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Plane Turbulent Submerged Jets in Shallow Tailwater

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Abstract

This thesis presents a discussion on plane turbulent submerged jets in shallow tailwater to study two main topics. The first topic is a theoretical and laboratory study of the deeply submerged hydraulic jump and a comparison between its characteristics and those of the classical wall jet. The momentum flux, in terms of that at the slot, was discussed theoretically. A theoretical expression for the depression in the water surface elevation at the gate (housing the slot) was also discussed. An extensive set of experiments, with different Froude numbers and tailwater depth ratios, was conducted to observe and quantify the eddy length, the growth of the deeply submerged hydraulic jump, the decay of the velocity scale, the bed shear stress, the drop in the water surface elevation and the momentum flux. The depression in the water surface elevation in the vicinity of the wall produced return flow with negative momentum which resulted in a considerable influence on the momentum flux of the forward flow in the deeply submerged hydraulic jump. The second topic is to present the effect of roughness on the flow characteristics of the deeply submerged hydraulic jump. Two sets of experiments were conducted on rough beds with different roughness. Expressions describing the different flow characteristics of the deeply submerged hydraulic jump, based on the experimental observations, were developed.

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Symbol	Description
A	flow pattern, function of the tailwater depth ratio;
B	flow pattern, constant;
b	length scale [L];
b_o	slot width [L];
b_τ	shear stress length scale [L];
C	flow pattern;
C_1, C_2, C_3	constants;
C_f	skin friction coefficient;
C_{fo}	skin friction coefficient = $\tau/(\rho U_o^2/2)$;
d	external diameter of the Preston tube [L];
Δp	dynamic pressure [FL^{-2}];
E	kinetic energy, per unit weight, of the flow at any section [L];
E_o	the value of E at the slot [L];
F_1	supercritical Froude number in the hydraulic jump;
$F_{\delta w}$	loss in the hydrostatic pressure force at the wall [F];
F_o	supercritical Froude number at the slot;
F_τ	integrated bed shear stress, per unit width, from the slot till the jump surfaces [FL^{-1}];
$F_{\tau x}$	integrated bed shear stress, per unit width, over a distance x from the slot [FL^{-1}];
g	acceleration due to gravity [LT^{-2}];
H_j	Height of the hydraulic jump = (y_2-y_1) [L];
h	the backup behind the gate in submerged hydraulic jump [L];
h_{c1}	lower critical baffle height [L];

h_{c2}	upper critical baffle height [L];
h_{min}	the minimum flow depth in submerged hydraulic jump [L];
L	the distance where $u_m = 0.5\ U_o$ [L];
L_e	length of recirculating flow region (eddy length) [L];
L_{ef}	the eddy length of the free hydraulic jump [L];
L_{fj}	the length of the free hydraulic jump [L];
L_j	the length of submerged hydraulic jump [L];
M	momentum flux, per unit width, at a distance x from the gate [FL^{-1}];
M_∞	momentum flux, per unit width, at the section where the jet occupies the whole depth [FL^{-1}];
M_o	momentum flux, per unit width, at the slot [FL^{-1}];
m	constant = cot $(\theta_w/2)$;
p	mean pressure at any point [FL^{-2}];
Q	jet discharge, per unit width, at a distance x measured from the slot [L^2T^{-1}];
Q_o	value of Q at the slot [L^2T^{-1}];
q	discharge per unit width [L^2T^{-1}];
R	hydraulic radius [L];
R_n	Reynolds number;
S	submergence factor;
s	channel slope;
t	thickness of roughness [L];
U_1, U_2	mean velocities at depths of y_1 and y_2 [LT^{-1}];
U_o	velocity issuing from the slot [LT^{-1}];
$-\rho\overline{uv}(y)$	Reynolds stress [FL^{-2}];
u	time-averaged velocity at any point [LT^{-1}];