Controlling Factors of Phase-shift of Fine Sediment in Large-scale Debris Flows

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INTRODUCTION

Large-scale debris flows have sometimes had serious impacts on humans. Therefore, it is important to identify large debris flow hazard area. However, previous studies have shown that the commonly used debris flow numerical simulation models may not be applicable for large-scale debris flows. Previous studies indicated that the fine sediment in large-scale debris flows might be considered to fluid phase rather than solid phase [e.g., Iverson, 1997]. Based on this phase-shift concept, we defined a maximum diameter of sediments that behave like a fluid as D_c [Nishiguchi et al., 2011]. Moreover, we 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 our numerical simulation. However, there is no adequate information about controlling factors of D_c. Here we argued controlling factors of D_c.

METHOD

The “Kanako” numerical simulator has been used widely for a variety of objectives, particularly since the Kanako had a graphical user interface. We used Kanako-LS, which was modified version of Kanako to describe the phase-shift for fine sediment. We assume that sediments can be classified into two groups in terms of sediment diameter (i.e., fine and coarse), and define the critical diameter of the sediment (D_c) as the smallest diameter at which sediments behave as a solid phase. We assumed that the relative proportion of fine/coarse sediments of the riverbed was equal to the relative proportion of fine/coarse sediments in the landslide mass and that fine sediment was deposited as a solid. We conducted numerical simulation for five past deep catastrophic landslides induced debris flow. The study sites (Sites A–E) are all in Japan and debris flows have occurred in 2003–2009. The landslide volumes including void volume ranged from 1.9×10^4 to 6.2×10^5 m^3 and travel distance of debris flow ranged from 0.6 to 2.1 km. The simulation parameter of grain size distributions and porosity of soil and bedrock were determined from field measurements. In the simulation, we searched for the best-fit value of D_c, that is, the simulated travel distance for which agreed well with that of observations.

RESULTS AND DISCUSSIONS

When all sediment particles in the debris flow were considered to behave as solids ($D_c = 0$), the simulated travel distances from the lower ends of the landslide scars to the lower ends of the debris flow deposits were about half of the observed travel distances. However, when D_c was 15, 10, 50, 8 and 200 mm at Sites A, B, C, D and E, the simulated travel and erosion distances agreed well with our observations.We compared the settling velocity of the best-fit D_c, the friction velocity of debris flow and turbulent velocity of interstitial water. We found that the settling velocities of the best-fit D_c were considerably smaller than both the friction velocities of debris flow and the turbulent velocities of interstitial water. The results suggest that the sediment smaller than D_c can be suspended and behave as fluid.

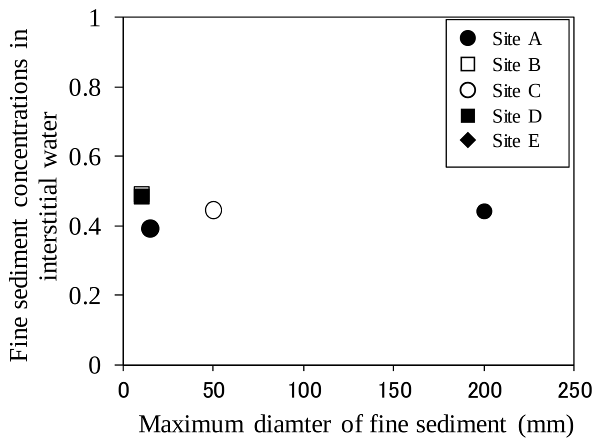

Fig.1 Simulated results for volumetric fine sediment concentration in interstitial water

The best-fit D_c varied considerably between debris flows, ranging from 8 to 200 mm and we did not found any correlation between D_c, volume of debris flow and grain size distribution. However, the variation in volumetric fine sediment concentration in interstitial water was small, ranging from 0.4 to 0.5 (Fig.1). The range corresponded with the upper limits of the results of fine sediment concentrations in debris flows in previous research. According to these evidences, it can be thought that amount of fine sediment which can be suspended are large enough compared to volume of water. This might be common characteristics of large-scale debris flow, since water content in landslide mass was generally small and included a large amount of fine sediment. These were supported by our previous studies [Nishiguchi et al., 2011, 2012]. For example, Nishiguchi et al., [2012] compiled grain size of large-scale debris flows triggered by deep catastrophic landslide and showed that the percentage of sediment smaller than 10 mm was commonly almost 30 %. Consequently, the fine sediment concentration of interstitial water became close to the upper limit concentration which can be behave as turbulent flow in debris flow, regardless of scale of debris flow and grain size distribution.

CONCLUSIONS

In this study, it is shown that the concept that fine sediments behave as fluids in the simulation may be applicable to various large-scale debris flows. It is also found that the best-fit value of D_c shows considerable variation but the volume concentration of fine sediment behaving like a fluid varied little between the five different debris flows. Compared with the results of previous research, our results indicate that there may be a limit to the volume concentration of fine sediment in the interstitial water of debris flows.

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