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Landslide Stability Analysis and Comprehensive Treatment Research

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ABSTRACT

Landslide disaster is a serious threat to human survival and reproduction, and will also cause adverse effects on the natural environment. In this paper, the influence factors of landslide are analyzed from rock and soil, rock mass structure, man-made and natural aspects. The methods of landslide stability analysis are introduced from qualitative, quantitative and semi-quantitative aspects. The principle of prevention and control of slippery slope is introduced. Prevention should be the main and treatment should be the auxiliary. The landslide control measures are introduced from the slope top surface water cut-off, anti-slide pile, anti-slide retaining wall, clamp rod (cable) reinforcement and so on. The landslide disaster occupies the first place in the natural disaster, so the in-depth study on the relevant problems of landslide control is of great significance to the guarantee of people's life and property safety.

KEYWORDS

Landslide Disaster, Influencing Factors, Stability Analysis, Control Measures.

1. INTRODUCTION

Since the Industrial Revolution, with the continuous growth of the world's population, the gradual expansion of the spatial scope of human activities, the increasing scale of engineering activities, and the impact of global climate change, landslide disasters have occurred more and more frequently, causing economic losses and casualties[1]. Landslides are widely distributed, and there is a possibility of landslides in almost all parts of the range of human activities, so landslides have become one of the three major geological disasters in the world, along with earthquakes and volcanoes[2].Geological disasters occur frequently in mountainous areas of China, and landslides are the most common[3]. During the period of 1949~2022, the number of deaths caused by landslides is conservatively estimated to be more than 25,000, with an average of more than 400 per year, and the average annual economic loss is about 50 million US dollars. According to the survey, in 2022, a total of 5,659 geological disasters occurred across the country, with landslides accounting for more than 69%, with a total of 3,919 cases. In recent years, governments at all levels have invested a lot of money and human resources in landslide control, and have explored a series of effective control measures. However, with the rapid economic and social development and the continuous intensification of human activities, landslide control is facing new challenges and problems. Therefore, it is of great significance to study the relevant issues of landslide control in depth to ensure the safety of people's lives and property.

2. DISCUSSION AND ANALYSIS

2.1. Structural factors of rock and soil and rock mass

2.1.1. Influencing factors of landslides

The stability of the slope is affected by its own rock mass and rock and soil material structure. The rock and soil structure is more complex, containing a lot of water substances, clay minerals, etc., and also contains some quartz, talc schist and marl and other layered rocks, as well as strengthened wind rock, slope soil rock and fully weathered rock, etc., there are also a lot of argillaceous fillers, broken rocks and other materials, because the rock and soil composition is more complex, it is easy to be dissolved, weathering, reduce its own wind resistance, once there is water accumulation, it will cause landslide disasters. Rock integrity is closely related to rock mass structure, once the rock loses its integrity, its own shear strength is reduced, and rock mass pores appear, which is likely to cause landslide problems[4].

2.1.2. The human factor

Human activities are a part that can not be ignored due to the stability of the slope, with the economic development, the infrastructure construction efforts are increased, the railway, highway engineering is gradually extended, the coverage area in the mountainous area is increased, the stability of the mountain slope is greatly disturbed, especially in the slope, the slope foot excavation is not standardized, it is easy to appear steep ridge-like rock and soil mass, increase the slope infiltration, water accumulation problem, lead to the increase of the slope weight, cause collapse, landslide phenomenon. With the increase of development efforts, the slope gradually takes on a vertical state, which increases the probability of collapse. When excavating by blasting, it is easy to cause large vibration to the geology, and in the case of multi-frequency operation, it will cause problems such as rock mass dislocation and cracks. In addition, the wanton felling of trees by humans will reduce the water retention of soil, cause soil erosion, and increase the probability of landslide geological disasters[56].

2.1.3. Natural factors

Rainfall is the main influencing factor of geological disasters. In the case of heavy precipitation, a large amount of rainwater on the surface of the mountain causes the water content of the slope to increase, increase the weight of the rock mass, and under the long-term erosion of rainwater, the soil is softened and the shear resistance of the soil is reduced. Groundwater can cause changes in static and dynamic water pressure, causing landslides. The softening of groundwater, argillaceous rock formations and soft rock formations may increase the risk of landslides. The occurrence of earthquakes will increase the loosening degree of the rock mass of the slope, reduce the resistance of the rock mass structure, and even cause the rock mass structure to fracture and form a landslide[78].

2.2. Landslide stability analysis method

2.2.1. Qualitative analysis

Qualitative analysis method: firstly, the engineering geological conditions in the study area are analyzed, the internal conditions for the formation of induced landslides are determined, and then the influence of rainfall and human activities is analyzed, and the stability of landslides is comprehensively compared.

(1). Engineering geological analysis method

There are two main types of engineering geological analysis methods: natural genesis history analysis method and engineering analogy method. The former is mainly based on the geological environment conditions of the slope and the basic law of slope deformation and failure, traces the whole process of slope evolution, and then predicts the general trend of slope stability development and its possible failure mode, and is suitable for the overall stability evaluation of natural slope. The engineering analogy law is based on the geological conditions of the slope, and the existing slope research and design experience is applied to the new slope with similar conditions, which is an empirical method and is commonly used in the engineering analysis of small and medium-sized slopes. The engineering geological analysis method is based on qualitative evaluation, so the application has greater arbitrariness, which is not convenient for design and application, such as the design of diseased slopes, such as solid treatment design, etc., and requires users to have rich engineering experience.

(2). Graphical method

The diagram method is made by analyzing the change formula of structural plane, lithology, groundwater, slope and other factors, so that the main and secondary control landslide bodies can be quickly and intuitively distinguished, the stability type is determined, and the shape, scale and sliding direction of the unstable blocks are determined. Diagram method, Konomo diagram method and chiping polar projection diagram method.

2.2.2. Quantitative and semi-quantitative analysis methods

There are currently three methods for quantitative analysis of slope stability: limit equilibrium method, numerical analysis method, and artificial intelligence.

(1). Limit equilibrium method

The limit equilibrium method is the most commonly used analytical method, which is based on the mechanical equilibrium principle of the sliding body and the sliding body block on the slope, that is, the static equilibrium principle, to analyze the stress state of the slope in various failure modes and the relationship between the anti-sliding force and the sliding force on the slope sliding body to evaluate the stability of the slope. There are a variety of limit equilibrium analysis methods, such as Fellenius, Bish-op, Taylor, Janbu, Morgenstern-Price, Spencer, Sarma, wedge, planar line, transfer coefficient, and Baker-GarberCritical sliding surface method, etc[9].

(2). Numerical analysis methods

After the 70s of the 20th century, with the development of numerical calculation theory and computer science, many numerical calculation methods have been applied to the slope stability analysis, and now the numerical analysis method has become a more effective analysis method in slope engineering, and is increasingly applied to the analysis of slope stability and deformation problems, the numerical analysis methods of slope stability commonly used at present mainly include finite element method (FEM), discrete element method (DEM), fast Lagrangian analysis method (FLAC), discontinuous deformation analysis method(DDA), Block Theory (BT), Elementless Method, etc.

Finite element method: It is one of the most widely used numerical methods for stability evaluation. It is often used to calculate elasticity, elastoplasticity, etc. Due to the consideration of the heterogeneity and discontinuity of the slope rock mass, the stress, strain magnitude and distribution of the rock mass can be given, which avoids the shortcomings of the limit equilibrium analysis method, which treats the sliding body as a rigid body and oversimplifies. However, it is not yet able to solve the problems of large deformation and displacement discontinuity well, and the solution of infinite domain and stress concentration is not ideal[10].

Discrete element method: This method is based on the conditions for discontinuous media, assuming that the rock mass is a variable block composed of faults, joints, fractures and other structures, and translation, movement and deformation can occur between the blocks. The equilibrium state is achieved by integrating the acceleration and displacement of the block. However, this method has certain shortcomings, the hypothetical conditions are insufficient, and the joints and other conditions need to be treated, which is very different from the actual results, but after years of research, it has been improved and developed[11].

(3). Artificial intelligence

With the rapid development of computers and the maturity of landslide research methods, more and more attention has been paid to the methods of artificial functions, among which fuzzy analysis methods, gray system theory, and artificial neural networks are widely used[1213].

2.3. Comprehensive study on landslide control

2.3.1. Landslide management principles

(1). Prevention first: prevention is the first principle of landslide control. Through comprehensive landslide potential assessment and risk analysis, preventive measures can be taken in time to reduce the probability of landslides and the scope of damage.

(2). Multidisciplinary integration: Landslide control requires the comprehensive application of multiple disciplines, including knowledge and technology in the fields of geology, geological engineering, hydrology, civil engineering, etc. Integrate a team of experts from different disciplines to jointly develop a governance plan.

(3). Comprehensive management: Landslide management should adopt a comprehensive management approach, including planning, design, monitoring, maintenance and other stages of work. Factors such as engineering measures, ecological restoration, and socio-economic impacts need to be considered in an integrated manner.

(4). Differentiated governance: Formulate differentiated governance strategies according to the type, scale and characteristics of landslides. For different types of landslides, corresponding engineering measures, geological improvement technologies or ecological restoration methods are adopted.

(5). Sustainable development: Landslide control should be combined with the principle of sustainable development, focusing on ecological environmental protection, rational use of resources and social and economic sustainability. Avoid irreversible damage to the environment and ensure long-term benefits.

(6). Participation and communication: The governance process should fully consider the opinions and needs of stakeholders, and carry out effective participation and communication. Collaborate with local governments, community residents, experts and relevant institutions to form consensus and support.

(7). Safety first: The primary goal of landslide control is to ensure the safety of people's lives and property. When developing a governance plan, safety should be a top priority, following relevant laws, regulations, and safety standards.

(8). Governance monitoring and evaluation: After the governance is completed, continuous monitoring and evaluation is required, and problems are identified in a timely manner and corresponding measures are taken. The evaluation of the effect of landslide control should be carried out regularly to ensure the sustainability and effectiveness of the treatment effect.

2.3.2. Landslide control measures

Landslide disaster management is divided into three aspects: one is to reduce or avoid the role of landslide inducing factors, that is, water hazard control, and the other is to change the internal mechanical characteristics of the slope, that is, to enhance the strength of the rock mass and increase the anti-slip strength; The third is measures to improve the blasting method[1415].

(1) Interception of water on the surface of the slope top Since a large amount of rainwater may collect at the top of the slope, this part of the water will penetrate into the soil structure of the landslide body and affect the stability of the slope body, so a water interception ditch can be set up to remove this part of the water body from the surface of the slope top .

(2) Anti-slide pile. Anti-slide pile is a discontinuous retaining structure, which can use the soil arch formed between the piles, and can effectively improve the stability of the slope by balancing the sliding thrust generated by the soil mass of the slope under the load, and the steel bar or waste rail is used as the skeleton, inserted into the borehole, and the concrete is poured, which is also widely used. Moreover, the anti-slide pile has simple anti-slide structure, good sliding ability, flexible layout, and little difficulty in construction, so it has become one of the main measures for landslide disaster control.

(3) Anti-slip retaining wall. The anti-slip retaining wall is one of the most effective landslide control measures, and the anti-slip retaining wall needs to be understood according to the basic geological and topographic conditions of the landslide body, and different forms are adopted according to the location, type and size of the landslide body. Commonly used forms are gravity retaining walls, cantilevered retaining walls, and buttressed retaining walls. Gravity type retaining wall is made up of concrete or slurry masonry, utilizes its own gravity to maintain the stability of slope; The cantilever retaining wall is composed of a base plate and a straight wall fixed on the bottom plate, and the retaining wall is mainly maintained by the filling weight on the bottom plate, and it is mainly composed of three reinforced concrete components: the vertical wall, the toe plate and the heel plate; The buttress retaining wall is a kind of reinforced concrete thin-walled retaining wall, which is characterized by simple structure, convenient construction, small wall cross-section, light weight, better performance of the strength of the material, can adapt to the foundation with low bearing capacity, and is suitable for areas lacking stone and earthquakes [44]

(4) Weight reduction and slope presser foot. The steps are slowed down and stones are built at the foot of the slope, and this kind of slope stabilization measure is mostly used for individual step slopes.

(5) Control blasting. When the step mining is close to the design boundary of the stope, in order to maintain the stability of the slope, shock absorption measures should be adopted, also known as the controlled blasting method. Such as smooth blasting, pre-cracking blasting, buffer blasting, etc.

(6) Clamp rod (cable) reinforcement. The sliding body is anchored with a tracing rod or anchor cable and pre-applied tensile stress, and sometimes combined with slope protection measures such as hanging net spraying. This is a more common measure for the management of stopes in open-pit mines.

(7) Land Use Management. Rational planning and management of land use: Avoid development activities in potential landslide areas, or rationally plan and manage existing developments to reduce the risk of landslides.

(8) Monitoring and early warning system: Establish a monitoring and early warning system for landslides, grasp the changes of landslides in a timely manner, and take emergency measures and evacuation plans.

These landslide control measures can be used separately or in combination, and selected and implemented according to the characteristics of landslides and the treatment objectives. The selection of treatment measures should be comprehensively considered in combination with the geological characteristics, hydrogeological conditions, soil types, rainfall and other factors of the landslide to ensure the feasibility of treatment.

3. SUMMARY

Landslide natural disasters have a huge impact on people's lives and social and economic development, so it is very important to clarify the formation mechanism and influencing factors of landslides, to find economically reasonable, technically feasible, ecologically secure treatment methods and put forward reasonable treatment measures, to implement real-time monitoring of landslides in a timely manner. Try to minimize the damage caused by landslide disasters.

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