

Abstract

This research work investigates the hydraulics of flow taking place in low-head trapezoidal weirs, with and without sluice gates. Such structures are commonly employed in India for diverting some of the river flow to a canal for irrigation or hydropower generation. The research also follows up on the processes of energy dissipation and scour as the flow leaves the structure and moves over to the unprotected riverbed downstream. The following paragraph summarizes the research contribution in the context of low-head hydraulic structures mentioned above. The conclusions are drawn from an analysis of experimental observations supported by two-dimensional RANS–VOF computational simulations.

The influence of the downstream slope of trapezoidal weirs is examined, showing that steeper slopes increase the discharge coefficient (C_d) under free-flow, whereas milder slopes enhance conveyance under submerged conditions. A new equation for C_d under free-flow is proposed that incorporates both upstream and downstream slopes. For vertical sluice gates, adding semi-cylindrical lips straightens streamlines, increases contraction coefficients (C_c) by 43–52%, and correspondingly enhances C_d relative to sharp-edged gates, with larger lips yielding greater improvement. The increase in C_c is identified as the primary cause of the enhanced C_d , while the reduction in energy loss contributes secondarily. Gates fitted with inclined plate attachments exhibit two distinct flow regimes under free-flow: separated flow from the plate (regime S) and attached flow to the plate (regime A), governed by the plate length and inclination angle. Under regime A, the streamlines are guided gradually, which substantially increases C_c and C_d . A regime-specific equation is proposed for accurate discharge estimation. Combined gate–weir systems demonstrate synergistic behavior, where semi-cylindrical lips increase C_d by 28–36%, and a steeper downstream slope further increases the C_d , although with lower pressure over the weir crest, which may raise cavitation concerns. The modular limit increases with the addition of lips and with milder weir slopes, indicating delayed onset of submergence. Energy dissipation and local scour are examined experimentally for stilling basins equipped with baffle blocks, solid end sills, and dentated end sills under low Froude numbers (2.5–4.5). End sills increase energy dissipation by 6–15%, while the inclusion of baffle blocks enhances it by 27–40%. Scour tests for hydraulic jump types A and B show that dentated end sills provide the most effective protection, reducing maximum scour depth by up to 40%, and by 62% when combined with baffle blocks. The combination of baffle blocks and dentated end sill also produce milder upstream scour slope and the lowest turbulent kinetic energy on the scour hole. Overall, this study presents new empirical relationships and design insights that advance the understanding of flow behavior, energy dissipation, and scour control. The findings provide practical guidance for improving discharge efficiency, structural safety, and the downstream scour protection, supporting the design and rehabilitation of hydraulic structures.

Keywords: Trapezoidal weir; Discharge coefficient; Contraction Coefficient; CFD; semi-cylindrical lipped gate, Inclined plate gate; Energy dissipation; Scour.