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Effect of sediment deposition on the efficiency of Fayoum weir

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A B S T R A C T

Weirs are one of the main heading-up water structures. It is constructed along waterways to control the head, discharge and sometimes load sediment. The sedimentation depth increases upstream a weir due to decreasing velocity in the zone of backwater curve and the flow passes over the crest level. The main objectives of this research are to study the effect of bed sediment depth and length in upstream of weir on the flow characteristics and the weir efficiency. The research methodology included experimental, theoretical and statistical studies. The depths of sedimentation are taken 25%, 50%, 75%, and 100% of the weir height and the lengths of sedimentation are taken 50%, 100%, 150%, 200% and 250% of the weir height. All models are tested at different channel bed slopes, 0:0, 1:500, 1:250, 1:200 and 1:150. The discharge coefficient C_d increases as the ratio of H/P increases for no sediment and for different upstream sediment depths. New discharge stage relationship is developed for case of sediment and no sediment upstream the Fayoum weir. In addition, different empirical formulae are obtained for computing the discharge coefficient in case of upstream sediment Fayoum weir.

1. Introduction

Bed sediment upstream water structures along waterways affect the weir efficiency. The sediment has different shapes, heights, and upstream lengths, as shown in Fig. 1. The bed sediment upstream Fayoum weir effect on discharge coefficient C_d of weir, head losses in upstream and downstream weir and the length of hydraulic jump. Omran et al. [1] developed an experimental model for removing sediments from open channel. They studied the effect of weir height, slope channel and height of sediment on removing sediment from the channel. Lauchlan [2] investigated experimentally the bed–load and suspended–load transportation over the weir. He found that upstream of a vertical weir a strong down flow vortex forms and increase scour hole downstream weir. Guan et al. [3] developed a measurement and data-processing technique for the study of scour downstream the submerged weirs under extreme measurements. They deduced equations for the prediction of the scour depth downstream the weirs. Rosier et al. [4] found that the lateral loss of water reduces the sediment transport capacity leading to the formation of a local sediment deposit close to the flow. Verelst et al. [5] investigated the erosion and sedimentation by analyzing the regular bathymetric monitoring data. They computed the equilibrium profile for the new bypass channel and numerical modeling of the flow pattern around the weir lock complex. Ogden et al. [6] investigated experimentally the effect of sedimentation on flow characteristics of V-notch weirs. They found that sedimentation increases the discharge coefficient for given channel slope and discharge coefficient is not constant over the range of depths from 20% to 100% of the design depth. Zhang et al. [7] used the computational model CCHE2D to simulate the sediment transport of the JiJi weir reservoir. Bhuiyan et al. [8] studied experimentally the effect of vanes and W-weir on sediment transport in meandering channels. Weggel [9] introduced an analytical method for studying sedimentation patterns. Raju and Kothyari [10] presented the methods of design of sediment extraction devices like settling basins and vortex chambers.

Wang et al. [11] monitored the hourly events based suspended sediment concentration due to storms in Jiasian diversion weir in southern Taiwan using artificial neural network models. Wang et al. [12] developed neural networks approaches for modeling river suspended sediment concentration due to tropical storms. Chen et al. [13] simulated the runoff and sediment transport in a basin with multiple watersheds using different simulation models. Dabral et al. [14], EL-Belasy [15], Banihabib and Bahram [16], Arvanaghi and Oskuei [17], and Emiroglu [18] developed new formulae to determine the discharge coefficient and head–discharge for different hydraulic structures.

2. Dimensional analysis

Many different parameters control the design criteria of the weirs. In general, the design of weirs depends on the upstream depth over it is vertical face. Bed sediment along the backwater

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Fig. 1. Sediment upstream weir.

curve upstream the weir affect the flow characteristics. To deduce this effect, we correlate formula between the different flow parameters. The main parameters according to the systematic diagram in Fig. 2 can be summarized as follows: Q_w (discharge above the weir, L^3/T), C_d (discharge coefficient), b (channel width, L), H (head above the weir, L), P (height of weir, L), S (channel bed slope), L_e (length of bed sediment in upstream, L), h_e (depth of sediment in upstream, L), y_1, y_2 (initial and sequence water depths of downstream hydraulic jump, L), y_t (tail water depth, L), and L_j (length of the hydraulic jump, L). These parameters can be written in the following function

$$f\left(c_d, \rho, v, g, \mu, Q_w, H, P, S, b, h_e, L_e, w, y_1, y_2, y_t, L_j\right) = 0.0 \quad (1)$$

The general discharge equation for rectangular weir can be written as follows:

$$Q_w = \frac{2}{3} c_d b \sqrt{2g} H^{1.5} \quad (2)$$

$$C_d = \frac{0.10812 * Q_w}{b * H^{1.5}} \quad (3)$$

Using the dimensional analysis Buckingham's π theory in which ρ, H, and v are selected as repeated variables representing fluid properties, pipe geometry characteristics and the flow characteristics respectively, then the discharge coefficient C_d can be written as follows:

$$C_d = f\left(F_o, \frac{P}{H}, S, \frac{b}{H}, \frac{h_e}{H}, \frac{L_e}{H}, \frac{w}{H}, \frac{V_s}{VT}\right) \quad (4)$$

$$\frac{L_j}{y_1} = f\left(S, \frac{y_2}{y_1}, \frac{y_t}{y_1}, F_o, F_1, \frac{h_e}{L_e}\right) \quad (5)$$

in which V_s is the actual volume of sediment at any sediment height and length, VT is the maximum sediment volume at L_e =50 cm, and h_e=20 cm.

To investigate the effect of sediment in upstream weir head losses, apply the energy equation between sec. no. 00 and sec. no. 0, then

$$y_{u.s.} + \frac{v_{00}^2}{2g} = Hp + H + \frac{v_o^2}{28} + h_L \quad (6)$$

in which $E_0 = Hp + H + \frac{v_o^2}{28} + h_L$, $E_{00} = y_{u.s.} + \frac{v_{00}^2}{2g}$, then $h_L = E_{00} - E_0$.

3. Experimental work

Experimental study is conducted to study the effect of suspended load sediment upstream the weir on the flow characteristics. Rectangular channel with a smooth bottom and two glass walls 10 cm wide, 31 cm deep, and 300 cm long is used. The tail gate is fixed nearly at the end of the working section. It is an aluminum plate provided with a rubber cover at both sides to prevent leakage. The flume support includes a jacking system, which allows positive and negative bed slopes to be achieved. The flume is a recirculation type and the flow system is a closed circuit. The flume takes its water from the 50 mm feeding a P.V.C. pipe, which is connected to a mild steel sump tank, which is sited below the working section. At the outlet of the working section of the flume, the water falls vertically into the sump tank and is re-calculated by the pump. The discharge is measured by means of a pre-calibrated electronic flow meter and calibrated orifice meter connected at the middle of the feeding pipe. The upstream water depth at different distance from weir at top level of crest and at 10 cm, 20 cm, 30 cm, and 40 cm. In addition, initial depth, sequent depth and tail water depth are measured by point gages. Fig. 3 shows details of all elements of the experimental equipment. Fayoum weir of 20.0 cm height with different bed sediment lengths upstream of 50 cm, 40 cm, 30 cm 20 cm, and 10 cm. Deposition sediment heights of 20.0 cm, 15 cm, 10 cm and 5 cm are used. Each model tested under different inclined channel bed angles. The following slopes, 0.0, 1:500, 1:250, 1:200 and 1:150 are used.

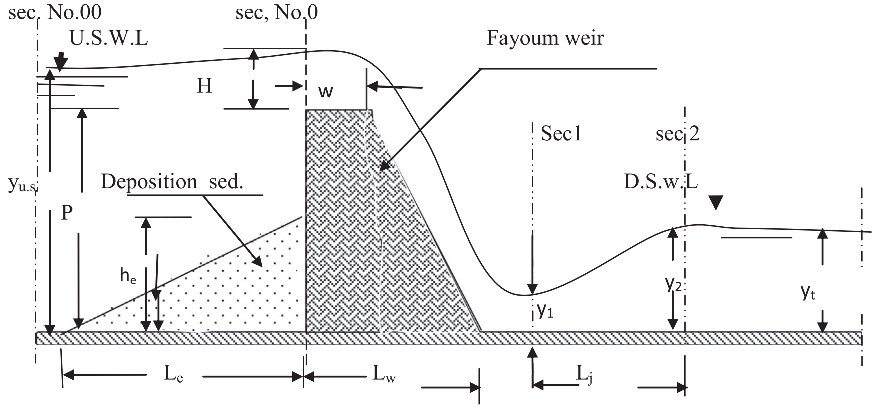

Fig. 2. Schematic diagrams to flow parameters.