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Section : B

Subject : Hydraulic Structure

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Ans Stage discharge relationship for a concrete rectangular box culvert;

"Given data"

Width = 1.4m
Height = 0.9m
Length = 26m
Slope = 1 : 1000
mannings ; η = 0.013
Square edged entrance ; Ke = 0.5
Range = 0 - 3m

Solution

$H/D = 1.4m$
$H < 0.9$

Discharge is given by;

$$Q = 2.92 y_o \left[\frac{1.2 y_o}{1.2 + 2y_o} \right]^{2/3} \quad \text{— "A"}$$

y_o (m)	Q ($m^3 s^{-1}$)	y_c (m)
0.3	0.299	0.166
0.6	0.785	0.317
0.9	1.330	0.451

By putting the values of "yo" we will get the corresponding discharge

- $Q1 = 2.92\,(0.3)\left[1.2(0.3)/1.2+2(0.3)\right]^{2/3}$

$= 0.299\,m^3/s$

- $Q2 = 2.92\,(0.6)\left[1.2\,(0.6)/1.2+2\,(0.6)\right]^{2/3}$

$= 0.785\,m^3/s$

- $Q3 = 2.92\,(0.9)\left[1.2\,(0.9)/1.2+2\,(0.9)\right]^{2/3}$

$= 1.330\,m^3/s$

Critical depth

$$y_c = (q^2/g)^{1/3} \quad \text{— "A"}$$

$$q = Q/B \quad \text{— "B"}$$

By putting values in eq "B"

$$q1 = Q_1/B = \frac{0.299}{1.4} = 0.213$$

$$q2 = Q_2/B = \frac{0.785}{1.4} = 0.561$$

$$q3 = Q_2/B = \frac{1.330}{1.4} = 0.95$$

Now by putting the values in eq "A"

$$y_{c_1} = (q_1^2/g)^{1/3} = \left(\frac{(0.213)}{9.81}\right)^{1/3} = 0.166m$$

Scanned with CamScanner

$y_{c2} = (q_2^2/g)^{1/3} = \left(\frac{0.561^2}{9.81}\right) = 0.317\ m$

$y_{c3} = (q_3^2/g)^{1/3} = \left(0.95^2/9.81\right)^{1/3} = 0.451$

At the inlet over a short reach

"$H = y_0 + \frac{V_2}{2g} + K_e \frac{V_2}{2g}$"

$V_1 = 1.142\ m/s$

So,

$H_1 = y_{o,1} + \frac{v_2}{2g} + k_e \frac{v_2}{2g}$

$= 0.3 + \frac{(1.142)^2}{2\cdot(9.81)} + 0.5\left(\frac{(1.142)^2}{2(9.81)}\right)$

$= 0.399m$

$H_2 = 0.6 + \frac{(1.142)^2}{2(9.81)} + 0.5\left(\frac{(1.142)^2}{2(9.81)}\right)$

$= 0.699m$

$H_3 = 0.9 + \frac{(1.142)^2}{2(9.81)} + 0.5\left(\frac{(1.142)^2}{2(9.81)}\right)$

$= 0.99m$

Yo(m)	H (m)	Q ($m^3 s^{-1}$)
0.3	0.399	0.299
0.6	0.699	0.785
0.9	0.999	1.330
Orifice "1.2D"	1.08 →	1.477 By interpolation

"2" $H/D \geq 1.4$

"a" For Orifice Flow;

$$Q = Cd\,(1.4 \times 0.9)\left[(2g\,(H - D/2)\right]^{1/2}$$

$$Q = 0.62(1.4 \times 0.9)\left[2(9.81)\left(1.08 - \frac{(0.9)}{2}\right)\right]^{1/2}$$

$$\boxed{Q = 2.746\ m^3/s}$$

The following results are obtained

H (m)	Q ($m^3 s^{-1}$)	Yo (m)
1.08	2.746	> 0.9

→ No orifice flow exists

"b" **For pipe flow the energy equation gives**

$$H + S_0 L = D + h_L$$

Where

$$h_L = K_e V^2/2g + (V_n)^2\, L/R^{4/3} + \frac{V^2}{2g}$$

Thus $Q = 2.08\,(H - 0.57)^{1/2}$

During rising stages the barrel flows full from $H = 1.08$ and during falling stages the flow becomes free-surface flow when $H = 0.999$ m

"The following table sommarizes the result

H (m)	Q (m^3/s)	Type of flow
Rising stages		
0.399	0.299	open channel
0.699	0.785	open channel
0.999	1.330	open channel
1.080	1.477	pipe flow
2.000	2.487	pipe flow
3.000	3.242	pipe flow
Falling stages		
2.000	2.487	pipe flow
1.080	1.477	pipe flow
0.999	1.330	pipe flow
0.699	0.785	open channel
0.399	0.299	open channel

Mechanism of Scour:-

All the obstruction in form Peir abutment or abudment the unidirectioDal flow changes into three dimensional as the water pile up in from face of the obstruction and the flow accelarates around the nose. This phenomenon results in formation of verter at the base of the pier known as horseshoe Vortex and the vortex forms in our vatical direction downstream of the pier know as wake Vortex as shown in figure 1 taken from kin et al (2015)

The pileup of water due to obstruction because of declearation of flow due to stagnation pressure of water cause a downward flow result in horseshoe Vortex. The vertical component of downward flow cause evosion around the base of the pier.

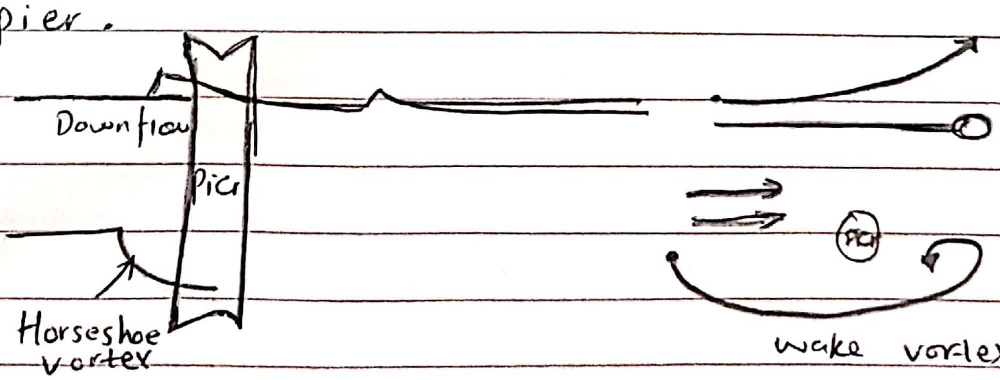

Fig 1 Presentation of Vortex around a circular vortex.

Due to rolling of unstable shear type layer of the surface of the pier wake vortex are generate as the seperation line and moves forward with flow downstream of the pier. It can be shown in fig 1 and 2 from Brandimarte. In the practical case of riverbed is generally composed of mixture of different size of material. Due to washing out of ~~finer~~ finer material an ~~arm~~ armor layer is formed of coarse material which protects the underlying finer particle from further scour. Due to presence of armor layer the clear water regime can be extended as the value of critical velocity ~~increases~~ increases.

The Armor layer is shown in Fig 3 taken from Raikar and Dey (2009)