THE EFFECT OF GRAIN SIZE IN DIKE BREACHING DUE TO OVERTOPPING FLOWS

SHINICHIRO ONDA
Kyoto University, Kyoto, Japan. onda.shinichiro.2e@kyoto-u.ac.jp

KOICHI SHIMIZU
Kyoto University, Kyoto, Japan. shimizu.koichi.72x@st.kyoto-u.ac.jp

YOSUKE HIGO
Kyoto University, Kyoto, Japan. higo.yohsuke.5z@kyoto-u.ac.jp

TAKASHI HOSODA
Kyoto University, Kyoto, Japan. hosoda.takashi.4w@kyoto-u.ac.jp

ABSTRACT

Dike breaching due to overtopping flows causes serious damages and for risk management, it is of great importance to understand the mechanism of dike breaching and consider the countermeasures. The dike failure process is thought to be affected by the sediment material condition such as grain size and cohesiveness. In this study, therefore, the hydraulic experiments of dike breaching are carried out to examine the effect of grain size in this process. Three kinds of sediment materials (No.5 and No.7 non-cohesive sands, and cohesive sand) are used for the dike model, and the fundamental characteristics of dike breaching process are compared. It is shown that the eroded region of the dike is different, based on the sediment material condition.

Keywords: Dike breaching, hydraulic experiment, overtopping flow, non-cohesive and cohesive sands

1. INTRODUCTION

Dike breaching during floods is reported as torrential rain have become to occur frequently. Therefore, it is of great importance for river management to understand the mechanism of dike failure due to overtopping flows and consider the countermeasures. A number of experimental studies concerning on levee breaching due to overtopping has been reported in the literature (Fujisawa et al., 2011; Schmocker et al., 2009; Sekine et al., 2017; Yoden et al., 2010), however, the detailed mechanism of dike breaching has not been obtained. In this study, hydraulic experiments of dike breaching are carried out by changing sediment materials and the fundamental characteristics of breaching process are compared.

2. HYDRAULIC EXPERIMENTS

Hydraulic experiments of dike breaching due to overtopping are conducted. The schematic diagram of experiments is shown in Figure 1. In the rectangular channel with the 0.2 m wide, dike model is implemented, and the crest height, crest length, slope gradient and basement height are 0.3 m 0.1 m, 1:2 and 0.05 m, respectively. Three kinds of sand materials are used for the dike model, such as No.5 and No.7 non-cohesive sands, and cohesive sand, as shown in Table 1. The cohesive sand is prepared by mixing the No.7 sand the Kasaoka cohesive soil in the ratio of 7:3 and water is added to the optimum moisture content. The grain size distributions in three cases are presented in Figure 2. To make the dike model, dike and basement are divided vertically to four portions of the basement (0.05 m), lower part of dike (0.1 m), middle part of dike (0.1 m) and upper part of dike (0.1 m). Enough sand to each portion is thrown to the channel and compounded by using lumber, then the dike is formed. The dike breaching process due to overtopping flows are recorded by digital video camera from the side, and temporal changes of water and bed surfaces are compared.

3. RESULTS AND DISCUSSIONS

Temporal changes of flow fields and bed surface in Case1, Case2 and Case3 are shown in Figure 3 and 4. It is assumed that t = 0 s when the overtopping flows pass the front side of dike crest. In Case1, it is observed that the erosion starts at the behind of dike crest and sediments on the back slope are uniformly eroded. The eroded sediment is transported to downstream and deposits behind the dike toe. Then, dike crest loses the height by the erosion and the dike toe gain the height because of deposition. Finally, the slope of back side is milder than the initial. During the erosion at the back slope, we focus on the interaction between overtopping flows and sediment transport. It can be observed that sediments of the bed surface layer where overtopping flows infiltrate are continuously eroded and transported to the downstream.

In Case2, the much erosion at the dike toe is observed than the dike crest, as shown in Figure 4(b) and the erosion reaches the bottom of channel at t =15 s. The sediments eroded from the back slope and toe of dike are transported to the downstream side without depositing, since the sediment diameter is too small. Erosion behind the dike crest does not proceed and the dike keeps its height, while the dike toe is remarkably eroded. Finally, the crest becomes sharp and the shape of dike shows an overhanging cliff around x =0.5 m at t = 80 s. In Case3, the considerable erosion at the dike toe is observed, as shown in Figure 4(c) and the erosion reaches the bottom of channel at t =60 s. The top of slope is hardly eroded and the dike keeps its height, while the erosion at the dike toe continues. Finally, the dike becomes rounded shape and has an overhanging cliff at x =0.95 m. Seepage flows in the surface layer of dike is not observed in Case3.

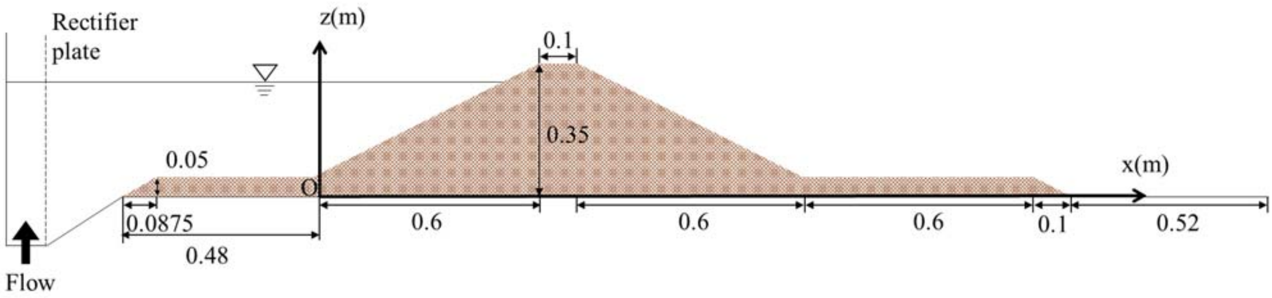


Figure 1. Schematic diagram of experiments

Table 1. Experimental conditions

Case	Sediment materials	Moisture content (%)	Discharge (l/s)
1	No.5	5.21	
2	No.7	11.46	3.3
3	Cohesive sand	15.59	

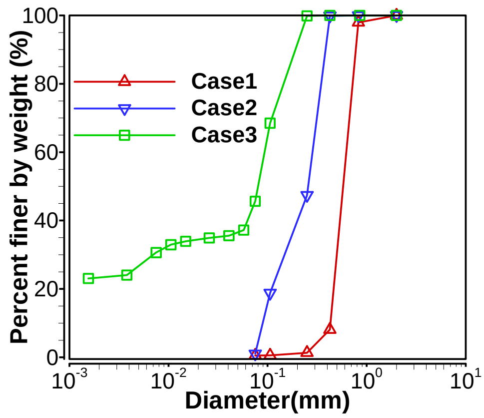
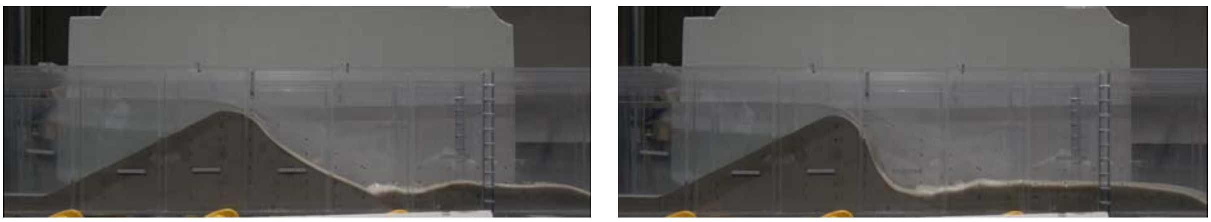


Figure 2. Grain size distribution

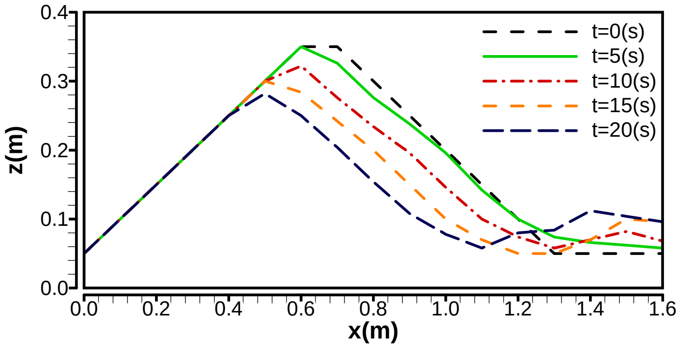
(a) Case1 (left: t =5 s, right: t =10 s)



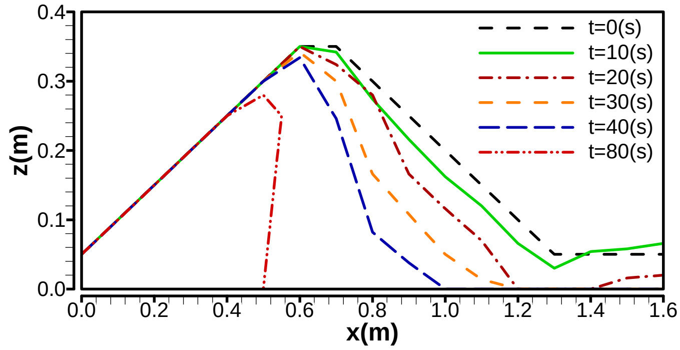
(b) Case2 (left: t =20 s, right: t = 40 s)

(c) Case3 (left: t = 60 s, right: t =300 s)

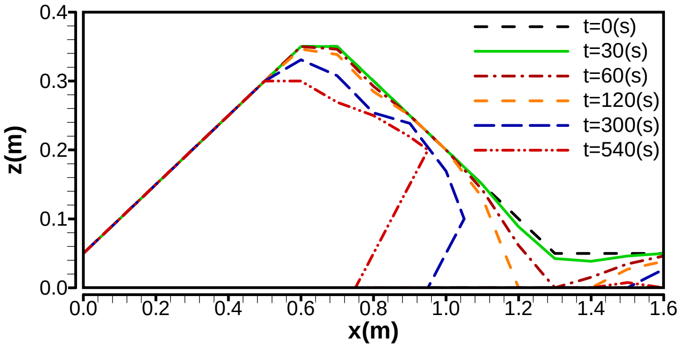
Figure 3. Temporal change of flow fields



(a) Case1



(b) Case2



(c) Case3

Figure 4. Temporal change of bed surface

4. CONCLUSIONS

In this study, hydraulic experiments of dike breaching are carried out and the effect of sediment diameter and cohesiveness to dike erosion process are investigated, by changing the sediment materials. It is concluded that the eroded region of the dike is different, based on the sediment materials. In the next step, numerical simulation is conducted by using the 3D flow model (Onda et al. 2019) and bed deformation model to verify the applicability.

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