International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.3 Issue No.3, pp : 231 – 234 1 March 2014

Flow Characteristic in Parshall Flume – A Review

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Abstract

Accurate flow measurement is very important for proper and equitable distribution of water among water users. Due to increasing utilization and the value of water, measuring techniques become more important and necessary information concerning the volume of available water is very useful in planning for its future use and distribution for hydraulic engineers. There are several types of flow measurement devices currently in surface flow among the major types of measurement devices used in surface water are: weirs, flumes, current meters, turbine meters, ultrasonic meters, pitot tubes etc. The most common water measurement devices are sharp crested weirs and Parshall flumes. This paper describes about the flow characteristics for Parshall Flume.

Keywords: ***Flow, Surface water, Parshall Flume,Weir, Sediment Laden flow***

1. Introduction

Flow measurement in any hydraulic structure is important design aspect for a hydraulic engineer. In the absence of suitable measuring device agricultural user do not able to use the appropriate use of water. Measurement may be accomplished by various methods more or less suited to individual conditions, such as grade of canal or ditch, quantity of water, or interference by sand and silt[10]. Sometimes the measurement of the flow by some practical device is also stipulated. Without such measurement, the appropriator of water cannot make a definite statement as to how much water he actually uses. Sometimes because of faulty measurements, the farmer's water supply is so restricted as to interfere seriously with the maturing of his crops where dependable measurements made, the increase in value of the crops would more than pay for the expense of installing and maintaining a good, practical, measuring device[10].

One of the devices most commonly used to measure large flows is the rating flume, which is a simple structure built in the open channel where the floor is level, set to the grade line, and with its side walls either vertical or inclined. This flume is calibrated by current meter measurements, or by other means, where the rate of discharge varies with the depth of the stream, which is indicated by a staff gage set on the inside face of the flume[10].

The improved Venturi flume is differs in design from the venture flume in the reduction of the convergence angle from 18º 26’ to 11° 19’ for its upstream or inlet section, a lengthening of the throat section from 1 foot to 2 feet, reduction of the divergence angle of the lower or outlet section from 18° 26’ to 9° 28’ and the placing of a depression in the floor at the throat section [10].The practical use of the improved Venturi flume has show that it has many desirable characteristics and is not subject to many of the disadvantages of other devices. Because of the contracted section at the throat, the velocity of water flowing through the structure is relatively greater than the natural flow of the stream, and for this reason any sand or silt in suspension or rolled along the bottom of the channel is carried through, leaving the device free of deposit .velocity of approach, which often becomes a serious factor in the operation of weirs, has little or no effect upon the rate of discharge of the flume.

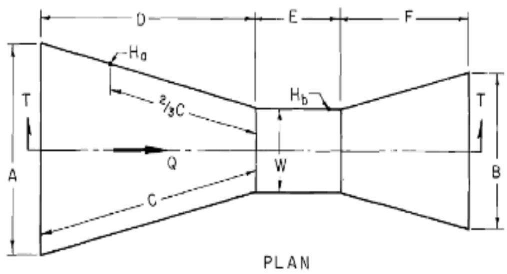

Fig 1 Plan view of Parshall flume [11]

Sediment-laden flows play an important role in the evolution of riverbeds, estuaries and coasts and are among the most important agents of geomorphic evolution of the Earth’s surface. As a consequence, interactions between turbulent flow and sand particle motion in sediment suspensions are important to hydraulic engineers,[14].It is reported that because of fluid-particle interactions, the velocity distribution and turbulence characteristics in sediment-laden flows are different from those of particle-free flows[14]. Much effort has been reported with the flow characteristics with clear water by analysing the velocity distribution. There is a need to work with sediment laden water for parshal flume. in attempting to quantify the effect of Suspended Sediment on the structure of open-channel flow. So some work should be done to analyse the effect of Sediment Particle movement on Parshall flume Operation and develop a new discharge relationship for Parshall Flume in Sediment Laden Flow.

2. Literature Review and Discusion

In this part of paper deals with a review of past research work in the field has been compiled by different authors to enable better understanding of the research in various region methods of analysis on the experiment subject. This part is presented under following headings.

1. The Parshall flume and flow measuring flumes.
2. Sediment Laden flow & its measurement.

2.1 The Parshall Flume and Flow Measuring Flumes

Parshall (1928) developed and studied that improved venturi flume operates successfully with relatively small loss of head, and for free flow this loss in standard weir is four times that in the flume. He also studied that because of the increased velocity of the water, flume will operate successfully in sediment laden streams. Discharge formula for improved venturi flume is given as

$$Q = 4\ W\ H_a^{1.522 W^{0.026}}$$

Parshall also found that the accuracy of measurement with improved venture flume is entirely under practical conditions. The observed discharge, free-flow, was within ±3 percent of the computed amount in 89 percent of the tests. For the submerged flow, 85 percent of the observed discharges were within ±5 percent of the computed amounts. The range of capacity of discharge from flume is 0.10 second-foot through the 6-inch flume to a maximum of 200 second feet thru the 10-foot flume.

Amanda *et al*.(2013) developed new rating equation specific to supercritical flow in large Parshall flumes. He identified and defined three zones by the convergence ratio: (1) subcritical ($0 < Cr < 0.6$), (2) transition ($0.6 < Cr < 1.0$), and (3) supercritical ($Cr > 1.0$). A full-prototype physical model was laboratory tested to determine a rating equation applicable to large Parshall flumes with supercritical flow. He composed a experimental program of a 1.5-m Parshall flume configuration and included 11 tests with discharges up to 0.854 m^3/s and Froude numbers varying from 0.67–1.31. The resulting 1.5-m Parshall flume data were compared to existing rating equations for predicting discharge in a Parshall flume with subcritical and supercritical flow.

Skogerboe *et al*.(1966**)** tested the Parshall flume in the laboratory under free-flow submerged condition. Under free flow conditions, the discharge depends on the upstream depth of flow, H_a. Using this relation they gave the free flow discharge in second-feet (cfs) for most possible H_a values, and for Parshall flumes ranging in size from 3 inches to 8 feet. Under submerged flow condition they prepared calibration curve for Parshall flume from 3 inch to 18 feet.

Bennett (1972) developed a discharge relationship for cutthroat flume under free flow and submerged condition. Based on his experiment he found that flumes less than 3 feet in length were satisfactory for free flow operations. He also concluded that, in order to obtain the best rating accuracy, it is recommended that flumes with throat width to length ratios between 0.1 and 0.4 be used. This critical depth makes possible to determine the discharge by knowing only the upstream depth, h_a. It is possible because whenever critical depth occurs in the flume the upstream depth, h_a is not affected by changes in the downstream depth, h_b, thereby resulting in a unique relation between discharge, .Q, and upstream flow depth, h_a.

For free flow operation a plot is made of flow rate, Q, against upstream depth, h_a, with Q as the y ordinate and h_a as the x ordinate. When Q and h_a were plotted on logarithmic paper, all of the points will fall on a straight line. The discharge relationship for the free flow condition is given as

$$Q = KW^{1.025} h_a^{n1}$$

Manekar *et al*. (2007) developed discharge relation for Cutthroat Flume under Free-Flow Condition. He tested and fabricated seven different sizes of cutthroat flumes, having different length to throat width ratios, in the laboratory under free-flow condition. Under free-flow conditions, discharge through cutthroat flume depends on upstream head and the dimensions of a cutthroat flume. The discharge relationship for cutthroat flume is given as:

$$Q_L = 0.9169\ (h_a / L)^{1.7053}$$

with coefficient of determination, R^2=0.9912.

Inglish (1928) developed the Standing Wave Flume consists of about the same sections as the Venturi

Flume namely, a converging section, a throat section, and a diverging section. The hump in the floor provided to same purpose as the drop in the improved Venturi flume (Parshall flume). One main benifit of the Standing Wave flume over the Parshall flume is that only one gage reading is required for submergences of at least 80 percent and in some cases, as high as 94 percent if long gently curving sides are used. The equation of flow for vertical walls and neglecting friction is

$$Q = 3.088\, C_1\, B\, D^{3/2}$$

He found that this equation hold only for flumes in which $B= D^{1.5}$. The coefficient C_1 also varies with the rate of discharge, therefore making it necessary to rate every flume geometry for the range of desired discharge.

Torres & Merkley (2008) conducted a series of detailed laboratory measurements under steady-state flow conditions through a 0.914 m Cutthroat flume in an attempt to more accurately define transition submergence for four standard throat widths. They found that the change from free to submerged flow is gradual and that there is no transition point to easily observation. It is also found that the gradual transition between the flow regimes looks forward to a new calibration approach in which a single equation could more accurately fit the laboratory measurements, in the form of free- and submerged-flow equations, and Such an equation was found, providing greater calibration accuracy up to 95% submergence in 0.914-m Cutthroat flumes.

Heiner & Barfuss (2011) utilized numerical modelling to create a correction procedure for 2–8-ft nonstandard Parshall flumes. They used basic background information regarding Parshall flumes and the numerical model. They determined the results and correction procedures when head measurements were taken at any location (other than the standard design location) on the converging wall or along the longitudinal centreline of the flume with either standard or nonstandard entrance wing walls.

Abt & Staker (1990) installed a 7.62-cm Parshall flume in a channel and flow rates were measured with lateral flume crest slopes of 0, 3.6, 6.5, 9.0, 13.3, -3.8, -4.8, -7.2, and -11.8%. They compared apparent discharge to the measured discharge for each slope with free outfall conditions. They found that the Parshall flume accuracy is in error approximately 7% at a lateral slope of ±10%. Experiment also show that the flow measurement requires a 0.75% adjustment for each l % of lateral settlement at the flume crest.

Wright *et al* (1994) developed the rating equations for Parshall flumes which indicate that the calibration tests were not conducted for discharges as low as is currently recommended for the flumes use. In this study numerical model was developed to predict the effect of fluid viscosity on the depth-discharge relation. An experimental investigation for several flume sizes indicates that the original rating equations and data over predict the discharge at flow rates that are less than about 15% of the maximum rated discharge for the flume. The discrepancy can be as much as 25% for the range of flows for which the flume is recommended to be used. The numerical model successfully matches the experimental data for the flume sizes studied. Alternative rating equations are developed for use at low discharges.

2.2 Sediment Laden flow & Its Measurement

Lyn (1992) studied the turbulence characteristics of sediment-laden flows in open channels using two-component laser-Doppler velocimetry in open channels Suspensions of well-sorted sands with diameters ranging from 0.15 mm to 0.24 mm, flowing over nominally flat beds, both fixed and erodible. For the range of experimental conditions studied and for the flow regions where the most reliable measurements were obtained (y/h.> 0.1), the effect of sediment on turbulence characteristics is, at best, moderate or negligible.

Yang (2005) analyzed a theoretical analysis of suspended sediment-laden flow in an open channel. For clear water flows, the wall-normal velocity could be induced by secondary currents or no uniformity, which subsequently results in an additional momentum flux (Uv) and leads to the velocity deviation from the classical log law. This additional momentum flux is larger in the upper layer relative to that in the bed region. For sediment-laden flows, the magnitude of wall normal velocity v could be influenced by the presence of sediment. The momentum flux Uv and mass flux C_v jointly exert significant influence on the vertical profiles of horizontal velocity and sediment concentration.

Cheng (2004) investigated velocity lag analytically based on the drag force exerting on a particle in the presence of other neighbours. They derived velocity lag by relating the hindrance coefficient to the shear stress distribution for uniform sediment-laden open channel flows. The analysis shows that the profile of the velocity lag, when normalized by the shear velocity, is associated with the shear Reynolds number, dimensionless particle diameter and specific gravity. For the dilute condition, the velocity lag distribution varies only with the shear Reynolds number.

Lyn (1991) investigated the effect on flow resistance in uniform flat-bed open-channel flows due to suspended sediment. Flows with and without equilibrium sand beds are studied in a laboratory channel. Three well-sorted natural sands are used. Point velocity measurements, as well as estimates of local wall shear, are obtained with a laser-Doppler anemometry system, and are used to evaluate friction factors. The results indicate that, contrary to recent models, the presence of suspended sediment does not necessarily lead to a reduction in flow resistance, but will generally result in an increase. The relation between changes in the velocity profile and changes in friction factors is discussed.

3. Conclusion

During the literature view it is reported that much work has been carried out by past researchers to analyse the flow characteristics of Parshall flume with clear water by analysing the velocity distribution study. There is a need to work with sediment laden water for flow characteristics of Parshall flume. Hence there is an ample scope to analyse the effect of Sediment Particle movement on Parshall flume Operation and develop a new discharge relationship for Parshall Flume in Sediment Laden Flow. On the basis of past work it is observed that there is many work has been done for the free water flow in the Parshall flume. It is also found that not much work has been carried out for the measuring sedimentation through the Parshall Flume. So it is much needed to work on sediment laden flow to find flow characteristics in Parshall flume.

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