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Analysis of Hydraulic Characteristics of Vertical Seam Fishway

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Abstract: ***Vertical seam fishway is a kind of efficient crossing channel to meet the migratory needs of fishes. It has the characteristics of simple structure, strong ability to adapt to water level changes and good energy dissipation effect. It is also the most common crossing engineering facilities at present. The facility simulates the environment of a natural waterway, providing a safe path for fish and guiding fish to their destination, thus reducing the impact of water conservancy projects on the ecological environment. Its hydraulic characteristics have an important influence on the smooth migration of fish. Through research related literature, this paper briefly introduces the development of vertical tunnel in home and abroad and development status, organize and analyzes the vertical tunnel research method and research progress, and discusses the development trend of the future, in order to optimize the structure of tunnel design and ensure the efficiency of fish facilities.***
Keywords: vertical seam type fish path; hydraulic characteristics; fish path; numerical simulation; physical model test research

I. INTRODUCTION

With the rapid development of social economy, people's demand for irrigation, flood control, power generation, shipping and other functions is increasing day by day. In order to meet a series of requirements, a large number of water conservancy projects have been built on rivers, including embankments, canals, reservoirs, DAMS and hydropower stations[1]. The country with the highest number of reservoir DAMS in the world is China[2], Data from the 2022 National Statistical Bulletin on Water Conservancy Development, At the end of 2022,China has built 96348 sluices, including 957 large sluices with a flow of more than 5 m 3 per second; the total number of reservoirs is 95296; the number of existing rural hydropower stations is 41544[3]. The connectivity of rivers is also seriously affected by the construction and operation of hydraulic structures such as reservoirs and DAMS, thus blocking the migration channel of fish, causing the fragmentation of fish habitat and reproduction, destroying the survival and reproduction environment of fish, and even threatening to destroy the ecosystem of rivers[4]-[9]。

In order to solve the problems of fish reproduction and river ecosystem caused by the construction of water conservancy projects, a series of fish facilities such as fish channel can be built to connect the river. There are many types of fish paths, such as Daniel, weir flow, orifice, vertical seam, combined and imitation ecological fish paths[10]-[11]more common. Among them, as a special fish channel design, vertical seam fish channel[12]Through a series of vertical gap structures, fish can provide a safe and smooth migration path, with good energy dissipation effect, and strong adaptability to large water level changes. In the arrangement and size design of the gap, the width of the gap is usually moderate, which can not only ensure the passage of water flow, but also prevent large fish from straying. At the same time, the depth and spacing of the gaps are carefully calculated to ensure that the flow speed is moderate and does not cause excessive impact on the fish. Therefore, it is very important to ensure the migration conditions of fish, protect the ecological balance, and explore the hydraulic characteristics of the fish path.

II. THE DEVELOPMENT PROCESS AND RESEARCH STATUS OF THE FISH ROAD AT HOME AND ABROAD

A. Foreign Development and Research Process

In the 1660s, the concept of the fish path was first mentioned abroad. In 1662, southwest France (Ben) issued the construction of a passage on the weir dam for fish to migrate up and down[13]-[14]. However, the early exploration and construction of fish passage did not carry out scientific research on the scientific basis, and was more similar to the natural state[15]-[16]. The definition of fish path is mentioned in many the provisions of foreign regions. In 1842, Ireland passed the Fisheries Act, which provided that fish tracks must be built on levee dams to effectively pass fish such as salmon, but there are no specific fish track specification requirements[17]. In 1968, the Government of Canada stressed the need for the existence of fishing lanes[18]. In 1883, Scotland completed the Huri Dam Fishway[19], To become the world's first fishway.

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However, his lack of field investigation, coupled with the lack of design and research experience at that time, so that the fish road was abandoned, so this attempt ended in failure[20]. Due to the shortcomings in the design, operation and management, the lack of research on water conservancy and fish biology, the hydraulic conditions are poor, and the efficiency of passing fish is not high, so the fish path is gradually abandoned. In the 20th century, with the increasing demand for flood control, power generation and irrigation, water conservancy also tells us to move forward, the contradiction between the construction operation of water conservancy projects and ecological balance becomes more and more prominent, the demand for fish facilities also increases, and people pay more and more attention to the research of fish path. In 1909, Belgian engineer Daniel (Denil) after years of exploration, systematic research, independently developed a kind of close spacing in the groove wall and bottom of the resistance plate and bottom to reduce energy deceleration, called "Daniel type fish"[21]-[23], And spread it around the world. In 1938, the Bononnville Dam, built in the United States, is the world's first modern large fish road with a fish collection system[24]. In 1946, the Canadian building (Hill's Gate) symbolized the birth of the world's first vertical seam fish path[25]. Based on the approximate estimate of the number of fish facilities at that time, by the early 1960s, there were more than 200 in the United States and Canada, the number of Western European countries was more than 100, the former Soviet Union had more than 18, and the fish lanes were the main fish facilities[26].Among them, there are the Palton Dam and the North Branch Dam (North Fork) Fish Road in the United States, and the Pitlohri Dam (Pitlochry) in Britain, etc[27]more famous. By the end of the 20th century, the construction of fishways had increased significantly, with nearly 1,400 in Japan and about 400 in North America[28].Among them, the well-known examples are the estuary weir in Nagoragawa, Japan, and the Itaipu hydropower station on the Parana River in Brazil[29]. In addition, foreign lanes mainly through Atlantic salmon[30], Trout[31], Japanese fragrant fish[32], such as high economic value of the fish species, the fish object is relatively single[33]. At present, the fish road construction in most parts of European and American countries has formed a complete system because of its rich research experience.

B. Domestic Development and Research Process

In China, the time of fish research is relatively backward, mainly focusing on precious fish, carp fish, shrimp and crab seedlings and other fish objects. The research began in the 1960s[16],[20],[27],[31]. The development and research process of domestic fishway can be roughly divided into three stages: initial development period, basic stagnation period and secondary development period[34]. In 1958, when the researchers conceived the layout of the Fuchun River Qililong hydropower station, the concept of fish road was first mentioned in China, and the designer investigated the water ecological environment through physical model tests[20][27]. In 1960, China built China's first fish road near Xingkai Lake in Anhui province, called the New New Willow Fish Road[35]. Then in 1962, the carp Port fish Road was built, and in 1966, the Dulong Port Fish Road was built[36]. In 1980, the Nanyang Pond fish Road was built in Hunan province[37].

Although the fish road did not run, it also greatly promoted the process of fish road design and research in China. In the early stage of development, China conducted a preliminary study on the relevant content of fish facilities, and successively built more than 40 fish lanes[20],[27],[31],[36].

The construction of these fish paths is mainly designed and constructed according to foreign standards and fish path forms. In addition, there are deficiencies in technology, capital, management and maintenance and other aspects, and almost all the fish paths are very low utilization rate in the years after completion. In the 1980s, Gezhouba water conservancy project selected proliferation and release[38]. The measures to deal with the protection of rare fish and have achieved some effect. In addition, the operation effect of the fish path built in China is not satisfactory, so the research of the fish path in China has fallen into a basic standstill and lasted for more than 20 years.

Despite the new approach, the fish back-migration instinct cannot be changed[39], So the problem of fish conservation is still not fundamentally solved. In the 21st century, the construction of water conservancy projects in China has made rapid progress, the relevant laws and norms of fish facilities have been further improved, and the construction of fish road has entered the second stage of development. China successively built Changzhou water conservancy hub fish, Hubei Han river Xinglong water conservancy hub fish, Han Cui camp fish navigation and power hub project, Guangdong even Jiangxi cattle shipping hub project fish, Sichuan Dadu river pillow dam hydropower station, valley hydropower station imitation natural fish, shaping secondary hydropower station, Jilin plump Yongqing reverse regulation reservoir imitation natural fish, etc[40]. Not only that, China has also compiled relevant water conservancy technical standard documents, such as "Fish and Fish Road Design Guidelines for Water Conservancy and Hydropower Projects"[41]. And Code for Design of Fish Crossing Facilities in Hydropower Projects[42]Etc., promoted the construction and development of the fish road[40]。

III. ANALYSIS OF HYDRAULIC CHARACTERISTICS OF VERTICAL SEAM FISH PATH

In the current domestic fish path type, the most widely used is the vertical seam fish path[5],[27],[43],[44]. The flow of water in the vertical seam fish path is complex and changeable, both laminar and turbulent. Therefore, in order to optimize the design of the vertical seam fish channel, it is crucial to study and analyze its hydraulic characteristics.

A. Research method of hydraulic characteristics of vertical seam fish path

Nowadays, the domestic and foreign research scholars through the physical model test, numerical simulation and the combination of a variety of methods and means of vertical seam channel flow, velocity distribution, flow and depth change characteristics of the influence of research and analysis, in order to realize the ideal flow rate and flow, to fish on migration, for the design of the tunnel, optimization[45]. physical modelling experiment[46]. It is the most traditional research method to adjust the geometry, relative position and size of each part of the fish tunnel, and to explore the change of water flow conditions under different boundary conditions. And numerical simulation[47]. The mathematical model and computer numerical calculation method are used to establish the control equation describing the motion of water flow, and solve and analyze the Hydraulic parameters combined with appropriate initial conditions and boundary conditions, such as separation vortex (DES) model, PNG κ - ε model, and large vortex simulation (LES) model[45] And 3D CFD model[48]class.

B. Research progress on the hydraulic characteristics of vertical seam fish path

At present, a lot of physical model tests and numerical simulation studies have been carried out on the hydraulic characteristics of vertical seam fish path. Studies have shown that[49], the flow velocity distribution in the vertical seam has significant non-uniformity, and the flow of the upper, middle and lower layers of the vertical seam fish channel and the flow velocity distribution show obvious stratification phenomenon, and have certain similarity. The upper and middle flow rates are large, and the flow velocity of each water layer is similar, and the underlying flow velocity is less affected by friction resistance. At the same time, the flow velocity distribution also shows a certain rule, the flow velocity of the inclined guide board near both sides is small, but a drastic change; the flow velocity at the center of the vertical joint section is large, and the change is relatively gentle[50]. And Rajaratnam et al[51] comprehensive and in-depth analysis. The distribution characteristics and rules of the flow field are studied systematically. Wu S class[52] conducted on the flow velocity field, the results show that when the channel inclination is less than 5%, the horizontal flow velocity in the pool is obviously higher than the vertical flow velocity, and the flow velocity shows the characteristics of two-dimensional distribution in the horizontal direction. With the increase of the inclination, when the inclination changes to 10%~20%, the water flow structure shows three-dimensional characteristics.

The upstream migration effect of fish is influenced by the flow state of the fish channel pond chamber and the area distribution of the back flow area[53], the mainstream flow of different water depths is the best[54]. And Tarrade et al[55] through PIV (Particle Image Velocimetry) was used to study the effect of the change of pool chamber aspect ratio on the fish channel flow characteristics, and to change the pool length or pool width and slope. In 1992, Rajaratnam et al[56] through the exploration and analysis of the vertical seam fish channel of 18 different flow field structures, it is found that the internal structure size of the fish channel will act on the water flow state. The ideal scheme is the length and width ratio of the pool chamber is 10:8. Dong Zhiyong et al[57],[58]. In the study of the vertical seam fish path, it shows that the same side vertical seam fish path is normally distributed in the area near the vertical seam, and away from the vertical seam, the flow rate of the wall seam jet is close to the wall jet in the front half of the pool, which is similar to the Gaussian distribution, and the mainstream of the pool is "S" type curve. The study of Xu Tibing et al[59] showed that the water flow in the aspect ratio from 8:8 to 10.5:8 is good. Zhang Yu et al[60] 's hydraulic characteristic parameters of different fish channel pond chamber and vertical joints, including water flow structure, flow velocity distribution and back flow area distribution, are quantitatively analyzed.

IV. THE DEVELOPMENT TREND OF THE VERTICAL SEAM FISH PATH

A. Multi-disciplinary, interdisciplinary research development and cross-disciplinary integration

The in-depth research and extensive application of vertical seam fish path will provide valuable experience and important reference for the planning, design and construction of various water conservancy facilities. Comprehensive and thorough analysis of the hydraulic characteristics of vertical seam fish path, and its influence factors are fully considered, a series of universal design criteria and optimization schemes are summarized, giving beneficial enlightenment and professional scientific guidance to the design and construction of other water conservancy projects.

At the same time, in the follow-up research and application process, vertical seam path should focus on strengthening the cross integration of multiple disciplines, such as water conservancy engineering, fish behavior, ecological hydraulics, etc. With the help of multi-field crossover research, we can more fully understand the comprehensiveness of vertical slit fish tunnel research, and provide more effective solutions for solving practical problems.

B. Numerical Simulation, Experimental Studies, and Field Observations, the Deep Fusion

The deep tight fusion of numerical simulation, physical model test research and field observation promote the research field of hydraulic characteristics of vertical seam fish path to a new height. Numerical simulation methods are used as a powerful means to simulate and predict water flow states and fish behavior in the fish channel. The validity and accuracy of these models also need to be verified by physical model tests and field observations, so as to play a key role in validating the numerical simulation results and optimizing the model parameters through experimental studies. Through continuous verification and improvement of the optimization model, the flow situation in the fish path and the rules of fish activities are more thoroughly understood, so as to provide scientific and reliable support basis for the planning, design and optimization improvement of the vertical seam fish path.

C. New Materials, New Process and Technology Innovation

The planning layout and practical application of vertical seam fish path can effectively promote the development and breakthrough of related industries, and build a more complete, prepared and sound industrial pattern and ecological circle. With the help of new materials, new processes and other innovative technological measures, such as the use of new environmental protection materials to build vertical seam fishway, enhance the durability and stability of vertical seam fishpath, effectively reduce the maintenance cost, so as to further expand the application field and market development space of vertical seam fishpath. In addition, it actively explores and develops the cutting-edge technology of vertical seam tunnel, continuously optimizes its design scheme and actual operation effect, and strengthens the safety, stability and high efficiency of the tunnel operation. Through innovative exploration and research practice, further promote the development of in-depth research on vertical seam fish tunnel hydraulic characteristics, and provide more practical and effective measures for the protection of the ecological environment and the help of fish migration.

D. Development of Intelligent Monitoring and Management System

Carry out the research and development of intelligent monitoring and management system, to realize the intelligence, accuracy, real-time and safety of the channel management and monitoring, improve the channel parameters, the precision and efficiency of regulation. At the same time, the vertical seam fish channel operation will be more intelligent, efficient and rigorous. The real-time monitoring and regulation task of fish tunnel hydraulic characteristics can be completed by adopting advanced monitoring technology and numerical analysis model. Or sensor technology can use real-time monitoring to provide a strong guarantee for the operation and management of the fish track. Joint application of new materials, developed a highly intelligent, highly automated fishway management system, to achieve the goal of remote monitoring and intelligent control, improve the management efficiency of vertical seam, make the fishway safer and more stable.

V. CONCLUSION

In a word, as an eco-friendly water conservancy fish crossing facility, the vertical seam fish path has broad prospects for development and research work. As the global economy continues to develop, people's awareness of environmental protection is also strengthening. With the requirements for the construction of ecological civilization, more and more countries and regions will pay attention to the protection and restoration of fish resources. Through continuous optimization of design and application, the vertical seam fish tunnel will provide a safer and more convenient channel for aquatic organisms, and make greater contribution to the sustainable development of water conservancy projects. Although the research on vertical seam path has been greatly improved, there are still many areas for the construction for a long time, so as to optimize the design and operation of vertical seam path and improve the efficiency of over fish.

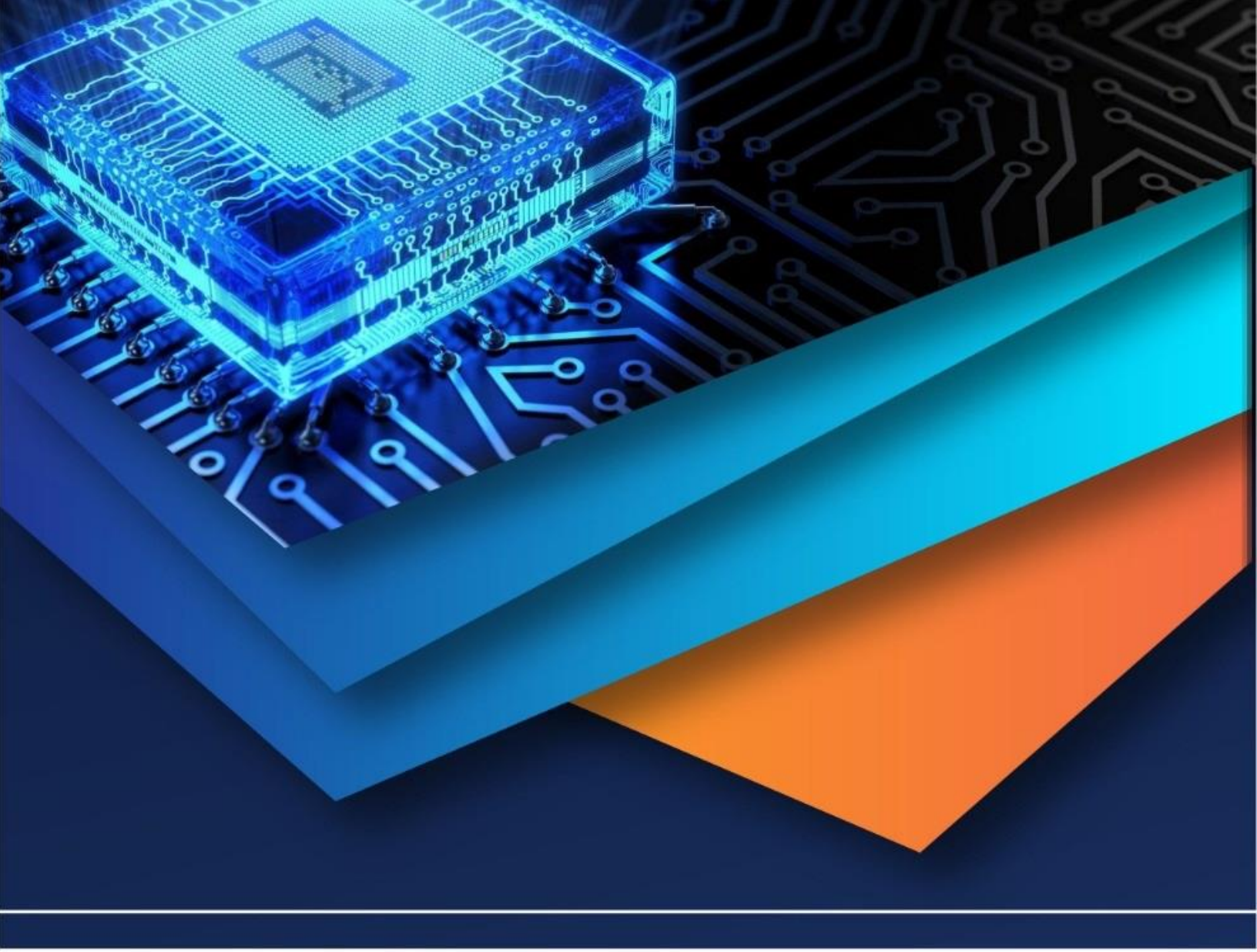
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