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Economic conceptions of the labyrinth weir allowing the improvement of the management of floods and the increase of the useful capacity of the reservoir

Abstract

The labyrinth weir can be at the same moment an effective way to improve the management of floods and the storage capacity. The concept of the labyrinth consists in modifying shape in plan of the existing weir to increase its crest length. This allows the passage of a big discharge under a low head. Furthermore, the labyrinth weir is characterized by an economic cost of construction.

More than a hundred labyrinth weirs are in operation with rather similar shape characterized by a trapezoidal or triangular layout, a vertical wall generally thin, an horizontal apron, a height of the walls which varies between 2 to 9 m, a depth of water nearly half of the height of walls, with specific discharges of the order of 5 - 50 m^3/s. The side walls are of important length (of the order of 8 times the height head of water).

The layout in plan of the labyrinth is probably not optimized (a symmetry upstream downstream unjustified, an entrance not profiled) and the volume of reinforced concrete is relatively important.

It is possible to improve the shape of the labyrinth weir by proposing a new conception which is characterized by a rectangular alveoli, a profiled entrance and a partial filling of the upstream and downstream alveoli which could be structurally and economically favorable. Tests carried out on several models showed that this configuration allows to optimize the conception of the labyrinth weir.

1 Introduction

In spite of efforts registered in the field of the prevention against the silting of the reservoirs of dams, storage capacity continues to be reduced under the influence of the siltation. On the other side, the updating of hydrological data and the importance of exceptional floods registered these last decades showed that most of the weirs of the existing dams do not allow the passage of extreme floods in complete safety.

These two problems which relate to the reduction of the storage capacity and the insufficiency of the capacity of the existing weirs can be circumvented by the rehabilitation of most of the existing weirs. Principle consists in modifying shape in plan of the weir (modification of the rectilinear shape of the crest of weir in the no rectilinear shape).

The sill of the existing weir can be heightened or keep the same initial level according to the fixed objective. Consequently, this disposal allows to double and even triple discharge evacuated through the weir in the case the objective is to increase the capacity of the weir. For the case of the silted dams, the disposal in labyrinth with the heightening of the sill of weir can increase the space of storage in a significant way (from 20 to 100 % as the case may be) [2].

The configuration of no rectilinear weir the most known corresponds to the labyrinth weir. This last one was the object of application for more than a hundred dams worldwide, one can quote the dam Ute in the USA. This dam was equipped with a rectilinear weir of Creager type which was replaced by a labyrinth weir to increase the storage capacity of the reservoir. [1].

The labyrinth weir is consisted of several cycles of the same geometrical configuration often trapezoidal or triangular repeated periodically. Obviously this increases quickly the length of the crest. Walls are arranged vertically and their thickness is relatively weak. The apron is often considered horizontal.

The cost of this type of weir is relatively low with regard to weirs equipped with gates, this leads to its use simultaneously to increase the space of storage and the capacity of evacuation [3].

It is possible that other shapes can be more effective than the trapezoidal and triangular shapes. So, for practical reasons, economic and of hydraulic performance, one can adapt a shape rectangular with a profiled entrance and the downstream alveoli apron as a step and that of the upstream alveoli partially inclined. These constructive peculiarities allow to improve the efficiency of the labyrinth weir and to reduce the cost of construction (Fig. 1).

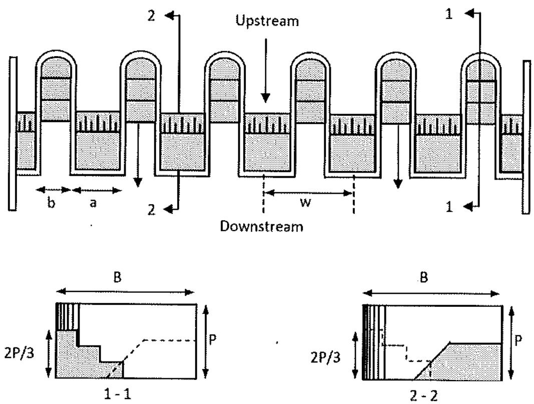

Fig. 1: Labyrinth weir of rectangular shape in plan with profiled entrance

a: width of the upstream alveolus
B: length of the lateral wall
b: width of the downstream alveolus
w: width of a cycle of labyrinth

The choice of the rectangular shape allows to vary the widths of upstream and downstream alveoli to obtain the report of the widths which allows to have a better hydraulic efficiency.

The profiled shape of the entrance and the slope of a part of the apron of upstream alveoli allow to improve the conditions of flow in the entrance of the labyrinth, consequently, the weir becomes more efficient.

The partial filling of upstream and downstream alveoli by the ordinary concrete allows to reduce the thickness of walls and the quantity of steel because part free of walls becomes reduced. The conception of the apron of the downstream alveoli under shape of stair allows also to dissipate a part of the energy in the outlet of the labyrinth weir.

2 Experimental Verification

To check the behavior and the performance of this new shape of labyrinth weir several tests detailed on selected forms at the Laboratory of Hydraulic Developments and Environment of the University of Biskra. The tests carried out on eight models of labyrinth weirs showed the effect of the rectangular shape in plan, the variation of the widths of alveoli and the conception of the upstream and downstream alveoli aprons in inclined shape or on the stepping of stairs.

Table 1: Geometrical characteristics of models

Shape	Entrance shape	P (cm)	a (cm)	b (cm)	w (cm)	L (cm)	n	L/W	W/P	Wt (cm)
Rectangular	Profiled (a)	15	9	6	15	540	6	6	1	90
Rectangular	Sharp (b)	15	9	6	15	540	6	6	1	90
Rectangular	Rounded (c)	15	9	6	15	540	6	6	1	90
Rectangular	Rounded	15	9	6	15	360	6	4	1	90
Rectangular	Rounded	15	7,5	7,5	15	360	6	4	1	90
Rectangular	Rounded	15	6	9	15	360	6	4	1	90
Trapezoidal	Flat	15	a'=3cm		15	360	6	4	1	90
Trapezoidal	Flat (d)	15			15	540	6	6	1	90

a': width of the frontal wall of the trapezoidal shape
a: width of the upstream alvèolus
b: width of the downstream alveolus
n: number of cycle
Wt: total width of the weir
P: height of the weir
L: total length of the crest
w: width of a cycle

2.1 Experimental setup

Experimental work was led in an experimental device of simulation of reservoir made up of a supply channel having a section 1 m x 1,5 m and 5 m of length. This channel is connected to a basin of simulation of reservoir having the form of a square 4 x 4 m and 2 m of height. The entry upstream of the basin of simulation of reservoir is equipped with a metal grid and a brick wall, which makes it possible to ensure a uniform flow. 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 3 m and of width 2 m is connected to the outlet of basin ensuring the role of a chute of spillway.

The models of P.K.Weir were built of steel with a thickness of 2 mm. All models are characterized by a shape of thin crest.

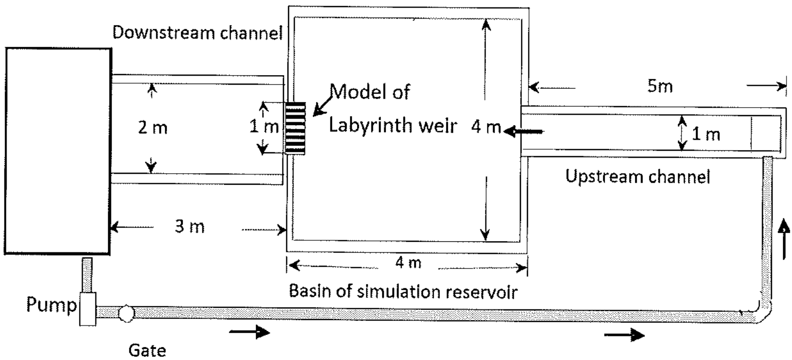

Fig. 2: Layout of the experimental device

2.2 Presentation of results

The capacity of labyrinth weir is generally expressed by the coefficient of discharge, which define the flow passing through a weir:

$$Cw = \frac{Q}{W\sqrt{2g}H^{*3/2}} \quad (01)$$

With:

Cw: coefficient of discharge
Q: discharge which pass through the weir (m^3/s)
W: width of the weir (m)
H*: total head on the silt of weir (m).

The coefficient of discharge is given according to the couple of the measured values, the discharge (Q) and the total head of water over the weir (H*), the other parameters of the equation (01) are constant for a given weir. For practical reasons, it is more suitable to represent the coefficient of discharge according to the adimensional parameter H*/P.

2.2.1 Comparative study with the trapezoidal shape

Often the labyrinth weir is conceived with a trapezoidal shape in plan which repeats periodically (Hinchliff on 1984). This is not justified. It is possible that the labyrinth weir can take another geometrical shape which can be as effective as trapezoidal shape. So, the choice of an rectangular shape can be also effective of point of view hydraulic and economic performance and its construction is more simple, especially when it is used as weir dam of small height in rivers. The tests of two models of labyrinth weirs with a same dimensions the first with a trapezoidal shape and the second with a rectangular rounded shape of upstream showed that the rectangular shape can be as effective as the trapezoidal shape and even more effective for the relative heads lower than 0,5, which corresponds to the practical range for the conception of labyrinth weirs (Fig. 3).

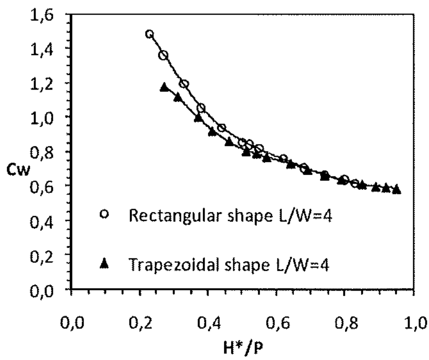

Fig. 3: Coefficient of discharge according to the shape of the labyrinth weir

2.2.2 Impact of the alveoli width

The geometry in plan of the proposed shape of labyrinth weir is characterized by two alveoli of rectangular form, the first of width (a) oriented towards the upstream and the second of width (b) directed towards the downstream, so the flow in the upstream and downstream alveoli can be different.

The choice of this rectangular shape leads to a conception of the weir with several variants of disposal of alveoli upstream and downstream (upstream wider than the downstream, with same width and upstream more narrow than the downstream). So, to verify the impact of the width of alveoli, three cases were considered ($a > b$, $a = b$, $a < b$) or ($a/b = 1.5$, 1.0 and 0.67). Obtained results showed that the conception of the weir with alveoli upstream wider than those of the downstream allows to have a better performance for the usual values of the relative heads $H^*/P < 0{,}5$. For values bigger the width of alveoli has no remarkable effect (Fig. 4).

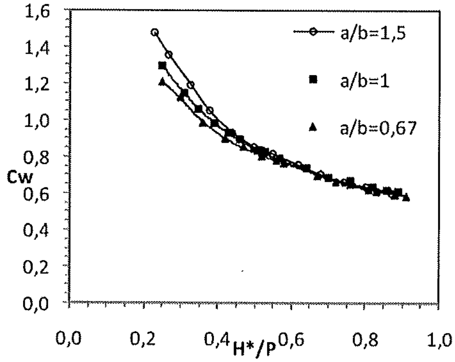

Fig. 4: Coefficient of discharge according to the width of upstream and downstream alveoli

2.2.3 Impact of the shape of entrance

The geometry of labyrinth weir makes that the weir becomes sensitive to the shape of entrance of the inlet alveolis. On the other hand, the rectangular disposal of the alveoli of the labyrinth weir can be more efficient if the entrance is profiled so as to improve the flow conditions to the entrance of the upstream alveoli. So, three models of labyrinth weir of various shape of entrance were tested (Fig. 5).

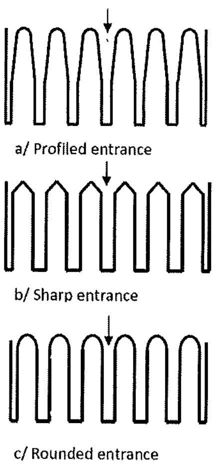

Fig. 5: Layout of the models of labyrinth weir with rectangular shape and profiled entrance

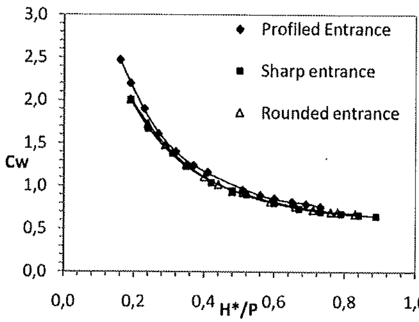

Fig. 6: Coefficient of discharge according to the shape of entrance

Experimental results show that the design of a better hydraulic form of the entrance (as for the pillars of a gated weir), would increase the efficiency of labyrinth weir for a low additional cost. The figure 6 shows that the profiled entrance (case a) is more effective than the two other shapes, it does not mean that the shapes of entrance sharp and rounded are not interesting of hydraulic point of view, the two cases of shape (b and c) allow also to have a better efficiency.

2.2.4 Impact of the conception of the downstream alveolis apron in stepping levels

It is possible to avoid the high very expensive walls by using the apron of alveoli as stepping of stairs by filling in ordinary concrete the inlet and outlet alveoli, this favors the reduction of the thickness of walls and can have a dissipator effect downstream. This type of conception can be advantageous in particular for weirs with big discharges. So, two cases of filling of alveoli were considered, the first on the quarter of the length of the inlet and outlet alveoli, the second on half of the length alveoli. Three heights of filling were considered for the rate of maximum filling which can be achieved without any effect in the hydraulic efficiency on the labyrinth weir.

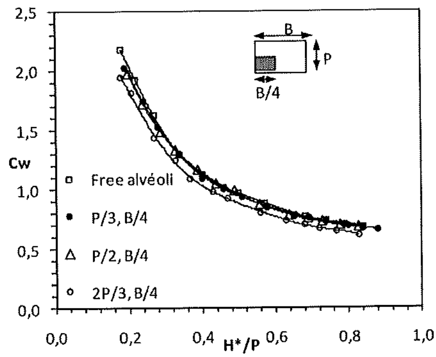

Fig. 7: Coefficient of discharge according to the height of the filling up in concrete (filling up on the quarter of the length of the alveolus)

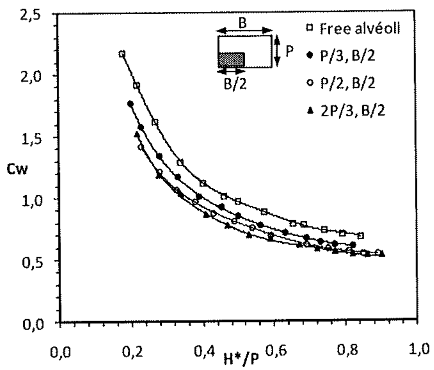

Fig. 8: Coefficient of discharge according to the height of the filling up in concrete (filling up on the half of the length of the alveolus)

The obtained experimental results shows that the filling of the quarter of the length of alveoli does not represent any effect on the efficiency of the weir for heights of filling up lower at two thirds of the height of the walls of the labyrinth weir (Fig. 7). On the other hand for a filling up corresponding at the half of the length of the alveoli the effect of filling and visible and expressed by a reduction of the coefficient of discharge for the various rates of filling up this can be noticed on the figure 8.

3 Conclusion

The labyrinth weir with a rectangular shape represents an effective solution for the increase in the storage capacity and/or the capacity of evacuation of floods of the majority of the existing dams. It can be an economic solution for new dams. The experimental study showed that the best conception of this weir is characterized by an upstream alveoli wider than the downstream alveoli, a profiled entrance and a filling up of alveoli, not exceeding the half of the height of walls and a quarter of the length of the alveolus.

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Mitteilungen

15. Deutsches Talsperrensymposium

Talsperren im Wandel

14.-16. April 2010
Eurogress Aachen

SHAKER
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Talsperren übernehmen als Multifunktionsbauwerke vielfältige Aufgaben u. a. in den Bereichen Hochwasserschutz, Trinkwasserversorgung, Energiegewinnung, Landwirtschaft und Freizeit und sind in Zeiten vielfältiger Veränderungen wie Klimawandel, demographischer Wandel, Landnutzungsänderungen, einem verstärkten Umweltbewusstsein und sich ändernden Sicherheitsbedürfnissen flexibel den Anforderungen und Herausforderungen von Gegenwart und Zukunft anzupassen.

Die Talsperren in Deutschland, aber auch in vielen anderen Ländern weltweit, haben ihre Funktionsfähigkeit und ihre hohe Zuverlässigkeit über viele Generationen eindrucksvoll unter Beweis gestellt. Im Laufe der Jahrzehnte und z. T. der Jahrhunderte wurden Talsperren permanent den veränderten Randbedingungen angepasst. Neue und veränderte Randbedingungen erfordern von den Talsperrenfachleuten die Entwicklung neuer und innovativer Maßnahmen, Methoden, Verfahren und Techniken.

Talsperrenfachleute, Wasserwirtschaftler und Wasserbauer haben sich vom 14. bis 16. April 2010 in Aachen zum 15. Deutschen Talsperrensymposium getroffen, um über laufende Projekte, den aktuellen Stand der Technik, planerische und bautechnische Innovationen sowie den Stand der Forschung zu berichten und die mit dem Wandel verbundenen Herausforderungen anzunehmen. Der vorliegende Tagungsband, der in der Reihe der Mitteilungshefte des Instituts für Wasserbau und Wasserwirtschaft der RWTH Aachen erschienen ist, enthält die auf dem Symposium präsentierten Fachbeiträge.

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