Hydraulic Characteristics of Flow

Over Compound Crested Weir

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Abstract

The hydraulic characteristics of a compound crested inclined weir which consists of both quarter round and sharp crest weir configuration under free conditions were studied experimentally in order to investigates the discharge coefficient C_d and the performance of weirs for discharge . The experimental tests were carried out on a model of weir manufactured of compound crest shape fixed perpendicular and inclined with an angles 35°,45° and 60° across the direction of flow in the experimental channel. Number of flow discharge were dependent.

Results showed that the model with an angle of weir inclination of 35° with the center line of the channel had a better performance than the other models (i.e α =45° ,60° and 90°). The conclusions concerning the flow characteristics over the compound crested weir agree with all the previous works on the semicircular and sharp crested weirs.

Key Words: weir, compound weir, flow, discharge coefficient.

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Introduction

Weirs may be defined as an over flow structures built across channels or rivers to divert or spill water. Designing spillway weir of high head in a dam with shorter length of overflow section may cause the height of non-overflow section of the dam to be increased. The maximum water levels in the reservoir is in-turn increase leading to a greater area of submergence which may be not permissible in area where the cost of land is high, [1]. In many situations where the topography of the site may have restrictions on the length of spillway weir that may be adopted , in such case aligning the weir to be included in plane so to compress the length of crest within the limited lateral space available which in-turn lead to reduction in the water head over the weir.

Many previous studies and researchers on the flow characteristics of flow in open channel with weirs obstruction were conducted. Those studies included the effect of crest configuration of weir on the characteristics of flow in which the crests were either fully sharp or fully circular or broad, [2], investigate the characteristics of flow over normal and oblique weirs with semicircular crests under free overflow condition. [3], used finite element technique to study the characteristics of flow over round crested weirs placed normal to the channel axis through three weir models with different height to base length ratio. [4], studied experimentally the characteristics of flow over normal weirs of semicircular to crescent shape. [5], studied experimentally the hydraulic of semi-circular crested weirs under flow conditions comparing with sharp crested weirs investigation of the discharge coefficient, water surface profiles and the performance of weirs.

In the present study an experimental model of compound crested weir which consist of two parts, the upstream part is quarter round shape while the downstream part has standard sharp crested weir shape was constructed and testes to compute the discharge coefficient and the weir performance. The effect of weir inclination with the direction of flow on the weir performance was studied too.

Experimental Work

The experiments were conducted in a rectangular laboratory flume 10 meter long, 0.4 meter wide and 0.5 meter deep .Discharge of the flume were measured volumetrically and calibrated with a rectangular weir fixed at the tail end of the channel,[6]. A laboratory weir model with a compound crest having a configuration of quarter round at the upstream and sharp shape at the downstream was conducted as shown in Figure(1). The quarter round part is a quarter circle with a radius of 2.5cm.This radius was depended according to the design criteria suggested by[7], in which the radius of the weir (R) should equal to the height of the weir (P) divided by (12) i.e. $R=P/12$.

The weir was 20cm high and 5cm thick. It was carefully aligned, leveled, fixed and sealed at 0, 35 , 45 and 60 degree with the direction of flow respectively. An accurate point gauge was used to measure the water depth during the experiments.

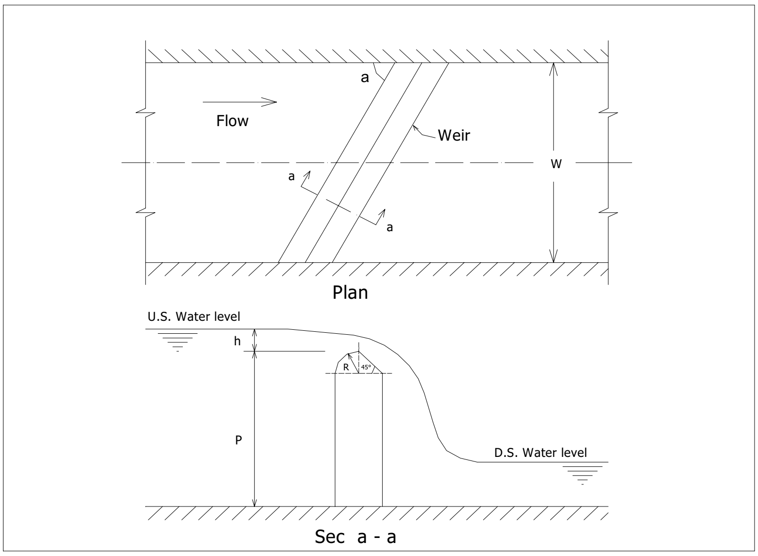

Figure (1): Schematic diagram of the compound crested weir.

Weir Equation

The proposed equation for designing the inclined compound crested weir using the basic equation developed for linear weirs is,[8]:

$$Q = \frac{2}{3} C_d L \sqrt{2g} H_L^{1.5} \text{..................................} \mathbf{(1)}$$

Where:
C_d = a dimensionless crest coefficient,
g = acceleration of gravity, m^2/sec.
L = effective length of the weir, m and
H_L= total head on the crest, m.

For a linear weir without side contractions and with normal approach flow, the effective length L is the actual measured length of the weir. The crest coefficient is dependent on the ratio H/P, the wall thickness t, crest configuration, and nappe aeration,.

Data Analysis

Six discharges were measured and fixed for all the experiments representing the four angles of the weir inclination with the flow direction. The head over the weir crest was measured for all the selected discharges as shown in

Table 1. Statistical analysis was carried out between the measured discharges and the head over the crest arriving to the following equation [4]:

$$Q = CH^{1.55} \qquad \text{……………..…………...………………………………………….(2)}$$

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

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

Where:
Cd = discharge coefficient,
Qact = actual discharge m3/sec.
Qtheo = theoretical discharge m3/sec.
The actual discharge was measured by using volumetric method, while the theoretical discharge was evaluated by using the following formula:

$$Q_{theo} = \frac{2}{3}\sqrt{2g}LH^{1.5} \qquad \text{……………………..………………………………….(4)}$$

Table:1, Measured data for weirs models.

	α=35°			α=45°			α=60°			α=90°		
Q l/s	h cm	h/P	Cd	h cm	h/P	Cd	h cm	h/P	Cd	h cm	h/P	Cd
1.45	0.74	0.037	1.102	0.86	0.043	1.091	1.05	0.053	0.986	1.27	0.063	0.859
4.03	1.35	0.068	1.245	1.64	0.082	1.152	1.93	0.096	1.103	2.31	0.115	0.973
6.86	1.85	0.093	1.320	2.26	0.113	1.205	2.67	0.134	1.152	3.12	0.156	1.055
11.95	2.57	0.129	1.405	3.10	0.155	1.313	3.86	0.193	1.157	4.25	0.212	1.154
16.95	3.18	0.159	1.448	3.83	0.191	1.354	4.54	0.227	1.285	5.24	0.262	1.198
19.65	3.47	0.174	1.473	4.15	0.207	1.392	4.95	0.247	1.310	5.77	0.288	1.201

Variation of Cd with h/P for Compound Crested Weir

Dimensional analysis to get non-dimensional groups which is significant to the flow characteristics over weir with semi circular shape perpendicular to flow direction was carried out by Rokaia, 2000 relating the following parameters:

$$C_d = \phi\left(\frac{h}{P}, \frac{R}{P}\right) \qquad \text{……………………………………….(5)}$$

Where:
h= depth of flow over weir crest, m
P= height of weir, m
R= radius of circular crest. m

The relationship between the discharge coefficient (C_d) and the ratio of the head over the weir to the crest height for all the present tested angles of weir inclination (α) was drawn as shown in Figure (2). All the experiments was carried out with one fixed height of weir (P) which is (cm). This figure shows that the C_d increased with increasing h/P. For a certain value for the ratio h/P, the C_d value increases, with decreasing the angle of weir inclination (α).

A statistical relation between the discharge coefficient and the ratio (h/P), (R/P) for all the angles of weir inclination (α) was predicted as follows:

$$C_d = 0.0035\frac{\left(\frac{h}{P}\right)^{0.2}}{\left(\frac{R}{P}\right)}(\sin\alpha)^{0.3} \quad \text{...(6)}$$

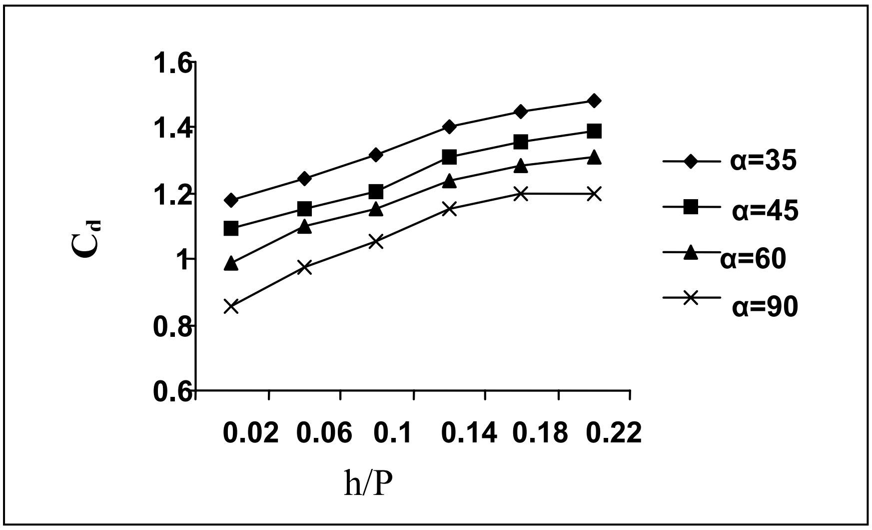

Figure (2) : Relationship between the discharge coefficient and the ratio h/P for all the tested angles of compound weir inclination.

Figure(3), shows the percentage of agreement between the measured coefficient of discharge and the predicted using equation(6). This figure indicated an obvious good agreement between the values of the coefficient of discharge.

The relationship between the measured values of the discharge coefficient with the tested angles of weir inclination (α) was drawn for all the used discharges in the experiment as shown in Figure(4). It is obvious that as the angle of weir inclination increases, the discharge coefficient decreases for certain discharge, while for certain angle of weir inclination as the discharge increases, discharge coefficient increases too. This conclusion agree with all the previous works on the hydraulic characteristics of flow over inclined semicircular and sharp crested weirs.

The ratio between the discharge coefficient for the inclined compound weir to the normal one ($C_{d\ In}/C_{d\ Nor}$) was used to examine the present compound (weir performance) as shown in Figure(5). It clear that the angle of weir inclination (α=35°) gave the higher value of the ratio ($C_{d\ In}/C_{d\ Nor}$) for certain ratio (h/P). This figure showed that the model (α=35°) had a good performance due to the less losses in the nappe interaction with the sides of the channel as the pocket between the channel sides and the weir was small comparing with the length of the inclined weir. The figure shows that for certain angle of weir inclination, as the ratio (h/P) increases, the ratio ($C_{d\ In}/C_{d\ Nor}$) decreases. This gave an indication that the degree of increment of the ($C_{d\ Nor}$) with the increment of (h/P) is more than ($C_{d\ In}$).

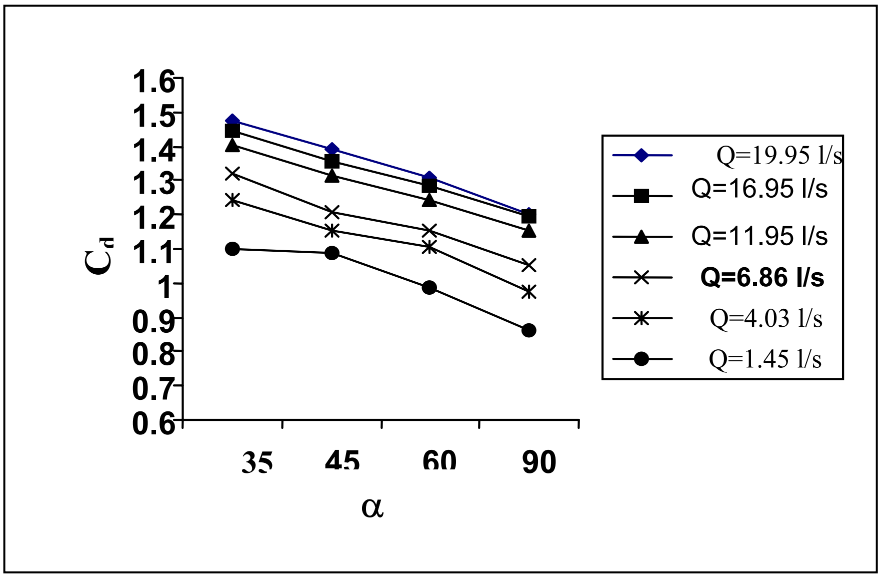

Figure (4) : Relationship between the discharge coefficient and weir indication angles.

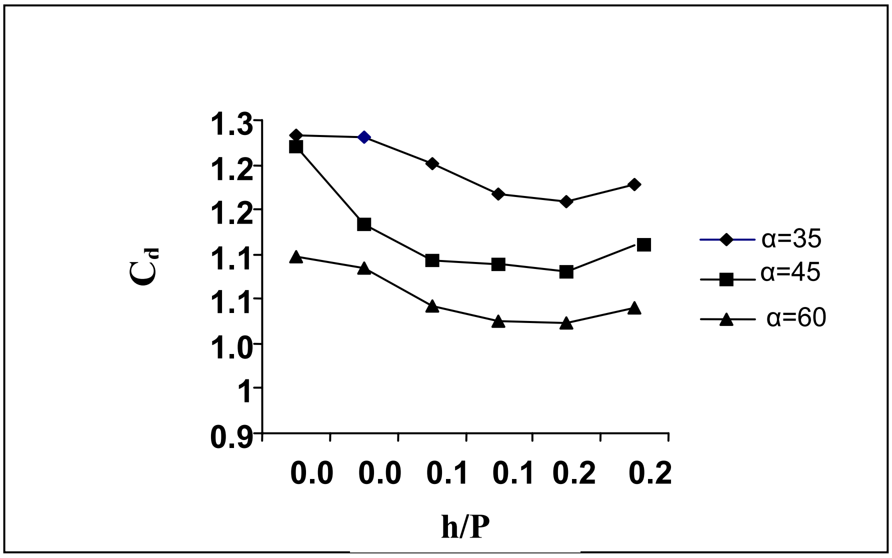

Figure (5) : Relationship between the ratio $C_{dIn.}/C_{dNor.}$ with the ratio h/P.

Conclusions

1. The (C_d) value increases as the ratio (h/P) increases for all the tested angle of compound weir inclination.
2. For certain value of the ratio (h/P), the(C_d) value increases with the decreasing of the angle of weir inclination.
3. Good agreement was found between the measured and predicted coefficient of discharge for the used compound weir.
4. The model with angle of weir inclination of (35°) with the center line of the channel had a better performance than other models (i.e. α=45°,60°,90).

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