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EXTENDED ABSTRACT

The Effect of Height and First Roughness Distance on Energy Dissipation in Piano Key Weirs

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Introduction

Along with the numerous developments and facilities for constructing large dams, there is a need for developing design and construction methods for systems that can correctly discharge the floods. Weirs refer to any barrier across a channel that raises the flow level and accelerates the flow when flowing over it (Abrishami and Hoseini, 2011). Piano key weirs are the newest type of long-crest weirs and one of the best solutions for modifying the existing weirs. Reducing the energy of the flow over the weirs before their transfer downstream is a solution for preventing possible damage to the structure itself and downstream structures as well as the excess costs incurred by the builders of hydraulic structures due to constructing strong protective structures (Katourani, 2012). Lempèrière and Ouamane (2003) described the piano key weirs and stated their advantages compared to other conventional nonlinear weirs as the ability to place the weir in the crest of the reservoir dam and thus increasing the specific flow rate. Erpicum and Machieles (2011) compared the energy dissipation between two different geometries for a piano key weir and a spillway weir. Concerning the application of a block, the tests and results obtained by the US Land Renewal Organization indicate that using large blocks that separate the flow jet and create turbulence can effectively dissipate the kinetic energy of the current.

Methodology

In the current study, the test flume had a length of 13m and a height of 1.5m. Considering the flume wall thickness, the useful width was 90cm. The flow rate was measured using a triangular weir and a limnometer at the end of the flume. The physical models featured two blocks with different heights in successive rows ($H_{b1} = 12cm$ and $H_{b2} = 8cm$) at different distances from the beginning of the weir outlet key ($D_1=\frac{1}{4}L_o$ and $D_2=\frac{1}{3}L_o$), respectively. After that, 45 tests were conducted with flow rates of 5–135 Lit/s in order to study the flow energy dissipation in a piano key weir with a blocked outlet key. Also, the weir dimensions were obtained based on the $\frac{P}{W_u} = 1.33$ ratio (optimal hydraulic model). First, the tests were conducted within the defined flow rate range without blocks (control tests). Then the tests on the blocked models were conducted using nine flow rates. A graded measure was used in order to measure water depth or water level at each section. The flow rate was calculated using the continuity of flow equation. The flow energy at the weir upstream was obtained using Equation (1).

$$E_0 = y_0 + \frac{V_0^2}{2g} \tag{1}$$

where E_0 is the total flow energy at the weir upstream, y_0 is the weir upstream depth measured using a graded tape at a proper distance from the weir upstream, and V_0 is the mean velocity at this section calculated via the continuity equation.

Results and Discussion

Figure (1-a) shows the energy dissipation variations versus the Webber number for different block heights, indicating that increasing the Webber number reduces the relative energy dissipation. In fact, increasing the flow rate also increases the flow depth and in turn the Webber number, consequently reducing the boundary friction effect on the flow. It shows that in the blocked models, energy dissipation is higher compared to the control model.

Figure (1-b) shows the energy dissipation variations versus the flow rate for different block intervals. It indicates that in the blocked models, energy dissipation is higher compared to the control model. Furthermore, with identical Webber numbers, different block distances from the beginning of the outlet key do not affect energy dissipation.

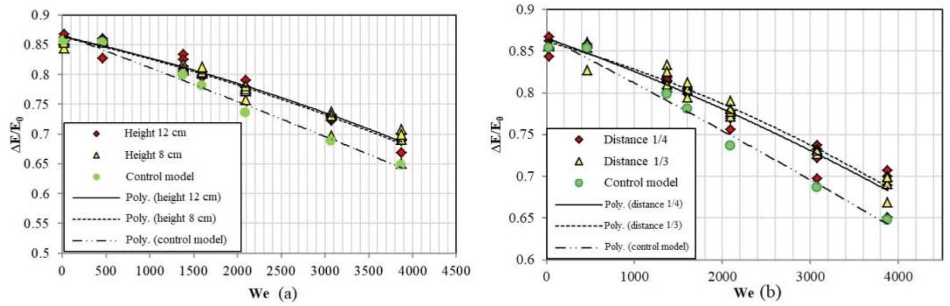

Fig 1. Variation of flow dissipating energy vs. the Webber number a) for different baffle's heights and b) for different baffle's distances compared to control model

Figure (2) shows energy dissipation variations versus the scalar parameter y_c/H respectively for different block heights and for different block intervals compared to the control model. Also, this figure shows that for lower values of flow rate (5–50 Lit/s), increasing this ratio reduces energy dissipation.

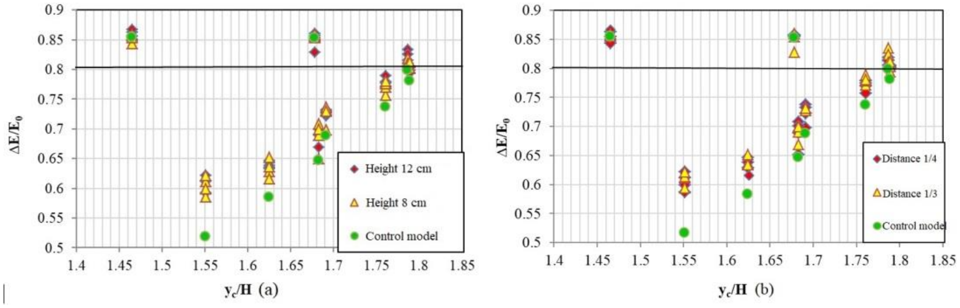

Fig 2. Variation of flow dissipating energy vs. parameter y_c/H a) for different baffle's height and b) for different baffle's distances compared to control model

Conclusion

In all models, the energy dissipation of blocked models was higher compared to the non-blocked models. Moreover, increasing the flow rate in different models decreased the relative energy dissipation of the flow. For low flow rates, due to a relatively low flow energy and very low water head on the weir, the surface tension force and interference resulted in a relatively high energy loss. However, increasing the flow rate reduced the effect of surface tension force, which resulted in a more realistic estimation of energy dissipation. For different block heights and intervals, increasing the flow rate also increased the energy dissipation variation. Block height was more effective on energy dissipation compared to the block interval. Difference in the distance of the first block row from the beginning of the outlet key did not result in a significant difference in relative energy dissipation of the flow; nevertheless, increasing this distance increased the flow energy dissipation compared to the non-blocked model.

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