NEW TECHNIQUE FOR DISCHARGE MEASUREMENT IN OPEN CHANNELS

Introduction:

Discharge measurement is of prime importance for management and distribution of water resources. All the design work and channel layout plans are govern by this data. Various portable and permanent equipments are being used for the measurement of discharge in open channels like Ultrasonic and Magnetic flow meter, Acoustic Doppler Current Profiler, Area-Velocity techniques, flow measuring structures etc. However, such equipments are costly, difficult to use, need skilled persons, require measurement of a number of parameters, etc. The present study is aimed to evolve a simple and cost-effective technique for discharge measurement.

Review of the available techniques:

Measurement of discharge is being carried out by using various flow meters like ultrasonic, Doppler, electromagnetic and insertion flow meters etc. But these instruments involve complex machinery, require operators with sound technical knowledge, have high maintenance cost and count heavy on the user's pockets. Apart from these, there are other conditions that must be borne in mind for the accurate results of these meters such as (a) minimum head loss; (b) Continuous measurements over a long period of time etc.

Hydraulic structures like Broad crested weirs, Sharp crested weirs, Parshall Flumes and Venturi Flumes etc are also being used to measure the discharge. Suppose one wishes to measure discharge across a particular section of river Ganga. Now it is not at all practical to construct a weir across Ganga. And if at all this has to be done large planning is required before hand. Thus such method's application area has narrowed down to small canals and streams. Since these methods require construction in situ which involves large planning beforehand, these are considered some what cumbersome.

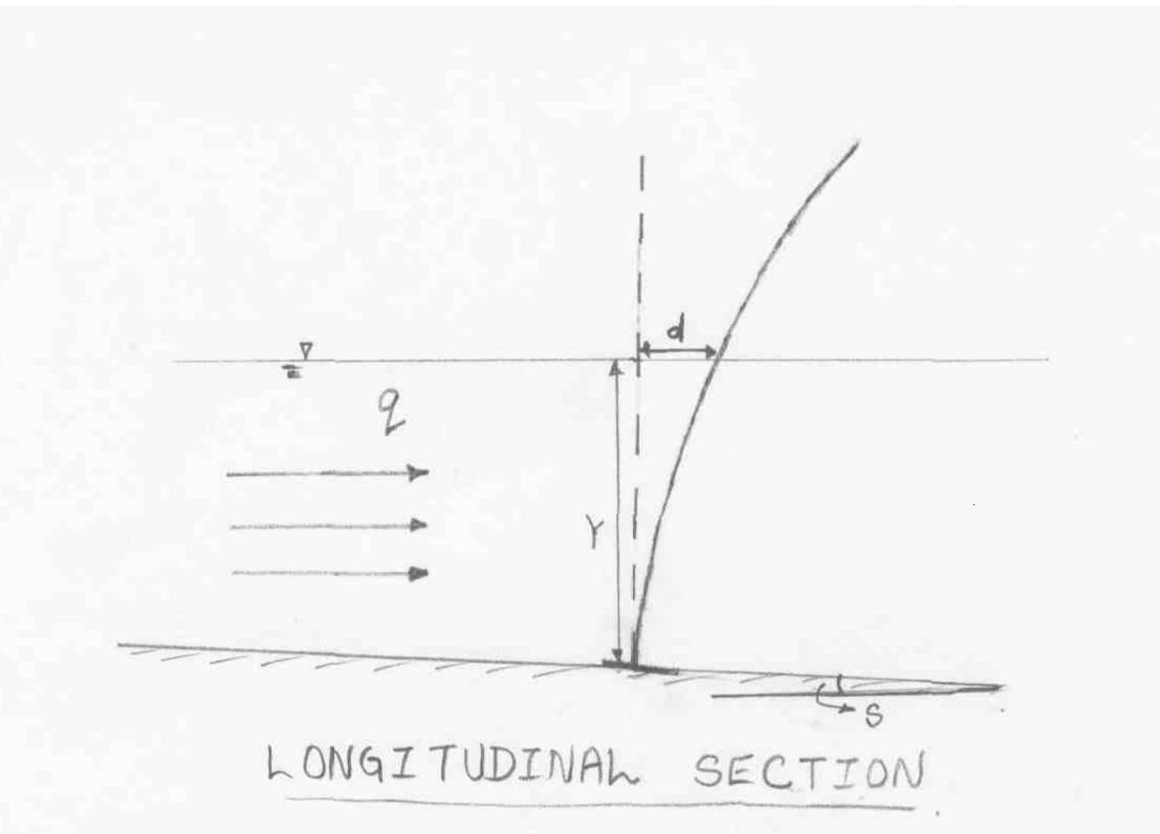
Thus a need of a new technique for discharge measurement in open channels popped up in our minds.

Objective:

The proposed technique is a solution to these above stated problems. This technique for discharge measurement in open channels that will be (a) Devoid of any sort of complex machinery, (b) Installed easily, (c) Zero technical support required, (d) Having low maintenance cost, (e) Economical, (f) Having a fair degree of accuracy.

Approach:

The discharge measuring instrument consists of a plastic strip fixed at the bottom and free at the upper end. When instrument is placed at the bed of the channel the strip bends due to the drag force. The deflection will be measured and correlated with the discharge intensity.



Theoretical Approach:

Velocity distribution in an open channel over a rough bed is given by:

$$\frac{u}{u^*} = 5.75 \log_{10}\left[\frac{y}{k}\right] + 8.5 \qquad (1)$$

Where :

$$u^* = \sqrt{\frac{\tau_0}{\rho}} = \sqrt{gRS}$$

τ_0 = Shear stress at bed; ρ = Mass density of water; R = Hydraulic mean radius, S = Slope of the bed; g = Gravitational Acceleration; k= bed roughness height. One can integrate Eq. (1) over the depth of flow to get discharge per unit width (q).

$$q = 14.85\sqrt{S}\, y_1^{1.5}\left[\ln\frac{y_1}{k} + 2.738\right] \ldots\ldots\ldots\ldots\ldots(2)$$

Where y_1 = Free surface height

Drag force on the strip upto the free surface can be computed by integrating the following drag force on the elemental area of the strip.

$$F_D = C_D \frac{\rho u^2}{2} A$$

To get

$$F_D = 1.559 \rho C_D bgSy^2\left(\left[\ln\frac{y}{k}\right]^2 + 5.808\left[\ln\frac{y}{k}\right] + 8.683\right) \qquad (3)$$

Where F_D is the total drag force on the strip upto y from fixed end; C_D is the drag coefficient; b is the width of the strip;

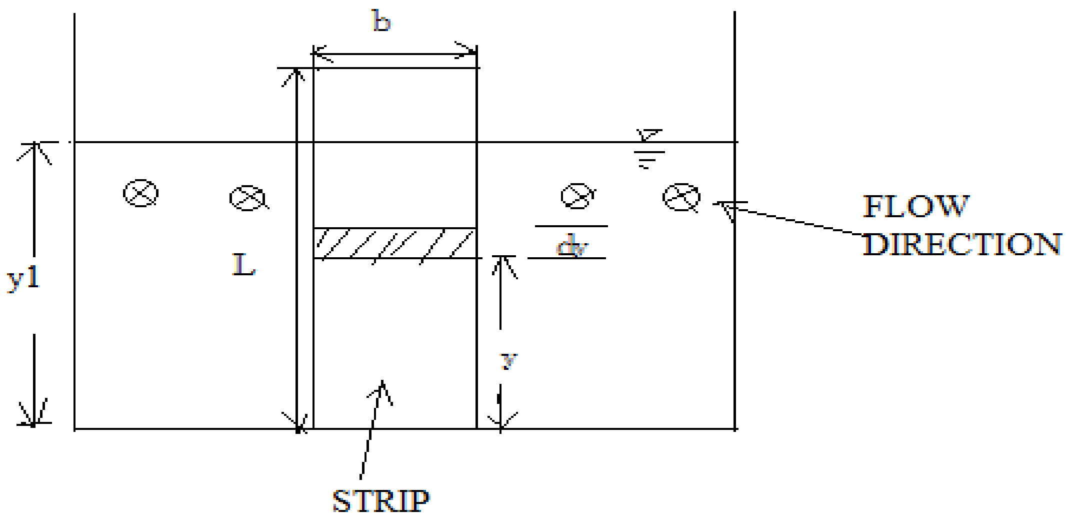


Figure: Channel Section

The strip behaves like a cantilever under the loading. Thus deflection δ of the strip may be calculated using any method like Unit load method for known value of strip's dimensions, modulus of elasticity (E).

$$\delta = \frac{0.285\rho C_D bgS}{EI} y_1^5 \left(\left[\ln \frac{y_1}{k} \right]^2 + 6.27 \left[\ln \frac{y_1}{k} \right] + 9.912 \right) \qquad (4)$$

Computed deflection is plotted for different values of q for its ready use.

Experimental Approach:

Experiments have been performed in the Hydraulics Laboratory of Civil Engineering Department. Velocity profile along vertical is measured using Pitot tube and ADV (Acoustic Doppler Velocity meter) to estimate the discharge per unit width. The experiment is carried out in wide open plume with smooth cement bed having slope of 1 in 1250. Then instrument is fabricated to measure the deflection of the strip at the water level surface. Corresponding deflection is noted. The observed values of deflection and discharge intensity are verified using the graph prepared.

Description of the Instrument:

Instrument consists of

1 iron base plate (360mm x 300mm x 3mm),

3 HYSD bars (8mm dia.) forming the frame for handling,

2 Al angle section (6mm x 6mm x 0.1mm) to fix the strip,

1 Measuring tape

Sliding wire arrangement

1 Plastic Strip

Length x Breadth x Thickness :(445mm x 25.52mm x 2.58mm)

Modulus of Elasticity: 0.078 GPa

Weight: 36.33 gm

Elevation view of Instrument fabricated followed by side view

Ankur holding the instrument in position. Notice the wooden wave suppressor used.

Arun measuring the deflection.

Computation of parameters:

Slope of the experimental bed was determined by water balance method and verified by using Total Station.

Modulus of elasticity (E) was determined by measuring the deflection of the simply supported strip at the span center under different loadings.

Deflection $\Delta = \frac{Pl^3}{48EI} + \frac{5wl^4}{384EI}$

Where P is point load and w is uniformly distributed load

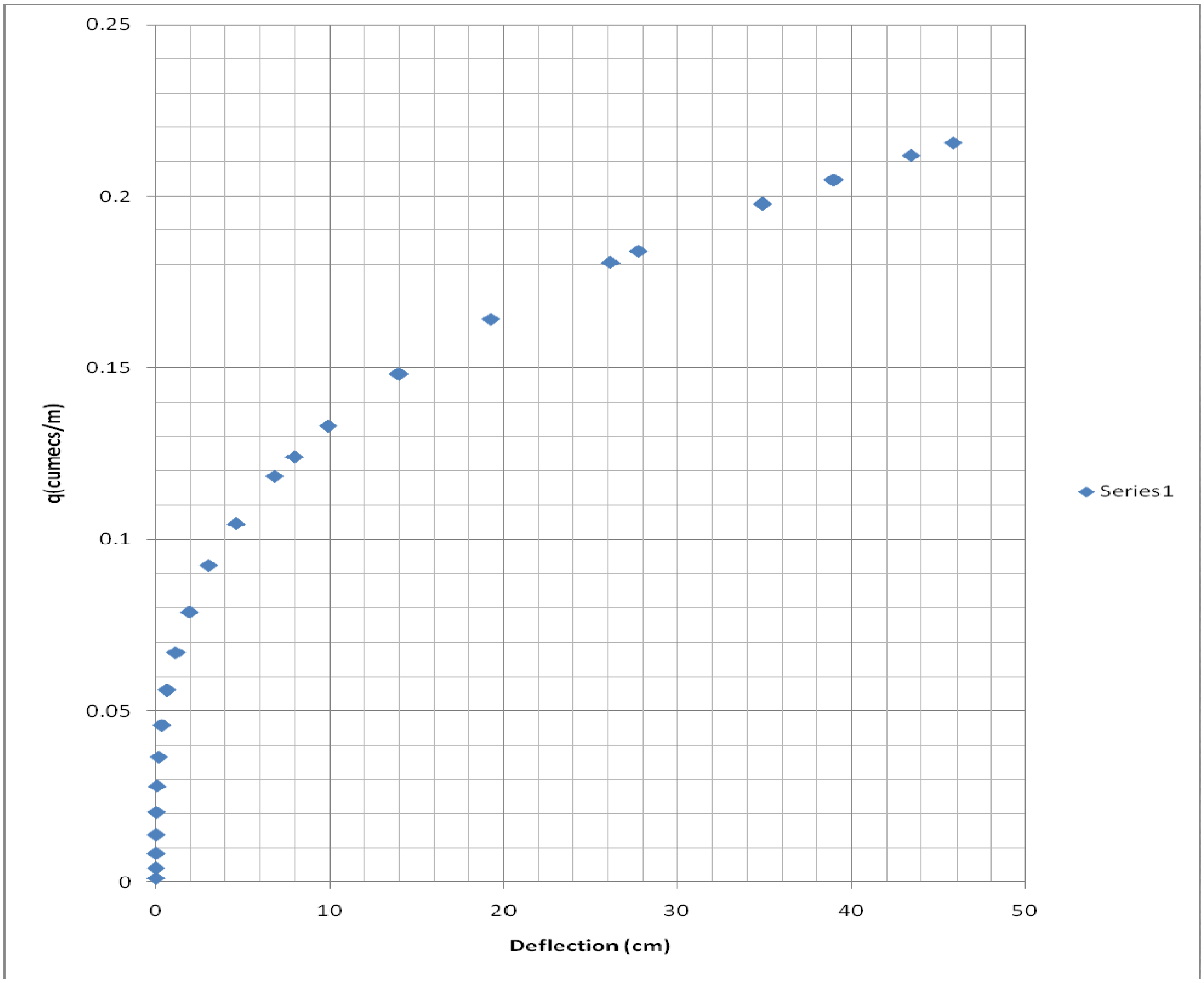
Observations:

Observation table for experimental values (to be used for verification):

Deflection (cm)	q(obs.) (cumecs/m)
4.7	0.102
5.2	0.105
5.4	0.1096
5.6	0.112
5.9	0.116

Graph:

Graph between theoretical deflection values and Discharge intensity values obtained from the formula derived above (2) and (4).



Verification:

The observed values are very close to the computed values .i.e. they are within the accuracy limits of about 3.5%.

Results and Discussion:

A new technique, based on deflection of strip placed on the bed of a channel, has been developed. The new methodology matches well with the experimental values under certain constraints, as all the derivations are based on basic fluid mechanics and structure analysis concepts that are applicable on ideal systems.

Highly turbulent flow produces absurd results. Thus as far as possible the flow should be laminar or wave suppressors must be used in upstream. Instrument must be kept at least 1m away from any kind of fall whether upstream or downstream.

Slope of the bed, channel roughness height, modulus of elasticity of strip material must be determined, if these are different from the experimental conditions and placed into the formula to determine the discharge intensity from the observed deflection values. Once the deflection value is measured then using the graph given above (that will get modified if different bed) the discharge intensity can be determined. This technique is very simple as it is just single parametric approach i.e. only deflection is to be measured which will directly give the discharge intensity.

This technique is very versatile as every site dependent parameter is given in symbol form in the formula. Knowing them the discharge intensity of manmade channels can be easily determined. Total cost incurred in fabricating the instrument is around Rs 250 + labor charges. Thus it is economically viable technique. The only maintenance required is for the strip support at the base plate.

Since the cost incurred is very low and accuracy is fair enough, the total cost/performance ratio is very low. Material used for fabricating the instrument is easily available in almost every market.

Utility:

This technique will be very helpful for the Water resource Engineers as well as Layman. With the help of the instrument and graph any person in need to measure the discharge can easily do it. It will have wide areas of application and will definitely prove a good replacement for the complex devices and methodologies available today. It can be used to assess discharge in industrial channels, drains and other natural or manmade channels. As far as using is concerned it will be so simple that even a farmer can use it to measure discharge of the stream that irrigates his crops.