A39

EXPERIMENTAL AND NUMERICAL ANALYSIS OF RIVERBANK EROSION MECHANISM

SHOJI FUKUOKA
Dept. of Social and Envirn. Engr., Graduate School of Engineering, Hiroshima University (1-4-1 Kagamiyama, Higashi Hiroshima City, 739-8527, JAPAN), E-mail: sfuku@hiroshima-u.ac.jp

AKIHIDE WATANABE
Dept. of Social and Envirn. Engr., Graduate School of Engineering, Hiroshima University (1-4-1 Kagamiyama, Higashi Hiroshima City, 739-8527, JAPAN), E-mail: awata@hiroshima-u.ac.jp

S. M. HABIBULLAH BAHAR
Dept. of Social and Envirn. Engr., Graduate School of Engineering, Hiroshima University (1-4-1 Kagamiyama, Higashi Hiroshima City, 739-8527, JAPAN), E-mail: bahar@hiroshima-u.ac.jp

SATOSHI YAMAGATA
Ministry of Land, Infrast. and Transport (Hakodate City, 040-8501, Okawa – cho, 1-27, JAPAN)

1. INTRODUCTION

There are many instances that the natural riverbank is consisting of cohesive and cohesive-silty soil. There were several studies about the cohesive bank erosion, but those were not enough to reveal its erosion process. The hydraulic properties near cohesive riverbank have significant influence on the bank erosion process. This paper has made an attempt to investigate the process of cohesive bank erosion more close to the nature. We studied undisturbed cohesive soil erosion and showed different erosion process of two types of eroded banks: near water surface and under water surface eroded bank. To reveal the erosion mechanism of the cohesive bank erosion, the authors at first did physical bank model experiment and numerical simulation of measured flow fields for near water surface eroded bank. Thereafter, physical model experiment of successive eroded banks of near water surface and under water surface eroded banks were done to understand erosion mechanism of the two bank shapes.

2. COHESIVE BANK EROSION PROCESS

Undisturbed cohesive soil samples were collected from flood channel of the Yoshino River, Shikoku, Japan and installed in a straight laboratory channel. The erosion of the cohesive soil sample initiated randomly at locations of the bank surface with lower resistance and loose particles on it. It continued to expand in the upstream and downstream direction, and upstream erosion surface angle became gradually steep until the erosion became stable. In this paper, "angle" will denote upstream erosion surface angle of the eroded bank. The angle of the eroded bank varied from 4^0 of (initial erosion stage) to 9^0 (equilibrium erosion stage). At one stage of bank erosion, two types of eroded bank shapes became prominent. One type of bank shapes existed near water surface and another bank shape located under water surface. It was observed that the erosion of the near water surface bank expands in the upstream direction; whereas the under water surface bank erosion expands in the down stream direction.

3. PHYSICAL MODEL EXPERIMENT

During the Yoshino River sample experiments, it was not possible to measure the flow fields inside the eroded bank because of continuous bank erosion. Therefore, physical bank erosion models, which are similar to the eroded bank shapes of 5.0 hours erosion stage and equilibrium erosion stage of the soil sample erosion experiment, were developed to measure the flow fields in detail. The bank models varied in angle, erosion length and height from the channel bed depending on 5.0 hours or equilibrium erosion stage. The authors did 3 types of physical model experiments depending on the erosion stage and location of erosion. These are Case (a) different bank shapes of near water surface varying in angle and erosion length, Case (b) near water surface and under water surface together of initial erosion stage, Case (c) a series of eroded bank shapes similar to the soil sample erosion experiment for equilibrium erosion stage. The physical models were installed in a straight channel maintaining 25cm channel width, same width as the Yoshino River soil sample experiments, in the upstream and downstream of the erosion part.

3. 2-D NUMERICAL MODEL FOR NEAR WATER SURFACE ERODED BANK

The Yoshino River soil sample erosion experiment showed that the near water surface eroded banks experienced larger and most dominant erosion compared to that of under water eroded bank. In this study, we at first attempted to measure flow fields in detail for model bank shapes of Case (a) and then applied a 2-D numerical model to reproduce the measured flow fields for the case. The shapes of these eroded banks varied in erosion length (60cm and 90cm) and angle (4^0, 6^0 and 8^0). For this study, a two-dimensional flow regime is approximated to understand the cohesive riverbank erosion mechanism. The governing equations of the 2-D numerical model were obtained by depth integration of the continuity equation and the Reynolds equations in orthogonal curvilinear coordinate system. The computation used 1st order convective terms and upstream finite difference of control volume. It used staggered grid to compute velocity flux in $\xi - \eta$ direction and water depth at the center of the grid. Depending on the size of computational meshes, the time steps were different for the different bank erosion shapes. It was supposed that vortex viscosity coefficient ν_t is proportional to local frictional velocity u_* and water depth h. For this computation, right bank of the channel was assigned slip condition because of smooth glass, and the left bank was assumed to have non-slip condition due to presence of artificial roughness.

The numerical model could reproduce the flow field of this Case (a) including flow separation inside the eroded bank. Its accuracy is higher for small 4^0 angle with 60cm erosion length, but there are some discrepancies between the computed and measured flow fields for large angle and erosion length (6^0 with 90cm erosion length and 8^0 angle with 60cm erosion length). The reasons are that in the experimental case of the larger angle and erosion length the flow field might be of 3-dimensional. Both the computed and measured results showed that water depth increases inside eroded bank and flow separation area is larger for larger erosion length and angle.

4. SUCCESSIVE ERODED BANK MODEL EXPERIMENT

In order to understand erosion mechanism of the two types of eroded bank shapes, we also did physical model experiments for successive eroded bank shapes installed along the left bank of the channel depending on the 5.0 hours and equilibrium erosion stage. For the Case (b) of 5.0 hours erosion stage, one pair of near water surface and under water surface model banks was installed. The former model bank was in upstream of the latter model bank. There were two pairs of near water surface and under water surface physical bank models of Case (c) for the equilibrium erosion stage, where each pair was beginning with near water surface at upstream. The experimental results show that flow characteristics of the two eroded bank shapes are different. For the near water surface eroded bank, flow is separated or tendency to be separated inside the eroded bank even in the initial erosion stage. This flow separation area becomes larger during equilibrium erosion stage. Due to occurrence of the flow separation in this case, its erosion might expand in the upstream direction. Even though, the velocity inside of under water eroded bank decreases, but there is no flow separation at any stage of bank erosion. Velocity differences on the downstream eroded surface of under water eroded bank are larger than those on the upstream surface. Therefore, erosion of under water bank shape might progress in the downstream direction.

The 2-D numerical model made for the near water surface eroded bank cannot be applied to compute flow fields of the under water eroded bank because of constant water depth and confined flow inside its eroded bank. Further development of numerical model is under progress to compute the partially confined flow field of successive eroded bank.