Advances in Environmental Biology, 8(25) Special 2014, Pages: 370-374

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/

Flow Simulation in the Orifice and Weir Fishways (Case Study: Diversion Dam of Karkhe)

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ARTICLE INFO

Article history:
Received 13 September 2014
Received in revised form 26 November 2014
Accepted 25 December 2014
Available online 15 January 2015

Keywords:
fishway, environment, orifice and weir, simulation

ABSTRACT

Since the construction of dam can have negative effects on the environment, and given the importance of protecting the environment and preserving aquatic ecosystems that live in rivers, fishway is a structure that allow fish to go upward the dam section and provides fish with quick access to their habitats and reduces the negative effects of dam construction on the environment, but most of the fishways built in the world have not enough performance. This problem can be seen in Iran even considering the low number of this structure. Given the importance of providing measures of designing to enhance the performance of the fishways type weir and orifice, in the study, the fluent model was used to simulate the hydraulic behavior of the flow by applying different geometric and hydraulic conditions. The results showed that when fish passes the orifice, the safest route is the inner edge of the orifice that lower speed occurs in the non-submerged orifice. Also in the middle of pool the minimum speed has occurred.

To Cite This Article: Rouholah Alipour and Ebrahim Nohani, Flow Simulation in the Orifice and Weir Fishways (Case Study: Diversion Dam of Karkhe). ***Adv. Environ. Biol., 8(25),*** *370-374, 2014*

INTRODUCTION

If there is a barrier for fish when moving toward the upstream, it will not stop the movement and continues the effort and it will succeed to cross the barrier and move upward or it will be lost. However, small and large dams constructed on the river impede fish and cause its death behind the dam and extinct various species of fish that one of the ways to reduce the damaging effects of dams and preventing the extinction of species of fish is constructing proper fishways for fish to pass the dam section. This is subject to the proper design and then proper implementation of the fishway. In designing different species of fishways, some points should be observed until the fishway function properly and the fish can overcome the height difference of the river at the dam site and pass it [1]. Many studies have been done on hydraulic characteristics of fishways and immigrant fish behavior. Recently, studies have shown that the water velocity and turbulence can play a fundamental role in the successful passage of fish through the fishway [2,5]. In the natural waterways, during migrating to upstream, fish mainly use constant and long speed and sometimes moves with explosive speed to overcome high speed areas such as chutes [3]. Identifying the types of migratory fish, the amount and size and their migration season are biological information necessary for designing a fishway. Fish behavior is also important in choosing the type of fishway so that it has been identified that some fish prefer a type of fishways than other types. The maximum water flow through the orifice should not exceed tan the suicide speed. The speed is too high that the fish can swim in less than 15 seconds in the opposite direction. The main limitation of fishway is the pool and narrow range weir of the operating flow [4]. Increasing the discharge, flow regime in the fishway of pool and weir varies from the immersed flow to skimming flow.

MATERIALS AND METHODS

In this study, the flow pattern in the fishway type orifice and weir was stimulated in Karkhe diversion dam (located in Hamidieh) in Khuzestan province. Each pool in the fishway is a length of 25 m, width of 3 m and a height of 75 cm that is made of reinforced concrete and it is able to provide a constant flow by a system of internal rotation. Fishway bed slope is 27.4%. The orifice and weir fishway has 11 pools, one of which is 4

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meters long and the remaining 2 meters. The ponds are in a submerged orifice and in the form of zigzag. Two consecutive orifice and weirs are placed in front of the wall section that creates a sinusoidal current path. (Figure 1)

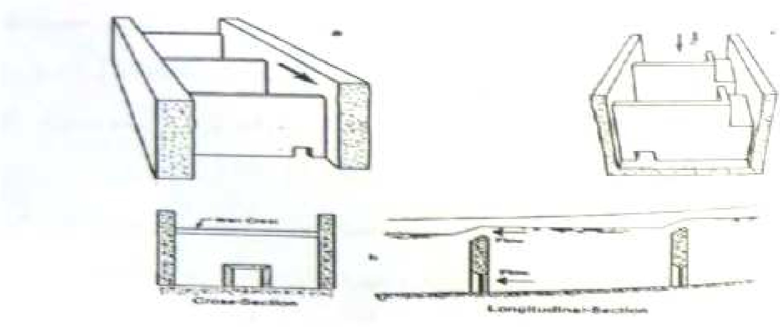

Fig. 1: View of Karkhe diversion dam fish way.

Micro Mooline was used to measure the speed. Measurements were done in different horizontal plates and parallel to the floor (in depth of 20 cm and 60 cm), a network of 150 points as reference for measuring on each plate for each fishway pool. For each point, the average speed is (V_{med},U_{med}) and the maximum speed (U_{max}, V_{max}) that are the velocity components in the direction of X and Y. To calculate the horizontal component of the Reynolds shear stress, to determine the velocity fluctuations (V', U') for axis X and Y were defined according to the following equation:

$$U' = U_{max} - U_{med} \quad (1)$$

$$V' = V_{max} - V_{med} \quad (2)$$

Because in this type of fishway, discharge is controlled in weir so the fishway discharge will be estimated using a wide edged weir as follows:

$$Q = 1.984 * C * L_W * H^{1.5} \quad (3)$$

L_W= Length of the weir crest that is in fact the width of fishway pool (m)
H = water prolapse in each pool (m), which is usually assumed to be 0.3.
C = coefficient of weir and equals to

$$C = \tfrac{2}{3} * C_d * \sqrt{2g} \quad (4)$$

in which
C_d= Coefficient of flow rate

Coefficient C_d is a function of water level over the spillway (H_d) and the breadth of weir in the direction of flow (B_W).

Average rate in pools have presented almost identical figures (for non-submerged orifice).

Average velocity in the pool No. 7 $V = \frac{11.584}{24} = 0.482$ m/sec

Average velocity in the pool No. 5 $V = \frac{11.161}{24} = 0.490$ m/sec

Average velocity in the pool No. 4 $V = \frac{11.256}{24} = 0.469$ m/sec

The flow rate in the fishway plays an important role in attracting fish [7]. They show the differentiation of fish and various abilities to understand the changes in the aquatic environment [1]. A discharge can be proper for a given group of fish and limitation for others. Reynolds shear stress represents a force per unit area and occurs when two masses or several layers of water have velocities parallel or close to each other [2]. In this study, the horizontal component of the Reynolds shear stress was studied as a major factor in the hydraulic design of fish type orifice and weir. The horizontal component of the Reynolds shear stress can be defined as follow.

$$\tau = \boldsymbol{\rho} \,.\, u' . ' \mathbf{v} \quad (5)$$

Where ρ is the water specific gravity, U' and V' are fluctuation velocities in X and Y.

The maximum speed of water on the weir or inside the orifice should not exceed the high speed of fish passage. Suicidal rate is a so high swimming rate in which fish can continue in less than 15 seconds. Average maximum speed on the weir and inside the orifice in designing the fishway for mature salmon is considered 2.5 meters per second.

DISCUSSION AND CONCLUSIONS

After simulation of the fishway of Karkheh diversion dam and determination of the conditions and hydraulic specifications of speed lines were drawn (Figure 2). Speed vectors as well as turbulence contours are also stimulated in the fishway (Figure 3 and 4). As can be seen, in front of the orifice (when it is not submerged) the speed is relatively high. Especially in the outer margin of the orifice the maximum speed has happened. For fish, it seems that motion in the fishway is done without major problems. The average speed of the water in the pool 4 is more than 25% of the capacity of the fish swimming.

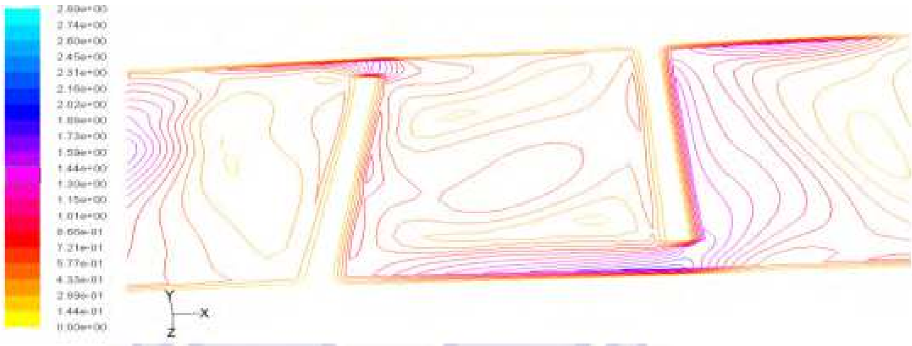

Fig. 2: Speed lines in the fourth fishway pool.

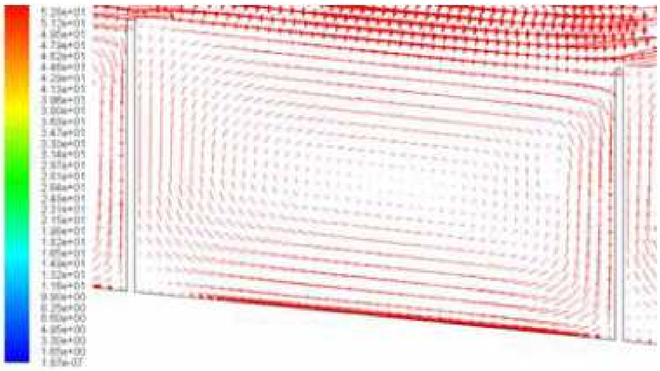

Fig. 3: Velocity vectors in the fishway pool.

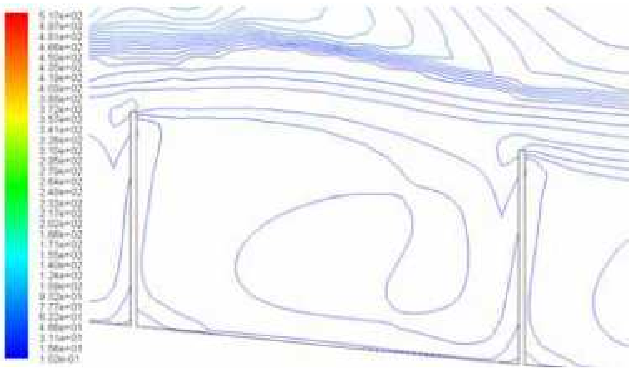

Fig. 4: Contours of turbulence intensity.

As can be seen, for pool No. 4 the flow height in the pool was increased, so that about 5 cm of water was discharged from the weir. Usually, the minimum speed occurs in the middle of the pool. Meanwhile, the average rate in the submerged state shows an acceptable figure. In most cases, fish is remained in areas with low Reynolds shear stress, as it is found in areas with low average speed. In Karkheh River, the aquatic species including Cyprinidae has large swimming capacity which makes ascending in the fishway successful. Fish may prefer areas with low average speed, although average speed may not be the only hydraulic parameter appropriate for explaining the behavior of the fish. The horizontal component of Reynolds shear stress field with low values was specified for two discharges (Fig. 5).

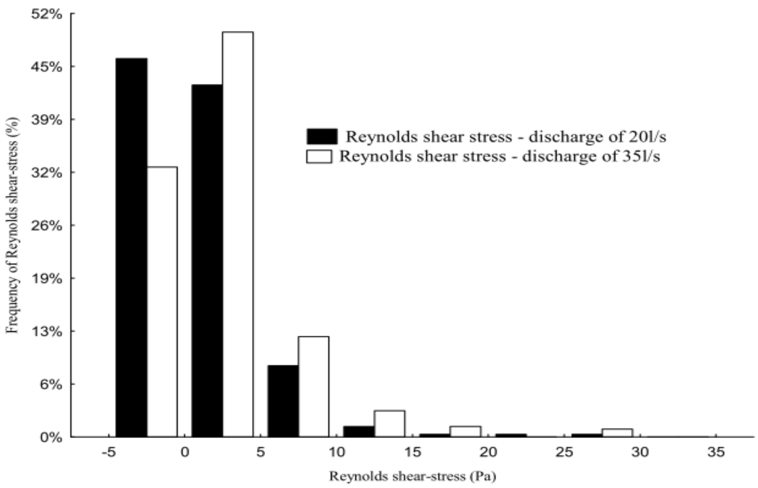

Fig. 5: Reynolds shear stress for discharge 20 L/S and 35 L/S.

Based on these observations, fish may be attracted to swim in areas of low Reynolds shear stress, although in it the average speed is high. Areas with low Reynolds shear stress can be a less chaotic environment that can increase the performance of swimming. According to studies of the fishway, it was found that fish has left for more time in areas of low Reynolds shear stress that was evaluated for both flows. Fish avoid areas with high Reynolds shear stress. Furthermore, fish has often left in area in front of the orifice on the right side of the pool. Otherwise, the fish could use areas in which the flow velocity was reduced, where the fish can take refuge from the mainstream, and the operation of the flow rate decreases. Fish remains more time in areas with low average velocity field (Fig. 6 and 7).

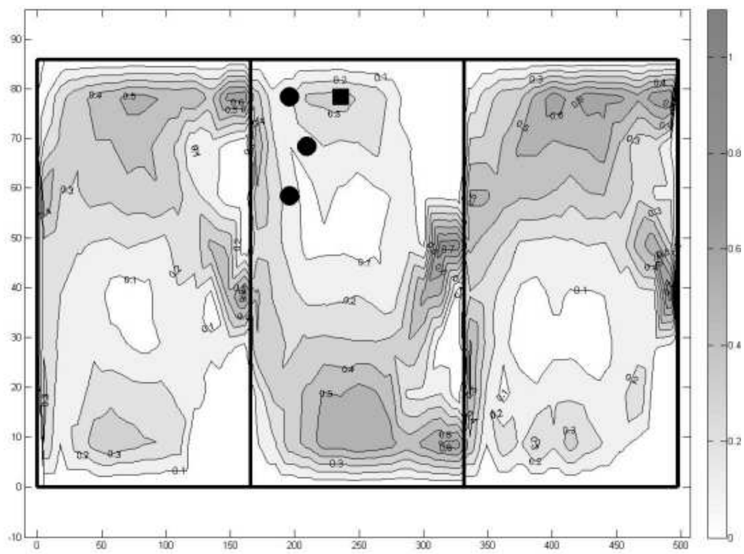

Fig. 6: Average velocity field for discharge 20 L/S.

Conclusions:

In this study, the weir-orifice fishway of the Karkheh diversion dam was simulated. It was observed that at the place, the speed reaches 1.6 and even 1.8 m/s. The speed is close to suicide rate. At the orifice input to the pool (upstream orifice), the speed is higher than the outlet orifice. This means that at the upstream of outlet orifice, velocities were about 0.6 m/s which are a tolerable figure for fish. The safest route for fish passage is the inner edge of the orifice and speed is lower at non-submerged orifice. Areas with low Reynolds shear stress have a promising appearance to attract some fish species. By providing a more stable environment and slope, the

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speed is lower. At the submerged orifice, at low depths, lower speeds are observed makes the fish passage from the bottom binding.

Water velocity is an important parameter for the success of the fish in the fishway, because the flow rate can affect the movement of fish. In facing the speed obstacles, fish choose its pass from one area with a lower flow rate, or from an area in which the flow rate is much lower than swimming ability.

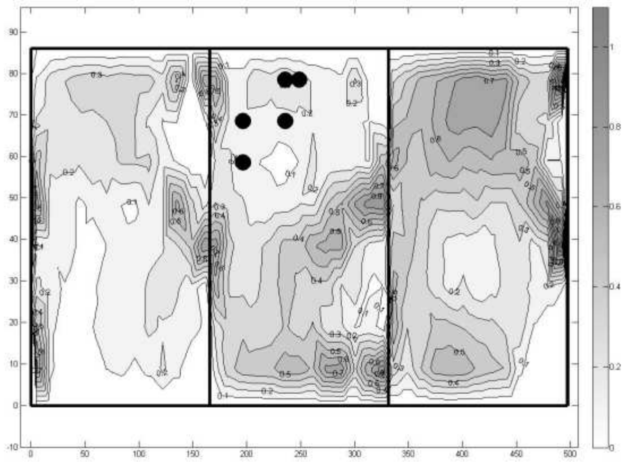

Fig. 7: Average velocity field for discharge 35 L/S.

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