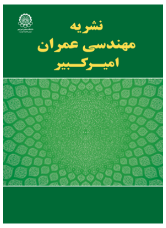

Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(5) (2021) 387-390
DOI: 10.22060/ceej.2019.16931.6399

Investigation of the Stage-Discharge Relation and Discharge Coefficient in Sharp-Crested Weirs with Triangular Shape in Plan

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ABSTRACT: The triangular in plan sharp-crested weirs do not have a direct and straight edge and are in good agreement with the broken line. The present study aims to provide an equation for discharge coefficient (C_d) for these types of weirs. Cd is between 0.53-0.88 based on the observed data. For α=15 degrees Cd has the highest value and thus weir can convey maximum discharge. Using laboratory data based on h/p and α parameters, a regression equation was presented. The results of the regression equation were compared with the results of the numerical model (Ansys Fluent) and the results showed the high precision of this equation. Ansys fluent software works based on the finite volume method. The numerical simulation is 3D. In addition, the performance of MR-Linear and MR-nonlinear regression models on the application of the stage-discharge equation the triangular in plan sharp-crested weirs were investigated and indicated that the result of this equations is very similar to results of the experimental data. The results also showed that due to the angle of the triangular in plan sharp-crested weirs, the Cd is increased from 1 to 8 % to the suppressed weir. In a situation where the head on the crest of these weirs is low, they will show better performance.

Review History:

Received: Jul. 29, 2019
Revised: Oct. 12, 2019
Accepted: Oct. 19, 2019
Available Online: Oct. 30, 2019

Keywords:

Triangular in plan sharp-crested weirs
Discharge coefficient
Stage-discharge
Ansys fluent

1- Introduction

There are many methods to measure the inflow of water into the channels and also to control the water level. The most common of these methods are weirs, flumes, orifices, and measuring stations. Weirs are more commonly used because of their simple and relatively accurate relations. Weirs due to the simplicity of construction and economically are one of the most common measurement structures as well as water level regulation in canals and rivers [1]. The first studies on the design and hydraulic performance of labyrinth weirs were performed by Hey and Taylor [2], and Taylor [3] on models with triangular, rectangular, and trapezoidal geometrical shapes with sharp edges. Distefano and Ferro [4] studied the overflow process through a triangular shape in the plan and obtained the stage-discharge relation for this type of structure using dimensional analysis and similarity theory. Norouzi et al. [5] studied a comparative study of artificial neural networks and support vector machines to estimate the discharge coefficient of labyrinth weir. The performance of the MLP model with RMSE, R, and DC of 0.019, 0.985, and 0.971, respectively, was more acceptable and closer to the experimental data. In the present study, the performance of linear (MR-linear) and non-linear (MR-nonlinear) regression methods in determining the stage-discharge relation (correlation between h/P as a dimensionless quantity of stage and K_s/P as a dimensionless quantity of discharge) will be evaluated. Then, a numerical model will be developed using Ansys Fluent software to compare the results among the experimental results, the results of the proposed relationships in the present study, and the results of other researchers.

2- Methodology

To determine the discharge in a rectangular sharp edge weir, Eq. (1) is established. Where Q is the discharge parameter, L is the total weir crest length, h is the total upstream head, g is the gravity acceleration and Cd is the discharge coefficient. By simplifying Eq. (1), Eq. (4) is obtained.

$$Q = \frac{2}{3} C_d \sqrt{2g}\, L\, h^{\frac{3}{2}} \tag{1}$$

$$h = \left(\frac{9}{8\, C_d^{\,2}}\right)^{\frac{1}{3}} \left(\frac{Q^{\frac{2}{3}}}{L^{\frac{2}{3}} g^{\frac{1}{3}}}\right) \tag{2}$$

$$K_s = \left(\frac{Q^{\frac{2}{3}}}{L^{\frac{2}{3}} g^{\frac{1}{3}}}\right) \tag{3}$$

$$\frac{h}{P} = \left(\frac{9}{8C_d^{\,2}}\right)^{\frac{1}{3}} \left(\frac{K_s}{P}\right) \quad \rightarrow \quad C_d = \frac{3}{\sqrt{8}} \left(\frac{\frac{K_s}{P}}{\frac{h}{P}}\right)^{\frac{3}{2}} \tag{4}$$

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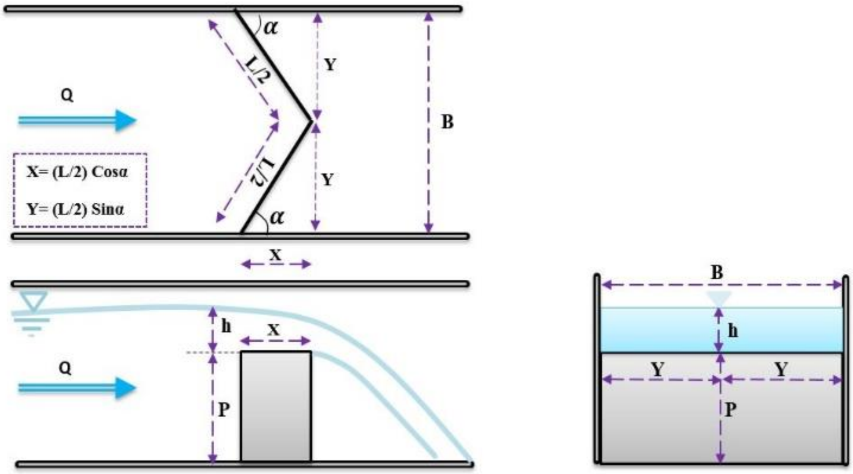

Fig. 1. Schematic sharp-crested weirs with triangular shape in plan

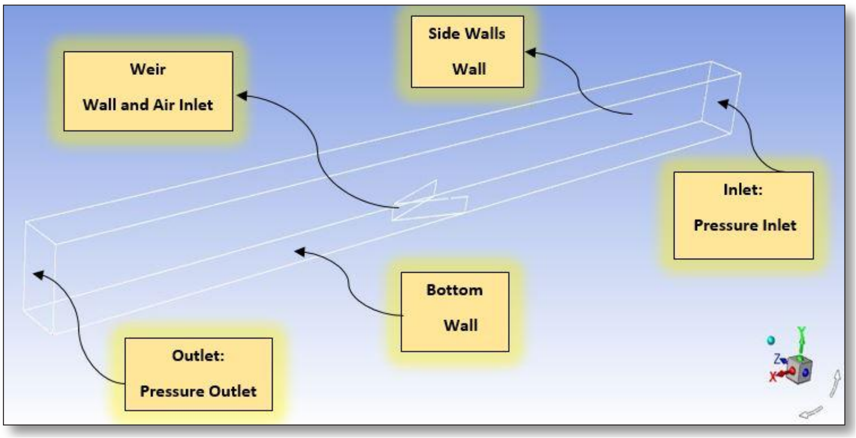

Fig. 2. Boundary conditions applied in the numerical model of the present study

For a triangular sharp-edged overflow shown in Fig. 1, the stage-discharge relation can be expressed in the form of Eq. (5):

$$\varnothing(h,\ Q,\ p,\ L,\ g,\ \mu,\ \rho,\ \sigma,\ B) = 0 \qquad (5)$$

Using Buckingham theory, Eq. (6) is derived:

$$\frac{h}{P} = f\left(\frac{K_s}{p}, \frac{L}{P}, Re, We, \frac{B}{L}\right) \qquad (6)$$

By simplifying the Eq. (6) and B/L=Sinα, Eq. (7) is produced:

$$\frac{h}{P} = \omega\left(\frac{K_s}{p}, \frac{L}{P}, \text{Sin}\alpha\right) \qquad (7)$$

Using the experimental results as observational data, a model similar to the laboratory conditions was developed. Numerical simulations were performed in the present study using the dimensions used under the experimental conditions in a 6 m long channel, 0.28 m wide, and 0.41 m high.

3- Results and Discussion

In the present study, the relations of linear multiple regression and nonlinear multiple regression were extracted using the experimental data presented in Table 1. The nonlinear multiple regression model with a high correlation coefficient (R2) and low relative error rate (RE %) has a high accuracy compared to linear multiple regression.

As the angle increases, the relation between two parameters h/P and Ks/P becomes out of proportion and tends to a linear relation. When the angle is 90 degrees, the geometry of the weir from the triangular plan to the weir of the channel is changed. Regarding angular data of 15 to 75 degrees, high precision regression relation was extracted between the three parameters h/P, Ks/P, and sinα in the form of Eq. (8). In Eq. (8), sinα was used instead of α, where α is in degrees

$$\frac{K_s}{p} = 0.66 \times \left(\frac{h}{P}\right)^{0.878} \times (\text{Sin}\alpha)^{0.04} \qquad (8)$$

Table 1. Linear and nonlinear regression equations

Relation	$RE\%$	R^2
$\frac{h}{P}=1.505\times\left(\frac{k_s}{p}\right)+0.006\times\alpha-0.031\times\left(\frac{P}{L}\right)-0.031$	4.16	0.986
$\frac{h}{P}=1.568\times\left(\frac{k_s}{p}\right)^{1.104}\times\alpha^{-0.023}\times\left(\frac{P}{L}\right)^{0.003}$	4.09	0.987

Table 2. Comparison between the results of the proposed relationships in the present study with the numerical and laboratory models

α°	P (m)	h (m)	h/p	Experimental Q (Lit/s)	Numerical Q (Lit/s)	Eq. (12) Q (Lit/s)
15	0.092	0.0142	0.0757	1.972	2.201	2.014
15	0.092	0.0252	0.1059	3.263	3.588	3.169
15	0.092	0.0371	0.15	5.493	4.981	3.613
15	0.092	0.0523	0.197	8.271	8.78	9.464
15	0.092	0.069	0.237	10.296	11.75	12.11
45	0.103	0.0142	0.138	1.492	1.353	1.491
45	0.103	0.0252	0.245	3.468	3.1509	3.176
45	0.103	0.0371	0.36	6.085	3.892	5.277
45	0.103	0.0523	0.507	9.063	8.517	8.295
45	0.103	0.0691	0.6701	12.084	13.265	11.951

By combining the two Eq. (4) and Eq. (8), the Eq. (9) can be derived for the discharge coefficient of the triangular sharp-edged weirs plan in the following form:

$$\mathrm{C_d}=0.568\times\left(\frac{\mathrm{h}}{\mathrm{P}}\right)^{-0.183}\times\left(\mathrm{Sin}\alpha\right)^{0.06} \tag{9}$$

Given the value of the discharge coefficient of Eq. (9), it is possible to calculate the value of the discharge through the triangular sharp-edged weirs using the general relation of weirs (Eq. (10)):

$$Q=2/3\times(0.568\times(h/P)^{(-0.183)}\times(Sin\alpha)^{0.06})\times\sqrt{2g}\times L\times h^{(3/2)} \tag{10}$$

Table 2 compares the proposed relationship in the present study (Eq. (10)) with the numerical model and the experimental results in estimating the discharge of triangular sharp-edge overflows at angles of 15 and 45 degrees, respectively. As can be seen with a relative error of about 10%, the proposed equation (Eq. (10)) can estimate the discharge.

4- Conclusion

In the current study, using laboratory data, the discharge coefficient and the stage-discharge relationship in triangular sharp-edged weirs were investigated. Numerical simulation was also performed by Ansys-Fluent software. The performance of MR-Linear and MR-Nonlinear regression models on the application of the stage-discharge relation of triangular sharp-edged weirs was also investigated. Laboratory data were used for this purpose. The obtained values were compared with the models with the extraction relation of Distefano and Ferro [4] and the laboratory data of Kumar et al. [6] Also, a regression relation was derived for the discharge coefficient of triangular sharp-edged weirs using geometrical properties. This relation was compared with the extraction relations of other researchers and the results of the Fluent Numerical Model that give relatively good results. The discharge coefficient in triangular plan weirs can be increased from 1 to 8% (depending on the angle α) relative to the suppressed weir, so these weirs can pass more discharge.

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HOW TO CITE THIS ARTICLE

B. Nourani, R. Norouzi, F. Rezaei, F. Salmasi , Investigation of the Stage-Discharge Relation and Discharge Coefficient in Sharp-Crested Weirs with Triangular Shape in Plan, Amirkabir J. Civil Eng., 53(5) (2021) 387-390.

DOI: 10.22060/ceej.2019.16931.6399