論 文 の 内 容 の 要 旨

論文題目　Practical implications of formation and failure of Hattian Bala landslide dam for breach and flood hazard assessments of landslide dams
(ハティアン・バラ天然ダムの生成および崩壊過程が天然ダム決壊と洪水ハザード評価に与えた実用的意味)

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Landslide dams are a particular kind of natural dams which are formed when the earth or a rock mass reaches a river channel causing a partial or a complete blockage. The landslide dams can possess the potential risk of breaching that will threaten areas at significant distances upstream or downstream of the dam. Rapid assessment to identify the probability of catastrophic failure of a dam associated with the impounded water is essential for emergency management. Longevity of the landslide dam and possible outflow flood are the two major concerns that need to be addressed immediately after the damming event. Blockage indexes approach is normally used for assessing the stability of the landslide dam, which is based on the compiled dam breach cases. Parametric analyses are normally conducted to estimate the outflow from a breached landslide dam, in which down

cutting rate plays significantly important role. Normally, selection of parameters is made based on compiled historical records of similar dam breach events or is based on engineering estimates and often lacks the consideration of the properties of the dam material.

Routing of flood caused by breaching, which is essential for proper hazard zonation and establishing an emergency action plan, is mostly conducted assuming a pure water flow. However a flood caused by landslide-dam-breaching is accompanied by transportation of a tremendous amount of soil in various forms. As the water from the lake is released during the breaching process, the clear water entrains the sediments from the dam body and the carried sediment transform into the bed and suspended load as the flow develops. Consequently the flood inundation estimates that are based on water flood assumption can lead to an under-estimate of the expected inundation levels.

Major portion of the literature related to the landslide dams consists of documented case histories and is mostly descriptive in character. This shows the difficulty of observation during the formation, after the formation and during the breaching of a landslide dam, and therefore the reason of low scientific understanding about these important issues related to landslide dams.

A magnitude 7.6 earthquake on 8th October, 2005 triggered a 62 million m^3 landslide at 3.5 km upstream of Hattian-Bala City in Pakistan. The landslide blocked two tributaries of the Karli branch of Jhelum River forming Karli Lake (Large lake) and Tang Lake (Small lake). The dam was sustained for about four years and four months. The water of Karli lake of Hattian dam breached the north-western part of the debris deposit on 9th February 2010 after five days of incessant rains/snowfalls, and the water of Tang lake breached the north-eastern lobe of debris deposit during the monsoon rains of July-August, 2010.

The Hattian landslide dam provided a unique opportunity to study the post formation geomorphic changes that occurs in the body of a landslide dam, and later on, the study of its breaching process and the resulting flood was conducted. In order to understand deformation occurring in the body of

the dam, physical measurements using a Differential Global Positioning System (DGPS) were conducted. Gradual deformation and slowly developing backward erosion initially were observed, leading eventually to a sudden creation of a deep hollow on the downstream slope of the landslide dam. TRMM-data-based rainfall estimate over the Hattian catchment area indicates that the precipitation of February 2010 that caused the breaching was less significant than the other heavy rainfalls that the area had experienced since the overflowing from Karli Lake that started in April 2007. Slaking was discussed as a possible cause of the deterioration of the dam body that may have led to the dam breaching failure.

The influence of the geotechnical parameters of the dam material on the outflow discharge was investigated to identify the most significant factors affecting the breach outflow discharge. For this purpose a breach progression model was formulated. Data acquired from the Hattian dam breach was utilized for validating the model, and the model performed well such that it rationally described the observed feature of flooding. The method can serve as a rational guideline for determining the peak discharge and developing hazard zonation for a dam breach case.

Conventional water flood simulation requires estimation of probable bed roughness because a sediment laden water flow results from breaching of landslide dam. Assumption of a hyper concentrated fluid flow is made to simulate the outflow from the Hattian dam breach, and better correlation is found between the measured and simulated flow depths.

Field measurements conducted after the failure of the Hattian dam revealed that the inundation level estimated by using flood models underestimated the flood levels at close proximal to the dam body because of the reasons explained above. The morphological change resulting from a dam breach is successfully simulated using a moveable bed model. However the results show that the information about the elevation of the bed rock is important for accurate simulation.

Implications of the results obtained from field observations and simulations are more elaborate

when considering the possibility of the breaching of the Attabad landslide dam, in Gilgit Pakistan, formed on 4th January 2010, which remains yet as a huge social and economic problem for the people of the region and a threat to the downstream population.