Hydraulic Characteristics of Flow over Circular Crested Weirs

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Abstract:

In this investigation nine models of circular crested weir were constructed and tested during an experimental study. Crest radius(r) of the weir was varied three times; 2.5 cm, 3.1cm and 3.75cm. For every crest radius the weir height (p) was varied three times; 15cm, 20cm and 25cm.

The result was showed that the discharge coefficient (C_d) affected by two factors; head above the weir to the crest height (h/p) and head above the weir to the crest radius (h/r). It was observed that coefficient of discharge (C_d) increased with increasing (h/p) for the similar height of weir and for definite value for the ratio h/p the (C_d) value increased with increasing the crest height (p). Also it was found that coefficient of discharge (C_d) increased with increasing (h/r) for the similar crest radius and for definite value for the ratio (h/r), the (C_d) value increased with increasing the crest radius (r). A simple power experiential expression was found for the variation of (C_d) with (h/p) and (h/r) with high correlation coefficient.

Keywords: *Circular weir, Discharge coefficient, crest shape.*

1. Introduction

Weir is the eldest hydraulic structure used for measuring the discharge in open channel and it is used for other purposes such as divert water, regulation of water flow and many other application in hydraulic engineering.. Circular crest weir or cylindrical weir related to the ogee weir shape has simplicity to design with low cost, over flow form was stable, pass floating material at surface of water easily, and has large coefficient of discharge.

Ramamurthy A, and Ngoc-Diep Vo. (1992): Experimentally studied of characteristics circular crested weirs to show the effects of weir slopes on coefficient of discharge. The result showed that varying the upstream slopes doesn't change the weir discharge coefficient, but, increased the downstream weir slopes seemed to increase the discharge coefficient. The experimental data indicate that the circular-crested weir acted like a sharp crested weir when dimensionless total head to radius of circular crest was large**.**

Chanson H and Montes J.S. (1998): Experimentally investigated circular weir overflows. The researchers tested eight cylinder sizes for several weir heights and for five different types at inflow condition, partially developed inflow, fully developed inflow, upstream ramp, upstream undular hydraulic jump and upstream (breaking) hydraulic jump. The experiments results showed that the cylinder size, the weir height D/R and the attendance of an up stream ramp had no influence on discharge coefficient, flow depth at crest and energy dissipation; however, the inflow conditions had large influence on the discharge characteristics and flow properties at the crest. Upstream flow condition had important affected for circular weir discharge measurement.

Noori B. M.A and Chilmeran T. A.H. (2005) Experimentally studied the characteristics of normal and oblique weirs with semicircular crests for free flow condition. The radius of weir crest was changed three times, height of weir was changed four times and the oblique angle was varied three times. The experimental result indicated that normal weirs of semicircular crests were better than those of sharp crests weirs for all values of weir height and crest radius. For normal weirs the discharge coefficient (Cd) increased with the increase of head to crest height ratio for the same height of weir. In case of oblique weirs, it was found that (Cd) decreases with the increase of (h/p) values and weirs of small oblique angle give high values of (Cd).

Hayawi H. A. and Al-Moula S. J. (2006): experimentally studied the coefficient of discharge of normal and oblique weirs with semicircular crest under free over flow conditions. The oblique angle, downstream face slope, and weir height were changed during the experimental programme. While the upstream slop was fixed for all models .The experimental results of the study showed that the discharge coefficient (Cd) increases with the increase of water depth above the crest to the weir height ratio (H/P), and with the increase of downstream slope .In case of oblique weirs, it was found that (Cd) decreases with increase of (H/P) values. Also it was found that (Cd) increases with the increase of the downstream slope (β) & weirs of small oblique angle (θ) give low values.

Thabet M. Abdul-latif et al.(2010) studied the evaluation of discharge coefficient of semicircle crested weir across the full width of the channel. They proposed an empirical equation showed that the discharge coefficient is proportional with upstream head above weir crest but inversely with the radius of curvature**.**

Emad Abdul_Gabbar Al Babely et. al (2011) investigated the overflow characteristics of cylindrical shape weirs in laboratory for various cylinder radii. The result was showed that the increase in the ratio of head to weir radius ratio (Hw/R) value causes an increase in discharge coefficient (Cd) value for the same height of weir and the discharge coefficient was influenced by radius of cylindrical weir.

Benyamin Naghavi et al (2011) pressure and velocity distributions of different circular weirs were compared between experimental and simulated by computational fluid dynamics (CFD) and Fluent software. They proposed analytical formulations to recognize the location of critical flow and nape separation, depending on weir size and inflow conditions. The results were showed good agreement between the analytical predictions and experimental observations.

2. Theoretical Considerations

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

$$Cd = \frac{Q_{act}}{Q_{theo}}$$

where,
Cd = coefficient of discharge,
Q_{act} = actual discharge and,
theoretical discharge=Q_{th}
The actual discharge was measured by reading the electro-magnetic flow meter, then calibrated using slandered weir, while the theoretical discharge was evaluated by using the following formula:

$$Q_{theo} = \frac{2}{3}\sqrt{2g}LH^{1.5}$$

Where, L= length of weir , g = acceleration due to gravity and H = total head above crest level.

So H= h+ $v^2/2g$

$v^2/2g$ is upstream velocity head, is very small compared to h so that it is negligible. This assumption is less acceptable when the channel is narrow.

eq.(2) can be rewrite as:

$$Q_{theo} = \frac{2}{3}\sqrt{2g}Lh^{1.5}$$

Where, h = flow depth above crest level at upstream.

A general relationship for the variables affecting the discharge coefficient (Cd) for a flow over circular crested weir can be expressed as:

$$C_d = f_1(q, p, L, r, \mu, g, h, B, \rho)$$

where, q= discharge per unit length p = weir height, r = crest radius , μ = dynamic viscosity , g =acceleration due to gravity ρ = mass density of fluid, , B = main channel width and ρ= specific weight of water .

Using Buckingham Pi-theorem and after certain permissible manipulation Eq.(3) becomes:

$$f_2\left(\frac{q}{\sqrt{g}h^{3/2}}, \frac{p}{h}, \frac{r}{h}, \frac{\mu}{\rho g h^{3/2}}\right)$$

$$q = \sqrt{g}h^{3/2} f\left(\frac{p}{h}, \frac{r}{h}, \frac{\mu}{\rho g h^{3/2}}\right)$$

$$Cd = f\left(\mathrm{Re}, \frac{h}{p}, \frac{h}{r}\right)$$

After neglecting the effects of viscosity the final relationship the Cd and other dimensionless groups will be:

$$Cd = f\left(\frac{h}{p}, \frac{h}{r}\right)$$

3- Experimental setup

The experiments were carried out in a rectangular prismatic flume which had a working length (5m) with cross section (0.3m) wide and (0.45m) high. The glass of 10mm thicknesses was used for both sides of the flume and the bed of stainless steel which gives high degree of rigidity and stability.

Water is rotation through the flume by an electrically driven centrifugal pump mounted on the floor beneath the flume providing a maximum flow (30 l/sec), this draws water from a sequence of connected sump tanks mounted on the floor and running alongside of the channel, the tanks connected together by large diameter plastic sleeves so that the water can flow through the tanks of circulation, the flow of water into the channel was controlled by using a manually valve. Flow rate was measured by an electro-magnetic flow meter and shown on digital readout placed on the control console

Nine models of circular crested weir were built and tested during the experimental program, all models were manufactured from Perspex sheet of 6mm thickness and (pvc) pipes, the pipe was furrowed longitudinally and the Perspex sheet was sit at the furrow and height of circular crest weir was checked.

Table (1): detail of the circular crested weir models tested

No.	height (cm)	radius of circular weir (cm)	no. of run	Discharge(L/sec)
1	15	2.5	6	6,9,12,15,18,21
2	15	3.1	6	6,9,12,15,18,21
3	15	3.75	6	6,9,12,15,18,21
4	20	2.5	6	6,9,12,15,18,21
5	20	3.1	6	6,9,12,15,18,21
6	20	3.75	6	6,9,12,15,18,21
7	25	2.5	6	6,9,12,15,18,21
8	25	3.1	6	6,9,12,15,18,21
9	25	3.75	6	6,9,12,15,18,21

Fig.(1): flow over weir

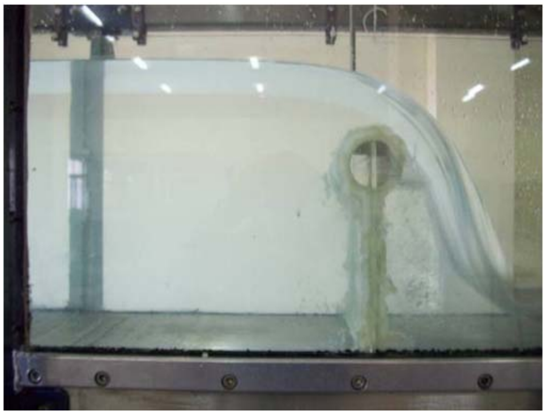

Fig.(2): Side view of flow over weir

4. Analysis of Results

4.1 water surface profile

The flow depth measured above crest level and along the center line of channel were plotted against the distance from the weir edge as a zero point toward upstream of it. The experimental results were showed downward near and above the weir crest and become uniform at distance (3-4 h). This gradually varied flow along upstream of circular crested weir can be classified as (H2) because slope of flume take zero (s=0) during tested all models.

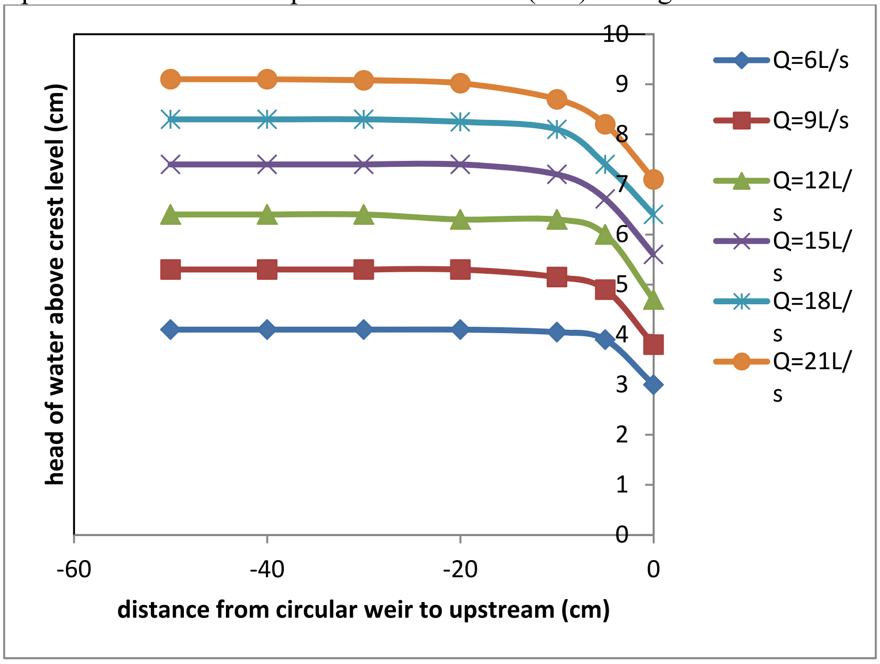

Fig. (3): water surface profile for p=15cm and R=2.5cm

4.2 factors effects in coefficient of discharge

4.2.1 Head over the weir to the crest height h/p

The relationship between discharge coefficient (C_d) and the ratio of the head over the weir to the crest height for different crest radius values (r=2.5 cm, r=3.15cm and r=3.75cm) was plotted as shown in Figs. (4,5 and 6) respectively.

The figures were shown that (C_d) increased with increasing h/p for the similar height of weir and for definite value for the ratio h/p, the (C_d) value increased with increasing the crest height (p), it is remarkable to recognize that weir of height (p=25 cm) gave higher value of (C_d) than other heights . **Noori B. M.A and Chilmeran T. A.H. (2005)** take four heights of circular weir at normal condition (20,25 and 30,35). They found that at weir of height 30 give higher values of Cd than other heights. So that when the height of weir increase Cd increased until limited height (p=30) then when height of weir become large (p=35cm) Cd will be decreased.

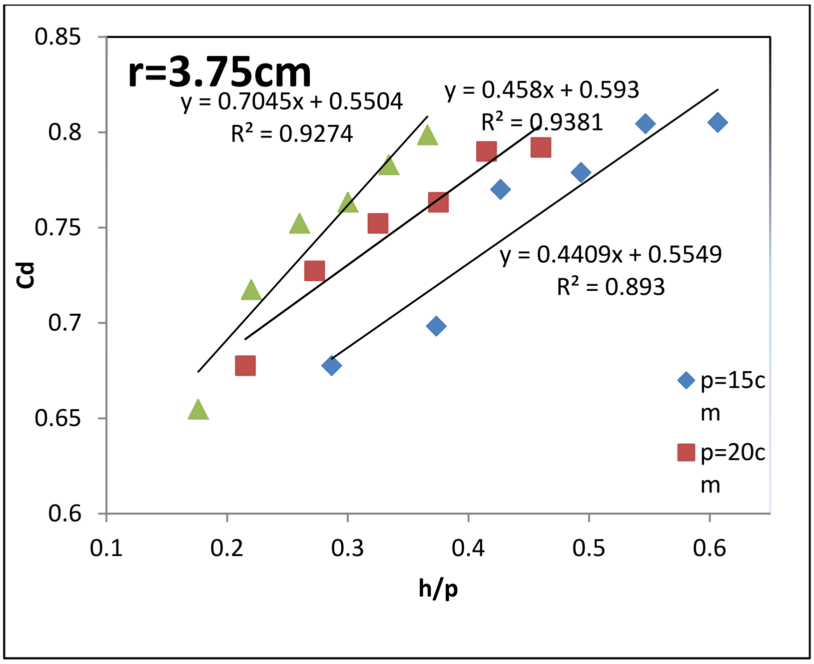

Fig. (4): Variation of Cd with h/p for circular crest radius r=3.75cm

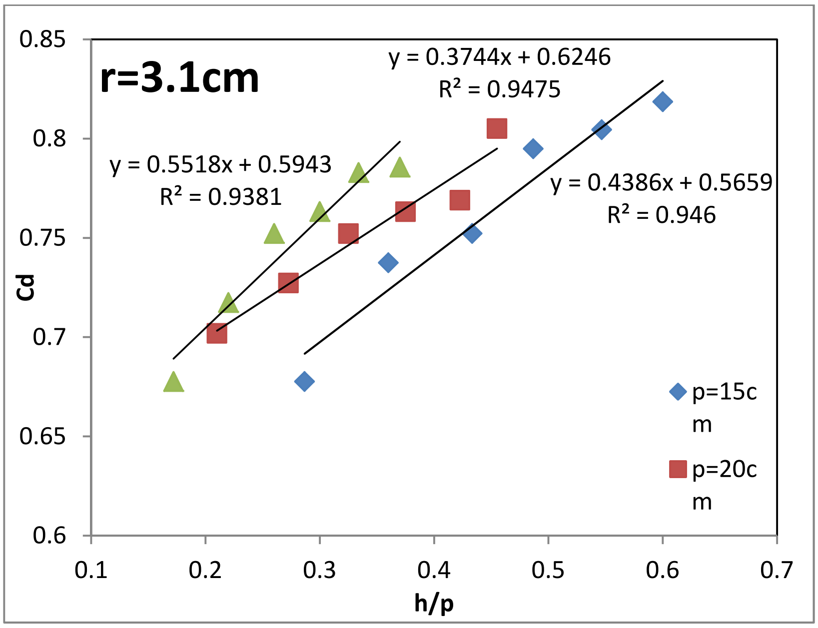

Fig. (5): Variation of Cd with h/p for circular crest radius r=3.1cm

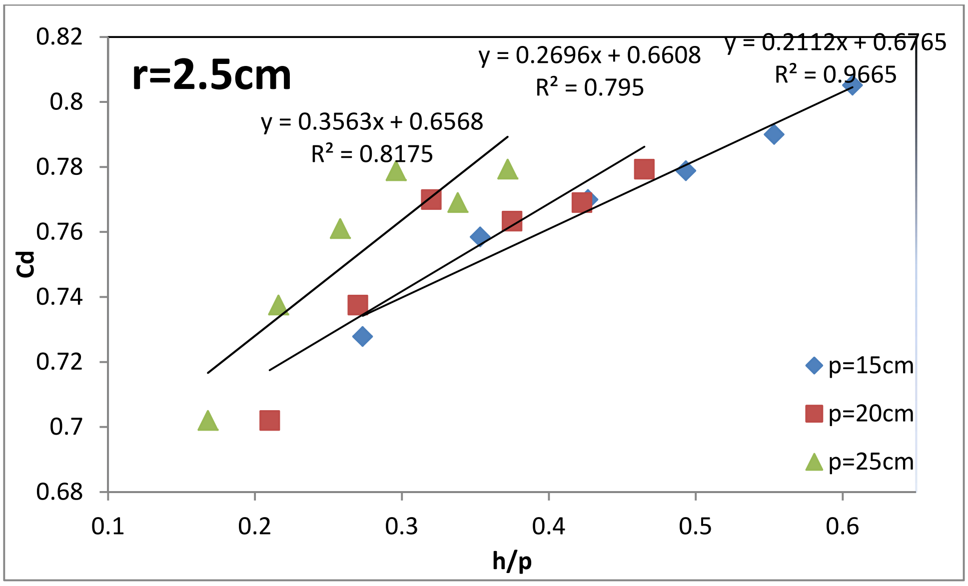

Fig. (6): Variation of Cd with h/p for circular crest radius r=2.5cm

4.2.2 Head over the weir to the crest radius h/r

The relationship between discharge coefficient (C_d) and the ratio of the head over the weir to the crest radius for different crest height values (P=25 cm, P=20 cm and P=15cm) were plotted as shown in Figs. (7,8 and 9) respectively.

The figures were shown that (C_d) increased with increasing h/r for the similar crest radius and for definite value for the ratio h/r, the (C_d) value increased with increasing the crest height (r), it is remarkable to recognize that weir of radius (3.75 cm) gave higher value of (C_d) than other radius.

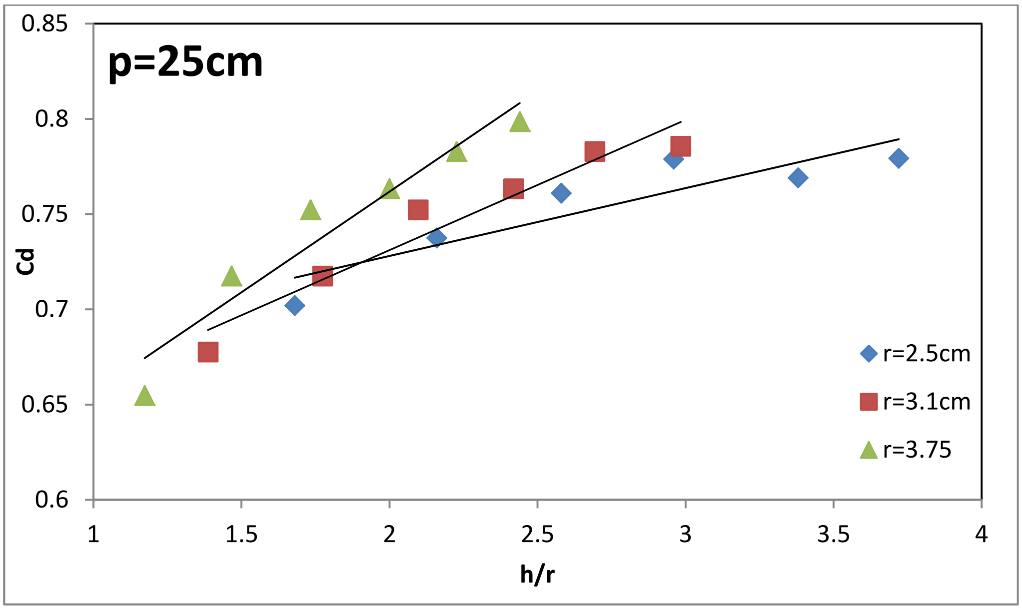

Fig. (7): Variation of Cd with h/r for circular crest height P=25cm

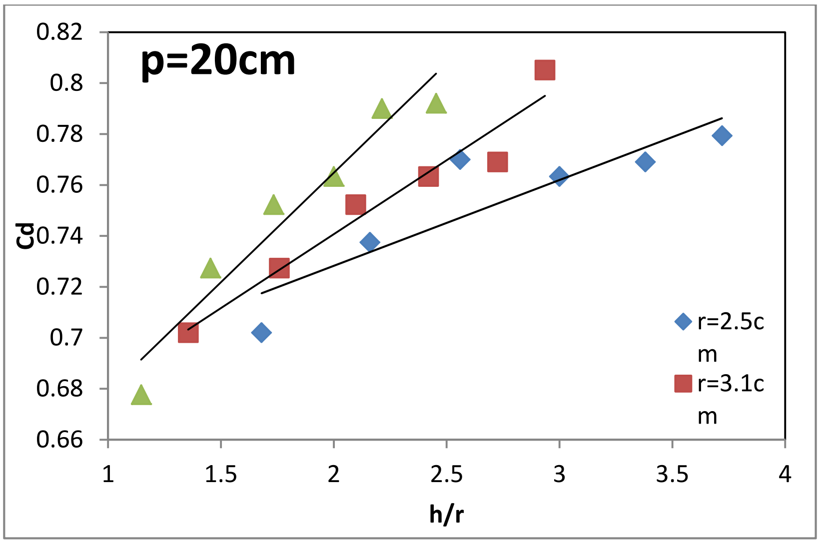

Fig. (8): Variation of Cd with h/r for circular crest height P=20cm

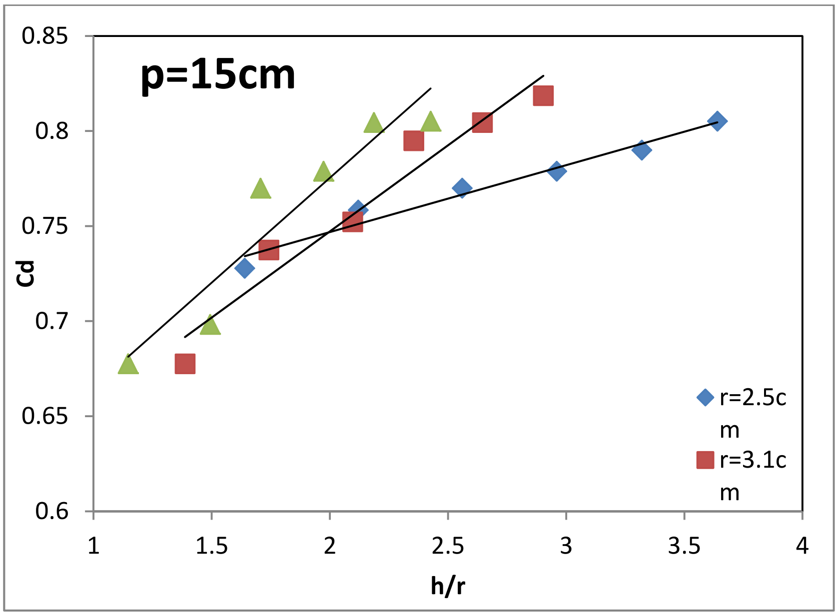

Fig. (9): Variation of Cd with h/r for circular crest height P=15cm

4.3 Variation of Cd with h/p and h/r

The function relationship for the discharge coefficient C_d of free flow over circular crest weir with different crest radius can be written as a function of h/p and r/p as shown in dimensional analysis Eq.(4)

$$Cd = f\left(\frac{h}{p}, \frac{h}{r}\right)$$

All experimental results of free flow over circular crest weir were used as input data in the regression analysis program (spss) to obtain an experimental power expression of the following form:

$$Cd = 0.769 \times \left(\frac{h}{p}\right)^{0.077} \times \left(\frac{h}{r}\right)^{0.084}$$

Output table of (spss):

Parameter Estimates

Parameter	Estimate	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
a	.769	.017	.738	.807
b	.077	.013	.058	.110
c	.084	.014	.061	.117

ANOVA[a]

Source	Sum of Squares	df	Mean Squares
Regression	27.272	3	9.091
Residual	.014	45	.000
Uncorrected Total	27.286	48	
Corrected Total	.077	47	

Dependent variable: cd

a. R squared = 1 – (Residual Sum of Squares) / (Corrected Sum of Squares) = .818.

As shown in (ANOVA) coefficient of determination R^2=0.818, correlation coefficient will be (R) =0.9.

Fig.(10) showed the relation between (C_d) values predicted by Eq.(5) and those observed experimentally showing good agreement.

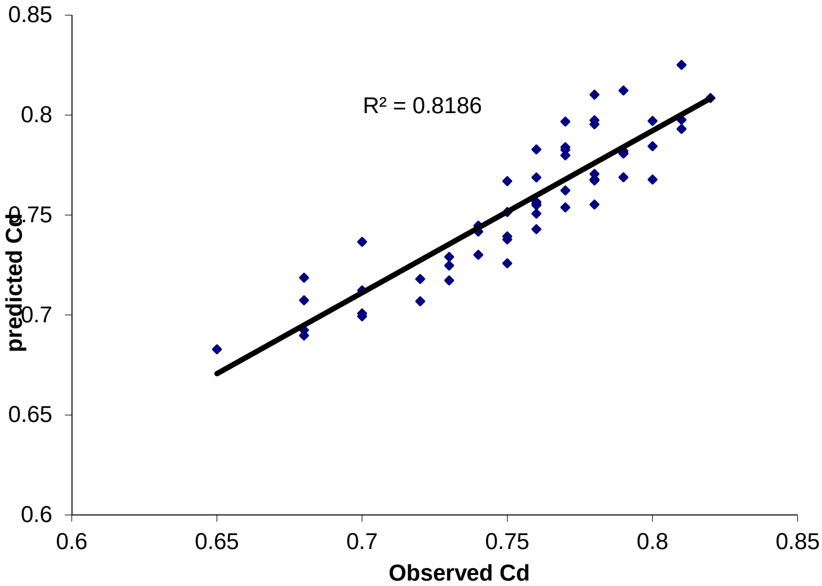

Fig.(10): Comparison between predicted and experimental value of Cd

5- Conclusion

Nine models were tested every model six discharges were permitted to pass over circular weir, coefficient of discharge for every run was calculated to study the effect of C_d to another affecting factor , the following conclusion can be summarized:

1. The water surface profiles for all models tested were found to be smooth and continuous as shown in figs (3).
2. The (C_d) increased with increasing h/p for all the tests models for definite value for the ratio h/p, the (C_d) value increase with increasing the crest height (p).
3. that (C_d) increased with increasing h/r for the same crest radius and for definite value for the ratio h/r, the (C_d) value increased with increasing the crest height (r)
4. Good agreement was found between the measured and predicted coefficient of discharge.
5. The model with weir height (P=25cm) and (r=3.75 cm) gave higher coefficient of discharge so had better performance than other models.

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کورتیا لێکولینێ:

ڤێ ڤەکولینێ دا دناڤ تاقیگەهێ دا نەھ نمونە ژ سکرێن نوقوم یێن سەر بازنەی هاتەکرن. سێ جاران نیوە تیرا بازنەی هاتە گوهورین (r =2.5cm,3.1, 3.75cm) و بو هەر نیوە تیرەکی سێ جاران بلنداهیا سکرێ نوقومێ یێ سەر بازنەی هاتە گوهورین (p=15cm,20cm,25cm).

تاقیکرنێن تاقیگەهێ ئاشکەرا بو کو فاکتەرێ ب رێڤەچونا ئاڤێ (Cd) پەیوەندی ب دوو فاکتەرا هەیە: یا ئیکێ کویراتیا ئاڤێ ل سەر سکرێ نوقمێ بو بلنداهیا سکرێ نوقمێ (h/p)و یا دووێ کویراتیا ئاڤێ ل سەر سکرێ نوقمێ بو نیوە تیرا بازنەی ل ل سەرێ سکری(h/r). بهایێ (Cd) دگەل زێدەبونا (h/p) زێدە دبیت هەر بلنداهی یەکێ بەلام بو هەر ئێك (h/p) بهایێ (Cd) زێدە دبیت دگەل زێدەبونا بلنداهیا سکرێ. بهایێ (Cd) دگەل زێدەبونا (h/r) زێدە دبیت بو هەر یەکێ نیوە تیرەکی بازنەی بەلام بو هەر یك (h/r) بهایێ (Cd) زێدە دبیت دگەل زێدەبونا نیوە تیرا بازنەی . دیسان پەیوەندی یەکا توانەیی وتاقیگەهی ژبو گوهورینا (Cd) ل گەل هەر ئێك (h/p) و (h/r) ب دەست هینا و ب فاکتەرێن گرێدانێ یێن بەرز.

خصائص الهيدروليكية لجريان فوق الهدارات ذو حافة دائرية

الخلاصة:

يتناول هذا البحث تسعة نماذج لهدارات ذو حافة دائرية شغلت خلال برنامج العمل. تم تغير نصف قطر القمة ثلاث مرات 2.5 cm, 3.1cm and 3.75cm. لكل نصف قطر القمة تم تغير الارتفاع ثلاث مرات 15cm, 20cm and 25cm.

وعند ملاحظة النتائج وجد أن قيم معامل التصريف تتاثر بمعاملين :الاول نسبة عمق الماء فوق الهدار الى ارتفاع الهدار و الثاني نسبة عمق الماء فوق الهدار الى نصف قطر القمة. تزداد تزدادمعامل التصريف (Cd) بزيادة h/p لنفس ارتغاع الهدار. عند قيمة محددة ل (h/p) (Cd) تزداد بزيادة الارتفاع. تزدادمعامل التصريف (Cd) بزيادة(h/r) لنفس نصف قطر الهدار. عند قيمة محددة (h/r) (Cd) تزداد بزيادة نصف قطر الهدار. وتم الحصول على علاقة وضعية اسية لتغير (Cd) مع (h/p)و(h/r) بمعامل ارتباط عالي

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