e ISSN-0976-7223 | Visit Us - *www.researchjournal.co.in* DOI : 10.15740/HAS/IJAE/7.2/293-298

RESEARCH PAPER **International Journal of Agricultural Engineering | Volume 7 | Issue 2 | October, 2014 | 293–298**

Co-efficient of discharge variation for different semi-circular weirs

D. SAI GANGADHARA RAO, T.V. SATYANARAYANA AND H.V. HEMA KUMAR

Received : 18.06.2014; **Revised :** 18.07.2014; **Accepted :** 02.08.2014

See end of the Paper for authors' affiliation

Correspondence to :

D. SAI GANGADHARA RAO
Department of Agricultural Engineering and Technology, College of Agricultural Engineering, Bapatla, GUNTUR (A.P.) INDIA

ABSTRACT : Critical flow in control sections prevents the downstream water level and flow conditions from affecting the flow through the critical sections, and the discharge can be computed as a function of the measured upstream head. Measurements of irrigation water flows in field channels have usually been expensive, too often of questionable accuracy and otherwise difficult to apply to all field situations. The techniques available in open channel hygrometry are the use of hydraulic structures (devices), velocity-area methods, dilution techniques and slope-hydraulic radius and area methods. Considering the constraints in the measurements of low discharges in open channels, hydraulic structure technique is best suited. Crest height had been increased from 10 cm to 25 cm then the C_d values also decreased from 0.82 to 0.50 for discharge decreased from 24 to 6 Ls^{-1} under free flow conditions. The co-efficient of discharge for the different weirs under 60 per cent submergence conditions, if the increased crest height was from 10 cm to 25 cm then the C_d values also decreased from 0.75 to 0.43 for 24 to 6 Ls^{-1} discharge. Under 75 per cent submergence conditions, if the increased crest height was from 10 cm to 25 cm then the C_d values also decreased from 0.7 to 0.42 for discharge decreased from 24 to 6 Ls^{-1}. Under 90 per cent submergence conditions, if the increased crest height was from 10 cm to 25 cm then the C_d values also decreased from 0.69 to 0.42 for 24 to 6 Ls^{-1} discharge. For 24 Ls^{-1} discharge, the co-efficient of discharge has been decreased from 0.72 to 0.62 for increased submergence levels from 60 per cent to 90 per cent due to increase in contact surface area and friction and less discharge have low velocity of approach.

KEY WORDS : Flume, Weirs, Co-efficient of discharge, Crest height, Discharges

HOW TO CITE THIS PAPER : Rao, D. Sai Gangadhara, Satyanarayana, T.V. and Kumar, H.V. Hema (2014). Co-efficient of discharge variation for different semi-circular weirs. *Internat. J. Agric. Engg.*, **7**(2) : 293-298.

The enormous increase in cost for on–farm irrigation development due to indiscriminate use of all available water resources requires adoption of reasonable accurate water measurement in the field channels. The major problems encountered in measurement of discharges in field channels are the need to reshape the channels where the measurements have to be done and the errors in installation and measurement. Most of these problems can be eliminated by creating critical flow condition in these devises such as semi-circular crested weirs. Comprehensive review of studies dealing the simultaneous flow over weirs and below gates can be found in (Chow, 1959) as reported in (Negm *et al.*, 2002) and El-Saiad *et al.* (1995) investigated the effect of the notch angle of a triangular opening when it is used above and below the rectangular opening, they found that a triangular above a rectangular opening is more efficient than reversed. In Al-Hamid *et al.* (1997) discussed the effect of hydraulic and geometrical parameters on the combined discharge and presented discharge equations for triangular weirs above rectangular contracted gates and contracted rectangular weirs above triangular gates. They proved that the prediction of the combined discharge through the use of common discharge coefficients produces significant errors. The characteristics of the combined flow over the sharp – edged rectangular weir and below the sharp – edged rectangular gate with contractions was studied by (Negm *et al.*, 2002), they introduced a general dimensionless relationship for predicting the discharge of the combined device. Recently, Hayawi *et al.* (2009) investigated experimentally the free flow through a combined hydraulic measuring device consists of rectangular weir over a semi circular gate and pro-posed a model for predicting the discharge co-efficient through it. Mahboubeh *et al.* (2011) studied the effect of contraction on scouring in downstream of combined flow over weirs and below gates and various relationships characterizing the scour hole are found on the basis of experimental results. Ismail (2012) investigated the characteristics of the combined flow over sharp crested trapezoidal weir and below rectangular sluice gate and studied the effect of the hydraulic and geometrical parameters on the co-efficient of discharge and introduced two equations to evaluate it. The channel contraction may be formed either from the bottom or from the side contraction or from both. During the past decades, numerous types (sharp crested and broad crested) of flow measuring structures have been designed whose characteristics meet modern demands of accurate water measurement and regulation in water resources management, particularly in irrigation schemes and hydrological studies. The sharp crested weirs and broad crested weirs have their own advantages, disadvantages and limitations for use in specific field situations. Combining the advantages of sharp crested weirs and broad crested weirs and minimizing the disadvantages of both types of weirs, a semi-circular bottom contraction weir has been selected and used in the present study. The most effective way to obtain a good understanding of the flow measuring structures is providing the necessary basic principles and practical outlines to select the most appropriate structure for specific demands and to make the hydraulic design of a flow measuring structure.

■ METHODOLOGY

The experiments were conducted in Fluid Mechanics and Hydraulics Laboratory of College of Agricultural Engineering, Bapatla and Hydraulic flume (Plate A) of 10 m long and 0.3 m width with motorized bed slope alteration facility. Four semi-circular bottom contraction critical flow weirs with different crest heights (25 cm, 20 cm, 15 cm and 10 cm) have been developed on the design of simple flume for flow measurement in open channel proposed by Castro-Orgaz *et al.* (2008) (Fig. A) and tested under free flow and three different submergence levels (60, 75 and 90 %) with four different discharges (24 Ls^{-1}, 18 Ls^{-1}, 12 Ls^{-1} and 6 Ls^{-1}).

Plate A : Hydraulic flume used for experimentation

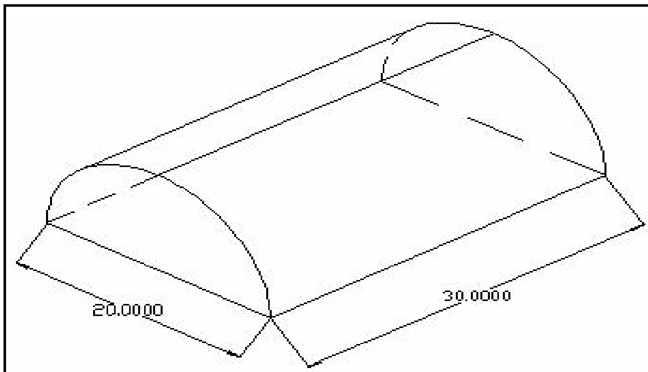

Fig I : Crest height of weir 10 cm

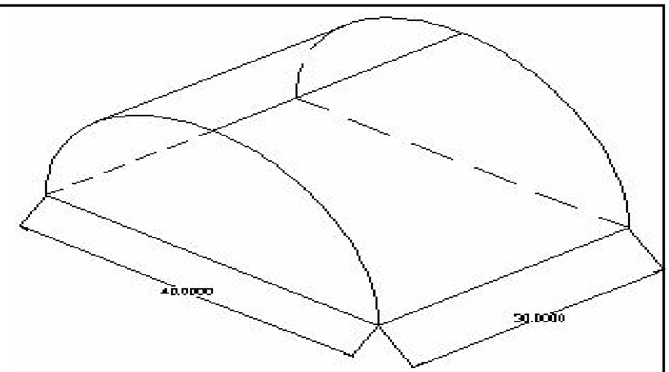

Fig III : Crest height of weir 20 cm

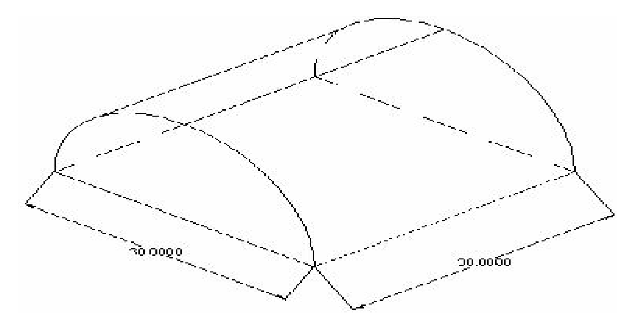

Fig II : Crest height of weir 15 cm

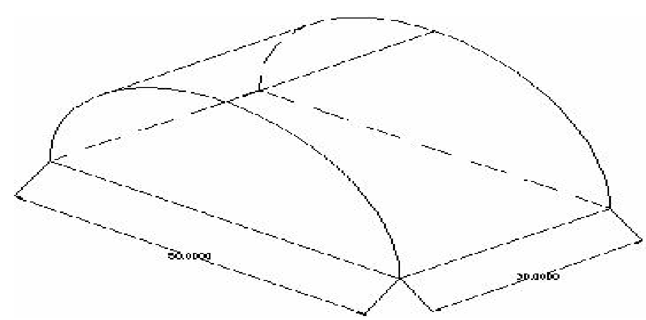

Fig IV : Crest height of weir 25 cm

Fig. A : Isometric view of semi-circular weirs with different crest heights of 10, 15, 20 and 25 cm

These ranges were selected finally to use them in field channels where discharges varied between 5 and 30 Ls^{-1}. A series of laboratory experiments were conducted to investigate the effect of crest height, discharge and submergence conditions. Starting with the free flow condition, the submergence condition was increased gradually to 60 per cent submergence, 75 per cent submergence and 90 per cent submergence with the help of tailgate provided at the end of the flume. The semi-circular bottom contracted were used and replaced one after the other in the hydraulic flume by taking all precautions in the installation of weirs. The occurrence and location of critical depths in the throat section and their suitability for water measurements under different submergence condition studied.

Computation of critical depth :

Critical depth was calculated by using the following equation :

$$Y_c^3 = \frac{Q^2}{gB^2}$$

where,

Y_c = critical depth, cm

Q = Discharge, Ls^{-1}

g = acceleration due to gravity, ms^{-2}

B = crest width, cm

Computation of co-efficient of discharge :

The following discharge equation was used to determine the co-efficient of discharge (C_d) value for different discharges with different diameter of weirs.

$$Q = \frac{2}{3} C_d L \sqrt{2g} H^{3/2}$$

$$Q = KH^{3/2}$$

where,

$$K = \frac{2}{3} C_d L \sqrt{2g}$$

Q = Discharge rate, Ls^{-1}

H= Upstream depth of flow, cm

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Variation of co-efficient of discharge (C_d) :

The co-efficient of discharge for the different weirs under free flow conditions, if the increased crest height was from 10 cm to 25 cm then the C_d values decreased from 0.82 to 0.72, 0.72 to 0.64, 0.6 to 0.56 and 0.53 to 0.50 for 24, 18, 12 and 6 Ls^{-1} discharges, respectively (Fig. 1) due to increase in contact surface area and friction and less discharge had low velocity of approach. The co-efficient of discharge for the different weirs under 60 per cent submergence conditions (Table 1), if the increased crest height was from 10 cm to 25 cm then the C_d values also decreased from 0.75 to 0.66, 0.7 to 0.63, 0.58 to 0.55 and 0.49 to 0.43 for 24, 18, 12 and 6 Ls^{-1} discharges, respectively (Fig. 2) due to increase in contact surface area and friction and less discharge had low velocity of approach. The co-efficient of discharge for the different weirs under 75 per cent submergence conditions (Fig. 3), if the increased crest height

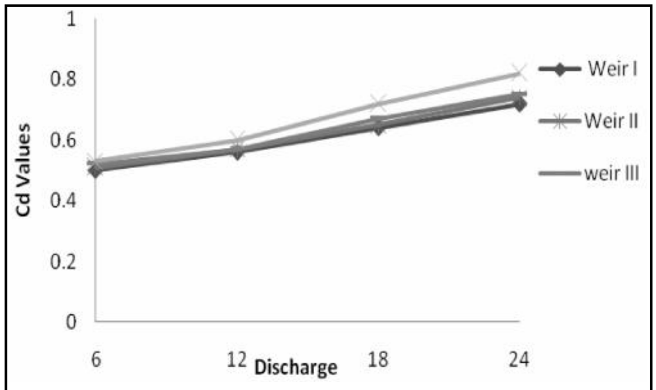

Fig. 1 : Variation of C_d with discharge and weir diameter under free flow condition

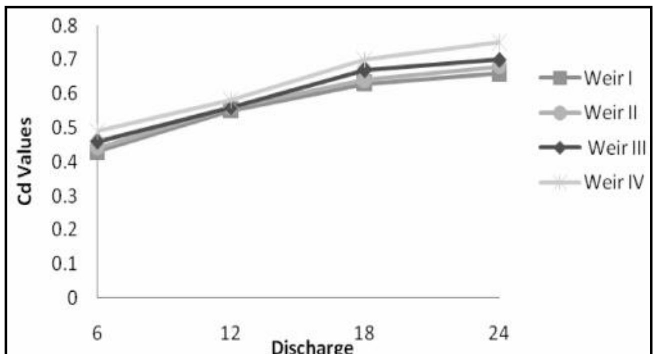

Fig. 2 : Variation of C_d with discharge and weir diameter under 60 per cent submerged condition

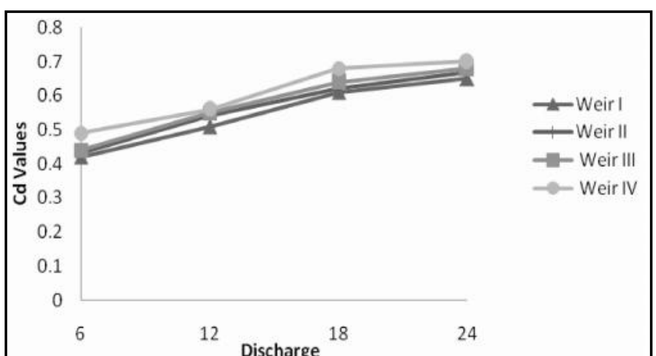

Fig. 3 : Variation of C_d with discharge and weir diameter under 75 per cent submerged condition

Table 1 : C_d values for different discharges of different sizes of weirs

Sizes of weirs	Under free flow conditions	Submerged conditions		
		60 %	75 %	90 %
Q = 24 Ls^{-1}				
Weir I (Crest height 25 cm)	0.72	0.66	0.65	0.62
Weir II (Crest height 20 cm)	0.74	0.68	0.67	0.63
Weir III (Crest height 15 cm)	0.75	0.7	0.68	0.64
Weir IV (Crest height 10 cm)	0.82	0.75	0.7	0.69
Q = 18 Ls^{-1}				
Weir I (Crest height 25 cm)	0.64	0.63	0.61	0.58
Weir II (Crest height 20 cm)	0.65	0.64	0.62	0.6
Weir III (Crest height 15 cm)	0.67	0.67	0.64	0.61
Weir IV (Crest height 10 cm)	0.72	0.7	0.68	0.61
Q = 12 Ls^{-1}				
Weir I (Crest height 25 cm)	0.56	0.55	0.51	0.5
Weir II (Crest height 20 cm)	0.57	0.56	0.54	0.52
Weir III (Crest height 15 cm)	0.57	0.56	0.55	0.53
Weir IV (Crest height 10 cm)	0.6	0.58	0.56	0.54
Q = 6 Ls^{-1}				
Weir I (Crest height 25 cm)	0.5	0.43	0.42	0.42
Weir II (Crest height 20 cm)	0.51	0.44	0.43	0.42
Weir III (Crest height 15 cm)	0.52	0.46	0.44	0.43
Weir IV (Crest height 10 cm)	0.53	0.49	0.49	0.46

Table 2 : Head-discharge relationships

Weir type	Discharge (Ls^{-1})	Upstream crest referenced head ,cm			
		Free flow	Submergence levels		
			60 %	75 %	90 %
Weir-I	24	11.19	11.94	12.04	Not recommended
(Crest height, 25 cm)	18	10.01	10.14	10.44	Not recommended
	12	8.33	8.47	8.93	Not recommended
	6	5.71	6.34	6.43	Not recommended
Weir-II (Crest height, 20	24	11.01	11.71	11.81	Not recommended
cm)	18	9.91	9.91	10.30	Not recommended
	12	8.31	8.41	8.61	Not recommended
	6	5.61	6.21	6.31	Not recommended
Weir-III (Crest height, 15	24	10.91	11.41	11.68	Not recommended
cm)	18	9.71	9.81	10.01	Not recommended
	12	8.29	8.41	8.51	Not recommended
	6	5.57	6.01	Not recommended	Not recommended
Weir-IV (Crest height, 10	24	10.30	10.91	11.41	Not recommended
cm)	18	9.31	9.41	9.61	Not recommended
	12	8.01	8.21	8.41	Not recommended
	6	5.46	5.81	Not recommended	Not recommended

was from 10 cm to 25 cm then the C_d values also decreased from 0.7 to 0.65, 0.68 to 0.61, 0.56 to 0.51 and 0.49 to 0.42 for 24, 18, 12 and 6 Ls^{-1} discharges, respectively.

The co-efficient of discharge for the different weirs under 90 per cent submergence conditions (Fig. 4), if the increased crest height was from 10 cm to 25 cm then the C_d values also decreased from 0.69 to 0.62, 0.61 to 0.58, 0.54 to 0.50 and 0.46 to 0.42 for 24, 18, 12 and 6 Ls^{-1} discharges, respectively. For 24 Ls^{-1} discharge, the co-efficient of discharge decreased from 0.72 to 0.62 for increased submergence levels from 60 per cent to 90 per cent.

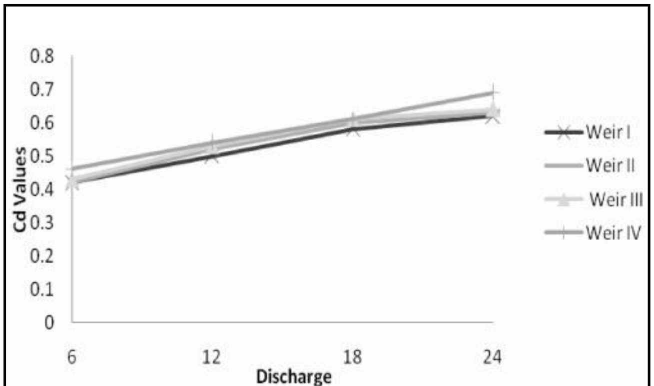

Fig. 4 : Variation of C_d with discharge and weir diameter under 90 per cent submerged condition

Head- discharge relationships for the weirs :

All weirs have found to possess critical section at the throat section under 90 per cent submergence levels (Samani *et al.*, 1991), they can be used for water measurement. Weir-III and Weir-IV models (Table 2) have also found to be sensitive towards submergence of 75 per cent and above for the lowest discharge of 6 Ls^{-1}.

Since a unique head-discharge relationship exists under critical flow conditions, these relationships provide an easy means of determination of discharge.

Conclusion :

– The co-efficients of discharge have been computed for each type of weir. They varied between 0.42 and 0.82 for different conditions of discharge, crest height and submergence.

– The head-discharge relationships developed for the weirs can be used for determination of discharges with a single and simple measurement of upstream head. These relationships will be unique since the critical conditions existed within the throat section except at for 90 per cent submergence. This provides an easy method of computation of discharges.

– The co-efficient of discharge was found to increase with increase in discharges. It can be concluded that these weirs will be best suited to higher discharges (10 to 25 Ls^{-1}) in the range tested.

– The co-efficient of discharge was found to increase with increase in discharges. It can be concluded that these weirs will be best suited to higher discharges (10 to 25 Ls^{-1}) in the range tested. The co-efficient of discharge was found to increase with decrease in crest height and submergence levels.

Authors' affiliations:

T.V. SATYANARAYANA AND H.V. HEMA KUMAR, Department of Agricultural Engineering and Technology, College of Agricultural Engineering, Bapatla, GUNTUR (A.P.) INDIA

REFERENCES

Al-Hamid, A.A., Negm, A.M. and Al-Brahim, A.M. (1997). Discharge equation for proposed self- cleaning device. *J. King Saud Univ. Eng. Sci.,* **9** (1): 13 – 24 .

Baddour, R.E. (2008). Head-discharge equation for sharp-crested polynomial weir. *J. Irrigation & Drainage Engg., ASCE.,* **134**(2) : 260-262.

Castro-Orgaz, O., Giraldez, J.V. and Ayuso, J.L. (2008). Critical flow over circular crested weirs. *J. Hydraulic Engineering, ASCE,* **134**(11) : 1661-1664.

Chow, V.T. (1959). Open channel hydraulics. Mc Graw-Hill Book Company Ltd., NEW YORK, U.S.A.

El-Saiad, A.A., Negm, A.M. and Waheed El-Din, U. (1995). Simultaneous flow over weirs and below gates, Civil Engineering Research Magazine, Civil Engineering Department, Faculty of Engineering. *Al-Azhar University, Cairo, Egypt,* **17** (7): 62-71.

Gogus, M., Define, Z. and Ozakandemir, V. (2006). Broad crested weirs with rectangular compound cross sections. *J. Irrigation & Drainage Engg., ASCE,* **132**(1) : 272-280.

Hayawi, H. A. M., Hayawi, G. A. M. and Alniami, A. A. G. (2009). Co-efficient of discharge for a combined hydraulic measuring device. *Al Rafidain Engg.* , **17** (6) : 92-100 .

Ismail, M.H. (2012). Experimental investigation for flow through combined structure weir and gate. Thesis, College of Engineering, Kufa Universit.

Mahboubeh, S., Nasser, T., Dehghani, A. A., Abdoul Rasoul, T. and Reza, R.G. (2011). Experimental investigation of the effect of contraction on scouring in downstream of combined flow over weirs and below gates. 5th SASTech, Khavaran Higher – education Institute, Mashhad, IRAN.

Negm, A.M. (2002). Discussion of analysis and formulation of flow through combined V – Notch – Gate – device by A. A. Al-Hamid. *J. Hydraulic Res.,***40** (6): 755 – 765.

Negm, A. M., Al-Brahim, A.M. and Al-Hamid, A.A. (2002). Combined free flow over weirs and below gates. *J. Hydraulic Res.*, **40** (3): 359 – 365.

Ramamurthy, S.A., Junying, Q.U., Zhai, Ch and Diep, V. (2007). Multislit weir characteristics. *J. Irrigation & Drainage Engg., ASCE,* **133**(2) : 198-200.

Raouf, E. and Baddour, M. (2008). Head-discharge equation for sharp-crested polynomial weirs. *J. Irrigation & Drainage Engg., ASCE,* **134**(2) : 260-262.

Samani, Z., Jorat, S. and Yousaf, M. (1991). Hydraulic characteristics of circular flume. *J. Irrigation & Drainage, ASCE,* **117**(4) : 558-566.

Satyanarayana, T.V. and Satyanarayana, T. (1994). Effect of weir geometry on co-efficient of discharge of modified trapezoidal broad crested weirs. *J. Institution of Engineers (India), Agric. Engg. Division,* **74**(1) : 38-42.