Comparative Study of Flows in Four Types of Stones Embedded Slope Type Fishways

Masayuki Fujihara* and ○Subas Chhatkuli**

1. Introduction

Migration of fishes from upstream to downstream or vice versa takes place for the purpose of food, spawning and so on. Man made obstructions like weir, dam, culvert etc in the course of migratory fishes may lead the migratory fishes to the verge of extinction. To fascilitate the passage of these fish species through obstructions, fishways are constructed.

Fishways are the hydraulic structures which dissipate the energy of flowing water to maintain the water depth and velocity that enable fishes to pass through these obstructions. Lately stones embedded slope type fishways are gaining popularity in place of traditional pool and weir type fishways as they are in more harmony with the natural stream and provide an easy passage to the fishes which do not prefer to jump.

2. Method

A Godunov type numerical method of two dimensional shallow water equations is applied for the analysis of flows in stones embedded fishway. The numerical experiment is carried out for four different stone shapes; circular (Type C), square (Type S), triangular stones with those bases facing the upstream (Type Tb) and with those vertexes facing the upstream (Type Tv). The radius of circular stone is set 0.2 m and the areas of other three types of stones are set equal to the area of circular stone. Length and width of the fishways are set 25 m and 2 m respectively with the slope 1:20. In all cases, top of stones are kept not to be submerged. Total slot openings for Type C, Type S Type Tb and type Tv are 0.8 m, 0.92 m, 0.38 m and 0.38 m, respectively.

At first, the quadtree grids which represent the flow domain of the fishways are created. The finest grid size is 5.96 cm^2 and the largest grid size is 95.36 cm^2. Shallow water equations are then discretised on these rectangular panels of grid by finite volume method. The solution uses a second order Godunov type approximation, with the inviscid fluxes at the interface between two cells calculated by using Roe's approximate Riemann solver. Fourth order Runge Kutta scheme is used for temporal integration. Smagorinsky model is used to evaluate kinematic viscosities. No slip condition is applied on solid boundaries of fishways and Manning's coefficient is taken 0.03 $m^{-1/3}$ s. For the comparative analysis of fishways, water depths at upstream and downstream ends are set 0.2 m as boundary conditions.

3. Results and Discussion

Since both the upstream and downstream water depths are fixed 0.2 m as boundary conditions, discharges of four fishways are all different: Type C, 0.080 m^3/s; Type S, 0.086 m^3/s; Type Tb, 0.033 m^3/s; and Type Tv, 0.046 m^3/s. This shows Type S provides the least resistance to flow among the all cases. It also indicates that the discharge increases as the slot opening widens. Comparing the discharges of Type Tb and

*Faculty of Agriculture, Ehime University,
**Graduate School of Agricultural Science, Ehime University
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Type Tv, it is clear that the configuration of stones also have the significant effect on discharge. Therefore, it is clear that the differences of stones shape and total length of slot openings generates the discharge differences.

Figure 1 shows the velocity vectors in all cases. For all the four cases, velocity is found higher in between the stones. The maximum velocities for Type C, Type S, Type Tb and Type Tv are obtained to be 1.24 m/s, 1.16 m/s, 0.926 m/s and 0.84 m/s, respectively. Counter flow is seen behind every stones in all the cases, though the area of counter flow is very small in Type Tb compared to the other three cases.

Average water depths for Type C and Type S are 0.159 m and 0.152 m, respectively. Water depth contours in all pools except the 1st and the last a few pools are almost the same. In the last a few pools, average water depth in a pool becomes larger from one pool to next pool downstream to fit boundary conditions. Average water depth in a pool of Type Tb gradually decreases from the 1st pool to the 12th pool and then increases to fit the boundary conditions. The difference of water depths in the 1st and the 12th pools is around 0.02 m. On the other hand, average water depth in a pool of type Tv gradually increases upto the 18th pool and then decreases downstream. The difference of water depths in the 1st and the 18th pools is around 0.08 m.

4. Conclusions

Comparative study of stones embedded fishways was numerically conducted under the condition that the total areas of stones are set equal in all four cases. The results show that the configuration of stones, shape of stones and slot opening length have great effect on deciding the flow properties in stones embedded slope type fishways.

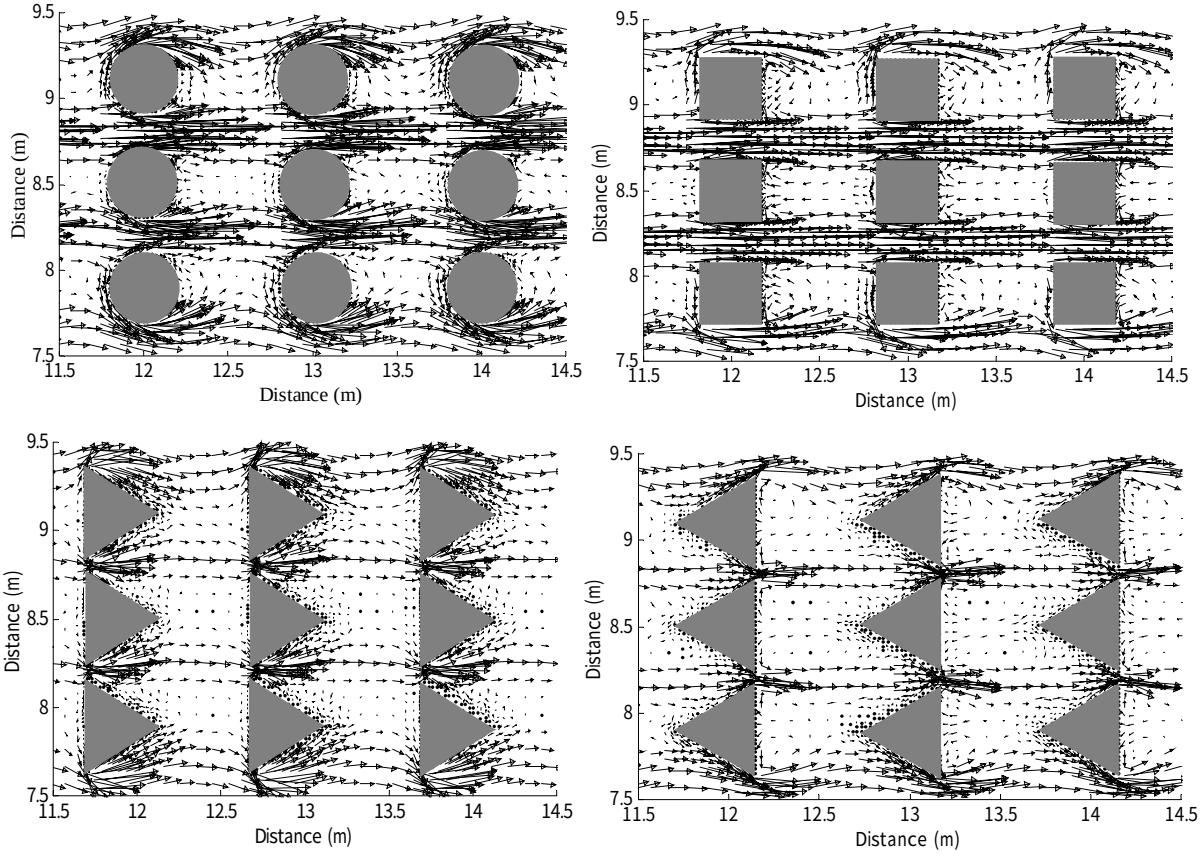

Figure 1. Velocity vectors of four types of stones embedded slope type fishways.