EFFECT OF BAFFLE BLOCK PARAMETERS ON HYDRAULIC JUMP CHARACTERISTICS

MSC, THESIS

MEKONNEN BEKELE WORKU

MARCH , 2023

HAWASSA, ETHIOPIA

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A THESIS SUBMITTED TO THE SCHOOL OF WATER RESOURCE ENGINEERING, INSTITUTE OF TECHNOLOGY, SCHOOL OF GRADUATE STUDIES, HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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ADVISORS' APPROVAL SHEET

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This is to certify that the thesis entitled "EFFECT OF BAFFLE BLOCK PARAMETERS ON HYDRAULIC JUMP CHARACTERISTICS". Submitted in partial fulfillment of the requirements for the degree of Master's with specialization in hydraulic Engineering, the Graduate Program of Department/School of Hydraulics and Water Resource Engineering, and has been carried out by MekonnenBekele. ID No. GpHydrR/010/12 under my supervision. Therefore, I/we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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DECLARATION

I hereby declare that this M.Sc. thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been properly acknowledged.

Name: ----------------------------------

Signature:

This M.Sc. thesis has been submitted for examination with my endorsement as thesis advisor.

Name:.------------------------------

Signature:

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ABBREVIATION

ADV Acoustic Doppler Velocity-meter

BB Baffle Block

BCW Broad Crest Weir

DS Down stream

HU-IoT Hawassa University Institute of Technology

OCF Open Channel Flume

USBR United States Bureau of Reclamation

US Up stream

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ABSTRACT

The experimental determination of baffle blocks installed on stilling basins has been also utilized to stabilize the formation of the jump and increase the turbulence, there by assisting in the dissipation of energy. The main objective of this study is to assess the effects of baffle block parameters on hydraulic jump characteristics. Investigate the influence of baffle blocks on hydraulic jump properties of flow over a weir, to evaluate the effects of different shapes and arrangements of baffle blocks on hydraulic jump characteristics and identify the best shape and arrangement of baffle blocks increasing efficiency of energy loss. The experimental work was performed in a rectangular flume with a dimension of (14 m* 0.3 m* 0.45 m) long, wide, and deep, respectively with Steel, different shapes of baffle blocks (Trapezoidal, Rectangular, and Triangular) with the dimension of (0.05 m*0.0375 m*0.06 m) height, width and length bed material. The experiment was being tested with various flow rates for different shapes and arrangements to analyze the effect on the sequent depth ratio, energy loss, Froud number, and efficiency. Each shape and arrangement baffle have five discharges that were used to maintain the upstream depth the relationship between the Froude number and the discharge for different baffle depth and different velocity; where the average value of the depth was varied (10mm - 50mm). Froude number decreases (1.92-1.54) with the decreases in the average value of loss of energy (0.20–0.14), as the sequent of depth ratio decreases ($17.85*10^{-3}$–$13.41*10^{-3}$). The relation between Shape of Baffle Block, Energy Dissipation, and efficiency Trapezoidal (32.19, 70.86%), Rectangular (37.35, 83.98%), Triangular (32.03, 67.23%), and Mixed (34.41, 74.08%) respectively. From above clearly shows that rectangular baffle blocks have higher energy dispassion and efficiency which indicate that the energy dispassion and efficiency in row three and four arrangement 4*3*2 and 4*3*2*1 obtained best are energy dispassion (32.77%) and efficiency (83.98%) receptively under rectangular shapes, which is highest from baffle block shapes relatively better than the other baffle block shapes this is due to may be part of energy dissipate increases efficiency. From this observation rectangular baffle blocks are better for energy dissipation since higher efficiency.

Keywords: Hydraulic jump, Froude number, Baffles block, energy dispassion, Sequent depth.

1 INTRODUCTION

1.1 Background Of The Study

Local scour downstream of hydraulic structures such as low head and high head structures is an important research field due to its significant practical value. Different techniques to reduce local scour have been employed in previous studies by making use of splitter plates or collars. In the same context, baffle blocks installed on stilling basins have been also utilized to stabilize the formation of the jump and increase the turbulence, thereby assisting in the dissipation of energy. (Alireza H., 2013)

A hydraulic jump is one of the main applications to dissipate the excess kinetic energy downstream of the hydraulic structure. There are many devices to dissipate energy 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, use the baffle blocks as the main feature for dissipating the surplus kinetic energy. For low flow, baffle blocks help to compensate for a slight deficiency of tail water, and for high flow, they help to deflect the flow away from the river bed. The employment of baffles may help reduce the tail water depth required and also in shortening the basin length. Baffle blocks should be used in the stilling basin even if they are not required to form a stable hydraulic jump. Baffle blocks help to ensure good hydraulic jump action for unbalanced spillway gate operation or submerged conditions occurring at discharges greater than those for which the stilling basin is designed. There are many types and shapes of baffles that have been used and served their intended purpose. As with various types of baffles, many arrangements can be made with the floor blocks. (Maatooq&Jaafar 2018)

1.2 Statement Of The Problem

Local scour downstream hydraulic structures may result in damage or complete structural failure and loss of life and property. Baffle blocks are easily be used as an extra element to existing water structures to minimize local scour downstream these structures by creating hydraulic jump whereas it is rarely being used in the practical world. The absence of baffle blocks in the broad crested weir will make the downstream apron long, eroded, and scored. It will also lead the structure to fail. Also to be economical, different runs have to be carried out considering various shapes and positions of baffle blocks with different flow conditions. 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 the need to provide a chute block which potentially leads to bias in the hydraulic features outside the guidance of the Type III basin.

1.3 Objective

1.3.1 General Objective

The main objective of the study is to assess the effects of baffle block parameters on hydraulic jump characteristics.

1.3.2 Specific Objectives

- To investigate the influence of baffle blocks on hydraulic jump properties of flow over a weir.
- To evaluate the effects of different shapes and arrangements of baffle blocks on hydraulic jump characteristics.
- To identify the best shape and arrangement of baffle blocks increasing efficiency of energy loss.

1.4 Research Question

- What are the influences of baffle blocks on hydraulic jump properties of flow over a weir?

- How do the shape and arrangement of baffle blocks on hydraulic jump characteristics?
- What is the best shape and arrangements of baffle blocks to blocks increase the efficiency of energy loss?

1.5 Scope Of The Study

The hydraulic jump can affect downstream aprons in the different structures like Dam, weirs, and barrage. Even if the effects of hydraulic jump can be measured in different forms, the research will be restricted to the baffle block and its shape.

1.6 Significance Of The Study

In many cases, constriction of hydraulic structures downstream of weirs is not used regardless of their importance. So, the study will give an idea for the design and construction of baffle blocks to dissipate kinetic energy and also design and construct economic structures. Also, the result of the study will be used for the renovation of previously constructed dams, weirs, and barrages.

2 LITERATURE REVIEW

2.1 Apparatus Structure Downstream Of The Structure

The major function of a hydraulic project is to alter the natural behavior of a water body by concentrating its flow fall. It is intended for purposeful use for the benefit of the national economy and to protect the environment, including electric power generation, flood control, water supply, silt mitigation, navigation, irrigation and draining fish handling and farming, ecologic protection, and recreation. Commonly, many hydraulic structures of general or special purposes are constructed to form a single or integrated hydraulic project to comprehensively serve the foregoing purposes (Zuo DQWang Wet, 1987)

Measurement of discharge in open channels is difficult because of no uniform channel dimensions and variations in velocities across the channel. Weirs allow water to be routed through a structure of known dimensions, permitting flow rates to be measured as a function of the depth of flow through the structure. Baffles, which were energy dissipaters, were installed the downstream of fixed weir and movable weir in multiple directions and the hydraulic experiment (Lee, J. 2016)

The purpose of studying of effect of baffle blocks on hydraulic jump characteristics is to determine the hydraulic performance of baffle-post structures, simple hydraulic structures of possible use in controlling flow, and bed-sediment transport in open channels. Baffle-post geometry influences the headloss and discharges coefficients associated with flow through baffle-post structures and, relatedly, the increase in approach flow depth associated with such structures (Cho, S. 2015).

2.2 Baffle Blocks

Baffle blocks are many normally identical elements arranged in one or several rows orientated perpendicular to the direction of flow. Whereas a sill generates an overflow of the main current, blocks force the water both between the obstacles and above it. The standard stilling basin, which uses the baffle blocks as the main feature for dissipating the surplus kinetic energy, is introduced in the late 1950s by Bradley &Peterka

The baffled basin was named “Type III” in this Monograph. Type III stilling basin, according to USBR, is conventionally designed for single discharge, which is usually the design discharge, and provided the tail water equals the full sequent depth. This basin provided a conservative design (Vittal and AL-Garni, 1992; Frizell and Svoboda, 2012).

Most modifications include the 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 the effect of location, relative size, and curvature curved on the hydraulic jump properties and dissipation of energy. However, the most effective position of the baffle blocks was 1.3 y2* downstream from the gate, where y2* is the sequent depth.

Nabil and Rezak (2002) carried out an experimental study on the baffle block with a sloping vertical face arranged 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 was 30% to50% and 16.5% to 30%, respectively, compared to those with smooth beds. Several investigations have been carried out to determine the properties of hydraulic jump including, the length of the jump, the sequent depth ratio, and the energy dissipation.

2.3 Broad-Crested Weir

A broad-crested weir is an overflow structure with a horizontal crest above which the deviation from a hydrostatic pressure distribution because of centripetal acceleration may be neglected. It is also a robust structure that is generally constructed from reinforced concrete and which usually spans the full width of the channel. They are used to measure the discharge of rivers and are much more suited for this purpose than the relatively flimsy sharp-crested weirs. (R Z Al-Zubaidy et. al. 2016)

2.4 Hydraulic Jump

Hydraulic jump is the transition phenomenon from supercritical flow to subcritical flow, which is generally observed in an open channels, such as rivers and spillways. The most important applications of the hydraulic jump in open channels are dissipation of energy, mixing of chemicals, and aeration of flows. A jump formation in the open channels with smooth bed conditions (classic jump) and roughened beds has been widely investigated by many researchers. Shaker A. et.al. (2015). Hydraulic jump has extensively been studied in the field of hydraulic engineering. It is an intriguing and interesting phenomenon that has caught the imagination of many researchers since its first description by Leonardo da Vinci. Italian engineering in 1818 is credited with the first experimental investigation of the hydraulic jump (Chow, 1959).

From above clearly shows that rectangular baffle blocks have higher energy dispassion and efficiency which indicate that the energy dispassion and efficiency in row three and four arrangement 4*3*2 and 4*3*2*1 obtained best are energy dispassion (32.77%) and efficiency (83.98%) receptively under rectangular shapes, which is highest from baffle block shapes relatively better than the other baffle block shapes this is due to may be part of energy dissipate increases efficiency. From this observation rectangular baffle blocks are better for energy dissipation since higher efficiency.

Whenever energy dispersal is required, the stream should be either redirected or decelerated previously being let out of the scattering structure. If this energy decrease isn't achieved successfully disintegration of the downstream channel or harm to the water-powered design could happen.

The most well-known method for causing this energy misfortune is by utilization of a water-powered bounce. Upstream of the pressure-driven bounce there are elevated degrees of motor energy because of the great speed of water leaving the water-driven structure. This elevated degree of energy is decreased by moving dynamic energy to possible energy and by violent dissemination. The exchange to potential energy should be visible to the expansion top to bottom downstream of the leap in the subcritical segment of the stream. 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 the need to provide a chute block which potentially leads to bias in the hydraulic features outside the guidance of the Type III basin. Thus, different studies have been conducted to determine the appropriate characterization for each case of development that took place in 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 the 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 the effect of location, relative size, and curvature curved (in plan) on the hydraulic jump properties and dissipation of energy. It was found that the curved blocks have an efficiency of 3.2% to 33.3% more than a straight edge block for dissipation regarding the excess 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 a sloping vertical face arranged 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 was 30% to50% 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 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 the jump (Vittal and AL-Garni, 1992). This study has been conducted in keeping the use of the standard shape of baffle block 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, $\Delta E/E1$, the higher efficiency, $E2/E1$, and the lower with more uniform 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.

2.4.1 Jump Length

To determine the length of the apron and height of sidewalls for a stilling basin, the length of the hydraulic jump must be determined. It is difficult to determine the length of the hydraulic jump due to its complex and random flow patterns. The formation of rollers and eddies, air entrainment, and a highly turbulent flow surface make the beginning and end of the jump difficult to locate. For practical applications, experimental data have been summarized in a non-dimensional form relating to the approach Froude number, Fr1, and L/y1 or L/y2, where L =length of the jump (Chaudhry, 1993)

They conducted extensive experimental tests and introduced four types of hydraulic jump stilling basins; USBR types I, II, III, and IV. In addition, a SAF stilling basin similar to the USBR type III basin has been tested. In these types, the main problem which is caused by the flow impacting the floor block is the cavitation problem which causes the damage to the basin. Bestawy (2013) studied the effects of various shapes of baffle piers downstream of a spillway model on the dissipating water energy downstream and the scour hole. Results showed that the models with concave surfaces had better performance than other models discussed in his research, where this model had low turbulence intensity in recirculation zone downstream baffle piers and dissipated more energy than other models, which led to a stable hydraulic condition and shorter stilling basins. In an attempt to develop economic stilling basin structures, Hughes and Flack (1984) carried out experimental tests on hydraulic jumps over a bed of block elements and found that boundary layers would develop faster and the jump dimensions would decrease considerably. Mohamad Ali (1991) performed a series of experiments on a rough bed using cubed block elements and found that the hydraulic jump length is reduced, ranging from 27.4% to about 67.4% for F1ranging from 4 to 10. Alhamid (1994) conducted experiments on a horizontal rectangular channel bed using rough wooden blocks over a fixed length with different densities. Ead et al. (2000) performed tests on turbulent open channel flow and conducted hydraulic jump tests on a bed of trapezoidal-shaped corrugated roughness. Their results indicated that the integrated shear force in a rough bed is ten times that in a smooth bed. However, the studies of Ead et al. (2000), Ed and Rajaratnam (2002), and Izadjoo and Shafai-Bejestan (2007) indicated that if the rough elements are placed on the bed, the jump occurs above the rough elements. In another word, if the crest of the rough element is just below the lower level of the incoming jet, the elements would not protrude into the flow and will not cause any cavitation. Therefore, it is the purpose of this study to investigate the effects of semicircular shapes of artificially rough elements on the sequent depth and length of hydraulic jumps.

2.4.2 Hydraulic Jump Forms

Energy absorption characteristics vary for different hydraulic jump forms. Therefore it is important to be able to classify the hydraulic jump into distinct forms. The hydraulic jump may occur in at least four different distinct forms on a horizontal apron.

Pre jump ($1 < Fr1 < 2.5$). For $1 < Fr1 < 1.7$, y1 and y2 are approximately equal to each other, and only a slight ruffle is formed on the surface. This undulation results in very little energy dissipation. However, as Fr1 approaches 1.7, many small rollers are formed on the water surface, although the downstream water surface remains smooth.The energy loss is again low in this jump.
Oscillating jump ($2.5 < Fr1 < 4.5$) the jet at the entrance to the jump oscillates from the bottom to the top at an irregular period. Turbulence may be near the channel bottom at one instant and at the water surface the next. These oscillations result in the formation of irregular waves, which may persist for long distances downstream of the jump. They may cause considerable damage to the channel banks. Therefore, this range of Fr1 should be avoided while designing an energy dissipater.
Steady jump ($4.5 < Fr1 < 9$). For this range, the jump forms steadily at the same location and the position of the jump are least sensitive to the downstream flow conditions. The jump is well balanced and energy dissipation is considerable.
Strong jump ($Fr1 > 9$). In this case, the difference between the conjugate depths is large. At irregular intervals, slugs of water roll down the front of the jump face into the high-velocity jet and generate additional waves. The jump action is very rough and the dissipation rate is high (Chaudhry, 1993).

2.5 Benefits Of Hydraulic Jump

One of the main applications of a hydraulic jump is dissipating the excess kinetic energy downstream of the hydraulic structure. The stilling basin is the most common form of structure to contain the hydraulic jump to achieve the required dissipation of kinetic energy. There are many devices 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 (Maatooq, Jaafar 2018).

Wuand Rajaratnam (1996), Bessaih and Rezak (2002), and Afzal and Bushra (002) have developed various analytical and empirical models from the experimental studies for hydraulic jump characteristics. Debabecheand Achour (2007) experimentally investigated the effects of both the thin-crested and the broad-crested sills on the characteristics of the hydraulic jumps in a horizontal symmetric triangular channel. Alikhaniet and al.(2010), have proposed design criteria for an estimation of the stilling basin length without consideration of tailwater. Mohamed Ali (1991) carried out a series of experiments to study the effect of roughened beds using cube blocks, Ali found that the length of the hydraulic jump was reduced by around 27 to 67% for a Froude number range of 4 to 10.

2.6 Hydraulic Performance

The essential action of a baffle-post structure is to retard an approach flow, slowing it, spreading it, and dissipating a portion of its energy. The main requirement of application interest for baffle-post structures located in alluvial channels is an increase in water depth immediately upstream of structures. A depth increase is associated with retarding the approach flow to reduce the flow’s capacity to transport bed sediment (Caroline U. Ubing 2015).

Associated with this critical flow depth is a critical width, defined as the maximum contraction the flow can pass through it without becoming choked. In other words, any constrictions narrower than this will produce an “overcritical” contraction so that there is not enough energy to maintain the given flow rate through the constriction.

According to Jain (2001), Hydraulic jump at the adverse bed slope represent an unstable phenomenon that generates some difficulty in the controlling it, previous studies showed that the hydraulic jump at adverse slopes greater than (- 0.025) is impossible to control, and other studies showed an impossible to keep the jump completely on the adverse slope.

There are many types and shapes of baffles that have been used and served their intended purpose. Because of the many variables, no one solution may be applicable for all conditions. As with various types of baffles, many arrangements can be made with the floor blocks. It should be noted that sufficient water will not pass between the blocks if they occupy too much of the floor width. When the blocks occupy too much of the floor space, they tend to act like a sill more than individual blocks (Hydraulics Research Institute, National Water Research Centre. 2013).

Supercritical flow, in which the Froude number is greater than unity, can be transformed into a subcritical flow through a hydraulic jump. This rapid transformation occurs when the tail water depth is equal to the subcritical sequent depth of the incoming supercritical flow. The hydraulic jump under these circumstances is called a free hydraulic jump and this flow has been studied extensively.(Mignot and Cienfuegos 2010).

The transition from a high-velocity flow to a slow one is associated with high turbulence generated at the shear interface between the forward flow and the backward surface roller which helps in dissipating the excess energy of the supercritical flow. As a result, the hydraulic jump is a beneficial phenomenon and an efficient energy dissipater (Chow 1959).

2.7 Tail Water

If the tail water depth is less than the subcritical sequent depth, the jump will be swept out of the basin, resulting in scour of the downstream channel. However, when the tail water depth is greater than the subcritical sequent depth, the jump will become submerged. It has been observed that when the submergence of the jump increases, jet mixing decreases. This results in less dissipation of energy compared to free jumps, and the decay of the high-velocity jet is retarded. Stilling basins below low-head structures are often required to operate under submerged conditions, and as a result, submerged jumps often occur in basins designed for free jumps (Rajaratnam 1967. et.al)

3 MATERIALS AND METHODS

3.1 Study Area Description

Experimentswasconductedundercontrolledlaboratory conditionsinHydraulicLaboratory of Hawassa University to find out the effects of baffle block parameters on hydraulic jump characteristics in open channel flow. This study investigation was conducted in a straight simple rectangular channel with a uniform cross-section built-in side metallic flume. The flume is 0.3 m wide and 0.45 m deep, with a total length of 14 m. The slope of the flume was a fixed constant of 0% for all runs. The geometrical parameters of the experimental channel are shown in Table3.1. Steel plate walls were added to the inlet part of the flume to access a high head upstream of the sluice gate.

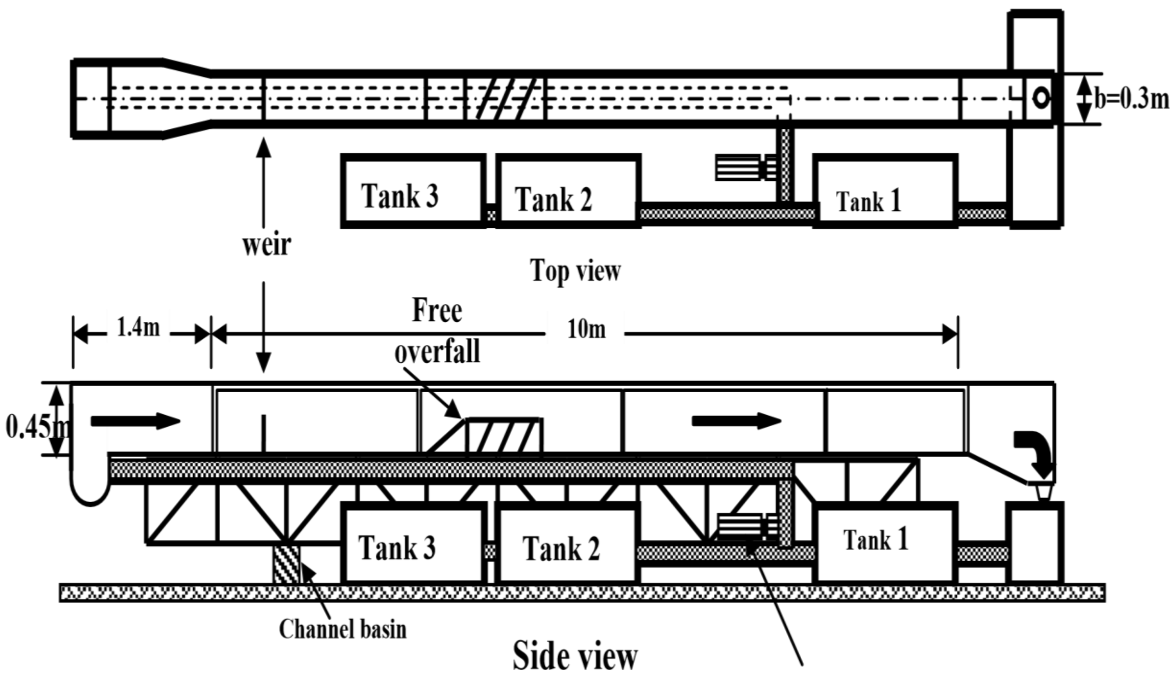


Figure 3-1: Plan view of the experimental channel

Table 3-1 Geometrical Parameter of the Experimental Channel section

S.NO	Item description	Experimental channel
1	Channel type	Straight
2	Geometry of channel section	Rectangular
3	Channel base width (B)	0. 3 m
4	Top width of channel (B)	0. 3 m
5	Depth of channel (H)	0.45 m
6	Bed slope of the channel (S)	0 %
7	Length of whole channel	14m
8	Experimental section Length	10m
9	Nature of surface of bed	Rough, rigid baffle block

3.2 Water Supply System

Waterfortheexperimentwassuppliedfromsurfacetanktowhichawaterlevelindicator is attached to show the maintaining of constant water level in the overhead tank. A pump was installed for surface pumping water from the tank. Water was delivered from the 3 tanks, passing over the experimental channel under gravity, and made to fall onto the volumetric tank situated at the end of the flume.

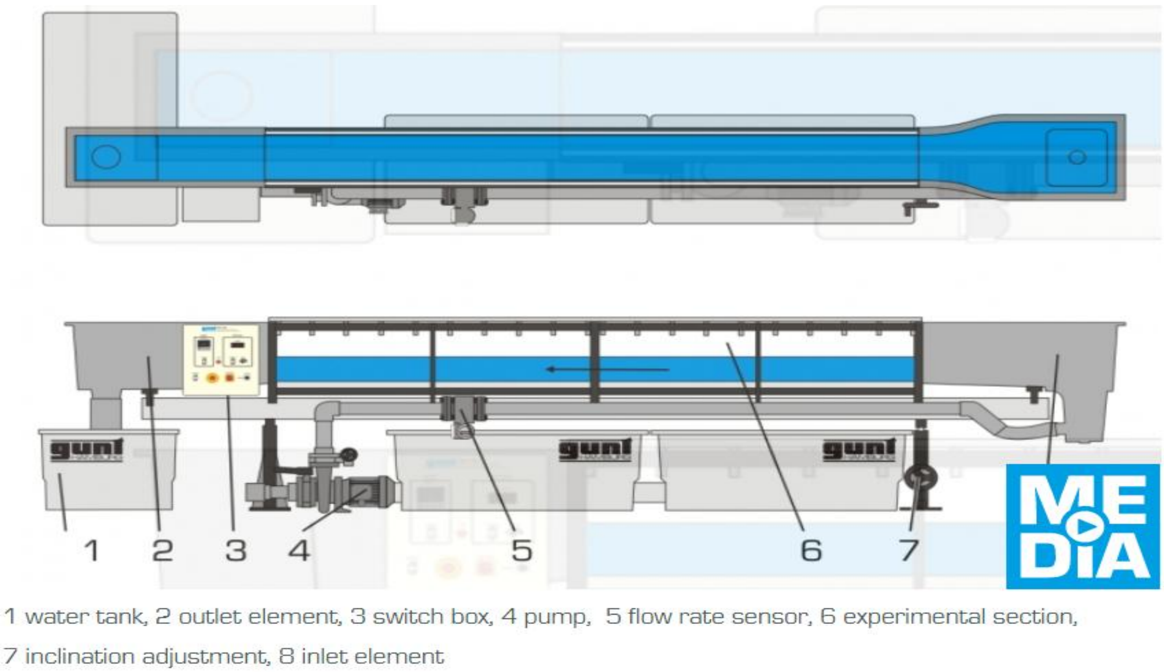


Figure 3-2 Open Channel Tilting flumes (gunt)

3.3 Weir Used For The Study

The model weir used for this study was25cm high, 30cm wide, and 65cm long. The interchangeable crests of the model have a thickness of 0.02m. The model was located at a given distance from the flume’s entrance section and was knotted to the flume’s bottom and glass walls to prevent water infiltration along with the connections.

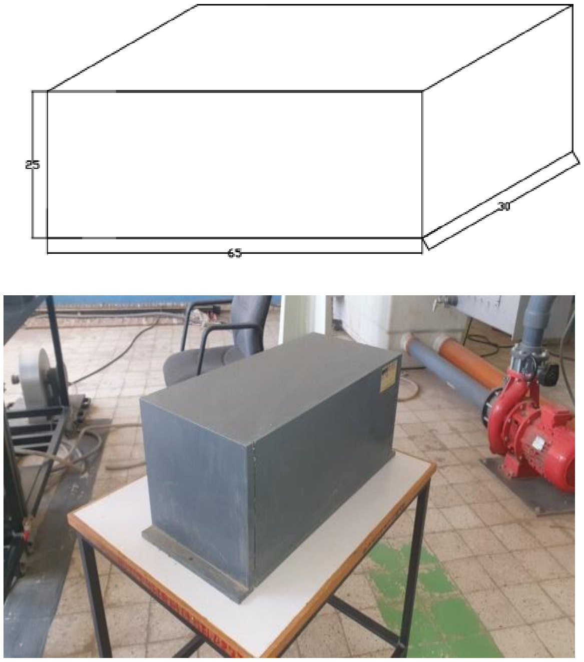


Figure 3-3 Broad Crested Weir

3.4 Design And Construction Of Baffle Block

The shape and dimensions of the baffle block as recommended by USBR at which the upper longitudinal dimension and width of the block are selected as a function of block height (Peterka, 1984). The baffle blocks were made from mortar fixed at the height of 5 cm for the entire Froude number range, so that the upper longitudinal dimension is 1cm, the width is 3.75 cm and the length of the base is manufactured at 6 cm. The baffles have been arranged at a blockage ratio “η” so they do not exceed 0.5. The calculation of the blockage ratio is according to; (7th International Symposium on Hydraulic Structures Aachen, Germany, 15-18 May 2018)

$$\eta=\sum Wb/\sum(Wb+S) \quad (3.1)$$

Where:

Wb is the 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 0.5Wb for each side of the baffle as shown in Figure3.4.A general sketch of the hydraulic jump over USBR baffle block for Different configurations has been arranged in single and double rows. The location of the first baffle block from the toe of the gate was selected equal to X0/Y2*= 1.3, where X0 is a distance from the gate to the first row of baffle blocks illustrated in Figures 3.4 the X0 related to the sequent depth of jump that was calculated by the Belanger equation. Since the maximum Y2* is 17.11 cm, where Y2* is a gate opening according to minimum gate opening and incoming Froude number was recommended by Eloubaidy et al. (1999), hence X0 was fixed at 22.24 cm downstream of the gate for all runs undertaken.

Figure 3-4 baffles block Model arrangement

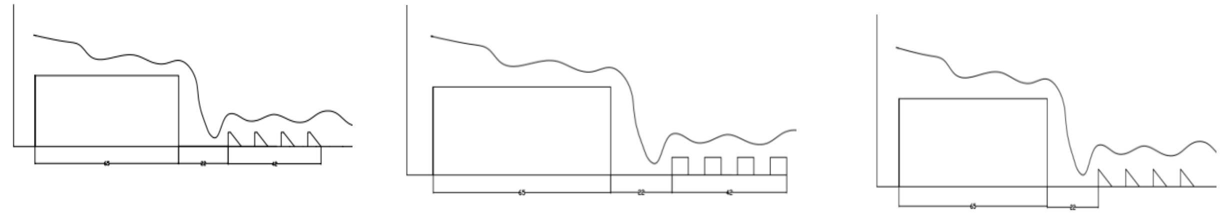
For this study, trapezoidal concrete with dimensions of 0.05*0.06*0.0375m, rectangular block concrete 0.05*0.06*0.0375m and triangular block 0.05*0.06*0.0375m were used to simulate baffle blocks.The blocks were pinned in to sheet metal plat and thus are attached to the flume bed.The top of the block averaged 0.05m above the surface of the sheet metal plate bed for all baffle bocks.Staggered pattern of block arrangement in the bed of open channel with spacing of 3.75 cm was used as shown infig.3.3.A testr each of length64.24 cm in the center of the tiltin ghydraulic flume were situated with a concrete block which simulates the baffle block zone. Sufficient water was not passed between the blocks if they occupy too much of the floor width, as they tend to act like a sill more than individual blocks.

Table 3-2Detailed geometrical features of the baffle block elements

S.No.	Elements	Description
1	Type	Rigid
2	Shape	Trapezoidal, rectangular and triangular
3	Length (L)	0.06 m
4	Height	0.05 m
5	Width	0.0375 m
6	Material	concrete
7	Distribution pattern	Staggered
8	Spacing	0.06 m longitudinal
9	No. of blocks	10
10	Test reach dimension	0.3 * 0.6424m

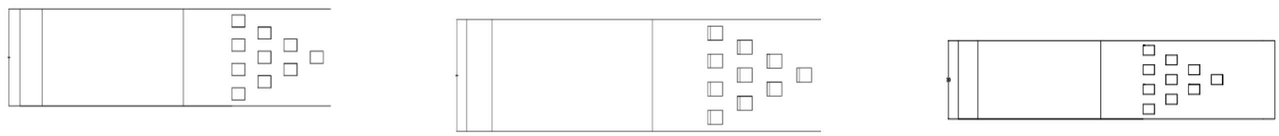
(a)Tripezodial block (b) Rctangular block (c) Triangular block

Figure 3-5 USBR baffle block for all configuration



(a)Tripezodial block (b) Rctangular block (c) Triangular block

*Figure 3-6*Schematic diagram for forced hydraulic jump side view



(a)Tripezodial block (b) Rectangular block (c) Triangular block

Figure 3-7Model Arrangement of Standard USBR Baffle Blocks top view

3.5 Experimental Procedure

3.5.1 Apparatus And Methodology

Main parameters measured during the experiment were discharge,bed slope, depth of flow, velocity of flow, and sequent depths, critical depth, hydraulic jump length, relative energy loss, and efficiency. Depth of flow in the channel was measured using a point gauge fitted to the travelling bridge operated manually having leastcountof0.1 mm. Point velocities were measured using a current meter or ADV(AcousticDopplerVelocity-meter) at a number of locations across the pre-defined channel section.Measuring devices used include flow meter, current meter, and point gauge. Both flow meter and current meter were electromagnetic type. The flow meter used for measuring the flow discharge has ±1% accuracy. The current meter used for measuring the flow velocity has ±2% accuracy. The point gauge used for adjusting the water level at the upstream and downstream gates has ±0.1mm accuracy. Dischargeinthechannelwasmeasured by the time rise method.The water flowing out at the down stream end of the experimental channel wasted to a volumetric tank of 1.6 cubic meters, which are three of the same volume. The change in the depth of water with time was measured by a stop watch in a glass tube indicators with a scale having least count of 0.1mm. The bed slope was set by adjusting the whole structure, tilting it up wardsand down wards with the help of a lever.

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Figure 3-8 Preparation of baffle block and arrangement model

Figure 3-9Photographsofexperimentalarrangementwithbaffle block modeling open channel flume.

3.5.2 Calculation Of Bed Slope

Throughout tofindoutthe channel bed slope, the tailgate of the flume was closed, and the channel was ponded with water.Thedepthofwateratthetwoendpointsalongthecenterlineoftest reach was measured with the help of a point gauge having least count of 0.1mm.The point gauge was attached to the travelling bridge,with which the point gauge was a bleto move in transverse as well a sinlongitudinal direction of the channel.The slope ofthe bed was found out by dividing the difference in depthof water at two ends of the testr each by the test length. For this study horizontal flume was seated along a straight line hence the slope was taken as constant

3.5.3 Discharge Measurement

A volumetric tank located at the end of channel receives water flowing through the channels. Dependingontheflowrate,the time of collection of water in the volumetric tank gets varied;lower value of time Change in the mean water level in the tank over the time interval was recorded. From the knowledge of the volume of water collected in the measuring tank and the corresponding time of collection,the discharge flowing in theexperimentalchannelforeachrunwasobtained.Simultaneously,the depth of water flowing in the channel was also measured by the point gauge.

3.5.4 Measurement Of Velocity Using Currentmeter

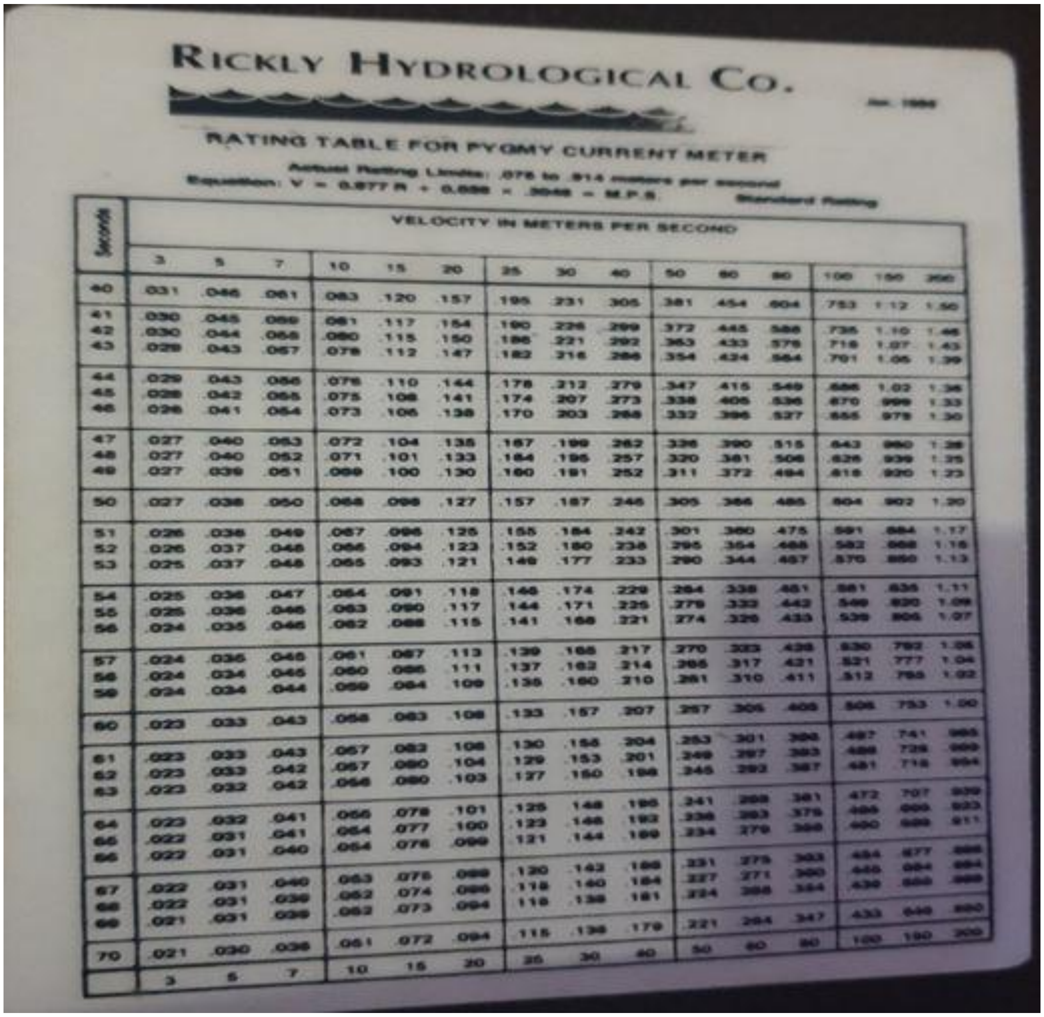
Velocity at various longitudinal distances along the path perpendicul arto flow direction measured by mechanical current meter, experimental runs in the vegetated open channel under both emergent and submerged cases.Velocities were measured at every 0.1 h intervals where his the flow depth. These measured values of velocities were used to plot velocity profiles and the values were used for study of velocity distributions.

Figure 3-10Mechanical Current Meter with accessory (Hu-IoT laboratory)

This small,light weight mechanical current velocity meter has a measuring range of approximately0.1m/sec.to7.9m/sec.Themeterisusedforcurrentvelocitymeasurements in rivers,channels,sewage systems,pipes,etc.Suspendedfromawire the meter canbe applied at great depth.The meter is balanced in such away that it will remaininahorizontal position even if the meter for instance is pulled at speed by aline.The propeller is linked directly to a six digit counter that registers and visualizes every single rotation of the propeller,similar to the mileage counterin car. The counteris placed within the instrument. After retriev alitis possible to read the over all number of rotations of the propeller on the counter through a clear synthetic window. The meter can be mounted to a wire as well as to a telescopicrod(with an extended length of 2.4 meter).The velocity at different stage will computed and measured byVelocity scale curve for both low and high curren trotor(*Eijkelkamp,model2030).*

Using head phone and counting number of blow,can measure the velocity at different depth of channel,and to get the value of velocity can use the calibrated table 3.3.

Table 3-3Mechanical Current Meter



RICKLY HYDROLOGICAL CO.

RATING TABLE FOR PYGMY CURRENT METER

Actual Rating Limits: .076 to .914 meters per second

Standard Rating

Seconds	3	5	7	10	15	20	25	30	40	50	60	80	100	150	200
	VELOCITY IN METERS PER SECOND														
40	.031	.046	.061	.083	.120	.157	.195	.231	.305	.381	.454	.604	.753	1.12	1.50
41	.030	.045	.060	.081	.117	.154	.190	.226	.299	.372	.445	.588	.735	1.10	1.46
42	.030	.044	.058	.080	.115	.150	.186	.221	.292	.363	.433	.576	.718	1.07	1.43
43	.029	.043	.057	.078	.112	.147	.182	.216	.286	.354	.424	.564	.701	1.05	1.39
44	.029	.043	.056	.076	.110	.144	.178	.212	.279	.347	.415	.549	.686	1.02	1.36
45	.028	.042	.055	.075	.108	.141	.174	.207	.273	.338	.405	.536	.670	.999	1.33
46	.026	.041	.054	.073	.106	.138	.170	.203	.268	.332	.396	.527	.655	.979	1.30
47	.027	.040	.053	.072	.104	.135	.167	.199	.262	.326	.390	.515	.643	.960	1.28
48	.027	.040	.052	.071	.101	.133	.164	.195	.257	.320	.381	.506	.628	.939	1.25
49	.027	.039	.051	.069	.100	.130	.160	.191	.252	.311	.372	.494	.616	.920	1.23
50	.027	.038	.050	.068	.098	.127	.157	.187	.246	.305	.366	.485	.604	.902	1.20
51	.026	.038	.049	.067	.096	.125	.155	.184	.242	.301	.360	.475	.591	.884	1.17
52	.026	.037	.048	.066	.094	.123	.152	.180	.238	.295	.354	.466	.582	.868	1.16
53	.025	.037	.048	.065	.093	.121	.149	.177	.233	.290	.344	.457	.570	.850	1.13
54	.025	.036	.047	.064	.091	.118	.146	.174	.229	.284	.338	.451	.561	.835	1.11
55	.025	.036	.046	.063	.090	.117	.144	.171	.225	.279	.333	.442	.549	.820	1.09
56	.024	.035	.046	.062	.088	.115	.141	.168	.221	.274	.326	.433	.539	.806	1.07
57	.024	.035	.045	.061	.087	.113	.139	.165	.217	.270	.323	.428	.530	.792	1.06
58	.024	.034	.045	.060	.086	.111	.137	.162	.214	.265	.317	.421	.521	.777	1.04
59	.024	.034	.044	.059	.084	.109	.135	.160	.210	.261	.310	.411	.512	.765	1.02
60	.023	.033	.043	.058	.083	.108	.133	.157	.207	.257	.306	.406	.506	.753	1.00
61	.023	.033	.043	.057	.083	.106	.130	.156	.204	.253	.301	.396	.497	.741	.985
62	.023	.033	.042	.057	.080	.104	.129	.153	.201	.249	.297	.393	.489	.729	.969
63	.023	.032	.042	.056	.080	.103	.127	.150	.198	.245	.292	.387	.481	.718	.954
64	.023	.032	.041	.056	.078	.101	.125	.148	.195	.241	.288	.381	.472	.707	.939
65	.022	.031	.041	.054	.077	.100	.123	.146	.192	.236	.283	.375	.466	.696	.923
66	.022	.031	.040	.054	.076	.099	.121	.144	.189	.234	.279	.369	.460	.686	.911
67	.022	.031	.040	.053	.075	.098	.120	.142	.186	.231	.275	.363	.454	.677	.898
68	.022	.031	.039	.052	.074	.096	.118	.140	.184	.227	.271	.360	.446	.664	.884
69	.021	.031	.039	.052	.073	.094	.116	.138	.181	.224	.268	.354	.439	.656	.869
70	.021	.030	.038	.051	.072	.094	.115	.136	.179	.221	.264	.347	.433	.646	.860
	3	5	7	10	15	20	25	30	40	50	60	80	100	150	200

From the above table, these commonly used current meters convert velocity into counts of rotations. Conventional meters are of two general types the propeller type with the horizontal axis of rotation and the conical cup type with a vertical axis. The relationship between the velocity of the water and the number of revolutions per unit of time for various velocities is determined for each instrument by experiment. Individual meters of models that have had long and extensive use without structural or mechanical changes can use previous experimental calibrations with confidence.

Governing equations

The relationship between depths (sequent depths) in a hydraulic jump. Head loss through the jump and the energy equation for the jump are given by (Roberson et al, 1995) for rectangular channels:

$$y_2/y_1 = \frac{1}{2}\left(\sqrt{1+8Fr_1^2}-1\right) \text{--} (3.4.1)$$

$$\frac{v_1^2}{2g} + y_1 = \frac{v_2^2}{2g} + y_2 + h_L \text{---} (3.4.2)$$

$$h_L = \frac{(y_2-y_1)^3}{4y_1y_2} \text{---} (3.4.3)$$

Where y1 and y2 are the upstream and downstream depths respectively, V1 and V2 are the

upstream and downstream velocities and Fr1 is the upstream Froude number. The Froude number, Fr, is a dimensionless parameter and is important in establishing similitude between the model and prototype. The Froude number is given as:

$$Fr = \frac{V}{\sqrt{gy}} \text{---} (3.4.4)$$

Where: Fr, is the Froude number, V and y are the velocities and hydraulic depth and g is the acceleration due to gravity.

Q=VA -- (3.4.5)

Where: V, Velocity (m/s); Q, discharge (m3/s); A, Area (m^2)

q =Q/B --- (3.4.6)

Where: Q discharge, q discharge, B Width of channel

$$\Delta E = E_1 - E_2 \text{---} (3.4.7)$$

Where: E1 before energy, E2 after energy, ΔE change energy

$$\frac{\Delta E}{E_1} * 100\% \qquad (3.4.8)$$

Where: E1 before energy, ΔE change energy

$$Y_c = (\frac{q^2}{g})^{\frac{1}{3}} \qquad (3.4.9)$$

Where: q discharge, Yc critical depth, g is the acceleration due to gravity.

The length of a hydraulic jump is the length between the two sections where one section is taken before the hydraulic jump and the second section is taken after the hydraulic jump. For a rectangular channel, the length of the hydraulic jump is found to be 5 to 7 times that of the height of the hydraulic jump. For this study length of a hydraulic jump is L jump = 6hj=6*(y2-y1)

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4 RESULTS AND DISCUSSIONS

4.1 GENERAL

In this study, based on standard experimental procedure, the determination of baffle blocks on hydraulic jump properties in open channel flow had been carried out to different shapes and arrangements of baffle blocks on hydraulic jump characteristics. Also to identify the best shape and arrangement of baffle blocks, increasing efficiency of energy loss in open channel flow had been determined

4.2 Effect Of Baffle Block Arrangement On Hydraulic Jump Parameter

Effect of baffle block arrangement based on sequent depth ratio from experimental laboratory contacted in open channel with different baffle block arrangement i.e.; 4, 4*3, 4*3*2, 4*3*2*1 with different arrangement of blocks the sequent depth ratio presented in below table

Table 4-1 Baffle Block Arrangement Based on Sequent depth ratio

	Row	**The average value of the row**					
		Arrangement	Triangular	Rectangular	Trapezoidal	mixed	Better
Y2/Y1	1	4	$13.44*10^{-3}$	$14.42*10^{-3}$	$14.65*10^{-3}$	$14.11*10^{-3}$	
	2	4*3	$13.82*10^{-3}$	$14.65*10^{-3}$	$14.98*10^{-3}$	$14.55*10^{-3}$	
	3	4*3*2	$13.41*10^{-3}$	$16.19*10^{-3}$	$14.82*10^{-3}$	$15.15*10^{-3}$	$13.41*10^{-3}$
	4	4*3*2*1	$13.96*10^{-3}$	$17.85*10^{-3}$	$14.94*10^{-3}$	$16.17*10^{-3}$	

As it is presented in table 4.1, arrangement for sequent depth ratio, row one has 4 arrangements of baffle block from those the best and most effective arrangements are rectangular, trapezoidal, and mixed, and also row three has a 4*3*2 arrangement. The effective arrangement of these rows is triangular. Generally, from the arrangements shown on the table, the best result is the triangular shape of row three (4*3*2).

According to an experimental study finding by Ali Abbas et al. in the laboratory of fluid mechanics, Baghdad, 2018 on the Effect of baffle block configurations on characteristics of hydraulic jump in adverse stilling basins, the average reduction, in this case, reaches about 18.3%. As per the excremental conducted on the effect of baffle block arrangement with barer shape and row i.e. triangular shape, rectangular shape, trapezoidal shape, and mixed shape with aligned with different arrangement i.e. 4, 4*3, 4*3*2 and 4*3*2*1, the triangular shape in row three: 4*3*2 baffle block arrangement calculating sequent depth ratio (Y2/Y1) result is $13.41*10^3$ the average reduction is 13.67%.

In case of implantation of the hydraulic structure i.e. Dam, Weir, Barrage construction, etc., the sequent depth ratio Y2/Y1 reduction indicates the length of the hydraulic jump also reduce this implies associate different merit such as economical in cost, prevent surface scouring and also minimized the erosion of soil in downstream of the hydraulic structure.

4.2.1 Effect Of Baffle Block Arrangement Based On Energy Loss

To determine the energy loss of hydraulic jump with deferent baffle block arrangement in (4, 4*3, 4*3*2, 4*3*2*1) excremental investigation of open channel flume, the energy loss result was calculated and the output is presented in the following table 4.2.

Table 4-2Baffle Block Arrangement Based on Energy Loss

		The average value of the row					
	Row	Arrangement	Triangular	Rectangular	Trapezoidal	mixed	Better
ΔE	1	4	0.20	0.18	0.17	0.19	0.20
	2	4*3	0.18	0.17	0.16	0.18	
	3	4*3*2	0.19	0.14	0.17	0.16	

The arrangement for energy loss which is presented in table 4.2 depicts that row one has 4 arrangements of baffle blocks. From these, the best and most effective arrangements are triangular, rectangular, trapezoidal, and mixed and also row three has a 4*3*2 arrangement, the effective arrangements of these row are trapezoidal; i.e. from the total arrangements shown in the table, the best result is arrangement four (0.20) of triangular shape.

4.2.2 Effect Of Baffle Block Arrangement Based On Fround Number With Efficiency

With the different arrangements of baffle blocks (4, 4*3, 4*3*2, 4*3*2*1), experimental investigation of open channel flume with constant slope (0%), the Froud number and efficiency determined value are presented in the following table 4.3.

Table 4-3 Baffle Block Arrangement Based on Fround number with Efficiency

			The average value of the row				
	Row	Arrangement	Triangular	Rectangular	Trapezoidal	mixed	Batter
Fr	1	4	1.90	1.80	1.78	1.84	
	2	4*3	1.83	1.78	1.72	1.79	
	3	4*3*2	1.89	1.64	1.73	1.71	
	4	4*3*2*1	1.85	1.54	1.92	1.65	1.92
%E2/E1	1	4	62.65	67.86	67.81	65.59	
	2	4*3	66.29	67.97	70.86	67.91	
	3	4*3*2	67.23	74.89	69.97	71.62	
	4	4*3*2*1	42.43	83.98	70.71	74.08	83.98

On the arrangement presented in Table 4.3 for Froud number, row one has 4 arrangements of baffle block. From those, the best and most effective arrangements are triangular, rectangular, and mixed, and also row four has a 4*3*2*1 arrangement. The effective arrangements of this row are trapezoidal. As a result, efficiency discussion row two has a 4*3 arrangement of baffle block. From those, the best and most effective arrangements are trapezoidal and also row three has 4*3*2 arrangements. The effective arrangement is triangular and row four has a 4*3*2*1 arrangement; the effective arrangements for this row are triangular and mixed. As above desiccation, row four is beset arrangement (4*3*2*1) both for Froud number under trapezoidal shape (1.92) and efficiency under rectangular shape (83.98%).

4.3 Shape Of Baffle Block On Hydraulic Jump Parameter

With the different shapes of baffle blocks (Triangular, Rectangular, Trapezoidal, and mixed), experimental investigation of open channel flume with constant slope (0%) the sequent depth ratio, Froud number, energy dispassion, and effeminacy determined value is presented in the following table 4.4

Table 4-4 the relationship between sequent depth ratio, Energy loss, Froud number, and Efficiency

	The average value of the row					
	Row	Triangular	Rectangular	Trapezoidal	mixed	Better
Y2/Y1	1	$13.44*10^{-3}$	$14.42*10^{-3}$	$14.65*10^{-3}$	$14.11*10^{-3}$	
	2	$13.82*10^{-3}$	$14.65*10^{-3}$	$14.98*10^{-3}$	$14.55*10^{-3}$	
	3	$13.41*10^{-3}$	$16.19*10^{-3}$	$14.82*10^{-3}$	$15.15*10^{-3}$	$13.41*10^{-3}$
	4	$13.96*10^{-3}$	$17.85*10^{-3}$	$14.94*10^{-3}$	$16.17*10^{-3}$	
ΔE	1	0.20	0.18	0.17	0.19	0.20
	2	0.18	0.17	0.16	0.18	
	3	0.19	0.14	0.17	0.16	

	4	0.18	0.09	0.16	0.14	
Fr	1	1.90	1.80	1.78	1.84	
	2	1.83	1.78	1.72	1.79	
	3	1.89	1.64	1.73	1.71	
	4	1.85	1.54	1.92	1.65	1.92
%ΔE/E1	1	18.18	37.35	32.19	34.41	37.35
	2	32.03	33.71	29.14	32.09	
	3	25.11	32.77	30.03	28.38	
	4	25.91	32.11	29.29	25.92	
%E2/E1	1	62.65	67.86	67.81	65.59	
	2	66.29	67.97	70.86	67.91	
	3	67.23	74.89	69.97	71.62	
	4	42.43	83.98	70.71	74.08	83.98

According to JammalS.mokkiet et al. (2019)., the highest efficiency (~55%) in dispersing energy when coppered with other proposed configurations. As it is presented in the above table 4.4, in the experimental laboratory test conducted on baffle blocks with different shapes and arrangement the highest efficiency and energy dissipation attend in the rectangular shapes of baffle blocks with 4*3*2*1 arrangement in row four (~83.98%) and (~37.35 %).

4.3.1 Rectangular Shape Of Baffle Block On Hydraulic Jump Parameter

To determine the energy loss of hydraulic jump with deferent baffle block shapes in (Triangular, Rectangular, Trapezoidal, and mixed) excremental investigation of open channel flume, the energy loss result is calculated and the amount is present in the following table (Table 4.5).

Table 4-5 The Rectangular shape relationship between sequent depth ratio, Energy loss, Efficiency and Energy dissipation

Row	Y2/Y1	ΔE	Fr	%ΔE/E1	%E2/E1
1	$14.42*10^{-3}$	0.18	1.80	37.35	67.86
2	$14.65*10^{-3}$	0.17	1.78	33.71	67.97
3	$16.19*10^{-3}$	0.14	1.64	32.77	74.89
4	$17.85*10^{-3}$	0.09	1.54	32.11	83.98

As it is demonstrated from the entire test runs which are shown in table 4.5, sequent depth ratio and Froude number are obtained for different hydraulic conditions i.e., increasing sequent depth ratio with increasing baffle block row and Froud number are decreasing with increasing baffle block row.

The sequent depth ratio of a free jump shown, generally, the sequent depth ratio in the rough bed stilling basin for all blockage ratios was smaller than that achieved for the Pre jump. However, the rectangular shape has better performance in reducing the sequent depth ratio (Y2/Y1) 14.42*10-3compared to the other row of configurations and Froud number was 1.80 Pre jump.

($1 < Fr < 2.5$). For 1 Fr1 < 1.7, y1 and y2 are approximately equal to each other, and only a slight ruffle is formed on the surface. This undulation results in very little energy dissipation. However, as Fr1 approaches 1.7, some small rollers are formed on the water surface, although the downstream water surface remains smooth. The energy loss is again low in this jump.

According to Vischer and Hager (1995), as the degree of submergence increases, the jump becomes less efficient, translating into a reduced capacity to dissipate energy. From a design standpoint, the submerged hydraulic jump presents the advantage of developing a reduced sensitivity to tail water variations being on fine to the same downstream region, in comparison with the free hydraulic jump which displaces along the downstream region as a function of the local tail water level. However the submerged hydraulic jump is a less efficient mechanism to dissipate energy and consequently, the downstream region affected by the jump is larger in comparison with the free jump. As a result, a longer stilling basin must be considered if the downstream is working under submerged conditions (Habibzadeh, 2013).

The observation that this configuration has led to lengthening the roller region. This, consequently, increases the energy dissipation. As is demonstrated in the above table (Table 4.5) in row one, the rectangular shape of the baffle has better energy dissipation than the other rows (37.35%). The higher performance of the forced hydraulic jump can be measured by noting the increase in the amount of kinetic energy dissipation. The relative loss of energy ΔE and the efficiency %E2/E1 where ΔE is a difference between the specific energy at the supercritical flow before jump E1 (at the location of y1) and the specific energy at the subcritical flow after the jump E2 (at the location of sequent depth y2).The higher the value of this term, the higher the percentage of energy dissipation through the jump. The higher dissipation of energy (37.35%) with high efficiency (83.98%) has been achieved by using the rectangular shapes of baffles.

According to Abbas et al. (2018) describe the energy dissipation ratio (ΔE /E1) is reduced by using the adverse slope instead of the horizontal slope, but using the double row of the baffle model (D) at the adverse slope to increase the efficiency of the stilling basin and to convert the energy dissipation reduction to benefit, the average gaining the slope (-0.06) ratio (ΔE/E1) reaches about 10.7% when using a double slope model (D) baffle instead of a smooth horizontal bed. But Jaafar and Maatooq (2018) reported that the double rows of the baffle block with a blockage ratio of 50 % and 37.5 %, respectively, were very successful in improving the hydraulic jump properties and, thus, the quieting basin efficiency.

Table 4.5 presented that result by the constant slope (0%) open channel with a single row of the baffle block arrangements of energy dispassion ratio (%ΔE/E1) is 37.35%. However, the efficiency with single row rectangular shape baffle block arrangement is 67.86%, and also at row four baffle block arrangement decreases by 14.02%. Yet it enhances the efficiency of rectangular shape baffle block with four-row by 23.75%.

4.4 Identify arrangements, shape, and efficiency of baffle block on hydraulic parameter

Summarized experimental laboratory result effect of baffle blocks arrangement and shape on hydraulic parameter result is presented in table 4.6 as follows.

Table 4.6 arrangements, shape, and efficiency of baffle block hydraulic Parameter

Shape	Baffle Block Arrangement and Row															
	One Row				Tow Row				Three Row				Four Row			
	4				4*3				4*3*2				4*3*2*1			
	Y2/Y1	%ΔE/E1	Fr	%E2/E1	Y2/Y1	%ΔE/E1	Fr	%E2/E1	Y2/Y1	%ΔE/E1	Fr	%E2/E1	Y2/Y1	%ΔE/E1	Fr	%E2/E1
Triangular	13.44	18.18	1.90	62.65	13.82	32.03	1.83	66.29	13.41	25.11	1.89	67.23	13.96	16.02	1.85	42.43
Rectangular	14.42	37.65	1.80	67.86	14.65	33.71	1.78	67.97	16.19	32.77	1.64	74.89	17.85	32.11	1.54	83.98
Trapezoidal	14.65	32.19	1.78	67.81	14.98	29.14	1.72	70.86	14.82	30.03	1.73	69.97	14.94	29.29	1.92	70.71
Mixed	14.11	34.41	1.84	65.59	14.55	32.09	1.79	67.91	15.15	28.38	1.71	71.62	16.17	25.92	1.65	74.08

On the Table above (Table 4.6), the general result for all shapes and arrangements of baffle block is described for sequent depth ratio, Energy dissipation, Froud number, and efficiency i.e on row one arrangement 4 best result of Froud number is obtained (1.9) under triangular shape,

on row three arrangement, 4*3*2 obtained best sequent depth ratio result (13.41) under triangular shape and for row three and four arrangement 4*3*2 and 4*3*2*1 obtained best are energy dispassion (32.77%) and efficiency (83.98%) receptively under rectangular shapes. From this study, the best shape of baffle block for better result of energy dissipation and efficiency rectangular shape is recommended with the arrangement of baffle block 4*3*2*1 in row four.

Energy dissipaters for energy reduction at the sluice gate were found to dissipate energy by more than 50% per unit length compared with the non-dissipater installation status if installed at a 10% height of the average river water depth in a location as far as approximately 70% of the average river water depth. Although the sluice gate-type movable weir showed similar hydraulic jump lengths to those of the fixed weir, its supercritical flow length increased, so its length to the hydraulic jump start point rose considerably. For this reason, it is deemed that aprons for bed protection from scouring need to be 2–4 times sufficiently longer by considering the Froude numbers upon discharge. Regarding hydraulic jump or the energy dissipation issues of sluice gate-type movable weirs, when movable-weir downstream water level differences grow larger or the discharge flow increases, their openness height should be elevated ($Fr < 2.5$) to protect the downstream area (Bhowmik 1971). In the same manner, the present study also revealed that, as demonstrated in table 4.6 ($Fr = 1.90$), less Froud number can protect the downstream section of the channel.

Concerning rectangular baffle blocks with Froude number for different rows and arrangements which accompany huge hydraulic changes, (Bhowmik 1971) rectangular energy dissipaters (baffle blocks), presented different types of energy dissipaters and examined each of their energy dissipation performances(MacDougall .et. al 1983) reported that partially submerged baffle bloc dissipaters showed approximately a 50%

reduction in scour depth compared with the completely submerged flow, whereas its scour length increased by 25%–50%. Yoon et al. (1995) analyzed the scour hole characteristics in a free-falling jet generated by drop structure dependent upon the existence of rectangular baffle blocks in their weir experiment. They found that if a density Froude number increased, not only the equilibrium scour depth the flow velocity at the weir discharge jump to the post-hydraulic jump velocity to suggest the maximum scour depth. The researchers proposed that the maximum scour depth appeared at a distance amounting to two times as far as the maximum scour depth from the scour start. They also suggested that scour-caused riverbed variation could be observed up to 5–7 times longer than the maximum scour the length and 3–4 times wider than the maximum scour depth. And also reported that scour depths decreased as downstream water levels increased. Noshi (1999) measured velocity changes at the river bottom to assess the energy dissipation of end sills in spillway flow. The researcher analyzed downstream hydraulic jump lengths and suggested they were approximately 2.3 times as long as the downstream water level (Goelet.al., 2003) performed a hydraulic experiment and proposed a new shape of energy dissipater (wedge-shaped block) as a way to reduce the jet flow discharged through culverts. The researchers also stated that formed energy rectangular baffle block dissipaters were more useful than the triangular and trapezoidal dissipaters in energy dissipation.

The energy dissipation ratio ($\Delta E / E1$) was reduced by using the adverse slope instead of the horizontal slope but using the double row of the baffle model (D) at the adverse slope to increase the efficiency of the stilling basin and to convert the energy dissipation reduction to benefit, the average gaining the slope (-0.06) ratio ($\Delta E/E1$) reaches about 10.7% when using a double slope model (D) baffle instead of a smooth horizontal bed. But Jaafar and Maatooq (2018) show that the double rows of the baffle block with a blockage ratio of 50 % and 37.5 %, respectively, were very successful in improving the hydraulic jump properties and, thus, the quieting basin efficiency (Abbas et al 2018).

The present study also found that in row three arrangement 4*3*2 obtained the best sequent depth ratio result (13.41) under triangular shape and for rows three and four arrangements 4*3*2 and 4*3*2*1 obtained the best are energy dispassion (32.77%) and efficiency (83.98%) receptively under rectangular shapes. From this study, the best shape of baffle block for better result of energy dispassion and efficacy rectangular shape is recommended with the arrangement of baffle block 4*3*3*1 in row four.

5 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The baffle bocks downstream were provided for experiment with increasing water flow rate, velocity, and area cross-section. To estimate the energy dissipation, sequent depth ratio and efficiency of baffle blocks with a variation of discharge and flow depth were applied upstream of the broad crest weir. The sequent depth ratio increased as the discharge changed from one row to four rows in each baffle block and changed in depth. Both discharge and velocity increased as the depth of flow changed from each stage the flow. The property of hydraulic sequent depth ratio increased as discharge and baffle blocks increased in each arrangement and shape of baffle blocks while the energy loss varies for each flow depth and baffle block shape. The loss of energy and percentage dissipation of baffle blocks decreases as efficiency and sequent ratio depths increase. The best baffle blocks in channel flow were the rectangular shape of baffle blocks which has higher efficiency and energy dispassion. The results verified that Froud number decreases as the sequent depth ratio increases. The relation between the shape of baffle Block, Energy Dissipation, and efficiency Triangular (32.03, 67.23%), rectangular (37.35, 83.98%), trapezoidal (32.19, 70.86%), and mixed (34.41, 74.08%) respectively. It was observed from the result that the present study also obtained that on row three arrangement 4*3*2 obtained best sequent depth ratio result (13.41) under triangular shape and for row three and four arrangement 4*3*2 and 4*3*2*1 obtained best are energy dispassion (32.77%) and efficiency (83.98%) receptively under rectangular shapes. From this study, the best shape of baffle block for better result of energy dispassion and efficacy rectangular shape is recommended with the arrangement of baffle block 4*3*2*1 in row four.

5.2 RECOMMENDATION

This study is about the experimental determination of the effect of baffle blocks on hydraulic jump characteristics (sequent depth ratio, Froud number, energy dispassion, and efficiency) for different selected shapes and arrangements of baffle blocks of the artificial rectangular channel (flume) model. The experimental channel (flume) is limited in the artificial rectangular channel, discharge amount and does not consider natural channels like meandering form of channel and prototype apparatus for comparison of field and laboratory results because of budget constraints to perform this action. Based on the findings of the study and conclusions made, the following recommendations are forwarded.

- ✓ The new and pervious hydraulic structure (dam, weir, and culverts) designs shall consider baffle blocks and flow up to their implementation during construction;
- ✓ To find the different hydraulic parameters at the wide range of discharges and flow depths, bed slopes and different shapes of baffle blocks and characteristics like height, thickness, and putting patterns need to be taken into account;
- ✓ Researchers shall consider the different arrangements of baffle blocks;
- ✓ Future research works may consider meandering channel form and natural channel for determination of the effect of baffle block on hydraulic jump characteristics.
- ✓ Finally, it is recommended that before using the hydraulic jump characteristics in the field, must be calibration in the laboratory for determination of hydraulic jump characteristics on their baffle block is very important to increasing the flow rate and life span of the hydraulic structure

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7 ANNEX

Annex A: Experimental data

Table A.1. Valueofmodel Arrangement Of Standard USBR Baffle Blocks Trapezoidal

Four Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	60	1.46	0.390	0.3	0.003	0.00438	0.0146	0.11864	0.06775	0.05089	42.8944707	7.24295E-06	4.661421	0.50834	300
2	20	70	1.39	0.366	0.3	0.006	0.00834	0.0278	0.11848	0.07683	0.04165	35.1536124	2.62603E-05	3.138089	0.477058	300
3	30	75	1.34	0.332	0.3	0.009	0.01206	0.0402	0.12152	0.08062	0.0409	33.6570112	5.49113E-05	2.470072	0.432741	270
4	40	100	1.33	0.320	0.3	0.012	0.01596	0.0532	0.13016	0.10522	0.02494	19.1610326	9.61685E-05	2.123182	0.4171	360
5	50	110	1.30	0.311	0.3	0.015	0.01950	0.065	0.13614	0.11493	0.02121	15.5795505	0.000143561	1.856196	0.405369	360

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge,

E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Three Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	60	1.46	0.390	0.3	0.003	0.00438	0.0146	0.11864	0.06775	0.05089	42.89447	7.24295E-06	4.661421	0.50834	300
2	20	70	1.39	0.366	0.3	0.006	0.00834	0.0278	0.11848	0.07683	0.04165	35.15361	2.62603E-05	3.138089	0.44167	300
3	30	75	1.34	0.332	0.3	0.009	0.01206	0.0402	0.12152	0.08062	0.0409	33.65701	5.49113E-05	2.470072	0.387055	270
4	40	95	1.33	0.326	0.3	0.012	0.01596	0.0532	0.13016	0.10042	0.02974	22.8488	9.61685E-05	2.123182	0.329142	330
5	50	110	1.30	0.311	0.3	0.015	0.01950	0.065	0.13614	0.11493	0.02121	15.57955	0.000143561	1.856196	0.299385	360

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge,

E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Two Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	60	1.46	0.390	0.3	0.003	0.00438	0.0146	0.11864	0.06775	0.05089	42.89447	7.24295E-06	4.661421	0.50834	300
2	20	70	1.39	0.366	0.3	0.006	0.00834	0.0278	0.11848	0.07683	0.04165	35.15361	2.62603E-05	3.138089	0.44167	300
3	30	80	1.34	0.344	0.3	0.009	0.01206	0.0402	0.12152	0.08603	0.03549	29.20507	5.49113E-05	2.470072	0.38831	300
4	40	95	1.33	0.326	0.3	0.012	0.01596	0.0532	0.13016	0.10042	0.02974	22.8488	9.61685E-05	2.123182	0.337692	330
5	50	110	1.30	0.311	0.3	0.015	0.01950	0.065	0.13614	0.11493	0.02121	15.57955	0.000143561	1.856196	0.299385	360

One Row

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	60	1.46	0.390	0.3	0.003	0.00438	0.0146	0.11864	0.06775	0.05089	42.89447	0.0146	4.661421	0.50834	300
2	20	70	1.39	0.366	0.3	0.006	0.00834	0.0278	0.11848	0.07683	0.04165	35.15361	0.0278	3.138089	0.44167	300
3	30	75	1.34	0.354	0.3	0.009	0.01206	0.0402	0.12152	0.08062	0.0409	33.65701	0.0402	2.470072	0.412703	270
4	40	90	1.33	0.332	0.3	0.012	0.01596	0.0532	0.13016	0.09562	0.03454	26.53657	0.0532	2.123182	0.353331	300
5	50	100	1.30	0.326	0.3	0.015	0.01950	0.065	0.13614	0.10522	0.03092	22.71191	0.065	1.856196	0.329142	300

discharge, E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Table A.2. Value Of Model Arrangement Of Standard USBR Baffle Blocks Rectangular

Four Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	70	1.46	0.381	0.3	0.003	0.00438	0.0146	0.11864	0.07740	0.04124	34.76062	0.0146	4.661421	0.459771	360
2	20	80	1.39	0.360	0.3	0.006	0.00834	0.0278	0.11848	0.08661	0.03187	26.89905	0.0278	3.138089	0.406371	360
3	30	100	1.34	0.332	0.3	0.009	0.01206	0.0402	0.12152	0.10562	0.0159	13.08427	0.0402	2.470072	0.3352	420
4	40	120	1.33	0.311	0.3	0.012	0.01596	0.0532	0.13016	0.12493	0.00523	4.018132	0.0532	2.123182	0.286639	480
5	50	130	1.30	0.290	0.3	0.015	0.01950	0.065	0.13614	0.13429	0.00185	1.358895	0.065	1.856196	0.256798	480

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge, E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Three Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	65	1.46	0.372	0.3	0.003	0.00438	0.0146	0.11864	0.07205	0.04659	39.27006	0.0146	4.661421	0.465856	330
2	20	75	1.39	0.360	0.3	0.006	0.00834	0.0278	0.11848	0.08161	0.03687	31.11918	0.0278	3.138089	0.419698	330
3	30	90	1.34	0.344	0.3	0.009	0.01206	0.0402	0.12152	0.09603	0.02549	20.97597	0.0402	2.470072	0.366102	360
4	40	100	1.33	0.323	0.3	0.012	0.01596	0.0532	0.13016	0.10532	0.02484	19.0842	0.0532	2.123182	0.326113	360
5	50	110	1.30	0.311	0.3	0.015	0.01950	0.065	0.13614	0.11558	0.02056	15.1021	0.065	1.856196	0.299385	360

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge, E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Two Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	60	1.46	0.390	0.3	0.003	0.00438	0.0146	0.11864	0.06775	0.05089	42.89447	0.0146	4.661421	0.50834	300
2	20	70	1.39	0.366	0.3	0.006	0.00834	0.0278	0.11848	0.07683	0.04165	35.15361	0.0278	3.138089	0.44167	300
3	30	75	1.34	0.354	0.3	0.009	0.01206	0.0402	0.12152	0.08139	0.04013	33.02337	0.0402	2.470072	0.412703	270
4	40	90	1.33	0.332	0.3	0.012	0.01596	0.0532	0.13016	0.09562	0.03454	26.53657	0.0532	2.123182	0.353331	300
5	50	100	1.30	0.326	0.3	0.015	0.01950	0.065	0.13614	0.10542	0.03072	22.56501	0.065	1.856196	0.329142	300

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge, E1 before energy, E2 after energy, ΔE change energy, Yccritical depth, Fr fraud number

One Row

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	60	1.46	0.390	0.3	0.003	0.00438	0.0146	0.11864	0.06775	0.05089	42.89447	0.0146	4.661421	0.50834	300
2	20	65	1.39	0.372	0.3	0.006	0.00834	0.0278	0.11848	0.07205	0.04643	39.18805	0.0278	3.138089	0.465856	270
3	30	75	1.34	0.354	0.3	0.009	0.01206	0.0402	0.12152	0.08139	0.04013	33.02337	0.0402	2.470072	0.412703	270
4	40	90	1.33	0.332	0.3	0.012	0.01596	0.0532	0.13016	0.09562	0.03454	26.53657	0.0532	2.123182	0.353331	300
5	50	105	1.30	0.320	0.3	0.015	0.01950	0.065	0.13614	0.11022	0.02592	19.03922	0.065	1.856196	0.315298	330

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge, E1 before energy, E2 after energy, ΔE change energy, Yccritical depth, Fr fraud number

Table A.3. Value Of Model Arrangement Of Standard USBR Baffle Blocks Triangular

Four Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	55	1.46	0.396	0.3	0.003	0.00438	0.0146	0.11864	0.06299	0.05565	46.90661	0.0146	4.661421	0.539112	270
2	20	60	1.39	0.381	0.3	0.006	0.00834	0.0278	0.11848	0.06739	0.05109	43.1212	0.0278	3.138089	0.496609	240
3	30	80	1.34	0.363	0.3	0.009	0.01206	0.0402	0.12152	0.08672	0.0348	28.63726	0.0402	2.470072	0.409758	300
4	40	95	1.33	0.326	0.3	0.012	0.01596	0.0532	0.13016	0.10042	0.02974	22.8488	0.0532	2.123182	0.337692	330
5	50	105	1.30	0.320	0.3	0.015	0.01950	0.065	0.13614	0.11022	0.02592	19.03922	0.065	1.856196	0.315298	330

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge,

E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Three Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	52	1.46	0.405	0.3	0.003	0.00438	0.0146	0.11864	0.06036	0.05828	49.123399	0.0146	4.661421	0.567047	252
2	20	60	1.39	0.381	0.3	0.006	0.00834	0.0278	0.11848	0.06739	0.05109	43.121202	0.0278	3.138089	0.496609	240
3	30	75	1.34	0.354	0.3	0.009	0.01206	0.0402	0.12152	0.08139	0.04013	33.023371	0.0402	2.470072	0.412703	270
4	40	90	1.33	0.332	0.3	0.012	0.01596	0.0532	0.13016	0.09562	0.03454	26.53657	0.0532	2.123182	0.353331	300
5	50	115	1.30	0.305	0.3	0.015	0.01950	0.065	0.13614	0.11974	0.0164	12.046423	0.065	1.856196	0.287155	390

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge,

E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Two Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	55	1.46	0.396	0.3	0.003	0.00438	0.0146	0.11864	0.06299	0.05565	46.90661	0.0146	4.661421	0.539112	270
2	20	60	1.39	0.372	0.3	0.006	0.00834	0.0278	0.11848	0.06705	0.05143	43.40817	0.0278	3.138089	0.484878	240
3	30	80	1.34	0.344	0.3	0.009	0.01206	0.0402	0.12152	0.08603	0.03549	29.20507	0.0402	2.470072	0.38831	300
4	40	90	1.33	0.334	0.3	0.012	0.01596	0.0532	0.13016	0.09569	0.03447	26.48279	0.0532	2.123182	0.35546	300
5	50	100	1.30	0.326	0.3	0.015	0.01950	0.065	0.13614	0.10542	0.03072	22.56501	0.065	1.856196	0.329142	300

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge,

E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

One Row

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	55	1.46	0.396	0.3	0.003	0.00438	0.0146	0.11864	0.06299	0.05565	46.90661	0.0146	4.661421	0.539112	270
2	20	65	1.39	0.372	0.3	0.006	0.00834	0.0278	0.11848	0.07205	0.04643	39.18805	0.0278	3.138089	0.465856	270
3	30	70	1.34	0.366	0.3	0.009	0.01206	0.0402	0.12152	0.07683	0.04469	36.77584	0.0402	2.470072	0.44167	240
4	40	80	1.33	0.344	0.3	0.012	0.01596	0.0532	0.13016	0.08603	0.04413	33.90443	0.0532	2.123182	0.38831	240
5	50	90	1.30	0.323	0.3	0.015	0.01950	0.065	0.13614	0.09532	0.04082	29.98384	0.065	1.856196	0.343753	240

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge,

E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Table A.4. Value Of Model Arrangement Of Standard USBR Baffle Blocks Mixed

Four Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	65	1.46	0.372	0.3	0.003	0.00438	0.0146	0.11864	0.07205	0.04659	39.27006	0.0146	4.661421	0.465856	330
2	20	75	1.39	0.366	0.3	0.006	0.00834	0.0278	0.11848	0.08183	0.03665	30.93349	0.0278	3.138089	0.426693	330
3	30	90	1.34	0.344	0.3	0.009	0.01206	0.0402	0.12152	0.09603	0.02549	20.97597	0.0402	2.470072	0.366102	360
4	40	100	1.33	0.326	0.3	0.012	0.01596	0.0532	0.13016	0.10542	0.02474	19.00738	0.0532	2.123182	0.329142	360
5	50	105	1.30	0.305	0.3	0.015	0.01950	0.065	0.13614	0.10974	0.0264	19.3918	0.065	1.856196	0.300518	330

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge,

E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Three Rows

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	60	1.46	0.390	0.3	0.003	0.00438	0.0146	0.11864	0.06775	0.05089	42.89447	0.0146	4.661421	0.50834	300
2	20	70	1.39	0.366	0.3	0.006	0.00834	0.0278	0.11848	0.07683	0.04165	35.15361	0.0278	3.138089	0.44167	300
3	30	85	1.34	0.332	0.3	0.009	0.01206	0.0402	0.12152	0.09062	0.0309	25.42791	0.0402	2.470072	0.363575	330
4	40	95	1.33	0.326	0.3	0.012	0.01596	0.0532	0.13016	0.10042	0.02974	22.8488	0.0532	2.123182	0.337692	330
5	50	110	1.30	0.311	0.3	0.015	0.01950	0.065	0.13614	0.11493	0.02121	15.57955	0.065	1.856196	0.299385	360

discharge, E1 before energy,

Two Rows

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	60	1.46	0.390	0.3	0.003	0.00438	0.0146	0.11864	0.06775	0.05089	42.89447	7.2429E-06	4.661421	0.50834	300
2	20	70	1.39	0.366	0.3	0.006	0.00834	0.0278	0.11848	0.07683	0.04165	35.15361	2.626E-05	3.138089	0.44167	300
3	30	75	1.34	0.354	0.3	0.009	0.01206	0.0402	0.12152	0.08139	0.04013	33.02337	5.4911E-05	2.470072	0.412703	270
4	40	85	1.33	0.334	0.3	0.012	0.01596	0.0532	0.13016	0.09069	0.03947	30.32422	9.6169E-05	2.123182	0.365765	270
5	50	105	1.30	0.320	0.3	0.015	0.01950	0.065	0.13614	0.11022	0.02592	19.03922	0.00014356	1.856196	0.315298	330

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge, E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

One Row

No.	Y_1(mm)	Y_2(mm)	V_1(m/s)	V_2(m/s)	B(m)	A(m^2)	Q(m^3/s)	q(m^3/s)	E_1	E_2	ΔE	%ΔE	Yc(mm)	Fr1	Fr2	Lj (mm)
1	10	60	1.46	0.390	0.3	0.003	0.00438	0.0146	0.11864	0.06775	0.05089	42.89447	7.24295E-06	4.661421	0.50834	300
2	20	65	1.39	0.381	0.3	0.006	0.00834	0.0278	0.11848	0.07239	0.04609	38.90108	2.62603E-05	3.138089	0.477127	270
3	30	70	1.34	0.347	0.3	0.009	0.01206	0.0402	0.12152	0.07614	0.04538	37.34365	5.49113E-05	2.470072	0.418741	240
4	40	85	1.33	0.334	0.3	0.012	0.01596	0.0532	0.13016	0.09069	0.03947	30.32422	9.61685E-05	2.123182	0.365765	270
5	50	100	1.30	0.326	0.3	0.015	0.01950	0.065	0.13614	0.10542	0.03072	22.56501	0.000143561	1.856196	0.329142	300

Note:- Y_1 water depth before the hydraulic jump, Y_2 water depth after the hydraulic jump, Lj Length of a hydraulic jump, V_1 initial velocity, V_2 final velocity, b Width of the flume, Q discharge, q discharge, E1 before energy, E2 after energy, ΔE change energy, Yc critical depth, Fr fraud number

Table A.5. Average Value Of Model Arrangement Of Standard USBR Baffle Blocks

Average Value of Model Arrangement of standard USBR Baffle Blocks Trapezoidal												
Four Rows												
E_1	E_2	ΔE	%ΔE	Yc(m)	Fr1	Fr2	Lj (mm)	Y2/Y1 Average	%ΔE Average	Fr1 Average	Fr1 Average	Lj (m) Average
0.119	0.068	0.051	42.894	7.24E-06	4.661	0.508	300	14.94	0.163	12.764	1.916	1590
0.119	0.077	0.042	35.154	2.63E-05	3.138	0.477	300					1.59
0.122	0.081	0.041	33.658	5.49E-05	2.470	0.433	270					0.318
0.130	0.106	0.025	19.161	9.62E-05	2.123	0.417	360					
0.136	0.115	0.021	15.580	0.000144	1.856	0.405	360					
Three Rows												
0.119	0.068	0.051	42.894	7.24E-06	4.661	0.508	300	14.815	0.167	12.76	1.726	1560
0.118	0.077	0.042	35.153	2.63E-05	3.139	0.442	300					1.56
0.122	0.081	0.041	33.657	5.49E-05	2.470	0.387	270					0.312
0.130	0.100	0.030	22.849	9.62E-05	2.123	0.329	330					
0.136	0.115	0.021	15.580	0.000144	1.856	0.299	360					
Two Rows												
0.119	0.068	0.051	42.894	7.24E-06	4.661	0.508	300	14.982	0.162		1.736	1590
0.118	0.077	0.042	35.154	2.63E-05	3.138	0.442	300					1.59
0.122	0.086	0.035	29.205	5.49E-05	2.470	0.388	300					0.318
0.130	0.100	0.030	22.850	9.62E-05	2.123	0.338	330					
0.136	0.115	0.021	15.580	0.000144	1.856	0.299	360					
One Row												
0.119	0.069	0.052	42.894	7.24E-06	4.6612	0.5084	300	14.65	0.174		1.782	1470
0.118	0.077	0.042	35.154	2.63E-05	3.138	0.442	300					1.47
0.122	0.081	0.041	33.657	5.49E-05	2.470	0.413	270					0.294

0.130	0.096	0.035	26.537	9.62E-05	2.123	0.353	300					
0.136	0.105	0.031	22.712	0.000144	1.856	0.329	300					
Average Value of Model Arrangement of standard USBR Baffle Blocks Rectangular Four Rows												
0.119	0.0774	0.041	34.761	7.24E-06	4.661	0.460	360	17.850	0.095		1.540	2100
0.118	0.087	0.032	26.900	2.63E-05	3.138	0.406	360					2.1
0.122	0.106	0.016	13.084	5.49E-05	2.470	0.335	420					0.42
0.130	0.125	0.005	4.018	9.62E-05	2.123	0.287	480					
0.136	0.134	0.002	1.359	0.000144	1.860	0.256	480					
Three Rows												
0.119	0.072	0.047	39.270	7.24E-06	4.661	0.466	330	16.19	0.138		1.638	1740
0.118	0.082	0.037	31.119	2.63E-05	3.138	0.420	330					1.74
0.122	0.096	0.025	20.976	5.49E-05	2.470	0.366	360					0.348
0.130	0.105	0.025	19.084	9.62E-05	2.123	0.326	360					
0.136	0.116	0.021	15.102	0.000144	1.856	0.299	360					
Two Rows												
0.119	0.068	0.051	42.894	7.24E-06	4.661	0.508	300	14.65	0.173		1.782	1470
0.119	0.077	0.042	35.154	2.63E-05	3.138	0.442	300					1.47
0.122	0.081	0.040	33.023	5.49E-05	2.470	0.413	270					
0.130	0.096	0.035	26.537	9.62E-05	2.123	0.353	300					
0.136	0.105	0.031	22.565	0.000144	1.856	0.329	300					
One Row												
0.119	0.068	0.051	42.894	7.24E-06	4.661	0.508	300	14.42	0.177		1.803	1470
0.118	0.072	0.046	39.188	2.63E-05	3.138	0.466	270					1.47
0.122	0.081	0.040	33.023	5.49E-05	2.470	0.412	270					0.294
0.130	0.096	0.035	26.537	9.62E-05	2.123	0.353	300					
0.136	0.110	0.026	19.040	0.000144	1.856	0.315	330					
Average Value of Model Arrangement of standard USBR Baffle Blocks Triangular Four Rows												

0.119	0.063	0.056	46.907	7.24E-06	4.661	0.539	270	13.962	0.177		1.846	1470
0.118	0.068	0.051	43.121	2.63E-05	3.138	0.497	240					1.47
0.122	0.087	0.035	28.637	5.49E-05	2.470	0.410	300					0.294
0.130	0.100	0.030	22.849	9.62E-05	2.1232	0.338	330					
0.136	0.110	0.026	19.039	0.000144	1.856	0.315	330					
Three Rows												
0.119	0.060	0.058	49.123	7.24E-06	4.661	0.567	252	13.41	0.187		1.887	1452
0.118	0.067	0.051	43.121	2.63E-05	3.138	0.497	240					1.452
0.122	0.081	0.040	33.023	5.49E-05	2.470	0.413	270					0.290
0.130	0.096	0.034	26.537	9.62E-05	2.123	0.353	300					
0.136	0.120	0.016	12.046	0.000144	1.856	0.287	390					
Two Rows												
0.119	0.063	0.056	46.907	7.24E-06	4.661	0.539	270	13.817	0.183		1.834	1410
0.118	0.067	0.051	43.408	2.63E-05	3.138	0.485	240					1.41
0.122	0.086	0.035	29.205	5.49E-05	2.470	0.389	300					0.282
0.130	0.096	0.034	26.483	9.62E-05	2.123	0.356	300					
0.136	0.105	0.031	22.565	0.000144	1.856	0.329	300					
One Row												
0.119	0.063	0.056	46.907	7.24E-06	4.661	0.539	270	13.443	0.199		1.904	1260
0.118	0.072	0.046	39.188	2.63E-05	3.138	0.466	270					1.26
0.122	0.077	0.045	36.776	5.49E-05	2.470	0.442	240					0.252
0.130	0.086	0.044	33.904	9.62E-05	2.123	0.3883	240					
0.136	0.095	0.041	29.984	0.000144	1.856	0.344	240					
Average Value of Model Arrangement of standard USBR Baffle Blocks Mixed **Four Rows**												
0.119	0.072	0.047	39.270	7.24E-06	4.661	0.466	330	16.17	0.139		1.648	1710
0.118	0.082	0.037	30.933	2.63E-05	3.138	0.427	330					1.71
0.122	0.096	0.025	20.976	5.49E-05	2.470	0.366	360					0.342
0.130	0.105	0.024	19.007	9.62E-05	2.123	0.329	360					

0.136	0.110	0.026	19.392	0.000144	1.856	0.300	330					
Three Rows												
0.119	0.068	0.051	42.894	7.24E-06	4.661	0.508	300	15.148	0.157		1.711	1620
0.118	0.077	0.042	35.154	2.63E-05	3.138	0.442	300					1.62
0.122	0.091	0.031	25.428	5.49E-05	2.470	0.364	330					0.324
0.130	0.100	0.030	22.849	9.62E-05	2.123	0.338	330					
0.136	0.115	0.021	15.580	0.000144	1.856	0.299	360					
Two Rows												
0.119	0.068	0.051	42.89447	7.24E-06	4.661	0.508	300	14.545	0.177		1.792	1470
0.118	0.077	0.042	35.15361	2.63E-05	3.138	0.442	300					1.47
0.122	0.081	0.040	33.02337	5.49E-05	2.470	0.413	270					0.294
0.130	0.091	0.039	30.32422	9.62E-05	2.123	0.366	270					
0.136	0.110	0.026	19.03922	0.000144	1.856	0.315	330					
One Row												
0.119	0.068	0.051	42.89447	7.24E-06	4.661	0.508	300	14.108	0.188		1.836	1380
0.118	0.072	0.046	38.90108	2.63E-05	3.138	0.477	270					1.38
0.122	0.076	0.045	37.34365	5.49E-05	2.470	0.419	240					0.276
0.130	0.091	0.039	30.32422	9.62E-05	2.123	0.366	270					
0.136	0.105	0.030	22.565	0.000144	1.856	0.329	300					

Table A.6. Value of Model Arrangement of standard USBR Baffle Blocks of Energy Dissipation and Efficiency

	Single row					Average	Average	Average	Average
	Rectangular	Triangular	Trapezoidal	mixed		Rectangular	Triangular	Trapezoidal	mixed
%ΔE/E1	42.894	46.907	42.894	42.894	%ΔE/E1	145.4503	186.7588	160.9536	172.0284
	39.188	39.188	35.154	38.901		18.18129	37.35175	32.19071	34.40569
	33.023	36.776	33.657	37.344					
	26.537	33.904	26.537	30.324					
	19.039	29.984	22.712	22.565					
%E2/E1	57.10553	53.09339	57.10553	57.10553	%E2/E1	339.3183	313.2412	339.0464	327.9716
	60.81195	60.81195	64.84639	61.09892		67.86366	62.64825	67.80929	65.59431
	66.97663	63.22416	66.34299	62.65635					
	73.46343	66.09557	73.46343	69.67578					
	80.96078	70.01616	77.28809	77.43499					
	Two-row								
	Rectangular	Triangular	Trapezoidal	mixed					
%ΔE/E1	42.89447	46.90661	42.89447	42.89447	%ΔE/E1	160.173	168.5677	145.6815	160.4349
	35.15361	43.40817	35.15361	35.15361		32.03461	33.71353	29.1363	32.08698
	33.02337	29.20507	29.20507	33.02337					
	26.53657	26.48279	22.8488	30.32422					
	22.56501	22.56501	15.57955	19.03922					
%E2/E1	57.10553	53.09339	57.10553	57.10553	%E2/E1	339.827	331.4324	354.3185	339.5651
	64.84639	56.59183	64.84639	64.84639		67.96539	66.28647	70.8637	67.91302
	66.97663	70.79493	70.79493	66.97663					
	73.46343	73.51721	77.1512	69.67578					

	77.43499	77.43499	84.42045	80.96078					
	Three-row								
	Rectangular	Triangular	Trapezoidal	mixed					
%ΔE/E1	39.27006	49.123399	42.89447	42.89447	%ΔE/E1	125.5515	163.851	150.1334	141.9043
	31.11918	43.121202	35.15361	35.15361		25.1103	32.77019	30.02669	28.38087
	20.97597	33.023371	33.65701	25.42791					
	19.0842	26.53657	22.8488	22.8488					
	15.1021	12.046423	15.57955	15.57955					
%E2/E1	60.72994	50.8766	57.10553	57.10553	%E2/E1	374.4485	336.149	349.8666	358.0957
	68.88082	56.8788	64.84639	64.84639		74.8897	67.22981	69.97331	71.61913
	79.02403	66.97663	66.34299	74.57209					
	80.9158	73.46343	77.1512	77.1512					
	84.8979	87.95358	84.42045	84.42045					
	Four-row								
	Rectangular	Triangular	Trapezoidal	mixed					
%ΔE/E1	34.76062	46.90661	42.894471	39.27006	%ΔE/E1	80.12097	160.5531	146.4457	129.5787
	26.89905	43.1212	35.153612	30.93349		16.02419	32.11062	29.28914	25.91574
	13.08427	28.63726	33.657011	20.97597					
	4.018132	22.8488	19.161033	19.00738					
	1.358895	19.03922	15.579551	19.3918					
%E2/E1	65.23938	53.09339	57.10553	60.72994	%E2/E1	419.879	339.4469	353.5543	370.4213
	73.10095	56.8788	64.84639	69.06651		83.97581	42.43086	70.71087	74.08426
	86.91573	71.36274	66.34299	79.02403					
	95.98187	77.1512	80.83897	80.99262					
	98.6411	80.96078	84.42045	80.6082					

Note: - %ΔE/E1Energy Dissipation, %E2/E1Efficiency

Figure A.1 Preparation of Baffle Block Bed Material Modes Used in this Research

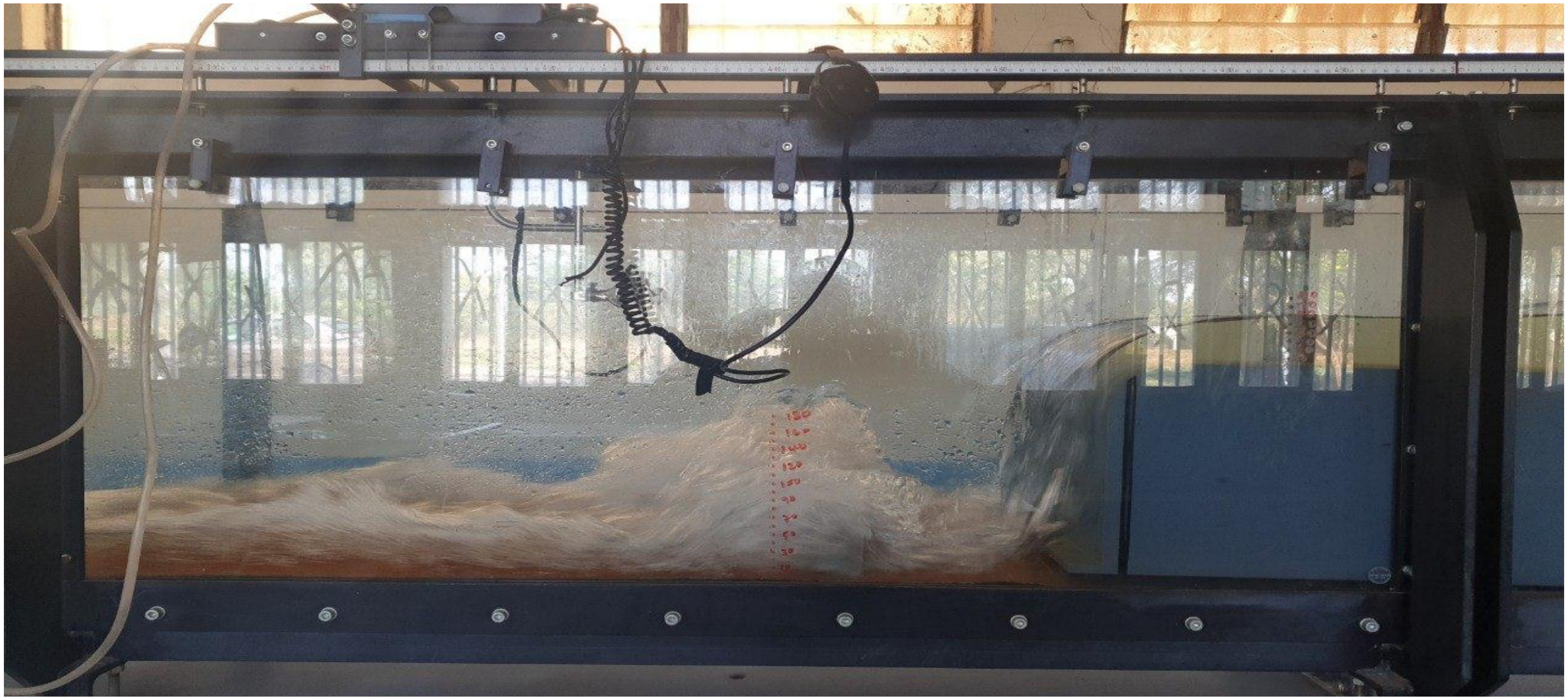
 

(a) Trapezoidal Baffle Block (b) Rectangular Baffle Block

(c) Triangular Baffle Block (d) Mixed Baffle Block

Figure B.1 Putting Baffle Block Bed in the experimental Flume



figures.1 Flow Over the Baffle Block Bed Material

FigureD.1. Measuring the depth of flow over baffle block bed material during the experiment