68 流下に伴う土石流の変形に関する実験的研究

AN EXPERIMENTAL STUDY ON THE DEFORMATION OF DEBRIS FLOW

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1.Introduction

Owing to the specific properties, a debris flow always changes in its shape greatly during the processes of formation and transportation as it is constantly under the influence of flowing condition. Deformation is a major property of a debris flow, which makes it different from a common water flow and even from a flood. Research on the deformative characteristics of debris flow not only can contribute to studying on the kinetic properties of debris flow but also to adopting a suitable measure to prevent or to mitigate the damages incurred by debris flows. This paper attempts to study the deformative characteristics of debris flow by discussing the flow patterns, velocity and formation of the maximum discharge through experiments with different combinations of water and grain supplied. Basing on observation and calculation, a description and an analysis of the tests are mentioned herein.

2.Experimental Method and Procedure

The tests were carried out on an experimental flume of 14 meters long, 20 centimeters wide and 40 centimeters high, whose bed slope is 30° at the upstream end and 12° at the downstream end (Fig. 1).

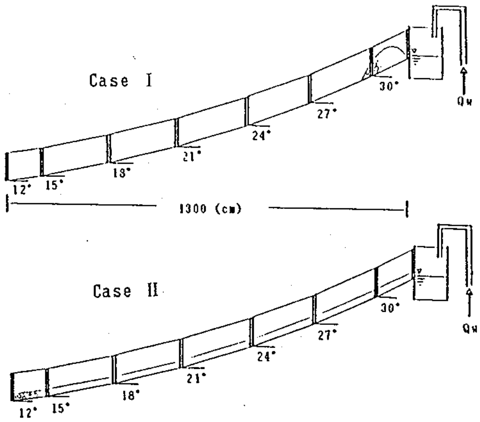

Fig. 1 Experimental Flume

For the sake of simulating a real debris flow, the tests can be classified into two cases according to the different conditions of solid-material supply. In Case I, the grains were piled upon the upstream end of the flume and then triggered by water supplied from the upper end of the flume in three predetermined discharges controlled by a water pump so as to mimic a concentrated supply of solid materials. In Case II, the grains were layered on the bed of the flume at a thickness of 5 centimeters so as to mimic a situation in which the water flow initiates bed materials to form a debis flow. The discharges of water flow are Q_{w1}=485, Q_{w3}=1,050, Q_{w3}=1,533 (cm^3/s) in both cases. The size distribution of the grains used in the tests is given in Figure 2. The whole processes of the tests were recorded by three video cameras simultaneously and then flowing tracks were drawn down on transparent films from the screen of a T.V set at desired intervals of time. The various data concerning deformation of the fluids were obtained by means of conversion.

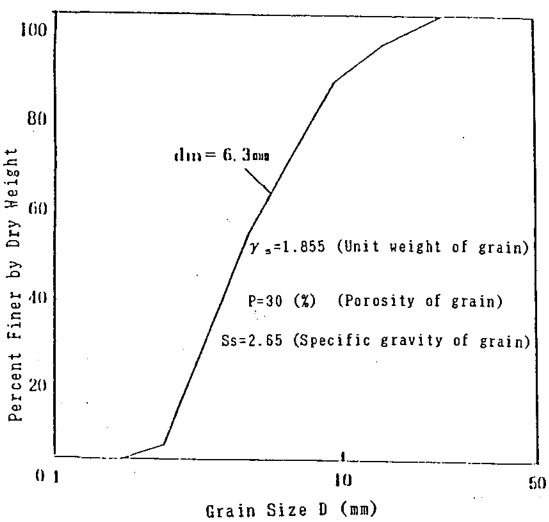

Fig. 2 Grain Size Distribution Used in the Test

3. Description and Analysis of the Results obtained from the Tests

3.1 Water filled up the interstices between the grains and increased their volumetric weight. As the increment of water volume, the equilibrium condition of the grains on the flume was disrupted, the mixture of water and grains was liquidized to form into a fluid moving downstream. Time taken for triggering the fluid and the duration in which the fluid travelled through the flume shortened as the water discharge increased as shown in Figure 3. At the moment when the fluids started moving, the water contents were 32%, 49%, 51% under the water discharges of Q_{w1}, Q_{w2} and Q_{w3} individually in Case I. While the porosity of grains is 30%, i.e., when the fluid started moving, the grains had been saturated by water in some degree. Therefore the onset of a fluid on the flume not only depends on the water content but also on the sliding force of the fluid itself. The sliding force in unit area under three discharges of water supply is 14 gf/cm² approximately.

The changes of water discharge not only exert an influence on the fluid at the beginning but also throughout the whole process because the average velocity of water was always larger than that of the fluid. The water flow supplied later increased the water content of the fluid successively as well as exerted a push force on the back of the fluid. Therefore water supply played an important role in the deformation of the fluid from beginning to end.

As the gradient turned small, the velocity of fluid slowed down. On the other hand, the water flow supplied later enabled the fluid to obtain a new energy by increasing weight and exerting a push force on the back of the fluid to make it move again. It is under a complex condition that the fluid had an evident discontinuity, especially in Case II. This is because the resistance in the lower part of the fluid is larger than that in the upper part, at which the fluid moves at a much faster speed. The fluid actually moved downstream in a rolling pattern.

In Case I, although the shapes of the fluid deformed repeatedly, there exists a major tendency that the shape of the fluid changed from quasi-triangle to rectangle. While in Case II, due to the increment of volume of the fluid along the flume, the entire process of flow was that of the formation and development of the fluid. The length of fluid extended successively and the height reached a certain level under different conditions of water supply. The larger the water supply, the higher the height of the fluid became. Moreover, when the front of the fluid arrived at the reach of a gradient of 15°, the fluid could not move any farther.

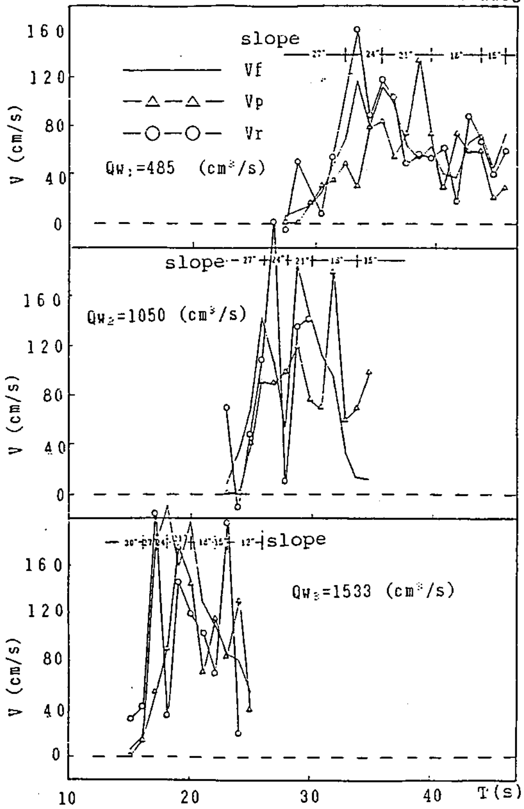

Fig. 3-1 Variations in Velocity of Different Parts of The Fluids in Case I

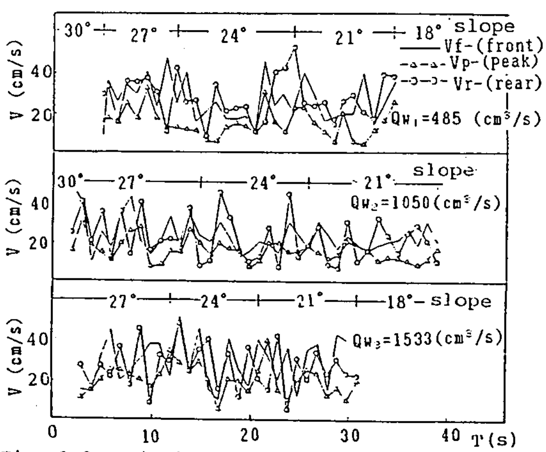

Fig. 3-2 Variations in Velocity of Different Parts of The Fluids in Case II

3.2 Every part of the fluid does not flow downstream at the same speed, which is the most basic cause of the deformation of debris flow. For analyzing the properties of the velocity in different parts of the fluid, we selected three points at the front, peak and rear portions to measure and compute their velocities as shown in Fig. 4. The velocities obtained were plotted on Figure 3 as shown in the previous section. The velocity at peak portion varies the most which may become minus in some cases. This is because when the front part of the fluid starts moving, the rear portion may not move at the same time. Therefore, the length of the fluid extended and the highest point moved backwards. By comparing the velocities Vp is the maximum velocity since the resistance which the upper part of the fluid encounts is smaller than that does the bottom part of the fluid. But that is not to say that Vp is always larger than Vr or Vf. The variation of Vr and Vf reflects the deformation of fluid more directely. In Case I, if Vf > Vr, the fluid extended; while if Vf < Vr the fluid shortened. As the discharge of water supply increased, the reach at which Vf < Vr moved downstream after the same intervals of time. This kind of phenomena can also be illustrated in Figure 5, in which the shapes of the fluid at the respective reaches were drawn down. With the increase in discharges of water supply, the positions of Vf < Vr can be found in the reaches of 21°, 18°, 12° respectively.

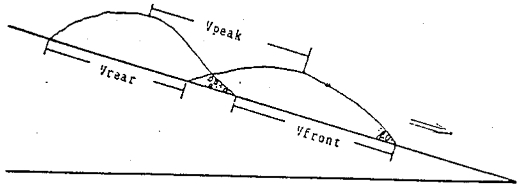

Fig. 4 Characteristic Velocities of the Fluid

In Case II, because solid material took part in the movement constantly, the fluid extended gradually from beginning to end.

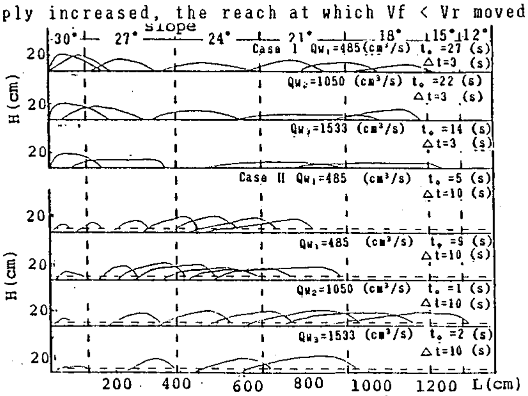

Fig. 5 The Shapes of The Fluids at Different Reaches

3.3 The peak discharges of the fluid under various experimental situations were calculated and the relationship between peak discharge and time and that of peak discharge and water discharge were shown in Figure 6. Unexpectedly, the maximum discharge of the fluid was not caused by the maximum discharge but the second discharge of water supply, Q_{w2}=1,050 (cm³/s). When the discharges of water supply were Q_{w2} and Q_{w3}, the maximum velocities were almost the same, the discharges of fluid were different owing to different flow areas. When the water discharge was Q_{w3}, the fluid differed greatly and had a relatively small peak discharge due to a contracted flow area. This phenomenon can also be observed in field. In the same gully, a relatively small rainfall may bring about a debris flow with a large peak discharge. Besides the affection of rainfall distribution in time and space, the deformative characteristics of debris flow play an important role in the formation of the maximum discharge. In the experiment, all the maximum discharges of fluid occured in the reaches with a slope of 27° or 24° and the larger the discharge of water supply, the earlier the maximum peak discharge appeared.

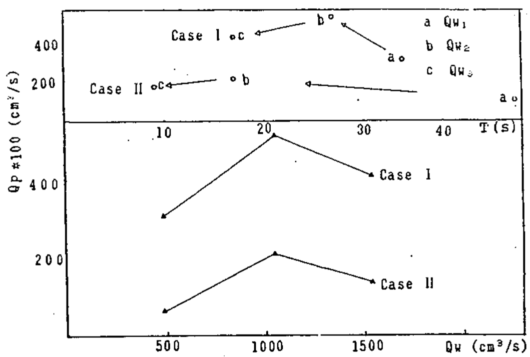

Fig. 6 The Relationship Between Peak Discharge And Time, And That of Peak Discharge And Water Discharge.

In the respective flowing sections, the hydrographs are of distinct characteristics. Four cross sections have been chosen and the discharges of fluid passing through these sections have been calculated and plotted on Figure 7. Though every part of the fluid flowed downstream at different velocities, taking a consideration of the movement of the fluid as a whole, the mean velocity can be used to compute the discharges of fluids through the sections. Due to a larger resistance, The fluids almost stopped at section IV in Case II. The calculating interval of time is 0.5 second.

In Case I, the shape of the hydrographs varied very fast. The duration in which the fluids passed through every section was very short (within 3 to 6 seconds) but the shape is somewhat similar to that of a flood hydrograph, especially at the last section Ⅳ. The rising segment is steep while the falling segment is relatively gentle. Comparing the four peak discharges at four cross sections, the maximum discharges appeared at section Ⅱ under all the three conditions of water discharge and the maximum discharge of the fluid was caused by Q_{w2} as mentioned previously. Results of the hydrograph show that the peak discharge increased first and then decreased after passing through section Ⅱ. The shape of the hydrograph becomes lower and longer in sections Ⅲ and Ⅳ.

In case Ⅱ, due to the incorporation of grains in movement, the fluid could not move downstream continuously from start to finish under a relatively small water supply. For example, when Q_{w1}=485 (cm^3/s), the fluid stopped at sections Ⅱ and Ⅲ, and the hydrograph became disconnected. The discharge of the fluid was zero. While as long as water supply is sufficient, the fluid will have enough energy to move downstream uninterruptedly and the deformative characteristic of the fluid will be similar to that of the fluid in case Ⅰ.

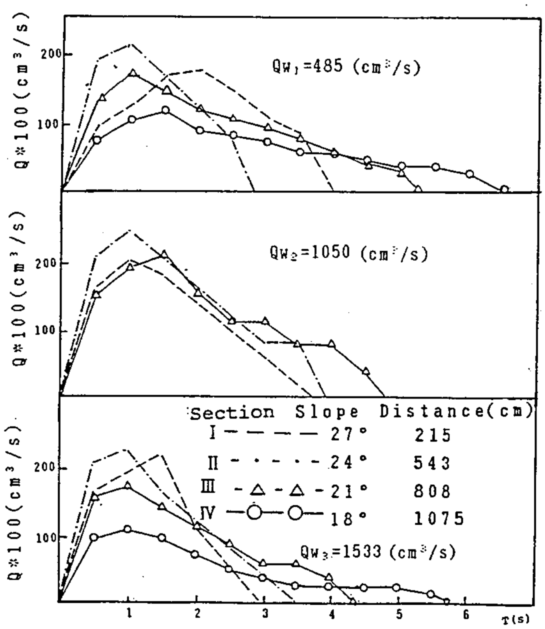

Fig. 7-1 Hydrographs of The Fluids in Case Ⅰ

4. Conclusions

4.1 Under a concentrated grain supply, the larger water supply does not mean that the peak discharge of the fluid will be larger correspondingly. Owing to the deformative properties, a relatively small rainfall may also bring about a larger-scale debris flow under a certain condition in field. That is to say rainfall and peak discharge of debris flow may not have the same frequency sometimes.

4.2 The deformation of debris flow, in fact, reflects an adjustment function of gully. Making full use of this property reasonably is significant for us to protect the drainage works downstream and to eliminate the damage by contracting the flow area and by reducing the peak discharge of a debris flow.

4.3 The data used in the research were extracted from the screen of a T.V set and could not be accurately determined, nonetheless they still satisfy the research on movement characteristics qualitatively. In adition, more detailed experiments should be carried out repeatedly in order to master more valuable data for taking further steps to study the deformative characteristics of debris flow.

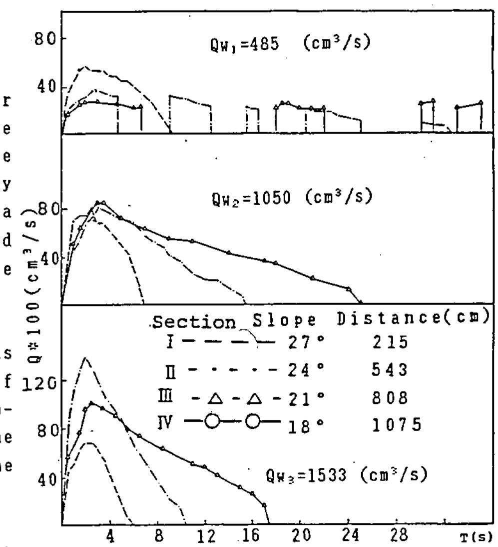

Fig. 7-2 Hydrographs of The Fluids in Case Ⅱ

Reference:

Tamotsu Takahashi and Sang Fu Kuang: Formation of Debris Flow on Varied Slope Bed, Annuals, Disas. Prev. Res. Inst., Kyoto Univ., No.29B-2, 1986, pp.343-359.