Three-Dimensional Analysis of Flow Velocities through a Large Pool Fish Pass in the Trzebuńka Stream [†]

Kamil Suder ^{1,*}, Karol Plesiński ¹ and Artur Radecki-Pawlik ²

¹ Department of Hydraulic Engineering and Geotechnics, Faculty of Environmental Engineering and Land Surveying, University of Agriculture in Krakow, al. Mickiewicza 21, 31-120 Kraków, Poland;

k.plesinski@ur.krakow.pl

² Division of Structural Mechanics and Material Mechanics, Faculty of Civil Engineering, Cracow University of Technology, ul. Warszawska 24, 31-155 Kraków, Poland; rmradeck@cyf-kr.edu.pl

* Correspondence: kamil.suder2@student.urk.edu.pl

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Abstract: This paper presents the hydrodynamic parameter values of a large pool fish pass joined with block ramps in the Trzebuńka stream. The aim of this work is to evaluate the large pool fish pass patency in terms of fish and to answer the question of whether fish migration upstream is possible. The assessment of hydrodynamic parameters was carried out on the basis of water flow velocity measurements using a flow tracker device and by calculating the following parameters: Water depth, shear stresses, and Froude's and Reynold's numbers. Velocity measurements were carried out in 23–30 hydrometric points which were determined in each of the pools. A survey was done using the Topcon GTS-226 (Topcon Corporation, Tokyo, Japan) total station. The data were processed in order to obtain the results of hydrodynamic parameters prevailing in flowing water. The graphs were prepared using the Grapher 11 software, showing the distribution of individual hydrodynamic parameters for fish pass chambers and overflows in the fish passage. We concluded that the fish pass in Stróża was designed and constructed correctly. However, from a technical point of view, some deficiencies could be found.

Keywords: large pool fish passage; boulder block ramp; hydrodynamic parameters; mountain stream

1. Introduction

Fish migration is considered one of the most important stages of a fish's entire life cycle. When individuals grow, the type of food they assimilate changes, and they migrate in search of a new feeding ground rich in the food they absorb [1]. Technical hydraulic construction in watercourses hinders all attempts of fish to migrate upstream. Dams and weirs crossing the entire width of the river bed create an obstacle impossible for aquatic organisms to overcome. For this purpose, fish passes and boulder block ramps are built [2,3]. Currently, it is obligatory in many countries to build fish passes parallel to hydraulic structures, to regularly check their technical condition, and, if necessary, to revitalize and repair them. This allows their functioning time to be prolonged and allows aquatic organisms to freely overcome these hydraulic structures [1,3,4].

2. Aim of the Research

In this paper, the hydrodynamic evaluation of a large pool fish pass built together with the boulder block ramps in the Trzebuńska stream was analyzed and presented. The scope of the work covers hydrodynamic and geometric measurements of the object.

3. Description of the Research Object

The catchment area of the Trzebuńska stream is a part of the Beskid Średni, which belongs to the Western Beskids macro region, which is located in the Western Outer Carpathians [5]. The Trzebuńska drainage basin is administratively located in the Lesser Poland voivodship, Myślenice district. The research object, which is a large pool fish pass constructed together with the boulder block ramp, is located in the Stróža village. The research object is a combination of two main hydraulic structure elements. In the central part of the structure is a fish pass which consists of 12 pools, each of which are about 2.2 m long and 6 m wide. On both sides of the fish pass there is a boulder block ramp, constructed with boulders (height $k_{\text{Smean}} = 6$ cm, $k_{\text{Smax}} = 13$ cm) and put in to the concrete plate. The block ramp is 3.1 m wide on one side (Figure 1).

Figure 1. The check dam before being rebuilt in 2012 (A) and the new large pool fish pass (central) together with the boulder block ramp (sides) after rebuilding in 2016 (B).

4. Material and Methods

4.1. Field Measurements

Field measurements were carried out in order to measure the size of the structure and the point velocity values using a Flow Tracker hydroacoustic meter. The Flow Tracker is used to determine the flow rate in open channels and natural river channels using the one or multi-point velocity measurement method [6]. It determines the average velocities in individual hydrometric divisions. Velocity measurements and water depth were carried out in 23–30 hydrometric points in each pool of the fish pass (Figure 2).

Additionally, the same hydrodynamic parameters were measured in all the overflows. The structure was surveyed using the Topcon GTS-226 (Topcon Corporation, Tokyo, Japan) total station. The measurements were carried out for low flow water conditions ($Q = 0.1 \text{ m}^3 \cdot \text{s}^{-1}$) and medium flow water conditions ($Q = 2.0 \text{ m}^3 \cdot \text{s}^{-1}$).

Figure 2. The arrangement of hydrometric verticals in the fish pass chambers (pools).

4.2. Study Measurements

The graphs were produced in the Grapher 11 software (Golden Software, LLC, Golden, CO, USA), showing the distribution of individual hydrodynamic parameters for the fish pass chambers and overflows. Optimal values of hydrodynamic parameters for migrating brown trout (*Salmo trutta*) are as follows: Velocity $V \leq 2.0 \text{ m}\cdot\text{s}^{-1}$ [7] and water depth $h \geq 0.6 \text{ m}$ [8]. The optimal geometric parameters of fish pass chambers (pools) are as follows: Pool length $> 1.0 \text{ m}$ [8] and pool width $B \geq 0.8 \text{ m}$ [8].

5. Results

Hydrodynamic conditions for the fish pass pool Number 1 are shown in Table 1.

Table 1. Hydrodynamic parameters for the fish pass chamber (pool) Number 1 under different water discharge conditions.

6. Conclusions

The obtained results allowed us to determine the functioning of the fish pass based on water velocity measurements. Field measurements, study work, and analysis of the results allowed us to draw the following conclusions:

1. A check dam in Stróža did not fulfill its task in terms of fish movement, which is why it was necessary to build a fish pass. The fish pass was designed and built correctly. From a technical point of view, some deficiencies can be found.

2. A new fish pass restored the longitudinal continuity of the watercourse, which allowed the aquatic organisms to migrate upstream.

3. Water velocities are following the guidelines and passing design requirements for fish passes. A problem may occur under low flow water conditions, because water depth may drop below the acceptable value ($h = 0.60$ m) for brown trout (*Salmo trutta*). During the low flow, the water depth in the fish pass chambers (pools) is equal from $h = 0.35$ to up 0.40 m—these values may be optimal for small fish (e.g., common minnow (*Phoxinus phoxinus*)).

4. The boulder block ramp, which is built together with the large pool fish pass, has a positive effect on fish migration. During the medium flow, in the central part of the structure (in the fish pass), the hydrodynamic boundary parameters that allow fish to migrate are excessive, especially the values of water velocity on overflows were too high. On the side parts of the boulder block ramp which are located higher than the central part, the parameters are optimal.

5. The water flow which is concentrated in the central part of the fish pass creates a strong attracting current, making it easier for aquatic organisms to reach the inlet of the hydraulic structure.

6. It should be noted that all measurements presented here were done at low and medium water stages. In order to determine if the fish pass is efficient for fish pass movement, it is necessary to perform numerical modeling using different discharge values and perform ichthyologic monitoring during fish migration.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Notation: Q —discharge [$\text{m}^3\cdot\text{s}^{-1}$]; h —water depth [m]; V_x —longitudinal water velocity [$\text{m}\cdot\text{s}^{-1}$]; V_y —across water velocity [$\text{m}\cdot\text{s}^{-1}$]; V_z —vertical water velocity [$\text{m}\cdot\text{s}^{-1}$].

References

1. Lubieniecki, B. *Przeławki i drożność rzek*; Instytut Rybactwa Śródlądowego: Olsztyn, Poland, 2002; p. 83, ISBN: 83-87506-87-7.
2. Radecki-Pawlik, A.; Plesiński, K.; Radecki-Pawlik, B.; Kuboń, P.; Manson, R. Hydrodynamic parameters in a flood impacted boulder block ramp: Krzczonówka mountain stream, Polish Carpathians. *J. Mt. Sci.* **2018**, *15*, 2335–2346.
3. Plesiński, K.; Gibbins, C.N.; Radecki-Pawlik, A. Effects of interlocked carpet ramps on upstream movement of brown trout *Salmo trutta* in an upland stream. *J. Ecohydraulics* **2019**, doi.org/10.1080/24705357.2019.1581102.
4. Radecki-Pawlik, A.; Plesiński, K.; Radecki-Pawlik, B. Rozkład prędkości oraz naprężeń stycznych w komorach przeławki typu wielkokomorowego. *Acta Sci. Pol. Formatio Circumiectus* **2017**, *16*, 149–159.
5. Kondracki, J. *Geografia regionalna Polski*; Wydawnictwo Naukowe PWN: Warsaw, Poland, 2000; p. 442, ISBN: 83-01-13050-4.
6. SonTek/YSI Inc. *Flow Tracker Handheld ADV Technical Manual*; SonTek/YSI Inc.: San Diego, CA, USA, 2007; p. 126.
7. Gebler, R.J. *Naturgemäße Bauweisen von Sohlenbauwerken und Fischaufstiegen zur Vernetzung der Fließgewässer*; Heft 181/1991; Universität Karlsruhe: Karlsruhe, Germany, 1991; p. 55.
8. DVWK, FAO. *Fish Passes. Design, Dimensions and Monitoring*; FAO and DVWK: Rome, Italy, 2002; p. 120. ISBN 92-5-104894-0.

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