EXPERIMENTAL STUDY ON THE HYDRAULIC PERFORMANCE OF TRAPEZOIDAL PLANFORM COMPOUND LABYRINTH WEIR

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Abstract

Labyrinth weir is considered one of the most efficient solutions to regulate upstream elevations of water and hence increasing in flow capacity through increasing the crest length without changing the existing width of the structure. The trapezoidal planform of Labyrinth Weir is common shape used to regulate the water flow. The major aim of the present study is to investigate the hydraulic performance of a newly developed geometry of compound labyrinth weir under free flow conditions in the rectangular laboratory flume. In this study, 10 lab scale models are fabricated to investigate major design parameters which affect the weir efficiency for sidewall angle, weir orientation and weir height. The compound discharge coefficient for flow through holes and over trapezoidal labyrinth weir will be quantified from the test measurements. The curves were found from experimental data that show the relationship between the discharge coefficient and dimensionless term HT/P of one cycle compound labyrinth weir. The result shows that reducing the weir height result in increasing the coefficient of discharge (Cd) values for a given total head over weir height (Ht/P). Test results confirmed that the value of Cdc does not change significantly when comparison orientation of labyrinth weir.

1. Introduction

A labyrinth weir is a barrier built across a channel to increase the water level on the upstream side and it is allowing the water to pass over all crest length to the downstream side. There is a need to improve the capacity of discharge of the existing labyrinth weirs due to increasing demand for storage capacity, increasing events of floods etc. Labyrinth weirs consist of a series of linear weirs which are folded in plan view to give a longer crest length compared with a normal weir that having the same width to increase the flow for a given water head. labyrinth weirs deliver large flood at a comparatively low head. therefore, it can be commonly utilised to pass a range of discharge with a limited variation in upstream water levels and also where the width of a channel is limited. Discharge (Q) over a labyrinth weir under free flow condition can be expressed by the following mathematical expression

$$Q = Cd * \frac{2}{3}\sqrt{2g} * L_c * H_T^{1.5} \qquad (1)$$

Where Cd = discharge coefficient, Lc = length of the labyrinth weir crest, Ht = total head over the crest, g = acceleration due to gravity. The Cd depends on the geometry of the channel and the labyrinth weir and flows characteristics [1].

[2,3] examined different shapes of labyrinth weirs and obtained the results in the form set of curves that it represents the relationship between the discharge ratio over labyrinth weir (Q) to corresponding traditional normal weir (Q) and h/p. where p = weir height. The outcomes for their study explained that

the triangular labyrinth weir is more efficient than the trapezoidal labyrinth weir. [4] studied two-cycle Hyrum Dam auxiliary labyrinth spillways and investigated labyrinth weir positions and orientation effect on discharge. He found an effect on the head values in the normal position slightly less than those comparatives to the inverted position. [5] demonstrated the labyrinth weir capacity is function depend on the discharge coefficient, total head and length of the effective crest. [6] illustrated dimensionless submerged head parameters to describe the relationship water head and discharge of the submerged labyrinth weir with sidewall angles of labyrinth weir. [7] suggested a methodology for the best value of the coefficient of discharge for design labyrinth weirs. [8] conducted tests on different crest shape of the weir and utilising dimensionless analysis, he proposed the equation for calculating discharge over labyrinth weir. [9,10] investigated the flow characteristics over triangular labyrinth weir and found the efficiency the triangular labyrinth weir is better than the traditional linear weir. [11] carried out experiments on a characteristic of flow over trapezoidal labyrinth weirs by utilising experimental work for a range of sidewall angles of 8^0 to 30^0. [12] investigated the hydraulic performance of labyrinth weirs. They studied effect crest elevation on the coefficient of discharge for labyrinth weir. [13] conducted experimental work for five models of rectangular labyrinth weir with gate. They examined affect the effective length and height of labyrinth weir with various slopes of flume on discharge coefficient. They studied two cases for flow under and over the rectangular labyrinth weir-gate. The following equation was used to calculate the discharge coefficient for compound labyrinth weir that derivated by depending on flow over crest labyrinth weir and the flow through the holes that located it on wall labyrinth weir [14]

$$Q_{act} = Cdc \left[\frac{4}{3} * \sqrt{\frac{2g}{3}} * b_1 * H_T^{1.5} + \frac{32}{25} * \sqrt{\frac{2g}{5}} * tan\frac{\theta}{2} * H_T^{1.5} + \frac{2}{3}\sqrt{2g} * L_c * H_T^{1.5} \right] \quad (2)$$

Where Cdc = compound coefficient of discharge, Lc = length of labyrinth weir crest, g = acceleration due to gravity, Ht = total head over the crest.

2. Experimental Setup

2.1 Instrumentation

This work conducted in a civil lab at Deakin University. All the models setup in the tilting rectangular laboratory flume that have dimensions (25 cm depth, 7.5 cm width, and 500 cm length). the flume walls made of acrylic panels and a steel framework. Adjustment bed slop by one jack manually. In this study, the longitudinal slope for flume bed was set to zero. The water supply to flume was through the flexible pipe with diameter 2 in (5 cm) as shown in (Fig. 1). There is a sluice gate in downstream of the flume to regulate and control on the tail water level. The flume contains on a tank with capacity 250 L. The flow capacity is rated between 10 - 150 L/min. The water level is measured using point gauges with an accuracy of 0.1 mm and located (3h) upstream of the weir. All models are setup in the flume at a distance of 1 m from the inlet point. A digital flow meter is used to measure rates water flow. A thermometer is used to measure water temperatures with a range of 58°F to 302°F and readable to ±0.05°F.

Figure 1. Tilting rectangular flume in civil lab at Deakin University

2.2 Model Description

A 10 models configurations were examined in the present study. The models were built of wood, thickness 0.5 cm and coating as shown in (Fig. 2). The form of models were trapezoidal compound labyrinth weirs. The details of the physical model are shown in the (Table.1). Each model was examined in reverse and normal flow orientation. [15] stated that normal orientation when the outside apexes of a labyrinth weir fix to the flume wall at the upstream. While it is inverse orientation when apexes fix to the flume wall at the downstream end of the apron.

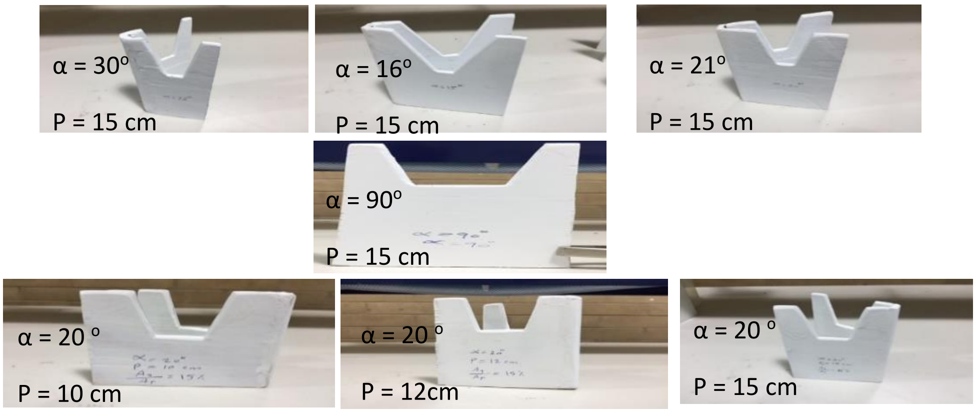

Figure 2. Explain the test models

Table 1. Physical model test program.

Model	α degree	P (cm)	B (cm)	Lc (cm)	Tw (cm)	A (cm)	D (cm)	N	Trapezoidal hole geometry			Crest shape	Type	Orientation
									B1 (cm)	B2 (cm)	Y (cm)			
1-2	16	15	10.7	23.3	0.5	0.5	1.25	1	1.18	7.2	5	Flat	Trap.	Normal & Reverse
3-4	21	15	8.1	18.3	0.5	0.5	1.19	1	1.4	6.4	5	Flat	Trap.	Normal & Reverse
5-6	30	15	5.5	13.6	0.5	0.5	1.08	1	1.6	4.1	5	Flat	Trap.	Normal & Reverse
7	90	15	-	7.4	0.5	-	-	-	3	4.1	5	Flat	Trap.	-
8	20	10	8.5	19.1	0.5	0.5	1.2	1	2.8	5.3	4	Flat	Trap.	Normal
9	20	12	8.5	19.1	0.5	0.5	1.2	1	3.1	5.1	4	Flat	Trap.	Normal
10	20	15	8.5	19.1	0.5	0.5	1.2	1	2.4	4.4	4	Flat	Trap.	Normal

Where: α is sidewall angle, P is height labyrinth weir, B is long labyrinth weir, Lc is crest length, Tw is wall thickness, A is inside apex width, D is out side apex width, N is number of cycles, B1 is bottom width for hole, B2 is top width for hole Y is hole depth.

3. Results and Discussions

In this study investigated the discharge coefficient of compound labyrinth weirs under free flow conditions. The first group of tests were conducted on the one-cycle models of trapezoidal compound labyrinth weir and used flat weir crest and four sidewall angles 16°,21°,30° and 90° leaner weir for comparing. The second group the tests carried out on labyrinth weirs have sidewall angle 20o and 10, 12, 15 cm weir height to examine the effective height of weir on the coefficient of discharge. 10 readings took for each run. The flow was measured for each run between 15 L/min to 150 L/min.

The current study applied the equations (Eq. 2) to compute the compound discharge coefficient. (Fig. 3), (Fig. 4) shows the relationship between the compound discharge coefficient Cdc with dimensionless term HT/P for inverse and normal direction for the flat labyrinth weir crest. In these figures seen that there is a maximum value for the compound coefficient of discharge in each of the curves. Then it follows by the long falling limb of the curve. The angles, α° = 90°,30°, 21° and 16° at HT/p = 0.15, the compound coefficient of discharge is increased slightly because the nappe flow was the sudden removal of the air cavity behind the nappe [15]. Also, the compound coefficient of discharge values are reduced with increasing HT/P due to the nappe of flow from nearby crests collides with another sidewall due to a non-aerated nappe (e.g., HT/P = 0.35 for α = 16°), also see (Fig. 5).

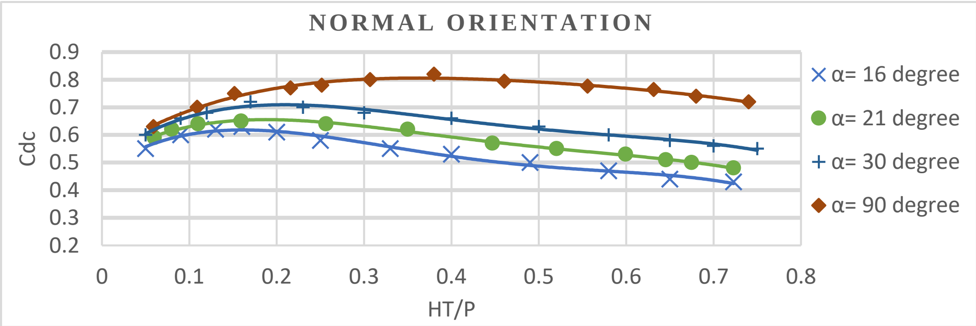

Figure 3. The relationship between Cdc values and Ht/P for flat crest of trapezoidal compound labyrinth weir

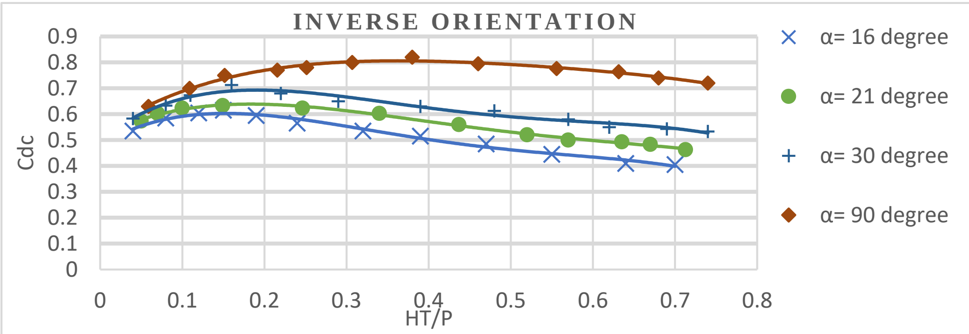

Figure 4. The relationship between Cdc values and Ht/P for flat crest of trapezoidal compound labyrinth weir

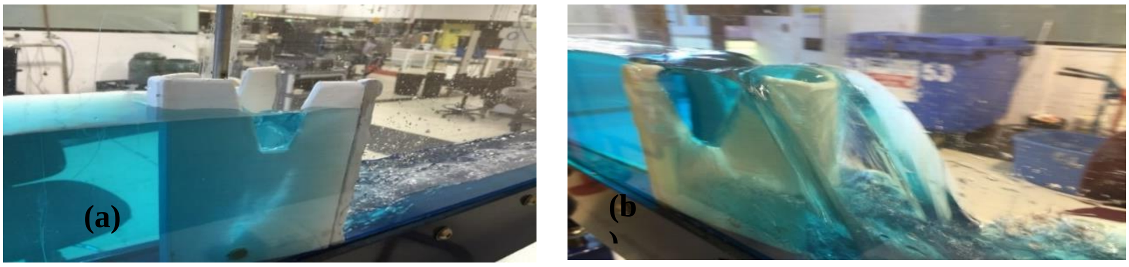

Figure 5. Explain nappe interference. (a) before the submerge for α°= 21°. (b) nearby crest that nappe observe collisions with nappe of other side for α°= 16°.

The compound coefficient of discharge is increased when the sidewall angle (α°) increases because reducing the crest length for the restrict width of labyrinth weir, hence reducing the effective region of the nappe interference. The results showed that the values of Cdc do not change significantly when comparison orientation labyrinth weir because the data are collected from examines one cycle labyrinth weir.The number of the apex is equal in both upstream and downstream of labyrinth weir that led to the nappe interference is less effective as shown in (Fig. 6).

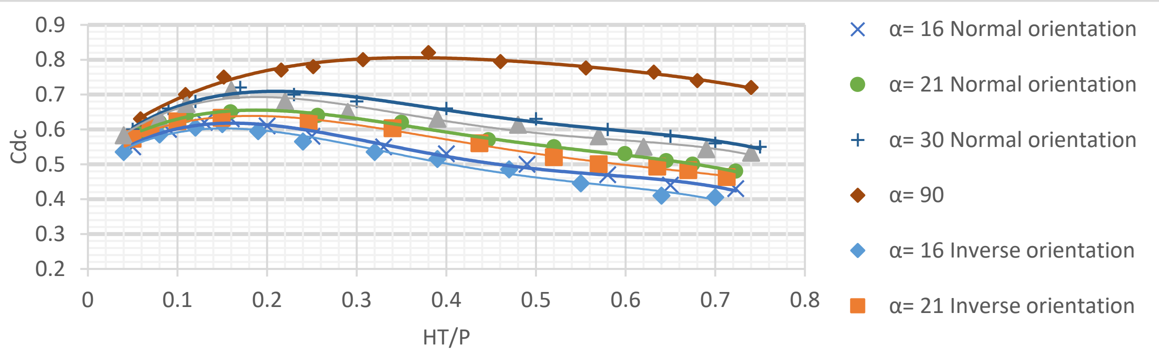

Figure 6. Comparison between the normal and inverse orientation of labyrinth weir.

(Fig. 7) shows comparison values of Cdc versus HT/P for different crest heights (P) for the flat crest of trapezoidal compound labyrinth weirs when (α) is 20 degrees. The compound discharge coefficient is increasing with reduced crest height of labyrinth weir for the same water head over the crest and reduces with the rise of water head over the crest of the labyrinth weir because of the interference of the water jets in downstream [16].

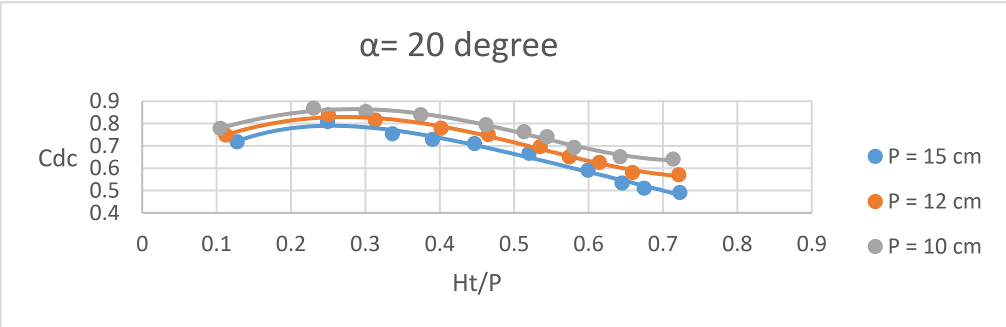

Figure 7. Comparison values of Cdc versus Ht/P for various (P) for flat crest trapezoidal labyrinth weir and α = 20°.

4. CONCLUSION

Labyrinth weirs are a hydraulic structure common in the world because of favorable in increasing ability the weir to pass greater amounts water through it in the flood seasons. The labyrinth weir is reflected an effective method for the improving in the storage capacity. From above results , The conclusions are obtained as the following:

1- The values of discharge coefficient were obtained from the design curves depend on tests that conducted on labyrinth weirs with four sidewall angle 16,21,30,90 degrees and flat labyrinth weir crest.
2- The compound discharge coefficient is increased initially when the water level over crest labyrinth weir reaches a higher value, then the curve gradually climbs down.
3- The results shown that the compound coefficient of discharge is the low value for a sidewall angle of 16^{o} and increases with high value for the sidewall angle under the limited width of the labyrinth weir.
4- The effect of orientation labyrinth weir was assessed. The present investigation demonstrates that labyrinth weir orientation does not significant effect on the discharge efficiency because the experimental data is obtained from one cycle labyrinth weir.
5- The compound discharge coefficient decreases with increasing crest height for the given water head over the crest.

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