A Brief Introduction to the First Natural-Like Fishway Project in Fujian Province, China

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Abstract. Due to the strengthening of the concept of ecological protection in China, many fishway projects are under construction. There is no natural-like fishway project in Fujian province before. In this study, different fish pass structures are described, and the important factors of the fishway design are illustrated. In addition, the advantages and disadvantages for different fish pass structures are discussed. Finally, the first natural-like fishway project in Fujian province is briefly introduced, including the project background, the project location, and the design information. This project will significantly improve the drinking water quality of people in Fuzhou city. More importantly, it will protect the fish species in Minjiang river.

1. Introduction

Fishways are hydraulic structures that enable fish to overcome obstructions in the passage to the spawning grounds and other upstream migrations [1]. A rocky ramp fishway is one of the natural-like fishway, comprises a long sloping channel and boulders on a slope [2]. For the natural-like fish way, the hydraulic conditions depend on flow rate, roughness on the slope, and geometry of the ramp [3]. Usually, fish can rest in the refuges of decreased local flow that created by the backwater and turbulence around the boulders.

However, recent studies have shown that turbulent flow may influence fish migration [4]. Therefore, a different arrangement of boulders would be needed to address the particular swimming physiology of each species [5]. So more and more researchers have focus on the natural-like fishway in recent years.

2. Fish pass structures

A fish pass, also known as a fishway, fish ladder or fish steps, is a structure on or around artificial and natural barriers (such as dams, locks and waterfalls) to facilitate diadromous fishes' natural migration [6]. Most fishways enable fish to pass around the barriers by swimming and leaping up a series of relatively low steps (hence the term ladder) into the waters on the other side [7].
2.1. Considerations of fishway design

In the design of a fishway, the following important factors should be considered: hydraulic characteristics for different fishway types, the swimming behavior and performance for the different fish species. These factors (biological and hydraulic criteria) depend on the fish size and fish species. In addition, the fishway efficiency depends on attraction, safe and speedy transport of fish with minimum energy loss. The motivation and the species behavior are the key factors of attracting fish to the entrance. Therefore, the best guide for designing fishway entrances is the experience with the target species.

Although there are several variations of each fishway type, fishways are usually classified into four types: the Vertical Slot Fishway, the Denil Fishway, the Weir Fishway, and the Culvert Fishway (shown in Figure 1). The flow velocity in the fishway is reduced by backwater conditions.

Figure 1. Overview of different types of fishways [8].

2.2. Advantages and disadvantages for different fish pass structures

There are many different fish pass structures with different advantages. The traditional fishway, the natural-like fishway, the fish lift, the fish lock, and the fish transportation facility are introduced as follows.

For the traditional fishway, the advantages are as follows: 1) It has a good energy dissipation for the water flow; 2) The structure is stable; 3) It covers a small area; 4) The fish can transport continuously. However, there is still a disadvantage, i.e. the artificial facilities are not easy to modified. Generally, the application for the fishway is in middle and low water head engineering.

For the natural-like fishway, the advantages are as follows: 1) Fish are easier to adapt; 2) The fish can transport continuously; 3) The artificial facilities are easy to modified. However, there are some disadvantages: 1) The energy dissipation for the water flow is not good; 2) The structure is not stable; 3) It does not adapt to the change in the water level; 4) It covers a large area. Generally, the application for the natural-like fishway is in low water head engineering.

For the fish lift, the advantages are as follows: 1) It covers a small area; 2) It can be used in the high water head engineering. However, it is not easy for fish to enter the lift, and the working condition is complicated. In addition, the operating cost for the fish lift is relatively high. Generally, the application for the fish lift is in middle and low water head engineering, as well as the high water head engineering.

For the fish lock, the advantages are as follows: 1) It covers a small area; and 2) It can be used in the high water head engineering. However, it is not easy for fish to enter the lock chamber, and the working condition is complicated. In addition, the operating cost for the fish lock is relatively high. Generally, the application for the fish lock is in middle and low water head engineering, as well as the high water head engineering.
For the fish transportation facility, the working condition is flexible, and it can also be used in the high water head engineering. However, same as fish lock and fish lift, the working condition is complicated, and the operating cost for it is relatively high. Generally, the application for the fish transportation facility is in middle and low water head engineering. Also, it can be used as an additional fish passage facility.

As mentioned above, different types of fish passage facilities have different applications. For the middle and low water head engineering, the fish way is widely used.

3. Selected fishway projects in China

Normally, the fishway is a sloping channel which partitioned by weirs, baffles, or vanes. There are openings for fish to swim through. The devices in the channel produce the suitable flow, which can navigate the fish. Due to different arrangements of the in-channel devices, many types of fishways have been developed. The main goal of the fishway is to attract the fish to enter the entrance, pass through the channel, and then exist safely within the reasonable time and energy cost.

Recently, since the strengthening of the concept of ecological protection in China, many fishway projects are under construction. Some selected fishway in China are listed in Table 1, including natural-like fishway and vertical slot fishway. However, there is no natural-like fishway in Fujian province. Therefore, the first natural like fishway are going to construct in Fujian province, which is described in this paper.

Table 1. Selected fishway in China [9].

| Project                    | River               | Fishway type                    | Progress  |
|----------------------------|---------------------|---------------------------------|-----------|
| Angu hydropower station    | Dadu River          | Natural-like & vertical slot    | Built     |
| Shiquanhe hydropower station | Yindu River        | Vertical slot                  | Under construction |
| Shaping level 2 hydropower station | Dadu River         | Vertical slot                  | Designed |
| Zhentouba level 1 hydropower station | Dadu River | Vertical slot                  | Built     |
| Fengman hydropower station | Second Songhua River | Fish lift & vertical slot       | Under construction |
| Xinji hydropower station   | Han River           | Vertical slot                  | Under design |
| Xunyang hydropower station | Han River           | Vertical slot                  | Under design |
| Duobu hydropower station   | Niyang River        | Vertical slot                  | Built     |
| Chuosijia                  | Dadu River          | Vertical slot                  | Under design |
| Jinsha                     | Jinsha River        | Vertical slot                  | Under design |
| Fulongkou                  | Heng River          | Vertical slot                  | Under design |

4. Natural-like fishway in Fujian province

Fujian province is a province on the southeast coast of mainland China. Fujian is bordered by Zhejiang to the north, Jiangxi to the west, Guangdong to the south, along with Taiwan 150 km (93 mi) to the east, across the Taiwan strait. No natural-like fishway has been built in Fujian province yet.

4.1. Project background

The project is about the water resources allocation in Pingtan and Minjiang of Fujian province, which is called the One-gate and Three-line Project. The one gate is a sluice gate in Dazhangxi river. The three lines are three water pipelines that deliver the water from the river to the reservoir, and then from the reservoir to the cities. The total investment of this project is about 6.4 billion RMB, and the total construction period is about 4 years. This project will significantly improve the drinking water quality of millions of people in Fuzhou city, Fujian province.
4.2. Project location
The first natural-like fishway is located in Dazhangxi river. Dazhangxi river is the largest tributary of the lower Min river, originated from Daiyun mountain in Chishui township, Dehua county. Its source is Guobao river. The Dazhangxi river basin covered 4,843 square kilometers, and the river length was 234 kilometers, with an average gradient of 2.1‰. The locations of the Dazhangxi and the fishway were shown in Figure 2.

4.3. Design information
The natural-like passages include high and low inlets, fish passages, confluence pools, flood gates, exits, observation pools and sampling pools, as well as necessary water supply facilities and imported bottom linking facilities.

In order to improve the efficiency of the fishway, the entrance of the fishway should be located in the fish intensive area. In addition, the entrance of the fishway facilities should be arranged as close as possible to the migratory route of fish.

Table 2. Design information for the first natural-like fishway in Fujian province.

| Section       | Item            | Configuration               | Remarks                                      |
|---------------|-----------------|-----------------------------|----------------------------------------------|
| Channel section | Structure types | Staggered stone             |                                              |
|               | Bottom width    | 2.0 m                       |                                              |
|               | Water depth     | 2.0 m                       |                                              |
|               | Side slope      | 1:1.5                       |                                              |
|               | Pool room length| 10 m                       | Working water depth                          |
|               | Total width     | 8.0 m                       |                                              |
|               | Bottom slope    | 0.8%                        |                                              |
|               | Total length    | 625/925 m                   | Effective length including confluence pool   |
|               | Entrance elevation| -1.75 m                   |                                              |
|               | Exit elevation  | 6 m                         |                                              |
| Confluence pool | Length         | 20 m                        | No slope for the bottom of the confluence pool |
|               | Width           | 10 m                        |                                              |
|               | Water depth     | 2.00 m                      |                                              |
|               | Bottom slope    | 0                           |                                              |
|               | Elevation       | 1 m                         |                                              |
5. Summaries and conclusions
This paper presents the first fishway project in Fujian province, China. Different fish pass structures are described. The considerations of fishway design are illustrated. The advantages and disadvantages for different fish pass structures are discussed. The selected fishway projects in China are listed. Finally, the first natural-like fishway project in Fujian province is briefly introduced, including the project background, the project location, and the design information. This project will significantly improve the drinking water quality of millions of people in Fuzhou city, Fujian province, China.

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