Answer no : 1

Establish the stage (headwater level)–discharge relationship for a concrete rectangular box culvert, using the following data: width = 1.2 m; height = 0.6 m; length = 30 m; slope = 1 in 1000; Manning's $n = 0.013$; square-edged entrance conditions; free jet outlet flow; range of head water level for investigation = 0–3 m; neglect the velocity of approach.

Solution

1. $H/D \le 1.2$. For $H < 0.6$ m, free flow open-channel conditions prevail. Referring to Fig. 10.6 and assuming that a steep slope entry gives entrance control, i.e. the depth at the inlet is critical, for $H = 0.2$ m, ignoring entry loss $y_c = (2/3) \times 0.2 = 0.133$ m and $V_c = 1.142\ \text{m s}^{-1}$. This gives the critical slope $(Vn)^2/R^{4/3} = 0.00424$. Therefore the slope of the culvert is mild and hence subcritical flow analysis gives the following results:

$$Q = 1.2y_0[1.2y_0/(1.2 + 2y_0)]^{2/3}\,(0.001)^{1/2}/0.013$$

$$= 2.92y_0[1.2y_0/(1.2 + 2y_0)]^{2/3}; \qquad \text{(i)}$$

y_0 (m)	Q ($m^3 s^{-1}$)(equation (i))	y_c (m)
0.2	0.165	0.124
0.4	0.451	0.243
0.6 (= D)	0.785	0.352

At the inlet over a short reach,

$$H = y_0 + V^2/2g + K_e V^2/2g. \qquad \text{(ii)}$$

The entrance loss coefficient, K_e, is as follows:

for a square-edged entry, 0.5;

for a flared entry, 0.25;

for a rounded entry, 0.05;

y_o (m)	H (m) (equation (ii))	Q ($m^3 s^{-1}$)
0.2	0.236	0.165
0.4	0.467	0.451
0.6	0.691	0.785
orifice ←→ 0.6 ← (1.2D =)	0.72 ⟶	0.817 (by interpolation)

2. $H/D \geq 1.2$.
   (a) For orifice flow

$$Q = C_d(1.2 \times 0.6)[2g(H - D/2)]^{1/2}. \qquad \text{(iii)}$$

With $C_d = 0.62$ the following results are obtained:

H(m)	Q ($m^3 s^{-1}$)	y_c (m) (equation (i))
0.72	1.29	>0.6 → no orifice flow exists

   (b) For pipe flow the energy equation gives

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

where

$$h_L = K_e V^2/2g + (Vn)^2 L/R^{4/3} + V^2/2g.$$

Thus

$$Q = 2.08(H - 0.57)^{1/2}. \qquad \text{(iv)}$$

	H (m)	Q ($m^3 s^{-1}$) (equation (iv))
y_c = 0.6 (equation (i)) ←	0.691 ←	0.723
	0.72 ↓	↑ 0.805
	1.00	1.364
	2.00	2.487
	3.00 ↓	3.242

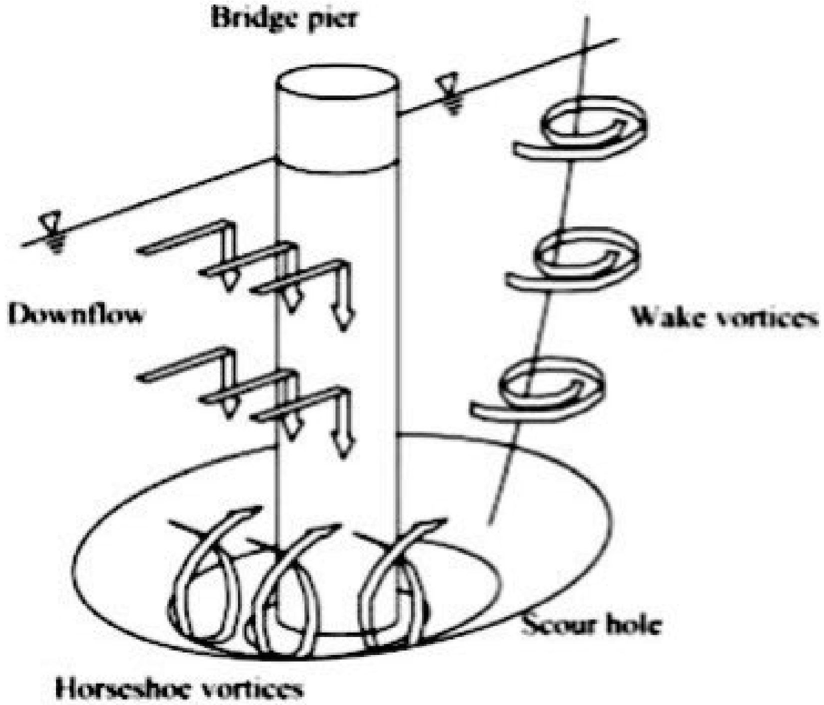
During rising stages the barrel flows full from $H = 0.72$ m and during falling stages the flow becomes free-surface flow when $H = 0.691$ m.

The following table summarizes the results:

H (m)	*Q (m³s⁻¹)*	*Type of flow*
Rising stages		
0.236	0.165	Open channel
0.467	0.451	Open channel
0.691	0.785	Open channel
0.720	0.805	Pipe flow
1.00	1.364	Pipe flow
2.00	2.487	Pipe flow
3.00	3.242	Pipe flow
Falling stages		
2.00	2.487	Pipe flow
1.00	1.364	Pipe flow
0.72	0.805	Pipe flow
0.691	0.723	Pipe flow
0.691	0.785	Open channel
0.467	0.451	Open channel
0.236	0.165	Open channel

Answer no : 2

Scour of sediments around bridge foundations by the stream is the most significant contributing factor for bridge failures. The scour failures tend to occur without prior warning and have led to fatalities and economic loss every year. A significant amount of work has been conducted on bridge scour. Such efforts can be broadly classified into two major categories, namely science driven and engineering driven. The science-driven research focuses on understanding the scour mechanism and aims to explain the cause of scour due to different factors. Meanwhile, engineering-driven research focuses on the estimation, monitoring and countermeasures of bridge scour. This paper presents a comprehensive and up-to-date literature review of bridge scour research and practice. Firstly, a brief introduction is given which includes recent cases of failures caused by bridge scour. Then, both scientific and technical research on bridge scour is reviewed, which are categorized into four aspects: macroscopic and microscopic mechanism, scour depth prediction carried out by experimental and field data, direct and remote monitoring methods and active and passive countermeasures. Finally, a summary is provided covering both experimental and computational methods for scour research. Discussion is also provided on emerging ideas to investigate bridge scour from both science and engineering perspectives.



Scour can be defined as the excavation and removal of material from the bed and banks of streams as a result of the erosive action of flowing water. Scour occurs in three main forms, namely, general scour, contraction scour and local scour. General scour occurs naturally in river channels and includes the aggradation and degradation of the river bed that may occur as a result of changes in the hydraulic parameters governing the channel form such as changes in the flow rate or changes in the quantity of sediment in the channel . It relates to the evolution of the waterway and is associated with the progression of scour and filling, in the absence of obstacles . Contraction scour occurs as a result of the reduction in the channel's cross-sectional area that arises due to the construction of structures such as bridge piers and abutments. It manifests itself as an increase in flow velocity and resulting bed shear stresses, caused by a reduction in the channel's cross-sectional area at the location of a bridge. The increasing shear stresses can overcome the channel bed's threshold shear stress and mobilize the sediments . Local scour occurs around individual bridge piers and abutments. Downward flow is induced at the upstream end of bridge piers, leading to very localized erosion in the direct vicinity of the structure . Horseshoe vortices develop due to the separation of the flow at the edge of the scour hole upstream of the pier and result in pushing the down-flow inside the scour hole closer to the pier. Horseshoe vortices are a result of initial scouring and not the primary cause of scour. Furthermore, separation of the flow at the sides of the pier results in wake vortices . Local scour depends on the balance between streambed erosion and sediment deposition. Clear-water scour is the term given to describe the situation when no sediments are delivered by the river whereas live-bed scour describes the situation where an interaction exists between sediment transport and the scour process . The presence of live-bed conditions leads to smaller ultimate scour depths than in clear-water conditions.