Comprehensive Prevention and Control Project of a Debris Flow

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Abstract: This paper describes the geological conditions of a mudslide in Sichuan in detail. According to the possible hazards caused by the mudslide and the improvement of the built projects, it puts forward a treatment plan: setting protective dikes on both sides of the village road to protect the lives and property of residents. Clean up the gravel deposited in the township road, and then set up the bottom, so that the debris flow can be discharged smoothly and the safety of residents' travel can be protected.

Keywords: Debris Flow; Analysis of Geological Conditions; Comprehensive Control

1. Source of Tasks

Debris flow is located in the southwest of Sichuan province, and geological disasters such as debris flow, collapse and landslide are relatively developed in the local jurisdiction. In recent years, under extreme working conditions such as rainstorm and earthquake in flood season, debris flow gullies are prone to occur again. In order to maintain the safety of local people, the debris flow was designed to eliminate dangers.

2. Meteorological and Hydrological Conditions

According to the geographical latitude, the debris flow area belongs to the mountain subtropical climate, which has the characteristics of large evaporation, sufficient sunshine, strong radiation, large temperature difference between day and night, diverse climate types and significant vertical changes. From the valley to the top of the mountain, there are mountain subtropical zone, mountain warm temperate zone, mountain temperate zone, mountain cold temperate zone and mountain sub-cold zone in turn, and the temperature decreases with the increase of altitude.

The local average annual rainfall for many years is 330.6mm, and it varies greatly from year to year. The maximum annual rainfall is 515.7mm, and the minimum annual rainfall is 142.1 mm. The maximum annual rainfall is 3.2 times of the minimum annual rainfall. Mainly concentrated in June-September, accounting for about 86% of the total annual rainfall, the maximum monthly rainfall is 193.7mm, and the minimum is only zero, showing frequent showers and night rain in summer, with a high incidence of heavy rain.

There is a Dingqu River in the survey area, which runs through the county from north to south, crosses the county seat and joins the tributary Maqu River in Bendu Township, and then flows into Jinsha River after the confluence of Guxue and Xuqu River, with a drainage area of 2055km^2 and a total length of 222.5km, with a flow length of 70km in the county.

3. Geological Environment Conditions

3.1 Topography

The landforms of debris flow work area are mainly composed of two types: structural denudation, karst mountain canyon landform and structural erosion accumulation valley basin landform. See Figure 1 for the debris flow pattern.

(1) Geomorphology of tectonic erosion accumulation valley basin

The landform of the valley basin in the survey area is mainly the old accumulation area formed by debris flow and the new accumulation area around Dingqu River, with a distribution area of 0.4km^2, accounting for 20% of the whole basin.

Due to the inhomogeneity of neotectonic movement, the deposits in this survey area basically preserve the dual structure. The left bank of Quding River is an erosion bank, and most terraces are destroyed. The accumulation thickness in the old debris flow accumulation area is 10-20m.

(2) structural denudation and dissolution of mountain and canyon landforms

Distributed in the whole survey area, with a distribution area of 1.6km^2, accounting for 80% of the whole basin. The cutting in the area is intense, with high mountains and deep valleys, showing a narrow "V" shape. The slope angle is more than 30, and the top of the mountain is round and gentle.

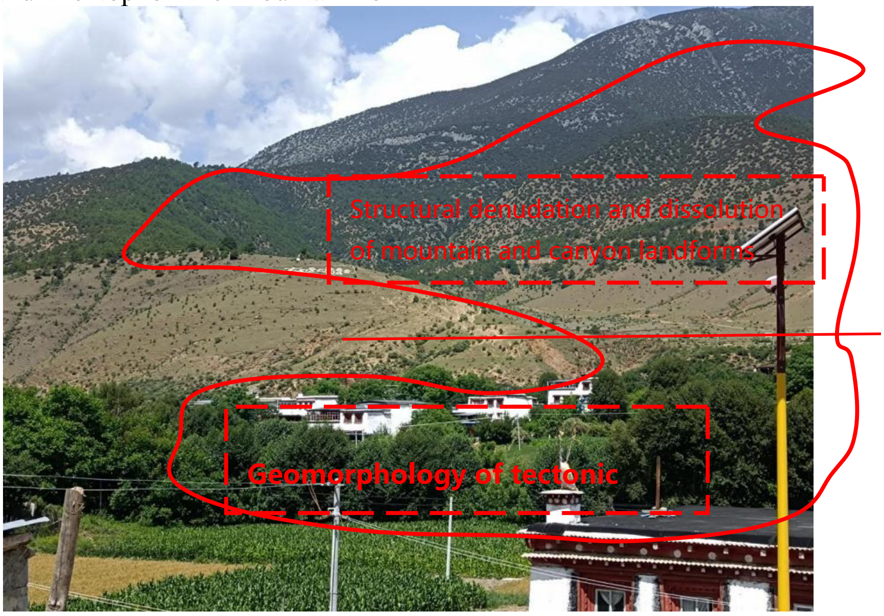

Figure 1. Debris Flow Geomorphology Zoning

3.2 Formation Lithology

According to the field survey and regional geological data, the exposed strata in the basin are mainly Palaeozoic (P) and Quaternary (Q), and the strata from new to old are briefly described as follows:

(1) Quaternary (Q_4)

Quaternary (Q_4) mainly includes debris flow deposits (Q_4^{sef}), scouring proluvial (Q_4^{al+pl}), residual slope deposits (Q_4^{el+dl}) and mixed types of alluvial, diluvial and glacial deposits (Q_4^{ad}).

(2) Paleozoic (T)

The Upper Carboniferous Dingpo Formation of Paleozoic is mainly distributed at an altitude of 3140 m ~ 3400m. Lithology is gray thick layered limestone mixed with biological limestone and purple marl; The Zapu Formation of Upper Carboniferous in Paleozoic is mainly distributed at an altitude of 3,400m ~ 3,900m. The lithology is thick bedded limestone and biotite limestone mixed with oolitic limestone.

3.3 Geological Structure

The geological structure in the county is complex. Because this area is located at the northern end of Hengduan Mountains, it belongs to the northernmost section where the Sichuan-Yunnan north-south structural system is merged and compounded in the middle of the Tibetan-Yunnan-Nepal "bad" structural system. Under the strong regional compressive stress, a series of large faults and tight folds extending for hundreds to thousands of kilometers are produced, forming a large-scale fold belt. The tectonic lines in the area are distributed in the northwest direction, and the distribution direction is consistent with the river. From northeast to southwest, the development of folds decreases and the development of faults increases.

The main fault of debris flow is Ciwu fault, which strikes about 20 northeast and is about 10km long. The strata in the west panel are Zapu Formation of Upper Carboniferous in Paleozoic, and the strata in the east panel are Dingpo Formation of Upper Carboniferous in Paleozoic. The cross section tends to the northwest, and there are often co-strike secondary sections and I-shaped branch compression-torsion fractures nearby. The above structure makes the stratum very broken, which provides sufficient material source for the occurrence of debris flow and also provides conditions for the existence of collapse and landslide.

3.4 Neotectonic Movement and Earthquake

The nature of neotectonic movement in the county area is mainly oscillatory movement, and the rise is dominant. The performance is as follows: ① The neotectonic movement in the project area is mainly characterized by intermittent vertical lifting movement, and the rising is accompanied by multiple falls, forming planation plane and multi-level valley terraces, with layered topography, ice bucket and valley terraces distributed in a ladder shape. For example, the terraces in Dingqu Valley are up to 4-5 levels. ② The lifting movement reflects the asymmetry of valley shape. The imbalance of neotectonic movement, the rising range on the east coast is smaller than that on the west coast. It is shown that the terraces on the east bank of major rivers in the region are well developed and preserved, while the terraces on the west bank are destroyed and the bedrock is exposed, forming steep walls.

Earthquake is one of the important factors that cause deformation and damage in the area. The area is located in the concentrated area of multiple groups of structural features (faults), and the ground stress is quite concentrated. The Qudinghe earthquake area has frequent seismic activities, which often occur and have a high earthquake magnitude. The basic earthquake intensity is VII degree.

3.5 Hydrogeological Conditions

(1) Pore phreatic water in loose accumulation layer

Pore water of loose rocks is mainly distributed sporadically along the Quding River and its tributaries or along the valley slopes, that is, it is mainly distributed in the floodplain and the first terrace, and occurs in the alluvial and diluvial deposits of the Quaternary river bed and ice water deposits. Pore water in unconsolidated layer is closely related to river water, which is generally rich in water and has great difference in water-bearing capacity, and is only distributed along the valley bottom of the river. The local slope gravel soil contains a small amount of pore water, and the water content is small. It is replenished by atmospheric precipitation, and the deep bedrock fissure water is discharged or replenished in the form of falling springs. The water inflow of single well is generally less than $100m^3$ /d, the water consumption of can reach $100\text{-}500m^3$ /d only in partial floodplain and a single well of first terrace.

All kinds of loose deposits on the valley slope often do not have water storage conditions, but their permeability has a great influence on the occurrence of geological disasters such as landslides, collapses and mudslides along the river (valley). Their formation is usually multi-stage, which leads to the difference of permeability of accumulation layer in profile and plane, and the weak permeable zone becomes the sliding zone or sliding surface of landslide, and also provides loose material source for debris flow.

Generally speaking, the pore water distribution area of loose rocks is small, and its water abundance is also poor.

(2) Carbonate fractured karst cave water

It is widely distributed in the county, mainly composed of Lower Triassic (T1), Permian (P), Carboniferous (C), Devonian (D), Silurian (S) and Ordovician (O). The lithology is mostly limestone, dolomite, dolomitic limestone, marl, etc., and the flow of big springs is 10-100 L/s.

(3) Conditions of recharge, runoff and discharge

The main source of groundwater recharge in the area is atmospheric precipitation, followed by melting water of snow and ice in alpine mountainous areas, and the supply of agricultural irrigation is very limited. The runoff path is short, and it turns into surface water after discharge. Groundwater movement is closely related to meteorology and hydrology in the region, and is also controlled by geological structure, stratum, lithology, topography and vegetation development. As far as geomorphology is concerned, because of the steep terrain and strong cutting in the area, precipitation becomes surface runoff and is quickly discharged, which is not conducive to infiltration and recharge of groundwater. For different water-bearing rock groups or different sections of the same water-bearing rock group, the amount of precipitation absorbed is related to the size of water collection range, which mainly depends on the landform and shape of the recharge area. The recharge area is located at the bottom of the valley far more favorable than the valley slope; the gentle slope is more favorable than the steep slope, and the watershed area is better than the slope area. When the precipitation seeps into the groundwater, it generally flows and migrates in shallow or valley slope areas, with short paths and shallow circulation depth. The valleys cut in the aquifer are discharged in the form of falling springs, and in the dry valley areas, they are discharged by evaporation. However, the groundwater runoff path in the fault zone is long and the circulation depth is large. To sum up, the characteristics of groundwater movement in the area are mainly precipitation infiltration and recharge, and the groundwater runoff path is short, and it is discharged by spring water and seepage and converted into surface water. In the Quding River and its tributaries, most of the groundwater is discharged in the form of spring points; In karst area, groundwater is mainly discharged in the form of concentrated confluence, and it is distributed in a beaded shape along water-filled faults, active faults and regional structural faults. However, the pore water of loose rocks is discharged into river valleys or gullies in the form of surface seepage. The hydraulic gradient is large, the alternating activity of water is strong, and the dynamic change is great. The hydrochemical type of groundwater is mainly bicarbonate.

4. Human Engineering Activities

The population in the area is mainly agriculture, and the land use types are mainly woodland, grassland and cultivated land. Agricultural economy is an important part of the national economy, and farming and animal husbandry activities are mainly farming and animal husbandry, and cultivated land and grassland are distributed in pieces. Due to the growing population, the per capita possession of cultivated land and grassland has decreased correspondingly, resulting in more and more prominent contradictions between people and land. The spread of bad economic activities such as blindly expanding cultivated land, deforestation, steep slope reclamation and overgrazing has a great impact on the geological environment, which is also one of the important reasons for the frequent occurrence of geological disasters in this area.

5. Comprehensive Prevention and Control Plan

5.1 Existing projects

In 2016, some villagers constructed private protective dikes to protect their courtyard walls. The protective dikes are 1.7m high, 0.5m deep, 0.5m wide at the top and 0.5m wide at the bottom, with a total length of approximately 126.5m. However, these private protective dikes can only protect the villagers' own courtyard walls and fail to effectively and promptly remove the silt deposited by debris flows. Moreover, only some residents have built such protective dikes, while others have not, resulting in incomplete protection coverage.

5.2 Comprehensive Treatment Project

At the request of local residents, to mitigate the impacts of debris flows and floods, protect the safety of residents' lives and property, beautify the regional environment and promote the tourism development of Ciwu Township, a comprehensive treatment scheme is formulated based on the potential hazards of the debris flow and the improvement of existing projects:

(1) Build protective dikes on both sides of the village road: The dikes will be designed with reasonable height and width according to the maximum debris flow discharge, to form a comprehensive protection system covering all residents along the road, effectively blocking the invasion of debris flow and safeguarding residents' lives and property.

(2) Clean up and reinforce the township road: First, thoroughly clean up the gravel and silt deposited on the township road to restore the original traffic function. Then, reinforce the channel bottom along the road with anti-scour materials to enhance the anti-erosion capacity of the channel, ensure the smooth discharge of debris flow, and guarantee the safety of residents' travel.

References

[1] Liu S, Lei Q, Jiang B, et al. Evaluation of Treatment Effect of Highway Subgrade Reconstruction Damaged by Large Landslide [C]//International Conference on Civil Engineering. Springer, Singapore, 2024.

[2] Qiming Z, Lingchun C, Shengyao M, et al. Numerical investigation of hydromorphodynamic characteristics of a cascading failure of landslide dams [J]. Journal of Mountain Science, 2024(6).

[3] Wei X, Gardoni P, Zhang L, et al. Improving pixel-based regional landslide susceptibility mapping [J]. Geoscience Frontiers, 2024, 15(4): 102345.

[4] Chen W, Li Y, Wang J, et al. Stability Analysis of Debris Flow Protective Dikes in Mountainous Areas of Southwest China [J]. Journal of Disaster Prevention and Mitigation Engineering, 2023, 43(2): 312-320.

[5] Zhang H, Zhao X, Liu C. Geological Hazard Susceptibility Assessment of Debris Flow Prone Areas in Sichuan Province [J]. Natural Hazards, 2022, 110(3): 1895-1918.

[6] Wang L, Zhang Y, Chen Z. Design and Construction of Debris Flow Channel Improvement Projects in Hengduan Mountains [C]//Proceedings of the

International Symposium on Geological Engineering and Disaster Management. CRC Press, 2021: 456-465.

[7] Li D, Guo Q, He M. Influence of Human Activities on Debris Flow Occurrence in Agricultural Mountainous Areas [J]. Catena, 2020, 195: 104892.

[8] Standardization Administration of the People's Republic of China. GB 50287-2012 Code for Geological Investigation of Water Conservancy and Hydropower Engineering [S]. Beijing: China Planning Press, 2012.

[9] Xu J, Yang S, Zhang W. Study on Debris Flow Prevention and Control Technology in Southwest Sichuan Mountainous Areas [J]. Journal of Mountain Science, 2021, 19(8): 2105-2116.

[10] Tang C, Li J, Liu Y. Hydrogeological Conditions and Their Impact on Debris Flow in Karst Mountainous Areas [J]. Hydrogeology and Engineering Geology, 2020, 47(5): 38-45.