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ANALYSIS OF THE HYDRAULIC INTERFERENCE BETWEEN THE BAFFLES AND THE COMPOSITE HYDRAULIC STRUCTURE

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Abstract

The purpose of the present study is to examine the influence of baffles presence at downstream system on weir gate hydraulic response. Two baffles configuration (triangle and angle shapes) are installed in bed flume. Two different spacing are used between the baffles and two different directions for baffles are also adopted. The study tries to investigate the variation in upstream Froude number, downstream Froude number, Reynolds number, actual discharge, discharge coefficient, downstream average water depth and the hydraulic system efficiency which is expressed as function of downstream water depth. It has been shown that the number of baffles has a direct and significant impact on flow hydraulic characteristics of weir-gate structure regardless of the spacing between baffles and the direction of baffles related to flow. Baffles number and spacing have essential impact on the water flow velocity of system and this impact leads to increase the flow resistance. The results clarify that the upstream Froude number, downstream Froude number, Reynolds number, actual discharge and discharge coefficient are decreased with the increase in baffles number except the average downstream water depth which increases with increase in baffles number. The efficiency of hydraulic system gives a good indicator for using baffles with weir-gate structure. At the end this paper shows a fruitful result of efficiency. This experiment run condense on the baffle's numbers and directions with respect to the water flow direction at the downstream regime. So, the rises in the water level relies on the numbers and directions of the baffles as compare to the case without using baffles at the flume downstream region. The actual discharge and weir-gate discharge coefficient are more sensitive to the increase in the baffles' numbers and the baffles direction with respect to the water flow direction.

Keywords: composite structure, baffles, varied flow, rapid flow, weir-gate, hydraulic structure.

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1. Introduction

The composite weir-gate hydraulic structure comprises two different hydraulic elements; it can be operated under the flow conditions of both of them with an accepTable operational efficiency. The main goal of composite hydraulic structure concentrated on removing both of the sediment materials and floating materials, simultaneously without any fluctuation in flow-rate quantity or/and lack in distribution, control and divert of the flow in channel or river. Generally, the flow suffers from the lack in supply discharge quantity because of the existence of some objects like pier, obstacles, dike, debris material, and plants in channel and river which produce loss in flow energy and a loss in flow momentum. Therefore, it is significant to investigate the interaction between the flow-rate that crosses weir-gate structure and any special obstacle which is present at downstream system. No research considered the present work in the preceding time. A significant effort was made to examine the characteristics of the flow around an abutment or dike which adopted the numerical simulation. The research study, concentrated on this field was carried out by [1–8]. The above studies referred immediately to the abutment or a dike of the main feature of the flow area, such as the values of the time-averaged velocity, and they did not discover much about the impact of the dike or abutment on objective the separation zone at downstream.

The main target of the current study deals with the impact of the obstacles presence in the downstream system on the hydraulic variables which describe the weir-gate device structure. This work examines the impact of the baffles number on upstream Froude number, downstream Froude number, Reynolds number, discharge coefficient of device, actual discharge of device, and the average downstream water depth. These features have an effect on the workability of the hydraulic system. Furthermore, this work deals with another challenge represented by the calculation of hydraulic system efficiency. The efficiency is used to assess the hydraulic behaviour of system under the impact of baffles.

2. Materials and methods

The theoretical discharge of water that passes weir-gate hydraulic structure (parabolic weir and parabolic gate) can be determined by the combination of the discharge of both gate and weir:

$$Q_{theo} = Q_w + Q_g. \quad (1)$$

The theoretical discharge that passes parabolic weir is explained in [9]:

$$Q_w = \frac{\pi}{2}\sqrt{fg}h^2. \quad (2)$$

The discharge of water flow that passes the gate can be calculated and based on the continuity equation as in [10]:

$$Q = VA, \quad (3)$$

$$Q_g = VA = \sqrt{2gH}A, \quad (4)$$

$$Q_{act} = C_d Q_{theo}, \quad (5)$$

$$Q_{act} = C_d\left[\frac{\pi}{2}\sqrt{fg}h^2 + \sqrt{2gH}A\right]. \quad (6)$$

For free flow condition:

$$H = d + y + h. \quad (7)$$

For submerged flow condition:

$$H = d + y + h - h_d, \quad (8)$$

where H – upstream water depth; h – head of water above weir sharp crest; y – vertical distance between weir and gate; d – water depth at the gate opening; A – flow cross sectional area that passes the gate; V – water flow velocity that passes the gate; f – focal distance; h_d – depth of water at downstream; g – acceleration due to gravity; Q_g and Q_w represents the gate discharge and weir discharge respectively, whereas Q_{theor}, Q_{act}, and C_d represent theoretical discharge (flow rate), actual discharge (flow rate), and coefficient of discharge.

The Froude Number can be obtained from [11]:

$$F_r = \frac{V}{\sqrt{gy}}, \quad (9)$$

where, V flow velocity and y: water depth.

To estimate the Reynolds Number of the hydraulic regime [12]:

$$R_e = \frac{V\,d_d}{\upsilon}, \tag{10}$$

where, d_d is depth of water and υ is the kinematic viscosity of water.

To assess the vulnerability in discharge coefficient of composite structure due to the presence of baffles at the bed flume, the calculation of efficiency gives a good reasonable indicator of these baffles at bed flume. The option to calculate the efficiency of hydraulic system is based on the average downstream water level of weir-gate hydraulic device:

$$E\% = \frac{h_{d\,with Baffles} - h_{d\,without Baffles}}{h_{d\,without Baffles}}, \tag{11}$$

where, E is the efficiency of hydraulic system.

The present work is concerned with a complex hydraulic problem resulted from the interference between gradually varied flow and rapidly varied flow. So, this problem also occurs due to the associate between those two different types of flow in the hydraulic open channel system. It is noticeable that the gradually varied flow is attributed to the presence of obstruction (Baffles) and the rapidly varied flow is attributed to the presence of measuring device structure (composite structure). Both structures are dominant on the evaluation of the quantity of actual discharge and discharge coefficient.

A set of runs were carried out at flume in Basra Engineering Technical College, Hydraulic Laboratory. The flume has rectangular section with 2 m long, 15 cm depth and 7.5 cm width. The volume method is used to measure the actual discharge while a scale point gauge is used to measure the water depth. Weir – gate device (hydraulic structure) models are manufactured from wood sheet with thickness 5 mm beveled along all the edges at (45°) and with sharp edges of thickness (1 mm) [13]. The baffles are manufactured by wood with 5 mm thickness. Two different shapes of baffles structures are adopted in this study. The first shape is triangle and the second one is angle shape. Two different spacing between baffles are adopted in this study and these spacing are 10 cm and 20 cm. Regardless of the direction of baffles with respect to flow, for the first case, the first baffles located at distance, equaling to 10 cm, measured from the beginning of weir-gate hydraulic device while for the second case, the first baffles located at distance equaling to 20 cm, measured from the beginning of weir-gate hydraulic device. The weir-gate device is fixed into flume by using plexiglass supports. To perform the hydraulic run, the following steps must be adopted:

1. Ensure that the flume bed is often in horizontal position.
2. The weir-gate device is fixed inside the flume at 80 cm from the beginning of the flume.
3. The presence of baffles leads to the submerged flow condition; while without the baffles free flow condition must occur.

For each run, weir-gate actual discharge, weir water head, water depth at upstream system and downstream system are measured for free flow condition and submerged flow condition. **Fig. 1** shows the whole system of weir-gate structure and baffles.

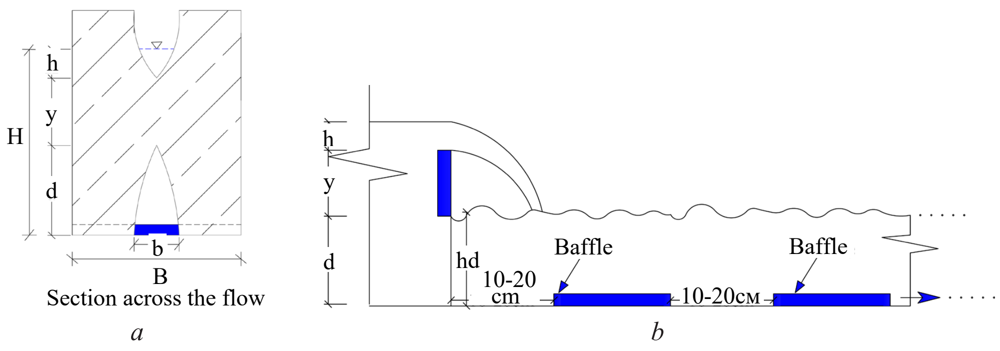


Fig. 1. Definition sketch for weir-gate structure and baffles: *a* – cross-section; *b* – longitudinal flow and geometry section

Fig. 2 shows the position of weir-gate structure and arrangement of baffles which are adopted in the current study. While, **Table 1** views the output model information for the present work, note that the model number and its geometry were listed in **Table 2**. The parabolic shape that is adopted in the present study follow the nonlinear relationship. The independent variable equal to square of dependent variable, in other word the variable (y) equal to square of the variable (x).

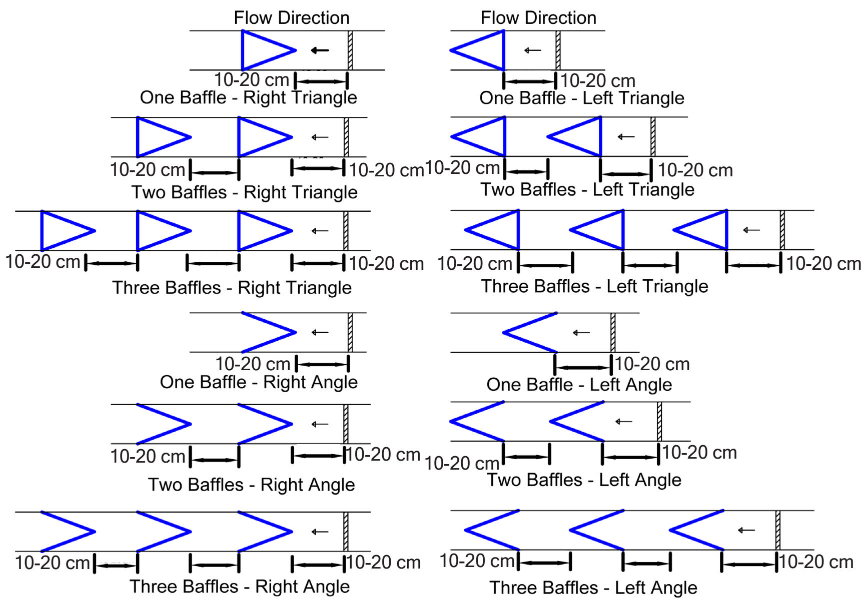


Fig. 2. The position of weir-gate structure and arrangement of baffles

Table 1

The model number and output information of the selected experimental runs

Model No.	Q_{act} (l/sec)	Q_{theo} (l/sec)	C_d	h_{d1} (cm)	h_{d2} (cm)	h_{d3} (cm)	h_{d4} (cm)	h_{d5} (cm)
21	0.6073	0.6100	0.9956	4.0	3.0	3.0	3.0	2.8
34	0.8130	1.2805	0.6349	4.2	2.2	2.2	3.2	3.2
56	0.6220	0.8762	0.7098	3.8	4.0	4.0	3.8	3.6
68	0.5890	0.5875	1.0026	3.5	4.2	4.0	4.0	3.8
72	0.5762	0.6032	0.9551	3.8	4.0	3.0	3.0	3.0
89	0.6169	0.7796	0.7912	2.5	3.5	3.5	3.5	3.5
95	0.6881	0.7712	0.8922	3.2	3.5	3.5	3.5	3.5

Table 1 focuses heavily on the downstream water levels. The levels begin to decrease or increase along the downstream flow distance, depending on the number of baffles used in the channel. The reason for the decrease in levels is the friction losses, while the reason for the increase levels is the use of more numbers of the baffles. A detailed explanation will be given in the discussion.

Table 2

Efficiency values due to baffles at downstream regime

Model No.	*hu* (cm)	*y* (cm)	*d* (cm)	Case	No. of Baffles	Spacing (cm)	Average hd (cm)	Eff. (hd)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	3	3	3	W.O(*)	W.O	W.O	1.44	–
2	3	3	3	3	1	10	2.20	0.53
3	3	3	3	3	1	20	2.44	0.69
4	3	3	3	3	2	10	3.20	1.22
5	3	3	3	3	3	10	3.43	1.38
6	3	3	3	3	2	20	3.47	1.41

Continuation of Table 2

1	2	3	4	5	6	7	8	9
7	3	3	3	3	3	20	3.81	1.65
8	3	3	3	1	1	10	3.20	1.22
9	3	3	3	1	1	20	3.12	1.17
10	3	3	3	1	2	10	3.68	1.56
11	3	3	3	1	3	10	3.76	1.61
12	3	3	3	1	2	20	3.83	1.66
13	3	3	3	1	3	20	4.09	1.84
14	3	4	2	W.O	W.O	W.O	1.58	–
15	3	4	2	3	1	10	2.54	0.61
16	3	4	2	3	1	20	2.76	0.75
17	3	4	2	3	2	10	3.16	1.00
18	3	4	2	3	3	10	3.52	1.23
19	3	4	2	3	2	20	3.24	1.05
20	3	4	2	3	3	20	3.90	1.47
21	3	4	2	1	1	10	3.16	1.00
22	3	4	2	1	1	20	3.32	1.10
23	3	4	2	1	2	10	3.66	1.32
24	3	4	2	1	3	10	3.69	1.33
25	3	4	2	1	2	20	3.67	1.32
26	3	4	2	1	3	20	4.11	1.60
27	3	2	4	W.O	W.O	W.O	1.65	–
28	3	2	4	3	1	10	4.30	1.61
29	3	2	4	3	1	20	4.00	1.42
30	3	2	4	3	2	10	4.20	1.55
31	3	2	4	3	3	10	4.58	1.78
32	3	2	4	3	2	20	4.41	1.68
33	3	2	4	3	3	20	4.61	1.79
34	3	2	4	1	1	10	3.00	0.82
35	3	2	4	1	1	20	3.80	1.30
36	3	2	4	1	2	10	4.14	1.51
37	3	2	4	1	3	10	4.11	1.49
38	3	2	4	1	2	20	4.03	1.44
39	3	2	4	1	3	20	4.56	1.77
40	2	4	3	W.O	W.O	W.O	1.50	–
41	2	4	3	3	1	10	1.82	0.21
42	2	4	3	3	1	20	2.47	0.64
43	2	4	3	3	2	10	3.17	1.11
44	2	4	3	3	3	10	3.59	1.39
45	2	4	3	3	2	20	3.46	1.30
46	2	4	3	3	3	20	4.17	1.78
47	2	4	3	1	1	10	3.30	1.20
48	2	4	3	1	1	20	3.20	1.13
49	2	4	3	1	2	10	4.00	1.67
50	2	4	3	1	3	10	4.16	1.77
51	2	4	3	1	2	20	3.99	1.66
52	2	4	3	1	3	20	4.70	2.13
53	3	3	3	2	1	10	3.56	1.47
54	3	3	3	2	1	20	3.58	1.49

Continuation of Table 2

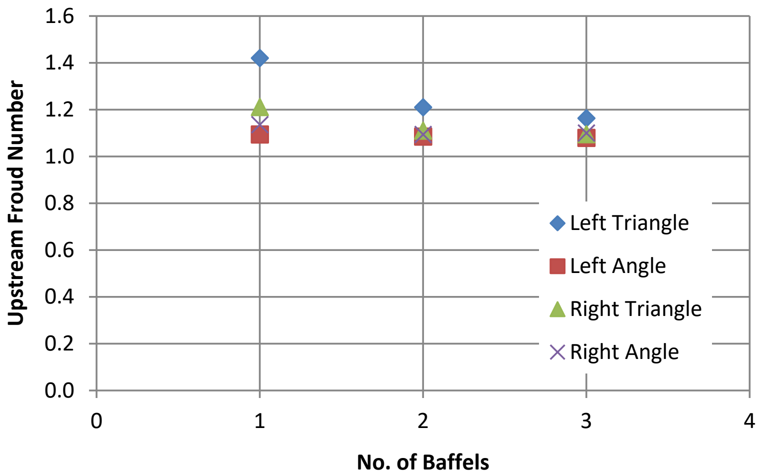
1	2	3	4	5	6	7	8	9
55	3	3	3	2	2	10	3.76	1.61
56	3	3	3	2	3	10	3.73	1.59
57	3	3	3	2	2	20	3.88	1.70
58	3	3	3	2	3	20	3.88	1.69
59	3	3	3	4	1	10	3.76	1.61
60	3	3	3	4	1	20	3.62	1.51
61	3	3	3	4	2	10	3.80	1.64
62	3	3	3	4	3	10	3.83	1.66
63	3	3	3	4	2	20	3.80	1.64
64	3	3	3	4	3	20	3.91	1.72
65	3	4	2	4	1	10	3.80	1.41
66	3	4	2	4	1	20	3.72	1.35
67	3	4	2	4	2	10	3.82	1.42
68	3	4	2	4	3	10	3.82	1.42
69	3	4	2	4	2	20	3.54	1.24
70	3	4	2	4	3	20	3.53	1.24
71	3	4	2	2	1	10	3.56	1.25
72	3	4	2	2	1	20	3.36	1.13
73	3	4	2	2	2	10	3.65	1.31
74	3	4	2	2	3	10	3.43	1.17
75	3	4	2	2	2	20	3.76	1.38
76	3	4	2	2	3	20	3.53	1.24
77	3	2	4	4	1	10	3.75	1.27
78	3	2	4	4	1	20	3.75	1.27
79	3	2	4	4	2	10	3.73	1.26
80	3	2	4	4	3	10	3.78	1.29
81	3	2	4	4	2	20	3.77	1.29
82	3	2	4	4	3	20	3.89	1.36
83	3	2	4	2	1	10	3.87	1.34
84	3	2	4	2	1	20	3.82	1.31
85	3	2	4	2	2	10	3.83	1.32
86	3	2	4	2	3	10	3.89	1.36
87	3	2	4	2	2	20	3.80	1.30
88	3	2	4	2	3	20	3.78	1.29
89	2	4	3	2	1	10	3.30	1.20
90	2	4	3	2	1	20	3.26	1.17
91	2	4	3	2	2	10	3.47	1.31
92	2	4	3	2	3	10	3.79	1.52
93	2	4	3	2	2	20	3.60	1.40
94	2	4	3	2	3	20	4.43	1.95
95	2	4	3	4	1	10	3.44	1.29
96	2	4	3	4	1	20	3.34	1.23
97	2	4	3	4	2	10	3.93	1.62
98	2	4	3	4	3	10	4.00	1.67
99	2	4	3	4	2	20	3.71	1.48
100	2	4	3	4	3	20	3.97	1.65

**W.O: Without*

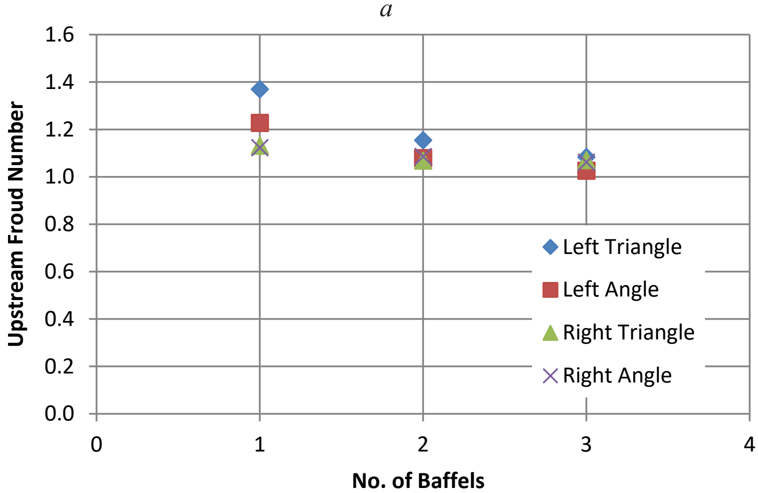
3. Results and discussion

Baffles in open channel and rivers represent the source of water flow losses , energy dissipation and momentum losses, therefore, considering the impact of these baffles on weir-gate hydraulic structure represents a significant work, overall the important benefit which results from using baffles which is based on rising the water level to a required elevation at downstream of hydraulic system. Ninety Six models were tested (24 of left triangle baffles, 24 left angle baffles, 24 right triangle baffles, and 24 right angle baffles), in addition to four models, without using baffles. In each test, combined flow rate, Q_{act}, downstream flow depth, h_d at different locations are measured under free flow conditions and submerge flow conditions.

Fig. 3, *a, b* illustrate the relationship between the Froude number at upstream of composite device and number of baffles at downstream of hydraulic system for different shapes of baffles and directions. The figure shows that as the baffles number increases the upstream Froude number decreases gradually, regardless of the baffles number, baffles spacing and baffles arrangement. Also, it is obvious that the super critical flow is prevalent and this means that the high flow velocity will dominate on the upstream system. As the flow velocity increases, the Froude number must be increased due to direct proportional between them. When the flow velocity is high, the inertia force is dominated. The reduction in values of Froude number will occur due to the presence of baffles at downstream. The baffles in downstream system, work as a barrier which confined the discharge quantity when it crosses the composite structure, this will lead to reduce the flow velocity which is reflected on Froude number owing to the direct proportional between them.



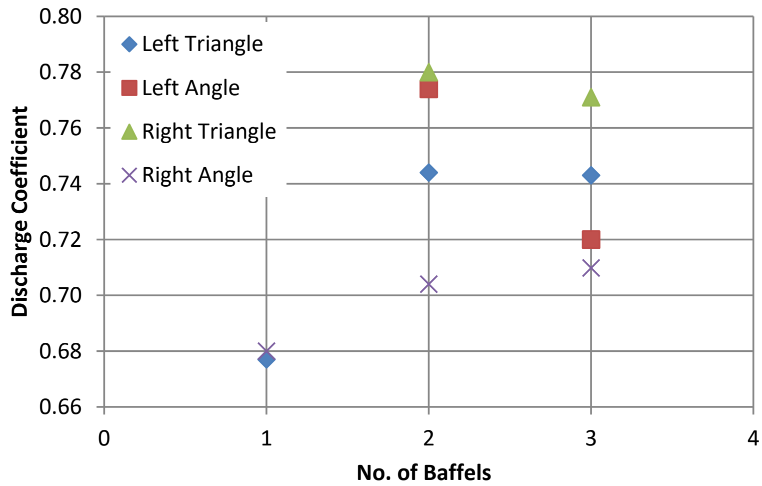
a



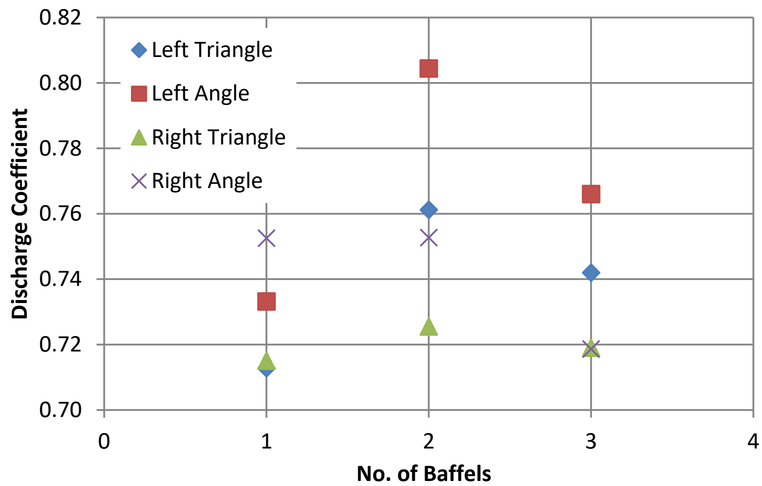
b

Fig. 3. The relationship between the Upstream Froude number and the number of baffles for different shapes of baffles and directions: *a* – 10 cm spacing; *b* – 20 cm spacing

Fig. 4, *a, b* illustrates the variation in relationship between the discharge coefficients and baffles number for the different shapes of baffles and directions. When the spacing between the baffles equals to 20 cm, the values of discharge coefficient rise moderately till it reaches the maximum value this case happens, approximately when to use two baffles at downstream and then it drops dramatically. For the case of two baffles the values of the discharge coefficient with the presence of baffles are higher. So, when the water crosses the composite structure, it faces a baffle which confines a portion of water stream. The reduction in water cross sectional area will occur at the baffles. Therefore, the coefficient of discharge increases as the cross-sectional area of flow decreases with the consideration of baffles dimension and location. This inference matches with inversely proportional between cross sectional area of flow and discharge coefficient.



a



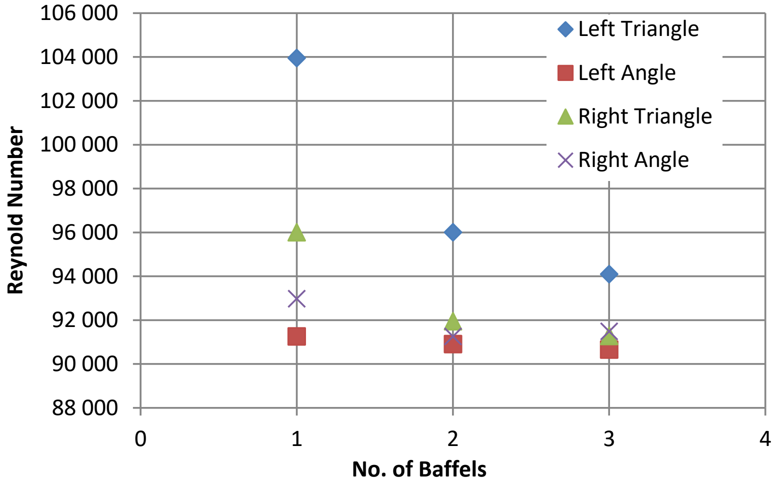
b

Fig. 4. The relationship between the discharge coefficient and the baffles number for different shapes of baffles and directions: *a* – 10 cm spacing; *b* – 20 cm spacing

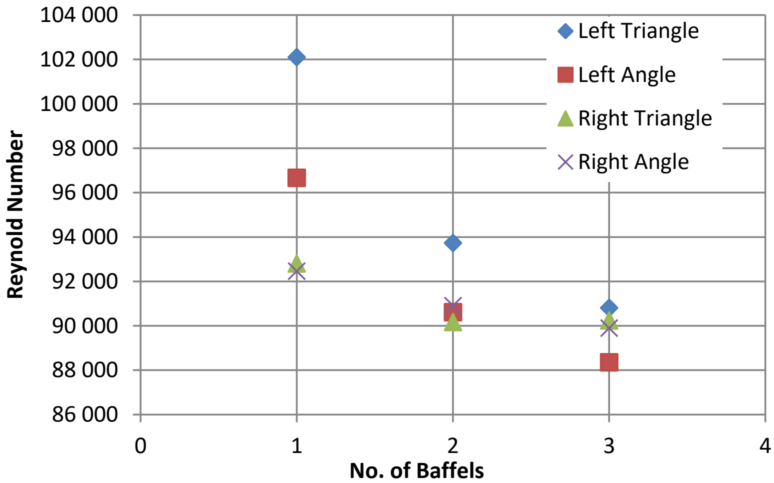
As the number of baffles increases, the discharge coefficient of composite structure decreases because of the height of baffle which confined the water had no effect in this case, the spacing between the baffle will dominate the hydraulic behavior of downstream system. Also, the same justifications which were mentioned above are applicable when the spacing between baffles is 10 cm and the variations in results occur because of the impact of the baffles presence and the spacing that has reflection on the interaction between over flow velocity from weir and under flow velocity from gate.

Fig. 5, *a, b* show the variation of Reynolds number at downstream system with reference to the numbers of baffles. Basically, Reynolds number depends on water flow velocity and water depth at downstream system. The figures show, as baffles number increases, the Reynolds number decreases sharply regardless of the spacing between the baffles. The flow velocity suffers from losses due to the fluid resistance which can be described by the interface resistance and form resistance. The interface resistance produces and develops by the turbulent shear and viscous which leads to reduce the water flow kinetic energy. While the form resistance grows as shear and develops between solid-water boundaries at flume bed, flume walls and baffles or it is possible to say wetted perimeter of channel include baffles. So, it is possible to infer that the shear losses or friction losses represents the source in reducing the water flow velocity and this will be reflect on Reynolds number. Also, the fluctuation in water depth is represented by confining a portion from the water depth due to the presence of baffles which are reflected on Reynolds number. The trend between Reynolds number and baffles number is consistent for both spacing between baffles regardless of the direction of baffles with respect to flow.

Fig. 6, *a*, *b* show the variation of actual discharge with numbers of baffles. From **Fig. 6, *a*, *b***, it is clear that the figure trend in relationship between the actual discharge and baffles number is similar with the relationship between the discharge coefficients and baffles numbers because of the direct proportion between the discharge and discharge coefficient. The variations in results occur owing to the impact of the baffles presence and the spacing that will be reflected on the interaction between over flow velocity from weir and under flow velocity from gate, Also, the height of baffles shares in result variation regardless of the baffles direction which is related to flow.

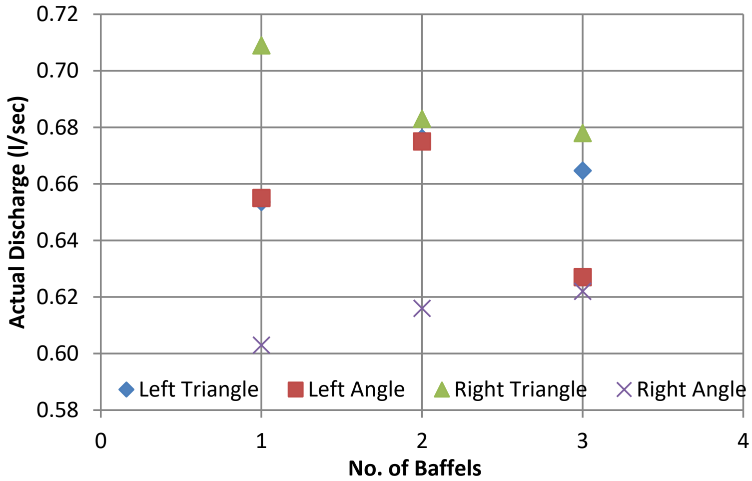


a

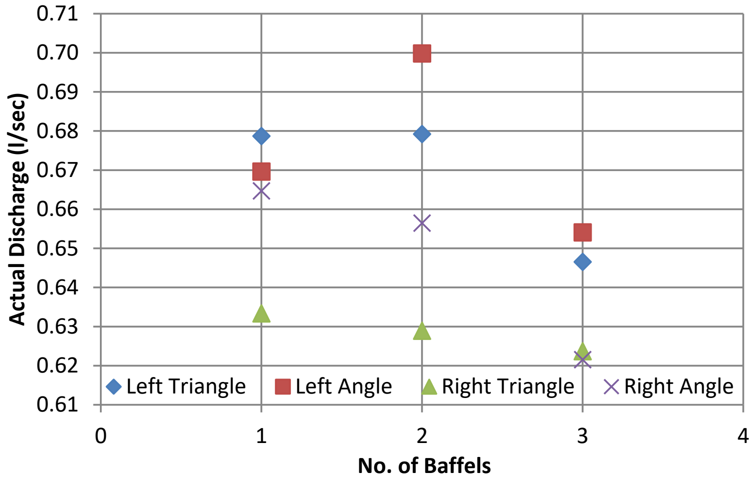


b

Fig. 5. The Relationship between downstream Reynolds number and Baffles Number for different shapes of baffles and directions: *a* – 10 cm Spacing; *b* – 20 cm Spacing



a



b

Fig. 6. The relationship between actual discharge and baffles number for different shapes of baffles and directions: *a* – 10 cm spacing; *b* – 20 cm spacing

Fig. 7, *a, b* illustrate the relationship between average downstream water depth and baffles number. From figure it is evident that the baffles number increases the rise in water depth which happens gradually regardless of the spacing between baffles and the baffles direction related to flow. The rise in water depth will occur because of the presence of baffles. These baffles work as barrier leading to an increase in the water depth beside the baffles. The consistence in relationship trend appeared clearly for both spacing between baffles.

Fig. 8, *a, b* illustrate the relationship between the Froude number at downstream of composite device and the number of baffles at downstream of hydraulic regime. It is clear from the figures as that the baffles number increases the downstream Froude number decreases gradually, regardless of the baffles number, baffles spacing and baffles arrangement. Also, it is obvious that the subcritical flow is prevalent and this means that the low flow velocity will dominate on the downstream regime and as the flow velocity decreases, the Froude number must be decreased due to the direct proportional between them. When the flow velocity is low, the gravity force will be dominant. The reduction in values of Froude number appears due to the presence of baffles at downstream. The baffles in downstream system work as a barrier which confined the discharge quantity that crosses the composite structure; this will lead to reduce the flow velocity which is reflected on Froude number owing to the direct proportional between them.

Table 3 shows the variation between area of gate ratio and the actual discharge. The area of gate ratio is represented by the flow cross section area that cross the gate divided by the product of width of flow and total height of upstream flow. **Table 4** also shows the variation between area of gate ratio and the discharge coefficient for some selected results. **Table 3** illustrates, as the area of gate ratio increases, the actual discharge increases. Generally, the actual discharge has direct proportional with the cross sectional area of flow that crosses the gate, this fact will be reflected on the final result; also the gate here always remains under the full condition of flow, therefore. The large quantity of discharge crosses the gate without any lack. **Table 4** illustrates as the area of gate ratio increases the discharge coefficient decreases because of the inversely proportional between the crosses sectional area of flow that crosses the gate and discharge coefficient. The hydraulic efficiency of the whole hydraulic system is calculated, it is based on the average downstream water depth of two different flow conditions. The first condition refers to free flow while the second one refers to the submerged flow which results in the existence of baffles at downstream system. Approximately, from these tables, it seems obvious that all efficiency values are greater than unity. This inference encourages using baffles at downstream system (**Table 2**). **Table 5** illustrates the statistics of the **Table 2**.

Table 5 comprises of the statistical information of the downstream water depth. It is observed that the average of maximum and minimum values is 3.07. This average is very closer to the arithmetic mean (3.75), and this gives an index that the results obtained from the experimental work for the downstream water depths follow the normal distribution.

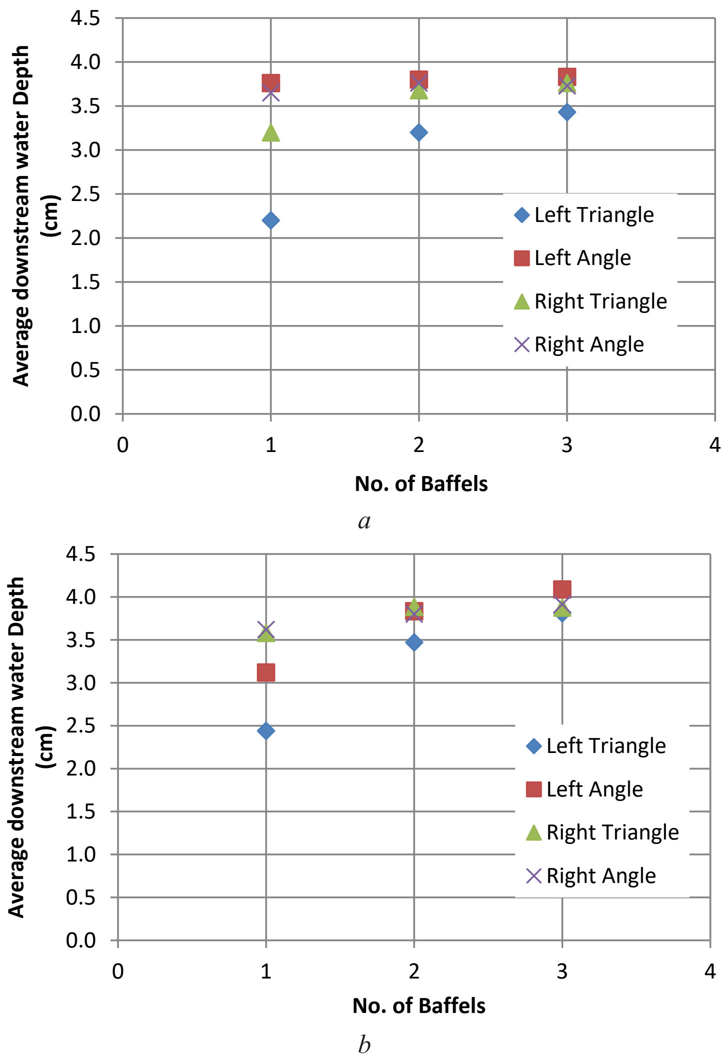
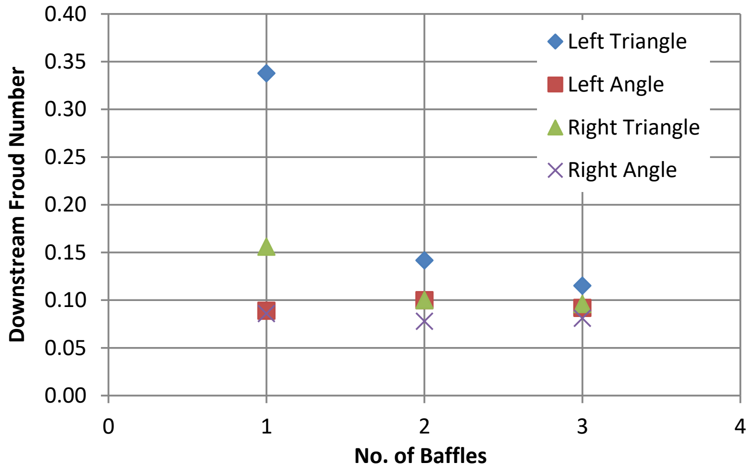
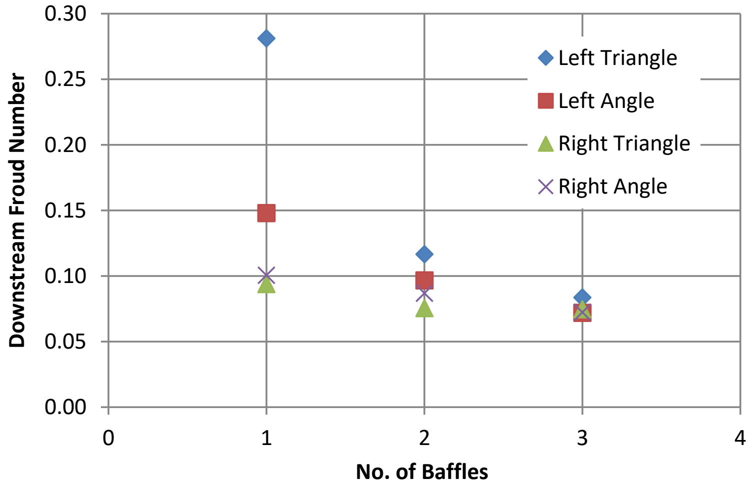


Fig. 7. The Relationship between downstream water depth and Baffles Number for different shapes of baffles and directions: *a* – 10 cm Spacing; *b* – 20 cm Spacing



a



b

Fig. 8. The Relationship between downstream Froude Number and Baffles Number for different shapes of baffles and directions: *a* – 10 cm Spacing; *b* – 20 cm Spacing

Table 3
Variation of actual discharge with the area of gate ratio for (h_u = 3 cm, No. of Baffles = 2, Spacing = 20 cm)

Ag/BH	Q_{act} (l/sec)			
	Left Triangle	**Left Angle**	**Right Triangle**	**Right Angle**
0.0538	0.628	0.543	0.648	0.601
0.0954	0.699	0.629	0.679	0.656
0.1440	0.757	0.839	0.82	0.751

Table 4
Variation of discharge coefficient with area of gate ratio for (h_u = 3 cm, No. of Baffles = 2, Spacing = 20 cm)

Ag/BH	C_d			
	Left Triangle	**Left Angle**	**Right Triangle**	**Right Angle**
0.0538	0.99	0.921	0.99	0.99
0.0954	0.804	0.681	0.761	0.753
0.1440	0.639	0.695	0.715	0.619

Table 5
Statistics of average downstream head versus efficiency values

–	Average h_d (cm)	Eff. (h_d) %
Minimum	1.44	21
Maximum	4.70	213
Mean	3.57	137
Standard Deviation	0.63	31
Median	3.74	137
Variance	0.39	9

Study limitations have been referred to in using these baffles in any lined channel (artificial channel) in order to regulate flow direction and share in the rise in water level downstream of the combined hydraulic structure, but here it is necessary mention that before using these baffles, many experiments should be done with various baffle dimensions (length, width, and thickness) in order to produce a good vision about the function of these submerged structures. Furthermore, optimization analysis and probabilistic analysis must be used in order to reach suiTable dimensions for the baffle, especially thickness. Due to the direct effect of thickness on the rising water, a probabilistic analysis must be applied to show the confidence and probability of using this submerged structure. This note must be adopted in further theoretical studies. Any study has strengths and weaknesses. The disadvantage of this study is represented by the hard work that should be applied during the construction of these baffles in situ, and the advantage of this study is represented by increasing the water depth in any lined channel by constructing these baffles. Moreover, the use of baffles reduces the intensity of turbulent flow owing to the dissipation energy that occurs along the wetted perimeter of the baffle surface. The baffles also reduce the water intensity on the floor or bed of the lined channel.

4. Conclusions

The upstream Froude number and downstream Froude number decrease with an increase in the baffle number. The Reynolds number decreases with an increase in the baffles number. The average water depth increases with an increase in baffle numbers. The actual discharge and coefficients of discharge are decreasing with an increase in the baffle number. The presence of baffles downstream leads to a higher water depth as compared with the case of not using them. A high hydraulic efficiency occurs in the presence of baffles in the downstream system. The baffle direction has a minor effect on the hydraulic characteristics of the weir-gate structure as it is compared with the spacing between them. The flow that crosses the gate of the composite structure has a major influence on the actual discharge and the discharge coefficient. The presence of baffles leads to an alteration in the flow velocity and water depth, and this will be reflected directly in the hydraulic features of the combined structure and the downstream hydraulic regime of the channel. The theoretical benefit of using these results is that it leads to obtaining an equation to describe the non-linear water surface profile, in addition to deriving an equation to describe water depth or flow head losses downstream of the combined hydraulic structure, respectively. The experimental results (model results) give an image of the hydraulic behavior of flow in the lined channel in situ, especially when the channel design depends on the same results that are obtained from the experimental works.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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The study was performed without financial support.

Data availability

Manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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