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Stability Assessment of Water-Influenced Landslides in the Three Gorges Reservoir Area: A Case Study of the Liujiabao Landslide

Siyuan Sheng[1], Bing Yan[1,*] Min Xiao[2] and Chengze Tang[3]
[1] School of Earth and Planetary Sciences, Chengdu University of Technology, Chengdu, Sichuan, 610000, China
[2] The 7th Geological Brigade of Sichuan Province, Chengdu, Sichuan, 610000, China
[3] Sichuan Yunlixiang Construction Engineering Co., Ltd., Chengdu, Sichuan, 610000, China
Corresponding authors: (e-mail: ssy000925@163.com).

Abstract The Three Gorges reservoir area is a high incidence of landslide disasters, many landslide development law and its influencing factors are not clear, and due to the Three Gorges reservoir area for a long time by the Yangtze River water level changes, rainfall infiltration and groundwater and other factors, resulting in landslide destabilization and deformation damage in the reservoir area, the threat to the people's lives and properties, so to identify the stability of the landslide of the Liujiabao not only for the future of the study of this type of landslide to provide a theoretical basis, but also for the prediction of some potential landslides has very important significance in guiding. This paper combines the regional geological background with the results of the actual field investigation, using the transfer coefficient method to evaluate the stability of the landslide, the stability evaluation results are: 2-2 profile is now in a stable - basically stable state, the possibility of destabilization is relatively small. 1-1 profile in the reservoir water level rose to 175m and there are heavy rainfall conditions, the stability evaluation results are: 1-2 profile in the reservoir water level rose to 175m and there are heavy rainfall conditions, the possibility of destabilization is relatively small. 1-1 profile is unstable under the condition of 175m and heavy rainfall, and the rest is stable-basically stable.

Index Terms Three gorges reservoir area, water-related landslide, transfer coefficient method, stability evaluation

I. Introduction

There are three main types of landslide stability assessment methods[1], [2]: qualitative analysis, quantitative analysis and non-quantitative analysis methods.Qualitative analysis is one of the most common methods, mainly through on-site geological environment survey, investigation of surface cracks, determination of landslide boundaries, and analysis of possible deformation and failure modes of landslides (collapse, dumping, sliding, etc.), influencing factors of stability (geological structure, topography, human engineering activities, rainfall, etc.) and mechanical mechanisms of instability (creep-tensile cracking, slip-bending, etc.)[3] .Based on geological data, it analyzes the triggering factors and mechanical principles of deformation and failure that lead to slope instability through field geological exploration, and then evaluates the stability and development trend of landslides . At present, the commonly used methods include engineering geological comparison method, diagram method, genetic history analysis method, slope analysis database and expert system, SMR method, etc.[4]-[6].Quantitative analysis is based on rock mechanics and soil mechanics, using classical physical and mathematical methods to calculate the stability of landslides, the limit equilibrium method is a commonly used method, it is to cut the sliding body below the terrain line, above the potential sliding surface along the potential sliding surface into a number of oblique bars or vertical bars, one by one to analyze the force between the blocks, and establish the balance equation of moment or force, so as to evaluate the stability of the landslide[7]. The limit equilibrium method mainly includes the Swedish method, the Bishop method, the Janbu method, the M-P method, the Spencer method, the Sarma method[8], [9], etc.With the continuous change of technical means, the numerical simulation method has made great progress in the analysis of landslide stability. The numerical simulation method is to establish a model through a computer, combined with the concept of finite element or finite volume, and analyze the internal stress, strain and other characteristics of the landslide, so as to analyze the stability of the landslide.

II. Geological Background

II. A. Geographic location

The Liujabao landslide is located in Querxiang Township, Wushan County, Chongqing Municipality (right bank section of the Yangtze River), which is situated in the northeastern part of Chongqing Municipality in the E-Chongqing junction area. The Hurong Expressway, national and provincial trunk roads and internal hardened roads in Wushan County together constitute the main transportation network in the study area. The east side of Wushan County is Badong County of Hubei Province, and the west side is Fengjie County. The straight-line distance between the landslide of Liujiabaos and Wushan County is about 14 km, and the nearest point to the Hubei provincial border is 26 km, and the landslide of Liujiabaos is located in the confluence of the Yangtze River and the Xigou. The geological environment of the landslide area is complex, and there are typical geologic hazards such as Gongjiafang avalanches and slides, Shuping landslides and Baishui River landslides distributed in the surrounding area, which together constitute a cluster of geologic hazards in the Three Gorges Reservoir Area, and the location has the typical geologic characteristics of water-related landslides in the Three Gorges Reservoir Area.

II. B.Topography

The work area is located in Yueming Village on the right bank of the right bank of the Yangtze River main stream at the mouth of the Xigou River in Qixiang Township, Wushan County, which belongs to the Daxi~Sanxi low hill landscape, and the microgeomorphic features of the landslide are mainly characterized by gentler slopes, flatter platforms and steeper slopes. By constructing a three-dimensional model, it can be observed that the landslide area shows a topographic distribution of higher in the south-east direction and lower in the north-west direction, and its topographic inclination usually ranges from 20° to 35°. The central part of the slope is relatively flat, with an inclination of about 3°~5°, while the front and back of the slope are steeper, with an inclination of about 15°~20°, and the inclination in local areas is even greater, up to 20°~30°, and the back edge and both sides can be seen locally as steep canyons with slopes greater than 40° (Fig.1).

Figure 1: Schematic of Landslide Topography and Extent

II. C.Stratigraphic lithology

The exposed strata in the landslide area from new to old are: Quaternary artificial fill layer (Q_4^{ml}), Quaternary landslide accumulation layer (Q^{4del}), and the fourth member of the Middle Triassic Badong Formation (T_2b^4).

(1) Quaternary artificial fill layer(Q_4^{ml})

This layer is located in the middle of the landslide, covering the entire road and residential area. It is composed of mixed fill soil, with a variety of colors, appearing mottled and dark brown. The main components include gravel, concrete blocks, tiles, and coal cinder, among others. The particle size of the gravel ranges from 8 to 15 cm, and its content accounts for about 85%. The soil is dry and has a slightly dense structure, formed through manual backfilling and mechanical compaction. This fill soil is mainly distributed in areas with dense roads and residences, and the backfilling work has been ongoing for a considerable period.

(2) Quaternary landslide accumulation layer (Q_4^{del})

This layer is widely distributed throughout the work area and consists of gray marl, yellow-brown gravelly soil, and reddish-brown sandstones with purple-red inclusions, with a thickness ranging from 20m to 50m. The gravel mainly consists of gray marl and gray-white sandstones, with occasional sightings of purple-red mudstones. The shapes are mostly sub-angular, with a content of about 40% to 90%, and diameters generally range from 5cm to 100cm, with a few reaching 100cm to 200cm. Within the range of 0m to 5m at the surface of the landslide's leading edge, it is primarily silty clay, exhibiting hard plastic to plastic state, with moderate humidity. The study area is mainly distributed at the leading edge of the landslide area, primarily in shades of gray and yellow-brown, dominated by gravelly soil, dry, with structure from loose to slightly dense, with uneven distribution of gravel particle size and content. The thickness varies greatly, typically between 5m and 30m, and can reach 76m in the gently sloping areas of the middle and rear sections. The parent rock of the gravel is mainly gray to dark gray marl, with gravel content between 40% to 90%, and particle sizes generally range from 5cm to 200cm, with occasional sizes exceeding 300cm, primarily in sub-angular shapes.

(3) The fourth member of the Middle Triassic Badong Formation (T_2b^4)

In the Triassic Ba Dong Formation of the study area, the primary rock types are light gray and gray-green limestone, interbedded with medium-thick layers of purple-red and light gray marl. These strata exhibit thin to medium-thick layered structures, experiencing moderate weathering, with some areas showing a higher degree of weathering and developing abundant joints and fractures. In certain areas, thinly layered interbeddings of purple-red siltstone and sandy mudstone can also be observed.

II. D.Hydrogeological condition

Liujiabao landslide is located in the mountain slope area, which is a ladder form of “steep slope-gentle slope-steep slope-gentle slope” from top to bottom, and is washed and cut by atmospheric rainfall and surface water runoff.According to its distribution characteristics, the groundwater in this area can be divided into two types: pore water in loose soil layer and bedrock fissure water. The groundwater in this area is mainly composed of precipitation and domestic water used by surrounding residents, which drains down the slope and enters the Yangtze River. During the period of water rise, as the water level rises and the surface water level exceeds the depth of groundwater buried along the river bank, the groundwater below the river bank is permeated and replenished, the groundwater on the slope continues to rise with the rise of the river. And followed the water level of the Yangtze River changes, the connection between groundwater and the ground water is also changed.

II. E. Tectonics

Wushan County is located in the upper Yangtze gap platform of the Yangtze paraplatform. In Geographical, Wushan County is at the intersection point of uplift fold belt of the Dabashan Arc, the eastern Sichuan fold belt and the Sichuan-Hubei Hunan-Guizhou, which is an important component of the third uplift belt of the neocathaysian structural system, and has quite complex geological structure. The structural features here are mainly folds, and a series of parallel North-East to South-West trending anticlines and synclines occur alternately. Notable large structures include Qiyaoshan anticline, Wushan syncline, Hengshixi anticline and Guandu syncline. In the north of the temple, anticlines and synclines are roughly equal in width, and anticlines are mostly box-shaped, while the drawer syncline with a narrow or flat bottom is alternately arranged, forming a unique folding structure of slot. The fractures are not well developed, mainly distributed in the Dengjia complex anticlinal structure area. In general, the fractures are small in scale, the joints and fissures are developed, and the structural stress can change the rock and soil structure.

The landslide is located in the southeast wing of Wushan syncline, affected by secondary tectonic action, the rock strata are broken, and the cracks are filled with silty clay. The rock strata occurrence is 286°-345°∠28°-46°, and the plane bonding is poor. There are three main groups of structural cracks:

Fissure 1 occurs at 168°∠72°, the opening degree is about 1 ~ 3cm, the extension length is about 2 ~ 6m, the spacing is 0.5-1.5m, the fracture surface is straight and there is no filling.(2) Fissure 2 occurs at 305°∠81°, the opening is about 1-3cm, the extension length is 2-3m, the spacing is 0.5-1.5m, the crack surface is straight, and the local silty clay is filled.(3) Fissure 3 occurs at 26°∠86°, the extension length is 3-20m, the spacing is 0.2-1.5m, the opening is 0.5-2cm, and the fissure combination degree is poor.The structural outline map of Wushan County is as Figure 2:

III. Spatial Structure Characteristics of Landslide

Sliding mass characteristics

Through geological drilling, it can be seen that the sliding mass is mainly composed of gravel soil and silty clay (see Figure 3). The surface of the sliding mass 0-2m is mostly composed of silty clay with gravel, and the local thickness can reach 5m, which is mainly yellow brown. The gravel mother rock is mainly gray-dark gray marl, occasionally a small amount of sandstone gravel, the gravel content varies from 5-20%, the diameter of the gravel is about 1-10cm, and a small amount is greater than 10cm. The overall weathering of the gravel is strong. Below the land surface is mainly broken stone mixed with silty clay, and locally can be defined as gravel soil. Broken stone parent rock is mainly gray-dark gray marl, followed by gray-gray white sandstone, occasionally purple mudstone, the content of the breakstone is about 40-70%, and the local content can reach 80-90%.

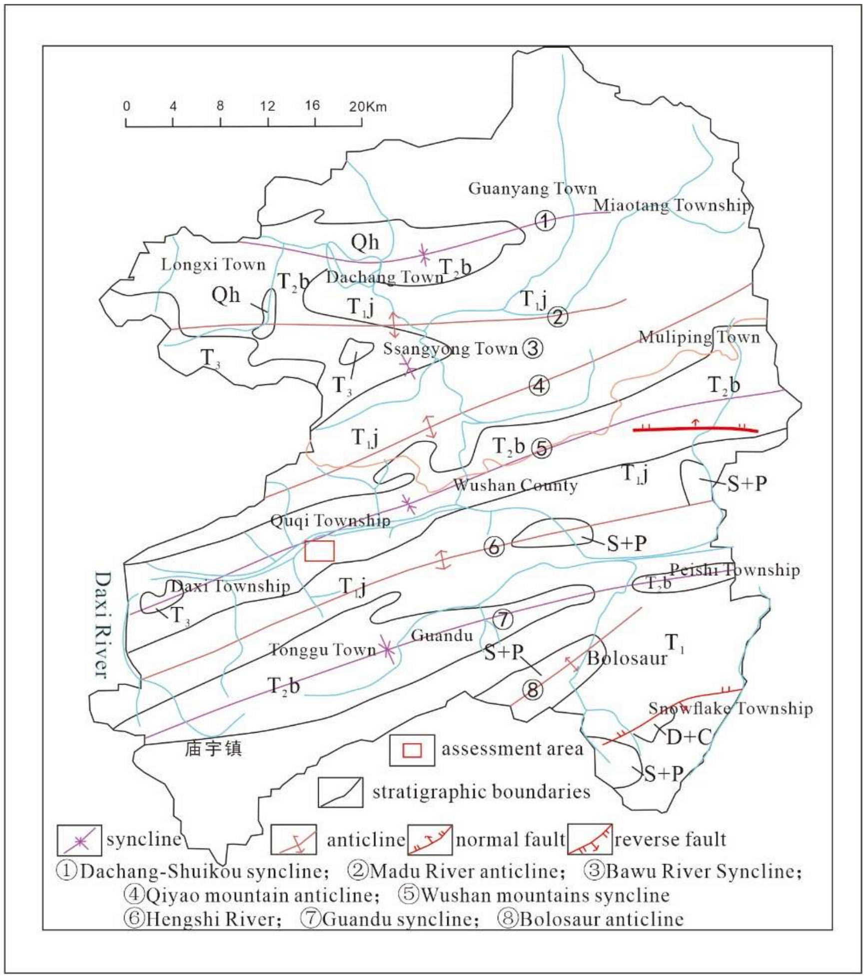


Figure 2: Tectonic outline map of the survey area

Figure 3: Silty clay with gravel

III. A. Slip zone characteristics

At present, Liujiabao landslide is in the weak deformation stage as a whole, but no obvious deformation intensification has been observed in recent years and there is no obvious through crack on the side boundary of landslide. According to the exploration, drilling ZK03 revealed slight scratches and mirror signs, drilling ZK01, ZK02, ZK04 only revealed the soft layer of gravel soil with high clay content, the gravel grinding has roundness, and no obvious signs were revealed (see Figure 4). The spatial distribution pattern of the slip zone varies greatly depending on the location. The potential slip zone revealed is yellow-brown gravel soil with loose or slightly dense structure, gravel content of about 10-20%, particle size of 1-5cm, as subangular shape, gray-black marl of the parent rock, strong weathering degree of the gravel block and easy to be dispersed by hand. At the same time, the mirror and scratch extrusion deformation signs are seen, the mirror is smooth, there is a certain reflection, and the inclination is close to the level.

There is a large amount of groundwater in the slip zone, and the rock mass in the slip zone will be affected by strong weathering after being eroded by groundwater, etc. There is a large amount of gravel in the slip zone soil, which also leads to the existence of a large number of clay particles in the slip zone soil, resulting in decline in its shear strength, which in a sense reflects the sliding state of the slip zone soil and the cause of the slip zone soil.

Figure 4: Mirror and scratch characteristics of ZK03

III. B. Characteristics of sliding beds

See Figure 5, the lithology of the slide bed is mainly composed of medium weathered marl, the surface rock layer is mostly strongly weathered, and the rock body is broken and fissured, the lower part is generally medium weathered, and the rock body is more broken ~ more complete. The field investigation of the sliding bed rock layer yield 345° ∠35°, the main slope of the terrain to 320°, the two intersection angle of 25°, is a downward relationship. The morphology of the slide bed is basically consistent with the topography, with an overall inclination of 320°, a general dip angle of 25-35°, and an average dip angle of about 30°.

a)ZK01 Slide bed lithology

b)Bedrock outcrops in the left center and rear of the landslide

Figure 5: Characteristics of sliding beds

IV. Landslide Stability Analysis

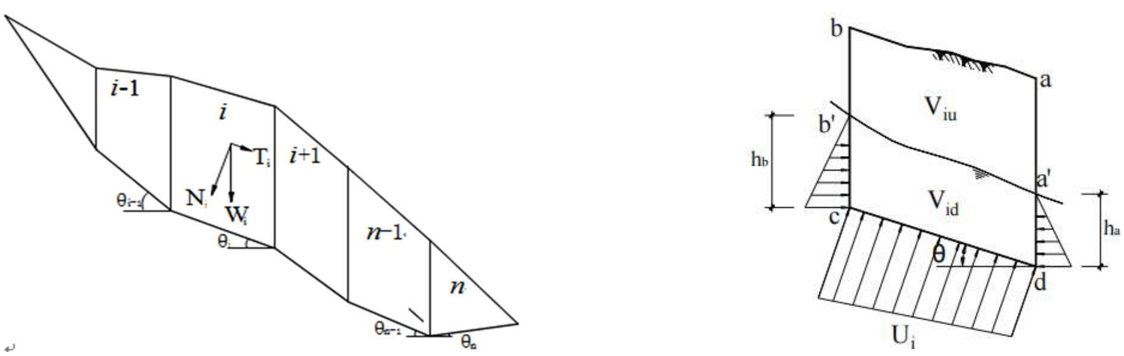
For the stability analysis of the Liujiabao landslide, the transfer coefficient method + FLAC3D numerical simulation method is adopted to systematically analyze the stability of the Liujiabao landslide, and the transfer coefficient method is chosen in the quantitative analysis because: the leading edge of the Liujiabao landslide is involved in water, and there exists groundwater on the slip surface, and the transfer coefficient method is more suitable for the calculation of the model according to the basic characteristics of the potential slip surface of the landslide as an undulating and uneven folding line type.

IV. A. Qualitative inorganic analysis

Liu Jia Bao landslide is an ancient landslide, and small landslides have occurred many times in history. Since the 1990s, the landslide deformation signs are not obvious, the landslide body range is mainly for the fragmented stone soil, the landslide body rock layer production is messy, the fragmented stone soil can be seen in the mud, calcium cementation characteristics, it is assumed that Liujiabao landslide in the past the whole for the deep rocky landslides. Three Gorges reservoir storage to 135m after the deformation signs are not obvious. Since 2006, the landslide professional monitoring work, landslide deformation in general presents nearly uniform creep and slip deformation trend, the overall deformation is small, only in the artificial cut slope section and reservoir water subsidence zone can be seen in the small-scale collapse deformation phenomenon.Recently, the deformation characteristics found in Liu Jia Bao landslide are mainly hardened surface deformation, recent local collapse deformation of the surface as well as deformation of the house cracks, as the surface of the landslide area is mostly dry land, perennial tilling has led to the original signs of cracks have been extinguished, and the past deformation of the residents of the serious housing has been relocated and dismantled, according to the existing deformation characteristics in the study area combined with the previous data analysis that Liu Jia Bao to the last time the overall deformation of the slip after At present, the whole has been in the basic stability - stable state; at present, the deformation in the landslide area is mainly caused by the local deformation and shallow surface soil deformation, mainly affected by the micro-geomorphology and rainfall.

IV. B. Quantitative analysis

The transfer coefficient method for its stability and thrust calculation model sketch is shown below (Figure 6):



a)Sketch of the computational model for the stability of a water-related landslide with a folded slip surface

b)Pore water pressure calculation model sketch

Figure 6: sketch of the computational model

The formula is as follows:

$$F_S = \frac{\sum_{i=1}^{n-1}\left(R_i \prod_{j=i}^{n-1}\Psi_j\right) + R_n}{\sum_{i=1}^{n-1}\left(T_i \prod_{j=i}^{n-1}\Psi_j\right) + T_n}$$

$$\Psi_j = \cos\left(\theta_i - \theta_{i+1}\right) - \sin\left(\theta_i - \theta_{i+1}\right)\tan\varphi_{i+1}$$

$$\prod_{j=i}^{n-1}\psi_j = \psi_i \cdot \psi_{i+1} \cdot \psi_{i+2} \cdots\cdots \psi_{n-1}$$

$$R_i = N_i \tan\phi_i + c_i l_i$$

$$T_i = W_i \sin\theta_i + \Delta P_i \cos\theta_i$$

$$N_i = W_i \cos\theta_i - \Delta P_i \sin\theta_i - U_i$$

$$W_i = V_{iu}\gamma + V_{id}\gamma_{sat} + F_i$$

$$\Delta P_i = \frac{1}{2}\gamma_W\left(h_b^2 - h_a^2\right)$$

$$U_i = \frac{1}{2}\left(h_a^2 + h_b^2\right)\gamma_W l_i$$

where, F_s - Landslide Stability Factor, ψ_i - The transfer coefficient (j=i) for the transfer of the residual downward force from the ith block segment to the i+1 segment, R_i - the ith calculated bar block slider slip force (kN/m), T_i -th i calculation bar block slider sliding force (kN/m), N_i -th i calculation bar block slide body in the sliding surface normal to the reaction force (kN/m), c_i -standard value of bond strength of the rock and soil body on the sliding surface of the ith calculated strip block (kPa), ϕ_i -standard value of internal friction angle (°) of the soil in the potential sliding zone of the ith calculated strip block, l_i -the length of the sliding surface of the i-th calculation block (m), W_i -the sum of the self-weight of the ith calculated strip and the ground load such as building (kN/m), θ_i -the angle of inclination of the bottom surface of the ith calculated strip block (°), and take negative value when it is anti-inclined, $W_i \sin\alpha_i + P_i \cos\beta_i + \Delta F_i - R_i - T_i = m_i a_i$ - the combined hydrostatic pressure on both sides of the soil body of the ith strip block (kN/m), $\beta_i = \theta_i - \alpha_i$ -void pressure at the bottom of the soil body of the ith bar (kN/m), $T_i = N_i tg\varphi_i + c_i l_i$ -water capacitive weight (kN/m3), $P_i = \gamma_W \sin\theta_i V_{id}$ -volume above the infiltration line of the unit width geotechnical body of the ith calculation strip block (m3/m), c_i -volume below the infiltration line of the geotechnical body of the unit width of the ith calculation block (m3/m), θ_i -natural bulk weight of the geotechnical body (kN/m3), α_i t-saturated capacity weight of geotechnical body (kN/m3), l_i -ground load on the ith calculated block (kN).

When the water level of the reservoir drops, the groundwater level infiltration line can be calculated according to the following formula:

$$h_{x,t} = h_{0,0} - \left(h_{0,0} - h_{0,t}\right)F(\lambda)$$

$$\lambda = \sqrt{\frac{x^2}{4at}}$$

$$\alpha = \frac{KM}{\mu}$$

$$M = \frac{h_{0,0} - h_{0,t}}{2}$$

where, $h_{0,0}$- Reservoir water level before descent (from the top surface of the diaphragm) (m), *h0,t*-the reservoir water level after the drop (counted from the point surface of the water barrier) (m), *hxt*-groundwater level (from the top surface of the water trap) at the point of calculation after the fall of the reservoir water level (m), *F(λ)*-the coefficient of influence of reservoir water level on groundwater level, *t*-The time experienced by the reservoir water level falling (s), *a*-number of hydraulic conductivity (m^2/s), *K*-permeability coefficient (m/s), *M*- thickness of aquifer (m), μ-degree of water supply, *x*-distance from the calculation point to the bank of the reservoir after the water level drops (m)

IV. C. Determination of geotechnical physical and mechanical parameters

Calculation of landslide stability through the strip method mainly utilizes the weight index of the slide body and the shear strength index of the slide zone soil, and its value process is as follows:

According to the indoor test data, the slip body (gravel soil) take the soil sample natural weight 21.0kN/m3, saturated weight 22.0kN/m^3. Combined with the value of engineering experience, the weight parameter of pulverized clay soil sandwiched with gravel soil is corrected according to the increase coefficient of 1.10, and the gravel soil is obtained: the natural weight is 23.1kN/m^3; the saturated weight is 24.2kN/m^3.

Table 1: synthesized recommended values for the slide soil weight parameter

state of affairs \ norm		Indoor experimental values	Suggested values based on regional experience
capacity(kN/m^3)	natural	21.0	23.1
	saturated	22.0	24.2

Slip zone soil shear strength values were determined using a combination of geotechnical test data, empirical values from engineering analogs, and parametric inversion results.Based on geotechnical test data, the range of natural shear strength of slip zone soils:c=23.1kPa~38.4kPa,φ=17.5°~25.6°;Saturated shear strength range:c=15.5kPa~19.6kPa,φ=10.8°~11.6°.

The parameter values of similar landslide projects in the work area were collected and organized to obtain the range of standard values of natural shear strength for gravelly pulverized clay containing soils in the work area:c=20kPa~35kPa, φ=20°~25°;ange of standard values of saturated shear strengthc=12kPa~18kPa,φ=13°~18°.

This field investigation found that the surface deformation of I area on the left side of Liu Jia Bao landslide is more and more deformation degree is stronger. I area in the back of some residential houses and hardened surface more serious cracking deformation, I area in the front of the houses and hardened surface cracking and deformation and wall tilt deformation, so the use of 1-1 'section in the most unfavorable conditions 3: self-weight + surface load + 175m water level in front of the dam + rainstorms according to the lack of stability of the inversion, stability coefficient of 1.04.

Combined with the experience of similar landslides in the Three Gorges reservoir area of Wushan County, the potential slip surface shear strength parameters of the Liu Jia Bao landslide are comprehensively determined. According to the above synthesized value taking method, it is suggested that the physical and mechanical parameters of the soil in the slip zone are as follows:

Table 2: Suggested values for slip-strip shear strength parameters

Category	natural		Saturation		weighting factor
	c(kPa)	*φ*(°)	*c*(kPa)	*φ*(°)	
inverse analytical value	-	-	16.77	24.20	0.8
analogous empirical value	24.7	33.0	16.5	27.0	0.2
Calculate the synthesized value	24.7	33.0	16.72	24.76	

IV. D. Calculate the operating conditions

Liu Jia Bao landslide for water-related landslides, from the geological conditions, triggering factors and deformation and other factors, the main factors affecting the stability of landslides for rainfall and changes in the reservoir level, combined with the actual study area, the use of the transfer coefficient method of the stability of landslides are calculated for the following five working conditions:

Case 1: self-weight + surface load + current water level.

Case 2: Self-weight + surface load + static water level of 145m in front of the reservoir dam + heavy rainfall.

Case 3: Self-weight + surface load + static water level of 175m in front of the reservoir dam + heavy rainfall.

Case 4: Self-weight + surface load + 175m static water level in front of dam down to 145m static water level.

Case 5: Self-weight + surface load + 175m water level in front of dam down to 145m water level + heavy rainfall.

Theoretical calculations of different profiles of landslides in five working conditions were carried out to obtain the stability coefficients of two profiles under different working conditions, Fs. According to the relevant engineering specifications, as shown in Table 3

Table 3: Steady-state classification

Stability coefficient(Fs)	Fs<1.00	1.00≤Fs<1.05	1.05≤Fs<Fst	Fs≥Fst
stability	instability	Lack of stability	Basically stable	stable

In the table, the Fs landslide safety factor, which is taken as 1.15 for Case 1, Case 2 and Case 3; and 1.10 for Case 4 and Case 5.The stability calculations for the 1-1' and 2-2' profiles are shown in Table 4:

Table 4: results of stability calculations

landslides	Profile number	Potential slippery surface	Case	Stability coefficien	Safety	stability decide	Residual sliding force(KN/m)
Liu Jia Bao landslides	1-1' profile	Deep potential slippery surface	Case 1	1.27	1.15	stable	0
			Case 2	1.09		Basically stable	9572.58
			Case 3	1.04		Lack of stability	3799.80
			Case 4	1.11	1.10	stable	0
			Case 5	1.07		Basically stable	4845.46
	2-2' profile	Deep potential slippery surface	Case 1	1.37	1.15	stable	0
			Case 2	1.11		Basically stable	8142.61
			Case 3	1.13		Basically stable	5333.94
			Case 4	1.25	1.10	stable	0
			Case 5	1.08		Basically stable	3451.64

Through the stability calculation, the overall Liujiabao landslide is in a stable-basically stable state. The left side Ⅰ area is in the basic stable state under the conditions of working condition 1, 2, 3, 4 and 5, and is in the unstable state under the condition of working condition 3. The right side Ⅱ area surface powdery clay sandwiched with crushed stone soil sub-slip surface is in a stable state under working conditions 1 and 4, and is in a basically stable state under working conditions 2, 3 and 5, and the conclusion of the calculation is basically in line with the analysis of the field investigation and professional monitoring.

IV. E. Analysis of landslide stability sensitive factors

The shear strength sensitivity analysis was carried out on the potential sliding surface of the 1-1' profile under condition 5 (self-weight + surface load + 175m water level in front of the dam to 145m water level and heavy rain in 20 years during the flood season), and the results are shown in the following table for shear strength sensitivity analysis, and the results are shown in the following table. It can be seen from Fig. 7~Fig. 8 that there is an obvious linear relationship between c, φ value and stability coefficient, the angle between the Fs-c relationship curve and the horizontal axis is smaller than that between the Fs-φ relationship curve and the horizontal axis, and the stability of the landslide is more significantly affected by the φ value than by the c value, and is more sensitive.

Table 5: Sensitivity analysis results table

Φ(°) c(kPa)	22.5	23	23.5	24	24.5	25	25.5
15.5	0.959	0.982	1.005	1.029	1.053	1.077	1.101
16	0.96	0.983	1.006	1.03	1.054	1.078	1.102
16.5	0.962	0.985	1.008	1.032	1.056	1.08	1.104
17	0.963	0.986	1.009	1.033	1.057	1.081	1.105
17.5	0.965	0.988	1.011	1.035	1.059	1.083	1.107
18	0.966	0.989	1.012	1.036	1.06	1.084	1.108
18.5	0.968	0.991	1.014	1.038	1.062	1.086	1.11

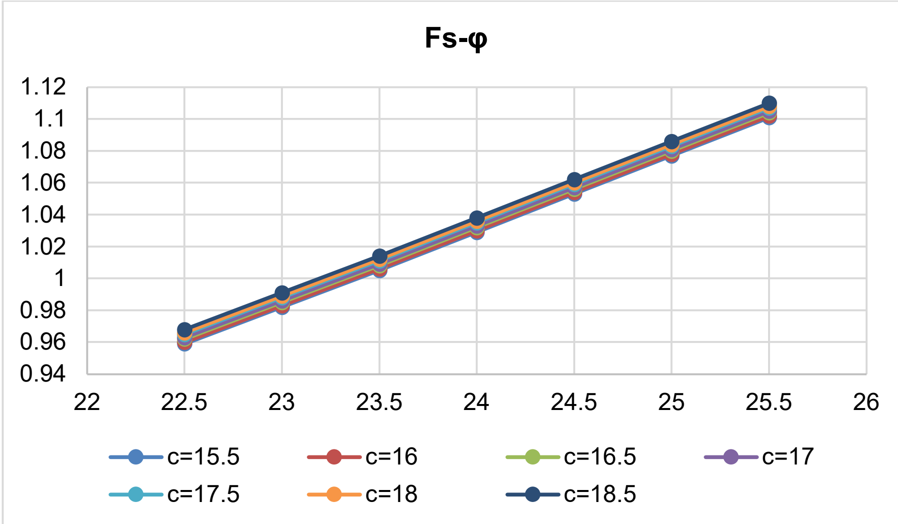


Figure 7: Sensitivity analysis of Fs-φ relationship curves

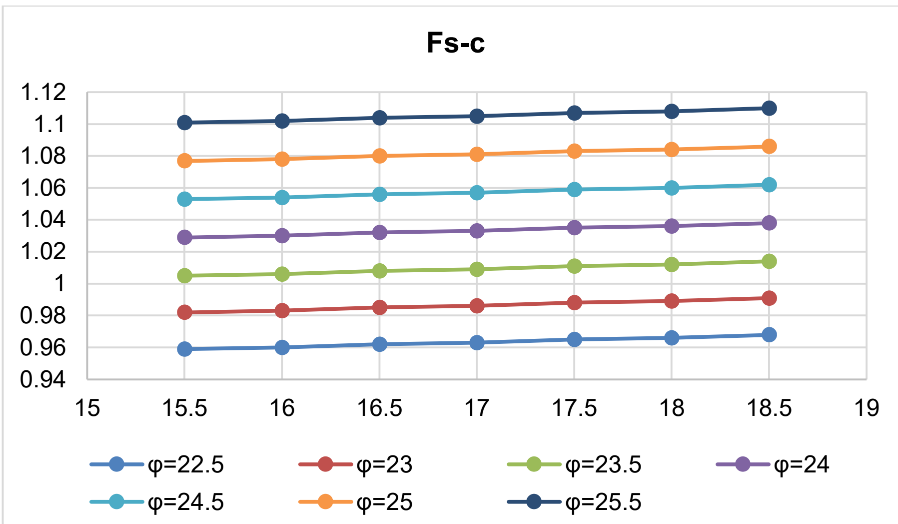


Figure 8: Sensitivity analysis Fs-c relationship plot

V. Conclusion

This chapter focuses on evaluating the stability of the landslide in Liujiabao, and adopts the method of qualitative + quantitative analysis to evaluate the stability of the landslide respectively, and the specific results are as follows:

(1) Liu Jia Bao landslide deformation in the current landslide area is mainly caused by local deformation and shallow surface soil deformation, mainly affected by micro-geomorphology and rainfall, according to the existing deformation characteristics of the landslide area combined with the previous data analysis that Liu Jia Bao to the last time the whole slip deformation is now in a basic stable - stable state;

(2) According to the transfer coefficient method to calculate the stability of the landslide results can be seen, in five different conditions, the landslide is in a basic stable - stable state, but in the reservoir level rises to 175m and the existence of heavy rainfall conditions, the landslide is in the unstable state.

(4) Combined with the recent deformation characteristics of the Liujiabao landslide and the stability evaluation results, the current status of the landslide is more dangerous area in the middle and back section of the landslide, Liujiabao landslide, if followed by the influence of unfavorable working conditions, the landslide leading edge destabilization will be more serious, and the landslide area within the human engineering activities will also exacerbate the destabilization of the landslide, which may result in the intensification of the landslide creep-slip deformation.

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