8 Sedimentation Pattern of Debris Flows: A Laboratory Study.

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ABSTRACT

The growth of a debris flow cone involves many different geomorphological processes. A series of experiments was performed (1) to understand the growth of a cone by different debris flow events and (2) to understand and assess the major controlling parameters of the sedimentation processes. The growth of the cones was primarily due to the overriding of existing deposits by the new debris flows and only secondary due to sediment rework by subsequent water floods. The accumulation process is mainly controlled by the early deposits of the flow itself, rather than by existing deposits and obstructions.

INTRODUCTION

Alluvial fans or so called debris flow cones are prominent landforms in mountainous areas. These cones are mainly built by depositional processes of a great number of debris flows, mudflows or similar mass movements. The morphology of the cones is characterized by a rugged relief. The surface is uneven and steeper than that of fluvially shaped fans. In most cases nearly all the material transported by the debris flow is accumulated on the fan area (Zimmermann 1990). However, in some cases large parts of the transported materials may reach the receiving river.

Experiments with laboratory-built alluvial fans are not very common. Takahashi and Yoshida (1979) studied the deposition process of debris flows due to a sudden change of slope angle. Mizuyama and Uehara (1983) performed experiments in a long steep flume with different slope angles. They investigated the stop conditions with reference to a change of slope and channel width. The construction of laboratory-built fans is extensly described by Hooke (1967) and Hooke and Rohrer (1979), were fans were created by using different flow types (debris flows, water floods). It is probably due to the complexity of the sedimentation phenomena on existing deposits that debris flow experiments have been mostly performed considering only one single flow.

The present paper provides preliminary results of an ongoing research project on the sedimentation characteristics of debris flows on laboratory-built debris flow cones.

LABORATORY APPARATUS

The experiments described here were carried out in a 3 m long and 0.1 m wide flume (fig.1). The gradient was 22° and the bed of the flume had an artificial roughness of about 2 mm. A flat board of 1.8 m x 2.5 m and a slope of 8° served as an accumulation area. In order to prevent sliding of the material on the smooth surface an initial roughness was given by an iron grid of 1 cm spacing. Water was supplied by pumping from a tank through a pipe into an inlet box. The cones were built with a series of 12 to 18 single debris flow events. The discharge and the time of water flow in the flume was held constant during each series. In order to produce the debris flows, about 8 liters of material were piled in the flume behind a wooden board. The debris was initially fully saturated with a watering-can. The flows were released by pulling the board after the water from the inlet box overtopped the pile. After each run the deposits were covered with a thin layer of fly ash in order to distinguish the recent from the older deposits.

Two types of material were used with the grain size distributions given in fig.2. Material I was a coarse gravel with no fines. Material II could be characterized as a well-graded coarse sand with a small amount of fines.

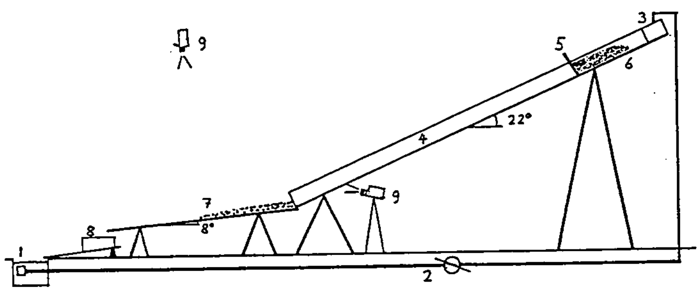

Fig. 1 Schematic view of the laboratory apparatus.
1: water tank with pump, 2: valve, 3: water inlet box 4: flume,
5: release board, 6: piled debris, 7: accumulation board with cone,
8: sediment trap, 9: video cameras

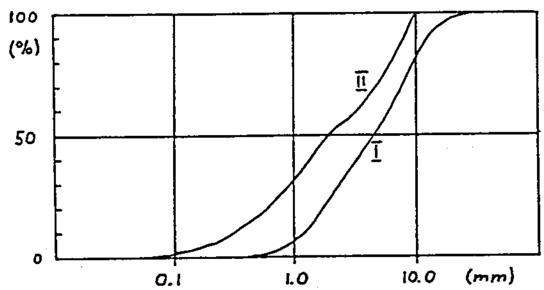

Fig. 2 Grain size distribution for the different materials.
Mean diameter: Material I: 5.2 mm, Material II: 3.2 mm.
Maximum diameter: Material I: 25 mm, Material II: 10 mm.

OBSERVATIONS AND RESULTS

In the first series of experiments the coarse material (Material I) was used. The first run, in general, clearly indicates the formation of a debris flow deposit on the flat board. However, further flows didn't override the existing deposits. They followed either the previously eroded channel on the board or stopped immediately on the existing deposit. Backfilling occurred in the apex and the flume itself.

The cones constructed with Material II had many features in common with those found on natural cones: a segmented surface, distinctly overlapping lobes, inversed grading of the deposits, and levees at the lateral margin of a long debris flow tongue. Longitudinal and transversal profiles were steep and irreguliar. The debris flows released in the steep channel showed a distinct and clearly visible segregation of the different grain sizes after a flow distance of only two to three metres. The highly concentrated flow lasted about 5 to 7 seconds and was followed by a less concentrated flow of about the same duration. The clear water discharge in the flume was set to 0.16 l/s.

In spite of rather different velocities of the frontal surge in the flume there exists no relation between runout distance and flow velocity (fig.3). It is assumed that the stopping of the first surge is in general controlled by the permeability of the underlying material. However, there is presently little evidence to prove this to be true. The stop condition of this first surge seems to control largely the subsequent development of the deposit during the same run. In most cases backfilling processes take place behind the frontal lobe without affecting areas outside the debris flow tongue. In fig.4 it may be seen

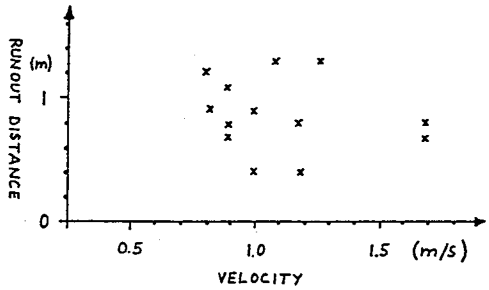

Fig. 3 Correlation between the velocity of debris flow in the flume (m/s) and the runout distance of the first surge (m). Results from cone 15, run 5 to 18.

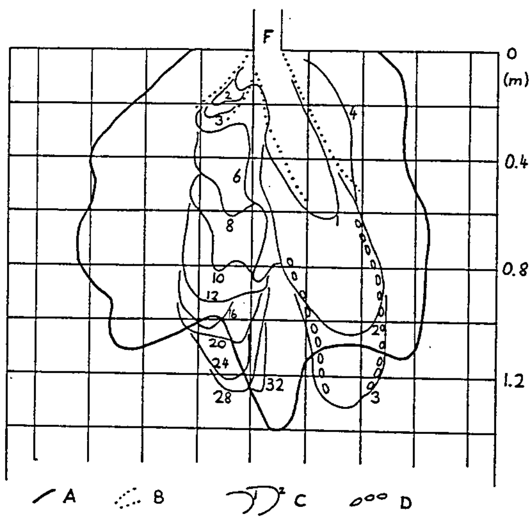

Fig. 4 Pattern of deposits on cone 15, run 8.
A: shape of cone after 7 runs; B: channel incision prior run 8
C: Development of deposits in seconds (1-32); D: coarse levees
F: Flume

that the first surge traveled rather fast over the existing deposit reaching 1.3 m after 3 seconds. The following surges filled the area between the levees. The water flow following the main surges was forced to run on the right side (in the flow direction). The initial direction of the first surge was mostly guided by preexisting channels (fan incision by water flood of the preceding run), but such channels were quickly aggradated and the deposits spread out.

With increasing age of the cone, the accumulation of the single debris flows shifted over the whole cone. It could be estimated from photographs, taken after each run, that the area on the cone affected by the debris flow itself decreased with the increasing number of debris flows. However, the area inundated by subsequent water flows was in general much bigger than that by the debris flow. After four or five runs the longitudinal profile got a convexe shape with a mean gradient of about 12 to 14°.

Trenches made trough the cone showed clear layers (one to two cm thick) of fine and coarse grained material. Samples taken at the distal end of the cone consists in general of much coarser material than samples taken near the apex. This resembles the deposits of the relatively coarse front of the surge.

CONCLUSIONS

It is possible to produce in the laboratory small alluvial cones shaped mainly by debris flows. The cones show certain features similar to natural cones (segmented surface, debris flow lobes, levees). In an initial stage, the direction of the debris flow surge seems to be guided by preexisting channelization. The aggradation of the channnel and subsequent spreading is largely controlled by the flow distance of the first surge on the cone. Further investigations should show the influence of different permeabilitis of existing deposits. It can be assumed that these differences in permeabilty largely control the runout distance and lateral spreading of debris flows.

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