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Genetic mechanism and stability assess of the Boai landslide in northeastern Yunnan province

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Abstract. Field and drilling data shows that, the boai landslide, located in Funing country, northeast Yunnan province, has length of 800m and width of 250-570m, covering square of $40\times10^4 m^2$ and volume of $1600\times10^4 m^3$. On basis of investigation and experimental data, we illustrate the basic characteristics and formation progress of the Boai landslide, analyze its safety assess, and put forward some feasible treatment measures.

1. Introduction

The Boai landslide was located in Funing county, northeast Yunnan province. Affected by a long term heavy rain, ground surface began to deform since 2008, residential buildings and roads began to crack, then the Boai landslide breakout. According to the monitoring data, there were no signs to show that the deformation was slowing down. The Boai landslide was threatening the safety of 1400 lives and property of the local residents.

The Boai landslide goes to the narrow width of the funnel-shaped in the plane, which has length with 800m and width with 250-570m, covering square of $40\times10^4 m^2$ and volume of $1600\times10^4 m^3$. In this paper, we will systematically analyze geological characteristics and the basic features of the Boai landslide, discuss its causes and stability. Finally, based on the actual investigation, we propose the appropriate engineering control measures.

2. Geological background conditions

2.1. Topography

Regional geomorphology is a hilly region, with some basins. The symbiotic relationships between the slope and slow stage, slope and gully are the overall performance.

2.2. Lithology and structure

Exposed strata in the study area are the Quaternary and the Triassic rocks. Drilling data results showed that the Quaternary silty clay scattered in the surface of the landslide, with thickness of 2.0-10.0m. While the Triassic siltstone and clay distributed widely in the range of the landslide, with thickness of 4.0-58m.

Study area is located in Yunnan western edge of plate fold belt, the crustal movement rise slowly. The main territory faults are the Wenshan-Malipo and Napo faults, and some north-trending secondary activity fractures.

2.3. Hydrogeology
There are three surface gullies in study area, and its cutting depth varies (4-20m). The trend of gullies is 100-130°, and perennial water is found in these gullies.

Rainfall infiltration, town water supply and drainage and mountain side recharge are the main source of supply of the landslide groundwater [1]. Groundwater is mainly bedrock fissure water and pore water. Most of the former is diving water, the latter overflow from low lying areas as springs due to water effect of slip zone.

3. Characteristics of the Boai landslide

3.1. Spatial distribution
The Boai landslide is the funnel-shaped in planar (Fig.1), the length is 800m and the width is 250-570m, with distribution square of $40\times10^4m^2$ and volume of $1600\times10^4m^3$. The main slip direction is 115°, average thickness of landslide is 40m, and leading edge was thicker (64m).

Figure 1. The panorama image of the Boai landslide

3.2. Material component
Drilling sonic test results indicate that the slider longitudinal wave velocity is in the range of 1.61-2.98 km/s, with large amplitude, suggesting landslide composition is extremely uneven and significant overhead localized. From bottom to up, the material component is gravel soil with shale stone, siltstone fragments of stone, mudstone with gravels and silty clay with gravels.

3.3. Slip zone and slip bed
Slip zone soil consists of clay minerals and debris, which have high active minerals content (illite), indicating that slip zone soil has a certain expansion (Fig. 2), it will be a water-swellable, and intensity decrease significantly.

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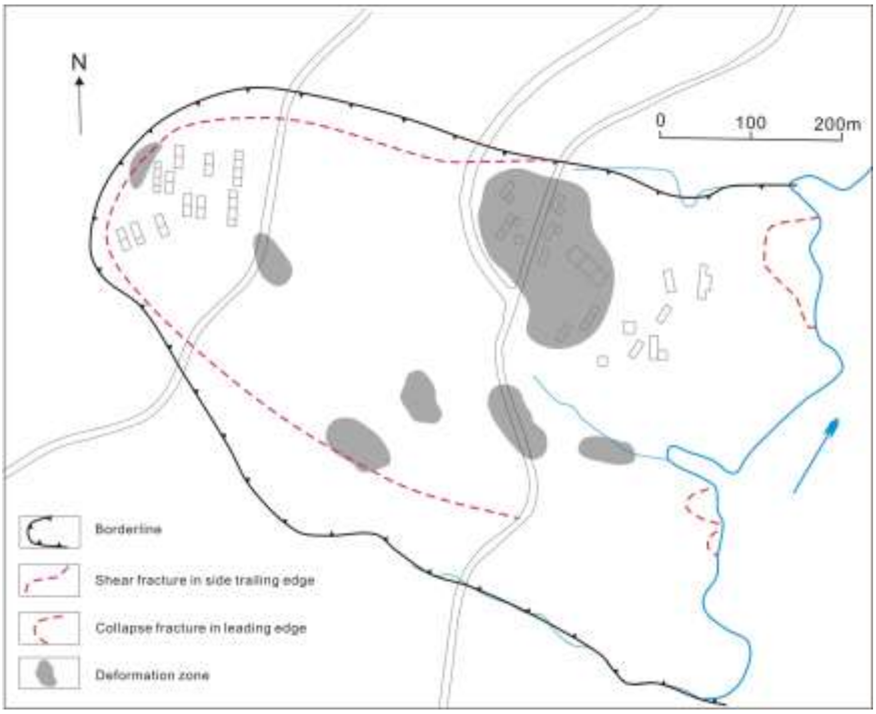

Figure 2. Schematic diagram of displacement and deformation of the Boai landslide

The bedrocks in slip bed are the Triassic mudstone and siltstone, dark gray, medium-thick layer. The lithology is weak, develops the interlinear shear zone. Longitudinally, trailing edge is steeper (20°), front area is gradual (5-7°), while leading edge is plane and reverse rock-layer (-3- -5°). Laterally, it presents an asymmetric groove.

4. Discussions

4.1. Genetic mechanism

Firstly, slippery rocks provide the material basis for the formation of the landslide [2]. The combination of the exposed strata in the landslide area is hard in upper and soft in bottom, the upper part is mainly fine sandstone and siltstone, while the lower part is weak mudstone. And the interlayer shear zone develops due to effect of structure, all the causes constitute the typical slippery layer. Secondly, monoclinic, gently inclined and forward slope geological structure forms unfavourable geological structure. Thirdly, occurrence of rock-layers is 150º-170º∠17º-25º, while the general trend of slope is 20°-25°. Moreover, fractures and terrain cutting provide favourable condition to form airport and landslide boundary.

Therefore, we indicate that the formation of the Boai landslide is as following: (1) the landslide was located in monoclinic structure, apparent slope position. As consequent erosion and cutting of the Jiacun river, the upper hard rocks had been cut, the soft layer rocks exposed (Fig. 3a). (2) Under the long-term weight action of the slope body, the through slip surface in the landslide formed progressively (Fig. 3b). (3) With the erosion of the Jiacun river, the airport surface of the accumulation front was increasing (Fig. 3c). (4) Many factors including heavy rainfall infiltration, urban water supply and drainage system leakage and reservoir pressure, made the landslide deformation and displacement, and outbreak in 2008 (Fig. 3d).

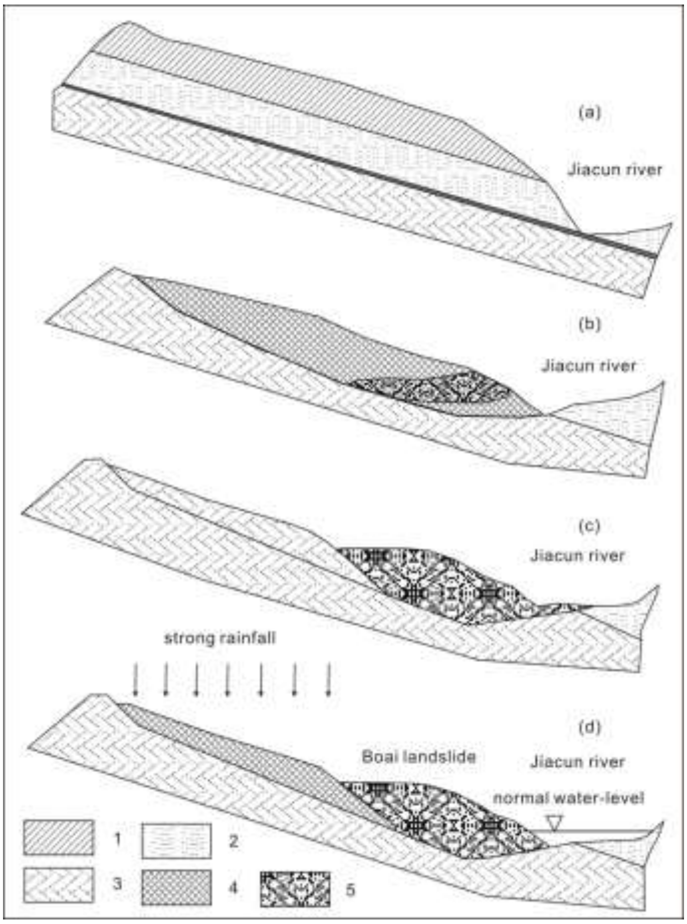

Figure 3. Cartoons of the Boai landslide formation mechanism (1-sandstone, 2-mudstone, 3-sility clay, 4-alluvial materials, 5-slope accumulation)

4.2. Stability calculation

The rigid body limit equilibrium method has been frequently used for stability calculation of landslide [3, 4]. In this paper, we will adopt the unbalance method or transfer coefficient method [5] to evaluate the stability of the Boai landslide, with the concrete calculation formula as follows:

$$F_S = \frac{\sum_{i=1}^{n-1}(Ri\prod_{j=i}^{n-1}\psi_j) + Rn}{\sum_{i=1}^{n-1}(Ti\prod_{j=i}^{n-1}\psi_j) + Tn}$$

Based on the results mentioned above, we inverse the gravity calculation of landslide, the results are listed in Table 1.

Table 1. Collected gravity values of inversion calculation from the Boai landslide

sequence	lithology	Native / saturated wet
V	silty clay	19.5/21.0 11.0
III	mudstone	20.5/22.0 12.0
II	siltstone fragments of stone	22.0/23.0 13.0
I	gravel soil	22.0/23.5 13.5

We select a section (Z2-2′) to calculate the stability coefficient (F_s) under different working conditions (weight, weight and rain, and weight and earthquake). The result shows that, the F_s values under different working conditions are 1.00, 1.05 and 1.09, respectively. So, we consider the Boai landslide is in unstable to under-stable, and it will breakout once heavy rain encountered.

5. Engineering treatment

According to some special factors, including the sliding body thickness of leading edge, steep slope and, long and gentle sliding bed and reverse rock-layer, we believe that the leading edge of the landslide is the key to prevent the overall deformation and instability. Therefore, it is necessary to carry out the backfill and surface drainage engineering, meanwhile, anti-slide retaining projects should be implemented in middle parts.

Acknowledgments
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References

[1] Rahardjo, H., Li, X. W., Toll, D. G. The effect of antecedent rainfall on slope stability. Geotechnicaland Geological Engineering, 19 (2001) 371-399.
[2] Peng, Y. L, Guo, D. L., Hu, X. W., Gu, C. Z., Zhou, J. Characteristics and stability analysis of a landslide in Kuancheng country, Hebei province. Journal of Mountain Science, 29 (2011) 591-597. (In Chinese)
[3] Specification of geological investigation for landslide stabilization. DZ/T0218 -2006. Chinese Standard Press, Beijing, 2006.
[4] Zhang, X. Z., He, J. D. The application and compare of the rigid limit balance method and finite element approach in the slope stability analysis. Jilin Water Research, 8 (2007) 32-35. (In Chinese)
[5] Code for investigation of geotechnical engineering. GB50021-2001, Beijing, 2001.