OUTFLOW ANGLE FOR SIDE WEIRS AT FLOOD DISCHARGES

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In flood protection engineering, side weirs or overflow dams are used to divert water in a controlled way into flood plains as soon as the discharge capacity of the channel is reached. Due to the lateral loss of water the sediment transport capacity in the main-channel is reduced yielding to aggradation and the formation of a local sediment deposit in the downstream weir alignment. The reduced cross section generates backwater effects and additional contraction and expansion losses resulting in an increased and uncontrolled side overflow discharge.

Designing side weirs, an appropriate knowledge of the lateral outflow angle, amongst other parameters, plays an important role. Based on an extensive flume study, a rather simple relationship for the determination of the lateral outflow angle is developed, thus allowing a sound application in engineering practice.

ANALASYS OF EXPERIMENTAL DATA AND RESULTS

Mean outflow angles have been determined using the flow velocities in longitudinal and transverse direction (v_x, v_y) for the entire overflow water depth. In general, the overflow depth has been the part between z / y = 0.75 and 1.0 or approximately the upper 1/4 of the total flow depth. The resulting angle is defined as $\tan \phi_D = v_y / v_x$.

In Fig. 1 a typical streamwise evolution of the outflow angle is presented. It can be seen that up- and downstream of the weir the angle is close to zero. In the weir alignment the outflow angel increases towards its maximum located at $x_{\phi D,max} = 7.00$ m or 2/3 L_D (L_D weir crest length) before decreasing towards the downstream weir corner. With respect to the entire data set, the location of the maximum outflow angle is shifted towards the downstream weir corner with increasing weir length. The average location for ϕ_D might be expressed by the relation:

$$\frac{x_{\phi D,\max}}{L_D} = 0.76 \quad \text{or} \quad x_{\phi D,\max} = 0.76 L_D \approx \frac{3}{4} L_D \tag{1}$$

For the determination of the outflow angle, a logarithmic relationship is supposed to be valid:

$$\phi_D = a \cdot \ln(x) + b \tag{2}$$

Herein, x is a function of channel and side weir geometry. To account for flow conditions, it can be expected that the Froude number (Fr) of the main-channel will be a significant parameter. Hence, x is assumed to depend on a product of power relationships of the type:

$$x = x_1^{\alpha} \cdot x_2^{\beta} \cdot x_3^{\gamma} \cdot x_4^{\delta} \tag{3}$$

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Using dimensional analysis, the coefficients x_1 through x_4 and α to δ were found to be $x_1 = Q$ (upstream discharge), $x_2 = g\,B$ (g acceleration due to gravity, B channel width), $x_3 = L_D$, $x_4 = Fr$, $\alpha = 1$, $\beta = -1/2$, $\gamma = -2$ and $\delta = -1$. Consequently, Eq. 3 reads:

$$x = Q \cdot \frac{1}{\sqrt{gB}} \cdot \frac{1}{L_D^2} \cdot \frac{1}{Fr} \tag{4}$$

Finally, by curve fitting, the coefficients a and b in Eq. 2 were determined to be a = 3.27 and b = 23.56. As a result, the mean overflow angle follows the relation:

$$\phi_D = 3.27 \cdot \ln\left(\frac{Q}{\sqrt{\mathrm{g} \cdot \mathrm{B}} \cdot L_D^2} \cdot \frac{1}{Fr}\right) + 23.56 \tag{5}$$

Since Q = v B h and $Fr = v / (g\,h)^{1/2}$ (with h approach flow depth), Eq. 5 reduces to:

$$\phi_D = 3.27 \cdot \ln\left[\left(\frac{B}{L_D}\right)^{1/2} \cdot \left(\frac{h}{L_D}\right)^{3/2}\right] + 23.56 \tag{6}$$

Since the second ratio in Eq 6 is raised to the power of 3/2, the influence of flow conditions (h) is of greater importance than the one of channel geometry (B) raised to the power of 1/2.

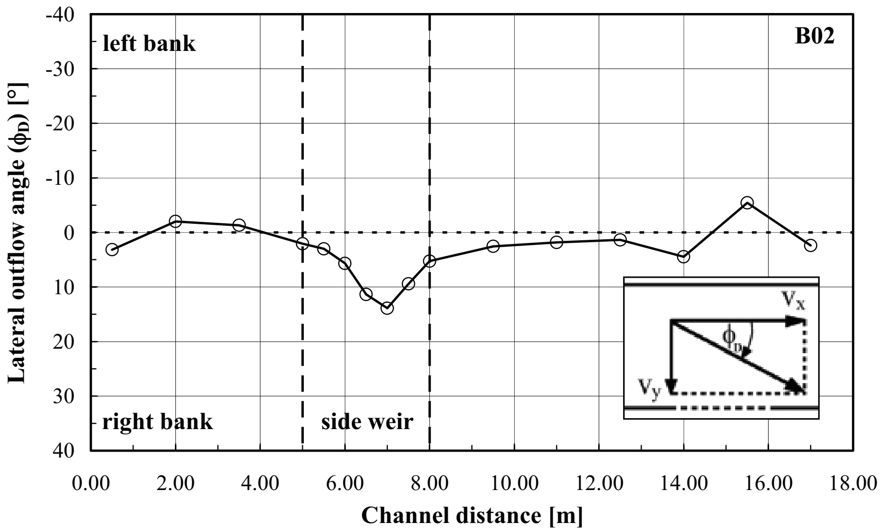

Fig. 1: Example of the streamwise evolution of the lateral outflow angle (side weir location is on the right bank)

DISCUSSION AND CONCLUSION

The application range of the proposed relation is focused on rather elevated discharges as encountered in high flood seasons. With respect to measured Froude numbers, comparatively high values are observed ($0.55 \leq Fr \leq 1.10$, mean Froude number $Fr = 0.79$). This means the longitudinal velocity component is much greater than the lateral one, resulting in small lateral outflow angles. For Q_D/Q - ratios < 0.5 (Q_D spill discharge), a considerable part of the approach flow remains in the main channel and there is a strong forward velocity which has a dominant effect on flow conditions.
The effect of sediment aggradation in the side weir reach is implicitly included in the new expression. Important input parameters are channel and side weir geometry as well as hydraulic variables.

Keywords: Side weir, overflow angle, flood protection.