Chapter 1

Laboratory exercise 1: Open channel flow measurement

Laboratory exercise Open channel flow measurement is placed on the Faculty of Civil and Geodetic Engineering, on Department of Environmental Civil Engineering (Hydraulic Department) at Hajdrihova street 28, 1000 Ljubljana.

Figure 1.1: Directions from Faculty of Mechanical Eng. (Aškerčeva 6) to Department of Environmental Civil Eng. (Hajdrihova 28).

1.1 Introduction

Flow measurement is the quantification of bulk fluid movement and can be measured in a variety of ways. When dealing with liquids, flows can be divided between open-channel flows and pipe flows. Free surface flow can be always found in open-channel flows and also in some cases in
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pipe flows.

![Image of pipe flows](image)

Figure 1.2: A: pipe flow, B: pipe flow (free surface), C: open channel flow.

1.1.1 Flow measurement

Most common flowmeters for pipe flow are differential pressure flowmeters (orifice plates, flow nozzles, Venturi tubes and rotameters), turbine flowmeters, electromagnetic flowmeters...

By open channel flows all the upper mentioned flowmeters are not appropriate, that is why other methods must be used. A common method of measuring flow through an open channel is to measure the height of the liquid as it passes over an obstruction as a flume or weir in the channel.

Most common types of weirs are broad-crested (rectangular) and sharp-crested (rectangular, triangular and trapezoidal). Sharp-crested weirs are usually used to measure the discharge of smaller rivers and channel, while broad-crested weirs are usually used to measure the discharge of larger rivers and canals.

![Image of weir shapes](image)

Figure 1.3: Common sharp-crested weir shapes.
1.1.2 Thomson V-notch

The Thomson V-notch provides a simple and reliable way of measuring water flow. The method is particularly suitable for measuring flows in contaminated water, for example in sedimentation basins. The V-notch, sharp-crested weir is especially good for measuring low flow rates.

\[ b = 2(H - h) \tan \left( \frac{\theta}{2} \right) \]  

(1.1)

The hatched element area $\delta A$ on figure 1.4 can be defined as a product of height and width of the element (equation 1.2).

\[ \delta A = 2(H - h) \tan \left( \frac{\theta}{2} \right) \delta h \]  

(1.2)

Discharge velocity can be written as a velocity of the fluid flow from a reservoir (equation 1.3):

\[ v = \sqrt{2gh} \]  

(1.3)
Flow through the infinitesimal element of the overflow can be written as a product of it’s surface and velocity (equation 1.4):

\[ \delta Q = 2(H - h)\tan\left(\frac{\theta}{2}\right) \sqrt{2gh} \cdot \delta h \]  

(1.4)

If one integrate the equation 1.4 between \( h = 0 \) and \( h = H \), the following expression comes to place (equation 1.5):

\[
Q = 2\tan\left(\frac{\theta}{2}\right) \sqrt{2g} \int_{0}^{H} \left[ H h^{1/2} - h^{3/2} \right] dh = \\
2\tan\left(\frac{\theta}{2}\right) \sqrt{2g} \left[ \frac{2}{3} H^{5/2} - \frac{2}{5} H^{5/2} \right] = \\
\frac{8}{15} \tan\left(\frac{\theta}{2}\right) \sqrt{2g} H^{5/2}
\]

(1.5)

Theoretically calculated flow is not the same as the actual flow, thus a correction coefficient \( C_d \) is used and the final expression is written as (equation 1.6):

\[
Q = C_d \frac{8}{15} \tan\left(\frac{\theta}{2}\right) \sqrt{2g} H^{5/2}
\]

(1.6)

For the V-notch used in the laboratory, the coefficient can be read from a poster placed on the wall in the laboratory (Fig. 1.5).

Figure 1.5: Thomson V-notch correction coefficient.
1.2 Experimental set-up

Experimental set-up (Fig. 1.6) is placed in the Laboratory for Fluid Mechanics. Figure 1.6 shows Thomson V-notch, placed in the stainless steel open reservoir. Reservoirs in the laboratory are used for several different experimental set-ups, that is why one must considered which valves must be closed and which open to achieve flow through the Thomson reservoir. The complete experimental set-up (Fig. 1.7) contains a main large reservoir ($60 \, m^3$) in the basement, from which water is pumped into the upper overflow reservoir, from the upper overflow reservoir it flows into the lower overflow reservoir, which height position can be manually set. These two overflow reservoirs also serve as flow settlers. From the lower overflow reservoir the water flows through the surge reservoir into the last reservoir, where the Thomson V-notch weir is placed. After the water passes through the weir, it flows back to the main reservoir.

The pump which is used to maintain the flow through the station is placed in the basement and can be controlled by the frequency controller placed in the laboratory.

For successful measurements one must ensure constant flow through the Thomson V-notch weir, that means that water level in the lower overflow reservoir must be high enough to ensure, that part of the flow goes directly back to the main reservoir.

For the reference value of the flow rate an electromagnetic flowmeter is installed before the surge reservoir. To measure the flowrate by the V-notch weir the height of the water level is needed, which can be measured by different measurement methods. For the laboratory exercise one can use ultrasonic level measurement device, a pressure transducer or a regular hand ruler.
1.3 Student task list

1. Connect all the necessary data acquisition equipment,

2. Chose ten working points,

3. Measure the height of the water surface, with at least two measuring methods,

4. Compare experimental data $H(Q)$ with theoretical $H(Q)$ curve (Fig. 1.5),

5. Draw a scheme of the experimental set-up,

6. Write a report about the laboratory exercise. Comments about the measurements and the results must be included.

1.3.1 Additional work

For grade 10, student can perform the following tasks:

- Describe at least two additional measuring methods for flow measurements in open channels.

- Compare the described methods with the Thomson V-notch weir method.

Additional work can contain maximum 3 A4 pages of material.