Development of debris flow

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Abstract This study provides a method to predict debris flow peak discharge. It was obtained through flume experiments on the development of debris flow. It is found that, in steep torrents, steeper than about 25 degrees, debris flow develops monotonously as it flows down. The longitudinal shape of developing debris flow is a similar triangle. When debris flow comes into flatter reaches, the height of debris flow is kept almost constant. Based on the experimental results, the debris flow peak discharge can be predicted if the total amount of sediment available in the debris flow developing reach and the width of torrents is known. The method was applied to actual debris flows and the calculated flow heights show a good agreement with the values estimated in the field.

INTRODUCTION

Debris flow has been studied from various aspects. Its mechanism has been made clear in some degree (Takahashi, 1991). Thanks to those studies, torrents where debris flow may occur can be recognized, and debris flow prone areas and critical rainfall conditions triggering debris flows can be estimated. It is, however, still impossible to predict the hydrograph of debris flow discharge. It is most necessary information to design appropriate debris flow control structures and to estimate debris flow flood areas accurately. Some empirical and hydrological methods to predict debris flow peak discharge have been debris flow peak discharge have been proposed by authors (Ou *et al.*, 1991; Ou *et al.*, 1991; and Mizuyama, 1992). Some experiments were carried out to observe the development of debris flow and to develop a method to predict debris flow hydrograph.

EXPERIMENTS

A 1-m-long, 7.5-cm-wide flume was used for the experiments. The slope gradient of the flume can change every five degrees; 15, 20, 25, 30 degrees. Sand grains used are a uniform diameter of 5.5 mm. Water is supplied from the upper end of the flume after the material are set with 3 cm thick in the flume. Discharge rate is 10, 15, 20 and 25 litres per minute. Flow conditions were recorded with a high speed video camera. The recorded data is analyzed every 0.005 second.

DEVELOPMENT OF DEBRIS FLOW

The development of debris flow is classified into three types (Fig. 1):

Type 1: Flow develops in a short distance and keeps the flow height;

Type 2: Flow develops continuously and monotonously; and

Type 3: Flow does not develop to mature debris flow. Sand grains do not disperse in the entire depth.

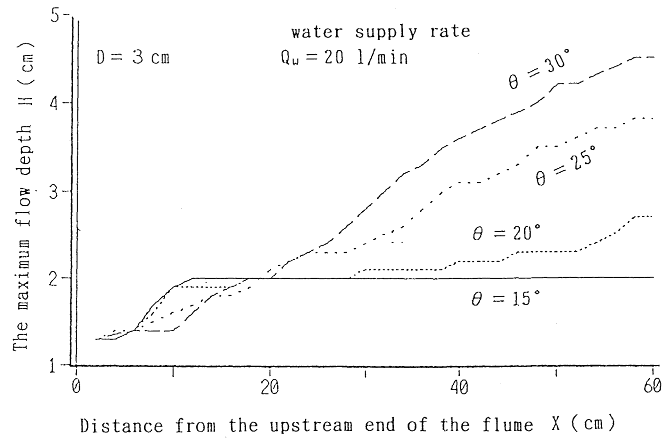

Fig. 1 Change of the maximum height of debris flow with traveling distance.

The lines in Fig. 1 are from Takahashi (1977).

$$\tan\theta_1 = \tan\varnothing \cdot C_*(\sigma - \rho)/(C_*(\sigma - \rho) + \rho(1 + h_0/d))$$

$$\tan\theta_2 = \tan\varnothing \cdot C_*(\sigma - \rho)/C_*(\sigma - \rho) + \rho) \qquad (1)$$

$$\theta_3 = \varnothing$$

where θ is the gradient of channel; C_*, the sediment concentration of torrent deposit; $\varnothing$, the angle of repose of the sediment; σ, ρ, the densities of sediment and water respectively.

h_0/d is converted to qw^2/gd^3 by the following equation:

$$(h_0/d)^3 = 0.14^*qw^2/gd^3 \qquad (2)$$

Type 1 appears under the gradient between θ_2 and θ_3 (Fig. 2).

LONGITUDINAL PROFILE OF DEBRIS FLOW

Figure 3 shows several longitudinal profiles at different positions. It is found that they are similar triangles. The shape is also similar for different given water discharges. The ratio of height to length is 0.08 and 0.09 for channel degrees of 25 and 30 degrees respectively.

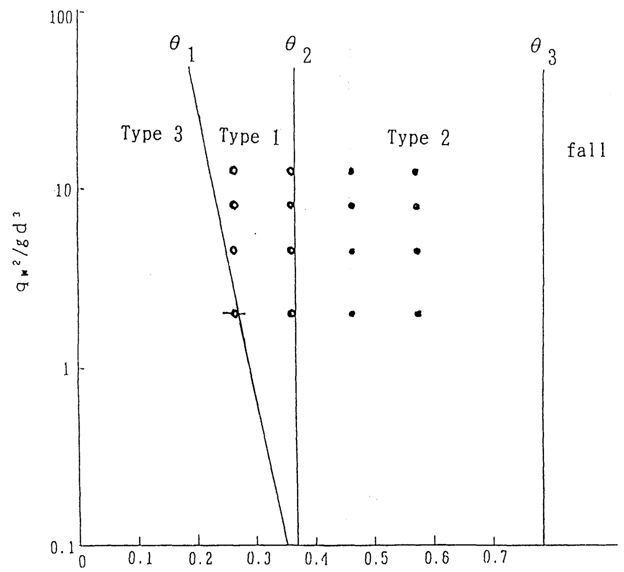

Fig. 2 Types of the development of debris flow.

APPLICATION

Figure 4 is an example of debris flows occurred at a torrent of Kyoto Prefecture, Japan in 1986. The height of debris flow and the longitudinal profile of the torrent are shown there. The height of debris flow was measured from flood marks on banks of the torrent. It is clear that the height of the debris flow is almost constant along the torrent.

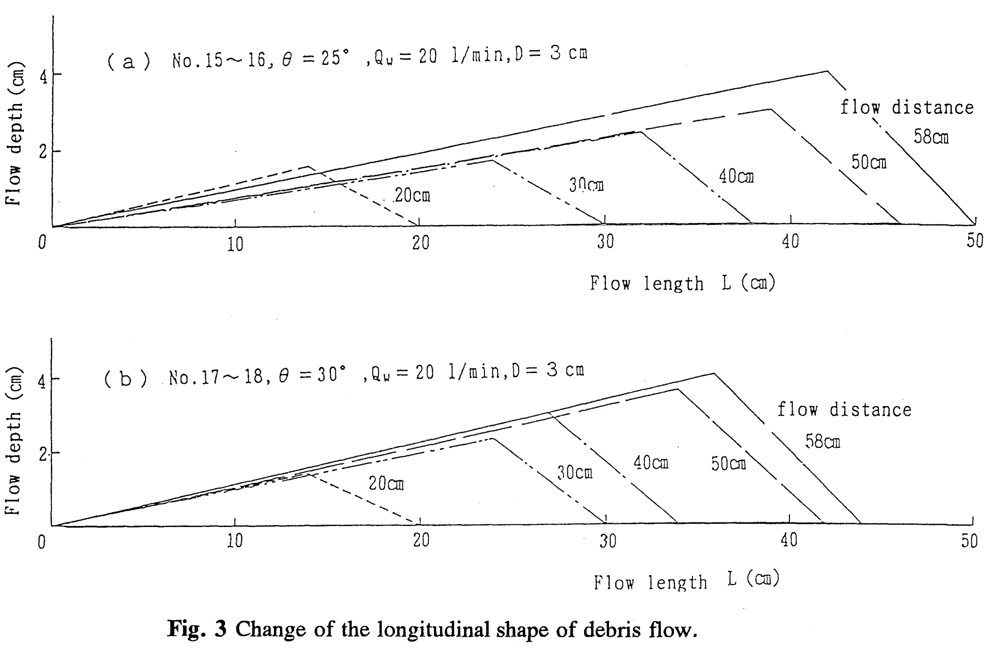

Fig. 3 Change of the longitudinal shape of debris flow.

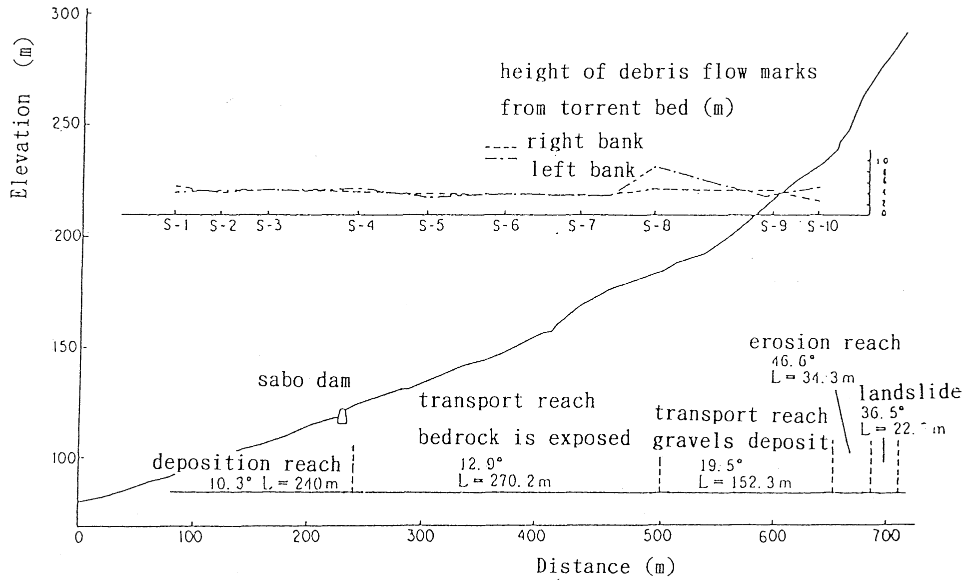

Fig. 4 An example of the debris flow height estimated in the field and the longitudinal profile of the torrent.

The height had been determined at the reach of $\theta > \theta_2$. The height of debris flows were calculated according to the experimental study mentioned above. The volume of sediment eroded at the debris flow develop reach ($\theta > \theta_2$) and width of torrents are given for the calculation. Sediment concentration of debris flow was assumed 0.5.

The calculated height of debris flow is compared with the measured one in the field (Fig. 5). The result shows good agreement.

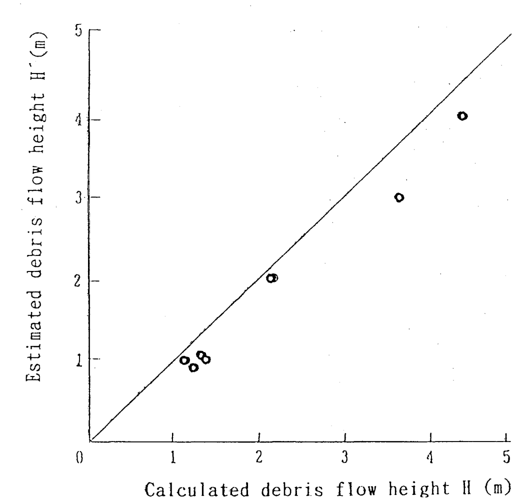

Fig. 5 Comparison between calculated debris flow heights (*H*) and actual heights estimated in the field (*H'*).

CONCLUSIONS

The development process of debris flow was observed in an experimental flume. It was found that debris flow develops at a steep reach of $\theta > \theta_2$ and the height is kept at the reach of $\theta < \theta_2$. The longitudinal profile is a similar triangle. The result was applied to debris flows occurred actually. The result shows good agreement. When debris flow peak discharge is needed to know, the velocity of debris flow must be multiplied to the height. A following equation on velocity was obtained through the experiment.

$$u/u_* = 6*(h/d)^{-1} \quad (3)$$

where u is average velocity of debris flow; u_*, frictional velocity; h, the height of debris flow; and d, representative grain size.

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