A Numerical Simulation Study on Pressure Propagation along the Path of Landslide Surge Waves in Straight Channel Reservoirs

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Abstract — the surge waves generated by the collapse of reservoirs bank have brought great harm to the safety of people downstream. Therefore, it is vital to prevent and reduce the disaster and losses by landslide surge to the channel and it is necessary to study landslide surge characteristics. This paper uses software FLOW-3D to study pressure propagation along the path of landslide surge waves to determine the underlying general physical laws.

Keywords- landslide, ground swell, reservoir, pressure, numerical simulation, FLOW-3D

I. INTRODUCTION

Most of the researches at home and abroad, whether in physical model experiment or in numerical calculation are all do the research based on broad plain reservoir landslide surge and little research has been done on narrow River landslide surge [1]. On the other hand, in terms of the research of landslide surge propagation process and evolution mechanism, most scholars and experts are explore the regularity from the characteristics of the surge, wavelength and the angle of the first wave. This paper presents another angle, it do the research on surge generated by hydrodynamic pressure process.

Moreover, the current research on Landslide at home and abroad is mainly in model test, empirical formula and regression statistical analysis. There are relatively few studies on numerical simulation, such as the Pan Jiazheng method[2], Noda method[3], Switzerland method[4,5], Kamahis method and Bowering method[6] etc. the most of these landslide surge prediction theory and empirical formula are mainly estimate landslide sliding speed and initial wave height. With the help of Flow-3D 3D flow calculation software, this paper establishes simulation model based on the actual physical experiment model and uses RNGk-ε turbulence model and VOF method[7] to make free surface tracking.

In the VOF method is used to track the free surface accurately in order to simulate the free surface fluctuation. The framework of VOF method is that in the simulation domain, each divided unit defines a fluid volume function F, F is the volume ratio between volume of fluid within a unit and the fluid volume in the unit. If the control unit was filled with the fluid then the volume function of fluid F =1; if the control unit is empty then the volume function of fluid F =0; there are little fluid in the control unit then the volume function of fluid 0<F<1, that is to say the free surface within the inner of control unit. By using this method, the tracking of free surface is realized.

II. COMPUTATIONAL MODEL

The model is divided into three parts, the sliding block, the sliding plate and the water tank. The size of the rectangular sliding block is 0.4m*0.2m*0.15m; the density of material is 2200kg/m3; the size of the sliding block is 1.5m*0.3m; The water tank is formed by the connection of the straight line type rectangular channel section of 2.5m*0.5*1.0m and the rectangular reservoir of 1.5m*1.0m*1.0m[8].

As shown in Figure 1.

Figure 1. Computational Model

Total grid number is 3,729,800, overall grid quality is good and the top is the free surface boundary.

III. NUMERICAL SIMULATION STUDY ON PRESSURE PROPAGATION

A. Constant Depth and Variable Angle

The block slide from the same height (the distance from the water H=1.0m), Fixed water depth h=0.5m, the calculation of all the parameters is the same, change the slope angle and then calculate. The working conditions including the landslide angle of 40 degrees, 50 degrees, 60 degrees, 70 degrees, 80 degrees. Choosing 7 sections as the monitoring section of swell propagation process.
monitoring point are $x=1.5m$, $x=1.9m$, $x=2.3m$, $x=2.5m$, $x=2.7m$, $x=3.0m$, $x=4.0m$.

Take the 60 degree conditions for example analyze the pressure distribution in the wave propagation process of monitoring section, the most dangerous situation is the pressure generated by the first waves in the process of wave propagation, so the monitoring section is monitoring the pressure distribution in the process of first wave propagation. The following is the monitoring section of the pressure curve, because there are a lot of data, it is only selected four representative section of the data analysis. The specific can be seen from the following figure.

Figure 2. The wave crest pressure characteristic line on $x=1.5m$ and 60 degree

Figure 3. The wave crest pressure characteristic line on $x=2.5m$ and 60 degree

Figure 4. The wave crest pressure characteristic line on $x=2.7m$ and 60 degree

Figure 5. The wave crest pressure characteristic line on $x=4.0m$ and 60 degree

The conclusion can be obtained as follows due to the above pressure characteristic line of the first wave crest of the monitoring section.

In the figure there are 4 curves, initial static water pressure refers to static water pressure in initial state (Initial water level is 0.5m). Therefore, the hydrostatic pressure is the same in each section; First wave peak pressure line refers to the pressure distribution of the first wave spread to the section (surge pressure is also the maximum in the entire process); depth static water pressure of the first wave refers to the hydrostatic pressure of take the first wave as the static water level when the first wave spread to the section.

To sum up the above several sections of the data chart, the 4 curves show the consistency of the rules: the wave pressure in the first wave propagation process is stronger than initial hydrostatic pressure and it is weaker than hydrostatic pressure. It shows that the effects of surge on the pressure are not simple to measure the pressure take the depth of the whole section.

Look these 4 curves, in a certain range of water depth, the pressure of the first wave near the hydrostatic pressure of the depth and the bottom water depth distribution is close to the initial static water pressure. Through the analysis, we can see that due to water depth is too deep and the landslide is too small, the waves can only affect the surface water, which is generate shallow waves and it has a small effects to river and even there is no effect to river. Then the waves generate
great effects on the water surface and the effect gets small with the increase of the depth.

![Figure 6. The pressure characteristic line of the first wave crest of the monitoring section on 60 degree](image)

From the above chart we can see that gathering all the pressure curves of the first wave crest of all monitoring sections, figure 6 is the complete curves of the entire section, we can clearly see that with the increase of transmission distance the peak pressure of first wave gradually decrease, that is to say, the surge propagation distance is increasing, the energy of surge is decreasing. In the process of propagation, the energy in the water is dissipating, but the decay rate is not a linear change, the initial decay amplitude is bigger, the attenuation becomes smaller with the increase of the propagation distance. The decrease becomes larger in the depth of 2.3m to 2.7m. It is because the channel becomes narrow and water surface become wide, the energy of water becomes large therefore the difference is more clearer. For the four situation of 40 degrees, 50 degrees, 70 degrees, 80 degrees, the wave peak pressure characteristic line is consistent with the level of 60 degrees, so nothing more to say.

Now let’s compare the five situations, pressure characteristic line of the same monitoring section of the first wave peak, different angles under the conditions of the first wave peak pressure characteristic line of the same section drawn on the same chart, as follows:

![Figure 7. The first wave peak pressure characteristic line of x=1.5m at 5 kinds of working conditions](image)

The above picture is to compare the first wave peak pressure curve at x=1.5m level under five condition. Observation and analysis of the curve can be seen:

The maximum surge pressure is 60 degrees, followed by the condition of 40 degrees and 50 degrees, the smallest is the condition of 70 degree and 80 degree. It does not follow the linear change with the angle. In terms of energy, the condition is shown that 60 degrees is the most dangerous slope angle of the narrow channel and the pressure of condition of 50 degree is larger than the pressure of 40 degree, the pressure condition of 70 degree is larger than the pressure of 80 degree. This shows that the 60 degrees is the most dangerous point of view and it becomes lower from the central to both sides.

Changing 10 degree angle under the condition of 40 degree to 50 degree and 70 degree to 80 degree, the pressure is greater under the condition of 70 degree to 80 degree, that is to say, over the most dangerous angle, angle of landslide surge pressure variation range is more obvious.

### B. Constant Angle and Variable Depth

The block slid from the same height (the distance from water surface is H=1.0m), the angle of slide is 60 degree. The calculations of all the parameters are the same, change the depth of the reservoir and then calculate. The condition including the depth of h=0.5m, h=0.6m, h=0.7m, h=0.8m, h=0.9m. Choosing 7 sections as the monitoring section of swell propagation process. The monitoring point is x=1.5m, x=1.9m, x=2.3m, x=2.5m, x=2.7m, x=3.0m, x=4.0m.

In the process of the pressure surge of 7 monitoring sections, take the first wave crest process as the research object, because the first wave crest is the most dangerous in the process of landslide surge, the monitoring section is the pressure distribution of in the process of the first wave. The data is too many; it is not easy to list it. Then we only lists three features of monitoring sections as the target, Namely: 1.5m (the highest peak of the first wave crest), 2.5m (the narrow river channel change to wide). Here, we take the water depth of 0.7m as the example; the following is the pressure data and pressure curve of the monitoring section of the first wave in corresponding conditions:

![Figure 8. The wave crest pressure characteristic line on x=1.5m and 0.7m water depth](image)
From the list of the three characteristics of monitoring section data and curve, under the condition of 0.7m water depth, the distribution law of pressure of section when swell slide falling into the water generated along the transmission same as the pressure under water depth of 0.5m, the law also same as the other not listed 4 sections, namely, the hydrodynamic pressure of the first wave in the initial hydrostatic pressure and the pressure of first wave water depth. Because the depth of water is large and the size of block is small, the waves is still the shallow wave. The surge can only influence the water surface water, affecting the water at the bottom is negligible. The first surge wave propagate in water surface and to climb in front of the dam is only 8mm, it is basically gone.

Pressure distribution in 4.0 level is the dam climbing pressure distribution. We can find that the pressure in water surface is larger than the pressure of initial (this condition is 580mm level), instead the pressure value is less than the initial hydrostatic pressure, that is to say the negative pressure in the section. Through analyze the surface water climb along the dam and there is reflection under water and then present reverse direction velocity, namely negative pressure, and the surge is not enough climbing deeper influence water, so in the certain depth of water the pressure value is less than initial hydrostatic pressure. To observe the condition of 0.5m, it is still the same. Under this condition, the section pressure value is positive, indicating that under 0.5m depth, the influence of surge height is larger than the velocity in the opposite direction.

IV. CONCLUSIONS

In a certain range of water depth, the first wave crest time pressure near the hydrostatic pressure of the first wave crest and peak pressure of bottom water is close the initial hydrostatic pressure. Through analysis the reason is water depth is too big and the block is too small so the surge can only affect the surface water, namely, the deep water wave and the influence to the bottom of the channel and even have no effects, therefore the effects of the surge is only on the water surface and it will decrease with the increase of the depth.

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