D09

Mechanisms and Hazard Assessment of Rainfall-Induced Landslide Dams

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1. Introduction

Landslide dams are one of the most dangerous geomorphic hazards, which often pose cascading hazards to the communities in both upstream and downstream areas (Costa and Schuster 1987). It is important to investigate physical mechanisms and the formation process of landslide dams for hazard assessment of sequent events and scenario planning to disaster prevention and preparedness. Particularly, there is a need to conduct a computer simulation model incorporating the landslide initiation and motion into the formation process of dams, which employs the parameters measured in laboratory experiments.

This paper presents a comprehensive study on the mechanical mechanism and entire formation process of rainfall-induced landslide dams through three typical cases of the Kuridaira and Akatani slopes in the Kii Peninsula, Japan, and the Jure slope in Sindhupalchok district, Nepal. The understanding of these typical cases studies significantly contributes to the advancement of landslide dams' knowledge.

2. Methodology

The research was initiated by conducting site investigations and collecting soil samples in order to examine geological and morphological characteristics of the landslide dams comprehensively. The soil samples of the sliding surfaces were then tested by using the mean of the high-stress dynamic-loading ring shear apparatus ICL-2 in order to understand the mechanical mechanisms of the landslide dams. Finally, the entire formation process of the landslide dams was reproduced in the LS-RAPID computer simulation model that employed physical parameters measured in the ring shear tests.

3. Results

The site investigations pointed out that the strata of heavily weathered bedrocks, broken and fractured formations, and bedding-plane faults in the narrow and steep-sided valley terrains were major geological and morphological factors for the formation of the landslide dams. In this regard, broken formations, discontinuities, fractured rocks, faults and shear zone were the favorable conditions for the rapid build-up of groundwater table within the slopes under heavy rainfall.

Ring shear tests revealed that the Kuridaira and Akatani landslides resulted from excess pore water pressure generation under a small shear displacement between 2 and 7 mm or under rainfall with a critical pore water pressure ratio ranging from 0.33 to 0.37. Very low mobilized friction angles at the steady state were clearly observed in the tests of shale samples of the Kuridaira landslide and sandstone-rich samples of the Kuridaira landslide. These samples experienced extensive grain crushing and sliding surface liquefaction due to a significant loss of shear strength and rapid excess pore water pressure generation. The test results implied that the rapid motion of the Kuridaira and Akatani landslides was due to the high mobility behavior of shale sample and sandstone-rich samples, respectively. The sliding surface liquefaction phenomena observed in the ring shear tests were highly in agreement with the evidence in sites.

The mechanisms of the upper and lower blocks of the Jure landslide were totally different. The rainfall-induced landslide in the upper slope was due to an increase of pore water pressure ranging from 0.22 to 0.26. The sliding mechanism of the lower slope was due to a dynamic loading process from the downward movement of the upper slope. In the dynamic loading process, an increment of 162 kPa in shear stress would trigger the mass movement of the lower slope. The phyllite and schist samples presented a high level of landslide mobility.

In the computer model, local failures of the Kuridaira, Akatani and Jure landslides took place when pore pressure ratios due to rainfall reached the critical values of 0.33, 0.36 and 0.24, respectively. The motion of the Kuridaira and Akatani landslides initiated from the lower middle part of their bodies where geological boundary in the bordering area exists in the slopes, while the landslide initiation of the Jure slope was nearby the head scarp of the upper slope. In the dynamic loading process in the Jure slope, when the landslide body of the upper slope traveled downward and overrode the lower slope, the landslide of the lower slope initiated to move together with the landslide block of the upper slope. After that, the failures in the Kuridaira, Akatani and Jure slopes were expanded to adjacent areas and accelerated mass movements with increasing velocities during the transient stage. The landslide blocks rushed down the valley channels and collided with the opposite walls. The sufficiently massive volume of landslides completely dammed the river to form natural reservoirs in a short period of time (**Fig. 1**).

4. Conclusion

In addition to geomorphic features, the results from ring shear tests and computer model indicated that the landslide mobility is a crucial factor in the formation of landslide dams. In the computer simulation, the entire formation process of landslide dams was characterized by four stages: from the stable stage of the slopes to local failures in the failure stage, through progressive failures in the transient stage up to rapidly massive movement in the whole slope and river blocking in the steady state. The large volumes of materials produced from the deep-seated landslides are sufficient to completely obstruct the rivers. Whereas the wide-spreading and rapid motions of the landslides dammed the river valleys in a short period before the debris blocks were swept away by upstream water flows.

Reference

Costa J.E and Schuster R.L (1987) The Formation and Failure of Natural Dams, *US Geological Survey*, Open-File Report, pp. 87-392.

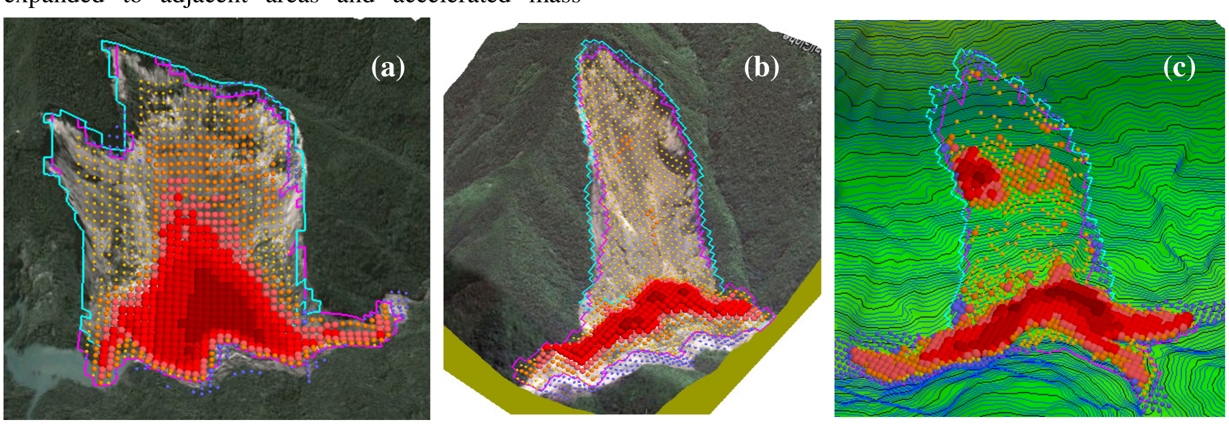

Fig. 1 Computer simulation model of the rainfall-induced landslide dams: (a) Kuridaira, (b) Akatani, and (c) Jure