HYDRAULICS & IRRIGATION ENGINEERING

MODULE IV

IRRIGATION STRUCTURES

An irrigation system consists of storage reservoirs, diversion structures, canals and related structures, outlets and drainage facilities. The different structures in an irrigation system are

1. Main Reservoir- which can be a masonry dam or concrete dam or earth dam, or rock fill dam.
2. Diversion Headworks -which include weirs and barrages
3. Canals-which may be main canals, secondary canals, and water courses
4. Canal Structures -which include canal falls. Canal regulators, canal escapes
5. Cross Drainage works -which include aqueducts, syphon aqueducts, super passages, level crossings, canal inlets and outlets

HEAD WORKS AND WEIRS.

A **head work** is a hydraulic structure which supplies water to the off-taking canal. They are constructed at the head of the canal, at the point of take-off. The object of a head work is to divert clear water in to the canal for irrigation purposes.

CLASSIFICATION OF HEAD WORK (from Engineering Aspect)

1. Diversion work

2. Storage work

1. DIVERSION HEAD WORK:

They serve to divert the required supply into the canal from the river. It serves the following purposes:

a) It raises the water level in the river so that the command area can be increased

b) It regulates the intake of water into the canal

c) It controls the silt entry into the canal

d) It reduces fluctuation in the level of supply in the river

Diversion head works are suitable when sufficient supplies are available in the river. Weirs and barrages are examples of diversion headworks

2. STORAGE WORK

A storage headwork includes the construction of a dam across a river. It stores water during the period of excess supplies in the river and releases it when demand is greater than

available supplies. Here the canal starts from a high level receives sufficient quantity of water from head work and water is supplied to the field by gravity.

CLASSIFICATIONS ACCORDING TO THE PURPOSE SERVED

1. Irrigation schemes: The water from the head work is used only for irrigation purpose
2. Hydroelectric schemes : The water from the head work is used only for the power generation
3. Multipurpose schemes : The water from head work is used both for irrigation and power generation

SUITABILITY OF STORAGE AND DIVESRION HEAD WORK

Storage Headworks are suitable when the perennial river has a steep gradient, flows through a valley and where storage in the form of a reservoir is possible. Here the canal starts from a high level receives sufficient quantity of water from head work and water is supplied to the field by gravity

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Diversion Headworks- Diversion head works are suitable in deltaic tract when the river is perennial and flows on a mild gradient and sufficient supplies are available in the river. Since delta tract is a plain country, a little amount of rise of water will be enough to divert water into canal and storing is not possible.

FACTORS SUITABLE FOR SELECTION OF SITE FOR HEADWORK

1. The material required should be locally available
2. Section of river should be narrow to reduce magnitude of head work & river training work
3. Economical and safe disposal of water should be available
4. Transportation of material to the site should be convenient,
5. Percolation losses in the region should not be excessive
6. Demand for water should be sufficiently large
7. No: of cross drainage should be less
8. Economical canal lining should be available
9. They may be located in a sub mountainous stage and site located at hill reach is not suitable.

STORAGE HEADWORK

A storage headwork includes the construction of a dam across a river. It stores water during the period of excess supplies in the river and releases it when demand is greater than available supplies.

DAM

A dam is a hydraulic structure constructed across a river to store water on its upstream side

It serves two purposes

1. It retains water to form a reservoir

2. It passes water over or through it to canals when required

CLASSIFICATION OF DAMS

A. According to material used in construction

1. Rigid Dams -are dams which are constructed of rigid materials

i) Timber Dams ii) Steel Dams iii) Arch masonry or concrete dam iv) Concrete Buttress dams v) Solid masonry or Concrete gravity dam

2. Non-Rigid Dam-are dams which are constructed of non-rigid materials

i) Rock fill Dam (ii) Rock and earth fill dam (iii) Earth dam

B. According to purpose served/based on function

i) Storage dams : is constructed to impound water to its upstream side during the periods of excess supply in the river and is used in periods of deficient supply. A storage dam may be constructed of stone, concrete, earth or rockfill

ii) Diversion dams: A diversion dam raises water level slightly in the river and provides a head for diverting water into the canals. A diversion dam is of smaller height and no reservoir is formed to store water. Eg: Weirs and Barrages.

iii) Detention Dams: A detention dam is constructed to store water during floods and release it gradually at a safe rate, when the flood recedes. Small dams constructed to delay and to detain the flow are called detention dam or check dam

iv) Coffer dam

v) Debris dam

C. According to Hydraulic design :

i) Over flow dam : A dam which is designed to carry surplus discharge over the crest of dam. The crest of the dam is kept lower than the top of the other portion of the dam.: Solid gravity dam made of masonry or concrete

ii) Non-over flow dam : Here water is not allowed to flow over the crest of the dam. The top of the dam is kept at a higher elevation than the maximum expected high flood level. Ex: Earth and Rock fill dam.

D**. According to Principles adopted for stability/based on structural behaviour**

i) Arch dam : An arch dam is mainly curved in plan and carries a major part of load horizontally to abutments by arch action. In this type of dam, load is mainly transferred to the abutment by arch action

ii) Buttress dam : A buttress dam consist of a number of buttresses along its length. In buttress dam load is mainly transferred to the supporting buttresses.

iii) Gravity dam : A gravity dam is one in which the external forces such as water pressure, wave pressure, uplift pressure etc are resisted by the weight of the dam. A gravity dam may be straight or curved in plan. Gravity dams are relatively more strong and stable.

According to the design features of gravity dam:

- Low dam : It is designed on the basis of theoretical profile of a solid gravity dam.
- High dam : It is not a simple structure as a low dam. Dam section is accordingly modified to achieve the required stability when allowable stresses are exceeded.

E. Based on size

i) Small Dam

ii) Intermediate Dam

iii)Large Dam

COMPONENTS OF A DAM/ CROSS SECTION OF A DAM

1. Heel- The part of dam meeting with the upstream side or ground water is called heel

2. Toe-The portion of the dams meeting with the groundwater or downstream side is called the Toe,

3. Abutments-are the structures extending to sides of valley

4. Crest -The topmost level of a dam is called crest of dam. It is the upper area of dam which is used as roadway or walkway

5. Galleries-These are hollow openings passing through the dam to collect seepage water from the foundation and body of dam and then drain it out. It is known as drainage gallery. Inspection galleries are also provided in dams for inspection purpose

6. Spillways-Spillway helps in emergency discharge of water from upstream side to downstream side.

7. Sluiceway-is provided to remove the accumulated silt

8. Full Reservoir Level **(FRL)**: It is a level up to which water is generally stored.

9. Maximum water level (MWL) or High flood level: During flood seasons, the reservoir attains this level. The dam and spillway sections are designed to with stand water pressure at this level.

10. Free-Board: To prevent overtopping of dam, during the period of peak flood a sufficient margin is left between FRL and top of dam.

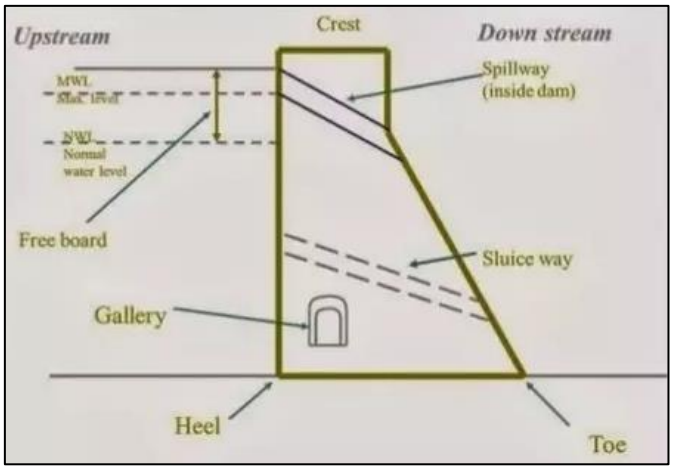
. Gross free Board: Difference of level between FRL and Dam top

. Net Free Board: Difference of level between MWL and Dam top

11. Dead Storage: Storage of water below bed level. It is provided to contain the silt load coming in the reservoir.

12. Gross storage: Volume of water stored up to FRL

13.Live storage : Also called available storage. It is the difference between gross storage and dead storage.



GRAVITY DAM

A gravity dam is a structure which is designed in such a way that its own weight resists the external forces acting on dam. Gravity dams can be constructed of masonry or concrete. Gravity dams are more strong and stable. They need a strong foundation. A gravity dam may be either straight or curved in plan.

PARTS OF GRAVITY DAM

- **Heel:** It keeps contact with the ground on the upstream side
- **Toe:** It keeps contact on the downstream side
- **Abutment**: It is the sides of the valley on which the structure of the dam rest
- **Galleries**: Small rooms like structure left within the dam for checking operations.
- **Diversion tunnel**: Tunnels are constructed for diverting water before the construction of dam. This helps in keeping the river bed dry.
- **Spillways**: It is the arrangement near the top to release the excess water of the reservoir to downstream side

- **Sluice way**: An opening in the dam near the ground level, which is used to clear the silt accumulation in the reservoir side.

Forces acting on a gravity dam

The various forces acting on a gravity dam are

1. Weight of the dam- Weight of the dam body and its foundation is the major resisting force. The c/s of dam can be divided into rectangles and triangles. The weight of each along with their centre of gravity can be determined. The resultant of all those downward forces will represent the total weight of the dam acting at the centre of gravity of the dam

2. Water Pressure- water pressure varies from 0 at the water surface to wH at the base, where w is the density of water.

   The resultant force due to water pressure = $wH^2/2$ acts at H/3 from base

3. Uplift Pressure- Water seeping through the pores, cracks and fissures of foundation and water seeping through dam body exerts an uplift pressure on the base of the dam. Such an uplift force reduces the weight of dam and acts against dam stability.

4. Pressure due to earthquake forces- When dam is located in a region prone to earthquake, allowance must be made for the stresses generated by earthquake.

5. Silt Pressure- Silt gets deposited against the upstream face of the dam. If h_S is the height of silt deposited, then the force exerted by this silt should be calculated in addition to the external water pressure.

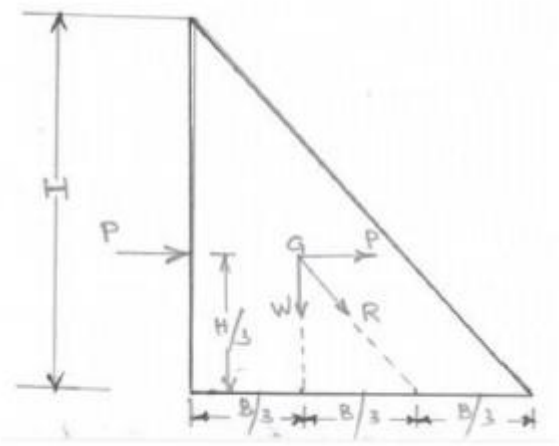
   Silt pressure, $P_s = (w_s h_s^2 K) / 2$, acts at $h_s/3$

   Where, K is coefficient of active earth pressure

   w_s = Submerged unit weight of silt material

6. Wave Pressure- Waves are generated on the surface of the reservoir by the blowing wind, which exerts a pressure towards the downstream side. Wave pressure depends upon the wave height.

Elementary profile of a gravity dam



FAILURE OF A GRAVITY DAM

A gravity dam may fail by overturning, sliding, crushing or tension

1. Overturning- The overturning of a dam may take place if the resultant of all forces acting on the dam passes outside the base.

2. Sliding- A dam will fail in sliding when the horizontal force causing sliding are more than the resistive force. The resistance against sliding is induced by frictional force between the dam and the soil.

3. Crushing- A dam may fail by the failure of its material, when compressive stresses produced may exceed the allowable stresses and the dam material may get crushed.

4. Tension-A dam should be designed in such a way that no tension develop at the base of dam. To avoid tension, bending stress should be less than direct stress.

GALLERY IN DAMS

A gallery is a formed opening left in a dam. Galleries may be provided transverse or in longitudinal direction or may run horizontally or on a slope. The shape and size of a gallery vary from dam to dam. Galleries may be provided as drainage gallery or inspection gallery. Galleries can be provided as rectangular shape with corners rounded or as oval shaped.

Purpose of providing gallery in dam

1. To provide drainage of dam section. Some amount of water constantly seeps through the upstream face of dam which is drained off through galleries-drainage gallery
2. To provide facilities for drilling and grouting operations for foundations.
3. To provide access to observe and measure the behaviour of structure after its completion and examine the development of cracks-inspection gallery
4. To provide an access for mechanical devices for operating outlet gates and spillway gates.

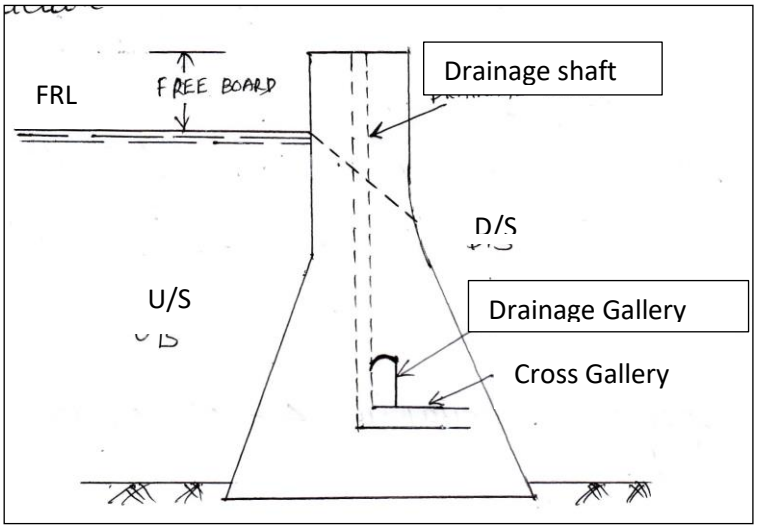
DRAINAGE GALLERY

A drainage gallery is an opening provided in the body wall of gravity dam in the longitudinal direction to the dam. Purpose of a drainage gallery

1. Drainage of water percolating from upstream face or seeping through foundation of dam.

2. Drainage gallery may be provided as an access for drilling and grouting operation for foundation etc.

3. Drainage gallery may also be provided as an access to observe and measure behaviour of the structure



SHAFTS- Vertical openings in the dam are called shaft. Shafts are provided to connect galleries at various levels

EARTH DAM

Earth dams are constructed of locally available soils and gravels. Earthen dams can be easily constructed on earthen foundations. Earthen dams are trapezoidal in cross section and has a wider width at the base.

An earth dam is an embankment generally less than 30 m in ht with two faces having slopes. The u/s face called as the water face is given a slope of 2:1, if ht of the dam is < 15m.

It is given a slope of 3:1 in U/s and 2:1 in D/s, if height of dam is > 15 m.

Top width varies from 1.5 m to 7.5 m

Free Board varies from 1.5 m to 3.5 m

The water face is generally protected by dry stone pitching to protect the dam from wave action.

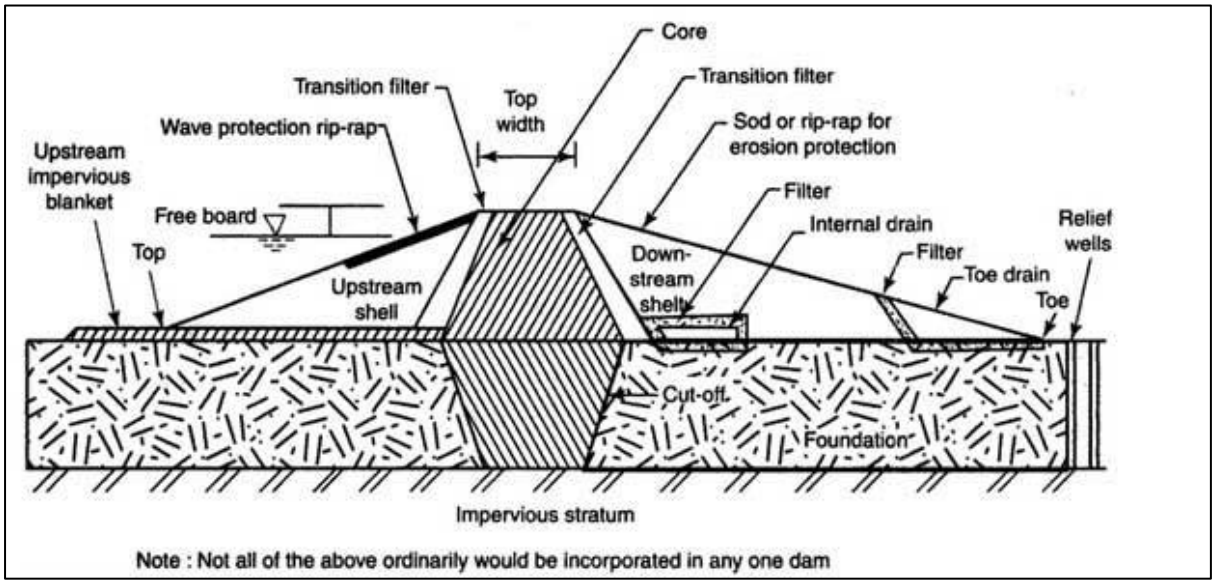
TYPES OF EARTHEN DAMS

Earthen dams are of following types

1. **Homogeneous Embankment Type**-It consist of a single material and is homogeneous throughout. Sometimes a layer of impervious material may be placed on the upstream face. Homogeneous sections may be added with an internal drainage system such as horizontal drainage filter.
2. **Zoned Embankment Type**- Zoned embankments are provided with a central impervious core covered by a pervious transition zone, which is finally surrounded by a much more pervious outer zone. Clay mixed with sand and gravel in small quantities is used for the central impervious core. Coarse sands and gravels are used in outer layer. Transition filters are provided between inner zone and outer zone. The central core prevents seepage, transition zone prevents piping through the cracks, outer zone gives stability to the core
3. **Diaphragm type Embankments**- Diaphragm type embankments have a thin impervious core, which is surrounded by earth fill or rock fill. The impervious core called diaphragm

is made of impervious soils, concrete, steel or timber. It act as a water barrier to prevent the seepage of dam

CROSS SECTION OF EARTHEN DAM



1. Shell, Upstream Fill, Downstream Fill or Shoulder: These components of the earthen dam are constructed with pervious or semi-pervious materials upstream or downstream of the core. The upstream fill is called the upstream shell and the downstream portion is the downstream shell.

2. Upstream Blanket: It is a layer of impervious material laid on the upstream side of an earthen dam, to reduce seepage. Low permeable soils are used as natural blanket

3. **Drainage Filter:** It is a blanket of pervious material constructed at the foundation to the downstream side of an earthen dam, to discharge the water seeping at the downstream side and minimize the possibility of piping failure.

4. **Cutoff Wall or Cutoff:** It is a wall, provided in foundations to reduce percolation of water through porous strata.

5. **Riprap:** Broken stones or rock pieces are placed on the slopes of embankment particularly the upstream side for protecting the slope against the action of water, mainly wave action and erosion.

6. **Core Wall, or Core:** It is an impervious wall in the dam. It prevents the flow of water through the dam section. It may be of compacted clay, masonry, or concrete built inside the dam.

7. **Toe Drain:** It is a drain constructed at the downstream slope of an earthen dam to collect and drain away the seepage water collected by the drain filters.

8. **Transition Filter:** It is a component of an earthen dam section which is provided with core and consists of an intermediate grade of material placed between the core and the shells to serve as a filter and prevent lateral movement of fine material from the core

<u>Causes of Failure of Earth Dams: Refer Assignment</u>

SPILL WAY

A Spillway is a structure at dam site, for effective disposal of surplus water of dam from upstream to downstream. Spillway will not let the water rise above the maximum level.

A spillway can be located in the body of the dam or at one end of the dam or away from the body independently.

FUNCTIONS OF SPILLWAY

- It maintains the level of water.
- It protects the bank of the dam from erosion and failure of the dam.
- It controls the overflow of water over the dam.
- It makes the way of water to transfer from the reservoir to different required sectors like irrigation, hydropower plant, etc.

COMPONENT PARTS OF SPILLWAY:

1. Entrance 2) Conduits 3) Outlet

1. Entrance when the reservoir level goes above FRL the entrance structure admits this excess water and controls the discharge

2. Conduits. This is a pipe like structure which carries the discharge to low level on d/s side

3. Outlet: The structure built at the exit end of the spillway to convey water to the d/s side.

TYPES OF SPILLWAY

1. Open spillway 2. Siphon spill way
3. Straight drop spill way 4. Shaft spill way
5. Trough spill way 6. Side channel spillway.

LOCATION OF SPILLWAY

- Spillways may be provided within the body of the dam.
- Spillways may sometimes be provided at one side or both sides of the dam.
- Sometimes by-pass spillway is provided which is completely separate from the dam.
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ENERGY DISSIPATORS

Energy dissipator is a device designed to protect downstream areas from erosion by minimizing the flow velocity up to an acceptable limit. It is an important element of hydraulic structures as a transition between the high-velocity flow and the sensitive tail water. The spillway is always designed to dissipate considerable amount of energy. If the average energy of the flow just downstream of the spillway is greater than the critical energy this can damage the spillway. Hence energy dissipators are provided to dissipate the energy of falling water from the spill way.

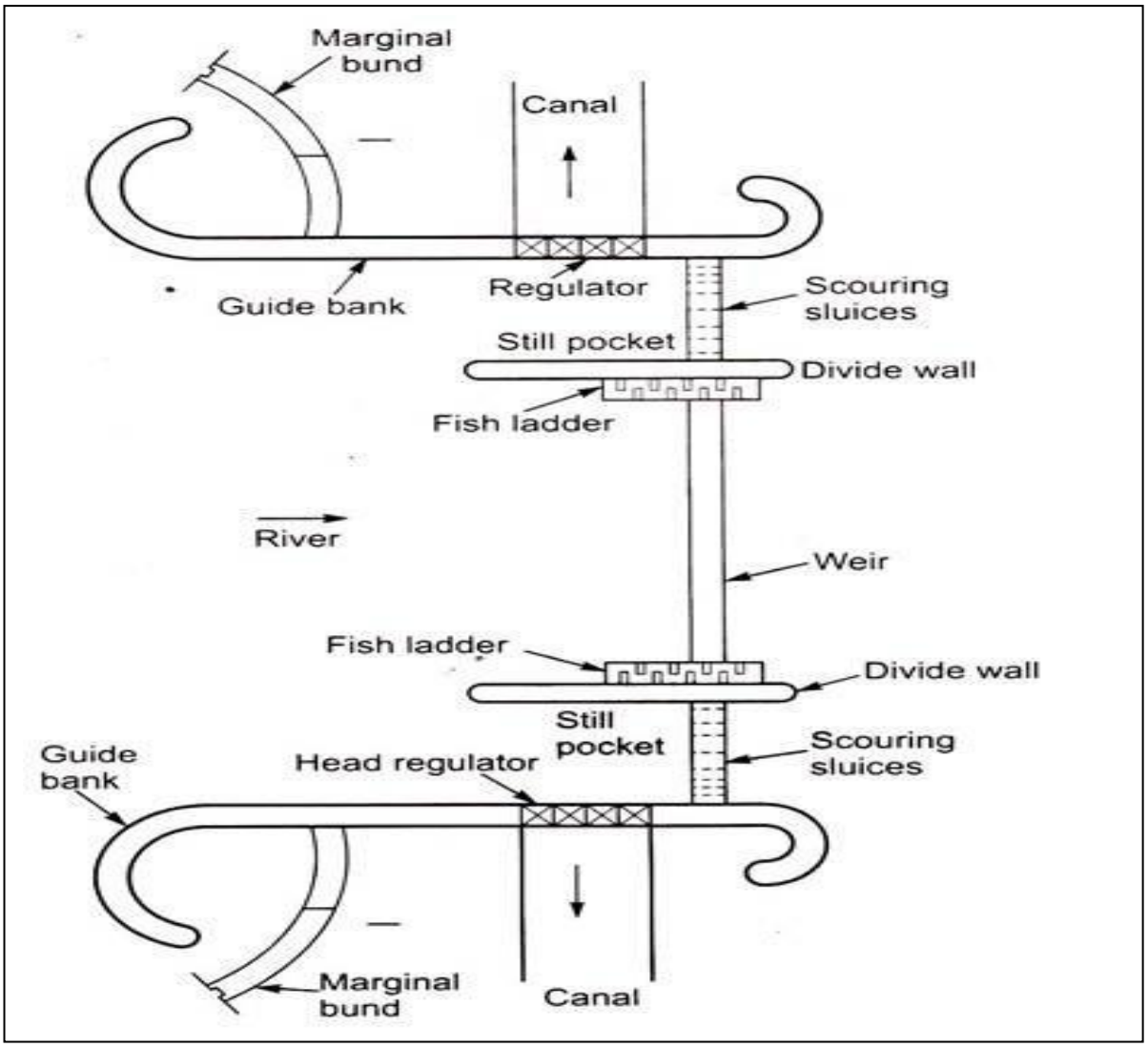
Energy dissipators can be provided as

(1) Provision of a Water-Cushion, (2) Baffle Wall, (3) Deflector, (4) Staggered Blocks, (5) Ribbed Pitching (6) Hydraulic Jump on Sloping Glacis.

DIVERSION HEADWORKS

COMPONENT PARTS OF A DIVERSION WORK

1. A weir or an anicut
2. Divide wall
3. Under sluices or scouring sluices
4. Fish ladder
5. Head regulator
6. Silt exclusion device



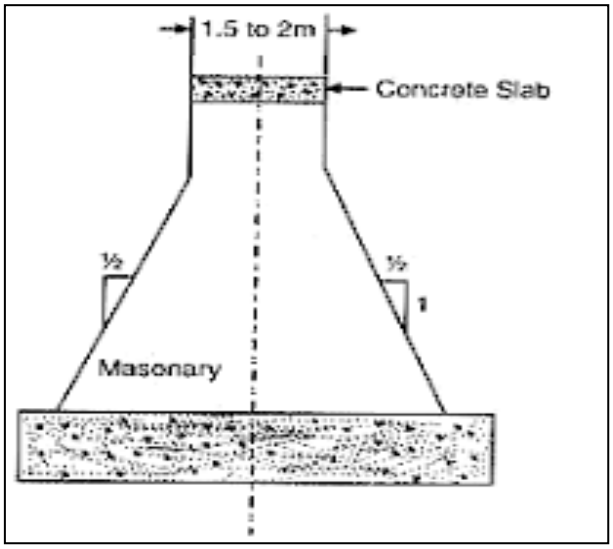
1. A WEIR OR AN ANICUT :

It is a barrier constructed across the river at right angle to the direction of flow of river. It is of small height and raises the water level on the upstream side and thereby divert the water from the river to the canal. They are also called anicut.

2. DIVIDE WALL

It is a long wall constructed at right angle to the weir. It divides the river channel into two compartments. In the smaller compartment which is near to the head regulator a still pond is created. It separates the turbulent floodwaters from the pocket in front of the canal head

Generally a divide wall is constructed with masonry. The top width of the wall varies from 1.5 to 2.0m constructed on a strong foundation. The divide wall retains water on both faces.

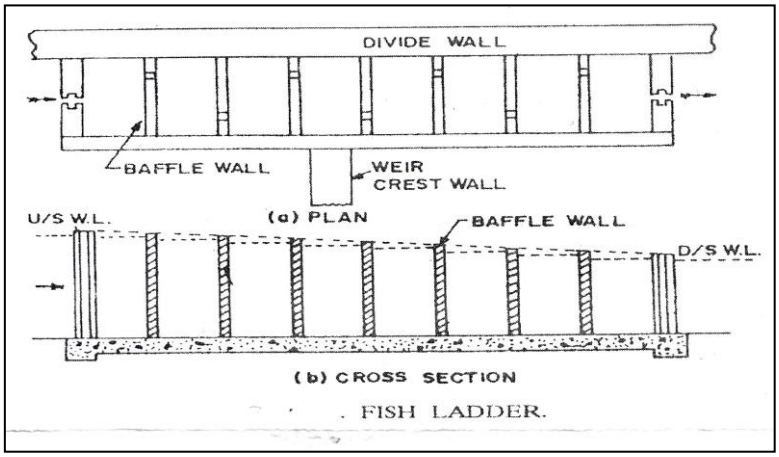


3. UNDER SLUICES OR SCOURING SLUICES

There are the openings provided in the body of a weir at low levels to remove the silt deposited in front of the still pond. These sluices are fully controlled by means of gates which are operated from top.

4. FISH LADDER

If a weir is constructed across the river the passage is totally closed by a masonry wall. As a result movement of fish is also obstructed. The structure provided for the movement of fish from one side of the river to the other side is called fish ladder.



FISH LADDER.

5. HEAD REGULATOR

It is a structure constructed at the entrance of a canal where it takes-off from the river. The main function of the head regulator are

(i) Regulate the flow of irrigation water entering the canal

(ii) Measure discharge of canal

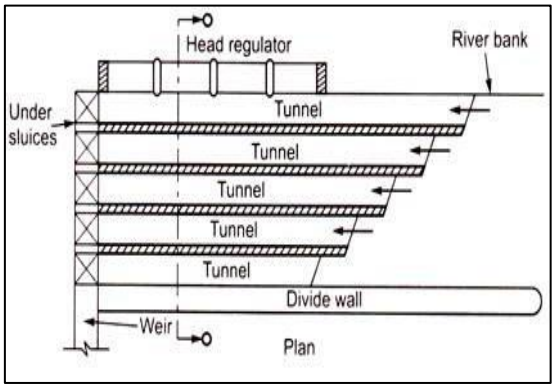
(iii)Prevent excessive silt entry into the canal

It is constructed with stone masonry consisting of number of openings provided with lifting shutters. The sill of head regulator is kept at a higher level to prevent the entry of coarse silt into the canal.

6. SILT EXCLUDING DEVICES

They remove silt from irrigation water. It separates the lower silt laden portion of water from the upper portion which is free of silt. It consists of a series of parallel tunnels of low height. They are constructed parallel to the flow of river.

The lower portion of the flow which contain heavy silt enters the tunnel and it is then driven towards the scouring sluices. This water passes on the down stream side of the weir through the sluices. Thus only clear water is allowed to enter the canal.



STORAGE WEIR

A weir is a solid obstruction constructed across the river to raise its water level and divert water into the canal. If a weir also stores water for tiding over small periods of short supplies, it is called a storage weir.

BARRAGE

A barrage is an artificial barrier constructed across a river provided with gates for heading up of water. During flood, gates are raised to enable the high flood to pass downstream. When

the flood recedes, gates are lowered and the flow is obstructed thus raising the water level on the upstream side.

COMPONENT PARTS OF A WEIR

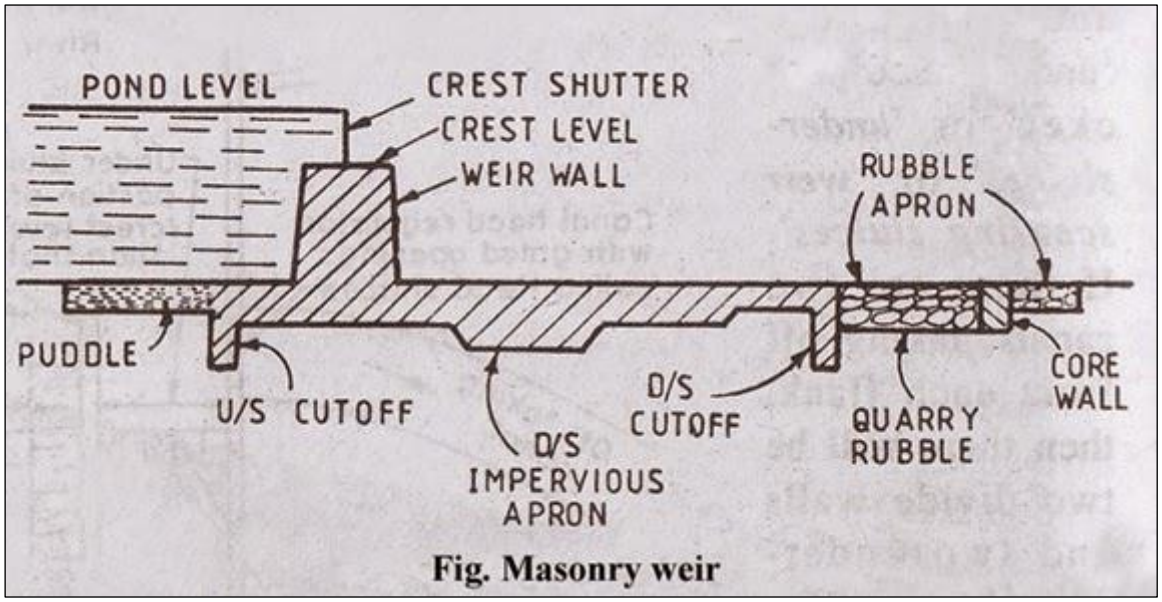


Fig. Masonry weir

1. Body Wall of Weir- It is a wall which is constructed to raise the water level on u/s. It should be strong enough to resist water pressure and upstream pressure.

2. Upstream Apron- Protect weir from erosive forces during floods. Length of apron depends upon discharge in river and length of weir

3. Downstream apron:-To reduce the kinetic energy of water. Length depends upon height of fall of water. Apron is extended up to the point where there is no scope for erosion

4. Upstream curtain wall:-provided on upstream side to **reduce uplift pressure**

5. Downstream curtain wall:-Protect downstream flow from uplift pressure.

6. Crest:-Top of weir is called crest. It should be strong enough to resist excessive pressure during floods. Shutter will be laid flat during floods over the crest

7. Shutters:-Provided on the crest. Can be raised during flood. Shutters should be strong enough to resist water pressure

TYPES OF WEIR

Based on the Design Criteria, weirs are classified as gravity weirs and No-gravity weirs

1. **Gravity weirs**- A gravity weir is one in which the uplift pressure due to the seepage of water below the floor is resisted by the weight of floor.

2. **Non-gravity weir**- In this type, the floor thickness is relatively less and uplift pressure is largely resisted by the bending action of floor

Depending on the material and design features, gravity weir is further classified as

1. Vertical Drop Weir

2. Sloping Weir-Masonry or Concrete Slope Weir & Dry Stone Slope Weir

3. Parabolic Weir

1. **Vertical Drop Weir**-A vertical drop weir consist of a vertical drop wall or crest wall with or without crest gates. At upstream and downstream side cut off piles are provided. Aprons are provided at u/s and d/s to protect against scouring. These weirs are suitable for any type of foundation.
2. **Masonry or Concrete Sloping Weir-** These weirs are suitable for soft sandy foundations and are used when the difference between crest of weir and downstream river bed is limited to 3m.
   Dry Stone Slope Weir-A dry stone weir or rockfill weir consist of a body wall and u/s and d/s rockfills with few core walls
3. **Parabolic Weir**-A parabolic weir is similar to the spillway section of a dam. The body wall for such a weir is designed as low dam. A cistern is provided at the downstream side to dissipate the energy.

BARRAGES

COMPONENT PARTS OF A BARRAGE

1. Main body of the barrage,- Main body of the barrage is an RCC slab which supports the steel gate. It consist of

   a. Upstream concrete floor, to lengthen the path of seepage
   b. A crest at the required height above the floor on which the gates rest in their closed position.
   c. Downstream floor is built of concrete and is constructed so as to contain the hydraulic jump

2. Divide Wall-refer notes of diversion headwork
3. Fish Ladder-refer notes of diversion headwork
4. Sheet Piles- Sheet piles are made of mild steel and are of three types-u/s sheet piles, intermediate sheet piles and d/s sheet piles. U/s sheet piles are located at u/s end of concrete floor. Intermediate sheet piles are situated at the end of u/s and d/s glacis. Downstream sheet piles are provided at the downstream end of the concrete floor
5. Inverted filter-An inverted filter is provided between the d/s sheet piles and the flexible protection. It typically consists of 6” sand, 9’’ coarse sand and 9” gravel. It prevents the escape of fine soil particles in the seepage water.
6. Flexible Apron-A flexible apron is placed d/s of the filter and consists of boulders
7. Under sluices-refer notes of diversion headwork

CANAL REGULATION WORKS

Canal Regulation works include Canal Regulator, Canal Escape, Canal fall, Canal Outlet

CANAL REGULATORS

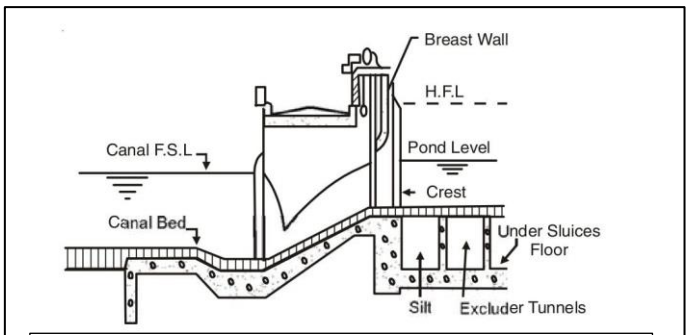
Canal Regulator is a structure provided on a canal to regulate the supply of water in the canal. It consist of a number of spans separated by piers and operated by gates. Canal Regulators can be of two types-Head Regulator and Cross Regulator

1. Canal Head Regulator

A canal head regulator is a structure constructed at the head of a canal taking off from a reservoir. It consist of a number of spans separated by piers and operated by gates.It is constructed with stone masonry consisting of number of openings provided with lifting shutters. The sill of head regulator is kept at a higher level to prevent the entry of coarse silt into the canal. To prevent high flood water spilling into the canal, R.C.C. breast wall should be provided on the U/S side of the regulator.

Functions of head regulator

- To regulate the water supply in the canal
- To control the silt entry into the canal
- To shut out river floods



CANAL HEAD REGULATOR

2. Canal Cross Regulator

A cross regulator is a structure constructed across a canal to regulate the water level in the canal upstream of itself and the discharge passing downstream of it .

Purpose of Canal Cross Regulator

- To feed off taking canals located upstream of the cross regulator.
- To help water escape from canals in conjunction with escapes.
- To control water surface slopes in conjunction with falls for bringing the canal to regime slope and section.

- To control discharge at an outfall of a canal into another canal or lake

CANAL ESCAPE

A canal escape is a side channel constructed to remove surplus water from an irrigation channel into a natural drain. The water in the irrigation channel may become surplus due to excessive rainfall or due to difficulty in canal regulation or agricultural demand for water becomes less or when a canal breach occurs. Canal escapes must be provided at suitable intervals where a suitable drain is available for disposal of water.

Types of Canal Escapes

1. **Weir Type Escape**- In weir type escape, the crest of weir is kept at a level equal to the FSL of canal. When water level rises above the FSL, it gets escaped. Weir type escape may be provided at the tail end of a canal to maintain the required FSL at the tail reaches of the canal and is called tail escape
2. **Regulator Type Escape**- In this type, the sill of the escape is kept at canal bed level and the flow is controlled by gates. The regulator type escape maybe constructed for scouring off the excess silt deposited in head reaches of canal and is called Scouring Escape

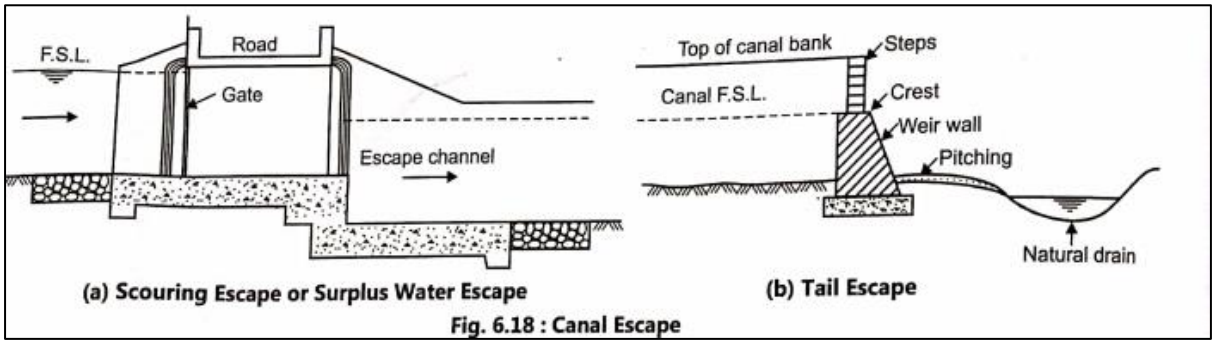


Fig. 6.18 : Canal Escape

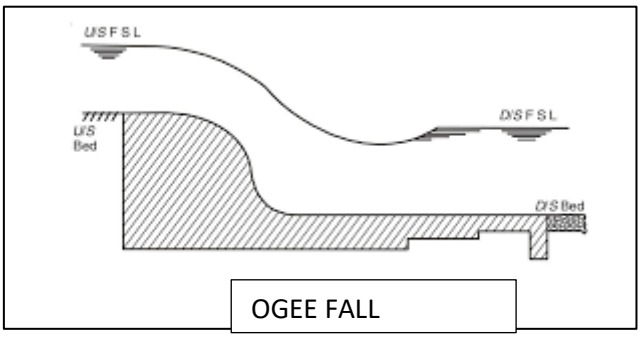
CANAL FALLS (CANAL DROP)

A canal fall is an irrigation structure constructed across a canal to lower down the water level. By providing a canal fall, the surplus energy generated from the falling water can be reduced and thus scouring of canal bed can be eliminated. The slope of canal may vary from 1 in 4000 to 1 in 8000 which is quite flat. But the ground slope may be steeper in some places and canal may have to be constructed in embankments when the ground level is less than canal bed level. In such cases huge volume of earthwork may be required to construct a canal on a steeper ground. To overcome this difficulty, canal falls can be constructed at suitable places and water surface of canal can be lowered. Suitable protection like aprons, cut off walls must be provided to prevent the scouring of canal bed

TYPES OF CANAL FALLS

1. Ogee fall- This type of fall has gradual convex and concave curves to smoothly allow the falling of water
2. Rapid fall- it consists of a glacis sloping at 1 vertical to 10 to 20 horizontal.
3. Stepped fall- Canal bed is lowered through a steps

4. Notch fall- A drop wall or a notch pier is constructed across a canal and water is allowed to fall through the notches



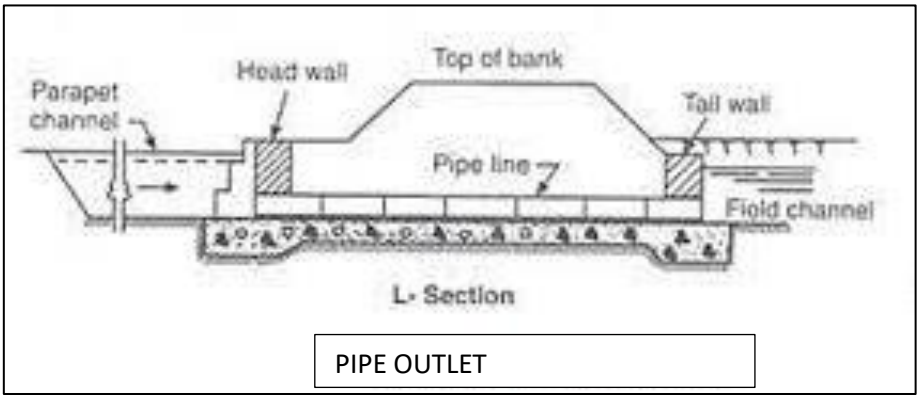
OGEE FALL

CANAL OUTLET

A canal outlet is a small structure which admits water from the distributing channel to a water course or field channel. Canal outlets has a very important role in controlling the flow of water to different areas. An outlet should be designed so that the farmer cannot with its functioning

TYPES OF CANAL OUTLET

1. **Non-modular outlet-** The discharge depends on the difference in water level between the distributing channel and the water course.
2. **Semi modular outlet**-The discharge depends on the variations of water level in the distributing channel only and does not depend on the variations in water level of the field channel
3. **Rigid outlet-** It maintains constant discharge and does not vary with the variations in distributing channel and field channel



PIPE OUTLET

CROSS DRAINAGE WORKS

A cross drainage work is a structure constructed at the crossing of a canal and a natural drain so as to dispose the natural drain without interrupting the canal supplies. A cross drainage work is a costly construction and must be avoided as far as possible.

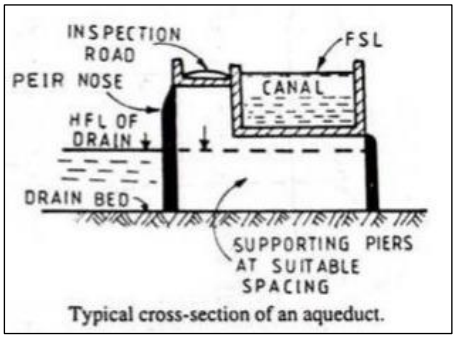
Types of Cross Drainage Works

(1)Aqueduct (2) Syphon aqueduct (3)Super passage

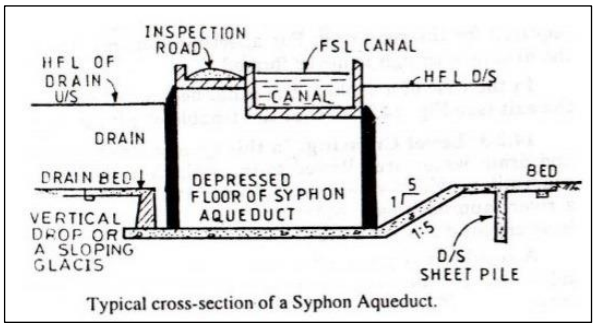
(4) Syphon (5)Level crossing (6) Inlet and outlet

1. **AQUEDUCT** (Canal bed level above HFL)

An aqueduct is a cross drainage structure constructed for carrying the canal water above the natural drainage. The bed level of canal will be above the HFL of natural drain. The canal water is taken across the drainage in a trough supported by piers. An inspection road is provided near the trough



Typical cross-section of an aqueduct.



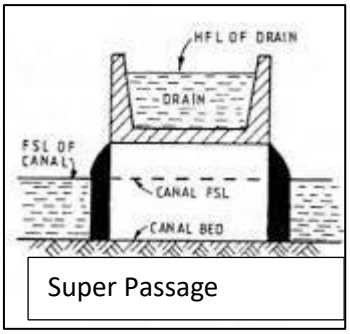
Typical cross-section of a Syphon Aqueduct.

2. **SYPHON AQUEDUCT** (Canal bed level below HFL)

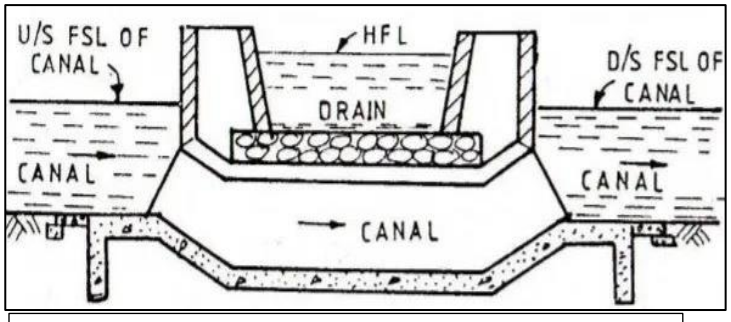
A syphon aqueduct is a cross drainage structure for carrying the canal water over a natural drain, but the HFL of natural drain is above the canal bed level and water passes through the aqueduct barrels under symphonic action. It also consists of trough supported on piers and inspection road. In addition a vertical drop will be provided on u/s side and a sloping glacis will be provided on d/s side

3. **SUPER PASSAGE** (Drain Bed Level Higher than FSL of canal)

A super passage is a cross drainage structure constructed to carry a canal across a natural drain such that the canal water runs below the drain. Here the FSL of canal is below the bottom of natural drain so that the canal water flows freely by gravity. The natural drain will be carried over the canal in a trough supported by piers.



Super Passage



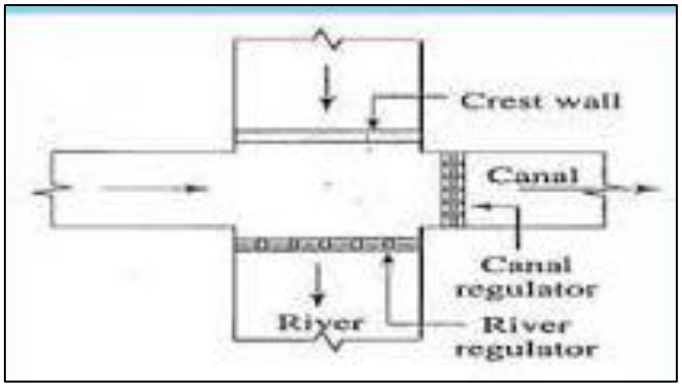
Canal syphon

4. CANAL SYPHON

A canal syphon is a cross drainage structure constructed to carry a canal across a natural drain such that the canal water runs below the drain. Here the FSL of canal is sufficiently above the bed level of natural drain so that the canal water flows under symphonic action under the trough.

5. LEVEL CROSSING

A level crossing is a cross drainage structure in which the canal water and natural drain are allowed to intermingle with each other. A level crossing is provided when a large canal and a huge natural drain meets at same level. A regulator is provided on the d/s side of natural drain so as to control the discharge into it. A regulator is also provided at the outgoing canal so a to control the discharge into the canal.



LEVEL CROSSING

6. INLETS AND OUTLETS

An inlet is a structure constructed to allow the drainage water to enter the canal and gets mixed with the canal water. Such a structure is provided when the drainage discharge is small and crosses the canal with a bed level equal to or slightly higher than the canal FSL. An outlet is a structure constructed to discharge the drainage water entering into the canal. It is provided when the drainage discharge is high and canal cannot take the entire drainage water