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Laboratory study of stilling basin using trapezoidal bed elements

Key words: baffle blocks, stilling basins, energy dissipation, spillway, hydraulic jump

Introduction

Stilling basins can be characterized as vitality dissipaters built downstream of water system frameworks. These dissipaters' elements mostly rely upon the hydraulic jump's properties. Ordinarily, the stilling basins have more elements, which implies that they require an enormous region and that the development costs are high. For example, Eshkou, Dehghani and Ahmadi (2018) investigated the impact of calculated confuse hinders for improving water-driven hop attributes in a continuously veering stilling bowl with an unfavorable bed incline. The best assembly point (i.e. the edge between longitudinal pivot and stream course) of the elements was found to be 30°, which decreased the length and profundity proportions of the water-driven bounce by up to 35–16%. Whereas Habibzadeh, Loewen, Mark and Rajaratnam (2016) presented laboratory estimations of the disturbance in lowered water-driven bounces with squares downstream of a floodgate entryway, our work provides knowledge regarding the creation and scattering of choppiness in lowered streams and clarifies why a lowered hop with obstructs with a low submergence factor (i.e. the DSJ stream system) is as powerful as free hops in disseminating vitality.

Ali and Elhamaimi (2020) examined stream boundaries with a lowered hop under door-utilizing physical and mathematical models. Twenty test runs were completed to consider the effect of dispersed layered beds on fundamental attributes of a lowered pressure-driven hop for estimations of Froude numbers from 1.5 to 9.5. Substantial agreement was found among trial results and mathematical simulations; creased beds decreased bounce length and sequent profundity by 5.69% and 12.96%, respectively. Disturbance models $k–\varepsilon$ and RNG $k–\varepsilon$ can simulate this observation. Finally, the RNG $k–\varepsilon$ model gives results that are more in agreement with tests.

Recently, the concept of baffle blocks has been used in advanced water treatment units to mix water and dissipate excessive energy (Al-Mansori, 2014; Al-Baidhani, Al-Mansori & Al-Khafaji, 2018). The impacts of a chute hindering both the length and increased dependability of water-driven bounce were recently numerically analyzed by Valero Huerta, Garcia-Bartual and Marco (2015) for both designed and adverse conditions. The developed model showed an impressive ability to reproduce the change in the length and stability of the hydraulic jump.

Numerous examinations have been performed on sills under vertical sluice gates for both free and submerged flow conditions (e.g.: Mohamed, Saleh & Ali, 2015; Elsaeed, Ali, Abdelmageed & Ibrahim, 2016). Abdelhaleem (2017) studied the lowered move through outspread doors with and without an entryway ledge. He combined the negative effect of ledges under lowered outspread entryways and found that the close by scour phenomenon occurred instantly downstream of the stilling bowl of some current lowered spiral doors with a door ledge in Egypt.

Ibrahim (2017) investigated the effect of block shapes on the flow pattern downstream of a radial gate. The blocks were highly proficient in limiting the detached impact of the flow pattern downstream of the gate. Abbas, Alwash and Mahmood (2018) concluded from their study that utilizing an astound square caused a decrease in sequent profundity extent, length of hop extent and roller length; however, vitality dispersal increased. Maatooq and Taleb (2018) found that utilizing a two-column arrangement of standard USBR Recommendations astound hinders blockage by 50–37.5%; at predefined separations, this arrangement can diminish sequent profundity, and the speed becomes approximately consistently circulated over the bowl width. Al--Husseini (2016) indicated that the stream vitality dispersal diminishes with stream rate increases, and the roughed step spillway surface increasingly contrasts with the other spillway surfaces at low or high stream rates.

Aydin and Ulu (2018) observed a decrease in scour downstream of a weir by utilizing vitality dissipaters with various calculations. The stream and scouring events on the weir were demonstrated in two measurements utilizing computational fluid dynamics (CFD). The findings were discussed in the context of various downstream conditions.

Hilo and Lafta (2019) used stream 3D programming in their mathematical examinations. The recreation model utilized an RNG $k–\varepsilon$ disturbance model with VOF. Utilizing three half balls (one on the internal edge and two at the external edge of steps) gave higher vitality dispersal by approximately 54% in the skimming stream system; expansions of at least 57% are considered to be at an advanced level.

Mohammadzade-Habili, Heidarpour and Samiee (2018) examined the vitality scattering and downstream stream system of maze weirs. To correlate the results, the condition of highest conceivable vitality dispersal ΔE_{max} on maze weirs was acquired by utilizing the particular vitality bend. Dimensional investigations demonstrated that the relative vitality dissemination on maze weir ΔE / E_0 was uniformly diminished with expanding relative basic profundity y_c / E_0, where E_0 is the absolute upstream vitality. Consequently, vitality dissemination structures are not required downstream of the weir. The impact of napes, coursing stream in constructed pools behind the nappes, and a water-driven bounce on weirs downstream of the face are primarily responsible for the substantial vitality differences observed on maze weirs. Mohammadzade-Habili and Honar (2018) examined a pressure-driven hop on a creased bed, with a specific vitality bend being utilized. A wide scope of existing test information from water-powered bounces on smooth and folded beds was similarly utilized; the vitality dissemination of a water-powered bounce on a layered bed was found to be affected by level good ways from the floodgate door area to the beginning of the ridged bed. These baffle blocks could be used, for example, to enhance water treatment unit performance (Abdulhadi, Kot, Hashim, Shaw & Khaddar, 2019; Hashim et al., 2019; Hashim, Ali, Al Rifaie et al., 2020; Hashim, Kot, Zubaidi et al., 2020).

In this context, the current examination explored the observation of a new three-puzzle-square structure in terms of reducing the number of required components of stilling bowls in water system frameworks. Moreover, this new bewilder square contrasts to a substantial degree with standard perplex squares. Because of the ongoing advancements in innovation and utilization of perplex plates in various water treatment offices, Ryecroft et al. (2019) suggested utilizing detection devices to screen drag power and water bounce conduct, providing useful data for future investigations. Teng et al. (2019) carried out a naval laboratory study to evaluate the pressure-driven execution of another plan for bewilder squares utilized in stilling bowls. These new three squares differed from standard trapezoidal blocks.

Material and methods

Examined blocks

Another three shapes with standard trapezoidal bewilder squares have been produced at the research center of design at the University of Babylon, utilizing local wood as suggested by USBR proposals. The shapes were painted with waterproof paint to avoid water spillage that could damage their shape. The examined customary confuse obstruct as per USBR proposals (model A) has a trapezoidal-formed segment with outer elements of 37.5 cm in width and 5.0 cm in height. Three baffle block models were used with a trapezoidal shape. Figure 1 illustrates the baffle block arrangement inside the stilling basin and Figure 2 shows the flow inside the stilling basin with the baffle blocks of model D provided as an example of flow. Each model was made with a specific apex angle (55° for model B, 75° for model C and 85° for model D). Table 1 provides the baffle model dimensions.

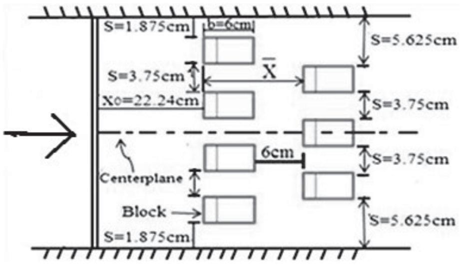

FIGURE 1. Arrangement of studied baffle blocks of model A

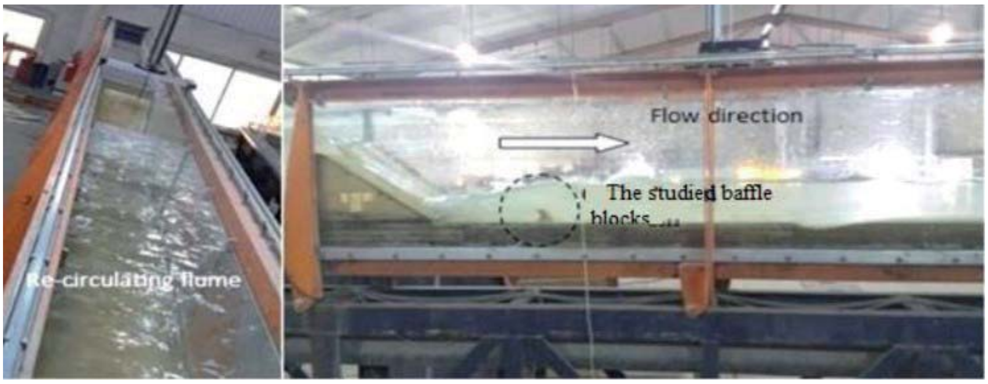

FIGURE 2. Flow inside stilling basin with blocks of model D

TABLE 1. Baffle block model dimensions

Baffle model	Height (hb) [mm]	Width [mm]		Length (b) [mm]	
		W1	W2	upper side	lower side
A	50	37.5	37.5	10	60
B	50	25	37.5	21.5	21.5
C	50	25	37.5	15.4	15.4
D	50	25	60	12	12

Experimental setup

Trial work was completed utilizing a rectangular open-inclining flume produced using Perspex. The flume was 17.5 m, 0.3 m and 0.3 m in length, width and height. It was provided with a spillway, 0.355 m in height, introduced 6.50 m upstream of the flume. Water profundity and scour opening were estimated utilizing a point gage, with a precision of 0.1 mm, mounted on an aluminum outline that could be moved vertically and horizontally along the flume bed. The territory and length of the scour hole were estimated utilizing a scale introduced on the inside mass of the flume. A rear end was utilized to control the downstream water profundity. Figure 3 provides longitudinal cross--section of the experimental setup.

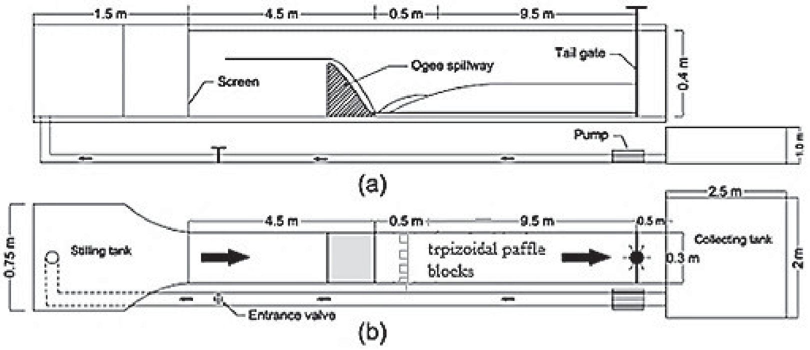

FIGURE 3. Experimental setup: a – cross-section; b – longitudinal section

Experimental procedure and measurement

Three different baffle block shapes were used as vitality dissipaters of the spillway model downstream. An aggregate of 120 runs was made. Six distinct releases were considered for the discharge (6.50, 10.70, 12.50, 16.33, 17.75 and 19.62 *L* / *s*). At each run, water must be fixed, and a profundity of *Y*2 was utilized. All utilized models were organized in the flume with approximately the same level of conduit (around 40%) The row location of the baffle block models from the spillway end (*X*0 and *Y*2) was downstream of the water depth.

Because for the given delivery, the pressure-driven hop must be framed consistently in the stilling bowl, there should be several impediments for the Froude number of the approaching stream, with Fr_1 indicating the profoundly waviness and flimsiness of the water surface; Fr_1 was observed to increase from 6.5 to 9.2.

The experimental work began with the backwater first until the *Y*2 profundity was more than the ideal water profundity of a specific release. At that point, the upstream section was progressively and balanced. The back end was deliberately brought down until the ideal downstream water profundity (*Y*2) was achieved. When there were no obvious changes in scour hole estimations (from this exploratory work, a run took approximately 2 h to arrive at an almost steady condition), the flume delta valve was shut. Finally, scour hole estimations were assessed using a point check and scale.

Results and discussion

Sequent depth proportion

Figures 4 and 5 illustrate that a 0.08 and 0.00 slope respectively explained a decrease in y_2 / y_1 for model D when compared with the smooth bed and models A, B and C. For a specific incline, a decrease in the extent of y_2 / y_1 was noted for the confound model D compared to the smooth bed (Fig. 5). Examination was conducted for two cases (at slopes of 0.00 and 0.08), as seen in Table 2. Moreover, replacing baffle model A at 0.00 slope (horizontal slope) by baffle model D with 0.08 slope caused a reduction in

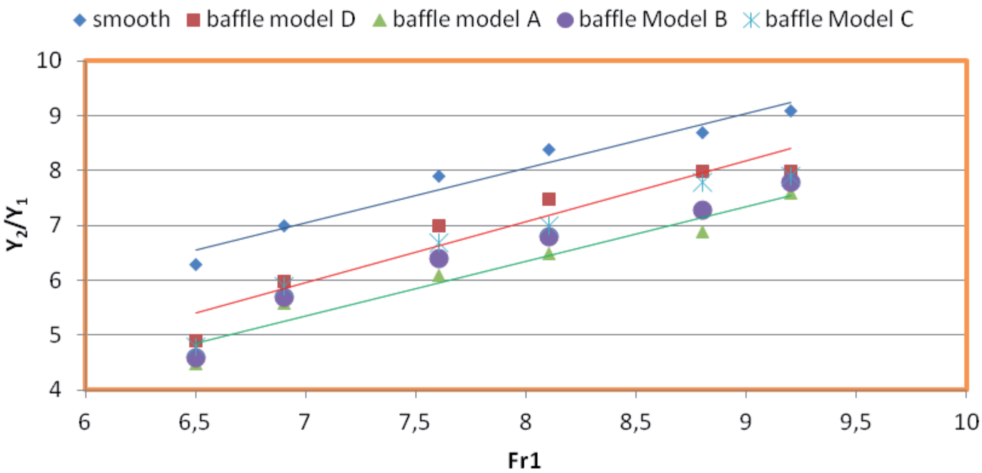

FIGURE 4. Relation of y_2 / y_1 with Fr_1 for suggested models at bed slope 0.08

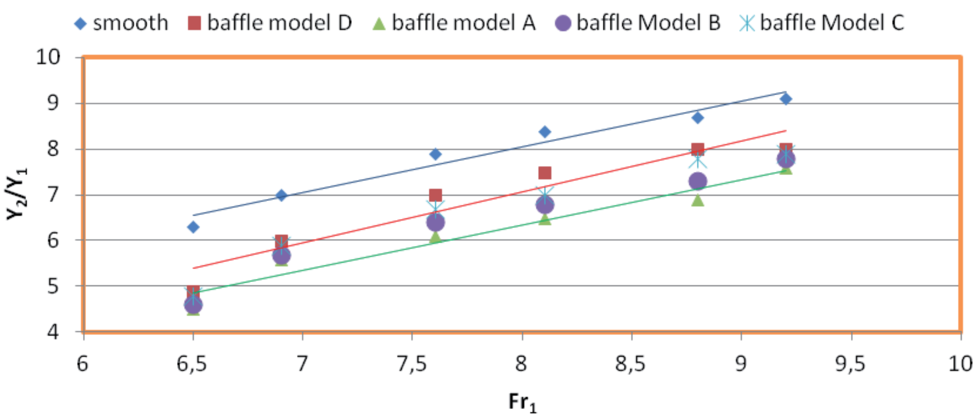

FIGURE 5. Relation of y_2 / y_1 with Fr_1 for suggested models at bed slope 0.00

TABLE 2. Decrease in y_2 / y_1 various cases with 0.00 and 0.08 slopes

Bed state	Percent of reduction in y_2 / y_1 for	
	0.08 slope	0.00 slope
Smooth	27.4	23.2
Model D	12.8	10.3
Model C	11.3	8.5
Model B	9.6	7.9
Model A	7.3	4.3

y_2 / y_1 of approximately 12.8%. The decrease in y_2 / y_1 when model D utilized was due to water particles facing constant obstacles in the column and having to course within the constrained zone; hence, reducing the tail water is fundamental for reducing submerged jump arrangements. Comparing baffle model A with 0.00 slope with baffle model D with 0.08 slope led to a suitable reduction in sequent depth proportion (7.3%). A reduction in y_2 / y_1 resulted in a decreased basin sidewall and, therefore, lower stilling basin construction costs.

Jump proportion length

Regarding basin bed changes due to jump proportion (L_j / y_1) length variations, outcomes for a specific incline showed decreases in the extent of L_j / y_1. For instance, compare the results for the model D baffle with smooth bed cases and models A, B and C shown in Figures 6 and 7 for bed slopes of 0.08 and 0.00. Results of various cases with 0.08 slope are provided in Table 3. Additionally, replacing the model A baffle with the model D baffle with 0.08 slope reduced L_j / y_1 by 18.9% because water particles constantly push and confine its movement; hence, the jump does not stretch out in the downstream direction. Replacing the model A baffle with the model D baffle with 0.00 slope produced a significant decrease in jump proportion length (L_j / y_1) of approximately 13.8%. This result was indicative of a stilling basin length decrease and a subsequent decrease in the total cost.

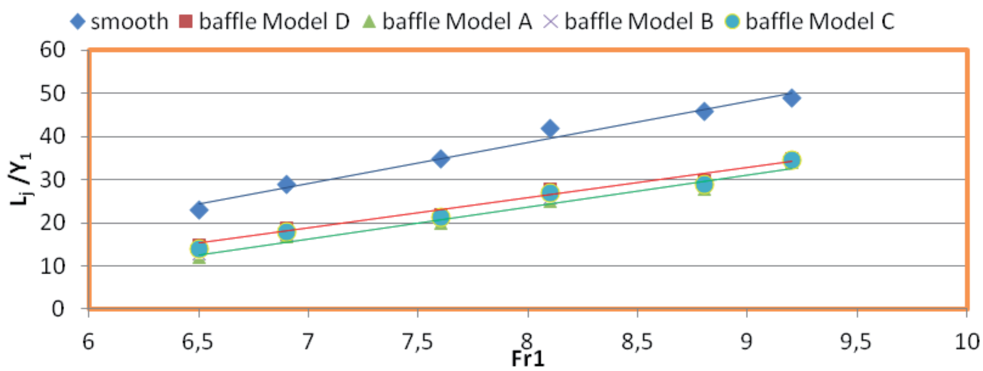

FIGURE 6. L_j / y_1 in bed conditions for 0.08 slope

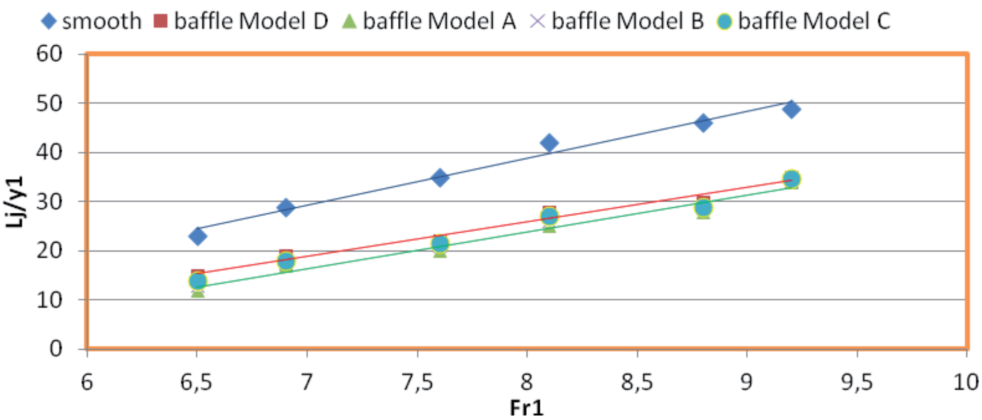

FIGURE 7. L_j / y_1 in bed conditions for 0.00 slope

TABLE 3. Decrease in L_j / y_1 for various cases with 0.08 and 0.00 slope

Bed state	Percent of reduction in L_j / y_1 for	
	0.08 slope	0.00 slope
Smooth	32.5	29.2
Model D	18.9	13.8
Model C	15.7	10.7
Model B	12.3	9.4
Model A	8.7	5.3

(2018) was plotted, as shown in Figures 7 and 8. For both 0.00 and 0.08 bed slopes, at the bed surface, the highest velocity tended to lead to a larger momentum exchange between the eddies trapped in corrugations and the main flow. The normal addition of energy ($\Delta E / E_1$) reached 8.3% when the model D baffle with slope 0.08 was utilized rather than the level smooth bed (Fig. 8); for slope 0.00, this value was 5.2 (Figs. 8 and 9). The results for various cases are listed in Table 4. The additional effect activity produce from the blocks increased $\Delta E / E_1$, and the chosen shape (trapezoidal) of the model D baffle made the water particles affect each one of it and lose their vitality. Such streams are flimsy and must be avoided downstream of water-powered structures because even relatively small changes in bed rise lead to a substantial variety of stream profundity. Given these clarifications, arriving at the best conceivable measure of vitality dissemination is not reasonable.

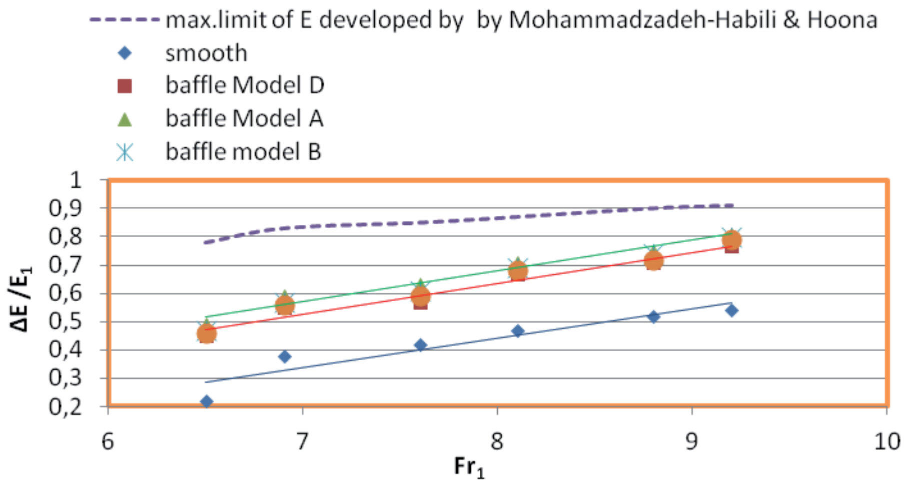

FIGURE 8. $\Delta E / E_1$ in bed conditions on 0.08 slope

Proportion of energy dissipation

When the bed situation changes, the hydraulic jump energy dissipation proportion also alters, as referenced previously by utilizing a smooth stilling basin with 0.08 slope rather than an even, smooth bed, which caused a decrease in vitality dissemination. However, utilizing puzzle squares led to this decrease increasing vitality scattering. For comparison of energy dissipation, the curve of maximum possible limit of energy dissipation developed by Mohammadzadeh-Habili and Hoonar

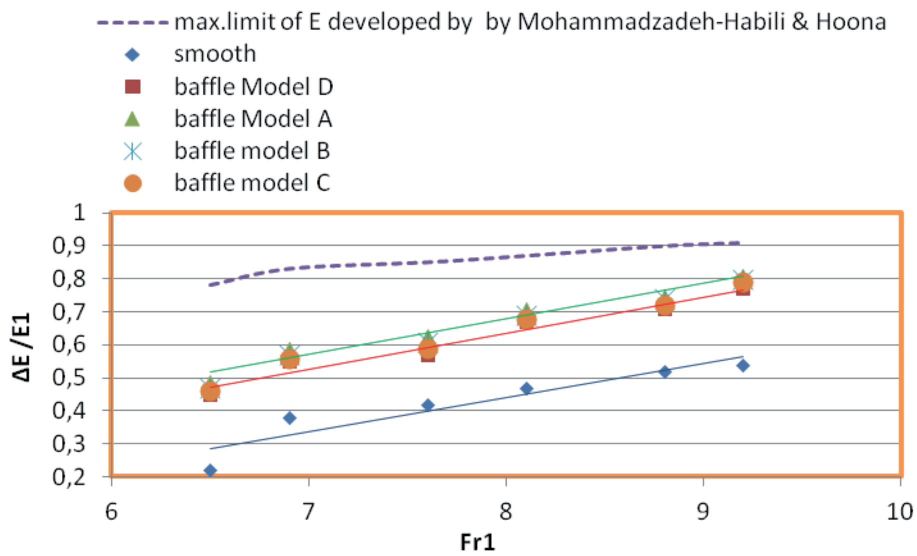

FIGURE 9. $\Delta E / E_1$ in bed conditions on 0.00 slope

TABLE 4. Decrease in L_j / y_1 for various cases on 0.08 and 0.00 slopes

Bed state	Gain in $\Delta E / E_1$ for	
	0.08 slope	0.00 slope
Smooth	23.2	20.7
Model D	8.3	5.2
Model C	6.2	3.4
Model B	4.9	3.1
Model A	3.4	2.5

Conclusions

The main conclusions from this study are:

– For the model D, the hydraulic jump in the stilling basin led to a lower L_j / y_1, y_2 / y_1 and higher $\Delta E / E_1$ compared to the models A, B and C and smooth state. Therefore, the most suitable model (trapezoidal) appeared to be the model D, utilized with the model A on different inclines showing their effects when the bed slants are changed.

– When the model D baffle was used instead of a smooth bed at 0.08 slope, y_2 / y_1 decreased by 12.8%, and L_j / y_1 was 18.9%.

– Among the difference in bed slopes of 0.00, 0.04, 0.06, 0.08, the average decrease in y_2 / y_1 was approximately 10.3%, whereas the average decrease in L_j / y_1 was about 13.8 % when the model D baffle was used instead of the model A baffle with a horizontal slope bed (0.00).

– At 0.08 slope, $\Delta E / E_1$ was 8.3% when the model D baffle was utilized rather than the smooth bed. However, at 0.00 slope, $\Delta E / E_1$ was 5.2% when the model D baffle was used rather than the smooth bed.

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Summary

Laboratory study of stilling basin using trapezoidal bed elements. When designing dam spillway structures, the most significant consideration is the energy dissipation arrangements. Different varieties of baffle blocks and stilling basins have been used in this context. However, the hydraulic jump form of stilling basin is considered to be the most suitable. The main objective of this research was to introduce four different baffle block shapes (models arranged from A to D, installed at slopes 0.00, 0.04, 0.06 and 0.08 in the stilling basins). To illustrate the consequences for the qualities of pressure--driven bounce, each model was attempted in the bowl. The trials applied Froude numbers between 6.5 and 9.2. The puzzle square model D provided the best outcomes compared to the models A, B, C and smooth. Model D with different models at inclines 0.00, 0.04, 0.06 and 0.08 was used to consider the impacts of perplex hinders on water driven-bounce when bed slants were changed. When the model D baffle used instead of a smooth bed at 0.08 slope, the reduction in y_2 / y_1 reached 12.8%, and L_j / y_1 was 18.9%. Among the different bed slopes, a normal decrease in y_2 / y_1 ranged from approximately 10.3%, whereas the normal decrease in L_j / y_1 was about 13.8% when the model D baffle was used instead of the model A baffle with a horizontal slope bed of 0.00. The results show that the new shapes led to a decrease in sequent profundity proportion and length of jump proportion; however, the energy dissipation proportion increased.

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