Mechanisms and Modeling of the Catastrophic Landslide Dam at Jure Village, Nepal

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Abstract: This study clarifies the failure mechanisms of the 2014 catastrophic large deep-seated landslide and simulates the dam formation process at Jure Village, Nepal, through site investigations, ring shear tests, and LS-RAPID computer simulation model. The detailed analyses suggest that the Jure landslide triggered by a high cumulative rainfall slid along bedding-plane faults of weathered phyllite and schist on the slope of an ancient landslide terrain. The landslide comprised two separate subblocks; the upper and lower slopes, whose sliding mechanisms differed from each other. The test results indicate that the upper subblock of the landslide was triggered by rainfall with a critical pore pressure ratio of 0.22–0.26. The lower slope failure resulted from a dynamic loading process initiated by the downward movement of the upper slope. In the LS-RAPID model, the evolution process of landslide damming the river was reproduced and verified based on the observed geomorphic evidence and recorded data. The study shows landslide mobility acted as the critical factor leading to the landslide dam formation, in addition to the geomorphic indexes. **DOI: 10.1061/(ASCE)GT.1943-5606.0002637.** *© 2021 American Society of Civil Engineers.*

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Introduction

Landslide dams commonly form via natural processes whereby the downslope movements of earth materials block a river channel, leading to the formation of a reservoir in the upstream valley (Costa and Schuster 1988). The formation of landslide dams often poses secondary hazards to the people living around either the upstream or downstream regions. Hazard assessments of landslide dams have been conducted by many researchers all over the world, and notable examples include the work of Costa and Schuster (1988), Korup (2002, 2005), Ermini and Casagli (2003), Dal Sasso et al. (2014), and Stefanelli et al. (2016). Korup (2002) concluded that the majority of the previous studies were descriptive and mainly focused on the landslide dam susceptibility to failure. Those studies separately addressed the landslide dam problems as a single process constituting the phenomena of dam formation, dam breaching, and subsequent hazards. In addition, the investigation on the mechanism and conditions of landslide dam formation is commonly based on the geomorphic approach using global and regional datasets of the events (Costa and Schuster 1988; Ermini and Casagli 2003). The model approaches to landslide dam formation are still under development since the hydrodynamic interference between landslides, rivers, and dam formation has not been consolidated into an accredited theory (Dal Sasso et al. 2014). Most early numerical models were based on a trial-and-error basis [e.g., the distinct element method involving a two-dimensional particle flow code (PFC) by Li et al. (2012), and the LSFLOW model by Sako et al. (2014)], back-analyses (e.g., the PFC2D model by Zhou et al. 2013, and SPH model by Braun et al. 2017), or calibration-based analyses (e.g., the new continuum shallow-water model by Kuo et al. 2011, and the SHALTOP model by Yamada et al. 2016). The previous 2D models attempted to study the kinematic effects of the slope movement and its interaction with the slope topography, but they were unable to simulate the effects of pore water pressure increments due to rainfall, which has resulted in gaps in the understanding of the subject (Tien 2018). This study on the most recent catastrophic rainfall-induced landslide dam at Jure Village, Nepal, therefore, aims to address that gap in landslide dam simulations through the application of an integrated simulation model using an undrained ring shear apparatus (ICL-2) and a 3D LS-RAPID computer model.

The Jure landslide, also called the Sunkoshi landslide, was a catastrophic large deep-seated, rockslide-debris avalanche that was triggered by rainfall around 2:30 a.m. local time on August 2, 2014, at Jure Village, Sindhupalchok district, Nepal [Figs. 1(a–d)]. Rainfall data before and after the landslide occurrence at the Barhabise station 3.5 km away from the sliding site are presented in Fig. 1(e). The landslide is situated within the Sunkoshi River basin in the

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