II-272 An Experimental Study on Resistance to Debris Flow on Fixed Bed

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1 Introduction

Flow resistance is one of characteristics of debris flows, which is very required for the establishment of the countermeasures to prevent the disaster due to debris flows. This study stresses the importance of determining resistance to flow on the fixed bed, because those are the conditions found in natural stream whose bed is stone or clay. This paper is limited to experimental investigation. The results show the relation among average velocity, concentration, flow depth, particle size and velocity profile.

2. Experimental Method

The flume was used for the experiments, as shown in Fig.1. The open flume section is made of acrylic board 12 m in length, 12.5 cm in width and 20 cm in depth, and the slope was variable from 4° to 18°. The plywood was used as bed of flume which is placed at the downstream of the flume with 5 m length. The experimental conditions are presented in Table 1, in which d is diameter of grain; ρ is density of water; σ is density of grain; q_{wo} is water discharge per unit width; C_T is flux-averaged concentration; h is flow depth and θ_0 is bed slope.

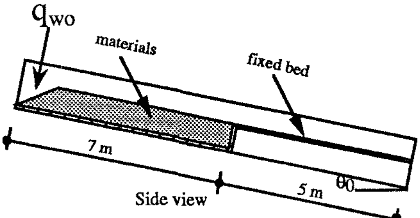

Fig. 1. Sketch of experimental flume

Table 1. Experimental conditions

d (mm)	$\frac{\sigma}{\rho}$	q_{wo} cm^2/s	C_T	h (cm)	θ_0
0.07	2.63	100	0.3092~0.3422	1.300~1.393	14°
0.09	2.60	100-460	0.1316~0.3219	1.020~2.728	4° - 18°
0.17	2.65	100	0.2358~0.3666	1.120~1.417	6° - 18°
0.29	2.62	100-332	0.3521~0.3979	1.204~2.561	14°
0.55	2.65	100-315	0.2868~0.3456	1.196~2.582	14°
0.80	2.64	100-315	0.1066~0.4553	1.096~2.927	8° - 14°
1.24	2.65	100	0.3185~0.3266	1.527~1.621	14°
1.90	2.61	100-337	0.2660~0.3009	1.594~1.732	14°
4.40	2.59	100-325	0.2733~0.3023	1.541~2.964	14°- 18°

The material was spread upstream, 7 m in length and about 10 cm in thickness and was saturated with seepage water. A constant rate of water was supplied from upstream end of flume, and then mixture flow of the grains and water was produced. The films of the moving sediment grains were taken with a 16 mm high-speed camera running at 500 frames/sec. Velocity profiles at the downstream of the flume were obtained by measuring the distance that the individual grains traveled between successive frame of the film.
The depth of debris flow in the flume was recorded by VTR and the duration of catch of the debris flow in a bucket at the downstream end of flume was also recorded by a VTR. Therefore, the flux-averaged concentration was obatained by dividing the volume of the grains by the volume of the grains and water. The discharge was obtained by dividing the volume of grains and water by duration of the catch.

3. Experimental Results

Figure 2 shows a nondimensional average velocity, $\bar{u}/u_*$ as a function of the relative depth, h/d with bed slope of 14° . It can be seen that the nondimensional average velocity, $\bar{u}/u_*$ has almost constant value of 10, although it slightly increases with increasing h/d.

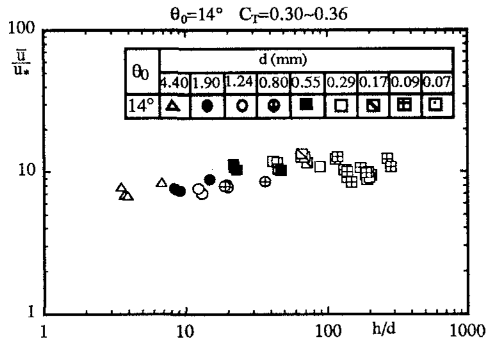

Fig.2 Plot of $\bar{u}/u_*$ versus h/d for the fixed bed with the bed slope of 14°

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Figures 3 and 4 show the relation of the nondimensional average velocity to the flux-averaged concentration, C_T . As shown in Fig.3, the nondimensional average velocity slightly decreases with increasing flux-averaged concentration of sediment for smaller value of h/d. Figure 4 also shows nondimensional average velocity gradually decreases with increasing flux-averaged concentration for larger value of h/d . In both figures, similar conclusion is obtained, which indicates that nondimensional average velocity depends on the concentration of sediment.

Figures 5 and 6 show examples of nondimensional velocity profiles for finer and coarser materials, respectively. The velocity profiles have concave shape, in which velocity is equal to zero at base of channel, and velocity gradient is large in lower region of y/h of 0 - 0.5 but small in the upper region, as shown in Fig.5. As seen in Fig.6, velocity is not equal to zero at base of flume, the velocity gradient is relatively low and similar in all regions, and the velocity profiles have stright shape. Figure 7 has been obtained from these velocity profiles. This figure shows that, the value of u_0/u_s increases with increasing bed slope and grain diameter of materials, while the velocity becomes zero at particle diameter, d < 0.8 mm. Figure 7 also shows that, velocity is equal to zero at the base of flume which is rough condition.

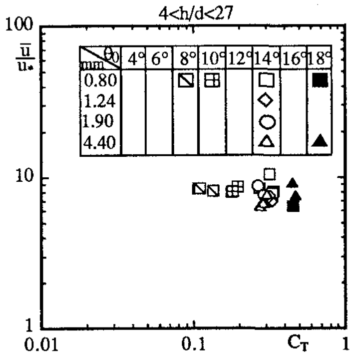

Fig.3. Plot of $\bar{u}/u_*$ versus C_T for the fixed bed with the coarser materials

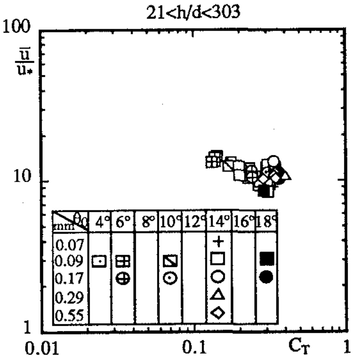

Fig.4. Plot of $\bar{u}/u_*$ versus C_T for the fixed bed with the finer materials

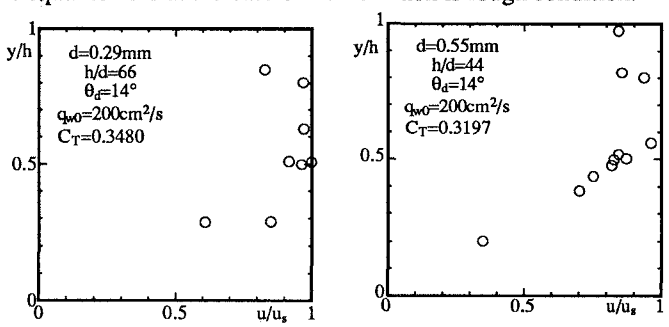

Fig. 5. Velocity profiles on the fixed bed with finer materials

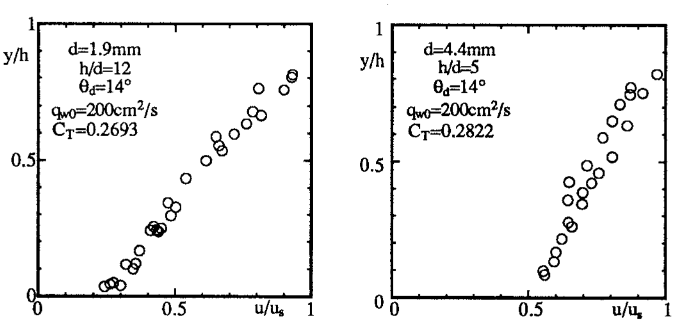

Fig. 6. Velocity profiles on the fixed bed with coarser materials

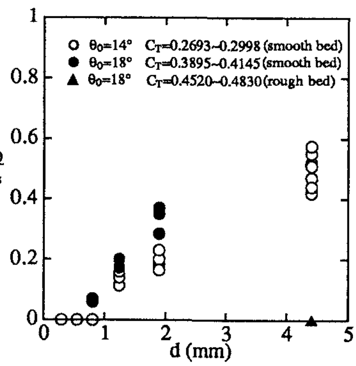

Fig.7. Plot of nondimensional flow velocity at the bottom versus grain diameter

4. Conclusions

The results obtained in this study are as follows:

1. The value of nondimensional average velocity was found to increases with increasing the relative depth, and with decreasing concentration of sediment.
2. The flow resistance of debris flow is strongly related to particle size.
3. For finer materials, the flow velocity becomes equal to zero on the base of flume.