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Efficiency of Slit Dam Prevention against Non-Viscous Debris Flow

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Abstract: This paper describes an experimental work in order to assess the efficiency of slit dam on non-viscous debris flow. Some results have been acquired as follows: ① there are three kinds of blocking type: Total-blocking, opening and part-blocking. The blocking conditions of slit dam are closely link to b/d_{max} (the ratio of slit width to maximum diameter of solid matter), as b/d_{max} is less than 0.739, the slit dam is total- blocking; and b/d_{max} is more than 1.478, the slit dam will be opening; whereas b/d_{max} ranges from 0.739 to 1.478, the slit dam is part-blocking. ② Variation of the mean density passing through slit dam is the most obvious as b/d_{max} ranges from 0.739 to 1.232. ③ According to experimental results, slit dams have been shown to be effective in reducing debris flow density while slit density $\sum b/B$ (B is slit dam width) ranges from 0.2 to 0.5.

Key words: non-viscous debris flow; slit dam; blocking ratio; mean density passing through slit dam

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0 Introduction

Debris flow is a kind of dense mixture of water and sediment. Large boulders in the surge front and big impact force are quite common for debris flow. In mountainous areas of China to vast development and utilization of hills, debris flows are important from the point of hazards prevention; they frequently occur and often bring about heavy loss of lives and properties. Therefore, much research on debris flows countermeasures has been conducted in the past twenty years. Current countermeasures to cope with such disasters are either structural or non-structural in nature. The most commonly used structural method is to construct check dams, levees and channels to capture all the sediment transported by debris flows. Ordinary check dams are closed-type and made of massive concrete. Check dams, which are often constructed in series, have been widely used in China, Japan and Europe to reduce the debris flow hazards. However, due to the nature of their narrow storage space and poor permeability, check dams are filled with sediment by small discharge before debris flow occurs. Check dams have failed to catch the debris flow efficiently. To make up for this disadvantage, open-type dams have been developed in countries such as Austria, Japan, and China[1,2].

With regard to research on efficiency of the slit dams in the prevention of debris flows, some results have been acquired home and abroad. Watanabe, *et al*[3] firstly put forward four basic function indices, which evaluate efficiency of debris flow countermeasures. As follows: attenuating the debris flow peak discharge; retarding the arrived time of peak discharge; reducing the total volume of debris flow; separating large boulders from debris flow. The slit width has effects on the trapping capacity of a slit dam. When the $b/d_{max} <$ 2.0, where b is the slit width and d_{max} is the maximum diameter of the debris flow, the volume of the debris flow could be reduced by at least 50% during peak time. Mizuyama[4,5] studied various types of open-type dams and pointed out that the debris flow will be trapped when the $b/d_{max} <$ 1.5-2.0, and proposed the formula of the reduction rate of peak sediment discharge by flume experiment. Li Sanwei[6] firstly proposed concept of permeable check dam, and considered that permeable check dam can capture a good deal sediment during the flood period and discharge it during normal water, as well as can decrease erosion of downstream areas. Lin yuyi *et al*[7-10] discussed the efficiency of slit dam, A-type slit dam, grid dam and bottom screen dam against stony debris flow by qualitative flume experiment, and proved that such dam type have good efficiency in the prevention of stony debris flow.

But researcher of Japan and Taiwan et al focused on the efficiency of permeable check dams against stony debris flow; however ,there exists very little research work on the effects of open-type dam on controlling non-viscous debris flow and viscous debris flow, then non-viscous debris flow occur frequently during the rainy season in mountainous areas of southwest and northwest China.

The objective of this paper is to present and discuss the preliminary results of experiment work aimed at clarifying the efficiency of slit dam against non-viscous debris flow.

1 Experiment Setup and Procedure

1.1 Experiment Setup

The experiments were carried out at debris flow dynamics laboratory of Chengdu Institute of Mountain Hazards and Environment of Chinese Academy of Sciences, the experiment flume (see Fig. 1) consists of hopper(including a movable strobe), glass flume and exalt-equipment. It has 6 m long, 0.2 m wide, 0.45 m deep, and its slope is continuously adjustable between 0% and 42.48%.

1.2 Experiment Procedure

First, according to experimental design procedure, adjusted the flume's slope by exalt-equipment. The tests were carried out by setting the flume slope at 11.2 degrees. Second, slit dam models fixed to bed bottom using an L shaped steel devices were located 1 m upstream from the flume mouth. Third, poured debris flows which are confected before the experiment into the hopper and

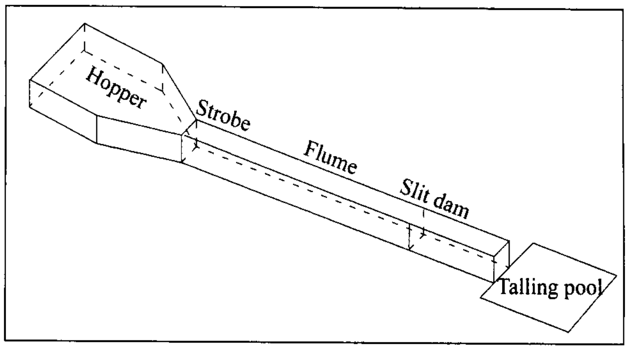

Fig. 1 Schematic diagram of experiment setup

mixed it. Forth, non-viscous debris flow was then triggered by manually unleashing the movable strobe very quickly thus simulating a natural dam-break process, whereas recording the whole experiment process to measure the debris flow transportation parameter by pickup camera[11].

1.3 Experiment Conditions and Method

1.3.1 Grain size distribution of sediment

Sediment used in the experiment comes from debris flow sample of Jiangjia Gully in Yunnan Province, which grain size distribution is shown in Fig. 2. Physical parameters of sediment is shown in Table 1, which D, Φ and σ express the mean diameter, the inner friction angle and particle density respectively.

Because maximum diameter of solid matter is related to blocking ratio and sediment trap efficiency etc, measured some large particle diameter used in experiment by vernier caliper. The X-axis, Y-axis and Z-axis of maximum particle are 26.34 mm, 18.35 mm and 17.26 mm respectively. The maximum particle diameter can be expressed as follows:

$$d = \sqrt[3]{abc} \tag{1}$$

Where a is the X-axis diameter, b is the Y-axis diameter, and c is the Z-axis diameter. The value of d calculated from Eq. (1) with a=26.34 mm, b=18.35 mm and c=17.26 mm is 20.281 mm.

Table 1 Physical parameters of sediment

D/mm	5.327
Φ/(°)	36.130
σ/g·cm^{-3}	2.650
Grain size distribution/mm	0.001-20.810

1.3.2 Experiment conditions

Design density of debris flow is 1.50 g·cm^{-3}, and experimental flume slope is 11.2°. Seven kinds of slit width and 11 kinds of slit density were been carried out in

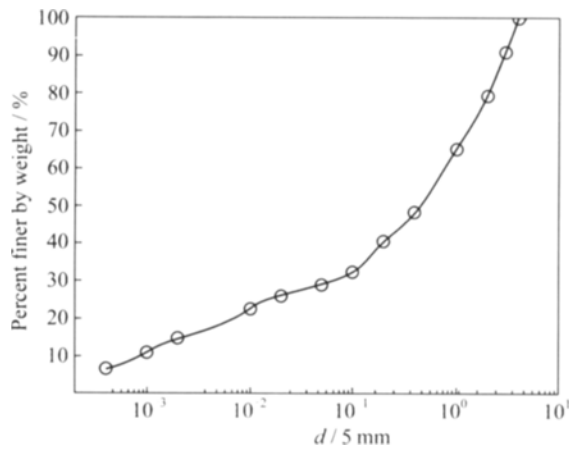

Fig. 2 Grain size distribution of sediment

experiments. Schematic diagram of slit dam model is shown in Fig. 3. Slit dam thickness is 2.4 cm. H, B, h, b and $\sum b/B$ express slit dam height, slit dam width, slit depth, slit width and slit density respectively, and dimension of slit dam is shown as following: The values of b(cm) are 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0; the values of $\sum b/B$ are 0.15, 0.2, 0.225, 0.25, 0.3, 0.375, 0.4, 0.5, 0.6, 0.7, 0.8 respectivelly.

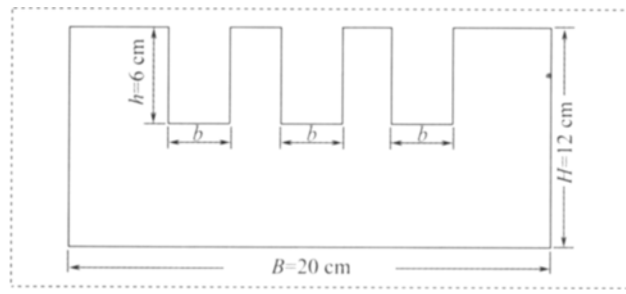

Fig. 3 Schematic diagram of slit dam model

1.3.3 Measurement item and method

The experiment mainly measured height of captured sediment by slit dam, debris flow depth, mean density through slit dam, mean surface velocity and slit blocking ratio. Detailed measurement methods are shown in Table 2.

Table 2 Measurement item and method

Item	Method
Height of captured sediment by slit dam	At the end of flume experiment, measured along transect every 10 cm and along vertical section every 5 cm by ruler
Debris flow depth	Measured by ruler
Mean density through slit dam	At the end of flume experiment, measured debris flow volume and weight
Mean surface velocity	Buoyage method
Slit blocking ratio	At the end of flume experiment, measured slit blocked height by ruler, and calculate blocking ratio according to the equation (2) in text

2 Blocking Type and Condition

2.1 Blocking Type

According to the flume experiment results, it shows that there are three kinds of blocking type: total-blocking, opening, part-blocking (see Fig. 4).

Total-blocking: during the beginning of experiment, the slit exist the phenomenon of passing through debris flow. While experiment is finished, the slit is totally blocked by the subsequent debris flow.

Opening: in the process of the whole experiment, total slit isn't blocked by solid matter of debris flow, that is to say, debris flow can fluently pass through the slit dam.

Part-blocking: In the process of the whole experiment, the slit can pass through debris flow, but the end of the experiment, the slit is partly blocked by solid mat-

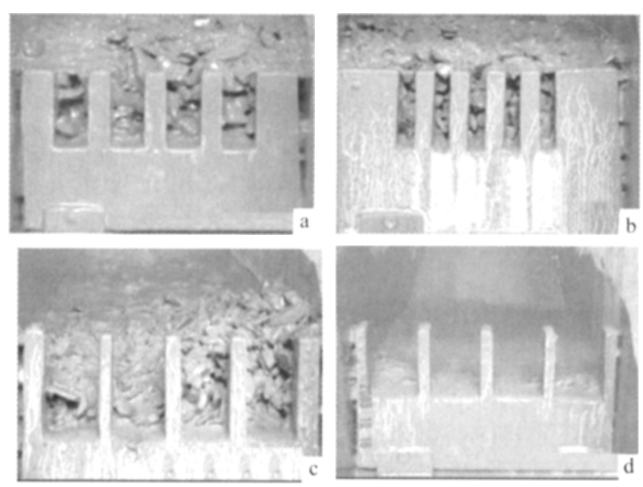

Fig. 4 Schematic diagram of three kinds of slit blocking type

a. total blocking, $b/d_{max}=0.739$; b. total blocking, $b/d_{max}=0.493$; c. part blocking; d. opening ter of debris flow[12].

2.2 Blocking Condition of Slit

The blocking conditions of slit is related to concentration of debris flow, size distribution of sediment, flow depth, surface velocity, the flume slope and b/d_{max} (the ratio of slit width to maximum diameter of solid matter) etc, so the blocking conditions is very complicated. The experiment mainly discusses the relationship between the b/d_{max} and the blocking ratio. The dimensionless blocking ratio, C is defined as

$$C=\sum_{i=1}^{n}(h_i/h)/n \qquad (2)$$

Where h is the depth of slit, n is the slit number, i mean the ith slit, h_i is the height blocked by solid matter of debris flow. Data are used to test Eq. (2) and the results are shown in Fig. 5.

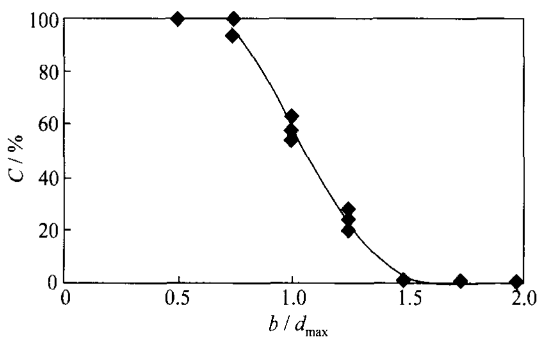

Fig. 5 The relationship between blocking ratio and b/d_{max}

According to experiment results and regression analysis, attained the relationship between the threshold value of b/d_{max} and blocking type of slit dam. As follows: as the b/d_{max} is less than 0.739, the slit dam is total-blocking type; as the b/d_{max} is more than 1.478, the slit dam is opening type; as the b/d_{max} ranges from 0.739 to 1.478, the slit dam is part-closing type. So we can consider $b/d_{max}=1.5$ as the threshold value of blocking or opening of slit dam.

3 Experiment Results and Analysis

3.1 Experiment Results

Mean density passing through slit dam which taked for a quantitative index in the text is to evaluate the efficiency of slit dam preventing against non-viscous debris flow. Table 3 is part of experimental results.

3.2 The Relationship between P_t and b/d_{max}

The relationship between P_t and b/d_{max} is shown in Fig. 6. According to experiment results shown in Fig. 6

Table 3 Part data of flume experiment

b/cm	$\sum b/B$	b/d_{max}	P_t/ g·cm^{-3}	R/%
1.0	0.15	0.493	1.4010	6.60
1.0	0.15	0.493	1.3869	7.54
1.0	0.2	0.493	1.3677	8.82
1.0	0.25	0.493	1.3611	9.26
1.5	0.3	0.739	1.2602	15.99
1.5	0.3	0.739	1.2562	16.25
1.5	0.225	0.739	1.3086	12.76
1.5	0.225	0.739	1.3080	12.80
1.5	0.375	0.739	1.3000	13.33
2.0	0.3	0.986	1.3118	12.55
2.0	0.3	0.986	1.3125	12.50
2.0	0.4	0.986	1.3273	11.51
2.0	0.5	0.986	1.346	9.71
2.5	0.5	1.232	1.3492	9.93
2.5	0.5	1.232	1.3335	11.10
3.0	0.6	1.478	1.3753	10.31
3.0	0.6	1.478	1.3687	10.82
3.5	0.7	1.724	1.3885	7.43
3.5	0.7	1.724	1.3942	7.05
3.5	0.7	1.724	1.4091	6.06
4.0	0.8	1.972	1.3820	7.87
4.0	0.8	1.972	1.3966	6.89

P_t expresses the mean density passing through slit dam, and R expresses the reduction rate of design density

and regression analysis, fitting curve suggests that the P_t decrease with an increase in the b/d_{max} as b/d_{max} is less than 0.986; while b/d_{max} is more than 0.986, the P_t increase with an increase in the b/d_{max}. Variation of the P_t is the most obvious as b/d_{max} ranges from 0.739 to 1.232. It can be explained as follows: as the b/d_{max} is very small, the slit dam is quickly blocked by large solid matter of debris flow and is similar to close-type dams. Once debris flow magnitude exceed the trapping capacity of slit dam. The part debris flow will overflow slit dam and harm downstream. However, the b/d_{max} is very large; the slit dam is opening and fluently passes through the slit dam. Thus efficiency of slit dam against non-viscous debris flow is best as b/d_{max} ranges from 0.739 to 1.232.

3.3 The Relationship between P_t and $\sum b/B$

The relationship between P_t and $\sum b/B$ is shown in Fig. 7. Slit dams have been shown to be effective in reducing debris flow density while $\sum b/B$ ranges from 0.2 to 0.5. The P_t is less than 1.35 as $\sum b/B$ in above-mentioned range. The minimum value is 1.256 2 g·cm^{-3}. So slit dam is most effective as $\sum b/B$ ranges from 0.2 to 0.5.

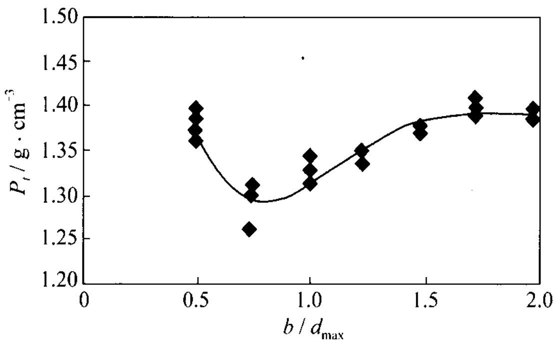

Fig. 6 The relationship between P_t and b/d_{max}

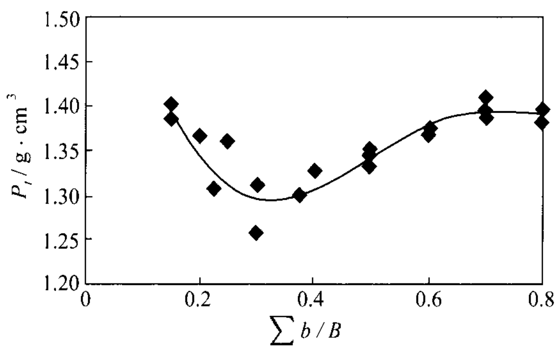

Fig. 7 The relationship between P_t and $\sum b/B$

4 Conclusion

Slit dams have been shown to be effective in prevention of non-viscous debris flow, thus preventing damages to the downstream areas. According to the analysis of the experimental results, we get the conclusions as follows:

① The experimental results show that there are three kinds of blocking type, which are total-blocking, opening and part-blocking.

② The blocking conditions of slit dam are closely link to b/d_{max}. As the b/d_{max} is less than 0.739, the slit dam is total-blocking type; as the b/d_{max} is more than 1.478, the slit dam is opening type; as the b/d_{max} ranges between 0.739 and 1.478, the slit dam is part-closing type. So we can consider $b/d_{max}=1.5$ as the threshold value of blocking or opening of slit dam.

③ The P_t decrease with an increase in the b/d_{max} as b/d_{max} is less than 0.986; while b/d_{max} is more than 0.986, the P_t increase with an increase in the b/d_{max}. Variation of the P_t is the most obvious as b/d_{max} ranges from 0.739 to 1.232.

④ According to experiment results, slit dams have been shown to be effective in reducing debris flow density as $\sum b/B$ ranges from 0.2 to 0.5.

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