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 – 3 m

"Solution";

$H/D \leq 1.4m$
$H < 0.9m$

Discharge is given by;

$$Q = 2.92 y_0 \left[1.2 y_0 / 1.2 + 2y_0 \right]^{2/3} \quad \text{— "A"}$$

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y_0 (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 values of "y_0" we will get the corresponding discharge.

$$Q_1 = 2.92(0.3)\left[1.2(0.3)/1.2+2(0.3)\right]^{2/3}$$

$$= 0.299\ m^3/s$$

$$Q_2 = 2.92(0.6)\left[1.2(0.6)/1.2+2(0.6)\right]^{2/3}$$

$$= 0.785\ m^3/s$$

$$Q_3 = 2.92(0.9)\left[1.2(0.9)/1.2+2(0.9)\right]^{2/3}$$

$$= 1.330\ m^3/s$$

"Critical depth";

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

$$q = Q/B \quad \text{— "B"}$$

By putting values in eq "B".

$$q_1 = Q_1/B = \frac{0.299}{1.4} = 0.213$$

$$q_2 = Q_2/B = \frac{0.785}{1.4} = 0.561$$

$$q_3 = Q_3/B = \frac{1.330}{1.4} = 0.95$$

Now by putting values in eq "A".

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

$$y_{c_2} = \left(q_2^2/g\right)^{1/3} = \left(\frac{0.561^2}{9.81}\right)^{1/3} = 0.317\,m$$

$$y_{c_3} = \left(q_3^2/g\right)^{1/3} = \left(\frac{0.95^2}{9.81}\right)^{1/3} = 0.451$$

At the inlet over a short reach;

$$\text{“} H = y_o + \frac{V^2}{2g} + K_e \cdot \frac{V^2}{2g} \text{”}$$

$\therefore$ $V_1 = 1.142\, m/s$

So;

$$H_1 = y_{o_1} + \frac{V^2}{2g} + K_e \cdot \frac{V^2}{2g}$$

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

$$\boxed{= 0.399\, m}$$

$\therefore$

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

$$\boxed{= 0.699\, m}$$

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

$$\boxed{= 0.999\, m}$$

y_0 (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
orifuce > 0.9 "1.2D"	1.08 →	1.477 By interpolation.

"2" $H/D \geq 1.4$

"a"; For orifice flow;

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

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

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

The following results are obtained.

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

→ no orifice flow exists.

"b" For pipe flow the energy equation gives;

$$H + S_oL = D + h_L$$

Where;

$$h_L = k_e\frac{V^2}{2g} + (Vn)^2\frac{L}{R^{4/3}} + \frac{V^2}{2g}$$

Thus;

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

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

"The following table Summarizes 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

3 MECHANISM OF SCOUR

At the obstruction in form of pier or abutment, the unidirectional flow changes into three dimensional as the water pileup in front face of the obstruction and the flow accelerates around the nose. This phenomenon results in formation of vortex at the base of the pier known as horseshoe vortex and the vortex form in the vertical direction downstream of the pier known as wake vortex as shown in figure 1 taken from Kim et al. (2015).

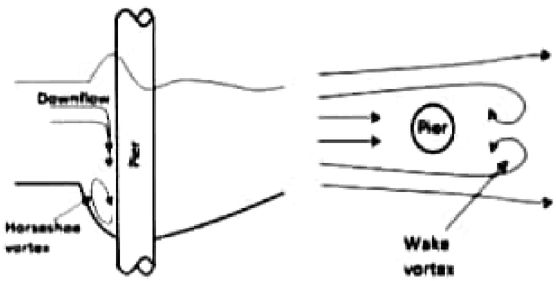


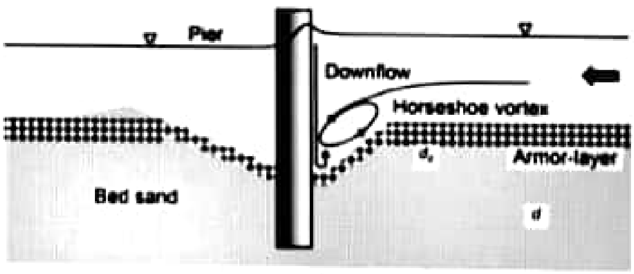
Figure 1: Presentation of vortex around a circular pier

The pileup of water due to obstruction because of decelerations of flow due to stagnation pressure of water causes a downward flow results in horseshoe vortex. The vertical component of the downward flow causes erosion around the base of the pier.

Figure 2 System of vortex at a bridge pier

Due to rolling of unstable shear layers at the surface of the pier wake vortex are generated at the separation line and moves forward with flow downstream of the pier. It can be shown as in figure 2 taken from Brandimarte et al. (2012).

In the practical case the river bed is generally composed of mixture of different sizes of material. Due to washing out of finer materials an armor layer is formed of coarser materials which protect the underlying finer particles from further scour. Due to presence of armor layer the clear water regime can be extended as the value of critical velocity increases. The armor layer is shown in figure 3 taken from Raikar and Dey (2009).



location and purpose. Engineers consider three main types of loads: dead loads, live loads and environmental loads:

- **Dead loads** include the weight of the bridge itself plus any other permanent object affixed to the bridge, such as toll booths, highway signs, guardrails, gates or a concrete road surface.
- **Live loads** are temporary loads that act on a bridge, such as cars, trucks, trains or pedestrians.
- **Environmental loads** are temporary loads that act on a bridge and that are due to weather or other environmental influences, such as wind from hurricanes, tornadoes or high gusts; snow; and earthquakes. Rainwater collecting might also be a factor if proper drainage is not provided.

Values for these loads are dependent on the use and location of the bridge. Examples: The columns and beams of a multi-level bridge designed for trains, vehicles and pedestrians should be able to withstand the combined load all three bridge uses at the same time. The snow load anticipated for a bridge in Colorado would be much higher than that one in Georgia. A bridge in South Carolina should be designed to withstand earthquake loads and hurricane wind loads, while the same bridge in Nebraska should be designed for tornado wind loads.