ESTIMATION OF CORRELATION BETWEEN STRING ANGLE AND VELOCITY OF FLOW BY USING BALLS OF DIFFERENT MATERIAL AND DIFFERENT DIAMETER IN LABORATORY FLUME

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ABSTRACT
Velocity is usually measured in a Laboratory flume by various method (Ref1) using Pitot tube, current meter and float. Pitot tube requires high velocity, measurement of velocity by current meter is time consuming and float method gives only free surface velocity. This paper intends to provide new simple method for velocity measurement in laboratory flume. We studied here new method for the measurement of velocity of flow in laboratory flume by using concrete ball and steel ball. Then by suspending these balls by using string in flow of water, experiments were performed in laboratory flume. In this study we propose however a correlation between string angle and velocity of flow. The velocity measured by using ball proves to be in good agreement with the experimental velocity measured by using continuity equation.

KEYWORDS: *Ball, Experimental velocity (VE), Theorotical velocity (VT), String angle, Drag force.*

I. INTRODUCTION

The accuracy of a flow measurement depends largely upon the accuracy with which the cross-sectional area and the velocity are measured. There is no specific difficulty in measuring the cross sectional area but the second factor i. e. the velocity is very difficult to measure, for the reason that it is constantly fluctuating, It not only varies (Ref3) from the surface to the bottom but also from one bank of the stream to the other, so that it is necessarily to measure at many points, So knowledge of these phenomena is evidently of vital importance in making flow measurements and computing flow parameters.

1.1. Methods of measuring velocity

Normally measurements of velocity can be carried out either directly by measuring the parameters length and time by mechanical, electrical or electronic devices based on requirements of accuracy. However some times, the number of revolution, dispersion of dye or change in magnetic field are measured by accurate instruments and velocity is computed using recorded data. These types of measurements are summarized below.

1.1.1 The direct method

The direct method measure exactly the velocity of flow. The direct methods include (Ref 2) measurements with the mechanical or digital current meter, Pitot tube etc. Pitot tube is used to measure relatively high velocity in the channel, Current meter is the most commonly used equipment for measuring the velocity flow in the channel; It consists of a wheel containing blades or cups and a tail on which flat vanes are fixed. The number of revolutions of the wheel per unit time is proportional to the velocity of the flowing water (Ref 1).

1.1.2 The Indirect method

The indirect methods include measurements with the Color velocity and salt velocity method. Color velocity method consists of determining the velocity of a dye between two locations of known stations in a channel. Commercial fluorescent or potassium permanganate is used as the coloring pigment. Fluorescent produces a greenish color when dissolved in water and potassium permanganate produces a purple color which disperses with velocity of water. Salt velocity method is based on the fact that the addition of salt increases the electrical conductivity of water. As a slug of salt, usually sodium chloride, is forced into the stream under pressure through quick closing pop valves, mixing occurs with the stream and the mean velocity of the flow is obtained by measuring the speed of the solution as it moves with the stream (Ref 6).

II. ORGANIZATION OF MANUSCRIPT

The present research paper contains ten main headings. A brief review of different methods of velocity measurement is given under introduction. Literature review provides a theoretical background & work carried out by earlier researchers related to present study. Objective of study gives aim of the entire study. Balls used in the study are given in Materials. Details of flume and arrangement for string angle measurement are given in experimental setup and description of flume. Result and discussion provides the overview of the entire study and ranges of velocity for balls. 30mm ball provide maximum acceptable range useful for measurement of velocity is given in the conclusion. Detail studies could be carried out in future is discussed in the further scope.

III. LITERATURE REVIEW

Prof R K Rai has studied (Ref4) method for measurement of velocity in a 600mm wide flume. The method was based on the principle of drag force exerted by flowing fluid on a submerged spherical body. In his study a concrete ball of diameter 61mm, mass 283 grams and submerged weight 1.614N was used.

IV. OBJECTIVE OF STUDY

In the present studies therefore it was proposed to study the method of Prof R K Rai by taking concrete ball of diameter ranging from 20mm to 50mm and quick studies using steel ball diameter ranging from 6mm to 15mm to suit the limitation of our setup of experiment.

To give the correlation between string angle and velocity of flow for concrete ball of diameter 50mm to 20mm and 15mm to 6mm steel ball in laboratory flume and to identify the ball suitable for velocity measurement in laboratory flume.

The submerged spherical body remains in static equilibrium under the action of following forces, The submerged weight of the body (W) acting vertically downwards direction, Drag forces (F_d) acting on the body in the direction of fluid flow, The tensile force (T) in the string acting at an angle (θ) with the vertical. Then application of Lami's theorem or the equation of static equilibrium for the submerged body which is in the equilibrium under the action of the forces W, F_d and T yields equation (1). For a body held stationary in a stream of real fluid moving at a uniform velocity, the drag force is expressed as equation (2) (Ref1). Equating equations (1) and (2) and substituting the values of constants we can write equation (3).

$$F_d = W\tan\theta \quad \text{-----------------} \quad (1)$$

$$F_d = \frac{1}{2}\left(C_d A \rho V^2\right) \quad \text{-----------------} \quad (2)$$

$$V = C\sqrt{\tan\theta} \quad \text{-----------------} \quad (3)$$

Where,

F_d = Drag force
W= Submerged weight of spherical body
θ =Angle made by string with the vertical
C_d = Coefficient of drag
A = Exposed area of the body on a plane perpendicular to the direction of motion.

ρ= Mass density of the fluid

V = Velocity of the flow.

Equation (3) is used for calculating velocity of flow. For velocity measurement note the deflection of string i.e. angle θ and then put it in equation (3) we will get velocity of flow. The constant C is depending on diameter and material of ball.

V. MATERIALS

For the present study concrete ball of 50mm to 20mm for preliminary experiments were taken. Then experimentation were carried out by submerging ball in laboratory flume.

Figure1. Balls used in Experiment

VI. EXPERIMENTAL SETUP AND DESCRIPTION OF FLUME

Experimentation were carried out in the Tilting Fume size 3.00m length, 300mm width, 300mm depth (Fig 2). At the inlet suitable arrangement steadying section is provided so that there will be fewer disturbances at the test section. Depth was measure with the help of a hook or pointer gauge mounted on a trolley which provides longitudinal and transverse movement.

The experimental setup is the arrangement for the angle measurement of the string and the arrangement for towing the ball in laboratory flume. The arrangement for the angle measurement consists of a protractor on which degrees are marked to read up to one degree.

In the present set experimentation a string connected to ball were used to measure the corresponding deflection of the string under the influence of prevailing velocity. For various strings angle discharge was measured using pressure gauge by observing pressure difference. These studies were carried out with bottom clearance of d=2.5cm for the ball and for a depth D=12.5cm i.e d/D ratio 20%.

. **Figure 2.**Ttilting Hydraulic Flume

Table-I provides below velocity equation for different concrete balls.

Table I: Properties of Concrete Ball

Sr. No	Diameter of concrete ball in mm	Weight in gm	Constant for equation (3)
1	50	159.6	1.461
2	45	114.8	1.363
3	35	53.8	1.194
4	30	33.9	1.104
5	06	0.88	1.088
6	20	10.0	0.898

VII. RESULT AND DISCUSSION

1. As the diameter reduces from 50mm to 20mm the deflection θ reduces from 4° to 16°.
2. From Table-II, the range of max velocities is from 0.41m/sec for a 50mm diameter concrete ball upto 0.60m/sec for a 30mm diameter concrete ball.
3. Similarly the range of minimum velocity from 0.12m/sec to 0.19m/sec
4. The range of velocity for 30mm diameter is 0.14m/sec to 0.60/sec is wider as compared to other concrete ball
5. Hence detailed experiment were carried out with 30mm diameter concrete ball.

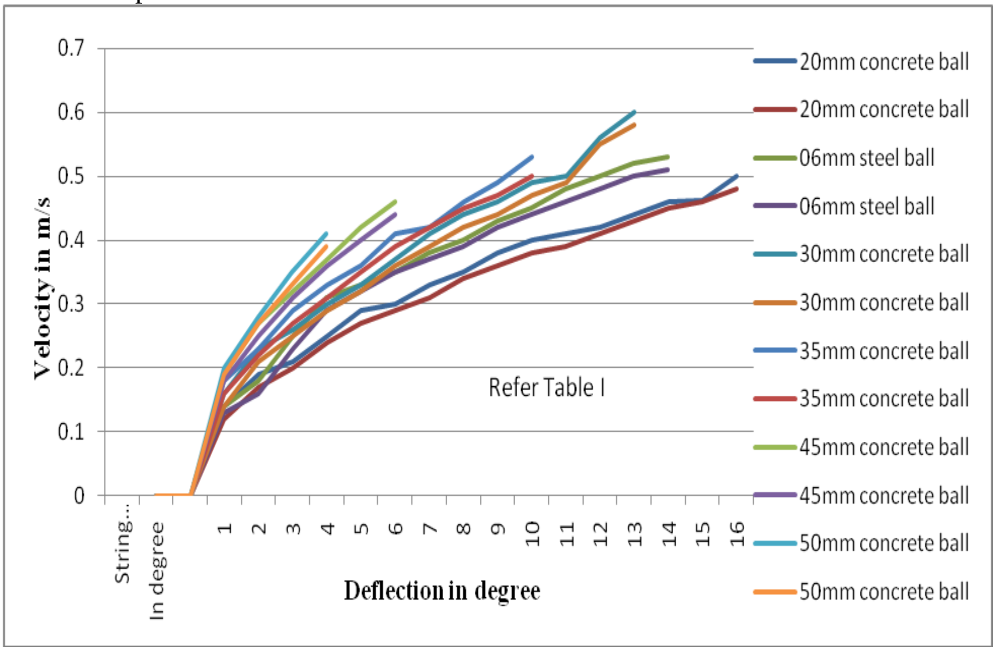

Figure3. Velocity Vs Deflection for Concrete and Steel Ball

Table II. Experimental Velocity (VE) and Theorotical Velocity (VT) for Ball

BallString angle(ϴ) In degree	20mm concrete ball		06mm steel ball		30mm concrete ball		35mm concrete ball		45mm concrete ball		50mm concrete ball	
	VE m/s	VT m/s	VE m/s	VT m/s	VE m/s	VT m/s	VE m/s	VT m/s	VE m/s	VT m/s	VE m/s	VT m/s
1	0.14	0.12	0.14	0.13	0.16	0.14	0.18	0.16	0.19	0.18	0.2	0.19
2	0.19	0.17	0.18	0.16	0.23	0.21	0.23	0.22	0.27	0.25	0.28	0.27
3	0.21	0.2	0.25	0.23	0.26	0.25	0.29	0.27	0.32	0.31	0.35	0.33
4	0.25	0.24	0.31	0.29	0.3	0.29	0.33	0.31	0.37	0.36	0.41	0.39
5	0.29	0.27	0.33	0.32	0.33	0.32	0.36	0.35	0.42	0.4		
6	0.3	0.29	0.35	0.35	0.37	0.36	0.41	0.39	0.46	0.44		
7	0.33	0.31	0.38	0.37	0.41	0.39	0.42	0.42				
8	0.35	0.34	0.4	0.39	0.44	0.42	0.46	0.45				
9	0.38	0.36	0.43	0.42	0.46	0.44	0.49	0.47				
10	0.4	0.38	0.45	0.44	0.49	0.47	0.53	0.5				
11	0.41	0.39	0.48	0.46	0.5	0.49						
12	0.42	0.41	0.5	0.48	0.56	0.55						
13	0.44	0.43	0.52	0.5	0.6	0.58						
14	0.46	0.45	0.53	0.51								
15	0.461	0.46										
16	0.5	0.48										

In the above Table II VE is experimental velocity and VT is the Theorotical velocity.

VIII. CONCLUSION

Since earlier studies carried out by Prof R K Rai (Ref4) were with single concrete ball only, the series of experiment discussed above indicate that the results obtained with 30mm diameter provide maximum acceptable range useful for measurement of velocity.

It could be seen from Fig 3 that for laboratory facilities of small size less than 600mm the experiment carried out by using equivalent concrete and steel ball indicate acceptable results for various velocities and deflection which are in agreement.

IX. FUTURE SCOPE

Detail studies could be carried out in future using steel ball for smaller size flume of the size 450mm, 300mm etc and propose a correlation between string angle and velocity of flow.

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