Characteristics of Hazardous Rock Avalanche Disasters on High and Steep Slopes and Countermeasures for Prevention and Control in Wuling Mountain Area of Chongqing

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Abstract. Chongqing Wuling Mountain area has complex geological conditions and frequent geologic disasters, which bring severe challenges to the construction of highways along the route, especially affected by the topography and meteorological conditions in the Chongqing region, the distribution of disaster points is dense, and the disaster management is difficult. This paper takes a highway in Chongqing Wuling Mountain area as an example, fully analyzes the development characteristics of geologic disasters along the route, and concludes that dangerous rock collapse is a typical geologic disaster on the slope in Chongqing Wuling Mountain area. The influencing factors of dangerous rock failure on the slope are divided into three categories: geological conditions, meteorology and hydrology, and slope design pattern, and their influencing mechanisms are elaborated respectively. Finally, 16 high and steep slopes along the route are analyzed in depth, divided into four grades according to the degree of influence on slope safety, and targeted prevention and control measures are proposed. It can provide certain reference for the construction of highway along the Wuling Mountain area in Chongqing.

Keywords: Chongqing Wuling Mountain Area; dangerous rock failure; high steep slope; disaster influencing factors; prevention and control countermeasures.

1. Introduction

Wuling Mountain area in Chongqing has steep slopes and dense forests, deep river valleys, complex topographic and geological conditions, abundant rainfall, plus the excavation and unloading of high and steep slopes during the construction period, which brings serious safety hazards to the high and steep slopes along the highway, coupled with the frequent occurrence of geologic hazards along the highway, which seriously threatens the safety of the road traffic, and brings a greater challenge to the construction of the highway. Therefore, it is of great significance to carry out the research work on slope geohazards along the highway to ensure the safe operation of the road section.

At present, although the research results on highway slope geohazards are quite abundant, the disaster characteristics and types of highway slopes in different regions are different due to the different factors such as geological environment, climatic conditions and excavation, and thus their prevention and control countermeasures are also different. In view of this, this paper on the basis of extensive data research, through the field survey, a highway in Chongqing along the development characteristics of geological hazards to carry out research, typical geological hazards as a further object of study, from the cause of the disease to start, analyze the factors that affect it. Combined with the slope design parameters and support measures of the high and steep slopes along the route, the impact degree on the safe operation of the highway is analyzed, divided into different impact levels, and according to different impact levels, corresponding prevention and control countermeasures are put forward to provide references for the management and maintenance of the slopes.

2. Project overview

A highway in Chongqing is located in the Wuling Mountain area, a two-way six-lane highway in the mountainous and hilly area, with a design speed of 100Km/h, a roadbed width of 33.5m, and a
2.1 Topography and geomorphology

Route corridor is located in the south of Chongqing, the southeast edge of the Sichuan Basin and the northern end of the Yunnan-Guizhou Plateau of the convergence zone, the type of geomorphology by the tectonic and lithological constraints, by a series of north-east of the strip dorsal sloping, to the slope of the comb-shaped tectonics and the formation of a narrow strip of tectonic basis of the formation of the low mountains and hills. The mountains and hills are generally 500-1000 meters above sea level, with dense forests and abundant water sources; the valleys and dams are generally 250-500 meters above sea level, with densely cultivated land. The topography and geomorphology are generally complex, with large vertical undulations and steep horizontal slopes. The geomorphology is strictly controlled by the geological structure, and there are mainly three types of landforms: tectonic denudation landforms, erosion and dissolution landforms, and erosion and accumulation landforms.

2.2 Stratigraphic lithology

The surface of the route area is covered by the Holocene stratum of the Quaternary System, and the underlying and exposed strata are mainly the Penglai Town Formation and Suining Formation of the Upper Series of the Jurassic System, the upper and lower Shaximiao Formation of the Middle Series, Xintiangou Formation, the middle and lower Ziriusui Formation, and the lower Pearl Rushing Formation, as well as the upper Shujiahe Formation of the Triassic System, middle Leikoupo Formation, and the lower Jialingjiang Formation; the main lithological properties of the area are sandstones, feldspathic quartz sandstones, mudstones, siltstone, siltstones, chert, dolomites, shales, breccias, shale, and so on. Shale and conglomerate. The outcrops are roughly oriented from north-west to south-east, from new to old.

2.3 Geological Tectonics

The line corridor area through the main tectonic traces for a series of north-east to south-west direction of the tight folds, the line area of the main folds for the Huaying Mountain dome fold bundle Dasheng field oblique, Mingyuexia dorsal oblique, moraine oblique, Taozidang dorsal oblique, Liangshui dorsal oblique; Wanzhou concave fold bundle Fenshen field dorsal oblique, the Fenshen field fault, Shixibao sub-field oblique, Tongmawan dorsal oblique; the main rupture structure for the Changshou Zunyi basement rupture.

2.4 Meteorology and hydrology

The project area belongs to subtropical humid monsoon climate zone, with mild climate, abundant rainfall, four distinct seasons and long frost-free period. Early return to temperature in spring, but often affected by the cold wave appeared inverted spring cold, abundant rainfall in early summer, hot summer drought, more rain in the fall, winter without severe cold, more clouds. The average relative humidity for many years is 79%, the absolute humidity is 17.6 mb. The average temperature for many years is 17.72 °C, the extreme minimum temperature is -4.5 °C, and the maximum temperature is 42.9 °C. The average annual rainfall for many years is 1104.5mm, but the rainfall is unevenly distributed in time, generally concentrated in May to September, the rainfall accounts for about 2/3 of the year, and there are many heavy rainfall, heavy rain, the maximum daily rainfall of 363.8mm. The average wind speed is 0.9m/s, and the instantaneous maximum wind speed reaches 27m/s. The surface water along the route is extremely developed.

Surface water along the line is extremely developed, generally originated in the middle and low mountain valleys, controlled by the tectonic structure, showing a dendritic spread. Due to the high mountains and deep valleys, the water flow kicks, in case of heavy rainfall, easy to trigger flash floods, the rivers and gullies in the territory have the hydrological characteristics of rainwater-borne rivers with instantaneous changes in flood and dry flow, which are easy to rise and fall. The
stream-type gullies in the area have the characteristics of ups and downs, and the water volume is generally small in the dry season, which is easy to form flash floods in the rainy season and entrain a large amount of mud and sand and drifting gravel, and the river dries up in the dry season, exposing a large number of pebbles in the riverbed. The development of tectonic fissures and dissolution fissures in each water-bearing rock group in the route area lays the foundation for groundwater runoff and discharge, and the abundant atmospheric rainfall and good vegetation provide good conditions for groundwater recharge. The burial, distribution and water-richness of each type of groundwater are controlled by the geological structure, topography and geomorphology, lithology and the degree of development of fissures.

3. Dangerous rock collapse disaster mechanism and influencing factors

Through the survey along the line and combined with the statistical analysis of investigation and design data, along the line of dangerous rock collapse is more developed, along the line of the development of a total of 37 dangerous rock body, the total volume of about 27.6 × 104m3, rock body is cut into fractured blocks, local rock protruding, overhanging, in the tunnel blasting, seismic effects are prone to collapse, affecting highway construction and operation safety.

3.1 Mechanism of disaster

Dangerous rock collapse refers to the rock and soil body located on steep slopes, under the action of external force and its own gravity, it will fall and roll away from the parent body, and pile up at the foot of the slope as a geological disaster, which mostly occurs on steep slopes with a gradient of 45°-50° and a height of more than 20m. Dangerous rocks along this highway are mainly developed in the sandstone steep canyons and steep cliffs formed by the thick bedded sandstone of the Upper Jurassic Penglai Town Group and Suining Group. Due to the gentle rock layer, steeply dipping fissures are mostly developed in the rock body, and the sandstone steep canyons and steep cliffs are affected by the cutting of outwardly inclined steeply dipping fissures, which are cut by the horizontally developed rock layer level of the rock body in the lower part of the road. The rock at the top of the slope is unloaded by micro-cracks under the action of wind, water, vibration and other camping forces, and the cracks on the surface of the rock and soil body are further developed vertically under the continuous infiltration deterioration of water. Suspension occurs due to weathering, erosion and hollowing of its lower part. Under the action of self-weight, the center of the geotechnical body gradually shifted to the critical surface. Eventually, the tensile strength of the geotechnical body is insufficient to resist its overturning force, and the geotechnical body continues to crack until it completely detaches from the parent body, rolls and jumps along the free surface or slope surface, and finally piles up at the foot of the slope.

3.2 Influencing factors

By investigating and counting the historical disasters of slopes of the operated highways in Chongqing Wuling Mountain area, taking full consideration of the actual development along this highway, based on the relevant data statistics, combined with the experience of the experts, the influencing factors of dangerous rock collapse of high and steep slopes in Chongqing Wuling Mountain area are classified into three major categories, namely, geological conditions, meteorological and hydrological, and the design form of the slopes.

1) Geological conditions

The influencing factors of geologic conditions for the development of dangerous rock failure can be divided into: topography and geomorphology, stratigraphic lithology, rock structure and geologic structure.

①Geological structure

Geological structure has various influences on the formation and evolution of slope hazards, which affects the stability and operation safety of highway slopes.
Fracture zones provide a lot of material resources for the occurrence of geologic disasters, and various geologic interfaces determine the spatial location and damage range of the fissure surface or damage surface of the dangerous rock body, and the geologic structure also influences the distribution and flow direction of the groundwater.

② Strata lithology

Influenced by the cause and components of the rock and soil body, the structure and strength of the large differences. It directly affects the overall stability of the rock body and the degree of weathering. In terms of the disaster distribution law of the slope along the Wuling Mountain area, sandstone, mudstone and shale are more distributed, which is more likely to cause dangerous rock collapse disaster.

③ Structure of rock body

Rock and soil body is the material basis for the occurrence of slope geologic disaster, the type and nature of rock and soil body and geologic disaster correlation is high, and the type of disaster, the mechanism of disaster are different. According to the different types of rock body, its rock-forming structure can be divided into whole structure, layer structure, block structure, mosaic structure, fracture structure and bulk structure.

④ Topography and geomorphology

Topography and geomorphology have a great influence on the safety of slopes, the topography and geomorphology type determine the water catchment conditions, water level, rock stratum direction and structure of slopes, and steep rocky slopes, staggered heights and steep slopes and other characteristics breed better material conditions for dangerous rock collapses.

2) Meteorological and hydrological

① Atmospheric rainfall

A large number of disaster data show that water is directly related to most of the disasters, and it is the main disaster-causing factor leading to slope disasters. Rainfall-induced slope disasters are mainly affected by rainfall amount and intensity. The regional rainfall is large, and the rainfall is unevenly distributed in time, concentrated in May to September, and there are many heavy rainfalls and torrential rainfalls, with the maximum daily rainfall of 363.8mm. The adverse climatic conditions will directly lead to slope geologic hazards, and in the case of hazardous rock failures, the concentration of a large amount of rainfall increases the self-weight of the rock and soil body of the slope, and the mechanical strength deteriorates rapidly, the pore space continues to develop, and the overturning moment toward the critical surface increases, and it can be developed into hazardous rock failures further. Further, it can be developed into dangerous rock collapse.

Groundwater

The rise and fall of groundwater has a big influence on the internal force of slope geotechnical body, through the rise and fall of water level, the effective stress and pore water pressure of slope body will change. At the same time, groundwater will lead to rock and soil body strength and physical and mechanical properties change, resulting in slope damage.

③ Slope design form

The construction of mountain highway often need to transform the geotechnical body along the line, the design form of the slope for the slope construction is completed after the formation of artificial structures features, including slope height, slope length, slope gradient and protection. Slope height, slope directly affects its construction difficulty, through the excavation of the slope, the geotechnical body stress is released, coupled with the geological factors of high and steep slopes, easy to develop into a slope disaster. As a result, the development of slope disaster can be avoided or mitigated by adopting certain slope protection measures. Through the investigation of taking highway slopes along the Wuling Mountain area, slope protection is mainly based on face protection wall, retaining wall, active protection network, anchor rods (anchor cable) lattice beams, anti-slip piles, etc., whose working condition is affected by the nature of the rock and soil body, climate and hydrology, construction quality and other factors, and whether it is effective or not is more associated with the slope disaster.
4. Measures to prevent and control high and steep slopes

On the basis of the research on the development characteristics of dangerous rock collapse on high and steep slopes in Wuling Mountain area of Chongqing, combined with the actual situation of 16 high and steep slopes along the line, we start from the influencing factors, combined with the support measures adopted, to determine the degree of their influence on the operational safety of the slopes. On this basis, slope prevention and control measures are proposed. See Table 1.

Table 1. Suggested Measures for Prevention and Control of High and Steep Slopes

<table>
<thead>
<tr>
<th>serial number</th>
<th>starting and ending post numbers</th>
<th>high degree (m)</th>
<th>Existing protection</th>
<th>Degree of impact on slope safety</th>
<th>Recommendations for preventive and curative measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K5+432-K5+826</td>
<td>58</td>
<td>Anchor frame beams</td>
<td>serious</td>
<td>monitoring and early warning</td>
</tr>
<tr>
<td>2</td>
<td>BK0+240~BK0+300</td>
<td>36</td>
<td>Anchor frame beams</td>
<td>general</td>
<td>Daily maintenance+Regular inspections</td>
</tr>
<tr>
<td>3</td>
<td>K37+040-K37+575</td>
<td>52.9</td>
<td>Anchor (cable) frame beams+net grassing</td>
<td>serious</td>
<td>monitoring and early warning+emergency plan</td>
</tr>
<tr>
<td>4</td>
<td>K51+960~K52+060</td>
<td>13</td>
<td>skid pile+net grassing+trench wall</td>
<td>comparatively large</td>
<td>Enhanced inspections+monitoring and early warning</td>
</tr>
<tr>
<td>5</td>
<td>K60+170~K60+360</td>
<td>33</td>
<td>Anchor frame beams+Anchor cable anti-slip pile</td>
<td>comparatively large</td>
<td>Enhanced inspections+monitoring and early warning</td>
</tr>
<tr>
<td>6</td>
<td>AK0+230-AK0+420</td>
<td>54</td>
<td>Anchor (cable) frame beams</td>
<td>serious</td>
<td>monitoring and early warning+emergency plan</td>
</tr>
<tr>
<td>7</td>
<td>K89+688-K89+869.054</td>
<td>32.8</td>
<td>Anchor frame beams+net grassing</td>
<td>general</td>
<td>Daily maintenance+Regular inspections</td>
</tr>
<tr>
<td>8</td>
<td>K90+652.096-K91+022.789</td>
<td>52.1</td>
<td>Anchor frame beams+net grassing</td>
<td>serious</td>
<td>monitoring and early warning+emergency plan</td>
</tr>
<tr>
<td>9</td>
<td>K94+620~K94+850</td>
<td>40.0</td>
<td>skid pile+Anchor frame beams+skeleton slope+net grassing</td>
<td>comparatively large</td>
<td>Enhanced inspections+monitoring and early warning</td>
</tr>
<tr>
<td>10</td>
<td>ZK123+725-ZK123+920</td>
<td>70.7</td>
<td>skeleton slope+Anchor (cable) +skid pile+retaining wall</td>
<td>particularly important</td>
<td>Focused Monitoring and Early Warning+Specialized Emergency Response Plan</td>
</tr>
<tr>
<td>11</td>
<td>AK0+344-CPB0+246.48</td>
<td>42.2</td>
<td>skeleton slope+Anchor (cable)</td>
<td>comparatively large</td>
<td>Enhanced inspections+monitoring and early warning</td>
</tr>
<tr>
<td>12</td>
<td>EK0+220-AK0+330</td>
<td>54.8</td>
<td>skeleton slope+Anchor (cable)</td>
<td>serious</td>
<td>monitoring and early warning+emergency plan</td>
</tr>
<tr>
<td>13</td>
<td>CK0+260-CK0+480</td>
<td>52.1</td>
<td>Anchor (cable) frame beams</td>
<td>serious</td>
<td>monitoring and early warning+emergency plan</td>
</tr>
<tr>
<td>14</td>
<td>BK0+070-240</td>
<td>29.8</td>
<td>Anchor (cable) frame beams+skid pile</td>
<td>comparatively large</td>
<td>Enhanced inspections+monitoring and early warning</td>
</tr>
</tbody>
</table>
5. Conclusion

This paper takes a highway in Chongqing Wuling Mountain area as an example, studies the development characteristics of slope geologic hazards and puts forward prevention and control measures, and mainly draws the following conclusions:

(1) Geological hazards along the Wuling Mountain area of Chongqing are more developed, and the percentage of dangerous rock collapse along a highway in Chongqing is higher, which is a typical type of geological hazards in the region;

(2) Chongqing Wuling Mountain area dangerous rock collapse mainly developed in thick sandstone, by the gentle rock layer production, easy to develop steeply inclined fissures, coupled with the rock layer under the weathering, hollowing out the role of the overhang, in the vibration, water and other factors under the further action of the steeply inclined fissures continue to carry out, and ultimately lead to the collapse;

(3) The influencing factors of dangerous rock collapse of slope are divided into three major categories: geological conditions, meteorological and hydrological, and slope design morphology, which are further subdivided into influencing factors such as geological structure, stratigraphic lithology, rock structure, topography and geomorphology, atmospheric precipitation, groundwater, slope height, and slope gradient;

(4) Investigate the characteristics of 16 high and steep slope sites along a highway, combined with the support measures taken, according to the size of the impact on the safety of highway operation is divided into four levels: general, large, major, and especially major, and targeted slope prevention and control measures are proposed.

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References


[6] YU Xianggui, TANG Yonghua, LI Shiming et al. Analysis of disaster development law during construction period of highway graben slope in mountainous area of southwest Yunnan [J]. Highway and