THE EFFECT OF CHARACTERISTICS OF FLOW ON DISCHARGE COEFFICIENT FOR OBLIQUE WEIR

Jumana hadi sahib, Ghssan Naeem, Yousif Hani and Ahmed Kaduhim

Civil department, Faculty of engineering/University of Kufa, Iraq

ABSTRACT

Any flow taking place over a hydraulic structure under the free surface condition is analyzed with the weirs formula because is good advice and easy measured. Experimentally using a laboratory flume for compound crested weir models were investigated. The crests weir for models divided two parts; the first part is a quarter rounds shape in upstream. The second part is sharp crested in downstream. Series of experiments were used for weir crest radius of \( R = 1.5 \) cm, and angles of weir inclination \( \alpha = 10^\circ, 15^\circ, 25^\circ \) and \( 90^\circ \) to the direction of flow with a different weir height \( P = 15 \) cm, \( 20 \) cm, and \( 25 \) cm to measure discharges and water heads over the weir models. This kind of weir can used to increase the efficiency by increased the length weir and discharge for same head and width of channel. By the eddy and hydraulic jump in downstream is aerating automatically. Finally, this paper used three formulas for discharge coefficient related for each height weir included oblique angles tested and the equations gave a good correction.

Keywords: Discharge Coefficient, Compound Crested, Experimental Data, Oblique, Weir.


http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=6

1. INTRODUCTION

The weir is good measuring flow devices and is one of oldest structures used to measure the flow in open channels. Weirs are commonly used to alter the flow regime of the river, prevent flooding, measure discharge and to help render a river navigable.

In channel applications where is required to increase the freeboard, the normal weir is specific to the water level, it is not possible to increase the amount of discharges passing through the channel. The expansion of the channel is impractical and expensive. For example, if a spillway weir is designed for a dam, with short length caused to raise water over the dam and spillway. The maximum water level led to increase the area of submergence where the
cost is very high (Ibrahim et al, 1988). The oblique weir is one easy and practical solution to reduce the head for higher discharge with the limiting channel width and less energy loss.

(Ibraheem et al, 1988) cited by [1] "studied the performance of oblique sharp crested weirs for different angles (45, 30, and 15) and constant weir height (P= 10 cm). He suggest some equations for the performance of oblique weirs" (Borghei et al, 2003) [2] determined by experimental work the Cd for oblique sharp-crested weirs for free and submerge flow to variables angle (0-64), two type of weir height (460-511)mm for free flow and (505-511)mm for submerge flow, and downstream water head (6.5-87)mm. (Noori et al, 2005) [3] determined by experimental work the Cd for oblique with half round crests to variables angle (0-64), two type of weir height (460-511)mm for free flow and (505-511)mm for submerge flow, and downstream water head (6.5-87)mm. (Noori et al, 2005) [3]

2. WEIR FORMULA
Free flow (unsubmerged flow) over a weir exists when the downstream water surface is at or below the crest of the weir (Froude number is 1) as shown in Fig (2)[8]

By using momentum conservation can straightforwardly be analyzed the imperfect condition (sub-critical) for the downstream part. The exact solution by this approach can be obtained; but the energy loss in downstream is often described multiplying with loss coefficient Cd [9]

\[
Q_{act} = Cd^2 b \sqrt{2gH^{1.5}} \quad \text{..........1}
\]
$Q_{act}$ = the actual discharge

Cd is a dimensionless, coefficient of discharge with the weir geometry was determined experimentally

g=gravitational acceleration.

H= headwater over crest weir.

b= effective length for weir

Therefore, the increase in length of the weir is one of the methods used to pass a large amount of water without any changing to the water level of the canal. In other words, the use of a linear weir which installed with angle $\alpha < 90^\circ$ respected to channel centerline (oblique weir). The length of the weir (L) is longer then the width of the channel, when the weir is pleased under the angle with direction of main flow. The resulting is decreased discharge per unit weir length and enhanced the efficiency of the weir. The effective length of weir ($L = \frac{W}{\cos \alpha}$) is increasing discharge for the same water head and channel width,[8] as shown in Fig (3). Also, an oblique weir was automatically aerated since, by diverting the flow passing over the weir, air can flow under the lower nappe and, then, no aeration is needed to assure a free flow. [5], [2]

Figure 3 top view of (a) normal weir and (b) oblique weir

3. DISCHARGE COEFFICIENT

The value of the coefficient Cd depends upon a number of factors such as the length of weir, the height (H), degree of sharpness of the edge and the position of the weir wall with respect to the sides and bottom of the channel. The actual value of Cd for a particular notch should be obtained from experiments.

In general the equation form using to calculate the coefficient of discharge is

$$cd = a + b \frac{H}{P} \ldots \ldots 2$$

Where

P=is height of crest weir.

a, b= are experimentally numerical coefficient
The Effect of Characteristics of Flow on Discharge Coefficient for Oblique Weir

[2] used above formula as a basic to calculate coefficient discharge formula for oblique weir. He modified the formula by using the effect \((L/w)\):

\[
    cd = (a + b \frac{L}{w}) + (c + d \frac{L}{w}) \frac{H}{p} \quad \text{………3}
\]

This relationship is basic weir equation and can be modified to account for weir blade shape and approach velocity.

4. EXPERIMENTAL WORK

In present paper, a rectangular flume of 15 m long, 30 cm wide, and 45 cm deep was used to make all the tests at the Hydraulic Laboratory in Kufa University/Engineering Faculty/Structures and Water Resources Department. Twelve models were tested have a compound crested weirs as shown below

![Figure 4 Schematic diagram of the compound crested weirs](image)

The crests of these weir models involve of two parts; the upstream part has a quarter round shape. The downstream part has standard sharp crested weir shape. Series of experiments were conducted by measuring discharges and water heads over the weir models for weir crest radius of \(R = 1.5\) cm and the angles of weir inclination \(\alpha = 10, 15, 25\) and 90° respectively to the direction of flow with a different weir height \((P = 15, 20,\) and \(25\) cm). The slope of flume was equal to zero all experiments. At least 10 discharges for each model were taken in order to draw the rating curve and find the value of discharge coefficient. But not all these discharge used in calculation because these had negative effect as shown in Fig (5)

![Figure 5 show the flow over the oblique weir.](image)

5. THE RESULT AND DISCUSSION

The flow over the oblique weir is a straight line until crest weir where the flow is deflection on the weir. In downstream will occur a circulation zone and hydraulic jump zone, as shown in Fig (5).

The four different weirs were tested with length \((2.367-5.767)\) times the width channel. It is mean the oblique angles \((10, 15, 25)\). The shape of compound crest is constant for all models. The height of water \((h)\) over weir is measured from tests then computed total head over weir \((H)\), ratio \((H/p)\), and the coefficient of discharge \((cd)\). The Fig (6) was drawn \((cd)\) against \((H/p)\) for each angle. The value of \((H/p)\) is between \((0.05-0.4)\) approximately and the \((cd)\) is between \((0.5-1.3)\) approximately. The linear relationship between \((H/p)\) and \((cd)\) can
draw. Moreover, the value of cd is decrease when the Value of (H/P) increases. It is same result in [2] as well as [4], Although they used the different crest. The behaver is different with [5], Although, he used the same crest shape because he used angle > 45° [2].

Some value of cd was ideal because the ratio (H/p) and velocity were small. The contraction effect was neglected means the heads over weir were same along the weir. The higher value of (Cdw) was happened in angle 10 then 15 and 25 because angle 10 had longer path. The higher values of (Cdw) was happened in height p= 20 cm.

**Figure 6** he relation between (Cd) and (H/P)

### 6. THE COEFFICIENT OF DISCHARGE EQUATION

The data in Fig (6) is linear behaver therefore draw a linear. To estimate the coefficient of discharge can use equation (2) for calculated. The fitting line given a good correlation for each model. In first draw the relationship between cd and (L/w) for each height of weir. The parameter a and b was tabled as shown in table (1)

<table>
<thead>
<tr>
<th>L/w</th>
<th>p=15cm</th>
<th>p=20 cm</th>
<th>p=25 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td>5.766667</td>
<td>1.5078</td>
<td>-4.079</td>
<td>1.5828</td>
</tr>
<tr>
<td>3.866667</td>
<td>1.2059</td>
<td>-1.7775</td>
<td>1.5526</td>
</tr>
<tr>
<td>2.366667</td>
<td>1.1448</td>
<td>-1.2869</td>
<td>1.0456</td>
</tr>
</tbody>
</table>

In an attempt to estimate the coefficient of discharge, for oblique weir used the equation (3) to represent all model, but that equation gave low correlation. So, the equation (3) was used to each height of oblique weir as shown below.

For p=15

\[
Cd = (0.0349 \left( \frac{L}{W} \right)^2 - 0.1768 \frac{L}{W} + 1.3677) + (-0.26 \left( \frac{L}{W} \right)^2 + 1.2941 \frac{L}{W} - 2.8928) \frac{H}{P} \text{....4}
\]

For p=20

\[
Cd = (0.0947 \left( \frac{L}{W} \right)^2 + 0.9285 \frac{L}{W} - 0.6213) + (0.2679 \left( \frac{L}{W} \right)^2 - 3.4599 \frac{L}{W} + 5.1593) \frac{H}{P} \text{....5}
\]

For p=25

\[
Cd = (0.0522 \left( \frac{L}{W} \right)^2 - 0.4995 \frac{L}{W} + 2.4396) + (-0.1725 \left( \frac{L}{W} \right)^2 + 0.9639 \frac{L}{W} - 5.1005) \frac{H}{P} \text{....6}
\]

Fig (7) shows an accuracy range using the equations (4-6). Which are acceptable for most data point. The limitation of driven equations are tabled in (2)

One of important result is that, the head over crest is decreased in using oblique weir instead of the normal weir to same discharge. The efficiency of oblique weir for each angle is tabled in (2) to range (L/w) from 2.367 to 5.767 for all models. The Highest efficiency happed in angle 10 than 15 and 25. The relationship is inverse between efficiency and ratio (H/p).
The Effect of Characteristics of Flow on Discharge Coefficient for Oblique Weir

Figure 7 Comparison of formulas with experimental result

Table 2 the limitation of equations and the efficiency

<table>
<thead>
<tr>
<th>θ</th>
<th>Efficiency max</th>
<th>Efficiency min</th>
<th>H/p</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>78%</td>
<td>45%</td>
<td>0.25</td>
</tr>
<tr>
<td>15</td>
<td>66%</td>
<td>34%</td>
<td>0.05</td>
</tr>
<tr>
<td>25</td>
<td>54%</td>
<td>13%</td>
<td>0.04</td>
</tr>
</tbody>
</table>

7. CONCLUSIONS
After the end work for estimate the coefficient of discharge for an oblique compound crested weir, the set of tests done. The following results below

1. The oblique weir is good and easy a device to measure discharge less than normal weir.
2. The standard equation for rectangular weir can used to calculate discharge over oblique weir with effective length and coefficient of discharge equation is applicable too.
3. The oblique weir is more efficient than the normal weir because the head over oblique weirs give lower than the normal weir to same discharge. The less reduced in the head is 13%.
4. Recommended used equations (4-6) for limitation in table (2) to calculate coefficients of discharge.

REFERENCES