Stability Analysis and Treatment Measures of a Landslide

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Abstract: In this paper, the characteristics of the landslide are described in detail, the stability of the landslide is analyzed, the stability safety factor under different working conditions is calculated, and finally the treatment measures are proposed.

Keywords: Landslide Deformation Characteristics; Stability Analysis; Governance Measures

1. Overview of the landslide

The landslide is located in Langzhong City, Sichuan Province, and the landform in the survey area is a middle hill area of tectonic denudation, which is inclined, with an altitude of 300~500m, which is mainly characterized by high terrain in the east and low in the west. Due to the stacking of sand and mudstone, soft and hard, the slope is partially formed with small steps, the steps are generally 20~50m wide, and the valley slopes on both sides are relatively low and gentle, and the valley width is 10~50m. the main valley is wide and flat, medium landform, and the cutting depth of the valley is generally 50~100m, so the slope of the valley slope is about 20°, and the local slope is greater than 60°. the landslide is semi-arc-shaped on the plane of the exploration area, and the landslide plane is semi-arc-shaped, with a longitudinal length of about 50m and a width of about 80m, which is a traction landslide, with an area of about 4000m2, a thickness of about 1.5~7.0m, and a volume of about 15, 000m3. the elevation of the front edge of the slope is about 324m, the elevation of the ridge at the back edge is about 370m, and the relative elevation difference is about 46m. the slope slope is about 20°~60°, the average slope is about 31°, and the landslide direction is 265°, see Figure 1.

The landslide began to deform during the rainstorm in August 2009 and intensified during the rainstorm in August 2011. the deformation characteristics of each area of the landslide are as follows:

(1) Front edge fence: the original fence inside the playground at the front edge of the landslide was buried by the sliding of the upper landslide during the rainstorm in August 2009, and the existing fence was deformed during the rainstorm in August 2011. At present, the fence is inclined, about 10 ° to the outside of the slope; the surrounding wall has cracked locally, forming three cracks with a length of about 5-7.5m and a width of about 2-5cm. There is groundwater seepage at the corner of the left wall.

(2) Landslide front edge: During the rainy season from 2009 to 2011, the ground cracked and the front edge slope collapsed, forming a local landslide ridge with a length of about 10-30m and a height of 2-6m. the trees on the upper part of the leading-edge slope are skewed.

(3) In the middle of the landslide: During the rainy season from 2009 to 2011, two cracks LF1 and LF2 appeared on the ground in the middle of the landslide. LF1 was about 35m long and 2cm to 10cm wide, with a strike of 185 °. LF1 experienced local sliding during the rainy season, forming a landslide ridge with a height of about 0.6-1.5m. LF2 is approximately 25m long, 2cm to 8cm wide, and runs at an angle of 190 °.

Figure 1. Overall view of the landslide

1.1 Main Hazardous Objects

The main hazard of the landslide is the safety of the lives and property of more than 400 teachers and students in the school. According to the investigation, the sliding of the landslide will pose a threat to the three-story teaching building, toilets, and school sports field below the landslide mass. In summary, the landslide poses a threat to the lives and property safety of over 400 people in the school, with a potential threat to property worth 5 million yuan.

According to the "Code for Investigation of Landslide Prevention and Control Engineering" (DZ/T0218-2006), the potential danger level of landslides is classified as level three.

1.2 Estimation of Losses Caused by Landslide Instability and Failure

At present, no engineering treatment measures have been taken in the landslide area. Landslides are significantly affected by water and are generally stable in their natural state; Under the influence of continuous rainfall, heavy rain, etc., it is in an unstable state. It is estimated that the indirect economic loss is about 5 million yuan, and the hazard level is classified as level one.

2. Deformation Characteristics of Landslide

Through field survey and engineering geological investigation, the landslide began to deform during the rainstorm in August 2009, and the deformation intensified during the rainstorm in August 2011. the deformation characteristics of each area of the landslide are as follows:

(1) Front fence: the original fence on the inner side of the playground at the front of the landslide was buried by the upper landslide during the rainstorm in August 2009, and the existing fence was deformed during the rainstorm in August 2011. At present, the fence is inclined to the outside of the slope by about 10; the enclosure cracked locally, forming three cracks, which were about 5 ~ 7.5m long and 2 ~ 5cm wide. There was groundwater oozing from the corner of the left enclosure.

(2) Landslide front: During the rainy season in 2009 -2011, the ground cracked and the front slope collapsed, forming a local sliding sill, which is about 10-30m long and 2-6m high. the trees on the upper part of the leading edge slope are skewed.

(3) Central part of landslide: During the rainy season in 2009 -2011, two cracks LF1 and LF2 were produced on the ground. LF1 was about 35m long, 2 cm ~ 10 cm wide, and the strike was 185. LF1 partially slipped during the rainy season to form a sliding ridge with a height of about 0.6 ~ 1.5 m. LF2 is about 25m long, 2cm~8cm wide, and it runs 190.

3. Topography

Langzhong is located in the northern edge of the central Sichuan Basin, belonging to the branch veins of Daba Mountain and Longmen Mountain, with a total of five mountain systems: Jianmen Mountain, Panlong Mountain, Fang Mountain, Longshan Mountain, Dayi Mountain and other mountain systems. the terrain is high in the northwest and low in the southeast. the Jialing River runs through the territory from north to southeast. the highest point in the territory is located in the Tianmaoshui Mountain of Longquan Town in the northeast, with an elevation of 888.8 meters, and the lowest point is located at the anchor Erjing River at the exit of Jialing River in Zhuzhen, with an elevation of 328 meters above sea level and a relative elevation difference of 560.80 meters.

The landform types of the city can be divided into six types: low mountainous area, deep hill area, middle hill area, shallow hill area, gentle hill area and Pingba area.

The complexity of topographic conditions and the slope slope control the air conditions for the occurrence of geological disasters. the steep and gently changing slope area is prone to landslides, and the upper and lower steep and gentle middle curved slopes, when the upper part of the slope becomes a horseshoe-shaped ring terrain and the catchment area is large, it is easy to produce soil landslides along the bedrock surface; the concave banks of rivers washed and eroded by the current are prone to landslides and collapses.

4. Joint Fissures

(1) Tectonic fractures

The development direction of the fractures shifts with the direction of the fold axis, and most of them are dominated by two groups of torsional fractures that are obliquely crossed by the tectonic line, namely the "X" fractures. One part is tension fractures, one group is parallel to the tectonic line (longitudinal tensioning) and the other group is perpendicular to the tectonic line (transverse tensioning). Most of the fractures are perpendicular to the plane, so the dip angle of the fracture surface is mostly the after-angle of the dip angle of the rock layer. the fractures are more developed in the anticline wings, such as the Shuanghe field anticline. the fractures in the thick sandstone are wide and sparse, and the fractures in the mudstone and siltstone are dense but small.

(2) Layer fissures

Thin-bedded sandstone, siltstone, and shale interlayer fissures are developed, and are communicated with tectonic fissures and weathering fissures. the dry cracks of the mudstone are more developed, and these fractures are reticulated on the plane and wedge-shaped on the profile.

The tectonic fissures developed in the sandstone layers are actually weathered and widened over a long period of geological history. Moreover, it is often intertwined with weathering fractures to form a superficial fracture system. In the deeper part, not only the weathering fractures disappear, but also the tectonic fractures tend to weaken or disappear.

Fissures are a major factor in the development of geological hazards in the control area, especially the development of collapse geological hazards.

5. Structural characteristics of landslide materials

According to the data of field mapping, drilling, trench exploration and well exploration, the material composition of the whole slope is Quaternary fill, Quaternary residual slope soil (Q_4^{ml}), Jurassic Penglai Town Formation (J_3^p) layered sand and mudstone from top to bottom.

(1) Quaternary earth fill (Q_4^{ml})

It is distributed around buildings and on both sides of roads in the landslide area, mainly composed of silty clay with crushed gravel, containing a small amount of construction waste, with different block diameters, poor uniformity, good water permeability and low bearing capacity.

(2) Quaternary broken soil (Q_4^{el+dl})

It is distributed in most surface layers of the slope, with uneven thickness. According to the drilling, the thickness is about 1 ~ 6m, which is mainly silty clay mixed with a small amount of broken gravel. the main components of the parent rock are sandstone and mudstone, and the block diameter varies, generally 1 ~ 5 cm, which is angular. the soil in this layer is relatively wet and generally in a loose-slightly dense state. Soil has poor engineering geological properties, low bearing capacity and good water permeability, which is easy to form slope collapse.

(3) Upper Jurassic Penglai Town Formation (J_3^p)

It is distributed in the whole slope, buried under the broken alluvium and alluvial soil, with shallow burial depth, and bedrock can be exposed around the boundary of landslide. According to the borehole exposure, the deepest burial depth of bedrock can reach 7m, and its lithology is mainly layered sandstone and mudstone (exposed in the lower part of borehole ZK1), with interbedded structure, and the rock occurrence is 125 ∠ 10. the bedrock is stable, the structure is complete, and it is not easy to slide. According to the weathering degree, the bedrock can be divided into two sub-layers: strongly weathered and moderately weathered. According to the drilling, the rock mass of the strongly weathered bedrock is relatively broken, with a short column core and a weathering depth of 1.8 ~ 3.9m. the moderately weathered bedrock has complete rock mass, long columnar core and high bearing capacity. This layer has not been exposed in this survey.

6. Landslide stability evaluation

According to the landslide calculation model, the stability coefficient and thrust calculation results of 1-1', 2-2' and 3-3' sections under three working conditions are shown in **Table 1**. According to the calculation results in Table 1, the landslide is stable under natural, rainstorm and earthquake conditions under the overall mode, and the residual sliding thrust of the landslide is 0. In local mode, the stability coefficient under natural working conditions ranges from 1.085 to 1.171, which is in a basic stable to stable state, and the residual sliding thrust of the landslide is 0; Under earthquake conditions, the stability coefficient ranges from 0.979 to 1.100, indicating an unstable to basically stable state. the remaining sliding thrust of the landslide is 27.59KN; Under the rainstorm condition, the stability coefficient of the landslide is 0.957~1.039, the landslide is in an unstable~unstable state, and the residual sliding thrust of the landslide is

39.89KN~95.03KN. From the calculation results, it can be seen that only in the case of rainstorm, local sliding and collapse of the landslide will occur, which is basically consistent with the actual deformation.

Table 1. Statistical Table of Stability Coefficient And Thrust Calculation Results of Each Section of Landslide

Section number	Operating conditions	Stability factor	Safety	Residual Slip Force (KN)	remark
1-1 '(Overall Mode)	Natural conditions	1.330	1.15	0.00	stable
	Rainstorm condition	1.174	1.10	0.00	stable
	Earthquake condition	1.199	1.05	0.00	stable
1-1 '(local mode)	Natural conditions	1.133	1.15	0.00	Basically stable
	Rainstorm condition	1.002	1.10	43.93	Lack of stability
	Earthquake condition	1.053	1.05	0.00	Basically stable
2-2 '(Overall Mode)	Natural conditions	1.290	1.15	0.00	stable
	Rainstorm condition	1.139	1.10	0.00	Basically stable
	Earthquake condition	1.169	1.05	0.00	stable
2-2 '(local mode)	Natural conditions	1.085	1.15	0.00	Basically stable
	Rainstorm condition	0.957	1.10	95.03	instability
	Earthquake condition	0.979	1.05	27.59	instability
3-3'(Overall Mode)	Natural conditions	1.374	1.15	0.00	stable
	Rainstorm condition	1.213	1.10	0.00	stable
	Earthquake condition	1.219	1.05	0.00	stable
3-3 '(local mode)	Natural conditions	1.171	1.15	0.00	stable
	Rainstorm condition	1.039	1.10	39.89	Lack of stability
	Earthquake condition	1.100	1.05	0.00	Basically stable

7. Governance Engineering Design

After scheme comparison, a comprehensive treatment plan combining anti slip piles, interception and drainage, and crack backfilling was adopted for landslide control engineering.

(1) the front edge of the landslide collapsed significantly, mainly due to surface sliding. An anti slip pile was built on the inner side of the front edge wall to block the upper sliding body. Set a retaining wall of 100.0m, with a height of 4.0m, an embedded depth of 1.0m, a bottom width of 3.0m, a top width of 1.0m, a slope of 1:0.2 for the face slope, and a slope of 1:0.2 for the back slope. Adopting one extended wall toe step, with a width of 0.5m and a height of 1.0m, and a slope of 1:0.2 on the wall toe step surface. the wall is constructed with MU30 mortar block stones.

(2) At the rear edge of the landslide, it is recommended to rectify and harden the existing excavated drainage ditch, and intercept and drain surface water on the slope. the drainage ditch is planned to be arranged at the rear edge of the landslide, consisting of a transverse intercepting ditch, a steep slope, and a waterfall, with a total length of about 125 meters. Install drop water energy dissipation wells at steep slopes, and set up rapid flow channels in areas with steep slopes. the rapid flow channels generally dissipate energy in the form of stepped slopes or pebble beds, and increase the roughness coefficient for deceleration energy dissipation.

(3) Crack backfilling

The landslide mass has formed a large number of cracks on the slope during its previous deformation process. Although these cracks do not show obvious signs of widening at present, they are easily penetrated by the cracks during the rainy season, increasing the weight of the slope and affecting its overall stability. Therefore, it is necessary to seal and fill the cracks on the slope. the amount of crack sealing and filling is about 40m, using high-quality clay and lime for sealing and compacting.

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