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An experimental study of baffle blocks as flow energy dissipation in the launch channel of a spillway structure

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ABSTRACT

Energy dissipation in a launch channel focused on increasing the dissipation of initial water flow energy to protect against hydraulic structure failure. This was achieved by using rectangular baffle blocks placed within the launch channel, varying in angles and flow rates. The aim of this study was to determine the impact of different angles of the rectangular baffle blocks on flow energy dissipation downstream of a spillway structure. A two-dimensional experimental research method was employed to assess the water energy dissipation by varying the angles of the baffle blocks in the launch channel. The results of this study indicated that in the rectangular baffle block type with an angle variation of 300, the relative energy dissipation was directly proportional to the upstream and sequential Froude numbers. In contrast, for the baffle blocks with an 1800 angle variation, the relative total energy dissipation decreased as the upstream and sequential Froude numbers increased. The maximum value of the relative total energy dissipation occurred when the water level above the crest was high, but the minimum value happened when the water level above the crest was low. One key finding of this study was that the rectangular baffle blocks with a 300-angle variation and a relative water surface height of 2.5 cm above the crest provided a maximum total relative energy dissipation of 53.66%. The advantage of using rectangular baffle blocks was in their ability to gradually slow down the flow velocity through the gaps between the angled blocks, preventing the formation of back momentum in the flow.

Keywords: Launch Channel, Spillway, Baffle Block, Flow Energy

1. INTRODUCTION

A spillway is a hydraulic structure whose existence is very essential because it is built to release water surplus or flood discharge that cannot be accommodated in the dam (Parsaie et al., 2018; Chanson, 2021; Djunur et al., 2023). The spillway functions as a building to overflow water if there is an increase in discharge at the dam (Djunur et al., 2023; Felder and Chanson, 2014; Matos, 1999). The spillway consists of five parts, namely the guide channel, transition channel, launch channel, overflow channel, and stilling basin building (Akramov et al., 2011; Rasoul et al., 2020; Hai-sheng et al., 2010; Daneshfaraz et al., 2020). The launch channel section is an open channel with supercritical flo properties at high speed (Zhao et al., 2012). A very high flow velocity can cause damage to the downstream section of the spillway channel structure (Johan et al., 2011).

Changes in flow conditions from supercritical to subcritical cause a hydraulic jump (Ujjawal and Parthajit, 2023; Rajaratnam and Hurtig, 2000; Xiaoguang et al., 2011). In this condition, there is a change in water depth from low to high depth (Wei, 2002; Sujit et al., 2003). This change causes the flow energy to be reduced. This hydraulic jump phenomenon is used by energy dissipation structures to reduce the energy of water flow from the spillway (Cakir, 2003; Kumar and Deswal, 2002; Mykhaylovskyy et al., 2002; Zdzislaw and Halina, 2010). The most commonly used type of energy damper is a stilling basin equipped with damper blocks (Liu, 2013; Sadeghfam et al., 2014; Wűthrich and Chanson, 2014; Xiao-li et al., 2007). The damper blocks that function to cause a hydraulic jump is baffle blocks. The baffle blocks also have an effect on reducing flow momentum which will reduce flow velocity (Ghaderi et al., 2020; Jinli et al., 2012; Ascuitto et al., 2001; Stefan et al., 2010).

The change in water level due to the hydraulic jump and the decrease in flow velocity causes a reduction in flow energy (Chun-Xiao, 2010; Lifeng and Mary, 2010; Mathias et al., 2010; Peter et al., 2012; Kolodezhnov and Koltakov, 2001). Investigated energy dissipation downstream of a sluice gate using a weir and found that the optimal weir location is in the first half of the hydraulic jump. Investigated the performance of the Group Method of Data Handling (GMDH) and the Developed Group Method of Data Hand, ling (DGMDH) machine learning algorithms in predicting the characteristics of a submerged hydraulic jump at a sluice gate. The study demonstrated that both models could accurately estimate the relative submersion depth, jump length, and relative energy loss. Examined the effectiveness of five models in identifying flow regime conditions, estimating the discharge coefficient (Cd), and determining flow rate.

To calculate Cd for the energy-momentum model with losses (EML) and HEC-RAS, new equation forms and techniques were developed (Kuldeep et al., 2021). Ujjawal and Parthajit, (2023) explored the effectiveness of perforated screens as energy dissipators in a mixed three-wall configuration for small hydraulic structures. Various efforts have been made to reduce flow energy downstream of spillway structures by engineering energy dissipation methods, including Stepped Spillways, Chute Spillways, and reducing flow velocity using various obstacle models (Yehia et al., 2018; Doron, 2000; Mohammadzadeh-Habili et al., 2018; Kuang et al., 2012). To minimize hydraulic jumps downstream of the spillway and protect riverbed and bank geometry Bainian et al., (2000); Chanson, (2015); Lifeng et al., (2011), energy dissipation structures are used. These structures modify flow parameters by altering baffle block dimensions, spacing, quantity, and the angle of the baffle blocks relative to the flow direction (Nakashima et al., 1996; Peyras et al., 1992; Daneshfaraz et al., 2017; Afangideh and Udokpoh, 2022).

The significance of placing baffle blocks in increasing the reduction of water flow energy has long been recognized (Alsabery et al., 2024). Although numerous studies have explored the effectiveness of baffle blocks in reducing flow energy, both with and without the baffle blocks Ahmadi and Azimi, (2024), however there are still several important parameters that need to be studied and researched for the development of innovative methods in an effort to fill the gaps in previous research. The history of flow energy reduction itself has long been the subject of research, starting from the concept introduced by Leonardo da Vinci in the sixteenth century and progressing to Giorgio Bidone's pioneering experiment in 1820 (Dashtban et al., 2024; Karamma et al, 2020). However, with the technology and scientific advancements, there remains significant potential for deeper research to understand the impact of baffle blocks on energy dissipation and their role in shortening hydraulic jumps across various structural contexts.

Further research on the effect of variations in baffle block models on energy dissipation downstream of the spillway is crucial for enhancing the efficiency of hydraulic structures. In an effort to overcome energy reduction downstream of the spillway structure, found that baffle blocks with an upstream angle of 1200 and a cat-back design with a 90° angle on the rear side were more effective in reducing flow energy and shortening hydraulic jumps without causing cavitation hazards (Hadday et al., 2024: Rincón et al., 2024). However, in the recent literature, there is still a need to deepen our understanding how the shape, orientation and composition of rectangular baffle blocks influence the efficiency of spillway protection system. The reduction of energy downstream of spillway structures to mitigate the risks of landslides and erosion caused by hydraulic jumps is increasingly critical. Preliminary research about the flow characteristics of submerged hydraulic jumps with baffle blocks serves as an essential first step in addressing this issue.

This study will provide valuable insights into the efficiency of energy dissipation in both submerged and free jumps, while also exploring the influence of factors such as the Froude number and damping factor on hydraulic behavior. To address this phenomenon, a laboratory study is needed to investigate the energy damping that occurs downstream of the launch channel in the process of water flow movement. Understanding the energy dissipation process is essential for identifying the flow parameters that influence energy reduction downstream of the channel. This knowledge will support further control and protection measures to prevent damage or collapse of the spillway structure. For this purpose, the effectiveness of rectangular baffle blocks with varying angles in reducing flow velocity and energy will be examined, as this configuration is expected to minimize hydraulic jumps and mitigate damage downstream of the spillway.

2. RESEARCH METHOD

The experiment was conducted at the Hydraulic Laboratory of the Department of Civil Engineering, Universitas Hasanuddin. The scouring depth research was carried out in a recirculating flume measuring 600 cm in length, 100 cm in width, and with an effective depth of 30 cm, as shown in (Figure 1).

Table 1 Data Description

No	Description	Dimension Size(cm)
A	Spillway Dimension	
1	Lighthouse Type	Ogee I (upstream upright)
2	Lighthouse Height	5
3	Spillway Width	68
4	Regulating Channel Length	57.5
5	Straight Launcher Channel Length	120
6	Trumpet Launcher Channel Length	20
7	Stilling Basin Length	32
B	Rectangular-Type Baffle Block	
1	Height	30
2	Length	50
3	Width	20

Figure 1 Overview of the Research Flume

(a) (b)

Figure 2 Variation of rectangular porous baffle block angle (a) Angle 1800; (b) Angle 300

Figure 3 Rectangular-Type Baffle Block Model

Dimensional Analysis

Based on the experiment of placing various baffle block models on the launch channel to reduce water flow energy, several parameters affecting energy reduction on the launch channel were obtained as follows:

y = f (hd, hm, y0, yt, ϱw, g, v, ɑ, he)

Based on the dimensional analysis, the dimensional equation for energy dissipation in relation to other variables can be written as follows:

$$f = \left(\frac{hm}{hd}, \frac{y_0}{hd}, \frac{v}{\sqrt{g.hd}}, \frac{y_t}{hd}, \frac{h_e}{hd}, ɑ\right)$$

Based on the combination of several dimensionless parameters, the dimensionless equation is used to analyze its relationship to energy damping against changes in flow energy. Based on the results of the simplification of several dimensionless parameters, it can be expressed as a function of a dimensionless relationship.

$$\frac{h_e}{h_d} = f\left(\alpha, \frac{h_m}{h_d}, \frac{y_t}{y_0}, \frac{v}{\sqrt{gh_d}}\right)$$

Where $\frac{h_m}{h_d}$: relative height of water above the crest, $\frac{v}{\sqrt{g.hd}}$: Froude number, ɑ: model variation angle, $\frac{y_t}{y_0}$: relative height of water surface before and after the baffle block model, $\frac{he}{hd}$: energy dissipation dimension.

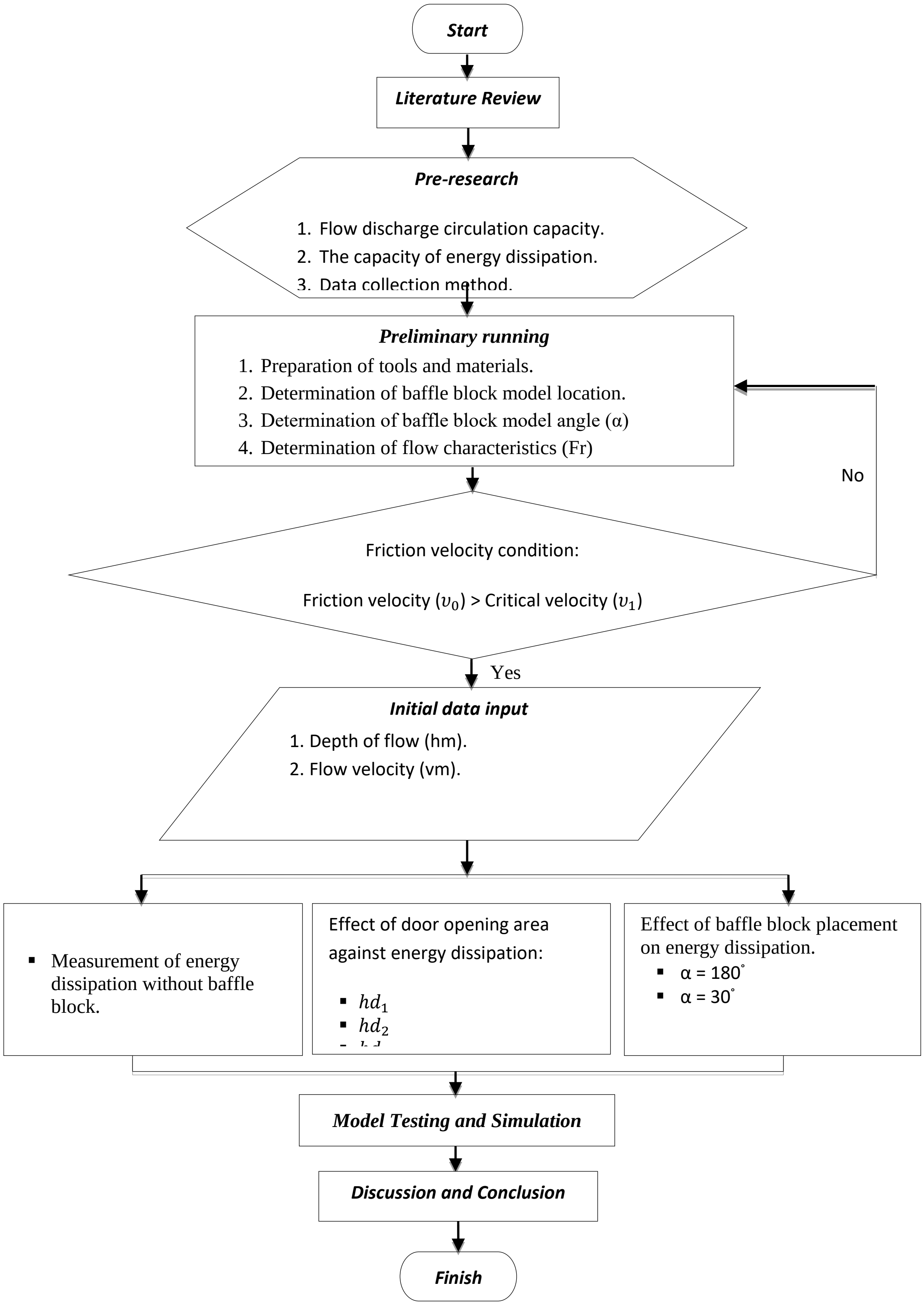


Figure 4 Flowchart of research

Flow Measurement

The method for measuring flow depth and velocity involved dividing the channel into 36 observation point segments. Then the measurements of the flow depth and velocity were conducted at 12 observation point segments within each segment, focusing on the left side, right side, middle side and between the baffle blocks. These measurements were taken using buoys and current meters to calculate the river discharge, using the formula: Discharge (Q) = Volume (V) × Area (A). Fixed parameters during the observations were flow discharge (Q), water level above the crest (hd), baffle block location, flow velocity measurement location (vm) and flow height measurement location (hm).

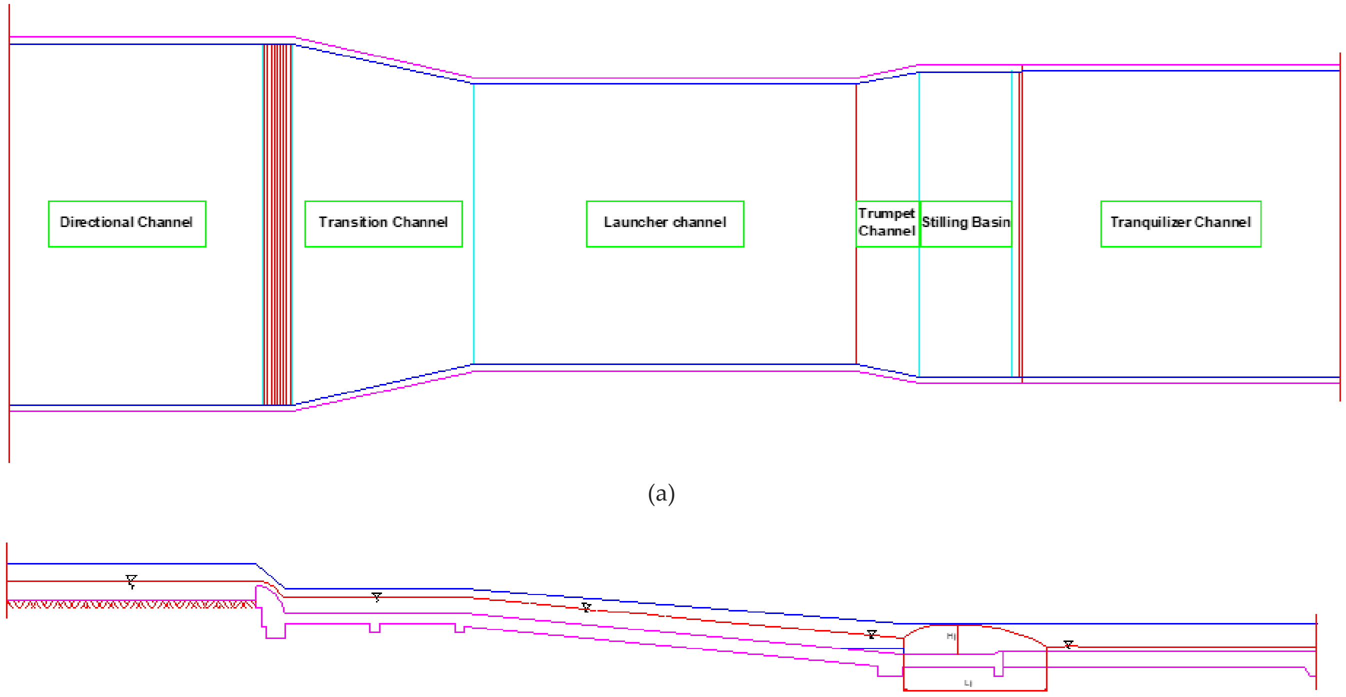
3. RESULTS AND DISCUSSION

Result

Hydraulic Dimensions of the Spillway Structure

The hydraulic dimension of the spillway structure was determined through the analysis of maximum rainfall data using the Thiessen Polygon Method. The annual maximum rainfall data were analyzed using the Log-Normal and Log-Pearson Type III methods, with goodness-of-fit tests evaluated using the Chi-square and Smirnov-Kolmogorov methods. Based on this analysis, the design rainfall for a 1,000-year return period was determined to be 201.17 mm, and the corresponding design discharge was 402.37 m³/s. These values were then used to determine the dimensions of the spillway structure. The hydraulic dimensions of the baffle block were calculated based on flow velocity measurements at the upstream section of the spillway chute.

Using a trial-and-error method, the flow velocity was calculated to be 2.431 m/s. The flow was classified as supercritical, with a Froude number (Fr) of 6.50, which was used as the basis for defining the baffle block's hydraulic dimensions. The determination of the geometric scale was adjusted to the capacity of the flume tank and pump in the laboratory, the availability of materials, and the required accuracy for measurements. The spillway model, as shown in Figure 5, was constructed at a scale of 1:50. This model represents a perfect geometric congruence (without distortion) and dynamic congruence, adhering to the conditions dictated by the Froude number.



(a)

(b)

Figure 5 (a) the Layout of the Spillway Structure; (b) Longitudinal Section

Flow Characteristics in Spillway Structures

The Froude number is defined to identify the type of flow occurring in the spillway model with three variations of flow discharge during the flow process. This can be described based on the Froude number (Fr). The results of the Froude number analysis are as follows:

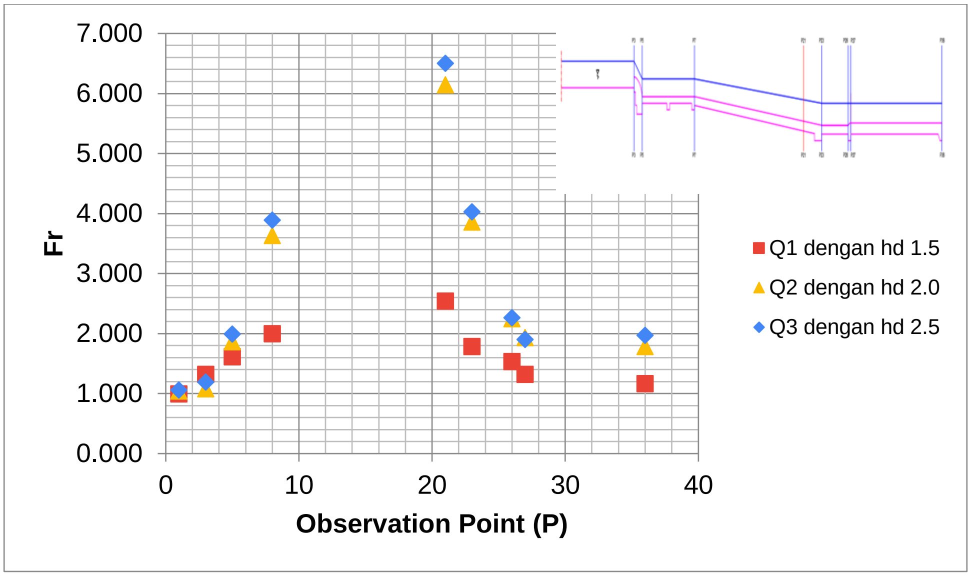


Figure 6 The relationship between the distance of observation points (P) and the Froude number in the spillway structure

Based on the figure above, it can be stated that the flow characteristics that occurred in the spillway channel model in this study were classified as supercritical flow with a value of Fr> 1, where the highest Froude number value occurred in section 21 when the water flow was downstream of the launch channel with a water level above the crest hd1 = 1,5 cm with a Froude number value of (Fr) = 2.54 (supercritical), water level above the crest (hd2) = 2.0 cm with a Froude number value of (Fr) = 6.14 (supercritical) and water level above the crest (hd3) = 2.5 cm with a Froude number value of (Fr) = 6.50 (supercritical).

Flow Energy at the Downstream Section of the Launch Channel

The amount of energy that occurred downstream of the launch channel was obtained by comparing the amount of energy in the upstream section with the downstream energy of the launch channel. The amount of energy reduction in section 22 was obtained by comparing the amount of energy in section 8 with section 22.

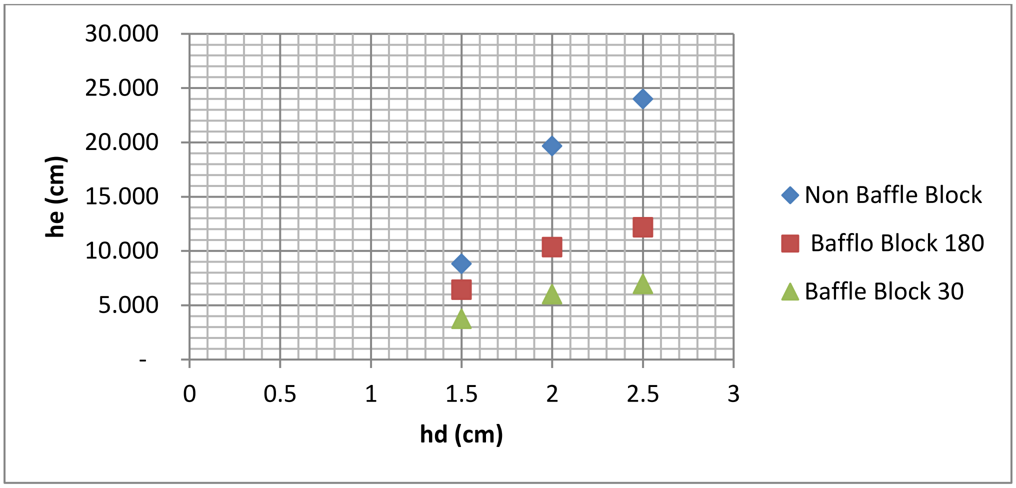


Figure 7 The Relationship between water level above the crest (hd) and flow energy downstream of the launch channel (he) in non-porous baffle block model variations

From the image above, it can be stated that the amount of water flow energy downstream of the launch channel that occurred due to changes in flow parameters that had an impact on increasing flow energy, namely when Q1 = 3303.91 cm3/sec, the water level above the crest hd3 = 2,5 cm with an angle (α) = without an angle with the water flow energy at downstream of the launch channel of he = 23,994 cm. The decrease in water flow energy occurred downstream of the launch channel, namely at Q3 = 6861.66 cm3/sec, the water level above the crest (hd1) = 1.5 cm with an angle (α) = 300, resulting in downstream energy of (he) = 3,749 cm.

The flow in the launch channel model without any variation of the baffle block produced greater flow energy. This occurred because the speed of the water flowing in the launch channel model did not have hydraulic resistance that could hold the speed of the water flow. The decrease in flow energy occurred in the baffle block model variations due to the presence of hydraulic resistance, which reduced the flow speed. Additionally, the water flow, that was held back by the baffle block model, gradually slowed down, further reducing the flow energy.

Flow Characteristics Downstream of the Launch Channel

The flow characteristics that occurred in the flow process in the channel model can be described based on the Froude number (Fr), where the water flow velocity greatly affected the Froude number and energy attenuation in the launch channel. Analysis of the relationship between the water level above the spillway crest and the Froude number (Fr) during the flow can be seen in the following description:

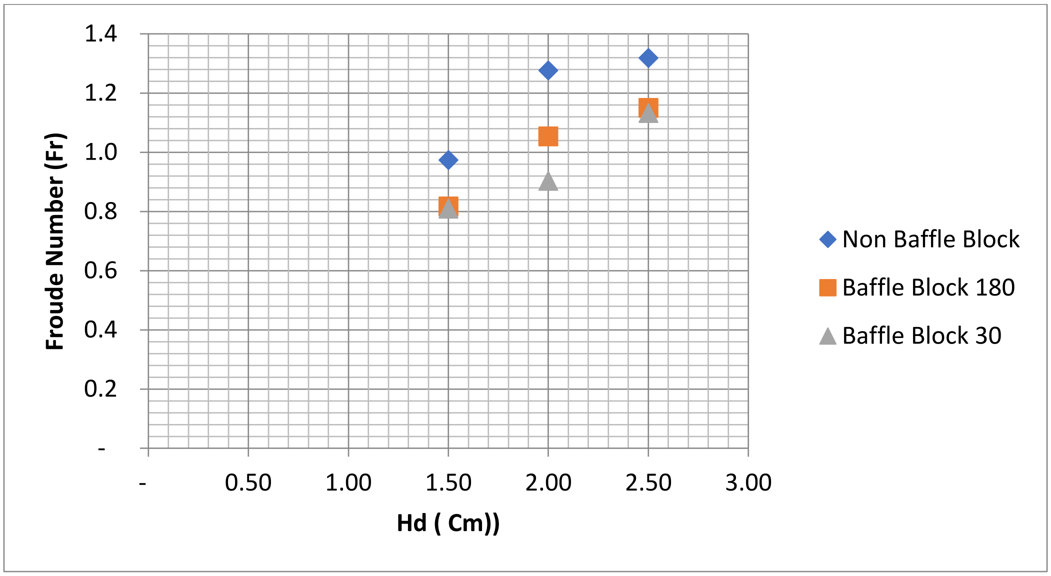


Figure 8 Relationship between water level above the crest (hd) and the Froude number (Fr) downstream of the launch channel in variations of the Non-Porous Baffle Block Model

From the figure above, it can be stated that the magnitude of the Froude number that occurred downstream of the launch channel due to changes in flow parameters and variations in the non-porous baffle block model had an impact on increasing the Froude number that occurred downstream of the launch channel model with variations in the model without baffle blocks. The increase occurred when Q3 = 6861.66 cm3/sec, the water level above the crest (hd3) = 2.5 cm with α = no angle with a Froude number (Fr) downstream of the launch channel of Fr = 1.3. The decrease in the Froude number occurred at Q1 = 3303.91 cm3/sec, the water level above the crest (Hd1) = 1.5 cm with an angle (α) = 300 with a Froude number (Fr) downstream of the launch channel of Fr = 0.7.

The downstream flow at the launch channel without any variations in the baffle block model produced a higher Froude number. This occurred because the water flow in the launch channel did not have hydraulic resistance that could hold the water flow rate back. A decrease in the Froude number occurred downstream of the launch channel in the variation of the non-porous baffle block model due to hydraulic resistance, which reduced the flow velocity. As a result, there were changes in flow characteristics along with changes in the Froude number downstream of the launch channel.

Relationship between parameters that influence energy dissipation downstream of the launch channel

The Relationship between Froude Number (Fr) and Water Energy Damping at Downstream of the Baffle Blocks $\left(\frac{h_{je}}{h_m}\right)$.

Froude number is a characteristic of water flow required at each stage of flow. In this study, the Froude number was generated at each observation point along the spillway channel. Based on the test, the resulting Froude numbers varied but showed a certain trend. Because the Froude number was a function of the length of the water jump downstream of the spillway, in this study the Froude number (Fr) was considered important because it was related to the length of the jump downstream of the spillway. In this test, a relationship was found between the Froude number (Fr) and the water energy dissipation downstream of the baffle blocks $\left(\frac{h_{je}}{h_m}\right)$.

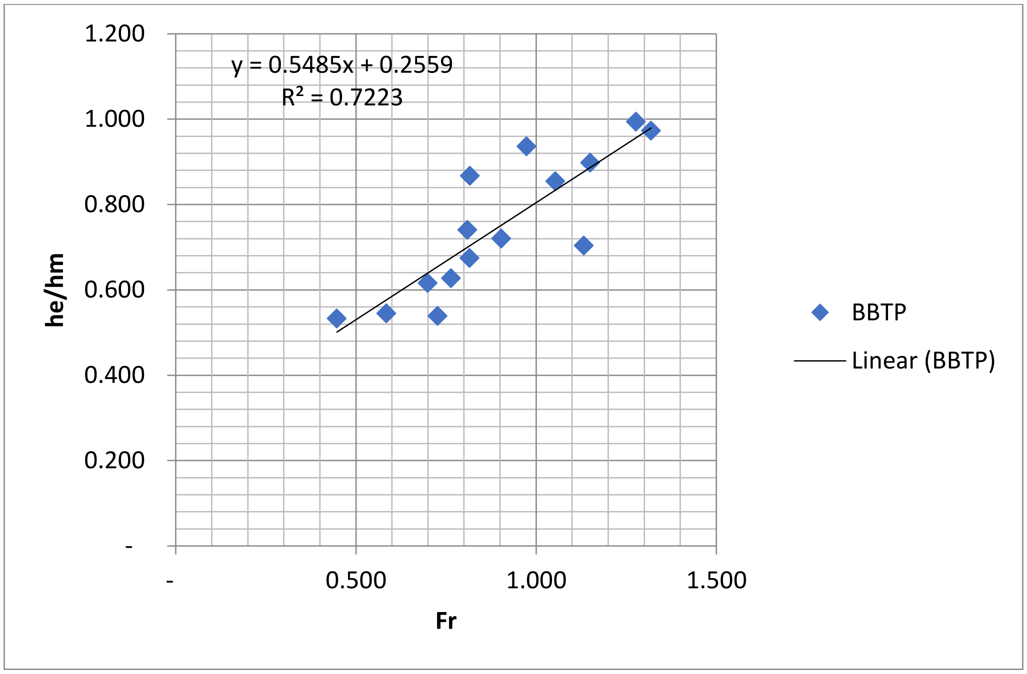


Figure 9 The Relationship between Froude number (Fr) and energy dissipation $\left(\frac{h_j}{h_m}\right)$

From the figure above, it can be stated that the relationship between the Froude number (Fr) and the magnitude of water energy dissipation downstream of the baffle blocks $\left(\frac{h_j}{h_m}\right)$, at both stages of flow showed a similar tendency, where at the discharge flow stage, it tended to be linear. The R-squared (R^2) suitability value was based on the data distribution pattern on the graph which indicated that the flow stage had a good trend. The tendency of the relationship was linear and had a strong relationship with an R-squared (R^2) value = 0.7233.

Relationship between Water Jump $\left(\frac{y_t}{y_o}\right)$ ***and Energy Dissipation at Downstream of Baffle Blocks*** $\left(\frac{h_e}{h_m}\right)$.

The height of the water jump upstream and downstream of the baffle block model is a crucial factor required at each stage of flow in the launch channel. The height of the water jump in this study was produced at the observation points of the upstream and downstream parts of the baffle block model variations in the launch channel. Based on the tests, the water jump height upstream and downstream of the baffle blocks showed varying observation data but followed a certain trend. Therefore, the height of the jump upstream and downstream of the baffle blocks functions as the energy dissipation in the flow downstream of the spillway structure. The height of the jump upstream and downstream of the baffle blocks was considered important in this study because it was related to the dissipation of the water flow energy downstream of the spillway structure. In this test, a relationship was found between the water jump $\left(\frac{y_t}{y_o}\right)$ and the energy dissipation downstream of the baffle blocks $\left(\frac{h_e}{h_m}\right)$.

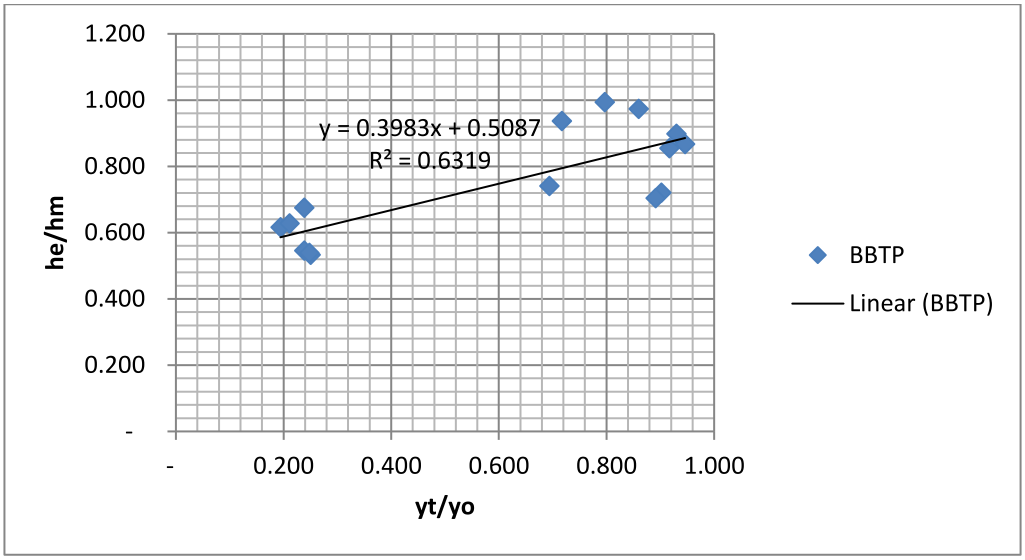


Figure 10 The Relationship between Water Jump $\left(\frac{y_t}{y_o}\right)$ and Energy Dissipation $\left(\frac{h_e}{h_m}\right)$.

The relationship between water jump $\left(\frac{y_t}{y_o}\right)$ and energy dissipation downstream of the baffle blocks $\left(\frac{h_e}{h_m}\right)$. At both stages of flow, it showed the same tendency, where at the stage of discharge flow, the trend tended to be linear. The R-squared (R^2) suitability value was based on the data distribution pattern on the graph which showed that the flow stage had a good trend. The linear relationship tendency in the variation of the baffle block angle showed a strong correlation, with an R-squared value of $R^2 = 0.6319$.

The Relationship between Water Flow Height $\left(\frac{y_t}{y_o}\right)$ and Energy Dissipation downstream of the Baffle Blocks $\left(\frac{h_e}{h_m}\right)$.

The height of water flow upstream and downstream of the baffle block model was the required height at each stage of flow in the launch channel. The height of water flow in this study was produced at the observation points at the upstream and downstream parts of the variation of the baffle block model in the launch channel. Based on the tests, the observed water flow heights varied but displayed a consistent trend. Therefore, the height of the water flow upstream and downstream of the baffle blocks was a function of the energy dissipation of the water flow downstream of the spillway structure. This height was considered significant in this study because it was closely related to the energy dissipation occurring downstream of the spillway structure. In this test, a relationship was found between the water jump $\left(\frac{y_t}{y_o}\right)$ and the energy dissipation downstream of the baffle blocks $\left(\frac{h_e}{h_m}\right)$.

The relationship between water flow height $\left(\frac{y_t}{y_o}\right)$ and the dissipation energy downstream of the baffle blocks $\left(\frac{y_t}{y_o}\right)$ at both stages of flow showed the same tendency, where during the flow stage the discharge tended to be linear. The R-squared suitability value was based on the data distribution pattern on the graph, which showed that the flow stage had a good trend. The tendency of the relationship was linear, and the variation of the baffle block angle tended to have a strong relationship with $R^2 = 0.7707$.

The Presentation of Energy Dissipation

The flow energy dissipation profile at various conditions in the launch channel is presented in (Figure 10). The flow energy dissipation increased with changes in the water level above the crest and the flow rate, due to changes in the channel cross-section from the zero point in the launch channel to the maximum value at y = d0, which was the depth of the boundary layer. The boundary layer increased as the distance from the transition channel to the launch channel grew. Momentum changes occurred when the flow velocity flowed in the same direction and formed a cross flow. On the other hand, the flow velocity decreased with the presence of the baffle blocks, and this decrease in flow velocity made the flow energy dissipation greater.

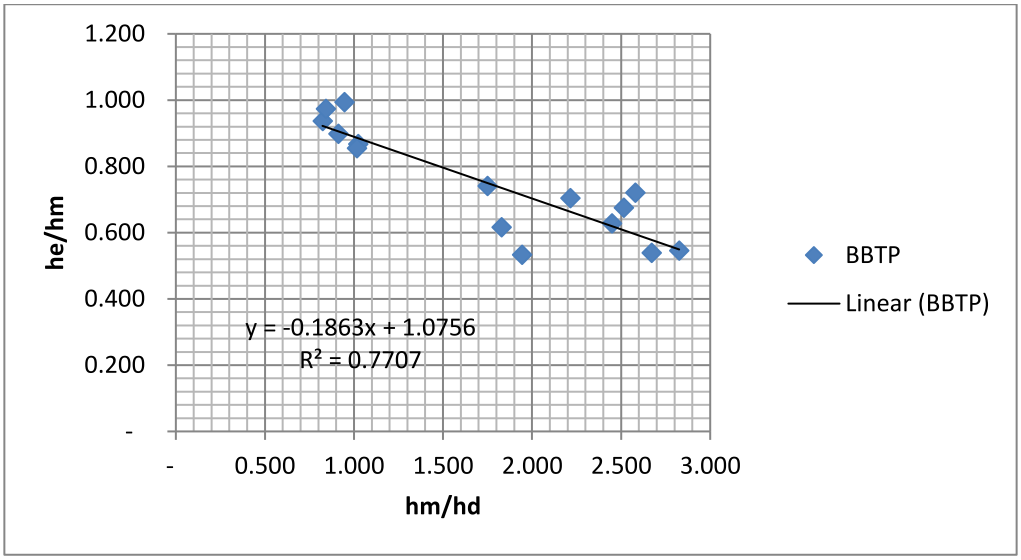
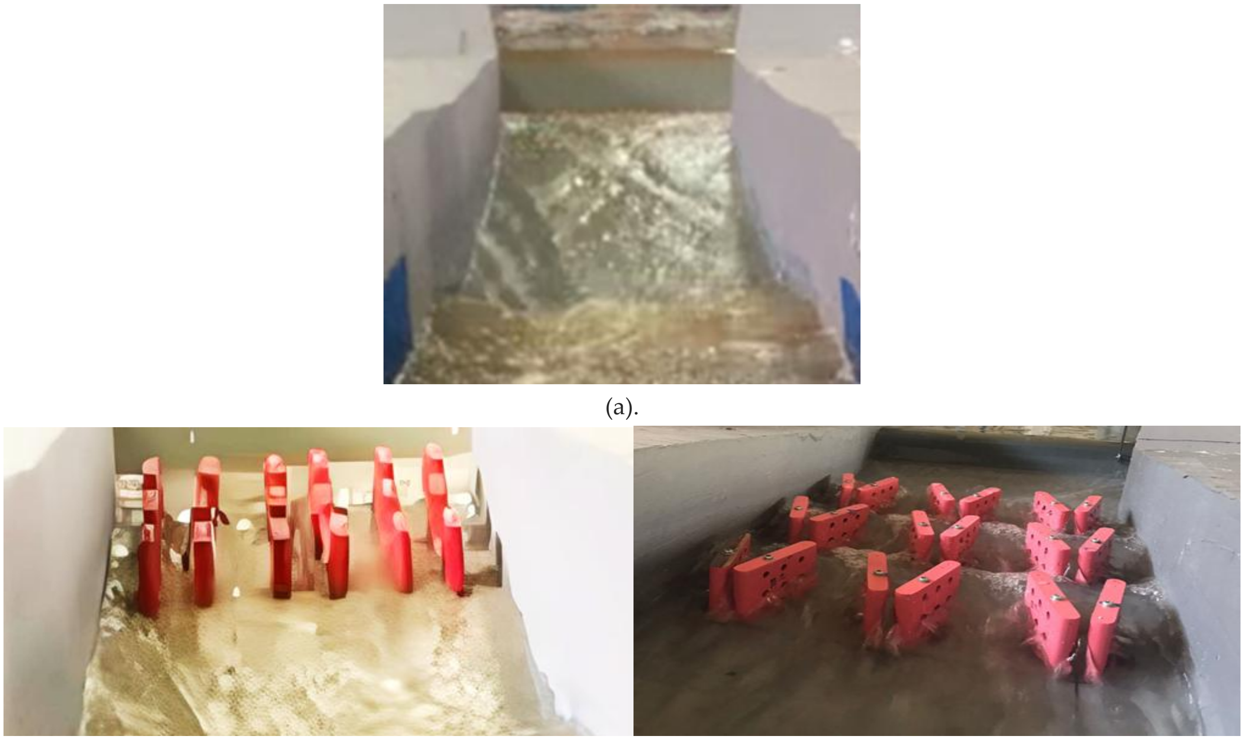


Figure 11 The relationship between water flow height $\left(\frac{y_t}{y_o}\right)$ and energy dissipation $\left(\frac{h_e}{h_m}\right)$.



(a).

(b)

(c)

Figure 12 The Angle Variation of Rectangular Baffle Block during Water Flow Energy Dissipation (a) Non-Baffle Block; (b) Baffle Block 1800; (c) Baffle Block 300;

The maximum flow energy dissipation in all experiments occurred after passing through the baffle blocks and the intensity of the flow energy dissipation decreased along with the movement of the flow towards the downstream of the launch channel. The peak of the flow energy dissipation shifted slightly towards the free surface in the direction of the flow. The maximum velocity of the flow occurred in water that was held in small amounts and gradually decreased as the baffle block angle changed. Flow with low energy upstream of the spillway passed over the crest of the structure and reached a high speed in the spillway channel. This high-energy flow resulted in a hydraulic jump, and the presence of the baffle block angle caused energy loss in the flow without damaging the structure and the channel bed.

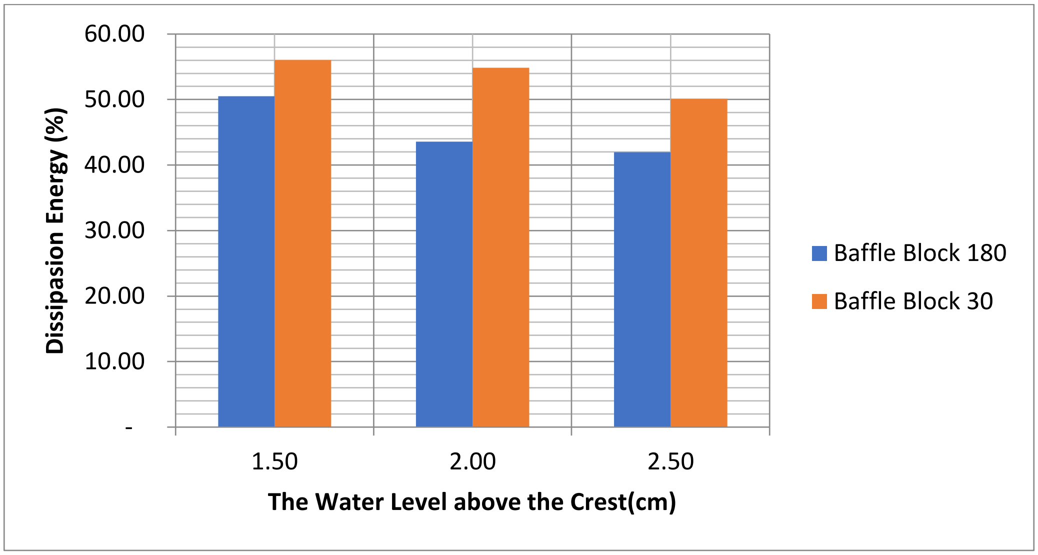


Figure 13 The Presentation of the Flow Energy Dissipation

From the analysis of the relationship between the water level above the crest and energy dissipation, it can be concluded that the variation of the baffle block model with a larger angle variation was able to dissipate energy better. This was largely due to the magnitude effect of the baffle block angle and with the gap between the baffle block angles being able to dampen or regulate the water flow to slow down the water flow speed that would pass through the variation of the baffle block model in the launch channel. From the figure above, it can be stated that the greatest energy dissipation in the variation of the baffle block model at the angle variation (α) = 300, resulting in an average energy dissipation of (he) = 53.66% in the launch channel.

Discussion

The placement of rectangular-type baffle block angle variations upstream of the launcher channel significantly contributes to energy attenuation downstream of spillway. The use of rectangular-type baffle block on the slope of the launcher channel causes an increase in bistable flow. An increase in flow discharge correlates with greater turbulence downstream of the stilling basin and the smaller the energy loss value. Specifically, energy loss efficiency increases as discharge variation decreases, showing the effect of placing porous rectangular-type baffle block angle variations at the start of launcher channel to reduce energy and water surges in spillway structures.

Research on reducing flow energy to shorten water jumps in an effort to protect downstream spillways, including: Abdelhaleem, (2013) researched about baffle block type semi-circular, by considering the flow pattern, it can be seen that the tip of the water jump flows upstream and downstream, but when the tip of the water jump approaches the baffle block, the flow hits the baffle block resulting in a dotted line and a large negative pressure on the upper surface of the beam has increased the lift. Researched about baffle block type semi-cylinder. the flow pattern across the baffle block arrangement results in overtopping flow over the bulkhead, diverting the flow between the screens to form a curved eddy current, which forms a vortex in front of the screen. Eshkou et al., (2018) researched about angled baffle block. the flow pattern indicates that using baffle blocks in a convergent arrangement decreases the relative length and depth ratio of the hydraulic jump sequences.

High pressure in front of the baffle block and low pressure behind it causes secondary flow, which tends to increase the energy loss in the head tank. Al-Mansori et al., (2020) researched about baffle block type V. with a change in angle, the ratio of the length of the hydraulic jump to the initial depth is inversely proportional to the angle of intersection in the vertical and horizontal positions and directly proportional to the value of F. The value of the drag coefficient in the form of Froude's number shows the value of the drag coefficient with the arrangement of baffle blocks with a vertical position having pattern conditions relatively good flow compared to the baffle block arrangement in a horizontal position.

Placing baffle blocks in a hydraulic jump with a particular slope causes hydraulic jump stability, increases bistable flow, and produces a stable hydraulic jump. Using baffle blocks in a convergent arrangement improves the hydraulic jump characteristics compared to a diverging configuration. The selection of the baffle block type considers that when the discharge outflow of a small overflow does not occur in full flow, it avoids air vacuum. The water jumps in the churning pond when the large discharge does not overflow the wall. One way to reduce the energy due to the jumping of water from the turbulent pond into the river is to build an energy dissipation (Plunge Poll) in the chute channel so that it can change the type of supercritical flow to subcritical flow.

4. CONCLUSION

The total energy dissipation relatively increases with the rising initial Froude number (F*1*) and decreases with the increasing upstream Froude number (Fu) and sequential Froude number (F*2*). The maximum value of the relative total energy dissipation is obtained when the water level above the crest is higher, and the minimum value is obtained when the water level above the crest is lower, regardless of the magnitude of the baffle block angle. The presence of baffle blocks in the launch channel with an angle variation of 300, provides a greater energy dissipation value compared to baffle blocks with an angle of 1800. In the case of baffle block angle variations, a water level above the crest of 2.5 cm results in the maximum value of relative total flow energy dissipation, whereas a water level of 1.0 cm above the crest provides the minimum value of flow energy dissipation.

Suggestions

This study requires a further testing to determine more accurate flow constant values. Additionally, a more in-depth analysis of the hydraulic structure of the baffle block is necessary to enhance its effectiveness in dissipating flow energy within water structure constructions. This effort aims to advance and develop sustainable water resource management strategies.

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Author Contribution

Conceptualization: LHD, MSP, RK, and BB; methodology: LHD; software: LHD; validation: MSP, RK, and BB; formal analysis: LHD; investigation: LHD; resources: LHD; data curation: LHD; writing—original draft preparation: LHD; writing—review and editing: LHD; visualization: LHD; supervision: MSP, RK, and BB; project administration: LHD; funding acquisition: LHD. All authors have read and agreed to the published version of the manuscript.

Informed consent

Not applicable.

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Ethical approval

Not applicable.

Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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