Field measurement of debris flow using the force plate and a laser profile scanner

Naoki Fujimura, M.S.[1]; Takeshi Shimizu, B.A.[1]; Shiki Yoshinaga, B.A.[1]; Tadanori Ishizuka, B.A.[1]; Satoshi Tagata, Dr.[2]; Hitoshi Katoh, B.A.[3]; Takahisa Mizuyama, Dr.[4]

INTRODUCTION

Field measurements of physical quantities is one of the difficult problems about debris flow research. McArdell et. al. (2007) succeeded in field measurements of normal stress and pore fluid pressure by using the force plate installed at Illgraben catchment, Switzerland. When sediment concentration or unit weight of debris flow is calculated, it is necessary to use volume of the flow on the whole plate. Thus the flow depth is also one of the most important physical quantity to measure.
On the other hand, one of the classifications based on sediment concentration is shown in Takahashi (2014) and Pierson (2005). Sediment concentration which is a function of material constitution and gradient of the mountain river was possible to differ by observation of different debris flow type site by site. Thus it is worth measuring debris flow at a mountain river in Japan by using the similar instruments as McArdell et. al.(2007). However, our study site which is different geomorphological character from Illgraben catchment cause us to install new device of measurement of flow depth. The objective of this paper are 1) introducing new devices of measurement of the debris flow depth, 2) showing the result of time series of cross sectional area on the force plate and sediment concentration on the our installed force plate and 3) mentioning the effectiveness of new devices based on the above.

DEVICES OF OBSERVATION

In fields, observation station is in many cases inevitably selected depending on the geomorphological condition and existing facilities.
Sakurajima volcano in Japan has debris flow prone rivers at very high frequencies. The authors installed the force plate at the crest of the check dam which was constructed as countermeasure against debris flow by Ministry of Land, Infrastructure, Transport and Tourism, Japan. The check dam is located immediately downstream of the curved portion of the river, so debris flow is assumed to be affected by the drift. The force plate and related device is called as the Sakurajima force plate in this article. The size of the plate is 4 x 2 m (8 m^2) as the same size of McArdell, et. al. (2007). The plate is installed between bending part and straight part of the river. If a debris flow pass through the place, the surface of the flow has gradient in transverse direction due to Centrifugal force. That means special device is necessary to measure accurately the flow depth on the plate. Thus we chose the laser profile scanner (hereafter, LPS), UXM-30LX-EW (Hokuyo Automatic Co. Ltd.), which is used in Robotics to measure the distance at one rotational plate with high frequency. The LPS gets cross section depth data 20 times during 1 second. The image of installed LPS and Sakurajima force plate is shown in Fig.1.

RESULT

Fig.2 shows the result of cross section depth of the debris flow measured by LPS. By measuring the surface shape of the debris flow with this device, it was possible to obtain a cross sectional area. This made it possible to estimate the volume of the flow being affected by Centrifugal force.
We estimated the unit weight and sediment concentration of debris flows with the basal normal stress and sectional area (Eq.(1), Eq.(2)):

$$\gamma_d = \frac{P A_{FP}}{AL} \qquad (1)$$

$$C = \frac{\gamma_d - \gamma_\rho}{\gamma_\sigma - \gamma_\rho} \qquad (2)$$

where γ_d is unit weight of debris flow [kN/m^3], P is Basal normal stress [kPa], A_{FP} is Plane area of force plate [m^2],A is Cross sectional area of debris flow [m^2], L is Longitudinal length of force plate [m], C is sediment concentration, γ_σ is unit weight of grains [kN/m³] and γ_p is unit weight of fluid [kN/m³]

Fig.3 shows the result of a) time series of basal normal stress (black line) and cross sectional area (gray line) on the Sakurajima force plate and b) time series of unit weight (black line) and sediment concentration (gray line) of the flow on the plate. The photo included in Fig.3 shows the state of debris flow at peak discharge. The graph clarifies that sediment concentration does not follows changes of the depth of the flow and the value of sediment concentration is about 0.38 constantly during flowing. The category of debris flow of this value is ‚debris flow' by classification of Takahashi (2014).

CONCLUSION

Using the LPS we measured a cross sectional area being affected by Centrifugal force.

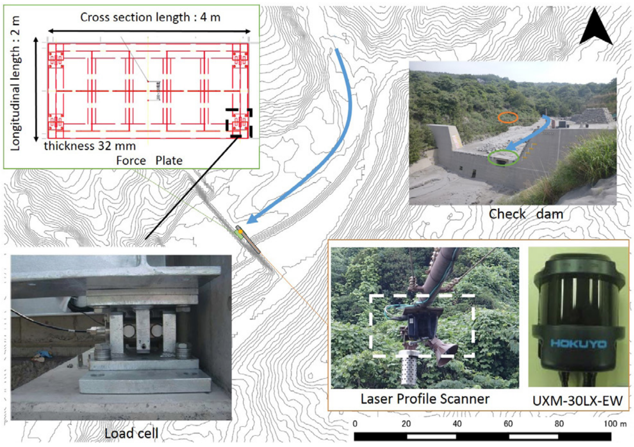

Figure 1. The image of installed LPS and Sakurajima force plate

Based on these data and value obtained by the force plate, we estimate time series of sediment concentration.

Our result of field measurement of debris flow using the LPS and the force plate shows that these make it possible to observe more accurately specification of the debris flow under the geomorphic condition that affect the surface of the flow.

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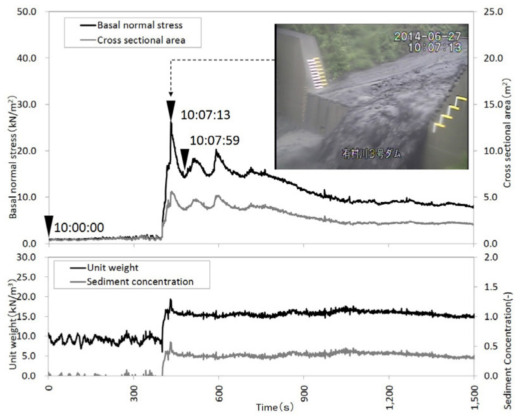

Figure 2. Data from the 27 June 2014 debris flow. (a)Basal normal stress and cross sectional area, (b) unit weight and sediment concentration

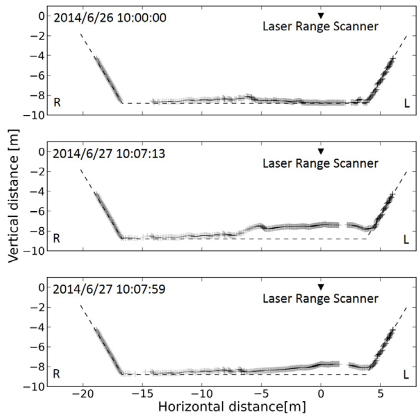

Figure 3. Cross section depth of the debris flow obtained by the laser range finder from 10:00:00 to 10:07:59 , 27 June, 2014

KEYWORDS

debris flow; force plate; laser profile scanner; unit weight of debris flow; sediment concentration

1 Public Works Research Institution, Tsukuba, Ibaraki, JAPAN, n-fujimura@pwri.go.jp
2 Nippon Koei Co.,Ltd, JAPAN
3 Ohsumi Office of River and Highway,Kyushu Rigional Bureau, Ministry of Land, Inflastructure, Transport and Tourism, JAPAN
4 Graduate School of Agriculture, Kyoto University, JAPAN