A INVESTIGATION OF THE DRAG COEFFICIENT IN A OPEN CHANNEL WITH GROUP OF COLUMNS

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ABSTRACT

The C_D of the single column and group of columns has been calculated to be approximately 1.0 using uniform flow velocity. It has been pointed out that the C_D of the group of columns is not constant due to the fact that the reproducibility drops when calculating the C_D of the group of columns constantly and due to the irregular flow past the group of columns. Therefore, it is necessary to make clear the C_D of individual columns constituting of group of columns or the entire group of columns, to reproduce the flow in the group of columns. In this study, numerical analyses and experiments were carried out to reproduce the flow in the group of columns and verify the C_D. As the results, when the C_D is 1.0, the experimental result could not be reproduced. Therefore, it was calculated using the C_D of the entire group of columns. However, result could not reproduce experimental results. By using C_D of the entire group of columns, reproduction rate improved by about 20 (%). In conclusion, since there was a place where the flow velocity remarkably decreased within the group of columns, the C_D was not constant. In addition, the ultimate purpose of this study is to reproduce a flow around the group of columns exactly and to carry out the fish habitat assessment in greater detail.

1 INTRODUCTION

The river law of Japan was revised in 1997. As a result, **water control**, **water utilization** and **river environment** are considered.

water control 1896 — water utilization 1964 — river environment 1997

For river environment, it is very important to protect and preserve for eco.

Additionally,

implementing the nature-rich river management was required for all rivers in Japan.

Year	Policies for river in Japan
1896	Water control (River law of Japan)
1964	Water utilization (River law of Japan)
1990	The nature-rich river management
1991	Model projects for the promotion of river works to fish migration facilitate
1997	River environment (River law of Japan)
2005	Guidance for the promotion of river works to fish migration facilitate
2006	The nature-rich river management for all rivers

In this study,

the attention is focused on freshwater fish habitat evaluation and fell of trees in rivers.

(main -> fish habitat evaluation)

Especially, Fish behavior mainly depends on

1) hydraulic quantity; flow velocity and water depth etc.,

2) presence or absence of river structures,

3) configuration and material of riverbed and bank,

4) water quality,

5) climate condition,

6) others.

Moreover,

1) flow velocity and water depth vary depending on the 2) presence or absence of river structures.

For example, it is known groin and trees have the **hydraulic function** to decrease flow velocity.

[Groin as examples]

Crib spur — Pile dikes — Krippen groin

And all that Subject for this study

[Trees as examples]

[*Purpose*]

Eventually, this study aimed at using the suitable C_D for numerical analyses.

At first, the part of this study is examined the C_D of group of column.

To complete them, the experiments in small open channel were done.

To examine the forecasting calculation of river stream are implemented.

for fish habitat evaluation

for management of trees

Drag coefficient (C_D) of pile dikes and trees are using approximately 1.0 in the anamnestic research. Column is using in the similitude of those.

C_D of group of column equals C_D of single column that is approximately 1.0.

Value of its C_D is the result of a single column in the **same flow velocity**.

However, the **flow velocity distribution is formed in actual river stream**.

C_D is guessed to be different depending on the positions, arrangements, density and all that of pile dikes and trees.

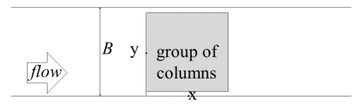
There is a possibility that the value of C_D is different in a single column and a group of column.

When C_D is calculated, it is important to use appropriate the characteristics flow velocity (U) and the water depth (h).

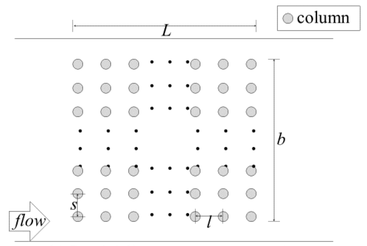
$$F_{Dx} = \frac{1}{2}\rho \cdot C_D \cdot A \cdot U^2 = \frac{1}{2}\rho \cdot C_D \cdot d \cdot h \cdot U^2$$

2.1 EXPERIMENTAL METHOD

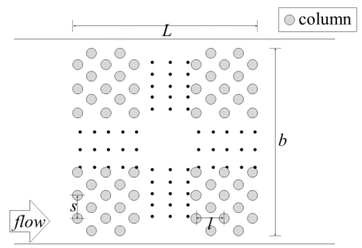
The experiments were carried out by using the small open channel in the laboratory, to measure the **flow, water depth and fluid force**.



a) Experimental channel



b) Run1 (alignment arrangement)



c) Run2 (zigzag arrangement)

Figure 1. Plain view of open channel for the experiments

[Columns for experiments]

- Stainless column whose diameter is 0.01 (m)
- Set up in the center part of the open channel
- Direction l(m) and s(m) are both 0.04(m)

Table 1. Cases considered in the experiments

Experimental case	Quantity of flow Q(l/s)	Number of Column T	Group of columns		
			Arrangement	L(cm)	b(cm)
Run1	16.0	361	alignment arrangement	73.0	73.0
Run2		721	zigzag arrangement	73.0	77.0

[Experiments]

- Group of column
  - alignment arrangement
  - zigzag arrangement
- 2 cases
- s/d = 4 and l/d = 4

<To measured the flow velocity and the water depth>

- Flow velocity
  - one-point method
  - -> Decided the characteristics flow velocity U

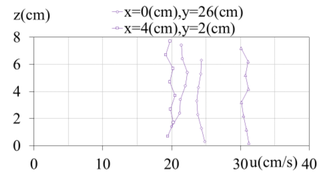


Figure 2. The water depth direction the flow velocity distribution in the group of columns inside.

<To measured the fluid force acting on the columns>

- The multi component load cell was used to measure the drag force acting on **each column**.

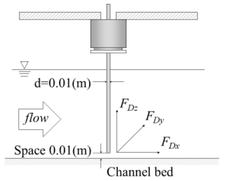


Figure 3. Set up the multi-component load cell for measuring the **drag force**

2.2 NUMERICAL ANALYSIS METHOD

Flow in an open channel with group of columns is computed using a two-dimensional shallow water equation and an equation of continuity. Dynamic equation in x and y direction, and equation of continuity is defined Eq. (1), (2) and (3).

<Dynamic equation in x direction>

$$\frac{\partial M}{\partial t} + \frac{\partial uM}{\partial x} + \frac{\partial vM}{\partial y} = -gh\frac{\partial H}{\partial x} - \frac{gn^2 u\sqrt{u^2+v^2}}{h^{\frac{1}{3}}} + \frac{\partial}{\partial x}\left(\varepsilon\frac{\partial M}{\partial x}\right) + \frac{\partial}{\partial y}\left(\varepsilon\frac{\partial M}{\partial y}\right) - \frac{g}{K^2}M\sqrt{u^2+v^2} \quad (1)$$

<Dynamic equation in y direction>

$$\frac{\partial N}{\partial t} + \frac{\partial uN}{\partial x} + \frac{\partial vN}{\partial y} = -gh\frac{\partial H}{\partial y} - \frac{gn^2 v\sqrt{u^2+v^2}}{h^{\frac{1}{3}}} + \frac{\partial}{\partial x}\left(\varepsilon\frac{\partial N}{\partial x}\right) + \frac{\partial}{\partial y}\left(\varepsilon\frac{\partial N}{\partial y}\right) - \frac{g}{K^2}N\sqrt{u^2+v^2} \quad (2)$$

<Equation of continuity>

$$\frac{\partial h}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} = 0 \quad (3)$$

Where, u is velocity in the x direction, v is velocity in the y direction, $M(=uh)$ is flux in the x direction, $N(=vh)$ is flux in the y direction, h is water depth, H is water level and ε is eddy viscosity.

K in eq. (1) and (2) is the coefficient of permeation and is represented as follows.

$$K = \frac{1}{\sqrt{\frac{C_D \cdot a_W}{2g}}} \quad (4)$$

where, a_W is the projected area by group of columns in mass of water with unit volume and is shown as follows.

$$a_W = \frac{T \cdot A}{L \cdot b \cdot h} \quad (5)$$

where, T is total number of columns, L is interval in x direction of group of columns and b is interval in y direction of group of columns.

Table 2. Cases considered in the numerical analyses.

Numerical analyses case	Number of column T	Group of columns			C_D	a_w
		Arrangement	L(cm)	b(cm)		
Run3-1	361	alignment arrangement	73.0	73.0	1.0	whole group of columns
Run3-2					each value	
Run3-3						single column
Run4-1	721	alignment arrangement	73.0	77.0	1.0	whole group of columns
Run4-2					each value	
Run4-3						single column

- Direction l(m) and s(m) are both 0.04(m)

3 RESULTS

3.1 Experiments

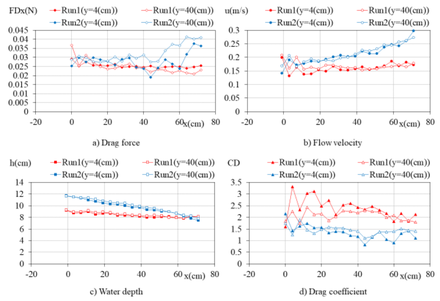


Figure 4. The results of experiments.

Figure 4 shows the flow velocity u, water depth h, and drag force F_{Dx} in Run1 and Run2. In addition, Figure 4 d) is drag coefficient C_D using the characteristics flow velocity U and the water depth. In Run1(aligned arrangement), the drag coefficient C_D of the second column was increasing. This is because the drag force F_{Dx} of the second column from the upstream has been reduced. Because l/d is 4, wake effects are possible.

Figure 5 shows the longitudinal change in the velocity u at the right bank of the channel (y=4(cm)) and at the center of the channel (y=40(cm)). In Run3-1, the flow velocity u tends to decrease downstream. The remarkable flow velocity reduction tendency, such as Run1, could not be reproduced. In Run4-1, the tendency of the flow velocity u to increase downstream could be reproduced. However, the recall was low especially at the center of the channel (y=40(cm)). In Run3-2, Run4-2 and Run3-3, Run4-3, the calculation was performed by applying the drag coefficient C_D of each column constituting the group of columns. Run3-2 and Run4-2 showed the same tendency as the calculation results (Run3-1 and Run4-1) that the drag coefficient C_D was fixed. In Run3-3, the flow velocity u became slower overall, but the tendency of the flow velocity u could be reproduced. In Run4-3, the flow velocity u also became slower overall, but the tendency of the flow velocity u could be reproduced. Therefore, the tendency of the drag coefficient C_D obtained in the experiment is considered to be appropriate. In addition, it is considered that the calculation result is affected by the column installation area A. This is because the result of the flow velocity u differs between Run3-2, Run4-2 and Run3-3, Run4-3. It was possible to reproduce the tendency of flow velocity u that the column installation area A was the area of one column. Therefore, it is considered appropriate to handle this installation area. In Run3-3 and Run4-3, the flow velocity u became slower overall. This is probably due to the drag coefficient C_D.

3.2 Numerical analyses

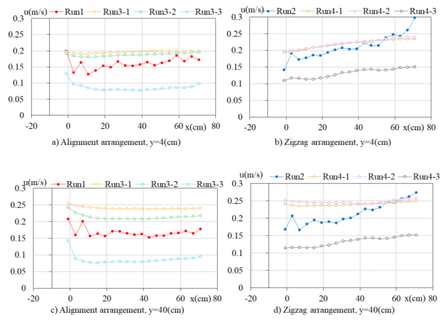


Figure 5. The results of numerical analyses.

CONCLUSION

In the experiment, drag coefficient C_D increased in Run1 (aligned sequence). This is because the second column (y=4(cm)) from the upstream of the group of columns was affected by the flow velocity reduction. In Run2 (zigzag arrangement), the flow velocity u tended to increase downstream. For these reasons, it was found that the drag coefficients C_D of the individual columns constituting the group of columns were different values.

As the results of calculation with the drag coefficient C_D as a constant value, the flow velocity u of Run3-1 decreased toward the downstream, and the remarkable reduction of the flow velocity observed in the experimental results could not be reproduced. In Run4-1, the increasing tendency of the flow velocity u could be reproduced, but the reproducibility was low in the upstream part of the group of columns.

The calculation was performed by applying the drag coefficient C_D of each column constituting the group of columns. As a result, it was found that the calculation results varied depending on the installation area A of the column.

In Run3-3 and Run4-3, the flow velocity u became slower overall, but the tendency of the flow velocity u could be reproduced. Therefore, the tendency of the drag coefficient C_D is considered appropriate.