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Improve the Efficiency of Stilling Basin Using Different Types of Blocks

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ABSTRACT: *Stilling basins are utilized to disseminate the energy of water exiting the heading-up hydraulic structures. The essential technique for scattering energy is to create a hydraulic jump to move spill out of supercritical to subcritical. In this paper, an experimental study was led to explore the impacts of block shapes on the flow pattern downstream a radial gate. Forty-five (45) exploratory runs were done. Four different states of baffleblocks were considered, notwithstanding an instance of level floor without blocks was incorporated into the test program to evaluate the impact of utilizing the blocks. Each case was tried with various flow conditions; three unique discharges and three diverse tail water depths were utilized. Results were investigated and graphically exhibited. The tests demonstrated that the blocks exhibited a high proficiency in limiting the detached impact of the flowpattern downstream the gate.*

Keywords*: Stilling basin, Baffle blocks, Flume, Velocity, Hydraulic jump, Hydraulic structures.*

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I. INTRODUCTION

Flow over spillways or underneath gates have a colossal measure of potential energy, which is changed over into dynamic energy down flow control structures. This energy should be scattered to keep the probability of over the top scouring of the downstream waterway bed, limit crumbling and undermining of structures, which imperil the structure prosperity.Close-by scour downstream of water structures, for instance, low head and high head structures is a basic investigation field in view of its critical utilitarian quality. Unmistakable procedures were utilized to expand the productivity of the stilling basin regarding diminish nearby scour by making use of splitter plates or collars.In a similar setting, astound blocks presented on stilling basin have been in like manner used to settle the game plan of the bounce and grow the turbulence, subsequently helping in the diffusing of energy. For low stream, confuse obstructs to make for a slight deficiency of tail water, and for high flow, they divert the flow a long way from the conduit bed. The vocation of blocks may be helpful in reducing the tail water significance required moreover in shortening the basin length.

With a specific end goal to lessen the excessive kinetic energy of flowing water downstream of the structures such as spillways, floodgates, pipe outlets, and so forth.Stillingbasins with appurtenances are utilized,Negm AM. [1]. The level apron furnished with positive multi-blocks at the end of apron makes a smaller length of relative submerged hydraulic jump and furthermore most reduced estimations of most extreme relative velocity and shear Reynolds number.

The characteristics of hydraulic jump and the associated energy loss were investigated and experimentally discussed [2-4], they concluded the following equations:

$$\frac{L_j}{y_2} = 6.1 + 4.9S \quad (1)$$

$$S = \left(\frac{y_t - y_2}{y_2}\right) \quad (2)$$

$$\mathrm{H}_u + \frac{q^2}{2gH_u^2} = \mathrm{y}_3 + \frac{q^2}{2gy_1^2} \quad (3)$$

$$\Delta E = \frac{E_1}{E_2} = \frac{\left(\psi - \frac{(1+S)}{2}\phi\right) + \frac{F_{r_1}^2}{2}\left(1 - \frac{4}{(1+S)^2\emptyset^2}\right)}{\psi + \frac{F_{r_1}^2}{2}} \quad (4)$$

$$\emptyset = (1 + 8F_{r_1}^2)^{\frac{1}{2}} - 1 \qquad (5)$$

$$\psi = \frac{y_3}{y_1} = \sqrt{\frac{(1+S)^2}{4}\phi^2 - 2F_{r_1}^2 + \frac{4F_{r_1}^2}{(1+S)\phi}} \qquad (6)$$

$$\mathrm{H_c} = \mathrm{C_c} * \mathrm{G.O} \qquad (7)$$

$$\mathrm{C_c} = 1\text{-}0.75\theta + 0.36\theta^2 \qquad (8)$$

$$\theta = ACOS\left(\frac{(Gate\ axis\ level - Sill\ gate\ level) - Gate\ opening}{Gate\ Radius}\right) \qquad (9)$$

Tiwari et al. [5] examined experimentally the impact of sill downstream the stilling basins for pipe outlet. It is because of truth that scattering of energy in a basin having inclining end sill is more when contrasted with other state of end sill tried, in light of the fact that incline of the end sill decreases the energy of water along these lines decrease in energy is advanced. Comparative perception was additionally announced by some past examiners [6-9] dissected the submerged water driven bounce framed in an outspread stilling basin furnished with sudden drop hypothetically and experimentally.

The nearness of a sill under a gate diminishes its height, and appropriately diminishes the weight strengths following up on it. Also, the sill decreases the heaviness of the gate and the operation constrain, and subsequently the gate turns out to be more monetary. Numerous examinations have been performed on sills under vertical sluice gate for both free and submerged flow conditions [10-14].

Abdelhaleem F.S. [15] experimentally investigated to foresee the scour geometry downstream a Fayoum sort weir and to limit the scour utilizing a line of semi-roundabout baffleblocks. An instance of level floor without astounds was incorporated into the test program to gauge the impact of utilizing the baffle blocks. The establishment of blocks had a noteworthy impact on the scour opening, which is littler than the case with no baffles, for the confounded floor tests, the incline points increment however the downstream slopes are more extreme than the upstream slopes.

Mohamed et al. [16] surveyed the impact of various sill setups and courses of action on submerged flow attributes downstream the outspread entryways of new Naga Hammadi controller in Egypt. They demonstrated that the sill over stilling basin greatly affects flow attributes and nearby scour depth framed downstream the controller particularly for a sill with right and slopped countenances at the upstream, and downstream, separately. Also, the impact of end step of stilling basin on submerged move through radial gate was cleared up by Elsaeed et al. [17]. They also used a multiple linear regressions to predict a statistical equation that correlates a relationship between the jump length over the depth vena contracta (L_j/y_1) and the Froude number (F_r) which represented by equation 10.

$$\frac{\mathrm{L_j}}{y_1} = 11.43\mathrm{F_r} + 9.1,\ \text{with } \mathrm{R}^2 = 0.96 \qquad (10)$$

Abdelhaleem F.S. [18] experimentally investigated the submerged flow through radial gates with and without a gate sill. He finished up the negative impact of sills under submerged radial gates and legitimized the nearby scour marvels occurred promptly downstream the stilling basin of some current submerged radialgates with a gate sill in Egypt.Alirezaet al. [19] carried out an exploratory review was led researching submerged hydraulic hump with confound blocks. Exact conditions were determined for foreseeing the basic estimations of the submergence calculate at which each flow administration shapes. The proficiency of the submerged hydraulic jump with blocks in dispersing energy was contrasted and that of free without blocks as a component of submergence element.

The present study essentially plans to investigate the effect of various block shapes and dimensions erecting on stilling basin downstream a radial gate on the hydraulic attributes exhibited as far as the near bed velocity, the proficiency of blocks on the energy scattering, and their impacts influence on the characteristics of hydraulic jump.

II. THE EXPERIMENTAL WORK

2.1 Model description

The experimental tests were led in a flume situated at the Hydraulics Research Institute test hall of the National Water Research Center, Egypt. The flume was 1.0m wide, 26.0m long and 1.20m deep flume. The side dividers along the whole length of the flume were made of glass with steel-edges, to permit visual examination of the flow pattern and dependability of bed protection. The flume bed was made of concrete and furnished with a steel pipe to drain the water out of the flume. The tail water depth was controlled by a rear end situated at flume end. The flume inlet was comprised of a brick work basin of 3.0m width, 3.0m length and 2.5m depth.
The flume exit was comprised of a basin began specifically before the finish of the mimicked reach took after by steel flap gate. The rear end was pivoted at the base to give a customizable slant, to control the downstream tail water depth.

An electro- magnetic flow meter was introduced on a feeder pipe of 10 inch diameter to quantify the discharge. The water discharged the flume through two pumps with various capacities; 150, and 500 l/s. The pumps were associated with two pipelines 16 and 10 inches, separately. The most extreme bolstering capacity of the framework was 650 l/s. This limit was sufficiently adequate for every single required test.

2.2 Model construction

2.2.1 The sluiceway and apron

A sluiceway bay was built at a separation of around 10.7m downstream flume inlet. A bras radial gate with a radius of 60cm was utilized to manage the flow. An elastic strip was settled and packed at both flume sides to guarantee no spillage from the flume sides. The radialgate is refreshed on a raised ledge with a length of 0.5m and width of 0.80m took after by a slanted cover of 2.0m length with various inclines. An even apron of 1.50m length began from the end purpose of the apron to the downstream side.

2.2.2 The bed material

The flume bed was comprised of two mobile bed materials sand as an establishment layer and shrouded by riprap in particular areas. The d_{50} of the utilized sand and riprap were 0.563 and 25.32mm, respectively. The sand was secured by the riprap at the initial 9.0m upstream the stilling basin and the initial 7.0m downstream it.

2.3 Measuring devices

These measuring devices in the present review were flow meter, current meter, and point gage. Both flow meter and current meter were from electromagnetic sort. The flow meter has ±1% accuracy, utilized for measuring the flow discharge. The current meter has ±2% accuracy, utilized for measuring the flow velocity. The point gage has ±0.1mm accuracy, utilized for adjusting the water level at the upstream and downstream gates.

2.4 Model runs

Forty-five experimental runswith various block models were accounted for. The analyses were intended to fluctuate the independent variables of flowdischarge, tail water depth, shapes and measurements of blocks. The depth of the flowjet at vena contracta downstream the radial gate and the backupwater depth simply downstream the radial gate were characterized for each trial, fig. 1.

To distinguish the impact of blocks geometry on the flowpattern; four sorts of baffles (cases B-E) were utilized as a part of expansion to the essential stage without any blocks (case A) were tried. The indistinguishable blocks were organized in five positions (L_b/L_f= 0.25, 0.40, 0.55, 0.70, and 0.85), the subtle elements of blocks geometry and their arrangement were cleared up in fig. 2. Scope of exploratory parameters was recorded in Table 1.

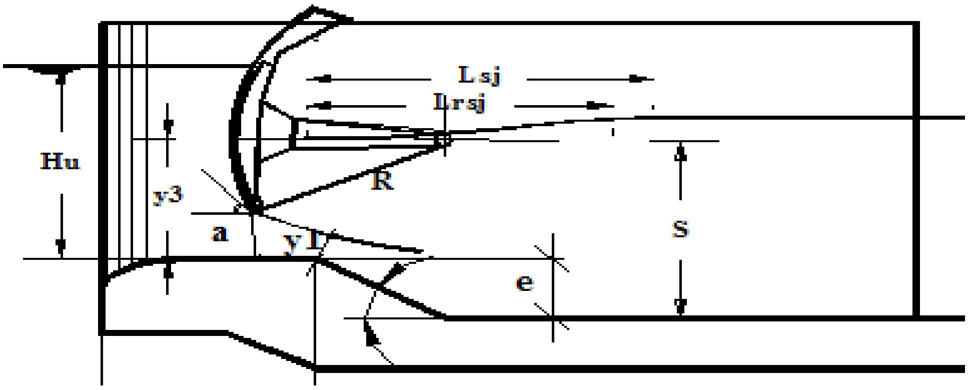

Figure 1: Definition sketch of the experimental mode

Table I: *Range of variables for laboratory experiments*

Parameter	Symbol	Value	Range		Units
			From	To	
Discharge	Q	50,75,100	50	100	l/s
Tail gate water depth	y_{tail}	40,45,50	40	50	cm
Depth of vena contracta	y_1	Varied	1.5	5.8	cm
Gate opening	G.O.	Varied	4.01	9.65	cm
Initial Froude No.	Fr_1	Varied	2.822	10.728	-----
Types and dimensions of blocks	See fig.2				

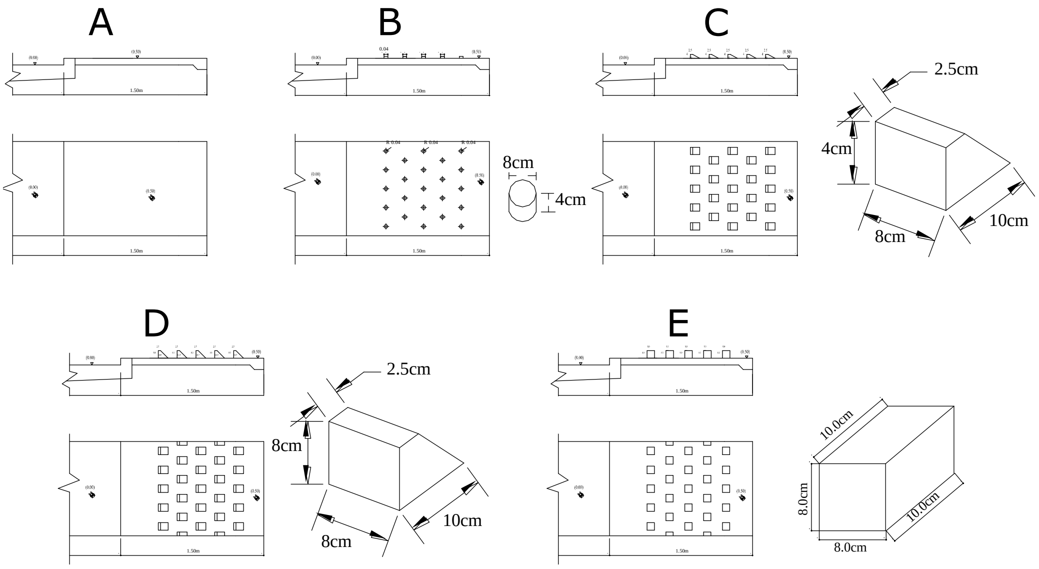

Figure 2: Geometry of stilling basin and baffle blocks

III. THE EFFECT OF BLOCK GEOMETRY ON THE BOTTOM VELOCITY

As the near bed velocity (at 0.9 flowdepth) is viewed as a central parameter required in sediment transport downstream the stilling basin, consequently the need of its examination was discovered, Negm AM. [1]. Thevelocity was measured at four positions (x/L_f= 0.03, 0.25, 0.5, and 1), that were precisely chosen to cover the aggregate floor length with uncommon emphasize on the initial segment.

Figure 3 was plotted to represent the impact of blocks geometry on the near bed velocity under 100l/s settled discharge. It was seen that after x/L_f= 0.6 the tests gave a similar velocitypattern with immaterial contrasts in values. The instances of utilizing no blocks or cylindrical ones (cases A and B) demonstrated a negative velocity esteems with respect to the vast majority of the primary portion of the floor contrasted with alternate cases. For case B, the base flow moves easily around the cylindrical blocks, thus they couldn't be viewed as a solid hindrance contrasted with blocks of straight face towards the flow. These discoveries were concurred with Abdelhaleem F.S. [15].

Concentrating on cases C and D, the blockheight indicated precious impact on the base velocity. Additionally fig. 3 exhibited that for case E, the rectangular blocks impede the base flow than the trapezoidal ones under settled blockheight. That outlines the velocity lessening for case E, subsequently demonstrates a superior execution with respect to the development of bed material downstream the floor.

To examine the impact of tail water depth on the near bed velocity; fig. 4 was introduced for case E, under 100l/s settled discharge. The reverse connection between the two factors was obviously taken note. The blocks impact was very initiated on the near bed velocity at $x/L_f \leq 0.25$ where the main line of blocks were raised, where the velocity was conversely corresponding to the distance. At that point after, the effect of tail water depth generally vanished.

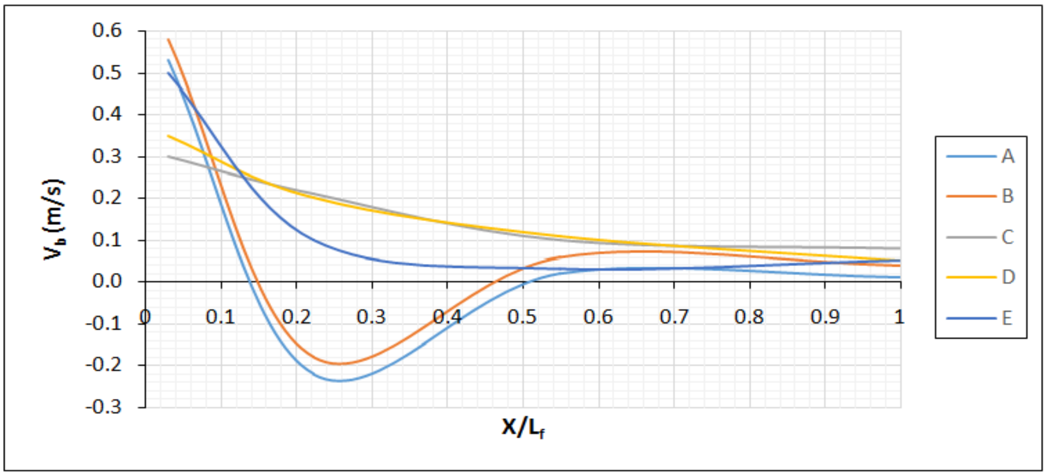

Figure 3: Effect geometry of baffle blocks on near bed velocity

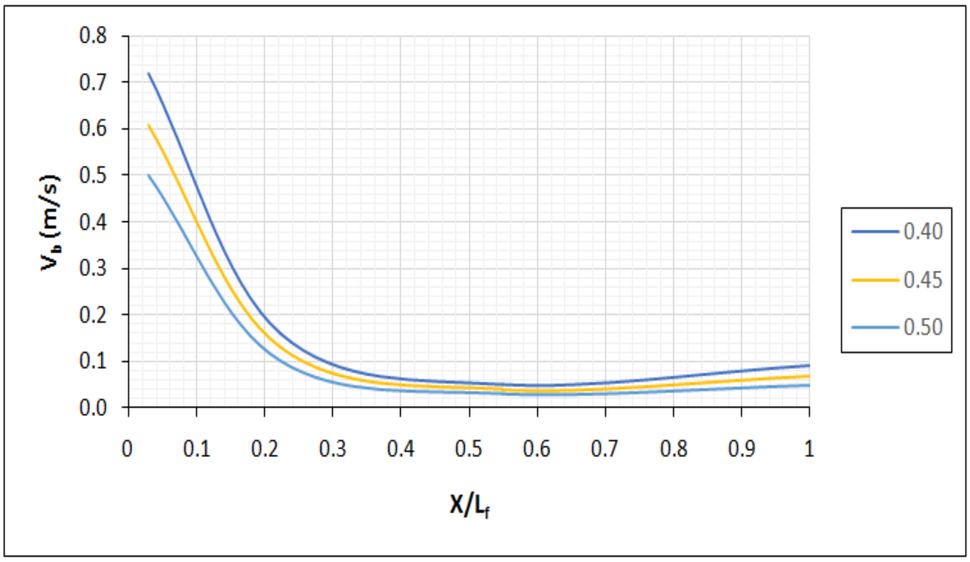

Figure 4: Effect tail water depth on near bed velocity

IV. THE EFFECT OF BLOCK GEOMETRY ON THE VENA CONTRACTA DEPTH

Figure 5 was plotted for 0.5m settled tail water depth to explore the impact of discharge on the depth of vena contracta for various block shapes incorporated into the present study. An immediate corresponding connection was unmistakably seen for various sorts of blocks. Concentrating on case "E", it has the minimum vena contracta depth for low discharge (50l/s) contrasted with other block models, however the comments was turned around on account of (100l/s). Figure 6 demonstrated the relation between the deliberate depth of vena contracta and the relating ascertained values by applying eq (7). The relationship between the two values was under estimation; thusly the precision of the estimations was demonstrated. As a twofold check for the precision a relation between the underlying Froude number, measured and calculateddepth of vena contracta by [4]; henceforth fig. 7 was plotted for the diverse block sorts under 0.5m settled tail water depth. It was seen that both measured and figured values gave a similar example that conversely relative to the Froude number. That can be shown, for settled discharge, as the depth of vena contracta gets littler the velocity increments subsequently the Froude number increment. Underscoring the blocktype, the figure showed that for depth of vena contracta higher than 0.037m the impact of blocktype was irritated. In any case, underneath that depth the block type "E" demonstrated the most astounding Froude number under settled depth of vena contracta in contrasted with other block types. Consequently, the expected associated hydraulic jump towards to be rough. (See section 6)

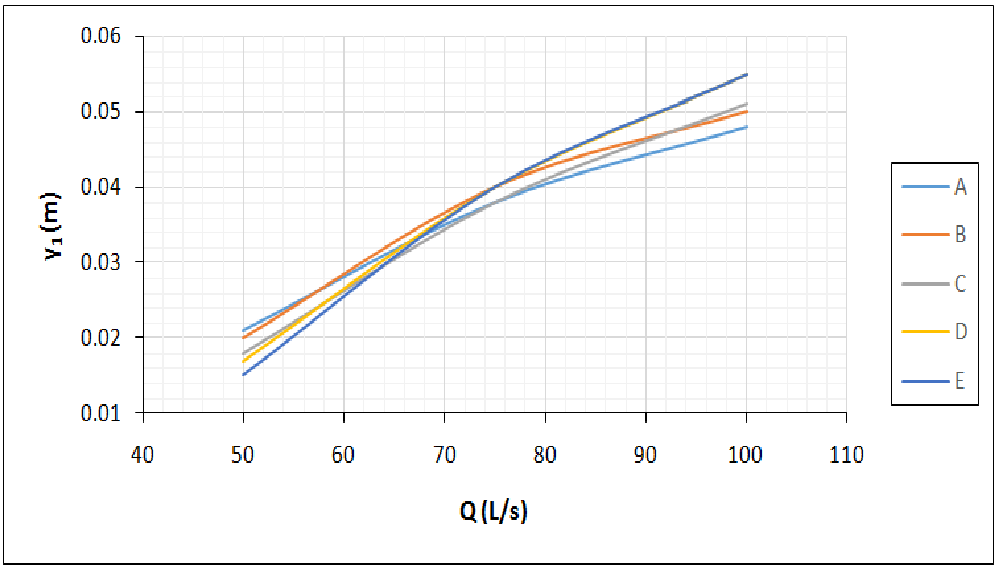

Figure 5: Effect of discharge on the depth of Vena contracta

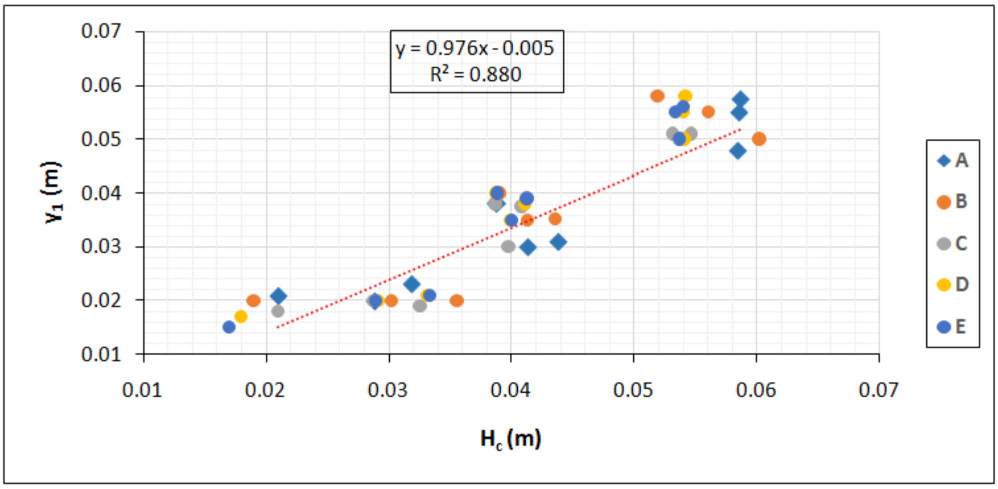

Figure 6: Relation between the measured and calculated depth of Vena contracta

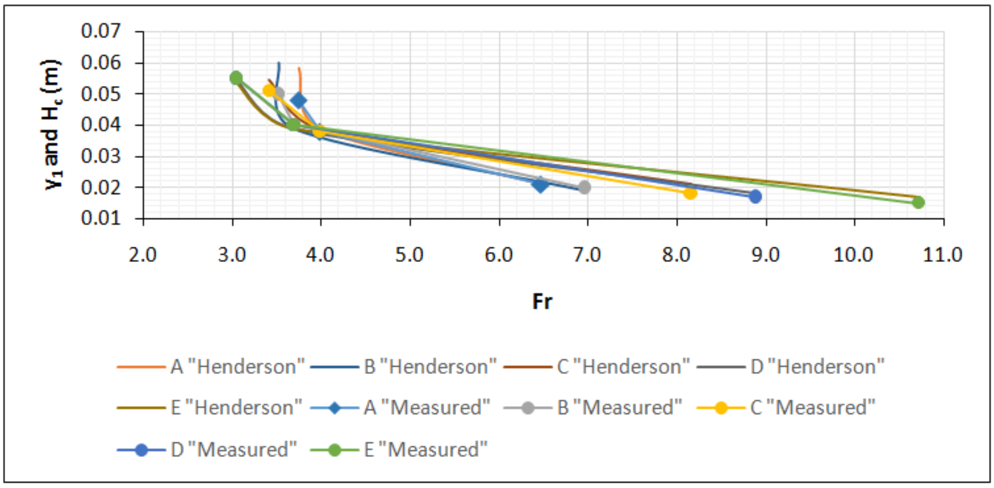

Figure 7: Relation between the measured and calculated depth of Vena contracta and the Froude No. for all tests

V. THE EFFECT OF BLOCK GEOMETRY ON THE ENERGY

To recognize the relation between the discharge and the relative energyloss computed utilizing eq(4); fig. 8 was plotted for the tried block types under 0.5m settled tail water depth. It was seen that the discharge of 75 l/s introduces a control point for bends incline from the perspective of the association with the relative energyloss and block type.

On account of discharges littler than 75 l/s, it was seen that the relative energyloss was conversely corresponding to the discharge. Concentrating on block type, the figure outlined that utilizing blocks of sort "E" delivers the best values for the relative energyloss contrasted with different sorts. Nonetheless, the case "A" of no blocks gave the minimum values.For discharges higher than 75 l/s, the relationship has a tendency to be steady without noteworthy fluctuations in values. In addition, the impact of blocktypes towards to be vanished.

Concentrating on the relation between the initial Froude number and the relative energyloss; fig. 9 was introduced. From figure investigations, an immediate corresponding relation between the two factors was seen in any case the block type. That can be shown as the central parameters influence the Froude number and the relative energyloss were the velocity and water depth. Toward the begin of thehydraulic jump downstream the gate, the velocity was most extreme related with least water depth. Therefore, the Froude number and the relative energyloss increment in a similar pattern.

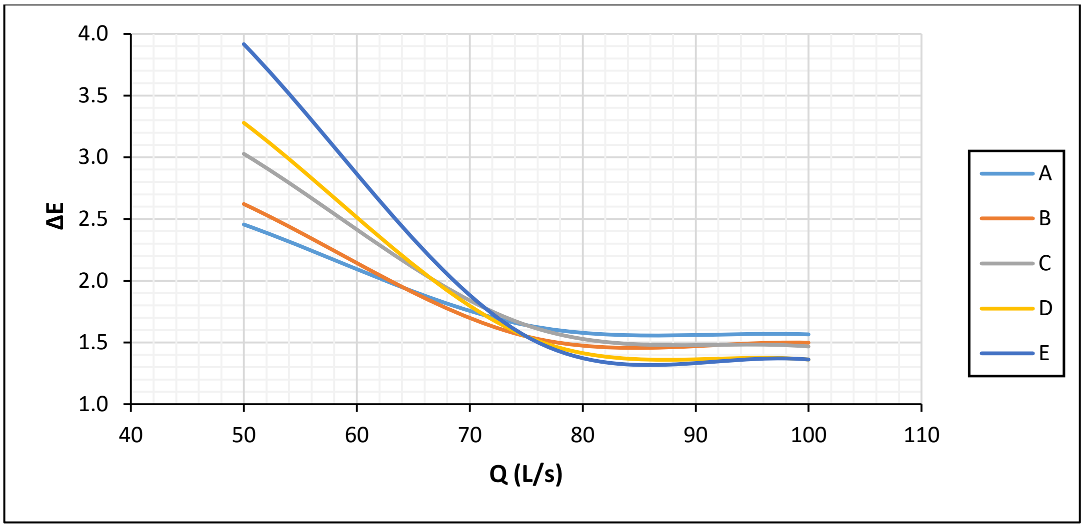

Figure 8: Effect of discharge on the energy

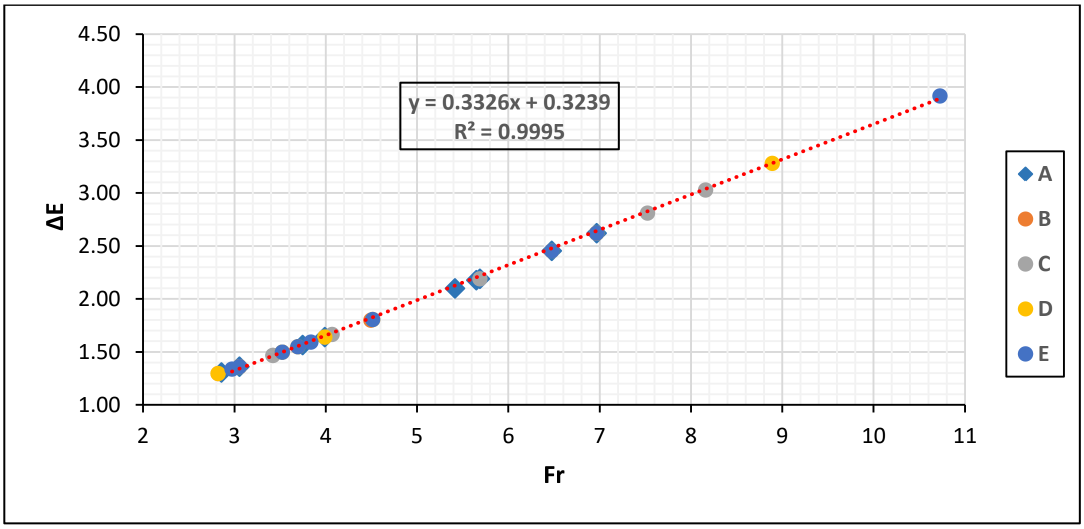

Figure 9: Effect of Froude No. on the energy

VI. THE EFFECT OF BLOCK GEOMETRY ON THE LENGTH OF HYDRAULIC JUMP

As indicated by [1-4] and [19], the water control structure including the gates are associated with downstream hydraulic jump whether it was free or submerged. Baffles are given for the most part to abbreviate hydraulic jump without increasing extra tailwater level. Contrasted with a straightforward hydraulic jump basin in which the approach flow energy is adjusted by a satisfactory tail water level, stilling basins have moreover chute and baffles components. Those components are situated on the basin base and include steps, sills or blocks. The impact of scattering can be expanded with a veering basin. Henceforth, figs. 10-12 were exhibited to examine the characteristics of the hydraulic jump regarding length.

Figure 10 examined the impact of discharge on the deliberate length of the hydraulic jump for block types incorporated into this study under 0.5m settled tail water depth. An immediate corresponding relationship between the discharge and the jump length was shown, that concurred with what was accounted for by [1-4], notwithstanding the block types. The figure outlined that for the case "A" where no blocks were utilized, the minimum jump length were accounted for various discharges; as no deterrents used to obstruct the bottom flow. Underlining the block type, the most noteworthy and least values for the measured jump length under settled discharge were accounted for blocks of sort "B" and "E",respectively.

Likewise, it was seen that as the discharge increment, the impact of block type on the jump length towards to be vanished. The reasons were centered around the relative energy loss; as no noteworthy contrasts were found for various types of blocks under settled discharge; fig. 8.

Figure 11 demonstrated a dimensionlessrelation between the initial Froude number and the measured jump length over the depth of vena contracta for various sorts of blocks. The figure showed that for settled block sort the jump length was specifically corresponding to the initial Froude number. That can be delineated as the depth of vena contracta diminish the initial Froude number increment as far as the velocity toward the start of the jump therefore, the jump length increment. In light of the estimations, the numerous direct relapses examination were applied to anticipate a statistical relation correlates L_j/y_1 and the initial Froude number F_r, exhibited in eq(11).

$$\frac{L_j}{y_1} = 7.02F_r + 9.1, \text{ with } R^2 = 0.94 \qquad (11)$$

The got discoveries were contrasted with Elsaeed et al. [17]. It was seen that eq (11) introduced in the present study gave nearer values for various types of blocks contrasted with eq (10) that gave roughly 68.25% higher in the normal values. To check the exactness of the measured jump lengths; a correlation with the calculated lengths utilizing eq (1) was displayed in fig. 12. It was seen that the relationship between the measured and calculated lengths were under estimation.

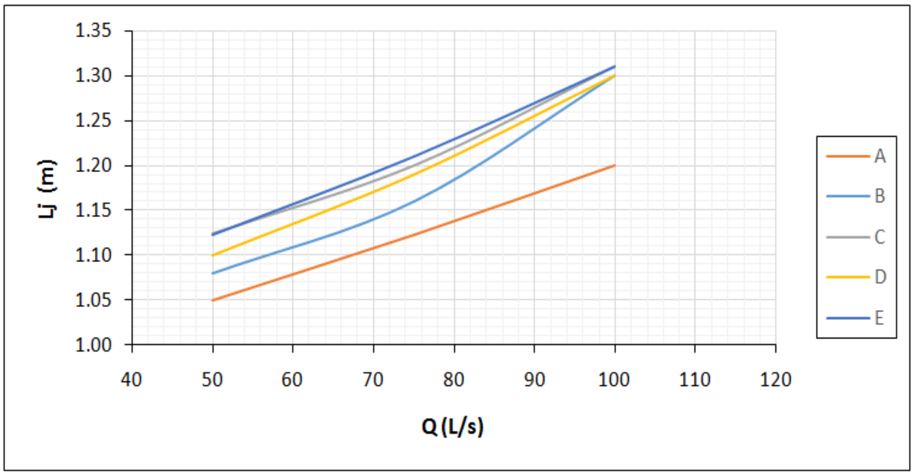

Figure 10: Effect of discharge on the jump length

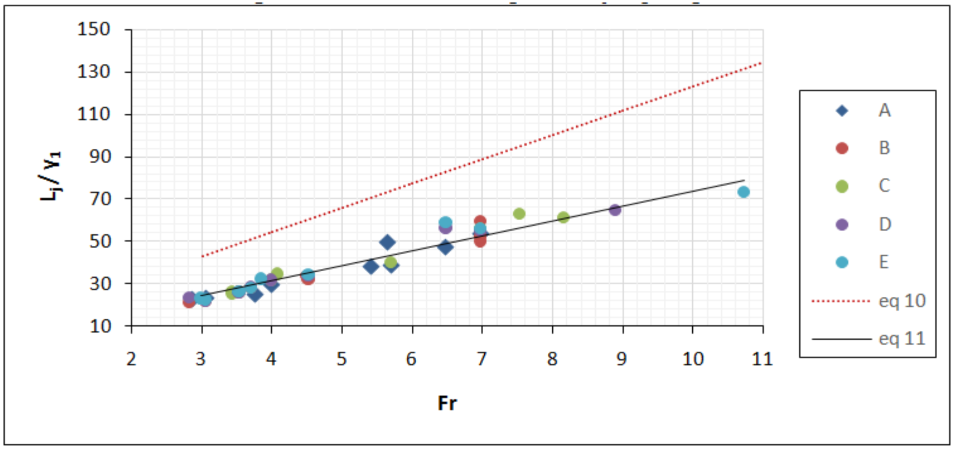

Figure 11: Effect of Froude No. on the jump length

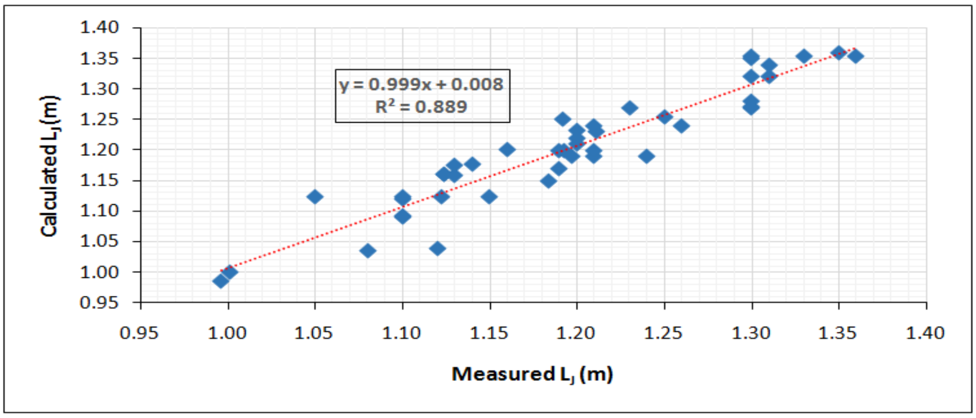

Figure 12: Relation between the measured and calculated jump length

VII. CONCLUSION

The exploratory examination essentially game plans to investigate the effect of the baffle blocks geometry raised on stilling basin downstream a radial gate on different hydraulic parameters prompted the accompanying conclusions:

- Cylindrical blocks indicated irrelevant impact with respect to the near bed velocity.
- The effect of height on account of trapezoidal bocks on the near bed velocity was vanished.
- The near bed velocity was inversely proportional to the tail water depth.
- The depth of vena contracta increments as the discharge increment.
- The initial Foude number was inversely proportional to the depth of vena contracta.
- The relative energy loss was inversely proportional to the discharges smaller than 75 l/s.
- Using blocks of type “E” delivers the greatest values for the relative energy loss for discharges smaller than 75 l/s.
- No significant influences were accounted for regarding the effect of block types and the discharge on the relative energy loss for discharges more prominent than 75 l/s.
- The relative energy loss was straightforwardly corresponding to the initial Foude number regardless the block type.
- The length of hydraulic jump was directly proportional to the discharge.
- The jump length associated to the cylindrical blocks was the most limited.
- The effect of block type on jump length was vanished at discharge of 100l/s.
- The jump length was directly proportional to the initial Froude number.

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NOTATIONS

C_c =Contraction Coefficient
E_1 =Energy loss at the beginning of the jump [m]
E_2 =Energy loss at the end of the jump [m]
ΔE= Relative Energy Loss
Fr= Froude number
g = Gravity acceleration [m/s^2]
H_c = Vena contracta depth according to Henderson’s formula [m]
H_u = Upstream water depth [m]
L_b = Distance from floor first point to the face of the block [m]
L_f = Floor length [m]
L_j = Length of hydraulic jump [m]
Q = Discharge [m^3/s]
q = Dischargeper unit width [m^3/s/m’]
S= submergence ratio
V_b = Near bed velocity [m/s]
x= Horizontal distance measured from the beginning of the floor length [m]
y_1 = Vena contracta depth [m]
y_2 = Sequent water depth [m]
y_3 = Back up water depth, just downstream gate [m]
y_t = Tail gate water level [m]

GREEK SYMBOLS

θ= Angle of the lower lib of the radial gate (rad)

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