HYDRAULIC JUMP
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1. Outcomes

- Conduct various civil engineering experiments related to the course, analyze and evaluate the results with regard to real application.
- Write a well organized work report with good verbal, graphical content.

2. Objectives

- Observe the flow patterns before the jump and after the jump
- Quantify the energy lost due to a hydraulic jump
- Name the characteristics of hydraulic jump, from the percent energy dissipation using table-1 given by (USBR 1995).
- Compare observed and theoretical ratios of upstream and downstream depths.
- Evaluate and discuss the results.

3. Theory

The hydraulic jump, also known as standing wave, is a rapid transition from supercritical flow to subcritical flow. The transition is generally a turbulent process with a significant energy loss (\(\Delta E\)) that can not be neglected. A hydraulic jump is commonly used to dissipate energy, and reduce the downstream velocity. Figure 1 shows the variable included in a hydraulic jump.

![Figure 1: Specific Energy Curve [2]](image)

If supercritical flow occurs (by any hydraulic control such a gate) in a channel where the normal flow condition is subcritical (due to slope, roughness, and flow rate), a hydraulic jump will occur. In horizontal rectangular channels, the relationship between the downstream and upstream depths is given by the following equation:

\[
\frac{y_2}{y_1} = \frac{1}{2} \left( \sqrt{1 + 8F_i^2} - 1 \right)
\]  

(1)

where,

- \(y_1\) = upstream depth of water (m)
- \(y_2\) = downstream depth of water (m)
- \(F_i\) = upstream Froude number
$F_1 = \frac{V}{\sqrt{gy}}$ where $y =$ Depth of water (m)

Equation (1) is derived from the momentum equation in a controlled volume between section 1 and 2 i.e. $P_1 - P_2 = \rho Q (V_2 - V_1)$

Where $P_1$ and $P_2$ are pressure at section-1 and $V_1$ and $V_2$ are velocity at section 1 and 2 respectively

$\rho =$ density of water in the controlled section

$Q =$ flow in the controlled section

In addition, the energy loss is given by the following equation:

$$\Delta E = E_1 - E_2 = \frac{(y_2 - y_1)^3}{4y_1y_2}$$

where,

$E_1 =$ upstream energy, (m)

$E_2 =$ downstream energy, (m)

$\Delta E =$ energy loss, (m)

According to the U.S. Bureau Reclamation (USBR), a hydraulic jump can be classified in undular, weak, oscillating, steady, and strong jump. Table 1 shows the classification.

### Table 1: Characteristics of Hydraulic Jump (USBR 1955) [1]

<table>
<thead>
<tr>
<th>Name</th>
<th>$F_1$</th>
<th>Energy dissipation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undular jump</td>
<td>1.0 – 1.7</td>
<td>&lt; 5%</td>
</tr>
<tr>
<td>Weak jump</td>
<td>1.7 – 2.5</td>
<td>5 – 15%</td>
</tr>
<tr>
<td>Oscillating jump</td>
<td>2.5 – 4.5</td>
<td>15 – 45%</td>
</tr>
<tr>
<td>Steady jump</td>
<td>4.5 – 9.0</td>
<td>45 – 70%</td>
</tr>
<tr>
<td>Strong jump</td>
<td>&gt; 9.0</td>
<td>70 – 85%</td>
</tr>
</tbody>
</table>

4. **Experimental Procedure**

- A sluice gate installed in the flume, which has to be leveled used to generate the hydraulic jump. The flume should be leveled. The sluice gate will create a supercritical flow immediately after the gate, followed by a hydraulic jump, and then a subcritical flow downstream of the hydraulic jump.

- One vernier is located upstream of the hydraulic jump to measure the supercritical depth, $y_1$, and the other downstream of the hydraulic jump to measure the subcritical depth, $y_2$. The verniers are zeroed with the bed of the channel and have to be moved depending on the location of the hydraulic jump.

- The procedure consists of five (5) runs. Each run consists of a constant flow rate and two (2) different opening gates. Measure the accurate flow rate, the upstream depth, and the downstream depth.
Run | Flow rate (L/s) | Initial opening gate (mm) | Final opening gate (mm) |
---|---|---|---|
1 | 0.5 | 8 | 14 |
2 | 1.0 | 14 | 20 |
3 | 1.5 | 20 | 26 |
4 | 2.0 | 26 | 32 |
5 | 2.5 | 32 | 38 |

Use the following tables as guide to record the experimental data.

<table>
<thead>
<tr>
<th>Run</th>
<th>Volume (L)</th>
<th>Time (sec)</th>
<th>Q (L/s)</th>
<th>$y_a$ (mm)</th>
<th>$y_1$ (mm)</th>
<th>$y_2$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>14</td>
<td>14</td>
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<tr>
<td>2</td>
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<td>10</td>
<td>10</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
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<td>10</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>26</td>
<td>26</td>
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<tr>
<td>5</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>

5. Calculations

- Calculate $E_1$, $E_2$, and $\Delta E$.
- Calculate $F_j$.
- Calculate $y_2/y_1$ from the experimental data.
- Determine the theoretical value of $y_2/y_1$.
- Plot the theoretical $y_2/y_1$ and the experimental $y_2/y_1$ in one graph.
- Classify the type of hydraulic jump using $F_j$ and $\Delta E$ as criteria.
- Analyze the results

6. Analysis and discussion of the results

- Comment on the graph of the theoretical $y_2/y_1$ and the experimental $y_2/y_1$
- Suggest other ways, different from a gate, to generate a hydraulic jump.
- Name some applications where the loss of energy in a hydraulic jump would be desirable [4].
7. Content of the report

It is required to submit a formal report by next class. The report should cover the following:

- Introduction and objectives
- Theory
- Experimental procedure
- Experimental data
- Calculations: Explain in detail the procedure and include the Excel tables.
- Evaluate and discussion of results
- References

8. References used for this guide