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Effect of crest height on flow characteristics of semi-circular bottom contraction weirs

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ABSTRACT : Accurate water measurements systems enable accurate accounting of water use, and permit the available water to be supplied at optimum rates to the areas where it is intended to be used. A perfect understanding of some of the primary principles relating to the subject of water measurement is, therefore, necessary for establishing any water measurement system in the canal commands of irrigated agriculture. All the four weir types have enabled creation of critical flow conditions within the throat section, which indicate their suitability for measurement of water in open channels in general. All the four design crest heights (25 cm (Weir-I), 20 cm (Weir-II), 15 cm (Weir -III) and 10 cm (Weir-IV)) are found to be acceptable excepting for 90 per cent submergence level condition. Critical depth (section) has occurred at only one location in the throat section for all the weirs under all possible conditions. The crest height has increased from 10 cm to 25 cm and then location of the critical section has moved towards the upstream side from 1.6 to 0.8 cm, 1.7 to 1.0 cm, 1.8 to 1.1 cm for 24 Ls^{-1} discharge under free flow, 60 per cent, 75 per cent submergence conditions, respectively. For 18 Ls^{-1} discharge, crest height has increased from 10 cm to 25 cm, and then location of the critical section has moved towards the upstream side from 7.0 to 3.1cm, 7.1 to 3.3 cm, 7.3 to 3.5 cm under free flow 60 per cent, 75 per cent submergence conditions, respectively. For 12 Ls^{-1} discharge, crest height has increased from 10 cm to 25 cm and then location of the critical section has moved towards the upstream side from 8.1 to 4.7 cm, 7.1 to 4.9 cm, 8.3 to 5.0 cm under free flow 60 per cent, 75 per cent submergence conditions, respectively. Crest height has increased from 10 cm to 25 cm and then location of the critical section has moved towards the upstream side from 8.4 to 6.0 cm, 8.6 to 6.1 cm, 6.3 cm for 6 Ls^{-1} discharge under free flow, 60 per cent, 75 per cent submergence conditions due to increased the contact surface and friction and not found for 90 per cent submergence levels for all the four weirs.

KEY WORDS : Hydraulic flume, Semi-circular crested weirs, Characteristics of semi-circular weirs, Open channels, Point gauge, Critical depth, Crest height, Discharges

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Measurement of inflow and outflow is the only way to determine how much water is being lost from that portion of the irrigation system (Ahmad *et al.*, 1991). Due to failure in proper water measuring structures, in India, compared to other countries, the farmers lag behind in receiving equitable distribution of irrigation water in the canal commands and in other irrigation projects. Cylindrical weirs were common in late 19th century and early 20th century prior to the introduction of Ogee shape. During 19th century, developments in improving weir discharge capacity lead to the design of semi-circular crested weirs. The characteristics of the flow over semi-circular crested weirs with different discharges have been of interest to many investigators.

A large numbers of studies have been carried out on the flow characteristics and curvilinear flow over the weir under critical conditions for rectangular, triangular and trapezoidal channels. However, very few studies are available on the flow characteristics and curvilinear flow in the circular channels. In most of the cases, it is not possible to incorporate suitable parameters fully representing all the involving variables such that strict mathematical equations could be formulated and evolved. The design and development of models is based on the design of simple flume for flow measurement in open channel proposed by Castro-Orgaz *et al.* (2008).

■ METHODOLOGY

Experimental setup :

A commercial make of hydraulic flume (Fig. A) with motorized bed slope alteration facility installed in Fluid Mechanics and Hydraulics Laboratory of College of Agricultural Engineering, Bapatla was used in the experimentation.

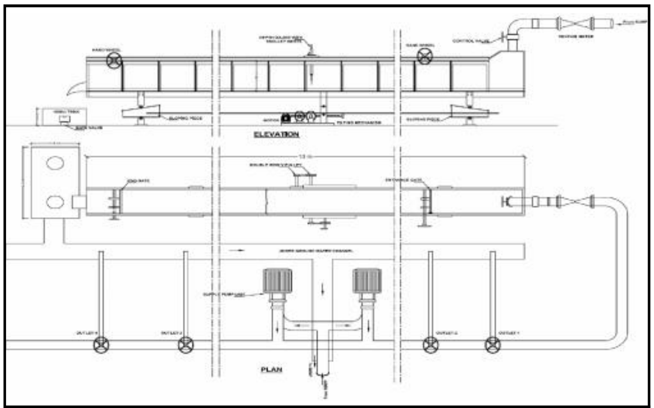

Fig. A : Layout of Hydraulic Flume

Scheme of experiments :

The following levels of experimental variables were chosen for the study.

Weir types :

Following four diameters were selected to suit the channel dimensions of the hydraulic flume (Plate 1).

Weir-I with diameter of 500 mm
Weir-II with diameter of 400 mm
Weir-III with diameter of 300 mm
Weir-IV with diameter of 200 mm.

Plate 1 : Semi-circular bottom contraction weirs of different crest heights

Discharges :

Following four discharges were selected to suit to field channels keeping in view the flow range of field channels and the possibility of maximum discharge by the Pumps of the Hydraulics Laboratory.

24 Ls^{-1}, 18 Ls^{-1}, 12 Ls^{-1} and 6 Ls^{-1}.

Submergence conditions :

As submergence is one of the most important parameter which influences the accuracy of a weir, for testing the efficiency of the developed weirs, three following levels of submergence were selected.

60 per cent , 75 per cent and 90 per cent.

$$\text{Submergence level (\%)} = \frac{\text{downstream depth}}{\text{upstream depth}} \times 100$$

Depth of water levels over the rectangular weir before the semi-circular weirs: Following four flow depths were arrived based on the discharges chosen from standard weir formula.

20.12 cm (24 Ls^{-1}), 16.62 cm (18 Ls^{-1}), 12.68 cm (12 Ls^{-1}) and 8.0 cm (6 Ls^{-1}).

Experimental procedure :

A semi-circular bottom contraction Weir-I was fixed to the side walls of hydraulic flume. A point gauge was used to take the water surface profile before starting the experiment. The depth of water level was maintained at 20.12, 16.62, 12.68, and 8.0 cm by operating valves for different discharges.

A constant head has been maintained throughout the experimental run. Initially the hydraulic flume was run to attain a constant discharge, after a constant discharge was attained the water surface level drops were recorded at each 2 cm intervals along the centre line of hydraulic flume by moving the point gauge on the rails. The starting of the water surface profile measurement is from 55 cm away on upstream side of the weir to 33 cm on downstream side of the weir. The readings were taken in three trials at each experimental setup. Starting with the free flow condition, the submergence condition has been increased gradually to 60 per cent submergence, 75 per cent submergence and 90 per cent submergence with the help of tail gate provided at the end of the flume.

The process of recording the water surface profiles has been repeated with remaining three discharges of 18 Ls^{-1},12 Ls^{-1} and 6 Ls^{-1} and depth of 16.62 cm, 12.68 cm and 8.0 cm. The semi-circular crested Weir-I is replaced with Weir-II by taking all precautions as in the installation of Weir-I. Again water surface profile for discharges of 24 Ls^{-1}, 18 Ls^{-1}, 12 Ls^{-1}, 6 Ls^{-1} and for depths of 20.12 cm,16.62 cm, 12.68 cm and 8 cm are noted as in the previous run. The semi-circular bottom contracted Weir-II has been replaced by Weir-III and Weir-IV subsequently by taking all precautions as in the installation of Weir-I. Again water surface profiles for discharges of 18 Ls^{-1}, 12 Ls^{-1} and 6 Ls^{-1} and for submergence conditions 60 per cent, 75 per cent and 90 per cent have been noted as in the previous run.

■ RESULTS AND DISCUSSION

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

Characteristics of critical depth :

The critical depths for different discharges with different heads have been computed. The critical depth has been found to occur at only one location in the throat for all heads (discharges).

Crest height has increased from 10 cm to 25 cm and then location of the critical section (Fig. 1) has moved towards the upstream side from 1.6 to 0.8 cm for 24 Ls^{-1} discharge under free flow conditions. For 24 Ls^{-1} discharge, location of the critical section moved towards the upstream side from 1.7 to 1.0 cm, 1.8 to 1.1 cm under 60 per cent, 75 per cent submergence conditions, respectively. Crest height has increased from 10 cm to 25 cm and then location of the critical section (Fig. 2) has moved towards the upstream side from 7.0 to 3.1cm for 18 Ls^{-1} discharge under free flow conditions and for 18 Ls^{-1} discharge, location of the critical section has

Table 1 : Location of critical depth for different weirs and discharge under free flow and submergence conditions

Weir type (crest height, cm)	Discharge (ls^{-1})	Critical depth (cm)	Upstream crest referenced head ,cm			
			Free flow	Submergence levels		
				60%	75%	90%
Weir-I (25 cm)	24	8.67	0.8	1.0	1.1	--
	18	7.15	3.1	3.3	3.5	--
	12	5.5	4.7	4.9	5.0	--
	6	3.5	6.0	6.1	6.3	--
Weir-II (20 cm)	24	8.67	1.0	1.1	1.3	--
	18	7.15	4.5	4.7	4.9	--
	12	5.5	5.9	6.1	6.4	--
	6	3.5	6.8	6.9	7.3	--
Weir-III (15 cm)	24	8.67	1.3	1.4	1.5	--
	18	7.15	5.8	6.0	6.2	--
	12	5.5	7.2	7.3	7.4	--
	6	3.5	7.6	7.7	--	--
Weir-IV (10 cm)	24	8.67	1.6	1.7	1.8	--
	18	7.15	7.0	7.1	7.3	--
	12	5.5	8.1	8.2	8.3	--
	6	3.5	8.4	8.6	--	--

moved towards the upstream side from 7.1 to 3.3 cm, 7.3 to 3.5 cm under 60 per cent, 75 per cent submergence conditions, respectively. Crest height has increased from 10 cm to 25 cm, and then location of the critical section (Fig. 3) has moved towards the upstream side from 8.1 to 4.7 cm for 12 Ls^{-1} discharge under free flow conditions and for 12 Ls^{-1} discharge, location of the critical section has moved towards the upstream side from 7.1 to 4.9

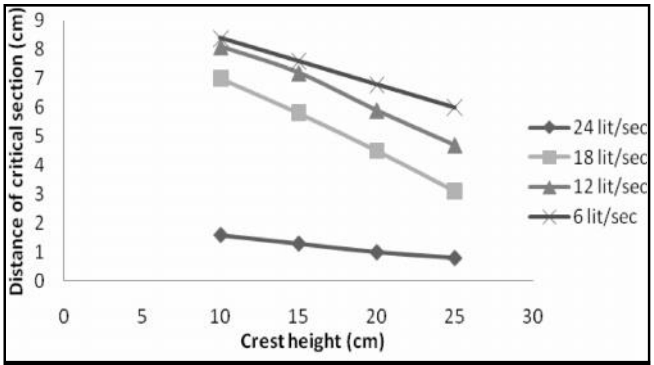

Fig. 1 : Relationship between crest height and distance of critical section from the crest for different discharges under free flow condition

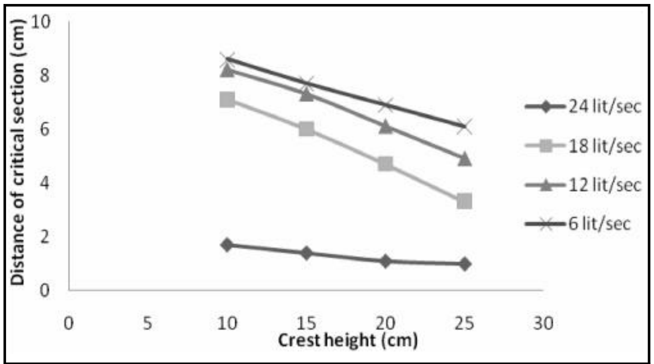

Fig. 2 : Relationship between crest height and distance of critical section from the crest for different discharges under 60 per cent submerged condition

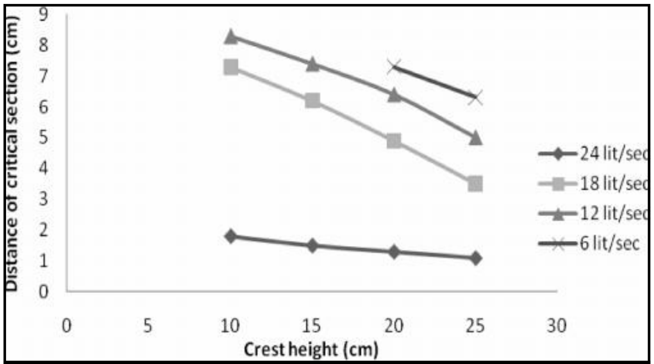

Fig. 3 : Relationship between crest height and distance of critical section from the crest for different discharges under 75 per cent submerged condition

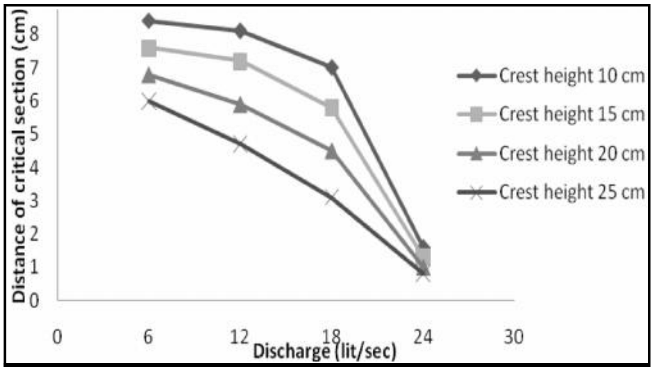

Fig. 4 : Relationship between discharge and distance of critical from the crest for different crest heights under free flow condition

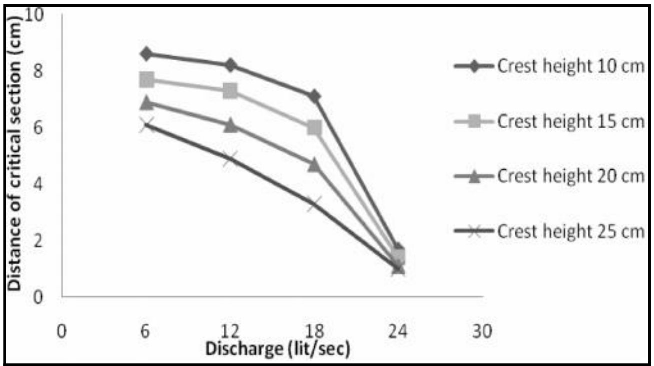

Fig. 5 : Relationship between discharge and distance of critical from the crest for different crest heights under 60 per cent submerged condition

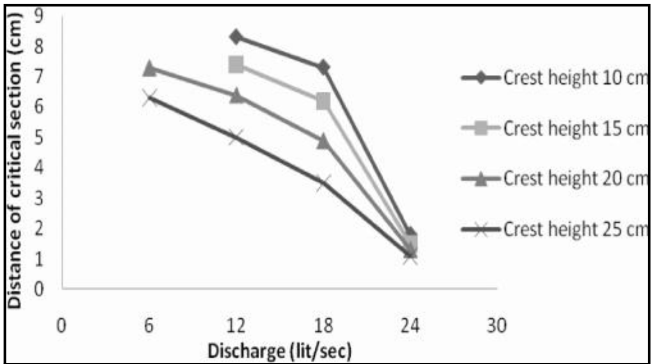

Fig. 6 : Relationship between discharge and distance of critical from the crest for different crest heights under 75 per cent submerged condition

cm, 8.3 to 5.0 cm under 60 per cent, 75 per cent submergence conditions, respectively. Crest height has increased from 10 cm to 25 cm and then location of the critical section has moved towards the upstream side from 8.4 to 6.0 cm for 6 Ls^{-1} discharge under free flow conditions. For 6 Ls^{-1} discharge, location of the critical section has moved towards the upstream side from 8.6 to 6.1 cm, 6.3 cm under 60 per cent, 75 per cent submergence conditions, respectively due to increased the contact surface and friction and critical section has not found for 90 per cent submergence levels (Samani *et al.*, 1991) for all the four weirs.

The discharge has increased from 6 Ls^{-1} to 24 Ls^{-1} and then the location of critical depth has moved towards the upstream side from 6.0 to 0.8 cm, 6.1 to 1.0 cm and 6.3 to 1.1 cm for weir-I under free flow, 60 per cent and 75 per cent submergence (Fig. 4) conditions, respectively. The discharge has increased from 6 Ls^{-1} to 24 Ls^{-1} and then the location of critical depth has moved towards the upstream side from 6.8 to 0.8 cm, 6.9 to 1.1 cm and 7.3 to 1.3 cm (Fig. 5) for weir-II under free flow, 60 per cent and 75 per cent submergence conditions, respectively. The discharge has increased from 6 Ls^{-1} to 24 Ls^{-1} and then the location of critical depth has moved towards the upstream side from 7.6 to 1.3 cm, 7.7 to 1.4 cm and 1.5 cm (Fig. 6) for weir-III under free flow, 60 per cent and 75 pe cent submergence conditions, respectively. The discharge has increased from 6 Ls^{-1} to 24 Ls^{-1} and then the location of critical depth has moved towards the upstream side from 8.4 to 1.6 cm, 8.6 to 1.7 cm and 1.8 cm for weir-IV under free flow, 60 per cent and 75 per cent submergence conditions, respectively due to increased the contact surface and friction and location of critical section has not found for 90 per cent submergence levels for all the four weirs.

Conclusion :

The following conclusions were drawn :

- All the four design crest heights (25 cm (Weir-I), 20 cm (Weir-II), 15 cm (Weir -III) and 10 cm (Weir-IV) are found to be acceptable excepting for 90 per cent submergence level condition. The location of critical depth moves towards upstream from centre with decreasing submergence levels.
- The location of critical depth (section) moves downstream from the centre of the crest with decrease in discharge under free flow conditions and submerged conditions. Measurement of inflow and outflow is the only way to determine how much water is being lost from that portion of the irrigation system (Ahmad *et al.*, 1991). Due to failure in proper water measuring structures, in India, compared to other countries, the farmers lag behind in receiving equitable distribution of irrigation water in the canal commands and in other irrigation projects.

A large numbers of studies have been carried out on the flow characteristics and curvilinear flow over the weir under critical conditions for rectangular, triangular and trapezoidal channels. However, very few studies are available on the flow characteristics and curvilinear flow in the circular channels. In most of the cases, it is not possible to incorporate suitable parameters fully representing all the involving variables such that strict mathematical equations could be formulated and evolved. The design and development of models is based on the design of simple flume for flow measurement in open channel proposed by Castro-Orgaz *et al.* (2008).

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REFERENCES

Ahmad, S., Yasin, M. and Ahmad, M.M. (1991). Flow measurement with portable cut-throat flume and broad crested weir in flat gradient channels. *Irrig. & Drain. Syst.,* **5**(2) : 141-150.

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

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

Samani, Z., Jorat, S. and Yousaf, M. (1991). Hydraulic characteristics of circular flume. *J. Irrig. & Drain. 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. Instit. Engi. (India), Agric. Engg. Div.,* **74** (1) : 38-42.