Treatment of a Landslide in Sichuan

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Abstract: The article provides a detailed description of the shape and deformation characteristics of a certain slope, analyzes the harmfulness of the slope, proposes a support design scheme, and explains the construction techniques of each sub item.

Keywords: Transgender Features; Harmfulness; Support Design

1. Terrain and Landforms

The topography of the landslide area is characterized by the fact that the topography in the area is generally high in the north and low in the south, and the cutting depth of the rivers in the territory is large, so the river valleys are mostly narrow and show a "V" shaped valley. the highest peak, Guangwu Mountain, is 2508m above sea level, and the Mumen River Valley at the southern end is 370m, with a relative elevation difference of 2138m.

The landslide belongs to the low mountain landform, presenting a multi-level plateau, with an average slope of 15~20°, a gentle trailing edge, a slope of about 6~8°, a steep middle part, and a rural road at the leading edge. At the same time, gullies are developed on both sides of the landslide, among which the right gully is obviously developed, with a width of about 3m and a depth of about 2~3m, and stones are piled up in the ditch. the left side is a gully, about 3~4m wide, and stones are piled up in the ditch.

2. Stratum Lithology

According to the investigation, the main exposed strata in the exploration area are the Penglaizhen Formation of the Jurassic System (J_3p) and the residual slope soil layer of the Quaternary System (Q_4^{el+dl}).

The lithological characteristics of the strata in the area are described from old to new as follows:

The Penglaizhen Formation (J_3p) of the Upper Jurassic System is exposed in the area, consisting of gray and gray purple blocky fine-grained lithic feldspar sandstone, interbedded with purple red mudstone, interbedded with gray purple siltstone. the rock strata have a southwest orientation with an orientation of 195 ∠ 15 °, and the surface rocks are weathered and fragmented.

The Quaternary slope residual soil layer (Q_4^{el+dl}) is mainly covered by slope residual soil in the exploration area, which is formed by rock weathering and mainly composed of clay, silt, fragmented stones, etc.

3. Geological Structure and Earthquakes

This area belongs to the southern part of the complex east-west tectonic belt of the Qinling Mountains in terms of geological structure, with a relatively complex stress field. It is generally believed that there are three tectonic systems in the area: the ancient Huaxia system, the east-west tectonic system, and the new Huaxia system. the interrelationships between the three tectonic systems are: inclusion, interception, oblique connection, reverse connection, and convergence.

The new tectonic activity in the region is weak, and no active faults have been found in the site area. There are also no records of moderate to strong earthquakes, and its seismic hazard mainly comes from the influence of strong earthquakes in the peripheral tectonic seismic zones.

The seismic activity in this area is weak, and there have been no earthquakes of magnitude 5 or above in history. the main activity is small earthquakes below magnitude 4, with occasional earthquakes of magnitude 4-5. On May 12, 2008, a 8.0 magnitude earthquake struck Wenchuan, with strong tremors felt in Bazhong City, which is an area affected by the earthquake. According to the partially revised provisions of the "Code for Seismic Design of Buildings" (GB50011-2001) approved by the Ministry of Housing and Urban Rural Development on August 1, 2008, as well as the zoning maps of peak ground acceleration in some areas of Sichuan, Gansu, and Shaanxi

(GB18306-2001 Figure 2-5) and the characteristic period zoning map of seismic response spectrum (GB18306-2001 Figure 2-6). the seismic fortification intensity of the buildings in the exploration area is 6 degrees, the designed basic seismic acceleration value is 0.05g, the characteristic period value of the seismic response spectrum is 0.40s, and the designed earthquake group is the second group. For densely populated construction such as schools, the seismic fortification intensity of the building should be set at 7 degrees.

4. Hydrogeology

(1) Surface water

The main river in town is Mumen River, which originates from Jiuzhi Mountain in the northeast of the county. After passing through the two and three rivers, it flows into Baihe River in Zhengzheng Town and enters Nanjiang County through Zhangjia River. the main stream in the county is 46km long, with a drainage area of 791km2, accounting for 26.3% of the total area, and an average annual flow of 17.47m3/s. There are no rivers passing through the landslide area, and the surface water is mainly accumulated in paddy fields and ponds, mainly supplied by atmospheric precipitation. There are many spring points in the landslide area, mainly concentrated below the steep slope at the front edge of the landslide, and less distributed on the slope and rear edge of the landslide. the exploration period is the dry season, and there is still water accumulation at the spring point. the flow rate of the spring point is visually less than 0.01L/s.

(2) Groundwater

The groundwater types in the landslide area are Quaternary loose layer pore water and bedrock fissure water.

1. Quaternary loose layer pore water

It mainly occurs in the pores of the Quaternary alluvial layer. Due to the uneven structure of the covering layer, the sorting is poor, the permeability is strong, and the underground water storage conditions are poor. When it is replenished by atmospheric rainfall, it quickly infiltrates into it, and the runoff path is short. It infiltrates in a surface or strip manner and finally converges to the lower part.

2. Bedrock fissure water

It mainly occurs in weathered and unloaded fractured media, and the main source of replenishment in the area is atmospheric rainfall. When atmospheric precipitation and fog seep into the surface soil layer, due to the development of vegetation, they will slowly move down the valley slope or penetrate through the surface soil layer into the bedrock cracks, and be discharged in the low-lying areas of the valley. the shallow network weathering fissures are well-developed and have good permeability. the fissure water is replenished by atmospheric precipitation and shallow pore water. After on-site investigation and drilling, it was revealed that the underlying bedrock of the landslide is mudstone from the Penglaizhen Formation of the Jurassic System, which is an aquitard. the spring points in the exploration area are mainly pore water from the Quaternary loose layer, and the fissure water in the bedrock is not developed.

5. Characteristics of Landslide Disaster Body

5.1 Landslide Morphological Characteristics

The landslide belongs to a tectonic erosion landform. the landslide area is located within a groove terrain. the ridge is located outside the gullies on both sides, and the steep ridge on the right bank of Mumen River is about 400m outside the wide and gentle platform at the rear edge. the terrain is extremely conducive to the collection of rainwater. the landslide area has been artificially transformed into terraced fields and ponds, with a generally gentle terrain and steep slopes. the middle and southwest sides of the slope are higher, while the northwest side is lower. the surface of the slope has been artificially transformed into a multi-level platform shape. Distribution of residential buildings on and below the front edge of the landslide.

The overall shape of the landslide is similar to that of a circular chair, with a narrow upper part and a wide lower part. Below the steep slope approximately 50m above the tensile crack L4 from the trailing edge; the steep slope from the front edge to about 60m below the rural road has a height of about 3m (Figure 1). the left boundary is determined by a combination of gullies and terrain; the right boundary is determined based on the surface gullies and terrain. According to the deformation characteristics of landslides, they can be divided into two sub zones: collapse deformation zone and strong deformation zone. the collapse deformation zone is located in the front left side of the landslide, with tension cracks and staggered ridges as the boundary at the rear edge, shear cracks as the boundary on both sides, and steep ridges below the highway at the front edge. the strong deformation zone is located on the front right side of the landslide, with tension cracks as the boundary at the rear edge. the left and right sides are determined according to the terrain, and the front edge is bounded by a retaining wall. the collapse is severe, and the spring points are distributed in a linear pattern. the landslide is about 300m long, with an upper width of about 190m and a lower to front edge width of about 290m, covering an area of about 7.99 × 104m2. the top elevation of the rear edge is 619-623m, the foot elevation of the front edge slope is 555m, and the height difference is 68m. the thickness of the sliding body is about 8.3-17.3m, the average thickness of the sliding body is about 10.8-12.7m, and the volume is about 94.3 × 104m3. There is no exposed bedrock in the landslide area, but the bedrock in the downstream of the right gully outside the area is exposed. the rock type is silty mudstone with an attitude of 195 °∠ 15 °. the main sliding direction of the landslide is 247 °. According to the "Code for Investigation of Landslide Prevention and Control Engineering" (DZ/T0218-2006), it belongs to a medium-sized soil landslide.

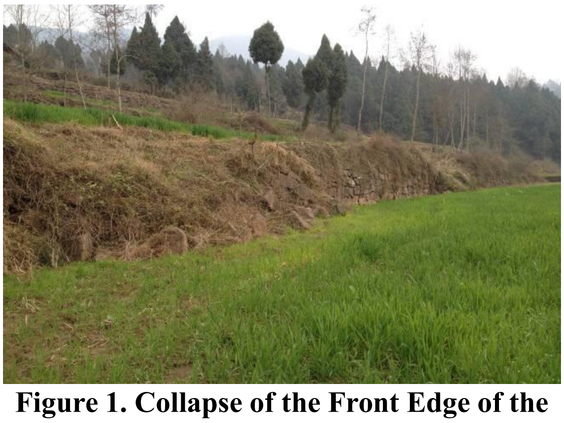

Figure 1. Collapse of the Front Edge of the Landslide and Tilting of Trees

5.2 Characteristics of Landslide Deformation

According to survey data and resident interviews, the landslide was in a stable state before the May 12, 2008 earthquake. During the 5.12 earthquake, the landslide experienced strong deformation, especially in the strong deformation zone on the lower left side of the landslide. A tensile crack L4 developed at the rear edge of the landslide, which penetrated through residential buildings and caused damage to them; the tensile crack L7 passes through the residential house and the pond, causing serious damage to the residential house and water leakage from the pond. At the same time, the earthquake caused local collapses along the roadside, with clear boundaries, mainly manifested as scattered ridges at the rear edge, extrusion at the front edge, and tensile and shear deformation composed of L1, L2, and L3. Subsequently, during the rainy season in previous years, the landslide experienced varying degrees of creep deformation, manifested as the collapse of the front edge of the landslide and the intensification of the deformation of the L7 tensile crack in the middle. Due to the strong deformation of the landslide nearly four years ago, some surface traces have been leveled or stopped from deforming. the deformation signs of the landslide are described as follows:

Tensile crack L4: It is a tensile crack below the rear edge of the landslide, with a direction of 160 ° and a linear distribution. the crack was formed during the May 12th earthquake in 2008. the crack penetrated through the residential house, causing damage to the house. At present, the surface traces are clear, with cracks about 60m long and 2-3cm wide, and a trench depth of 1.2m exposed.

Tensile crack L5: It is a tensile crack located below the left rear edge of the landslide, with a strike of 90 ° and a linear distribution. the crack was generated during the 7.6 rainstorm in 2011. the crack passed through the front yard dam of the residential house, causing the surface of the dam to sink and collapse. At present, the surface traces are clear, with cracks about 40m long and 2-3cm wide.

Tensile crack L7: It is a tensile crack located in the middle of the left side of the landslide, with a strike of 168 ° and a nearly arc-shaped distribution. the crack was generated during the 5.12 earthquake in 2008, and the deformation was further intensified during the 7.6 rainstorm in 2011. the crack passes through residential houses and roadside ponds, causing serious structural damage to the houses, subsidence and collapse of the courtyard surface, and water leakage from roadside ponds. At present, the surface traces are clear, with cracks about 45m long and 5-8cm wide. According to residents and local monitoring institutes, the crack is still active during the rainy season.

Front edge of landslide: the steep slope at the front edge of the landslide is about 2-3m high, with obvious swelling visible, and some areas have collapsed. the spring point at the bottom of the fortress is exposed in a linear pattern.

The strong deformation zone is about 130m wide and 125m long along the slope. the front part of the slope is messy, with trees skewed and signs of deformation mainly concentrated in this area. In addition, bulging phenomenon can be seen on the dry block stone retaining wall next to the drainage ditch on the inner side of the highway. After analysis, it was found that under the condition of saturated slope, the excavation of the slope formed a free face, and local residents built houses on the retaining wall, resulting in local small-scale deformation of the slope.

The local government built a highway in the middle and lower parts of the slope, excavated the slope, and filled the outside of the highway, forming a free face on the outside of the highway, changing the stress distribution of the slope, and a small-scale collapse occurred during the rainstorm on June 6, 2011. the collapse area was about 20m long, 100m wide, 210 ° in the direction of instability, and about 30cm in the height of the rear edge of the stagger. Because it was mainly caused by the rainstorm after the slope excavation, the retaining wall on the inside of the highway was accompanied by bulging phenomenon. Its deformation and boundary characteristics are as follows:

Shear crack L1: It is a shear crack on the right side of the collapsed body, with a strike of 225 ° and a nearly arc-shaped distribution. the crack was generated during the 7.6 rainstorm in 2011. the crack passes through the highway, with clear surface traces. the crack is about 20m long and 2cm wide.

Tension crack L2: it is a group of tension cracks in the middle and rear of the collapse area, with a strike of 120 ° and linear distribution. the crack spacing is 2~3m, and the time of occurrence is 7.6 rainstorm in 2011. the group of cracks cracked the drainage ditch on the inner side of the highway and caused the outer side of the highway to sink and collapse. At present, the surface traces are clear, with cracks about 100m long and 2-3cm wide.

Shear crack L3: It is a shear crack on the left side of the collapsed body, with a direction of 170 ° and a linear distribution. the crack was generated during the 7.6 rainstorm in 2011. the crack passes through the highway, with clear surface traces. the crack is about 20m long and 3cm wide.

6. Design of Landslide Prevention and Control Engineering Scheme

According to the basic situation and cause mechanism of the landslide, the main treatment plan is "anti slip pile support+surface drainage+collapse deformation zone treatment".

The main measure taken in the plan is to arrange a row of anti slip piles along the 6-6 'section between boreholes ZK06 and ZK09 in the front of the strong deformation zone to provide local support for the landslide threat to local residents. At the same time, support and block the local collapse bodies in the landslide area and the high steep slope deformation zone on the inner side of the road behind the strong deformation zone. Repair the original drainage ditch on the inner side of the highway to improve the water content conditions of the slope, and set up a drainage ditch to isolate rainwater in the rear edge area of the landslide. the design ideas and layout of each project are as follows:

(1) Anti slip pile support engineering

Due to the fact that the threat objects in the strong deformation zone are mainly concentrated on the right side of the strong deformation zone, local support is provided to the main threat areas in the strong deformation zone to ensure the safety of local residents' lives and property.

(2) Surface drainage

At present, no surface drainage engineering has been constructed in the landslide area. Surface water and atmospheric precipitation can directly collect and infiltrate the slope, promoting the stability of the landslide to develop in an unfavorable direction. Therefore, a drainage ditch was set up at the rear edge of the landslide area, and the damaged original drainage ditch on the inside of the road was repaired.

(3) Governance of collapse deformation zone

Gravity retaining walls are used to support the collapsed bodies on the inner side of the highway and the high steep slope deformation zone at the rear of the strong deformation zone.

References

[1] Fan Z, Wang S, Hu N Y. Emergency treatment effect evaluation of rear?slope cutting and front?slope pressing on a hydrodynamic pressure landslide: a case study of the Shuping landslide in the Three Gorges Reservoir Area [J]. Bulletin of engineering geology and the environment, 2024, 83(1):38.1-38.20. DOI:10.1007/s10064-023-03539-z.

[2] Li J, Hu B, Sheng J, et al. Failure mechanism and treatment of mine landslide with gently-inclined weak interlayer: a case study of Laoyingzui landslide in Emei, Sichuan, China [J]. Geomechanics & Geophysics for Geo-Energy & Geo-Resources, 2024, 10(1). DOI:10.1007/s40948-024-00775-9.

[3] 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. DOI:10.1007/978-981-97-4355-1_18.

[4] Qiming Z, Lingchun C, Shengyao M, et al. Numerical investigation of hydro-morphodynamic characteristics of a cascading failure of landslide dams [J]. Journal of Mountain Science, 2024(6). DOI:10.1007/s11629-023-8411-0.

[5] Wei X, Gardoni P, Zhang L, et al. Improving pixel-based regional landslide susceptibility mapping [J]. Geoscience Frontiers, 2024, 15(4). DOI:10.1016/j. gsf. 2024.101782.

[6] 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). DOI:10.1007/s11069-023-06363-6.

[7] An K, Zhang J. Research on Coupling Model of Foundation Treatment and Geological Hazard Risk Assessment [J]. Applied Mathematics and Nonlinear Sciences, 2024, 9(1). DOI:10.2478/amns-2024-1528.

[8] Zhang X. A Case Study for Analysis of Stability and Treatment Measures of a Landslide Under Rainfall with the Changes in Pore Water Pressure [J]. Water, 2024, 16. DOI:10.3390/w16213113.

[9] Piercy H, Nutting C. The experiences of parents of children diagnosed with cerebral adrenoleukodystrophy [J]. Child: Care, Health & Development, 2024, 50(1). DOI:10.1111/cch. 13184.

