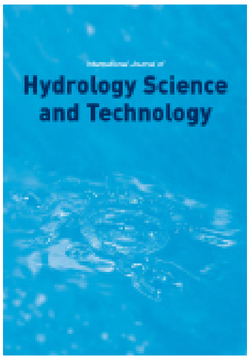


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# Hydraulic characteristics of combined weir-gate structure

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# Hydraulic characteristics of combined weir-gate structure

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**Abstract:** Hydraulic structures are used for multiple purposes, such as measuring discharge, controlling flow, reducing flood risks. Weir structures are designed for flow passing over them, while sluice gates are designed for flow passing beneath them. This study used combined weir-gate structures (a folded structure made up of two planar walls inclined at various angles to the channel making a triangular arrangement in plan) with four interior angles (60, 90, 120, and 180)° and two triangular openings at the top and bottom of the combined structure. There are four types of flow according to combined structure operation. The results show that the discharge coefficient values increased when the interior angle increased at the same upstream head values, the average percentage increasing values are 27%, 48%, and 54% respectively concerning lower interior angles, because of decreasing crest length. Four empirical equations for $C_d$ were predicted for every case of flow and compared with their experimental values with percentage error not exceeding 20% and coefficient of determination $R^2$ reached 0.99.

**Keywords:** weir; sluice gate; combined structure; weir-gate structure; discharge coefficient; empirical equation; open channel hydraulics.

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## 1 Introduction

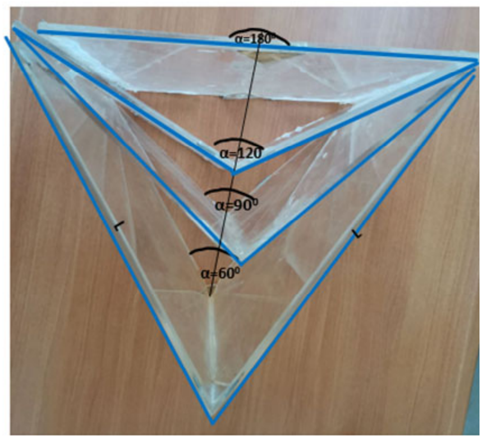
Compound hydraulic structures, i.e., consisting of a weir and a gate, are considered modern and important facilities at present due to their ease of use and low cost. Weir is usually used to measure discharge, gates are used as a means of controlling flow, but they cause the return and retention of suspended materials. To solve such problems, weirs were combined with gates, and this is known as combined hydraulic structures. The gates work to get rid of the problem of sediment accumulation under the weir, and the weirs also work to push out suspended materials. Weirs and gates take different forms. Al-Suhaili et al. (2014a) studied the hydraulic properties of a composite physical model consisting of a weir and a lower gate containing three openings. The study showed that the largest value for the discharge coefficient was in the third case (discharge is over the crest and from opening), while the lowest value occurred in the first case (discharge is from opening only). Also, they used the program of artificial neural network (ANN) software to simulate the discharge coefficient. Al-Suhaili et al. (2014b) studied the effect size of the rectangular opening and the level of water passing through the compound weir, the experimental showed a greater value of the discharge coefficient may be obtained where the flow passing from the bottom rectangular gate and over the weir. Hussein and Jalil (2020) used the numerical simulation computational fluid dynamics software ANSYS CFX to study the effect of a compound trapezoidal weir containing three lower openings, the first in the form of a rectangular gate, and the second and third in the form of a trapezoidal gate, with different inclinations slope. The results showed the value of discharge coefficient $C_d$ that the weir containing the lower openings in the shape of a trapezoid with a slope of 1:2 and 1:4 gives a greater value than a rectangular opening. Jalil et al. (2018) studied the flow characteristics through 60 semi-cylindrical models containing a lower gate with four different diameters and each operating diameter with four different heights. A model of a thin rectangular slice placed perpendicular to the flow was also used for comparison. The results proved that the semi-circular shape gives a better discharge coefficient than the rectangular shape. Also, the weir begins to operate at a low flow discharge, and increasing the gate opening from 2 to 5 cm causes an increase in the discharge by 80% and causes a decrease in the discharge by 3% with an increase in height by 50%. In addition, the effect of the cylinder diameter decreases with increasing height for all openings when the ratio between height to gate opening is >2. The hydraulic effect of the composite shape consists of a weir and a gate studied by Qasim et al. (2019), this study expresses that the velocity and depth of flow are one of the most dimensional variables that affect the flow over the compound weir. Qasim et al. (2020) conclude the head over the compound weir is the major factor that affects the discharge coefficient. Khassaf et al. (2013) studied the behaviour of discharge coefficient in compound rectangular weir and triangular gate containing trapezoid shape, also a lower gate in semi-circular shape. The study showed the parameters head of water over notches of the compound weir to the diameter of the gate leads to increases in discharge coefficient, also discharge coefficient decreases with increases in width gate and distance between the weir and gate. Jalil and Ibrahim (2015) studied the surface roughness. They conclude that the discharge coefficient increases with decreased surface roughness. Jalil and Sarhan (2013) concluded that the coefficient of discharge increases with an increasing ratio between the length of the weir to the distance between the weir and gate, the head of water over the weir to the distance between the weir, and the gate angle inclination of a compound weir. Tanimu et al. (2021) conclude that some of the parameters that affect the discharge coefficient through a compound weir consisting of a trapezoidal weir and a semi-circular gate are the diameter of the semi-circular gate, weir crest length, and total head. Arvanaghi and Mahtabi (2014) studied the effect of a compound weir on the discharge coefficient by using FLUENT software, and they got a good result. Pesarakloo and Emadi (2018) showed an experimental study that used a compound weir consisting of a circle, trapezoid, and rectangle and a gate that has three heights 1.5, 3, and 4.5 cm. They found that the discharge coefficient decreases with increasing gate height. Diwedar et al. (2022) showed a discharge coefficient increases with increasing angle using a compound weir containing a triangular weir and triangular inverse gate. Obead and Hamad (2014) reached that a compound weir consisting of a circular weir and a gate of a rectangular shape gets good results in increasing the discharge coefficient. The effect of hydraulic characteristics on the discharge coefficient using a composite weir consisting of a triangular, semicircular, and rectangular weir and a lower gate in the same shape as the weir studied (Al-Saadi, 2013). The results showed that the compound semicircular weir with a semicircular bottom gate gives the largest discharge coefficient, the value of $C_d$ for the semicircular weir is compared to the other shapes. (Alsaydalani, 2024a) investigated a combined weir, with two rectangles and an inverted semicircular gate focusing on hydraulic jump characteristics. The results show that the head loss ratio through hydraulic jumps is a significant factor in hydraulic structures and the energy loss ratio decreases as the Froude number increases. The hydraulic characteristics of combined weir-gate structures were studied by Alsaydalani (2024b). The experiments investigate various dimensions of the weir and gate, as well as using a weir without a gate. The results data were used to develop more equations for discharge coefficient calculating. Jomaa and Mohammed (2022) study compared cylindrical and traditional stepped weirs finding that cylindrical weirs dissipate flow energy 10% more efficiently with optimal performance achieved in fully cut step designs. Energy dissipation improved with increasing weir height, step diameter and step number. Mala Obaida et al. (2022) given a review highlights screen walls as effective tools for reducing flow energy and structural scour emphasising the impact of geometric configurations and the role of AI simulations in optimising hydraulic performance. Gupta and Dwivedi (2023) examined the combined influence of channel slope and surface roughness on hydraulic jumps showing enhanced energy dissipation and developing correlations for optimising hydraulic structure designs. Alkattan et al. (2024) assessed compound gates' performance finding that higher elevations and smaller openings enhance flow energy dissipation making these gates efficient for low-elevation hydraulic structures. Gupta and Dwivedi (2023) studying hydraulic jumps on sloping rough beds this research demonstrated improvements in energy efficiency and jump height offering insights for optimising hydraulic systems. This study aims to investigate the effect of a combined triangular weir-gate hydraulic structure with upper and lower triangular openings, as well as the impact of flow operation passing through this structure on the discharge coefficient.

## 2 Materials and methods

### 2.1 Experimental setup

The experiments took place at the hydraulic laboratory of Mosul University in a 10 m long laboratory channel with a (B = 30 cm) width and 45 cm depth, with glass sides. The actual discharge was measured volumetrically using a standard weir fixed at the end of the channel.

**Figure 1** Models of combined weir with different values of $\alpha$ and crest length L, (a) opened all (b) opened down (c) opened up (d) closed all (e) front view of the combined weir (see online version for colours)




The combined weir-gate structure (a folded structure made up of two planar walls inclined at various angles to the channel, forming a triangular arrangement in plan) was made from plastic (P = 30 cm) in height and (1 cm) in thickness while the crest length was between (L = 30 to 60) cm according to the interior angles ($\alpha$) of the models, fixed at a distance (4.5) m from the channel upstream.

There are four models used with different interior angles ($\alpha$ = 180°, 120°, 90° and 60°) so the crest length differs according to these angles (L = 30, 34.6, 42.4 and 60 cm), Figure 1, each model has two similar triangular openings (d=5 cm height and width) in the middle up and down of the model, and (Θ) is the angle of the vertex of the triangle opening which is (90°, 70.53°, 60° and 53.13°) for ($\alpha$ = 60°, 90°, 120° and 180°) respectively. There are four different cases of flow for discharge passing through each model according to open or closed of these openings:

1 closed all (when all openings closed and flow passes through the upper crest of the weir)

2 opened down (when the bottom triangular opened and the flow passing through the bottom opening only or both bottom and upper crest of the weir)

3 opened up (when the upper triangular opened and the flow passing through the upper opening only or both upper triangular and crest of the weir)

4 opened all (when the bottom and upper triangular opened and the flow passing through the bottom opening only or both bottom and upper triangular only or both bottom and upper triangular as well as crest of the weir) (Figure 2).

Figure 3 shows the flow for different values of total head upstream weir crest. The discharge uses in the experiments ranged between (3 to 15.66) L/s. There are six values of discharge and four interior angles with four cases of openings, so there are 96 runs (Table 1).

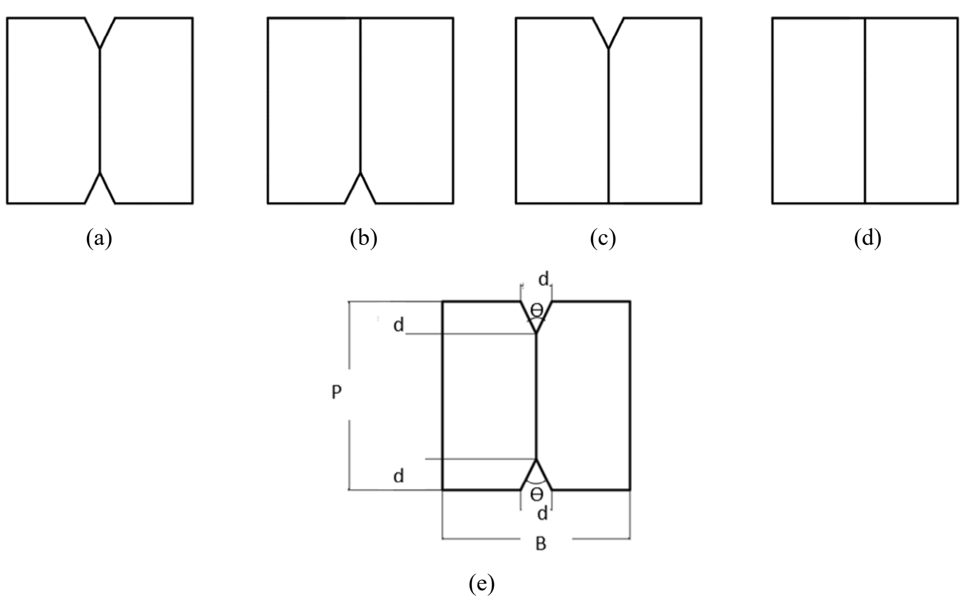
**Table 1** Experimental model cases

| | | | | | |
|---|---|---|---|---|---|
| $\alpha = 60°$, L = 60 cm | closed all | $Q$ = 3 L/s | $\alpha = 90°$, L = 42.4cm | closed all | $Q$ = 3 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | closed all | $Q$ = 4 L/s | | closed all | $Q$ = 4 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | closed all | $Q$ = 5 L/s | | closed all | $Q$ = 5 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | case: closed all | $Q$ = 6.5 L/s | | closed all | $Q$ = 6.5 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | closed all | $Q$ = 10 L/s | | closed all | $Q$ = 10 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | closed all | $Q$ = 15.66 L/s | | closed all | $Q$ = 15.66 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |

**Table 1** Experimental model cases (cotinued)

| | | | | | |
|---|---|---|---|---|---|
| $\alpha$ = 120°, L = 34.6 cm | closed all | $Q$ = 3 L/s | $\alpha$ = 180°, L = 30 cm | closed all | $Q$ = 3 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | closed all | $Q$ = 4 L/s | | closed all | $Q$ = 4 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | closed all | $Q$ = 5 L/s | | closed all | $Q$ = 5 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | closed all | $Q$ = 6.5 L/s | | closed all | $Q$ = 6.5 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | closed all | $Q$ = 10 L/s | | closed all | $Q$ = 10 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |
| | closed all | $Q$ = 15.66 L/s | | closed all | $Q$ = 15.66 L/s |
| | opened down | | | opened down | |
| | opened up | | | opened up | |
| | opened all | | | opened all | |

**Figure 2** Cases of openings with dimensions



The point gage with 0.1 mm accuracy was used to measure the water head upstream weir crest (h) at (3–4) of water head and water surface profile (Figure 4).

**Figure 3** Four cases flow for the combined weir (see online version for colours)

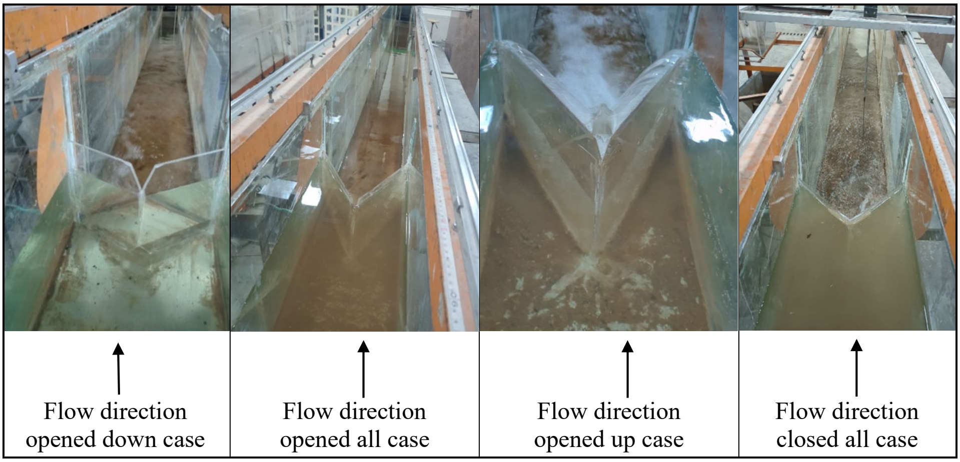
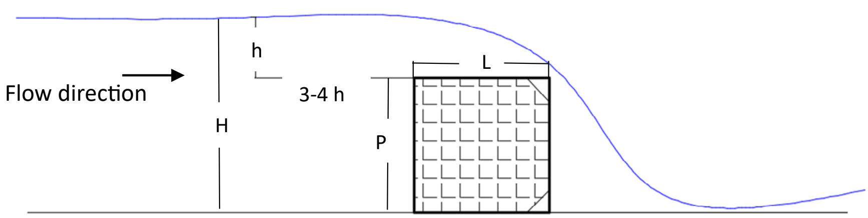



**Figure 4** Model side view and experimental measurements (see online version for colours)




## 2.2 *Theoretical methodology*

The flow passing through and beneath the combined weir-gate hydraulic structure can be represented according to the following equation depending on if the flow passing over or beneath the combined structure as well as if the upper or lower opening closed or opened:

$$Q = Q_w + Q_g + Q_c \tag{1}$$

$Q$ is the total discharge passing from the combined structure, $Q_w$ is the triangular weir discharge, $Q_g$ is the gate discharge and $Q_c$ is the rectangular weir discharge. Streeter and Wylie (1981) represented the equations for each case:

$$Q_w = \frac{8}{15}\sqrt{2g}\tan\frac{\theta}{2}h^{\frac{5}{2}} \tag{2}$$

$$Q_g = \sqrt{2gh}A \tag{3}$$

$$A = \frac{d^2}{2} \tag{4}$$

$$Q_c = \frac{2}{3}\sqrt{2g}Lh^{\frac{3}{2}} \quad (5)$$

$$C_d = Q_{actual} / Q_{theoretical} \quad (6)$$

where

- $g$: acceleration due to gravity (m/s$^2$)
- $\theta$: angle of the triangle opening
- $h$: water head over the combined weir crest (m)
- $A$: cross-section area of the triangle opening (m$^2$)
- $d$: width and height of triangle opening (m)
- $L$: crest length (m)
- $C_d$: discharge coefficient.

According to the above equations, there are four flow cases:

1 In case of closed all (all structure opening closed) then the flow passes only over the weir this means the total discharge equal to the discharge over the rectangular weir, $Q = Q_c$.

2 In the case of opened down (only the lower opening opened) then there are two flow cases.
   - When the water depth is low and the flow passes only from the lower opening, this means $Q = Q_g$ when $H <= P$.
   - When water depth increases and flow passes from both the lower opening and over the weir crest, this means $Q = Q_g + Q_c$ when $H > P$.

3 In the case of opened up (only the upper opening opened) then there are two flow cases.
   - When the water depth is low and the flow passes only from the upper opening, this means $Q = Q_w$ when $H <= P$.
   - When the water depth is increased and flow passes from both the upper opening and over the weir crest, this means $Q = Q_w + Q_c$ when $H > P$.

4 In the case of opening all (both upper and lower openings are opened) then there are three flow cases.

5 When water depth is low and the flow passes only from the lower opening, this means $Q = Q_g$ when $H <= P$.

6 When the water depth increased and the flow passed from lower and upper openings this mean $Q = Q_w + Q_g$ when $H <= P$.

7 When the water depth increased and the flow passed from lower and upper openings as well as over the weir crest this mean $Q = Q_w + Q_g + Q_c$ when $H > P$ (Gupta, 2024a, 2024b; Nouri, 2020).

### *2.3 Dimensional analysis*

The hydraulics of flow over and beneath the combined weir-gate structure could be considered in different variables based on the researched aim, so, the discharge coefficient for the combined weir–gate structure can be written as:

$$C_d = f(H, d, B, V, g, \rho, \mu, \sigma, \alpha) \tag{7}$$

In which *H* is the total head upstream, *d* is the width and height of the triangle opening, *B* is the channel width, *V* is the average velocity upstream weir crest, *g* is the acceleration due to gravity, $\rho$ is the water density, $\mu$ is the water dynamic viscosity, $\sigma$ is the surface tension, and $\alpha$ is the angle of the triangle model, which is important in calculating the crest length of the combined structure, so, it was taken into consideration instead of crest length L. The effect of model height was not considered because all experiments took only 30 cm.

By using Buckingham`s theory in dimensional analysis, equation (7) can be rewritten as:

$$C_d = f\left(\frac{\rho VH}{\mu}, \frac{V}{\sqrt{gH}}, \frac{V}{\sqrt{\frac{\sigma}{\rho H}}}, \frac{H}{B}, \frac{H}{d}, \alpha\right) \tag{8}$$

which $\frac{\rho VH}{\mu}$ is the Reynolds number Re, $\frac{V}{\sqrt{gH}}$ is the Froud number Fr, and $\frac{V}{\sqrt{\frac{\sigma}{\rho H}}}$ Is the Weber number We. Re can be neglected because all experiments are turbulent flow, Re > 4,000, so, equation (8) can be rewritten as follows:

$$C_d = f\left(\text{Fr, We, H/B, H/d}, \alpha\right) \tag{9}$$

## 3 Results and discussion

Figure 5 shows the relationship between the discharge coefficient of ($C_d$) and Weber number (We), it is noted that increasing $C_d$ when We increased and the maximum value of $C_d$ appeared in open up case then at open all cases than at open down the case and the lowest $C_d$ value happened at closed all case with increasing percentage (85%, 57%, and 29%) respectively.

Figures 6 and 7 represent the relationships between the coefficient of discharge ($C_d$) and (H/B) and (H/d) respectively. It can be shown increasing $C_d$ when H/B and H/d increase. The maximum $C_d$ values appeared at open up case then open all case then open down case and the lowest values of $C_d$ happened at closed all case.

Figures 8 and 9 represent the relationship between the coefficient of discharge ($C_d$) and Froud number (Fr). Figure 8 represents the effect of four case openings for interior angle $\alpha$= 120°, while Figure 9 represents the effect of internal angles ($\alpha$= 60°, 90°, 120° and 180°) for discharge 6.5 L/s. In all these figures it was shown increasing $C_d$ values when Fr increased.

**Figure 5** The relation between $C_d$ and We for $\alpha = 120°$ for four case openings (see online version for colours)

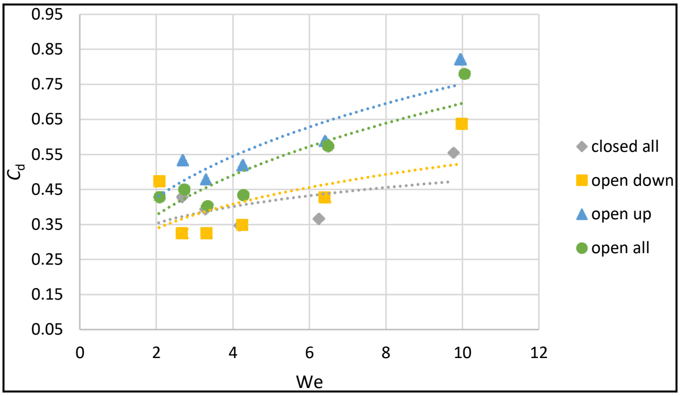



**Figure 6** The relation between $C_d$ and H/B for $\alpha = 120°$ for four case openings (see online version for colours)

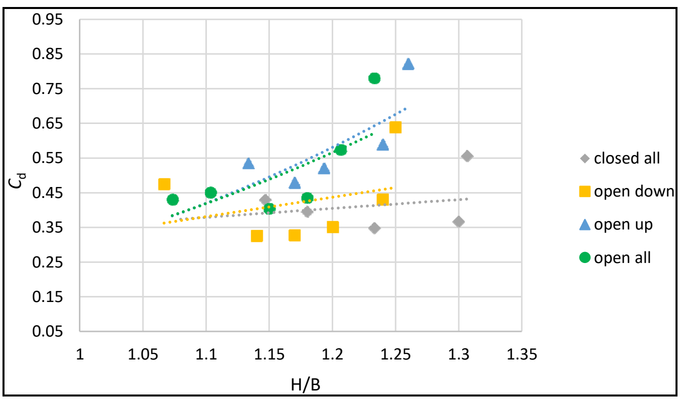
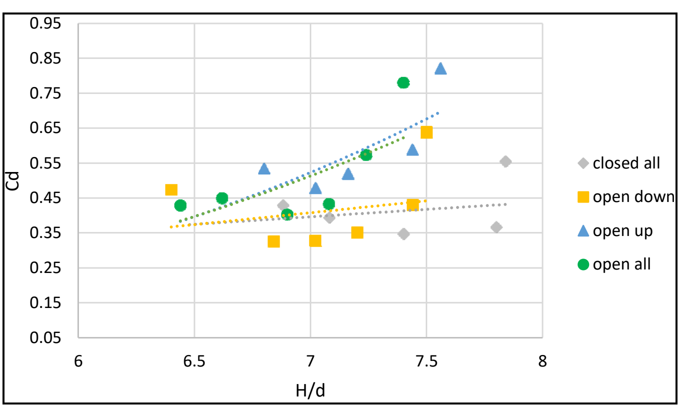



**Figure 7** The relation between $C_d$ and H/d for $\alpha = 120°$ for four case openings (see online version for colours)



In Figure 8 the maximum value of $C_d$ happened at case opened up by 66% concerning the lower case closed all and the percentage of increasing values reached 44% for case opened all then 22% for case opened down.

**Figure 8** The relation between $C_d$ and Fr for $\alpha$ = 120° for four case openings (see online version for colours)

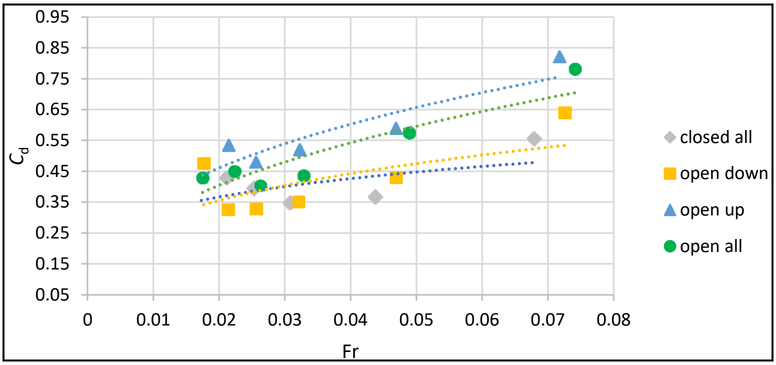
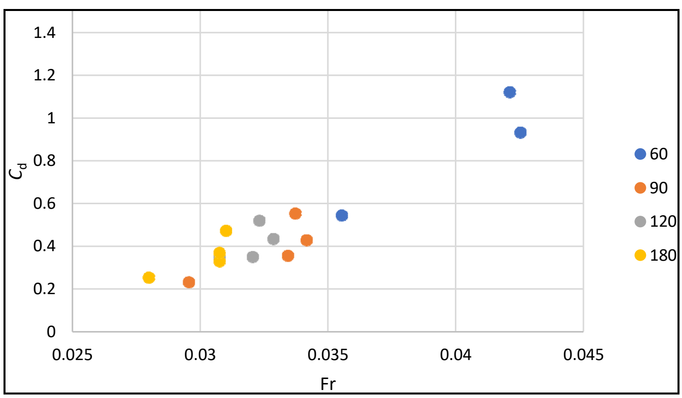



**Figure 9** The relation between $C_d$ and Fr for different $\alpha$ values and discharge $Q$ = 6.5 L/s (see online version for colours)



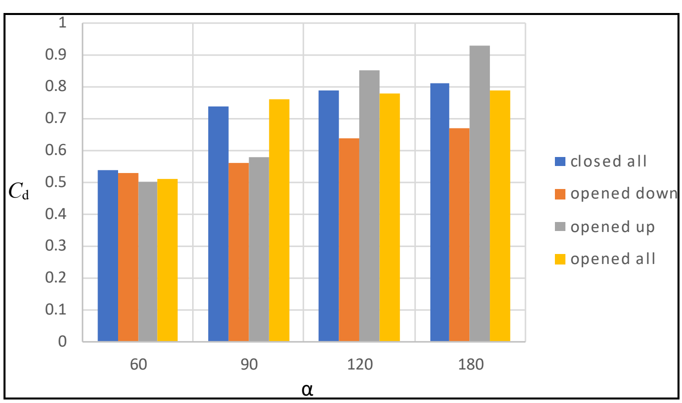

In Figure 9 the maximum $C_d$ values happened at the interior angle $\alpha$ = 60° then at $\alpha$ = 90° and 120° respectively, while the minimum $C_d$ value happened at $\alpha$ = 180° for the same discharge $Q$ = 6.5 L/s. The percentage of increasing values for angles ($\alpha$ = 60°, 90°, and 120°) are (100%, 10%, and 7%) respectively concerning the angle $\alpha$ = 180°, because of increasing crest length when interior angle decreased (when the interior angle decreases, the crest length increases, causing the flow to become less concentrated reducing flow velocity and increasing friction losses. These results in a lower discharge coefficient ($C_d$), while at constant head Table 2, it can be seen increasing $C_d$ values when $\alpha$ values increased for all four cases of flow. So the average percentage of increasing values concerning $\alpha$ = 60° is (27%, 48% and 54%) for ($\alpha$ = 90°, 120° and 180°).

Figure 10 illustrates the discharge coefficient ($C_d$) values across different interior angles ($\alpha$ = 60°, 90°, 120°, 180°) for four operational cases: (closed all, opened down, opened up and opened all). The plot reveals that the $C_d$ values increase with the interior angle ($\alpha$) for all operational cases, indicating an enhanced flow performance at larger angles. Among the cases, opened up demonstrates the highest $C_d$ values for $\alpha = 120°$ and $\alpha = 180°$, highlighting its superior efficiency in discharging flow. Conversely, the opened down configuration shows relatively lower $C_d$ values across all angles, indicating less effective flow conditions. This figure visually confirms the relationship between $\alpha$ and $C_d$, emphasising the influence of interior angle and operational mode on flow efficiency, which aligns with the trends discussed in the results section.

**Table 2** Values of $C_d$ for different $\alpha$ values with constant head

| *Case* | *A* | *H/B* | $C_d$ | *% of increasing* |
|---|---|---|---|---|
| Closed all | 60 | 1.10 | 0.54 | |
| | 90 | 1.07 | 0.74 | 37 |
| | 120 | 1.08 | 0.79 | 46 |
| | 180 | 1.08 | 0.81 | 50 |
| Opened down | 60 | 1.14 | 0.53 | |
| | 90 | 1.23 | 0.56 | 5 |
| | 120 | 1.25 | 0.64 | 21 |
| | 180 | 1.27 | 0.67 | 26 |
| Opened up | 60 | 1.07 | 0.50 | |
| | 90 | 1.1 | 0.58 | 16 |
| | 120 | 1.07 | 0.85 | 70 |
| | 180 | 1.07 | 0.93 | 86 |
| Opened all | 60 | 1.03 | 0.51 | |
| | 90 | 1.09 | 0.76 | 49 |
| | 120 | 1.20 | 0.78 | 53 |
| | 180 | 1.20 | 0.79 | 55 |

**Figure 10** The relation of $C_d$ and different $\alpha$ values for different operation system (see online version for colours)



## 4 Empirical equations

From dimensional analysis and equation (8), it can be reached to empirical equations for each flow case. Using the statistical program SPSS 21, the empirical equation formula can be written as follows:

$$C_{d\ fitted} = c_1 \mathrm{Fr}^{c_2} + c_3 \mathrm{We}^{c_4} + c_5 (\mathrm{H/B})^{c_6} + c_7 (\mathrm{H/d})^{c_8} + c_9 \alpha^{c_{10}} \quad (10)$$

**Figure 11** The relation between $C_d$ and $C_{d\ fitted}$ for opened all cases: ±10% percentage error (see online version for colours)

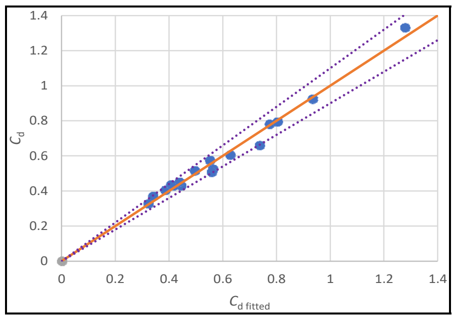



**Figure 12** The relation between $C_d$ and $C_{d\ fitted}$ for opened up case: ±20% percentage error (see online version for colours)

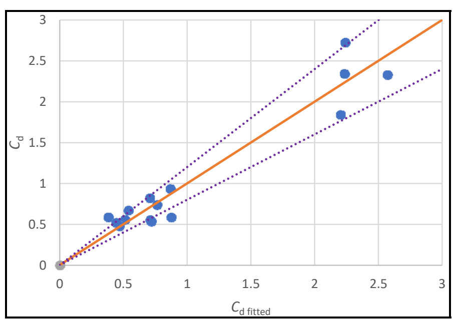
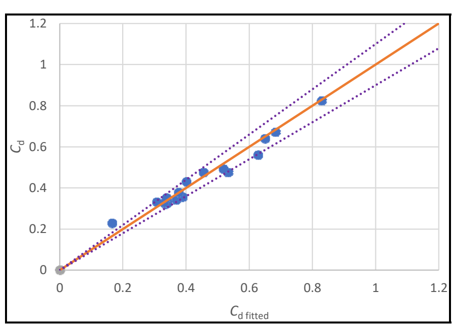



**Figure 13** The relation between $C_d$ and $C_{d\ fitted}$ for opened down case: ±10% percentage error (see online version for colours)



The coefficient values for each flow case are shown in Table 3. The correlation coefficient is between 0.85 and 0.99. Also, the mean percentage absolute error (MPAE) does not exceed 20%.

**Figure 14** The relation between $C_d$ and $C_{d\,fitted}$ for closed all case: ±20% percentage error (see online version for colours)

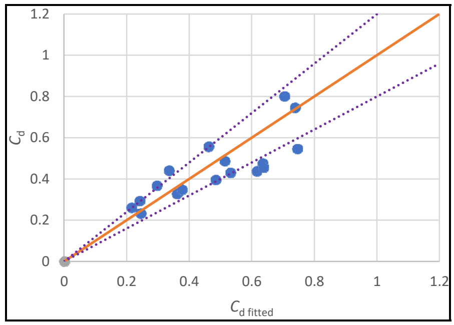



**Table 3** Values of coefficients and MPAE for model cases

| | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $c_6$ | $c_7$ | $c_8$ | $c_9$ | $c_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| MPAE: 4.6%<br>$R^2$: 0.98<br>Case: opened all | 6.894 | 0.671 | 0.358 | 0.081 | –0.464 | 3.895 | –0.047 | 0.2 | 0.123 | 1.012 |
| MPAE: 18.7%<br>$R^2$: 0.85<br>Case: opened up | 4.784 | 0.159 | 0.5 | 0.501 | –11.2 | –0.032 | 99.402 | –1.08 | –4.389 | –0.098 |
| MPAE: 6.5%<br>$R^2$: 0.97<br>Case: opened down | 1.461 | 0.633 | 0.881 | 0.306 | –1.204 | 3.168 | 1.091 | 0.585 | –2.743 | –0.118 |
| MPAE: 20%<br>$R^2$: 0.99<br>Case: closed all | 2.498 | 0.058 | 14.548 | 0.02 | 40.406 | –119.873 | –9.555 | 0.277 | –3.349 | –75.933 |

Figures 11 to 14 represent the relationships between $C_d$ experimental values and $C_d$ fitted calculated from empirical equations. From figures for all cases, it can be seen good agreement between experimental and calculated $C_d$ values with a percentage error between 10% to 20%.

## 5 Conclusions

Measurements have been made of several gate arrangements, investigating their hydraulic performance under various conditions, and the following points conclude:

1 There are four types of flow according to the type of operation of this structure, closed all, opened up, opened down, and opened all. For each type of flow, there are theoretical equations applied.

2 The maximum value of $C_d$ happened in the opened-up case, while the lowest value happened in the closed-all case.

3 For constant discharge, the maximum $C_d$ values happened at interior angle $\alpha = 60°$, while the minimum $C_d$ values happened at interior angle $\alpha = 180°$, while at the constant head, this case is revised because of crest length increased when the interior angle decreased.

4 Four empirical equations are predicted for each case of flow with a correlation coefficient reaching 0.99 and a maximum percentage error not exceeding 20%.

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## Notation list

| *Symbol* | *Notation* | *Unit (MLT)* |
|---|---|---|
| $\mu$ | Water dynamic viscosity | M/LT |
| $A$ | Area of the triangular opening | $L^2$ |
| $B$ | Channel width | L |
| $c_1$–$c_{10}$ | Coefficients for empirical equations | |
| $C_d$ | Coefficient of discharge | -- |
| $C_{dspss}$ | Coefficient of discharge calculated by SPSS | -- |
| $d$ | Height and width of triangular openings | L |
| Fr | Froud number | -- |
| $g$ | Acceleration due to gravity | |
| $H$ | Total head upstream | L |
| $h$ | Water head over the combined weir crest | L |
| $L$ | Weir crest length | L |
| Θ | Angle of the vertex of the triangle opening | -- |
| $P$ | Weir height | L |
| $Q$ | Total discharge passing from a combined structure | $L^3$/s |
| $Q_c$ | Rectangular weir discharge | $L^3$/s |
| $Q_g$ | Gate discharge | $L^3$/s |
| $Q_w$ | Triangular weir discharge | $L^3$/s |
| Re | Reynolds number | -- |
| $V$ | Average velocity upstream weir crest | L/s |
| We | Weber number | -- |
| $A$ | Internal angle | -- |
| $P$ | Water density | $M/L^3$ |
| Σ | Surface tension | $M/T^2$ |