Failure Mechanism of an Embankment due to Overflow

K. Fujisawa, A. Kobayashi, K. Yamamoto, S. Aoyama
Graduate School of Agricultural Science, Kyoto University
Kyoto, Japan

ABSTRACT
Experiments using small embankments were carried out to observe and understand the failure of an embankment due to overflow. Noncohesive silty sand was used to construct the embankments. The experimental results were quite similar to previous studies. Headcut advance was a key behavior of the failure as reported by the previous studies. In this paper, theoretical concepts for headcut advance and profiles of an embankment during overtopping failure are also discussed.

KEY WORDS: Overtopping; failure; overflow; headcut; embankment; erosion; water infiltration

INTRODUCTION
When the water level at an embankment, such as dams and levees, exceeds the level of the crest, water will flow over it. This is called overflowing or overtopping by water level (Visser, 1998). Interest in failure of an embankment due to overflow has been growing because of increasing occurrence of storm rainfall. Recent examples of dam-break in the world were reported by Coleman et al. (2002). Considerably many irrigation tanks in Awaji Island, Japan, also suffered overflow and failed in 2004 when a typhoon hit the area. Levees in Fukui prefecture, Japan, failed due to overtopping caused by localized heavy rain in the same year. Overtopping failure of an embankment has been known as a complex phenomenon involving hydraulics of overflowing water and the erosion and stability of the embankment.

Several studies of failure of an embankment due to overflow have been carried out. Suga et al. (1981) experimentally examined the effect of slope protection of levees against overflowing. Coleman et al. (2002) and Kimura et al. (1999) investigated overtopping failure of noncohesive homogeneous embankments. Visser (1998) investigated the breaching process during overtopping failure, and divided the breaching process into five stages. Hanson et al. (2005) conducted large-scale overtopping embankment tests and supported the stage-dependant process of the failure. They provided four stages and included the stage of headcut migration in the failure process of a cohesive embankment. A headcut is a vertical drop or change in elevation occurring where there is concentrated flow (Hanson et al., 1997). According to their definition, stage 1 is erosion of the downstream slope and creation of a headcut, stage 2 is headcut migration, stage 3 is lowering of the crest and the break of the embankment, and stage 4 is breach widening. Hunt et al. (2005) performed experiments focusing on breach widening observed during overtopping failure. Breach widening is lateral erosion or breaching of an embankment.

However, physical understanding of overtopping failure of an embankment is still inadequate because of the complexity. The objective of this study is to understand the behavior of embankment failure in more depth. This paper begins by providing experimental results in the laboratory. The experiments were conducted to observe the difference of the failure behavior due to overflow between an embankment with and without water infiltration. The experiments clarified how water infiltration in embankments affected the failure mechanism. The experimental results indicated the upstream advance of a headcut was an important process as shown by Hanson et al. (2005). On the basis of the experimental observation, the theoretical concept of the headcut advance is added after presenting the experimental results.

OVERTOPPING EMBANKMENT TEST

Testing Apparatus and Procedure
Overtopping embankment experiments were carried out in a water tank with the dimensions of 45 cm in height, 102 cm in width, and 10 cm in thickness. On the back of the water tank, some piezometers were attached to measure the hydraulic head. The schematic illustration of the experimental apparatus is shown in Fig. 1. A reservoir was connected to the upstream end of the water tank to supply water. The rate of water supply was controlled by the water-level difference between the reservoir and the water tank, and the rate was calibrated measured before the experiments.

Overflow started by setting the water level of the reservoir higher than the top or crest of the embankment. The transparent acrylic front allowed for observation of the inside of the water tank, where breaching was induced by overflowing water. During the experiment, the profile...