STABILITY OF OLD STONE GROINS IN THE KATSURA RIVER DURING FLOODS

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Traditional techniques of river works have been reconsidered from the view point of design with nature by hydraulic engineers in Japan. While natural resources such as woods or stones are used for hydraulic structures, strength of those structures has not been fully investigated. In this paper, stability of old stone groins remained for over 400 years in the Katsura River of Kyoto is investigated to clarify the reason why the groins still function. Field survey and laboratory experiments were conducted to measure the structure and velocity distributions around the groins. From the results, it is found that the stiffness of groins is based on the structure and layout. They are composed of two groins made up of a big rock and stones. The layout of two separate groins function to reduce the flow velocity attacking to the groin where is made of stones. These observed features are the reasons why these groins have remained without changing their forms for long time.

Key Words : *Old stone groin, Two-steps deflection of flow, Stability of groins, Velocity distribution*

1. INTRODUCTION

The environmental design has become one of important factors in river works recently. Hydraulic engineers recognized that some traditional techniques are good skills to mitigate the impact on natural environment from the view point of design with nature. However, these techniques have not been fully investigated yet. Such traditional techniques have been investigated experimentally by not so many researchers except Ishigaki et al.[1), 2)] and Rahman et al. [3)].

A stone groin discussed in this paper is one of traditional techniques. Stone groins are still remaining in the Katsura River of Kyoto, Japan. The Katsura River is a tributary of the Yodo River on the west of Kyoto and the catchment area is 1152 km^2. In the midstream, this river run through a narrow valley called "Hozu Gorge" of which length is about 16 km. As this gorge was a difficulty of navigation, any boat could not pass there. To open a navigation route, Mr. Ryoi Suminokura directed the river works along the stream in 1606. Then, stone groins were set for keeping the water depth to pass a boat through riffles. This route was used for transportation of goods for many years. However, many people enjoy a go-down river boat nowadays. Many groins were washed out those stones by floods and have been reinforced by mortar or sheet-piles, but a pair of groins still work without any reinforcement. These groins were surveyed and it is investigated the reason why they have retained those nearly-original forms in this paper.

2. THE OLD STONE GROINS IN HOZU GORGE

There are pools and riffles on the studied site, and stone groins are set on riffles. The old stone groins are located on the riffle of Asahigase in the middle of Hozu Gorge as shown in Figure 1. Field surveys were done in 2005 and 2007, and the form, flow velocity around them and stone size were measured. The groins are composed of two groins and the two groins are shown in Photo 1. Each groin has a big rock at the

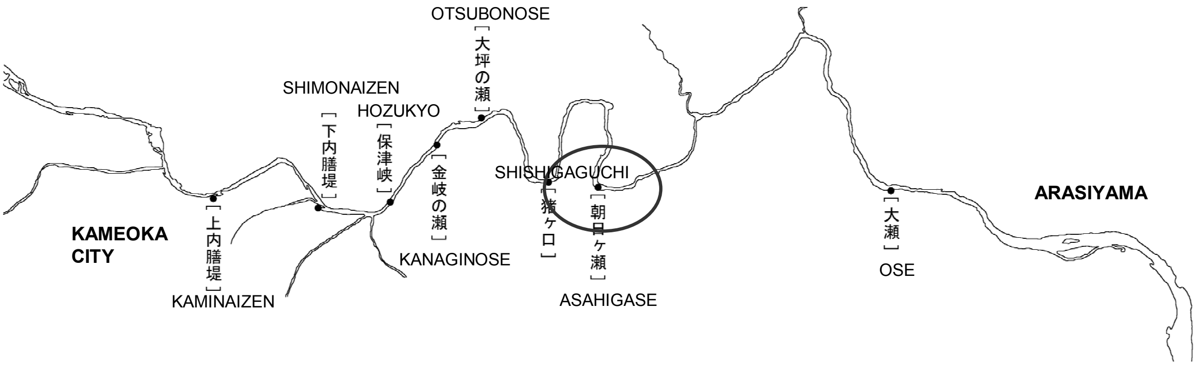


Figure 1 Map of Hozu Gorge in the Kastura River

The upstream groin

The downstream groin

Photo 1 The old stone groins located in Asahigase of Hozu Gorge

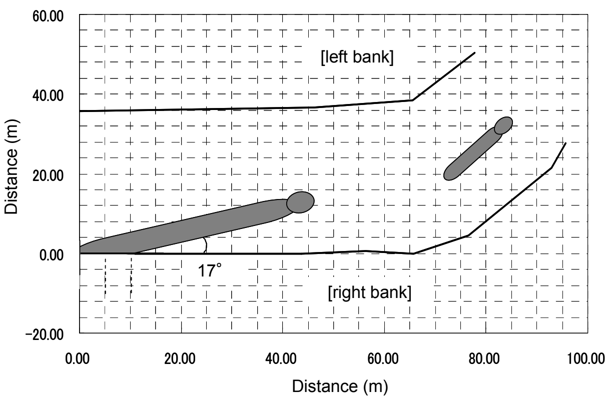


Figure 2 Layout of the old stone groins in Asahigase

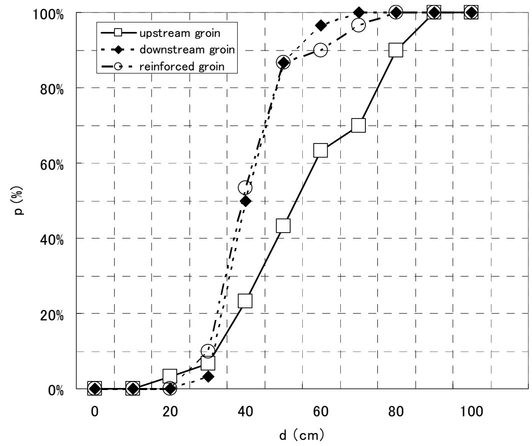


Figure 3 Cumulative distributions of stone diameter of three groins

downstream end and stone-made part on the upstream side. Figure 2 is the layout of two groins. The upstream groin is set on the right hand side of stream and the other one is set in the middle of

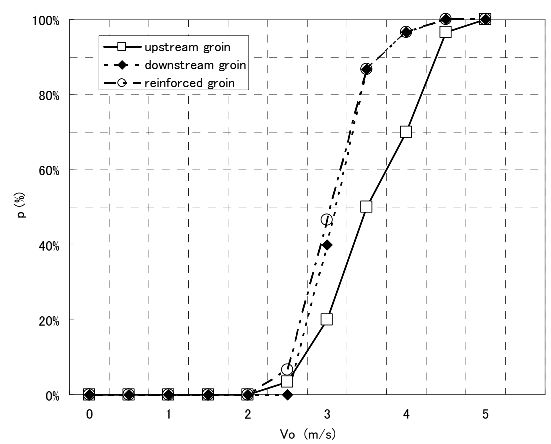


Figure 4 Cumulative distributions of critical velocity, Vo, in the loose bond condition

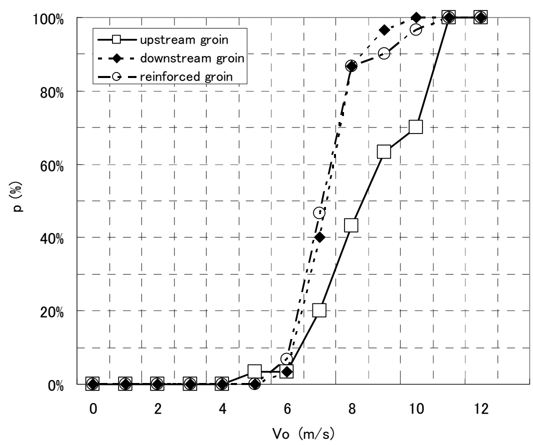


Figure 5 Cumulative distributions of critical velocity, Vo, in the tight bond condition

stream. Approaching flow is deflected by the first groins to the channel center and the second groin is laid to deflect the flow again. This pair of groins is called as a two-step groin in this paper on the basis of the doubly deflecting function of them.

The height of groins is nearly equal to normal water depth of around 1.0 m. As coefficient of river regime, which is the ratio of maximum to minimum discharge, is very large in Japanese rivers, the groins are destroyed by high speed flow during floods. To evaluate the stability of groins, major and minor axis lengths on the surface were measured in the field survey. Mean diameter of each stone was evaluated by using the mean value of major and minor axis lengths. Figure 3 is the cumulative distribution of mean diameter of 30 stones for three groins. Data of a reinforced groin located in Ose shown in Figure 1 are also shown in the figure. Stone sizes made up of upstream groin are larger than those of downstream one. And the sizes of downstream groin are as same as those of the reinforced groin. It seems that flow velocity around the downstream groin is lower than the velocity around the upstream one, because the both groins have retained their forms in the same place.

3. STABILITY OF THE GROINS

To investigate the stability of groins during floods, the hydraulic design criteria[4)] proposed by US Army Corp of Engineering is used here. They are used for checking the stability of blocks used for bank protection works. The criteria have two equations. One is used in the case of loose bond conditions, Equation (1), and the other is in tight bond conditions, Equation (2).

a) Loose bond conditions;

$$d_m = \frac{1}{E_1{}^2 \cdot 2g\left[\frac{\rho_s}{\rho_w} - 1\right]} V_0{}^2 \quad (1)$$

b) Tight bond conditions;

$$d_m \geq V_0{}^2 / [\{6.0 + 5.75\log_{10}(H_d / k_s)\}^2 \cdot \tau_{*sd} \cdot s \cdot g] \quad (2)$$

where, dm is the mean diameter, E_1 is the coefficient of turbulence intensity obtained by experiments (E_1=0.86 here), g is the gravity acceleration, and are the density of stone and water, Hd is the design depth, k_s is the equivalent height of roughness ($k_s=d_m$ here), is the Shields' critical tractive force considered the bank slope (=0.05 here), and s is the submerged specific gravity of stones.

By using these equations, the critical velocity, V_0, is calculated with the following Equations (3) and (4). H_d in Equation (4) is calculated by Manning equation with velocity value obtained by Equation (3).

a) Loose bond condition;

$$V_0 = \sqrt{d \cdot E_1^2 \cdot 2g\left[\frac{\rho_s}{\rho_w} - 1\right]} \quad (3)$$

b) Tight bond condition;

$$V_0 = \sqrt{d \cdot [\{6.0 + 5.75\log_{10}(H_d / k_s)\}^2 \cdot \tau_{*sd} \cdot s \cdot g]} \quad (4)$$

Figure 4 and Figure 5 show the cumulative distribution of velocity, V_0, for the two conditions. In the loose bond condition, V_0 for d_{50} is 3.1 to 3.6 m/s. And V_0 for d_{50} is 7.3 to 8.4 m/s in the tight bond

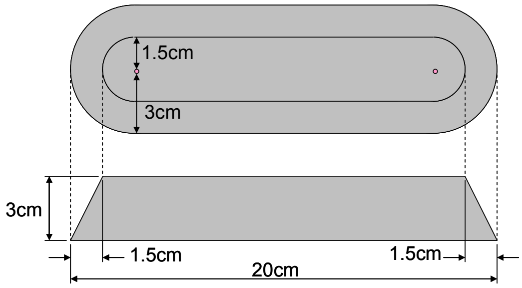


Figure 6 Model of Groin

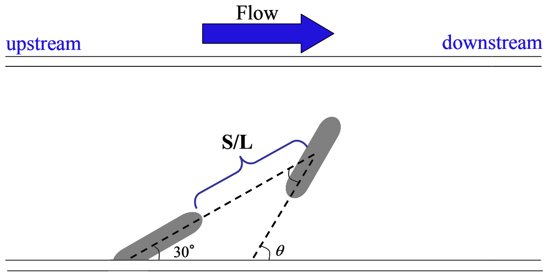


Figure 7 Layout of a two-step groin

Table 1 Hydraulic conditions

Case	Dr=h/H	S/L	Q (m^3/s)
Non-submerged	1	1	0.005
Submerged	2	1	0.0155

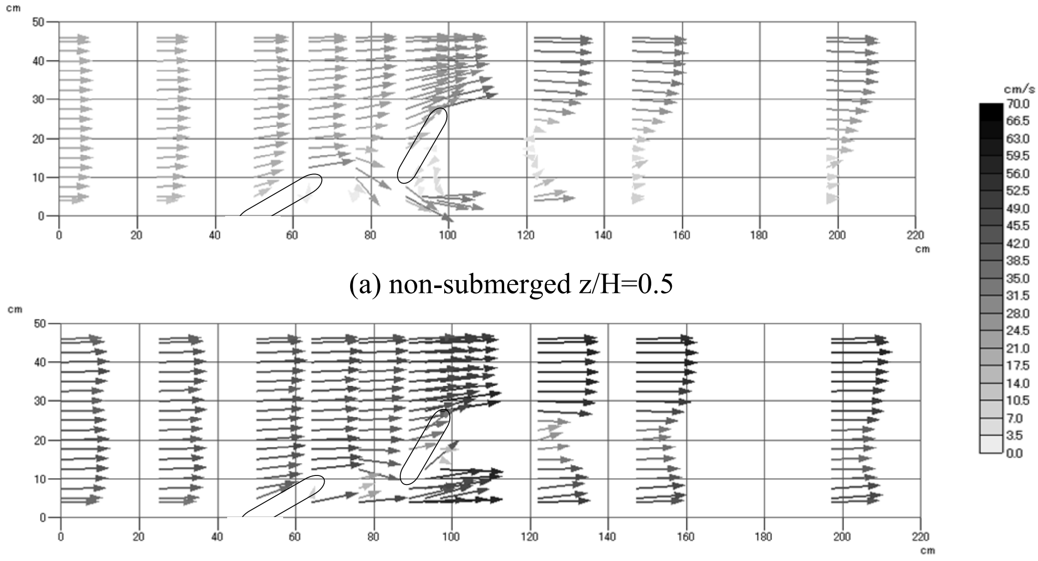
H=0.03m: height of model, h: water depth, Dr: relative depth,
S: space b, L: length of downstream groin, Q: discharge,

condition. The velocity for downstream groin is 86 percent of the value for the upstream groin. As it is considered that the groins are in the tight bond condition shown in Photo 1, the groins would not be broken by floods when the flow velocity is less than 7.3 m/s. The occurrence probability of such rapid flow is very low, because valley slope of the site is very mild. The slope figured by using a topographic map is milder than 1/400.

4. VELOCITY AROUND A TWO-STEPS GROIN

The downstream groin has been made up of smaller stones, and the both groins are not reinforced. This thing implies that the velocity of impinging flow to the downstream groin is slower than the velocity to the upstream one. To investigate the magnitude of velocity around a two-step groin, laboratory experiments were conducted by using a model groin shown in Figure 6. Two models were made of mortar and set them to deflect the flow by the first groin toward the second groin, deflecting the flow again by the second. The layout of two groins is shown in Figure 7. This layout was set up from velocity measurements of 12 different cases. Longitudinal and lateral components of velocity were measured by an ultra-sonic velocimeter. Results of the two hydraulic conditions in Table 1 are discussed here.

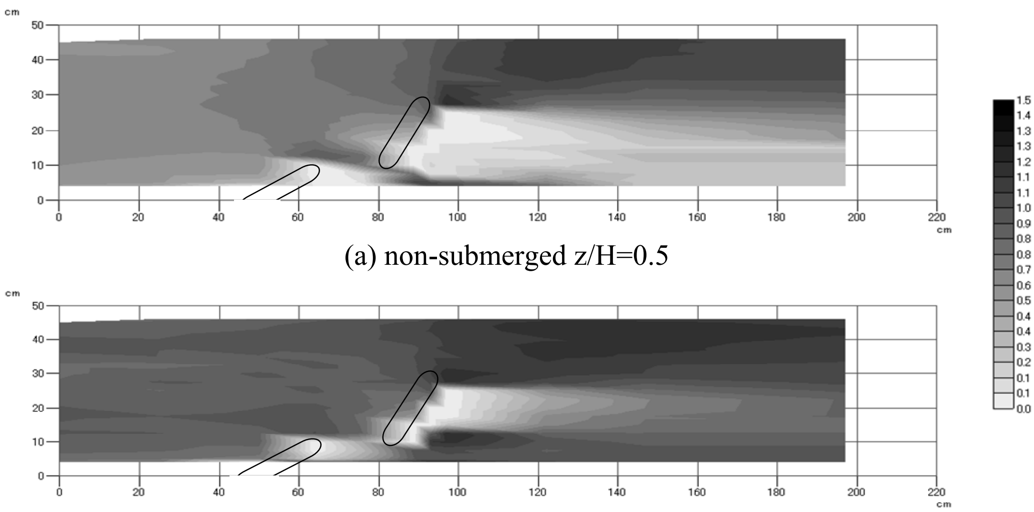
Figure 8 is the distributions of velocity vectors at the half level of groin height, z/H=0.5, in the non-submerged case and submerged case. Figure 9 shows the contours of velocity normalized by the discharge velocity of approaching flow. Approaching flow is deflected by groins and main stream is converged to the left side of channel in both cases. Velocity around the downstream side of the second groin becomes faster. As a big rock is set at the downstream end of the groin mentioned before, it is able to avoid being washed out by rapid flow. On the other hand, some parts of flow run through the interval between two groins. However, the velocity of impinging flow to the upstream side of the second groin becomes slower than the discharge velocity in submerged case. This reduction of velocity is observed in this layout case. It means that the layout of two groins is a factor of avoiding disruption by floods.



(a) non-submerged z/H=0.5

(b) submerged z/H=0.5

Figure 8 Distributions of velocity vectors



(a) non-submerged z/H=0.5

(b) submerged z/H=0.5

Fifure 9 Contour lines of velocity normalized by discharge velocity

5. CONCLUSIONS

A pair of old stone groins is studied here as a traditional technique of river works in Japan, and the stability of the groins during floods is discussed from the results of field survey and laboratory experiments. The main conclusions are as follows.

1) This pair of groins has a two-step function of deflecting flow. It means that approaching flow is deflected by the first groin to the channel center and the flow is deflected again by the second groin. These features function to keep the water depth for navigation.
2) Stability analysis of groins shows that the groins are able to keep their form when the flow velocity is less than 7.3 m/s. The occurrence probability of such rapid flow is very low, because valley slope of the site is very mild. This is one of the reasons why the groins have retained their form for many years.
3) The groins have unique structure to prevent damages during floods. A point is that the groins

are made up of a big rock at the downstream end and uniform size stones on the upstream side. The other point is concerned with the layout of two groins. As upstream side part of the second groin is made up of smaller stones, velocity of impinging flow to the part should be reduced to avoid the disruption. From the results of velocity measurement, it is found that the layout must be considered to reduce the velocity around the part. This structure is another reason why the groins have retained their form for many years.

In this paper, structure and flow around the groins have been investigated. However, another factor concerning with the stability of groins is local scour around them. Then, experiments in the case of mobile bed will be conducted in future.

REFERENCES

1) Ishigaki, T., Ueno, T., Rahman, M.M. and Khaleduzzaman, A.T.M. : Scouring and flow structure around an attracting groin, River Flow 2004, Balkema, Vol.1, 521-525, 2004.
2) Ishigaki, T. and Kawanaka, R. : Traditional Flood Management in the Kameoka Basin by Open Dyke System, Pre-Conference Paper Volume of International Conference on Water and Flood Manegement, ICWFM 2007, Dhaka, Bangladesh, Vol. 2, pp.479-485, 2007.
3) Rahman, M.M., Nakagawa, H., Haque, A., Islam, T. and Ishigaki, T. : A sustainable solution for the stabilization of navigational channels in floodplain environment", Proceedings of XXXI IAHR Congress, IAHR, Seoul, Korea , 2005. (on CD-ROM).
4) U.S. Army Corps of Engineer : Hydraulic design Criteria, Chart 712-4, 1970.