Shahid Chamran University of Ahvaz

Irrigation Sciences and Engineering (JISE) **Vol. 41, No. 4, Winter 2019, p. 17-28**

EXTENDED ABSTRACT

Numerical Simulation of Chute Energy Dissipation with Submerged Cylindrical Obstacle using Flow 3D Model

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Received:30 May 2016 Revised: 15 December 2016 Accepted: 18 December 2016

Keywords: Chute, Energy Dissipation, Submerged Obstacle, Numerical Simulation, Flow 3D.

Introduction

In general, the energy dissipating structures are used in order to prevent the destructive effects of high flow velocities through the spillways. Among these structures, the most commonly used structures are chutes in water conveyance systems in dams, irrigation and drainage networks, alluvial rivers and wastewater collecting and disposal systems. The energy dissipating structures are used at the downstream of this systems. The advantage of this method to the previous methods such as stepped spillway is that the risk of cavitation is less and it is more economical. One of the ways to reduce the size or eliminate low energy dissipating structures is to use methods for reducing the flow energy over the chutes. One of these techniques, which has been used so far, is to create steps over the spillway. Another method is the application of obstruction or roughness on the spillway's bottom. Baffled chute is a type of the dissipaters that is used extensively in open drainage networks and where the tailwater level has large fluctuations. The significance of this type of energy loss becomes more evident where the tailwater has obvious fluctuations. The purpose of this study is to numerically simulate the effect of cylindrical baffles over the chutes on the energy dissipation magnitude. In particular, the purpose of this study is to determine whether the cylindrical baffles can effectively reduce the kinetic energy and reduce the dimensions of the stilling basin.

Methodology

In this research, three-dimensional FLOW-3D code has been used for numerical analysis. The FLOW-3D software has the ability to analyze the three-dimensional flow field in a finite volume. The governing equations for fluid motion are the continuity equation and the momentum equation, which is used for an incompressible flow with a constant viscosity and density. In addition, the RNG (k-ε) turbulent model has been used. This numerical model was calibrated based on a laboratory model performed at Shahid Chamran University of Ahvaz. After that, the effect of different parameters, such as the chute's slope and the relative submergence of the baffles are investigated (Rashidi-Avandi and Fathi, 2015). The experiments were carried out in a flume with a width of 30 cm, a height of 80 at the beginning and 40 cm at the end, and a length of 7 m. The chute is made of Plaxi-glass and has an inlet broad-crest with the length of 30 cm. In this research, a total of 80 runs were implemented (40 runs for a smooth chute and 40 runs for the cylindrical baffled chute). In order to achieve the objectives of this research, the various effective parameters on the energy dissipation were first investigated and, by dimensional analysis a general relationship including non-dimensional parameters was extracted. The effective parameters in this study are q (the flowrate per unit width), $\Delta E/E0$ (relative energy loss), H (chute height), μ (dynamic viscosity of water), ρ (density of water), g (gravity acceleration), θ (chute bed slope) and σ (surface tension).

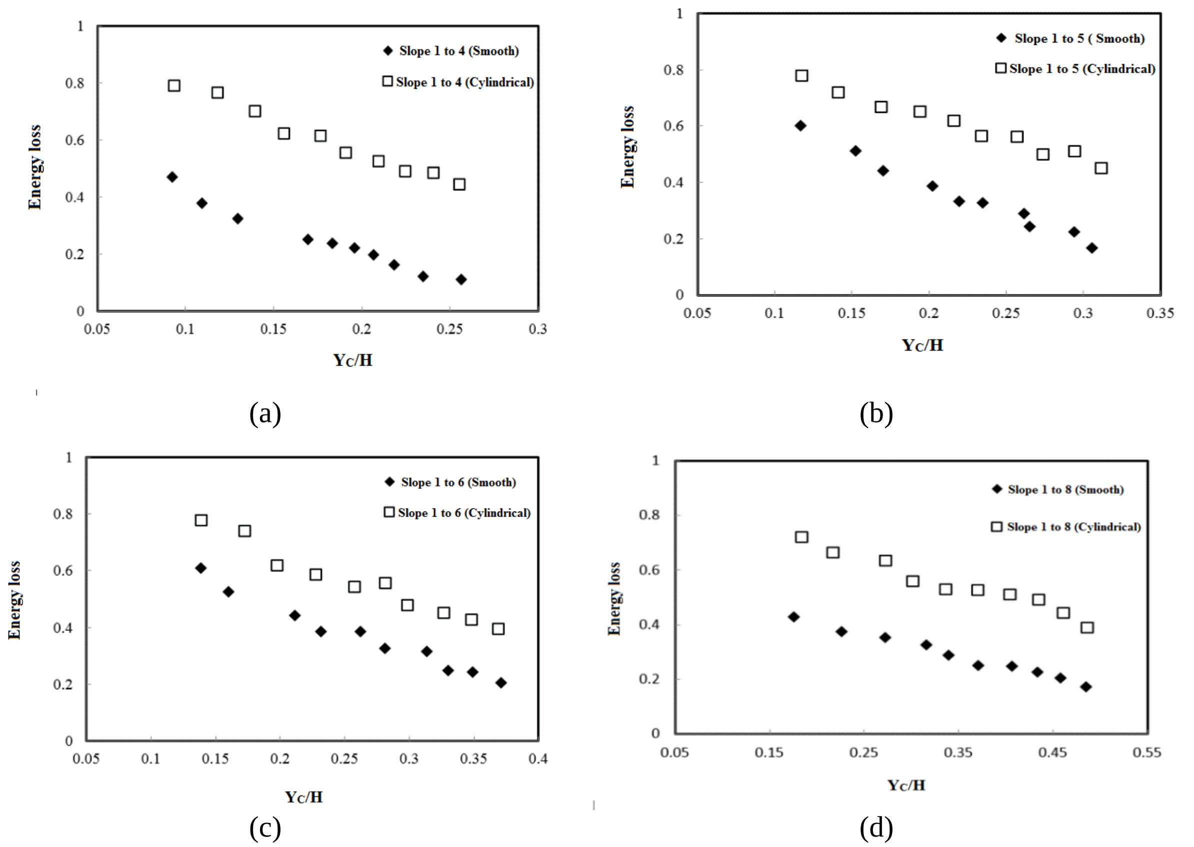

Figure 1 - Comparison of energy loss in barrier models and the control model with slopes of a) 1 to 4, b) 1 to 5, c) 1 to 6 and d) 1 to 8

Results and Discussion

In Figures 1 (a to d), the energy loss comparison is shown in a flat chute and cylindrical model with different slopes.

Conclusions

The main purpose of this study was to investigate the effect of submerged baffles over the chute on the energy dissipation using a FLOW-3D model under different hydraulic conditions. In the present study, a numerical model was used for four different slopes and flowrates. The results of this study indicated that the FLOW-3D model has a very good accuracy to model the flow for this type of chute. The study of energy loss in all models showed that the amount of energy loss in all slopes reduces significantly with a downward trend by increasing the Y_C/H ratio. In addition, the comparison of energy loss in smooth chute models shows that by decreasing the slope of chute bed, the process of lowering the energy loss occurs with a lower rate. In general, it can be concluded that energy dissipation in the control models varies from 10% for a model with a slope of 1:4 to 64% for a model with a slope of 1:5. The results of the comparison of energy loss in the baffled chute models showed a decreasing trend in all models with a fairly steep slope, with a linear rate. Comparing the energy loss on different slopes, the relative energy loss in slopes 1:4 is highest and at slopes of 1:6 and 1:8 has the lowest values. It can be said that energy dissipation in these models as compared to upstream conditions varies from up to 81% for the model with a slope of 1:4 to 43% in a model with slope of 1: 8 and cylindrical baffles. In addition, the energy dissipation has increased from 16 to 39 percent compared to the control model. Also, the numerical results and obtained values from the extracted relationships have relatively good correlation. The correlation coefficient between these two values was %95 and significant at probability level of 1 percent. Finally, using the multivariate nonlinear regression, many relationships were found for smooth and roughed chutes to calculate the relative energy loss.