Experiment No. 1

DETERMINATION OF STATE OF FLOW AND CRITICAL DEPTH IN OPEN CHANNEL



1.1 General

The state of open channel flow is mainly governed by the combined effect of viscous and gravity forces relative to the inertial forces. This experiment mainly deals with determination of the state of flow in an open channel at a particular section. The state of flow is very important, as the flow behavior depends on it. In order to construct different structures in rivers and canals and to predict the river response, the state of flow must be known. The experiment also deals with determination of critical depth, which is very useful in determining the types of flow in practice.

1.2 Theory

1.2.1 State of flow

Depending on the effect of viscosity relative to inertia, the flow may be laminar, turbulent or transitional. The effect of viscosity relative to the inertia is expressed by the Reynolds number, given by

$$Re = \frac{VR}{\nu} \qquad (1.1)$$

Where, V is the mean velocity of flow, R is the hydraulic radius (=A/P), A is the wetted cross-sectional area, P is the wetted perimeter and ν is the kinemetic viscosity of water.
Kinematic viscosity varies with temperature. The values of kinematic viscosity of water at different temperatures are given in Table 1.1. The value of υ at 20^0C (=1.003×10^{-6} m^2/s) is normally used to compute the Reynolds number of open channel flow.

When, Re <500	the flow is laminar
500 ≤ Re ≤ 12,500	the flow is transitional
Re > 12,500	the flow is turbulent.

Most open channel flows including those in rivers and canals are turbulent. The Reynolds number of most open channel flows is high, of the order of 10^6, indicating that the viscous forces are weak relative to the inertia forces and do not play a significant role in determining the flow behavior.

When the flow is dominated by the gravity, then the type of flow can be identified by a dimensionless number, known as Froude Number. Given by

$$Fr = \frac{V}{\sqrt{gD}} \qquad (1.2)$$

Where, V is the mean velocity of flow, D is the hydraulic depth (= A/T), A is the cross-sectional area, T is the top width and g is the acceleration due to gravity (= 9.81 m/s^2).Depending on the effect of gravity relative to inertia, the flow may be subcritical, critical or supercritical-

When, Fr < 1	the flow is subcritical
Fr = 1	the flow is critical
Fr > 1	the flow is supercritical.

The flow in most rivers and canals is subcritical. Supercritical flow normally occurs downstream of a sluice gate and at the foot of drops and spillways. The Froude number of open channel flow varies over a wide range covering both subcritical and supercritical flows and the state or behavior of open channel flow is primarily governed by the gravity force relative to the inertia force. Therefore, the Froude number is the most important parameter to indicate the state or behavior of open channel flow.

Depending on the numerical values of Reynolds and Froude numbers, the following four states of flow are possible in an open channel:

i)	Subcritical laminar	Fr < 1, Re < 500
ii)	Supercritical laminar	Fr > 1, Re < 500
iii)	Subcritical turbulent	Fr < 1, Re > 12,500
iv)	Supercritical turbulent	Fr > 1, Re > 12,500

The first two states of flow, subcritical laminar and supercritical laminar, are not commonly encountered in applied open channel hydraulics. Since the flow is generally turbulent is open channel, the last two states of flow are encountered is engineering problems.

Table 1.1 Kinematic viscosity of water at different temperatures

Temperature, ^{0}C	Kinematic viscosity, $\nu \times 10^{-6}$, m^2/s
0	1.781
5	1.518
10	1.307
15	1.139
20	1.003
25	0.890
30	0.798
40	0.653
50	0.547
60	0.466
70	0.404
80	0.354
90	0.315
100	0.282

1.2.2 Critical depth

Flow in an open channel is critical when the Froude number of the flow is equal to unity. Critical flow in a channel depends on the discharge and the geometry of channel section. For a rectangular section, the critical depth is given by

$$y_c = \sqrt[3]{\frac{Q^2}{gB^2}} \qquad (1.3)$$

Where, y_c is the critical depth, Q is the discharge and B is the width of the channel.

When the depth is greater than the critical depth, the flow is subcritical. When the depth is less than the critical depth, the flow is supercritical.

1.3 Objectives of the experiment

1) To measure water depth both upstream and downstream of a weir.
2) To determine the Reynolds number (Re) and the Froude number (Fr).
3) To determine the state of flow.
4) To determine critical depth (y_c).
5) To observe the subcritical and the supercritical flows.

1.4 Experimental setup

To develop different states of flow, the following laboratory setup is used.

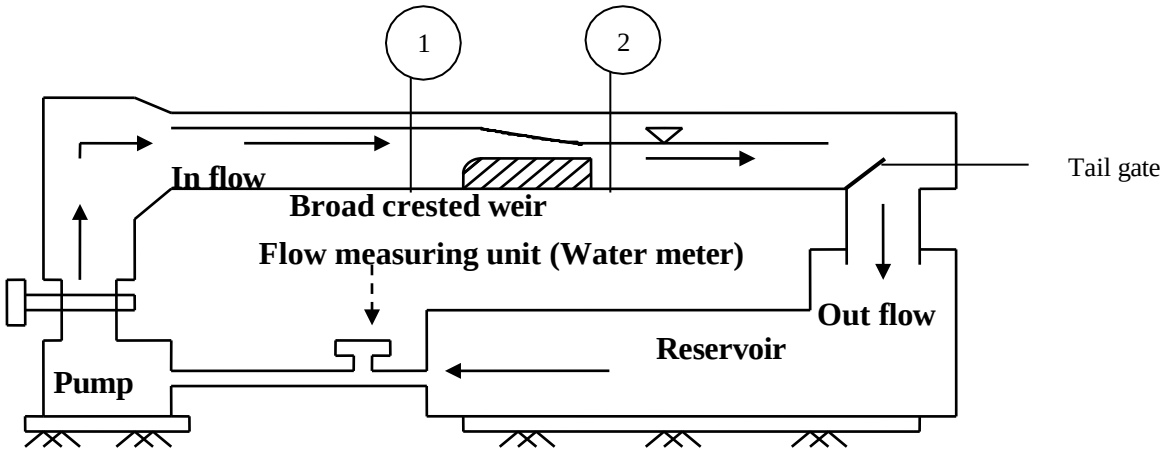


Fig. 1.1 Schematic diagram of experimental setup

1.5 Procedure

i) Measure the depth of flow at sections 1 and 2 by a point gage.
ii) Take the reading of discharge.
iii) Calculate the velocity at both the sections.
iv) Calculate Re and Fr for both the sections using Eqs. (1.1) and (1.2) and determine the state of flow.
v) Calculate the critical depth y_c using Eq. (1.3).

1.6 Assignment

1. Why the state of flow and the critical depth of a river or canal need to be determined?
2. How can you determine that the flow in a river is subcritical, critical or supercritical without taking any measurement?
3. State why the Froude number is more significant than the Reynolds number to determine the state of open channel flow.