Experimental Study on the Erosion and Collapse of Weak Cohesive Riverbanks

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1. Introduction

The distribution process of the collapsed bank material has not been well understood and requires more investigation. The collapsed bank material can improve the stability of the bank by reducing bank height and slope. In addition, accumulation of collapsed bank material at the bank toe pushes the high flow velocity zone away from the bank protecting the bank from fluvial erosion. Few studies investigate the mass wasting of riverbank after collapse and implement only simple special methods. Some other studies assume that the collapsed bank materials disappear and neglect its effect which is found to improve the bank stability for a while. The specific objective of this paper is to describe the shape of the collapsed bank material via experimental approach.

2. Experimental Set up and Hydraulic conditions

A riverbank with slope angles of $\theta =$ 45, 60, 75, and 90° and with height of 35 cm is tested in an experimental flume as shown by **Fig.1**. The flume consists of channel and bank parts. Since the two channels are perpendicular to each other, the flow cannot generate any fluvial erosion on the bank. We designed an eroding jet-pipe, **Fig.2,** to produce fluvial erosion at the bank toe. Silica sand (S6), with d_{50} = 0.24mm, was used as the bank material. Although this sand is a non-cohesive material it can exhibit some cohesion with moisture due to the fine particle size which can allow banks to stand at steep angles.

Two digital video cameras, at front and top sides, were used to capture the fluvial erosion progress, and the mass failure process. Fixed photos captured just before failure explain the development of cracks while those captured 1~2 seconds after failure illustrate the initiated cracks marking the failure plane and the distribution of collapsed material.

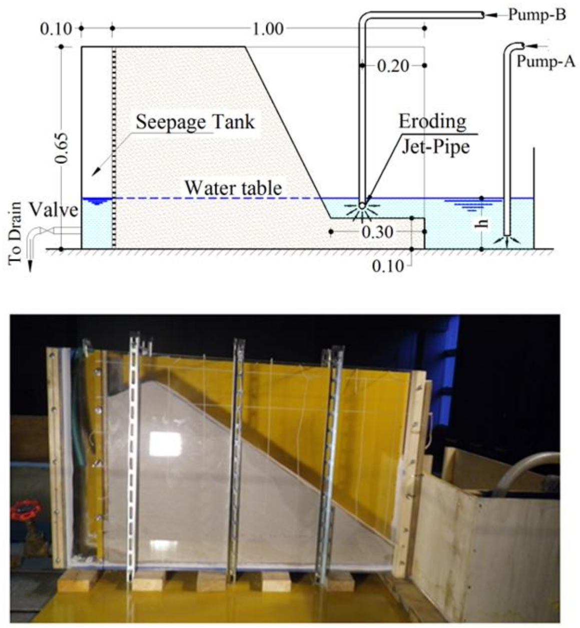

Fig.1 Sketch and front view for the experimental flume

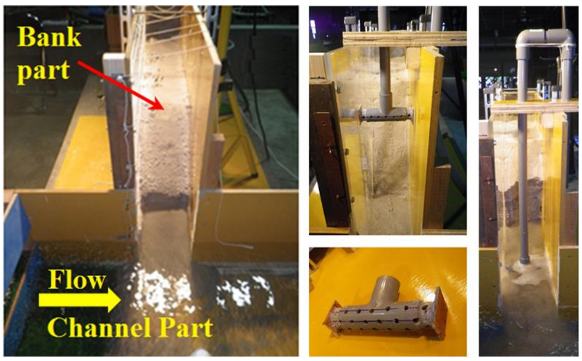

Fig.2 Side view and details of the eroding jet-pipe.

3. Results and discussions

Bank shapes just before collapse, and 1~2 seconds after collapse are shown in **Fig.3.** Three processes were observed:

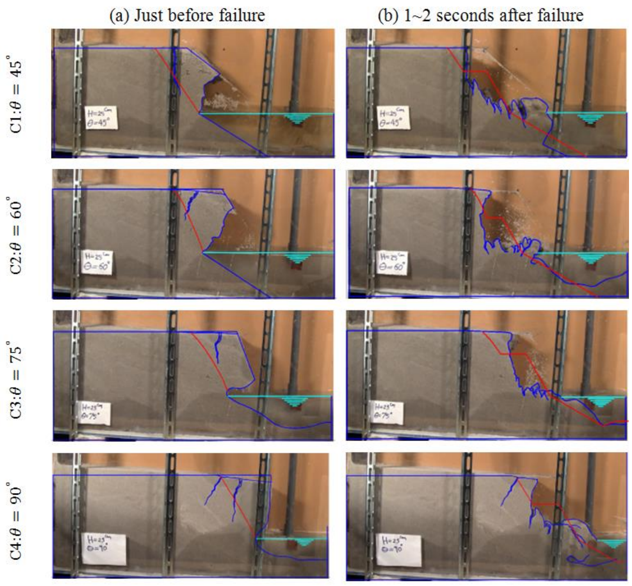

Fig.3 Results from experimental and model, (a) Just before failure, (b) 1-2 seconds after failure

1) Hydraulic erosion process caused by the jet-pipe: detached sediment particles were removed away from the channel bed and the bank toe. The stable bank part under the water surface rests at the submerged angle of repose which was measured and found to be 30° as shown in Cases C1,C2,C3, **Fig.3.a** , except for case C4 because mass failure occurs quickly before the lower part reaches the stable condition.

2) Local mass failure process: local failure (collapse of small blocks approx. 5cm in diameter) occurs by tensile failure mechanism just above the bank-water contact point. The region above that contact point is saturated by the capillary action and loses its cohesion and strength. Local collapse occurs when the tensile stress due to the saturated block weight overcomes the tensile strength of soil mass. Local failure was observed in all cases.

3) Main mass failure process: deformation and development of cracks was observed. Cracks develop down-words from the bank topline some distance left to the bank edge because of tensile stress in this region. Initiation of cracks reduces the effective length of the potential failure surface and decrease bank stability. Overhanging part collapses by beam failure mechanism where a block rotates forward about a horizontal axis somewhere in the block. Above the axis, failure is in tension and below it is in compression. Failure occurs because the moment of the weight of the block about the neutral axis overcomes the resistive moments of the soil's strength in tension and/or compression.

In banks with θ= 45, 60, and 75° cracks are nearly vertical while for θ = 90° (vertical banks), cracks are slightly sloping and are formed perpendicular to the direction of tension stresses. In most cases, main mass failure occurs when crack depth reaches nearly half the height of the bank above WSL, **Fig.3.a**.

4. Conclusions

1- Hydraulic erosion and local mass failure are the main reason for the progress of undercutting and the formation of overhangs as observed in all cases.

2- The collapsed bank material becomes loose and turned into small separate pieces (crumbs) that rest at the submerged angle of repose (ϕ_s) under water surface.

3- There are many cracks are developed just before failure so there is no distinguished plane of failure.