Analysis of the Factors Affecting the Stability of a Landslide

Zeng Yuping
Sichuan College of Architectural Technology, Deyang, Sichuan, China

Abstract: The geological conditions of a landslide in Sichuan province are analyzed in detail, and it is pointed out that the influencing factors of landslide stability are topography, rainfall, surface water, groundwater and human engineering activities, which provides a basis for further control design of landslide.

Keywords: Landslide; Geological Condition; Stability Influencing Factors

1. Project Overview

Landslide is located in Liangshan Prefecture, Sichuan Province. According to site interview and data records, slope deformation started in flood season of 2017, mainly manifested as partial slip at the leading edge and falling terrace at the trailing edge. During rainy season in recent years, the slope front has collapsed continuously, and tensile cracks and steep falls have appeared at the top of the slope. Landslide directly threatens residential areas and rural roads at the foot of the slope, and threatens 96 residents from 20 households below the slope. The potential economic loss is estimated at $6.5 million and will have serious social impact. In order to ensure the safety of people's life and property, it is necessary to carry out geological disaster prevention and control work for this landslide disaster.

2. Landform

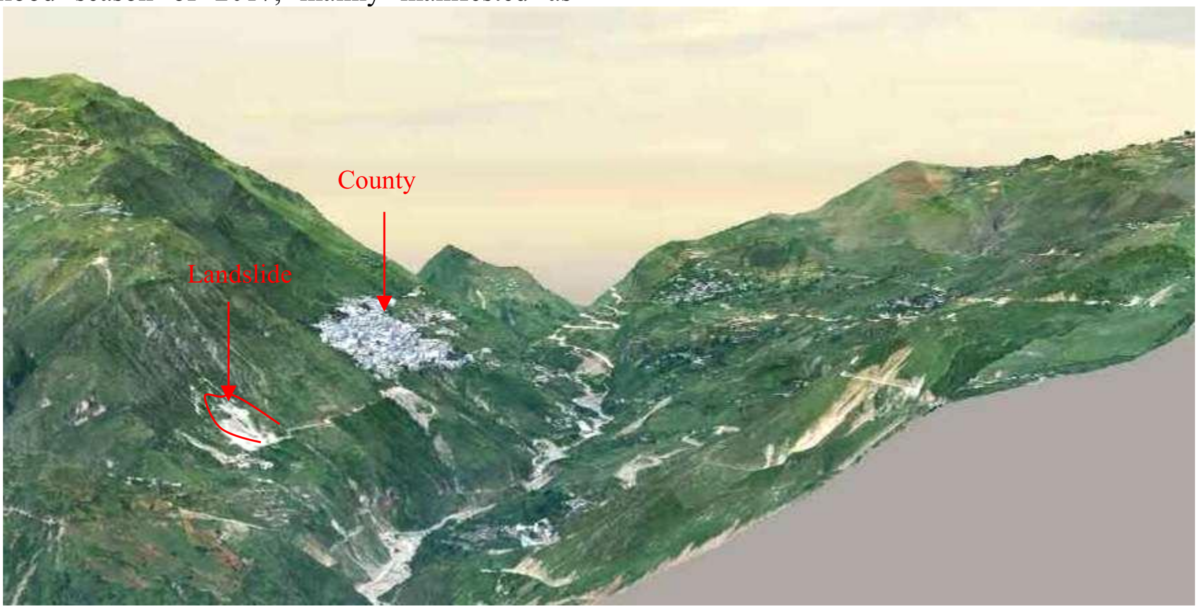

Figure 1. Landslide Three-Dimensional Image Topographic Overview

The exploration area is located in the southwest of Sichuan Province, on the eastern edge of Liangshan Yi Autonomous Prefecture, and on the north bank of the Jinsha River. The mountainous rivers have strong erosion and cutting. The area has high mountains and deep valleys, rapid water, steep terrain, overlapping mountains, and thick mountains. The mountains are controlled by regional geological structures and mostly extend in a north-south or northeast direction. The overall terrain is high in the west and low in the east. Shizi Mountain, the highest point of the county, is 4076 meters above sea level, and Hulupingzi, the lowest point, is 460 meters above sea level. The relative height difference is more than 3600 meters. According to the geomorphological origin, it can be divided into tectonic erosion high mountain canyon topography, tectonic erosion middle high mountain canyon topography, tectonic erosion low mountain platform topography, tectonic erosion low mountain platform topography,

 Copyright @ STEMM Institute Press

narrow erosion accumulation topography distributed in local sections along river valley. The geomorphological type of landslide area belongs to tectonic erosion high mountain canyon topography. See Figure 1.

3. Formation Lithology

According to the regional geological data and field survey, the main strata in the landslide area are mainly Quaternary artificial accumulation (Q_4^{ml}), Quaternary new colluvial deposit (Q_4^{col+dl}) and Upper Ordovician Baota Formation (O_2^b) from the exposed strata in the area to the old, and are described as follows.

(1) Quaternary

① Quaternary artificial accumulation (Q_4^{ml}): miscellaneous fill soil and cultivated soil, widely distributed in the shallow layer of disaster body, variegated, slightly wet, loose ~ slightly dense, mainly composed of gravel, silty clay, etc. The parent rock of gravel is limestone, sandstone, etc., the particle size is generally 0.5~ 10cm, the maximum can reach 12cm, angular ~ sub-angular, the content is about 40~60%, and the rest is gray brown silty clay.

② Quaternary Holocene colluvial deposit (Q_4^{col+dl}): broken stone soil, grayish brown, slightly wet, slightly dense ~ medium dense, mainly composed of gravel and silty clay, etc. The parent rock of gravel is limestone, dolomite, etc., the particle size is generally 0.5~20cm, the maximum particle size can reach 30cm, subangular, short ~ short long columnar, the content accounts for about 55~65%, and the cementation is good.

(2) Upper Ordovician Baota Formation (O_2^b)

Limestone: gray, strongly to moderately weathered, cryptocrystalline texture, medium thick layered structure; influenced by faults, rock mass fractures are relatively developed, and calcite veins filled locally. Partial dissolution is developed, dissolution pores are honeycomb-like, and the filling materials are mainly gravel and clay. The core is mostly short to short long columnar, partially flat columnar and fragmented. Bedrock is exposed on the slope cut of the highway at the upper part of the slope, and the occurrence of bedrock is 290° 37°.

4. Geological Structures

Structurally, the county seat belongs to Liangshan Xiaojiang fault zone in Liangshan fold area of Yangzi quasi-platform, which is the junction of "Sichuan-Yunnan north-south structural belt" and "Cathaysian structure". It is located near the suture line where Eurasian plate collides with Indian subcontinent plate, and is the middle part of Sichuan-Yunnan-Guizhou plate. The main structural system is Jinsha River fault bundle, belonging to the secondary collision belt parallel to Lvzhijiang deep fault of main suture line-Xiaojiang fault.

Since Sinian System to late period, subsidence, uplift, folding and fault movement have been experienced repeatedly, and various types of structural deformation have occurred in different ages, resulting in various structures with different properties, scales and shapes. The area belongs to the eastern edge of the northern section of Sichuan-Yunnan meridian structural belt, and the eastern section is connected with Cathaysian structure. The NE and NS structures are the most obvious and are the main structures in the area. The two are intertwined in an obvious complex relationship. NW-trending structures are dominated by small-scale faults, besides, there are also small-scale twist structures. The main structural framework in the area is the product of Yanshan movement.

The landslide is mainly affected by Jinyang main fault (F1) and Jinyang secondary fault (F2). The landslide is about 1km away from the fault line.

5. Hydrogeological Conditions

Controlled by stratum lithology, topography and structure, groundwater in this area can be divided into loose accumulation layer pore water and bedrock fissure water according to its hydraulic property, hydraulic characteristics and occurrence conditions.

(1) pore water of loose accumulation layer

It mainly occurs in Quaternary residual slope layer, colluvial slope layer and other loose soil layers, mainly phreatic water, with large variation of water level buried depth, thin aquifer, small distribution area, obvious seasonal influence, strong permeability, close hydraulic connection with surface water, and complementary relationship in different sections. This type of groundwater mainly receives surface water and atmospheric precipitation recharge, surface water such as rivers in dry season directly controls groundwater recharge, and has dynamic characteristics such as short groundwater runoff time, even nearby recharge and discharge, and large variation range of water level affected by seasons and surface water.

(2) Bedrock fissure water

It mainly occurs in shale, limestone and sandstone. Due to the difference of groundwater occurrence conditions and rock mass fracture development degree, the rich water content in each stratum is very uneven. This type of groundwater is mainly supplied by atmospheric precipitation. Because of uneven distribution of bedrock fractures and no unified hydraulic connection, it shows anisotropic seepage characteristics after receiving atmospheric precipitation and surface water recharge, and its migration is limited. Most of them are discharged to river valleys and valleys in the form of falling springs. The existence of this type of groundwater can reduce the shear strength of rock mass, accelerate rock weathering and reduce the stability of rock mass.

Surface water and groundwater in the area are mostly light calcium carbonate and calcium carbonate magnesium type water. Most areas in the exploration area are located above the local erosion datum, the terrain is favorable for natural drainage, the aquifer has relatively high water content, and the hydrogeological conditions are relatively complex.

6. Human Engineering Activities

The exploration area is mainly located above the residential area. Due to the intensification of human engineering activities in the area, the change of geological environment by human beings is correspondingly increased. Some unreasonable engineering activities, such as road construction, large-scale quarrying and slope excavation above the landslide area, reclamation and other human activities, are easy to cause soil erosion, and then cause slope deformation and develop into landslide.

7. Analysis of Influencing Factors on Landslide Stability

The main influencing factors of the landslide stability are topography, rainfall, surface water and groundwater, human engineering activities, etc., which are described as follows.

(1) Influence of topography on disaster body

The slope surface is steep and structurally eroded alpine canyon landform. The main material composition is Quaternary colluvial deposit. The front edge of slope body is affected by artificial excavation, which forms certain free space conditions, which is not conducive to the stability of slope body.

(2) Impact of rainfall on disaster bodies

The main material of slope body is broken stone soil, and the debris accumulation body of highway forms the debris flow source of slope surface. The slope material is loose, rain water is easy to form slope debris flow under the action of gravity; in addition, rain water infiltrates into the landslide body, increases the weight of the slope body, softens the potential sliding surface, reduces the shear strength parameters of the sliding zone soil, and affects the stability of the slope body. Therefore, heavy rainfall is also the main factor of landslide sliding.

(3) Influence of surface water and groundwater on slope

Groundwater in the area is mainly supplied by atmospheric precipitation, and rainfall infiltration is transformed into groundwater runoff along slope. Landslide slope is gentle locally, slope structure is loose, which is not conducive to groundwater drainage. Therefore, groundwater has great influence on slope stability. During rainstorm or continuous rainfall, rainwater is transformed into groundwater infiltration to potential sliding surface, and uniform groundwater level is formed on slope, which will have great influence on slope stability.

(4) Impact of human engineering activities on landslides

There are 20 households and 96 people living in the area. The residents are engaged in farming on the slope and highway construction above the slope, which has certain loading effect on the slope. Meanwhile, human engineering activities cause the slope soil to loosen and deform and change the original slope shape, which affects the stability of the landslide.

8. Conclusions

Through a systematic analysis of the geological conditions (including landform, stratum lithology, geological structures, and hydrogeological conditions) of the landslide in Liangshan Prefecture, Sichuan Province, it is confirmed that the stability of the landslide is jointly affected by topography, rainfall, surface water, groundwater, and human engineering activities. Among them, the steep terrain and loose slope materials provide the inherent geological basis for landslide formation; rainfall and groundwater are key triggering factors by changing the weight and shear strength of the slope mass; human engineering activities further aggravate slope deformation by disturbing the

 Copyright @ STEMM Institute Press

geological environment. This study clarifies the main factors affecting the stability of the target landslide, providing important technical support for the subsequent formulation of scientific and reasonable landslide control measures and disaster prevention plans.

References

[1] 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): 1245-1263.
[2] Wei X, Gardoni P, Zhang L, et al. Improving pixel-based regional landslide susceptibility mapping [J]. Geoscience Frontiers, 2024, 15(4): 897-912.
[3] Mir R A, Habib Z, Kumar A, et al. Landslide susceptibility mapping and risk assessment using total estimated susceptibility values along NH44 in Jammu and Kashmir, Western Himalaya [J]. Natural Hazards, 2024, 120(5): 3891-3915.
[4] Chen W, Li S, Wang Y, et al. Effects of geological structure and rainfall on landslide stability in mountainous areas of Southwest China [J]. Engineering Geology, 2022, 298: 106458.
[5] Liu J, Zhang H, Zhao L, et al. Assessment of landslide stability influenced by groundwater seepage and human activities [J]. Bulletin of Engineering Geology and the Environment, 2023, 82(7): 289-305.
[6] Wang C, Xu Q, Li D, et al. Topographic control on landslide distribution and stability in high mountain canyon regions [J]. Journal of Asian Earth Sciences, 2021, 215: 104789.
[7] Zhang Y, Liu G, Chen J, et al. Landslide stability analysis considering the coupling effect of rainfall and geological faults [J]. Landslides, 2022, 19(8): 1879-1894.