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Lateral flow through the sharp crested side rectangular weirs in open channels

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ABSTRACT

A side rectangular weir is a flow diversion structure provided in the side wall of a channel to divert water from main channel to a branch channel. They are widely used in hydraulics, environmental and irrigation engineering for controlling and directing flow of water in irrigation–drainage systems, waste water channels, drainage canal systems, diverting excess water into relief channels for flood-protection works, and as storm overflows from urban sewage systems. The present study is aimed at to compile the past observations on coefficient of discharge for side rectangular sharp crested weir, supplement them with new experimental results and reanalysing resulting data bases with a view towards seeing if better prediction are possible. Therefore, a new model for determination of coefficient of discharge of side rectangular sharp crested weir is developed. It is observed that approach Froude number is an important parameter for coefficient of discharge. The ratio of the crest height of side weir to length of the side weir, ratio of width of the main cannel to length of side weir and ratio of the upstream depth in the channel to length of side weir also affect the coefficient of discharge. The performance of the present model is based on the coefficient of correlation of the linear regression line between predicted values from the present model and desired output *(R),* mean absolute percentage error (*MAPE*), average percentage error (*APE*), root means square error (*RMSE*) etc. The qualitative performance of the present predictor indicates that it has highest R (0.865) and lowest MAPE (4.8936), RMSE (0.0337), APE (−0.346) as compared to other existing predictors. Flow profile and flow pattern are also observed in the vicinity of side weir in the main channel.

1. Introduction

Flow through side weir represents gradually varied flow with non-uniform discharge. The discharge in the channel varies along the length of channel due to lateral withdrawal of water from the channel. The side weirs are widely used in river-control structures, river-intake facilities, irrigation canals, water and wastewater-treatment plants, reservoirs and dams. They commonly convey excess flows into an off-stream storage (for flood control) or to divert clean water into a diversion channel. The study of diversion of flow from main channel to sub-channel, main river to another river or main canal to sub-canal are important aspects for the hydraulic engineering. The various hydraulic structures used to divert flow are weirs, spillways, sluice gates, intakes, orifices etc. [15,17,18,20,28,29]. Typical example of flow with decreasing discharge is channel side weir used for diverting water for drainage or irrigation, flood schemes relief etc.

A side weir, also known as lateral weir, is a free overflow weir set into the side of a channel, allowing part of the liquid to spill over the side when the free surface of the liquid in the channel rises above the weir crest. This type of structure is usually a long rectangular notch installed along the side of channel. In irrigation engineering, side weirs of broad crests are used as head regulators of distributaries and escapes.

In previous studies, side weirs were studied extensively because of their wide range of applications in hydraulic and environmental engineering. Probably the first theoretical approach to the hydraulics of a side weir in a rectangular channel was reported by De Marchi [8]. Most of the earlier experimental studies and theoretical analyses were limited to the flow over side weirs in rectangular channel [8,11–13,25,27,31,7]; triangular channel [32], trapezoidal channel [33], and circular main channels [31,14].

Many Researchers have formulated coefficient of discharge equation for side weirs [2]. Expression for coefficient of discharge for simple rectangular sharp-crested side weirs have been developed by Subramanya and Awasthy [27], El-Khashab [10], Ranga Raju et al. [25], Hager [14], Singh et al. [26], Jalili and Borghei [21], Borghei et al. [7], Emiroglu et al. [12] and Honar and Javan [16] investigated the effect of oblique side weirs on the coefficient of discharge under subcritical flow condition in rectangular channels. Aghayari et al. [1] investigated

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Nomenclature

V	average velocity of flow
y_1	upstream depth of flow in channel
g	acceleration due to gravity
L	crest length of side weir
B	width of main channel
P	crest height of side weir
b	width of diverted channel
μ	dynamic viscosity of water
ρ	density of water
F_1	approach flow Froude number
R_e	Reynolds number
C_d	coefficient of discharge
h	water depth over crest of side weir
R	Coefficient of correlation
APE	Average percentage error
MAPE	Mean absolute percentage error
AAD	Absolute average deviation
RMSE	Root mean square error
STDV	Standard deviation
E	Nash-Sutcliffe Efficiency coefficient
SI	Scattering index

experimentally the effect of height, width and side weir crest slope on the coefficient of discharge over broad crested inclined side weirs under subcritical flow conditions in a rectangular channel.

Dominguez [9] consider a side weir of crest height "*P*" fitted in the side of the wall of an open channel as shown in Fig. 1. He presented the following discharge equation for side weir.

$$Q = 4/15 C_d L \sqrt{2g}\left[\frac{h_2^{2.5} - h_1^{2.5}}{(h_2 - h_1)}\right] \quad (1)$$

where g is acceleration due to gravity, L is crest length of side weir, C_d is coefficient of discharge and h is the water depth over crest of side weir. Subscript 1 and 2 refers to upstream and downstream section with respect to side weir respectively as shown in Fig. 1. In developing a general expression (Eq. (4)) for discharge through a side weir, it is assumed that flow in the main channel is uniform, specific energy along the weir in the main channel is constant and the edges of the side weir are sharp.

2. Dimensional analysis

Discharge coefficient of side weir can be expressed as a function of average velocity of flow over the cross section of the channel (V), upstream depth of flow in channel (y_1), acceleration due to gravity (g), crest length of side weir (L), width of main channel (B), crest height of side weir (P), width of diverted channel (b), dynamic viscosity of water (μ) and density of water (ρ).

$$C_d = f(P, L, B, g, V, y_1, b, \rho, \mu) \quad (2)$$

Applying the Buckingham-π theorem, non-dimensional equations in functional forms can be written as below:

$$C_d = f(P/L, B/L, y_1/L, F_1, b/L, \mu/\rho VL) \quad (3)$$

where F_1 represents the approach flow Froude number. Influence of the Reynolds number, $R_e = PVL/\mu$ is relatively insignificant in open channel flows and b/L in the present study is constant. Hence, may be dropped from Eq. (3). The final functional relationship for C_d may, therefore, be expressed as

$$C_d = f(P/L, B/L, y_1/L, F_1) \quad (4)$$

To see the effect of various parameters on coefficient of discharge, C_d and to establish a generalized relationship among the dependent and independent parameters of Eq. (4), experimental programmes are carried out in present study.

3. Experimental programme

Experimental programme for this study were conducted in Advance Hydraulic Laboratory of Department of Civil Engineering, Aligarh Muslim University, India. The plan and L-section views of the experimental set-up are shown in Fig. 2. The photographic view of the experimental setup are shown in Figs. 3 and 4. The set-up consisted of a main channel of 12.8 m length, 0.29 m width and 0.4 m depth. Water was supplied to the main channel from two 0.15 m diameter supply pipes. A side weir was provided in the right wall of the main channel at a distance 8.20 m from the upstream end of the channel. Flow through the side weir was passed into a diversion channel of 4.18 m length, 0.2 m width and 0.35 m depth and, then, to a return channel. A rectangular sharp- crested weir-B was provided at the end of diversion channel to measure the discharge flowing through the side weir. The discharges from the main and the diversion channels were passed into a return channel of 8.30 m length, 0.73 m width and 0.45 m depth and, then, to a sump. A rectangular sharp-crested weir-A was provided at the end of this channel to measure the total discharge. Splitter plates and flow suppressors were provided at the diversion channel to break large size eddies and to dissipate the surface disturbances, respectively.

In the present study four different crest height of rectangular side

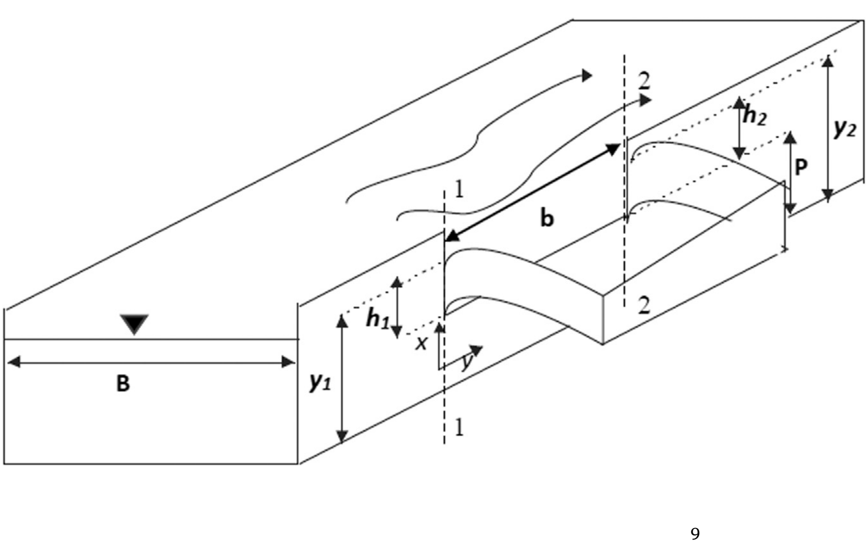

Fig. 1. Schematic sketch of flow over a rectangular sharp crested side weir.