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Routing Debris Flow with Limestone

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Synopsis

In the recent decade, several debris flow events have occurred and caused hundreds of deaths, injured people and damaged many facilities. Consequently, there is a strong need to devise a method to evaluate the possible debris flow hazard areas. To comprehend precisely this problem, this study sets up debris flow experimental channel at Ujigawa Open Laboratory. The model apparatus are consisted with three main components: a flume open channel, a deposition board and a water intake box. To understand the particle segregation and movement mechanism of the limestone grain (2.5mm and 6mm) flow, a high-speed video camera (HSVC) is used to capture a video footage during short intervals of 0-40s. Besides using HSVC, video recordings of the tests were performed to analyze debris flow characteristics. This paper presents about the routing of limestone grains at two different slope angles which of 18° (mild) and 25° (steep). Results of the deposition patterns for each case are discussed.

Keywords: debris flow, non cohesive, physical model, limestone

1. Introduction

Debris flows are mass movements consisting of granular solids, water and air moving as a viscous flow, surge down slope in response to gravitational attraction (Iverson, 1997). Debris flows include many events such as debris slides, debris torrents, debris floods, mudflows, mudslides, mudspates, hyperconcentrated flow and lahar (Johnson, 1984). Interaction of solid and fluid forces not only distinguishes debris flow physically but also gives the unique destructive power. Because of their high velocities in the order of several meters per second, they are the most dangerous type of mass movements and cause significant economic loses as well as casualties (Martinez et al., 1995). Debris flow mainly dealt with laboratory study (Bagnold, 1954), modeling trigger and movement mechanisms (Takahashi, 1981 and Takahashi et al., 1992), deposits (Innes, 1985) and case studies of extreme events that caused damage or casualties (Villi and Dal Pra, A. 2002)

This paper was a preliminary study about the routing of the debris flow with limestone. These paper presents and discusses about the routing of limestone grains at two different slope angles which are 18° (mild) and 25° (steep) by conducting a physical model of experimental study. This paper starts with the presentation of the experimental set up which includes material used, data collection and experimental procedure. Comparison results of the deposition patterns for each case will be discussed and finally conclusions of the limestone grains deposition pattern had been made.

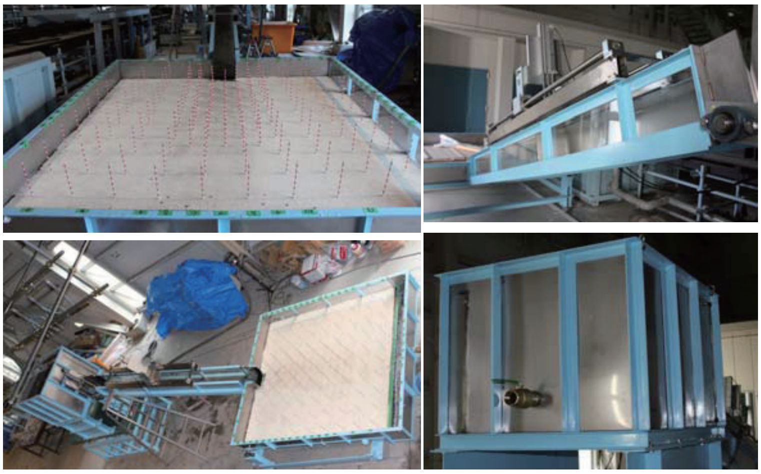


Fig. 1 The debris flow experimental model

2. Experimental Set-up

In order to investigate the debris flow and its deposition process, experiments were conducted in laboratory. They were carried out in an indoor experimental flume near Ujigawa Open Laboratory, Kyoto University. The model consists of three main parts which are debris flow water box, debris flow rectangular flume and the debris flow deposition board. Fig.1 shows the debris flow experimental model.

2.1 Water intake box

At the top end there is storage container (debris flow water box) with 1m long, 0.8m width and 0.7m height can be filled up to 0.56m^3 of water. It is equipped with a gate that can be opened instantaneously by a gate controller. This gate is located at the bottom of the box as a function to supply water through the rectangular flume.

2.2 Rectangular flume

The debris flow rectangular flume dimensions were 20 cm width, 20cm depth and with 300 cm effective flow length. The flume was supported with a moveable prop, which could be moved back and forth to adjust the flume slope ranging from 5° to 33°. Rectangular flume with transparent sidewall closely connected the downstream end of the deposition board. This transparent side wall is very useful during observation and image captured by a video camera.

2.3 Deposition board

The debris flow deposition board with at each side 2m long was divided into grid. The gridding system is different depend on the deposition area. In the middle of the deposition board, the grid size was smaller than other part because in this area the concentration of the materials is higher. The board was designed as an experimental device, so that its slope could be adjusted as one wanted. The board and flume were smoothly connected. The deposition board slope varied from 0° to 7°.

2.4 Materials

In this study, two different sizes of materials were used. Each material can be easily differentiated by looked at the color. The materials were white and black color respectively. The unit weight and mean grain size of black grain were 1.5g cm^{-3} and 6mm respectively; the unit weight and mean size of the white grain were 2.7g cm^{-3} and 2.5mm, respectively. For single run the total weight of each material had been used were 10.1kg (white) and 8.64kg (black). These materials were mixed up before been used for the experimental study.

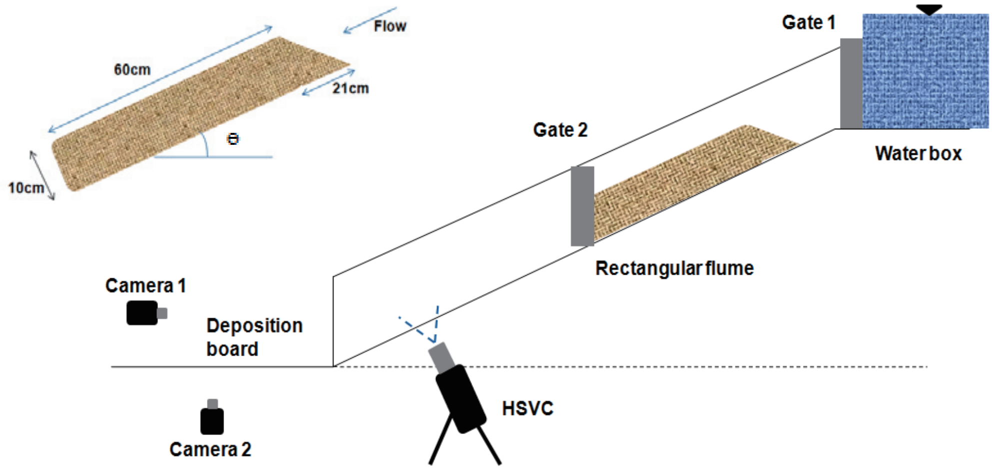


Fig. 2 The diagram of the experimental set-up

3. Experimental Procedure

Two cases of laboratory experiments were conducted in this study with 18° and 25° slope angle. Experiments were conducted separately but the water discharge was set as same for each case. The debris was placed 2m from the bottom of the rectangular flume. The detail of debris load in the rectangular flume is shown in Fig.2. This debris was well mixed up between black and white materials. For each case of study, at least three times the experiments had been made to understand the limestone particle distribution and movements. Discharge was supplied from the upstream end of the channel through Gate 1.

A constant discharge (3.0l/s) was supply within 10s until the water was fully saturated inside the debris materials. When the debris was fully saturated then Gate 2 will be opened. High speed video camera (HSVC) had been placed under the rectangular flume to capture the movement characteristic of the individual particle grain. HSVC can capture a video footage during short intervals time (0-40s). Two video cameras were set at different locations to record continuous and simultaneous process of debris flow deposition process. Video recording of the experiments were performed to analyzed debris flow characteristics and captured the formation of debris flow deposition process. The diagram of experimental set-up is shown in Figure 2.

4. Data collection

In this study, the data collection can be separate to two parts which are sampling of the materials and observation of the material depositions. Fig.3 shows the summarized of the steps taken for data collection.

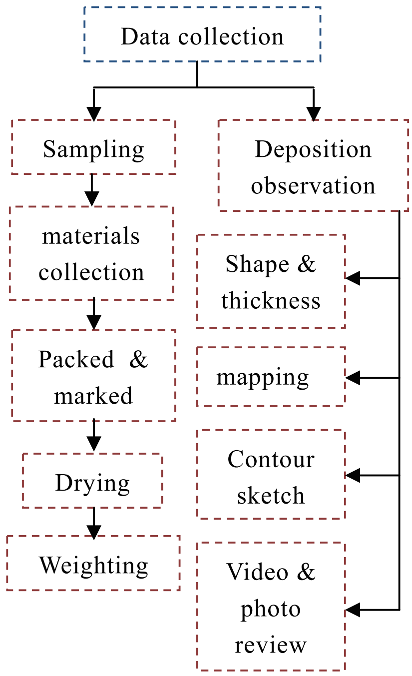


Fig. 3 Steps taken for data collections

3.1 Sampling

The objective of the sampling processes is to get the percentage of materials at different node at different height. This process involved four steps. First step was materials collection at certain node that been identified. This method was done by using special equipment made by the author. After that, materials at different height had been packed and marked. Then each packed had to be dried at 105°C for 24 hours. The last step just after drying process was by take a weight of each sample.

3.2 Deposition observation

The objectives of this method are to understand the particle characteristics, particle distribution and the physical data of the deposition materials. Observation of the deposition processes included (1) measuring deposit shape and thickness distribution, (2) mapping surface structure, (3) deposition contour sketch and (4) reviewing video and still photographs of the stages of the debris deposition formation. These four processes had to be done and repeated more than once time to get the accurate results.

5. Results and discussions

The deposition formation observation had been done at three stages which were 3s, 5s and final stage.

Figure 4 and Figure 5 shows three stages of material deposition formation for cases 18° and 25° respectively. Fig.4 shows the highest contour was 6cm during 5s and the shape of the deposition looked symmetry at each side. From the results it can be concluded that the slope angle 18 ° did not gave a high impact on the deposition shape however, the materials segregation were well distributed. In case of 25° slope angle, the movements of the materials were much faster than case 18°. This can be seen clearly during 3s observation. The dispersion of the materials in this case was at Row I but for case 18° was just at Row F. This phenomenon exists because of the kinetic energy got from the materials itself.

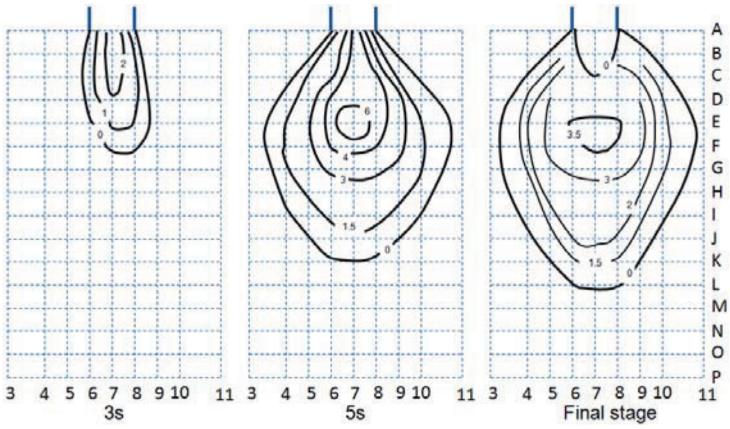


Fig. 4 Three stages of debris formation for case

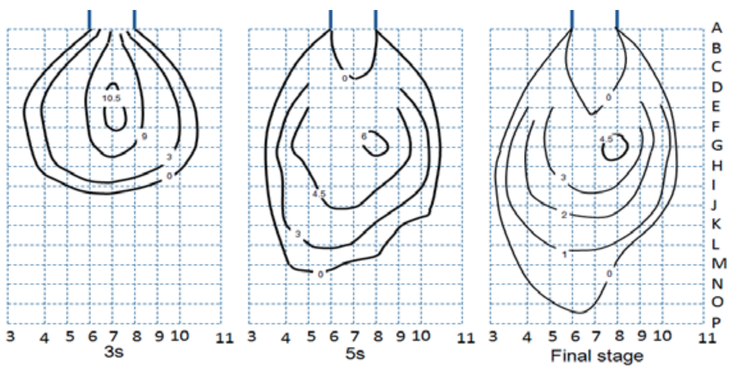


Fig.5 Three stages of debris formation for

Materials placed at higher slope angle have a greater kinetic energy compared to the lower once. Furthermore, occurrence of the high kinetic energy gives a big impact at the materials deposition shape. As a result, the deposition was not symmetry and the debris run out was further then case 18° . Fig.5 shows the three stages of debris formation for case 25°. Table 1 shows the percentage of materials at 18°. For the sampling reason, 10 nodes were selected as marked in yellow color. The trend of white material was decreased from nodes C9 to K7. In contrast, the black material was increased. The volume of the debris covers up starting from Row A to L and Colum 3 to11. The debris length was 1.13m and the width was 0.9m. Table 2 shows the percentage of material deposition at 25°.

In this case, 9 nodes were selected as marked in yellow color. The length and width of the debris for case 25° was 0.32m longer and 0.1m shorter than the case 18°. Results of the materials distribution for this case can be concluding as no trend. White material so as black material was distributed in their own characteristic. This situation happen because of the deposition shape was not symmetry affected of high kinetic energy. For future study, more sampling node should be taken to get more data to understand the shape and materials composition distribution. Fig.6 and 7 shows the composition of the materials at different height at each node for case 18° and 25° respectively. The numbers in the bracket means the height (cm) of the deposition.

Table 1 Percentage of materials at 18°

Node	White (%)	Black (%)
C9	75	25
D8	80	20
E9	59	41
E7	67	33
F8	63	37
G9	54	46
G7	54	46
H8	47	53
I7	45	55
K7	35	65

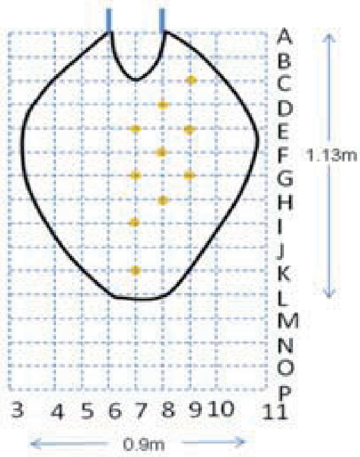
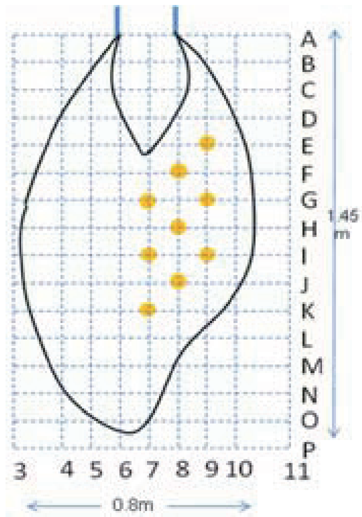


Table 2 Percentage of materials at 25°

Node	White (%)	Black (%)
E9	60	40
F8	69	31
G9	53	47
G7	62	38
H8	60	40
I9	50	50
I7	57	43
J8	44	56
K7	67	33



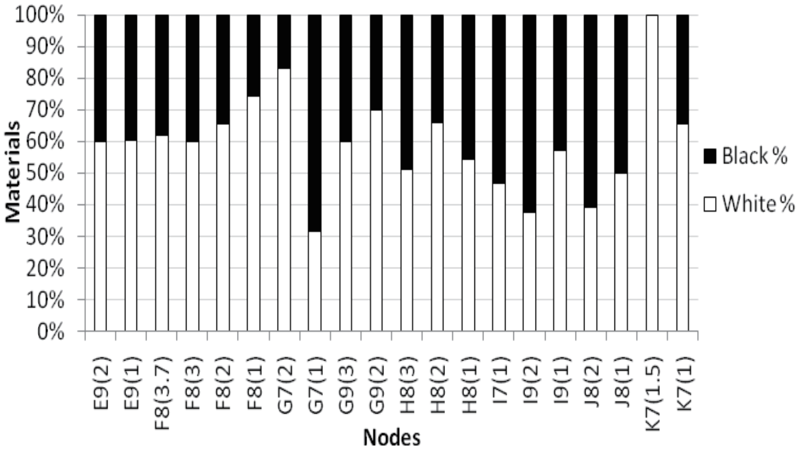


Fig.6 Materials distribution at different height for Case 18°

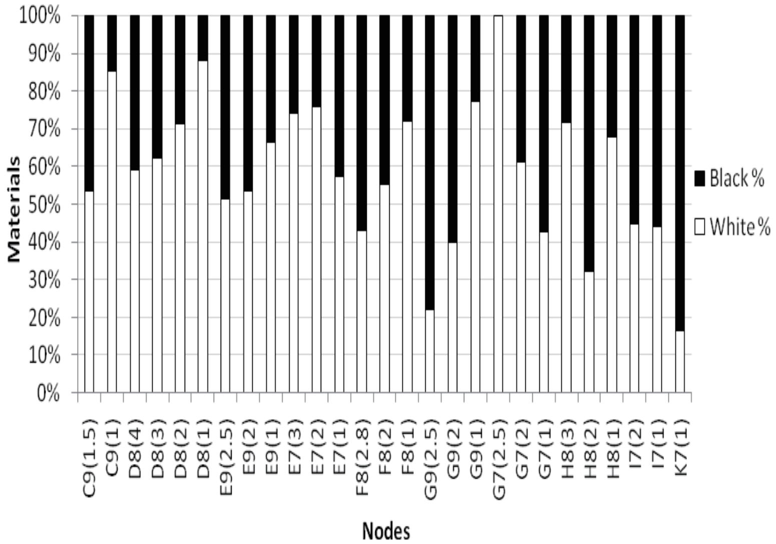


Fig.7 Materials distribution at different height for Case 25°

4. Conclusions

The size of the deposition is represented by the area, length, width and thickness, and it may be affected by rectangular flume base slope. Larger slope angle shows that the deposition run-out length is bigger than the smaller slope angle. On other hand, contrast results for the width of the deposition. The materials composition at deposition area clearly showed the characteristics of the particle segregation. This data can be used as an input data for computational numerical simulation. The following future works will be done for this research. Firstly artificial rainfall will be used to understand in more details about the occurrence of debris flow phenomena. Besides that, different type of materials will be used with combination of different case of studies.

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石灰岩を用いた土石流追跡実験

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要　旨

本研究は石灰質による流下土石流と土石流扇状地の形成過程を宇治川オープンラボラトリに設置された急勾配水路を用いて解析を行なったものであり，土石流発生と発達過程における分級および，扇状地における粒度分布解析結果を明らかにするものである。本研究においては混合粒径土石流の分級を議論する基礎実験として二つの異なる流径(2.5㎜と6㎜)を用いた土石流扇状地の形成実験と高速ビデオカメラを用いた粒子追跡を行なった。扇状地の形成過程の初期段階において荒い流径粒子が前方に集中し，これらが扇状地の発達に影響を与える事を明らかにした。

キーワード: 土石流，石礫，模型実験，石灰岩