CHARACTERISTIC OF FLOW OVER SEMICIRICULAR SUBMERGED WEIR

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Abstract

The main objects of this investigation are to obtain convenient expressions for the estimation of discharge coefficient for submerge flow over concave and convex semicircle shape crested weirs. Sixteen weir models were constructed and tested. these,models were classified into four groups. The first and second groups were of single cycles having concave and convex shapes, respectively, with curvature radius of 15cm.The third and forth groups were of double cycles having concave and convex shapes, respectively, with curvature radius of 7.5cm.In each group the weir height, p was varied four times 10cm, 7.5cm, 5cm and 2.5cm .Based on results of this study it was found that for constant weir radius, R, the discharge coefficient, Cd, increases with the increase in the relative upstream head, h/p, while, for constant upstream head, weirs of small heights give higher discharge coefficient than those of large height .Two general expressions were obtained for the estimation of Cd as function of, relative upstream head ,h/p, and relative radius,R/P, one expression for single and double cycle concave submerged weirs and the other for convex submerged weirs.

List of Notion

q = discharge (m^3/sec).

q_1= free flow discharge due to upstream head h_1(m^3/sec).

sf = submergence factor.

a_1 = sectional area of weir below head water level (m^2).

a_2 =-sectional area of weir below tail water level (m^2)

h_1=upstream head above weir crest for submerged flow(m).

h_2=downstream head above weir crest for submerged flow(m).

n,m &k=constant.

B=width of the channel (m).

g= acceleration due to the gravity (m/sec^2).

P = the height of the weir.

R= radius of the weir.

Cd=discharge coefficient of semicircular weir.

f = drowned flow reduction factor.

Introduction

Hydraulic engineers are always looking for simple and efficient hydraulic structures.For field and Laboratory measurements of flow. Semicircular weirs have an advantage over normal weirs in that they allow higher discharge and wide flow ranges for the same width of the channel.

The principle advantage of submerged flow operation is the smaller head loss, which occurs in the flume as compared with free flow.

The effect of submerged on sharp - crested weirs has been investigated by several researchers including Vennard and Weston (1943), Steven and others (1949). All of their tests were run on sharp crested weirs. In addition, a method of analyzing submerged flow in open channel constrictions has been developed at Utah state university (1967). Mavis (1949) conducted submerged experiments on six different sharp-crested weirs, Viz, sutra rectangular, parabolic, circular, V- Noch, and developed a general empirical discharge formula of the following form:

$$q/q_1 = 1 - (0.45Sf + \frac{0.4}{2^{16-10Sf}}) \qquad ..(1)$$

Where

q= discharge,q_1= free flow discharge due to upstream head h_1 and sf= submerged factor,

$$Sf = (a_2\sqrt{h_2} / a_1\sqrt{h_1});$$

a_1=sectional area of weir below head water level

a_2= sectional area of weir below tail water level

h_1=upstream head above weir crest for submerged flow,and

h_2= downstream head above weir crest

Villemout (1947) assumed that the submerged discharges, q_s, is a function of the free flow discharge, q, due to an upstream head, h_1, minus the free flow discharge due to a downstream head h_2.He also assumed that the free flow discharge was given by an equation of the form $q=ch^n$ in which c and n are functions of weir shape only,and showed that:

$q_s=k(1-S^n)^m q$.................................. (2)

in which $S=h_2/h_1$ and (m , k) are constants. The final equation is

$q_s=q(1-S^n)^{0.385}$ .... (3)

Where, k=1,m=0.385,and n is the exponent in the free- flow equation=1.5. He compared the results of this equation with those described by Vennard and shows fairly good agreement.

Donn G. (1970) Studied the flow analysis of large triangular weir under submergence and gave empirical formula .The submerged factor founded nearly the same as that of Villemontes, both are based on the water surface elevation for h_1.

Ramamorthy (1988) showed that the discharge over broad crested weir q_s under submergence can be obtained by the introduction of drowned flow reduction factor

$f = q_s/q$.

Where q_s=discharge under submerged flow, q=discharge under free- flow accordingly

$$q_s = \frac{2}{3}\sqrt{\frac{2}{3}}gCd * B * f * H^{\frac{3}{2}} \;\;\ldots\ldots\ldots\ldots(4)$$

Where, H is the upstream measured,head

Negm et.al (2000b) developed a model for both free and submerged flow through combined flow structures having different opening shapes. The model takes the formula:

$$F = 1.0486 + 0.00084 * \left(\frac{h}{d}\right).$$

Where h =upstream water depth, d =gate opening.

C.chalterjes et.al (1998) developed a simple empirical equation relating the discharge factor, submergence ratio, and ratio of upstream head to crest height.

Bagzad et.al (1996) studied the hydraulic characteristics of flow over semicircular sharp crested weir single and double cycles with concave and convex shape experimentally under free flow conditions and obtained two general expression for the estimation of C_S as afunction of both relative upstream head h/p and relative weir radius of R/p.Equation (5) for single and double cycle concave weirs, while equation (6)for single and double cycle convex weirs,

$$C_s = 0.49 * \frac{\left(\frac{R}{P}\right)^{0.11}}{\left(\frac{h}{P}\right)^{0.24}} \;\;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$C_S = 0.48 * \frac{\left(\frac{R}{P}\right)^{0.23}}{\left(\frac{h}{P}\right)^{0.10}} \;\;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots6)$$

Where, C_s = Discharge coefficient for semicircular weir.

The main objective of this investigation is to study experimentally the characteristics of flow under- submergence over semicircular sharp crested weir single and double cycles with concave and convex shape. The study presents a theoretical submerged flow equation for the weir and experiments are conducted to evaluate the accuracy of the theoretical equation.

Experimental Set-up

The experiments were carried out in a horizontal channel of 10m, with across section 0.3m wide and 0.55m high. The walls of the channel were of toughened glass with annular of perspex panels incorporated .The bed of the channel consisted of stainless steel plates. Apair of adjustable instrument rails were fitted on the top of channel sides through the working length of the channel. Two movable equipped with point gauges were mounted on the rails as shown in figure (1).

Four groups of weir models were manufactured from a large sheet of perspex of 4mm thickness. The first and second groups were of single cycles having concave and convex shapes, respectively and a curvature radius of 15cm.The third and fourth groups were of double cycles having concave and convex shape respectively and curvature radius of 7.5cm. In each group, the weir height was varied four times 10cm, 7.5cm, 5cm and2.5cm. The edge of each weir model was sharp-crested with a thickness of 2mm. Details of the tested weir models are shown in figure. (2) and table (1).

All weir models were fixed at a distance 1.5m upstream from the channel outlet section and the discharges were measured with a standard full width, thin- plate sharp-crested rectangular weir of 35cm height, located 2.5m downstream the channel inlet section. This standard weir was manufactured according to British standard (British standard institutions 1965), the upstream flow h_1 was measured at a location of $4h_1$ upstream of the weir and the downstream flow head h_2 was measured below nape turbulence .

Discussion of Results

1-Variation of f with h_2/h_1

For flow over the semicircular weirs discharge (q_s) under submerged conditions can be obtained by the introduction of the drowned flow reduction factor $f=q_s/q$, which is the ratio of discharge under submerged flow conditions to the free flow discharge that would have passed upstream total head h_1.Figure (3) and figure. (4) show the variation of the drowned flow reduction factor f, with h_2/h_1 for convex submerged weir and concave submerged weir respectively, for various values of p, h. It is observed that the drowed flow reduction factor (f) for submergence predict with Maves (1949).

2-Verification of theoretical submerged flow equation:

The coefficient of discharge Cd for various upstream and downstream heads and corresponding discharges were calculated using equation (3), for each of the weir tested,figure (5) and figure (6) show a plot of coefficient of discharge Cd versus the ratio of upstream head and crest height (h_1/p) for convex and concave weirs, respectively.Regression analysis was performed to correlate the Cd, h_1/p and R/p values, Equations of the following forms is found to be the best fit convex and concave weirs respectively:

$$Cd=0.683\left(\frac{h_1}{p}\right)^{0.313}\left(\frac{R}{P}\right)^{0.103} \quad \ldots\ldots \quad (7)$$

with a correlation coefficient = 0.75.

$$\&Cd=0.6914(\frac{h_1}{p})^{0.07}(\frac{R}{p})^{0.136} \ldots\ldots \quad (8)$$

with a correlation coefficient = 0.738.

Conclusion

From the experimental results of this study, the following conclusions can be drown:

1-The drowned flow reduction factor f decrease with the increase of the value of h_2/h_1 and weirs of small heights give small reduction factor at a constant value of h.

2-Two general expression were obtained for the estimation of Cd with respect to both relative upstream head h_1/p and relative weir radius, R/p; one for single and double cycle convex weir, while the other for single and double cycle convex weirs.

3-For constant values of relative weir radius R/p the discharge coefficient Cd increase with the increase of relative upstream head h_1/p for constant values of h.

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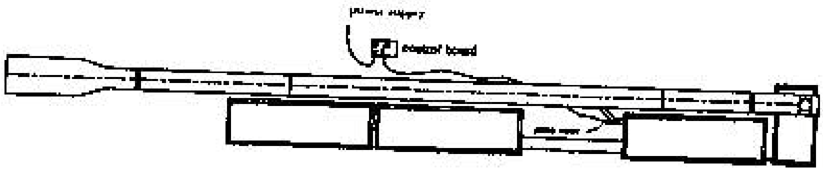
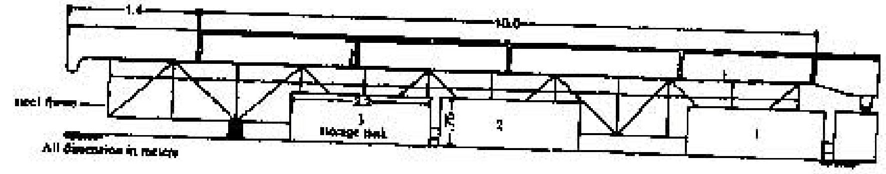
Table 1: Details of the submerged weir models tested.

Group No. and shape of weir model	No. of weir model	No. of cycle	Run No.	Radius of weir model R(cm)	Crest height p (cm)
1 concave	1	1	1-6	15	2.5
	2	1	7-12	15	5.0
	3	1	13-18	15	7.5
	4	1	19-24	15	10
2 convex	1	1	25-30	15	2.5
	2	1	31-36	15	5.0
	3	1	37-42	15	7.5
	4	1	43-48	15	10
3 concave	1	2	49-54	7.5	2.5
	2	2	55-60	7.5	5.0
	3	2	61-66	7.5	7.5
	4	2	67-72	7.5	10
4 Convex	1	2	73-78	7.5	2.5
	2	2	79-84	7.5	5.0
	3	2	85-90	7.5	7.5
	4	2	91-96	7.5	10

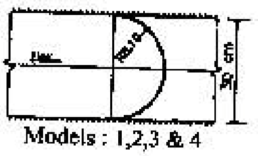


Plan of the Flume

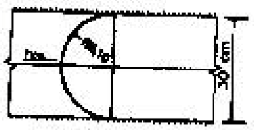


Side view of the Flume

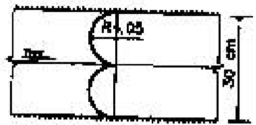
FIGURE (1) DETAILS OF THE FLUME



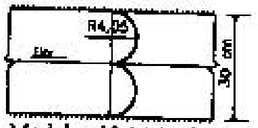
Models : 1,2,3 & 4



Models : 5,6,7 & 8

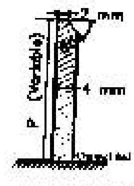


Models : 9,10,11 & 12

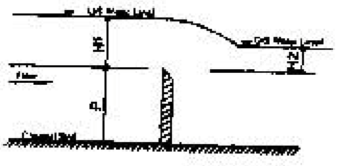


Models : 13,14,15 & 16

Plans of Submerged Weir Models



Crest Details



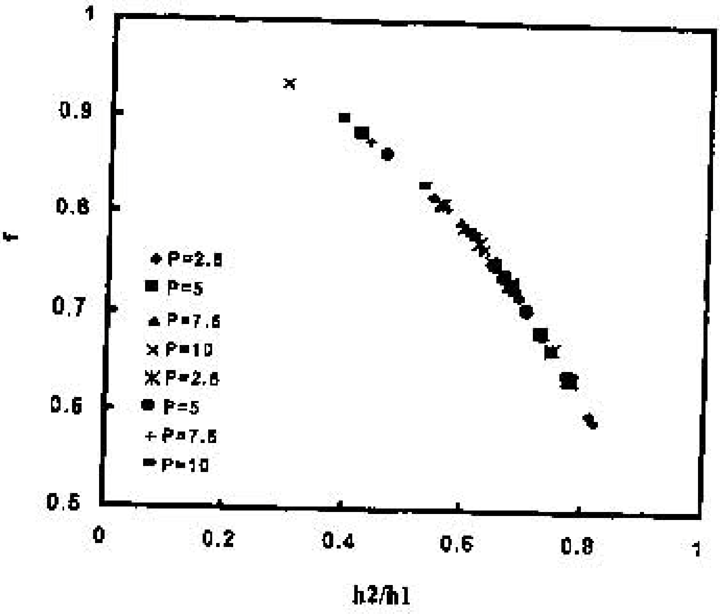


FIGURE. (3) THE RELATION BETWEEN FLOW DUCTION FACYOR f & h2/h1 FOR CONVEX SUBMERGED WEIR

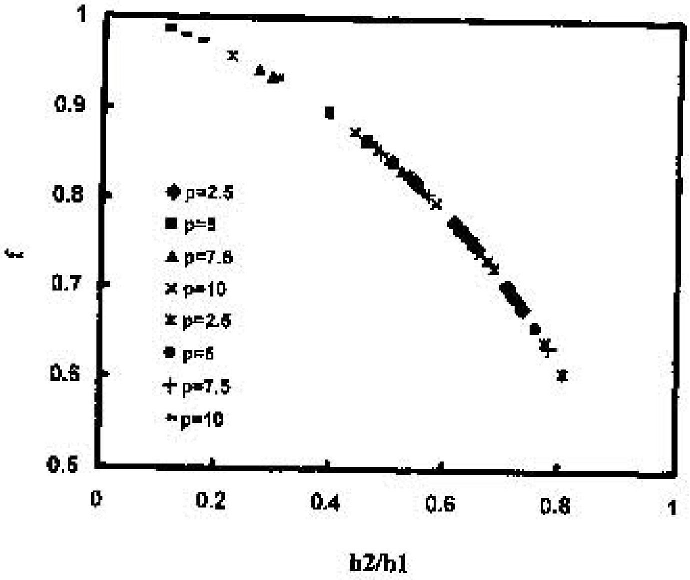


FIGURE. (4) THE RELATION BETWEEN FLOW REDUCTION FACTOR f & h2/h1 FOR CONCAVE SUBMERGEDWEIR

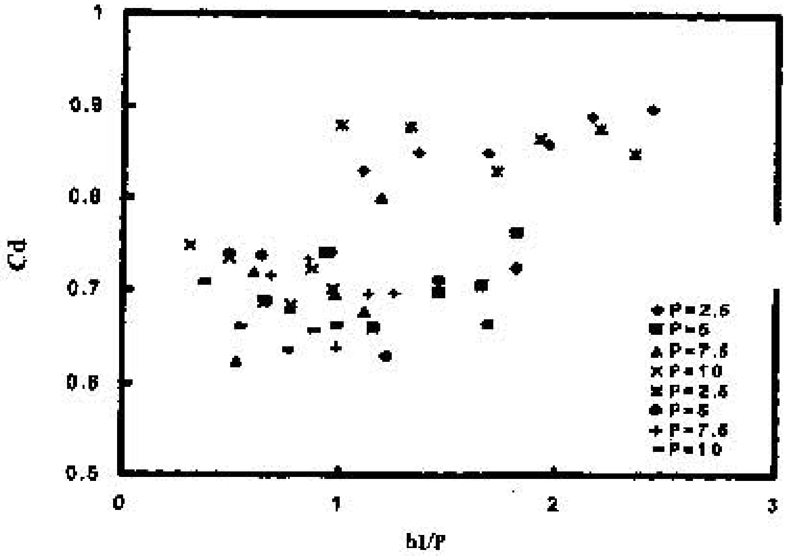


FIGURE. (5) THE RELATION BETWEEN COEFFECENT OF DISCHARGE Cd & h1/P FOR CONVEX SMBERGED WEIR SIDE

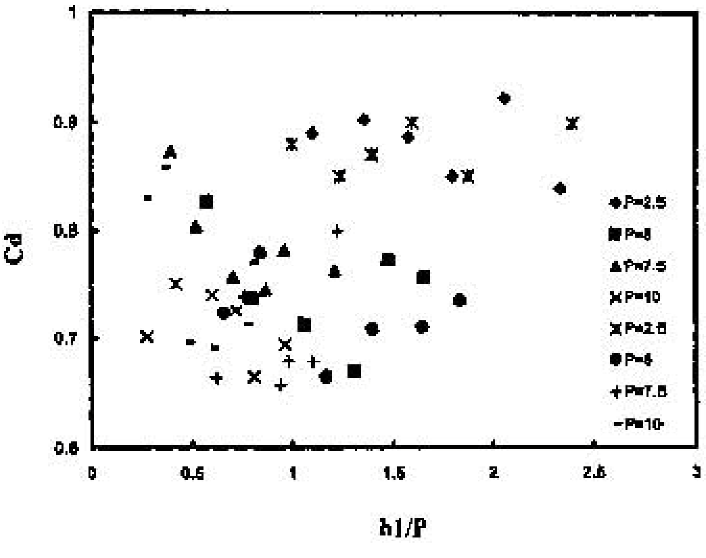


FIGURE. (6) THE RELATION BETWEENCOEFFECENT OF DISCHARGE Cd&h1/P FOR CONCAV SUMBERGED WEIR SIDE

خصائص الجريان فوق الهدارات نصف الدائرية المغمورة

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الخلاصة

الهدف الرئيسي للبحث هو إجراء دراسة مختبريه للحصول على العلاقات الملائمة لحساب معاملات التصريف للجريان المغمور فوق الهدارات نصف الدائرية المقعرة والمحدبة حادة الحافة0 تم إنشاء واختبار ستة عشر نموذج صنفت إلى أربعة مجاميع تضمنت كل من المجموعة الأولى والثانية نماذج للهدارات أحادية الدورة المقعرة والمحدبة على التوالي وبنصف قطر (R=15cm) بينما تضمنت كل من المجموعة الثالثة والرابعة نماذج للهدارات ثنائية الدورة المقعرة والمحدبة وبنصف قطر (R=7.5cm) وقد تم تغير ارتفاع النموذج P في كل مجموعة أربع مرات (2.5,5.0,7.5 and 10cm) وتبين أن معامل التصريف Cd يزداد بزيادة العمق النسبي (h_1/p) في حالة ثبوت عمق الماء المقدم فان الهدارات المغمورة الواطئة الارتفاع تعطي معامل تصريف أعلى من الهدارات العالية الارتفاع, وقد تم الحصول على علاقتين عامتين لحساب معامل التصريف للهدارات المغمورة بدلالة العمق النسبي (h_1/p) ونصف قطر الهدار النسبي (R/p) إحداهما للهدارات أحادية وثنائية الدورة المقعرة .