第 II 部門

A Study on Segregation of Particles with Two Different Sizes in Debris Flow

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1. Introduction

To understand the general behavior of particle segregation in debris flow, a physical model experiment for debris flow with two distinct diameters was conducted. Furthermore, the high-speed video camera (HSVC) results tracing each particle movement are compared with the solutions of Hydro Debris 2-D Model (HD2DM), a Lagrangian sediment particle tracing numerical experiment. In order to accommodate the main concern and challenges of debris flow particle routing mechanism study, the following objectives are set up. These designated objectives will serve as the basis of the problem solving and also a guideline for this paper. The objectives are: 1) to understand the particle segregation and movement mechanism of the grain flow (2.5 mm and 10 mm), 2) to delineate the deposition pattern and contour mapping, 3) to collect data as input data for particle routing computational simulation (HD2DM), and finally 4) to develope the HD2DM of particle routing segregation.

2. Experimental set-up

In order to investigate the debris flow and its deposition process, experiments were conducted at the Ujigawa Open Laboratory, Kyoto University. The model consists of three main parts: water intake, rectangular flume and the deposition board. Two different sizes of materials are used: 10 mm and 2.5 mm. The unit weight of each grain is 2.7 g cm^{-3}. These materials were mixed up well before they can be used for experimental study. This study involves three slope angles: 15º (low), 20º (intermediate) and 25º (high). A constant discharge (3.0 l/s) was supply within 10 s. A HSVC had been placed nearly downstream of the rectangular flume to capture the movement characteristic of the individual particle grain. Two video cameras were set at different locations to record continuous and simultaneous process of debris flow deposition process. For the purpose of data collections, sampling of deposition and observation of the materials deposition had been done.

3. Hydro 2D Model

The principal aim of a vertical two-dimensional numerical model development is for estimating the particle tracing and mechanism of 10 mm and 2.5 mm debris. The model development in this study is based on a model developed by Yamashiki et al. (1997). The particle tracing movement can be visually analyzed by using HSVC. A numerical model was developed using the Marker and Cell Method, which involves a SGS (Subgrid-Scale) model and the PSI-Cell (Particle Source in Cell) Method. The transportation processes of debris and air bubble were simulated in Lagrangian form by introducing air bubble and debris markers. Air bubble movement characteristics were simulated by this numerical model.

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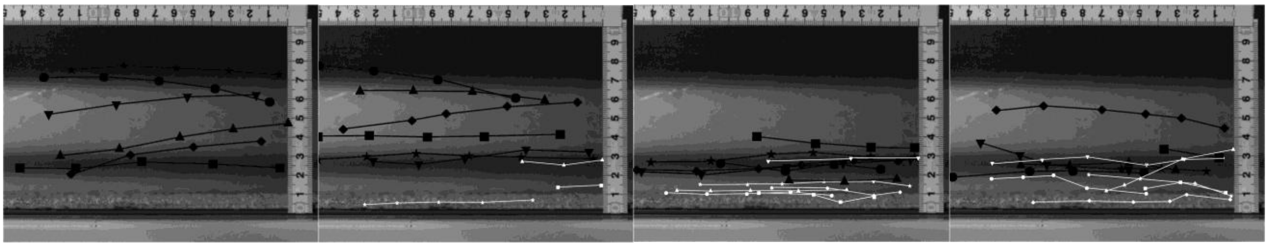
4. Results and Discussions

Tracing positions of 10 mm and 2.5 mm particles are represented by black and white colors, respectively. In each frame they are shown using circular, square, rectangular, star, diamond and opposite rectangular. The images of particle tracing were captured between 0.015s. By knowing the distance of each particle distribution, the velocity of each particle can be calculated. Particle tracing images captured by the HSVC are traced and presented in Figure 1 which shows the results for 25º case. The results fully demonstrate the debris flow development mechanism. The bigger particle movements (high velocity) were concentrated at the upper part of the fluid, while small particles (low velocity) were concentrated near the bottom. By understanding the particle movements and analyzed the velocity distribution, these data can be used as an input data for HD2DM.



(a) (b) (c) (d)

Figure 1: Particle tracing captured by HSVC: (a) initial, no flow; (b) starting with flow; (c) Intermediate, 2s; and (d) last, 4s

Figure 2 shows the air bubble flow (a) and debris mechanism flow (b) produced by the HD2DM for a 25º case. By referred at the HD2DM results, tracing of 10-mm and 2.5-mm particles can be seen clearly. Bigger particles flow at the upper part, while smaller particles attach near to the bottom. This phenomenon happens the same as what we observed in the experimental study.

(a) (b)

Figure 2: Examples by the HD2DM: (a) Air bubble flow and (b) debris mechanism flow

5. Concluding Remarks

The size of the deposition, which is represented by the area, length, width and thickness, may be affected by the rectangular flume base slope. Larger channel slope angle shows that the deposition run out length is bigger than the smaller slope angle. On the other hand, contrast results are obtained for the width of the deposition. The HD2DM using the soil erosion process qualitatively can be described as a well-performing model dealing with the process of particle motion. Analyses of the HSVC fully demonstrated the debris flow development mechanism. The following future works will be done: (1) some modification focusing on the particle movement mechanism (bed load motion), (2) developing a model for the deposition mechanism characteristics, and (3) Hydro Debris-3D Model (HD3DM).

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