EXPERIMENTAL STUDY OF THE ENERGY DISSIPATION IN THE STEPPED CHANNELS: COMPARISON WITH THE EMPIRICAL MODEL

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ABSTRACT

Water flowing over stepped chute can dissipate a major proportion of its energy. To show the importance of studying these flows, we made an experimental approach in the laboratory of civil engineering at the University of Laghouat (Algeria), in three models: model A (4cm x 4cm x7.5cm) , model B (8cm x 8cm x 7.5cm), and model C (12cm x 12 cm x 7.5 cm). In what follows, we set the rate of flow and vary the slope of the channel.

As result, the effect of the rate flow allowed us to see that: For low flows, the energy dissipation (nappe flow) is maximum is around 95% for the three models. For a large flow, the energy dissipation (nappe flow) is minimal and in the order of 82%, 80% and 77% for models A, B and C respectively, The energy dissipation relative maximum and minimum flows in skimming flow are of the order of 73% and 70% respectively.

Keywords: energy dissipation, nappe flow, skimming flow, empirical model, comparison.

1. INTRODUCTION:

Water flowing over stepped chute can dissipate a major proportion of its energy. On a spillway chute, the steps increase substantially the energy dissipation taking place on spillway face, and lead to a reduction in the depth and dimensions needed for the stilling basin at the toe of the chute (Very Dermawan and all, 2010).

Several research models have distinguished themselves in the field of flow in channels stairs, among the most recent works are Benmamar (2006), Kerbache and Benmamar (2008a, 2008b, 2010, 2012), Gafsi and Benmamar (2012, 2013a, 2013b), and the most popular are those of Chanson (1994, 1996, 2000).

Our work is experiment and concerned with the study of different flows on the stepped channels, the quantification of dissipative energy. To show the importance of studying these flows, we made an experimental approach in the laboratory of civil engineering at the University of Laghouat (Algeria), in three reduced stepped channels models: model A (4cm x 4cm x 7.5cm) , model B (8cm x 8cm x7.5cm), and model C (12cm x 12 cm x 7.5 cm) developed "Plexiglas." In what follows, we set the rate of flow and vary the slope of the channel to show the effect of the slope on the energy dissipation.

As result, the effect of the rate flow allowed us to see that:

- For low flows, the energy dissipation (nappe flow) is maximum is around 95% for the three models. For a large flow, the energy dissipation (nappe flow) is minimal and in the order of 82%, 80% and 77% for models A, B and C respectively;
- The energy dissipation relative maximum and minimum flows in skimming flow are of the order of 73% and 70% respectively.

2. PHYSICAL MODEL

Experimental studies were conducted on three (3) models stairs developed "Plexiglas". The model "A" consists of channel totaling (20) steps and model "B"(10) steps and model "B"(07) steps. Three slopes were studied in this experiment: α = 20 °, 30 ° and α = 45 °, with flow rates ranging from 0.072 l/s to 2.569 l/s.

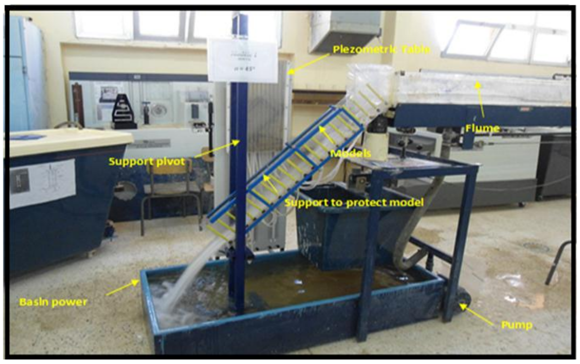

Photo.1 : Experimental device (Gafsi et al, 2013b)

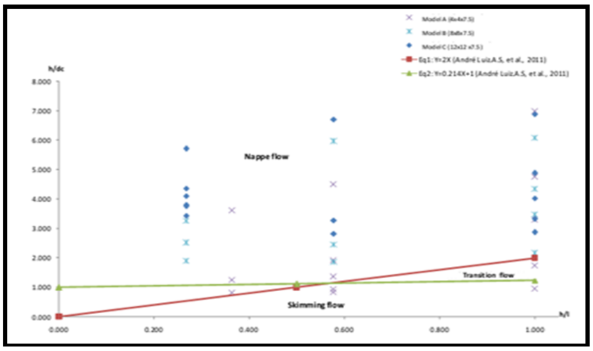

Figure.1: Determination of the limits of different flow in the three models following of Simões (2011) schemes

3. ANALYSIS OF RESULTS :

3.1. Determination of flow regime :

From our observations and our measurements, we have observed two different flow regimes observed (see fig. 1).

The appearance of the nappe flow is leading for models B and C on the model A. This is explained by the fact that models B and C have large steps relative to model A. It can be inferred that the steps of important dimensions rather promote nappe flow that skimming flows. This result is confirmed by Chanson (1995) and Simões (2011).

3.2. Determination of energy dissipation:

For a nappe flow with jump fully developed Chanson (1994), give one expression adimensionnelle:

- For a spillway without valve:

$$\frac{\Delta H}{H_{max}} = 1 - \left(\frac{\frac{d_1}{d_c} + \frac{1}{2}\left(\frac{d_c}{d_1}\right)^2}{\frac{3}{2} + \frac{H_{bar}}{d_c}} \right) \quad (1)$$

According Chanson (1994), the energy dissipated in skimming flow is expressed by:

➢ For ungated spillway:
$$\frac{\Delta H}{H_{max}} = 1 - \frac{\left[\left(\frac{f_e}{8\sin\alpha}\right)^{1/3}\cos\alpha + \frac{1}{2}E_c\left(\frac{f_e}{8\sin\alpha}\right)^{-2/3}\right]}{\frac{3}{2}+\frac{H_{bar}}{d_c}} \qquad (2)$$

Where E_c is the correction coefficient of kinetic energy:

$$E_c = \frac{(n+1)^3}{n^2(n+3)} \qquad (3)$$

$$n = \kappa\sqrt{\frac{8}{f}} \qquad (4)$$

Where K is the von Karman constant, equal to 0.41 and f is the friction coefficient for a non-aerated flow.

In the case of a stepped channel, Chanson (1994) recommends taking f = 1.

H_d: Height of the dam crest above the foot downstream. f_e: coefficient of friction for an aerated flow. α: Slope of the channel. d_c: depth of critical flow. H_{max}: maximum load available.

The initial load of the total flow above the threshold H_{max} is given by:

$$H_{max} = H_{bar} + d_{bar} \qquad (5)$$

The residual charge H_{av} at the foot of weir is expressed by:

$$H_{av} = d_{av} + \frac{V_E^2}{2g} \qquad (6)$$

where V_E is the flow velocity in the section considered.

Figures 2 , 3and 4, show the comparison between experimental curves of energy dissipation based on Froude number in the three models A, B and C respectively, and analytical curves plotted according to equation (1).

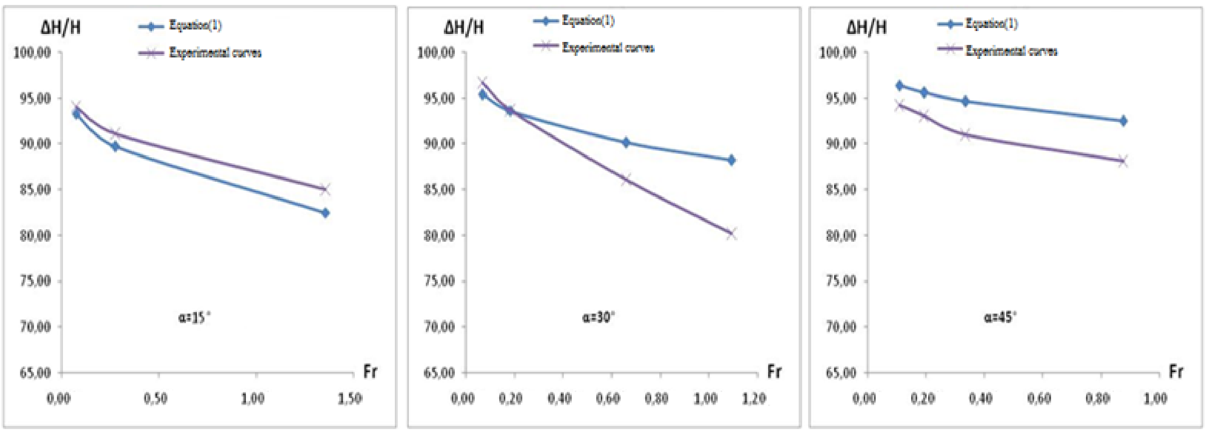

Figure.2: Variation of energy dissipation as a function of Froude number (nappe flow) on the Model A (Gafsi et al, 2013b)

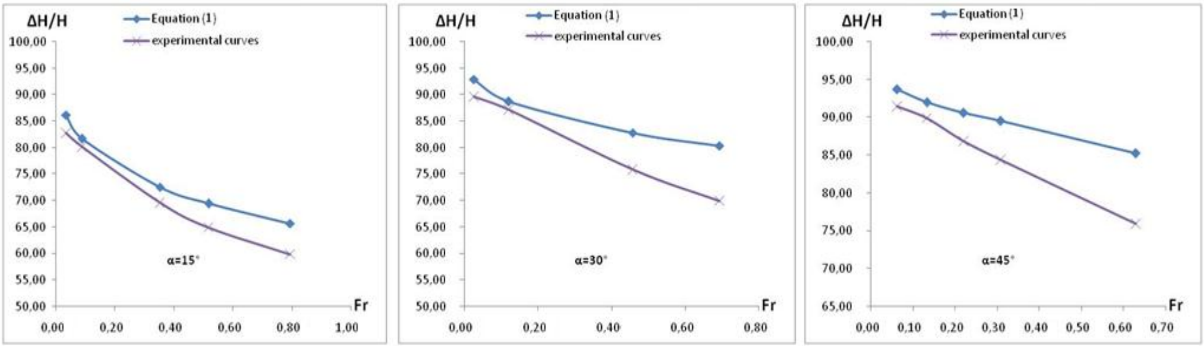

Figure.3: Variation of energy dissipation as a function of Froude number (nappe flow) on the model B (Gafsi et al, 2013b)

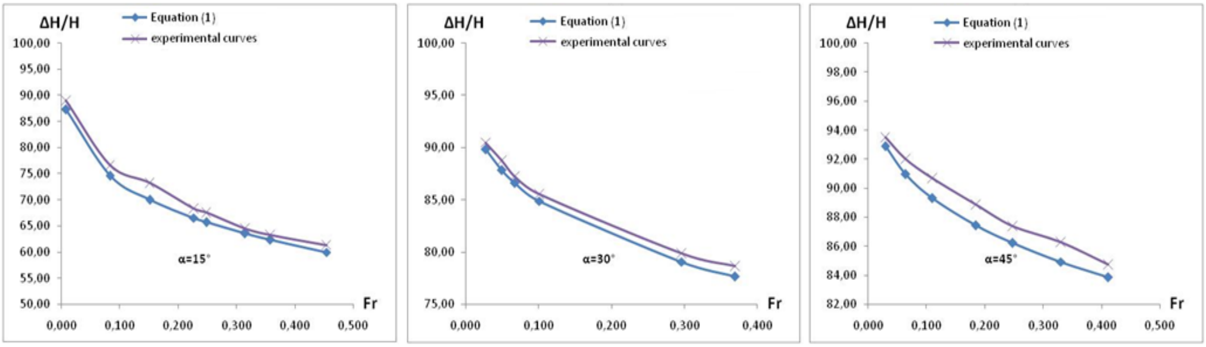

Figure.4: Variation of energy dissipation as a function of Froude number (nappe flow) on the model C (Gafsi et al, 2013b)

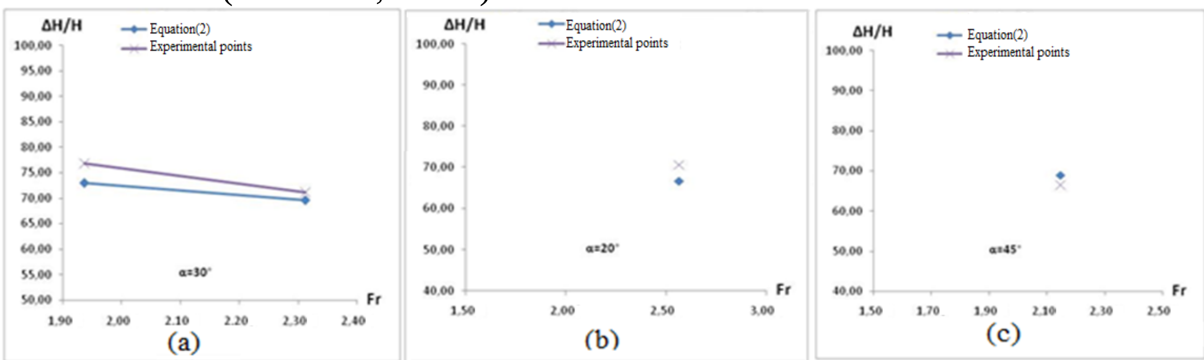

Figure.5: Variation of energy dissipation as a function of Froude number (skimming flow) on the model A (Gafsi et al, 2013b).

Comment:

- Energy dissipation in model A is greater than B and C models, and values as e.g. for $\alpha = 30°$ and Fr = 0.2: $\Delta H/H = 93.48$ % (model A), $\Delta H/H = 86.79$ % (mode B), $\Delta H/H = 81.41$ % (model C);
- For a given (Figures 2, 3 and 4) rate flow, the energy dissipation increases to a relative increase in the slope. This is explained by the increase in slope of the first channel which influences the increase in the height of the weir ($H_{chan} = L.\sin\alpha$), and therefore the increase of the kinetic energy.
- For a given (Figures 2, 3 and 4) slope, the energy dissipation decreases with increased flow. This is explained by the effect of the increase of macro-roughness with increasing speed. Therefore the energy dissipation is reduced.

4. GENERAL CONCLUSION:

- The experimental and analytical curves of energy dissipation show the same profiles, that is, decreasing trends, of low (low value of the Froude number) at high flow rate (high value of the Froude number). Also, theses curves merge almost for small flows, so that, for high flows, both curves show a visible difference. This is mainly due to the leakage rate is greater at high flow and low flow less.
- For steep slopes and low-flow steps, the flows in stepped channels, cause significant dissipation of energy in the nappe flow and skimming flow.
- The flows with average to high flow rates, favor rather skimming flows on the steps of small dimensions than those large, which verifies the assumption made by H.CHANSON 1995.
- The influence of the slope of large energy dissipation is more visible on the nappe, those on skimming flows.
- The larger values of energy dissipation are obtained on the nappe flows, those on the skimming flows. This is explained by the effect of the macro-roughness which is less on the small steps.
- The energy of dissipation on the nappe flow and skimming flow is influenced by three parameters, namely: the slope of the channel, the flow rate and the geometry of the stairs.

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