– Bottom width (B) of the weir should not be less than

$$B \nless \frac{H + \text{Height of weir}}{\sqrt{G-1}}$$

1. A weir with a vertical drop has the following particulars:
   Nature of bed : Coarse sand with the value of Bligh's C = 12
   Flood discharge = 300 cumecs
   Length of weir = 40 m
   Height of weir = 2 m
   Height of falling shutter = 0·6 m
   Top width of weir = 2·0 m
   Bottom width of weir = 3·5 m.

Design the length & thickness of aprons & draw the cross-section of the weir.

Solution:- Total max. head loss = H_L = (2 + 0·6) = 2·6 m

Total length of creep required including creep along cut-off

$$= L = C H_L = 12 \times 2·6 = 31·2 \text{ m}.$$

The length of d/s floor is given by,

$$L_2 = 2·21\, C \sqrt{\frac{H_L}{13}}$$

or $L_2 = 2·21 \times 12 \times \sqrt{\frac{2·6}{13}} = 2·21 \times 12 \times 0·447 = 11·8 \text{ m}$; say 12 m.

The bottom width of weir = 3·5 m.

Provision of cut-offs.

Let us first calculate as to what will be the head over the weir when high flood discharge is passing.

Using $q = 1·7\, H^{3/2}$

$$q = \frac{Q}{L} = \frac{300}{40} = 7·5$$

$$7·5 = 1·7\, H^{3/2}$$

or $H^{3/2} = \frac{7·5}{1·7} = 4·41$.

or $H = (4·41)^{2/3} = 2·68 \text{ m}$.

Head over the weir crest in accordance with HFL = 2·68 m.

∴ U/S HFL (assuming bed level as 100·0 m) & crest level as 102 m

$$= 102 + 2·68 = 104·68 \text{ m (RL)}$$

Now, R = Lacey's regime scoured depth $= 1·35 \left(\frac{q^2}{f}\right)^{1/3}$

or $R = 1·35 \left(\frac{7·5^2}{1·0}\right)^{1/3} = 1·35 \times 3·84 = 5·18 \text{ m}$.

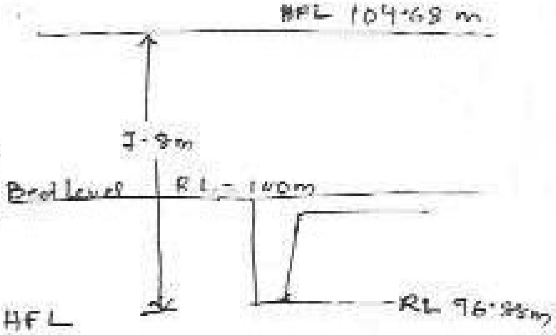
Assuming f = 1·0.

Depth of u/s sheet pile from below u/s HFL

$= 1.5R = 1.5 \times 5.18 = 7.8\,m$

∴ Level of bottom of u/s sheet pile

$= (104.68 - 7.8) = 96.88\,m$



Provide a depth of $(100 - 96.88)\,m$

$= 3.02$, say 3 m for u/s cutoff.

Since afflux is not known, the d/s HFL is not known; and the exact calculation for the depth of d/s sheet pile cannot be done.

Use a similiar d/s cut off of 3m depth below the weir floor.

Now, total creep length provided except u/s floor

$= (2 \times 3m + 3.5 + 12 + 2 \times 3) = 27.5\,m$

The balance length = Total length of creep required including creep along cut-off − Total creep length provided except u/s floor.

$= (31.2 - 27.5)\,m = 3.7\,m$; say 5m.

∴ Total creep length provided $= (27.5 + 5)\,m = 32.2\,m$.

Now,

$$L_2 + L_3 = 18\,C \cdot \sqrt{\frac{H_L}{13} \times \frac{q}{75}}$$

where L_3 is the length of downstream loose talus.

$$q = \text{Discharge intensity} = \frac{Q}{L} = \frac{300}{40} = 7.5$$

$$L_2 + L_3 = 18 \times C \sqrt{\frac{2.6}{13} \times \frac{7.5}{75}} = 18 \times 12 \times 0.141 = 31.6\,m$$

But $L_2 = 11.8\,m$;

$L_2 + L_3 = 31.6$

or $L_3 = (31.6 - 11.8)\,m = 19.8\,m$; Say 20.0 mts.

Hence provide (say 1m thick) d/s loose talus of 20m in length. This length of 20 m can be partly provided as blocks over inverted filter & partly as launching apron.

Length of u/s talus $= \frac{1}{2} \times$ length of d/s talus $= 10\,m$.

D/S Floor Thickness

The H.G line is now plotted as shown in figure. The max. ordinate of the H.G line above the bottom of the floor for the downstream portion at the junction of weir wall $= h = \frac{2.6}{32.2} \times 18$

or $h = 1.45\,m$.

Solution:

(1) For Upstream Pile No.(1)

Total length of the floor = b = 57.0 m

Depth of u/s pile line = d = (154 - 148) = 6.0 m.

$$\alpha = \frac{b}{d} = \frac{57.0}{6.0} = 9.5$$

$$\frac{1}{\alpha} = \frac{1}{9.5} = 0.105$$

From curve plate 11.1 (a)

$$\phi_{C_1} = 100 - \phi_E = 100 - 29 = 71\%$$

$$\phi_{D_1} = 100 - \phi_D = 100 - 20 = 80\%$$

These values of ϕ_{C_1} and ϕ_{D_1} must be corrected for three corrections

Corrections for ϕ_{C_1}

(a) Correction at C_1 for Mutual Interference of Piles.

ϕ_{C_1} is affected by intermediate Pile No. 2 [Influence Pile = 02, Effect Pile = 01]

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

where D = Depth of Pile No. 2 = 153 - 148 = 5.0 m

$$\text{Correction} = 19\sqrt{\frac{5}{15.7}}\left(\frac{5+5}{57}\right) = 1.88\%$$

d = Depth of pile No. 1 = 153 - 148 = 5.0 m

b' = Distance b/w two piles = 15.8 m

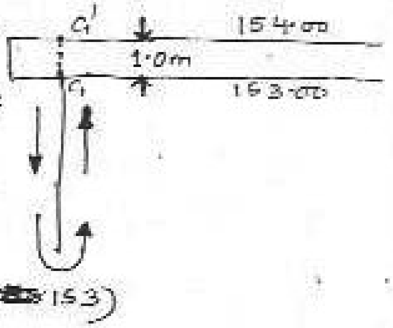
b = Total floor length = 57.0 m

Since the point C_1 is in the rear in the direction of flow, the correction is +ve.

∴ Correction due to pile interference on C_1 = 1.88 % (+ve)

(b) Correction at C_1 due to thickness of floor.

Pressure calculated from curve is at C_1', but we want the pressure at C_1. Pressure at C_1 shall be more than at C_1' as the direction of flow is from C_1 to C_1'; and hence, the correction will be +ve &



$$(154 - 148) = (80 - 71)\%$$

$$(154 - 153) = \frac{80\% - 71\%}{(154 - 148)} \times (154 - 153)$$

$$= \frac{9}{6} \times 1 = 1.5\%\ (+ve)$$

(c) Correction due to slope at C_1 is nil, as this point is neither situated at the start nor at the end of a slope.

$$\therefore \text{Corrected } \phi_{C_1} = (71\% + 1.88\% + 1.5\%) = 74.38\%$$

Hence Corrected ϕ_{C_1} = 74.38 %

$$\phi_{D_1} = 80\%$$

The thickness of D/S floor at this point is then obtained by:

$$t = 1.33\left(\frac{h}{G-1}\right)$$

$$\text{or} \quad t = 1.33 \times \left(\frac{1.45}{2.4-1}\right) = 1.35 \text{ ; say } 1.4\,m.$$

Hence provide 1.4m thickness for D/S floor from just near its junction with weir wall.

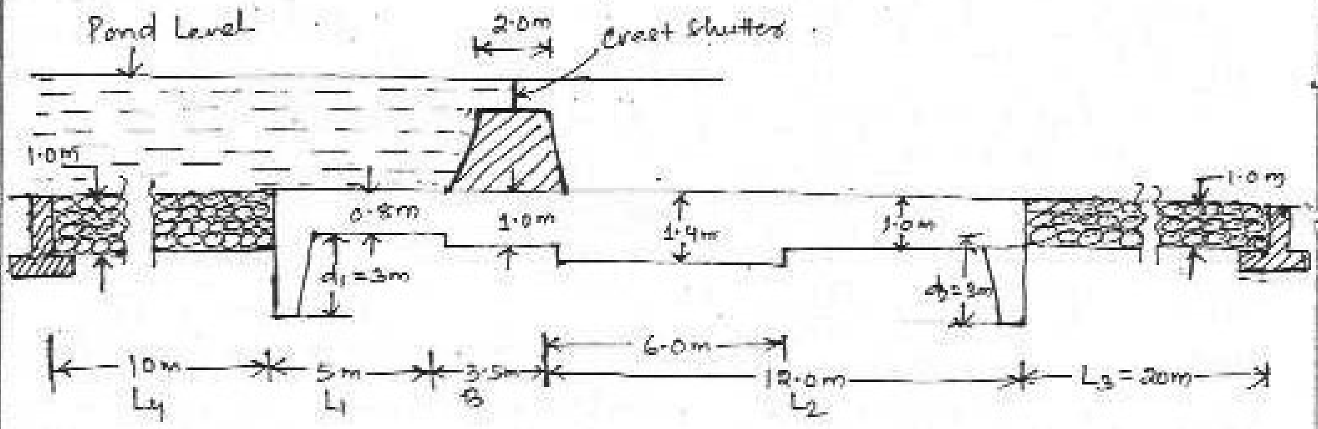
The thickness can be curtailed as below.

The thickness required at half way of d/s floor length.

$$= \frac{1.33h}{1.4} \text{ ; where } h = \frac{2.6}{32.2} \times 12 = 0.97m$$

$$= \frac{1.33 \times 0.97}{1.4} = 0.92\,m \text{ ; say } 1m.$$

Further, provide a nominal thickness of 0.8m below the u/s floor and 1m below the weir wall.

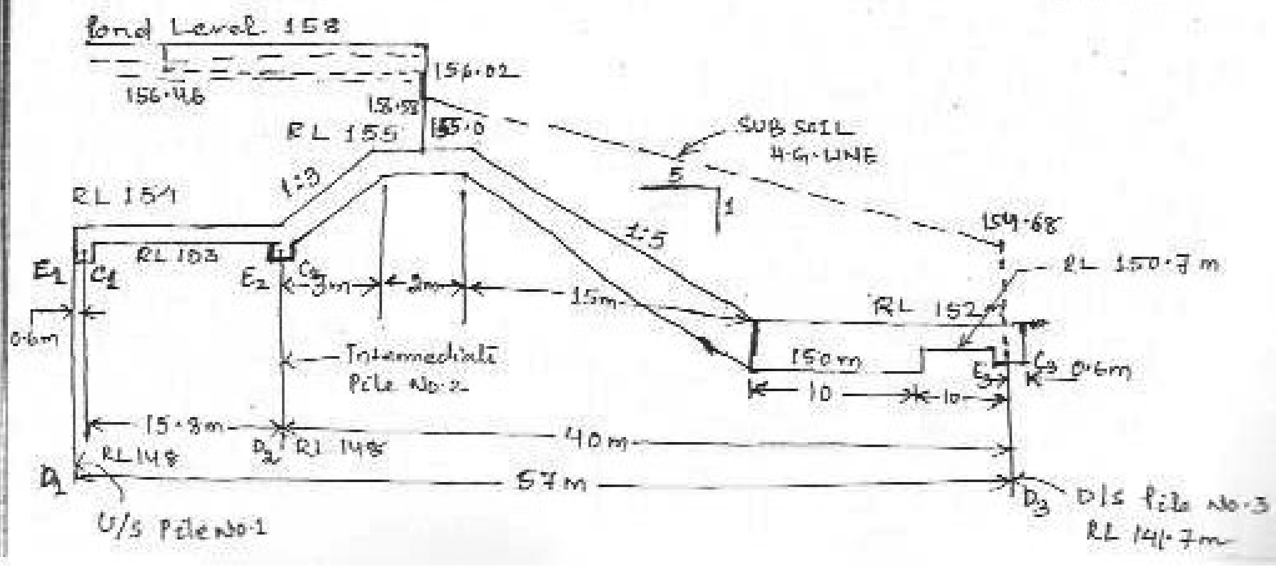


Khosla's Theory of Independent Variables

Problems: Determine the percentage pressures at various key points. Also determine the exit gradient & plot the hydraulic gradient line for pond level on u/s & no flow on d/s.

1V : 3H

1V : 5H



Solution.

(1) For Upstream Pile No. (1)

Total length of the floor = b = 57.0 m

Depth of u/s pile line = d = (154 − 148) = 6.0 m

$$\alpha = \frac{b}{d} = \frac{57.0}{6.0} = 9.5$$

$$\frac{1}{\alpha} = \frac{1}{9.5} = 0.105$$

From curve plate 11.1 (a)

$$\phi_{C_1} = 100 - \phi_E = 100 - 29 = 71\%$$

$$\phi_{D_1} = 100 - \phi_D = 100 - 20 = 80\%$$

These values of ϕ_{C_1} and ϕ_{D_1} must be corrected for three corrections

Corrections for ϕ_{C_1}

(a) Correction at C_1 for Mutual Interference of Piles.

ϕ_{C_1} is affected by intermediate Pile No. 2 [Influence Pile = 2, Effect Pile = 1]

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

where D = Depth of Pile No. 2 = 153 − 148 = 5.0 m

$$\text{Correction} = 19\sqrt{\frac{5}{15.7}}\left(\frac{5+5}{57}\right) = 1.88\%$$

d = Depth of pile No. 1 = 153 − 148 = 5.0 m

b' = Distance b/w two piles = 15.8 m

b = Total floor length = 57.0 m

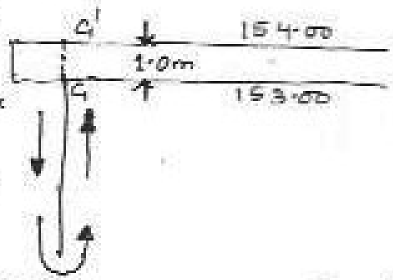
Since the point C_1 is in the rear in the direction of flow, the correction is +ve.

∴ Correction due to pile interference on C_1 = 1.88 % (+ve)

(b) Correction at C_1 due to thickness of floor.

Pressure calculated from curve is at C_1', but we want the pressure at C_1.

Pressure at C_1 shall be more than at C_1' as the direction of flow is from C_1 to C_1'; and hence, the correction will be +ve &



$$(154 - 148) = (80 - 71)\%$$

$$(154 - 153) = \frac{80\% - 71\%}{(154 - 148)} \times (154 - 153)$$

$$= \frac{9}{6} \times 1 = 1.5\% \ (+ve)$$

(c) Correction due to slope at C_1 is nil, as this point is neither situated at the start nor at the end of a slope.

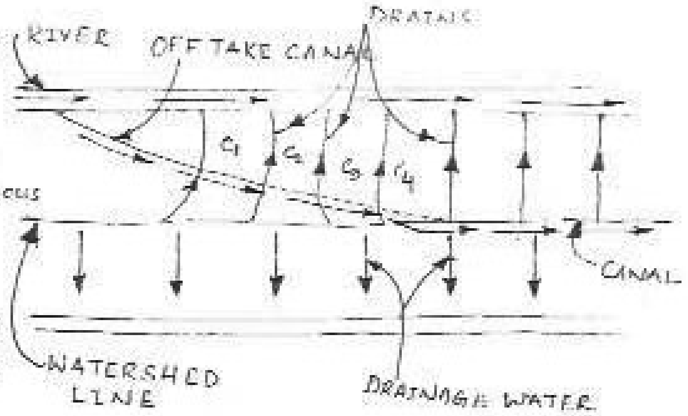
∴ Corrected $\phi_{C_1} = (71\% + 1.88\% + 1.5\%) = 74.38\%$

Hence Corrected ϕ_{C_1} = 74.38 %

ϕ_{D_1} = 80 %

INTRODUCTION

- A cross drainage work is a structure which is constructed at the crossing of a canal & a natural drain, so as to dispose of drainage water without interrupting the continuous canal supplies.



- Inorder to reduce the cross drainage works, the artificial canals are aligned along the ridge line called watershed. When once the canal reaches the watershed line, CD-works are generally not required, unless the canal alignment is deviated from the watershed line.
However, before the watershed is reached, the canal which takes off from the river has to cross a no. of drains, which moves from the watershed towards the river. At all such crossings C_1, C_2, C_3, C_4 cross drainage works are required.

- CD-works ~~are~~ is generally a costly construction. The no. of CD-works may be reduced by
(i) diverting one drain into another
(ii) changing the alignment of the canal, so that it crosses below the junction of two drains.

TYPES OF CROSS-DRAINAGE WORKS

The drainage water intercepting the canal can be disposed of in either of the following ways:

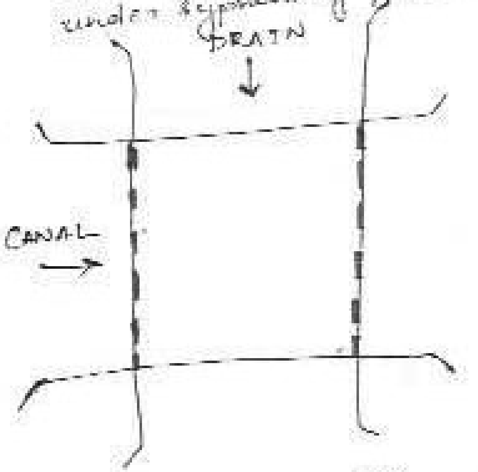
(1) By passing the canal over the drainage.
(a) an aqueduct; or through a (b) Syphon-aqueduct.

(2) By passing the canal below the drainage.
(a) Super-passage; (b) Canal Syphon (Syphon).

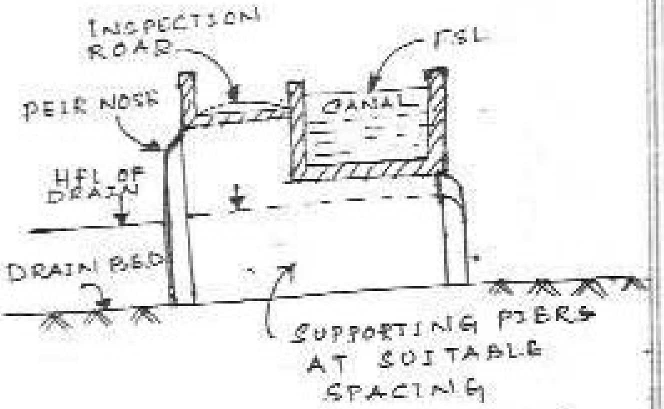
(3) By passing the drain through the canal, so that the canal water and drainage water are allowed to intermingle with each other.
(a) level crossing (b) inlets & outlets.

AQUEDUCT AND SYPHON AQUEDUCT

- In these works the canal is taken over the natural drain, such that the drainage water runs below the canal either freely or under syphoning pressure.



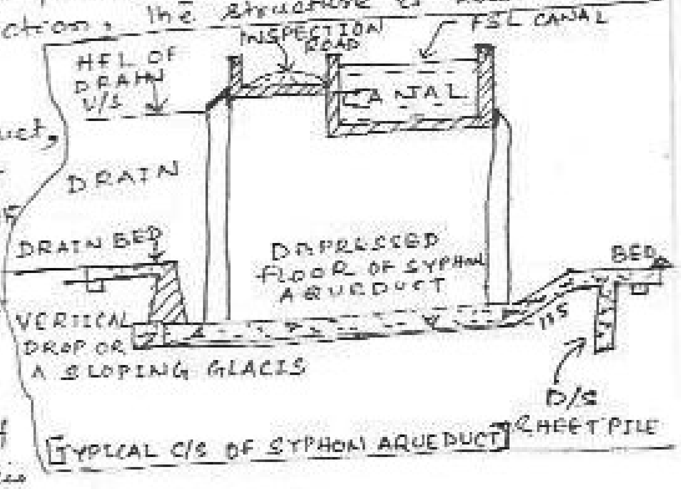
Canal taken over the drain on an aqueduct or a syphon aqueduct (Line Plan of Crossing)



[TYPICAL CROSS-SECTION OF AN AQUEDUCT]

AQUEDUCT :- When the HFL of the drain is sufficiently below the bottom of the canal, so that drainage water flows freely under gravity, the structure is known as an Aqueduct.

SYPHON AQUEDUCT :- If the HFL of the drain is higher than the canal bed & the water passes through the aqueduct barrels under syphonic action, the structure is known as syphon aqueduct.



[TYPICAL C/S OF SYPHON AQUEDUCT]

- In the case of syphon aqueduct, the drain bed is generally depressed and provided with pucca floor.
- On the u/s side, the drainage bed may be joined to the pucca floor either by a vertical drop (when drop is of order of 1 m) or by a glacis of 3:1 (when drop is more).
- D/s rising slope should not be steeper than 5:1.

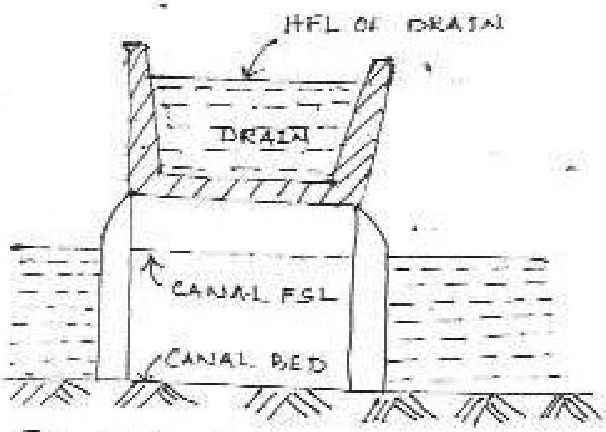
Aqueduct (contd...)

- An aqueduct is just like a bridge except that instead of carrying a road or a railway, it carries a canal on its top.
- An aqueduct is provided when sufficient level difference is available between the canal & the natural drainage, and canal bed level is sufficiently higher than the torrent level.

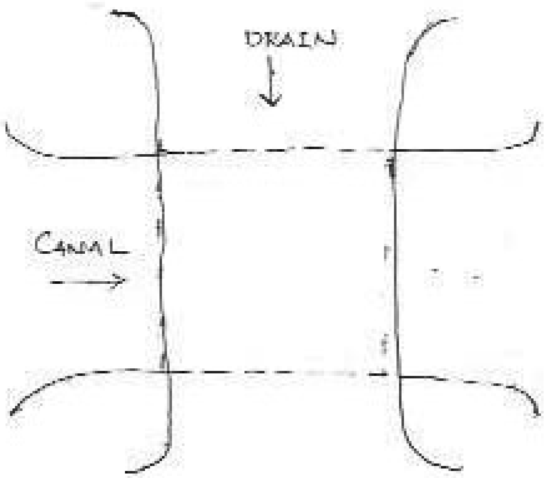
- In this type of C.D. works (i.e. when the canal is taken over the drainage), the canal remains open to inspection throughout, & the damage caused by floods are rare. However, during heavy floods, the foundations of work may be susceptible to scour, or waterway of the drain may get choked with debris, trees etc.

SUPER PASSAGE AND CANAL SYPHON.

- In these works, the drain is taken over the canal such that the canal water runs below the drain either freely or under syphoning pressure.



[Typical c/s of a super passage]



[Drain taken over the canal in a superpassage or in a syphon. (Line Plan of crossings)]

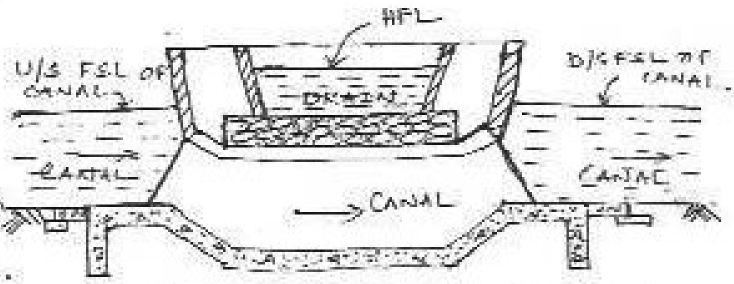
SUPER - PASSAGE

- When the FSL of the canal is sufficiently below the bottom of the drain trough, so that the canal water flows freely under gravity, the structure is known as a superpassage.

- A superpassage is the reverse of an aqueduct, and similarly, a syphon is a reverse of an aqueduct syphon.

SYPHON

- If the FSL of the canal is sufficiently above the bed level of the drainage trough, so that canal flows under syphonic action under the trough the structure is known as a canal syphon or a syphon.



[Typical cross-section of a canal syphon]

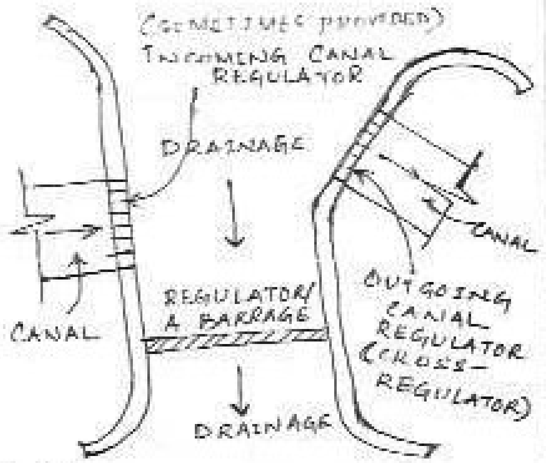
- In case of a syphon, the canal bed is depressed & a ramp is provided at the exit so that the trouble of silting is minimised.

LEVEL CROSSING AND INLETS & OUTLETS :-

In this type of cross drainage work, the canal water & drain water are allowed to intermingle with each other.

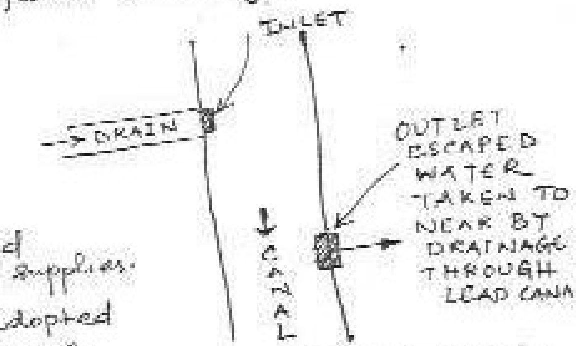
LEVEL CROSSING

- A level crossing is generally provided when a large canal & a huge drainage (such as stream or a river) approach each other practically at the same level.



- A regulator is provided across the torrent (drainage) just on the d/s side of the crossing so as to control the discharge passing into the torrent.
- At the outgoing canal, a regulator is also provided so as to control the discharge into the canal. A regulator at the end of the incoming canal is also sometimes required.
- This arrangement is generally provided when a huge sized canal crosses a large torrent (drainage) carrying a very high but short-lived (when floods are intermittent & not continuous) flood discharge.
- During dry season, when there are no floods, the torrent regulator is generally kept ~~open~~ closed & the outgoing canal regulator is kept fully open, so that canal flows without interruption. During floods, the torrent regulator is opened so as to pass the flood discharge.

INLETS AND OUTLETS



Inlet and Outlet (Plan)

INLETS :-

- An inlet structure constructed inorder to allow the drainage water to enter the canal & get mixed with the canal water and thus to help in augmenting canal supplies.
- Such a structure is generally adopted when drainage discharge is small & the drain crosses the canal with its bed level equal to or slightly higher than the canal FSL.
- Inlet consists of an open cut in a canal bank, suitably protected by pitching, to admit the upland drainage water into the canal. The bed & sides of the canal are also pitched for a certain distance u/s & d/s of the inlet.

OUTLETS :-

- But, when the drainage discharge is high or if the canal is small, so that the canal section cannot take the entire drainage water, an outlet may sometimes be constructed to escape out the additional discharge at a suitable site, a little d/s along the canal.

- Similiarly the outlet is another open cut in the canal bank with bed and sides of the cut properly pitched. The escaping water from the outlet is taken away by a lead channel to some nearby drain, on d/s side of the surface outlet.

Applicability (or) Suitability of CD works.

→ Aqueduct or Superpassage type of works are generally used when high flood drainage discharge is large and continues for a sufficient time.

→ A level crossing is used when the high flood drainage is large but short-lived.

→ Inlets & Outlets are used when the high flood drainage discharge is small. Inlets and outlets are inferior to aqueduct or superpassage type of works, but they are cheaper.

SELECTION OF A SUITABLE TYPE OF CROSS-DRAINAGE WORK.

- The relative bed levels, water levels & discharge of the canal and the drainage are the primary factors which govern & dictate the type of cross drainage work that may prove to be most suitable at a particular place. [Rajan & K. Garg Pg No. 724]

- In actual field, such ideal conditions may not be available & the choice would then depend upon many other factors such as :

(i) Suitable canal alignment

(ii) Nature of available foundation

(iii) Position of water table & availability of dewatering equipment.

(iv) Suitability of soil for embankment

(v) Permissible head loss in canal

(vi) Availability of funds.

→ Conveying a canal over a natural watercourse may be accomplished in 2 ways.

(a) Trough Type Aqueduct :- Normal canal section is reduced to a rectangular section & carried across the natural stream in the form of bridge resting on piers & foundations.

(b) Barrel Type Aqueduct :- Normal canal section is continued across the natural stream but the stream section is flumed to pass through 'barrels' or rectangular passages. "

- It may be observed that the trough type aqueduct (or) syphon aqueduct would be suitable for the canal crossing a large stream or river. whereas the barrel type is suitable if the natural stream is rather small.

TROUGH TYPE

- Canal is flumed to not less than 75% of the bed width (keeping in view the permissible head loss in the canal).

- Transitions 3:1 on the u/s and 5:1 on the d/s are provided to join the flumed section to the normal canal section.

- For Trough-Type Syphon Aqueduct, the upward thrust during high floods in the natural streams when the stream water flows under pressure below the trough base must be considered.

- For worst condition (considered while design): the canal may be assumed to be dry at that time.
The dead weight of the trough may be made more than that of the upward thrust (or) it may be suitably anchored to the piers inorder to counteract the uplift condition mentioned.

BARREL TYPE

- For barrel-type syphon aqueducts, the barrel is horizontal in the central portion but slopes upwards on the u/s & d/s side at 3H:1V and 4H:1V respectively.
an inclination of 3H:1V and 4H:1V respectively.
A self-cleaning velocity of 6 ms⁻¹ & 3 ms⁻¹ is considered while designing RCC & masonry barrels respectively.
- Precast RCC pipes may be economical for small discharges.