DISCHARGE COEFFICIENT FOR CYLINDRICAL WEIRS

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ABSTRACT

The hydraulic characteristics of cylindrical weirs under free flow conditions were studied experimentally in order to investigate the discharge coefficient (C_d) and the influence of some significant factors and performance of weirs for discharge measuring.

The experimental tests were carried out on three models of weirs in which the diameter of weir (D) was varied three times as: 8.0, 10.0 and 12.0 cm. For each model, a series of measurements were taken to measure coefficients of discharge.

Results showed that the coefficient of discharge (C_d) increase with increasing the ratio of head to weir diameter (h/D), and for the same ratio (h/D),the discharge coefficient (C_d) increases with increasing weir diameter.

KEY WORDS

Discharge Coefficient , Cylindrical weirs

NOTATIONS

The following symbols are used in this paper:

C_d = Discharge Coefficient of weir

g = Gravitational acceleration

h = Head over weir

L = Channel width

D = Weir diameter = weir height (p)

q = Discharge per unit width

Q_{act} = Actual discharge

Q_{theo} = Theoretical weir discharge

R = Radius of weir

Re = Reynolds number

ρ = Mass density

μ = Dynamic viscosity

INTRODUCTION

Weir is one of the oldest, simplest and most reliable structure that can be used for many purposes [1]. The weir may be defined as an overflow structure built among which to measure the discharge across a river or open channel.

Weirs can be classified according to shape and thickness. In the present study, laboratory experiments were carried out to establish the coefficient of discharge (C_d) for cylindrical weirs and find their efficiency. The circular weirs have the following advantages [2] :-

1-The simplicity of design and the associated lower cost compared with ogee-crested weir.

2-Circular weir permits larger discharge capacity than broad and sharp crested weirs.

3-Stable overflow pattern.

4-Ease to pass floating debris.

An experimental tests were presented for the present study in which many experimental results were obtained. These results are very useful for the design and construction of this type of weir.

There were many studies and researches dealing with cylindrical ,circular and semi- circular weirs , the most important of them are :-

Chanson [2] studied the effects of inflow conditions on the behavior of cylindrical weir. Laboratory experiments were carried out on eight cylindrical weirs-sizes ranged from $0.029\ m < R < 0.117m$.

Results obtained from this research for cylindrical weir are as the empirical formulas:

For partially developed flow

$C_d = 1.12676\ (h/R)^{0.1811}$ ....(1) $(0.35<h/R<3.5)$

For fully developed flow

$C_d = 1.1854\ (h/R)^{0.1358}$ ....(2) $(0.45<h/R<1.9)$

Where:

h = head over weir.

R =curvature radius of weir crest

C_d= discharge coefficient

Haveen M. Rashid [3] used semi-circular and circular models. laboratory experiments carried out on three circular and semi-circular in which the radius was varied three times: (3.0,4.0.and 5.0cm).

Results obtained from this research were:

For circular	For semi-circular
Q: 0.242-1.534 l/s	Q: 0.197-1.484 l/s
h: 1.4-4.41 cm	h: 1.31-4.4 cm
h/R: 0.28-1.373	h/R: 0.262-1.36
C_d: 0.996-1.31	C_d: 0.896-1.305

Rokaia A.H.Al-Tikrity[4] studied the characteristics of flow over the semi-circular crested rectangular weirs under free flow condition. Laboratory experiments were carried out on nine models in which the crest radius (R) was varied three times as : 0.5,0.75 and 1.0cm

Result obtained from this research were:

Q: 0.4-2.657 l/s

h: 1.88-6.07 cm

h/p: o.235-0.759

R/p: .063-0.125

C_d: 0.996-1.31

Where:

P=Height of weir

The range of dimensional and hydraulic limitations which are used in the present study are:-

Discharge (Q): 0.193 – 1.889 l/sec

h : 1.37 – 4.94 cm

h/D: 0.114 – 0.538

Where:

D = Diameter of weir = Height of weir.

Q = measured discharge.

EXPERIMENTAL WORK AND EQUIPMENTS

The experimental work was carried out in a flume having a working length of 6 m with cross section 7.6 cm wide and 25 cm height. The side walls of this flume made from toughened glass with perspex panels in corporate. The bed was made from steel and supported to a frame in order to permit accurate alignment. Water was supplied to the channel by an electrically driven centrifugal pump. The flume was equipped with a downstream storage tank from which the water was drawn by the pump through a return pipe of 5 cm in diameter. A view of this flume is shown in fig. (1).

The laboratory experiments were carried out on three cylindrical models of three different diameters,(8, 10, 12 cm) , the models are made of well-varnished wood in order to have a smooth surfaces.

The model is fixed and sealed properly by an adhesive material. The discharge of the pump was regulated by using two valves in the operating system. For each of the three models a set of 10 tests were carried out, measurements were taken after a steady state is insured. In the experimental program, the following aspects of flow were investigated:

1-Measuring the water head over the weir (h) in order to compute the theoretical discharge ($Q_{theo.}$) by using ($Q_{theo.} = 2/3\sqrt{3}\ \sqrt{2g}\ h^{1.5}\ L$)[2].

Where:

L = channel width

2-Measuring the actual discharge ($Q_{act.}$). Through the weir by using direct volumetric method.

Discharge Coefficient Calculation

The discharge coefficient was taken as the ratio of actual discharge to theoretical discharge, thus:

$$C_d = \frac{Q_{act.}}{Q_{theo}} \qquad \text{.......................................(3)}$$

Where :

Q_{act}= actual discharge (m^3/sec)

$Q_{theo.}$=theoretical discharge (m^3/sec)

Dimensional Analysis

Dimensional analysis [5,6] was carried out using Buckingham's pi-theorem in order to achieve a rational correlation for the different variables. It's consideration for the present study was to arrive certain non-dimensional grouping that might be of significance to the problem.

A functional relationship for the characteristics of flow over cylindrical weir can be expressed as:

$$q = \theta_1 \,(h, D, g, \rho, \mu) \qquad \text{........................(4)}$$

Where:

q = discharge passing over the weir per unit width of the flume $(L^3T^{-1}L^{-1})$

ρ = mass density of flowing liquid (ML^{-3})

g = gravitational acceleration (LT^{-2})

μ = dynamic viscosity of the flowing liquid $(ML^{-1}T^{-1})$

The general relationship among all variables is

$$\theta_2(q, h, D, g, \rho, \mu)=0 \qquad \text{...............(5)}$$

Performing dimensional analysis with q, h, and μ as repeating variables and by using the (pi-theorem) , leading to the fact that the variables can be classified in the following groups :

$\pi_1 = q, h, \mu, D$

$\pi_2 = q, h, \mu, g$

$\pi_3 = q, h, \mu, \rho$

By dimensional analysis :-

$\pi_1 = \frac{h}{D}$ $\qquad \pi_1 = \frac{q^2}{gh^3}$ $\qquad$ and $\quad \pi_3 = \frac{\mu}{\rho q} = \frac{\nu}{q}$

or in more convenient $\quad \pi_3 = \frac{q}{\nu}$

Therefore eq.(5) becomes:

$$\frac{q^2}{gh^3} = \theta_3\left(\frac{h}{D}, \frac{q}{\nu}\right) \qquad \text{...(6)}$$

Taking the square root of the left hand side and replacing q/ν by VD/ν respectively, eq.(6) can be written as:

$$\frac{q}{\sqrt{g}h^{1.5}} = C_d = \theta_4\left(\frac{h}{D},\frac{VD}{\nu}\right) = \theta_4\left(\frac{h}{D},R_e\right) \quad \text{.....................(7)}$$

in which

C_d = The coefficient of discharge of flow over the cylindrical weir.

V= average velocity in approach channel

ν= kinematics viscosity of the following liquid

$$C_d = \theta_4\left(\frac{h}{D},R_e\right) \quad \text{.......................................(8)}$$

according to (Kindsvater and Carter[7] , Ackers et al[1]), the effects of Reynolds number can be neglected except at very low heads. Thus eq.(8) can be written as

$$C_d = \phi_5\left(\frac{h}{D}\right) \quad \text{.....................................(9)}$$

RESULTS AND DISCUSSION

Table (1) shows the range of (C_d) values which were resulted from the experiment work of this study for all models.

Variation of C_d with h/D for cylindrical weirs

For cylindrical weir models, the relationships between the discharge coefficient (C_d) and the ratio of a head over the weir to the weir diameter (h/D) for three different diameter (D), (8, 10, 12 cm) were drawn as shown in Fig. (1). From this figure, the following results can be noticed:-

1-The coefficient of discharge increases with increasing the ratio (h/D).

2-For the weirs with a same ratio of (h/D), the coefficient of discharge increases with increasing the diameter of the weir.

Variation of $Q_{act.}$ with C_d and h/D for cylindrical weirs

Fig. (2) was drawn to show the relation between actual discharge and coefficient of discharge for weir models under free flow. From this Fig. it can be noticed that coefficient of discharge (C_d) increases with increasing actual discharge (Q_{act}) Also, the actual discharge increased with increasing the diameter of the weir (D), for the same ratio h/D as shown in fig. (3) this mean that the weir with large diameter have large discharge capacity than small diameter cylindrical weir, consequently its performance is better because with increase the diameter will have best parallel stream lines

CONCLUSIONS

From the present study and it's limitations the following conclusions can be drawn:

1-The discharge coefficient (C_d) increases with increasing (h/D).The range of C_d is between (0.853-1.34)

2-For the same ratio (h/D), the coefficient of discharge (C_d) increases with increasing the diameter of cylindrical weir (D).

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Table (1): Experimental Results of cylindrical weirs

D = 8.0 cm					D = 10.0 cm					D = 12.0 cm				
h (cm)	$Q_{act.}$ (l/s)	$Q_{theo.}$ (l/s)	h/D	C_d	h (cm)	$Q_{act.}$ (l/s)	$Q_{theo.}$ (l/s)	h/D	C_d	h (cm)	$Q_{act.}$ (l/s)	$Q_{theo.}$ (l/s)	h/D	C_d
1.63	0.241	0.270	0.204	0.893	1.47	0.197	0.231	0.147	0.853	1.37	0.193	0.209	0.114	0.925
1.93	0.331	0.346	0.241	0.956	1.68	0.264	0.282	0.17	0.936	1.8	0.298	0.298	0.15	1.0
2.04	0.387	0.378	0.255	1.023	2.05	0.396	0.380	0.205	1.042	2.11	0.433	0.399	0.176	1.085
2.55	0.565	0.528	0.318	1.07	2.2	0.444	0.423	0.22	1.05	2.47	0.583	0.503	0.206	1.16
2.7	0.648	0.575	0.338	1.127	2.6	0.610	0.543	0.26	1.124	2.93	0.807	0.649	0.244	1.242
3.0	0.779	0.673	0.375	1.158	3.41	1.017	0.815	0.341	1.248	3.48	1.091	0.841	0.29	1.297
3.48	1.002	0.842	0.435	1.19	4.07	1.37	1.064	0.407	1.287	3.99	1.370	1.032	0.333	1.327
3.85	1.228	0.979	0.481	1.254	4.5	1.618	1.236	0.45	1.309	4.49	1.639	1.232	0.374	1.330
4.15	1.385	1.096	0.520	1.263	4.72	1.740	1.328	0.472	1.310	4.8	1.814	1.362	0.4	1.332
4.305	1.488	1.157	0.538	1.286	4.94	1.866	1.422	0.494	1.312	4.91	1.889	1.41	0.41	1.34

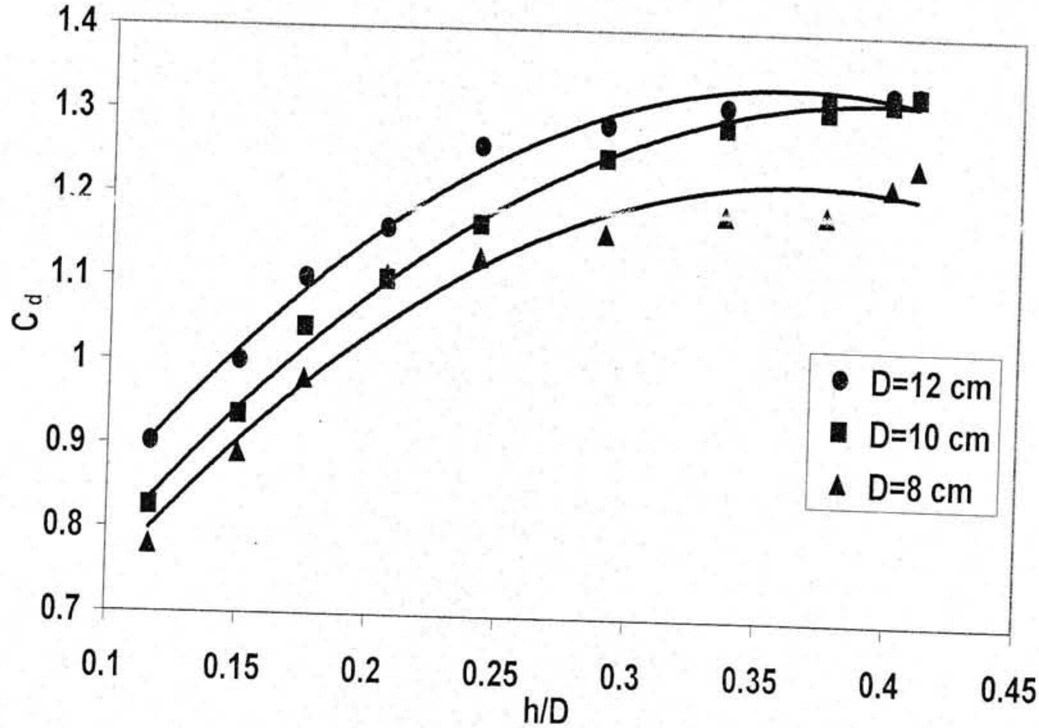

Fig.(1) Variation of C_d with h/D for cylindrical weirs

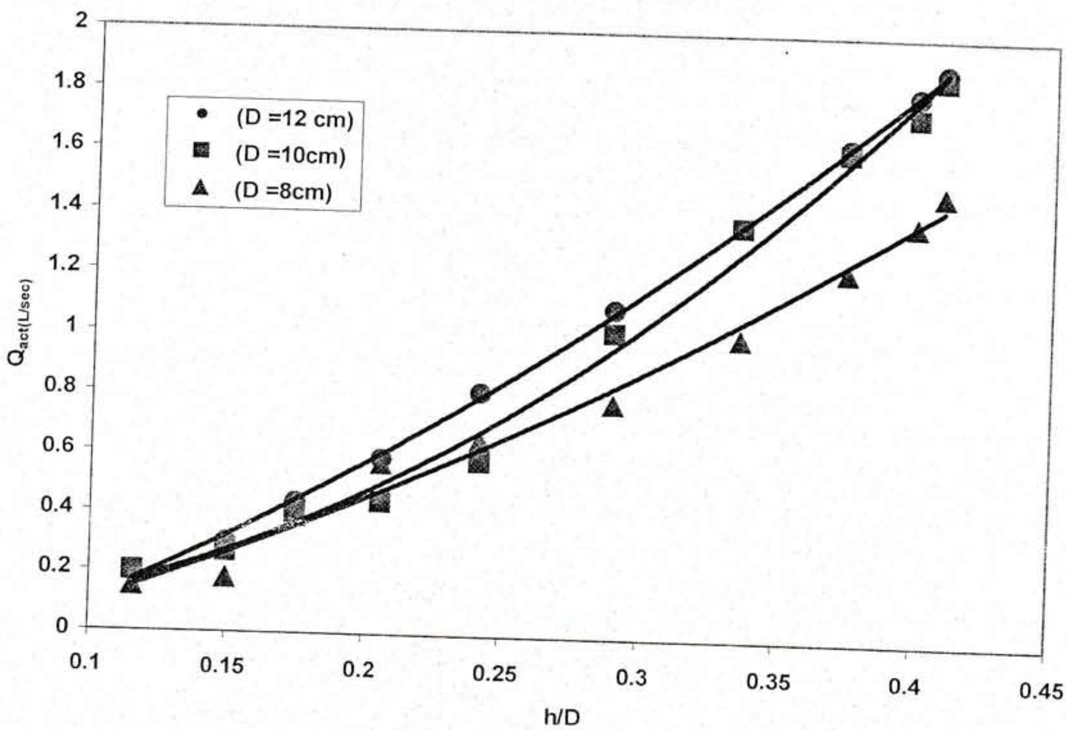

Fig.(2) Variation of Q_{act}. with h/D for cylindrical weirs

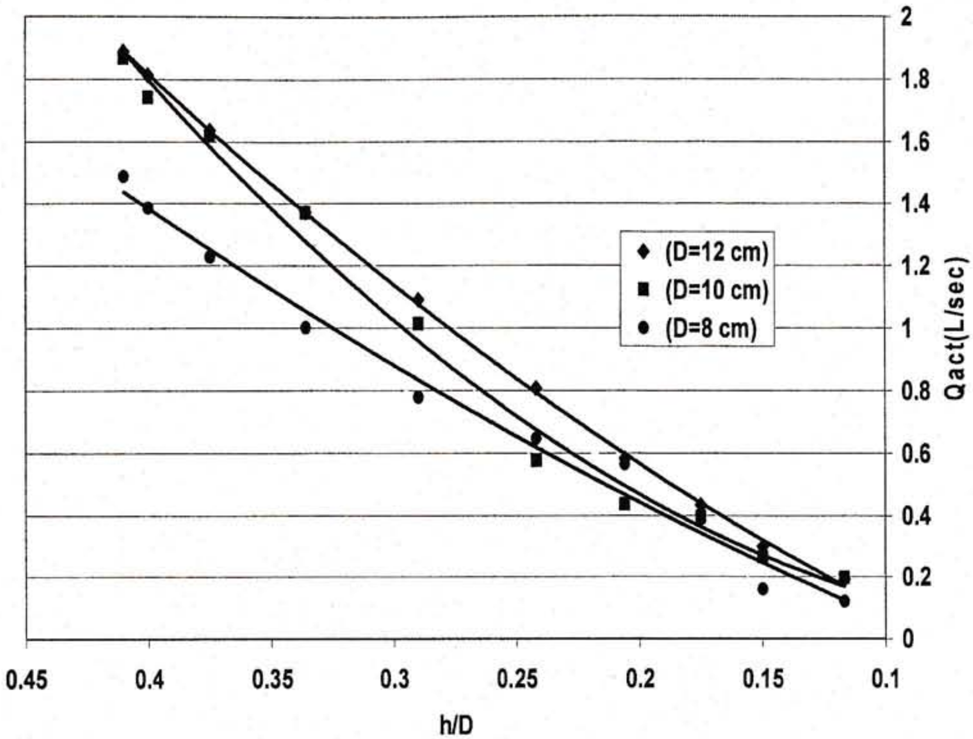

Fig.(3) Variation of $Q_{act.}$ with h/D for cylindrical weirs

معامل التصريف للهدارات الأسطوانية

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الخلاصة

في هذا البحث تمت دراسة الخواص الهيدروليكية للسد الغاطس الاسطواني مختبريا تحت حالات الجريان الحر. وذلك بايجاد معامل التصريف (C_d) وتأثير بعض العوامل المهمة علىاداء هذه السدود في حساب التصريف.

اجريت التجارب المختبرية على ثلاثة نماذج من السدود الغاطسة، حيث ان قطر السد الغاطس (D) والذي يساوي ارتفاع النموذج ايضا (p) تم تغيره ثلاث مرات ٨، ١٠، ١٢ سم ولكل نموذج تم اجراء سلسلة من القياسات لحساب معامل التصريف.

بينت النتائج بان معامل التصريف (C_d) يزداد بزيادة العلاقة بين شحنة الماء فوق السد الى قطر السد (h/D) كما انه لنفس العلاقة فان معامل التصريف (C_d) يزداد بزيادة قطر السد الغاطس (D).

الكلمات الدالة

معامل التصريف ، الهدارات الاسطوانية