Sediment Runoff Mechanism from a Landslide Dam: Case of Lake Ohatakedoro in Totsukawa Village, Nara Prefecture, JAPAN

Yoshihiro HIRAIDE[1], Kunihiro YUKAWA[1], Akinori OGA[2], Toru SHIMADA[2], and Daiichiro HORI[2]

INTRODUCTION

Lake Ohatakedoro is located in the southern part of Totsukawa Village in Nara Prefecture, and the only extant landslide dam from the 53 river course blockages was formed during the Great Flood in Totsukawa Village in Meiji (1889). During the massive flooding caused by the Great Floods on Kii Peninsula in September 2011, this dam was heavily eroded, and it collapsed generating a sediment discharge, and caused damage so great as to make the neighborhoods isolated. This paper discusses the results of the examination of the stability of the landslide dam based on the geological and hydraulic studies of the landslide dam, and future preventive measures, because a large portion of the landslide dam still remains as a risk.

OUTLINE OF LAKE OHATAKEDORO

(1) Damage
Lake Ohatakedoro stretches over Shigesato in Totsukawa Village, Nara Prefecture. It has a watershed area of 1.02 km^2, and a left side tributary branched off from Nishikawa River of the Shingu River Catchment Area. Its landslide dam measures 70 m in height and 450 m in length, with 0.02 km^2 of watershed area.In the Great Floods on Kii Peninsula, the landslide dam was eroded, and it collapsed, over an extended area of about 450 m in length, 30 m in maximum height and 75 m in maximum width. A cutbank was clearly formed downstream of Nishikawa River. The total volume of runoff sediment, calculated by comparing the topographic base map and the post-disaster LiDARdata, is estimated at about 300,000 m^3.
(2) Geological survey
The area is consistent with the distribution of shale-dominant sandstone and shale alternation of the Hidakagawa Group in the Cretaceous (the Mesozoic) Shimanto Belt. Large-scale landslides in the Great Flood in Totsukawa Village in Meiji appear to be triggered by dip slope. Results from the boring survey, seismic prospecting, and electrical prospecting in the area revealed that the landslide dam is formed with rocks that had been weathered by moderate to strong wind, and sand and gravel mixed in amongst the clumps, which contained a few granules, all in a layer of maximum thickness of 65 to 70 m.
(3) Hydrological survey
Investigations of change in water level of Lake Ohatakedoro, field tests during boring survey, and observation of groundwater level in the lake, etc., were conducted, and the results discovered the following: the landslide dam holds high water permeability, and the water level of Lake Ohatakedoro and that of the landslide dam are linked together.
Water path with average 2.0×10^{-4} (m/sec) of relatively high water permeability was formed in the dam. After the Great Floods on Kii Peninsula, a large amount of spring water with this high water permeability has been constantly flowing out from the water path exit.

1 Totsukawa Post-Disaster Recovery and Reconstruction Division, Gojo Public Works Branch, Nara Prefecture, JAPAN
2 Kokusai Kogyo CO., LTD., JAPAN (e-mail: daiichiro_hori@kk-grp.jp)

COUNTERMEASURES

(1) Purpose
In the Great Floods on Kii Peninsula, “overflow erosion” by surface-water flowing down the crest of the landslide dam is thought to be the biggest disaster factor possessed by the lake, from the results of the investigations in the past. However, the river basin is too small (1.03 km^2) to generate 300,000 m^3 of sediment. “piping erosion” and “landslide” were studied as the possible disaster factors, to reflect the results of the study in countermeasure development.
(2) Study methods
In order to evaluate the impact on “piping erosion” and “landslide”, geological and hydraulic models were built based on the results from the various geological surveys. Sediment dam stability in the future was examined based on the results of the simulation of infiltration and the stability analysis.
(3) Results of “piping erosion”
Horizontal and vertical hydraulic grade lines obtained by the simulation of infiltration, and critical hydraulic gradient of the sediment dam, estimated by soil tests, etc. were examined. The results relative to the critical hydraulic gradient of ic= 1.02 were: horizontally: approximately 0.2 , vertically: approximately 0.1. They are significantly small. Therefore, a possible “piping erosion” of the dam in the future is extremely small.
The geological and water quality conditions used were obtained before the disaster. The results in this case are, horizontally: approximately 0.5, vertically: approximately 0.3. It shows that pore-pressure easily occurs locally.
(4)Results of “Landslide”
Stability analysis of landslide was conducted based on the ground factor estimated from hydraulic and soil properties of the landslide dam obtained by the simulation of infiltration.
The results show Safety factor Fs= 1.940 in stability, which indicates that sufficient safety is guaranteed at this point. In the case of using geological and water quality conditions obtained before the disaster for calculation, Fs= 1.058, which indicates about 45 % less stability, was obtained.

CONCLUSIONS

According to the results of the stability study of the landslide dam with current geological and water quality conditions, a possible disaster caused by “piping erosion” or “landslide” is small. What we need to discuss are countermeasures, mainly to prevent “overflow erosion”.
Possible “piping erosion” or “landslide” is still on the table, because topographical features and stabilities can change due to abrupt water level increase of Lake Ohatakedoro at the time of local severe rain, causing erosion by spring water at the landslide dam. Therefore, it is necessary to continue to monitor the topographical change and water level at the landslide dam, to reflect the outcomes of the study for countermeasure development.

Keywords: landslide dam, piping erosion, overflow erosion, landslide