Discharge Equations of Broad crested weir with Triangular End Lip

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Abstract

In this paper, a triangular end lip broad crested weir was investigated and studied through six models with three selected angles (60^o,75^o,90^o) the experiments were conducted in a rectangular laboratory flume in hydraulic laboratory of water resources department of Mosul University, with two shapes of crest and three angles of inclination. The first model was installed with inclination toward inside while the second model inclined toward out. An empirical discharge equations were obtained depending on the values of brink depth (y_b), normal depth (y_n) and angles of triangular broad crested weir (θ).The discharge values from empirical equations were compared with experimental values with total percentage of error not exceeding 6%.When coefficient of discharge increases, the ratio of brink depth to critical depth at centerline, right or left for first and second cases decreases. The average value of (y_b/y_c) for second case at centerline is greater (17%) than the first case, while it became at right or left of models in first case greater (21%) than its value the second case.

Keywords: Overfall, brink depth, bed roughness

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1. INTRODUCTION:

A free overfall occurs when the water draw down from the solid boundary to form a free nappe owing to an abrupt decrease in channel bed elevation that is a drop structure, Dey (2002a) this is a similar case of broad crested weir in open channel.

It offers a method of discharge measuring in open channels from measuring the depth at the brink known as end depth y_b. The value of the end depth depends on the shape of the approach channel, Ahmed (2005).

Davis et.al.(1998) investigated the effect on the ratio y_b/y_c of the cross-sectional shape,slope and roughness of the channel,they obtained discharge equation depending on roughness and slope of channel .

Davis et.al.(1999) presented the results of a study to model the upper surface profile of free rectangular overfall. It was found that an empirically adjusted free fall parabola equation adequately describes this profile.

Day (2001) presented a simplified approach for the computation of end-depth of a free overfall in horizontal or mildly sloping inverted semicircular channels, the end-depth relationship has been found as 0.705 for critical depth diameter ratio up to 0.42.

Dey (2002a) studied two separate methods to analyze the free overfall in circular channels with flat base. First is applying a momentum approach based on the Boussinesq assumption, this need to determine pressure coefficient experimentally, and the end-depth relationship has been related to the critical depth. Secondly, a simplified approach to computation of end-depth for a free overfall from critical channels with flat base has been presented by simulates the flow over a sharp crested weir.

Dey (2002b) presented a comprehensive state for the art review of the important laboratory. Experimental and theoretical investigations on free overfall in various channels high lighting the hydraulic back ground and the mathematical treatment of the problem. In this review articale,120 references are included.

Ahmed (2005) presented the simulation of the free overfall in an inverted semi-cirular channel with a sharp-crested weir, for the determination of discharge from a single measurement of end depth. The end-depth ratio is almost constant with average value 0.713.

Pal and Goel (2006) discussed the usefulness of the support vector machine based modeling approach in predicting the end-depth ratio and the discharge for semi-circular as well as circular shaped channel in both subcritical and supercritical flow regimes. The end-depth ratio is found to be 0.704 and discharge computed in this way is quite well to experimental computation.

In the present work empirical discharge equations were found by knowing brink depth (y_b) and normal depth (y_n) depending on parameters appears from dimensional analysis for triangular free overfall with different end lip shape angles inclined with flow direction and opposite of flow direction.

2. EXPERIMENT INSTALLATION AND MEASUREMENTS:

The experiments were conducted in a metal rectangular flume with glass sides, 300mm in width and 10m in length which are shown in figure (1). the discharge were conducted by made a rectangular sharp crested weir 300mm in width and 300mm in height installed upstream of the channel and upstream steady-state normal depths of approximately 30,45,68,82 and 93mm were produced in flume. 6 wooden models of broad crested weir were made 300mm in width and 150mm in height with triangular end lip shape with three different angles (60^0,$75^0$and 90^0) set in two ways, with flow direction and opposite flow direction which are shown in figure (2).

A point gauge mounted on rails along the channel allowed measuring the water surface profile (W.S.P.) at broad crested weir.

Flow over brink y_b was measured at

two position one at the centerline of model y_{bcl} and another at mid distance right or left centerline y_{brl}, also normal depth over broad crested weir y_n and head over sharp crested weir upstream H_w were measured, so actual discharge Q_{act} can be calculated from the following equation which is the calibration in the volumetric way by measuring H_w and volume of water with respect to time:

$Q_{act}=0.714\ H_w^{1.5}$…………..……..….(1)

Where Q_{act} in (l/s) and H_w in (cm)

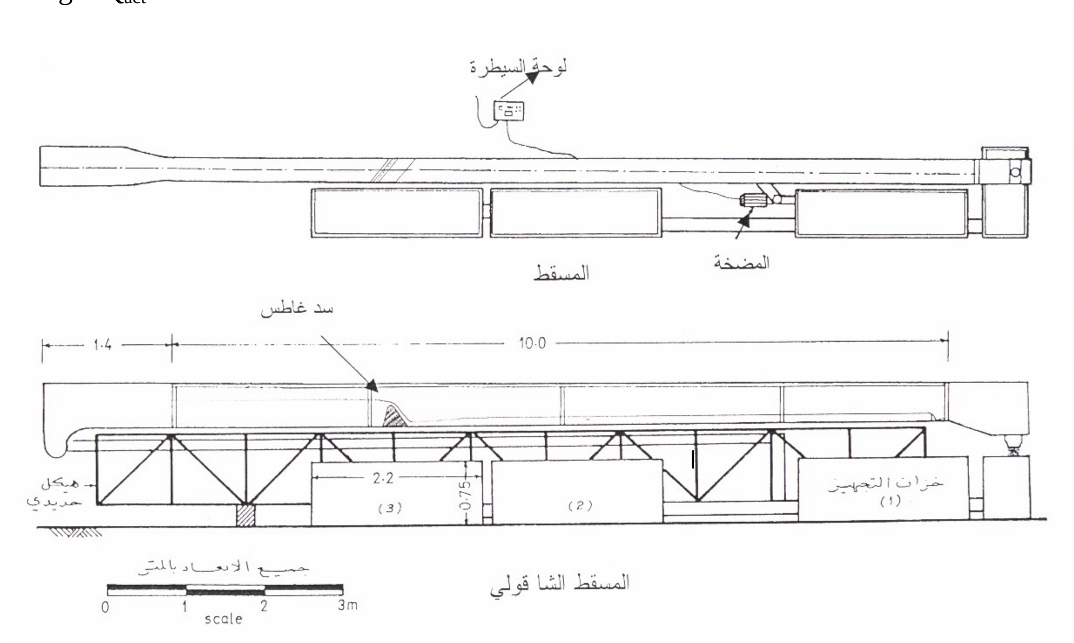
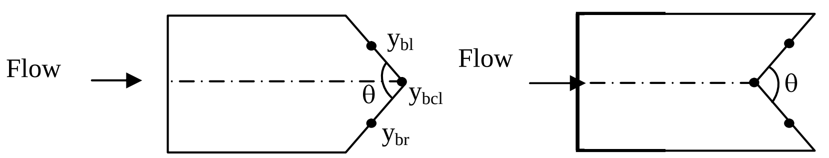


Figure 1:The laboratory channel



a

Triangular end lip shape with flow direction

b

Triangular end lip shape opposite flow direction

Figure 2:The experimental models of broad crested weir used in present study

3. RESULTS:

Thirty flows were found to satisfy the required criteria (15 flows on models (60^0,$75^0$and 90^0) with flow direction and 15 flows on models opposite flow direction).For these flows the values of Q, y_b, y_{bcl}, y_{brl}, y_n, H_w, were recorded while q was calculated from equation (2) and y_c was calculated from equation (3):

$q=Q_{act}/b$…………………………(2)

$y_c=\sqrt[3]{q^2/g}$ …………….…………….(3)

where q is the discharge per unit width , y_c is the critical depth, b is the width of channel (300mm) and g is the acceleration due to gravity.

The relation between y_c ,y_{bcl} and y_{brl} are presented in figures (3 to 6) respectively. The best fit shown have been fitted through the data for each angle with flow direction and opposite it. It can be seen that y_b increases for both centerline and right or left of the model when y_c increases for both first and second cases.

In figures (3 and 6) brink depth at centerline y_{bcl} for angle 60^0 is greater than angles 75^0 and 90^0 for the second case while these values are opposite in the first case.

In figures (4 and 5) brink depth at right or left of the centerline of models y_{brl} for angle 90^0 is greater than 75^0 and 60^0, for first and second cases.

The average values of y_{bcl} for the second case for angle 60^0 is greater 1.3% than angle 75^0 and 2.5% than 90^0 while these values at first case for angle 90^0 is greater 1.8% than angle 75^0 and 3.5% than angle 60^0.

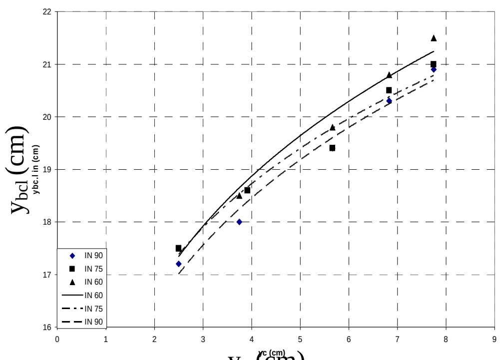


Figure 3: shows the relation between y_{bcl} and y_c for the second case

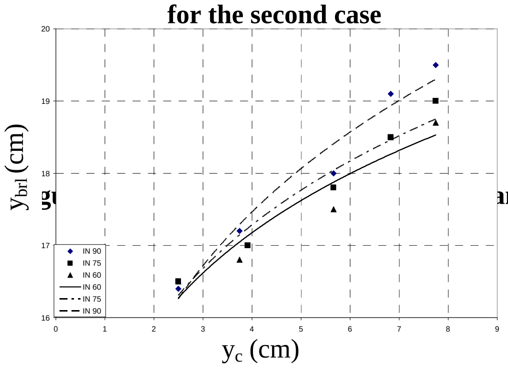


Figure 4: shows the relation between ybrl and y_c for the first case

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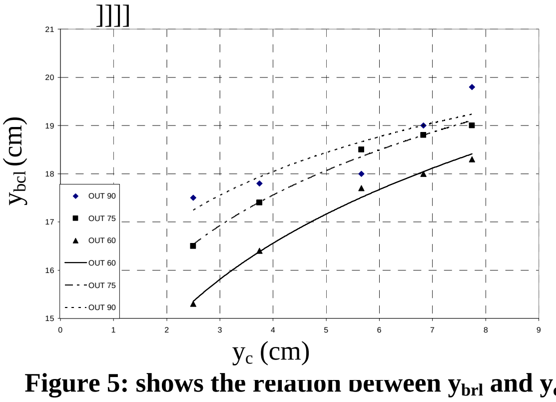

Figure 5: shows the relation between y_{brl} and y_c for the first case

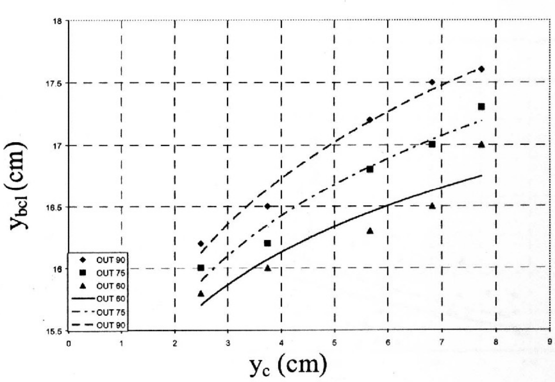

Figure 6: shows the relation between y_{bcl} and y_c for the first case

4. PREDICTING DISCHARGE:

The set of characteristic parameters appropriate for flow over broad crested weir can be given in a functional form as follows:

Q_{th}= f (y_b, y_n, g, ρ, b, θ).... ....(4)

Where Q=discharge of the channel (m^3/s), y_b=brink depth of broad crested weir (m), g=gravity acceleration (m/s^2), ρ=water density (kg/m^3), b=channel width (m) and θ=angle of end lip shape of broad crested weir in radian. Using the Buckingham π-theorem and selecting the parameters ρ, y_b and g as repeating variables, the non dimensional parametric equation in functional form can be given by:

$$Q_{th}= y_b^{2.5}g^{0.5}f\,(\theta, \frac{y_n}{b}) \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

One of the most important corollaries of the agreement as established of the data reported of various origins is the possibility of obtaining a discharge relationship for triangular end lip shape broad crested weir using θ , y_b and y_n.

From the experimental results and equation (5) we obtain the following simple depth-angle-discharge relationship.

$$Q_{th}= y_b^{2.5}g^{0.5}\, c_1\theta^{c2}\,(\frac{y_n}{b})^{c3} \ldots\ldots\ldots\ldots\ldots(6)$$

This equation dependent on position of y_b measuring at centreline or right-left for the first and second cases, where Q in (m^3/s) so the following equations can be obtained:

For the second case (C.L)

$Q_{th}= y_{bcl}^{2.5} g^{0.5}\, 0.448\, \theta^{0.43}\, (\frac{y_n}{b})^{3.2}$............(7)

R^2=0.97,e_{av}%=4.2%

For second case (R.L)

$Q_{th}= y_{brl}^{2.5} g^{0.5}\, 0.658\, \theta^{0.088}\, (\frac{y_n}{b})^{3.46}$..........(8)

R^2=0.97,e_{av}%=5.77%

For first case (C.L)

$Q_{th}= y_{bcl}^{2.5} g^{0.5}\, 1.0\, \theta^{-0.44} (\frac{y_n}{b})^{3.82}$.............(9)

R^2=0.97,e_{av}%=1.48%

For first case (R.L)

$Q_{th}= y_{brl}^{2.5} g^{0.5}\, 0.79\, \theta^{-0.55}\, (\frac{y_n}{b})^{3.38}$.........(10)

R^2=0.97,e_{av}%=4.34%

Results of discharge for all models are compared with experimental values in figure (7). It can be seen resulting estimated discharge values with respect to experimental discharge values with total average percentage error not exceed 6%.

The coefficient of discharge ($c_d=Q_{act}/Q_{th}$) with relation y_b/y_c is given in figures (8 and 9). It can be seen that an average values of ybcl/yc for the second case are greater (17)% than the first case, and opposite at right or left from centreline to be for the first case (21)% greater than the second case, so the relation of y_b/y_c at centreline and right or left for the first and second decrease when coefficient of discharge increase.

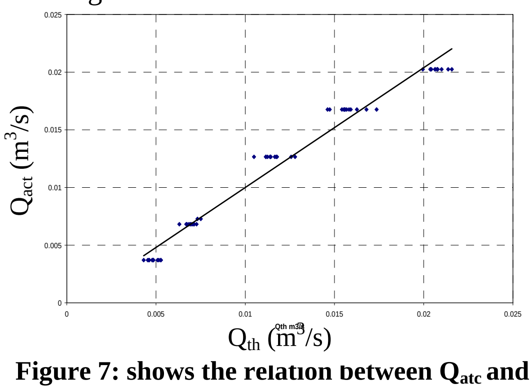

Figure 7: shows the relation between Q_{atc} and Q_{th} for all models

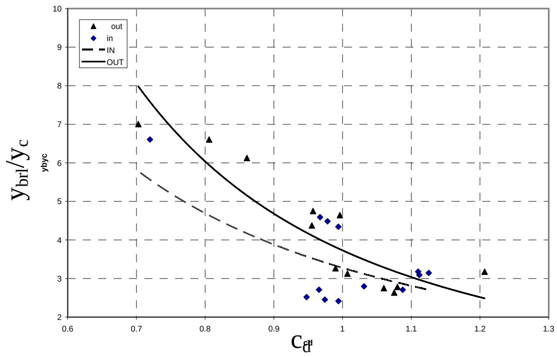

Figure 8: shows the relation between y_{bcl}/y_c and c_d

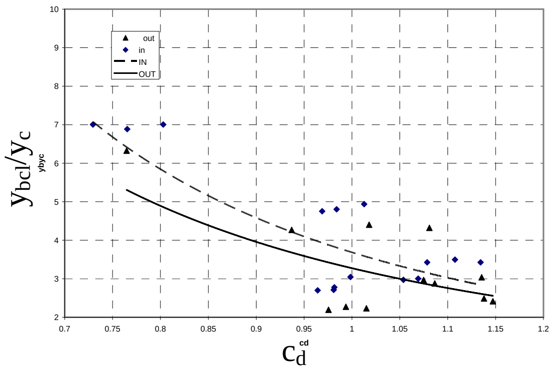

Figure 9: shows the relation between y_{brl}/y_c and c_d

5. CONCLUSION:

This paper presents the results of a study to assess the effect of end lip shape angle on the broad crested weir. It was found that the ratio of y_b/y_c influenced by end lip shape angle and position of measurements centreline or right or left of the centreline.

Four relationships were obtained to predict channel discharge and compared to measured values. The first two relationships for y_b centreline and right or left for the second case with average percentage of error not exceed 6%, while the two other relationships for y_b centreline and right or left for the first case with average percentage of error not exceed 5%.All these relationships require the value of brink depth at centreline or right or left (y_{bcl},y_{brl}) and normal depth at broad crested weir (y_n).

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