The Journal of **Macro**Trends in Energy and Sustainability

MACROJOURNALS

Study of the Energy Dissipation of Nape Flows and Skimming Flow on the Stepped Channels

Gafsi Mostefa*, Benmamar Saadia, Djehiche Abdelkadera, and Goteicha Khadidja***

**Research Laboratory of Civil Engineering: RLCE, ResearchTeam Water Resources, University of Ammar Telidji Laghouat, Laghouat , Algeria*

***Laboratory Research in Water Science: LRW-Water/ENP National Polytechnic School El Harrach, Avenue Hassen Badi, Algiers, Algeria*

Abstract

The present work is experiment and concerned with the study of different flows on the stepped channels, the quantification of dissipative energy as well as localization of inception point. We had, then, effected our experimentation on three models of stepped channels with different dimensions in order to see the impact of this effect on the physical and hydraulically properties of different flows observed and, hence, obtain some conclusion. There are two modes of flow in the stepped channels. The nape flow is characterized by partially developed and fully developed jump. The skimming flow is characterized by a non aired flow in the upstream of the point of inception and is aired in the downstream of the point of inception. The nape flow dissipates more energy than the skimming flow because of the presence of the hydraulic jump. The appearance of the skimming flow is a function of dimensions of the steps, the flows and the slopes. Our results enabled us to propose empirical formulas making it possible to study the flows in the channels with macro roughness with low and steeply sloping.Two different types of regimes are apparent in the behavior of hydraulic weirs stairs and both change over time and position. As results: 1) The larger values of energy dissipation are obtained on the nape flow than the very turbulent flows; this is verified by the assumption made by ELIS 1989 PEYRAS et al 1991 and shamanic RAJARATNAM 1994); 2) The energy dissipation in the nape and the very turbulent flow is influenced by three parameters, namely: the slope of the channel, the flow rate and geometry of the stairs.

Keywords: *Aeration - The channels with strong slopes - The nape flow - The point of inception - The skimming flow – The step.*

1. Introduction

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), and the most popular are those of Chanson (1994 , 1996, 1997, 2000) and Chanson et al (2000, 2002).

We have made series of experiments on several models of stepped channels. It has come out from these that there are various modes of flow in the stepped channels. The nappe flow is characterized by partially developed and fully developed jump. The skimming flow is characterized by a non aered flow in the upstream of the point of inception and is aired in the downstream of the point of inception. The nappe flow dissipates more energy than the skimming flow because of the presence of the hydraulic jump in the nappe flows. The appearance of the skimming flow is a function of dimensions of the steps, the flows and the slopes (Benmamar, 2006).

As part of this work, we tried to experience the hydraulic behavior of weirs stairs. These aspects are illustrated by measurements in the laboratory of Hydraulics of the Polytechnic School, performed on three channel models in stairs of different dimensions. Four slopes were performed: 12 °, 16 °, 22 °, 5 and 42 ° for model A and C and 12 °, 16 °, 22 °, 5 and 40 ° for the model B.Our experimentation on three models of stepped channels, have been conducted with different dimensions in order to see the impact of this effect on the physical and hydraulically properties of different flows observed, to propose empirical relationships on flow regimes.

2. Experimental model

The experimental phase of our work consists of two sets of experiments (Gafsi, 1999, Benmamar, 2006):

The experimental studies were conducted in three (03) models developed stairs "Plexiglas".

2.1. Model "A"

The model "A" (photo No. 1) consists on a channel containing ten (10) steps of constant dimensions. The height of the march counter is equal to h = 11.5 cm, and the length of the march equals to l = 8 cm.

2.2. Model "B"

The model "B" (Photo N ° 2) consists on a channel comprising thirteen (13) of constant dimensions steps. The height of the march counter is equal to h = 8 cm, and the length of the march equals to l = 8 cm.

2.2. Model "C"

The model "C" (Photo N ° 3) consists on a channel having fifteen (15) of constant dimensions steps.The height of the march counter is equal to h =5, 7 cm, and the length of the march equals to = 4 cm.

It can be that the steps in the different models have a angle equals to 90 °, and the main measures were carried out on measuring the water level, pressure measurement, flow measurement, and measurement of slopes.

Four slopes were performed: 12 °, 16 °, 22,5° and 42 ° for model A and C and 12 °, 16 °, 22, 5° and 40 ° for the model. B.

Photo No. 1: Model A
(Gafsi, 1999; Benmamar, 2006)

Photo No. 2: Model B
(Gafsi, 1999; Benmamar, 2006)

Photo No. 3: Model C
(Gafsi, 1999; Benmamar, 2006)

3. Results

3.1. Determination of flow regimes

3.2. Energy dissipation

The total initial load flow above the threshold is given by (Gafsi, 1999):

$$\mathbf{H_{am} = H_{dev} + d_{am}} \qquad \mathbf{(3)}$$

The residual charge at the foot of the weir is expressed by (Gafsi, 1999):

$$H_{av} = d_{av} + \frac{V^2}{2g} \qquad (4)$$

Where: V = flow velocity in the section considered.
Finally, the energy dissipation is deduced from the difference between the total load on the upstream and the residual charge: H_{am}-H_{av}.

3.3.1 The nappe flow

- Effect of slope

The figures (1 ÷ 3), show the variation of energy dissipation based on dc / h for models A, B and C respectively. I can be seen that the change in relative energy dissipation for a given slope is decreasing for an increase in flow. This means that the energy dissipation reaches its maximum for low flows (which verifies the assumption made by H.CHANSON (1995).

- Flow effect

The figures (4 ÷ .6) show the evolution of energy dissipation depending on the channel slope in the three models A, B and C respectively.

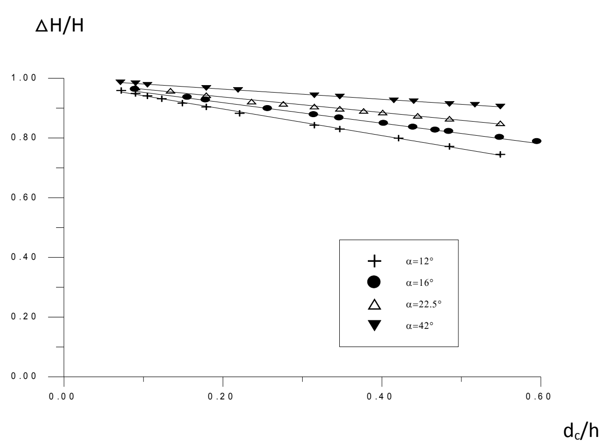

Fig.1. Variation of energy dissipation as a function of (d_c/h) in model A for different slopes (Gafsi, 1999).

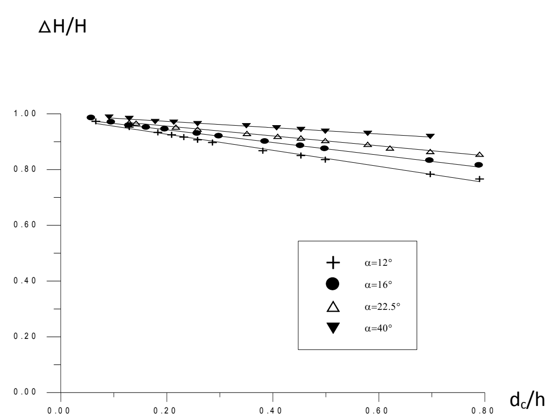

Fig.2. Variation of energy dissipation as a function of (d_c/ h) in model B for different slopes (Gafsi, 1999).

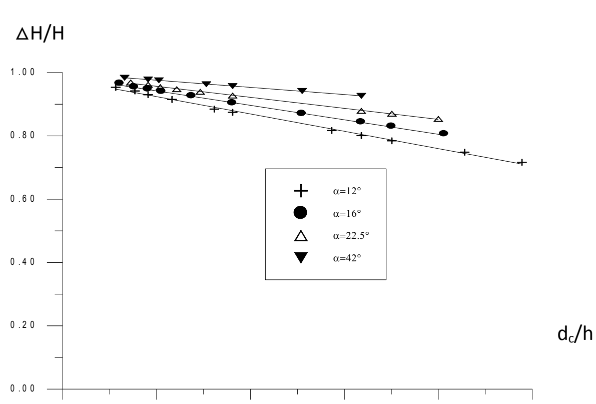

Fig.3 Variation of energy dissipation as a function of (d_c/h) in model different slopes (Gafsi, 1999)

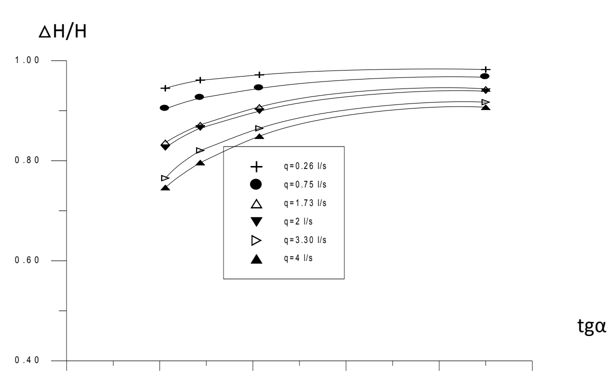

Fig.4 Variation of the energy dissipation as a function of the slope of the channel A in the model for different flow rates (Gafsi, 1999) .

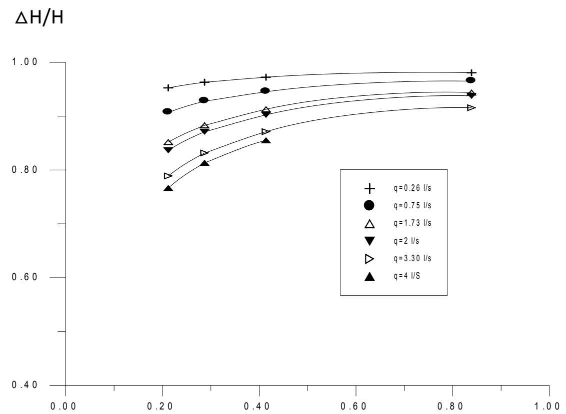

Fig.5. Variation of the energy dissipationas a function of th slope of the channel B in the model for different flow rates (Gafsi, 1999).

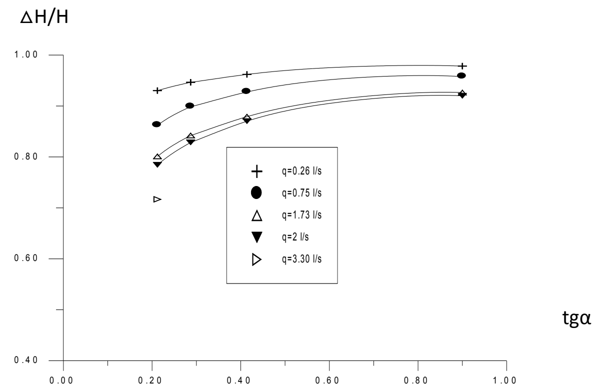

Fig.6. Variation of the energy dissipation as a function of the slope of the channel C in the model for different flow rates (Gafsi, 1999).

3.3.2 The skimming flow.

- *Effect of slope*

The figure 11 shows the variation of energy dissipation based on (d_c/h) on the C model. These variations decrease if we increase the flow.

- *Flow effect*

The Figure 9 shows the evolution of the relative energy dissipation depending on the channel slope in model C. This variation of the energy is increasing for an increase in channel slope.

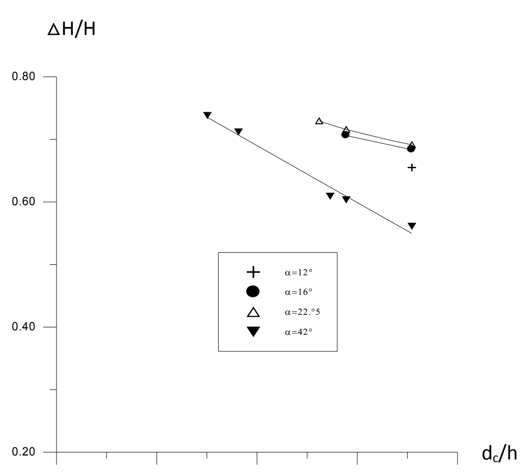

Fig. 7. Variation of energy dissipation as a function of (d_c/ h) in model C for the different slopes (Gafsi, 1999).

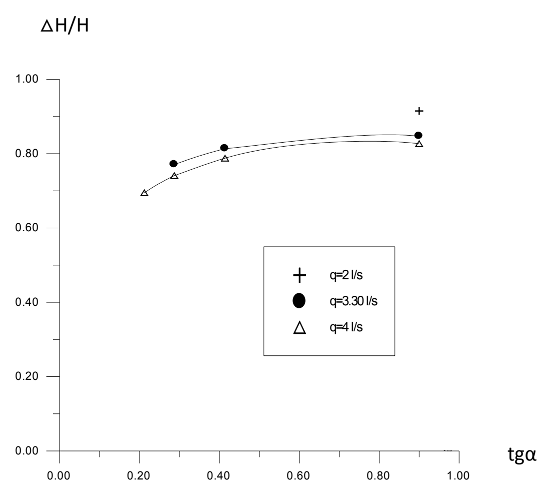

Fig. 8. Variation of energy dissipation as a function of (d_c/ h) in model C for the different flow rates (Gafsi, 1999).

4. Conclusion

The work is carried out has allowed us to draw the following conclusions:

- The flow in the stepped channel to steep slopes and low flows are causing significant energy dissipation in the flow sheet and turbulent;
- The flows to middle at high flows tend to favor the skimming flow on the steps of small dimensions as those with large dimensions, which verifies the assumption made by Chanson (1995);
- The influence of channel slope on the major energy dissipation is more pronounced on the nappe flows as the skimming flows.
- The larger values of energy dissipation are obtained on the nappe flow as the skimming flows. This is verified by the assumption made by Elis (1989), Peyras et al (1991), and Chamani and Rajaratnam (1994);
- Compared to the nappe flows, the energy losses in skimming flows are much lower. This is explained by the effect of macro-roughness that is lower on small steps;
- The dissipation of energy flows in very skimming flows is influenced by three parameters namely: the channel slope, flow rate and geometry of the stairs.

References

Benmamar S., (2006). -Etude des écoulements dans les conduits à motifs périodique- Application aux évacuateurs de crues. Thèse de Doctorat d'état, Ecole Nationale Polytechnique d'Alger, 198 pages.

Chamani, M.R., and Rajaratnam, N. (1994). Jet Flow on Stepped Spillways. Jour. of Hyd.. Eng., ASCE, Vol. 120, N°2, pp.254-259.

Chanson, H. (1994). Comparison of Energy Dissipation between Nappe and Skimming Flow Regimes on Stepped Chutes. Jour. of Hyd. Res., IAHR, Vol. 32, N° 2, pp 213-218. Errata: Vol. 33, No. 1, p. 13. Discussion: Vol. 33, No. 1, pp. 114-143.

Chanson, H. (1995). Hydraulic Design of Stepped cascades, Channels, Weirs and Spillways. Pergamon, Oxford, Uk, Jan., 292 pages (ISBN 0-08-041918-6).

Chanson, H. (1996). Prediction of the Transition Nappe/ Skimming Flow on a Stepped Channel. Jour. of Hyd. Res., MIAHR, Vol. 34, N°3, pp. 421-429.

Chanson, H. (2000). Forum article. Hydraulics of Stepped Spillways: Current Status. Journal of Engineering, ASCE, Volume 126, No. 9, pp. 636-637.

Chanson, H. & Yasuda, Y. & Ohtsu, I. (2000). Flow Resistance In Skimming Flow: A Critical Review. International Workshop on Hydraulics of Stepped Spillways, Zurich, H.E. Minor & W. H. Hager Editors, Balkema, Publication, pp. 95-102.

Chanson, H. & Toombes, L. (2002). Air- Water Flows down Stepped chutes: Turbulence and Flow Structures Observation. International of Multiphase Flow, volume 27, N°11, pp. 1737-1761.

Christoulou, G. C (1993). Energy Dissipation on Stepped Spillways. Jour. of Hyd. Eng., ASCE, Vol. 117, N°. 3, pp. 371-389.

Diez-cascon, J., Blanco, J.L., Revilla, J., and Garcia, R. (1991). ''Studies on Behaviour of Stepped Spillways.'' Intl Water Power and Dam Construction, Vol. 43, N°. 9, Sept., pp. 22-26.

Ellis, J. (1989). Guide to Analyse of Open-Channel Spillway Flow. CIRIA Technical Note N°. 134, 2nd edition, London, UK.

Gafsi Mostefa, Benmamar Saadia. (1999). Etude Expérimentale des Ecoulements dans les Canaux à Motifs Périodiques. Thèse de Magister, Ecole Nationale Polytechnique d'Alger (ENP), soutenu le 20 Novembre, 1999 à l'ENP.

Goubet, A. (1992). Evacuateurs de Crues en marches d'escalier. (Stepped Spillways).
La Houille Blanche, No. 2/3, pp. 159-162. Discussion: No. 2/3, pp. 247-248 (in French).

Kherbache K., (2008a) - Elaboration d'un code de calcul régissant les écoulements sur les coursiers d'évacuateurs de crues. Mémoire de magister en hydraulique, Ecole Nationale Polytechnique d'Alger, Algérie, p. 138

Kherbache K. & Benmamar S., (2008b). Simulation des écoulements dans les canaux en marches d'escaliers par la méthode des volumes finis . Algerian Journal Of Technology, pp. 153-163.

Kherbache K. & Benmamar S., (2010). Simulation numérique de l'écoulement graduellement varié aéré sur les coursiers d'évacuateur de crues en marches d'escaliers . 5ème conférence internationale sur : les Ressources en Eau dans le Bassin Méditerranéen. Lille, France.

Kherbache K. & Benmamar S., (2012). Modélisation de l'écoulement turbulent dans un canal a ciel ouvert. Communication acceptée pour publication à la 6 ème conférence internationale sur : les Ressources en Eau dans le Bassin Méditerranéen ; Octobre ; 10-12 ; Tunis, Tunisie, Septembre 2012

Stepped Gabion Weirs. Jour. of Hyd. Eng., ASCE, Vol. 118, No. 5, pp. 707-717.
Sorensen. R.M. (1985). Stepped Spillway Hydraulic Model Investigation. Jour. of Hyd . Eng., ASCE, Vol. 111, N°. 12, pp. 1461-1472. Discusion : Vol. 113, N°. 8, pp. 1095- 1097.