FLOW CHARACTERISTICS OF COMPOUND OPEN CHANNEL FLOW WITH DISCONTINUOUS FLOOD PLAIN

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ABSTRACT

An embayment set up in the river are connected to the main stream of the river, but are terrain that looks like a pond surrounded by river structures. It provides a stable habitat for aquatic organisms such as fish, and is a place where various vegetation breeds. To conserve the environment inside the wand, it is necessary to understand the structure of the flow inside the wand. During a flood, the embayment may be submerged, and the flow field is considered to be a complex three-dimensional turbulent flow consisting of backward facing step flow with an end and a side wall flow. In this study, in order to reproduce the flow field of a submerged embayment, a compound open channel flow with discontinuous flood plain was created, and the characteristics of the flow structure were examined by measuring the flow velocity and flow visualization.

Keywords: compound open channel flow with discontinuous flood plain, embayment, three dimensional turbulent flow, PTV, flow visualization

1. INTRODUCTION

An embayment is a stagnation area where sediment has accumulated on a dike installed in a river channel. The low flow velocity within the embayment makes it an ideal habitat, breeding and evacuation site for a variety of organisms. In addition, various vegetation is seen, and a rich natural water environment is created. Artificial embayment is created by dug a part of a flood plain of compound river. In order to conserve the environment inside the embayment, it is necessary to control sedimentation and water circulation. For this, it is necessary to understand the flow structure in the embayment. In particular, during a flood, the embayment is submerged and becomes a compound channel flow with discontinuous flood plain, which causes a great change in sedimentation in the embayment. Therefore, detailed elucidation of such flow is necessary. For this purpose, this study clarifies the detailed three-dimensional flow velocity characteristics of the flow field, the spatio-temporal characteristics of the cohenrent structure formed in the flow field, the correlation between the behavior of the cohenrent structure and the flow velocity distribution, and a conceptual model of the flow field.

2. EXPERIMENTAL EQUIPMENT AND EXPERIMENTAL METHOD

In the study, a straight open channel made of a total acrylic resin plate with a length of 10 m, a width of 60 cm and a height of 15 cm is used. A 15 cm wide, 4 cm high, 1cm long board made of PVC resin will be laid on

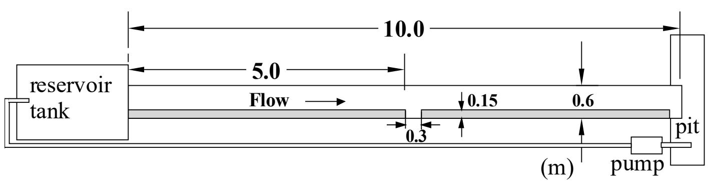

Figure 1. Outline of the test channel

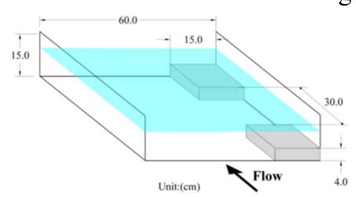

Figure 2. Outline of observation area

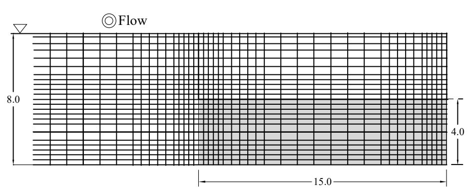

Figure 3. PTV measurement cross section position

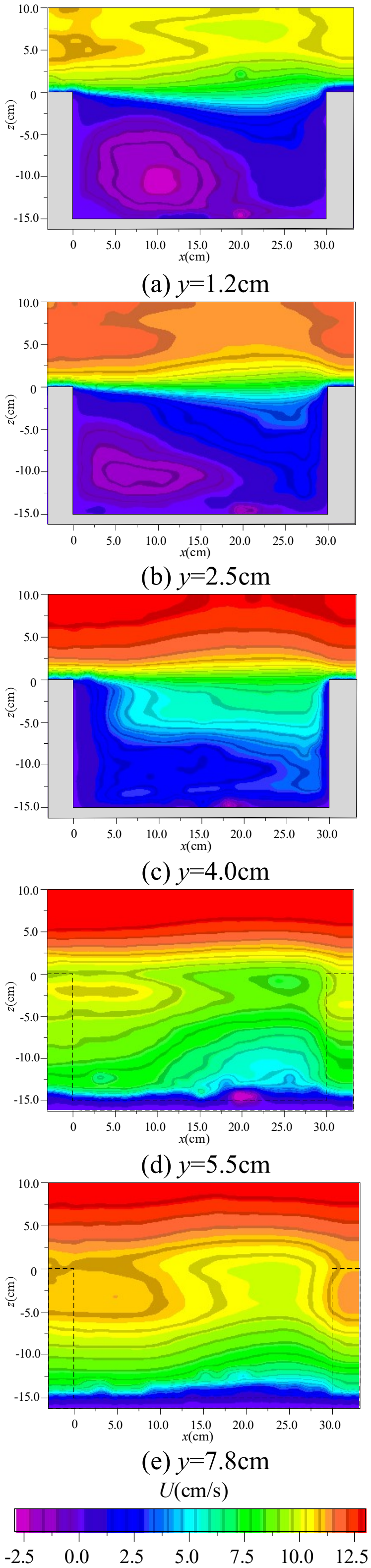

Figure 4. Average primary velocity distribution (*U*)

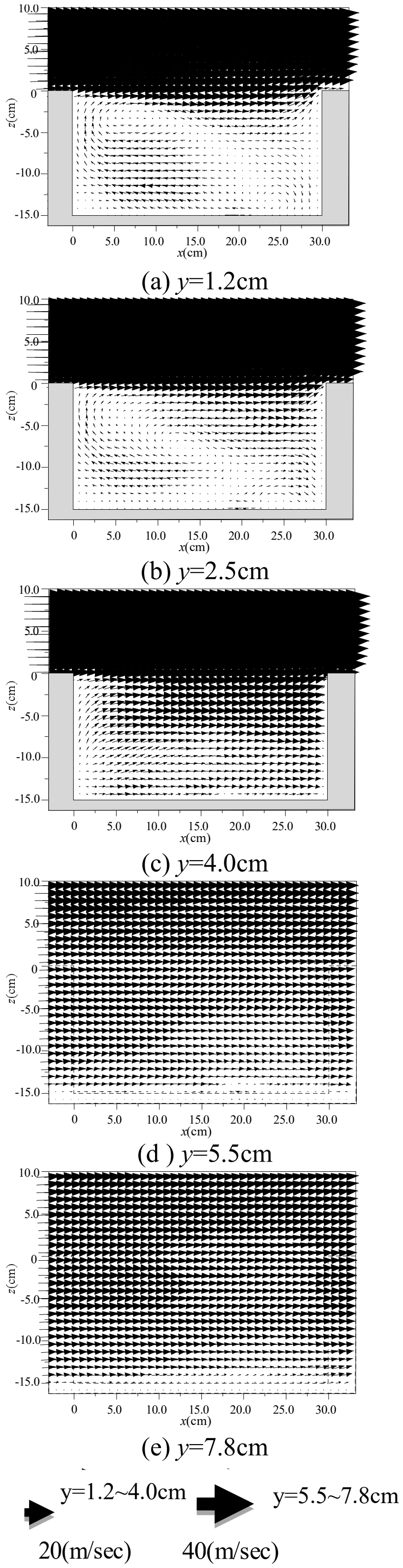

Fig 5. Flow velocity vector distribution (*U*, *W*)

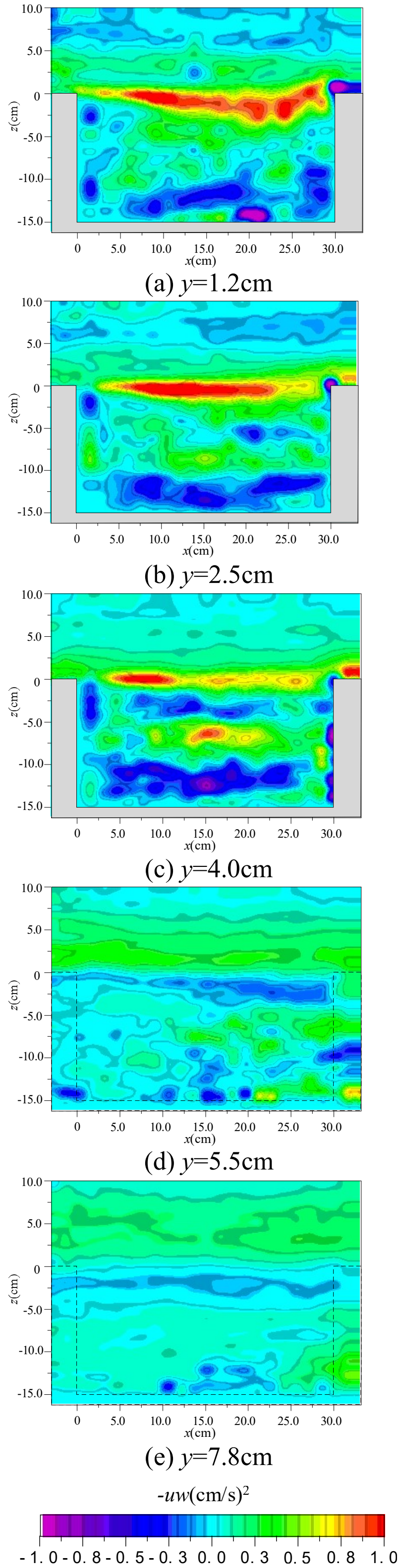

Fig 6. Reynolds stress distribution (*-uw*)

the right side wall of the channel. At that time, a space of 30cm in length is provided at a point 5m from the upstream, and it is used as a notch on the high water floor. An overview of the experimental channel is shown in Figure 1, and the cutout is shown in Figure 2. PTV (Particle Tracking Velocimetry) was adopted for flow velocity measurement. Figure 3 shows the irradiation position of the laser slit light film. Fluorescent dye injection method was used to visualize the internal structure of flow.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 4 shows the mean primary velocity distribution (*U*). At y = 1.2 ~ 4.0cm, the inside of the notch of the flood plain is relatively slower than the main stream side, and the backflow occurs near the side wall. At y = 5.5 ~ 7.8cm, it is noticeable that the speed near the downstream end of the notch is low. Figure 5 shows the

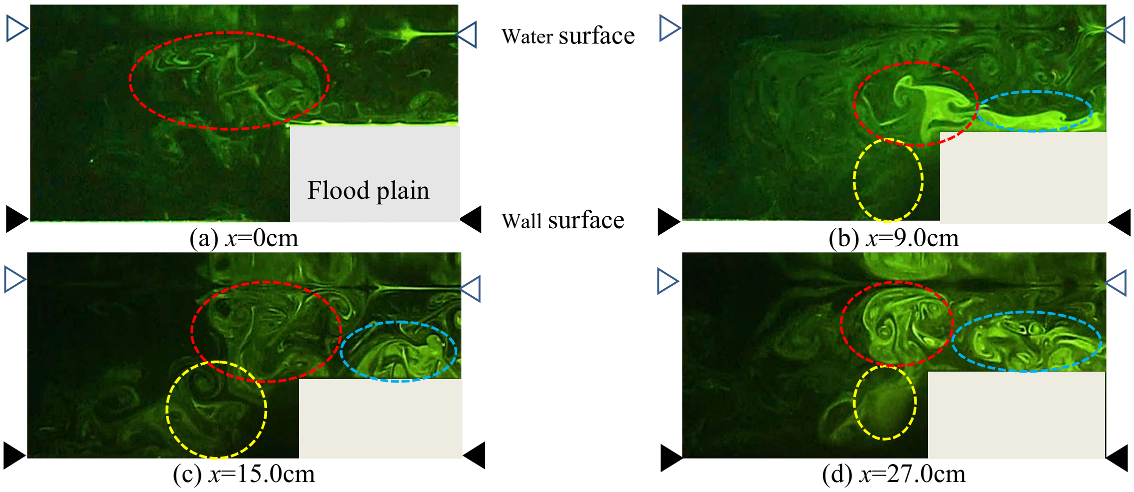

Figure 7. Results of cross-sectional view

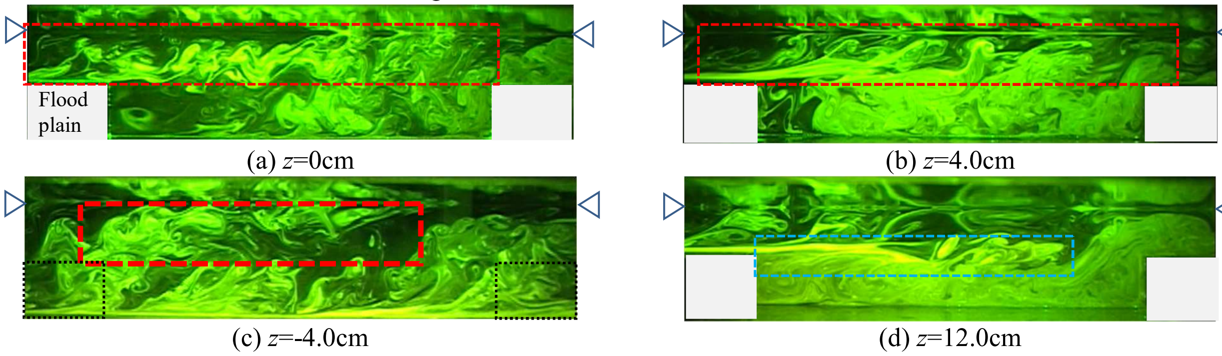

Figure 8. Result of side section

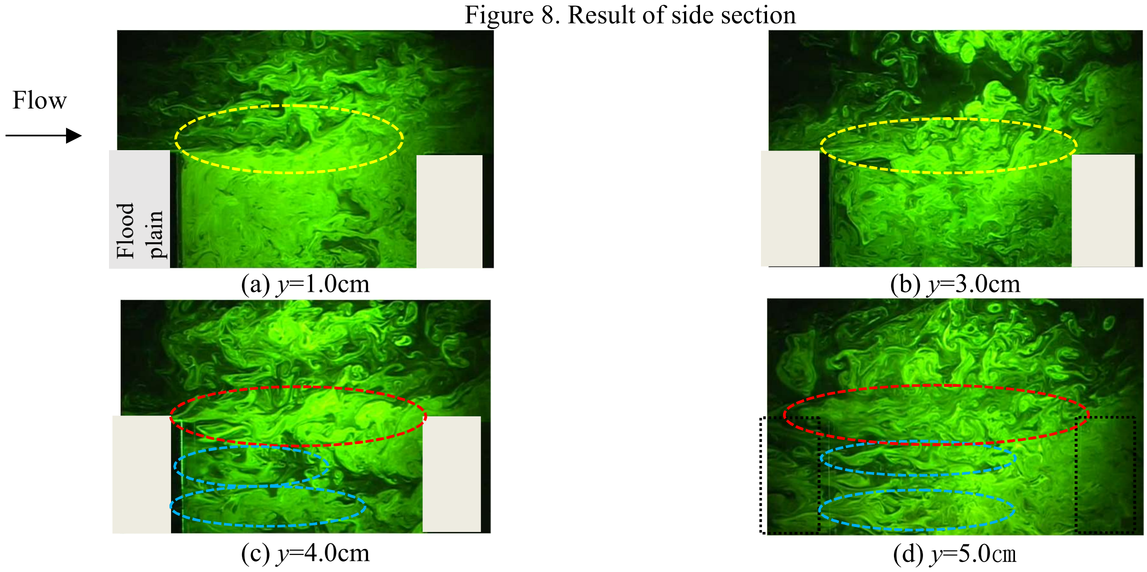

Fig 9. Horizontal cross-sectional view results

velocity vector (*U, W*) to y = 2.5cm. In the, the formation of a swirling flow in the hour hand direction is recognized on the upstream side. disappears. Figure 6 shows the Reynolds stress (-*uw*). From *y* =1.2cm to *y*=4.0cm, the boundary between the notch and the low channel is large. Near the side wall, there is a negative region. In addition, the distribution of positive and negative Reynolds stress is formed in parallel in the boundary region between the notch of y = 5.5cm to 7.8cm and the main channel.

Figures 7, 8, and 9 show the results of horizontal, vertical, and horizontal cross-sections, respectively. The visualization of these flows revealed that three longitudinal vortex structures were formed in this flow field. One is that the longitudinal vortex structure formed at the tip of the flood plain upstream of the notch is also formed at the tip of flood plain at the notch. Its cross-sectional view corresponds to the area surrounded by the red dashed line in Fig. 7. The existence of this longitudinal vortex structure has been elucidated by Watanabe et al. (Watanabe et al. (2009)), and it has been elucidated that the longitudinal vertical structure is constantly formed at the tip of the flood plain and is a cause of oblique upward flow and turbulence. The vortex pattern that develops in the downstream direction indicated by the red dashed line at *z* = 0 cm, *z* = -4.0 cm, and *z* = 4.0 cm in Figure 8 corresponds to this longitudinal vortex structure. The region shown by the red dashed line in Fig. 9 also corresponds to the horizontal cross-section of the longitudinal vortex structure formed at the tip of flood plain. The second is a group of longitudinal vortices formed downstream of the main channel side wall.

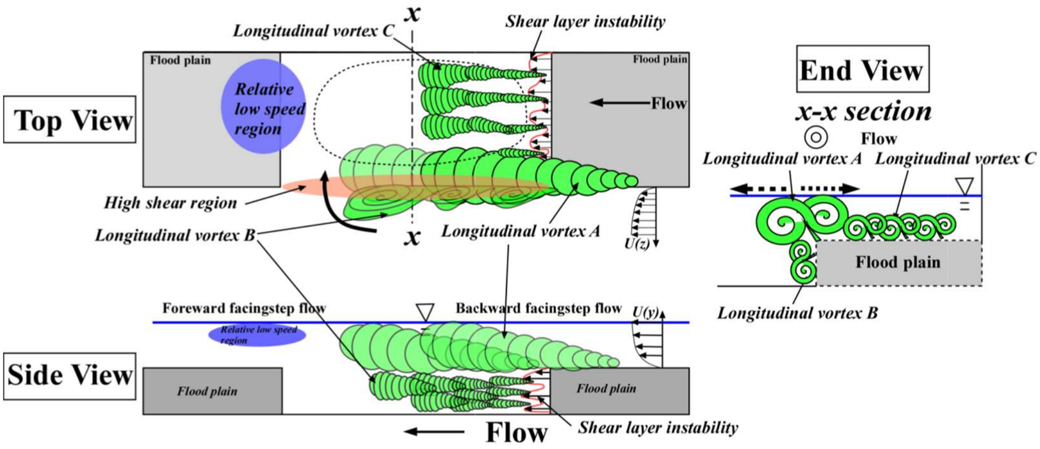

Fig 10. Conceptual model of multi-section flow with discontinuous high water bed

It corresponds to the area enclosed by the yellow dashed line in Figure 8. The horizontal cross section of this longitudinal vortex structure corresponds to the area surrounded by the yellow dashed line in Figure 9. The third is formed downstream from the upstream end of the flood plain. It is a longitudinal vortex structure group. The cross-sectional shape is shown by the blue dashed line in Figure 9. The vertical cross-sectional shape is shown by the blue dashed line at z = 12.0cm in Figure 8. It is recognized that this vortex structure crosses the flood plain at the downstream end. The horizontal cross-sectional shape of this longitudinal vertical structure corresponds to the area surrounded by the blue dashed line in Figure 9.

3.1 Flow conceptual model

Figure 10 shows a conceptual model of a compound open channel flow with a discontinuous flood plain. The flow field is dominated by the tip of the flood plain (longitudinal vortex A), the downstream of the flood plain (longitudinal vortex B), and the top of the flood plain (longitudinal vortex C), respectively. These are considered to play an important role in the characteristics of the velocity distribution in the flow field. Longitudinal vortex A is considered to form a positive and negative high Reynolds stress (-*uw*) region of y = 4.0cm or more at the boundary between the notch and the main channel due to fluid transport accompanying vortex motion. It plays a role in the formation of regions and highly disordered regions. Longitudinal vortex B is a group of longitudinal vortices formed by the instability of the separated shear layer downstream of the flood plain and the coexistence of two shear layers. This is thought to form a Reynolds stress (-*uw*) region at the boundary between the notch and the low channel, as in longitudinal vortex A. Longitudinal vortex C is a longitudinal vortex structure group formed downstream of the upper surface of the flood plain. It is generated by the coexistence of two high shear layer ($\partial u/\partial y, \partial u/\partial z$). This contributes to the generation of turbulence near the height of the flood plain.

4. CONCLUSIONS

In this study, the characteristics of the internal structure of the open channel flow with a double cross section with discontinuous high water floor were investigated using the velocity measurement method and the flow visualization. The following shows the conclusions obtained in this study.

(1) A large swirling flow in the direction of the hour hand is formed below the upper surface of the high water bed at the notch. A relatively low-speed region is formed near the downstream end of the notch.

(2) Positive and negative high Reynolds stress (-*uw*) regions at the boundary between the notch and the low waterway. In addition, a region where the turbulence intensity (u_{rms}, w_{rms}) is remarkable is formed near the height of the upper surface of the high water bed.

(3) In this flow field, vertical vortex structures were observed at the tip of the high water bed, downstream of the side of the high water floor, and downstream of the top of the high water floor. It is suggested that the vortex motion of these vertical vortex structures plays an important role in turbulence generation and swirl flow formation.

(4) A conceptual model of the internal structure was shown based on the characteristics of the flow field.

REFERENCES

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