Estimation of Debris Flow Hydrograph by Coupling Between Camera Image and Acceleration by Vibration Meter

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INTRODUCTION

Debris flow with boulders and driftwoods triggered by rainfall of typhoon Neogri took place in Nagiso-Town, Nagano Pref., Japan in 2014. Nashizawa (catchment area, A=3.28 km^2) where debris flow occurred is composed of Onashizawa (A=2.55 km^2) and Konashizawa (A=0.73 km^2) (**Fig.1**). Onashizawa had Nashizawa sabo dam (closed-type, dam height, H=20.0m)) and Nashizawa No.2 sabo dam (partial slit dam, H=14.5m), and Konashizawa had Nashizawa No.1 sabo dam (slit dam with iron grid, H=12.5m), and some groundsills were installed along those creek. Debris flows took place at both those creeks, and a part of debris flow was trapped in some sabo dams, but the others caused a disaster including the human damage even though installed sabo structures were caught debris flow sediments.

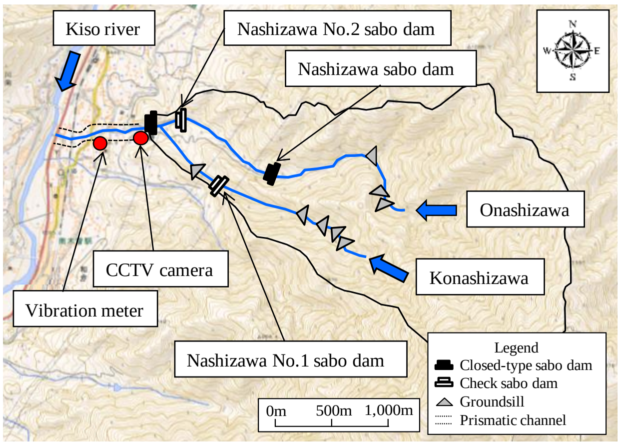

Fig.1 Plan map of the study site in Nashizawa creek

For design discharge of Nashizawa debris flow plan, we estimated temporal changes of debris flow discharge by camera image recorded by CCTV camera and ground vibration caught by vibration meter, and estimated hydrograph was verified by free surface trace measured by field survey and hydraulic model tests.

STUDY AREA

Nashizawa is a torrent of stream endangered by debris flow. The average bed slope of Onashizawa and Konashizawa in Nashizawa basin is 1/3.4 and 1/2.9. The bedrock underlying the watershed is granite. There are many boulders around over 2 m in diameter on the bed after disaster.

A CCTV camera is located in the confluence of Onashizawa and Konashizawa. A vibration meter (High Sensitivity Seismograph Network Japan, Hi-net) is installed under the ground about 104 m in depth and 10 m apart from the river center and located 500 m apart from the confluence.

LONGITUDINAL DISTRIBUTION OF PEAK DISCHARGE

Nine free surface traces were investigated at fixed cross section such as spillway of sabo dam in Onashizawa, Konashizawa, and the downstream of the confluence. Applying Manning formula for mean velocity, in which roughness coefficient was set 0.1 (m$^{-1/3}$s) in Onashizawa and Konashizawa, 0.04 ($m^{-1/3}s$) in the downstream of the confluence, peak discharges of debris flow were estimated at each observation section of free surface trace. Estimated peak discharge took wide range from 490 m^3/s to 889 m^3/s in the downstream of the confluence.

ESTIMATION OF DEBRIS FLOW HYDROGRAPH

1. Estimation of debris flow discharge by camera image: Surges of debris flows were recorded by CCTV camera, though the camera was destroyed by those surges. Water level and surface velocity are measured by camera image. Surface velocity is corrected using the relationship of 3/5 times of surface velocity for mean velocity during debris flow is passing through the dam. Discharges were estimated from 79 m^3/s to 428.4 m^3/s during debris flow.

2. Synchronizing between discharge and acceleration of vibration: Vertical component of acceleration of vibration calculated using root mean square (RMS) was two remarkable peaks. Some testimonies were obtained by hearing survey from local inhabitants, and there was debris deposit in Kiso river before the large scale of debris flow occurs twice. Debris flows were recorded by CCTV camera before two remarkable peaks. The peak time of acceleration and discharge obtained by camera images is synchronized the time when the pattern of increase and decrease is almost equal before two remarkable peaks because CCTV camera and vibration meter are installed separately.

3.Estimation of debris flow peak discharge and hydrograph: Debris flow with bolder is known to generate strong ground vibration. Referring to previous study of high correlations between peak discharge of the surge and peak acceleration of the vibration, a fitting curve is proposed by the form of $Q = a(G-b)^{\frac{25}{42}}$ (**Fig.2**). Q is the discharge, G is the acceleration of vibration (gal). Coefficient a and b are determined by minimized least-squares method. Peak discharge extrapolated from peak acceleration of the vibration is about 756 m^3/s. **Figure 3** shows estimated hydrograph of debris flow using the fitting curve during debris flow.

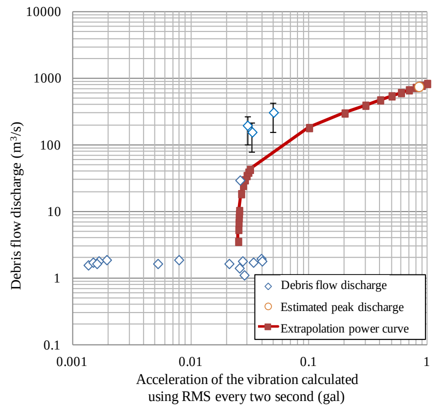

Fig.2 Relations between discharge and acceleration calculated in every two

Estimated peak discharge and hydrograph were inspected by discharge estimated by free surface trace and hydraulic model tests focused on debris inundation and maximum water level.

CONCLUSIONS

Discharges estimated by camera image and acceleration of the vibration calculated using root mean square (RMS) were synchronized by the time until debris surges destroying the camera before two remarkable peaks of acceleration. Correlation curve was proposed by both synchronized values. Estimated peak discharge and hydrograph were inspected by discharge estimated using free surface trace and hydraulic model test, and the validity for present estimation would be shown.

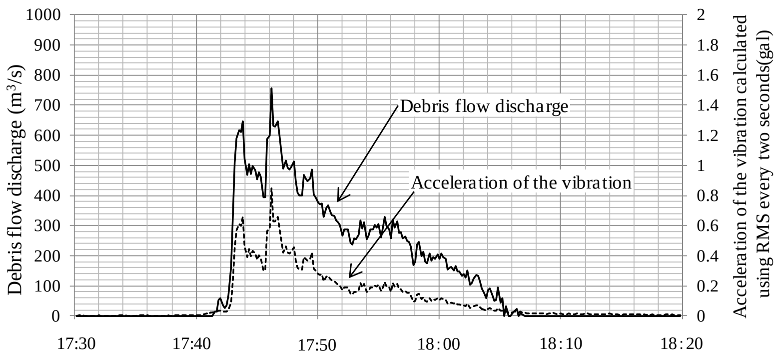

Fig.3 Estimated hydrograph of debris flow

Keywords: Peak discharge of debris flow, Hydrograph, Camera image, Vibration meter, Free surface traces