Discussion of “Characteristics of free overfall for supercritical flows”\(^1\)

H. Chanson and L. Toombes

In their paper, the authors claim that the characteristics of free overfall with supercritical inflow conditions had not been studied to date. This is incorrect, as the Canadian Journal of Civil Engineering published a pertinent study almost 10 years ago (Chanson and Toombes 1998). After a review of that study, it is emphasized that the authors' results must be considered with caution. The supercritical flow at an abrupt drop is strongly three-dimensional and unsteady, and this aspect has direct implications for engineering designs.

The discussers conducted experimental studies of supercritical flows at an abrupt drop in two rectangular channels (Chanson and Toombes 1998; Toombes 2002). The drop height was 0.143 m in both channels. The small channel was 0.25 m wide, 3.2 m long, and lined with glass. The abrupt drop was located 0.62 m downstream of a sluice gate. The large flume was 0.5 m wide and lined with timber (marine ply). The abrupt drop was located 2.4 m downstream of a 0.030 m high nozzle. Both channels had supercritical inflow conditions of \(2 < F_r < 10\), where \(F_r\) is the approach flow Froude number. The experiments were performed with discharge per unit widths between 0.038 and 0.163 \(m^2/s\). Table 1 summarizes the investigated flow conditions. For all experiments, nappe ventilation was provided at the first drop by sidewall splitters. Detailed air–water flow properties and downstream dissolved oxygen contents were further measured (Chanson and Toombes 1998; Toombes 2002; Toombes and Chanson 2005).

The experimental observations demonstrated that the flow was three-dimensional for all investigated flow conditions downstream of the overfall brink. At the nappe impact, the change in flow direction on the invert resulted in the formation of sidewall standing waves and shock waves in the downstream supercritical flow (Fig. 1). The characteristics of the flow patterns were thoroughly documented. The location of the nappe impact was reasonably predicted by a simple trajectory equation (Chanson 1995; Toombes 2002). Downstream of the nappe impact, flow was characterised by a highly fragmented spray. The spray and splashing appeared to be concentrated towards the centreline of the channel. Sidewall standing waves, similar to ship bow waves, formed on both sidewalls downstream of the nappe impact. Properties of these standing waves compared reasonably with the properties of waves observed on the opposite mitre bends and channel junctions, and at abrupt channel expansions (Chanson and Toombes 1997, 1998). The flow was supercritical in the downstream channel. No hydraulic jump was observed. Shock waves were observed in the downstream channel, originating from the sidewalls at or close to the nappe impact. The angle of the crosswaves was inversely proportional to the inflow Froude number. The shock waves intersected on the channel centreline and continued to propagate towards the opposite wall (Fig. 1). Energy dissipation at the overfall was the result of friction losses, jet disintegration, nappe impact on the downstream invert, and recirculation within the pool of water beneath the free-falling jet. The energy dissipation was roughly equal to the drop height within the range of the experimental flow conditions (Table 1).

The discussers are concerned by some broad conclusions contained in the original paper, which ignored the three-dimensional nature of the flow, the existence of sidewall standing waves, and strong splashing and spray in the centre of the downstream channel. These three-dimensional flow patterns have direct implications in terms of channel design. The discussers observed a maximum sidewall standing height \(y_M\) that satisfied

\[
\frac{y_M}{E} = 1.06 \exp(-0.35 F_r)
\]

where \(E\) is the upstream specific energy. For practical purposes, the chute sidewalls must be designed to at least 20% higher than \(y_M\). Downstream of the nappe impact, flow fragmentation and splashing drastically enhanced the air–water interfacial area and air–water mass transfer. Experimental observations showed that the rate of aeration increased rapidly in the highly aerated spray region, while it decreased gradually near the downstream end of the channel as the specific interface area decreased. The aeration efficiency in

---


2Corresponding author (e-mail: h.chanson@uq.edu.au).

3Present address: Connell Wagner, 433 Boundary Street, Spring Hill QLD 4000, Australia.
terms of dissolved oxygen was found to be proportional to the inflow Froude number and inversely proportional to the relative drop length (Toombes and Chanson 2005). The aeration performances of supercritical flow at an overfall may be a significant water quality criterion in urban drainage systems, water treatment plants, and river training structures.

**References**


<table>
<thead>
<tr>
<th>Reference</th>
<th>(z) (m)</th>
<th>(W) (m)</th>
<th>(y_e) (m)</th>
<th>(z/y_e)</th>
<th>(Fr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokyay and Yildiz (2007)</td>
<td>0.10</td>
<td>0.25</td>
<td>0.012–0.033</td>
<td>2–9</td>
<td>1.3–4.0</td>
</tr>
<tr>
<td></td>
<td>0.20</td>
<td>0.25</td>
<td>0.01–0.035</td>
<td>5–18.5</td>
<td>1.4–3.9</td>
</tr>
<tr>
<td>Chanson and Toombes (1997, 1998)</td>
<td>0.143</td>
<td>0.25</td>
<td>0.024–0.040</td>
<td>3.6–6.0</td>
<td>1.9–6.2</td>
</tr>
<tr>
<td></td>
<td>0.143</td>
<td>0.50</td>
<td>0.03–0.038</td>
<td>3.9–4.8</td>
<td>2–10</td>
</tr>
</tbody>
</table>

**Note:** \(z\), vertical drop height; \(W\), channel width; \(y_e\), inflow depth; \(Fr\), inflow Froude number.