I 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.

1.1 THE DIFFERENT COMPONENTS OF A SOLID GRAVITY DAM ARE

• Crest.

• Free Board.

• Heel.

• Toe.

• Sluice Way.

• Drainage Gallery.

1.2 TYPICAL CROSS SECTION OF GRAVITY DAM:

Heel: contact with the ground on the upstream side

Toe: contact on the downstream side

Abutment: Sides of the valley on which the structure of the dam

Galleries: small rooms like structure left within the dam for checking operations.

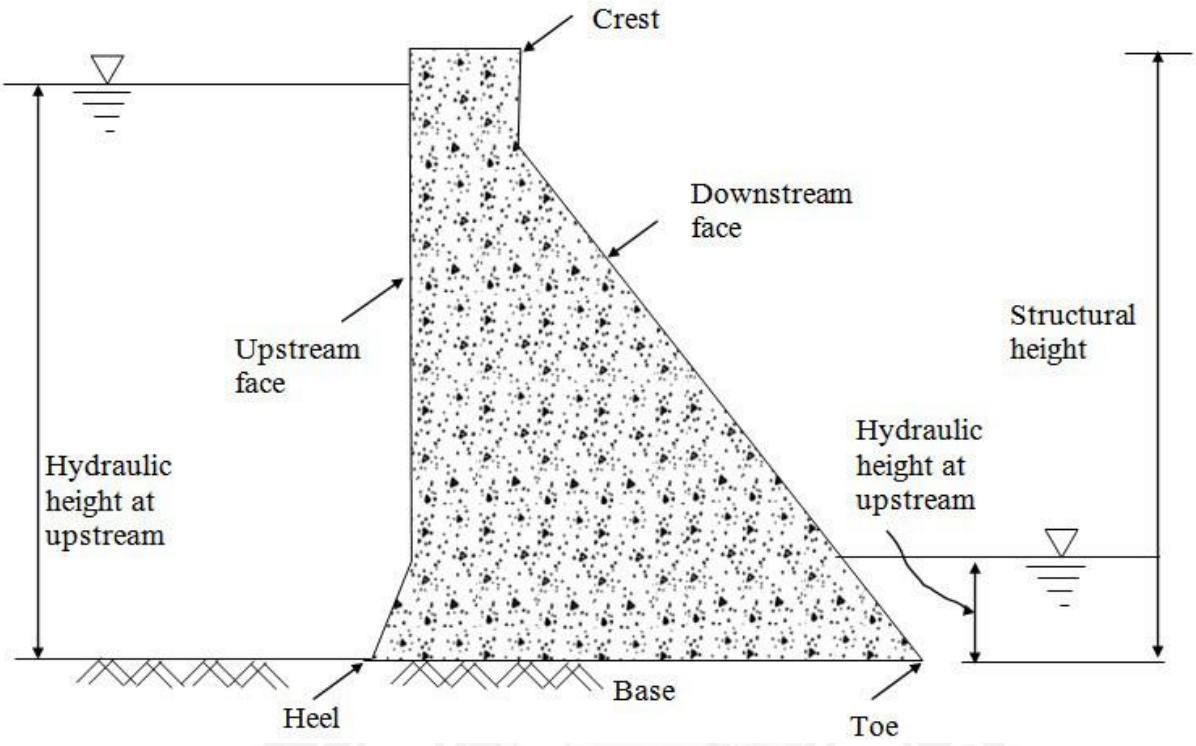
Diversion tunnel: Tunnels are constructed for diverting water before the construction of dam. This

helps in keeping the river bed dry.

Spillways: It is the arrangement near the top to release the excess water of the reservoir to downstream side

Sluice way: An opening in the dam near the ground level, which is used to clear the silt

accumulation in the reservoir side.



1.3 FORCES ACTING ON GRAVITY DAM

The Various external forces acting on Gravity dam may be:

- Water Pressure
- Uplift Pressure
- Pressure due to Earthquake forces
- Silt Pressure
- Wave Pressure
- Ice Pressure
- The stabilizing force is the weight of the dam itself

- **Self weight of the Dam**

Self weight of a gravity dam is main stabilizing force which counter balances all the external forcesacting on it.For construction of gravity dams the specific weight of concrete & stone masonry shouldn't be lessthan 2400 kg/m3 & 2300 kg/m3 respectively.The self weight of the gravity dam acts through the centre of gravity of the.

Its calculated by the following formula – *W=γ m X Volume*

Where γm is the specific weight of the dam's material.

- **Water pressure**

• Water pressure on the upstream side is the main destabilizing force in gravity dam.

• Downstream side may also have water pressure.

• Though downstream water pressure produces counter overturning moment, its magnitude is much smaller as compared to the upstream water pressure and therefore generally not considered in stability analysis.

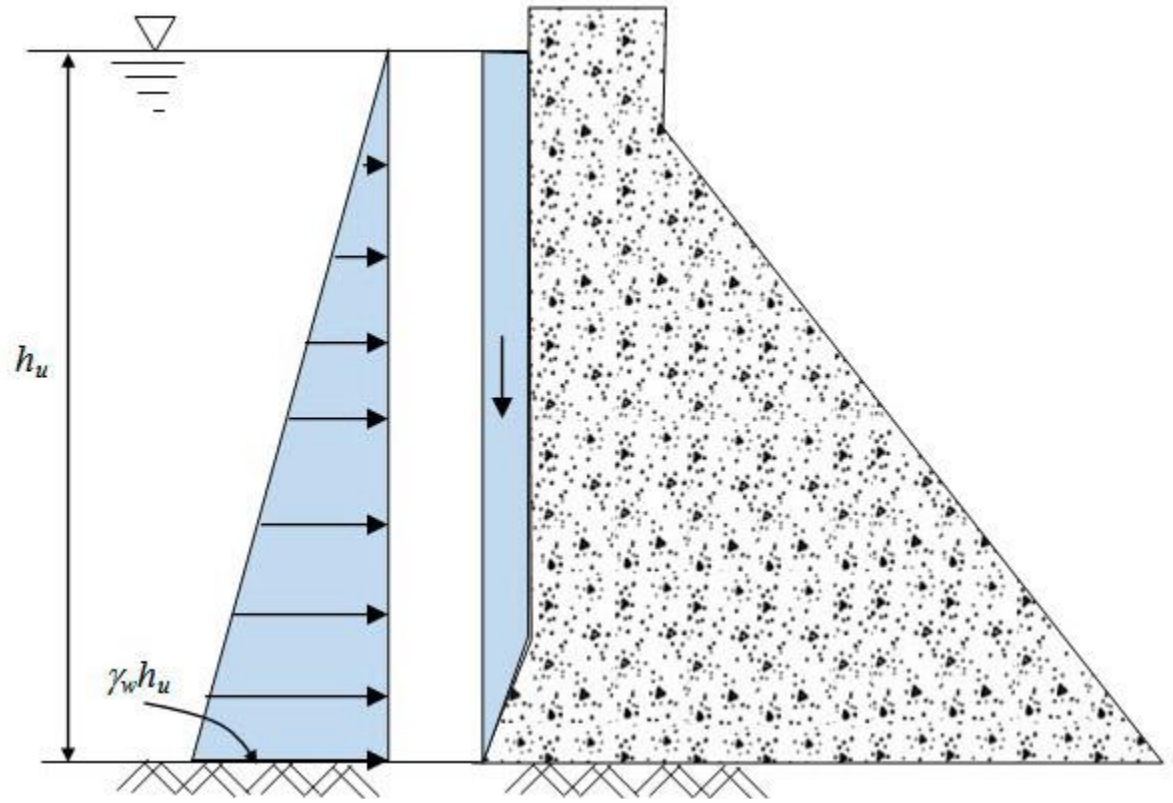
Water Pressure is the most major external force acting on a gravity dam.

• On upstream face pressure exerted by water is stored upto the full reservoir level. The upstream face may either be vertical or inclined.

• On downstream face the pressure is exerted by tail water. The downstream face is always inclined. It is calculated by the following formula

$$P=1/2\gamma\ w\ x\ h2$$

Where γw is the unit weight of water & h is the height of water.



- **Uplift water pressure**

• The uplift pressure is the upward pressure of water at the base of the dam as shown in Figure. It also exists within any cracks in the dam.

• The water stored on the upstream side of the dam has a tendency to seep through the soil below foundation.

• While seeping, the water exerts a uplift force on the base of the dam depending upon the head of water.

• This uplift pressure reduces the self weight of the dam.

• To reduce the uplift pressure, drainage galleries are provided on the base of the dams.

• It is calculated by the following formula –

$$U = 1/2\gamma\ w\ x\ h\ x\ B$$

Where 'B' is the width of the base of the dam.

- **Wave Pressure**

When very high wind flows over the water surface of the reservoir, waves are formed which exert

pressure on the upstream part of the dam.

The magnitude of waves depend upon –

▪ The velocity of wind.

▪ Depth of Reservoir.

▪ Area of Water Surface.

It is calculated by the following formula - $Pv = 2.4\gamma\ w\ x\ hw$

Where 'hw ' is the wave height.

- **Wind Pressure :**

• The top exposed portion on the dam is small & hence the wind pressure on this portion of dam is negligible. □

• But still an allowance should be made for the wind pressure at the rate of about 150 kg/m^2 for the exposed surface area of the upstream & downstream faces.

- **Seismic Forces :**

• Dams are subjected to vibration during earthquakes.

• Vibration affects both the body of the dam as well as the water in the reservoir behind the

dam.

• The most danger effect occurs when the vibration is perpendicular to the face of the dam. □

• Body Forces: Body force acts horizontally at the center of gravity and is calculated as: □

$$Pem=\alpha\, xW$$

• Water Force: Water vibration produces a force on the dam acting horizontally & calculated by: $Pew=2/3Ce\alpha\, h2$

1.4 ELEMENTRY PROFILE

• When water is stored against any vertical face, then it exerts pressure perpendicular to the face which is zero at top & maximum at bottom.

• The required top thickness is thus zero & bottom thickness is maximum forming a right angled triangle with the apex at top, one face vertical & some base width.

• Two conditions should be satisfied to achieve stability

• **When empty -** The external force is zero & its self weight passes through C.G. of the triangle.

• **When Full -** The resultant force should pass through the extreme right end of the middlethird.

The limiting condition is – $h=\sigma/c\gamma\ (1+S)$

where, σc=allowable compressive stressc=allowable compressive stress

1.5 Practical Profile

• Various parameters in fixing the parameters of the dam section are,

• Free Board –IS 6512, 1972 specifies that the free board will be 1.5 times the wave height above normal pool level.

• Top Width – The top width of the dam is generally fixed according to requirements of the roadway to be provided. The most economical top width of the dam is 14 % of its height.

• Base Width – The base width of the dam shall be safe against overturning, sliding & no tension in dam body.

For elementary profile

• When uplift is considered, $B= h\sqrt{S}$

• When uplift isn't considered $B= h\sqrt{S}-1$

1.6 Low Gravity Dam

• A low gravity dam is designed on the basis if of elementary profile, where the resultant force passes through the middle-third of its base.

• The principal stress is given by – σc=allowable compressive stress = γ H (S – C + 1) Where, σc=allowable compressive stress=principal stress, γ=unitweight, S=Specific Gravity and C=A constant.

• The principal stress varies with 'H' as all other terms are constant. To avoid failure of the dam the value of 'σc=allowable compressive stress' shouldn't exceed allowable working stress(f). F = γ H (S – C + 1)

1.7 High Gravity Dam

• The high gravity is a complicated structure, where the resultant force may pass through a point outside the middle-third of the base.

• The section of the dam is modified by providing extra slope on the upstream and downstream side.

• The condition for the high gravity dam are $H > fw(S+1)$

Where, f=allowable workingstress.

1.8 Failure of Gravity Dam

Failure of gravity dams are caused due to,

• Sliding – It may take place on a horizontal joint above formation, on the foundation. Sliding takes place when total horizontal forces are grater than the combined shearing resistance of the joint and the static friction induced by total vertical forces.

• Overturning – A dam fails in overturning when total horizontal forces acting on the dam section are quite great in comparison with total vertical forces. In such cases the resultant of two passes outside the limits of the dam.

• Dam may fail when tension is produced in the concrete.

• Dam may fail in crushing.

1.9 Precautions against Failure

• To prevent overturning, the resultant of all forces acting on the dam should remain within the middle-third of the base width of the dam.

• In the dam, the sliding should be fully resisted when the condition for no sliding exists in the dam section.

• In the dam section, the compressive stresses of concrete or masonry should not exceed the permissible working stress to avoid failure due to crushing.

• There should be no tension in the dam section to avoid the formation of cracks.

• The factor of safety should be maintained between 4 to 5.

Temperature Control

During setting of concrete heat of hydration is evolved producing internal temperature stresses resulting in development of internal cracks can get formed.

To control the temperature the following steps may be taken

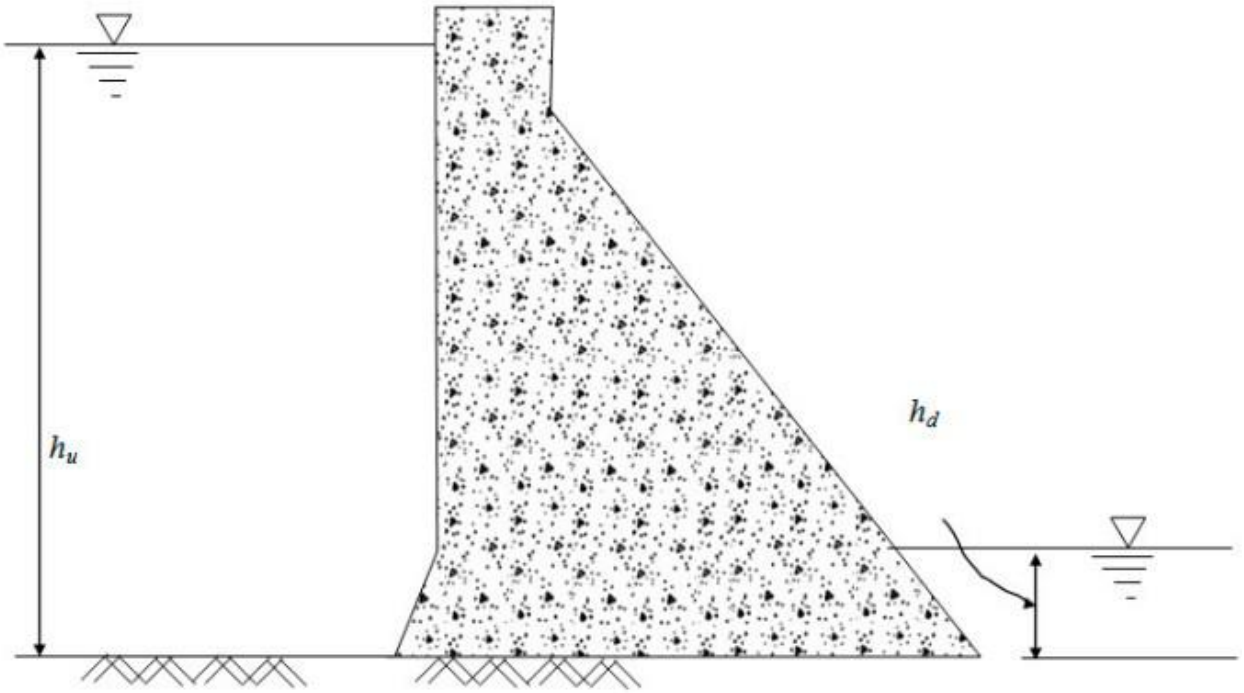
1. Low heat cement may be used in concrete.
2. The water & coarse aggregates should be cooled down to 5°C by suitable means before mixing.
3. During laying the height of concrete blocks should not be more than 1.5 m. It helps radiate heat to the atmosphere more quickly.
4. The water is cooled by crushed ice before using it for the curing purpose.

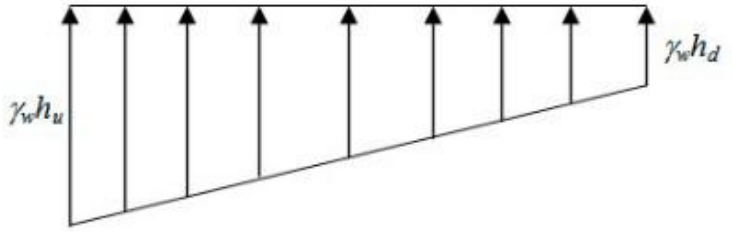
Advantages

1. Gravity dams are more suitable in narrow valleys.
2. Maintenance cost is lower
3. Failure of these dams is not very sudden.
4. Gravity dams may be built to any height.
5. Loss of water by seepage in gravity dams is less

Disadvantages

1. Initial cost for construction of gravity dams is very higher.
2. Gravity dams of greater height can only be constructed on sound rock foundations.
3. Require skill labour for construction.
4. Design of gravity dams is very complicated.





General Requirement for Stability

A gravity dam may fail in the following modes,

- Overturning
- Sliding
- Compression
- Tension

Therefore, the requirements for stability are,

• The dam should be safe against overturning.

• The dam should be safe against sliding.

• The induced stresses (either tension or compression) in the dam or in the foundation should not exceed the permissible value

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