Local Scouring due to Flow Jet at Downstream of Rectangular Sharp-Crested Weirs

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Abstract: - Structures built in rivers and channels are subjected to scour around their foundations. If the depth of scour becomes significant, the stability of the foundations endangered, with a consequent risk to the structure of damage or failure. One of the structural measures to maintain or restore a river’s habitat diversity is provision of weir. One of the important problems in weirs accumulate sediments and prevent their downstream flow, resulting in erosion and scouring downstream of the weirs. It is established that the extent of scour depends on characteristics of flow, bed material composition and geometry of structure.

In this study for assessing the local scour hole characteristics downstream of weirs, 23 tests were designed and performed in a straight rectangular channel under various geometry and hydraulic conditions.

Results confirmed the validity of the assessment method of the maximum scour depth, \( h_s \), at equilibrium; uncertainties arose about the length of the scour hole, \( l_s \). It can be found that in a specific \( Fr \) by increasing of weir height, the maximum depth of scouring increases. It also found that the scouring phenomena has an oscillatory manner to reach equilibrium condition.

Key-Words: - Scouring, sharp crested weirs, laboratory experiments, sediment, dimensional analysis.

1 Introduction

A weir is a structure (including a dam, lock, regulator, barrage or causeway) across a defined watercourse that wills pond water, restrict flow or hinder the movement of fish along natural flow paths, in normal flow conditions. Weirs are normally provided for any one or more of the following fundamental functions: Water Level Management, Flow Measurement, Environmental Enhancement and Channel Stabilization. For mobile bed rivers, the bed is constantly subjected to special and temporal changes which modify the habitat characteristics. One of the structural measures to maintain or restore a river’s habitat diversity is provision of weir. It is established that the extent of scour depends on characteristics of flow, bed material composition and geometry of structure.

Scour is the removal of material from the bed and banks of a river or channel by the action of water. Although it may be greatly affected by the presence of structures encroaching on the flow path of the river or a channel, scour is a natural phenomenon caused by the flow of water over an erodible boundary. In a river, scour is normally most pronounced when the bed and riverbanks consist of granular alluvial materials.

Structures built in rivers and channels are subjected to scour around their foundations. If the depth of scour becomes significant, the stability of the foundations endangered, with a consequent risk to the structure of damage or failure. The factors influencing the development of scour are complex and vary according to the type of structure. Protection works for preventing scour need to be designed to withstand the flow forces imposed on mobile bed at downstream of the structures in order to get a successful solution to control scour.

The scouring at downstream of the hydraulic structures is an important problem and was studied by many hydraulic engineers in order to identify the variables governing this phenomena and also to find the solutions for it.


2 Materials and Methods

2.1 Dimensional analysis

Fig. 1 shows the definition sketch of flow and scouring over weir. By applying dimensional analysis the following relation can be obtained:

\[
\frac{h_s}{y_0} = \xi \left( \frac{w}{a} \right) Fr
\]

Where, \( h_s \) is the maximum depth of scour, \( y_0 \) is the upstream depth of water, \( w \) is head of water above the weir and \( a \) is the height of weir.

2.2 Experiment setup

The experimental study was conducted in hydraulic laboratory of Gorgan University of agricultural sciences and natural resources in Iran. The experiments were done in a laboratory flume, 3.7m long, 0.12m width and 0.17m depth with bed slope, \( S_0 \), of 0.0001. The bed material consists of uniform sediment by median size of 1.5 mm and \( \sigma = 1.3 \). Two parts of both side walls consist of glass plate, useful for the direct observation of the flow and sediment transport process (Fig. 2).

The 8 cm layer of uniform sand was placed on the bed along the channel. The weir was installed at a section 1.4 m from the inlet. The sand bed surface was properly leveled by a plate attached to the instrument carriage.

3 Results and Discussion

Figure 5 shows, the scouring in downstream of weir. Also the conceptual model of flow pattern has been shown in this figure. During the experiments an interesting phenomenon was observed. So that there is an oscillatory manner for scouring pattern downstream of weir structure.
In the other hand, after starting the experiment, the impinging jet of flow over the weir cause the scour hole formed and the scouring material is transported to downstream as a ridge (Fig. 6). By increasing the time the flow pattern was changed, such as Figure 7, and the scouring hole was filled due to recirculating flow. So cut and fill process is continued until equilibrium condition. The rate of cutting and filling is decreasing with increasing the time.

The 3D bed change at the downstream of weir is shown in Figure 8. The local scouring was formed downstream of structure and the scoured sediment is accumulated as a ridge in downstream of scour hole. The maximum scour depth of this hole is found very close to the weir.

Fig. 9 shows the variation of $h_s$ against $Fr$ for each weirs when height of weir is equal to 3, 3.5 and 4 cm.
It can be found that in a specific $Fr$ by increasing of weir height, the maximum depth of scouring increases. Also it is obvious, for each weir by increase of $Fr$, the maximum depth of scouring increases. Fig. 10 and 11 also present the variation of $l_1$ (length of scouring hole) against $Fr$ and $l_2$ (length of sedimentation after scouring hole) versus the $Fr$ respectively. These figures have same trend similar to figure 9.

Fig. 9 variation of $h_s$ against $Fr$ for different weirs

Fig. 10 variation of $l_1$ against $Fr$ for different weirs

Fig. 11 variation of $l_2$ against $Fr$ for different weirs

Fig. 12 show the variation of $h_s/y_0$ against $w/a$. It is obvious that by increasing $w/a$, the $h_s/y_0$ increases. The scattering of data also indicates that the data can be classified in three groups according to Froude number.

4 Conclusions
An experimental study was performed to observe the scouring geometric characteristics of weir scouring at the downstream in clear water and with uniform non-cohesive sediment. The results indicated that an increase in Froude number established new hydraulically conditions for scouring mechanism and so a growth was observed in the amount of scouring dimensions. In addition, in specific $Fr$ by increasing of weir height, the maximum depth of scouring increases. Further experiments are necessary by using different size, shape and graduation of bed material, under different hydraulic conditions to conform the results obtained from this study.
References: