Local Scour by Offset and Propeller Jets

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Outline

- Introduction
- Dimensional analysis
- Effect of densimetric Froude number on jet scour
- Effect of offset height on scour
- Initiation of scour
- Conclusions
Introduction

(a) Sewage plant

(b) Dam

Ship-propeller jet

Propeller wash induced erosion

Submerged horizontal jet
One Week Vessel Track at PPT (25 - 31 May, 2011)

Source: Maritime Port Authority of Singapore, MPA
Scour by (a) offset jet; and (b) propeller jet
Objective

- To investigate the characteristics of a 3-D scour hole in non-cohesive sediment beds due to a submerged horizontal 3-dimensional offset and propeller jet
Dimensional Analysis

\[ d_{sem} ; L_{sem} ; W_{sem} = f(U_o, d_o, d_{50}, y, \rho, g, \rho_s, \mu, h_t) \]

\[ \frac{d_{sem}}{d_o} = f\left( \frac{U_o}{\sqrt{\frac{\Delta \rho}{\rho} gd_{50}}} , \frac{U_o d_o}{v} , \frac{y}{d_o} , \frac{h_t}{d_o} \right) \]

\[ F_o = \frac{U_o}{\sqrt{(\Delta \rho / \rho) gd_{50}}} \]

\[ R_{ej} = \frac{U_o d_o}{v} \]

\[ \frac{d_{sem}}{d_o} = f\left( F_o , \frac{y}{d_o} \right) \]

\[ \frac{d_{sem}}{d_o} = f\left( F_o - F_{oc} , \frac{y}{d_o} \right) \]
### Range of data collected on scour cause by submerged 3D jets

<table>
<thead>
<tr>
<th>Investigators</th>
<th>$y/d_o$</th>
<th>$F_o$</th>
<th>$d_{sem}/d_o$</th>
<th>$L_{sem}/d_o$</th>
<th>$W_{sem}/d_o$</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamill (1987)</td>
<td>1.14</td>
<td>5.55 - 7.73</td>
<td>0.91 – 1.00</td>
<td>—</td>
<td>6.89 – 20.98</td>
<td>propeller jet</td>
</tr>
<tr>
<td>Chiew and Lim (1996)</td>
<td>0.50 – 15.75</td>
<td>13.14 – 60.74</td>
<td>0.47 – 12.76</td>
<td>9.88 – 42.20</td>
<td>27.07 – 95.12</td>
<td>circular jet</td>
</tr>
<tr>
<td>Karki (2007)</td>
<td>1.00 – 2.00</td>
<td>10.00</td>
<td>2.03 – 2.87</td>
<td>11.28 – 12.85</td>
<td>28.02 – 29.65</td>
<td>square jet</td>
</tr>
<tr>
<td>Hong et al. (2012)</td>
<td>0.50 – 1.50</td>
<td>6.08 – 10.69</td>
<td>0.50 – 1.50</td>
<td>2.57 – 6.65</td>
<td>5.62 – 11.26</td>
<td>propeller jet</td>
</tr>
</tbody>
</table>
**Effect of $F_o$ on jet scour**

- Circular wall and propeller jets
- Chiew and Lim's (1996)'s circular wall jet formulas form the upper limit
- The offset height ratio also plays an important role
Effect of $y/d_o$ on scour depth

\[ \frac{d_{sem}}{d_o} = 0.265 \left( F_o - \left( 4.114 \frac{y}{d_o} \right) \right)^{0.955} \left( \frac{y}{d_o} \right)^{-0.022}, \quad \frac{y}{d_o} \geq 0.5 \]
Effect of $y/d_o$ on scour length

\[
\frac{L_{sem}}{d_o} = 8.824 \left( F_o - (4.114 \frac{y}{d_o}) \right)^{0.535} \left( \frac{y}{d_o} \right)^{0.286}, \quad \frac{y}{d_o} \geq 0.5
\]
Effect of $y/d_o$ on scour width

\[
\frac{W_{\text{sem}}}{d_o} = 3.834 \left( F_o - (4.114 \frac{y}{d_o}) \right)^{0.585} \left( \frac{y}{d_o} \right)^{0.202}, \quad \frac{y}{d_o} \geq 0.5
\]
Initiation of 3-D jet scour

\[ F_{oc} = 4.114 \frac{y}{d_o}, \quad \frac{y}{d_o} \geq 0.5 \]
Conclusions

1. The offset height ratio, $y/d_o$ and densimetric Froude number, $F_o$, affects both offset and propeller jets.

2. The 3-D wall jet equations proposed by Chiew and Lim (1996) form the upper limits for scour induced by both types of jets.
Conclusions

3. The variation between the scour length, width and offset height is non-linear.

4. Eq. 11 (Fig. 9) in the paper may be used to determine the critical condition for the initiation of scour.

\[ F_o = (4.114 \frac{y}{d_o}) \]
Questions & Comments