PRESSURE HEAD AND RESIDUAL ENERGY IN SKIMMING FLOW ON STEEPLY SLOPING STEPPED SPILLWAYS

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Experimental research was conducted on a stepped chute assembled at the National Laboratory of Civil Engineering (LNEC), 2.90 m high (from crest to toe), slope of 1V:0.75H, and width of 1.00 m. Two different chutes were tested, respectively with 4 or 8 cm high steps on the constant slope. Further details on the experimental facility can be found in Matos (1999) and in Meireles (2004).

New dimensionless formulae are presented for predicting the pressure head ($P/(\rho_w g)$, where P is the pressure, ρ_w the mass density of water and g the gravity acceleration) along the stilling basin floor, next to the stepped chute, in particular in the vicinity of the impact flow region (Fig. 1)

$$\frac{P/(\rho_w g)}{d_c} = \frac{3.68 - 5.23\ln\frac{x}{d_c} + 5.67(\ln\frac{x}{d_c})^2}{1 - 0.86\ln\frac{x}{d_c} + 3.85(\ln\frac{x}{d_c})^2} \qquad \frac{x}{d_c} < 3.5 \qquad (r = 0.91) \qquad (1)$$

$$\frac{P/(\rho_w g)}{d_c} = \frac{2.68}{1 + e^{\frac{5.57 - \frac{x}{d_c}}{4.05}}} \qquad \frac{x}{d_c} \geq 3.5 \qquad (r = 0.99) \qquad (2)$$

In the above equations, dc is the critical depth and x is the streamwise coordinate along stilling basin originating at the toe of the chute.

Fig. 1 shows that the maximum and the minimum values of the piezometric pressure are 4.40 d_c (for x = 1.00 d_c) and 0.70 d_c (for x = 2.38 d_c), respectively.

Simple formulae are also presented for correcting the equivalent clear water depth as well as the specific energy at the upstream end of the hydraulic jump (d_{1B} and H_{1B} - hypothesis B), when they are calculated assuming the hydrostatic pressure distribution on that section (d_{1A} and H_{1A} - hypothesis A): $d_{1B}/d_{1A} = 1.20$ and $H_{1B}/H_{1A} = 0.77$ (Figure 2).

Assuming the hypothesis of hydrostatic pressure distribution at the upstream end of the hydraulic jump instead of considering the non-hydrostatic pressure distribution, leads to an underestimation of the equivalent clear water depth at the upstream end of the jump of about 17%, as well as an overestimation of the residual energy of about 30%.

For chute slopes typical of RCC dam spillways (i.e. ~ 1V:0.75H), similar to that analyzed in the present study, Fig. 2 can be used to estimate the equivalent clear water depth and the specific energy at the upstream end of the jump from physical model studies where sequent flow depths of the hydraulic jump may be obtained, but no information is available on the pressure head at the chute toe.

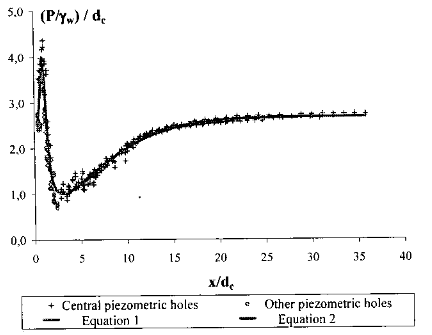

Fig. 1 Dimensionless pressure head along the stilling basin floor, for all step heights and discharges.

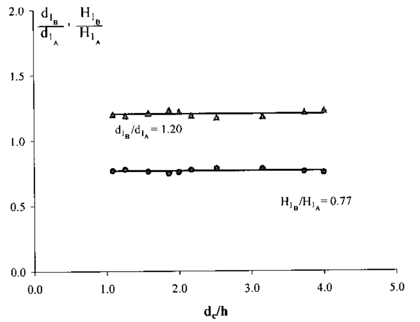

Fig. 2 Equivalent clear water depth and specific energy ratios at the upstream end of the jump, considering hypothesis A and B, for $18.2 \leq H_s/d_c \leq 33.4$, where H_s is the chute height.

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