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HYDRAULIC INTERACTION BETWEEN COMPOSITE STRUCTURE AND BLOCK OBSTACLE

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Abstract- Composite hydraulic structure is more sensitive to the presence of the obstacle which is located at downstream region of this structure. The obstacle's flow condition was changed from free to the submerged and this would make a contrast in hydraulic variables' value and distribution. Several experimental runs are performed in consideration of different obstacle lengths and thicknesses while the width is considered constant. The following variables are normalized and plotted with ratio (L/B) where L refers to the obstacle length and B refers to the channel width. These variables are actual discharge and average downstream depth. Also, the relation between upstream Froude number, downstream Froude number, Reynolds number and discharge coefficient and the ratio (L/B) is investigated. The investigation concentrated on the effect of cross sectional area flow which passes the gate on the actual discharge and average water depth. The study reveals that the obstacle length and thickness have direct impact on the water surface profile. This study includes a comparison between the hydraulic variables which control the composite hydraulic structure with and without the obstacle. It is clear that the water surface profile without obstacle is always below the water surface profile with obstacle. The influence of the obstacle thickness is considered and expressed with the relation (t/B). The optimal dimension of obstacle block to achieve proposed downstream water depth is determined.

Keywords: Block Obstruction, Flume, Gate, Weir, Composite Structure.

1. INTRODUCTION

Composite hydraulic structure can be described as a device employed to measure, distribute and divert the over and under flow with a noticeable workability, in addition to remove the floating material and deposited material simultaneously. So, it is very important to inspect and enhance the hydraulic workability of the composite structure and avoid and/or prevent any vulnerability in its hydraulic workability.

Reference [1] investigated the influence of barrier on combined weir-gate hydraulic structure depending on experimental runs. The investigation concentrated on the effect of the barrier number, spacing and location on the discharge coefficient, discharge throughout flume, water level and water depth at the downstream of the flume. Reference [2] carried out many experiments works to investigate the obstacles influence which was located at downstream with a specified distance from the composite hydraulic structure, so when the flow passed the hydraulic structure and met the obstacles the behavior of flow field will alter for both free flow and submerged flow conditions. They inferred from the experiment that the existence of obstacles will have effect on the flow field characteristics in comparison to a condition without obstacle. The study indicates that the hydraulics and dimensions variables which share or attribute in changing the flow field at downstream. A feasible and reasonable result is obtained from this investigation.

Reference [3] investigated the performance of new baffle blocks which are designed to reduce the stilling basin dimension. A satisfactory result is obtained to express the performance of the adopt blocks as compared to the standard blocks. Reference [4] investigated the performance of the blocks at stilling basin by making a comparison between the physical model and computational fluid dynamic model in order to the assess of the result.

Reference [5] investigated the impact of stilling basin with adverse slope on the hydraulic jump characteristics (depth ratio, jump length ratio, length of the roller and the ratio of energy dissipation). Also, they used different configuration of baffle blocks. They found that the baffle block led to the reduction on depth ratio, jump length ratio, and length of the roller, but led to the rise in the energy dissipation. Reference [6] investigated the hydraulic jump performance under using such elements as appurtenances of stilling basin. Experimental runs has been carried out to inspected four various intensities. Three ratios of width to height and length to height are considered in this work.

Cubic roughness group's elements are used. Reference [7] performed an experimental works to study the impact of using rough semicircular element on the hydraulic jump characteristics. This element fixed on downstream stilling basin floor of the spillway. He concluded from the result that the existence of these element leads to the increase in the shear force, also lead to the decrease in sequent flow depth and jump length. In addition, he made a comparison with previous studies which adopted rough semicircular element.

Reference [8] carried out an experimental run to explore the blocks shapes influence on the flow pattern at the downstream zone of the radial gate. Forty-five experimental runs were executed. Four various blocks were considered. The obtained results are investigated and graphically exhibited. Reference [9] used the Werner-Wengle wall model to perform the large eddy simulation in channel with channel bed containing rib elements, and the flow being turbulent. The investigation included the influences of roughness intensity and flow submergence, also the applied model validate. The profiles of turbulent intensity, mean velocity, turbulent production and kinetic energy of turbulent flow are compared with the related data of experimental.

Reference [10] studied the influence of the relative size, curvature, and the location of the curved baffle blocks in the energy dissipation and the hydraulic jump control by performed experimental work. The results illustrated that the curved baffle blocks are more effective in reducing the downstream kinetic energy as compared with regular blocks which have straight edges. The objective of the present work concentrated on the investigating of the influence of the block obstacle presence at the downstream region on the hydraulic response of the composite hydraulic structure.

2. THEORETICAL INFORMATION

To estimate the actual discharge that crosses the combined structure (rectangular weir and rectangular gate), when the flow condition is described free or submerged the actual discharge can be calculated from:

$$Q_{theor} = Q_{weir} + Q_{gate} \tag{1}$$

Theoretical discharge which crosses the weir can be calculated from Equation (12) [11].

$$Q_{weir} = \frac{2}{3}\sqrt{2g}.b\,h^{3/2} \tag{2}$$

Theoretical discharge which crosses the gate can be calculated by using the continuity equations [11]:

$$Q = VA \tag{3}$$

$$Q_{gate} = VA = \sqrt{2gH}\,A \tag{4}$$

$$Q_{act} = C_d\,Q_{theor} \tag{5}$$

$$Q_{act} = C_d\left[\frac{2}{3}\sqrt{2g}\,b\,h^{3/2} + \sqrt{2gH}\,A\right] \tag{6}$$

For free flow condition

$$H = d + y + h \tag{7}$$

For submerged flow condition

$$H = d + y + h - h_d \tag{8}$$

where, b: Rectangular weir width, A: Gate cross section flow area, H: Water depth at upstream, h: Weir water head, y: Vertical distance between weir and gate, d: Gate opening depth, g: Acceleration due to gravity, Q_{weir}: Weir discharge, Q_{gate}: Gate discharge, Q_{theor}: Theoretical discharge, Q_{act}: Actual discharge, and C_d: Coefficient of discharge.

The Reynolds number is calculated by utilizing the Equation (9) [12].

$$R_e = \frac{V.h_d}{\nu} \tag{9}$$

where, h_d is the average downstream water depth, V is the flow velocity, and ν is the kinematic viscosity.

The Froude number is calculated by utilizing the Equation (10) [13].

$$F_r = \frac{V}{\sqrt{g\,y}} \tag{10}$$

3. EXPERIMENTAL SETUP

The experimental work is performed in the hydraulic laboratory of the Basrah Engineering Technical College, Iraq. The glass flume of 2m length is used in the present work. The cross-section was rectangular, 7.5 cm wide and 15 cm deep. The flume bed is horizontal and fixed flat. The actual discharge is measured by utilizing the volume method, while the depth of water is measured by utilizing the point gage device which is moveable on the flume wall. The composite structure models are made from 5 mm wood sheet thickness and beveled along all the edges at (45°) with sharp edges of thickness (1 mm).

Obstacles blocks models are made from the wood material. Table 1 illustrates the dimensions of different blocks. The blocks are located at a certain distance which is equal to 10 cm at the downstream zone from the composite structure. Table 2 illustrates the selected dimension of composite structure which consist of rectangular weir and rectangular gate. The width of both weir and gate is selected to be fixed value of 3 cm. Figure 1 shows the whole hydraulic system which composed of composite structure and block. In each experiment, the following are measured: water head above weir sharp crest, actual discharge and water depth at flume downstream. The current work deal with free submerged flow conditions.

Table 1. Dimensions of the blocks

Block	Length (cm)	Thickness (cm)	Width (cm)
1	5	1	7.5
2	5	1	7.5
3	5	1	7.5
4	10	1.5	7.5
5	10	1.5	7.5
6	10	1.5	7.5
7	15	2	7.5
8	15	2	7.5
9	15	2	7.5

Table 2. Dimensions and details of composite structure

Model No.	*H* (cm)	*Y* (cm)	*d* (cm)	*H* (cm)	A_w (cm^2)	A_g (cm^2)
1	3	2	4	9	9	12
2	2	2	4	8	6	12
3	1	2	4	7	3	12
4	3	3	3	9	9	9
5	2	3	3	8	6	9
6	1	3	3	7	3	9
7	3	4	2	9	9	6
8	2	4	2	8	6	6
9	1	4	2	7	3	6

4. RESULTS AND DISCUSSION

Composite hydraulic structure is spread widely in irrigation work due to it is ability to solve the problem of floating and sediment materials therefore it is very important to evaluate this structure under the action of obstacle presence at downstream region. Figure 2 shows the relation between actual discharge and the ratio (*L*/*B*). It is clear from Figure 2, the reduction in actual discharge occurs for all cases with ratio (*L*/*B*) expect the case where the ratio (*t*/*B* = 0.2) in Figure 2a. This reduction based on friction force which grow and develop between the flow path and obstacle surface in addition to the friction which caused by the solid boundary of the flume. So, the friction force reduce the flow velocity and lead to the reduction in actual discharge because of the direct proportional between the discharge and flow velocity.

This clarification is applicable for all values of (*L*/*B*) and (*t*/*B*) with actual discharge. The variation occurs because of the interference between weir flow discharge and gate flow discharge. However, the obstacle confined some quantity of flow beside it. Also, this figure illustrates case without obstacle in Figure 2a this case has location near by the lower limit, while in Figure 2b the case has upper limit. The variation in limit occurs due to change in the ratio (*Ag*/*BH*) regardless the ratio (*L*/*B*) or (*t*/*B*). The actual discharge increase with increase in the ratio (*Ag*/*BH*).

Figure 3 shows the relation between downstream Froude number and the ratio (*L*/*B*). It is clear from Figure 3, the increase in downstream Froude number occurs for all cases with ratio (*L*/*B*) except the case where the ratio (*t*/*B* = 0.26) in Figure 2b. The increase in values occurs due to increase in flow velocity which reflect on Froude number owing to the direct proportional relationship between them, while the decrease in values occurs due to increase in water depth which reflect on Froude number owing to the inversely proportional relationship between them. This behavior is more sensitive to the presence of downstream obstacle. It is clear from figure that the case of without obstacle represent the upper limit for both figure a and b. Figure 3a shows a super critical flow for the case without obstacle, while Figure 3b shows a sub critical flow for the case without obstacle. The previous behavior would control the flow velocity which has direct proportional with Froude number.

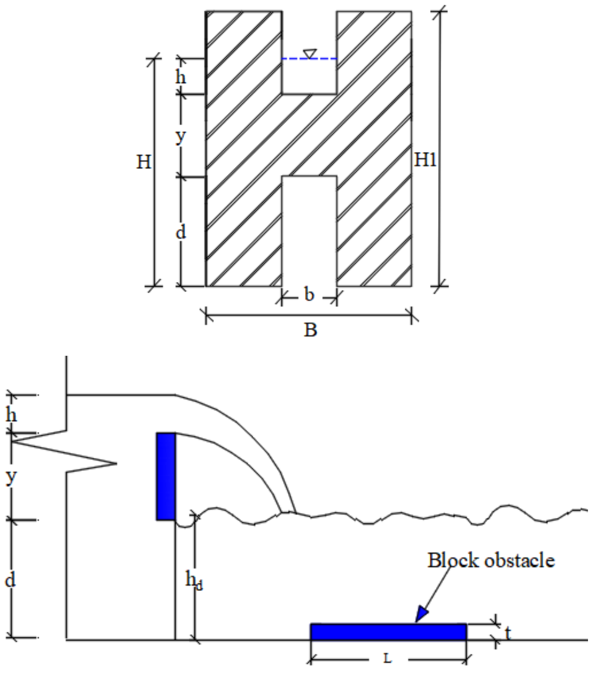
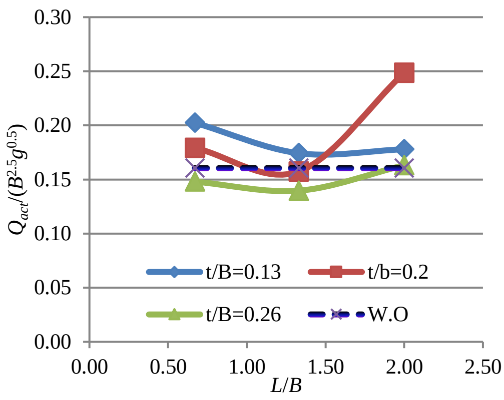
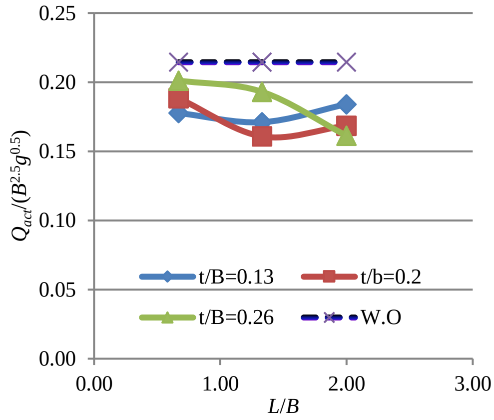


Figure 1. Section across the flow and profile section

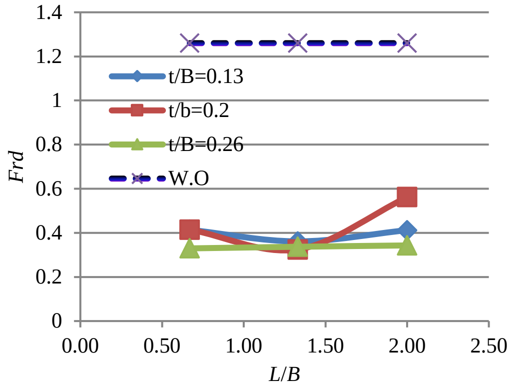


(a)



(b)

Figure 2. Variation of Actual discharge with length of block for different values of block thickness; (a) *Ag*/*BH*=0.15, *Ag*/*BH*=0.1, *y*/*B*=0.4, (b) *Ag*/*BH*=0.2, *Ag*/*BH*=0.1, *y*/*B*=0.26



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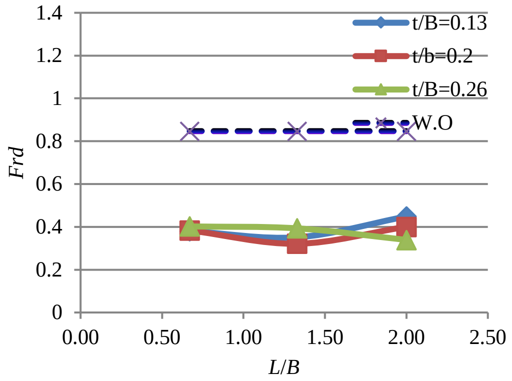
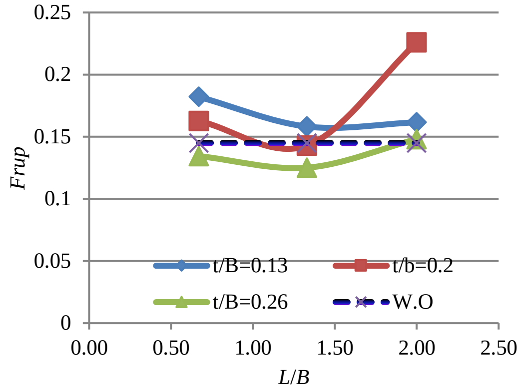
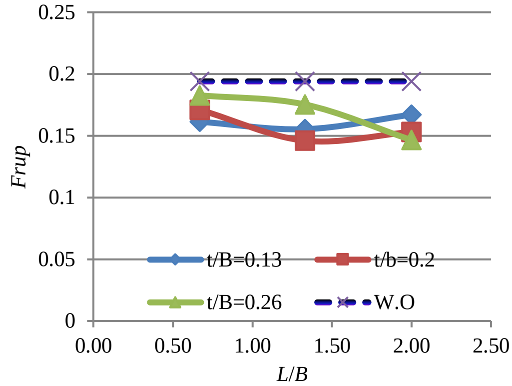


(b)

Figure 3. Variation of Downstream Frode Number with length of block for different values of block thickness; (a): Ag/BH=0.15, Aw/BH=0.1, y/B=0.4, (b): Ag/BH=0.2, Aw/BH=0.1, y/B=0.26



(a)



(b)

Figure 4. Variation of Upstream Frode Number with length of block for different values of block thickness; (a): Ag/BH=0.15, Aw/BH=0.1, y/B=0.4, (b): Ag/BH=0.2, Aw/BH=0.1, y/B=0.26

Figure 4 shows the relation between upstream Froude number and the ratio (L/B). It is clear from Figure 4, the increase in upstream Froude number occurs for all cases with ratio (L/B). The behavior of the relation is similar to the behavior of the relation in Figure 3 and any contrast relies on flow velocity and flow depth, both of them control the values of Froude number. Also Figure 3 illustrates case without obstacle in Figure 2a this case has location near by the lower limit, while in Figure 2b the case has upper limit. For both Figure 3a and 3b the sub critical flow is dominate and this mean low flow velocity.

Figure 5 shows the relation between Reynolds number and the ratio (L/B). It is clear from figure 5, the relation between Reynolds number for all cases with ratio (L/B) considering various ratio of (t/B). In general Reynolds number depend on flow velocity and flow depth so any increase or decrease in both of them would reflect directly on Reynolds number because of the direct proportional among them. For the case when Reynolds number decrease with ration (L/B), this occurs due friction force which grow and develop between the flow path and obstacle surface in addition to the friction which caused by the solid boundary of the flume, therefore this force will reduce the flow velocity, and this will reflect on Reynolds number. Also, the reduction in flow depth near and/or over the obstacle will reflect on Reynolds number. Also figure illustrates case without obstacle in Figure 5a this case has location near by the lower limit, while in figure 5b the case has upper limit.

Figure 6 shows the relationship between discharge coefficient and the ration (L/B) for different values of the ration (t/B). The behavior of the relation is similar to the behavior of the relation in Figure 2 owing to the direct proportionality between the actual discharge and discharge coefficient regardless the presence of obstacle. Also figure illustrates case without obstacle in Figure 6-a this case has location near by the lower limit, while in Figure 6-b the case has upper limit. Figure 7 shows the relation between average water depths at downstream with the ration (L/B) considering various ration of (t/B). It is obvious from figure the presence of the obstacle lead to the increase in average water depth as compare with the case of without obstacle. The presence of obstacle lead to the raise the flow depth regardless the dimension and depth of obstacle and this occurs because of the flow confinement beside the obstacle and lead to increase the depth of incoming flow.

Figure 8 shows the relation between the actual discharge and the ration (Ag/BH) considering various values of the ratio (t/B). It is clear from figure when the ratio (Ag/BH) increase the actual discharge would increase due to the direct proportional relationship between the discharge and cross-sectional area of flow. The increase occurs regardless the presence of obstacle. The variation in distribution of results will occurs owing to the interaction between overflow discharge and under flow discharge.

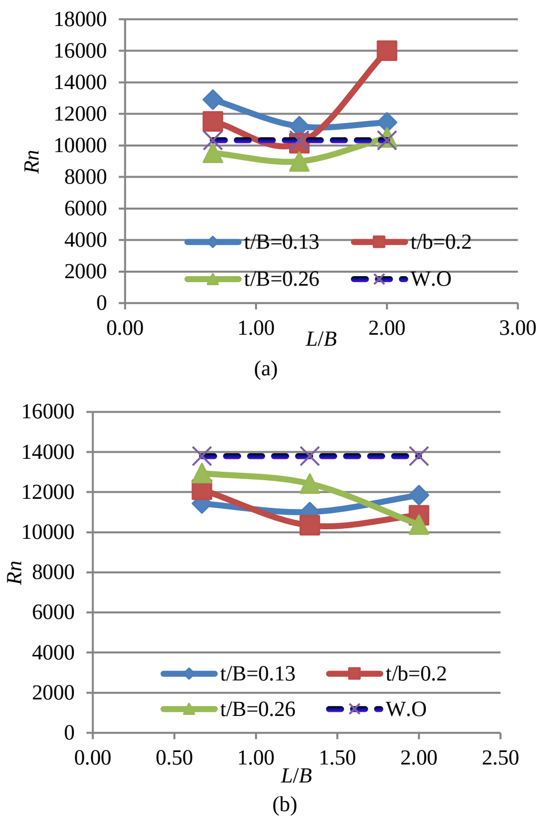


Figure 5. Variation of Reynold's Number with length of block for different values of block thickness; (a): *Ag*/*BH*=0.15, *Aw*/*BH*=0.1, *y*/*B*=0.4, (b): *Ag*/*BH*=0.2, *Aw*/*BH*=0.1, *y*/*B*=0.26

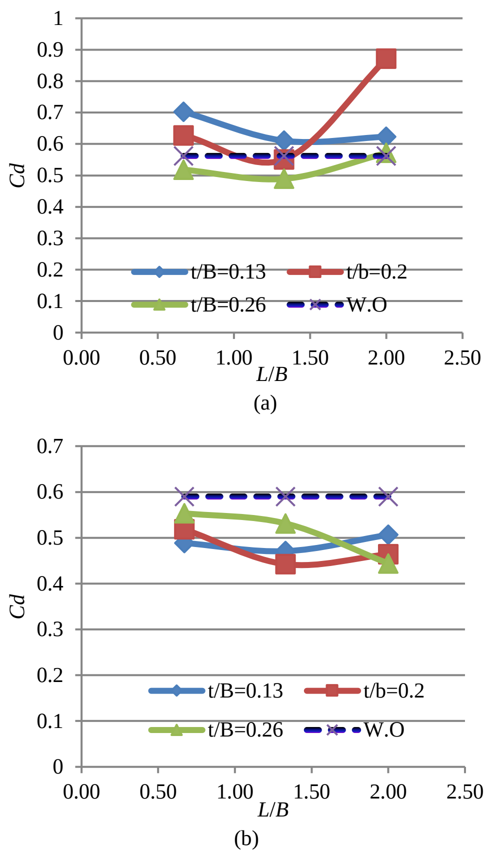


Figure 6. Variation of Discharge Coefficient with length of block for different values of block thickness; (a): *Ag*/*BH*=0.15, *Aw*/*BH*=0.1, *y*/*B*=0.4, (b): *Ag*/*BH*=0.2, *Aw*/*BH*=0.1, *y*/*B*=0.26

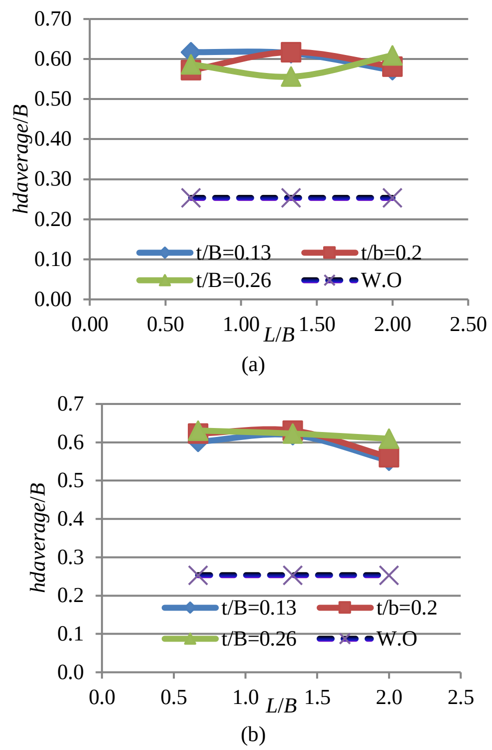
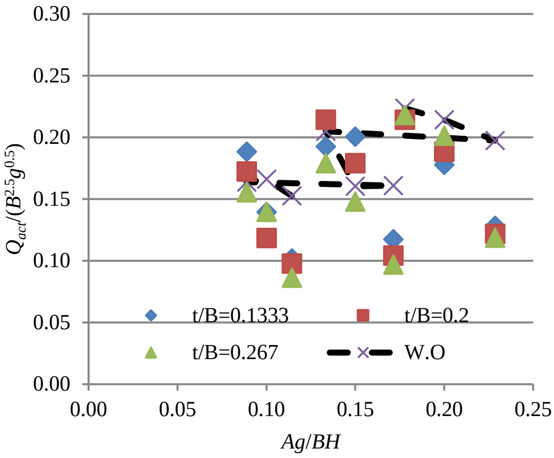


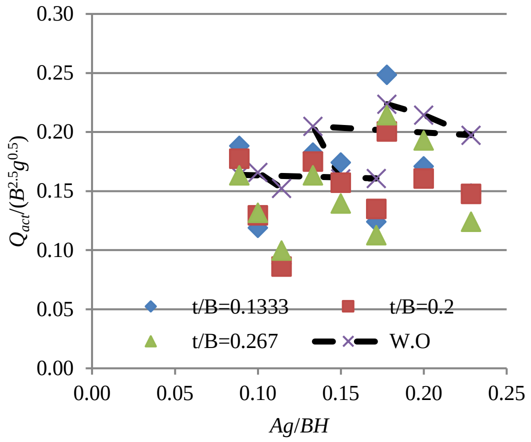
Figure 7. Variation of Downstream Water Depth with length of block for different values of block thickness; (a): *Ag*/*BH*=0.15, *Aw*/*BH*=0.1, *y*/*B*=0.4, (b): *Ag*/*BH*=0.2, *Aw*/*BH*=0.1, *y*/*B*=0.26

Figure 9 shows the relation between the average downstream water depth and the ration (*Ag*/*BH*) considering various values of the ratio (*t*/*B*). It is clear from figure when the ratio (*Ag*/*BH*) increase the average downstream water depth would increase due to the accumulation of water quantity beside the obstacle and this led to the rise in average water depth, while in the case of without obstacle the interaction between over flow velocity and under flow velocity will dominate the raise in water depth. The variation in distribution of results will occurs owing to the interaction between overflow discharge and under flow discharge.

Figure 10 shows downstream water depth profile for different values of block thickness, also this figure includes a comparison study between the case with obstacle and the case without obstacle. The water profile for the case without obstacle always below the water profile with obstacle. Actually, the presence of obstacle lead to the raise the water profile in comparison to not using it. It is clear from figure that before and after the obstacle all the water profile interact at one point. Figure 11 shows downstream water depth profile for different values of block length. Also, this figure include a comparison study between the case with obstacle and the case without obstacle. The water profile for the case without obstacle always below the water profile with obstacle. Actually, the presence of obstacle lead to the raise the water profile as compared without using it. It is clear from the figure that before the obstacle all the water profile interacts at one point while after the obstacle there is no interaction between water profiles. Overall Figures 10 and 11 based on flow quantity which crosses the weir and gate.



(a)



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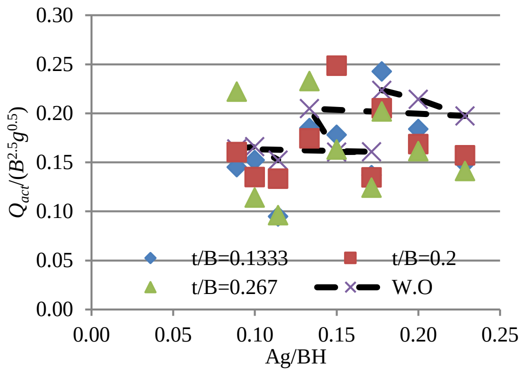
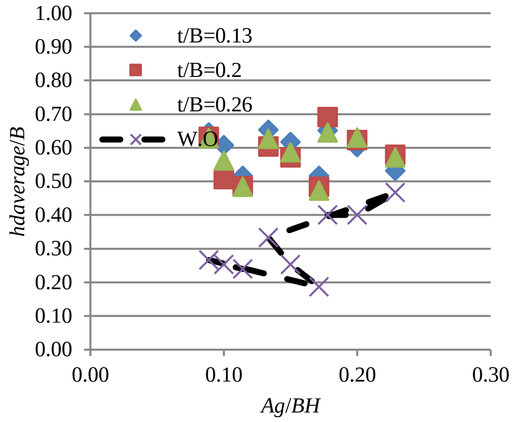
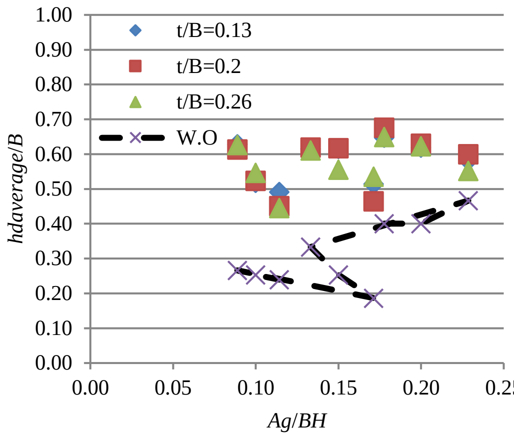


(c)

Figure 8. Scatter Distribution of Actual Discharge with Area of Gate for different values of block thickness; (a): *L*/*B*=0.67, (b): *L*/*B*=1.33, (c): *L*/*B*=2.0



(a)



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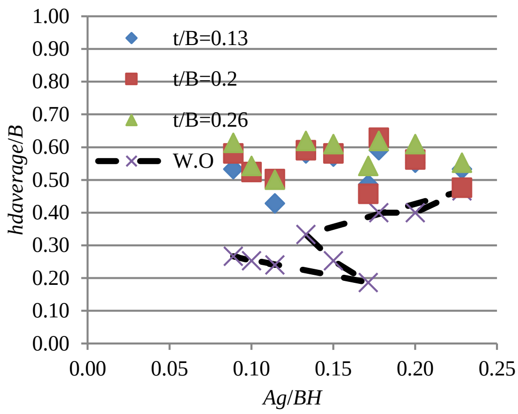

(c)

Figure 9. Scatter Distribution of Average Downstream Water Depth with Area of Gate for different values of block thickness; (a): *L*/*B*=0.67, (b): *L*/*B*=1.33, (c): *L*/*B*=2.0

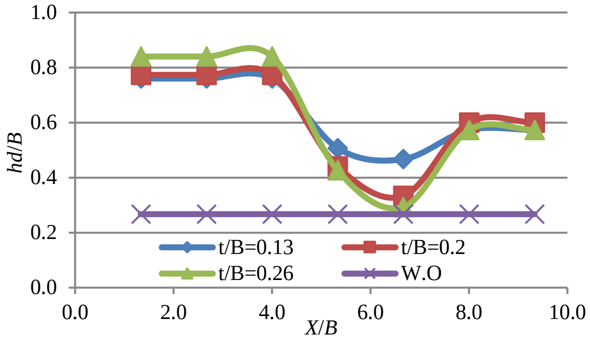

Figure 10. Downstream Water Depth Profile for different values of block thickness (*Ag*/*BH*=0.0889, *Aw*/*BH*=0.1333, *L*/*B*=1.33)

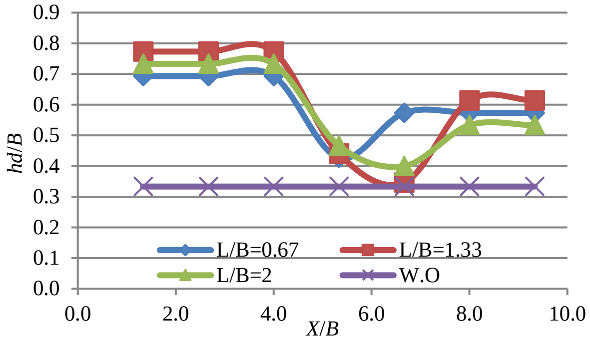

Figure 11. Downstream Water Depth Profile for different values of block length (*Ag*/*BH*=0.1333, *Aw*/*BH*=0.1333, *t*/*B*=0.2)

4.1 Dominate Parameter at Downstream Region

It is observed that the weir - gate structure operation is affected by the dimensions of the block obstacle. Therefore, the discharge quantity as well as the downstream water depth affected by the thickness and length of the block obstacle. The downstream water depth is written as function of discharge quantity, downstream velocity flow, density, gravity, block thickness and block length as follow:

$$h_d = f\left(Q, V, \rho, g, t, L\right) \tag{11}$$

Where f is unknown function, Q is the discharge quantity, V is the downstream flow velocity, t is the block height or thickness, L is the block length, g is the acceleration due to gravity, and ρ is the water density. The functional relationship which describes the downstream water depth is derived from the fundamental of dimensional analysis, which describes the condition at downstream region and can be written as Equation (12).

$$\frac{h_d\sqrt{V}}{\sqrt{Q}} = f\left(\left(\frac{t\sqrt{V}}{\sqrt{Q}}\right), \left(\frac{L\sqrt{V}}{\sqrt{Q}}\right), \left(\frac{g\sqrt{Q}}{V^{2.5}}\right)\right) \tag{12}$$

To obtain an effective formula between the downstream water depth h_d and different variables that mentioned above, the curve fitting method is used to produce a relation between the h_d and those variables. Depending on the natural of the resulting relationships between the h_d and the influencing variables and by feeding the corresponding data (90 sets of data) into curve expert professional program software, a nonlinear formula is obtained to predict the non- dimensional value of the h_d as Equation (13).

$$\frac{h_d\sqrt{V}}{\sqrt{Q}} = 0.608 + 0.312\left(\frac{t\sqrt{V}}{\sqrt{Q}}\right)^{0.485}\left(\frac{L\sqrt{V}}{\sqrt{Q}}\right)^{0.2\times10^{-6}} - 0.00018\left(\frac{g\sqrt{Q}}{V^{2.5}}\right)^{2} \tag{13}$$

The equation reveal that the block thickness has important role in control the downstream water depth in comparison with the block length.

4.2. Optimal Design of Block Obstacle

Hydraulic structures such as weir and gate structures are costly water resources projects. A safe and optimal design of hydraulic structures is always being a challenge to water resource researchers. The hydraulic structures such as composite weir-gate structure sometimes needs to subject to block obstacle structure in order to increase the downstream water depth. The variation of block obstacle dimensions affects the downstream water depth and exhibits nonlinear variation. An optimization problem may be formulated to obtain the optimum block obstacle dimensions that maximize the downstream water depth.

The optimization problem for determining an optimal dimension for the block obstacle consists of maximizing the non-dimensional value of downstream water depth that computed from Equation (13). This process comprises of solving the nonlinear optimization formulation problem using complex method [14], [15]. This method used to determine the optimal solution for single objective function represented by non-dimensional downstream water depth subjected to multi state variables represented by non-dimensional value of thickness, length and flow characteristics values. The optimization problem may be represented as follows:

maximize

$$Z = \frac{h_d\sqrt{V}}{\sqrt{Q}} \tag{14}$$

subjected to

$$0 \le \left(\frac{t\sqrt{V}}{\sqrt{Q}}\right) \le 0.399 \tag{15}$$

$$0 \le \left(\frac{L\sqrt{V}}{\sqrt{Q}}\right) \le 3.055 \tag{16}$$

$$0 \le \left(\frac{g\sqrt{Q}}{V^{2.5}}\right) \le 21.83 \tag{17}$$

A program using Fortran 95 is developed to solve the above optimization problem [16]. Table 4 presents the optimal solution for the above objective function and the constraints.

Table 3. Optimal objective function and non-dimensional dimensions of the blocks

$F^* = \frac{h_d\sqrt{V}}{\sqrt{Q}}$	$X_1^* = \left(\frac{t\sqrt{V}}{\sqrt{Q}}\right)$	$X_2^* = \left(\frac{L\sqrt{V}}{\sqrt{Q}}\right)$	$X_3^* = \left(\frac{g\sqrt{Q}}{V^{2.5}}\right)$
0.8078	0.3994	2.628	0.582

From above table, it was observed that the value of X_1* reaches the highest limited value and X_3* reaches the lowest limited value, while the value of X_2* is an average. It was also observed that changing the upper and lower limits of X_2* and X_3* does not affect the optimal solution of the problem, while changing the upper limit of X_1* value affects the optimal solution of the objective function. Table 4 shows the optimum solution of the objective function with different upper values of X_1*. Therefore, feasible limit of X_1* ranges from 0.24 to 0.608.

Table 4. Feasible solution of obstacle block

X_1*	X_2*	X_3*	F*
0.230	2.248	–1.721	0.742
0.240	**3.055**	**0.582**	**0.764**
0.250	3.055	0.582	0.767
0.300	2.628	0.582	0.782
0.400	2.628	0.582	0.807
0.450	2.628	0.582	0.819
0.500	2.628	0.582	0.831
0.550	2.628	0.582	0.841
0.600	2.628	0.582	0.851
0.607	2.628	0.582	0.853
0.608	2.628	0.582	0.853
0.609	2.248	–1.721	0.852

Note that the optimal value of X_3* remain as in table 3, while the optimal value of X_2* start changes when upper value of X_1 less than 0.3. It was also found that the value of X_3* becomes negative when the upper value of X_1* is greater than 0.608 or less than 0.24.

5. CONCLUSION

The following points appear from the current study.

1. The ratio (L/B) and the ratio (t/B) have direct impact on the hydraulic variables which control the composite hydraulic structure.
2. The variation of Froude number at upstream or downstream with the ratio (L/B) is identical in the case of the obstacle presence, while in the case without obstacle the variation is not identical.
3. The actual discharge more sensitive to the obstacle length and thickness.
4. The variation of Reynolds number with the ratio (L/B) depends on flow velocity and flow depth.
5. The discharge coefficient of composite hydraulic structure based on discharge quantity.
6. The presence of obstacle cause increase in water depth as compared without using the obstacle.
7. When the cross-sectional area of flow which passed the gate increase the actual discharge would increase simultaneously.
8. When the cross-sectional area of flow which passed the gate increase the average downstream water depth would increase simultaneously.
9. The obstacle length and thickness have major effect on the water surface profile.
10. The presence of obstacle cause rise in water surface profile as compared without using obstacle.
11. The block thickness has important role in control the downstream water depth as compare with block length.
12. The optimal downstream water depth, optimal dimension of block obstacle, and optimal flow characteristics are determined.
13. The optimal downstream water depth equal to,

$$h_d = \frac{0.764\sqrt{Q}}{\sqrt{V}}$$

whereas the optimal state variables are

$$t = \frac{0.24\sqrt{Q}}{\sqrt{V}} \ , \ L = \frac{3.055\sqrt{Q}}{\sqrt{V}}$$

REFERENCES

[1] R.M. Qasim, I.A. Abdulhussein, K. Al Asadi, "The Effect of Barrier on the Hydraulic Response of Composite Weir-Gate Structure", Archives of Civil Engineering, Vol. 66, pp. 97-118, 2020.

[2] R.M. Qasim, I.A. Abdulhussein, A.A. Mohammed, Q. A. Maatooq, "The Effect of the Obstacle on the Hydraulic Response of the Composite Hydraulic Structure", INCAS Bulletin, Vol. 12, pp. 159-172, 2020.

[3] N.J.H. Al Mansori, T.J.M. Alfatlawi, K.S. Hashim, L. S. Al Zubaidi, "The Effects of Different Shaped Baffle Blocks on the Energy Dissipation", Civil Engineering Journal, Vol. 6, No. 5, 2020.

[4] H.A. Huseein, S.A. Mohsen, "Investigation of Blocks Performance at Stilling Basin Using Computation Fluid Dynamics", Journal of Engineering and Applied Sciences, Vol. 14, No. 17, pp. 6312-6316, 2019.

[5] A. Abbas, H. Alwash, A. Mahmood, "Effect of Baffle Block Configurations on Characteristics of Hydraulic Jump in Adverse Stilling Basins", MATEC Web of Conferences 162, 03005, 2018.

[6] J. Maatooq, E. Taleb, "The Performance of Hydraulic Jump over Rough Bed Stilling Basin Consisting of Cubic-Shape Elements", MATEC Web of Conferences 162, 03001, 2018.

[7] A.M. Hayder, "Laboratory Study on Stilling Basin with Semicircular Rough Bed Elements", Jordan Journal of Civil Engineering, Vol. 11, No. 2, 2017.

[8] M.M. Ibrahim, "Improve the Efficiency of Stilling Basin Using Different Types of Blocks", American Journal of Engineering Research (AJER), Vol. 6, Issue 8, 295-304, 2017.

[9] H. Shamloo, B. Pirzadeh, "Analysis of Roughness Density and Flow Submergence Effects on Turbulence Flow Characteristics in Open Channels Using a Large Eddy Simulation", Applied Mathematical Modelling, Vol. 39, pp. 1074-1086, 2015.

[10] A.F. Eloubaidy, J.H. Al Baidhani, A.H. Ghazali, "Dissipation of Hydraulic Energy by Curved Baffle Blocks", Pertanika J. Sci. and Technol., Vol. 7, No. 1, pp. 69-77, 1999.

[11] V.L. Streeter, E.B, Wylie, "Fluid Mechanics", First SI Metric Edition, 1983.

[12] A.M. Negm, M. Al Brahim, A.A. Al Hamid, "Combined-Free Flow Over Weirs and Below Gates", J. Hydraul. Res., Vol. 40, pp. 1-7, 2002.

[13] R.W. Fox, A.T. Mc Donald, Introduction to Fluid Mechanics, Fourth Edition, SI Version, John Wiley and Sons, Inc., 1994.

[14] M.J. Box, "A New Method of Constrained Optimization and Comparison with Other Methods", Computer Journal, Vol. 8, No. 42, pp. 42-52, 1965.
[15] S.S. Rao, "Engineering Optimization: Theory and Practice", Fourth Edition, John Wiley and Sons, Inc. 2009.
[16] J.L. Kuester, J.H. Mize, "Optimization Technique with Fortran", McGraw-Hill, Inc., 1973.

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