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Disaster prevention and mitigation in railway engineering

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Abstract. With the rapid development of railway engineering, the scope of railway construction has been extended to mountainous areas, basins and other geological environments. In these areas, railway construction needs to pay attention to landslides, earthquakes and other disasters, otherwise it will threaten unnecessary economic losses and even personal safety. The purpose of this paper is to introduce the disaster threats faced by railways and the measures to prevent these disasters, especially earthquakes and landslides, and to look at the future development trend of prevention and control. Earthquake early warning is one of the effective means to improve the safety of high-speed railway. As for the railway crossing the high earthquake wind area, it can be considered to establish the earthquake early warning and monitoring system for effective protection. For landslide disaster, interference should be reduced in the construction process, and special evaluation and targeted engineering treatment.

Keywords: railway engineering, disaster prevention and mitigation, earthquake, landslide, disaster management.

1. Introduction

With the continuous development of society and economy, railway engineering is developing rapidly at present. The scope of railway construction is not only limited to plain, but also extended to mountainous areas, basins and other geological environments. In these areas, construction is difficult, maintenance is complex, and may be accompanied by landslides, earthquakes and other disasters. The investment of railway engineering is huge and the difficulty of construction and maintenance is great. Therefore, it is very important to prevent and control natural disasters in railway engineering. Railway transportation is playing an increasingly important role in the development, which requires that railway should have a stronger capacity of disaster prevention and reduction. Therefore, it is more urgent and important to study the causes of natural disasters, master the law of their changes, build a scientific system of railway disaster prevention and reduction, and ensure the driving safety [1].

The research of natural disaster prevention and control in railway engineering mainly focuses on project planning and route selection, engineering reinforcement, shelter construction and so on. These methods, while effective, are passive. With the development of science and technology, human gradually began to study data monitoring, disaster prediction and so on. The wide application of aerospace technology and optical remote sensing technology makes disaster identification more efficient. With the accumulation of scientific research on the "cloud-edge interaction" model, the technology has become increasingly mature. If applied to railway construction, it will greatly improve the existing system in

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information perception, transmission, calculation and decision saving, application security and timeliness. Video and image technology benefits from the development and popularization of the Internet, big data, drones and robotics. Drones and robots embedded with artificial intelligence algorithms such as computer vision play a great role in disaster assessment as auxiliary means of post-disaster field investigation.

This paper first introduces the disaster threats faced by railway and the prevention measures of these disasters. The development trend of prevention and control in the future is also discussed, including how to establish the framework of railway disaster prevention system and the possibility of applying existing technologies to prevent and control disasters.

2. Analysis of types and characteristics of disasters

2.1. Earthquake

Earthquake is one of the major natural disasters threatening railway safety. For destructive earthquake, ground motion may cause train derailment and other accidents, leading to great loss of life and property.

2.1.1. Subgrade earthquake damage. The region along the line is prone to shallow focal, high magnitude and intensity earthquakes, which will seriously threaten the safety of the railway subgrade. The earthquake will not only directly lead to the serious subgrade subsidence of railway abutment. Earthquake induced large-scale collapse, landslide and other secondary geological disasters to a greater extent or even completely destroy the subgrade. Once the above-mentioned subgrade damage occurs, due to the narrow space in the valley area, large engineering equipment or even important engineering equipment cannot be quickly constructed on site, and it is difficult to restore the normal operation of the line in a short time.

2.1.2. Earthquake damage to railway bridges. High intensity earthquakes in the region can cause serious damage to bridges built in river valleys. In general, longitudinal and transverse displacement and partial cracking of Bridges occur after an earthquake. The anchor bolt and rocking shaft of the support are damaged and the structure is damaged. Pier concrete cracking and spalling; Foundation slip occurs on abutment. Bridge is the controlling node of the line. Once destroyed, the whole line cannot be opened to traffic normally, which will cause particularly serious economic losses and negative social impacts.

2.1.3. Earthquake damage to railway tunnel. Tunnel inlet and outlet and lining are also extremely susceptible to seismic waves. The shallow buried section at the inlet and outlet of the tunnel is prone to severe damage from earthquake, and the lining will be deformed, cracked and collapsed under the influence of earthquake, and even the cracks will basically run through the entire lining [2]. The cracks may intersect with the axis at a large Angle, or develop along the axis of the tunnel, resulting in the uplift of the floor and invert. The destruction of the tunnel greatly affected railway traffic.

It is difficult to avoid active faults completely in the route selection design of long trunk lines, which may pass through multiple earthquake prone areas. In this case, it is necessary to fully assess the risk to the line in an earthquake scenario. Japan's experience proves that earthquake warning is one of the effective ways to improve the safety of high-speed railway. For the railway crossing areas with high earthquake risk, it can be considered to set up earthquake early warning and monitoring system for effective protection [3].

2.2. Mountain landslide

The factors of landslide are very complex, which can be summarized into bad geological conditions, engineering activities, and the action of water. The internal cause of landslide is bad geological conditions, while the external cause of landslide is human engineering activities and the action of water [4].

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Cutting slope landslide can cause serious accidents, which not only causes great losses to the economy, but also causes the loss of construction period in the post-treatment of landslide, and even causes the loss of personnel in the landslide accident. In railway construction, cutting slope landslide will cause serious influence on engineering construction and later railway operation. The prevention and control of the landslide section in the high cut slope of railway directly affects the safety of railway operation, but also reflects the comprehensive evaluation of railway construction quality of an important index, has important significance to the operation of railway.

3. Existing prevention and control methods for railway disasters

3.1. Optimized route design

Railway line selection in mountain area has experienced "terrain selection", "geological selection" and "disaster reduction selection". Three stages of development. From the beginning of this century to the present, with the development of construction technology, railway route selection attaches more importance to the judgment and release of environmental and ground disasters, and the general operation is from surface to surface.

The route selection method of line and from line to point adopts high-pier and long-span Bridges and long tunnels to avoid bad soil quality and special geology in order to achieve the effect of disaster prevention and reduction. In the practice of construction process, the new principle of geological line selection with disaster prevention and reduction as the core has been formed through continuous improvement [5].

The selection of railway line reduction can be divided into :(1) The risk of geological disaster should be comprehensively identified. (2) Measures should be taken to avoid the risk of major geological disasters. (3) Measures should be taken to prevent and control the risk of geological disasters. (4) Potential geological disasters should be monitored and warned. This is also the basic working method of disaster reduction line selection. In the realization of line selection for disaster reduction, the first thing is to identify geological disaster risk comprehensively. The key lies in "comprehensive identification", and the difficulty also lies in "comprehensive identification". In terms of methods, multi-disciplinary knowledge should be applied to investigate the source of disasters from different scales and different means, from geomorphic contours, formation mechanism and regional differentiation, and to identify disaster risks from formation mechanism, evolution law and failure characteristics. On the basis of identifying risks, it is necessary to apply life-cycle management and system engineering methods to study the project durability, failure mode and mechanism, risk breeding mechanism, disaster prevention and management, prediction and early warning during the life-cycle of railway service, and accurately estimate the expected loss and risk cost caused by geological disaster risk within the time range of railway service life cycle. Therefore, the measures or engineering schemes to avoid or prevent geological disasters can be reasonably selected, and the potential geological disasters can be monitored and warned [6].

When selecting railway lines, attention should be paid to avoid areas with potential hazards, areas prone to large-scale geological disasters induced by earthquakes, and areas with obvious large relief terrain, steep slope and relatively developed water system, which are conducive to geological disasters. In particular, V-shaped valleys are relatively developed in the study area. For example, Jilong Zangbu alpine canyon area has narrow terrain, steep banks and poor geological conditions. It is not suitable to adopt subgrade to pass through the bottom of such terrain. At the same time, the deep cutting should be changed into a tunnel form, using the form of bridge through the steep slope of high embankment. The study area has a wide range of mountains and valleys, and the tunnel damage is relatively small in the high-intensity earthquake mountainous area. Therefore, it is possible to adjust the line position and use the tunnel when the line is large excavation [2,7].

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3.2. Earthquake early warning system station layout scheme

If the line crosses the high-risk area of earthquake, in order to ensure the construction safety, the earthquake early warning and monitoring system should be established at the beginning of the project. After the construction of the project is completed and entered the operation stage, the earthquake early warning and monitoring system can continue to exert its effect and provide pre-warning protection for the construction of railway infrastructure and trains.

The relationship between station spacing *D* and blind area radius *b*, as well as the contribution ratio of adding one station to the blind area radius decline, is calculated according to the average distributed station model, as shown in table 1. For the same station spacing, the more stations needed to publish, the larger the blind area radius and the worse the relative timeliness. For the same publishing scheme, the smaller the spacing between the stations, the more stations per unit area, and the smaller the radius of the blind area. However, there is a nonlinear relationship between the distance between the stations and the radius of the blind area. As the distance between the stations decreases gradually, the contribution ratio of each additional station to the radius of the blind area decreases gradually.

Considering the actual situation and economy, it is theoretically suggested that the average platform spacing should not be less than 20 km. When the average distance between the stations is less than 20 km, each 1 km reduction of the distance between the stations contributes no to the reduction of the radius of the blind area it is 0.1% [3].

Table 1. The relationship between station spacing *D* and blind area radius *b* and the contribution ratio of one more station to blind area radius reduction [3].

		Single station early warning scheme		Three or four early warning schemes			
				Three stations		Four stations	
Stage spacing *D* (km)	Per unit area Number of stations (PCS)	Blind area radius (km)	Single station against blind area Radius reduction contribution ratio (%)	Blind area radius (km)	Single station against blind area Radius reduction contribution ratio (%)	Blind area radius (km)	Single station against blind area Radius reduction contribution ratio (%)
60	11	33.12	4.59	46.82	4.91	48.83	4.94
50	16	29.17	1.62	40.63	1.74	42.31	1.75
40	25	25.24	0.90	34.41	0.97	35.76	0.98
30	45	21.37	0.40	28.16	0.44	29.17	0.44
20	101	17.73	0.08	21.99	0.09	22.64	0.10
15	180	16.12	0.04	19.03	0.05	19.50	0.05
10	404	14.79	0.01	16.37	0.02	16.63	0.02

3.3. Precautions against mountain landslide

The disturbance of construction excavation to the slope should be reduced. During the construction of railway and auxiliary engineering, avoid excavating unstable slope and slope foot of landslide, forbid piling up engineering waste slag in the middle and upper part of unstable slope and landslide, and strengthen the influence of blasting on landslide and unstable slope during construction. At the same time, carry out special evaluation and targeted project management. It is suggested to carry out special evaluation on the stability of the overburden and its potential impact on the railway, identify the potential deformation area and the scope of the impact area, and carry out targeted engineering treatment to prevent and control the geological safety risk from the source [8].

4. Optimization of disaster prevention and reduction based on emerging technologies

4.1. Cloud-edge interaction mechanism

Cloud edge interaction mechanism refers to the collaboration between cloud computing and edge computing. The autonomous high-speed railway disaster prevention system based on cloud-edge interaction mechanism has a logical structure of "one cloud multilateral", in which "cloud" refers to system data processing and dispatching command center, "edge" refers to each roadside computing unit nearest to the disaster monitoring sensor on the site floor. Under the new architecture, the center ("cloud") will send part of the processing, decision-making, control resources and corresponding functions to each computing unit ("edge"), and each computing unit can process the data in the region in real time, identify the occurrence of events in real time, and realize regional autonomy. The center is mainly responsible for global data processing and decision-making, and can undertake data processing tasks with low real-time performance and high complexity.

The center and any computing unit are connected through the communication transmission network to realize the interoperation between the center and computing unit. By considering the influence range, real-time requirements and data processing complexity of the event region, regional autonomy or central unified decision of computing units was selected for different events, and the event attribute driven disaster warning decision was realized. When the computing and storage pressure of the center or any computing unit is too great, the logical architecture of the system can be reconstructed through dynamic scheduling of computing and storage resources and dynamic assignment of tasks to realize "cloud-edge interaction" [9].

4.2. Intelligent disaster prevention

Traditional mechanics knowledge system plays an important role in civil engineering structures to cope with natural and man-made disasters, including earthquake engineering, wind engineering, fire engineering, etc. The research connotation of disaster prevention and reduction technology includes disaster resistance design method based on motion equation and resistance-effect criterion, development of disaster prevention and reduction equipment and system based on vibration control, development of risk assessment theory from individual structure to regional disaster, and establishment of disaster early warning and emergency rescue system after disaster.

Video images play a vital role in the field of intelligent disaster prevention because of their simple, safe, wide sources, low cost and intuitive perception. With the development and popularity of the Internet, big data, drones and robotics, drones and robots embedded with artificial intelligence algorithms such as computer vision are used as AIDS in post-disaster field investigations. By presetting autonomous inspection routes and adjusting different shooting fields of view, multi-scale disaster information can be obtained to realize rapid, automatic, safe and accurate post-disaster site assessment [10].

5. Conclusion

Natural disasters are unavoidable, however, mastering the laws of disasters and taking targeted measures can prevent and reduce disasters. This paper mainly introduces the disaster prevention of earthquake and landslide in railway engineering, and the development prospect of some new technologies. Then, how to improve the accuracy and reliability of disaster judgment is studied, and the causes of disaster are also discussed. The comprehensive measures of disaster prevention and reduction and rescue tools after the development of science and technology are analyzed. From the point of view of railway line construction, line design can avoid bad geological areas in advance and avoid the situation of no excavation. Geological survey before construction can improve the poor geology, using drainage grouting reinforcement and other methods. For railway construction and railway safety, the awareness of disaster prevention and reduction must be strengthen. At the same time, disasters can be prevented by relying on science and technology to minimize the losses caused by disasters.

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