POOLS EFFECT ON B-JUMP CHARACTERISTICS

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ABSTRACT

The pools are considered a modern technique for controlling the hydraulic jump by creating a drop followed by a rise in the bed level accompanied by a gradual expansion in the bed width as well .

In this study both theoretical and experimental studies were performed in a radial stilling basin with an expansion ratio of 0.667. The studies were executed to find out the effective pool position, geometrical dimensions and plan view shape which give the maximum energy loss, minimum jump length and minimum relative depth.

The equations obtained in the theoretical study were verified, and the experimental results were found in a reasonable agreement with the theoretical equations.

ملخص

تعد القناطر من اهم منشآت التحكم والتى تستخدم على نطاق واسع فى جمهورية مصر العربية .

هذه المنشآت قد تتسبب فى احداث تغيرات فى خواص السريان خلال المجرى المائى ، وتعتبر ظاهرة القفزة الهيدروليكية من اهم الظواهر المترتبة على وجود منشآت التحكم والجديرة بالبحث والدراسة .

يتم انشاء احواض التهدئة خلف منشآت التحكم لتلافى الآثار الضارة للطاقة الزائدة الموجــودة فــى السريان .

هذا البحث يهدف الى دراسة امكانية زيادة الطاقة المشتتة المتولدة عن السريان فى احواض التهدئة خلف المنشآت وذلك باستخدام ظاهرة البرك .

وقد تم دراسة عناصر مختلفة خاصة بالبرك تتضمن انسب طول وانسب مكان وانسب عمق للبركة .

كما تم دراسة افضل اداء للبركة والذى يعطى اعلى تشتت للطاقة لأقل طول للقفزة الهيدروليكية .

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1. INTRODUCTION

When the hydraulic jump occurs, the water surface rises rapidly, surface rollers are formed, air entrainment starts to be formed, and intense mixing occurs . This phenomenon increases the energy dissipation in a short reach of the channel .

Stilling basins are generally used to control the hydraulic jump and to protect the channel bed from erosion . Some researchers studied the stilling basin itself and others studied the effect of stilling basin on the channel bed at the downstream side of the structure.

Regulators and Barrages are used in the Egyptian irrigation system . They have several advantages compared to the weirs especially during the flood season as the gates can be kept in a full-open mode which prevents any heading-up in the waterway . The maximum heading-up of the Nile Barrages during flood does not exceed 30 cm (Shukry et al, 1987) .

In this study, a model of one-vent regulator having a gradually expanded stilling basin was used and the effect of pre-described pool on the hydraulic characteristics of the B-jump was studied .

2. THE CONTROL OF A HYDRAULIC JUMP

The hydraulic jump may be controlled by several methods to ensure the formation of the jump within the stilling basin and to control its position under all possible operating conditions .

Generally, there are two different ways to control a hydraulic jump :

2.1. USING A HYDRAULIC STRUCTURE

Two types of structures are used to control the hydraulic jump in stilling basins, either sharp crested weir (sill) or broad crested weir .

2.2. PROVIDING STILLING BASIN MODIFICATIONS

The stilling basin is a short length of paved channel at the end of any structure where supercritical flow occurs .

To maximize the performance of the stilling basins to dissipate the energy, the following may be done :

1. Rise in bed level (positive step) .
2. Drop in bed level (negative step) .
3. Expansion in bed width (gradual or sudden) .

3. THEORETICAL STUDY

3.1. DIMENSIONAL ANALYSIS

A definition sketch for both a basin containing a pool and a pool provided with sloped inlet and outlet ends are shown in Figure (1) .

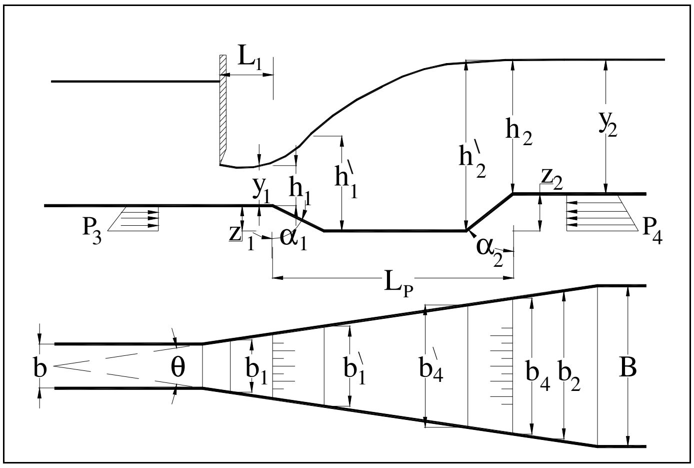

Figure (1): Definition Sketch of a Pool.

The angle of divergence of bed width was fixed at θ = 4.776^{o}, the contracted width of the channel was fixed at b= 20.0 cm and the channel width was fixed at B=30.0 cm throughout the experimental study .

The other variables were tabulated and the relationships between them were obtained using the Matrix Method Technique .

$$y_0, \frac{L_j}{y_1}, \frac{\Delta E}{E_1} = f\left\{ \begin{array}{l} B_1, B_2, B_3, B_4, B'_1, B'_4, H_1, H_2, H'_1, H'_2 F_1, Z_1, Z_2, \alpha_1, \alpha_2 \\ \frac{G}{B}, \frac{L_p}{L_b}, \frac{L_1}{L_b} \end{array} \right\} \quad \ldots\ldots\ldots\ldots..(1)$$

In which:

y_o= y_2/y_1= relative depth of jump,

F_1= Froud number at the beginning of jump,

H_2=h_2/y_1= relative height,

Z_1=z_1/y_1= relative pool depth at inlet,

Z_2=z_2/y_1 = relative pool depth at outlet,

$\frac{L_p}{L_b}$= pool length ratio, $\frac{L_1}{L_b}$= relative pool position B_1=b_1/B

B_2=b_2/B B_3=b_3/B and B_4=b_4/B $B'_1 = b'_1/B$

$B'_4 = b'_4/B$ H_1=h_1/y_1 $H'_1 = h'_1/y_1$ $H'_2 = h'_2/y_1$

The following were assumed:

i. The flow is steady and uniform U.S & D.S. the jump .
ii. The flow is a linear distribution through the jump .
iii. The losses within the jump zone are due to the jump effect only .

3.2. POOL WITH INLET AND OUTLET SLOPES

If the downward step or the upward step is inclined by an angle (α) the pressures exerted on them are changed. Assuming that h_1 and $h_1^\backslash$ are the depths of water at the start at the and end of inlet slope respectively, h_2 and $h_2^\backslash$ are the outlet slopes respectively, b_1 and $b_1^\backslash$ are the bed widths at the inlet slope respectively, and b_2 and $b_2^\backslash$ are the bed widths at pool outlet respectively, as shown in Figure (1) .

The governing equation is :

$$P_2 + P_4 - P_1 - P_3 - 2P_s \sin(\theta/2) = \frac{\gamma}{g} Q(\beta_1 v_1 - \beta_2 v_2) \quad \ldots\ldots\ldots\ldots\ldots\ldots..\ldots(2)$$

In which:

P_1 is the hydrostatic pressure at the beginning of the jump .
P_2 is the hydrostatic pressure at the end of the jump .
P_3 is the hydrostatic pressure on the face of the downward step .
P_4 is the hydrostatic pressure on the face of the upward step .
P_s is the channel side pressure due to the gradual expansion of the basin .
β_1, β_2 are the momentum correction factors at section 1 and section 2 respectively, and their values are estimated to be approximately 1.0 .

$$P_1 = \frac{\gamma y_1^2}{2} b_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...(3)$$

$$P_2 = \frac{\gamma y_2^2}{2} b_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...(4)$$

$$P_3 = \gamma \; \frac{b_1 + b_1^\backslash}{2} \frac{z_1}{\cos\alpha_1} \left(\frac{y_1 + h_1^\backslash}{2} \right) \cos \alpha_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots(5)$$

$$P_4 = \gamma \; \frac{b_4 + b_4^\backslash}{2} \frac{z_2}{\cos\alpha_2} \left(\frac{h_2 + h_2^\backslash}{2} \right) \cos \alpha_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots(6)$$

By substitution in equation number 2 above :

$$P_s = \gamma \left(\begin{array}{c} \dfrac{(b_1^\backslash - b_1)}{2\sin(\theta/2)} \dfrac{(y_1^2 + h_1^{\backslash 2} + y_1 h_1^\backslash)}{6} + \dfrac{(b_4^\backslash - b_1^\backslash)}{2\sin(\theta/2)} \dfrac{(h_1^{\backslash 2} + h_2^{\backslash 2} + h_1^\backslash h_2^\backslash)}{6} + \\ \dfrac{(b_4 - b_4^\backslash)}{2\sin(\theta/2)} \dfrac{(h_2^{\backslash 2} + h_2^2 + h_2^\backslash h_2)}{6} + \dfrac{(b_2 - b_4)}{2\sin(\theta/2)} \dfrac{(h_2^2 + y_o^2 + y_o h_2)}{6} \end{array} \right) \quad \ldots..\ldots\ldots(7)$$

By substitution in the general equation :

$$\frac{b_2 y_2^2}{2} - \frac{b^1 y_1^2}{2} + \frac{b_4 + b_4^\backslash}{2} z_2 \left(\frac{h_2 + h_2^\backslash}{2} \right) - \frac{b_1 + b_1^\backslash}{2} z_1 \left(\frac{y_1 + h_1^\backslash}{2} \right) -$$

$$\left(\begin{array}{l} \frac{1}{6}(b_1^\backslash - b_1)(y_1^2 + h_1^{\backslash 2} + y_1 h_1^\backslash) + \frac{1}{6}(b_4^\backslash - b_1^\backslash)(h_1^{\backslash 2} + h_2^{\backslash 2} + h_1^\backslash h_2^\backslash) \\ + \frac{1}{6}(b_4 - b_4^\backslash)(h_2^{\backslash 2} + h_2^2 + h_2^\backslash h_2) + \frac{1}{6}(b_2 - b_4)(y_o^2 + h_2^2 + y_o h_2) \end{array} \right) = \frac{Q v_1}{g}(1 - v_2/v_1) \quad \ldots.(8)$$

Equation (8) can be simplified as follows :

$$3B_2y_0^2 + 3\,B_1 - 1.5\left(B_4 + B_4^{\backslash}\right)Z_2\left(H_2 + H_2^{\backslash}\right) - 1.5\left(B_1 + B_1^{\backslash}\right)Z_1\left(1 + H_1^{\backslash}\right) - (B_1^{\backslash} - B_1)\left(H_1^{\backslash 2} + H_1^{\backslash} + 1\right) -$$
$$(B_4^{\backslash} - B_1^{\backslash})\left(H_1^{\backslash 2} + H_2^{\backslash 2} + H_1^{\backslash}H_2^{\backslash}\right) - (B_4 - B_4^{\backslash})\left(H_2^{\backslash 2} + H_2^2 + H_2^{\backslash}H_2\right) - (B_2 - B_4)\left(y_o^2 + H_2^2 + y_oH_2\right)$$
$$= 6F_1^2B_1\left(1 - \frac{B_1}{B_2y_0}\right) \quad \ldots\ldots(9)$$

$$F_1 = \sqrt{\frac{\begin{array}{l}3B_2y_0^2 - 3B_1 + 1.5\left(B_4 + B_4^{\backslash}\right)Z_2\left(H_2 + H_2^{\backslash}\right) - \\ 1.5\left(B_1 + B_1^{\backslash}\right)Z_1\left(1 + H_1^{\backslash}\right) - (B_1^{\backslash} - B_1)\left(H_1^{\backslash 2} + H_1^{\backslash} + 1\right) - \\ (B_4^{\backslash} - B_1^{\backslash})\left(H_1^{\backslash 2} + H_2^{\backslash 2} + H_1^{\backslash}H_2^{\backslash}\right) - \\ (B_4 - B_4^{\backslash})\left(H_2^{\backslash 2} + H_2^2 + H_2^{\backslash}H_2\right) - \\ (B_2 - B_4)\left(y_o^2 + H_2^2 + y_oH_2\right)\end{array}}{6B_1\left(1 - \frac{B_1}{B_2y_0}\right)}} \quad \ldots\ldots(10)$$

Equation (10) is considered the general equation for the stilling basin provided with pool, if the pool has entrance or exit slopes.

3.3. ENERGY EQUATION FOR B-JUMP

Since the end of the control volume for a B-jump is at the end of the jump and the energy loss relation through the pool can be calculated by applying the energy equation between the pool entrance and the jump end :

E_1= the total energy at the beginning of the pool .

E_2= the total energy at the end of the jump .

$$E_1 = z_1 + y_1 + \frac{v_1^2}{2g} \quad \ldots\ldots(11)$$

$$E_2 = z_2 + y_2 + \frac{v_2^2}{2g} \quad \ldots\ldots(12)$$

ΔE = the energy loss through the jump.

$$\frac{\Delta E}{E_1} = \frac{y_1 + \frac{v_1^2}{2g} + z_1 - y_2 - \frac{v_2^2}{2g} - z_2}{z_1 + y_1 + \frac{v_1^2}{2g}} \quad \ldots\ldots(13)$$

$$\frac{\Delta E}{E_1}=\frac{y_1-y_2+z_1-z_2+\frac{v_1^2}{2g}\left(1-\frac{v_2^2}{v_1^2}\right)}{z_1+y_1+\frac{v_1^2}{2g}} \quad \text{..................................(14)}$$

From the continuity equation : $b_1y_1v_1= b_2y_2v_2$, and
Dividing equation (14) by 'y_1' leads to an expression for the initial relative energy loss as follows:

$$\frac{\Delta E}{E_1}=\frac{1-y_o+Z_1-Z_2+\frac{F_1^2}{2}\left(1-\frac{B_1^2}{B_2^2y_o^2}\right)}{Z_1+\frac{F_1^2}{2}+1} \quad \text{.......................................(15)}$$

Equation (15) may be considered as the general equation for the energy dissipated by the hydraulic jump which occurs in a stilling basin with a pool .

4. EXPERIMENTAL PROGRAM

The experimental work was performed at the Hydraulics and Water Engineering Laboratory of the Faculty of Engineering, Zagazig University, Egypt . The flume used is 30 cm wide and 15.6 m long . It is re-circulating flume with a closed operating system. The discharge can be measured using an orifice meter installed in the pipe connecting the pump and the inlet tank.

Point gauge of 0.01 cm accuracy was used to measure the flow depth . The physical model is made of transparent plastic (Perspex) which consists of the false bed of height 10.0 cm as an extension to the inlet part, a 0.30 m bed wide for a length of 1.50 m and then a sudden contraction to 0.20 m bed width at the gate zone. The contracted part has a length of 0.50 m, and has two grooves for the gate. The distance between the working gate and the end of the contracted part is 6.0 cm, then starts the radial stilling basin with a diverging angle θ= 4.776° .

5. RESULTS AND ANALYSIS:

5.1. EFFECT OF CHANGING THE POOL POSITION

Three different pool positions were studied, L_1 within the vena contracta range, L_1 = 24.0 cm and L_1 = 48.0 cm . The relationships between the relative depth, and relative energy loss as a function of initial Froude number were presented in the Figure (2).

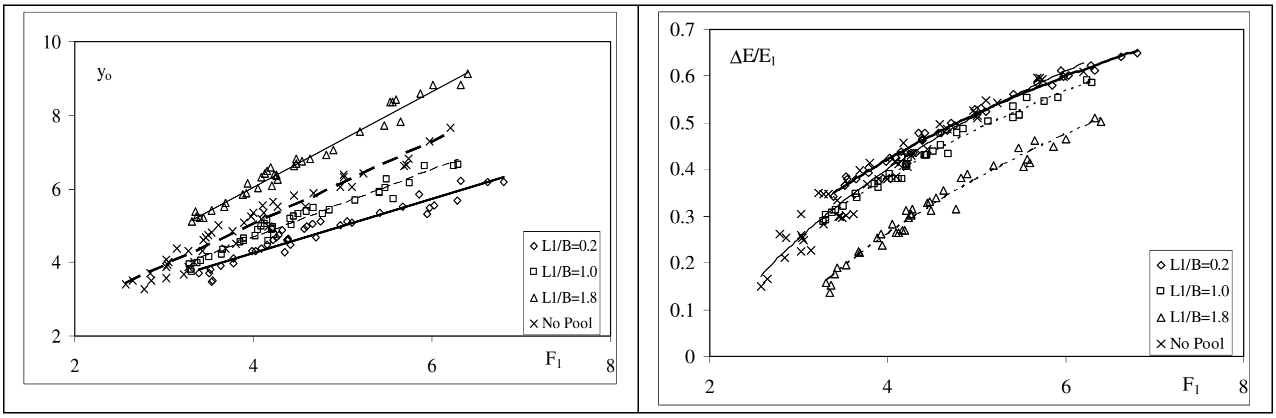

Figure (2): The Relation Between y_o and $\Delta E/E_1$ with F_1 for different pool positions.

Figure (2) shows that, the closer the pool from the gate, the better results were obtained. Moreover, as the relative position of pool, L_1/B, increases, the relative depth of jump increases, while the relative energy dissipated decreases.

If the pool inlet started just under the gate, instability of jump characteristics were obtained and fluctuations in the water surface were noticed upstream the gate. These fluctuations lead to change the discharge passing through the gate. Also, the existence of pool inlet just under the gate increases the gate height, consequently its weight increases which –in turn- increases both the required lifting force and maintenance costs .

5.2. EFFECT OF CHANGING THE POOL LENGTH RATIO

The analysis was made to reach the appropriate length of the pool to control the jump position within the pool length and minimize the length of the stilling basin. The relationship between y_o and F_1, $\Delta E/E_1$ and F_1 and L_j/y_1 and F_1 were studied for different pool length ratios. The case of B-jump was studied for (L_p/L_b = 0.2, 0.4, 0.5, and 0.55).

Figure (3-a) shows that the radial basin is more effective than the rectangular basin, and as the sequent depth ratio increases as the initial Froude number increases. Moreover, for the same flow condition the relative depth of jump decreases as the pool length ratio increases till the pool length ratio reaches 0.4, then it increases slightly with the increase of L_p/L_b.

Figure (3-b) shows that the relative energy dissipation increases as the initial Froude number increases. In addition, for the same value of initial Froude number, the relative energy dissipated increases by the increase of the pool length ratio till L_p/L_b=0.4, then it decreases slightly with the increase of L_p/L_b.

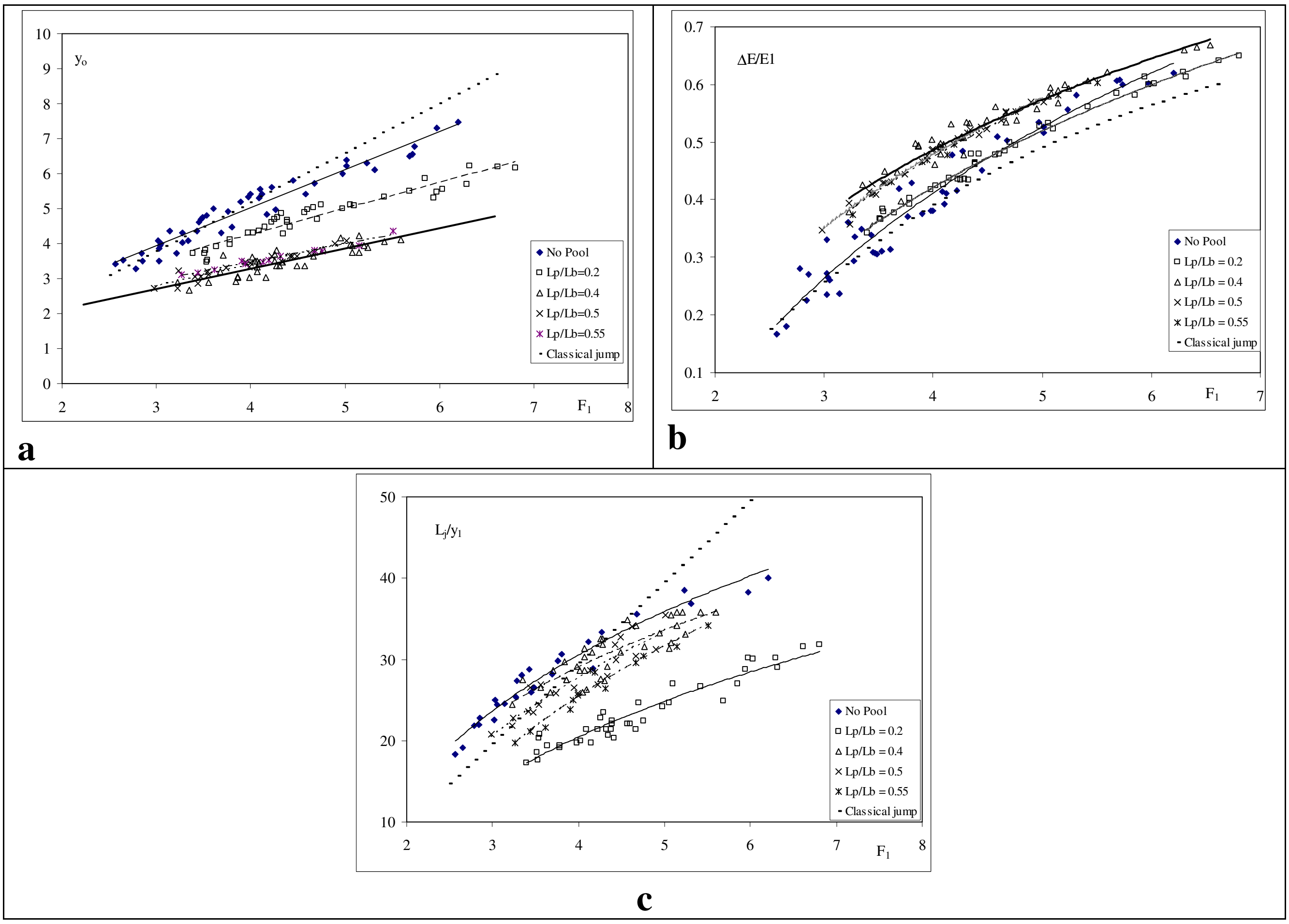

Figure (3): Relationship Between y_o, $\Delta E/E_1$, and L_j/y_1 with F_1 for Different Pool Length Ratios.

Figure (3-c) shows the relationship between L_J/y_1 and F_1. It can be noticed that, for different pool length ratios, the relative length of jump increased with the increase of the initial Froude number .

It was noticed that the pool length ratio $L_p/L_b = 0.2$ had a minimum relative length of jump, and as the pool length ratio increases the relative length of jump increases . The case of $L_p/L_b = 0.4$, an unstable nonuniform water surface profile was formed after the pool outlet, and the length of jump can not be measured with an acceptable accuracy. Therefore, the relative length of jump, in this case, is more than the corresponding values of the other pool length ratios .

For the pool length ratios between 0.2 and 0.4 an unstable jump was formed and the measurements were not possible .

Generally, incase of the B-jump, the existence of the pool improved the relative depth of the jump. The best relative length was 0.4 since the pool length ratio L_p/L_b=0.4 which contains the length of roller as shown in Figure (4). Consequently the pool length ratio L_p/L_b=0.4 controls the jump depth and maximizes the energy dissipated; otherwise it generates waves after the pool outlet.

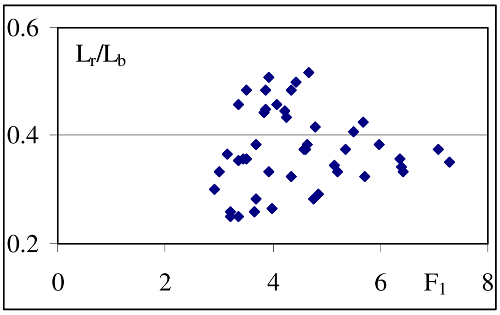

Figure (4): The Relationship Between the Roller Length Ratio and F_1

5.3. THE EFFECT OF CHANGING THE POOL DEPTH

The relationships between y_o, $\Delta E/E_1$, and L_j/y_1 as a function of F_1 were studied for different pool depth/width ratios z/B, starting from $z_1/B = z_2/B$ = 0.066 to 0.20. The relationships are shown in Fig. (5-a-b and c) respectively.

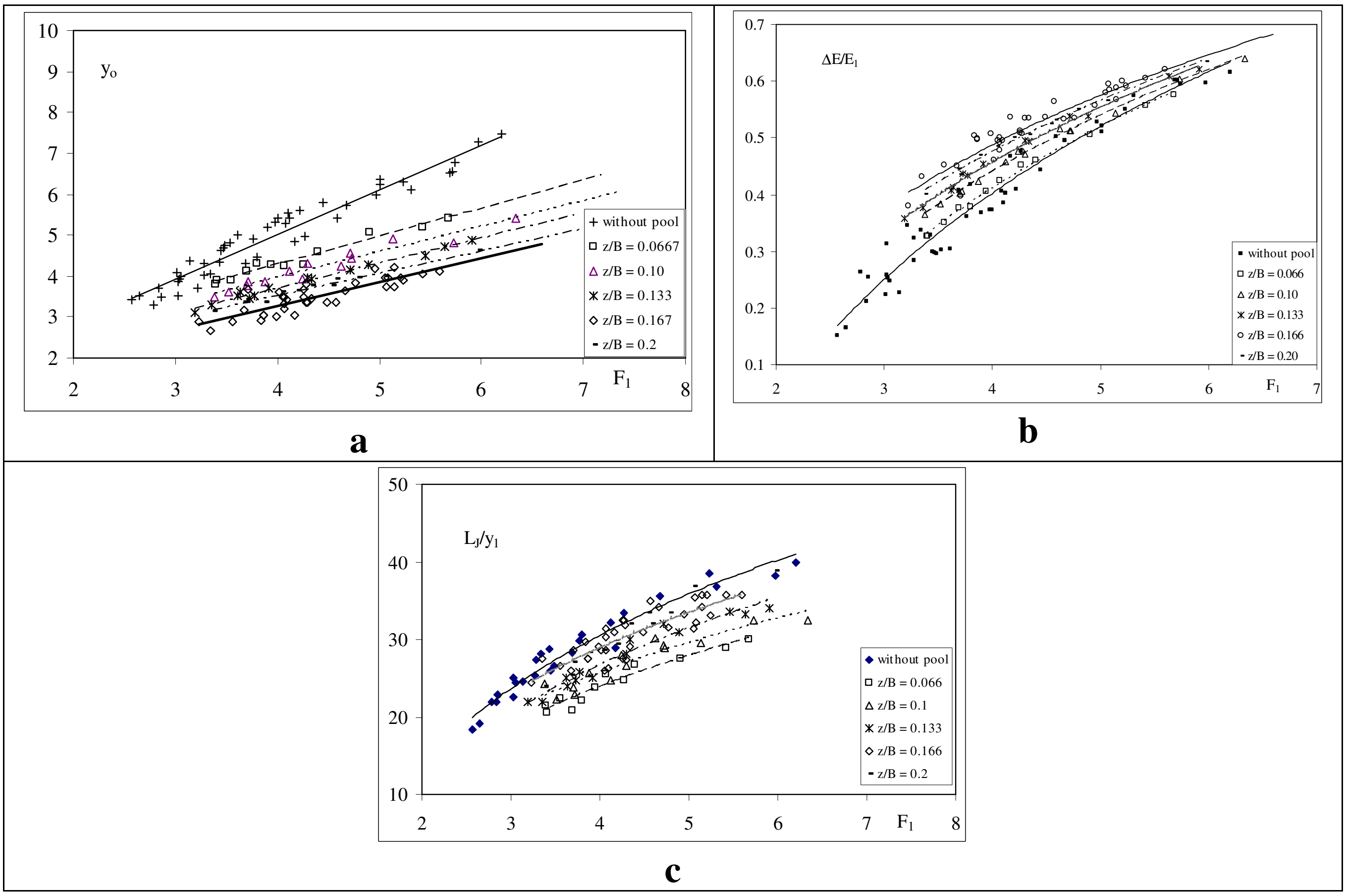

Figure (5): Relationship Between y_o, $\Delta E/E_1$, and L_j/y_1 with F_1 for Different Values of z/B.

Figures (5-a-b and c) show that the pool depth/width ratio z/B = 0.166 gave the maximum relative energy loss and the minimum relative depth of the jump. Although this ratio did not give satisfying results as far as the length of jump, but it gave better results than that of using radial basin only .

If the pool depth/width ratio increases, both the relative depth and length decrease and the relative energy loss increases until the value of z/B=0.166, the pool performance is changed and both the relative depth and length increased, while the relative energy loss decreased .

If the pool depth/width ratio z/B increases more than 0.2, the pool outlet rise behaves as a weir and another jump may be formed after the pool border .

An analysis was made for the relative depth, length and energy loss as a function of the initial Froude number for different relative pool depths z_1/y_1 starting from $z_1/y_1 = z_2/y_1 = 0.57$ to 3.3 as shown in Fig. (6-a-b and c).

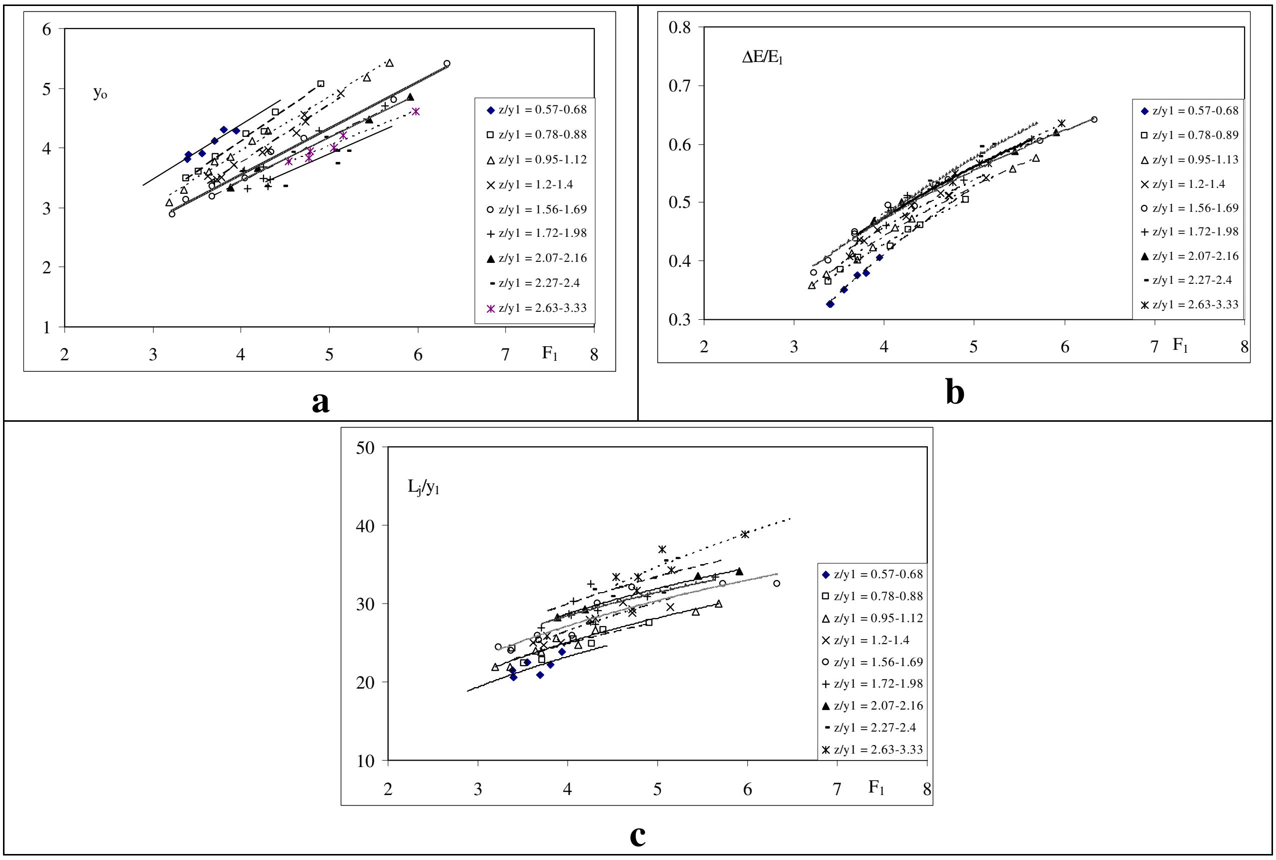

Figure (6): Relationship Between y_o, $\Delta E/E_1$, and L_j/y_1 with F_1 for Different Values of z/y_1

Figure (6-a) shows that, for the same initial Froude number, the relative depth of jump decreases as the relative height of pool z/y_1 increases until the range of values (2.27-2.4), then it tends to have a slight increase.

From Figure (6-b) it can be noticed that the relative energy loss increases by the increase of the relative pool depth z/y_1 until the range (2.27-2.4), then it decreases again.

From Figure (6-c), the relative length of jump increases with the increase of Froude number.

It can be concluded that the best relative pool height is approximately z/y_1 = 2.3. The negative aspect of applying the best result of pool length ratio L_p/L_b=0.4 with the best result from the pool depth/width ratio z_1/B =0.166 is the formation of unstable-nonuniform water surface profile after the border of the pool which may lead to the increase of the length of the basin.

To overcome this problem, minimizing the length of jump, preventing the formation of the wavy water surface profile after the pool border and sloping the pool exit were studied to increase the smoothness of pool border.

5.4. EFFECT OF CHANGING THE POOL OUTLET ANGLE WITH VERTICAL INLET

A study was made by changing the angle of inclination at the pool outlet instead of using a vertical rise and with vertical drop at the pool inlet. The angle of inclination (α_2) ranges from 0.463 to 1.47.

The relations between the relative depth, relative energy loss and relative length with initial Froud number are shown in Figures (7-a-b and c) respectively.

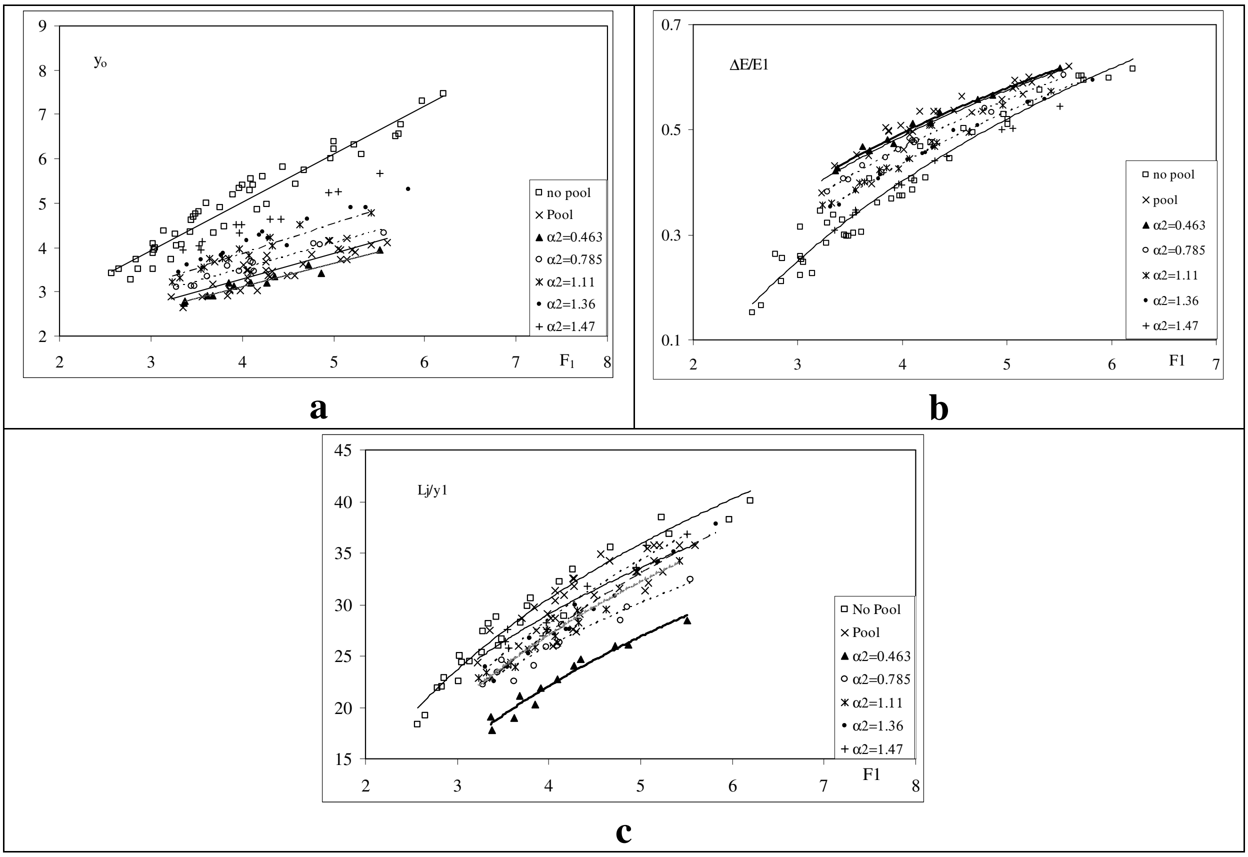

Fig. (7): Relationship Between y_o, $\Delta E/E_1$, and L_j/y_1 with F_1 for Different Pool Outlet Angles.

Figures (7-a-b and c) show the relationship between y_o, $\Delta E/E_1$, L_j/y_1 and F_1 respectively. It is noted that the existence of sloped pool outlet decreases the relative depth and length and increases the relative loss compared to the radial basin without a pool . Moreover, as the angle of slope decreases, the relative depth and length decreases while the relative energy loss increases .

Using α_2 = 0.463 affects considerably the pool performance and stabilize the wavy water surface profile after the border of the pool .

This means that if the slope of the pool at exit is 2 vertical to 1 horizontal, it gives a maximum relative energy loss, minimum relative depth of jump and minimum relative length of jump within the range of this study.

6. CONCLUSIONS

This study is a new technique to control the hydraulic jump by using more than one traditional method. This new technique "the Pool" is defined as a combination between the following techniques:

- Expanding basin.
- Drop in bed level.
- Rise in bed level.
- Sloping pool outlet.

The main conclusions of the study may be summarized as follows:

1- The pool position :
Several pool positions were studied for fixed pool length and depth. It was found that the pool inlet should lie in the range of vena contracta .

2- The length of the pool :
Several pool length ratios were studied for the case of $z_1/B= z_2/B=0.166$, vertical inlet and outlet slopes. The pool length ratio $L_p/L_b=0.4$ gave minimum value for the relative depth of the jump and maximum value of the relative energy loss . The relative jump length was approximately the same as for the radial basin without a pool .

3- The depth of the pool :
Several pool depth ratios were studied for the case of $L_p/L_b=0.4$, vertical inlet and outlet slopes. The pool depth ratio $z/B=0.1667$, $z/y_1=2.27$ gave minimum value for the relative depth of the jump and maximum value of the energy loss . The relative jump length was also approximately the same as for radial basin without a pool.

4- The effect of pool outlet slopes :
Several outlet pool slopes were studied with a vertical pool inlet. The pool with a vertical pool inlet and outlet slope angle of $\alpha_{2r}=0.463$ gave the best jump characteristics within the range of this study .
The best hydraulic design parameters for the pool were $L_p/L_b=0.4$, $z_1/B=z_2/B=0.167$, $z/y_1=2.3$, vertical pool inlet and sloped pool outlet with 1 horizontal to 2 vertical "$\alpha_{2r}=0.463$".

The pool with the best design parameters was compared with other pervious studies which used other energy dissipation techniques. This comparison showed the following conclusions :

1- The relative depth ratio was decreased by using the pool with the best design parameters to 40% of its value compared to the prismatic channel, while using the radial basin without a pool decreases the relative depth by 15% only .

2- The relative energy loss was increased by using the pool with the best design parameters to 21% of its value compared with the prismatic channel .

3- The relative jump length was decreased by using the pool with the best design parameters to 33% of its value compared to the prismatic channel.

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SYMBOLS

Symbol	Definition
b	The bed width at the contracted part
b_1	The channel width at the jump start
b_2	The channel width at the end of the jump
b_3	The channel width at the pool inlet
b_4	The channel width at the pool outlet
B	The flume bed width
B_1	The ratio b_1/B
B_2	The ratio b_2/B
B_3	The ratio b_3/B
B_4	The ratio b_4/B
E_1	The specific energy at the beginning of the jump
E_2	The specific energy at the end of the jump
F_1	The initial Froude number
F_2	The Froude number at the end of the jump
g	Gravitational acceleration
G	The gate opening
h_1	The water depth above the pool inlet edge
h_2	The water depth above the pool outlet edge
h	the differential manometer reading
H_1	The ratio h_1/y_1
H_2	The ratio h_2/y_1
$h_1^{\backslash}$	The water depth above the end of the pool inlet slope
$h_2^{\backslash}$	The water depth above the start of the pool outlet slope
$H_1^{\backslash}$	The ratio $h_1^{\backslash}/y_1$
$H_2^{\backslash}$	The ratio $h_2^{\backslash}/y_1$
L_b	The length of the stilling basin
L_1	The length of the basin in front of the pool inlet
L_p	The pool length
L_j	The length of hydraulic jump
L_r	The length of rollers
P_1	The hydrostatic force at the beginning of the jump
P_2	The hydrostatic force at the end of the jump
P_3	The hydrostatic force at the face of the pool inlet
P_4	The hydrostatic force at the face of the pool outlet
P_s	The hydrostatic side pressure due to gradual expansion
Q	The discharge

q	The discharge per unit width
v_1	The velocity at the beginning of the jump
v_2	The velocity at the end of the jump
y_1	The initial water depth
y_2	The sequent water depth
y_o	The relative depth of jump=y_2/y_1
z_1	The pool depth at inlet
z_2	The pool depth at outlet
α_1	Angle of inclination of pool entrance measured in radian
α_2	Angle of inclination of pool exit measured in radian
β_1	The momentum correction factor at the beginning of the jump
β_1	The momentum correction factor at the end of the jump
ΔE	The energy loss
$\Delta E/E_1$	The initial relative energy loss
π	Non dimensional term
μ	The dynamic viscosity
ρ	The mass density
θ	The expansion angle of the basin
γ	The specific weight