Estimating the shape of a landslide dam (river blockage), attributed to a deep catastrophic landslide, using the LSFLOW model

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1. Introduction

A deep catastrophic landslide is a phenomenon that occurs much less frequently than other natural disasters. However, it is important to take preparatory measures considering the large amount of moving sediment and enormous potential impact on society. The Ministry of Land, Infrastructure, Transport and Tourism researches deep catastrophic landslide risks in various regions to specify unit river basins that are at risk from landslides. It is important to predict sediment movements associated with deep catastrophic landslides when studying preventive measures and preliminary measures, not only for primary disasters but also secondary disasters.

Using LSFLOW, a landslide sediment movement simulation method developed by the Public Works Research Institute[1)], it is possible to estimate a landslide process from sediment movement to flow to deposition. This study estimates the shape of a landslide dam (river channel clogging) formed by landslide sediment deposition associated with a deep catastrophic landslide through numerical calculations using LSFLOW. As an example, a numerical simulation is performed on a landslide dam formation in the Kii Peninsula caused by Typhoon No. 12 in 2011 using LSFLOW to verify the possibility of predicting it.

Through a combination of landslide dam overflow/failure analysis and two-dimensional debris flow inundation analysis technology, it is possible in this study to conduct a prediction analysis on a series of phenomena from formation of a landslide dam caused by a deep catastrophic landslide to overflow/failure and inundation in a downstream basin.

2. Estimating the shape of a landslide dam using the LSFLOW model

2.1 LSFLOW

LSFLOW solves shallow water long-wave and continuity equations on the assumption that a landslide is a flow of incompressible viscous fluid. In a LSFLOW calculation, topographic data (3-D DEM) of a ground surface before a collapse, topographic data of a slip surface (sliding surface), and soil parameters are used as input data. The calculation allows the deformation process and velocity changes of sliding mass to be obtained on an area-wide basis. It is important to set appropriate soil parameters for this simulation. In LSFLOW, two coefficients of kinetic friction, $\tan\varphi_s$ (coefficient of kinetic friction of slip surface) and $\tan\varphi_m$ (coefficient of internal kinetic friction of mass), are particularly important parameters. Rou and Nakamura [2)] investigated the optimum soil parameters for LSFLOW in 20 cases, suggesting Equation (1). Where, $\tan\varphi_c$ is the coefficient of static friction of a slip surface.

$$\tan\varphi_s + \tan\varphi_m = 0.41 \tan\varphi_c + 0.10\ (\pm\tan 4^\circ) \cdot\cdot\cdot\cdot (1)$$

Because the total numerical value of $\tan\varphi_s + \tan\varphi_m$ can be estimated from Equation (1), how to set the numerical values for $\tan\varphi_s$ and $\tan\varphi_m$ becomes the problem to be solved.

2.2. Numerical simulation of landslide dam using LSFLOW

A numerical simulation was carried out for a case in the Akatani area of the Kii Peninsula due to Typhoon No. 12.

First, $\tan\varphi_c$ was estimated in a slope stability calculation. Then, numerical values, $\tan\varphi_s$ and $\tan\varphi_m$, were set up based on the relation with Equation (1). Through a repetition of trial calculations, the best repeatability was found, according to a comparison of topographical variations between the Laser Profiler survey and calculation. As a result of these calculations, the topographical variation is shown in **Fig. 1. Fig 2** shows the A-A' longitudinal section of this case.

Thus, it is confirmed that LSFLOW can simulate the shape of the deposition of a landslide dam caused by a deep catastrophic landslide by setting up appropriate values for tanφ_s and tanφ_m.

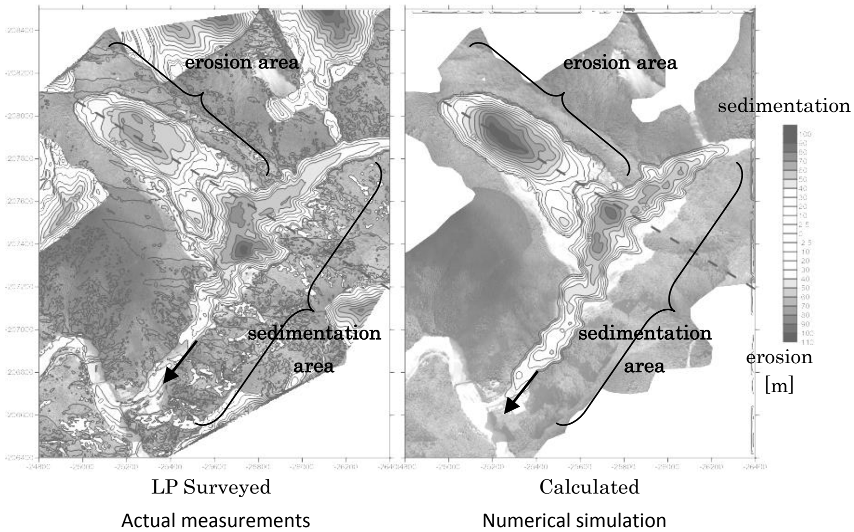

Fig. 1 Comparison of topographical variation

2.3. Predictive numerical simulation of landslide dam using LSFLOW

Unlike the numerical simulation of an actual example above, a concept is necessary to set up φ_s and φ_m for a predictive numerical simulation.

When estimating debris flow damage caused by the failure of a landslide dam as damage increases, if the upper limit (including + tan4º) of Equation (1) is adopted as the total value of tanφ_s + tanφ_m, the relation between tanφ_s and tanφ_m is in proportion. Generally, the dynamic coefficient of friction is $\varphi_s \leqq \varphi_m$ during a mass earth movement. The simulation result shows that there is a tendency as φ_s becomes larger (the lower the flowability earth mass becomes), for the landslide dam to become higher. Thus, when setting parameters, dam height is maximized when $\varphi_s = \varphi_m$.

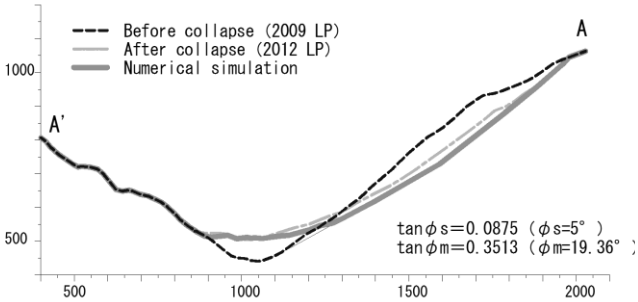

Fig. 2 numerical simulation result (longitudinal section)

When $\varphi_s = \varphi_m$, the calculated topographic feature of the Akatani area is about 30% higher at the lowest point on the cross-section, which is presumably the overflow start point, than the measured topographic feature after a landslide. Thus, the feature is calculated.

3. Summary

The deposition of a landslide dam caused by a deep catastrophic landslide was calculated using LSFLOW, a landslide sediment motion simulation method. The result shows that the shape of a landslide dam can be reproduced through a trial calculation by changing the soil parameters.

When using LSFLOW to make a prediction, by setting the parameter $\varphi_s = \varphi_m$, it is possible to predict the shape of deposition with which the most dangerous dam height is maximized when estimating the range of debris flow damage associated with the collapse of a formed landslide dam. This can be used in a preliminary examination of disaster prevention measures against deep catastrophic landslides.

An application examination is to be carried out continuously for cases with different soils and factors.

Keywords: deep catastrophic landslide, landslide dam (river blockage), damage estimate, sediment discharge analysis

1) Land Slide Laboratory, Public Works Research Institute (1992): Prediction of land slide collapse damage range through quasi-three-dimensional land slide motion analysis program, Public Works Research Institute document No.3057, issued in March 1992, p. 107

2) Ikuka Rou and Hiroyuki Nakamura (1998): Characteristics of loess sliding surface shape and prediction of spreading range of landslide, land slide, Vol.35, No.1, pp. 9-18.