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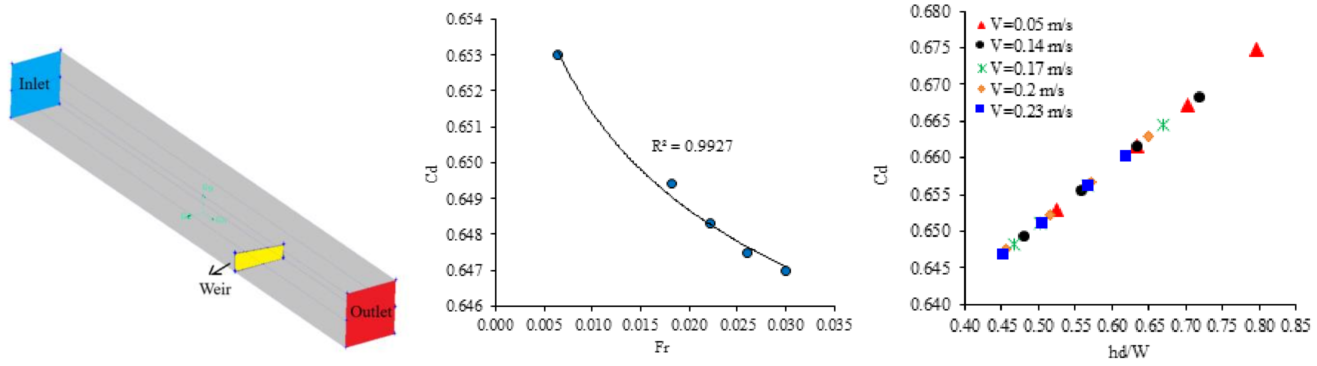
Determination of discharge coefficient in the tilted crown sharp-crested weirs

Salma Ajeel Fenjan[1], **Ali Akbar Akhtari**[*,1], **Mohammad Hadi Tavana**[2]

[1]*Department of Civil Engineering, Faculty of Engineering, Razi University, Kermanshah, Iran.*
[2]*Department of Civil Engineering, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran.*

GRAPHICAL ABSTRACT



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ABSTRACT

In this study, the performance of vertical and tilted crown weirs with different angles of the weir crest across the flow has been investigated using numerical and experimental models. Accordingly, various experiments are conducted on tilted crown sharp-crested weirs under different free-flow conditions. Moreover, computational fluid dynamic (CFD) modeling has been done using Fluent software to determine the best form of the discharge coefficient (C_d). In this study, the RNG model is used to define turbulence in the fluid flow and the two-phase volume of fluid (VOF) method is applied to define the interface of water-air in the flume. To verify the accuracy of the CFD model, the experimental data that was done in this research are used. Moreover, another goal of this research is to investigate the influence of the different angles of weir on hydraulic characteristics of flow such as pressure, velocity and C_d parameters. The results show that by increasing the weir crest angle across the flow (α), the C_d values are almost constant. Furthermore, the numerical results are in good agreement with the experimental models. As, the comparison of numerical and experimental data shows that the maximum absolute relative error (ARE) obtained are 2.8 %, which indicates the high accuracy of the CFD model. The vortex area with return velocity vectors can be seen in downstream of the weir and these vectors increase near the weir. In all velocity values, by decreasing the angle of weir to the flow direction, the C_d values increased and tends to a constant value while, the pressure values decreased. As for the velocity values in ranges of 0.05-0.23 m/s, the C_d value is ranged in 0.64-0.675. Finally, as the Reynolds and Froude number increase, the discharge coefficient decreases and tends to a constant number of 0.65 approximately.

1. Introduction

Various hydraulic structures have been designed and built to manage and transfer water. One of the common structures in many dams and water transfer channels are weirs. The weirs have different types based on their shape and use. Weirs are overflow structures that locate across the open channel width. Weirs are commonly used to measure or regulate flow in rivers, streams, irrigation canals, etc. Installing a weir in an open channel system causes critical depth to form over the weir. Indeed, they change the flow characteristics to easier measure of volumetric rate of flow discharge. Besides the discharge flow measurements, the weirs can prevent from flooding and flow turbulency and make rivers more shippable. Based on the shape of the weir's crested, the weirs are included two types as sharp-crested and broad-crested. The flow through the weir has a direct relationship with the hydrostatic height on the weir. This relationship with coefficients related to the size and shape of the weir becomes the general equation of weirs.

Sharp-crested weirs are divided into triangular, rectangular, circular, trapezoidal and parabolic based on the crown shape. So far, many studies have been done in the field of studying flow hydraulics in these weirs and various solutions have been proposed to increase the efficiency of simple weirs. Beveling the sharp edge weir increases its effective length and thus increases the efficiency of the weir (Yousif and Karakouzian. 2020). Various designs such as beak weirs, duck tip and congress weirs have also been investigated, in which the horizontal

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[*] Corresponding author Email: akhtari@razi.ac.ir

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section of the weir crest is not a straight shape and the discharge capacity increases with the increase of the crest length. Among these types of weirs, we can refer to the non-linear weirs with a triangular horizontal section (trapezoidal weirs) (Bagheri et al. 2010). Johnson (2000) investigated the discharge coefficient along two flat-topped and sharp-crested weirs experimentally. Indeed, the main aim of his study was to examine the variation of C_d value along a weir with w/*p*=0 (sharp-crested weir) and w/p= 0.25, 0.5, 0.75, and 1. The main focus of Johnson' paper is study of the h_d/w influence in hydraulic behavior of weirs where h_d is the flow head over the weir, w is the weirs thickness and p is the weirs height. This study also showed that the important variable governing discharge over flat-topped weirs was h_d/w. also they pointed out that weirs should be classified based on their physical geometry and the number of head associated with the flow passing over the weir. Ramamurthy et al. (2009) done more studies in simulation of the flow pattern in a rectangular sharp-crested weirs using a Flow3D modeling with consideration of VOF method, and k-ε turbulence model. Their results represented the high correlation of numerical results and experimental data. Arvanaghi and Oskuei (2013) experimentally investigated three different sharp-crested weirs and compared their results with numerical data. In their study, the empirical Rehbock equation was used to calculate the discharge coefficient based on the general weir equation. Accordingly, water surface profile was measured at first over the weir. After that they used CFD modeling of the flow over the weir. The impact of weir's height on C_d values was investigated by Naderi et al. (2014). The behavior of the flow over the weir and C_d values as the real behavior of the flow was studied by them. Naderi et al.'s results represented that by increasing the h/P values (h is the water head over the weir and P is the weir's height) to 0.6, the C_d values has tendency to fix number of 0.7. However, C_d values is not fix and it is not suggested to use a unique C_d for different flow hydraulic conditions. As the highest C_d value which is related to the highest weir's length is equal to 1.4. Using Fluent software, Samadi and Arvanaghi (2014) simulated the three-dimensional flow over the contracted compound arched rectangular sharp-crested weirs. Using experimental researches, Shariati et al. (2015) measured the C_d values on parabolic sharp-crested weirs. They developed a simple equation to calculate flow discharge using the parabolic crest weirs equations. Accordingly, they used a physical model by different weir angles, weir heights, and flow hydraulic characteristics. Their results specified that with increasing the angle and height of weirs, the C_d values was increased. The mean value of C_d of experiments model was measured as 0.605. Moreover, using the regression method, an appropriate equation to calculate the C_d values with coefficient of determination (R^2) of 0.922 was suggested.

Gupta et al. (2015) experimentally studied the effect of height of rectangular sharp-crested weir on flow pattern. The experimental investigation done on 24 different sharp-crested rectangular plan form weir models which as made by mild steel plates to describe the effect of crest height on the flow pattern with the different lengths of weir's crest. Farzin et al. (2018) investigated the discharge coefficient of cylindrical weir. The accuracy of numerical Flow3D model was examined with a validated experimental model with different values of cylinder diameter of 11, 9, and 6.35 cm and different angles of 45, 90 and 135 degree toward the wall. Accordingly, Standard k-ε turbulency model yielded acceptable adaption with experimental model compared to RNG and Large eddies simulation (LES) models. The results showed that in models with complementary angles, because of the similarity of these models in the flow pattern, the discharge coefficients will be almost equal to each other. Ionesu et al. (2019) experimentally studied the accuracy of measuring different shapes of sharp-crested weirs. Moreover, a sensitivity analysis was done to evaluate the effect of the weir's shape on C_d values to detect the best shape yielded the highest accuracy for measuring small discharges

Rezazadeh et al. (2019) experimentally and numerically investigated the influence of the geometric shapes of the sharp-crested weirs on different flow variables as velocity, pressure, water surface profiles and C_d values. The CFD model was used to investigate the flow characteristics and scour around four shapes of submerged weir: inclined sharp-crested weirs with 30° and 120° slopes, respectively, and two different vertical arch weirs. The results represented that the inclined sharp-crested weir with the 120° angle decreased the maximum scour depth by more than three times compared to the vertical sharp-crested weir.

Generally, discharge coefficient value depends on to geometry of the channel and weir and also the flow characteristics. Indeed, by measuring the flow height over the weir (h_d), the discharge value can be calculated. The optimum h_d value can yielded the best discharge value. Thus, the h_d amount and its variation along weir's width is vital. Variation of weir angles in horizon, plan and along the width of channel (chord angle of upper line of the tilted weir) can be affect the h_d variations and also discharge value. Therefore, some studies in the field of flow hydraulic of weirs have been done and various solutions have been proposed. Such as, using oblique sharp-crested weirs increases the efficiency of weirs and effective length in both free and submerged flow. Furthermore, Kumar et al. (2012) stated that the discharge coefficient is raised by changing the geometric characteristics of weirs. In such a way, by changing weirs geometry, the flow transferring over the weir for a specified water surface height is increased. In another research, Kumar et al. (2012) presented a relationship between C_d and H/P, for a circular sharp-crested weir. Esmaiyli varaki and Safarrazavizadeh (2013) investigated the discharge coefficient in the weirs with variable crown height and pointed out to more efficiency of these weirs compared to fixed-crown height of weirs. As discussed earlier, many authors studied the vertical weirs with different shapes such as rectangular, circular and triangular. While the investigation of the chord angle effect of the triangular part of the upper line of the tilted weir has not been done. On the other hands, as seen in the laboratory, when the upper line of the weir was tilted, h_d value is increased along the weir in the side with low height. Therefore, this issue causes the change in the discharge value and also downstream free-fall flow height on a bed. Moreover, according to experimental findings, this issue and variations is changed in different hydraulic characteristics and flow velocity. In low discharge value passing from the channel, the h_d value over the weir is close to zero value and the h_d value is reached to the most value in the other side. Therefore, using chord angle of upper line of the tilted weir, can controlled the flow situation and turbulency after the weir in the downstream which is the desirable issue of weir applications.

Now, based on the last two studies, in the present paper, was decided to investigate the discharge coefficient variation based on this kind of weirs with different angles and variable crown height which is named "tilted crown sharp-crested weirs". Therefore, the changes of two tilted heights or the chord length of the upper triangle in the tilted weir is the innovation of the current paper which is not seen in no previous papers. Actually, the main purpose of this paper is to compare and investigate the effects of different angles of weirs on C_d variations. On the other hands, the most investigations about weirs with angles are related to weir with angle along horizon and plan. Whereas, in this paper the effect of tilted weir along plan with different heights of weirs (three heights) is examined. Moreover, in this study, the different hydraulic characteristics such as velocity vectors and contours, pressure and the discharge coefficient values in the channel with tilted crown sharp-crested weirs were investigated. This research focused on investigate the effect of the horizontal line of the weir crest with different angles (α) with respect to the horizon and their effect via experimental study and CFD modeling.

2. Experimental procedure

Laboratory measurements have been done in the laboratory of Islamic Azad University of Kermanshah. The real photo of the studied laboratory flume is shown in Fig. 1. The length, width and height of the flume are 7.5, 0.58 and 0.6 m, respectively. Using stilling system, the flow enters to the channel and stream over the sharp-crested weir. Finally, the flow goes on the settling channel basin. In the downstream of the settling basin, a V-notch weir is located and calibrated for measuring the rate of the flow. The sharp-crested weirs which is made of PVC plates, is as the same width of the flume (L = b = 0.58 m) but in four different heights according to Fig. 2. The weirs are tilted along the width of the channel with different angles across the flow. These four heights are (a=20 cm, b=20 cm), (a=20 cm, b=17.5 cm), (a=20 cm, b=15 cm). The angle actually shows the changes of two tilted heights or the chord length of the upper triangle in the tilted weir. Each adjusted weir height is examined with various water heads (hd) from 1 cm up to the channel height. The V-notch weir measures the discharge rate when the h_d value is fixed. For measuring the flow height over the weir, in the downstream of the channel, a digital caliper including needle indicator with the 0.01 mm accuracy is used to read the low height of flow after the weir. In the upstream of the weir, another digital caliper is applied with the shorter bar length due to more flow height before the weir. The accuracy of this caliper is 0.01 mm. Both calipers are installed on a Vernier ruler in the transverse direction with the 0.5 mm accuracy. In the present paper, five different hydraulic characteristic and discharge values are used for tests. The used discharges in this paper are 0.011, 0.0368, 0.0406, 0.490, and 0.0580 m^3/s. Five different tests with different velocity values were conducted for each weir height. There were three different weir heights with constant *a* value and three different b values. Totally, 15 tests were done in the laboratory.

Fig. 1. The real photo of the investigated laboratory flume.

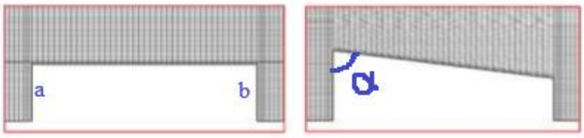


Fig. 2. Schematic front view of the investigated tilted weir.

2.1. Numerical method and parameters

2.1.1. Equations

The Fluent software (Version 6.2) is used for numerical modeling in this paper. Fluent is a powerful and common CFD commercial software. The governing equations in this subject is depth averaged Navier-Stokes equations (Reynolds equations) consist of continuity and motion equations. These equations satisfy the conservation of the mass and momentum equations for the fluid flow.

Mass conservation equation

All equations must be in table without border and have a special number and references in body same as Eq. 1 (Azimi et al., (2021)).

$$\frac{\partial(\rho)}{\partial t}+\nabla.(\rho U_i)=0 \tag{1}$$

Momentum conservation equation

$$\frac{\partial(\rho U_i)}{\partial t}+\nabla.(\rho U_i U_j)=-\nabla p+\nabla.(\mu\left(\nabla U_i+\nabla.\vec{U_i}^{T}\right)) \tag{2}$$

where, ρ, t, x, p, and μ are the density of fluid, time, axis coordinates, pressure, and dynamic viscosity, respectively. Ui is the mean component of velocity. The VOF equation are used to specify the free surface between fluids (water and air) (Liu et al. (2009)).

$$\frac{\partial\alpha_w}{\partial t}+u_i\frac{\partial\alpha_w}{\partial x_i}=0 \tag{3}$$

where, α_w is the volume fraction of water, and u_i is the velocity in x_i-direction. The volume component equation (α_w) for the first phase is not solved and the value of the volume component of the air (α_a) is obtained based on the following Eq.

$$\alpha_a=1-\alpha_w \tag{4}$$

Discharge equation for a rectangular sharp-crested weir with the same channel width can be written as (Henderson et al. (1966)).

$$Q=\frac{2}{3}(0.611+0.08\frac{h_d}{W})\,\mathrm{L}\sqrt{2g}h_d^{\frac{3}{2}} \tag{5}$$

where, L is the length of the weir crest, C_d is the discharge coefficient, g is the gravitational acceleration and hd is the static head over the crest. W is the weir height. Accordingly, the discharge coefficient is as follows (Mahtabi et al. (2019)).

$$C_d=0.611+0.08\frac{h_d}{W} \tag{6}$$

C_d is related to the several parameters and is mathematically described by the following Eq.

$$\mathrm{C_d}=\mathrm{f}\left(\mathrm{Re},\mathrm{W_e},\frac{\mathrm{h_d}}{\mathrm{W}}\frac{\mathrm{h_d}}{\mathrm{b}}\right) \tag{7}$$

where, b is the width of the weir opening, R_e is the Reynolds number, and W_e is the Weber number.

2.1.2. Turbulent model

Turbulent flows are characterized by fluctuating velocity. These fluctuations mix transported quantities such as momentum, energy, kinetic energy and species concentration, and cause the transported quantities to fluctuate as well. Since these fluctuations can be of small scale and high frequency, they are also computationally expensive to simulate directly in practical engineering calculations. Instead, the exact governing equations can be time-averaged, ensemble-averaged, or otherwise manipulated to remove the small scales, resulting in a modified set of equations that are computationally less expensive to solve and describe it. Turbulent models have been classified based on to one equation model, two equation model and Re. stress model. The models have also been divided into the following classes: k – ε model (standard k – ε model, renormalization group (RNG) k – ε model and realizable k– ε model) and k – ω model (standard k – ω and shear stress transport (sst) k –ω). At first, turbulence models of two equations were used in this research, k-ε (Standard) and k-ε (Realizable), k-ε (RNG). Finally, the results obtained from the k-ε (RNG) model were more consistent with the experimental results and the amounts of residuals in the error diagram were lower in this model. k-ε(RNG) method is derived from statistical intensity. VOF represent the sharp interface between the air and water phases. A flow which consists of two immiscible phases, in this case water and air is called a multi-phase flow. With the VOF model, the location and shape of the interface also known as the free surface profile can be determined.

2.1.3. Geometry and boundary conditions

The schematic of the investigated flume and tilted weir is represented in Fig. 3. Boundary conditions defined for this problem are as: Velocity Inlet in channel inlet, Pressure Outlet in channel outlet and channel upper surface, and Interior boundary condition in water-air interface. Other surfaces such as channel bed and sides have been considered as Wall. In order to mesh, the geometric shape is divided into small control volumes. The more number of meshes and the smaller their size, the slower, longer and more accurate the calculations in the Fluent software. Triangular meshes with size of 1 mm are used for meshing the weir surfaces and 1.5 mm one are used for meshing the inlet and outlet surfaces of the flume. The geometry of the mesh can be seen in Fig. 4.

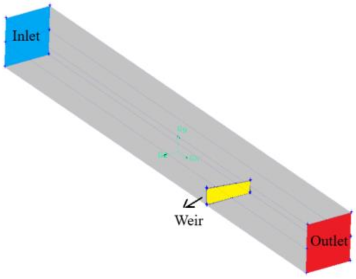


Fig. 3. The schematic of the investigated flume and tilted weir.

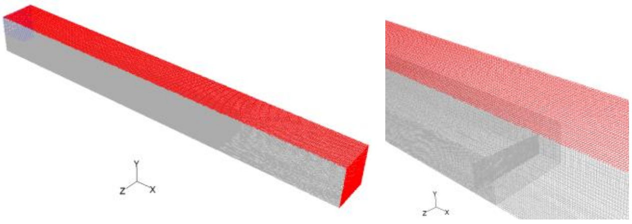


Fig. 4. The mesh adaption for the flume and weir.

2.1.4. Mesh dependency

To ensure the independence of the solution from the size of the meshes, five sizes are checked for meshing, and the volume of the resulting controls are 1.3×10^6, 1.5×10^6, 1.7×10^6, 1.9×10^6 and 2.3×10^6. The discharge coefficient parameter in each model is considered as a criterion to check the independence of the model from the mesh size.

A significant change in the mentioned parameter is not observed with the number of controls more than 1.9×10^6. Therefore, to reduce the calculation time, this mode is chosen for meshing.

3. Results and discussion

3.1. CFD and experimental results

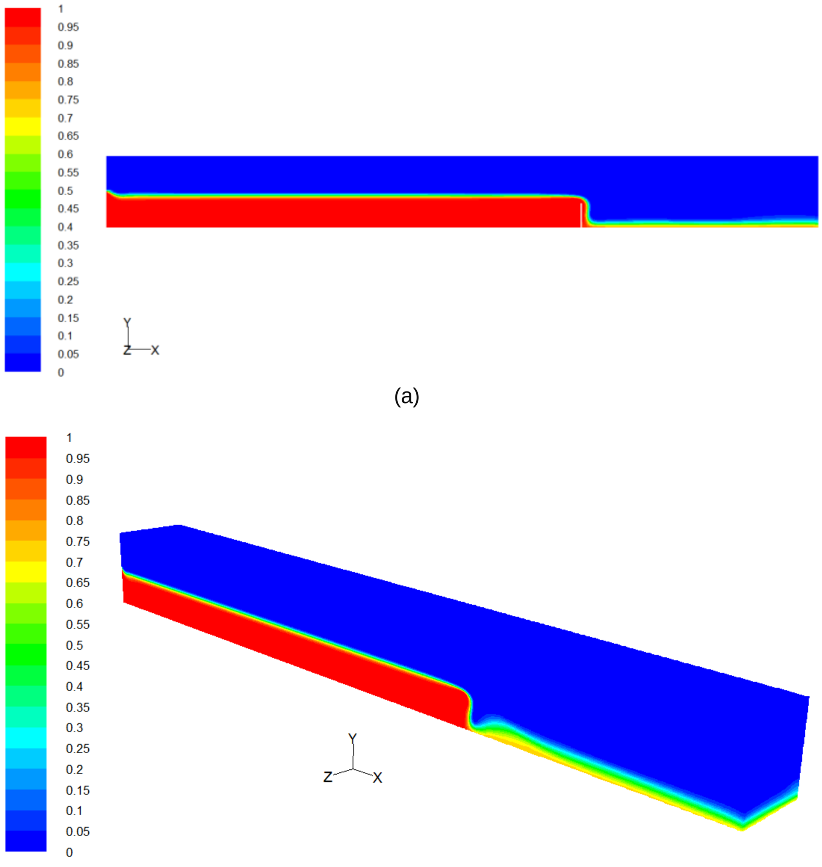
Table 1 displays the results of the experimental study of the tilted weir with different dimensions. It is clear that by increasing the angle of tilt, the amount of hd and C_d increased.

Table 1. Experimental values of hd and discharge coefficient (C_d) at different flow rates (v=0.23 m/s).

A, m	B, m	W, m	hd, m	hd/W	C_d
0.2000	0.2000	0.2000	0.12	0.480	0.6470
0.2000	0.1750	0.1875	0.1100	0.550	0.6578
0.2000	0.1500	0.1750	0.1050	0.525	0.6563

Fig. 5 a and b shows the water surface profile at Z= 0 and whole of the channel. As seen, the CFD can accurately enable to predict the flow discharge and water surface profile. Accordingly, after passing flow through the weir, the contours of water surface changes which is shown the mixture of air and water.

The velocity contour and vectors passing through the weir are shown in Figs. 6 and 7, respectively. Based on Fig. 6, the vortex area with return velocity vectors is found downstream of the weir. Moreover, return velocity vectors increase near the weir. Approaching the weir, the velocity vectors start to increase almost over the weir and reach a uniform distribution at the end of the vortex region. This uniform distribution of velocity continues until the end of the channel, approximately. In the center of the vortex region, the velocity tends to almost zero value. Also, upstream of the weir, a stagnant area with smaller dimensions compared to the vortex area after the weir is seen.



(a)

(b)

Fig. 5. Contour of water inside the flume (a=0.2 m, b=0.2 m) (a) at the slice of Z=0, and (b) Whole of flume.

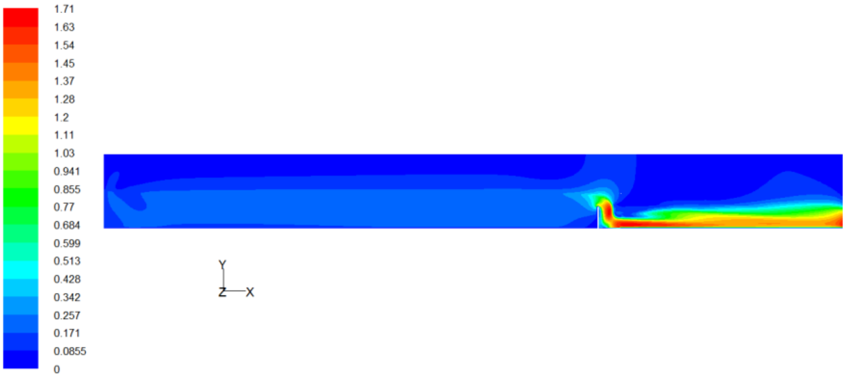


Fig. 6. Velocity contour of water flow inside the flume at the slice of Z=0 (a=0.2 m, b=0.2 m) (a) (V_{inlet}=0.14 m/s).

The pressure contours and its modelling at the velocity of 0.14 m/s is shown in Fig. 8 (a-b). The pressure values are divided into two major parts before and after the weir. Before the weir, when the height of the upstream water is high, naturally the pressure values are also maximum equal to 2.56 kPa . Moreover, as can be seen, the pressure value before the weir has a positive value. But in the downstream part of the weir, the behavior of the structure is different for various angles of weir. Moreover, after the weir, the pressure values are negative which causes sedimentation in this section. As can be seen, the minimum pressure values move away from the weir and downstream with increasing angle. However, the at least pressure value is occurred in the weir location. The other noteworthy point is the considerable changes in the pressure values downstream of the weirs which is decreased highly. In general, it can be said that by increasing angle of weir to horizontal line, the pressure and sedimentation values are increased especially in the downstream of the weir.

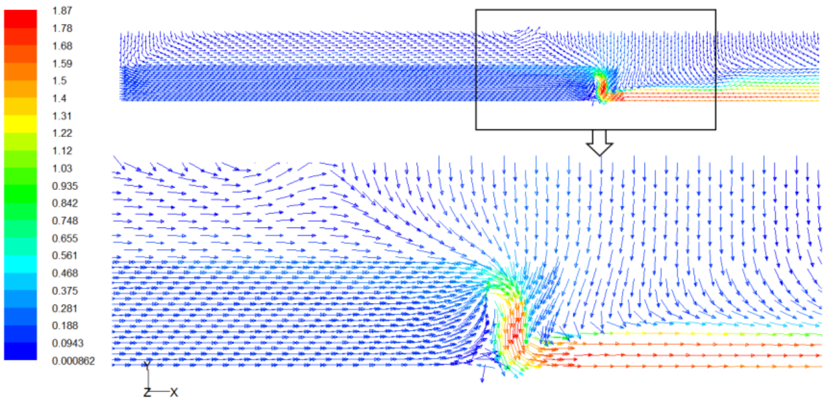
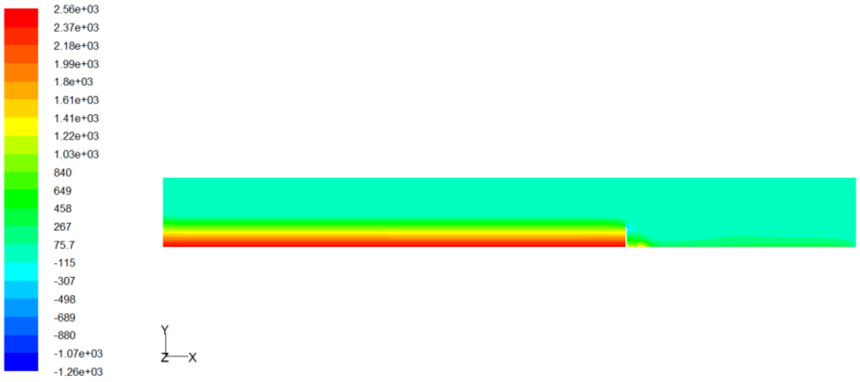
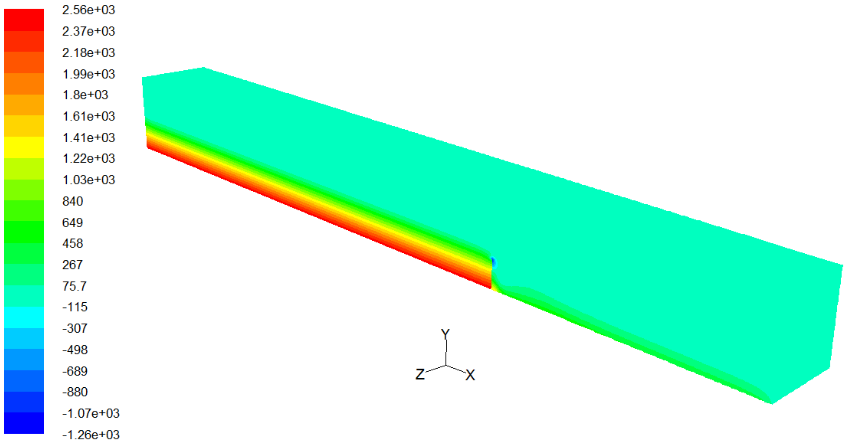


Fig. 7. Velocity vector of water flow inside the flume at the slice of Z=0 (a=0.2 m, b=0.2 m) (b) (V_{inlet}=0.14 m/s).



(a)



(b)

Fig. 8. Contour of pressure variation in the flume (a=0.2 m, b=0.2 m) (V_{inlet}=0.14 m/s), (a) (a): at the slice of Z=0, and (b) Whole of the flume.

Figs. 9 and 10 represents the change of C_d values in different Reynolds and Froude numbers. As figures shown, as the Reynolds number and Froude number increase, the discharge coefficient decreases and tends to a constant and fix number of 0.647.

In Fig. 11, C_d represents the discharge coefficient and hd represents the water height on the weir. The value of W corresponds to the average height of the tilted weir, which is different for each weir with a specific vertex angle. The hd/W ratio is used to compare the water head in dimensionless mode.

Table 2 shows the results of the numerical model of the tilted weir with different dimensions. As it is clear, by increasing velocity of water at inlet, the C_d values are decreased in all weir's angles. Moreover, in high velocity values, the C_d values have a less different which is in accordance with the CFD results that was observed in Fig. 9. Indeed, C_d is the actual flow ratio with the theoretical flow and makes allowances for flow contractions and friction impacts. The C_d is function of the Re while Re is the function of the velocity calculated using the discharge coefficient value. On the other hands, in all the velocity values, by decreasing the angle of weir to the flow direction, the discharge and C_d values is increased and tends to constant value. While, the pressure values are decreased. These findings are in accordance with the Borghei et al. (2003) results also.

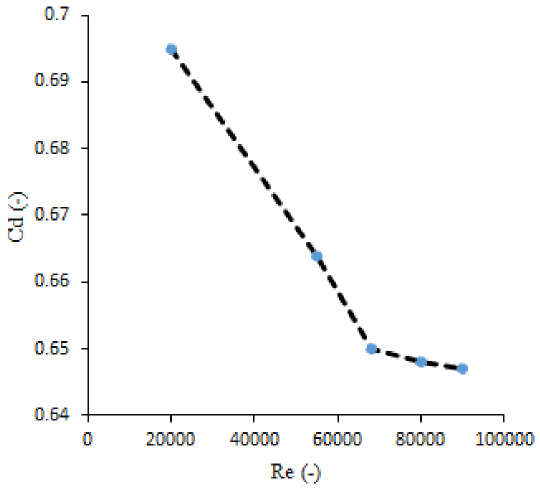


Fig. 9. Variation of C_d versus Reynolds number (a=0.2 m, b=0.2 m).

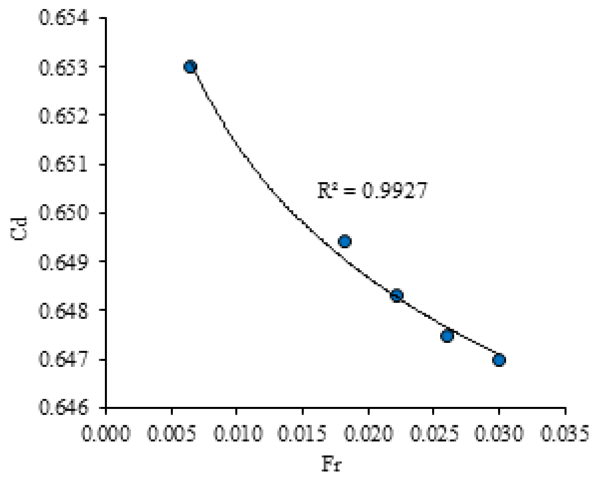


Fig. 10. Variation of C_d versus Froude number (a=0.2 m, b=0.2 m).

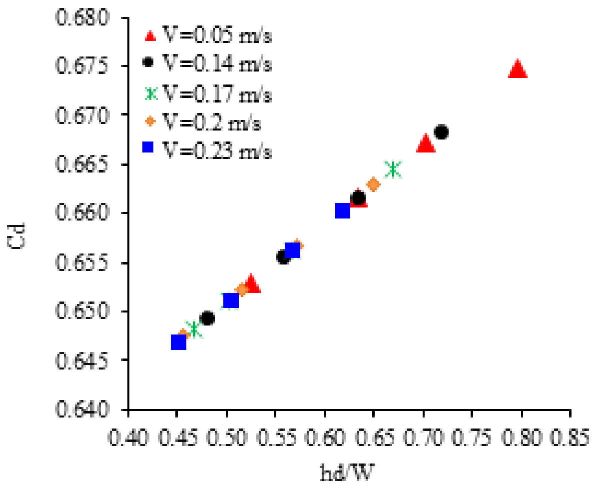


Fig. 11. Variation of C_d versus hd/W at different values of water inlet velocity.

3.2. Validation of CFD results

The C_d data obtained in CFD modeling was validated by experimental Cd which obtained by measurements at the different angles of weir from the experimental flume. An absolute relative error (ARE (%)) was calculated using the following Eq. (Azimi et al. 2021).

$$ARE(\%)=\frac{Expermental\ C_d\text{-}Numerical\ C_d}{Expermental\ C_d}\times 100 \tag{8}$$

The results of Table 3 shows that the maximum error obtained are 5.6 %, which indicates the high accuracy of the CFD model (v=0.23 m/s).

3.3. Outlook and future perspectives

To figure out the proposed weir with different angles, further investigations must be conducted based on change in the weir angle along the horizon and plan. Indeed, investigation of the effect of variation in the angle of weir respect to horizon in the tilted weir with different angle of the triangular part of the upper line can be interesting study.

3.4. Limitation of current work

The main limitation of the presented work can be in low velocity values when the turbulency of flow is low upstream of the weir. In this way, the flow height over the weir in a point (constant side of weir) is close to zero and the flow height in b point (variable weir height) is reached to the highest values. Accordingly, the flow situation downstream of the weir is turbulent. In low discharge values, cannot be trust to results easily. As for the velocity values in ranges of 0.05-0.23 m/s, the Cd value is ranged in 0.64-0.675. Finally, as the Reynolds and Froude number increase, the discharge coefficient decreases and tends to a constant number of 0.65 approximately.

Table 2. Numerical values of h_d and discharge coefficient (C_d) at different flow rates.

		V=0.05 m/s			
a	**b**	**W, m**	**hd**	**hd/W**	**C_d**
0.2000	0.2000	0.2000	0.1050	0.5250	0.6530
0.2000	0.1750	0.1875	0.1188	0.6336	0.6617
0.2000	0.1500	0.1750	0.1229	0.7023	0.6672
		V=0.14 m/s			
a, m	**b, m**	**W, m**	**hd, m**	**hd/W**	**C_d**
0.2000	0.2000	0.2000	0.0960	0.4800	0.6494
0.2000	0.1750	0.1875	0.1045	0.5573	0.6556
0.2000	0.1500	0.1750	0.1108	0.6331	0.6617
		V=0.17 m/s			
a, m	**b, m**	**W, m**	**hd, m**	**hd/W**	**C_d**
0.2000	0.2000	0.2000	0.0932	0.4660	0.6483
0.2000	0.1750	0.1875	0.0942	0.5024	0.6512
0.2000	0.1500	0.1750	0.0992	0.5669	0.6563
		V=0.20 m/s			
a (m)	b (m)	W (m)	hd (m)	hd/W	C_d
0.2000	0.2000	0.2000	0.0912	0.4560	0.6475
0.2000	0.1750	0.1875	0.0967	0.5157	0.6523
0.2000	0.1500	0.1750	0.1001	0.5720	0.6568
		V=0.23 m/s			
a (m)	b (m)	W (m)	hd (m)	hd/W	C_d
0.2000	0.2000	0.2000	0.0899	0.4495	0.6470
0.2000	0.1750	0.1875	0.0942	0.5024	0.6512
0.2000	0.1500	0.1750	0.0992	0.5669	0.6563

Table 3. Comparison between the CFD-predicted C_d and experimental C_d.

a	**b**	**Experimental Cd**	**Numerical Cd**	**Error, %)**
0.2	0.2	0.6602	0.6470	2.08
0.2	0.175	0.6578	0.6512	1.003
0.2	0.15	0.6534	0.6563	0.4405

4. Conclusions

In this research, the performance of vertical weirs with tilted geometry with different angles of the weir crest throughout the flow direction was investigated numerically and experimentally. Accordingly, the experiments were done for three different weir heights as 20-20, 20-17.5 and 20-15 cm weir heights. These changes in weir heights are along the width of channel. Moreover, five different hydraulic characteristics with different flow discharges were used in the experimental work for each weir height. The most essential parameter of discharge equation of this type of weirs is the discharge coefficient. CFD modeling was done with fluent software, and in order to model turbulence, RNG model and two-phase VOF method were used to determine the position of the open water surface profile. The results showed that the CFD results have good conformity with experimental results with error index of 2.8 %, 1.005 %, and 0.44 % for 20-20, 20-17.5, and 20-15 cm weir heights, respectively. Moreover, with the increase of the angle of the weir crest throughout the flow (α), the discharge coefficient (C_d) results are almost constant. The vortex area with return velocity vectors was found downstream of the weir. Return velocity vectors increased near the weir. Approaching the weir, the velocity vectors started to increase almost over the weir and reached a uniform distribution at the end of the vortex region. In the center of the vortex region, the velocity reached almost zero value. Also, upstream of the weir, a stagnant area with smaller dimensions compared to the vortex area was seen. Finally, CFD data showed that as the Reynolds number and Froude number were increased, the discharge coefficient decreased and tends to a constant number of 0.65 approximately.

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