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Research Article

Numerical study of the effect of non-continuous step on the residual energy of a vertical drop

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Extended Abstract

Introduction
In irrigation and drainage channels, vertical drops are commonly used to transfer water from a higher elevation to a lower one. To prevent bed erosion and reduce the destructive kinetic energy downstream of these structures, various measures are implemented. This study investigates the effect of non-continuous steps on the residual relative energy of vertical drops using the FLOW-3D software and the RNG turbulence model. The residual relative energy was analyzed as a function of the relative step height, relative step width, and relative critical depth. Two relative heights and three relative widths were considered for the steps, with the relative critical depth ranging from 0.2 to 0.5. The results indicate that the numerical simulations closely match experimental data, and the use of continuous and non-continuous steps yields similar outcomes. Increasing the relative step height reduces the residual relative energy. Additionally, the use of a stilling basin downstream of the drop significantly reduces the height and length of the basin by more than 12% when steps are incorporated.

Materials and Method
The study employed the FLOW-3D software to simulate the hydraulic behavior of vertical drops with non-continuous steps. The RNG turbulence model was used due to its accuracy in simulating turbulent flows with high computational efficiency. The simulations considered two relative step heights (0.3 and 0.4) and three relative step widths (0.11, 0.143, and 0.2). The relative critical depth ranged from 0.2 to 0.5. The numerical model was validated using experimental data from previous studies, ensuring the accuracy of the simulations. The computational domain was discretized using a mesh with approximately 1.75 million cells, optimized through sensitivity analysis to balance accuracy and computational cost.

Results and Discussion
The results demonstrated that the numerical simulations accurately predicted the downstream relative depth, with a strong correlation to experimental data. The use of non-continuous steps did not significantly differ from continuous steps in terms of energy dissipation and flow characteristics.

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Increasing the relative step height led to a reduction in the residual relative energy, indicating enhanced energy dissipation. The study also found that the relative step width had minimal impact on the flow dynamics. When a stilling basin was used downstream, the incorporation of steps reduced the required height and length of the basin by more than 12%, offering economic benefits in construction.

Conclusion

The study concludes that non-continuous steps are an effective and economical solution for enhancing energy dissipation in vertical drops. The numerical simulations validated the experimental results, showing that non-continuous steps perform similarly to continuous steps in terms of energy dissipation and flow characteristics. The use of steps reduces the dimensions of the stilling basin, making it a cost-effective option for hydraulic engineering applications. Future research could explore the effects of varying step geometries and flow conditions to further optimize the design of vertical drops with steps. This study provides valuable insights for engineers and researchers aiming to improve the efficiency and sustainability of hydraulic structures.

Keywords: Downstream depth, Energy loss, non-Extended step, Turbulence, Vertical drop