LEARNING RESOURCE MATERIAL

COURSE CODE- (**Th-3**)

HYDRAULICS & IRRIGATION ENGG.

DEPARTMENT
OF
CIVIL ENGINEERING

GOVERNMENT POLYTECHNIC, KORAPUT

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Irrigation Engineering

Topic:

Introduction

IRRIGATION

DT-11.01.16

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INTRODUCTION

* DEFINITION OF IRRIGATION:

→ The process of artificial application of water to the soil for the growth of agricultural crops is termed as Irrigation.

→ It is practically a science of planning and designing a water supply for the agricultural land to protect the crops from bad effect of drought or low rainfall.

→ It includes the construction of weirs, dams, barrage and canal system for the regular supply of water to the cultivable lands.

* NECESSITY OF IRRIGATION:

(a) Insufficient Rainfall: When the seasonal rainfall is minimum and insufficient for the crops then irrigation is necessary.

(b) Uneven Distribution of Rainfall: When the rainfall is not distributed evenly throughout the crop period, then irrigation is necessary.

(c) Improvement of perennial crops: some of the perennial crops required water throughout the year but the water requirement can be fulfil only rainy season. On the other days irrigation is necessary.
Ex: Sugarcane, cotton, etc.

(d) Development of agriculture in desert area: The desert area where rainfall is very low, the irrigation system is required.

* BENEFITS OF IRRIGATION:

(a) Yield of crops: In the period of low rainfall or drought, the yield of crops may be increased by the irrigation system.

(b) Protection from famine: The food production of a country can be improved by ensuring the growth of crops by availing the irrigation facilities. This helps a country to prevent famine situation.

(c) Improvement of cash crops: Irrigation helps to improve the cultivation of cash crops like vegetables, fruits, etc.

(d) Prosperity of farmers: When the supply of irrigation is assured the farmers can grow two or more crops in a year on the same land. Thus the farmers may earn more money and improve their living standard.

(e) Source of Revenue: When irrigation water is supplied to cultivators in lieu of some taxes, it helps to earn revenue which may be spent on the development schemes.

(f) Navigation: The irrigation canals may be utilised for inland navigation which is further useful for communication and transportation of agricultural goods.

(g) Hydroelectric power Generation: In some river valley projects multipurpose reservoirs are formed by constructing high dams where hydroelectric power may be generated along with the irrigation system.

(h) Water supply: The irrigation canals may be source of water supply for domestic and industrial purpose.

(i) General communication: The inspection road along the canal banks may serve as a communication link with the otherwise remote villages.

(j) Development of fishery: The reservoirs and the canals can be utilised for the development of fishery projects.

* ILL-EFFECTS OF IRRIGATION:

(a) Rising of Water table:
Due to the excessive seepage of water through the bed and banks of the canal, the water table in the surrounding area may be raised which may constantly saturate the root zone of the crops and soil may develop alkaline property which is harmful to the crops.

(b) Formation of Marshy Land:
Excessive seepage and leakage of water from the irrigation canals may lead to formation of marshy lands along the course of the canals. These marshy lands form colonies of mosquitos which may responsible for diseases

→ The Mechanical power is used where the crop area is more and when the mechanical power is not available then the Irrigation is done by

doon, mote, persian wheel, swinging basket, Pulley, windlass

→ The mechanical power by open well, shallow tube well, deep tubewell

* **Flow Irrigation:**

→ When water flows under gravitional force through the artificial canal towards the agricultural land, it is termed as flow Irrigation.

→ In this system, the head of the canal should always at the higher Level of the crop area.

This system is divided by

a) Inundation system: In this system, a canal is excavated from the bank of inudation river (i.e the river which flows in the rainy season and dried of the summer season)

b) Perennial system: In this system, a weir or barrage is constructed across the perennial river (i.e the river which flows throughout the year in full capacity)

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Distribution of Irrigation water

Distribution System
- Surface Method
  - Furrow contour Method
  - flooding Method
    - Controlled flooding
      - Free flooding
      - Basin flooding
      - Check flooding
      - Border strip
      - Zigzag
    - uncontrolled flooding
- Sub-surface Method
- Sprinkler Method

(c) Dampness in weather: The temperature of the commanded area of an irrigation project may be lowered considerably and the area may become damp. Due to dampness, the people residing around the area may suffer from cold, cough and other such diseases originating from dampness.

(d) Loss of Valuable Lands:

Valuable land may get submerged when storage reservoirs are formed by constructing barrage or dams, and it also may be lost while constructing irrigation canals.

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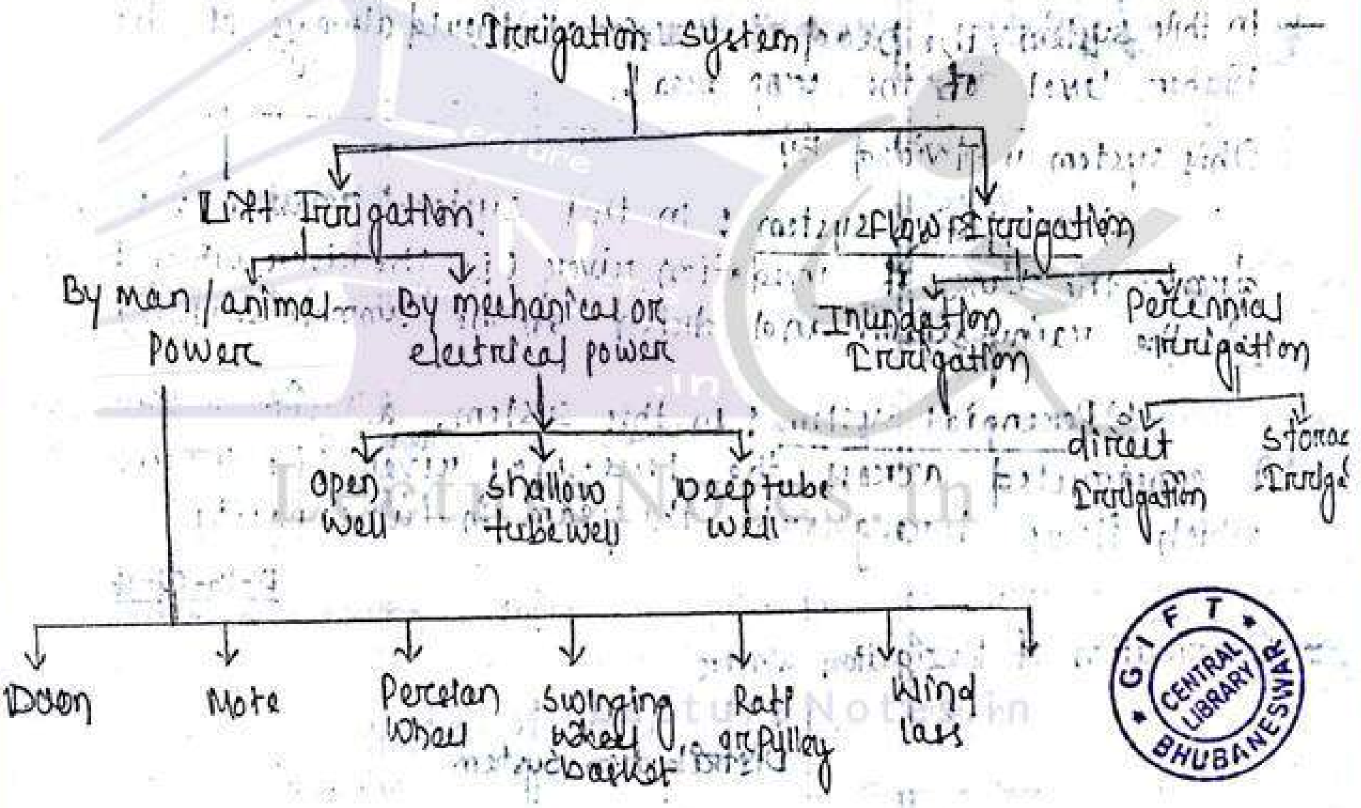
SYSTEM OF IRRIGATION



* Lift Irrigation:

→ When water is lifted from the source to the cultivable land or crop area by any mechanical device or any man power, then this system is called Lift Irrigation.

→ The Lift Irrigation system is done by

a) By animal / Man power

b) By Mechanical / electrical Power.

* Surface Method :

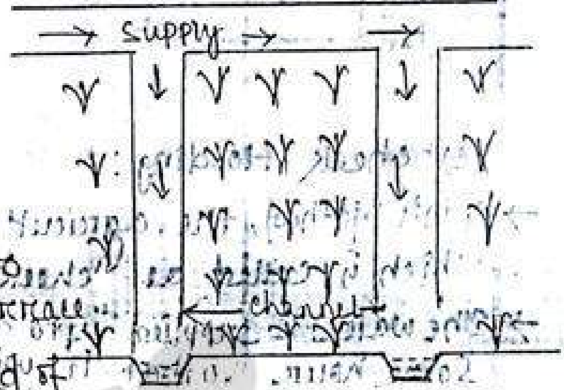
→ In this Method, water is distributed into the crop area by small channels which flood up the area upto required depth.

→ This is sub-divided into

(a) furrow Method :

i) In this Method the irrigation water is supplied by digging narrow channels at rectangular interval.

ii) Some of the crops which furrow Method is used, they are Potato, tobacco, sugarcane etc.

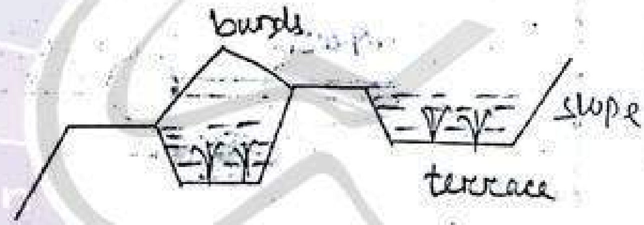


(b) Contour farming :

i) In this Method the land is divided into series of horizontal strip which is called terrace.

ii) Small bunds are provided at the end of each surface terrace to holds the water of the required depth.

→ This Method is used in hilly areas.



(c) Flooding Method :

→ In this Method, the water is flooded in the crop area which has having flat topography.

→ This is sub-divided into

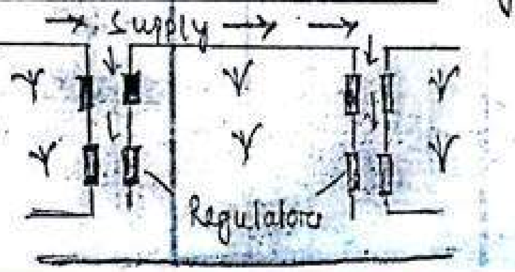
(a) uncontrolled flooding : These are applicable for inundation irrigation system, here the land is flooded by.

→ This results in wastage of water, and over irrigation

(b) Controlled flooding :

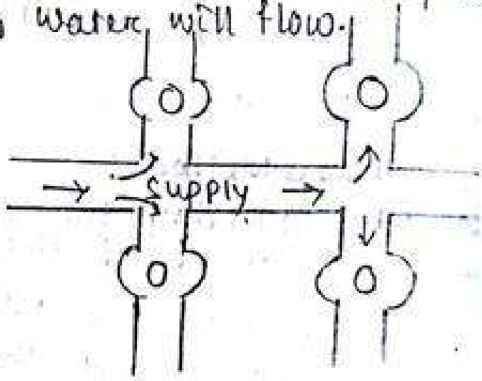
→ This Method is applicable for perennial Irrigation system

→ Here the water is regulated by regulators. This is sub-divided into a) free flooding : In this Method, the agricultural area is divided into small strips by a series of channels connected to the supply of water.



(b) Basic flooding :

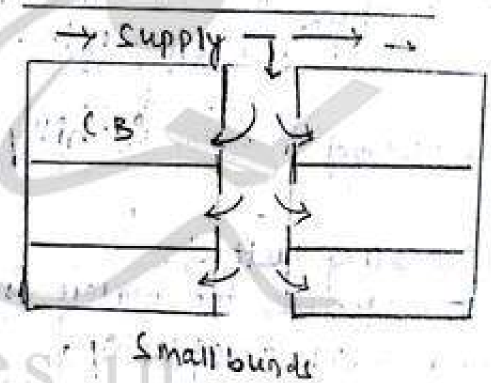
→ In this Methods, each tree or a group of tree are enclosed b a circular channels through which water will flow.



(c) check flooding :

→ In this Method, the agricultural area is divided into small plots. which is called as check basin.

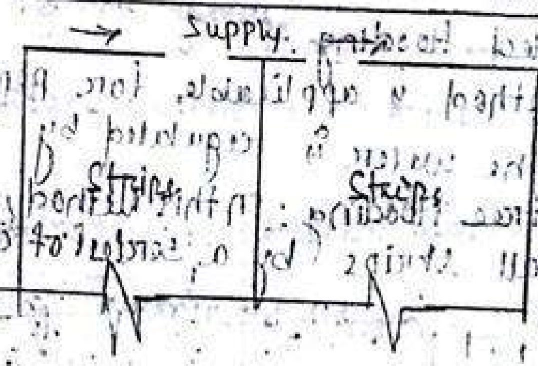
→ The water is supplied upto desired depth and water is retain for some hour so that it will infiltrate to the soil.



(d) Border strip:

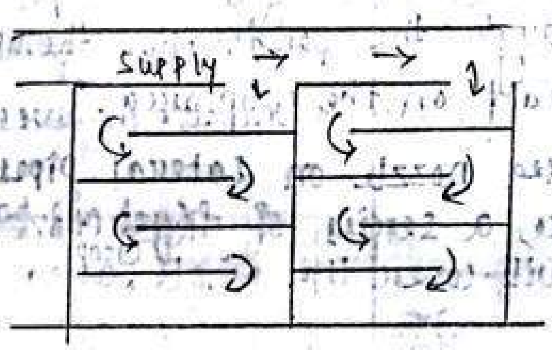
→ Here the area is divided into long narrow strips by levees (similar to the small bunds).

→ The strips are aligned with country slopes



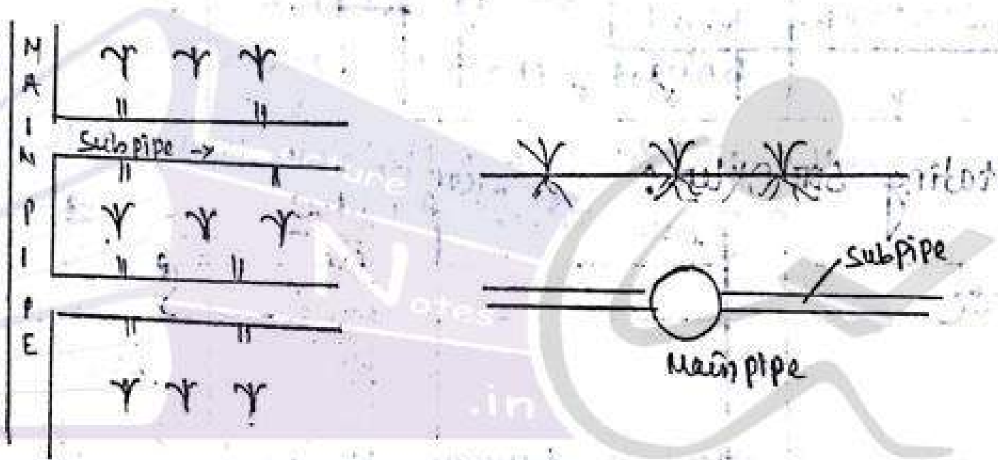
(e) Zig-Zag Method:

→ In this Method, the area is divided into small plots by low bunds in zig-zag manners.



* Sub-Surface Method:

→ In this method, water is supplied to the root of the crop by under ground network of pipes.



→ This Method is suitable for sandy soil.

→ Here the water is supplied slowly and continuously so that, the root of the crop will absorb the water continuously.

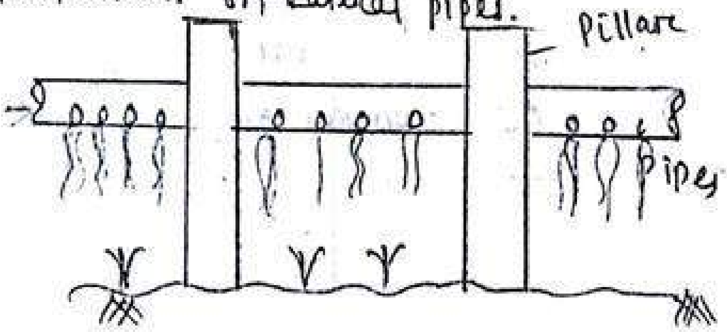
* Sprinkler Method:

→ Here the water is supplied to the crop in the form of spray like rain.

→ The spray is done by network of pipes, lateral pipes and nozzles.

→ Different form of sprinkler are

a) Perforation on lateral pipes.

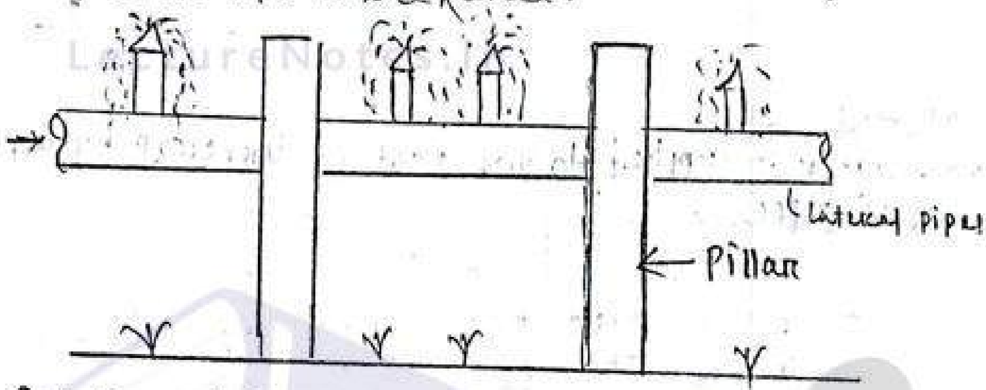


→ Here the pipes perforated at the top of the pillar and water is supplied with high velocity or more pressure.

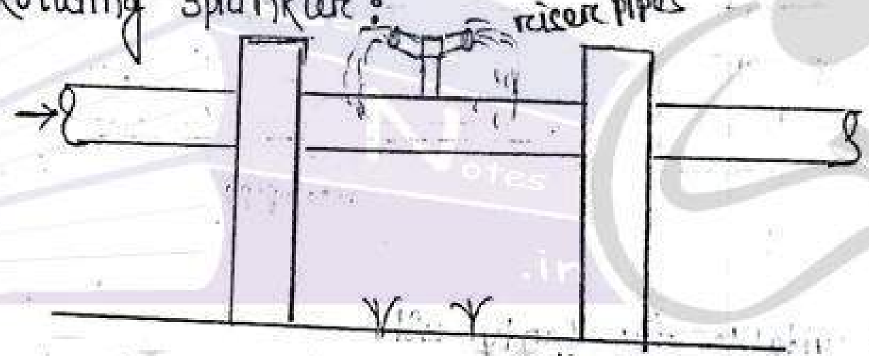
→ Through the perforation the water will comes out and it will spread on the crop area.

(b) Fixed nozzle on lateral pipes.

→ Here, a series of fixed nozzle are supply with some spacing it will cover the whole crop area.



(c) Rotating sprinkler:



→ Here, a riser pipes are fitted on the lateral pipe with the equal interval.

→ Water is supplied to the lateral pipes, through riser the water will rise to the nozzel and nozzel will rotate. So that the water will distribute in circular area.

Assignment:

Q Write a short notes on important irrigation project present in India. L10

Topic:

Water Requirements Of Crops

Water Requirement of crops: ②

* **Base, Duty and Delta**

i) Base period : The period from first watering to the last watering to the crop just before maturity.

→ This is denoted by 'B'. and expressed in number of days.

Crop	Base period (in day)
Rice	120
Cotton	200
Sugarcane	320

ii) Duty : It is defined as number of hectares that can be irrigated by constant supply of water at the rate of 1 cumec throughout the base period. [1 hector = 10,000 m^2]

→ This is denoted by 'D' and expressed in hectares / cumec

Crop	Duty (in hectare/cumec)
Rice	900
Cotton	1400
Sugarcane	800

iii) Delta : Each crop required, amount of water per hectare and if this much of water is supplied to the crop (first watering to last watering)

→ Water is stored in the field without loss then a layout will be made which is called Delta.

→ This is expressed in cm and denoted by 'Δ'.

Crop	Delta (in cm)
Rice	125
Cotton	
Sugarcane	
Patato	75
Groundnut	30

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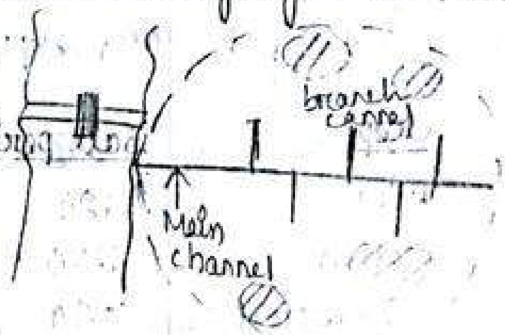
* Important terms :

i) G.C.A (Gross Command area) :

→ The imaginary area for which we are designing the channels is called as gross command area.



ii) CCA (Culturable Command area)

→ The area where we cultivate the crop is called as culturable command area.

a) culturable uncultivable area.

b) culturable cultivable area.

iii) Unculturable area :

→ The area where agriculture can't be done is called as unculturable area.

→ This includes ponds, rivers, hills, forest, villages etc.

* Crop period :

→ The period from sowing of the crop to the harvesting of the crop is called crop period.

* Crop rotation.

→ The process of changing of crop for cultivation on the same field is called crop rotation.

Ex: Rice - wheat

Rice - groundnut

* Crop seasons :

→ The season during which a particular type of crop can be grown on the same land every year is called as crop season.

Prince

→ It is classified into
a) Kharif (June - October) - Rice, Groundnut
b) Rabi (October - March) - onion, wheat

* Cumec Day:

The quantity of water flowing continuously for one day at the rate of 1 cumec (m^3/sec) is called as cumec day.

$$1 \text{ cumec day} = \frac{1 m^3}{sec} \times 24 \times 60 \times 60$$

$$= 86400 m^3$$ [1 hectare = 10,000 m^2]

$$= 8.64 \text{ hectare-mt}$$

* Relation between Base, Duty and Delta: Δ

Base (B) in days
Duty (D) in hectare/cumec
Delta (Δ) in (m)

⇒ The water flowing continuously by 1 cumec gives Delta (Δ) over an area Duty (D) for base (B) periods.

1 cumec for B days gives Δ over D hectares
1 cumec for 1 days give Δ over $\frac{D}{B}$ hectare
1 cumec for 1 day = $\frac{D}{B} \times \Delta$ (hectare-mt)

$\Rightarrow$ 8.64 (hectare-mt) = $\frac{D}{B} \times \Delta$ (hectare-m)

$\Rightarrow$ Δ (in mt) = $\frac{8.64 B}{D}$

Problem no- 01

Q. A channel is to be designed for irrigation for 5000 hec in Kharif season and 4000 hectares in Rabi season. The water requirement is 60 cm and 25 cm respectively. The Kor period (Base period) is 3 weeks for Kharif and 4 weeks for Rabi. Determine the discharge for the channel.

Solu^n:

For Kharif area 5000 hectare

$\Delta = 60\text{ cm} = 0.6\text{ mt}$

$B = 3\text{ weeks} = 21\text{ days}$

$D = \dfrac{8.64 \times B}{\Delta}$

$= \dfrac{8.64 \times 21}{0.6} = 302.4$ hectare / cumec

Discharge $= \dfrac{\text{Area}}{\text{Duty}} = \dfrac{5000}{302.4} = 16.53$ cumec

For Rabi, area 4000 hectare

$\Delta = 25\text{ cm} = 0.25\text{ mt}$

$B = 4\text{ weeks} = 28\text{ days}$

$D = \dfrac{8.64 \times B}{\Delta} = \dfrac{8.64 \times 28}{0.25}$

$= 967.68$ hectare / cumec

Discharge $= \dfrac{\text{Area}}{\text{Duty}} = \dfrac{4000}{967.68}$

$= 4.13$ cumec

Discharge = 16.53 cumec (Which ever is greater)

Problem no-02 Dt-22-01-16

Q. Design a irrigation channel. from the following data
The time factor is 0.75

Crop	Base period in days	Area (in hectare)	Duty in (hectare/cumec)
Rice	120	4000	1500
Wheat	120	3500	2000
Sugarcane	310	3000	1200

Solu^n:

For rice

$$\text{Discharge} = \frac{\text{Area}}{\text{Duty}} = \frac{4000}{1500} = 2.67 \text{ cumec}$$

For wheat

$$\text{Discharge} = \frac{\text{Area}}{\text{Duty}} = \frac{3500}{2000} = 1.75 \text{ cumec}$$

For sugarcane

$$\text{Discharge} = \frac{3000}{1200} = 2.5 \text{ cumec}$$

For kharif, $D = 2.67 + 2.5 = 5.17$ cumec
For Rabi, $D = 1.75 + 2.5 = 4.25$ cumec
} whichever is greater.

Final design discharge is $\frac{5.17 \text{ cumec}}{\text{Time factor}}$ (Ans) $= \frac{5.17}{0.75} = 6.89$ Ans

Problem no-3

Q The GCA value is 1.5 lakhs, from which 7500 are unculturable area. Then area for kharif crop is 60,000 hectare and area for Rabi crops is 40,000 hectare. Duty for kharif crop is 3000 hectare/cumec and for Rabi duty is 4000 hectare/cumec. find out
i) Design the discharge of channel assuming 10% of transmission loss.
ii) Intensity of irrigation for kharif and Rabi.

Solu^n:

i) GCA = 1.5 lakhs
UCA = 7500
Culturable area (C.C.A) = G.C.A − U.C.A
= 150000 − 7500 = 142500 hect

For kharif

A = 60,000 hectare
Duty = 3000 hect/cumec

$$\text{Discharge} = \frac{\text{Area}}{\text{Duty}} = \frac{60,000}{3000} = 20 \text{ cumec}$$

$$\text{Design discharge} = 20 + 10\% \text{ of } 20 \text{ cumec}$$
$$= 22 \text{ cumec}$$

For Rabi

Area = 40,000 hect

Duty = 4000 hectare/cumec

$$\text{Discharge} = \frac{\text{Area}}{\text{Duty}} = \frac{40,000}{4000} = 10 \text{ cumec}$$

$$\text{Design discharge} = 10 + 10\% \text{ of } 10 \text{ cumec}$$
$$= 11 \text{ cumec}$$

$$\text{Final Design discharge} = \frac{22 \text{ cumec}}{\text{Time factor}} = \frac{22}{0.75}$$

(b) Intensity of Irrigation.

Note

→ Intensity of Irrigation is defined as the ratio bet^n cultivation area for particular crops to cultivable command area.

$$I.I. = \frac{\text{Area}}{CCA} \times 100 \ (\%)$$

For Kharif

$$\text{Intensity} = \frac{60,000}{142500} \times 100 = 42.10\%$$

For Rabi,

$$\text{Intensity} = \frac{40,000}{142500} \times 100$$
$$= 28.07\%$$

Prm

Dt-27-01-16

* Factors affecting Duty :

(i) soil characteristic :

→ If the soil is sandy then the duty will be Less.

→ If the soil is Loamy then the duty will be more.

(ii) climatic condition :

→ If the climate is hot then the duty will be less.

→ If the climate is cool then the duty will be more.

(iii) Rainfall :

→ If the rainfall is sufficient then the duty will be more.

→ If the rainfall is more or less then the duty will be less.

(iv) Base period :

→ If the base period is more then the duty will be less.

→ If the base period is less then the duty will be more.

(v) Types of crops :

→ Depending upon types of crops, duty will be affect.

(vi) Topography :

→ If the crop area is sloping, then duty will be less. because the water will flow out due to slope and the soil will percolate less water.

→ For flat area, then duty will more because it will holds the more water.

(vii) Water Tax :

→ If the tax will be more then duty will be more.

→ If the tax is less then duty will be less or more it depends upon the farmer

(viii) Types of Irrigation :

→ The duty will be more for perennial Irrigation

→ The duty will be less for Innundation Irrigation

* Methods to Improove Duty :

(i) Proper ploughing :

→ Ploughing should be proper and deep so that the moisture content capacity of soil will be more.

(ii) Methods of supply of Water :

→ The Methods should be decided according to the field condition.

Ex: Furrow Method – For crop sown in rows

Basin Method – Orchards.

Contour Method – hilly area.

Flood Method – flat topography

(iii) Canal Lining:

→ If canal lining is provided then the percolation loss of water will be reduced.

(iv) Transmission Loss:

→ The canal should be designed nearer to the crop area. So that there will be Minimum transmission Loss.

(v) Implimation of Tax:

→ The tax should be impliment w.r.t volume of water used.

vi) Crop rotation:

→ The principle of crop rotation should be adopted to improove the fertility of soil.

* Consumptive Use:

→ The water which is used by plants for transpiration and evaporation from soil is called as consumptive use.

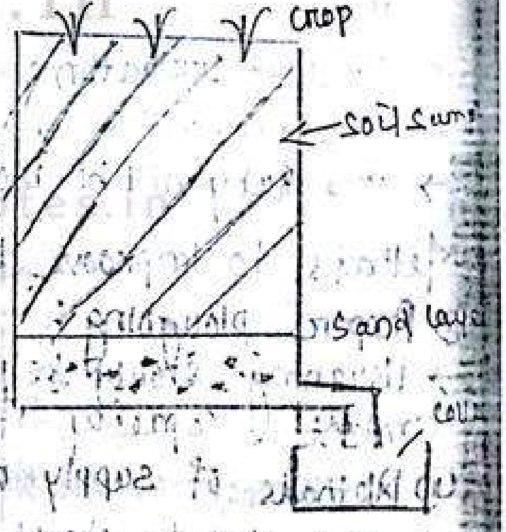
→ It is also called as evapo-transpiration. It is expressed in as depth(cm)

* Methods to determine consumptive use: Dt-30-01-16

There are

a) Lysimeter Method:

→ In this Method, a water tight tank of cylindrical shape having diam of 2Mt and depth 3mt is placed vertically on the ground, the tank is filled with sample of soil at the bottom of the tank, a sand layer will be given below the sand layer, a pan will be there to collect the surplus water.



→ The consumptive use can be determine by the measuring the water required from for the crop for the satisfactory growth.

Where,

$$C_u = W_a - W_d$$

W_a = Water applied

W_d = Water drained off

C_u = Consumptive use.

Soil

(b) Moisture study :

→ Here, several plots are selected where irrigation water is to be supplied.

→ Soils samples are taken from the different layer, from the different depth; soil will be taken for the moisture study.

→ For moisture study, we can findout the watercontent of the soil sample just before the water supplied; and after the water supplied

$$D_r = \frac{Pwd}{100}$$

Where,

D_r = Required depth of water.

P = Percentage of water content.

w = Sp. gravity of soil

d = Depth of soil.

(c) Field Experimental Method :

→ Here, some of the fields are selected for the experiment then water is supplied sufficiently for the growth of the plants.

→ It is to be noted here that, there shouldn't be any runoff and deep percolation.

→ If there will be any percolation, then it should be measure and deducted from the total quantity of water supply. but practically it is not possible to determine the percolate value. So, a correction factor is taken into considered.

* Frequency of Irrigation :

→ The frequency of irrigation can be determined by the following formula.

i) $$D_w = \frac{W_s \times d}{W_w} \times [F_c - M_0]$$

Where,

D_w = Depth of water applied.

W_s = Unit weight of soil.

W_w = Unit weight of water

d = Depth of the soil at root zone.

f_c = Field capacity.

M_0 = Optimum moisture content.

ii) $$f_w = \frac{D_w}{C_u}$$

Where

f_w = frequency of watering

D_w = Depth of water applied.

C_u = Consumptive use

Note:

→ The frequency of water should be workout in advance for proper Irrigation system.

→ The water is supplied to the field to increase the Moisture cont upto field capacity.

→ When the application of water is stoped, there will be red in moisture content due to transpiration and evaporation.

→ To Mentain the Moisture content for sufficient growth of water should be applied in equal Interval. This application of water in proper intervals is known as frequency of Irrigation.

Problem no - 4

Q: Determine the frequency of Irrigation from the following data

i) Field capacity = 35%.

ii) Permanent welting point = 18%.

iii) Density of soil = 1.5 g/cm³

iv) Depth of root zone = 70 cm

v) Daily Cu = 17 mm

Soln:

Available Moisture = F.C − W.P

= 35% − 18% = 17%

∴ let the readily available Moisture (for crop 0.75 % of available Moisture)

$$RAM = 0.75\% \text{ of } 17\%$$

$$= 0.75 \times 17 = 12.75\%$$

$$OMC = FC - RAM$$

$$= 35\% - 12.75\%$$

$$= 22.25\%$$

$$\therefore D_W = \frac{W_s \times d}{W_W} \times [FC - M_o]$$

$$\Rightarrow D_W = \frac{1.5 \times 70}{1} \times [35\% - 22.25\%]$$

$$= 13.38 \text{ cm}$$

$$\therefore f_W = \frac{D_W}{Cu} = \frac{13.38}{1.7} = 7.87 \approx 8 \text{ days}$$

The water should be applied in 8 days intervals.

Dt: 03-02-16

* Types of soil water:

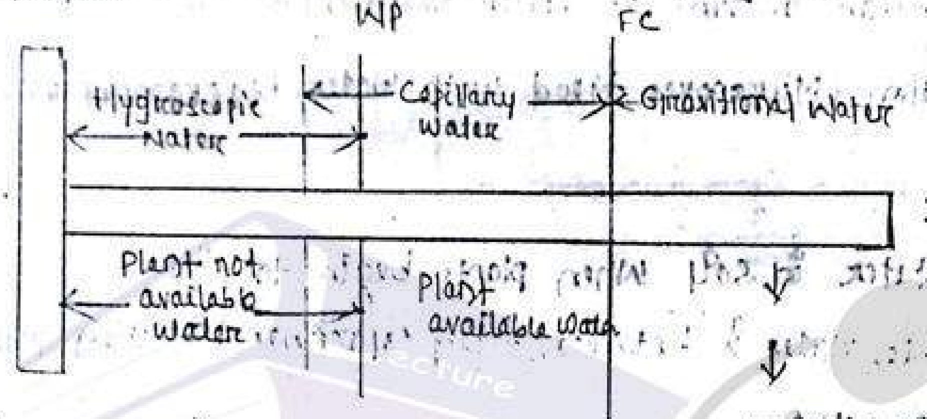
soil water & following types

(i) Hygroscopic water:

→ Here hygroscopic water is removed by oven drying only and it is not available to plants.

(ii) Capillary Water:

→ Here the capillary water is removed by air drying and it is most available to plants.



* Difference betn Hydroscopic coefficient and wilting point:

At Wilting Point	At hygroscopic co-efficient
→ The soil will be air dried	→ The soil will be oven dried
→ Can't squeeze water	→ can be ovendried to remove the water
→ Plant can't get water	

(iii) Gravitional Water:

→ Gravitional Water is not available to plants

→ Drains through soil water influence of gravity.

→ Through Large pores.

* Small pores can hold water against pull of gravity through capacity.

* Capillarity:

This is an adhesion properties due to which the water will rise in its surface level.

* Critical Levels of Water in soil :

i) Field capacity
ii) Wilting point.
iii) Hygroscopic co-efficient.

(i) Field Capacity :

→ Amount of water in soil after free drainage has removed gravitational water (2-3 days)

→ Soil is holding max^m amount of water available to plants.

→ Optimal aeration (Micropores filled with water, Macropores with air)

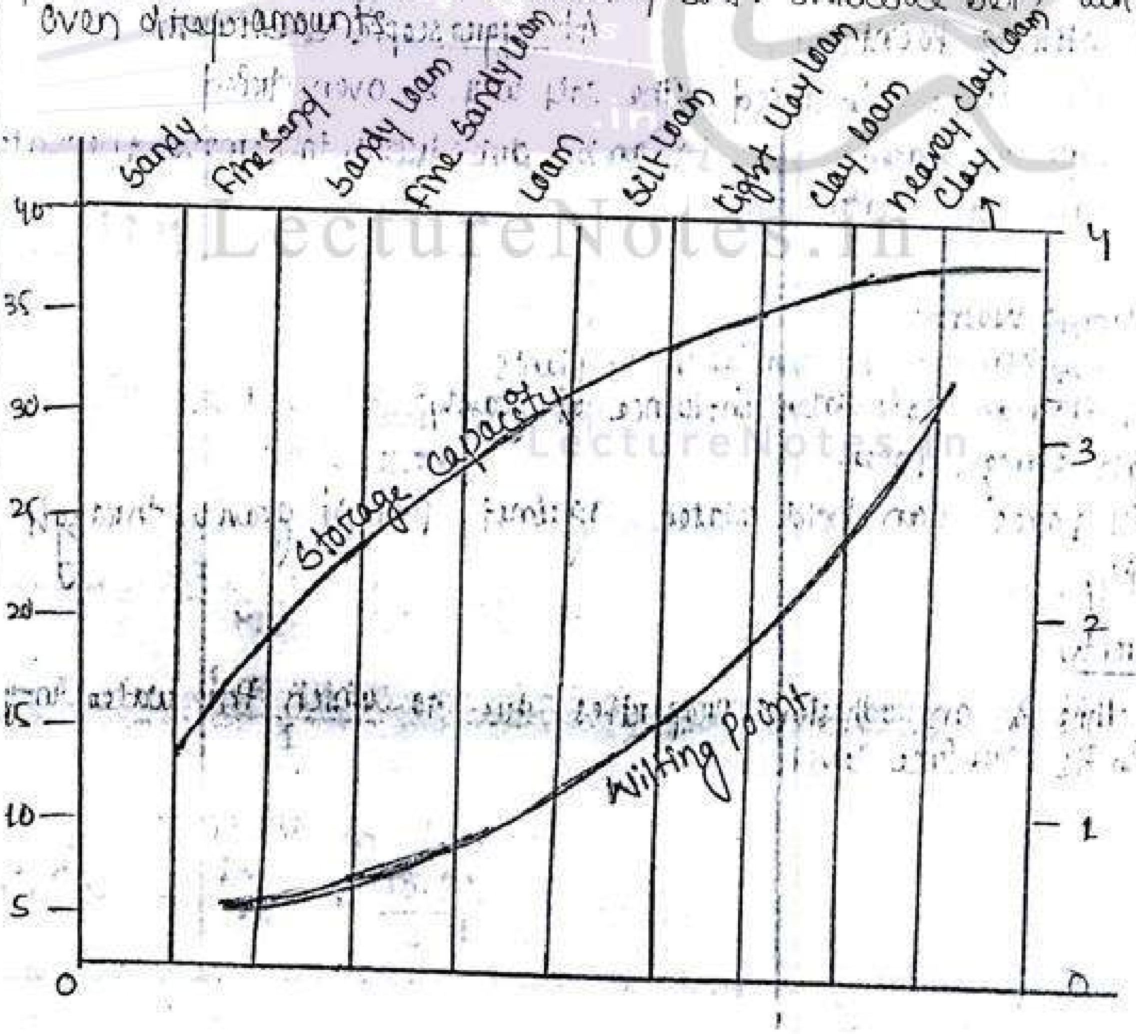
(ii) Wilting point :

→ Amount of water in soil when plants begin to wilt.

→ Plant available water is between field capacity and wilting point.

(iii) Hygroscopic co-efficient :

→ Amount of moisture in air dry soil. Difference bet^n air dry and oven dry amounts.



Topic:

Canal Irrigation

Irrigation. (3) (1)

Chapter - 3

canal Irrigation.

Introduction:- As we know about the Irrigation system, In which the flow of water under gravity from the resource to the agricultural fields. is known as flow Irrigation, This system involves.

(1) Diversion head works.
(2) Formation of storage reservoirs.
(3) Net work to cover the commanded area.

* Diversion head works by constructing of weir/ barrage across the river @ higher elevation level, and there by divert the water through Diversion system throughout the year Enti full capacity. the Dam.

* the formation of storage reservoirs by construction of Dam sections across the river (or) stream valley

* after these above ~~two systems~~ i.e head work (or) storeage reservoirs ~~comp~~ formation completed, then the net works of canals ie main, branch, distributory are constructed from there to ~~agr~~agricultural lands. Here Head regulator is must to construct constructed to control the flow of water through the canal to throughout the year.

Def:- canal is an artificial channel, generally trapezoidal shape constructed on the ground to carry water to the fields either from the river, (or) from tank or ~~from~~ reservoir.

Types of canals.

broadly canals can be classified as 4 types. As according its purposes and utility. availability of water, and due to alignment etc.

(1) Based on purpose:

The canals classified based its purpose of service as

(a) Irrigation canals, (b) power canals (c) Navigation canals, (d) Feeder canal

(a) Irrigation canals:- The ~~ob~~ main objective purpose to irrigate the agricultural land is known as Irrigation canals.

Ex:- ~~Bh~~ Bhakra canal & Rajasthan canal etc.

(b) power canals:- The canal which is constructed to supply water with ~~th~~ very high force to the hydroelectric power station for purpose to move and rotate turbines and there by generate electric f. er is ~~called~~ known as power canal (or) hydel canal

Ex: - Nangal Hydel canal.

(c) Navigation canals:-

These canals also utilised for irrigation, the main object to construct for the purpose of inland navigation is known as Navigation canals

Ex:- Ganga - Bramhaputra.

(d) Feeder canals:-

These are the canals are constructed to feed another canals (or) natural chanels or rivers ~~to~~ for the purpose of irrigation and navigation etc:

Ex:- Farakka Barrage feeder canal.

(2) Based on Nature of Supply:-

— the canals can be designated by (a) ~~Free~~ Inundation canals, (b) perennial canals.

(a) Inundation canals:-

These canals are excavated from the banks of the Inundation rivers (or) Small streams, to carry water to Agricultural fields in the season of rainy only. No head works and regulators require for, this canals. The flow of canals depends on fluctuation of water level in the river. whenever the flow of water levels above bed level. Starts flow in the canal & below bed level flow ~~cut~~ stops so. strictly say that: Seasonally the river flows to its full capacity is known as Inundation canal.

(b) perennial canal:-

The supply water to Agricultural land throughout the year is known as ~~pere~~ perennial canals. These canals are formed at from the U/S side of the diversion head works (ie weir (or) barrage (et) (or) from storage reservoirs. ~~the~~ The main function is to regulate the head water level in the canal.

(3) Based on discharge.

The canals classified according to the ~~dis~~ discharge capacity are. (a) Main canal, (b) Branch canal (c) Distributory canals and (d) field channels.

(a) Main canal:

The main function of this canal to supply water to network of all other canals. Main canal having large length and construct directly from a diversion head work or, storage reservoir.

(b) Branch canals:-

The canals are constructed on either side of a main canals at suitable levels, to cover a maximum ~~commade~~ commanded area by network. it's discharge varies from 5 to 10 m3. which is always less to main main canal.

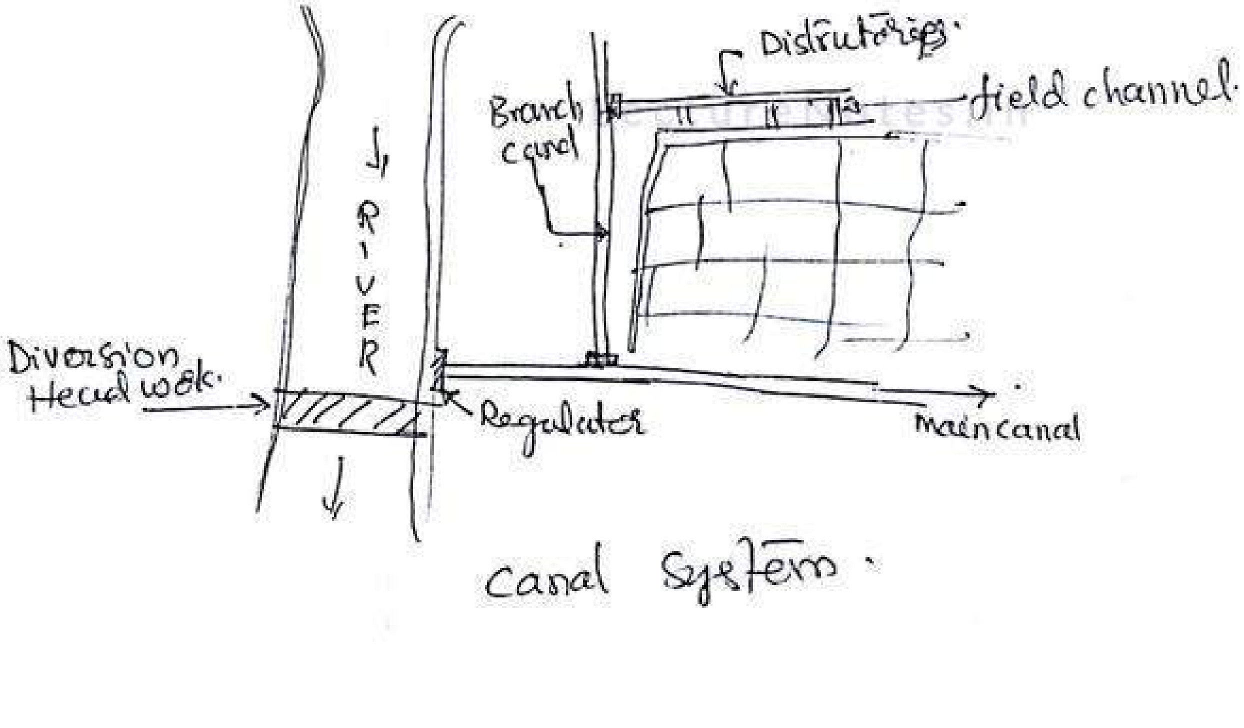
(c) Distributory canals:-

These canals are taken from a branch canals to supply water for different sectores of levels. the discharge capacity varies from 0.25 to 3m3. According to functional purpose divide into (1) major distributory (2) Minor distributory.

(d) Field channels:-

The channels are taken from a outlets of a distributory channels ~~co~~ by cultivators to supply water to their own lands. These are maintained by a co cultivators.

Fig:

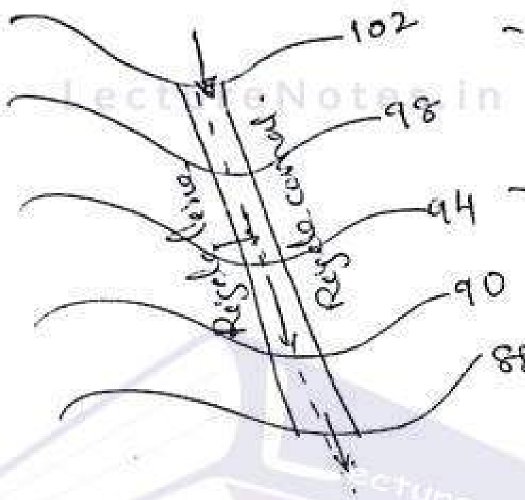


Canal System.

(4) Based on Alignment

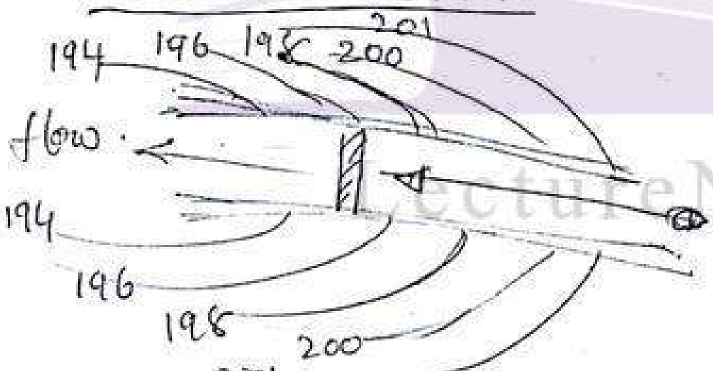
Depending on alignment the canal are designated as:
(a) Ridge (or) water shed canal (b) contour canals (c) side slope canal.

(a) Ridge (or) watershed canals



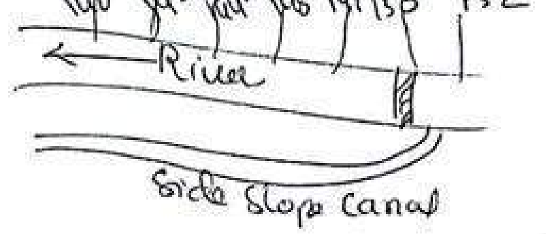
- the canal which is aligned along a ridge line (watershed line) is known as ridge / watershed canal
- the advantage of these type of canal is that it can irrigate the area both side of the canals. there is no possibility of crossing any natural drainage hence no cross-drainage work is required.

(b) contour canals.



- the canal which is aligned approximately parallel to the contour lines is known as contour canal. these canals can irrigate the area on one side only. these may cross natural drainages and hence to required cross-drainage works.

(c) side slope canals:



Side slope canal

These canals are aligned approximately at right angles to the contour lines. By these canals, the area to be irrigated one side only.

advantage of these canals are not crossing any natural drainage and hence need not required cross-drainage works.

(5) Based on financial output

(a) productive canal (b) protective canal

(a) Productive canal :-

– are those which yield a net revenue to the nation after full development of irrigation in the area.

(b) Protective canal :-

– is a sort of relief work constructed with the idea of protecting a particular area from famine.

(6) Classification based on boundary surface of the canal:

(a) Alluvial canals (b) Non-Alluvial canals (c) Rigid boundary canals

(An alluvial canal is the one which is excavated in alluvial soils. Such as silt, clay, hard soil (murram) rock etc. are non-alluvial soils, the canal excavated in these soils are called non-alluvial canals.

– The Rigid boundary canals are those which have rigid sides and rigid base, such as lined canals.

Canal Alignment

A canal has to be aligned in such a way that it covers the entire area proposed to be irrigated, with shortest possible length and at the same time its cost including the cost of cross-drainage works is a minimum.

A shorter length of canal ensures less loss of head due to friction and smaller loss of discharge due to seepage and evaporation, so that additional area can be brought under cultivation.

According to alignment canals may be of following types.

(1) Ridge canal (2) contour canal (3) Side slope canal

[for these explanation see previous classification of canal]

CANAL LOSSES

When water continuously flow through a canal, losses takes place due to seepage, deep percolation and evaporation. These losses are some time known as transmission losses. These losses should be properly accounted for, otherwise lesser quantity of water will be available for cultivation at the tail end. Water losses in canal can broadly classified under three heads.

(1) Evaporation losses (2) Transpiration losses. (3) Seepage losses

(1) Evaporation losses:-

The loss due to evaporation is generally a small percentage of the Total loss in unlined canal. It hardly exceeds 1 to 2% of the total water entering into the canal. The evaporation losses depends upon.
(1) climatic factors → temp, humidity, & wind velocity.
(2) canal factors → water surface area, water depth, & velocity of flow.

Max loss is there in summer months when temperatures are high and wind velocities are also high. Similarly losses are maximum in unlined canals due to wider water surface area. Shallower water depth and low velocity. The average evaporation loss per day may vary bet. 4mm to 10mm.

(2) Transpiration losses:-

The transpiration loss takes place through lot of vegetation and weeds growth along the bank of canals. However, forms a extremely small part of total loss.

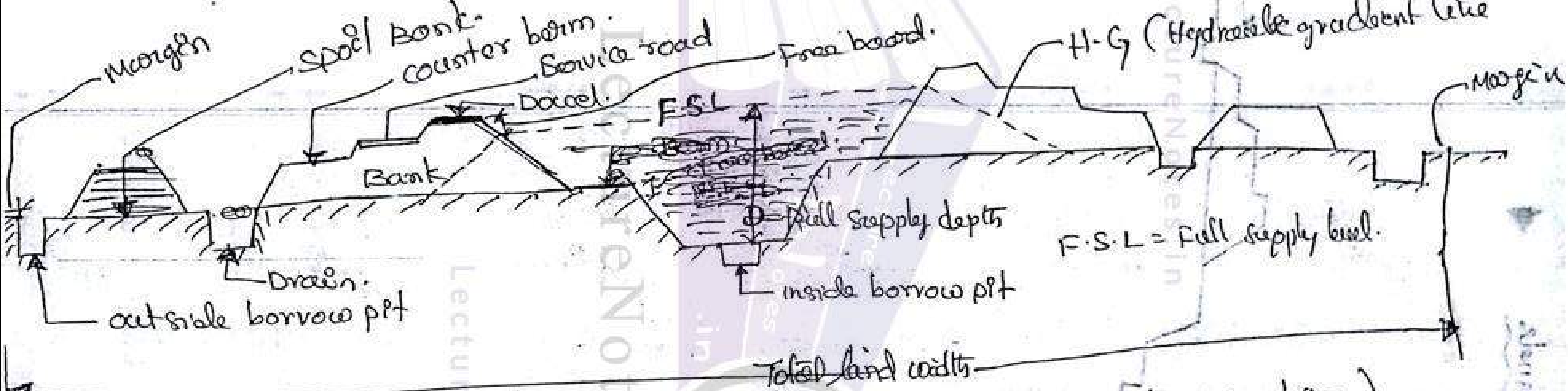
(3) Seepage Losses:-

Seepage losses constitute major portion of loss in an unlined canals. The seepage losses are due to:
(1) absorption of water in the upper layer of soil below the canal bed.
(2) percolation of water into the water table, thus rising of water table. If however water table is much lower, seepage losses are only due to absorption. percolation losses are always much more than the absorption losses

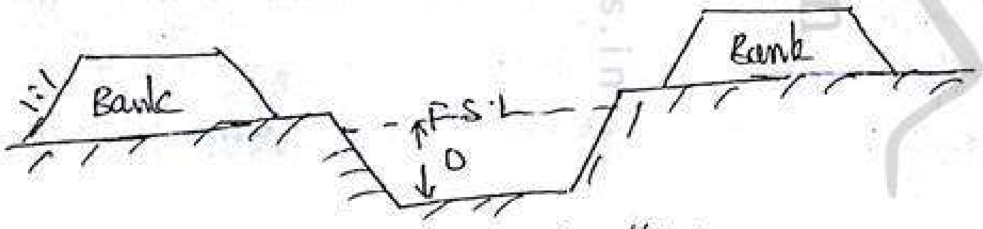
Canal section

The cross-section of canal may be in fully cutting or fully embankment, and partial banking according to the natural ground surface and permissible bed slope of the canal.
The different terminologies should before going to canal section
(1) canal bank, (2) Berm, (3) Hydraulic gradient, (4) center berm
(5) Free board, (6) side slope (7) service road or Inspection road.
(8) Dowel or Dowla, (9) Borrowpit, (10) spoil bank, (11) land width

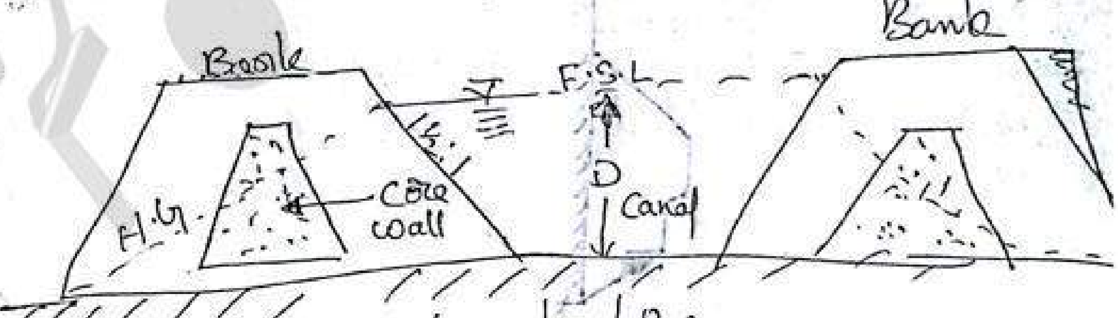
Canal C/S :



Canal section (partial cutting partial banking)

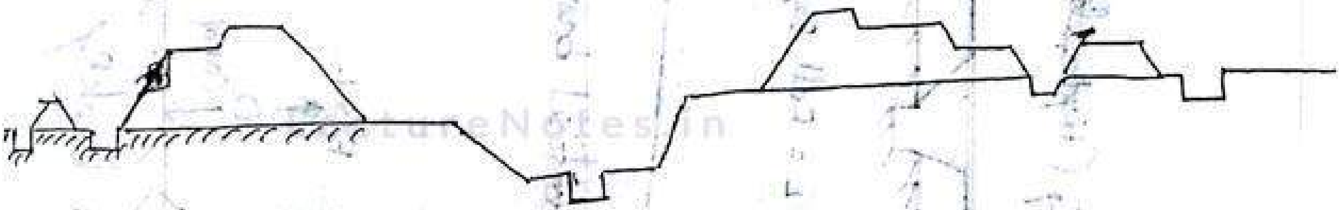


canal in full cutting

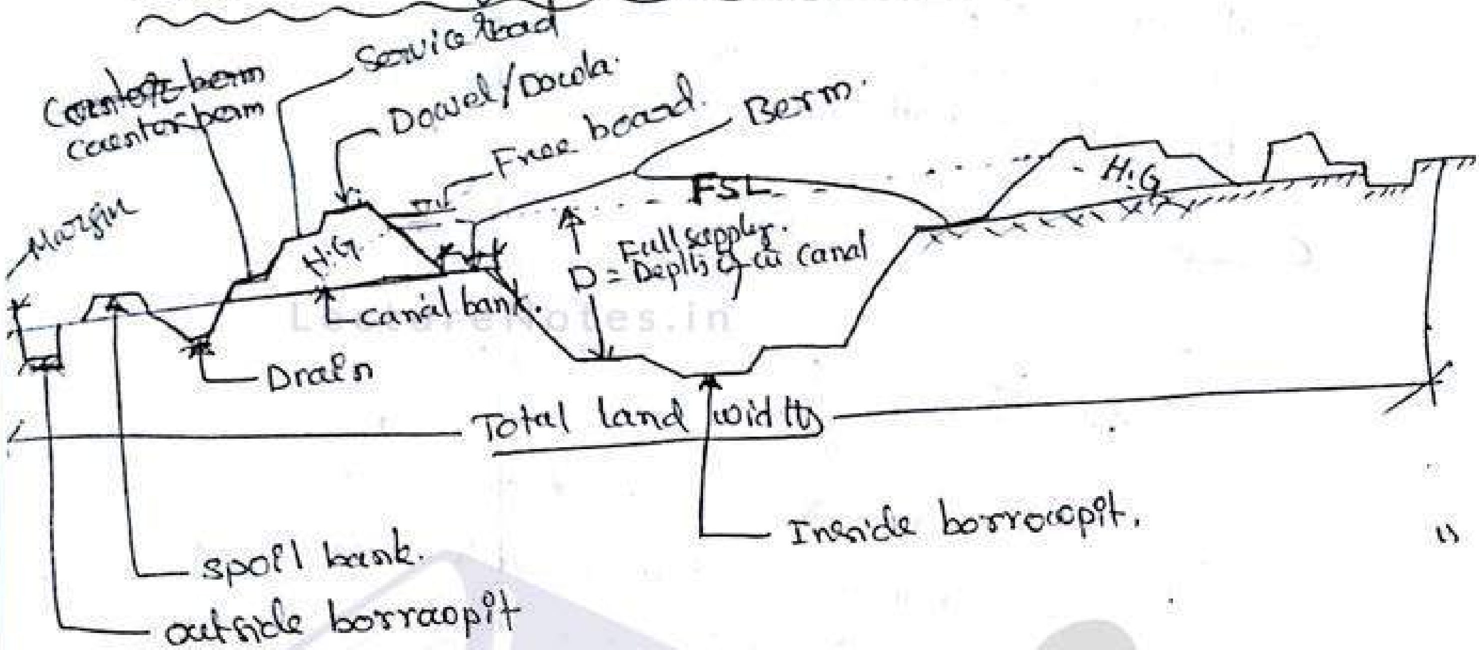


Canal in banking.

c/s of canals.



Cross-section of ~~canals~~ irrigation canal.



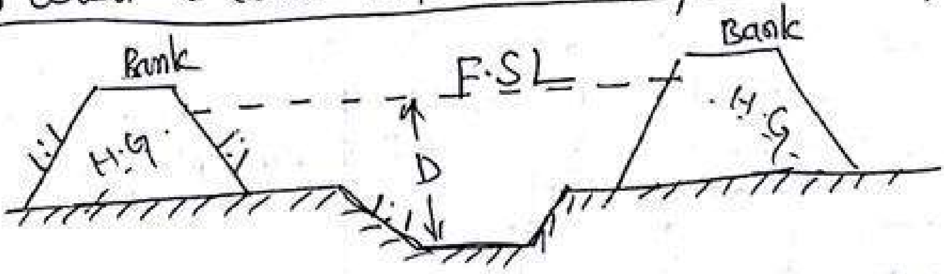
(1) Canal bank

— is necessary to retain water in the canal to the full supply level. Canal banking depends on different site conditions. It forms as

(a) when canal fully in cutting

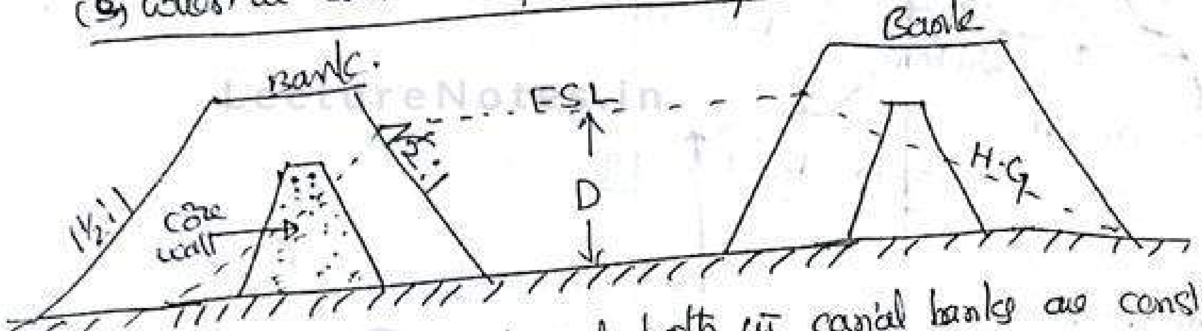
In this case, the banks are constructed on both sides of the canal to provide only an inspection road. Here the hydraulic gradient has no function so the height of the bank will be low and Top width will be Min just to provide the road way. The side slopes will be 1:1, 1½:1, 2:1 according to nature of the Soil.

(b) when the canal in partial cutting and Banking:



In this case, the banks are constructed on sides of the canal to retain water. The height of the banks depends on the fully supply level of the canal. Again the section of the canal depends on the hydraulic gradient. The section of the bank should be such that the top width and the side slope of the bank should have a min cover of 0.5m. The hydraulic gradient should have a min cover of 0.5m.

(5) When the canal is full Banking:



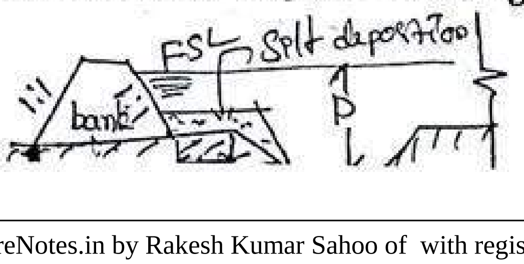
In this case, the canal and both the canal banks are constructed above the ground level. The height of the bank will be high and its section will be large due to the hydraulic gradient. But to minimise the cross-section of the bank a core wall of puddle clay is provided which deflects the hydraulic gradient downwards.

② BERM

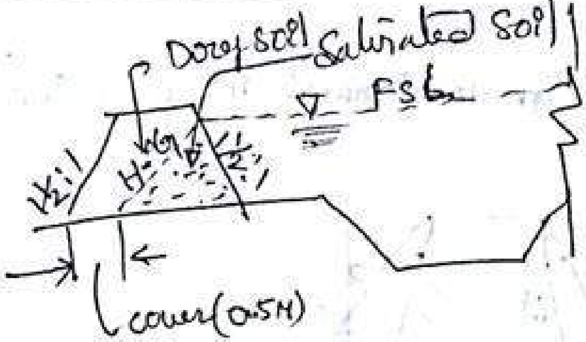
- The distance bet the toe of the bank and top edge of cutting is termed as berm.

functions: - To protect the bank from ~~ero~~ erosion.
- To provide a space for widening the canal section in future if necessary.
- To protect the bank from sliding down towards the canal section
- The silt deposition on the berm makes an impervious lining.
- If necessary borrow pit can be excavated on the berms.

The width of berm depends on various factors such as capacity of the canal, the nature of the soil, the site condition, etc. However, the width of berm ~~varies~~ varies from D to 2D. when D = full supply depth of the canal.



Hydraulic gradient

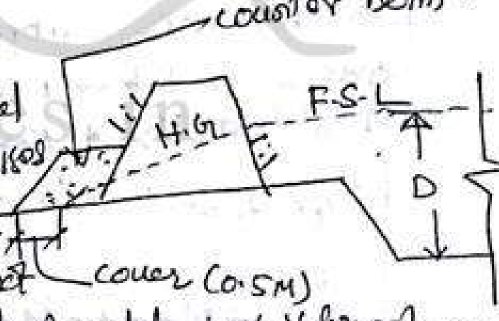


whenever the water is retained by the canal bank, the seepage occures through the body of the bank. Due to the resistance of the soil, the saturation line forms a sloping line which may pass through countryside of the bank.

This sloping line is knowns as the hydraulic gradient or saturation gradient. The soil below this line is saturated, but the soil above this line is dry. The hydraulic gradient line depends on the permeability of the soil. So while constructing the bank, the soil should be tested in soil testing laboratory and the nature of the hydraulic gradient should be ascertained. This will help in fixing the height. Top width and side slopes of the bank the hydraulic gradient for different soils are.

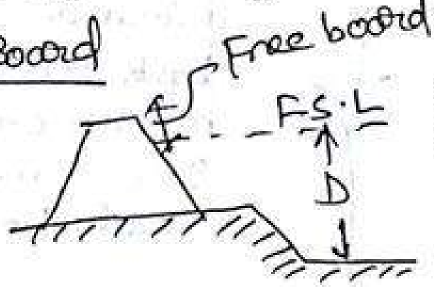
soil	clayey soil	Alluvial soil	sandy soil
H.G	1:4	1:5	1:6

Counter Berm:



when the water is retained by a canal bank the hydraulic gradiant line passes through the body of the bank. For stability of the bank, this gradient should not intersect the outer side of the bank. It should pass through the base and a minimum cover of 0.5m should always be maintained. Sometimes, it may occur that the hydraulic gradient line intersects the outer side of the bank. In that case, a projection is provided on a outer side of the bank to obtain min cover. This projection is known as counter-berm. The width of this berm depends on the site condition.

Free Board

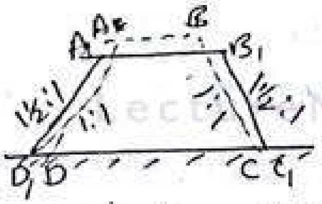


It is the distance bet F.S.L and Top of the bank. It is varies from 0.5m to 0.75M.

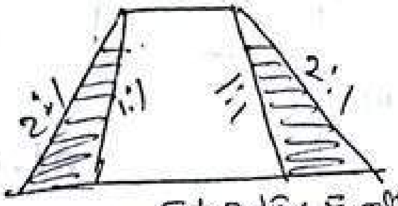
function: ① To keep a sufficient margen so that the canal water be not overtop the bank in case of heavy rainfall (or) fluctuation in water supply.

② To keep the saturation gradient much below the Top of the bank

SIDE SLOPE



Sliding of bank.



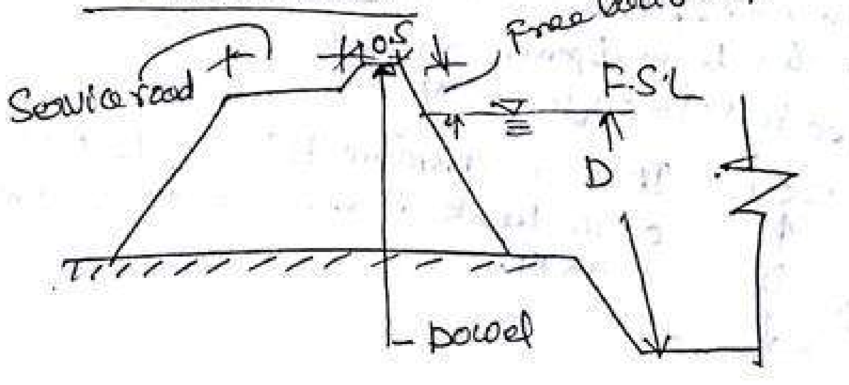
Extra Earthwork.
(Extra earth filling)

The side slopes of the canal bank and canal section depend on the angle of repose of the soil existing on the site. So, to determine the side slopes of different sections, the soil samples should be collected from the site and should be tested in the soil testing Lab. The necessary of such test is that if the permissible slope (to maintain angle of repose) is not provided in an embankment or cutting then the soil in that place will go on sliding gradually until the angle of repose for that particular soil is attained.

For instance, suppose an embankment was constructed with side slope 1:1 but according to the nature of the soil, the side slope should be 1½:1

Type of soil	clayey soil	Alluvial soil	Sandy soil	Sandy loam
side slopes in Cutting	1:1	1:1	2:1	1½:1
side slopes in Banking	1½:1	2:1	3:1	2:1

SERVICE ROAD



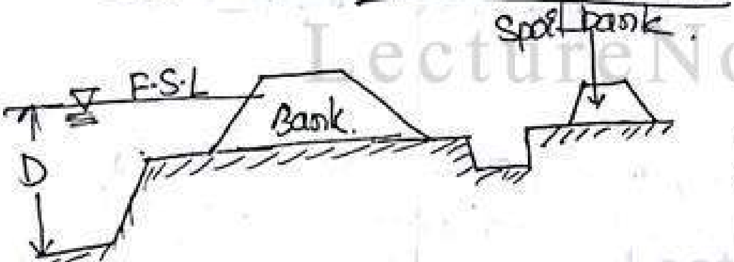
The roadway which is provided on the Top of the canal bank, for inspection and maintenance works is known a Service road (or) Inspection road. For main canal the service roads are provided on both the banks. But for Branch canals, the road is provided on one bank only. The width of the service road for main canal varies from 4m – 6m. for branch canals varies from 3m to 4m.

The initial purpose of the service road is to conduct inspection and maintenance works. But finally these roads serve the ~~pu~~ purpose of communication bet the different villages and for transporting agricultural ~~good~~ goods. Therefore it becomes necessary to construct metalled road to serve the purpose

Dowel (or) DOWLA

The purpose of protective small embankment which is provided the purpose of service road for the safety of the vehicles on the canal side of the service road ... practically of plying on it is known as dowel or dowla. practically, it acts as a curb on the canal side of the road. It is provided above the F.S.L. with a provision of free ~~bo~~ board. The Top width is generally 0.5m and the ht above the ground level is about 0.5m. The side slope is similar to the side slope of the bank.

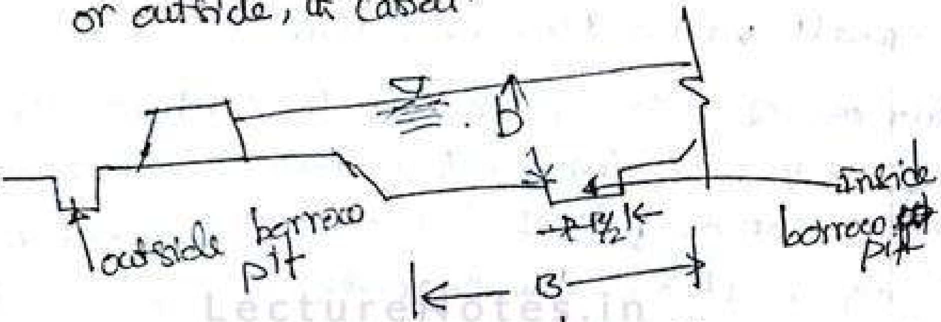
~~BOTTOM~~ SPOIL BANK



When the canal is constructed in full cutting, the excavated (soil) earth may not be completely required for forming the bank. In such a case, the extra earth is deposited in the form of small banks which are known as ~~sp~~ spoil banks. The spoil banks are provided on one side or both sides of the canal bank depending on the quantity of excess earth and the available space. The spoil banks seen parallel to the main bank. But not continuous, sufficient space are left between the adjacent spoil banks for proper drainage.

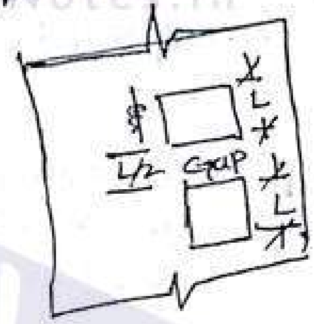
BORROW PITS

when the canal is constructed in partial cutting and partial ~~fullcutting~~ ~~the excav~~ banking, the excavated earth may not be sufficient for forming the required bank. In such a case the extra earth required for the construction of banks is taken from some pits which are known as borrow pits. The borrow pits may be inside or outside, the canal.



The inside borrow pit may be located at the centre of the canal. The width of the borrow pit should be 1/2 of the base width of the canal.

- The max depth of borrow pit should be 1m.
- The excavation is done in a no. of borrow pits leaving a gap between them generally (L/2) half length of borrow pit



will acts as water pockets where the silt will be deposited and ultimately the canal bed will get leveled up.

- The outer borrow pits may be adjacent to the heel of the bank with a clearance of 1m bet the heel and edge of borrow pit. But the outer borrow pit may create some inconvenience. So it is better to borrow earth from the barren land far away from the canal.

LAND WIDTH

The total land width required for the construction of a canal depends on the nature of the site conditions. Such as fully in cutting or fully in banking or partly in cutting & partly in banking. These conditions come according to the designated bed level of the canal and the natural ground surface. So total land width differs with the site conditions. For it following are added.

(1) Top width of canal.
(2) Twice the berm width
(3) Twice the bottom width of bank.
(4) A margin of one meter from the heel of the bank on both sides
(5) width of external borrow pit if any.
(6) A margin of 0.5m from the outer edge of borrow pit on both sides

Design of Canal on Non-Alluvial Soil.

(Q, N, m & S given)

Q. Design an irrigation canal with the following data.

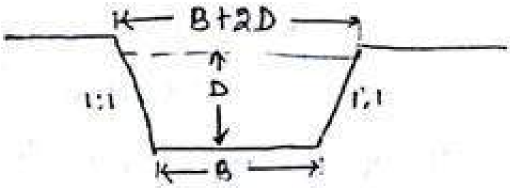
(a) Discharge of the canal = 24 cumec.

(b) Permissible mean velocity = 0.80 m/sec.

(c) Bed slope = 1 in 5000.

(d) Side slope = 1:1

(e) Chezy's ~~consta~~ constant, C = 44.



Soln: Given data. $Q = 24$ cumec

$V = 0.80$ m/sec.

$S = \frac{1}{5000} = 0.0002.$

Side slope = 1:1

Let, B = bed width, D = depth of water.

Cross-sectional area, $A = (B+D)D.$

Again, $A = \frac{Q}{V} = \frac{24}{0.8} = 30\ m^2.$

$\Rightarrow 30 = (B+D)D$

Wetted perimeter, $P_w = B + 2\sqrt{2}D = B + 2.828D$. —— (1)

Hydraulic mean depth, $R = \frac{A}{P_w} = \frac{30}{B+2.828D}$ —— (2)

From Chezy's formula.

$V = C \times \sqrt{RS}$

$\Rightarrow 0.80 = 44\sqrt{R \times 0.0002}$

$\Rightarrow 0.64 = 1936 \times R \times 0.0002$

$\Rightarrow R = 1.65$

From (2) & (3) $1.65 = \frac{30}{B + 2.828D}$ —— (3)

or, $1.65B + 4.67D = 30$

$\Rightarrow B = 18.18 - 2.83D$ —— (4)

Putting the value of B in Eq(1)

$30 = (18.18 - 2.83D + D)D$

$= (18.18 - 1.83D)D$

$= 18.18D - 1.83D^2$

or, $1.83D^2 - 18.18D + 30 = 0$

or $D = \frac{18.18 \pm \sqrt{(18.18)^2 - 4 \times 1.83 \times 30}}{2 \times 1.83} = \frac{18.18 \pm 10.53}{3.66}$

$= 7.84$ or 2.09 m.

When, $D = 7.84$ m

$B = 18.18 - 2.83 \times 7.84$

$= -4.00$ (It is absurd)

When, $D = 2.09$ m

$B = 18.18 - 2.83 \times 2.09$

$= 12.27$ m (It is acceptable)

Check, $A = (B + D) D$

$= (12.27 + 2.09) \times 2.09$

$= 30.01$ (Checked & found correct)

So, finally bed width $= 12.27$ m

depth of water $= 2.09$ m. (Ans)

Q.2 (Q, N, m & B/D ratio given)

Find the bed width & bed slope of a canal with the following data.

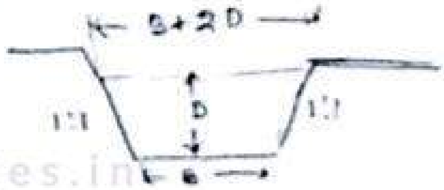
(a) Discharge of canal = 40 cumec

(b) Permissible mean velocity = 0.95 m/sec

(c) Coefficient of rugosity (N) = 0.0225

(d) Side slope = 1:1

(e) B/D ratio = 6.5



Soln

Let B = bed width, D = depth of water

Cross-sectional Area, $A = (B + D) \times D$ — (1)

Wetted perimeter $P_w = B + 2\sqrt{2} D$ — (2)

Now $A = \frac{Q}{V} = \frac{40}{0.95} = 42.11 \text{ m}^2$

$B/D = 6.5$ (given)

$B = 6.5 D$

From eq (1) $42.11 = (6.5D + D) D$ (Putting the value of B in eqn (1))

$D = 2.37$ m, $B = 6.5 \times 2.37 = 15.40$ m.

From eq^n (2). $P_w = 15.40 + 2\sqrt{2} \times 2.37 = 22.10\,m$.

Hydraulic mean depth

$$R = \frac{A}{P_w} = \frac{42.11}{22.20} = 1.90\,m.$$

From Manning's formula.

$$V = \frac{1}{N} \times R^{2/3} \times S^{1/2}$$

$$0.95 = \frac{1}{0.0225} \times (1.90)^{2/3} \times S^{1/2}$$

or $0.95 = 44.44 \times 1.534 \times S^{1/2}$.

$S^{1/2} = 0.01394$.

or $S = 0.000194$.

or $S = \frac{1}{5154.6} = \frac{1}{5155}$ (say)

So, bed width of canal = 15.40m.

Bed slope = $\frac{1}{5155}$.

∴ Bed slope of canal is 1 in 5155. (Ans).

Solved it

Q.1 Design a most economical trapezoidal section of a canal having the following data:

(a) Discharge of canal = 20 cumec

(b) Permissible mean velocity = 0.85 m/sec

(c) Bazin's constant K = 1.30.

(d) Side slope = $1\frac{1}{2}:1$

find also the allowable bed slope of canal.

Q.2 find the efficient c/s of a canal having the dischange 10 cumec. Assumed, bed slope 1 in 5000, N = 0.0025. C.V.R (m) = 1, full supply depth ~~sho~~ not to exceed 1.60m. & Side slope = 1:1.

* Design of Unlined Canal on Alluvial soil by Kennedy's Theory

⇒ A theory is produced by R.G Kennedy (Executive Engineer of Punjab)

Steps -

a) Critical velocity, $V_0 = 0.546 \times m \times D^{0.64}$

b) Mean velocity, $V = C \times \sqrt{RS}$

where, m = C.V.R, D = full supply depth in m.

R = hydraulic mean depth in m, S = bed slope as 1 in n.

The value of C is calculated by Kutter's formula.

$$C = \frac{23 + \frac{0.00155}{S} + \frac{1}{N}}{1 + \left(23 + \frac{0.00155}{S}\right) \times \frac{N}{\sqrt{R}}}$$

N ⇒ Rugosity coefficient.

(c) B/D ratio assumed b/w 3.5 to 12.

(d) Discharge ; $Q = A \times V$.

where A = C/S area in m^2, V ⇒ mean velocity in m/se.

(e) The full supply depth is fixed by trial to satisfy the ~~mean~~ value of 'm'. Generally trial depth is assumed b/w 1 to 2 m. If the condn not satisfied then assumed accordingly.

* Assumption Made in Kennedy's theory

a) The eddy current is developed due to ~~mud~~ the roughness of the bed

b) The quality of the suspended silt is proportional to the bed width.

c) It is applicable to those channels which are flowing through the bed consisting of sandy ~~soil~~ silt or same grade of silt as of in upper Bari Doab canal system.

Kennedy's Theory

Design Procedure

Case 1 : (Given Q, N, m and S)

1. Assume a trial value of D in metres.
2. Calculate the velocity V_0 from the eq^n.

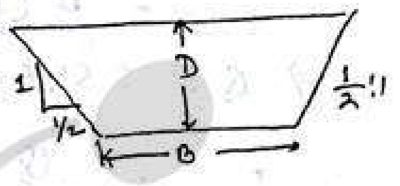
$$V_0 = 0.546\ m\ D^{0.64}$$

3. Get area of section A from the continuity eq^n:

$$A = \frac{Q}{V_0}$$

4. Knowing D & A, calculate the bed width B.

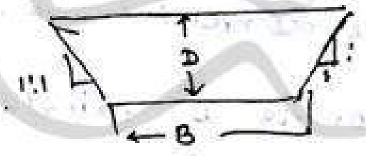
* For side slope $\frac{1}{2}:1$



$$A = BD + \frac{D^2}{2}$$

* B can be calculated.

* For side slope 1:1



$$A = (B+D)D$$

5. Calculate the perimeter & hydraulic mean depth

$$P = B + D\sqrt{5}$$

$$R = \frac{A}{P} = \frac{BD + D^2/2}{B + D\sqrt{5}}$$

6. Calculate the actual mean velocity of flow (V) from Kutter's eq^n.

$$V = C\sqrt{RS}$$

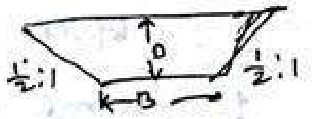
$$C = \frac{23 + \frac{1}{N} + \frac{0.00155}{S}}{1 + \left[\left(23 + \frac{0.00155}{S}\right) \times \frac{N}{\sqrt{R}}\right]}$$

* If V is same as V_0 then ans is B & D.
  If $V_0 < V$, increase the depth.
  If $V_0 > V$, decrease the depth

Case-2 Given Q, N, m & B/D ratio (from wood's table)

1. Calculate A in terms of D.

$\frac{B}{D} = x$ or $B = Dx$.



$A = BD + \frac{D^2}{2} = xD^2 + \frac{D^2}{2} = D^2(x+0.5)$

2. Calculate the V_0 in terms of D by Kennedy's eq^n.

$$V_0 = 0.546\, m\, D^{0.64}$$

3. Substitute the value of V_0 & A in continuity eq^n.

i.e $Q = A \times V_0$
$= D^2(x+0.5) \times 0.546 \times m \times D^{0.64}$

$\Rightarrow Q = 0.546 \times m \times (x+0.5)\, D^{2.64}$

$\therefore D = \left[\frac{Q}{0.546\,(x+0.5)}\right]^{\frac{1}{2.64}}$

Hence determine D.

4. Knowing D, calculate B & R

i.e $B = xD$

$R = \frac{BD + D^2/2}{B + D\sqrt{5}}$

5. Calculate the velocity V_0 from Kennedy eq^n.

$V_0 = 0.546 \times m \times D^{0.64}$

6. Knowing V_0 & R determine slope S. from Kutter's eq^n.

i.e $V = C\sqrt{RS}$, find S. value.

(Q1) Design an irrigation channel on Kennedy's theory to carry a discharge of 45 cumecs. Take $N = 0.0225$ & $m = 1.05$. The channel has bed slope of 1 in 5000.

(Q2) Design an irrigation canal to carry a discharge of 14 cumecs. Assume $N = 0.0225$, $m = 1$ & $B/D = 5.7$.

Ans ① $D = 2.2$ m, $B = 20.28$ m $\simeq 20.3$ m. ② $B = 9.73$ m, $D = 1.71$ m, $S = 1$ in 5100.

---

* Drawbacks in Kennedy's theory

1. Silt grade & silt charge were not defined.
2. Kennedy did not give any slope equation.
3. He aimed to find out only average regime condⁿ for the design of a channel.
4. Kennedy used Kutter's eqⁿ for the determination of the mean velocity which is got incorporated in the theory.
5. No account was taken of silt concentration & bed load.
6. Kennedy did not notice the importance of B/D ratio.

Lacey's Theory

- According to Lacey "Dimensions, width, depth and slope of a regime channel to carry a given discharge loaded with a given silt charge are all fixed by nature".

Regime conditions

A channel is said to be in regime when the condⁿ are:

1) The channel is flowing in unlimited incoherent alluvium of the same character as that transported.
2) Silt grade & silt charge are constant.
3) Discharge is constant.

Design Procedure

1. Calculate the silt factor $f = 1.76\sqrt{m_d}$
2. Compute velocity $V = \left(\frac{Qf^2}{140}\right)^{1/6}$
3. Determine area $A = Q/V$
4. Compute perimeter $P = 4.75\sqrt{Q}$.
5. Find out bed width B & depth D since A & P.

Assuming side slope $\frac{1}{2}:1$

Area $A = BD + \frac{D^2}{2}$

& perimeter $P = B + D\sqrt{5}$

Hence $D = \frac{P - \sqrt{P^2 - 6.944A}}{3.472}$; $B = P - 2.236D$

6. Calculate $R = \frac{5}{2}\frac{V^2}{f}$

Also ~~calculate~~ check calculate $R = \frac{A}{P} = \frac{BD + D^2/2}{B + 2.236D}$

- ~~BD~~ * Compare both R values.

7. Find the slope $S = \frac{f^{5/3}}{3340\, Q^{1/6}}$

Lacey's Regime Equations (fundamental)

① $V = \sqrt{\frac{2}{5}fR}$ — ①

② $Af^2 = 140V^5$

③ $V = 10.8\, R^{2/3} S^{1/3}$ (regime flow eq^n)

Regime slope eq^n.

$$S = \frac{f^{3/2}}{4980\, R^{1/3}}$$

$$S = \frac{f^{5/3}}{3340\, Q^{1/6}}$$

Derived relation (P-Q)

① $V^4 = \frac{4}{25}f^2R^2$, $f^2 = \frac{140V^5}{A}$ —②

$\Rightarrow f^2 = \frac{25V^4}{4R^2}$ —①

$\Rightarrow$ ~~$\frac{140V^5}{A}$~~ $= \frac{25V^4}{4R^2}$ $\Rightarrow$ ~~$140V^5$~~

$\frac{25V^4}{4R^2} = \frac{140V^5}{A}$

$\Rightarrow \frac{25V^5}{4R^2} \times A = 140V^5$

$\Rightarrow \left[\frac{25}{4R}\right]A = 140V$.

$\Rightarrow \frac{25A^2}{} = 140VA$ $\Rightarrow \frac{25}{4}P^2 = 140V$ ...

② Multiplying by V on both sides in eqⁿ ②

$$AVf^2 = 140V^6$$

$$\Rightarrow Qf^2 = 140V^6$$

$$\Rightarrow \boxed{V = \left[\frac{Qf^2}{140}\right]^{1/6}}$$

③ $R^2 = \frac{25}{4}\frac{V^4}{f^2}$ or $\boxed{R = \frac{5}{2}\frac{V^2}{f}}$

Example

Q. A channel section has to be designed for the following data.

Discharge $Q = 30$ cumecs

Silt factor $f = 1.00$

Side slope $= \frac{1}{2}:1$

Find the longitudinal slope.

Solⁿ 1. $f = 1.00$.

2. Velocity $V = \left(\frac{Qf^2}{140}\right)^{1/6} = \left(\frac{30\times1}{140}\right)^{1/6} = 0.773$ m/sec.

3. Area $A = \frac{30}{0.773} = 38.8$ sq m.

4. $P = 4.75\sqrt{Q} = 4.75\sqrt{30} = 26$m.

5. $D = \frac{P - \sqrt{P^2 - 6.944A}}{3.472} = \frac{26 - \sqrt{26^2 - (6.944 \cdot 38.8)}}{3.472} = 1.67$ m.

$B = P - 2.236D = 26 - 2.236\times1.67 = 22.26$ m.

6. Hydraulic mean Radius.

$R = \frac{5}{2}\frac{V^2}{f} = \frac{5}{2}\times\frac{1}{1}(0.773)^2 = 1.49$m - ①

Also $R = \frac{BD + D^2/2}{B + D\sqrt{5}} = \frac{1.67(22.26) + 1.67^2/2}{22.26 + 1.67\sqrt{5}} = 1.49$ m. - ②

Both are same. Checked.

7. Slope $S = \frac{f^{5/3}}{3340(Q)^{1/6}} = \frac{1}{3340(30)^{1/6}}$

$= \frac{1}{3340(1.764)} = \frac{1}{5880}$

Ans: Bed width is 22.26, depth is 1.67 m.

& slope is $S = \frac{1}{5880}$. (Ans).

Q Design a channel section with the following data.
(a) Full supply discharge = 10 cumec
(b) Mean dia of silt particles = 0.33 mm.
(c) Side slope = $\frac{1}{2}:1$
Also find the bed slope of channel.

Soln → silt factor, $f = 1.76\sqrt{0.33} = 1.0$

→ Mean velocity $V = \left(\frac{Qf^2}{140}\right)^{1/6} = \left(\frac{10\times1^2}{140}\right)^{1/6}$

$= 0.64$ m/sec

→ C/S area $A = \frac{Q}{V} = \frac{10}{0.64} = 15.62\,m^2$.

→ $P_w = 4.75\sqrt{Q} = 4.75\sqrt{10} = 15.02$ m.

→ $R = \frac{5}{2}\cdot\frac{V^2}{f} = \frac{5\times(0.64)^2}{2\times1} = 1.02$ m.

Check. $R = \frac{A}{P} = \frac{15.62}{15.02} = 1.03$ (correct)

→ Bed slope, $S = \frac{f^{5/3}}{3340\,(Q)^{1/6}} = \frac{(1)^{5/3}}{3340\times(10)^{1/6}} = \frac{1}{4902}$

C/S Area. $A = BD + \frac{D^2}{2}$

⇒ $15.62 = BD \times 0.5D^2$. —(1)

$P = B + \sqrt{5}D$

⇒ ~~15.02~~ $B = 15.02 - 2.24D$ — (2)

$$D = \frac{P - \sqrt{P^2 - 6.944A}}{3.472}$$

$$= \frac{15.02 - \sqrt{(15.02)^2 - 6.944\times15.62}}{3.472}$$

$\simeq 1.21$ m

$B = 15.02 - 1.21$ m $= 13.81$ m.

$$S = \frac{(1)^{5/3}}{3340\,(10)^{1/6}} = 2.03\times10^{-4}$$

$= 1$ in 4902 Ans

* Garret's Diagram

→ Garret's diagrams give the graphical method of designing the channel dimensions based on Kennedy's theory.

→ The original diagrams were prepared in F.P.S units, but they have been changed into M.K.S / S.I system.

→ The diagrams are shown in Plates 4.1 (a), (b) & (c).

The procedure adopted are

Note: The diagram has Discharge plotted on abscissa,
The left ordinate indicates slope.
The right ordinate indicates water depth in the channel & critical velocity V_0.

1. The Q, S, N, value of C.V.R are given for the channel to be designed
2. Find out the point of intersection of the given slope line & discharge curve. At this point of intersection, draw a vertical line intersecting the various bed width curves.
3. For diff. bed widths (B) the corresponding values of water depth (D) & Critical velocity (V_0) can be read on right ordinate.
   Each such pair of B & D satisfy Kutter's eq^n.
   So choose one such pair & determine actual velocity (V).
4. Determine the critical velocity ratio (V/V_0). ~~taking V as~~
5. If the value of C.V.R is not same as given in eq^n. repeat the procedure with other pairs of B & D.

Q. Design a channel section by Kennedy's theory from the following given data. (Internal question)

Discharge = 2828 cumecs.

Kutter's N = 0.0225

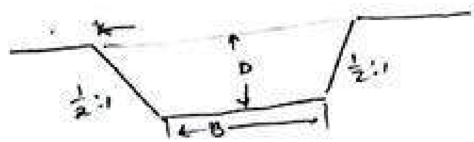
C.V.R (m) = 1.

Side slope = $\frac{1}{2}:1$

B/D = 7.6

Find also the bed slope of channel.

Soln



Given Q = 2828 cumecs.

1. $\frac{B}{D} = 7.6$

$\Rightarrow B = 7.6 \times D$

Area $= BD + \frac{D^2}{2}$

$= D^2(7.6 + 0.5)$

$= 8.1 D^2$

2. Critical velocity ratio $V_0 = 0.546 \times m \times D^{0.64}$

$= 0.546 \times 1 \times D^{0.64}$

3. Q from continuity eqn.

$Q = A \times V_0$

$= 8.1 D^2 \times 0.546 D^{0.64}$

$\therefore D = \left[\frac{2828}{0.546(7.6+0.5)}\right]^{\frac{1}{2.64}}$

$= 11.56$ m.

4. $B = 7.6 \times 11.56 = 87.83$ m

Hydraulic mean depth $R = \frac{(87.83 \times 11.56) + \frac{(11.56)^2}{2}}{87.83 + \sqrt{5} \times 11.56}$

$= 9.52$.

5. Critical velocity $V_0 = 0.546 \times 1 \times (11.56)^{0.64} = 2.61$ m/sec.

6. According to Manning's $V = \frac{1}{N} \times R^{2/3} \times S^{1/2}$

$\Rightarrow S^{1/2} = \frac{V \times N}{R^{2/3}} = \frac{2.61 \times 0.0225}{(9.52)^{2/3}}$

$\Rightarrow S = 1.71 \times 10^{-4} = 1$ in 5852.63

Topic:

Lining Of Irrigation Canals

* Lining of Irrigation Channels

* Necessity

(i) To minimize the seepage losses in canal.
ii) To increase the discharge by increasing the velocity.
iii) to prevent erosion of bed and side due to high velocities.
iv) to retard the growth of weeds.
v) to reduce maintenance of canal.

* Advantages of canal lining

→ It reduces the loss of water due to seepage & hence the duty in enhanced.
→ It controls the water logging hence bed effects of water-logging are eliminated.
→ It provides smooth surface. So, velocity of flow will increased.
→ Due to increased velocity the discharge capacity also increased.
→ It controls the growth of weeds on canal bed & canal sides.
→ It reduces the requirement of land width for canal. because smaller section can produce greater discharge.
→ It reduces the maintenance cost for the canals.

Disadvantages

1. The initial cost of canal lining is very high.
2. It is much ~~difficult~~ difficult for repairing the damaged section of lining.
3. It takes too much time to complete project work.
4. It becomes difficult; if the outlets are required to be shifted or new outlets are required to be provided because the dismantling of lined section is difficult

* Economics of Canal Lining

⇒ To recommend the canal lining in canal, it is necessary to ascertain the total annual cost incurred for lining can recovered within specified period or during the life time of the project.

⇒ If the annual benefits cost exceed the annual cost incurred, then lining should be considered economical.

1. Determination of Annual Cost

(a) Annual depreciation charge = $\frac{\text{Initial cost}}{\text{Useful Life}}$ = X (say)

(b) Average annual interest = $\frac{\text{Initial cost}}{2}$ x Rate of interest = Y (say)

Average annual cost of lining = (X + Y)

2. Determination of Annual Benefits.

(a) Saving by eliminating seepage loss = S_1

(b) Saving in maintenance works = S_2

(c) Other benefits (if any) = S_3.

Total benefit = $S_1 + S_2 + S_3$

* If the total benefit $(S_1 + S_2 + S_3)$ is found greater than the total cost (X+Y), then the implementation of lining in canal ma be considered as economical.

---

* Types of Lining

(a) Hard surface type Lining:

1. Cement concrete Lining
2. Precast concrete Lining
3. Brick Lining
4. Shotcrete Lining
5. Cement mortar Lining
6. Asphaltic Lining.
7. Stone, blocks or undressed stone Lining

(b) Earth type Lining:

8. Soil cement Lining, 9. Clay puddle Lining
10. Sodium carbonate Lining.

(c) Buried and protected membrane type Lining:

11. Prefabricated Light membrane Lining, 12. Road oil Lining.

Types of Lining

(a) Hard surface type lining:

1. CEMENT CONCRETE LINING:

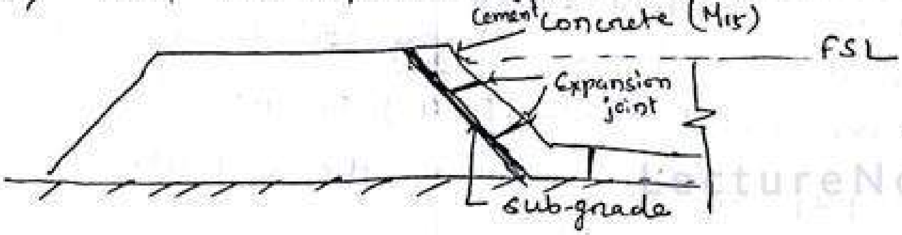
→ This lining is recommended for the canal in full banking.
→ The cement concrete lining (cast-in-situ) is widely accepted as the best impervious lining.
→ It can resist the effect of scouring and erosion very efficiently.
→ It eliminate completely growth of weeds.
→ The velocity of flow may be kept above 2.5 m/sec.

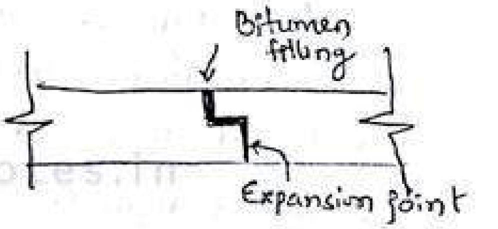
(a) Preparation of sub-grade:

→ The subgrade is prepared by ramming the surface properly with a layer of sand (about 15cm). Then, a slurry of cement and sand (1:3) is spread uniformly over the prepared bed.

(b) Laying of concrete:

→ The cement concrete of grade M15 is spread uniformly according to the desired thickness (thickness varies from 100mm to 150mm)
→ After laying, the concrete is tapped gently until the slurry comes on the top,
→ The curing is done for two weeks.
→ Then the expansion joints are provided at appropriate places





Advantages

i) Longer life than any other type.
ii) Most resistance to erosion.
iii) low maintenance changes.

Disadvantages.

i) Higher initial cost
ii) Greater possibility of temperature cracking.
iii) Skilled supervision & construction necessary.
iv) Less flexible.

2. Shotcrete lining:

→ In this type of lining, a mixture of cement and sand (1:4) is shot at the subgrade through a nozzle of cement gun.

→ The thickness of this type of lining varies from 2.5 to 6.5 cm. (generally 3.5 cm)

→ Shotcrete consumes large amount of cement.

→ Excavation, compaction, curing etc for a ~~shot~~ shotcrete lining are same as cement concrete lining.

3. Pre-cast concrete lining:

→ This lining is recommended for canal in full banking.

→ It consists of pre-cast concrete slab of size 60 cm × 60 cm × 5 cm which are set along the canal bank & bed with cement mortar (1:6)

→ A network of 6 mm dia rod is provided in the slab with spacing 10 cm c/c.

→ The proportion of ~~con~~ concrete is 1:2:4.

→ Expansion joints are provided at a suitable interval.

→ The joints are grouted with cement or is sealed with asphalt to prevent any seepage through joint.

4. Cement Mortar lining

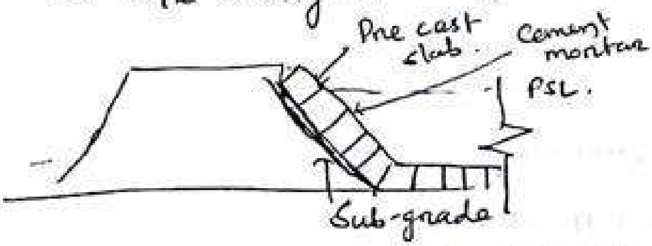
→ This type of lining is recommended for the canal fully in cutting where hard soil or clayey soil is available.

→ The thickness of the cement mortar (1:4) is generally 2.5 cm.

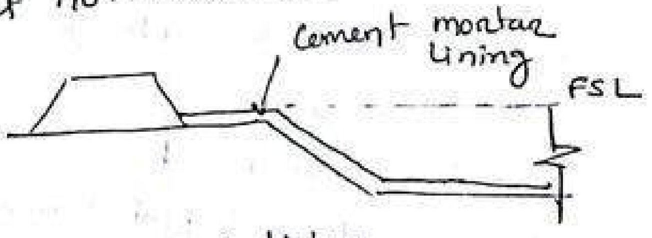
→ The subgrade is prepared by ramming the soil after cutting.

→ Then, over the compacted sub-grade, the cement mortar is laid uniformly.

→ The lining is impervious but not durable



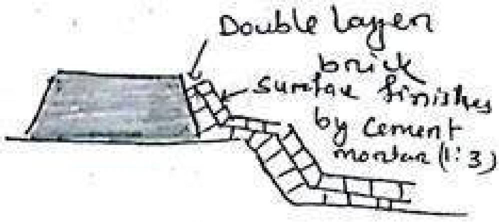
Pre-cast concrete ~~slab~~ lining



C.C. Lining

5. Brick lining

→ This lining is prepared by the double layer brick flat soling laid with cement mortar (1:6) over the compacted sub-grade.
→ The first class bricks should be recommended for the work.
→ The surface of lining is finished with cement plaster (1:3) the curing is done.
→ This is provided because
a) This is economical.
b) Work can be done very quickly.
c) Expansion joints are not required
d) Repair works can be done easily.
e) Bricks can be manufactured from the exavated earth near the site



Brick Lining

6. Asphaltic lining

→ This lining is prepared by spraying asphalt (i.e bitumen) at a very high temperature (about 150°C) on the subgrade to a thickness varies from 3mm to 6mm.
→ The hot asphalt when becomes cold forms a water proof membrane over the sub-grade.
→ this membrane is covered with a layer of earth & gravel.
→ The lining is very cheap & can control seepage of very effectively but can not control the growth of weeds.

earth type
7. Soil-Cement Lining

→ The Lining is prepared with a mixture of soil and cement.
→ The usual quantity of cement is 10 per cent of the wt. of dry soil.
→ The soil and cement are thoroughly mixed to get an uniform texture.
→ The Lining is efficient to control the seepage of water but cannot control the growth of weeds.
→ So this is recommended for small channels only.

8. Clay puddle lining:

→ Clay puddle is produced from clay by first exposing clay to weathering.

→ It is then mixed with water to bring it to saturation and is pugged throughly by trampling under man's or cattle's feet.

→ the thickness of lining is 30 cm.

→ It is then protected by a layer of earth material.

9. Sodium carbonate lining:

→ The mixture consists of clayey soil and sodium carbonate in a proportion of at least 10% clay & 6% sodium carbonate.

→ Thickness is kept as 10 cm.

→ This type of lining is used on small canal & water coarse is not durable

10. Stone block lining or Boulder lining

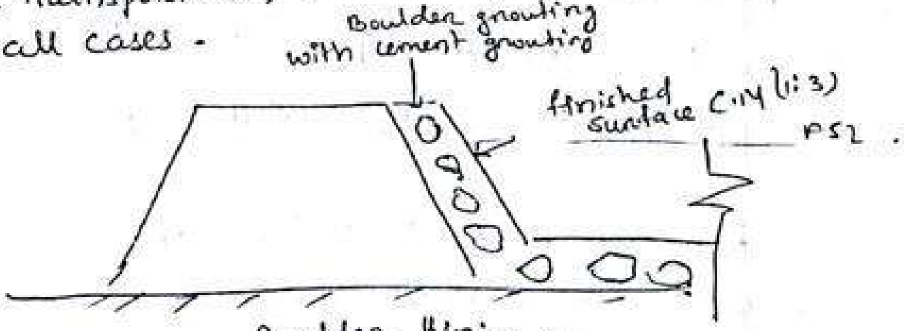
→ In hilly areas where the boulder/stone blocks are available this type of lining is recommended.

→ The boulders are laid in single or double layer maintaining the slope of the banks & the bed level of canal.

→ The joints of the boulders are grouted with cement-mortar (1:6)

→ The surface is finished with cement mortar (1:3) & curing is necessary.

→ The transportation cost is high so cannot be recommend for all cases.



Boulder lining.

11. Pre-fabricated light weight membrane:

→ They are matted fibres of asbestos or jute and is coated with asphalt.

→ It is laid on a smooth and prepared sub-grade, and is covered with a layer of earth material.

12. Bentonite and clay membrane:

→ This consists of bentonite or clay blanket 4 cm thick laid over a prepared subgrade, and covered with earth.

13. Road oil lining:

→ The road oil sprinkled on subgrade in a thickness of about 1.5 mm is sufficient enough to saturate subgrade to a depth of 8 cm.

→ The subgrade is then rolled so that oil enters the soil pores.

— X —

* Design of Lined Canal

→ The lined canal are not designed by use of Lacey's & Kennedy's theory because the section of the canal is rigid.

→ Manning's eqn is used for designing.

The design considerations are

a) The section should be economical (i.e C/s area should be maximum with minimum wetted perimeter)

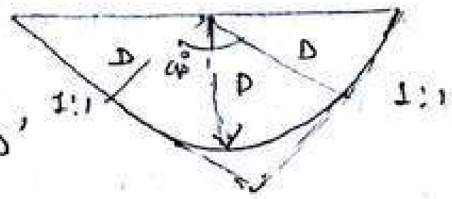
b) The velocity should be maximum so that C/s area becomes minimum.

c) The capacity of lined section is not reduced by silting.

* Design of Lined Canal :

Section of Lined Canal

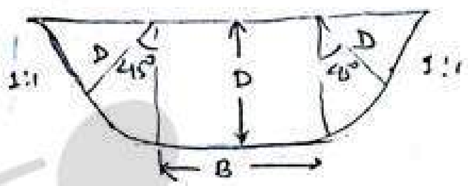
1. Circular Section : / triangular section.



→ The bed slope is circular with its centre at the full supply level & radius equal to the full supply depth 'D'

→ The sides are tangential to curve.

2. The Trapezoidal Section :



→ The horizontal bed is joined to the side slope by a curve of radius equal to full supply depth D.

Note :- For the discharge up to 50 cumec, the circular section is suitable.
For discharge above 50 cumec, trapezoidal section is suitable.

Design parameters . for circular section

Design parameters.	side slope 1:1	1.5 :1	1.25 :1
C/S area (A)	$1.785\ D^2$	$2.058\ D^2$	$1.925\ D^2$
wetted perimeter (P)	3.57 D	4.176 D	385 D
Hydraulic mean depth (R)	0.5 D	0.5 D	0.5 D
Velocity (V)	$\frac{1}{N} \times R^{2/3} \times S^{1/2}$	—	—
Discharge (Q)	A×V	—	—

Design parameters for trapezoidal section

Design parameters.	Side slope 1:1	1.5:1	1.25 : 1
C/S area (A)	$BD + 1.785\ D^2$	$BD + 2.058\ D^2$	$BD + 1.925\ D^2$
wetted peremeter (P)	B + 3.570 D	B + 4.176 D	B + 3.85 D
Hydrauli mean depth (R)	A/P	A/P	A/P
Velocity (V)	$\frac{1}{N} \times R^{2/3} \times S^{1/2}$	—	—
Discharge	A×V	—	—

* Free board

Sl.No	Type of canal	Discharge in cumec	Values of freeboard in m
1	Main & Branch canal	Q > 10 cumecs	0.75
2	Branch & Distributary	(i) Q < 10 cumec but > 5 cumec	0.60
		(ii) Q = 5.0 to 1.0 cumecs	0.50
3.	Minors	Q < 1.0 cumec	0.30
4.	Water courses	Q < 0.06	0.1 to 0.15

Problem

1. Design a lined canal to carry a discharge of 40 cumec. Assume bed width slope as 1 in 5000, N = 0.0225 & side slope 1:1.

Soln. Since discharge is less than 50 cumec so section is circular. ~~Area~~ Area A = 1.785 D^2

P = 3.57 D

D = full supply depth.

R = 0.5 D.

So $V = \frac{1}{0.0225} \times (0.5D)^{2/3} \times (0.0002)^{1/2}$ $\left[S = \frac{1}{5000} = 0.0002 \right]$

$= 0.38 D^{2/3}$

Again $Q = A \times V$

$\Rightarrow 40 = 1.785 D^2 \times 0.38 D^{2/3}$

$\Rightarrow D^{8/3} = 58.99$

$\Rightarrow D = 4.61$ m.

$V = 0.38 \times (4.61)^{2/3} = 1.05$ m/sec

$A = 1.785 \times (4.61)^2 = 37.93$ m²

$P = 3.57 \times 4.61 = 16.45$ m.

· Free board of 0.75 m. Total depth D = 4.61 + 0.75 m

= 5.36 m Ans

Q.2 Design a lined canal having following data.
(a) full supply discharge = 200 cumec.
b) side slope = 1.25 : 1
(c) Bed slope = 1 in 5000
(d) Rugosity coefficient = 0.018
(e) Permissible velocity = 1.75 m/sec.

Soln Since discharge is more than 50 cumec, the trapezoidal section will be acceptable,

from table 2 :

C/S $A = BD + 1.925 D^2$ —— (1)

$P_w = B + 3.85 D$ —— (2)

$A = \frac{Q}{V} = \frac{200}{1.75} = 114.28 \ m^2$

Again $V = \frac{1}{N} \times R^{2/3} \times S^{1/2}$

$1.75 = \frac{1}{0.018} \times R^{2/3} \times (0.0002)^{1/2}$

$R^{2/3} = 2.227$

$R = 3.32 \ m.$

$P = \frac{A}{R} = \frac{114.28}{3.32} = 34.42 \ m.$

from (1) $114.28 = BD + 1.925 D^2$ —— (3)

from (2) $34.42 = B + 3.85 D$ —— (4)

Multiplying Eqn (4) by D & deducting Eq(3) from it.

$34.42 D = BD + 3.85 D^2$

$(-) \ 114.28 = {}_{(-)}BD \ {}_{(-)}{+} 1.925 D^2$

$34.42 D - 114.28 = 1.925 D^2$

$\Rightarrow D = 13.47$ or 4.4 m.

when $D = 13.47$, $114.28 = B \times 13.47 + 1.925 \times (13.47)^2$

$B = -17.44$ (absurd)

when $D = 4.4$ m $\therefore 114.28 = B \times 4.4 + 1.925 \times (4.4)^2$

$B = 17.5$ m (acceptable).

full supply depth = 4.4 m   free board = 0.75 m.

Total depth = 4.4 + 0.75 = 5.15 m.   Bed width B = 17.5 m.

Ans

Losses of Water in Canals

During the passage of water from the main canal to the outlet at the head of the watercourse, water may be lost either by evaporation from the surface or by seepage through the peripheries of channels.

Types of losses are

1. Evaporation Loss:

→ The water lost by evaporation is very small i.e 2 to 3 percent of the total losses.

→ It depends upon temperature, wind velocity, humidity etc.

→ In summer season these losses may be more but not exceeds about 7% of total water.

2. Seepage loss:

There may be two different condⁿ for seepage
(i) Percolation (ii) Absorption

(i) Percolation:

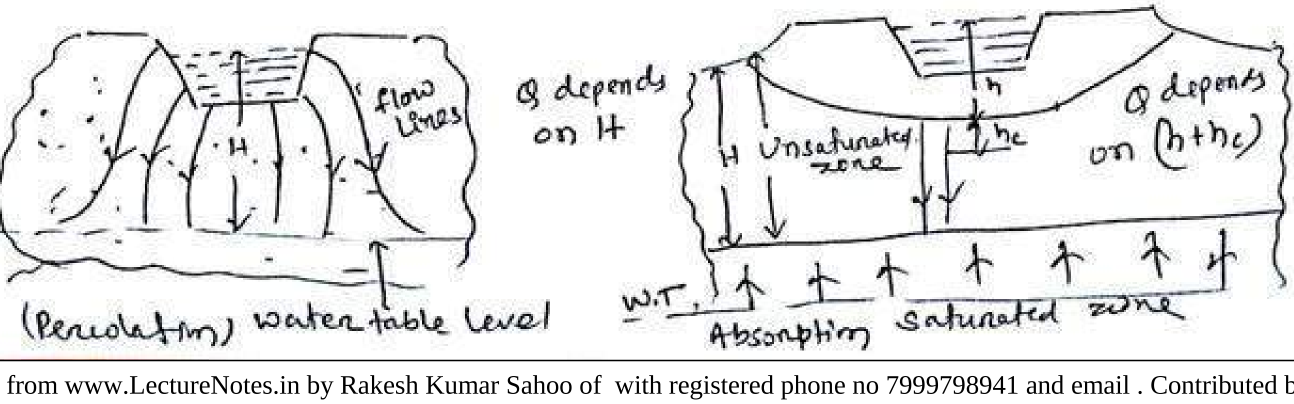
In percolation, there exists a zone of continuous saturation from the canal to the water-table & direct flow is established.

→ The loss of water depends upon the difference of the top water surface level of the channel & level of water table.

(ii) Absorption:

In absorption, a small saturated soil zone exists round the canal section & is surrounded by zone of decreasing saturation.

→ In this case, the rate of loss is independent of seepage head (H) but depends only upon the water head h (i.e distance b/w water surface level of canal & bottom of the saturated zone) plus the capillary head h_c.



Topic:

Reclamation Of Water Logged And Saline Soils

MODULE - II (5)

Reclamation of Water Logged and Saline Soils

Water logging

→ An agricultural land is said to be water-logged, when its productivity gets affected by the high watertable.

→ In agricultural land, when the soil pores within the root zone of the crops get saturated with the subsoil water the air circulation within the soil pores gets totally stopped.

→ This phenomenon is termed as water logging.

Causes of Water logging:

1) Over Irrigation : The excess water irrigated is responsible for water logging.

2) Seepage from canal : The seepage in case of canal in banking in low laying area is responsible for water table rises.

3) Inadequate Surface Drainag:
when the rainfall is heavy & there is no proper surface drainage then water logging will occurs.

4) Obstruction in natural water course:
If a bridge or culverts are constructed and no provision of sufficient discharge the this water will logged.

5) Nature of soil:
Soil having low permeability like black cotton soil the water retains in this type of soil cause water logging.

6) Topography of land:
If the agricutural land is flat, i.e no sloping then this leads to logging.

7) Poor Irrigation Management:
If the canal is kept open for long period unnecessarily, then this leads to water logging.

* Effects of Water Logging :

~~1.~~ ~~Gan.~~ 1. Salinization of soil :

→ Due to water logging the dissolved salts like sodium carbonate sodium chloride come to the surface of the soil.

→ When the water evaporates from the surface, the salt gets deposited.

→ This process is called salinization of soil.

→ But excessive concentration of salt make the land alkaline which will reduce ~~to~~ the yield of crop.

2. Lack of Aeration:

The crops requires some nutrients for their growth which is supplied by the ~~ox~~ air. But due to water logging there is no available of air or oxigen. So yield of crop will reduce.

3. Fall of Temperature:

→ Due to water logging soil temperature is lowered due to which the ~~bad~~ useful bacteria becomes very slow for plants so growth of plants will hampered.

4. Growth of weeds & Aquatic Plants.

Due to excess water the land is converted to marshy ~~to~~ land & weeds & aquatic plants are grown which will consume soil food in advance so crops will destroyed.

5. Diseases of crops:

Due to low temperature & poor aeration, the crops get some diseases which may destroy the crop.

6. Difficulty in Cultivation :

→ In water logged area ~~to~~ it is very difficult to [illegible] out the diseases which may destroy the crops or [illegible] the yield

* Control of water logging:

1) Lining of Canals & water courses:
→ Attempts should be made to reduce the seepage of water from the canals & water courses.
→ This can be achieved by lining them.

2) Reducing the Intensity of Irrigation:
In areas where there is a possibility of water-logging the intensity of irrigation should be reduced.

3) By introducing Crop-rotation:
Certain crops require more water and others require less water. In order to avoid water logging, a high water requiring crop should be followed by one requiring less water.

4) By Optimum Use of Water:
It is a known fact that only a certain fixed amount of water gives best productivity. Less than that & more than that reduce the yield.
So we should be aware about the requirement of water in the crop field.

5) By providing Intercepting Drains:
The intercept drains can prevent the seeping canal water from reaching ~~are~~ the water-logging area so it should be provided.

6) By provision of an Efficient Drainage System:
An efficient drainage system should be provided in order to drain away the storm water & excesss irrigation water.

7) By adopting Consumptive Use of Surface & Subsurface water.
The introduction of lift irrigation to utilize ground water helps in reducing the water logging.

* Reclamation of saline and alkaline land :

→ Land reclamation is a process by which an unculturable land is made fit for cultivation.

→ Saline & water logged lands gives very less crop yields and almost unfit for cultivation.

→ The following are the methods of land reclamation;

(1) Leaching :

→ Leaching is a process for reclamation of the saline soil.

→ In this process, the agricultural land is flooded with water to a depth of about 20-30 cm.

→ The salt deposits on the surface are dissolved.

→ Some portion of salt is then drained off through the sub-soil system & some portion is ~~removed~~ removed by surface drainage system.

→ This operation is repeated several times at specific interval.

(2) Addition of Chemical Agent :

→ For improving the alkaline soil a chemical like gypsum is generally added with irrigation water.

→ The gypsum neutralises the alkaline effect of the soil and yield of crop is increased.

→ The application of gypsum is not necessary every year.

(3) Addition of Waste Products :

→ Waste product like ground nut shells, saw dust etc are added to the alkaline soil & these are very effective in removing the salinity of the soil.

→ The distillary waste also found every ~~ef~~ effective in removing the ~~salt~~ salinity of soil.

(4) Surface Drainage:

Proper surface drainage should be provided in the agricultural land so that the water does not accumulate for long time.

The surface drains also help in draining the saline water in case of leaching operation.

(5) Sub-surface Drainage:

The subsurface drainage system on the ~~agricul~~ agricultural land should also be provided for draining the excess water from the root zone.

It also helps in draining of saline water in case of ~~leac~~ leaching operation.

(6) Excavation of Ponds:

→ Ponds are excavated at suitable places within the water logged area then the excess run-off is collected in the ponds.

→ The pore water flows towards the pond thus saturation in the root zone of crops is reduced.

→ These ponds control the water logging in rainy season & in dry season, the water is utilized for lift irrigation.

(7) Pumping of Water from Tube Wells:

→ Some tube wells (deep or shallow) are sunk within the water logged area.

→ The water is pumped contineously from the tube wells.

→ Initially this water is discharged to a river or ponds.

→ When the reclamation of the land is complete, the water may be utilised for lift irrigation.

—

Topic:

Types Of Cross-Drainage Works And Diversion Head Works

CROSS DRAINAGE WORK

→ A cross drainage work is a structure which is constructed at the crossing of a canal and a natural drain or river, so as to dispose of drainage water without interrupting the continuous canal supplies.

→ Cross drainage work is a construction of suitable structure at the cross crossing point for easy flow of water of the canal & drainage.

+ Types of Cross - Drainage Work:

(1) By passing the canal over the drainage
- (i) By an Aqueduct
- (ii) By a syphon aqueduct

(2) By passing the canal below the drainage
- (i) By a super-passage
- (ii) By a syphon

(3) By passing drain through canal
- (i) By a level crossing
- (ii) By inlets and outlets.

~~(1) Aqueduct~~ :

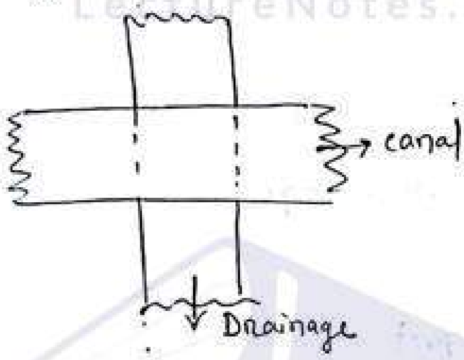
* Selection of type of Cross-drainage work

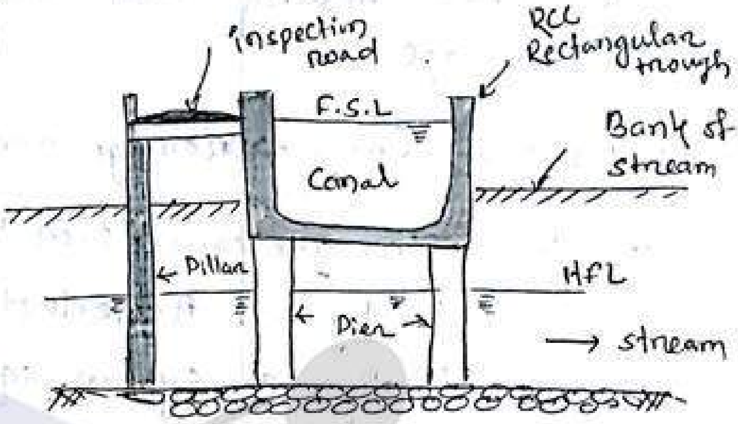
(1) Relative bed levels :
(2) Availability of suitable foundation
(3) Economical consideration
(4) Discharge of the drainage
(5) Construction problems

(1) Aqueduct:

→ In these works, the canal is taken over the natural drain such that the drainage water runs below the canal ~~either~~ freely.

→ When the HFL of the drain is sufficiently below the bottom of the canal, so that the drainage water flows freely under gravity, the structure is known as Aqueduct.

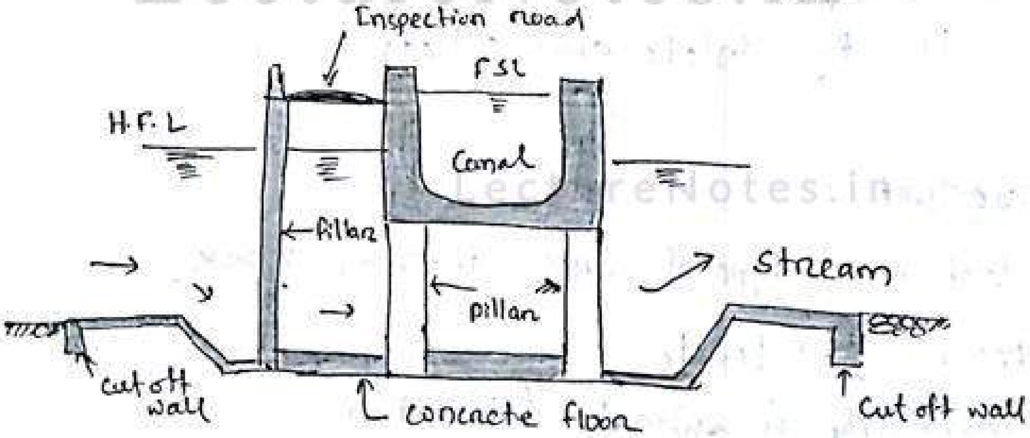




Aqueduct

(2) Syphon Aqueduct:

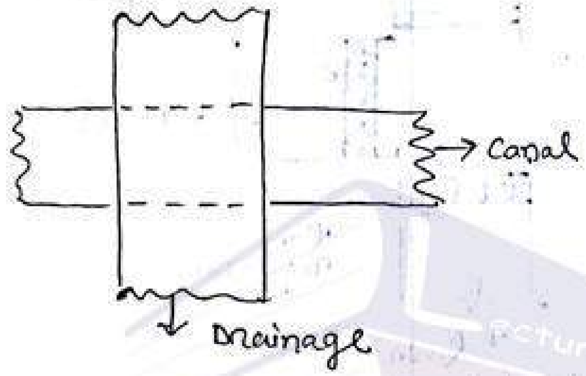
If the HFL ~~lo~~ of the drain is higher than the canal bed and the water passes through the aqueduct barrels under syphonic action, the structure is known as syphon aqueduct.

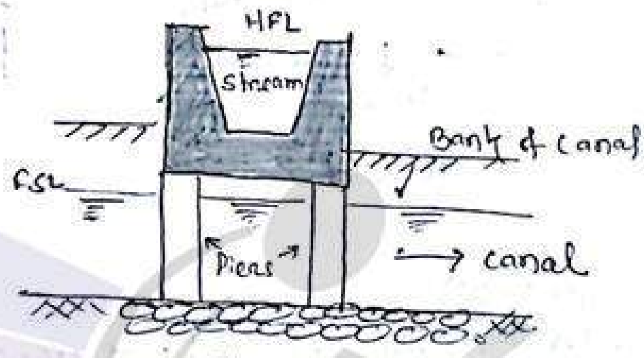


Syphon Aqueduct.

3. Super Passage:

→ In these case, the drain is taken over the canal such that the canal water runs below the drain, freely
→ When the FSL of the canal is sufficiently below the bottom of the drain trough so that the canal water flows freely under gravity. the structure is called as super-passage.





Super passage

(4) Syphon Super Passage:

→ If the FSL of the canal is sufficiently above the bed level of the drainage trough, so that the canal flows under syphonic action under the trough. the structure is known as a canal syphon.

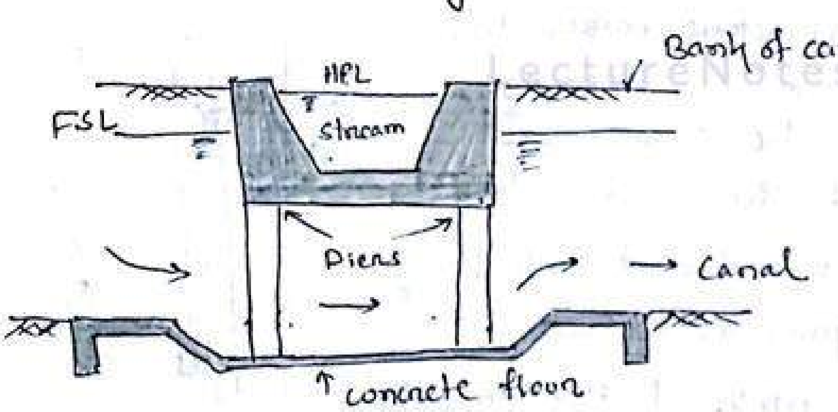
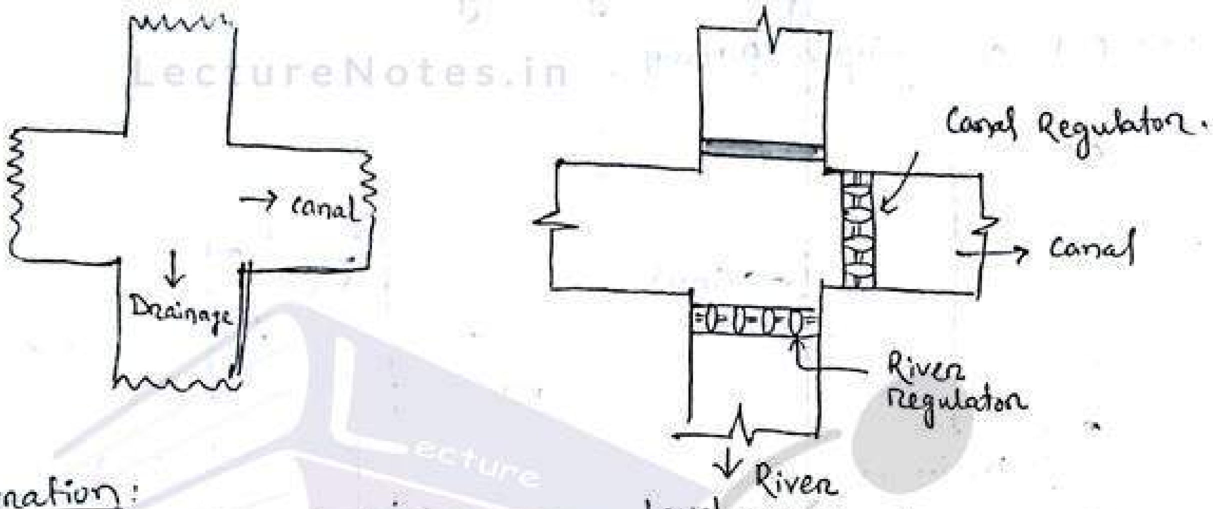


Fig Syphon super passage.

(5) Level Crossing:

→ In this type of cross-drainage work, the canal water and drain water are allowed to intermingle with each other.

→ A level crossing is generally provided when a large canal and a huge drainage approach each other practically at the same level.



Level Crossing:

Operation:

→ In dry season, when the discharge of the drainage is very low, the drainage regulator is kept closed and the canal water is allowed to flow as usual.

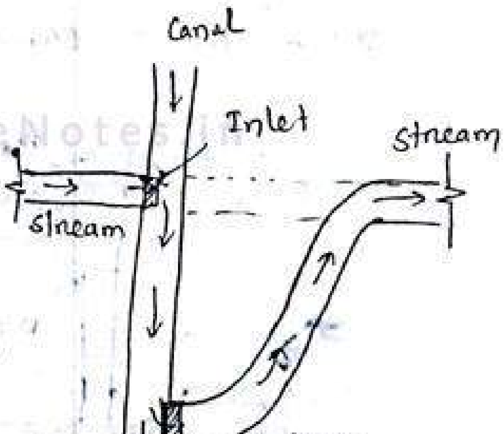
→ In rainy season, when the discharge of the drainage is very high the regulator is kept completely open & canal regulator is operated according to requirement.

(6) Inlet & Outlet:

→ An inlet is a structure constructed in order to allow the drainage water to enter the canal and get mixed with the canal water.

→ An outlet is provided to discharge the ~~surf~~ surplus water.

→ The bed and banks of the irrigation channel b/w inlet & outlet points should be protected by stone pitching.



Inlet & Outlet.

—— x ——

DIVERSION HEAD WORK

→ The works, which are constructed at the head of the canal, in order to divert the river water towards the canal, so as to ensure a regulated contineous supply of silt-free water with a certain minimum head into the canal are known as Diversion Head works.

* Object of Diversion Head Works.

(a) To raise the water level at the head of canal.

(b) To form a storage by constructing dykes on both the banks of river so that water availability is throughout the year.

(c) To control the entry of silt into the canal.

(d) To control the fluctuation of water level in the river during different seasons.

* Selection of site for Diversion Head Works:

→ At the site, the river should be straight & narrow.

→ The river bank should be well defined.

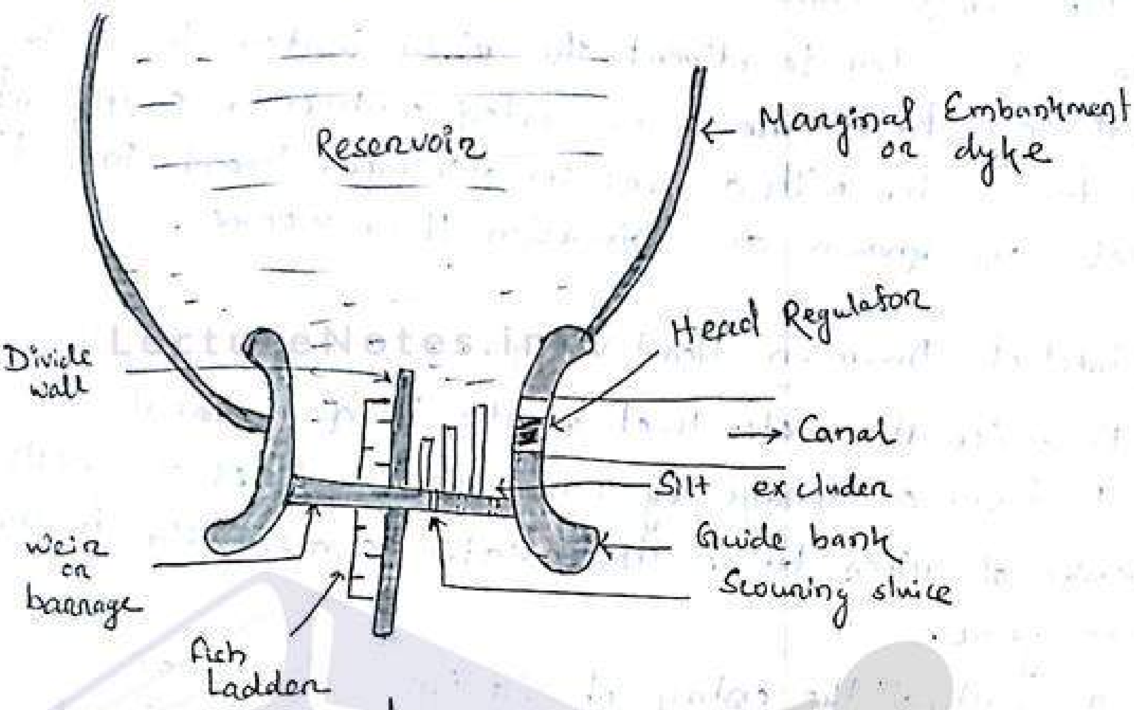
→ The valuable land should not be submerged when the weir or barrage is constructed.

→ The site should be easily accessible by roads or railways.

→ The elevation of the site should be much higher than the area to be irrigated.

→ The material of construction should be available near the site.

* Layout of a Diversion Head works.



: Diversion Head Work :

* Components parts of Diversion Head works :

1. Weir or barrage
2. Divide wall
3. Scouring sluice or under sluice.
4. Fish ladder
5. Canal head regulator
6. Silt excluder
7. Guide bank
8. Marginal embankment or Dyke.

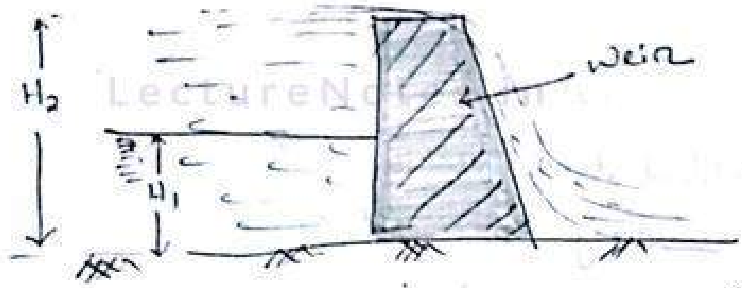
① Weir or Barrage :

(a) Weir :
→ When the bed level of canal is at higher than the river level then the water can not be diverted towards the canal.

→ So as to raise the water level an obstruction is constructed which is called as weir.

→ In weir most of the water is obstructed by ~~the~~ raising the crest.

→ It may be constructed with masonry or concrete

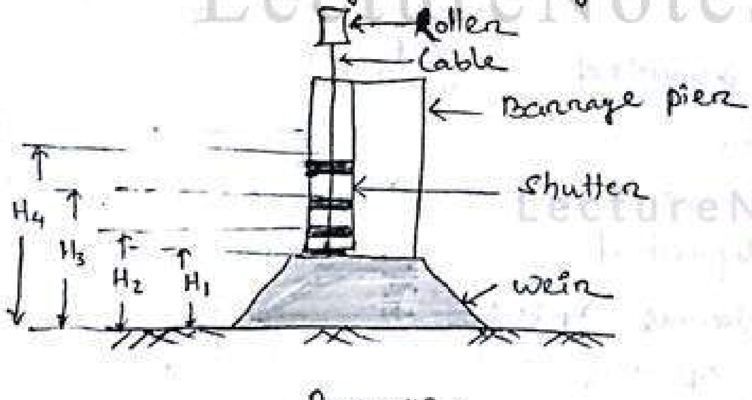


→ Here the water level is raised from H_1 level to H_2 level.

(b) Barrage:

→ When the water level on the up stream side of the ~~river~~ weir is required to be raised to different levels at different times, then the barrage is constructed.

→ Barrage is an arrangement of adjustable gates or shutters etc. by operating the adjustable gates.



Barrage.

→ Here the water level can be raised by shutter.

2. Divide Wall :

→ The divide wall is a long wall constructed at right angles to the weir or barrage. ~~ab~~ may be by stone masonry or cement concrete.

→ On ~~up~~ U/s side the wall is extended upto canal cover & on D/s it is extended upto launching apron.

Functions

→ To form still water pocket at the canal head so that the silt can be settled down ~~ab~~ & later which can be cleaned through ~~so~~ scouring sluice from time to time.

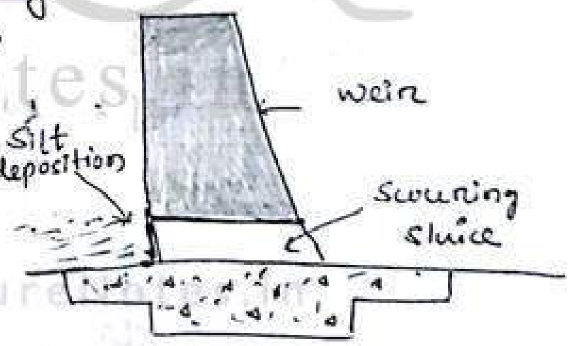
→ It controls the eddy current / cross current in front of canal head

→ Provides straight approach in front of canal head.

→ It resist the overturning effect of the weir/barrage caused by pressure of water.

(3) Scouring Sluices or Under Sluices :

→ The scouring sluice are the opening provided at the base of the weir or barrage.



→ These openings are provided with adjustable gates.

→ Normally gates are kept closed, so that the silt get deposited.

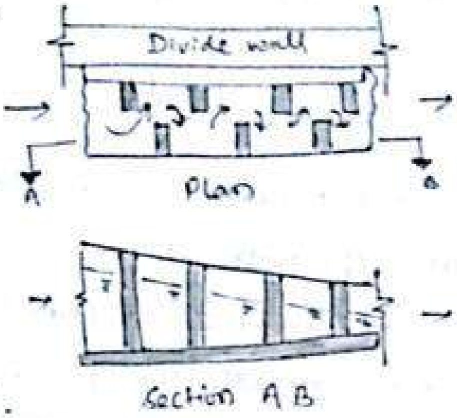
→ When silt deposition become appreciable the gates are ~~opening~~ opened and it is agitated.

→ The muddy water flows towards D/s side.

→ The gates are then closed.

→ But at the period of flood, the gates are kept opened.

(4) Fish Ladder :



Fish ladder

→ The fish ladder is provided just by the side of the divide wall for the free movement of fishes.

→ The tendency of fish is to move from upstream to downstream in winters & from downstream to upstream in monsoons.

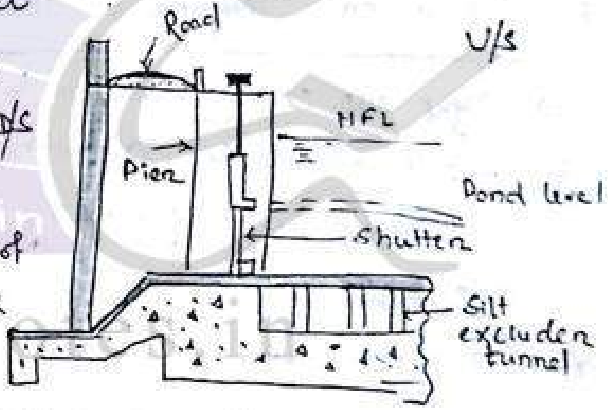
→ This movement is essential for survival.

→ So fish ladder is provided.

→ In the fish ladder, the baffle walls are constructed in a zigzag manner so that the velocity of flow does not exceed 3m/sec.

(5) Canal Head Regulator :

→ A structure which is constructed at the head of the canal to regulate flow of water is known as D/S canal head regulator.

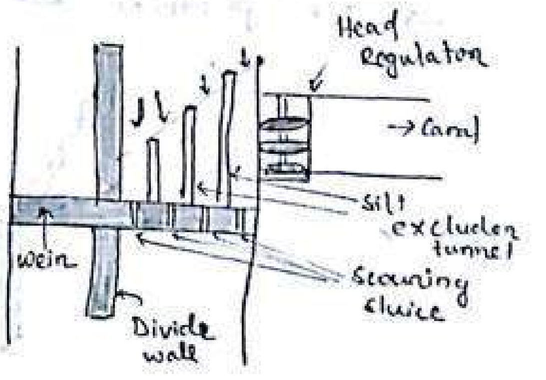


→ It consist of no. of piers having no of tiers on which the adjustable gates/ shutters are placed.

→ The gates are operated from top by suitable mechanical device.

→ Again some piers are constructed on D/s side for the support of roadways.

(6) Silt Excluder :



→ The heavy silt cause sedimentation in the pocket. So to eliminate the suspended heavy silt, the silt excluder is provided.

→ It consists of a series of tunnels starting from the side of the head regulator upto divide wall.

→ The suspended heavy silt carried by the water enters the silt excluder tunnels and passes out through the scouring sluices.

(6) (7) Guide Bank:

→ Guide bank is an earthen embankment with curved heads on both side..

→ The upstream curved head extends upto 1.5 L & D/s curved head extends up to 0.25L from centreline of the barrage, where L is distance between abutments:

* The Guide bank serves following purposes:

→ It protects the barrage from the effect of scouring & erosion.

→ It provides a straight approach towards the barrage.

→ It controls the tendency of changing the course of the river.

→ It control the velocity of flow near the structure.

(8) Dyke or Marginal Embankment:

→ Dyke are earthen embankment which are constructed parallel to the river bank on both sides.

→ The top width is generally 3m to 4m.

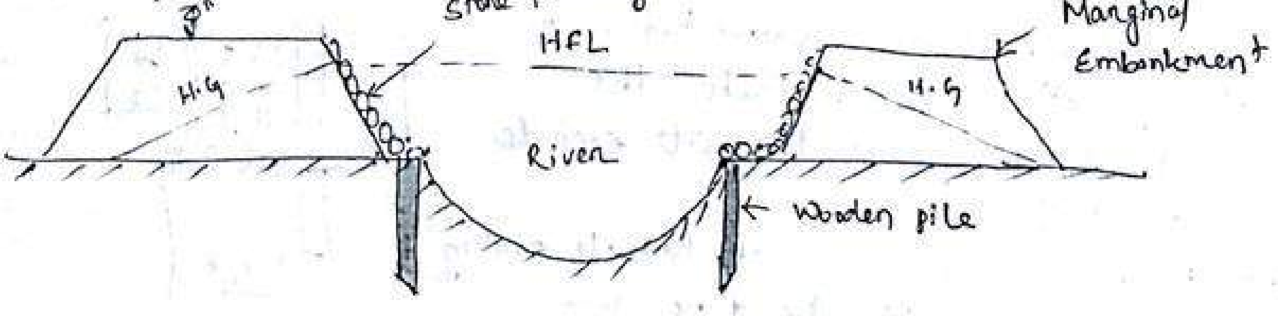
→ Side slope of river side is $1\frac{1}{2}:2$.

* The dyke serves following purposes:

→ It retains the flood water or storage water within a ~~specif~~ specified section.

→ It protects the towns & villages from devastation during heavy flood.

→ It protects ~~vall~~ valuable agricultural lands.



Topic:

Design Of Weirs And Barrages

Design of Weir & Barrages

→ The subsurface flow of water plays an important role for the stability of hydraulic structures like weir or barrage.

→ The seepage water exerts uplift pressure on the foundation.

→ To counter balance this uplift force, neccssary measures should be taken.

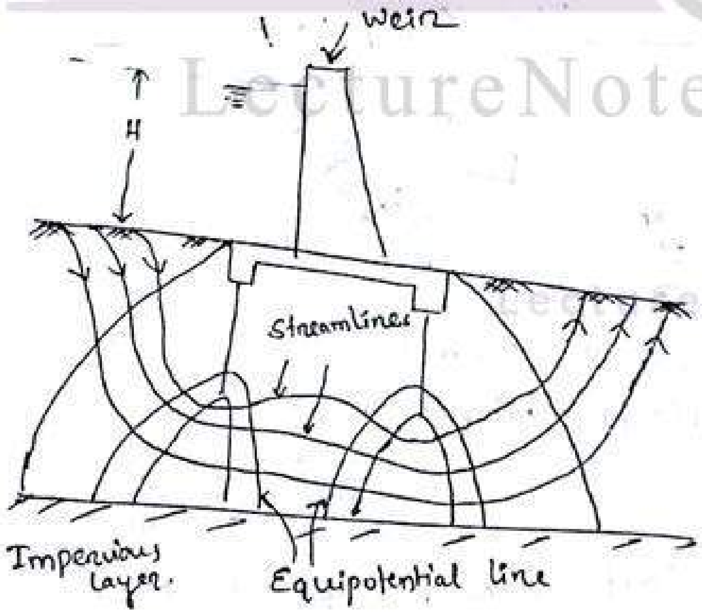
Streamline:

The path along which the sub-surface water flows through the soil indicates the streamline.

Equipotential Lines:

Every streamline possesses a certain head H (i.e the depth of water on upstream side), when it just enters the soil. This head goes on decreasing as it travels towards the downstream & ultimately becomes zero.

→ If these height are joined, then a curve is obtained which is known as equipotential line.



Flow Lines

~~* Causes of Failure of Weir or Barrage~~

* Exit Gradient :

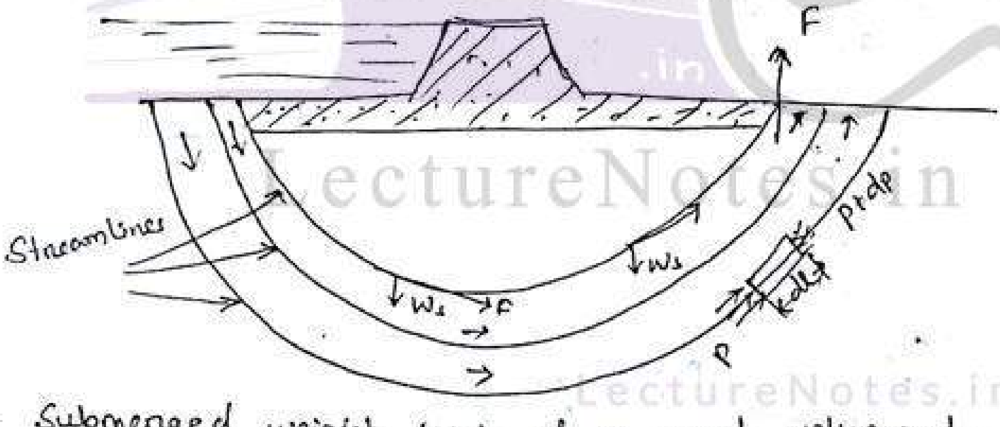
→ The seepage water exerts a force at each point in the direction of flow and tangential to the streamline.

→ For stabilization, the upward component of this force should be counterbalanced by the submerged weight of soil grain.

→ This force has maximum disturbing tendency at the exit end, because the direction of this force at the exit point is vertically upward.

→ The disturbing force at any point is proportional to the gradient of pressure of water at that point (i.e dp/dl)

→ This gradient pressure of water at the exit end is called as exit gradient.



→ Submerged weight (W_s) of a unit volume of soil is

$$W_s = \gamma_w (1-n)(G-1)$$

where, γ_w → unit. wt. of water
G → sp. gravity of soil
n → porosity of soil.

For critical cond^n.

$$F = W_s$$

when F → upward disturbing force ($\frac{dp}{dl}$)

$$\frac{dp}{dl} = W_s$$

$$\Rightarrow \gamma_w \frac{dh}{dl} = \gamma_w (1-n)(G-1) \Rightarrow \frac{dh}{dl} = (1-n)(G-1)$$

→ Under critical condⁿ, the critical exit gradient is equal to $(1-\eta)(G-1)$.

→ For most river sand

$G = 2.65$

$\eta = 0.4$

So value of critical exit gradient

$= (1-0.4)(2.65-1)$

$= 0.6 \times 1.65$

$= 0.99 \approx 1.0$

* Hence, an exit gradient equal to $\frac{1}{4}$ to $\frac{1}{5}$ of the critical gradient means that an exit gradient equal to $\frac{1}{4}$ to $\frac{1}{5}$ has to be provided for keeping the structure safe against piping.

* Types of Weir:

The following are diff. types of weirs.

(a) Masonry weir.

(b) Rock-fill weir

(c) Concrete weir.

(a) Masonry weir:

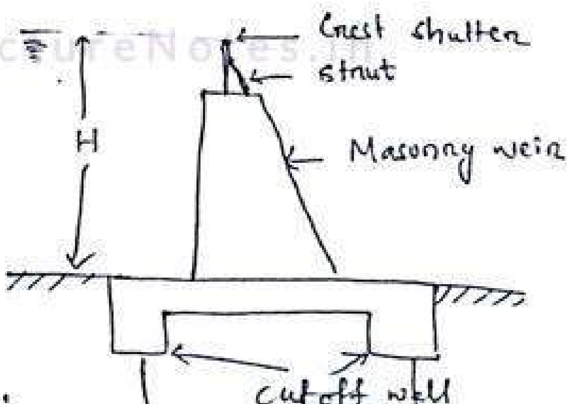
→ Masonry weir is constructed over the impervious floor.

→ Cut-off walls are provided at both sides of floor.

→ Sheet piles are provided below cutoff walls.

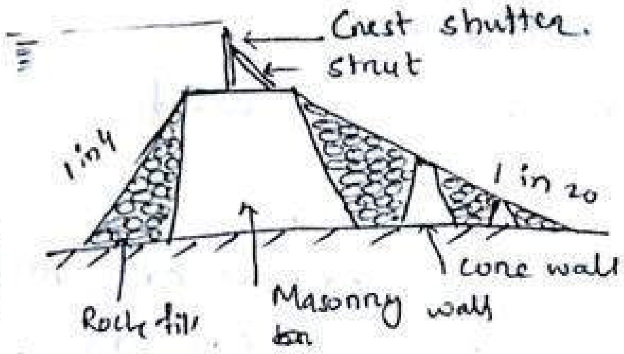
→ The crest shutter are provided to raise the water level if required.

→ The shutters are dropped down during flood.



(2) Rock-fill weir:

→ It consist of masonry wall which is provided with adjustable crest shutters.



→ The U/s rock fill is constructed with boulder forming slope of 1 in 4 and grouted with cement mortar.

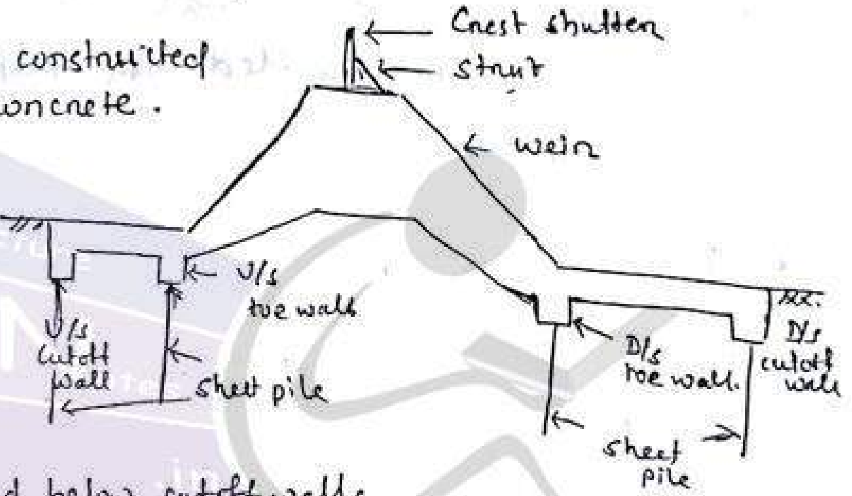
→ The downstream sloping consist of core walls and boulder grouted with cement mortar maintaining a slope of 1 in 20.

(3) Concrete weir:

→ Now-a-days, the weir is constructed with reinforced cement concrete.

→ The impervious flood & weir are made monolythic.

→ The cutoff walls are provided at the U/s & D/s end of floor.



→ Sheet piles are provided below cutoff walls.

→ The crest shutter are also provided which are dropped down during flood.

* Causes of failure of Weir / Barrage on Permeable Foundation:

The combined effect of subsurface flow and surface flow may cause the failure of weir / Barrage.

1. Failure due to Subsurface flow:

(a) By piping or undermining:

→ The water from the U/s side contineously percolates through the bottom of the foundation and emerges at the down stream end of the weir/barrage floor.

→ The force percolating water may lift up the soil particles.

→ This leads to increased porosity of the soil by progressive removal of soil from beneath the foundation.

→ The phenomenon is known as failure by piping or undermining.

(b) By uplift pressure:

→ The percolating water exerts an upward pressure on the foundation of the weir / barrage.

→ If this uplift pressure is not counterbalanced by the self weight of the structure, it may fail by rapture.

(2) Failure By Surface flow:

(a) By hydraulic Jump:

→ When the water flows with a very high velocity from crest of weir, then hydraulic jump developed which causes a suction pressure or negative pressure on the D/s side which acts as uplift pressure.

→ If the thickness of impervious floor is not sufficient then structure fails by rapture.

(b) By scouring:

→ During flood the gates are kept open & water flows with high velocity which results in scouring in d/s side & may fails by shearing.

* Precautions Against Failure:

(a) The length of the impervious layer should be carefully designed so that the path of percolating water is increased consequently reducing the exit gradient.

(b) Sheet piles should be provided on U/s & D/s to reduce the uplift pressure

(c) The thickness of impervious floor should be such that weight of floor is to counterbalance the uplift pressure.

(d) Deep foundation like well foundation should be provided for the barrage piers.

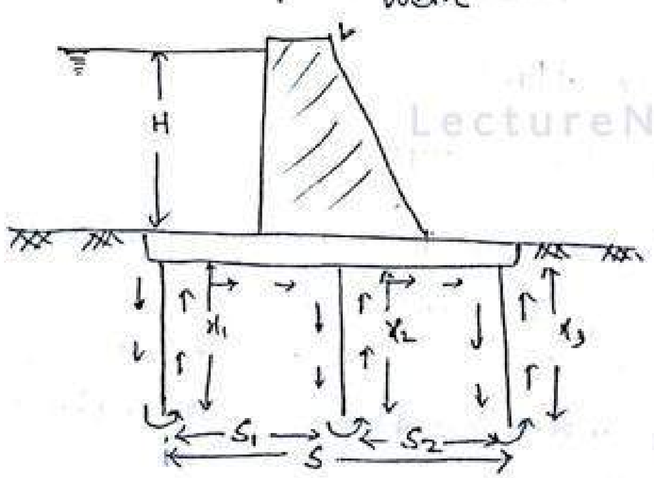
* BLIGH'S CREEP THEORY:

→ Bligh's creep theory states that the percolating water creeps along the profile of the bottom of the hydraulic structure which is contact with the subsoil.

→ The path traced by the percolating water is known as creep length.

→ The loss of head per unit creep length is known as hydraulic gradient, which is constant throughout it's passage.

→ loss of head is proportional to creep length.



Creep length

Let H = depth of water on U/s side

S = length of impermeable floor

x_1, x_2, x_3 = length of sheet piles.

. Then length of creep $= S + 2x_1 + 2x_2 + 2x_3$.

Hydraulic gradient per unit creep length $= \frac{H}{L}$

$$= \frac{H}{S + 2x_1 + 2x_2 + 2x_3}$$

* The reciprocal of hydralic gradient i.e $\frac{L}{H}$ is known as Bligh's creep co-efficient (C).

$\therefore \quad C = \frac{L}{H} \Rightarrow \boxed{L = C \cdot H}$

or $\boxed{\frac{H}{L} = \frac{1}{C}}$

(a) Safety Against piping:

The creep length should be sufficient to have safe hydraulic gradient i.e $\boxed{\frac{H}{L} = \frac{1}{C}}$.

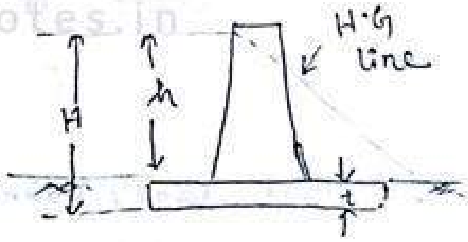
According Bligh's creep theory $\frac{H}{L} \leq \frac{1}{C}$, there will be no danger of piping.

(b) Safety Against Uplift Pressure:

For equilibrium the uplift pressure must be counterbalanced by self weight of floor.

$$\boxed{\gamma_w H = \gamma_w G \cdot t}$$

where. γ_w = unit wt. of water.
H = ordinate of H.G line from floor
G = sp.gr. of material.
t = thickness of floor.
h = ordinate of H.G from top floor.



$\therefore \quad H = G t$

$\Rightarrow H - t = Gt - t$

$\Rightarrow h = t(G-1) \quad [h = H - t]$

$\Rightarrow \boxed{t = \frac{h}{G-1}}$

Considering FOS $\frac{4}{3}$. Floor thickness $\boxed{t = \frac{4}{3} \cdot \frac{h}{G-1}}$.

* Limitation of Bligh's Creep Theory

→ There is no distinction b/w horizontal & vertical creep.
→ There is no significance of exit gradient.
→ The assumption that the loss head is proportional to creep length may not be true.
→ There is no distinction between the short & long sheet piles.

* Lane's Weighted Creep Theory :

→ Lane on the basis of ~~bligh~~ his analysis carried out on about 200 dams all over the world, stipulated that the vertical creep is less effective in reducing uplift than the vertical creep.
→ So he suggested a weightage factor of $\frac{1}{3}$ for the horizontal creep, as against 1.0 for vertical creep.

$$L_L = (x_1 + x_1) + \frac{1}{3} S_1 + (x_2 + x_2) + \frac{1}{3} S_2 + (x_3 + x_3)$$

$$= \frac{1}{3}(S_1 + S_2) + 2(x_1 + x_2 + x_3)$$

$$\boxed{L_L = \frac{1}{3} S + 2(x_1 + x_2 + x_3)}$$

→ To ensure safety against piping, the creep length L_L must not be less than $C_1 H_L$. ~~where H_L is the~~
where H_L is the head causing flow
C_1 is Lane's creep coefficient.

→. But Lane's theory is practically nowhere used & is having only a theoretical importance.

* Khosla's Theory:

→ Since 1910 the hydraulic structure were designed on the basis of Bligh's creep theory.

→ But some structure got badly affected because of undermining.

→ Further investigation were made by Dr. A. N. Khosla and detected the actual pressures acting and deduced the rational method of solution of subsurface flow problem is known as Khosla Theory.

Considerations of Khosla Theory:

(a) The outer sheet piles are more effective then the intermediate piles

(b) The outer face of sheet pile is more effective than inner face.

(c) If the intermediate piles are shorter than the outer piles, then these are not effective.

(d) Deep vertical cut off (i.e sheet pile) at the downstream end of the impervious floor prevents the undermining more effectively.

→ From the flow pattern below the base of the structure on permeable soil, the distribution of uplift pressure & the critical exit gradient are determined.

→ Depending on the various complex treatments following components are determined.

(a) Length of horizontal floor.

(b) Thickness of floor

(c) Depth of sheet piles on U/s & D/s side.

(d) Design of protective work like ~~launi~~ launching apron, ~~loo~~ loose talus, inverted filter etc

(e) Exit Gradient.

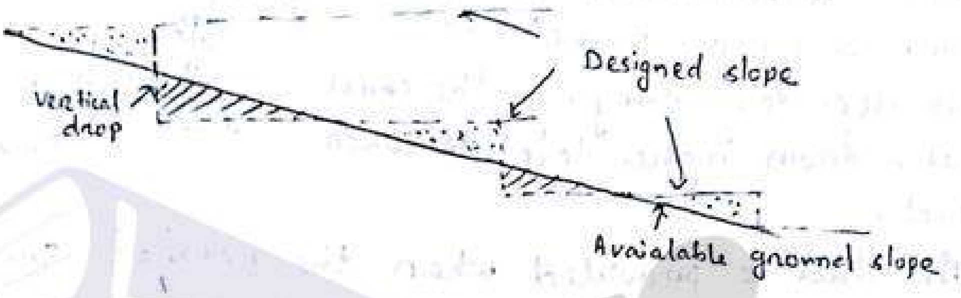
Topic:

Canal Falls

CANAL FALL (9)

Whenever a available natural ground slope is steeper than the designed bed slope of the channel, the difference is adjusted by constructing vertical 'falls' or 'drops' in the canal bed at suitable intervals.

Such a drop in a natural canal bed will not be stable & therefore in order to retain, the structure is constructed which is called as canal fall or a canal drop.

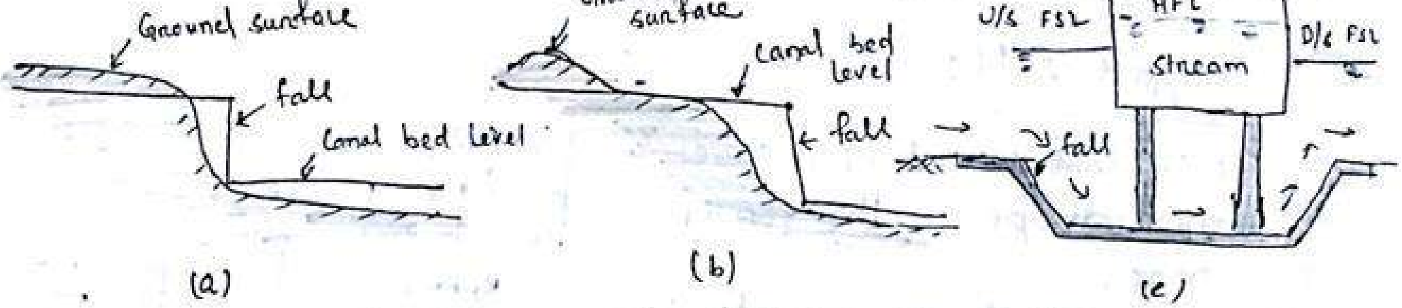


* Necessity of Canal Falls

(a) When the slope of ground suddenly changes to steeper slope it requires excessive earth work to maintain the slope. So to avoid the excessive earth work in filling canal fall is provided.

(b) When the slope of the ground is more or less uniform & slope is greater than permissible bed slope, then fall is provided

(c) In cross-drainage work, when diff. b/w bed level of canal & that of drainage is small, then it is necessary to carry the canal water below the stream or drainage. So fall is provided.

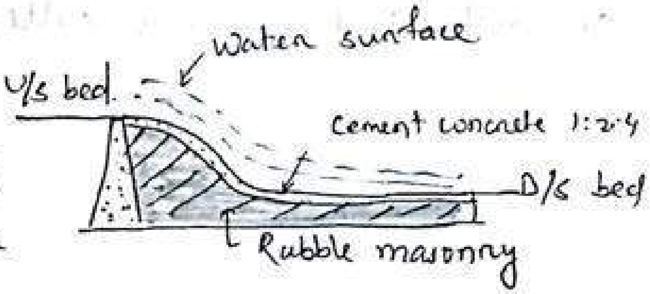


Types of fall:

1. Ogee fall
2. Rapid fall
3. Stepped fall
4. Trapezoidal Notch fall
5. Vertical drop fall or sarda fall
6. Glacis fall
7. Montague type fall
8. Inglis type fall.

① Ogee fall:

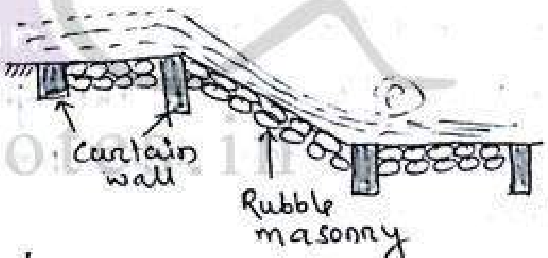
→ In this type of fall, an ogee curve (a combination of convex curve & concave curve) is provided for carrying the canal water from higher level to lower level.



→ This fall is provided when the natural ground surface suddenly changes to a steeper slope along the alignment of the canal.

② Rapid fall:

→ Rapid fall is suitable when the slope of the natural ground surface is even and long.



→ The slope is 1 in 10 to 1 in 20, longitudinally.

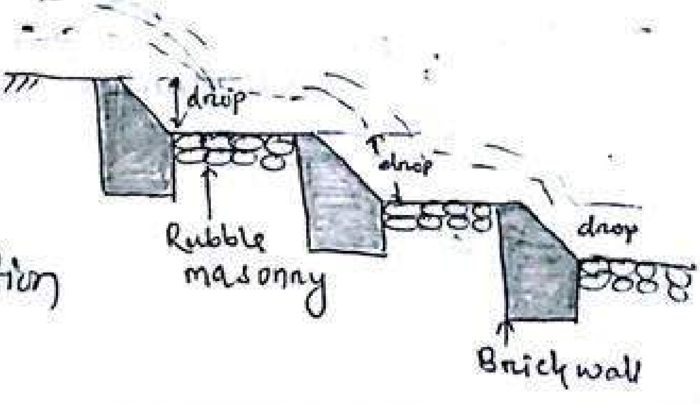
→ Curtain walls are provided on the upstream & down stream side.

→ The sloping bed is provided with Rubble masonry.

③ Stepped fall:

→ Stepped fall consist of a series of vertical drops in the form of steps.

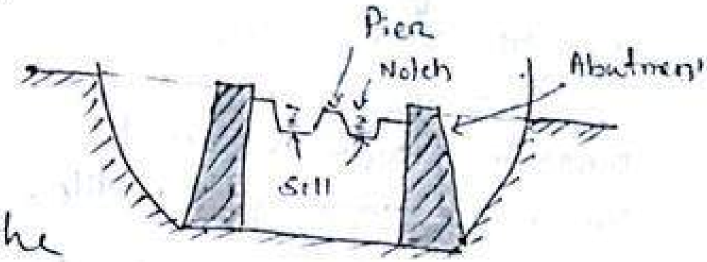
→ It is practically the modification of the rapid fall.



(4) Trapezoidal Notch fall :

→ In this type of fall a body wall is constructed across the canal.

→ The body wall consists of several trapezoidal notches between the side piers & the intermediate pier or piers.



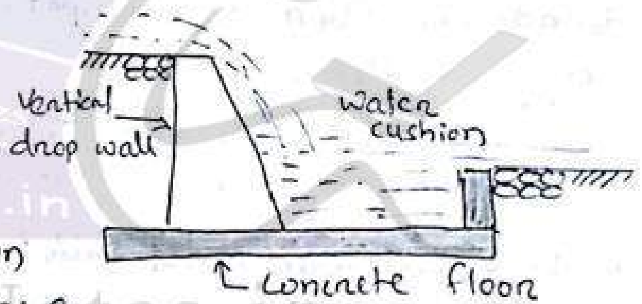
→ The sills of the notches are kept at the upstream bed level of the canal.

→ The body wall is constructed with masonry / concrete.

→ The size & no. of notches depends upon the full supply discharge of the canal.

(5) Vertical drop fall or Sarda fall :

→ It consists of a vertical drop wall which is constructed with masonry work.

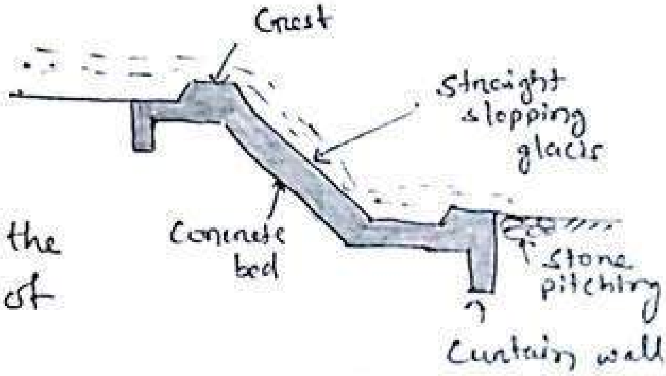


→ The water flows over the crest of the wall.

→ A water cistern is provided on the downstream side which acts as a water cushion to dissipate the energy of falling water.

→ This type of falls are provided on the Sarda ~~canal~~ canal in Utter Pradesh. Hence, it is known as Sarda fall.

(6) Glacis fall :



→ It consist of a straight sloping glacis provided with a crest.

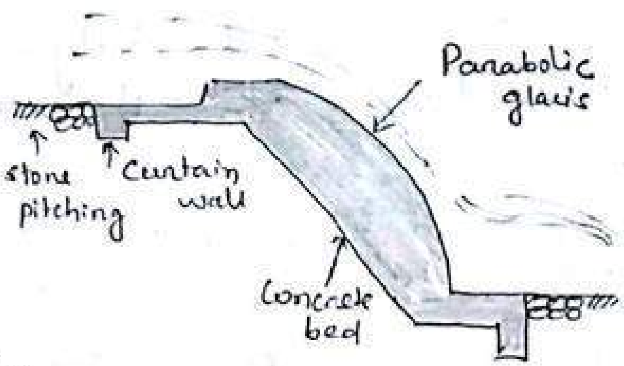
→ A water cushion is provided on the D/s side to dissipate the energy of flowing water.

→ Curtain walls & toe walls are provided on the upstream ~~&~~ & downstream side.

→ This type of fall is suitable ~~for~~ for drops up to 1.5 m.

(7) Montague type fall :

→ In this type of fall, the straight sloping glacis is modified by giving a parabolic shape which is known as montague profile.

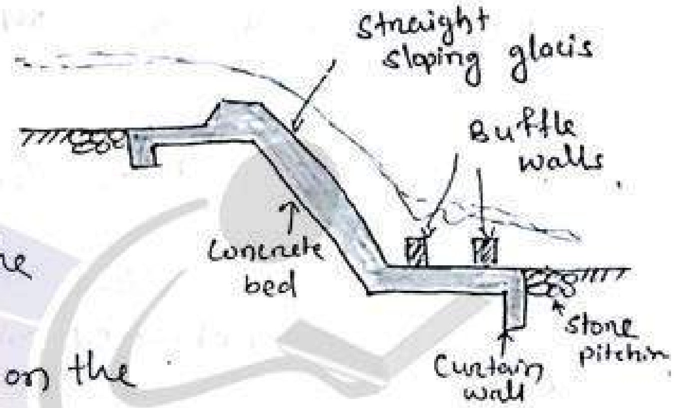


→ The main body of fall is constructed with cement concrete.

→ stone pitching, curtain wall etc are provided as in case of straight sloping glacis.

(8) Inglis Type fall :

→ In this type of fall the glacis is straight and sloping, but buffle walls are provided on the downstream floor to dissipate the energy of flowing water.



→ The height of buffle wall depends on the heigh head of water on u/s side.

→ The main body of the fall is constructed with cement concrete.

→ The protection works with stone pitching are as usual.

→ Sometimes, this fall is known as buffle fall.

—×—

Irrigation

Design of Sarda type fall.

The design consist of following parts:

(1) Crest, (2) cistern, (3) Impervious floor, (4) D/s protection

(5) U/s approach.

(1) Crest

(a) Length of crest (L)

L = bed width of the canal and no fluming is done for this type of fall.

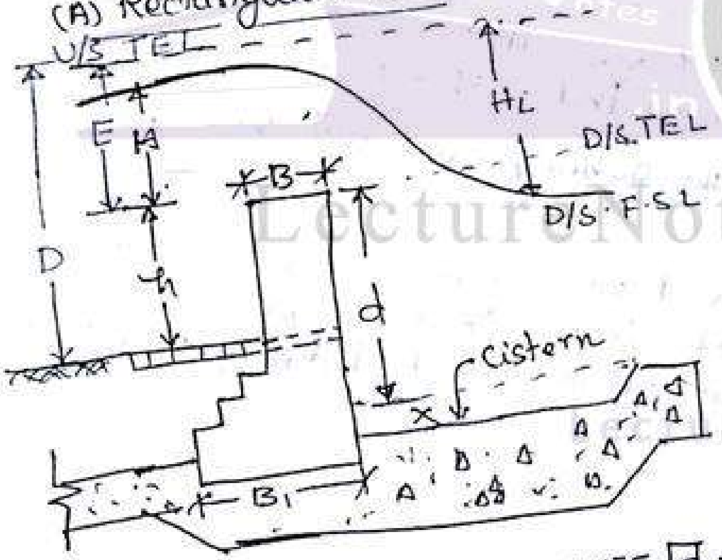
Sometimes

L = bed width of canal + the water depth.

(b) Shape of crest and discharge formula:

Two types: By its capacity: (A) < 14 mecs → rectangular crest
(B) > 14 mecs → Trapezoidal crest.

(A) Rectangular crest



Top width of crest. $B = 0.55\sqrt{d}$ m.

Base width $B_1 = \frac{H+d}{\rho}$

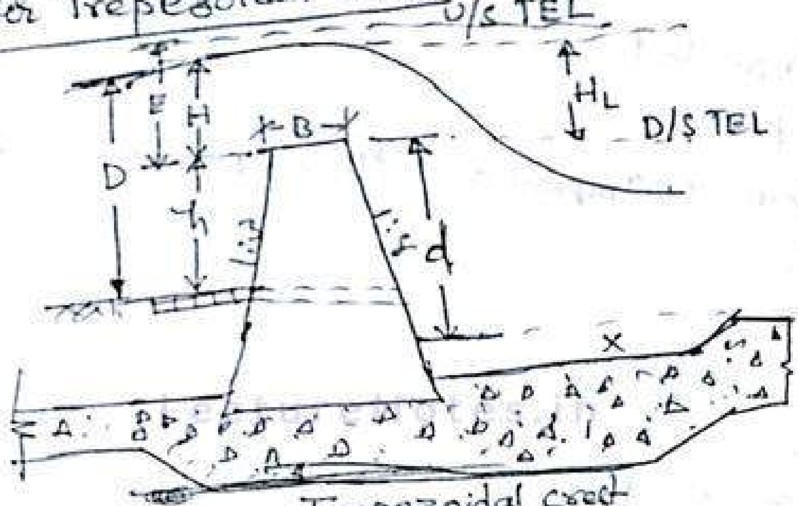
For masonry crest $\rho = 2$

Discharge is given by $Q = 1.835 L H^{3/2} (H/B)^{1/6}$ —— (1)

where Q = discharge in cumecs.

L = length of the crest in meters.

For Trepezoidal crest.



Trepezoidal crest
($Q > 14$ cumecs)

Top width of crest is given by $B = 0.55\sqrt{H + d}$

U/S batter = 1:3

D/S batter = 1:8

Thus the base width is determined by the batter.

Discharge is given by $Q = 1.99 L H^{3/2} (H/B)^{1/6}$ —— ②

(c) Crest level:

From equations (1) (or) (2) the value of H is known.

R.L. of crest = U/S F.S.L − H

Height of the crest above the bed = $h = D - H$.

- For falls over 1.5 m, the stability crest wall should be tested by actual analysis.
- Brick pitching is laid on a slope of 10:1 of for 2–4 m length U/S of the crest. and drain holes are provided in the crest at this level to drain out the U/S bed during the closure of the canal.

2. Design of cistern:

The length and depression of the cistern are given by following equations:

$$L_c = 5(E H_L)^{1/2}$$

$$x = \frac{1}{4}(E H_L)^{2/3}.$$

(3) Design of Impervious floor:

Total length of Impervious floor is determined by either by Bligh's Theory → for small works (or) Khosla's Theory.

(3) Design of impervious floor:

from above fig:

The Max seepage head = d.

out of the Total impervious floor (l_d) – to provide to the D/S of the crest length. Min length.

$\Rightarrow l_d = 2(D + 1.2) + H_L$ not to 2.

the balance of the impervious floor length may be provided under and U/S of the crest.

– the thickness of impervious floor is determined by $t = \frac{4}{3}\left[\frac{h}{\rho - 1}\right]$.

However min. thickness of 0.3 m to 0.4 m. – is provided for floor to U/S of the crest

– For the floor to the D/S of the crest, the actual thickness depends upon the uplift pressure subject to a min of 0.3 to 0.4 m – For small falls. 0.4 to 0.6 m – For large falls.

– the cistern and the d/s impervious floor should have a top lining of brick on edge in lime or cement mortar, so that the floor can be repaired as and when needed.

– A vertical cut-off of 1m to 1.5 m depth is always provided to the d/s of impervious floor.

(4) D/S protection

the D/S protection consist of (a) bed protection (b) side protection (c) d/s wings.

(a) BED PROTECTION:

– Consist of dry brick pitching about 20 cm thick resting on 10 cm ballast.

By table

Head over crest (m)	Total length of pitching on d/s (m)	Remarks	curtain walls Number	curtain walls Depth
upto 0.3	3.0	sloping @ 1 in 10	1	0.30
0.30 to 0.45	3.0 + 2H_L	Horizontal upto end of masonry wings & then sloping @ 1 in 10	1	0.30
0.45 to 0.60	4.5 + 2H_L		1	0.45
0.60 to 0.75	6.0 + 2H_L		1	0.60
0.75 to 0.90	9.0 + 2H_L		1	0.75
0.90 to 1.05	13.5 + 2H_L		2	0.94
1.05 to 1.20	18.0 + 2H_L		2	1.05
1.20 to 1.50	22.5 + 2H_L		3	1.35
			6	

(b) Side protection:

side protection consisting of one brick on edge, is provided after the warped wings. The side pitching is curtailed at any angle of 45^0 from the end pitching in plan.

- Generally, warping of masonry wings is done from vertical to slope of 1:1. Hence the side pitching is warped from a slope of 1:1 to 1½:1. the pitching supported on a Toe wall 1½ brick thick and of depth equal to half the d/s water depth.

(c) D/s wings:

the d/s wings are kept vertical for a length of 5 to 8 times $\sqrt{EH}$, from the crest, and are then warped or flared to a slope of 1:1 or 1½:1. An avg splay of 1 in 2.5m to 1 in 4 for attaining the required slope is given to the Top of the wings.

- the wings follow a circular arc. tangential to the straight pt. of warp. in plan.
- the wing walls are designed as earth retaining structure. In the absence of elaborate stability calculations. the width of wing at any level may kept = 1/3 of the ht. above that level.

(15) Design of U/s approach:

- For discharge upto 14 cumecs, the U/s wings may be splayed, straight at an angle of 45^0.
- For greater discharge, the wings are kept segmental with radius = 5 to 6 times H. subtending angle of 60^0 at the centre. Then are carried straight into the berm.
- the embankment in the berms. ~~kept on the U/S~~ (or) earth banks should be min of 1m.

Topic:

Gravity Dams

MODULE - III

Gravity Dam

Dam :

- A dam is a hydraulic structure constructed across a river to store water on its up-stream side.
- It is an obstruction or a barrier built across a stream or a river.
- At the back of the barrier water gets collected, forming a reservoir and then water is ultilized when needed.

Types of Dam :

a) Classification according to use :

Types	Examples
(i) storage dam	Gravity dam, earth dam, rockfill dam, arch dam etc.
(ii) Diversion dam	weir, barrage
(iii) Detention dam	Dike, water spreading dam, debris dam

b) classification by hydraulic design :

i) overflow dam : spillway

ii) non-overflow dam : gravity dam, earth dam, rockfill dam.

c) Classification by materials :

i) Rigid dame : gravity dam, arch dam, buttress dam, steel dam, timber dam

ii) Non-rigid dam: earth dam, rockfill dam.

d) Based on structural behaviour :

i) solid gravity dam : approximately triangular in section.

ii) Arch dam : It is a curved masonary or concrete dam which resists forces acting on it by the principle of earth arch action.

iii) Buttress dam : behaves like a retaining wall. It consists of sloping deck on upstream side supported by no. of buttress in the form of triangular reinforced concrete wall or counter forts.

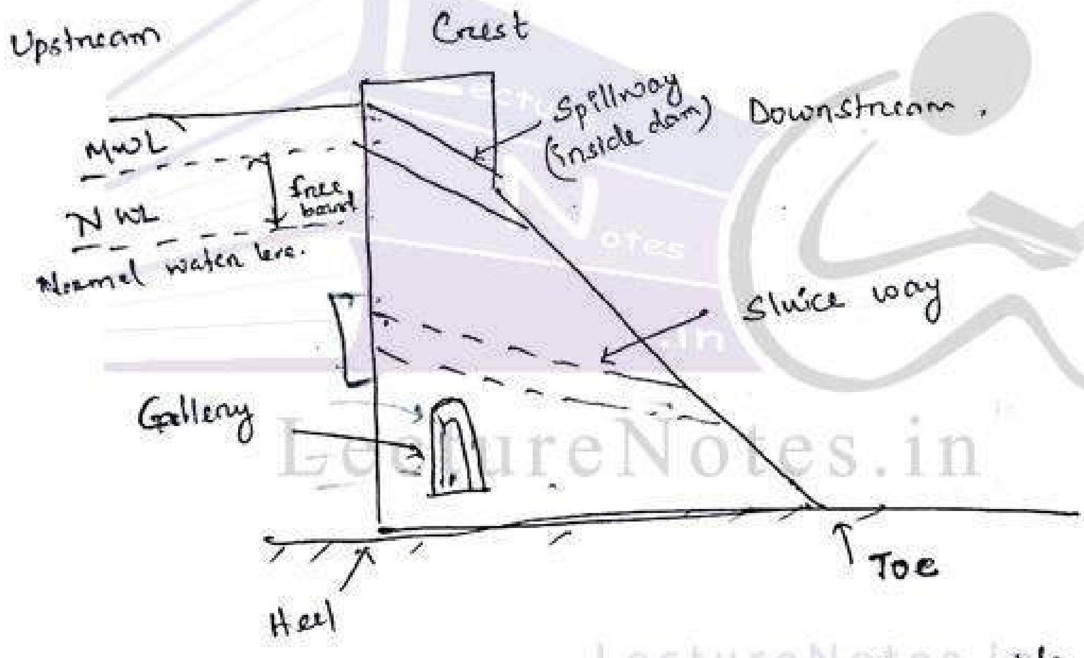
* Selection of site for Dam :

1. Good rocky foundation should be available at the dam site.
2. The river valley should be narrow and well defined so that the length of the dam may be short as far as possible.
3. Site should be in deep gorge section of the valley so that large capacity storage can formed with minimum surface area and minimum length of dam.
4. Valuable property and valuable land should not be submerged due to the construction of dam.
5. The site should be easily accessible by road or railway for the transport of construction materials equipments etc.
6. Sufficient space should be available near the site for the construction of labour colony, godowns and staff quarters for the personnel associated with construction activities.

GRAVITY DAM

→ A gravity dam is defined as a structure which is designed in such a way that its own weight resist the external forces.
→ This type of structure is most durable and solid and requires very less maintenance.
→ These are usually made of cement concrete & straight in plan.

Cross-section of Dam



→ Heel : contact with the ground on the upstream side
→ Toe : contact on the downstream side.
→ Abutments : Sides of the valley on which the structure of the dam rest.
→ Galleries : small rooms like structure left within the dam for checking operations.
→ Spillways : It is the arrangement near the top to release the excess water of the reservoir to d/s side.

Advantages of Gravity dam

→ Gravity dams are quite strong, stable & durable.
→ Gravity dams can be constructed of any height provided suitable foundations are available to bear the stress.
→ This requires least maintenance.

Disadvantages of Gravity Dam

→ This can be constructed only on sound rock foundation.
→ The initial cost is more.
→ It required skilled labour or mechanized plants for construction.
→ It takes a longer time in construction than earth dams.

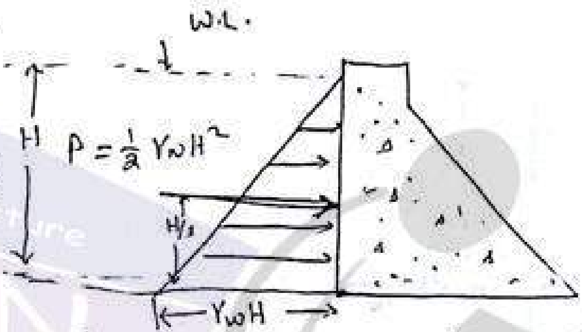
Forces Acting on Gravity Dam

(1) Water Pressure
(2) Uplift Pressure
(3) Pressure due to earthquake forces
(4) Silt pressure
(5) Wave Pressure
(6) Ice Pressure
(7) The stabilising force is the weight of the dam itself.

(1) Water Pressure:

→ Water pressure (P) is the most major external force acting on a dam.

→ The horizontal water pressure exerted by the wt. of the water stored on upstream side on the dam can be estimated from rule of hydrostatic pressure distribution, which is triangular in shape as shown in fig.

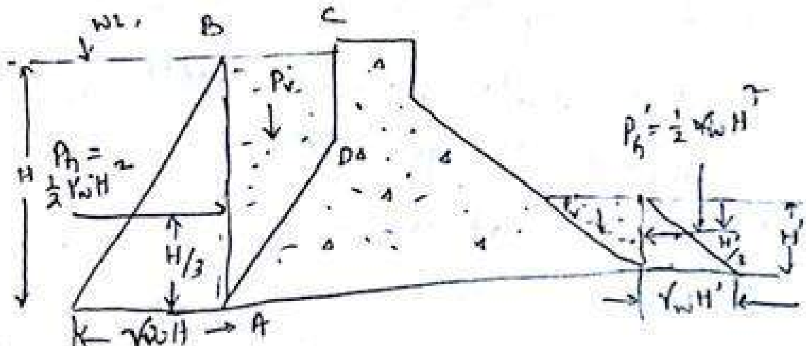


where γ_w = unit wt. of water (9.81 kN/m²)

→ When the upstream face is vertical, the intensity is zero at the water surface & to equal to $\gamma_w H$ at the base.
where γ_w → unit wt. of water
H → depth of water.

→ The resultant force due to external water is $= \frac{1}{2}\gamma_w H^2$ acting at H/3 from base.

⇒ When the upstream face is partly vertical & partly inclined the resulting water force can be resolved into horizontal component (P_h) & vertical component (P_v).



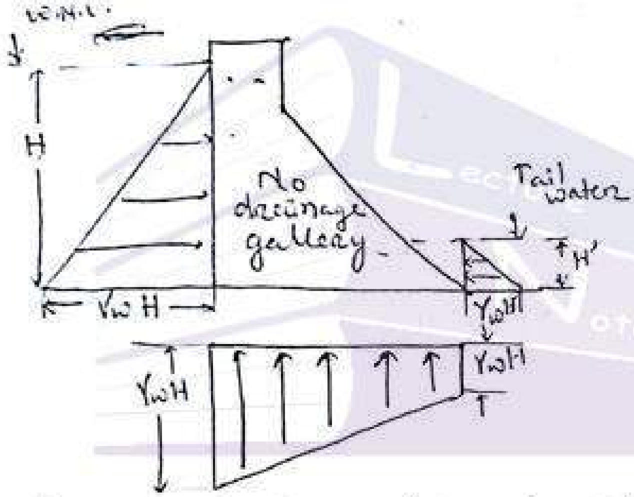
$P_h = \frac{1}{2}\gamma_w H^2$ act at H/3 from base

P_v = wt. of the water stored in column ABCD acts at C.G. of the area

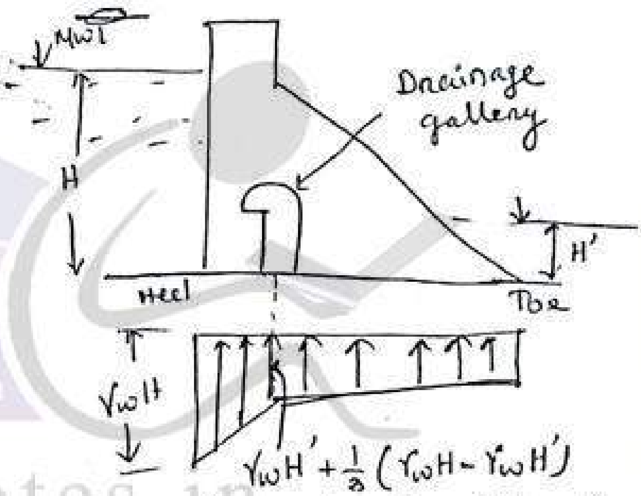
→ Similarly if there will be tail water at downstream side, it will have horizontal & vertical components.

(i) Uplift Pressure :

→ Water seeping through the pores, cracks and fissures of the foundation material and water seeping through dam body and then to the bottom through the joints between the body of the dam and its foundation at the base.
→ ~~It is second major~~
exert an uplift pressure on the base of the dam.
→ It is the second major external force and must be accounted for calculations.
⇒ Such an uplift force virtually reduces the downward weight of the body of the dam and hence acts against the dam stability.



(Uplift Pressure diagram when no drainage gallery is provided.)



(Uplift Pressure diagram when drainage gallery is provided.)

→ According to {U.S.B.R} (United States Bureau of Reclamation) The uplift pressure intensity is equal to the respective hydrostatic pressure.
→ Pressure at the face of gallery . $\gamma_w H' + \frac{1}{3}(\gamma_w H - \gamma_w H')$
→ This can be controlled by providing drainage channel b/w dam & foundation, & by pressure grouting the foundation.
→ uplift pressure is not affected by earthquake forces.

(3). Earthquake forces :

→ For dam design, allowance must be made for the stresses generated by the earthquakes.

→ An earthquake produces waves which are capable of shaking the earth upon which dam is resting, in every possible direction.

→ The effect of an earthquake is equivalent to imparting an accelaration to the foundation of the dam in the direction in which the wave is travelling at the moment.

→ for design purpose this forces are resolved into two components. horizontal acclaration (α_h) & vertical accelaration (α_v)

Effect of vertical accelaration (α_v)

→ Vertical accelaration may be either downward or upward.

→ when it is acting in the upward direction, then the foundation of dam will lifted upward & become closer to body of dam. thus the effective weight of dam will increase & stress develop will increase.

⇒ When the vertical accelaration is acting downward, the foundation tries to move downward away from the body thus reducing the effective weight & the stability of the dam. hence it is worst case of design.

Accelaration will exert inertia force.

$$F = \frac{W}{g}\alpha_v$$ (i.e force = Mass x accelaration)

W → wt. of dam.

∴ Net effective weight of dam = $W - \frac{W}{g}\alpha_v$.

If $\alpha_v = K_v . g$. [where K_v = fraction of gravity 0.1/0.2]

Net effective wt. of dam.

$$= W - \frac{W}{g}K_v . g = W[1-K_v]$$

* Vertical accelaration reduces the unit weight of the dam material & that of water to $(1-K_v)$ times their original unit weight.

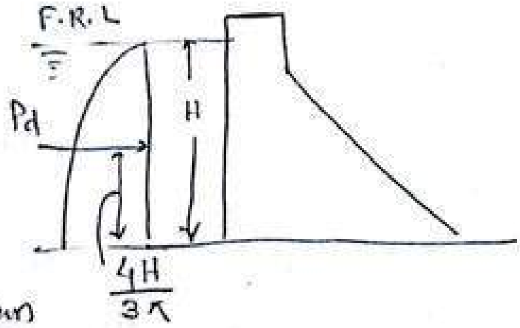
Effect of horizontal accelaration (α_h)

This may cause (i) Hydrodynamic pressure
(ii) Horizontal Inertia force.

(i) Hydrodynamic Pressure:

→ Due to horizontal accelaration α_h, the water pressure is increased momentarily.

→ This extra pressure caused by the earthquake waves is known as hydrodynamic pressure.



→ The expression given by Von-Karman for hydrodynamic force is

$$P_d = 0.555 \times \alpha_h \times w \times h^2.$$

where $P_d \rightarrow$ hydrodynamic force
$\alpha_h \rightarrow$ horizontal accelaration.
w = sp. wt. of water H = depth of water in reservoir.

→ This force acts at a height $\frac{4H}{3\pi}$ from the base of dam

→ The moment of this force = $P_d \times \left(\frac{4H}{3\pi}\right) = 0.424 \times P_d \times H$.

(ii) Horizontal inertia force

→ Due to the horizontal accelaration 'α_h' an inertia force will be developed on the body of the dam.

→ This force is given by $\boxed{I = \frac{W}{g} \times \alpha_h}$

but $\alpha_h = C_h \times g$

or $I = \frac{W}{g} \times C_h \times g = W \times C_h$ or $\boxed{I = W \times C_h}$

where I = inertia force
W = total weight of dam.
g = accelaration due to gravity
α_h = horizontal accelaration.
C_h = a coefficient adopted for horizontal accelaration.
0.1g to 0.3g.

(4). Silt Pressure:

→ Silt gets deposited against the upstream face of dam.

→ If h is the height of silt deposited, then the force exerted by silt in addition to external water pressure can be represented by Rankine's formula.

$$\boxed{P_{silt} = \frac{1}{2}\gamma_{sub} \cdot h^2 K_a}$$ and acts at $\frac{h}{3}$ from base.

where K_a → coefficient of active earth pressure $= \frac{1-\sin\phi}{1+\sin\phi}$

γ_{sub} → submerged unit. wt. of silt ϕ → angle of internal friction of soil.

h = height of silt deposited.

→ If upstream face is inclined the vertical wt. of the silt supported on the slope also acts as a vertical force.

(5) Wave Pressure:

→ Waves are generated on the surface of the reservoir by the blowing winds, which cause a pressure towards the downstream side.

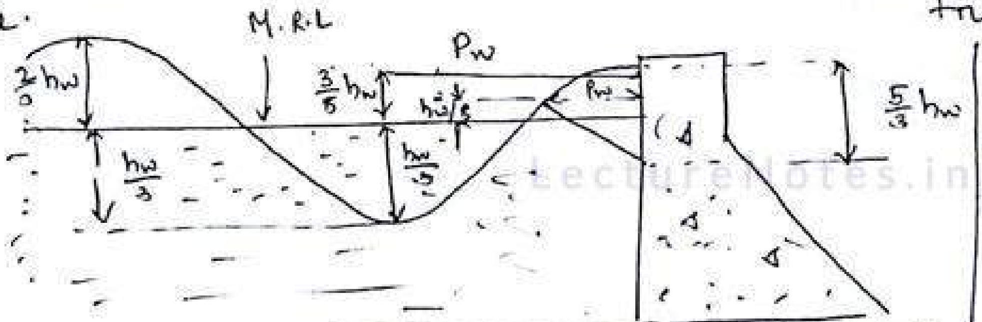
→ Wave pressure depends upon the wave height

→ wave height may be found out by

$$\boxed{h_w = 0.032\sqrt{V.F} + 0.763 - 0.271 (F)^{1/4}}$$ for $F < 32$ km

$$\boxed{h_w = 0.032\sqrt{V.F}}$$ for $F > 32$ km

where h_w = ht. of water from top of crest to bottom of trough in m.



V = wind velocity (km/hr)

F - Fetch / straight length of water expanse in km

* The pressure distribution is triangular of height $\frac{5}{3}h_w$

→ The max^m pressure intensity due to wave action may be given by $\boxed{p_w = 2.4\gamma_w \cdot h_w}$ acts at $\frac{h_w}{2}$ metres above the still water surface

Hence total force due to wave action (P_w)

$$= \frac{1}{2}(2.4\,\gamma_w h_w)\cdot\frac{5}{3}h_w.$$

or, $P_w = 2\gamma_w \cdot h_w^2 = 2\times 9.81\,h_w^2$ kN/m

$= 19.62\,h_w^2$ kN/m.

This force acts at a distance $\frac{3}{8}h_w$ above the reservoir surface

(6) Ice Pressure :

→ The ice which may be formed on the water surface of the reservoir in cold countries may some times melt & expand.

→ The dam face has then to resist the thrust exerted by the expanding ice.

→ This force acts linearly along the length of the dam & the the reservoir level.

→ The magnitude of this force varies from 250 to 1500 kN/m² depending upon temperature variations.

→ On an average a value of 500 kN/m² may be allowed under ordinary condn.

(7) Weight of Dam :

→ The weight of the dam body & its foundation is the major resting force.

→ In two dimensional analysis of a gravity dam, a unit length of the dam is considered.

→ The cross-section can then be divided into rectangles and triangles.

→ The wt. of each along with their c.g. can be determined.

→ The resultant of all these downward forces will represent the total weight of the dam acting at the c.g. of the dam.

Combination of forces for design:

The design of gravity dam should be checked for two cases i.e (i) when Reservoir is full
(ii) when Reservoir is empty.

(i) ~~The~~ Case I. Reservoir full case:

→ When reservoir is full, the major forces acting are: weight of dam, external water pressure, uplift pressure & earthquake forces in serious seismic zones.

→ The minor forces are:
silt pressure, ice pressure & wave pressure.

→ For the most conservative designs and from purely theoritical point of view, all the forces may act together. But such situation will never arises. hence all the forces not taken together.

(a) Normal load combinations

(i) → Water pressure upto normal pool level, normal uplift, silt pressure & ice pressure. ~~This class of~~
→ This class of loading is taken when ice force is serious

(ii) Water pressure upto normal pool level, normal uplift, earthquake forces & silt pressure.

(iii) Water pressure upto maximum reservoir level (max^m pool level), normal uplift & silt pressure.

(b) Extreme Load combination:

(i) Water pressure due to maximum pool level, extreme uplift pressure without any reduction due to drainage and silt pressure.

Case II: Reservoir empty case:

(i) Empty reservoir without earthquake force to be computed for bending diagrams etc for reinforcement design, for grouting studies or other purposes

(ii) Empty reservoir with a horizontal earthquake force produced towards the upstream is to be checked for non-development of tension at toe

* Modes of Failure and Criteria for Structural Stability of Gravity Dams :

A gravity dam may fail in the following ways.

(1) By overturning (or rotation) about the toe.
(2) By crushing
(3) By development of tension, causing ultimate failure by crushing
(4) By shear failure called sliding.

(1). Overturning:

→ A solid gravity dam may fail by over turning at its toe when the total horizontal forces acting on the dam are greater than the total vertical force (its self weight).

→ In such a case, the resultant force passes through a point outside the middle-third of the base of a dam.

→ The overturning may be caused at the downstream edge of any horizontal section.

(2) By crushing / over stress :

→ If the permissible working compressive stress of concrete or masonry exceeds due to some adverse condⁿ, then the dam may fail by crushing due to overstressing of the concrete or masonry.

(3) By Tension / cracking :

→ The tensile stresses should not be allowed to develop on the upstream face of the dam.

→ If due to some reasons, the tension is developed in the dam section crack will form in the body of the dam & ultimately this will cause the failure of the dam.

(4) By sliding :

→ The total horizontal forces acting on a dam tend to slide the entire dam at its base or along any horizontal section of the dam.

→ The sliding may take place when the total horizontal force acting on the dam are greater than the combined resistance offered by shearing resistance of joint & static friction

* Stability Analysis of Gravity Dam:

→ The stability of gravity dam can be approximately & easily analysed by two dimensional gravity method.

✓ Gravity Method or Two dimensional stability Analysis:

** Assumptions:

(i) The dam is considered to be composed of a no. of cantilevers, each of which is 1m thick & ~~which~~ each of which acts independent of each other.

(ii) No loads are transferred to the abutments by beam action.

(iii) The foundation & the dam behave as a single unit; the joint being perfect.

(iv) The materials in the foundation & body of the dam are isotropic & homogeneous.

(v) The stresses developed in the foundation & body of the dam are within elastic limits.

Procedure:

(a) Analytical Method:

(i) Consider unit length of dam.

(ii) Workout the magnitude & directions of all the vertical forces acting on the dam and their algebric sum i.e ΣV.

(iii) Similarly work out all the horizontal forces and their algebric sum i.e ΣH.

(iv) Determine the lever arm of all these forces about the toe.

(v) Determine the moments of all these forces about the toe and find out the algebric sum of all these moments i.e ΣM.

(vi) Find out the location of the resultant force by determining its distance from toe. $\bar{x} = \frac{\Sigma M}{\Sigma V}$

(vii) Find out the eccentricity (e) of the resultant (R) using $e = \frac{B}{2} - \bar{x}$. [It must be less than B/6 in order to ensure that no tension is developed any where in the dam.

(viii) Determine the vertical stresses at the toe and heel using $P_v = \frac{\Sigma V}{B}\left[1 \pm \frac{6e}{B}\right]$

Sometimes stresses are found by ignoring uplift.

(ix) Determine the maximum normal stresses i.e principal stresses at the toe and the heel using

$$\sigma_{\text{at toe}} = P_v \cdot \sec^2\alpha - (p' - p_e')\tan^2\alpha$$

$$\sigma_{\text{at heel}} = P_v \cdot \sec^2\phi - (p - p_e)\tan^2\alpha$$

Shear stress $\tau = (P_v - p')\tan\alpha$

They should not exceed the max^m allowable values.

The crushing strength of concrete varies between 1500 to 3000 kN/m² depending upon its grade M15 to M30.

(x) Determine the factor of safety against overturning as equal to $\frac{\Sigma \text{ Stabilising moment } (+)}{\Sigma \text{ Disturbing moment } (-)}$;

+ve sign is used for anti-clockwise moment & -ve sign is used for clockwise moments.

(xi) Determine the factor of safety against sliding using sliding factor $= \frac{\mu \cdot \Sigma V}{\Sigma H}$,

Shear friction factor (S.F.F) $= \frac{\mu \cdot \Sigma V + Bq}{\Sigma H}$.

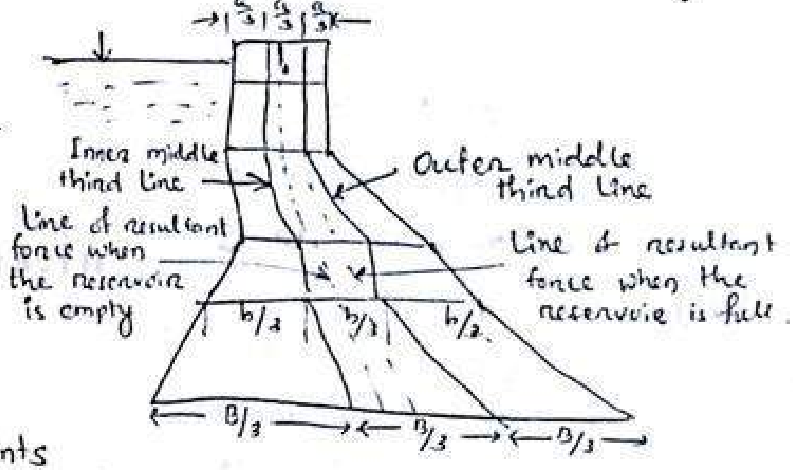
Note: Sliding factor must be greater than unity & SFF must be greater than 3 to 5.

→ The analysis should be carried out for reservoir full case as well as for reservoir empty case.

(b) Graphical method :

→ In the graphical method, the entire dam section is divided into a number of horizontal section at some suitable intervals, particularly at the place where the slope changes.

→ For each section, the sum of the vertical forces (ΣV) & the sum of all the horizontal forces (ΣH) acting above that particular section, are worked out and the resultant force(s) is drawn, graphically.



→ This is done for each section and a line joining all the points where the individual resultants cut the individual sections, is drawn.

→ This line represents the resultant force and should lie within the middle third, for no tension to develop.

→ The procedure should be carried out for reservoir full case as well as for reservoir empty case.

→ The resultant in both cases must show non-development of tension in the dam body.

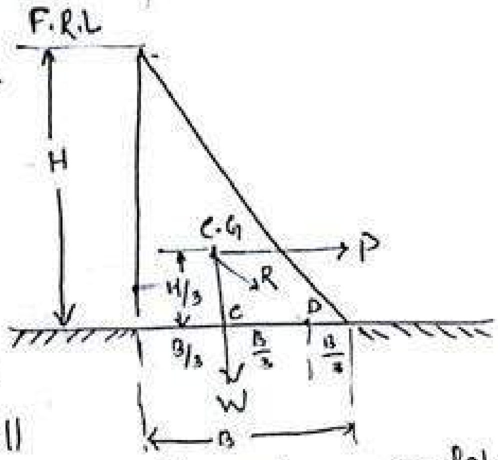
* Elementary / Theoretical profile of the Gravity Dam.

→ When the water is stored against any vertical face, then it exerts pressure perpendicular to the face.

→ The pressure is zero at the top and maximum at the bottom.

→ So, the thickness required at the top is zero and the maximum thickness is required at the bottom.

→ Thus, a right angled triangle will be formed with apex at the top, one face vertical & some base width.



Elementary profile

→ Let H be the height of water stored and B be the base width of the dam.

→ So, a right angled triangle with height H & base B is formed.

→ For stability, the resultant force should remain within the middle third. (i.e. b/w points C & D).

Two condn will arises to satisfy the stability.

(a) When Empty :

→ When the reservoir is empty.

→ The external force P is zero & its self weight W passes through the centre of gravity of the triangle.

→ So, the point C is at a distance of B/3 from the heel.

→ Thus the point C is the extreme left end of the middle third.

(b) When full :

→ When the reservoir is full, the resultant R should pass through the point D, the extreme right end of the middle-third.

→ Now for stability the base width B is to be determined in terms of height 'H'.

Taking moment about D,

$$W \times \frac{B}{3} = P \times \frac{H}{3}$$

or $\frac{W}{P} = \frac{H}{B}$ —— (1)

Again we know $P = \frac{wH^2}{2}$ & $W = w \times \rho \times \frac{1}{2} \times B \times H$

where w = density of water
ρ = sp. gr. of material of dam.

therefore $\frac{W}{P} = \frac{\frac{w \rho BH}{2}}{\frac{wH^2}{2}}$

or $\frac{W}{P} = \frac{\rho B}{H}$ —— (2)

from (1) & (2) $\frac{H}{B} = \frac{\rho B}{H}$

or $\rho B^2 = H^2$

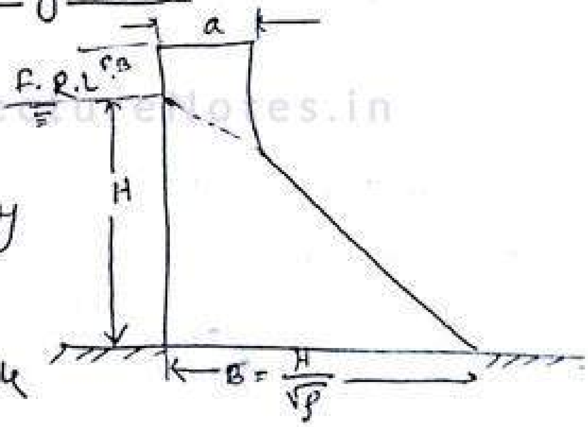
or $\boxed{B = \frac{H}{\sqrt{\rho}}}$

→ So, to keep the resultant force in the middle-third, the base width B should be equal to $\frac{H}{\sqrt{\rho}}$.

→ Thus, the elementary profile of a gravity dam is a right angled triangle with base width equal to $\frac{H}{\sqrt{\rho}}$.

* Practical Profile of a Gravity Dam:

→ In elementary profile, the max^m pool level is just at the apex of a dam. But in actual practice the water level may rise above M.P.L. due to various reasons such as heavy ~~[crossed out]~~ wind, waves, peak flood etc.



→ So, some safe margin called free board should be provided at the top so that water may not spill over the top of dam.

→ In normal practice 2m to 3m free board is provided.

→ Some top width is necessary for stability & for providing roadways over the dam,

→ The top width is given by Bligh's formula

$$a = 0.552\sqrt{H}$$

where a = top width
H = max^m height of water in reservoir.

→ Thus elementary profile is modified by providing free board & some top width.

→ The modified profile is known as practical profile.

LOW DAM & HIGH DAM

→ A dam is designed on the basis of elementary profile, where the resultant forces passes through the middle-third of the base of the dam.

→ The principal stress is calculated for the elementary profile

ie $$\sigma = wH(\rho - C + 1)$$

where σ = principal stress
w = unit wt. of water. (1000 kg/cm³.
ρ = sp. gr. of the material of dam. C = a constant.

→ The above eq^n shows that principal stress varies with H as all other terms are constant.

→ Now to avoid failure of a dam by crushing the value of principal stress 'σ' should not exceed allowable working stress 'f'.

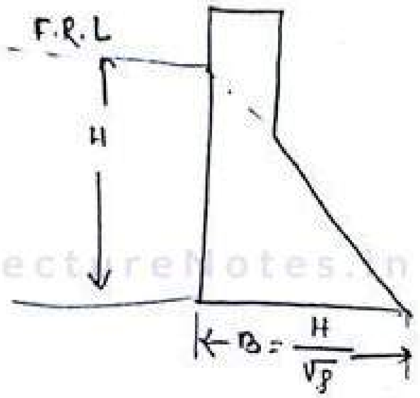
So, $f = wH(\rho - c + 1)$

or $$H = \frac{f}{w(\rho - c + 1)}$$

→ The value of 'H' will be minimum when $c = 0$.

So, the limiting height of low dam is given by

$$H = \frac{f}{\omega(\rho+1)}$$ i.e the dam is a low dam.



low dam

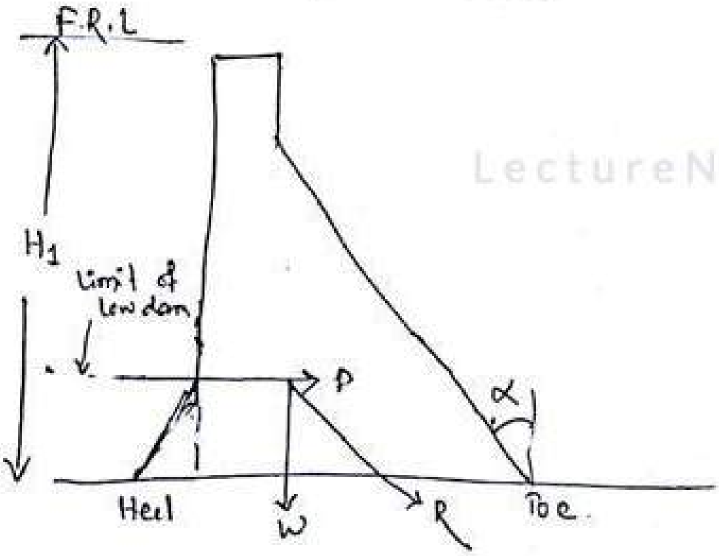
* When $H \leq \frac{f}{\omega(\rho+1)}$ ~~i.e high dam~~

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

→ In that case the section of the dam is modified by providing extra slope on the upstream & downstream side,

So, the condition for the high dam is

$$H_1 > \frac{f}{\omega(\rho+1)}$$



High Dam

Prob

1. To form a storage reservoir of required capacity a solid gravity dam of height 150 m is to be constructed. Comment whether the said dam will be designed as low dam or high dam. Taking permissible working stress as 40 kg/cm² sp. gr of material of dam as 2.5.

Solⁿ The limiting height of low dam is

$$H = \frac{f}{w(\rho+1)} = \frac{40 \times 10^4}{1000(2.5+1)} = 114.29\,m.$$

Here $f = 40\ kg/cm^2 = 40 \times 10^4\ kg/m^2$. $W = 1000\ kg/m^3$ $\rho = 2.5$.

∴ So the height proposed is greater than the limiting height of the low dam.

Hence the dam should be designed considering it as a high dam.

Q2 Find the maxⁿ height of the Low dam having the following data. F.O.S = 4, sp. gr of material = 2.4. Cement concrete = 1:2:4

Draw the section of the dam.

Solⁿ. The ultimate compressive strength of cement concrete (1:2:4) is 150 kg/cm².

Allowable comp. stress $(f) = \frac{150}{4} = 37.5\ kg/cm^2$
$= 37.5 \times 10^4\ kg/m^2$.

Here $\rho = 2.4$ $W = 1000\ kg/m^3$.

$$H = \frac{f}{\omega(\rho+1)} = \frac{37.5 \times 10^4}{1000(2.4+1)} = 110.30\,m.$$

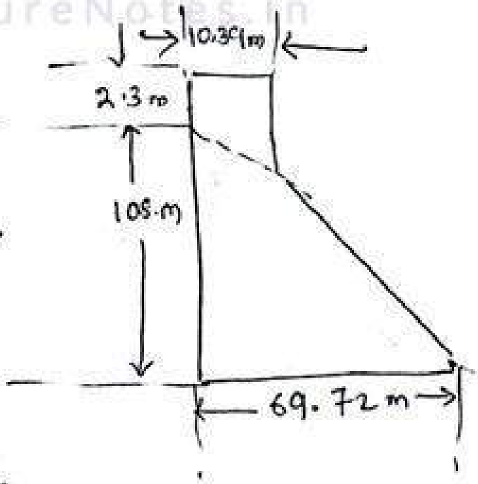
So. ht. of low dam should be 110.3 m. Assuming free board = 2.3 m.

Depth of water = 110.3 − 2.3 = 108 m.

Top width of dam $= 0.552\sqrt{H}$

$= 0.552\sqrt{105} = 10.39\ m.$

Base width $= \frac{H}{\sqrt{\rho}} = \frac{108}{\sqrt{2.4}} = 69.72\,m.$



Ans.

Topic:

Earth Dams

EARTHEN DAM

→ Earthen dam are constructed purely by earth work in trapezoidal section.

→ These are most economical & suitable for weak foundation.

→ These can be easily constructed on earth foundations.

* Types of Earthen Dams;

1. Homogeneous Embankment type.
2. Zoned Embankment type.
3. Diaphragm type.
4. Hydraulic-fill Dam.
5. Rolled fill Dam.

} based on construction method.

(1) Homogeneous Embankment type:

→ This type of dam is constructed purely with earth in trapezoidal section having the side slopes according to the angle of repose of the soil.

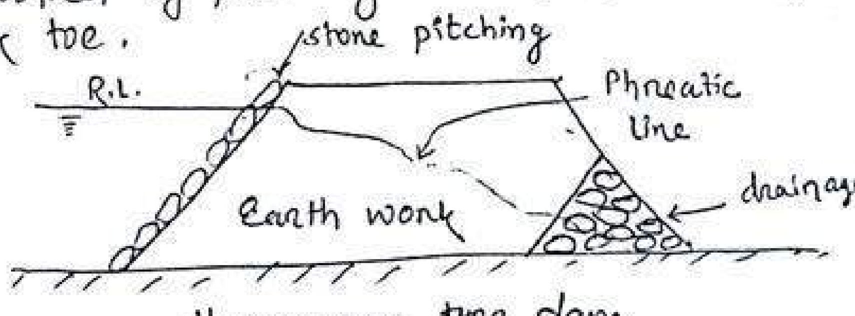
→ The top width & the height depends on the depth of water to be retained & the gradient of the seepage line.

→ The phreatic line (top level of seepage line) should pass well within the body of the dam.

→ This is completely pervious.

→ The upstream face is protected by stone pitching.

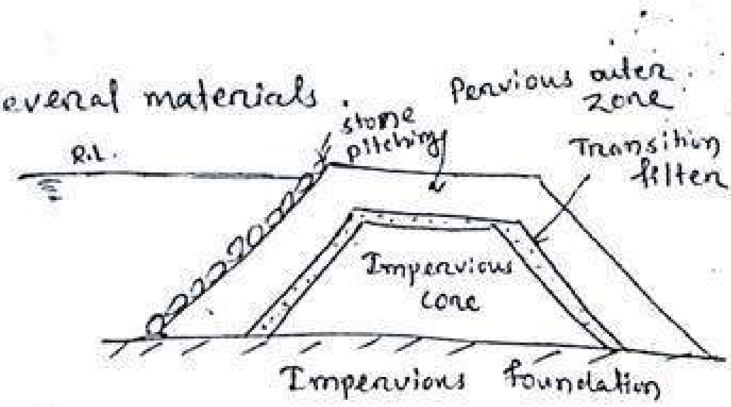
→ Modified by providing horizontal drainage blanket or rock toe.



Homogeneous type dam.

2. Zoned Embankment type:

→ This type of dam consists of several materials.



→ The impervious core is made of puddle clay & the outer ~~pervious~~ pervious shell is constructed with the mixture of earth, sand, gravel etc.

→ The core trapezoidal in section & its width depends on the seepage characteristics of the soil mixture on the upstream side.

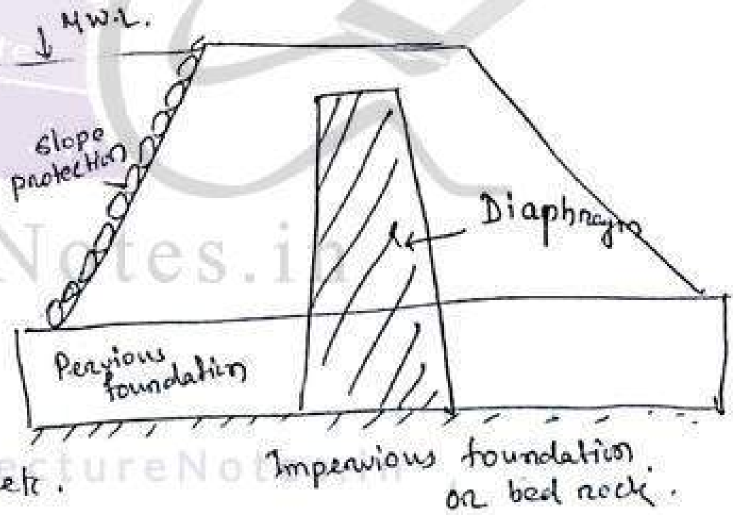
→ Transition filters are provided on the both sides of the impervious core to control the seepage.

→ The transition filter is made of gravel & coarse sand.

→ Upstream face is protected by stone pitching,

3. Diaphragm type Embankment:

→ In this type of dam a thin impervious core or diaphragm is provided which may consist of puddle clay or cement concrete or bituminous concrete.



→ The U/s & D/s body is constructed with pervious shell which consists of mixture of soil, sand, gravel etc.

→ The thickness of core is generally less than 3m.

→ Slope pitching is provided for slope protection.

→ The side slope of the dam should be decided according to the angle of repose of the soil mixture.

4. Hydraulic Fill Dam :

→ In this method, the dam section is constructed with the help of water.
→ Sufficient water is poured in the borrowpit & by pugging thoroughly, slurry is formed.
→ This slurry is transported to the dam site by pipe line & discharged near the U/s & D/s faces of dam.
→ The coarser material gets deposited near the face & the finer material move towards the centre & gets deposited there.
→ In this case compaction is not necessary.

5. Rolled Fill Dam :

→ In this method the dam is constructed in successive layers of earth by mechanical compaction.
→ The selected soil is transported from borrowpits & laid on the dam section to layers of about 45 cm.
→ The layers are throughly compacted by rollers & of recommended weight & type.
→ When the compaction of one layer is fully achieved, the next layer is laid & compacted.
→ The designed dam section hence is completed layer by layer.

* Causes of failure of Earthen Dam.

(1) Hydraulic failure: This may cause by:

(a) Overtopping : The water may overtop the dam, if the design flood ~~discharge~~ is under-estimated or if the spillway is of insufficient capacity or if the spillway gates are not properly operated.

* To overcome this additional free board should provided.

(b) Erosion of upstream face:

The wave developed near the top water surface due to winds, try to notch-out the soil from the U/s face & may cause slip of U/s slope.

* To overcome stone pitching should provided.

(c) Erosion of downstream face:

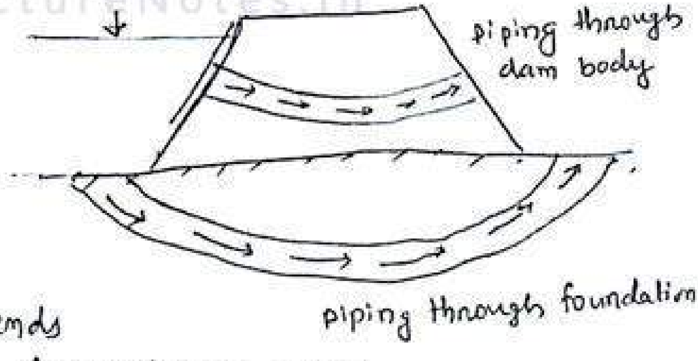
~~(i)~~ The erosion at ~~do~~ D/s face may cause due to
→ heavy rains falling directly on D/s face.
→ due to cross ~~[illegible]~~ current developed from spillway.
→ due to tail water.

* To overcome berms should be provided & ~~sufficient~~ side wall for spillway should be of sufficient height & length.

(2) Seepage failure: This may caused by:

(a) Piping or under-mining:

→ Due to contineous seepage flow through the body of the dam & through the sub-soil below the dam the downstream side get's eroded or washed out & a hollow pipe like groove is foamed which will extends gradually. It will weakens the dam & failure occur.



→ This phenomenon is known as piping / underemining.

(b) Sloughing: the crumbling of the toe of the dam is known as sloughing.

→ When the reservoir runs full, for a longer time, the D/s base of the dam remains saturated.

→ Due to the force of the seepage water the toe of dam goes on crumbling gradually & failure occurs.

(3) Structural Failure: This may cause due to:

(a) Sliding of the side slopes:

→ When the embankment slope/side slopes are too steep for the strength of the soil, they may slide causing dam failure.

(b) Damage by burrowing animals:

→ Some burrowing animals like crawfish, snakes, squirrel rats etc cause damage to the dam by digging holes through the foundation & body of dam.

(c) Damage by earthquake:

→ Due to earthquake cracks may develop on the body of the dam & the dam may eventually collapse.

* Seepage Control in Earth Dams :

The water seeping through the body of the earthen dam or through the foundation of the earthen dam, may prove harmful to the stability of the dam by causing softening & sloughing of the slopes due to development of pore pressure.

(i) Seepage Control Through Embankments :

→ Drainage filters called 'drains' are generally provided in the form of (a) rock toe
(b) horizontal blanket
(c) Chimney drain etc.

→ This provision of such filters reduces the pore pressure in the downstream portion of the dam & thus increases the stability of the dam, permitting steep slopes & thus affecting economy in construction.

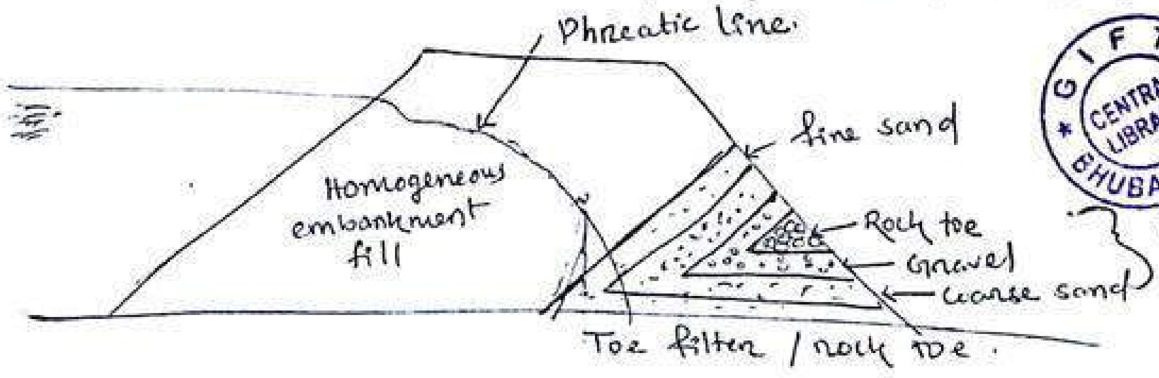
(a) Rock toe / Toe filters :

→ It consist of stones of size varying from 15 to 20 cm.

→ A toe filter (graded in layers) is provided as a transition zone, b/w the homogeneous embankment fill and rock toe.

→ ER. Toe filter consists of three layer of fine sand, course sand & gravel.

→ The height of rock toe is kept b/w 25 to 35 % of H.

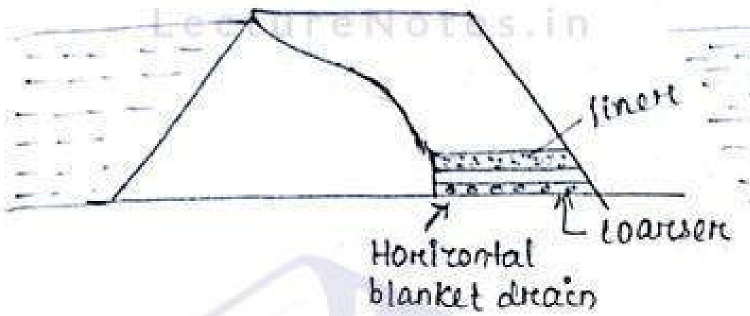


Rock Toe

b) Horizontal Blanket or Horizontal Filter :

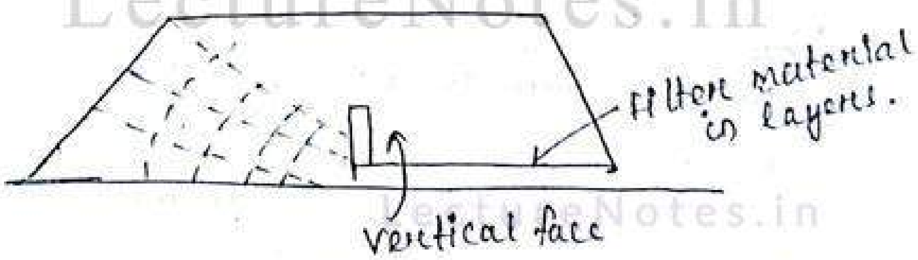
→ the horizontal filter extends from the toe (d/s end) of the dam, inwards, upto a distance varying from 25 to 100% of the distance of the toe from the centre line of the dam.

→ Generally, a length equal to three times the height of a dam is sufficient.



c) Chimney Drain :

- The horizontal filter tries to make the soil more pervious in the horizontal dirⁿ and thus causes stratification.
- To overcome this a vertical filter is placed along the horizontal filter, so as to intercept the seeping water effectively, such arrangement is called chimney drain



*. Chimney drain

(ii) Seepage control through foundations :

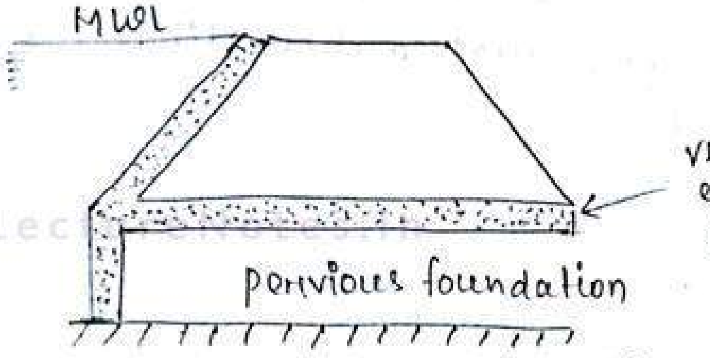
- The amount of water entering the previous foundations can be controlled by adopting following measures :

  a) Impervious cutoffs

  b) Relief wells and Drain Trenches.

a) Impervious cutoff :

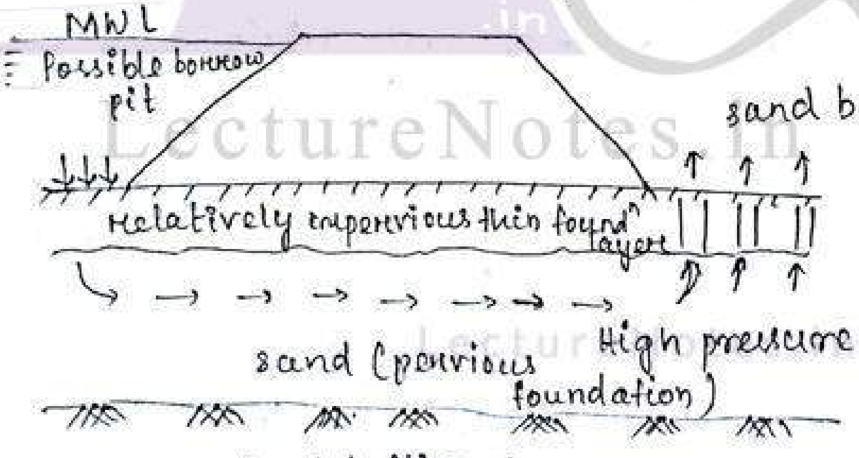
→ Vertical impervious cutoffs made of concrete or sheet piles may be provided at the upstream end (i.e. heel) of the earthen dam.



→ Such a cutoff reduces the seepage discharge by a smaller amount.

b) Relief wells and Drain Trenches :

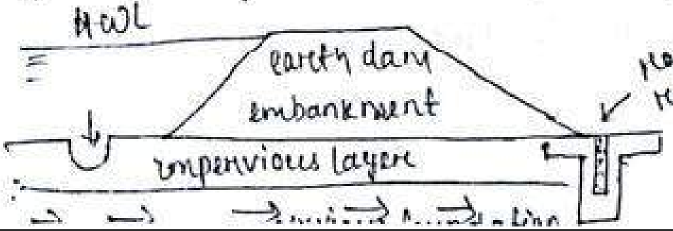
- When large scale seepage takes place through the pervious foundation, overlain by a thin less pervious layer there is a possibility that the water may boil up near the toe of a dam

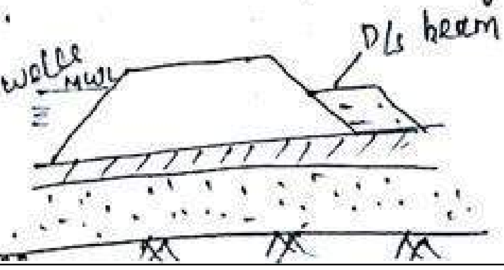


Sand boiling phenomenon

→ Such a possibility can be controlled by constructing relief well or on drain trenches through the upper impervious layer.

→ The possibility of sand boiling may also be controlled by providing d/s berm beyond the toe of the dam.





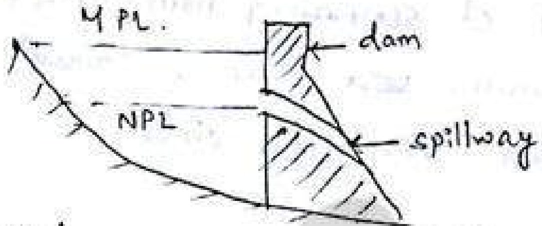
Topic:

Spillways

SPILLWAYS

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

→ The spillways are opening provided at the body of dam to discharge safely the excess water or flood water when the water level rises above the normal pool level.



Reason of providing spillway

→ For the safety against overturning. spillway is essential.

→ To stop over topping water spillway is extremely essential.

→ To protect the D/s base & floor of the dam from the effect of scouring & erosion.

* Location of Spillway:

The spillways are provided at the following places

(a) at the body of the dam

(b) at one side / both sides of the dam

(c) by pass spillway which is completely separate from the dam.

* Types of spill way:

(1) Straight drop spillway

(2) Overflow / ogee spillway

(3) Chute spillway / trough spillway

(4) Side channel spillway

(5) Shaft spillway

(6) Syphon spillway

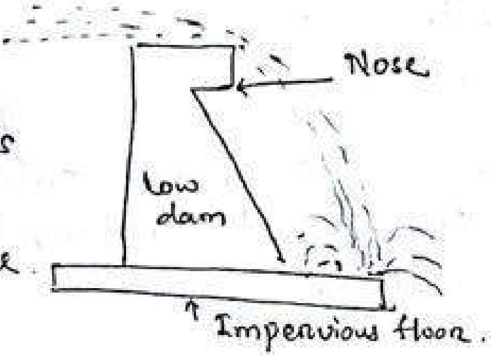
(1) Straight Drop Spillway:

→ In this spillway water falls freely from the crest under the action of gravity.

→ It is suitable for weirs or low dams.

→ The crest of the spillway is provided with nose so that the water jet may not strike the D/s base of the structure.

→ To protect the structure from the effect of scouring horizontal impervious apron should be provided on D/s side.



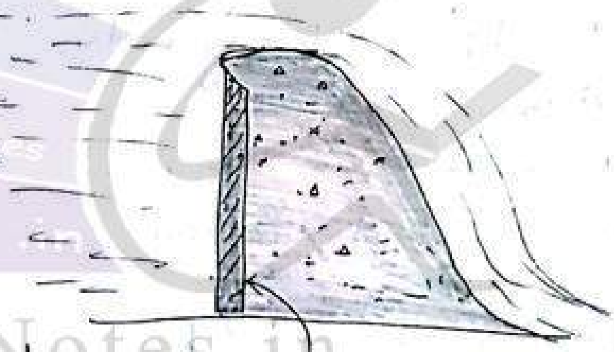
drop spillway

(2) Ogee spillway:

→ The ogee spillway is modified form of drop spillway.

→ The shape is like a 'S' structure.

→ The profile is made in accordance with the shape of lower nappe of a free falling jet.

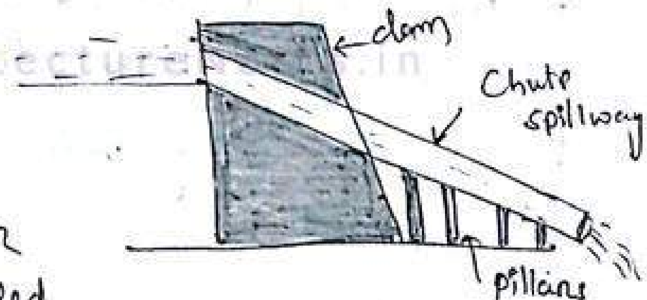


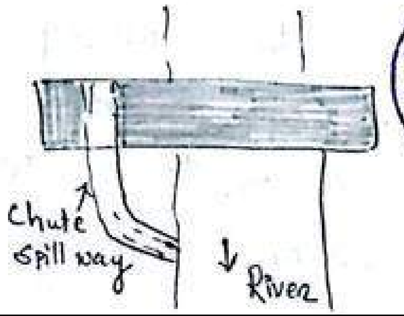
Sharp crest weir

(3) Chute Spillway:

→ This spillway is simply a rectangular open channel or trough (known as chute), provided on the dam to discharge the surplus water from the reservoir to the same river on D/s side

→ The channel are supported by pillars





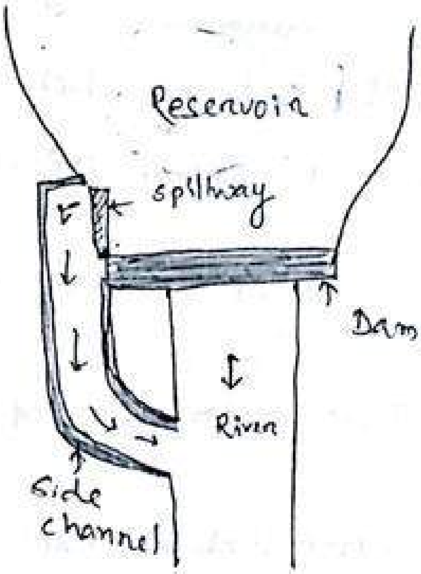
Plan view

(4) Side Channel Spillway :

→ Side channel spillway is completely separate from the main body of the dam.

→ It is constructed at right angle to the dam & at any side according to side condition.

→ The side walls of the channel may be constructed with brick masonry or stone masonry.



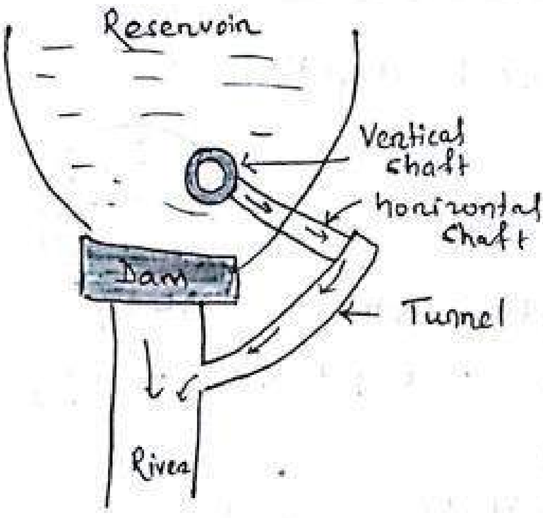
(5) Shaft Spillway :

→ It consists of a vertical shaft which is constructed with masonry work or plain cement concrete or reinforced cement concrete on the bed of reservoir just at the U/s side.

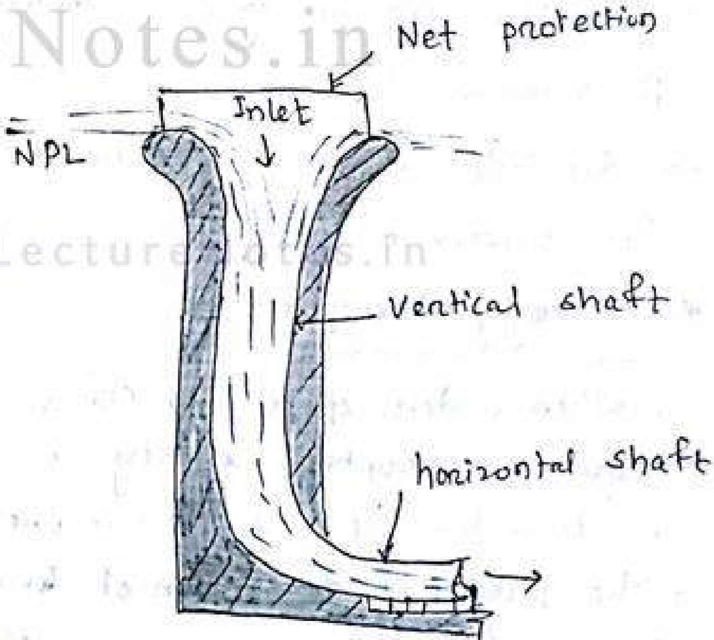
→ The inlet mouth of the vertical shaft is conical shaped.

→ The vertical shaft is connected with horizontal shaft.

→ In order to arrest the floating debris, a net protection is provided on the inlet mouth.



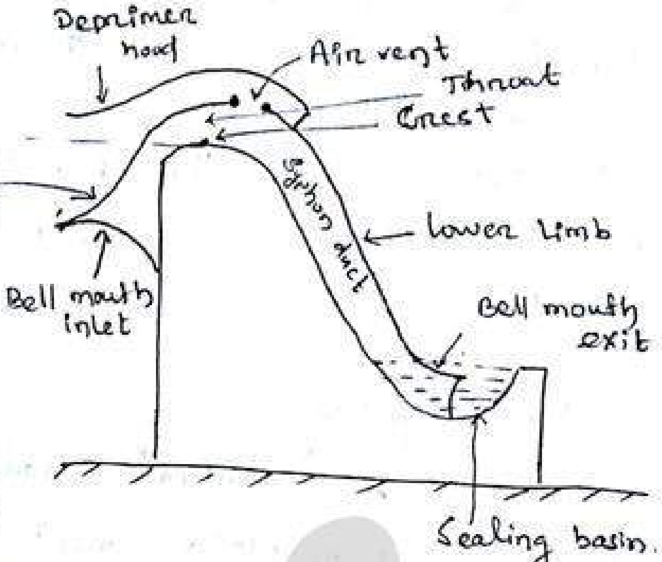
(a) Position of shaft



(b) Section of shaft.

(c) Siphon Spill way:

→ The spillway which acts on the principle of siphon is known as siphon spillway (saddle syphon spillway).



Saddle syphon spillway

→ It consist of a reinforced concrete hollow pipe in the shape of an inverted 'U'.

→ The upper limb is short & lower limb is longer.

→ The exit mouth is kept submerged below the water level of the sealing basin.

→ The idea to stop the entry of air into the syphon duct through the exit end.

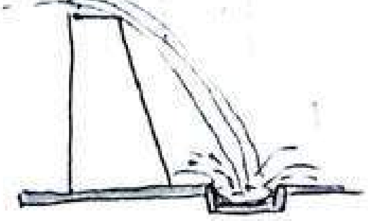
→ An air vent is provided on the top of syphon hood,

→ The air vent is again covered by another hood known as deprimer hood.

→ The inlet end of this hood is kept slightly above the full reservoir level.

* Energy Dissipation:

→ When water spills and flows over the spillways, then it acquires a very high velocity, as the whole potential energy is transformed into kinetic energy.



→ The process of destruction of this kinetic energy is known as energy dissipation.

→ To avoid this Solid roller bucket or slotted roller bucket is provided.