

UNIT - 5

Canal falls :-

Types of falls & their location :-

Falls (or) Canal falls (or) Canal drop :-

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

(or)

A canal fall is a hydraulic structure constructed across a canal to lower its water level.

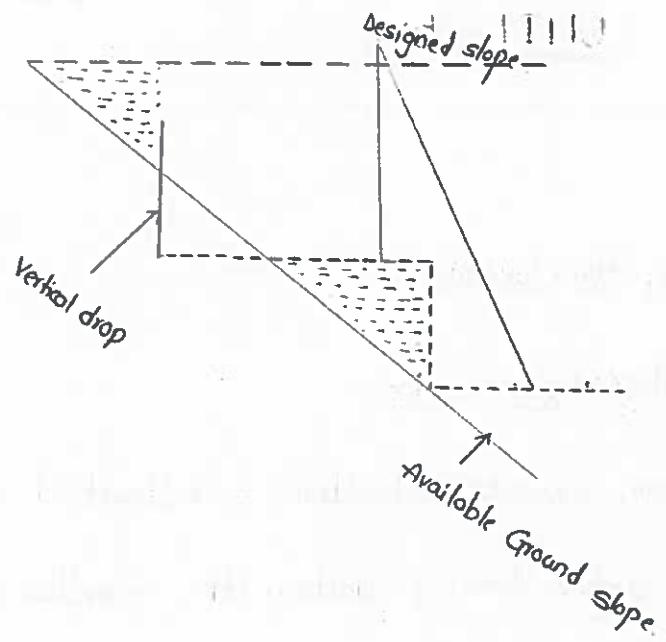
(or)

A hydraulic structure constructed to lower the water level & to act as an energy dissipation device is called 'Canal fall'

(or)

A drop (or) fall structure is a regulating structure which lowers the water level along its course.

→ Canal fall is also called as fall (or) Canal drop



Types of falls (or) Canal falls (or) Canal drop :-

Depending on the ground level conditions & shape of the fall, the following are the various types of falls :-

- Ogee fall
- Rapid fall
- Stepped fall
- Notch fall (or) Trapezoidal Notch fall.
- Vertical drop fall (or) Vertical fall (or) Sarda fall
- Glacis type fall (or) straight glacis fall.
- Montague type fall
- Well (or) Cylinder Notch fall
- English (or) Inglis (or) Baffle fall.

Ogee fall :-

- It was first constructed by "Sir proby cautley" on ganga canal.
- This type of fall has gradual convex & concave surfaces.
- The upstream & Downstream of the fall is protected by stone pitching.
- It is in the shape of "S" or "Ogee"
- It is limited to low depths.
- It has high discharging efficiency.
- It consists of a concrete vertical wall & Concrete bed.
- It is provided for carrying canal water from higher level to lower level.

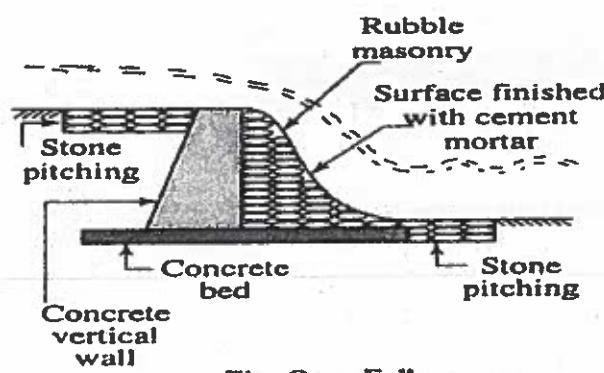
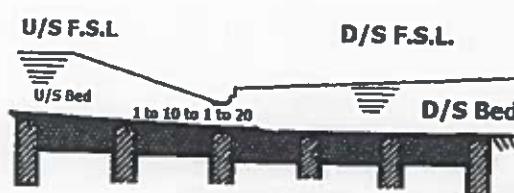


Fig: Ogee Fall

Fig:-OGEE FALL

Rapid fall :-

- It is suitable, when the natural ground level is even & rapid.
- It consists of long sloping glacis.
- Curtain walls are provided on both upstream & downstream sides of the sloping glacis.
- These are expensive, compared to others.
- It consists of a gentle longitudinal slope which varies from 1 in 10 to 1 in 20.
- It is commonly used at west yamuna canal.
- It was first designed by "Lieut. R.F. Crofton"
- The fall worked admirably.



Rapid Fall or Rapid

3. Stepped fall :-

- It is a modification or next development of the rapid fall.

- The cost of this fall is high.
- It consists of a series of vertical drops in the form of steps, so it is named as "Stepped fall"

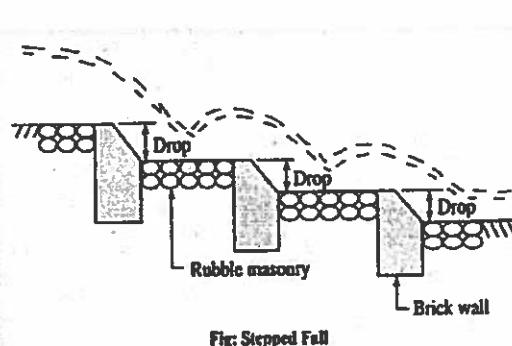
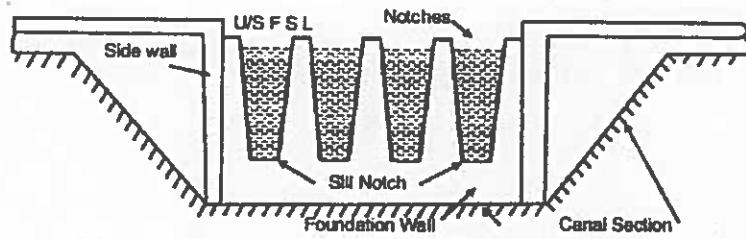


Fig: Stepped Fall

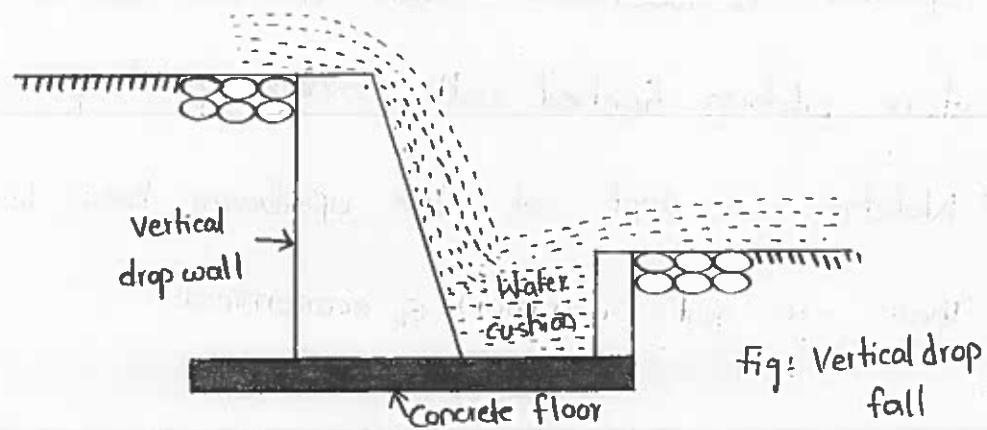
4. Notch fall (or) Trapezoidal Notch fall :

- It was first designed by "Ried" in 1864.
- In this type a body (or) foundation wall across the channel consisting of several trapezoidal notches between side pier & intermediate pier is constructed.
- The body of wall is made of concrete (or) masonry.
- Upstream & Downstream side of the fall is protected by stone pitching finished with cement grouting.
- Notches are kept at the upstream bed level of canal.
- These are quite common & economical.



5. Vertical drop fall (or) Vertical fall (or) Sarada fall :-

- This type of falls provided at sardar canal up. Hence known as "Sarda fall"
- floor is made of concrete upstream, & downstream side stone pitching with cement grouting is provided.
- Water flows over the crest of wall
- Curtain wall provided on upstream & downstream side.
- Easy to construct & economical.
- Losses may be high in case of height depths.
- It is constructed with "masonry" (or) "Concrete".



6. Glacis Type fall (or) Straight glacis fall :

- It utilised the standing wave phenomenon for dissipation of energy.
- The glacis fall may be
 - Straight glacis fall
 - Parabolic glacis fall.
- It consists of a straight glacis provided with a crest wall.
- Curtain walls are provided at toe & heel.
- Stone pitching is required at upstream & downstream of fall.
- Sloping is 2:1
- These have good performance.

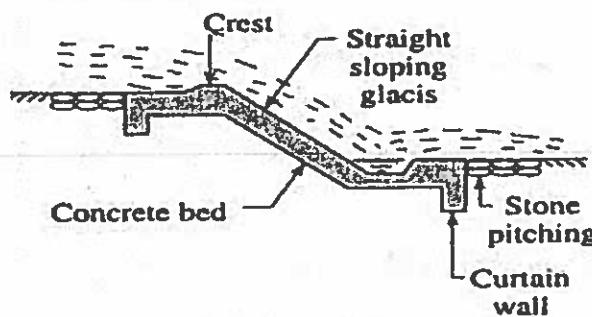


Fig: Glacis Fall

Fig: Glacis fall

7. Montague Type Fall :-

- Profile is parabolic.
- In the straight glacis type profile, energy dissipation is not completed.
- Therefore, montague developed this type of profile where energy dissipation takes place.

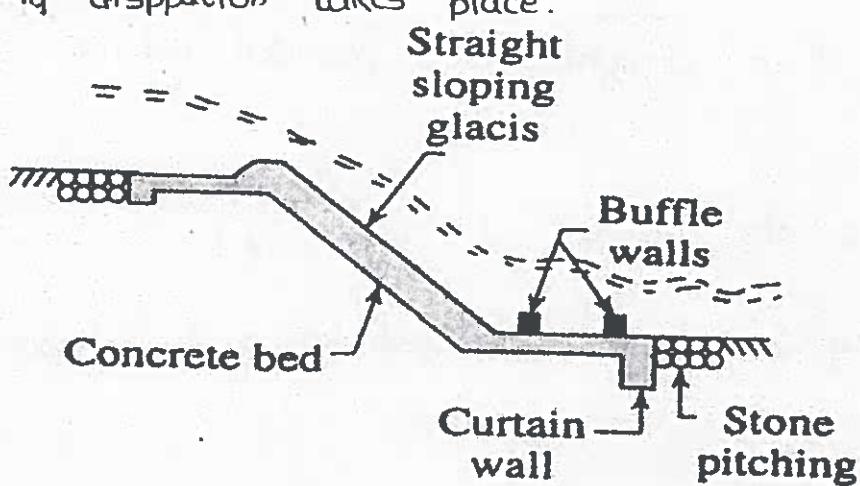


Fig: Inglis Type Fall

8. Well or Cylinder Notch fall :-

- It is economical.
- They are suitable for low discharge.
- Water of canal from higher level is thrown in a well (or) a cylinder from where it escape from bottom.

9. English or Inglis or Baffle fall :-

- Curtain walls provided at toe & heel.

- Stone pitching are essential both at upstream & downstream end.
- It is designed by C.C Inglis.

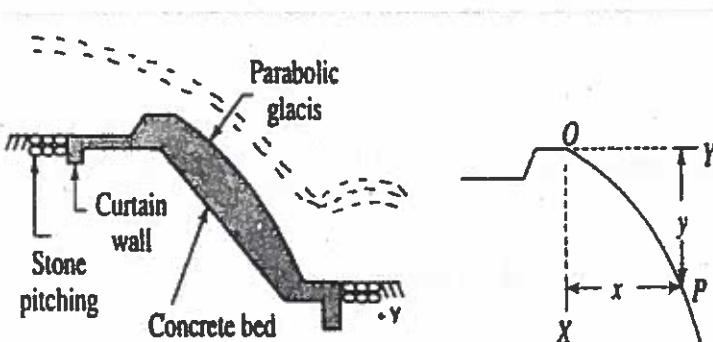


Fig: Montague Type Fall

Classification (or) Classes (or) Principal classes of falls :

Falls may be divided into four principal classes, they are :

Class-1 :

Falls designed to maintain the depth discharge relation.

Class-2 :

Falls designed to maintain a fixed supply level in the channel above the work.

Class-3 :

Falls designed to admit the variations of the surface level above the work at the will of the operator.

Class -4 :-

Miscellaneous type

- (a) Cylinder or Well fall
- (b) Chute or Rapids fall
- (c) Pipe falls.

- Selecting a suitable type of fall at a particular location :-

- The height of fall of water
- The discharge passing over the fall.
- Topography of site location
- Economy
- Type of soil.
- Amount of energy dissipated
- If the bed is soft in nature, then a baffle type of fall is used.
- If the bed is hard in nature, then other type of falls are used.
- Height of drop [H_L].

Purpose of providing falls :-

- It conveys the water from a higher to a lower elevation.
- It is provided on a canal to decrease its water level.

- It destroys the energy dissipated from the falling water.
- Helps to save earthwork.
- Helps to improve command & regulation of canal.

Location of a fall :-

The location of a fall is decided from the following consideration.

- 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.
- for a canal irrigating the area directly, a fall may be provided at a location where F.S.L out strips the ground level but before the bed of the canal comes into filling.
- The location of the may also be decided from the consideration of the possibility of combining it with a regulator.
- A relative economy of providing large number of small falls vs small number of big falls should be worked out.

Design principles of Notch fall & Sarda fall :-

Design of a Trapezoidal Notch fall:-

The procedure for designing the trapezoidal notch falls as described below.

Step-1:

Length of Notch wall:

The length of a trapezoidal notch wall between the abutment is generally considered as equivalent to the bed width of the channel upstream. In other words, the total width of the channel is divided into no. of notches.

Step-2

Length of crest level:

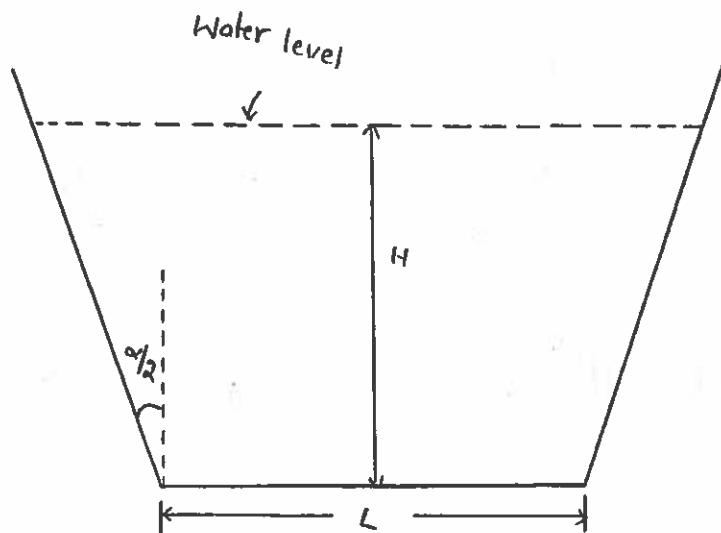
The length of crest level in trapezoidal notch fall is generally taken as at the bed level of the channel upstream. It can also be considered as greater than the level of upstream bed by 0.3 times the water depth which will require a large length of crest.

Step-3

Determination of Discharge (Q):-

The discharge passing through one notch of a notch fall can be obtained by adding the discharge of a rectangular notch &

a v-notch.



From the above figure, the discharge (Q) is given by

$$Q = \frac{2}{3} C_d \sqrt{2g} \cdot L \cdot H^{3/2} + \frac{8}{15} C_d \sqrt{2g} \tan\left(\frac{\alpha}{2}\right) H^{5/2}$$

$$\therefore \frac{2}{3} C_d \sqrt{2g} \left[L H^{3/2} + \frac{4}{5} \tan\left(\frac{\alpha}{2}\right) H^{5/2} \right]$$

$$Q = \frac{2}{3} C_d \sqrt{2g} \left[L H^{3/2} + \frac{2}{5} [2 \tan\left(\frac{\alpha}{2}\right)] H^{5/2} \right]$$

If $2 \tan\frac{\alpha}{2}$ is represented by 'n' then,

$$Q = \frac{2}{3} C_d \sqrt{2g} \left[L H^{3/2} + 0.4(n) H^{5/2} \right]$$

Where

$$C_d = 0.75 \text{ [Co-efficient of discharge]}$$

We know that : $g = 9.81$

$$Q = \frac{2}{3} \times 0.75 \times \sqrt{2 \times 9.81} \left[L H^{3/2} + 0.4(n) H^{5/2} \right]$$

$$Q = 2.22 H^{3/2} [L + 0.4nH]$$

Step-4:-

Discharge over a Drowned Notch:-

In case the trapezoidal notch is drowned then the following equation is used to determine the discharge (Q)

$$Q = C_d \sqrt{2g} [H - h_d]^{1/2} (L + 0.5h_d n) h_d + \frac{2}{3} C_d \sqrt{2g} [H - h_d]^{3/2} [L + 0.5n h_d + 0.4n(H - h_d)]$$

Step-5:-

Number of Notches:-

The no. of notches should be so adjusted by hit & trial method that the top width of the notch lies between $\frac{3}{4}$ to full water depth above the sill of the notch.

Step-6:-

Thickness of Notch piers:-

The thickness of notch piers should not be less than half the water depth & may be kept more if they have to carry a heavy super-structure. The top length of piers should not be less than their thickness.

Step-7

Shape of Notches:-

The shape of the Notches are trapezoidal shaped notch.

Design of a Sarda Type Fall:-

Step-1 :-

Design of Crest :-

i. Length of crest :-

It is kept equal to the bed width of the canal & no fluming is done in this type of fall.

ii. Shape of the crest & Discharge formula :-

Two types of crest are used :-

(a) Rectangular crest [It is used for discharge upto 14 cumecs (50 cuses)].

(b) Trapezoidal crest [It is used for discharge over 14 cumecs]

For the rectangular crest :-

$$\rightarrow \text{Top width of crest} : B = 0.55\sqrt{d} \text{ meter} \rightarrow ①$$

$$\rightarrow \text{Base width of crest} : B_1 = \frac{H+d}{S} \rightarrow ②$$

$$\rightarrow \text{Discharge } (Q) = 1.835 L H^{3/2} \left[\frac{H}{B} \right]^{1/6} \rightarrow ③$$

For the trapezoidal crest :-

$$\rightarrow \text{Top width of crest} : B = 0.55\sqrt{H+d} \rightarrow ④$$

\rightarrow Base width of crest : It is determined by the better

$$\rightarrow \text{Discharge } (Q) = 1.99 L H^{3/2} \left[\frac{H}{B} \right]^{1/6} \rightarrow ⑤$$

iii. Crest level :-

From eq(3) (or) eq(5) the value of 'H' is known

Now, R.L of crest = Upstream 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.

Step-2 :-

Design of cistern :-

The length & depression of the cistern are given by

$$\text{length} (l_c) = 5 [EHL]^{1/2}$$

$$\text{Depression} (x) = \frac{1}{4} [EHL]^{2/3}$$

Step-3 :-

Design of Impervious floor :-

The total length of impervious floor is determined either by

Bligh's theory (or) Khosla's theory.

→ Bligh's theory → For small works

→ Khosla's theory → For large works

The minimum length of floor on downstream of the toe of

the crest wall should be = $[2(\text{water depth} + 1.2\text{m}) + \text{drop}]$

→ The balance can be provided under the crest & on upstream.

The floor thickness required on the downstream side can be worked out for uplift pressure (using minimum thickness of 0.4m to 0.6m)

& only a nominal thickness of 0.3m is provided on the u/s side.

Step-4 :-

Downstream protection :-

The downstream protection consist of

- Bed protection
- Side protection
- Downstream wings

i. Bed protection :

It consists of dry brick pitching above 20cm thick resting on 10cm ballast.

ii. Side protection :

After the return wing, the side of the channel are pitched with one brick on edge. The pitching should rest on a toe wall $1\frac{1}{2}$ brick thick & of depth equal to half the downstream water depth. The side pitching may be curtailed at an angle of

45° from the end of the bed pitching.

iii. Downstream Wings :-

These are kept straight for a length of 5 to 8 times $\sqrt{H \times H_L}$ & may then be gradually wrapped. They should be taken upto the end of pucca floor. All wings walls must be designed as retaining walls, subjected to full pressure of submerged soil at their back when the channel is closed. Such a wall generally has a base width equal to $\frac{1}{3}$ rd of its height.

Step-5 :-

Design of upstream approach :-

For discharge upto 14 cumecs, the upstream 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 of "H" subtending an angle of 60° at the centre & then are carried straight into the berm.

Various regulation works used in canals :-

- Canal falls,
- Canal regulators

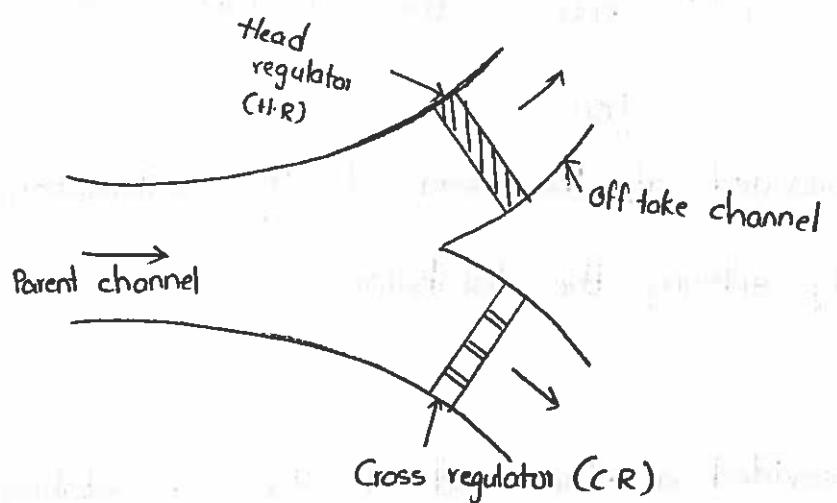
→ Canal escapes

→ Canal outlets

Canal regulation works:

Head regulators:

Definition: Regulators constructed at the off taking point are called as "Head Regulators"



Functions:

→ To control the entry of water either from reservoir (or) main canal.

→ To control the entry of silt into off taking (or) main canal.

→ To serve as a meter for measuring discharge of water.

Types: Two types

→ Distributary head regulator.

→ Canal head regulator.

Distributary Head Regulator :-

Definition :-

If the regulator constructed at the head of distributary canal, then it is known as "Distributary Head Regulator"

(or)

It is provided at the head of the off taking channel to control the supplies entering the off taking canal (or) distributary.

(or)

It is provided at the head of the distributary & controls the supply entering the distributary.

Introduction :-

- It is provided at the head of the off-taking canal to control the supplies entering the off taking canal.
- For regulating the supplies entering the off taking channel from the parent channel, abutments on either side of the regulator interval, crest are provided.
- Piers are placed long the regulator crest at regular interval.
- It is necessary link between the parent channel & the distributing channel.

functions :-

- The Distributary head regulator serves to
- They regulate (or) Control the supply of water to the off taking channel from the parent channel.
- They control the entry of silt in the off taking channel.
- They serve as meter for measuring the discharge entering into the off taking canal.
- They helps in shutting off the supplies when not needed in the off taking channel is required to be closed for repairs.

Figure/Sketch :-

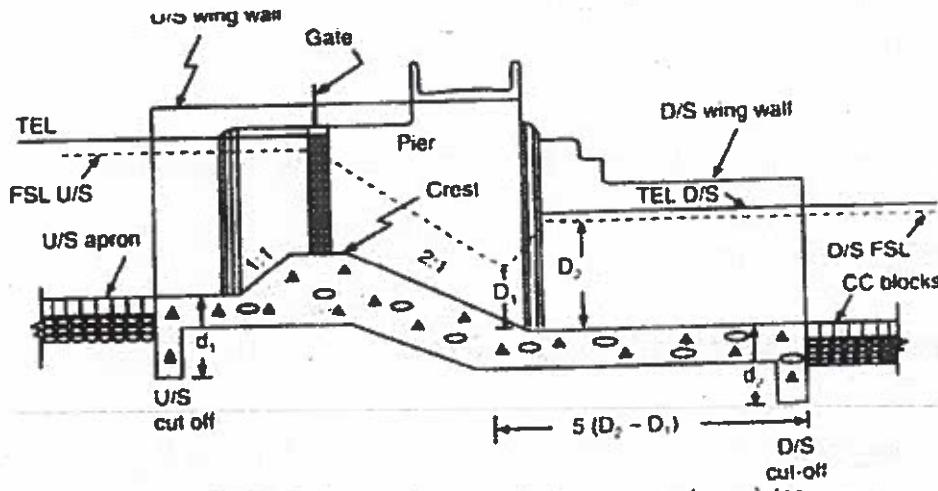


Fig. 19.7. Typical section of a distributary head regulator.

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Components :-

- Gate
- Upstream apron
- Pier
- Crest
- Downstream wing wall
- cc blocks
- Upstream cut off
- Downstream cut off

ii. Canal Head Regulator :-

Definition :-

If the regulator constructed at the head of main canal, then it is known as "Canal Head Regulator"

- Structure at the head of canal taking off from a reservoir may consist of number of spans separated by piers & operated by gates.
- Regulators are normally aligned at 90° to the water.
- upto 10' are considered preferable for smooth entry into canal
- These are used for diversion of flow.
- Silt reduces carriage capacity of flow.

→ Types of canal head regulators

→ Still pond regulation

→ Open flow regulation

→ Silt control devices

(a) Silt excluder

(b) Silt ejectors

i. Still pond regulation :-

Canal draws water from still pond

ii. Open flow regulation :-

Sluice gates are opened & allows the excess of the canal requirements.

iii. Silt Control devices :-

There are two types

(a) Silt excluders

(b) Silt ejectors

Functions :-

→ To control the entry of water either from reservoir (or) main canal.

→ To control the entry of silt into off taking (or) main canal

→ To serve as a meter for measuring discharge of water.

→ To admit water into the off taking canal

→ To regulate the supplies into the canal.

Figure Sketch.

Cross regulators:

Definition:-

A regulator constructed in the main canal (or) parent canal downstream of an off taking canal is called "Cross Regulators"
(or)

It is provided on the parent (or) main channel at the downstream off the off taking canal to head up the water level & to enable the off taking channel to draw the required supply.

Introduction:-

- To head up the water in the parent channel to divert some of the water through an off taking channel.
- It is generally provided downstream of an off taking channel so that the water level upstream of the regulator can be raised.
- It may be combined with bridges or fall for economics, other special considerations.
- It is provided on the main canal at the downstream of the off-take to head up the water level & to enable the off taking channel to draw the required supply.
- It is generally constructed at the distance 9 to 12 km along the main canal & 6 to 10 km along branch canal.

functions :-

- To control the flow of water in canal system
- To feed the off-taking canals.
- To enables closing of the canal breaches on the downstream.
- To provide roadway for vehicular traffic.
- To ensure the safety of canal lining
- It helps in closing the supply to the downstream of the parent channel, for the purpose of repairs.
- To raise the water level of upstream.
- To enables effective regulation of the entire canal system.
- Incidentally, bridges & other communication works can be combined with it.
- They helps in absorbing fluctuation in various sections of the canal system

Design of Gross-Regulator & Distributing Head Regulator :-

Step - 1 :-

Design of crest :-

The discharge is determined by the drowned Weir formula

$$Q = \frac{2}{3} C_1 L \sqrt{2g} \left[(h + h_a)^{3/2} - h_a^{3/2} \right] + C_2 L d \sqrt{2g(h + h_a)} \quad \rightarrow ①$$

Where

Q = Discharge (Cumecs)

L = Length of water-way [meters]

h = Difference in water level upstream & downstream of the channel (in meters)

h_d = head due to velocity of approach

d = Depth of downstream water level in the channel, measured above the crest

C_1 & C_2 = Constants

Where,

$$C_1 = 0.557$$

$$C_2 = 0.80$$

- For the cross-regulator, the crest level is kept equal to the upstream bed level of the parent channel.
- For the distributary head regulator, the crest level is kept 0.3 to 3m higher than the crest level of the crest cross regulator.
- The crest is joined to the downstream with a sloping glacis of 2:1

Step-2 : Design of downstream floor :

The level & length of the downstream floor is determined under

two flow conditions.

→ Full supply discharge passing through both the head regulator & cross-regulator.

→ The discharge in the parent channel being insufficient the cross-regulator gate is partially opened & the off-taking channel is running full & head regulator gate is fully open.

For both of these conditions, the discharge intensity 'q' & the head loss $H_L = h$ are known. Hence, the value of Ef_2 can be found from the Blenck curves.

→ Downstream floor level = $dls \text{ T.E.L} - Ef_2 \pm dlw \text{ F.S.L} - Ef_2$

However, the downstream floor level, calculated from the above relation should never be provided higher than the downstream bed level.

$$\text{Now, } Ef_1 = Ef_2 + H_L$$

Hence, the depth D_1 & D_2 corresponding to Ef_1 & Ef_2 respectively are found from the specific energy curves.

$$\text{Length of downstream floor} = 5[D_2 - D_1]$$

However, the downstream floor should be atleast $\frac{2}{3}$ rd of the total impervious length of the floor.

Step-3 Design of Impervious floor:-

Total length of the impervious floor should be found from the consideration of permissible exit gradient.

→ The depth of upstream cutoff

$$d_1 = \frac{1}{3} \text{ upstream water depth} + 0.6\text{m}$$

→ The depth of downstream cutoff

$$d_2 = \frac{1}{2} \text{ downstream water depth} + 0.6\text{m}$$

→ Maximum static head [H_s] = upstream F.S.L - downstream floor level

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

Then from the exit gradient curves, $\alpha = bdg$ is known. Hence, the total length 'b' of the impervious floor is known. The floor thickness is found from the considerations of uplift pressure. A minimum thickness of 0.3 to 0.5m is provided from the practical considerations.

Step-4 : Design of upstream & Downstream protection:-

→ Upstream scour depth d_1 is taken equal [$\frac{1}{3}$ upstream water depth + 0.6m]

→ Downstream scour depth d_2 is taken equal [$\frac{1}{2}$ downstream water

depth + 0.6m]

→ These scour depths are below the corresponding bed levels, & protection works are to be designed corresponding of these.

(a) Upstream protection :-

The upstream protection consists of a block protection having cubic contents = d_1 cubic meters/meters.

→ The cubic contents of upstream launching apron is kept equal to $2.25 d_1$ cubic meter/meter width of regulator.

(b) Downstream protection :-

The cubic contents d of downstream inverted filter is kept equal to d_2 cubic meter/meter. The cubic contents of downstream launching apron is kept equal to $2.25 \cdot d_2$ cubic meter/meter width of regulator.

Canal Outlets & Types of canal Modules :-

Outlets / canal Outlets / canal Modules / Farm turn outs :-

Definition :-

An outlet is a small structure which admits water from the distributing channel to a water course (or field channel

(or)

A canal outlet (or) module is a small structure which is built at the head of water course so as to connect it with a minor (or) distributory channel.

- It acts as a connecting link between the system manager & the farmers.
- Outlets are also called as canal outlets (or) canal modules (or) farm turnout.

(or)

Canal outlet is a structure (or) device through which water is released from a distributing channel into a water course (or) field channel. The discharge through an outlet is usually not less than 0.03 cumec & not more than 0.085 cumec.

Optimum size of an outlet:

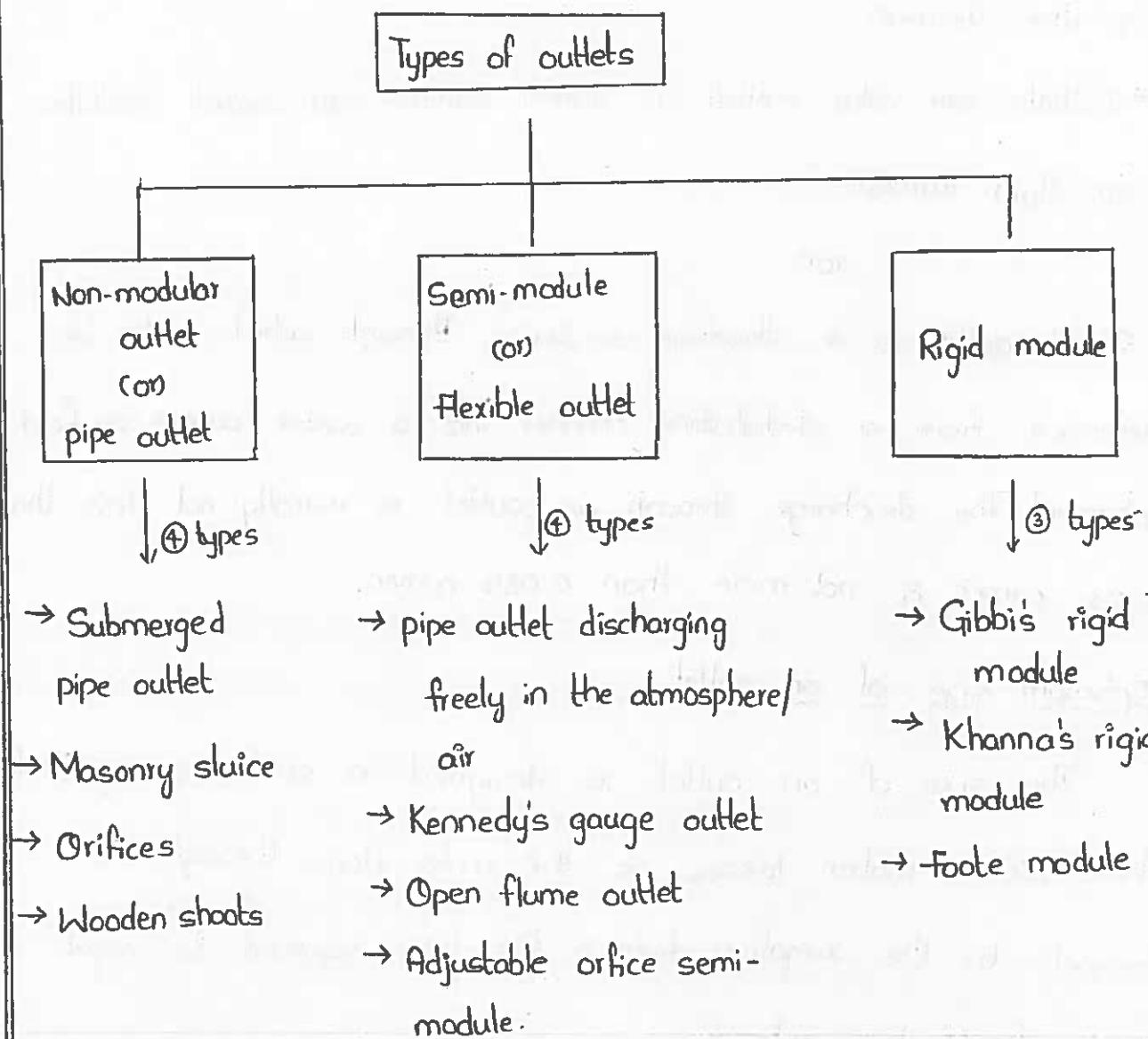
The size of an outlet is designed in such a way that there are no water losses as the water flows through the channels to the irrigation field & the time required to irrigate a field should be optimum.

Types (or) Classification:

Outlets (or) Canal outlets (or) canal modules may be classified

under the following three heads.

- Non-modular outlet (or) pipe outlet
- Semi-modular (or) Flexible module/Outlet
- Rigid modules (or) Modular outlet



Non-Modular Outlets (or) pipe outlet :-

Definition :-

Non-modular outlets are those modules through which the

discharge depends upon the head difference between the distributary & water course.

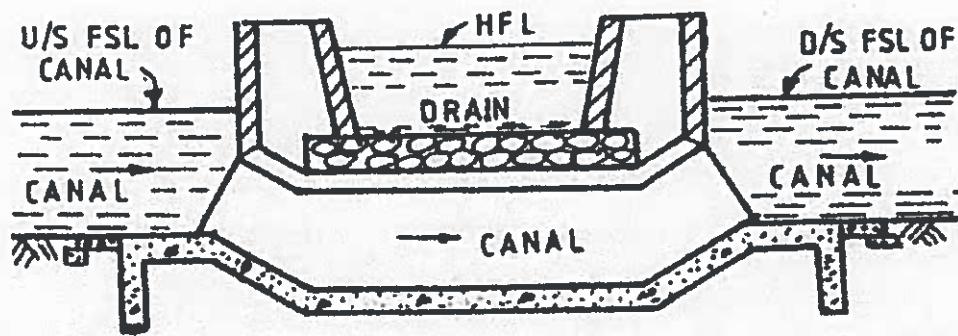
(or)

It is the outlet whose discharge depends upon the difference in water levels of both the distributing channel & water course.

Ex :- Open sluice, Masonry sluice & submerged pipe outlet

Description :-

- In this type of module, the discharge depends upon the head difference between the distributary & water course.
- Non-modular outlets are also called as pipe outlet.
- Head loss is less.
- The pipes vary from 10 to 30 cm dia.
- The pipe should be laid on a light concrete foundation to prevent uneven settlement & consequent leakage.
- Generally fixed horizontally at right angles to the direction of flow.
- The pipe outlet is the most common type of non-modular outlet
- Open sluice, masonry & orifice, submerged pipe outlet are the best examples of non-modular outlet.



Types

The following are the types of Non-modular outlet :

- Submerged pipe outlet
- Masonry sluice & orifice
- Wooden shoots

2. Semi-modular (or) Flexible Outlets :-

Definitions :-

Semi-modular or flexible outlets are those modules, through which the discharge is independent of the water level of the water course but depends only upon the water level of distributary.

(or)

It is the outlet whose discharge depends only upon the

water level in the distributary & is independent of the water level in the water course.

Examples :-

Pipe outlet, Kennedy's gauge outlet & open flume type etc.

Description :-

- In this type of module, the discharge is independent of the water level of the water course but depends only upon the water level of distributary.
- Semi-module is called as "flexible outlet".
- Head loss is more
- Pipe outlet, Kennedy's gauge outlet & open flume, type are the best examples of semi-module.

Types :-

- The following are the common type of semi-module.
- Pipe outlet discharging freely in the atmospheric air.
 - Kennedy's gauge outlet
 - Open flume outlet
 - Orifice semi-modules

i. Pipe outlet discharging freely in the atmospheric air :-

If the pipe outlet is so set that it is discharges freely in the atmosphere, the discharge through it becomes independent of the water level in the field channel & hence it acts as semi-module.

ii. Kennedy's gauge outlet :-

- It is also called as "Venturi flume outlet".
- It is an oldest one.
- It is designed by Kennedy in the year 1906 at punjab.
- This outlet is made of cast iron
- The discharge through this semi-module is

$$Q = C \alpha \sqrt{2gH_0}$$

iii. Open flume outlet :-

- The discharge through this semi-module is

$$Q = CB_t H^{3/2}$$

There are 2 types

- (a) Crump's open flume outlet
- (b) Punjab open flume outlet

- The formation of the hydraulic jump makes the discharge through the outlet independent of the water level in the water course, making it a semi-module.
- It is sort of weir with constructed throat at expanding flume on the downstream.

iv. Orifice Semi-modules :-

- An orifice semi-module consists of an orifice provided with a gradually expanding flume on the downstream side of the orifice.
- The flow through the orifice is hyper critical, resulting in the formation of hydraulic jump.
- This makes the discharge independent of the flow conditions in the water-course.
- It is also called as Crump's adjustable proportional module (Crump's A.P.M.).
- This type is the most commonly used outlet under this class.
- In this type of outlet, C.I base, C.I roof block & check plates on either side from the nuclear around which masonry is built.

→ The discharge through the outlet is

$$Q = 4.03B_t y \sqrt{H_s}$$

Where

Q = Discharge (cumecs)

B_t = width of throat (meter)

y = ht of the smallest section (meter)

H_s = Head measured from the water surface to the lowest point of the roof block (meter).

3. Rigid Module (or) Modular outlet :-

Definition:-

Rigid module (or) modular outlet are those modules, through which discharge is constant & fixed within limits, irrespective of the fluctuations of the water levels of either the distributary (or) the water course (or) both.

(or)

It is the outlet whose discharge is independent of the water levels of both the distributary & the water course.

Example :- Gibbs module.

Types :

The three common types of rigid modules:

- Gibbi's rigid module
- Khanna's rigid module
- Foote module

i. Gibbi's rigid module :-

- It is designed by A.S GIBB
- He is the formerly executive engineer in punjab, irrigation department.
- Discharge (q) between 0.03 to 0.45 cumec.
- Gibbi's gives the following formula for the discharge through the outlet

$$q = \gamma_0 \sqrt{2g} (d_i h_o)^{1.5} \left\{ \frac{m^2 - 1}{m^3} \log_e^m + \frac{1}{m} \log_e^m - \frac{m^2 - 1}{2m^2} \right\}$$

- The essential feature of the outlet is an eddy chamber, semi-circular in plan, round which water flows giving rise to a free vortex flow.

ii. Khanna's Rigid module :-

- It is similar to orifice semi-module.

Requirements of a good outlet :-

- i. It should be simple in design, construction & maintenance.

- It should be quite strong & durable
- It should be cheap.
- It should be easily constructed by local workers (or) masons.
- It should be sufficiently strong with no moving parts
- It should not be easily tampered.
- It should not be expensive.
- It should be worked efficiently with a small working load.

Advantages:

- It should be simple in design, construction & maintenance.
- It should be quite strong & durable.
- It should be cheaper
- It should be easily constructed by local workers (or) masons.
- It should be sufficiently strong with no moving parts
- It should not be expensive

Dis-advantages

- It should not be expensive.

Difference between Non-modular, semi-modular & Rigid module outlets:

Non-modular	Semi-modular	Rigid Module
The discharge depends upon the head difference b/w the distributary & water course	→ The discharge is independent of the water level of the water coarse but depends upon the water level of distributary	→ The discharge is constant, fixed within limits irrespective of the fluctuations of the water level of either distributary (or) water course (or) Both.
→ It is also called as "pipe outlet"	→ It is also called as "flexible outlet module"	→ It is also called as "Modular outlet"
→ Head loss is less	→ Head loss is more	→ Head loss is moderate
→ Variation of water level effects the discharge	→ In variation of water level in distributary increase the discharge.	→ Variation of water level in distributary does not effect discharge.
→ Ex:- Open Sluice Masonry sluice	Ex:- pipe outlet Kennedy's gauge outlet	Ex:- Gibbis module.

Cross Drainage Works:-

Definition:-

It is structure carrying the discharge of a natural stream across a canal intercepting the stream

(or)

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

Introduction:-

- It is a structure carrying the discharge from a natural stream across a canal Intercepting the stream.
- It is generally a very costly item
- It should be avoided as far as possible by:
 - i. Diverting one stream into another
 - ii. Changing the alignment of the canal so that it crosses below the junction of two streams.
- Once the canal is taken to the watershed, no cross-drainage works are normally necessary except when the canal leaves the watershed for some distance forming a loop.

→ When the canal is aligned as a contour canal, a no. of cross drainage works are necessary.

Types / Classification / Categories :-

Depending upon the relative levels & discharges cross-drainage works may be of the following types:

Type-1 [C.D works carrying canal over the drainage].

Type-2 [C.D works carrying drainage over the canal]

Type-3 [C.D works admitting the drainage water into the canal]

Type-1:

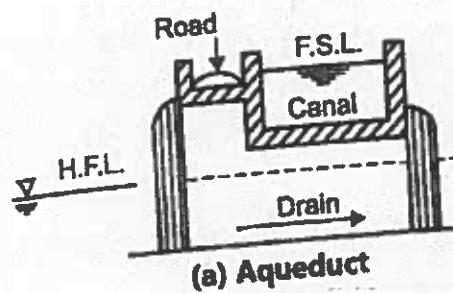
C.D works carrying canal over the drainage :-

- In this type of C.D work, the canal is carried over the neutral drain.
- The advantage of such arrangement is that the canal, running perennially, is above the ground & is open to inspection.
- The damage done by floods is rare
- However, sometimes during heavy floods the foundation can be scoured.
- The structures that fall under this type are :

i, Aqueduct ii, Syphon aqueduct

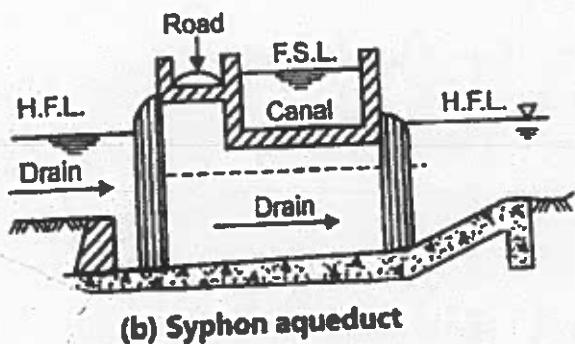
i. Aqueduct :-

When the HFL of the drain is sufficiently below the bottom of the canal such that the drainage water flows freely under gravity, then the structure is known as "Aqueduct".



ii. Syphon aqueduct:

When the HFL of the drain is much higher above the canal bed & water runs under siphonic action through the "Aqueduct barrels".

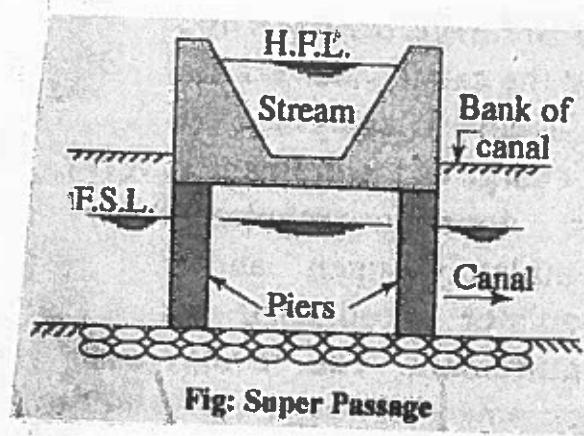


Type -II :

C.D works carrying drainage over the canal :-

- In this type of C.D work, drainage is carried over the canal
- The advantage of this type of C.D works, that 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 :
 - i. Super - passage.
 - ii. Canal Syphon.
- i. Super - passage :-

- The hydraulic structure in which the drainage is passing over the irrigation canal is known as "Super Passage"
- The structure is suitable when the bed level of drainage is above the flood surface level of the canal.
- It is similar to an aqueduct except in this case the drain is over the canal.
- It is the reverse of an aqueduct.



ii. Canal Siphon :

- If two canals cross each other & one of the canals is syphoned under the other, then the hydraulic structure at the crossing is called "Canal Siphon"
- It is reverse of an aqueduct siphon.
- In case of siphon the FSL of the canal is much above the bed level of the drainage through, so that the canal runs under the siphonic action.

Type -III :

C:D works admitting the drainage water into the canal :-

- In this type of work, the canal water & the drainage water are permitted to intermingle with each other.
- The only advantage of this type of work is its low initial cost.
- Such type of works have the following disadvantages
 - i. Regulation of such a work is difficult & requires additional staff
 - ii. There is additional expenditure of silt clearance.
 - iii. The faulty regulation of gates may damage the canal
- The structures that fall under this type are
 - Level crossing
 - Inlet & outlets

i. Level crossing :

It is the constructed in the circumstance when the beds of the canal & drainage are practically at the same level

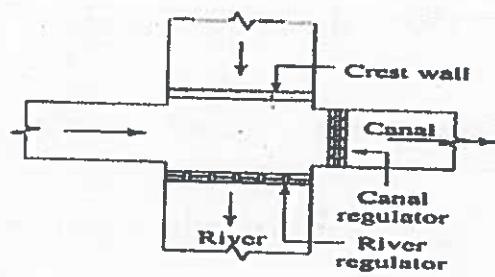
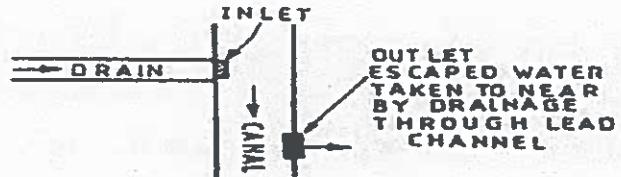
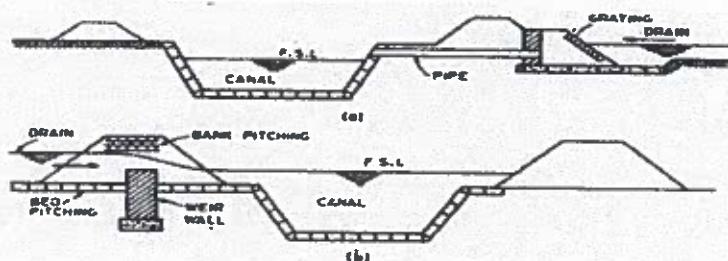


Fig: Level Crossing

ii) Inlet & Outlets :



Canal Inlet and Outlet Plan



→ A canal inlet is constructed when cross-drainage flow is small & its water may be absorbed into the canal without causing appreciable rise.

→ However, if the canal is small, an outlet may be constructed to pass out the additional discharge which has entered the canal.

Selection of suitable site of cross drainage work :-

- At the site, the drainage should cross the canal alignment at right angles.
- The stream at the site should be stable & should have stable banks
- For economical design & construction of foundations a firm & strong sub-stratum should exist below the bed of the drainage at a reasonable depth.
- The site should be such that long & high approaches of the canal are not required o.s
- In the case of an aqueduct, sufficient headway should available between the canal trough & the high flood level of the drainage
- The water table at the site should not be high, because it will create dewatering problems for laying foundations.
- A CD work should be combined with a bridge if required.

→ The site should be selected downstream of the confluence of two streams, thereby avoiding the necessity of construction of two CD works

Selection of suitable type of cross-drainage work :-

- If the bed level of the drain is well above the F.S.L of the canal, super-passage is provided.
- If it is not possible to change the canal alignment or if such a shifting does not give sufficient headway between the two levels, a syphon aqueduct may be provided.
- When, the canal bed level is much lower, but the F.S.L of the canal is higher than the bed level of the drainage, a canal syphon is preferred.
- When the drainage & the canal cross each other practically at the same level, a level crossing may be preferred. This type of work is avoided as far as possible.
- The considerations governing the choice between aqueduct

& syphon aqueduct (or) super - passage & syphon are :-

- i. Suitable canal alignment
- ii. Nature of available foundation
- iii. Suitable soil available for bank connections.
- iv. Availability of funds
- v. Permissible head loss in canal.
- vi. Relative bed levels.

Need/ Necessity :-

The following are the necessity of CD works

- The water - shed canals do not cross natural drainages
- At the crossing points, the water of the canal & the drainage get intermixed.
- The site condition of the crossing point & the drainage get intermixed.
- The site condition of the crossing point may be such that without any suitable structure, the water of the canal & drainage can not be diverted to their natural directions.
- The drainage water can be disposed easily.

Factors affecting CD works :-

- Accessibility of existing modes of communication.
- Availability of materials & labours
- Discharge in the channel & drainage
- Foundation conditions of the side
- Bed level of the channel
- Bed level of the natural drainage
- Existence of valuable resources.

Causes for the failure of CD works :-

- Improper investigation
- Inadequate maintenance
- Structure not located properly & the foundation is not strong.
- Negligence in quality control.

Features of design of cross-drainage works :-

The following are the some of the important features of design of cross-drainage works

A. Hydraulic Design:-

- Determination of maximum flood discharge & the High flood Level [H.F.L]
- fixation of water way of the drain.
- Contraction of canal waterway
- Clearance & free board.
- Head loss through siphon barrels.
- Determination of uplift pressure on the roof of trough.
- Determination of uplift pressure on the floor.
- Design of bank connections.

B. Structural Design :-

- Design of the cross-section of the siphon barrels & the aqueduct trough.
- Design of piers & abutments
- Design of foundations.

Difference between Aqueduct, Siphon aqueduct & super passage :-

Aqueduct	Syphon aqueduct	Super Passage
→ The hydraulic structure in which the irrigation canal is taken over the drainage [such as rivers & stream] is known as "aqueduct"	→ The hydraulic structure where the canal is taken over the drainage but the drainage water cannot pass clearly below the canal. It flows under siphon action. So, it is known as "Siphon aqueduct".	→ The hydraulic structure in which the drainage is taken over the irrigation canal is known as Super Passage.
→ It is also called as "ordinary aqueduct"	→ The flow in the barrel is a pipe flow.	→ —
→ The flow in the barrel is an open channel flow	→ It is also called as "Under tunnel"	→ The flow in the canal is an open channel flow.
→ The structure is suitable when the bed level of canal is above high est flood level of drainage	→ This structure is suitable when the bed level of canal is below the high est flood level of drainage.	→ The structure is suitable when the bed level of drainage is above the highest flood level at canal.
→ In this case, the drainage water passes clearly below the canal.	→ In this case, the drainage water passes clearly above the canal	→ In this case, the canal water passes clearly below the drainage.

Classification | Types of aqueducts & syphon aqueduct:-

Depending upon the nature of the sides of the aqueduct
(or) syphon aqueduct may be classified under three heads.

Type-I: Sides of the aqueduct in earthen banks, with complete earthen slopes

Type-II: Side of the aqueduct in earthen banks with outer slopes supported by masonry walls.

Type-III: Sides of aqueduct made of concrete (or) masonry.

Type-I Aqueduct:

Sides of the aqueduct in earthen banks with complete earthen slopes:

In the first type, the original canal section is retained & no fluming is done. The sides of the aqueduct are kept in earthen banks with complete earthen slopes.

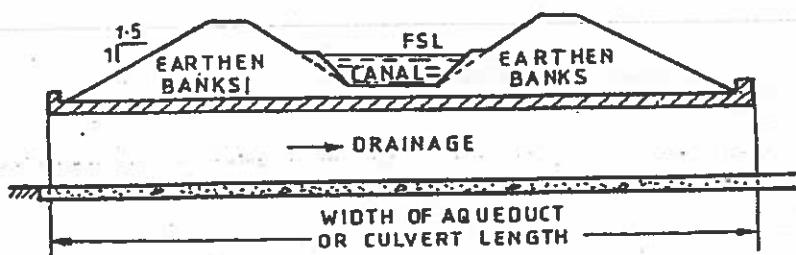


Figure 8. Type I Aqueduct

Type-2 Aqueduct

Sides of the aqueduct in earthen banks, with outer slopes supported by Masonry walls:-

Type-2 is intermediate b/w the two in which the sides of aqueduct are in earthen banks ^{but} the outer section is reduced by supporting it ~~b/w~~ by masonry (or) Concrete walls.

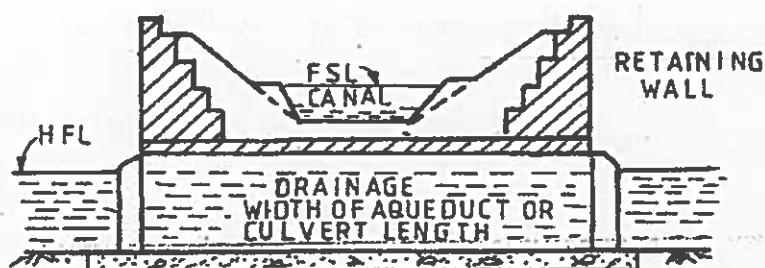


Figure 9. Type II Aqueduct

Type-3 aqueduct:-

Sides of the aqueduct made of concrete (or) Masonry:-

In the third type, on the contrary, the canal section is reduced, fluming is done & the sides of the canal are made of concrete or masonry.

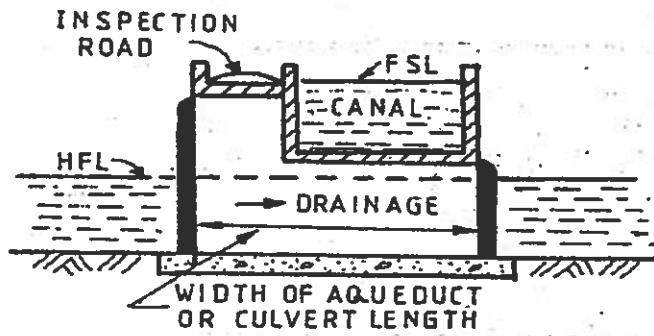


Figure 10. Type III Aqueduct

Selection of a suitable type of aqueduct:-

In order to select a suitable type of aqueduct out of three, it is necessary to understand three terms:

- Culvert length
- Length of the aqueduct
- Bank Connections

The correct way of selecting a type is to work out cost of three types & see which is cheaper.

Design principles of Aqueduct, Syphon aqueduct & super passage!

(a) Design of aqueduct:-

- By using Lacey's equation $P = 4.75 \times \sqrt{Q}$, compute the required water way.

- Select the span & the no. of spans
- After selecting the type of aqueduct & fluming ratio, determine the canal water way.
- Fix the dimensions of the canal & also the no. of compartments.
- Design the transition of the canal is flumed.
- Compute the height of piers, abutments, maximum scour.
- Design the foundation
- Provides the suitable bank connections.

(b) Design of Syphon aqueduct :-

- Design of drainage water-way.
- Design of canal water-way
- Design of level at different sections.
- Design of contradiction transistion
- Design of expansion transistion.
- Design of trough.
- Head loss through syphon barrels
- Uplift pressure on the roof

- Uplift on the floor of the barrel & its design
- Design of cutoff & protection works for the drainage.
- floor

c. Super passage :-

- Water way of the Drainage
- Splay
- Afflux
- Cut-off
- Impervious floor
- Waterway of the canal
- Concrete Block protection.

