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Analysis of Deformation Characteristics and Engineering Treatment of a Landslide

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Abstract: The article provides a detailed description of the characteristics of landslides, analyzes landslide stability, calculates stability safety factors under different working conditions, and finally proposes control measures.

Keywords: Landslide Deformation Characteristics; Stability Analysis; Governance Measures

1. Regional Geological and Environmental Conditions

1.1 Topography and Geomorphology

The exploration area is located in the Minshan Mountains of the Qionglai Mountains, in the northern part of Maoxian County. the elevation of the area is between 890 and 4969.8m, with a relative height difference of 1000 to 2500m. the mountains on both sides of the Minjiang River valley are majestic, with steep slopes and steep walls, and the valley is mostly in a "V" shape. the lower part of the northern valley slope is relatively steep, with a narrow terrain that gradually widens and flattens downwards. It is a transitional zone from high mountains and narrow valleys to mountainous plains.

The landslide area is a sloping terrain with a gradient of 20-30 °. the landslide is located in the upper part of the right bank slope of the Minjiang River, and the Minjiang River flows through the front side of National Highway 213 at the lower part of the landslide. the overall sliding direction in the landslide area is upward, with a gentle middle and steep lower part. the absolute elevation of the shear outlet at the front edge of the landslide is about 1900m, with a slope of about 30 °; the middle and rear parts of the landslide are stepped platforms with an overall gentle slope of about 15-20 °; the absolute elevation of the rear edge is about 2250m, and the relative total height difference between the front and rear edges of the landslide is about 350m. On the slope, there are houses and farmland for villagers. the vegetation coverage on the slope is generally average, with small amounts of fruit trees such as small Sichuan pepper trees.

1.2 Stratum Lithology

The main strata in Maoxian County are the Longmenshan and Markang zoning strata. the geological distribution of the Markang sub district is in the vast majority of the county, accounting for over 90% of the working area. There are mainly Triassic, Permian, Carboniferous, Devonian, Silurian, Ordovician, Cambrian and other strata. the Longmenshan area is mainly composed of Permian, Carboniferous, Sinian and pre Sinian strata. the magmatic rocks are mainly distributed in granite north of Qixingguan.

1.3 Geological Structure and Earthquakes

1.3.1 Geological Structure

The landslide area is located within the Longmen Mountain Huaxia tectonic belt and belongs to the gap fold between the Garze Songpan geosyncline fold belt and the Yangtze platform

Subtyles with complex structures. the main structural features are distributed in a northeast southwest direction (40 ° -50 °), diagonally running through the county and connected areas, with a length of about 156km and a width of 20-50 km. the Maowen Fault is the main fault passing through the urban area of Maoxian County, with a northeast direction of 30 degrees 45?, overall about 40?, Tend towards 300?~ 330?, Tilt angle of 45 degrees?~ 80?.

The exploration area is located within the arc-shaped structural belt of Shidaguan, and there is a reverse anticline and a reverse turning angle passing through the landslide area in the site.

1.3.2 Earthquake

This area is located in the strong uplift zone of

northwest Sichuan west of the Longmen Mountain fault zone. Since the Cenozoic era, it has mainly manifested as large-scale uplift and differential uplift of fault blocks. Recently, the fault activity and seismic activity have been strong, and the regional stability is generally poor. It is one of the earthquake active areas in China. In history, destructive seismic activity has been frequent in this area, with multiple earthquakes of magnitude 5 or above occurring within a range of 42km from the site, such as the 1713 Diexi earthquake of magnitude 7, the 1748 Zhangla North earthquake of magnitude 6.5, the 1933 Diexi earthquake of magnitude 7.5, and the 1960 Zhangla earthquake of magnitude 6.75; the epicenter of the 8.0 magnitude earthquake that occurred on May 12, 2008, Yingxiu Town, was approximately 93 kilometers away from this landslide in a straight line.

According to the first amendment of the national standard "Seismic Ground Motion Parameter Zoning Map of China" (GB18306-2001) and the "Code for Seismic Design of Buildings" (GB50011-2001) (2008 edition), the survey area belongs to the first group of seismic design earthquakes, with a seismic fortification intensity of 8 degrees and a peak ground acceleration value of 0.20g.

2. Hydrogeological Conditions

The groundwater in the exploration area mainly consists of pore water from Quaternary loose deposits and fissure water from bedrock.

Loose accumulation layer pore water: the Q_4 loose accumulation layer soil in the area is mainly composed of silty clay, which is widely distributed and has poor permeability. In sloping areas, due to strong terrain cutting and relatively weak permeability, groundwater is difficult to flow downward and discharge after receiving atmospheric precipitation recharge. Therefore, the loose accumulation aquifer in sloping areas has weak water yield. During this survey, a water seepage was observed on the left side of the upper part of the landslide. It is speculated that surface water from the gully on the left side of the slope infiltrated and flowed out of the slope, with a measured flow rate of approximately 0.12L/s.

Bedrock fissure water: It exists in the fissures of phyllite and sandstone, mainly supplied by atmospheric precipitation and surface pore water. Although the rock mass is relatively fragmented and the cracks are well-developed, which is conducive to the recharge and storage of groundwater, the permeability of phyllite is poor, and the water storage capacity of the rock layer is not large. No such groundwater was found to be exposed this time.

During the entire exploration period, due to its high and steep slope, atmospheric precipitation can be quickly discharged from the slope, and groundwater is generally scarce.

3. Human Engineering Activities

The main human engineering activities on the Diaolin Village landslide include the recent construction of village roads and housing buildings by villagers. A village road was built inside the slope, forming a soil slope with a height of about 3-5 meters and an approximate 90 ° angle. Under the action of gravity, this slope is prone to tensile and unloading deformation, leading to collapse. the land in Diaolin Village is scarce, and most of the residents' houses were damaged during the earthquake. In order to improve living conditions, most of the residents in the area built their own houses in their original locations. Due to the uneven terrain, during the construction of the houses, most of them had to excavate and form new steep slopes.

4. Basic Characteristics of Landslides

The landslide is located in the upper part of the slope on the right bank of the Minjiang River. the overall plane shape of the landslide is in the shape of a "circular chair", with steep and gentle slopes, as shown in **Figure 1**. the perimeter of the landslide is relatively obvious, with the original village road as the boundary at the front edge, mountain beams as the boundary at the right and rear edges, and a groove on the left side. the elevation of the landslide front edge is about 1900m, the elevation of the rear edge is about 2240m, and the elevation of the Minjiang River valley at the front edge is about 1630m. the landslide is about 800m long and 540m wide. the front part of the landslide is steep, with a slope of about 30-35 °, and the middle and rear parts have a slightly gentle slope between 10-20 °. the entire landslide area is about 0.54km2, and the main sliding direction is about NE12 °. According to the survey results, the average thickness of the landslide body is about 15m, with a volume of 6 million cubic meters.

Currently, most of the slope body is cultivated as dry land, with sparse vegetation. the main crops planted are Sichuan pepper trees, potatoes, and corn. There are steep ridges with a height of 2-4m evenly distributed along the longitudinal direction of the landslide. Bedrock is exposed at the boundaries on both sides of the landslide, and the bedrock inside the landslide body is covered by landslide accumulation, with no bedrock outcrop.

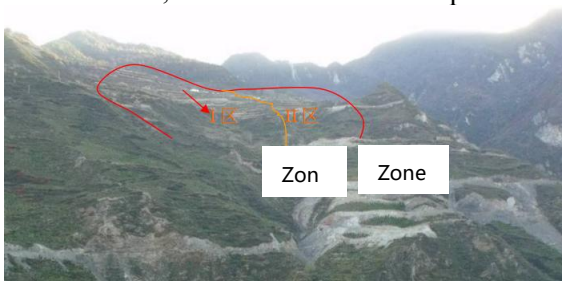

Figure 1. Overall View of the Landslide

5. Deformation Characteristics of Landslide

According to the landform and deformation, the landslide can be divided into two parts: area I and area II, with the ridge in the landslide as the boundary.

Deformation characteristics of Area I: This area is mainly in the right part of the landslide, and its elevation range is consistent with that of the landslide. the elevation of the leading edge is about 1900m, the elevation of the trailing edge is 2240m, and the relative height difference is about 340m m. the longitudinal oblique length is about 800m, the lateral average width is about 380m, its area is about 0.25Km2, the average thickness of the sliding body is about 15m, and its volume is about 400×104m3.

The slope of the leading edge in this area is steep about 30-35, and the slope angle of the trailing edge is 10-20. the obvious signs of landslide deformation also mainly appear in this area, mainly manifested in the front edge cracking and collapse, and the right boundary ground stretching.

Because of the development of local residents' cultivated land and steep slopes for road construction, the slope is mainly used for local residents' cultivated land except for a small number of residential houses.

Deformation characteristics of Area II: It is mainly located in the left part of the landslide. During the exploration, no obvious ground cracks and other surface deformations were found. This area is now the main residential area for local residents. However, there is a natural gully passing through the residential area in this area until the front of the landslide leads to the erosion of the front slope, resulting in local collapse and instability. In addition, there are many highway slopes in this area.

6. Material Structure Characteristics of Landslide

The sliding soil is mainly composed of three layers: 0.5-1.0m cultivated soil in the upper layer, 1-6m silty clay with a small amount of gravel in the middle, and 15-18m gravel soil.

(1) Cultivated soil: mainly distributed on the surface of the slope, yellowish brown, slightly wet and loose, with a thickness ranging from 0.5 to 1m, mainly composed of silty clay, with no bedding characteristics, no luster, low strength and low toughness, and containing plant roots, wormholes, broken gravel and broken gravel parent rock, mainly composed of phyllite, with a diameter of 6-23mm and a content of about 15-23mm. This layer is widely distributed in the range of landslide, with thin back and thick middle and front.

(2) Silty clay containing gravels: it is mainly distributed under the cultivated soil layer, yellowish brown, slightly wet, slightly dense and plastic, with a thickness ranging from 1 to 1~8m, mostly silty clay mixed with a small amount of breccia and gravels, accounting for about 10-15%. Generally, the particle size is 1.0 ~ 2.00 cm, and the maximum particle size is about 4cm, which is angular ~ subangular. the gravel is mainly composed of phyllite, which is strongly ~ moderately weathered. This layer is widely distributed in the range of landslide, with thin trailing edge and thick middle leading edge.

This soil layer is widely distributed in the landslide area, with the maximum thickness of 7.73m exposed by drilling hole ZK4 in the front of the slide body, 7.7m exposed by drilling hole ZK7 in the middle of the slide body and 2m exposed by drilling hole ZK9 in the back of the slide body.

(3) Gravel soil: grayish brown, slightly to moderately dense, slightly wet. Gravel content is 50 ~ 70%, with a particle size of 2.0 ~ 6.0 cm, and some stones are sandwiched, with a diameter of 20 ~ 70 cm and a maximum of 100 ~ 300 cm, with a content of about 5~15%, mainly phyllite. the phenomenon of block falling and hole collapse during drilling in this

layer is very serious. Broken stones are angular to sub-angular, piled up in disorder, and sometimes overhead. the broken stones are filled with fine (angular) gravel and yellowish brown clay, and the clay is mostly lumpy, with clay content accounting for about 10% of the total amount of broken stone soil. With the increase of depth, the clay content decreases.

4 Calculation results of thrust and stability coefficient of landslide sliding mode

The thrust and stability of four main sections of landslides I-I', II-II', III-II-II' and IV-IV' are calculated, and the results are shown in Table 1.

5 deformation characteristics of landslide

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4 Calculation results of thrust and stability

coefficient of landslide sliding mode

The thrust and stability of four main sections of landslides I-I', II-II', III-II-II' and IV-IV' are calculated, and the results are shown in **Table 1**.

Table 1. Landslide Stability Coefficient and Thrust

Calculate profile	Working conditions	Stability coefficient	stable state	safety factor	Remaining sliding thrust (KN/m)
I-I'(Main section)	Natural state	1.22	stable	1.15	0
	Rainstorm saturation state	1.10	Basically stable	1.08	0
	Natural+earthquake	1.16	stable	1.05	0
II-II'(Main section)	Natural state	1.265	stable	1.15	0
	Rainstorm saturation state	1.07	Basically stable	1.08	624.05
	Natural+earthquake	1.149	stable	1.05	0
III-III'(Main section)	Natural state	1.155	stable	1.15	0
	Rainstorm saturation state	1.077	Basically stable	1.08	268.03
	Natural+earthquake	1.115	stable	1.05	0
IV-IV'(Main section)	Natural state	1.34	stable	1.15	0
	Rainstorm saturation state	1.32	stable	1.08	0
	Natural+earthquake	1.48	stable	1.05	0

7. Engineering Governance

Based on the mechanism of landslide travel, the calculation results of landslide stability, and the protected objects, it is determined to construct retaining walls in residential areas near the landslide danger zone within the landslide body. the retaining wall is 161m long, 6.5m high, and buried 1.5m deep.

In addition, the rock and soil mass of the sliding mass has good water bearing capacity. the surface water and pore water in the loose layer are mainly supplied by atmospheric precipitation, with obvious seasonal changes. Under the conditions of continuous rainfall and rainstorm, the softening effect on the landslide soil mass is obvious, reducing the stability of the landslide, which is one of the main inducing factors of Diaolin landslide. the drainage ditch mainly discharges surface water, and the surface water within the landslide area is mainly a natural gully in the residential area on the left side of the landslide. Therefore, draining the surface water and groundwater on the landslide body as much as possible is also the key to controlling the landslide. In order to discharge atmospheric rainfall as much as possible and reduce its infiltration, a surface drainage system is designed on the landslide body to discharge the water entering the slope out of the slope.

For the surface cracks that appear, fill them one by one to prevent surface water from entering the soil through the cracks and reduce the stability of the landslide.

(1) Retaining wall project

According to the calculation results of the main profile of the landslide, the landslide is generally in a stable state. However, based on the stability calculation results of the secondary profile, there is local instability. Therefore, retaining walls are set up near residential areas for local protection.

The retaining wall is 162m long, 6.50m high, and has a top width of: 1.50m, surface slope gradient: 1:0.200, back slope gradient: 0.

(2) Surface interception and drainage engineering

According to the terrain characteristics of the landslide, a drainage ditch will be built at the natural gully in the residential area on the left side of the landslide to discharge the surface water entering the landslide body out of the landslide body.

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