IES MASTER

Civil Engineering

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- Previous Years Question With Solution

Open Channel Flow

DATE - 03/12/20

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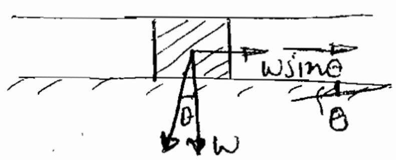
[1.] INTRODUCTION

DATE - 3/12

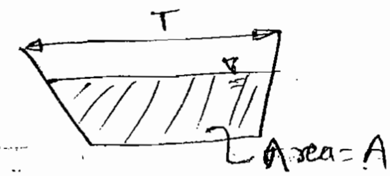
- In open channel flow, liquid flows with free surface. Free-surface is a interface of liquid & gas & shear stress = 0 on the free surface.

- The main driving force in case of OCF is Gravity.



- since Gravity is the most dominant force in OCF, the dimensionless no. used for analysis is Froude number.

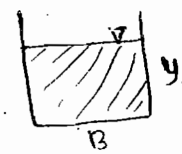
$$\text{Froude No.} = \frac{V}{\sqrt{g\frac{A}{T}}}$$



V = Avg. velocity of flow

$\frac{A}{T}$ = Hydraulic depth

T = Top surface width



$A = BY$, $T = B$, $\frac{A}{T} = Y$

$$F_r\Big|_{\text{for Rectangular channel}} = \frac{V}{\sqrt{gy}}$$

Type of channel

(1)

- Prismatic
  - (c/s is constt)
  - (shape, size, Bed-slope are constt)
  - (Artificial channel like canal)
- Non-Prismatic
  - (c/s isn't constt)
  - (Natural channels)

(2)

- Rigid Boundry channel
  - Boundry is not deformable.
  - Lined Canals & non-erodable unlined Canals
- Mobile Boundry channel
  - Boundry is Deformable.

- In Rigid boundry channel, only the depth of flow varies with discharge. Hence the channel said to have single degree of freedom.

- In mobile boundry channel, there can be change in depth of flow, c/s shape, Bed slope & layout. Degree of freedom = 4.
- In OCF, we will concentrate only on Prismatic-Rigid Boundry channel.

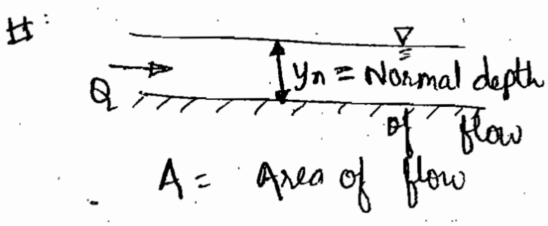
Type of Flow

- Steady Flow
  - Uniform
  - Gradually Varied flow (GVF)
  - Rapidly varied flow (RVF)
  - Spatially Varied flow (SVF)
  - (GVF, RVF, SVF) → Non-uniform flow
- Onsteddy flow
  - GVUF (Gradually Varied Unsteady flow)
  - RVUF
  - SVUF *

* Unsteady uniform flow is not practically possible.

- If the flow peroperties do not change with time → Steady flow.
- In steady 1-D flow, continuity equ^n leads to Q = constt.

#:

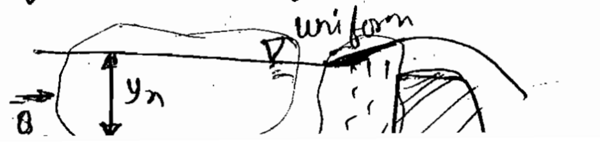


Q = Constt for steady flow

- For prismatic channel, if Q is constt, A will be constt ⇒ Depth = constt

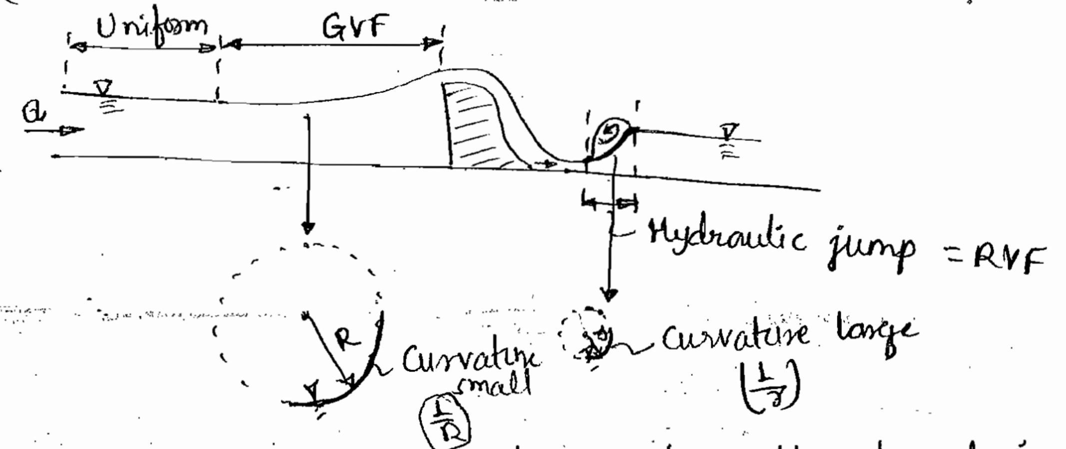
$$\Rightarrow \frac{Q}{A} = \text{constt} \Rightarrow V = \text{constt}$$

- A steady flow will be uniform, if depth & velocity of flow remain constt with space ⟶ Uniform flow.
- The constt depth of flow in uniform flow is called normal depth of flow.

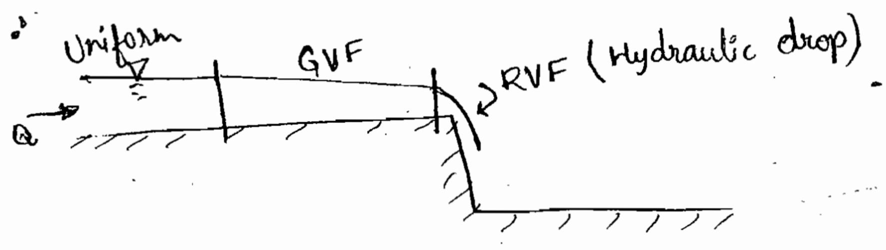


- If depth of flow does not remain const with space, the flow is called non-uniform flow.
- Steady - non-uniform flows are — GVF, RVF & SVF
- Unsteady - non uniform flows are — GVUF, RVUF & SVUF

Gradually Varied Flow (GVF) & Rapidly varied Flow (RVF)

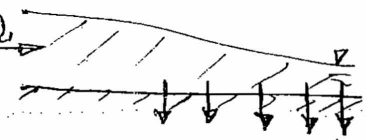


- If the depth of flow changes gradually along the channel in a steady flow, → GVF &
- If the depth of flow changes rapidly along the channel length in steady flow → RVF.
- In case of GVF, water surface curvature is small & it is large in case of RVF.
- Uniform flow sets up on a channel, if we have sufficient length of undisturbed flow.
- The flow upstream of dam, weir or sluice gate are an example of GVF.
- Hydraulic jump & hydraulic drop are examples of RVF.



Spatially varied flow (SVF)

- If discharge is added or extracted ~~flow~~ from the flow → SVF.

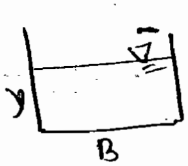


- If add^n or extraction rate is constt, the flow is called SVF & if it varies with time → SVUF.
- Flow over road side gutter, side channel spillway, wash water trough in filter & effluent channel around sewage treatment tank are examples of SVF.
- Runoff due to rainfall when infilteration rate is not constt is an example of SVUF.
- Passes of flood wave in a river when the river banks are not breached is an example of GVUF.
- Passes of flood wave in a river when the river banks are breached is an example of SVUF.
- Surge is an example of RVUF.

Laminar & Turbulent flows :-

- Most of the OCFs are turbulent in nature.
- Reynolds no. in OCF is defined as $\boxed{R_e = \frac{\rho V R}{\mu}}$

$$R = \text{Hydraulic radius} = \frac{\text{Area of flow}}{\text{wetted perimeter}} = \frac{A}{P}$$



Rectangular channel

$A = By$

$P = B + 2y$

$$\Rightarrow R = \frac{By}{B+2y}$$

$$\boxed{R = y} \quad \{\text{if } 2y << B\}$$

→ wide Rectangular

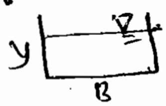
In OCF: $Re < 500$ — Laminar

$Re > 2000$ — Turbulent

Critical, Sub-critical & super-Critical flow :-

$$F_r = \frac{V}{\sqrt{g A/T}} \quad C_0 , \quad \frac{A}{T} = \text{Hydraulic depth}$$

For Rectangular channel : $F_r = \frac{V}{\sqrt{gy}}$ C_0



$\boxed{C_0 = \sqrt{gy}}$ C_0 = Celerity = Velocity of wave w.r.t. water

- The denominator in the Froude no. is called 'C_0', which is ~~best~~ wave speed at which disturbance wave of long wave length & small amplitude travels w.r.t. water of small depth.

	F_r	Depth = y	Velocity
Sub Critical	<1	$y > y_c$	$V < V_c$
Critical	$=1$	$y = y_c$	$V = V_c$
Super Critical	>1	$y < y_c$	$V > V_c$

y_c = Critical depth of flow

V_c = Critical velocity " " under critical condn

- Sub-critical flow is also called tranquil flow or streaming flow.
- Under sub-critical flow condn, Gravity force dominates the inertial force & the flow behaves in a slow & stable wave.
- Super Critical flow is also called shooting or porrential flow or rapid flow.

- In super critical flow, Inertial force dominates over Gravity force.

Velocity of disturbance wave w.r.t. Ground

$$\vec{V}_{wave\ ground} = \vec{V}_{wave\ water} + \vec{V}_{water\ ground}$$

$$\Rightarrow \vec{V}_{wave\ ground} = \vec{C_0} + \vec{V}_{water\ ground}$$

↳ $\vec{C_0}$ can travel both u/s & d/s

upstream travel speed of wave w.r.t. ground

$$V_{wave\ ground\ u/s} = C_0 \pm V_{water\ ground\ u/s}$$

$$V_{wave\ ground\ u/s} = C_0 - V$$

$\Rightarrow$ ✓ **u/s travel speed of wave = $C_0 - V$**

Downstream travel speed of wave w.r.t ground

$$V_{wave\ ground\ d/s} = C_0 + V_{water\ ground\ d/s}$$

$$V_{wave\ ground\ d/s} = C_0 + V$$

✓ **D/s travel speed of wave = $C_0 + V$**

For super critical flow ($V > C_0$)

u/s travel speed of wave $= C_0 - V < 0$

D/s " " " $= C_0 + V > 0$

For sub critical flow ($V < C_0$)

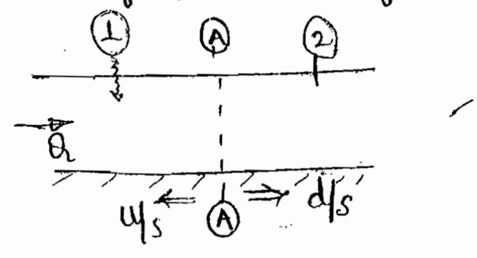
u/s travel speed of wave $= C_0 - V > 0$

D/s " " " $= C_0 + V$

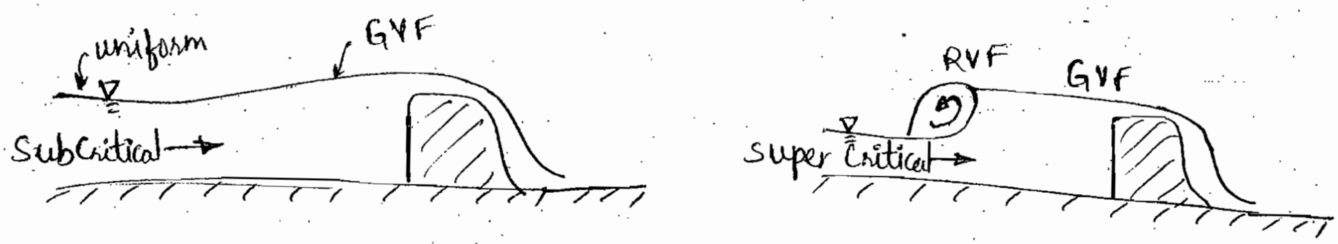
Small disturbance wave can not travel u/s, actually it will be washed d/s by super critical flow in case of super critical flow. But

In subcritical flow, small disturbance wave can travel u/s. And this is used to differentiate the type of flow in the field.

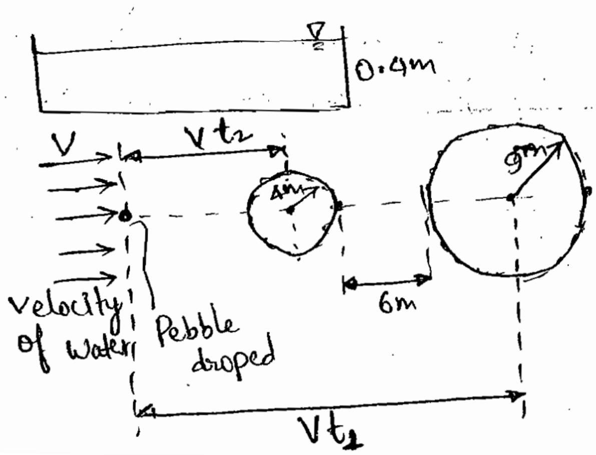
- Super Critical flow has u/s control.
- sub critical flow has d/s control. (also)
- If we want to change flow condn at secn A-A, Then we need to create change at Secn 1 for super critical flow condns.



- At control secn, there is fixed relationship b/w discharge & depth of flow.
- changing the flow condn(s) at control secn leads to change in flow condn at other location.



1Q. Water flows rapidly in a flat wide channel 0.4m deep. Pebbles drop sucessively in the water at the same spot creates two circular ripples as shown in the fig. Find the speed of water.



Soln: $C_0 = \sqrt{gy} = \sqrt{9.81 \times 0.4}$
$= 1.98$ m/s

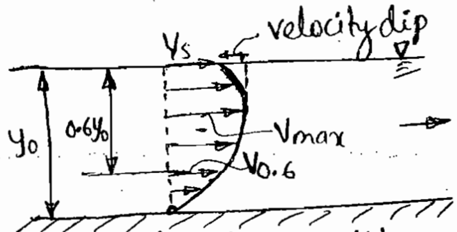
$Vt_1 = Vt_2 + 4 + 6 + 9$

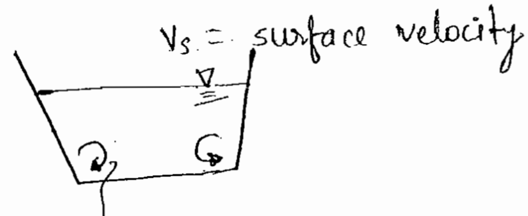
$\Rightarrow V(t_1 - t_2) = 19$

$t_1 = \frac{9m}{C_0} = \frac{9}{1.98} =$

$t_2 = \frac{4}{C_0} =$

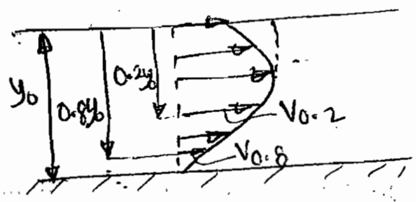
Velocity distribution





$$\boxed{V_{avg.} = V_{0.6}}$$ ⟹ single point observation method

- Velocity dip is due to secondary current.
- secondary current is a fun of ratio of depth to width (aspect ratio) of channel.



$$\boxed{V_{avg.} = \frac{V_{0.2} + V_{0.8}}{2}}$$ Two point observation method

$$\boxed{V_{avg.} = K V_s}$$ $K = 0.8 - 0.95$

- For larger $\frac{\text{depth}}{\text{width}}$ Ratio, 2°-current effect is more, i.e.
  In narrow channel, 2°-current effect is more.
- 2°-current effect is more in the presence of corner in channel.
- Effect of wind velocity on velocity dip is insignificant.
- Due to 2°-current a log of wood tends to float in the mid reaches of the river.

The K.E. correction factor & momentum correction factor ≃ 1 in OCF. b/c flow is mostly turbulent.

K.E correction factor $= \alpha = \dfrac{\int_A V^3 \, dA}{A V_{av}^3}$

Momentum Correction factor $= \beta = \dfrac{\int_A V^2 \, dA}{A V_{av}^2}$