Flow over oblique Side Weir

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Abstract

In this paper, an oblique side weir was studied by nine models installed at the entrance of side channel at an angles (30^0,45^0,60^0,75^0 and 90^0) respected to side channel wall and installed at two directions, with flow direction and opposite it. The models were tested by five different flows passing over them so, the number of runs is 45.

The hydraulic characteristics of flow over vertical and oblique side weir were studied, and the results show increasing of discharge over side weir when installed at an oblique direction and the average increases when their inclination at left direction was greater (6%) than that right direction.

Equations were predicted for calculation of discharge coefficient (C_d) and coefficient of energy loss (k) for two directions and the water surface profile for vertical and oblique side weir in two directions is plotted.

Keywords: Oblique side weir- discharge coefficient- energy loss coefficient

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1. Introduction

Most of side weirs serve mainly to measure discharge in side channel, so flow direction discharge control and other means due to the use of various geometric and hydraulic shapes of side weir, and there is much research work has been done from different types of side weir.

[1] Ramamurthy et.al.(1978) studied modification to the geometry of the main open channel is suggested as a means to obtain uniform flow over side weir discharging in to basins. [2] Ramamurthy et.al.(1986) , [3] Uyumaz & Smith (1991) and [4] Yilmaz (2001), analyzed flow over side weir theoretically.

[5] Ramamurthy et.al.(1990) skipping the assumption of critical condition, assumed no energy loss long the depth averaged stagnation dividing stream line surface to obtain an expression for the momentum transfer rate from the main to the side channel. They proposed a model for upstream Fruod number <0.75 which relates discharge of main channel to upstream Fruod number and water depth of main channel. Their predictions agree well with their data.

[6] Borghei et.al.(1999) ,there studied relate the discharge coefficient with the main channel's upstream Froud number and geometric parameters of the channel and the side weir.

[7] Samani A.R.(2010) studied flow over oblique weir through analytical models of flow are based on energy conservation for the upstream and downstream of weir momentum conservation and continuity equations and show that flow discharge over and oblique weir is greater than that over a straight or plain weir for the same water head due to its extra length with respect to the channel width.

The primary objective of this paper is to calculate the hydraulic characteristics for flow over vertical and oblique side weir inclined with and opposite direction as well as predicted an equation to calculate coefficient of discharge and energy loss.

2. Experimental setup

Tests were conducted at hydraulic laboratory of College of Engineering, Mosul University. In a rectangular flume shown in figure (1), it is (10m) long, (30cm) width and (45cm) height .the side channel was (2m) long, (15cm) width and (30cm) height. The discharge in the main channel was measured by sharp crested weir (standard weir) at (35cm) distance from the end of main channel with (10*30*0.1) cm dimensions, the side weirs were made of wood with (12*15*0.1)cm dimensions installed at the entrance of the side channel inclined at an angles (30^0,45^0,60^0 , 75^0 and 90^0) respect to side channel wall in two direction, with flow direction (inclined to the left) and opposite it (inclined to the right) figure (2),with five different discharge range from (7.3-16.5) l/s ,so the number of runs was (45).

The discharge at the main channel was found from eq.(1) using volumetric method,

$$Q=0.58*H^{1.5} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Were, Q: discharge (l/s), H: head over standard weir (cm)

Side channel was closed and measured the total discharge Q_1 then let flow pass at the side channel then measured the discharge of main channel Q_2, the difference between Q_1 & Q_2 gives the discharge of side channel Q_3.

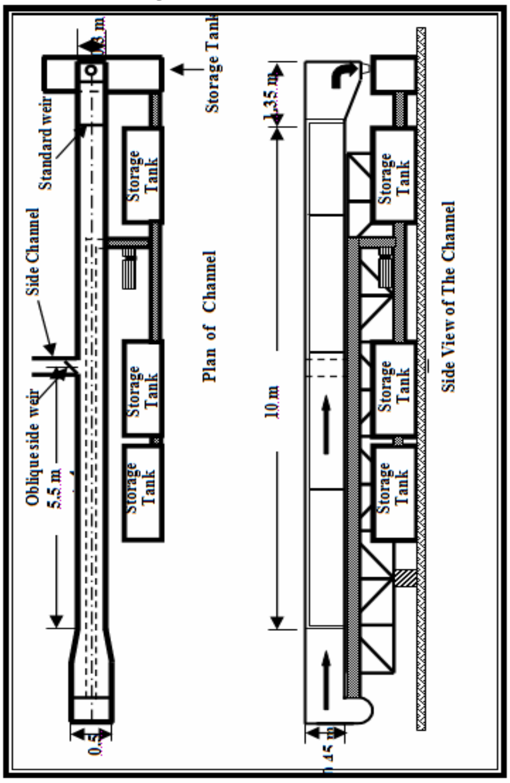


Fig. (1) Channel Cross Section

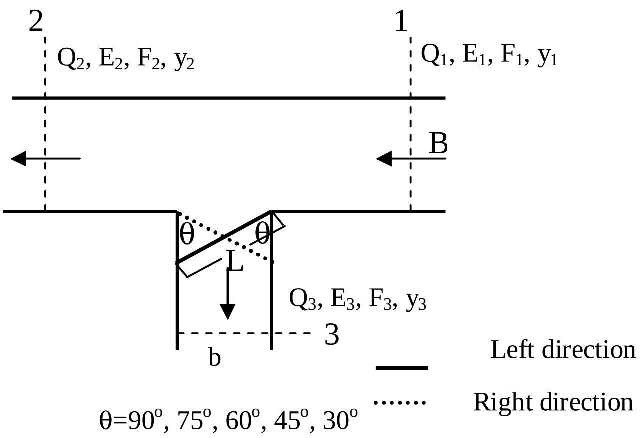


Fig. (2) details of laboratory measurements

	90	
x	y	z
8	3.75	20.5
8	7.5	20.3
8	11.25	20.45
15	3.75	20.4
15	7.5	20.25
15	11.25	20.4
22	3.75	20.3
22	7.5	20.05
22	11.25	20.2
30	3.75	18.8
30	7.5	18.2
β30	11.25	17.7
	30L	
32	3.75	18.8
32	7.5	18.5
32	11.25	17.6
34	3.75	18.4
34	7.5	18
34	11.25	17.8
36	3.75	18.1
36	7.5	17.8
36	11.25	16.8
38	3.75	18.2
38	7.5	17.9
38	11.25	17.2
40	3.75	18.1
40	7.5	17.7
40	11.25	16.3
42	3.75	17.85
42	7.5	17.3
42	11.25	15.4

Table 1: sample of laboratory measurements for water surface profile over side weir installed vertically at (90°) and inclined at (30°Left), all dimension in (cm) .

Where x= longitudinal distance in main channel upstream and downstream side weir in cm, y=distance along the width of the branch channel in cm, and z= water depth above the branch channel in cm

No.	Sample	H_{wm} (cm)	H_{wt} (cm)	y_1 (cm)	y_2 (cm)	h_b (cm)	y_3 (cm)	Q_1 (l/s)	F_1	Q_2 (l/s)	Q_3 (l/s)	b weir cm	k
1	90	5.2	5.4	17.18	17.05	3.6	1.9	7.278	0.1088	6.878	0.401	15	0.056
1	90	6.2	6.5	18.5	18.38	4.8	1.6	9.612	0.1286	8.954	0.658	15	0.067
3	75l	5.3	5.6	17.2	17.1	3.9	0.7	7.686	0.1147	7.077	0.609	15.5	0.075
3	75l	6.3	6.8	18.6	18.55	5	1.1	10.28	0.1364	9.171	1.113	15.5	0.096
4	60l	5.5	5.9	17.3	17.23	4	2	8.312	0.1229	7.481	0.831	17.32	0.087
4	60l	6.5	7.1	18.7	18.6	5.2	1.9	10.97	0.1444	9.612	1.361	17.32	0.107
6	45l	5.6	6.1	17.4	17.35	4.1	2.1	8.738	0.1281	7.686	1.052	21.2	0.097
6	45l	6.6	7.3	18.8	18.73	5.3	1.9	11.44	0.1494	9.834	1.605	21.2	0.114
8	30l	5.7	6.3	17.5	17.46	4.3	2	9.171	0.1333	7.893	1.279	30	0.111
8	30l	6.7	7.5	18.9	18.86	5.5	3	11.91	0.1543	10.06	1.854	30	0.122

Table 2: Sample of laboratory measurements and calculated used in equation estimated.

Where H_{wm}; water depth over the standard weir when branch channel opened, H_{wt}; water depth over the standard weir when branch channel closed, y_1; total water depth, y_2; main channel water depth, h_b; water depth over the side weir, y_3; water depth at side channel, Q_1 total discharge, F_1 Froude number upstream side weir,

Q_2 discharge of main channel, Q_3; discharge of side channel, bweir side weir width, and k coefficient of energy loss calculated from (3).

3. Energy loss coefficient

The discharge passing through the side channel can be calculated by the equation:

$$Q_3=Q_1-Q_2 \quad \text{.....................................(2)}$$

Were; Q_1:total discharge, Q_2:main channel discharge, Q_3:side channel discharge

The conservation of energy implies between upstream and down steam channel given in the equation below [8] Chow, 1959:

$$Q_1E_1(1-k)=Q_2E_2+Q_3E_3 \quad \text{..........................(3)}$$

Were; E_1: total energy, E_2: energy of main channel, E_3: energy of side channel, k: energy loss coefficient

The energy loss coefficient can be written as a function of parameters as following:

$$k=f\,(Q_1, Q_2, E_1, E_2, \rho) \quad \text{..........................(4)}$$

Were; ρ: water density

Using Π-theorem the equation (4) can be written as following:

$$k=f`\left(\frac{E_1}{E_2}, \frac{Q_1}{Q_2}\right) \quad \text{...............................(5)}$$

Equation (5) can be used for coefficient of energy loss calculation and can be written as following:

$$k=C_1+\left(\frac{E_1}{E_2}\right)^{C_1}+\left(\frac{Q_1}{Q_2}\right)^{C_3} \quad \text{.....................(6)}$$

Using statistical programming (SPSS V.17) the parameters C_1 to C_3 for (6) were estimated to adjust model parameters and excitations until the fit between (k) calculated from (3) and (6) are optimized in the weighted least square sense, so k can be calculated for inclined side weir (left & right direction) from the following equations:

- For weir inclined with flow direction (left direction) use the following equating with correlation (R^2 =0.917)

$$k=-1.959+\left(\frac{E_1}{E_2}\right)^{1.282}+\left(\frac{Q_1}{Q_2}\right)^{0.404} \quad \text{................(7)}$$

- For weir inclined opposite flow direction (right direction) use the following equating with correlation (R^2=0.928)

$$k=-1.978+\left(\frac{E_1}{E_2}\right)^{0.938}+\left(\frac{Q_1}{Q_2}\right)^{0.531} \quad \text{................(8)}$$

Figure (3) shows the compared between energy loss coefficients calculated from equations (7 & 8) and measured experimentally. It is clear that the average parentage error not exceed 4%.

The predicted k values for all angles at left direction versus upstream Froude number (F_1) are shown in figure (4) .from this figure (k) values increase with increasing F_1 and large values of k observed when side weir inclined at 30^0 with side channel sides, while the lower values shown when side weir installed at 90^0. k value of weir inclined at (30^0) is greater 44% than that at (90^0). All these vales for all angles inclined at left and right direction are shown in figure (5). From figure the larger values of (k) observed when side weir installed inclined towards left direction for all angles by (12.5%) respected to that inclined towards right direction.

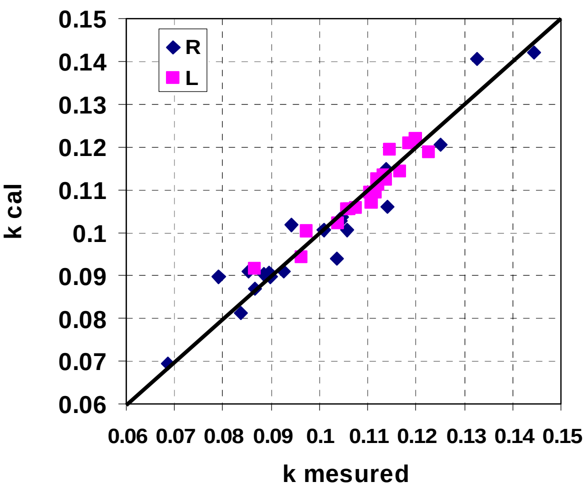


Fig. (3) Comparison between calculated (k) and measured (k)

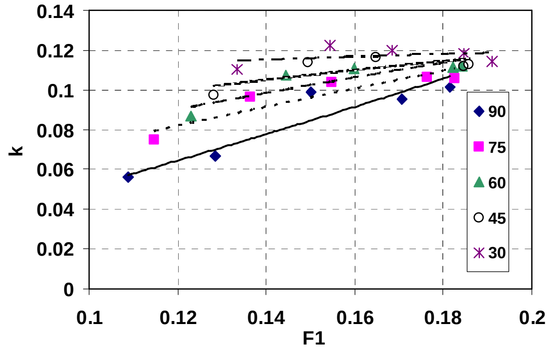


Fig. (4) Relation between (k) and (F_1) for all angles of models

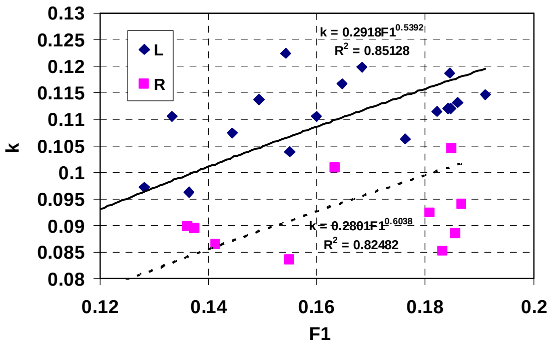


Fig. (5) Relation between (k) and (F_1) for two direction models

4. Water surface profile

The water surface profile were plotted at figures (6 to 8) using measured data collection at grid points from main to side channel for side weir installed at 90^0, 30^0 inclined towards left and right direction respectively for (16.5)l/s discharge. From water surface profile the figures indicate the volume of water passing from side weir at left and right direction are greater than that installed at 90^0 ,this mean increasing of discharge passing through side channel at the same water depth height.

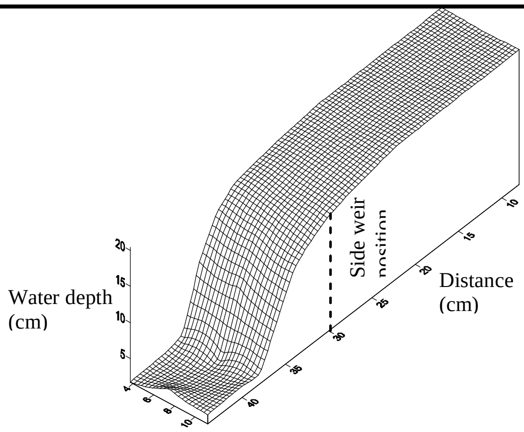


Fig. (6) Water surface profile for model installed 90^0 with channel side walls

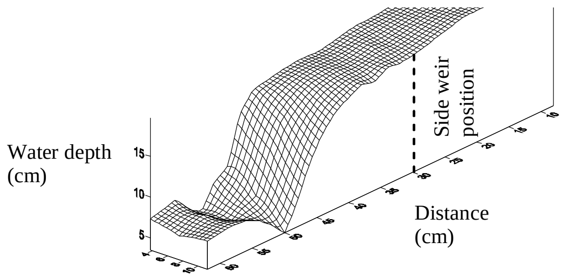


Fig. (7) Water surface profile for model installed 30^0 with channel side walls (left direction)

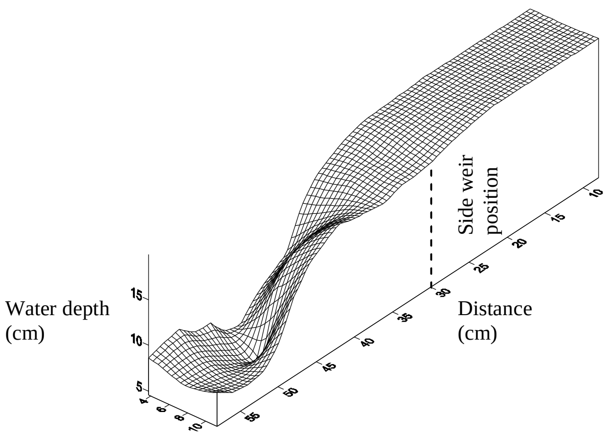


Fig. (8) Water surface profile for model installed 30^0 with channel side walls (right direction)

5. Discharge coefficient

The discharge coefficient of oblique side weir (C_d) is a function of many parameters such as the discharge of side channel (Q_3) , the side channel water depth (y_3),the total water depth (y_1) ,the width of side channel (b),the length of oblique side weir (L), the gravitational acceleration (g), and water density (ρ),so the discharge coefficient can be written as following:

$C_d=f(Q_3, y_3, y_1, b, L, g, \rho)$…………….(9)

The variation of parameters appeared in equation (9) can be measured experimentally; some of the proposed formulas for (C_d) are as following:

$$C_d = 0.7 - 0.48F_1 - 0.3\frac{P}{y_1} + 0.06\frac{L}{B}$$ [6](Borghei et.al.,1999) .(10)

$$C_d = 0.485\left(\frac{2+F_1^2}{2+3F_1^2}\right)^{0.5}$$ [9] (Hagar,1987)….(11)

Were; P: side weir height, B: width of main channel

Most investigators accept the upstream Froud number as the main variable in the formula. [10] Ramamurthy and Carballada (1980) showed the influence of L/B as another non dimensional parameter. [6]Borghei et.al.,(1999) showed the influnce of P/y_1 as well as L/B and F_1 as non dimensional parameters.
Using Π-theorem the equation (9) can be written as following:

$$C_d=f`(F_3, \frac{y_3}{y_1}, \frac{L}{b})$$ ………………………….(12)

Were; F_3: Froud number at side channel

Equation (12) can be used to calculate (C_d) and can be written as following:

$$C_d = C_1 + F_3^{C_2} + (\frac{y_3}{y_1})^{C_3} + (\frac{L}{b})^{C_4}$$ …………..(13)

Using statistical programming (SPSS V.17) the parameters C_1 to C_4 for (13) can be calculated to adjust model parameters and excitations until the fit between (C_d) observations and estimated are optimized in the weighted least square sense, so equation (13) can be written as following:

$$C_d = -2.38 + F_3^{0.057} + (\frac{y_3}{y_1})^{0.128} + (\frac{L}{b})^{-0.248}$$ ……..(14)

Equation (14) can be applied for oblique side weir (left direction) with correlation (R^2=0.88)

$$C_d = -2.08 + F_3^{0.237} + (\frac{y_3}{y_1})^{0.294} + (\frac{L}{b})^{-0.238}$$ …..(15)

Equation (15) can be applied for oblique side weir (right direction) with correlation (R^2=0.84)

To compare the computed c_d from equations (14&15) and the measured one, figure (9) presents that the average percentage error not exceed 10%.

The measured y_2/y_1 (y_2 is main channel water depth) with respect to Q_3/Q_1 for all angles inclined at left direction are shown in figure (10). From figure the values of y_2/y_1 increase with increasing values of Q_3/Q_1 and the large values of the two parameters observed when side weir inclined at 30^0 while the lower values observed when side weir installed at 90^0 (horizontally). These two parameters for all side weir angles located at left and right direction where shown in figure (11). From figure the ratio of y_2/y_1 is greater when side weir installed at left direction greater than that inclined to the right direction.

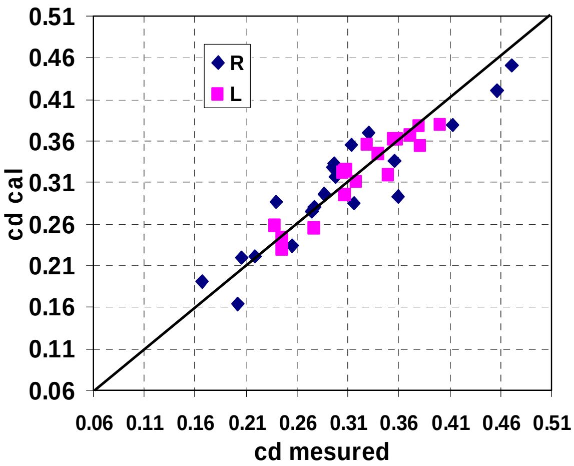
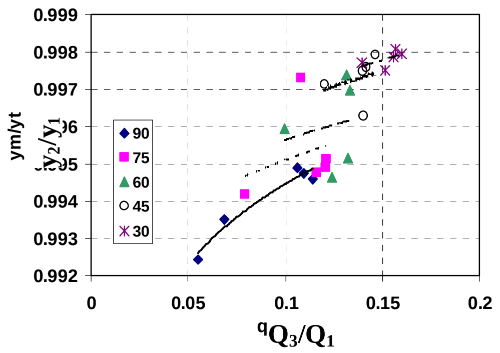


Fig. (9) Comparison between calculated (C_d) and measured (C_d)



q3/q1

Fig. (10) Relation between (y_2/y_1) and (Q_3/Q_1) for all angles of models

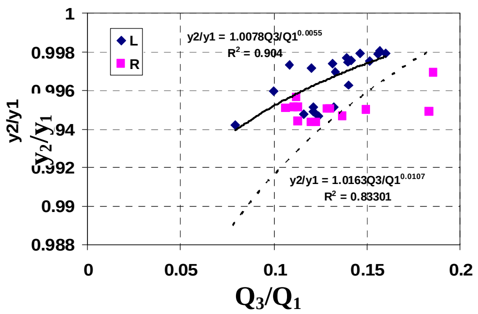


Fig. (11) Relation between (y_2/y_1) and (Q_3/Q_1) for two dimension models

6. Conclusions:

An experimental data were curried out for an oblique side weir with different angles, the results show increasing of discharge greater than 6% with respect to vertical one.

Equations to calculated coefficient of discharge (C_d) and coefficient of energy loss (k) were predicted and compared with other studies.

Notation:

B	width of main channel
b	width of side channel
bweir	side weir width
C_d	discharge coefficient
E_1	total energy
E_2	energy of main channel
E_3	energy of side channel
F_1	Froude number upstream side weir
F_3	Froud number at side channel
g	gravitational acceleration
H	head over standard weir
h_b	water depth over the side weir
H_{wm}	water depth over the standard weir when branch channel opened
H_{wt}	water depth over the standard weir when branch channel closed
k	coefficient of energy loss
L	length of oblique side weir
P	side weir height
Q	flow discharge
Q_1	total discharge
Q_2	discharge of main channel
Q_3	discharge of side channel
x	longitudinal distance
y	distance along the branch channel
y_1	total water depth
y_2	main channel water depth
y_3	side channel water depth
z	water depth above the branch channel
ρ	water density

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