AKGEC/IAP/FM/03

AJAY KUMAR GARG ENGINEERING COLLEGE, GHAZIABAD
DEPARTMENT OF CIVIL ENGINEERING
SESSIONAL TEST-II SOLUTION

Course: B.Tech.
Session: 2017-18
Subject: OPEN CHANNEL FLOWS
Max Marks: 50

Semester: VII
Section: CE-01, 02
Sub. Code: NCE -043
Time: 2 hour

Section A

1. (a) What are the limitations of GVF.

Ans - (1) The velocity distribution is fairly uniform over a C.S.
(2) The kinetic energy corr^n factor & momentum correction factor can be taken as unity.
(3) The Bed slope of channel is very small.

1. (b) Describe flow classification & its surface profile in GVF.

Ans -

S.No.	channel category	Symbol	Condition
1.	Mild slope	M	$y_0 > y_c$
2.	Steep slope	S	$y_c > y_0$
3.	Critical slope	C	$y_c = y_0$
4.	Horizontal slope	H	$S_0 = 0$
5.	Adverse slope	A	$S_0 < 0$

1. (c) Write the Basic differential eq^n in terms of conveyance & section factor

Ans

$$\frac{dy}{dx} = S \frac{1 - (K_0/K)^2}{1 - (Z_c/Z)^2}$$

1(d) Explain significance of critical depth flume.

Ans These are like broad-crested weirs but with a major change that these are essentially flow-measuring devices & cannot be used for flow regulation purposes.

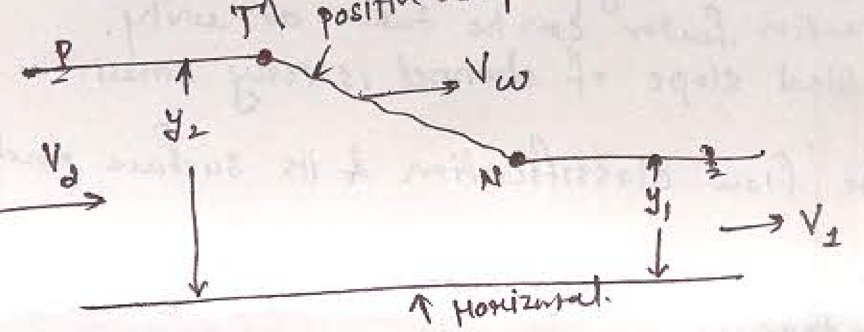
1. (e) Explain celerity of wave.

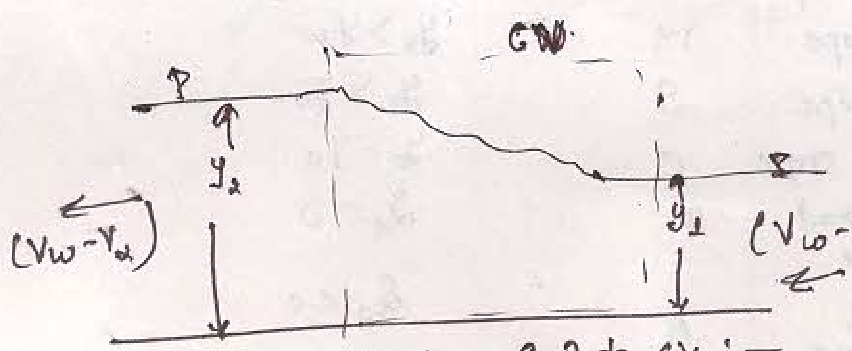
Ans The velocity of the surge relative to the initial velocity of surge in channel is known as celerity of surge. It is represented by C_s.

Section-B

2. (a) Derive expression for positive surge moving downstream and positive surge moving upstream.

Ans - Positive Surge Moving Downstream.





Applying continuity eq^n to CV :-

$$A_2(V_w-V_2) = A_1(V_w-V_1)$$

Applying momentum eq^n to control vol^m at sec^n (1) + (2)

$$P_1 - P_2 = M_2 - M_1$$

$$\gamma A_1\bar{y}_1 - \gamma A_2\bar{y}_2 = \rho Q V_2 - \rho Q V_1$$

$(\beta_1 = \beta_2 = 1)$

$$\gamma A_1\bar{y}_1 - \gamma A_2\bar{y}_2 = \frac{\gamma}{g} A_1 (V_\omega - V_1)\left[(V_\omega - V_2) - (V_\omega - V_1)\right]$$

(But $V_2 = A_1/A_2 \, V_1 + (1 - A_1/A_2) V_w$

$$(V_\omega - V_1)^2 = g \, A_2/A_1 \, \frac{1}{A_2 - A_1} (A_2\bar{y}_2 - A_1\bar{y}_1)$$

$$V_\omega = V_1 + \sqrt{g (A_2/A_1)\left(\frac{A_2\bar{y}_2 - A_1\bar{y}_1}{(A_2 - A_1)}\right)}$$

for Rectangular channel →

$$y_1 (V_\omega - V_1) = y_2 (V_\omega - V_2)$$

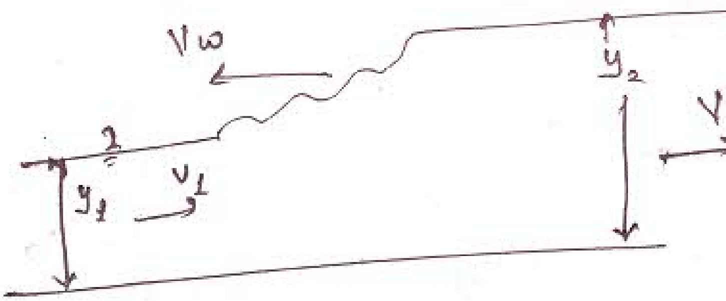
& momentum eqn is →

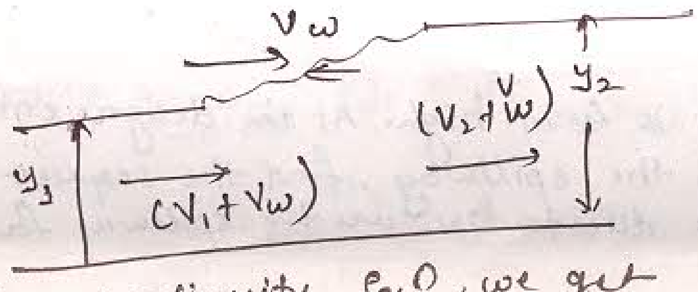
$$\frac{1}{2}\gamma y_1^2 - \frac{1}{2}\gamma y_2^2 = \frac{\gamma}{g} y_1 (V_\omega - V_1)(V_\omega - V_2)$$

So, $V_2 = y_1/y_2 \, V_1 + (1 - y_1/y_2) V_w$

So. $$\boxed{\frac{(V_\omega - V_1)^2}{g y_1} = \frac{1}{2} \, y_2/y_1 \left(y_2/y_1 + 1\right)}$$

Positive Surge moving downstream:-





Applying continuity eqn, we get

$$y_1 (V_w + V_1) = y_2 (V_w + V_2)$$

Applying momentum eq^n -

$$\frac{1}{2}\gamma y_1^2 - \frac{1}{2}\gamma y_2^2 = \frac{\gamma}{g} y_1 (V_w + V_1)\left[(V_w + V_2) - (V_w + V_1)\right]$$

But $V_2 = \frac{y_1}{y_2} V_1 - \left(1 - \frac{y_1}{y_2}\right) V_w$

$$\rightarrow \boxed{\frac{(V_w + V_1)^2}{g y_1} = \frac{1}{2} \frac{y_2}{y_1}\left(\frac{y_2}{y_1} + 1\right)}$$

2.(b) Water flows over a rectangular sharp crested weir 1.2m long, the head over the sill of the weir being 0.65m. The approach channel is 1.4m wide & depth of flow in the channel is 1.2m. Determine rate of discharge over the weir. $C_d = 0.6$.

Sol^n -

$$Q = \frac{2}{3} C_d (B - 0.1nH)\sqrt{2g}\, H^{3/2}$$

$$Q = \frac{2}{3} \times 0.6 \left[1.2 - 0.1 \times 2 \times 0.65\right] \sqrt{2 \times 9.81} \times 0.65^{3/2}$$

$$Q = 0.99\ m^3/s$$

$$V_0 = Q/A = \frac{0.99}{1.4 \times 1.2} = 0.589\ m/s$$

$$H + V_0^2/2g = 0.65 + \frac{0.589^2}{2 \times 9.81} = 0.667\ m$$

Discharge considering V_0 →

$$Q = \frac{2}{3} C_d (B - 0.1nH)\sqrt{2g}\left[\left(H + \frac{V_0^2}{2g}\right)^{3/2} - \left(\frac{V_0^2}{2g}\right)^{3/2}\right]$$

$$Q = \frac{2}{3} \times 0.6 (1.2 - 0.1 \times 2 \times 0.65)\sqrt{2g}\left[\left(0.65 + \frac{0.589^2}{2 \times 9.81}\right)^{3/2} - \left(\frac{0.589}{2 \times 9.81}\right)^{3/2}\right]$$

$$Q = 1.02\ m^3/s$$

Ans

2.(c) An overflow spillway is 40 m high. At the design energy Head of 2.5 m over the spillway, find the sequent depths. Neglect energy loss due to flow over the spillway face.

$C_d = 0.68$

Sol^n:-

$$q = \frac{2}{3} C_d \sqrt{2g}\, H_d^{3/2}$$

$$q = \frac{2}{3} \times 0.68 \times \sqrt{2 \times 9.81}\,(2.5)^{3/2}$$

$$q = 7.93 \ m^3/s/m$$

By using the eq^n -

$$P + H_d = y_1 + V_1^2/2g$$

$$y_1 + \frac{(7.93)^2}{2g\,y_1^2} = 42.5$$

$$y_1 = 0.28\,m$$

$$V_1 = q/y_1 = \frac{7.93}{0.28} = 28.32 \ m/s.$$

$$F_1 = V_1/\sqrt{g y_1} = 28.32/\sqrt{9.81 \times 2.81} = 17.088$$

$$y_2/y_1 = \frac{1}{2}\left[-1 + \sqrt{1 + 8F_1^2}\right]$$

$$\frac{y_2}{0.28} = \frac{1}{2}\left[-1 + \sqrt{1 + 8 \times 17.088^2}\right]$$

$$y_2 = 6.627\,m$$

(d) A Rectangular channel with a bottom width of 4 m & a bottom slope of 0.0008 has a discharge of 1.50 m³/s. In GVF in this channel, the depth at certain location is found to be 0.30 m. N = 0.016, Determine the type of GVF Profile.

Sol^n.

$$Q = \frac{1}{N} A R^{2/3} S_0^{1/2}$$

$$1.50 = \frac{1}{0.016}\, B y_0 \times \frac{(B y_0)^{2/3}}{(B + 2y_0)^{2/3}} \sqrt{0.0008}$$

$$\frac{(4 y_0)^{5/3}}{(4 + 2y_0)^{2/3}} = 0.8485$$

By trial and error method,

$y_0 = 0.426m.$

(b) Critical depth -

$q = Q/B = \frac{1.5}{4} = 0.375 \, m^3/s/m$

$y_c = (q^2/g)^{1/3} = \left(\frac{(0.375)^2}{9.81}\right)^{1/3}$

$= 0.243m.$

(c) Type of Profile.

Since $y_0 > y_c \rightarrow$ channel is mild slope channel

$y = 0.35m$ (given)

$y_0 > y > y_c$

Such profile is M_2 type.

e. Show that for wide rectangular channel, GVF eq^n is given by

$$dy/dx = S_0 \left[\frac{1-(y_n/y)^{10/3}}{1-(y_c/y)^3} \right]$$

Sol^n -

$$dy/dx = \frac{S_0 - S_f}{1 - Q^2T/gA^3}$$

$$= S_0 \left(\frac{1 - S_f/S_0}{1 - \frac{Q^2 T}{gA^3}} \right)$$

$$dy/dx = S_0 \left[\frac{1-(K_0/K)^2}{1-(Z_c/Z)^2} \right] \quad -(1)$$

K = conveyance of one channel

$K = 1/N \, AR^{2/3}$.

$K = 1/N \, By^{5/3}$

Similarly for K_0

$$K_0 = \frac{1}{n} B y_0^{5/3}, \text{ Hence } K_0/K = (y_0/y)^{5/3}$$

we know that,

$$Z^2 = C_1 y^M$$

M = First Hydraulic exponent

for Rectangular channel $M = 3$

$$Z^2 = C_1 y^3$$

$$Z_c^2 = C_1 y_c^3$$

$$(Z_c/Z)^2 = (y_c/y)^3$$

Put in (1),

$$dy/dx = S_0 \left[\frac{1-(y_0/y)^{10/3}}{1-(y_c/y)^3} \right]$$

Section-C

3. (a) A wide rectangular channel conveys a discharge of $4\ m^3/s/m$ with bed slope of 0.0001, $N = 0.02$. If the depth of flow is 4m. Determine how far u/s or d/s of the section, the depth would be within 10% of y_n. Take 1 step.

Sol^n:- For wide Rectangular channel,

$$R = y_0$$

$$q = Q/B = AV/B = y_0\left[\frac{1}{n} R^{2/3} S_0^{1/2}\right]$$

$$4 = y_0\left[\frac{1}{0.02} \times (y_0)^{2/3} \times (0.0001)^{1/2}\right]$$

$$B = y_0^{5/3}$$

$$y_0 = 3.48\ m$$

$$y_c = (q^2/g)^{1/3} = 1.17\ m$$

$y_0 > y_c \rightarrow$ Mild slope.

Since, $y = 4$ m is greater than y_0 & y_c the profile is

$y > y_0 > y_c$

In case of M_2 profile depth within 10% of mean depth means 10% more than Normal depth,

$$y = 1.1 y_0 = 1.1 \times 3.48 = 3.83$$

for computation of M_1 Profile.

Consider two steps with depth increment,

$$\frac{4 - 3.83}{2} = 0.085$$

Depth will be within 10% of Normal depth at a distance of 5092.72 m on upstream of section.

Depth	velocity	$V^2/2g$	$E = y + V^2/2g$	S_f	$\bar{S}_f$	$S_0 - \bar{S}_f$	ΔE	$dx = \frac{\Delta E}{S_0 - \bar{S}_f}$	Σx
3.83	1.04	0.055	3.885	0.72×10^{-4}					
					0.685×10^{-4}	3.05×10^{-5}	0.083	2721.3	
3.915	1.02	0.057	3.968	0.67×10^{-4}					
					0.65×10^{-4}	3.5×10^{-5}	0.083	2371.42	
4	1	0.051	4.051	0.63×10^{-4}					
								Σx =	5092.72 m

(5.) Write Short Notes on:

(1) Sharp crested Rectangular weir.

Ans It may be considered as large orifice of the rectangular shape placed in the channel in such a way that the head on its upper edge is zero. Consequently the upper edge is eliminated leaving only the lower edge known as the crest. The rate of flow is determined by measuring the head H over the weir crest, at a distance upstream at least four times the maximum head to be used.

(2) Suppressed Rectangular weir

Ans When the length of crest of the weir is the same as the width of the channel, the weir is said to be a suppressed weir. The width of Nappe for suppressed weir is equal to the length of the crest.

For suppressed weirs,

Length of weir crest = width of the channel

(3.) Francis weir.

Ans:- On the basis of a large number of experiments on sharp-crested rectangular weirs, J.B. Francis found that the flow varied as $H^{1.47}$, but for greater convenience he adopted $H^{1.5}$. He then selected a constant avg. value of $C_d = 0.622$., so that on suppressed weir with a negligible V_0.

$$Q = \frac{2}{3} C_d B \sqrt{2g}\, H^{3/2}$$

$$Q = 1.837\, B H^{3/2}$$

(4) Standing wave flume.

The critical-depth flume can be fitted into any shape. The throat is prismatic & can be of the parent channel. The throat is prismatic & can be of any convenient shape. A hydraulic jump on the downstream of the throat and holds back the tailwater. If the throat is submerged by the tailwater subcritical flow prevails all over the flume.

(5) Parshall flume.

The Parshall flume is a type of critical depth flume popular in the USA. The flume consists of a converging section with a level floor, a throat with a d/s sloping floor and a diverging section with an adverse slope bed. Unlike in the standing wave flume, the head (Ha) is measured at a specified location in the converging section. The discharge in the flume in the free flow mode is given by,

$$Q = K H_a^{n}.$$