IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 6 Ver. III (Nov. - Dec. 2017), PP 11-17
www.iosrjournals.org

Minimize the Scour Downstream Regulators Using Different Configurations of Blocks and Sills over Stilling Basin

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Abstract: *Scour is the consequence of the erosive action of flowing water, which removes material from the bed and banks of streams. Local scour downstream stilling basin is so complex that it makes it difficult to establish a general empirical model to provide accurate estimation for scour depth. Lack estimation of local scour can endanger to stability of hydraulic structure and can cause risk of failure. So minimizing this phenomenon is very important. The blocks and sills over stilling basin play very important role for reducing the scour, and dissipating excess energy of the flow. The present study was focused on investigating experimentally the effect of sill over stilling basin of regulator on scour formation downstream regulator and aims to select the dimensions of this sill. Experimental studies of different models with different heights and shapes are tested. It is found that the blocks and sills over stilling basin has great effect on flow characteristic and local scour depth formed downstream regulator especially for sill blocks with right faces at the upstream and downstream. This study shows that local scour depth downstream hydraulic structures were reduced by 33%.*

Keywords: *blocks, regulators, scour, sill, Stilling Basin*

Date of Submission: 25 -11-2017 Date of acceptance: 09-12-2017

I. Introduction

Scour is the removal of boundary material by the action of flowing water, it occurs naturally as a part of the morphological changes of rivers and man-made structures. When a hydraulic structure such as dam, regulator, spillway, or bridge, is placed in a hydraulic/marine environment, the presence of the structure will change the flow pattern in its immediate neighborhood, resulting in these changes usually cause an increase in the local sediment transport capacity and thus lead to scour. A particularly complex set of hydraulic engineering problems are faced when assessing the likelihood of scour at regulators. The complexities arise from considerations of the flow field, as well as from the mix of failure modes that may occur at and near regulators. The stilling basin is provided with current deflector at different positions from the sluice gate, to control and minimize the local scour depth downstream hydraulic structure. Many researchers studied scour downstream hydraulic structure. For example, M.A. Abourehim (1997) studied the local scour phenomenon done downstream culvert outlets, particularly culvert with triangular shape cross section, constructed on non-uniform bed materials. Gamal abouzied (2006) studied the scour reach behind three vents regulator due to a drowned and free hydraulic jump over a partially rigid apron extended to an erodible sand basin. He concluded that scour reach was found to be function in the head difference between the upstream and downstream water levels (H) ,downstream tail water depth (Y) the submergence of the under-gated regulation and the method of regulation (symmetrical and asymmetrical). Abdel-Aal, et al. (2008) studied local scour mitigation around bridge piles using protective plate. He investigated that, for all shapes of protective plates, the relative scour depth decreased as the dimensions of the protective plate around the bridge pile increased. The square protective plate was considered the best shape of collars for minimizing the scour whole dimension around the pile. Sills and baffles are provided to stilling basin to increase the energy dissipation efficiency, as well as to stabilize the hydraulic jump and minimize the local scour (Hager, W. H. 1992). Ali and Mohamed Ali (2010) studied the effect of stilling basin shape on submerged jump characteristics. Experimental studies on submerged hydraulic jumps with baffle walls and blocks downstream of a sluice gate were carried out by (Ali, N.A. 1995) and (Habibzadeh et al. 2001). Hassan and Narayanan (1986), Habib et al. (1994) and El-Gamel et al. (2002) studied experimentally the local scour depth downstream stilling basins. El-Gamel (2001) investigated the effect of three lines of angle baffles on scour downstream hydraulic structures. Saleh et al. (2003) studied the effect of sill on scour downstream expanding stilling basin. Subhasish and Airndam (2006) investigated the scour downstream stilling basin due to the submerged horizontal jets. Tiwari at al. (2011) investigated experimentally the effect of end sill on basin performance. Alireza et al. (2012) and (2014) studied the performance of baffle blocks and mean flow in submerged hydraulic jump. Chen et al. (2014) studied the characteristics of the velocity distribution in a hydraulic jump stilling basin with five parallel offset jets in a twin-Layer configuration. Tiwari (2013) and Tiwari and Seema (2013) investigated a design of stilling basin with end sill. Tiwari et al. (2013) and

(2014) studied scour depth downstream stilling basin. This study is carried out to minimize the scour downstream regulators using different configurations of sills over stilling basin and suggest a suitable stilling basin.

II. Experimental Work

The study was based on experimental tests. These tests were carried in a rectangular flume with 30 cm bed width, 0.468 m depth, and 15.60 m length and the flow is re-circulating. The total length is divided into three parts (The inlet, the outlet parts, and the working section of the flume). The vertical sides were made from toughened glass of thickness 1.2 cm. The smooth bed surface was made of cold-rolled steel sheets that were welded to each other by a water- tight agent. The bed is painted with anti- corrosive paint. At the top of the working section there are steel angles of (5cm x 5cm x 0.6cm). The movement of the bed material just downstream the apron was measured after each test run. The depth and length of the scouring hole was measured. The experimental results were analyzed and discussed to clarify the performance of blocks and sill over stilling basin. The effect of blocks and sills heights, configuration, and Froude number on length of submerged jump, energy dissipation, reverse flow length downstream of sill and local scour depth downstream stilling basin were investigated. The tested modles are made of wood blocks. Each stilling basin consists of an end sill at its end, and interior baffle blocks. The end sill and baffle blocks are made of wood in different heights and shape. A total of 6 models were tested. Each models was tested by using multivent regulators and different opinning of regulators gates. The different tested models and dimensions are listed in detail in Table (1).

"**Table" (1)** Different experimental models

Models	hb /LB	Wb /LB	Lb /LB	Se /LB	L1/LB	L2/LB
Model I	0.02	0.02	0.03	0.03	0.3	0.5
Model II	0.02	0.02	0.06	0.03	0.3	0.5
Model III	0.02	0.02	0.04	0.03	0.3	0.5
Model IV	0.03	0.02	0.06	0.04	0.3	0.5
Model V	0.03	0.02	0.09	0.04	0.3	0.5
Model VI	0.035	0.02	0.09	0.04	0.3	0.5

Where:
hb: is the height of block
Wb: is the width of block
Lb: is the length of block
Se: is the height of sill
L1: is the distance from 1st row of block to gate
L2: is the distance from 2nd row of block to gate
LB: is the total basin length

III. The Experimental Procedures

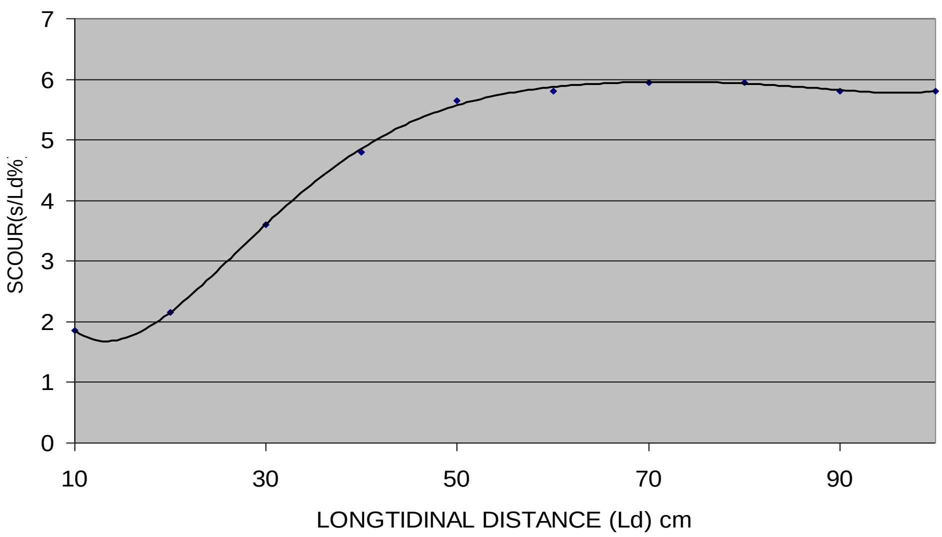
After the flume was filled with bed material (sand) and accurately leveled, the leveling accuracy was checked by means of a point gauge. The following steps were carried out for each test:1- The flume was set to the horizontal position, 2- Open the gates (0.02LB), 3- The studied models is installed in the testing flume upstream sides were sealed with smooth silicon rubber to ensure no leakage from any side, 4- The discharge control valve was closed, 5- The pump was allowed to operate, 6- The discharge control valve was opened, 7- The increase switch was pressed slightly to increase the discharge slowly to obtain suitable value of discharge, 8- The tail gate was opened such that a free hydraulic jump was formed at the downstream of the drop, 9- The initial depth of jump, the roller height and location, and sequent depth was measured, 10- The tail gate was raised till the hydraulic jump forced in the stilling basin, 11- Waiting for stable flow conditions (the upstream water depth become stable, and the hydraulic jump), 12- After the scour hole was drained, the maximum scour depth, length were recorded using point gauge at centerline of flume as the scour hole was symmetry, 13- Open the gates (0.04LB) and repeat steps from 3 to 12, 14- Open the gates (0.06LB) and repeat steps from 3 to 12.

IV. Analysis and Discussion of Results

The analysis and discussion of the experimental work is divided into three main groups depending on cases of gate opening and height of gate opening. These cases are: 1- All gates with 0.02 LB height for all models, 2- All gates with 0.04 LB height for all models, and 3- All gates with 0.06 LB height for all models. The factors which affecting the energy dissipation through the suggested stilling basin were studied, such as relative height of end sill, and the relative height of baffle blocks. A total of 6 models were tested. Table (2), (3), (4), (5), (6), and (7) shows the effect of models I, II, III, IV, V, and VI on the scour in downstream of the structure. Figure (1), (2), (3), (4), (5), and (6) shows the relation between longitudinal distance and vertical scour for models I, II, III, IV, V, and VI, where x is longitudinal distance, y1 is minimum depth of sand after scour occurred, y2 is maximum depth of sand after scour occurred, $y_{av.}$ is the average depth of sand after scour occurred, and scour d. is the scour occurred for each model. Two cases of sill arrangements were included, no sill, and double lines sill. Different heights of sills, different length of blocks, and different width of blocks were tested. Table (1) shows the dimensions and configuration of blocks and sills for six models. The depth of sand is 6 cm. The increase of Froude number generates more turbulence, and longer length for jet mixing that is leading to increase energy and length of jump. For case of no blocks and sill, it is found that the depth of scour equal 6 cm at length 10% of LB from the gates. From table 2 to 7, for case of Model III, IV, I, V, VI, and II, it is found that the effect of blocks and sills height over stilling basin on the local scour depth downstream stilling basin. The relative local scour depth decreased by (1.95/6) 33%, (1.85/6) 31%, (1.85/6) 31%, (1.7/6) 28%, (1.5/6) 25%, and (1.1/6) 18%, respectively for length 10% of LB from gates, compared to the no sill case. Through this, the experiments showed that for most considered values of sills, model III with the right face upstream of sills and dimension (Hb/Lb = 0.02, Wb/Lb = 0.02, Lb/LB = 0.04, and Se/LB = 0.03) gave the smaller values of local scour depth.

"Table" (2) Effect of model I on the scour

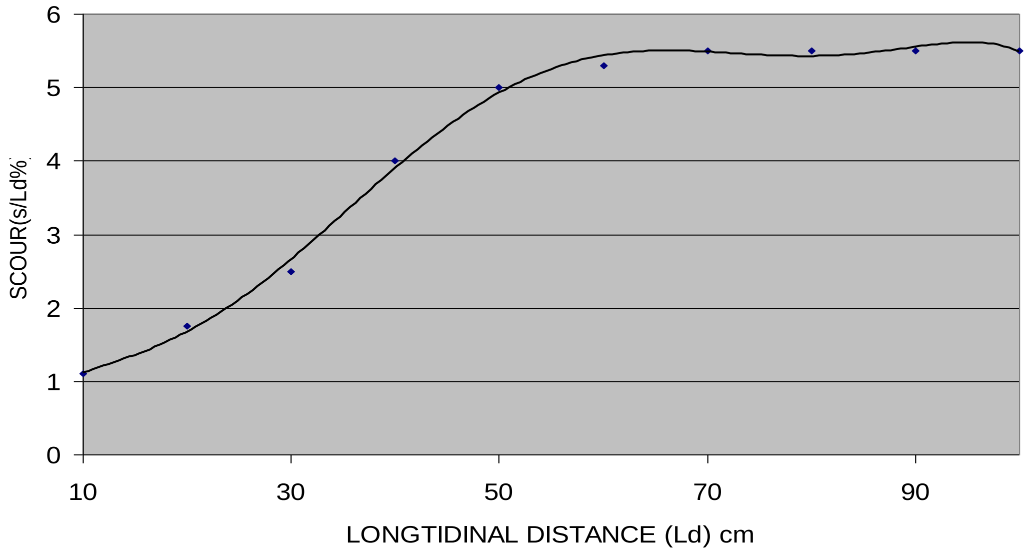
x (cm)	y1	y2	y av.	scour d.
10	1.5	2.2	1.85	4.15
20	2.1	2.2	2.15	
30	3.7	3.5	3.6	
40	5	4.6	4.8	
50	5.6	5.7	5.65	
60	5.6	6	5.8	
70	5.5	6.4	5.95	
80	5.9	6	5.95	
90	5.9	5.7	5.8	
100	5.9	5.7	5.8	



"Fig." (1) Effect of model I on the scour

"**Table" (3)** Effect of model II on the scour

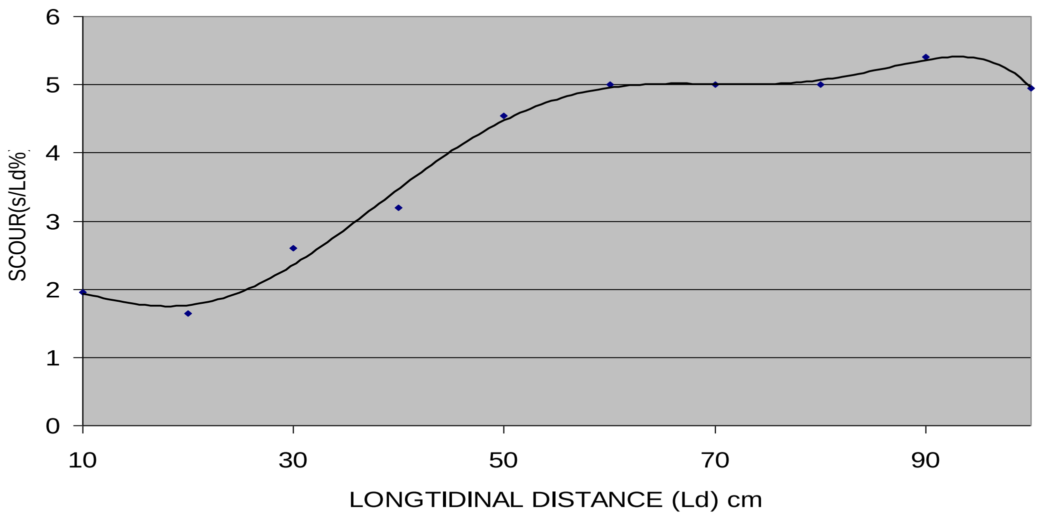
x (cm)	y1	y2	y av.	scour d.
10	1.2	1	1.1	4.9
20	1.5	2	1.75	
30	3	2	2.5	
40	4	4	4	
50	5	5	5	
60	5.2	5.4	5.3	
70	5.5	5.5	5.5	
80	5.5	5.5	5.5	
90	5.5	5.5	5.5	
100	5.5	5.5	5.5	



"Fig." (2) Effect of model II on the scour

"**Table" (4**) effect of III model on the scour

x (cm)	y1	y2	y av.	scour d.
10	1.9	2	1.95	4.05
20	1.8	1.5	1.65	
30	3	2.2	2.6	
40	3.5	2.9	3.2	
50	4.7	4.4	4.55	
60	5	5	5	
70	5	5	5	
80	5	5	5	
90	5.5	5.3	5.4	
100	5.2	4.7	4.95	

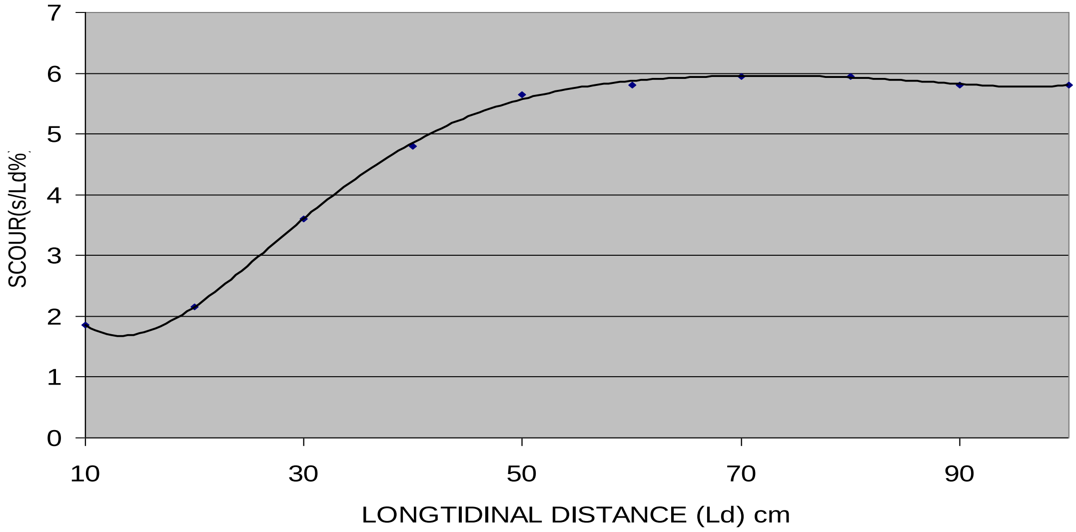


"Fig." (3) Effect of model III on the scour

"**Table" (5)** Effect of model IV on the scour

x (cm)	y1	y2	y av.	scour d.
10	1.5	2.2	1.85	4.15
20	2.1	2.2	2.15	
30	3.7	3.5	3.6	
40	5	4.6	4.8	
50	5.6	5.7	5.65	
60	5.6	6	5.8	

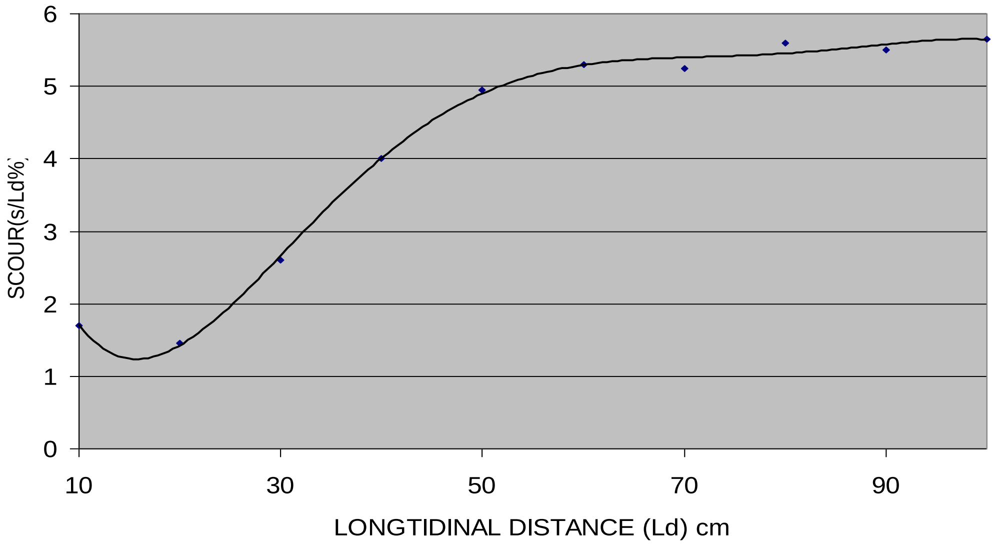
70	5.5	6.4	5.95	
80	5.9	6	5.95	
90	5.9	5.7	5.8	
100	5.9	5.7	5.8	



"Fig." (4) Effect of model IV on the scour

"**Table" (6)** Effect of model V on the scour

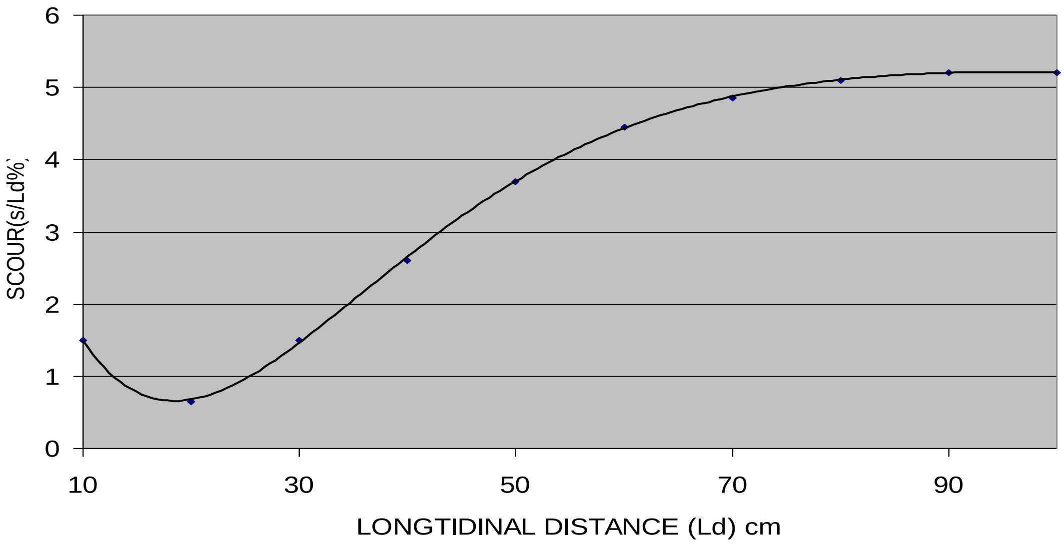
x (cm)	y1	y2	y av.	scor d.
10	1.5	1.9	1.7	4.3
20	1.5	1.4	1.45	
30	2.4	2.8	2.6	
40	3.8	4.2	4	
50	5	4.9	4.95	
60	5.2	5.4	5.3	
70	5.3	5.2	5.25	
80	5.5	5.7	5.6	
90	5.5	5.5	5.5	
100	5.5	5.8	5.65	



"Fig." (5) Effect of model V on the scour

"Table" (7) Effect of model VI on the scour

x (cm)	y1	y2	y av.	scour d.
10	1	2	1.5	4.5
20	0.2	1.1	0.65	
30	1	2	1.5	
40	2.5	2.7	2.6	
50	3.8	3.6	3.7	
60	4.3	4.6	4.45	
70	4.6	5.1	4.85	
80	5.1	5.1	5.1	
90	5.1	5.3	5.2	
100	5.2	5.2	5.2	



"Fig." (6) Effect of model VI on the scour

V. Conclusion

From this study, the following conclusions could be summarized as follow: 1- The sill over stilling basin has a great effect on flow characteristics and could share in the long time stability for such these huge hydraulic structures compared to the no sill case. 2- The reverse flow length downstream sill decreases as Fr and submergence ratio increase. 3- The relative energy loss and relative length of submerged hydraulic jump increase as the Froude number increases for all experimental models and different submergence ratios. 4-The scour of the all models deceases in range from 18 % to 33 % of no sills and blocks case at 10% of LB. 5- Sills with right upstream and dimension (Hb/Lb = 0.02, Wb/Lb = 0.02, Lb/LB = 0.04, and Se/LB = 0.03), increases energy dissipation, and decreases submerged length of hydraulic jump and local scour depth downstream stilling basin by 33%, compared to the case of no sill case.

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