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ABSTRACT

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Fish passages in water conservancy projects are important means of improving river connectivity and reducing the impacts on the ecological environment. Simulating natural fish passage, which repairs the fish ecological corridor by changing the structure and section type of the traditional artificial fish passage similar to a natural fish way, has been promoted and applied in recent years. Furthermore, the hydraulic research on the simulating of natural fish passage has made great progress. In this paper, the structural characteristics and requirements of the key factors that affect the fish's passing through these structures are analyzed by several cases of typical fish passage in China and other countries. The hydraulic problems involved, the determination method, and the interaction rules of the hydraulic essential factor of the simulating natural fish passage are presented in this paper.

Keywords: *Simulating natural passage, hydraulic essential factor, structure character, ecological corridor.*

1. RESEARCH BACKGROUND

In order to make full use of hydropower resources, dams, water gates, and other water retaining structures are built on rivers and lakes for flood control, power generation, irrigation, etc. At present, China has built more than 40 hydropower stations, covering nearly every major river. After the construction of dams and other hydraulic structures in the river, fish habitat environment is changed and fish activity is influenced. With the gradual enhancement of people's awareness of environmental protection, how to ensure the survival and reproduction of fish effectively, and how to balance the dam construction and ecological environment, there is an urgent need for water conservancy projects to consider an ecological study. The fish passage is the facilities constructed for fish, which can help the fish migrate through the dams and restore certain ecosystem function.

Traditional fishway mainly include the weir pool type, hole pool type, and Daniel type. As the engineering measures for the protection of fish resources within rivers, such fishway facilities have a large number of applications. Traditional fishways are designed to fulfill the requirements of the hydraulics, such as certain velocity, depth, and other indicators and use masonry or concrete for construction. Although the flow structure meets the needs of fish, the environment is far different from the natural environment, which led to ecological integrity declining. Therefore, the efficiency for fish passing was poor, which led to some of the fishway being abandoned.

Simulating natural fishway comes from the viewpoint of ecology. They are designed based on the fish habits, hydraulic characteristics, ecological protection, and natural river flow characteristics. In order to make fishes passing inside the fishway as similar as possible to the natural river and the migratory habits of fish, it is often used in low head dams.

The principle of simulating natural fishway is setting river tributaries that are similar to the natural river for fish migration through in position near the hydro-junction or other suitable location. Generally, at the bottom of the fishway, sand, gravel, and pebbles are used ups and downs to form the rough bottom slope. Soil, wood, vegetation, and rocks are used to form a curved slope surface of the fishway. Ecological gabion with natural materials, stone, or rock ridge are used to form a contraction section to control the flow, and a deep pool and shoal shape are used to

simulate the natural rivers or streams with abundant variety of slope as far as possible. Therefore, the channel has the character of "twists and turns, pool and shoal, fast and slow, deep and shallow."

Simulating natural fish passage in a fishway is a part of its ecological restoration function, and it compensates for the part of the water environment lost due to the water storage by the water reservation. After the natural materials at the bottom of the channel and the slope of the passage were eroded and nutrients transported by the water, stone clearance was filled with sand and aquatic organisms, which began to generate new benthic and planktonic communities to form places available for fish habitat, migration, and breeding. Therefore, imitation of natural fishway can not only realize need for fish migration as a traditional fishway, it can also effectively protect the ecological continuity and integrity. It has a strong ecological effect and has gradually become the new trend of fishway construction.

2. RESEARCH STATUS AND DEVELOPMENT TRENDS

In Europe, history of fishway building comes from 300 years ago. In 1662, Bearn province, which lies in southwest France, had enacted provisions to build passage for fish to up and down through the weir dam, and some simple fishway were built. From the end of 19th century to the beginning of the 20th century, Belgian Denil did long-time research on the rough chute and invented the Denil fishway, which is still in use today. In 1938, the first large-scale modern fish passage with a fish collection system in the world, the Bonneville dam on Columbia River in the United States, was built. After that, many more fishway were built: the fish lift, fish gate, fish collection boat, etc. According to incomplete statistics, by the early 1960s, there were more than 200 fish facilities in the United States and Canada, more than 100 in Western European countries, 18 seats in the former Soviet Union, and 67 seats in Japan in 1933. In the late 19th century, the number of fishway increased sharply; North America had nearly 400 seats; In Japan, it was more than 1400 seats. The highest is the North Branch Dam fishway (water head 60 meters), and the longest fishway is Brazil's Itaipu fishway (full-length 10K m). With the increasing awareness of environmental protection, more and more fishway projects were built at present [1].

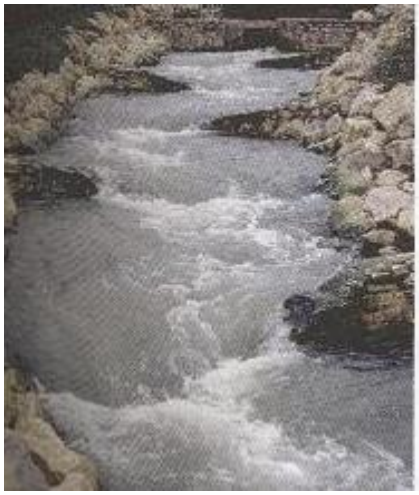

Figure 1. Natural Bypass Channel for Salmon in Loue River

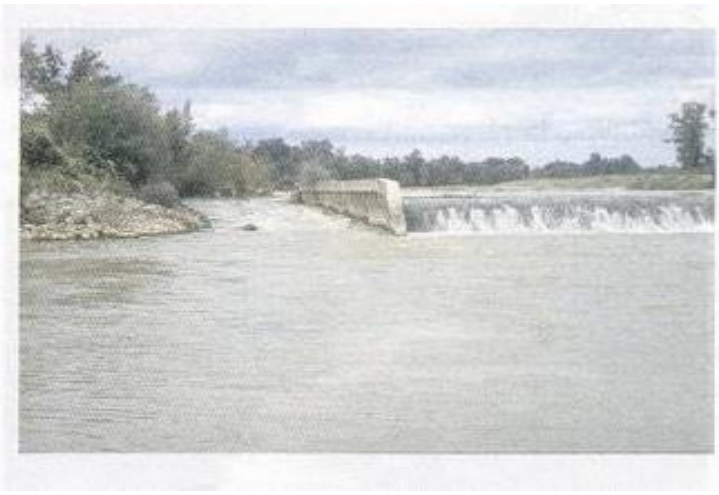

Figure 2. The Natural Bypass Channel for Shad the Adour River

In China, the first fish way is built in the Qililong Station in Fuchunjiang Rive in Zhejiang province in 1958. In 1960s, more than 30 fishway were built in Heilongjiang and Jiangsu province, such as the Liyu Port, the Doulong Bay, the Taiping gate, and so on. Up to year of 2000, water conservancy with all kinds of fishway is more than 40 in China. After the 1880s，a lot of research work was done for the protection of Chinese sturgeon before the construction of Gezhouba Water conservancy in the Changjiang River, but eventually, the artificial breeding and stocking method was chosen to solve the migration problem of rare fish such as sturgeon. After that, facilities for fish

were no longer considered when building the dam in all the rivers of China, which almost led to stagnation of fishway research work in the next 20 years [2].

A lot of research work has been done on the fishway by several major research institutes and universities in our country. Xingyong Wang and Jun Guo summarized the fishway research and construction of the domestic and foreign country. Zhiyong Dong studied the hydraulic characteristics of ipsilateral vertical slot fishway by a large-scale fishway model, investigated the response of fish to different flow, and proposed the ipsilateral vertical slot fishway the improvement measures. Qinglei Cao did a lot of study on the hydraulic properties of fishway by the style of vertical slot in opposite side, including the fishway flow, velocity, turbulence, kinetic energy, shear stress, etc.; almost all the hydraulic characteristic value impact on fish were comprehensively studied. Li Bao did research on the layout and structure of the corner of vertical slot fishway, and the results show when a "L" shaped baffle structure is settled in the curve of rectangular channel, it will form a better flow field for fish migration needs

Environmental protection in hydropower projects is a process of continuous development. In recent years, research on the imitation natural fishway is increasing. Imitation natural fishway is typical technology in line with the principle of harmony between man and nature. Germany, Switzerland, Finland, Australia, Japan, and other countries have carried out more practice since its inception. For example, the simulating natural fishway in Itaipu Hydropower Station meets fish migratory and spawning demands very well and improves fish spawning environmental condition downstream of the dam. The Antonio Santo project, Brazil, in the construction, also includes the imitation natural fish passage to reduce the damage to the environmental condition for fish. The natural bypass channel of the salmon in the Loue River in Germany, and on the natural bypass for the West herring in Adour River in the southwest of France, all have good effect on the ecological continuity [2].

In China, Shuangke Sun did some research work on an environment-friendly natural fishway. It was found that compared with traditional engineering fishway, the imitation natural fishway has higher efficiency of fish passing due to the environmental condition familiar to fish. He did a comprehensive study on the design concept, type, structure, design principles, and hydrodynamic calculation method of imitating a natural-type fishway. Guang Nian Yu and Yian Wang, by the means of the 1:20 model test, did the research on imitation natural fishway of low head hydropower station. By series of optimization experiments on the structure of the pool, they got the plane layout of the imitation natural fishway suitable for low head hydropower station in China. Yu Yang did research work on the ecological landscape function of fishway, introducing the idea of enhancing connectivity in ecology in the river by taking hydraulics and ecological hydraulics into account in the process of fishway design, which builds the fishway not only meet the requirements of the fish migration, but also to increase the requirement of connectivity of the ecological landscape [3][4].

3. CLASSIFICATION AND STRUCTURE CHARACTERISTICS OF THE IMITATION NATURAL FISHWAY

In this paper, according to the width and depth of the section and the internal structure, fish passage is divided into two kinds: wide–shallow shape and narrow-deep shape. Under normal conditions, when the space is adequate and the water head is low, it is more suitable to choose shallow-wide shape because it can meet the needs of the structural characteristics of imitation of natural fishway itself and flow condition needs the of fish. However, with the improvement of the consciousness of environmental protection, before the construction of hydropower station in some river with rich fish resources but the channel is relatively narrow, also called for the construction of the imitation of natural fishway, so the width of fishway is restrict by overall arrangement and quantity, thereby formed a deep-narrow shape cross section.

Shallow-wide shape imitation natural fishway are generally divided into pool-shoal type and roughness ramp type. Pool-shoal type fishway with step structure to form the pools and shoals, in steep short channels or shallow shoals formed by low weir, velocity is higher, and the pool is on the contrary, the higher the water level between the two adjacent pool, the bigger the velocity of the shoal between the pools. The velocity of shoal must be less than the rush speed of small fish, and the velocity in the pool should be in continued speed range of fish (showed in Figure 3). The roughness ramp type is constituted by a long chute, as shown in Figure 4. It can be divided according to the boulder

stacking rules regular piled and loose piled the block stone architecture, loosely stacked rubble structure and boulders staggered structure.

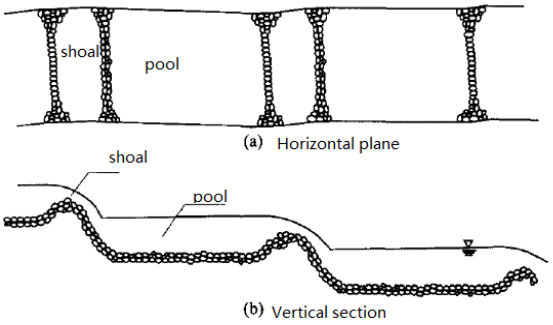

Figure 3. Pool-Shoal Type

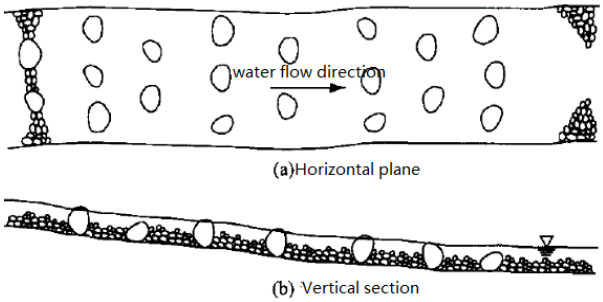

Figure 4. Roughness Ramp Type

Due to the water depth, the hydraulic characteristics of the flow are influenced by the change of the side wall, which leads to the change of the longitudinal and transverse distribution of the velocity. If the target fish is a single population, the swimming ability difference is small, so creating suitable condition is a little easier, but for the construction of the imitation natural fishway in the rivers with rich target fish population for migratory, it is more difficult to build an imitation natural fishway and meet the need of winding characteristics and a variety of fish migration flow requirements.

In order to solve this problem, a full investigation to the characteristics of the target species is required in order to know the parameters of fish populations, such as migration period, individual size, population size, behavior rules, and ecological requirements. Then by screening, classification and analysis, to determine the object of study and its requirements on flow, and then begin to study on the narrow deep fishway hydraulic. By fully understanding and grasping the flow structure, to find out the key factors that influence the structure of flow, and summarized the rules, then to optimize the size to make a channel to meet the target population migration needs.

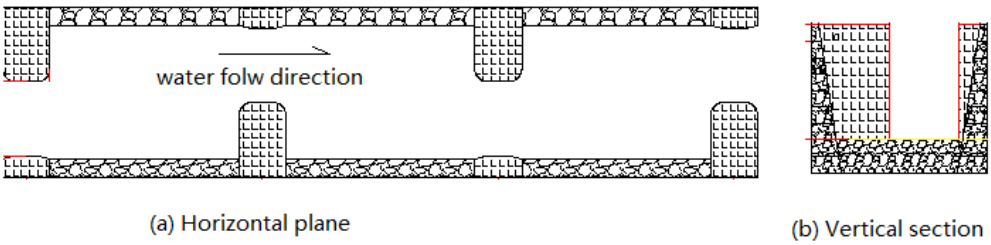

Figure 5. Deep-Narrow Type Simulating Natural Fishway

Preliminary results of the study show that the hydraulics characteristics structure of deep-narrow type fishway is generally affected by several parts, as shown in Figure 5. First of all, it is the shape and area of the contraction section. A bayonet is provided at a certain distance in the pool to forming flow contraction, to increase the internal resistance of the fishway, and to improve pool flow conditions. Bayonet in imitation natural fishway is a key factor that controls the flow and fall of the fishway, and the velocity of the contraction section is one of the most important hydraulic indexes of the fishway and should be controlled below the critical velocity of a fish. The area of the contraction section should not be too big or too small; on the one hand, if it is very small, velocity is relatively large, and if it is too big, the decrease of the fishway resistance will be declined and the flow, velocity, water drop, the volume dissipation rate index, will increase then it is unable to form a suitable flow environment. Therefore, the area of contraction section is one of the most important indexes of fishway hydraulic conditions.

Secondly, the length of the pool room. As water flows, passing through the contraction section and going into the pool room, the flow section becomes wider, so water flow will diffuse laterally due to the narrow section. During the diffusion process, the mainstream encountered two side walls to reciprocate so as to achieve water environment as

"twists and turns, pool and shoal." The length of the pool is the main factor to determine whether the flow can make full diffusion. If the pool room is too short, number of the bayonet will be increased, it will not only cause the loss of the project cost, but also can cause the flow diffusion insufficiency, which the effective water flow environment will not form. On the other hand, if too long, water drop between two pool rooms is too large, which will result in the flow velocity in bayonet too high, so the length of the pool room is an important indicator decided the flow conditions in the fishway.

Finally, it is the energy dissipation facilities in the pool and the bottom roughness. Narrow-deep imitation natural fishway, tend to cause concentrated velocity, auxiliary facilities for energy dissipation can be settled in the pool, which size and the position will decide the effect of energy dissipation, and the bottom roughness type will play a role in changing the flow field character.

For this kind of narrow and deep type imitation-natural fish passage, the water flow structure variety abundant and easy be affected by the figure of the side wall, the flow field is very complicated, and the related research is still in the initial stage, so it lacks reference experience for the layout of the internal structure at home and abroad.

4. EVERIMENTAL AND NUMERICAL STUDY ON DEEP -NARROW TYPE SIMULATING NATURAL FISHWAY

In this study, a deep-narrow type simulating natural fishway in Changjiang River is investigated by a 1:5 physical model. The fishway is designed to fulfil the needs of plenty of fish. The bottom velocity should be below 0.5m/s, and middle and surface velocity should not above 1.5m/s. The demand condition is critical, and former experiments have shown the velocity in contract section and bottom can't meet the demand.

After a series of modifications, an optimization plan is proposed by setting different configure of section along vertical direction to make the flow structure changing along the direction. Furthermore, the flows at different altitudes can impact and mediate each other, and so the small fish can get a friendly bottom passage to pass the fishway, and larger fishes can get though from the middle and surface of the fishway. Velocity distributions measured during experiments and numerical simulations are presented below.

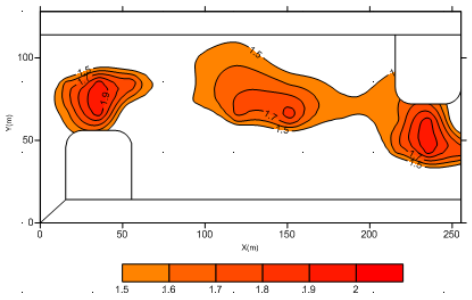

Figure 6. surface regions where velocity above 1.5m/s

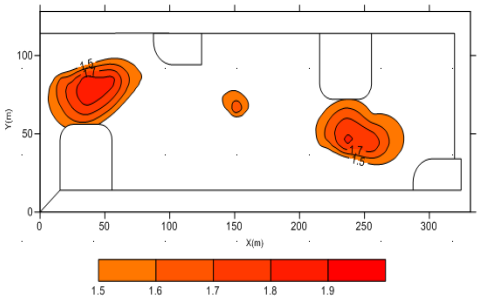

Figure 7. middle regions where velocity above 1.5m/s

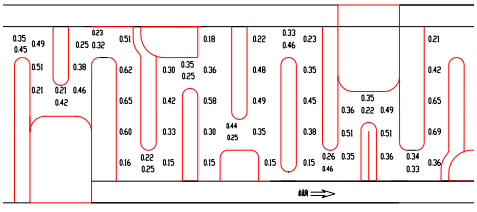

Figure 8. measured bottom velocity

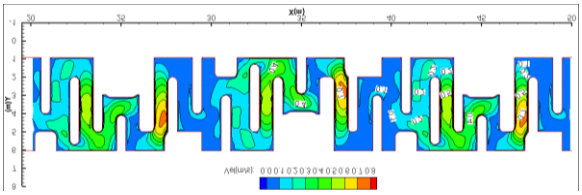

Figure 9. bottom velocity contour got by numerical simulation

5. EXISTING PROBLEMS AND PROSPECTS

Although there have been some achievements of imitation natural fishway research that can be applied in engineering, there are still some problems in need of further study:

Compared with the traditional fishway, the structure of the imitation-natural fishway contact with ecology more closely, so the investigator not only needs to understand the relevant knowledge of hydraulics, but also needs to master biology-related knowledge and the ecological corridor related to environmental art, which belongs to the diversity and complexity.

Generally, the traditional imitation-natural fishway is wide shallow type, but this kind of fishway calls for more area and higher requirements for the layout of the hydraulic structures. The deep-narrow type has good adaptability, but the fishway flow field is more complex and easily affected by the side wall and the internal structure. Researching how to layout the internal structure reasonably and forming a theory system that can be recognized in the industry and engineering application is the main goal for narrow-deep imitation natural fishway research work.

Like the traditional fishway, imitation-natural fishway is still faced with problems of sediment deposition. Sediment deposition is the main cause of abandoned fishway both at home and abroad. Therefore, while studying on simulating natural fishway, research on reducing the sediment deposition siltation should be in advanced by means other than the old way of repairmen after construction.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] LI Shengqing, DING Xiaowen, LIU Daoning, Overview of Nature-Simulating Fishway [J], Yangtze River, 2014.11:70-75

[2] ZULHASH U M，MAEKAWAK, OHKUBOH. Tumbling flow in steeped weir channel fishway[J]．Resources and Environment in the Yangtze Basin, 2001, l0(1)：60-67．(in Chinese)

[3]SUN Shuang-ke, ZHANG Guo-qiang, Environment-friendly flshway in close-to-nature types[J], Journal of China Institute of water resources and Hydropower Research,Vol.10 no.1 March. 2012:41-47

[4] WANG Xing-yong，GUO Jun. Brief Review on Research and Construction of Fishways at Home and Abroad [J], Journal of China Institute of water resources and Hydropower Research,Vol.3 no.3 Sept. 2005:222-228.