Analysis of flow field within and neighboring of eroded bank through experiment and computation

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1. Introduction

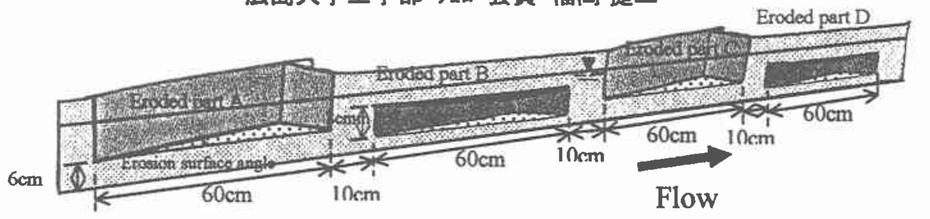


Figure. 1 Side view of model eroded bank shapes

There are many instances that the natural riverbank is consisting of cohesive and cohesive-silty soil. This paper has made an attempt to investigate the process of cohesive bank erosion more close to the nature. In the study of Yoshinogawa undisturbed soil sample bank erosion experiment[1], erosion initiated at locations of lower resistance to the given flow condition. It continued to expand in the upstream and downstream direction, and upstream erosion surface angle became gradually steep until the erosion became stable. The upstream erosion surface angle during cohesive soil sample experiment varied from 5^0 to 9^0. The cohesive bank erosion process was observed by measurement of erosion rate with time, widening and deepening of erosion. It was observed that the cohesive bank erosions were two types; near water surface and under water surface bank erosion. Between these two types, erosion rate was larger in the case of near water surface bank erosion. As the hydraulic properties near eroded bank impart most significant influence over the cohesive bank erosion, it was very important to measure the flow fields near the eroded bank to understand the cohesive bank erosion mechanism. During the Yoshino River sample experiments[1], it was not possible to measure the flow fields inside the eroded bank because of continues bank erosion. Therefore, physical bank erosion models, similar to the near water surface bank erosion, were developed[2] to measure the flow fields in detail near and inside bank erosion. The bank erosion models varied in upstream erosion surface angles (4 degrees and 8 degrees), each having bank erosion length of 60cm. A 2-dimensional numerical model was developed[2] to simulate the flow fields of the physical model experiments.

In this paper, physical bank erosion model shapes were developed, which were simplified from eroded bank shapes of 11.5 hours flow of Yoshinogawa soil sample experiment. Flow fields were measured in detail to analyze cohesive bank erosion mechanism. The numerical model is applied to reproduce the flow fields of one type near water surface bank erosion model.

2. Experimental procedure

Table 1 Experimental condition

	Upstream erosion surface angle (degrees)		Flow rate (l/s)
	Near water	Under water	
Case 1	8	6	34.4
Case 2	8	6	25.5
Case 3	4		36.5
Case 4	6		36.5

As the Yoshinogawa soil sample experiment had two types of bank shape; near water surface and under water surface, both the bank shapes were reproduced and installed in a straight channel for the present study. The side view of the model bank shapes are shown in the figure 1. A series of the near water surface and under water surface model bank shapes were installed along the left bank of the channel. A near water surface bank shape is preceded first, which is followed by a under water surface bank model. Another set of model bank shapes of same size is also placed in the immediate downstream. The upstream erosion surface angle of the near water surface and under water surface bank model are 8 degrees and 6 degrees respectively. Both the bank shapes has erosion surface length of 60cm. The bottom of the near water bank is 6 cm above from the channel bed. Whereas, the under water bank bed is 3cm above from the channel bed and its height is 8cm. The experimental channel is 25cm wide. As the model bank shapes are along the left bank of the channel, all the bank side is covered with artificial roughness. On the other hand, the right side of the channel has smooth glass. The hydraulic conditions of the experiments are shown in table 1. For the experiments of series of bank shapes, flow fields of the two downstream bank models (Eroded part C and D) were measured. The upstream two bank shapes (Eroded part A and B) were used as dummy.

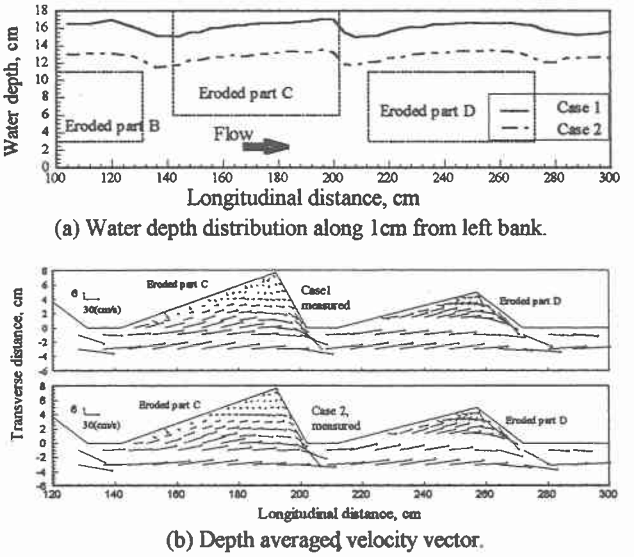
3. Analysis of flow field

In the previous study[2] of flow fields of one model bank erosion shape[2] existing near water surface, it was seen that water depth gradually increases near and inside eroded bank. There was flow separation area at location of maximum erosion depth for larger erosion surface angle of 8 degrees. But in the case of smaller erosion surface angle of 4 degrees, the reverse flow did not occur. The present analysis shows that the water depth 1cm from left bank increases (Fig. 2(a)) inside both the eroded part C and D (near water and under water surface respectively). The water depth decreases suddenly in the downstream of the eroded part C, but it decreases gradually in the downstream of the eroded part D. There is flow separation area at the location of the maximum eroded bank of C, but its flow separation area (Fig. 2(b)) and absolute magnitude of the reverse flow is smaller compared to near water surface eroded bank having no upstream eroded bank. On the contrary, there is no flow separation inside eroded part D (Fig. 2(b)), which exists under water surface. Therefore, the flow properties inside near water surface eroded bank and under water surface eroded bank are different.

3. Computation of flow field

In a companion study[2], the authors developed a 2-D numerical model to reproduce flow fields near water surface model bank erosion shape of 60cm erosion surface length. Its accuracy was higher for smaller erosion surface angle of 4 degrees. It could compute the flow fields for larger erosion surface angle of 8 degrees, but because of 3-D flow inside the eroded part there was some discrepancy between the measured and computed results. In the present study in an attempt to use for different shape of bank erosion, the 2-D numerical model is applied to reproduce the flow fields of Case 3 and Case 4, which have larger erosion surface length of 90cm and erosion surface angle of 4 degrees and 6 degrees respectively. The velocity vector of Case 3 shows (Fig. 3) that there is small flow separation area for larger erosion length of 90cm and 4 degrees erosion surface angle, which did not occur in the case of smaller erosion surface length of 60cm and 4 degrees erosion angle. This flow separation area (Fig. 4) is larger for larger erosion angle of 6 degrees and 90cm erosion length (Case 4).

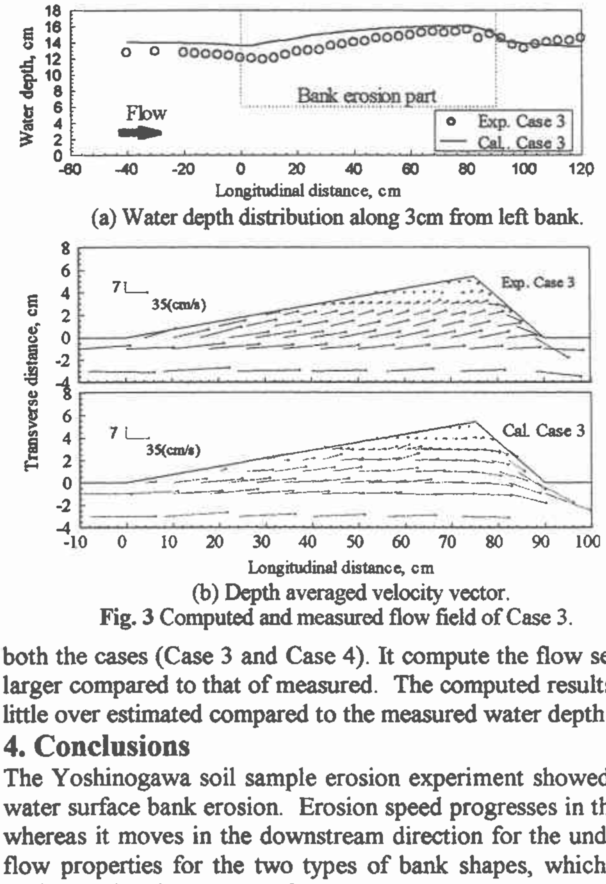
The numerical model could reproduce the flow field of both the cases (Case 3 and Case 4). It compute the flow separation area inside eroded part, but its absolute magnitude is little larger compared to that of measured. The computed results show that the predicted water depth near and inside eroded bank is little over estimated compared to the measured water depth.



(a) Water depth distribution along 1cm from left bank.

(b) Depth averaged velocity vector.

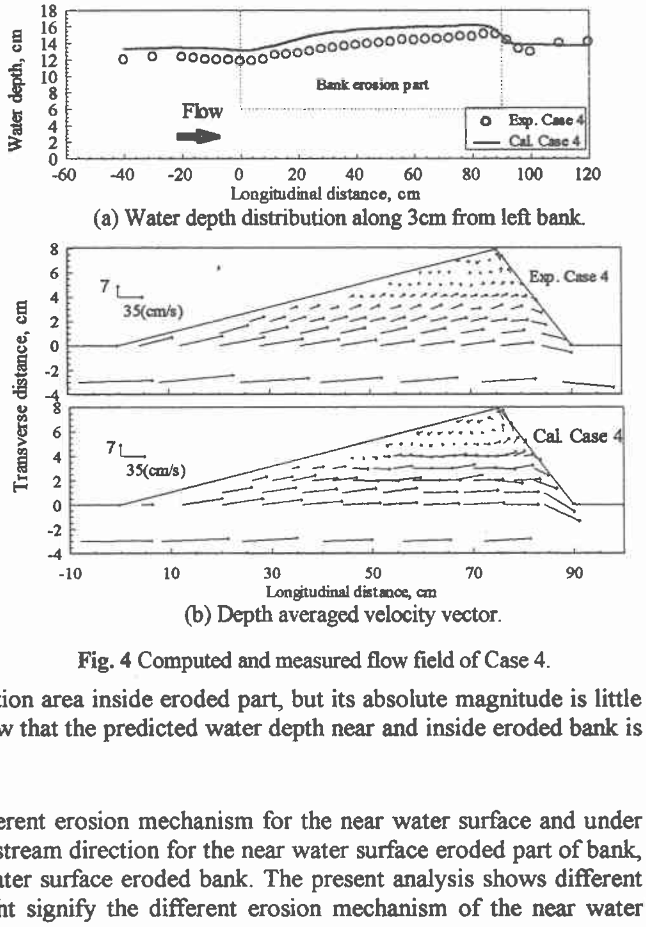
Fig. 2 Flow fields of Case 1 and Case 2.



(a) Water depth distribution along 3cm from left bank.

(b) Depth averaged velocity vector.

Fig. 3 Computed and measured flow field of Case 3.



(a) Water depth distribution along 3cm from left bank.

(b) Depth averaged velocity vector.

Fig. 4 Computed and measured flow field of Case 4.

4. Conclusions

The Yoshinogawa soil sample erosion experiment showed different erosion mechanism for the near water surface and under water surface bank erosion. Erosion speed progresses in the upstream direction for the near water surface eroded part of bank, whereas it moves in the downstream direction for the under water surface eroded bank. The present analysis shows different flow properties for the two types of bank shapes, which might signify the different erosion mechanism of the near water surface and under water surface.

The numerical model could reproduce the flow field for larger erosion surface length and angle, but there are some discrepancy between the measured and the computed results.

Reference:

1) Fukuoka, S., Watanabe, A., Katayama, T., Itaya, E., Kashiwagi, Y., Yamagata, S., and Hayashi, M.,: Erosion expansion mechanism of cohesive (silt) bank by the stream flow, Ann. J. Hydr. Engrg, JSCE, vol. 43, pp. 695-700, 1999. (in Japanese)

2) Bahar, S. M. H., and Fukuoka, S., Numerical analysis of flow field inside and near eroded part of bank , Ann. J. Hydr. Engrg, JSCE, vol. 45, pp. 583-588, 2001.