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The Research of the Attenuation Law about the Climbing Height under the Action of Landslipe Surge

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Abstract: Based on the formation of the reservoir landslide and the factors affecting the size of the surge , we have known the principle of the energy exchange between the solid and the liquid. At last, we choose the reservoir area of three gorges to simulate the generalized model experiment. After integrated and analyzed the experimental data, we used the analysis method of multiple regression to fit data. We got the relationships between the reservoir depth, width of landslide, dip Angle of landslide and the swell biggest climb in the other side .We found the attenuation law of the climbing height along the bank. We compared the calculated values of the fitted empirical formula with the measured data in the experiment. The results show that the fitted formula has certain reliability .This can provide certain reference basis to foreshore the damage to the bank slope and prevent the safety of the people along the bank.

Keywords: Land slide surge; Climbing height; Bank slope; Attenuation law

1. Introduction

With the impoundment of the three gorges reservoir ,the water level has changed frequently between high water and reservoir water. The bank slope of the reservoir is vulnerable to landslides. Accompanied the landslide , the surge will have damage to the dam and buildings in the ashore. It is a threat to the life and property of the people along the coast. In addition, with the continuous development of shipping industry, the reservoir vessels increased. Huge surges accompanied the landslide could overturn the ship and even make the ships sank. Therefore, it will cause huge casualties and economic losses. The stones and soils sliding in the water will be a threat to the passing ships and even block the sailing of the ships. The climbing of surge result from the interaction between swell and slope of the bottom. The occurrence of the big landslides have a great impact on the other side. It also causes damage to the human and the economy. Due to the limitation of channel width, the other side will be the area that first into damage. So the research of the attenuation law of the climbing height along the bank can offer reference for the prevention of surge disasters.

About the climbing height of the wave, predecessors have done some research. Wang Yang[3] considered the slope toe and climbing azimuth when studied the formulas for calculating the climbing height. The estimations of climbing height are given. The results show that the climbing height will decreases with the increase of slope gradient and the azimuth Angle of climbing .Through physical model experiment, Chen Guo-ping [4] studied the influence that the wave steepness , incident Angle and the width of platform have on the climbing height . He got the computational formula of seawall structure and different conversion relations of accumulation rate. Liu Zhou [5].analyzed the comprehensive influence of the angle that the wave got in and wave steepness, slope angle. He proposed a new method that use the equivalent grade to study of oblique waves. From the above researches, we know that the previous study about the swell climb are on the plain reservoir and seawalls. The studies on the surge of landslide in the mountainous areas are very little.

We select the landslide in the three gorges reservoir as the research .Considering the main factors such as the dip angle, width, thickness of the landslide. We obtained the computational formulas of the biggest climbing height in the other side and the attenuation law of climbing height along the bank .These provide the certain reference value for the regulations of the revetment engineering and the prevention for the damage of the surge.

2. The Experimental Designs

2.1. The selections of experimental factors and the determination of schemes

The scale of the generalized model test is 1:70.Combined with the model scale of the experiment and the convenience of operation, the landslide is made into a rectangle. Considering the limitations of the landslide own, the landslide is not whole sliding into the water when the landslide occurs. One part of landslide will accumulate on the surface of the water, so the length of the landslide is fixed to 1 m.

(1) The selection of the geometry parameters

We control the volume of the landslide by changing the length and width of landslide. Combined with statistical analysis of the generous rato in the actual landslide, we found the slide thicknesses are 0.2 m, 0.4 m and 0.6 m. The widths of sliding body are 0.5 m, 1.0 m and 1.5 m.

(2) The determination of sliding inclination

By analyzing the statistical data of sliding inclination happened in the reservoir area, we found that the sliding angle is between 20 to 60 degrees. So the sliding angles in the model test are 20 ,40 and 60 .

(3) The determination of the riverbed slope that the landslide sliding into the water

Even though the actual landslide slopes are not the same, they are big and small. When the riverbed slope is 90 degree, the degree of exchange between bed slope landslide and water is greatest. The energy that the friction consumed between the landslide and the bed is the smallest. Considering the most unfavorable situation, the bed slope that the landslide sliding into the water is 90 degree.

(4) The selection of state that the landslide closing to the water

In landslides, considering the contact states between the landslide and the water surface, there are three kinds of circumstances. They are overwater, underwater and nearby water. Considering the actual situation, the potential energy of the landslides only have relations with the volume of the landslide and the angle of the slide body sliding into the water when we fixed the leading edge of the landslide just contact with the surface of the water.

(5) The selection of the experimental water depths

Water levels in the runtime of the three gorges reservoir are mainly 145 m, 155 m, 175 m. The average elevation is about 93.55 m at the bottom of the reservoir area. Considering the actual operation of reservoir and the water depths, we determine that the experimental water depths are 0.74 m, 0.88 m and 1.16 m according to the geometric scale. Considering the above factors, the experimental schemes of landslide surge are shown in the below Table 1.

(6) The determination of experimental types

Combined with the considering factors when design the landslide model ,this experiment adopts single factor to design the experimental schemes. The number of the experimental types is 81.

Table 1. The experimental schemes of landslide surge

Factors	Levels		
sliding surfaces	20 °	40 °	60 °
water depths (m)	0.74	0.88	1.16
widths of landslide (m)	0.5	1.0	1.5
thicknesses of the landslide(m)	0.2	0.4	0.6

2.2. Model designs

(1) Channel model

River is mainly used to simulate the curved reach and the generalized object is the wharf of wan zhou jiang nan Tuo kou. The generalized channel plan is as shown in the below Figure 1.

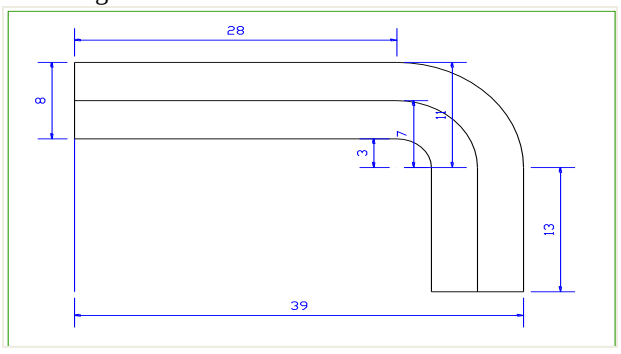

Figure 1. Generalized channel plan

(2) Chute, carriage and landslide

① chute

The chute is made of iron materials and the bottom iron plate is used to simulate the sliding surface. Considering the easy operation of the fall of the landslide and the length of the slide, the length of the chute is limited to 2 m. The baffle widths on both sides can change and the changing range is from 0.5 m to 1.5 m.

②landslide

Landslide is based on the similar density. We use the average density of sandstone and mudstone to make different sliding bodies. According to the experimental proportion, We simulated the whole landslide. The Chute and carriage is shown as Figure 2. The model diagrams of sliding blocks is shown as Figure 3.

2.3. Measuring technology

For the measurement of the climbing height[6], We lay measuring tapes in each measuring section and fined sand on the measuring tape in high water levels. The climbing height is known by reading the distance of the fine sand that the landslide surge wash away. We lay fine sands on the bank slope of measuring points along the water bank in low water level. We read the distance between the sand and the water surface after the landslide enters the water. In the last, measuring data are transformed into vertical climbing data according to the slope of the cross section.

Figure 2. Chute and carriage

Figure 3. Model diagrams of sliding blocks

Experiment is composed of five measuring point of climbing height. 1 # point of landslide is in the other side and is also the biggest climbing position. The arrangements of the rest measuring points are as follows Figure 4.

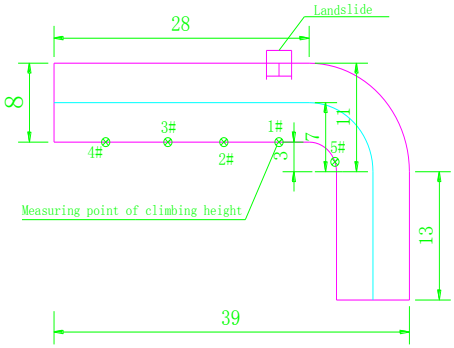

Figure 4. Climbing arrangement of measuring points

3. The analysis of experimental data

3.1. The calculation of the biggest climbing height in the other side of the landslide

When the landslide surge come to the bank slope, the distance between the elevation that the water climbed along the slope and the elevation of static water surface is caused climbing height of wave .Crest elevation is determined by the climbing height of wave in the revetment engineering and the design of breakwater. It has a direct influence on the safety and the cost of the engineering .So the research about the climbing height of landslide surge is of important value. Climbing height of wave is a result of the comprehensive action of wave force and bank. This article is main research the impact that the thickness, width of landslide and sliding surface inclination have on the swell climb. Through the study of the preliminary analysis of the test data, we found that the biggest climbing height is opposite to the landslide. Handling maximum climb R , width w and thickness b and depth h by means of the dimensionless method, we got the values of R/h, w/h ,b/h and β . We Respectively used linear function, power function and exponential function for multivariate function fitting and probed into the relationship between the maximum climbing, landslide width, thickness, depth and the slope of sliding body. In the last, We got the following three empirical formulas.

$$R_{\max}/h = 0.0534w/h + 0.0095b/h + 0.0411\beta + 0.0012 \quad (1)$$

$$R_{\max}/h = 0.1032\left(w/h\right)^{0.6131}\left(b/h\right)^{0.1117}\beta^{0.3116} \quad (2)$$

$$R_{\max}/h = 0.02926e^{0.6071w/h+0.0854b/h+0.4591\beta} \quad (3)$$

In the formula, h is the depth of the water; R is vertical height of the biggest climbing height based on static water; W is the width of the landslide; B is the thickness of the landslide; β is the inclination of the sliding surface.

Through the comparison and analysis of three empirical formula (Table 2), we found the formula (2) has the higher calculation accuracy .So we chose the regression fitting of power function as the empirical formula of the climbing height. For the calculation of the biggest climbing height of the landslide in experimental volume, the formula is suitable. For the calculation of the biggest climbing height of the landslide in larger volume , it has certain reference values.

Table 2. Formula analysis

Statistical indicators	Sum of squared residuals
The formula (1)	0.189
The formula (2)	0.125
The formula (3)	0.214

3.2. The attenuation law of climbing height along the straight

In the different water depths, the values of the each point of the climbing height on the other side also have certain differences. Using multivariate nonlinear regression and data-fitting, we get the empirical formula of attenuation law of the climbing height along the bank. The correlation coefficient is 0.97.

$$R_r/h = (R_{\max}/h)\ e^{-0.071x/h} \quad (4)$$

In the formula, R_r is the value of climbing height along the straight; $R_{\max}$ is the biggest climbing height on the side of the landslide; x is the distance between somewhere along the bank and the largest climbing height; h is the channel depth;

As you can see from the formula, because of the effects of scattering viscous resistance, air resistance and water

resistance in the process of the surge propagation, the climbing height will decrease quickly with the increase of propagation distance. The energy also losses quickly.
Combined the formula (2) with the formula (3), we can get the experimental formula of the relationships between the climbing height and the water depth ,the angle of the sliding surface ,width, thickness of the landslide.

$$R_r / h = 0.1032(w/h)^{0.6131}(b/h)^{0.1117}\beta^{0.3116}e^{-0.071x/h} \quad (5)$$

3.3. The attenuation law of the climbing height in the bend

Landslide surge will lose part of the energy after passing the band. Surge height is reduced, so climbing height will decrease. The bigger the corner, the greater the attenuation decreases. For the attenuation of the climbing height along the curve, its propagation distance conclude the calculation of straight and the horizontal distance of the arc segment .
We fitted the data of climbing height in the bend by means of the multiple linear. We got the empirical formula of the attenuation law about the climbing height in the bend. The correlation coefficient of the formula is 0.98.

$$R_2 / R_1 = 0.4381+0.1663\beta\text{-}1.1290R_1 / h \quad (6)$$

In the formula, R_1 is the climbing height before the bend; R_2 is the climbing height after the bend.

Compared the experimental data with the values of the formula (6) ,We discovered that the result of the calculation is a little small. It is mainly because of the little error of the measured data. But generally speaking, the calculated values are good agreement with the measured values.

4. Conclusions

Based on the experiment of single factor , we simulated the landslide in three gorges reservoir area and studied the effect that the landslide surge have on the climbing height of the other side. We analyzed the effects that the width, thickness of the landslide , inclination angle of the sliding surface have on the climbing height. Using multivariate nonlinear regression analysis, we obtained the calculated formula of biggest climbing height in the other side of the landslide and the formulas of the attenuation of the climbing height along the straight and bend .The calculated values have a good agreement with the actual values. Therefore, we got the attenuation law of climbing height under different water depths. They can provide certain reference for the prediction of climbing height of landslide when landslide happens in somewhere.
Due to the limitation of experimental conditions, we didn't study the attenuation rule in the bank that the landslide located in. We can predict them on the basis of the law of the climbing height in the other side. This can provide certain reference for the establishment of safety precautions.

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