Study of various alternatives of shape of piano keys weir

A. Ouamane
Laboratory of hydraulics planning and Environment
University of Biskra
BP 145 RP 07000
Biskra, Algeria

F. Lempérière
Hydrocoop_France
4, Cité Duplan
75116
Paris, France

Introduction

Most of the existing free flow weirs have a standardized shape (Creager Weir) and are placed on structures of gravity dam. Their inconvenience is their low specific discharge which is about 2,2 $H^{1.5}$ (in $m^3/s/m$) (H being the depth of the nappe in m).
Consequently, the loss of useful storage corresponding to the maximal depth of the nappe can be from 20 to 50 %. It must so be very attractive to increase specific discharge as much as possible while reducing the depth of the nappe.
More than a hundred existing weirs were as a consequence conceived as vertical walls on a horizontal apron with a trapezoidal labyrinth in disposal much longer than the width of weir (often 4 times). Usually they double the specific discharge of a Creager weir. Beyond the cost for big discharges the main inconvenience of this traditional solution of labyrinth consists of what it cannot be used on the summit of usual section of gravity dams and requires an important cross section. It can be so used only for few dams.

A totally different conception was studied and tested for more than eight years by Hydrocoop_France and the Laboratory of Hydraulics Planning and Environment of Biskra University in Algeria. The preliminary studies of this conception leaded to the choice of two general forms of P.K.Weir, the first with an upstream and downstream overhangs and the second with only an upstream overhangs.

This new type of weir has the advantage to be adopted for an earth dams and on reduced sections of existing or new gravity dams. It allows the evacuation of specific discharges until $100 m^3/s/m$, by multiplying at least by three the discharge of Creager weir, its construction is simple and easy and can be realized by local resources of every country.

The P.K.Weir will reduce considerably the cost of most of the new dams and will allow to increase at the same moment, the capacity of the spillway and the storage capacity of the reservoir of the existing dams without for all that decreasing the degree of safety of dam.
It is likely that the other conceptions based on the same general geometry of models A and B can be more effective but the range of cost would not be probably very different. It could be interesting to choose according to the type of dam and the local conditions in every country one or two basic solutions and to standardize drawings for different specific discharges.

1. Various geometrical configurations of the P.K.Weir

The general shape of the P.K.Weir is based essentially on:
-A rectangular disposal somewhat similar to the forms of Piano keys which explain the name of Piano Keys Weir (P.K.Weir)
-An oblique apron of the inlet and outlet. The part where discharge enters is below called the inlet, the other part outlet.
-A reduced width of elements due to the rectangular shape.
-A base of length reduced due to the use of overhangs.

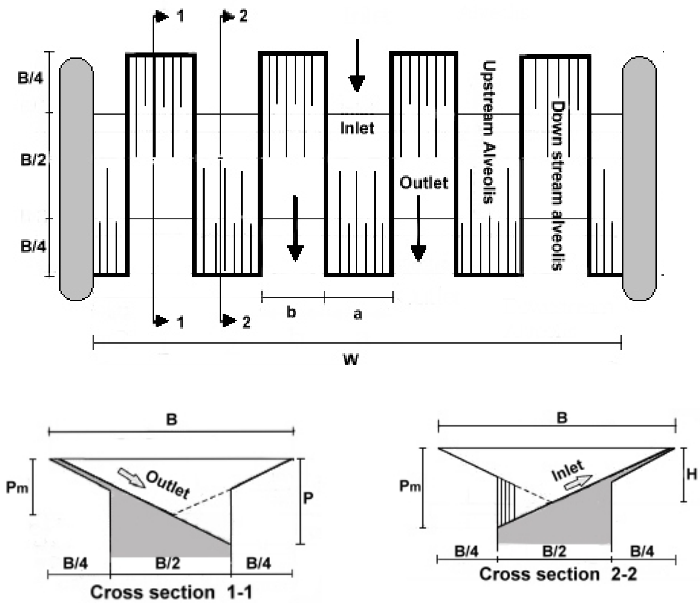

Fig. 1. Diagram showing the Piano Keys Weir model A.

The variation of the shape of the weir is possible; however, the most advantageous shape corresponds to the rectangular symmetric shape in plan as shown in the figure (1). The configuration of such a shape is defined by the height Pm, the width of the inlet and outlet a and b, the length of overhangs and the number of cycles n forming the weir. However, this geometrical disposal can undergo some modifications of secondary importance according to the type of the dam and the local conditions of the site. This modification can concern, the shape of overhangs and their disposal, the shape of the outlet apron (oblique, horizontal or in steps). For that purpose, four forms of P.K.Weir were suggested and studying in the laboratory to verify the type of flow and the hydraulic performance of these forms (Fig.2, 3et 4). The characteristics of these models are indicated in the following table.

Table 1. Geometrical characteristics of experimented models

Model	**L**	**P**	**P_m**	**a**	**b**	**a/b**	**a + b**	**N**	**nb**	**W_t**
	(cm)	(cm)	(cm)	(cm)	(cm)	-	(cm)	-	-	(cm)
A1	50	20	12	13,5	11,3	1,2	24,8	5,0	4	99,2
B1	50	20	12	13,5	11,3	1,2	24,8	5,0	4	99,2
C1	50	20	12	13,5	11,3	1,2	24,8	5,0	4	99,2
C2	50	20	12	9,0	7,5	1,2	16,5	7,1	6	99,0

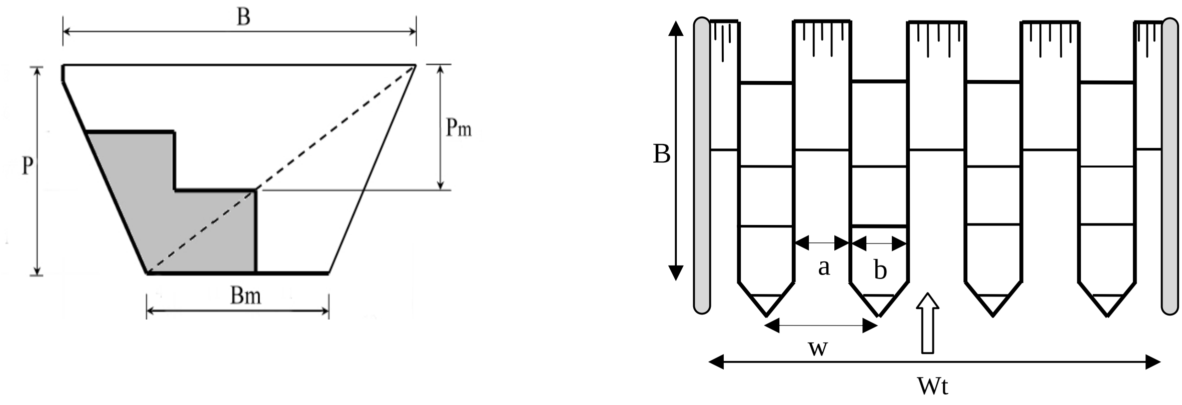

Fig.2. Diagram of the P.K.Weir (Model A1)

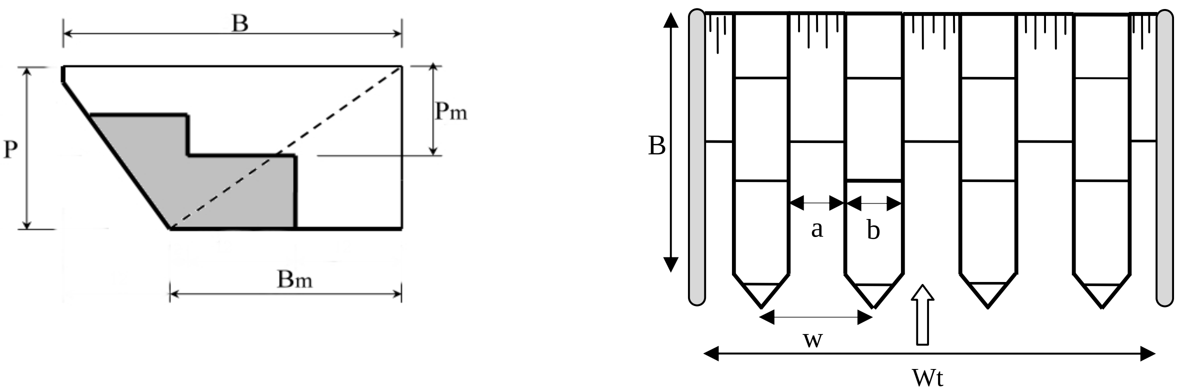

Fig.3. Diagram of the P.K.Weir (Model B1)

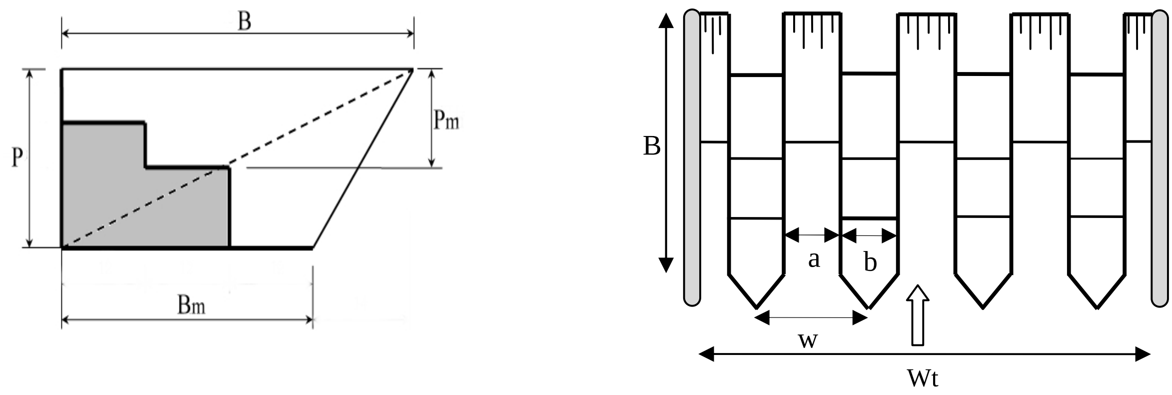

Fig.4. Diagram of the P.K.Weir (Model C1)

2. Experimental program

Experimental work was led in an experimental device of simulation of reservoir made up of a supply channel having a section 1.0 x 1.5m and 5.0 m of length. This channel is connected to a basin of simulation of reservoir having the form of a square 4x4m and 1,8m of height. The entry upstream of the basin of simulation is equipped with a metal grid and a brick wall, which makes it possible to ensure a uniform flow. A series of pressure outlet are placed in the basin of simulation at various places making it possible to measure the water pressure in each point. The models of labyrinth weir are inserted to the outlet of basin of simulation. A restitution channel of length 3m and of width 1m is connected to the outlet of basin ensuring the role of a chute of spillway.

Fig.5. Overview of experimental device

3.1 Impact of the geometry of overhangs

To verify the hydraulic performance of these three forms of P.K.Weir (Fig.2,3 and 4) several tests were realized recently with a free flow conditions and in conditions in the presence of the floating debris.
The effect of overhangs was studied for three cases:
1-P.K.Weir with upstream and downstream overhangs
2-P.K.Weir with upstream overhang and vertical wall in downstream
3-P.K.Weir with vertical wall in upstream and downstream overhang
The studies realized on the P.K.Weir for verifying the effect of overhangs in the hydraulic performance showed that shape profiled under overhangs is the most recommended (A. Ouamane and al. 2006). It is possible that the overhang will be tilted with the summit until the base of the P.K.Weir (fig.2), with this geometry the overhang can have a shape profiled on all its height, this can be interesting of hydraulic point of view and does not favor the jamming of the floating debris during the passage of floods. The results of tests realized on three models (fig.6) show that the hydraulic performance of weirs with upstream overhang is better than that of the weir without upstream overhang.

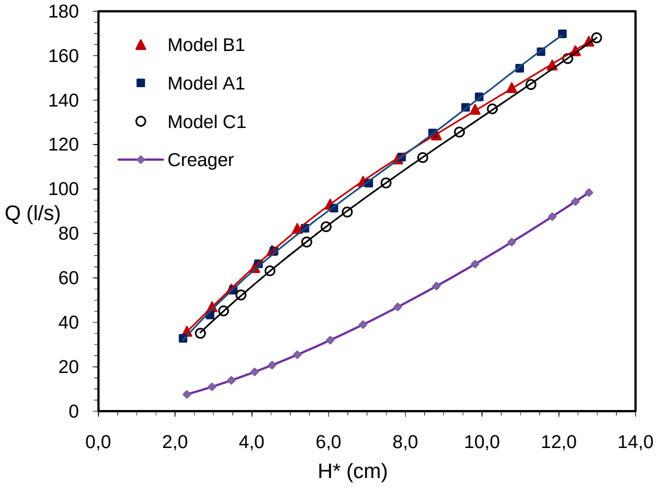

Fig.6. Curve discharges according to the head and to the presence of overhangs

The figure (6) shows that the increase of discharge with regard to the Creager weir is furthermore of four times for models with upstream overhangs (model A1 and B1) for the low heads (for H * < 0,2P) and furthermore of 3,5 times for the model without upstream overhang (model C1). On the other hand, for the great heads (H* > 0,45P) the increase of the performance is furthermore of twice.

3.2 Effect of the floating debris

The effect of the floating debris in the performance of the various models of P.K.Weir was studied to verify the consequences which overhangs can engender on the flow in the presence of the floating debris.

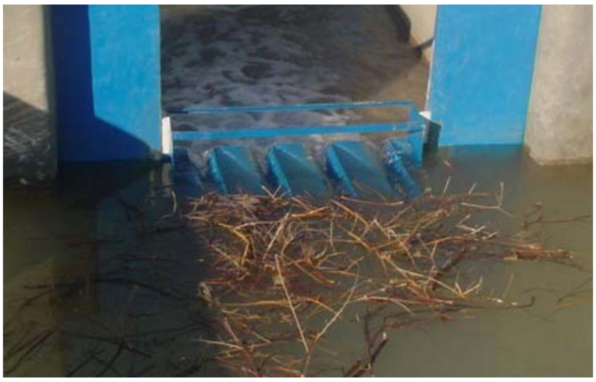

Fig.7. Flow on the model B1 with floating debris

During the experiment, it was noticed that the jamming of the floating debris by overhangs is tiny during the ascent of the water level from the base of the P.K.Weir to the crest and for the low heads. This justifies the low variation of the discharge noticed in the graphs of the figure (8) for the low heads. However, for the model A1 with overhangs upstream and downstream and for heads superior than 0,25P one notices a reduction of discharge which can be explained by the jamming of a part of the floating debris in the outlet of the P.K.Weir (P: total height of the P.K.Weir). When the head on the sill of the weir about 0,4P the floating debris begins to be evacuated systematically towards the downstream, what allows the P.K.Weir to find again his initial capacity.

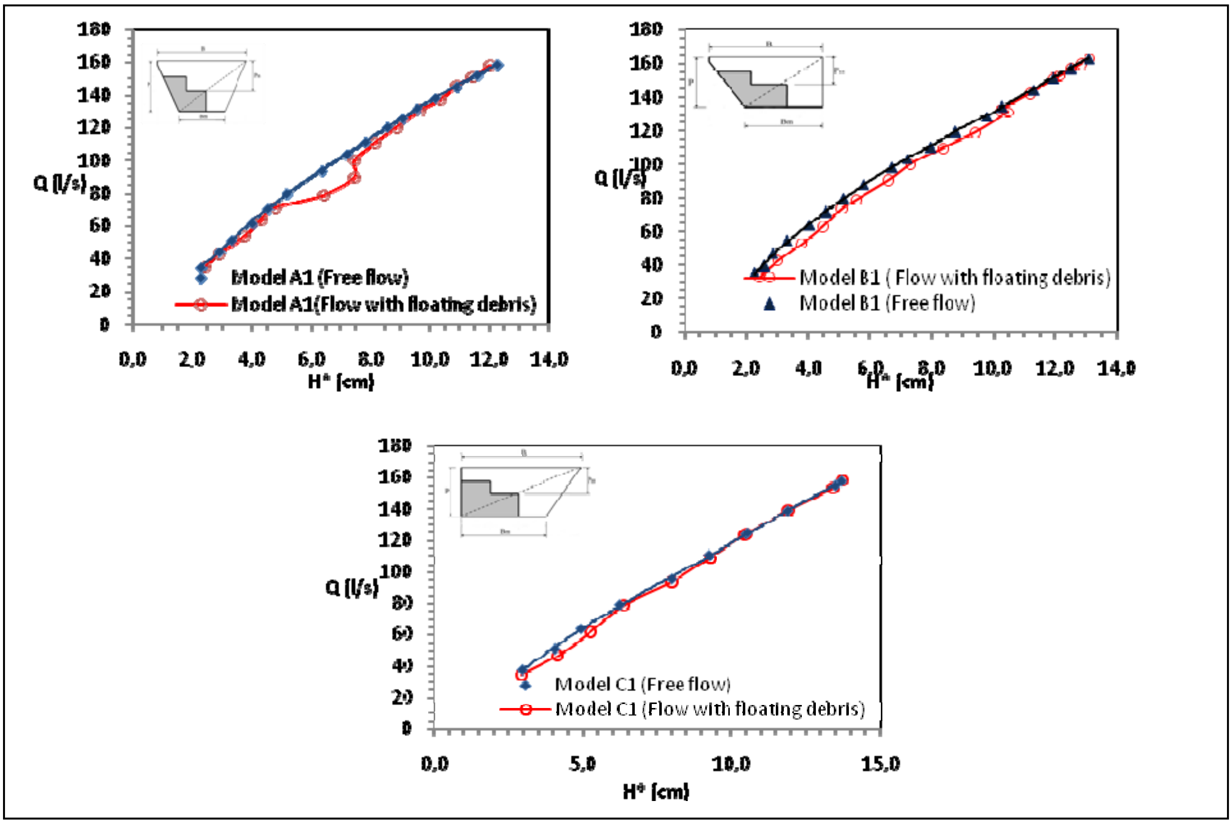

Fig.8. Effect of the floating debris over the flow of the P.K.Weir for the various configurations of overhangs

The graphs of the figure (8) show the effect of overhangs over the efficiency of the P.K.Weir in case of flow with floating debris, so , for the model A1 with upstream and downstream overhangs a low influence is noticed by the average heads, whereas for models B1 and C1, with a single overhang upstream or downstream influence is insignificant.

3.3 Impact of the conception of the outlet apron as steps

It is possible to avoid the high and thick walls very expensive by conceiving the apron of the outlet as steps by filling it by an ordinary concrete, it reduces the height of walls so, it favors the reduction of the thickness of walls and can have a role of energy dissipator in the outlet. This type of conception can be advantageous in particular for weirs with big discharges and can be used for RCC dams with downstream face as terraces.

Fig.9. P.K.Weir with the outlet apron as steps

Experimental tests realized on the model C2 of P.K.Weir showed that the realization of the outlet apron as steps (fig.9) has no effect on the hydraulic performance as long as the maximal height of steps is lower or equals by three quarter of the weir height (3P/4). The figure (10) shows that the two curves of discharges are identical and no difference is registered.

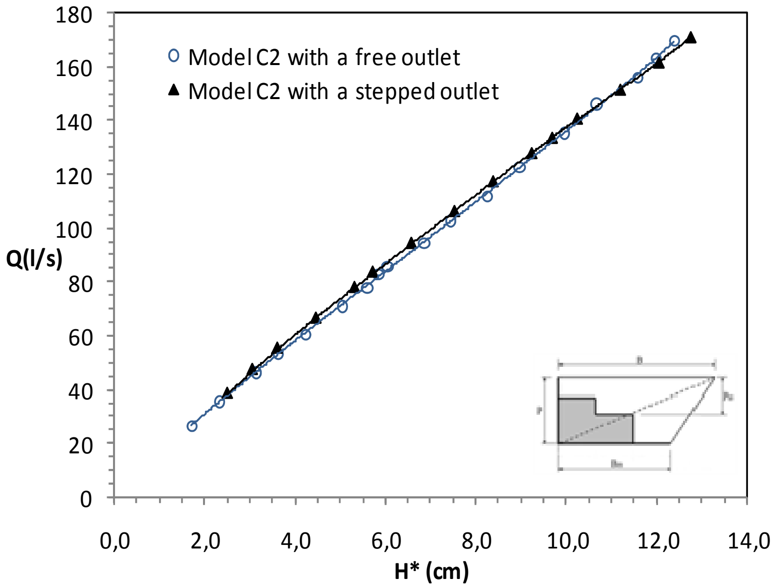

Fig.10. Curves of discharges according to the shape of the outlet apron

Result obtained from experimental tests show that the conception of the outlet apron as steps is interesting, especially for a big height of P.K.Weir. This conception can be also interesting for RCC dams in the case the weir is installed on the crest of the dam; in that case the steps conceived into the outlet can have a geometry similar to the shape of the terraces of the downstream face of the RCC dam.

Conclusion

The P.K.Weir with overhang continues from the summit to the base represent an effective solution for the reshaping of the existing weirs and the new dams. The shape is easy to build, it can be recommended for dams implanted in rivers characterized by a flow overloaded of floating debris and can be an adequate solution for RCC dams by settling the P.K.Weir on the crest of the dam and by fitting out steps into the outlet.

References

1- **Lempérière, F. and Ouamane, A**. "The Piano Keys Weir: a new cost-effective solution for spillways", *The International Journal on Hydropower & Dams*, Issue Four, 2003

2- **Ouamane, A. and Lempérière, F**. "Design of a new economic shape of weir", International Symposium on Dams in the Societies of the XXI Century, Barcelona, 2006.

3- **Ouamane, A.** "Hydraulic and Costs data for various Labyrinth Weirs", 22th Congress on Large Dams, ICOLD, Q84, Barcelona, 2006.

4- **Ouamane, A. and Lempérière, F**. "Increase of the safety of existing dams - Rehabilitation of weir", Symposium: Dam Safety Management. Role of State, Private Companies and Public in Designing, Constructing and Operating of Large Dams, ICOLD 75th Annual Meeting Saint Petersburg, Russia, 2007.

Ouamane, A. and Lempérière, F. "The Piano Key Weir is the solution to increase the capacity of the existing spillways" Hydro 2008 Conference, Ljubljana, Slovenia, 2008

The Authors

Dr. A. Ouamane has been a lecturer since 1986 in the Hydraulic Department of Biskra University in Algeria. He is Head of Research in the Laboratory of Hydraulic Planning and Environment. He has conducted various theoretical and experimental studies on shaft weirs, stepped weirs, labyrinth weirs and the P.K.Weir. University of Biskra, Department of Hydraulic Engineering, BP 918, RP 7000, Biskra, Algeria.

F. Lempérière bas been involved in the construction or design of fifteen hydraulic schemes on large rivers including the Rhine, Rhône, Mite and Zambezi. He is Honorary Chairman of the French Committee on Large Dams. He has been Chairman of the ICOLD Commitee on Costs of Dams (1991-2001). He is Chairman of Hydrocoop, a non-profit-making international association for technical exchanges.Hydrocoop, 4, Cité Duplan, 75116 Paris, France.