



1-Definition :

A dam is a hydraulic structure of fairly impervious material built across a river to create a reservoir on its upstream side for impounding water for various purposes. A dam and a reservoir are complements of each other.

Dams are generally constructed in the mountainous reach of the river where the valley is narrow and the foundation is good.

Dams are probably the most important hydraulic structure built on the rivers. These are very huge structure. Thousands of workers and engineers work for a number of years in the construction of a dam.

Generally, a hydropower station is also constructed at or near the dam site to develop hydropower.

2-Classification of Dams

Dams can be classified according to different criteria, as given below:

A- Based on Function Served:

Depending upon the function served, the dams are of the following types :-

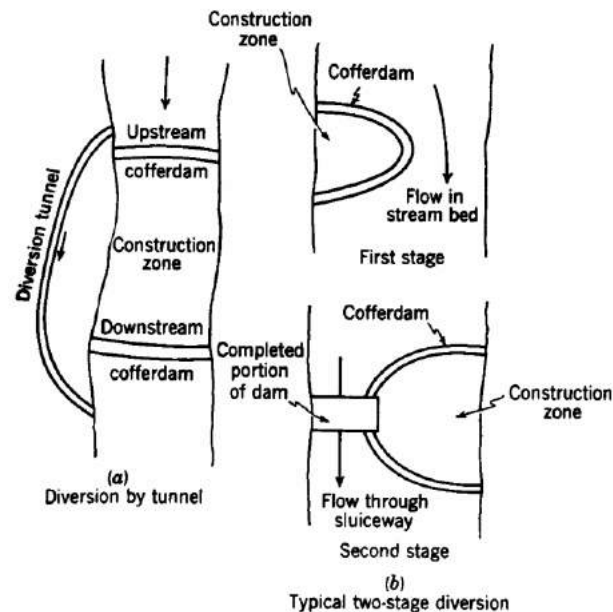
1. Storage dams: Storage (or conservation) dams are constructed to store water during the rainy season when there is a large flow in the river. The stored water is utilized later during the period when the flow in the river is reduced and is less than the demand. The water stored in the reservoir is used for a number of purposes, such as irrigation, water supply and hydropower. Storage dams are the most common type of dams and in general the dam means a storage dam unless qualified otherwise.

2. Detention dams: Detention dams are constructed for flood control. A detention dam retards the flow in the river on its downstream during floods by storing some flood water. Thus the effect of sudden floods is reduced to some extent. The water retained in the reservoir is later released gradually at a controlled rate according to the carrying capacity of the channel downstream of the detention dam. Thus the area downstream of the dam is protected against flood.

3. Diversion dams: A diversion dam is constructed for the purpose of diverting water of the river into an off-taking canal (or a conduit). A diversion dam is usually of low height and has a small storage reservoir on its upstream. The diversion dam is a sort of storage weir which also diverts water and has a small storage. Sometimes, the terms weirs and diversion dams are used synonymously.

4. Debris dams: A debris dam is constructed to retain debris such as sand, gravel, and drift wood flowing in the river with water. The water after passing over a debris dam is relatively clear.

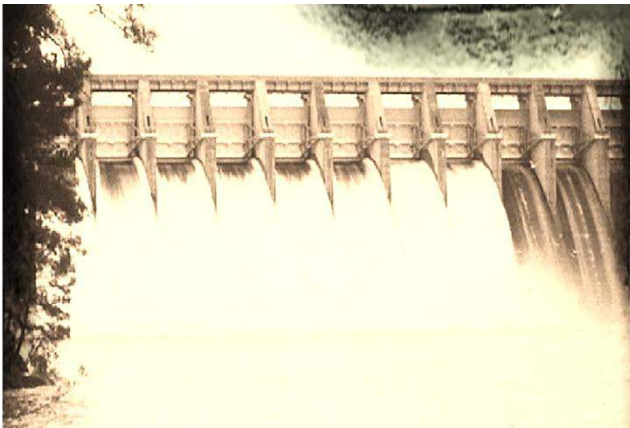
5. Cofferdams: A cofferdam is not actually a dam. It is constructed around the construction site to exclude water so that the construction can be done in dry. A cofferdam is thus a temporary dam constructed for facilitating construction. A cofferdam is usually constructed on the upstream of the main dam to divert water into a diversion tunnel (or channel) during the construction of the dam.

[DAMS]**(B) Based on Hydraulic Design:**

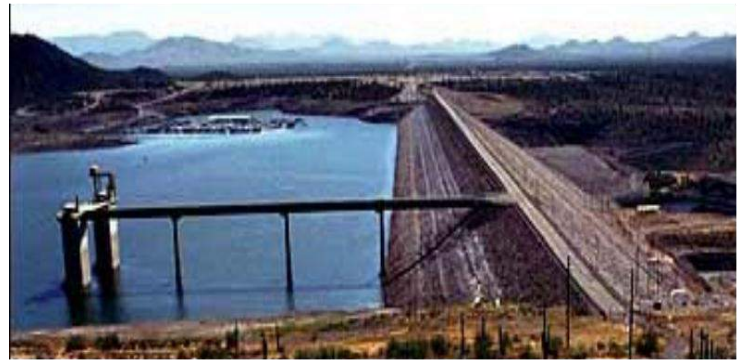
On the basis of hydraulic design, dams may be classified as;

1. **Overflow dams:** An overflow dam is designed to act as an overflow structure. The surplus water which cannot be retained in the reservoir is permitted to pass over the crest of the overflow dam which acts as a spillway. The overflow dam is made of a material which does not erode by the action of overflowing water. Generally, cement concrete is used in overflow dams and spillways. Most of the gravity dams have overflow sections for some length and the rest of the length as a non-overflow dam. However, sometimes the entire length of the dam of low height is designed as an overflow dam. The overflow dam is also called the spillway section.

2. Non-overflow dams: A non-overflow dam is designed such that there is no flow over it. Because there is no overflow, a non-overflow dam can be built of any material, such as concrete, masonry, earth, rock fill and timber. As already mentioned, the non-overflow dam is usually provided in a part of the total length of the dam. However, sometimes the non-overflow dam is provided for the entire length and a separate spillway is provided in the flanks or in a saddle away from the dam. Fig shows a non overflow earth dam.



Overflow Dam



Non-overflow Dam

(C) Based on Materials of Construction:

Based on the materials used in construction, the dams are classified as follows:

- * Masonry dam
- * Concrete dam

- * Earth dam
- * Rockfill dam
- * Timber dam
- * Steel dam
- * Combined concrete-cum-earth dam
- * Composite dam.

(D) Based on Rigidity:

On the basis of the rigidity, the dams are classified into 2 types;

1. Rigid dams: A rigid dam is quite stiff. It is constructed of stiff materials such as concrete, masonry, steel and timber. These dams deflect and deform very little when subjected to water pressure and other forces.
2. Non-rigid dams: A non-rigid dam is relatively less stiff compared to a rigid dam. The dams constructed of earth and rock fill are non-rigid dams. There are relatively large settlements and deformations in a non-rigid dam.

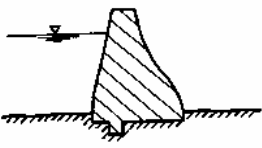
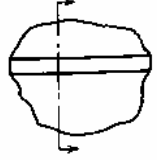
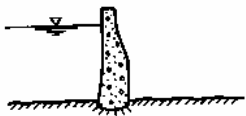
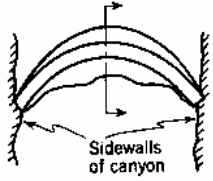
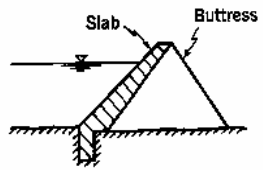
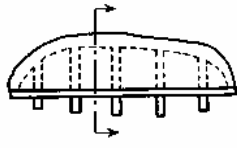
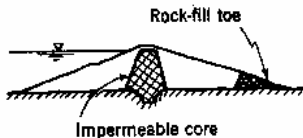
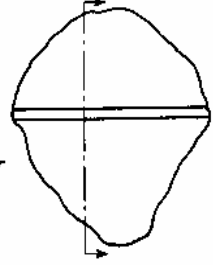
(E) Based on the structural action:

This is the most commonly used classification of dams. Such classification are ;

- (1) Gravity dams,
- (2) Earth dams,
- (3) Rock fill dams,
- (4) Arch dams,

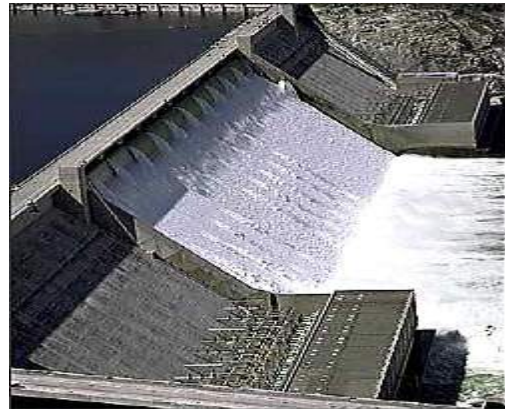
[DAMS]

- (5) Buttress dams,
- (6) Steel dams, and
- (7) Timber dams.

Type	Material	Sectional View	Plan (Top View)
Gravity	Concrete, rubble masonry		
Arch	Concrete		
Buttress	Concrete also timber and steel		
Embankment	Earth or rock		

[DAMS]**[Gravity Dam]**

Masonry Gravity Dam (non-over flow)



Concrete Gravity Dam (over flow)

A gravity dam resists the water pressure and other forces due to its weight (or gravitational forces). Thus the stability of a gravity dam depends upon its weight. The gravity dams are usually made of cement concrete. In the past, the gravity dams were made of stone masonry, but now the masonry dams are rarely constructed, except for very small heights.

Main Features of Gravity Dam

- The gravity dams are generally straight in plan (i.e. axis is straight from one abutment to the other)
- The gravity dams are approximately triangular in cross-section, with apex at the top.
- The gravity dams are generally more expensive than earth dams but are more durable.
- They are quite suitable for the gorges with very steep slopes.

- They require strong rock foundation. However, if the foundation consists of soil, the height of the gravity dams is usually limited to 20 m .

The most high dams over the world are :-

- *Grand Dixence Dam in Switzerland , (284 m high).*
- *Hoover dam in USA , (221m high) .*
- *Bhakra dam in India , (226m high) .*
- *Nagarjuna Sagar Dam (structural height of 125 m) is the highest masonry dam of the world. It is also the largest (storage capacity) dam of India.*

Advantages

- (i) Gravity dams are quite strong, stable and durable.
- (ii) Gravity dams are quite suitable across moderately wide valleys and gorges having steep slopes where earth dams, if constructed, might slip.
- (iii) Gravity dams can be constructed to very great heights, provided good rock foundations are available.
- (iv) Gravity dams are well adapted for use as an overflow spillway section. Earth dams cannot be used as an overflow section. Even in earth dams, the overflow section is usually a gravity dam.
- (v) Gravity dams are specially suited to such areas where there is very heavy downpour. The slopes of the earth dams might be washed away in such an area.
- (vi) The maintenance cost of a gravity dam is very low.

[DAMS]

(vii) The gravity dam does not fail suddenly. There is enough warning of the imminent failure and the valuable property and human life can be saved to some extent.

(viii) Gravity dam can be constructed during all types of climatic conditions.

(ix) The sedimentation in the reservoir on the upstream of a gravity dam can be somewhat reduced by operation of deep-set sluices.

Disadvantages

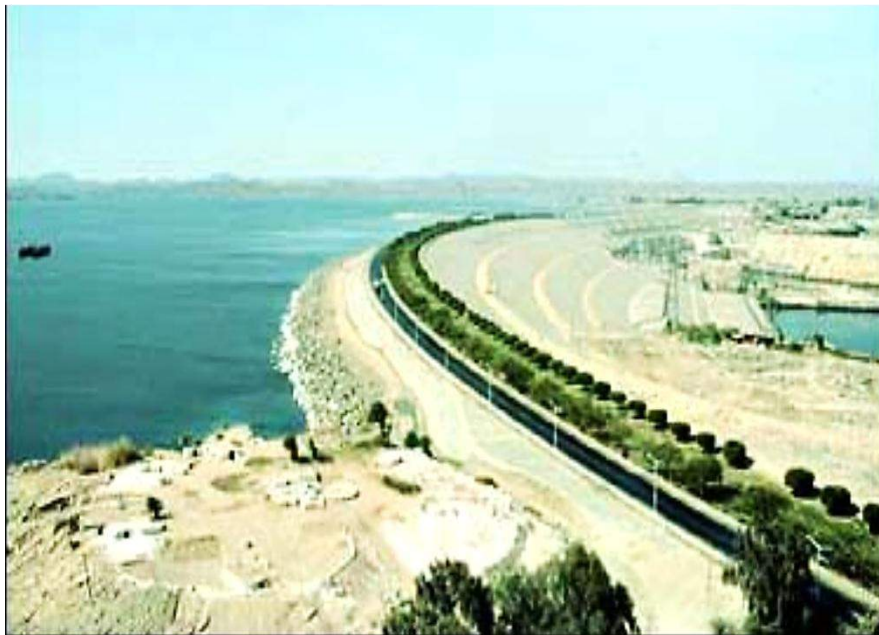
(i) Gravity dams of great height can be constructed only on sound rock foundations. These cannot be constructed on weak or permeable foundations on which earth dams can be constructed. However, gravity dams upto 20 m height can be constructed even when the foundation is weak.

(ii) The initial cost of a gravity dam is usually more than that of an earth dam. At the sites where good earth is available for construction and funds are limited, earth dams are better.

(iii) Gravity dams usually take a longer time in construction than earth dams, especially when mechanised plants for batching, mixing and transporting concrete are not available.

(iv) Gravity dams require more skilled labour than that in earth dams.

(v) Subsequent raising is not possible in a gravity dam.

[DAMS]**[Earth Dam]**

An earth dam is made of earth (usually local soils) , it resists the forces exerted upon it mainly due to shear strength of the soil . Although the weight of the dam also helps in resisting the forces, the structural behavior of an earth dam is entirely different from that of a gravity dam.

Main Features of Earth Dam

- The earth dams are usually built in wide valleys having flat slopes at (abutments).

[DAMS]

- The foundation requirements are less stringent than those of gravity dams, and hence they can be built at the sites where the foundations are less strong.
- They can be built on all types of foundations. However, the height of the dam will depend upon the strength of the foundation material.
- The section of an earth dam can be homogeneous when the height of the dam is not great.
- Generally, the earth dams are consists different zoned sections (see Fig. below) , these sections categorized as follow :-

-The impervious zone (called core) mainly located in the middle of cross section of dam .

-Relatively pervious zones (called shells or shoulders) enclosing the impervious zone (core) on both sides

- If the earth dam is built on a pervious foundation, a concrete cutoff wall or a steel sheet pile line is also provided in the continuation of the core section.
- Moreover, a drainage filter or a rock toe is provided on the downstream to carry away the water that seeps through the dam and its foundation.
- Earth dams are usually cheaper than the gravity dams if suitable earth in abundant quantity is easily available near the site.

The most high dams over the world are :-

The majority of dams constructed are of this type. The highest dams of the world are earth dams , such that ;

- ***Rongunsky dam , Rusia, 325m***

[DAMS]

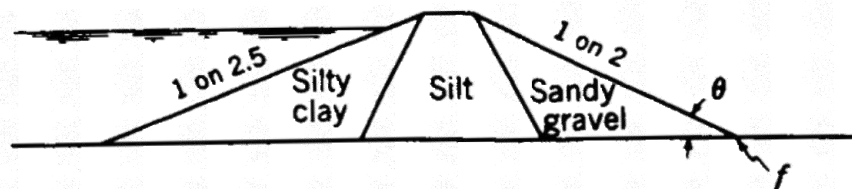
- *Nurek dam, Rusia, 317 m*

- *Tehri dam , India , 261 m , which is earth and rockfill type*

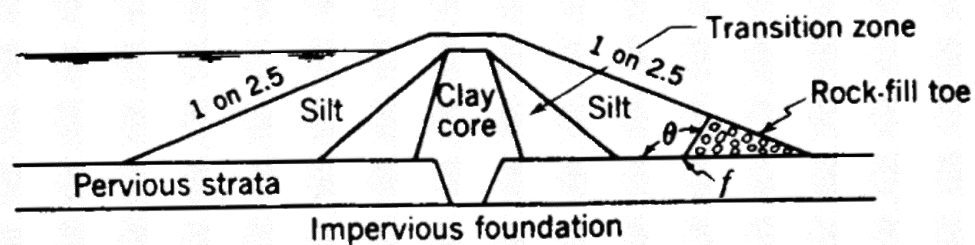
And the largest capacity dams are ;

- *New Cornelia dam, USA , and*

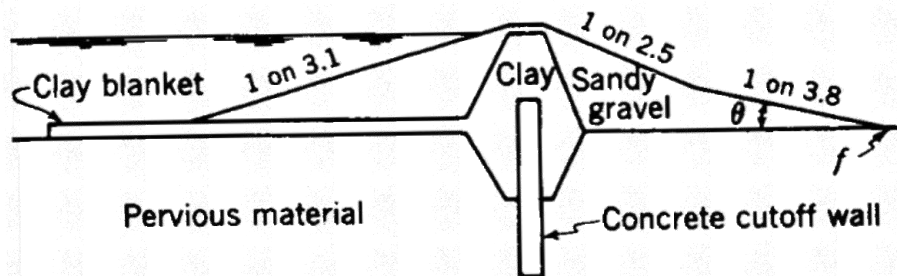
- *Tarbela dam, Pakistan.*



(a) Simple zoned embankment



(b) Earth dam with core extending to impervious foundation



Advantages

- (i) Earth dams are usually cheaper than gravity dams if suitable earth for construction is available near the site.
- (ii) Earth dams can be constructed on almost all types of foundations, provided suitable measures of foundation treatment and seepage control are taken.
- (iii) Earth dams can be constructed in a relatively short period.
- (iv) The skilled labour is not required in construction of an earth dam. Earth dams can be raised subsequently.
- (vi) Earth dams are aesthetically more pleasing than gravity dams.
- (vii) Earth dams are more earthquake-resistant than gravity dams.

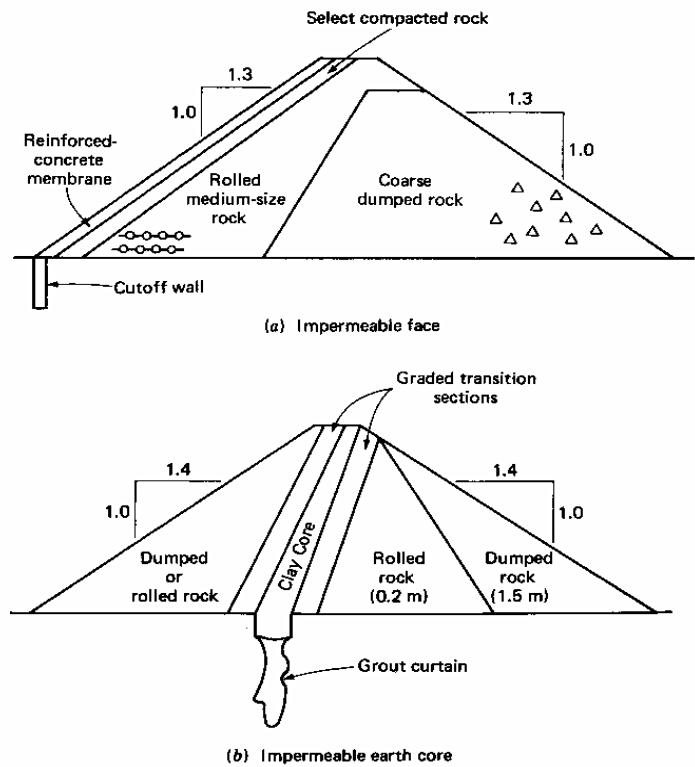
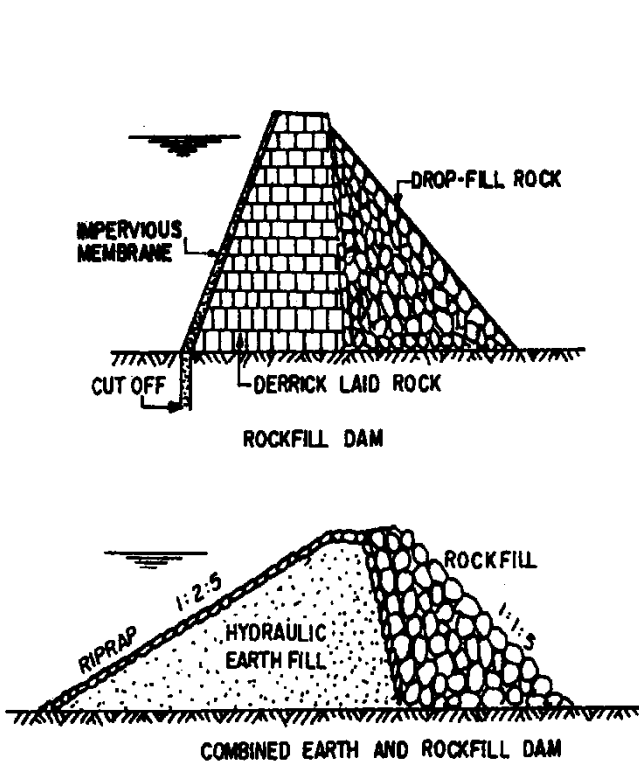
Disadvantages

- (i) Earth dams are not suitable for narrow gorges with steep slopes.
- (ii) An earth dam cannot be designed as an overflow section. A spillway has to be located away from the dam.
- (iii) Earth dams cannot be constructed in regions with heavy downpour, as the slopes might be washed away.
- (iv) The maintenance cost of an earth dam is quite high. It requires constant supervision.
- (v) Sluices cannot be provided in a high earth dam to remove silt.

[DAMS]

(vi) An earth dam fails suddenly without any sign of imminent failure. A sudden failure causes a major danger for lives and properties .

[Rockfill Dam]



A rockfill dam is built of rock fragments and boulders of large size.

Main Features of Rockfill Dam

- An impervious membrane is placed on the rockfill on the upstream side to reduce the seepage through the dam.
- The membrane is usually made of cement concrete or asphaltic concrete.
- A dry rubble cushion is placed between the rockfill and the membrane for the distribution of water load and for providing a support to the membrane.
- Sometimes, the rockfill dams have an impervious earth core in the middle to check the seepage instead of an impervious upstream membrane.
- The earth core is placed against a dumped rockfill.
- It is necessary to provide adequate filters between the earth core and the rockfill on the upstream and downstream sides of the core so that the soil particles are not carried by water and piping does not occur.
- The side slopes of rockfill are usually kept equal to the angle of repose of rock, which is usually taken as 1.4:1 (or 1.3:1).
- Rockfill dams require foundation stronger than those for earth dams. However, the foundation requirements are usually less stringent than those for gravity dams.
- Rockfill dams are quite economical when a large quantity of rock is easily available near the site.

The most high dams over the world are :-

The majority of dams constructed are of this type. The highest dams of the world, such that ;

- Thiem dam (PJ), Ramganga dam (UP), etc. are rockfill dams in India,
- Mica dam (242 m, Canada),
- Chicoasen dam (240m, Maxico) are highest rockfill dams.

Advantages

- (i) Rockfill dams are quite inexpensive if rock fragments are easily available.
- (ii) Rockfill dams can be constructed quite rapidly.
- (iii) Rockfill dams can better withstand the shocks due to earthquake than earth dams.
- (iv) Rockfill dams can be constructed even in adverse climates.

Disadvantages

- (i) Rockfill dams require more strong foundations than earth dams.
- (ii) Rockfill dams require heavy machines for transporting, dumping and compacting rocks.

[DAMS]

18 of 26

[Arch Dam]

An arch dam is curved in plan, with its convexity towards the upstream side.

Main Features of Arch Dam

- An arch dam transfers the water pressure and other forces mainly to the abutments by arch action.
- An arch dam is quite suitable for narrow canyons with strong abutments which are capable of resisting the thrust produced by the arch action.
- The section of an arch dam is approximately triangular like a gravity dam but the section is comparatively thinner.

[DAMS]

-
- The arch dam may have a single curvature or double curvature in the vertical plane.
 - Generally, the arch dams of double curvature are more economical and are used in practice.
 - The quantity of concrete required in an arch dam is less than that for a gravity dam, but it is not necessarily less expensive because of high cost of concrete and form work.
 - The arch dams are subjected to large stresses because of changes in temperature shrinkage of concrete and yielding of abutments.
 - The arch dam requires good quality concrete for resisting the stresses.

The most high dams over the world are :-

There are many arch dams over 200 m , such that ;

-Juguri dam (272 m), Russia,

-Vaiont dam (262 m), Italy,

-Manvoisin dam (237 m) Switzerland.

Advantages

- (i) An arch dam requires less concrete as compared to a gravity dam as the section is thinner.
- (ii) Arch dams are more suited to narrow, V-shaped valley, having very steep slopes.

(iii) Uplift pressure is not an important factor in the design of an arch dam because the arch dam has less width and the reduction in weight due to uplift does not affect the stability.

(iv) An arch dam can be constructed on a relatively less strong foundation because a small part of load is transferred to base, whereas in a gravity dam full load is transferred to base.

Disadvantages

(i) An arch dam requires good rock in the flanks (abutments) to resist the thrust. If the abutments yield, extra stresses develop which may cause failure.

(ii) The arch dam requires sophisticated formwork, more skilled labor and richer concrete.

(iii) The arch dam cannot be constructed in very cold climates because swelling of concrete occurs due to freezing .

(iv) The speed of construction is relatively slow.

3-Selection of Site for a Dam

A dam is a huge structure requiring a lot of funds. Extreme care shall be taken while selecting the site of a dam. A wrong decision may lead to excessive cost and difficulties in construction and maintenance. The following factors shall be considered when selecting the site of a dam ;

1. Topography: As far as possible, the dam should be located where the river has a narrow gorge which opens out upstream to create a large reservoir. In that case, the length of the dam would be small and the capacity of the

reservoir on its upstream would be large. In case there is a confluence of two rivers in the selected reach, the dam should be located downstream of the confluence to take advantage of the flow of both rivers. The dam should be preferably located where the river bed is high, to reduce the height and cost of the dam.

2. Suitable Foundation: Suitable foundation should exist at the site for the particular type of dam. If suitable foundation is not available but it can be improved by adopting various measures, the site may be considered for selection. However, in that case, the cost of such measures should not be excessive. For gravity dams of great height, sound rock is essential. However, earth dams can be constructed on almost any type of foundation provided suitable measures are adopted.

3. Good Site for reservoir: As the dam is constructed to store water in the reservoir, so the site should have the following characteristics to make a good site for a reservoir: (i) Large storage capacity: The topography of the site should be such that the reservoir has a large capacity to store water. (ii) Shape of reservoir basin: The reservoir basin on the upstream of the dam should preferably be cup-shaped, with a flat bottom but steep slopes. (iii) Water tightness of the reservoir: The geological conditions of the reservoir site should be such that the reservoir basin is watertight. The reservoir sites having pervious rocks are not suitable. The reservoir basins having shales, slates, schists, gneiss, granite, etc. are generally suitable. (iv) Good hydrological conditions: The hydrological conditions of the river at the reservoir site should be such that adequate runoff is available for storage. The catchment area of the river should give high yield. There should not be heavy losses in the catchment due to evaporation, transpiration and

percolation. (v) Deep reservoir: The site should be such that a deep reservoir is formed after the construction of the dam. A deep reservoir is preferred to a shallow reservoir because in the former the evaporation losses are small, the cost of land acquisition is low and the weed growth is less. (vi) Small submerged area: The site should be such that the submerged area is a minimum. It should not submerge costly land and property. It should not affect the ecology of the region. Monuments of historical and architectural importance should not be submerged. (vii) Low silt inflow: The dam site should be such that the reservoir would not silt up quickly. The life of the reservoir depends upon the rate of silting. The site should be selected such that it avoids or excludes the water from those tributaries which carry a high percentage of silt, i.e. if any tributary carries relatively large quantity of sediments, the dam should be constructed upstream of the confluence of that tributary with the river. (viii) No objectionable minerals: The soil and rock mass at the reservoir site should not contain any objectionable soluble minerals which may contaminate the water. The stored water should be suitable for the purpose for which the water is required.

4. Spillway site: A good site for a spillway should exist at or near the dam site. The valley should be sufficiently wide to locate the spillway if it is an integral part of the dam. If the spillway is to be located separately, the best site of spillway is that in which there is a saddle near the dam site which is separated from it by a hillock. In that case, the main dam can be located in the gorge and the spillway can be constructed in the saddle.

5. Availability of materials: The dam requires a large quantity of material for its construction. Suitable type of material in sufficient quantity should be available at or near the dam site to reduce the cost.

6. Accessibility: The site should be easily accessible. It should be preferably well-connected by a road or a railway line. This would facilitate transportation of labour, materials and machinery.

7. Healthy surroundings: The surroundings of the site should be healthy and free from mosquitos so that the labourers can comfortably live in colonies constructed near the dam site.

8. Low cost of real estate: The cost of real estate for the reservoir site, dam, dwellings, roads, railways, etc. should be low.

9. Minimum overall cost: The site should be such that it entails the minimum overall cost of the project, including subsequent maintenance. Generally, two or three probable sites are selected and rough estimates are made. The site which entails the minimum overall cost can be tentatively selected.

10. Other considerations: For the development of a particular backward area, the dam may be constructed in that region. Sometimes political considerations and public opinion may affect the site of a dam.

4-Selection Type of a Dam

Selection of the most suitable type of dam for a particular site requires a lot of judgment and experience. It is only in exceptional cases that the most suitable type is obvious. Preliminary designs and estimates are usually required for several types of dams before making the final selection on economic basis. The salient features of different types of dams discussed in the preceding sections should be kept in mind while selecting the type of dam. Various factors which govern the selection of type of dam are discussed below:

[DAMS]

1. Topography and valley shape. The choice or the type of dam for a particular site depends to a large extent on the topography and the valley shape. The following are the general guidelines. (a) If the valley is narrow, V-shaped and has sound rock in bed and abutments, an arch dam is generally the most suitable type. (b) If the valley is moderately wide, V-shaped and has sound rock in bed, a gravity dam or a buttress dam may be quite suitable. (c) For a low rolling plain country, with a fairly wide valley and alluvial soil or boulders in the bed, an earth dam or a rockfill dam may be quite suitable.

2. Geology and foundation conditions. A dam is a very huge structure. All the loads acting on the dam, including its own weight, are ultimately transferred to the foundations. While selecting the type of dam for a particular site, geologic character and thickness of rock, inclination of the bedding planes, existing faults and fissures, permeability of strata, etc. affect the selection.

3. Availability of construction materials. The construction of a dam requires a huge quantity of construction material. While selecting the type of dam, the availability of the required construction materials should be considered. If a particular material is available in abundance at or near the dam site, the maximum use of that material should be made to reduce the cost. The materials which are not available near the site should be either avoided or the minimum use shall be made of such materials. For example, if suitable aggregates such as crushed stone, gravel and sand are available, a gravity dam may be suitable. On the other hand, if suitable soil is available in large quantity, an earth dam may be cheaper.

[DAMS]

4. Overall cost. The overall cost is perhaps the most important factor which affects the selection of the suitable type of dam for a particular site. The initial cost of the dam depends upon the availability of material, the quantity of material required, labour and the construction methods. The cost of subsequent maintenance depends upon the durability of the materials used and the type of construction. The dam with a minimum overall cost is usually the best.

6. Earthquake hazards: If the dam site is located in a seismic zone, the most suitable type of the dam is one which can resist the earthquake shock without much damage. Earth dams and rockfill dams are generally more suitable for such sites, provided suitable modifications are made in the design. However, by adopting suitable measures and considering various forces and factors affecting the seismic design, other types of dams can also be provided.

7. Climatic conditions: Climatic conditions should also be considered while selecting the type of dam. In extremely cold climates, buttress and arch dams should be avoided.

8. Diversion problems: During the construction of the dam, the river water has to be diverted so that construction can be done in dry. If the river water cannot be diverted through a suitable tunnel (or channel) located in one of the flanks (abutments), it has to be passed over the partly constructed dam when the construction is done in the other part. In such a case, an earth dam cannot be provided, and the choice will be more in favour of a gravity dam or any other type of concrete dams.

[DAMS]

9. Environmental considerations: The dam and its appurtenant works should be aesthetically acceptable and they should not have any adverse effect on ecology and environment. Generally, earth dams are more suitable than concrete dams for aesthetical consideration .

10. Roadway: If a wide, straight roadway is to be provided over the top of dam, an earth dam or a gravity dam is more suitable than an arch dam or a buttress dam.

11. Length and height of dam: If the length of the dam is great and the height is low, an earth dam is generally better than a gravity dam. On the other hand, if the length is small and the height is great, a gravity dam is better.

12. Life of dam: If the expected life of the project is long, a concrete dam is usually preferred. Earth and rockfill dams have moderate life, whereas timber dams have short life.