"OPEN CHANNEL FLOW CHARACTERISTICS USING GABION WEIR"

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Abstract - *A solid weir consists of an impermeable body Constructed of concrete and its primary function is heading up water and reducing flow velocity. The wire mesh of the gabion basket serves to restrain any significant movement and also gabion weirs offer an alternative design that can be adopted for flash flood mitigation. In this study, a series of laboratory experiments was performed in order to investigate the open channel flow interaction with gabion and to reduce the flow velocity. Gabion weir was tested in horizontal laboratory flume of 4.7-m length, 0.21-m width, and 0.3-m depth for a wide range of discharge, upstream water depth, downstream water depth, slope and gabion filling gravel material size. The experimental results of the gabion weir were compared with solid weirs having the same dimension and found that there is a large deviation when the solid weirs equation is applied to gabion weirs. Discharge over weir was computed by using multiple regression equations which was developed based on the dimensional analysis theory.*

***Key Words*: Solid Weir, Gabion weir, Discharge co-efficient, Submerged Flow, Flume**

1. INTRODUCTION

A weir is a barrier across the horizontal width of the river that alters the flow characteristics of the water and usually results in a change in the vertical height of the river level. There are many designs of weir but commonly water flows freely over the top of the weir crest before cascading down to a lower level. Weirs are commonly used to prevent flooding, measure discharge and help render rivers navigable. In some locations the dam and weir are synonymous, but normally there is a clear distinction made between the structures. A dam is usually specifically designed to impound water behind a wall, where as a weir is designed to alter the river flow characteristics. A common distinction between dams and weirs is that water flows over the top of a weir or underneath it for at least some of its length. Weirs can vary in size both horizontally and vertically, with the smallest being only a few inches in height where as the largest may be hundreds of meters long and many meters tall.

Weirs are overflow structures that stretch across an open channel of water and are meant to alter the channel's flow characteristics making it easier to measure the volumetric rate of water flow. Weirs act like miniature dams, blocking the flow of water, and causing it to pool behind them until it is deep enough to flow over the top of the weir. The height of the water flowing over the crest of the weir correlates to the flow rate. Therefore, through equations, graphs and tables the volumetric flow rate can be determined from measuring the depth of water flowing over the weir with relatively high accuracy. In addition to measuring discharge, weirs can help make rivers more navigable and prevent flooding.

1.1 Objective

The main objective of this research work is to study the behaviour of open channel flow using stone gabion to reduce the flow velocity.

Specific Objective

- To determine the maximum velocity at varying depths and slopes
- To select the size of stones for Gabion for reduction in velocity
- To generalize the discharge equation for flow over gabion using regression analysis

1.2 Literature review

The studies have shown that conventional weir typically consists of an impermeable body constructed of concrete, since its primary functions are to heading up water and efficiently regulate flow. The impermeable body prevents the longitudinal movement of aquatic life and transportation of physical and chemical substances in water, eventually having a negative impact on the water. **Hassan I. Mohamed (2010)**, carried out the study on Flow over Gabion Weirs. One of the advantages of gabions as a building material is that the motion of individual stones comprising the gabion is not of much concern. The wire mesh of the gabion basket serves to restrain any significant movement. In this study, a series of laboratory experiments was performed in order to investigate the flow over gabion weirs. For this purpose, two different gabion weir models were tested in two horizontal laboratory flumes of 10m and 17m length, 0.3m width, and 0.3m and 0.5m depth, respectively, for a wide range of discharge, upstream water depth, downstream water depth, weir height, weir length, and gabion filling gravel material size.

Vegetation growing in the water along rivers has been the subject of several studies since it was recognized that it could have a significant impact on the water flow **Hamimed A et. al., (2013),** reviewed on a contribution to the study of the flow resistance in a flume with artificial emergent vegetation. The purpose of this paper is to investigate, how density and placement of emergent vegetation influence flow resistance, water depth and velocity profile. Experiments using artificial vegetation selected to simulate emergent vegetation were carried out in a laboratory flume instead of natural channel, and Manning's n is used to denote the resistance coefficient. The results show large variations in the Manning resistance coefficient with depth of flow and vegetative density. Vegetation causes resistance to flow. Later it was concluded that the measurements show that the water depth-discharge relationship depends strongly on the density of vegetation.

Mahyuddin Ramli et. al., (2013), carried out the study on the stability of gabion walls for earth retaining structures. The stability of earth retaining structures in flood prone areas has become a serious problem in many countries. The two most basic causes of failure arising from flooding are scouring and erosion of the foundation of the superstructure. According to the US Federal Highway Administration, up to 60% of bridge failures were caused by natural phenomena, especially from flooding. Gabion walls are also suited to the following cases; Poor orientation of bridge piers with respect to water flows. Large restrictions in flow imposed by the bridge superstructure. Fine-grained materials, susceptible to move with a small increase in flow velocity. Unpredictable increases in the water flow. The results indicate that the hexagonal gabion exhibits better overall structural integrity than the conventional gabion in terms of deformation resistance and susceptibility to collapse. The shear behavior exhibited by each wall illustrates the principal link between unit configuration and overall stability when cellular units are built into a continuum.

Experimental study on gabion stepped spillway paper was presented by **M.Shafai-Bajestan et. al., (2009),** Rocks in its natural form is the most abundant and economical material in hydraulic engineering practice. Rocks have been used in dam construction, river engineering works, river intakes etc. The size of rock in these practices depends on the hydraulic conditions such on flow velocity, shear stress, hydrostatic and hydrodynamic pressures. When these conditions are high, the required size of stone will be large and impractical Gabions are hexagonal mesh boxes filled with small sizes of stone. The advantage of gabion is their stability, low cost, flexibility, porosity. Use of rocks and gabions in hydraulic works especially in the area of river engineering has been increased during recent decades. Gabion stepped spillway is a type of hydraulic structures which is designed for river bed protection. Most of the flow kinetic energy is dissipated when flow cascade from one step to another. The main objective of this study is to conduct a series of experimental tests to investigate the mechanism of scour hole downstream of stepped spillway. A total of 19 tests were conducted.

To predict the scour dimensions downstream of gabion stepped spillway, experimental program was conducted. Three types of spillways with slope of 1V:3.5 H, were tested under different flow conditions and two bed material sizes. In this study three types of gabion stepped spillways under different flow conditions and bed materials were tested. Based on stability analysis of a particle at the point of incipient motion, a general formula was developed to predict the scour hole depth. By the help of regression analysis technique and use of the experimental data, three equations were developed for prediction of scour depth at downstream of stepped spillways. From these equations, one can predict the scour depth. It was found that the scour depth downstream of simple gabion stepped spillway is greater than the scour depth for pooled stepped spillway. A procedure for design of gabion stepped spillway is presented.

2. Materials and Methodology

2.1 Materials

Solid weir and gabion weir (fig 1 and fig 2) are manually prepared, for measured dimensions and these weirs are placed at different distances from the inlet of venturiflume and for different slopes. After conducting the experiments the velocities and pressures are measured.

Fig -1 Solid weir

Fig -2 Gabion weir

Gabion weir is fabricated using mild steel. Steel rods of 0.01m are used to provide framework to gabion weir. The clear spacing between the wires of gabions is 0.01m i.e., 1.5-2 times greater than the size of stones in order to avoid the stones coming out of gabion weir. Stones are used as filing material in the Gabion weir. Granite stones that are clean and durable are collected from the banks of Balmuri, Mysore. Fig 3 shows stone collection at the Balmuri,

Solid weir is fabricated using cement, fine aggregate and coarse aggregate in the ratio 1:2:4. The dimensions of the sold weir are kept as same as that of Gabion weir for the comparison purpose.

Fig- 3 Stones collected from Balmuri, Mysore

2.2 Equipments

- **Hydraulic flume**
- **Abrasion testing machine**
- **Angularity test apparatus**

Hydraulic fumes are engineered structures constructed to carry water and to measure the discharge. Hydraulic flume is also called as Venturi flume.

The dimension of laboratory hydraulic flume is 4.7m X 0.21m X 0.3m length, breadth and height respectively.

The flume has a provision for the direct measurement of discharge with the help of venturimeter.

The pressure difference at the inlet and throat region gives the discharge value.

This discharge valve is taken as actual discharge and the theoretical discharge value is calculated from weir by measuring the head over the weir. Fig 4 shows the hydraulic flume.

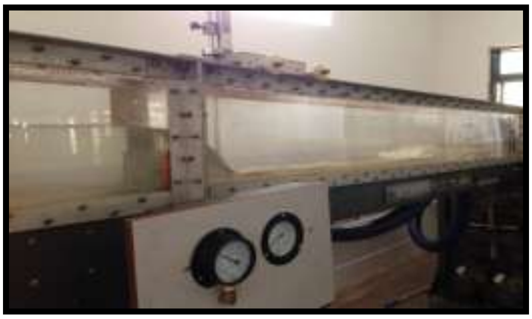

Fig- 4 Hydraulic flume

Fig- 5 Los-Angeles abrasion testing machine

Fig- 6 Angularity test apparatus

2.3 Methodology

Experiments are conducted in laboratory using the instrument called hydraulic flume. This study is deals with using Gabion weir as a flow reducing structure, which helps to reduce the velocity by cutting the water depth into number of layers and also it helps to reduce the turbulence.

2.3.1 Weir Design

Weir dimensions such as length, breadth and height are fixed based on maximum water depth in the flume and Bernoulli's equation.

Height, Width, Length

Weir height is maintained at 0.105m which is well maintained above the critical depth and below the maximum water level in the flume. The width of the weir should be equal to the width of the channel. Therefore, the weir breadth is taken as 0.21m.The length of the weir in the direction of water flow is taken as 0.10m.
Sieve analysis is carried to separate the different size of stones. For larger project works, stone size of 100mm-200mm are used. But for smaller works usually stone size below 20mm are selected. Hence the stone size selected for this project work is 16mm and 20mm. Abrasion Test and Angularity tests on stones are conducted in the laboratory.

2.3.2 Experiment conduction in Hydraulic Flume

- Experiment is carried out in Hydraulic flume of 4.7m X 0.21m X 0.3m, Length (L), width (B) and height (D) respectively
- Gabion weir is placed at L/4 and L/2 positions from the inlet of the flume
- Upstream water depth and downstream water depth is measured using hook gauge at 0^0, 1.5^0 and 3^0 slopes
- Experimental procedure is repeated for solid weir also and the corresponding upstream and downstream water depths are measure
- The pressure difference between the inlet and throat region of venturi meter is noted down to determine the actual discharge
- Dimensional analysis and regression analysis is carried out to develop new discharge equation for the gabion weir
- The discharge equation obtained from the multi-regression analysis is used to calculate theoretical discharge over the gabion weir
- Co-efficient of discharge is then calculated by taking ratio of actual discharge by theoretical discharge
- Chezy equation is used to determine the velocity over the weir i.e., $V_{th} = C_d \sqrt{2gH}$
- The velocity of solid weir and gabion weir is compared and the reduction in velocity is noted down

3. RESULT AND DISCUSSION

Experiments are conducted in hydraulic flume at different slopes and different depth with solid weir and gabion weir. The discharge value of solid weir and gabion weir are tabulated and test on stone is performed in the laboratory. The experimental discharge value for different stone sized gabion weir and solid weir are calculated using venture meter. The following table-1 shows the venturi meter readings.

Table-1: Venturi meter readings

Sl no	Particulars	Readings
1	Inlet diameter of venturimeter d_1	0.09 m
2	Throat diameter of venturimeter d_2	0.035 m
3	Area at inlet region a_1	0.0064 m^2
4	Area at throat region a_2	0.0010 m^2

For solid weir and gabion weir of 16mm stone size and 20mm stone size, fixed slopes and distances of weir position from the inlet of venturi flume are shown in table-2. Based on this table (slopes and distances) the readings are taken in the instrument venturi flume

The measured pressure, discharge values for one fixed distance and slope, of solid weir shown in table-3. The measured pressure and discharge values for one fixed distance and slope, of Gabion weir of 16mm stone size and 20mm stone size shown in table-4 and table-5. And for

Different distances (L/4 distance from the inlet) and varying slopes for solid weir and gabion weir are placed shown in fig 7 and fig 8

Table-2: Type of weir, slope and distance from inlet

Type of Weir	Slope in gradient	Distance of weir position from inlet of venturi flume
1 Solid weir 2 Gabion weir (16mm stone size) 3 Gabion weir (20mm stone size)	0 0 1 in 0.33 1 in 0.33 1 in 0.66 1 in 0.66	L/2 Position L/4 Position L/2 Position L/4 Position L/2 Position L/4 Position

Table -3: Discharge value at 1 in 0.33 gradient and L/2 position for solid weir

Slno	Venturi Flume reading for solid weir			
	P1(kg/cm²)	P2(kg/cm²)	H =(P1-P2) m	Q (m3/s)
1	0	0.1	-1	0.00387
2	0	0.1	-1	0.00387
3	0.05	0.05	0	0
4	0.1	0	1	0.00387
5	0.15	-0.05	2	0.00548
6	0.15	-0.05	2	0.00548
7	0.15	-0.05	2	0.00548
8	0.15	-0.1	2.5	0.00613
9	0.15	-0.1	2.5	0.00613
10	0.15	-0.1	2.5	0.00613
11	0.15	-0.1	2.5	0.00613

Table -4: Discharge value at 1 in 0.33 gradient and L/2 position for gabion weir of 16mm stone size

Sl no	Venturi Flume reading for gabion weir of 16mm stone size			
	P1(kg/cm²)	P2(kg/cm²)	H =(P1-P2) m	Q (m3/s)
1	0	0	0	0
2	0	0	0	0
3	0.05	-0.05	1	0.00387
4	0.05	-0.05	1	0.00387
5	0.05	-0.05	1	0.00387
6	0.05	-0.05	1	0.00387
7	0.1	-0.05	1.5	0.00474
8	0.1	-0.05	1.5	0.00474
9	0.1	-0.05	1.5	0.00474
10	0.1	-0.1	2	0.00548
11	0.1	-0.1	2	0.00548

Table -5: Discharge value at 1 in 0.33 gradient and L/2 position for gabion weir of 20mm stone size

Sl no	Venturi Flume reading for gabion weir of 20mm stone size			
	P1(kg/cm²)	P2(kg/cm²)	H =(P1-P2) m	Q (m3/s)
1	0	0	0	0.000000
2	0	0	0	0.000000
3	0	0	0	0.000000
4	0.05	-0.05	1	0.003878
5	0.1	-0.05	1.5	0.004750
6	0.1	-0.1	2	0.005484
7	0.1	-0.1	2	0.005484
8	0.15	-0.2	3.5	0.007255
9	0.15	-0.2	3.5	0.007255
10	0.15	-0.2	3.5	0.007255
11	0.15	-0.2	3.5	0.007255

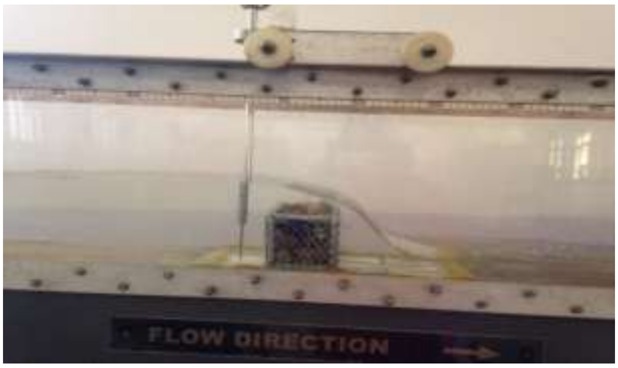

Fig -7: **Gabion weir placed at L/4 distance from inlet**

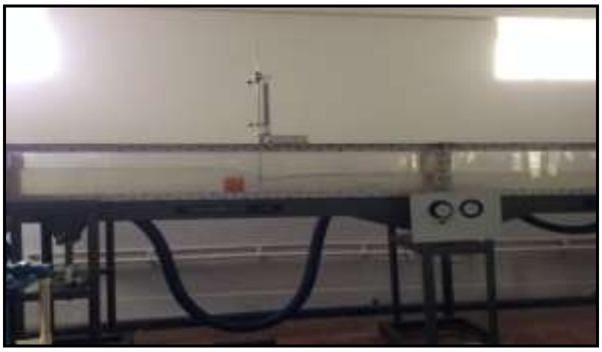

Fig -8: **solid weir placed at L/4 distance from inlet**

4. CONCLUSIONS

In this study, a series of laboratory experiments were conducted to investigate the flow through and over gabion weir. According to the results of the laboratory experiments, the following conclusions are drawn

1. The nature of flow over the gabion weir is different than that of the solid weir. As it is dividing into two parts one is above the weir and to other flowing through the weir
2. For the same discharge, the head over the gabion weir is less than that over the solid weir and the head decreases by increasing gabion material particle size
3. Multiple regression analysis equations based on the dimensional analysis concept were developed for computing the discharge over the gabion weir at free and submerged flow conditions
4. Gabion weir is more effective at slope than solid weir as the velocity of flowing water reduces as it pass through the weir

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