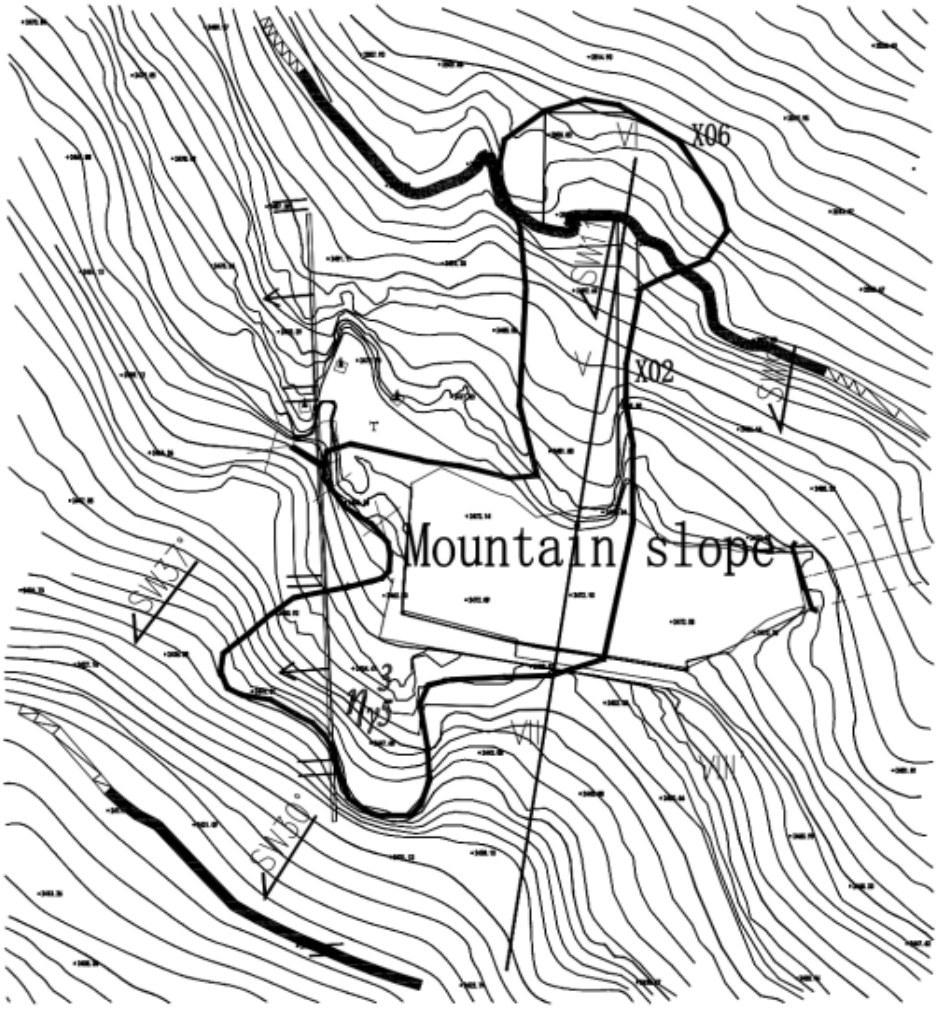

Fig 2. Layout plan of Jiazhaerjia Cave.
(Picture credit: Original)

Jiazhaljia Cave is located in a slope where the bedrock is exposed, rock layers are alternated between soft and hard, rock body weight stress and unloading stress are prominent, local geological structure compression is intense, fault fracture zone develops, joint cracks and unloading cracks develop. The development of faults in the zone controls the development, distribution, occurrence and structure type of the slope formation lithology, and indirectly intensifies the deformation and failure degree of the slope. The rock mass is broken along the fault zone, which is conducive to the deformation and failure development of slope rock mass. Under the influence of fracture activities for many times in geological history, the structural planes such as joints and cracks are relatively developed, which seriously destroys the integrity and strength of the rock mass of the slope and aggravates the degree of deformation and failure. When strengthening the cave slope, it is necessary to reduce the impact on the mountain, ensure the stability of the overall structure without damaging the cave itself, and adopt the anchor cable reinforcement with less damage to the overall slope. The slope is a granite contact alteration zone, and the rock mass is broken, which is prone to collapse and destruction under the cutting action of the reservoir. Therefore, the stability of the overall structure can be ensured by adopting anchor cable ground beam and anchor point reinforcement. The cable reinforcement has less disturbance to the overall rock mass to ensure the overall stability of the cave. The form of ground beam can strengthen the rock on the surface to avoid rock collapse, and at the same time, the ground beam can coordinate the environment well and provide convenience for the later appearance restoration work.

This project considers the impact of earthquakes, and the seismic parameters are shown in Table 1. After calculation, various parameters of the structure are shown in Table 2. The value of structural

stability coefficient is shown in Table 3. The safety factors of the slope before reinforcement are 1.06 and 1 respectively in natural and seismic conditions, and 0.77 and 0.72 respectively in natural and seismic conditions after taking into account the reduction factor of water storage. Under the condition of water storage, the stability coefficient F_s<1.35 (safety factor) under natural and seismic conditions, considering the reduction of parameters, the stability coefficient F_s<1.0, which does not meet the requirements of the slope in an unstable state. The calculated safety factors of the reinforced slope under natural and seismic conditions are 1.61 and 1.53, respectively, by using the anchor cable ground beam and anchor point reinforcement, and the safety factors under natural and seismic conditions are 1.17 and 1.11, respectively, taking into account the reduction factor of water storage. Under the condition of water storage, the stability coefficient F_s>1.35 (safety factor) under natural and seismic conditions, considering the reduction of parameters, the stability coefficient F_s>1.0, which meets the requirement that the slope is in a stable state.

Table 1. Value of the seismic parameters.

Name	Value
The seismic acceleration coefficient	0.100
The seismic importance coefficient	1.000
Comprehensive coefficient of seismic action	0.250

Table 2. Value of the structure calculation parameters (kN).

The parameter name	Value
Rock body weight	20169.4
Horizontal external load	0.0
Vertical external load	0.0
Horizontal earthquake action	504.2
Lateral fissure water pressure	7219.7
Bottom surface fissure water pressure	6541.7
Positive pressure on the structural surface	12877.7

Table 3. Structural stability coefficients before and after reinforcement.

Operating mode	Stability factor	
	Before reinforcement	After solid
Natural condition	1.06	1.63
Earthquake conditions	1	1.53
Natural working condition (water storage)	0.77	1.17
Seismic working condition (water storage)	0.72	1.11

5. Conclusion

This paper mainly studies the mountain slope reinforcement technologies, and obtain the following conclusions:

(1) The reasons for slope instability can be mainly divided into four reasons, including geological structure factor, hydrological factor, natural effect and human effect.

(2) In practical engineering, there are four common reinforcement methods: prestressed anchor cable, anti-slide pile, shotcrete, soil nailing wall. They are used in different engineering environments, and each has advantages and disadvantages.

(3) The slope of Jiazhaerjia Cave Mural protection project is broken and the rock mass is prone to caving under the influence of the reservoir. In this situation, in order to ensure that the reinforcement project has less disturbance to the slope, the method of anchor cable ground beam and anchor point reinforcement is adopted. Calculated results in this paper show that reinforcement can meet the requirements.

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