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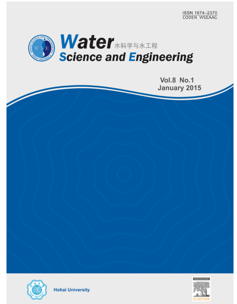

Experimental and numerical analysis of flow over a rectangular full-width sharp-crested weir

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Experimental and numerical analysis of flow over a rectangular full-width sharp-crested weir

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Abstract

Weirs are a type of hydraulic structure, used for water level adjustment, flow measurement, and diversion of water in irrigation systems. In this study, experiments were conducted on sharp-crested weirs under free-flow conditions and an optimization method was used to determine the best form of the discharge coefficient equation based on the coefficient of determination (R^2) and root mean square error (*RMSE*). The ability of the numerical method to simulate the flow over the weir was also investigated using Fluent software. Results showed that, with an increase of the ratio of the head over the weir crest to the weir height (h/P), the discharge coefficient decreased nonlinearly and reached a constant value of 0.7 for $h/P > 0.6$. The best form of the discharge coefficient equation predicted the discharge coefficient well and percent errors were within a ±5% error limit. Numerical results of the discharge coefficient showed strong agreement with the experimental data. Variation of the discharge coefficient with Reynolds numbers showed that the discharge coefficient reached a constant value of 0.7 when $h/P > 0.6$ and $Re > 20000$.

Keywords: Discharge coefficient; Measurement; Numerical model; Sharp-crested weir; Weir height

1. Introduction

Weirs are common structures used for water surface regulation and flow measurement in irrigation networks and environmental projects. They serve as the simple, accurate, and classical devices used both in the field and in the laboratory for flow measurement in open channels (Kumar et al., 2011). They come in a variety of shapes, including fully contracted, partially contracted, and full-width weirs. They can also be either broad- or sharp-crested, with sharp-crested weirs including rectangular, triangular, and trapezoidal weirs (Bos, 1989). The sharp-crested weirs are vertical obstructions placed normal to the flow direction. The simplest form of sharp-crested weirs consists of a plate set perpendicular to the flow in a rectangular channel. The horizontal crest of the weir crosses the full channel width. This feature means that the flow is essentially two-dimensional, without lateral contraction effects (Henderson, 1966). While the flow passes over the weir, there is a relationship between the head and discharge in the section upstream of the structure, turning the section into a control section.

Many researchers have developed relationships between the discharge and head for weirs. Commonly, the discharge over a sharp-crested weir (Q) under free-flow conditions in an open channel is expressed in terms of the following well-known equation (Henderson, 1966):

$$Q = \frac{2}{3} C_d b \left(2g \right)^{0.5} h^{1.5} \tag{1}$$

where b is the weir crest length (weir width), C_d is the discharge coefficient, h is the head over the weir crest, and g is the acceleration due to gravity. C_d depends on the flow characteristics and geometry of the channel and the weir. The discharge is a function of several parameters and is mathematically expressed by the following equation:

$$Q = f_1 \left(h, b, P, \rho, \sigma, \mu, g \right) \tag{2}$$

where P is the weir height, ρ is the density of fluid, σ is the surface tension, and μ is the dynamic viscosity of fluid. Dimensional analysis demonstrates that the discharge coefficient is a function of the following parameters:

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