ECOLOGICAL INTAKE FOR SAND-LESS WATER SOLUTION FOR RIVER MANAGEMENT

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ABSTRACT

The aim of this paper is the promotion of the Romanian invention called the ecological intake for sand-less water, an intake that do not block the river and do not produce erosions after it. This intake is a device that is naturally incorporated along the river and which allows the transit of the sediments downwards so that the equilibrium of the river is conserved. The main theoretical aspects for the computation of the flow are presented in addition with the experimental results related with the sediment transport. The final results justify the necessity of this intake compared with the old ones.

1. Introduction

The river management is an actual problem to save the wealth of the environment and it can be performed with new types of intakes. All the old intakes block the river course and conduct at the sedimentation inside the intake and both at erosions after the intake. They destroy the river equilibrium continuously. This is why a new kind of intake is a necessity both for the preservation of the river but also for the costs of the intakes [1], [2], [3]. The new simplified construction of the ecological intakes and the natural displacement integrated with nature justify the use of sand-less water intakes [4], [5].

It is presented also a new method used to determine the flow with a surface integral and both with a double sum. These are used to evaluate the flow captured by the ecological intake.

The experiment performed at the Department of Hydraulics, Hydraulic Machines and Environmental Engineering, Politehnica University of Bucharest, lead to the estimation of the solid flow which transits the intake downstream.

The water is no longer clean along the intake, so it produces less erosion after the intake, preserving the morphology of the river.

At the same time, the water which flows to the turbines contains less sediment, which is useful to preserve the turbines of the hydropower station.

The ecological intake for sand-less water assures a transit flow downstream which carries the sediments and satisfies the necessity of other water consumers than the hydropower station.

2. Transit flow computation for the ecological intake

The authors present the calculus of the transit flow used by the downstream consumers which remains after the water passes through the ecological intake.

The affluent flow is the sum between the distributed flow captured by the intake and the transit one which can be used by the consumers downstream:

$$Q = Q_d + Q_t \tag{1}$$

Because the ecological water intake has multiple orifices on both sides, disposed at different depths, on the lateral direction dew to the bank slope and on the longitudinal direction dew to the backwater curve, the total distributed flow captured by the intake will be calculated with a surface integral.

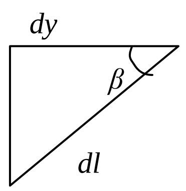
The infinitesimal flow on the unit surface is calculated with the variable velocity as a function of the depth *z*, as in figure 1:

$$dQ_d = \mu V \cdot dS = \mu\sqrt{2gz(x,y)} \cdot dx \cdot dl \tag{2}$$

The infinitesimal area is determined with the length dl because one considers the jet joining at the orifice wall and the medium velocity inside the orifice is perpendicular on the bank slope.

dl can be expressed as a function of *dy* from the triangle in the next small figure:

$$\cos\beta = \frac{dy}{dl} \Rightarrow dl = \frac{dy}{\cos\beta} \tag{3}$$



The infinitesimal flow in this new form is:

$$dQ_d = \mu\sqrt{2g}\,z^{1/2}(x,y) \cdot dx \cdot \frac{dy}{\cos\beta} \tag{4}$$

Because the flow takes place on both bank slopes, as in the previous figure, the total flow through the orifices obtained by integration both with *y* and with *x* is:

$$Q_d = 2\iint_S dQ_d = 2\int_L^0 \Big(\int_{y_i}^{\frac{B-b}{2}+a} \frac{\mu\sqrt{2g}}{\cos\beta} z^{1/2} dy \Big) dx \tag{5}$$

where S is the aria of the orifices of a bank slope, L the length of the intake, $(B\text{-}b)/2+a$ the horizontal width corresponding with the zone with orifices from one bank slope and y_i is given by:

$$y_i = \frac{Ltg\alpha_2}{tg\beta}, \tag{6}$$

a positive value necessary to calculate the integral.

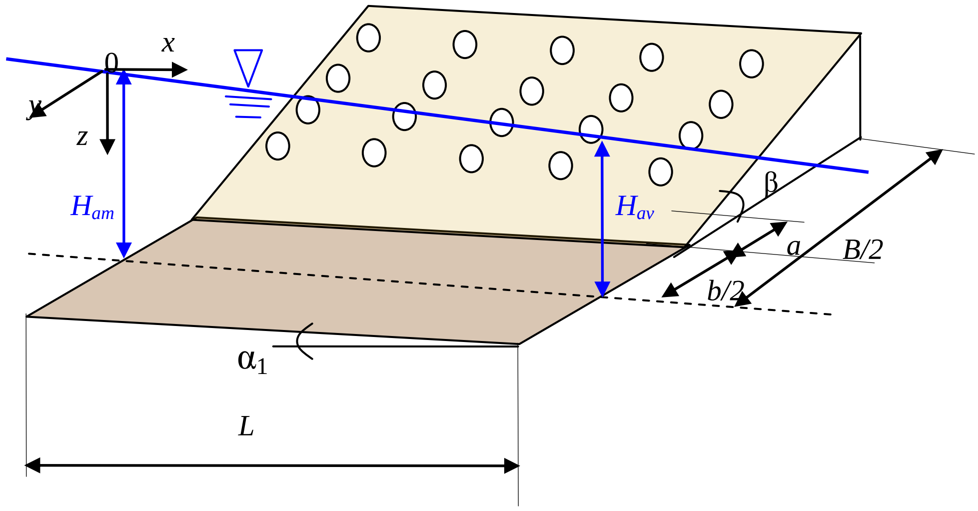


Figure 1. Longitudinal sight through the ecological intake, one bank view

From figure 2 there is obtained the relation of dependence between the variables x, y and z in the case of a fast flow through the intake:

$$ytg\beta = xtg\alpha_2 + z \tag{7}$$

from where the variable z is obtained:

$$z = ytg\beta - xtg\alpha_2 \tag{8}$$

One obtains also from the lateral verticals in Fig. 2:

$$Ltg\alpha_1 + H_{am} = Ltg\alpha_2 + H_{av} \tag{9}$$

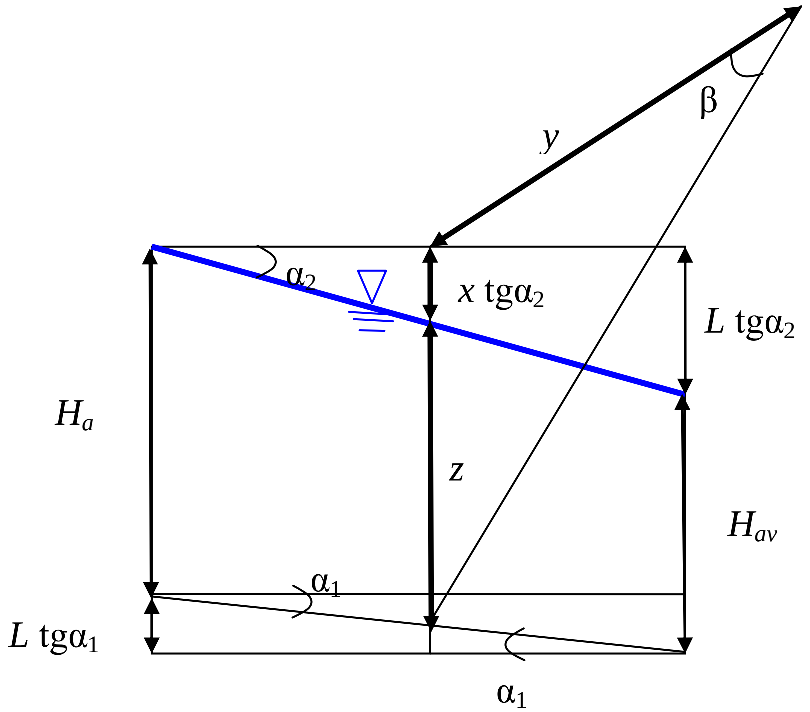


Figure 2. The dependence between the variables *x*, *y* and *z*

If the constants move in front of the double integral and replacing *z* as in (8), the volume flow *Q* becomes:

$$Q_d = 2\sqrt{2g}\mu\frac{1}{\cos\beta}\int_{L}^{0}\left(\int_{y_i}^{\frac{B-b}{2}+a}\sqrt{ytg\beta - xtg\alpha_2}\,dy\right)dx =$$

$$= \frac{8}{15}\sqrt{2g}\mu\frac{\sqrt{tg^3\alpha_2}}{\sin\beta}\left\{\left[\left(\frac{B-b}{2}+a\right)\frac{tg\beta}{tg\alpha_2}-L\right]^{5/2} - \left[\left(\frac{B-b}{2}+a\right)\frac{tg\beta}{tg\alpha_2}\right]^{5/2} + L^{5/2}\right\} \quad (10)$$

Result valid as long as the expression under the first radical remains positive.

The flow captured through discrete orifices can also be computed. While the previous calculus offers a more generally estimation, this kind of calculus can be considered more accurate.

If a limited number of orifices are taken into account, on both bank slopes of the intake, *m* along *Ox* and *n* along *Oy*, as in figure 3, then the total flow captured by the intake is given by:

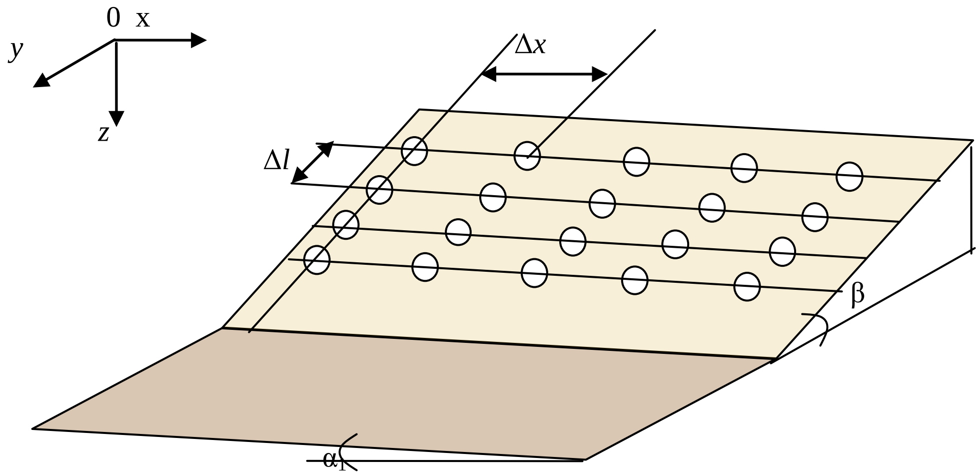


Figure 3. Steps of the discrete orifices from one of the bank slopes of the intake

$$Q_d = \sum_{i=1}^{n}\sum_{j=1}^{m}\mu\sqrt{2gz(x,y)}S = \mu\sqrt{2g}\,\frac{\pi d^2}{4}\sum_{i=1}^{n}\sum_{j=1}^{m} z^{1/2} = \\ = \frac{\pi\sqrt{2g}}{4}\mu d^2\sum_{i=1}^{n}\sum_{j=1}^{m}(y_j tg\beta - x_i tg\alpha_2)^{1/2} \tag{11}$$

As in figure 3, the current variables x_i and y_j are given by:

$$x_i = i\cdot\Delta x\ ,\ y_j = j\cdot\Delta l\cdot\cos\beta \tag{12}$$

As a consequence, the distributed captured flow by the intake becomes:

$$Q_d = \frac{\pi\sqrt{2g}}{4}\mu d^2\sum_{i=1}^{n}\sum_{j=1}^{m}(\Delta l\cdot\cos\beta\cdot tg\beta\cdot j - \Delta x tg\alpha_2\cdot i)^{1/2} \tag{13}$$

After summation the total distributed flow becomes:

$$Q_d = \frac{\pi\sqrt{2g}}{4}\mu d^2(\sqrt{\Delta l\sin\beta - \Delta x tg\alpha_2} + \ldots + \sqrt{\Delta l\sin\beta - n\Delta x tg\alpha_2} + \\ + \sqrt{2\Delta l\sin\beta - \Delta x tg\alpha_2} + \ldots + \sqrt{2\Delta l\sin\beta - n\Delta x tg\alpha_2} + \ldots \\ + \sqrt{m\Delta l\sin\beta - \Delta x tg\alpha_2} + \ldots + \sqrt{m\Delta l\sin\beta - n\Delta x tg\alpha_2}) \tag{14}$$

The result becomes more precisely if μ is considered variable with the depth z, but the calculus becomes more complicated. To increase μ and the flow the orifices must be chamfered on both sides [6].

The calculus can be effectuated both with the method which applies the integral and with the method which utilize the two sums, as long as the positive term under the radical is bigger than the negative one. This thing is justified from the physical point of view by the existence of a positive depth of the water.

One obtains at the end the transit flow through the intake with the formula:

$$Q_t = Q - Q_d \tag{15}$$

3. Experimental setup

An accurate installation was realized inside the Hydro-energy hall. The measurements were performed with sand of 1 mm mean diameter. The affluent flow was big enough to drag along most of the sediments. At this type of intake the water passes from the superior stage through all the holes performs on the banks to the inferior stage and then through pipes to the turbines.

Figure 4. The two stage ecological intake for sand-less water model

The intake is 6 m long and 0.4 m wide. The water flows in an open circuit and transports the sediments on both levels of the intake. The sediments who passes the holes of the intake with 5 mm diameter are then captured before entering the main pipe which leads the water to the turbines. After a half hour of constant flow the sediment balance sheet was made.

4. Results and discussions

The flow passes through a ”Măruță” diaphragm and can be computed with the formula:

$$Q = m_\alpha \frac{\pi D^2}{4} \sqrt{\frac{2 \cdot \Delta p}{\rho}} \tag{16}$$

where D is the interior diameter of the pipe, Δp the pressure difference on the diaphragm, ρ the liquid density m_α the flow coefficient. For our case, according with the dimensions of the diaphragm, $m_\alpha = 0.689$.

The pressure difference on the diaphragm is given by:

$$\Delta p = (\rho_m - \rho) g \cdot \Delta H \tag{17}$$

where $\Delta H = 0.12\ m$ is measured at the tube U manometer.

A flow of *8 l/s* was determined and at this flow *65%* of the sediments were transferred downstream.

It means that almost *2/3* of the sediments can be transported after the intake, which is a very good thing.

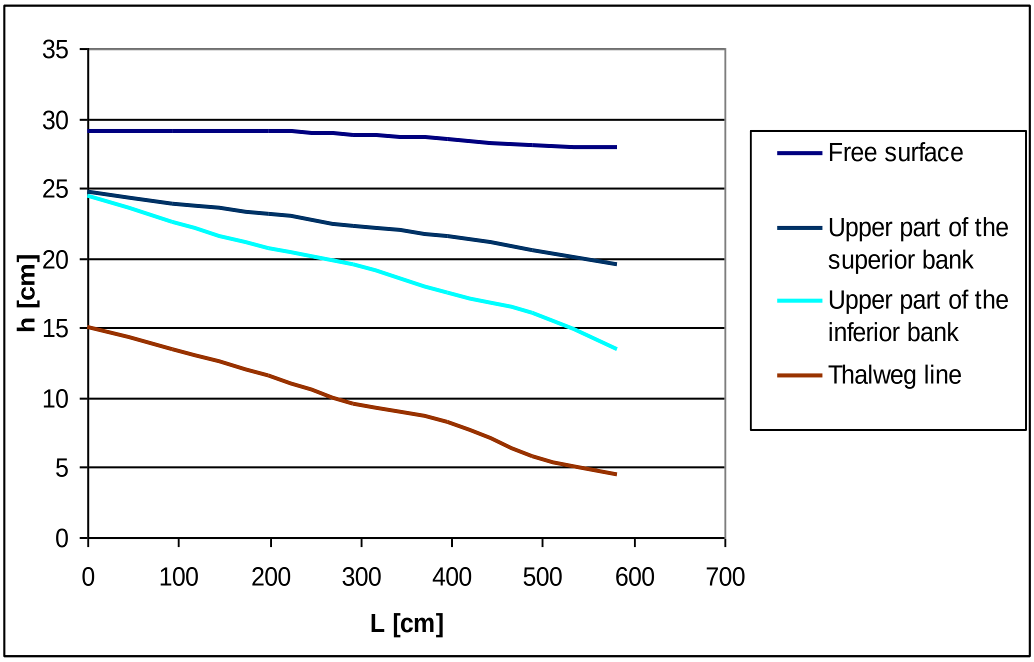


Figure 5. The main characteristics of the intake and flow in a vertical vie

Conclusions

The theoretical calculus of the flow with a surface integral is a complete original one.

At a volumetric flow of *8 l/s*, almost *2/3* of the sediments can be transported downstream after the intake, preventing further erosions and avoiding the sediments to reach the turbines.

The intake is very useful because a great part of the sediments are transported downstream. This intake has two advantages. A smaller part of the sediments enter in the intake and they are retained inside with proper systems.

The sediments which arrive again in the river after the intake prevent the erosion, so the morphology of the river is less changed.

Acknowledgement

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