Size Scale Effects and Labyrinth Weir Hydraulics

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Model studies of hydraulic structures are often conducted to replicate complex flow patterns and intricate transport situations that may occur at the prototype scale. Froude scaling is most often used for reservoir and open channel model studies (e.g., weir flow), which accounts for the dominant gravity and inertial forces, while other fluid forces (e.g., viscosity, surface tension, elastic) are assumed negligible. As the ratio of prototype characteristic length to model characteristic length (i.e., length ratio, L_r) increases, forces such as viscous and surface tension forces, can exceed the negligible level and influence flow behavior, a phenomenon referred to as size-scale effects. When size-scale effects are present, the hydraulic behavior of model do not accurately represent the behavior of the geometrically similar prototype structure. In an effort to extend the existing size-scale effects research with respect to weir flow, trapezoidal, single-cycle, 15º sidewall angle labyrinth weir models with two different crest shapes (half- and quarter-round) were hydraulically tested at five different length ratios. The largest model, which featured a weir height of 3 ft and a cycle width of 8 ft, served as the prototype for comparison purposes. The smaller scale models featured length-scale ratios of 2, 3, 6, and 12. Head-discharge data and nappe behavior for vented and non-vented conditions were collected for each model for dimensionless head ratios of $0.01 \leq H_T/P \leq 1.0$. Discharge coefficients were calculated and used to assess size scale effects among models. Size scale effects were determined to be negligible for $H_T/P > 0.3$ for model size scales tested. For $H_T/P < 0.3$, size-scale effects influenced the discharge coefficient and nappe behavior. For half-round crest shapes, nappe aeration began near $H_T/P = 0.05$ with the prototype weir whereas for the smallest scale model (length ratio = 12), nappe aeration began near $H_T/P = 0.3$. Similarly, for quarter-round crest shapes, nappe aeration began near $H_T/P = 0.02$ with the prototype scale whereas for the smallest scale model nappe aeration began near $H_T/P = 0.25$. Differences in the discharge coefficient, C_d, varied between 17% overestimation and 45% underestimation of the prototype weir for half-round crest shapes among models. For quarter-round crest shapes, C_d was not overestimated by any model yet was underestimated up to 153% of the prototype weir among models. The most error occurred at very low dimensionless head ratios. Furthermore, differences in the discharge coefficient were greatest between the prototype scale and smallest scale model.

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