The XXXVIII International School of Hydraulics, 21-24 May 2019, Łąck, Poland

Flow and Turbulence Structure in a Vertical Slot–Brush Fish Pass

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ABSTRACT

Vertical-slot fishway consists of a series of pools which are separated by long and short baffles at regular intervals. However, vertical slot fish passes are designed for large fish which have economic value, such as salmon and trout. But, in rivers there are small-bodied and weak-swimming capacity fishes which are also ecologically important. The European Union Water Framework Directive requires to ensure the continuity of those species in rivers in order to ensure good ecological status. In this context, it is necessary to make a structural modification to existing vertical slot fish passes to allow the passage of such small-bodied and weak swimming capacity fish. In the previous studies, impermeable and rigid hydraulic elements were placed in the pools to dissipate the flow energy and prevent turbulence. However, this configuration has caused two different turbulence fields around the obstacles and has not been particularly beneficial for the passage of small fish species. Another technical solution is using cylindrical flexible hydraulic elements as bristles to absorb flow energy which is proposed in this paper. In this design, with the help of the bristle, stagnation intervals are established to transform the hydraulic power of the flowing water and to form resting areas.

The vertical slot-brush fish pass was installed in a rectangular flume with width, height, and length being 2, 0.80, and 8.40 m, respectively and the flume has a bed slope of 4% in the hydraulics laboratory of Kassel University. The water surface elevation was measured by an ultrasonic displacement meter (Sonic Joker) that was mounted above the flow and scanned downwards the free-surface flow. An acoustic Doppler velocimeter (ADV) was used to measure the 3D instantaneous velocity fields for flow rates of 0.16 and 0.18 m^3/s. The height of brush play very important role when taking into account the hydraulic conditions of the water flow through the fish pass. The velocity profile can be divided into two parts: lower velocity profile below brushes level and higher velocity profile above the brushes. However, in the present physical model the velocity data were collected only for bellow the bristles level of h_b=0.47 m and we focused on 2D flow structures in the horizontal plane. Bristle Young's modulus of elasticity is E =0.95 GPa.

In Fig. 1, the velocity fields with and without brush blocks are compared. The flow characteristics start with an intensely turbulent flow in the slot region and change continuously to the calm and less turbulent flow pattern behind the main brush block creating a refuge for fish As can be clearly seen form Fig. 1, when the bush blocks are installed in the pool, jet and recirculation regions disappear and deceleration zones reduced. The experimental results showed that by placing brush blocks in the pool, the flow energy is effectively dissipated by the vibrations and bending of the bristles leading an about 17% reduction in the turbulence kinetic energy. Also, this reduced turbulent kinetic energy zone creates different migration corridors and favorable hydraulic conditions for different fish species. The flow-bristle interaction leads 46% reduction in spatially averaged vertical Reynolds shear stress. However, the horizontal Reynolds shear stress increased by 6.6% which can be due to the horizontal mixing in the vicinity of brush blocks.

Vertical slot-brush fish pass fulfill the requirements of an efficient fish passage by providing tranquil flows and different migration corridors. The main advantage is, that all the parts of this fish pass type can be scaled-up in order to adjust it to almost any demand based on the model test results without extraordinary cost. The bristles as energy absorbers represent a cost-effective option, which can be retrofitted at any time existing structures, to improve the hydraulic conditions in fish passages.

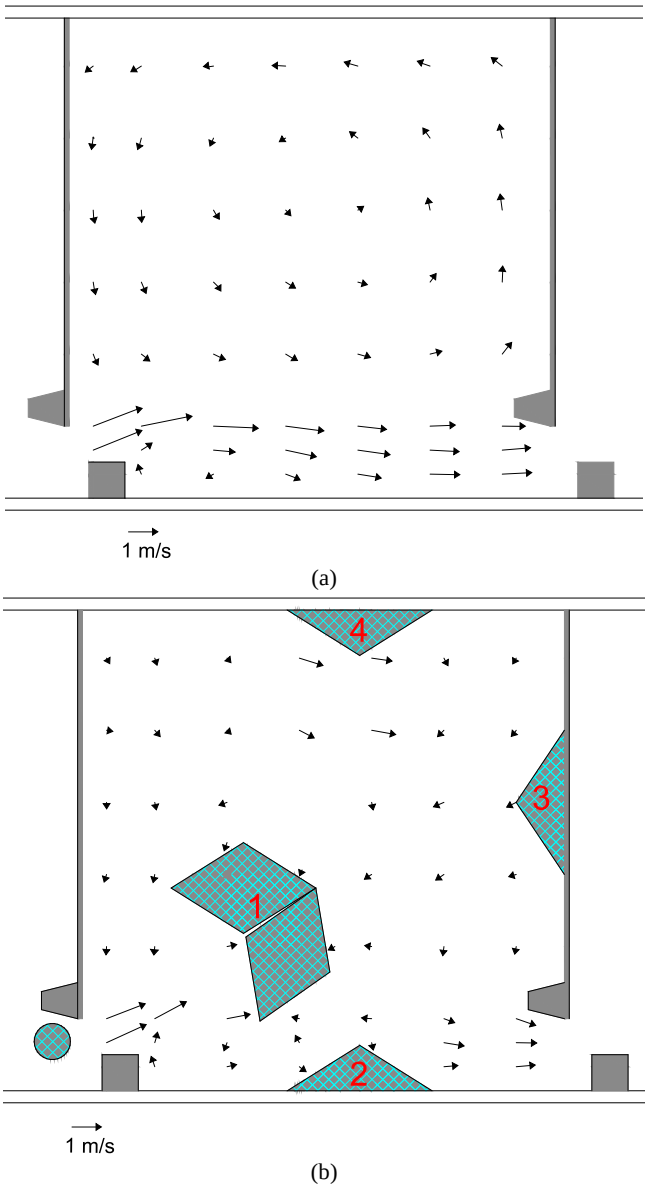

Fig. 1 Velocity field in horizontal plane at z/d=0.32: (a) without brushes, and (b) with brushes in a vertical slot fish pass