Numerical Simulation for Debris Flows Considered the Effect of Phase-shift of Fine Sediment

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INTORODUCTION

Large-scale debris flows have sometimes had serious impacts on humans. Therefore, it is important to identify large debris flow hazard area. In large-scale stony debris flow, it has been considered that the gravels move like laminar flow, but the interstitial water behave as turbulent flow. Moreover, fine particles can behave with the interstitial water as fluid and many previous studies call this process of fine sediment as shifting solid phase to fluid phase, “phase-shift” [e.g., Iverson, 1997]. Based on this phase-shift concept, Nishiguchi et al. [2014] proposed a maximum diameter of sediments that behave like a fluid as D_c and confirmed that if we use best-fit D_c, the run-out processes of several past of large-scale debris flow can be described by numerical simulation.

However, it remains the problems that how should the parameter of D_c determine in the simulation and that although D_c should be variable in time and space, Nishiguchi et al. [2014] assumed D_c to be constant in the simulation.

Here we developed the program in which maximum diameter of phase-shifted sediment is varied depend on hydraulic condition. Also, we conducted numerical simulations for recent debris flows and verified the applicability of our model.

CONCEPT OF SIMULATION MODEL

Nishiguchi et al. [2014] assumed that fine particles can be physically suspended due to riverbed shear stress or turbulent stress in debris flow and showed that the settling velocities of best-fit D_c were lower than both the friction velocities of the debris flow and the turbulent velocities of the interstitial fluid from the simulation results of past debris flows.

Then, we proposed that D_c is varied depending on the ratio of settling velocity of D_c to turbulent velocity or friction velocity of the debris flow. We considered the turbulent velocity, friction velocity and settling velocity can be calculated from turbulent stress, riverbed shear stress and equation of Rubey, respectively. We modified two-particle model of “Kanako-LS” developed by Uchida et al. [2013]. Kanako-LS can describe a variety of sediment transport processes ranging from stony debris flow to bed load and can describe the phase-shift effect, although D_c is fixed. So, we developed to multi-particle model and introduced our assumption of determining D_c to “Kanako-LS”.

MATERIALS AND METHODS

We conducted numerical simulation for five past deep catastrophic landslides induced de bris flow. All of studied debris flows were triggered by heavy rainstorms and were caused by a deep-seated rapid landslide. The characteristics of these debris flows are shown in **Tab.1**.

The longitudinal profiles of the riverbed which we used for the numerical simulation were established based on topographic data before the debris flow events. The parameters of grain size distribution and hydrograph were estimated from field measurements.

We searched best-fit critical ratio of the settling velocity of phase-shifted sediment to turbulence velocity or to friction velocity of debris flows, in terms of the reproducibility of travel distance, erosion and deposition pattern of five debris flows. Moreover, we considered whether they are in wide range, and whether they have a correlation to the debris flow characteristics.

Tab.1 Studied debris flows

Site	Date	Total volume of debris flow at the upper end*	Travel distance	Flow width	Maximum erosion depth
A	2003/7	31,000 m^3	1.6 km	50 m	5 m
B	2004/8	622,000 m^3	1.0 km	60 m	0 m
C	2005/9	272,000 m^3	2.1 km	40 m	0 m
D	2005/9	183, 000 m^3	0.9 km	20 m	0 m
E	2009/7	19,000 m^3	0.6 km	60 m	7 m

* including void volume

RESULTS

As the critical ratio of settling velocity of phase-shifted sediment to turbulent/friction velocity of debris flow increased, simulated travel distance of the debris flow decreased. If we set an appropriate ratio, the simulated travel and erosion distances agreed well with our observations. We also confirmed that, although the maximum size of phase-shifted sediment ranged from 8 to 200 mm and they were various for study cases, the variability of ratios was small. It means that phase-shifted sediment was variable in time and space and our assumption was effective to predict the particle size of phase-shifted sediment.

CONCLUDING REMARCS

We introduced the concept that the diameter of phase-shifted sediment is variable depending on turbulence of interstitial fluid or total stress of debris flow in our numerical simulations, then examined the applicability of our method for a variety of large scale debris flows. As a result, we showed that, although their volumes and topography were diverse, the simulated results for these debris flows reproduced well the observed erosion and deposition patterns. Thus, we believe that our new method and the information may be helpful for prediction of future risk of debris flow due to deep-seated landslide.

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