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Modification of Classical Horseshoe Spillways: Experimental Study and Design Optimization

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Abstract

Investigation of the hydraulic aspects of spillways is one of the important issues regarding hydraulic structures. This study presents a modified horseshoe spillway (MHS) constructed by adding a flow passage and an internal weir in the bed of a classical horseshoe spillway (CHS). This modification increased the discharge efficiency and eliminated the rooster-tail hydraulic jump in CHSs. Eighteen laboratory-scale MHSs in various geometric sizes, six various CHSs, and a rectangular weir of the same width were constructed and tested under the same flow conditions. Results showed that in terms of discharge efficiency and water head reduction, CHSs and MHSs were superior to the rectangular weir. Compared to CHSs, the increased discharge flowrate in MHSs due to the internal weirs could further reduce the water head and thus increased their overall efficiencies. Design parameters effecting spillways' discharge efficiencies were investigated based on dimensional analysis. The internal to external weir length ratio in MHSs was found to be a key design factor. To determine the optimal geometric design of CHS and MHS models, cubic polynomial models considering dimensionless parameters and their interactions were fitted to the experimental results. The cubic models revealed that higher discharge efficiencies in MHSs tended to occur at relatively low water heads and high internal to external weir lengths ratios.

Keywords: Curved Spillways; Discharge Coefficient; Dimensional Analysis; Stage-discharge Equation; Hydraulic Structures; Dam Construction.

1. Introduction

The main objective of building a spillway is to safely convey the excess flood from a reservoir to the downstream of a dam. According to the U.S. Bureau of Reclamation [1], a spillway usually consists of a control structure to control flow of water, a chute or conduit to convey water out of the reservoir, and a terminal stilling basin to dissipate the energy of water flowing downstream of the dam. The weir length in a spillway is one of the most important parameters to control the spillway's discharge capacity [2]. The flowrate in a standard weir can be calculated as [2, 3]:

$$Q = C_d L \frac{2}{3}\sqrt{2g}h^{3/2} \tag{1}$$

Where Q (m^3/s) is the discharge flow, h (m) is the water head over the spillway, g ($m^2.s^{-1}$) is the acceleration due to gravity, L (m) is the spillway crest length, and Cd is the discharge coefficient.

In the plan-view, spillways can have various shapes, including labyrinth, curved, and straight (known as rectangular weir) [4]. A labyrinth spillway is a corrugated form of a rectangular weir whose overall crest length is elongated in order

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