The Disaster Mechanism And Stability Evaluation Of Hanhe Landslide

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Abstract: Base on the treatment project Hanhe landslide, the mechanism of rainfall-induced landslide was carried out. SRM was used to analyze the stability of the landslide in the natural state and the rain state. The influencing factors of the landslide and the safety and stability of the landslide were analyzed. The research results are as follow: (1) Hanhe landslide body is developed in Wu dong Huang dong kou Formation (∈h) mudstone and silty mudstone, so the rock is highly weathered and easily softened by water. (2) According to this survey and the stability calculation, it shows that the Hanhe landslide is in an unstable state during heavy rain, and the shallow landslide is in unstable state. The theoretical analysis is basically consistent with the numerical results. (3) Stress is on the front edge of the landslide concentrated in the dangerous area, the landslide may continue to slide, and the trailing edge steep wall may also gradually collapse on a small scale. It is recommended to improve the drainage system and treatment measures as soon as possible. The mechanism of the landslide can provide engineering reference for the treatment and prevention of similar landslides.

1. Introductions
The causes of landslide disasters are complex and changeable, not only related to the topography, geological environment and other natural environments, but also related to external factors such as rainfall in engineering activities[1-2].

Landslide instability mechanism and stability analysis methods were carried out a lot of research at home and abroad. The landslide is caused by external forces such as erosion at the foot of the slope [3-4] or excavation [5]. Weakening or loosing with subsequent deformation and instability, the initial tensile crack splits into a large-scale sliding body. There have been many studies on the mechanism of traction landslides and corresponding treatment measures, and its action mechanism is mainly reflected in the change of hydraulic boundary conditions of landslide body [6] and the weakening of mechanical parameters of landslide rock and soil [7]. Li Xianghong [11] analyzed the causes of the heavy rain that caused the landslide in Xianshui Township, Guilin, Guangxi on May 9, 2011. The results showed that the landslide was a geological disaster induced by heavy rain. Short-term heavy rain was the direct cause of the landslide. Based on the traditional limit equilibrium method, Zheng Yingren [12] and Liu Hongshuai [13] proposed the finite element strength reduction method for slope stability analysis, and the research shows that it has good applicability.

Based on the Hanhe landslide, this paper analyzes the stability of the high mudstone slope by finite element strength reduction method (FESRM). Basis on this, the landslide deformation process was considered to provide a basis for guiding engineering practice.
2. Geological background of landslide area

2.1 Topography
The landform of the area where the landslide belongs is the middle and low mountain ridge valley, and the location of the landslide is the forward convex ridge. The elevation of the mountain peak is about 570m, the elevation of the foot of the slope is 360m, the landslide is distributed in the middle and upper part of the mountain, the distribution elevation is 360-390m, the slope of the landslide is 170°, the deformation and destruction of the landslide causes the slope to present a trailing ridge, and the ridge height is 0.5-1m. At present, the slope of the area where the landslide body is located is 25°~35°. The vegetation on the slope is mostly pine trees planted by the villagers, and the vegetation coverage on the slope reaches 80%. Han he tun lives by mountains and often has slopes to build houses, generally 2-5m high.

2.2 Lithology and engineering geological properties
The distribution of strata from the surface is quaternary residual slope product (Qel+dl) silty clay or silty clay containing gravel, and the underlying bedrock is mudstone and silty sand of Cambrian Huangdongkou Formation (∈h) Mudstone.

(1) Quaternary Pleistocene residual slope product (Qel+dl) gravel-containing clay layer
This layer is Quaternary residual slope accumulation, distributed on the surface of the slope body, single-layer structure, the thickness is generally 1 ~ 4m, lithology is yellow gravel containing silty clay or silty clay, yellow brown, hard plastic. The composition of gravel is argillaceous sandstone or mudstone, with a content of 5% to 25%, a particle size of 1 to 10cm, no sorting, and a small amount of iron nodules is found. Photos of local soil layers are shown in Figure 1.

![Fig1 Residual slope product in han he landslide](image)

(2) Cambrian Huangdongkou Formation (∈h) mudstone and silty mudstone
The rock mass is gray, gray-yellow, medium-thick layered, the upper part is 3-10m with strong weathering, it is strong cracked, the rock structure was destroyed, and the basic weathering is soil pillar. The lower part of the strong weathering is medium weathering, muddy structure. Most rock structure has been destroyed, the weathering intensity of the rock is uneven, the rock can be crushed into sand, and the core is in the form of crushed blocks and sand, with a block diameter range from 3cm to 10 cm. Photos of local cores are detailed in Figures 2 and 3.
2.3 Geological structure
The new Zhending fault is 0.5km to the north of the survey area, which is about 9km long. The new vibrating roof was cut by the Liubao double anticline. The curve is roughly obvious in the east-west direction, and there is a branch merge phenomenon. The Liubao compound anticline swelled at the east and west ends. It has small folds, few wings and many shafts, good symmetry, several hundred meters wide and several kilometers long. The north and south wings have reverse fractures, and the shaft has normal fractures and stepped fracture groups. In its bifurcation with the big fault, intrusive rock and spout rock are generated.

2.4 Hydrogeological conditions
According to the characteristics of the lithology and water-bearing medium of the water-bearing rock group, the groundwater type in the exploration area is karst rock tectonic fissure water. The groundwater mainly accumulates and migrates in tectonic fissures, and is mainly recharged by atmospheric rainfall, discharged from the mountain, discharged from the mountain. There are sporadic distribution of spring water on both sides of the gully along the river, and the exposed position is higher than the river surface. The groundwater is moderately rich in water, and the surface residual slope accumulation is moderate to weak. According to the borehole exploration, it is concluded that the groundwater level is low. According to the borehole depth measured in the borehole, the depth of the groundwater is between 0 and 15.2m, which is mostly exposed in the bedrock. However, the rainfall seepage above the soil-rock interface after infiltration into the slope during continuous rainfall. Therefore, it is believed that precipitation has a great influence on the groundwater level, and the rock-soil interface is in a saturated state during heavy rain.

3. Characteristics of landslide geological disaster development

3.1. Landslide boundary, scale and morphological characteristics
The Hanhe landslide is developed at the junction of the residual slope accumulation and the strong weathered weak structural surface, with the weak structural surface within the strong weathering as the sliding zone. The landslide is distributed in the middle of the mountain, with an elevation of 360-390m. The landslide is gentle front to back and steep, the slope of the landslide is about 35m long, the rear
edge is about 10m wide, the front edge is about 35m wide, the main sliding direction is 170°, and the area is about 600m². The body thickness is about 2m and the volume is about 1200m³. The sliding body is residual slope silty clay, and the sliding surface is located roughly in the rock-soil interface between the residual slope accumulation layer and the strongly weathered mudstone. The cracks on the trailing edge of the landslide are about 4m long, arc-shaped, with a maximum width greater than 0.2m and a strike of 85°. The cracks extending upward from the trailing edge investigation did not find new cracks, so the trailing edge cracks were designated as the trailing edge boundary of landslide.

Factors such as the composition of landslide deposits, the landslide body that has occurred is mainly composed of residual silty clay, and the sliding surface is located in the rock-soil contact surface. During the exploration, drilling revealed potential sliding surfaces with a thickness of 0.05m to 0.10m. In the natural state, the landslide is currently in a basically stable state. If local heavy rainfall occurs and surface water seeps into the ground and flows down along the potential sliding surface, the landslide will most likely experience larger-scale collapse and instability.

3.2. Deformation and failure characteristics of landslide

The surface deformation characteristics of Hanhe landslide mainly show that the leading edge forms a collapse zone. There are multiple horizontal and vertical tensile cracks and staggered ridges in the surface of the landslide body. The rear edge forms continuous tensile cracks and sliding walls. The typical section of landslides was shown in Figure 4.

(1) Features of trailing edge of landslide

① The trailing edge of the landslide is composed of a series of staggered steep ridges and tension cracks. The height of the steep ridge is about 0.2-0.6m, slope angle is about 30°-35°, there is local collapse at the front edge, and the vegetation on the slope is heavily inclined.

② The main fault wall and tension cracks are more developed, and the slopes are mostly represented by a series of small steep sills with a slope of 50°-60°. The steep sills are generally 0.3-0.5m high, and most of them retain the characteristics of the fault wall. Surface rain erosion and farming are not obvious.

(2) Sliding deformation characteristics of the upper and middle parts of the landslide
Vegetation on the hillside is developed mainly by pine trees. The vegetation coverage rate is 80%, which makes the bare soil loose and the infiltration of rain and rain increases. On-site investigation, an approximately ring-shaped crack with a length of about 10m can be seen on the slope. At present, the slope surface presents multiple steep ridges, the height of the steep ridge is generally 0.5 ~ 1m, and the local cut foot can see water seeping out under rainfall conditions, showing a planar flow, small flow, slightly muddy, and generally lasts until a few days after rain.

(3) Deformation of the leading edge of landslide
The leading edge is artificial slope cutting, the slope height is 1.5~2.5m, and the slope is greater than 40°. The slope cutting makes the slope free conditions change, to a certain extent, makes the slope stress redistribution and balance conditions change.

(4) Sliding zone
The performance characteristics of the sliding surface are not obvious. In drilling, the slip zone is inferred from differences in soil water content, degree of disturbance, flow pattern, etc. It is not very obvious, and it is believed to be due to drilling disturbance. The exploration trench exploration revealed that there was an obvious wet and soft soil zone in the residual slope layer in the landslide body, with a thickness of 5-10cm, and the soil body was fluffy and greasy by hand. The soil is squeezed locally visible mirror surface, inferred as a sliding zone. The disturbance of the soil structure above the belt is not obvious. Combined with drilling and surface investigation, this time it is considered that the sliding surface of the landslide is the rock-soil contact surface.

(5) Slide bed characteristics
The sliding bed is mainly a strongly weathered bedrock surface, and a mirror surface formed by extrusion is partially visible. This layer is distributed in the landslide area, the color is mainly grayish yellow, grayish brown, and is muddy. Rock bedding was explored in most of the sections, weathering fissures are densely developed, and the material is accompanied by mudstone or sandstone fragments. Dry drilling is difficult to drill, impact drilling is difficult to core, the core can be crushed by hands, it is easy to soften in water, and the strength is significantly reduced. The thickness of this layer is generally 5 ~ 10.0m. Based on the comprehensive drilling and coring conditions and regional engineering survey experience, it is judged that this layer of rock is relatively soft, the rock mass is relatively broken, and the basic quality grade of the rock mass is grade IV.

4. Analysis of the cause mechanism of landslide
According to the time and place of the deformation of the Hanhe landslide, the reasons for the formation of the Hanhe landslide mainly include the terrain conditions, material composition (stratigraphic lithology) of the slope body, heavy rainfall and human engineering activities.

1. Terrain conditions
The landform of the landslide belongs to the ridge and valley landform of the middle and low mountains. The relative height difference of the mountain is greater than 100m. The slope of the slope where the landslide is located is 30°-40°.

2. Formation lithology
The landslide was covered with Quaternary residual slope soil layer. The lithology is silty clay and gravel. Due to the planting of pine trees on the slope, the vegetation was destroyed, and the application of herbicides makes the surface soil directly exposed. The water permeability is good; the lower part of the weathered mudstone is water-proof. After the rainfall infiltrates the slope body, the slope soil is easily saturated, which further reduces the strength of the soil body and is prone to slip under the action of gravity.

3. Rainfall
Rainfall is closely related to the activity of this landslide, and it is the main motivating factor for landslide activity. Rainfall is concentrated in the working area, with an annual rainfall of 1600mm, especially in the rainy season, extreme rainy weather occurs from time to time, short-term strong rainfall and continuous strong multi-day rainfall and other rainfall characteristics reduce the shear strength of the soil layer, which is not conducive to the stability of the soil. On the one hand, the
weight of the saturated soil increases, on the other hand, the slope soil is softened, and the slope stability decreases under heavy rainfall, especially the local slope, which triggers the instability of the slope rock and soil to form a landslide. According to a survey visit, the Hanhe landslide occurred during heavy rainfall.

4. Human engineering activities

The crops on the landslide are cultivated, the vegetation on the slope is destroyed, and the surface water is infiltrated. The middle of the slope is a steep ridge, and the dynamic load of the vehicle affects the stability of the landslide.

5. Slope stability analysis

5.1 Model establishment and parameter selection

According to topographic and geological conditions, the most typical and most unfavorable slope stable section is selected as the calculation research section. The upper soil layer is clay, followed by fully weathered mudstone, strongly weathered mudstone, and moderately weathered mudstone. The calculation model is shown in Figure 5. The soil body adopts the M-C constitutive model. The left and right sides of the model are constrained, the bottom is constrained, and the upper part is free. The physical and mechanical parameters of the soil layer are shown in Table 1.

| Parameter Lithology | γ(kN/m³) | Shear strength |
|---------------------|----------|----------------|
|                     | Dry      | Saturated      | Dry c (kPa) | φ (°) | Saturated c (kPa) | φ (°) |
| Silty clay (①)      | 18.80    | 19.10          | 33.40       | 11.10 | 21.40            | 14.30 |
| Slippery soil       | 18.80    | 19.10          | 33.40       | 11.10 | 21.40            | 14.30 |
| Strongly weathered mudstone (②) | 19.3    | 19.54          | 21.40       | 14.30 | 7.90             | 12.00 |

5.2 Results analysis

It can be known from the calculation of the standard method and the strength reduction method that the Hanhe landslide is in a stable state under natural conditions; it is in an under-basic stable state under rainfall conditions. According to this survey and investigation combined with stability
calculations, the overall landslide in Hanhe was in an unstable state during heavy rain. Its development trend is mainly: the clay layer has strong water permeability, and the weathered layer is easy to soften when encountered with water, and the landslide area is also in the area with extreme rainfall and weather. The infiltration of rainwater is easy to form a weak interlayer, which induces local deformation of the landslide and even large-scale sliding. Take engineering control measures as soon as possible.

6. Conclusions
(1) Hanhe landslide mudstone, which has a high degree of weathering and is easily softened by water. It is an easily-deformable rock layer. Under the action of water, the mechanical strength index of semi-diagenetic conglomerate is greatly reduced. Loose strata composed of strong weathered mudstone and its overlying slopes and residual slope deposits. These deposits have good water retention, which provides conditions for the long-term enrichment of surface water. Anti-seepage measures are taken against cracks to reduce surface water infiltration.

(2) According to the formation conditions, topography and stability of the landslide, combined with the overall planning of the development zone, measures such as slope cut, gravity anti-sliding retaining wall and anchor lattice are adopted for the landslide, supplemented by drainage for comprehensive treatment.

(3) According to the on-site investigation, there is a dangerous area of stress concentration at the front edge of the landslide, the landslide may continue to slide, and the trailing edge steep wall may gradually collapse on a small scale, and there is no drainage system on the slope body. Surface water overflows on the slope surface, scours the slope foot and slope surface, and induces geological disasters such as landslide collapse. Therefore, it is recommended to install a drainage diversion system within the landslide area.

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