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Abstract: The forced hydraulic jump characteristics were studied experimentally using different configurations of a standard USBR baffle blocks. Each configuration was tested under Froude numbers ranged between 2.27 to 9.2 at which the hydraulic jump located within a description of oscillating and steady jump. Two groups of baffle block models were adopted. The first group installed at one row with two blockage ratios, whereas the second group consisted of two rows; the first was fixed at a specified location after sluice gate, while the second has been installed at three different distance ratio. During each test, the sequent depth and the transverse velocity distribution were measured. The results showed that the sequent depths for all configurations were less than the sequent depth of a classical jump. Among all configurations undertaken, the greater reduction of sequent depth was 30%. The new experimental formula was developed for determining the sequent depth ratio in term of the initial Froude number for this configuration which gives the better performance. The comparisons were also made with the previous relevant studies to show the reliability of the configurations undertaken. The analysis of the experimental results concluded that; when using two rows configuration of standard USBR baffle blocks with a blockage ratio 50% and 37.5%, respectively, and at a specified distances the best performance could be achieved by reducing the sequent depth beside the velocity become nearly uniformly distributed across the width of the basin.

Keywords: Hydraulic jump, Froude number, Baffles block, Blockage ratio, Sequent depth.

1. Introduction

The hydraulic jump is a common phenomenon generally observed in open channel flow especially at toe of hydraulic structures e.g., sluice gates and spillways. This phenomenon divided into two types according to the bed characteristics. The first type is a classical hydraulic jump occur over a smooth bed and has been studied extensively (see, e.g., Peterka (1984); Hager and Bremen (1989); Chanson (2006) on this subject). This type in honor of the first definition and put the relations between its initial and sequent depth, it was named after him as “Belanger equation” in the form;

\[
\frac{y_2}{y_1} = \frac{1}{2} \left( \sqrt{1 + 8Fr_1^2} - 1 \right)
\]

(1)

Where \(y_2\) is the sequent depth or the required tail water to get a free jump over a smooth bed and \(Fr_1\) is the initial Froude number.

The second type is called a forced hydraulic jump, which occurs over a rough bed, and this roughness takes different features and has been studied by many researchers as will be mentioned later.

One of the main applications of a hydraulic jump is dissipating the excess of kinetic energy downstream of the hydraulic structure. The stilling basin is the most common form of structure to contain the hydraulic jump for the purpose of achieving the required dissipation of kinetic energy. Moreover, different roughness can be facilitated at its apron to achieve more dissipation of surplus energy within a shorter distance of the basin apron. There are many devices in order to satisfy these principle criteria such as baffle blocks, sills, roughness elements, corrugated elements, screens, roller buckets, and riprap aprons that are installed into the basin. The standard stilling basin, which use the baffle blocks as a main feature for dissipating the surplus kinetic energy, is introduced in the late 1950’s by Bradley & Peterka and this study was further generalized and published as Reclamation Engineering Monograph No. 25 by Peterka A. J. on September 1958 (last re-print at May 1984). The baffled basin was named “Type III” into this Monograph. Type III stilling basin, according to USBR, is conventionally designed for single discharge, which is usually the design discharge, and provided the tailwater equal the full sequent depth. This basin provided conservative design (Vittal and AL-Garni, 1992; Frizell and Svoboda, 2012). Accordingly, the hydraulic
performance for a range of discharge needs to be tested, and a specific model study is recommended along with consideration for other possible factors such as higher or lower velocities. Flow under gates without need to provide a chute block which potentially leads to bias the hydraulic features outside the guidance of the Type III basin. Thus, different studies have been conducted in order to determine the appropriate characterization for each case of development which took place on this type of basin (e.g., Pillai and Unny, 1964; El-Gawhary et al., 1986; Vittal and AL-Garni, 1992; Eloubaidy et al., 1999; Nabil and Rezak, 2002; Ellayn and Sun, 2012). Most modifications include change in the geometric properties including lengthening the basin (Lueker et al., 2008) and adopting a shape other than the standard for baffle blocks (Eloubaidy et al., 1999; Frizell, 2009). Eloubaidy et al. (1999) adopted a cubic baffle block to investigate their effect of location, relative size, and curvature (in plan) on the hydraulic jump properties and dissipation of energy. It was found that the curved blocks have the efficiency of 3.2% to 33.3% more than a straight edge block for dissipation regarding the excessive kinetic energy for all flow conditions. However, the most effective position of the baffle blocks was 1.3 \( y_2^* \) downstream from the gate, where \( y_2^* \) is the Belanger equation sequent depth. Nabil and Rezak (2002) carried out an experimental study on the baffle block with sloping vertical face arranged at the downstream of a sluice gate, to investigate its effect on the length of the hydraulic jump. The results of this study show that baffle blocks with a sloping front face can reduce the jump's length by approximately 48% compared with the free jump. Ellayn and Sun (2012) used wedge-shaped, not protruding, baffle blocks to find their effect on the hydraulic jump properties. The results show that the reduction in the length of jump and sequent depth ratio were 30% to 50% and 16.5% to 30%, respectively, compared to those with smooth beds. The dynamic manner of this hydraulic field becomes attractive for further studies. In the present study, the try was attempted in order to investigate the effect of blockage ratio with the presence of two rows of baffle blocks on the hydraulic performance. The two rows in contrast to one in the USBR basin to improve the velocity distribution at end of jump (Vittal and AL-Garni, 1992). This study has been conducted with keeping the use of the standard shape of baffle block that recommended by Peterka (1984). The enhancement indicators are the lower sequent depth ratio, \( y_2/y_1 \), the higher deficit, D, the higher dissipation of energy, \( \Delta E/E_1 \), the higher efficiency, \( E_2/E_1 \), and the lower with more uniform in velocity distribution across the width at downstream. The later indicator gives significance to minimizing the chance of scour at the downstream and preventing the concentration at one side which, if it occurs, leads to increasing the likelihood of the collapse.

2. Experimental Program

The experimental investigation was carried out by using a flume available in the fluid laboratory of the Building and Construction Engineering Department at the University of Technology-Baghdad. A cross section of the flume was 0.3 m wide and 0.3 m deep, with a total length 15 m. Steel plate walls were added to the inlet part of the flume to access a high head upstream of the sluice gate. The length of the inlet part of the flume upstream of the sluice gate was 4.06 m with the new working depth up to 0.63 m. A vertical streamlined gate with a sharp beveled lower edge was fixed at the end of the inlet section to control the flow using the hand driven gear system to select a desired opening of the gate between 2 cm and 4 cm. These gate openings along with the range of discharge from 42 m³/hr to 89.4 m³/hr give the initial Froude from 2.72 to 9.2. A Plexiglas sheet 8 mm in thickness was mounted on the bed of the flume as a false floor to facilitate the installation of the baffle block. This false floor extended 1m upstream the gate and 2 m downstream. One set of experiments was performed with a total of 99 runs, using standard-USBR trapezoidal in cross-sectional shape baffle blocks to become a test facility. In each run, when the desired discharge was achieved, the tailgate was gradually adjusted till the hydraulic jump stabilized to the desired location of 10 cm downstream the gate (this distance was selected to achieve a modular flow). The initial depth of the jump, \( y_1 \) is the same as the gate opening where the contracted section below the gate would not occur under the effect of streamlined lip. Some previous researchers also used the streamlined lip gate such as Ead and Rajaratnam (2002), Izadjoo and Shafai Bejestan (2007), Ellayn et al. (2012). The sequent depth was measured by a point gauge with 0.1 mm accuracy at a section just after all eddies fully developed to the water surface and achieved the post jump normal depth. The local velocity was measured at location equal to 0.4 of the depth of the flow over the bed. This measurement was performed for each run to show the feature of the velocity distribution at the downstream transversely. The local streamwise velocity was measured by using a high speed propeller velocity meter with capacity in the range of 0.6 m/s to 3 m/s. The velocity meter connected to the “Armfield H33-10” digital indicator, which gives the frequency of the pulses when the propeller rotates the number of revolutions in a given time, was counted on panel every 10 seconds and recorded in Hertz. When the pulses became steady, they were converted to water velocity using the calibration chart.
In present study the value of Reynold’s number, Re can be neglected because the viscous force, generally, almost has a negligible effect in hydraulic jump and in open channel (Negm et al., 2003; Aboul Atta et al., 2011). Hager and Bremen (1989) introduced the expression that determines whether a scale is effectual or not. This expression is a comparison between the inflow aspect ratio \( \omega \) (equal to the ratio between supercritical flow depth \( y_1 \) and the flume width) and the limiting value \( \omega_L \) which is a function of the Reynold’s and Froude numbers at the incoming flow region (Hager and Bremen, 1989), the absence of scale effect when \( \omega \leq \omega_L \). This indicator was also adopted by Carollo et al. (2007). The limit values \( \omega_L \) of the scale effect according to the gate openings and discharges that were adopted in the experimental work are between 0.088 and 0.736. Since the investigated aspect ratios are between 0.066 and 0.133, the scale effect does not appear as a negative action on the results.

3. Configuration and Arrangement of Standard USBR Baffle Blocks

The shape and dimensions of the baffle block as recommended by USBR at which the upper longitudinal dimension and width of block are selected as a function of block height (Peterka, 1984). The baffle blocks were made from Plexiglas fixed at the height 5 cm for the entire Froude number range, so that the upper longitudinal dimension is 1 cm, the width is 3.75 cm and the length of base is manufactured at 6 cm. The baffles have been arranged at blockage ratio “\( \eta \)” so they do not exceed 0.5. Figure 1 shows the sketch of baffle undertaken. The calculation of the blockage ratio is according to:

\[
\eta = \sum W_b \sum (W_b + S)
\]  

(2)

Where the \( W_b \) is a width of the block, and \( S \) is a clear spacing between the adjacent blocks. It should be noted that the space between the first block and the wall of the flume was equal to 0.5\( W_b \) for each side Figure 2 represents a general sketch of the hydraulic jump over USBR baffle block.

Different configurations have been arranged in single and double rows. The location of the first baffle block from the toe of gate was selected equal to \( X_0/y_2^* = 1.3 \), it was adopted as recommended by Eloubaidy et al. (1999), where the \( X_0 \) related to the sequent depth of jump that was calculated by the Belanger equation. Since the maximum \( y_2^* \) is 17.11 cm according to minimum gate opening and incoming Froude number \( X_0 \) was fixed at 22.24 cm downstream of the gate for all runs undertaken. Two groups of baffle block models were used; the first group is one row of baffles with two blockage ratios, and the second group installed at two rows includes three different distance ratios \( X/b \), where \( X \) is a distance from the front face of blocks of the first row to the front of the second row as illustrated in Figures 3. All of these configurations were installed with different blockage ratios. Table 1 consists of these two groups, and Figure 4 presents the view of configuration-B1 for the two row configuration.

The blockage ratio 37.5 % was used with the two configurations on the single row. The same number of blocks have been used for configurations A2 and A3 but there was a difference in spacing (refer to Figures 5 and 6). The test was performed between these two models in order to select the most efficient one on improving the characteristics of a hydraulic jump such as depth ratio and transverse velocity distribution. The comparison between the results is shown in Figures 7 and 8. It is evident through these figures the better results were achieved by using A3 in terms of reducing the depth ratio and reducing the velocities in width, which provided more uniformity in distribution, especially with the range of Froude number 4.5-9. However, good stability of the hydraulic jump was clearly observed when using A3, while this feature was difficult achieve by using A2. The performance with the configuration of model A3 can be attributed to the closer distance between the baffle blocks of configuration A3 as opposed to the baffle blocks in configuration A2. More turbulence was observed, which lead to the dissipation of more energy and, therefore, reduced sequent depth \( y_2 \). On the other hand, there is a greater possibility to divide the incoming flow to the almost equal sections, suggesting more regularity in distribution of velocity, especially with higher Froude numbers. This efficient performance of configuration A3 lead to its further use in other run series as opposed to using A2.
Figure 1. USBR baffle block (Peterka (1984))

Figure 2. Schematic diagram for forced hydraulic jump

Figure 3. Model arrangement-B2 two rows, $X/b=2$ and $\eta=50\&37.5\%$

Figure 4. Model arrangement-B1 two rows, $X/b=1$ and $\eta=50\&37.5\%$

Figure 5. Model arrangements-A2 one row, $\eta=37.5\ I\%$

Figure 6. Model arrangements-A3 one row, $\eta=37.5\ II\%$

Figure 7. The variation of $y_2/y_1$ with configurations of single row
As mentioned previously, equipping the bed of the channel that contains the hydraulic jump by appurtenances (e.g., baffle blocks) eventually has an appreciable effect through the decrease in the sequent depth ratio \(y_2/y_1\). This decrease is a pointer to the hydraulic performance improvement. Figure 9 shows the variation of the sequent depth ratio \(y_2/y_1\) with the initial Froude number for all models of configurations A and B. In this figure the line that represents the sequent depth ratio of a free jump of Belanger equation is also shown. As observed from the figure, generally, the sequent depth ratio in the rough bed stilling basin (i.e. equipped with baffle block) for all blockage ratios was smaller than that achieved for the classical jump (Belanger equation). However, the configuration-B1 of group B gives a better performance in reducing the sequent depth \(y_2\) compared to the other configurations. The observations refer that this configuration has led to lengthening the roller region. This, consequently, increases the energy dissipation. However, it increases from the length of the stilling basin.

Table 1. Characteristics of the models tested

<table>
<thead>
<tr>
<th>Group</th>
<th>Config.</th>
<th>No. of Rows</th>
<th>No. of runs</th>
<th>Blockage Ratio</th>
<th>Dimensions (cm)</th>
<th>(S_1^*) cm</th>
<th>(S_2^#) cm</th>
<th>(S_3^\€) cm</th>
<th>(S_4^$) cm</th>
<th>(X/b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A1</td>
<td>one row</td>
<td>11</td>
<td>50%</td>
<td>5 6 3.75</td>
<td>1.875</td>
<td>3.75</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>one row</td>
<td>11</td>
<td>37.5%(I)</td>
<td>5 6 3.75</td>
<td>1.875</td>
<td>7.50</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>A3</td>
<td>one row</td>
<td>11</td>
<td>37.5% (II)</td>
<td>5 6 3.75</td>
<td>5.625</td>
<td>3.75</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>B</td>
<td>B1</td>
<td>Two rows</td>
<td>11</td>
<td>50 &amp; 37.5(II)</td>
<td>5 6 3.75</td>
<td>1.875</td>
<td>3.75</td>
<td>5.625</td>
<td>3.75</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>Two rows</td>
<td>11</td>
<td>37.5% (I)</td>
<td>5 6 3.75</td>
<td>1.875</td>
<td>3.75</td>
<td>5.625</td>
<td>3.75</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>Two rows</td>
<td>11</td>
<td>37.5% (II)</td>
<td>5 6 3.75</td>
<td>5.625</td>
<td>3.75</td>
<td>5.625</td>
<td>3.75</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>B4</td>
<td>Two rows</td>
<td>11</td>
<td>25 &amp; 37.5%</td>
<td>5 6 3.75</td>
<td>9.375</td>
<td>3.75</td>
<td>5.625</td>
<td>3.75</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>B5</td>
<td>Two rows</td>
<td>11</td>
<td>37.5% (I)</td>
<td>5 6 3.75</td>
<td>3.75</td>
<td>3.75</td>
<td>5.625</td>
<td>3.75</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>B6</td>
<td>Two rows</td>
<td>11</td>
<td>37.5% (II)</td>
<td>5 6 3.75</td>
<td>3.75</td>
<td>3.75</td>
<td>5.625</td>
<td>3.75</td>
<td>3</td>
</tr>
</tbody>
</table>

\(S_1^*\)=the spacing between block and the wall of flume for the first row
\(S_2^\#\) and \(S_4^\$\)=the spacing between adjacent blocks for the first and second row
\(S_3^\€\)=the spacing between block and the wall of flume for the second row

4. Results and Discussion

4.1. Sequent Depth Ratio

As mentioned previously, equipping the bed of the channel that contains the hydraulic jump by appurtenances (e.g., baffle blocks) eventually has an appreciable effect through the decrease in the sequent depth ratio \(y_2/y_1\). This decrease is a pointer to the hydraulic performance improvement. Figure 9 shows the variation of the sequent depth ratio \(y_2/y_1\) with the initial Froude number for all models of configurations A and B. In this figure the line that represents the sequent depth ratio of a free jump of Belanger equation is also shown. As observed from the figure, generally, the sequent depth ratio in the rough bed stilling basin (i.e. equipped with baffle block) for all blockage ratios was smaller than that achieved for the classical jump (Belanger equation). However, the configuration-B1 of group B gives a better performance in reducing the sequent depth \(y_2\) compared to the other configurations. The observations refer that this configuration has led to lengthening the roller region. This, consequently, increases the energy dissipation. However, it increases from the length of the stilling basin.
The results of configuration-B1 have been compared with the results of those previously presented by Peterka (1984), Eloubaidy et al. (1999) (for curved in plan baffle block) and Ellayn and Sun (2012) (for wedge shaped baffle block). Figure 10 illustrate this comparison and shows the same trend between the results of the present study and those of the previous works. At the same time, however, less sequent depth ratios are clearly associated with using the configuration-B1, which indicates that the hydraulic jump performance improved with the use of this configuration. The percent improvement in the reduction of $y_2/y_1$ relative to the results of Peterka (1984), Eloubaidy (1999), and Ellayn and Sun (2012), are 55%, 20%, and 15%, respectively. Consequently, it could construct a new relationship between the sequent depth ratio and the Froude number for the best configuration-B1 with correlation $R^2$ equal to 0.967;

$$\frac{y_2}{y_1} = 0.8694Fr1 + 0.2035$$

(3)

4.2. Deficit Indicator

In order to show the amount of difference between sequent depth $y_2$ and sequent depth of classical jump $y_2^*$, the dimensionless depth deficit parameter $D$ was used. This parameter indicator was adopted previously by numerous researchers such as Ead and Rajaratnam (2002), Izadjoo and Shafai Bejestan (2007), and Ellayn and Sun (2012) as follows:
As is clear from Eq. (4), the higher the D, the more the sequent depth decreased which is associated with the forced jump. According to a specified configuration, that means there is more improvement in sequent depth parameter. The average deficit indicator was computed for all configurations of baffle blocks and listed in Table 2. The required tail water to achieve a sequent depth, $y_2$ is also listed in the table. It can be deduced that, with using the configuration-B1, the higher D was achieved with less tail water. On the other hand, the worst performance was registered with the use the configuration-B6, as evident from Figure 11 and Table 2. Figure 11 shows the trend variation of the deficit indicator with Fr1 for all configurations undertaken. As seen, generally the variation of D with Fr1 is not constant, unlike shown in the results of Ead and Rajartnam (2002), and Izadjoo and Shafai Bejestan (2007) who indicated that D is almost constant by an average value equal to 0.25 and 0.2 respectively. The comparison of the deficit indicator that resulted from using configuration B1 with the results of Eloubaidy et al. (1999) for curved baffle blocks and Ellyan and Sun (2012) for wedge shaped baffle block are shown in Figure 12. The figure shows the value of D that was obtained by Eloubaidy et al. (1999) in the order of 0.15-0.25 and obtained by Ellyan and Sun (2012) in the order of 0.15-0.3. However, the configuration-B1 induces the higher deficit indicator in the range between 0.2-0.4.

![Figure 11. Variation of the depth deficit parameter D](image1)

![Figure 12. Comparison of deficit indicator with previous studies](image2)

<table>
<thead>
<tr>
<th>Config.</th>
<th>No. of rows</th>
<th>average value of D</th>
<th>The sequent depth required for forced jump by baffle blocks compared with that required for free jump (Belanger equation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>1 row</td>
<td>0.16</td>
<td>$0.84y_2^*$</td>
</tr>
<tr>
<td>A3</td>
<td>1 row</td>
<td>0.12</td>
<td>$0.88y_2^*$</td>
</tr>
<tr>
<td>B1</td>
<td>2 rows</td>
<td>0.30</td>
<td>$0.7y_2^*$</td>
</tr>
<tr>
<td>B2</td>
<td>2 rows</td>
<td>0.20</td>
<td>$0.8y_2^*$</td>
</tr>
<tr>
<td>B3</td>
<td>2 rows</td>
<td>0.18</td>
<td>$0.82y_2^*$</td>
</tr>
<tr>
<td>B4</td>
<td>2 rows</td>
<td>0.20</td>
<td>$0.8y_2^*$</td>
</tr>
<tr>
<td>B5</td>
<td>2 rows</td>
<td>0.13</td>
<td>$0.87y_2^*$</td>
</tr>
<tr>
<td>B6</td>
<td>2 rows</td>
<td>0.10</td>
<td>$0.9y_2^*$</td>
</tr>
</tbody>
</table>

### 4.3. Relative Dissipation of Energy and Efficiency

The higher performance of the forced hydraulic jump can be measured through noting the increase in the amount of kinetic energy dissipation. There are two indicators for its good performance: the relative loss of energy $\Delta E/E_1$ and the efficiency $E_2/E_1$. Where $\Delta E$ is a difference between the specific energy at the supercritical flow before jump $E_1$ (at location of $y_1$) and the specific energy at the subcritical flow after the jump $E_2$ (at location of sequent depth $y_2$). The higher the value of this term the higher the percentage of energy dissipation through the jump. However, the less value of the second indicator refers to better efficiency.
These two indicators have been calculated for all configurations adopted in this study, and the average value for each model is listed in Table 3. As evident from values, that the higher loss of energy with high efficiency has been achieved by using configuration-B1.

Table 3. Average values of the Relative loss of Energy and Efficiency of Force Hydraulic Jump with different Configurations undertaken

<table>
<thead>
<tr>
<th></th>
<th>Single Row</th>
<th>Two Rows</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A1</td>
<td>A2</td>
<td>A3</td>
</tr>
<tr>
<td>%ΔE/E1</td>
<td>53.9</td>
<td>50.8</td>
<td>52.14</td>
</tr>
<tr>
<td>%E2/E1</td>
<td>46.1</td>
<td>49.2</td>
<td>47.87</td>
</tr>
</tbody>
</table>

4.4. Transverse Local Velocity Distribution

The Local velocity at 0.4 y₂ over the flume bed has been measured by the current meter across the flume width at end section of jump (location of y₂) in order to show the feature of velocity distribution transversely. The 99 runs were conducted with baffle block configurations installed for testing. The aim is to get a uniform distribution of velocity across the width at the end of the stilling basin along with the reducing its value. Approaching this aim considered as the positive indicators in terms of minimize the ability of scouring and preventing its negative effect downstream. Figures 13 and 14 illustrate the lateral velocity distribution with different block configurations with the incoming Froude number range of 2.5-4.5 (oscillating jump) and 4.5-9 (steady jump), respectively. Figure 13 shows little disagreement both in the amounts and features of velocity distribution between single and double rows. However, with the double row configurations the velocity tend towards the uniformly distribution across the channel width. The most symmetrical in distribution along with the less amount of velocity registers with the use of configuration-B6 and at a lesser degree, with B2 and B3. Whereas, at a higher Froude number (within a range of steady jump), the inverse situation was observed, the best distribution was registered with configurations-B3 and B2, followed by the configuration-B6, which is illustrated in Figure 14. For the entire range of flow, the velocity distribution when using the configuration-B1 tends to become more uniform across the width despite its values seeming greater than those that were observed with the other configurations. This gives significance to minimizing the chance of scour at the downstream by preventing the concentration of the flow at one side which, if it occurs, leads to increasing the likelihood of the collapse.

\[(a)\text{ Fr}_1=2.72\]  
\[(b)\text{ Fr}_1=3.36\]
Figure 13. Variation of Transverse local velocity with configurations of baffle blocks for oscillating jump Fr1 = (2.72-4.46).

Figure 14. Variation of transverse local velocity with configurations of baffle blocks for steady jump Fr1 = (4.95-9.2).
5. Conclusions

Experimental tests were performed by adopting different configurations of trapezoidal standard USBR baffle blocks with different blockage ratios aimed to develop the hydraulic jump characteristics. In this study, the measurements were focused on the hydraulic jump sequent depth ratio \( y_2/y_1 \) and the transverse distribution of average flow velocity at end of basin for the range of incoming Froude numbers between 2.72 and 9.2. As stated above the following conclusions were found:

1. For all configurations of baffle blocks, the sequent depth ratio increases as the initial Froude number increases. However, all ratios are smaller than those of the classical jump (Belanger equation).

2. It was found that the best configuration of baffle block, which leaned toward the minimum of sequent depth was B1, at which the percent improvement in reducing of \( y_2/y_1 \) relative to the results of Peterka (1984), Eloubaidy (1999) and Ellayn and Sun (2012) are 55\%, 20\%, and 15\%, respectively.

3. More uniformity in the distribution of velocity was achieved when using the B6 Configuration within the range of the pre-jump Froude number 2.72 - 4.46. The configuration-B2 appear more efficient within the steady jump classification when the Froude number ranged between 4.95 and 9.2.

4. Double rows of the baffle block with blockage ratio 50\% and 37.5 \%, respectively, was very effective in improving the properties of the hydraulic jump and, hence, the performance of stilling basin.

6. Acknowledgements

The authors are grateful to the Hydraulic Laboratory of the Building and Construction Engineering for approving the use of the flume and measurement facilities. Appreciation to the laboratory technicians for assistance in preparing models.

7. References


