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Research Article

STUDY OF THE EXPERIMENTAL APPROACH OF THE RELATIVE LENGTH OF THE SURFACE ROLE OF THE HYDRAULIC JUMP EVOLVING IN RECTANGULAR CHANNEL OF SECTION COMPOSED WITH ROUGH BOTTOM

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ABSTRACT

The aim of this experimental study is to analyze the relative length of the surface roll in a hydraulic jump evolving in a rectangular channel composed of a rough minor bed. We obtain a functional relationship, in non-dimensional terms, connecting the different characteristics of the jump.

Keywords: roughness, compound channel, rough background, hydraulic jump, rough minor bed, length of the surface roll.

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1. INTRODUCTION

Our study concerns the establishment of the empirical approach of the relative length of surface roll for a hydraulic jump controlled by a thin-walled threshold evaluating in a rectangular channel of composite shape with a rough minor bed. The bibliographic study clearly shows that the fundamental dimensionless characteristics, intervening in the phenomenon of the hydraulic jump which evolves in a rectangular channel of compound form are the incident Froude number F_1 or the volume flow Q, the upstream height h_1 (h_1 is the height at the foot of the jump), the downstream height h_2 (h_2 is the maximum height measured downstream of the jump) and the ratio Lr / h_1 is the relative length of the surface roll of the hydraulic jump.

The primary objective of our experimental study is to develop purely empirical approaches to the relative length of the surface roller for a hydraulic jump evolving in a rectangular channel of a composed section with a rough bottom, thus to appear the effect of the roughness tested. experimentally on the characteristics of the hydraulic jump.

2. POSITION OF THE PROBLEM

The modification of the conditions upstream (flow, heights, ... etc.) and downstream (a type of obstacle, its position, its height, ... etc.), Can lead to different configurations of a jump. The projection is said to be classic when it forms in a rectangular channel of little or no slope, without obstacle to the downstream. It is said to be controlled when its formation is conditioned by the installation of an obstacle downstream of the flow. It is said to be forced when it is formed on either side of the obstacle. The hydraulic jump can operate in prismatic or non-prismatic channels, with smooth or rough bottoms.

For our study which is presented is a hydraulic jump controlled by a thin-walled threshold which evolves in a rectangular channel of a composite section with a rough bottom with different openings h_1 (photograph 1). Thus, for a fixed initial height h_1, several experimental measurements with different threshold heights and different relative roughnesses ε / b were obtained.

The hydraulic and geometrical characteristics interesting for our experimental study are the flow volume Q or number of incident Froude F_1, the height h_1 of the incident flow, the final height h_2 of the hydraulic jump, the relative length of surface roll Lr / h_1 and the relative roughness ε / b. therefore the following dimensionless parameters:

- The number of Froude F_1 such as: $F_1 = Q / (gb^2\, h_1^3)$

• The ratio Lr / h_1 of the relative length of a surface roll of the hydraulic jump in the minor bed.

• The ratio Lr / h_1 of the relative length of a surface roll of the hydraulic jump in the major bed.

3. DESCRIPTION OF THE TESTS

The experimental of hydraulic jump controlled by a thin-walled sill in a rectangular channel with a rough bottom were made at the Laboratory for the exploitation and development of natural resources in arid zones (EVRNZA) of the Department of Civil and Hydraulic Engineering of the University of Ouargla. The bottom of the canal is perfectly horizontal (with no slope). A supply basin is connected to the channel by means of a circular pipe 150 mm in diameter. This is connected to a closed metal box, on which is inserted an opening with a flat sheet metal wall of determined width opening into the channel. The role of this wall is to generate an incident flow at high speed. The outlet section is variable and its height will correspond to the initial height h_1 of the hydraulic jump. The volume flows are adjusted by manipulating the valve. The channel is supplied by a pump delivering up to 55.55 l / s.

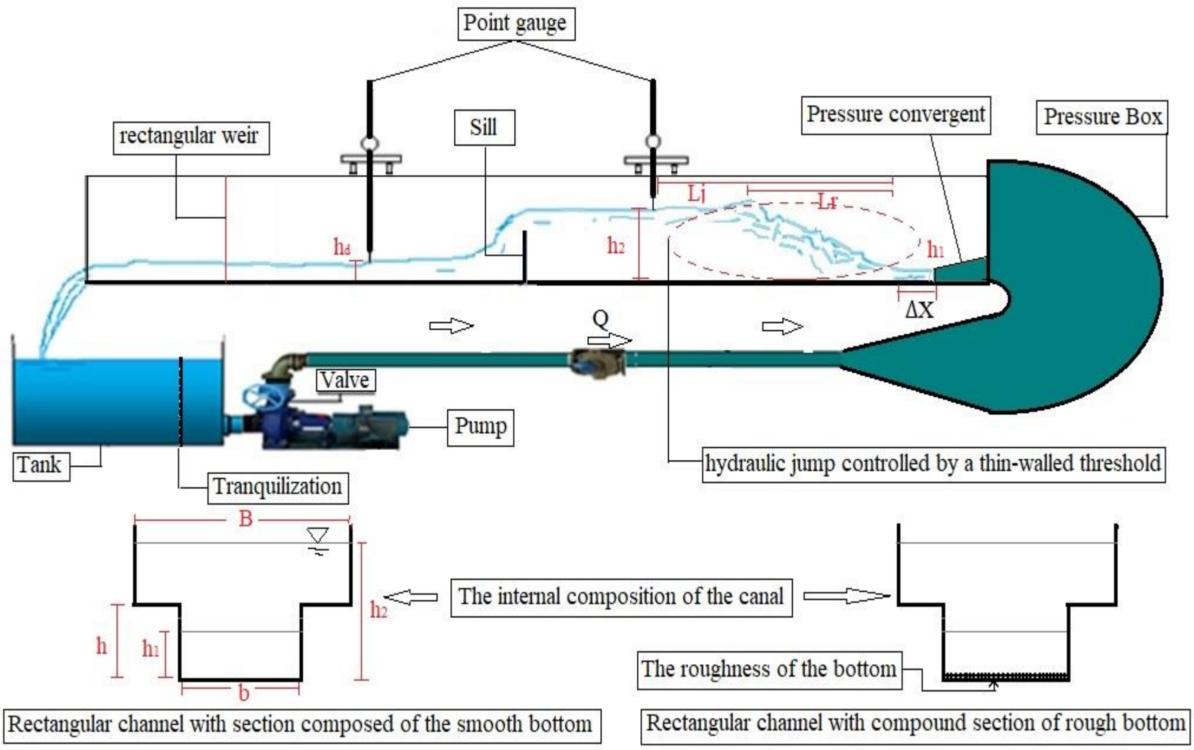


Fig.1. Schematic definition of the hydraulic jump controlled by a thin-walled continuous

threshold in a rectangular channel with a composite section with a rough bottom.

Photograph 1. the formation of the surface roll length for a hydraulic jump in a rectangular channel of a compound section with a rough bottom.

The experiment was conducted under five initial heights of flow: h_1 (cm) = 2; 2.5; 3; 3.5 and 4. The formation of the controlled hydraulique jump is conditioned by the establishment of a threshold downstream of the flow. We used thresholds of different heights (2.5 cm to 21 cm) for the formation and control of the hydraulic jump (**Photograph 2**).

Photograph 2. Thin-walled thresholds 2.5 à 21 cm

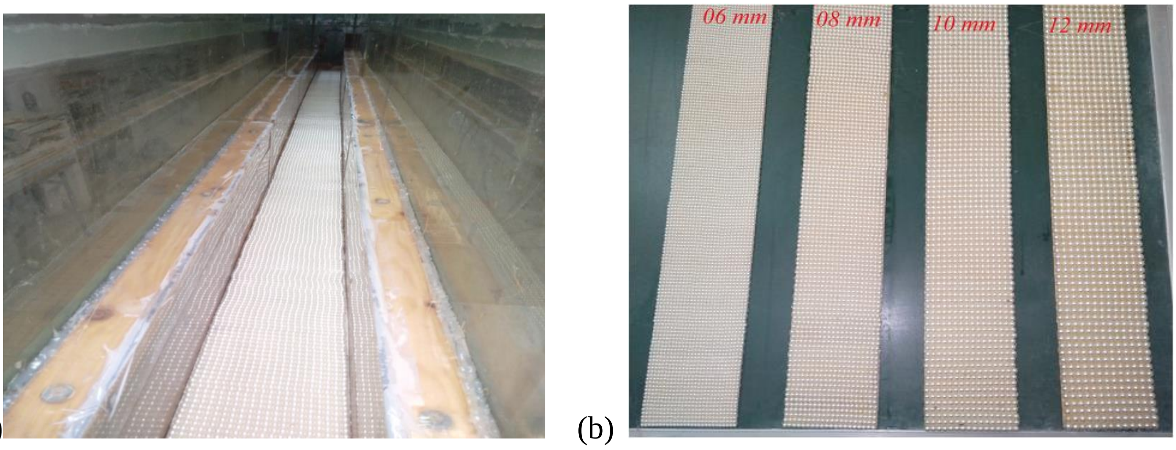
Concerning the rough bottom of the channel, we tested various roughnesses which are imposed on the bottom of the channel of a compound section, we proceeded the following stages:

1. We stuck plastic balls on a carpet in a linear and regular way, on 4 meters of the test channel.

2. The rough carpet obtained is then carefully glued to the minor bed of the rectangular channel of the composite section.

3. The roughnesses obtained are ε=06 mm, ε=08 mm, ε=10 mm et ε=12 mm

(a) (b)



Photograph 3. (a): Photograph of a rough carpet carefully glued to the bottom of the rectangular channel of composite section. (b): Photograph of the four rough carpets: ε = 06 mm, ε = 08 mm, ε = 10 mm and ε = 12 mm.

So when we obtain a configuration of the controlled hydraulic jumb, we perform, for an initial height h_1 and a fixed threshold position x, the following operations:

1. Reading of the overflow height h_{dev} of the rectangular overflow.
2. Calculation of the corresponding volume flow, by applying the relationship of the rectangular flow meter (HachemiRachedi L.2006):

$$Q = 0,3794\sqrt{2g}\,\beta\left(1+0,16496\beta^{2,0716}\right)^{3/2} h_{dev}^{3/2} \qquad [1]$$

With:

Q: the flow in (m3 / s);

β = b / B: Ratio of the enlargement. ;

b: width of the notch (m). ; B: the width of the channel (m). ;

g: the acceleration of gravity (m /s^2) ;

h_{dev}: The height of the overhanging blade in (m).

3.Calculation of the Froude number F_1 of the incident flow, by applying the relation [1].

4.Measurement of the final height h_2 of the hydraulic jump.

4. RESULTATS EXPERIMENTAUX

4. 1. Variation of the relative length of surface roller Lr / h_1 as a function of the Froude number F_1 in the minor bed.

The relative length of the surface roll is the distance from the start of its formation to its end. Figure 2 shows the variation of the relative length of the surface roller Lr / h_1 as a function of the Froude number for five values of absolute roughness: ε = 00 mm; ε = 06 mm; ε = 08 mm; ε = 10 mm and ε = 12 mm in the minor bed. There are thus five-point clouds, where each depends on a well-defined absolute roughness.

Furthermore, the analysis of the experimental measurement points of the hydraulic jump with a rough bottom, shows that for each roughness value "ε" tested corresponds a linear type curve of the form $Lr/h_1 = a_1(F_1)$.

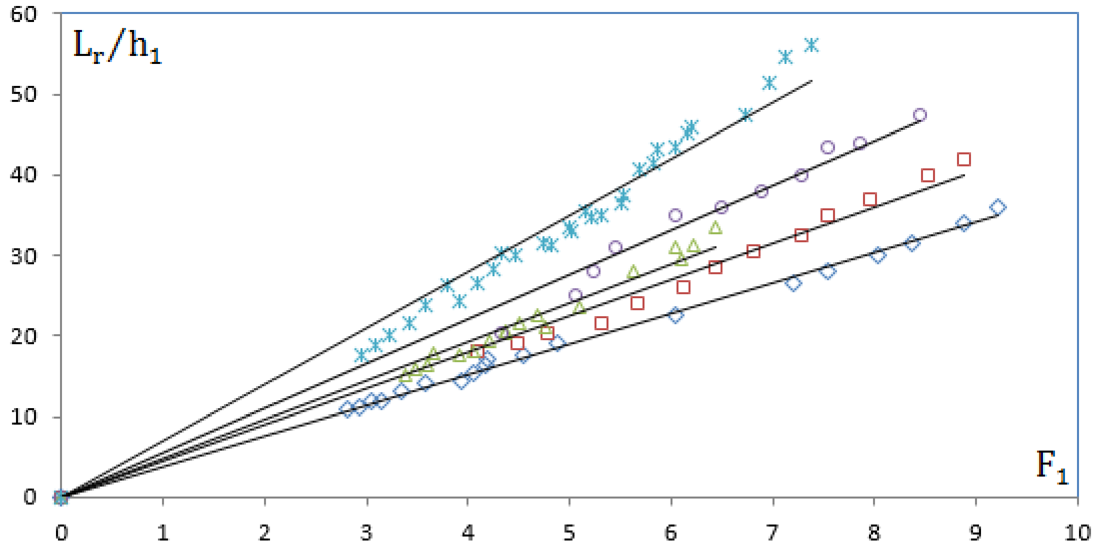


Fig.2. Variation of the relative length of the surface roll Lr / h_1 as a function of the Froude number F_1, for five different roughnesses "ε" (□) 12 mm ;(□) 10 mm; (Δ) 08 mm; (O) 06 mm and (∗) 0 mm. (—) Adjustment curves

Analysis of these results shows that the relative length Lr / h_1 increases as the number of

Froude F_1 also increases and this for all roughness. In addition, the relative increase in roughness ε / b causes the decrease in the ratio of the relative length Lr / h_1, this is due to the roughness of the bottom of the channel which generates the compactness of the hydraulic jump.

Table 1 groups the values of the coefficient a_1.

Table 1. Coefficients a_1 of the adjustment curves

ε/b	a1	R2
0,08	3,817	0,995
0,06666667	4,501	0,985
0,05333333	4,809	0,976
0,04	5,528	0,983
0	6,986	0,966

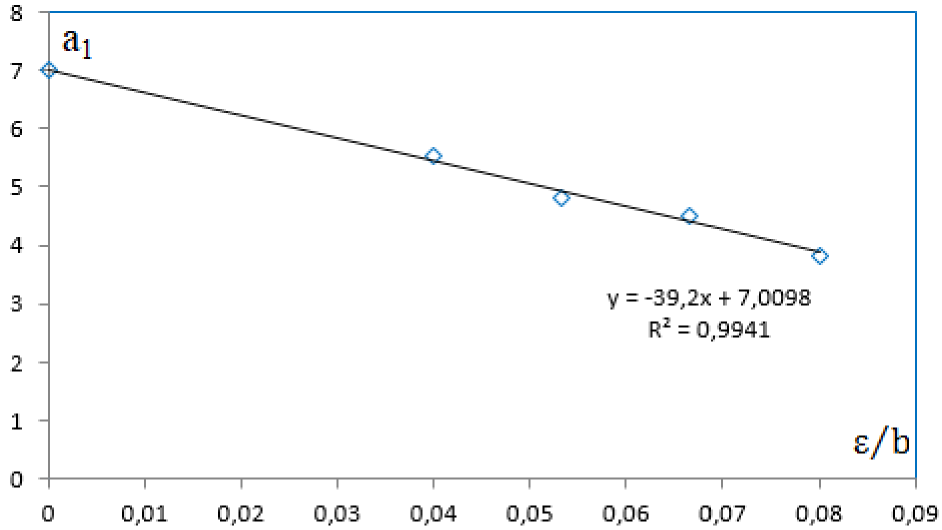


Fig.3. Variation of the coefficient " a_1" as a function of the relative roughness ε/b in the minor bed

The adjustment of the couples of values (a_1, ε/b) of table 1 made it possible to arrive with a good correlation according to the following linear relation: a_1 = -39,2*ε/b + 7,0098, with R^2 = 0,9941. This equation is presented in Figure 3. The equation linking the upstream relative length of the surface roll Lr / h_1, the Froude number F_1 and the relative roughness ε/b are then written:

$$Lr / h_1 = (-39{,}2 * \varepsilon / b + 7{,}0098)\, F_1 \qquad [2]$$

With $0 \leqslant \varepsilon / b \leqslant 0.8$

Figure 4 also shows that the relation Lj / h_1 = f (ε / b, F_1) adjusts with a good correlation for the minor bed in majorities of the experimental measurement points and these follow perfectly the first bisector.

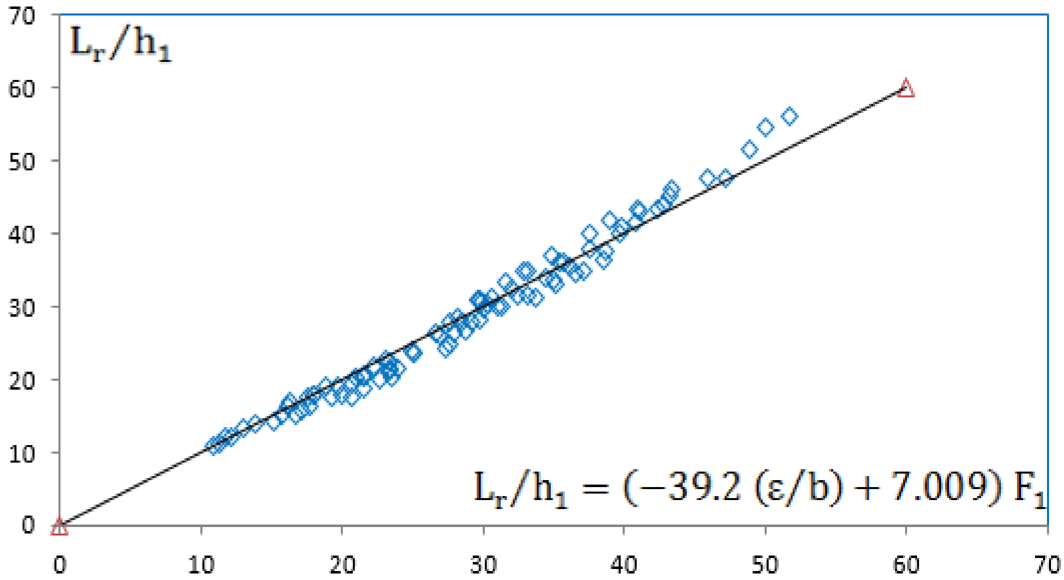


Fig.4. Variation of the relative length of the surface roll Lr / h_1 as a function of f (ε / b, F_1). (□) The experimental points of the controlled jump with a rough bottom. (—) First bisector

4.2 Variation of the relative length of the surface roll Lr / h_1 as a function of the Froude number F_1 in the major bed.

As we did with the minor bed, we have plotted the graph of the variation Lr / h_1 as a function of the Froude number F_1 for five values of absolute roughness in the major bed. There are also five-point clouds, each of which depends on a specific roughness.

Furthermore, the analysis of the experimental measurement points of the hydraulic jumb with rough bottom for the major bed, also shows that for each roughness value "ε" corresponds a linear type curve of the form Lr/h_1 = a_2(F_1).

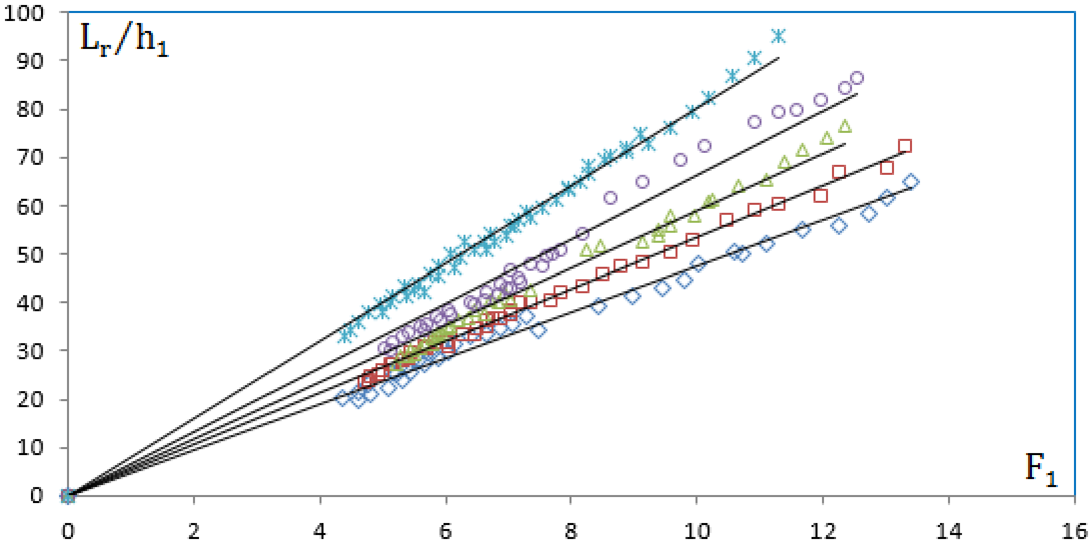


Fig.5. Variation of the relative length of the surface roll Lr / h_1 as a function of the Froude number F_1, for five different roughness "ε" :(□) 12 mm ;(□) 10 mm; (△) 08 mm; (O) 06 mm and (∗) 0 mm. (—) Adjustment curves

The analysis of these curves shows that the relative length of the surface roll Lr / h_1 increases with the increase in the number of Froude F_1 and this for all the roughnesses tested. In addition, the relative roughness ε / b increases with the decrease in the ratio of the relative length of the surface roll Lr / h_1, this is due to the roughness of the bottom of the channel, which causes energy dissipation.

Table 2 groups the values of the coefficient a_2.

Table 2. Coefficients a_1 of the adjustment curves

ε/b	a_2	R^2
0,08	4,744	0,989
0,06666667	5,346	0,996
0,05333333	5,899	0,987
0,04	6,642	0,973
0	8,008	0,992

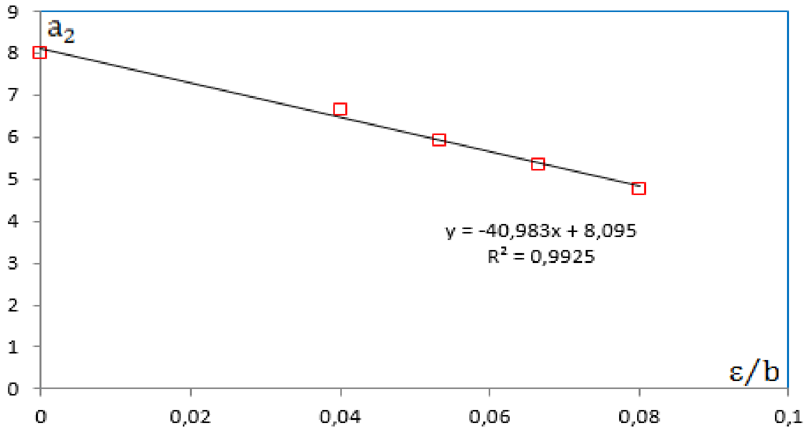


Fig.6. Variation of the coefficient " a_2" as a function of the relative roughness ε / b in the major bed

Adjustment of value pairs (a_2, ε / b) of Table 6 made it possible to arrive with a good correlation to the following linear relationship: $a_2 = -40.983\ (\varepsilon/\ b\ ) + 8.095$.

The equation linking the upstream relative length of the surface roll Lr / h_1, the Froude number F_1 and the relative roughness ε / b for the major bed is written as follows:

$$Lr\ /h_1 = (--40.983^*\ (\varepsilon/\ b\ ) + 8.095)\ F_1 \qquad [3]$$

With $0 \leqslant \varepsilon/b \leqslant 0.8$

Figure 7 also shows that the relation Lr / h_1 = f (ε / b, F_1) adjusts with a good correlation for the major bed in the majority of the points of experimental measurements, and these last perfectly follow the first bisector.

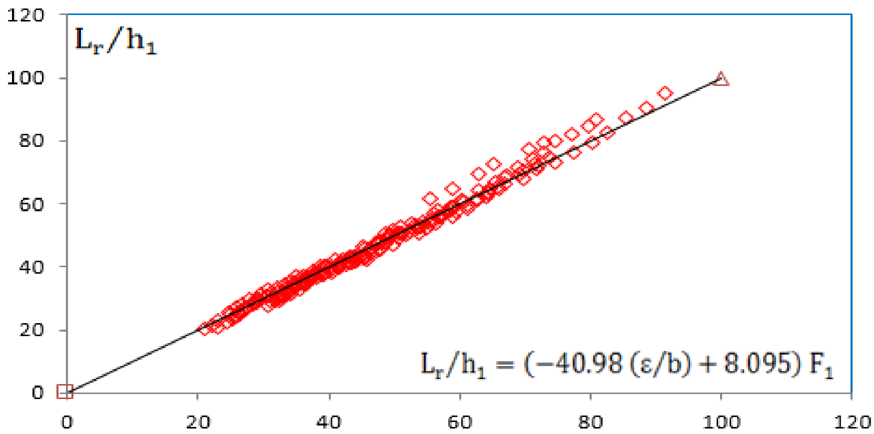


Fig.7. Variation of the relative length of the surface roll Lr / h_1 experimental as a function of f (ε / b, F_1). (□) The experimental points of the controlled projection with a rough bottom in the major bed. (—) First bisector

Figure 8 shows the variation of the experimental relative length of the surface roll Lr / h_1 as a function of f (ε / b, F_1) for the compound section.

This figure shows the comparison between experimental measurements of the relative length of the surface roll Lr / h_1 with their global relationships obtained for the two beds of the component.

We deduce that the compound section presents a reduction in the relative length of the surface roll Lr / h_1 of the hydraulic jumb in the minor bed than that in the major bed.

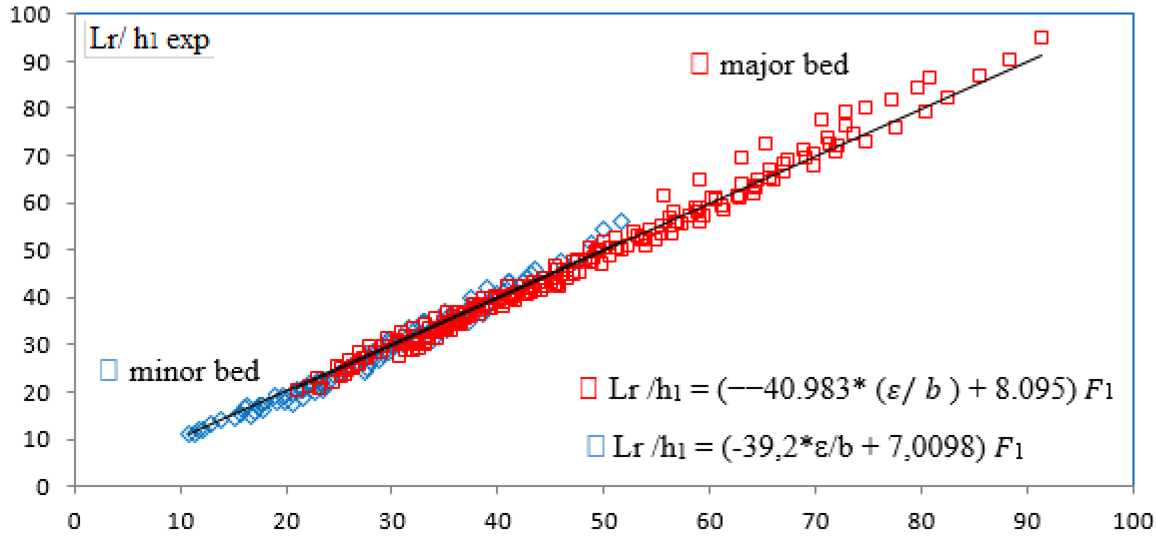


Fig.8. shows the variation of the experimental relative length of the surface roll Lr / h_1 as a function of f (ε / b, F_1) for the two cases (□ minor bed; □ major bed)

It is concluded that the composite section of the rectangular channel has a positive effect reducing the relative length of the surface roll in the minor bed than that in the major bed.

6. CONCLUSION

From the tests and results obtained at the laboratory level, it appears that the effect of roughness appears clearly on the characteristics, this type of hydraulic jump studied against the effect of the opening h_1 no longer appears on their characteristics.

Initially, the study was interested in the variation of the relative length of surface roll Lr / h_1 according to the number of Froude F_1 for five different openings and five roughness tested experimentally for the two beds of the channel experimentation. Secondly, we note that the increase in the number of Froude F_1 leads to that of the relative length of the surface roll of the hydraulic jump Lr / h_1 for the two beds of the channel. Furthermore, for the same number of Froude F_1, the relative length of the surface roller Lr / h_1 diminishes with the increase in the relative roughness ε / b imposed on the bottom of the experimental channel.

we can conclude that for a range of Froude numbers and different roughness tested, the hydraulic jump in a rectangular channel of a compound section, presents two global experimental approaches $Lr / h_1 = f (F_1, \varepsilon / b)$ by which could be used in the design of ancillary works such as the sinking basin.

Finally, one could judge that the hydraulic jump evolving in a rectangular channel of a section composed of the rough font has a reducing effect on the characteristics of the flow in minor bed more than the major bed.

MAIN RATINGS

b width of the minor channel bed [m]

B Width of the major bed [m]

F_1 Number of Froude upstream of the hydraulic jump [ ]

g Acceleration of gravity [m / s]

h_1 Initial height of the projection [m]

h_2 Final height of the projection [m]

h Full edge height of minor bed [m]

Lr length of the surface roll of the hydraulic jumb [m]

Lr / h_1 Relative length of the surface roll of the hydraulic jumb [ ]

Q Volume flow [m^3/s]

ε Absolute roughness [m]

ε / b Relative roughness [ ]

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