Experimental Investigation of the effect of Contraction on Scouring in Downstream of Combined flow over Weirs and below Gates

SHAHABI MAHBOUBEH, M.Sc. Student, Civil Engineering Department of Shiraz University, Shiraz, Iran. Email: mahboobeh.shahabi@gmail.com
TALEBBEYDOKHTI NASSER, Professor, Department of Civil Engineering, Engineering, Shiraz University, Shiraz, Iran. Email: nassertaleb@gmail.com
DEHGHANI AMIR. AHMAD, Assistant professor, Dept. of Water engineering, Gorgan University of Agricultural Science & Natural Resources,. Email: a.dehghani@gau.ac.ir
TELVARI ABDOULRASOUL, Assoc. Prof., Department of Civil Engineering, Engineering Campus, Islamic Azad University Ahvaz Branch, Iran. Email: telvari@Gmail.com
RAKHSHANDEROO GHOLAM. REZA, Assoc. Prof., Department of Civil Engineering, Engineering Campus, Shiraz University, Email: rakhshan@shirazu.ac.ir
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Name of the Presenter: Mahboubeh Shahabi

Abstract

Weirs and gates are the common and important structures which are used in controlling and adjusting the flow in irrigation channel. One disadvantage of the sluice gates is the possibilities of retaining the floating materials which can be resolved if they combined with the weirs. Also sedimentation problem in weir can be resolved by combination of weirs with sluice gates. These combined structures have a new hydraulic condition that is different with weir condition solely or we have only gate. This paper presents the result of an experimental study on the characteristics of scour hole resulted by contracting the weir and gate cross section. The results showed that by contraction, the ratio of hs/(w+a) (hs is maximum scour, w is the vertical distance between the gate top and the weir bottom and a is the gate opening) increase and the length of scouring and sedimentation decrease. And with increasing the gate opening the maximum scour decreases. The results also show that the maximum depth of scour in combined flow structure is less than weir or gate.

Key words: Scour, Combined flow, Weir, Gate, Contraction.

1. Introduction

Gates and weirs have been used extensively for flow control and discharge measurement in open channel flow (Negm et al., 2002). Discharge equations for rectangular weirs are available in many sources such as Kindsvater (1957), BSI (1965), Swamee (1988) and (1992). Also, flow equations for sluice gate can be found in literature in different ways, e.g., Swamee (1992). Works concerning the use of sluice gates as a discharge measurement structure may be found, e.g. by Henry (1950), Rajaratnam and Subramanya (1967), Rajaratnam (1977), French (1986) and Subramanya (1986).

Swamee (1992) developed a generalized discharge equation for sluice gates based on Henry's curves. Providing a top opening for the gate allows simultaneous underflow and overflow conditions.

Regarding the flow over weirs, many works have been reported in the literature such as by Ackers et al. (1978), Bos (1989), Herschy (1978), Kindsvater and Carter (1957), Swamee (1988) and Munson et al. (1994). The specifications and the proper installation of weirs for flow measurements are discussed by BSI (1965) and USBR (1967).

Few studies were available about the use of these combined devices for flow measurements past to 1985. The first idea of simultaneous flow over the weir and under the gate was introduced by Majcherek (1984). Negm, (1995and 1997) analyzed the characteristics of the combined flow over contracted weirs and below contracted gates of rectangular shape with unequal contractions. The prediction model was based on dimensional analysis. Alhamid et al,(1999) studied combined flow over V-notch weir and below contracted rectangular gate. Based on dimensional analysis and using non-linear regression analysis, discharge equation was developed for both free and submerged gate flows.

Recently, Negm et al. (1997) discussed the effect of hydraulic and geometrical parameters on the combined discharge and presented discharge equations for triangular weirs above rectangular contracted gates and contracted rectangular weirs above triangular gates. They proved that the prediction of the combined discharge through the use of common discharge coefficients produces significant errors.

The characteristics of the combined flow over the sharp-edged rectangular weir and below the sharp edged rectangular gate with contractions was studies by Negm in 2002. He introduced a general dimensionless relationship for predicting the discharge of the combined flow.

In order to maximize their advantages, weirs and gates can be combined together in one device, so that water could pass over the weir and below the gate simultaneously. The combined weir and gate systems can be used in minimizing sedimentations and depositions (Samani, 2007).

Scour downstream of weir or gate only has been investigated by many researchers such as: Schoklitch 1932; Veronese (1937), Hartung (1957);Carstens (1966); Sarma (1971), Uymaz (1976), Mason (1985), Amanian (1993), Daemi et al. (1996) and Mahboobi (1997).

Problems concerning sedimentation and depositions are minimized by combined weirs and gates as outlined by Alhamid, Negm and Al-Brahim (1997). Dehghani and Bashiri (2009) discussed the characteristics of scour hole downstream of combined free flow over weir and below gate.

In this Study, The effect of Contraction on Scouring in downstream of combined flow over weirs and below gates has been investigated. Various relationships characterizing the scour hole are found on the basis of experimental results.

2. Research Methodology

2.1. Experimental Setup

The experiments were conducted in a straight rectangular channel at the hydraulic laboratory of Gorgan University in Iran. The channel was 3.7 m long, 0.125 m wide and 0.3 m deep with bed slope, S0, of zero. The bed material consists of uniform sediment by median size of 1.5 mm and σ=1.18. The 8 cm layer of uniform sand was placed on the bed along the channel.

The combined structure was installed at a section 1.3 m from the inlet. The sand bed surface was properly leveled by a plate attached to the instrument carriage. The experiments were conducted using clear-water applying various hydraulic conditions.

In order to find out the time required to achieve equilibrium state, i.e. when the maximum scour depth is approximately time invariant, the primarily experiments were performed for 600 minutes. Figure 1 shows the variation of maximum scour depth against time. As seen in Figure 1, almost 95 percent of maximum scour depth was achieved beyond the 300 minutes. During each run of experiment, the maximum depth of scour was measured at given time intervals. At the end of each experiment, the water was drained slowly and bed topography was measured with digital point gauge.

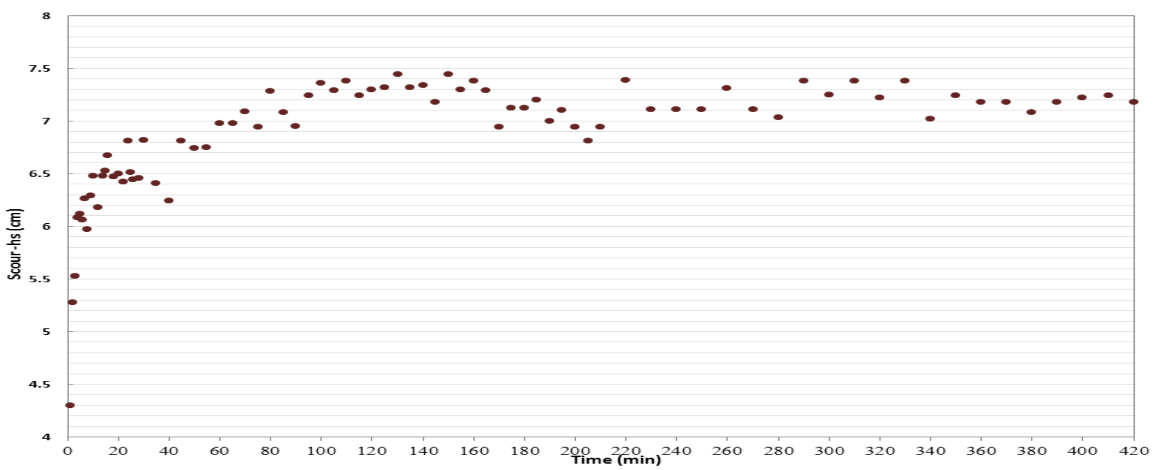

Fig 1: Variation of scour depth against time for Q= 0.7 lit/s, b/B= 0.76, h=3.5cm.

2.2. Dimensional analysis

Figure 2 shows the parameters affecting the local scour at combined weir and gate with contraction.

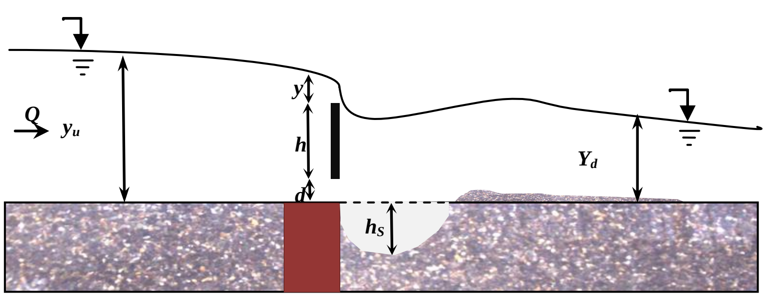

Fig 2: Definition sketch for combined flow over weir and below the gate with contraction

$$h_s = f(Q, y_u, y_d, d, h, y, \rho_s, \rho_w, d_{50}, g, b, b1, B, S_0) \quad (1)$$

In which:

hs is the maximum depth of scour, yu is the approaching water depth,yd is the tailwater depth, h is the vertical distance between the gate top and the weir bottom, d is the gate opening, y is the head over the weir, b and b1 are the weir and gate width,Q is Discharge and ρ_s, ρ_w are density of sediment and water.

By applying dimensional analysis for example Buckingham π theorem , the following relation can be obtained:

$$\frac{h_s}{h+d} = f(\frac{h}{d}, \frac{y_u}{y_d}, \frac{y_d}{h}, \frac{d}{y}, \frac{d}{d+h}, \frac{\rho_s}{\rho_w}, \frac{Q}{\sqrt{2gd^{2.5}}}, \frac{b}{B}, \frac{b_1}{B}, S_0, Fr) \quad (2)$$

4. Results and Analysis

The scouring downstream of combined flow over the weir and under the gate with contraction is shown in Figure 3. This Figure plots the surface software after working.

Figures 4 and 5 show the variation of hs/y0 against y/a and w/a for Q=0.53,0.82 L/s and w=3 cm, respectively. It is clear that by decreasing the y/a and w/a, the ratio of hs/y0 increases, because the structure mostly acts like gate.

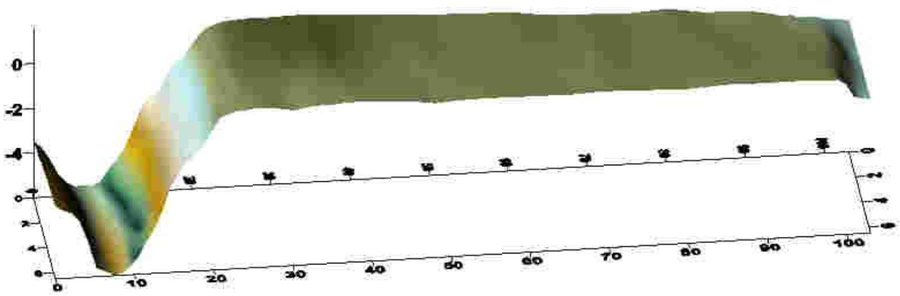

Fig 3: The 3D bed changes at downstream of combined flow over the weir and under the gate

Figure 4 shows the profile of scour and sedimentation for 3 cases of contraction. (Other parameters are constant). It is clear that with an increase in contraction, maximum scour (hs) has been increased.

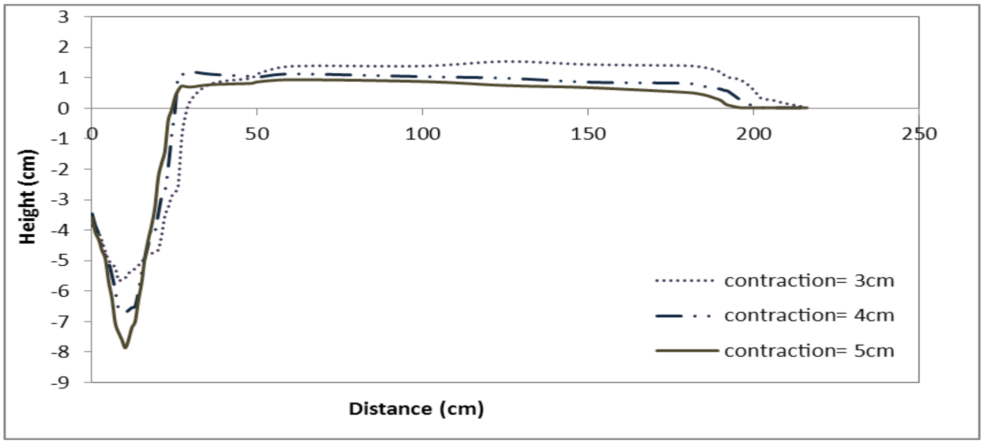

Fig 4: The comparison of scour and sedimentation profile for 3 different amount of contraction of combined weir and gate structure

For example at the Tables 1 and 2 a part of data that obtained in this analysis has been presented. Figure 5 show variation of maximum scour against contraction for Q=0.7,1.02 L/s and h=3.5 cm, respectively. It is clear that by decreasing the contraction, maximum scour increases, because the jet force has been centralized and stronger than without contraction.

Figure 6 shows variation of non dimensional parameters hs/(h+d) against b/B for Q=0.7,1.02 L/s and h=3.5 cm, respectively. It is clear that by increasing the b/B, the ratio of hs/(h+d) decreases.

h (cm)	d (cm)	B (cm)
3.5	1	12.5

Table 1. Constant parameters

Q (lit/s)	**b (cm)**	**b/B**	**hs (mm)**	**hs/(h+d)**
0.70	10.50	0.84	62.8	1.40
0.70	9.50	0.76	67.8	1.51
0.70	8.50	0.68	70.8	1.57
0.70	7.50	0.60	76.3	1.70
1.02	10.50	0.84	68.5	1.52
1.02	9.50	0.76	73.8	1.64
1.02	8.50	0.68	80.7	1.79
1.02	7.50	0.60	88.6	1.97

Table 2. Results of experimental runs

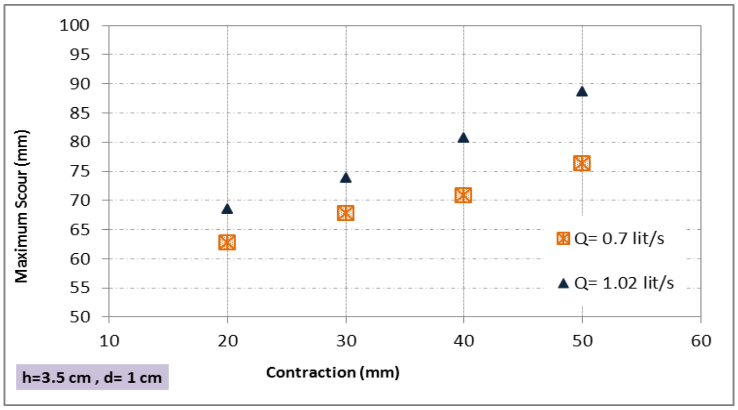

Figure 5. Variation of hs against B-b , for Q=0.7, 1.02 L/s and h=3.5 cm.

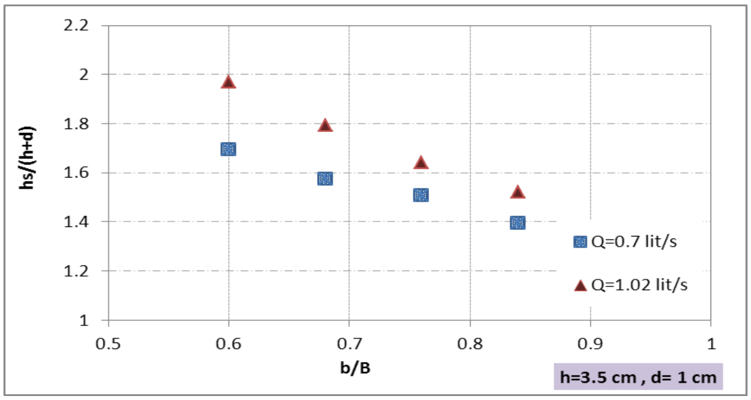

Figure 6. Variation of hs/(h+d) against b/B, for Q=0.7, 1.02 L/s and h=3.5 cm.

5. Conclusions

The results of this research show that:

1. In h constant, with increase discharge of flow hs increased.
2. In Q constant, with increase contraction the force of jet has been centralized and scour increased.
3. In Q constant, with increase contraction the length of scour and erosion (L1) decrease and the length of sedimentation (L2) has been increased.
4. In Q constant, with decrease in height of structure (h) maximum scour (hs) increase.
5. The conceptual model of flow field downstream of combine flow over the weir and under the gate indicates that there are interactions between the flows over the weir and under the gate and the scour hole cuts and fills alternatively

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