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Study on drainage outlet layout of step water arresting weir

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Abstract

In the north of China, the method of cascade water barrage is usually used to improve the river ecological environment, but the construction of cascade water barrage will cause negative impact on the river. In order to reduce the negative effect, it is necessary to arrange the drainage outlet.

Keywords

Step weir, Back, River connectivity.

1. Introduction

The construction of cascading weirs brings benefits to the river but also negative impacts, such as blocking the free migration of fish and greatly affecting the connectivity of the river ecosystem. Wu Junjun et al[1] mentioned in their research on the design of imitation natural fishway that in order to create a better ecological landscape, the construction of fixed weir or movable weir on natural rivers may hinder the migration of fish and cause degradation of the quality of commercial fish. Han Mengjun[2] mentioned in the analysis of the impact of river sluice on river ecology and the discussion on operation optimization that during the construction of river sluice, there are no fish channels, which will cause migration and reproduction difficulties of aquatic organisms. Therefore, it is suggested to add fish channels. Based on the above background research, this paper proposes the layout of the drainage outlet of the stepped water retaining weir, and carries out experimental research, in order to provide the basis for similar design.

2. Hydraulic model test

2.1. Model device condition

According to the model specification, gravity similarity criterion was adopted to construct the test model according to the geometric scale of 1:30. The model size is: river length 6m, river width 0.3m, slope 1:2000. And set the energy dissipation device, submersible pump and other components of the self-circulation system, so that the water flow into the river when the state of stability.

2.2. Test plan

2.2.1. A water test

In this experiment, the main objective is to observe the flow pattern change, and the test water depth is measured by the water level needle. The river entrance was set as the origin point, and the section between 1.25m and 5.25m from the origin point was selected as the test section in this experiment. In the test section, there are five water-retaining mounds with a height of 16.6mm, an interval of 1m, and a length of 26.6cm. The outlet is set on the same side of the water-retaining weir.

2.2.2. Fish test

In this fish experiment, grass carp was selected as the research object with 90 samples and a body length of 4.5±0.5cm. Three groups of experiments were conducted. Before the test began, tap water was first injected into a $3m^3$ square pool, and the dissolved oxygen concentration in the pool was measured by aeration for 7 days. The dissolved oxygen concentration in the pool was kept at 6.5mg/L, the water temperature was 22℃, and the ammonia nitrogen concentration was controlled below 0.01 mg/L. The test was carried out under indoor natural light. And stopped feeding for the first two days of the trial.

First open loop system, under the action of water pump, let the water from the tank through a pipeline, through energy dissipation device to initial water, and then start from the initial flow water flow through the bottom of the channel model to reservoir, such as the circulatory system running time of more than 100 s, the model in the depth of the water is no longer change, when measuring water temperature and dissolved oxygen content in the equivalent channel model, Ensure that the dissolved oxygen content in the water is greater than or equal to 6.5 mg/L, and confirm that fish still remain active in the channel model. After recording the external factors, in order to avoid the boundary influence in the reach, we set the test section at a distance from 1.25m to 5.25m from the origin. We put the fish in the test section at a distance from 4.25m to 5.25m from the origin and closed the fish barrier. At this time, the fish in the test could not complete upstream behavior. Remove the fish trap after the test fish have acclimated. In order to avoid the influence of the front and back boundaries, we will test the fish through the middle three weir, and the tracing time within 5min is considered as the tracing success. With waiting for the test fish through the distance to the origin of 4.25 m of the discharge opening, start time, the test through the distance to the origin of 2.25 m in decorate with fish sink after stop timing, do back long time record at this time, if test fish after the start time, more than 5 min river is still not up to par, remember back failed. Then calculate the success rate of up-tracing under each scheme, and the formula is as follows:

$$S_C = \frac{S_T}{S_Z} \tag{1}$$

Where, S_C is the upward tracing success rate of the fish used in the experiment; S_T is the number of fish successfully traced in each group; S_Z is the total number of fish in each group.

3. Numerical simulation

3.1. Mathematical model

In order to better analyze the flow, this paper establishes a mathematical model through numerical simulation software. The model in this study belongs to the turbulent flow of incompressible fluid, and the turbulent flow model is mainly divided into K -ε model, RNGk-ε model and Realizable K -ε model[3-5] . The RNGk-ε model is used in this paper.

3.2. The governing equation

The governing equations include continuity equation, momentum equation, K equation and equation.

3.3. Meshing and boundary conditions

In this numerical simulation, a 0.4cm×0.4cm×0.4cm Cartesian grid was selected, and an encrypted grid was selected near the outlet. Boundary conditions are as follows: there is an initial water level at the origin, and the inlet shall be set as the Specified pressure; Outflow Outflow will be set as Outflow boundary; The upper part of the model is set as Symmetry with no fluid passing through. The bottom and sides of the channel are set as the fixed Wall boundary.

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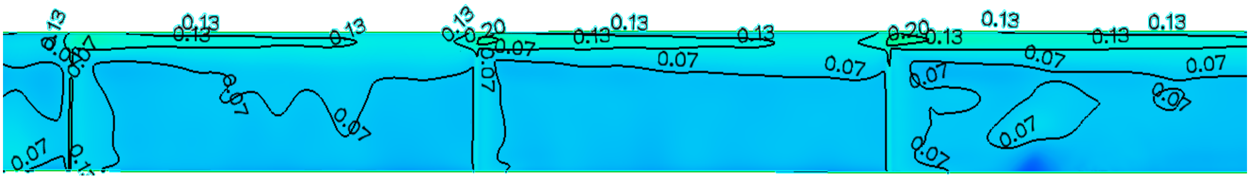
4. Result analysis

4.1. Model analysis

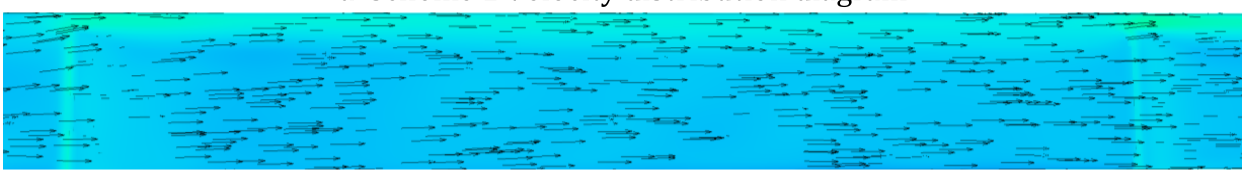
When carrying out CFD simulation, it was found that the change of water flow tended to be stable after the model was simulated at the time of 80s. However, in order to ensure the accuracy of the results, we took the simulation results after 100s for analysis. In this paper, the water depth calculated by numerical simulation of scheme 1 is compared with the water depth measured by measuring needle in physical experiment to verify the results of numerical simulation. Through the analysis of the water depth comparison table, the maximum error of the comparison between the measured value and the simulated value is 13.8%, which is lower than the allowable error value of 15%[6]. Therefore, the simulation results are verified and can be analyzed for the numerical simulation results.

4.2. Flow field analysis

Through the analysis of the simulation results, when the water flows from the upper reach to the next reach, the water suddenly shrinks before entering the drainage outlet, and then diffuses in the next reach. Because the drainage outlet is arranged near the pool wall, the water can only diffuse in the non-pool wall direction, and the side near the side wall is the mainstream area. When the water flows through the outlet, the flow line continues to shrink under the action of the inertia of the water flow, forming the contraction section with the smallest water depth in the downstream of the outlet, and the current velocity is the maximum velocity through the outlet. In scheme 1, the flow velocity in the mainstream zone is distributed in 0.13-0.22m /s, and the average flow velocity is 0.18m/s. In the observed reach, the area with flow velocity greater than 0.12m/s accounts for about 10% of the reach area, and the non-mainstream zone is located between the mainstream zone and the approximately static water zone. The velocity of non-mainstream area is about 0.06m/s-0.12m/s, accounting for about 25% of the reach area, while the area of near-static area is larger, and the velocity is less than 0.05m/s, accounting for about 66% of the reach area.



a. Scheme 1 Velocity distribution diagram



b. Scheme 1 Flow rate trajectory diagram

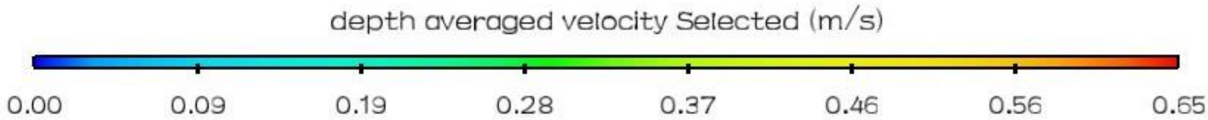


Fig. 1 Surface velocity field

4.3. Fish test results

The results of fish passing test are shown in the following figure and table:

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Table 1 Number of grass carp passing under different working conditions

plan	Total mantissa	Successfully passed mantissa	Pass rate
Scheme 1	30	18	60%
Scheme 1	30	19	63.33%
Scheme 1	30	19	63.33%

It can be seen from Table 1 that in scheme 1, the upward tracing success rates of experimental fish are 60%, 63.33% and 63.33% respectively, thus the average upward tracing success rate of experimental fish in Scheme 1 is 62.22%.

5. Conclusion and Discussion

In this paper, through the METHOD of CFD simulation calculation, the layout of drainage outlet on the stepped water barrier was analyzed, and the following conclusions were obtained:

1. The average upward passage rate of fish is 62.2%, which proves that it is feasible to improve the river connectivity by arranging drainage outlets on the stepped water barrier, and provides upward passage for migratory fish represented by "four major fish";

2. Fish in scheme 1, the mainstream area and non-mainstream area of the reach are clearly differentiated, and the flow rate at the outlet is within the range of fish induced flow rate, proving that the flow rate field at this time is suitable for fish upstream.

The drainage outlet arranged on the cascade water barrier can not only improve the connectivity of the river, but also provide upward passage for migratory fish. However, the relevant research is still in the research stage. This paper only studies the influence of drainage outlet arrangement, and does not carry out a detailed study on the drainage outlet type.

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