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Hydrolink

Developing chinese fish passage: testing and simultation technology

By Xiaogang Wang, Yun Li and Nanbo Tang

To balance the environmental conservation and economic development, ecological issues have received the attention of the Chinese Government. In November 2012 the Chinese Government proposed the concept of "ecological civilization", which focused on the continued development of humankind in the future. The main idea behind ecological civilization is to respect and maintain the ecological environment, based on sustainable development. Subsequently, a series of acts and regulations on hydropower development and ecological and environmental protection were issued, where aquatic ecosystems conservation is important.

These acts and regulations include the notice on "Further Strengthening Environmental Protection in Hydropower Construction", which was issued by the Ministry of Environmental Protection in 2012 and restated that "hydropower projects must include fish passage construction".

The revised Fisheries Law of the People's Republic of China, issued in 2013 by the Standing Committee of the National People's Congress, stipulated that "fish passages must be provided on segments of rivers where dams, locks and other water-blocking structures have already been built".

The notice on "Deepening the Implementation of Eco-environmental Protection Measures for Hydropower Development" issued in 2014 by the Ministry of Environmental Protection and National Energy Administration, requires that hydropower development "fully demonstrate the fish-passing methods and earnestly implement fish-passing measures".

The opinions on strengthening the protection of aquatic life in the Yangtze River[10] and on key watershed aquatic biodiversity conservation programs[11] set out requirements for both the construction of fish passages and the ecological protection of rivers and lakes.

The study of fish passages started in China in 1958, but stopped for approximately 20 years from 1980 to 2000. Since 2000, due to the gradual strengthening of environmental protection policies, the significance of fishways in restoring river connectivity has been emphasized, a group of new fishways have been planned and designed, and the construction of domestic fishways has entered a new stage. With the rapid progress in the evolution of measurement methods and devices, the base data on fish behavior and life cycle are growing significantly. Fishway physical models and numerical simulations have been developed over the years. This article focuses on the progress in the research on fish passage testing and simulation techniques in China.

The entrance layout is the most important segment in a fish passage, since the fish passage is a kind of needle-eye projection compared to the river width. The fish passage efficiency always is the key measure for the assessment of all fish passages built in China. The hydraulic characteristics around the entrance which affect fish behavior are studied using novel simulation technologies that reveal the details of water flow in this area.

Study on the layout of fishway entrance and exit

Fishways consist of an entrance, a chamber, a resting pool and an exit. The flow of water from the river towards the entrance allows the fish to find their way and guides them to the fishway, which is usually a smaller structure relative to a wide river, usually up to 5 m in width, with the characteristic of "needle-eye", especially obvious for the big river[5]. Therefore, it is of vital importance to locate the entrance of the fishway so that fish can easily find it and enter the channel. The flow outside the fishway exit should be smooth, preferably away from the power station discharge, the entrance of any diversion structures, the exit of diversion channels, and water quality pollution areas, while being able to adapt to changes in upstream water levels to ensure that a certain depth of water is maintained[7] during the fish passing season.

The layout of the fishway entrance is optimized mainly on the model of the entire project, in combination with two-dimensional numerical modeling, which can be used to analyze the flow characteristics of the fishway entrance and exit during the main fish passing season, to get to know even the possible migration path of target fish populations.

Accumulation of energy in the pool and entrance flow conditions

The change in water depth between entrance and exit affects the flow rate distribution in different chambers of the fishway. If the water level of the entrance is lower than the design water level, then the water depth near the entrance will be shallower than normal and the amount of energy consumed by the pond will be insufficient, and will result to flow energy accumulation and excessive flow velocity in the lower depth pond. If the entrance water depths are higher than normal, then the velocities near the entrance will decline, which will make it hard for fish to find the entry[9]. In order to solve this problem, it is usually necessary to establish a model of part of the fishway (which was named 'quasi-whole' fishway model in China) with more than 100 stepped pools (if the number of pools is too large, the cost of the test increases, and otherwise it may be difficult to simulate the accumulation of insufficient energy dissipation effects). The model can be used to study the phenomenon of energy accumulation of the flow in the channel, and to analyze the quantity of water filling for higher flow around the entrance.

To address the effect of flow energy accumulation in the fishway pool and the changes of the water flow conditions at the fish entrance, the entire (or part of) fishway model is needed to study the overall hydraulic characteristics of the fishway under different water levels (flow rate, water surface line, velocity of flow through the orifice and the pool, water level difference between adjacent pools, etc.), verify the velocity of flow in the fishway pool, optimize the number and arrangement of fishway entrances and exits, the slope of the fishway, and pool size. Especially for fishways with large variation of the water level at the downstream end of the fishway, researchers need to adjust the number and layout of entrances to adapt to the water level, analyze the need for auxiliary water, and determine the size of appropriate auxiliary water systems, location of the water supply pipe, the flow rate and the layout of energy dissipation facilities, etc. The scope of an entire (or quasi-whole) fishway model simulation usually includes the entire length of the fishway, the plant fish attraction system, and fishway entrance and exit. The model scale can be selected between 1:10 and 1:40 depending on the specific local conditions[7].

Flow conditions in fish passages channel

Flow conditions in the fish passage are mainly related to the arrangement of the partitions in the fish passage pond. The purpose of the baffle is to divide the total water head into segments with smaller water heads to control the flow velocity under the fish swimming speed and adjust the flow patterns to help the fish find the next exit and continue moving upstream. There are many factors that affect the flow conditions in the pool, including the water head in an adjacent pond and the volume of the pond[6].

At present, the main methods for selecting the fishway baffle type are partial physical models and 3D numerical simulations. Researchers use 3D turbulence numerical models to determine the reasonable baffle (plate) arrangement, analyze the water flow characteristics in the pool. The recommended fishway baffle type can be used, and the hydraulic condition can be checked in quasi-whole fishway model tests.

The most commonly used numerical simulation approach for three-dimensional turbulence is the k-ε turbulence model. Large eddy simulation (LES) and the k-ε turbulence model have both been used by Chinese scholars[2,4,8] to study the baffle type and hydraulic characteristics of flow in the pool. 15 to 20 typical pools of the fishway are usually modeled in partial physical tests. The scale of the model can be 1:3 to 1:10. In order to match the swimming characteristics of fish, the velocity, water head, turbulent energy and power dissipation per unit volume between the pools should be controlled.

Fish collection gallery around the tailwater

The hydraulic characteristics of fish collection systems downstream of turbines are also one of the main concerns. The Bonneville Dam fish passage, which was built on the Columbia River in 1938, included the design of a fish collection system downstream the plant, which was used later successfully all over the world. The Hunan Yangtang Hydropower Station, which was built in 1980 in China, was equipped with a fish collection system on the tailwater platform. This fish collection system was also used successfully in China. The reasonable design of the fish collection gallery is significant for fish, as it can help them find their way to the entrance. It is a good example of the type of fish collection systems used in Chinese hydropower stations[6].

Fish collection systems mainly include an inlet, a fish collection channel, and an auxiliary water system. The scale of a fish collection system model can be 1:3 to 1:10. In addition to controlling the flow rate, it is important to avoid reverse currents in the collector channel that can cause fish to swim in the opposite direction and delay access to the fishway.

Fish lift

Fish lifts have been developed at different levels in China and abroad, and their effects on fish protection vary. In some countries, fish lifts have been successfully used as a fish passage. In China, the construction of fish lifts has received renewed attention in the last 10 years[3].

A fish lift may be the only type of fish passage that may be appropriate for high dams. Fish lifts are installed in many high dam projects such as the Laingjiangkou Hydropower Station, the Huangdeng Hydropower Station and the Dahuaqiao Hydropower Station in China. Fish trapping facilities are used to lure fish into a metal cage or flume carrier box, and then fish passing over the dam is achieved by a vertical or an inclined lift. The key to the successful operation of fish lifts is the efficient attraction of the target fish into the cage or box. At present, the injection of continuous attraction flows at entrance is often used. The attraction flow must be obvious and sufficient, and the speed of flow should be based on the swimming ability of different target fish.

Field observation and assessment of fish passage effectiveness

Due to the lack of sufficient fish behavior data, the design of fishways is not well adapted to fish habits and migratory patterns. As a result, the fish are unable to find the entrance or are prevented by unsuitable water flow conditions in the fishway pool. Field observations are perhaps the most direct and effective method to confirm the effectiveness of fish passages, despite their high costs.

Recently Chinese researchers have conducted a series of field observations and assessment of fish passage effectiveness, such as in the Cuijiaying fishway on Hanshui River, Xinglong fishway, Zangmu fishway on Yarlung Zangbo River, Guangxi Changzhou fishway, and Qinghai Lake fishway among others. **Figure 1** and **Figure 2** show these fishways.

Several previously unnoticed problems have been identified that could strongly improve fishway design. For example, after the operation of the turbines , the riverbed downstream of the dam is scoured severely, resulting in the original fish passage entrance elevation that is no longer optimal; water

Figure 1 | Stepped fishway of Shaliu River in Qinghai Lake, China.

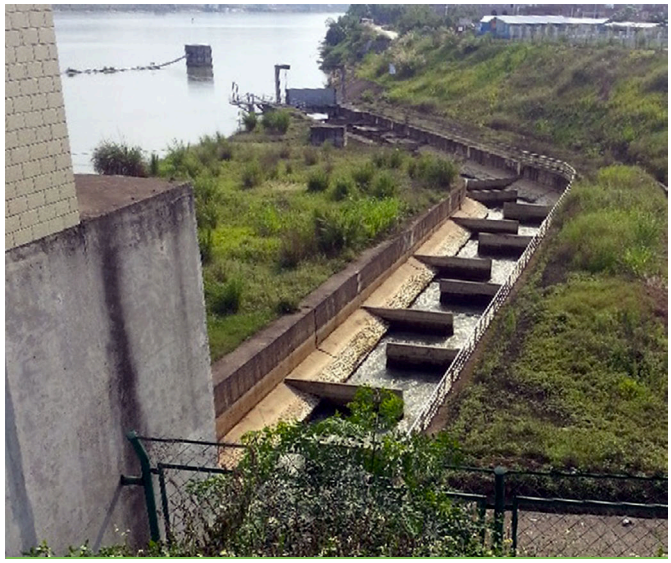

Figure 2 | Distribution of rivers in Zhengzhou.

plants and floating objects can block parts of the entrance into the fish passage; fishermen below the dam set many fish nets to catch fish, and even electrocute fish near the tailwater of the power station. Operational management of fishways should be strengthened[1].

Conclusion

Fishway testing and simulation techniques are advancing in China. The various target fish, hub layout, hydrometeorology, geography and other aspects affecting the design and operation of fishways have been considered. A relatively complete set of experimental simulation methods have been developed. The 2020 revision of the code titled "Guideline for Fishway in Water Conservancy and Hydropower Project" is also underway. More efficient and well-designed fishways are anticipated to be designed and constructed over the next decade.

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