CMR
INSTITUTE
OF TECHNOLOGY

## Department of Civil Engineering

### 17CV832 – HYDRAULIC STRUCTURES

Scheme and Evaluation

| Q.No. | Question | Mark | CO | PO | RBL |
|---|---|---|---|---|---|
| 1a | Draw the typical layout of the diversion head work and name its components | 5 | CO3 | PO1 | L2 |

Ans — 5M

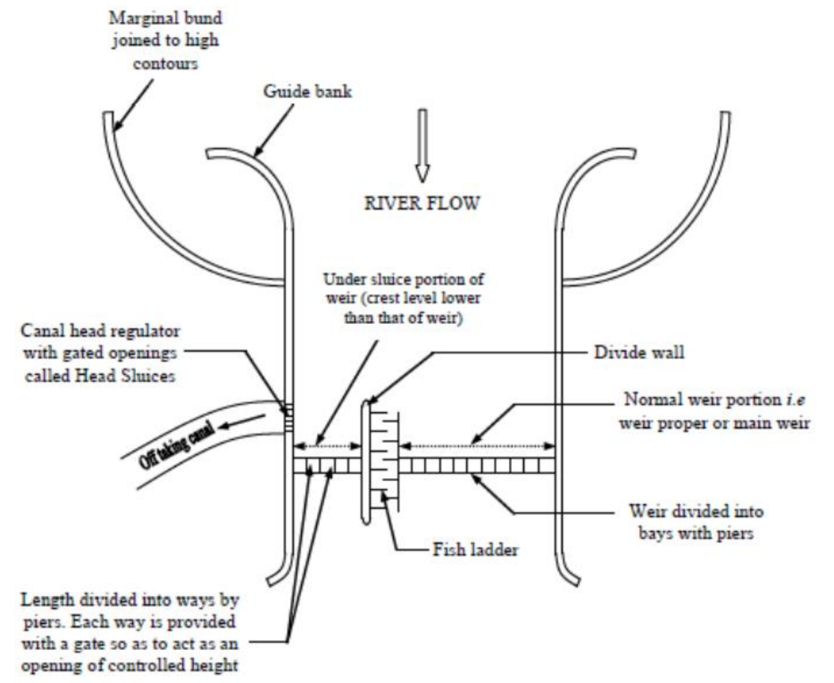



**Fig. Typical Layout of Diversion Head-Works.**

A typical layout of a canal head-works is shown in Fig. Such a head-works consists of:

(1) Weir proper.
(2) Under-sluices.
(3) Divide wall,
(4) River training works, such as marginal bunds, guide banks, groynes, etc
(5) Fish Ladder.
(6) Canal Head Regulator.
(7) Weir's ancillary works, such as shutters, gates, etc.
(8) Silt Regulation Works

5M

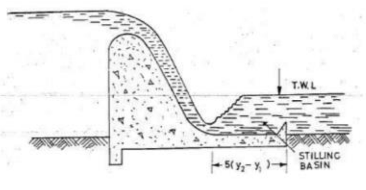
| Q.No. | Question | Mark | CO | PO | RBL |
|---|---|---|---|---|---|
| 1b | Explain energy dissipation structures | 5 | CO3 | PO1 | L2 |

Ans

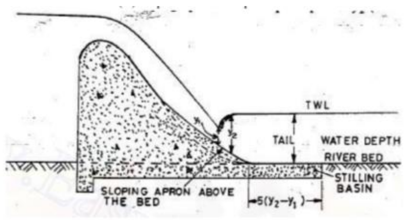
**Energy dissipation devices:** — 2M

The flood water discharging through the spillway has to flow down from a higher elevation at the reservoir surface level to a lower elevation at the natural river level on the downstream through a passage, which is also considered a part of the spillway. At the bottom of the channel, where the water rushes out to meet the natural river, is usually provided with an energy dissipation device that kills most of the energy of the flowing water. These devices, commonly called as Energy Dissipaters, are required to prevent the river surface from getting dangerously scoured by the impact of the out falling water.

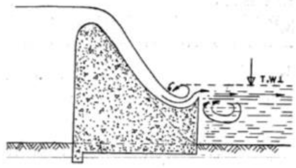
Types as per cases — 3M



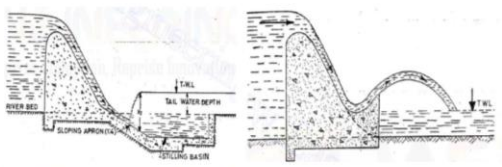

(A)Simple Horizontal Apron




(B) Sloping Apron above the bed

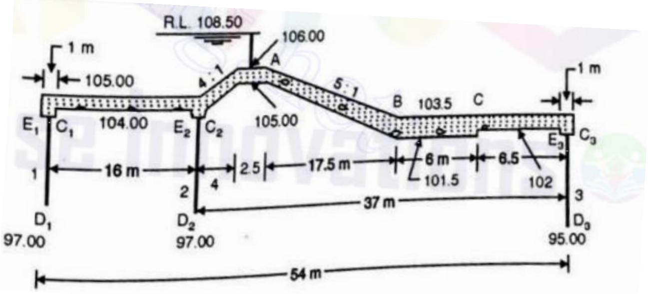



(C) Roller Bucket Types



(D)Sloping apron partly above and partly below ground level

2\. The figure shows a section of barrage. The various dimensions and levels are in meters. Determine the uplift pressures at key points and the exit gradient. Also find weather the section provided is safe against uplift and piping if it is founded on fine sand with permissible exit gradient of 1/6. — 10 | CO4 | PO2 | L3




Ans

**Solution**

**(1) First pile line**

$$d = d_1 = 105.00 - 97.00 \text{ m} = 8.00 \text{ m}$$

$$b = 54 \text{ m} \;;\; b_1 = 0.5 \text{ m}$$

$$\therefore \quad \alpha = \frac{b}{d} = \frac{54}{8} = 6.75 \;; \quad \frac{b_1}{b} = \frac{0.5}{54} \simeq 0$$

$\therefore$ From the curves, for $\frac{b_1}{b} = 0$ and $\alpha = 6.75$

$$\Phi_{C1} = 66.5\,\% \;; \quad \Phi_{D1} = 76\,\% \;; \quad \Phi_{E1} = 100\,\%$$

***Correction for floor thickness,***

$$t = 105.00 - 104.00 = 1.00 \text{ m}$$

$$\therefore \quad \text{Correction} = \frac{\Phi_{D1} - \Phi_{C1}}{d_1} t = \frac{(76 - 66.5)}{8} \times 1 \simeq 1.2(+)$$

***Correction for interference of pile No.2***

$$C = 19 \sqrt{\frac{D}{b'}} \left(\frac{d + D}{b}\right)$$

Here $d = 104.00 - 97.00 = 7$ m ; $b' = 16$ m ; $b = 54$ m ; $D = 104.00 - 97.00 = 7$ m

$$\therefore \quad C = 19 \sqrt{\frac{7}{16}} \left(\frac{7.00 + 7.00}{54}\right) = 3.3\,\%\,(+)$$

$\therefore$ Corrected pressures are $\Phi_{C1} = 66.5 + 1.2 + 3.3 = 71\,\%$ and $\Phi_{D1} = 76\,\%$.

**(2) Intermediate pile line**

$$d = d_2 = 105.00 - 97.00 = 8.00 \text{ m} \;;\; b = 54 \text{ m};\; b_1 = 16.5 \text{ m}$$

$$\therefore \quad \alpha = \frac{b}{d} = \frac{54}{8} = 6.75 \;; \quad \frac{b_1}{b} = \frac{16.5}{54} = 0.306$$

From curves, for $\alpha = 6.75$ and $\frac{b_1}{b} = 0.306$, we get

$$\Phi_{C2} = 52\,\% \;; \quad \Phi_{E2} = 72.5\,\% \;; \quad \Phi_{D2} = 61.5\,\%$$

***Correction for floor thickness***

$$\text{Correction for } \Phi_{C2} = \frac{61.5 - 52}{8} \times (105.00 - 104.0) \simeq 1.2\,(+)$$

$$\text{Correction for } \Phi_{E2} = \frac{72.5 - 61.5}{8} \times 1 \simeq 1.4\,(-)$$

***Correction for interference of pile No.1***

Since pile No. 1 and 2 are of the same length, and are fixed at the same level.

Correction for interference of pile No. 3.

$$d = 104.0 - 97.0 = 7.0 \text{ m} \;; \quad D = 104.0 - 95.0 = 9.0 \text{ m};\; b' = 37 \text{ m}$$

$$\text{Correction to } \Phi_{C2} = 19 \sqrt{\frac{9.0}{37}} \times \left(\frac{7 + 9}{54}\right) \simeq 2.7\,\%\,(+)$$

***Correction due to slope of 4 : 1***

Correction (from Table 12.4) $= 3.3\,\%\,(-ve)$

Correction is negative due to upward slope in the direction of flow.

Horizontal length of the slope $= 4$ m

$$\therefore \quad \text{Actual correction, to be applied to } \Phi_{C2} = 3.3 \times \frac{4}{37} \simeq 0.4\,\%\,(-\text{ ve})$$

***Hence the corrected pressures are***

$$\Phi_{E2} = 72.5 - 1.4 - 3.3 = 67.8\ \%$$

$$\Phi_{C2} = 52 + 1.2 + 2.7 - 0.4 = 55.5\ \%$$

**(3) Pile No. 3 at the d/s end**

$$d = d_3 = 103.5 - 95 = 8.5 \text{ m}$$

$$\therefore \quad \frac{1}{\alpha} = \frac{d}{b} = \frac{8.5}{54} \simeq 0.158.$$

Hence, for curves for pile at d/s end, we get

$$\Phi_{E3} = 35\ \% \;;\quad \Phi_{D3} = 24.2\ \%$$

***Correction for thickness*** $= \dfrac{35 - 24.2}{8.5}(103.5 - 102) = 1.9\ \%\ (-\text{ve})$

***Correction for interference of pile No. 2***

$$d = 102.0 - 95 = 7 \text{ m} \;;\; D = 102.0 - 97 = 5 \text{ m}$$

$$\therefore \quad \text{Correction for } \phi_{E3} = 19\sqrt{\frac{5}{37}}\left(\frac{5+7}{52}\right) \simeq 1.5\ \%\ (-)$$

Hence the corrected pressures are :

$$\phi_{E3} = 35 - 1.9 - 1.5 = 31.6\ \%.$$

The percentage pressures and the actual pressure heads at the key points are tabulated below :

**TABLE 12.5. MAXIMUM PERCOLATION HEAD** = 108.5 − 103.5 = 5 m

| *Point* | *% Pressure* ($\phi$) | *Pressure head (P) m* | *Point* | *% Pressure* ($\phi$) | *Pressure head (P) m* |
|---|---|---|---|---|---|
| $C_1$ | 71 | 3.55 | $C_2$ | 55.5 | 2.78 |
| $E_2$ | 67.8 | 3.39 | $E_3$ | 31.6 | 1.58 |

The pressures at intermediate points may be computed by linear variation.

**(4) Check for thickness of floor**

Let us check the floor thickness at the three points *A*, *B* and *C* (Fig. 12.19).

Pressure head at $A = P_{C1} - \left(\frac{P_{C1} - P_{E3}}{37} \times 6.5\right) = 2.78 - \frac{2.78 - 1.58}{37} \times 6.5 \simeq 2.57$ m

Pressure head at $B = 2.78 - \frac{2.78 - 1.58}{37} \times 24.0 = 2$ m

Pressure head at $C = 2.78 - \frac{2.78 - 1.58}{37} \times 30 = 1.81$ m

Taking the specific gravity ($\rho$) of the concrete $= 2.24$, we have

Thickness required at $A = \frac{P_A}{\rho - 1} = \frac{2.57}{1.24} = 2.07$ m.

Actual thickness provided at $A = 107.0 - 105 = 2$ m

Hence increase the thickness at $A$ to 2.1 m

Thickness required at $B = \frac{P_B}{\rho - 1} = \frac{2.0}{1.24} = 1.61$ m

Actual thickness provided at $B = 103.5 - 101.5 = 2$ m

Thickness required at $C = \frac{P_C}{\rho - 1} = \frac{1.81}{1.24} = 1.46$ m

Actual thickness provided $= 103.5 - 102.0 = 1.5$ m

Hence, the floor thicknesses at $B$ and $C$ are adequate.

**(4) Exit gradient**

Seepage head $= H = 108.5 - 103.5 = 5$ m

Depth of cut off $= d = 103.5 - 95 = 8.5$ m

$$\alpha = \frac{b}{d} = \frac{54}{8.5} = 6.35$$

Hence, from exit gradient curve, for $\alpha = 6.35$, $\frac{1}{\pi\sqrt{\lambda}} \simeq 0.165$

Alternatively, $\lambda = (1 + \sqrt{1 + \alpha^2})/2 = (1 + \sqrt{1 + (6.35)^2})/2 = 3.716$

and $\frac{1}{\pi\sqrt{\lambda}} = \frac{1}{\pi\sqrt{3.716}} = 0.165$

$$\therefore \quad G_E = \frac{H}{d} \times \frac{1}{\pi\sqrt{\lambda}} = \frac{5}{8.5} \times 0.165 = 0.097 = \frac{1}{10.3}$$

Permissible exit gradient $= 1/6$. Hence, safe

| 3. | Explain types of cross drainage works | 10 | CO3, CO4 | PO1 | L2 |
|---|---|---|---|---|---|

Ans

**Types of Cross-Drainage Works:**

**(1) Type I (Irrigation canal passes over the drainage)** :

(a) Aqueduct (b) Siphon aqueduct

**(2) Type II (Drainage passes over the irrigation canal)**:

(a) Super passage (b) Siphon super passage

**(3) Type III (Drainage and canal intersection each other of the same level):**

(a) Level Crossing (b) Inlet and outlet

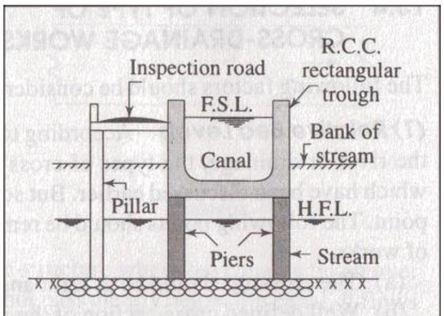



**Fig: Aqueduct**

**Aqueduct:** The aqueduct is just like a bridge where a canal is taken over the deck supported by piers instead of a road or railway. Generally, the canal is in the

2M

shape of a rectangular trough which is constructed with reinforced cement concrete. Sometimes, the trough may be of trapezoidal section. An inspection road is provided along the side of the trough. The bed and banks of the drainage below the trough is protected by boulder pitching with cement grouting.

**Siphon Aqueduct**: The siphon aqueduct, the bed of the drainage is depressed below the bottom level of the canal trough by providing sloping apron on both sides of the crossing. 2M

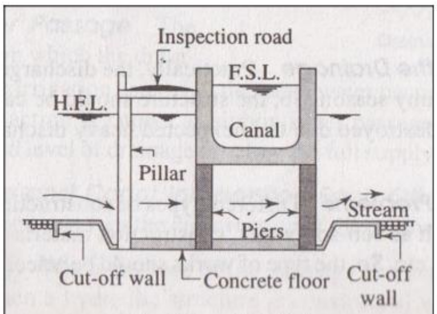


Fig: Siphon Aqueduct

- The sloping apron may be constructed by stone pitching or cement concrete.
- The section of the drainage below the canal trough is constructed with cement concrete in the form of tunnel. This tunnel acts as a siphon.
- Cut off walls are provided on both sides of the apron to prevent scouring.
- Boulder pitching should be provided on the upstream and downstream of the cut-off walls.
- The other components like canal trough, piers, inspection road, etc. should be designed according to the methods adopted in case of aqueduct.

**Super Passage:** The super passage is just opposite of the aqueduct. In this case, the bed level of the drainage is above the fully supply level of the canal. The drainage is taken through a rectangular or trapezoidal trough of channel which is constructed on the deck supported by piers. 2M

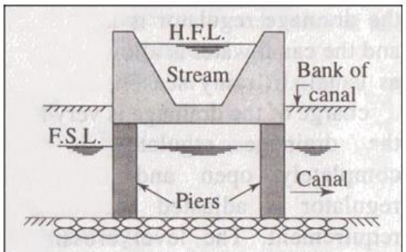


Fig: Super Passage

• The section of the drainage trough depends on the high flood discharge.
• A free board of about 1.5 m should be provided for safety.
• The trough should be constructed of reinforced cement concrete.
• The bed and banks of the canal below the drainage trough should be protected by boulder pitching or lining with concrete slabs.
• The foundation of the piers will be same as in the case of aqueduct.

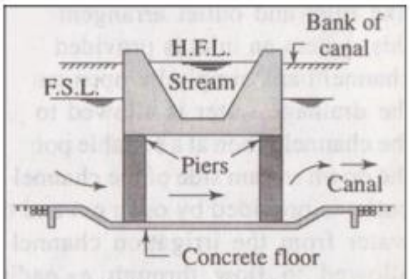
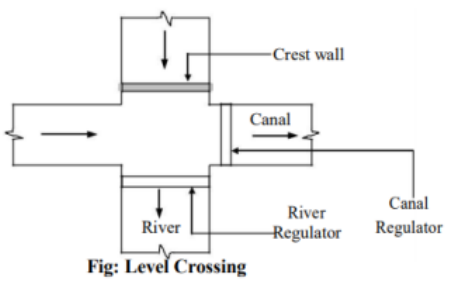


Fig: Siphon Super Passage

**Siphon Super Passage:** It is just opposite siphon aqueduct. In this case, the canal 2M

<table>
<tr><td></td><td colspan="4">passes below the drainage trough. The section of the trough is designed according to high flood discharge. The bed of the canal is depressed below the bottom level of the drainage trough by providing sloping apron on both sides of the crossing.<br>• The sloping apron may be constructed with stone pitching or concrete slabs.<br>• The section of the canal below the trough is constructed with cement concrete in the form of tunnel which acts as siphon.<br>• Cut-off walls are provided on upstream and downstream side of sloping pron.<br>• Other components are same as in the case of siphon aqueduct<br><br>Level Crossing: The level crossing is an arrangement provided to regulate the flow of water through the drainage and the canal when they cross each other approximately at the same bed level. The level crossing consists of the following components:<br><br><br>Fig: Level Crossing<br>• Crest Wall: It is provided across the drainage just at the upstream side of the crossing point. The top level of the crest wall is kept at the full supply level of the canal.<br>• Drainage Regulator: It is provided across the drainage just at the downstream side of the crossing point. The regulator consists of adjustable shutters at different tiers.<br>• Canal Regulator: It is provided across the canal just at the downstream side of the crossing point. This regulator also consists of adjustable shutters at different tiers.</td><td>2M</td></tr>
<tr><td>4.</td><td>Design a suitable cross drainage work for following data at the crossing of canal and drainage<br><u>CANAL:</u><br>Full supply discharge = 32 cumecs<br>Full supply level = R. L 213.5m<br>Canal bed level = R.L 212.0m<br>Canal bed width = 20m<br>Trapezoidal canal section with 1.5H : 1V<br>Canal water depth = 1.5m<br><u>DRAINAGE:</u><br>High flood discharge = 300 cumecs<br>High flood level = 210.0m<br>High flood depth = 2.5m<br>Ground level = 212.5m</td><td>15</td><td>CO3</td><td>PO2, PO3</td><td>L4</td></tr>
<tr><td>Ans</td><td colspan="4"></td><td></td></tr>
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| | | |
|---|---|---|
| | Solution :- Since the canal bed level (212.0m) is much above the H.F.L (210.0m) of drainage, an Aqueduct will be constructed.<br>The earthen banks of the canal will be discontinued and the canal water taken in a concrete trough. For effecting economy, the canal shall be flumed. | |

Step 1) Design of Drainage Waterway

The wetted perimeter of the river is found by Lacey's P-Q formula:

$P = 4.75\sqrt{Q}$ Q = HFD of drain = 300 m³/s (Given)

$\therefore P = 4.75\sqrt{300}$

$P = 82.3\,m$

* Let the clear span b/w piers be 9m & the pier thickness be 1.5m.
* using 8 bays of 9m each, clear waterway = 8×9 = 72m
* Using 7 piers of 1.5m each, length occupied by piers = 7×1.5 = 10.5m

Total length of waterway = 72 + 10.5 = 82.5m

Step 2) Design of canal canal waterway

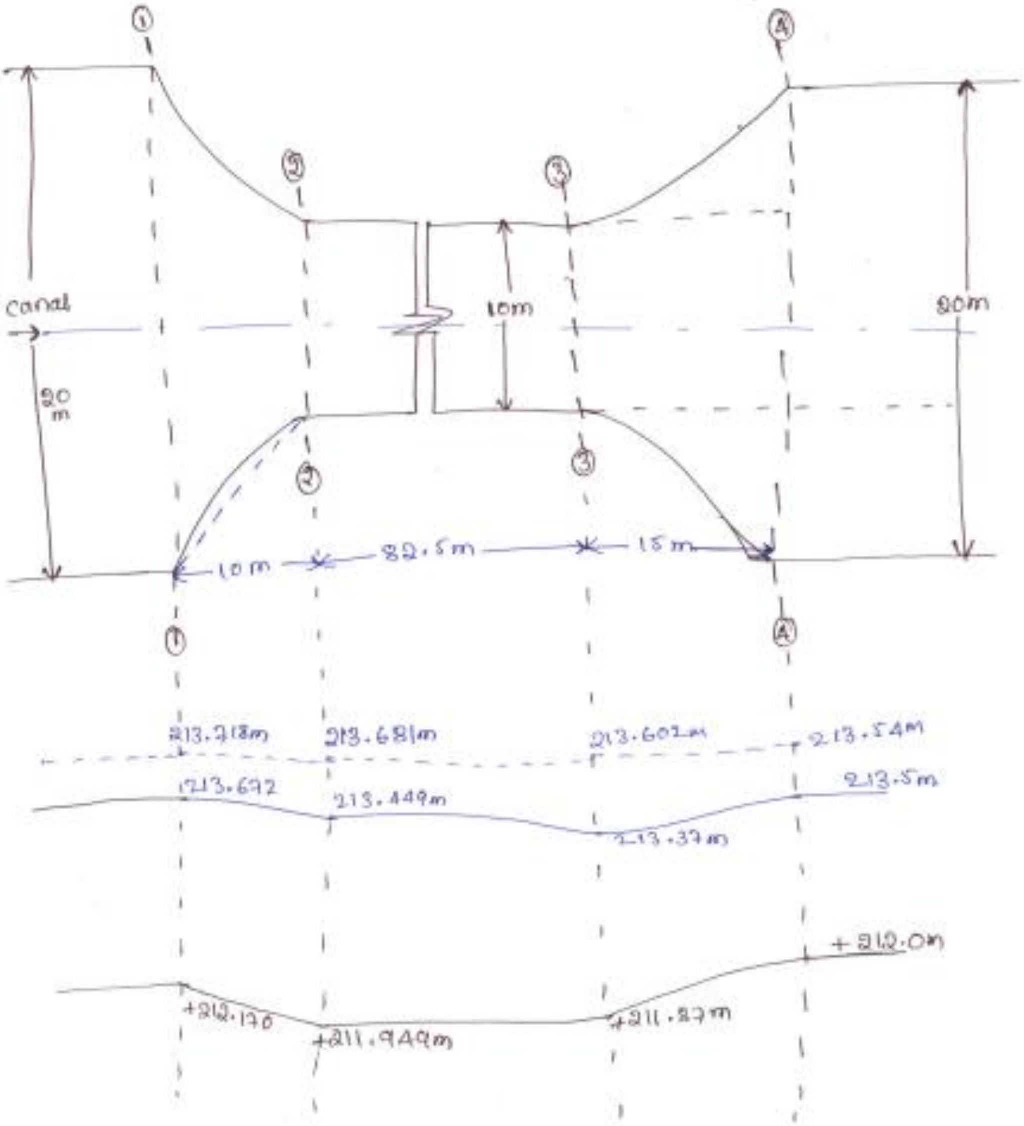
Bed width of canal = 20.0m

* Let the width be flumed to 10.0m
* Providing a splay of 2:1 in contraction, the length of contraction transition = $\frac{20-10}{2} \times 2 = 10.0m$
* Providing a splay of 3:1 in expansion, the length of expansion transition = $\frac{20-10}{2} \times 3 = 15.0m$

Length of flumed rectangular portion of the canal b/w abutments = 82.5m (provided)

In transitions, the side slopes of the canal section will be warped in plan from the original slope of $1\frac{1}{2}:1$ to vertical.

Step 3) Head loss & bed levels at different sections (with reference to fig)



(a) At section A-4 :

@ section A-4, the canal returns to its normal section. ∴ The Area of trapezoidal canal section

$= (B + 1.5D) D$

$= (20 + 1.5 \times 1.5) 1.5$

$= 33.75 \, m^2$

velocity of flow $= V_4 = \frac{Q}{A} = \frac{32}{33.75} = 0.947$ m/sec

velocity head $= \frac{V^2}{2g} = \frac{(0.947)^2}{2 \times 9.81} = 0.046$ m.

R.L of bed @ A-4 = 212.0 (Given)

R.L of water surface @ A-4 = 212 + 1.5 = 213.5 m

R.L of T.E.L at A-4 = 213.5 + 0.046 = 213.546 m

The known condition of A-4 shall now be utilised for finding the bed levels etc. @ 3-3.

b) At section 3-3:

Keeping the depth of 1.5 m throughout the channel,

@ section 3-3: Bed width = 10 m.

Area of channel $= 10 \times 1.5 = 15 \, m^2$

velocity $= V_3 = \frac{Q}{A} = \frac{32}{15} = 2.13$ m/s

∴ velocity head $= \frac{V_3^2}{2g} = \frac{2.13^2}{2 \times 9.81} = 0.232$ m

* Assuming head loss in expansion from section 3-3 to 4-4 is taken as

$$= 0.3\left[\frac{V_3^2 - V_4^2}{2g}\right] = 0.3(0.232 - 0.046)$$

$= 0.0558\ m$

$\simeq 0.056\ m$

∴ R.L of T.E.L @ section 3-3

↳ R.L of T.E.L @ 4-4 + loss in expansion

$= 213.546 + 0.056 = 213.602m$

∴ R.L of water surface @ 3-3 = RL of T.EL. @ 3-3 − velocity head

$= 213.602 - 0.232$

$= 213.370m$

R.L of bed @ 3-3 $= 213.370 - 1.5 = 211.87m$.

c) At section 2-2:

From section 2-2 to 3-3, the trough section is constant.

∴ Area & velocity @ 2-2 are same as at 3-3.

But, there is a friction loss b/w 2-2 & 3-3 which may be computed by Manning's formula

$$H_L = \frac{n^2 \cdot V^2 \cdot L}{R^{4/3}}$$

where
n ← Rougosity co-eff = 0.016 (concrete)
L = 82.5 m (trough length)
R = hydraulic mean depth
A = Area of trough section
P = wetted perimeter

$$R = \frac{A}{P} = \frac{(10 \times 1.5)}{(10 + 2 \times 1.5)}$$

$\boxed{R = 1.16m}$

velocity in trough $= \frac{Q}{A}$

$$V = \frac{32}{15} = 2.13 \text{ m/s}$$

$$\therefore H_L = \frac{(0.016)^2 \times (2.13)^2 \times 82.5}{(1.16)^{4/3}}$$

$H_L \simeq 0.079 m$

R.L of T.E.L @ 2-2 = R.L of T.E.L @ 3-3 + friction loss in trough

= 213.602 + 0.079

= 213.681 m

R.L of water surface @ 2-2

= 213.681 − 0.232

= 213.449 m

R.L of bed @ 2-2 = 213.449 − 1.5 = 211.949 m

d) At section ①-①

Loss of head in contraction transition from ①-① to ②-②

$$= 0.2\left[\frac{V_2^2 - V_1^2}{2g}\right] \qquad \left\{\begin{matrix} V_2 = V_3 \\ V_1 = V_4 \end{matrix}\right\}$$

$$= 0.2\left[\frac{2.13^2 - 0.947^2}{2 \times 9.81}\right]$$

= 0.037 m

R.L of T.E.L @ 1-1 = RL of T.E.L @ 2-2 + Loss in contraction

= 213.681 + 0.037

= 213.718 m

RL of water surface @ 1-1

$= 213.718 - 0.046 = 213.672\,m$

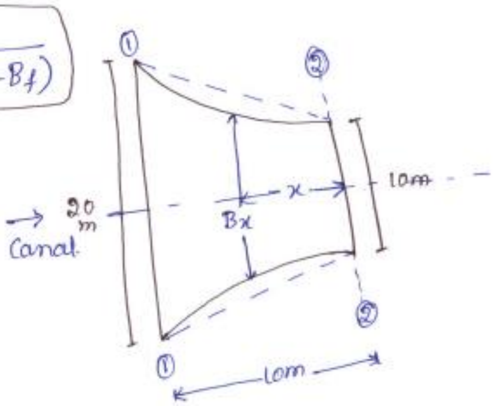
RL of bed @ 1-1

$= 213.672 - 1.5 = 212.172\,m$

Step 4) Design of Transitions:

(a) Contraction Transition:→ Since the depth is kept constant, the transition can be designed on the basis of Mitra's Hyperbolic transition eqn

$$B_x = \frac{B_n \cdot B_f L_f}{L_f B_n - x(B_n - B_f)}$$




where $B_f = 10\,m$

$B_n = 20\,m$

$L_f = 10\,m$

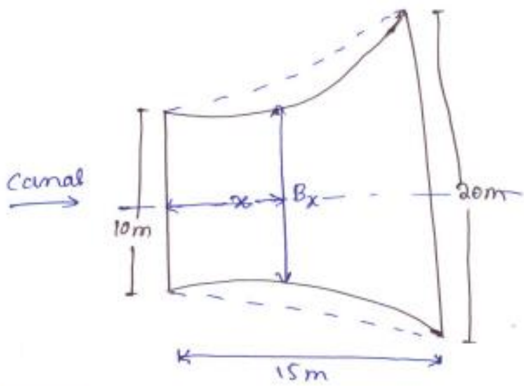
$$\therefore B_x = \frac{20 \times 10 \times 10}{10 \times 20 - x(20-10)}$$

$$B_x = \frac{2000}{200 - 10x}$$

where $x$ is measured from section 2-2. ($x = 0$ to $10\,m$)

| $x$ | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|
| $B_x$ | 10.0 | 11.11 | 12.5 | 14.29 | 16.67 | 20.0 |

b) Expansion Transition:




$$B_x = \frac{B_n \cdot B_f \cdot L_f}{L_f B_n - x(B_n - B_f)}$$

here $B_f = 10m$; $B_n = 20m$

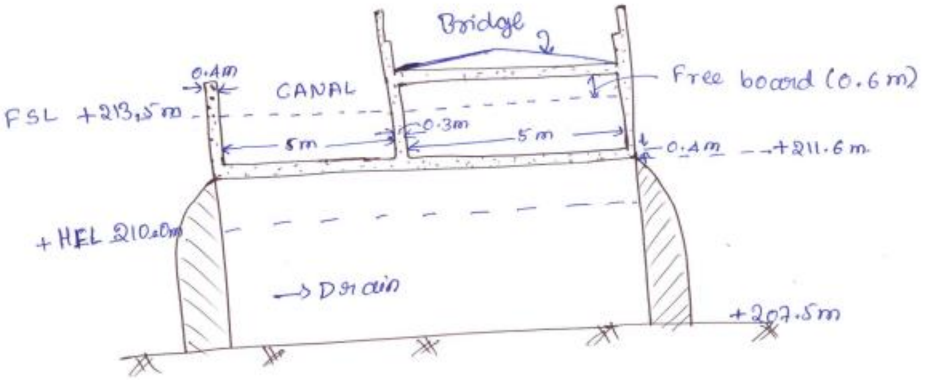
$$= \frac{20 \times 10 \times 15}{15 \times 20 - x(20-10)}$$

$$B_x = \frac{3000}{300 - 10x}$$

$x$ varies from 0 to 15

| $x$ | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|
| $B_x$ | 10 | 10.71 | 11.54 | 12.5 | 13.64 | 15 | 16.67 | 18.75 | 20.0 |

Step 5) Design of Trough:




* The trough shall be divided into two equal compartments of 5m each & separated by an intermediate wall of 0.3m thickness.

* The inspection road shall be carried on the top of left compartment as shown in fig.

* A free board of 0.6m above the normal water depth of 1.5m is provided.

∴ Bottom level of bridge slab over the left compartment above the bed level of trough.

$\Rightarrow 1.5 + 0.6 = \underline{2.1m}$

The height of trough ∴ 2.1m.

* The entire structure (trough section) is constructed using concrete. Thickness of outer wall = 0.4m thick

Bottom slab of trough = 0.4m thick.

| | | | | | |
|---|---|---|---|---|---|
| 5 | What are the factors to be considered for the selection of site for C.D works | 5 | CO3 | PO1 | L2 |
| Ans | Selection of type of cross-drainage works<br>• Relative bed levels<br>• Availability of suitable foundation<br>• Economical consideration<br>• Discharge of the drainage<br>• Construction problems | | | | 5M |

CI: **Prof. Usha A**

CCI: **Prof. Divya Viswanath**