INFLUENCE OF SEDIMENT COMPOSITION ON BREACHING PROCESS OF MODEL RIVER LEVEE

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Introduction

In recent years, we have often experienced a torrential rain, which is due to the effect of global climate change. Therefore, inundation damage has occurred frequently in various places in Japan. One of the most serious damage was caused by river levee breach. For example, a heavy rainstorm in the Kanto and Tohoku regions in September 2015 caused the levee collapse of the Kinugawa River. River levee is most important structure that will be our final defense line to protect our lives from the river floods. Considering the above, it must be an urgent research topic to elucidate the mechanism of this collapse due to the flow over it dynamically for disaster prevention and mitigation. However, as far as the authors know, there is almost no research on the effect of mixture ratio of gravel, sand and clay on the levee collapse. The authors have started a systematically arranged experimental research on this collapse mechanism of river levee since April 2015. According to these studies, it was found that the levee which was composed of the mixture of clay and sand becomes much hard to be eroded and collapse due to the cohesiveness of sediment. In this study, we attempted to clarify the effect of the content ratio of gravel, sand and clay on the mechanism of levee collapse. In this paper, it was paid particular attention to the fact that the erosion resistance of the levee is significantly improved if some amount of sand in levee is replaced by gravel under the condition that clay is contained to some extent.

Outline of the Experiment

(1) Experimental apparatus

Summary of an experimental apparatus is shown in Figure 1. The height of the model levee was made with a top width of 0.05 m, a height of 0.15 m, and a slope angle of 30 degree. In order to prevent from overflow near the side wall of the flume in the stage of experiment, the surface elevation of levee top around its central axis was slightly lower than the other. In this experiment, the space surrounded by the levee and the channel wall was regarded as a river, and water was injected into this space to generate a flow over the levee.

(2) Sediment composed of model river levee

Silica sand No.1 (particle diameter 4.3 mm), silica sand No.7 (particle diameter 0.15 mm), and T.A. kaolin (particle diameter 7.0 × 10^{-3} mm) were used as gravel, sand or clay. Specific gravity of each is equaled to 2.65. In this paper, the three experiments of Cases 1 to 3 shown in Table 1 are explained for discussion. In Table 1, the clay content R_{cc} represents the "weight ratio of clay to the total weight", and the gravel content R_{gc} represents the "weight ratio of gravel to the total weight".

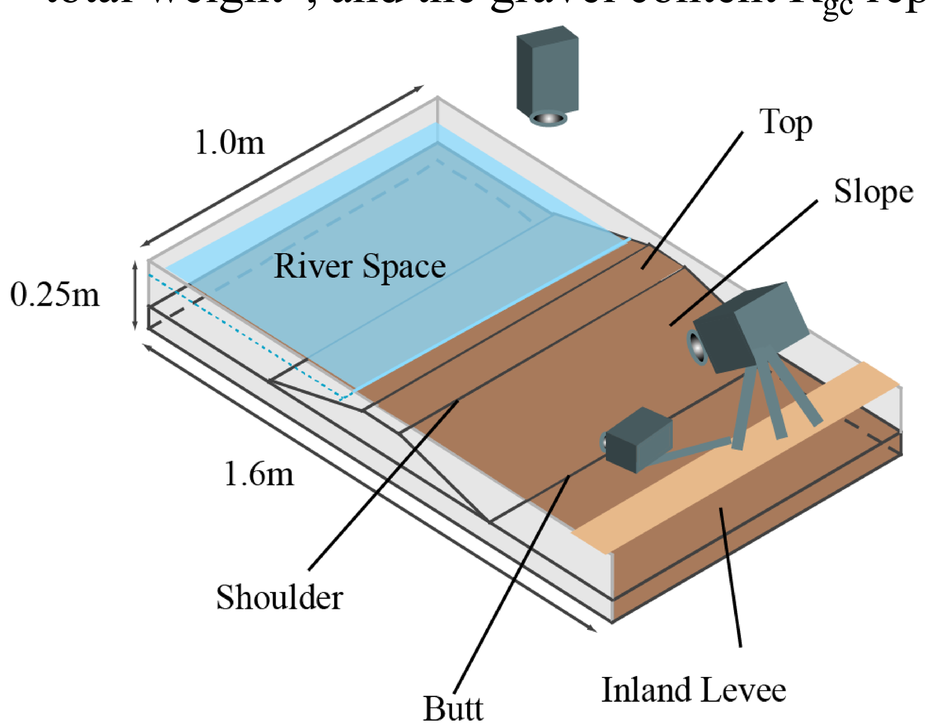

Figure 1. Experimental setup

Table 1. Experimental conditions

	Case 1	Case 2	Case 3
Clay Content R_{cc} (%)	0	30	30
Gravel Content R_{gc} (%)	0	0	30
Time to Breach	100	3960	No Breach

Results

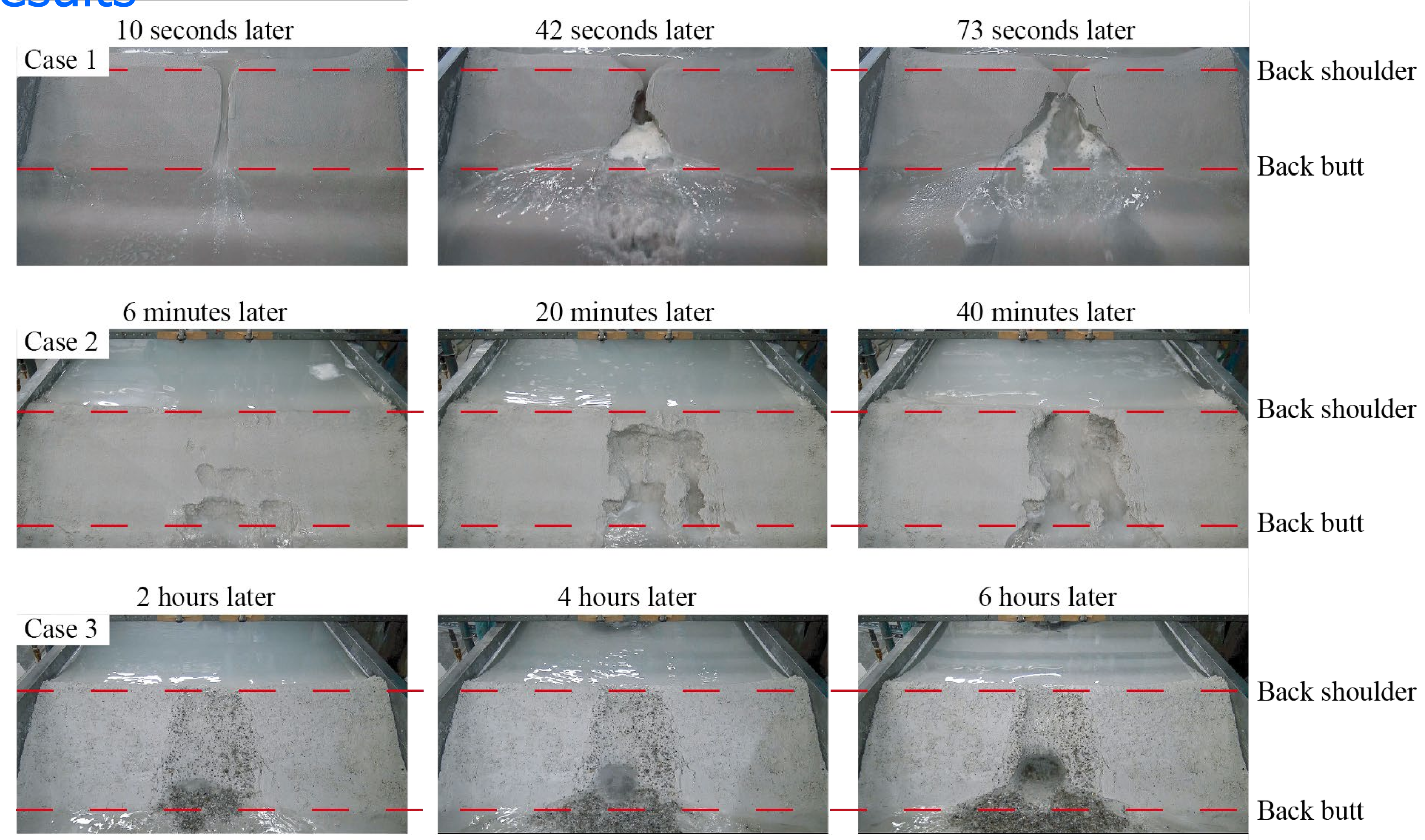

Figure 2. Breach process of model levee

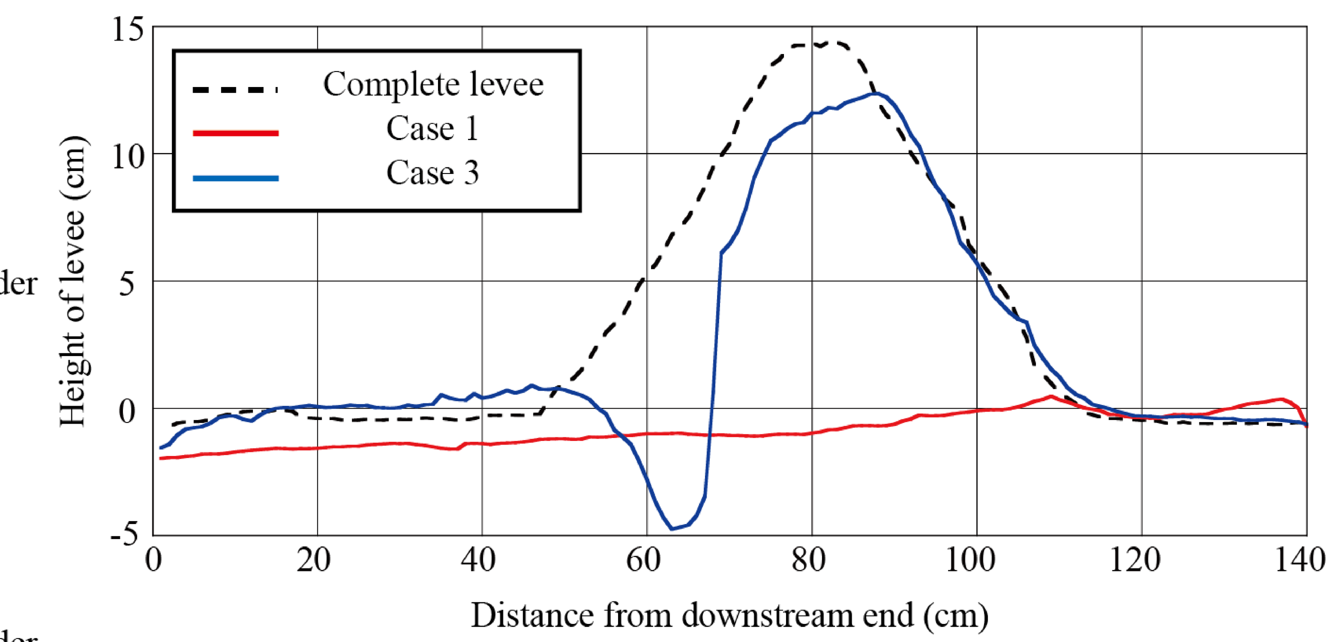

Figure 3. longitudinal profile of levee

In this section, the process of levee collapse is discussed. Figure 2 shows a series of photographs in Case 1 (upper), Case 2 (middle), and Case 3(lower), from which we can recognize the process of levee collapse. The dotted red lines in Figure 2 represent the back shoulder and the back butt of levee. Figure 3 is the longitudinal profile of levee measured by laser placement sensor at the end of each experiment. In Table 1, the time required for levee collapse are listed under each condition. No collapse occurred in Case 3.

1. Collapse process of levee made only of sand (Case 1)

   After the beginning of the flow over the levee, the erosion initiates on the back slope and proceeds downward with forming a narrow channel. When the erosion reaches the foundation ground, lateral erosion becomes dominant, and the channel side wall starts to be eroded. As a result, the width of the channel increases rapidly. When this lateral erosion reaches the bottom of the levee, the sediment mass above it loses its support, and then cracking and collapsing is repeated, causing the channel mouth to be opened widely.

2. Effect of clay on the collapse process of levee (Case 2)

   Erosion of the levee top edge and the back slope of levee has occurred slightly even at about 2 minutes from the beginning of the overflow, and only it occurred near the foot of slope. Then, erosion progressed from back side to front side slope of levee with a step-like topography was formed gradually. When the erosion along the top reaches the front shoulder of levee, vertical erosion due to overflow becomes dominant, and the step disappears.

3. Effect of gravel on collapse process of levee (Case 3)

   Erosion started to occur on the back slope in a manner that sand and clay on the surface of levee were washed out by the running water, and then the exposed gravel moved down on the slope. The erosion of the levee surface was very slow and no stepwise erosion was observed. However, remarkable local scour occurs near the back slope. Under these conditions, the levee collapse did not occur even at 6 hours from the beginning of the overflow.

4. Influence of clay on collapse process (Case 1 and Case 2)

   It is obvious that the erosion resistance of levee in Case 2 is much higher than the one in Case 1 due to the cohesiveness of clay. Furthermore, the erosion rate tends to be smaller as R_{cc} is larger, which results in significant time lag before collapse occurs. If this rate is set initially too large, however, loss of stability becomes significant and the levee can not stand independently.

5. Influence of gravel on the collapse process (Case 2 and Case 3)

   From the comparison, it was found that if the levee contains gravel in addition to clay and sand, the levee would be more difficult to break. This is because the interlock effect between the gravel particles. In this state, the gravel particles keep contact with each other and the gap among them is filled with clay and sand, resulting in a mechanically strong structure.

Conclusion

In this study, experimental investigation was conducted on the river levee containing clay, sand and gravel as well as that composed only of sand, focusing on the process of levee erosion and collapse and its mechanism to be made clear. Followings are the summary of this study.

(1) In case of the model levee made only of sand, erosion proceeds vertically along the surface of the levee, and then lateral erosion and the levee collapse occurs for a short period of time. If clay is contained by a certain ratio or more, on the other hand, the erosion proceeds in different way to form steps and pools on back side of levee.

(2) There is the appropriate volume ratio of gravel and clay to sand can exist to prevent from levee collapse. If the levee is composed of certain amount of clay and gravel in addition to sand, its erosion resistance can be improved in comparison with the levee only of sand. This means that the mixture ratio is extremely important to make the levee be hard to collapse.

References

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