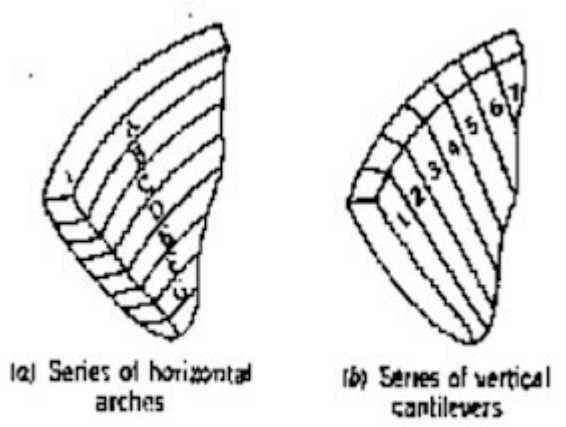
DESIGN OF ARCH DAM

- Dam, Barrage and a weir structure is a natural or man-made obstruction or barrier build across a river in-between the two ends of the river to raise the water, called head of the structure as well produce a massive storage.
- A barrage is built to divert this river water into the nearby link canals by regulating head for irrigation purpose.
- A dam is built to utilize the head for power generation and for storage.
- Dams are classified in different categories based on the type of material used; shape of the core structure; purpose of the project etc.
- 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.
- Let us now discuss in detail about the distribution of the load by an arch dam, which is briefly explained above;

- Let us consider an arch dam made up of two connected components one is series of arches and other is series of vertical cantilevers; as shown:-



Series of horizontal arches and vertical cantilevers

- The load caused due to thrust of impounded water in the arch dam is transferred to the abutments rested on solid / stable rocky side walls of the valley / canyon.
- Thus the load on the cantilever wall is reduced in arch dam as compared to that of the gravity dam. It is one of the major benefit due to which arch dam is considered economic.

Situations When Arch Dam is a must to use

1. Arch dam is proved most economical and efficient when the width of the canyon or valley to be spanned on the river is least.
2. As a major share of the impounding water thrust is taken by abutment walls resting on the sides of the canyon, thus these must be stable, strong and firm.
3. Arch dam can be used most economically on a terrain where width of the valley is less than 6 times of its height or in other words B/h ratio is less than 6.
4. If the area is remote such that the naturally available material are not enough to provide sufficient supply of concrete or earth-fill arch dam should be used as it needs minimum amount of construction concrete.
5. The slope of the adjoining hills for the abutment should be steep i.e. more than 45 degrees.
6. During the design of the arch dam it is considered that the stresses generated are upto that of allowable stresses of the concrete.

Advantages of Arch Dam – Few but long lasting

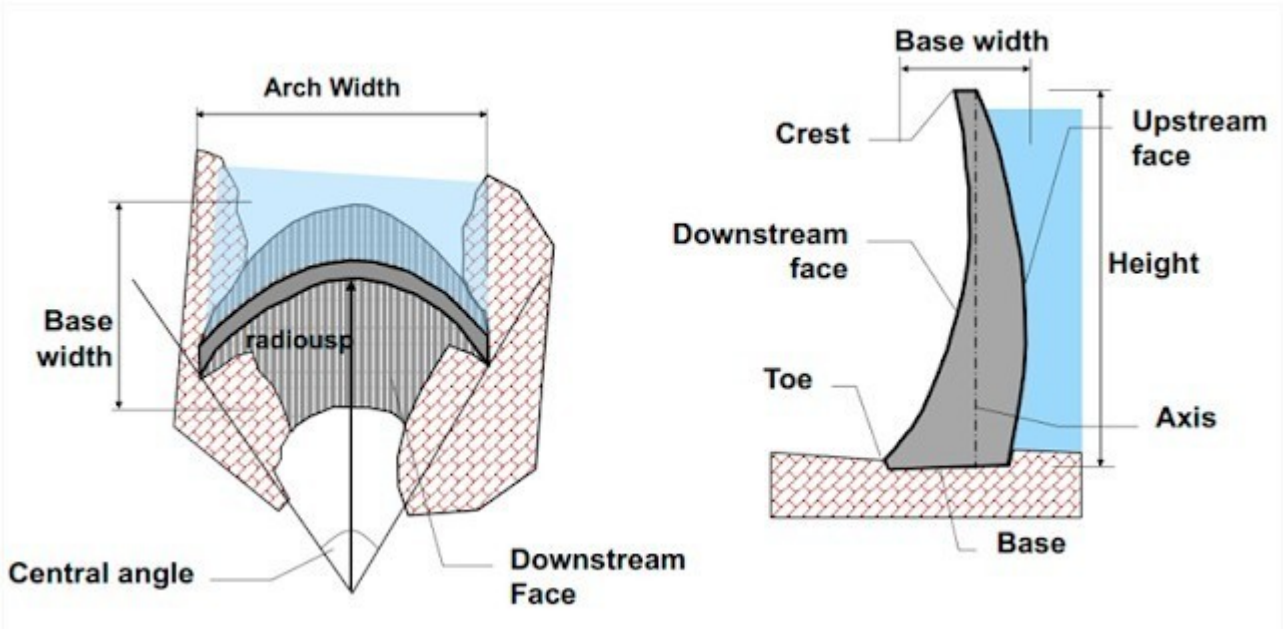
1. The major advantage derived from Arch dam is minimal amount of concrete / filling material required as the stresses of the thrust of water is taken care by both arch action and cantilever action requiring considerably small width at the bottom.
2. These dams are best suited for a narrow canyon passage and can store water as well as generate electricity.

3. Arch dams are particularly adapted to the gorges where the length is small in proportion to the height.
4. For a given height, the section of an arch dam is much lesser than a corresponding gravity dam.
5. Hence, an arch dam requires less material and is, therefore, cheaper.
6. Because of much less base width, the problems of uplift pressure are minor.
7. Since only a small part of water load is transferred to the foundation by cantilever action, an arch dam can be constructed in moderate foundations where gravity dam requiring sound foundation rock may be unsuitable.

Disadvantages of Arch Dam.

1. Arch dams are particularly adapted to the gorges where the length is small in proportion to the height.
2. For a given height, the section of an arch dam is much lesser than a corresponding gravity dam.
3. Hence, an arch dam requires less material and is, therefore, cheaper.
4. Because of much less base width, the problems of uplift pressure are minor.
5. Since only a small part of water load is transferred to the foundation by cantilever action, an arch dam can be constructed in moderate foundations where gravity dam requiring sound foundation rock may be unsuitable.

Components a Typical Arch dam is composed of



Above is a typical plan and cross-section of an arch dam showing typical components / parts of an arch dam.

Types of Arch Dams

Shell – Arch Dam – A famous and Aesthetic marvel

- Researchers have shown that greater the curvature of the arch dam in plan, the greater is the stresses on the abutments and thus lesser is the base width or thickness required.
- This economy can be further increased by providing curvature in the section making it a shell like or plate like structure.
- Such a non-vertical and shell like arch dam is termed as double curvature arch dam or shell-arch dam.
- Simple arch dams whose major part is distributed through the cantilever part of the arch dam can also be divided into different types as their faces can be either curvilinear or non-linear.

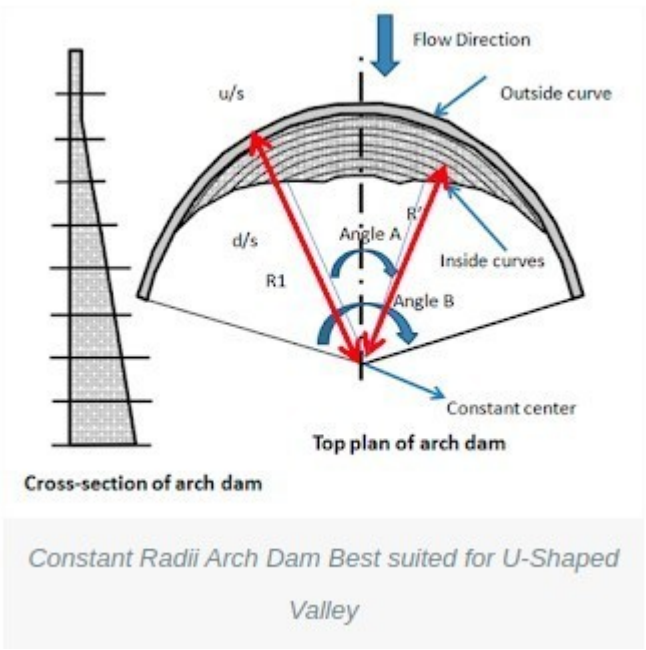
    1. Constant Radii Arch Dam
    2. Variable radii arch dam
    3. Constant angle arch dam

Constant Radii Arch Dam Best suited for U-Shaped Valley

The picture above clearly explains the definition of Constant Radius Arch dam;

In Constant Radius Arch Dam, the radius of the outside Circular Curve (as shown in fig R1) is constant throughout the height / elevation of the dam creating a linear upstream face of the dam.

However, the inner curves of the arch are of variable radii i.e. from top to bottom elevation of the arch dam the radius of the curves reduces creating a triangular cross-section of the arch dam as shown in the figure.



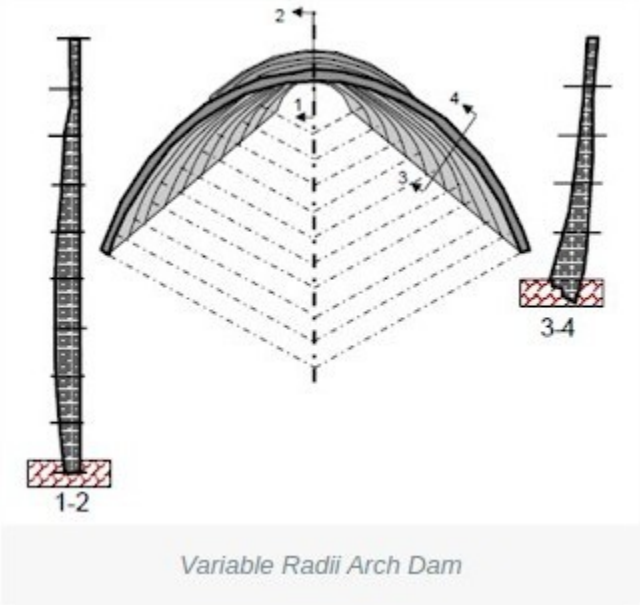
Constant Radii Arch Dam Best suited for U-Shaped Valley

- The increased thickness of the dam at the base will take care of the proportionally increasing hydrostatic thrust of the impounding water.

- It is to be noted here that the outside (upstream side) circular curves are sometimes termed as extrudes while that of inside curves are termed as intrudes.
- The constant Radii arch dam is sometimes referred as constant center arch dam; it is because of the fact that although the radii of the introdes decreases as we move down the elevation of the dam however the center of the curve is at the same line / point i.e. center of the curves are fixed.
- There is one more term associated with the arch dam which is central angle of the arch curves. If you see at the above figure; the central angle of the introdes decreases from top to bottom i.e. maximum central angle is at the top while minimum is at the bottom.
- Constant Radii or variable angle arch dams are most suitable for U-shaped valleys and is for easy construction providing vertical upstream face for efficient stress taking capacity.

Variable Radii Arch Dam Best Suited for V-shaped valley

- Now after reading Constant radii arch dam you might be able to define what is variable radii arch dam. If not let me do this for you; a Variable radii arch dam is the one in which the radius of the introdoes as well that of extrodos vary along the height.
- Making it maximum at the top and minimum at the bottom elevations. Along with the radius the central angle also become bigger and wider making it more effective and economical.



Variable Radii Arch Dam

- In a typical design of such a dam, the downstream face of the dam at the central line (crown) is vertical; while at all other locations, there is a batter on both the sides except at the abutments, where again, the upstream side becomes vertical.
- If overhangs are permitted, due to availability of stronger foundations, then the faces at the crown as well as abutments, may be provided with overhangs, affecting saving in the designed thickness.

- Evidently, since in such an arch dam, the centers of the various arch rings at different elevations, do not lie on the same vertical line; it is also known as variable center arch dam. Such dams are preferred for V-shaped valleys.

Constant Angle Arch Dams – An intermediate and most economic

- The constant angle arch dam is a special type of variable radius arch dam, in which the centeral angles of the horizontal arch rings are of the same magnitude at all elevations.
- The design of such a dam can, thus be made by adopting best central angle of 133 degrees and 34 minutes; and hence such a dam proves to be the most economical, out of the three types of ordinary arch dams.
- However, the design of such a dam usually involves providing overhangs at abutments, which require stronger foundations, and hence such a type cannot be used if the foundations are weak.

Design of Arch Dams – a complex hectic job

- As already explained above that the arch dam is a complex structure which is a bit difficult to design and construct.
- The design procedure adopted is a hit and trial type, a hydraulic dam design is proposed which is carried out through lengthy calculations for testing and checking through different criterions thus after several tries an economical, feasible and safe working design of the dam is developed.
- As far as the loads are concerned, the arch dam is designed for the same types of loads a concrete gravity dam is designed for. These loads includes :-
    - Water Pressure
    - Earthquake pressure
    - Wave pressure
    - Ice pressure
    - Temperature forces
    - Silt load
- However it is important here to understand that importance of above mentioned factor may be a bit for some types of loads and may be not for the other one.
- Like in case of arch dams we know the base width is comparatively very small to that of the concrete gravity dam, thus the uplift forces will be small.
- Mostly in the design of arch dams the uplift forces are neglected.

Arch dams are designed and engineered by three famous methods :-

1. Thin cylinder theory
2. Theory of elastic arches
3. The trial load method

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 offtaking 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.