Preliminary design of laboratory experiment on flow pattern in natural-like fish way ponds

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Abstract. In the design of fish way, the flow pattern of the pool is an important design basis. Many factors need to be considered in the preliminary test of fish way in the laboratory. This paper introduces the design method and preliminary results of flow measurement test of fish way pond chamber. The results show that the layout and porosity of the partition wall should be considered in the design of natural fish way. Different partition arrangements and porosities have obvious influence on the flow pattern in the pool. In the flow pattern of the pool chamber, there is a clear main flow, but the flow rate is low behind the partition wall and near the side wall of the pool chamber.

1. Introduction
Fish way is a kind of fish-passing structure set up to communicate the fish migration channel at the sluice, dam or natural barrier. Fish way is mainly divided into fish way, imitation natural fish way, fish lock, fish lifter and collecting vessel, among which fish way is the most widely applicable. Vertical slit fish way is one of the basic layout forms of fish way, which has the characteristics of clear mainstream, stable structure of flow field and strong ability to adapt to changes in upstream and downstream water level.

In practical projects, the species of fish that need to be protected in the same river are often diverse, and the fish differ greatly in body size, life habits and flow capacity [1]. Compared with the traditional technical fish way, the flow pattern constructed by imitating the natural fish way is closer to the natural state familiar to fish, which tends to have wider applicability and higher efficiency for fish [2-3]. The natural fish way is a kind of natural fish way, which is characterized by a partition made of pebbles that divides the fish way into multiple pools. Such a new type of artificial fish way can not only save the engineering cost, but also possess the dual flow characteristics of vertical slit fish way and artificial fish way. There are many designs for vertical slot fish way [4], including single-and double-slot fish ways [5]. The flow patterns were also investigated by researchers [6].

Therefore, the different structure of fish way leads to the different flow patterns in fish way [7]. This paper introduces the preliminary test setup and results of fish way chamber flow state measurement, which is expected to be helpful to the development of fish way test.
2. Physical modelling experiment
Since the purpose of this experiment is to provide reference for the design of fish way in engineering, the design process of fish way must be studied first. In the existing guidelines for fish way design for water conservancy and hydropower projects, specific fish way design steps are given.

2.1. Determine the design flow rate
Design flow rate is the first step of fish way design, its physical significance is the average flow rate of vertical slit fish way, so its value cannot be greater than the explosion flow rate of the fish object, and otherwise it will directly affect the upstream of the fish object. The specific value should be determined by studying the swimming ability of the fish.

2.2. Determine the water level difference in the pool
After deciding the partition layout of the pool, the calculation of the pool water level difference can be carried out. In the case of normal operation, the water level difference should be fixed, so that the velocity difference between the upstream and downstream of the fish way will not be too large, affecting fish upstream and downstream.

2.3. Determine the slope
The slope should be determined according to the water level difference of the pool, and the length of the pool and the thickness of the partition should also be considered.

2.4. Determine the minimum water depth and vertical slit width
The minimum depth of the pool should be more than 2.5 times the maximum body length; Vertical seam width is designed according to the fish object. It is not specified here how wide it needs to be, only if the maximum size of the fish object can be passed. In this experiment, the concept of partition porosity was added on the basis of previous studies to study the changes of fish way design indexes and fish way chamber flow field structure and hydraulics indexes under different porosity conditions.

3. Preliminary experimental setup
This experiment takes a proposed fish way project as an example. The structure layout and size of fish way model are as follows: fish way section is rectangular, bottom width is 40cm, bottom slope J=1%, roughness is about 0.009. Glass is used to facilitate the observation of the flow model, including a total of 5 level pool rooms, which are separated by a staggered partition wall. The partition wall is a permeable pebble wall made of PC board. The porosity of the pebble wall ranges from 0% to 30%. The vertical seam width b is 5cm, the deviation rate of the short guide wall is 0.7b, 1.3b, 1.9b, and the length-width ratio of the pool room is 8:8, 10:8, and 12:8. There are three kinds of arrangement of fish way: the same side type, the different side type and the double side type.

A total of five stage pools were simulated in the experiment, and sufficient length was set aside in the upper and lower reaches. The water flow in the third stage pool was taken as the research object to reduce the errors caused by the water level in the upper and lower reaches.

3.1. The partition layout of the fish way
According to different needs, there are three kinds of partition layout of fish way, which are the same side type, the different side type, and the double side type respectively (shown as Figure 1).
3.2. Fish way partition porosity setting
The porosity of the partition wall of the fish way is shown in figure 2. From left to right, the porosity is 0%, 6%, 12%, 18%, 24% and 30%, respectively. Among them, the first row is the double side type, and the second row is the same or different side type.

3.3. Experimental conditions
The experimental conditions depend on the partition layout and the porosity of the partition wall. In the preliminary experiment, 18 cases were conducted, i.e. 3 partition layouts × 6 porosities, which is listed in table 1.
Table 1. Experimental conditions.

| Arrangement          | porosity |
|----------------------|----------|
| Same side type       | 0%       |
|                      | 6%       |
| Different side type  | ×        |
|                      | 12%      |
|                      | 18%      |
| Double side type     | 24%      |
|                      | 30%      |

4. Test procedure
PIV (particle image velocimetry) was used to measure the water flow conditions in the indoor part of the third-stage pool
(1) Clean the water tank and change the water in the underground pool to ensure that no impurities in the water affect the PIV shooting.
(2) Glue the customized PC board in the water tank according to different working conditions.
(3) Open the pump and adjust the frequency of the pump. Under the condition of ensuring steady flow, adjust the tailgate opening to make the water depth of each chamber in the fish way equal. Record the water depth at the centre of the third chamber, the water depth at the third vertical joint, and the water depth at the upstream and downstream of the three vertical joints.
(4) Place the camera under the sink and connect it to the computer. Place the laser transmitter on the side of the sink.
(5) Add tracer particles to the upstream of the tank, adjust the focal length and particle concentration of the camera, so that the bright tracer particles can be clearly seen on the PC end, and then start shooting.
(6) Take particle pictures of different depths of water in turn, and then the PC terminal can process the data as needed.

5. Preliminary results
Taking the 12% porosity as an example, figure 3 shows the flow pattern in natural-like fish way ponds for double side type, different side type, and same side type arrangements, respectively. The results show that the main flow in the pool is clear. The flow rate is maximum at vertical joints. There are low flow zones behind the partition walls for fish to rest. The flow rate is also lower near the wall of the chamber. These preliminary results are useful for design of the nature-like fish way.

Figure 3. The partition layout of the fish way.
6. Summaries and conclusions
In this paper, based on the nature-like fish way engineering, the design of the measurement of fish way flow pattern in the laboratory is introduced, and the preliminary tests were carried out. The design factors include the layout of fish way partition and the porosity of partition. In addition, the measurement results of flow pattern in the tank can provide some help for the design of fish way.

Acknowledgments
This work was financially supported by the Research on Key Technologies of Ecological Sustainable Fishery in Minjiang River Basin Project (FCCDRI-JS-KY-201805-002).

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