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Experimental Investigation of Flow Characteristics over Crump Weir with Different Conditions

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Abstract: Weirs are the most extensively used hydraulic structures in the different fields of hydraulics, environmental, irrigation, and chemical engineering, as flow measuring and flow control devices in open Channels. The object of the present paper is to study the effect of the geometry of crump weir on the coefficient of discharge (C_d) under different flow conditions. The experimental work was conducted in rectangular laboratory flume; fifteen physical models were used with five upstream angles (17^o, 22^o, 27^o, 32^o and 37^o) and three different crest heights (10, 15 and 20) cm under free flow conditions. The results show that C_d value will increase with the decrease of crest height as well as with increasing flow rate; it is also directly proportional to the upstream slope and inversely to the downstream slope. Computational fluid dynamic (FLOW 3D) were used to conduct new experiments.An empirical relation was obtained to estimate the coefficient of discharge Cd under different height and upstream slopes crump weirs.

Keywords: weir, angle, flow

INTRODUCTION

Weirs are the most usually hydraulic structures; they have been widely used for flow measurement in channels and rivers because of its simplicity. There are four function uses of weirs, namely, water level management, flow gauging, for environmental aims or for channel stabilization [1].

There are many types of weirs; according to their geometry (Broad crested weir such as rectangular broad crested weir, and Sharp crested weir such as rectangular, triangular, and trapezoidal crested weir),function(flow gauging, flood control, irrigation), and flow conditions(free or submerged) **[2].** ne of the interesting types is the triangular short crested weir (crump weir), which is a special type of broad crested weir.The Crump consists of two parallel walls with a specially shaped overflow wall on the downstream side. The wall top is sloped at 1:2 on the upstream side and 1:5 on the downstream side**.**

It is very essential to study the behavior of the flow over the crump weir. A limited number of studies have been dedicated to the flow over this sort of weirs, Keller, [3] studied the behavior of crump weir under different transverse crest slopes, he concluded that for the was concluded that for the same transverse crest slope, the structure behaves as one half of flat-V weir at relatively large heads. Hudson *et al.,* [4] Checked the calibrations performed on the Crump weirs, he showed that accurate operation of Crump weirs is feasible in non-standard Conditions. John Demetriou and Eugene Retsinis, [5] studied the discharge coefficient for different bed slope of the open channel; he conducted three equations for zero, positive and negative channel slope. Mohd Adib Mohd Razi *et al,* [6] studied the relationship between the rate of flow and upstream head over crump weir besides obtaining an approximate free surface profile in unsteady open channel flow. Safaa N Hassan, [7] studied the influence of different quantities of total solids (TS) on the pattern of flow and coefficient of discharge in open channels and water treatment plant for crump weir, he conducted that the coefficient of discharge changes with the value of the total solid (TS). In this paper experimental work for a crump weir is performed, in order to find out the effect of height and upstream and downstream slope on discharge coefficient and flow characteristics over the weir.

EXPERIMENTAL SETUP AND PROCEDURE

The laboratory flume used in this study is a rectangular flume of 18.6 m long, 0.5 m wide and 0.5m deep. The flume walls are made from a glass fiber to provide visual observation, while the bed is stainless steel. A V-notch sharp crested weir is located below the outlet of the inlet tank measuring the actual discharge which passes through the flume section as shown in figure 1.

Fig-1: The flume

Fifteen different model of crump weir were used, five upstream angles (17°, 22°, 27°, 32° and 37° with three crest height for each angle (10, 15 and 20) cm. The channel was adjusted to the horizontal position. each model of crump weir were put just 9 meters from the upstream channel in order to provide sufficient distance to settle the water and take accurate results. The flow stability is attained. When the upstream water level became constant, the parameters required are measured. The procedures have been repeated for each crump weir model with different cases. For each type of the crump weir a series of tests under different flow rates were conducted. A total of 120 runs were conducted at the experimental work.

THEORETICAL ASPECTS

Weirs are elevated hydraulic structures used to measure flow and/or to control the water elevation at outflows from basins and channels. The crump weir has a triangular profile as it shown in Figure 2. There are two different types of flow conditions: the modular flow condition, and the non-modular flow condition. Modular Flow occurs when the weir operates under owned, with high downstream water level low Figure 3. In this condition, the upstream head is not affected by the downstream head; therefore it is possible to determine the flow rate by taking a single measurement of upstream.

$$Q_m = C_d \, B \, H^{3/2} \sqrt{g} \qquad \text{……………..} (1)$$

Where:

Qm = Flow rate for modular flow (L3T-1)
Cd = Modular discharge coefficient
g = Gravity (LT-2)
B = Breadth of weir (m). b = 0.5 m
H= Total Head upstream of weir crest (L).

While, non-modular flow occurs when the weir operates drowned, with high downstream water level Figure (4). In this condition, a single measurement of upstream head is not adequate to determine the actual flow because the upstream head is affected by changes in the downstream head. Then, a dimensionless reduction factor is required to correct the non-modular flow:

$f = Q/Q_m$,

Where

Q = Flow rate for Non-Modular Flow (m3/s), C_d is the discharge coefficient.

By using the data obtained from the laboratory work and equation 1, the value of C_d for each model has been calculated under different flow rates, in order to discover the outcome of upstream slope and crest height of crump weir on the value of the C_d.

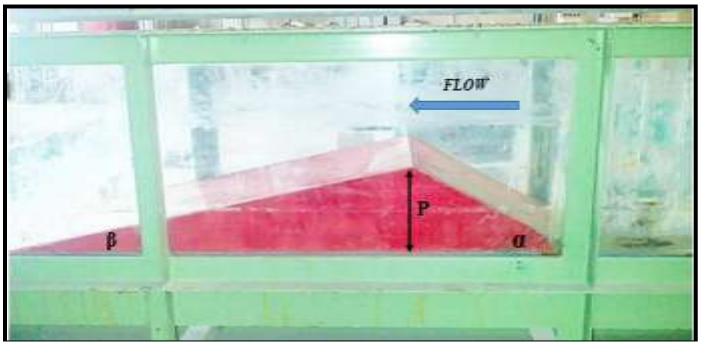

Fig-2: crump weir model

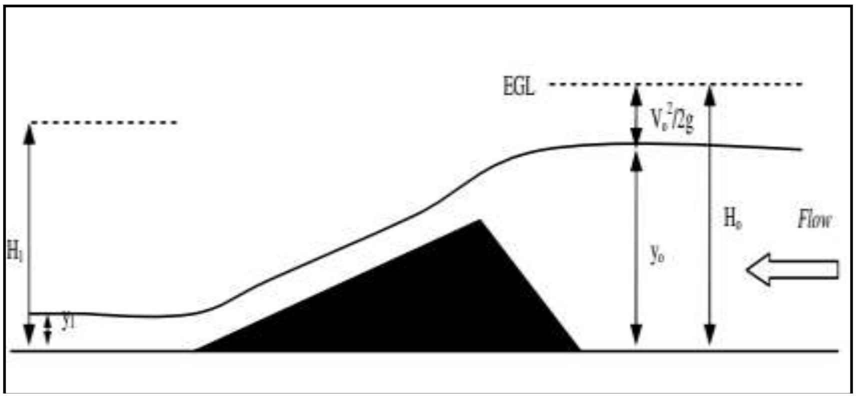

Fig-3: Crump weir during modular flow condition (Redahegn, 2009)

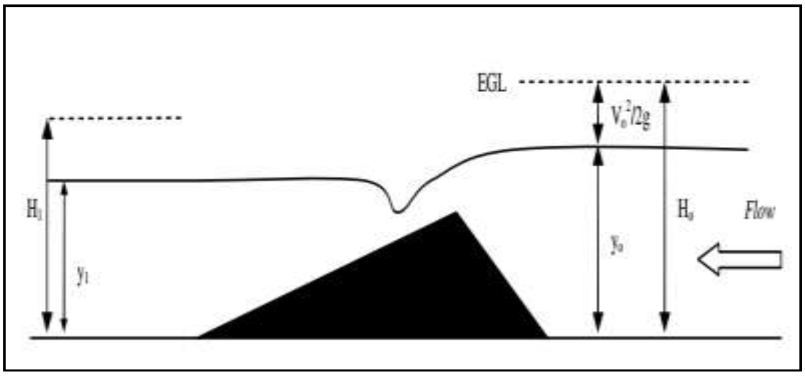

Fig-4: Crump weir during non-modular flow condition (Redahegn, 2009)

EFFECT OF DISCHARGE AND CREST HEIGHT ON C_D:

The values of C_d are plotted against the unit discharge for different weir upstream slopes under the same weir height as shown in Figures (5, 6 and 7) in order to explain the variation of C_d value with the discharge. It is clear from these figures that there is Increase in C_d values with increased flow rate. While figures (8 and 9) shows that the C_d value decreases by increasing crest height.

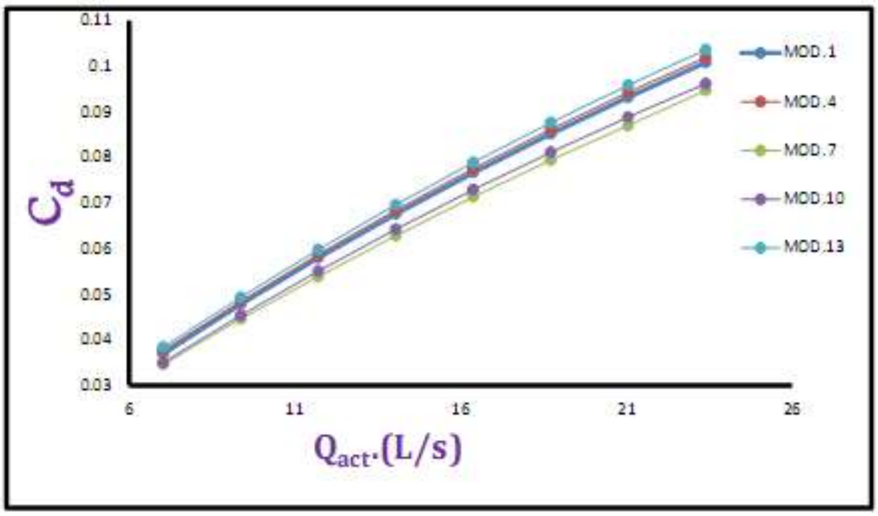

Fig-5: variation of (C_d) with (Q_{actual}) for the five upstream angle with crest height of 0.2m

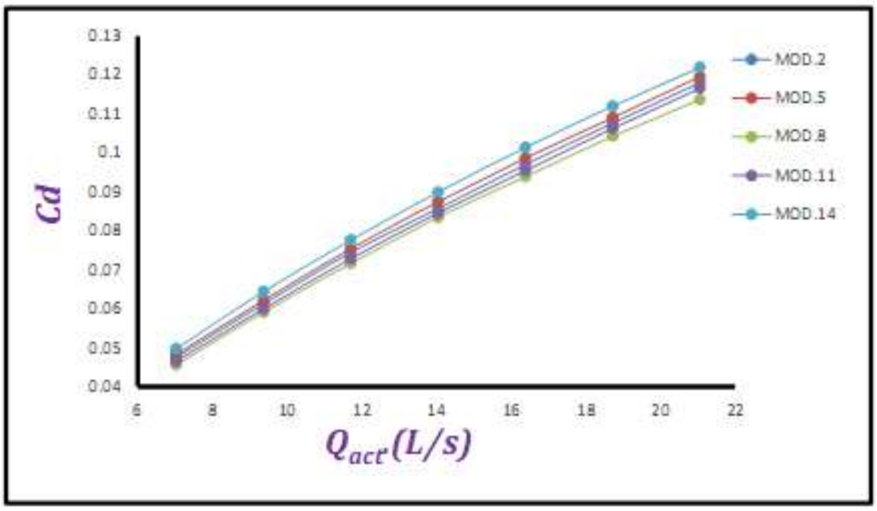

Fig-6: variation of (C_d) with (Q_{actual}) for the fiveupstream angle with crest height of 0.15m

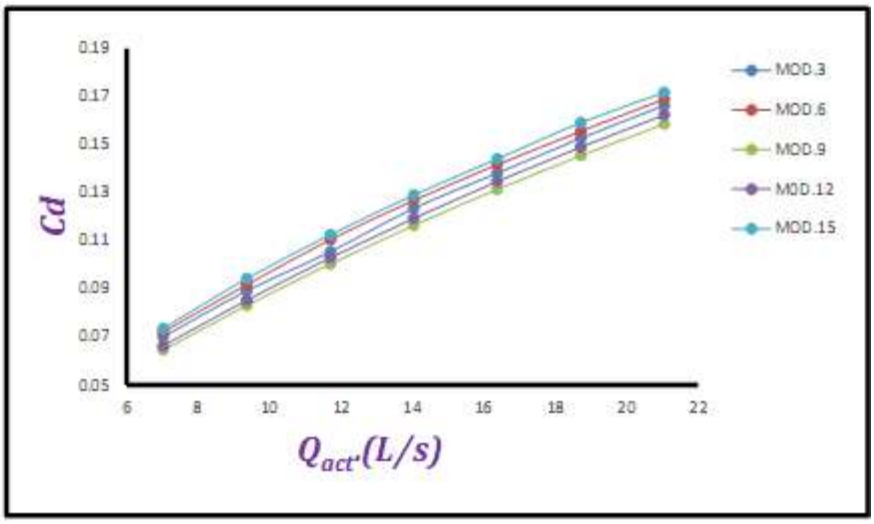

Fig-7: variation of (C_d) with (Q_{actual}) for the fiveupstream angle with crest height of 0.1m

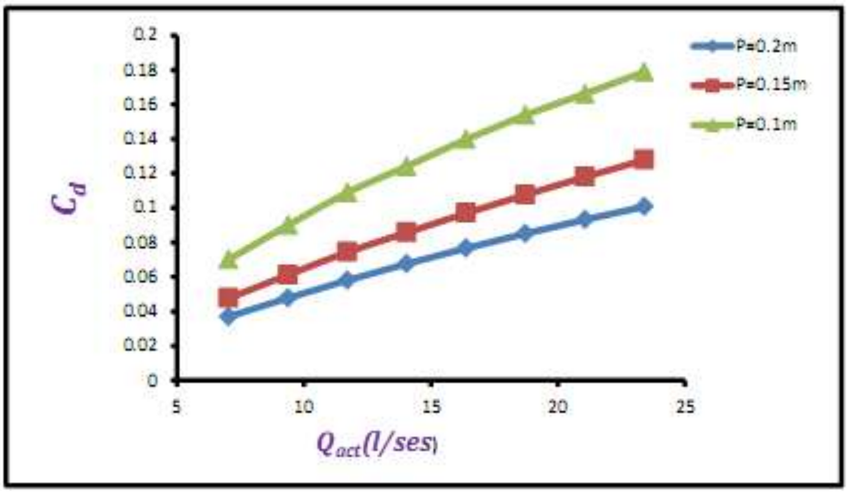

Fig-8: variation of (C_d) with (Q_{actual}) for upstream angle 27 degree

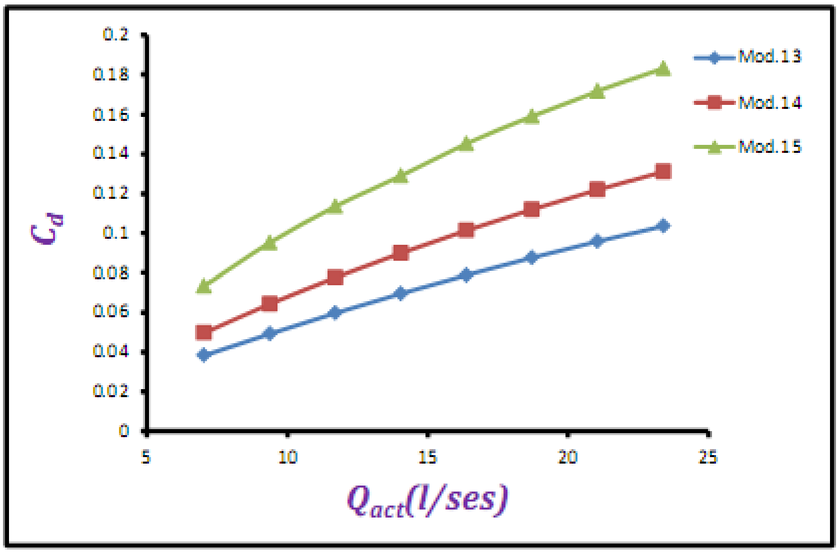

Fig-9: variation of (C_d) with (Q_{actua}l) for upstream angle 17 degree

EFFECT OF UPSTREAM AND DOWNSTREAM SLOPE ON C_D:

The coefficient of discharge C_d is inversely proportional the upstream slope as shown in figures (10, 11 and 12). For the same crest height and flow rate, Cd value decrease by increasing upstream angle value and increase by decreasing the same angle. It notices that an increase in upstream angle (from 27^o to 32^o) and (from 27^o to 37^o) reducing Cd value about (5.1 % and 7.2 %) respectively. While reducing upstream angle (from 27^o to 22^o) and (from 27^o to 17^o) make an increase of Cd value about (1.5 % and 3.7 %) respectively.

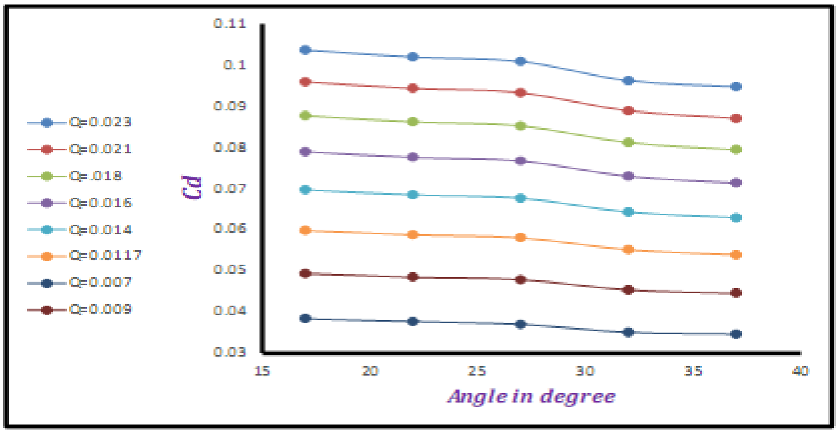

Fig-10: variation of (C_d) with upstream angles for different discharge and crest height 0.2 m

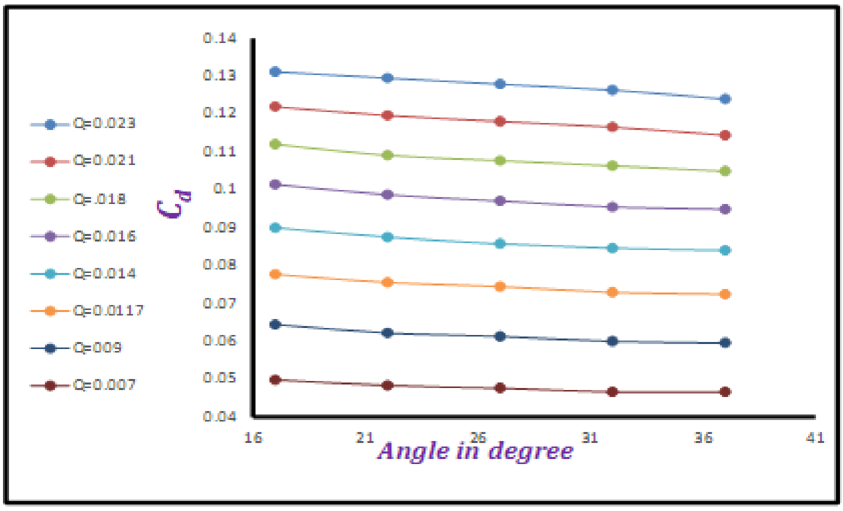

Fig-11: variation of (C_d) with upstream angles for different discharge and crest height 0.15m

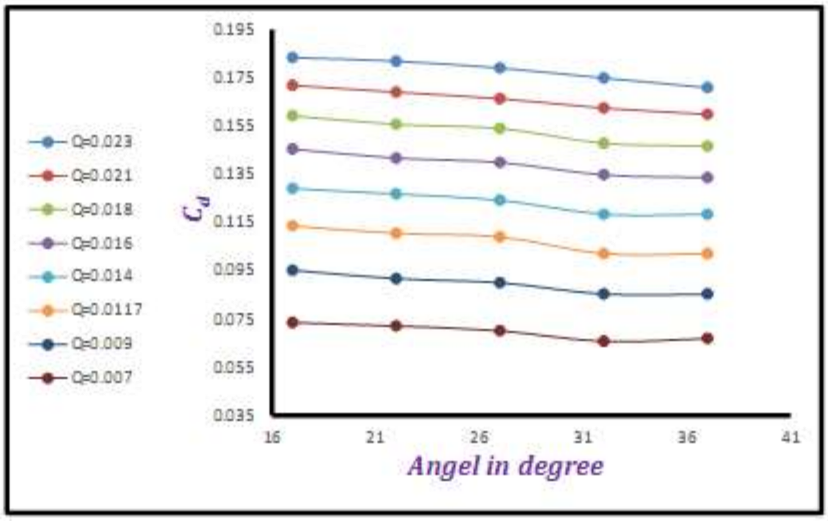

Fig-12: variation of (C_d) with upstream angles for different discharge and crest height 0.1m

CONCLUSIONS

The researchers have arrived at the following conclusions:

1. For the same crest height and flow rate, C_d value decrease by increasing upstream angle value and increase by decreasing the same angle. It notices that an increase in upstream angle (from 27^o to 32^o) and (from 27^o to 37^o) reducing C_d value about (5.1 % and 7.2 %) respectively. While reducing upstream angle (from 27^o to 22^o) and (from 27^o to 17^o) make an increase of C_d value about (1.5 % and 3.7 %) respectively.
2. An increase in discharge of (-232.9 %) led to an increasing in C_d of (172.5, 168.3, 155.2) % for crest height 20 cm, 15 cm, and 10 cm respectively for (α= 27^o, β=11^o). While for weir with (α= 22^o , β=11^o) the rates of the increase in C_d value are (170.4, 167.7, 152.03) % , for weir with (α= 37^o , β=11^o) the rates of the increase in C_d value are (173.3, 165.8, 155.2) % , for weir with (α= 32^o , β=11^o) the rates of the increase in C_d value are (174.3, 170.7, 165.9) % , and for weir with (α= 17^o , β=11^o) the rates of the increase in C_d value are (169.7, 163.3, 149.2) % .
3. For the same flow rate and upstream angle, the coefficient of discharge inversely proportional to the crest height. An increase in crest height from 10 cm to 15 cm (50% increases) cause a reduction in Cd value about 29.9%. While anincrease in crest height from 20 cm to 10 cm (100 % increases) reducingCdvalue about (45.9 %)

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