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Examining Free Jump Parameters under the Effect of Two Vertical Overlapping Gates (TVOG)

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ABSTRACT

The Jump downstream vertical gate is an effective tool to waste the flow energy. The current experimental work deliberates for the parameters of jump downstream Two Vertical Overlapping Gates (TVOG). The proposed TVOG allows dividing the flow via two openings. The lower one is under the lower gate, while the upper one is proposed between the gates. Experiments are examined on a rectangular flume of 66 cm width, 65.5 cm depth and 16.2 m length. The ideal percentage of the upper opening related to the lower one is detected experimentally. It is found that, working TVOG by upper opening fifty percent of the lower one wastes the flow energy by 52% and shrinks the basin length by 4.3%.

Nomenclature

$(E_{UP}- E_2)/ E_2$	The percentage of lost energy
G_1	The lower gate opening,
G_2	The upper gate opening,
H_1	The measured depth between gates
H_2	The depth on the upper gate
L_J/y_2	The percentage of length of H. jump
Q_{ml}	The lower discharge
Q_T	The total discharge
y_2/ H_{UP}	The end jump depth percentage
y_2/y_1	The ratio of the jump depths
F_2	The sequent Froude value
W	Constant width W=7.5cm

1. Overview

The adjustments of the basins downstream gates are a need to reduce the high cost of constructions and to increase the structure's safety. The simplest way to adjust the basin is increasing the energy lost through H. jumps and shortening the basin. The main categories of the adjustments contain the following: accessories into the basin, adapting of the geometrical basin shape and enhancing of gates. The three categories are reviewed below.

The first category includes many papers discussed the issue of locating accessories into apron. Negm, et al. (2003) identified that the negative "B" jump is longer than the negative "A" jump for the similar flow circumstances. In addition, locating the step at fifty percent of the basin gave the smallest length of H. jumps downstream gates.

Negm, et al. (2002b) researched the submerged H. jump in a basin, including an end sill and negative step. Theoretical and statistical equations are proposed to estimate the jump properties.

Habib and Nassar (2014) proposed a movable sill in a basin to reduce the lengths and depths of jumps. The proposed sill increased the energy lost by 35%. Habib and Nassar (2013) examined properties of jumps at a presence of roughness. It was indicated that, coverings of the basin by 90% of the proposed

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elements lift the ratio of lost energy to 17%. Alikhani, et al. (2010) supposed that the vertical sill is significantly affecting the jump parameters.

The second category includes researchers studied adjusting of the geometry of the basin. Saleh, et al. (2003) studied locating asymmetric sill on the scour downstream of sudden expansion basin. The proposed sill expressively decreased the scour depth. Matin, et al. (1998) presented a model to predict the ratio of the jump depths in abrupt enlargement case.

The third category includes the improving of the gates or the use of multiple openings. Abdel-Aal et al. (2014a) explored the mixture between Fayoum weir and adjusted gates up the weir's crest. Abdel-Aal et al., (2014b) proposed a gate with an inclined hose of 330^{o} to decrease the jump depth ratio by 12.3%.

Abdel-Aal et al., (2004) explored the jump parameters downstream multi-gates in lateral direction. The optimum operation of the gates was defined to reduce the extent of jump and to increase energy loss.

Negm, et al. (2007) studied the effects of submerged jump downstream multi-gates on scour patterns. It was referred that, the scour depth depended the near bed velocity and the operated gates. Negm, et al. (2002a) and Dehghani, et al. (2010) widely studied the effects of the mixture between gates and weir.

The current experimental work studied the geometry prosperities of jump downstream of Two Vertical Overlapping Gates (TVOG). TVOG allows passing the flow under the lower gate and between proposed two gates. The previous revision proved that, using two vertical overlapping gates were not investigated.

2. The Description of Tests

The tests were applied in a fixed bed flume of the lateral breadth = 66 cm, the section depth = 65.5 cm and the total length of working part =16.2m. The water source exists in a sump tank and is used by a suitable pump.

The model consists of two simple overlapping vertical gates move through 2cm side slots in wing walls. The walls were made from a woody material with a protective layer of paint; see the model particulars as showing in Fig. (1).

Figure (2) presents an image for tested models. The used apparatus for measuring of discharge (Q_T) is a calibrated sharp edge rectangular weir. The used weir is galvanized steel plate prepared to the measuring conditions. The apparatus was calibrated by an ultrasonic flow meter.

The measures of the investigated phenomenon are applied in the hydraulics laboratory in Water engineering and water structures Dept., Faculty of Eng., Zagazig Univ., Egypt.
The tests include two groups of measures:

- The first group contains the measures of jump parameters in the situation of operating the lower gate only. It is titled as the lower gate situation, and
- The second group includes the operating of the upper gate with opening height of a definite percentage of the lower gate. The different investigated percentages are G_2/G_1 =50%, 75%, 100% and 150%.

3. A Comparison with the Previous Studies.

As mentioned before, the proposed apparatus consists of two gates, see figure (1). Measuring the amount of discharge of each opening is an important during the analysis. As well as, the calibration of experimental measures is very urgent.
The measured data of the ratios of the jump depths for the lower gate needs to be compared with some equations of similar cases. Hager (1985) presented an statement for ratios of the jump depths for abrupt enlargement case as assumed in Eq. (1). Herbrand (1973) as notified by Kordi and Abustan (2011) presented another formula for ratios of the jump depths for abrupt enlargement case as assumed in Eq. (2).The Blanger equation describes the ratio of the jump depths for classical jump can be written as Eq. (3). Another form for the classical jump case can be rewritten as equation (4).

$$(y_2/ y_1) =(1/ \alpha^{1/2}) [(2^{0.5} F_1)-0.5] \quad (1)$$

$$y_2= (1/ \alpha)^{3/8}(y_2)_{classic} \quad (2)$$

$$(y_2/ y_1)_{classic}= 0.5[(8F_1^2+1)^{0.5}-1] \quad (3)$$

$$(y_1/ y_2)_{classic}= 0.5[(8F_2^2+1)^{0.5}-1] \quad (4)$$

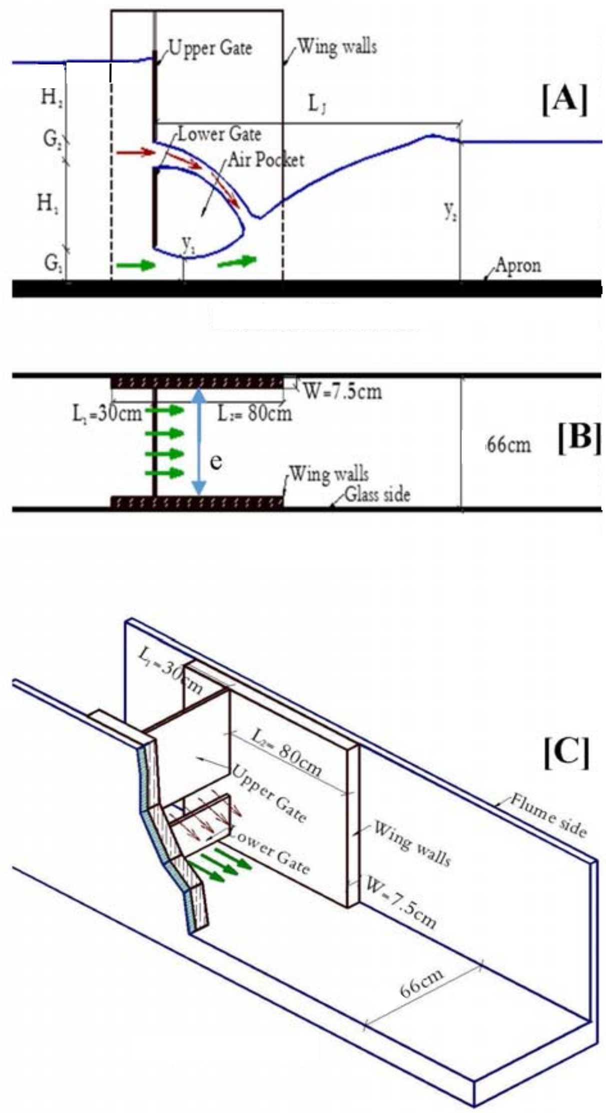

Fig. 1: Definition drafts of the fixed bed flume including the proposed gates [A] an elevation [B] a horizontal plan [C] an isometric

Fig. 2: An image of the tested model

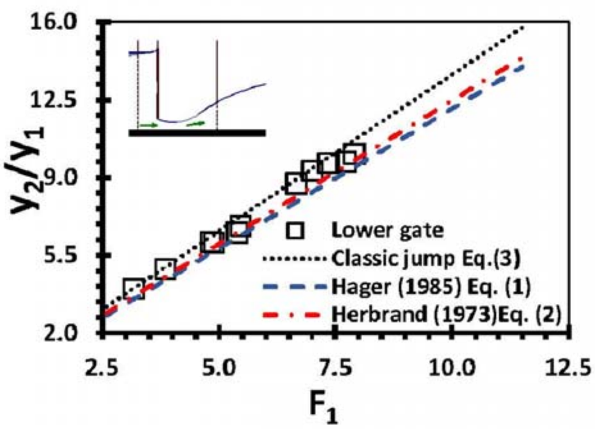

Fig. 3: The relationships between y_2/y_1 against F_1 for the recent measurements and the available equations.

The present experimental data for the case of the lower gate situation with expansion value of α=B/e =1.26 was compared with the Blanger Equation (3) & Hager (1985) for abrupt enlargement and Herbrand (1973). The measures of the ratio of the jump depths y_2/y_1 are figured against initial Froude value F_1 , see figure (3). The figure proves the high accuracy of the recent measures. In fact, the differences are due to the effectiveness of the place of the enlargement's start. The line of Blanger Equation (3) shows the effectiveness of the enlargement on the jump phenomena as it reduces the values of y_2/y_1.

4. Jump Parameters for Only the Lower Gate Situation (G_2/G_1=0)

The jump parameters for the lower gate situation are figured against the sequent Froude value F_2 as existing in figure (4). The parameters are inclusive of the percentage of the end depth of jump to flow upstream gates y_2/H_{UP}, the percentage of length of H. jump to the end depth L_J/y_2 , and the percentage of lost energy via the apparatus to the sequent energy $(E_{UP}-E_2)/E_2$.

5. Jump Parameters For Two Vertical Overlapping Gates (TVOG)

The jump parameters for different investigated situations of the Two Vertical Overlapping Gates (TVOG) are figured against the sequent Froude value F_2 as existing in figures (5, 6 and 7). Figure (5) presents the percentage of the end depth of jump to flow upstream gates y_2/H_{UP} for G_2/G_1 =50%, 75%, 100% and 150% against F_2. It is apparent that, the y_2/H_{UP} magnifies by the developing of the sequent Froude value F_2 for all studied amounts of G_2/G_1. Figure (6) presents the percentage of length of H. jump to the end depth of jump L_J / y_2 for G_2/G_1 =50%, 75%, 100% and 150% against F_2.

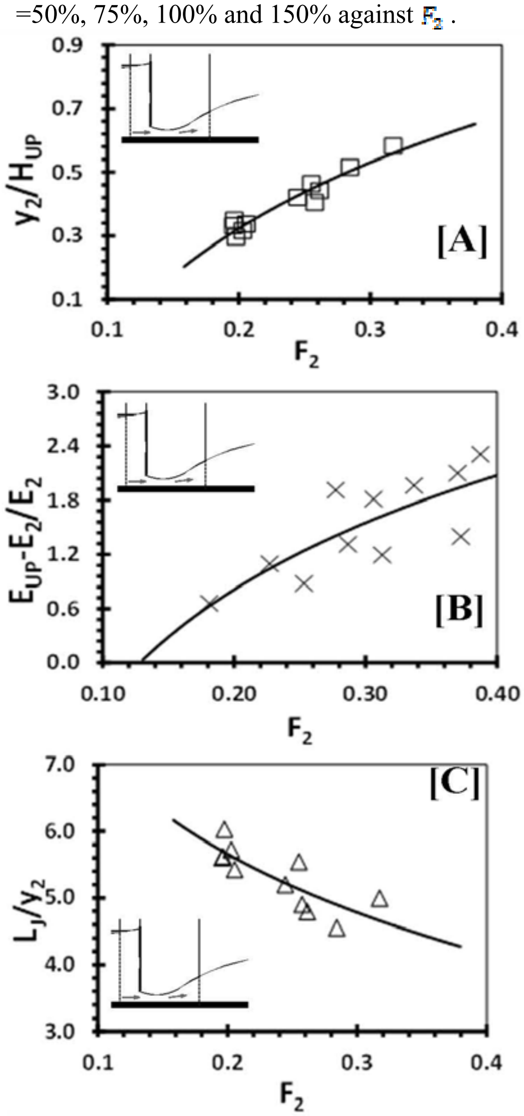

Fig. 4: The jump parameters against F_2 for the lower gate situation [A] y_2/H_{UP} [B] $(E_{UP} - E_2)/E_2$ [C] L_J / y_2

It is apparent that, L_J / y_2 decreases by the developing of the sequent Froude value F_2 for all studied amounts of G_2/G_1.

Figure (7) presents the percentage of lost energy via the apparatus to the sequent energy $(E_{UP} - E_2)/E_2$ for G_2/G_1 =50%, 75%, 100% and 150% against F_2. It is apparent that, $(E_{UP} - E_2)/E_2$ decreases by the developing of the sequent Froude value F_2 for all studied percentages of G_2/G_1.

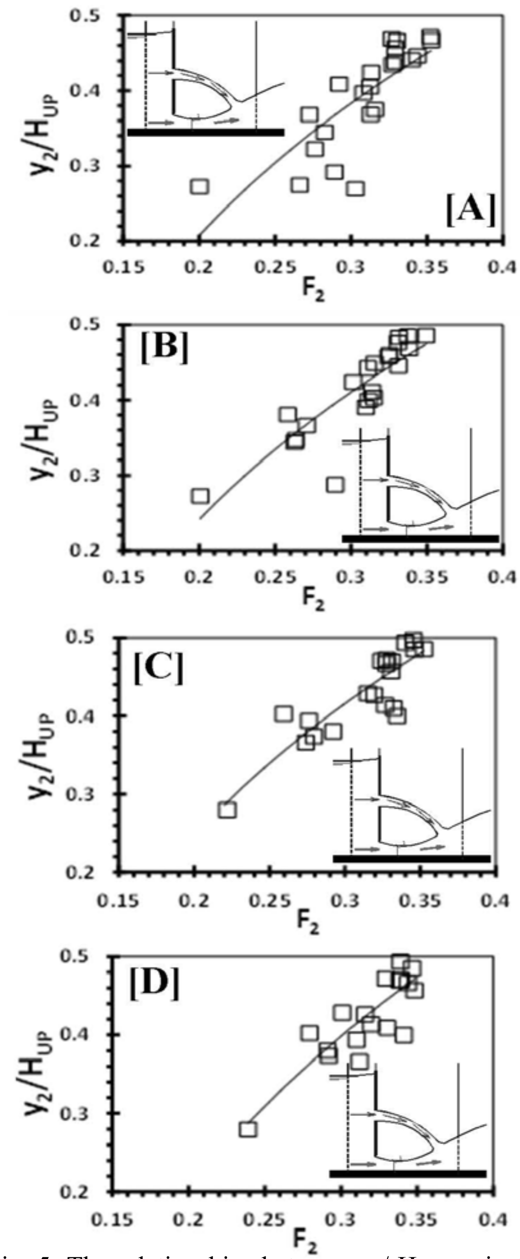

Fig. 5: The relationships between y_2/H_{UP} against F_2 [A] G_2/G_1=50% [B] G_2/G_1=75% [C] G_2/G_1=100% [D] G_2/G_1= 150%

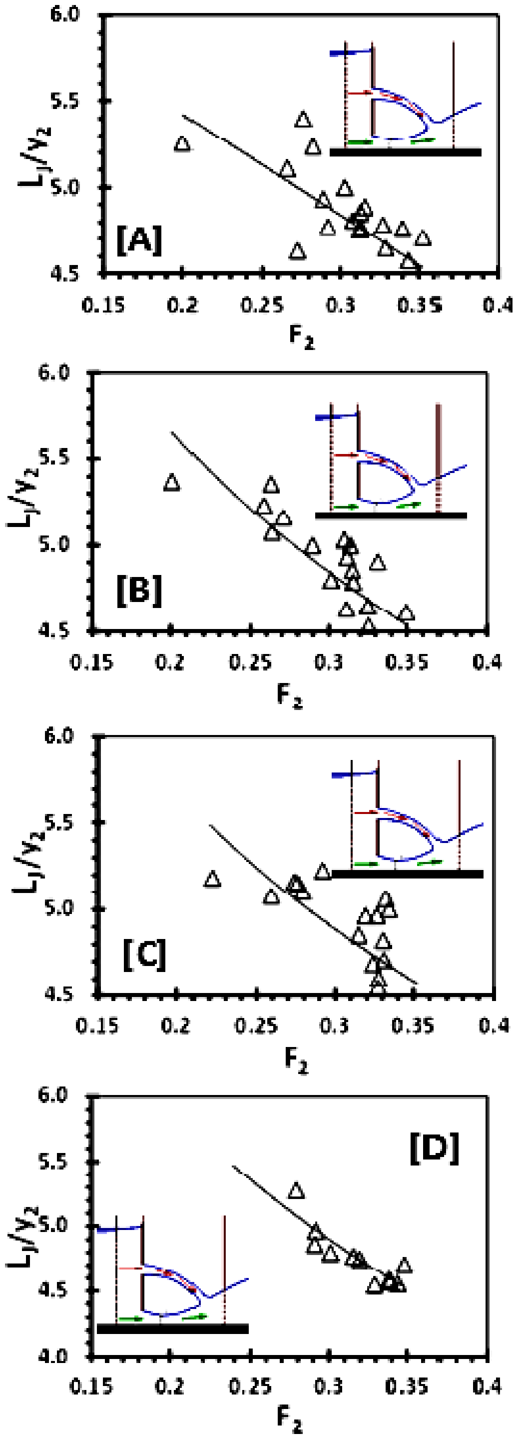

Fig. 6: The relationships between L_J / y_2 against F_2 [A] G_2/G_1 =50% [B] G_2/G_1 =75% [C] G_2/G_1 =100% [D] G_2/G_1 = 150%

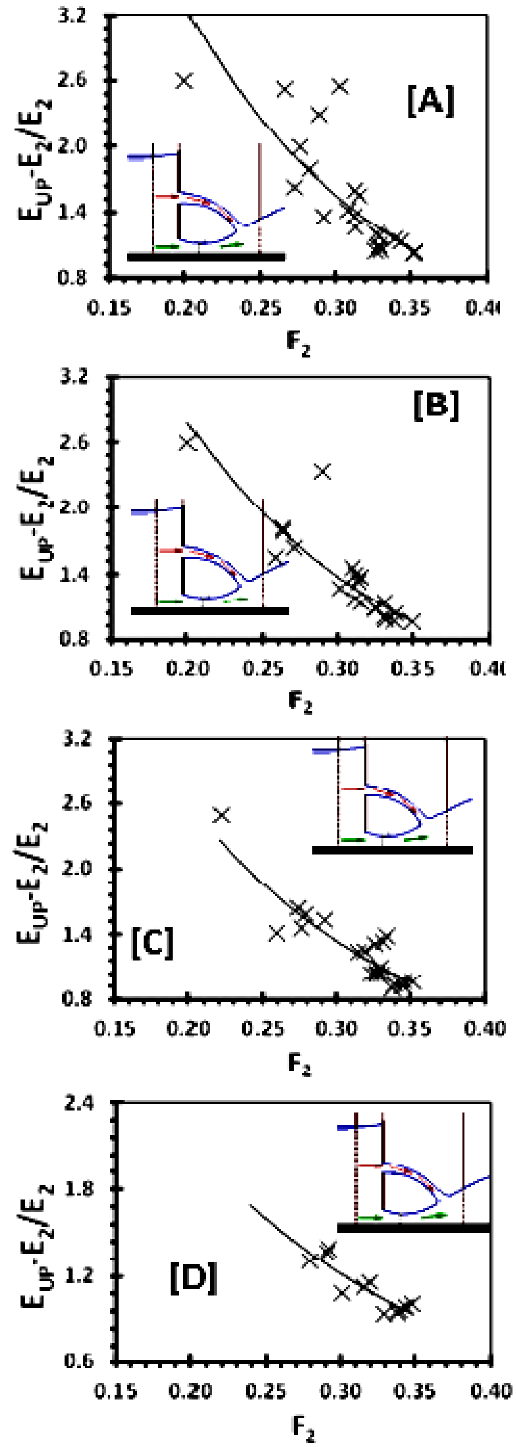

Fig. 7: The relationships between $\frac{E_{UP} - E_2}{E_2}$ against F_2 [A] G_2/G_1 =50% [B] G_2/G_1 =75% [C] G_2/G_1 =100% [D] G_2/G_1 = 150%

Figure (8) presents relationships between jump parameters for different investigated situations of the Two Vertical Overlapping Gates (TVOG) against F_2. It can be gotten that, the situation of G_2/G_1=50% gives the lower percentage of the end depth of jump to flow upstream gates y_2/H_{UP}, as existing in figure (8A).

In the opposite way, the situation of (TVOG) of G_2/G_1 =50% gives the major percentage of lost energy via the apparatus to the sequent energy $(E_{UP} - E_2)/E_2$, see figure (8B).

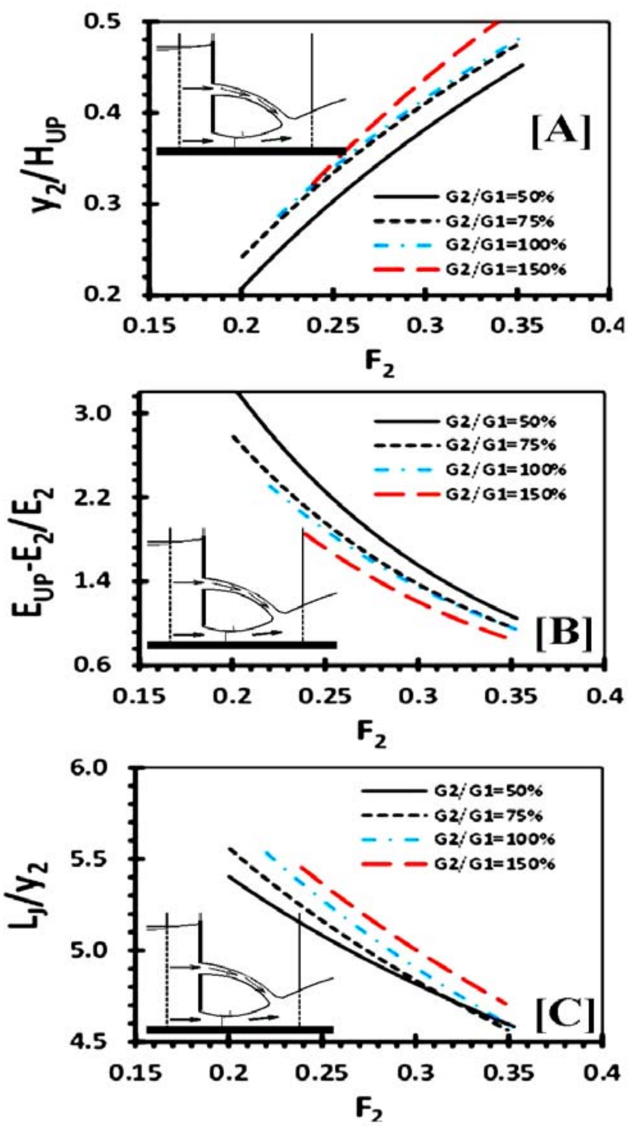

Fig. 8: The jump parameters against F_2 for G_2/G_1=50%, G_2/G_1=75%, G_2/G_1=100% and G_2/G_1=150% [A] y_2/H_{UP} [B] $(E_{UP} - E_2)/E_2$ [C] L_J/y_2

In addition, (TVOG) of G_2/G_1=50% gives the less percentage of length of H. jump to the end depth of jump L_J/y_2, see figure (8C).

Figure (9) presents the jump parameters for the situation of (TVOG) of G_2/G_1=50% and the situation of lower gate only against F_2. It can be gotten that, the situation of G_2/G_1 =50% decreases percentage of the end depth of jump to flow upstream gates y_2/H_{UP} by about 31.2% compared to the situation of the lower gate only, as existing in figure (9A).

In addition, the situation of (TVOG) of G_2/G_1=50% reduces percentage of length of H. jump to the end depth of jump L_J/y_2 by about 4.3% compared to the situation of the lower gate only, as existing in figure (9C). In contrast, the situation of (TVOG) of G_2/G_1 =50% magnifies the percentage of lost energy via the apparatus $(E_{UP} - E_2)/E_2$ by about 52% compared to the situation of the lower gate only, as existing in figure (9B).

Through the current experimental works, there was a noticeable effect of the percentage of G_2/G_1on the jump parameters including y_2/H_{UP}, L_J/y_2 and $(E_{UP} - E_2)/E_2$ for the situations of Two Vertical Overlapping Gates (TVOG). That relation is existing in figure (8). It can be gotten that, as G_2/G_1 decreases the jump parameters are improved. The reason for the improvement of jump parameters is due to the decreasing the amount of discharge passing across the upper gate to the optimum limit.

Generally, as G_2/G_1 magnifies the amount of discharge passes across the lower gate decreases and the upstream depth decreases, see figures (10A and 10B), respectively. As a direct result, the discharge through the upper gate magnifies. It plays as a pusher for the body of jump. The flow from the upper gate pushes the formed hydraulic jump. As a result, it needs a longer basin. In addition, it requires more tail flow depth to keep it in the same location in the basin, as sketched in Figure (11).

6. The Conclusions

This experimental paper debates the parameters of jump downstream Two Vertical Overlapping Gates (TVOG). The main concluded points are listed below:

- The experimental data for the case of the lower gate situation was compared with the Blanger Equation & Hager (1985) and Herbrand (1973). It proves a high accuracy of the recent measures.
- Two Vertical Overlapping Gates (TVOG) of

G_2/G_1=50% gives the smaller amounts of y_2/H_{UP}, L_J/y_2 and the greatest $(E_{UP} - E_2)/E_2$.

- TVOG of G_2/G_1=50% decreases the average amounts of y_2/H_{UP} and L_J/y_2 by about 31.2% and 4.3% compared to the situation of the lower gate only, respectively.
- TVOG of G_2/G_1 =50% magnifies $(E_{UP} - E_2)/E_2$ by about 52% compared to the situation of the lower gate only,
- The amount of discharge passes across the lower gate decrease and the upstream depth decreases as G_2/G_1 increases.

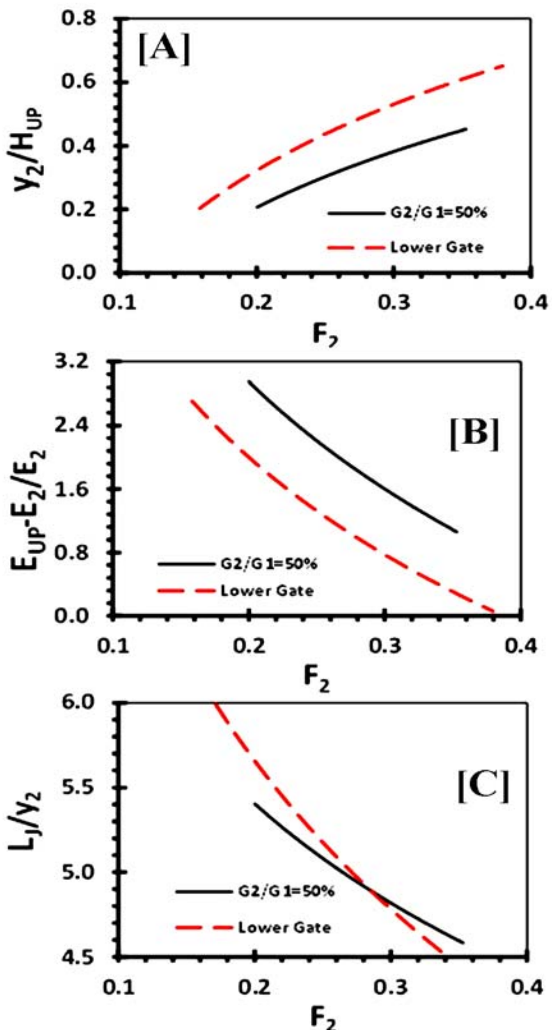

Fig. 9: The jump parameters against F_2 for G_2/G_1=50%, and the lower gate situation [A] y_2/H_{UP} [B] $(E_{UP} - E_2)/E_2$ [C] L_J/y_2

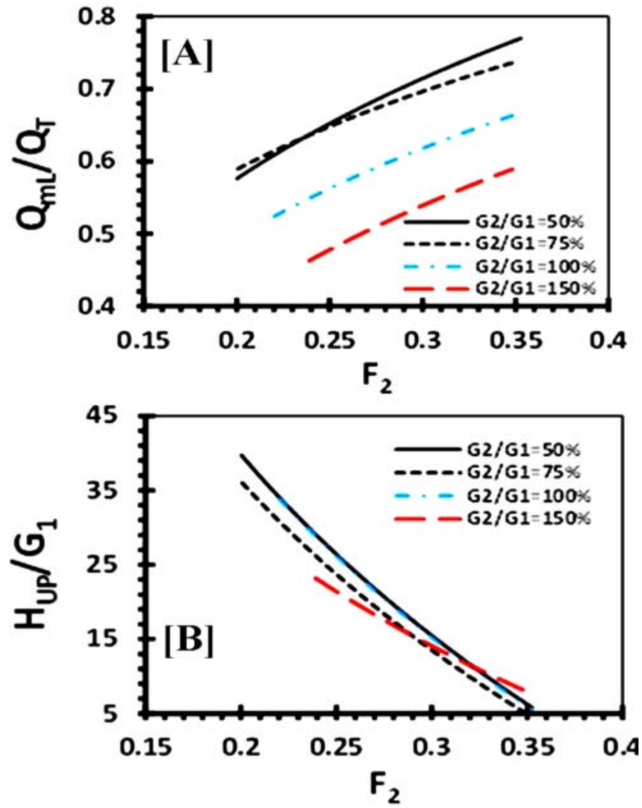

Fig. 10: [A] The percentage of Q_{ml}/Q_T against F_2 [B] The percentage of H_{UP}/G_1 against F_2

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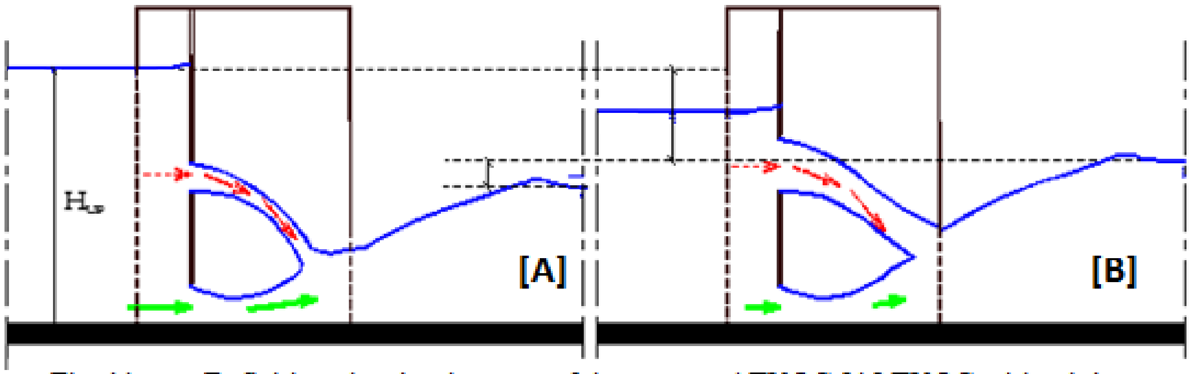

Fig. 11: Definition sketches in cases of the proposed TVOG [A] TVOG with minimum G_2/G_1 [B] TVOG with most G_2/G_1

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