

UNIT -4

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Diversion Head Works & Weirs on permeable foundationTypes, Layout & Components:-Head Work:-

Any hydraulic structure which supplies water to the off-taking canal is called a "Head Work"

Types of Head Works:-

Two classes

- Storage head Work
- Diversion head work

Storage Head Work:-

It comprises the construction of a dam across the river. It stores water during the period of excess supplies in the river & releases it when demand overtakes available supplies.

Diversion Head Work:-

It serves to divert the required supply in to the canal from the river.

Necessity (or) Purposes of Diversion Head Work:-

- It serves the following purposes.
- It raises the water level in the river
 - It regulates the intake of water into the canal

- It controls the silt entry into the canal.
- It reduces the fluctuations in the level of supply in the river.
- It stores water for tiding over small periods of short supplies

Location of Headworks :-

4 distinct regions (or) stages

- The torrential, rocky (or) mountainous stage.
- The sub - mountainous (or) Boulder stage.
- Through stage (or) Alluvial plain
- Delta stage.

Types of Diversion Head Works:-

Two principal classes

- Temporary spurs (or) Bunds
- Permanent weirs & Barrages.

(a) Temporary Spurs (or) Bunds :-

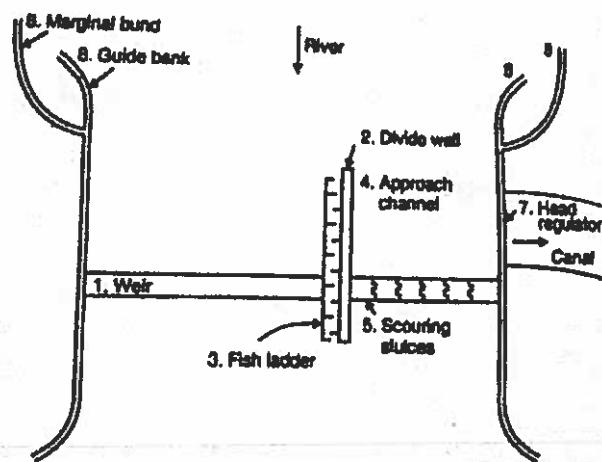
- These are those which are temporary.
- It is constructed every year after the floods

(b) Permanent Weirs & Barrages :-

Layout & Component parts of a Diversion Head work :-

A diversion head-work consists of the following component parts

- Weir (or) Barrage.
- Divide wall (or) Divide grogne.
- Fish ladder
- Pocket (or) Approach channel
- Scouring sluices
- Silt prevention devices
- Canal head regulator
- River training works (marginal bunds & Guide banks)
- These are shown in the below layout



LAYOUT & COMPONENTS OF DIVERSION HEAD WORKS

Functions| Importance| Purpose of Components:-

a. functions of weirs/ Barrages :-

- It raise water level
- It divert water into the canal
- It effect pondage.

b. functions of Divide wall :-

- To facilitate one side of fish ladder.
- To prevent the generation of cross current.
- To minimise the effect of current
- To provide a pocket for silt deposition in it.

c. Fish ladder functions :-

- Availability of water throughout the year
- Top & sides of fish way are more than normal waterlevel
- Smooth flow at low velocity.

d. Scouring sluices :-

- To lowest highest level of flood.
- Prevents the slit entry into the canal.

e. functions of canal head regulators:-

- To control silt entry into the canal.
- To regulate the supplies into the canal.

- It directs the water into off taking canal.

Important Considerations while selecting the site for diversion head:

- Foundation of the site should be good.
- Overall cost of the project is to be minimum.
- The reverse should be high, well defined.
- The river should be narrow.
- The construction materials should be available near the site.

Weirs & Barrages: Causes and failures on permeable foundation:

Barrage preferred to a weir in modern days/times:

- As the barrage consistses low crest wall which is provided with the high gates.
- Barrage control over the river flow betterly.
- The barrage have an approximate control over the gates compared with weirs.
- Though, the construction of a barrage is quite expensive, it is still preferred over a weir in the modern days.

Difference Between Weir & Barrage :-

Weir	Barrage
→ An impervious barrier which is constructed across a river to raise the water level on the upstream side is known as "Weir"	→ When adjustable gates are installed over a weir to maintain the water surface at different levels at different times is known as "Barrage"
→ Low cost	→ High cost
→ Low control on flow	→ Relatively high control on flow.
→ It is a solid construction put across a river to raise the water level in the river.	→ No solid construction put across a river.
→ No control over the water level.	→ Better control over the water level.
→ After long time, silting problem is there	→ No silting problem
→ High set crest	→ Low set crest
→ Shorter construction period	→ Longer construction period
→ Not possible to provide - rail bridge	→ Road & Rail bridge can be constructed.
→ Overall cost of structure is cheap	→ Structure is costly.

Weir :-

An impervious barrier which is constructed across a river to raise the water level on the upstream side is known as "Weir"

Types/Classification :-

- Weirs are classified into two heads, depending upon the orientation of the design of their floors:
- Gravity Weirs (or) Simply Weirs
- Non-gravity weirs

Depending upon the materials & certain design features, gravity (or) simply weirs can be further sub-divided into

- Vertical drop weir
- Sloping weir :
 - (a) Masonry (or) Concrete slope weir
 - (b) Dry stone slope weir (or) Rockfill weir.

- Parabolic weir

a. Gravity Weirs :-

It is one in which the uplift pressure due to the seepage of water below the floor is resisted entirely by the weight of floor. These are further classified into the following

i. Vertical Drop Weir :-

- It consists of a vertical drop wall (or) Crest wall.
- At upstream, & downstream ends of the impervious floor, cutoff piles are provided.
- Launching apron is provided at upstream & downstream ends of the floor.
- Vertical drop weirs are suitable for any types of foundation.

ii. Sloping Weir :-

There are two types

- (a) Masonry (or) Concrete slope weir
- (b) Dry stone slope weir

(a) Masonry (or) Concrete sloping weir :-

- It is suitable for soft sandy foundations.
- It is generally used where the difference in weir crest & downstream river bed is limited to 3 meters.

(b) Dry stone slope weir :-

- It is called as "Rockfill weir".
- It consists of a body wall (or) weir wall and upstream & downstream rockfills laid in the form of glacis Ex: Yamuna river

iii, Parabolic Weir :-

- It is similar to spillway section of a dam.
- The body wall for such weir designed as a low dam.

(b) Non-Gravity Weirs :-

It is the one in which the floor thickness is kept relatively less & the uplift pressure is largely resisted by the bending action of the reinforced concrete floor.

Materials :-

The following are the materials which are used for the construction of weirs

- (a) Masonry (b) Rock (c) Concrete

Effects of construction of a weir on the regime of river :-

The weir is an obstruction thrown in the path of water. Due to its construction, the regime of river is affected in the following ways :-

- i. The silt supporting power of a river (or channel mainly depends upon the hydraulic scope
- ii. Due to decrease in the water surface slope, the silt carrying capacity is decreased.

- iii, Also, due to silt excluding devices provided at the head regulator, the canal takes less silt.
- iv, The water passing over the weir & through the scouring sluices now contains a deficient silt charge, because much of it has been deposited upstream.
- v, In order to maintain a constant silt charge, the flowing water at the downstream scours the bed.

Causes of failure of weirs & their Remedies:

A weir may fail due to the following reasons

- i, Piping
- ii, Rupture of floor due to suction caused by the standing wave.
- iv, Scour at the upstream & downstream side of the weir floor.

i, Piping :-

Water seeps under the base of the weirs founded on permeable soils.

Remedies:-

- (a) Providing sufficient length of the impervious floor so that path of percolation is increased & the exit gradient is decreased.

(b) Providing pile at downstream end.

ii. Rupture of floor due to uplift:-

If the weight of floor is insufficient to resist the uplift pressure, the floor may burst & effective length of impervious floor is thereby reduced.

Remedies:-

(a) Providing impervious floor & sufficient length.

(b) Providing impervious floor of appropriate thickness.

→ Examples of such failures are Khanki & Narora weirs.

iii. Rupture of floor due to suction caused by the standing wave:-

The standing wave (or) hydraulic jump formed at the downstream of the weir causes suction which also acts in the direction of uplift pressure.

→ Examples of such failures are Marala & Rasul weirs.

Remedies:-

(a) Providing additional thickness of floor.

(b) Constructing the floor thickness in one concrete mass instead of in masonry layers.

iv. Scour on the upstream & downstream of the weir:-

The scour holes so formed may progress towards the structure

causing its failures.

→ Example: Islam & Deoha weirs.

Remedies:

- (a) Taking the piles at upstream & downstream ends of the impervious floor, much below the calculated scour level.
- (b) Providing suitable length & thickness of launching at upstream & downstream sides, so that stones of the aprons may settle in the scour holes.

Silt control at head works:

The entry of silt in to the canal can be controlled by

- i. Providing a divide wall in the river at the canal side.
- ii. Paving the bottom of the approach channel to reduce disturbance.
- iii. Installing a silt excluder.
- iv. Making entry of clear top water in the canal.
- v. Reducing the velocity of water.
- vi. Handling carefully the regulation of weir.

The entry of silt into a canal which takes off from a head works, can be reduced by constructed certain special works, called "silt control works"

→ These works may be classified into the following two types.

(a) Silt ejectors (or) Silt Extractors

(b) Silt excludes

Silt Ejectors	Silt Excludes
→ Silt ejector (or) silt extractor is a contrivance by which the silt after it has entered the canal is extracted (or) thrown out.	→ Silt excluder is a device by which silt is excluded from water entering the canal.
→ It is constructed on the canal at some distance away from the head regulator.	→ It is constructed in the bed in front of head regulator
→ The cost of the structure is low.	→ The cost of the structure is high.
→ It is a light structure	→ It is a heavy structure.
→ It is subjected to small forces	→ It is subjected to large forces.
→ It is an entirely additional structure on the canal.	→ It is a combined structure.
→ It requires canal head regulator to carry extra discharge	→ It does not require canal head regulators to carry extra discharge.

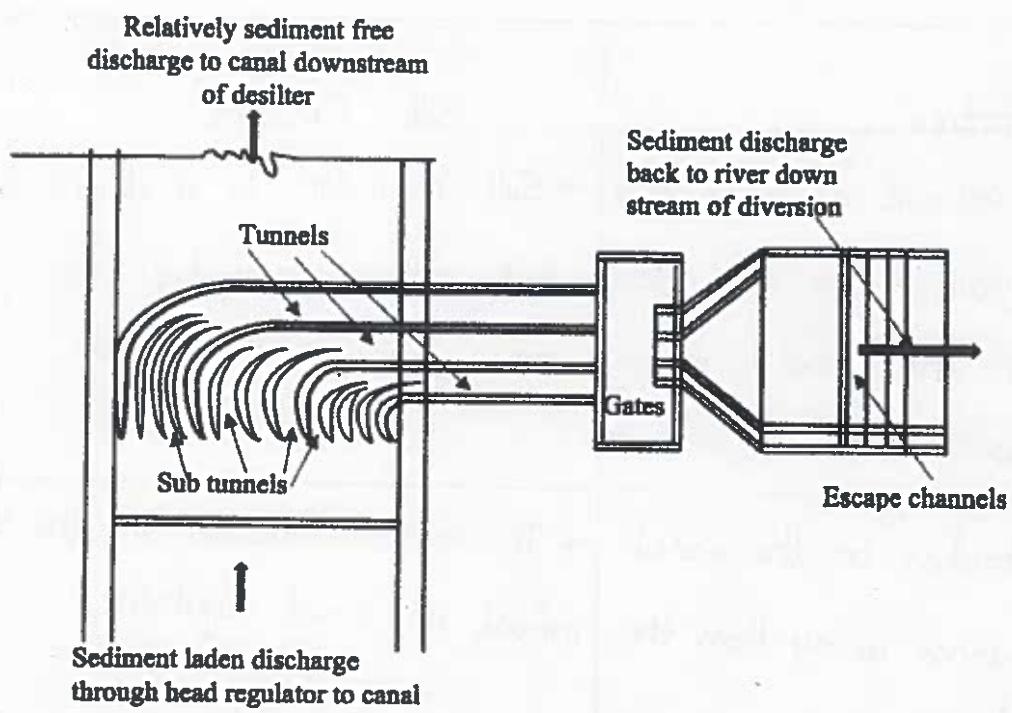


Fig : SILT EXTRACTOR

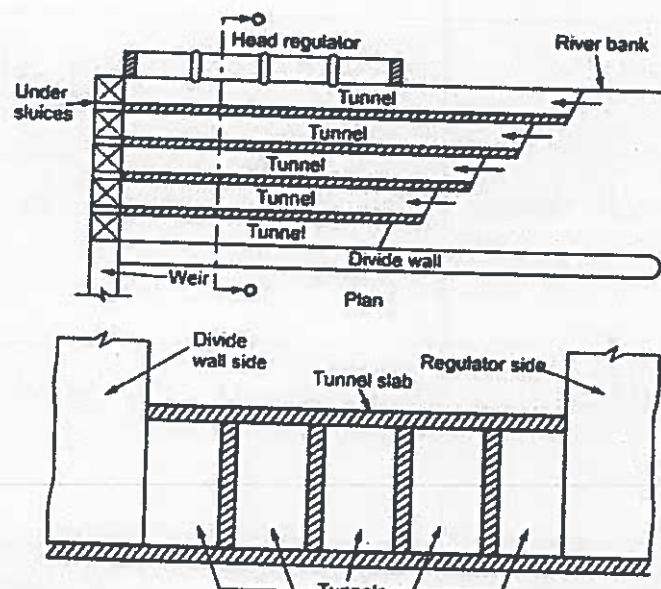


Fig. 5.11 Silt excluder

Fig : SILT EXCLUDER

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Weirs on Permeable Foundations :-

Creep Theories:-

The following are the three creep theories

- Bligh's creep theory.
- Lane's weighted creep theory.
- Khosla's Theory

Bligh's Creep Theory:-

Description:-

The design of the impervious floor over the apron is directly dependent on the possibilities of percolation in the porous soil on which the apron is built.

- Bligh's assumes as an approximation that the hydraulic slope (or) gradient is constant throughout the impervious length of the apron.
- Bligh's further assumed the percolating water to creep along the contact of the base profile of the apron with the sub-soil, losing head enroute, proportional to the length of its travel.
- He designed the length of the travel as the creep length (or) length of creep.

→ Bligh's asserted that no amount of sheet piling could ever stop the percolation.

→ Thus, according to Bligh's theory, the total creep length L is

$$L = l$$

→ The total creep length is

$$L = 2d_1 + l + 2d_2$$

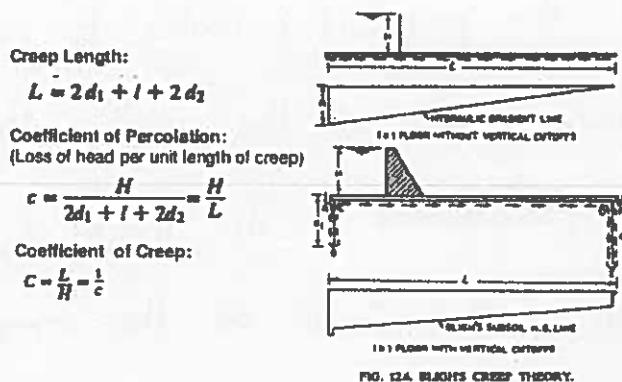
This means that in calculating the length of creep, the depth of every cutoff is multiplied by the co-efficient '2'.

→ Now, the loss of head per unit length of the creep 'c'

$$c = \frac{H}{2d_1 + l + 2d_2}$$

$$c' = \frac{H}{L}$$

Figure



Design Criteria :-

Bligh's gave two criteria for design

- Safety against piping
- Safety against uplift pressure.

Limitations :-

Bligh's theory are having following limitations.

- i. Bligh made no distinction between horizontal & vertical Creep.
- ii. Bligh's method holds good so long as the horizontal distance between the pile lines is greater than twice their depth.
- iii. Bligh's did not explain the idea of exit gradient.
- iv. Bligh's makes no distinction between outer & inner faces of sheet piles (or) intermediate sheet pile.
- v. Bligh does not specify the absolute necessity of providing a sheet pile at downstream end.

Significance/ Importance :-

- The safety of impervious floor is ensured by satisfying safety against piping.
- By satisfying safety against uplift pressure, there is no chance of failure.
- The loss of head per unit length is constant throughout the

path of seepage.

→ The piping failure can also be prevented by providing pile at downstream end.

2. Lane's Weighted Creep Theory:-

Description :-

→ Based on statistical investigations of as many as 278 dams, weirs & barrages all over the world.

→ It is modified from Bligh's creep theory.

→ According to this theory, the weighted creep length (L_w) is

$$L_w = \frac{1}{3} l + v$$

Where

l = Sum of all horizontal constants

v = Sum of all vertical constants

$$L_w = \frac{1}{3} l + 2d_1 + 2d_2$$

→ To ensure safety against piping, Lane suggested that the weighted creep length must not be less than

$$L_w = c_w t$$

Where L_w = Weighted Creep Length

c_w = Lane's creep co-efficient.

Limitations :-

- This theory has the same limitations as Bligh's theory.
- The weightage provided to the vertical & horizontal creep is same.
- It does not provide accurate results.
- It is not popular in India.

3. Khosla's Theory :-

Description :-

The following are the provisional conclusions by the khosla's:-

- The outer faces of the end sheet piles were much more effective than the inner ones & horizontal length of the floor.
- The intermediate piles is smaller in length than the outer ones were ineffective.
- Undermining of the floor started from the tail end.
- It was absolutely essential to have a reasonable deep vertical cutoff at the downstream end.

Specific Cases :-

Case-1 : Pile at some intermediate point

Case-2 : Pile at down stream [d/s] end

Case-3 :- Pile at upstream [uls] end.

Limitations :-

- Uplift pressure in the half of the downstream floor is neglected.
- The slope of uplift pressure between the two points is infinite.

Utility/Use/Advantages/Benefit/effectiveness :-

- Exit Gradient
- Independent variables
- Horizontal impervious floor without pile.
- Specific cases of composite profile
- Hydraulic structure with composite profile.

Various corrections & Khosla's Theory :-

The following are the various corrections that are needed in its applications.

- Correction for thickness of the floor.
- Correction for the mutual interference of the piles
- Correction due to the sloping floor.

1. Correction for thickness of the floor :-

The correction (C) is given by

$$\phi_{e1} = \phi_E - \frac{\phi_E - \phi_D}{d_2} \times t_2$$

2. Correction for the mutual interference of the piles:-

The correction [c] is given by

$$c = 19 \sqrt{\frac{D}{b'}} \left[\frac{d+D}{b} \right]$$

Exit Gradient :-

Definition :-

The exit gradient is the hydraulic gradient at the downstream end of the flow line where percolating water leaves the soil mass & emerges into the free water at the downstream

→ It is provided in order to protect the floor against piping.

→ The value of Exit gradient should be less than the value of safe gradients.

→ Exit gradient is denoted by ' G_E '

Determination :-

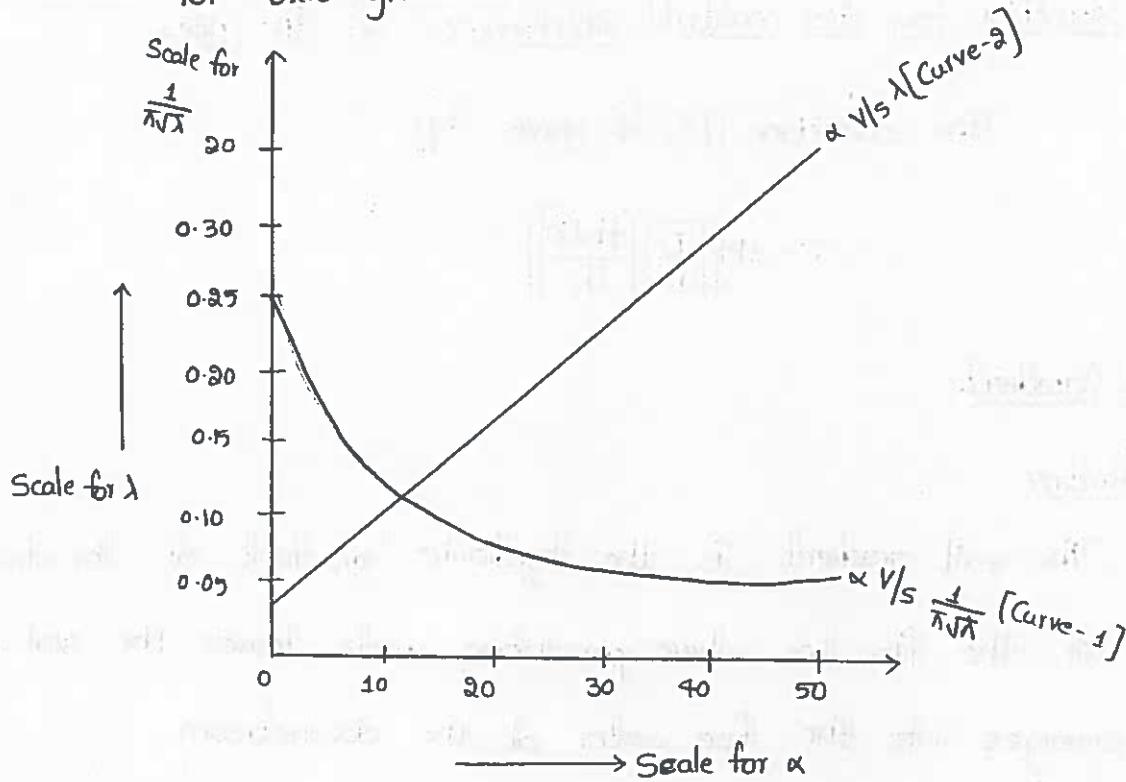
The exit gradient (G_E) is given by the following expression

$$G_E = \frac{H}{d} \cdot \frac{1}{\pi \sqrt{\lambda}} \quad \longrightarrow ①$$

Where $\lambda = \frac{(1 + \sqrt{1 + \alpha^2})}{2} \quad \longrightarrow ②$

$$\alpha = \frac{b}{d} \rightarrow ③$$

→ Curves for Exit gradient :



From the above graph :

$$\text{Curve-1} \rightarrow \alpha V/s \frac{1}{\pi\sqrt{\lambda}}$$

$$\text{Curve-2} \rightarrow \alpha V/s \lambda$$

x - axis → Scale for α

y - axis → Scale for λ

→ Now, for example Take $b = 20m$; $d = 4m$; $H = 5m$

Now sub b, d & H values in eq(3) & ① & ②

from equation → ③

$$\alpha = \frac{b}{d}$$

$$\alpha = \frac{30}{4}$$

$$\alpha = 5$$

Now, substitute all values in eq(1)

$$\text{From eq(1)} \quad G_E = H_d \cdot \frac{1}{\pi J \lambda}$$

$$= \frac{5}{4} \times 0.185$$

$$G_E = 0.23$$

from eq(2)

$$\lambda = \frac{(1 + \sqrt{1 + \alpha^2})}{2}$$

$$= \frac{1 + \sqrt{1 + 25}}{2}$$

$$\lambda = 3.0495$$

Permissible Exit Gradient:

Type of soils	G_E
Fine Sand	1/6 to 1/7
Coarse sand	1/5 to 1/6
Shingle	1/4 to 1/5

Launching Apron:

Definition:

At the end of the down-stream filter (or) upstream block protection launching aprons consists of loose boulder (or) stones

of size 300mm & weight 40 kg (a) precast cement concrete blocks are provided to protect against the scour holes formed during floods. The length of downstream launching apron is in between $1.5d_g$ to $2.5d_g$. The slope of the launched apron depend on the grade & size of river bed material, as indicated below

Sl.No	River bed Material	Slope(n)
1.	River in alluvium sandy reach	Not steeper than 2:1
2	River in very fine sand & silty bed	Not flatter than 3:1
3	River in boulder reach	up to 1.5:1

Explanation:-

- Generally, for sloping glacis weirs, where energy dissipation is more effective due to formation of hydraulic jump
- The length of the downstream launching apron is taken equal to $1.5d_g$ & its launched slope is taken equal to 2:1.
- However for vertical drop weirs, the length of downstream launching apron is taken equal to $2.5d_g$ & its launched slope is taken equal to 3:1

→ Similarly, The length of the upstream launching apron is taken equal to $1.5d_1$, to $2d_1$.

- i. If the length of the upstream launching apron is taken equal to $1.5d_1$, then the launched slope is taken as $2:1$
- ii. If the length of the upstream launching apron is taken equal to $2d_1$, then the launched slope is taken as $3:1$

Upstream & Downstream sheet piles:-

Definition:-

The sheet piles are made up of mild steel, which are provided in barrages depending upon their relative functions.

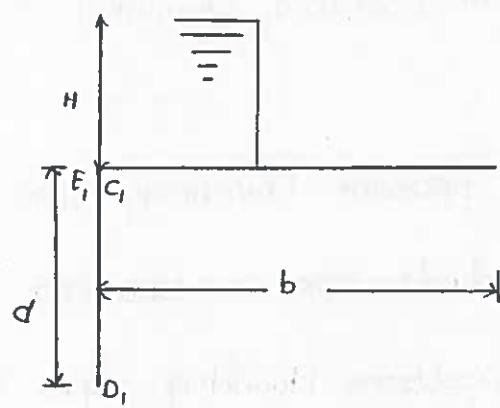
Types:-

The different types of sheet piles are listed below

- Upstream [U|S] sheet piles.
- Intermediate sheet piles.
- Downstream [D|S] sheet piles.

(a) Upstream [U|S] sheet piles:-

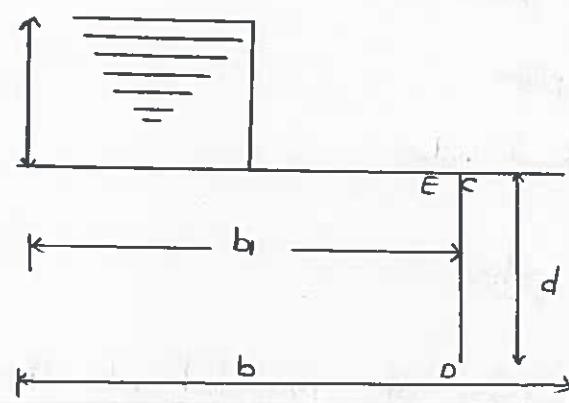
- The upstream sheet piles are provided at the upper end of the upstream concrete floor.
- These piles protect the structure from the scour & increases the bearing capacity.



Pile at upstream end

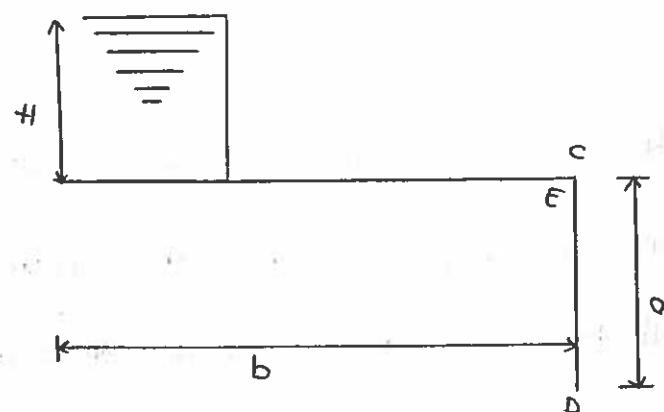
(b) Intermediate sheet piles:

- The intermediate sheet piles are provided at the intermediate of the intermediate concrete floor.
- The main structure of the barrage is protected by intermediate sheet piles.
- These piles are also minimize the uplift pressure



Intermediate pile

(c) Downstream [o/s] sheet piles :-

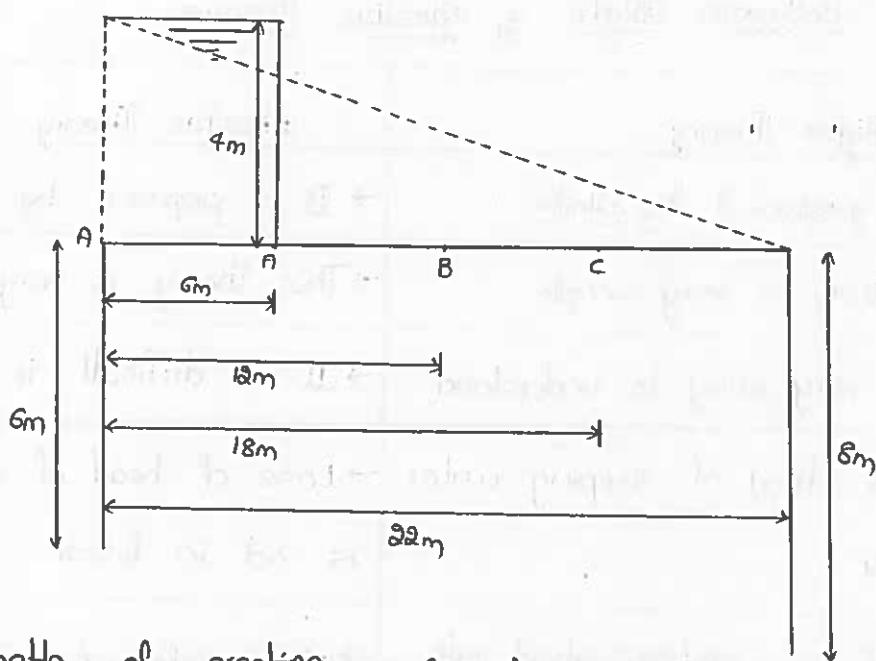


Difference between Bligh's & Khosla's Theories :-

Bligh's Theory	Khosla's Theory
→ It is proposed by 'Bligh's'	→ It is proposed by "Khosla's"
→ This theory is very simple	→ This theory is very complex
→ It is very easy to understand.	→ It is difficult to understand.
→ Loss of head of seeping water is linear	→ Loss of head of seeping water is not in linear.
→ He did not explain about exit gradient	→ He explained about exit gradient
→ It does not have any corrections	→ It is having three corrections
→ Seeping water follows the path along the surface in contact with the under side of the impervious floor profile.	→ Seeping water follows parabolic stream line path

Diversion Head works & Weirs on permeable foundation :-

Prob Figure shows the section of a hydraulic structure founded on sand. Calculate the average hydraulic gradient. Also, find the uplift pressures at points 6, 12 & 18m from the upstream end of the floor & find the thickness of the floor at these points taking $\gamma = 2.24$.



$$\begin{aligned} \text{Total length of creeling} &= (2 \times 6) + 22 + (2 \times 8) \\ &= 50 \end{aligned}$$

$$\text{Hydraulic gradient} = \frac{4}{50} = \frac{1}{12.5}$$

i) Uplift pressure at a point A, 6m from upstream:

$$\text{Length of creep up to A} = (6 \times 2) + 6 = 18\text{m}$$

$$\therefore \text{Unbalanced head } [h_i] = 4 \left[1 - \frac{18}{50} \right] = 2.56 \text{ m}$$

$$\text{Uplift pressure} = w \times h_i = 9.81 \times 2.56$$

$$= 25.14 \text{ kN/m}^2$$

$$\begin{aligned}\text{Thickness } (t) &= \frac{4}{3} \frac{b_1}{\rho - 1} \\ &= \frac{4}{3} \cdot \frac{h_1}{\rho - 1} \\ &= \frac{4}{3} \times \frac{2.56}{2.24 - 1} \\ t &= 2.76 \text{ m}\end{aligned}$$

ii. Uplift pressure at a point B, 18m from upstream :-

$$\text{Length of creep up to B} = (6 \times 2) + 12 = 24 \text{ m}$$

$$\begin{aligned}\therefore \text{Unbalanced head } (h_2) &= 4 \left[1 - \frac{24}{50} \right] = 2.08 \text{ m} \\ \therefore \text{Uplift pressure} &= \omega \times h_2 \\ &= 9.81 \times 2.08 = 20.4 \text{ kN/m}^2\end{aligned}$$

$$\begin{aligned}\text{Thickness } (t) &= \frac{4}{3} \times \frac{h_2}{\rho - 1} \\ &= \frac{4}{3} \times \frac{2.08}{2.24 - 1}\end{aligned}$$

$$t \sim 2.23 \text{ m}$$

iii. Uplift pressure at a point C, 18m from upstream :-

$$\text{Length of creep up to C} = (6 \times 2) + 18 = 30 \text{ m}$$

$$\therefore \text{Unbalanced head } (h_3) = 4 \left[1 - \frac{30}{50} \right] = 1.6 \text{ m}$$

$$\text{Uplift pressure} = \omega \times h_3$$

$$\approx 9.81 \times 1.6$$
$$= 15.7 \text{ kN/m}^2$$

$$\text{Thickness } (t) = \frac{4}{3} \times \frac{h_3}{\rho - 1}$$
$$= \frac{4}{3} \times \frac{1.6}{2.24 - 1}$$
$$t = 1.72 \text{ m.}$$