DEVELOPMENT OF THE SIPHON SYSTEM PIPE-TYPE FISHWAY AND MONITORING OF FISH MIGRATION

Kiyoshi Wada [a,*,†], Yukio Ota[b],
[a] Department of Civil Engineering, National Institute of Technology, Gifu College, Japan
Email: wada@gif-nct.ac.jp
[b] Research Center, Nishi-Nippon Institute of Technology, Fukuoka, Japan
Email: otayukio@sage.ocn.ne.jp
*Presenter; † Corresponding author.

Abstract: In this study, the function of fishway was evaluated using preliminary data, the siphon-pipe type fish passage with cost performance and portability has been developed, and local river experiment with indigenous fish was conducted. The structure form that the flow velocity should be reduced below at the burst swimming speed of fishes was examined. As results, dissipative energy can be attenuated greatly by the form loss of joints. The calculation formula of the design flow velocity and the required number of joint was proposed. The siphon-pipe fishway was designed using this formula, and the amount of ascension of the indigenous fish by local river experiment was investigated. Although the complete range of the fishes used for the experiment permeated into the pipe, the Oikawa (Zacco platypus) ascended to exit of the fish passage for a short time, and it is the whole dominate species. This fish passage can be used for choosing fishes, as the predetermined flow velocity is changed. It was shown that the ascension difficulty of fishes is cancelled by installation of the siphon-pipe type fish passage. A siphon system pipe-type fishway have several typical characteristics, such as free from overflowing, not expensive, easy to make, transport and install, and some pipe-type fishways already works as tentative fishaways and semi-permanent fishways in Japan. Therefore, as a pipe-type fishway has high flexibility of design, siphon-pipe fish passage is effective in improving the river ecological habitat.

Keywords: Fishway design;pipe-type fishway; siphon;migration; habitat

INTRODUCTION

There are many dams and weirs not only in developed countries but also in developing countries, and some rivers have fishways to keep river condition suitable for fish. However, many dams and weirs still do not have fishways, and sometimes fishways do not work effectively.

Fishways are constructed to enable fishes to overcome obstructions such as weirs in rivers to their migrations under the condition of allowed small discharge. In other words, the fishway should be able to control the discharge precisely and to keep the proper flow field (velocity). Fishways are classified into four groups: (i)pool and weir;

(ii)steam-type; (iii) operation-type; and (iv) other-types.

In this study, a siphon system pipe-type fishway has developed by the members of Indonesian Rivers Ecosystem Conservation Project (Ir-ECO Project)[1] [2]. This fishway belongs to (iv) other-types. Moreover, the researchers precisely investigate its characteristics, namely, loss coefficient of reducer, velocity and pressure profiles in the pipe and fish behavior between reducer. The new-type fishway makes it possible that river condition can be improved.

CHARACTERISTICS OF SIPHON SYSTEM PIPE-TYPE FISHWAY

Essential Characteristics

A siphon system pipe-type fishway has some typical characteristics, and they are quite different from usual fishways. These characteristics make a pipe-type fishway suitable for not only developed countries but also many developing countries.

1) Not need overflowing: There are many weirs that often do not overflow in dry season. A pipe-type fishway is able to work even if the top of weir becomes dry.
2) Not expensive: The cost of pipe-type fishway materials is usually within some ten thousand yen.
3) Easy to made: Almost all materials are available at the shops in Padang City and Jogyakarta City in Indonesia. A pipe-type fishway can be assembled without electric tools, and it is no problem that the site of weir does not have electric power.
4) Easy to transport: All fishway parts are not heavy and can be carried with human power.
5) Easy to install: The installation of pipe-type fishway usually finishes in a few hourswith 1-2 workers, and its removal is almost the same.

The first characteristics, not need overflowing, is the most important subject from the view of technical matters. Siphon system is maybe the only way to overcome this subject. Fig.1 is the pipe-type fishway at Padang City in Indonesia, and sometimes there is no overflowing at the weir. As shown in Fig.1, it is found to easily make fishes ascend to upstream in the pipe-type fishway. The water level difference is 1.80m when the gate is opened.

Flow reduction System

A pipe-type fishway gets the suitable velocity with some reducers in the main pipe.

Figure 1. Pipe-type fishway at Parak Buruk Weir in the Kandis River

Fig.2 is the flow reduction system of pipe-type fishway, where, D_1: internal diameter of main pipe, D_2: narrow part diameter of reducer, D_3: enlarge part diameter of reducer, L: reducer interval. The loss coefficient of each reducer consists of some contraction and expansion, and it can be estimated with formula (1). The loss coefficient of each reducer can be calculated theoretically, and the number of reducers controls the velocity of main of main pipe. As the flow energy is dissipated by turbulence around the reducer inserted in pipe, total energy loss due to friction and shape is increased.

The shape energy loss dominates than friction energy loss in the pipe flow.The shape loss coefficient of pipe-type fishway is calculated with formula (2).Almost all of coefficient occurs from reducers, and the correction coefficient (□) from other parts is estimated around 5 in the formula.

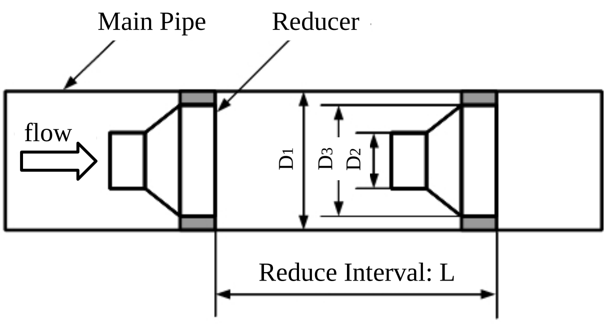


Figure 2. Flow reduction system of pipe-type fishway

$$f_r = f_{sc} + f_{ge} + f_{se} \qquad (1)$$

$$f_T = N \cdot f_r + □□ \qquad (2)$$

where, f_r, f_{sc}, f_{ge}, f_{se}: energy loss coefficient of each reducer, sudden contraction from D_1 to D_2, gradual expansion from D_2 to D_3, sudden expansion from D_3 to D_1 for each one, and f_T: total loss coefficient of pipe-type fishway, N: number of reducers.

Design of Pipe-type Fishway

Fig.3 shows the relationship between number of reducers and main pipe velocity of pipe-type fishway under the condition of D_1, D_2 and D_3 is 100, 50 and 75mm, respectively. In the case of the fishway at Fukano weir in Fig.4, the energy loss coefficient of each reducer is 9.73 and the water level difference is 1.60m. This fishway has 39 reducers in the pipe, and its main pipe velocity becomes 0.29 m/s and the narrow part velocity becomes 1.04 m/s.

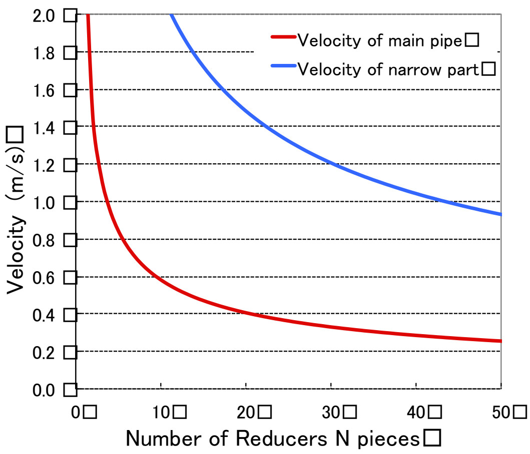


Figure 3. Main pipe velocity of pipe-type fishwayFigure 4. Install to Fukano weir in the Kii river

Pipe-type fishways consist of two models, the one is a connecting model and the other is an integrated model such as Fig.4. A connecting model is a tentative fishway, and it sometimes can be used at another weirs. Some short flexible tubes connect the inlet, several bodies and the outlet, and it is easy to change these parts. An integrated model is installed as a tentative fishway and a semi-permanent fishway. This model is tougher than connecting model, and it is easy to fix tightly to weir. The production costs of integrated model are less than connecting model, and an integrated model is the first selection of pipe-type fishway. A vertical type fishway is one of the integrated models, and it really has a vertical part in the fishway. Fig.4 is an example of vertical type fishway. As there are many square-type low weirs in Japan, vertical type fishways are very useful for these weirs.

Theoretically, the velocity of main should be less than the cruising speed (maximum sustained speed) of target fish, and the velocity of narrow part should be less than the burst speed (maximum swimming speed) of them. However, it is confirmed that the velocity of pipe-type fishway fluctuates quickly and suddenly, and fish maybe use this velocity fluctuation when they move up more easily in vertical pipe than in horizontal pipe. Empirically 0.3-0.4 m/s of main pipe velocity is suitable for many species of fish, not only swimming fish but also demersal fish.

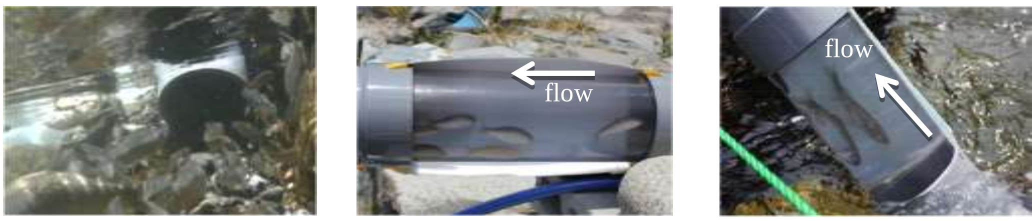
INSTALLING PIPE-TYPE FISHWAY TO RIVER AND IRRIGATION SYSTEM

Design for river with an pool-and-weirfishway

A local experiment was conducted to confirm the fish behavior to easily make fish ascend in the pipe-type fishwayinstalled on a weir in the Neo-River in Gifu Prefecture[3]. Although it is installed pool-and-weir type fishway in the river, a function is lost by damage.

Fig.5 shows that the pipe-type fishway was installed todropwork such as groundsill.As for water level differences between upper and downstream is 0.80m; the maximum height of the fishway is 1.47m. The field experiment of ascending fish was conducted approximately one hour, 19 kinds of fish and 242 individuals. Water area was secured in the fishway entrance surrounded withsandbags and nets. The experiment method released fish into the fishway entrance and observed swimming behavior using by a video camera. Fish were gathered at the fishway exit by a trap.Under the calculated condition of the low velocity is 0.30m/s and the high velocity is 1.09m/s, 22 reducers were installed in the pipe. Using the electromagnetic current meter, it was confirmed to the velocity at the entrance of fishway decreased to 0.31m/s.As shown in Fig.5, fish in the pipe started to ascend upstream after the experiment immediately.

(a) Pool-and-weir fishway (b) Assembling of the fishway (c) Installed pipe-type fishway



(d) Entrance of the fishway (e) Ascending fishes(f) Exit of the fishway

Figure 5. Installing pipe-type fishway to the Neo river with impaired fishway in

function

Design For Irrigation System Without Fishway

It was experimentally conducted that fish ascended in the pipe-type fishwayinstalled to the agricultural irrigation system in Gifu prefecture[4].Fig.6 shows that the pipe-type fishway was installed to dropwork such as diversion gate of weir. As for water level differences between upper and downstream are 1.60m. Fish were gathered at the fishway exit by a trap.Under the calculated condition of the low velocity is 0.36m/s and the high velocity is 1.30m/s, 31 reducers were installed in the pipe. Using the electromagnetic current meter, it was confirmed to the velocity at the entrance of fishway decreased to 0.36m/s. As shown in Fig.6, fish in the pipe ascend using a resting areaafter the experiment.

Figure 6. Installing pipe-type fishway to the irrigation system without fishway

RESULTS AND DISCUSSION

Fig.7 demonstrates the ratio of fish via the control sections of visible acryl pipe installed to river.As the figure, it is pointed out that ratio of strong Pale chub (*Zacco platypus*) of the swimming power increase toward the upstream from 51% to 84%.

Cruising speed (sustained speed) and burst speed (maximum swimming speed) characterize the swimming ability of fish. In general, cruising speed is 2-4 BL (body length)/s, and burst speed, 10-15 BL/s, although results of the measurement of swimming speed vary greatly according to the apparatus and criteria such as the definition of swimming time, the duration for which a fish can maintain a certain swimming speed.

Fig.8 shows the relation between the swimming speed of Ayu (*Plecoglossusaltivelis*) and the progress distance. Cruising speed and burst speed is written jointly in the figure, as the body length is calculated as 10cm. From the figure, the fish ascend towards resting area while repeating break and burst.The fish slows down in

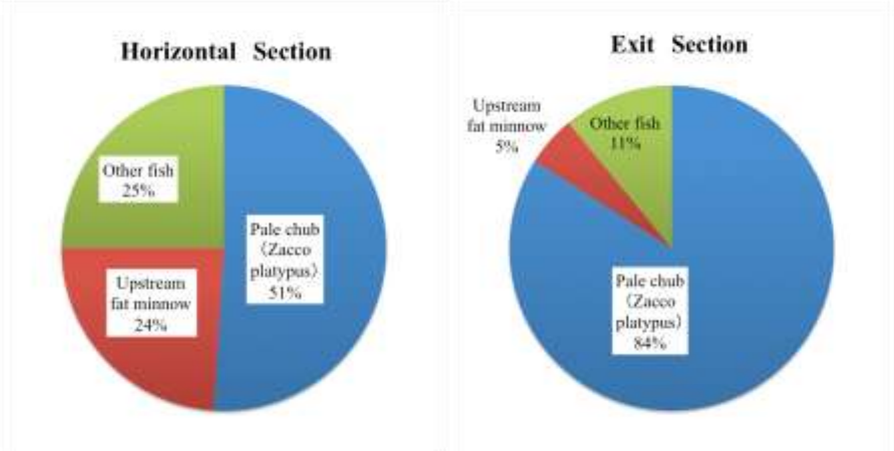


Figure 7.The ratio of fish via the control sections of visible acryl pipe

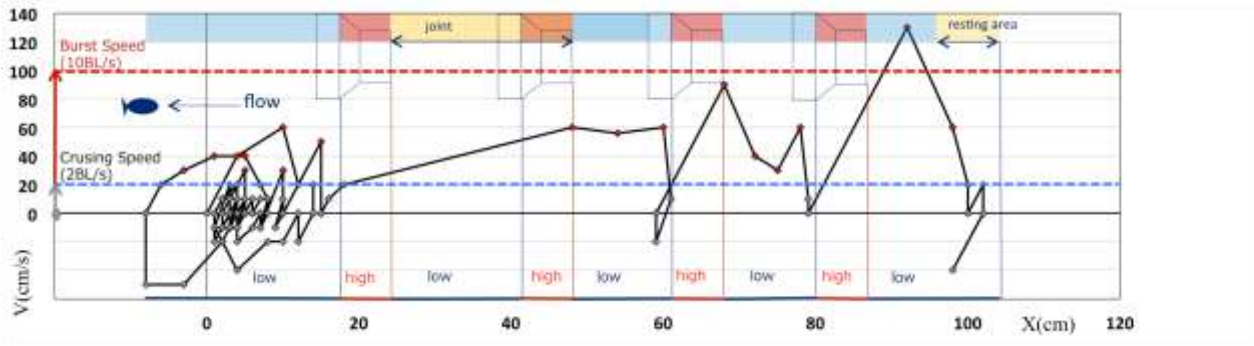


Figure 8.The relation between the swimming speed of the fish and the progress distance

enlarged part and accelerates in the narrow part from a detailed viewpoint.

According to the fish physiology, metabolism in red muscle was aerobic, while anaerobic process was confirmed in white muscle[5]. Therefore, once the white muscle was activated, accumulation of lactate occurred rapidly, and fish would be exhausted soon. To minimize the activity of white muscle, fishway should provide current velocity lower than the cruising speed at some part of any cross sections of fishway. Consequently, the fish ascend upstream through each reducerbefore arriving at bending corners. Also, it seem to the fish use gentle flow area adjacent to the mainstream skillfully and take a break outside reducer temporarily until lactic acid is broken down.

Ability or function of fish, e.g. swimming speed, has been dealt in fishway design as biological knowledge. However, tendency of behavior or preference might be more important as a life history strategy in the wild, and thus more useful for fishway design.

CONCLUSIONS

A siphon system pipe-type fishway has several typical characteristics, such as free from overflowing, not expensive, easy to make, easy to transport and to install, and some pipe-type fishways already works as tentative fishways and semi-permanent fishways in Indonesia and Japan. A pipe-type fishway has high flexibility of design, and its flow characteristics, the velocity of main pipe and reducers, are also designed with some numerical formulas. Fish in a pipe-typefishway are able to move up easily with using its flow fluctuation, and the complicated flow at the water pocket of reducers sweeps away the sediment such as sand and soil in the pipe. Actually the pipe-type fishway in the Kii-River, Fukuoka Prefecture helps a lot of fish ascend upstream every year.

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