Formation Mechanism and Prevention Countermeasures of Geological Hazards on Roadbed and Slope in Mountainous Area

Zhidan Liu[1], Rongjian Li[2*]
[1]Zunyi Survey and Design Institute of Water Conservancy and Hydropower, Zunyi, 563000, China
[2]Institute of Geotechnical Engineering, Xi'an University of Technology, Xi'an, 710048, China

Abstract: Aiming at the problem that the prevention and control strategy of the geological disaster of the traditional highway slope is not suitable for the protection of the mountain highway disaster, the formation mechanism of the geological disaster of the roadbed and slope of the mountain highway is studied, and the prevention and control strategy is put forward. The formation mechanism of collapse, landslide and debris flow disaster in mountainous area is analyzed. Based on the analysis results, the identification method of geological hazards is designed, and the corresponding prevention and control methods are put forward. The geological hazard identification method is used to identify the slope hazards that may occur in different mountainous areas, and the corresponding methods are used to form the prevention and control countermeasures of highway slope hazards in mountainous areas. Through the example verification, it is proved that compared with the traditional geological disaster prevention and control strategy, the proposed prevention and control strategy is more targeted, and the disaster prevention and control effect is better.

Keywords: Mountain roads; Subgrade slope; Geological hazards; Formation mechanism; Countermeasures for disaster prevention and control

1. Introduction

Mountain road refers to the road located in mountainous area, route twists and turns, longitudinal slope is larger, more special structures. The roadbed of mountain roads is often filled with high and deep excavation, and the special difficult places are usually crossed by tunnels or viaducts. Due to the special geological and geographical conditions and meteorological characteristics of mountainous areas, roads in mountainous areas are prone to landslide, landslide and other accidents to destroy roads, leading to high construction and maintenance costs [1]. There are a lot of geological and geomorphic types in mountainous areas in China. In addition, the research on the geological hazards of roadbed and slope in mountainous areas started late in China. There are still some problems to be solved.

Mountain highway route is of low grade and seriously restricted by topography. Slope geological disaster has always been one of the main factors affecting the safe operation of mountain highway, and the economic loss caused by it is very huge [2]. Therefore, a targeted study on the formation mechanism of geological hazards of mountain roadbed slope is helpful to better study the corresponding prevention and control measures. For this reason, this paper will study the formation mechanism and prevention countermeasures of the geological disaster on the mountain roadbed slope, and put forward more targeted prevention countermeasures through the analysis of the formation mechanism of the geological disaster.

2. The Formation Mechanism of Geological Hazards on Roadbed and Slope in Mountainous Area

Mountain highway special section form, slope geological disaster type is various, cause of formation is complex, influence factor is numerous. According to the scale of the disease body and the occurrence mechanism of the disease, the slope disease is divided into five basic types: rock fall, collapse, strewn at random, landslide and dumping. In practical engineering, two or more basic types are often combined together to form a more complex disaster failure mode, a single slope disaster is very rare. This paper will focus on the formation mechanism of collapse, landslide and debris flow.

2.1. Formation mechanism of slope collapse

In order to meet the requirements of route elevation planning, roadbed excavation is required in some areas,

which leads to large rock slope. At the same time, in the process of highway construction, the blasting charge of highway stone is large, which makes the slope rock mass loose and causes certain disturbance to the slope. After the excavation of the slope, there was no timely protection, so that the large area of the slope was exposed to the air, and the physical and mechanical changes occurred due to the strong effect of natural factors for a long time, resulting in serious wind erosion and instability of the rock mass. Slope drainage measures are not perfect, when the flow of water directly erosion slope, resulting in collapse. Unreasonable mining activities cause sections of roads to collapse and slopes to become steep, leading to collapses that can block roads and wash away vehicles. Coupled with the subtle effect of natural geology, rock slope collapse is also an inevitable factor [3].
Earthquake and other sudden external forces are also the main factors that cause the highway subgrade slope collapse. As shown in the figure below, due to the impact of external forces such as earthquake, the rock mass in the upper part of the slope is easy to be cracked. Seismic fractures develop along tension fractures and compression-shear fractures between layers. When the tension fractures in the vertical layer connect with the compression-shear fractures in the parallel layer in the process of deepening and expanding, these seismic fracture blocks will slip along the smooth structural surface or weak surface inclined to the slope below [4]. Under the influence of external conditions, as long as the shear stress on the sliding surface exceeds its shear strength, it will collapse. In addition, the hydrostatic pressure and dynamic pressure generated by continuous heavy rain penetrating into the cracks of rock mass, as well as the softening and weak surface of rain water, are the main inducements of slope rock mass slippage.

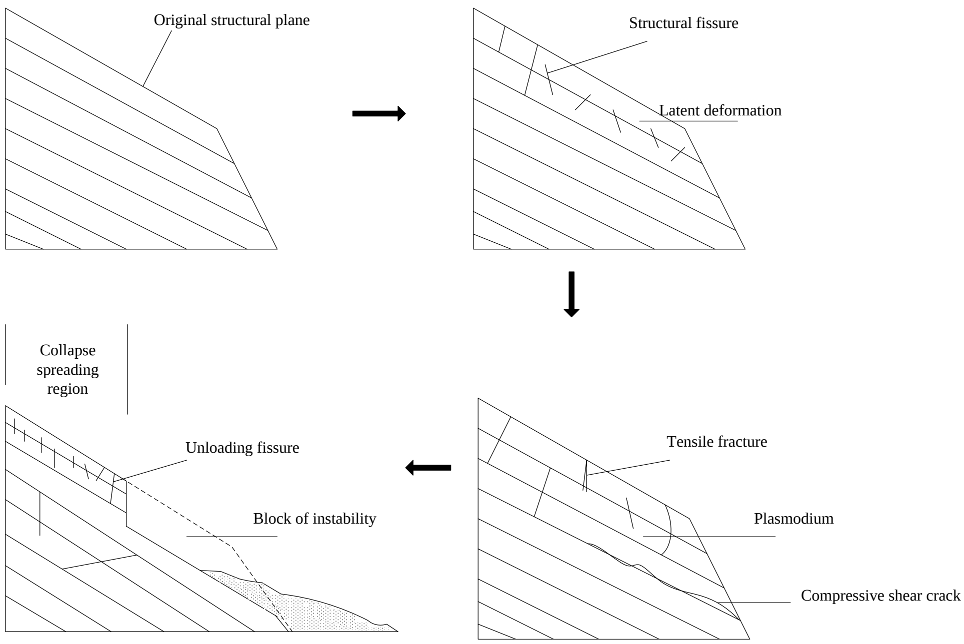

Figure 1. Schematic diagram of earthquake collapse formation

2.2. Mechanism of landslide formation

The main part of the formation mechanism of landslide disaster is the internal conditions such as the nature, structure and structure of rock and soil, hydrogeological conditions and external factors such as climate, weathering, vegetation conditions and human factors.
Analysis the factors of forming inside the landslide slope analysis, such as shale, schist rock and soil shear strength, resistance to weathering and erosion of water resistant ability is weak, when these geotechnical rock layer, fault surface, cracks and other body parts easy to weathering and slope surface inclination towards consistent, is likely to happen in the bedding landslide and the accumulation slide along the bed rock [5]. At the same time, the section size of subgrade slope is another internal factor of landslide disaster formation mechanism. The following figure shows the standard roadbed cross section. Based on the analysis of the mechanics principle, the size of the slope cross section also has a great relationship with the stability of the slope. The steeper the slope is, the worse its stability is, and the easier it is to slide. If the slope height is the same as the horizontal length of the slope, but one is to let the slope to the top, and the other is to set a platform in the middle of the slope, the anti-pressure effect of

the platform on the slope will increase the stability of the slope.

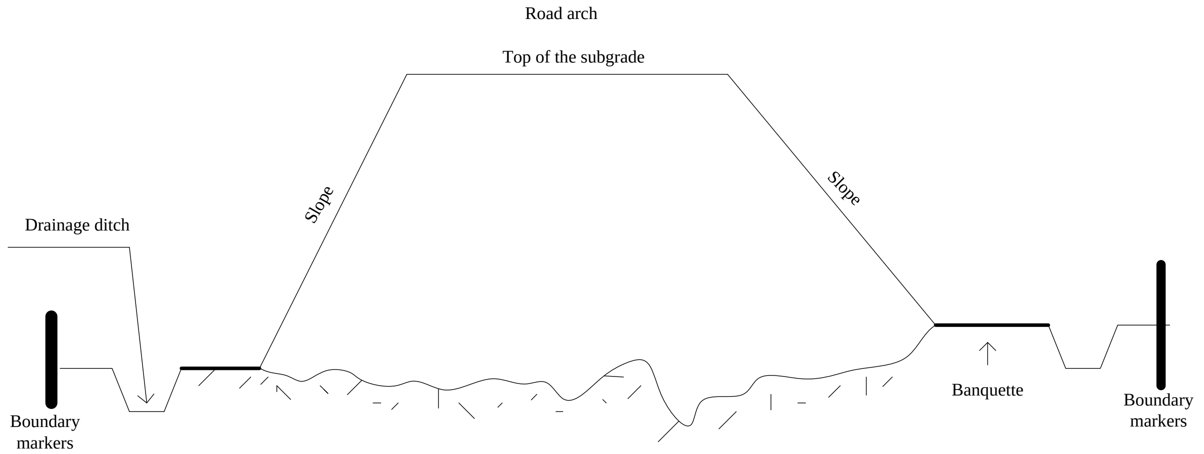

Figure 2. Roadbed standard cross section

The effect of refuse water, unreasonable excavation, loading, vibration and mining on slope are the external factors that form the slope slope of highway in mountainous area. Water into the slope rock body, it will increase the heavy of geotechnical and softening effect, reduce the shear strength of geotechnical, hydrostatic pressure and dynamic hydraulic scour or at the foot of the slope erosion, the impervious layer overlying rock and soil layer on the lubrication, the local water in impermeable layer on the ceiling to assemble, it also to create buoyancy effect in the overlying strata, etc., will be the nature of the change of slope of rock and soil, status, structure and construction, etc. [6]. In addition, in the construction of highway in mountainous areas, unreasonable excavation of slope foot or improper filling of soil, building of houses or piling of materials on the slope will often occur, which will destroy the balance of the slope and lead to the occurrence of landslide.

2.3. Mechanism of debris flow formation

Debris flow is a unique geological disaster in mountainous areas. Most highways in mountainous areas are distributed along rivers and mountains. When debris flow occurs, it will damage the highway, cause the roadbed to lose stability and cause serious road obstruction. Impact road, serious erosion of road subgrade and slope, resulting in highway damage.

The formation of debris flow must have strong surface runoff. Rainfall promotes the accumulation of loose debris. As a result of weathering, a large amount of loose debris materials are usually accumulated on the slopes of debris flow gullies, and these materials are often transported into gullies and collected in gullies under splashing erosion and scouring of rain water, forming abundant gully bed deposits [7]. And rain can make in the limit equilibrium state of collapse and landslide body weight increase, the collapse and slide bed body between the friction coefficient decreases, and damage state of equilibrium and produce movement, make a lot of debris into the ditch, gully bed debris further increase, even within the valleys formed a blockage, create more favorable for the formation and development of debris flow conditions. Secondly, rainfall provides water composition and dynamic conditions for debris flow formation. The potential energy of loose solid material is converted into kinetic energy and the kinetic energy of rain runoff are the two power sources of debris flow.

3. Prevention and Control Measures of Geological Disaster of Highway Subgrade and Slope in Mountainous Area

Generally, when the geological disaster occurs on the highway subgrade and slope in mountainous areas, it is not a single disaster. Therefore, according to the analysis of the formation mechanism of the geological disaster on the highway subgrade and slope in mountainous areas, combined with advanced science and technology, this paper puts forward the following countermeasures for the prevention and control of the geological disaster on the slope.

3.1. Identification of slope geological hazards

There are many influencing factors and inducing factors of highway slope geological disasters, and the environmental conditions in the region of the slope are complex and diverse, and the types of slope geological disasters will be different due to their different combinations. Single factor cannot accurately and comprehensively reflect the characteristics of highway slope geological disasters, so it cannot be used for the identification of geological disasters [8]. The method of superposition of influencing factors is used to identify the geological hazard of highway slope. The superposition identification method of influencing factors refers to the superposition or combination of influencing factors from macro to micro based on the analysis and classification of the factors affecting the highway slope geological hazards, so as to obtain the corresponding disaster types and realize the identification of the highway roadbed slope geological hazards in mountainous areas.

Table 1. Influencing factors and identification methods of highway slope geological hazards

Relationship between highway trend and slope bottom trend	Slope body structure	Rock and soil properties	Possible disaster type
Parallel	Base type	Hard rock	Collapse
		Soft rock	Falling rocks
Oblique	Stratiform	Extremely soft rock	Slump
	Massive	Such as gravel soils	Collapse
Vertical	Loose broken body	Powder soil	Landslide
	Class homogenate	Earth-Rock mixture	…

The geological conditions of different mountainous areas are different, so the above methods are used to identify the possible geological disasters in the target areas, and corresponding prevention methods are used according to the identification results.

3.2. Countermeasures against geological disasters

Landslide is the most common geological disaster in every mountain road. Considering the project cost, the stability of landslide prone areas is calculated to take different landslide protection measures. The sliding thrust of landslide is the main basis of slope engineering design. As shown in the following slide force calculation diagram, the slope rock mass slide force is calculated by the thrust calculation formula of transfer coefficient method.

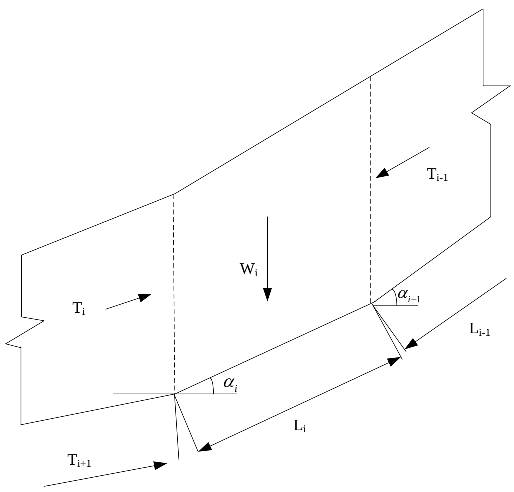

Figure 3. Schematic diagram of sliding force calculation

$$T_i = F_s W_i \sin\alpha_i + \psi_i T_{i-1} - W_i \cos\alpha_i \tan\phi_i - c_i L_i \quad (1)$$

In formula (1), F_s is the stability coefficient, W_i is the self-gravity of the ith slide block, α_i is the dip Angle of the sliding surface corresponding to the ith slide block, α_{i-1} is the dip angle of the sliding surface corresponding to the I slide block, ϕ_i is the friction Angle of the sliding surface of the I slide block, c_i is the geotechnical cohesion of the sliding surface of the I slide block, L_i is the length of the sliding surface of the I slide block, and ψ_i is the transfer coefficient. The calculation formula of ψ_i is as follows [9].

$$\psi_i = \cos(\alpha_{i-1} - \alpha_i) - \sin(\alpha_{i-1} - \alpha_i)\tan\phi_i \quad (2)$$

After calculating the landslide stability, according to the boundary range, deformation characteristics, landslide properties, rock-soil physical and mechanical characteristics, design thrust size and protected objects, the reinforced concrete anti-slide pile, anti-drainage measures or brush-side load reduction combined prevention and control scheme are selected. There is more precipitation in mountainous areas, so rain water and groundwater will humidify the subgrade slope, increasing the probability of geological disaster. Therefore, in addition to setting up the necessary open drainage system, horizontal drainage holes should be set up at both sides of the highway and the bottom of the roadbed retaining wall according to certain requirements for drainage. Grouting reinforcement technology is used to effectively prevent groundwater intrusion into the foundation.

Slope protection net is used for surface protection of slope with weathering phenomenon. For the rock slope without weathering and other phenomena, we can use the frame beam, spray grouting, broken surface protection groove and other concrete or masonry block stone broken surface reinforcement, the formation of broken surface fixed framework on the slope, in order to improve the surface roughness factor of the slope, slow down the flow of water, and stabilize the slope. For very steep rock slope, it is necessary to repair the surface rock mass as shown in the figure below, so that the rock mass camber is not large; By means of support, support and embedded reinforcement, necessary surface reinforcement and protection are carried out for the rock slope with great safety risks [10].

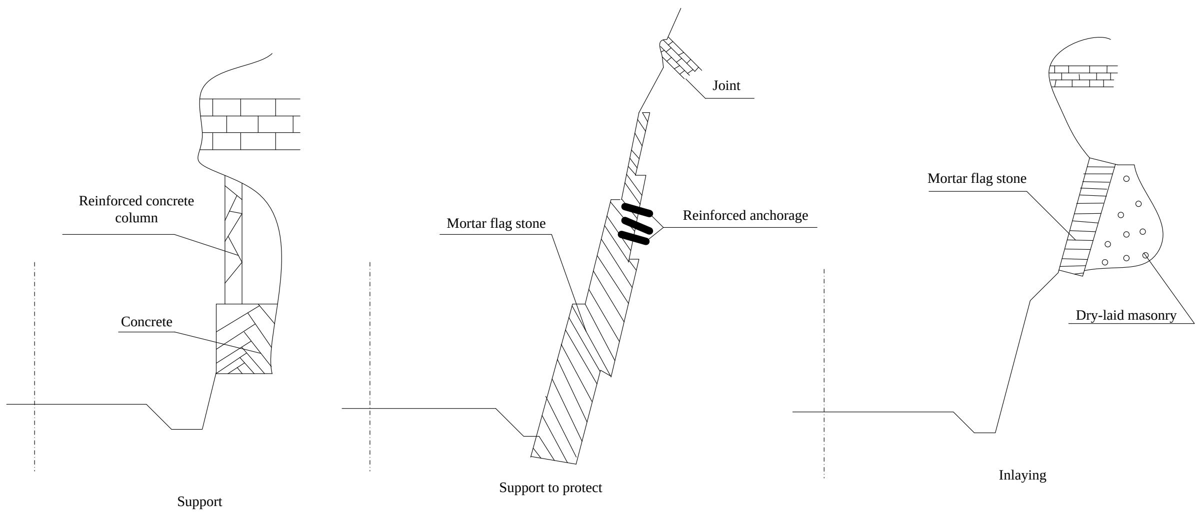

Figure 4. Surface protection of steep slope

For the road prone to debris flow disaster in mountainous areas, the slope on both sides of the road should be slowed down to reduce the impact of landslide debris flow disaster, and the load should be reduced by steps to remove the falling soil by steps. We will comprehensively harness surface water and groundwater, build some low dams in areas prone to mud-rock flows, intercept a large number of silt and rocks brought by mud-rock flows, weaken the impact force of mud-rock flows when they come, reduce the flow velocity, and reduce losses. At the same time, soil and water conservation, planting trees and grass, repair terraces, closed mountains and forest, reduce soil erosion. Build protective walls, stone retaining walls are used on the mountains on both sides of the road to prevent landslides, debris flows and other disasters. Water is an important factor to induce debris flow and landslide. Above, the prevention and control measures are proposed for the formation mechanism of geological hazards on roadbed and slope in mountainous areas.

4. Example Verification

This paper puts forward the corresponding prevention and control countermeasures for the formation mechanism of slope geological disasters. In order to verify the pertinence of prevention and control countermeasures, it compares with the traditional highway geological disaster prevention and control strategies, and draws effective conclusions through the verification of examples

4.1. Verify the content

Consider examples demonstrate the feasibility and economy, choose a mountainous area highway as experimental object, the highway happened small geological disasters during the rainy season last year, before the rainy season to disaster prevention and control of the road, the road were divided into experimental group and control group in the experimental road section, each section is divided into 5 groups, the experimental group used in this paper, the geological hazard prevention and control countermeasures of the control group used the traditional highway geological hazard prevention and control countermeasures. Before the experiment, according to the experimental group of prevention and control countermeasures survey site, considering the rainy season proximity and construction difficulties and other factors, the experimental group of highway slope to set up a mountain protection network and lay more drainage system. In the control group, according to the traditional control strategy, drainage ditches were dug in the highway section of the control group to deal with the exposed and dangerous rock blasting. In the process of the experiment, the real time monitoring of the target highway, through comparing the damage rate of the two groups of roads, to verify the effectiveness of the two groups of geological disaster prevention countermeasures.

4.2. Verification result

In the course of the experiment, the mountain area where the experimental highway was located experienced short and heavy rainfall, and the small debris flow disaster occurred in the experimental area. After the disaster, the comparison of the highway damage of the two disaster prevention strategies is as follows.

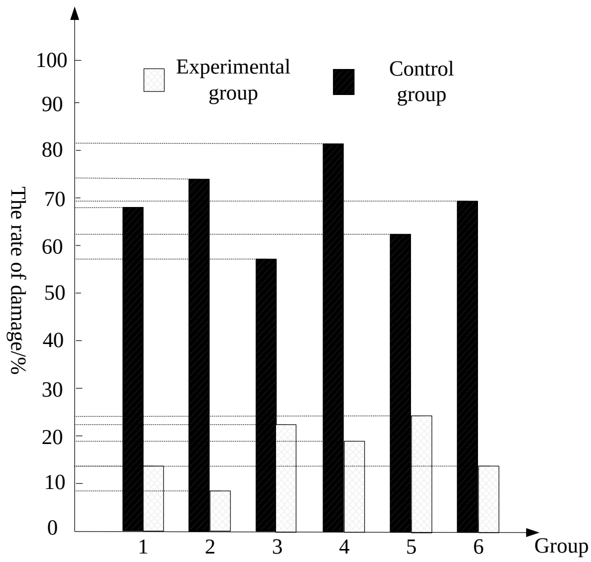

Figure 5. Comparison of damage rate

By analyzing the above figure, a comparison conclusion is drawn. All the target sections of the experiment have debris flow disasters due to precipitation, and the road slope has rock fall, landslide and other disasters. In the actual monitoring process, it was found that there was a small debris flow disaster in this section. When the precipitation stopped, the slope of the two groups of roads suffered disasters after the debris flow disaster. The damage rate of the experimental group was much lower than that of the control group. The damage rate of roads in the experimental group was less than 25%, while that in the control group was higher than 55%. The damage degree of roads in the experimental group had little impact on the road opening and could be restored to traffic quickly. Moreover, only rockfall and reinforcement in the protective net were needed, and the road maintenance cost was less. The control group road was seriously damaged, and due to the heavy rockfall, the section of the road could not resume traffic for a short time. To sum up, the slope geological disaster prevention countermeasures proposed in this paper have better effects on the prevention and control of geological disasters.

5. Conclusion

Slope geological disasters pose a direct threat to the operation safety and stability of mountain roads and have great safety risks. Therefore, protection and disposal should be carried out in construction or operation. This paper discusses in detail the formation mechanism of the slope geological disaster in mountainous areas and puts forward the prevention and control measures against the slope geological disaster. Finally, the practical engineering case verifies the prevention and control measures of slope geological disaster proposed in this paper, which have good protective effect and can provide engineering reference.

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