

UNIT-3

Headworks

Headworks is a civil engineering term for any structure at the head or diversion point of a waterway.

Supply water to the off taking

Types of Canal Headworks

1. Storage headwork
2. Diversion headwork

Diversion headwork.

- Any hydraulic structure, which supplies water to the off-taking canal, is called a headwork.
- A diversion headwork serves to divert the required supply in to the canal from the river.

Storage headwork

When dam is constructed across a river to form a storage reservoir, it is known as storage head work. It stores water during the period of excess supplies in the river and releases it when demand overtakes the available supplies.

Dam

A dam is a hydraulic structure constructed across a river to store the supply for a longer duration and release it through designed outlets.

Types of Dams

Based on Materials of Construction

- Rigid.
- Non-Rigid.

Based on Structural Behaviour

- Gravity Dam.
- Arch Dam.
- Buttress Dam.
- Embankment Dam.

Based on Functions

- Storage Dam.
- Detention Dam.

- Diversion Dam.
- Cofferdam.

Based on Hydraulic Behaviour

- Over Flow Dam.
- Non Over Flow Dam.

General Types

- Solid gravity dam (masonry, concrete, steel and timber)
- Arch dams
- Buttress dams
- Earth dams
- Rockfill dams
- Combination of rockfill and earth dams

Diversion headwork.

- Any hydraulic structure, which supplies water to the off-taking canal, is called a headwork.
- A diversion headwork serves to divert the required supply in to the canal from the river.

The purposes of diversion headwork.

1. It raises the water level in the river so that the commanded area can be increased.
2. It regulates the intake of water in to the canal.
3. It controls the silt entry in to the canal.
4. It reduces fluctuations in the level of supply in the river.
5. It stores water for tiding over small periods of short supplies.

LOCATION OF DIVERSION HEADWORKS

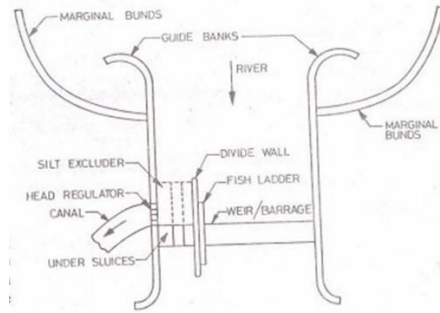
- The diversion headworks are generally located in the boulder stage or trough stage of the river at a site which is close to the commanded area of the off-taking canals.
- If there are a number of sites which are suitable, the final selection is done on the basis of cost.
- The site which gives the most economical arrangement for the diversion head works and the distribution works (canals) is usually selected.

1. The river section at the site should be narrow and well-defined.
2. The river should have high, well-defined, inerodible and non-submersible banks so that the cost of river training works is minimum.
3. The canals taking off from the diversion head works should be quite economical and should have a large commanded area.
4. There should be suitable arrangement for the diversion of river during construction.
5. The site should be such that the weir (or barrage) can be aligned at right angles to the direction of flow in the river.
6. There should be suitable locations for the undersluices, head regulator and other components of the diversion headworks.
7. The diversion headworks should not submerge costly land and property on its upstream.
8. Good foundation should be available at the site.
9. The required materials of construction should be available near the site.
10. The site should be easily accessible by road or rail.
11. The overall cost of the project should be a minimum.

COMPONENT PARTS OF A DIVERRSION HEADWORK

A diversion headwork consist of the following component parts

1. Weir or barrage
2. Undersluices
3. Divide wall
4. Fish ladder
5. Canal head regulator
6. pocket or approach channel
7. Silt excluders/ Silt prevention devices/
8. River training works (Marginal bunds and guide banks)



Undersluices

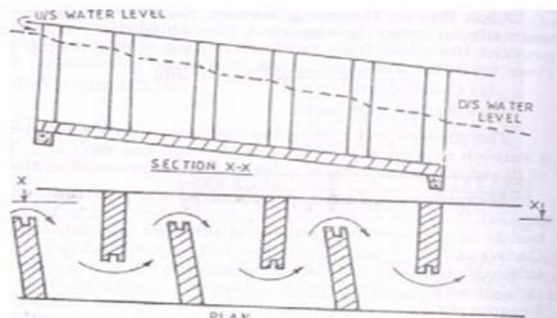
- Undersluice sections are provided adjacent to the canal head regulators.
- The undersluices should be able to pass fair weather flow for which the crest shutters on the weir proper need not be dropped.
- The crest level of the undersluices is generally kept at the average bed level of the river.

Divide Wall

- A divide wall is a wall constructed parallel to the direction of flow of river to separate the weir section and the undersluices section to avoid cross flows.
- If there are undersluices at both the sides, there are two divide walls.

Fish Ladder

- A fish ladder is a passage provided adjacent to the divide wall on the weir side for the fish to travel from the upstream to the downstream and vice versa.
- Fish migrate upstream or downstream of the river in search of food or to reach their sprawling places.
- In a fish ladder the head is gradually dissipated so as to provide smooth flow at sufficiently low velocity.
- Suitable baffles are provided in the fish passage to reduce the flow velocity.



Canal Head Regulator

- A canal head regulator is provided at the head of the canal off taking from the diversion head works.
- It regulates the supply of water into the canal, controls the entry silt into the canal, and prevents the entry of river floods into canal

Silt Excluder

- A silt excluder is a structure in the undersluices pocket to pass the silt laden water to the downstream so that only clear water enters into the canal through head regulator.
- The bottom layer of water which are highly charged with silt pass down the silt excluder an escape through the undersluices.

Guide Banks and Marginal Bunds

- Guide banks are provided on either side of the diversion headworks for a smooth approach and to prevent the river from outflanking.
- Marginal bunds are provided on either side of the river upstream of diversion headworks to protect the land and property which is likely to be submerged during ponding of water in floods.

Weir or Barrage

- A diversion head works is a structure constructed across a river for the purpose of raising water level in the river so that it can be diverted into the off taking canals.
- A weir is a raised concrete crest wall constructed across the river.
- It may be provided with small shutters (gates) on its top. In the case of weir, most of the raising of water level or ponding is done by the solid weir wall and little with by the shutters.

barrage has a low crest wall with high gates. As the height of the crest above the river bed is low most of the ponding is done by gates. During the floods the gates are opened so afflux is very small.

- A weir maintains a constant pond level on its upstream side so that the water can flow into the canals with the full supply level (F.S.L.). If the difference between the pond level and the crest level is less than 1.5 m or so, a weir is usually constructed.
- On the other hand, if this difference is greater than 1.50 m, a gate-controlled barrage is generally more suitable than a weir. In the case of a weir, the crest shutters are dropped during floods so that the water can pass over the crest.
- During the dry period, these shutters are raised to store water upto the pond level. Generally, the shutters are operated manually, and there is no mechanical arrangement for raising or dropping the shutters.

- On the 'other hand, in the case of a barrage, the control of pondage and flood discharge is achieved with the help of gates which are mechanically operated

ADVANTAGES AND DISADVANTAGES OF WEIRS AND BARRAGES

1. Weirs Advantages: The initial cost of weirs is usually low.

Disadvantages:

- i. There is a large afflux during floods which causes large submergence.
- ii. Because the crest is at high level, there is great silting problem
- iii. The raising and lowering of shutters on the crest is not convenient. Moreover, it requires considerable time and labour.
- iv. The weir lacks an effective control on the river during floods.

2. Barrages Advantages

- i. The barrage has a good control on the river during floods. The outflow can be easily regulated by gates.
- ii. The afflux during floods is small and, therefore, the submerged area is less.
- iii. There is a good control over silt entry into the canal.
- iv. There is a good control over flow conditions, shoal formations and crosscurrents on the upstream of the barrage.
- v. There are better facilities for inspection and repair of various structures.
- vi. A roadway can be conveniently provided over the structure at a little additional cost.

Disadvantages:

The initial cost of the barrage is quite high.

Conclusion: A barrage is generally better than a weir. Most of the diversion headworks these days usually consist of barrages.

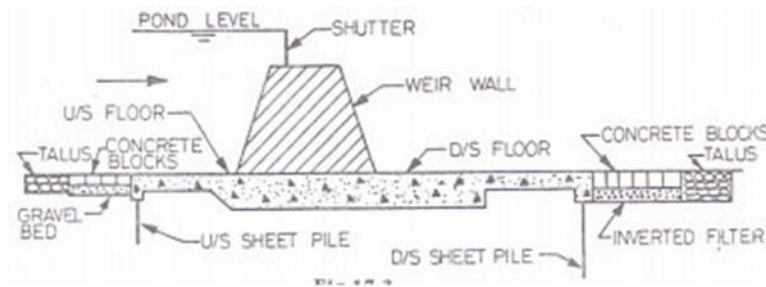
TYPES OF WEIRS

The weirs may be broadly divided into the following types

1. Vertical drop weirs.
2. Rockfill weirs.
3. Concrete glacis or sloping weirs.

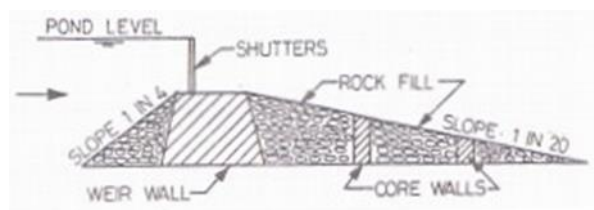
1. Vertical drop weirs

- A vertical drop weir consists of a masonry wall with a vertical (or nearly vertical) downstream face and a horizontal concrete floor.
- The shutters are provided at the crest, which are dropped during floods so as to reduce afflux. The water is ponded upto the top of the shutters during the rest of the period.
- Vertical drop weirs were quite common in early diversion headworks, but these are now becoming more or less obsolete.
- The vertical drop weir is suitable for hard clay foundation as well as consolidated gravel foundations, and where the drop is small.
- The upstream and downstream cutoffwalls (or piles) are provided upto the scour depth. The weir floor is designed as a gravity section.



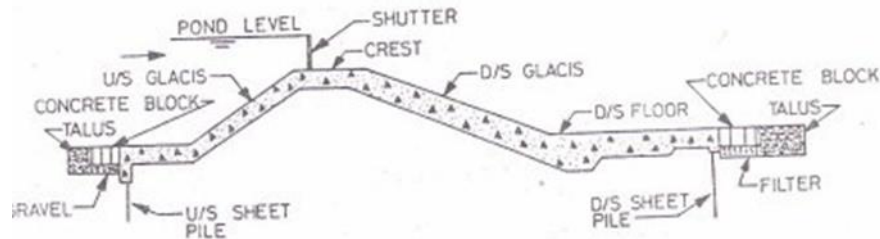
2. Rockfill weirs:

- In a rockfill type weir, in addition to the main weir wall, there are a number of core walls. The space between the core walls is filled with the fragments of rock (called rockfill).
- A rockfill weir requires a lot of rock fragments and is economical only when a huge quantity of rockfill is easily available near the weir site.
- It is suitable for fine sand foundation. The old Okhla Weir across the Yamuna river is a rockfill weir.
- Such weirs are also more or less obsolete these days.



3. Concrete sloping weir :

- Concrete sloping weirs (or glacis weirs) are of relatively recent origin.
- The crest has glacis (sloping floors) on upstream as well as downstream.
- There are sheet piles (or cut off walls) driven upto the maximum scour depth at the upstream and downstream ends of the concrete floor.
- Sometimes an intermediate pile is also driven at the beginning of the upstream glacis or at the end of downstream glacis.
- The main advantage of a sloping weir over the vertical drop weir is that a hydraulic jump is formed on the d/s glacis for the dissipation of energy.
- Therefore, the sloping weir is quite suitable for large drops



Dam

General Types

- Solid gravity dam (masonry, concrete, steel and timber)
- Arch dams
- Buttress dams
- Earth dams
- Rockfill dams
- Combination of rockfill and earth dams

Gravity dam

- A gravity dam is a structure so proportioned that its own weight resists the forces exerted upon it. It requires little maintenance and it is most commonly used.
- A Gravity dam has been defined as a “structure which is designed in such a way that its own weight resist the external forces”.
- This type of a structure is most durable and solid and requires very less maintenance.

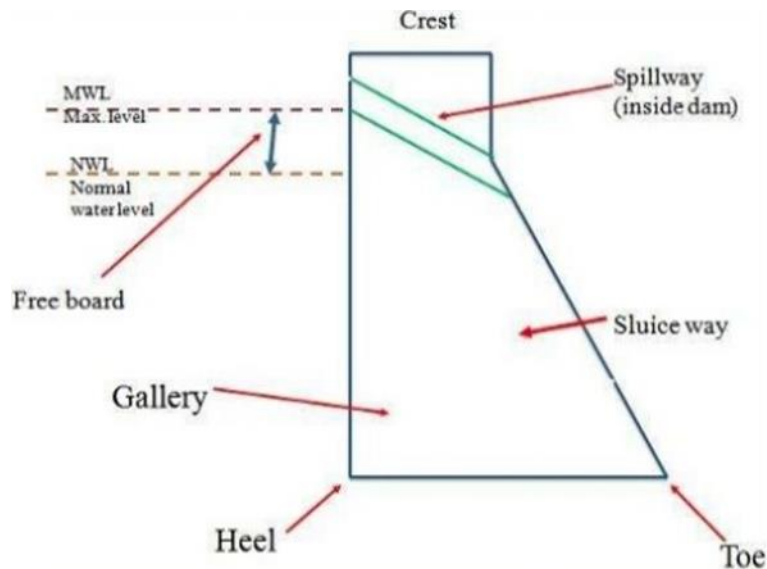
- Such dams are constructed of masonry or Concrete.
- However, concrete gravity dams are preferred these days and mostly constructed.
- The line of the upstream face or the line of the crown of the dam if the upstream face is sloping, is taken as the reference line for layout purpose etc. and is known as the Base line

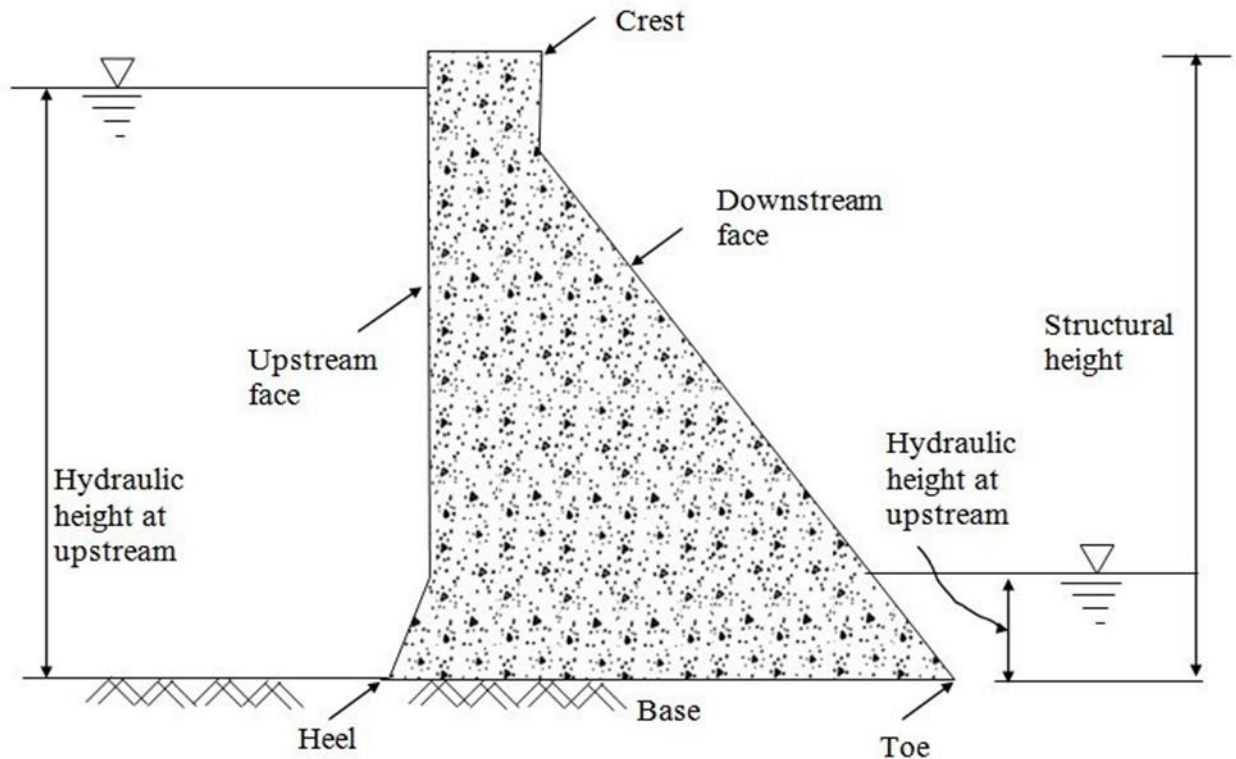
of the dam or the “Axis of The Dam” When suitable conditions are available such dams can be constructed up to great heights.

The different components of a solid gravity dam are

- Crest.
- Free Board.
- Heel.
- Toe.
- Sluice Way.
- Drainage Gallery.

Typical cross section of gravity Dam:





Arch dam

Arch dam, as the name implies, is a curved obstruction from the upstream side singly spanned that mainly carries the load of the impounded water through arch action as well as cantilever action.

- Arch dams through arch action transfers portion of the load of the water thrust horizontally to the side abutments and the other portion of that load is transferred to the dam foundation vertically by cantilever action.
- In the arch action, hydrostatic pressure / force of water press against the face of the arch which in return compresses and strengthens the matrix of the arch dam structure.
- Arch Dams throughout the world are mostly made of concrete (either conventional concrete or roller compacted concrete); however, in the past some are also made with rubble and stone masonry.

CANAL:-

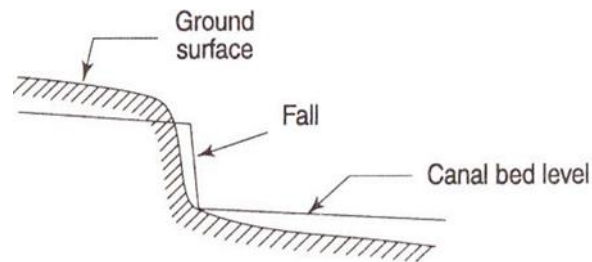
A canal is an artificial channel generally trapezoidal in shape constructed on the ground to carry water to the field either from the river or from a reservoir.

Control structures

Canal drop or Fall

A canal fall or drop is an irrigation structure constructed across a canal to lower down its bed level to maintain the designed slope when there is a change of ground level to maintain the designed slope when there is change of ground level.

This falling water at the fall has some surplus energy. The fall is constructed in such a way that it can destroy this surplus energy



Types of Canal Fall:

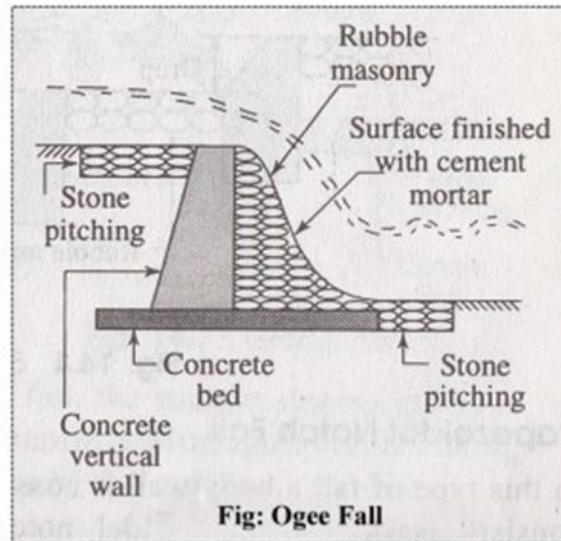
1. Ogee Fall - to provide smooth transition and to reduce disturbance and impact
2. Rapid Fall - consists of a glacis sloping at 1: 0 to 1:20. Very high cost of construction
3. Stepped Fall - next development of rapid fall. Cost of construction is high
4. Notch Fall - the fall is consists of one or more trapezoidal notches
5. Vertical Drop Fall - high velocity jet enters the deep pool of water in the cistern and dissipation of energy is affected by turbulent diffusion
6. Glacis Type Fall - utilizes standing wave phenomenon for dissipation of energy

Ogee Fall

In this type of fall, an ogee curve (a combination of convex curve and concave curve) is provided for carrying the canal water from higher level to lower level. This fall is recommended when the natural ground surface suddenly changes to a steeper slope along the alignment of the canal.

- The fall consists of a concrete vertical wall and concrete bed.
- Over the concrete bed the rubble masonry is provided in the shape of ogee curve.
- The surface of the masonry is finished with rich cement mortar (1:3).
- The upstream and downstream side of the fall is protected by stone pitching with cement grouting.

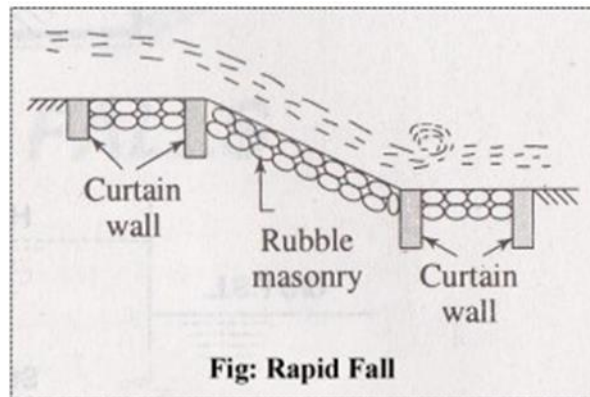
- The design consideration of the ogee fall depends on the site condition.



Rapid Fall

The rapid fall is suitable when the slope of the natural ground surface is even and long. It consists of a long sloping glacis with longitudinal slope which varies from 1 in 10 to 1 in 20.

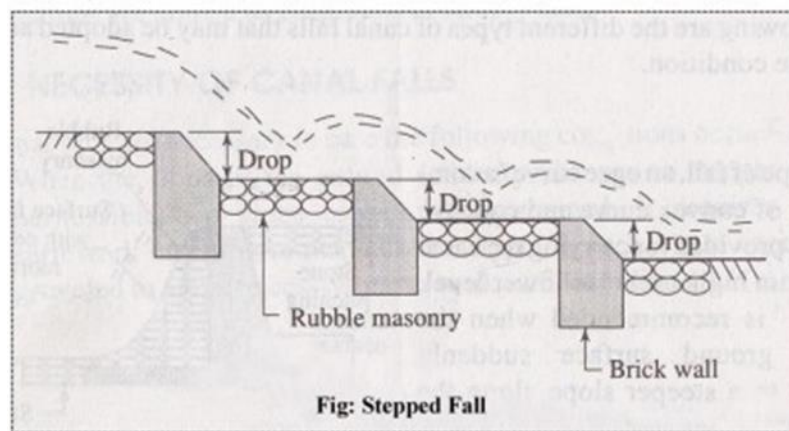
- Curtain walls are provided on the upstream and downstream side of the sloping glacis.
- The sloping bed is provided with rubble masonry.
- The upstream and downstream side of the fall is also protected by rubble masonry.
- The masonry surface is finished with rich cement mortar (1: 3).



Stepped fall consists of a series of vertical drops in the form of steps. This fall is suitable in places where the sloping ground is very long and requires long glacis to connect the higher bed level with lower bed level.

- This fall is practically a modification of the rapid fall.
- The sloping glacis is divided into a number of drops so that the flowing water may not cause any damage to the canal bed. Brick walls are provided at each of the drops.

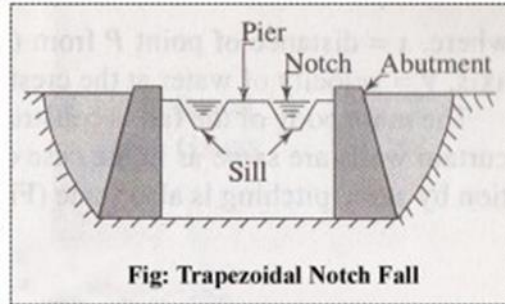
The bed of the canal within the fall is protected by rubble masonry with surface finishing by rich cement mortar (1:3).



Trapezoidal Notch Fall

In this type of fall a body wall is constructed across the canal. The body wall consists of several trapezoidal notches between the side piers and the intermediate pier or piers. The sills of the notches are kept at the upstream bed level of the canal.

- The body wall is constructed with masonry or concrete.
- An impervious floor is provided to resist the scoring effect of the falling water.
- The upstream and downstream side of the fall is protected by stone pitching finished by cement grouting.
- The size and number of notches depends upon the full supply discharge of the canal.

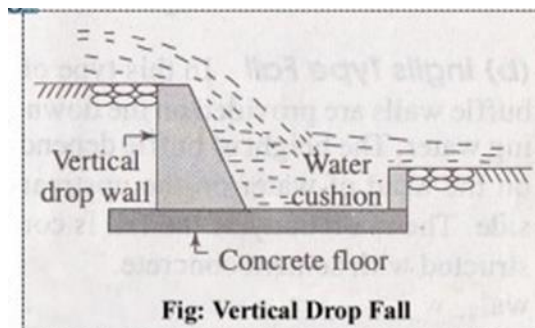


Vertical Drop Fall

It consists of a vertical drop wall which is constructed with masonry work. The water flows over the crest of the wall. A water cushion is provided on the downstream side which acts as a water cushion to dissipate the energy of falling water.

- A concrete floor is provided on the downstream side to control the scouring effect of the flowing water.
- Curtain walls are provided on the upstream and downstream side.

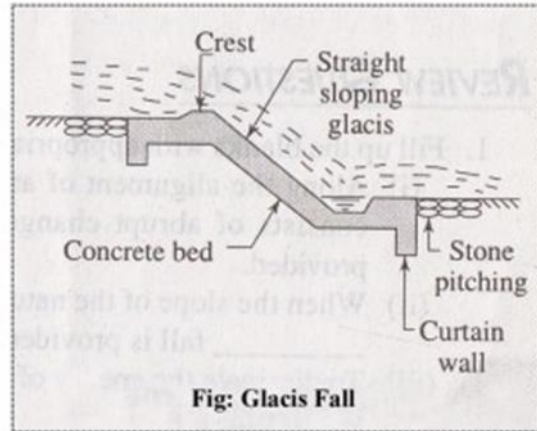
Stone pitching with cement grouting is provided on the upstream and downstream side of the fall to protect it from scouring.



Glacis Fall

It consists of a straight sloping glacis provided with a crest. A water cushion is provided on the downstream side to dissipate the energy of flowing water.

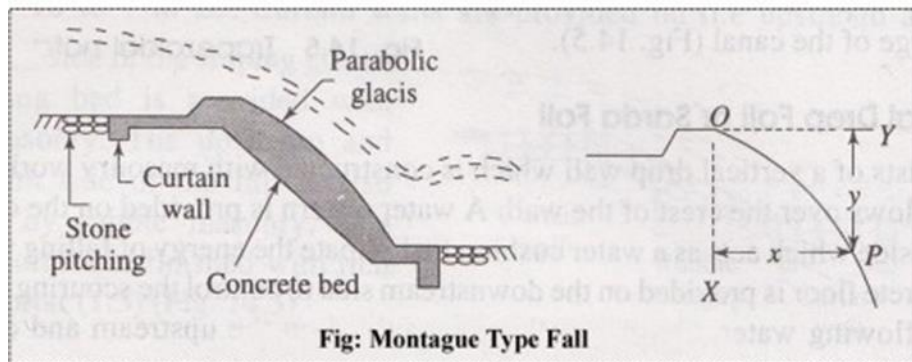
- The sloping glacis is constructed with cement concrete.
- Curtain walls and toe walls are provided on the upstream and downstream side.
- The space between the toe walls and curtain walls is protected by stone pitching.
- This type of fall is suitable for drops up to 1.5 m.



For the improvement in energy dissipation, the glacis falls have been modified as follows:

(a) Montague Type Fall

In this type of fall, the straight sloping glacis is modified by giving parabolic shape which is known as Montague profile.



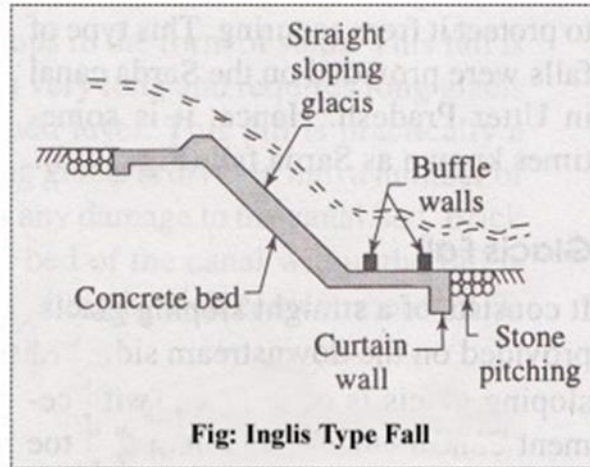
The main body of the fall is constructed with cement concrete. Toe walls and curtain walls are same as in the case of straight sloping glacis. The bed protection by stone pitching is also same.

(b) Inglis Type Fall

In this type of fall, the glacis is straight and sloping, but baffle walls are provided on the downstream floor to dissipate the energy of flowing water.

- The height of baffle depends on the head of water on the upstream side.
- The main body of the fall is constructed with cement concrete.

- The toe walls and curtain walls are same as straight glacis.
- The protection works with stone pitching are also same. Sometimes, this fall is known as baffle fall.



Unlined Canals

Unlined canals consist of beds and banks made of natural soil. They are not provided with a lining of impervious materials. It produces the growth of aquatic weed retards the flow which leads to massive maintenance cost. Unlined canals can tolerate velocities no more than 0.7 m/s because of erosion. In unlined canals, there is a danger of canal bank breakage caused by overtopping, erosion and animal burrowing. Weeds had severely slowed down the water flow of the canals, preventing up to 50% of the water from reaching the tail end of the canal. It also causes waterlogging of the adjacent net.

Canal Linings

Canal Linings are provided in canals to resist the flow of water through its bed and sides. These can be constructed using different materials such as compacted earth, cement, concrete, plastics, boulders, bricks etc. The main advantage of canal lining is to protect the water from seepage loss.

Canal Lining is an impermeable layer provided for the bed and sides of canal to improve the life and discharge capacity of canal. 60 to 80% of water lost through seepage in an unlined canal can be saved by construction canal lining.

Types of Canal Linings

Canal linings are classified into two major types based on the nature of surface and they are:

1. Earthen type lining
2. Hard surface lining
1. Earthen Type lining

Earthen Type linings are again classified into two types and they are as follows:

- i. Compacted Earth Lining
- ii. Soil Cement Lining

Compacted Earth Lining

Compacted earth linings are preferred for the canals when the earth is available near the site of construction or In-situ. If the earth is not available near the site then it becomes costlier to construct compacted earth lining.

Compaction reduces soil pore sizes by displacing air and water. Reduction in void size increases the density, compressive strength and shear strength of the soil and reduces permeability. This is accompanied by a reduction in volume and settlement of the surface. Proper compaction is essential to increase the stability and frost resistance (where required) and to decrease erosion and seepage losses.

Soil Cement Lining

Soil-cement linings are constructed with mixtures of sandy soil, cement and water, which harden to a concrete-like material. The cement content should be minimum 2-8% of the soil by volume. However, larger cement contents are also used.

In general, for the construction of soil-cement linings following two methods are used. Dry-mix method

Dry-mix method

Plastic mix method

For erosion protection and additional strength in large channels, the layer of soil-cement is sometimes covered with coarse soil. It is recommended the soil-cement lining should be protected from the weather for seven days by spreading approximately 50 mm of soil, straw or hessian bags over it and keeping the cover moistened to allow proper curing. Water sprinkling should continue for 28 days following installation.

2. Hard Surface Canal Linings

It is sub divided into 4 types and they are

- i. Cement Concrete Lining
- ii. Brick Lining
- iii. Plastic Lining
- iv. Boulder Lining

Cement Concrete Lining

Cement Concrete linings are widely used, with benefits justifying their relatively high cost. They are tough, durable, relatively impermeable and hydraulically efficient. Concrete linings are suitable for both small and large channels and both high and low flow velocities. They fulfill every purpose of lining.

There are several procedures of lining using cement concrete

- i. Cast in situ lining
- ii. Shortcrete lining
- iii. Precast concrete lining
- iv. Cement mortar lining

Brick Lining

In case of brick lining, bricks are laid using cement mortar on the sides and bed of the canal. After laying bricks, smooth finish is provided on the surface using cement mortar.

Plastic Lining

Plastic lining of canal is newly developed technique and holds good promise. There are three types of plastic membranes which are used for canal lining, namely:

- a) Low density poly ethylene
- b) High molecular high density polythene
- c) Polyvinyl chloride

The advantages of providing plastic lining to the canal are many as plastic is negligible in weight, easy for handling, spreading and transport, immune to chemical action and speedy construction.

The plastic film is spread on the prepared sub-grade of the canal. To anchor the membrane on the banks 'V' trenches are provided. The film is then covered with protective soil cover.

Boulder Lining

This type of lining is constructed with dressed stone blocks laid in mortar. Properly dressed stones are not available in nature. Irregular stone blocks are dressed and chipped off as per requirement.

When roughly dressed stones are used for lining, the surface is rendered rough which may put lot of resistance to flow. Technically the coefficient of rugosity will be higher. Thus the stone lining is limited to the situation where loss of head is not an important consideration and where stones are available at moderate cost.

Advantages of Canal Lining

1. Seepage Reduction
2. Prevention of Water Logging
3. Increase in Commanded Area
4. Increase in Channel Capacity
5. Less Maintenance
6. Safety Against Floods

1. **Seepage Reduction**

The main purpose behind the lining of canal is to reduce the seepage losses. In some soils, the seepage loss of water in unlined canals is about 25 to 50% of total water supplied. The cost of canal lining is high but it is justifiable for its efforts in saving of most of the water from seepage losses. Canal lining is not necessary if seepage losses are very small.

2. **Prevention of Water Logging**

Water logging is caused due to phenomenal rise in water table due to uncontrolled seepage in an unlined canal. This seepage effects the surrounding ground water table and makes the land unsuitable for irrigation. So, this problem of water logging can be surely prevented by providing proper lining to the canal sides.

3. **Increase in Commanded Area**

Commanded area is the area which is suitable for irrigation purpose. The water carrying capacity of lined canal is much higher than the unlined canal and hence more area can be irrigated using lined canals.

4. **Increase in Channel Capacity**

Canal lining can also increase the channel capacity. The lined canal surface is generally smooth and allows water to flow with high velocity compared to unlined channel. Higher the velocity of flow greater is the capacity of channel and hence channel capacity will increase by providing lining.

On the other side with this increase in capacity, channel dimensions can also be reduce to maintain the previous capacity of unlined canal which saves the cost of the project.

5. **Less Maintenance**

Maintenance of lined canal is easier than unlined canals. Generally there is a problem of silting in unlined canal which removal requires huge expenditure but in case of lined canals, because of high velocity of flow, the silt is easily carried away by the water.

In case of unlined canals, there is a chance of growth of vegetation on the canal surface but not in case of lined canals. The vegetation affect the velocity of flow and water carrying capacity of channel. Lined canal also prevents damage of canal surface due to rats or insects.

6. **Safety against Floods**

A line canal always withstand against floods while unlined canal may not resists and also there is chance of occurring of breach which damages the whole canal as well as surrounding areas or fields. But among the all concrete canal linings are good against floods or high velocity flows.

Canal Types Based on Discharge

Main Canal

Canals are having discharge more significant than ten cumecs are called as main canals. The main canal is also known as the **arterial canal**. In drainage, the main canal is the superior canal of the drainage system; it collects water from the drainage canals and conducts it to the water intake. The main canal

carries discharge directly from the river. It takes off directly from the upstream side of weir head works or dam. Usually, no direct cultivation is proposed. It supplies water from a river, reservoir, or canal to irrigated lands by gravity flow. It supplies water to a branch canal. We cannot use the main canal for direct irrigation.

Branch Canal

Branch canals have discharge in the range of 5-10 cumecs. The branches of the main canal go in either direction at regular intervals. It off takes from the main canal where the head discharge is not more than 14-15 cumecs. Branch canal also plays the role of feeder channel for major and minor distributaries. Branch canals do not carry out direct irrigation, but they provide direct outlets.

Major Distributary

Canals who off take from the main canal or branch canal with head discharge from 0.028 to 15 cumecs are termed as significant distributaries. It takes off water from branch canals. Sometimes getting supply from the main canal, their discharge is less than branch canal. These are mostly known as **irrigation channels** because of their supply of water to the field directed through outlets.

Minor Distributary

Canals in which discharge ranged from 0.25 up to 3 cumecs are termed as minor distributors. It offtakes from a major distributary carrying discharge less than 0.25 cumecs are termed as minor distributary. Sometimes minor distributary gets supply from the branch canals. The discharge in minor distributary is less than in the major distributary. They also provide water to the courses through outlets provided along with them.

Watercourse or Field Channel

The discharge in watercourses is less than 0.25 cumecs. A field channel either take off from a significant distributary or minor- it solely depends on which extent the irrigation will happen. In a few cases, it also takes off water from the branch canal for the field. Small channels which carry water from the outlet of a major or minor distributary or a branch canals to the areas to be sprayed. There are small channels for feeding water to the irrigation fields.