II-33 INITIATION MECHANISM OF DEBRIS FLOW BY DESTRUCTION OF NATURAL DAM IN STEEP SLOPE CHANNELS

Graduate School of Science and Eng., Ehime University Krishna Raj Pathak (Student M.)
Graduate School of Science and Eng., Ehime University Kouki Matsuda (Student M.)
Dept. of Civil and Environmental Eng., Ehime University Koichi Suzuki (Member)
Dept. of Civil and Environmental Eng., Ehime University Akihiro Kadota (Member)

Introduction

The initiation of debris flows have been related to the following three reasons. Firstly, landslide that turns into debris; secondly destruction of naturally built dam turning into debris flow and last one is surface water flow on a gully bed during heavy rainfall cause to mobilize the accumulated mass [1].

Natural dam is formed across the steep-slope channel of mountainous area, mainly because of landslides. Forces of flowing water in and over the dam and pressure of detained mass of water cause the movement of dam forming materials along with the water and debris flow is likely to occur in the downstream areas of channel. The initiation mechanism of destruction of a natural dam is varied with the characteristics of dam forming materials and channel as well as discharges.

The main objective of this study is to observe the process of initiation mechanism of flow that exist frequently in steep slope channels by abrupt collapsing of a natural dam causing debris flow to occur in downstream areas.

Experimental Set-up and procedure

Experiments were carried out in an indoor laboratory flume of cross sectional dimension 15cm × 30cm and 10m in length. The flume has transparent sidewall at both sides and could be tilted to vary its slope. The slope of the experimental channel was set to 1/5.57 for all experiments of present study. The dam (15cm wide, 10cm deep and 1m long) was made of sand or gravel with almost uniform grain size of 1mm, 4mm, 7mm and 15mm. Experiments were conducted separately, changing the flow rate of water five times in each case. A constant discharge was supplied continuously until the destruction of dam completed out of its original position and the rate of flow was reckoned manually using a measuring bucket and a stopwatch. Three video cameras were fixed at different locations to take continuous and simultaneous measurements of initiation process of debris flow. Schematic figure of experimental set-up is shown in Fig.1.

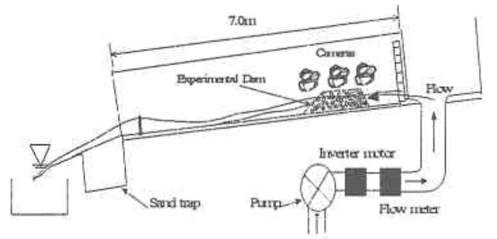

Fig.1 Schematic diagram of experimental set-up

Results and discussion

Types of collapse of natural dam

General observation during the time of experiments revealed that the grain size of dam forming material is one of the important parameters governing the initiation mechanism of debris flow at the destruction process of the natural dam.

Schematic diagrams in Fig.2 show how the collapse of dam proceed with the grain size of dam forming materials. Graphs (a-1) and (b-1) show the actual process of destruction phenomena of experiments for gravel and sand respectively. In case of smaller particles, flow proceeds as shown in diagram (b-2) and eventually collapse resulted in like diagram (b-3). A portion of flow entered into the dam body itself and the remaining part accumulated resulting in rise of water level upstream of dam. Surface flow over the dam resulted as water level surpasses the height of dam. Seepage and over topped flow advanced downstream direction. As overtopping of flow begun, it eroded particles from the dam surface and a part of downstream face collapsed initiating the destruction of dam and continued as shown in (b-1). But in case of larger particles, considerable part of flow percolated through dam body itself as shown in (a-2). The rate of percolation was faster than the rise of water level at the

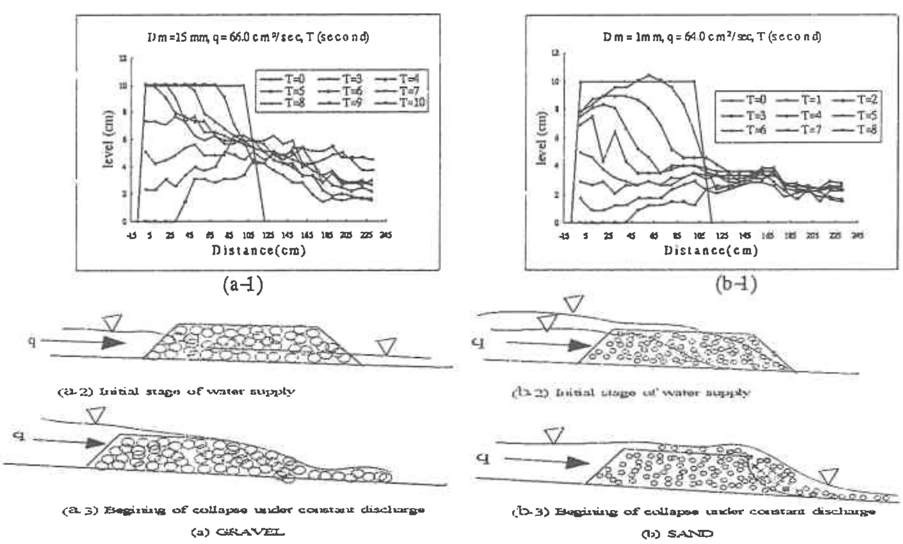

Fig.2 Actual and schematic diagrams of collapse phenomena with the size of dam forming materials

upstream of dam. Initiation of destruction started at the toe of dam somewhere the seepage water emerged on the surface as shown in (a-3).

Example of experimental results are depicted in the graphical plots in (a-1) and (b-1) of Fig.2. Initial destruction was started near the downstream face of the dam and proceeded rapidly and progressively towards the upstream direction in case of the dam made of larger-sized particles. Progressive failure seems to proceed in upstream direction. The destruction was rather faster in case of small-sized particles.

Time of complete collapse t_f

Fig.3 shows the relationship between the grain size of dam forming materials and time required to initiate the destruction and complete wash out of dam from the original position. it can be seen in figure that initiating time of destruction of dam gradually decreases as the size of dam forming materials increases.

It may be because of poor permeability and higher water holding capacity of smaller particles than bigger ones. But, time required for complete collapse of larger particles is more than smaller ones, once destruction is started. It means the dam made of small-sized particles collapse faster than the dam made of large-sized particles.

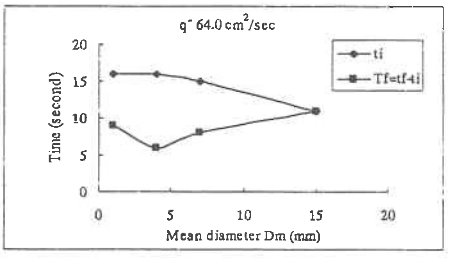

Fig.3 Mean diameter versus time for initiating and completing collapse

Temporal variation of eroded volume

The eroded volume, V_e is defined by the volume eroded (accumulated) and transported from the original dam volume V_0 at a time concerned. Fig.4 comply with the experimental observation made during intiation process of debris flow with different grain sizes under almost same discharge. The eroded volume, at the onset of the destruction, is larger in case of smaller particles and keeps advancing almost steadily. However, in the event of large-sized particles, the rate of eroded volume is smaller at the beginning of destruction and increases as the time goes by. It implies that in case of small-sized particles, surface erosion and collapse of frontal part because of large differential pressure (large pressure difference saturated and unsaturated mass) of dam cause eroding more volume than that of large-sized particles.

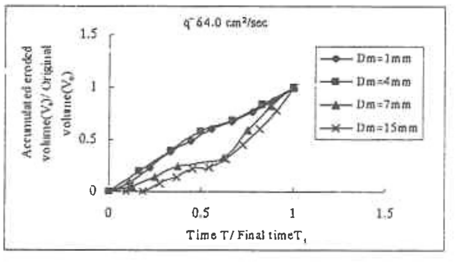

Fig.4 Relationship between non-dimensional eroded volume versus time under size variation of dam forming materials at approximately same discharge

Depth of debris flow downstream of dam

Fig.5 shows the debris flow depth at 130 cm downstream of the original position of the dam. Occurrence time of peaks is short for smaller particles than larger ones. Peaks of debris flow depths have been appeared after a time lag resulting in multiple peaks. Peaks of debris flow depths are higher in case of larger particles than smaller ones. The implication of this could be partial destruction of dam. The partial destruction was observed during the experiments. The capacity withholding the water behind the dam decreases as the size of dam decreases because of subsequent erosion and collapse. Partial remaining of dam could bear some pressure of water until it reaches some critical level. Once the exerted pressure of accumulated water is more than a critical value, the dam collapses abruptly appearing the peaks of flow just a moment after of previous peak and repeats the same process again and again until dam materials wash out completely. This process causing the eroded volume of dam increases intermittently.

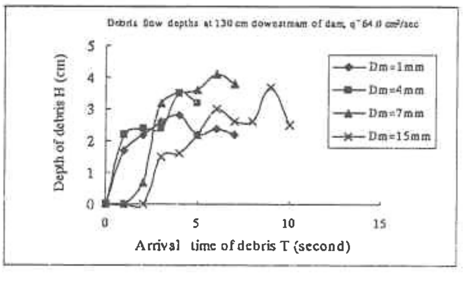

Fig.5 Debris flow depths downstream of the original dam body

Conclusion

As for the larger particles, part of the discharge seepage through the dam body creating a slippage and collapse proceeded in upstream direction. Eroded volume of the dam forming material is smaller at the beginning of collapse and increases as the time goes by. The nature of destruction of the dam, made of larger-sized particles, is rather progressive. On the other hand, dam made of smaller particles, destruction process is sudden in comparison with larger particles. The destruction process of natural dam is a complex process and seems governed by many factors. Among them supplied discharge, depth of flow, characteristic of dam forming materials i.e. permeability, size, cohesion, angle of repose of materials and so on are seem the important factors to be considered in future research to analyze the phenomena.

Reference

[1] Takahashi, T.: Debris flow, IAHR Monograph Series, Balkema, 1991,1-162.