International Journal of Advance Research in Science and Engineering
Volume No.06, Special Issue No.(03), December 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

DISCHARGE COEFFICIENT FOR SIDE COMPOUND WEIRS IN OPEN CHANNEL

Ali Shariq[1], Ajmal Hussain[2],Mujib Ahmad Ansari[3]

[1] Research Scholar, Department of Civil Engineering, Zakir Hussain College of Engineering & Technology, Aligarh Muslim University, Aligarh, U.P., (India)

[2] Assistant Professor, Department of Civil Engineering, Zakir Hussain College of Engineering & Technology, Aligarh Muslim University, Aligarh, U.P., (India)

[3] Professor, Department of Civil Engineering, Zakir Hussain College of Engineering & Technology, Aligarh Muslim University, Aligarh, U.P., (India)

ABSTRACT

A side compound sharp crested weir is a flow diversion structure provided in one or both side walls of a channel to spill/divert water from the main channel Experimental programme for this study were conducted in Advance Hydraulic Laboratory of Department of Civil Engineering, Aligarh Muslim University, India. Dimensional analysis is carried out to estimate the functional relationship for the coefficient of discharge for side compound weir. It is found that the coefficient of discharge depends on the approach flow Froude number, the ratio of the weighted crest height of the side weir to the length of the side weir and the ratio of the upstream depth in the channel to the length of side weir. On the basis of F-test, it is observed that $\overline{P}/L$ is the most significant parameter for the prediction of C_d. The developed relationship using regression approach for the coefficient of discharge for side compound weir gives root means square error is 0.0634. The performance of the present model is based on the coefficient of correlation of the non-linear regression line between predicted values from the present model and desired output (R=0.8609), average percentage error (APE=-2.356), Absolute average deviation (AAD=13.406), Standard deviation (STDV=10.13) and scattering index (SI=0.1675).

Keywords: Coefficient of discharge, Side compound weir, Froude number, Rectangular channel

I.INTRODUCTION

A side weir is a flow diversion structure, which is widely used in irrigation, environmental and hydraulic engineering as a head regulator of distributaries and escapes. Side weirs are also used in channel systems river-control structures, irrigation canals, water and wastewater-treatment plants and for storm water overflow from urban drainage systems. Other hydraulic structures used to divert flow are weirs (Ramamurthy et al. [1]); spillways, sluice gates (Swamee et al. [2]); orifices (Hussain et al. [3]), [4], [5]) etc. The flow over a side compound weir is a special case of spatially varied flow. A side weir is designed to divert a certain amount of flow, and therefore knowing an accurate flow is important.

Due to the use of numerous geometric and hydraulic shapes of the side weir, and the various cross sections of channel in which the compound weir is placed, extensive research work has been conducted from various points view for numerous types of side weir. Most of the earlier experimental studies and theoretical analyses were limited to the flow over side weirs in rectangular channel (e.g., De Marchi [6], Emiroglu et al. [7]), triangular channel (Vatankhah [8]), trapezoidal channel (Vatankhah [9]), and circular main channels (Uyumaz and Muslu [10]). Normally weirs are rectangular in shape and have a restriction in cases where there is a need to divert flow varying from high to low -water levels. Therefore, a new shape of side weirs have been presented known as side compound weirs.

Some researchers have studied flow hydraulics in compound normal weirs, which are built across the channel. The first of them was the work of USBR [11], Martinez et al. [12] and Jan et al. [13] on different shapes of compound weirs. Their study describes the calibration and design of a normal compound sharp-crested weir consisting of two triangular parts with various notch angles. Rahimpour M. et al. [14] used experimental and theoretical approach to estimate the best flow of trapezoidal side weir under subcritical flow conditions. Aydin M. C. [15] studied the water surface profiles of the (triangular labyrinth side weirs) to describe the flow characteristics in the case of sub-critical flow, using CFD with Fluent code. They compared the discharge coefficients found from CFD results with experimental data of Aydin et al [16]. Zahiri et al. [17] carried out an experimental study on a rectangular compound side weir with variable heights and widths. They found that the discharge coefficient of compound side weirs has a high correlation with three dimensionless parameters including upstream Froude number (F_1), ratio of weighted crest height to upstream flow depth ($\overline{P}/y_1$) and the ratio of weir length to upstream flow depth (L/y_1).

The present study conducted laboratory experiments on free flow over side weirs that are composed of three rectangular weir. The lower weir is suitable for diversion and measurement of low-flow discharges, while the upper sections are appropriate for high-flow discharges. The main advantage of this special kind of side weir is that overflow discharges are measured and regulated with a reasonable sensitivity over wide flow ranges.

II.DIMENSIONAL ANALYSIS

There are different parameters involved in achieving the discharge coefficient of side compound weir. The physical characteristics of the experimental condition could be mentioned such as average velocity of flow over the cross section of the basin (V), upstream depth of flow in channel (y_1), acceleration due to gravity (g), crest length of side weir (L), width of main channel (B), weightedcrest height of side weir ($\overline{P}$), dynamic viscosity of water (μ) and density of water (ρ).The schematic view of side compound is shown in Fig. 1.Due to different crest heights of upper and lower weirs in a compound weir, the crest height should be replaced with the weighted crest height $\overline{P}$ as following

$$\overline{P} = \frac{w_1 L_1 + w_2 L_2 + w_3 L_3}{L}$$

Where, w_1, w_2, w_3, L_1, L_2 and L_3 are the parts of side compound weir as shown in Fig. 1.

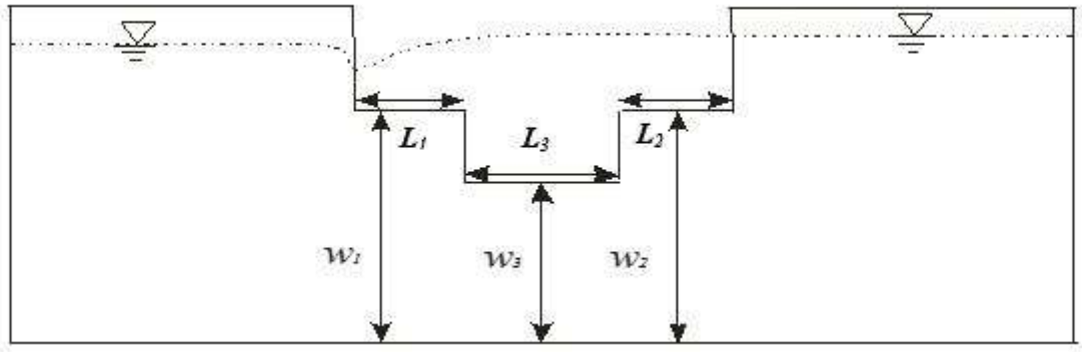


Fig. 1: Schematic view of side compound weir

The functional relationship for the compound side weir may be expressed as

$$C_d = f\left(\overline{P}, L, B, g, V, y_1, \rho, \mu,, L\right) \quad (1)$$

Non-dimensional equations in functional forms can be written as below:

$$C_d = f\left(\overline{P}/L, B/L, y_1/L, F_1, \mu/\rho VL\right) \quad (2)$$

So that F1 represents the approach flow Froude number. Influence of the Reynolds number, Re=PVL/μ is relatively insignificant, and B/L is constant in the present study, hence, may be dropped from Eq. (2). The final functional relationship for Cd may, therefore, be expressed as

$$C_d = f\left(\overline{P}/L, y_1/L, F_1\right) \quad (3)$$

To see the effect of various parameters on the coefficient of discharge, Cd and to establish relationship among the dependent and independent parameters of Eq. (3), experimental programme are carried out in present study.

III.EXPERIMENTAL PROGRAME AND ANALYSES

1. Set-up and working principle

Experimental programs have been carried out in the Advanced Hydraulics laboratory of Department of Civil Engineering, Zakir Hussain College of Engineering & Technology (A.M.U.), Aligarh, India. The schematic representation of experimental set-up i.e. plan are shown in Fig. 2. The set-up consisted of a main channel and diverted channel. The length, width and height of main channel were 12.8 m, 0.29 m and 0.39 m, respectively. From the upstream end of the main channel at a distance 8.20 m, the side compound weir was provided in the right wall of the main channel. Discharge through the side weir was passed into a diversion channel of length, width and height were 4.18 m, 0.2 m width and 0.35 m, respectively and, then, move to a return channel. Discharge flowing through the side weir (Q_3) was measured by a rectangular sharp-crested weir-A_2 provided at the end of diversion channel. The total discharge measured by a rectangular sharp-crested weir-A_1 was provided at the end of the channel. Height of weir-A_1 and weir-A_2 are 20 cm and 10 cm respectively. Weir-A_1 and weir-A_2 were calibrated using well. Theoretical discharge through side compound weir has been calculated as Zahiri et al. [17].

In the present work four different weighted crest height i.e. 11.5 cm, 12.5 cm, 13.5 cm and 15.0 cmof side compound weir have been used. The width of each side weir was 20 cm. All side weirs were placed in the groove and levelled with wall of channel.

For each set of $\overline{P}$ twenty three to twenty five discharge Q_1 in the main channel were measured. The nappe were fully ventilated during the experimentation. Experiments were performed under free flow through the side weir and conducted under subcritical flow conditions only. The range of data collected in the present work have been listed in Table 1.

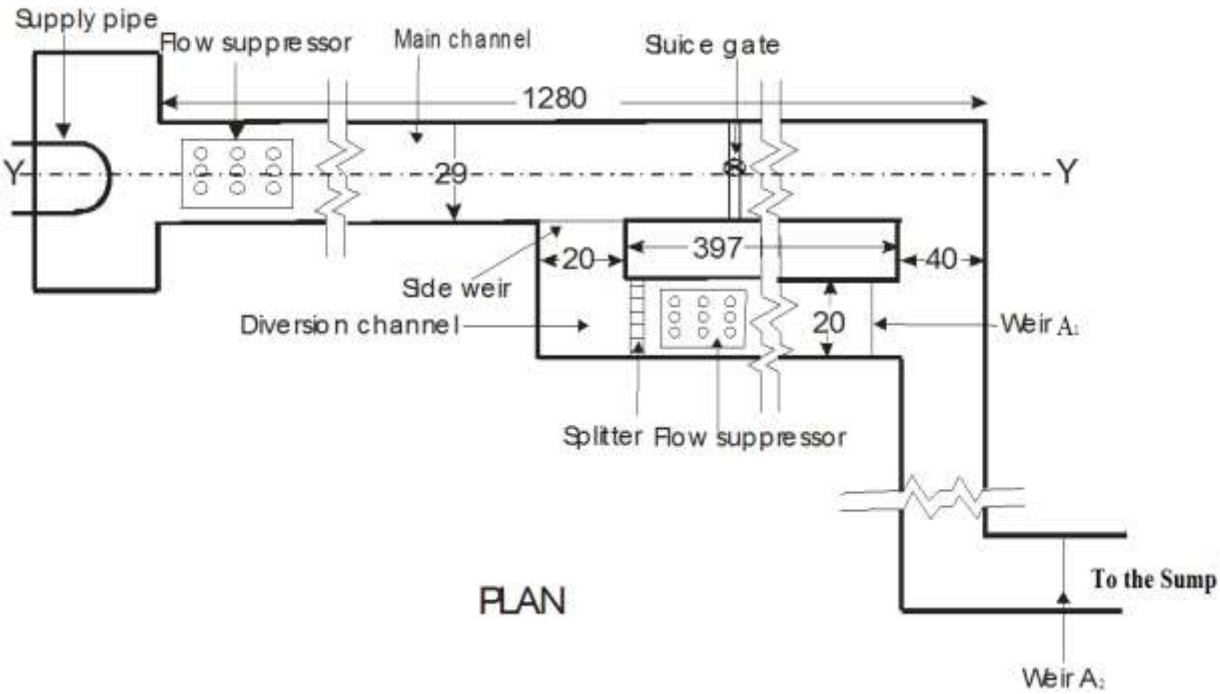


Fig. 2 Layout of the experimental setup

Table 1: Range of data collected for side weir in the present study

Parameter	Unit	Range of data	
		Min.	Max.
Q_1	m^3/s	0.0028	0.0780
Q_3	m^3/s	0.002	0.031
B	m	0.39	0.39
y_1	m	0.125	0.340
L	m	0.20	0.20
$\overline{P}$	m	0.115	0.15
F_1	-	0.003	0.531

2. F-Test

To seek the importance of different independent parameter in predicting Coefficient of discharge, feature selection and parameters screening i.e. F-test have been carried out. When F-value of any variable compared to the F-value of other variable is very low. Then the least F value variable is dropped because this variable is considered as not affecting the whole value of the equation (Hussain et al. [18], Lomax [19]). All the three variables of Eq. (3) were taken for feature selection and variable screening process with Cd as dependent variable. The effect of different dimensionless variable i.e., $\overline{P}$/L, Y_1/L and F_1 on the coefficient of discharge (C_d) was examined by F-Test is shown in Fig. 3. Figure 3 shows that $\overline{P}$/L possesses a high F-value i.e. it is the most effecting variable followed by Y_1/L and F_1.

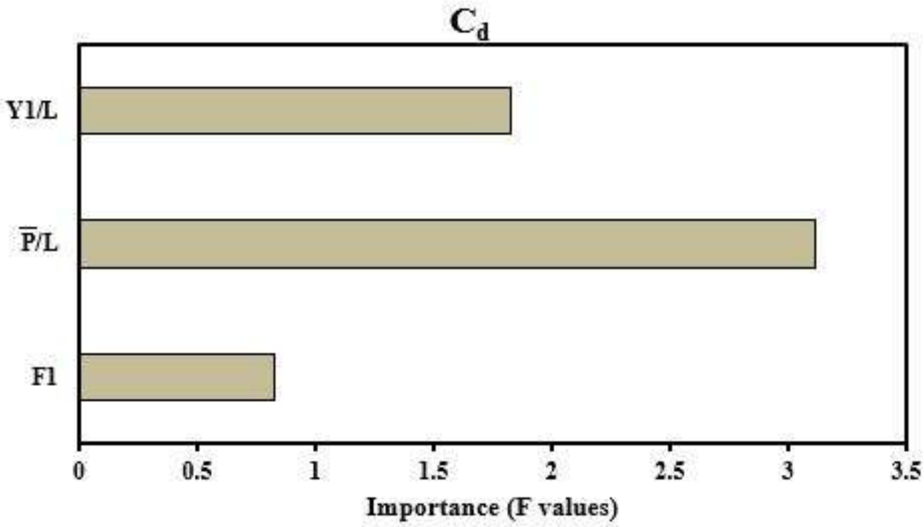


Fig. 3 Importance of various independent inputs in predicting output (C_d)

3. Effect of various parameters on coefficient of discharge

The effect of the dimensionless parameter $\overline{P}/L$, y_1/L, B/L and F_1 as obtained by dimensional analysis on this computed C_d is examined. A thorough data analysis reveals that F_1, $\overline{P}/L$ and y_1/L is the predominant parameters which can affect the C_d. For the range of data used in present study, C_d is unaffected by parameter B/L. Variation of C_d with upstream Froude number is shown in Fig. 4, which clearly indicates a decrease in C_d with increase of F_1. Variation of C_d with y_1/L is shown in Fig. 5, which clearly indicates an decrease of C_d with increase of y_1/L. Variation of C_d with $\overline{P}/L$ is shown in Fig. 6, which clearly indicates a increase of C_d with increase of $\overline{P}/L$.

IJARSE
ISSN: 2319-8354

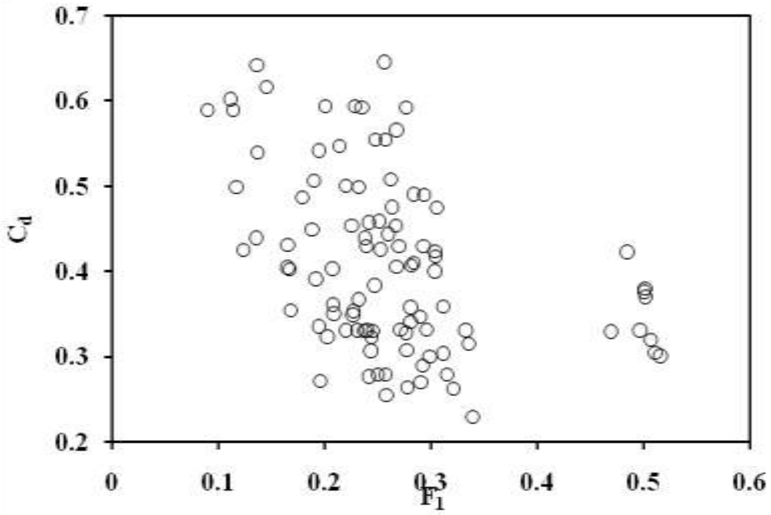


Fig. 4 Variation of C_d with upstream Froude number

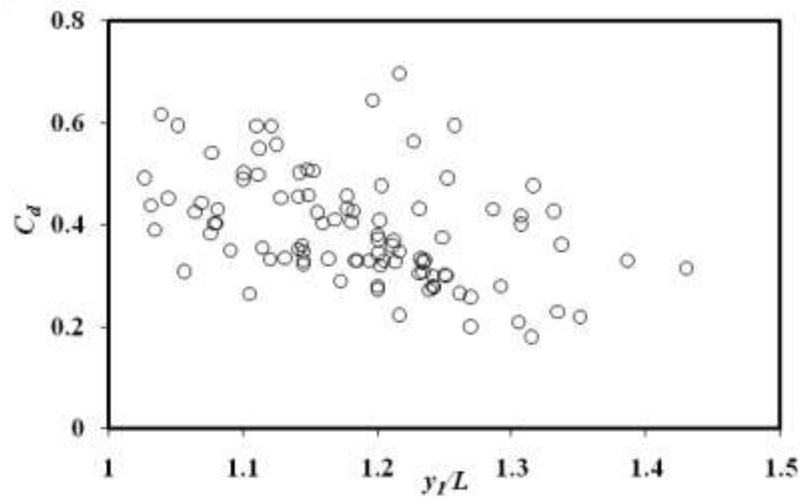


Fig. 5 Variation of C_d with y_1/L

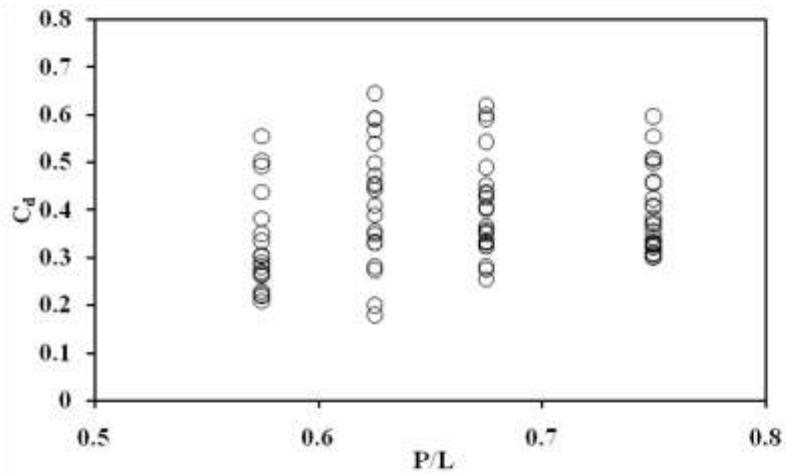


Fig. 6 Variation of C_d with $\overline{P}/L$

International Journal of Advance Research in Science and Engineering
Volume No.06, Special Issue No.(03), December 2017
www.ijarse.com

IJARSE
ISSN: 2319-8354

IV.RESULT AND DISCUSSION

The present study is aimed at to compile the past observations on coefficient of discharge for side compound sharp crested weir, supplement them with new experimental results pertaining to effect of $\overline{P}/L$, y_1/L and F_1 on C_d and reanalysing resulting data bases by applying the technique of non-linear regression analysis with a view towards seeing if better prediction are possible. On the basis of the dimensional analysis (Eq. 3) and the existing relationships, C_d can be expressed in the following linear model form:

$$C_d = k_1 + k_2\left(\overline{P}/L\right) + k_3(F_1) + k_4\left(y_1/L\right) \tag{4}$$

where k_1, k_2, k_3 and k_4 are constant. Using the available experimental data the values of constant k_1, k_2, k_3 and k_4 of above equation may be computed. Regression analysis has been carried out to obtain the values of constant k_1, k_2, k_3 and k_4 for the prediction of coefficient of discharge of side compound sharp crested side weir, in which 80% of the available data were selected randomly and contains maximum and minimum values. Following equation for the prediction of coefficient of discharge of side compound sharp crested weir has been obtained.

$$C_d = 0.738 + 0.899\left(\overline{P}/L\right) - 0.785(F_1) - 0.231\left(y_1/L\right) \tag{5}$$

Observed and calculated values of coefficient of discharge of rectangular sharp crested weir using *Eq. (5)* or the test data are compared graphically in *Fig.7*, which revealed that the computed discharge is within ±10% of the observed ones, which is a satisfactory prediction of coefficient of discharge for side rectangular sharp crested weir. The qualitative comparison in terms of the performance parameters such as coefficient of correlation of the linear regression line between predicted values from the present model and desired output *(R)*, mean absolute percentage error (*MAPE*), and root means square error (*RMSE*) is shown in Table 2 for proposed relationship.

Table 2 Performance parameters of proposed models

Source		**Performance**							
		R	**APE**	**MAPE**	**AAD**	**RMSE**	**STDV**	**E**	**SI**
Proposed Eq. 5	Training	0.860	-2.356	14.284	13.406	0.0634	10.130	0.741	0.1675
	Testing	0.8207	-1.391	14.175	14.263	0.0733	9.7268	0.662	0.1799
	All	0.8609	-2.356	14.284	13.406	0.0634	10.130	0.741	0.1675

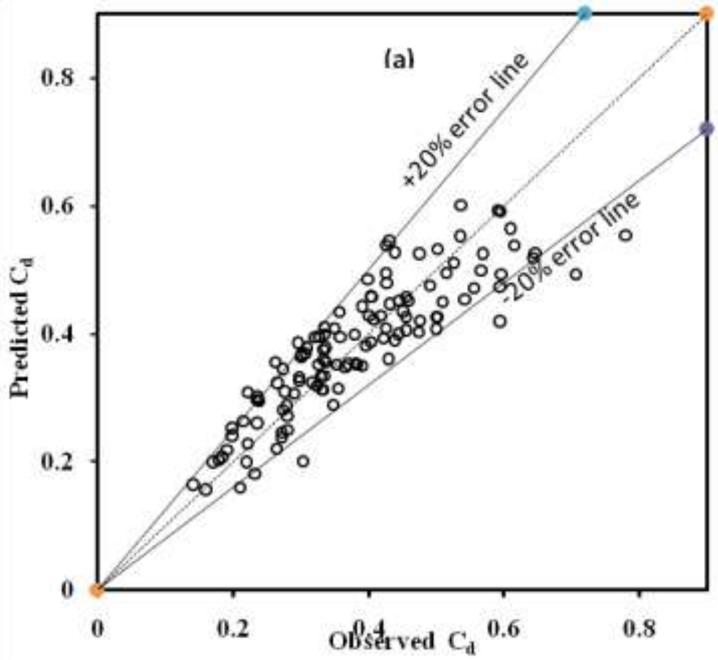
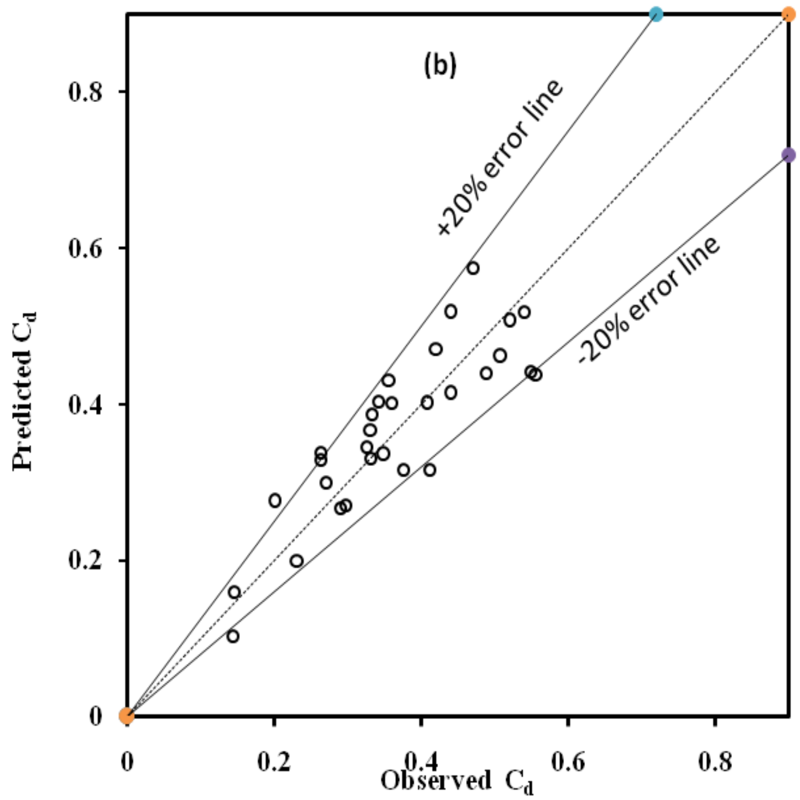


Fig. 7(a) Comparison between computed and observed values of $C_{d.}$ using present model for Training



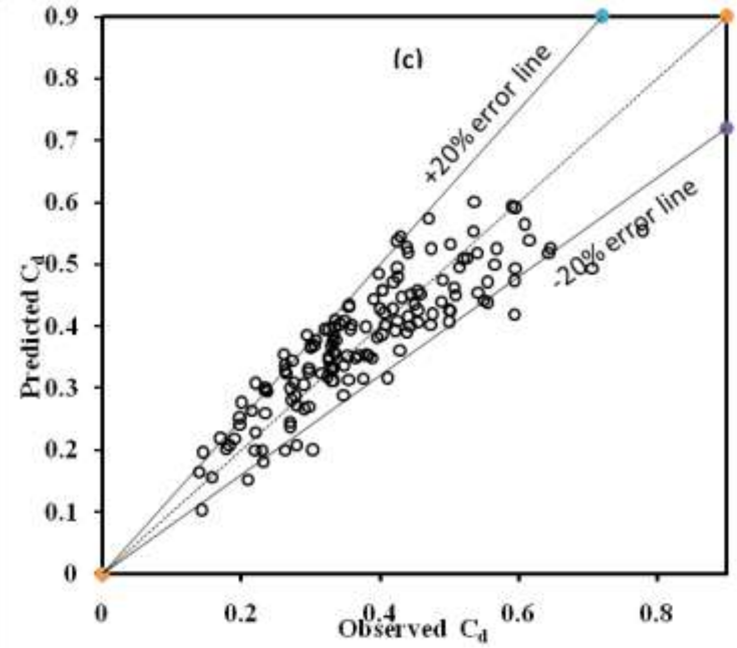


Fig. 7 Comparison between computed and observed values of C_d. using present model (b) Validation (c) All data set

V.CONCLUSIONS

In this study, an experimental investigation was performed to evaluate the discharge coefficient of side compound weir. Variation of C_d with Froude number which clearly indicates the decrease of C_d with increase of Froude number. It should be noted that the ratio of weighted crest height to crest lenght is an important parameter in the flow over a side weir. Therefore, its effect on C_d for side weir is apparent. The variation of C_d with $\overline{P}/L$ indicates C_d increases as $\overline{P}/L$ increase. The variation of C_d with Y_1/L indicates that C_d is inversely proportion to Y_1/L. Coefficient of discharge value decreases with increase of upstream Froude number which shows that coefficient of discharge is inversely proportional to upstream Froude number. Observed and calculated values of coefficient of discharge of side compound sharp crested weir using *Eq. (5)* for the test data are compared graphically, which revealed that the computed discharge is within ±20% of the observed ones, which is a satisfactory prediction of coefficient of discharge for side compound sharp crested weir. The proposed equation in found to produce results with a maximum error of ±20% for almost 100% of the total data. The qualitative performance of the present predictor indicates that it has lowest MAPE (14.284), RMSE (0.0634) and highest R (0.8609) as compared to other existing predictors.

REFERENCES

[1] Ramamurthy, A.S., Udoyara, S.T., Serraf, S. Square Lateral orifices in open channel. Journal of Environmental Engineering 135(5), 1986, 292-298.

[2] Swamee PK, Pathak SK, Ali MS. Side-weir analysis using elementary discharge coefficient. J Irrig Drain Eng, ASCE, 120(4), 1994, 742–755.

[3] Hussain, A., Ahmad, Z., Asawa, G. L. Discharge characteristics of sharp-crested circular side orifices in open channels. Journal of Flow Measurement and Instrumentation, Elsevier. 21(3), 2010, 418-24.

[4] Hussain, A., Ahmad, Z., Asawa, G. L. Flow through sharp-crested square side orifices under free flow in open channels. Journal of Agricultural Water Management, Elsevier. 98(10), 2011, 1536-1544.

[5] Hussain, A., Ahmad, Z., Ojha. C.S.P. Analysis of flow through lateral rectangular orifices in open channels. Journal of Flow Measurement and Instrumentation, Elsevier 36(10), 2014, 32-35.

[6] De Marchi, G. Essay on the performance of lateral weirs. L Energia Electrica Milano, Italy, 11(11), 1934, 849–860.

[7] Emiroglu, M.E., Agaccioglu, H., Kaya, N. Discharging capacity of rectangular side weirs in straight open channels. Flow Meas. Instrum 22, 2011, 319–330.

[8] Vatankhah, A. Analytical solution for water surface profile along a side weir in a triangular channel. Flow Measurement and Instrumentation., 23 (1), (2012), 76–79.

[9] Vatankhah, A. New solution method for water surface profile along a side weir in a circular channel. J. Irrig. Drain. Eng. 10.1061/(ASCE) IR.1943 4774.0000483: 2012b, 948–954.

[10] Uyumaz A, Smith R. H. Design procedure for flow over side weirs. J Irrig Drain Engg, ASCE, 117(1): 1991, 79–90.

[11] United States Bureau of Reclamation (USBR). Compound weir study, Hydraulic Laboratory Report No. Hyd. 505: 1963, 34p.

[12] Martinez, J., Recca, J., Morillas, M.T., Lopez, J.G. Design and calibration of a compound sharp-crested weir. J. Hydraul. Eng., ASCE, 131 (2): 2005, 112–116.

[13] Jan, C.D., Chang, C.D., Lee, M.H. Discussion of ‘‘Design and calibration of a compound sharp-crested weir’’, by Martinez, J., Recca, J., Morillas, M.T., Lopez, J.G. J. Hydraul. Eng., ASCE, 132 (8): 2006, 868–872.

[14] Rahimpour, M., Keshavarz, Z., Ahmadi, M. Flow over trapezoidal side weir, Flow Measurement and Instrumentation, 22: 2011, 507-510.

[15] Aydin, M. C., CFD simulation of free-surface flow over triangular labyrinth side weir. Advances in Engineering Software, No.45, 2012, 159-166.

[16] Aydin, M. C., Emiroglu, M.E., Determination of capacity of labyrinth side weir by CFD. Flow Measurement and Instrumentation, No.29, (2013), 1-8.

[17] Zahiri A., Azamathulla H.M., Bagheri S. Discharge coefficient for compound sharp crested side weir in subcritical conditions. Journal of Hydrology, 480, 2014, 162-166.

[18] Hussain, A., Ahmad, Z., Ojha. C.S.P. Flow through lateral circular orifice under free and submerged flow conditions. Journal of Flow Measurement and Instrumentation, Elsevier. 36(10), 2016, 32-35.

[19] Lomax, R.G.. Statistical Concepts: A Second Course. Lawrence Erlbaum Associates, Mahwah, NJ, 2007.