(JZS)Journal of Zankoy Sulaimani, April 2004,Vol.7(1) Part A(87-94)

گۆڤاری زانكۆی سلێمانی ئەیریلی ٢٠٠٤ بەرگی ٧(١) بەشی A لاپەرە (٨٧-٩٤)

An Experimental Investigation of the Coefficient of Discharge for Circular and Semi-Circular Weirs

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Abstract

The hydraulic characteristics of circular and semi-circular weirs under free flow and submerged flow conditions were studied experimentally and compared. Eighteen different weir models were tested. The first nine models were circular weirs, the rest of the models were semi-circular weirs. Within the range of the experiments it is shown that the weir height (p), upstream head over the weir(h_1) , submergence ratio(h_2/h_1) and channel slope had significant effect on the coefficient of discharge (C_d). The results confirmed that the coefficient of discharge for circular weirs was greater than semi-circular weirs under free flow and submerged flow conditions, also the value of (C_d) for submerged flow for both circular and semi-circular weirs was lower than that at free flow condition by(1-15)%.

Keywords: - weir, coefficient of discharge, circular, semi-circular, free flow, submerged flow, channel slope.

Introduction

Weir is one of the oldest, simplest and most reliable structures that can be used for many purposes. The weir may be defined as an overflow structure built across a river or open channel to measure the discharge [1].The most common types of weirs are the broad crested weir, the sharp-crested weir , the circular crested weir and ogee crest weir. Advantages of the circular weir compared with other types include: stable overflow pattern, the ease to pass floating debris, the simplicity of design compared to ogee crest design, and the associated lower costs [2]. Weirs under free and submerged flow conditions were studied by many researchers, among them Matthew[3] introduced a theoretical analysis to explain the influence of surface tension, and viscosity on the discharge of water over round-crested weirs. Al-Tabatabaie et. Al [4] investigated experimentally the characteristics of flow over circular weirs of the forms changed from semi-circular to a crescent shape. Ramamurthy[5] studied the influence of downstream and upstream weir slopes on the discharge coefficient values for circular weir. Chilmeran[6] studied experimentally the characteristics of flow over normal and oblique weirs with semi-circular crests. Chanson and Montes [2] studied the effects of inflow conditions on the behavior of cylindrical weirs. Al-Tikrity[7] studied the characteristics of flow over the semi-circular crested rectangular weirs and compared with those of sharp-crested weirs under free flow.

Smith[8] , studied the characteristics of embankment weir under free flow and submerged flow.

Rao and Rao[9] investigated the characteristics of hydrofoil weir under free and submerged flow. Al-Neima[10] studied the discharge coefficient for inclined sharp -crested weirs under free and submerged flow conditions. Fritz and Hager [11] studied hydraulics of embankment weirs with side slopes(1V:2H) for both upstream and downstream under free and submerged flow.

In the light of the foregoing studies, it was found that the flow over mentioned types of weirs is a function of the upstream head (h_1) and the geometrical dimensions of the weir. From these studies no effort was put in to the circular and semi-circular crested weirs under submerged flow condition and the effect of channel slope on the behavior of these types of weirs is limited. So in the present study a special care is given to submerged flow condition, furthermore the effect of channel slope on the characteristics of these types of weirs are studied.

Experimental Setup

Laboratory experiments were carried out on eighteen models of weirs, nine of them have circular crests, and the other nine have semi-circular crests with the same dimensions see table (1).

Table (1): Details of the Weir Dimensions

Group No.	Crest Radius r(cm)	Crest Width B(cm)	Crest height p(cm)
A	3	8.6	12
			14
			16
B	4	8.6	12
			14
			16
C	5	8.6	12
			14
			16

Models were made of smooth wood (varnished surface) and the downstream face of the weir was not ventilated in all the experiments. The work was carried out in a flume having a working length of (2.86m) with cross section (8.6cm) wide×(30cm) as shown in fig.(1).The water discharge was measured by a volumetric method. The head over the weir models was measured by using a point gauge with accuracy of (0.5mm). Water temperature was recorded by a thermometer fixed at the inlet of the flume. The slope of the channel was adjusted as required with a screw type jack. For submerged flow the downstream water level (h_2) was controlled with the help of flashboard.

Discharge Coefficient Calculations

The discharge coefficient (C_d) was taken as the ratio of actual discharge to theoretical discharge. thus:

$$C_d=\frac{Q_{act.}}{Q_{theo.}} \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

where:

$Q_{act.}$ =actual discharge

$Q_{theo.}$ = theoretical discharge

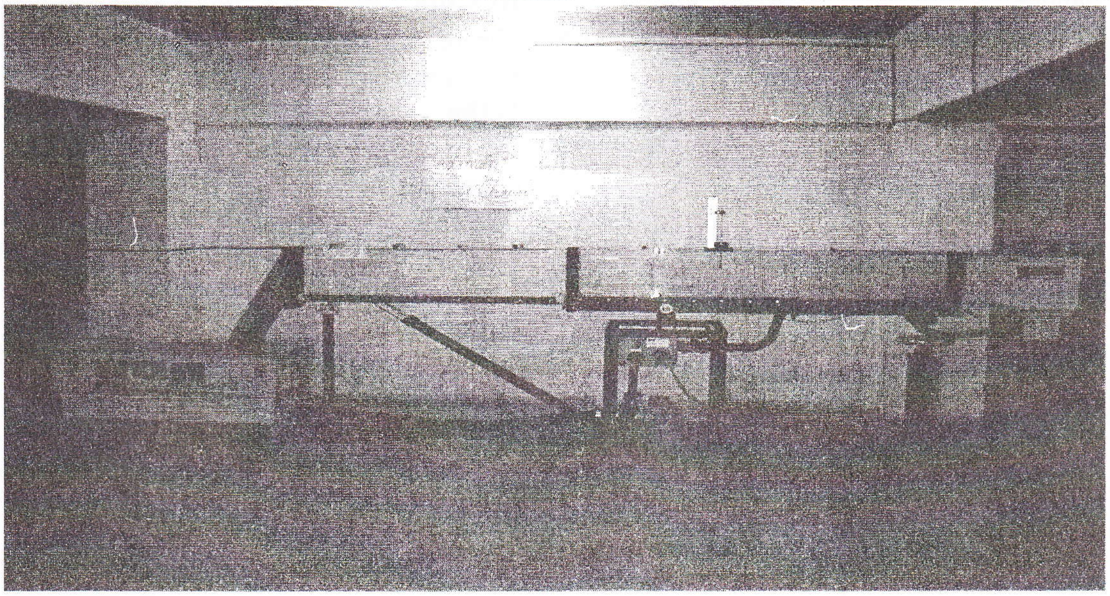

Fig. (1) Photograph of the Flume.

The actual discharge ($Q_{act.}$)was measured by using volumetric method, while the theoretical discharge was calculated by using the following formula[2]:

$$Q_{theo.} = \frac{2}{3\sqrt{3}}\sqrt{2g}Bh_1^{\frac{3}{2}} \quad \ldots\ldots\ldots\ldots(2)$$

where:

h_1=upstream head above weir crest at a distance of (20cm).

B= channel width

g= acceleration due to gravity

A functional relationship for the characteristics of flow over weirs with circular and semi-circular crests under free flow can be expressed as:

$q=\phi_1 (h_1,p,r,g,\rho,\mu,\sigma,S_o)$

where:

q= Discharge passing over the weir per unit width of the channel.

ρ=Mass density of the flowing liquid.

μ=Dynamic viscosity of the flowing liquid.

σ=Surface tension of the flowing liquid.

So= channel slope

From the dimensional analysis,coefficient of discharge is a function of :

$$Cd = \phi_2\left[\frac{h_1}{r},\frac{h_1}{p},\mathrm{Re},W^2,S_o\right] \quad \ldots\ldots\ldots(3)$$

Where:

h_1/r= upstream head over the weir to weir radius.

h_1/p= upstream head over the weir to weir height.

Re= Reynold's number

W= Weber number

A functional relationship for the characteristics of flow over weirs with circular and semi-circular crests under submerged flow can be expressed as:

$q=\phi_1 (h_1,h_2,h_c,g, S_o)$

where:

h_2=downstream head above weir crest at a distance of 193cm.

h_c= head above weir crest.

From the dimensional analysis, coefficient of discharge is a function of:

$$Cd = \phi_2\left[\frac{h_c}{h_1},\frac{h_2}{h_1},S_o\right] \quad ....(4)$$

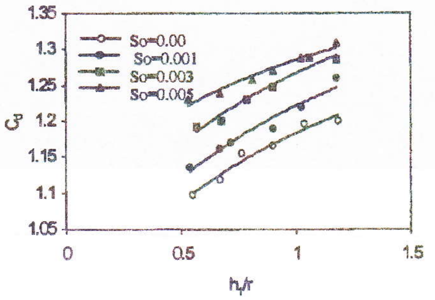

Fig.(2) Variation of Cd with h_1/r For Circular weir for different channel slopes,p=12cm

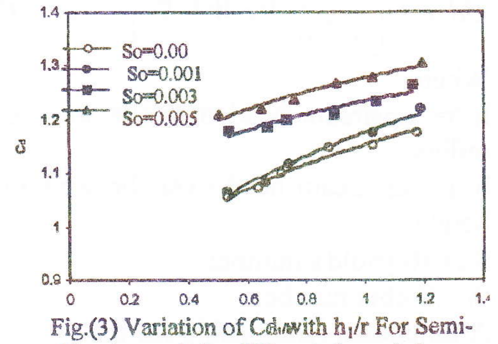

Fig.(3) Variation of Cd with h_1/r For Semi-Circular weir for different channel slopes p=12cm

Results

From the experimental results, following points were noticed:

1-The coefficient of discharge (C_d) increases with increasing (h_1/r) ratios and channel slopes (S_o) for both circular and semi-circular weirs as shown in fig.(2),(3).

2- (C_d) for circular is greater than semi-circular for the same (h_1/r) ratio as shown in figs.(4,5,6).

3- (C_d) increases with increasing (h_2/h_1) under submerged flow for both circular and semi-circular weirs and (C_d) for circular is greater than semi-circular for the same (h_2/h_1) ratio as in Figs.(7,8,9).

4- (C_d) for submerged flow is lower than free flow for both circular and semi-circular weirs for the same actual dischge (Q_{act}) as infigs.(10-12)

Conclusions

1. (C_d) increases with decreasing height of crest (p)for both circular and semi-circular weirs.
2. (C_d) for circular weir under free and submerged flow is greater than that for semi-circular weir.
3. C_d) for both circular and semi-circular weirs under submerged flow is lower than that at free flow by(1 - 15)%.
4. Flow magnification factor (Q_c/Q_{sc}) under free flow [which is the ratio between actual discharge for circular to . actual discharge for semi-circular weirs] increases with increasing height of weir, and decreases with increasing the ratio (h_1/r) within the range of (1.004 – 1.111).
5.(C_d) increases with increasing both Reynold's and Weber numbers.

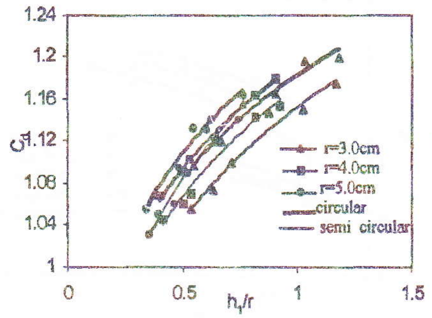

Fig.(4) Variation of Cd with h_1/r for Circular and Semi-Circular Weirs (p=12 cm)

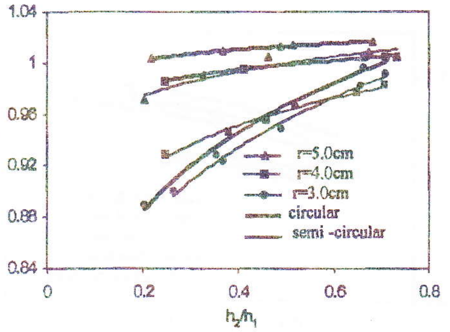

Fig.(7) Relation between C_d and h_2/h_1 For Circular and Semi-Circular Weirs (p=12)

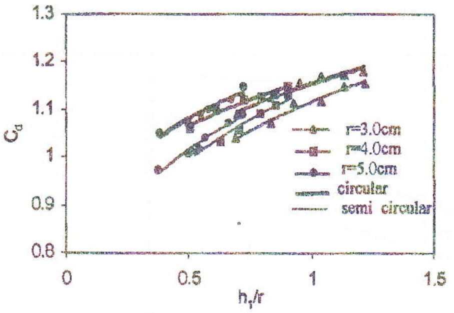

Fig.(5) Variation of Cd with h_1/r for Circular and Semi-Circular Weirs (p=14cm)

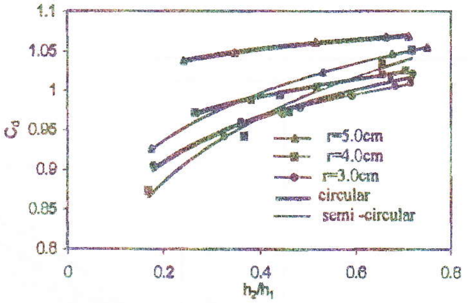

Fig.(8) Relation between C_d and h_2/h_1 For Circular and Semi-Circular Weirs (p=14)

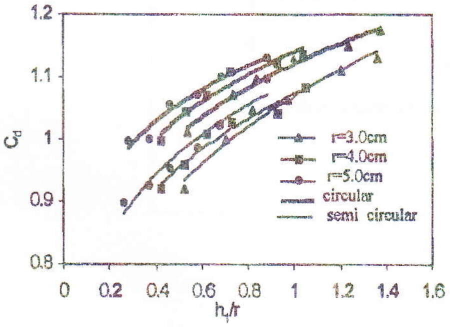

Fig.(6) Variation of Cd with h_1/r for Circular and Semi-Circular Weirs (p=16 cm)

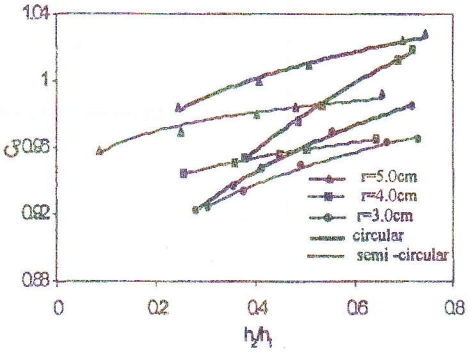

Fig.(9) Relation between C_d and h_2/h_1 For Circular and Semi-Circular Weirs (p=16)

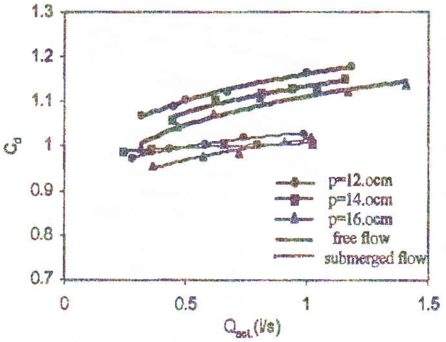

Fig.(10)Variation of Cd with Qact. for Circular Weir (r=4.0cm)

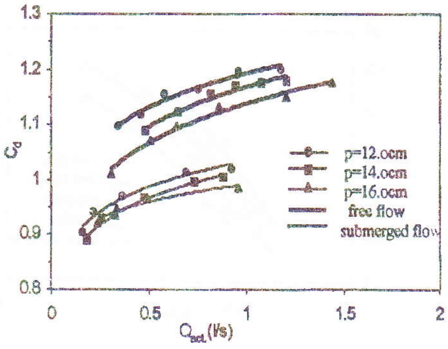

Fig.(11)Variation of Cd with Qact. for Circular Weir (r=3.0cm)

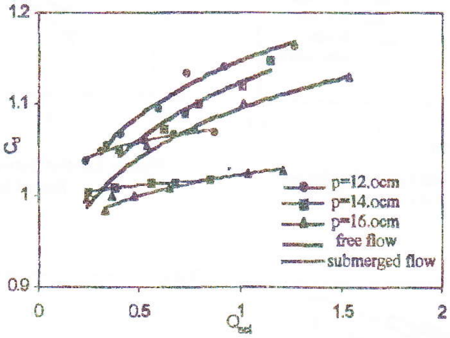

Fig.(12)Variation of Cd with Qact. for Circular Weir (r=5.0cm)

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لێكۆڵینەوەی كرداری هاوكۆلكەی ڕەوانەكردن بۆ بەربەستی بازنەیی و نیمچە بازنەیی

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پوختە

لەم توێژینەوەیەدا لێكۆڵینەوەو بەراورد لەسەر سیفەتی هایدرۆلیكی بەربەستی بازنەیی و نیمچە بازنەیی لە دۆخی ڕۆیشتنی سەربەست و ژێر ئاو كەوتوودا كرا. لەم توێژینەوەدا هەژدە مۆدێلی جیاواز بەكارهاتووە. نۆ دانەی یەكەم بریتی بوون لە بەربەستی بازنەیی وسەبارەت بەمودێلەكانی تربریتی بوون لە بەربەستی نیمچە بازنەیی.

لە ئەنجامی لێكۆڵینەوەكان وا دەركەوت كە بەرزی مودێل(p)، بەرزی ئاولە پێش بەربەستەكە(h_1) وڕێژەی (h_2/h_1)، لاری جۆگە كاریگەریان هەیە لە سەر هاوكۆلكەی ڕەوانەكردن(C_d) . لە ئەنجامی لێكۆڵینەوەكان هاوكۆلكەی ڕەوانەكردن(C_d) بۆ بەربەستی بازنەیی گەورەتربوو لەبەربەستی نیمچە بازنەیی بۆ هەمان ڕێژەی (h_1/r) بۆ دۆخی ڕۆیشتنی سەربەست و ژێر ئاوكەوتوو . هاوكۆلكەی ڕەوانەكردن(C_d) بۆ ڕۆیشتنی ژێرئاوكەوتوو وە بۆ بەربەستی بازنەیی و نیمچە بازنەیی كەمترە بە بەراود لەگەڵ ڕۆیشتنی سەربەست دا بە ڕێژەی (١ – ١٥) ٪.

التحري العملي لمعامل التصريف للسدود الغاطسة الدائرية والنصف الدائرية

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الخلاصة

في هذا البحث تمت دراسة ومقارنة الخواص الهيدروليكية للسد الغاطس ذو الحافة الدائرية والنصف الدائرية مختبرياً تحت حالات الجريان الحر والمغمور. استخدم فى هذا البحث ثمانية عشر نموذجا مختلفا . النماذج التسعة الأولى هي ذات حافة دائرية ، اما بالنسبة لبقية النماذج فقد كانت نصف دائرية. أثبتت النتائج ان ارتفاع النموذج(p)، ارتفاع الماء فوق السد (h_1) ، نسبة (h_2/h_1)،ميل القناة له تاثير على معامل التصريف(C_d).أثبتت النتائج ان معامل التصريف(C_d) للسدود الغاطسة الدائرية اكبر من النماذج النصف الدائرية تحت حالات الجريان الحر والمغمور. ان قيم معامل التصريف(C_d) للجريان المغمور لكل من السدود الغاطسة الدائرية والنصف الدائربة اقل مما هي عليها في حالة الجريان الحر بنسبة (١ – ١٥) ٪.

Received 1/6/2003 Accepted 20/8/2003.

وەرگیرا لە ٢٠٠٣/٦/١ وپەسەندكرا لە٢٠/٨/ ٢٠٠٣دا.