An Introductory Notes on

- **Earth & Rock fill Dams**
- **Coffer Dams**
- **Tunneling**

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Earth & Rock fill Dams

Dam:

A dam is a hydraulic structure which is constructed across a river to store water on its up-stream side. This water is then utilized where it is needed. Dams form part of an irrigation system but they also have other roles to play as:

i) Flood control
ii) Hydraulic Power generation
iii) For water supply schemes
iv) Reservoir may be used for water reports and recreational purposes.
v) Soil conservation.
vi) Fishing and wild life

Types of Dams: Dams can be classified on the various bases as follows:

a) w.r.t. the material of construction

- Earth fill dam
- Rock fill dam
- Concrete dam
- Steel dam
- Timber dam
- Masonry dam

b) w.r.t the purpose

- Storage dam (to store water, e.g. Tarbela, Mangla etc.)
- Diversion dam (to divert the water from river to canal, e.g. all barrages)
- Detention dam (to control floods and soil conservation)

c) w.r.t. the hydraulic design

- Over-flow dam (e.g. spill way)
- Non over-flow dam (Tarbela, Mangla, Khanpur dams etc.)

d) w.r.t design criteria

- Gravity dams (stability is due to the weight of the dam)
- Arch dams (water pressure is resisted by arch action)
- Buttress dams (a thin inclined concrete slab resting on support system called buttresses)

e) w.r.t the size

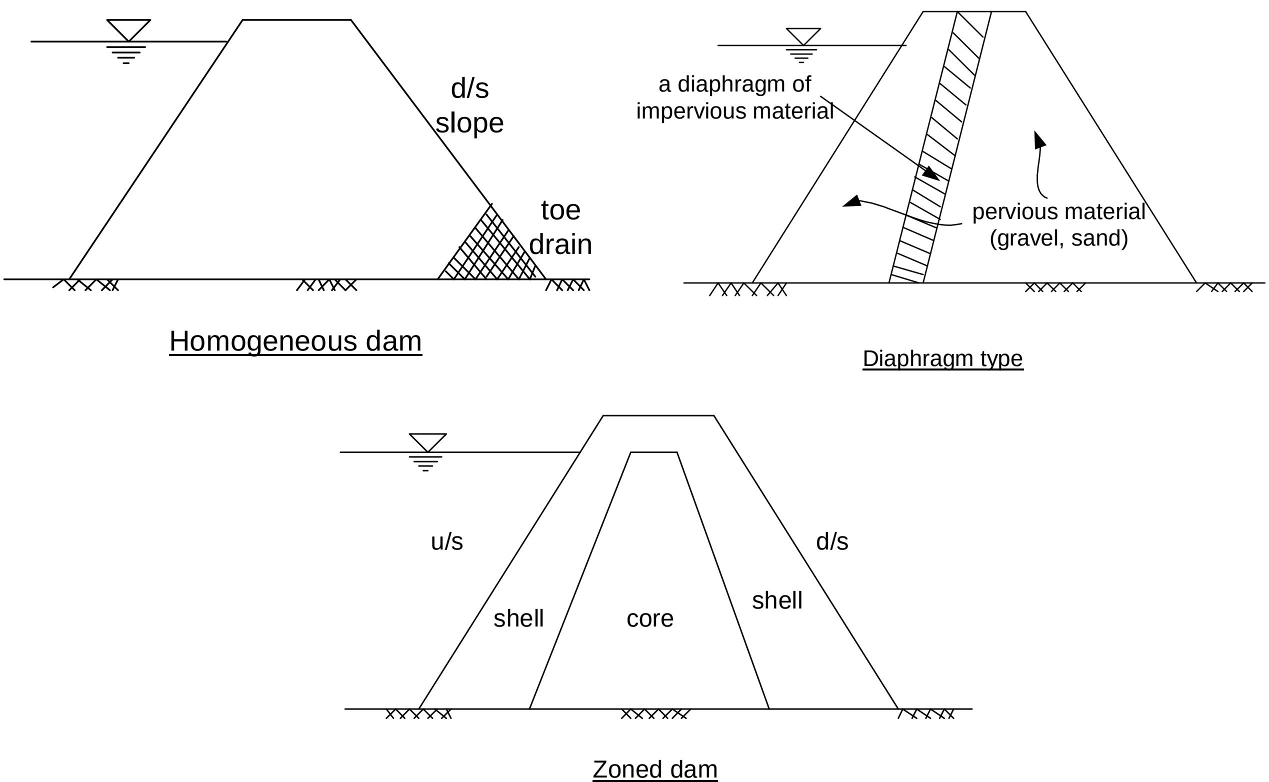
- Large or high dams (more than 100 ft)
- Medium or moderate dams (50 – 100 ft)
- Small or low dams (less than 50 ft)

Earth fill Dam:

An embankment dam constructed preliminary of compacted earth in either homogeneous or zoned areas containing more than 50% earth material. The material from the borrow pits and that which is suitable for other structures is delivered to the embankment, usually by trucks or scrapers. It is then spread and properly compacted.

Types of Earth fill dam

- Homogeneous dams (for medium to low height)
- Diaphragm dam (for medium to low heights)
- Zoned dams (for dams of large size)



Typical cross sections of different type of earth fill dams

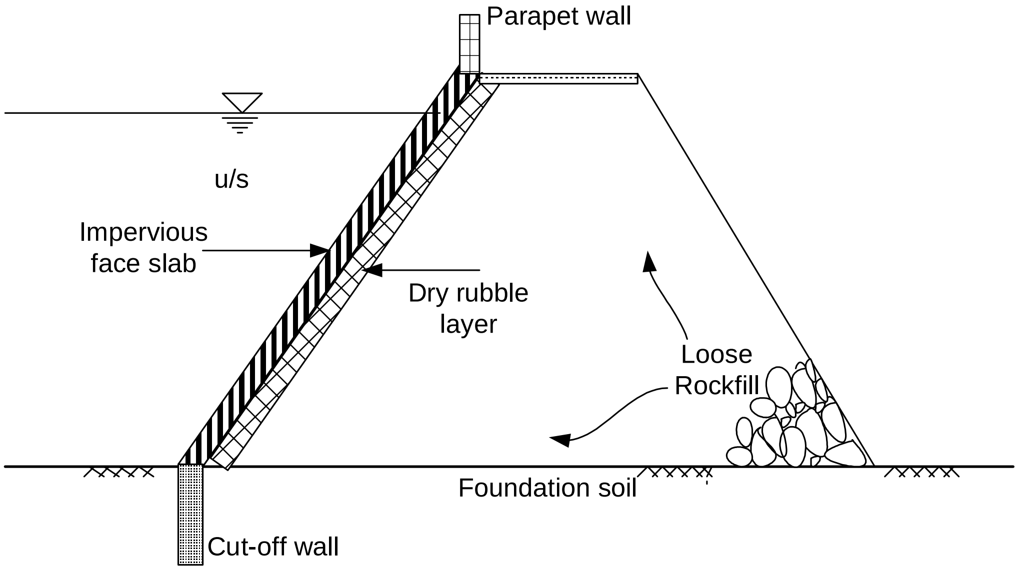
The difference b/w diaphragm and zoned dam is that both have the impervious core in the centre but in case of zoned dam, its thickness is more than diaphragm type dam.

Rock fill Dam:

Instead of earth fill, if rock is available in abundance near the dam site, it can be used as a main body of the dam protected by concrete slab, impervious soil, steel plate etc. on the water side, and resting at an angle of repose on the down steam side.

A rock fill dam consist of

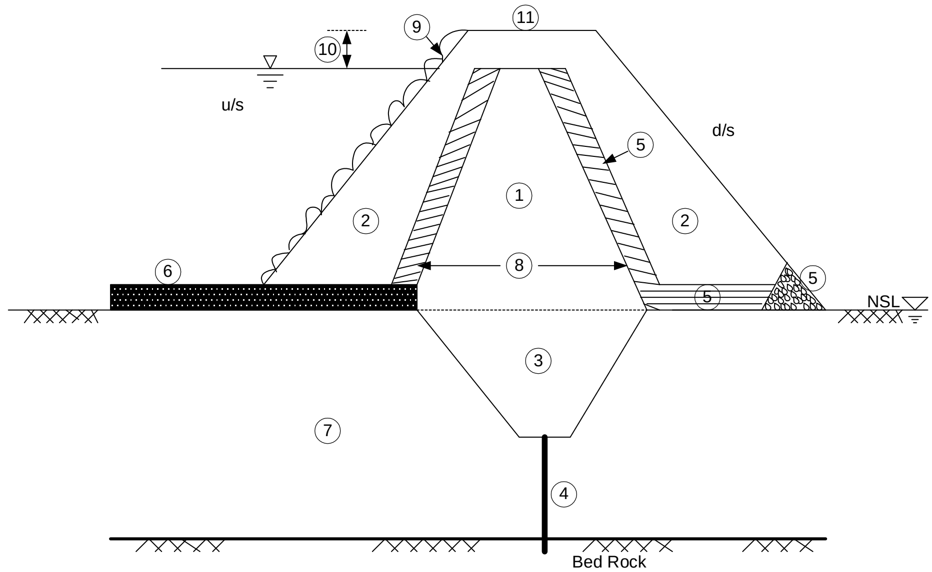
i) Rock fill i.e. big size stones dumped in the form of trapezoidal profile.
ii) A thick layer of dry rubble masonry (hand placed) on the up steam slope to form support for the slab.
iii) A concrete slab of suitable thickness.



Typical cross section of a concrete face rock fill dam (CFRD)

Components of an Earth fill Dam

The figure shows a typical cross section of a zoned earth fill dam. The various components and their function are as under.



Typical cross section of a zoned earth fill dam

1) Core of the dam:

This part of the dam is made with relatively impervious soil. Its function is to make the body of the dam water eight and reduce seepage through the embankment.

2) *Shells:* Shells provide structural support to the core and distribute pressure to the underlying foundation soil/rock.

3) ***Cut-off Trench:***

It reduces the seepage through the foundation. It can be partial cut-off or a complete cut-off reaching to the bed rock.

4) Cut-off sheet pile or grout curtain:

The function of providing cut-off sheet pile is to reduce the seepage through the foundation. It may be partial cut-off or total cut-off reaching the bedrock level.

5) *Drainage system (toe & chimney drains):* To effectively dispose off the seepage water and dissipating build-up of pore water pressures.

6) *Up-steam blanket:* An apron of sufficient thickness of water tight material like clay is laid in the river bed on the u/s side to lengthen the path of percolation and thereby reduce the seepage.

7) *Foundation:* To provide support to the main body of the dam.

8) *Transition Filters:* In order to allow the seepage of water without washing of soil particles of the core material. There are two conditions for the deign of filter for proper functioning.

i) The voids in the filter material should be small enough to hold the larger particles of the protected materials.

ii) The filter material should have high permeability to prevent the build up of pore water pressure.

To meet the above mentioned conditions for the filter, filter should be designed according to the filter design criteria.

9) Rip Rap:

It is provided for u/s slope protection against the wave action. Good quality stones are placed on the surface of the up stream slope of the dam.

10) Free Board:

The vertical distance between the highest water level and the crest of the dam is call free board. It is provided to protect the dam against over topping by wave action.

11) Crest of dam:

The top part of the dam is called crest which is used as a passage or a highway road.

Merits of Earth fill Dams

i) Materials are available at a large proportion at dam site.
ii) Construction material can be easily handled by manual lab our & machinery
iii) Suitable for weak foundation as it can with stand larger deformation
iv) Cheaper the other type of dams.

Demerits of Earth fill Dams:

i) Suitable materials are not always available.
ii) Greater maintenance cost
iii) Separate spillway is required
iv) Overtopping is dangerous.

General Design Criteria for Earth fill Dams:

An earth fill dam must be safe and stable during all phases of construction and operation of the reservoir. To accomplish this, the following criteria must be met.

- The embankment must be safe against overtopping during occurrence of the inflow design flood by the provision of sufficient spillway and outlet works capacity.
- The slope of the embankment must be stable during construction and during all conditions of reservoir operation, including rapid draw down of the reservoir.
- The embankment must be design so as not to impose excessive stresses upon the foundation.
- Seepage flow through the embankment, foundation, and abutments must be controlled so that no internal erosion takes place and there is no sloughing in the area where the

seepage emerges. The amount of water lost through seepage must be under controlled condition.

- The embankment must be safe against overtopping by wave action.
- The u/s slope must be protected against erosion by wave action, and the crest and d/s slope must be protected against erosion due to wind and rainfall.
- If dam is located in a region subject to earthquakes, the design must be such that the most severe earthquake which can be reasonably anticipated will not impair the function of the structure.

Coffer Dams

It is a temporary structure which is built to exclude earth and water from an area in order that work may be performed there under reasonably dry conditions. They are usually required for projects such as dams and piers those are constructed in a river or in other bodies of water. Also they may be installed to prevent the flow of earth and water in to foundation pits excavated on land.
A coffer dam does not have to be entirely water tight in order to be successful. After the construction of coffer dam in the water, the enclosed area is dewatered by pumping. During the entire life of a coffer dam, a certain amount of water is to be pumped out of the enclosed area constantly because some water will leak through the coffer dam and the foundation. The most satisfactory coffer dam is the one that has the exclusion from or control of water inside the dam at the lowest total cost.

Forces acting on Coffer Dam:

The forces acting on a coffer dam may include the weight of the dam, the pressure of the water, the scouring effect of water, the up lift reaction of the earth/water in contact with the dam. A dam should be designed to resist the combined effect of all the forces that will act on it.

Types of Coffer Dam:

A variety of coffer dam have been used in civil engineering, the most common types and their relative merits are as follows:

1) Cantilever Sheet Pile Coffer dam

It is made from steel, wood or concrete sheet piles. This type is suitable in cases where the height of the coffer dam is very small. Such dams are normally subjected to large leakage and flood damage.

2) Braced Sheet Pile Coffer Dam
It is suitable for low to moderate height. The sheet piles are braced from inside the dam to increase its stability. It is also susceptible to leakage and flood damage.

3) Embankment type Coffer Dam

It can be made either by earth material or rock fills

a) Earth fill coffer dam

When impervious earth is available for a project, a satisfactory and economical earth fill coffer dam may be constructed in shallow water. The earth material offers little resistance to erosion from moving water or wave action. An earth fill coffer dam should not be used where there is a danger of overtopping by water.

b) Rock fill coffer dam

This type of dam is constructed by placing rock around an area to be dewatered. This type of dam is quite satisfactory and economical if a large quantity of rock is available. A dam of this type is constructed by placing earth with the rock or by placing a layer of earth around the outside (water side) of the rock. The weight of the rock gives stability to the dam, while the earth acts as a watertight membrane. It may be overtopped with out serious damage.

4) Double-walled Sheet Pile Coffer Dam

In this case the wall of the coffer dam is constructed by two lines of sheet piles which are tied up by tie rods. The space between the two sheet piles is filled by granular material, such as gravel or sand. It can be used for moderate to high heights.

5) Cellular Coffer Dam

This type of coffer dam is suitable from moderate to large heights. It can be consistently used in case of excavation in water. When excavation in a large area overlain by water, as in river or lake bottom, cellular coffer dam is generally used to provide a water barrier. This type of structure is widely used to provide dry work area where dams are constructed in river, and for waterfront construction.

Figures on next page shows the different type of coffer dams

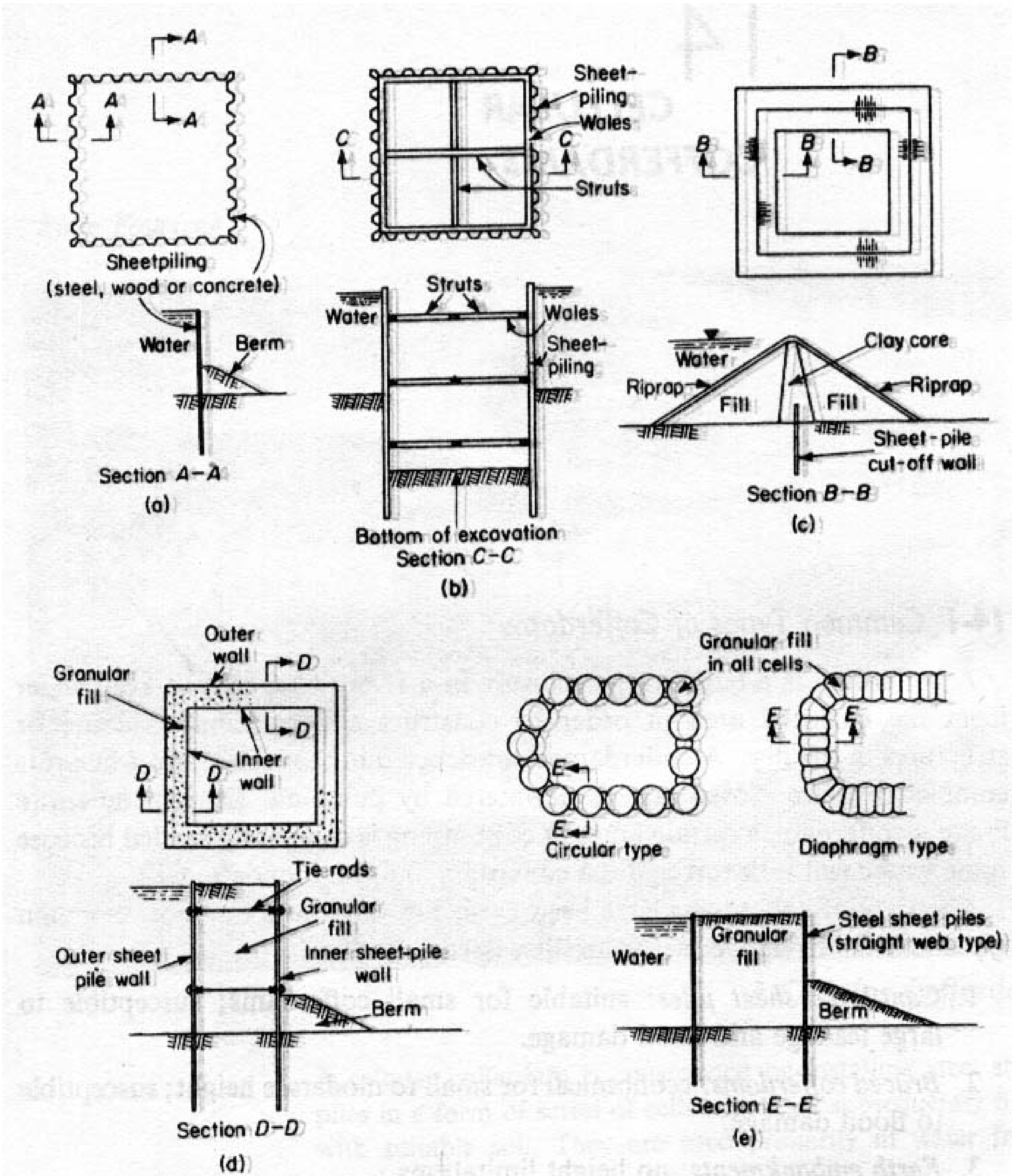


Figure: Common types of coffer dams (a) cantilever sheet pile coffer dam (b) braced cantilever sheet pile coffer dam (c) Earth and rock fill coffer dam (d) double sheet pile coffer dam (e) cellular coffer dam

Tunneling:

Tunnel: An underground passage open to daylight at its both ends is called a tunnel.

Purposes of Tunneling

Tunnels are constructed for various purposes such as follows:

1- Passageways for railroads and automotive vehicles through mountains and under the bodies of water
2- Conduits for water and other liquids
3- Access to mines and underground spaces
4- Conduits for water and other utility services
5- Passageways for pedestrians

Preliminary Explorations for Tunneling

The location of a tunnel should be based on the results of surface and subsurface explorations. Such explorations are made prior to selecting the exact location of a tunnel in order to determine the kinds of formation that exist and the extent to which ground water is present in the formation along the route of a proposed tunnel.
The formation may include unconsolidated muck, sand, gravel, or clay with or without ground water. These may be solid or badly broken rock, or there be faults and folds in the rocks. If a tunnel is driven through a solid rock, little or no roof support may be required, whereas if it is driven through badly broken rock, it will be necessary to provide extensive wall and roof supports. If exploration indicates the presence of significant quantity of underground water, plan should be made to have adequate pumps available to remove the water.

Number of Entrances:

If a tunnel is relatively short, not more than 100 m long, it may be driven from one entrance only. However, as the length of the tunnel is increases, conducting all operations from one entrance may result in excessive haul distance and high haulage costs. Such a condition may be eliminated by driving a tunnel from ends. For long tunnels, it may be advantageous to provide intermediate openings, such as shaft to facilitate the removal of muck and water and the delivery of materials, supplies, air and other utilities.

Sequence of Operation in Tunneling

As soon as the construction of a tunnel is under way, the various operations should be carried on in a well planned sequence. The actual operations will vary with the type and size of the tunnel, the method of attacking the heading, and kind of formation encountered. The construction may be on the basis of one, two or three shifts per day.
For a tunnel driven through rock, the following operation might apply.

1) Setting up and drilling the holes for explosive
2) Loading the holes with explosive and shooting the explosions
3) Ventilating and removing the muck following the explosion

4) Loading and hauling the muck
5) Removing ground water if necessary
6) Erecting supports for the roof and sides if necessary
7) Placing the steel reinforcement for lining work
8) Placing the concrete lining

The first four operations are related to the driving of the tunnel and frequently establish the rate of progress in constructing a tunnel.

Methods of Driving Tunnels in Rocks

There are several methods of attacking the faces of tunnels driven through rocks. The method selected will depend on the size of the bore, the equipment available, the condition of formation, and the extent to which support system is required. The more common methods are

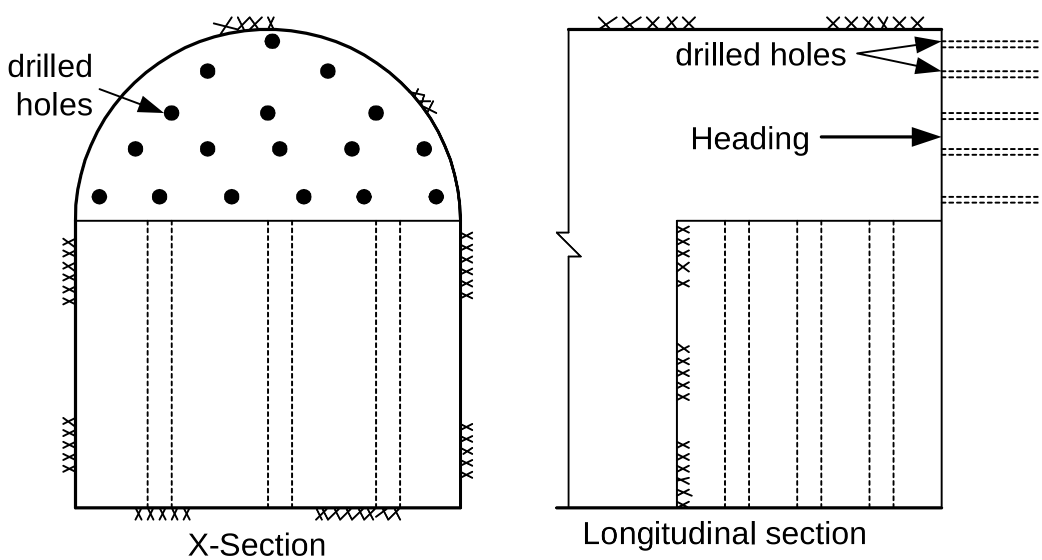
a) Full-face attack method
b) Heading and bench
c) Drift method

a) Full- face Attack Method:

When a tunnel is driven by the full-face attack method, the entire bore or face is drilled, the holes are loaded, and then explosives are discharged. Small tunnels, whose dimensions do not exceed about 10 ft, are always driven by this method. Large size tunnels in rock are also driven by this method provided a sound formation is encountered.

b) Heading and Bench Method

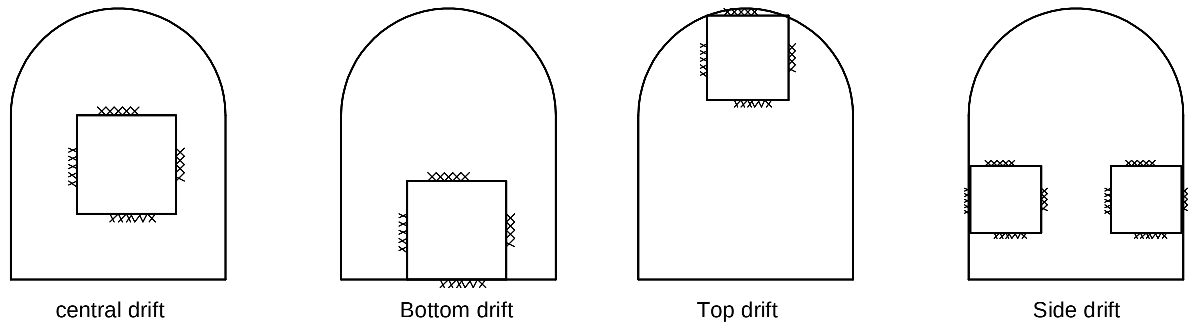
The heading and benching method of driving a tunnel involves the driving of the top portion of the tunnel ahead of the bottom portion. If the rock is sound enough to permit the roof to stand with out the supports, the top heading is advanced one round ahead of the bottom heading. However, if the rock is badly fractured, the top heading may be driven well ahead of the bench and the bench is used as a base for installing timbers to support the roof.



Heading and Bench Attack Method

3) Drift Method

In driving a large tunnel, it may be advantageous to drive small tunnels, called a drift, through all or a portion of the length of the tunnel prior to excavating the full bore. A drift may be classified as centre, bottom, side or top depending on its position relative to the main bore as shown in the following figure.



Drift Method

Lining of Tunnels

There are few tunnels which do not require a lining of some sort. From economy point of view, it is desirable that the lining wall to be as thin as practical. The thickness may be determined by the condition of the ground around the tunnel, the size and shape of the cross section, the requirement of construction conditions, or the internal pressure in case of water conduit.

A rule which has been used to some extent as a guide is to allow one inch of wall thickness for each foot of diameter of tunnel cross section.

If a tunnel is driven through a solid rock or if the support system is durable to prevent any movement of the rock until the bore is drilled, it is desirable to delay the lining process until the excavation is finished. However, if the rock is so fractured that it is difficult to restrain the rock movements, it will be necessary to install the lining as quickly as possible after the blasting and mucking the each round.