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Studying the Performance Characteristics of Cut Throat Flume

Shravankumar S M[1], Mora Sandeep[2], Mantripragada Aditya Raj[3] and Koratikanti Shubham Kumar[4]

[1]Assistant Professor, Sreenidhi Institute of Science and Technology, Hyderabad-501301
[2]Student, Sreenidhi Institute of Science and Technology, Hyderabad-501301
[3]Student, Sreenidhi Institute of Science and Technology, Hyderabad-501301
[4]Student, Sreenidhi Institute of Science and Technology, Hyderabad-501301
E-mail: [1]shravankumarsm@sreenidhi.edu.in, [2]morasandeep18@gmail.com, [3]mantripragadaadityaraj@gmail.com, [4]koratikantishubham2108@gmail.com

Abstract—*The water distribution to the irrigation field is a very tedious job, and in the present scenario due to climate change impact it is necessary to distribute the water very rationally, the current instruments used in the field have low coefficient of discharge the paper aims in increasing the coefficient of discharge of Cut throat flume which has been widely used. A series of experiments were conducted in the laboratory under steady-state flow conditions through a Cutthroat flume of throat width 5.5cm (2.16") and length 57.5cm (22.63") in 6m tilting flume. Cutthroat flume of throat-width 5.5cm (2.16") is very rare to find out, the work emphasises the importance of use of Cutthroat flume. Experiments were conducted in laboratory designed and constructed 2.16" throat width Cutthroat flume. Free flow and submerged flow calibrations were done within flow range. Equations applicable for both free flow and submerged flow regime were proposed. Results of the calibration show that under favourable operating conditions of the discharge within calibrated flow, the proposed equation can determine accurately the discharge with maximum error up to +5% in both free flow and submerged flow regime.*

Keywords: *Cut throat flume, tilting flume, coefficient of discharge, water distribution, and irrigation canals.*

1. INTRODUCTION

The management of water in today's scenario is very important, and the management of such water in an open channel is one of the basic elements of water management in irrigation engineering. There are umpteen methods for measuring flow in open channels. The most common method of measuring flow in an open channel is based on the concept of critical flow and depth discharge relation. This helps in monitoring the discharge continuously. The Parshall flume developed in 1926 enabled the easy measurement of discharge from then tremendous effort has been put to simplify the discharge measurement process in open channels. The discharge can be measured by either contracting the flow section or by decreasing the bottom elevation so that flow attains critical flow which enables to easily measure the discharge. This paper describes the simple Cut Throat flumes for an open channel where critical flow is created by cutting the throat sectional area of the flow of the Venturiflume as shown in figure section as shown below.

2. THEORETICAL ANALYSIS OF FLOW

The principle of critical flow is used in the analysis of the cut throat flume, and also to measure the discharge, by providing only diverging and converging sections without any throat sections, this enables a critical flow at the junction of converging diverging section. Using the principle of hydraulics and critical flow the discharge can be measured by simply measuring the energy at upstream. For uniform velocity the specific energy is given by

$$E = y + V^2 / 2g,$$

Where, E = energy upstream of the critical flow section;

y = upstream depth;

V = Q / A1 flow velocity; and

A1 = upstream flow cross section.

Assuming a level flume and negligible energy loss between upstream and critical flow section, the upstream energy will be equal to the energy at the critical flow section and can be described as,

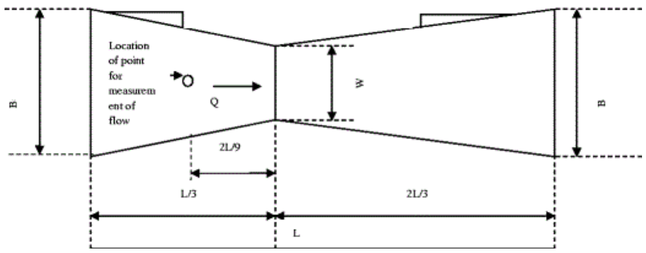
$$E_c = y_c + \frac{V_c^2}{2g} \quad \text{……….(1)}$$

Where, E_c = energy upstream of the critical flow section;

y_c = upstream depth;

V_c = Q / A1 flow velocity; and

A_c = flow cross section at critical section



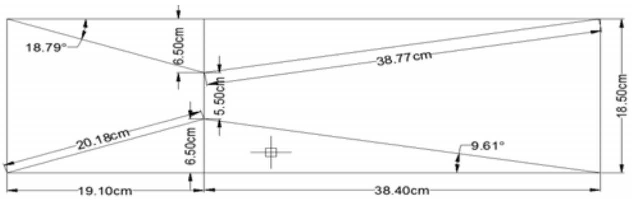
At the critical cross section the critical flow equation can be described as

$$\frac{Q^2}{A_c^3} * \left(\frac{dA}{dy_c}\right) = 1 ......(2)$$

Combining equation (1) and (2), we get

$$E = y + \frac{A_c}{2\left(\frac{dA_c}{dy_c}\right)}$$

3. TAKEN DIMENSIONS OF CUT-THROAT FLUME



4. V. EXPERIMENTAL INVESTIGATION

a) Model preparation

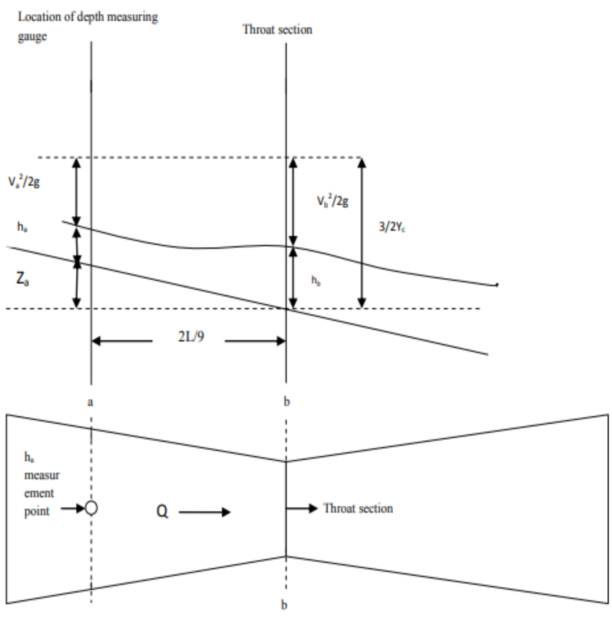


Fig. 1: Cut throat flume

To check specially for scale effect in the experimentally determined stage – discharge relationships from geometrically similar flumes. A non dimensional relationship is to be developed linking the pertinent variables. Buckingham's π method of dimensional analysis is used to develop the discharge relationship in terms of Discharge vs. Head. Dimensional analysis is extremely useful in reducing the number of variables in the problem by formulating them into non dimensional parameters. The reduction of the number of variables in a problem provides a systematic presentation of experimental results in a more concise and useful form.

The discharge passing through Cutthroat flume is a function of upstream head and dimension of Cutthroat flume under free flow condition. Therefore, functional relationship for discharge of cut throat flume may be expressed as, a f (ρ,μ, Q, h , L,W, g), where,

f = Functional symbol

Q = Discharge

h_a = Upstream head at 2/3 rd section

L = Total length of Cutthroat flume

W = Throat width of Cutthroat flume

g = Acceleration due to gravity

μ = Dynamic viscosity

ρ = Fluid density

Total numbers of variables are = 7 (seven) Number of primary dimensions are = 3 (Mass, Length, Time) Therefore, number of dimensionless π terms are 4.

The functional relationship given by equation ϕ(π1, π2, π3, π4) and can be expressed by using only four dimensionless group (Where π1, π2, π3, π4 are the dimensionless terms whose expression has to be determined.

Let L, Q, ρ are the repeating variables.

Therefore, π terms have been grouped as follows,

$\pi_1 = L^{a1} Q^{b1} \rho^{c1}$

$\pi_2 = L^{a2} Q^{b2} \rho^{c2}$

$\pi_3 = L^{a3} Q^{b3} \rho^{c3}$

$\pi_4 = L^{a4} Q^{b4} \rho^{c4}$

where a1, b1, c1, a2, b2, c2, a3, b3, c3, a4, b4 and c4 are numerical constants.

$\pi_1 = ha / L$,

$\pi_2 = W / L$,

$\pi_3 = \rho Q / L \mu$

$\pi_4 = Q / (\text{sqrt}(g) L^{2.5})$

Therefore,

$$\phi\left(\frac{h_a}{L}, \frac{W}{L}, \frac{Q}{\sqrt{g}L^{2.5}}, \frac{\rho Q}{L\mu}\right) = 0$$

5. RESULTS AND DISCUSSIONS

The research topic has been totally motivating, many new aspects of open channel flow have been discovered while carrying out experiments and better understanding of open channel flow has been achieved. However, as a matter of document the concentration of the research work was on supercritical flow and during the course of observation it was concluded:

- The equation developed can be used to calculate the discharge at the super critical section using the cut throat flume which is usually not possible from the Venturiflume and Parshall Flume
- The roller formation at downstream of throat section enables to establish a critical section.
- Under super critical flow the following equation can be used to calculate the discharge

$$Q' = 0.4565 * E^{0.85277}$$

- For the super critical flow at the downstream the discharge is calculated as flows

$$Q'' = 0.4565\ E^{1.28}$$

- For the cut throat flume the coefficient of discharge in super critical flow regime is

$$Cd = 0.8406\ E^{0.028}$$

- Therefore

$$Q' = 0.544 * Cd * E^{1.3}$$

- The laboratory experiments has shown a encouraging results in measurement of discharge in the field with higher coefficient of discharge among all the discharge measuring instrument available in the field.