Evaluation of Landslide Disaster Mechanism and Control Scheme in Beixi Village

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Abstract. Taking beixi village landslide as an example, the cause and mechanism of rain-induced landslide are deeply analyzed. The stability of landslide under natural state and rainfall state is analyzed respectively by using finite element strength reduction method, and the influencing factors of landslide are analyzed and the safety and stability of landslide is evaluated. The results show that :(1) The disaster mechanism of beixi village landslide is due to the strong water permeability of clay layer, and the weathering layer is easy to soften when it meets water, and rainwater infiltration is easy to form weak interlayer, which induces local deformation and finally slides.(2) The landslide of Beixi Village is in a stable state under natural conditions; the landslide was in an basically stable state under saturation condition. (3) According to the plastic cloud map of sliding surface, there is stress concentration in the landslide front, which endangers the lower buildings. It is suggested that slope cutting + gravity retaining wall + drainage engineering prevention and control measures. The formation mechanism of the landslide can provide engineering reference for the disposal and prevention of similar landslides.

Keywords: Traction Landslide, Prevention Technology, Rainfall, Stability analysis.

1. Introductions

Rainfall-induced landslide is a common type of geological disaster, which is characterized by strong disaster-causing, wide region and large affected area. According to statistics, 90% of the landslides in China are rainfall landslides, which have brought serious personnel and economic losses to our country [1-3].

At present, many scholars have carried out large number of studies on landslide instability mechanism and stability analysis methods at home and abroad. Tao Zhigang [4] monitored the stability of the open dump through optical fiber. Guo-qing Chen [5] proposed dynamic stability evaluation method with dynamic and overall strength subtraction of the slope, the dynamic strength subtraction to search out the gradual extension of sliding surface, and combining with the advantage of the overall strength subtraction calculation of safety factor, in the process of gradual slope instability dynamic safety coefficient calculation, so as to realize the analysis of the whole process of slope unstability and regulation. Ma Beiqing [6] used FLAC3D software to calculate and simulate the influence of crack development on slope stability under the condition of continuous rainfall, and studied the stability of loess slope under the condition of continuous rainfall. Artificial rainfall device was used to conduct outdoor field tests and measure soil moisture content, density, location of landslide shear zone and crack development. Zhou Zihan [7] established a theoretical model of sharp point mutation of rock slope instability under the action of open-pit blasting load based on the two-dimensional mechanical model of slope plane sliding instability by introducing blasting load. Tang Dong [8] studied the influence of different initial conditions on slope stability of different soils based on measured rainfall data in the Three Gorges Reservoir area.

In the existing literature, the influence of rainfall on slope stability mainly considers the increase of dead weight in shallow surface transient saturated zone of slope caused by rainfall and the decrease of negative pore water pressure in soil caused by rainwater infiltration [9-10]. However, for the soil slope, long-term rainfall infiltration leads to the softening and reduction of soil strength, which further deteriorates the stability of the slope [11-13]. In this paper, the stability of strongly weathered sandstone is analyzed by means of normative theory analysis and finite element strength reduction method. On this basis, the process of landslide deformation and evolution is considered, and the graded control scheme is put forward to provide basis for guiding engineering practice.

2. Geological environment condition

2.1 Topography and Landform

Beixi village landslide is located at an erosive structure of zhongshan geomorphology with developed valleys and strong cutting. The mountain top is extremely steep, and the ridge is obviously serrated. The slope is steep with a slope of 35° ~ 60°, up to 70° locally. The top elevation of the slope is 1390m, the foot elevation is 690m, the relative elevation difference is 700m, and the slope slope is 37°. The vegetation develops luxuriant, the vegetation type is evergreen broad-leaved forest, the coverage rate is about 90%. The villagers of Beixicong cut and built houses on the hillside, located at the lower part of the southern slope of the mountain, with an elevation of 770 ~ 870m. The overall width of the shear slope where the collapse is located is 160m, with a height of 5~ 8m and a slope of about 70°. The distance between the rear wall of the house and the foot of the cutting slope is 0.5 ~ 1m, and the buffer zone is seriously insufficient.

2.2 Formation lithology

The stratigraphic lithology mainly includes upper subgroup lower Group of Cambrian Shuikou Group and quaternary residual slope deposit in the exploration area.

According to the investigation and data analysis, the strata exposed at the landslide point include Quaternary residual slope deposit (Qel+ dl) and Cambrian Bianxi Formation (∈ B).

1. Quaternary residual slope deposit (Qel+ dl)

The slope of the landslide site is covered by the quaternary residual slope containing gravel clay, which is gray yellow and purple red, and mostly hard plastic. The content of gravel is 30 ~ 60%, the particle size is 5 ~ 20cm, and locally it can reach more than 50cm. The thickness is 3 ~ 8m, and the soil structure is loose.

2. Cambrian Bianxi Formation (∈B)

The Cambrian Bianxi Formation (∈ B) is distributed under the quaternary soil layer and is gray-dark gray fine-grained quartz sandstone with medium-thick bedded to thick bedded. There is no exposed rock formation on the jianfang cutting slope. According to the regional geological data and exposed rock mass of the nearby mountain, the occurrence of rock formation is 115°∠60°.

2.3 Hydrogeological condition

According to the occurrence form and burial conditions, the groundwater types in the exploration area can be divided into pore water of loose rock and fracture water of clastic rock according to the characteristics of stratum lithology and aquifer.

1. Pore water of loose rocks

This kind of groundwater mainly occurs in the pore fissures of quaternary soil layer and is mainly replenished by infiltration of atmospheric precipitation, mainly by evaporation. Local infiltration replenishes clastic rock fissures or flows out along mountain valleys. This kind of water is poor in water quantity and has no stable groundwater level, with great dynamic change and obvious seasonal change.

2. Clastic rock fissure water

This kind of groundwater occurs in the strata structural cracks and weathering cracks of the Cambrian Bianxi Formation (∈ B) siltstone, and is mainly supplied by the infiltration of atmospheric precipitation and upper pore water. It is discharged in the form of diffuses or springs on the drainage datum of gullies and low-lying areas. controlled by factors such as weather, topography and crack development degree, the water distribution is not uniform.

According to the regional hydrogeological data and field visit on-the-spot investigation, exploration area in the spring or outlet, etc. there are not found in the mountain area stable water level elevation is akin to exploration area, 1.2 km north of shuikou river river water level elevation, roughly 96 m to 98 m, water level amplitude about 0.5 ~ 2.0 m, below ground lowest elevation (276 m). The water volume is medium, the groundwater runoff modulus is 3-6L /s•km^2, the hydrochemistry type is mainly HCO_3-Ca•Mg, HCO_3•SO_4-Mg, PH is 5-7.05, salinity is 0.016-0.045 g/L. Groundwater has little influence on landslide control.The project to be arranged in the exploration area is located at an elevation of 279 ~ 285m, which is basically not affected by groundwater.

3. The landslide characteristics

3.1 Distribution characteristics of landslides

The landslide type is soil landslide, located in the slope behind the house of villagers Huang Chengzhang and Zhao Wanxiang, happened at about 5 o 'clock on June 7, 2020. The elevation of the front edge of the landslide is 278.8m, the elevation of the back edge is 290m, the width of the landslide is 12m, the height is 6m, the average thickness is 0.5m, the volume is about 36m^3, the scale is small, belongs to the soil landslide, the landslide direction is 120°.The plane shape of the landslide is tongue, the profile shape is nearly linear, the main sliding direction is 120°, the sliding surface is located in the contact surface of residual slope accumulation soil layer and strong weathering layer, the buried depth is 0.5-1.0 m, it is a shallow soil landslide, a traction landslide. The slope soil slipped and accumulated behind the house, causing no casualties and direct economic losses, threatening 2 families of 10 people, the disaster is small.

Fig1 Slide down（Mirror to 0 °）

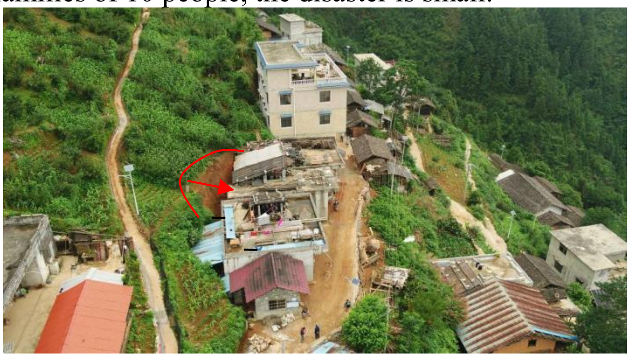

Fig2 Overall of the landslide（Mirror to 20 °）

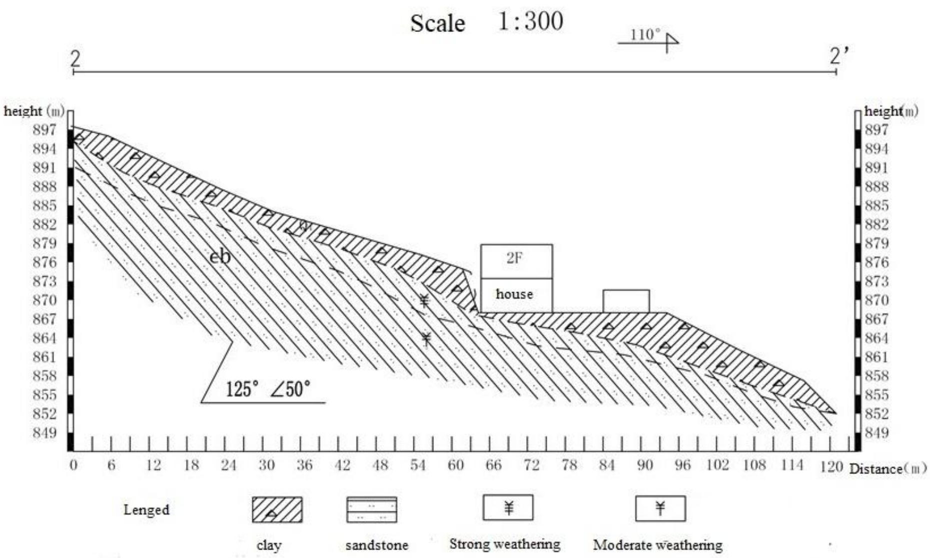

Fig 3 Cause analysis of landslide

3.2 Factors analysis of landslide

Slope instability is the result of many factors, which are closely related to topography, stratum lithology, human engineering activities, rainfall and other factors.

(1) The exploration area is located in the Zhongshan geomorphic area, and the slope is artificial cut slope without protection, which provides favorable topography and surface for the formation of collapse and landslide. The top of the slope is steep, and there is no perfect interception and drainage measures. When the rain falls, it is easy to infiltrate the slope and reduce the stability of the slope.

(2) The sandy clay composed of the slope is easy to be disturbed and softened by water, and its strength, physical and mechanical properties and stability are reduced.

（3）In the rainy season, the infiltration of slope precipitation further softens rock mass, reduces the strength of rock mass, increases the dead weight of soil, increases the sliding force, and aggravates the slope instability.The rainfall penetrates horizontally into the bottom rock face, and the groundwater pressure increases the sliding force of soil. Surface flow is formed by precipitation collected during rainstorm, which scour the surface of slope body and take away soil directly, resulting in slope instability. Therefore, water is the main factor inducing slope instability.

4. A graded control scheme for the stability of geological disasters

4.1 Selection of calculation scheme

The slope is mainly composed of gravel-bearing clay, which is a kind of soil slope. Local slope body has collapsed, and arc (arc) landslide or collapse may occur under the influence of rainfall.

The values of rock mass γ, c and φ are determined comprehensively according to the survey and sampling results. Recommended values of parameters of each rock and soil layer are shown in Table 1.

Tab1 Recommended values for parameters of each layer

Ground layer		γ（kN/m3）	c (kPa)	φ (°)
Clayer	Natural state	18.5	7.6	21.7
	Saturated state	19.6	5.3	17.5
Strongly weathered sandstone	Natural state	20.1	22.0	31.5
	Saturated state	21.0	20.0	26.0

The purpose of this calculation is to evaluate the stability of slope under various possible working conditions, and to provide a basis for slope stability evaluation and prevention. Two working conditions, namely working condition natural state and working condition Saturated state, were selected for stability analysis and checking. In the calculation of condition, the soil of each layer is calculated according to the saturated state, and the pressure caused by groundwater is not considered.

4.2 Modeling establish

Finite element method (FEM) by natural rainfall and the mechanical parameters of rock mass under the condition of different, to study the stability of the landslide under natural state and working condition of rainfall, soil, Moore coulomb constitutive model is adopted to model is fixed at the bottom, the sides level constraints, apply gravity load, analyzes the influence factors of landslide and evaluation, as shown in figure 6.

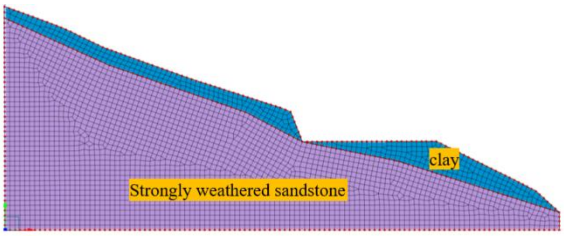

Fig4 Numerical model diagram

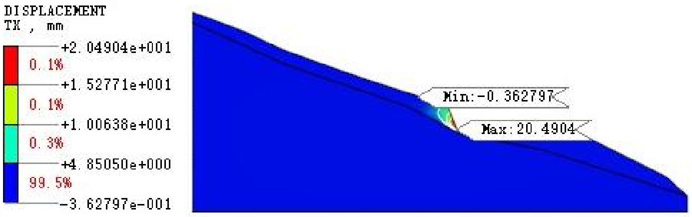

Fig 5 The displacement nephogram

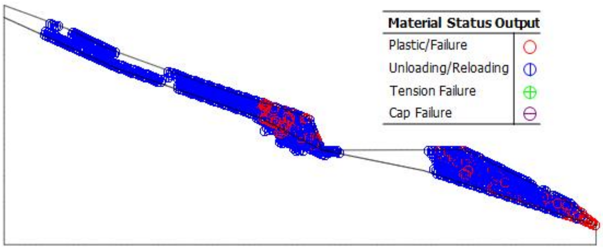

Fig. 6 Plastic state

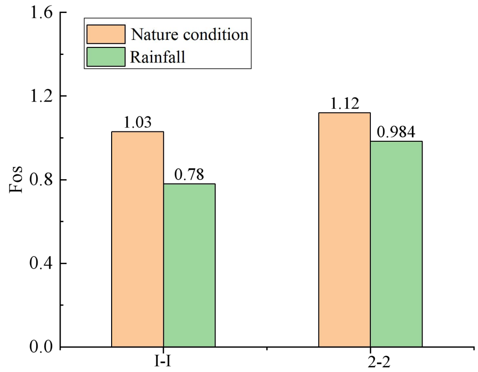

Fig7 Safety factor of two sections

Tab 2 Calculation results of stability coefficient

Calculation of section	Safety factor	
	Natural conditions	Rainfall condition
Section 1-1	1.03	0.78
Section 2-2	1.12	0.98

As can be seen from Fig. 5~Fig. 7, the sliding trend of the slope is in the leading edge of the upper slope, so the risk is high. The maximum level of the slope is 2.0cm. the plastic failure area of the slope is in clay layer, and there is a cutting slide trend.

It can be seen from Figure 8 and Table 2 that the safety factor of section 1-1 of Beixi Village landslide is 1.03 under natural conditions, and the whole landslide is in an unstable state. Under saturation condition, the safety factor of landslide is 0.78, and the whole landslide should be in an unstable state. In natural working conditions, the safety factor of 2-2 section is 1.12, which is basically stable, while in rainstorm working conditions, the safety factor of slope is only 0.98, which is unstable. In summary, both sections are prone to instability, and 1-1 section is of higher risk. Therefore, in order to ensure sufficient safety reserve of landslide and the safety of pine landslide, it is suggested to take engineering treatment measures as soon as possible.

4.3 Geological disaster prevention and control scheme and evaluation

Based on the survey of geological disasters and combined with the comprehensive analysis of their influencing factors and threatened objects, the following comprehensive prevention and control measures are suggested to ensure the stability of slopes and reduce the occurrence of disasters, and to consider the factors of safety, effectiveness, economic and reasonable treatment projects and feasible construction technology as follow.

Scheme one: "grading slope release + lattice anchor bolt + grass revetment + foot retaining wall + drainage project", release slope on artificial cut slope and natural slope, protect slope surface with lattice anchor bolt, protect slope surface with grass, build retaining wall at slope foot, and set drainage ditch around slope and bottom. The advantages of the scheme are beneficial to slope greening and environmental protection; The disadvantage is to occupy a larger area of land.

Scheme two: "slope cutting + gravity retaining wall + drainage engineering", specifically for the steep artificial slope cutting slope, the construction of gravity retaining wall at the foot of the slope, the construction of drainage ditch around the slope and slope foot.

The advantages of the scheme are low cost, simple construction, less land occupation, and the disadvantage is the lack of protection of the natural slope.

Scheme comparison and selection: after multi-party consultation, combined with the actual situation of the project, in order to meet the safety factors, from the technical feasibility, work cost, construction difficulty and other aspects of the treatment scheme for comprehensive comparison, recommend the scheme two for treatment scheme.

5. Conclusions and Recommendations

1. Due to human engineering activities, aggravated the instability of the slope, the slope surface without any protection measures, at present, the cutting slope surface appears too small collapse, in the natural working condition, the overall slope is basically stable to stable state. Under the saturated condition, that is, under the action of dead weight + heavy rainfall + groundwater, the slope is in a basically stable to unstable state, which should be supported and treated.
2. Beixi Village is a potential threat to the safety of life and property of the villagers in group 3 and group 4 in Beixi Village, and the risk of geological disasters is high, so the protection and management of geological disasters is imperative. The disaster risk level is medium, and the geological disaster prevention and control project level is three.
3. It is suggested to adopt "slope cutting + gravity retaining wall + drainage project" to comprehensively control the geological disaster

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