The XXXVIII International School of Hydraulics, 21-24 May 2019, Łąck, Poland

Discharge Characteristics of Triangular Weir with Upstream Ramp and its CFD Modelling using Ansys CFX Module

Subhojit KADIA[1], Binit KUMAR[2], Zulfequar AHMAD[2]

[1] Department of Water Resources Development and Management, Indian Institute of Technology Roorkee
Roorkee, Uttarakhand – 247667, India
email: subhojitkadia@gmail.com

[2] Department of Civil Engineering, Indian Institute of Technology Roorkee
Roorkee, Uttarakhand – 247667, India
email: binit.nit2010@gmail.com, zulfifce@iitr.ac.in

ABSTRACT

A transverse hydraulic structure placed across a stream can cause flow and sediment discontinuity. A triangular weir with an upstream ramp (TW-UR) looks promising in sediment passage than sharp-crested and broad-crested weirs due to the presence of the upstream ramp. The flow field near a TW-UR and a sharp-crested weir was simulated in Ansys CFX using the standard k-ε turbulent model, and also compared to each other. The Computational Fluid Dynamics (CFD) simulation was based on the finite volume technique and Volume of Fluid (VOF) method. A less active flow field (low velocity magnitude) in the upstream of a sharp-crested weir, especially below the crest level was observed, whereas the flow field in the upstream of a TW-UR was more active and the flow velocity and eventually the hydrodynamic force over the ramp increased along the direction of flow due to the vertical contraction in the flow area as shown in Figs. 1(a-b). The head-discharge characteristics of a TW-UR model was studied experimentally for 23 discharges out of which 5 discharges were simulated. The experiments were conducted in the Hydraulics Engg. laboratory, Dept. of Civil Engg., IIT Roorkee in a 15 m long glass walled flume with a cross section 0.39 m × 0.52 m. The TW-UR model was fabricated by 0.006 m thick sheet, and had length (L), height (P) and width (B) as 0.189 m, 0.105 m and 0.39 m, respectively. The discharge was measured with an ultrasonic flow meter (accuracy ± 1%) connected to the inlet pipe and the head (H) was measured using a point gauge (least count = 0.0001 m), which was placed at 0.2 m upstream from the weir crest. The CFD simulation was performed in the Spatial Sciences Laboratory, Department of WRD & M, IIT Roorkee. A part of the flume was simulated in CFD model. It was observed that the TW-UR model had about 9.8% to 14.3% higher discharging capacity than the sharp-crested weir as shown in Fig. 2. It was also found that the observed coefficient of discharge (C_d) increased initially with an increase in H and attained almost a constant value beyond H/P ≈ 0.65. To pass a discharge over TW-UR, CFD simulation estimated lesser head over the crest than the observed head and it was found that about 10% to 15% higher discharge was estimated in the CFD simulation as compared to the observed data under the same head. Therefore, the presence of the upstream ramp and a highly active flow field near it are increasing the discharging capacity of TW-UR and enhancing the possibilities of sediment passage over it. Authors are presently investigating the sediment transport over a TW-UR.

Two existing equations for C_d suggested by Azimi et al. (2013) and Di Stefano et al. (2016) were checked for their accuracy after analysing 200 datasets collected from previous and present experimental studies. Graphical illustration indicated that the % of total number of datasets lay within 5%, 10% and 15% absolute error ranges for Azimi et al. (2013) was 43.0%, 72.5% and 92.5%, respectively. Whereas, for the equation suggested by Di Stefano et al. (2016) it was 61.7%, 92.3% and 100%, respectively. The maximum absolute error in calculated C_d was 18.2% and 13.8% for Azimi et al. (2013) and Di Stefano et al. (2016), respectively. Statistical analysis showed that in most of the cases, Di Stefano et al. (2016)

predicted C_d with more accuracy than Azimi et al. (2013). For the present experimental datasets, the root mean square error (RMSE) and mean absolute percentage error (MAPE) of calculated C_d were 0.05 and 6.54% for Azimi et al. (2013) and 0.012 and 1.41% for Di Stefano et al. (2016), respectively. Combining all datasets, the RMSE and MAPE of calculated C_d were 0.062 and 6.86% for Azimi et al. (2013) and 0.04 and 4.33% for Di Stefano et al. (2016), respectively. Overall, Di Stefano et al. (2016) equation performed better than Azimi et al. (2013) equation and it can be concluded that the equation proposed by Di Stefano et al. (2016) is more accurate than the equation proposed by Azimi et al. (2013) for the used datasets. Further, these 200 datasets can be utilized in the development of a more accurate equation.

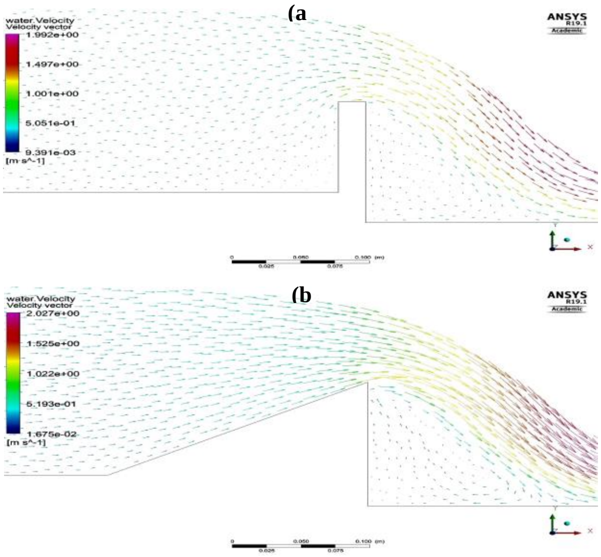

Fig. 1. Flow field at 0.02076 $m^3 s^{-1}$ discharge for: (a) sharp-crested weir, (b) TW-UR

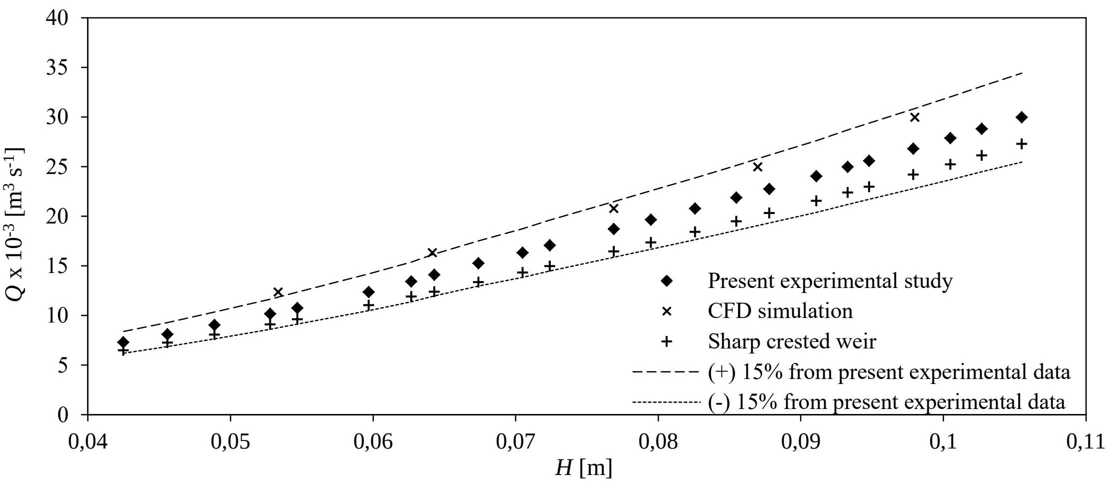

Fig. 2. Head-discharge correlation