Study on the design of imitative-ecological fishway in Xinjiang low-head hub

Shijiao Luo
Country School of Soil and Water Conservation, Beijing Forestry University, Beijing 100083, China
*Corresponding author’s e-mail: 704982475@qq.com

Abstract. This paper first introduces in detail the design concepts and the structure of the imitative-ecological fishway in Xinjiang low-head hub. Then, combined with the operation of fishway in a water diversion project in Xinjiang, this paper summarizes the key points to be followed in the construction of low-head imitative-ecological fishway in order to achieve the expected effect, thereby providing relevant design basis and ideas for similar projects in the future.

1. Introduction
The hydro-junction built in the waterway may separate the fish in breeding migration into the upstream population and the downstream population, blocking individual and genetic communication. The fragmentation of environment in which the fish lives can hinder the inter-species genetic communication, thus affecting various species and even damaging the aquatic environment. It is necessary to protect the aquatic and ecological environment and fish resources by ensuring the communication of upstream and downstream fish population and maintaining the connectivity of fish in the river. The construction of ecological fish passages in water conservancy hubs can help alleviate the adverse impacts of engineering on the fish and the aquatic ecology, and at the same time, it can meet the requirements of environmental assessment for hydro-power planning.

2. Introduction to fish passage facility
The fish passage facility, making use of the rheotaxis of the fish, can produce a stream at the inlet that flows quicker than the surrounding water to attract the fish. Whether the fish will respond to this facility and overcome the velocity of the surrounding water is related to the effectiveness of the fish passage facility. Facility used in the early days are a pool-type chute dug on the rock for the fish to swim up, so it is also called the fish ladder, which may be the prototype of the fish passage facility. Later, the wooden fish ladder became popular, with a partition inside to slow down the flow rate. Most of the fish passage facilities nowadays are made of reinforced concrete structures. The types of these facilities in the dams include fish passages, bypass waterways with natural features, fish gates, fish-raising machines, fish-carrying vessels, and special fish passages (pool-type fish passages and Daniel fish passages).

3. Design ideas of imitative-ecological fishway
The principle of the pool-type fishway is to divide the height to be passed into several small sections to form a series of pools, which are used to connect the whole fishway. Between adjacent pools, there
is a partition with weirs, slots, vertical slits or submerged orifices. The pool has two functions: on the one hand, it helps to dissipate energy, so that the flow state can be improved and the flow rate can be reduced; on the other hand, it can provide a place for the fish to rest.

A bypass waterway with natural features is designed for the fish to bypass specific obstacles similar to the natural tributaries of a river. These waterways are characterized by low slopes (typically 1-5%, and even smaller in lowland rivers). Energy is dissipated by a generally regular rapids or small waterfalls similar to natural conditions. The bypass waterway with natural features is very similar to the natural river channel, making it more conducive to fish migration.

With the advantages of the pool-type fish passages and the bypass waterways with natural characteristics and the characteristics of rivers and fish in Xinjiang taken into consideration, this paper designs an imitative-ecological fishway suitable for low-head hubs.

The imitative-ecological fishway is mainly composed of a T-shaped fish passage and a pool lounge. The former one adopts a T-shaped section with a gentle longitudinal slope (generally 1/500~1/1000), and the section size can be determined according to the demand for flow discharge. The T-shaped fish passage uses the dry-stone pitching, and the water is relatively slow. The section is not only similar to the natural topographic conditions of the river channel, but also produce a flow field with different hydraulic gradients, which can meet the needs of fish of different sizes. A pool lounge is set up at intervals (the distances is determined according to the swimming ability of fish) in T-shaped fish passage. According to the model test results, the height difference between the entrance and exit of the lounge is 7 cm~15 cm. The lounge not only provides a place for fish to rest, but also effectively reduces the height difference and shortens the length of the fishway.

4. Key points of design
The conditions of the fishway boundary mainly include the fish target, fish passing period, flow control and the water depth. The first two conditions are determined based on the ecological habits of fish in the river. The flow rate in the fishway and at the inlet and outlet are determined based on the swimming ability of the fish.

The fishway inlet should avoid to be arranged near the strong vortex, recirculation zone, stagnant water zone, and sedimentation area. The elevation of the inlet floor should be adjusted according to the change of downstream water level. The inlet water depth should not be less than 1 m in the main fish migration season. The inlet flow rate of is usually larger than the main river flow, thereby attracting the fish inside. But the inlet flow rate should less than the fastest swimming speed of fish. The entrance should be exposed to natural light, and can be equipped with fish blocking and attracting facilities to improve the fish passage efficiency. At the same time, it is necessary to keep the entrance away from the water inlet of buildings and the area with many floating objects. In main fish migration season, when the water level changes greatly, it is necessary to set multiple outlets at different parts and different elevations. The outlets should be connected using imitative-ecological fishways, which can effectively reduce the amount of excavation work. The water flow outside the outlet should be smooth with a flow rate less than 0.5 m/s, which is good for guiding the fish to swim upstream.

5. Composition of fishway

5.1. T-shaped fishway
The section size of T-shaped fishway is determined based on the longitudinal slope and the design flow rate. In Xinjian, the river runoff is relatively small and the water resource is scarce. Therefore, the section size and discharge flow of the T-type fishway should be relatively small. At present, the imitative-ecological fishway has a bottom width of 1 m, a slope of 1:1.5, a depth of 1.5 m, and a design flow rate of about 1.5~2.0 m³/s. The T-shaped fishway adopts 15~25 cm dry-stone pitching, the bottom of which is fixed with 10 cm thick mortar sub-crust for stabilization and is laid with thin film for anti-seepage. The trapezoidal channel using the dry stone pitching described above can have a larger surface exposed to water, thus forming more prominent velocity layer and a low-velocity zone
near the dry stone, making it possible for fish with poor swimming abilities or smaller sizes to pass. The natural river channels in Xinjiang are rich in gravel reserves, so the dry stone can be obtained by screening sand gravels in the natural river bed. Based on the fish types in Xinjiang rivers and their ecological habits and relatively poor swimming ability, this paper designs the longitudinal slope of imitative-ecological fishway to be relatively gentle. According to the experience of existing projects, the longitudinal slope is often set as 1/500~1/1000. A typical section of the T-shaped fishway is shown in Figure 1.

5.2. Pool lounge
According to the imitative-ecological fishway that has been built in Xinjiang, the lounge is generally a rectangular pool, which is 4 m long, with a net height of 1.8 m and a net width of 5.5 m. The height difference between the entrance and exit of the lounge is generally 7 cm~15 cm, and the bottom is also laid with 20 cm-thick dry stone so as to simulate the migratory conditions of fish in natural rivers. The water discharge test shows that the design water flow in and out of each lounge is gentle, and the height difference is very small (0.02 m~0.05 m). Gravels in the lower part of the lounge and the slow water flow are conducive to the fish in need. The lounge interval should be designed according to the swimming ability of the fish and the design flow velocity of the T-shaped fishway. Since the T-shaped fish passage has a gentle longitudinal slope, the lounge interval should be appropriately reduced without affecting the flow pattern, so as to effectively eliminate the elevation difference between the inlet and outlet and shorten the length of the fishway.

5.3. Fishway outbuildings
In order to better observe the effect of the fish passage, it is necessary to set observation equipment and observation room as the fishway outbuildings. In addition, a fish-blocking system can be added to increase the efficiency of fish passage.

Xinjiang is hot in summer and cold in winter (the rivers tend to freeze in winter), and it is windy and sandy. Based on the climate characteristics, this paper designs a retractable electric-pole fish-blocking system, so that the equipment can be recovered in winter when it is not running. The fish-blocking equipment is mainly composed of an electric fish-blocking system, a supporting structure and an underwater electrode.

The supporting structure is composed of a column, a main cable, a sling, a C-shaped steel slide rail, an electrode movable frame, a traction rope and a fixing cable.

The two columns are located on the left and right banks of the river. The main cable is fixed on the top of the column by hoops. The slings are fixed to the lower part of the main cable using U-shaped wire ropes. The slings are made of Φ 8 plastic-shielded steel wire ropes with a spacing of 5 m. The C-shaped steel rail is directly linked to the lower part of the sling and the top of the C-shaped steel rail is also connected to the sling and is horizontally arranged. The C-shaped steel slide is made of C-shaped stainless steel with an electrode movable frame. The traction rope adopts the Φ 2 plastic-shielded steel wire ropes which is tightly wound around the fixed pulleys at both ends. The up-link of the traction
rope is fixed on each of the electrode movable frames, while the down-link is not fixed, so that the operator can move the frame when pulling the traction rope.

6. Effect of imitative-ecological fishway
During the operation of the imitative-ecological fishway project in Xinjiang in 2018, it is monitored that about 8,000 different kinds of fish have passed the fishway and the passage effect is quite satisfactory. At present, an electric-pole fish-blocking facility is under construction, with an aim to further improve the fish passage effect, thus providing relevant design basis and ideas for similar projects in the future.

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