Free Combined Flow Over a Triangular Weir and Under Rectangular Gate[1]

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Abstract

The main objective of this investigation is to find the characteristics of free flow through the combined triangular weir and a rectangular gate. Nine combined weirs were constructed and tested for three different triangular angles $(\theta = 30^\circ, 45^\circ \; and \; 60^\circ)$ over a rectangular gate .The distance between the weir and the gate were change three times for each angle $(y = 5, 10 \text{ and } 15)$ cm.The coefficient of discharge (Cd) were found to be inversely proportional to the weir angle(θ) and with $(\frac{B}{h}, \frac{y}{h}, \frac{D}{h})$ while the theoretical discharge (Q_{theo}) were inversely proportional with $(\frac{B}{h}, \frac{y}{h}, \frac{D}{h})$ and directly proportional to the distance (y) between the weir and gate. A general expression were obtained between froud number ($\frac{Q_{theo}}{\sqrt{g}h^{2.5}}$) and $(\frac{B}{h}, \frac{y}{h}, \frac{D}{h})$.The estimated value of $\frac{Q_{theo}}{\sqrt{g}h^{2.5}}$ from the expression were plotted against the calculated value and it was found to be good.

[1] For the paper in Arabic see pages (37-38).

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Introduction

Gates and weirs have been used extensively for flow control and discharge measurement in open channel flow. Works concerning the use of sluice gates as a discharge measurement structure may be found , e.g. by Rajaratnam and Subramanya (1967) , Rajaratnam (1977), French(1986) ,Swamee (1992) .developed a generalized discharge equation for sluice gates based on Henrys curves, Abdel-Azim et al.(2002). Regarding the flow over weirs, many works have been reported in the literature such as by Herschy (1978) ,Swamee(1988),Bos (1989), and Munson et al.(1994). Weirs and gates may be combined together in one device yielding a simultaneous flow over the weir and below the gate. The flow through combined devices may be free when both the flow over weir and below the gate are free it is termed submerged when the flow below the gate is submerged (and the flow over the weir may or may not be submerged). Problems concerning sedimentation and depositions are minimized by combined weirs and gates as outlined by Alhamid,Negm and Al-Brahim (1997), Fadil (1997) developed a meter for the combined flow through contracted sluice gate and weir, also combined-submerged flow through weirs and below gates were analyzed and discussed by Negm et al.(1999),Negm(2000).The characteristics of the combined flow over weirs and below gates of equal contraction are discussed by Abdel-Azim et al.(2002), different geometrical combination are used, the discharge characteristics of a combined weirs and gate structure are discussed, they found that the flow parameter ($\frac{H}{D}$) (the ratio between the upstream water depth and the height of the gate opening) and the geometrical parameter ($\frac{y}{D}$) (the ratio of the vertical distance between the lower edge of the weir and the upper edge of the gate opening and the height of the gate opening) have major effects on the discharge.

In the present work the characteristics of the combined flow over a triangular weir with different angles and below a rectangular gate are studied.

Theoretical Background:
To compute the discharge through a combined weir (V-notch with sharp crested rectangular gate) the following equation may be obtained by adding the discharge over the weir and gate as:

$$Q_{theo} = Q_g + Q_w \quad ... (1)$$

$$Q_g = \sqrt{2g} H^{0.5} BD \quad … (2)$$

$$Q_w = \frac{8}{15}\sqrt{2g} \tan\frac{\theta}{2} h^{2.5} \quad … (3)$$

$$Q_{act} = Cd\sqrt{2g}\left[H^{0.5} BD + \frac{8}{15}\tan\frac{\theta}{2} h^{2.5}\right] ... (4)$$

Where:
H: total $H = h + y + D$. (L)
head; h: head of water through weir. (L)
y: vertical distance between the lower edge of the weir and the upper edge of the gate opening (L)
D: the gate height. (L)
B: the gate width. (L)
g: acceleration due to gravity . (LT^{-2})
θ:V-notch angle. (Degree)
Cd: coefficient of discharge.
Q_g: Discharge through the gate. (L^3T^{-1})
Q_w: Discharge through the triangular weir. (L^3T^{-1})
Q_{theo}: Total theoretical discharge. (L^3T^{-1})
Q_{act}: Total actual discharge. (L^3T^{-1})
Based on equation (4) and using dimensional analysis, the following functional obtains:

$$Q_{theo} = F(h, y, B, D, \rho, \mu, g.\sigma, \theta) \quad … (5)$$

$$\frac{Q_{theo}}{\sqrt{g}h^{2.5}} = F(\frac{y}{h}, \frac{B}{h}, \frac{D}{h}, \theta, \frac{\mu L}{Q\rho}, \frac{\sigma h^3}{Q^2\rho}) \quad …(6)$$

($\frac{\mu L}{Q\rho}$) is a form of Reynolds number (Re) And ($\frac{\sigma h^3}{Q^3\rho}$) is a form of In(Weber number (We) .

and because ($\frac{Q_{theo}}{\sqrt{g}h^{2.5}}$) is a type of Froud number

$$Fr = F(\frac{y}{h}, \frac{B}{h}, \frac{D}{h}, \theta, \text{Re}, We) \qquad \ldots(7)$$

Where

Fr: Froud number.

At high discharges the effect of surface tension and viscosity will be neglected so Weber number and Reynolds number had been neglected. Fig (1) shows a definition sketch for the combined weir .

Experimental Set Up:

The experiments were carried out in a (10) m long horizontal tilting channel (Slope equal zero) of cross section (0.3) m width and (0.45) m height. The channel consisted of toughened glass walls and a stainless steel floor. Two movable carriages with point gauges were mounted on brass rails at the top of channel sides see Fig.(2).Nine combined weir model were manufactured from a 2mm thick aluminum plates. In these models, a V-notch with three different angles ($\theta = 30^\circ, 45^\circ$ *and* 60°) over a gate opening at different distance ($y = 5, 10$ and 15) cm between the gate and the weir, details of the models are shown in table (1) and Fig. (1). For discharge measurements, a full width thin-plate sharp-crested rectangular weir (15) cm height fixed at the tail end of the channel section manufactured according to British standard (1965). The water surface profile were recorded for each test, the head upstream of the standard weir and the combined weir were measured with a precision point gauges whose least count was (0.1) mm .

Result and Discussion:

1- Variation of (Cd):

The coefficient of discharge (Cd) for combined flow condition are calculated and discussed for a case when the angle (θ) of the weir increase (Cd) decrease i.e. For ($\theta = 30^\circ, 45^\circ$ *and* 60°) the average value of ($Cd = 0.694, 0.691$ and 0.665) ,respectively and as the value of ($\frac{D}{h}$) increase (Cd) decrease and the trend of variation of ($\frac{B}{h}$), ($\frac{\mathrm{y}}{\mathrm{h}}$) with (Cd) equal to that of ($\frac{D}{h}$) with (Cd) an average value of (Cd =0.683).i.e. the combined weir with triangular opening over a rectangular gate seems to give higher values of (Cd) than the a rectangular weir over a rectangular opening (Abdel-Azim, 2003).

2- Variation of (Q_{theo}):

Variation of(Q_{theo}) with ($\frac{B}{h}$), ($\frac{\mathrm{y}}{\mathrm{h}}$) and ($\frac{D}{h}$) for all model tested is presented in Figs.(3-a) ,(3-b),(3-c), Figs.(4-a),(4-b), (4-c) and Figs.(5-a),(5-b),(5-c), respectively. Figs.(3-a) ,(3-b),(3-c), indicate that (Q_{theo}) increases as ($\frac{B}{h}$) decreases and when the distance between the gate opening and the triangular weir (y) increases,(Q_{theo}) increases for the same value of of.($\frac{B}{h}$). Similar variation between (Q_{theo}) with ($\frac{\mathrm{y}}{\mathrm{h}}$), ($\frac{D}{h}$) ,is also shown in Figs: (4-a),(4-b), (4-c), and Figs.(5-a),(5-b),(5-c), the Figs. indicate that (Q_{theo}) increases as (y) increases for a certain value of ($\frac{\mathrm{y}}{\mathrm{h}}$), ($\frac{D}{h}$) and as ($\frac{\mathrm{y}}{\mathrm{h}}$), ($\frac{D}{h}$) decrease ($Q_{theo}$) increase.

3- Predication of Combined Discharge:

A multiple linear regression analysis is used to correlate the values of ($\frac{Q_{theo}}{\sqrt{g}h^{2.5}}$) to both hydraulic and geometrical parameters ($\frac{B}{h}, \frac{\mathrm{y}}{\mathrm{h}}, \frac{\mathrm{D}}{\mathrm{h}}$).

The following equation fits the data with coefficient of determination R^2=0.9994 and standard error of estimate, (SE=0.126).

$$\frac{Q_{theol}}{g^{0.5}h^{2.5}} = 0.0197(\frac{y}{h})^{0.2195}(\frac{B}{h})^{1.647}(\frac{D}{h})^{0.543}$$
... (8)

Fig.(6) shows the relation between the predicated value of equation (8) and the measured value. The Fig. indicates an obvious a good agreement between the measured and predicated values ($\frac{Q_{theo}}{\sqrt{g}h^{2.5}}$) .

4-Water surface profile:

The water surface profile for all weir models were recorded and developed at longitudinal section along the center line of the combined weir (at 15 cm from the channel edge) sample of the dimensionless center-line profiles are shown in Fig.(7) for weir model No.(3) $(\theta = 30^\circ, y = 15cm)$. From all water-surface profiles recorded,(h) was observed that the approximate location where the profiles of triangular weir and gate are met at a point $(x = 6 \rightarrow 21)$ cm down stream the weir.

Conclusion:

The discharge characteristics of a combined weir and gate structure are discussed and the following conclusion are drawn:

1- Cd decreases as (θ) increase.
2- Cd decreases as $(\frac{B}{h})$, $(\frac{y}{h})$ and $(\frac{D}{h})$ increases.
3- Q_{theo} increases as $(\frac{B}{h}, \frac{y}{h}, \frac{D}{h})$ decreases.
4- Q_{theo} increases as (y) increases.
5- The developed equation agrees well with the measured values of($\frac{Q_{theo}}{\sqrt{g}h^{2.5}}$) for the combined weir.
6- A model was predicted from the measured parameter show in equation (8).

List of Notations:

B: the gate width.	(L)
D: the gate height.	(L)
Cd: coefficient of discharge.	-
H: total head	(L)
h: head of water through weir.	(L)
g: acceleration due to gravity .	(LT^{-2})
Fr: Froud number.	–
Q_{act}: Total actual discharge.	(L^3T^{-1})
Q_g: Discharge through the gate.	(L^3T^{-1})
Q_{total}: Total theoretical discharge.	(L^3T^{-1})
Q_w: Discharge through the triangular weir.	(L^3T^{-1})
Re: Reynolds number.	–
We: Weber number.	-
W: channel width.	(L)
y: vertical distance between the lower edge of the weir and the upper edge of the gate opening	(L)
θ :V-notch angle.	(Degree)

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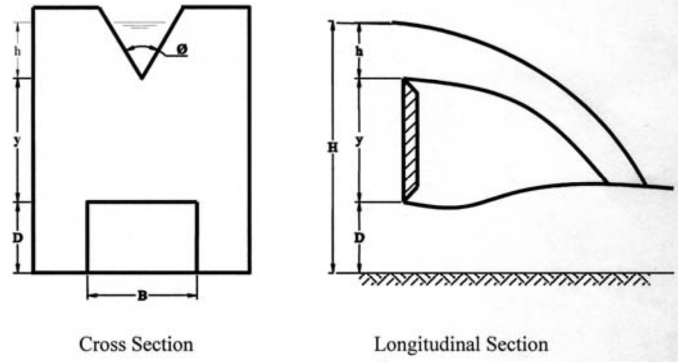
Table1: Details of weir models investigated

Model NO.	Run No.	Weir Angle (θ)	Distance (y)cm
1	1-6	30	5
2	7-13	30	10
3	14-19	30	15
4	20-24	45	5
5	25-29	45	10
6	30-34	45	15
7	35-39	60	5
8	40-44	60	10
9	45-50	60	15



Fig(1): Definition Sketch FOR Combined Flow Over and Below Gates

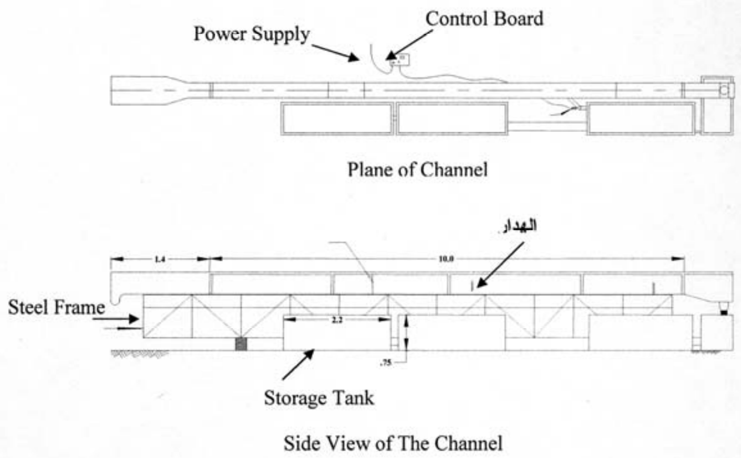
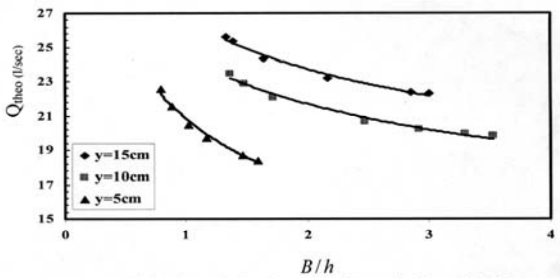
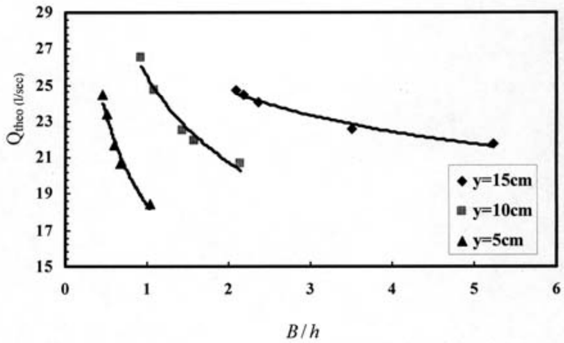


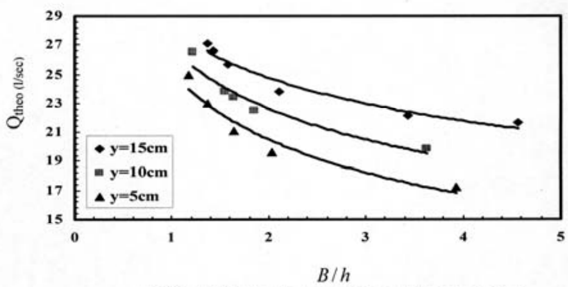
Fig.(2) : Channel Cross Section



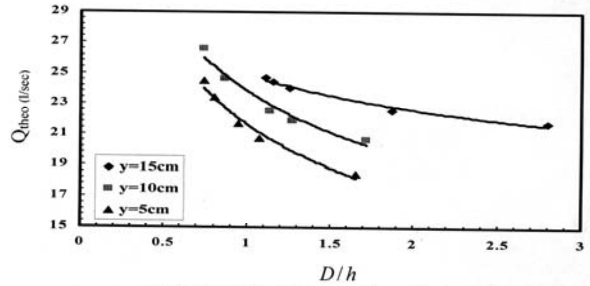
Fig(3-a) Relation between theoretical combined discharge (Q_{theo}) and (B/h) for $\theta = 30^{\circ}$



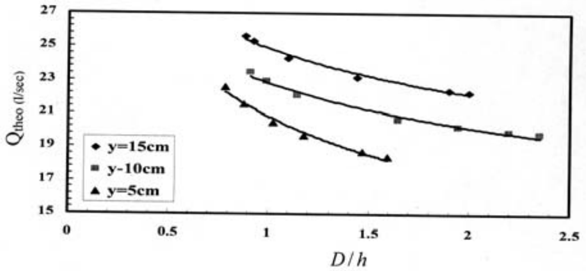
Fig(3-b) Relation between theoretical combined discharge (Q_{theo}) and (B/h) for $\theta = 45^{\circ}$



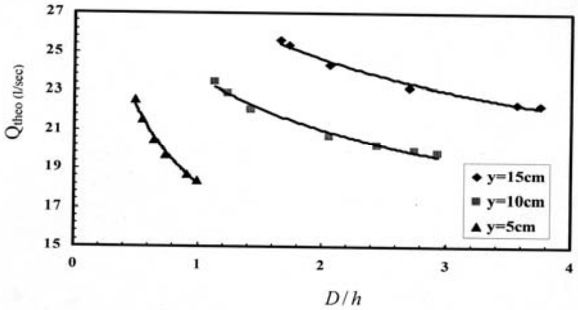
Fig(3-c) Relation between theoretical combined discharge (Q_{theo}) and (B/h) for $\theta = 60^{\circ}$



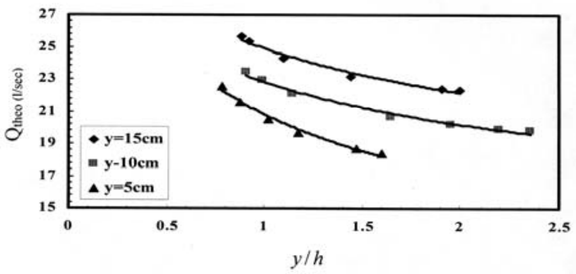
Fig(5-a) Relation between theoretical combined discharge (Q_{theo}) and (D/h) for $\theta = 30^{\circ}$



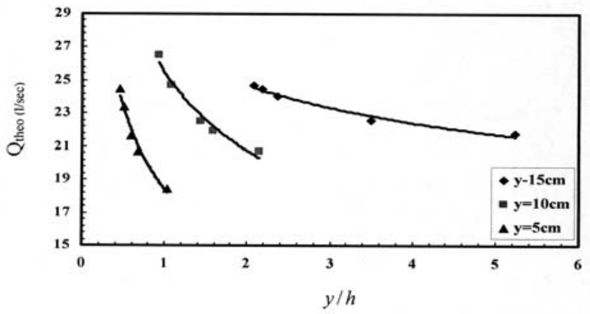
Fig(5-b) Relation between theoretical combined discharge (Q_{theo}) and (D/h) for $\theta = 45^{\circ}$



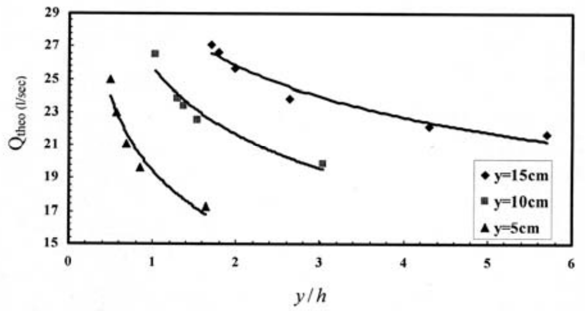
Fig(5-c) Relation between theoretical combined discharge (Q_{theo}) and (D/h) for $\theta = 60^{\circ}$



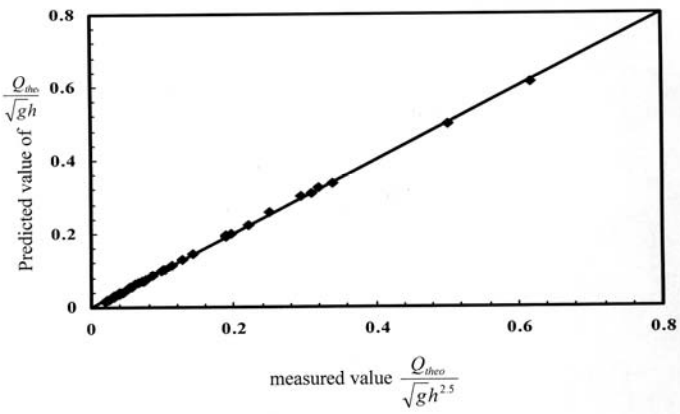
Fig(4-a) Relation between theoretical combined discharge (Q_{theo}) and (y/h) for $\theta = 30^\circ$



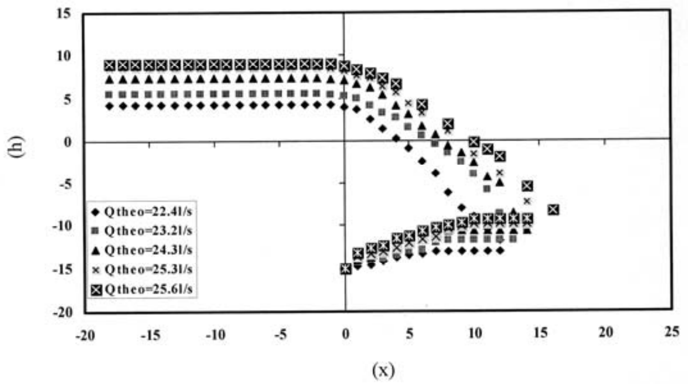
Fig(4-b) Relation between theoretical combined discharge (Q_{theo}) and (y/h) for $\theta = 45^\circ$



Fig(4-c) Relation between theoretical combined discharge (Q_{theo}) and (y/h) for $\theta = 60^\circ$



Fig(6) Relation between predicted and measured value of $\frac{Q_{theo}}{\sqrt{g}h^{2.5}}$



Fig(7) Variation of(h) with (x) along the center line for weir model between predicted and measured value of

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