Laboratory Study of Head loss for Trapezoidal Weirs with Vegetation Elements

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Abstract-Rivers, the natural drainage, are the most important water resource in the world but it is difficult to measure accurate value of discharge of river during floods, due to change in bed formation of river. Accurate measurement of river during flood is very important because underestimation of flow may cause more disaster and overestimation may lead to wastage of resources. Embankment weirs, in this regard, e.g. railway embankment or highway embankment may be used for the measurement of discharge during flood. In this research paper, Embankment weirs with symmetrical side slope in open channel flow were investigated. Three different discharges were used in this study and graphs were plotted against each discharge to observe the effects of discharge on head loss. Moreover, embankment weirs with different side slopes were also investigated. This research will help to understand the effects of discharge on head loss in Laboratory and also in the field. Recommendations for future work have also been provided at the end.

Keywords-Embankment Weirs, Head Loss, Open Channel Flow, Sharp Crested Weir, Vegetation Rods

I. INTRODUCTION

Rivers, also the beauty of nature, are important for life. These are the most important source of water for domestic, industrial and commercial use. The discharge of river is always point of interest for hydraulic engineers to make maximum use of it and to keep people safe from its adverse effects. The unpredictable behavior of water makes it very difficult to measure the discharge accurately. However, studies in this topic convinced hydraulic engineers for the construction of big structures like weirs, barrages and even dams for storage of water and production of power. Regardless of all the benefits of river, these are responsible for destructions of a society, humans, animals, agriculture etc. It has been reported that sixty six million people a year were victimized during 1973 to 1997. Therefore it is the most challenging job for hydraulic engineers to safeguard the damages cause by floods. The development of hydraulic structures gave some solution to the problem but how to estimate the flow of river once flood came. Accurate measurement of flow during flood in flood plain is important to know for making some concrete decision to avoid damages in future. In this regard, embankment weirs e.g. railway embankment or highway embankment may be used for the estimation of flow. In this research paper, Laboratory investigations were carried out on embankment weir with symmetrical side slopes using different discharges. Weirs are the simplest arrangement in open channel due to the simple design, easy construction and accurate measurement. They may be classified into two categories i.e. sharp crested weirs and weirs of finite crest length [i]. Weirs of finite crest length may be divided into three categories i.e. long crested, broad crested and narrow crested weirs depends upon the ratio between head over the weir and crest length measured in direction perpendicular to the flow. If one considers head over the weir as "h" and crest length as "L" then ratio h/L shows long crested weir in the range 0 to 0.1 while ratio shows broad crested weir in the range 0.1 to 0.4. The ratio represents narrow crested weir in the range 0.4 to 2 whereas sharp crested weir in indicated by the ratio greater than 2. Different studies have been carried out for circular type or sharp edge of upstream weir end. Broad crested weirs were investigated by different researchers using ramps at upstream or downstream or at both ends. Broad crested weir with ramps at both upstream and downstream end may be called as trapezoidal weir.

The weirs in this research were kept fully submerged i.e. downstream water level higher than crest level of weir. Data was then found and using the data different calculations were performed and graphs were plotted with different parameters. The detailed work on different embankment weirs is presented in the paper.

II. LITERATURE REVIEW

The broad crested weir without ramps at upstream and downstream end i.e. vertical ends is known as standard trapezoidal weir. In this type of weir, cavitation occurs in downstream end and deposition of sediment may occur in upstream end. In this situation significant head loss will occur and it will be difficult to operate the hydraulic structure.

Reference [ii] showed that if vertical end of broad crested weir is changed to rounded end, the coefficient of discharge will increase. Reference [iii] showed that if vertical ends of weir are replaced with ramps, the deposition of sediments at upstream and scouring at downstream may be avoided. Trapezoidal weirs are of interest by the researchers in recent years and some experimental work was performed to develop discharge-head relationship. The importance of trapezoidal weirs lies in the fact that these represents embankment weir e.g. road or railway embankment and discharge during floods may be estimated using road or railway embankment without construction of some new hydraulic structure. Different studies were made but no general relation was developed yet. However, Reference [iv], developed an equation presenting discharge depth relation for finite crest length weir as

$$Q = Cd\,B \times (\sqrt{(8/27) \times g})\ h^{3/2} \qquad (1)$$

Where Q = discharge, Cd = Co-efficient of discharge, B = width of channel, g = acceleration due to gravity. In case of broad crested weir, the flow layers are smooth and hydrostatic conditions are achieved approximately [v]. If the edge corner of broad crested weir is rounded, the coefficient of discharge increases up to 8% [vi] (Woodburn). Experimental study was carried out by [vii] to highlight the effects of surface tension and viscosity on coefficient of discharge. The author of [viii] performed different experiments to investigate the effects of geometry of weir. They investigate the square edge and circular type edge weir. Different studies were carried out to find the inflow geometry of weir and pattern of discharge. The author of [ix] carried out embankment study based on experiments by considering embankment slopes of 2H: 1V. The author of [x] investigated the characteristics of discharge of Broad crested weirs. References [xi-xii] studied the hydraulic resistance offered by vegetation weir like structure during high stage.

III. EXPERIMENTAL SETUP

A smooth re-circulating rectangular-flume was used for the experimentation located in Hydraulics Laboratory, Department of Civil Engineering, University of Engineering and Technology, Taxila. The dimensions of flumes were 12.5 m length, 0.30 m width and 0.40 m depth and attached with the computer as shown in Fig. 1. The channel was kept horizontal throughout the experiments. Water entered the channel at the upstream end while the discharge was measured using sharp crested weir installed at the downstream end. Weirs were also used to control the depth of flow in the channel. Point gauges were used to measure the depth of flow. Water level was measured 1 m upstream from crest of trapezoidal weir and 2 m downstream from the crest of trapezoidal weir. Three different discharges were used for each weir and different depths were measured using point gauge for each discharge. The weir was kept fully submerged during whole experimentation.

Fig. 1. Channel used for experimentation

Trapezoidal weir, made of wood, was selected for this research. The crest height of model is 12cm, crest width is 6cm and side slopes are 1V:3H, 1V:5H and 1V:10H. Side slopes are symmetrical in upstream and downstream. Weirs were made by joining upstream and downstream faces with the rectangular crest as shown in Fig 2. Fig. 3 shows provision for vegetation elements. Fig. 4 represents installed vegetation elements over the weir crest while Fig. 5 shows the vegetated weir installed in the channel with water flowing in the channel. Vegetation in the form of circular rods was provided over the weir crest. Experiments were performed in three manners for each weir which includes experiment over (i) smooth weir (ii) weir with sparse vegetation and (iii) weir with dense vegetation. Vegetation was kept partially submerged during experimentation. Sparse vegetation contains five circular rods of 12cm height, 2cm dia. and offers 33% blockage while dense vegetation contains nine circular rods of same dimensions and offers 60% blockage.

Fig. 2. Trapezoidal weir used

Fig. 3. Holes for installing vegetation elements

IV. RESULTS AND DISCUSSIONS

The experiments were conducted using trapezoidal weirs with three different slopes and three different discharges including vegetation for each weir. Different depths were measured at upstream i.e. 1m from crest of weir and 2m downstream from crest of weir. The discharge coefficient was measured using eq.

$$qo = \frac{2}{3}C\sqrt{\frac{2}{3}g}Ho^{3/2} \qquad (2)$$

Where "qo" is discharge per unit width, "C" is discharge coefficient for fully submerged weir, "g" is acceleration due to gravity and "Ho" is the upstream energy head. Graphs were plotted between downstream water depth and head loss for weirs with three different slopes i.e. 1:3 1:5 and 1:10. For each weir, three different discharge values were used. Vegetation condition over the crest also varies in the above mentioned cases i.e. for 1:3 slope weir, there is no vegetation whereas sparse vegetation exists in case of 1:5 slope and it becomes dense for 1:10 slope weirs. Results have been shown in Fig. 6-8 below. It can be concluded from these graphs that the head loss reduces as the downstream water depth increases. Also, the curves depart from the origin when the discharge increases with all other parameters remaining constant. It is also clear from these graphs that head loss increases with increasing discharge. Graphs were also plotted again between downstream water depth and head loss for different slopes by maintaining the discharge as constant to observe the effect of slope on head loss. Results have been shown in Fig. 9-11. It was observed that with the increase in slope of weir the curve moves away from the origin which indicates that the head loss increases with increasing slope values for the same downstream depths of flow. Head loss vs d/s water depth for a weir with side slopes of 1:10 and discharge intensity of 9.23 l/sec with varying vegetation conditions have been shown in Fig. 12.

Fig. 4. Vegetation elements installed over the weir crest

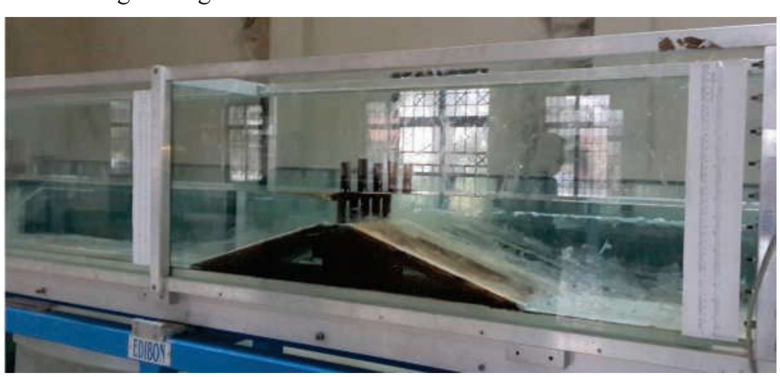

Fig. 5. Channel flow with partially submerged vegetation

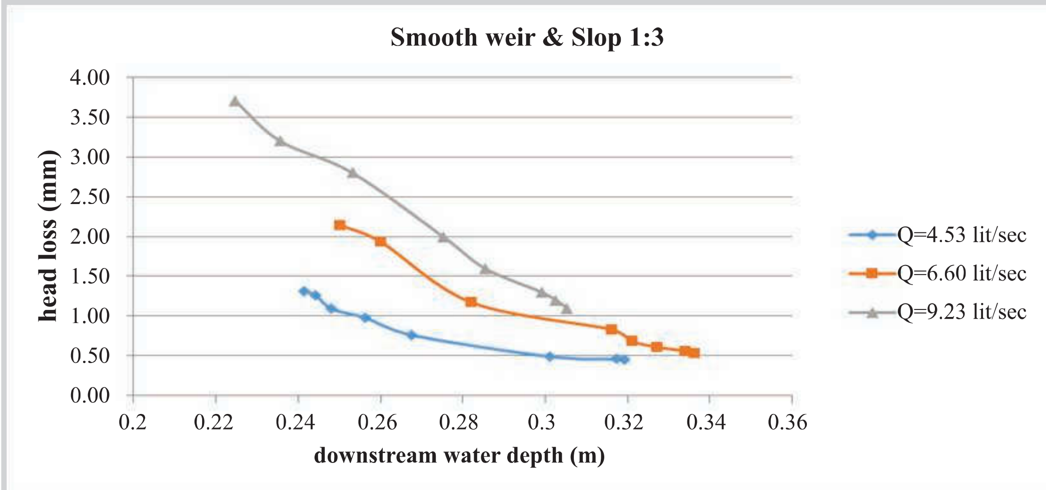

Fig. 6. Head loss vs d/s water depth for slope 1:3

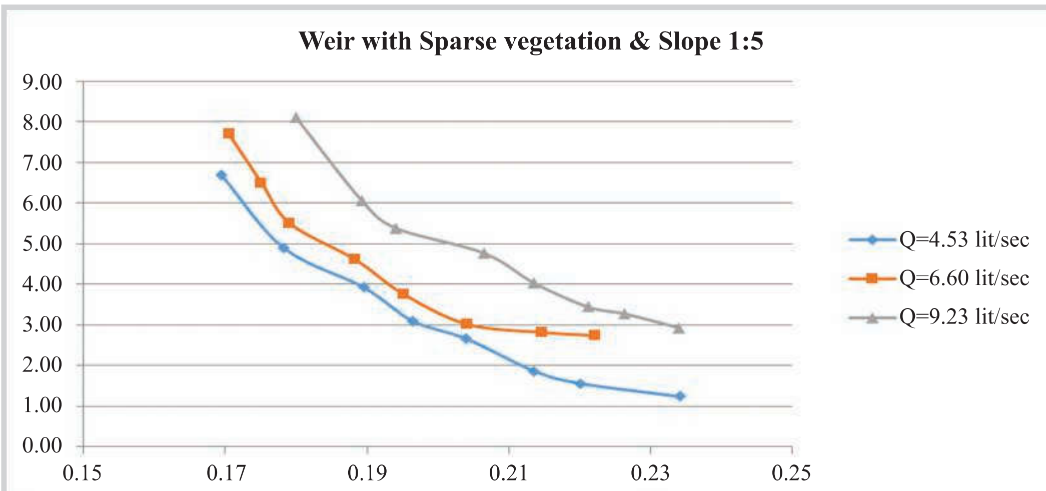

Fig. 7. Head loss vs d/s water depth for slope 1:5

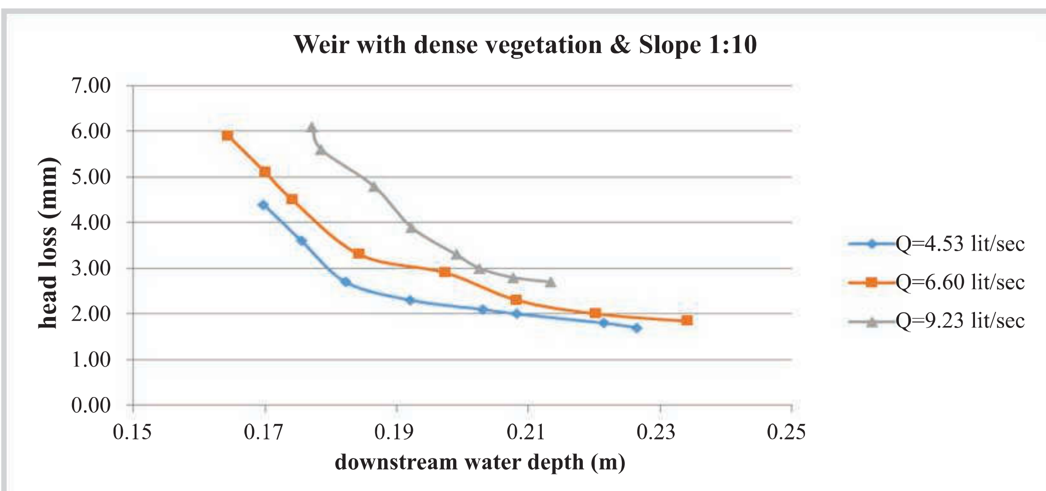

Fig. 8. Head loss vs d/s water depth for slope 1:10

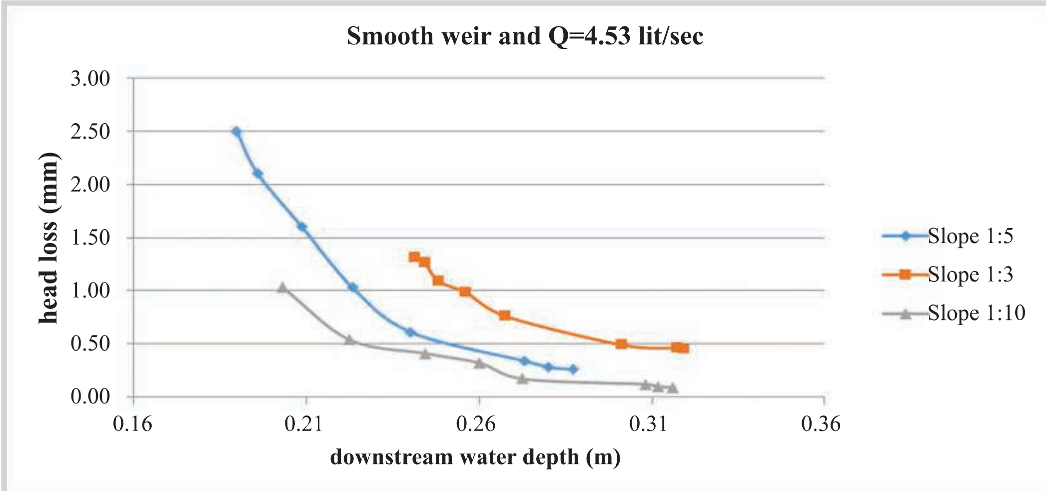

Fig. 9. Head loss vs d/s water depth for discharge 4.53 l/sec and different slopes

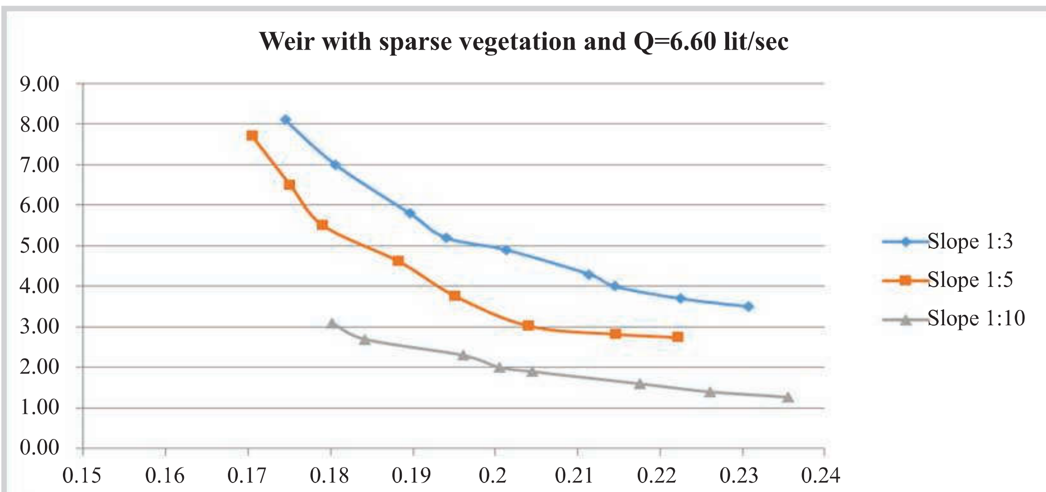

Fig. 10. Head loss vs d/s water depth for discharge 6.60 l/sec and different slopes

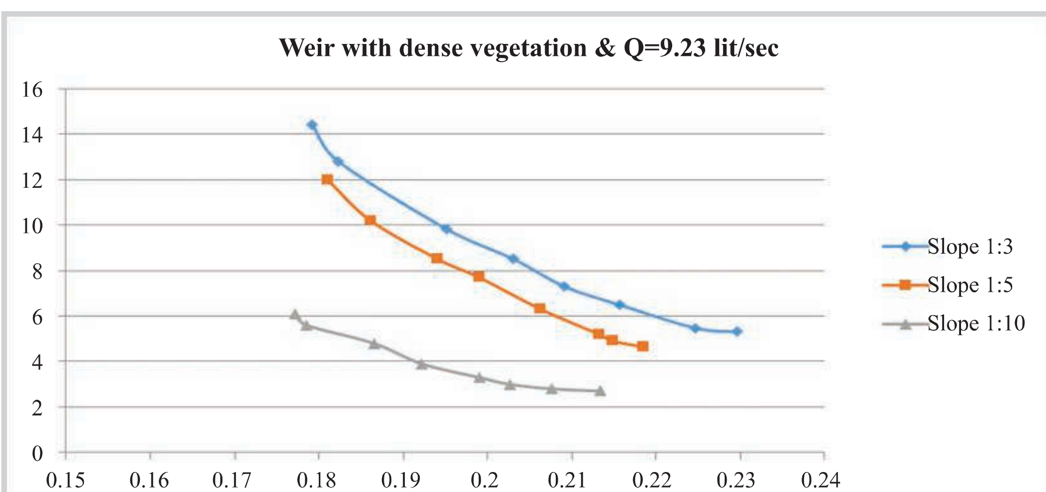

Fig. 11. Head loss vs d/s water depth for discharge 9.23 l/sec and different slopes

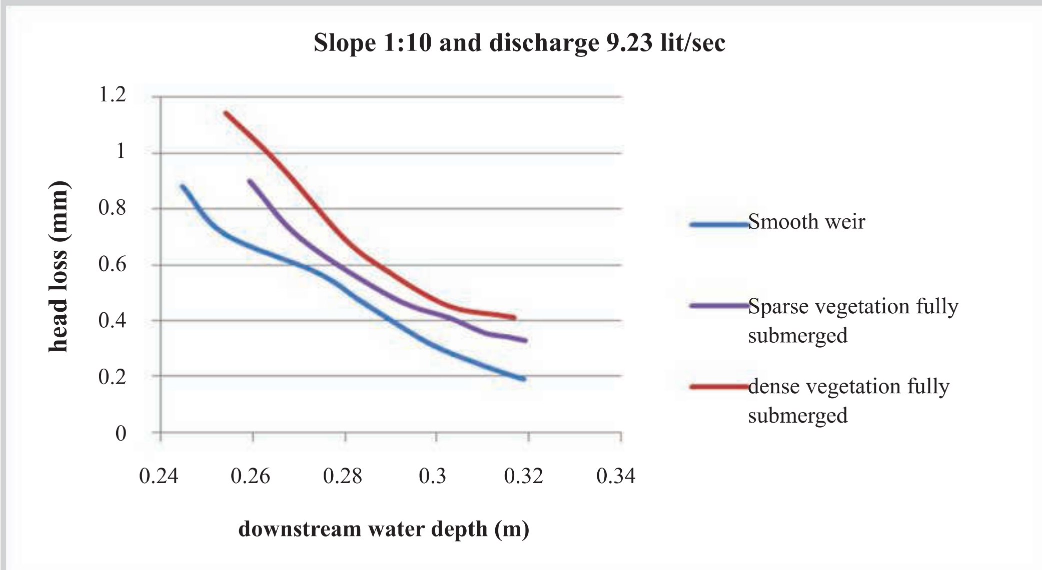

Fig. 12. Head loss vs d/s water depth for discharge 9.23 l/sec and different vegetation conditions

V. RECOMMENDATIONS

Experimental investigations of embankment weir were made on laboratory scale and it gives reliable results therefore, these results may be used to incorporate the flow resistance caused by weir like structure in flood plain for design discharge during flood protection measures. However, following recommendations may be considered for future work;

Usually, the channel section is not uniform but comprises of different sections e.g. flood plain, dikes etc. and flume used for this experimental work was smooth and prismatic. Therefore, it is recommended that more experimental work may be performed using compound channel to find the effects of different components in laboratory.

Weirs used in this case were not possessing any type of gravel or other rough surfaces but vegetation elements alone. Hence rough weirs with different types of vegetation may be used to find the effects of roughness on flow characteristics.

The discharge intensities utilized in this experimental work were small. High discharges may be considered for future work. Vegetation considered in this work was in the form of circular rods. More experiments may be performed using flexible vegetation.

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