

Hydraulic Characteristics Of Flow Through Rectangular Vertical Openings

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In this study an experimental work was conducted to characterize the hydraulic properties of flow through a wall containing rectangular vertical openings under both partially and fully submerged conditions. Laboratory tests were carried out at the hydraulics and hydrology laboratory at Mustansiriyah University in a tilting recirculating flume with controlled opening configurations and flow rates. Dimensional analysis was performed to derive the governing parameters, and in contrast, empirical correlations were determined through regression analysis. It was found that the discharge coefficients are highly dependent on submergence, head loss ratio, and Froude number. For partially submergence, the discharge coefficient for partially submerged outlets increases with flow and Froude number, while for fully submerged outlets, discharge coefficients decrease with increasing discharge, but positively with Froude number. The head loss was dependent on the flow discharge and showed a direct proportion which confirms the importance of dissipation of energy effects. With strong coefficients of determination, the empirical equations that are produced are accurate and dependable for hydrological design predictive analysis. The improvement of rivers, sluice gates, spillways, and drainage systems is made possible by these studies, which also help to clarify the flow patterns through rectangular apertures.

Keywords: orifice flow, fully and partially submerged outlet, discharge coefficient, experiments, head loss.

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1. Introduction

The flow through a wall containing rectangular vertical openings is studied to understand its applications in hydraulic engineering like drainage systems, sluice gates, and spillways. Flow through vertical openings is influenced by a number of parameters like geometry of the openings (size and spacing), fluid dynamics (Reynolds number, flow velocity, pressure head difference across the openings, discharge) and fluid properties like water density and viscosity. Hydraulic characteristics of flow through vertical openings are including discharge coefficient, flow pattern, and velocity distributions. This efficiently helps engineers to predict flow rates. The subject of the flow of water through a wall containing rectangular vertical openings

relies on the fundamentals of fluid mechanics. Fluid behavior through vertical openings is crucial for the designer of hydraulic structures, like controlled structures (spillways and sluice gates), and for drainage systems. Mohamed and Abdelhaleem [1] performed experimental study to examine the characteristics of flow and the bed configurations downstream opening of sluice gate. Rapp [2] investigated outflow from openings and provided us a comprehensive overview of many phenomenon that relay on many parameters like fluid properties, sizes of the openings, and the discharge. His findings show that the flow behavior through the openings is influenced by a number of parameters like opening's aspect ratio, Reynolds number, and fluid viscosity. Large aspect ratio improves the flow efficiency which increases the discharge coefficient. Hager

[3] correlated the various parameters that influences the flow behavior through the openings like flow depth, flow properties and geometry of the openings. The flow through vertical opening is a complex, so many studies have been performed numerically using CFD simulation Yildiz et al. [4]. Their findings of complexity of flow through the openings are due to non-uniformity of velocities and turbulence. Tomaszewski et al. [5] carried out physical models to correlate the roughness ratio to flow and the aspect ratio. They found that the discharge coefficient and flow uniformity are influenced by the geometric of the openings and to better correlation of empirical equations is at high Reynolds number.

The flow through a side opening in an open channel was numerically simulated and validated to test the effect of different parameters on the discharge coefficient and propose a suitable predictive equation [6]. The results showed that the discharge coefficient is inversely proportional to the Froude number (Fr) and the ratio of the side opening length to the approaching flow water depth. Saad and Fatouh [7] investigated the effect of using one opening or more in weirs on coefficient of discharge. The results show that decreasing the ratio of diameter of openings to height from the bed of the channel decreases the discharge coefficient. Mulahasan and Mohammed [8] conducted experimental work to investigate relationship of hydraulic loss coefficient and drag coefficient with discharge flow on a bridge opening. The results show these coefficients increase as the impact of the blockage increases. Experimental work and CFD simulations were conducted by Cheng et al. [9] to present the effect of coefficient discharge through orifice. The results show the relationship between the velocity of flow and the discharge coefficient was linear. Zeinivand, Ghomeshi, et al. [10] performed experimental analysis to investigate characteristics of passing flow discharge through several square orifices were adopted in the weir of the sharp crested triangular weir with different dimensions and numbers. The results observed that increasing the ratio of the side square of the orifice length to the flume width, the discharge coefficient increased.

Das et al. [11] demonstrate that the hydraulic intake width and intake height have a significant impact on the coefficient of discharge of flow. The coefficient of discharge was found to decrease as the aspect ratio of the intakes increases. Hussain and Haroon [12] developed a mathematical model to analyze the flow characteristics of a rectangular side orifice by using CFD program and comparing with experimental observations. The result indicates that CFD model was found to be consistent with experimental observations. An experimental study was developed by

Irzooki et al. [13] to study the characteristics of flow over weir with semicircular opening. The results indicate that the discharge passing increased with increased radius of the semicircular opening. Characteristics of flow were investigated through weir gate when subjected to free flow and submerged flow [14]. The results show a significant correlation between the Froude number and the discharge coefficient, while a random trend is observed between the discharge coefficient and the Reynolds number. This highlights the importance of taking the environment into account when studying flow through apertures. Al-Naely et al. [15] conducted experimental work to show the effect of number of openings in weir to verify the energy dissipation and find better behavior of flow for increasing number of holes. Hussein and Jalil [16] conducted experimental and numerical model that included combined hydraulic structure. The results presented that the combined system of bottom opening had a better performance for discharging weir flow. Zhang et al. [17] investigate the flow characteristics of gates in open channel to explore the velocity distribution and turbulent kinetic energy under different gate opening conditions. Yang et al. [18] investigated flow turbulence models for flow through openings which demonstrated that different turbulence models produce varied discharge coefficients. The effect of backwater rising was investigated in a blocked open channel flow close to a spur dike. Results showed that the Froude number and backwater rise downstream of the spur dike were linearly correlated [19]. A compound weir's discharge coefficient and free surface profile were examined in relation to different rectangular slot widths. A formula that links the discharge coefficient to the fluctuating parameters was created using dimensional analysis and the SPSS technique. The results show that the discharge coefficient of the compound weir increases with slot width [20]. The amount of energy dissipated by the flow through a stepped weir with step end geometry was examined. The results showed that the rounded sill had the greatest head loss when compared to other shapes [21]. Through a series of experiments on different rectangular openings, this study attempts to expand on previous research by methodically examining the hydraulic characteristics discharge coefficients, velocity profiles, and flow regimes and providing useful data to support and improve current theoretical and empirical models.

2. Materials and methods

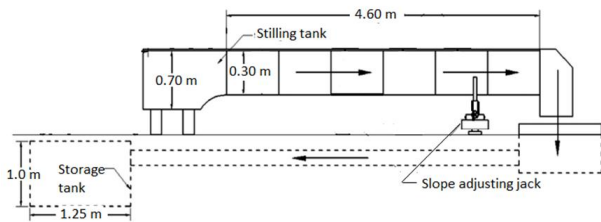
2.1. Experimental setup

In the hydraulic and hydrology lab of the college of Engineering, Mustansiriyah University, Baghdad, Iraq, the hydraulic experiments were conducted in a tilting glass

walled recirculating laboratory flume with a working section length of 5.0 m and dimensions of 30 cm wide and deep under uniform flow conditions. A tail gate at the downstream of the flume’s working portion regulates the water level, and the upstream and the downstream reservoirs supply the flume with water. The upstream end of the flume was provided by a honey comb screen to dissipate the flow turbulence of the incoming flow. The flume is supplied by water from the upstream tank with the dimensions (1.5 m length, 1.25 m width and 1.0 m depth) by a pump through a pipe (see Figs. 1 and 2). A point gauge with an accuracy of ± 0.01 mm was used for measuring the water surface profiles. The flume was set to a constant bed slope of 0.0005 .



(a)



(b)

Fig. 1. The experimental flume.

The model height was 9.5 cm and has six openings of the same height 7.5 cm with a constant length of 10 cm , and of a 30 cm wide which is equal to flume width. The model was located at 215 cm from the flume inlet. The rectangular openings were designed with equi-spaced start at 2.5 cm from the right-hand side edge of the model and end at 2.5 cm before the second edge of the weir model (Fig. 3). More details about the designing model are provided in reference number (20). To obtain multiple measurement readings, a 5 cm thick impermeable barrier was constructed across the width of the flume and fixed at the upper edge of the model (see Fig. 3, the blue barrier). This idea was copied from previous study of flow completely through rock fill by Shariq et al. [22].

Five flow rates (14, 16, 18, 20, and 22 m³ /hr) were examined for the case of fully submerged office and eight



(a)



(b)

Fig. 2. Experimental flume with partially (a) and fully submerged outlets (b).

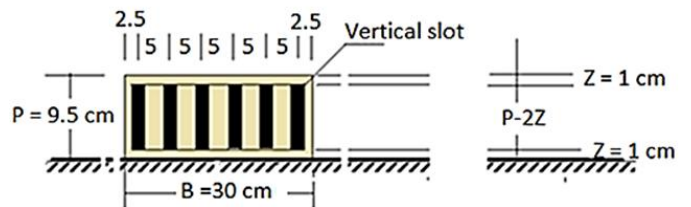
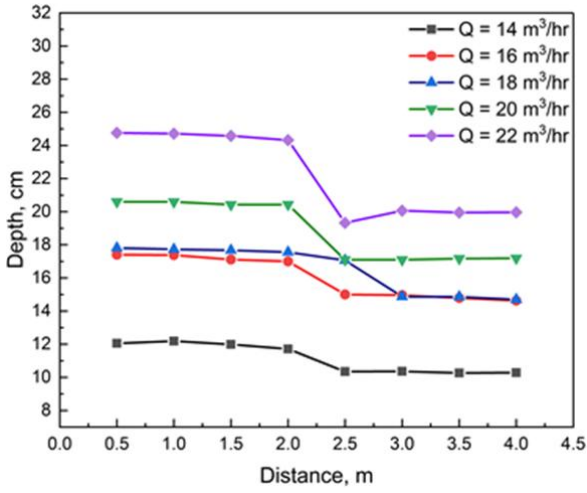
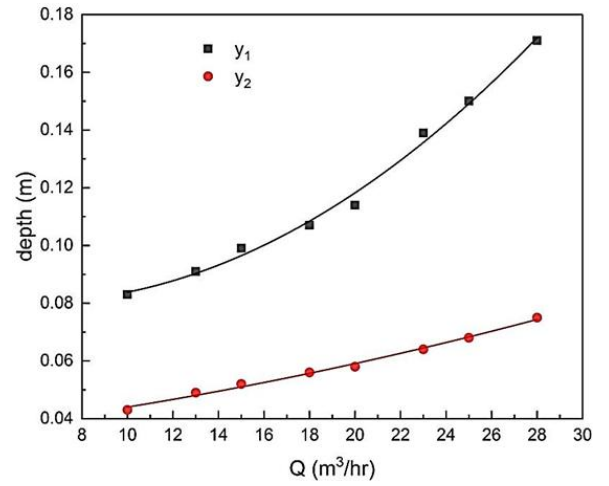


Fig. 3. The front view of model with its the opening dimensions.

flow rates (10, 13, 15, 18, 20, 23, 25, and 28 m³ /hr) for case of partially submerged orifice. A flow meter was used for measuring the flow rates and calibrated by a volumetric method. The down-stream flow depths were measured at each 0.5 m. Fig. 4 shows the measured depth for full submerged orifice. Water depth was measured using point gauge with accuracy ± 0.01 mm. Fig. 5 shows the measured of water depth, y_1 at upstream depth and y_2 at downstream water depth for the case of partially submerged orifice. Full details of flow measurements are provided in Table 1.

Table 1. Details of flow measurements.

Type of submergence	Q, m ³ /hr	y ₁ , cm	y ₂ , cm	$\frac{y_1 - y_2}{b_w}$	F _r	C _d
Fully	12	9.49	8.065	0.57	0.154	0.520
	14	11.99	10.313	0.67	0.125	0.439
	16	17.22	14.845	0.95	0.083	0.292
	18	19.1	16.5	1.04	0.080	0.283
	20	21.51	18.1	1.36	0.077	0.250
	22	24.59	21	1.44	0.068	0.231
Partially	10	8.3	4.3	1.6	0.331	0.175
	13	9.1	5	1.64	0.344	0.198
	15	9.9	5.9	1.6	0.309	0.201
	18	10.7	5.8	1.96	0.381	0.215
	20	11.4	5.7	2.28	0.434	0.217
	23	12.1	5.8	2.52	0.487	0.228
	25	12.9	6	2.76	0.503	0.226
	28	13	7.3	2.28	0.420	0.250

**Fig. 4.** Measured water depth for fully submerged orifice flows.**Fig. 5.** Measured depth for partially submerged orifice flow.

2.2. Dimensional analysis

It is a mathematical model that used to relate experimental data such as discharge coefficient C_d to other geometric and flow variables. The discharge passing through the rectangular openings of the water structure depends on the water height at the upstream of the water structure, y_1 , the water height at the downstream of the water structure, y_2 , channel width, b , opening width, b_w , water viscosity, μ , mass density, ρ and gravitational acceleration, g . These variables are written as

$$Q = f(y_1, y_2, b, b_w, \mu, \rho, g) \quad (1)$$

By using Buckingham's π - theory, then the dimensionless forms are obtained:

$$f_2 \left(\frac{y_1}{b_w}, \frac{y_2}{b_w}, \frac{b}{b_w}, Re, Fr \right) \quad (2)$$

Because the Reynolds number Re was insufficient in open channel flow, therefore we can neglect it. Thus Eq. (2) can be written as

$$f_3 \left(\frac{y_1 - y_2}{b_w}, \frac{b}{b_w}, Fr \right) \quad (3)$$

The difference between upstream and downstream depth about the structure is the head loss, Δh .

3. Results and discussions

The type of flow from rectangular opening depends on levels of water surface at upstream and downstream of the structure. The types of flow are specified by the following descriptions:

1. The inlet is submerged and the tail water is not high enough to submerge the outlet (the flow pattern is

similar to that downstream of a sluice gate or orifice equation).

$$Q = C_d A \sqrt{2gH} \tag{4}$$

C_d = coefficient of discharge, A = cross section area of inlet, and H = upstream depth.

- The inlet is submerged and the tail water level is fully submerged (the discharge equation is controlled by downstream level or using energy equation).

$$y_1 + \frac{v_1^2}{2g} + z_1 = y_2 + \frac{v_2^2}{2g} + z_2 + h_a \tag{5}$$

v_1 and v_2 are velocities of flow at upstream and downstream respectively, h_a = friction head loss between approach section and entry.

3.1. Partially submerged outlet

An experimental investigation specifically aimed to calculate losses at rectangular opening. The variation of a discharge coefficient was shown to be dependent upon different dimensionless variables. The influences of these variables were determined laboratory. Fig. 6 shows the relationship between the discharge coefficient (C_d) and the discharge (Q) for partially submerged outlet. The results reveal a direct relationship, where C_d increases with increasing discharge. The regression equation $y = 0.089x^{0.3}$, provides a good fit to the data with

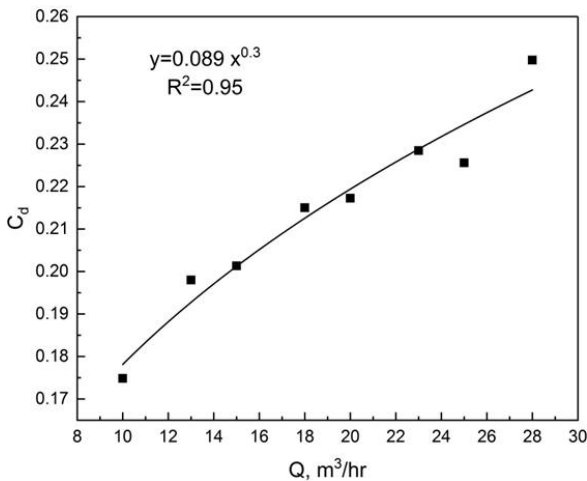


Fig. 6. Relationship between coefficient of discharge and discharge for partially submerged outlet.

$R^2 = 0.95$, confirming the reliability of the trend. Head loss through a wall with vertical openings is a complex phenomenon due to the friction and turbulence within the openings and behind the wall. Factors affecting the

energy dissipated through vertical openings are opening size, spacing of the vertical openings, upstream and downstream water depths, flow velocity and fluid properties. Fig. 7 illustrates the relationship between the loss ratio, expressed relative to the flow opening width, and the discharge coefficient. The trend indicates a slight increase in C_d with the increase in the ratio, although the correlation is relatively weak ($R^2 = 0.6$), reflecting the influence of additional hydraulic factors and possible flow fluctuations. Fig. 8 presents the relationship between the discharge coefficient and the Froude number. The analysis reveals that the discharge coefficient demonstrates a positive correlation, increasing consistently with higher values of the Froude number.

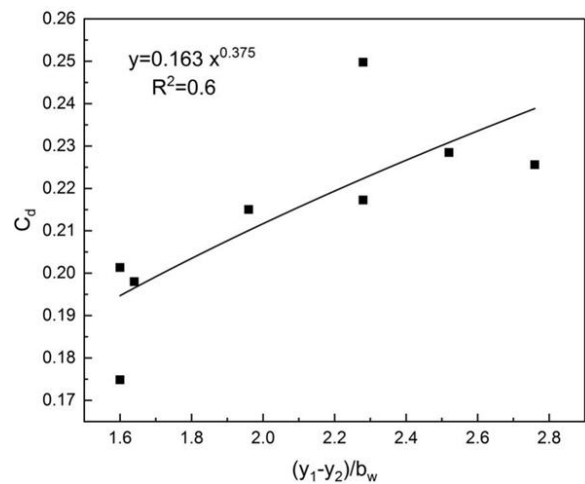


Fig. 7. Relationship between coefficient of discharge and ratio of head loss to opening width for partially submerged outlet.

Statistical regression analysis of the experimental results for partially submerged was developed using the SPSS software program. The discharge coefficient was calculated as in the following equation:

$$C_d = \frac{\left(\frac{\Delta h}{b_w}\right)^{1.407}}{8.037 + 110.559 F_r^{3.511}} \tag{6}$$

$R^2 = 0.813$

The positive exponents show that C_d increases with both Froude number and the relative head loss (as shown in Figs. 7 and 8). The additive constant represents a baseline efficiency, while the moderate goodness-of-fit ($R^2 = 0.813$) indicates noticeable scatter, thus the correlation is suitable for preliminary design within the calibration range and should not be extrapolated without validation.

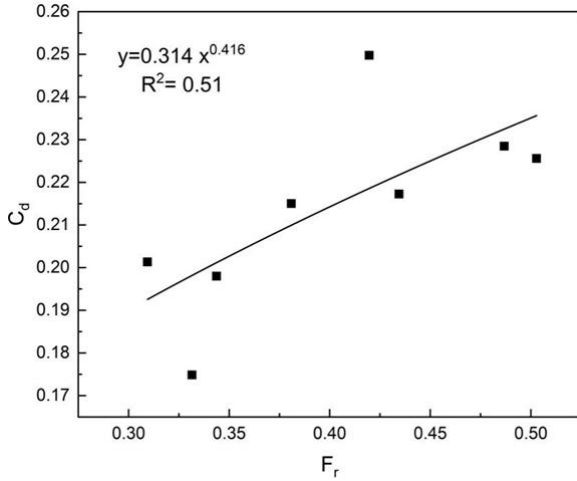


Fig. 8. Relationship between discharge coefficient and Froude number for partially submerged outlet.

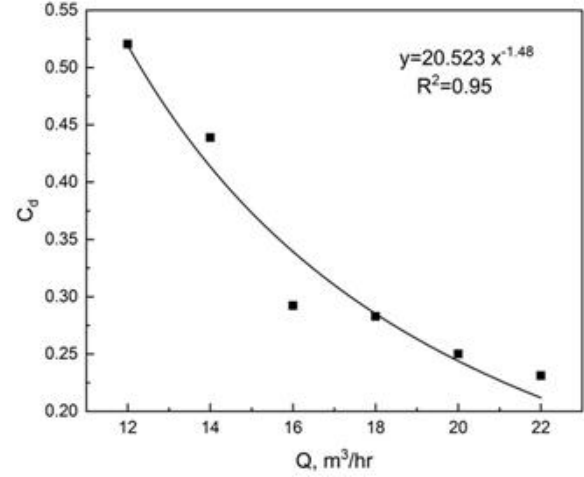


Fig. 9. Relationship between coefficient of discharge and discharge for fully submerged outlet.

3.2. Fully submerged outlet

Fig. 9 illustrates the relationship between the discharge coefficient and the discharge for a fully submerged outlet. The figure shows that the discharge coefficient decreases progressively as the discharge increases. The fitted curve demonstrates a strong correlation with a coefficient of determination (R^2) of 0.95. In contrast, the relationship shown in Fig. 9 (for a fully submerged outlet) exhibits an inverse trend, where C_d decreases as Q increases. This comparison highlights the significant influence of the submergence condition: while partial submergence enhances the discharge coefficient with increasing flow, full submergence reduces it due to increased flow resistance and energy losses. When compared with other figures, a clear distinction emerges. Fig. 6 (partially submerged outlet) shows a strong direct relationship between C_d and discharge, with a high correlation ($R^2 = 0.95$). In contrast, Fig. 9 (fully submerged outlet) exhibits an inverse relationship, where C_d decreases with increasing discharge, highlighting the negative impact of full submergence on flow efficiency. Meanwhile, Fig. 8 demonstrates a positive correlation between C_d and Froude number, underlining the role of hydraulic dynamics in enhancing C_d . Collectively, these figures emphasize that the discharge coefficient is highly sensitive to both hydraulic parameters and submergence conditions. While partial submergence and higher Froude numbers tend to enhance C_d , full submergence reduces it, and the effect of head loss ratio (Fig. 7) appears less dominant, as Fig. 9.

The Fig. 9 indicated by the weaker correlation. The results presented in Fig. 10 demonstrate a clear inverse relationship between the discharge coefficient C_d and the ratio of head loss to opening width for a fully submerged outlet.

As the ratio increases, the discharge coefficient decreases steadily, ranging from approximately 0.52 at lower values of the ratio to about 0.22 at higher values. This decline indicates that greater relative head losses are associated with reduced flow efficiency through the outlet. The experimental data were successfully correlated using a power-law expression of the form $y = 0.305x^{-0.917}$, with an excellent coefficient of determination ($R^2 = 0.98$). The high value of R^2 suggests that the proposed empirical equation provides a reliable predictive tool for estimating C_d under the tested conditions, with very limited data dispersion around the regression curve. From the standpoint of hydraulics, this behavior aligns with theoretical predictions. Higher head loss in relation to opening width results in higher flow resistance and energy dissipation, which decreases the outlet's capacity to convey discharge. The discharge coefficient is extremely sensitive to hydraulic head conditions, as confirmed by similar results in earlier research on submerged orifices and outlet structures [10, 16]. These results have practical implications for totally submerged outlet design and optimization. Using the correlation to forecast discharge performance under various hydraulic situations could lead to the development of more effective hydraulic systems. Further highlighting how important it is for engineers to examine outlet design and operating circumstances is the fact that C_d is sensitive to head loss.

Fig. 11 presents the relationship between the discharge coefficient C_d and the Froude number F_r for a fully submerged outlet. The results indicate a strong positive correlation, where the discharge coefficient increases almost linearly with increasing Froude number. Specifically, C_d rises from approximately 0.23 at lower Froude numbers (

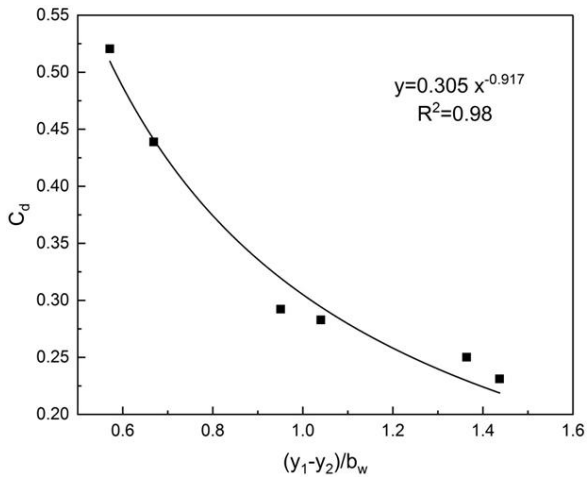


Fig. 10. Relationship between coefficient of discharge and ratio of head loss to opening width for fully submerged outlet.

$F_r = 0.07$) to about 0.52 at higher values ($F_r = 0.16$). The experimental data were fitted using a power-law expression of the form: $y = 3.26x^{0.976}$ where y represents the discharge coefficient C_d and x denotes the Froude number F_r . The coefficient of determination confirms an almost perfect fit, demonstrating that the proposed correlation captures the observed hydraulic behavior with exceptional accuracy and minimal scatter. From a hydraulic standpoint, this behavior is physically justifiable. Higher Froude numbers correspond to increased inertial forces relative to gravitational forces, which promote more efficient flow through the submerged outlet, leading to a higher discharge coefficient. This observation contrasts with the trend reported in Fig. 10, where higher energy losses reduced C_d . The combined results thus emphasize the dual influence of both head loss and flow regime on outlet efficiency. The strong dependency of C_d on the Froude number underscores the importance of considering flow regime characterization in hydraulic design.

The derived empirical correlation provides a reliable predictive tool for estimating discharge coefficients in submerged outlet applications under different flow conditions. These findings are consistent with established hydraulic principles and support previous studies highlighting the role of dimensionless parameters, such as the Froude number, in governing outlet performance. The results illustrated in Figs. 10 and 11 provide a comprehensive understanding of the factors influencing the discharge coefficient C_d for a fully submerged outlet. Fig. 10 shows that C_d decreases as the ratio of head loss to opening width increases. This inverse relationship highlights the adverse effect of en-

ergy losses on outlet performance, as higher relative head loss reduces flow efficiency, leading to lower values of C_d . The proposed power-law correlation, with $R^2 = 0.98$, confirms that this dependency is both statistically significant and hydraulically meaningful. In contrast, Fig. 11 demonstrates a strong positive relationship between C_d and the Froude number F_r . The discharge coefficient increases almost proportionally with increasing F_r , rising from about 0.23 to 0.52 across the tested range. This trend reflects the enhancing role of inertial forces relative to gravitational forces in promoting more efficient discharge through the outlet. The derived correlation, with an exceptionally high determination coefficient $R^2 = 0.99$, provides an accurate predictive tool for evaluating C_d as a function of F_r .

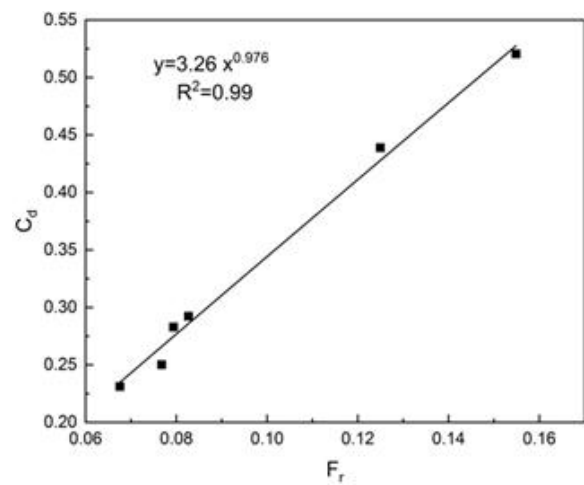


Fig. 11. Relationship between coefficient of discharge and Froude number for fully submerged outlet.

Taken together, these findings highlight the dual influence of hydraulic conditions on the discharge coefficient. While greater energy losses diminish C_d , stronger flow inertia—represented by higher Froude numbers—leads to an increase in C_d . This complementary analysis emphasizes that both energy dissipation and flow regime characterization must be considered simultaneously in the design and optimization of submerged outlets. The empirical equations developed in this study can therefore serve as valuable tools for predicting outlet performance under varying operational conditions, offering practical insights for hydraulic engineering applications. Fig. 12 illustrates the relationship between head loss and discharge for a fully submerged outlet. The results indicate a clear linear trend, where head loss increases proportionally with increasing discharge.

Specifically, head loss values range from approximately 0.014 at lower discharges ($Q = 12\text{ m}^3/\text{hr}$) to about 0.037 at

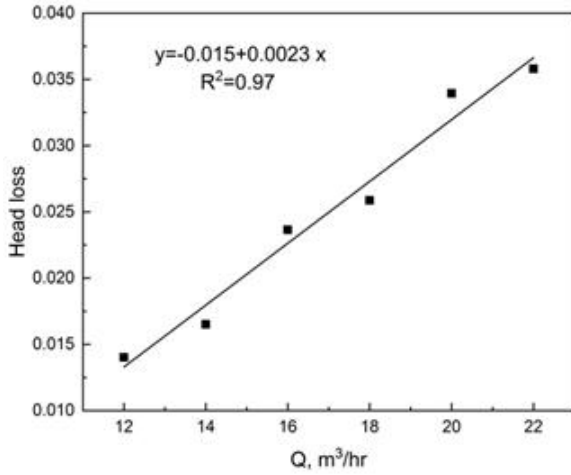


Fig. 12. Relationship between head loss and discharge for fully submerged outlet.

higher discharges ($Q = 22\text{m}^3/\text{hr}$). The experimental data were fitted with a linear regression equation. The obtained coefficient of determination ($R^2 = 0.97$) demonstrates an excellent fit, confirming that head loss is strongly dependent on the discharge rate and that the linear model reliably describes the observed hydraulic behavior. From a hydraulic perspective, this relationship is consistent with energy principles in fluid mechanics. As discharge increases the velocity through the outlet, more frictional and turbulent losses occur. This explains why head loss increases proportionately with higher flow rates. In contrast to Figs. 10 and 11, this emphasized the influence of Froude number and relative head loss on the discharge coefficient, Fig. 12 further highlights that head loss is correlated with the flow rate and not an independent parameter. These findings highlight the significance of taking discharge variations into consideration when calculating head losses in submerged outlets. The strong correlation that was discovered offers a practical empirical tool for predicting head loss under different operating discharges, which is advantageous for hydraulic design optimization and system efficiency. The hydraulic performance of submerged outlets is clearly shown in Figs. 10 to 12. The dual effects of inertial forces and energy dissipation on outlet efficiency are demonstrated by the fact that higher Froude numbers increase the discharge coefficient while higher head ratios decrease it. Additionally, the relationship between head loss and discharge rate is direct, highlighting the interdependence of hydraulic parameters. These findings not only validate fundamental fluid mechanics principals but also provide practical empirical correlations that can be applied in the design and optimization applications.

$$C_d = \frac{\left(\frac{\Delta h}{b_w}\right)^{-0.292}}{0.791 + 0.258F_r^{-0.93}} \quad (7)$$

$$R^2 = 0.999$$

Eq. (7) demonstrates a highly accurate empirical correlation ($R^2 = 0.999$) for predicting the discharge coefficient of fully submerged outlets. The analysis confirms that the discharge coefficient is primarily governed by relative head loss $\frac{\Delta h}{b_w}$, which exhibits a strong negative effect on hydraulic efficiency, while the Froude number exerts only a minor inverse influence. These findings emphasize the critical role of energy losses in submerged flow conditions and validate the proposed model as a reliable predictive tool for engineering design and hydraulic performance assessment. To explained the verification of the equations obtained from dimensional analysis (Eqs. (6) and (7)) in comparison with the corresponding measured values, the results are presented in Fig. 13. As adopted in the figure, the relationship has a good correlation coefficient, and for fully submergence is stronger than that for partially submergence. In Fig. 13, the measured and predicted values of C_d demonstrated that the percentage of errors were found very small in comparison to Mohamed and Abdelhaleem [1], where the last reference found it between 8% and 3%.

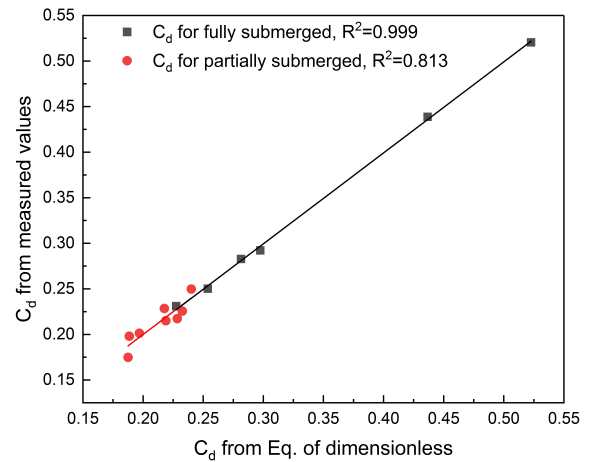


Fig. 13. Comparison between values of Cd obtained from measured and that calculated from equation of dimensionless analysis.

4. Conclusions

An experimental work was investigated to characterize the hydraulic properties of flow through a wall containing rectangular vertical openings under both partially and fully submerged conditions and supported by dimensional analysis and SPSS program. The experiments model used in the

present study has limited conditions such as size, shape, number of openings and barrier thickness. The main conclusions are summarized as follows:

- It was found that the discharge coefficients are highly dependent on submergence, flow rate, head loss ratio, and Froude number.
- For partially submerged the discharge coefficient C_d increases with discharge and Froude number, while for fully submerged conditions the discharge coefficient decreases with increasing discharge and increases with Froude number.

Generally, the discharge coefficient C_d for submerged flow through perforated wall influences by a number of factors such submergence ratio (downstream water depth/upstream water depth), opening geometry (shape and size) and characteristics of the approach flow. As the submergence ratio increases, the discharge coefficient C_d becomes more crucial and highly variable. The novelty of the present study showed the impact of the submergence ratio on the hydraulic parameters under partial and fully submergence conditions.

The head loss results for partially submerged conditions illustrated the relationship between the loss ratio, expressed relative to the flow opening width, and the discharge coefficient. The trend indicates a slight increase in C_d with the increase in the ratio with relatively weak correlation ($R^2 = 0.6$), reflecting the influence of additional hydraulic factors and possible flow fluctuations. While for fully submergence, the relation is in contrast to partially submerged condition. As the ratio increases, the discharge coefficient decreases steadily with an excellent coefficient of determination ($R^2 = 0.98$).

Energy dissipation and flow rate are strongly correlated, as evidenced by the direct proportionality of head loss to discharge. The empirical equations generated by statistical regression analysis had a good predictive accuracy ($R^2 > 0.95$), making them appropriate for real-world engineering applications within the specified calibration ranges.

An excellent match was found between the results of the discharge coefficient from the experiments and from the dimensional analysis with coefficient of determination of 99%. In future more experiments are required to carrying out with varying number and size of the openings. In addition, Computational Fluid Dynamics (CFD) is useful to apply to confirm our experimental results. The study confirms basic hydraulic concepts and highlights how important it is to take energy dissipation and flow regime into account when constructing hydraulic structures.

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nomenclature

Greek Symbols

μ Water viscosity
 ρ Mass density of water

Roman Symbols

g Gravitation acceleration

Subscripts

b Channel width
 b_w Opening width
 C_d Coefficient of discharge
 v_1 Flow velocity at upstream section
 v_2 Flow velocity at downstream section
 y_1 Water height at upstream section
 y_2 Water height at downstream section

Other Symbols

Δh Difference of water depths between upstream and downstream sections.
 F_r Froude number
 H Difference of water depths between upstream and downstream sections.
 Q Flow discharge
 R_e Reynolds number

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