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EXTENDED ABSTRACT

Study of the Characteristics of The Hydraulic Jump in A Stilling Basin with An Adverse Slope and Different Baffle Blocks

Rasoul Daneshfaraz [a,*], Amir Ghaderi [b], Shahram Rajabi [c]

[a] *Professor, Department of Civil Engineering, Faculty of Engineering, University of Maragheh, Maragheh, Iran*
[b] *Assistant professor, Department of Civil Engineering, Faculty of Engineering, Urmia University, Urmia, Iran*
[c] *MSc Student, Department of Civil Engineering, Faculty of Engineering, University of Maragheh, Maragheh, Iran*

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1. Introduction

Hydraulic jump is a type of rapidly varying flow that occurs when the flow regime transitions from supercritical to subcritical. In this phenomenon, the flow depth increases rapidly over a short distance, accompanied by high turbulence, which results in significant local energy loss and a marked reduction in flow velocity. Hydraulic jumps are commonly utilized in energy dissipators downstream of various hydraulic structures, such as stilling basins, to enhance the dissipation of flow energy. While substantial research has focused on the performance of stilling basins and the control of hydraulic jumps within them, there has been limited comprehensive study on the characteristics of hydraulic jumps within stilling basins under different adverse slopes and with various baffle block configurations. The present study investigates the impact of baffle blocks with varying shapes and dimensions placed on a horizontal bed, along with three adverse slopes of 2.60%, 5.20%, and 7.55%, positioned downstream of a stepped chute. The primary objective of this study is to examine the relative residual energy and the characteristics of the hydraulic jump, including the variations in jump length, sequent depth ratios, and the percentage reductions in both jump length and sequent depth.

2. Methodology

2.1. Experimental study

The laboratory tests were conducted in a rectangular flume at the hydraulics laboratory of Maragheh University, with dimensions of 1.2m in width, 0.8m in depth, and 12m in length. The flume featured glass walls to enhance flow visibility and reduce friction. Flow was supplied by a pump with a maximum capacity of 55 l/s, which transferred water into the flume's head tank. An ultrasonic flow meter with a precision of ±1l/s was installed on the transmission pipe to measure discharge. Two screen plates were used to facilitate flow relaxation, and a floating Styrofoam plate was fixed along the flow direction to minimize water level fluctuations. Flow depth was measured using a pointer gauge with an accuracy of ±1mm. Measurements were taken 2 meters upstream of the smooth chute and after the hydraulic jump in the stilling basin. The tests were designed based on the USBR III stilling basin model, with a Froude number of 8. The stilling basin had a length of 1.3m and a width of 1.2m, with three rows of square and lozenge-shaped wooden blocks at two heights (0.045m and 0.09m). The tests were performed on a horizontal bed with three adverse slopes: 2.60%, 5.20%,

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* Orcid Cod Corresponding Author: 0000-0003-1012-8342
E-mail addresses: daneshfaraz@maragheh.ac.ir (Rasoul Daneshfaraz), a.ghaderi@urmia.ac.ir (Amir Ghaderi), shahrm.rajjabi@gmail.com (Shahram Rajabi).

and 7.55%. Upstream of the stilling basin, a stepped spillway with a 26.60° slope consisted of 10 steps, each with a step length (l) of 0.06m and a step height (h) of 0.12m. In total, 13 stilling basin models with varying block shapes and dimensions on the horizontal bed, and 36 models with different block configurations on adverse slopes, were tested.

3. Results and discussion

3.1. sequent depth ratios

According to dimensional analysis, the sequent depth ratio is a function of the baffle block height, block arrangement, adverse slope of the bed, and the initial Froude number. Laboratory observations indicate that changes in the arrangement and dimensions of the baffle blocks affect the vortex flow formed between them. The baffle blocks induce vortex flow, enhancing the mixing of water and air compared to the horizontal bed. This effect is further intensified as the height of the baffle blocks increases. The greatest and smallest reductions in sequent depth ratios were observed in the AD2S2D2 and AD1S2D1 models, which showed decreases of 22.12% and 8.33%, respectively, compared to the classical jump. The application of an adverse slope resulted in a significant decrease in sequent depth ratios relative to the horizontal bed. On average, the reduction was 72.25% and 37.44%, compared to the horizontal bed.

3.2. The relative jump length

The length of the hydraulic jump increases with an increase in the Froude number. The effect of altering the arrangement of the baffle blocks becomes particularly evident at higher Froude numbers. Comparison of different block arrangements revealed that the largest reduction in hydraulic jump length occurred with the AS2D2S2 model, while the smallest reduction was observed with the AS1D1S1 model, showing decreases of 35% and 13.24%, respectively, compared to the stilling basin without blocks. The maximum and minimum reductions in hydraulic jump length were observed with the AD2S2D2 model (-7.55%) and the AS1D1S1 model (-2.60%), respectively. On average, the jump length decreased by 42.15% and 8.20% compared to the horizontal bed.

3.3. The relative residual energy

The relative residual energy in the stilling basin with baffle blocks is lower than that in the smooth bed (classical jump) and decreases as the Froude number increases. The maximum and minimum reductions in relative residual energy were observed in the AS121 and AD121 models, with decreases of 10% and 32%, respectively, compared to the classical jump. When compared to the horizontal bed, the relative residual energy in the adverse slopes of -5.20% and -7.55% decreased by 14.60% and 32.78%, respectively.

4. Conclusions

This study investigated the effects of adverse slopes and baffle blocks on the characteristics of hydraulic jumps. Various baffle block arrangements were tested at adverse slopes of 2.60%, 5.20%, and 7.55%, and the results were compared to those of a stilling basin without baffle blocks. The findings showed that the use of baffle blocks in the stilling basin reduced the sequent depth ratio, jump length ratio, and relative residual energy by an average of 22.12%, 35%, and 32%, respectively, compared to the classical jump. Additionally, at an adverse slope of 2.60%, the sequent depth ratio, jump length ratio, and relative residual energy decreased by 72.25%, 8.20%, and 23.52%, respectively; at 5.20%, by 44.50%, 23.33%, and 14.60%; and at 7.55%, by 37.44%, 42.15%, and 32.78%, respectively, compared to the horizontal bed.

Overall, the combination of both adverse slopes and baffle blocks led to reductions in the sequent depth ratio, jump length ratio, and relative residual energy of the hydraulic jump. This approach not only makes the construction of stilling basins more economical but also improves the control of hydraulic jumps.