Analysis and Treatment Design of a Landslide Deformation Mechanism

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Abstract: This paper details the deformation characteristics of a medium-sized soil landslide in Liangshan Prefecture, Sichuan Province. Through on-site investigation and data analysis, the landslide mechanism is systematically studied: the combined effects of Quaternary loose overburden, artificial slope cutting-induced suspended terrain, and long-term soil soaking by surface water lead to reduced soil shear strength, ultimately forming a traction-type soil landslide. Additionally, two accumulations of unfavorable geological hazards formed by highway construction waste stacking on the slope are prone to inducing debris flow under heavy rainfall. Based on the disaster characteristics and threat scope, two comprehensive treatment schemes are proposed, focusing on diversion of hazard sources and retaining engineering. The research provides technical support for the safe governance of similar landslide disasters in mountainous areas.

Keywords: Landslide Mechanism Analysis; Engineering Governance; Scheme Comparison

1. Engineering Background

The landslide is located in Liangshan Prefecture, Sichuan Province, and according to on-site interviews and data, the deformation of the landslide began in the flood season of 2017, mainly manifested as local slippage on the front edge and a setback on the trailing edge. In recent years, every rainy season, the leading edge of the slope has continued to collapse, and the top of the slope has tensile cracks and steep slopes. Once the landslide is destabilized and damaged, it directly threatens the residential areas and rural roads at the foot of the slope, and threatens the safety of the lives and property of 96 people from 20 households below the slope, and the potential economic loss that may be caused is about 6.5 million yuan.

2. Basic Characteristics of Landslides

The overall length of the landslide area is about 95m, the average width is about 75m, the thickness of the sliding body is 15~20m, the volume is $10.7\times10^4 m^3$, and the main slip direction is about 120°. The elevation of the front edge of the landslide is about 1129.8~1133.11m, the elevation of the trailing edge is about 1177.17~1172.01m, the relative height difference between the front and rear edges is about 39~48m, and the right side of the front edge is air-empty, which creates favorable terrain conditions for the generation of landslides. The scale of the landslide is medium-sized soil landslide. The landslide pattern is shown in Figure 1.

Figure 1. Landslide Satellite Image Overview

3. Analysis of Landslide Deformation Characteristics and Mechanism

(1) Deformation and failure characteristics

According to this survey and combined with the visit, two adverse geological hazards accumulated due to the construction of highway waste on the left side of the slope, which is easy to form a broken debris flow under heavy rainfall conditions. The landslide area is located on the right side of the slope, and the strong deformation area of the leading edge has collapsed, which develops every rainy season. The overall view of the landslide of the Degugou Formation is shown in Fig. 2.

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Figure 2. Landslide Overview

The strong deformation zone is located near the shear outlet of the landslide front, as shown in Figure 3. The deformation zone is arc-shaped, with a width of about 50m and a height of about 30m. Two adverse geological hazard accumulations caused by highway slope cutting at the upper left of the slope are shown in Figure 4. Accumulation body D1 is located at the upper left of the landslide, with a total volume of about $0.5\times10^4m^3$, and accumulation body D2 is located at the upper left of the landslide, with a total volume of about $0.9\times10^4m^3$.

Figure 3. Landslide Leading Edge Slump

Figure 4. Road Slope Cut Waste Slag Accumulation Body

(2) Analysis of deformation mechanism

The landform type of this exploration area is tectonic erosion mountain landform, and the Quaternary overburden is relatively rich around, which provides a certain material basis for landslide breeding. The steep slope formed by artificial slope cutting at the front of the landslide creates certain vacant conditions for the formation of the landslide. Meanwhile, the material of the landslide is mainly rubble and rock soil of colluvium, and the structure of the slope soil is loose, which is beneficial to the infiltration and storage of surface water and irrigation water. The surface water soaking the soil for a long time not only increases the bulk density, hydrodynamic pressure and hydrostatic pressure of the soil, but also softens the lower soil and reduces the shear strength, which may lead to the gradual development of the slope. The possible type of landslide is traction soil landslide. In addition, highway waste slag accumulates on the steep slope to form two unfavorable geological hazards, and under the condition of heavy rainfall, hydrodynamic action is easy to form slope debris flow.

4. Assumption of Treatment Project Scheme

4.1 Existing Protection Works

In 2020, a retaining wall was constructed on the right side of the landslide, with a height of 4.0m and a top width of 0.3m, which has been operating effectively. According to field investigations, the county bureau of natural resources has installed warning signs and broadcasting facilities at the landslide leading edge, and arranged for village cadres to conduct regular monitoring during rainfall periods to prevent traffic disruption and property losses caused by landslide disasters.

4.2 Engineering Governance Schemes

Based on the deformation signs and mechanism analysis, the disaster body is a composite hazard consisting of unfavorable geological hazard accumulations and traction-type landslides. The landslide mass is characterized by a free surface formed by leading-edge collapse and a scarp at the trailing edge; under heavy rainfall, increased soil pore water pressure and intensified hydrodynamic effects easily lead to slope instability. The debris flow-prone area on the slope is dominated by the two aforementioned artificial waste accumulations, which slide annually during rainy seasons and pose a continuous threat to downstream residents and rural roads.

Therefore, the comprehensive governance of the disaster body should focus on the following two core objectives: first, diverting the two unfavorable geological hazard accumulations to guide the debris into the lower gully; second, strengthening the retaining engineering for the landslide mass to prevent collapse in the strong deformation zone, and connecting the new retaining structure with the existing right-side retaining wall to form a continuous protection system for downstream residents and roads. Two alternative treatment schemes are proposed as follows:

Scheme 1: Diversion Dike/Gabion + Pile-sheet Wall + Retaining Wall

① Pile-sheet walls shall be installed on the left side of the landslide leading edge (covering the strong deformation zone and platform). The proposed pile-sheet walls and the existing gully platform will form a debris storage zone to restrict the lateral and forward movement of the landslide mass.

② A retaining wall shall be constructed on the right side of the landslide, connected to the existing retaining wall project, to form a closed protection system and prevent overall sliding of the landslide mass.

③ Diversion dikes or gabions shall be constructed at the two unfavorable geological hazard accumulation sites to guide the debris sources into the lower gully platform, eliminating the debris flow risk.

Scheme 2: Diversion Dike/Gabion + Retaining Wall

① A retaining wall shall be built on the left side of the landslide leading edge (covering the strong deformation zone and platform) to flatten the steep slope. The proposed retaining wall and the gully platform will form a debris storage zone. Meanwhile, a retaining wall on the right side shall be connected to the existing project to prevent overall sliding of the landslide mass, achieving comprehensive governance.

② Diversion dikes or gabions shall be installed at the two unfavorable geological hazard accumulation sites to divert the debris sources into the lower gully, ensuring the safety of downstream residents and infrastructure.

The two schemes will be optimized through technical feasibility analysis and engineering cost comparison to determine the optimal governance plan.

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