Open Channel Flow

3;

ntroduction

Uniform flow

Energy Depth relationship

. Gradually varied flow (GVF)

5. Rapidly varied flow (Hydraulic Jump)

6. Surges.

→ $\sqrt{9.81} = 3.13 \approx \sqrt{10} = 3.16$

→ $\sqrt{2} = 1.414$

→ $\sqrt{3} = 1.732 \approx \sqrt{\pi} = 1.772$

→ $\sqrt{5} = 2.24$

→ $\sqrt{7} = 2.65$

→ $\sqrt{11} = 3.32$

→ $\sqrt{13} = 3.61$

→ $\sqrt{17} = 4.12$

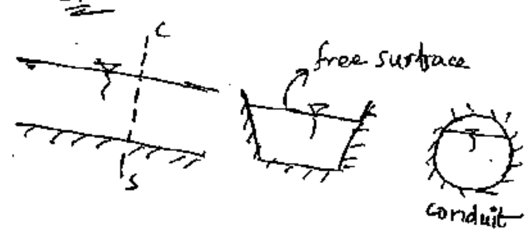
→ $\sqrt{19} = 4.36$

1. Introduction

→ Open channel flow refers to the flow of liquid in channel open to atmosphere or in a partially filled conduit (pipe) and characterised by the presence of liquid gas interface called "Free surface".

→ The driving force in OCF is "Gravity".

Ex:-



Note:-

→ Shear stress on free surface is "zero".

→ Types of channel :-

Channels are broadly classified as,

1. Prismatic channel
2. Non-prismatic channel

Other classification of channel are

1) Rigid boundary channel → only depth varies with space & time
   - → Boundary is not deformable
   - → Shape & roughness Parameters are not function of flow.
   - Ex:- Lined-channels, Sewers
   - → Degree of freedom = 1 (depth)

2) Mobile Boundary channel
   - → In this case, the depth, Bedslope, width as well as layout are function of space (length of flow) and time.

Note:-

→ Thus rigid boundary channel have 1 degree of freedom while mobile boundary channel have four degree of freedom.

→ We will study only Rigid boundary channel

→ Rigid boundary channel → 1 degree of freedom
  Mobile boundary channel → 4 degree of freedom

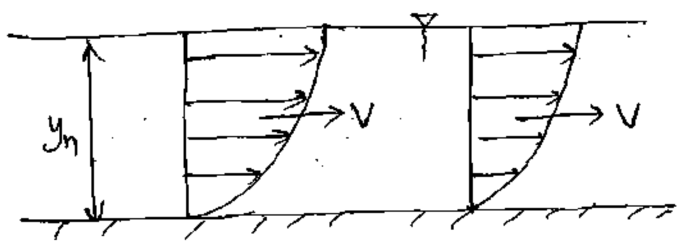
⇒ <u>Types of flow</u>

- steady
  - uniform
  - Varied
    - Gradually varied flow (GVF)
    - Rapidly varied flow (RVF)
    - Spatially varied flow (SVF)
- unsteady
  - GVUF
  - RVUF
  - SVUF

Uniform flow :-

→ Flow is called steady uniform if the depth of flow doesnot varies in space.

→ The underlined assumption is that, the velocity also doesnot vary which means that cross-section parameters, roughness parameters slope parameter are not varying.



y_n → normal depth of flow.

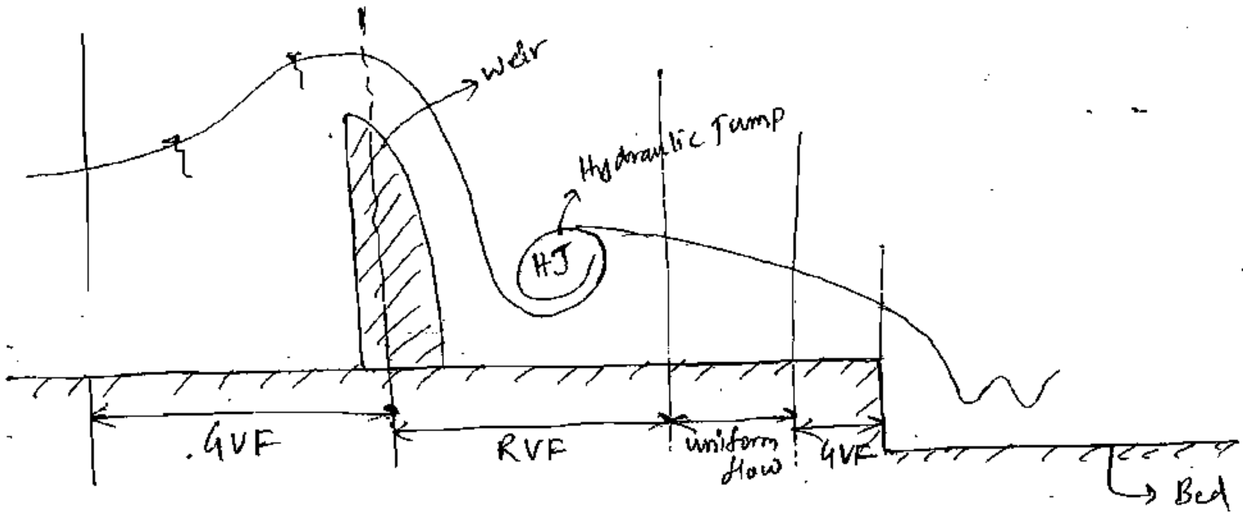
→ In uniform flow, the energy gained due to elevation fall is lost due to the flow i.e, frictional losses.

→ In Prismatic channel constant depth flow means uniform flow and depth of flow is called "<u>Normal depth of flow (y_n)</u>".

Varied flow :-

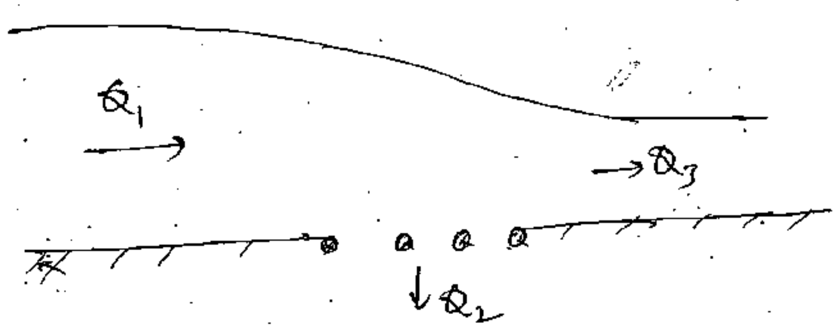
→ Presence of obstructions in channels such as weir, drop in bed, Sluice gate, change in slope (or) cross-section causes the flow to vary. This flow is called "Non-uniform flow" (or) "varied flow".

→ Flow is called "Gradually varied" if depth changes gradually over a long distance of channel, it occurs generally between RVF & Uniform flow region.



→ Curvature of stream line is Gentle in this case
→ if depth of flow changes significantly over a short distance such that the curvature changes rapidly. The flow is "RVF".
ex: Hydraulic Jump (HJ)

Note:-
→ Friction Plays an Important role in GVF, but not an important role ~~in~~ RVF
→ If some flow is added or extracted from the system then the flow is called "Spatially Varied Flow (SVF)".
ex: Flow over bottom rocks



$$Q_1 = Q_2 + Q_3$$

Where, Q_1, Q_2, Q_3 → Discharges

Unsteady flow :-

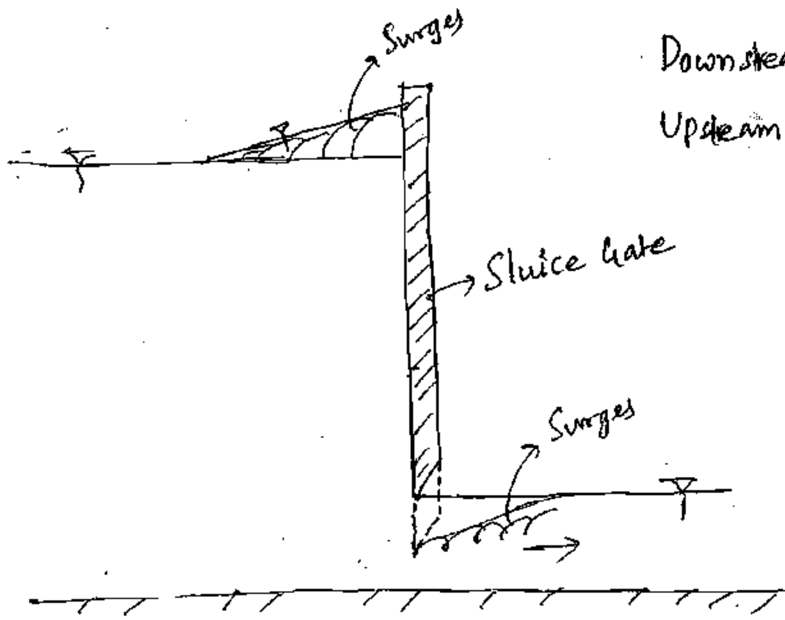
→ Unsteady flow is classified as

a) Gradually varied Unsteady flow (GVUF) ;-

Ex:- Floods, Passage of flood wave in a river

b) Rapidly varied Unsteady flow (RVUF) ;-

Ex:- Surges (or) breaking of waves on shore

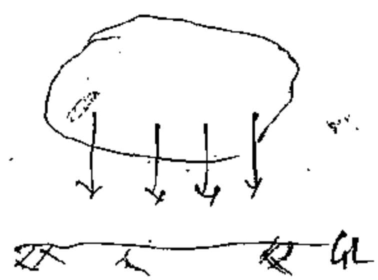


Downstream → Along direction of flow

Upstream → Against direction of flow

c) Spatially varied Unsteady flow :- (SVUF)

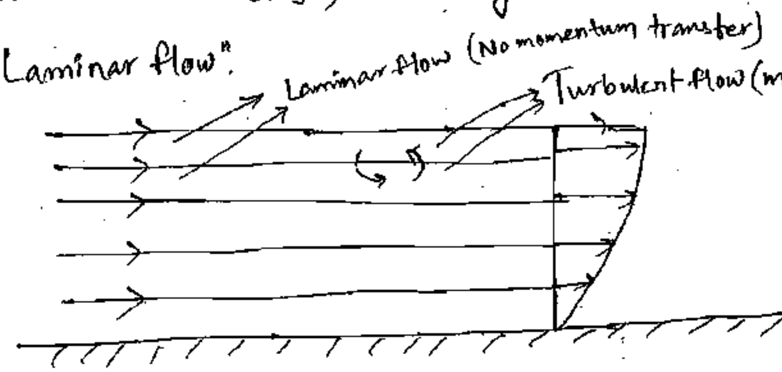
Ex:- Surface runoff due to rainfall



→ Means soil permeability capacity will change from one place to other.

⇒ Laminar & Turbulent flow :-

→ When the flow occurs such that one layer of the liquid slides past the other as if one lamina (layer) is sliding over the other, then the flow is called "Laminar flow".



→ there would be no momentum transfer between different layers in Laminar flow. However if water from one layer goes into the other and vice-versa, there would be momentum transfer between different layers, such a flow is called "Turbulent flow".

→ **Reynold's Number :- (R_e)**

R_e → Reynold's number

$$\boxed{R_e = \frac{VR}{\nu}}$$

where, V = Average Velocity of flow

R = Hydraulic radius

ν = kinematic viscocity

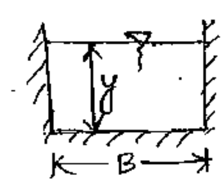
$$\therefore \boxed{\nu = \frac{\mu}{\rho}}$$

μ → dynamic viscocity

$$\rightarrow \boxed{R = \frac{A}{P}}$$

where, A = Area of c/s

P = Wetted Perimeter



$P = B + 2y$

→ $R_e < 500$ → Laminar flow

$R_e > 2000$ → Turbulent flow

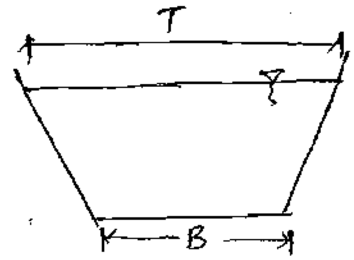
$500 < R_e < 2000$ → flow is Transition (means neither Laminar nor Turbulent flow)

→ Critical, Subcritical, Supercritical flow :-

Critical	Subcritical	Supercritical
→ $F_r = 1$	$F_r < 1$	$F_r > 1$

Where, F_r = Froud's number

$$F_r = \frac{V}{\sqrt{\frac{gA}{T}}}$$



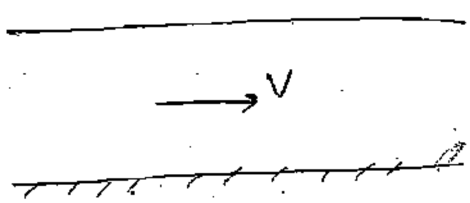
V → Avg. velocity of flow
A → Area of c/s of flow
T → Top width & g = acc. due to gravity.

Critical	Subcritical	Supercritical
→ $V = V_c = \sqrt{\frac{gA}{T}}$	$V < V_c$	$V > V_c$
→ $y = y_c$	$y > y_c$	$y < y_c$

→ Denominator of Froud's number represents a speed with which the disturbance created to flow travels in still water. i.e, "Celerity (C)".

(**) ∴ $\text{Celerity } (C) = \sqrt{\frac{gA}{T}}$

⇒



$$\underset{(US)}{V_{wave/ground}} = \underset{(U/S)}{V_{wave/water}} + \underset{(U/S)}{V_{water/ground}}$$

∴ $\underset{(US)}{V_{wave/ground}} = C - V$ [∵ US → upstream]

→ At Low Flow Velocity
$F_r < 1$
$C > V$
$C - V > 0$.

→ At low flow velocity, $F_r < 1$ and a small disturbance to the flow will cause disturbance wave which travels upstream with a velocity of (C−V) w.r.t a stationary observer.

→ Due to the upstream movement of waves upstream conditions gets affected,

Incase of Subcritical flow, condition upstream is affected by condition at downstream. Hence downstream section is taken as "Control section".

At high flow velocity $F_r > 1$

$V > C$

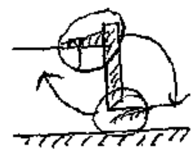
$C - V < 0$

Thus upstream flow velocity of waves $(C-V)$ will become negative. i.e, the disturbance waves will not travel upstream, It will travel downstream with a velocity of $V-C$. Hence flow condition Down stream would be affected. Thus 'Supercritical flow has upstream control'.

Note:-

Subcritical flow has downstream control while supercritical flow has upstream control.

* Subcritical flow → Down stream Control
* Supcritical flow → Up stream control



→ When $F_r = 1$, i.e, flow is critical, the disturbance velocity $C-V=0$

i.e, the disturbance wave will not travel at all.

—x—

IE:- (6)

Q:- A wide channel is 1m deep and has a velocity of flow $V = 2.13$ m/sec, if a disturbance is caused and elementary wave can travel upstream with a velocity of ——?

a) 1 m/sec b) 2.13 m/sec c) 3.13 m/sec d) 5.26 m/sec

Sol:- $V = 2.13$ m/sec , wide channel (1m) → Rectangular channel

$y = 1m$

W.K.T, $C = \sqrt{\frac{gA}{T}}$

$\therefore$ celerity, $C = \sqrt{\frac{g \times y T}{T}} = \sqrt{gy} = \sqrt{9.81 \times 1} = 3.13$ m/sec