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## Effect of transverse bottom slope and bed roughness on hydraulic jump flow in an asymmetrical trapezoidal stilling basin: an experimental approach

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### Abstract

Controlling hydraulic jump is critical for maximizing energy dissipation, minimizing erosion, and improving the performance of stilling basins. This study presents the first comprehensive experimental investigation of the combined effects of transverse bed slope and surface roughness on hydraulic jump characteristics, energy dissipation, and free-surface flow dynamics in an asymmetrical trapezoidal channel. An innovative stilling basin configuration was implemented, featuring a transversely inclined rough bed ( $\theta = 17^\circ$ ) with vertical sidewalls and three distinct roughness heights (14.32, 24.47, and 30.76 mm), tested across a wide range of Froude numbers ( $3.3 < F_1 < 9.4$ ). The experimental setup allowed the exploration of previously unexplored three-dimensional flow structures, revealing pronounced secondary turbulence that contributed significantly to energy dissipation. The results demonstrated that increasing bed slope and roughness substantially altered hydraulic jump behavior, reducing the sequent depth ratio by approximately 31.16% and the secondary depth by nearly 18.6% compared to classical jump. Additionally, the roller length decreased by an average of 39.11%, while greater slope and roughness height increased relative energy dissipation by 9.53% compared to a classical jump. Beyond the experimental work, new empirical relationships were developed to predict key hydraulic jump parameters, achieving error margins of  $\pm 10\%$  to  $\pm 20\%$  and closely matching the observed data, offering practical guidance for the design of efficient and resilient stilling basins.

### List of symbols

$g$	Acceleration due to gravity [ $m/s^2$ ]. $V_1$ Average velocity in section 1 [ $m/s$ ].
$k_s$	Relative roughness height [—]. $k_e$ Roughness element height [mm].
$E_1$	Charge in the first section of the jump [m]. $b$ Channel width [m].
$E_2$	Charge in the last section of the jump [m]. $Q$ Flow discharge [ $m^3/s$ ].
$d_1$	Average depth of upstream sequences [m]. $A_2$ Second section of water [ $m^2$ ].
$d_2$	Average depth of downstream sequences [m]. $A_1$ First section of the water [ $m^2$ ].
$D$	Difference in transverse bed elevation [m]. $f_1, f_2, f_3, f_4, f_5$ Functional symbol.
$\rho$	Water density [ $kg/m^3$ ]. $\mu$ Dynamic viscosity [ $N.s/m^2$ ]
$E_L$	Energy loss associated with hydraulic jump [m]. $x_l$ The jump toe position [m].