APPLICATION OF RIVER BANK PROTECTION WITH PRIMARY VELOCITY REDUCTION FUNCTION TO CURVED FLOW

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ABSTRACT

In this study, in order to improve the disaster prevention performance of the Ganlock bank protection where the retaining wall method was put into practical use as a river bank protection, the characteristics of the flow velocity distribution and the internal flow condition of the rough surface of the new Ganlock improved from the old Ganlock were investigated. It was studied by a model experiment. In addition, the effect of controlling the primary flow velocity was studied by applying the rough surface of the new Ganlock to the curved channel. As a result, a large-scale and strong secondary flow was formed in the new Ganlock rough flow compared to the old Ganlock, and the effect of reducing the main flow velocity around the bank protection was recognized. In addition, a large-scale vortex structure was formed around the new Ganlock, and it was supposed that it contributed to the reduction effect of the primary flow velocity and the generation of the secondary flow. Furthermore, in the Ganlock flow, it became clear that the velocity near the side wall was lower than that in the smooth surface flow, and the high speed region moved more toward the center of the channel. From this, the effect of the main velocity control on the curved flow of the Ganlock rough surface flow was recognized.

Keywords: *Ganlock, bank protection, velocity control, secondary flow, vortex structure,*

1. INTRODUCTION

Since the revision of the River Law in Japan, the purpose of the River Law was to clarify the maintenance and conservation of the river environment. The realization of this is the creation of a multi-natural river, which has been vigorously promoted in rivers in Japan. Figure 1 shows a reinforced concrete block called Ganlock (Kikko Japan Co., Ltd). This block has a shape combining a "Ⅱ" shaped member (hereinafter referred to as "bar") and a bar-shaped member (hereinafter referred to as "tail"). By filling stones behind it, a retaining wall as shown in Figure 2 can be constructed. This method is called Ganlock method. This method has sufficient strength as a retaining wall and can be applied to various alignments, and the living space for tree planting and small animals can be secured in the gaps between the stones. Based on these characteristics, application of Ganlock to river bank protection was sought. The authors examined the hydraulic characteristics of the Ganlock bank protection and clarified its features in order to make this method applicable to river bank protection (Watanabe et al., 2018).

Figure 1. Ganlock overview

Figure 2. Example of slope construction by Ganlock method

As mentioned above, the Ganlock method can be applied to various alignments, but it is important to avoid bank protection and damage to the riverbed at the water junction when installed on a river bend. For that purpose, it is essential to reduce the primary flow velocity around the bank protection. Ganlock bank protection has such performance

To this end, the authors conceived to apply the function of reducing the zigzag roughness main flow velocity shown in Figure 3. When the zigzag roughness is installed on the side wall of the channel, the low-speed fluid near the side wall concentrates at the center of the side wall as shown by the arrow in the figure, and a large-scale vertical vortex structure is generated.

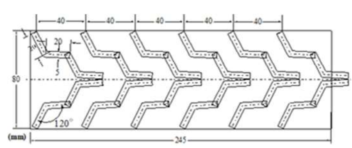


Figure 3. Zigzag roughness top view

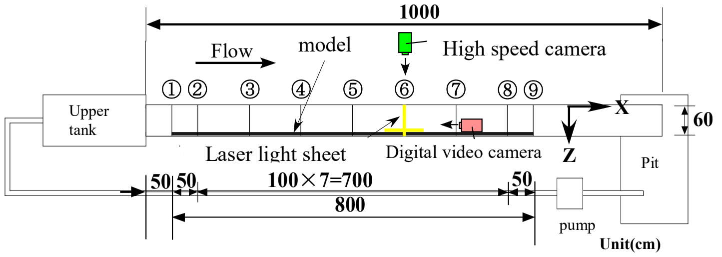


Figure 4. Plan view of the straight test channel

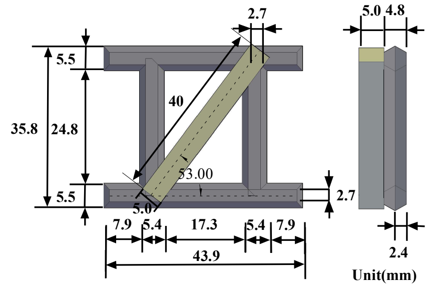


Figure 5. New Ganlock model scale

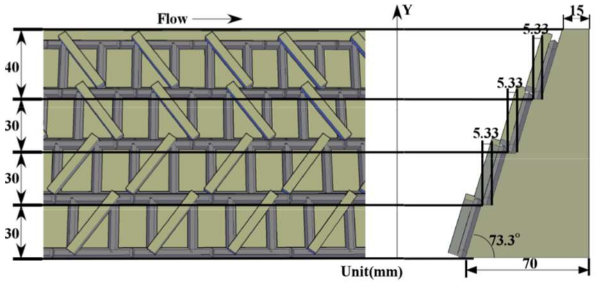


Figure 6. New Ganlock model layout overview

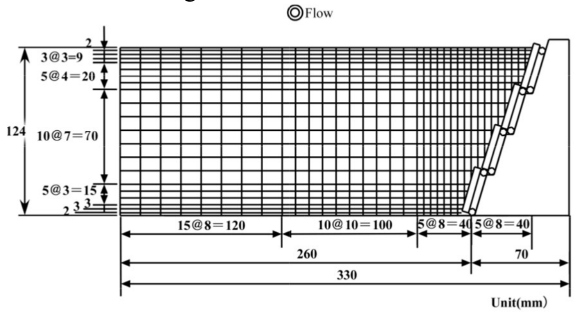


Figure 7. New Ganlock velocity measurement slit position

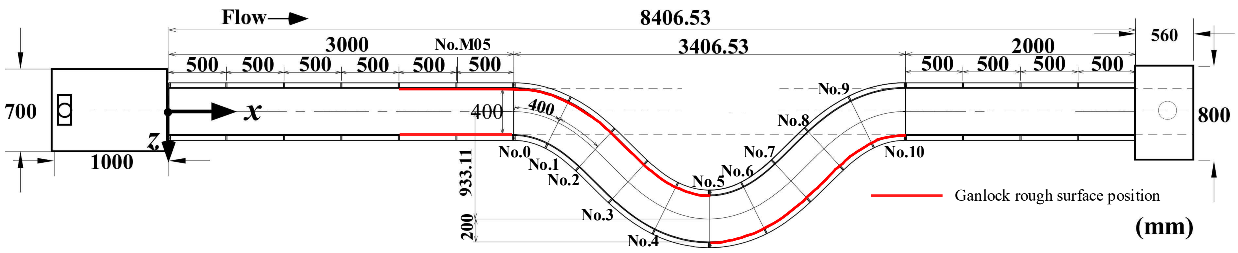


Figure 8. Plan view of curved test channel

Table 1. Experimental conditions

Case	$Q(cm^3/s)$	Hm(cm)	Um(cm/s)	$\nu(cm^2/s)$	Re(Umh/ν)	Fr(Um/√(gH))	Content
NGL1	8228	12.40	12.16	0.008654	17420	0.1102	Velocity measurement using new Ganlock
OGL1	6647	11.00	11.97	0.008970	14679	0.1150	Velocity measurement using old Ganlock
NGL2	3967	12.40	5.861	0.008856	8207	0.0531	Flow visualization with new Ganlock
OGL2	3141	11.00	5.65	0.009296	6686	0.0540	Flow visualization with old Ganlock
CVSM	12625	13.5	23.38	0.012	26303	0.43	Velocity measurement using smooth channel in curved channel
CVGL	12625	13.5	23.38	0.012	26303	0.43	Velocity measurement using new Ganlock in curved channel

It has been proved in a curved channel experiment that it can reduce the main flow velocity. (Watanabe, et al.,2017)

Based on the above, the purpose of this study is to improve the disaster prevention function by adding the performance of reducing the primary flow velocity, taking into account the application of the Ganlock bank protection to the curved part of the channel. For this purpose, the Ganlock was improved (hereinafter referred to as the new Ganlock), and the difference between its hydraulic characteristics and the conventional Ganlock (hereinafter referred to as the old Ganlock) was examined in a straight waterway. In addition, we applied Ganlock bank protection to curved channel flow and examined its effect.

2. EXPERIMENTAL EQUIPMENT AND METHOD

In this experiment, we used a smooth acrylic channel with a total length of 10 m, a width of 60 cm, and a height of 15 cm made of an acrylic resin plate with the water channel gradient adjusted to 1/1000 as shown in Figure 4 Using this canal, we measured the water surface profile, measured the flow velocity, and visualized the internal flow condition.

The new Ganlock model was made at a scale of 1/33 with the addition of diagonal materials as shown in Figure 5. As shown in Figure 6, the new Ganlock model has the diagonal members facing upwards between the half height of the bank protection and the bottom wall, and the diagonal members facing downward to the top of the bank protection. As a result, the low-speed fluid near the bank protection, such as zigzag roughness, is concentrated in the central part of the bank protection, and a large-scale longitudinal vortex structure is generated. The model was installed on the right bank when measuring the flow velocity, and on both banks of the narrow channel when measuring the water surface shape, over a distance of 8 m from the position 50 cm upstream of the channel.

PTV (Particle Tracking Velocimetry) was adopted for flow velocity measurement. Rilsan particles with an average particle size of 100 μm and a specific gravity of 1.04 were used as the tracer, and a laser slit optical film (PIV Laser G100, Kato Koken) was used for illumination. Figure 7 shows the irradiation position of the laser slit light film when the new Ganlock was installed. The number of sections was 32 in the vertical direction and 20 in the horizontal direction. Particle flow images at each section were taken at 100 frames / second using a high-speed camera (DITECT HAS-LH1). To obtain the flow velocity vector from the particle flow image, the image was sent to a computer for 60 seconds (6000 images). The data was analyzed using FlowPTV (Library Co., Ltd.), and statistical analysis was performed to determine the average flow velocity distribution. In the water surface profile measurement, new Ganlock models were installed on both sides of the channel with a channel width of 30 cm, and the water depth was measured at each of the cross sections (1) to (4) shown in Figure-4. A digital point gauge was used for measurement.

On the other hand, the experiment shown in Figure 8 was used for the curved channel. This channel has straight lines of 3m and 2m respectively in the upper and lower stream, and the curved part is 4m, made of vinyl chloride resin with a total length of 9m. The channel width (B) is 40cm and the height is 25cm. The sine-generated curve as shown in equation (1) was adopted for the channel alignment of the curved part. In this channel, the straight length (L) was 4 m and the maximum deflection angle (α_0) was 40 °. The channel slope was horizontal. The terms in this equation are α: declination, α_0: maximum declination, s: channel center distance, and L: wavelength. A new Ganlock model was installed in this channel as shown in Figure 7.

$$\alpha = \alpha_0 \sin(2\pi s / L) \qquad (1)$$

Two-component electromagnetic current meter (KENEKK ENVMT2-200-04) was used to measure the flow velocity in a curved channel.

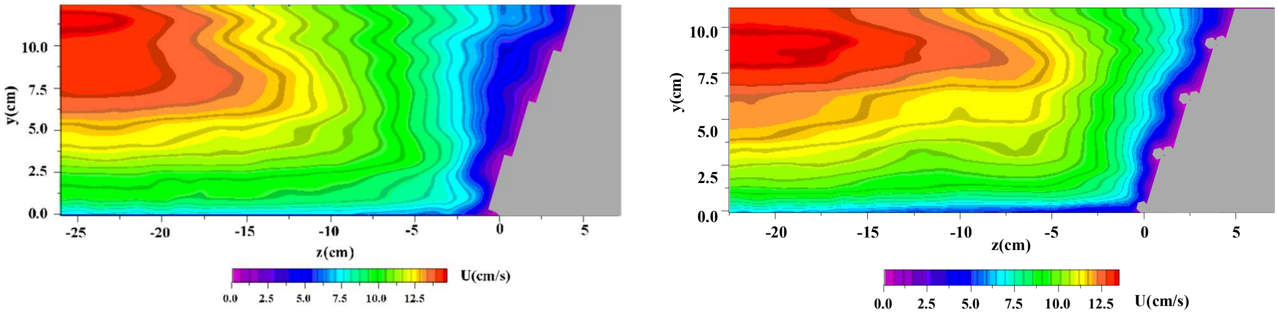
Fluorescent dye injection was used to visualize the internal flow conditions. In this method, about 200 cc of a fluorescent dye aqueous solution (specific gravity: 1.005) was gently injected from the upstream of the visualization section, and the cross section of the flow was irradiated with the laser slit light film mentioned above. The flow state of the fluid motion visualized by the tracer was photographed with a digital video camera (Sony DCR-VX2000) through a mirror (5 cm×5 cm) placed about 1.5 m downstream from the visualized cross-sectional position.
The experimental conditions are as shown in Table 1 NG is the experimental condition of new Ganlock, and OG is the experimental condition of flow velocity measurement and flow visualization of the old Ganlock. CV is an experimental condition in a curved channel. In the table, Q is the flow rate, H_m is the average water depth, ν is the kinematic viscosity coefficient, U_m is the mean sectional velocity, Re (= $U_m H_m$ / ν) is the Reynolds number, and Fr (=$U_m / \sqrt{(gH_m)}$) is the Froude number represents.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Flow velocity distribution characteristics

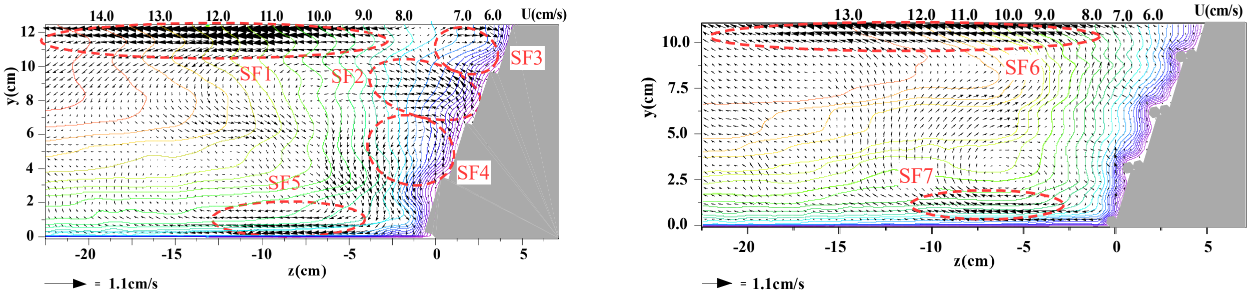
Figure 9 shows the contour distribution of the primary flow velocity when the new Ganlock model is installed (hereinafter referred to as the new Ganlock rough surface flow) and when the old Ganlock model is installed (hereinafter the old Ganlock rough surface flow). It is noted that a remarkable low-velocity region is formed around the bank protection model in the new Ganlock rough surface flow. In addition, a relatively high-speed region is formed up to around z = 10 cm, but in the old Ganlock rough surface flow, a high-speed region is distributed at the same position, and the new Ganlock rough surface flow tends to be slow near the bank protection.

Figure 10 shows the contours of the secondary flow distribution and the main flow velocity in the new Ganlock rough surface flow and the old Ganlock flow, respectively. In Figure 10 (a), the formation of a lateral flow in the opposite bank direction is strongly observed in SF1, which is also formed in the old Ganlock SF6, but the new Ganlock is stronger. In the vicinity of the bank protection of the New Ganlock, a rising flow in the opposite wall direction such as SF2 and swirling flows SF3 and SF4 forming a pair on both sides are formed. It is presumed that a large-scale longitudinal vortex structure is formed concentrated in the part. Similar to the old Ganlock SF7, the SF5 has a cross flow near the wall in the opposite wall direction. This is considered to contribute to scouring and sediment movement of the riverbed when applied to actual rivers, and its effect



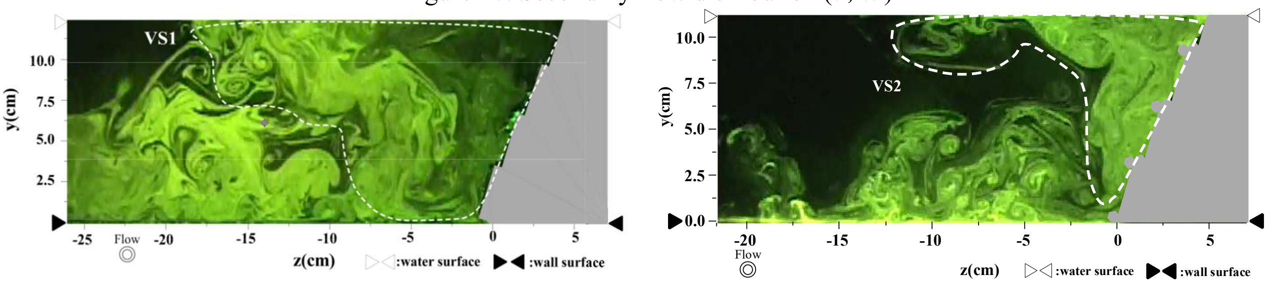
(a) New Ganlock rough surface flow (Case NGL1) (b) Old Ganlock rough surface flow (Case OGL1)

Fig. 9 Contour of primary flow velocity (U)



(a) New Gunlock rough surface flow (Case NGL1) (b) Old 4 Gunlock rough surface flow (Case OGL1)

Figure 10. Secondary flow distribution (V, W)



(a) New Ganlock rough surface flow (Case NGL2) (b) Old Ganlock rough surface flow (Case OGL2)

Figure 11. Example of internal flow condition visualization results

to be verified by moving bed experiments.

3.2 Characteristics of internal flow

Figure 11 shows an example of a cross-sectional view of the new Ganlock rough surface flow and the old Ganlock rough surface flow. In both flow fields, it was observed that a longitudinal vortex structure was formed near the bank protection. The new Ganlock rough surface flow is formed around the bank protection like VS1 in the figure and has a large scale. The formation region of such a large logitudinal vortex structure is relatively slow and has been shown to play a major role in generating instantaneous secondary flows and turbulence (Watanabe et al.,2006). In view of this, the spatio-temporal concentration of this large-scale longitudinal vortex structure plays a major role in the formation of a large-scale secondary flow of the new Ganlock rough surface flow and the formation of a remarkable low-velocity region near the bank protection. It is assumed that A vertical vortex structure like VS2 was formed in the old Ganlock rough surface flow, but its scale was observed to be relatively smaller than that of the new Ganlock rough surface flow.

3.3 Application of Ganlock rough surface to curved flow

In order to determine the effect of the Ganlock on the curved flow, the flow fields of the smooth surface and the rough surface of the Ganlock were compared. Figures 12 and 13 show the contour of the primary flow velocity (hereafter referred to as the U component) and the transverse velocity (hereinafter called the W component) in a smooth surface flow.

For the U component, the high-speed region spreads in the center of the channel at the straight line (No. M05, No. 0) and No. 1 at the inlet of the bend, the high-speed region moves to the right bank wall. In No.2, the high-speed area began to shift to the center of the channel, and in No.3, No.4, No.5, and No.6, the high-speed area was a water-shock formed very near the left bank side wall. In particular, No.4 and No.5 maximum velocities or values close to them are generated, and in actual rivers, scouring of riverbeds and side walls is feared. In No.7, the high-speed area was far from the left bank, and in No.8, No.9, and No.10, the high-speed area approached near the right bank side wall, and the water colliding section was formed again. In the curved part of the channel, the maximum velocity point is formed near the low wall as the water flows down.

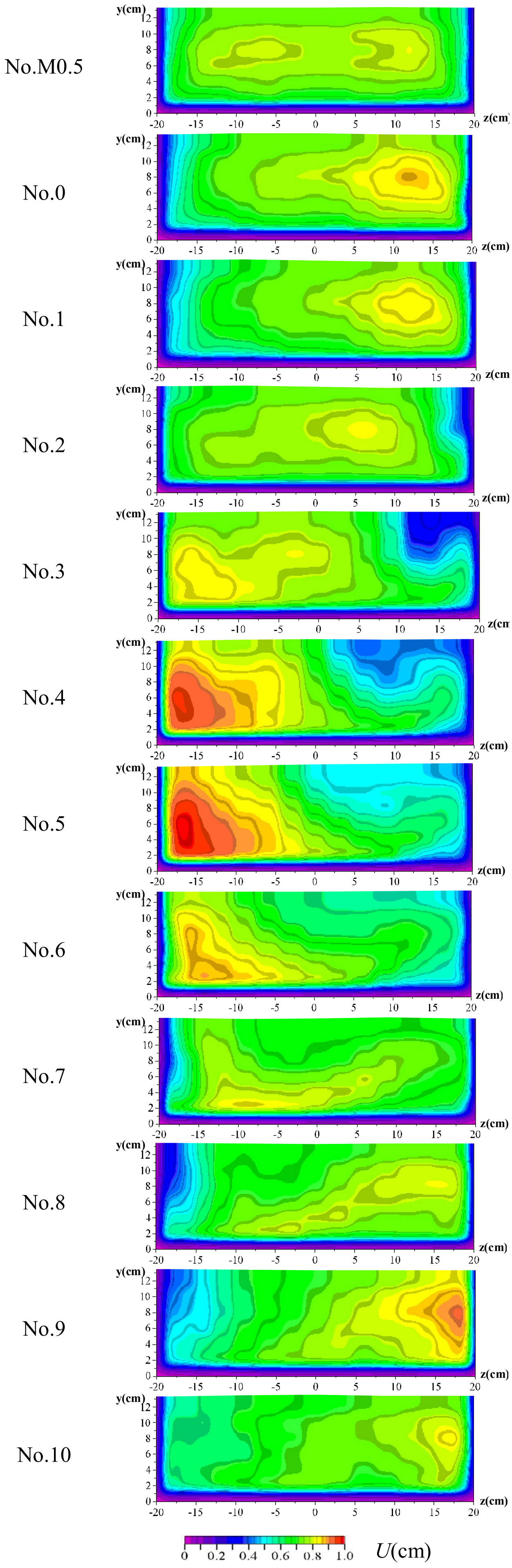


Fig. 12 Contour of primary velocity (U) in smooth channel (Case CVSM)

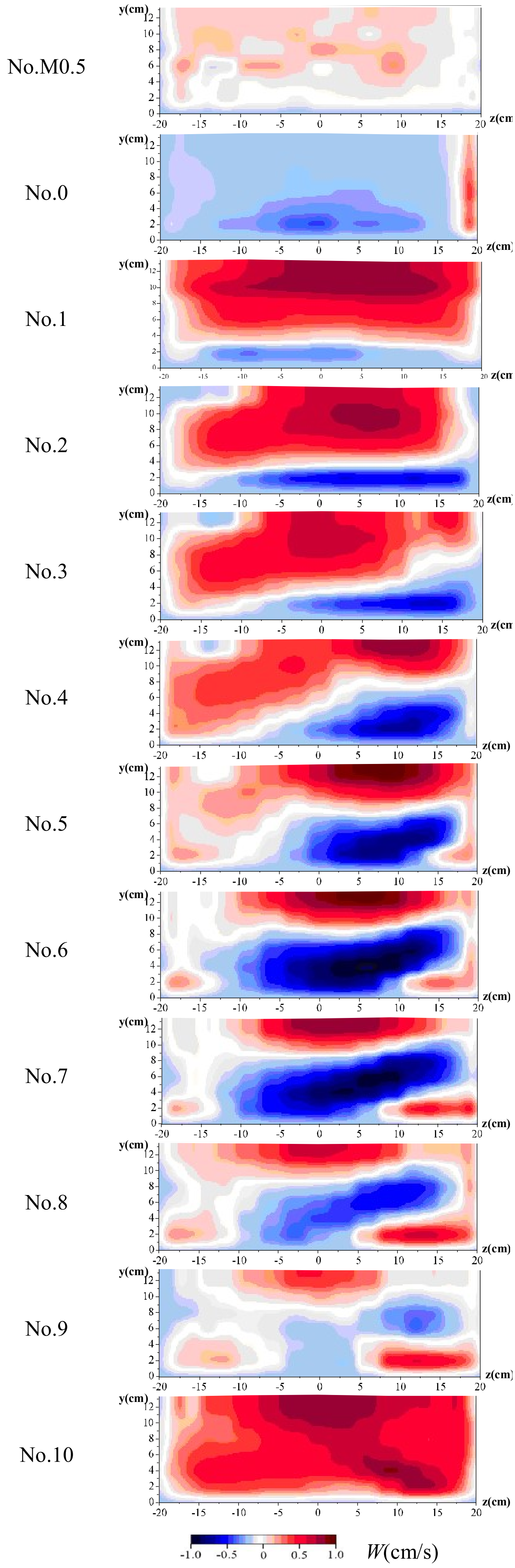


Fig. 13 Contour of transverse velocity (W) in smooth channel (Case CVSM)

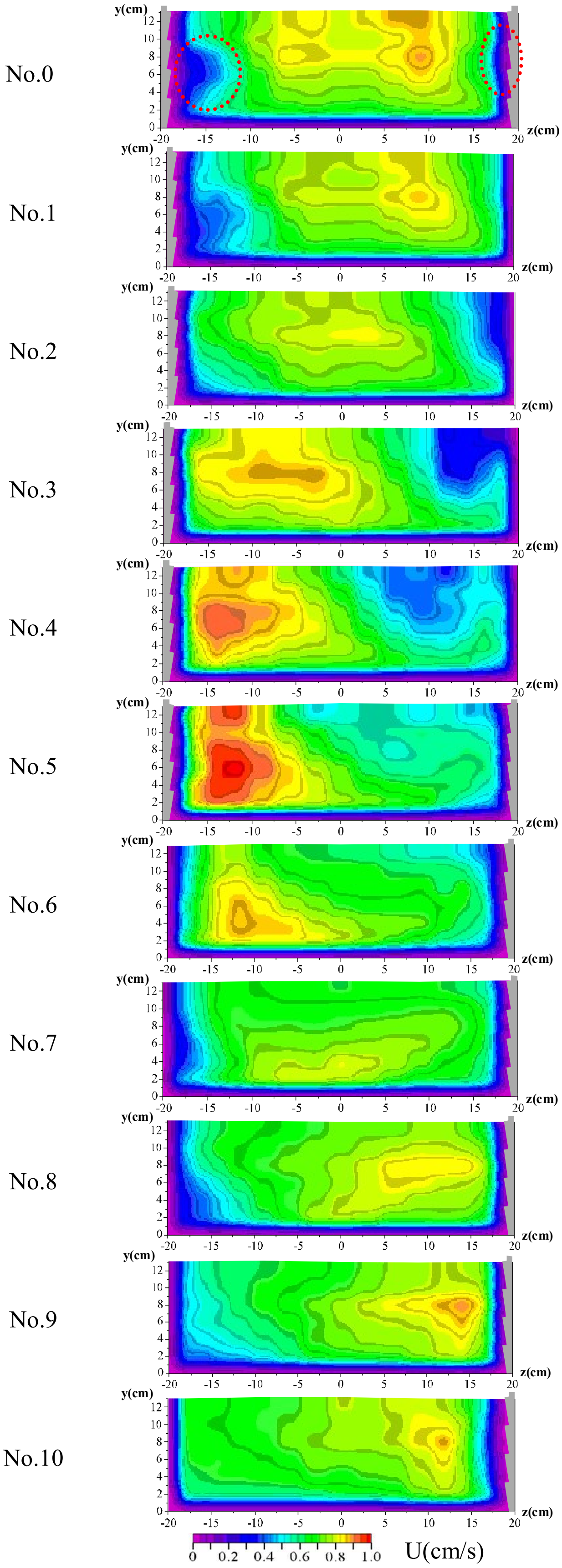


Figure 14. Contour of primary velocity (U) in new Gunlock water channel (Case CVGL)

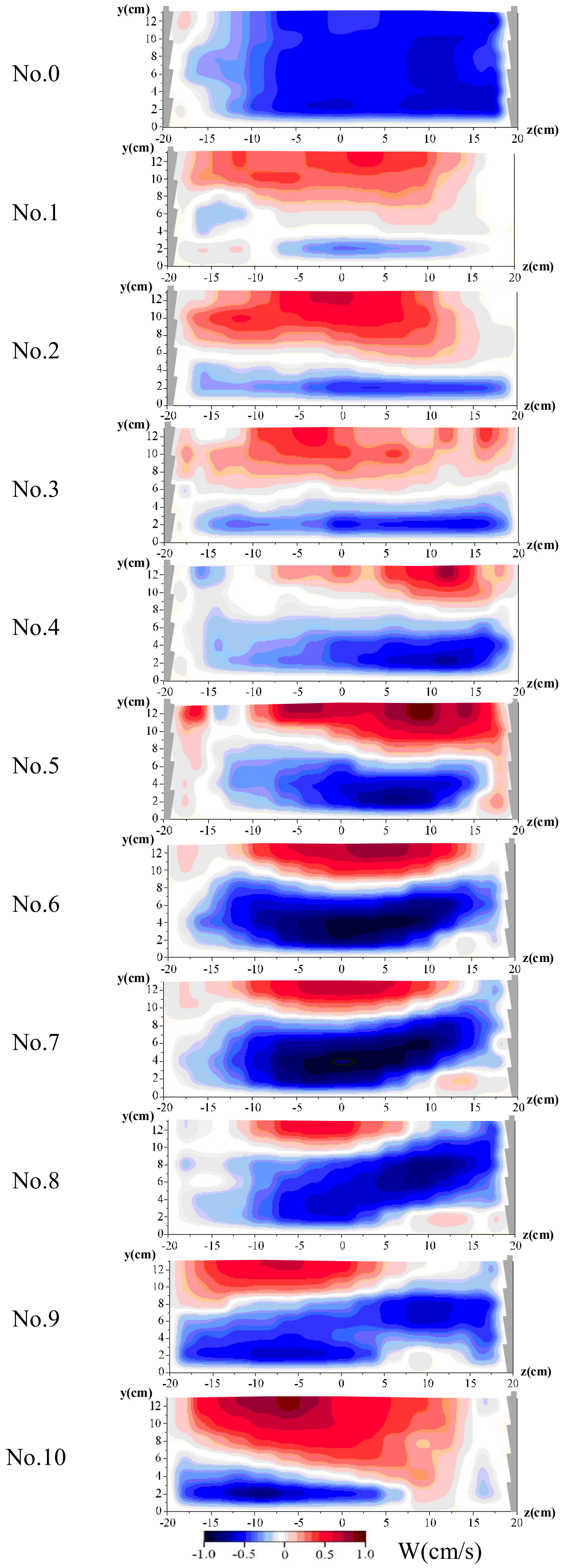


Figure 15. Contour of transverse flow velocity (W) in new Gunlock water channel(Case CVGL)

In the W component, a positive value indicates a flow toward the left bank, and a negative value indicates a flow toward the right bank. In the straight section (No.M0.5), a flow toward the left bank is generated slightly over the entire cross section. At No. 0 at the inflow of the bend, the flow changes to the right bank, and the right bank flow becomes dominant with the bending. In No.1, a right bank flow is formed on the water surface side, and a left bank flow is formed on the bottom wall side. This is due to the centrifugal instability caused by the channel curvature, which indicates that a large swirling secondary flow in the counter-hour hand direction

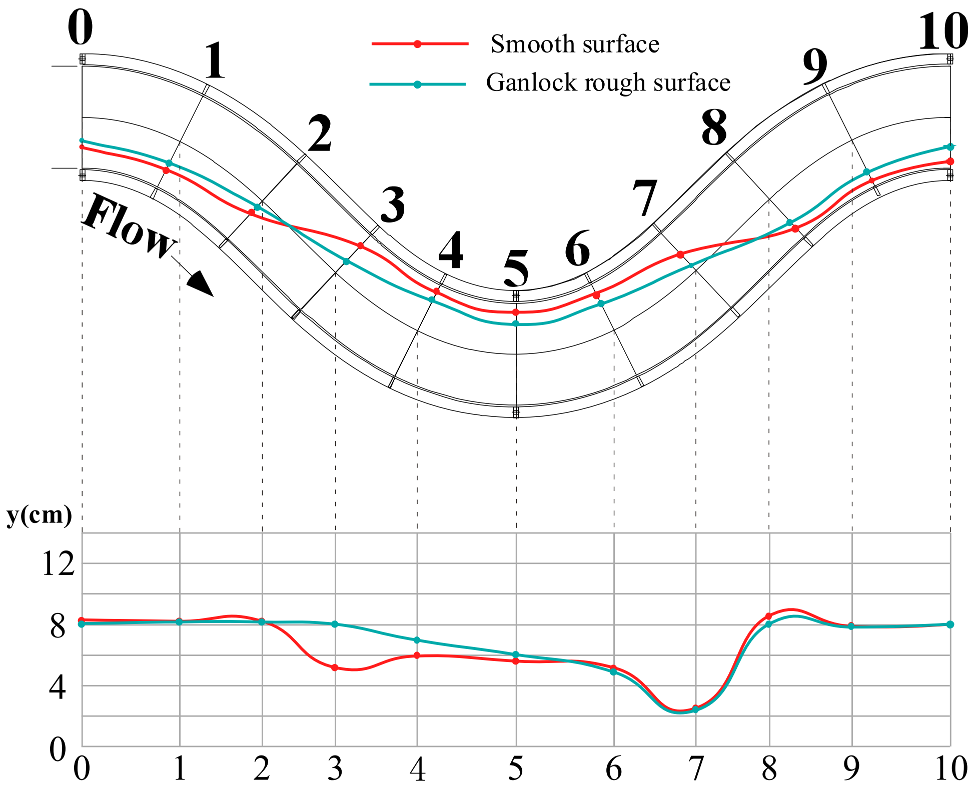


Figure 16. Horizontal position and vertical position of maximum flow velocity

is generated throughout the channel. From No.2 to No.5, the flow toward the right bank from the right bank bottom wall gradually began to spread over a wide area. In No. 10, the flow toward the left bank is dominant.

Figures 14 and 15 show the contour of *U* and *W* components in the new Ganlock flow. In new Ganlock flow, in No. 0, the high-speed region is formed almost at the center of the channel. On both sides, a bulge is formed in the low-speed region opposite the shore, as indicated by the red dashed line. This is because the large-scale vertical vortex structure shown in Figure 14 was formed due to the roughness of the new Ganlock bank protection installed on both sides of the straight section, and the low-speed fluid was transported in the opposite shore direction. Conceivable. From No.1 to No.3, the high-speed area moves to the left bank, and in No.4 and No.5, the high-speed area approaches the side wall. However, the position is about 7 cm away from the side wall, and it is considered that the safety of the side wall for scouring is higher than the position of the high-speed flow near the side wall pole in the smooth flow. Near the side wall, a low-speed layer wider than the smooth flow is formed. From No. 6 to No. 10, the high-speed area moves from the left bank to the right bank. Regarding the formation position of the high-speed region in No. 9 and No. 10, it is located far from the side wall and safety is recognized. As for the *W* component, in No. 0, the flow toward the right bank becomes dominant with the curvature, similar to the flow on the smooth side wall. From No.1 to No.5, a left bank flow is generated on the water surface side and a right bank flow is generated on the bottom wall side. From No. 6 to No. 9, the flow distribution is almost the same as the smooth flow. However, near the side wall of No.4 and No.5, the W component to the left bank disappeared compared with the same cross section of the smooth flow. It is considered that this was offset by the strong rightward bank flow generated by the longitudinal vortex structure created by the new Ganlock.

Figure 16 shows the path of the position of the maximum velocity point at each cross section in the smooth surface flow and Ganlock rough surface flow. It is clear that the Ganlock flow passes through the center of the channel more in the plane path at the maximum velocity point. In the vertical plane, the two cases are almost the same. As for the W component, in No. 0, the flow toward the right bank becomes dominant with the curvature,

4. CONCLUSIONS

The main conclusions obtained in this study are as follows.

(1) From the flow velocity measurement using the PTV method, it was clarified that the flow near the side wall of the new Ganlock rough surface flow became slower than that of the old Ganlock, and the high-speed region was moved away from the side wall. It was also shown that stronger cross currents were formed on the surface of the water.

(2) Visualization experiments using the fluorescent dye injection method show that a large-scale longitudinal vortex structure is formed in the rough surface of the new Ganlock near the water surface and the bottom wall of the bank protection compared with the flow of the old Ganlock. It became clear that. It was speculated that this large longitudinal vortex structure formed a horizontal flow and a secondary flow, and contributed to the reduction of the main flow velocity.

(3) As a result of applying the new Ganlock rough surface to the curved flow, it became clear that the speed near the side wall became slower and the high speed region moved more to the center of the channel than the smooth surface flow. From this, the effect of curving flow control of Ganlock bank protection was confirmed.

(4) Manning's roughness coefficient was calculated using the water surface profile measurement in a channel with the new Gunlock model installed and the standard sequential calculation method, and 0.041 was obtained. This was about 20% larger than that of the old Gunlock.

(5) The critical velocity for drag and lift was obtained from the dynamic model for the new gunlock, and the stability against flood flow was verified.

The conclusions (4) and (5) are the results verified in this study, but their contents have been omitted due to the number of papers.

ACKNOWLEDGMENTS

In the course of this research, we received a subsidy from the Technical Development Support Project of the Chugoku Kensetsu Kousaikai in 2018. Thank you for writing here.

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