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The Occurrence Mechanism of Geological Disasters and Countermeasures in a Certain Area

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Abstract

In recent years, natural disasters in China have occurred frequently, especially large disasters such as earthquakes, floods and droughts, which have posed a serious threat to local public safety. In addition, the geological environment of local mountainous areas in China is complex and diverse, and climate change is large. Considering the dynamic coupling effect of rainfall conditions to stimulate geological disasters, this paper takes dynamic risk assessment technology as the guide, constructs a dynamic risk early warning model of geological disasters, establishes a prototype system, realizes dynamic risk assessment and emergency early warning of geological disasters at the regional level, and provides feasible technical support for targeted emergency disaster prevention. At the same time, the investigation and evaluation, mechanism research and monitoring and early warning related to the comprehensive prevention and control of geological disasters are important tasks that cannot be ignored, an important link in the emergency response system for geological disasters, and a key stage process to guide scientific disaster prevention. On the basis of exploring the mechanism and catastrophic effect of rainfall to stimulate landslides and mudslides, we will carry out in-depth research on disaster prevention countermeasures such as systematic engineering disposal, monitoring and early warning.

Keywords

Geological Hazards, Landslide, Emergency Warning, Prevention and Control Measures

1. Introduction

Under the action of rainfall, the concurrency and mass occurrence of landslide and debris flow are one of the basic characteristics of mountain geological disasters. Due to similar geological environment conditions and the same rainfall triggering effect, landslides and debris flows in mountains are often accompanied, and mass occurrence often occurs. Some landslides even directly start and transform into debris flows after instability, forming a continuous process of (Hu, 2007; Yang et al., 2020; Zhejiang Province Geological Environment Bulletin, 2017). According to the provincial comprehensive research of debris flow data and geological environment statistics, the province mountain debris flow (including hidden dangers) a total of more than 620, more than 80% is formed by landslide or collapse, the proportion is relatively large, and distributed in the southeast volcanic area, often show valley type of sparse water flow characteristics. Relatively speaking, landslide transformation and debris flow is one of the main types of debris flow, which is the main way to start the formation of debris flow. It is a technical problem to study how to form and effectively prevent it.

Geological disaster refers to the disaster (Yin et al., 1996) related to geological effects, such as mountain collapse, landslide, debris flow and ground subsidence, caused by natural factors or human activities that endanger people's life and property safety. The occurrence of geological disasters is mainly affected by geological, landform, lithology, precipitation, soil and vegetation. With the rapid development of economy and the rapid increase of population, the threat of geological disasters gradually increases, and the impact of human activities on geological disasters is more and more obvious. At present, the research on geological disasters mainly focuses on (Van Den Eeckhaut et al., 2012) in occurrence mechanism, prediction, monitoring and early warning, risk assessment and prevention. China has a wide variety of geological disasters, frequent outbreaks, the intensity and scale of the top in the world. From 2000 to 2012, there were 339,000 geological disasters and 45,381 casualties (Liu & Liu, 2012). Iverson uses the simplified form of the Richards equation to evaluate the effect of rainfall infiltration to affect the occurrence of landslides, timing, depth and acceleration in different situations, and explores the landslide response to rainfall and related physical process (Xu, Wu, Dai, & Li, 2011) at different time scales. This paper selects Baiyu debris flow in Qujiang District as the research object, evaluates the basic characteristics and cause conditions of debris flow, carries out the chain action mechanism of landslide transformation into debris flow under the action of rainfall, analyzes the starting mode and determines the early warning criterion, and explores the feasible technical method of comprehensive prevention and control (Ma et al., 2011; Ministry of Land and Resources, 2006; Zhao, Satellite, Wang, & Lei, 2020).

1.1. Base Situation

Baiwu debris flow in Qujiang District is located in the northwest mountain gully of Libaiwu Natural Village in Baiwukou Village, which occurred during the heavy rainfall on June 19, 2011. The occurrence of the debris flow is caused by the landslide of the loose rock and soil on the upper slope of the gully under the action of rainfall infiltration and surface water flow erosion. The loose landslide material is then concentrated in the gully under the action of erosion and carrying of a large number of concentrated surface water flow, and the mixed soil and rock flow is discharged, which causes the geological disasters of debris flow (Lee, 2004).

1.2. Geological Environment Background

The study area is located in the subtropical monsoon climate zone with abundant precipitation, the annual average precipitation above 1900 mm and the maximum annual rainfall of 2495.1 mm (1983), from June to mid-July and mid-July to mid-September, when the rainfall accounts for more than 70% of the annual rainfall. The debris flow gully is located in the hilly area. The plane shape of the basin is almost "tongue". Elevation is between 155 and 260 m. The watershed elevation difference is between 100 and 120 m. The trench cutting depth is between 50 and 100 m. The main ditch is more obvious. Near the east-west direction, long, steep, the relative height difference is about 70 m. The horizontal length is about 240 m. The average longitudinal slope drops at 350‰. The cross-section is of a "V" type. The relative height difference between the mountains on both sides of the gully is 50 - 100 m, At 25˚ - 40˚, vegetation development is generally in general. The relative elevation difference of the downstream gully mouth area is between 5 and 15 m. The overall terrain is high in northwest and low in southeast, terrain slope of, within 10˚, mainly for the village residential area.

The stratum lithology of this area is mainly the Lower Cretaceous Xishan Head Formation (K1x) tuff and the Quaternary loose deposits. The lithology of mountain slope is gray and black rhyoid molten tuff, block structure, exposure is medium weathering, fissure development is general, rock mass structure integrity is good, the local section fissure development is dense, the rock mass structure integrity is poor, the upper strong weathering layer is loose sand with silty clay, thickness in about 0.5 - 1.0 m. The mountain surface is covered with gray brown, earth yellow with gravel silty clay, loose structure, plastic, medium compressibility, gravel content is about 10% - 25%, particle size is generally about 1 - 5 cm, local large can reach about 5 - 15 cm, the thickness is generally about 0.5~1.5 m, the terrain depression thickness is about 1.0 - 3.0 m, the downstream gully area slow terrain is 2.0 - 4.0 m. In the front side of the village, the lithology is gray brown and yellow gravel silty clay, with the thickness of between 3.0 and 5.0 m (Li et al., 2018; Lin, 1958).

2. Basic Characteristics and Evaluation of Debris Flow

2.1. Basic Characteristics of Partition

Debris flow gully watershed form is small watershed closed, watershed area of 0.025 km^2, from the back edge mountain slope to gully downstream gully area, the overall terrain gradually reduced, gully is located in the mountain valley, is a narrow strip, for debris flow source formation and main circulation area, the downstream gully area is relatively low slow and debris flow loose solid material accumulation in open area. On the whole, the debris flow area is restricted by certain terrain, the perimeter of the basin is relatively clear, and the partition has a certain sense of hierarchy.

1) Formation area

The debris flow formation area is located in the elevation range of 230 - 240 m in the upstream of the main ditch, with the horizontal length of 20 - 30 m and the relative height difference of 10 - 15 m. During the heavy rainfall of 2011 June 19 of the mudslide, landslide in the loose rock and soil of the formation area (**Figure 1(a)**), The width of the sliding collapse area is 15 - 25 m, slope surface oblique long 20 - 30 m, plan area of 300 - 350 m^2, slide body thickness: 1 - 3 m, the square quantity of the landslide material is 450 - 500 m^3, main slide direction, 140˚, for the small shallow rock soil landslide, due to the loose rock and soil (mainly containing gravel silty clay with sand) along the underlying stress shear weak surface (**Figure 1(b)**). It is the initiator source of debris flow formation. At present, the loose rock and soil thickness is 1.5 - 3.0 m, the landslide area is 15 - 25 m wide, the slope length is 20 - 30 m, and the plane area is 300 - 400 m^2, and the estimated hidden mass is 550 - 650 m^3. The landslide can constitute the starting source of debris flow again.

2) Circulation area

The elevation of the gully circulation section is between 170 - 230 m, the relative height difference is about 60 m, the gully is long and narrow and straight, the horizontal length is 160 m, the average longitudinal slope drops at about 350‰, the cross section is "V", the relative height difference of the mountains on both sides of the gully is 50 - 100 m, and the slope slope is about 25˚ - 40˚. After the landslide in the forming area, a large number of surface water flow along the gully to the lower circulation, a large number of debris flow material from the upstream of the gully to the downstream of the gully and the gully area, the gully is mainly circulation, local scraping and roll. The debris flow material is mainly loose gravel with sand soil, the mud and sand are mostly carried away by

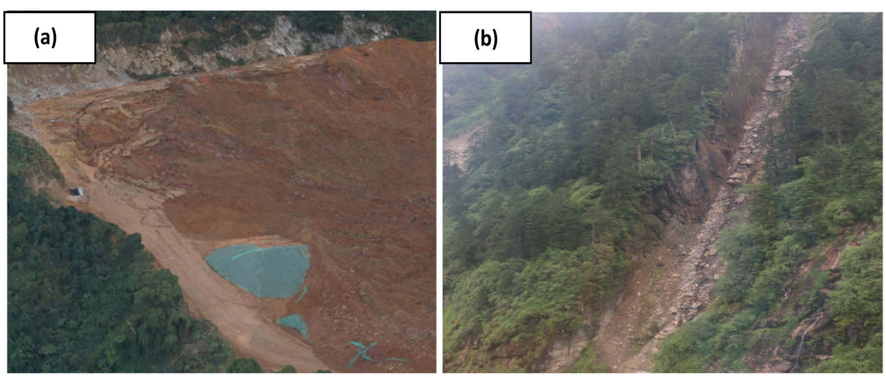

Figure 1. Overview of landslides formed upstream.

the later torrent, disorderly and directional and sorting, it can be seen that the fluid nature is mainly sparse broken (block) stone with mud and sand mixture.

3) Accumulation area

The elevation of the accumulation area is between 155 and 170 m, the relative height difference is 5 - 15 m, the overall terrain is high in the northwest and low in the southeast, the terrain slope is within 10˚, which is mainly the concentrated residential area of the village. Due to the open terrain and the reduction of the terrain height difference, the accumulation is mainly concentrated in the area. To sum up, it can be seen that Baiyu debris flow is a low frequency, one-time burst scale of small, sparse, gully debris flow, from the analysis of the formation and initiation mechanism of (Qin, 2015).

2.2. Evaluation of Prone Degree

Due to the favorable landform conditions, combined with the upstream area of loose rock and soil and landslide adverse geological distribution, under the action of even heavy rain, a large number of concentrated surface water infiltration, erosion of loose solid source and unstable landslide, and a large number of surface water flow with loose material along the circulation, handling and even carrying roll, and start along the ditch, according to the exploration specification and debris flow prone comprehensive evaluation table, that low prone debris flow.

2.3. Scope and Extent of Harm

The risk area of debris flow includes the formation area, circulation area and accumulation area, which is the main disaster-causing area of debris flow. The landslide hidden body and loose rock and soil matter still remain. The landslide can form again under the action of heavy rainfall, and the hazard degree is relatively large.

3. The Chain Action Model of Landslide Flow

Landslide formation start debris flow refers to under the action of heavy rainfall, forming area slope loose rock and soil in rainwater or surface water infiltration saturation and erosion, strength and liquefaction instability landslide, loose material mixed with a large number of surface water flow along the gully below circulation and excretion, to form the process of start debris flow (Zhang, Hu, Tan, & Cui, 2009).

Balance Equation of Rock and Soil Mass Instability

According to the analysis, the loose rock and soil bodies accumulated or distributed on slopes or ditches are simultaneously subjected to unstable shear force and skid force resistance action (Cheng & Li, 2015), as shown in **Figure 2(a)**, and the relevant basic assumptions are as follows:

1) The stability of the slope body is the plane strain problem;

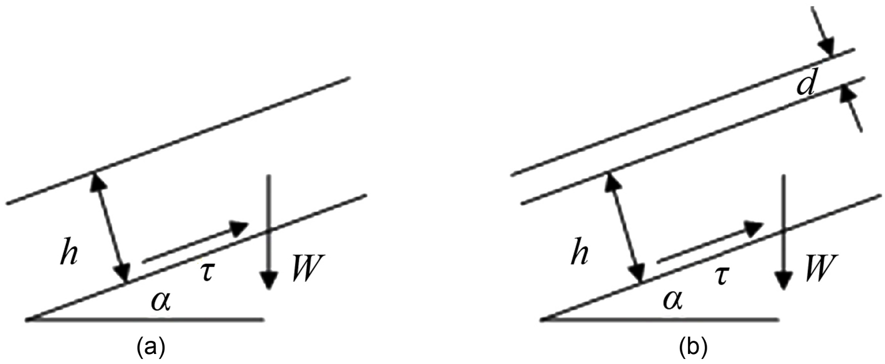

Figure 2. Generalized calculation model of loosely packed soil layer mechanics.

2) The stability coefficient on the potential sliding surface (i.e. the property difference surface or stress weak surface in the lower part) is a certain value, defined by the ratio of sliding force, and the resultant force line of all loads acts on the shape of the loose rock and soil body;

3) When the rainfall is greater than the infiltration rate of rock and soil mass, After the surface rock and soil reach saturation or oversaturation, it gradually seeps vertically to the unsaturated zone, and produce the surface runoff, so only consider the influence of gravity and the tangential force of the surface runoff on the slope;

4) The groundwater is relatively small, and the impact force of rainfall is not affected by the environment.

According to the above model, the unstable sliding force of the loose rock and soil body on the slope or ditch v:

$$\upsilon = W\sin\alpha = \gamma h\sin\alpha \tag{3-1}$$

Formula: W is accumulation mass weight; α is slope or channel inclination; γ is accumulation mass heavy; h is accumulation mass thickness.

Considering the distribution of pores in the loose accumulated rock and soil bodies, the upper formula can be converted into

$$\upsilon = h\left[\gamma_d\left(1-n\right)+\gamma_w\eta_e n\right]\sin\alpha \tag{3-2}$$

Formula: γ_d is the dry mass of accumulated rock and soil; n is the accumulated porosity; γ_w is the water mass; η_e is the water filling coefficient of the pore, whose value is 1 when the pore is completely saturated by water.

The sliding force for loose accumulation is τ:

$$\tau = W\cos\alpha\tan\varphi + C = \gamma h\cos\alpha\tan\varphi + C \tag{3-3}$$

$$\tau = h\left[\gamma_d\left(1-n\right)+\gamma_w\eta_e n\right]\cos\alpha\tan\phi + C \tag{3-4}$$

Formula: c is the cohesive force of the potential sliding surface; φ is the internal friction angle of the potential sliding surface.

Under the action of heavy rainfall, the loose accumulation is gradually infiltrated and saturated, and the surface runoff occurs on the surface. The unstable sliding force should consider the action of the surface runoff d (see **Figure 2(b)**), and the unstable sliding force of the loose accumulation is

$$\upsilon = (W + \gamma_w d)\sin\alpha = (\gamma h + \gamma_w d)\sin\alpha \tag{3-5}$$

$$\upsilon = \left\{h\left[\gamma_d (1-n) + \gamma_w n\right] + \gamma_w d\right\}\sin\alpha \tag{3-6}$$

Formula: W is the accumulation weight after water filling; γ is the accumulation weight after water filling; d is the runoff depth.

Accordingly, the anti-skid force when the loose accumulation body is saturated under heavy rainfall is

$$\tau = (W + \gamma_w d)\cos\alpha\tan\phi + C = (\gamma h + \gamma_w d)\cos\alpha\tan\phi + C \tag{3-7}$$

$$\tau = \left\{h\left[\gamma_d (1-n) + \gamma_w n\right] + \gamma_w d\right\}\cos\alpha\tan\phi + C \tag{3-8}$$

According to the anti-sliding force and instability sliding force of the loose accumulation body along the potential sliding surface, the instability balance coefficient K of the loose rock and soil body in the forming area can be determined to be

$$K = \frac{\tau}{\upsilon} \tag{3-9}$$

From the formula: 1) $K < 1$, under the action of heavy rainfall, the loose accumulation instability landslide formed the debris flow; 2) $K > 1$, the loose accumulation is basically stable state; 3) $K = 1$, it is in critical state.

Under actual circumstances, combined with the loose accumulation basic physical and mechanical properties parameters, can be established under the action of heavy rainfall, gully formation area loose rock and soil in the surface water infiltration and saturated and surface runoff, the strength of reduced and liquefaction instability landslide, start the instability of debris flow balance equation is:

$$K = \frac{\tau}{\upsilon} = \frac{\left\{h\left[\gamma_d (1-n) + \gamma_w n\right] + \gamma_w d\right\}\cos\alpha\tan\phi + C}{\left\{h\left[\gamma_d (1-n) + \gamma_w n\right] + \gamma_w d\right\}\sin\alpha} \tag{3-10}$$

4. Debris Flow Control Countermeasures

According to the above analysis of the action mechanism of debris flow, the prevention countermeasures of landslide conversion debris flow include as follows:

Cut and Drainage of Loose Source Area System

Build drainage system in the potential landslide area and nearby areas in the upstream of the gully, mainly including:

1) builds intercepting ditch at the rear edge, by-topographic conditions, effectively divert the converging slope water flow next to the field area, avoid entering potential landslides;

2) makes full use of terrain and natural valleys, "Dendritic" drainage system, in order to prevent surface water erosion and infiltration into the slope;

3) excluding the groundwater inside the slope can effectively reduce the water content of rock and soil and improve its effective stress, promote slope body stability, horizontal drainage hole and blind drainage ditch can be used, if necessary, it can be used in combination with gravity gear;

4) cuts surface runoff and groundwater through siphon drainage technology, set the blind ditch and collecting pool at the rear edge of the potential landslide area, the diversion pool is set up in the stable zone of the ditch side slope below it, a siphon drainage pipe is set in the top collecting pool to drain the water flow into the lower diversion pool, then the siphon drainage pipe is set up from the diversion pool to drain the water flow to the current ditch in the accumulation area of the ditch mouth.

5. Conclusion

In summary, the chain action model of debris flow initiated by landslide transformation and the liquefaction instability of loose material source under rainfall are constructed. The equilibrium equation is used to analyze the influence of the change of internal water content of rock and soil on its shear strength, sliding trend and overall stability, and to determine Early Warning Criterion for Starting Debris Flow Caused by Landslides, Implementation of System Drainage in Loose Source Area and Rock and Soil for Starting Debris Flow Caused by Landslides. The prevention countermeasure of real-time dynamic monitoring of body water content provides a simple, reliable and feasible way for the comprehensive prevention of landslide transformed debris flow Effective disaster prevention ideas and technical methods.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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