Experimental Study about Open Channel Flow with Groins

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1. Introduction

Evaluation of influence to river or river bed by hydraulic structure, such as spar dike, is an important issue in river planning. And recently "*nature-oriented river works*" has been conducted. It is a work of making meandering river to create the rapids and pools for the waterside various living thing. For this reason, there are a lot of studies conducted about groins. All of these studies were the topics with single groin[1)] or groins positioned in one side of the river or groins positioned symmetrically in both sides[2)]. There are no studies about groins that were positioned in stagger in the river. It is a very important pattern to make meandering river and form rapids and pools.

The purpose of this study is to know characteristics of open channel flow with groins positioned in stagger in rigid-boundary channel by measuring two-dimensional flow velocity.

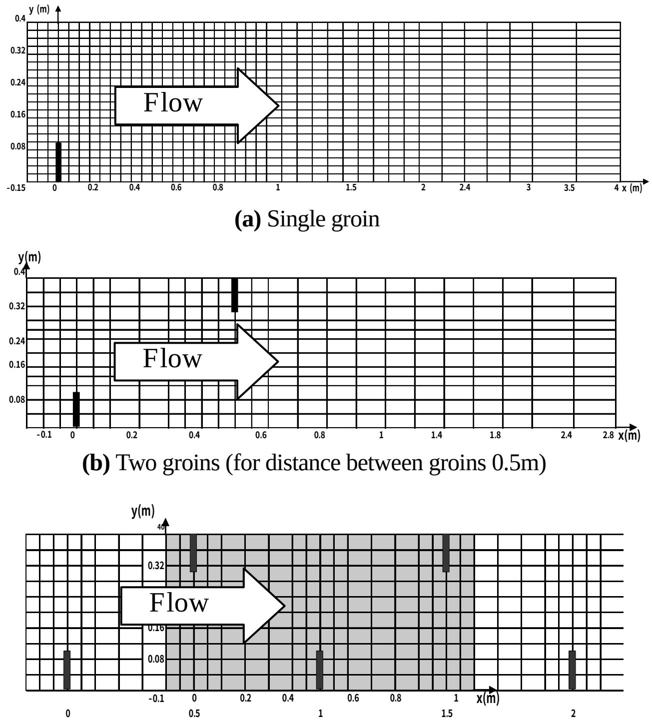
2. Outline of experiments

Although there are many parameters to make meandering flow, the number of groin and distance between groins were only focused in this study. The experimental conditions are shown in **Table1**.There were three patterns about the number of groin (single groin, two groins, and five groins) and there were three cases about distance between groins (d) (0.5m, 1m, and 2m).

Experiments were conducted in the Hydraulic Laboratory of Department of Civil Engineering, Tokyo Institute of Technology. The experimental open channel length and width are 14m and 0.4m, respectively. Model of groins were made of acrylic plate with a size of 0.1m×0.45m×0.005m (length × height × thickness), and positioned in open channel as shown in **Fig.1**. The measurement points were lattice points in **Fig.1**, and the gray part was only measured for five groins case (see **Fig.1 (c)**). Flow conditions without groins are: bed slope, $\boldsymbol{I}$ = 0.001, averaged depth of flow, $\boldsymbol{H}$ = 0.052m, depth-averaged flow velocity, $\boldsymbol{U}$ = 0.175m/s, friction velocity, $\boldsymbol{u_*}$ = 0.0231m/s, Reynolds number, $\boldsymbol{Re}$ = 9100, Froude number, $\boldsymbol{Fr}$ = 0.25. The measurements for two components in a horizontal plane of flow velocity were carried out by using an electromagnetic velocimeter (KENEK JAPAN CO, LTD). Time series with 1024 data were sampled with 0.01 sec. interval for all variables.

Table1 Experimental conditions

	Case1	Case2			Case3	
Number of Groin	1	2			5	
Distance d [m]		0.5	1	2	0.5	1



(a) Single groin

(b) Two groins (for distance between groins 0.5m)

(c) Five groins (for distance between groins 0.5m)

Fig.1 Installation situations of groins

3. Results and discussion

In order to grasp the whole characteristics of open channel flow with groins, flow field was measured. A focused horizontal plane was 0.021m from the bottom (about 40% of flow depth).

Flow velocity vector of Case1 is shown in **Fig.2**. It is well known that the flow field was subdivided into four main zones[3)]: main flow zone, shear layer, back flow zone, and reattachment zone. The former three zones and the averaged reattachment point can be seen clearly in **Fig.2**. The position of time-averaged reattachment point is about x=1.4m, the distance from groin to the reattachment point is 14 times of the length of groin. The flow was almost not influenced by the groin from x=4m downstream. The length is 40 times of the length of

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groin.

Flow velocity along side wall in Case1 is shown in **Fig.3**. Flow velocity for y=0.04m is about zero at x=1.4m, this point is the averaged reattachment point in **Fig.2**. The maximum flow velocity is 0.3m/s, and the position of the maximum flow velocity for y=0.36m is about x=0.8m. The length is 8 times of the length of groin. The minimum flow velocity is 0.1m/s, and the position of the maximum flow velocity for y=0.04m is about x=0.65m. The length is 6.5 times of the length of groin.

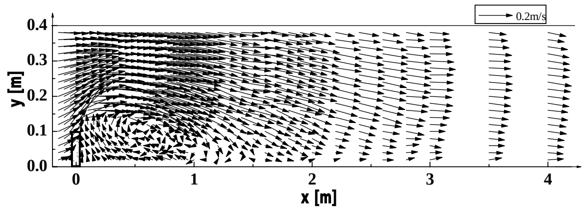

Fig.2 Flow velocity vector of Case1

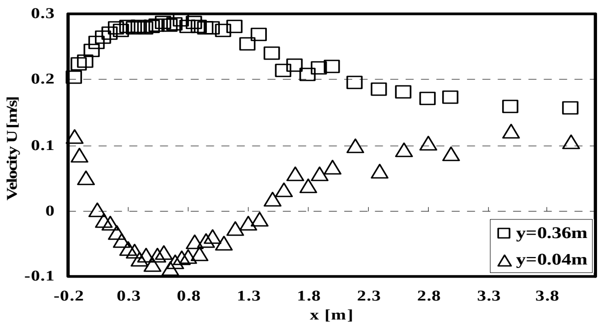

Fig.3 Flow velocity of Case1 along side wall

Table2 Averaged angle between flow and x direction of Case2

Distance d[m]	$\bar{U}$ [m/s]	$\bar{V}$ [m/s]	θ [degree]
0.5	0.237	0.153	32.8
1	0.249	0.125	26.6
2	0.253	0.1	21.5

Table3 Averaged angle between flow and x direction of Case3

Distance d[m]	x[m]	$\bar{U}$ [m/s]	$\bar{V}$ [m/s]	θ [degree]
0.5	0	0.213	0.129	31.2
	1	0.226	0.181	38.7
1	0	0.23	0.115	26.5
	2	0.225	0.137	31.4

Table4 Relationship between d and L

d[m]	L_1[m]	L_2[m]	L_3[m]	L_4[m]
0.5	0.2	0.2	0.4	0.45
1	0.4	0.4	0.8	0.85
L/d	2/5	2/5	4/5	≈4/5

Table2 shows the averaged angle in Case2 at the cross section of the 2nd groin. $\bar{U}$ is defined as the averaged velocity of x direction at the cross section of the 2nd groin, and $\bar{V}$ is defined as the averaged velocity of y. θ is defined as the averaged angle between flow and x direction. When d increased, $\bar{U}$ increased, $\bar{V}$ decreased, and the angle decreased.

Table3 shows averaged angle of Case3 at the cross section of the 1st and 3rd groin. When groins were positioned in stagger in open channel flow, although d was different, $\bar{U}$ was almost the same, $\bar{V}$ and θ changed. θ decreased as d increased.

Table4 shows relationship of d and L_i. L_i are the distance between the groin and the position of the maximum flow velocity along side wall of channel or the distance between the groin and reattachment points in Case3. L_1 or L_2 is the distance from the 1st or 2nd groin to the position of the maximum flow velocity between the 1st and the 2nd groin or between the 2nd and the 3rd groin. L_3 or L_4 is the distance between the 1st or 2nd groin and reattachment point in downstream. In **Table4**, the maximum flow velocity appeared at two-fifths length of d. The reattachment point appeared at about four-fifths length of d.

4. Conclusions

In this study, open channel with groins positioned in stagger was used. The experiments were focused on the number of groin and distance between groins.

The conclusions of this study are as follows:

1) For Case 1, time-averaged reattachment point was at about 14 times of the length of groin in downstream. The position of the maximum flow velocity along side wall was behind 8 times of the length of groin. The position of the minimum flow velocity along side wall was behind about 6.5 times of the length of groin.
2) For Case 2, When d increased, $\bar{U}$ increased, $\bar{V}$ decreased, and the angle decreased. So distance between groins is the parameter to make a meandering shape.
3) For Case 3, near walls of channel, the maximum flow velocity appeared at two-fifths length of distance between groins. The reattachment point was about four-fifths length of distance between groins behind.

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