UNIT - 6

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Canal Structures

1. Falls —

Necessity and Location of falls —

A fall is an irrigation structure Constructed across a canal to lower down its water level and distroys the supply surplus energy liberated from the falling water which may otherwise scour bed & and banks of the canal.

① For the canal which does not irrigate the area directly, the fall should be located from the Considerations of economy in cost of excavation of the channel with regard to balancing depth, and cost of the falls itself.

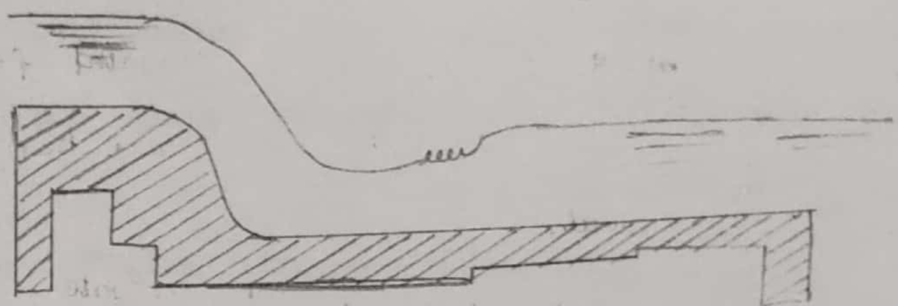
② For a canal irrigating the area directly, a fall may be provided at a location where the F.S.L outstrips the ground level, but before the bed of the canal comes into falling.

③ The location of the fall may also be decided from the Consideration of the possibility of combining it with a regulator or a bridge or any other masonry works.

④ A relative economy of providing large number of small falls v/s small number of big falls should be worked out. The provision of small number of big falls results in unbalanced earthwork, but there is always some saving in the cost of the fall, structure

⊛ Types of falls —

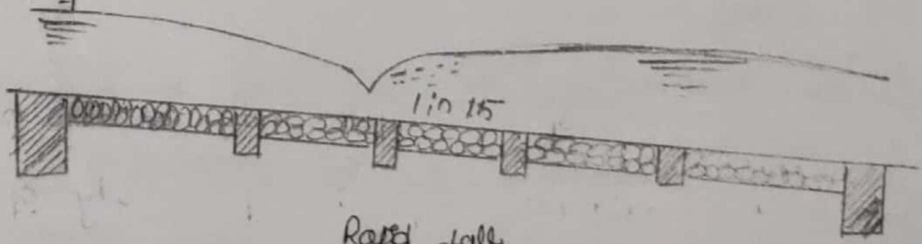
1. **Ogee fall** :— The ogee fall was first constructed by Sir Proby Cautley on the Ganga canal. This type of fall has gradual convex and concave curves with an aim to provide a smooth transition and to reduce disturbance and impact.



OGEE FALL

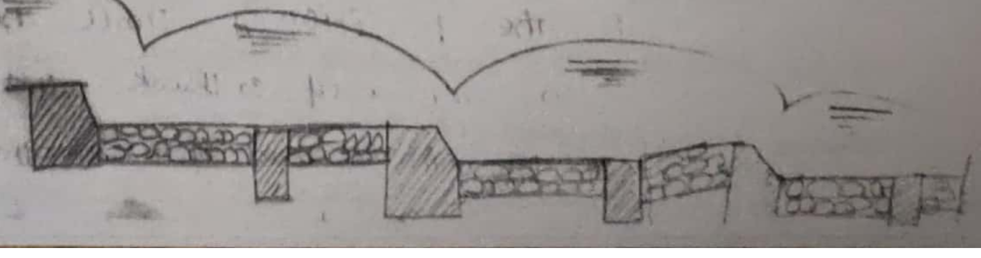
2. **Rapid fall** :—

Such falls were provided on western Yamuna canal and were designed by Lieut R.L Crofton. Such a fall consists of glacial sloping at 1 vertical to 10 to 20 horizontal. Hence a fall worked admirably, however there was very high cost of construction.



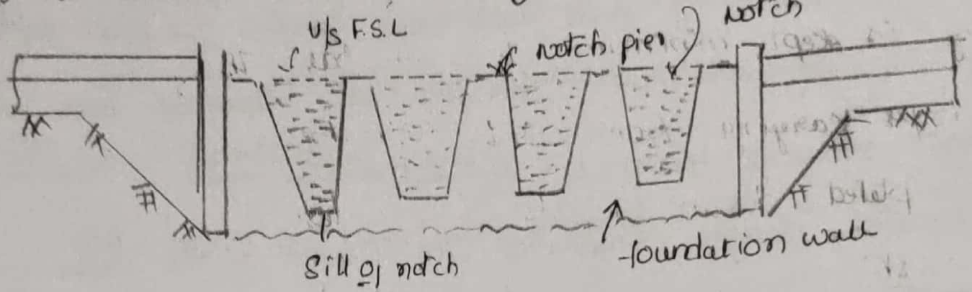
Rapid fall

3. **Stepped fall** :- Stepped falls was a next development of the rapid fall one such type was provided at the tail of main canal escape of Sarda canal.



4. Notch fall :—

Soon after the development of stepped fall, the efficiency of vertical impact on the floor for energy dissipation came to be recognised. The vertical fall came in the field along with the cistern. However with greater discharges.



5. Vertical Drop fall :—

In the vertical drop fall, the nappe impinges clear into the water cushion below. The dimensions of cistern were put in arbitarily in light of experiance of the disigners. Another device in the form of grid was usually used in the cistern intercepting the dropping Jet of water

6. Glacis Type fall :—

The efficiency of the hydraulic Jump as a potent means of distroying the energy of canal falls was brought out clearly by the research work of the many Conservency.
The glacis fall may be in straight glacis Type or parabolic glacis Type commonly known as Montague Type. The straight glacis fall may be with baffle platform and baffle wall. formation of Jump Takes place from baffle platform.

Meter and Nonmeter falls :—

Meter falls are those which also measure the discharge of the canal. The non metre falls do not measure discharge. For a fall to act as a metre, it must have a broad weir Type crest so that discharge coefficient is Constant under Variable head.

Design of SARDA Type fall :-

This Type of fall was designed and developed for Sarda Canal System of U.P. In that area, thin veneer of Sandy clay overlies a stratum of pure sand. Hence the main requirement was to provide a number of falls, with small drops. So that depth of cutting is kept minimum. This fall has, therefore been Constructed for drops varying from 0.9 to 1.8 metres.

The Completed design Consists of the design of the following Parts.

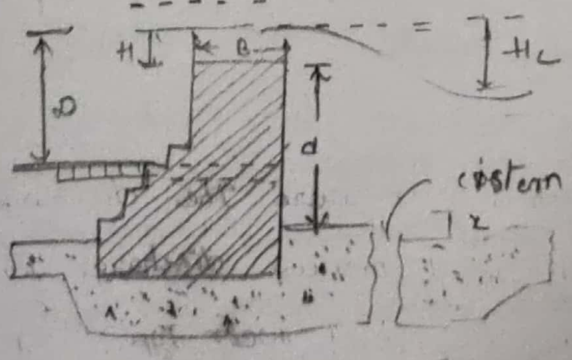
1. Crest
2. cistern
3. Impervious floor
4. d/s protection
5. U/s approach.

1. Design of Crest

(i) Length of crest : The length of the crest is kept equal to bed width of the Canal. and no flumming is done in this Type of fall. Hence the length of the crest is kept equal to bedwidth of the Canal. plus the water depth to take into account the anticipated increase in discharge at a future date

(ii) Shape of the crest and discharge formula

Two Types of crests are used. the rectangular crest is used for discharge upto 14 Cumecs (500 cusecs) and Trapezoidal crest is used for discharge over 14 cumes



Rectangular crest

For the rectangular crest :- (5)

The width of the crest is given by $B = 0.55\sqrt{d}$ metre

Base width is given by $B_1 = \frac{H+d}{P}$

for masonry crest P may be taken equal to 2

Discharge is given by $Q = 1.835 \, L H^{3/2} (H/B)^{1/6}$ —(1)

Q = discharge in cumes L = length of crest in metres

For a Trapezoidal crest :-

Top width of crest is given by $B = 0.55\sqrt{H+d}$

U/s batter = 1 : 3

D/s batter = 1 : 8

Thus the width is determined by the batter

$Q = 1.99 \, L H^{3/2} (H/B)^{1/6}$ —(2)

(ii) **Crest Level :-**

From eq (1) & (2) the value of H is known

RL of crest = U/s F.S.L − H

Height of crest above bed = h = D − H

For falls over 1.5m the stability of the crest wall should be tested by actual analysis.

(3) **Design of Cistern :-**

The length and depression of the cistern are given by the following equation

$l_c = 5 (E H_L)^{1/2}$

$x = \frac{1}{4} (E H_L)^{2/3}$

3. Design of Impervious floor :-

The Total length of impervious floor is determined either by Bligh's theory or by Khosla's theory. The maximum seepage head occurs when there is water on the u/s side upto the top of the crest and there is no flow to the d/s side. out of the total impervious floor length, and a maximum length (d_d) to be provided to the d/s of the crest is given by the following expression.

$$d_d = 2(D+1.2)+H_L \text{ metres}$$

The thickness of the impervious floor is determined a minimum thickness of 0.3 to 0.4m is provided for the floor to u/s crest.

④ D/S protection :-

The d/s protection Consists (i) bed protection (ii) side protection (iii) d/s wings.

(i) Bed protection :- The bed protection Consists of dry bricks pitching about 20cm thick resting on 10cm ballast.

(ii) Side protection :- The side protection Consists of one dry brick pitching as on edge, is provided after the wrapped wings. The side pitching is wrapped from a slope of 1:1 to 1½:1.

(iii) D/s wings :- The d/s wings are kept vertical for a length of 5 to 8 metres times $\sqrt{EH_L}$ from the crest and are then warped or flared to a slope of 1:1 or 1½:1

The wing walls are designed as earth retaining structure In the absence of elaborate stability calculation the width of wings at any level may be kept equal to ⅓rd the height above bed level

The earthquake

(5) Design of U/s approach :-

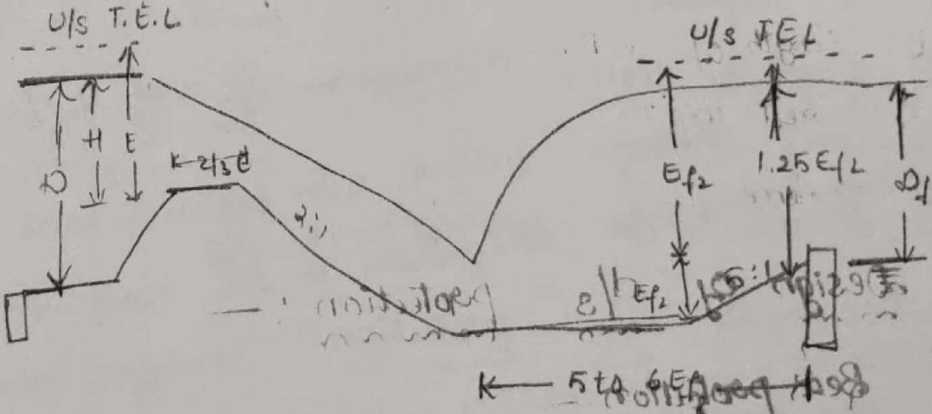
For discharge upto 14 cumes the U/s wings may be splayed straight at an angle of 45°. For greater discharges the wings are kept segmental with radius equal to 5 to 6 times H, subtending at angle of 60°. at the time of Centre, and then are carried straight into the berm.

* Design of Straight Glacis fall

1. Crest Design:—

(a) For a non-meter falls, the U/S glacis is given a slope of 1/2:1 and is joined tangentially to the crest with a radius of E/2 where E = height of U/S TEL above crest

(b) The d/s glacis is given a slope of 2:1 and is joined tangentially to the cistern with a radius = E.



Straight glacis fall

(c) The width of the crest is kept equal to 2/3 E.

(d) The glacis fall may sometimes be flumed if it is to be combined with a bridge etc. However the minimum clear length of the crest.

The value of E calculated from the discharge equation

$$Q = 1.84\, L_t\, E^{3/2}.$$

L_t = length of the crest

Q = discharge in cumecs

If there are n number of piers, the effective length to be equal to (L_t - 0.2n)

crest level = U/S T.E.L - E

U/S T.E.L = U/S F.S.L + Velocity head.

② Design of cistern :—

knowing the discharge intensity and the drop H_L the energy of flow (E_{f2}) below the hydraulic jump is known.

Then R.L cistern = d/s T.E.L - 1.25 E_{f2}

3. Design of impervious floor :—

The total length of the impervious floor is found from the consideration of permissible exit gradient. The total length of the impervious floor may be provided in the following

① length of cistern ② Horizontal length of d/s glacis

③ crest width ④ " " of u/s glacis

⑤ Balance to be provided to the u/s

④ Design of d/s protection :—

ⓐ Bed protection :—

Since a deflector wall is provided at u/s end of the floor no bed pitching is provided.

ⓑ side protection

Dry brick pitching of 1½ brick thick is done upto a length of $3D_1$. The pitching is supported on a toe will 0.4m wide and $D_1/2$ deep.

ⓒ curtain wall : depth of curtain wall = $D_1/2$ width 0.4m

5. Design of Energy Dissipators :—

(a) friction blocks :—

Four rows of friction blocks are provided in case of flummed glacial falls. The height of each block is kept equal to $D/8$ and length equal to 3 times the height of the block. The distance between the rows is equal to height of the blocks

(b) Glacis blocks :-

The falls more than 2m one row of glacis blocks is of the same dimensions as that of friction blocks. is provided at the d/s end of glacis

(c) Deflector wall :—

Deflector wall height $D/10$ and width 0.4m is provided at the d/s cistern. The same wall may be provided at the d/s cistern.

6. Design of d/s Expansion :—

In a flummed fall the d/s expansion starts from the toe of the glacis. The A rectangular hyperbolic expansion is generally preferred

The Bed width B_x at a distance x from the d/s toe of the glacis is given by

$$b_x = \frac{B_1 \times B_2 \times L_e}{(L_e \times B_2) - (B_2 - B_1)x}$$

7. upstream Approach :—

For a non meter falls the side walls are splayed at an angle of 45° from the U/s edge of the crest.

Head Regulators and Cross Regulators

Head Regulator and Cross-regulator regulate the supplies of the off-taking channel and the parent channel respectively. The distributary head regulator is provided at the head of the distributary and control the supply of entering the distributary

FUNCTIONS OF DISTRIBUTARY HEAD REGULATOR:

1.) They regulate or control the supplies to the off taking channel.
2) They serve as a meter for measuring the discharge entering into the off taking.
3) They control silt entry in the off taking canal.
4) They help in shutting of the supplies and not needed in the off taking canal or when the offtaking canal is required to be closed for repairs.

Functions of Cross regulator:

1) The effective regulation of the whole canal's system can be done with help of cross regulator.
2) During the periods of low discharges in the parent channel, the cross regulator raises water level of the up stream and feed's the off take channel in rotation.
3) It help's in closing the supply to the D/S of the parent channel for the purpose of repair's.
4) They help in absorbing fluctuation in various section's of the canal system and in preventing the possibilities of breaches in the tail reaches.
5) Incidently bridges and other communication work's can be combined with it.

Design of Cross Regulator:-

1) Design of Crest:

The discharge is determined by the drowned weir formula:

$$Q = \frac{2}{3} C_1 L \sqrt{2g}\left[(h+h_a)^{3/2} - h_a^{3/2}\right] + C_2 L d \sqrt{2g(h+h_a)}$$

Q = discharge, in cumecs
L = length of water-way, in metre's
h = Difference in water level u/s and d/s of the Channel, in metre's
h_a = Head due to velocity of approach.
d = Depth of d/s water level in the channel measured above the crest
C_1 = Constant = 0.557
C_2 = Constant = 0.80

Generally the velocity of approach in small, and may be neglected while using Eq. 18.24. Knowing the discharge Q, the length of water way L can be calculated.

For the cross regulator, the crest level is kept equal to the upstream bed level of the parent channel.

2) Design of d/s floor :-

The level and length of the d/s floor is determined under two flow condition's.
(i) full supply discharge passing through both the head regulator and cross regulator.
(ii) The discharge in the parent channel is running full.

The discharge intensity q and the head loss H_L (= h) are known. Hence, the value of E_{f2} can be found from the Blench Curve's.

D/s floor level = d/s T.E.L − E_{f2} = d/s F.S.L − E_{f2}

The d/s floor level, calculated from the above relation should never be provided higher than the d/s bed level. $E_{f1} = E_{f2} + H_L$

The depth D_1 and D_2 corresponding to E_{f1} and E_{f2} respectively are found from specific energy curves.

The length of d/s floor = $5(D_2 - D_1)$.

3) Design of Impervious floor :-

Total length of the impervious floor st. be found from the consideration of permissible Exit gradient.

The depth of U/s. Cutoff $d_1 = \frac{1}{3}$ U/s waterdepth + 0.6m

The depth of d/s Cut off $d_2 = \frac{1}{2}$ d/s water depth + 0.6m

Maximum static head H_s = U/s F.S.L. - d/s floor level

$$G_E = \frac{1}{\pi\sqrt{\lambda}} \frac{H_s}{d_2}$$, from which $\frac{1}{\pi\sqrt{\lambda}}$ is known.

The Exit gradient Curves, $\alpha (= b d_2)$ is known. The floor thickness is found from considerations of uplift pressure. A minimum thickness 0.3 to 0.5m is provided from the pratical Consideration.

4) Design of U/s and d/s protection :-

U/s Scour depth d_1 is taken Equal ($\frac{1}{3}$ U/s water depth + 0.6m). The d/s Scour depth d_2 is taken Equal to ($\frac{1}{2}$ d/s water depth + 0.6m). There scour depths below the corresponding bed levels, and protection works are to be designed corresponding

(a) U/s Protection :-

The U/s Protection Consist of a block protection having Cubic Contents = d_1 Cubic meters/m. Cubic Contents of U/s launching apron is kept equal to 2.25 d_1 Cubic meter/Meter width of regulator.

(b) D/s Protection :-

The Cubic Contents d of d/s inverted filter is kept Equal to d_2 Cubic meter/Meter. The Cubic Contents of d/s launching apron is kept equal to 2.25 d_2 Cubic Meter/Meter width regulator

Cross Drainage Works :—

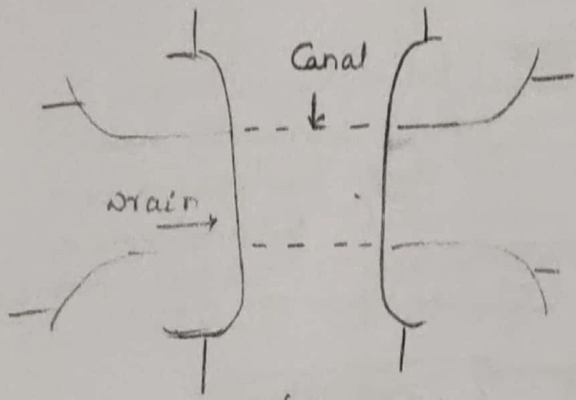
A cross drainage work is a structure carrying the discharge of a natural stream across a canal intercepting the stream.

Types of cross Drainage Works :—

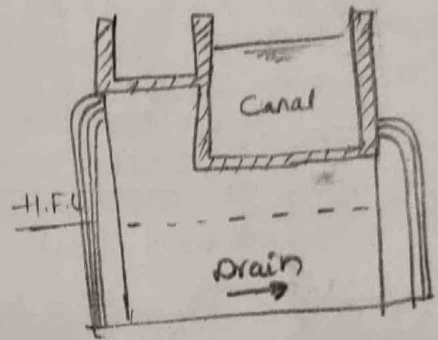
1. C. D works carrying canal over the Drainage

In this type of C.D work, the canal is carried over the natural drain. The advantage of such arrangement, is that the canal running permanently is above the ground.

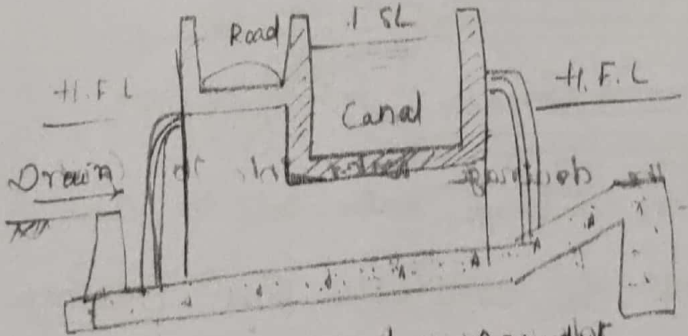
① Aqueduct ② syphon Aqueduct.



plan of crossing



Aqueduct.



syphon Aqueduct.

Shows the Aqueduct and syphon Aqueduct respectively. The H.F.L of the drain much below the bottom of the canal through in the case of aqueduct so that discharge water flows freely under gravity.

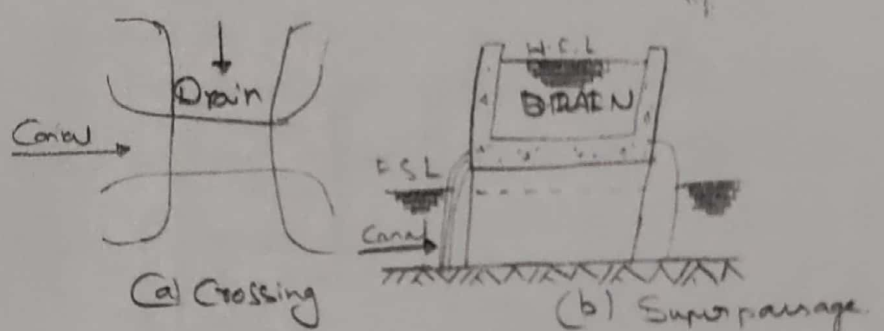
② C.D works carrying Drainage over the Canal

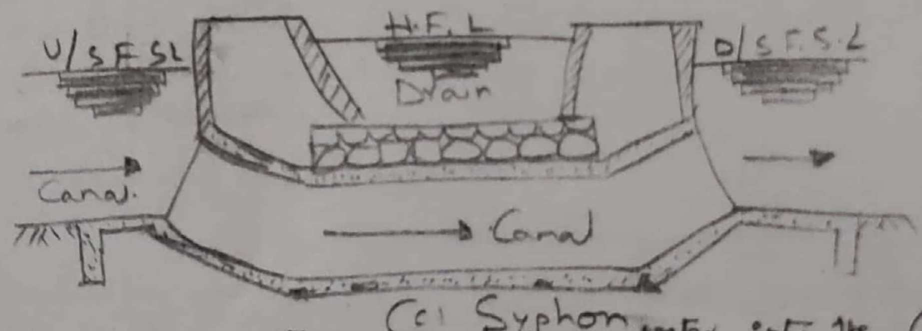
In this type of C. D works drainage is carried over the canal. The advantage of this Type is that the C.D work themselves are less liable to damage than the earth work of the canal.

The major disadvantage of this work is that the perennial canal is not open to inspection.

The structures that fall under this Type are 1 Super passage
2 canal syphon

Shows a supper passage. A super passage is similar to an adequet except in this case the drain is over the canal





(c) Syphon

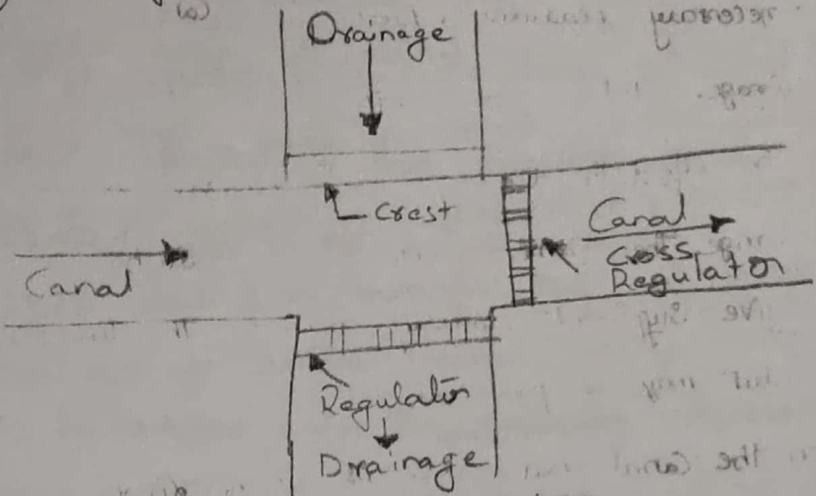
③ C.D works admitting the drainage water into the Canal

In this type of work the canal water and drainage water are permitted to intermingle with each other

① level crossing. ② Inlet and outlets

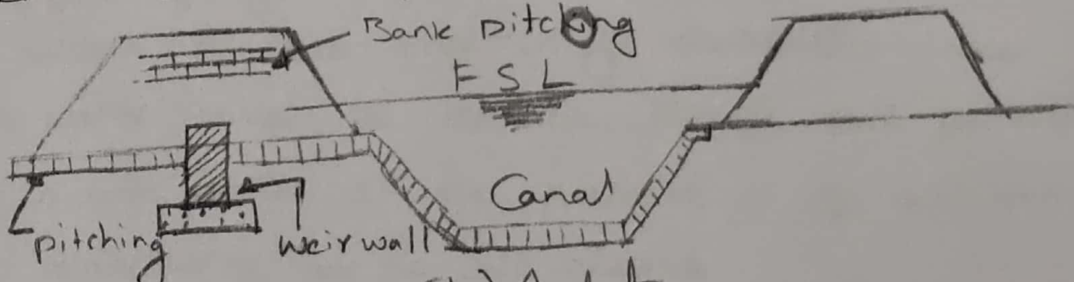
(i) Construction of a Crest with its top at the F.S.L of the Canal and drainage at the U/s junction with canal.
(ii) Provision of the head regulator across the drainage at its d/s junction with the drainage.
During the floods, however the drainage regulator is opened so that the flood discharge, after spilling over the crest and mixing with the Canal water.

The accurate supplies in the Canal are maintained by a Cross Regulator. level Crossing are suitable for Canals of all sizes.



(a) level Crossing

A Canal inlet [Fig. 19.3b] is Constructed when Cross drainage flow is small, and its water may be absorbed into the Canal without Causing appreciable rise. However, if the Canal is smaller an outlet may be Constructed to pass out the additional discharge which has Entered the Canal.



(b) Inlet

Selection of Suitable Type of cross Drainage works

The factors which affects the Selection of the Suitable Type of cross Drainage works are (i) relative bed levels and water levels of the Canal and Drainage.

(ii) Size of the Canal and the Drainage.

1. When the bed level of the Canal is much above the H.F.L of the Drainage, so that sufficient head way is available for floating rubbish etc. and also for the

structural elements of the work, an adequate is the obvious choice.

(2) The necessary headway between the Canal bedlevel and the Drainage H.F.L Can be increased by shifting the crossing to the d/s of the Drainage. If, however it is not possible to change the Canal alignment or if such shifting doesn't not give sufficient headway between the Two levels, a syphon aqueduct may be provided.

(3) when the Canal bed level is much lower, but the F.S.L of the Canal is higher than the bedlevel of the drainage a Canal syphon is preferred.

(4) when the drainage and the Canal cross each other practically at the same level, a cross drainge may preferred

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Outlets

An outlet is small structure which admits water from the distributing channel to a water course or field channel. Thus, an outlet is a sort of head regulator for the field channel delivering water to the irrigation fields.

Types of outlets: —

outlets may be classified under the following heads

1. Non modular outlet
2. Semi - module or flexible module
3. Rigid module.

Non modular outlet: — A non-modular outlet is the one in which the discharge depends upon the difference in level between the water level in the distributing channel and the water course. The discharge through such an outlet varies in wide limits. with the fluctuations of the water levels in the distributing and the field channels.

Semi module or flexible outlet: — A flexible outlet or semi-module is one which the discharge is affected by the fluctuation in the water level of the distributing channel while the flutation in water levels of the field channel do not have any effect on its discharge. The various outlets in common use that fall under this category are pipe outlet, Kennedy's gauge outlet, crump's open flume outlet

③ **Rigid Module** :— A Rigid module is the one in which maintains Constant discharge within limits irresp- of the fluctuations in water levels in the distributing channel and/or field channel. This is most Common outlet that falls under this Category is the Gibb's rigid module.

④ **proportionality** :—

A proportional outlet is the one in which the flexibility (F) is equal to unity. Thus in a proportional outlet, the rate of change of its discharge is equal to the rate of change of the discharge of the distributing channel. For proportionality, putting F=1 in equation $F = \frac{m}{n}\frac{D}{H}$

The ratio of H/D is known as the setting. In a proportional unit therefore, setting is equal the ratio of outlet and canal indices.

From the view of proportionality, an outlet is classified into three Types.

ⓐ proportional outlet
ⓑ hyper proportional outlet
ⓒ Sub proportional outlet.

⑦ **Flexibility** :— It is the ratio of rate of change of discharge of an outlet to the rate of change of the discharge of the distributing channel.

Thus $F = \frac{dq}{q} / \frac{dQ}{Q}$.

Thus where F = Flexibility

q = Discharge through the outlet

Q = Discharge of the distributing channel

Now for the field channel

$$q = KH^{m}$$

K = Constant m = outlet index

H = head acting on the outlet

$$dq = mKH^{m-1}\,dH$$

$$\frac{dq}{q} = \frac{mKH^{m-1}\,dH}{KH^{m}} = m\frac{dH}{H} \longrightarrow (1)$$

Similarly for the parent channel

$$Q = CD^{n}$$

C = Constant n = Canal index

D = Depth of water in the Canal

$$dQ = nCD^{n-1}\,dD$$

$$\frac{dQ}{Q} = \frac{nCD^{n-1}\,dD}{CD^{n}} = \frac{n\,dD}{D} \longrightarrow (2)$$

Dividing (1) & (2) we get

$$F = \frac{\frac{dq}{q}}{\frac{dQ}{Q}} = \frac{m\frac{dH}{H}}{n\frac{dD}{D}} = \frac{m}{n}\frac{D}{H}\frac{dH}{dD}$$

Since any change in the water depth results in an equal change in the head causing flow we have $dH = dD$. Thus the expression for flexibility becomes

$$\boxed{F = \frac{m}{n}\frac{D}{H}}$$

Sensitivity :—

It is defined as the ratio of rate of change of discharge of an outlet to the rate of change in the level of distributing surface, referred to normal depth of the channel. Thus,

$$S = \frac{dq/q}{dG/D}$$

where S = Sensitivity of the outlet

q = Discharge through the outlet

dq = change in the discharge of the outlet

G = Guage reading, so set that $G=0$ when $q=0$

D = Depth of water in the Distributing channel

$$dG = dD$$

$$S = \frac{dq/q}{dD/D} \longrightarrow (1)$$

$$F = \frac{dq/q}{dQ/Q} \quad \text{where } \frac{dQ}{Q} = n\frac{dD}{D}$$

$$F = \frac{dq}{q} \Big/ n\frac{dD}{D} \longrightarrow (2)$$

Comparing (1) and (2) we get

$$\boxed{S = nF}$$

River Training

The expression for river Training implies various measures adopted on a river to direct and guide the river flow, to Train and regulate the river bed or to increase the low water depth. The purpose of river Training is to establish the channel along a certain alignment. There may be various objects for Training a river these are discribed below.

(1). High flood discharge may pass safely and quickly through the reach.

(2) sediment load including bed and suspended load may be Transported efficiently

(3) To make the river course stable and reduce bank erosion to minimum

(4) To provide a sufficient draft for navigation as well as good course for it.

(5) To fix direction of flow through certain defined reach

Classification of River Training Works

1. High water Training :- This is also Called Training for discharge. The river is Trained to provide sufficient and efficient cross Sectional area for the expedition passage of maximum food.

2. Low water Training :- In Case the river is Trained to provide sufficient depth for navigation during low stage of river. This is also Called Training for depth. and is usually achieved by contraction of the width of the channel.

③ Mean Water Training

In the case of river is Trained to Correct the configuration of river bed for the efficient Transport of sediment load in order to keep the channel in good shape It can be called Training for Sediment.