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Calibration of discharge co-efficient for labyrinth weir

Labyrinth weir

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Abstract — *Trapezoidal labyrinth weir offer significant flow for the available width of approach channel and that of the downstream chute. These types of weirs may find great utility and hence will have to be designed and provided for river linking projects. Total length of labyrinth weir is typically three to five times the spillway width of straight overflow weir. In this paper, mathematical model for double and triple cycle labyrinth weir are proposed and analysis carried out for co-efficient of discharge and various parameters for double and triple cycle labyrinth weir. The experimental results are in good agreement with the results obtained by Tulli's and other investigations.*

Keywords- *labyrinth wier, mathematical model, double and triple cycle*

I. INTRODUCTION

A weir is a controlling device used to regulate the continuous supply of silt free water and which is normally placed perpendicular to the direction of river flow. The most important parameters for determining the capacity of a weir is head relative to the height of weir, the crest shape and the crest length. Hence capacity refers to the flow rate or discharge for a given depth of flow over the crest of weir. If the capacity of weir is to be increased for a given width of approach, the labyrinth spillway or weir offers a feasible alternative. Labyrinth weirs can be used to increase outlet capacity for a given spillway, crest elevation and length or to increase storage by raising crest while maintaining spillway capacity. Over the past 72 years, numerous research studies, case studies, and design methods have been published that have advanced hydraulic understanding of labyrinth weirs. Taylor (1968), Hay and Taylor (1970), Darvas (1971), Hinchliff and Houston (1984), Lux and Hinchliff (1985), Magalhães and Lorena (1989), Tullis et al. (1995), Melo et al. (2002), Tullis et al. (2007) are a selection of notable investigations conducted with physical models to quantify the hydraulic behaviours of labyrinth weirs, with emphasis on geometric and hydraulic influences on discharge capacity.The variables that need to be considered in designing labyrinth weir includes the length and width of labyrinth, the crest height, the labyrinth angle, the number of cycleas, and several other less important variables such as wall thickness, crest shape and apex configuration.

II. METHODOLOGY

A. Experimental set up

The channel setup was established and the dimension of the setup was fixed as 3m × 1m. The tank of 0.96m × 0.46m × 0.50m was constructed for measuring discharge. To minimize the turbulence caused due to inflow of water at inlet small sump were constructed. Its size was 0.61m × 0.61m × 0.61m.

Storage tank → Submersible pump → Flume → Small sump → Labyrinth weir 1.double cycle 2.triple cycle → Measuring tank

B. Experimental procedure

The following procedure followed for performing the experiments.

The triple cycle labyrinth weir was fixed in the setup as shown in fig. and all the leakages were made water tight with M-seal. All the pipes were connected and submersible pump was started also for particular valve the flow was made constant. Head of the labyrinth weir was measured above weir away from the labyrinth weir and for same discharge more readings were taken. The discharge was collected in a measuring tank for the fixed time period and tank was emptied by operating valve

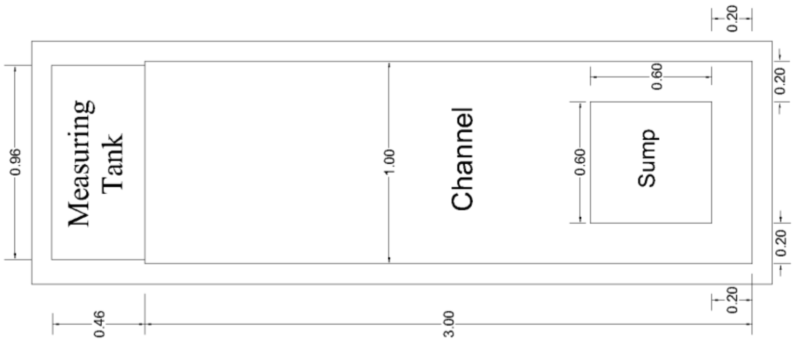

Figure 1. Experimental Setup

and dewatered water was re-circulated in to the main tank. For the different inflow through different valve operation repeat above procedure.

III. DESIGN OF WEIR SECTIONS

Case 1.Trapezoidal double cycle

As per the definition fig.2 and for the convenient design of double cycle trapezoidal weir take $\alpha=25^0$ and B= 0.2m. From the calculation and geometry of channel section

X= B tanα

X= 0.093m

From fig.2; $B^2 + X^2 = L^2$

L= 0.22m

Now, A= [1 – (3 X 0.05) –(4 X 0.093)]/2

A= 0.24m

Total length of weir,

L_1= (0.05 X 3) + (0.22 X 4) + (2 X 0.24)

L_1 = 1.51m

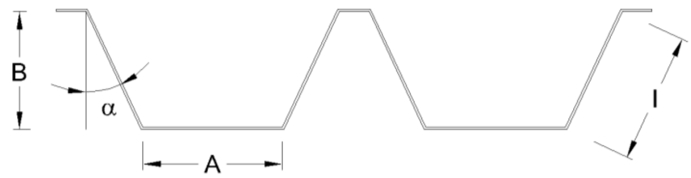

Figure 2. Trapezoidal double cycle

As H/P should not be greater than 0.9, for different values of head obtained P= 0.10m is selected.

Case 2. Trapezoidal triple cycle

As per the definition fig.3 and for the convenient design of triple cycle trapezoidal weir take $\alpha=8^0$ and B= 0.2m. From the geometry of fig.3 and calculations of other parameters

X= 0.028m

L= 0.20m

A= 0.21m

L_1= 2.03m

As H/P should not be greater than 0.9, for different values of head obtained P= 0.10m is selected.

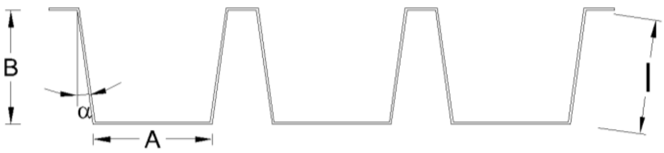

Figure 3. Trapezoidal triple cycle

Parameters in meter	P	B	L_1	L_n	A	L	α in degree
Trapezoidal double cycle	0.10	0.2	1.51	1	0.24	0.22	25^0
Trapezoidal triple cycle	0.10	0.2	2.03	1	0.21	0.20	8^0

Table 1. Dimensoins of double and triple cycle weir

IV. RESULT ANS RESULT ANALYSIS

The observations are presented in tables and following steps have been followed to develop coefficient of discharge mathematical model.

- The H/P ratio was maintained by opening valve of flume.
- The discharge (Q) was calculated from actual volume of water measured.
- The calibrated value of discharge (Q) , the value of C_d was computed.

$$Q = 2/3\, C_d\, L\, (2g)^{0.5}\, H^{1.5}$$

- Using the experimentaal value of $C_{d,}$ Q_n, Q_l, Q_n/Q_l and H/P ratio, multiple regration analysis and mathematical model was proposed using Origin Pro 7.5 version.

Sr. No.		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
Ht. of tank	Initial	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Final	8	8	19	17	18	25	24	23	25	28	25	31	29	32	32	35	34	34
Head (cm)		0.6	0.6	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5	2.5	2.5	2.5	3.0	3.0	3.0	3.5	3.5
Time (sec)		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Volume V (m^3)		0.04	0.04	0.095	0.085	0.090	0.125	0.120	0.115	0.125	0.140	0.125	0.155	0.145	0.160	0.160	0.175	0.170	0.170
Discharge Q (m^3/sec)		4.00	4.00	9.50	8.50	9.00	12.5	12.0	11.5	12.5	14.0	12.5	15.5	14.5	16.0	16.0	17.5	17.0	17.0
C_d		1.93	1.93	1.16	1.03	1.10	0.99	0.95	0.91	0.71	0.79	0.71	0.88	0.82	0.69	0.69	0.60	0.58	0.58
H/P		0.046	0.046	0.115	0.115	0.115	0.154	0.154	0.154	0.192	0.192	0.192	0.192	0.192	0.231	0.231	0.23	0.269	0.269
Q_N (10^{-3})		0.83	0.83	3.27	3.27	3.27	5.03	5.03	5.03	7.03	7.03	7.03	7.03	7.03	9.25	9.25	9.25	11.65	11.65
Q_L/Q_S (10^{-3})		4.82	4.82	2.905	2.59	2.75	2.48	2.38	2.286	1.778	1.99	1.78	2.205	2.062	1.73	1.73	1.892	1.46	1.46

Table 2. Observations for double cycle labyrinth weir

Sr.no.		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Ht. of tank	Initial	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Final	13.3	14.5	19.0	18.0	28.0	28.0	30.0	30.2	35.2	36.5	37.0	36.4	45.5	48.0
Head (cm)		1.1	1.1	1.2	1.2	2.0	2.2	2.5	2.7	2.9	3.0	3.1	3.1	3.2	3.7
Time (sec)		10	10	10	10	10	10	10	10	10	10	10	10	10	10
Volume V (m^3)		0.066	0.072	0.095	0.090	0.140	0.140	0.150	0.151	0.176	0.182	0.185	0.182	0.227	0.240
Discharge Q (m^3/sec)		6.6	7.2	9.5	9.0	14.0	14.0	15.0	15.1	17.6	18.2	18.5	18.2	22.7	24.0
C_d		0.95	1.04	1.20	1.14	0.82	0.71	0.63	0.56	0.59	0.58	0.56	0.55	0.66	0.56
H/P		0.0846	0.0846	0.0923	0.0923	0.154	0.169	0.192	0.207	0.223	0.230	0.238	0.238	0.246	0.284
Q_N (10^{-3})		2.05	2.05	2.34	2.34	5.03	5.81	7.04	7.891	8.79	9.25	9.71	.9.71	10.18	12.66
Q_L/Q_S (10^{-3})		3.22	3.51	4.06	3.84	2.78	2.06	2.13	1.91	2.0	1.967	1.904	1.87	2.23	1.895

Table 3. Observations for triple cycle labyrinth weir

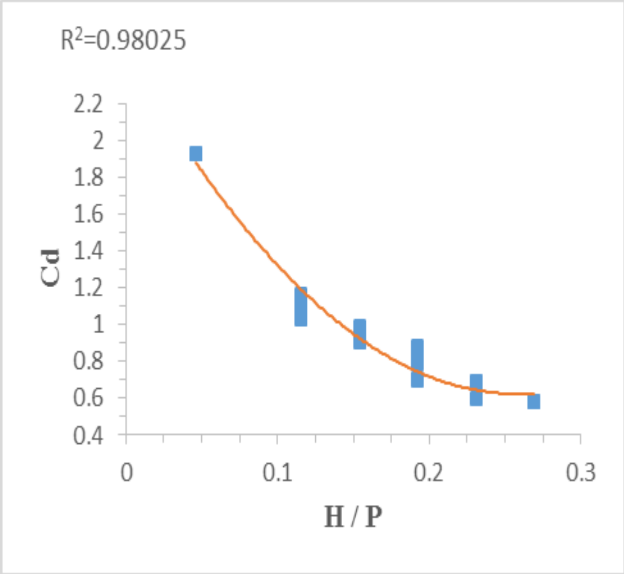

Figure 4. C_d vs H/P for Trapezoidal double cycle

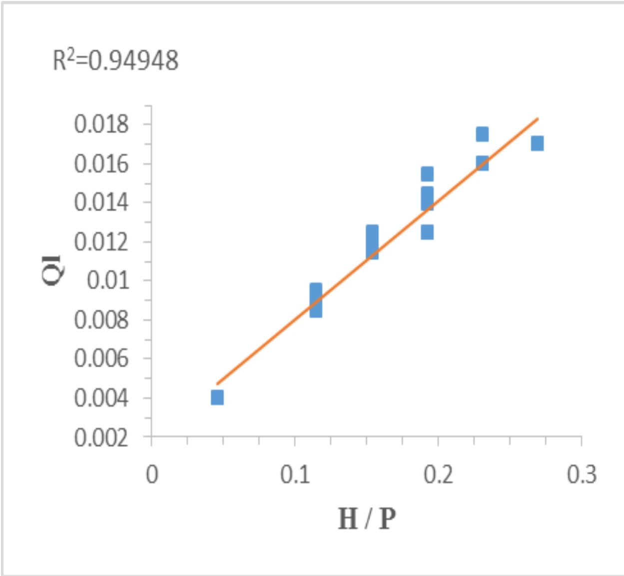

Figure 5. Q_l vs H/P for Trapezoidal double cycle

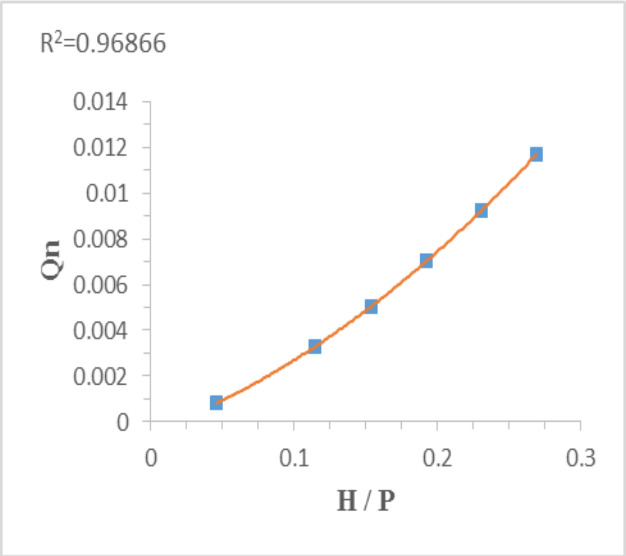

Figure 6. Q_n vs H/P for Trapezoidal double cycle

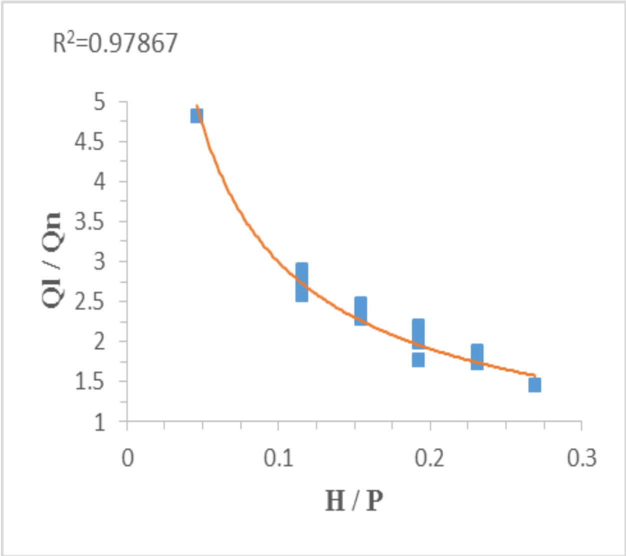

Figure 7. Q_l/Q_n vs H/P for Trapezoidal double cycle

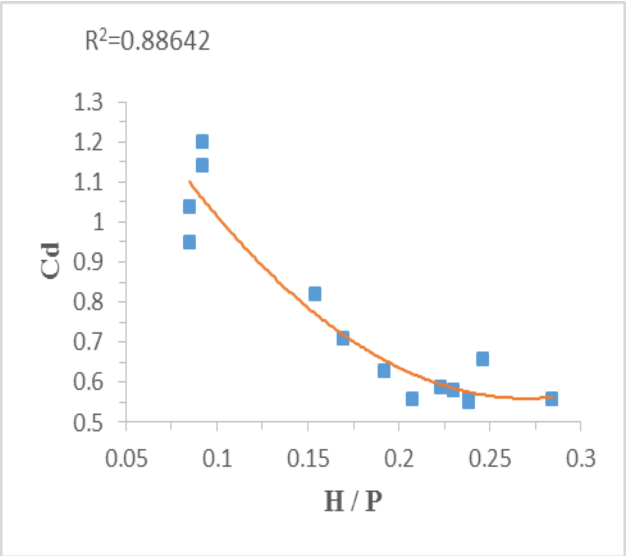

Figure 4. C_d vs H/P for Trapezoidal triple cycle

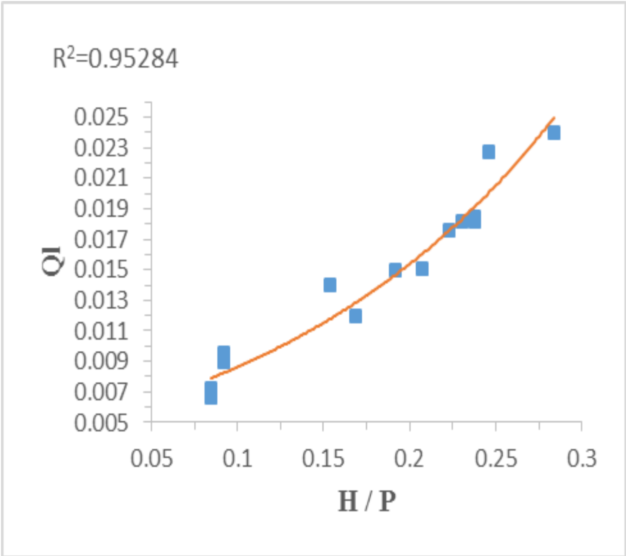

Figure 5. Q_l vs H/P for Trapezoidal triple cycle

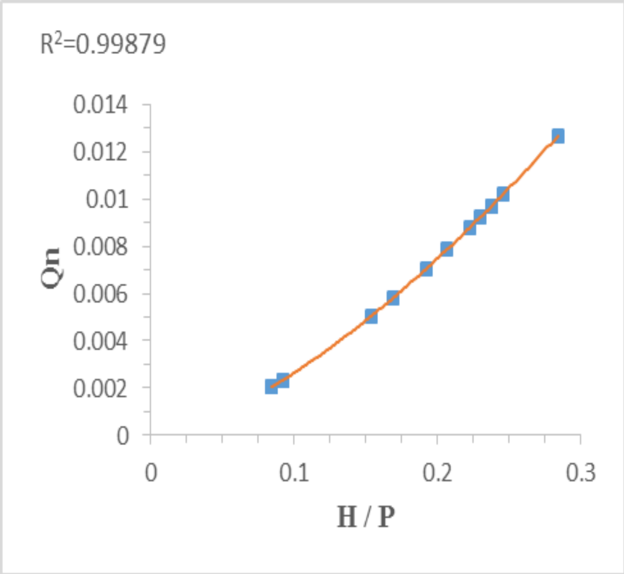

Figure 6. Q_n vs H/P for Trapezoidal triple cycle

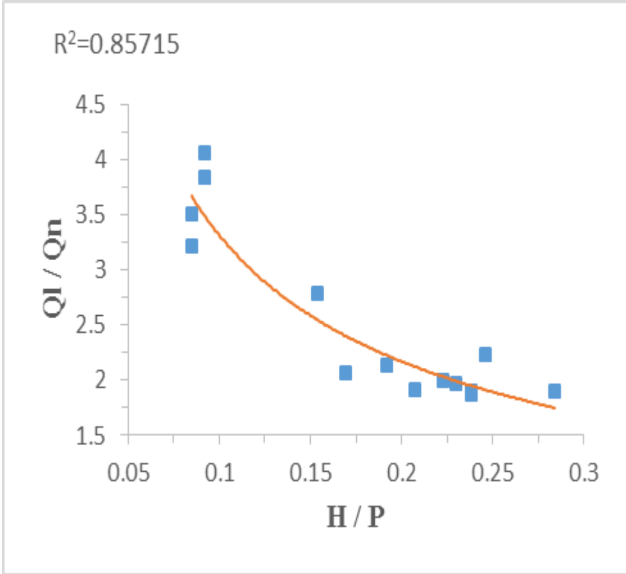

Figure 7. Q_l/Q_n vs H/P for Trapezoidal triple cycle

	Equation	y_0	x_0	A_1	t_1	R^2
Double cycle Layrinth weir	C_d Vs H/P $y = y_0 + A_1$*exp((x-x0)/t_1)	0.49579	0.04147	1.49864	0.08771	0.98025
	Q_l Vs H/P $y = y_0 + A_1$*exp((x-x0)/t_1)	-167.72645	-2827.19943	61.08289	2798.88859	0.94948
	Q_n Vs H/P $y = y_0 + A_1$*exp((x-x0)/t_1)	-0.01031	-0.28722	0.00421	0.33456	0.96866
	Q_l / Q_n Vs H/P $y = y_0 + A_1$*exp((x-x0)/t_1)	1.46	0.046	3.30428	0.07764	0.97867
Triple cycle Layrinth weir	C_d Vs H/P $y = y_0 + A_1$*exp((x-x0)/t_1)	0.51158	0.084	0.58947	0.07807	0.88642
	Q_l Vs H/P $y = y_0 + A_1$*exp((x-x0)/t_1)	-0.00965	-0.38627	0.00385	0.30932	0.95284
	Q_n Vs H/P $y = y_0 + A_1$*exp((x-x0)/t_1)	-0.02635	-1.08016	0.00467	0.64656	0.99879
	Q_l / Q_n Vs H/P $y = y_0 + A_1$*exp((x-x0)/t_1)	1.87	0.084	1.86979	0.04883	0.85715

Table 4. Proposed mathematical model for double cycle and triple cycle labyrinth weir

V. CONCLUSION

The capacity of labyrinth spillway is a function of the total crest head H, the effective crest length L and the crest coefficient C_d depends on weir height P, total head H, weir wall thickness t, crest shape, apex configuration and the angle of side legs α. With the crest geometry fixed C_d is only a function of α and head.

Following relation is proposed from the experimental study of double cycle labyrinth weir.

$$y= 0.49579 + 1.49864* \exp(-(x – 0.04147)/ 0.08771)$$

Where, x= H/P and y= C_d

Following relation is proposed from the experimental study of triple cycle labyrinth weir.

$$y= 0.51158 + 0.58947*\exp(-(x – 0.084)/ 0.07807)$$

Where, x= H/P and y= C_d

Following findings can be summarized as a result of experimental work.

1. The value of coefficient of discharge decreases initially and increases with the increase in value of H/P ration, where as in triple cycle Labyrinth weir initially value decreases, increases and then decreases with the increases in the value of H/P ratio.
2. In the case of triple cycle Labyrinth weir the crest length is more when compared with double cycle Labyrinth weir.

3. With the increase in the crest length for constant head and discharge value of coefficient of discharge decreases.
4. With the increase in the crest length the discharge increase with the increase with the increase in the head.
 The discharge of Labyrinth weir is more than normal weir for constant head and constant length.

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