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Shear strength reduction in progress of shear displacement on the landslide near dam reservoir

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Abstract

Landslides may cause enormous human casualties, economic losses, infrastructure damages and the change of physical environment and geomorphology. Landslides on the upstream of dam reservoir obviously occur when reservoir impoundment has affected groundwater level of the upstream slope that penetrates into the susceptible soil layers which can fall down to the reservoir. The falling landslide mass into reservoir would significantly reduce the reservoir capacity as sustainable water resource for human and agriculture needs. The study of shear strength reduction in landslide mass is important as part of the landslide dynamics science which covers mobility after failure associated with landslide hazard level, risk assessment, landslide velocity and affected area. In this paper, the shear strength reduction in progress of shear displacement on the landslide near dam reservoir is obtained by means of ring shear tests. Examined samples were taken from the 2008 deep-seated large-scale landslide near Aratozawa reservoir that is located in Miyagi Prefecture, Japan. The observed data indicated that during eight months before landslide event on 14 June 2008, the Aratozawa reservoir was impounded significantly and caused high pore pressure in the suspected slip surface layer. The undrained cyclic loading tests and earthquake loading tests are conducted to explain the shear strength reduction in progress of shear displacement and high initial pore pressure from pre-failure state to the steady-state motion. The results of the tests implied that the sample from secondary collapse zone was the weakest specimen which is vulnerable to be mobilized in a long distant shear displacement. In addition, the ring shear test results indicated that the rapid shear strength reduction of landslide mass was mainly caused by initial high pore pressure and exacerbated by the 2008 Iwate-Miyagi inland earthquake as a main shock in the case of deep and large-scale landslide near Aratozawa dam reservoir.

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1. Introduction

The term landslide is defined as 'the movement of a mass of rock, earth or debris down a slope'[1]. Landslide occurs particularly on slope where soil strength decreases because of the increment of pore water pressure and finally fails due to disturbance from outside of soil structure. Landslide could take place due to erosion near rivers, rainfall, rapid increase of groundwater level, rapid drawdown, ground shake by earthquakes, impact loading from outburst and rapid flow of volcanic eruption materials and instability or overload slope by land use change and human infrastructural activities. The impacts of landslides include human casualties, economic losses, infrastructure damages and the change of physical environment and geomorphology. Landslide near the river occurs when the water due to high precipitation and runoff flows through unstable slopes of the riverside while groundwater increases in parallel with the river discharge.

Landslides on the upstream of dam reservoir obviously occur when reservoir impoundment has affected groundwater level of the upstream slope that penetrates into the susceptible soil layers which can fall down to the reservoir. The falling landslide mass into reservoir would significantly reduce the reservoir capacity. A particular case of landslide near the dam reservoir is chosen to analyze the cause and mechanism of such landslide which affect the service and sustainability of reservoir as water resource for human and agriculture needs.

The study of landslide near reservoir could be carried out by slope-stability analysis approach and landslide dynamics approach. Slope-stability analysis is to study whether or not a slope failure occurs. It is also the main tool for the study of landslide initiation, while landslide dynamics is to study landslide mobility after failure [6]. The study of shear strength reduction in landslide mass is important as part of the landslide dynamics science which covers mobility after failure, associated with landslide hazard level, risk assessment, landslide velocity and affected area. In this paper, the shear strength reduction in progress of shear displacement on the landslide near dam reservoir is investigated by means of ring shear tests.

2. Materials and Methods

2.1. Impoundment of Aratozawa reservoir and the 2008 large-scale landslide

The Aratozawa dam (Fig. 1) is located in the southeast of Mount Kurikoma in the Iwate-Miyagi Prefecture of Japan. The height of Aratozawa dam is 74.4 m and length of about 414 m with the geographical position at 38°53'4.98'' of north latitude and 140°51'42.93'' of east longitude.

Fig. 1. Aratozawa dam and reservoir in Miyagi Prefecture of Japan (photo taken in June 2013)

According to Ministry of Land, Infrastructure and Transport of Japan, this dam was built in 1983 and categorized as rock-fill dam with central core. The main purpose of the Aratozawa dam and reservoir are flood control and