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THE EFFECT OF BARRIER ON THE HYDRAULIC RESPONSE OF COMPOSITE WEIR-GATE STRUCTURE

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The composite weir-gate structure is considered an important hydraulic structure. This is because of its widely used in civil engineering hydraulic works especially in an irrigation system to measure, control, divert and keep the required water level. This study focuses on the influence of barrier existence on the hydraulic parameters that described the hydraulic characteristics of composite weir-gate hydraulic structure. In this study, several experimental runs were conducted to determine the effect of barrier's location, spacing and number on the water level and depth at the downstream region of flume, discharge coefficient of composite hydraulic structure, and flow rate throughout the flume. Our experiments indicated that the turbulence intensity, inlet effect, and position, gap, and number of barriers have affected the hydraulic behavior of weir-gate structure. This appears clearly by obtaining different results of discharge coefficient and flow rate that cross the weir-gate structure comparing with same cases without barriers. Also this study gives some insights on the significance roles of fluid separation, eddies generation near the barrier, fluid resistance and overlap between overflow and underflow velocities and their effects on hydraulic factors that dominate the problem. These hydraulic factors must be considered in the design and construction of barrier/barriers in open channel to prevent any fluctuation or drop in discharge, water elevation and the required water depth at downstream region.

Keywords: Hydraulic Structure, baffle or barrier, composite weir-gate, water level.

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1. INTRODUCTION

Managing the natural water resources requires controlling hydraulic structures. Weir and gate are considered examples of these structures and they were used for decades to measure, regulate, and control the flow in the waterway systems, i.e. irrigation system. Although of their advantages, these two hydraulic structures may cause problems. The weir structure causes an accumulation of deposited materials at the upstream region of the waterway system, whereas the gate retained floating materials. To overcome these problems, a composite weir-gate hydraulic structure is used. This type of hydraulic structure is designed and constructed to divide the flow into two regimes, overflow and underflow.
The overflow regime is developed at the weir section and it prevents the retention of floating materials before the structure, whereas the underflow regime is generated at the gate section which in turn prevents the accumulation of deposited materials before the structure.

In this study, the hydraulic response of the weir-gate composite structure with the existence of barrier (baffle wall) is investigated. In practice, barrier has played an important role in dissipating the water energy and control the path of flow by increasing the velocity and raise water elevation in the downstream region. The hydraulic response of the composite hydraulic structure depends primarily on discharge coefficient, discharge quantity, head above the weir, and interaction between overflow and underflow velocities. So it is very important to understand the impact of barrier on these factors to control the operation of the composite system by preventing any fluctuation in discharge quantity and reducing the excessive kinetic energy of flowing water. So it satisfies two different jobs at the same time.

The authors did not find literatures about the effect of barrier on the hydraulic response of composite weir-gate structure. The literature in this paper is restricted to the analysis of barrier effect on flow structure in open channel.

Arie and Rouse [5] have placed a low wall transversely in a wind tunnel test section. The two dimensional (2D) uniform flow produced by the above wall was described. The air flow in a 0.914m wide test section is studied. The low wall should be occupied only small portions (5%) of the local flow cross section. The main features of the above study are; the wall contracts the flow resulting in two flow regions one in the upstream and the other in the downstream, the downstream region produced by the wall extends about 18 of the length of the wall, the wall produces turbulence, which first grows then disperse across much of the channel, including across the stream line of maximum velocity.

Substantial efforts have been carried out to investigate the flow characteristics around a dike or an abutment using numerical simulation. The most often research studies in this field were conducted by Tingsanchali and Maheswaran [17], Michiue and Hinokidani [6], Jia and Wang [19], Muneta and Shimizu [7], Mayerle et al. [14], Ouillon and Dartus [16], Chen and Ikeda [2], and Kimura and Hosoda [4]. All above mentioned studies have explored the main feature of the flow field immediately at a dike or abutment, such as the values of the time-averaged velocity, and they did not reveal much about the effect of dike or abutment on the downstream separation region.

Ettema and Muste [13] have documented the studies that used to determine the accuracy of micromodels, small hydraulic models, in simulating the flow around spur dikes. Some districts of the U.S. Army Corps of Engineers (USACE) have used micromodels to design channel-control works [11]. Ettema and Muste [12] conducted a series of experiments to determine scale effects around a single dike- wing dam. This work shows that using of a shear –stress parameters influences the flow separation region at a dike.

Jamshidnia et al. [3] conducted an experimental work to investigate the effect of the intermediate barrier on the flow structure in a rectangular open channel. They observed the flow field along the channel by measuring the instantaneous timed-average velocity profiles using a 3D acoustic Doppler velocimeter. They found that the approach flow is fully developed upstream of the barrier. By analyzing the space-averaged power spectra of stream wise velocity, they observed a peak structure in the upstream baffle region, whereas downstream of the baffle this peak structure has been alleviated by the baffle. The same analysis for the vertical component indicates the existence of a peak structure both up- and downstream of the baffle. They concluded that the baffle affects the stream wise energy dissipation but not the vertical energy dissipation.

2. CONCEPTS OF FLUID MECHANICS

Total theoretical discharge (Q_{theo}) that passes through the weir-gate hydraulic structure, shown in Fig. 1, is represented by the summation of theoretical discharge over the weir ($Q_{theo.weir}$) and theoretical discharge under the gate ($Q_{theo.gate}$);

(2.1) $$Q_{theo.} = Q_{theo.weir} + Q_{theo.gate}$$

The equation of the theoretical discharge over rectangular sharp crested weir ($Q_{theo.weir}$) is [18];

$$Q_{theo.weir} = \frac{2}{3}\sqrt{2g} \cdot b \cdot h^{3/2} \tag{2.2}$$

where g is the gravity acceleration (m/s^2); b represents the width of the weir (m); h is the water head above the crest of the weir (m).

The continuity equation is utilized to determine the theoretical discharge that passes under the gate ($Q_{theo.gate}$) [18];

$$Q_{theo.gate} = V_{theo.gate} \cdot A_g \tag{2.3}$$

where A_g is cross-sectional area of the gate opening (m^2); $V_{theo.gate}$ is the theoretical velocity through the gate opening.

For free flow condition, $V_{theo.gate}$ is a function of the water depth at the upstream region of flume (H) [8, 9, and 10];

$$V_{theo.gate} = \sqrt{2gH} \tag{2.4}$$

and;

$$H = d + y + h \tag{2.5}$$

where d is height of the gate opening (m); y is the vertical distance between the weir and gate (m). Assuming that the weir-gate structure has one discharge coefficient [1], the total actual discharge ($Q_{act.}$) through the weir-gate structure is:

$$Q_{act} = C_d \cdot Q_{theo.} \tag{2.6}$$

thus;

$$Q_{act} = C_d \left[\frac{2}{3}\sqrt{2g}\, bh^{3/2} + \sqrt{2gH}\, A_g\right] \tag{2.7}$$

where C_d is the discharge coefficient for the weir-gate structure.

3. EXPERIMENTAL RUNS

A set of experiments were conducted in a rectangular flume at the hydraulic laboratory of Basrah Engineering Technical College, Southern Technical University. The flume is 2 m long, 15 cm height and 7.5 cm width with glass sidewalls. The volume method is used to measure the discharge of water. The average water depth is measured by scales fixed at the wall of the flume. A rectangular sharp-crested weir with a rectangular gate model, as illustrated in Fig. 1, is fabricated from wood material of height (H1) equals 10 cm and wide equal to flume width (B=7.5cm), and installed at the beginning region of the flume. The weir is beveled along all the edges at 45^0 with sharp edges of thickness 1mm [15]. The barrier is of height 1 cm and made of wood sheet of 5mm thick. The barrier has fixed to flume using plexiglass supports. The selection of the flume and model material was based on the available laboratory facilities.

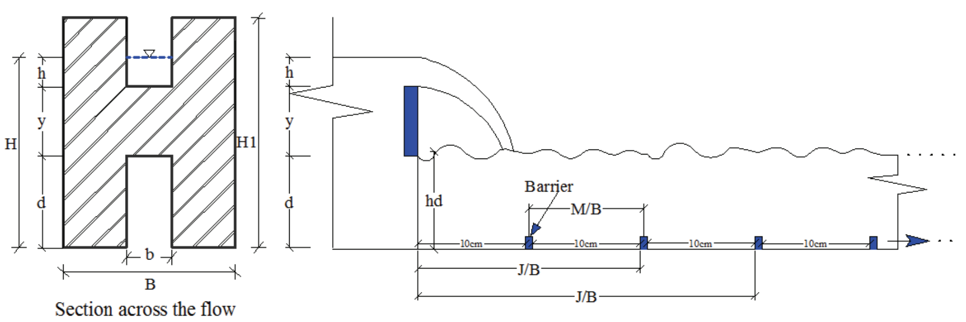

Fig. 1. Section Profile and Section across the Flow

Sixty six models (experiments) were conducted. Twenty two models were conducted for every dimensionless value of gate area (Ag/BH). Three values of Ag/BH is adopted and equal to 0.059, 0.089, and 0.12 and involving the following limitations: 2cm≤ y ≤4cm, 2cm≤ d ≤4cm, b=2cm, H=9cm, h= 3cm, 4cm ≤ Aw ≤6 cm^2, 6 cm^2≤ Ag ≤8 cm^2, where Aw is represent the flow cross sectional area at the weir. In each experimental run, combined flow rate, $Q_{act.}$, and downstream water depth, h_d, at each barrier are measured under free flow conditions. Only the rectangular shape was adopted in the present study in order to focus on the hydraulic response of the barriers.

The following procedures were adopted for all model runs:

1- The slope of the flume is always in horizontal position.

2- The models were fixed into flume at distance 80cm from the beginning of the flume.

3- The barriers are fixed at a certain distance from the composite structure equals to 10, 20, 30, 40, 50, and 60cm for the case of single barrier.

4- The second barrier is fixed by a distance ranges from 10 to 50 cm from the first barrier for the case of double barriers.

5- The free flow condition is satisfied by removing the tail gate from the flume.

Table 1 review selected outcomes were obtained from experimental runs. The M and J values represent Barriers' spacing and location.

4. UNCERTAINTY OF A MEASURED QUANTITY

Uncertainty can be termed as a positive parameter which characterizes the dispersion of values assigned to a measure and (the measured quantity) [20]. To express the errors that may occur during measurements of a quantity x, the following equation can be used:

(4.1) $$u_x = \sqrt{S_x^2 + b_x^2}$$

where, S_x represents the random errors, while the term b_x accounts for systematic errors and u_x is termed the standard uncertainty in x. The S_x value can be determined by calculating the standard deviation of a sample:

(4.2) $$S_x = \left\{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2\right\}^{1/2}$$

Table 1 Results of the Selected Experimental Models (Ag/BH=0.12)

Experimental Run No.	h_d (cm)	J/B	M/B	$Q_{act.}$ (l/sec.)	Q_{theo} (l/sec.)	C_d
1	2.75	----	----	0.7282	1.370	0.532
2	3.50	1.33	----	0.8130	1.370	0.593
3	2.50	2.67	----	0.8036	1.370	0.587
4	2.50	4.00	----	0.8654	1.370	0.632
5	2.50	5.33	----	0.8768	1.370	0.640
6	2.30	6.67	----	0.9783	1.370	0.714
7	2.50	8.00	----	0.9615	1.370	0.702
8	3.50	1.33	1.33	0.8571	1.370	0.626
9	3.50	1.33	2.67	0.9240	1.370	0.674
10	3.75	1.33	4.00	0.8303	1.370	0.606
11	3.85	1.33	5.33	0.8036	1.370	0.587
12	3.90	1.33	6.67	0.8789	1.370	0.642
13	2.80	2.67	1.33	0.8687	1.370	0.634
14	3.50	2.67	2.67	0.8867	1.370	0.647
15	3.90	2.67	4.00	0.8738	1.370	0.638
16	3.00	2.67	5.33	0.8380	1.370	0.612
17	3.00	4.00	1.33	0.8357	1.370	0.610
18	3.00	4.00	2.67	0.8372	1.370	0.611
19	2.50	4.00	4.00	0.8621	1.370	0.629
20	2.70	5.33	1.33	0.8755	1.370	0.639
21	2.50	5.33	2.67	0.9000	1.370	0.657
22	2.00	6.67	1.33	0.8905	1.370	0.650

The uncertainty of a mean value ($U_{\bar{x}}$) obtained from a series of N measurements with the same instrumentation is estimated using following equation:

$$U_{\bar{x}} = \sqrt{S_{\bar{x}}^2 + b_{\bar{x}}^2} \tag{4.3}$$

where, $S_{\bar{x}}$ is the standard uncertainty of the mean and equal to ($=S_x/\sqrt{N}$) whereas the variable $b_{\bar{x}}$ is the standard deviation associated with systematic errors. It turns out that $b_{\bar{x}} = b_x$.

The expanded uncertainty can be defined by the multiplication of the standard uncertainty and a factor k which is called coverage factor. For instance the following equation can be applied to uncertainties in x:

(4.4) $$U_{\bar{x}} = k.u_{\bar{x}} = k.\sqrt{S_{\bar{x}}^2 + b_{\bar{x}}^2} \qquad (P\%)$$

The k value depends on a variety of variables, such as level of confidence P and the number of data points. The k factor value can be equal to 2 which correspond to P value of 0.95 [21].

Knowing a variable's uncertainty provides an indication of an interval at which the true value of the measurement is likely to lie within it. The uncertainty interval can be in the following form:

(4.5) Uncertainty interval = middle value ± uncertainty (P%)

We are interested in evaluating the uncertainty interval for the mean of a population (μ). The uncertainty interval for the true mean value is given by:

(4.6) $$\mu = \bar{x} \pm U_{\bar{x}} \qquad (P\ \%)$$

5. RESULTS AND DISCUSSION

The hydraulic design of any hydraulic structure must take into consideration the kinetic energy of flowing water and how to dissipate or minimize it. This energy dissipation is of high importance to ensure the structure stability during its service life. Many problems arise from a hydraulic power of flowing water in open channel and scour or erosion is considered one of them. The present work represents studying the influence of constructed barrier (standing baffle) on open channel flow containing composite weir-gate structure. This structure consist of two parts, the first part controls the overflow regime and represented by a weir, whereas the second part controls the underflow regime and represented by a gate. The present work has studied the interaction between the composite hydraulic structure and barrier and its effect on the flowing water kinetic energy without any change in the hydraulic behavior in the open channel flow which always in turbulence condition.

Fig. 2 shows the variation of downstream water depth, represented by dimensionless variable (h_d/B), with the length along the flume (L/B) for cases of single barrier located at a distance of 50 cm from the composite structure (J/B=6.67) and different dimensionless values of gate area $\left(A_g/BH\right)$.It is intelligible from the figure that the downstream water depth increases with increasing in gate cross-sectional area (increasing in gate height opening and constant gate width). Increasing in the in gate height opening leads to increase in the wetted perimeter which in turn increases the resistance to flow and decreases the flow velocity. This situation is developed due to effect of barrier plate. The variation of water level at the upstream region of the barrier is very small comparing with that at the downstream region of the barrier. High deviation of the water level occurred at the downstream region of the barrier. This is happened because of high turbulence intensity which generated due to the existence of the barrier. Also the presence of barrier leads to difference in pressure head that generated on the upstream and downstream regions of barrier comparing with the surrounding pressure head.

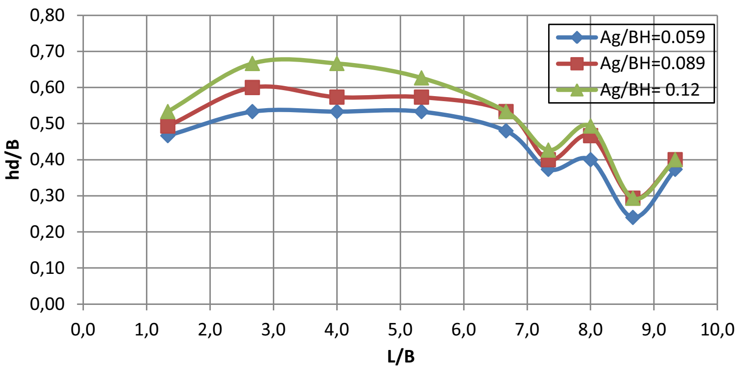

Fig. 2 Downstream water surface profile for single barrier of constant location (J/B=6.67) with different (Ag/BH) values

Fig. 3 shows the variation of dimensionless downstream water depth (h_d/B) with the dimensionless length at the downstream region of the flume (L/B) for cases of double barriers, the first barrier is located at constant distance from the composite structure (J/B=4) and the second one is located at different locations from the first one (M/B=1.33, 2.67, and 4), and constant value of (Ag/BH = 0.059). As indicated from the figure, the water surface profile showing high variation when M/B=1.33, and 2.67 whereas it is smooth for M/B=4. When (M/B) values equal to 1.33 and 2.67, the barriers are located close to one another, therefore the flow separation zone does not grow or develop at the upstream region of the second barrier. The flow crosses the first barrier and progress towards the next barrier. So when the barriers are located close to one another (M/B= 1.33 and 2.67) the spacing among/between barrier have major and significant effect on fluid separation zone and eddies generation and the geometrical dimension of barrier do not have any effect. When (M/B =4), the spacing between barriers is large enough to make each individual barrier works alone. So the flow separation zone is developed at the upstream region of the first barrier before traveling to the next one. So for the case of (M/B=4), height of the barrier is considered very important factor and has major effect on hydraulic response on the whole system.

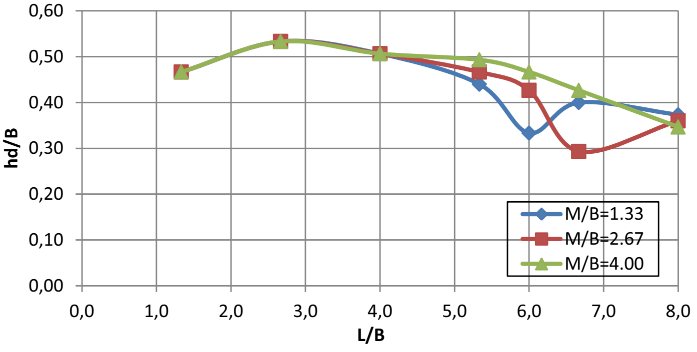

Fig. 3 Downstream water surface profile for double barrier (J/B=4) with different (M/B) values and (Ag/BH=0.059)

In order to study the effect of inlet flow and barrier location on relationship between downstream water level and downstream flume length, Fig. 4 is drawn to review the variation of (h_d/B) with (L/B) for cases of constant (Ag/BH) and (M/B) values which equal to 0.059 and 1.33, respectively and different (J/B) values. As shown in the Fig., the downstream water surface profile is varied smoothly for the case of (J/B=1.33), whereas it experienced high variation for the cases of (J/B= 2.67, 4, and 5.33). When J/B=1.33, the distance between the inlet and barrier is small and this increases the turbulence intensity, which generated due to the barrier, and inlet effects. For cases of (J/B) equal to 2.67, 4, and 5.33, the variation in water surface profile is related to the reduction in turbulence intensity and inlet flow effects. Also there is a reduction in the effects of recirculation zone near barrier and flow resistance.

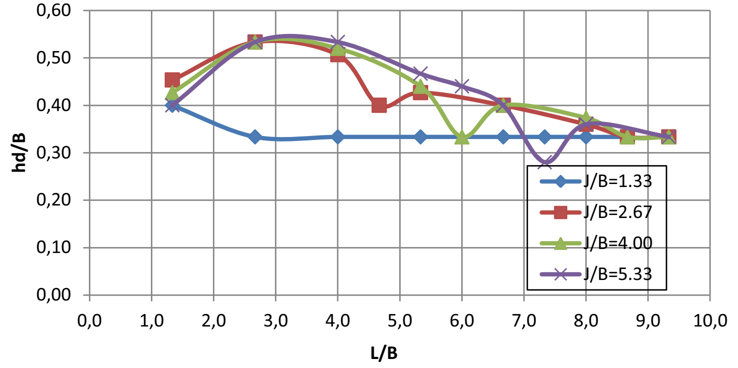

Fig. 4 Downstream water surface Profile for different values of (J/B) (Ag/BH=0.059 and M/B=1.33)

Fig. 5 shows the variation of composite hydraulic structure discharge coefficient (C_d) and location of single barrier for different (Ag/BH) values. For all cases the discharge coefficient values of the composite structure with the existence of barrier are always bigger than that without barrier. When the water crosses and/or passes the combined structure, it encounters a barrier which restricts a portion of flowing water. This leads to decrease the cross sectional area of flow at the barrier. So it can be concluded that the discharge coefficient increases with decreasing in flow cross sectional area taking into consideration the barriers' location and dimension. This conclusion coincides with inversely proportional between the discharge coefficient and flow cross sectional area. So it can be inferred that the discharge coefficient increases with existence of barrier regardless of its distance from to composite weir-gate structure.

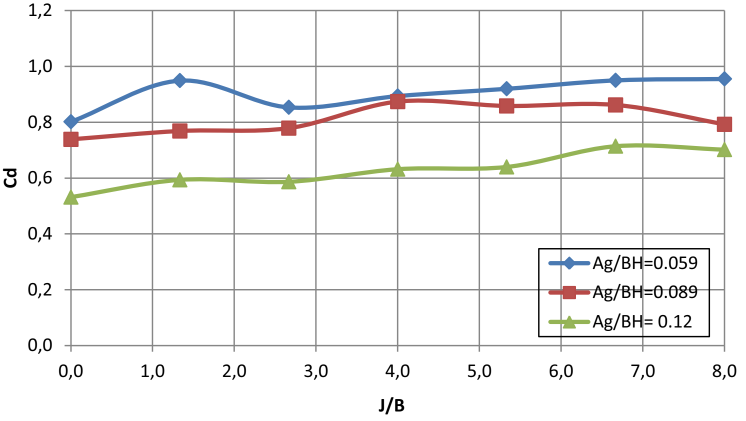

Fig. 5 Variation of Coefficient of Discharge with Single barrier for different (Ag/BH) values

Fig. 6 shows the variation of C_d with location of double barriers for constant (M/B) value and different values of (Ag/BH). The same discussion of Fig. 5 is applicable to Fig. 6 but take into consideration that there is a high velocity gradient will generated due to the existence of double barriers. This is happened due to a sudden change in the flow cross sectional area and high growing eddies at the zone between barriers. So it can be inferred that there is an increase in the value of C_d. Also the interaction between the overflow and underflow velocities will share with barrier dimension especially its height to control the value of discharge coefficient.

Fig. 7 shows the variation of C_d with spacing between double barriers for cases of constant (J/B) value and different values of (Ag/BH). It exhibits that the cross sectional area of flow passes through the gate has vital role in dominate the value of discharge coefficient. The change in flow cross sectional area at the gate does not restrict flow cross sectional area beside the barrier because the barrier cross sectional area is constant regardless of the barriers' location and spacing. Depending on inversely proportional between the flow cross sectional area and discharge coefficient, it can be inferred that the discharge coefficient increases with the existence of single or double barriers regardless of barriers' location. The discharge quantity has direct proportional with discharge coefficient, so any increase or decrease in discharge coefficient value will reflect directly on the discharge quantity.

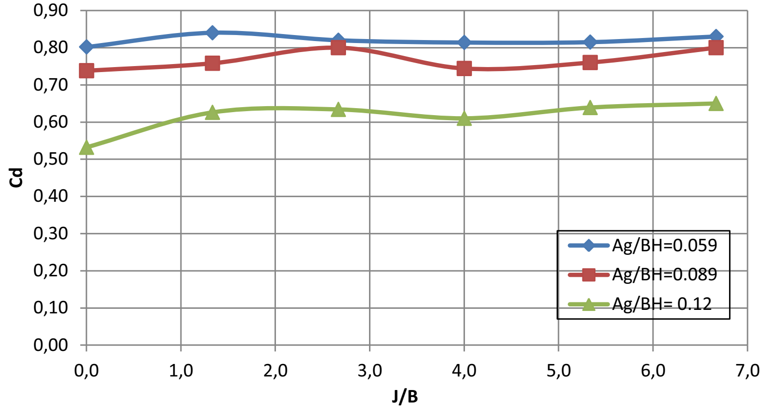

Fig. 6 Variation of Coefficient of Discharge with Double Barriers' location for different (Ag/BH) values and (M/B=1.33)

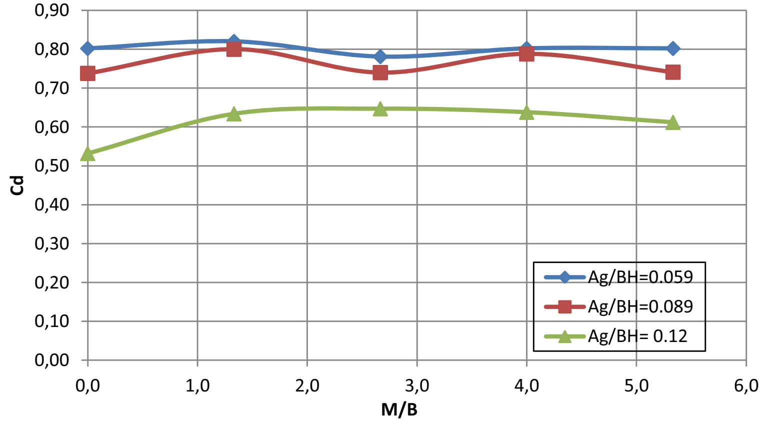

Fig. 7 Variation of Discharge coefficient with Double Barriers' spacing for different (Ag/BH) values and (J/B=2.67)

From Fig. 5 the value of discharge coefficient increases with increasing in (J/B) value, so it can be inferred that the discharge quantity increases with increasing in (J/B) value and this obvious in Fig. 8. Also from Fig. 6, the value of discharge coefficient increases with increasing in (J/B) value, so it can be inferred that the discharge quantity increases with increasing in (J/B) value and this obvious in Fig. 9. From Fig. 7 the value of discharge coefficient increases with increasing in (J/B) value, so it can be inferred that the discharge quantity increases with increasing in (J/B) value and this obvious in Fig. 10.

The hydraulic response of combined hydraulic structure depends primarily on discharge coefficient, discharge quantity, head above weir, and interaction between overflow and underflow velocities. So it is very important to investigate the impact of barrier on these factors to control the operation of the composite system by preventing any fluctuation in discharge quantity and reducing the excessive kinetic energy of flowing water. In practice, barrier has played an important role in dissipating the water energy and controls the path of flow by increasing the velocity and raises the water elevation in the downstream region. So it satisfies two different jobs at the same time.

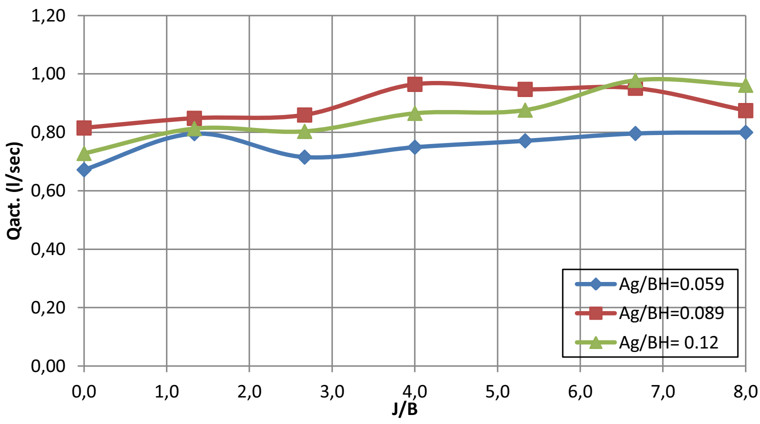

Fig. 8 Variation of Actual Discharge with Single barrier for different Areas of Gate

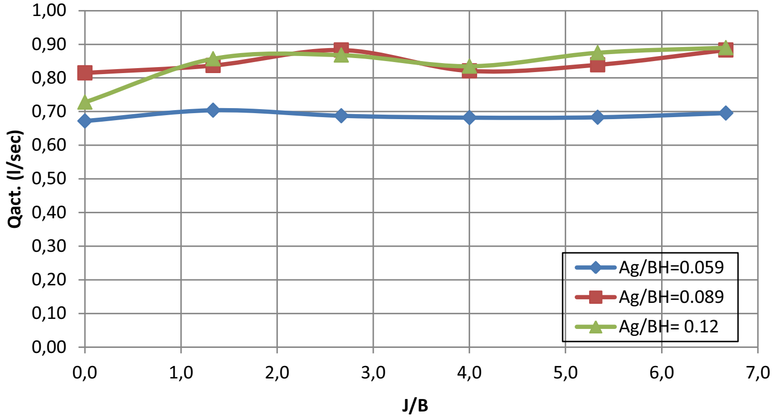

Fig. 9 Variation of Actual Discharge with Double Barrier for different Areas of Gate (M/B=1.33)

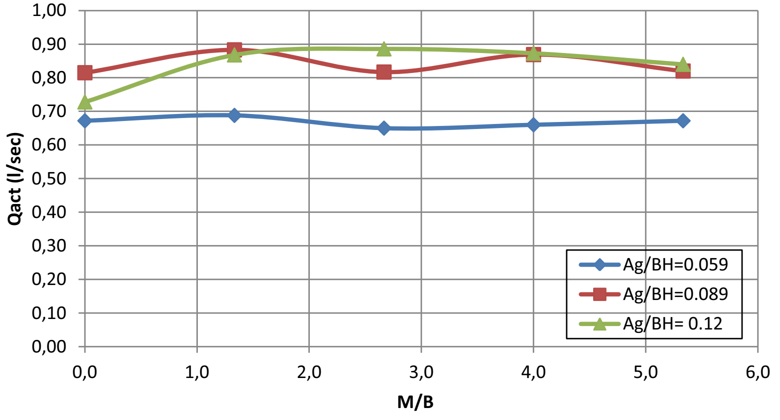

Fig. 10 Variation of Actual Discharge with Double Barrier for different Areas of Gate (J/B=2.67)

5.1 Estimation of Uncertainty Intervals of State Variables:

The systematic errors and random errors must be estimated using the best information available at a time. The random error S_x is computed using equation (4.2). Then the standard uncertainty of the mean $S_{\bar{x}}$ is equal to $(=S_x/\sqrt{N})$. There are no measurements or statistical procedures that can be used generally to provide estimates of systematic uncertainties. The first step in estimation the systematic uncertainty for single variable is to consider the elemental error sources that affect each of the measurements.

Table 2 illustrates the possible sources for the two variables (actual discharge and average downstream water depth) that will be measured in this experiment:

Table 2 Details of Systematic Uncertainty

Source	Systematic Uncertainty	
	Actual Discharge (l/s)	Downstream Water Depth (cm)
Conceptual	0.0808	0.247
Calibration	0.008	0.100
Calibration	0.005	0.200

Systematic uncertainty is estimated based on potential sources of error. One of the most important sources of errors in calculating experiment of composite structure is conceptual errors. This type of error appears from the difference between the measured values at specific points and the mean value of these points. Table 3 shows the actual discharge values measured for three attempts with the average of these values and the percentage difference between the values and the average. Also, table 4 shows the downstream depth of water values for different locations with the average of these values and the percentage difference between these values and the average. Based on these values, the conceptual uncertainty value is assumed to be equal to 10% of the mean value of actual discharge and average downstream water depth. Thus, it can calculate from the product of the percentage difference by the arithmetic mean of the actual discharge and the downstream depth of the water, respectively. It was found that these values equal to (0.1*0.808=0.0808l/s) and (0.1*2.47=0.247 cm).

Table 3 Selected Values of Actual Discharge and Differences

Q_1 (1)	Q_2 (2)	Q_3 (3)	Q_{act} (4)	$D_1=[\frac{(1)-(4)}{(4)}]$	$D_2=[\frac{(2)-(4)}{(4)}]$	$D_3=[\frac{(3)-(4)}{(4)}]$
0.8645	0.7264	0.7595	0.7792	-0.1095	0.0678	-0.0253
0.9375	0.8695	0.9259	0.9100	-0.0302	0.0444	0.0175
0.9118	0.8645	0.8522	0.8755	-0.0415	0.0125	-0.0265

Table 4 Selected of Average downstream water depth and Differences

h_{d1}	h_{d2}	h_{d3}	h_{d1}	h_{d2}	h_{d3}	hd_{avg}	D_1	D_2	D_3	D_4	D_5	D_6
3.5	3.0	3.0	3.0	2.6	2.6	2.95	0.186	0.017	0.017	0.017	-0.118	-0.118
4.0	4.0	4.0	3.8	3.8	3.0	3.76	0.062	0.062	0.062	0.008	0.008	-0.203
3.5	4.0	3.7	3.5	3.5	3.2	3.56	-0.018	0.12	0.037	-0.018	-0.018	-0.102

Regarding the uncertainty resulting from the calibration and in relation to the downstream depth of the water, it was imposed by arbitrary values, where a value of (0.1 cm) was given to the scalar readability and a value of (0.2 cm) was given to flow ripple in the downstream. Also, regarding the uncertainty resulting from the calibration and in relation to the actual discharge, the value of (0.008 l/s) and (0.005 l/s) were given to errors resulting from time estimation and other invisible errors, respectively. Table 5 illustrates the statistics of the actual discharge and downstream water depth along with the components of the uncertainty.

Table 5 Statistics and Uncertainty parameters of the State variables

Variable	Mean	S_x	$S_{\bar{x}}$	$b_{\bar{x}}$	u_x	$U_{\bar{x}}$	Min.	Max.
Q_{act} (l/s)	0.8082	0.0929	0.0114	0.082	0.0829	0.1657	0.6424	0.9740
hd_{avg} (cm)	2.4699	0.6647	0.0818	0.547	0.553	1.106	1.3600	3.5730

The data results from table 5 are plotted in Figs. 11 and 12. These figures show the mean as solid line and the 95% uncertainty interval for the true mean of the data for both actual discharge and downstream water depth. It is observed that the uncertainty intervals comprises of 97% of the actual discharge values and 95.4% of downstream water depth values.

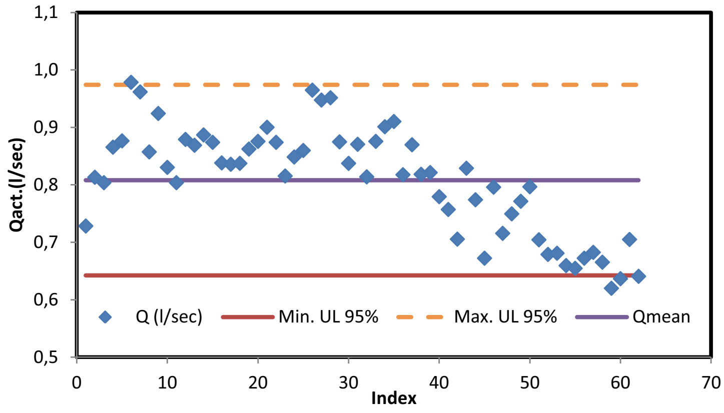

Fig. 11 The Actual Discharge and its mean and uncertainty interval.

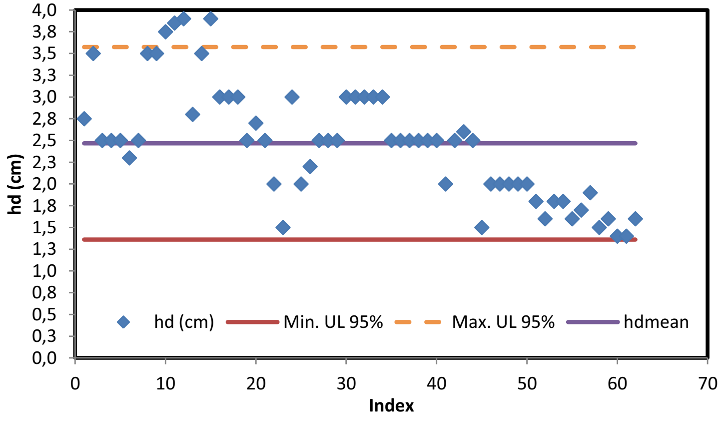

Fig. 12 The downstream water depth and its mean and uncertainty interval

6. CONCLUSION

This experimental study aims to investigate the influence of barrier on hydraulic behavior of composite hydraulic structure. Several substantial points were inferred and can summarize as follows:

1-The upstream and downstream regions of barrier have direct effect on water level at the downstream region of channel or flume.

2-Turbulence intensity of flow in open channel or flume has major effect on interaction between weir-gate structure and barrier and major influence on fluid resistance.

3-The existence of barrier in flume will contribute in distribution of pressure around barrier or baffle.

4-The spacing between neighboring barrier has major effect on developing of eddies and separation zones near barrier and this reflects on the interaction between overflow and underflow velocities.

5-The location of barrier has major effect on hydraulic properties of whole system.

6-The distance between the inlet and barrier has major effect on water level at the downstream region of the flume. Also the position of inlet has major influence on turbulence intensity in the downstream region of flume.

7-The location, spacing, and dimension of barrier have main effect on discharge coefficient value and discharge quantity passes through the weir-gate structure.

8- Using of more than one barrier has main influence on discharge coefficient value and discharge quantity passes through the weir-gate structure.

9- Using of more than one barrier has main influence on controlling the water elevation at the downstream region of flume.

10-The flow cross sectional area at the gate has direct effect on discharge and discharge coefficient values regardless of the barriers' location, spacing, and number.

11-The barrier has direct influence on dissipation of flowing water kinetic energy and this reflects on hydraulic factors.

12- The uncertainty intervals of actual discharge and downstream water depth are estimated and it is observed that the uncertainty intervals comprises of 97% and 95.4 of the actual discharge values and downstream water depth values, respectively.

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NOTATION

The following symbols are used in this paper:
H: Upstream water level
H1: Total height of composite structure
h: Depth of water above crest weir
y: Distance between top of gate and bottom of weir
d: Depth of gate
b: width of weir and gate
B: Total width of flume and/or composite structure
h_d*: Downstream water depth*
M: Barriers' spacing
J: Barriers' location
A_g*: Area of gate*
A_w*: Area of weir*
$Q_{act.}$*: Measured discharge*
$Q_{theo.}$*: Theoretical discharge*
C_d*: Discharge Coefficient*
L: Distance along downstream
S_x*: Random errors*
b_x *: Systematic errors*
u_x *:The standard uncertainty .*
$U_{\bar{x}}$*:The expanded uncertainty*
N: Number of measurements
$\bar{x}$ *: Mean Value*
$S_{\bar{x}}$*: The standard uncertainty of the mean*
$b_{\bar{x}}$ *: The standard deviation associated with systematic errors*
k : Coverage factor

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