Experimental study on debris flow deposit dam formation and overflow process on large scale physical model

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INTRODUCTION

It is known that large-scale landslide dams often formed by landslide due to heavy rain or strong earthquake in Japan. Once landslide dam formed and overflow occurs, huge damage happens in downstream area due to debris flow. Sediment runoff in mountain stream may cause debris flow deposit dam formation. Here, we defined that landslide dam and debris flow deposit dam as same phenomena. Due to unclearness of sediment transportation from head stream of the mountain, the formation process of debris flow deposit dam is not clear. In this study, we constructed large scale model experiment facilities for Inari-River basin, Japan, and conducted experiments to confirm debris flow deposit dam formation occurs due to sediment runoff from head stream of the mountain. We also carried out a verification using the GUI-equipped debris flow simulator „Kanako" (Nakatani et al., 2008).

MODEL EXPERIMENT

The model scale was 1/40, and the height was 10 m. Two branches named Akana Branch and Nanataki Branch located in upstream of Inari River. To supply sediment from the branches, we set rectangular straight open channel with a length, width, and slope of 5m, 0.5m, and 14° for each branch. We describe the results in real scale value. In Akana Branch, deposition did not occur along the stream though supplying with Takahashi's equilibrium sediment concentration for upstream area (Takahashi and Nakagawa, 1991). When sediment moves intermittently deposition occurred such as small landslide dam. Then, debris flow deposit dam formed with 21.5m height and downstream slope gradient was 1/4.3. In Nanataki Branch, when supplying small discharge at the beginning and then supplying large discharge case, debris flow deposit dam formed near the confluence similar to Akana Branch case. Debris flow deposit dam formed was 28.7 m height, downstream slope gradient was 1/2.5. After l debris flow deposit dams formed, we supplied 105.5m^3/s from Akana Branch and supplied 52.8m^3/s from Nanataki Branch. While debris flow deposit dam was constituted from coarse sediment, water did not accumulated at the upstream of deposit dam due to infiltration. After deposit dam formed, sediment remained in the riverbed at upstream of deposit dam. Then supplying small scale discharge from upstream caused fine sediment runoff and fill up the void of deposit dam. Therefore, after supplying small discharge, deposit dam formed with 31.3 m height, 1/2.5 downstream slope gradient, 44,300m^3 total sediment volume, and 8,900m^3 storage water in the upstream of the dam. Figure 1 show time series of sediment concentration and discharge. When deposit dam collapse and overflow occurs, peak discharge was 205m^3/s and maximum sediment concentration value was 0.22. Outflow discharge

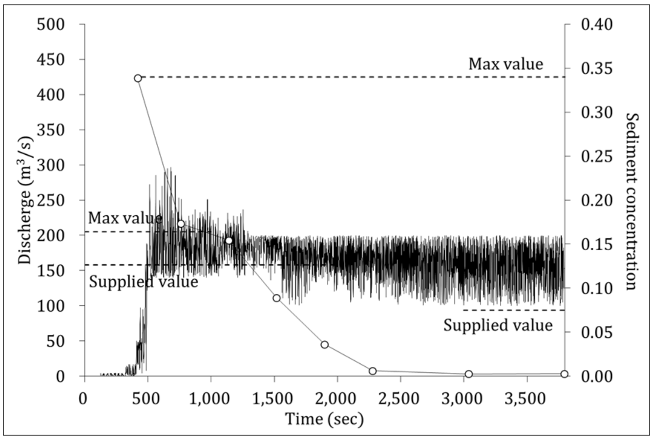

Figure 1. Time series of sediment concentration and discharge

was 1.3 times larger than the inflow discharge. Sabo dam located in downstream end of the experimental model, and slope of sedimentation was 1/6.5. Applying Takahashi's equilibrium sediment concentration C from deposition slope, C was calculated as 0.148. From experiment result, C was 0.22. We considered that fine sediment was taken into fluid phase, then fluid phase density ρ becomes large, and causing high fluidity even at a high concentration and low-gradient. From the experiment result, when ρ is 1.10g/cm^3, C becomes as 0.22. We calculated sediment incorporated into the liquid phase from the fluid density as D22. D22 was 25mm, and the sediment with diameter D22 or below was incorporated in liquid phase.

NUMERICAL SIMULATION

We used the GUI-equipped debris flow simulator „Kanako". The debris flow simulation model used in Kanako is based on Takahashi model (Takahashi and Nakagawa, 1991). From the simulation results, debris flow deposit dam did not form along the stream. This is because slope is steeper along the stream than upstream end, and erosion/deposition process simulated from Takahashi's model is due to equilibrium sediment concentration related to slope degree. In Takahashi's model, when equilibrium sediment concentration is higher than sediment concentration, deposition did not occur. In Kanako system, uniform size diameter is considered. Therefore in wide sediment size distribution case, fine sediment influence cannot be considered when applying average diameter. In that case, part of the sediment remains along the stream. Comparing simulation results and experiment results of downstream discharge, experiment results was larger. When considering fine sediment taken into fluid phase, setting larger fluid phase density in the simulation, more sediment flowed down to the downstream and become similar as the experiment.

CONCLUSION

In the experiment, due to the collapse of small deposit dam, we confirmed that sediment moved intermittently and deposition occurred. Outflow discharge was 1.3 times larger than the inflow discharge. In the numerical simulation, results showed good relation to the experiment in the equilibrium supplied condition. However, simulation results did not describe following phenomena; 1) intermittently sediment movement, 2) effect of infiltration because of considering saturated riverbed, 3) effect of fine sediment behavior as fluid phase. These phenomena are complicated and still in the process of research and development, they cannot described with the proposed debris simulation models. In future study, we will develop a model which can consider these phenomena and describe the enlargement of the discharge due to the formation and collapse of the deposit dams.

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KEYWORDS

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