10 - 7 - 2018

Water resource engineering - I.

Water resources are planned and developed either to use or to control ground and surface water.

A developmental activity for the use of water comprising of studying the availability and demand of water and contemplating a project which can meet the expected needs. from available supplies by means of engineering works. and non structural measures.

Water Demand (km^3)

S No	Purpose	1990	2000	2025
1.	Domestic use	25	33	52
2.	Irrigation	460	630	770
3.	Energy	19	27	71
4.	Industrial use	15	30	120
5.	others	33	30	37
	Total	552	750	1050

Continue →

a	Surface water	362	500	700
b	ground water	190	250	350

Classification of water resources development Projects :-

water resources development Projects can be Classified in following categories.

(i) single purpose project.

(ii) multi purpose project.

a single purpose project is the one which serves only one purpose such as need for irrigation or for water power generation or for flood control.

a multi purpose project is the one which serves two or more purposes such as

i) storage & control of water for irrigation

ii) storage & diversion of water for domestic use

iii) water supplies for industrial uses.

iv) preservation & cultivation of aquatic life.

(v) development of Hydro electric power

(vi) inland navigation.

MAITHON DAM :

1) Height = 165 ft

2) length = 15,712 feet

3) Type = concrete cum Earthen dam

4) River = Bara kar River

5) Location = Jharkand

6) Year inaugrated = 1957

goals achieved by this multi purpose project are

(i) flood control.

(ii) promotion & operation of schemes for irrigation,

(iii) water supply for domestic & Industrial use.

(iv) navigation & drainage.

(v) generation, Transmission & distribution of electrical energy.

maithon dam is one of the most popular dams in Jharkand & one of the most successfull multi purpose project in India.

functional Requirements in multipurpose Project:-

a multi purpose project has uses of water for several purposes. the water storage in these reservoirs has to be used jointly for these purposes.

(i) Requirements for irrigation

maximum demand for irrigation is ~~from~~ during winter season to start of summer season.

The indian cropping season is classified into two main seasons kharif & ~~rafi~~ rabi based on ~~season~~ monsoon.

The kharif cropping season is from July to October during South west monsoon.

The Rabi cropping season is from October to march.

(ii) Requirements for domestic supply:

The water requirement for domestic use is more or less constant, though the requirement is slightly more during summer season.

(iii) Requirements for industrial use:

The water requirements for industrial use is constant throughout the year, However with the steady growth of industries and power plants the requirements of water for these are ~~stead~~ steadily increasing.

Paper, petrochemicals & steel industries are some of the highly water consumptive industries.

The water used by thermal & nuclear power plants is also very high.

(iv) Requirements for Hydro electric Power:

Water Requirement for Hydro Power generation may vary with Power demand.

which intern may depend upon the type of area served.

The water power production is not a consumptive use of water, the water discharge through turbines may be used for irrigation purpose also.

(v) Requirements for flood control:-

The basic requirement of a reservoir for flood control is that it should have sufficient empty space for absorption of flood.

(vi) Requirements for navigation:-

The water is required to maintain a desired down stream ~~flow~~ flow for navigation. Peak releases are required during later part of dry season.

Scanned by CamScanner

11-7-2018

General Principles of water Irrigation Rates

-> The Present System of ~~water~~ Irrigation Rates (charges) has developed differently in different States.

-> a broad classification of these charges would be

(i) those payable by cultivators in return for the Service of irrigation and thus forming an item in the cost of production.

(ii) those payable by the owner's of Lands benefitted in consideration of the increase in the value of land.

The most important System of levying water charges may be grouped under the following

(i) <u>volumetric rate</u>:-

It is the charge according to the quantity of water delivered.

The main advantage claimed for this system is that it promotes the economical use of water.

The difficulty in this system is relates to purely the mechanical mode of measurement which is not an easy device which can measure perfectly. and with no system of malpractice by officials.

(ii) Consolidated Rates:-

This water charge is consolidated with land revenue and fixed on settlement principle.

The Advantage of this system is it avoids multiplying of taxes and reduces the cost of assessment to some extent.

This system provides compulsory payment of water charges which would ensure minimum return of the project.

Scanned by CamScanner

(iii) differential Rate:

The rate of water taken on dry land from government sources of irrigation corresponding to difference between Assesment of Dry lands and Wet lands.

The Advantage claimed for this system is that it provides the change of rate between Drylands and wet lands. This system However requires large complicated calculations which cannot be easily applied by village officers and satisfy the cultivators.

(iv) occupier's Rate:-

a fixed Rate ~~chart~~ charged on the area actually irrigated and which usually varies with the type of crop the rates for different crops are mainly based on this consideration.

(a) Quantity of water normally required by the crop.

(b) Scarcity or abundance of supply at the time of crop.

(c) value of crop.

(v) Agreement Rate:-

This charge is based very much on the same lines of occupier's Rate. But this is fixed with agreement for a period of years and is paid for that period whether water is taken or not.

12/07/2018

~~Riparian Rights:~~

Riparian Rights:-

a person whose land is beside any water body, has rights to use water from that water body.

Components of water:-

The components of water allocation system are

1) The water of international river system and aquifers are allocated b/w nation based on international law, treaties, custom, agreement.

2) In India water of interstate river basins are allocated b/w states based on agreement negotiated b/w States and approved by the government.

3) Certain rights are reserved for military installation & other government own lands

4) Separate system of laws and customs guides the allocation of water resources, ground water aquifer.

5) An Administrative system that brands, limits and modifies water rights and enforces the allocation of water resources may or may not include formed issuance of to water right holder

6) water users and water management in entities implement various contracts and other formed agreements

7) Sharing of water resources may be governed by cultural traditions and informal agreements that evolved "historically" many years ago.

17/07/2018

Ground Water Rights :

Ground water is the water that is found underground in the cracks and spaces in soil, sand and rock.

ground water stored beneath the soil and it moves slowly through layers of soil, sand and rocks called aquifers.

The area where water fills the aquifer is called saturated zone. The Top of this zone is called the water table. The water table may be located only a foot below the ground surface or it can Hundreds of feets down.

The Government introduced a model bill in 1970 which was revised later many times until 2005. to regulate and control the development & management of ground water.

This bill made that every user of groundwater must apply for a permit from the authority, unless the user only proposes to use a Hand pump or a well from which water is drawn manually.

Decisions of the authority in granting and denying permits are based on number of factors. Such as

-> availability of ground water, quantity and quality of water to be drawn and spacing b/w groundwater structures.

In the last 10 years only a few states in India had enacted specific groundwater legislature.

The owner of the land has an unrestricted right to use the ground water beneath land it. However this owner's right has changed in recent years.

Andhra High court had made it clear in 2002 that deep ~~underwater~~ underground water is the Property of state under the doctrine of Public Trust.

The Holder of Land has only user right towards the drawing of water from Tubewells.

Environmental & Water Quality management of Reservoir Systems:-

water Quality has become increasingly more important in Reservoir management. for a number of Reasons.

existing reservoirs are subjected to intense multi-objective demands on limited resources, thus water use attracts more attention causing water quality to draw closer ~~scrutiny~~ scrutiny.

Reservoir managers and the Public

have come to the realisation that water quality effects other environmental interests such as fish and wildlife and can impact or impair water use.

Some of the water quality considerations are discussed below:-

(i) Temperature and dissolved oxygen are of primary interests for most reservoirs since temperature regulates biotic growth rates and life stages and defines fishery habitat and oxygen is necessary to sustain aquatic life.

(ii) Nutrient enrichment is very essential since it can lead to oxygen depletion and taste and odour problems.

(iii) Dissolved iron, manganese and sulphide which can accumulate in reservoir that are low in dissolved oxygen, can lead to water quality problems in inpool and when released down ~~stream~~. stream.

(iv) Iron and manganese effect water colour and can lead to water treatment problems.

(v) Pathogens such as bacteria, viruses and protozoa ~~present~~ present can cause public health Problems.

(vi) Sulphide causes odour problems when it escapes during reaeration and can be dangerous at high atmospheric considerations.

Basically only three types of measures are there that can impact water quality. They are:-

(i) Pretreatment or control of reservoir inflows

(ii) In Pool management or treatment techniques.

(iii) Management of Reservoir outflows

(a) Hydraulic or pneumatic pumping can be used to disrupt or prevent stratification. destratification produces isothermal warm water.

Scanned by CamScanner

(b) phospholous in activation is achieved through the addition of aluminium sulphate or sodium aluminate form aluminium Hydroxide. This treatment method can reduce formation of algae, and increase water transparency and help seal the phospholors in sediments.

(c) Sediment removal can be used to ~~add~~ deepen reservoirs and increase volume and to remove nutrient rich or toxic sediments.

~~(d) Harvesting of aquatic~~ plants, this can improve water ~~quality & aquatic~~ life

~~(e) Restructuring of fish communities~~

d) Harvesting of aquatic plants is a procedure that can quickly improve portions of reservoir for recreation and at the same time improve water quality.

(e) Restructuring of fish communities offers algae control.

18/07/2018

STORAGE WORKS :

Dams are constructed across the river and streams to create an artificial lake or reservoir behind it. Dams and Reservoirs are the most important and expensive elements in multi-purpose ~~Reservoir~~ River basin development.

Storage works are constructed to serve many purposes which include

(i) Storage & control of water for irrigation.

(ii) Storage & diversion of water for domestic use.

(iii) water supplies for industrial use.

(iv) Development of Hydro electric power.

(v) Increasing ~~in~~ water Depth for Navigation

(vi) Storage space for flood control.

(vii) Reclamation of low lying lands.

Depending upon the Purposes served Reservoirs may be classified as

1. Storage or conservation Reservoir.
2. Flood control Reservoir.
3. Distribution Reservoir.
4. Multi-purpose Reservoir.

Storage or Conservation Reservoir

Storage Reservoirs are primarily used for water supplies for irrigation, Hydro-electric development, domestic and industrial supplies.

a storage reservoir is constructed to store the excess water during the Period of large supplies and release it gradually as and when required.

Flood control Reservoir :-

Flood control Reservoirs are those which store water and release it gradually at a safe rate when the flood reduces. By Provision of artificial storage during the floods. The flood damage is reduced.

Distribution Reservoir :

It is a small storage Reservoir used for water supply in a city Such distribution reservoir permits the pumping plants and water treatment works to operate at a constant Pace.

Multi - Purpose Reservoir :-

This Reservoir serves more than one purpose for example a reservoir designed to Protect the downstream area from floods & to store water for irrigation & Hydro electric purposes.

1) Selection of a site for a Reservoir :-

The final selection of a site for a reservoir depends upon the following factors :-

(i) The Geological condition of the catchment area should be such that the percolation losses are minimum and maximum Runoff is obtained.

(ii) The Reservoir sight should be such that the quantity of leakage through it is minimum. Rocks which are not likely to allow passage of water include Shales, Slates, Schists, genisses & crystalline igneous rocks.

(iii) Suitable Dam sight should ~~exists~~ exist. the dam should be founded on water tight rock base. the cost of the dam is often a controlling factor in selection of a sight.

(iv) The Reservoir basin should have narrow opening in the valley, so that the length of the dam is less.

19/07/2018

(v) The cost of the real estate for the reservoir including roads, railways, dwelling relocation must be as least as possible.

(vi) The Topography of the reservoir sight should be such that it should have adequate capacity without submerging excessive land and other properties.

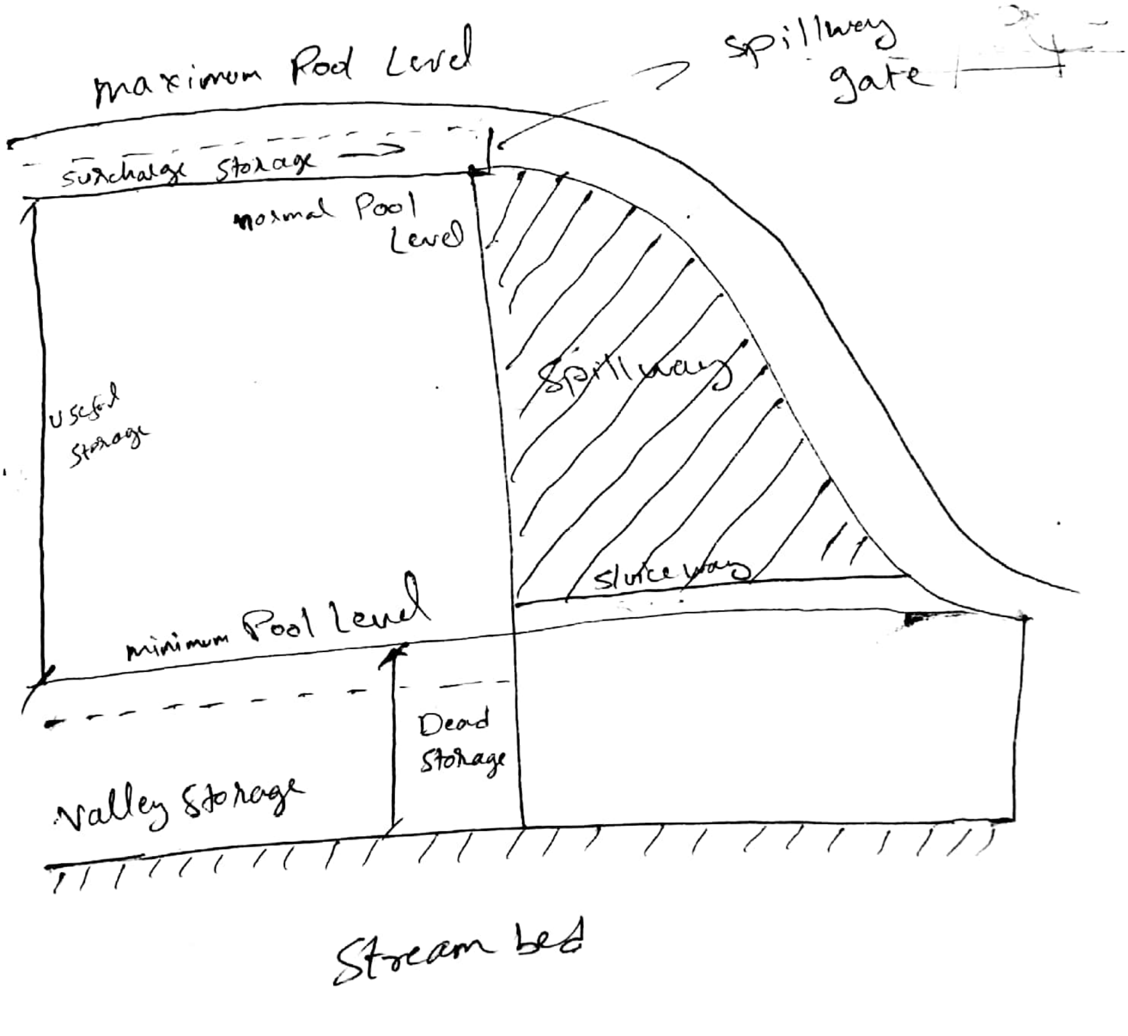
(vii) The sight should be such that a deep reservoir should be easily formed.

(viii) The Reservoir sight should be such that the water stored in it is suitable for a purpose for which the project is undertaken. The soil and rock mass at the reservoir sight must not contain any objectionable minerals & salts.

Scanned by CamScanner

(ix) The reservoir sight should be such that it avoids or excludes water from those tributaries which carry a high percentage of silt in water.

2) Zones of storage in a Reservoir



The following are the various zones of storage in a Reservoir

(i) useful storage

(ii) Surcharge Storage

(iii) Dead Storage

(iv) Bank Storage

(v) Valley Storage

The maximum level to which the water will rise in the reservoir during ordinary operation condition is called normal Pool Level.

The level to which water rises during the design flood is known as maximum Pool Level.

The lowest elevation to which the water in the reservoir is to be drawn under ordinary operation conditions is known as minimum pool Level.

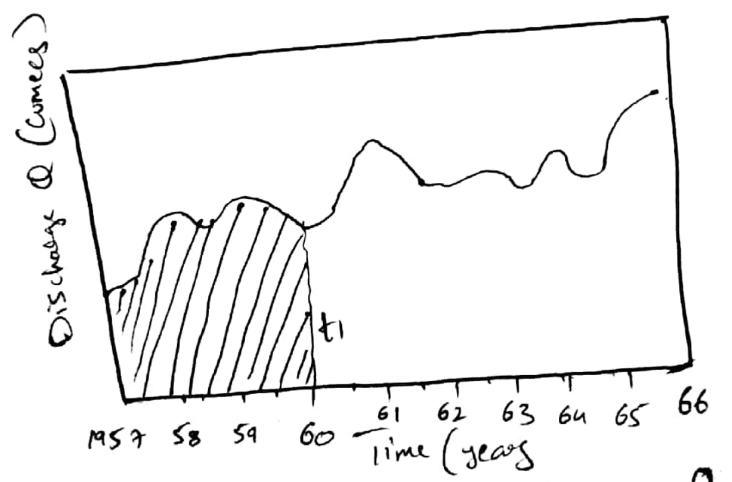
The volume of water stored b/w normal Pool Level & minimum pool Level is known as useful storage.

The volume of water below the minimum pool level is known as the dead storage & is not useful under ordinary conditions.

The volume of water stored between the normal pool level and the maximum level corresponding to a flood is called as surcharge storage.

The terms bank storage & valley storage are referred to the volume of water stored in the pervious formations of the river banks and soil above it.

3) STORAGE CAPACITY & Yield.



flood hydrograph of Inflow

Yield is the amount of water that can be supplied from the reservoir in a specified interval of time. The Interval of time chosen for design varies from a day for small distribution reservoirs to a year for large conservation reservoirs.

For example if 25000 cubic meters of water is supplied from a reservoir in one year, its yield is 25000 cubic meters per year or 2.5 hectare meters per year.

Safe Yield:-

The maximum quantity of water that can be guaranteed during a critical dry period is known as Safe Yield

Secondary Yield:-

Secondary yield is the quantity of water available in excess of safe yield during the Periods of high flood.

Average yield :-

The Arithematic average of safe yield & the secondary yield over a long period of time is called average yield.

mass inflow curve :-

The Reservoir capacity corresponding to a Specific yield is determined with the help of mass inflow curve and the demand curve.

a mass inflow curve is plotted between the cumulative inflow in reservoir with time.

Computation of Storage capacity :-

Analytical method

Problem

① The amount of water flowing from a certain catchment area at the Proposed Dam sight are tabulated below. determine the minimum capacity of reservoir if the water is to be used to feed the turbines

months	Jan	feb	march	April	may	Jun	July	Aug	Sep	oct	Nov	Dec
Inflow ($\times 10^5 m^3$)	2.83	4.25	5.66	18.4	22.64	22.64	19.81	8.49	7.1	7.1	5.66	5.66

Sol

$$\text{Average demand} = \frac{\Sigma \text{inflow}}{12}$$

$$= 10.853 \times 10^5 \ m^3$$

Months	I Inflow ($\times 10^5 m^3$)	O Avg demand ($\times 10^5 m^3$)	(O−I) Deficit ($\times 10^5 m^3$)	(I−O) Surplus ($\times 10^5 m^3$)
Jan	2.83	10.853	8.023	−8.023 x
Feb	4.25	10.853	6.603	−6.603 x
march	5.66	10.853	5.193	−5.193 x
April	18.4	10.853	−7.547	7.547
may	22.64	10.853	−11.787	11.787
June	22.64	10.853	−11.787	11.787
July	19.81	10.853	−8.957	8.957
Aug	8.49	10.853	2.363	−2.363 x
Sep	7.1	10.853	3.753	−3.753 x
Oct	7.1	10.853	3.753	−3.753 x
Nov	5.66	10.853	5.193	−5.193 x
Dec	5.66	10.853	5.193	−5.193 x

Assuming there is no loss over spillway

Since no water is to be spilled, minimum capacity will be equal to the sum of surplus water

should take only positive values

minimum capacity = Σ surplus water

$= 7.547 + 11.787 + 11.787 + 8.957$

$= 40.078 \times 10^5 \, m^3$

(Q) The yield of water from catchment area during each successive month is given below. Determine the minimum capacity of the reservoir required to allow the above volume of water to be drawn off at a uniform rate assuming that there is no loss of water over the spillway.

months	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Inflow ($\times 10^5 m^3$)	1.4	2.1	2.8	5.4	11.9	11.9	7.7	2.8	2.52	2.24	1.96	1.58

(Sol)

Average demand $= \frac{\Sigma \text{inflow}}{12}$

$= 4.525 \times 10^6 \, m^3$

months	I Inflow ($\times 10^6 m^3$)	O Avg demand ($\times 10^6 m^3$)	(O−I) Deficit ($\times 10^6 m^3$)	I−O Surplus ($\times 10^6 m^3$)
Jan	1.4	4.525	3.125	−3.125
Feb	2.1	4.525	2.425	−2.425
mar	2.8	4.525	1.725	−1.725
April	5.4	4.525	−0.875	0.875
may	11.9	4.525	−7.375	7.375
Jun	11.9	4.525	−7.375	7.375
July	7.7	4.525	−3.175	3.175
August	2.8	4.525	1.725	−1.725
Sept	2.52	4.525	2.005	−2.005
oct	2.24	4.525	2.285	−2.285
Nov	1.96	4.525	2.565	−2.565
Dec	1.58	4.525	2.945	−2.945

minimum capacity = Σ surplus water

$= 18.8 \times 10^6 \, m^3$

(5) 4/8/2018

UNIT- I (Continuation)

Evaporation Reduction Techniques

-> floating cover act as an impermeable barrier against evaporation. many different materials have been trialed in the past including ~~poly ethelyn~~ polyethylene wax, foam & polystyrene. covers are one of the most effective evaporation reduction techniques (cooley & Myser 1973)

-> Floating objects use the same principle as floating covers, however rather than a ~~continou~~ continuous cover multiple individual units are used, often floating freely. This allows for easier installation & maintenance of the cover but reduces the evaporation reduction efficiency.

-> Shade structures reduce the energy available for evaporation, reduce ~~Zoind~~ wind action over the water surface and trap humid air under the cover, all factors that contribute to evaporation.

These structures are generally suited to smaller water storages, -> chemical covers are based on the use of long chain alcohols to form a thin layer on

Surface of the water to reduce evaporation. These layers are biodegradable and need to be reapplied every 1 to 4 days. chemical methods are not as effective as physical method. [Erick 2007].

24/7/2018

Unit - II

Dams

Dam is a hydraulic structure constructed across a river to store water on its upstream side, due to the construction of the dam water level in the river at its upstream side is very much increased. and a large area may be submerged depending upon the water spread.

Classification of Dams :-

Dams may be classified into different categories depending upon the purpose or basis of classification.

Basis of classification	Types	Common examples
(a) Classification according to use	1. Storage dam 2. Diversion dam 3. Detention dam	→ Gravity dam, earth dam → weir, barrage → water spreading dam, debris dam.
(b) Classification by hydraulic design	1) Overflow dam 2) Non overflow dam.	→ Spillway → gravity dam, rockfill dam

(c) classification by materials	1) Rigid dams	- masonry dam, arch dam.
	2) Non rigid dams	-> Earth dam, rockfill dam.

Classification according to use:

Based on use dams are classified as follows

1) Storage dam:-

This is the most common type of dam normally constructed. it is constructed to impound water to its upstream side during the period of excess supply in the river. i.e during rainy season and it is used in the Periods of deficient supply. a storage dam may be constructed of wide variety of materials such as concrete, stone, earth and rockfill.

2) Diversion dam:-

The purpose of a diversion dam is essentially different while the storage dam stores water at the upstream side for future use, a diversion dam simply raises water level slightly in the river and thus provides head for diverting water into ditches, canals ~~oth~~ or other conveyence systems. a diversion dam may be constructed for irrigation or municipal or industrial use.

3) Detention dam :-

a detention dam is constructed to store water during floods and release it gradually at a safe rate when the flood recedes. There are usually two types of detention dams in one water is ~~temporal~~ temporarily stores and releases through a suitable outlet structure. The other type of detention dam water is not released and no outlet structure is provided. instead water is held in the reservoir as long as it is ~~possid~~ possible. This stored water seeps into pervious banks and foundation strata. ~~A~~ Due to this seepage the water levels is the wells of adjoining area is increased. and the lift irrigation may be possible.

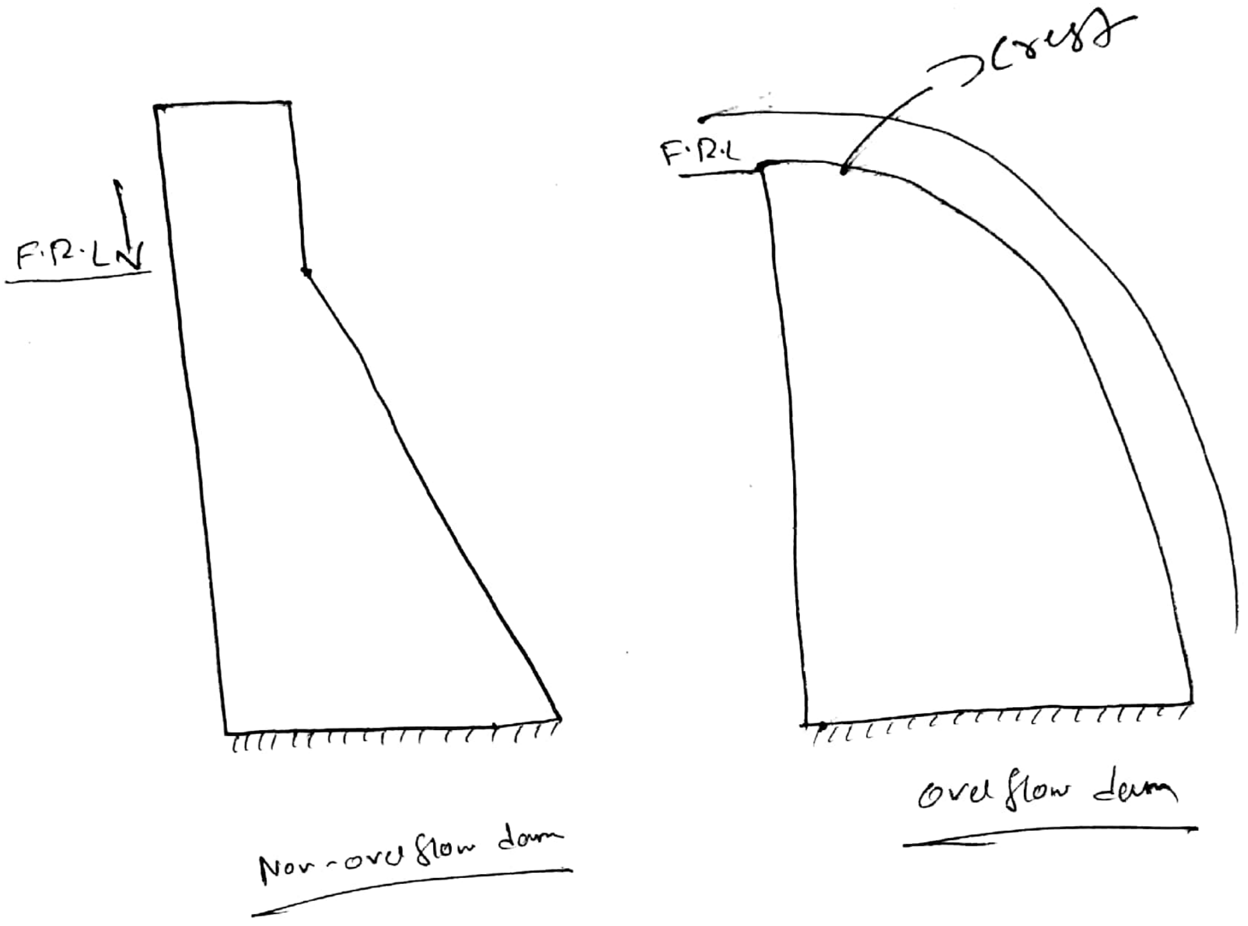
According to hydraulic design dams may be classified as 1) Non-overflow dam:-

It is the one in which top of the dam is kept at a higher elevation than the maximum expected high flood level., water is not permitted to overflow the dam. Therefore a non-overflow dam is constructed of wide variety of materials such as earth, rockfill, masonry and concrete.

2) over flow dam:

an over flow dam is the one which is designed to carry surplus discharge over its crest. Its crest level is kept ~~lower~~ Lower than the Top of the other portion of the dam. Since water ~~moves~~ flows over its downstream face it should be made of such a material which is not easily eroded by flowing water.

This type of dam is generally made of concrete or masonry. an overflow dam is commonly known as spillway



25/07/2018

Classification according to materials

According to this, most common classification the Dam may be classified as
1) rigid Dams.
2) Non-rigid Dams.

Rigid Dams are those which are constructed of rigid materials such as masonry, concrete, steel or timber.

Non Rigid Dams are those which are constructed of non-Rigid materials such as earth, or rock fill or combination of both earth & rock fill.

Sight Selection for a Dam

the following are the requirements of good sights for various types of dams:

(i) foundation

Suitable foundation should be available at the sight selected for a particular type of Dam.

for gravity dam a sound (single) rock is essential.

for earth dams any type of foundation is suitable with proper treatment.

foundations in which hard & soft layers are present alternately are not good, As the penetration of water may weaken the soft layers and lead to movement along them. No dam should be built across a fault line known to have been active in recent times.

the best conditions are when a dam can be built on one uniform formation, whereas if different kinds of rocks are present then different bearing strengths may lead to settlement of structure.

ii) Topography:

The river cross-section at the dam sight should preferably have a narrow place to reduce the length of the dam. This narrow openings should provide large basin and a major portion of a dam should be on high ground as this would reduce the cost and facilitate drainage.

(iii) Sight for Spillway:-

good sight for the location of a separate spillway is essential especially in the case of earth or rockfill dam. incase of gravity dam spillway may be located at the middle

(iv) materials:-

materials required for a particular type of dam should be available nearby without requiring much of transportation. This will very much reduce the cost of construction.

(v) reservoir & catchment area:-

the sight should ensure adequate storage capacity of reservoir basin at a minimum cost. The geological conditions of the catchment area should be such that the percolation losses are minimum & maximum runoff is obtained. The reservoir sight should be such that it avoids or excludes water from those tributaries which carry high percentage of silt in water.

(vi) Communications:

It would be preferable to select the sight which is connected by a road or ~~railing~~ rail link or can be conveniently connected to the sight for transportation of cement, labour, machinery, food & other equipments.

(vii) Locality:

The surroundings near the sight should preferably be healthy and free of mosquitoes as labour and staff colonies have to be constructed near the sight.

26/7/2018

Physical factors Governing Selection of Type of dam:

1) Topography
2) Geology and foundation conditions
3) Materials of construction
4) Spillway size & location
5) Roadway
6) Length & height of dam
7) Life of dam.

The selection of a type of a dam at a given sight depends upon many physical factors preliminary design & estimates are required for several types of dams before one can be shown to be the most economical.

Some of the physical factors governing the selection of type of dam are following :-

1) Topography

The first choice of dam is usually governed by the topography for the sight. a low rolling plane suggest an earth dam with the separate spillway.

a low narrow 'V' shaped valley suggest an arch dam, provided the top width of valley is less than 1/4th its height and separate sight for spillway is also available. a narrow stream flowing between high rocky walls which gives rise to

"U" shaped valley would suggest a concrete over flow dam.

2) <u>Geology and foundation conditions:</u>

if the foundation consists of sound rock with no fault or ~~fist~~ fissules any type of dam can be constructed on it.

rocks like granite, gniss & schist make very satisfactory foundation for gravity dam,

Poor rock or gravel foundations are suitable for earth dams, rockfill dam or low concrete gravity dam. Silt or fine sand foundations have the Problems of settlements, seepage and ~~toe~~ toe erosion ~~an~~ Therefore these foundations are suitable only for earth dam or low concrete gravity dam. gravity dams or rockfill dams are not suitable on clay foundations

3) materials of construction :-

The cost of construction of a particular type of dam depends upon the availability of material in the nearby area so that the transportation charges are reduced. the preliminary selection of a particular type is ~~pto~~ based on first two physical factors but these factors must correspond with the easy availability of the materials required for its construction otherwise that type of dam construction should be dropped.

4) Spillway size and location :-

The safe discharge of flood water through dam is very essential and for that suitable sight for spillway should be available if the area is such that a large spillway capacity is required ~~and over~~ an over flow concrete gravity dam should be preferred. If no other sight is available for spillway separately it has to be accomodated with the main dam across the main river section.

5) Roadway:-

if a Roadway is to be passed over the top of the dam an earth dam or gravity dam would be preferred.

6) Length & height of dam:-

if the length of the dam is very long and its height is low an earth dam would be a better choice.

if the length is small but the height is more the gravity dam is prefered.

7) life of dam:-

concrete or masonry gravity dam have very long life whereas earth & rockfill dam have intermediate life, However timber dams are adopted ~~for~~ only for temporary storages.

GRAVITY DAMS:-

a gravity dam is the one in which the external forces such as water pressure, wave pressure, silt pressure, uplift pressure are resisted by the weight of the dam it self.

The gravity dam may be constructed either of masonry or of concrete. masonry gravity dams are now a days constructed of only small heights. all major and important gravity dams are constructed of concrete only.

a gravity dam may be either straight or curved in a plan.

Advantages of gravity dam

-> There is no type of dam more permanent than the gravity dam which is made up of solid concrete

-> Gravity dams are relatively more strong and stable than earth dams.

-> ~~Gravit~~ Gravity dams are well adapted for use as an overflow spillway crest.

-> earth dam's cannot be used as overflow dam's.

-> gravity dams can be constructed of any height provided suitable foundations provided ~~or~~ suitable foundations available to bear the stresses.

-> The height of an earth dam is usually limited by the stability of its slope requiring a very wide base width

-> heighest dams in the world are made of gravity dam's only.

-> the gravity dam requires the least ~~maintanance~~ maintainance.

-> Gravity dam is specially suited for such areas where there is likely hood of very high downpour.

-> The failure of a gravity dam if any, is not sudden, it gives enough warning time before the area to downstream side is flooded due to the damage to the gravity dam. whereas earth dam fails suddenly.

-> Gravity dam is cheaper in long run since it is more permanent than any other type of dam.

Disadvantages of gravity dam:-

The disadvantages of gravity dam are compared to an earth dam as follows :-

-> Gravity dams can be constructed only on sound rock foundations. ~~They~~ They are unsuitable on weak foundations or permeable foundations on which earth dam can be constructed.

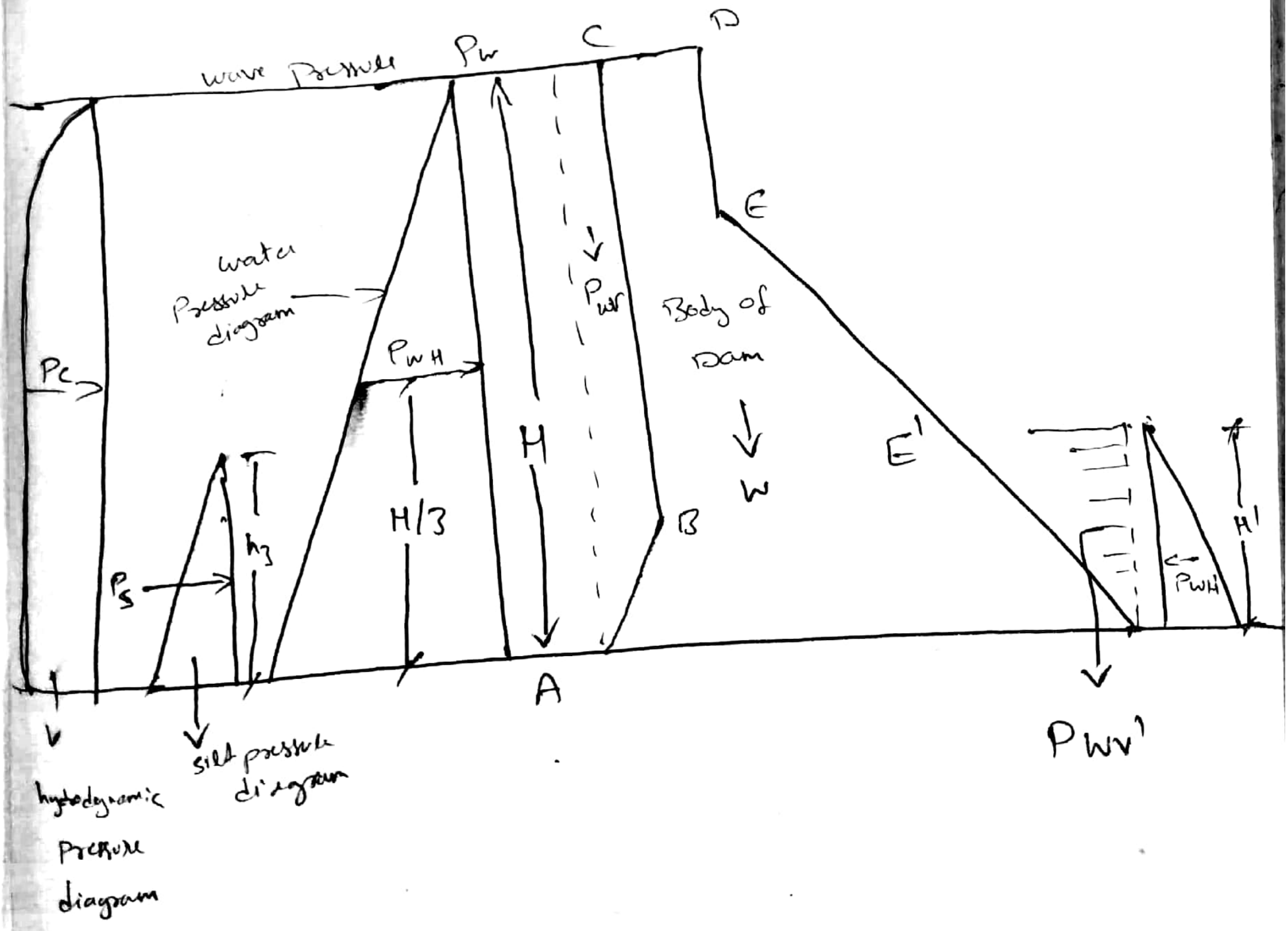
whereas earth dam can be constructed with suitable foundation treatments.

-> the initial cost of a gravity dam is always higher than ~~the~~ earth dam. Hence when funds are limited & where suitable materials are available for the construction of an earth dam, the earth dam may be preferred.

-> gravity dams require skilled labour or mechanised plants for its construction.

-> It is very difficult to allow rise in the height of the gravity dam, unless specific provisions have been made in the initial design.

-> If mechanised plants such as manufacturing and transporting concrete, curing of concrete are not available a gravity dam may take more time to construct.

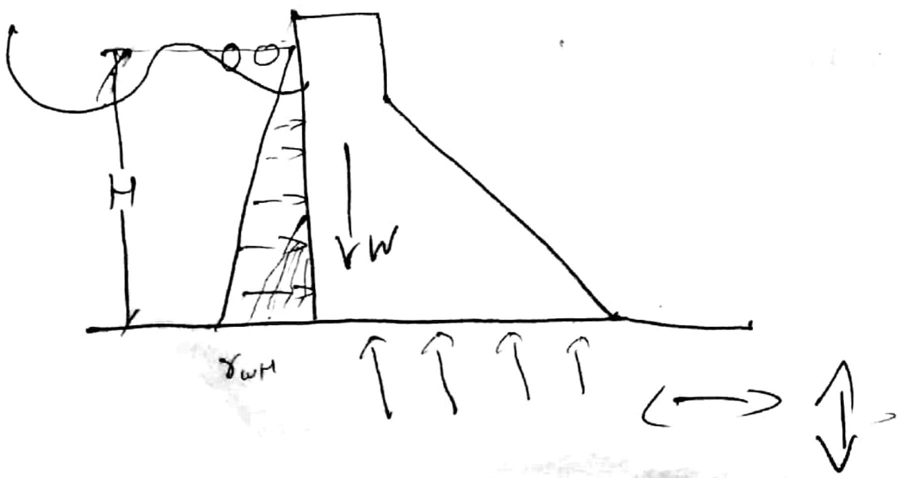


~~10 Aug~~ 01/08/2018

Forces Acting on Gravity Dam

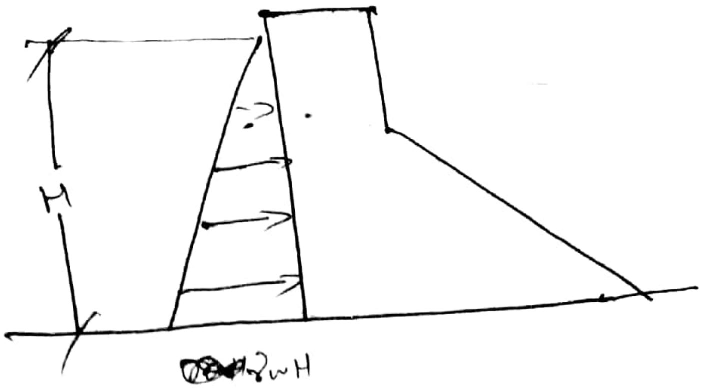
1. Water Pressure
2. Uplift Pressure
3. Pressure due to Earth quake forces
4. Silt Pressure
5. Wave Pressure
6. Ice Pressure
7. Weight of Dam
8. Wind Pressure

(1) Water Pressure



(1) Water Pressure

Case (1)



Water pressure will act linearly and will increase from top to bottom, water pressure is "$\rho_w g H$", $\rho_w g = \gamma_w$ (unit wt of water).

γ = gamma

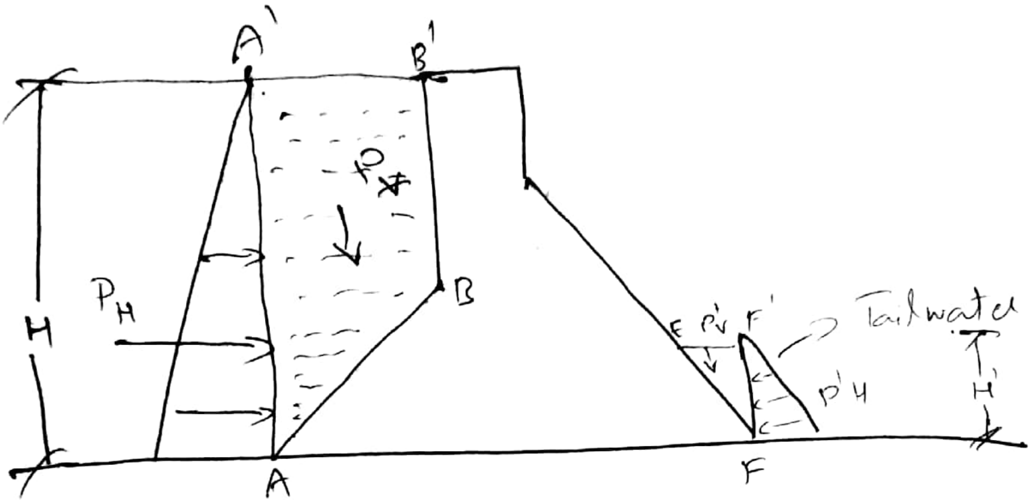
Water pressure is equal to $\frac{1}{2} \times \gamma_w H \times H$

$= \frac{\gamma_w H^2}{2}$ it will act

at centroid of triangle i.e $\frac{H}{3}$ from base &

$\frac{2H}{3}$ from top.

Case (2)



Upstream face is Partially vertical & partially inclined.

- The Resultant water Pressure can be resolved into two components Horizontal & vertical

The Horizontal force is $P_H = \gamma_w \frac{H^2}{2}$

The vertical force is = weight of water ~~content~~ contained in $AA'BB'$,

Similarly there is Tailwater of height H' on the down stream up, it exerts both Horizontal Pressure ie P'_H as well as

Vertical Pressure P'_V.

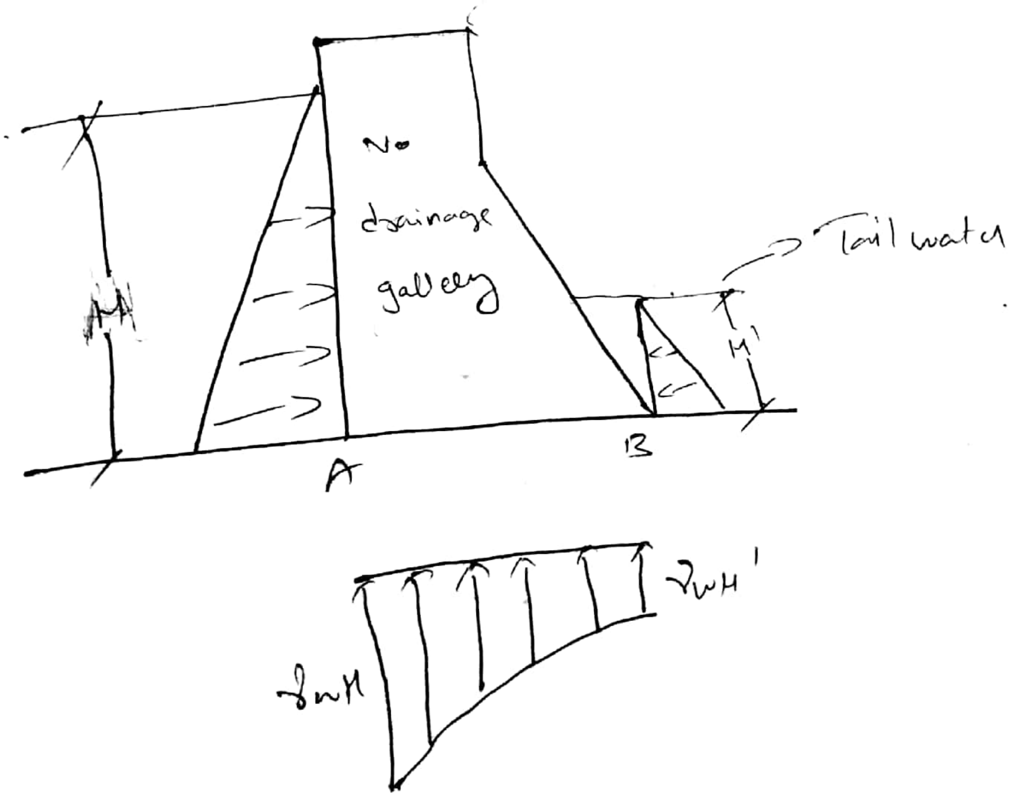
Horizontal Pressure P'_H due to Tailwater is

$$\frac{\gamma_w H'^2}{2}$$

Vertical Pressure due to Tailwater is weight of water contained in EFF'

② Uplift Pressure

Case ① when gallery is not provided



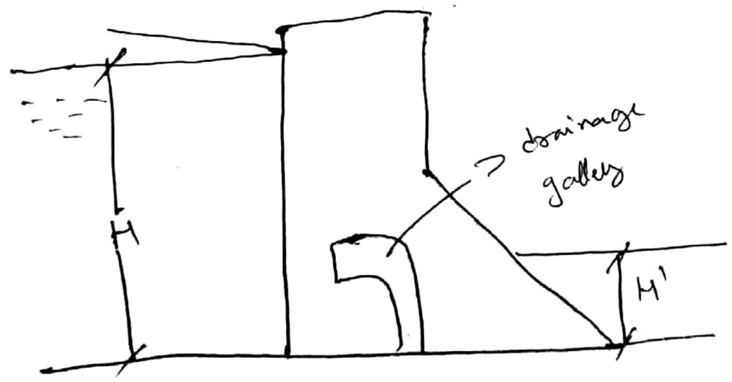
water has tendency to seep through Pores of foundation, it also seeps through the joints between the body of the dam & its foundation at the base. The uplift Pressure is defined as the upward Pressure of water as it flows or seeps through the body of the dam or its foundation

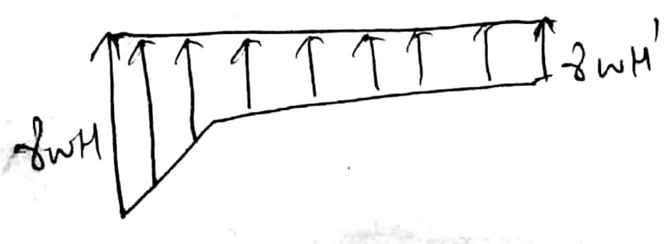
uplift Pressure at heel A = $\gamma_w H$

uplift Pressure at Toe B = $\gamma_w H'$

Case 2

When gallery is Provided.





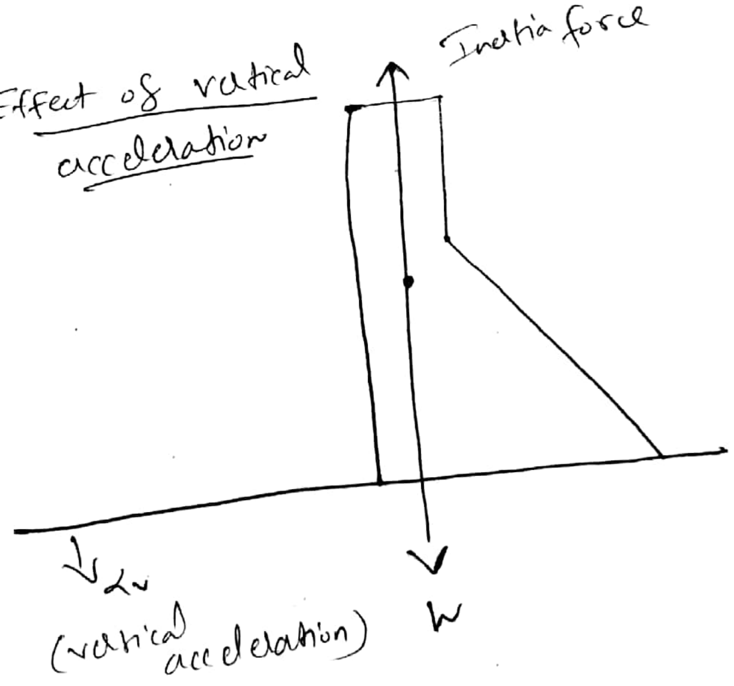
drainage gallery reduces uplift Pressure

uplift pressure when drainage gallery is provided is equal to $\gamma_w H' + \frac{1}{3}[\gamma_w H - \gamma_w H']$

(3) Earth quake forces

when an earth quake occurs the foundation tends to move in vertical or horizontal direction with acceleration, this moment's occuring should be defined

Case 1: Effect of vertical acceleration



$\alpha_v = K_v \cdot g$

K_v = fraction of gravity (b/w 0.1 to 0.2)

g = acceleration due to gravity

Inertia force = mass x acceleration

$= m \times a$

$= \frac{W}{g} \times \alpha_v$

Inertia force $= \frac{W}{g} \times K_v \cdot g$

$= W \times K_v$

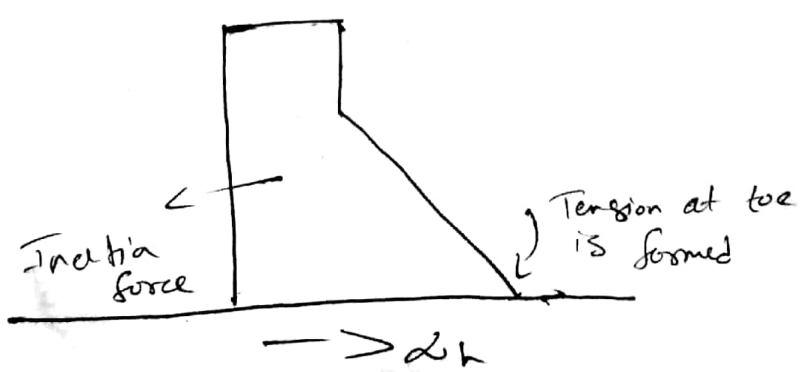
Net effective weight

= Total wt of dam − Inertia force

$= W - W \times K_v$

$$= W[1 - K_v]$$

Case ② : Effect of horizontal acceleration



$\alpha_h = K_h \times g$

K_h = fraction of gravity (b/w 0.1 to 0.2)

Horizontal Inertia force

$= m \times a$

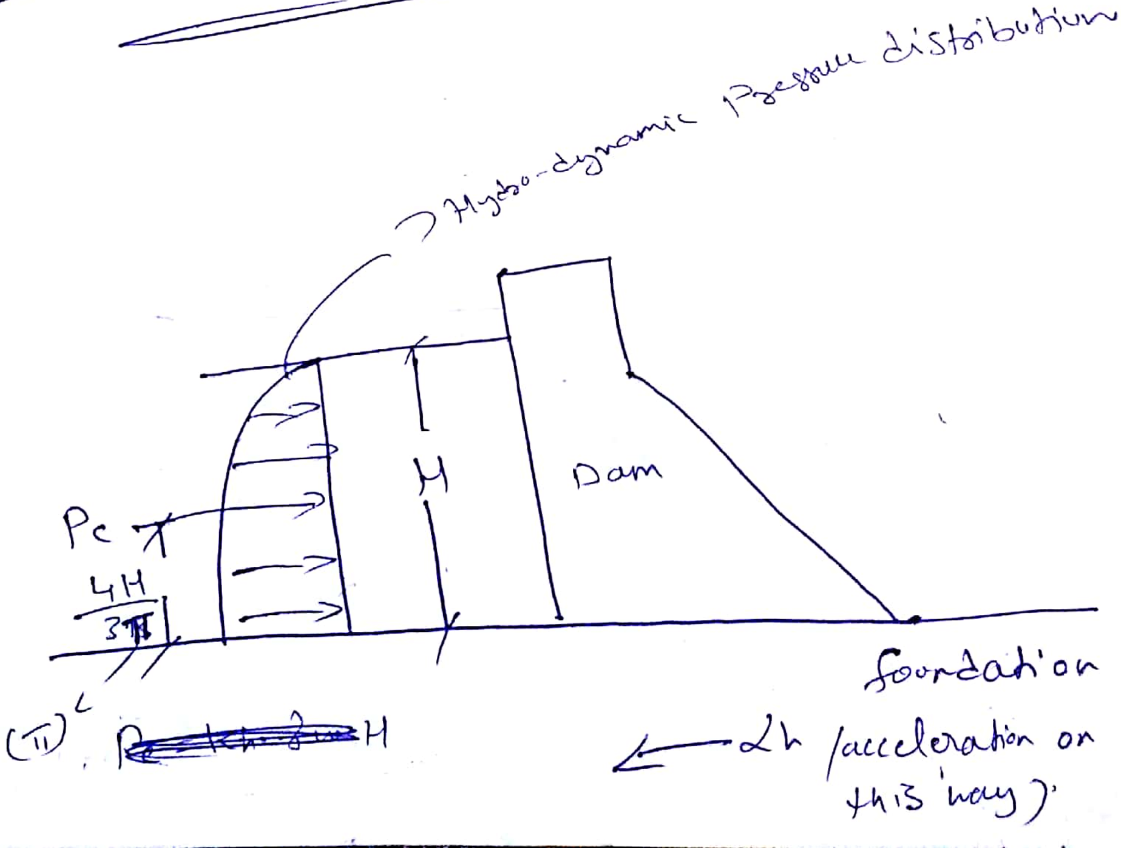
$= \frac{W}{g} \times \alpha_h$

$= \frac{W}{g} \times K_h \times g$

$$= W \times K_h$$

2/8/2018

Case (3) Effect of Hydro-dynamic Pressure



$P_e = 0.555\ k_h . \gamma_w H^2$

when the acceleration of earth quake is in one direction the Pressure of water ie hydro dynamic pressure will act in the opposite direction in the form of Parabola or eliptical, Von Karman has defined this extra Pressure of water as

$$P_e = 0.555\ k_h . \gamma_w H^2$$

moment of this force about base is

M_e = force × perpendicular distance

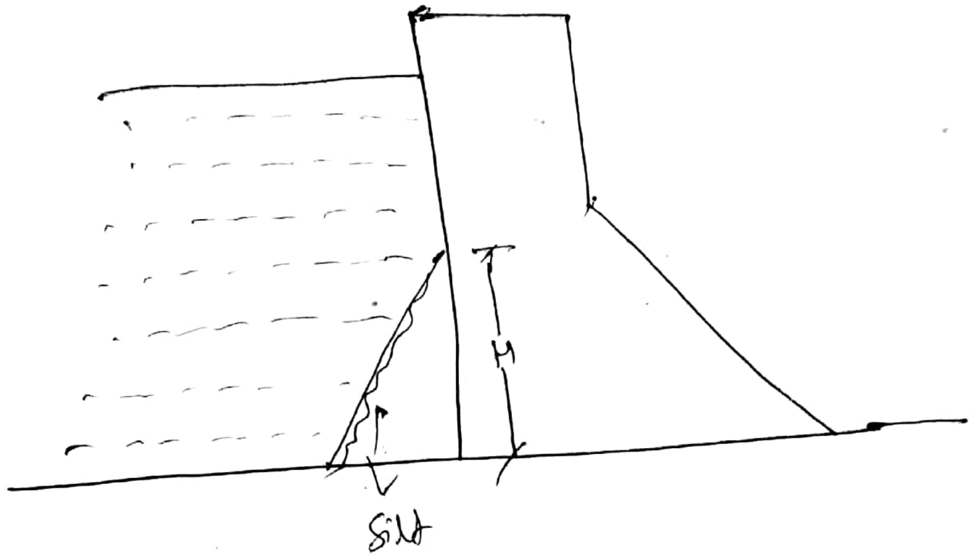
$$= P_e \times \frac{4H}{3\pi}$$

$$= ~~0.555\ k_h . \gamma_w H^2 .~~ \frac{4H}{3\pi}$$

$$M_e = 0.424\ P_e H$$

Scanned by CamScanner

(4) Silt Pressure :



According to Rankine's formula

Silt Pressure, $P_{silt} = \frac{1}{2} \gamma_{sub} \cdot H^2 \cdot K_a$

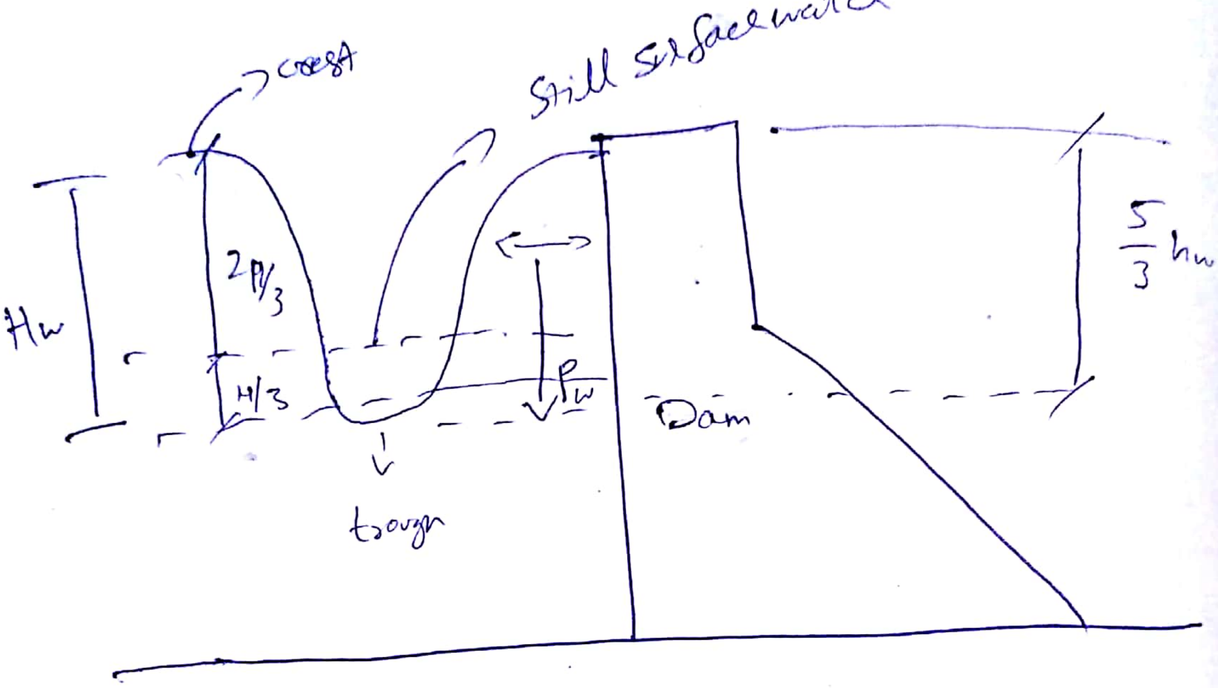
, K_a - active earth pressure $K_a = \frac{1 - \sin\phi}{1 + \sin\phi}$

γ_{sub} = Submerge unit wt of Silt

H = height of silt material.

In most gravity dams, silt pressure is neglected.

(5) wave Pressure:-



In a dam, when air is flowing waves are formed in the dam, Hw is the height of the wave, it is the distance between crest & trough,

$H_w = 0.032\sqrt{VF}$ for $F > 32$ Km

F = fench (Straight line of water in kms, without waves)

V = wind velocity in km/hr

(6)

The height from the still surface water will be more for crest (2H/3) compared to trough (H/3).

Pressure Intensity on Dam (P_w)

$P_w = 2.4\gamma_w H_w$

It acts at a Height of $\frac{H_w}{8}$ i.e from above still water,

Total force $= \frac{1}{2}(2.4\gamma_w H_w)\frac{5}{3}H_w$

$= 2\gamma_w H_w^2$ kN/m ~~$= 2\gamma_w H_w^2$~~

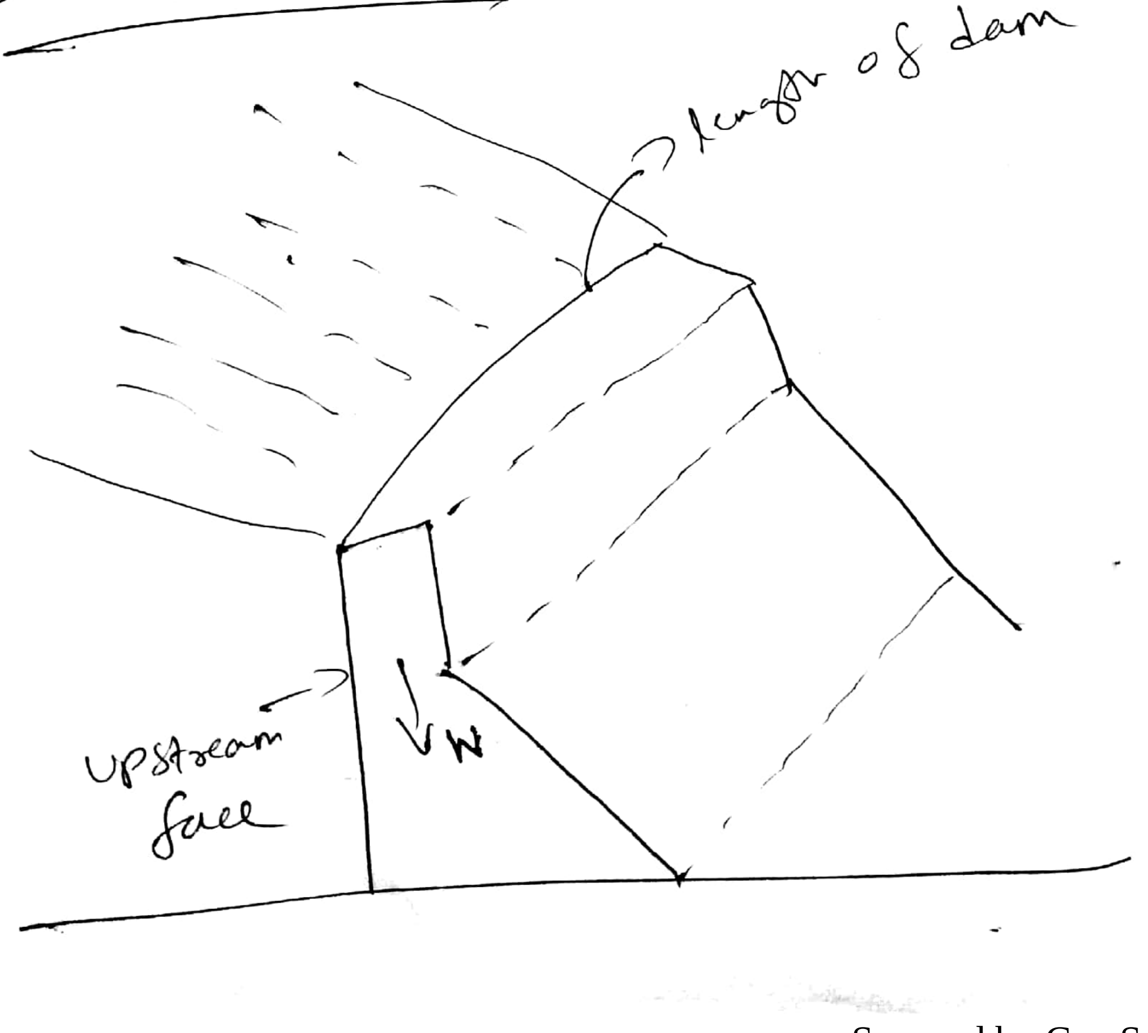
~~$= 19.62\, H_w^2$ kN/m~~

(6) Ice Pressure

When Ice is formed due to Cold weather & when it melts later, a pressure is created causing thrust linearly along the length of Dam. We know that thrust is force by area magnitude of this thrust varies from 250 – 1500 kN/m^2

Average thrust taken for calculation is 500 kN/m^2

⑦ Weight of Dam



The weight of dam is the major resisting force. The cross-section of the dam may be divided into several triangles & rectangles and the weights W_1, W_2, W_3 etc of each of these may be computed conveniently along the determination of the lines of action. The total weight "W" of the dam acts at the centre of gravity of section.

(8) Wind Pressure

It is the minor force & it is hardly taken into account for design of dams, normally wind pressure is taken as 1-1.5 kN/m^2 for the area exposed to wind pressure.

Modes of Failure:

Stability Requirements

following are the modes of failure of gravity dam:-

1. overturning
2. sliding
3. compression or crushing
4. Tension

overturning

The overturning of the dam section takes place when the resultant force at any section cuts the base of the dam, downstream of the toe. On the other hand if the resultant cuts the base within the body of the dam, there will be no overturning.

for Stability Requirements the dam ~~must~~ Should be Safe against overturning. The factor of Safety against overturning is defined as the ratio of righting moment to the overturning moment.

$$\text{Factor of Safety} = \frac{\Sigma \text{ Righting moment}}{\Sigma \text{ overturning moment}} = \frac{\Sigma M_R}{\Sigma M_o}$$

The factor of Safety ~~must~~ Should not be less than 1.5

Sliding

a dam will fail in sliding at its base or any other level if the horizontal force causing sliding are more than the resistance available to it at that Level. The Resistance against sliding may be due to friction alone, or due to friction and Shear Strength of the joint.

if Shear Strength is not taken into account then the factor of Safety is known as factor of Safety against Sliding.

Scanned by CamScanner

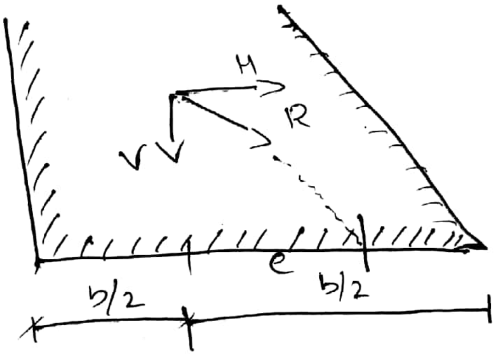
$$\text{Sliding factor} = \tan\theta = \frac{\Sigma H}{\Sigma V}$$

$$\text{factor of safety against sliding} = \frac{\mu}{\frac{\Sigma H}{\Sigma V}}$$

$$\Rightarrow \frac{\mu \times \Sigma V}{\Sigma H}$$

(μ is 0.65 to 0.75)

Compression or crushing



In order to calculate the normal stress distribution at the base or at any section let "H" be the total horizontal force & "V" be the total vertical force & "R" be the Resultant force cutting the base at eccentricity "e", from the centre of base of width "b". The normal stress at any point on the base will be sum of direct stress & Bending stress.

Direct stress $= \frac{V}{b \times l}$

Bending stress => we know

$$\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$$

$$f = \frac{My}{I} = \frac{\pm Ve}{\frac{1}{6} b^2}$$

The total stress P_n is given by

$$P_n = \frac{V}{b}\left(1 \pm \frac{6e}{b}\right)$$

Normal stress at toe is

$$P_n (toe) = \frac{V}{b}\left(1 + \frac{6e}{b}\right)$$

Normal stress at heel is

$$P_n (heel) = \frac{V}{b}\left(1 - \frac{6e}{b}\right)$$

The maximum compressive stress occurs at toe and for safety it should not be greater than allowable compressive stress.

$$P_n(\text{toe}) \leq f$$

$$\frac{V}{b}\left(1+\frac{6e}{b}\right) \leq f$$

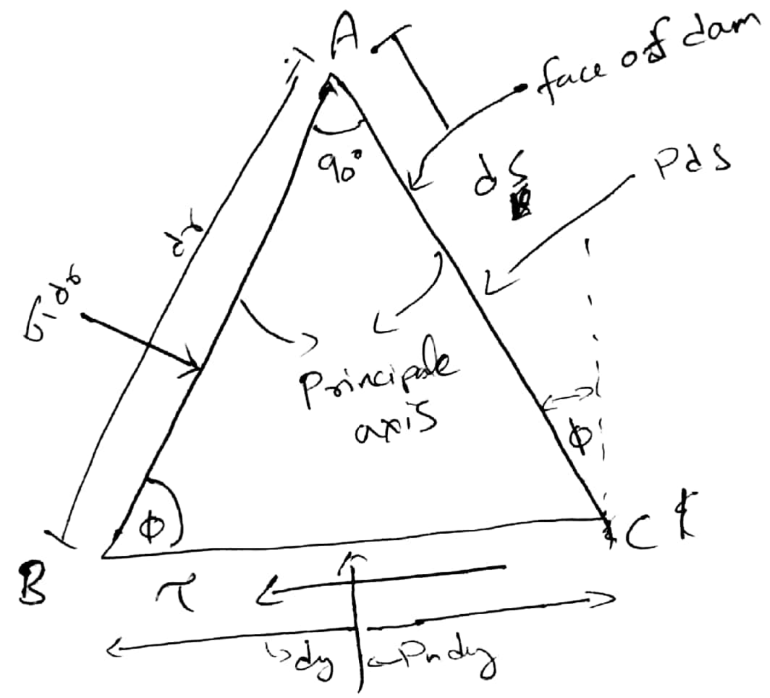
(4) Tension

The Normal stress at heel is

$$P_n(\text{heel}) = \frac{V}{b}\left(1-\frac{6e}{b}\right)$$

if $e > \frac{b}{6}$, then Normal stress at heel will be Tensile or negative. For no tension to develop at ~~face~~ base, eccentricity should be less than $\frac{b}{6}$

Principal & Shear Stresses



Consider an elementary triangular Section at either the heel or toe of the dam section the face of the dam will be ~~Principal~~ Principle plane as the water Pressure acts on it in perpendicular ~~direction~~ direction. let ds, dr, dy be lengths of AC, AB & BC side.

p = intensity of water pressure acting normal to the face of the dam.

σ_1 = ~~Principal~~ Principle stress on plane AB

τ = Shear stress on plane BC

P_n = normal stress on plane BC

7/8/2018

Considering unit length of dam the normal forces on the planes AB, BC & CA are $\sigma_1 dx$, $P_n dy$, $P \cdot ds$ respectively, resolving all the forces in vertical direction.

$$P_n \cdot dy = P\,ds \sin\phi + \sigma_1\,dx \cos\phi \quad \longrightarrow (1)$$

$$dx = dy \cos\phi \qquad \& \quad ds = dy \sin\phi$$

Sub dx & ds values in eq (1)

$$P_n\,dy = P \cdot dy \sin^2\phi + \sigma_1\,dy \cos^2\phi$$

$$P_n \cdot dy = dy\,(P \sin^2\phi + \sigma_1 \cos^2\phi)$$

$$P_n \times \frac{dy}{dy} = P \sin^2\phi + \sigma_1 \cos^2\phi$$

$$\boxed{\sigma_1 = \frac{P_n - P\sin^2\phi}{\cos^2\phi}}$$

σ_1 is known as principle stress relationship and it is applicable to both upstream side and downstream side

Shear stress

Resolving all the forces in horizontal direction we get

$$\tau\, dy = \sigma_1\, dx \sin\phi - p \cdot ds \cos\phi$$

$$\tau = \sigma_1 \sin\phi \frac{dx}{dy} - p \cdot \cos\phi \frac{ds}{dy}$$

but $\frac{dx}{dy} = \cos\phi$ & $\frac{ds}{dy} = \sin\phi$.

$$\tau = \sigma_1 \sin\phi \cos\phi - p \cdot \cos\phi \sin\phi$$

$$\tau = (\sigma_1 - p) \cos\phi \sin\phi$$

sub value of σ_1 in above equation

$$\tau = \left(\left(\frac{p_n - p\sin^2\theta}{\cos^2\theta}\right) - p\right) \cos\phi \sin\phi$$

$$\tau = \left(\frac{P_n - P\sin^2\phi}{\cos^2\phi}\right)\cos\phi\sin\phi - P\cos\phi\sin\phi$$

The above equation is applicable for downstream side only,

Shear stress for upstream side is given by

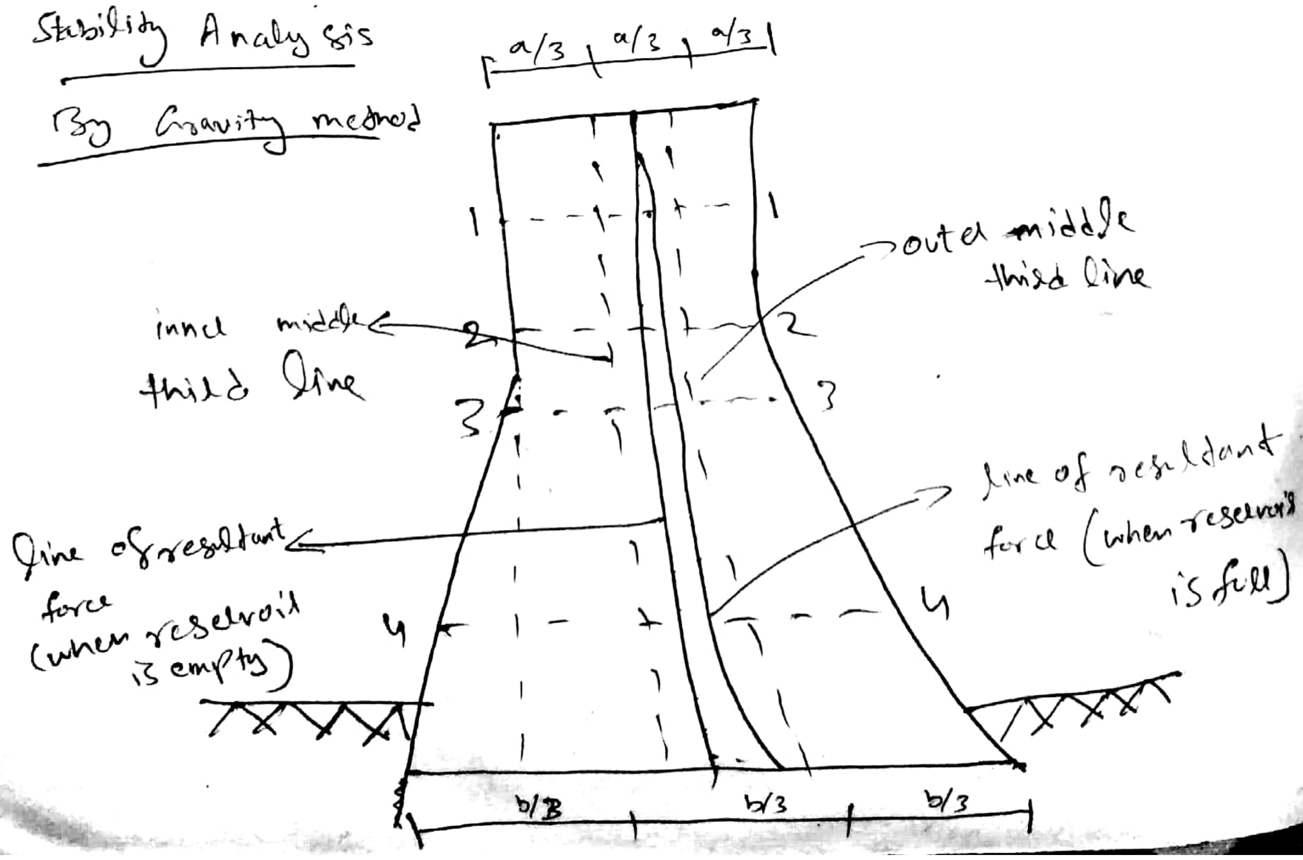
$$\tau = -\left[P_n - \left(p + p'_e\right)\right]\tan\phi$$

if upstream side is vertical $\phi = 0$ &

$\tau = 0$

Stability Analysis

By Gravity method



The Stability Analysis of a gravity dam Section can be carried out by following methods

(i) gravity method
   (a) graphical method
   (b) Analytical method.

gravity method is an approximate method in which the dam is considered to be composed of parallel sided vertical cantilevers, each of which is free to act without supporting or interfering with the adjoining. cantilevers.

graphical method

In the graphical method the dam is divided into Horizontal sections i.e 1-1, 2-2, 3-3, 4-4 at suitable intervals or at places where the slope changes.

for each section sum of Horizontal forces i.e (ΣH) & sum of vertical forces i.e (ΣV) acting above the section are calculated and the line of action are graphically located. The resultant force "R" is found and its line of action is located graphically. This is done for each section and finally a line is drawn joining the points at which the resultant cuts the various sections. The line of resultant should lie within the middle third for no tension to develop. This procedure is adopted for reservoir full & reservoir empty conditions

Analytical method

The Stability Analysis by Analytical method is done in the following methods

(i) consider unit length of a dam & calculate all the vertical loads acting which include weight of the dam, weight of water acting on inclined surfaces, uplift pressure, inertia forces due to vertical acceleration. and thereby we will be finding the ~~algebric~~ algebraic sum of these vertical forces { ie ΣV

(ii) find out sum of Horizontal forces ie ΣH & the Horizontal Pressure due to Hydro-dynamic Pressure.

8/8/2018

(iii) find out the sum of overturning moments i.e ΣM_o & The sum of righting moments

ΣM_R at the toe of the section, also find the algebraic sum of all the moments

$$\Sigma M = \Sigma M_R - \Sigma M_o$$

(iv) find out the location of the resultant force 'R' from toe by the relation $\bar{x} = \frac{\Sigma M}{\Sigma V}$.

(v) find out the eccentricity "e" of the resultant "R" from the centre by the relation $e = \frac{b}{2} - \bar{x}$

where 'b' is base width of the section.

(vi) find the normal stress at the toe of the dam

$$P_{n_{toe}} = \frac{\Sigma V}{b}\left(1 + \frac{6e}{b}\right) \quad \&$$

also find normal stress at heel of the dam

$$P_{n_{heel}} = \frac{\Sigma V}{b}\left(1 - \frac{6e}{b}\right)$$

(vii) find out Principle stress & shear stress at toe & heel

$$\text{Principle stress} = \sigma_1 = \frac{P_n - P \sin^2\phi}{\cos^2\phi}$$

Shear stress $= \tau = -\left[P_n - (p + p'e)\right] \tan\phi$

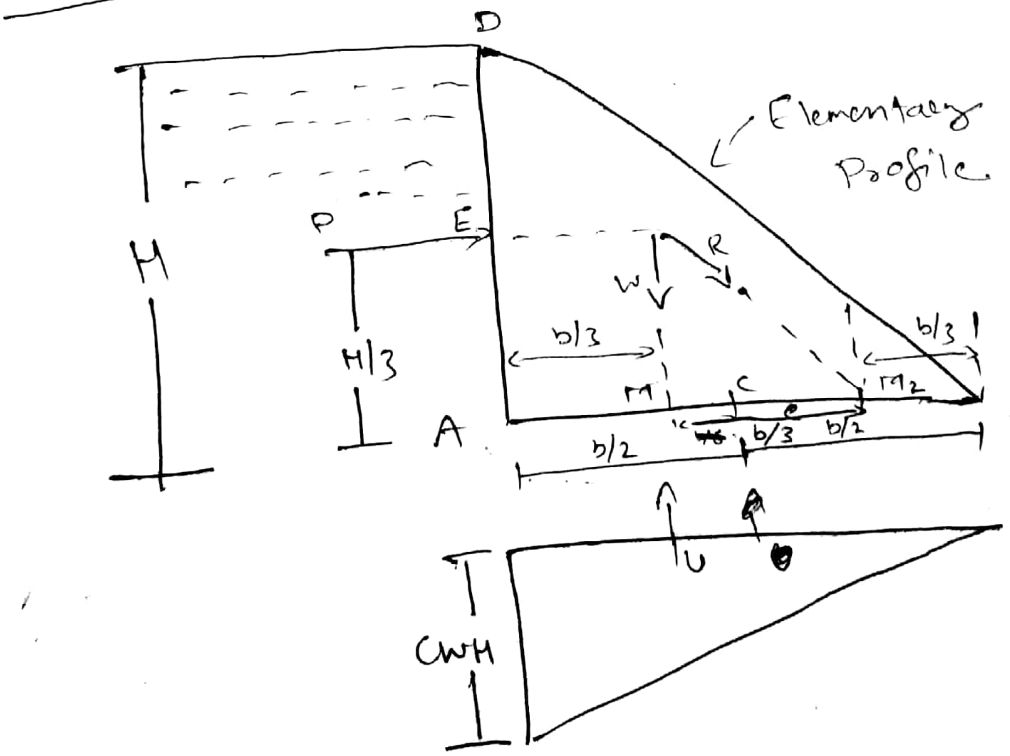
(viii) find out factor of safety against overturning.

$$F.S = \frac{\Sigma M_R}{\Sigma M_O}$$

(ix) find out factor of safety against sliding

$$F.S.S = \frac{\mu \Sigma V}{\Sigma H}$$

Elementary Profile of a Gravity Dam.



in absence of any other force other than the forces due to water an elementary Profile will be triangular in Section having zero width at the water Level i.e at the Top. where water Pressure is zero and a maximum base width "b" where the maximum pressure acts.

for a reservoir empty condition a right angle triangular Profile will Provide maximum Possible stabilizing force against overturning without causing tension at base.

we shall consider the following forces acting on elementary profile of a dam.

1) Weight of dam (W)

$$W = \frac{1}{2} b H \gamma_w \times \rho$$

ρ = specific gravity of dam material

γ_w = unit wt of water

2) Water Pressure (P)

$P = \frac{1}{2} \gamma_w H^2$ acting at $\frac{H}{3}$ from base

3) Uplift Pressure (U)

$$U = \frac{1}{2} C \cdot \gamma_w \cdot b \cdot H$$

C = uplift pressure intensity coefficient

Base width of elementary profile :-

The Base width of elementary Profile can be found under two criteria

1) Stress criteria.
2) Stability or sliding criteria.

Stress criteria :-

when the reservoir is empty for more tension to develop the resultant should act at inner third point i.e M_1 .

for reservoir full condition for no tension to develop, The Resultant "R" must pass through the outer third Point i.e "M_2".

Taking moment of all the forces and equating it to zero. we get

$\Sigma M = 0$.

$$P \times \frac{H}{3} + U \times \frac{b}{3} - W \times b/3 = 0$$

~~$\frac{1}{2} \times \gamma_w H^2 \times \frac{H}{3} + \frac{1}{2} \times b H \gamma_w \times$~~

$$\left(\frac{1}{2} \times \gamma_w H^2\right) \times \frac{H}{3} + \left(\frac{1}{2} \cdot c\, \gamma_w\, b \cdot H\right) \times \frac{b}{3} - \left(\frac{1}{2}\, b H \rho \gamma_w\right) \times \frac{b}{3} = 0$$

9/8/2018

multiply all the terms with $\frac{6}{\gamma_w H}$

$$\frac{\gamma_w H^3}{6} \times \frac{6}{\gamma_w H} + \frac{c \cdot \gamma_w b^2 H}{6} \times \frac{6}{\gamma_w H} - \frac{b^2 H \gamma_w \rho}{6} \times \frac{6}{\gamma_w H} = 0$$

$$H^2 + c \cdot b^2 - \rho b^2 = 0$$

$$H^2 + b^2 (c - \rho) = 0.$$

~~$b^2 = \frac{H^2}{(c-\rho)}$~~ $b^2 = \frac{H^2}{(\rho - c)}$

~~$b = \frac{H}{\sqrt{(c-\rho)}}$~~ $b = \frac{H}{\sqrt{\rho - c}}$

$b = \frac{H}{\sqrt{\rho - c}}$

if uplift pressure is not considered,

the value of ~~pressure~~ "C" is zero

Stability or sliding criteria :-

for no sliding to occur the horizontal force causing sliding should be balanced by the frictional forces opposing them.

~~R = H (W - U~~

$$P = \mu (W - U)$$

$$\frac{1}{2} \gamma_w H^2 = \mu \left(\left(\frac{1}{2} b H \gamma_w \rho \right) - \left(\frac{1}{2} C \cdot \gamma_w b \cdot H \right) \right)$$

multiply all terms by $\frac{6}{\gamma_w H}$

$$\frac{\gamma_w H^2}{2} \times \frac{6}{\gamma_w H} = \frac{\mu b H \gamma_w \rho}{2} \times \frac{6}{\gamma_w H} - \frac{\gamma_w \cdot b \cdot H \cdot C \cdot \mu}{2} \times \frac{6}{\gamma_w H}$$

$$3H = 3\mu b \cdot \rho - 3 b \cdot C \cdot \mu$$

$$3H = 3 b \mu (\rho - C)$$

$$b = \frac{H}{\mu(S - C)}$$

if uplift pressure is neglected,

then C will be zero.

Stress developed in Elementary Profile

The normal stress is given by

$$P_n = \frac{V}{b}\left(1 \pm \frac{6e}{b}\right)$$

for full reservoir the normal stress at toe is given by

$$P_n(\text{toe}) = \frac{2(W-U)}{b}$$

$$P_n(\text{toe}) = \frac{2}{b}\left(\frac{1}{2} b H \gamma_w S - \frac{1}{2} \cdot C \cdot \gamma_w b \cdot H\right)$$

$$P_n(\text{toe}) = H \gamma_w S - C \cdot \gamma_w H.$$

Scanned by CamScanner

$P_n (\text{toe}) = H \gamma_w (S - C)$

The normal stress at heel is zero.

<u>Principal</u> stress at toe is

$$\sigma_1 = P_n \sec^2\phi = \gamma_w H (S-C) \left[\left(\frac{b}{H}\right)^2 + 1 \right]$$

$$\text{but } \left(\frac{b}{H}\right)^2 = \frac{1}{S-C}$$

$$\sigma_1 = \gamma_w H (S-C) \left[\frac{1}{S-C} + 1 \right]$$

$$\sigma_1 = \gamma_w H (S-C) \left[\frac{1 + (S-C)}{(S-C)} \right]$$

$$\sigma_1 = \gamma_w H (S - C + 1)$$

<u>Shear stress</u> at toe is

$$\tau = P_n \tan\phi$$

$$\tau = \gamma_w H (S-C) \times \frac{b}{H}$$

but $= \left(\frac{b}{H}\right)^2 = \frac{1}{S-C}$

$$\tau = \gamma_w H (S-C) \times \sqrt{\frac{1}{S-C}}$$

$\sqrt{2} \times \sqrt{2} = 2$

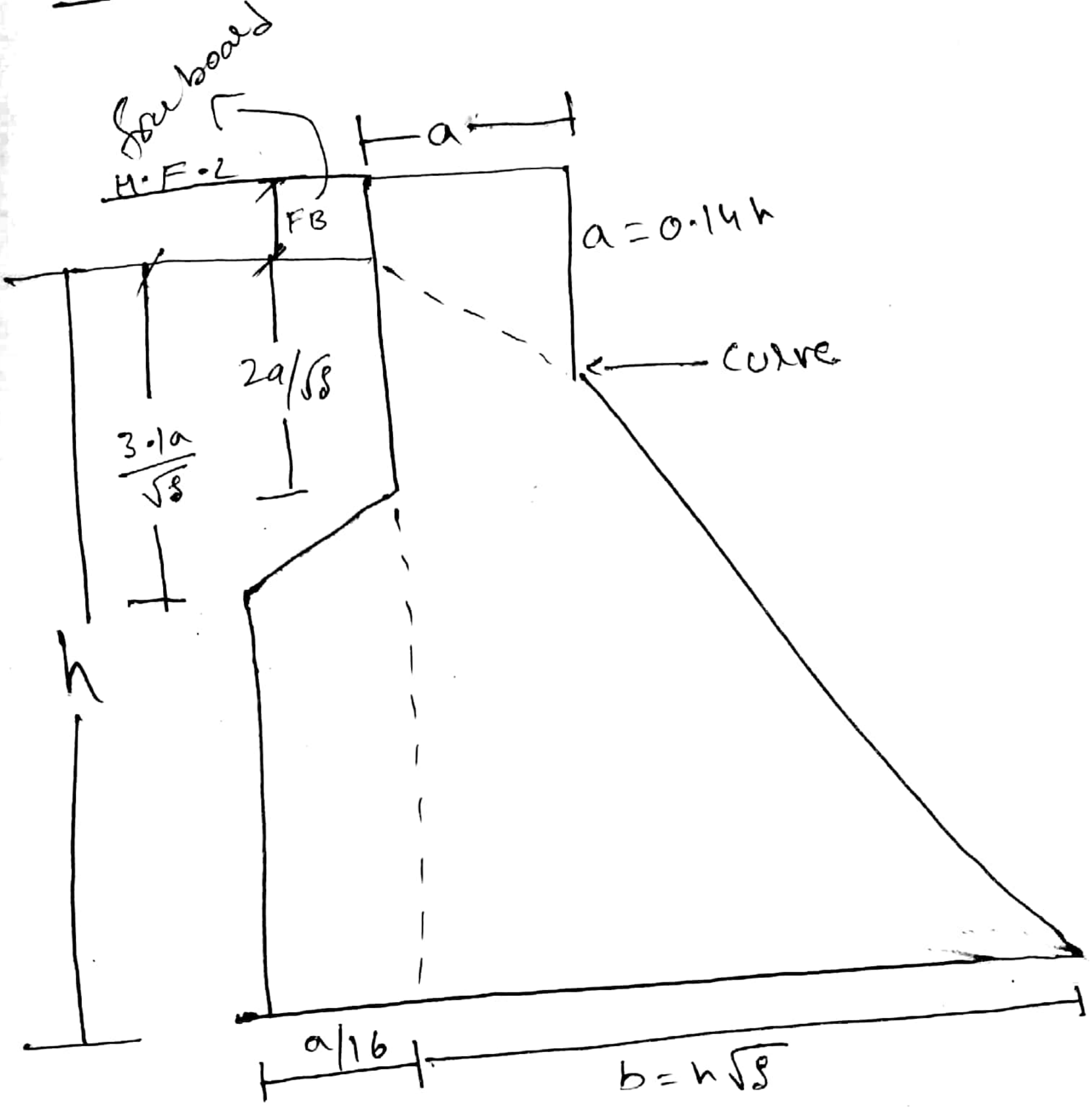
~~$\tau = \gamma_w H \sqrt{S-C}$~~

$$\tau = \gamma_w H \sqrt{S-C} \cdot \sqrt{S-C} \times \frac{\sqrt{1}}{\sqrt{S-C}}$$

$$\boxed{\tau = \gamma_w H \sqrt{S-C}}$$

- As the normal stress is zero at Heel, the Principle stress & Shear stress will also be zero at heel.

Practical Profile of a Gravity Dam



The elementary profile of the gravity dam is only a theoretical profile. However such a profile is not possible in practice because of provision of

(i) roadway at the top.

(ii) additional loads due to roadway

(iii) free board

Due to these provinces the resultant force of the weight of the dam & the water pressure falls outside the middle third of the base of the dam, when reservoir is full. To eliminate tension some masonry is provided at the upstream side.

~~Fre~~

Free board

it is the margin between the Top of the dam & high flood Level, in the reservoir to prevent splashing of waves over the non over flow section.

The free board usually provided is $\frac{3}{2}$ hw where h_w = wave height

$$h_w = 0.0322\sqrt{FV}$$

F = fetch or straight line in kms

V = wind velocity in km/hr

according to IS code 6512 : 1984 the free board shall be equal to ~~4/3 hw +~~ 4/3 hw + wind setup

the wind setup is the piling of the water at the one end of the reservoir & is determined by the following formula

$$S = \frac{V^2 \cdot F\cos\beta}{62000 D}$$

S = wind setup in meters

V = wind velocity in km/hr

F = Fetch (kms)

β = angle b/w wind direction & fetch

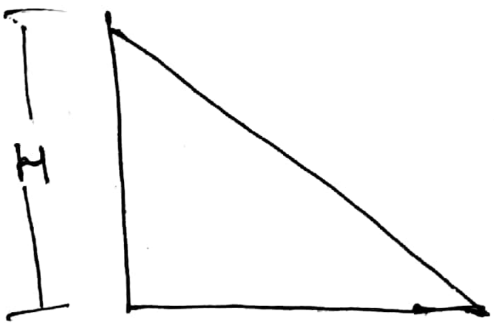
D = average depth of water in meters

The wind velocity is taken as 120 km/hr for normal reservoir level conditions & 80 km/hr for maximum water level condition.

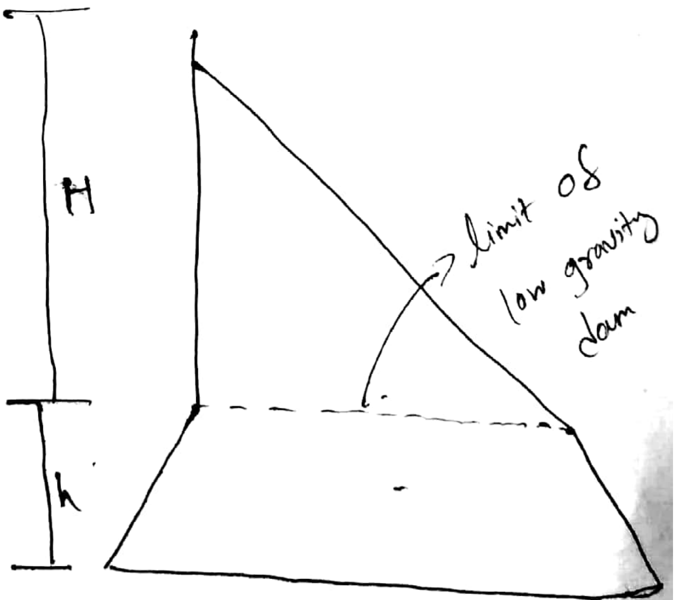
High & Low Gravity Dams

The principle stress at toe is given by

$$\sigma_1 = \gamma_w H (S - C + 1)$$



Low Dam



High Dam

The maximum value of this principle stress must not exceed the allowable stress (f) for the material.

$$f = \sigma_1 = \gamma_w H (S - C + 1)$$

~~whole~~ height is given by

$$H = \frac{f}{\gamma_w (S - C + 1)}$$

for finding limiting height do not consider ~~uplift~~ uplift, therefore putting $C = 0$

limiting height
$$\boxed{H = \frac{f}{\gamma_w (S + 1)}}$$

if the height of the dam is more than the height got from the above equation, the maximum compressive

Stress will exceed the ~~permiss~~ Permissible Stress, which is undesirable.

This limiting height defines the difference between low & high gravity dam

A low gravity dam is the one in which the height is less than the height got from the equation

$$H = \frac{f}{\gamma_w (S+1)}$$

So that the compressive stress is not greater than allowable Stress

$\gamma_w = 9.81\ kN/m^3$

$S = 2.4$

$f = 2940\ kN/m^3$ (or $30\ kg/cm^2$) for concrete dam

$$H = \frac{2940}{9.81 \times (2.4+1)} = 88.145\ m \simeq 88\ m$$

if the height of the dam to be constructed is more than $\frac{v}{b}\left(1+\frac{6e}{b}\right)$ then the dam is known as High gravity dam.

for such a dam, the section will have to be given extra slopes to the ~~upstream~~ upstream & downstream sides to bring the compressive stress within the limits.

14/08/2018

Types of Galleries in a Gravity Dam :-

Gallery is a formed opening left in a Dam. This may run in transverse or Longitudinal direction and may run Horizontally or on a Slope. The shape & size varies from Dam to Dam and is generally governed by the functions it has to perform.

The ~~vat~~ various purposes for which a gallery is formed in a Dam are:-

(i) To provide drainage of the dam section
(ii) when some amount of water seeps through upstream face of the dam is drained by these galleries

(ii) To provide facilities for drilling & grouting operations for foundations.

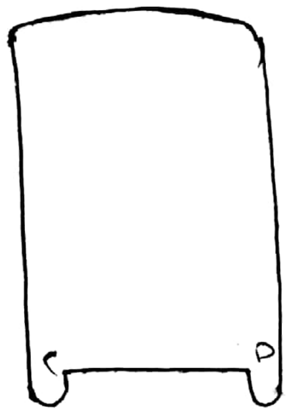
(iii) To provide access to observe & measure the behaviour of the structure after its completion & examining development of cracks.

The two typical shapes of galleries are

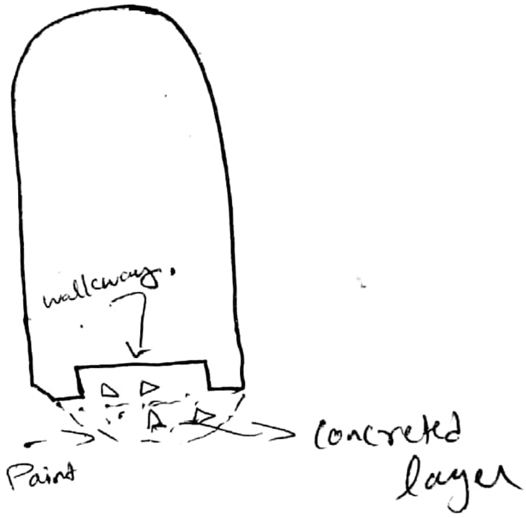
(i) Rectangular &
(ii) Oval

In the Rectangular Gallery all the corners Should be rounded so that the stress concentration is minimum.

an Oval shape Gallery is provided with a walkway & a semi circular bottom is filled with an unbounded Slab.



Rectangular Gallery



oval shaped gallery.

Foundation Treatment for a Gravity Dam

The foundation should be Strong enough to withstand any amount of pressure or Loads acting onto the foundation. one of the main reason for failure of dams is failure of foundation only. As foundation is an important Part of any big Structure thereby it is needed to Study, investigate and adopt remedial measures is very important or else there are high chances of failure of Structures.

Common treatments for foundation of Gravity Dams are:

(i) Preparing the Surface

(ii) Grouting the foundation.

Preparing the surface

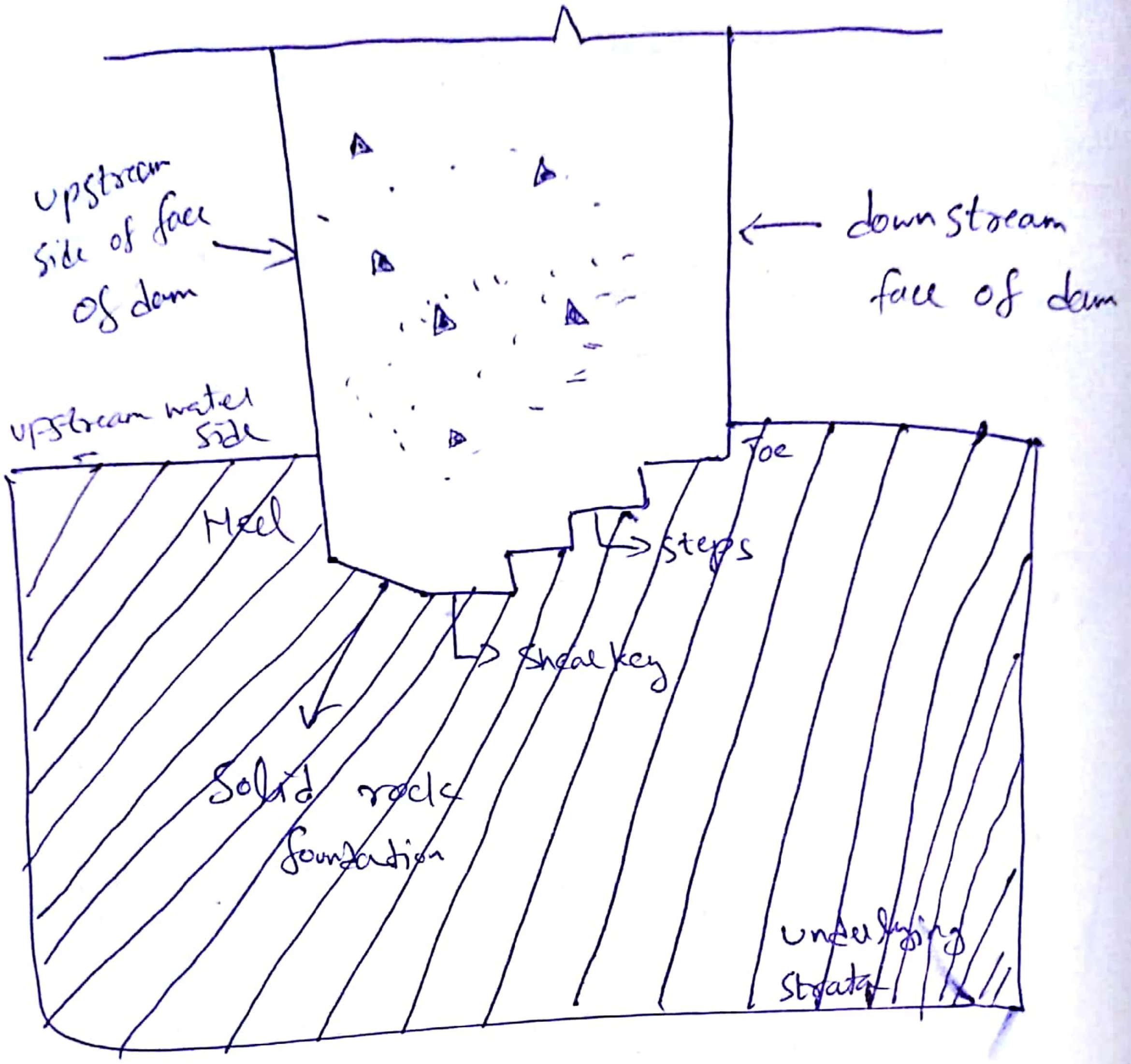
(i) removing the entire loose soil i.e all loose boulders, loose soil is excavated until hard rock is exposed. i.e the solid rock foundation is got..

(ii) excavation should be carried out in such a way that underlying rock is not damaged.

(iii) final underlying section is steeped, the reason for stepping is to get frictional resistance against sliding.

(iv) Provision of shear key. it is also provided for resistance against sliding.

(v) The top surface is cleaned & washed properly before concreting.



Grouting the foundation

(i) when excavation is done, explosive are used for it. because of these explosives cracks are formed into the rock foundations. filling of these cracks by a mixture called Grout is called as Grouting.

Grout is a mixture of Cement & water in which admixtures are also added as per requirement.

The two Types of Grouting are

(i) ~~consi~~ consolidation grouting &

(ii) curtain grouting.

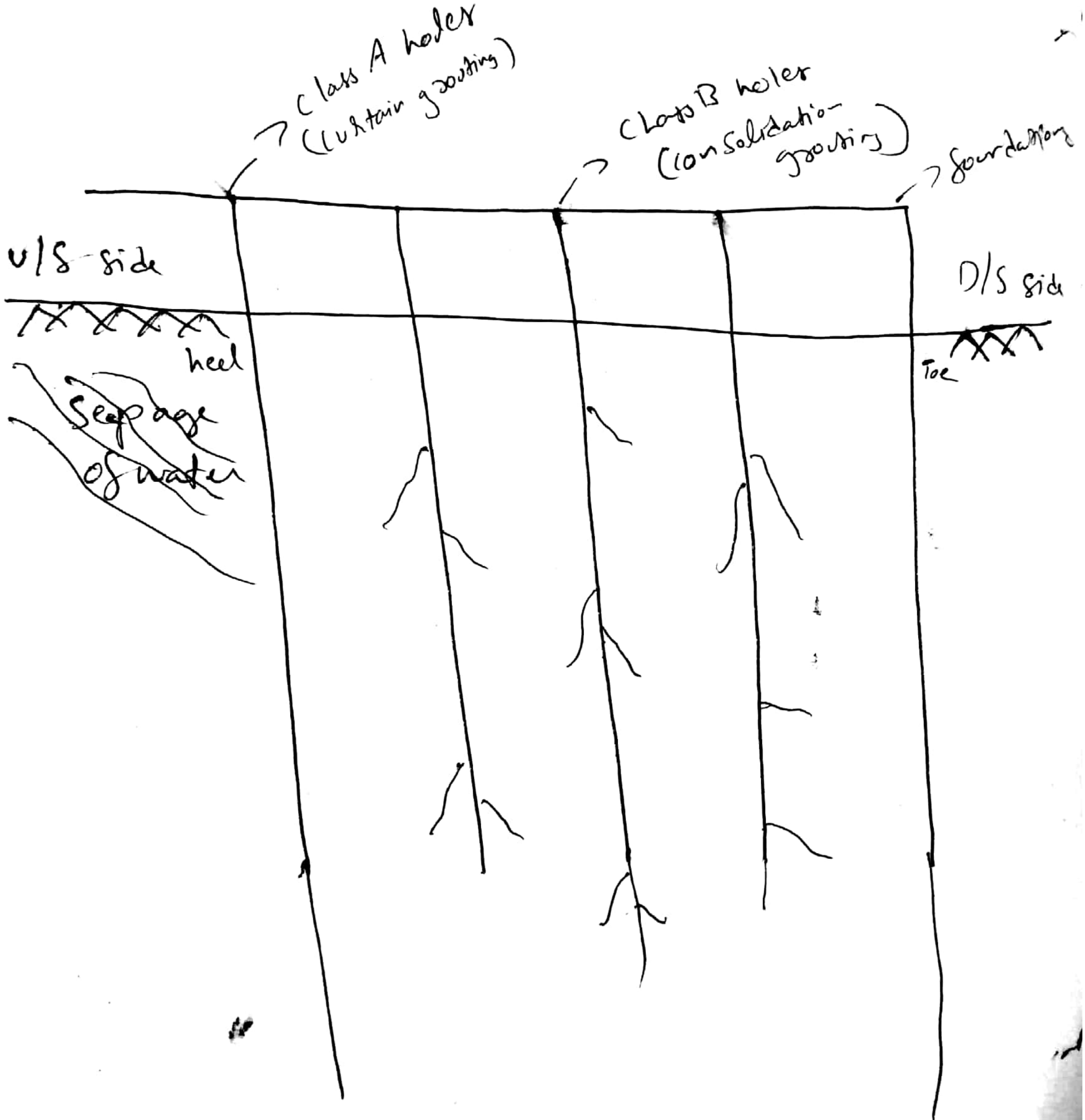
In consolidation grouting, the grouting is done by consolidation. It is consolidated upto a depth of 10-15 meters with a spacing of 5-20 meters. it is done by shallow holes called as class "B" holes. as per Geological conditions the depth & spacing can change.

Curtain grouting:

It is the forming of principle barrier against seepage, It is done by

Scanned by CamScanner

Shallow holes called as Class "A" holes. it is done upto a depth of 15 meters & spacing of 1.2 - 1.5 meters



es -

s

-dations

s side

30/08/2018

UNIT - III

Earth Dams

Types of earth dams :-

Earth dams constitutes to be the most common type of dam since it is generally build by locally available materials. in their natural state with a minimum of processing. earth dam's are composed of fragmental materials which maintain their individual property. depending upon the method of construction earth dam's can be divided into Two categories

1) rolled filled Dam

2) Hydraulic filled Dam

1) In the rolled filled Dam the embankment is Constructed in successive mechanically compacted layers. the suitable materials are transported from the borrow pits to the construction sites by earth moving machinery, it is then spread by bulldozers and sprinkled to form layers of limited thickness having proper water content. They are then thoroughly

compacted and bonded with the preceeding layer by means of power operated rollers of proper design and weight

2) In case of Hydraulic filled Dam, the materials are excavated, transported and placed by Hydraulic methods. flumes are laid at a suitable falling gradient along the outer edge of the embankment. The materials mixed with water at borrow pits is pumped and washed into these flumes. The slush is discharge through the outlet in the flumes at suitable intervals along their length. The slush thus flows towards the centre of the bank. The coarse material of the slush ~~settles~~ settle at the outer edge while the fine material settle at the centre. and no compaction is done

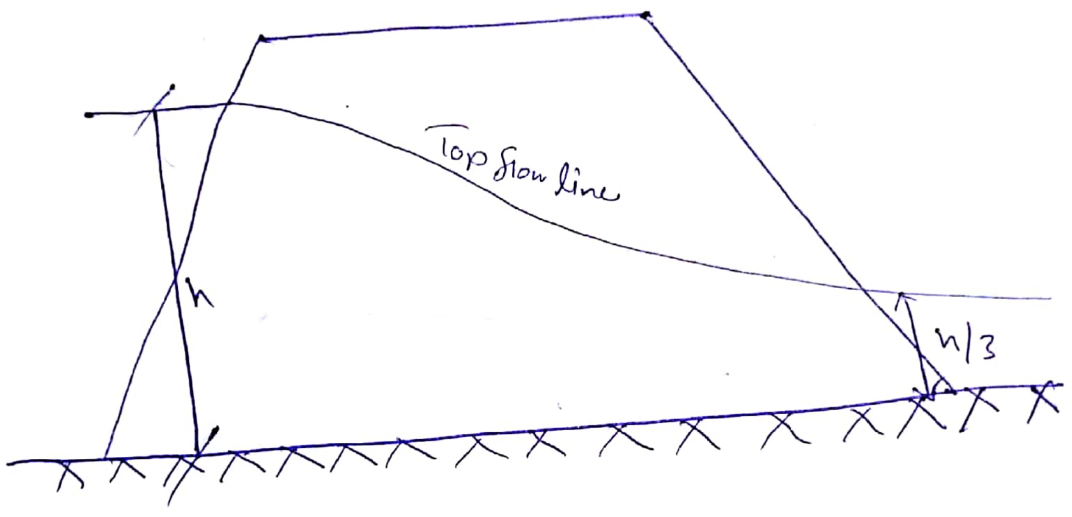
Rolled filled Dams can be further ~~divi~~ sub divided into following types

1) Homogeneous embankment type
2) Zoned embankment type
3) ~~Diaphgram~~ Diaphragm embankment type

by

and

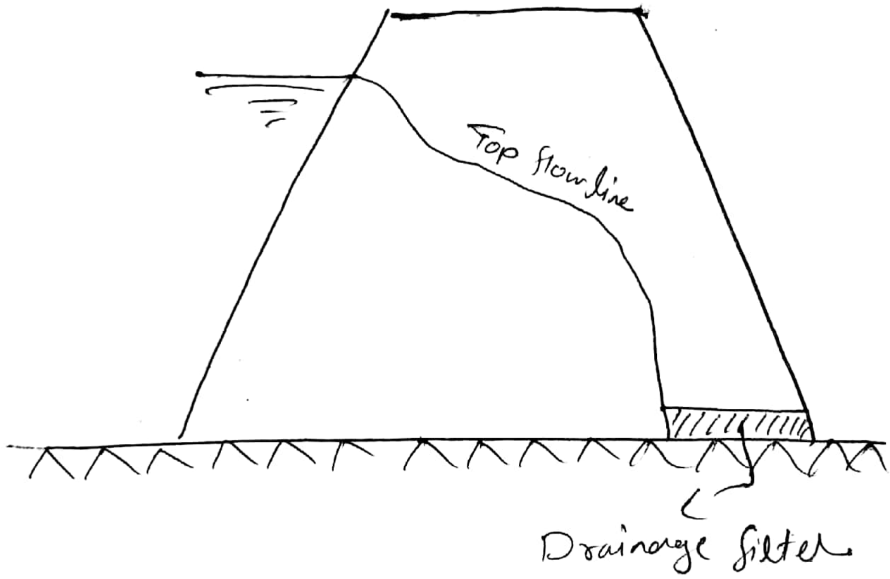
Homogeneous embankment type



Impervious foundation

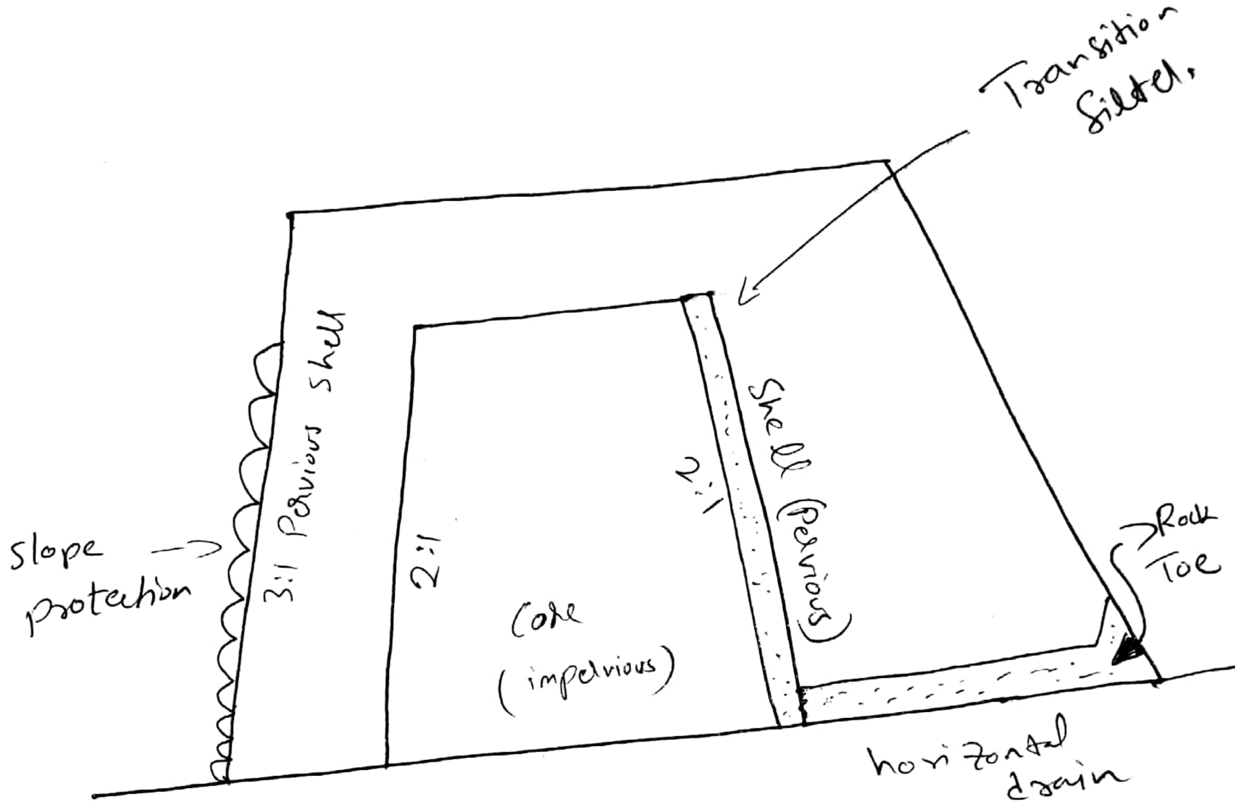
Purely homogeneous Dam.

a Purely homogeneous type earth dam is composed of a single ~~kind~~ type of material this type of dam is used whenever only one type of material is economically available. However these dams are used only for low to moderate heights. a purely homogeneous section is replaced by a modified homogeneous section in which internal drainage system ~~di~~ in the form of Horizontal filter drain is provided. This controls the action of seepage so as to permit steeper slopes. homogeneous dams are usually composed of impervious or semi-impervious soils to provide adequate water barrier. However the ~~upstream~~ upstream slope has to be flat. to make it safe during the sudden draw down condition. many successful embankments have been built to relatively pervious sands and sand gravel mixtures.



modified homogeneous dam

Zoned embankment type



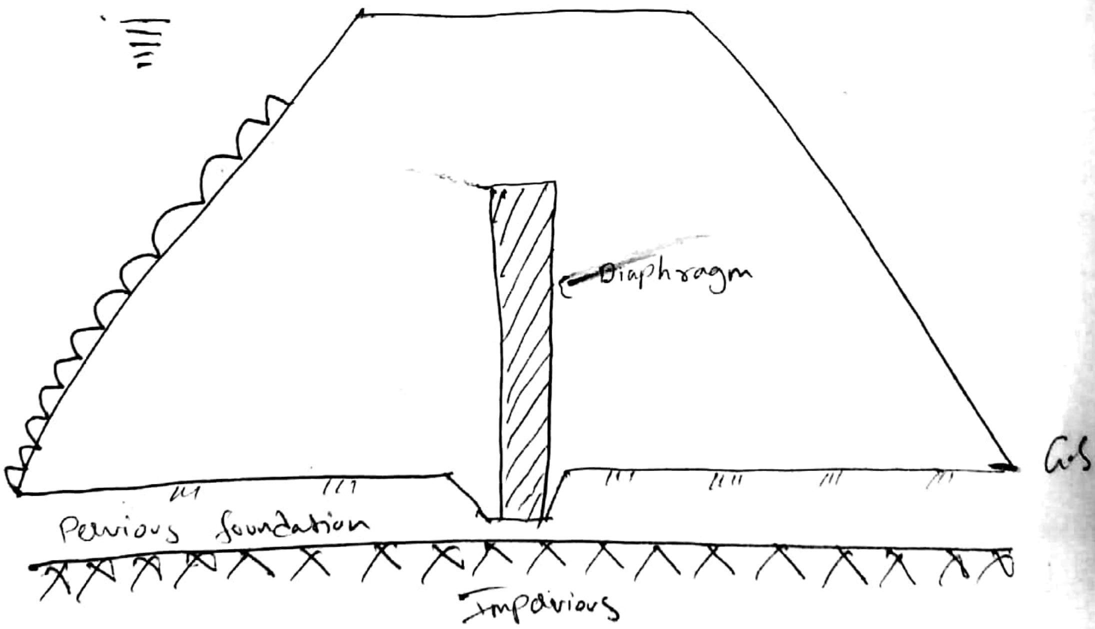
Zoned embankment type earth dam is the one in which the dam is made up of more than one material. the most common type of rolled earth dam section is that in which a central impervious core is provided with different zones of materials beside it. a suitable drainage system in the form of Horizontal drain or Rock Toe is also provided at the downstream side.

if variety of soils are readily available, the Zoned embankment type is best suited as it has many advantages leading to less cost of construction.

in the zone embankment type the outer shells are made of pervious, freely draining material. the shell gives stability to central impervious fill and at the same time distributes the load over a larger area in the foundation.

Sometimes semipervious zone is provided to serve as a medium between outer shell and central core. The upstream pervious zone acts as stability against rapid drawdown while the downstream pervious zone acts as a drain to control the line of seepage.

~~Diaphgram~~ Diaphragm embankment type



04/09/2018

This is a modification Dam over the homogeneous embankment type in which the bulk of embankment is constructed of a pervious material and a thin diaphragm of ~~impervious~~ impermeable material is provided to check the seepage. The diaphragm may be of impervious soil, cement concrete, bituminous concrete or any other material may be placed either at centre of the section as a central vertical core or at the upstream side. if the horizontal thickness of diaphragm at any elevation is less than 10 mts or less than the height of embankment above any corresponding elevation, in the dam the dam is of diaphragm type.

Causes of failures of earth dam :-

on the basis of investigation reports, on most of the past failures the main causes of failures has been categorized into three main classes:

a) Hydraulic failures — 40%

b) Seepage failures — 30%

c) structural failures — 30%

1) Hydraulic failures

a) Overtopping

b) wave erosion

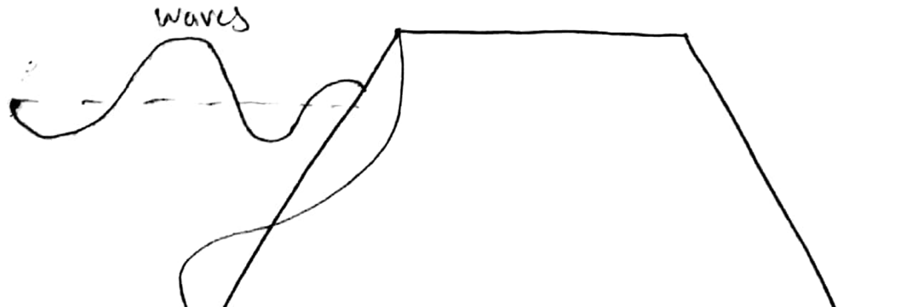
c) Toe erosion

d) Gullying.

Overtopping:-

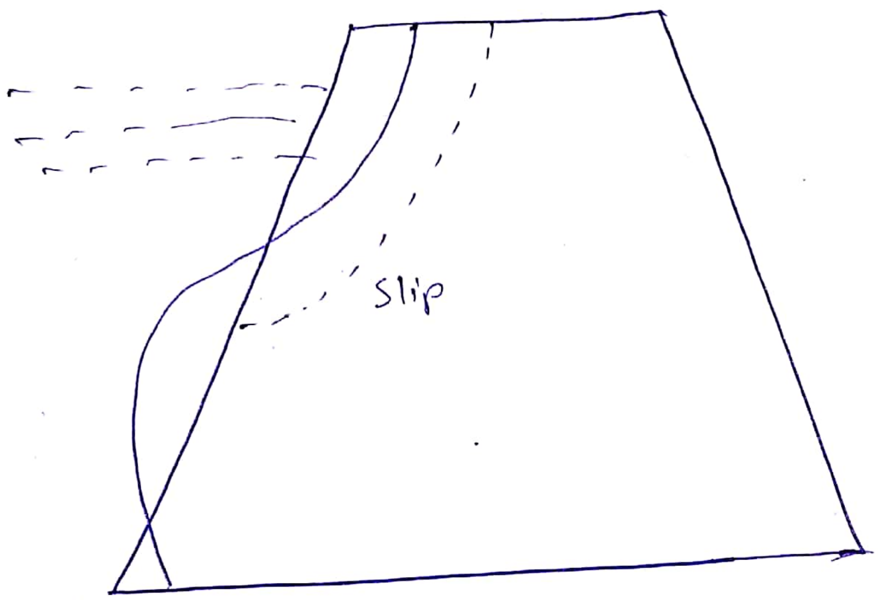
The earth dam may get overtop if the designed flood is underestimated or ~~the~~ if the Spillway is of insufficient capacity. faulty operation of Spillway gates may also sometimes leads to overtopping. insufficient free board or settlement of foundation and embankment may also lead to overtopping.

~~wave~~ wave erosion:-



a) Roller Action

The effects of wave is to notch out Earth from the upstream slope. in absence of proper slope protection. rollers are developed in the waves which try to remove the earth, waves can also cause upstream slips.



b) upstream slip

Toe erosion:

Toe erosion may occur due to Two reasons.

(i) Due to Tail water

(ii) erosion due to cross currents that may come from Spillway or from exit areas of outlets.

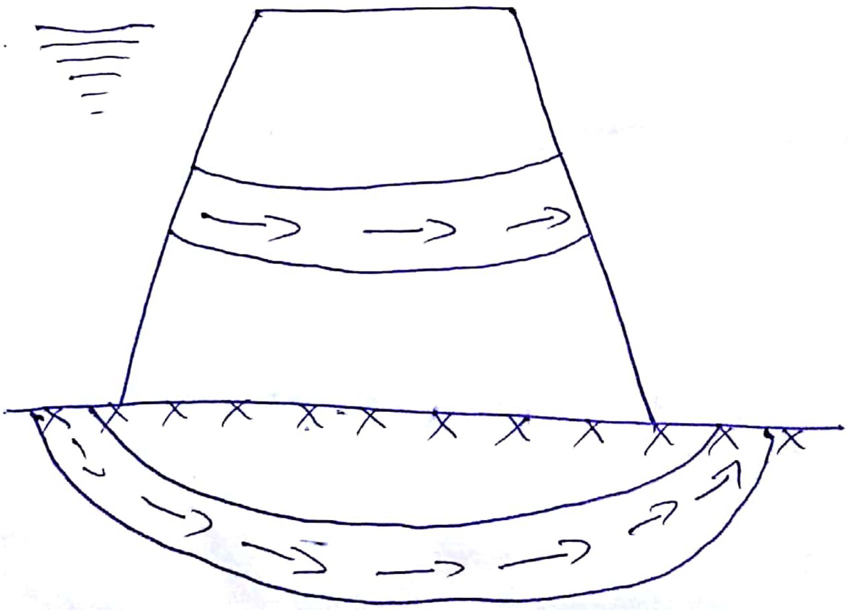
The toe erosion can be avoided by providing thick material ~~or~~ on the downstream slope upto a height slightly above the tail water level. diaphragm balls of sufficient length and height should be provided to check the cross flow towards the earth dam. 05

gullying:-

Downstream may fail due to formation of ~~gully's by~~ gulleys due to heavy downpour. To eliminate failure due to gullying proper beams, turfing and good drainage system should be provided at ~~to~~ downstream side.

Seepage failures:-

Seepage failures may be of Two types
1) Piping
2) Sloughing



Piping or seepage erosion through dam & through foundation

05/09/2018

The seepage of water through body and foundation of earth dam may leads to Piping. water seeping through earth dam may have four bad effects.

(i) seeping water generates erosive forces which ~~distog~~ dislodge particles from the soil structure and causes rearrangement of voids between large grain.

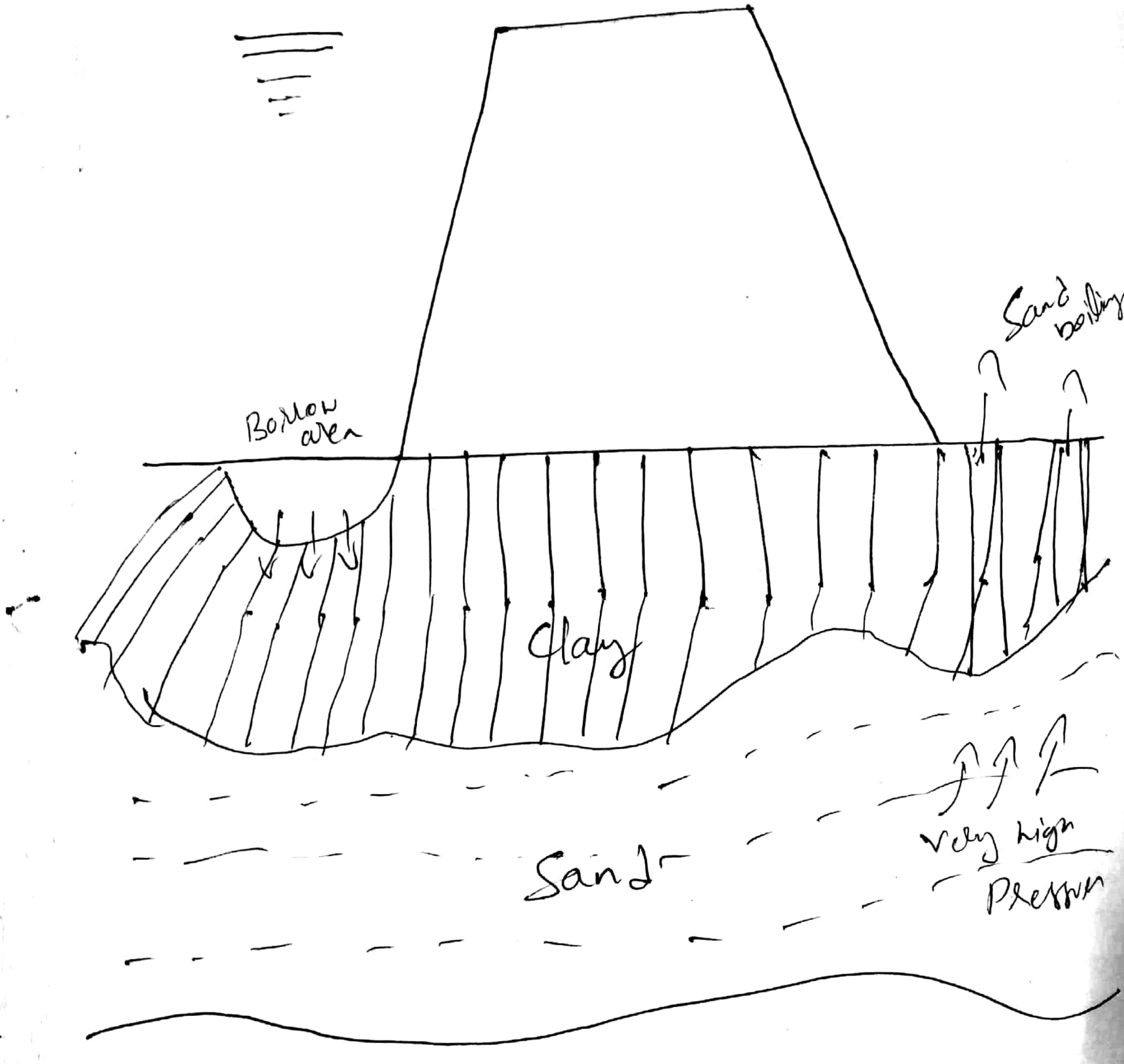
(ii) the flow with its associated Pore Pressure can lift a portion of ~~sot~~ soil mass causing sand boiling.

(iii) internal erosion of soil mass leads to formation of ~~soil mass~~ open passage through the soil. ~~mass.~~

(iv) the internal pressures in the soil water can reduce ~~the par~~ that part of soil strength that is are developed by internal friction. and there by lead to weakning of soil mass and even failure by shear.

~~(v)~~ leaks in the embankment may also lead to Piping failure.

Piping due to excess gradient & due to removal U/S blanket near the dam



failure due to progressive Sloughing is closely related to Piping. under Full Reservoir condition the downstream toe remains Saturated and may erode producing a small Slump or small slide. This slurring process continues till the remaining portion of the dam is too thin to withstand the water Pressure and complete failure occur suddenly at the reservoir 'brake through.

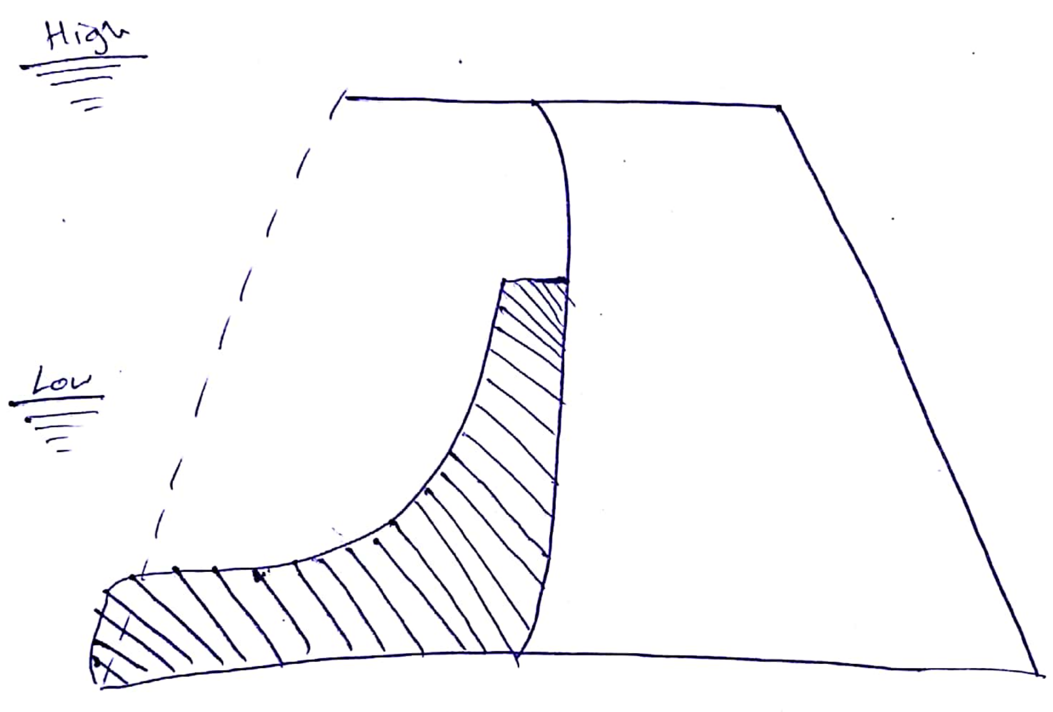
11/09/2018

Structural failures

i) upstream & downstream failure due to construction pore pressure.

-> when a Dam is build of relatively impervious compressible soil. The drainage is extremely slow and excess pore pressure is developed during and immediately after construction. Experience Indicator

2) Upstream slope slide during sudden drawdown



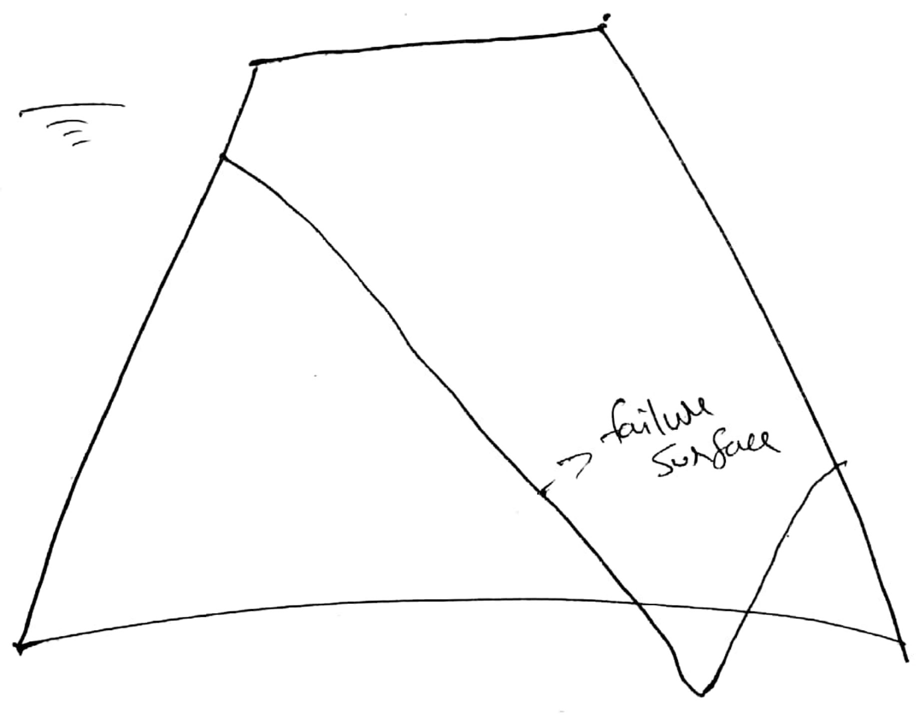
upstream slope failure during sudden drawdown

for the upstream slope the critical condition is when the reservoir is suddenly emptied without allowing any appreciable change in water level within the

Saturated soil mass. This stage is known as sudden drawdown.

When the upstream slide occurs due to sudden drawdown the pore pressure along the surface of the slide are released to a large extent.

3) Downstream slope slide during full Reservoir condition



Deep D/s slides during sudden seepage

Critical condition for Downstream slope occurs when reservoir is full & percolation or seepage is at its maximum rate. The direction of seepage forces tend to decrease stability. There are two types of downstream slides deep slides & Shallow Slides. The deep slides generally pass through the clay foundation and reduce the fraboard by extending further than the upstream edge of the crest. Shallow slides do not extend in the embankment in a direction normal to the slope more than 1-2 cm

4) foundation Slides

when the earth dam has foundation of fine silt or soft soil it can slide wholely. Sometimes the soft and week clay exists under the foundation and the dam can slide over it causing failure. One of the most difficult problems faced by the earth dam designer is the Analysis of stability of loose sand foundations against the possibility of liquifaction.

5) failure due to Earth Quake

Most of the failure due to Earthquake have occured only with respect to those Dams which may be constructed before 1920. Some of the serious damages and failure may be due to the following effect of earth quake

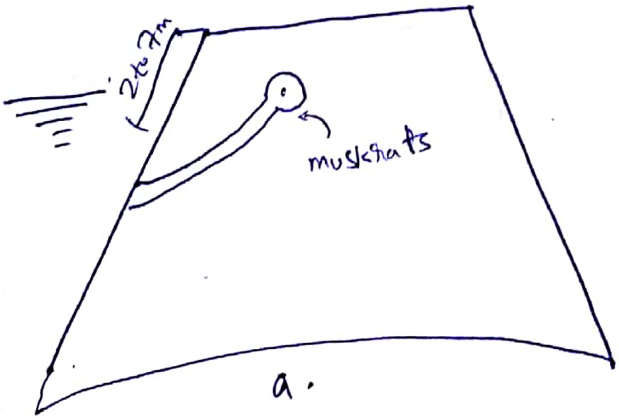
→ Cracks in the ~~pose~~ core of Dam leading to leakage and ~~pipe~~ Piping failure.

-> liquifaction of sand below foundation

-> Shaking of reservoir bottom causing slow waves and Hence the failure due to overtopping

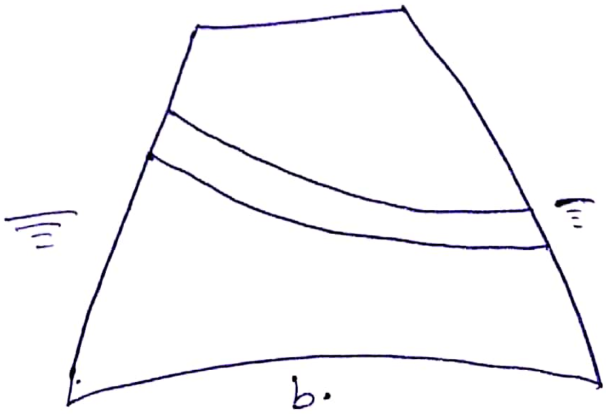
6) failure due to damage caused by burrowing animals :-

Burrowing animals may cause ~~animal~~ Piping failure of small Dams only. animals like musk Rats burrow into embankment either to make homes or to dig passage from one pond to another. if many musk Rats are involved their holes may dangerously make a honey comb weakening the earth dam. Ground squirrels normally dig in dry soil and stop at the point where seepage is encountered However if the water level in the dam is very low for a number of years. The squirrels may completely dig dam.



a.

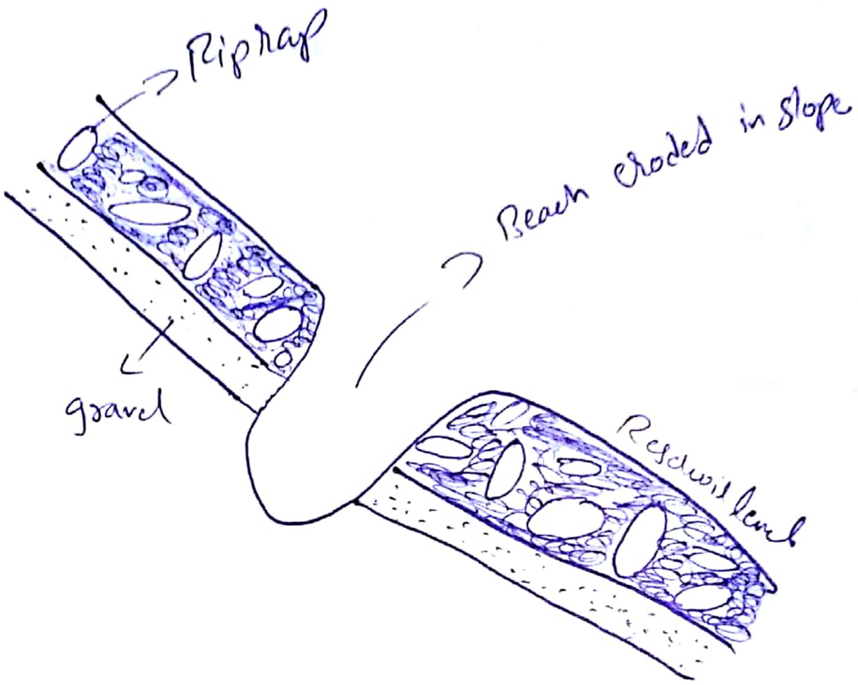
Holes made by muskrats



b.

Holes made by ground squirrels

7) Slope protection failure :-



Slopes are generally provided by riprap which is a layer of gravel or filter blanket. during a heavy storm the waves on the surface of the reservoir beat repeatedly against the slope which is above the reservoir level. Due to this constant wave pressure voids are formed in the riprap and this may wash away the filter layer exposing the riprap layer and embankment.

20/09/2018

Criteria for Safe Design of earth dam:

an earth dam may be safe and stable during phases of construction and operation of the reservoir. the safe criteria for design of earth dams will be stated briefly

(i) The embankment must be safe against over topping during occurence of inflow design flood by providing sufficient spillway

(ii) The dam must have sufficient ~~freeboat~~ freeboard so that it is not overtopped ~~by~~ by wave action

(iii) The seepage line should be well within the downstream face so that no sloughing of slopes takes place.

(iv) Seepage flow through the embankment and foundation must be controlled by suitable design provisions so that no internal erosion takes place.

(v) there should be no opportunity for free passage of water from upstream to downstream side through the dam or through the foundation.

(vi) The portion of the downstream of the impervious core should be properly drained

(vii) The upstream and downstream slopes should be so designed that they are safe during and immediately after the construction.

(viii) The downstream slope should be so designed that it is safe during steady seepage under full reservoir condition.

(ix) The upstream slope should be stable during a sudden drawdown condition.

(x) The dam as a whole should be earth quake resistant.

(xi) The upstream slope must be protected against erosion by wave action and crest and the downstream slope should also be protected against erosion due to wind and rain.

Design of Earth Dams to Suit Available materials :-

The Section of a zoned earth Dam should be selected in such a way that the available materials are utilized to the maximum and very limited amount of other materials are imported to the sight. The available materials may be classified as

(i) Gravel or coarse sand available along with clayey silt.

(ii) Only fine gravel or coarse sand is available.

(iii) only silt clay is available.

The general foundation conditions may be

(i) foundations impervious to large depth

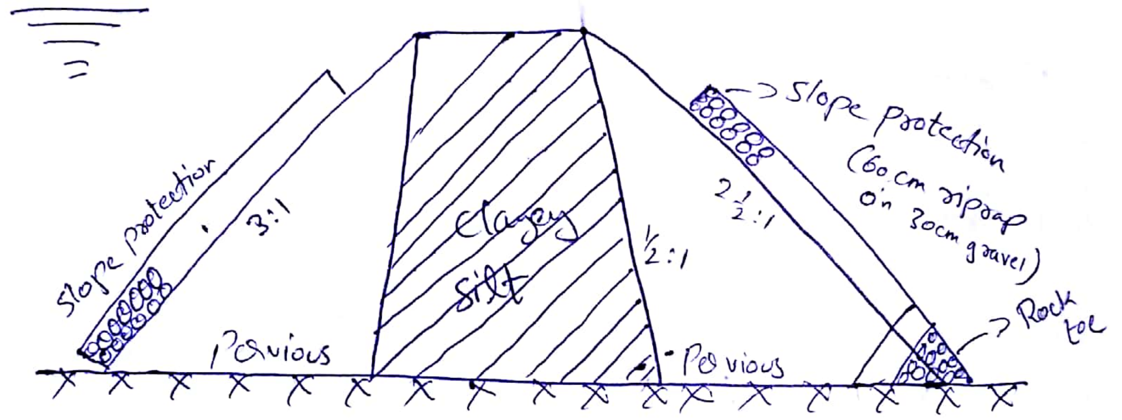
(ii) foundations pervious to moderate depth after which impervious strata is available.

(iii) foundations pervious to large depth.

25/9/2018

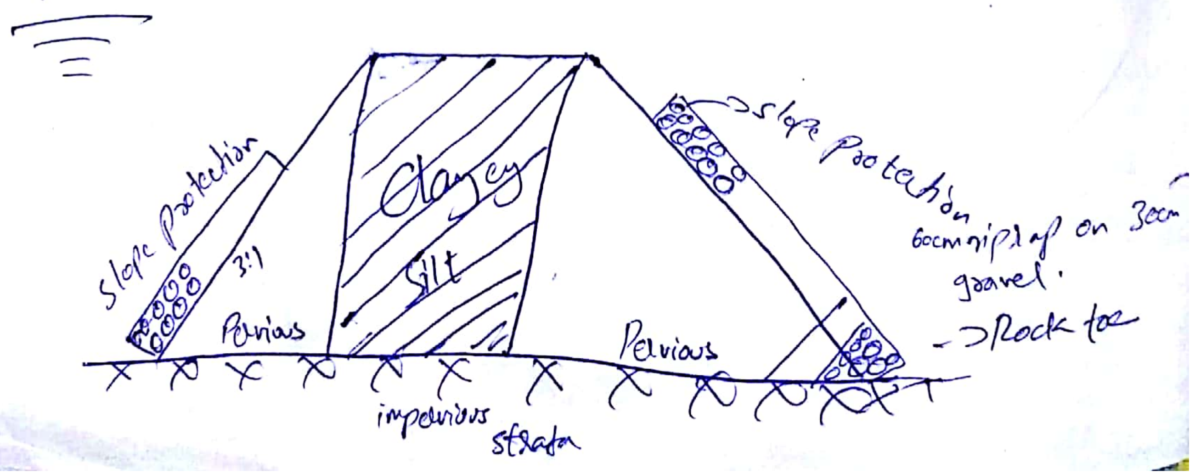
Case(1) a) Gravel or coarse sand available along with clayey silt.

b) foundations impervious to large depth



Impervious Strata

The impervious or hard strata is exposed to the surface and the foundations are impervious to large depth. The outer shells are made of pervious material available at nearby site. The central core of the clayey silt may have its ~~access~~ axis either vertical or inclined.

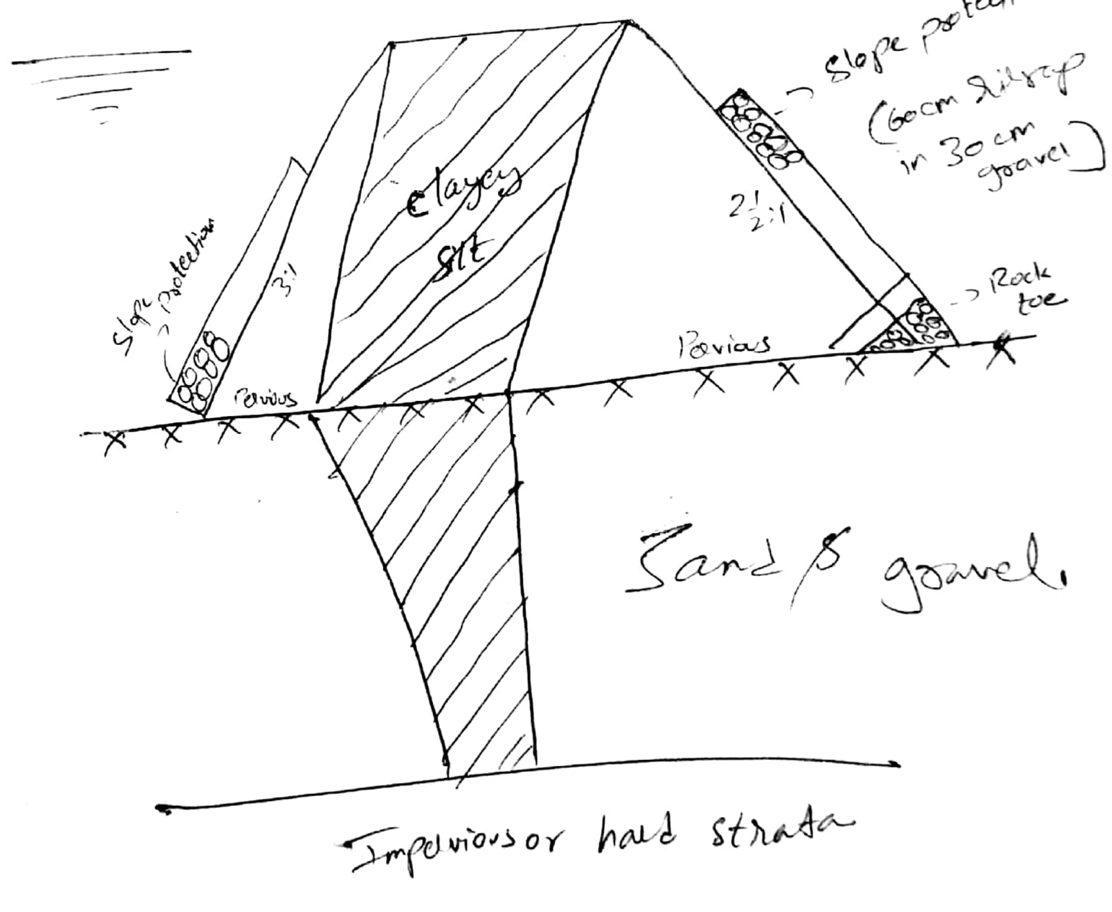


Case (2):

a) Gravel or coarse sand available along with clayey silt.

(b) foundation s pervious to moderate depth after which impervious strata is available.

The construction is similar to previous ~~one~~ case except the central core is taken upto impervious foundation level

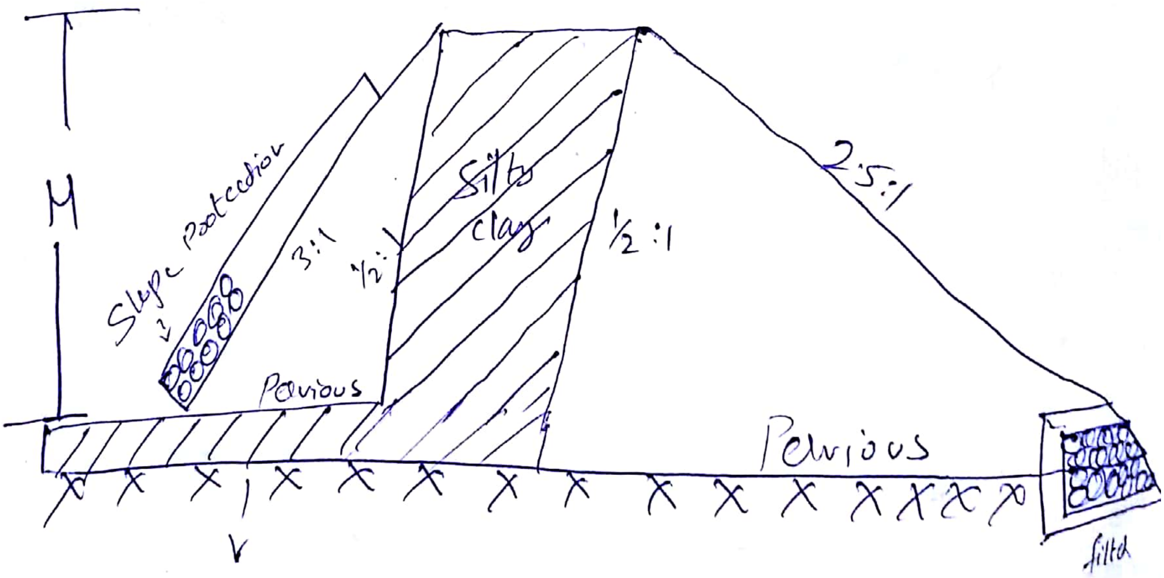


Case ③

a) Gravel or coarse sand available along with clayey silt

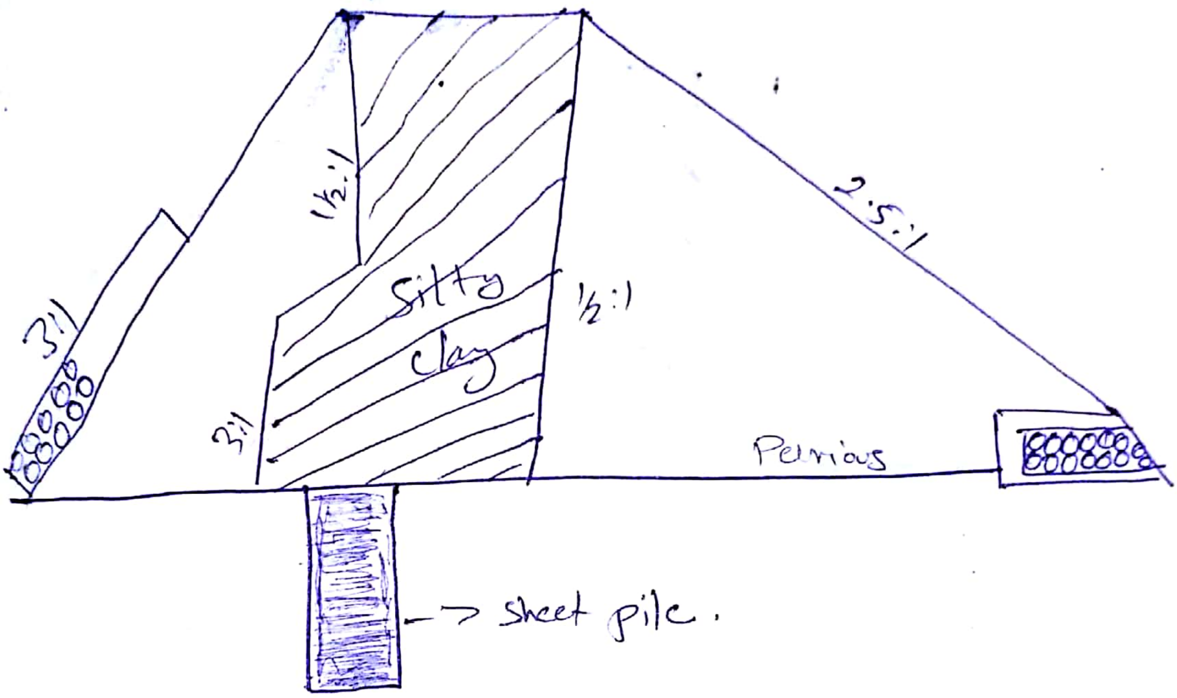
b) foundation pervious to large depth.

In this case there is a possibility of large seepage through foundations. if sufficient impervious material is available & upstream clay blanket is suggested. a sheet pile may also be provided to some reasonable depth.



upstream impervious

blanket of 1 to 3m thick.



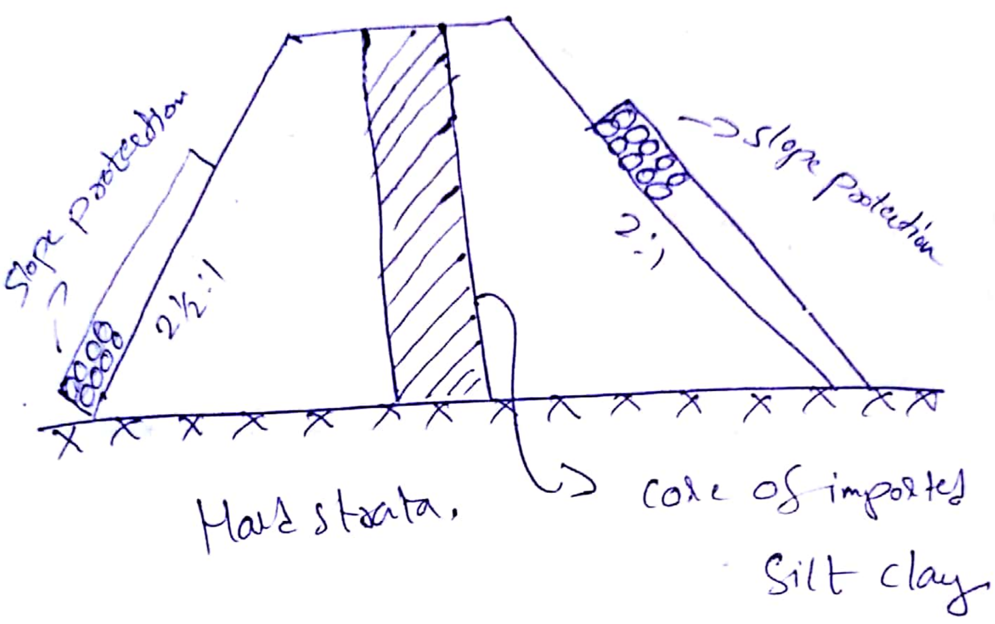
Case (4)

(a) only fine gravel or coarse sand is available

(b) foundations impervious to large depth.

Since the impervious material is to be imported therefore the central core is provided upto large depth as this central core ~~provided~~ provides resistance to a great extent.

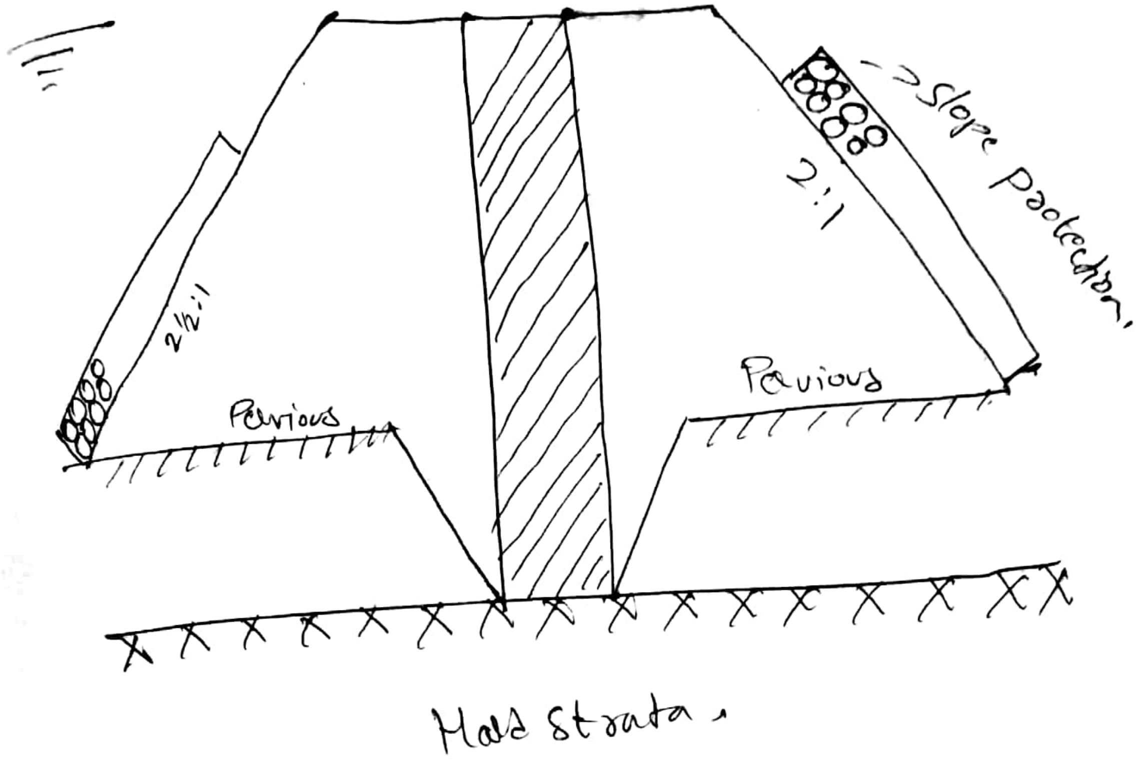
Scanned by CamScanner



(Case 5) (a) only fine gravel or coarse sand is available

(b) foundation pervious to moderate depth after which impervious strata is available.

a thin central core is taken upto impervious strata as the foundation is of moderate depth. This central core provides big resistance against seepage



remaining cases in photos.

26/9/2018

Flownets ~~Computation of Seepage through flownet~~

when the seepage is in Two dimensional, which means if soil mass is moving in Two directions i.e Horizontally & vertically this flow of Two dimensional was represented by laplace as

$$\frac{\partial^2 H}{\partial x^2} + \frac{\partial^2 H}{\partial y^2} = 0$$ where H is head

this above equation was given for isotropic soil.

for anisotropic soil the eqn is

$$k_x \frac{\partial^2 H}{\partial x^2} + k_y \frac{\partial^2 H}{\partial y^2} = 0$$

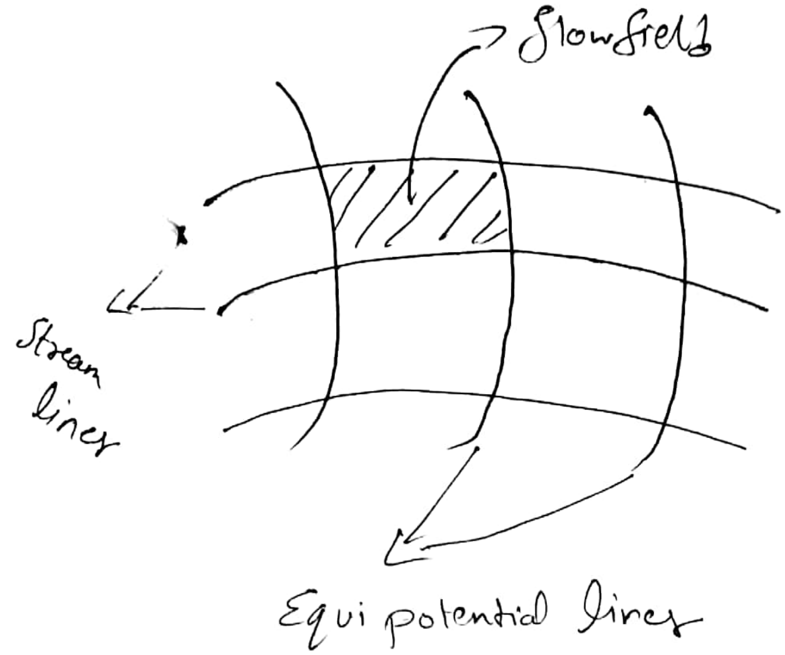
where k_x is permeability of soil in x-direction

k_y is permeability of soil in y-direction

The graphical solution for the equation given by laplace is called as flownet.

The flownet is made up of equi potential lines & stream lines flownet

ich means
r i.e
of Two
are as
t is head
tropic soil.
kx is permeability
il in x-direction
permeability
l in y-direction
given by
lines &



Equi-potential line is the line which joins points of Equi potential. it is denoted by "φ".

Stream line is the line along which the flow occurs & it is denoted by "ψ".

Equipotential lines & stream lines always cut each other at 90°.

The flow always occurs from higher potential to lower potential.

Flow line:-
The line along which flow occurs is called as flowline

The region formed between two stream lines and Equipotential lines is called as flow field.

for isotropic soil the flow field's are always Square. for anisotropic soil flow field's are rectangular.

Equi potential drop:

The difference in equi potential lines is called as Equi potential drop & it is denoted by N_d. It is calculated as

N_d = no. of equi potential lines − 1.

flow channels :-

It is the difference of ~~flow cha~~ no. of flow lines − one, It is denoted by N_f.

Computation of seepage through flownet

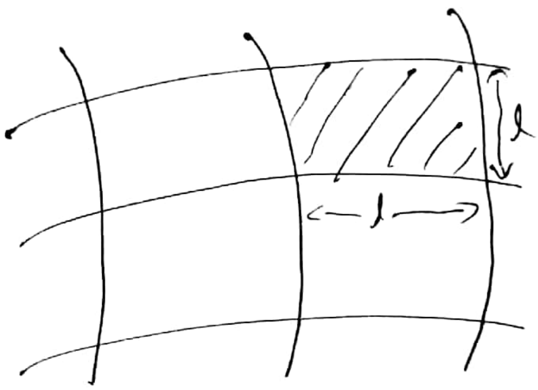
If we have taken a flownet, let the number of flow channels be N_f and the equipotential drop be N_d. The amount of

discharge flowing through one flow channel is "Δq". and assuming unit width of structure.
we know that the total discharge is given by

Δq = Area × velocity
= $k i \times A$

$$Q = N_f \times \Delta q$$

we are assuming it is square field with isotropic soil.



$i = \frac{\Delta h}{l}$ &

Area = $(l \times 1)$

as we have assumed it as a square field, let us take the sides of the square as "l", "k" is permeability of soil.
"i" is Hydraulic (or) Exit gradient.
"A" is the Area of field.

$$= k \times \frac{\Delta h}{l} \times (l \times 1) \times N_f$$

$$Q = k \times \Delta h \times N_f$$

$\Delta h = \frac{H}{N_d}$

$$Q = k \times \frac{H}{N_d} \times N_f$$

H = Total Head
N_d = Equipotential drop

$$Q = K \times H \times \frac{N_f}{N_d}$$

Suppose we have a flownet of Two types of soils i.e soil 1 & soil 2 which is above and below the inclined line having different permeabilities.

Suppose a flow of water is coming and the discharge will be same for both the soils

i.e $Q_1 = Q_2$

$$k_1 i A_1 = k_2 i A_2$$

let the inclined line make the angle of ~~θ_1 & θ_2~~ θ_1 & θ_2, and the length be "l" between two equipotential lines. and k_1 & k_2 be different permeability coefficients for different soils.

types of

h is above

ing different

oming and

oth the soils

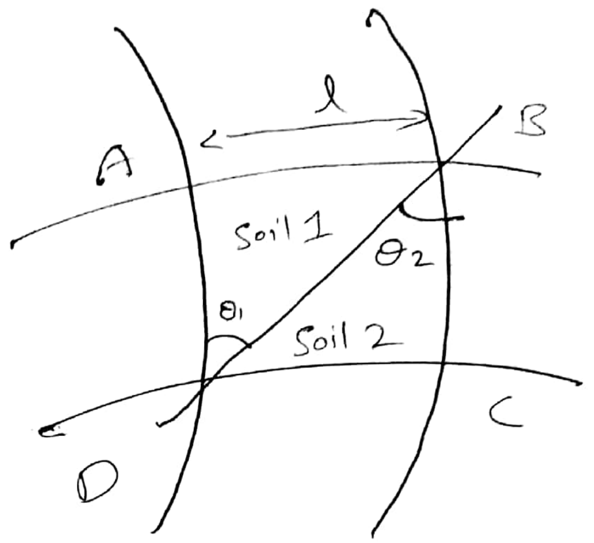
angle of

ngth be "l"

and k_1 &

coefficients

$$k_1 \times \frac{\Delta h}{AB} \times \underbrace{(AD \times 1)}_{\text{Area 1}} = k_2 \times \frac{\Delta h}{DC} \times \underbrace{(BC \times 1)}_{\text{Area 2}}$$



$$k_1 \times \frac{AD}{AB} = k_2 \times \frac{BC}{DC}$$

$$\frac{1}{\tan\theta} = \cot\theta$$

$$k_1 \times \cot\theta_1 = k_2 \cot\theta_2$$

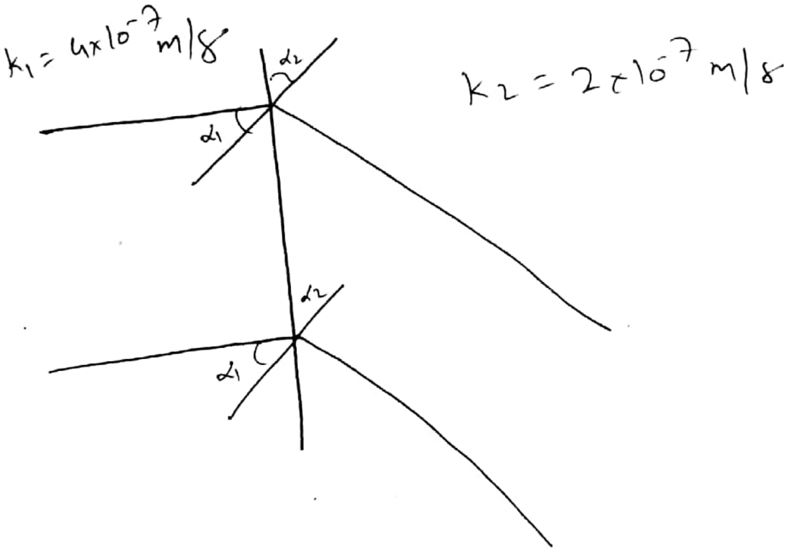
$$k_1 \times \frac{1}{\tan\theta_1} = k_2 \times \frac{1}{\tan\theta_2}$$

$$\boxed{\frac{k_1}{k_2} = \frac{\tan\theta_1}{\tan\theta_2}}$$

//

27/9/2018

(Q) The figure shows Two flow lines for seepage across a interface between Two soil medium of different coefficient of permeability. The entrance angle $\alpha_1 = 30°$, then what is the exit angle α_2.



Sol

$k_1 = 4\times10^{-7}$ m/s

$k_2 = 2\times10^{-7}$ m/s

$\alpha_1 = 30°$

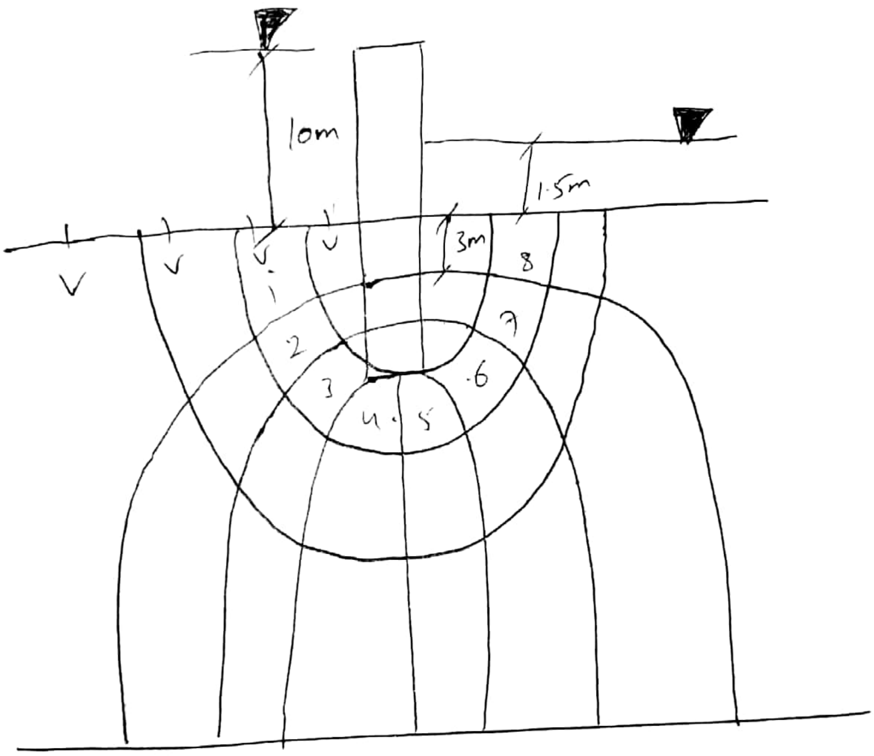
$\alpha_2 = ?$

$$\frac{k_1}{k_2} = \frac{\tan\theta_1}{\tan\theta_2}$$

$$\frac{4\times10^{-7}}{2\times10^{-7}} = \frac{\tan(30)}{\tan\theta_2} \Rightarrow \theta_2 = 16.10$$

Scanned by CamScanner

(Q) The flow net around a sheet pile wall as shown, the properties of soil are permeability coefficient is 0.09 m/sec, sp gravity = 2.7, void ratio = 0.85, the sheet pile wall and the bottom of the soil are impermeable. what is the seepage loss of water.



(Sol)

$k = 0.09$

$H = 10 - 1.5 = 8.5 \text{ m}$

$N_f = 4 - 1 = 3$

$N_d = 8 - 1 = 7$

$Q = k \times H \times \frac{N_f}{N_d}$

$Q = 0.09 \times 8.5 \times \frac{3}{7}$

$Q = 0.327 \text{ m}^3/\text{s}$

Scanned by CamScanner

for the previous question what is the factor of Safety against Piping failure?

(Sol)

$$F.O.S = \frac{i_{\text{critical gradient}}}{i_{\text{hydraulic gradient}}}$$

$$i_{critical} = \frac{G-1}{1+e}$$, G = specific gravity, e = Void ratio.

$$i_{hydraulic} = \frac{\Delta h}{L}$$

$$\Delta h = \frac{H}{Nd} = \frac{8.5}{7} = 1.214$$

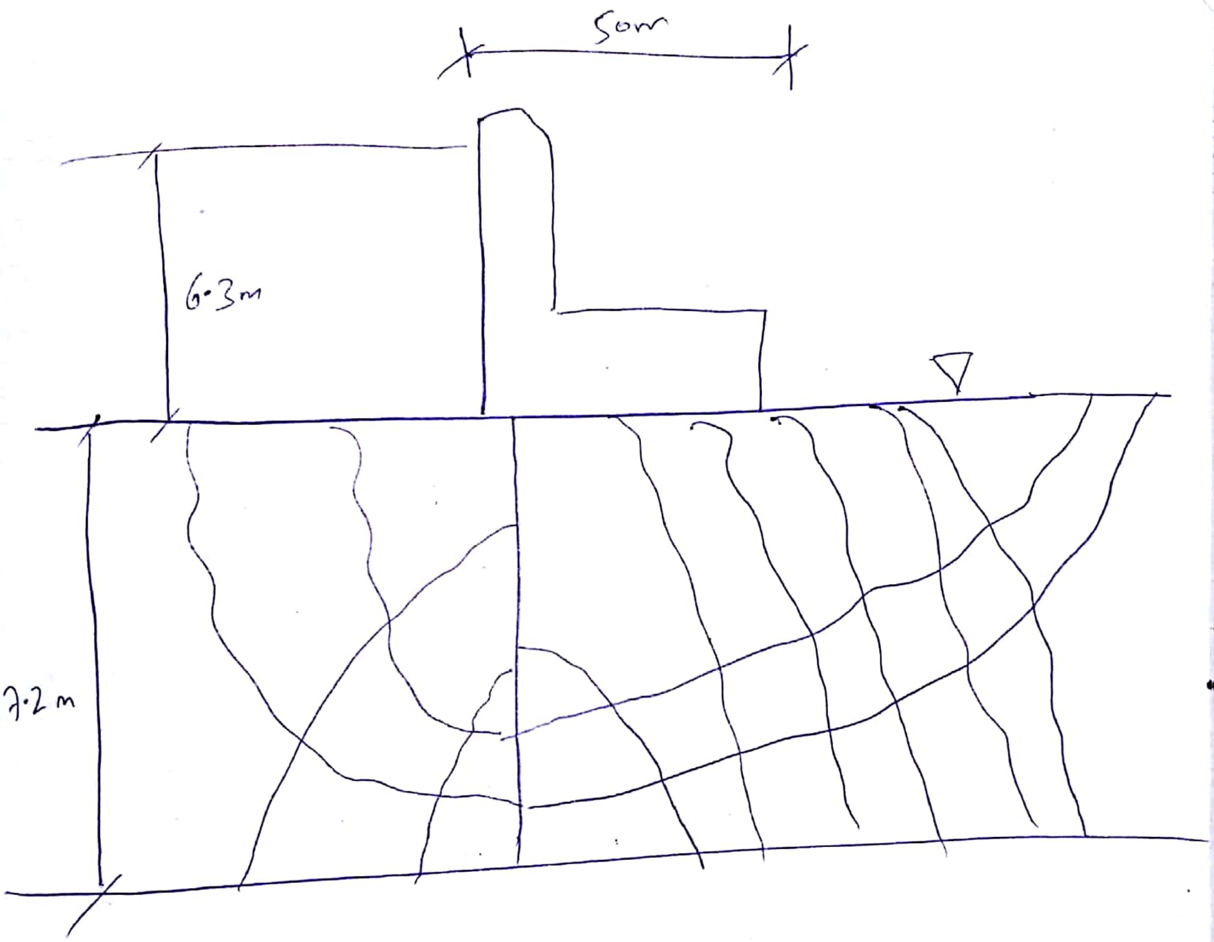
$L = 3m$

$$i_{critical} = \frac{2.7-1}{1+0.85} = 0.918.$$

$$i_{hydraulic} = \frac{1.214}{3} = 0.404$$

$$F.O.S = \frac{0.918}{0.404} = 2.272$$

Q) The flownet constructed for the dam & coefficient of permeability as 3.8×10^{-6} m/s. ~~is~~ the quantity of flow under the dam.



Sol)

$$Q = k \times H \times \frac{N_f}{N_d}$$

$k = 3.8 \times 10^{-6}$

$H = 6.3$

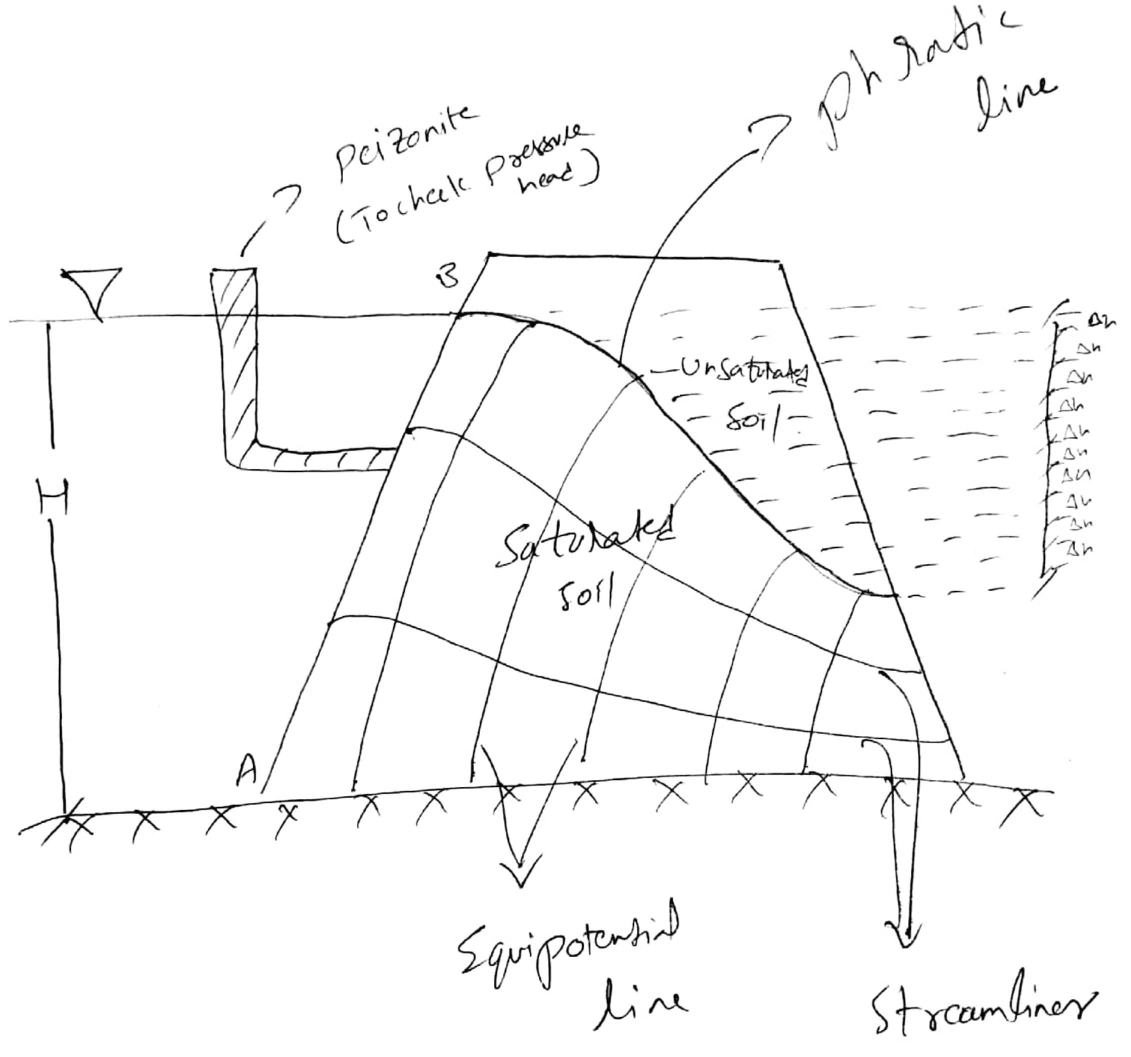
$N_f = 3 - 1 = 2$

$N_d = 10 - 1 = 9$

$$Q = 3.8 \times 10^{-6} \times 6.3 \times \frac{2}{9}$$

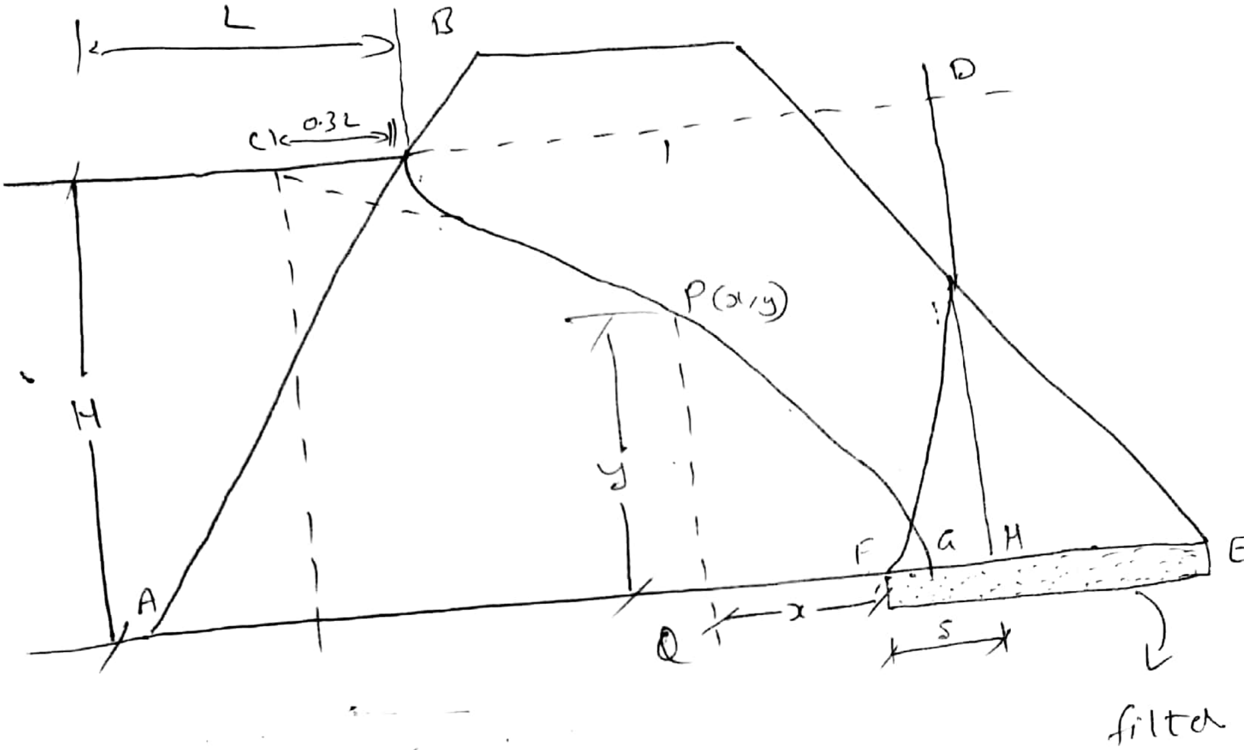
$Q = 5.32 \times 10^{-6}$ m³/s

Phreatic line in Earth Dam.



Phreatic line is that top most line below which seepage takes place. The phreatic lines separates Saturated soil mass from unsaturated soil mass.

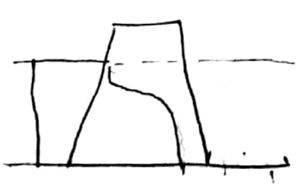
The Hydrostatic pressure acts below the ~~Phrea~~ phreatic line & atmospheric pressure acts above the phreatic line.



In order to find the equation of the base parabola, consider any point "P" on it with co-ordinates "x & y" with respect to focus "f" as origin, from property of parabola we have $PF = QH$

$$\sqrt{x^2+y^2} = x+s \quad \text{— (1)}$$

where S = focal distance.



$$x^2+y^2 = (x+s)^2$$

$$\cancel{x^2}+y^2 = \cancel{x^2}+s^2+2xs$$

$$x = \frac{y^2 - s^2}{2s}$$

~~$y^2 = 2s$~~

$$y^2 = 2sx + s^2$$

In order to get an expression for discharge "Q" through the body of the dam. we observe through the vertical section "PQ" i.e "y".

$$Q = kiA$$

$$i = \frac{\partial y}{\partial x} \text{ \& Area} = y \times 1.$$

$$Q = k \frac{\partial y}{\partial x} (y \times 1)$$

$$Q = k \cdot \frac{\partial (y^2)}{\partial x}$$

$$= k \cdot \frac{\partial (2sx + s^2)}{\partial x}$$

$$Q = k \cdot 2s$$

but from (1) $S = \sqrt{x^2 + y^2} - x$

at C, $x = D$ & $y = H$

$$S = \sqrt{D^2 + H^2} - D$$

$$Q = 2k\sqrt{D^2 + H^2} - D$$

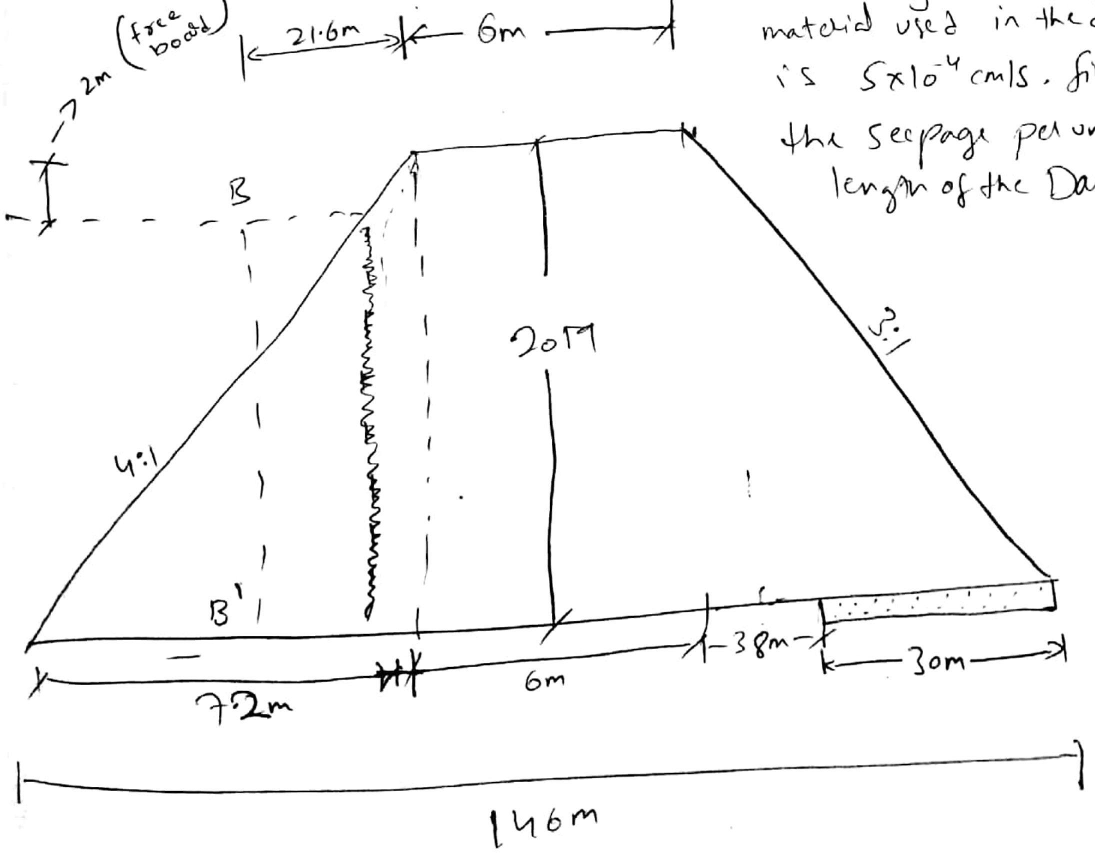
(or)

$$Q = 2k\sqrt{x^2 + y^2} - x$$

S:

Pg Not

Q) For the earth Dam of Homogeneous Section with the Horizontal filter. Draw the Top flow line. If the coefficient of Permeability of the soil material used in the dam is 5×10^{-4} cm/s. find the seepage per unit length of the Dam?



(Sol) Taking the Focus "F" as origin the equation of parabola is given by $\sqrt{x^2+y^2} = x+S$, where S is the focal distance & x, y are co-ordinates of any point on the parabola.

The Parabola cuts the reservoir water surface at Point "B'" Such that FB'

$x = 65.6\,m$

Solve this problem, refer textbook.

Next topic :- Seepage control measures

refer text book Pg No:- 489

01/10/2018

Spillways – Unit IV

a spillway is a structure constructed at dam site for effectively disposing of the dam's surplus water from upstream side to downstream side.

a Spillway must have the capacity to discharge major floods without damaging the dam.

Based on utility spillways are of two types.

(i) main Spillway

(ii) Subsidiary or emergency Spillway.

The main Spillway is the one which is used to work under the designed floods. The Subsidiary Spillway is provided for additional safety and is used in emergencies. when flood greater ~~than~~ than designed flood occurs.

The main types of Spillways are

(i) Straight drop Spillway

(ii) overflow or ogee spillway

(iii) side channel spillway

(iv) Shoot or open channel spillway

(v) conduit or Tunnel spillway

(vi) Siphon's spillway.

(vii) Shaft spillway. (or) morning glory Spillway.

Straight drop spillway

This is the simpliest type of spillway which is constructed in the form of low height weir. having downstream face vertical. Sometimes the crest is extended in the form of overhanging lip to direct the small discharge away from the face of the overfall Section.

Overflow or ogee Spillway:-

this is the most common type of spillway provided on gravity dam. ~~The~~ The profile of the Spillway is "S" Shape. The overflowing water is guided smoothly over the crest and profile of the spillway so that the overflow water doesnot break contact with the spillway surface.

the main difference between straight drop spillway and overflow spillway is that the pressure of water falls away from the face of the spillway. whereas in overflow spillway the falling water is made to glide over the curved profile of the spillways.

Side channel Spillway :-

The Side channel spillway is the one in which the flow after passing over a wier or crest is carried away by channel running parallel to the crest. This type of Spillway is Suitable for earth or rock fill dams where direct overflow is not permissable

Shoot or open channel Spillway

This Spillway is the one which passes the Surplus discharge through a Steep slope open channel called a Shoot or trough placed either along a dam abutment or throw a Saddle. This type of Spillway is provided for earth or rockfill dam. and is isolated from main dam,

Conduit or Tunnel spillway

It is the one in which a close channel is used to discharge the flow of water around or under a dam. The close channel may be in the form of vertical or inclined shaft. and a horizontal tunnel is placed through earth dam which is back filled with earth materials.

Shaft spillway

It is the one which has horizontally positioned ~~lid~~ lip through which water enters and drops through vertical or sloping shaft and then ~~throw a~~ through a horizontal tunnel which conveys the water out of the Dam. This type of spillway is used when there is inadequate space for other type of spillways

~~Spp~~ Siphon Spillways

a siphon spillway is the one which utilizes the siphonic action to discharge the surplus water, a siphon spillway consists of closed tunnel system formed in the shape of inverted "U".

Dischalge equation for ogee Spillway

$$Q = Cd \times Le \times He^{3/2}$$

Cd = coefficient of dischalge (2·1 to 2·8)

He = total head of crest $\Rightarrow He = h + \frac{v^2}{2g}$

h = pressure head

v = velocity head

Le = effective length of crest.

$$Le = L - 2(N \cdot Kp + Ka) He$$

L = Net length

N = no of peirs

Kp = peir contraction coefficient.

Ka = abutment contraction coefficient.

Dynamic Force on ogee Spillway

$$D.F = \Sigma F = \rho Q \Delta V$$

Q = Dischalge

$\rho = w/g$ = mass density of water

$\Delta v =$ change in value.

3/10/2018

Energy Dissipation Below Spillways

When flood discharge passes over the spillway crest, it has high potential energy which gets converted into kinetic energy as it glides along it. This high energy has to be dissipated orelse it will cause erosion at the downstream toe.

This can be done by two ways

(i) by dissipating the energy by means of Hydraulic Jump

(ii) by directing the pressure of water so as to fall away from the structure by a deflector bucket or lip and dissipating the energy by impact.

When the energy of flow is to be dissipated before the discharge is directed to main river channel, the hydraulic jump basin is very effective. whereas the discharge may be safely delivered directly to the river channel, without providing dissipator device. Then the pressure of water is often projected beyond the structure by deflector bucket..

Hydraulic Jump ~~cor~~ computations :-

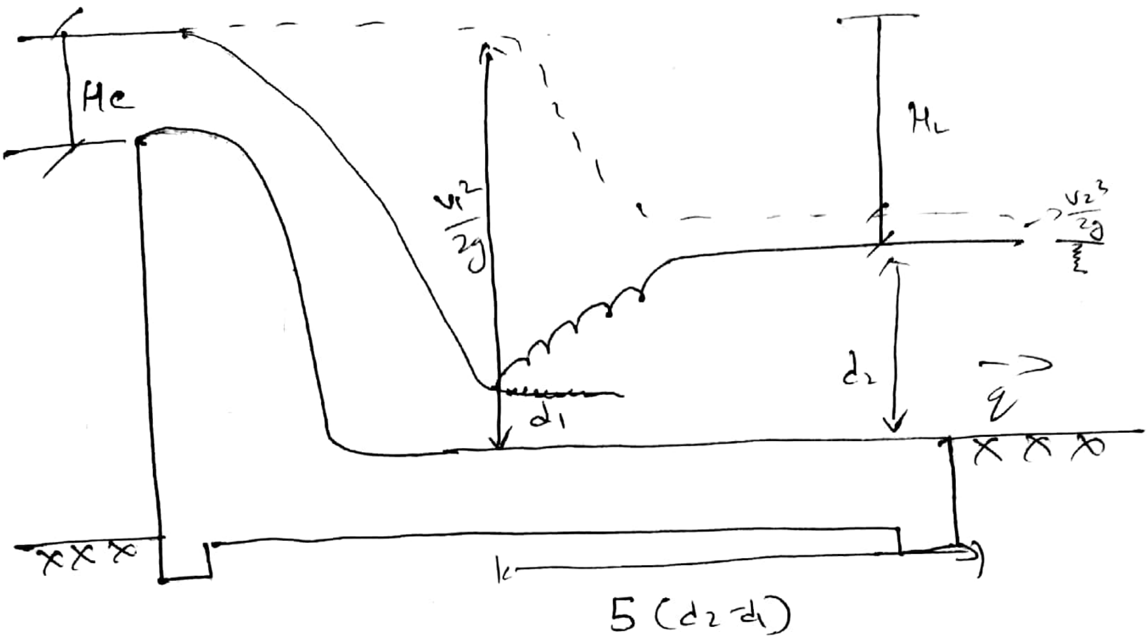
The Hydraulic Jump that occurs at stilling basin has some characteristics. & Assumes a definite form depending upon the energy of flow. to be dissipated. in relation to depth of flow. The Jump form and flow depends upon following characteristics.

(i) discharge entering the basin.

(ii) critical depth of flow (d_c)

(iii) froude number parameter. i.e $f = \frac{v}{\sqrt{gd}}$.

The post jump d_2 can be computed for a given discharge as follows.



(i) for a given discharge "q" per meter length of the Spillway, calculate the Head He over the crest To total energy level.

$$He = \left(\frac{q}{Cd}\right)^{2/3}$$

Cd is coefficient of discharge

q is discharge

(ii) find Total energy at upstream level

total energy at upstream level = crest level + He

(iii) assuming no losses the specific gravity "E_1" at toe of the spillway will be equal to total energy level at up stream side.

$$E_1 = \text{T.E.L @ upstream side}$$

(iv) knowing E_1 & q_1 find the pre jump depth d_1 by trial & error method from relation

$$E_1 = d_1 + \frac{v_1^2}{2g} \quad (\text{or}) \quad d_1 + \frac{q^2}{2g d_1^2}$$

(v) Calculate Froude no

$$F_1 = \frac{v_1}{\sqrt{g d_1}} \quad (\text{or}) \quad \frac{q}{\sqrt{g d_1^3}}$$

(vi) Calculate the post jump depth d_2.

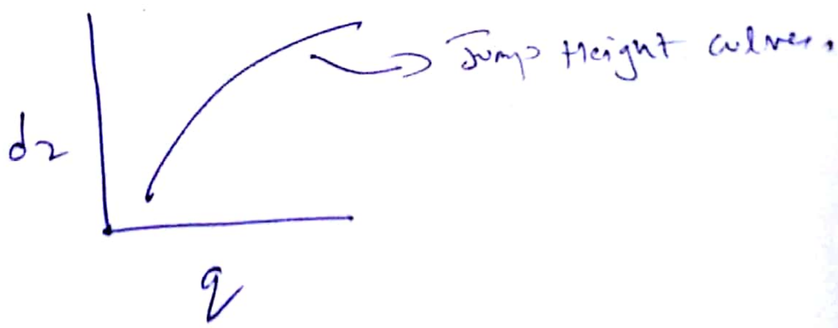
$$d_2 = \frac{d_1}{2}\left[\sqrt{1+8F_1^2} - 1\right] \quad (or)$$

$$\frac{d_1}{2}\left[\sqrt{1 + \frac{8q^2}{gd_1^3}} - 1\right]$$

(vii) length of Stilling basin

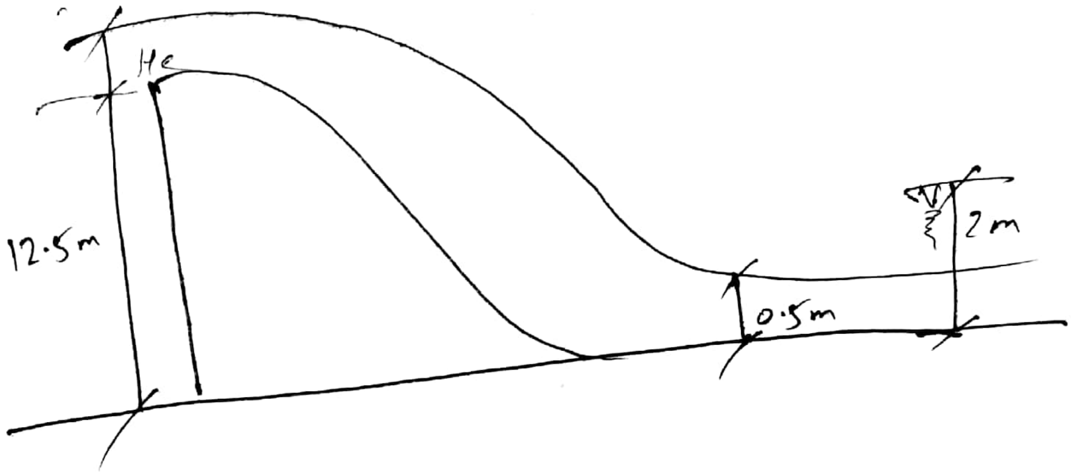
$$= 5(d_2 - d_1)$$

for a given dischalge and post jump depth a curve can be plotted known as jump height curve.



Problem

(a) an overflow spillway shown in figure passes a discharge of 7.83 m^3/sec. per meter width. with a fall of 12.5 mts and the depth of water available on the downstream side is 2mts. Calculate the dimensions of hydraulic jump stilling basin.



(S1) Depth of flow at front of spillway i.e pre jump depth "d_1"

$$d_1 = 0.5m$$

(1) He - Total Head of crest

(2) T.E.L = crest level + He = 12.5m

(3) E_1 = T.E.L @ u/s = 12.5m

(4) $E_1 = d_1 + \frac{v_1^2}{2g}$

$12.5 = d_1 + \frac{v_1^2}{2 \times 9.81}$

$12.5 = 0.5 + \frac{v_1^2}{2 \times 9.81}$

$v_1^2 = 15.34$ m/sec

(5) Froude no.

$F_1 = \frac{v_1}{\sqrt{g d_1}}$

$F_1 = \frac{15.34}{\sqrt{9.81 \times 0.5}}$

$F = 6.92$

(6) $d_2 = \frac{d_1}{2}\left(\sqrt{1 + 8F_1^2} - 1\right)$

$d_2 = \frac{0.5}{2}\left(\sqrt{1 + 8 \times 6.92^2} - 1\right)$

$d_2 = 4.649$ m

(7) Stilling basin = $5(d_2 - d_1)$

$= 5(4.649 - 0.5)$

$= 20.745$ m

Spillway crest gates

Spillway's are of Two types

(i) controlled &

(ii) uncontrolled

Controlled spillway is the one in which the flow of water is controlled by using gates. over its crest by using these gates additional storage of water can be made.

gates over spillways should be used with caution since faulty operation may lead to failure of the dam. Some of the common type of gates used in spillways are

1. Flash boards, Stop logs & Needle
2. Radial gates
3. Drum
4. vertical lift gates.
5. Bear Trap gates
6. Rolling gates.

4/10/2018

flash boards :-

these are temporary gates used only for small spillway of minor importance they consists of wooden panels supported by pins on their edges.

Stop logs

They consists of horizontal timber planks spanning across piers having grooves.

Needles

Needles consists of wooden planks kept in inclined position with lower end resting in a key way on the spillway crest and upper ends at the Top of a bridge girder.

Radial gates :-

A Radial gate is also known as tainter gate. which has its water supporting face made of steel plates in the shape of a sector of circle. The gate can be lifted by means of ropes and chains acting simultaneously at both ends. or with the help of power driven Vinches.

Drum gates :-

These are normally used for long span, the gate consists of a circular sector in cross-section formed by skin plates attached to internal bearings. it is hinged at the center of curvature in such a way that the entire sector may be raised above the crest or may be lowered so that the upper surface becomes co-incident with the crest line.

Vertical lift gates :-

A vertical gate consists of a framework of skin plate at upstream face along with the beams and girder suitably placed. vertical gates are rectangular in shape and they move vertically in their own plane. There are several types of vertical lift gates such as

(i) Sliding gates
(ii) fixed wheel gates

(iii) Stoney gates

Bear Trap gates

a Bear Trap gate consists of two leaves of either timber or steel hinged to the dam. These gates are lifted up by releasing the water to the space under the leaves. These are gates are often used for low navigation dams

Rolling gates

a Rolling gates essentially consists of steel cylinder as large in diameter as the height of opening and spanning between piers, a heavy angular ring having gear teeth at its periphery encircles each end of the cylinder. This gate is rolled up the inclined rack by means of pull from the hoisting cable operated from the hoist room

Stilling Basin Appartanences (descriptive details only)

Pg No: 550

Tank irrigation

Tank irrigation may be defined as storage irrigation scheme which utilizes the water stored on the upstream side of a smaller earth dam called as bund.

These earthen bund are infact called as Tanks ~~tres~~ specifically in south india. where ~~these~~ such works are very common ~~(struck)~~ The technical difference between a reservoir and the tank is that a large size tank will be termed as reservoir which is generally formed by tanks of ~~generally~~ any material, whereas the tank is generally set to be formed by earth dams only.

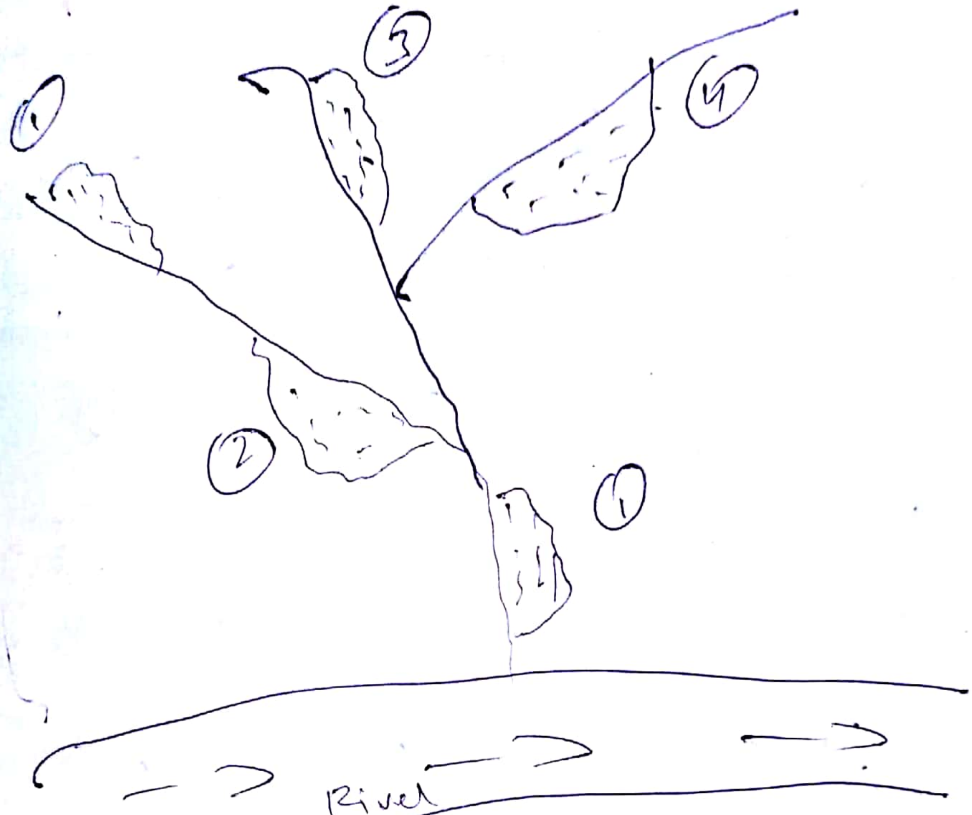
The existing tanks of South india posses a maximum depth of 4.5 mts while a few are as deep as 5-9 mts, only a few exceptionals one exceed 11 mts in depth. when the depth of ~~resev~~ tank ~~is~~ exceeds 12 mts. The Tank is refered as reservoir.

Types of Tanks

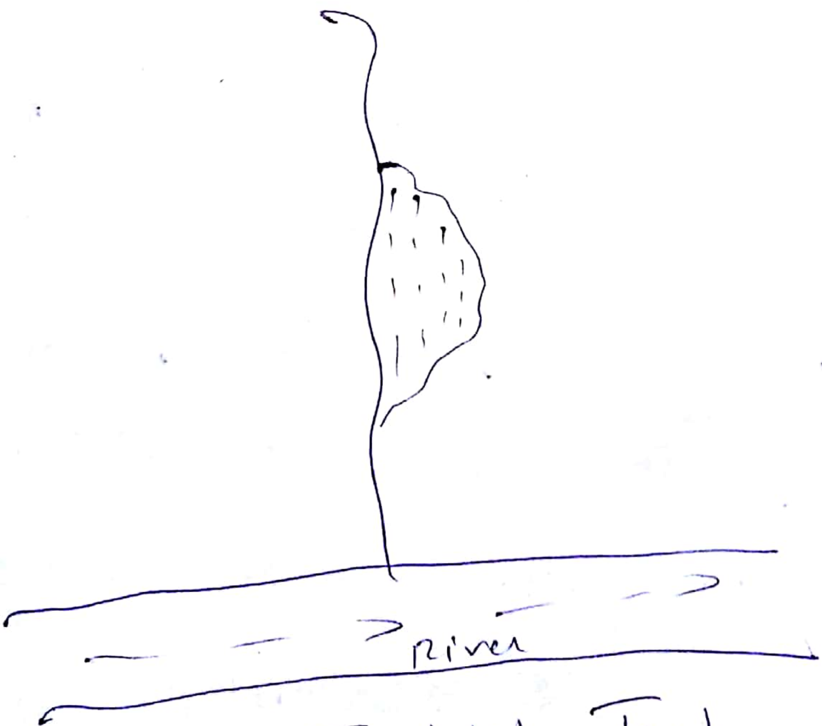
most of the existing small size tanks of South india from ~~a group~~ part of group of tanks which are connected together in series, such that any tank either receive the surplus water of upper tank or sends its own surplus water into some lower tank.

~~when~~ a Tank which neither receives water from upper tank nor discharges its own surplus water into a lower Tank is called as isolated tank.

y
nds
epth
Tank
india
which
any
pper
water
s water
n surphs
lled as



Tanks in series



Isolated Tank.

It is evident that the considerable amount of water can be obtained from the system of grouping, because the surplus water of each tank and also the drainage of its wet cultivation are caught up by next lower tank.

The disadvantage of grouping of tanks is if a breach (→leak) occurs in an upper tank; it exposes all the tanks in the series below. The extent of danger to lower ~~dam~~ tanks due to breach of an upper tank however depends upon their relative capacities.

for example if a small upper tank breaches an passes its storage into lower capacity tank it may pose little danger. However the Danger will be more if the case is opposite & the large size upper tank breaches & passes its storage into lower small size tank.

Design of Tank ~~with~~ weir.

The excess surface water is filled from the tank into downstream tank. So as to avoid the rise of water in the tank above the maximum level. The discharging capacity of the weir will be designed so as to pass the full maximum flood discharge with a depth over the weir equal to the difference between FTL (full Tank Level) & MWL (maximum water Level)

The effective storage capacity of a Tank is limited by FTL. but the area submerged by the Tank is dependent on MWL.

The usual difference between FTL & MWL is kept from 0.3 – 0.6 mts and is rarely allowed to exceed 0.9 mts formula for determining width of floor

= by Tank weir.

the width of the Horizontal floors of Type "A" & Type "D" weirs from the foot of the Drop wall to the downstream edge of ~~ft~~ the floor should ~~be~~ never be less than

$$2(D+H)$$

where "D" = Depth ~~of~~ in Height of Dropwall

i.e F.T.L − G.L

H = Max water Head over the wall.

i.e T.W.L − ~~F.W.L~~ F.T.L.

~~Type A = masonry weirs with vertical drop~~

~~Type B = Rockfill weir with a sloping ap~~

~~Type C = Masonry weirs with a sloping~~

~~Type D =~~

formula for determining length of Tank weir.

$$Q_p = C_1 A^{2/3} - C_1 a^{2/3}$$

Q_p = Peak flood discharge

A = combined Catchment Area

a = intercepted Catchment area