Objective:

- To determine the velocity distribution profile
- To calculate the channel roughness height K.
- To calculate the cross sectional mean velocity.
- To calculate the velocity distribution coefficients

Experimental Setup:

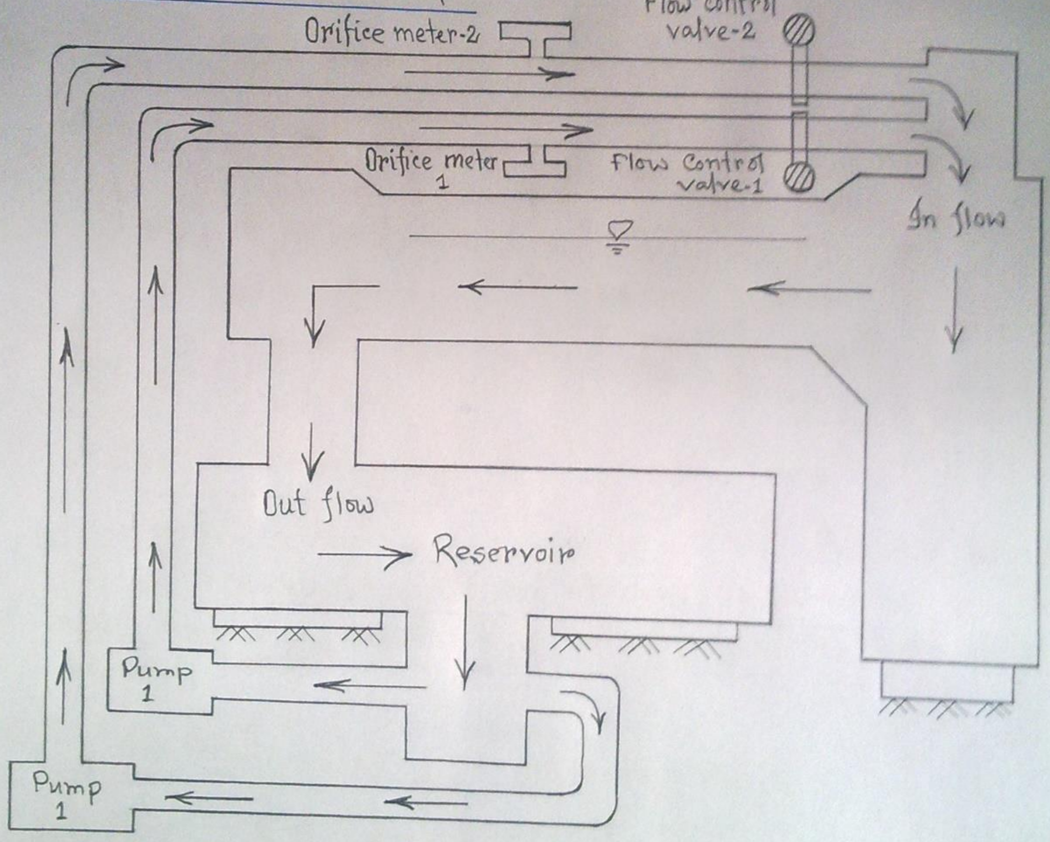


figure: Setup for Velocity distribution in Open Channel

⊞ Related formula:

* The boundary layer:

Even in a turbulent boundary layer, there is a very thin layer near the boundary in which the flow is laminar is known as laminar sublayer. The thickness of this layer is given by,

$$\delta_0 = \frac{11.6\,\nu}{V_f}$$

where, ν = kinematic viscosity of water
V_f = shear velocity or friction velocity.

Again, $V_f = \sqrt{gRS}$

where, R = hydraulic radius.
S = slope of the channel bottom.
g = acceleration due to gravity.

* Surface roughness:

Surface roughness depends on the effective height of the irregularities of the channel bottom i.e roughness height k and the thickness of the boundary sublayer.

for hydraulically smooth channel,

$$0 \le \frac{kV_f}{\nu} \le 5 \quad \text{and} \quad k < \delta_0$$

for hydraulically rough channel,

$$\frac{kV_f}{\nu} \geq 70 \text{ and } k > \delta_0$$

There also exists a transition zone of flow from laminar to turbulent where,

$$5 < \frac{kV_f}{\nu} < 70$$

* Velocity distribution in turbulent flow:

According to Karman-Prandtl logarithmic velocity distribution law, the velocity distribution in an open channel having rough bottom surface is given by

$$v = 5.75 V_f * \log \frac{30y}{k}$$

where, v = velocity at any point at a vertical distance of y from the channel bottom.

* Cross sectional mean velocity:

Cross sectional mean velocity represents the average velocity over the cross section. It is given by,

$$V = V_f \left(6.25 + 5.75 \log R/k\right)$$

* Velocity distribution coefficient :

Mathematically, the energy coefficient and momentum coefficient is given by,

$$\alpha = \frac{\int v^3 dA}{V^3 A} = \frac{\Sigma v^3 \Delta A}{V^3 A}$$

for a rectangular channel, is reduced as

$$\alpha = \frac{\Sigma v^3 \Delta y}{V^3 Y}$$

where, Y = depth of flow,

V = cross sectional mean velocity.

Again, $$\beta = \frac{\int v^2 dA}{V^2 A} = \frac{\Sigma v^2 dA}{V^2 A}$$

similarly, for a rectangular channel it is reduced as follows,

$$\beta = \frac{\Sigma v^2 \Delta y}{V^2 Y}$$

Sample Calculation:

Flume width, $B = 0.762\,m$

Total depth of flow, $Y = 0.385\,m$

Slope of the channel, $S = \frac{1''}{70'} = \frac{1''}{840''}$

$= 1/840$

Cross sectional area of the channel,

$A = BY = 0.762 * 0.385$

$= 0.29337\ m^2$

Wetted perimeter, $P = B + 2Y$

$= 0.762 + 2 * 0.385$

$= 1.532\ m$

∴ Hydraulic radius, $R = A/P = \frac{0.29337}{1.532}$

$= 0.1915\ m$

Shear velocity, $V_f = \sqrt{gRS}$

$= \sqrt{9.81 * 0.1915 * 1/840}$

$= 0.04729\ ms^{-1}$

current meter constants,

$a = 0.1334$

$b = 0.029$

Calculation is provided for measurement taken at depth 0.4Y :

Depth from water surface $= 0.4 * Y$

$= 0.4 * 0.385$

$= 0.154$ m

$\therefore$ Depth from bottom, $y = (0.385 - 0.154)$

$= 0.231$ m

No. of revolution, $N = 85$

Time ellapsed, $t = 15.0$ sec.

$\therefore$ Revolution per second, $n = \frac{85}{15}$

$= 5.667$ rev. s^{-1}

Point velocity at 0.4Y depth, $v = an + b$

$= 0.1334 * 5.667 + 0.029$

$= 0.785$ ms^{-1}

Roughness height, $k = \frac{30 * y}{\text{anti}\log\left(\frac{v}{5.75 v_f}\right)}$

$= \frac{30 * 0.231}{\text{anti}\log\left(\frac{0.785}{5.75 * 0.0473}\right)}$

$= 9.00 \times 10^{-3}$ m

Group No- 04
St. ID. 1016022

9.9 Data sheet:

Measurement of point velocity and roughness height.

Flume Width, B= 0.762m Total depth of flow, Y= 0.385 m

Slope of channel, S= 1/840

Hydraulic radius, R = 0.1915 Shear velocity, V_f= 0.0473 ms^{-1}

Current meter constants, a = 0.1334 b = 0.029 m

Vertical location of current meter			Current meter reading			Point velocity v (m/s)	Roughness height k (m)	Average k (m)
Location	Depth from water surface (m)	Depth from bottom y (m)	No of revolution N (rev)	Time of observation t (sec)	Revolution per second n (rev/sec)			
At top surface	0.05	0.335	84	14.9	5.6381	0.781	0.0135	0.0076
At 0.2 Y	0.077	0.308	83	14.7	5.6463	0.782	0.0123	
At 0.4 Y	0.154	0.231	85	15.0	5.666	0.785	0.0090	
At 0.6 Y	0.231	0.154	87	15.0	5.800	0.803	0.0052	
At 0.8 Y	0.308	0.077	86	15.1	5.695	0.789	0.0029	
Near bottom	0.335	0.05	80	14.9	5.369	0.745	0.0027	

Ahmed 15.03

Determination of energy and momentum coefficient:

Cross sectional mean velocity, V= 0.69 ms^{-1}

No of strip	Average velocity in the strip ,v (m/s)	Thickness of the strip Δy, (m)	$v^2\Delta y$	$v^3\Delta y$	α	β	(α-1)/(β-1)
1	0.7500	0.077	0.043	0.032	1.43	1.27	1.59
2	0.7820	0.077	0.047	0.0368			
3	0.7910	0.077	0.048	0.038			
4	0.7890	0.077	0.0479	0.0378			
5	0.7807	0.077	0.0469	0.0366			
Σ=		0.385	0.232	0.1812			

Average roughness height,

$$k = \frac{0.0135 + 0.0123 + 0.009 + .0052 + 0.0029 + 0.0027}{6}$$

$$= 0.0076$$

Cross sectional mean velocity,

$$V = v_f(6.5 + 5.75 \log R/k)$$

$$= 0.0473 * \left(6.5 + 5.75 * \log \frac{0.1915}{0.0076}\right)$$

$$= 0.6885$$

$$= 0.69 \ ms^{-1}$$

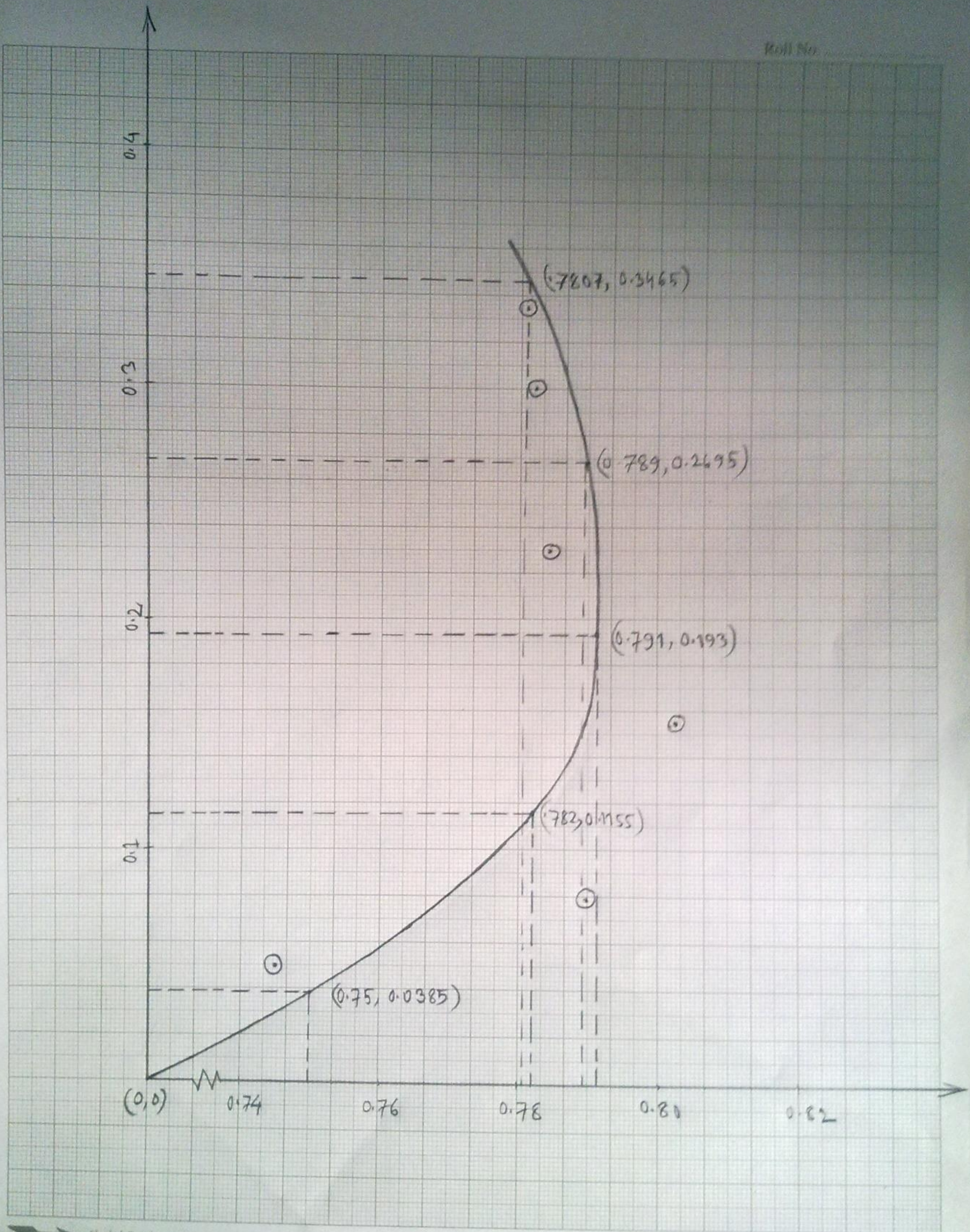
Energy coefficient, $\alpha = \frac{\Sigma v^3 \Delta A}{V^3 Y} = \frac{\Sigma v^3 \Delta Y}{V^3 Y}$

$$= \frac{0.1812}{.69^3 * 0.385} = 1.43$$

Momentum coefficient, $\beta = \frac{\Sigma v^2 \Delta y}{V^2 Y}$

$$= \frac{0.232}{0.69^2 * 0.385} = 1.27$$

Ratio of $(\alpha - 1)/(\beta - 1) = \frac{1.43 - 1}{1.27 - 1} = 1.59$


Roll No.
0.4
0.3
0.2
0.1
(.7807, 0.3465)
(0.789, 0.2695)
(0.791, 0.193)
(.782, 0.1155)
(0.75, 0.0385)
(0,0)
0.74
0.76
0.78
0.80
0.82
Shohid Products
20 cm x 25 cm

Result:

- Average roughness height, $K = 0.0076$
- Cross sectional mean velocity, $V = 0.69\ ms^{-1}$
- Energy coefficient, $\alpha = 1.43$
- Momentum coefficient, $\beta = 1.27$
- Ratio of $\frac{(\alpha-1)}{(\beta-1)} = 1.59$

Discussion:

BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY.

WRE - 302
Open-Channel Hydraulics

Experiment No. : 09

Name of the Experiment: Velocity Distribution Profile in Laboratory Flume.

Date of Performance : 15-03-14
Date of Submission : 22-03-14

Md. Raiful Islam
Student ID : 1016022
Level : 3 ; Term : I
Department : WRE

Objective:

- To determine the velocity distribution profile.
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- To calculate the cross sectional mean velocity.
- To calculate the velocity distribution coefficients.

Experimental Setup:

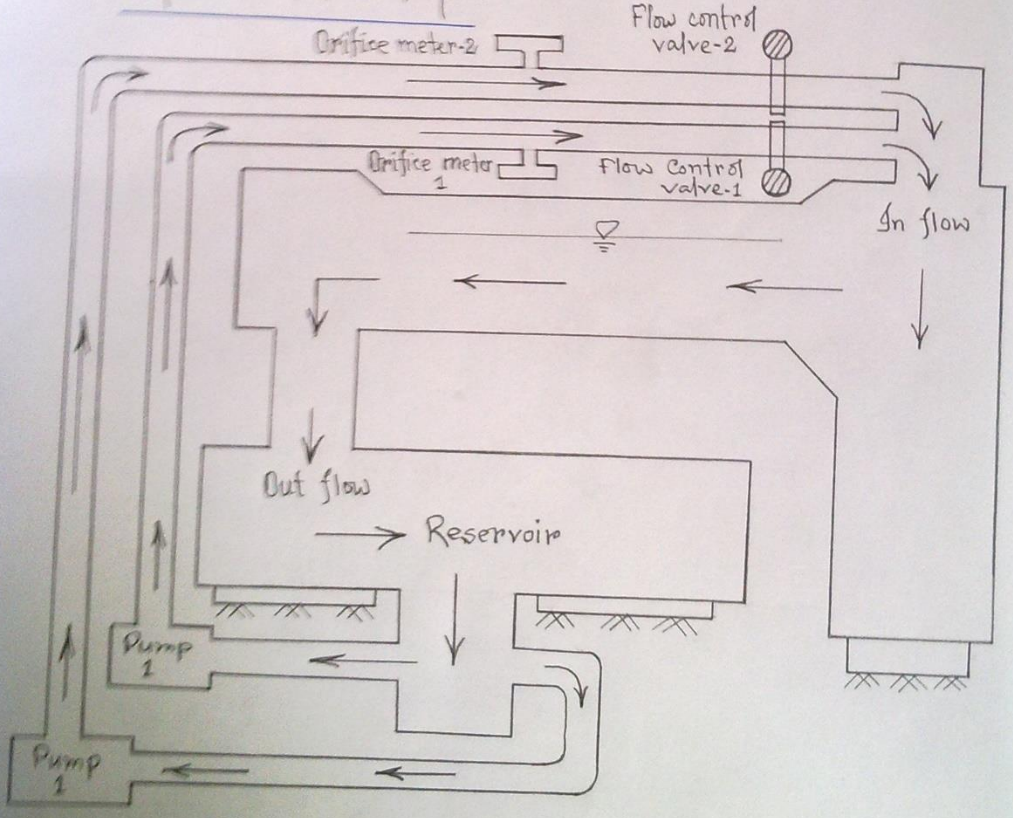

figure: Setup for Velocity distribution in Open Channel

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Group No. 04
St. ID. 1016022

9.9 Data sheet:

Measurement of point velocity and roughness height.

Flume Width, B= 0.762 m   Total depth of flow, Y= 0.385 m

Slope of channel, S= 1/840

Hydraulic radius, R = 0.1915   Shear velocity, V_f = 0.0473 ms^{-1}

Current meter constants, a = 0.1334   b = 0.029 m

Vertical location of current meter			Current meter reading			Point velocity v (m/s)	Roughness height k (m)	Average k (m)
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Ahmd 15.03

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Point velocity at 0.4Y depth, $v = an + b$

$= 0.1334 * 5.667 + 0.029$

$= 0.785$ ms^{-1}

Roughness height, $K = \frac{30 * y}{\text{anti log}\left(\frac{v}{5.75 V_f}\right)}$

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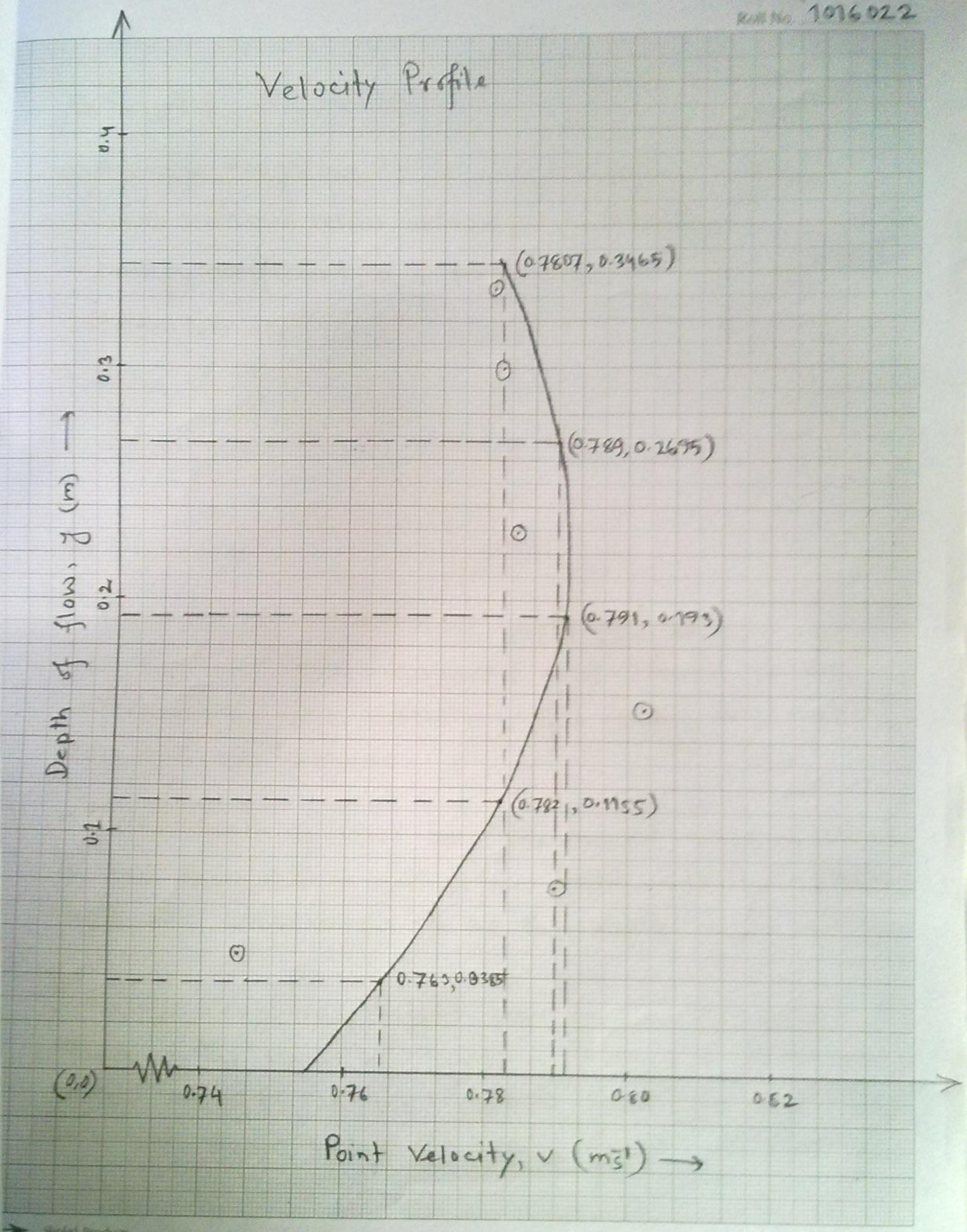
Group No - 04
Roll No. 1016022



Result :

- Average roughness height, $K = 0.0076$
- Cross sectional mean velocity, $V = 0.69\ ms^{-1}$
- Energy coefficient, $\alpha = 1.43$
- Momentum coefficient, $\beta = 1.27$
- Ratio of $\frac{(\alpha-1)}{(\beta-1)} = 1.59$

Discussion :

- Point velocity at different depth (i.e at 0.2Y, 0.4Y, 0.6Y, 0.8Y etc) were measured and found to be different. Therefore velocity profile along any vertical strip was not uniform.

- Total depth of flow was measured 0.385 m which is less than 0.61 m. Therefore point velocity at 0.6Y depth was considered to be the depth mean velocity.

- Average roughness height was found 0.0076 m. Whereas the value of laminar sublayer, δ_0 is calcuted as 2.95×10^{-4} m which is less than the value 0.0076 m. Again value of $\frac{KV_f}{\nu}$ is found 359.48. So the channel bed is being fulfulled the condition $\frac{KV_f}{V} \geq 70$ and $K > \delta_0$ and exhibiting as hydraulically rough channel.

- The cross sectional mean velocity using the equation $V = V_f(6.25 + 5.75 \log R/K)$ is found 0.67 m/s. Again mean velocity calcuted from the computed discharge was about 0.69 ms^{-1}. Therefore, these values converge within short range.

- Velocity profile is obtained plotting depth vs point velocity at different depth. It is a logarithmic profile but do not pass through the origin.

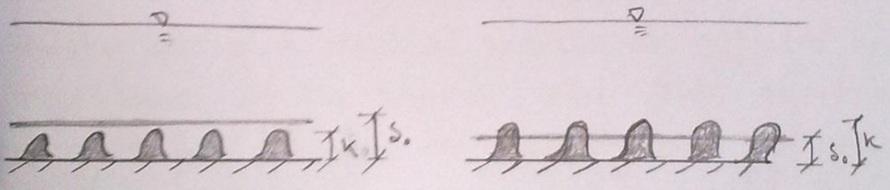
- Coefficient of energy correction, α is found to be 1.43 whereas the typical value of α ranges from 1.03 - 1.36.

- Momentum coefficient β is calculated as 1.29 which much greater than the typical value 1.01 to 1.12. Again the ratio of $(\alpha-1)/(\beta-1)$ is 1.49 instead of 3.0

⊕ Assignment Question:

Q.1 What do you mean by hydraulically smooth and rough channel? What is the criterion used to determine wheather a surface is hydraulically rough or smooth.

The surface of a channel is composed of irregular peaks and valleys. The effect of height of the irregularities is called roughness height K. When this height is less the viscous or laminar sublayer these effect of irregularities do not play significant role for making disturbance of the flow.



hydraulically smooth   hydraulically rough.

When the forming laminar sublayer is less than the roughness height the channel bed is considered as hydraulically rough channel.

for hydraulically smooth channel,

$$0 \leq \frac{k v_f}{\nu} \leq 5 \quad \text{and} \quad k < \delta_0$$

for hydraulically rough channel,

$$\frac{k v_f}{\nu} \geq 70 \quad \text{and} \quad k > \delta_0$$

where, v_f = shear velocity
ν = Kinematic viscosity of water.
k = roughness height
δ_0 = laminar sublayer.

Q.2 Explain why the velocity distribution over a channel section is not uniform?

- Velocity along a vertical section is affected by the roughness of the channel bed. This effect is greater at the interface between channel bed and water thus velocity is zero at the near of the channel bed. This effect is gradually vanquishes with increasing of depth.
- Viscosity of water also create resistant to flow over consequentive layers of water, thus varies along the depth.
- for open channel at the free surface there exist the effect of surface tension.