Study on numerical simulation of impact factor on debris flow to bauxite tailings dam

The geological disaster in Guizhou is serious, especially the debris flow, brings many hidden dangers to the mine construction. In this study, we set up the three dimensional numerical model of dam break, changing the viscosity coefficient, yield stress and height of dam break to study the impact of every factor on debris flow. Set different forms of landslide and diversion dam, studied the impact of dam on characteristics of debris flow, and obtained the optimal location and angel of landslide and diversion dam.

Keywords: *Debris flow, tailings dam, bauxite, geology.*

1. Introduction

The debris flow from dam break has strong, sudden and huge danger. So there is little on field observation data. The main methods to study the debris flow are model experiment and numerical simulation. Model experiment is the mostly reliable method to study the debris flow from dam break. The initial model experiment study on dam break of tailing pond appeared in France in mid nineteenth century. Yin [1] according to a tailing pond in Yunnan province, designed a model test to simulate the flow characteristics when the dam break occurs, obtained the variation law of submerge depth at different height of dam break and the impact force at different flow section. Wang [2] according to a tailing pond in Sichuan province, set up the model experiment by model similarity theory, accurately predicted the coverage area of debris flow by measuring the impact force, submerge depth and velocity.

The researchers abroad studied the flow characteristics of debris flow by different numerical model. Takahashi and Tshjimoto [3] based on expansion flow model and dispersed stress theory, considered the collision motion of particle in debris flow, proposed the two-dimensional finite difference model. Takahashi [3] modified the numerical model so that the model could simulate the process of erosion and deposition. Jin [4] takes a tailing pond in Liaoning province as example, used the ANSYS CFX software; simulated the process of the dam break; analyzed the flow characteristics and the condition of final accumulation; and predicted the influence area of dam break. The work provided the scientific basis for downstream protection of people. According to the relative articles, there are a lot of people studied the reason of dam break and the inner forces, however little people studied the impaction of flow parameters on debris flow and the protection measure. This article based on Flow3D software, studied the flow law and protection measure by numerical simulation.

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The detailed content as follows:

(1) Set up the simple three dimensional dam break numerical model of tailing pond, obtained the impaction of viscosity coefficient, yield stress and height of dam break on evolution of debris flow.

(2) Discuss the effect of protection measure on debris flow from dam break. Set up different form of landslide and diversion dam, study the impaction law of protection measure on debris flow. Obtain the optimal combination of landslide and diversion dam by analyzing the protection effect and construction cost.

(3) Take a tailing pond as example, set up the three dimensional numerical model of dam break, simulate the evolution of debris flow and verify the numerical results by measured data.

(4) Use the verified numerical model to analyze the velocity and pile thickness of debris flow. Set up the protection measure at downstream, obtain the optimal combination of landslide and diversion dam by comparing the effect of protection on debris flow.

2. Control equation and basic hypothesis

2.1 Theoretical analysis of fluid-solid coupling

(1) Continuity equation:

$$\frac{\partial \rho}{\partial t}+\frac{\partial \rho u_i}{\partial x_i}=0 \qquad \text{...} \qquad (1)$$

(2) Momentum equation:

$$\frac{\partial \rho u_i}{\partial t}+\frac{\partial}{\partial x_j}\left(\rho u_i u_j\right)=$$

$$-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left[(\mu+\mu_l)\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\right]+\rho g_i \quad ... \quad (2)$$

(3) Turbulence kinetic energy:

$$\frac{\partial(\rho k)}{\partial t}+\frac{\partial(\rho u_i k)}{\partial x_i}=$$

$$\frac{\partial}{\partial x_i}\left[\left(\frac{\mu-\mu_l}{\sigma_k}\right)\cdot\frac{\partial k}{\partial x_i}\right]+G_k-\rho\varepsilon \quad ... \quad (3)$$

(4) Turbulence dissipation rate:

$$\frac{\partial(\rho\varepsilon)}{\partial t}+\frac{\partial(\rho u_i\varepsilon)}{\partial x_i}=$$

$$\frac{\partial}{\partial x_i}\left[\left(\frac{\mu+\mu_l}{\sigma_\varepsilon}\right)\cdot\frac{\partial\varepsilon}{\partial x_i}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}G_k-C_{2\varepsilon}^{x}\rho\frac{\varepsilon^2}{k} \quad ... \quad (4)$$

In equation, ρ is the density of debris flow. u And u_t tare dynamic viscosity coefficient and Turbulent viscosity coefficient respectively, $\mu_l=\rho C_\mu\frac{k^2}{\varepsilon}\cdot P$ is the pressure of debris flow, u_1 is the velocity component. $k=\overline{u_i^{'}u_i^{'}}/2$ is the turbulence kinetic energy of unit mass. ε is the turbulence dissipation rate. G_k is the turbulence kinetic energy production term induced by average velocity gradient.the other are constant used in numerical model.

After the dam break occurs, the sand flow is in essence belongs to debris flow, so the hypothesis of this article as follows:

(1) The basement rock and surrounding mountain is slightly permeable or impermeable.

(2) During the evolution of debris flow, only consider the deformation caused by stress tensor, do not consider the volumetric deformation caused by isotopic stress.

(3) Assume the debris flow as homogenous viscous fluid, use the Bingham fluid model to simulate it.

3. Impact factors on debris flow

In order to analyze the impact factors on debris flow, set up the simple numerical model of dam break, the model is shown in Fig.1. The model consists of accumulation area and flow area. The accumulation area is the accumulation location at the initial time before the dam break occurs. The flow area is the evolution area after the dam break occurs. Size of the numerical model are 500m×500m×55m (length×width×height). The length of accumulation area is 150m. The length of flow area is 400m. There is 118000m³ tailing sand compiled in accumulation area at initial time.

3.1 Impaction of viscous coefficient on debris flow

Keep the yield stress and height of dam break as constant, set three conditions (viscous coefficient is 0.5 pa.s, 100 pa.s, 500 pa.s respectively) to simulate the debris flow. The results show that the maximum flow length is 232m, the maximum accumulation depth is 4.25m, the maximum coverage area is 46518 m^2 when the viscous coefficient is 0.5 pa.s. The maximum flow length is 222m, the maximum accumulation depth is 4.48m, the maximum coverage area is 44622 m^2 when the viscous coefficient is 100 pa.s. The maximum flow length is 206m, the maximum accumulation depth is 4.91m, the maximum coverage area is 35589 m^2 when the viscous coefficient is 500 pa.s. When the yield stress and height of dam break keep constant, the larger of the viscous coefficient, the smaller of the flow length and the thicker of the accumulation depth. The viscous coefficient has evident effect on debris flow. Flow length and accumulation depth of three different viscous coefficients are shown in Fig.2. Coverage area of three different viscous coefficients is shown in Fig.3.

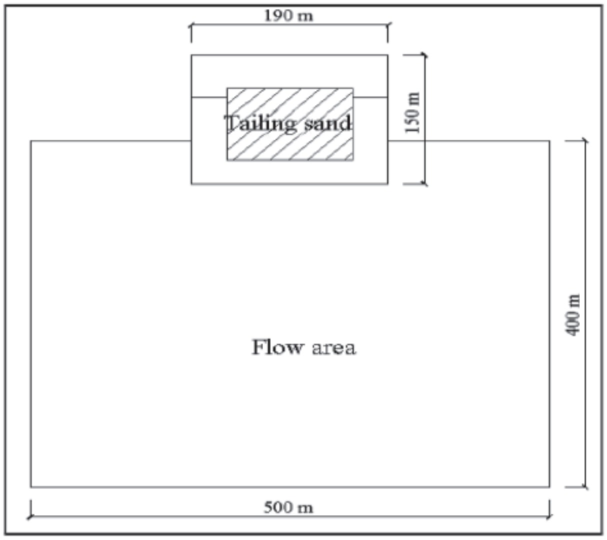

Fig.1 Plan graph for dam break of tailing dam

3.2 Impaction of yield stress on debris flow

Keep the viscous coefficient and height of dam break as constant, set three conditions (yield stress is 2000 pa, 5000 pa, 10000 pa respectively) to simulate the debris flow. The results show that the maximum flow length is 247m, the

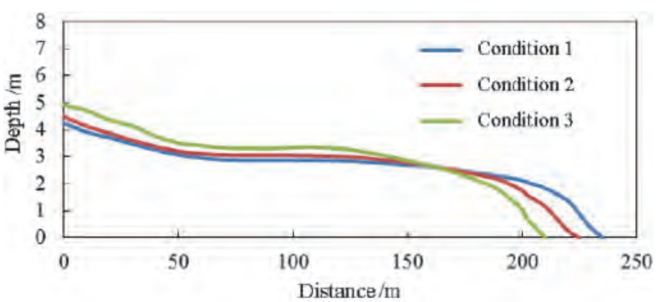

Fig.2 Flow length and accumulation depth of three different viscous coefficients

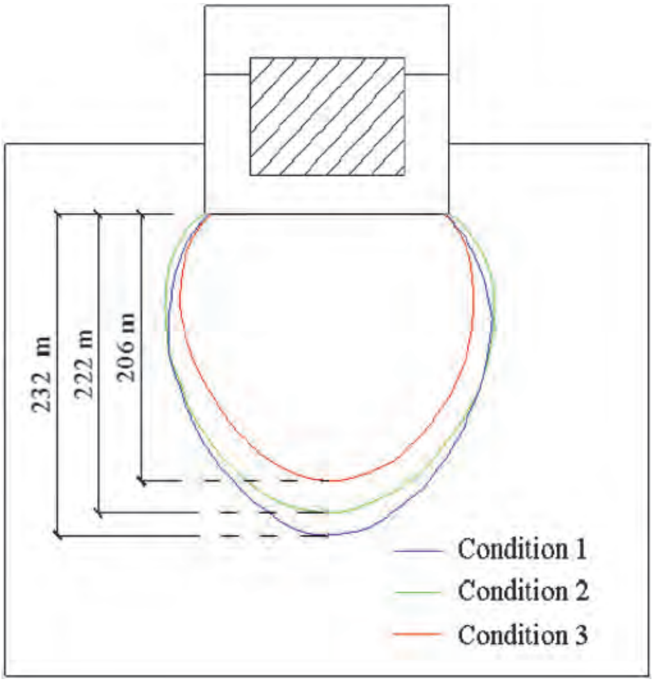

Fig.3 Coverage areas of three different viscous coefficients

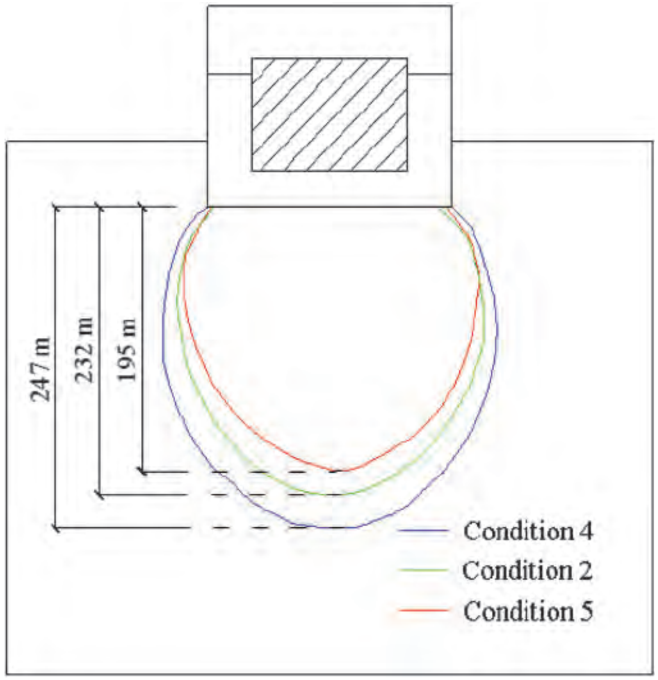

Fig.5 Coverage area of three different yield stresses

maximum accumulation depth is 3.51m, and the maximum coverage area is 53924 m^2 when the yield stress is 2000 pa. The maximum flow length is 232m, the maximum accumulation depth is 4.45m, the maximum coverage area is 43854 m^2 when the viscous coefficient is 5000 pa. The maximum flow length is 195m, the maximum accumulation depth is 4.73m, the maximum coverage area is 37977 m^2 when the viscous coefficient is 10000 pa. When the viscous coefficient and height of dam break keep constant, the larger is the yield stress, the smaller is the flow length and the thicker is the accumulation depth. The yield stress has evident effect on debris flow. Flow length and accumulation depth of three different viscous coefficients are shown in Fig.4. Coverage area of three different viscous coefficients is shown in Fig.5.

3.3 Impaction of height of dam break on debris flow

Keep the yield stress and viscous coefficient as constant, set three conditions (height of dam break is 70m, 75m, 80m respectively) to simulate the debris flow. The results show that the maximum flow length is 223m, the maximum accumulation depth is 4.51m, and the maximum coverage area is 41869 m^2 when the height of dam break is 70m. The maximum flow length is 229m, the maximum accumulation depth is 4.34m, and the maximum coverage area is 44108 m^2 when the height of dam break is 75m. The maximum flow length is 243m, the maximum accumulation depth is 3.98m, and the maximum coverage area is 45587 m^2 when the height of dam break is 80m. When the yield stress and viscous coefficient keep constant, the larger is the height of dam break, the larger is the flow length and the thinner is the accumulation depth. The height of dam break has evident effect on debris flow. Flow length and accumulation depth of three different height of dam break are shown in Fig.6. Coverage area of three different height of dam break is shown in Fig.7.

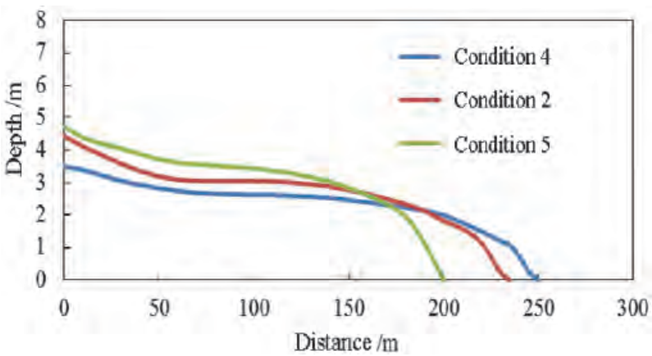

Fig.4 Flow length and accumulation depth of three different yield stresses

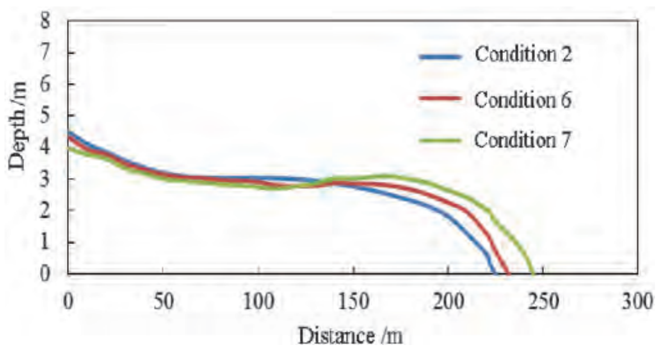

Fig.6 Flow length and accumulation depth of three different height of dam break

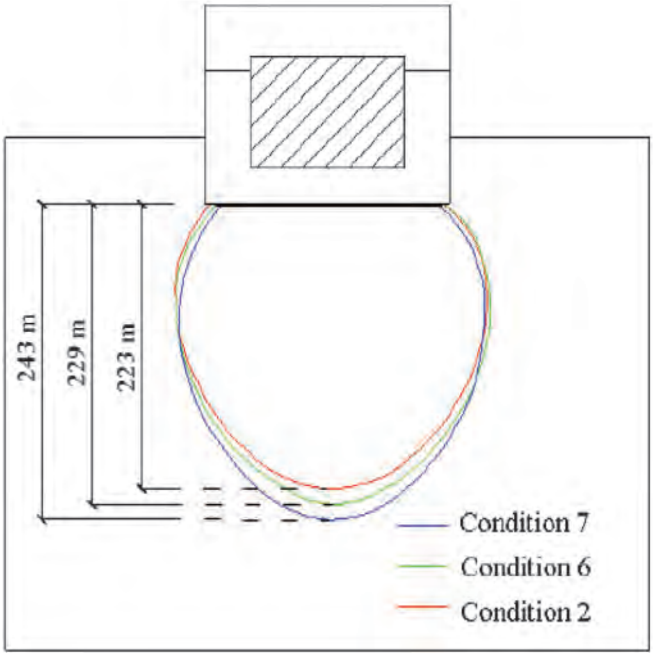

Fig.7 Coverage area of three different height of dam break

4. Protection measure for debris flow

The main method to defend debris flow is landslide and diversion dam. There are little research about landslide and diversion dam, so this part uses the numerical model to simulate the effect of location angle and dam height on debris flow. Obtain the optimal combination of the landslide and diversion dam by comparing the debris flow characteristics.

4.1 The optimal angle for landslide and diversion dam

Set four conditions to analyze the effect of location angle on debris flow, length of the landslide and diversion dam is 100m, height is 6m. Condition 1 is located 100m away from the embankment and perpendicular to the flow direction. Condition 2 counter-clockwise rotation 15°. Condition 3 counter-clockwise rotation 30°. Condition 4 counter-clockwise rotate 45°. The numerical results are shown in Figs.9-12.

By comparing the four conditions we can see that the best effect of blocking is condition 1, but there is little effect of diversion. The maximum accumulation depth is 5m, the maximum distance of debris flow is 148m. Effect of blocking of condition 2 is still little. The maximum accumulation depth is 4.3m, the maximum distance of debris flow is 172m. The best effect of blocking is condition 3. The maximum accumulation depth is 3.3m, the maximum distance of debris flow is 152m. Effect of blocking decrease is of condition 4, but the accumulation depth and flow distance is larger than condition 3. The maximum flow distance of condition 4 is 155m.

4.2 The optimal combination for landslide and diversion dam

Selection of the condition 3 which has the best effect of blocking as research object, and discuss three conditions as follow:

Condition 1: Landslide and diversion dam located away the accumulation is 100m. The height is 6m and the length is 100m.

Condition 2: The first landslide and diversion dam located away the accumulation is 80m. The second landslide and

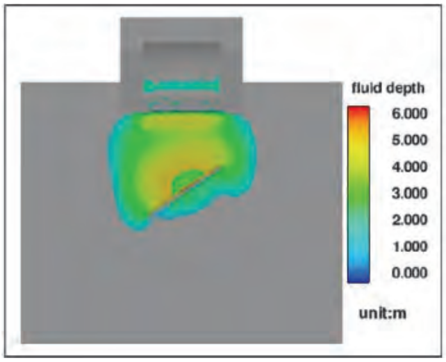

Fig.10 Coverage area of condition 3

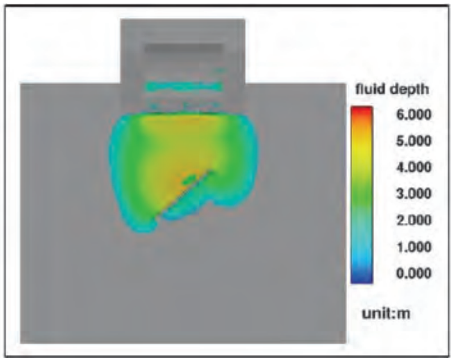

Fig.11 Coverage area of condition 4

diversion dam located away the accumulation is 120m. Height of both the two dam is 3m and length is 100m.

Condition 3: The first landslide and diversion dam located away the accumulation is 70m. The second landslide and diversion dam located away the accumulation is 100m. The third landslide and diversion dam located away the accumulation is 130m. Height of the entire three dam is 2m and length is 100m. The numerical results are shown in Figs. 13-14.

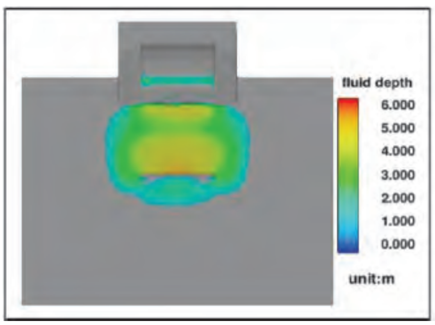

Fig.8 Coverage area of condition 1

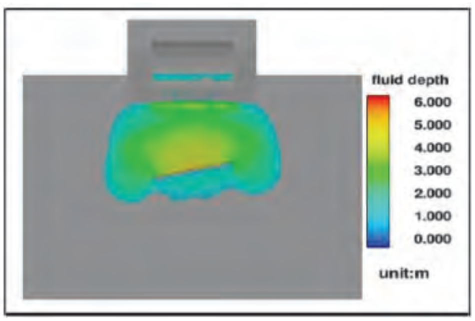

Fig.9 Coverage area of condition 2

By comparing the results we can see that the best effect of blocking and diversion is condition 1. The flow distance is also the smallest of condition 1. Also the effect of diversion is evident but the effect of blocking is less evident. The maximum accumulation depth before the second

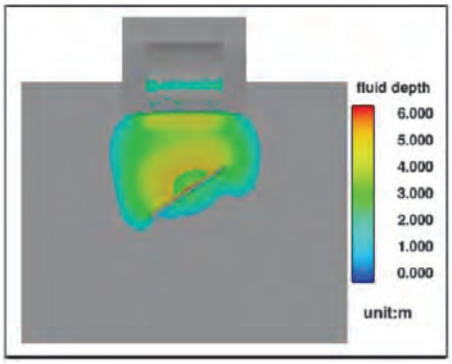

Fig.12 Coverage area of condition 1

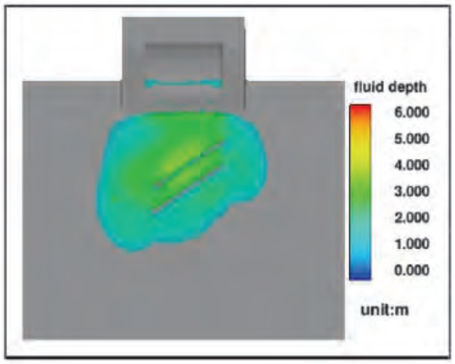

Fig.13 Coverage area of condition 2

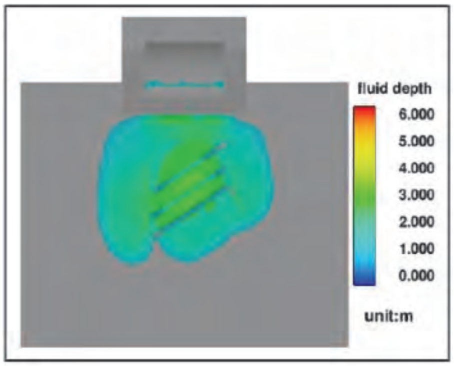

Fig.14 Coverage area of condition 3

dam is 2.98m. Because of the small height of condition 3, the first and second dam is submerged rapidly by debris flow. The maximum accumulation depth occurs between the first and second dam, the value is 3.39m. Effect of blocking and diversion is the worst of condition 3.

5. Conclusions

This article takes a simple tailing pond as example, simulates the debris flow of different viscous coefficient, yield stress and height of dam break.

Obtains the effect law of parameters on debris flow. In order to obtain the optimal combination of the landslide and diversion dam simulates the debris flow of different location angle and arrangement. The conclusion as follows:

(1) The larger is viscous coefficient, the smaller is the flow distance, the larger is the maximum accumulation depth, the smaller is the coverage area. The larger is yields stress, the smaller is the flow distance, the larger is the maximum accumulation depth, the smaller is the coverage area. The larger is height of dam break, the larger is the flow distance, the smaller is the maximum accumulation depth, the larger is the coverage area.

(2) Compares the debris flow under four conditions, finds that the best blocking effect is the dam which is perpendicular to the flow direction, but there is little effect of diversion. When the dam location angle is 30° between the flow directions, the effect of diversion is most evident, and also there is some effect of blocking.

(3) Compare the debris flow of different combination, when the engineering quantity are same, the protection effect of one higher dam to debris flow is better than that of several lower dams.

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