Ain Shams Engineering Journal (2014) 5, 17–28

Ain Shams University

Ain Shams Engineering Journal

www.elsevier.com/locate/asej
www.sciencedirect.com

CIVIL ENGINEERING

Minimizing scour downstream of hydraulic structures using single line of floor water jets

Esam El-Deen Yousry El-Azab Helal *

Civil Eng. Dep., Faculty of Eng., Menoufia University, Egypt

Received 12 November 2012; revised 24 May 2013; accepted 6 June 2013
Available online 12 July 2013

KEYWORDS

Local Scour;
Floor water jets;
Hydraulic structure;
Stilling basin;
Physical model

Abstract Local scour downstream of control structures may result in damage or complete failure of the control structure. In this paper, one hundred and seventeen runs were carried out to study the effect of single line of floor water jets on the scour hole parameters downstream of a control structure (Fayoum type weir) with different jet discharges, locations, and tailwater depths. Cases of floor without water jets were included to estimate the influence of using the suggested system. Obtained results were analyzed and graphically represented. The suggested system is easy to be used as an extra element to the existing structures to increase the performance of stilling basin. Results indicated that the system of suggested floor water jets gave from 50% to 90% reduction in maximum scour depth and from 42% to 85% reduction in scour hole length compared to the case of the floor without water jets.

1. Introduction

The cost of protection works downstream of control structures can be reduced if suitable appurtenances are used to dissipate the excessive energy in an efficient manner. Operating any hydraulic-energy dissipators depends largely on expending a part of the energy of the high-velocity flow by boundary shear stress. Floor water jets will help in deflecting the flow away from the canal bed. Appurtenances such as sills, chute blocks, and baffle blocks are often installed to help in increasing the performance of a stilling basin, Edward [1] and Peterka [2]. In addition, they are helpful in stabilizing the flow, increasing the turbulence, and distributing the velocities evenly through the basin. In some cases, a reduction in the required tailwater depth and length of the basin may be possible by the addition of the appurtenances to the basin, Edward [1].

Sills stabilize the flow, deflect the current away from the river bottom, and may help in reducing the tailwater depth. Laboratory tests indicated that the sill greatly increases the efficiency of the stilling basin, Edward [1]. Abdallah [3] studied the influence of both the height and the shape of end sill on the scour hole dimensions downstream of solid apron. He found that the sill height had a great effect on scour hole dimensions than the sill shape. Nashat [4] studied experimentally the proper location of floor sill which minimized the scour downstream of heading-up structure. Abdel Razek and Baghdadi [5] studied experimentally the influence of sills upon the scour characteristics. They investigated the effect of gate opening, downstream

* Tel.: +20 1005437289.
E-mail address: Esameman@yahoo.com
Peer review under responsibility of Ain Shams University.

ELSEVIER Production and hosting by Elsevier

2090-4479 © 2013 Production and hosting by Elsevier B.V. on behalf of Ain Shams University.
http://dx.doi.org/10.1016/j.asej.2013.06.001

Nomenclature

B	channel width	L_{mw}	distance between floor end and location of maximum scour depth in case of floor without jets
B	basin width	L_s	scour hole length in flow direction
D_s	maximum scour depth	L_{sw}	scour hole length in case of floor without jets
D_{sw}	maximum scour depth in the case of floor without water jets	Q	channel discharge
D_{50}	median size of bed material	Q_j	jets discharge
F_r	tail Froude number	Y_t	tail water depth
L_j	distance from the weir toe to the location of the water jet	$\tan\alpha_s$	scour index ($\tan\alpha_s = 2D_s/L_m$)
L_f	floor length	$\tan\alpha_{sw}$	scour index in case of floor without jets ($\tan\alpha_s = 2D_{sw}/L_{mw}$)
L_m	distance between floor end and location of maximum scour depth	σ	standard deviation of bed material

Froude number, relative length of the apron, height of the sill, and the distance between the gate and the sill on the formation of local scour downstream of the apron. They concluded that the maximum scour depth decreased with the increase in the distance between the sill and the gate until it reached its maximum reduction at a distance from the gate equals one third of the apron length. Saleh et al. [6] studied the effect of a symmetric side sill on the scour hole characteristics downstream of sudden expanding stilling basin. Determination of the optimum location of a symmetric side sill was the main objective of that study. Hitham et al. [7] studied experimentally the effect of semicircular sill on the scour hole and hydraulic jump parameters downstream of a pipe culvert. They found that the semicircular sill decreased the scour hole dimensions and increased the hydraulic jump efficiency.

Chute blocks are installed at the entrance of the stilling basin to increase the effective depth of the entering stream, break up the flow into a number of jets, and help in creating the turbulence that is required for energy dissipation, Edward [1] and Peterka [2]. The chute blocks also tend to lift the jet off the floor and result in a shorter basin length than would be possible without them. Baffle blocks are installed in stilling basins principally to stabilize the formation of the jump and increase the turbulence. Baffle blocks are normally arranged in one or several rows that are oriented perpendicular to the direction of approach flow. Baffle blocks help to compensate slight deficiency of tailwater, and for high flow, they help to deflect the flow away from the river bed. Pillai [8,9] studied the effect of using wedge-shaped baffle blocks of vertex angle 120° cut back at right angle. Good results were obtained for Froude number ranged between 5 and 9. Vischer and Hager [10], Bradley and Peterka [11], Peterka [2], El-Masry and Sarhan [12], El-Gamal [13], El-Masry [14,15], and Helal [16] discussed the baffle blocks parameters and concluded the following recommendations:

- The optimum block front face is vertical and perpendicular to the approach flow with sharp corners.
- One row of block is used because the effect of the second row or staggered block row is small relative to the first one.
- Baffle blocks should not be used for approach velocity above 20 m/s.
- The floor blocks should occupy between 40% and 55% of the floor width.

Abdelhaleem et al. [17] studied experimentally the effect of using three different shapes of corrugated beds on the characteristics of a hydraulic jump and downstream of local scour. The study confirmed the effectiveness of corrugated beds for energy dissipation downstream of hydraulic structures and corrugating the stilling bed can decrease the cost of stilling basin. Sobeih et al. [18] studied experimentally the openings fixed in the body of weirs. Three cases of opening arrangements were included: no opening, one opening, and three openings. Empirical formula was developed for estimating scour hole depth in terms of downstream of flow conditions, Froude number, height of the weir, number of openings, area of openings, and diameters and heights of the openings.

Herein, this study is concerned with the installation of a single row of water jets to the floor of the structures in various locations under different flow conditions to minimize the scour hole parameters.

2. Criteria for performance evaluation

There are two factors that should be taken into consideration in evaluating the performance of stilling basin: firstly, the safety of the structure against scour and secondly the cost of maintenance. The safety of the structure against scour and the cost of maintenance depend on both of maximum scour depth, D_s, scour hole length, L_s, and the distance of maximum scour depth from the toe of the solid floor, L_m Fig. 1. The safety of the structure against scour required smallest scour depth and its location should be farthest from the toe of the

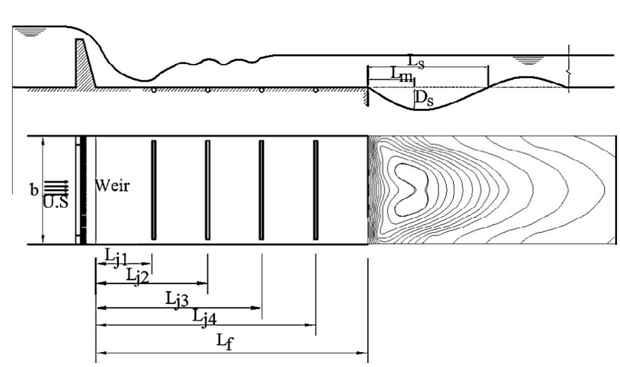

Figure 1 Layout of the considered case of jets arrangements.