Available online at www.CivileJournal.org

Civil Engineering Journal

Vol. 2, No. 9, September, 2016

Flow Simulation and Energy Loss Estimation in the Nappe Flow Regime of Stepped Spillways with Inclined Steps and End Sill: A Numerical Approach

Amirmasoud Hamedi [a*], Mohammad Haji Gholizadeh [a], Abbas Mansoori [b]

[a] *Department of Civil and Environmental Engineering, Florida International University, Miami, USA.*

[b] *Department of Civil and Environmental Engineering, Azad University Central Tehran, Tehran, Iran.*

Received 12 August 2016; Accepted 19 September 2016

Abstract

Recently, the usage of stepped spillways, as energy dissipaters, has increased and led to a reduction in the size of the stilling basin. Extensive experimental considerations, plus the high cost and extended time required for laboratory methods, are among the major issues that require precise attention to determine optimal step design. This research deals with comparing the 2-D numerical simulation and experimental description in stepped spillways equipped with inclined steps and end sill together and presents a brisk, reliable, low-cost, and non-experimental approach to designing the steps. In this new type and complicated geometry, simulation is more complicated than horizontal steps, because it needs more accuracy around the end sills. The VOF Method and the k-ε standard turbulence model are proposed to simulate the flow pattern and evaluate the energy loss over stepped spillway. Energy dissipations obtained through the numerical approach have been compared with laboratory measurements and demonstrate reasonable agreement. Also, the flow pattern, velocity vectors and flow direction resulted from numerical simulation is in a good agreement with the experimental results.

Keywords: Stepped Spillway; Energy Dissipation; End Sill; Finite Volume Method; $k-\varepsilon$ Standard Model.

1. Introduction

Selection of an efficient hydraulic structure to dissipate flow energy affects the length and size of the stilling basin. In recent years, numerous studies have addressed different aspects of stepped spillways; these studies have also introduced them as an efficient energy dissipater [1, 2]. The discharge rate in stepped spillways leads to three different flow regimes. The Nappe Flow is observed in the low-rate flows; the Transition Flow is represented when the discharge rate increases; and the Skimming Flow is caused by high discharge rates [1, 2]. Chen et al. analyzed the flow on stepped spillways by using the finite volume method and utilized the k-ε turbulent model to determine flow turbulence in spillways [3]. Tabbara et al. analyzed the stepped spillway by the finite element method using ADINA software with the k-ε standard turbulence model [4]. Musavi-Jahromi et al. simulated the flow over stepped spillway using ANSYS software [5]. Their outcomes indicate that numerical results have a six percent differential with experimental ones. The k-ε model was initially formulated by Launder et al. [6]. As the appropriate formulas, two equations for the k-ε turbulence model have been recognized to simulate spillway flow. Other work has been conducted on flow condition, aeration, and energy loss in stepped spillways with horizontal steps [7]. Zare and Doering considered flow characteristics on stepped channels and spillways [8, 9].

Moreover, other works on flow condition, and energy dissipation in stepped spillways equipped with inclined steps or an end sill, have been conducted and the results indicate that inclined steps are reduced more energy than horizontal steps [10-13]. Among all the investigations conducted on spillways, the research performed by Chaturabul [14] can be

[*] Corresponding author: amirmasoud.hamedi1@fiu.edu