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Research on geological hazard warning and prevention technology in railway roadbed engineering

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Abstract: *This paper discusses the technical measures of geological disaster prevention and control, focusing on the mechanism and comprehensive application of physical prevention and control, chemical control and biological control technical measures. Physical prevention and control technology can enhance the stability of geological body by means of anchoring and anti-slide pile. Chemical control technology uses grouting, soil stabilizer and other methods to improve the properties of rock and soil. Biological control technology realizes the purpose of control through ecological means such as vegetation restoration and microbial solidification. The integrated application of the three forms a diversified geological disaster prevention system, which reflects the concept of ecological environmental protection and sustainable development. The research shows that with the progress of science and technology, the geological disaster prevention and control technology will be more refined and integrated, providing strong support for disaster prevention and reduction in China.*

Keywords: *Geological disaster prevention; Physical prevention and control; Chemical control; Biological control; Comprehensive application*

1. Introduction

With the rapid development of China's economy and the advancement of urbanization, the impact of human engineering activities on geological environment is increasingly increasing, and the frequency and scope of influence of geological disasters are constantly expanding, which brings a serious threat to people's life and property safety. Therefore, the research of geological disaster prevention and control technology and the improvement of scientific and effective prevention and control measures have become the top priority of disaster prevention and reduction in our country. This paper aims to discuss the technical measures of geological disaster prevention and control, including physical prevention and control, chemical control and biological control technology, analyze the advantages and disadvantages of various technical measures and their applicable conditions, and explore their comprehensive application strategies, in order to provide theoretical basis and practical guidance for geological disaster prevention and control. Through in-depth analysis of prevention and control technology measures, this paper aims to promote the innovation and development of geological disaster prevention technology, and contribute to the realization of China's geological environment safety and sustainable development.

2. Analysis of types and causes of geological disasters

2.1 Common types of geological hazards in railway roadbed engineering

The analysis of the types and causes of geological disasters is a very important work, especially in the construction of railway roadbed, which is related to the safety and stability of the project. In the field of railway subgrade engineering, there are various types of common geological disasters, and their causes are also complicated. The types of common geological hazards in railway roadbed engineering will be analyzed in detail below [1].

Landslide is one of the most common geological disasters in railway roadbed engineering. The occurrence of landslide is often closely related to landform, geological structure, hydrological conditions and human engineering activities. In the slope area, due to the decrease of shear strength of rock and soil mass, the slope material slides along a certain sliding side under the action of external forces, thus forming a landslide [2]. Debris flow is also a major hidden danger of railway roadbed engineering. The formation of debris flow usually requires three conditions: sufficient material source,

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steep terrain and concentrated water source. In the construction of railway in mountainous areas, once it encounters heavy rainfall, it is easy to cause debris flow disaster and cause serious damage to the roadbed. Ground subsidence is also a type of geological disaster that cannot be ignored in railway roadbed engineering. The causes of land subsidence mainly include the drop of groundwater level, soil compression, mineral exploitation and so on. In soft soil area, ground settlement is particularly serious, it will lead to uneven settlement of roadbed, and then affect the smoothness and safety of railway lines. Moreover, karst collapse is also a special geological disaster in railway roadbed engineering. Karst collapse mainly occurs in karst developed areas. The development and expansion of underground karst caves lead to surface collapse and damage to roadbed.

2.2 Analysis of the mechanism of geological disasters

The mechanism analysis of geological disasters is the basis for understanding the phenomena of geological disasters and scientifically formulating prevention and control measures. The occurrence of geological disasters is often the result of a series of internal factors and external induced factors. The following will analyze the occurrence mechanism of geological disasters from two aspects of internal and external causes [3].

From the perspective of internal causes, the occurrence of geological disasters is closely related to the inherent attributes of geological environment. Crustal tectonic activity, stratigraphic lithology, geological structure and hydrogeological conditions are all important internal factors affecting the occurrence of geological disasters [4]. For example, the crustal activity near the fault zone is frequent, the rock is broken, and the geological disasters such as earthquake and landslide are easy to occur. Due to its poor stability, loose deposits are prone to ground collapse and debris flow under external forces. The role of groundwater can not be ignored, it can not only change the physical properties of rock and soil mass, but also affect the stability of rock and soil mass through chemical action. External inducement factors play the role of trigger in the occurrence of geological disasters. Climate change, hydrological cycle, human engineering activities, etc., may be the inducement of geological disasters. Taking climate change as an example, extreme weather events such as heavy rain and drought can rapidly change the distribution of surface water and groundwater, thus inducing landslides, debris flows and other disasters[5]. Human engineering activities, such as over-exploitation of groundwater and unreasonable land development and utilization, will also destroy the original geological environment balance and lead to the occurrence of geological disasters. Furthermore, the occurrence mechanism of geological disasters also involves mechanical mechanism and dynamic process. The mechanical mechanism of geological hazards mainly studies the deformation, failure and movement of disaster bodies under the action of stress. The dynamic process is concerned with the speed of the disaster body, the influence range and the formation of the disaster chain. For example, the mechanical mechanism of landslide involves many forms such as shear failure and tensile failure, while its dynamic process is manifested as the change of sliding speed, energy release and secondary disasters caused by it.

2.3 Influencing factors of geological disasters and their mechanism of action

The study of geological hazards focuses on the interwoven effects of natural and human factors and their mechanisms. The influencing factors are divided into two categories: natural and man-made. Natural factors include topography (such as steep slopes prone to landslides), geological tectonic activity (increased risk of fractures and folds), climate (hazards induced by extreme weather), and hydrogeological conditions (effects of changes in water tables). Human factors such as over-exploitation, irrational land use and infrastructure development disrupt the geological balance. The action mechanism is multi-factor coupling and multi-process interaction, for example, the superposition of natural and human factors reduces the stability of geological bodies, the breeding and development of geological disasters involve stress accumulation and energy release, etc., and the action of different factors has temporal and spatial differences, such as rainfall reducing the shear strength of soil mass, and earthquake causing instantaneous stress changes leading to the destruction of rock and soil mass.

3. Geological disaster early warning technology research

3.1 Construction of geological disaster early warning system

The geological disaster early warning system is the core of the disaster prevention and reduction

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system, aiming to reduce disaster risks and ensure people's safety through early identification, real-time monitoring and timely warning. The key elements of the system construction include: first, the establishment of a complete geological disaster database, covering historical cases, geological environment, induced factors, etc., to provide data support for early warning; The second is to use GIS and remote sensing technology to accurately identify potential hidden trouble points; Third, the construction of surface and underground monitoring network, comprehensive use of high-precision instruments and intelligent sensors to monitor the disaster process; The fourth is to develop an early warning model that combines time series analysis, machine learning and other methods to predict the probability and time window of disaster occurrence, and has the ability of self-learning optimization; The fifth is to establish an efficient and stable early warning information release platform to realize real-time data processing, early warning grade determination and information push; The sixth is to ensure that the early warning system is connected with the government's emergency plan to quickly start the emergency response. Early warning system construction is complex, but crucial, can effectively improve the ability to prevent and reduce disaster.

3.2 Early warning model and method selection

TThe choice of early warning model and method is the key to the study of geological hazard early warning technology, which affects the accuracy and reliability of early warning system. The selection should follow the principles of scientific, practical and forward-looking. Statistical models, such as logistic regression and linear regression, establish early warning thresholds through correlation analysis of historical data, but are limited in dealing with nonlinear relationships. Machine learning models, such as SVM and ANN, have powerful nonlinear mapping ability and high warning accuracy, but there are limitations in the interpretation of black box characteristics. Data-driven models such as time series analysis and pattern recognition, which build models through data feature analysis, are suitable for large-scale data, but are affected by data quality. The physical process model, such as numerical simulation, can understand the disaster from the mechanism, and the theory is complete, but the practical application is limited by the uncertainty of geological parameters and computing resources.

3.3 Optimization of early warning parameters and model verification

The optimization of early warning parameters and model validation are the key links in the study of geological disaster early warning technology. The purpose is to improve the prediction performance of the early warning model by fine-adjusting the input parameters of the early warning model, and to ensure the reliability and stability of the early warning results through rigorous verification process. In this process, the selection of parameters, the application of optimization methods and the strategy of model validation need to be carefully considered and scientifically demonstrated.

The selection of early warning parameters should be based on the in-depth understanding of the formation mechanism of geological hazards, combined with the field investigation and monitoring data, and select the indicators with high correlation with the occurrence of disasters. These parameters may include rainfall, groundwater level change, ground stress, terrain slope, etc. The selection of each parameter needs to be statistically tested and compared with actual cases. In terms of parameter optimization, the commonly used methods include grid search, genetic algorithm, particle swarm optimization, etc. These methods seek the optimal combination of parameters through iterative search to maximize the prediction accuracy of the early warning model. For example, the grid search method is used to scan the model parameters in an all-round way, combined with cross-validation technology to prevent the model from overfitting and improve its generalization ability. As for model verification, it is necessary to adopt a variety of indicators and methods. On the one hand, statistical indicators such as goodness of fit, accuracy and recall rate can be used to evaluate the prediction effect of the model. On the other hand, it is necessary to use independent test sets or time series segmentation methods to conduct prospective validation of the model to test its ability to predict future disaster events. ROC curves and AUC values are also important tools for evaluating the performance of early warning models. However, the optimization of early warning parameters and model verification are not accomplished overnight, but a dynamic adjustment and continuous iteration process. In this process, we may encounter problems such as the interaction between parameters, and the tradeoff between model complexity and predictive power.

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4. Discussion on prevention and control technical measures

4.1 Technical measures for physical prevention and control

Physical prevention and control technology measures, as an important part of the geological disaster prevention system, its core is to change or control the physical state of the geological environment through a series of physical means, so as to effectively prevent and reduce the risk of geological disasters. The application of physical prevention and control technology not only involves a deep understanding of the mechanism of geological disasters, but also includes the accurate grasp of the principle of prevention and control technology and the skilled use of construction technology. For geological disasters such as landslide and collapse, the common physical prevention and control technologies include anchorage, anti-slide pile, retaining wall and so on. Anchoring technology can enhance the overall stability and resist the sliding force by setting the anchor rod or cable in the rock and soil mass. The anti-slide pile uses the friction between the pile body and the surrounding soil to form anti-slide torque and prevent the slope from sliding. The retaining wall supports and prevents soil deformation through the weight of the structure itself and the interaction with the soil. For debris flow disaster, the physical prevention and control technology mainly includes drainage, interception and protection. Drainage measures, such as the construction of drainage channels, diversion levees, etc., are designed to guide the smooth passage of debris flow and reduce its impact on downstream areas; Interception measures, such as sand bar, grid dam, etc., are used to intercept solid material in debris flow and reduce its destructive power; Protective measures, such as vegetation restoration and slope protection nets, are designed to reduce the material sources of debris flows and reduce the risk of disasters. The physical prevention and control of geological disasters, such as ground subsidence and ground cracks, focuses on groundwater control and foundation treatment. Groundwater control, such as the construction of groundwater interceptor walls, dewatering Wells, etc., aims to control the groundwater level and reduce its impact on the surface structure; Foundation treatment technology, such as grouting reinforcement, foundation replacement, etc., is used to improve the engineering properties of soil, improve its bearing capacity and deformation resistance. It is worth noting that the implementation of physical prevention and control technical measures needs to comprehensively consider many factors such as geological conditions, environmental factors, economic costs and construction feasibility. In actual operation, it is often necessary to cooperate with a variety of technical measures to form a comprehensive prevention and control system to achieve the best prevention and control effect.

4.2 Technical measures for chemical control

As another important branch in the field of geological disaster prevention and control, chemical control technology is unique in changing the physical and chemical properties of rock and soil mass by chemical means, so as to improve its stability and achieve the purpose of preventing and controlling geological disasters. The application of the technical measures not only requires researchers to have a deep understanding of the chemical properties of rock and soil bodies, but also to master the properties of chemical materials and the interaction process with rock and soil bodies to ensure the effectiveness and durability of control measures. Chemical grouting is one of the most widely used methods in chemical control technology. By injecting chemical grout into cracks or pores of rock and soil mass, the consolidation of grout can enhance the integrity and shear strength of rock and soil mass, and effectively prevent the occurrence of landslides and collapses. The choice of grouting materials, including cement slurry, chemical slurry, etc., needs to be determined according to the specific geological conditions and control needs. Chemical reinforcement technology, such as shotcrete, electrochemical reinforcement, etc., by applying chemical substances on the surface or inside the rock and soil body, promote the rock and soil structure reinforcement and improve its deformation resistance. Shotcrete technology can form a hard protective layer in a short time, and electrochemical reinforcement through electrochemical reaction in the rock and soil body to generate cement material, so as to achieve the purpose of reinforcement. Chemical control techniques also include the application of soil stabilizers. By changing the chemical composition of soil, soil stabilizers reduce its water sensitivity and improve the carrying capacity and erosion resistance of soil. This has a remarkable effect in preventing and controlling geological disasters such as debris flow and land subsidence. It is worth noting that the implementation of chemical control technical measures should fully consider the environmental impact and long-term effects of chemical materials. The selection of chemical slurry and soil stabilizer must meet the requirements of environmental protection and avoid secondary pollution to the surrounding ecological environment. At the same time, the application of chemical control technology should also take into account the cost-benefit ratio to ensure the economic rationality of

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prevention and control measures.

4.3 Biological control technical measures and comprehensive application

Biological control technology, as a new force in the field of geological disaster control, is unique in the use of biological life activities and their metabolites to repair and strengthen the geological environment, so as to achieve the purpose of preventing and controlling geological disasters. This technical measure not only reflects the idea of ecological environmental protection, but also provides a new perspective and method for geological disaster prevention through the interaction between biological and geological environment. The comprehensive application of biological control technology integrates ecology, geology, biology and other multidisciplinary knowledge, showing its unique control effect and wide application prospects. Vegetation restoration and ecological slope consolidation are important components of biological control technology. By planting plants with developed roots, such as herbs, shrubs and trees, it can not only fix the soil, reduce soil erosion, but also improve the shear strength of the slope, and effectively prevent the occurrence of landslides and debris flows. Transpiration by vegetation helps to improve the physical properties of the soil and lower the water table, thereby reducing the risk of land subsidence. Microbial technology also plays an important role in biological control. For example, the use of specific microorganisms for soil biocurrenization, through microbial metabolic activities to generate cementing substances, enhance the cohesion of the soil and erosion resistance. At the same time, microorganisms can decompose organic matter in the soil, improve the soil structure and improve its stability. The integrated application of biocontrol technology also includes the introduction of animal measures. For example, soil animals such as earthworms are used to improve soil aeration and water status, promote plant growth, and thus improve slope stability. The restoration and utilization of biodiversity provides a more comprehensive ecological solution for the prevention and control of geological disasters. It is worth noting that the implementation of biological control technology needs to fully consider the particularity of geological environment and biological adaptability. In the selection of plant species and microbial strains, it is necessary to combine the local climate, soil and other conditions to ensure the effectiveness of biological measures. At the same time, the application of biological control technology needs to be combined with other control technologies to form a comprehensive geological disaster control system.

5. Conclusions

This paper systematically discusses three kinds of technical measures for the prevention and control of geological hazards: physical prevention and control, chemical control and biological control, and analyzes their respective action mechanism, technical characteristics and comprehensive application strategies. It is found that single technical measures have limitations in preventing and controlling geological disasters, but the organic combination of multiple technologies can play a synergistic effect and improve the control effect. At the same time, biological control technology, as a green control means, has shown a good application prospect. This paper emphasizes that the prevention and control of geological disasters should follow the principle of ecological priority and comprehensive management, combine the specific situation of geological environment, and scientifically select and optimize the prevention and control technology. In the future, the research and application of geological disaster prevention technology will pay more attention to technological innovation, environmental protection and sustainable development, in order to provide more solid technical support for China's geological disaster prevention and control work.

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