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Research Article

Experimental study of the effect of obstacles on flow energy loss in piano key weir

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Extended Abstract

Introduction

Piano key weirs (PKWs) are characterized by their increased crest length compared to linear weirs, which enhances their discharge capacity. Given their importance in hydraulic engineering, strategies to reduce energy dissipation and minimize scour are critical. This study investigates the energy dissipation in a trapezoidal Type C piano key weir using four flow rates (0.025, 0.03, 0.035, and 0.04 m^3/s) and three obstacle heights (0.01, 0.03, and 0.05 m) at the downstream end of the weir keys. The results demonstrate that increasing obstacle height enhances energy dissipation, while higher flow rates reduce it. Energy dissipation increased by 1.20%, 2.13%, and 2.53% for obstacle heights of 0.01, 0.03, and 0.05 m, respectively, compared to a weir without obstacles. The average energy dissipation for weirs with obstacles of 0, 0.01, 0.03, and 0.05 m was 57.8%, 58.5%, 59.06%, and 59.3%, respectively. A correlation equation with a 98.9% coefficient of determination was developed to estimate energy dissipation in trapezoidal Type C piano key weirs with downstream obstacles.

Materials and Method

The experiments were conducted in the hydraulic laboratory at Islamic Azad University, Isfahan (Khorasgan). A trapezoidal Type C piano key weir with two cycles and a width of 0.6 m was used. The weir had a height (P) of 0.2 m, inlet key width (Wi) of 0.215 m, outlet key width (Wo) of 0.075 m, sidewall length (B) of 0.5 m, and thickness (Ts) of 0.01 m. Four flow rates (0.025, 0.03, 0.035, and 0.04 m^3/s) and three obstacle heights (0.01, 0.03, and 0.05 m) were tested. The upstream and downstream water depths were measured using sensors placed at 4y and 10P distances from the weir toe, respectively, where y is the flow depth over the weir crest and P is the weir height. The hydraulic parameters influencing energy dissipation were analyzed, and dimensional analysis was performed to derive a relationship for energy dissipation.

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Results and Discussion

The study revealed that energy dissipation decreases with increasing flow rate and the ratio of upstream energy head to weir height (H/P). The presence of obstacles at the downstream end of the weir keys significantly increased energy dissipation. For obstacle heights of 0.01, 0.03, and 0.05 m, energy dissipation increased by 1.20%, 2.13%, and 2.53%, respectively, compared to a weir without obstacles. The average energy dissipation for weirs with obstacles of 0, 0.01, 0.03, and 0.05 m was 57.8%, 58.5%, 59.06%, and 59.3%, respectively. A correlation equation (Equation 4) was developed to estimate energy dissipation, demonstrating a strong correlation (R^2 = 98.9%) between observed and calculated values. The equation incorporates dimensionless parameters (H/P and h/H) and coefficients (K_1, K_2, K_3) specific to the obstacle heights.

Conclusion

This study highlights the effectiveness of downstream obstacles in enhancing energy dissipation in trapezoidal Type C piano key weirs. Increasing obstacle height and the ratio of obstacle height to upstream energy head (h/H) significantly improved energy dissipation, while higher flow rates reduced it. The developed correlation equation provides a reliable tool for estimating energy dissipation in similar weir configurations, aiding in the design and optimization of piano key weirs for improved hydraulic performance and reduced scour risk. Future research could explore the impact of varying weir geometries and obstacle configurations on energy dissipation to further refine design guidelines.

Keywords*:* Energy loss, Experimental study, Obstacle, Piano key weir (PKW), Type C